Astro2010: The Astronomy and Astrophysics Decadal Survey

Notices of Interest

1. 4 m space telescope for terrestrial planet imaging and wide field astrophysics

Point of Contact: Roger Angel, University of Arizona
Summary Description: The proposed 4 m telescope combines capabilities for imaging terrestrial exoplanets and for general astrophysics without compromising either. Extremely high contrast imaging at very close inner working angle, as needed for terrestrial planet imaging, is accomplished by the powerful phase induced amplitude apodization method (PIAA) developed by Olivier Guyon. This method promises 10-10 contrast at 2.0 l/D angular separation, i.e. 50 mas for a 4 m telescope at 500 nm wavelength. The telescope primary mirror is unobscured with off-axis figure, as needed to achieve such high contrast. Despite the off-axis primary, the telescope nevertheless provides also a very wide field for general astrophysics. A 3 mirror anastigmat design by Jim Burge delivers a 6 by 24 arcminute field whose mean wavefront error of 12 nm rms, i.e.diffraction limited at 360 nm wavelength. Over the best 10 square arcminutes the rms error is 7 nm, for diffraction limited imaging at 200 nm wavelength. Any of the instruments can be fed by part or all of the field, by means of a flat steering mirror at the exit pupil. To allow for this, the field is curved with a radius equal to the distance from the exit pupil. The entire optical system fits in a 4 m diameter cylinder, 8 m long. Many have considered that only by using two spacecraft, a conventional on-axis telescope and a remote occulter, could high contrast and wide field imaging goals be reconciled. Our proposal, with comparable optical performance and higher agility for exoplanet imaging, deserves serious evaluation as a potentially lower cost alternative.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Roger Angel, Olivier Guyon and Jim Burge, University of Arizona, Domenick Tenerelli, LMCO
Current Status: Coherent starlight suppression demonstrated to 10-8 contrast with PIAA in air in Guyon lab. An 8.4 m off-axis primary mirror being made at the University of Arizona.
Additional Information: A full description of the optical design will be available in a white paper by Burge and Guyon at caao.as.arizona.edu/rangel/4m. Tenerelli will also develop the spacecraft including I/F's to the telescope and systems level test program concepts. ITT will develop the telescope concept.

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2. A Program of Far-Infrared/Submillimeter Space Astronomy: Maximizing Scientific Returns in 2010-2020 while Preparing the Technologies for Further Major Advances in 2020-2035.

Point of Contact: Martin Harwit, Cornell University
Summary Description: The highest priority for the US Far-Infrared/Submillimeter

(FIR/SMM) space community in the decade of 2010 - 2020 is participation in the Japanese-led SPICA mission through inclusion of one of the four science instruments onboard, a US FIR background-limited spectrometer with highly-sensitive detector arrays covering the 38 – 433 micron wavelength range --- a natural contribution, given uniquely sensitive US FIR detectors. The combination of sensitive instrumentation with SPICA's 3.5-meter cryogenically cooled telescope will produce the world's first Great Observatory spanning the wavelength regime between JWST and ALMA, a relatively unexplored but crucial spectral range for studying the history of planetary systems, stars, black holes and galaxies. US contribution of a spectrometer to SPICA will provide our community with access to all of the SPICA instruments, including a coronagraph, and imaging spectrometers. The schedule for SPICA is very tight. On July 8, 2008, SPICA entered a "pre-project phase", corresponding to a NASA Phase-A study, and European astronomers are currently studying a contribution of the SPICA telescope and an instrument through ESA's Cosmic Visions program. To keep US options open, NASA should soon initiate steps for formal US participation with consent of the Decadal Review. A further priority and long-term goal for continuity into the 2020-2035 era is a program of sensitive imaging and spectroscopic observations capable of resolving small-scale cosmic structure across the entire FIR/SMM range. This will require both (i) the light-gathering power of a 10-m class cryogenically-cooled telescope in space to allow us to study the formation and evolution of galaxies throughout cosmic time, traced by H2, dust, and key cooling lines, and (ii) a similarly cooled FIR/SMM spatial interferometer with angular resolving power matching that of JWST around 25 micron and ALMA in the SMM range. To realize this goal we propose, in 2010 – 2020, to: (i) prepare the scientific and technical prerequisites and (ii) conduct full phase-A studies of both a 10-m class cryogenically cooled Single Aperture Far-Infrared Telescope, SAFIR, and a similarly cooled FIR/SMM spatial-spectral interferometer with angular resolving power matching that of JWST, before the end of the decade. These activities will allow the Decadal Review of 2020 to recommend which of these two missions best meets the scientific priorities and is technologically ready at that time. Our priority would be that one of these missions be launched before 2030, the other before 2035. Both a SAFIR-class telescope and a space-based infrared interferometer (now exemplified by the SPIRIT mission concept) were recognized in the 2000 Decadal Review, which stated (page 110) "A rational coordinated program for space optical and infrared astronomy would build on the experience gained with NGST to construct SAFIR, and then ultimately, in the decade 2010 to 2020, build on the SAFIR,TPF, and SIM experience to assemble a space-based, far-infrared interferometer." Although the envisioned schedule has slipped, the successes of the ISO and Spitzer missions have made this thrust even more compelling today than it was ten years ago, so that BLISS, SAFIR and SPIRIT have all undergone intensive studies commissioned by NASA since then --- for SAFIR as part of NASA's "Vision Missions," for BLISS and SPIRIT under the "Origins Probe" initiative. We believe that the program we propose for the decade 2010-2020 is both scientifically farsighted and technologically responsible. It will allow us to study the sky with balanced capabilities across the near-infrared to submillimeter electromagnetic spectrum, with a combination of space and ground-based observatories, enabling us to answer some of the deepest scientific questions of all time: "How did the first cosmic structures form? Where and when did the heavy chemical element abundances begin to rise? How did the ensuing chemical and mineralogical constituents influence the dynamics of stellar-system and black-hole formation? How did extrasolar planetary systems and their far-flung outer reaches attain a measure of stability? Where did the biogenic molecules, the seeds that led to the appearance of life, originate?

Anticipated Sponsor: NASA

Participating Individuals or Institutions: Participating Individuals: Martin Harwit (Cornell), George Helou (Caltech), Lee Armus (Caltech), C. Matt Bradford (JPL) , Paul F. Goldsmith (JPL), Michael Hauser (STScI), David Leisawitz (GSFC), Daniel F. Lester (U. Texas, Austin), George Rieke (U. Arizona, Tucson), and Stephen A. Rinehart (GSFC), With contributions from: Morten Andersen (Caltech), Philip Appleton (Caltech), Eric

Becklin (USRA), Chas Beichman (Caltech), Edwin A. Bergin (U. Michigan, Ann Arbor), Nicolas Billot (Caltech), Andrew Blain (Caltech), James J. Bock (JPL), Francois Boulanger (IAS, France), Michael E. Brown (Caltech), Adam Burrows (Princeton), Daniela Calzetti (U Massachusetts, Amherst), Sean J. Carey (Caltech), Christine H. Chen (STScI), Ed Churchwell (U. Wisconsin, Madison), Kalliopi Dasyra (Caltech), Peter K. Day (JPL), Vandana Desai (Caltech), Mark Devlin (U. Pennsylvania), Mark Dickinson (NOAO), C. Darren Dowell (JPL), Pierre Echternach (JPL), Fabiana Faustini (IFSI-Rome, Italy), Jacqueline Fischer (NRL), David T. Frayer (Caltech), Perry A. Gerakines (Birmingham, AB), Bob Gehrz (U. Minnesota), Varoujan Gorjian (Caltech), James G. Ingalls (Caltech), Kate G. Isaak (Cardiff, UK), Hannah Jang-Condell (UMD), Matthew E. Kenyon (JPL), Peter Lawson (JPL), Joseph Lazio (NRL), Matt Malkan (UCLA), Peter G. Martin (Toronto, Canada), Hideo Matsuhara (ISAS, Japan), Margaret Meixner (STScI), Gary Melnick (SAO), Sergio Molinari (ISFI-Rome, Italy), Mark Morris (UCLA), Eric J. Murphy (Caltech), Takao Nakagawa (ISAS, Japan), Patrick Ogle (Caltech), Christopher G. Paine (JPL), Yvonne Pendleton (NASA/ARC), Andreea O. Petric (Caltech), Judy Pipher (Rochester), Takashi Onaka (U. Tokyo, Japan), Simon Radford (Caltech), Jeonghee Rho (Caltech), Jane Rigby (Carnegie), Aki Roberge (GSFC), Samir Salim, Michael Shull, Robert F. Silverberg (GSFC), J. D. Smith (Toledo), Philip H. Stahl (GSFC), Christopher C. Stark (UMD), Haroyuki Sugita (JAXA, Japan), Motohide Tamura (Nat'l Astron Obs., Japan), Martin Ward (Durham, UK), Michael Werner (JPL), Al Wootten (NRAO), Harold W. Yorke (JPL), and Jonas Zmuidzinas (Caltech)

Current Status: The schedule for SPICA is very tight. On July 8, 2008, SPICA entered a "pre-project phase", corresponding to a NASA Phase-A study; and European astronomers are currently studying a contribution of the SPICA telescope and an instrument through ESA's Cosmic Visions program. Instrument resource allocations (volume, mass, power, etc) are currently underway, and to keep US options open, NASA should soon initiate steps for formal US participation with consent of the Decadal Review. A US Background-Limited Infrared Spectrometer for SPICA, BLISS, has been under pre-phase-A study in the US for more than 4 years. The effort was initiated with a NASA award as part of the Origins Probe studies in 2003, and has also received 3 years of modest detector development funds through the ROSES program. The anticipated end-to-end cost to NASA for participation on SPICA, from inception through instrument delivery, mission operations, data archiving and processing support for the mission, and grant support for participating US astronomers is expected to be in the range of $250--300M, approximately half of which will be devoted to construction and testing of instrument hardware. In return for this investment, the US scientific community will obtain access to all of SPICA’s instruments on a competitive basis, an arrangement paralleling NASA’s agreement with ESA on Herschel, where the US community is reaping similar benefits in return for a comparable investment of NASA funds.

Additional Information: A more detailed white paper draft can be found at http://www.ipac.caltech.edu/Main/files/WhitePaperDraftv8b.pdf

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3. A Program of Technology Development and of Sub-Orbital Observations of the Cosmic Microwave Background Polarization Leading to and Including a Satellite Mission

Point of Contact: Shaul Hanany, U. of Minnesota; Stephan Meyer, U. of Chicago

Summary Description: At times close to the big bang the Universe evolved in ways which are outside of our current understanding, including the nature and cause for an early inflationary epoch. Measurements of the polarization of the cosmic microwave background radiation (CMB) probe these early epochs to provide information on physics at energy scales unattainable by any other mean. They will also significantly improve our information on the masses of the neutrinos, constrain the level of dark energy, elucidate structure formation in the Universe, and be an excellent probe of the epoch of reionization. A detailed map of the polarization of the CMB may provide yet unanticipated discoveries that could revolutionize our understanding of the Universe. We are representing the US CMB community in advocating a comprehensive program of technology development and of sub-orbital observations that leads to and includes a dedicated satellite, which is the only definitive way to fully exploit the abundant cosmological and astrophysical information encoded in the cosmic microwave background.

Anticipated Sponsor: DOE, NASA, NSF, Other

All three agencies have supported aspects of technology development for, and observations of the CMB as well as in the analysis of data from these observations. We are advocating that this participation will continue into the next decade.

Participating Individuals or Institutions: The US CMB community.

Current Status: Pre-phase A

Additional Information:

The Primordial Polarization Program Definition Team, a NASA appointed committee, has been chartered to provide a point of contact with the CMB community. The committee's web site is http://pppdt.physics.umn.edu/. Our proposed CMB program is the collective work of the entire US CMB community. It is partially funded by NASA as part of its Strategic Mission Concept Study program. The web site for the Mission Concept Study work is http://cmbpol.uchicago.edu/. NASA funded 3 CMBPol concept studies in the middle of the current decade. A report summarizing the work of one of these concept studies is available at astro-ph/0805.4207

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4. A Soft X-ray Spectropolarimeter

Point of Contact: Herman L. Marshall, MIT

Summary Description: We would develop an instrument capable of measuring linear X-ray polarization over a broad-band using conventional spectroscopic optics. A set of multilayer-coated flats reflect the dispersed X-rays to the instrument detectors. The intensity variation as a function of energy and position angle is measured to determine three Stokes parameters: I, Q, and U. By laterally grading the multilayer optics and matching the dispersion of the gratings, one may take advantage of high multilayer reflectivities and achieve modulation factors over 80% over the entire 0.2 to 0.8 keV band. This instrument could be used in a small orbiting mission and later scaled up for the International X-ray observatory. Laboratory work has been proposed that would demonstrate the capabilities of key components.

Anticipated Sponsor: NASA

Participating Individuals or Institutions: Ralf Heilmann and Norbert Schulz (MIT)

Current Status: Currently in conceptual design. Early versions were proposed for the SMEX and University Explorer programs. The demonstration laboratory was proposed to the NASA Astrophysics and Research Analysis (APRA) program.

Additional Information:

http://space.mit.edu/home/hermanm/polarimeter/polarimeter2.html

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5. A technical activity dedicated to high-dimensional data management, analysis and visualization.

Point of Contact: Dr. Misha (Meyer) Pesenson, SSC, Caltech

Summary Description: The era of large data sets, collected with a density and depth

previously unimaginable, demands new ways of data processing, retrieval and visualization. For example, the LSST coming online will be generating 15 terabytes of raw data and more than 100 terabytes of processed data every night, thus making the high-dimensional information management crucial for effective data mining. The goal of the proposed technical activity is to implement and further develop novel nonlinear data dimension reduction methods for multitemporal/multispectral astronomy, massive data sets from very large numbers of distributed sensors, stellar spectra, data compression, image retrieval, etc.. The approach is based on the fact that the sets of eigenfunctions and eigenvalues of certain operators encode intrinsic geometric information about the graph that represents data and thus can be used for dimension reduction. The methods will be incorporated into a framework that will provide an integrated environment for advanced image/data processing, nonlinear spectral domain dimension reduction methods and visualization, thus facilitating automated analysis of high-dimensional data. A prototype of the framework is described in Pesenson, et al., "Multiscale Astronomical Image Processing Based on Nonlinear Partial Differential Equations", ApJ, 683:566, 2008. See also:
Pesenson, M., Pesenson, I., et al., "More to Astronomical Images than Meets the Eye: data Dimension Reduction for Efficient Data Organization, Retrieval and Advanced Visualization and Analysis of Large Multitemporal/Multispectral Data Sets," AAS 213th, Long Beach, January 5, 2009.
Pesenson, I., Pesenson, M., "Sampling, Filtering and Multiscale Approximation on Combinatorial Graphs", Journal of Fourier Analysis and Applications (submitted).
Pesenson, I., Pesenson, M., "Eigenmaps, Minimal and Bandlimited Immersions of Graphs into Euclidian Spaces," Journal of Computational Complexity (submitted).
Pesenson I., 2008, Variational splines in Paley-Wiener spaces on combinatorial graphs (to appear in Conctructive Approximation).
Pesenson I., 2008, Approximations to eigenvalues and eigenfunctions on combinatorial graphs (to appear in SIAM Journal of Discrete Mathematics).
Anticipated Sponsor: Other
A grant from the National Geospatial-Intelligence Agency (NGIA) for developing a framework for analysis and visualization of high-dimensional data sets and hyperspectral images has recently been awarded. The PI - Meyer Pesenson. It is a five-year, $150 K/year grant.
Participating Individuals or Institutions: Dr. Isaac Pesenson (Temple University)
Current Status: Design and Development
Additional Information:

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6. A Vigorous Explorer Program

Point of Contact: Martin Elvis, Harvard-Smithsonian Center for Astrophysics
Summary Description: We advocate a vigorous Explorer program in astrophysics, as a part of NASAs competed mission lines with a regular cadence of flight opportunities. The Explorer program is important to the Nation's astrophysics program because:
A. Explorers, with their sister sub-orbital and Discovery programs, allow a rapid response to changing science and technology compared with the flagship large missions, within the timescale of a Decadal report, while preserving the quality criteria imposed by peer review;
B. Explorers have a distinguished history of providing world-class (including Nobel Prize winning) science (e.g. UHURU, IUE, RXTE, COBE, Trace, SWAS, FUSE, Swift, GALEX, WMAP), with a high success rate, as shown by the number one ranking of Swift in the recent Senior Review, ahead of some flagship missions in 'science per dollar';
C. There is a large number of excellent Explorer missions that could be done, as evidenced by the 48 SMEX proposals submitted in response to the last SMEX AO, 6 of

which were selected for Phase A, with a downselection to 2 for flight;
D. The Explorer program is an important part of the career pipeline for developing and maintaining advanced instrumentation expertise in the USA.

Anticipated Sponsor: NASA
Participating Individuals or Institutions: Matthew Beasley (U. CO, Boulder), Roger Brissenden (SAO), Michael Cherry (Louisiana State U.), Mark Devlin (U. Penn), Jerry Edelstein (UC Berkeley), Martin Elvis (SAO), Paul Feldman (Johns Hopkins U.), Neil Gehrels (NASA/GSFC), Leon Golub (SAO), James Green (U.CO, Boulder), Jonathan Grindlay (Harvard), Mary Elizabeth Kaiser (Johns Hopkins U.), Philip Kaaret (U. Iowa), Lisa Kaltenegger (Harvard), Justin Kasper (SAO), Jeffrey W. Kruk (Johns Hopkins U.), David Latham (SAO), John MacKenty (STScI), Herman Marshall (MIT), John Mather (NASA/GSFC), Christopher Martin (Caltech), Stephan McCandliss (Johns Hopkins U.), Mark McConnell (UNH), Jonathan McDowell (SAO), Robyn Millan (Dartmouth), John Mitchell (NASA/GSFC), Warren Moos (Johns Hopkins U.), Steven S. Murray (SAO), Willian Oegerle (NASA/GSFC), Brian Ramsey (NASA/MSFC), George Ricker (MIT), Stephen Rinehart (NASA/GSFC), Suzanne Romaine (SAO), Paul Scowen (Arizona State U.), Eric Silver (SAO), George Sonneborn (NASA/GSFC), Mark Swain (NASA/JPL), Jean Swank (NASA/GSFC), Martin Weisskopf (NASA/MSFC), Michael Werner (NASA/JPL)
Current Status: Ongoing, at a modest level.
Additional Information: Explorer Program launches:
http://www.planet4589.org/space/misc/explorer.html
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7. ACCESS -- a science and engineering assessment of medium-class space coronagraph concepts for the direct imaging and spectroscopy of exoplanetary systems

Point of Contact: John Trauger, Jet Propulsion Laboratory, California Institute of Technology.
Summary Description: A space coronagraph mission has the potential to revolutionize our understanding of the nature and evolution of nearby exoplanetary systems. The ACCESS study develops the science and engineering case, and evaluates our technology readiness, for coronagraphic imaging and spectroscopy of exoplanetary systems from space at visible wavelengths. ACCESS evaluates the science performance and engineering readiness of the four major coronagraph architectures, in the context of a conceptual space observatory platform that provides a "level playing field" for comparisons among coronagraph types. The study uses laboratory validation on JPL's High Contrast Imaging Testbed (HCIT) as a technology "level playing field" for evaluation of coronagraph hardware readiness. We identify capable mission concepts with high technology maturity, and thereby estimate the science reach of a NASA medium-class coronagraph mission that could be built today with proven technologies. ACCESS is one of four medium-class exoplanet concepts selected this year by NASA as an Astrophysics Strategic Mission Concept Study (ASMCS).
Anticipated Sponsor: NASA
Participating Individuals or Institutions: John Trauger, Karl Stapelfeldt, Wesley Traub, John Krist, Dwight Moody, Eugene Serabyn, Dimitri Mawet, Peggy Park, Curt Henry, Robert Gappinger, Paul Brugarolas, Olivia Dawson, Stuart Shaklan, Laurent Pueyo (Jet Propulsion Laboratory, California Institute of Technology); Olivier Guyon (U Arizona and Subaru Telescope); Jeremy Kasdin, David Spergel, Robert Vanderbei (Princeton University); Geoffrey Marcy (UC Berkeley); Robert A. Brown (STScI); Jean Schneider (Paris Observatory); Bruce Woodgate (NASA Goddard), Ruslan Belikov (NASA Ames); Gary Matthews, Robert Egerman (ITT); Ronald Polidan, Charles Lillie, Connie Spittler (Northrop Grumman); Thomas Price, Mark Ealey (NGC/Xinetics)

Current Status: Concept study for NASA's ASMCS program.
Additional Information:
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8. Adaptive optics for frontier science in the coming decade

Point of Contact: Michael Hart, University of Arizona
Summary Description: In late 2007, with the support of the NSF, a broad community-based panel of adaptive optics experts formulated a Roadmap for the development of AO in the US over the coming decade. This continued a process begun with the first national AO Roadmap published in 2000 and updated in 2004. Both the 1990 and 2000 Decadal Surveys stated the importance of AO to astronomy and both recommended that significant funds be allocated to R&D as well as to the deployment of AO instrumentation on existing and future telescopes. The community consensus expressed in the 2008 Roadmap recognized the rapidly growing scientific impact of AO, demonstrated by the accelerating publication rate of refereed journal articles based on AO data, as well as the essential role that AO will play in fulfilling the scientific potential of the next generation of large telescopes. The 2009 June meeting of the AAS will highlight recent AO based science and its impact across nearly all areas of astronomical research. The Roadmap panel also foresaw a severe threat to the leading position of US astronomy posed by the rapidly growing disparity in funding for AO development between the US and Europe. Unfortunately, the NSF's Adaptive Optics Development Program, founded on a strong recommendation of the previous decadal survey, was terminated after its first year of competition. Furthermore, 2009 will be the last year of NSF support for the Center for Adaptive Optics at UCSC. Thus, two major sources of public funding for AO development and implementation have been removed. If the US is to remain competitive in frontier science in the coming decade, substantial renewed investment is required. At the very least, we call for the revival of the NSF's AO Development Program at the level of $40M over the next 10 years, with additional significant public support to field major AO facilities on existing and planned telescopes over the next decade.
Anticipated Sponsor: NSF
Participating Individuals or Institutions: The US telescope user community across all aperture sizes.
Current Status: AO is now built into the infrastructure of the US O/IR large telescope capability, with almost every telescope of D>5 m operating or building a science program to exploit the high angular resolution and the greatly increased sensitivity it affords. Basic research continues to show how the advantages of AO can be extended in scientifically valuable directions: to both larger and smaller apertures, to shorter wavelengths, larger fields of view, and higher contrast. These new advanced techniques must be proven and implemented over the next decade with renewed investment to realize the enormous potential scientific gain.
Additional Information: The 2008 AO Roadmap can be found here:
http://www.aura-astronomy.org/nv/AO_Roadmap2008_Final.pdf
The original 2000 AO Roadmap is at: http://www.noao.edu/dir/ao/ao_whitepaper.pdf
The 2004 update is here: http://www.aura.noao.edu/system/aodp/2004-roadmap-update.pdf
AURA's assessment of the present state and future value of AO in the coming decade is at: http://www.aura-astronomy.org/nv/AURAs%20assessment%20of%20AO%20V4.pdf
ACCORD's support for AO is summarized here: http://www.aura-astronomy.org/nv/AO_WhitePaper_Accord.pdf
An article by Jay Frogel drawing attention to the disparity in funding between US and European efforts in AO and the potential impact on the scientific competitive stance of the US can be found starting on p.82 of the following:
http://www.gemini.edu/files/pio/newsletters/nwsltr33_12_2006.pdf

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9. Adaptive secondary mirrors for wide field and high sensitivity thermal IR adaptive optics science

Point of Contact: Michael Hart, University of Arizona
Summary Description: The value of incorporating adaptive wavefront correction directly into a large telescope at the secondary mirror was appreciated over a decade ago. The approach offers key advantages over conventional deformable mirrors for adaptive optics:
1. Thermal IR performance is enormously improved by eliminating the need for warm relay optics. This is particularly important to GSMT where the diffraction limit at 3-10 microns is much sharper than the seeing limit, so AO is of correspondingly greater value than at present 8 m telescopes.
2. Because etendue is a constant, the wide corrected fields of view offered by ground-layer AO are difficult to achieve without a large deformable mirror. Again, this is of particular importance to GSMT.
3. The large size of an ASM allows actuators with stroke an order of magnitude greater than conventional deformable mirrors. An ASM can thus correct overall image motion as well as high-order wavefront errors, and in addition can accomodate chopping for thermal IR imaging.
4. The exquisite shape control enabled by built-in position sensors allows fine compensation of diffraction, for very high contrast imaging of exoplanets at small angular separation.
The use of ASMs has been pioneered at the 6.5 m MMT, still the only telescope in the world that uses one. Current mirrors are limited to approximately 1 m in diameter by the technology to manufacture the thin glass membrane of the deformable surface, and by the maximum stroke of the edge actuators needed to provide a given angular throw. The need now is to develop technologies to make larger mirrors: to investigate alternative materials for the deformable facesheet and to develop high stroke actuators that can be packed more densely. We anticipate a cost similar to the initial development cost of the MMT's ASM of $10M.
Anticipated Sponsor: NSF, Other
The Air Force Research Lab, which funded the development of the MMT's ASM, is expected to be interested in further work on large curved DMs because of their ability to handle high power densities and correct large aberrations in high power laser beam propagation applications.
Participating Individuals or Institutions: University of Arizona, Large Binocular Telescope Observatory, Giant Magellan Telescope Observatory
Current Status: Only one telescope in the world presently operates with an ASM. Two other ASMs are nearing completion for the LBT. ESO expects to equip one unit of the VLT with an ASM which is currently in the design phase. At least one GSMT design - the GMT - plans an ASM as baseline, building on the technology developed for the LBT.
Additional Information: A paper describing the MMT's ASM and the first astronomical results obtained with it is at:
http://athene.as.arizona.edu:8000/preprints/SPIE.0803_FL.pdf

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10. Advanced Gamma ray Imaging System (AGIS)

Point of Contact: Frank Krennrich, Iowa State University
Summary Description: The Advanced Gamma ray Imaging System (AGIS) is a concept

for a next generation observatory in very high energy gamma-ray astronomy. The AGIS project is planned as a follow-up to the successful current generation of imaging atmospheric Cherenkov telescopes including HESS, MAGIC and VERITAS. Those instruments have discovered more than 70 gamma-ray sources in the TeV regime, providing important constraints to supernova remnants, pulsar wind nebulae, pulsars, binary systems, dark matter annihilation, active galaxies and intergalactic radiation fields. The design goals for AGIS are a ten times improved sensitivity, a better angular resolution, and a wider energy range compared to the existing generation Cherenkov observatories.

Anticipated Sponsor: DOE, NSF

Participating Individuals or Institutions:

Larry Ciupik, Lucy Fortson, Geza Gyuk, David Steele, Niklas Karlsson (Adler Astronomy Department), Karen Byrum, Gary Drake, Victor Guarino, Bob Wagner (Argonne National Lab), Reshmi Mukherjee (Barnard College, Columbia University), Jose Franco, David Hiriart (Instituto de Astronomia Observatorio Astronomico Nacional, Mexico), Adrian C. Rovero (Instituto de Astronomia y Fisica del Espacio, Argentina), Giovanni Pareschi (Istituto Nazionale di Astrofisica-Osservatorio Astronomico di Brera, Italy) Frank Krennrich, Martin Pohl, Martin Schroedter (Iowa State University), Gus Sinnis, Brenda Dingus (Los Alamos National Lab), Brian Ramsey (Marshall Space Flight Center), David Hanna (McGill University, Canada), Abe Falcone (Penn State University), Alex Konopelko (Pittsburgh State University), John Finley (Purdue University), Stefan Funk, Roger Romani, Hiro Tajima (Stanford/SLAC Kavli Institute for Particle Astrophysics), Pat Slane, Wystan Benbow, Trevor Weekes (Smithsonian Astrophysical Observatory), Rene Ong, Vladimir Vassiliev (UCLA), David Williams (UCSC), Simon Swordy, Scott Wakely (University of Chicago), Jamie Holder (University of Delaware), Phil Kaaret (University of Iowa), David Kieda, Stephan LeBohec (University of Utah), James Buckley, Slava Bugaev, Henric Krawczynski (Washington University)

Current Status: The AGIS collaboration has carried out design studies using simulations, a survey of existing technologies and technology development that are relevant for maximizing the performance and reducing the cost of a large array of Cherenkov telescopes such as AGIS.

Additional Information: official AGIS website: http://www.agis-observatory.org/
official APS White Paper website: http://cherenkov.physics.iastate.edu/wp/

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11. Advanced Modeling, Simulation & Analysis Capabilities for future Large Space Telescopes

Point of Contact: Gary Mosier, NASA GSFC

Summary Description: The success of future large space telescopes will depend on establishing modeling, simulation and analysis (MS&A) capabilities beyond the current state of the art. Advances in MS&A -- such as those called for in 2005 with the publication of the NASA Advanced Modeling, Simulation, and Analysis Technology Capability Roadmap and the NASA Advanced Telescope and Observatory Capability Roadmap -- are absolutely necessary for effective and credible model-based design and verification of large optical systems. With the publication in 2007 of NASA-STD-7009, the NASA Technical Standard for Models and Simulations (M&S), the agency has placed an increased emphasis on the credibility of M&S results which affect all critical decisions throughout the mission life cycle. For the types of systems and missions envisioned, many critical system-level requirements cannot be verified and validated by tests given the sheer size of the structures, or else other facility limitations such as gravity loading, vibrations, and temperature instabilities preclude testing to the demanding performance levels. Recent experiences with JWST, TPF, and SIM have shown that advances in MS&A capabilities are also required in order to deal with the complex physics introduced by both the increased performance demands and the application of active compensation approaches to control telescope pointing and wavefront. Key, specific challenges are integration of physics-based performance models with Model-Based Systems Engineering (MBSE) and Product Data Management (PDM) tools and environments, establishment of Verification and Validation (V&V) processes for the physics-based models & simulations, development of methods for accurate and efficient sensitivity and uncertainty analyses, and development of tools with the ability to handle extremely large models and to couple effectively across discipline boundaries. It is envisioned that the required MS&A capabilities can be demonstrated via a sub-scale hardware testbed that provides a "blind test", and performing, in effect, a dress rehearsal of a prototype mission life-cycle for a large space telescope in which MS&A activities are tightly integrated throughout every mission phase to all relevant systems engineering activities.

Anticipated Sponsor: DOE, NASA, DoD

Participating Individuals or Institutions: NASA Goddard Space Flight Center, NASA Jet Propulsion Laboratory, NASA Marshall Space Flight Center, NASA Langley Research Center, Space Telescope Science Institute, Northrop Grumman Aerospace Systems, Ball Aerospace & Technologies Corporation, Lockheed Martin Corporation, Massachusetts Institute of Technology, Nightsky Systems, Inc.

Current Status: Pre-phase A

Additional Information: NASA Technical Standard for Models and Simulations:
http://standards.nasa.gov/public/public_count.taf?system=PUBLIC&event=PUBLIC_DD&Linkid=6365

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12. Advanced Technology Development for Long Term Astrophysics Objectives

Point of Contact: Peter M. Hughes, NASA GSFC; Paul E. Dimotakis, NASA JPL

Summary Description: The loss of NASA technology funding for medium- and long-term support of strategic Astrophysics goals has become a major threat to scientific accomplishment. A sustained technology-investment program, in support of likely future astrophysics missions, is one of the most enabling capabilities that NASA SMD and the Astrophysics Division could reintroduce. Until about 2006, when NASA HQ converted its cross-enterprise technology directorate into enabling technologies limited to human spaceflight, coordinated long-term investments included long-wavelength detectors for both astronomy and Earth science, radiation-hardened electronics for extreme environments, lightweight materials, precision-formation flying, spatial interferometry, and other capabilities. Such a sustained investment program is most enabling for small- and medium-size missions and can address the long-lead and maturation times that such technologies require. The current NASA SMD policy is to include major technology needs within large projects themselves, once the latter have been defined. Unfortunately, this approach does not recognize the different time scales required for technology development and maturation, vs. mission development and implementation. Other decade reviews, external assessments, and the US Congress have all encouraged NASA to re-institute its advanced technology program.

Anticipated Sponsor: NASA

Participating Individuals or Institutions: Paul E. Dimotakis (JPL) and John K. Northrop (Caltech), Peter M. Hughes (NASA GSFC)
http://scienceandtechnology.jpl.nasa.gov/ocsct/chieftechnologist/
http://gsfctechnology.gsfc.nasa.gov/

Current Status:

Additional Information:

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13. Advanced Technology Large Aperture Space Telescope (ATLAST): A Technology Roadmap for the Next Decade

Point of Contact: Marc Postman, STScI
Summary Description: Two of the most compelling astrophysical pursuits in the next two decades are the detection of life-bearing or habitable exoplanets in the local solar neighborhood and the direct determination of the evolution of the mass functions of astrophysical systems on a variety of scales (e.g., the stellar IMF, the growth of supermassive black holes over cosmic time, the masses of galactic halos). The former will be a major step in answering the long sought question - Are We Alone? The latter investigations will yield great leaps in our understanding of the dynamics of dark matter and the formation of structure in the universe. Definitive answers to these fundamental questions require resolutions and sensitivities that are provided by a UVOIR space telescope with an aperture of at least 8-meters. Making such an Advanced-Technology Large-Aperture Space Telescope (ATLAST) affordable is feasible if the nation invests in a coordinated technology development program that, at the end of the coming decade, enables the fabrication of 2.4 meter lightweight mirror segments and/or large space-qualified monolithic mirrors, milli-arcsecond attitude control systems, active wave front sensing and control systems, large deployable external occulters (a.k.a. starshades), photon counting Gigapixel detector arrays, and advances in the modeling and testing of large optical systems. The ATLAST Strategic Mission Concept study is a team of NASA, industry, and academic investigators studying three telescope point designs (an 8m monolithic telescope and 10m and 16m segmented telescopes) to assess the current state-of-the-art and develop an estimate of the cost and scope of the required technology development program, and its primary science drivers, that would enable a mission to be launched in a 15-year timeframe.
Anticipated Sponsor: NASA, ESA (European Space Agency)
Participating Individuals or Institutions: We have ~55 people participating in this study from the following institutions, centers, and corporations: Princeton University, Space Telescope Science Institute, University of Massachusetts, Amherst, University of Colorado, Boulder, NASA Goddard Space Flight Center, NASA Marshall Space Flight Center, NASA Jet Propulsion Laboratory, NASA Johnson Space Flight Center, Northrop Grumman Aerospace Systems, Ball Aerospace & Technologies Corporation, Xinetics, Inc.
Current Status: Pre-phase A (concept study)
Additional Information: http://www.stsci.edu/institute/atlast

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14. All Sky Monitoring in all time domains down to 1 micro second in the hard X-ray (about 10-100 keV)

Point of Contact: Mel Ulmer, Northwestern University
Summary Description: To be the equivalent of the LSST but in space for hard X-rays. There would be no trigger. All the data would be sent down. This would examine a phase space that has not been thoroughly examined. The project can be done for MidEx budget.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: TBD, At least Ball Aerospace said they would help, and perhaps Laboratoire d'Astrophsique de Marseille (LAM) might be interested.
Current Status: Full Blown Midex proposal plus a SPIE paper
Additional Information: http://www.astro.northwestern.edu/~ulmer/ then click on ALLEGRO

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15. All Sky Transit Mission

Point of Contact: Charles Beichman, NASA JPL
Summary Description: An All Sky Transit mission (generically called ASTM) would improve our understanding of the formation and evolution of planets by identifying and studying transiting planets orbiting the brightest, closest stars in solar neighborhood. By monitoring more than 2 million of the brightest stars over the entire celestial sphere (with somewhat lower accuracy in the confusion-limited Galactic plane) ASTM would find over 2,000 planets including hundreds of rocky planets. With a suite of ~20 small (10 cm aperture) cameras on a spacecraft in a stable orbit, possibly at L2, ASTM would provide <100 micro-mag photometric precision (50 micro-mag goal) with up to 60 days of un-interrupted coverage. This performance can be compared with ground-based surveys such as SuperWasp with a precision of 2,000 micro-mag and highly non-uniform temporal coverage. With its deep-red visible and/or near-IR operation, ASTM would be particularly well suited to studying late K and M stars where the detected planets will be in or near their "habitable zones." ASTM's planetary systems would be located between 25 and 300 pc away from the Sun making them well suited to intensive follow-up. ASTM would provide timing and light curves for systems 5-10 times closer and 25-100 times brighter than those found by earlier projects. The brighter magnitudes of these stars, compared with CoRoT and Kepler surveys, V=4-12 mag vs V=10-16 mag, will greatly improve the feasibility of a) visible spectroscopy for validation and mass determination with ground-based telescopes and b) space-based observations of primary and secondary transit observations for atmospheric characterization. A small scale version of this mission, the Transiting Exoplanet Survey Satellite (TESS; G. Ricker, MIT, PI), is presently under consideration as a SMEX. Depending on the specific mission requirements (precision, duration of uninterrupted coverage, wavelength band, etc), ASTM's scientific goals could be achieved at a cost between that of an Explorer project and ExoPlanet probe. An all-sky transit survey in the near-infrared explicitly focused on late type stars should be a high priority for the coming decade. In particular, execution of this project in a timely manner should be carefully considered to ensure overlap with JWST.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: C. Beichman (Caltech/JPL), M. Swain (JPL), D. Deming (GSFC), D. Latham (CfA), D. Charbonnneau (CfA)
Current Status: Mission Concept
Additional Information:

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16. An Imaging X-Ray Polarimetry Mission

Point of Contact: Martin C. Weisskopf, NASA MSFC
Summary Description: The goal of this mission is to probe the extreme, anisotropic astrophysical environments characterized by strong magnetic, electric, and/or graviational fields, such as those found near neutron stars, stellar-mass black holes, and supermassive black holes.
Anticipated Sponsor: NASA
We are in discussions with other foreign governments including Italy. The results of these discussions will be included in the white paper
Participating Individuals or Institutions: M. Weisskopf, A.Tennant, R.Elsner, S.Odell (NASA/MSFC), V. Zavlin (USRA), G. Pavlov (PSU), P. Coppi (Yale University), K.W. Wuh (University College London), others will be listed in the submission of the white paper
Current Status: All the experiment technology has been demonstrated by test to be at TRL 6. The S/C requirements are straightforward and met by off-the shelf hardware and

systems.
Additional Information:
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17. Ares V Heavy Lift Launch Vehicle

Point of Contact: Greg Sullivan, NASA MSFC/JI
Summary Description: The Ares V launch vehicle is a national asset that is being developed by NASA for the Constellation Program. This launch vehicle has potential multiple science applications as reported by the NRC "Science Opportunities Provided by NASA's Constellation Systems", NASA Ames sponsored workshops "Workshop Report on Astronomy Enabled by Ares V" (NASA/CP-2008-214588) among other national and international papers and presentations. The large volume and lift capabilities could provide a unique platform to enable breakthrough astronomy and future science discovery.
Anticipated Sponsor: NASA
The Ares V Heavy Lift Launch Vehicle is being developed by NASA at the present time.
Participating Individuals or Institutions: Greg Sullivan MSFC/JI, Bruce Morris/MSFC, Phil Sumrall/MSFC
Current Status: Critical Ares V technologies (core stage propulsion, upper stage propulsion, avionics, solid rocket boosters, other) are in design, development and ground testing on the associated Ares 1 and Air Force programs. The Ares V Vehicle is in the initial design phase.
Additional Information: The Ares V Heavy Lift Launch Vehicle has many applications above and beyond the Constellation Program. It is a national asset that has more lift and volume capability (5-6 times more) than any current or planned launch vehicle
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18. Argos-X: A Panoptic X-ray Observatory

Point of Contact: Dr. Ronald A. Remillard, MIT Kavli Center for Astrophysics and Space Research
Summary Description: Argos-X is the concept for an Explorer-SMEX observatory that instantaneously views 50% of the sky, while providing arcmin positions. The coded-mask cameras use Si pixel detectors to provide sub-ms time resolution, 1.5-28 keV sensitivity, and 600 eV spectral resolution. The quality of data products rises to the level associated with pointed instruments. The mastery of wide-angle X-ray spectroscopy provides unprecedented exposures of all sources and the unique capability to routinely collect data during times of critical interest. The primary objective is to advance the methods by which the radiation properties of accreting matter, under strong gravity, are used to investigate the physical properties of black holes and neutron stars, located in the Galaxy, the local universe, and beyond. Secondarily, Argos-X offers synergistic partnerships for Advanced LIGO, Fermi/GLAST, wide-angle radio observatories, TeV telescopes, and other programs. The rationale for submitting this Astro2010 NOI is to illustrate science opportunities, to substantiate interest in the NASA Explorer program, and to advocate for a funding balance between small and larger programs.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: A. Levine, E. Morgan, D. Chakrabarty, J. Homan (MIT), P. Ray, B. Phlips, K. Wood, E. Novikova (NRL), G. De Geronimo (Brookhaven), F. Marshall (NASA/GSFC), J. Bloom, E. Quataert (UC Berkeley), S. Eikenberry (U FL), M. Elvis (Smithsonian CFA), H. Krawczynski (Washington U), J. Miller (U MI), J. Orosz (SDSU), F. Aharonian (MPIK Heidelberg; DE), R. Fender, I. McHardy (U Southampton; UK), V. Kaspi (McGill; CA).

Current Status: Proposal
Additional Information: http://xte.mit.edu/~rr/astro2010_argosx.ppt
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19. Astronomy on Antarctic Plateau

Point of Contact: Prof. Lifan Wang, Texas A&M University
Summary Description: Antarctic Plateau may emerge as an exciting site for astronomy. Recent site surveys of Dome A and Dome C have revealed a very low boundary layer of the turbulent atmosphere of only about 30 m (Dome C) and 9.5 m (Dome A). The site offers unparalleled opportunity for high resolution optical/IR and sub-millimeter observations. We will conduct extensive surveys of these sites in the coming years, and gradually develop astronomical instruments to take advantage of the unique conditions of Dome A/C. In the white paper, we will highlights three areas that we expect huge scientific returns: (1) time-domain astronomy to take advantage of the continuously observable antarctic winter; (2) deep, high spatial resolution surveys in the optical and especially in the thermal infrared; and (3) sub-millimeter observations.
Anticipated Sponsor: DOE , NASA, NSF, Chinese Academy of Sciences, National Science Foundation of China
Participating Individuals or Institutions: Polar Research Institute of China, Purple Mountain Observatory, National Astronomical Observatory of China, University of New South Wales, University of Manchester, Texas A&M University, Caltech, University of California, Berkely, University of Chicago
Current Status: Design and Development
Additional Information: http://Dome-A.physics.tamu.edu/~lifanwang/APAP
http://ccaa.pmo.ac.cn
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20. Astrophysics Sounding Rocket Assessment Team

Point of Contact: Christopher Martin
Summary Description: The Astrophysics Sounding Rocket program has had, and will continue to have, a profound impact on the success of the nation's space science program. It provides fresh and timely scientific seeds, critical technology development, and irreplaceable recruitment and training of future mission leaders. The program has, however, lost much of its vitality and must be renewed. A rededication to this program will pay off dramatically in the scope, cost-effectiveness, and scientific discovery potential of NASA's future medium and large missions. The Astrophysics Sounding Rocket Assessment Team is considering steps that should taken in the next 5-10 years to revitalize this foundational program. We would welcome the opportunity to inform Astro2010 about the importance of the Astrophysics Sounding Rocket program and the direction the program should take to maintain its scientific impact and strategic benefits.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Supriya Chakrabarti, Ray Cruddace, Don Figer, Orlando Figueroa, Walt Harris, Chris Martin, Dan McCammon (prior to his participation in Astro2010), Steve McCandliss, Ken Nordsieck, Ron Polidan, Erik Wilkinson
Current Status: The Astrophysics Sounding Rocket Assessment Team has been active since January 2008 and has drafted a white paper with its findings.
Additional Information: Available soon.
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21. Atacama Large Millimeter/submillimeter Array Instrumental Development

Point of Contact: Alwyn Wootten, NRAO

Summary Description: Continuing technical and software upgrades and development of new capabilities will be required to maintain the Atacama Large Millimeter/submillimeter Array (ALMA) as the state-of-the-art facility for millimeter/submillimeter astronomy over the course of its projected life of 30+ years. In particular, the rapid progress of electronic technology should make new hardware components and subsystems offering improved performance and higher reliability available for incorporation into ALMA throughout the project lifetime. Equally important, advances in software and computing will offer improved performance and reliability that translate into more capability and reduced costs of operation. The tri-lateral project has recognized that continued hardware and software development are essential to keep ALMA up-to-date with the rapidly advances in these areas, thereby keeping ALMA at the fore-front of astronomical research for its projected 30+ year lifetime. ALMA is in the process of creating a science-driven long-range development plan with a particular focus on the 2010-2020 decade. The ALMA Operations Plan suggests example science goals and projects at a level of $5M fron North America; this was reviewed and endorsed by international and national reviewers. These include:

* Expansion of frequency coverage. Only 2/3 of the planned ALMA bands will be fully populated during construction. Coverage of the frequencies below 84 GHz and of frequencies around the 163-211 bands is to be accomplished with receivers developed during Operations, from Development funding. Science enabled by the former includes * the important $z>0.35$ range in the CO J=1-0 line; during this period the prodigious star formation which characterized the distant Universe calmed and spiral galaxies gained their familiar shapes and * imaging of the Sunyaev-Zeldovich decrement in the cosmic background radiation toward galaxy clusters.

* VLBI capability. ALMA will provide a two order of magnitude increase in submillimeter imaging capability. With very long baseline interferometry it may be combined with other facilities to provide another factor of one thousand, to enable imaging of the hot material spiraling into the black hole at the Galaxy's center, directly probing the physics of matter under the influence of very strong gravitational fields.

* Multifield capability: In the long term, ALMA's powerful capabilities may be multiplied through the use of multibeam receivers, greatly increasing its imaging and survey speed especially at the shortest wavelengths. With ALMA's high resolution and low sensitivity to confusion deep high resolution observations covering much wider fields than a single pixel can allow will enhance our understanding of regions from star and planet forming disks to distant galaxies.

This ALMA program is part of a broader NRAO vision that capitalizes on the major infrastructure investment in our facilities, and the scientific complementarity of these facilities, to address the major outstanding questions in modern astrophysics.

Anticipated Sponsor: NSF

Participating Individuals or Institutions: NRAO/AUI, HIA/NRC (Canada), ASIAA/TECRO/AIT (Taiwan), ESO, NAOJ/NINS

Current Status: Construction; Inauguration expected 2012. Most development enhancements have been roughly costed.

Additional Information: http://www.nrao.edu/A2010 (Web page to be implemented)

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22. Auger North

Point of Contact: Paul Sommers, Pennsylvania State University

Summary Description: Early results from the Pierre Auger Cosmic Ray Observatory have shown that a new realm of astrophysics will be opened by a systematic study of the highest energy cosmic rays. The arrival directions of trans-GZK cosmic rays exhibit the celestial distribution of the inhomogeneous matter in the local universe, correlating in particular with positions of nearby active galactic nuclei. The international Auger Collaboration is committed to its design for observatory sites in both the southern and northern hemispheres so as to map the entire sky and achieve sensitivity to discrete sources in all directions. Auger South was completed in 2008, and a small R&D array for Auger North will be constructed in 2009 at the Colorado site. Charged particle astronomy will only become a reality by greatly expanding the Auger aperture to acquire a rich data set of trans-GZK cosmic ray measurements. The proposed aperture for Auger North is seven times that of Auger South. Identifying sources of the highest energy cosmic rays will beautifully complement the information about high energy processes obtained from other messengers with detectors such as Fermi, VERITAS, and IceCube. The charged particle astronomy of Auger will also provide a new measurement of cosmic magnetic fields which should lead to breakthroughs in understanding the properties and dynamics of the interstellar and intergalactic media. Besides determining the arrival direction and energy of each cosmic ray, the Auger hybrid measurements of air showers provide information from which one can extract particle interaction cross sections, inelasticity, and multiplicity at center-of-mass energies above 250 TeV.

Anticipated Sponsor: DOE, NSF

Participating Individuals or Institutions: Institutions of the International Auger Collaboration: Centro Atómico Bariloche (Gerencia de Física), Comisión Nacional de Energía (Argentina), Centro Atómico Constituyentes (Laboratorio Tandar), Comisión Nacional de Energía (Atómica), Centro de Investigaciones en Láseres y Aplicaciones, CITEFA and CONICET, Departamento de Física, FCEyN, Universidad de Buenos Aires, IFLP, Universidad Nacional de La Plata and CONICET, Instituto Balseiro (CNEA-UNC), Instituto de Astronomía y Física del Espacio, CONICET, Universidad Tecnológica Nacional, FR-Mendoza (Atómica), University of Adelaide (Australia), Universidad Catolica de Bolivia, Universidad Mayor de San Andrés (Bolivia), Centro Brasileiro de Pesquisas Fisicas (CBPF), Pontifícia Universidade Católica, Rio de Janeiro, Universidade de Sao Paulo, Inst. de Fisica, Universidade Estadual de Campinas (UNICAMP), Universidade Estadual de Feira de Santana (UEFS), Universidade Estadual do Sudoeste da Bahia (UESB), Universidade Federal da Bahia, Universidade Federal do ABC (UFABC), Universidade Federal do Rio de Janeiro (UFRJ), Universidade Federal Fluminense (Brazil), Rudjer Boškovic Institute (Croatia), Charles University Prague, Institute of Particle and Nuclear Physics, Institute of Physics (FZU) of the Academy of Sciences of the Czech Republic, Palacký University Olomouc (Czech Republic), Centre de Calcul de l'In2p3, (CCIN2P3), CNRS-IN2P3, Institut de Physique Nucléaire d'Orsay (IPNO), Université Paris 11, CNRS-IN2P3, Laboratoire AstroParticule et Cosmologie (APC), Université Paris 7, CNRS-IN2P3, Laboratoire de l'Accélérateur Linéaire (LAL), Université Paris 11, CNRS-IN2P3, Laboratoire de Physique Nucléaire et de Hautes Energies (LPNHE), Universités Paris 6 et Paris 7, Laboratoire de Physique Subatomique et de Cosmologie (LPSC), Université Joseph Fourier, SUBATECH (France), Bergische Universität Wuppertal, Forschungszentrum Karlsruhe - Institut für Kernphysik, Forschungszentrum Karlsruhe - Institut für Prozessdatenverarbeitung und Elektronik, Max-Planck-Institut für Radioastronomie and Universität Bonn, Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen, Universität Karlsruhe (TH) - Institut für Experimentelle Kernphysik (IEKP), Universität Siegen, University of Hamburg (Germany), Dipartimento di Fisica dell'Università and INFN Genova, Dipartimento di Fisica dell'Università and INFN L'Aquila, Dipartimento di Fisica dell'Università and Sezione

INFN, Milano, Dipartimento di Fisica dell'Università del Salento and Sezione INFN, Lecce, Dipartimento di Fisica dell'Università di Napoli "Federico II" and Sezione INFN, Napoli, Dipartimento di Fisica dell'Università di Roma “Tor Vergata” and Sezione INFN Roma II, Dipartimento di Fisica e Astronomia dell'Università di Catania and Sezione INFN, Catania, Dipartimento di Fisica Sperimentale dell'Università and Sezione INFN, Torino, Dipartimento di Ingegneria dell'Innovazione dell'Università del Salento and Sezione INFN, Lecce, Istituto di Astrofisica Spaziale e Fisica Cosmica di Palermo (INAF) and Sezione INFN, Catania, Istituto di Fisica dello Spazio Interplanetario (INAF), Dipartimento di Fisica Generale dell'Università and Sezione INFN, Torino, Laboratori Nazionali del Gran Sasso, INFN, Osservatorio Astrofisico di Arcetri Sezione INFN, Napoli (Italy), Benemérita Universidad Autónoma de Puebla (BUAP), Centro de Investigación y de Estudios Avanzados del IPN (CINVESTAV), Universidad Michoacana de San Nicolás de Hidalgo, Universidad Nacional Autónoma de México (Mexico), Institute for Mathematics, Astrophysics and Particle, Physics (IMAPP), Radboud Universiteit, Nijmegen, Kernfysisch Versneller Instituut (KVI), University of Groningen, Nationaal Instituut voor Kernfysica en Hoge Energie Fysica (NIKHEF), Stichting Astronomisch Onderzoek in Nederland (ASTRON), Dwingeloo (Netherlands), The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, University of Lódz (Poland), Laboratory of Instrumentation and Experimental Particle Physics (Portugal), J. Stefan Institute, University of Nova Gorica (Slovenia), Instituto de Física Corpuscular, CSIC-Universitat de València, Universidad Complutense de Madrid, Universidad de Alcalá de Henares, Universidad de Granada, Universidad de Santiago de Compostela (Spain), Rudolph Peierls Centre for Theoretical Physics, University of Oxford, University of Leeds, School of Physics & Astronomy (United Kingdom), Argonne National Laboratory, Case Western Reserve University, Colorado School of Mines, Colorado State University, Fort Collins, Colorado State University, Pueblo, Fermilab National Accelerator Laboratory, Louisiana State University, Michigan Technological University, New York University, Northeastern University, Ohio State University, Pennsylvania State University, University of California, Los Angeles, University of Chicago, University of Colorado, University of Minnesota, University of Nebraska, University of New Mexico, University of Wisconsin-Madison, University of Wisconsin-Milwaukee (USA), Institute of Nuclear Science and Technology, Hanoi (Vietnam)

Current Status: The design for Auger North is complete, based largely on the successful implementation in Argentina. A large international collaboration exists which has demonstrated a strong partnership and successful management structure. A small R&D array of instrumentation is being deployed this year at the site of Auger North in Colorado to test some hardware modifications.

Additional Information: Auger web site: http://www.auger.org/
Public event display: http://auger.colostate.edu/ED/
Auger North: http://www.augernorth.org/

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23. BEST

Point of Contact: Mark R. Swain, NASA JPL

Summary Description: BEST, the Balloon-borne Exoplanet Spectroscopy Telescope, is a new concept for a suborbital mission that characterizes the atmospheres of exoplanets using molecules as probes of conditions, composition, and chemistry. By detecting and measuring the abundances of prebiotic molecules such as H2O, CH4, and NH3 in exoplanet atmospheres, BEST could be an important step towards characterizing habitable-zone planets. Following an approach demonstrated with both Hubble and Spitzer, BEST separates the star and exoplanet light by compiling spectral light curves of a spatially unresolved extra-solar system. This approach requires high photometric stability, making it necessary to place the telescope above the variable and absorbing

portion of the Earth's atmosphere. Floating at an altitude of approximately 38 km, BEST employs a 1–5 micron infrared spectrometer fed by a ~1 m telescope. Telescope pointing of ~1 arcsecond rms will be provided using a flight version of existing preflight technology (this benefits other astrophysics balloon-borne concepts as well). By detecting molecular signatures in both transmission and emission spectra, BEST probes the conditions, composition, and chemistry of exoplanet atmospheres. By systematically characterizing the brightest systems, BEST fills an important 2.5–5.2 micron gap between Hubble and Spitzer spectroscopic coverage and compliments the photometric capabilities of a warm Spitzer mission. BEST can efficiently repeat observations and thus relieve the James Webb Space Telescope of some of the burden for re-observing spectroscopic variations that we now know exist in some exoplanet atmospheres. BEST literally enables great-observatory class science for a cost of about 10-12 million dollars.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Mark Swain (NASA JPL), Drake Deming (NASA GSFC)
Current Status: Proposed to ROSES program in 2008.
Additional Information:
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24. Beyond Einstein Advanced Coherent Optical Network (BEACON) mission

Point of Contact: Slava G. Turyshev, NASA JPL
Summary Description: The primary objective of the Beyond Einstein Advanced Coherent Optical Network (BEACON) mission is a search for new physics beyond general relativity by measuring the curvature of relativistic space-time around Earth. This curvature is characterized by the Eddington parameter \gamma -- the most fundamental relativistic gravity parameter and a direct measure for the presence of new physical interactions. BEACON will achieve an accuracy of 1 x 10^{-9} in measuring the parameter \gamma, thereby going a factor of 30,000 beyond the present best result involving the Cassini spacecraft. Secondary mission objectives include: (i) a direct measurement of the "frame-dragging" and geodetic precessions in the Earth's rotational gravitomagnetic field, to 0.05% and 0.03% accuracy correspondingly, (ii) first measurement of gravity's non-linear effects on light and corresponding 2nd order spatial metric's effects to 0.01% accuracy. BEACON will lead to robust advances in tests of fundamental physics -- this mission could discover a violation or extension of general relativity and/or reveal the presence of an additional long range interaction in physics. BEACON will provide crucial information to separate modern scalar-tensor theories of gravity from general relativity, probe possible ways for gravity quantization, and test modern theories of cosmological evolution.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Slava G. Turyshev, Michael Shao, Andre Girerd (JPL), Benjamin Lane (Charles Stark Draper Laboratory)
Current Status: Pre-phase A study ant JPL and Draper
Additional Information: http://arxiv.org/abs/0805.4033
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25. CALISTO: Cryogenic Large Aperture Infrared Space Telescope Observatory

Point of Contact: Paul Goldsmith, NASA JPL
Summary Description: CALISTO, the Cryogenic Aperture Large Infrared Space

Telescope Observatory, will enable extraordinarily high sensitivity far-infrared continuum and moderate (R ~ 1000) resolution spectroscopic observations at wavelengths from ~30µm to ~300 micron - the decade of wavelengths between those accessible by JWST and ALMA and other ground based facilities. CALISTO's observations will provide vital information about a wide range of important astronomical questions including (1) the first stars and initial heavy element production in the universe; (2) structures in the universe traced by H2 emission; (3) the evolution of galaxies and the star formation within them traced by key cooling lines (4) the formation of planetary systems through observations of protostellar and debris disks; (5) the outermost portions of our solar system through observations of Trans-Neptunian Objects (TNOs) and the Oort cloud. With optics cooled to below 5 K, the photon fluctuations from the astronomical background (Zodiacal, Galactic, and extragalactic) exceed those from the telescope. Detectors with a noise equivalent power below that set by the background will make possible astronomical-background-limited sensitivity through the submillimeter/far-infrared region. CALISTO builds on studies for the SAFIR (Single Aperture Far Infrared) telescope mission, employing a 4m x 6m off-axis Gregorian telescope which has a simple deployment procedure. The unblocked telescope with a cold stop has minimal sidelobes and scattering. The clean beam is essential for astronomical background limited observations over a large fraction of the sky, which is what is required to achieve CALISTO's exciting science goals. The maximum angular resolution varies from 1.2" at 30 µm to 12" at 300 micron. The 5-sigma; 1 hr detectable fluxes are deltaS(d-upsilon/upsilon = 1.0) = 2.2x10-20 Wm-2, and deltaS(d-upsilon/upsilon = 0.001) = 6.2x10-22 Wm-2. The 8 beams per source confusion limit at 70 µm is estimated to be 5 microJy. The mission concept incorporates an agile spacecraft that can scan rapidly to take advantage of the high sensitivity that reaches the confusion limit in a few tens of seconds integration per pointing. The result is a capability of mapping a large fraction of the sky at this high sensitivity in a period of a few months. Additional information is available at http://safir.jpl.nasa.gov/.

The CALISTO/SAFIR mission has been analyzed by JPL TeamX in two studies in 2007 and 2008. The studies did not find any significant issues with successfully building and operating the observatory. The mission mass is 3920 kg, power required is 1925 W, and science data rate is estimated to be 2.8 Tbit per day. The latter is consistent with anticipated system being developed for JWST. The project cost is roughly $1.7 B '08 with appropriate contingencies, including 5-years of science operations. This estimate is based on a Pre-Phase-A design. Because the level of understanding of mission requirements in Pre-Phase-A is relatively immature, the resulting design should be viewed similarly. The accuracy of the cost estimate is commensurate with the level of understanding of the mission concept, and should be viewed as indicative rather than predictive. The baseline configuration for CALISTO/SAFIR is chosen to allow use of an Atlas V511, but if more capable launch vehicles become available, the aperture size can be expanded (while keeping the critical unblocked configuration), providing increased sensitivity and considerably lower confusion limits. The low level of pickup and cold optics leave the detector sensitivity as a critical requirement for achieving the desired system sensitivity. The umbrella SAFIR concept was endorsed for development by the 2000 Decadal Study, but funding has not been provided. To be able to credibly propose CALISTO/SAFIR at some point in the future, a technology development plan must be funded starting early in the upcoming decade. The most critical aspect is detectors, both in terms of sensitivity (for spectroscopy) and format (for imaging). Additional investment in cryogenic optics and cryogenics systems is required to enable a truly high sensitivity FIR/submm mission.

Anticipated Sponsor: NASA
Participating Individuals or Institutions: Dominic Benford (GSFC), Paul Goldsmith (JPL), Martin Harwit (Cornell), Bill Langer (JPL), Dan Lester (Univ. Texas), David Leisawitz (GSFC), Hal Yorke (JPL)

Current Status: Pre-Phase A
Additional Information: http://safir.jpl.nasa.gov/
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26. CASTER

Point of Contact: Mark McConnell, University of New Hampshire
Summary Description: The primary scientific mission of the Black Hole Finder Probe (BHFP), part of the NASA Beyond Einstein program, is to survey the local Universe for black holes over a wide range of mass and accretion rate. One approach to such a survey is a hard X-ray coded-aperture imaging mission operating in the 10-600 keV energy band, a spectral range that is considered to be especially useful in the detection of black hole sources. The development of new inorganic scintillator materials provides improved performance (for example, with regards to energy resolution and timing) that is well suited to the BHFP science requirements. Detection planes formed with these materials coupled with a new generation of readout devices represent a major advancement in the performance capabilities of scintillator-based gamma cameras. Here, we discuss the Coded Aperture Survey Telescope for Energetic Radiation (CASTER), a concept that represents a BHFP based on the use of the latest scintillator technology.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: University of New Hampshire, Louisiana State University, Univ of California – Berkeley, Univ of California - San Diego, University of Alabama – Huntsville, Los Alamos National Laboratory, Goddard Space Flight Center / USRA
Current Status: Conceptual Design, laboratory prototyping
Additional Information:
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27. CCAT - the Cornell-Caltech Atacama Telescope

Point of Contact: Riccardo Giovanelli, Cornell University
Summary Description: The CCAT consortium aims to building a telescope of 25 meter diameter, which will operate at Far Infrared/submm wavelengths as low as 200 micron. It will be located at an elevation of 5620 m, near the summit of Cerro Chajnantor in the Atacama Desert of Chile. Designed with a large Field of View, the instrumentation will exploit the revolution currently underway in submillimeter sensor technology to deploy large format array cameras and multi-object spectrometers in addition to heterodyne receivers. To be used in part for large-scale surveys, CCAT is planned to maximize synergy with ALMA capabilities. Science focus will be primarily on galaxy formation and evolution at high z, the SZE, the cosmic evolution of structure and metallicity, stellar and disk/planet formation and the ISM.
Anticipated Sponsor: NASA, NSF
CCAT is currently funded through private philanthropy, University and NASA (JPL) funds in the US and through public funds at foreign partner institutions. Site survey activities were partly supported by NSF. It is anticipated that US national agencies will be asked to participate in partial capital funding (e.g. instrumentation and/or facility construction), operations and scientific activities.
Participating Individuals or Institutions: Cornell University, California Institute of Technology (including JPL), University of Colorado at Boulder, Canada (through U. of Waterloo and U. of British Columbia), United Kingdom (through ATC at R.O. Edinburgh), Germany (Universities of Bochum, Bonn and Cologne)
Current Status: Feasibility Study completedm FS Panel (chaired by R. Wilson of CfA) Review completed, Initiating detailed Engineering Design phase

Additional Information: http://www.submm.net
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28. Center for Astronomy Signal Processing and Electronics Research (CASPER)

Point of Contact: Dan Werthimer, UC Berkeley
Summary Description: The intent of the Center for Astronomy Signal Processing and Electronics Research (CASPER) is to develop high performance instrumentation for the astrononomy community. The constant redesign and upgrade of custom instrumentation is fueled by the ever increasing need for high-performance real-time DSP computing power for applications such as beam forming, correlation, IF processing, RFI mitigation, and wide-band high-resolution spectroscopy. The next generation of radio telescopes (e.g. ATA, CARMA, Epoch of Reionization (EoR) arrays, ALMA, SKA, SZ arrays, focal plane, bolometer and receiver arrays, are being designed and built using large numbers of small antennas and/or very wide bandwidths. With computation scaling as bandwidth × Ntelescopes^2, DSP systems for these projects, especially those requiring several Gigahertz of continuous RF bandwidth over hundreds of physical antennas, can require peta-operations per second.
Traditionally, radio astronomy digital instrumentation has been highly specialized, with custom, complex, dedicated instruments being built for individual applications. Each instrument takes three to ten years to design, construct, and debug, and then when deployed, is partially obsolete owing to steady Moore's Law growth in the electronics industry.
Costs are high and are almost always dominated by NRE. Most large observatories have several of these custom backend instruments. CASPER seeks to shorten the instrument development cycle by designing modular, upgradeable hardware and a generalized, scalable architecture. Using Field-Programmable Gate Arrays (FPGAs), GPU's, CPU's, platform independent signal processing libraries, and packetized data routed through commercially available switches, CASPER architecture looks much like a Beowulf cluster with reconfigurable, modular computing hardware in place of CPUs. This architecture uses a small number of easily replaceable and upgradeable hardware modules connected with as many identical modules as necessary to meet the computational requirements of an application, known colloquially as "computing by the yard." In addition to having the advantage of built-in tolerance for hardware failure, as data can be routed to other identically reconfigured modules, this architecture can use multicast switches to allow commensal experiments to run simultaneously.

Headquartered at UC Berkeley, CASPER is a collaboration of Astronomers, Physicists, Engineers and Computer Scientists from thirty observatories and universities. CASPER research has revolutionized the cost and time scale for development of high performance radio astronomy signal processing instrumentation.

Anticipated Sponsor: NSF, Other
Current USA government Sponsors: NSF, NASA; Current Industry Partners and Sponsors: Xilinx, Agilent, Fujitsu, Sun Microsystems, Intel, Nvidia, Microsoft, National Semiconductor, Hewlett Packard, E2V; International Scientific Collaborators and Sponsors GMRT, MeerKAT, CSIRO/ATNF, SKADS, Oxford, Manchester, Bologna, Nancay
Participating Individuals or Institutions: UC Berkeley, JPL, Caltech, Stanford, Oxford, Cornell, Harvard/Smithsonian, MIT, Manchester, NJIT, UBC, Swinburne, Univ. Colorado, NRAO, NAIC, GMRT, SMA, FASR, CAEMA, ATA, PAPER, Haystack, ATNF, MeerKAT, Bologna Observatory, Metsovi Observatory, Jodrell Bank, Merlin, SKADS, Nancay, PARI, eVLBI, VLBA

Current Status: CASPER is an ongoing collaboration funded by NSF, NASA,industry and international partners. The CASPER program requires $600K per year to continue to track Moores law and provide student training and open source instrumentation for the community.
Additional Information: http://casper.berkeley.edu
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29. Center for Chemistry of the Universe

Point of Contact: Brooks Pate, University of Virginia; Anthony Remijan, National Radio Astronomy Observatory
Summary Description: The recently funded NSF Center for Chemistry of the Universe will assemble a group of researchers from across the United States to investigate and understand the chemical processes that control the synthesis of molecules in the interstellar medium. The chemistry occurring under the unique conditions of the interstellar medium produces the initial molecular starting materials for solar system formation. This chemistry, which produces a surprisingly rich set of common organic molecules along with more exotic reactive species, also supplies the molecules in meteorites and comets that may deliver the building blocks of life to young planets. The Center will place chemistry at the center of research efforts to describe the molecular composition of the universe. In this model, the powerful new tools being developed for observational astronomy will be used to test chemical hypotheses about novel reaction mechanisms that include photochemistry by extreme ultraviolet radiation on the surfaces of nanoscale solids and gas-phase chemistry of ions and radicals under low collision rates and at ultracold temperatures. These unique reaction conditions will allow the Center to explore new types of chemistry that go beyond the usual boundaries imposed by terrestrial conditions. The Center will establish connections between fields such as combustion chemistry, atmospheric chemistry, and materials processing that share the theme of "chemistry under extreme conditions".
Anticipated Sponsor: NSF
Participating Individuals or Institutions: Brooks H. Pate (UVa), Anthony J. Remijan National Radio Astronomy Observatory (NRAO), Lucy M. Ziurys (University of Arizona), Eric J. Herbst (The Ohio State University), Michael C. McCarthy (Harvard Center for Astrophysics), Frank J. Lovas (National Institute of Standards and Technology), Thomas J. Gallagher (UVa), Kevin Lehman (UVa), John T. Yates, Jr. (UVa), Philip R. Jewell (NRAO), Sarah Fitzgerald (UVa), Jennifer Maeng (UVa)
Current Status: Design and Development - Initial Funding for the Center was awarded in Oct. 2008 for 3 years of Proof of Concept. Full Center Funding will be applied for during the second year of this concept period.
Additional Information: http://www.virginia.edu/ccu/ - The Main Center for Chemistry of the Universe Website
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30. Coherent Detector Focal Plane Arrays

Point of Contact: John Carpenter, Caltech
Summary Description: Over the next decade, radio astronomy facilities will develop coherent detector focal plane arrays that contain upwards of hundreds if not thousands of elements. These coherent detector arrays will usher in an era of wide-field imaging and spectroscopy at centimeter through submillimeter wavelengths for a broad range of scientific applications, including imaging the cosmic microwave background, identifying the first galaxies, and mapping the interstellar medium. To reach the scientific promise of these coherent detector arrays, the scientific community must invest in a broad range of

technologies (e.g. Monolithic Millimeter-wave Integrated Circuits, or MMICs; superconductor-insulator-superconductor, or SIS) that provide superior performance over different wavelength regimes. The scientific community must also partner with industry to develop cost-effective devices that reach the high level of performance and signal processing demanded by astronomical observations, especially pertaining to noise levels, stability, and bandwidth. The Jet Propulsion Laboratory (JPL) and the California Institute of Technology are leaders in the development of focal plane arrays based on the MMIC technology. A main goal of this program for the next decade is to develop focal plane arrays with hundreds of pixel elements for continuum and spectroscopic surveys on single-aperture instruments. JPL is also partnering with the Combined Array for Research in Millimeter-wave Astronomy (CARMA) to explore paths to develop focal plane arrays for interferometers.

Anticipated Sponsor: NASA, NSF

Participating Individuals or Institutions: John Carpenter (Caltech), Jet Propulsion Laboratory (JPL), Charles Lawrence (JPL), Todd Gaier (JPL), Anthony Readhead (Caltech), Tim Pearson (Caltech), James Lamb (Caltech, OVRO), David Woody (Caltech, OVRO), Lee Mundy (Maryland)

Current Status: JPL is currently designing and developing focal plane arrays based on MMIC technology.

Additional Information:

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31. Construction of Twin 6-8m Automated Planet Finder Telescopes

Point of Contact: Steve Vogt, UCO

Summary Description: The proposed activity is the construction of twin 6-m or 8-m telescopes for Automated Planet Finding. Most likely, these wold be near-clones of the Magellan telescope. One of the telescopes would be cited in the northern hemisphere, and one in the south (for full sky coverage). Each telescope would be outfitted with a high resolution spectrometer optimized for precision radial velocity work (1 m/s precision) and high throughput. The entire facility (telescope, dome and instrument) would be operate automatically, 365 nights/year. Its primary mission would be to provide high cadence radial velocity data at the 1 m/s precision level on all the nearest K and M dwarfs (out to at least 10 pc), to determine a galactic census of habitable planets and to identify the nearest systems with earth-like planets for further space-based follow-up.

Anticipated Sponsor: DOE, NASA, NSF

Participating Individuals or Institutions: Steve Vogt- UCO/Lick Observatory, Paul Butler- Carnegie Institution of Washington

Current Status: Long-held pipe dream. No new technology needed- only money.

Additional Information: http://www.ucolick.org/~vogt/

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32. Coronal Solar Magnetism Observatory (COSMO)

Point of Contact: Steven Tomczyk, High Altitude Observatory, National Center for Atmospheric Research

Summary Description: Measuring magnetic fields in the solar corona is crucial to understanding and predicting the Sun's generation of space weather that affects communications, space flight, and power transmission. New prototype instrumentation developed at the University of Hawaii and at the NCAR High Altitude Observatory has demonstrated that routine measurements of coronal magnetic fields are now possible, using advanced infrared detector technology to observe weak coronal forbidden emission lines. However, current coronagraphic telescopes do not have large enough apertures to

collect sufficient light to constrain the coronal magnetic field at the spatial resolution and cadence required to address outstanding scientific problems. We propose to build the COronal Solar Magnetism Observatory (COSMO) consisting of a 1.5 m aperture solar coronagraph with spectro-polarimetric instrumentation. The telescope will take continuous daily measurements of coronal magnetic fields over a one-degree field-of-view in order to understand the generation of solar eruptive events that drive space weather and to investigate long-term and solar-cycle phenomena.
Anticipated Sponsor: NSF
Participating Individuals or Institutions: Steven Tomczyk (NCAR/HAO), Haosheng Lin (Univ. of Hawaii), Thomas Zurbuchen (Univ. of Michigan)
Current Status: Pre-phase A
Additional Information: www.cosmo.ucar.edu

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33. Cosmic Inflation Probe (CIP)

Point of Contact: Gary J. Melnick, Harvard-Smithsonian Center for Astrophysics
Summary Description: The Cosmic Inflation Probe (CIP) is a NASA Medium-Class mission designed to conduct a space-based large-area galaxy redshift survey in H-alpha between 1.8 and 5 microns capable of detecting 100 million objects between a redshift of 1.8 and 6.5. These data will be used to measure the galaxy power spectrum, P(k), to better than 1% over length scales between 1 and 50 Mpc with the goal being to estimate the shape of the primordial power spectrum, convert it to a scalar potential, and compare this to the predictions made by various Inflation theories. CIP will also either detect or set limits on non-Gaussianity that are one-to-two orders of magnitude more stringent than those currently set by WMAP. CIP will provide significantly improved constraints on Inflation models using a 1.5-meter passively-cooled aperture, proven observational techniques, and a well-studied mission design based on existing technology. Ancillary science possible with the CIP dataset include a determination of: (1) the star formation history of the Universe between redshifts of 1.8 to 6.5; (2) the neutrino mass; (3) the curvature of space to better than 0.1%; and, (4) the effects of dark energy at high redshift (which will be of particular interest if lambda is not a constant). The CIP survey will also detect many luminous objects at high redshift of interest for follow up using JWST.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Gary J. Melnick (1), Volker Bromm (2), Giovanni G. Fazio (1), Karl Gebhardt (2), Daniel T. Jaffe (2), Eiichiro Komatsu (2), Avi Loeb (3), Jonathan R. Pritchard (3), Charles Steidel (4), Volker Tolls (1), Michael W. Werner (5) and Robert A. Woodruff (6)
(1) Smithsonian Astrophysical Observatory, (2) University of Texas, (3) Harvard University, (4) California Institute of Technology, (5) Jet Propulsion Laboratory, (6) Lockheed Martin Corporation with industrial partners: Lockheed Martin Corporation, ITT Space Systems, and Teledyne Scientific & Imaging and the Jet Propulsion Laboratory
Current Status: The CIP mission concept has been refined as a result of three extensive design studies - first as a NASA-funded Origins Probe mission concept in 2004-2005, second as a candidate Beyond Einstein Inflation Probe in 2006-2007 and, currently, as a NASA-funded Astrophysics Strategic Mission Concept Study.
Additional Information: Additional information - originally presented at the January 2009 AAS Meeting - can be found at the following link:
http://www.cfa.harvard.edu/cip/

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34. Cosmic Ray Astrophysics

Point of Contact: Donald C. Ellison, NC State University

Summary Description: Observing cosmic rays by balloon-borne and space-based missions, and connecting their properties to the production and radiation of highly energetic particles in exotic environments, are vital keys for understanding our local solar environment and the high-energy universe in general. As shown by the following incomplete list of examples, Cosmic Ray-Astrophysics is connected, more or less directly, to all of the Science Frontier Panels. Planetary Systems and Star Formation (PSF): the collapse of molecular clouds is influenced by ionization produced by cosmic rays, so they have an important influence on the star formation rate and on galactic chemical evolution. Stars and Stellar Evolution (SSE): Cosmic rays observed at Earth (particularly isotopic ratios) provide direct information on nucleosynthesis, their production substantially influences the evolution of supernova remnants, and the highest energy cosmic rays may be produced in gamma-ray bursts. The Galactic Neighborhood (GAN): the pressure of cosmic rays is comparable to that of starlight and galactic magnetic fields so they influence galactic structure and the nature of interstellar media. Galaxies across Cosmic Time (GCT): the highest energy particles may be produced in active galaxies and the radio emission produced by the electron component provides much of the information we have on active galaxies, QSO's, etc. Cosmology and Fundamental Physics (CFP): Cosmic ray production may be important during large-scale structure formation, and recent observations indicate that they may contain the signature of Dark Matter. The last decade has been a good one for Cosmic Ray-Astrophysics; hints of dark matter have been found; the highest energy cosmic rays are being measured with unprecedented accuracy; the value of long-duration balloon flight measurements has been demonstrated; the sensitivity of spectral observations at Earth has improved to the point where "features" in the spectra may herald a new era of cosmic ray "astronomy;" there is absolute proof from TeV gamma-ray observations that cosmic rays (electrons at least) are produced in young supernova remnants; the theory of particle acceleration has advanced substantially through the discovery of magnetic field amplification; and the fundamental physics of space plasmas is being investigated with unprecedented accuracy using large-scale particle-in-cell simulations. The next decade promises to be the most exciting in the long history of cosmic ray research.

Anticipated Sponsor: NASA

Participating Individuals or Institutions: The following astrophysicists are members of the Cosmic Ray Program Assessment Group charged with writing a report that identifies key open questions and important scientific objectives for next generation experiments. This writing team represents only a small fraction of the currently active members of the cosmic ray community and others who would be involved in the future program. The report under preparation is based on the contributions of a large number of scientists to a community-wide workshop held in November 2007, as well as other solicited and unsolicited inputs. Don Ellison (North Carolina State University), John Krizmanic (Goddard Space Flight Center), Igor V. Moskalenko (Stanford University), Jonathan Ormes (University of Denver), Eun-Suk Seo (University of Maryland, College Park), Todor Stanev (University of Delaware), Scott P. Wakely (University of Chicago)

Current Status: Community assessment of Cosmic Ray Astrophysics in final stage of preparation.

Additional Information: Web site: http://cosmicray.umd.edu/vision2020

This evolving site will contain a draft of the community assessment report "Balloon and Space-based Cosmic Ray Astrophysics.

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35. Cosmic Web Mapping Using Intergalactic Medium Emission in the Space UV

Point of Contact: Christopher Martin, Caltech
Summary Description: A space UV spectroscopic mission optimized to detect and map redshifted emission from Lyman alpha and other UV lines could 1) determine the location and properties of the missing baryons, 2) construct maps of the cosmic web of matter threading the Universe and use these maps to test structure formation and for cosmology, and 3) map the flow of baryonic matter into and out of galaxies to determine the causes and impacts of the star formation history of the Universe. We are studying mission concepts and technology requirements for missions that range from a Small Explorer to a medium (Probe-class) mission. With the appropriate strategic technology investments, an Explorer-class mission could provide the first measurements and act as a pathfinder. A medium-scale mission, designed for both emission and absorption line spectroscopy of the IGM, could provide detailed maps of the cosmic web, the co-evolution of galaxies and the intergalactic medium, and perform unique cosmological tests that would complement JDEM and LSST.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: ISTOS [Imaging Spectroscopic Telescope for Origins Surveys] Science Team (Caltech; Laboratoire d'Astrophysique de Marseille (France); Columbia University; University of California, Santa Barbara; Leiden (Netherlands); Princeton University; The Observatories of the Carnegie Institute of Washington; Jet Propulsion Laboratory; Institut d'Astrophysique de Paris (France); Universitie de Lyon (France)
Current Status: Concept investigation/study
Additional Information:

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36. DAViNCI Dilute Aperture Nulling Coronagraphic Imager

Point of Contact: Michael Shao, NASA JPL
Summary Description: DAVINCI is a dilute aperture visible nulling coronagraph study that is funded through the NASA Advanced Mission Concept Study (AMSC) NRA. In addition, NASA is funding technology for visible nulling coronagraphs (EPIC and DAVINCI)at JPL and GSFC. DAVINCI consists of 4 telescopes configured as a phased array, nulling coronagraph, that has a ~40mas inner working angle at 800nm, comparable to a 8m telescope with a PIAA coronagraph, but at a team X cost of ~ $1.2B roughly the cost of a 2.5m visible coronagraph. This very small inner working angle lets DAVINCI search ~ 150 nearby stars for 1 Mearth mass planets in the middle of the habitable zone (1AU scaled to stellar luminosity), and obtain their spectra. A Earth at 10pc could be detected with SNR-5 in about 10 hrs and a R=80 spectra at SNR=10 would take ~ 500 hrs.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: M. Clampin (GSFC), E. Deems (JPL), O. Guyon (U. Ariz/Subaru), K. Havey (ITT), B. Lane (MIT/Draper), A. Leger (Univ Paris), B. Levine (JPL), R. Lyon (GSFC), F. Malbet (Grenoble), R. Samuele (NGST), V. Tolls (Harvard Smithsonian, CFA), G. Vasisht (JPL), G. Vasudevan (LMCO), R. Woodruff (LMCO). F. Zhao (JPL)
Current Status: Conceptual design. This concept was one of the NASA AMSC winners awarded ~1M concept study, including a JPL Team X study preliminary cost estimate. NASA also started technology effort in 2008, aimed at supporting nulling coronagraphs (DAViNCI and EPIC) at a level slightly larger than the combined (Davinci and EPIC) concept studies. Technology efforts before that were funded by competitive NASA grants

in a cooperative effort at JPL and GSFC.
Additional Information: DaVinciMission.jpl.nasa.gov
link will be active in ~ 1 week.
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37. Detectors and Arrays for Long-Wavelength Astrophysics

Point of Contact: James Bock, NASA JPL
Summary Description: Detector technology will determine what is scientifically possible in far-infrared to millimeter-wave astrophysics in the next decade. Focal planes with large, background-limited detector arrays will be the enabling capability for studies of inflation via CMB polarization, the evolution of large-scale structure via CMB lensing and SZ surveys, the formation and evolution of galaxies (especially the role of mergers), the early stages of star formation, and the development of accretion and debris disks in stellar systems. These ambitious goals are the centerpieces of both space-borne and ground-based programs. These programs seek to harness the ongoing revolution in long wavelength detector technology, with both pixel sensitivity and array format doubling roughly every two years. Much of this progress is due to the emergence of new superconducting detector and multiplexer concepts. Superconducting detectors also have scientific applications in X-ray astronomy, optical-UV astronomy, and dark matter detection, with numerous examples of technical cross-fertilization. Coherent (heterodyne) detector systems will allow high spectral resolution observations of key far-infrared cooling lines, rotational transitions of hydrides, and other critical probes of the star formation process. These will be required for follow-ups to and extensions of discoveries that will be made with the Herschel Space Observatory. A long-wavelength detector technology development program should thus encompass coherent as well as incoherent detectors, broadband and multiband detectors, polarization sensitive and polarization insensitive detectors, and both individual detectors and arrays. Successful continued development of these technologies relies on a small community of scientists and technologists who are also actively engaged in deploying and demonstrating these technologies in astrophysics projects and instruments.
Anticipated Sponsor: DOE, NASA, NSF
Participating Individuals or Institutions: Matt Bradford (JPL), Paul Goldsmith (JPL), Kent Irwin (NIST), James Lamb (Caltech), Andrew Lange (Caltech), Adrian Lee (UC Berkeley), John Mather (GSFC), Harvey Moseley (GSFC), Valentyn Nosad (Argonne National Laboratory), Harvey Moseley (GSFC), Dick Plambeck (UC Berkeley), Paul Richards (UC Berkeley), David Woody (Caltech), Jonas Zmuidzinas (Caltech)
Current Status: Design and development
Additional Information:
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38. Developing the Astronomical Information Sciences

Point of Contact: Thomas J. Loredo, Cornell University
Summary Description: Across its many subdisciplines, astronomy traditionally distinguishes between two categories of research, observation and theory. There is an emerging third category of research that happens at the interface between theory and observation, where the ever-growing complexity of data and models increasingly strains conventional approaches for data-based discovery and analysis. The growing community of researchers in this area draws heavily from the information sciences in their work, which has been variably called astrostatistics, astroinformatics, advanced data analysis, or data-intensive astronomy. This nascent research specialty is arising in response to urgent needs felt across nearly all astronomical subdisciplines. Nowhere is the need

greater than in discovery and analysis using huge "petascale" data sets from large surveys. But challenging data analysis problems arise across the full spectrum of sizes of data sets. Addressing these problems increasingly often requires collaboration between astronomers and scientists in statistics, applied math, and computer science, especially in the subdisciplines of machine learning, data mining, numerical analysis, and scientific visualization. Current funding and community structures in astronomy are poorly suited to support such interdisciplinary research. The team submitting this NOI is advocating for improved support of astronomical information sciences (AIS) research. We are developing specific recommendations for this, ranging from changes in grant review and funding practices to development of community structures supporting AIS research and education. This activity is neither a "project" nor a single, focused "initiative" in the terminology of the call for NOIs. Accordingly, we are supporting this NOI with Scientific White Papers to be submitted to the Science Frontier Panels (and, as appropriate, with input to the Subcommittee on the State of the Profession). The team's web site will describe our case and recommendations as work on the White Papers proceeds.

Anticipated Sponsor: DOE, NASA, NSF, Other

A possible avenue of community support for AIS endeavors would be an AAS Working Group on AIS (WGAIS), patterned after the Working Group on Astronomical Software (WGAS) and the Working Group on Laboratory Astrophysics (WGLA). The WGAIS would provide a forum for promulgating existing work, for fostering education of young astronomers in astrostatistics, and for establishing collaborations between astronomers who have challenging data analysis problems and colleagues in astronomy and other disciplines with the expertise to help them.

Participating Individuals or Institutions: This activity is not a single, focused research endeavor as such, and thus there are no formal co-investigators or partner institutions. A growing team of astronomers and information scientists is participating in making the case for improved ADA support. The team at the time of the submission of this NOI includes the following individuals; see the activity web site for an updated list.

Astronomers: cek Becla (SLAC National Accelerator Center), Kirk Borne (George Mason University) rian Connolly (University of Pennsylvania), Alanna Connors (Eureka Scientific), Eric Feigelson (Penn State University), Peter Freeman (Carnegie Mellon University), Vinay Kashyap (Harvard-Smithsonian, CfA) Brandon Kelly (Harvard-Smithsonian, CfA), William Jefferys (University of Vermont, University of Texas at Austin), Thomas Loredo (Cornell University), Ashish Mahabal (California Institute of Technology), Bruce McCollum (California Institute of Technology), Misha (Meyer) Pesenson (California Institute of Technology), Frank Primini (Harvard-Smithsonian Center for Astrophysics), Andy Ptak (Johns Hopkins University), Aneta Siemiginowska (Harvard-Smithsonian, CfA), Tom Vestrand (Los Alamos National Laboratory), Andreas Zezas (Harvard-Smithsonian, CfA)

Statisticians & Computer Scientists: ogesh Babu (Penn State University), David van Dyk (University of California, Irvine), Alexander Gray (Georgia Institute of Technology)

Current Status: Not applicable.

Additional Information: Our team has created a web site supporting this NOI at: http://inference.astro.cornell.edu/Astro2010/. It will grow in content through January and early February as we prepare a Scientific White Paper for Astro2010.

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39. Development of a Black Hole Imager

Point of Contact: Dr. Keith C. Gendreau, NASA GSFC

Summary Description: A Black Hole Imager (BHI) will answer the question: “What happens at the edge of a black hole?” by directly resolving the event horizon of Black Holes. The optimal band for this is in X-rays (0.1 keV and higher)- where these sources

have extraordinarily large surface brightness as well as line emission. The required resolution of better than 1 microarcsecond represents a six order of magnitude improvement over current capability in X-ray and will open up a vast discovery space in astrophysics. Spectral and time resolved imaging of Black Holes will provide observations of the behavior of matter in deep gravitational wells for direct comparison to that predicted by General Relativity. Mission architectures using grazing incidence, refractive, or normal incidence X-ray optics as well as formation flying between widely separated spacecraft require further technology development in the next decade to open up this field. As part of this development, it may also be possible to build a pathfinder mission which goes a long way toward black hole imaging within the next decade by imaging its immediate surroundings and the late stages of black hole mergers.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: NASA/GSFC, NASA/MSFC, NASA/JPL, University of Colorado, MIT, SAO, University of Maryland, Penn State, NRL, Cambridge University, Stanford, USRA, as well as several Industrial Partners.
Current Status: Design and Development
Additional Information: http://blackholeimager.gsfc.nasa.gov

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40. Development of a visible-light, diffraction-limited astronomy network for the post-HST era

Point of Contact: Dr. Richard Dekany, California Institute of Technology
Summary Description: Hubble Space Telescope (HST) has provided the astronomical community incomparable access to high-angular-resolution, high-sensitivity visible light observations. By far the most productive optical Observatory in human history, based on publication record, HST has answered many fundamental questions about the Universe and inspired an entire generation of visible light astronomers. With this success, however, many new and important questions have been raised, not all of which will be addressable by HST as it moves toward its end-of-lifetime in the 2010-2020 decade. To ensure the continuous progress forward on these important questions, the time is right for our nation to invest in a major new initiative to provide a network of diffraction-limited, visible-light observational capabilities for the post-HST era. Advances in ground-based Rayleigh laser guide star (LGS) adaptive optics (AO) now allow routine and wide-sky-fraction diffraction-limited visible access on apertures up to 3 meters, albeit with relatively small field of view. Advances in sodium LGS AO, suitable for diffraction-limited visible light science on 3-10 meter apertures are critically needed, as are pathfinding architectures for extending visible AO correction over wider fields of view. The national goal should be a diverse and robust network of high efficiency ground-based observational facilities enabling follow-up to key astrophysical questions so prolifically posed by HST.
Anticipated Sponsor: NASA, NSF
Participating Individuals or Institutions: The US astronomical community emphasizing visible-light science observations on apertures of all sizes, including the community so well served by HST to date.
Current Status: Prototypical visible-light LGS AO systems for larger-than-HST size apertures are currently being deployed at the 2.5m Mt. Wilson (UniSYS) and 5m Palomar (PALM-3000) Observatories for science in 2010-15. Preliminary design work for first-generation visible-light AO systems on 6-10 meter apertures is currently underway, with initial operation in 2016-20.
Additional Information: A summary of the broad range of HST-enabled science programs (going back at least to Cycle 6), can be found here: http://www.stsci.edu/hst/proposing, The 2008 AO Roadmap can be found here: http://www.aura-astronomy.org/nv/AO_Roadmap2008_Final.pdf

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41. Development of an 'all-digital' IF chain

Point of Contact: David Woody, Caltech
Summary Description: The goal of this activity is to develop an 'all-digital' intermediate frequency (IF) chain for coherent or heterodyne astronomy receivers. The wideband signals from low-noise analog receivers will be sampled directly or after a single block downconversion using state-of-the-art commercial analog to digital converters (ADCs). The filtering and processing will be done in the digital domain where Moore's Law performance to cost improvements can be exploited and the NRE, costs and imperfections associated with wideband analog electronics are minimized. The widebandth digital data stream will be divided into parallel sub-bands appropriate for further processing into high resolution spectra or cross-correlations by digital circuits of the type supported by the CASPER effort at Berkeley.

This technical development will benefit essentially all astronomy projects that use coherent receivers at frequencies above a few GHz. It is applicable both to single-dish and to interferometer array observations, and is essential for cost effective use of wideband coherent receiver arrays currently being developed for surveys and deep field imaging. Within ten years, several tens of GHz of bandwidth (whole atmospheric windows at millimeter wavelengths) will form a single data stream. The wider processed bandwidth will improve sensitivity for continuum observations and allow simultaneous access to multiple astronomical lines. The 'all-digital' IF also improves the performance of wideband correlation receivers by removing limiting analog components from the system. This will be particularly important for single aperture polarization and continuum observations that push the limits for sensitivity and systematic error removal, e.g. CMB fluctuations and E and B-mode polarization.
Anticipated Sponsor: NSF
Participating Individuals or Institutions: David Woody (Caltech), David Hawkins (Caltech), James Lamb (Caltech), Richard Plambeck (UC Berkeley), Lee Mundy (U. Maryland), Douglas Bock (CARMA), John Carpenter (Caltech), Carl Heiles (UC Berkeley), Richard Crutcher (U, Illinois)
Current Status: The engineering team in the CARMA consortium (mostly at the OVRO Caltech facilities) has proposed to the NSF to develop a 'Fast Sampler Module' that will sample a 10 GHz bandwidth signal and digitally downconvert and filter the signal into sub-bands for further digital processing. The proposal is to produce general use modules that can be easily configured for project specific tasks by different astronomy groups. Specific ADC devices have been identified and contact made with the manufacturers to obtain samples and engineering support. The project is ready for the design phase.

The initial application at CARMA will enable broad bandwidth molecular line and continuum observations. This will also lead to the development and implementation of a wideband dual polarization 23 element correlator that can handle the full capablities of the heterogeneous array of the CARMA antennas and receivers.

The long range plan is to continue the development of these 'Fast Sampler Modules' as the bandwidth of the state-of-the-art commercially available ADCs increases beyond 10 GHz and to help other astronomy groups use the modules for their projects.

Additional Information:

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42. Development of Large Format Far-Infrared Detectors

Point of Contact: Dr. Michael Ressler, Jet Propulsion Laboratory
Summary Description: Several far-infrared (30 to 300 microns) missions and/or instruments will be proposed for the next decade. Many important astrophysical processes have signatures at these wavelengths: the peak of the spectral energy distributions of protostars and ultra-luminous galaxies falls near 100 microns; there is a wealth of biologically interesting spectral lines to be found in this range, and lines such as the 158 micron line of singly ionized carbon are important for the energy balance of the interstellar medium in our own and in external galaxies.

The currently available technology for the far-infrared wavelength range is severely lacking: the state-of-the-art is small collections (up to ~ 400) of individual detectors, typically photoconductors or bolometers, individually connected to readout structures, such as those found in the Spitzer Space Telescope MIPS instrument or on the Herschel PACS instrument. Sizeable (>> 1,000 pixel) 2-D detector arrays should be developed for these wavelengths if the full power of SOFIA and proposed space missions like SAFIR are to be realized.

There are two fronts to be developed in order to bring the performance of far-infrared detectors up to that of their shorter wavelength cousins. The first is in the detector materials. The breakthrough for mid-infrared (5-30 micron) detectors was the invention of the Blocked Impurity Band (BIB) structure for doped silicon detectors. This solved most of the problems found in photoconductors and eventually led to the fantastic performance now being delivered by the Spitzer instruments. Germanium BIBs could provide wavelength coverage from about 50 to 200 microns, and there has been at least one successfully constructed device with a measured quantum efficiency curve. Gallium arsenide based BIBs could conceivably cover out past 300 microns, but again there has been little development work. These technologies and others should be explored to develop a better detector that has fewer performance issues than photoconductors, but is more amenable to 2-D scaling than bolometers.

The second front is in multiplexed readouts. The challenge is to develop readouts that can accommodate the large pixels typically needed with far-IR detectors and are compatible with the low bias voltages and currents required, yet can operate at a temperature of 2 K or below. Some development effort through an SBIR program has been done to construct a 32x32 cryo-CMOS readout array (compatible with Ge photoconductors), and a functional hybrid detector array seems to be just around the corner. Further development should be encouraged, and arrays with sizes of 64x64 or 128x128 appear to be reachable in the next few years.

The promise of a new generation of far-infrared detector arrays seems to be attainable, but getting there will require a focused development program with enough resources available to allow exploration of several paths. Development must be encouraged to maximize the return from future far-infrared missions.

Anticipated Sponsor: NASA, NSF
Participating Individuals or Institutions: Dr. Jordana Blacksberg (Jet Propulsion Laboratory), Dr. Jam Farhoomand (TechnoScience Corporation), Dr. Eugene Haller (University of California, Berkeley), Dr. Henry Hogue (DRS Technologies, Inc.)
Current Status: The detector technology described here is currently at TRL 1-3. Our vision would be to see at least one type of 128x128 pixel class, far-infrared (> 100 micron) detectors pushed to TRL 5-6.
Additional Information:

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43. Development of Large Low-cost High Performance Focal Plane Arrays for the Ultraviolet, Optical and NIR

Point of Contact: Paul Scowen, ASU
Summary Description: In partnership between ASU and JPL we intend to continue the development of a JPL initiative to fabricate large numbers of CCD and CMOS devices with the ultimate goal of providing a low-cost, high-fidelity, high-performance and high-reliability solution to the problem of producing large-area focal planes for space-based projects and missions over the next decade. The approach employed is to post-fabrication process common, fully-fabricated foundry devices to match their response functions to the specifications of the intended use, to drive down cost, and to bulk process large volumes of wafers and chips to maximize throughput. A key element is development of techniques and hardware to test and characterize large volumes of chips to produce the hundreds of flight-grade detectors needed for large focal-plane missions being conceived at this time. Another component will be the development of a large format camera for use on a ground-based telescope, to field test the detectors and the focal plane technology, as well as ultimately flying some sub-component of the design on a balloon mission to raise the TRL to flight-readiness. This work continues 2 years of work already completed at JPL and would provide a mature solution to the astronomical community with a minimal investment.
Anticipated Sponsor: Other
Components of this program are targeted at NASA-APRA and NSF-ATI or -MRI
Participating Individuals or Institutions: Paul Scowen (Arizona State U.) – co-lead and co-PoC, Shouleh Nikzad (JPL) – co-lead and co-PoC, Paul Goldsmith (JPL), Mike Werner (JPL), Jakob Van Zyl (JPL), Matthew Beasley (U. Colorado – Boulder), Rolf Jansen (Arizona State U.), Sangeeta Malhotra (Arizona State U.), James Rhoads (Arizona State U.), Ken Sembach (STScI), Bob O'Connell (U. Virginia), Bob Woodruff (LMCO), Daniel Stern (JPL), Debbie Padgett (IPAC / Caltech)
Current Status: Design & Development
Additional Information: http://largefpa.asu.edu

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44. Development of robust, high reflectivity optical coatings for the far ultraviolet.

Point of Contact: Matthew Beasley, University of Colorado
Summary Description: Far ultraviolet instrumentation can take advantage of better optical coatings for great increases in sensitivity without using larger optics and associated higher costs. Compared to current optical coatings, FUV coatings have several distinct disadvantages. Reflectivity is low, precluding sophisticated optical designs and rife with packing and performance compromises. In addition to low throughput, the highest reflectance coatings are hygroscopic which greatly increase the cost during integration and testing. Our approach is to work with recent advances in nanotechnology and improvements in multilayer coatings. Our work will focus on finding technological solutions providing the next generation of FUV instruments with the higher throughput and sensitivity that will answer the fundamental questions in astronomy.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Paul Scowen (ASU), James Green (CU)
Current Status: Design and Development
Additional Information: None.

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45. Direct Cherenkov Observatory (DCO)

Point of Contact: Simon Swordy, University of Chicago

Summary Description: The primary goal of Direct Cerenkov Observatory (DCO) is the investigation of cosmic ray abundances in the region of the spectral knee (particle energies ~10^14 - 10^16 eV) using a new experimental technique. It has long been realized that the key to understanding several of the central aspects of the origin and acceleration of cosmic rays is a detailed determination of elemental abundances. In particular, the measurements are important in the region where acceleration by SNR is expected to become exhausted near (beyond ~10^15eV), and where there is also a slight change in slope (or a "knee") in the overall particle spectrum. The origin of galactic cosmic rays for at least three decades higher in energy above this knee remains a mystery. The two methods for determining elemental abundances of cosmic rays at these energies have historically suffered fundamental limitations: Direct measurements on spacecraft or balloons have collection apertures limited to a few m^2 which does not allow an adequate sample of particles to be collected beyond ~10^16 eV because of the low intensity of cosmic rays at these energies. Indirect measurements do not suffer from low effective areas, but have the fundamental limitation that the knowledge of hadronic interactions at these energies is insufficient to accurately reconstruct the identity of the primary particle producing the air shower. An important realization was recently made that there is significant emission of Cerenkov light from the incoming nucleus in the upper atmosphere prior to the first nuclear interaction leading to an air shower. This effect, known as "Direct Cerenkov" emission provides a way to identify the incoming cosmic ray nucleus with high precision, and almost completely independently of hadronic models, overcoming the main limitation of indirect techniques. Importantly, it does so with an effective area orders of magnitude larger than is possible in Direct Experiments. The DC phenomenon has recently been observed by the imaging atmospheric Cerenkov telescopes HESS and VERITAS, gamma-ray instruments located in Namibia, and Tucson Arizona, respectively. Though not suited to fully exploit the technique, they have been able to verify the existence of the DC emission. The DCO concept consists of four 12m imaging Cerenkov telescopes spaced on a ~50m square. Each focal plane is instrumented with a ~10,000 pixel camera having ~10x10 degrees field of view. These are on fixed mounts - they do not need to track the sky. DCO has an effective collecting aperture for observing Direct Cerenkov events of ~500m^2sr which provides an energy reach in excess of ~10^16 eV. The expected cost of this array is ~16M$ for four telescopes. Several technology developments in recent years in both applicable ASIC devices and atmospheric telescope designs enable the construction of DCO at a reasonable cost with a relatively large channel count. In addition to unprecedented measurements of the nuclear component of cosmic rays, the DCO will have excellent sensitivity to cosmic electrons in the several hundred GeV->10TeV region because of the improved timing and angular pixel resolution over the existing generation of gamma-ray air Cerenkov telescopes. For the same reason, the DCO will “for free” generate a high-sensitivity deep survey of gamma-ray sources along the 10-degree strip of sky which views.

Anticipated Sponsor: DOE, NSF, Other
Foreign Science Agencies

Participating Individuals or Institutions: University of Chicago, Argonne National Lab, University of Sienna, Italy, University of Utah

Current Status: Design and Development

Additional Information: http://dco.uchicago.edu

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46. Direct high-contrast imaging of extrasolar planets with a GSMT

Point of Contact: Mitchell Troy, NASA JPL
Summary Description: Recent images of young extrasolar planetary systems highlight the fact that direct detection and spectroscopic characterization of extrasolar planets is a key area in the study of other solar systems. Next-generation systems, exploiting specialized adaptive optics techniques, will reach contrasts of 10^7 and extend this to older (but still self-luminous) planets. A dedicated high-contrast imaging spectrograph on a Giant Segmented Mirror Telescope (GSMT) could reach planet: star flux ratios of 10^8 or greater at angles as small as 30 milli-arcseconds, opening up science from characterization of mature ice giants through studies of massive asteroidal belts, imaging of accreting protoplanets in nearby star-forming regions, and detection and characterization of "super-earths".

Reaching such a capability will require sustained investment in technology development such as advanced wavefront sensors and detectors, deformable mirrors, coronagraphs, and calibration algorithms. A similar program for space based high-contrast imaging has been funded by NASA, but ground-based telescopes will require different technologies to reach their full potential. This development would cost on the order of $10M and should include both laboratory and on-sky prototyping leveraging existing ExAO capabilities. The ultimate goal is deployment of a facility-class system on a GSMT. The limited instrument budgets of private GSMT projects will necessarily preclude the deployment of dedicated high-contrast instruments - scientifically-driven funding at the level of $50M from a federal agency will be required to achieve this goal. Ground-based high contrast instruments will provide an important support role for NASA's Exoplanet Exploration Program, providing a natural role for NASA in this development, as well as NSF.
Anticipated Sponsor: NASA, NSF

Participating Individuals or Institutions: Bruce Macintosh (LLNL), Mitchell Troy and others (JPL), Olivier Guyon (Subaru), Ben Oppenheimer (AMNH), Michael Hart and Phil Hinz and others (University of Arizona)
Current Status: Detailed feasibility studies and simulations of high-contrast AO on GSMTs exist, but no program for technology development exists and no conceptual design phase has yet been funded.
Additional Information: Planet Formation Instrument for the TMT Feasibility Study Report: http://ao.jpl.nasa.gov/TMT/Publications/Technical/PFI_version_1_24.pdf
SPIE paper on TMT ExAO:
http://ao.jpl.nasa.gov/TMT/Publications/Technical/Advances_in_Adaptive_Optics_II_Edited_by_Ellerbroek_2006_Macintosh.pdf
SPIE paper on Exoplanet Imaging with the Giant Magellan Telescope:
http://ao.jpl.nasa.gov/TMT/Publications/Technical/Advancements_in_Adaptive_Optics_Edited_by_Domenico_B_Calia_2004_Codona.pdf

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47. Dual Focusing/Compton Gamma-Ray Telescope

Point of Contact: Steven Boggs, UC Berkeley
Summary Description: Gamma-rays at MeV energies provide a unique window on the high energy Universe, especially for both nuclear astrophysics and compact objects. The potential for significant contributions e.g. to the understanding of SNIa as well as the large potential for new discoveries has long been recognized, but technical progress in this challenging energy band has been slow. The groundbreaking discoveries of CGRO’s COMPTEL and INTEGRAL, however, have inspired and driven the development of powerful new instrumentation over the past decade. Novel detector technologies

developed in the US and Japan enable compact Compton telescopes, greatly improving the efficiency and field-of-view of this technique successfully employed by COMPTEL. In parallel, Laue diffraction lenses developed in Europe have demonstrated the ability to focus MeV gamma-rays over broad energy bands in a telescope configuration. The combination of these two developments, Laue lenses and compact Compton telescopes, have paved the way for the first ever focusing mission for gamma-ray astronomy. In such a configuration, the Compton telescope serves dual roles simultaneously, both as an optimal focal-plane sensor for deep focused observations (with the Compton imaging effectively collimating the focal plane), and as a sensitive wide-field Compton imager in its own right for all-sky surveys and monitoring. This combination addresses the issue of mass and cost inherent in previous Compton-only designs, yet can provide very good sensitivity for deep observations. Our international collaboration is studying this mission with the goal of proposing this as the next gamma-ray astrophysics mission.

Anticipated Sponsor: NASA

Given the strong interest in this mission in both Europe and Japan, CNES, ESA and JAXA would be potential partners.

Participating Individuals or Institutions: Steven Boggs, Cornelia Wunderer, Andreas Zoglauer (UC Berkeley), Neil Gehrels, Jack Tueller, Gerald Skinner (GSFC), Eric Wulf, Bernard Phlips, Neil Johnson, Eric Grove (NRL), R. Marc Kippen (LANL), Dieter Hartmann, Mark Leising (Clemson University), Grzegorz Madejski, Hiro Tajima (SLAC), Uwe Oberlack (Rice University), Peter von Ballmoos, Jürgen Knödlseder, Pierre Jean (CESR), Tadayuki Takahashi (ISAS), Jochen Greiner, Gottfried Kanbach, Roland Diehl (MPE)

Current Status: Novel Compton technologies have been demonstrated in both the laboratory and on balloon payloads in both the US and Japan. Tools and experience developed for the ACT concept study in the US have been utilized extensively in the performance studies of a focusing instrument. Laue lenses have been demonstrated in both the laboratory and on a balloon payload in Europe. Concept studies performed by CNES and ESA have demonstrated that such an instrument is technically feasible and affordable. Primary technologies have been demonstrated, making a focusing mission feasible in the next decade. A workshop on formulating an international approach to this mission is being held in Japan on March 10-11.

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48. Electronic Access to Astronomical Data

Point of Contact: Barry F. Madore, Carnegie Observatories

Summary Description: To facilitate on-line access to astronomical data across wavelengths and from multiple missions and observatories whether they are ground-based or Space-based.

Anticipated Sponsor: DOE, NASA, NSF

Participating Individuals or Institutions: NASA Mission, Wavelength and Thematic Archive Data Centers, NSF-funded ground-based Observatories, Professional Journals and their sponsoring Societies

Current Status: On-going and developing

Additional Information:

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49. Enabling a Wide-Field Multi-Object Spectroscopic Capability for the U.S. Astronomical Community

Point of Contact: Arjun Dey, NOAO
Summary Description: Spectroscopy is key to furthering astrophysical understanding. Most fundamental physical parameters that we measure for astronomical objects (velocity, kinematics, temperature, gravity/mass, ionization state, chemical abundance, age, etc.) are only feasible with spectroscopy. While there has been significant development of imaging capability on a variety of ground- and space-based platforms, there has been little advance in our ability to undertake large spectroscopic surveys to complement these ongoing and planned imaging surveys. At the same time, there is a growing awareness that answering many of the pressing astrophysical questions of the coming decade (e.g., the formation and evolution of galaxies, the assembly history of the Milky Way and its Local Group neighbors, the growth of structure in the universe, the chemical enrichment history of the universe, and questions related to the nature of dark matter and dark energy) require the capability of undertaking vast spectroscopic surveys on large aperture (i.e., 6.5 - 8m) telescopes. Our intent is to explore various paths to enabling a highly multiplexed wide-field spectroscopic capability for the benefit of the US astronomical community. Such a capability may take the form of a stand-alone facility or the conversion of an existing facility, with the trades being cost of implementation, the time available (to the US community) for dedicated surveys, and the cost of operations.
Anticipated Sponsor: DOE, NASA, NSF
Participating Individuals or Institutions: Marc Davis (UC Berkeley), Arjun Dey (NOAO), Daniel Eisenstein (U of Arizona), Sandy Faber (UC Santa Cruz), Jim Gunn (Princeton), Guinevere Kauffmann (MPA-Garching), James Larkin (UCLA), Francisco Prada (IIA), Connie Rockosi (UC Santa Cruz), David Schlegel (LBL), Charles Steidel (Caltech), Alex Szalay (JHU), Martin White (UC Berkeley), Rosemary Wyse (JHU)
Current Status: Pre-phase A
Additional Information: The science case and various implementations have been discussed in earlier documents: SWIFT - http://www.noao.edu/swift (stand-alone dedicated facility), KAOS - http://www.noao.edu/kaos (implementation on Gemini), WFMOS - http://www.gemini.edu/files/docman/science/aspen/WFMOS_feasibility_report_public.pdf (implementation on Subaru)
These previous concepts did not include any near-infrared spectroscopy, and we are currently looking into implementations that include an IR mode. The focus of this NoI is not necessarily to push a certain implementation, but to explore the feasibility and cost of different options. It is clear from the various science cases presented in these documents (and developed in further detail since then) that there is a need for a highly multiplexed spectroscopic capability on a large-aperture telescope. Our NoI is aimed at exploring various options for enabling this capability.

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50. Energetic X-ray Imaging Survey Telescope (EXIST)

Point of Contact: Jonathan Grindlay, Harvard-Smithsonian Center for Astrophysics
Summary Description: The Energetic X-ray Imaging Survey Telescope (EXIST) is a proposed NASA medium class mission to survey the Universe for black holes on all scales. It is a leading candidate to be the Black Hole Finder Probe, a satellite mission under study for NASA's Physics of the Cosmos Program. EXIST has three primary (and numerous secondary) science goals:

1. Detect and study cosmic gamma-ray bursts (GRBs) at high redshift to study stellar mass black hole formation and the epoch of re-ionization in the Early Universe.

2. Conduct an unbiased hard X-ray survey for supermassive black holes in galactic nuclei to measure the fraction that are obscured and/or dormant to constrain black hole evolution and the accretion luminosity of the Universe.
3. All-sky survey deep survey and studies of high energy transients, from stars to SMBHs, synoptic with ground and space temporal surveys.

The ASMC Study is nearing completion, and a mission concept and instrument design, optimized for science gain and minimal cost, has been developed which is much improved over what was proposed for the Beyond Einstein Program Assessment Committee (BEPAC). The mission includes three instruments: a High Energy Telescope (HET) employing a large area (4.5m^2) imaging CdZnTe (CZT) array and wide-field (90^o) coded aperture telescope for imaging the full sky every two orbits (3h) with 2' resolution and <20" source positions; a 1.1m aperture optical-IR Telescope (IRT), commercially developed for space, and instrumented with simultaneous imaging (0.15" pixels) and spectroscopy over the 0.3 – 2.2 micron band for rapid on-board redshifts of GRBs, AGN, and transients; and a Soft X-ray Imager (SXI), contributed by Italy/ASI, and providing ~15" resolution over a 20' field for 0.1-10 keV imaging spectroscopy of all targets. The mission would continuously survey the full sky by scanning for 2y (interrupted 2-3X per day for GRB followup and redshifts) followed by a 3y pointing (HET/IRT/SXI) phase to follow up on the most sensitive full-sky hard X-ray survey ever done. EXIST would include a GI program and complement Fermi, ALMA, JWST, JDEM, LSST, and IXO.

Anticipated Sponsor: NASA

Participating Individuals or Institutions: The current members of the ASMC Study Team for EXIST are listed below, by Institution. Names in (parentheses) are former Team members not now participating. Academic Partners: Branden Allen, Edo Berger, Martin Elvis, Pepi Fabbiano, Jonathan Grindlay, Lars Hernquist, Jaesub Hong, Avi Loeb, Matthew McQuinn, Arnold Rots, Alicia Soderberg (Harvard-Smithsonian), David Band, Scott Barthelmy, Neil Gehrels, Alexander Kutyrev, Harvey Moseley, Richard Mushotzky, Gerry Skinner, Jack Tueller, Bruce Woodgate (GSFC), Chryssa Kouveliotou, Mark Finger, Jerry Fishman, Brian Ramsey (MSFC), Josh Bloom, Phil Hopkins, Garrett Jernigan (UC Berkeley), Paolo Coppi, (Meg Urry) (Yale), Rick Cook, (Fiona Harrison), Ryan McLean (Caltech), (Roger Blandford), Greg Madejski (Stanford), Henric Krawczynski, Trey Garson (Washington University), Deepto Chakrabarty (MIT), Dieter Hartmann (Clemson University), Brad Peterson (Ohio State University), Phil Kaaret (University of Iowa), Suvi Gezari (Johns Hopkins), Leonidas Moustakas (JPL), Chris Belczynski (LANL/New Mexico State Univ.), Stan Woosley (UC Santa Cruz); Industry Partners: Dominick Conte (General Dynamics Advanced Information Systems), Craig Golisano (ITT Corp.); Foreign Collaborators: Italy: Giovanni Bignami , Patrizia Carveo, Gabriele Vila (INAF - Istituto di Astrofisica Spaziale e Fisica Cosmica Milan), Angela Bazzano, Fabrizio Fiore, Lorenzo Natalucci, Luigi Piro, Pietro Ubertini (INAF - Istituto di Astrofisica Spaziale e Fisica Cosmica Rome), Tomaso Belloni, Giovanni Pareschi, Gianpiero Tagliaferri (INAF - Osservatorio Astronomico di Brera), France : Stephane Corbel (Saclay/CEA), Didier Barret (Toulouse/CESR), Greece : Iossif Papadakis (Univ. Crete), Japan : Nobu Kawai (Tokyo Inst. Technology), Netherlands : Michiel van der Klis (Amsterdam), United Kingdom : Andy Fabian (Cambridge University), Martin Ward (Durham University)

Current Status: Considerable study has been carried out (e.g. GSFC IDL and MDL engineering studies) as part of the ASMC Study over the past year. Overall, EXIST is in Pre-Phase A development. Technology development has actively been going forward under NASA/APRA programs (e.g. the Harvard/GSFC/MSFC ProtoEXIST balloon-borne prototype wide-field hard X-ray imaging detector and telescope to be flown in 2009).

Additional Information: The EXIST website, on which additional information may be found, is at: http://exist.gsfc.nasa.gov

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51. Enhanced NASA Suborbital Program

Point of Contact: James C. Ling, NASA JPL

Summary Description: The need for a robust NASA suborbital program using high-altitude balloons and sounding rockets is well recognized and supported by the science community for achieving three major objectives: (a) a low cost and fast response and access to space for conducting top level scientific investigations that had led to several major discoveries in the past decades, (2) provide hands-on experience for training young scientists and engineers that the country would need to maintain its leadership in space exploration and space and earth science research in this century, and (3) provide a quick-access platform to validate performance of new technologies and instrumentation in the space environments that would be required for NASA missions. In order to achieve these objectives, we propose NASA establishes a new and stand-alone Suborbital program sufficiently funded as a separate item in the Congressional budget, that could (1) restore the flight rates to up to ~50 per year back to the early 1990's level, ~25 each for balloon and sounding rocket flights, and (2) provide adequate funding to build the state-of-the-art instrument payload for conducting top-level science investigations.

Anticipated Sponsor: NASA, NSF

Participating Individuals or Institutions: Jet Propulsion Laboratory – James C. Ling, Jeffrey Booth, Wes Traub, Mark Swain, Jamie Bock, Michael Seiffert

Current Status: We are proposing a significant enhancement to an ongoing program.

Additional Information:

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52. Exoplanet Exploration Program

Point of Contact: Michael Devirian, NASA JPL

Summary Description: The Exoplanet Exploration Program supports the Vision for Space Exploration objective to conduct "advanced telescope searches for Earth-like planets and habitable environments around other stars."

The Exoplanet Exploration Program will help address the following goal of NASA's 2006 Strategic Plan:

- Sub-goal 3D: Discover the origin, structure, evolution, and search for Earth-like planets.

The Exoplanet Exploration Program will help address the following research objectives from the Science Plan for NASA's Science Mission Directorate 2007–2016 (January 2007):

- Understand how individual stars form and how those processes ultimately effect the formation of planetary systems.
- Create a census of extrasolar planets and measuring their properties

Anticipated Sponsor: NASA

Participating Individuals or Institutions: NASA, NASA/JPL, NASA/GSFC, NASA/ARC Virtually all individuals in the community interested in exoplanet exploration. International collaborations will likely be formed, but are not formalized at this point.

Current Status: Some activities are in or near operation (Keck Interferometer, LBTI, Kepler); others are in Phase B (SIM); still others are pre-Phase A (various versions of high-contrast imaging and spectroscopy missions). In response to the 2001 Decadal Survey, significant investment has been made by NASA in enabling technologies, bringing some approaches to readiness for implementation, while others require continued technology development. The essential steps needed to accomplish the Program's goals are understood, although there are a variety of implementation strategies, with a range of cost, risk and schedule implications.

Additional Information: Exoplanet Exploration Program: http://exep.jpl.nasa.gov/, Exoplanet Community Report (draft, Nov 2008): http://exep.jpl.nasa.gov/documents/Forum2008_268_small.pdf; Terrestrial Planet Finder Coronagraph, Science and Technology Definition Team (STDT) Report (June 2006): http://planetquest.jpl.nasa.gov/TPF/STDT_Report_Final_Ex2FF86A.pdf, Terrestrial Planet Finder Coronagraph, Flight Baseline #1 Report (July 2005): http://planetquest.jpl.nasa.gov/documents/TPFC-FB1_Report.pdf, Terrestrial Planet Finder Coronagraph Technology Plan (March 2005), http://planetquest.jpl.nasa.gov/TPF/TPF-CTechPlan.pdf, http://planetquest.jpl.nasa.gov/TPF-I/tpf-I_index.cfm, http://planetquest.jpl.nasa.gov/

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53. Exoplanet Observations from Sub-Orbital Platforms

Point of Contact: Wesley A. Traub, NASA Jet Propulsion Laboratory

Summary Description: The purpose of this activity is to advocate sub-orbital platforms as low-cost, quickly-implementable platforms for photometric and spectroscopic observations of exoplanets, and as vehicles from which the technology readiness level (TRL) of components can be advanced, all in preparation for subsequent space missions to characterize exoplanets. Our ability to characterize the atmospheres, and possibly surfaces, of exoplanets is currently expected to depend on three main techniques: transits (including related light-curve methods), direct imaging at visible wavelengths, and direct imaging at infrared wavelengths. Since transits will be limited to the small fraction of transiting or near-transiting geometries, and are unlikely to be applicable to Earth-size planets, the bulk of future characterizations will be carried out by direct imaging techniques. Our experience has been that all space-based direct-imaging instruments that are capable of observing Earth-like exoplanets are relatively large in scale, and utilize advanced technologies that are currently at low TRL values; both factors militate against immediate adaptation into a space mission. However if we can test some of these techniques on low-cost, near-term sub-orbital platforms, then we can simultaneously carry out modest science observations while at the same time dramatically increasing the TRL of components. The goal of this activity is to investigate these opportunities, and provide advice on specific examples of science and technology advances that could be accomplished through the use of sub-orbital platforms. It should be noted that the readiness of coronagraph imaging technology has been steadily increasing through laboratory demonstrations and is higher than most people think. In particular, several testbeds (at JPL, Ames, Subaru, and Princeton) have been testing concepts that are readily applicable to a balloon-borne mission. At JPL, contrasts of 10^-9 have been demonstrated at 3 lambda/D, which is already sufficient to start imaging exo-Jupiters if this performance can be repeated on a balloon. At testbeds on Subaru and Ames, contrasts on the order of 10^-7 have been demonstrated at 2 lambda/D and are getting better. Technology development at these testbeds has a successful track record and is key in having a successful mission.

Anticipated Sponsor: NASA

Participating Individuals or Institutions: Jon Arenberg, Ruslan Belikov, Robert Brown, Pin Chen, Robert Fesen, Christ Ftaclas, Olivier Guyon, N. Jeremy Kasdin, Brian Kern, John Krist, Peter Lawson, Marie Levine, Mark Marley, Bruce Macintosh, Taro Matsuo, Dimitri Mawet, Calvin Barth Netterfield (Canada), M. Charley Noecker, Ronald Polidan, Steven Ridgway, Eugene Serabyn, Stuart Shaklan, Michael Shao, Remi Soummer, Karl Stapelfield, Mark Swain, Motohide Tamura (Japan), Wesley Traub, John Trauger, Steven Unwin, Robert Vanderbei, Yuk Yung

Current Status: Pre-phase A

Additional Information: none

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54. Exoplanet Spectroscopy

Point of Contact: Mark R. Swain, NASA JPL
Summary Description: Exoplanet molecular spectroscopy (EMS) is currently emerging as the most powerful tool available for detailed characterization of exoplanet atmospheres. Recent successes with "combined light" EMS include the detection of molecules (water, methane, carbon dioxide, and carbon monoxide) in a "hot-Jupiter" atmosphere using both the Hubble and Spitzer space telescopes. Based on the achieved signal-to-noise, these measurements demonstrate that detection of molecules of potential biological significance is feasible for some habitable zone planets where life could possibly exist. Significantly, the recent EMS results also demonstrate that new technology development is not required to begin the process of detailed characterization of exoplanet atmospheres. The leading teams in the field are addressing questions such as the role of dynamics in establishing atmospheric chemistry, the affect of photochemistry, the vertical and longitudinal thermal/chemical structure, and whether recently detected spectroscopic variations are primarily due to changes in temperature or changes in composition. Excellent opportunities exist for EMS using space, balloon-borne, and ground-based telescopes. However, the simultaneous need for broad spectral coverage (near-infrared to mid-infrared) and contemporaneous measurements (measuring the entire spectrum at one time) may imply a limitation for EMS using the James Webb Space Telescope if exoplanet variability is significant. The latest EMS results demonstrate that exoplanet spectroscopy is becoming a "field-spanning" discipline that benefits from contributions from both an astronomical and a planetary science perspective; EMS is growing rapidly, with new high-impact results from Hubble and Spitzer expected over the next few months.
Anticipated Sponsor: NASA, NSF
Participating Individuals or Institutions: Drake Deming (NASA GSFC), Carl Grillmair (Caltech SSC)
Current Status: The white paper covers work that ranges from published results to pre-phase A.
Additional Information: Swain et al. The presence of methane in the atmosphere of an extrasolar planet, 2008, Nature, 452, 329.
Grillmair et al. Strong water absorption in the dayside emission spectrum of the planet HD189733b, 2008, Nature, 456, 767.
Swain et al. Molecular Signatures in the Near-Infrared Dayside Spectrum of HD 189733b, 2009, ApJ, 690L, 114.

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55. Extrasolar Planetary Imaging Coronagraph (EPIC)

Point of Contact: Dr. Mark Clampin, NASA GSFC
Summary Description: The direct characterization of exosolar planets is predicated on the ability to unambiguously detect planets in the presence of diffracted and scattered light from the parent star, its exozodiacal light and other objects in the field of view. Astrometric missions can in principle detect Earth mass planets and determine their orbital parameters; however, astrometric missions cannot determine the amount of zodiacal light present in the system. EPIC is an innovative approach to both image and characterize Jovian planets and exozodi debris disks, which takes a more technologically conservative step toward meeting the long-term goal of imaging terrestrial planets in exosolar systems.
EPIC has been studied as a NASA ASMC concept mission with a 1.65 m aperture telescope coupled to a visible nulling coronagraph to suppress the starlight by a nominal factor of 109 in visible light from 0.4 – 1.0 microns. EPIC has previously been studied as

a Discovery mission concept with a 1.5-meter aperture. The level of starlight suppression required to detect super-Earths and Jovian-class exoplanets places less stringent tolerances on the telescope than that required to detect true Earth analogs, thereby keeping the EPIC cost at a level that fits within NASA's Medium-Class Mission category envisioned for Exoplanet Probes, without incurring unacceptable levels of risk.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Mark Clampin (NASA/GSFC), Gary Melnick (SAO/CfA), Richard Lyon (NASA/GSFC), Garth Illingworth (U of Cal), Volker Tolls (SAO/CfA), Michael Shao (NASA/JPL), Bruce Levine (NASA/JPL), Holland Ford (JHU), Robert Woodruff (LMCO), Larry Petro (STScI), Alycia Weinberger (Carnegie), Jean Schneider (Obs of Paris), Douglas Lin (UC Santa Cruz), George Hartig (STScI), Martin Harwit (Cornell U), Mark Marley (NASA/Ames), Sara Seager (MIT), Jian Ge (U of FL), Dimitar Sasselov (Harvard Obs), William Sparks (STScI), Scott Kenyon (SAO/CfA), David Golimowski (JHU)
Current Status: EPIC is in pre-phase A and has received 3 years of NASA/GSFC IRAD support and is a funded NASA/ Astrophysics Strategic Mission Concept Study. A detailed design exists for the EPIC spacecraft, visible nulling coronagraph and science instruments. Instrument and nuller models have been used to develop sensitivity analysis and error budget. In addition multiple laboratory testbeds have been developed at GSFC and JPL to demonstrate that broadband visible light nulling is a viable technology. Additionally Lockheed-Martin and Ball Aerospace have contributed as industrial partners.
Additional Information:

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56. Extreme Universe Space Observatory on the Japanese Experiment Module (JEM-EUSO)

Point of Contact: Yoshiyuki Takahashi, Kobe University
Summary Description: JEM-EUSO is an international mission that is designed to identify the astronomical origin of extreme energy cosmic ray particles with energies >10^20 eV. Its instrument uses a near-UV telescope with the diameter of 2.5-m and the field-of-view of 60-degrees for the detection of fluorescence and Cherenkov light along the linear track of a cosmic ray event in atmosphere. JEM-EUSO can detect at least 1,000 particles above 7 x 10^19 eV in a three year mission assuming the Greisen-Zatsepin-Kuzmin cutoff. Their energy and arrival direction will be accurately measured while all-sky is covered and monitored. These data will be used to identify the sources of the highest-energy particles (including neutrinos) and clarify their origin. The Japan Experiment Module (JEM) on the International Space Station (ISS) will host JEM-EUSO. Whereas an ordinary astronomical observatory looks up at the universe from earth, JEM-EUSO observes the universe by looking toward the earth because the earth's atmosphere is the largest detector yet employed in our quest to understand the origins of these elusive particles coming from the universe JEM-EUSO is a new type of astronomical space observatory, namely, an "earth-observing" astronomical telescope.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: US Institutions: University of Alabama in Huntsville, NASA Marshall Space Flight Center, Vanderbilt University, University of Arizona, Space Science Laboratory at the University of California at Berkeley (SSL at UCB), University of California at Los Angeles (UCLA); International Institutions: France: APC Paris 7, LAL Paris 11, CNRS / IN2P3 / CEA/ Obs. Paris, Germany: MPI Munich, Univ. Tuebingen, MPI Bonn, Univ. of Wuerzburg, Univ. of Erlangen, LMU & MPQ, Japan: RIKEN, Konan Univ, Fukui Univ. Tech, Aoyama Gakuin Univ., Saitama Univ., NIRS, Univ. of Tokyo, Tohoku Univ., ICRR at the Univ. of Tokyo, KEK, Chiba Univ., NAOJ, ISAS/JAXA, Kanazawa Univ., Nagoya Univ., STE Lab. at Nagoya Univ., Kyoto Univ., Yukawa Inst. at Kyoto Univ., Kobe Univ., Kinki Univ., Hiroshima Univ. and Hokkaido Univ.,

Italy: Univ. di Firenze, CNR-INOA Firenze, CNR-IFAC Firenze, IASF-PA/INAF, Univ. di Palermo, INFN & Univ. of Rome “Tor Vergata”, INAF-IFSI Torino, Univ. Torino, INFN & Univ. of Napoli <<Federico II>>, INFN-National Laboratories of Frascati, Republic of Korea: Ajou Univ., Ehwa Woman’s Univ., Yonsei Univ., Chonnam National Univ., Mexico: Mexico-UNAM, BUAP, UMSNH, Russia: SINP-MSU, Dubna JINR, Switzerland: CSEM (Centre Suisse d'Electronique et de Microtechnique SA), Spain:Univ. of Alcala, Poland: IPJ, Podlasie Univ, Kielce Univ., Jagiellonian Univ., Slovakia: Inst. Exp. Phys-KOSICE
Current Status: The EUSO (and later JEM-EUSO) mission has been under definition and development since 1999. It is currently in a Phase A/B Study in Japan. ESA completed Phase-A with the conclusion in 2004 that EUSO is technically ready for Phase-B. The U.S. NASA Explorer program (MIDEX) selected EUSO in 2002-2003 and successful Phase-A and an interim Phase-A/B were completed in 2004-5. There has already been extensive simulation, design, and prototype hardware development around the world. The US investigators have been invited to participate in JEM-EUSO by contributing to the optics design and development, trigger design and detector advisory, as well as in science analysis. The US investigators are seeking an endorsement of JEM-EUSO from the Decadal Survey so that NASA will restart EUSO and provide an opportunity for US participation.
Additional Information: http://jemeuso.riken.jp/en/index.html
http://www.universe-cluster.de/MaKaC/getFile.py/access?contribId=30&resId=0&materialId=slides&confId=461
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57. FacTel (Fast Compton Telescope)

Point of Contact: James Ryan, University of New Hampshire
Summary Description: The top scientific priority for medium-energy gamma-ray astronomy is a comprehensive all-sky survey with an order of magnitude improvement in sensitivity over the COMPTEL instrument on CGRO. A broad range of astrophysical sources is best studied via observation in the energy band from 0.4-10 MeV, including relativistic particle accelerators such as black holes, pulsars, and solar flares, nuclear decays in supernovae, novae, and stellar nucleosynthesis, and diffuse galactic and cosmic backgrounds. COMPTEL was able to detect examples of these phenomena, but was unable to study a representative sample of any source class. The simplest and most cost-effective was to make progress is via a new Compton telescope employing advanced scintillator technology. This approach makes direct use of the experience from COMPTEL while substantially improving performance, all while retaining a straight-forward, low-risk implementation. Specifically, the Fast Compton Telescope (FACTEL) concept combines a deuterated liquid scintillator scattering layer with a LaBr3:Ce calorimeter to create a compact instrument suitable for an Explorer-class mission. The improved stopping power, light output, and response time of LaBr3:Ce leads directly to improved efficiency, energy resolution, and imaging of the telescope, while the fast timing allows greatly improved background rejection via time-of-flight discrimination. FACTEL will improve on the sensitivity of COMPTEL by an order of magnitude and conduct a comprehensive survey of the MeV sky at reasonable cost.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: University of New Hampshire, Los Alamos National Laboratory
Current Status: Design and Development
Additional Information:
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58. Far-Infrared Interferometry using Suborbital Balloons

Point of Contact: Stephen Rinehart, NASA GSFC
Summary Description: The Balloon Experimental Twin Telescope for Infrared Interferometry (BETTII) is an eight-meter baseline interferometer designed to fly on a high-altitude balloon. Operation at these altitudes makes far-infrared (FIR; 30-300 microns) observations possible, and the eight-meter baseline provides unprecedented spatial resolution (~0.5 arcsec) in this band. No other existing or planned facility can provide this level of angular resolution in this wavelength regime. Our double-Fourier instrument will simultaneously obtain spatial and spectral information, a powerful new scientific capability for studying a wide range of astronomical subjects, including star formation, active galactic nuclei, and evolved stars. Technically, this work lays the groundwork for future space-based interferometry by demonstrating the feasibility of almost all of the necessary technologies in a space-like environment. By combining state-of-the-art astronomical observations with technology demonstration and risk reduction for future missions, BETTII is a uniquely powerful instrument that can be built and flown at a very low overall cost ($5M).
Anticipated Sponsor: NASA
Participating Individuals or Institutions: D. Leisawitz, D. Benford, W. Danchi, R. Silverberg, R. Barry (NASA GSFC) L. Mundy, J. Staguhn, D. Fixsen (University of Maryland, College Park)
Current Status: Design/proposal stage
Additional Information:

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59. General Antiparticle Spectrometer Experiment (GAPS)

Point of Contact: Chuck Hailey, Columbia University
Summary Description: GAPS is a balloon-borne experiment that attempts to indirectly detect dark matter through the antideuterons generated in WIMP annihilation. GAPS will improve antideuteron detection sensitivity by 3 orders of magnitude, directly probing the relevant SUSY parameter space for neutralinos. GAPS also has high sensitivity for antideuterons generated from the lightest particles in Kaluza-Klein and warped GUT theories. GAPS target design sensitivity is higher than any other planned or current antideuteron experiment.
Anticipated Sponsor: DOE, NASA, Other
GAPS has collaborators in Japan (JAXA/ISAS) and the Danish Technical University. These collaborators will bring separate national contributions to the project.
Participating Individuals or Institutions: Institution leads: Prof. Rene Ong (UCLA), Prof. Steve Boggs (UC Berkeley), Drs. Hide Fuke and Tetsuya Yoshida (JAXA/ISAS), Dr. Finn Christensen (DTU), Dr. Klaus Ziock (Oak Ridge National Laboratory), Dr. William Craig (Lawrence Livermore National Laboratory)
Current Status: NASA has funded this activity through launch of a prototype experiment in 2011. The full experiment would launch in 2014.
Additional Information: GAPS website: http://gamma1.astro.ucla.edu/gaps/index.html

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60. General astrophysics with New Worlds Observer: A 4-meter class UV/Visual/near-IR Telescope in Deep Space.

Point of Contact: John Bally, Univ. of Colorado
Summary Description: New Worlds Observer (NWO), a 4-meter class telescope

designed to detect and characterize Earth-like planets around nearby stars with a star-shade, will be a powerful observatory for general astrophysics. NWO will have extended UV and near-IR sensitivity, angular resolution nearly a factor of two better than Hubble or JWST, and unprecedented astrometric and photometric stability due to its high Earth orbit. Wide-field focal-plane array imaging conducted in parallel with star-shade assisted exo-planet observations will find background planets around field stars using transits and gravitational micro-lensing. Deep synoptic monitoring of these fields will detect distant supernovae, some of Type Ia, which can be used to measure cosmic acceleration and the properties of dark energy. These data will also set stringent new constrains on all types of variable and moving sources including comets, asteroids, variable stars, and GRB after-glows in the fields surrounding every NWO target star. The time-averaged data will enable mapping of the distribution of dark matter in distant galaxy clusters using the "weak-lensing" method of searching for correlations in gravitationally lensed galaxy shapes. While the star-shade is being moved to a new target, the NWO 4-meter telescope can be used for general astrophysics observations including spectroscopy of targets requiring precise pointing. Over half of NWO space-craft hours will be available for general astrophysics, enabling investigations being proposed for other, dedicated, but smaller space telescopes.

Anticipated Sponsor: NASA

Participating Individuals or Institutions: Webster Cash ,Margaret C. Turnbull, Aki Roberge, Amy Lo, Charley Noecker, Tiffany Glassman, Giovanna Tinetti, Phil Oakley, Daphne Stam, Sean Raymond, and Chuck Lillie

Current Status: pre-phase-A

Additional Information:

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61. General astrophysics with the Joint Dark Energy Mission

Point of Contact: I. Neill Reid, STScI

Summary Description: The NASA/DOE Joint Dark Energy Mission (JDEM) will probe the nature of dark energy through measurements of weak lensing, baryon acoustic oscillation and high redshift supernovae. JDEM will represent the first true foray into space-based wide-field, high angular-resolution, far-red optical and near-infrared imaging and spectroscopy. Regardless of the final mission design, the JDEM datasets have the potential to revolutionize general astrophysics, in addition to providing a more conclusive answer on dark energy. Implemented from the outset as an integral part of the JDEM design, this program will offer a key opportunity to significantly increase the overall scientific impact of the mission and to expand, by orders of magnitude, the community of astronomers supporting it. Experience with missions such as the Hubble Space Telescope, Spitzer and GALEX and with projects such as the 2-Micron All-Sky Survey and the Sloan Digital Sky Survey has demonstrated that the overall scientific impact is critically tied to the breadth of the community served. Many scientific discoveries were not planned during the conception and design of those missions, but were enabled by flexibility to go beyond the core mission objectives. A strong, diverse General Astrophysics program almost certainly can be achieved with little or no added cost to the mission. However, to ensure this, it is vital that the General Astrophysics program is included explicitly in the early phases of mission design

Anticipated Sponsor: DOE, NASA

Participating Individuals or Institutions: I.Neill Reid, Carol Christian, Harry Ferguson, Andy Fruchter, Mario Livio, Antonella Nota, Roeland van der Marel, Rick White and Marc Postman; Space Telescope Science Institute

Current Status: The expectation is that the JDEM AO will be issued early in 2009.

Additional Information:

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62. Generation-X Technology Program

Point of Contact: Roger J. Brissenden, SAO
Summary Description: The Generation-X (Gen-X) mission is a large effective area (~50 sq. m), high angular resolution (~0.1 arcsec) X-ray telescope with science goals to observe the formation and evolution of the first galaxies and black holes at high redshift - to z~10-15, and trace the chemical evolution of the Universe through X-ray spectroscopy. The mission is planned to follow the International X-ray Observatory (IXO), building on both the science and technology. We have produced a technology development plan (including costs) for Gen-X under NASA's Astrophysics Strategic Mission Concept Study program, and have identified the optics and X-ray detectors as the driving technology for the mission. The proposed program is structured around a series of technology gates that raise the technology readiness level to TRL-6 over approximately a decade.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Roger Brissenden, Martin Elvis, Giuseppina Fabbiano, Paul Gorenstein, Mike Juda, Paul Reid, Dan Schwartz, Harvey Tananbaum (Smithsonian Astrophysical Observatory), Simon Bandler, Ann Hornschemeier-Cardiff, Richard Mushotzky, Robert Petre, William Zhang (Goddard Space Flight Center), Steve O'Dell, Martin Weisskopf (Marshall Space Flight Center), Mark Bautz, Claude Canizares, Enectali Figueroa-Feliciano, Mark Schattenburg (Massachusetts Institute of Technology), Robert Cameron, Steve Kahn (Stanford University), Niel Brandt, Susan Trolier-McKinstry (Penn State), Melville Ulmer (Northwestern), Webster Cash (University of Colorado), Robert Rosner (University of Chicaco/Argonne National Laboratory), Chuck Lillie (Northrup Grummann), Steve Jordan (Ball Brothers), Linda Abramowixcz-Reed (Goodrich), Craig Golisano (ITT Corp.), Domenick Tenerelli (Lockeed-Martin)
Current Status: Under study as part of NASA's Astrophysics Strategic Mission Concept Study program.
Additional Information: http://www.cfa.harvard.edu/hea/genx/

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63. Gravitational redshift

Point of Contact: Ari Brynjolfsson, Applied Radiation Industries
Summary Description: The proposed work is in the thematic science area of Cosmology and Fundamental Physics (CFP). In light of my (Ari Brynjolfsson) theory of "Plasma redshift of photons penetrating hot sparse plasma" (arXiv:astro-ph/0401420) it became clear that the gravitational redshift of optical photons is reversed when the photons move from the Sun to the Earth. (Due to Uncertainty Principle in quantum mechanics, this does not conflict with the experiments of Pound et al. or any other experiments, which were all interpreted as if classical physics ruled the world.) Therefore optical photons emitted from the planets, for example, Mercury, Venus, Marsh, and Jupiter would show no gravitational redshift when measured on Earth. This contradicts the conventional gravitational redshift theory, which assumes that the optical photons emitted from, for example, from the planet Mercury are redshifted by 2.54 per 100 million (=1.56 per 100 million relative to the observer on Earth.) This can be measured with adequate accuracy using powerful telescope, long exposure time, and sensitive detectors and spectrographs. Assuming that my plasma-redshift theory is proven right, this would have tremendous consequenses for cosmology and gravitational theory. I suggest therefore that high priorities be given to these measurements.
Anticipated Sponsor: NSF
The thematic science area is "Cosmology and Fundamental Physics" (CFP). This project therefore could be sponsored by any of the above mentioned organizations.

Participating Individuals or Institutions: I, Dr. Ari Brynjolfsson, the point of contact will seek cooperation of University professors and their graduate students (in USA and abroad) with expertice in this field.
Current Status: Pre-phase A
Additional Information: This work will have enormous consequences for cosmology and general understanding of gravitational physics. See, Ari Brynjolfsson; "Plasmaredshift of photons penetrating hot plasma" in arXiv:astro-ph/0401420; and "Weightlessness of photons; A quantum effect" in arXiv:astro-ph/0408312

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64. Gravity and Extreme Magnetism SMEX (GEMS) to measure the polarization of the X-ray flux from astrophysical sources

Point of Contact: Jean Swank, NASA GSFC
Summary Description: A SMEX mission can measure or strongly constrain the 2-10 keV polarizations of samples of many important types of X-ray sources, not only Galactic black holes, but supermassive black holes in Active Galactic Nuclei, not only bright accreting neutron stars, but magnetars. It can measure average polarizations of a few faint Pulsar Wind Nebula as well as separate the polarization of the Crab pulsar from that of the Nebula and resolve the shells of a sample of supernova remnants. Such measurements can provide strong constraints on quantities of fundamental interest for the study of these sources, such as black hole spin or magnetar field structure.The goal of GEMS is to be able to achieve a sensitivity of 1% for point sources brighter than 2.4 x 10^-11 erg cm-2 s-1 (1 mCrab) and to be able to measure predicted polarizations in at least 2 energy bands to be diagnostic of competing models of the sources. Telescope area that can fit in the SMEX envelope, coupled with efficient detectors, will produce count rates that would achieve these measurements in observing times of days to a few weeks, so that the mission can observe multiple targets of each type. Such a mission will establish the level of polarizations that characterize these sources averaged over these times and as functions of phases or intensities of repeated variability.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Jean Swank, Timothy Kallman, Keith Jahoda, Kevin Black, Phil Deines-Jones, Joanna Hill, Tod Strohmayer, Peter Serlemitsos, Yang Soong, James Lochner, Lorella Angelini (GSFC), Philip Kaaret (U. Iowa), Jeffrey Scargle, Jesse Dotson, Robin Morris (ARC), Herman Marshall (MIT)
Current Status: Phase A
Additional Information: http://heasarc.gsfc.nasa.gov/docs/gems/

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65. Green Bank Interferometer for Neutrino Transients (GLINT)

Point of Contact: Glen Langston, West Virginia University, Vanderbilt University, National Radio Astronomy Observatory
Summary Description: Identifying the sources of the highest energy cosmic rays is a fundamental unsolved problem in both high-energy physics and astrophysics. Ultra-high energy (UHE) neutrinos provide a key probe to the nature and location of cosmic ray engines since they travel essentially unimpeded from their source to our solar system, providing a directional tracer of their origin. We seek to understand the physics of UHE neutrinos for the first time through a dedicated search for Cerenkov radio pulses associated with grazing neutrino interactions with the lunar regolith. Our approach is to connect an existing 43-meter diameter telescope with two 26-meter telescopes at the NRAO Green Bank WV, as a dedicated interferometer for detection of the very short

duration (few nano-second) pulses. Interferometry will be used to discern the spatial location of the events which, in turn, is used to distinguish neutrino-induced pulses from those resulting from cosmic rays. In addition, the temporal, spectral, and polarization characteristics of the neutrino-based pulses will be measured to determine the energy of the primary particle and its direction of arrival. All of this is made possible using high speed digital signal processing platforms, wide bandwidth receivers, and very long observing runs. This experiment will be 300 times more sensitive than previous searches for lunar neutrinos. The science goals require $2.7M for receiver construction, correlator development and antenna refurbishment. Our plan calls for two years of continuous operation at a cost of $1.3M per year.

Anticipated Sponsor: DOE

Participating Individuals or Institutions: Dr. Glen Langston (WVU, Vanderbilt University, NRAO), Dr. Richard Bradley (UVA, NRAO), Dr. Robert Mutel (University of Iowa), Dr. Tim Hankins (New Mexico Tech)

Current Status: Design and prototyping of critical components of this system is underway. All major antennas structures exist but the receiver, correlation and event detection systems require further development. All major hardware components have been identified, but significant work remains.

Additional Information: http://www.gb.nrao.edu/glint

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66. Hard X-ray Polarization with the HX-POL Experiment

Point of Contact: Henric Krawczynski, Washington University

Summary Description: Balloon-borne experiments can make substantial contributions to the field of hard X-ray astronomy. HX-POL is a proposed balloon borne-hard X-ray polarimeter experiments that operates in the 50 keV-500 keV energy range. On 15-30 day long duration balloon flights from Australia or Antarctica, HX-POL would be be able to measure the polarization of bright X-ray sources down to polarization degrees of 1%. Hard X-ray polarization measurements provide unique venues for the study of particle acceleration processes by compact galactic objects like accreting neutron stars, young high-magnetic-field pulsars, binary black holes, as well as X-ray bright extragalactic objects, i.e. active galactic nuclei and gamma-ray bursts.

As satellite-borne missions are becoming more expensive and launches less frequent, it is important for the education of the next generation of scientists and for the health of the field to have a vibrant balloon program that emphasizes as much scientific results as the validation of technologies that are relevant for future satellite-borne experiments.

Anticipated Sponsor: NASA

Participating Individuals or Institutions: H. Krawczynski (1), A. Garson III (1), Q. Li (1), M. Beilicke (1), , E. Wulf (2), J. Kurfess (2), E. Novikova (2) ((1) Washington University in St. Louis, (2) Naval research Laboratory)

Current Status: Design and Development

Additional Information: http://xxx.lanl.gov/abs/0812.1809

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67. HAWC (High Altitude Water Cherenkov) Observatory

Point of Contact: Jordan Goodman, University of Maryland

Summary Description: The HAWC (High Altitude Water Cherenkov) observatory is a second generation wide-field (2 Pi sr), high duty factor (>95%) gamma-ray telescope with 10-15 times the sensitivity of the first generation Milagro detector. Milagro discovered that at TeV energies the diffuse component to the Galactic radiation (arising from the interactions of cosmic ray protons and electrons with the matter and radiation fields in the

Galaxy) is significantly higher than model predictions. HAWC will be capable of mapping this diffuse emission and measuring its energy spectrum across the Galaxy at energies between 1 and 100 TeV. These measurements, coupled with similar measurements at lower energies by GLAST will enable the disentanglement of the different contributions to this emission and thereby allow one to determine if there are additional components arising from exotic phenomena. At the highest energies (above 5-10 TeV), HAWC will be the most sensitive gamma-ray instrument. Therefore, HAWC will be uniquely suited to study the energy spectra of Galactic sources up to the highest energies (near 100 TeV). These measurements are critical in finding the proton acceleration sites within our Galaxy and the individual sources of the cosmic radiation. To further our understanding of particle acceleration in the cosmos it is important to understand particle acceleration around supermassive black holes (active Galactic nuclei or AGN). These objects have the demonstrated ability to rapidly and dramatically increase their luminosity at TeV energies, yet because of the nature of previous instruments (pointed instruments with small duty cycles), we do not have a complete picture of the flaring nature of these objects. The HAWC telescope will monitor over 800 AGN within a redshift of 0.1 everyday and be capable of detecting 15 minute flares where the flux is at least 5 times that of the Crab Nebula from any of these objects. This data set will naturally enable a large multi-wavelength/multi-messenger campaign with which to study particle acceleration in relativistic jets. In addition to the rich physics described above, HAWC will be the most sensitive instrument for detecting prompt emission from gamma-ray bursts at energies above 100 GeV, monitor the thousands of sources discovered by GLAST, and search for new phenomena in the TeV sky. HAWC is being constructed inside the Parque Nacional Pico de Orizaba, a Mexican national park at 4100m above sea level located about two hours from Puebla. The observatory will consist of 900 water tanks (4.6m tall) instrumented with a single 20 cm diameter photomultiplier tube in each tank. The tanks will be arranged in a dense-pack configuration spread over 25,000 m2. HAWC can be built quickly (within three years) at a total cost less than $10M.
Anticipated Sponsor: DOE, NSF, CONACyT (the Mexican NSF)
Participating Individuals or Institutions: USA: Jordan Goodman, Andrew Smith, Greg Sullivan (University of Maryland), Gus Sinnis, Brenda Dingus, John Pretz (Los Alamos National Laboratory), Dave Kieda, Petra Huntemeyer (University of Utah), John Matthews (University of New Mexico), Jim Linnemann, Kirsten Tollefson (Michigan State University), Ty DeYoung, Patrick Toale, Kathryne Sparks (Pennsylvania State University), Julie McEnery (NASA/Goddard Space Flight Center), James Ryan (University of New Hampshire), Gaurang Yodh (University of California, Irvine), Ignacio Taboada (Georgia Tech University), Robert Ellsworth (George Mason University); Mexico: Alberto Carramiñana, Eduardo Mendoza (Instituto Nacional de Astrofísica Óptica y Electrónica (INAOE)), Magdalena González, Dany Page, William Lee, Hector Hernández, Deborah Dultzin, Erika Benitez (Universidad Nacional Autónoma de México (UNAM) Instituto de Astronomía), Arturo Menchaca, Rubén Alfaro, Andres Sandoval, Ernesto Belmont (Instituto de Física), Lukas Nellen, G. Medina-Tanco (Instituto de Ciencias Nucleares), José Valdés Galicia, Alejandro Lara (Instituto de Geofísica), Humberto Salazar, Oscar Martínez, Cesar Álvarez, Arturo Fernández (Benemérita Universidad Autónoma de Puebla), Luis Villaseñor (Universidad Michoacana de San Nicolás de Hidalgo), Arnulfo Zepeda (CINVESTAV), David Delepine, Gerardo Moreno, Marco Reyes, Luis Ureña, Victor Migenes (Universidad de Guanajuato)
Current Status: Design and Development - using MRI seed funding from NSF and CONACyT (Mexico), Full project proposed to NSF, DoE and CONACyT.
Additional Information: http://hawc.umd.edu/

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68. High-Contrast, Narrow-Field Exoplanet Imaging with a Close-Packed Multi-Aperture Telescope Array (MAT) Phased Array Coronagraph (PAC)

Point of Contact: Gene Serabyn, NASA JPL
Summary Description: The coronagraphic imaging of nearby solar systems with a densely-packed array of small, inexpensive collector telescopes is considered. With each small collector in the envelope pupil decoupled from the others, a reduced pupil can be assembled downstream of the collectors either by means of an array of delay lines, or more conveniently, by means of a single-mode-fiber array. Tuning the intensity and phase of the light in each pupil element allows control over the pupil plane field, thus enabling arbitrary, tunable, complex pupil-plane apodization. Calculations show that such a “phased array coronagraph” (PAC) can in principle provide the 10-10 image plane contrast required for terrestrial exoplanet observations near bright stars. A PAC may thus provide a route to coronagraphic observations of faint exoplanets which is potentially both flexible and relatively inexpensive.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: a few people at JPL
Current Status: definitely way before pre-phase-A!
Additional Information:

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69. Hobby-Eberly Telescope Dark Energy Experiment, HETDEX

Point of Contact: Karl Gebhardt, University of Texas at Austin
Summary Description: HETDEX, the Hobby-Eberly Telescope Dark Energy Experiment, will measure the expansion history of the universe from 1.9<z<3.5. The main goal is to better understand dark energy, with a primary focus on discovery space. We will use the shape of power spectrum of galaxies to constrain the local Hubble rate and angular diameter distance, each to about 0.8%. The main targets will be Lyman-alpha emitting galaxies (LAEs). Our baseline survey is 420 square degrees and we will find approximately 0.8 million LAEs and about 1 million low-redshift (z<0.5) OII emitting galaxies. The baseline survey is expected to run from 2011-2013, and requires about 140 nights. We will use the Hobby-Eberly Telescope, and are building a new top-end and instrument which includes a set of 150 spectrographs. All data from the survey will be made public. While the main focus is to understand dark energy, there is significant other science enabled by this survey. For example, HETDEX will measure curvature of the universe to about 0.1%, which is over a factor of ten better than currently known. This knowledge supports all other dark energy studies that are focussed at low redshifts. HETDEX is funded currently from local (state) and private funding, but does seek federal support as well.
Anticipated Sponsor: DOE, NSF, Other
state and private funding
Participating Individuals or Institutions: University of Texas, Texas A&M, Pennsylvania State University, MPE, Garching, LMU, Garching, AIP, Postdam
Current Status: Construction
Additional Information:

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70. Infrastructure Requirements for Human and/or Robotic Space Servicing including assembly, integration, deployment, repair or upgrade of future "Flagship" Astronomical and Astrophysics Observatories in or beyond Low Earth Orbit.

Point of Contact: Frank Cepollina, HST Deputy Associate Director, HST Development Office
Summary Description: Define the infrastructure requirements needed to enable the servicing of large observatories, with particular emphasis on missions at the Lagrange points and beyond, using Human, Teleoperations, and/or Robotics, as appropriate. Identify the technologies required to carry out the servicing activities and assess their technological readiness. Construct a roadmap for implementation based on these intermediate products.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: John Grunsfield (NASA Astronaut Office), Harley Thronson (Exploration Science Enabler), Matt Mountain (HST Science Institute Director), Paul Cooper (McDonnell Detwiler and Associates), Mark La Pole (Ball Aerospace), Ed Cheng (Advanced Programs, Conceptual Analytics)
Current Status: Regarding "GEO and Beyond" Satellite servicing, the infrastructure is Pre-phase A. Although LEO servicing has been practiced with great success over the last 25 years, it has been accomplished through the availability of the NASA Space Shuttle. With the Astro2010 Survey Panel's focus on looking further and deeper into the Universe, the resulting new missions will dictate the servicing needs and the on-orbit infrastructure required.
Additional Information: The History of Satellite Servicing at GSFC: A presentation at the June 2006 Systems Engineering Seminar: http://sst.seethelaunch.com/060502_Cepollina.pdf, The Technology Leap in Satellite Servicing: http://sst.seethelaunch.com/NRC_Presentation_CepiFINAL_(NXPowerLite).pdf), Renewing the Partnership between Astronomy and Human Space Flight Program: A White Paper accompanying the Technological Leap in Satellite Servicing: http://sst.seethelaunch.com/Renewing_Partnership_FINAL_(NXPowerLite).pdf, ASK Magazine Article: Applying the Secrets of Hubble to Constellation: http://sst.seethelaunch.com/NASA_APPEL_ASK_30s_hubbles_success.pdf, Launching Science: Science Opportunities Provided by NASA's Constellation System: http://books.nap.edu/openbook.php?record_id=12554&page=R1 (Chapter 4, Human and Robotic Servicing of Future Space Science Missions pages 87 through 101), MIT Report on the future of Human Space flight: http://web.mit.edu/mitsps/MITFutureofHumanSpaceflight.pdf

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71. Instrument development for Visible/NIR space astronomy.

Point of Contact: Bruce Woodgate, NASA GSFC
Summary Description: The value of investments in large space telescope systems, with their improvements in sensitivity and resolution, would be considerably diminished without optimization of the instruments used. While larger telescopes are very important, in many areas the benefit/cost ratio of technology improvements in the optics and detectors can be much higher. For faint objects such as exoplanets and high redshift supernovae and galaxies, the sensitivity of space spectrographs can be improved by an order of magnitude by removal of read noise using photon-counting array detectors, while maintaining high quantum efficiency, and improving radiation hardness. The simultaneous spectral coverage and throughput of imagers and spectrographs can be

improved substantially by leveraging and further improving multi-layer optical coatings. Further extension of very large detector arrays and compacting their electronics will be needed. These developments would support the ATLAST, NWO and ACCESS studies. This activity will address the visible and NIR aspects, while the UV will be addressed by that submitted by Ken Sembach.

Anticipated Sponsor: NASA
Participating Individuals or Institutions: GSFC, JPL, Ball Aerospace, Northrop Grumman, Other Universities and Industries
Current Status: Design and Development
Additional Information: http://www.stsci.edu/institute/atlast
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72. International X-ray Observatory (IXO)

Point of Contact: Dr. Jay Bookbinder, Smithsonian Astrophysical Observatory
Summary Description: The International X-Ray Observatory (IXO) is a facility-class mission that will address the leading astrophysical questions in the "hot universe" through its breakthrough capabilities in X-ray spectroscopy, imaging, timing, and polarimetry. IXO will measure the spin of black holes, a fundamental property driven by galaxy formation and evolution for supermassive black holes, and by the nature of core collapse for stellar mass black holes. IXO will reveal the physics of accretion near the last stable orbit, measuring General Relativistic effects in the strong field limit. For neutron stars, IXO will determine the mass-radius relationship, thereby constraining the equation of state and QCD models of matter at these densities. For neutron stars with ultra-high magnetic fields (magnetars), IXO's polarimeter will measure the predicted QED effects. In galaxy clusters, IXO will measure the velocity structure, mass, and metallicity distribution of the dominant baryon component, the hot intra-cluster gas. Not only will this provide a deep understanding of evolution of large-scale structure, but samples of clusters at various redshifts provide important and independent constraints on the cosmological model and dark energy. Extending away from clusters and groups is the Cosmic Web, where half of the baryons in the local universe are expected to reside, yet have not been detected. IXO will detect these missing baryons and it can test predictions for the formation and topology of the Cosmic Web. Furthermore, IXO will yield insight into feedback mechanisms in the universe on many scales: through studies of supernova remnants, outflows in starburst galaxies, and AGNs across cosmic time. Several of these and other science issues require a panchromatic approach. IXO covers the 0.1-40 keV energy range, complementing the capabilities of the next generation observatories, such as ALMA, LSST, JWST, and 30-m ground-based telescopes.
Anticipated Sponsor: NASA, Other
The International X-ray Observatory is being developed by an international collaboration between the National Aeronautics and Space Administration (NASA), the European Space Agency (ESA), and the Japan Aerospace Exploration Agency (JAXA). This project supersedes both NASA's Constellation-X and the joint ESA/JAXA XEUS mission concepts.
Participating Individuals or Institutions: IXO is an international collaboration with a consortium of U.S., Japanese and European institutes and universities (including Germany, Spain, France, Italy, the Netherlands, the United Kingdom and other ESA Member States). US INSTITUTIONS: Massachusetts Institute of Technology (MIT)/Kavli Institute, Cambridge, MA, NASA/Goddard Space Flight Center (GSFC), Greenbelt, MD, NASA/Marshall Space Flight Center (MSFC), Huntsville, AL., National Institute of Standards and Technology (NIST), Boulder, CO, Smithsonian Astrophysical Observatory (SAO)/High Energy Astrophysics Division (HEAD), Cambridge, MA, University of Colorado/Center for Astrophysics and Space Astronomy (CASA), Boulder, CO;

FOREIGN INSTITUTIONS: Centre d'Etude Spatiale des Rayonnements (CESR), Tolouse, France, Centre d'Etude Spatiale des Rayonnements (CESR) / Centre d'Etudes Nucléaires de Saclay (CEN), Saclay, France, Consejo Superior de Investigaciones Cientificas (CSIC)/University of Cantabria (UC), Cantabria, Spain, European Space Agency (ESA) / European Space Research and Technology Centre (ESTEC), Noordwijk, The Netherlands, Institute of Space and Astronautically Science (ISAS)/JAXA, Sagamihara, Japan, Istituto di Astrofisica Spaziale e Fisica Cosmica (IASF), Rome, Italy, Istituto Nazionale di Astrofisica (INAF), Padua, Italy, Max Planck Institute for Extraterrestrial Physics (MPE), Garching, Germany, Nagoya University, Nagoya, Japan, Netherlands Institute for Space Research (SRON), Utrecht, The Netherlands, Osaka University, Osaka, Japan, University of Leicester, Leicester, UK

ADVISORY GROUPS

The IXO development effort is being guided by several key advisory groups of scientists and engineers. More information on each group, along with the names of the committee members, can be found at the following URL:
http://ixo.gsfc.nasa.gov/people/advisingScientists.html

Current Status: Pre-Phase A

Additional Information: http://ixo.gsfc.nasa.gov/ is a website devoted to the IXO mission, including links to the mission science, performance requirements, technology, personnel, recent presentations, and resources such as response matrices for the various instruments.

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73. Joint Dark Energy Mission (JDEM)

Point of Contact: Neil Gehrels, NASA GSFC

Summary Description: Understanding dark energy is one of the most important scientific endeavors of our era. The Joint Dark Energy mission (JDEM) is designed to make substantial progress in the characterization of dark energy. A central goal of JDEM is a precision measurement of the expansion history and growth of structure in the universe to answer, among other key questions, whether the contribution of dark energy to the expansion rate varies with time or is consistent with Einstein's cosmological constant. JDEM, a medium-class space-based observatory, will perform measurements of the nature of the dark energy in the universe. It is jointly sponsored by NASA and DOE. JDEM offers the critical capabilities needed for progress in dark energy research that can be achieved only from a space observatory. These include wide-field infrared photometry and spectroscopy, good seeing above the NIR-bright, scintillating atmosphere, excellent systematics error control in the stable environment of L2, and round-the-clock full-sky survey measurement capability using well-characterized and unchanging instrumentation. The measurement technique is wide-field, sensitive (25th mag) surveys in the NIR and visible bands of galaxies and supernovae. The time is ripe for JDEM: the recent availability of high-quality flight-ready large-format CCDs and HgCdTe detectors enables the JDEM sky surveys. Hundreds of millions of galaxies will be mapped in both position and redshift for precision measurements of baryon acoustic oscillations and weak lensing. The light curves of Type 1a supernovae will be monitored over multiple wavelengths into the NIR. In addition to providing the optimum data for dark energy studies, the catalogs from these surveys and other JDEM data will be a treasure trove for astronomy, addressing topics of large-scale structure, galaxy clusters, high redshift AGN, galaxy evolution/structure/formation, stellar populations, star formation history, and solar system objects. Following a recommendation in the Quarks to the Cosmos report and prioritization by the 2007 NRC BEPAC review, the mission is now fully funded in both the NASA and DOE budgets.

Anticipated Sponsor: DOE, NASA

Participating Individuals or Institutions: - Science teams to be selected by competitive

AO with release in early 2009 and selection in summer 2009
- Managing institution & NASA project office: NASA/GSFC
- DOE project office: LBNL

Current Status: Phase A
Additional Information: http://jdem.gsfc.nasa.gov/

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74. Keck Observatory Next-Generation Adaptive Optics

Point of Contact: Taft Armandroff, W. M. Keck Observatory
Summary Description: The W. M. Keck Observatory (WMKO) has developed and operates a world-leading laser-guide-star adaptive optics system and related instrumentation. A key recommendation of WMKO's community-based scientific strategic planning process is the development of a Next-Generation Adaptive Optics System (NGAO). WMKO's NGAO System will use adaptive optics tomography and MEMS deformable mirrors to achieve both high performance and high sky coverage. Some of the key scientific drivers for NGAO are the formation and evolution of galaxies since z ~ 3, determining the mass of super-massive black holes in nearby galaxies, testing the theory of General Relativity at the Galactic Center, studying the formation of stars and characterizing their debris disks, and discovering exoplanets orbiting low-mass stars. When developed, NGAO will produce images that have very high Strehl at infrared wavelengths, and operate at red optical wavelengths for the first time. NGAO accomplishes this by measuring the atmospheric turbulence throughout the full cylinder of the atmosphere that the light passes through to reach the telescope, whereas today's systems only correct for turbulence in a cone above the telescope. To achieve this, NGAO will have multiple laser guide stars, compared to the single laser guide star with current systems. Optimized instrumentation will be developed for the NGAO System.
Anticipated Sponsor: NSF, Other
Other is checked to reference Keck's support from non-federal sources, e.g., private philanthropy, that provides leverage to federal investment. The total cost of NGAO is approximately $60M.
Participating Individuals or Institutions: The partners in the operation of Keck Observatory are Caltech, the University of California and NASA. The University of Hawaii participates in Keck observing by providing access to Mauna Kea. Yale University and the Swinburne Institute of Technology participate in observing via a partnership with Caltech. The broad U.S. community gains peer-reviewed access to the Keck telescopes via NASA and the NSF/NOAO Telescope System Instrumentation Program (TSIP). Development of NGAO is taking place at Keck Observatory, the University of California, and Caltech.
Current Status: The preliminary design phase of NGAO is currently underway.
Additional Information: http://www.keckobservatory.org/ A link for Astro 2010 materials will be added.

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75. Laboratory Astrophysics Instrumentation for the Next Decade

Point of Contact: David R. Schultz, Physics Division, Oak Ridge National Laboratory
Summary Description: Among the most important foundations of our ability to interpret astrophysical observations and to create models of diverse cosmic phenomena is the laboratory-derived spectroscopic data, atomic, molecular, and chemical properties, and reaction rates that underpin them. The next decade of progress in astronomy and astrophysics will present great new opportunities for observations and for elaboration of simulations but these will be placed greatly at risk without commensurate advancement

and range of new opportunities for laboratory astrophysics. To ameliorate this situation, we propose to develop a novel platform for the study of atoms, molecules, dust, and ices at the appropriate background temperatures relevant to planetary systems, star formation, and the interstellar medium, that is, a facility for astrochemistry. In particular, a molecular ion storage ring would allow development of accurate chemical networks needed for a wide range of astrophysical studies. Consequently, we wish to underscore the need for prominent and fundamental consideration of laboratory astrophysics and for priority of support for the facilities needed for the next decade of discovery.

Anticipated Sponsor: DOE, NASA, NSF

Participating Individuals or Institutions: The early participants in this project welcome broader collaboration: Oak Ridge National Laboratory, Columbia Astrophysics Laboratory, University of Kentucky, University of Georgia, University of California San Deigo, Auburn University, Stockholm University

Current Status: Conceptual design completed, pre-proposal white papers being developed

Additional Information:

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76. Laboratory Astrophysics: Supporting Future Space Observations with Molecular Ions and Highly-Charged Atomic Ions in an Electrostatic Ring

Point of Contact: Ara Chutjian, NASA JPL, Caltech

Summary Description: Based on the successful JPL electron energy loss-merged beams approach to electron-highly charged ions (HCI) collisions, it is proposed to expand this facility by the addition of a molecular ion source, a state-of-the-art refrigerated electron beam ion trap (REBIT) for production of highly-charged ions, and an electrostatic storage ring. This powerful and versatile combination of subsystems will allow one to measure HCI phenomena under energetic plasma conditions – such as in solar & stellar active regions and near black holes; as well as molecular phenomena in the cooler interstellar medium. This range of capabilities also includes the understanding of solar-wind interaction with comets and stellar winds with circumstellar clouds (measurement of high-resolution X-ray spectra and absolute single and multiple charge-exchange cross sections); coronal equilibrium in hot plasmas (measurement of HCI metastable-level lifetimes and HCI absolute excitation cross sections); host of astrophysical phenomena such as solar/stellar plasma properties, emissions near black holes, and line absorption of HCIs and molecular processes (lifetimes, ionization cross sections, laser photodissociation and electron dissociative recombination channels and cross sections of molecular positive and negative ions) in the interstellar medium.

Anticipated Sponsor: NASA, NSF

Participating Individuals or Institutions: Prof. N. G. Adams (U. Georgia), Prof. A. Chutjian (JPL and Caltech), Dr. J. A. MacAskill (JPL), Dr. S. R. Madzunkov (JPL), Prof. B. V. McKoy (Caltech), Dr. D. Schneider (LLNL), Prof. R. Schuch (Stockholm Univ.)

Current Status: 1. Plans for infrastructure expansion for increased laboratory and office space have been submitted to JPL.

2. Quotation for cost and delivery of a REBIT ion source and power supplies has been received.

3. A budget estimate has been derived for the Electrostatic Ring (ESR) components, including beam tubes, tables, cryopumps, power supplies, machining, and electrical systems.

Additional Information: None as yet.

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77. Large Synoptic Survey Telescope

Point of Contact: Tony Tyson, UC Davis
Summary Description: Imaging data from a large ground-based active optics telescope with sufficient étendue (~300 m2/deg2) can address many scientific missions simultaneously. By providing unprecedented sky coverage, cadence, and depth, the LSST makes it possible to attack high-priority scientific questions that are far beyond the reach of any existing facility. LSST will produce a 6-band (0.3-1.1 micron) wide-field deep astronomical survey of over 20,000 square degrees of the southern sky using an 8.4m (6.7m effective) telescope and 3.2 Gpixel camera. Each patch of sky will be visited 1000 times (2x15s exposures) in ten years, producing a trillion line database of 20 billion objects. The 30 terabytes of data obtained each night will open the time domain window on the deep optical universe for variability and motion. Rarely observed events will become commonplace, new and unanticipated phenomena will be discovered, and the combination of LSST with contemporary space-based missions will provide powerful synergies. The deep coverage of ten billion galaxies provides unique capabilities for cosmology. All LSST data will be non-proprietary (open-data and open-source), with public accessibility and usability a high priority.
Anticipated Sponsor: DOE, NASA, NSF, Other
Private donors and foundations, corporate sponsors, and foreign partners.
Participating Individuals or Institutions: California Institute of Technology, Carnegie Mellon University, Chile, Columbia University, Google Inc., Harvard-Smithsonian Center for Astrophysics, Institut National de Physique Nucleaire et de Physique des Particules, Johns Hopkins University, Kavli Institute for Particle Astrophysics and Cosmology at Stanford University, Las Cumbres Observatory Global Telescope Network, Inc., Lawrence Livermore National Laboratory, Los Alamos National Laboratory, National Optical Astronomy Observatory, Pennsylvania State University, Princeton University, Purdue University, Research Corporation for Science Advancement, Rutgers University, SLAC National Accelerator Laboratory, Space Telescope Science Institute, University of Arizona, University of California - Davis, University of California - Irvine, University of Illinois at Urbana-Champaign, University of Pennsylvania, University of Pittsburgh, University of Washington, Vanderbilt University.
In addition, to date over 270 US scientists have joined the current ten LSST science collaborations.
Current Status: NSF D&D funding start in 2005. Long-lead systems (mirrors, focal plane) are currently under construction with private funds. Design and development work continues on the rest of the system, including data management. NSF MREFC proposal submitted and reviewed, NSF CoDR passed in September 2007, PDR scheduled in late spring 2009; DOE CD-0 for mission need established in 2005.
Additional Information: http://www.lsst.org

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78. Las Cumbres Observatory Global Telescope (LCOGT)

Point of Contact: Timothy M. Brown, Las Cumbres Observatory Global Telescope
Summary Description: Las Cumbres Observatory Global Telescope (LCOGT) is a foundation-funded observatory that is building a worldwide network of robotic optical telescopes to pursue problems in time-domain astronomy. Our facilities now consist of the two Faulkes 2m telescopes located in Hawaii and Australia; by 2013 we expect to operate, in addition, at least 12 x 1m telescopes and 12 x 0.4m telescopes, occupying sites well-distributed in both longitude and latitude. This network will allow almost continuous coverage of targeted astronomical objects, as well as quick response to transient phenomena anywhere in the sky. We will provide instruments for both imaging and spectroscopy on the 2m and 1m telescopes, and for imaging on the 0.4m telescopes.

We will operate this network as a coordinated facility, which we expect to use predominantly to follow up discoveries of time-varying objects identified by major surveys such as PanSTARRS, PTF, LSST, and Kepler. We will make network observing time available to the general community via collaborations and also through a traditional proposal/TAC process. Moreover, a substantial fraction of our telescope time will be available for use by educational programs worldwide. We expect to accomplish all of this using private funding; in addition, we will partner with other institutions to extend the network's geographic coverage, instrumentation, and user base. As a notable example, we intend to collaborate with NOAO (under its ReSTAR initiative) to aid construction of additional 2m telescopes on NOAO sites. This plan will provide users with advanced spectroscopic facilities, as well as with the convenience and capabilities of a robotic telescope network.

Anticipated Sponsor: NSF, Other

LCOGT is funded exclusively by the TABASGO Foundation. If the ReSTAR collaboration with NOAO occurs, the related activities would receive NSF funding.

Participating Individuals or Institutions: Timothy M. Brown (LCOGT), Dale A. Howell (LCOGT), David Silva (NOAO), David Soderblom (STScI)

Current Status: Design and Development

Additional Information: http://lcogt.net

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79. Laser Astrometric Test of Relativity (LATOR) mission

Point of Contact: Slava G. Turyshev, NASA JPL

Summary Description: The Laser Astrometric Test of Relativity (LATOR) is an experiment designed to test the metric nature of gravitation -- a fundamental postulate of the Einstein's general theory of relativity. The mission architecture uses a light triangle formed by laser ranging between two spacecraft and a laser transceiver terminal on the International Space Station (ISS). The key element of the experiment is a geometric redundancy provided by the long-baseline (~100 m) fiber-coupled optical interferometer on the ISS and interplanetary laser ranging. The interferometer will perform differential astrometric measurements of the laser light sources on the two spacecraft as their lines-of-sight pass behind the Sun. By using a combination of independent time-series of highly accurate measurements of gravitational deflection of light in the immediate proximity to the Sun, along with measurements of the Shapiro time delay on interplanetary scales (to a precision respectively better than 0.01 picorad and 3 mm), LATOR will greatly improve our knowledge of relativistic gravity.

The primary mission objective is to measure the key post-Newtonian Eddington parameter \gamma with accuracy of a part in 10^9. ½(1-\gamma) is a direct measure for presence of a new interaction in gravitational theory, and, in its search, LATOR goes a factor 30,000 beyond the present best result, Cassini's 2003 test. Other mission objectives include: (i) first measurement of gravity's non-linear effects on light to ~0.01% accuracy; including both the traditional Eddington \beta parameter and also the spatial metric's 2nd order potential contribution (never measured before); (ii) direct measurement of the solar quadrupole moment J2 (currently unavailable) to accuracy of a part in 200 of its expected size of ~10^-7; (iii) direct measurement of the "frame-dragging" effect on light due to the Sun's rotational gravitomagnetic field, to 0.1% accuracy.

LATOR's primary measurement pushes to unprecedented accuracy the search for cosmologically relevant scalar-tensor theories of gravity by looking for a remnant scalar field in today's solar system. LATOR will lead to robust advances in the tests of fundamental physics: this mission could discover a violation or extension of general relativity and/or reveal the presence of an additional long range interaction in the physical law. There are no analogs to LATOR; it is unique and is a natural culmination of solar system gravity experiments.

Anticipated Sponsor: NASA, Other
European Space Agency has expressed interest in participating in this mission, so as CNES and DLR.
Participating Individuals or Institutions: LATOR USA: S.G. Turyshev, M. Shao, J. Yu, J. G. Williams, H. Hemmati, N. Yu, J. Prestage (JPL, Caltech, Pasadena, CA, USA), R.W.P. Drever (Caltech, Pasadena, USA), K. Nordtvedt (Northwest Analysis, Boseman, MT, USA), J. Degnan (Sigma Space, MD, USA), J. Plowman (U of Montana, Boseman, MT, USA), T. Murphy (U of San Diego, CA, USA); LATOR Europe: H.-J. Dittus, C. Laemmerzahl, S. Theil (ZARM, U of Bremen, Germany), C. Salomon, S. Reynaud (ENS/LKB, Paris, France), T. Damour (IHES, Paris, France), U. Johann (EADS Astrium, Friedrichshafen), P. Bouyer (IOTA, Orsay, France), W. Ertmer, E. Rasel (IQO, Hannover, France), P. Touboul, B. Foulon (ONERA, Châtillon, France), M.C.W. Sandford , R. Bingham, B. Kent (RAL, Didcot, UK), B. Bertotti (U of Pavia, Italy), L. Iess (U of Rome, Italy), E. Samain, J.-F. Mangin, A. Brillet, F. Bondu (OCA, Nice, France)
Current Status: Pre-phase A study
Additional Information: http://arxiv.org/abs/gr-qc/0701102
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80. Laser Interferometer Space Antenna (LISA)

Point of Contact: - Thomas Prince, US Co-Chair LISA International Science Team, Caltech/JPL; Robin Stebbins, NASA LISA Project Scientist, NASA GSFC
Summary Description: LISA is a joint NASA/ESA space mission designed to measure gravitational waves in the band from 0.1 mHz to 0.1 Hz, a band that is richly populated by strong sources of gravitational waves. Signals will come from a wide range of sources: massive black holes merging in galaxies at all distances; stellar-mass compact objects captured by massive black holes; ultra-compact Galactic binaries; and possibly other sources including relics of the Big Bang. These sources convey detailed information addressing a wide range of physics and astrophysics: the history of galaxies and black holes in the universe; general relativity and the behavior of spacetime; precision measurements of luminosity distances; the physics of dense matter and stellar remnants; and possibly new physics associated with events in the very early universe.
Anticipated Sponsor: NASA, ESA
Participating Individuals or Institutions: LISA International Science Team (representing the broader LISA science and technical community): Tom Prince (Co-Chair, Caltech/JPL), Robin Stebbins (NASA Project Scientist, NASA/GSFC), Peter Bender (University of Colorado), Sasha Buchman (Stanford University), Joan Centrella (NASA/GSFC), Neil Cornish (University of Montana), Curt Cutler (Caltech/JPL), Sam Finn (University of Pennsylvania), Jens Gundlach (University of Washington), Craig Hogan (Fermilab, University of Chicago), Scott Hughes (MIT), Piero Madau (University of California, Santa Cruz), Sterl Phinney (Caltech), Doug Richstone (University of Michigan), Kip Thorne (Caltech), Karsten Danzmann (Co-Chair, MPI/AEI and University of Hannover (Germany)), Oliver Jennrich (ESA Project Scientist, ESTEC), Pierre Binetruy, (APC Paris (France)), Massimo Cerdonio (Universita di Padova (Italy)), Mike Cruise (University of Birmingham (UK)), James Hough (University of Glasgow (UK)), Philippe Jetzer (University Zurich (Switzerland)), Alberto Lobo (Instituto de Ciencias del Espacio, CSIC-IEEC (Spain)), Yannick Mellier (IAP Paris (France)), Bernard F. Schutz (Albert Einstein Institut, Potsdam (Germany)), Tim Sumner (Imperial College, London (UK)), Jean-Yves Vinet (OCA Nice (France)), Stefano Vitale (University of Trento (Italy)); Project Management: ESA Project Manager: Alberto Gianolio, ESTEC, NASA Project Manager: Mansoor Ahmed, NASA/GSFC
Current Status: Formulation (Phase A) in ESA and NASA:
NASA/ESA Formulation Phase Letter Of Agreement in effect since October 2004. ESA Industrial contract for Mission Formulation study (with Astrium GmbH) has been running

since January 2005 at ESA and has recently been extended until end of 2009; LISA Pathfinder Mission for LISA technology validation in advanced phase C/D.
Additional Information: LISA Science Team: http://www.srl.caltech.edu/lisa/, LISA Science Community: http://www.lisa-science.org/, ESA LISA site: http://lisa.esa.int/, NASA LISA Project site: http://lisa.gsfc.nasa.gov

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81. Lightweight mirror technology for large UV-NIR telescopes

Point of Contact: David Content, NASA GSFC
Summary Description: Lightweight mirror technology is beneficial to a number of anticipated monolithic and segmented large aperture telescopes (such as the 8-m ATLAS-T concept) and is essential for even larger aperture segmented telescopes such as the 16-m ATLAS-T mission concept. ATLAS-T would enable terrestrial planet discovery and characterization and also ultraviolet-to-near infrared astronomy. Lightweight mirror technology advancements required beyond the JWST segments include improvements in ultralightweight mirror figure (3x to encompass visible and UV goals; shape control and mirror array phasing will also be to tighter requirements), areal density [kg/m^2] (2x), cost density [$M/m^2] (4x), and fabrication time (2x) to achieve the significantly larger, more precise segments needed for such applications. Recently developed near-replication and more rapid fabrication approaches must be brought along, competed, and matured to TRL6 to enable these missions. These include more rapid fabrication, aggressively lightweighted glass mirror types and nanolaminate replication on silicon carbide as examples. Coating technology would also be included as some exoplanet detection and characterization architectures require significantly tighter reflectance amplitude and polarization phase control in the 0.5-1.0micron bandpass than has been required for other applications.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Participating Individuals or Institutions: We have ~55 people participating in this study from the following institutions, centers, and corporations: Space Telescope Science Institute, University of Massachusetts, Amherst, University of Colorado, Boulder, NASA Goddard Space Flight Center, NASA Marshall Space Flight Center, NASA Jet Propulsion Laboratory, NASA Johnson Space Flight Center, Northrop Grumman Aerospace Systems, Ball Aerospace & Technologies Corporation, ITT Space Systems, Xinetics, Inc.
Current Status: R&D {NASA IPP fund, corporate IR&D)
Additional Information: http://www.stsci.edu/institute/atlast

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82. Long Wavelength Array (LWA)

Point of Contact: Greg Taylor, University of New Mexico
Summary Description: The Long Wavelength Array (LWA) will be a next generation radio telescope with 2-3 orders of magnitude improved sensitivity and imaging power over current or past capabilities below the broadcast FM bands (i.e., frequencies from 10 to 88 MHz, wavelengths 3 to 30 meters). The prime astrophysical goals of the LWA include (1) Probing the mechanisms of particle acceleration in the solar system, supernova remnants, clusters of galaxies, and active galaxies; (2) Cosmic evolution and the high redshift universe, primarily by constraining the evolution of large scale structure from cluster studies and by exploiting the spectral properties of high-z radio galaxies to search for the first such objects; (3) Plasma astrophysics and space science by using radio propagation effects to probe intervening media; and (4) Open the largely unexplored radio transient sky by virtue of the telescope's naturally large field of view.

The LWA will consist of ~50 phased dipole array "stations" spread across ~400 km in New Mexico, providing arcsecond angular resolution at meter and decameter wavelengths. In addition to its astronomical goals, the LWA is intended to serve as an ionospheric facility, providing high-precision, synoptic views of ionospheric structure and space weather events. It will be a premier international facility for conducting fundamental, pioneering research in space physics and astrophysics, for national security research, and for educating a next generation of US radio science and engineering students.

Anticipated Sponsor: NSF, DOD

Participating Individuals or Institutions: Greg Taylor (University of New Mexico), Namir Kassim (Naval Research Laboratory), Larry Cox (Los Alamos National Laboratory), Steve Ellingson (Virginia Tech), Robert Mutel (University of Iowa), Robert Navarro (Jet Propulsion Laboratory)

Current Status: Over the next decade, the LWA will have a phased construction plan. Currently in a process of design, development, and prototyping, the LWA is funded to construct the first station. Funding for the full LWA will need to be sought after in subsequent years.

Additional Information: http://lwa.unm.edu/

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83. Lunar Geophysics, Geodesy, and Dynamics with a Millimeter Laser Ranging to the Moon

Point of Contact: Sergei Kopeikin, University of Missouri-Columbia

Summary Description: The primary objective of this activity is the facilitation of a major progress in the lunar science that will be enabled by the new generation of advanced lunar laser ranging (LLR) instruments. To achieve this goal, we intend to drastically improve the modeling accuracy of existing relativistic LLR model by more than an order-of-magnitude in order to match the millimeter range precision anticipated from enhanced LLR technique and to explore the new science opportunities resulting from the accuracy gains. This work will promote the unique science capability needed to capture near-future lunar opportunities and enable an essential progress in the fundamental test of general theory of relativity in the solar system.

Anticipated Sponsor: NASA, NSF, Other

Funds provided by the participating foreign institutions

Participating Individuals or Institutions: University of Missouri-Columbia, USA; NASA Goddard Space Flight Center, USA; University of Maryland, USA; University of Valladolid, Spain; Leibniz University of Hannover, Germany; Kazan State University, Russia

Current Status: Research and Development of the Model

Additional Information: Preceding articles: doi:10.1016/j.physrep.2004.08.004, doi:10.1016/j.asr.2008.02.014, doi:10.1007/s00190-007-0168-7

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84. Lunar Low-Frequency Radio Array for Cosmology

Point of Contact: Jack Burns, University of Colorado at Boulder

Summary Description: I would like to make the Astro2010 committee aware of the previous NRC study entitled "The Scientific Context for the Exploration of the Moon" (http://books.nap.edu/openbook.php?record_id=11954). This study identified a low frequency radio telescope on the lunar farside as a high potential science project from the Moon. The report said that "such a telescope would be a powerful tool in investigating the “dark ages” of the universe, before the reionization era, in which highly redshifted 21

cm (1420 MHz) absorption (against the CMB) from neutral hydrogen would reveal the earliest structures in the universe before the first phase of nuclear enrichment.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Jack Burns (U. Colorado), J. Lazio (NRL), J. Hewitt (MIT), C. Carilli (NRAO)
Current Status: Early development toward a deployment of a prototype after a human return to the Moon around 2020.
Additional Information: NRC study:
http://books.nap.edu/openbook.php?record_id=11954
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85. Lunar Radio Array

Point of Contact: Joseph Lazio, Naval Research Laboratory
Summary Description: The Lunar Radio Array (LRA) is a concept for a telescope sited on the far side of the Moon with a prime mission of making precision cosmological and astrophysical measurements via observations of the highly-redshifted hyperfine H I line. During the Dark Ages and the epoch of first star formation, prior to the Epoch of Reionization, the intergalactic medium (IGM) was dominated by neutral hydrogen. The temperature evolution of the IGM should lead to a series of H I absorption and emission signatures against the cosmic microwave background (CMB). The far side of the Moon is likely the only site in the inner solar system for exploiting this potential fully as significant obstacles exist to ground-based telescopes, including heavy use of the relevant portion of the spectrum by both civil and military transmitters and distortions introduced by the Earth's ionosphere. Initial concept studies for the LRA have been funded under the NASA Astrophysics Strategic Mission Concept Studies program. These concept studies have identified a number of technologies that need to be developed and matured over the next decade in order for the LRA to be realized. These technologies include low-mass science antennas, rovers, ultra-low power electronics, high data-rate communications, and power generation and storage that can survive the punishing lunar environment. University researchers are developing many of these key technologies, which could be beneficial to many other science missions. We propose that these technologies be among the foci for development in the next decade in order to enable the LRA in following decades.
Anticipated Sponsor: NASA, Other
DoD - Services and agencies within the DoD have already funded technology development for ultra-low power electronics and point-to-point communications technologies with applicability to lunar and planetary surface missions.
Participating Individuals or Institutions: Naval Research Laboratory, Massachusetts Institute of Technology, NASA/Goddard Space Flight Center, Jet Propulsion Laboratory, University of Colorado, Boulder, California Institute of Technology, Harvard University, Haystack Observatory, National Radio Astronomy Observatory, Smithsonian Astrophysical Observatory, U. California, Berkeley, U. California, Los Angeles, U. Idaho, U. New Mexico, Virginia Polytechnic
Current Status: Pre-phase A
Additional Information: http://rsd-www.nrl.navy.mil/7213/lazio/LRA-Astro2010.pdf
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86. Making the Most of the EVLA: An Optimized Enhancement Program

Point of Contact: Bob Dickman, NRAO

Summary Description: Currently on time and on budget for completion at the end of FY2012, the first phase of the Expanded Very Large Array Project (EVLA) will offer the astronomical community an order of magnitude increase in sensitivity above the original VLA, contiguous frequency coverage between 1 and 50 GHz, and incomparable flexibility in the set up of the new WIDAR correlator. We propose a trio of relatively low-cost (< $12M total cost, FY09 dollars) enhancements to the EVLA:

(i) Adding 20 new pads for existing EVLA antennas to provide an ultra-compact array configuration that will offer enhanced speed and surface brightness sensitivity, improved sidelobe response, greatly improved image fidelity (by a factor of 7), as well as improved mosaicing. Scientific applications of these new capabilities will include large-angle low-surface brightness surveys and mosaic observations of large sources, ideally carried out in conjunction with the GBT and other large, single-dish antennas, imaging of the Sunyaev-Zeldovich CBR decrement in galaxy clusters, HI and non-thermal imaging of nearby galaxies, the imaging of Galactic chimneys and shell structures, maps of Zeeman splitting of HI, molecular, and recombination lines, the imaging of comet emission, and the imaging of diffuse synchrotron emission from particle acceleration sites throughout the universe.

(ii) A low-frequency improvement program that will replace the VLA's "legacy" 327 MHz and 74 MHz receiver systems with modern systems having lower noise, wider instantaneous bandwidth, and improved feeds. The proposed upgrade would especially enhance the capabilities of EVLA's unique long baseline configurations, and would offer enormously improved scientific access to studies of cosmic reionization, radio relics and halos, the lifecycle of AGNs, continuum and spectroscopic observations of high-redshift sources, free-free and synchrotron-self absorption, as well as Faraday rotation, scattering and interstellar medium studies in the Milky Way and other galaxies.

(iii) Adding a suite of compact water vapor radiometers (WVRs) to the EVLA to improve the array's phase stability at frequencies above 8 GHz by correcting for rapid tropospheric phase errors produced by water vapor fluctuations. Based on a proven prototype design, these devices will use measured fluctuations in the brightness temperature of the 22 GHz atmospheric water line to derive short-term phase corrections that will improve the quality of observations (especially those on longer baselines), increase observing efficiency at high frequencies, and significantly reduce seasonal constraints on array usage.

Each of these enhancements will greatly increase the scientific reach of the EVLA, has extremely low technical risk, and will strongly leverage the US astronomical community's ongoing and long-standing investment in this unique instrument.

Anticipated Sponsor: NSF

Participating Individuals or Institutions: Naval Research Laboratory

Current Status: Engineering design, with costing has been completed for the compact configuration and WVR programs. Costing is complete for the receiver components of the low-frequency improvement program; feed design and implementation are still to be determined.

Additional Information: http://www.nrao.edu/A2010 (Web page to be implemented); Interim web page: http://www.aoc.nrao.edu/evla/vla2010.shtml

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87. Mars Laser Ranging

Point of Contact: Slava G. Turyshev, Andre Girerd, NASA JPL; Thomas W. Murphy, Jr. UCSD

Summary Description: We develop a Mars Laser Ranging (MLR) experiment for the most advanced tests of relativistic gravity in the solar system. MLR requires deployment of a laser transponder onto the Martian surface, employing an active laser aimed at Earth and a photon-sensitive detector with picosecond performance. It is the impressive

precision of laser ranging techniques that allows tests of gravity in the weak field of the solar system to stay at the forefront. Interplanetary ranging is the obvious next step, Mars representing the ideal opportunity. The technology development associated with this mission is generically useful for other precision test architectures as well as for optical communication links across our solar system. Our most incisive tests of the fundamental properties of gravity derive from measurements of solar system dynamics. Einstein's general relativity so far survives all tests at ever-increasing precision. The best measurements of the curvature of spacetime, the nonlinearity of gravity (via the strong equivalence principle), the time-variation of the gravitational coupling, and the inverse-square nature of gravity are among the precision tests accomplished by lunar laser ranging and Doppler-radar techniques. We can extend these tests substantially by performing laser-range measurements to the surface of Mars, extending our measurement lever arm both in distance and in gravitational potential.
Anticipated Sponsor: NASA, NSF
Participating Individuals or Institutions: Slava G. Turyshev, André R. Girerd, James G. Williams, William M. Folkner, Hamid Hemmati, William H. Farr -- all JPL, Thomas W. Murphy, Jr. of UCSD, John J. Degnan of Sigma Space Corp, Kenneth L. Nordtvedt of Northwest Analysis, Robert D. Reasenberg of Harvard-Smithsonian CfA
Current Status: Pre-phase A mission concept study under NASA's Astrophysics Strategic Mission Concept Studies
Additional Information:

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88. Milliarcsecond Optical/Infrared Science: Access to Interferometry for the Community (MOISAIC) sponsored by the United States Interferometry Consortium (USIC)

Point of Contact: United States Interferometry Consortium (USIC) officers: Michelle Creech-Eakman, Chair, New Mexico Tech.; Theo ten Brummelaar, Vice-Chair, Georgia State University
Summary Description: We wish to advocate for leveraging the nation's investment in interferometric technology and in facility-class optical arrays already/shortly in operation. With some modest changes to current funding models and a small investment in the interferometric community's support structure, NSF can provide a funding opportunity to partially support operations of existing interferometers in exchange for open access to the U.S. scientific community through the O/IR System. This funding will also support technology development and preliminary planning for a next generation optical array and for future space-based facilities in the following decade.
Anticipated Sponsor: NSF
Participating Individuals or Institutions: Facility Name (Acronym) – Funding and operating agencies/partners:

- Center for High-Angular Resolution Astronomy Array (CHARA Array) – National Science Foundation (NSF), Georgia State University, W. M. Keck Foundation, State of Georgia
- Infrared Spatial Interferometer (ISI) - National Science Foundation (NSF), Office of Naval Research (ONR), Univ of California – Berkeley
- Keck Interferometer (KI) -- NASA Exoplanet Science Institute (NExScI), W.M. Keck Observatory
- Large Binocular Telescope Interferometer (LBTI) -- NASA Exoplanet Science Institute (NExScI), Univ of Arizona
- Magdalena Ridge Observatory Interferometer (MROI) – New Mexico Institute of Mining and Technology, Univ of Cambridge, Office of Naval Research (ONR)
- Navy Prototype Optical Interferometer (NPOI) – Oceanographer for the Navy (CNMOC), Office of Naval Research (ONR), Lowell Observatory

and the National Optical Astronomy Observatories (NOAO)
and the United States Interferometry Consortium (USIC) including over 100 contributing members

Current Status: Optical interferometry is following a pattern of development parallel to that of radio interferometry. A vigorous technology program has enabled a strong facility-class interferometry capability in the U.S., with several operating arrays of up to 6 telescopes. These arrays have different, unique observing capabilities, and most are in full-time operation, carrying out unprecedented sub-milliarcsecond resolution science in stellar and extragalactic physics. Presently most of these facilities are supported mainly for collaborative or mission-oriented operation. The interferometry community is eager to open these facilities to peer-reviewed access, but lacks resources to support such access. There is currently no funding opportunity available for this purpose (e.g. optical arrays are not explicitly eligible for TSIP and other types of observatory funding.)
A 2006 national workshop on the future of ground-based optical interferometry, organized and sponsored by NOAO, has developed a roadmap for technology development, with the objective of supporting preliminary planning for a next generation optical array in the 2020 time frame. As a community we believe this next decade is ripe for both making tremendous insights into many stellar phenomena, and developing the technology necessary for a next-generation facility.

Additional Information: See the Optical Long Baseline Interferometry Newsletter (OLBIN) website: http://olbin.jpl.nasa.gov/ for information on individual projects and the community.

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89. National Virtual Observatory / Virtual Astronomical Observatory

Point of Contact: Dr. Robert J Hanisch, Space Telescope Science Institute

Summary Description: The Virtual Astronomical Observatory is a facility that will enable astronomers, educators, students, and the public to find, access, and use astronomy data from around the world. With the VAO scientists can bring together diverse data products—-images, spectra, catalogs, light curves, and records of transient events—-in intelligent and useful ways. They can browse through distributed collections easily and quickly zero in on the most relevant data, and visualize these data together in scientifically meaningful ways, such as overlaying images from multiple wavelengths along with graphics showing observational footprints (sky coverage) and the locations of cataloged sources. Once data are discovered, chosen, and brought together, analysis can begin immediately. Astronomers can cross-correlate catalogs, resample images, accurately determine an image's world coordinates, calculate fluxes, and identify spectral lines. VAO tools and services are designed to work not just with data from a single mission or archive, but with data sets that span wavelength regimes, archives, missions, and time. [The VAO is the operational successor to the development initiative called the NVO.]

Anticipated Sponsor: NASA, NSF

Participating Individuals or Institutions: The primary partners in the US Virtual Observatory effort are the California Institute of Technology (Center for Advanced Computation Research, and Infrared Processing and Analysis Center), the High Energy Astrophysics Science Archive Research Center (HEASARC) at NASA Goddard Space Flight Center, The Johns Hopkins University, the National Center for Supercomputer Applications (NCSA) at the University of Illinois-Urbana/Champaign, the National Optical Astronomy Observatory, the National Radio Astronomy Observatory, the Smithsonian Astrophysical Observatory, and the Space Telescope Science Institute. The VAO will collaborate with Cornell University/NAIC, Gemini Observatory, George Mason University, Harvard University (Initiative for Innovative Computing), LSST, the NASA Planetary Data System, and PanSTARRS. The US Virtual Observatory is a founding partner of the

International Virtual Observatory Alliance (IVOA), the organization that formally establishes VO standards and protocols.

Current Status: NVO development work, funded for seven years by NSF, is coming to a close. The primary partners listed above submitted a proposal to NSF in April 2008 to undertake operation of the Virtual Astronomical Observatory. NSF has not yet announced a decision. The VAO is to be co-funded by NASA. (NASA provided support for NVO in FY2008 through funding augmentations to HEASARC at GSFC, MAST at STScI, and IRSA at IPAC/Caltech.)

Additional Information: The main NVO web site is http://www.us-vo.org/. The IVOA web site is http://ivoa.net/.

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90. Next Generation Lunar Laser Ranging

Point of Contact: Stephen Merkowitz, NASA GSFC

Summary Description: Laser ranging over the past 40 years to retroreflector arrays placed on the lunar surface by the Apollo astronauts and the Soviet Luna missions has been used to test alternate theories to General Relativity (GR) and to probe the nature of the lunar core. Current alternate theories for gravity, including those that explain dark matter and dark energy, predict deviations from GR at a level that is potentially within the grasp of the next generation of lunar laser ranging. The precision of the range measurements have historically been limited by the ground station capabilities. With the APOLLO instrument at the Apache Point facility in New Mexico now routinely achieving sub-centimeter level precision, future measurements are likely to be limited by errors associated with the Apollo retroreflectors. In addition, the clustering of the lunar arrays and similar latitudes of the available lunar ranging stations weakens our ability to precisely measure the lunar librations. Advanced retroreflectors placed at locations far from the Apollo sites would enable the study of additional effects, particularly those that rely on the measurement of the lunar librations. Active laser transponders are also under development that can provide a strong enough signal to enable the use of most of the more than 40 existing satellite laser ranging stations to make frequent range measurements, even during the daytime. With NASA's plans to return to the Moon, it is natural to consider including new lunar laser ranging instruments on a mission within the timeframe of the Astro2010 survey. We propose that the next generation of both lunar retroreflectors and laser transponders be included in the Astro2010 prioritization.

Anticipated Sponsor: NASA

Participating Individuals or Institutions: Thomas Murphy (University of California at San Diego), Douglas Currie (University of Maryland at College Park)

Current Status: Design and Development

Additional Information:

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91. Next Generation semiconducting X-ra, Gamma-ray and cosmic ray detectors using MEMS technology

Point of Contact: Bernard Phlips, Naval Research Laboratory

Summary Description: Future X-ray and gamma-ray space missions require detectors with excellent energy and position resolution. In addition, detectors need to consist almost entirely of active material to minimize backgrounds. Semiconducting detectors provide the excellent position and energy resolution and a host of other benefits. The technology for these devices is mostly derived from the electronics industry and relies on the processing of planar wafers. Each semiconducting material comes with specific limitations though: Germanium requires cryogenic operation, silicon has a low stopping power, CdZnTe has poor hole collection, CdTe has limited charge transport. By adopting techniques developed by the MEMS (Micro-Electro-Mechanical Systems) community, a whole new phase space of radiation sensors can be contemplated and explored. Examples are: 1) Curved detectors, required as focal plane instruments for Lobster-eye X-ray telescopes (and for cosmic-ray missions), can be produced using grey-tone lithography; 2) Thick Silicon and CdTe detectors, important for hard X-ray missions and polarimeters, can be depleted using deep micro-trenches or wells to collect the charge; 3)Thick drift detectors, important for high-resolution X-ray spectroscopy and very large area timing missions, can be developed using deep micro-trenches to shape the electric fields in three dimensions. The possibilities being opened by applying MEMS technologies to new X-ray, gamma-ray and cosmic-ray detectors should be explored in the next decade to ensure the best sensors are available to achieve NASA's scientific goals.

Anticipated Sponsor: NASA, DoD and DHS are other possible sponsors

Participating Individuals or Institutions: Naval Research Laboratory for sensors (using in-house facilities and NIST facilities), Brookhaven National Laboratory for electronics

Current Status: The development of new X-ray and gamma-ray sensors usimg MEMS technology is at the Proof of Concept stage (POC)

Additional Information:

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92. Next generation space ultraviolet sky survey (post-GALEX)

Point of Contact: David Schiminovich, Columbia University

Summary Description: We are actively considering the science and technical requirements for a future space ultraviolet sky survey mission. Our team developed and is operating a NASA small explorer, the Galaxy Evolution Explorer (GALEX), which was proposed in 1997 and launched in 2003. GALEX recently completed the first major survey of the sky in the space ultraviolet and is now pushing its nested surveys to deeper limits as part of its extended mission.   GALEX is providing a legacy data set to the astronomical community and continues to make important new discoveries as it explores the UV sky. While GALEX has been a scientific success, we recognize that many of the high priority scientific questions of the next two decades will only be addressed by a significantly more capable (x100-1000) observatory that incorporates emerging new technologies.   Such a mission would be highly synergistic with other wide-field surveys being developed or planned, including LSST, WFMOS and JDEM. With adequate funding, the necessary technologies should reach the required technical readiness level within 5-7 years, coinciding with the period during which the GALEX data set is expected to provide maximum value to the community. It therefore seems likely that serious consideration of the next generation UV sky survey mission, and possibly its early development phase, will take place before the end of the next decade.   We would be pleased to share our experience, technological insights and conceptual designs as part of the Astro2010 process.

Anticipated Sponsor: NASA

Participating Individuals or Institutions: GALEX Science Team (Caltech; Johns Hopkins University; Laboratoire d'Astrophysique de Marseille, France; The Observatories of the Carnegie Institute of Washington; University of California, Berkeley; University of California, Los Angeles; Yonsei University, Korea; Columbia University; Jet Propulsion Laboratory; Goddard Space Flight Center)

Current Status: Concept investigation/study

Additional Information:

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93. Next-Generation Astronomical Software Environment

Point of Contact: Jeffrey Kantor, LSST Corporation
Summary Description: Astronomical research depends on data processing and analysis software, much of which was designed and implemented twenty or more years ago. The effort spent on using, adapting, and developing software consumes a substantial fraction of research project budgets, with frequent duplication of capabilities in incompatible systems. The 2008 NASA Senior Review of data centers noted "NASA and their partner institutions have not agreed upon a common philosophy in the development of software... Whatever the agreed-upon policies, they should be long-lived and have international commitments." While the computing and data analysis paradigm has advanced rapidly in other scientific domains, astronomers are generally working behind the technology curve and outside of the software development mainstream.

The projects of the coming decade require a strategic investment in the software needed to reduce, analyze, and interpret the massive influx of complex new data. Our objectives are to 1) improve the efficiency of research and the astronomer's ability to deal with large data sets through better interfaces, visualization, and analysis tools, 2) exploit hardware advances such as 64-bit computing, multiple cores, cluster, grid, and cloud computing, 3) support direct access to distributed data sets, particularly through the Virtual Observatory, 4) increase software sharing, re-use, and transparency, and 5) phase replacement of obsolescent software with new systems, with careful attention to widespread community involvement and transfer of legacy applications.

Several major astronomy facilities have had to decrease their efforts in software development for the research community owing to budget pressure, but there is a long-term and much larger cost to be borne by the community and the funding agencies if common software solutions are not supported.

The collaborating organizations listed below have initiated design studies and prototyping efforts to determine a pragmatic approach to this challenge.

Anticipated Sponsor: NASA, NSF
Work to be done as part of ongoing activities at major national facilities.
Participating Individuals or Institutions: AURA centers (NOAO, STScI, Gemini), NRAO, NVO/VAO, LSST. International collaboration with European OPTICON software planning activities and Japan (Subaru telescope).
Current Status: Requirements analysis, design studies, prototypes.
Additional Information: http://nvo-twiki.stsci.edu/twiki/bin/view/data/AURAssw/WebHome, http://archive.eso.org/opticon/twiki/bin/view/Main/WebHome

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94. Next-Generation Medium- to High-Energy Gamma-Ray Mission (NGGM)

Point of Contact: Stanley D. Hunter, NASA GSFC
Summary Description: The NGGM activity will define a medium-scale NASA mission that will explore the gamma-ray energy range from ~0.5 to >500 MeV. The NGGM mission will address a wide range of science topics including Galactic and Extragalactic Diffuse Emission, Super Nova Remnants, Gamma-ray Blazars, Gamma-ray Bursts, Tests of Relativity with Polarization, Dark Energy, and Solar Flares. The NGGM instrumentation will include two imagers with overlapping energy ranges and a burst monitor. The design of the imaging instruments would stress angular resolution and polarization sensitivity with moderate energy resolution and wide field-of-views. NGGM would complement the Fermi/GLAST mission, future high-energy (E_g > 5 GeV) gamma-

ray instruments, and future very-high energy (E_g > 100 GeV) ground-based gamma-ray instruments.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: NASA/Goddard Space Flight Center, University of New Hampshire, Washington University, Max Plank Institute fur Terrestrial Physic, Los Alamos National Laboratory, Clemson University, Plus others
Current Status: Mission definition
Additional Information:
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95. Next-generation Underground Gravitational-wave Telescope (NUGT)

Point of Contact: Vuk Mandic, University of Minnesota; Stan Whitcomb, Caltech
Summary Description: The international ground-based gravitational wave community is currently engaged in R&D and design studies aimed at defining a further generation of gravitational wave detectors, beyond the currently-under-construction Advanced LIGO and Advanced Virgo. Underground detectors are favored for such a project to gain improved isolation from surface generated noise sources, and location at DUSEL is one option. These detectors would be aimed at another factor of 10 improvement in sensitivity in the 100 Hz region, corresponding, for example, to a detection distance of ~2 Gpc for neutron star-neutron star binary inspiral and coalescence. Furthermore, improved sensitivity for these detectors at low frequencies (perhaps as low as 1 Hz) would help bridge the gap between the LIGO/Virgo and LISA frequency bands. This low frequency capability would improve the sensitivity to intermediate mass black holes and give a far improved sensitivity to a cosmological stochastic background of gravitational waves. It would open the possibility of observing sub-10 Hz pulsars, which includes most of the known pulsar population.
Anticipated Sponsor: NSF
Participating Individuals or Institutions: LIGO Laboratory (operated by Caltech and MIT), LIGO Scientific Collaboration (approximately 50 institutions in 8 countries)
Current Status: This project is in the earliest stages of feasibility studies, and is unlikely to be proposed for a start before the next decadal survey. Technology development in precision interferometry, low noise cryogenics, and vibration isolation will need to be complemented by studies of background terrestrial noise sources to determine feasibility and costs. First observations from Advanced LIGO and Advanced Virgo will give improved estimates of sources and will refine the science capabilities. Similar design studies are underway in Europe under the name Einstein Telescope. It is expected that a US project will be a key element of a global gravitational-wave astronomy network, operating along with the anticipated underground facilities in Europe and elsewhere.
Additional Information:
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96. NOAO and the US O/IR System

Point of Contact: Dr. David Silva, Director, National Optical Astronomy Observatory
Summary Description: The National Optical Astronomy Observatory (NOAO) is the backbone of the ground-based US O/IR System and has responsibility for developing and extending that System on behalf of NSF and the open-access community. As envisioned by the 2000 Decadal Survey report, the US O/IR System is a network of public and private observatories from 2 to 10-m in aperture allied for excellence in scientific research, education and public outreach. This network enables experimentation

and exploration throughout the observable Universe. Indeed, the US O/IR System has played *the* fundamental role in the initial detection and characterization of the most important astrophysical topics of our time: dark matter, dark energy and exosolar planets. Current System science capabilities exploit the entire range of modern astronomical technology from (very) wide-field optical imaging to single (and soon multiple) conjugate laser guide star adaptive optics. Development of the US O/IR system is on-going and touches on many activities within the purview of Astro 2010 from instrumenting and modernizing mid-sized telescopes to enabling technology such as laser guide star adaptive optics development programs on existing large facilities to the design and development of extremely large (20-m plus) telescopes. Within the System, NOAO develops, operates and maintains key facilities on Kitt Peak and Cerro Tololo. NOAO facilitates US community access to the Gemini Observatory. The Telescope System Instrumentation Program (TSIP) managed by NOAO provides community access to independent observatories in return for NSF investment in new science capabilities at those facilities that benefit all. NOAO plays active leadership roles in several consortia-led development projects, such as the Dark Energy Survey (DES) and the Large Synoptic Survey Telescope (LSST) project. On behalf of the NSF, NOAO enables various activities related to the design and development of the Giant Magellan Telescope and Thirty Meter Telescope, the US-led GSMT projects.

Anticipated Sponsor: DOE, NSF

Participating Individuals or Institutions: Association of Universities for Research in Astronomy, Inc. (AURA), Dark Energy Survey (DES), Giant Magellan Telescope (GMT), International Gemini Observatory (IGO), Large Binocular Telescope (LBT), Large Synoptic Survey Telescope (LSST), Las Cumbres Observatory Global Telescope Network (LCOGT), Magellan Observatory, MMT, Small and Moderate Aperture Research Telescope System (SMARTS), Southern Observatory for Astrophysical Research (SOAR), Thirty Meter Telescope (TMT), Wisconsin-Indiana-Yale-NOAO (WIYN) Observatory, W.M. Keck Observatory

Current Status: Operational, On-going Development

Additional Information: http://www.noao.edu/dir/astro2010/noaoInSystemOverview-AAS-Jan09-D6.pdf, http://www.noao.edu, http://www.noao.edu/system/, http://www.noao.edu/system/tsip, http://www.noao.edu/system/restar, http://www.noao.edu/system/altair, http://www.noao.edu/system/lsst, http://www.noao.edu/system/gsmt, http://www.darkenergysurvey.org

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97. North American Nanohertz Observatory of Gravitational Waves (NANOGrav)

Point of Contact: Andrea N. Lommen, Franklin and Marshall College

Summary Description: We are engaged in a program of precision pulsar timing with the aim of detecting gravitational waves in the nanohertz band, a regime complementary to the bands targeted by LIGO and LISA. The main source of gravitational waves in the pulsar timing band is in-spiraling supermassive black holes (SMBH) binaries. Such binaries are a natural prediction of hierarchical structure formation. Pulsar timing techniques will be sensitive to the most massive binaries which are inaccessible to the LISA mission. The detection of gravitational waves would provide both a new window on the Universe as well as constraints on the density of such binaries over a substantial fraction of the Universe's history. Extrapolations from current pulsar timing limits suggest that at least a five-year timing program is required to detect gravitational waves, but our goals extend beyond detection to understanding the spectral characteristics of detected signals, particularly if unexpected signals in addition to the expected ones are found. Intermediate and on-going goals include the discovery of more millisecond pulsars suitable for this work, along with improvement in calibration, RFI rejection, pulse detection, and correlation analysis techniques – all required to make detection possible. Over the next decade, we plan to form a virtual NANOGrav Institute, modeled on the various NASA institutes (e.g. Astrobiology, Lunar Science). Through a combination of professional and student support, hardware development, and obtaining sustained access to telescope time (including Arecibo and the GBT in the U.S. but perhaps also a build-out of the Allen Telescope Array and other SKA-precursor arrays in Australia and South Africa), the NANOGrav Institute will conduct a sustained timing program to detect and characterize the gravitational wave universe in the nanohertz band.

Anticipated Sponsor: NSF

Participating Individuals or Institutions: Anne Archibald (McGill University), Zaven Arzoumanian (Goddard Space Flight Center), Don Backer (University of California, Berkeley), James Cordes (Cornell University), Paul Demorest (National Radio Astronomy Observatory), Rob Ferdman (CNRS, France), Paulo Freire (National Astronomy and Ionospheric Center), Marjorie Gonzalez (University of British Columbia), Fredrick Jenet (University of Texas, Brownsville, CGWA), Victoria Kaspi (McGill University), Vlad Kondratiev (West Virginia University), Joseph Lazio (Naval Research Laboratories), Andrea Lommen (Franklin and Marshall College), Duncan Lorimer (West Virginia University), Ryan Lynch (University of Virginia), Maura McLaughlin (West Virginia University), David Nice (Bryn Mawr College), Scott Ransom (National Radio Astronomy Observatory), Ryan Shannon (Cornell University), Ingrid Stairs (University of British Columbia), Dan Stinebring (Oberlin College)

Current Status: NANOGrav conducts millisecond pulsar observations roughly monthly at both the Arecibo Observatory at the Green Bank Telescope for the purpose of detecting gravitational radiation. Pulsar data currently place the most stringent limit on the gravitational wave background energy density. NANOGrav is part of the International Pulsar Timing Array which is comprised of NANOGrav, the European Pulsar Timing Array and the Parkes Pulsar Timing Array.

Additional Information: www.nanograv.org

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98. Orbiting Astrophysical Observatory In Space (OASIS)

Point of Contact: James H. Adams, Jr., Naval Research Laboratory

Summary Description: The unifying goal of OASIS is to identify local site(s) where galactic cosmic rays (GCRs) originate and are accelerated. This will allow an investigation of how the elements are made and distributed in the galaxy and improve our understanding of the sources of cosmic rays and the nature of cosmic particle acceleration. OASIS will allow us to investigate the recently reported feature in the cosmic ray electron spectrum in much more detail and to extend direct measurements to higher energies. This will make it possible to determine whether the electron spectrum is consistent with known astrophysical accelerators or indicates the presence of an additional, unseen source. OASIS will also allow us following up on the recent evidence from the ACE-CRIS and TIGER experiments, indicating that Galactic cosmic rays originate in OB associations, by providing individual element abundances of the rarest elements including the actinides. Definite answers will come from the two complementary instruments that comprise the OASIS system, high resolution measurements of ultra-heavy (trans-Ni) cosmic rays made with the Energetic Trans-Iron Composition Experiment (ENTICE) instrument and of high energy GCR electrons and ions using the High Energy Particle Calorimeter Telescope (HEPCaT).

Anticipated Sponsor: NASA

Participating Individuals or Institutions: Institutions participating in the Advanced Concept Study of OASIS: NASA Marshall Space Flight Center, NASA Goddard Space Flight Center, Louisiana State University, Washington University in St. Louis, New Mexico State University, University of Minnesota, Jet Propulsion Laboratory, Caltech; Note: We

foresee OASIS as a mission for the US Cosmic Ray Community and therefore expect that investigators from other institutions will be included in any proposal for this mission.
Current Status: We are in the final stages of an advanced concept study of the OASIS mission. The OASIS mission is to fly two instruments in space. The concepts for these instruments are based on actual instruments that have been successfully flown on balloons and in space. All of the detector technologies planned for the OASIS instruments have been flown in space successfully.
Additional Information: http://oasis.phys.lsu.edu/
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99. Orbiting Wide-angle Light-collectors (OWL)

Point of Contact: John W. Mitchell, NASA GSFC
Summary Description: The OWL mission (Stecker, et al.) is designed to answer one of the most perplexing mysteries in particle astrophysics, the source of ultra-high energy cosmic rays (UHECRs). These have been detected to energies greater than 10**20 eV, but their flux is minuscule, on the order of one per square kilometer per century, and instruments with exposures approaching a million km2sryr are needed. OWL will use downward looking UV telescopes on two co-orbiting satellites to stereoscopically image atmospheric fluorescence from extensive airshowers induced by UHECRs, effectively using the Earth's atmosphere as a immense particle calorimeter. These measurements will accurately determine the energy, arrival direction, and nature of UHECRs, shedding light on their source(s) and transport to Earth. OWL UHECR measurements offer two critical advantages over ground-based observations: 1) an approximately ×20 improvement in yearly sensitivity to UHECRs due to the vast atmospheric target viewed by OWL, and 2) sensitivity to astrophysical sources in both the Northern and Southern hemispheres. OWL measurements will enable the field of charged-particle astronomy, providing an important new means of investigating the astrophysics of the highest energy accelerators in the Universe. Furthermore, OWL has substantial sensitivity for UHE neutrinos. These are expected from photo-pion production interactions of UHECR and the interstellar and intergalactic gas (GZK effect) but with uncertain flux due to unknowns in the UHECR acceleration spectra and cosmological source evolution. The potential of neutrino astronomy is tremendous, UHE neutrinos are impervious to attenuation or deflection during transport and therefore can probe sources beyond the ~100 Mpc GZK horizon for UHECRs. The inherently small neutrino cross sections are very sensitive to the onset of physics beyond the Standard Model as proposed in some theoretical constructs, e.g. extra-dimensions, precocious unification, and micro-blackhole production (Dutta, et al.). Thus, the ability to detect and measure the properties of UHE neutrinos would test physics at energy scales, sqrt s ~ PeV, an energy that may never be achievable in terrestrial particle physics accelerators.
Stecker, FW, JF Krizmanic, LM Barbier, E Loh, JW Mitchell, P Sokolsky, and RE Streitmatter, Nucl. Phys. B136, 433 (2004)
Dutta, SI, MH Reno, and I Sarcevic, Physical Review D 66, 033002 (2002)
Anticipated Sponsor: NASA
Participating Individuals or Institutions: NASA Goddard Space Flight Center, NASA Marshall Space Flight Center, Rutgers, University of Alabama in Huntsville, University of California Berkeley, University of California Los Angeles, University of Denver, University of Utah, Vanderbilt University. Collaborations in Europe and Japan (Super-EUSO and JEM-EUSO) have scientific interests parallel those of OWL. It is likely that members of these collaborations would participate in an OWL mission.
Current Status: OWL was recommended by the NASA Roadmap: Cosmic Journeys as a high priority mission in 1999 and was highlighted in the NSF/DOE/NASA Connections: Quarks to the Cosmos. OWL was funded by NASA in 1999 for study as an advanced mission concept and was the subject of extensive instrument and mission design

development, including studies in 2002 by both the Instrument Design Lab and the Mission Design Lab of the Integrated Design Center at NASA/GSFC. The OWL baseline performance has been detailed via Monte-Carlo simulations (Krizmanic, et al. 2001) along with studies to quantify the effects of interference from clouds in the atmosphere (Sokolsky and Krizmanic; Krizmanic, et al. 2003; Abu-Zayyad, et al.). Recent measurements of UHECR by the Hi-Res and Pierre Auger ground instruments have highlighted the need for much greater event collecting power, which likely can only be realized using a space-based instrument with OWL's performance. Commercial improvements in photo-detector sensitivity in the past few years have strengthened the ability of OWL to perform decisive measurements of UHECRs. Combined with the potential to increase the light collecting ability of OWL, the resulting performance gain would enable OWL to measure the flux of cosmogenic UHE neutrinos as well as increasing OWL's UHECR performance.

Krizmanic. JF, et al., 27th ICRC (Hamburg), 861 (2001)

Sokolsky, P and JF Krizmanic, Astrop. Phys., 20, 391 (2004); Krizmanic, JF, P Sokolsky, and R Streitmatter, 28th ICRC (Tsukuba) (2003); Abu-Zayyad, T, CCH. Jui and EC Loh, Astrop. Phys. 21, 163 (2004)

Additional Information: http://owl.gsfc.nasa.gov, http://owl.gsfc.nasa.gov/booklet.html

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100. Pan-STARRS

Point of Contact: Nick Kaiser, Institute for Astronomy, University of Hawaii

Summary Description: The Pan-STARRS project has been supported by the USAF since September 2002 for the design and construction of a wide field optical/NIR observatory facility. PS features a distributed aperture approach to the telescope design with gigapixel array cameras on-chip fast guiding, and the AF funding has also supported the development of the image processing pipeline and database SW to make the image and catalog data usable for science. The PS1 system is now fully operational on Haleakala and embarking on a 4 year survey mission. PS2 is under construction and will join PS1 and then, at the end of 2012, these, together with two more telescopes, will form the PS4 observatory, to be sited on Mauna Kea and to operate through most of the coming decade to address goals for large area synoptic survey science such as those proposed in the "Astronomy and Astrophysics in the New Millennium" report and similar goals that may be forthcoming from the Astro2010 report. We strongly urge this committee to consider recommending, as a high priority, support to accelerate the completion of PS4 construction and to provide funding for operation. The result will be a survey facility of unparalleled power, which may form a natural step along the path to still more powerful surveys (see the LASST submission). Since the R&D development costs, and also the bulk of the costs of the construction, have been provided by the AF this presents a highly leveraged opportunity for the US astronomical community. In addition, this approach has the great benefit that the construction costs are known and construction time has been demonstrated so the risks for cost or budget overrun are low.

Anticipated Sponsor: DOE, NASA, NSF, Other

We propose that PS4 be supported through a combination of federal agency and private or institutional support. The project has been highly successful in forming an international consortium to provide much of the operations costs for PS1, along with significant additional operations support from NASA. We plan to extend this model for PS4 operations, with a negotiated policy for data release that features full release of all data to the National community, but with appropriate benefits accruing to institutional scientists.

Participating Individuals or Institutions: University of Hawaii; USAF

Current Status: Permitting; telescope construction; enclosure design.

Additional Information: http://pan-starrs.ifa.hawaii.edu/public/

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101. Pharos: A High Resolution X-ray and UV Spectroscopy Explorer for the Warm-Hot Intergalactic Medium

Point of Contact: Martin Elvis, Smithsonian Astrophysical Observatory
Summary Description: "Pharos" is a mission optimized for the detection of the 'Missing Baryons' in the Warm-Hot Intergalactic Medium (WHIM), in absorption against distant beacons (hence the name): blazars, quasars and GRBs. Pharos will measure Omega_WHIM(z), and the heating and enrichment history of the WHIM from z~0.5 to the present, along ~1000 WHIM systems in 2 years of operation. This heating and enrichment is sensitive to galaxy/AGN feedback models, and so will discriminate between them.
Pharos has a high resolution grating spectrometer with E/DE> 2000 (cf ~400 for RGS, LETGS, HETGS), operating *only* below 1 keV. By sacrificing higher energy response, with a clever use of ~15" HPD replica optics from MSFC, and new blazed 'CAT' gratings from MIT, we can approach ~600cm^2, only a factor of a few less than the grating effective area of IXO over the 0.1-1 keV band, and can detect 6-15 WHIM systems at z<0.5 in 300ksec. Multiple X-ray lines allow an ionization state to be determined. In addition, Pharos has a high througput UV spectrograph with R>2000 that will measure the 'broad' Lyman-alpha absorbers corresponding to the X-ray WHIM systems, which allows abundances to be determined, and so Omega_WHIM. A rapid slew capability to catch GRBs within 60s of their outburst, using a superAgile like X-ray ASM as a trigger, will give a much greater number of available lines of sight.
Pharos science would benefit other programs where long observations or rapid response are essential: e.g.
* The intimate surroundings of GRBs;
* Variability of Warm absorber winds from AGNs to determine their mass loss rate: relates AGN feedback to galaxy formation, evolution;
* X-ray binary accretion states and rare events: e.g. to pick up occasional bursts that illuminate neutron star structure via gravitational redshifts.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Martin Elvis (SAO), Steven S. Murray (SAO), Fabrizio Nicastro (SAO), Brian Ramsey (MSFC), Kathy Flanagan (STScI), Marco Feroci (INAF-IASF), Fabrizio Fiore (INAF-Rome, ITALY)
Current Status: Pre-phase A
Additional Information: Paper on Pharos: 2004cosp...35..563E

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102. Planet Hunter

Point of Contact: James C Marr, NASA JPL; Geoff Marcy, UC Berkeley
Summary Description: Planet Hunter is a micro-arcsecond (µas) astrometric mission that is focused on planet finding that meets the objectives identified in the AAAC Exoplanet Task Force (Lunine 2008) recommendation. Its architecture is identical to that of SIM Lite Astrometric Observatory except that it has only 30 cm science siderostats (as opposed to SIM Lite's 50 cm siderostats), has fewer operating modes and simpler ground science operations. Planet Hunter has the same exoplanet program as SIM Lite, including terrestrial habitable-zone search of 60 to 100 nearby stars, a broad survey of planetary system architectures, and a survey of young (<100Myr) stars for large planets. In essence, Planet Hunter is a slightly simpler version of SIM Lite that is focused on accomplishing the exoplanets portion of the SIM Lite mission but does not accomplish any of SIM Lite's astrophysics objectives.

Anticipated Sponsor: NASA
Participating Individuals or Institutions: Jet Propulsion Laboratory; Northrop Grumman Space Technology; Caltech; PI home institutions.
Current Status: Although a Planet Hunter study is funded as a NASA ROSES ASMCS, the design is so similar to SIM Lite, and uses the same now-completed technology (NASA 2005), that it could be considered in NASA Phase B along with SIM Lite.
Additional Information: Plaent Hunter's exoplanet discovery and characterization program is identical to that of SIM Lite which is described at http://planetquest.jpl.nasa.gov/SIM/index.cfm in the "Science Objectives" section. Also see the results of a recent SIM Lite exoplanet finding capability double blind study at http://planetquest.jpl.nasa.gov/SIM/researchOpps/roDoubleBlind/

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103. Planetary system and star formation science with non-redundant masking on space telescopes

Point of Contact: Anand Sivaramakrishnan, AMNH
Summary Description: Non-redundant masking (NRM) sets the bar for detection of high contrast companions at extremely high angular resolution. Successes on ground-based telescopes provide a stepping stone to NRM in space, where the technique offers great potential for future missions supporting both general astrophysics as well as missions dedicated to extrasolar planetary system and star formation science. NRM capability has recently been added to JWST's Fine Guidance Sensor Tunable Filter Imager (FGS-TFI) instrument. NRM rejects all telescope and instrument induced speckle noise. This ensures exquisitely precise PSF calibration, enabling faint companion detection as close as half an angular resolution element from a bright companion. Photon noise-limited imaging of structure around stars is achievable with NRM from space. The JWST FGS-TFI instrument's working area is an annulus between 50 and 400 mas at wavelengths longer than 3.8 microns, even in the event that the telescope's image quality is significantly worse than specification. Using conservative assumptions about JWST's stability, simulations predict a contrast of 10,000 in a 10 ks exposure on a 7th magnitude star at 5 microns, at a separation of 50 mas. This places protoplanets in Taurus within JWST's reach. Jovians younger than 300 Myr and more massive than 2 Jupiter masses orbiting solar type stars will also be observable with JWST's FGS-TFI. The late addition of NRM to FGS-TFI has had no impact on its planned observing techniques, data acquisition methods, or data pipeline. Dedicated NRM instrumentation on future space missions will significantly exceed JWST NRM benchmarks. Extending NRM capability into optical and UV bands is straightforward, and devoid of stringent requirements on wave front quality. On space telescopes NRM explores a realm inaccessible to both space-based coronagraphs and planned 30-m class ground-based telescopes, particularly in the mid-IR, optical, and UV regimes. Stretching beyond its science benefits, NRM provides interferometrically precise metrology of the telescope. It brings a flexible risk mitigation strategy to alignment and wave front sensing on segmented telescopes. With NRM, robust coarse and fine phasing capabilities can be integrated into telescope deployment and PSF maintenance, drastically reducing cost and risk associated with future segmented space and ground-based telescopes. Low cost, minimal impact on hardware, relaxed optical requirements, and high scientific payoff recommend NRM as a leading technology for any future missions possessing a high angular resolution imaging component.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Anand Sivaramakrishnan, Peter Tuthill, Remi Soummer, Frantz Martinache, Michael Ireland, Rene Doyon
Current Status: Pre-phase A
Additional Information:

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104. Plasma redshift of photons penetrating hot sparse plasma

Point of Contact: Ari Brynjolfsson, Applied Radiation Industries
Summary Description: The proposed work is in the thematic science area of "Cosmology and Fundamental Physics" (CFP). My (Ari Brynjolfsson) theory of "Plasma redshift of photons penetrating hot sparse plasma" (arXiv:astro-ph/0401420), which is deduced from only conventional axioms of physics (by using more exact deduction than those usually used) made it clear that photons with wavelength shorter than a certain cut-off wavelength (that depends on the density and the temperature of the plasma, as well as the magnetic field in the plasma), will be "plasma redshifted" as they penetrate the plasma. The cut-off wavelength makes it clear that the plasma must be sparse and hot. The conventional laboratory plasmas are usually too cold and dense, and the dimensions too small, so there is no plasma-redshift. But in the sparse hot plasma of the coronas of stars, galaxies, and of intergalactic space this plasma redshift is important. I suggest therefore that we measure the redshift of optical photons of star light grazing the Sun during solar eclipse. According to the conventional theory the Fraunhofer lines will not be redshifted as they penetrate the corona of Sun. However, according to plasma-redshift theory, a redshift of the Fraunhofer lines will be observed. This redshift is proportional to the electron-density integral along the line of sight through the solar corona. This redshift although small should be measureable. It decreases with the distance from the Sun. For example, if the line of sight to the star grazes the Sun at distance of R= 1.1, 1.4, and 2.o solar radii, the redshift should be 2.6, 1.4, and 0.46 per million, respectively. More extensive description of the plasma-redshift theory, and its many consequences are found in arXiv.org under the name Ari Brynjolfsson arXiv:astro-ph/0401420, and other related articles by the athor.
Anticipated Sponsor: NSF
The thematic science area, "Cosmology and Fundamental Physics" (CFP), could be sponsored by any of the above mentioned organizations.
Participating Individuals or Institutions: I, Dr. Ari Brynjolfsson, the point of contact will seek cooperation of University professors and their graduate students (in USA and abroad) with expertice in this field.
Current Status: Pre-phase A
Additional Information: This work will have enormous consequences for cosmology and for more thorough understanding of plasma physics. See Ari Brynjolfsson: "Plasma redshift of photons penetrating hot sparse plasma" in arXiv:astro-ph/0401420, and related articles by author.

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105. POET - Polarimeters for Energetic Transients

Point of Contact: Mark McConnell, University of New Hampshire
Summary Description: POET (Polarimeters for Energetic Transients) represents a concept for a Small Explorer (SMEX) satellite mission, whose principal scientific goal is to understand the structure of GRB sources through sensitive X-ray and gamma-ray polarization measurements. The payload consists of two wide field-of-view (FoV) instruments: a Low Energy Polarimeter (LEP) capable of polarization measurements in the energy range from 2-15 keV and a high energy polarimeter (Gamma-Ray Polarimeter Experiment or GRAPE) that would measure polarization in the 60-500 keV energy range. The POET spacecraft provides a zenith-pointed platform for maximizing the exposure to deep space. Spacecraft rotation provides a means of effectively dealing with any residual systematic effects in the polarization response. POET provides sufficient sensitivity and

sky coverage to measure statistically significant polarization (for polarization levels in excess of 20%) for about 80 GRBs in a two-year mission. High energy polarization data would also be obtained for SGRs, solar flares, pulsars and other sources of astronomical interest.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Space Science Center, University of New Hampshire, NASA Goddard Space Flight Center, Rice University, Rock Creek Scientific, Oklahoma State University, Max Planck Institute for Extraterrestrial Physics, Paul Scherrer Institute, Clemson University, Universities Space Research Association, Kyoto University, University of Iowa, INTEGRAL Science Data Center, Pennsylvania State University, Purple Mountain Observatory, Chinese Academy of Sciences, Hiroshima University, University of Nevada
Current Status: Pre-Phase A. Submitted (but not accepted) as a SMEX proposal in 2008. Both instruments are being developed independently under ROSES funding. GRAPE will fly on a balloon in 2011. The project is well-placed for future proposal opportunities.
Additional Information:
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106. Pupil mapping Exoplanet Coronagraphic Observer (PECO)

Point of Contact: Olivier Guyon, University of Arizona / Subaru Telescope
Summary Description: The Pupil-mapping Exoplanet Coronagraphic Observer (PECO) mission concept uses a coronagraphic 1.4-m space-based telescope to both image and characterize extra-solar planetary systems at optical wavelengths. PECO delivers 1e10 contrast at 2 lambda/D separation (0.15") using a high-performance Phase-Induced Amplitude Apodization (PIAA) coronagraph which remaps the telescope pupil and uses nearly all of the light coming into the aperture. For exoplanet characterization, PECO acquires narrow field images simultaneously in 16 spectral bands over wavelengths from 0.4 to 0.9 microns, utilizing all available photons for maximum wavefront sensing and sensitivity for imaging and spectroscopy. The optical design is optimized for simultaneous low-resolution spectral characterization of both planets and dust disks using a moderate-sized telescope. PECO will image the habitable zones of about 20 known F, G, K stars at a spectral resolution of R~15 with sensitivity sufficient to detect and characterize Earth-like planets and to map dust disks to within a fraction of our own zodiacal dust cloud brightness. Our proposal advocates an early moderate-scale mission opportunity to detect and characterize Earth-like planets and nearby planetary systems. We describe and recommend a technology development path that will rapidly prepare the PECO concept for mission development and launch in the coming decade. The PIAA coronagraph adopted for PECO reduces the required telescope diameter by a factor of two compared with other coronagraph approaches that were considered for Terrestrial Planet Finder Coronagraph Flight Baseline 1, and would therefore also be highly valuable for larger telescope diameters.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Institutions: University of Arizona, NASA JPL, NASA Ames, Lockheed Martin, ITT, PECO leads: Olivier Guyon (PI), Marie Levine, JPL (Study manager, Technology), Thomas Greene, NASA Ames (Science), Stuart Shaklan, NASA JPL (Architecture), Domenick Tenerelli, Lockheed Martin (Implementation). Other individuals: Roger Angel, Michael Meyer, Glenn Schneider, Neville Woolf (UofA), Wesley Traub, John Trauger, Mike Shao, Gene Serabyn, Amir Giveon (NASA JPL), Mark Marley, Ruslan Belikov, Kerri Cahoy, Dana Backman (NASA Ames), Robert Woodruff (Lockheed Martin), Robert Vanderbei, N. Jeremy Kasdin (Princeton), James Kasting (Penn State Univ.), Robert Egerman (ITT), Stephen Ridgway (NOAO), Motohide Tamura (National Astronomical Observatory of Japan)

Current Status: PECO is one of NASA's ongoing Advanced Mission Concept Studies. A report including expected science performance, mission design and technology development needs will be issued in April. In parallel to the PECO study, PIAA coronagraph technology is being validated in the laboratory.
Additional Information: http://caao.as.arizona.edu/PECO/index.html
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107. Radio Adaptive-Optics Seeing Correction

Point of Contact: James Lamb, Caltech
Summary Description: The intention is to develop a technique for tracking and correcting atmospheric refractive index variations over interferometric radio arrays. Tropospheric water vapor fluctuations present a major obstacle to ground-based high-resolution imaging in the millimeter and sub-millimeter wavelength ranges. These disturbances reduce sensitivity through decorrelation on short timescales, and degrade image quality through phase errors on both phase calibrators and science targets. Radio adaptive-optics are an essential component to realizing the potential of millimeter and sub-millimeter arrays to image planet-forming disks at sub-10 AU scales and to study the heart of active galactic nuclei, for example. CARMA has been pursuing a phase correction technique that involves monitoring atmospheric delay fluctuations directly using a dedicated interferometer array tracking a compact radio source within a few degrees of the science target. Operating in the centimeter band where receiver and atmospheric noise powers are low, it is possible to measure sub-picosecond atmospheric delay variations on sources with fluxes of about a jansky, with a time resolution of a few seconds. The low dispersion of the atmosphere (at frequencies high enough to avoid ionospheric scintillation) allows these delays to be used to directly compensate for atmospheric phase errors into the sub-millimeter. While our current investigations use existing hardware, we propose to construct a dedicated system that leverages current and developing technologies. By choosing the monitoring frequency and bandwidth with regard to the availability of bright sources, interference, and appropriate technologies we expect to develop a reliable and accurate system for atmospheric correction. Receivers will exploit amplifiers from the rapidly-developing area of integrated microwave amplifiers, and antennas will build on design and fabrication techniques currently being developed for large centimetric science arrays. Real-time pipeline correction will be evolved from our work on the CARMA pipeline and analysis methods presently being investigated. As a self-contained system, this would be directly applicable to any millimeter or sub-millimeter interferometer. In addition to providing a real-time correction of phases, it will be a valuable instrument for characterizing the nature of the atmospheric turbulence in terms of time and size scales, as well as height and layer thiskness.
Anticipated Sponsor: NSF
Participating Individuals or Institutions: James Lamb (Caltech), David Hawkins (Caltech), Richard Plambeck (UC Berkeley), David Woody (Caltech), Lee Mundy (U. Maryland), Douglas Bock (CARMA), John Carpenter (Caltech), Carl Heiles (UC Berkeley), Richard Crutcher (U, Illinois)
Current Status: Inclusion of the SZA array of eight 3.5-m antennas in CARMA has presented a unique opportunity to test this technique by pairing SZA antennas with the CARMA antennas. The SZA system was developed to investigate weak cosmic background signals and was therefore designed with outstanding continuum sensitivity. Initial tests have been extremely promising, yielding scientific results during the initial trial implementation. A clear result is that closer proximity of the monitor antennas delivers better compensation, indicating that there should optimally be at least one monitor antenna per science antenna. Our intention is to pursue this technique by developing a monitoring system optimized to the task.
Additional Information:

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108. Radio Cosmology Telescope

Point of Contact: Miguel F. Morales, University of Washington
Summary Description: The Radio Cosmology Telescope (RCT) is designed to map large scale structure in HI and provide precision pulsar timing. These low angular resolution/high surface brightness observations could trace the expansion history of space out to a redshift of ~4 (dark energy), provide detailed understanding of galaxy formation and gas dynamics through multi-wavelength correlation observations, and study gravitational waves and high field general relativity via pulsar studies. The RCT uses the instrumental and observational techniques developed for the Epoch of Reionization and recent correlator advancements to obtain precision calibrated cosmology observations. For baryon acoustic oscillations, the price/performance ratio of the RCT is nearly two orders-of-magnitude lower than proposed SKA observations. The RCT is in the design stage, and we are seeking development funds towards a late decade instrument proposal building on the lessons learned from the MWA and PAPER EoR observations.
Anticipated Sponsor: NSF
Participating Individuals or Institutions: Judd Bowman, Jacqueline Hewitt, Avi Loeb, Miguel Morales
Current Status: Design stage
Additional Information:

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109. Radio Sky Surveys Project

Point of Contact: Geoffrey Bower, UC Berkeley
Summary Description: We propose the Radio Sky Surveys Project (RSSP), a set of term-limited, wide-field, commensal surveys to be conducted with the Allen Telescope Array (ATA). The RSSP would form a radio complement to SDSS, Pan Starrs, LSST, and other surveys and connect to science programs with the EVLA, ALMA, and other next generation facilities. The scientific foci of the RSSP are exploration of the radio transient sky, gas assembly of nearby galaxies through study of neutral hydrogen, detection of the gravitational wave background through pulsar timing, star formation, galactic magnetism, structure of the Milky Way, and the search for extra-terrestrial intelligence. The surveys exploit the wide field of view, continuous frequency coverage, large number of antennas, and the flexible digital signal processing of the ATA. The science goals require a $40M expansion of the array to 256 antennas and $20M for operations and science over 5 years. These costs will be covered in public/private partnership. A consortium of US-based and international astronomers will carry out the surveys. Operation of an expanded, large-N ATA and implementation of commensal, multi-year surveys are enabling scientific and technical steps toward the mid- and high-frequency Square Kilometer Array.
Anticipated Sponsor: NSF, Other
The ATA has been funded through public-private partnership including NSF support. There is potential support from USAF as well as private donors.
Participating Individuals or Institutions: Don Backer, Leo Blitz, Geoffrey Bower, Carl Heiles, Jack Welch (UC Berkeley Radio Astronomy Laboratory), Peter Backus, Jill Tarter (SETI Institute), Crystal Brogan (NRAO), Jim Cordes (Cornell), Richard Crutcher (Illinois), Jeremy Darling (Colorado), Bryan Gaensler (Sydney), Paul Goldsmith (JPL), Patricia Henning (UNM), Richard Conn Henry (JHU), Steve Kilston (Ball), Glen Langston (NRAO), Joseph Lazio (NRL), Guillermo A. Lemarchand (Instituto Argentino de Radioastronomía),

Duncan Lorimer (WVU), Jean-Pierre Macquart (Curtin), Maura McLaughlin (WVU), D.J. Pisano (WVU), Mary Putman (Columbia), Snezana Stanimirovic (Wisconsin), Jacqueline van Gorkom (Columbia), Bart Wakker (Wisconsin), The North American NanoHertz Observatory of Gravitational Waves (NANOGrav): Anne Archibald (McGill University), Zaven Arzoumanian (Goddard Space Flight Center), Don Backer (University of California, Berkeley), James Cordes (Cornell University), Paul Demorest (National Radio Astronomy Observatory), Rob Ferdman (CNRS, France), Paulo Freire (National Astronomy and Ionospheric Center), Marjorie Gonzalez (University of British Columbia), Fredrick Jenet (University of Texas, Brownsville, CGWA), Victoria Kaspi (McGill University), Vlad Kondratiev (West Virginia University), Joseph Lazio (Naval Research Laboratories), Andrea Lommen (Franklin and Marshall College), Duncan Lorimer (West Virginia University), Ryan Lynch (University of Virginia), Maura McLaughlin (West Virginia University), David Nice (Bryn Mawr College), Scott Ransom (National Radio Astronomy Observatory), Ryan Shannon (Cornell University), Ingrid Stairs (University of British Columbia), Dan Stinebring (Oberlin College)

Current Status: This proposal is for additional construction of the Allen Telescope Array, and operation, and scientific use thereof. The ATA has been operating as a 42-element interferometer since its dedication in October 2007. The construction will replicate already built and tested components of the array. Costs are estimated from a bottom-up analysis. Array expansion will exploit existing scheduling, control, and analysis software. Significant development of data management tools is necessary.

Additional Information: RSSP web page including prospectus: http://etoile.berkeley.edu/~gbower/RSS/RSSP.html, ATA Page at Berkeley: http://ral.berkeley.edu/ata, ATA Page at SETI Institute: http://www.seti.org/Page.aspx?pid=503, USSKA Consortium Home Page: http://usskac.astro.cornell.edu, NANOGrav Consortium: http://nanograv.org

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110. Reionization and Dark Ages Radio experiment (RADARe)

Point of Contact: Donald Backer, UC Berkeley

Summary Description: Current models of the evolution of the early Universe make strong predictions about the epoch of reionization of hydrogen by the first stars and galaxies that begins around redshift 50 and is complete by redshift 6. Measurement of the 21cm emission from atomic hydrogen heated by UV and Xrays from the first generations of stars and galaxies will provide a remarkable data cube that can be used both to provide a basis for understanding the first stages of galaxy formation as well as to extract cosmological parameters at this intermediate epoch of the Universe. Several-low frequency arrays are seeking a detection of the power spectrum of 21cm-line brightness temperature fluctuations in the redshift range 6-12 (GMRT, LOFAR, MWA, PAPER, 21CMA). Theory and simulation predict rms signals at the level of a few mK, while interferometer array efforts have recently reached the level of a few K. The foregrounds (e.g., galactic synchrotron) are many orders of magnitude greater than the 21cm signals, but simulations and estimates suggest that these will be sufficiently smooth in angle and frequency to allow sensitive probes of the 21cm structures. Polarization properties of galactic synchrotron remain to be explored over the next few years. We expect that the power spectrum will be detected by one or more of these first generation efforts in the 2010-2014 time frame as they peel away technical and systematic limitations in successive annual campaigns. The proposed program is a for a second generation, US-led instrument that will provide a few hundred square degree data cube with sufficient angular and redshift (frequency) resolution to detail the evolution of density and ionization through an octave of cosmic time. The aggregate sum of current expenditures over the several current power spectrum detection efforts is approaching $10M; we will propose a fiducial array design at the $100M level based firmly on current construction costs for the next generation instrument, a sum that includes both construction and achievement of main scientific goal. The proposed activity: will complement current and planned low-frequency astrophysics projects: will serve as a scientifically productive step toward the low-frequency Square Kilometer Array; and will inform future efforts whose focus will be cosmological information embedded in hydrogen structures at earlier epochs. Use of the array for transient source detection, solar/heliospheric physics and other science is expected. Potential siting adjacent to SKA pathfinders is likely to limit infrastructure costs, and international participation is expected.

Anticipated Sponsor: NSF

Participating Individuals or Institutions: D. Backer, UC Berkeley; J. Hewitt, MIT; R. Bradley, NRAO/UVA; C. Carilli, NRAO Socorro, L. Greenhill, Harvard;_C. Lonsdale, Haystack Observatory; S. Furlanetto, UCLA; M. Morales, U Washington; J. Bowman, Caltech, J. Aguirre, Penn; F. Briggs, ANU; R. Subrahmanian, RRI India; Greg Taylor, UNM

Current Status: The PIs listed above are involved with either the Precision Array to Probe the Epoch of Reionization (PAPER) experiment, the Murchison Widefield Array (MWA), or Long-Wavelength Array (LWA) "first generation," low-frequency aperture array efforts. Costs are well identified for direct expansion. Current and planned collecting areas over the next few years are between 1000 and 10,000 m2. A fiducial design will be presented for a next-generation "21cm Cosmic Structure Imager" that is targeted for mid-decade deployment. Both MWA and PAPER are making use of the Murchison Radio Observatory (MRO) site in the radio-quiet outback of Western Australia. CSIRO with its ASKAP project and Curtin University and the University of Western Australia are developing and supporting infrastructure and activities at MRO.

Additional Information: http://www.haystack.mit.edu/ast/arrays/mwa/, http://astro.berkeley.edu/~dbacker/eor/, http://www.atnf.csiro.au/projects/askap/site.html

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111. Renewing Small Telescopes for Astronomical Research (ReSTAR)

Point of Contact: Caty Pilachowski, Indiana University

Summary Description: The ReSTAR Committee was convened by NOAO in response to the Report of the Senior Review of the NSF Division of Astronomical Sciences, to consider the system of telescopes available to the U.S. community in a comprehensive way. ReSTAR focused on telescopes in the range 1-6 meters to create a blueprint for developing a system of small and mid-sized telescopes, including the specific instrumentation and operational capabilities enabling front-line science with such telescopes and maximizing their scientific productivity. The ReSTAR report is available on the web at www.noao.edu/system/restar/files/ReSTAR_final_14jan08.pdf.

Anticipated Sponsor: NSF

Participating Individuals or Institutions: Pilachowski, the ReSTAR committee, and NOAO

Current Status: Implementation

Additional Information: www.noao.edu/system/restar

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112. SAMURAI (Science of AGNs and Masers with Unprecedented Resolution in Astronomical Imaging). U.S. support of Japanese Space VLBI mission VSOP-2 enabling U.S. scientists access to key mission science.

Point of Contact: David Murphy, NASA JPL
Summary Description: Enable U.S. participation in the the Japanese-led Space VLBI mission VSOP-2 which consists of a space radio telescope (ASTRO-G) operating in conjunction with ground VLBI arrays to produce the highest resolution images in astrophysics (~40 micro-arcseconds). Key SAMURAI science goals are (i) understand how super-massive black holes generate ultra-relativisitic jets and powerful gamma-ray emission and (ii) constrain the nature of dark energy by making the most accurate measurement of Hubble's constant. U.S. contributions to the VSOP-2 mission would include use of NRAO's VLBA, GBT, and EVLA, provision of 1 or 2 science telemetry (tracking) stations, high precision GPS orbit determination and support of a U.S.-led science team. U.S. participation in the VSOP-2 mission replaces the ARISE mission listed as a medium mission in the previous decadal survey. Furthermore, SAMURAI achieves the major science objectives of ARISE at a factor of 10 reduction in U.S. cost. Moreover. U.S. scientists and facilities are critical to VSOP-2 mission scientific success.
Anticipated Sponsor: NASA, NSF
Participating Individuals or Institutions: David W. Murphy (Jet Propulsion Laboratory), James Braatz (National Radio Astronomy Observatory), Lincoln Greenhill (Smithsonian Astrophysical Observatory), Daniel Homan (Denison University), Svetlana Jorstad (Boston University), Kenneth Kellermann (National Radio Astronomy Observatory), Matthew Lister (Purdue University), Alan Marscher (Boston University), David Meier (Jet Propulsion Laboratory), B. Glenn Piner (Whittier College), Robert Preston (Jet Propulsion Laboratory), Mark Reid (Smithsonian Astrophysical Observatory), Gregory Taylor (University of New Mexico), James Ulvestad (National Radio Astronomy Observatory), Frank Webb (Jet Propulsion Laboratory), Ann Wehrle (Space Science Institute), Oshiaki Hagiwara (National Astronomical Observatory of Japan), Makoto Inoue (National Astronomical Observatory of Japan), Seiji Kameno (Kagoshima University), Yasuhiro Murata (VSOP-2 deputy project scientist, Japan Aerospace Exploration Agency), Masato Tsuboi (VSOP-2 project scientist, Japan Aerospace Exploration Agency), Phillip Edwards (CSIRO Australia National Telescope Facility), Denise Gabuzda (University College Cork), Leonid Gurvits (Joint Institute for VLBI in Europe)
Current Status: Japanese VSOP-2 mission in Phase-A and space element ASTRO-G is due for launch in 2013. SAMURAI proposal was submitted to last SMEX Mission of Opportunity call and was rated category I (recommended for flight) and had 11 major strengths and 0 major weakness in NASA review. Unfortunately funding limitations prevented proposal from being funded.
Additional Information: http://www.vsop2.nrao.edu

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113. Scientific Ballooning Program

Point of Contact: Martin H. Israel, Washington University
Summary Description: The goal is to enhance substantially the support for scientific ballooning to allow funding of more cutting-edge science payloads and to open new balloon capabilities as, for example, ultra-long-duration flights exceeding 100 days. Scientific ballooning is AN IMPORTANT ELEMENT OF THE BALANCE AMONG SMALL, MEDIUM, AND LARGE MISSIONS. Ballooning supports important science investigations as well as technical developments for larger missions, and does so at a fraction of the cost of a SMEX; however, the cost of balloon payloads is still substantial (typically of

order $5M to $20M) and increased funding for payloads is necessary to maintain a viable program. Ballooning also addresses the need to DEVELOP NEW YOUNG SCIENTISTS FOR THE SPACE PROGRAM. Many leading NASA scientists learned how to do space missions as graduate students or young PhDs working on balloon-borne investigations. Completion, and extension, of the program to develop super-pressure balloons capable of long-duration or ultra-long-duration flights at all latitudes would be a SIGNIFICANT ENHANCEMENT OF THE INFRASTRUCTURE AND WOULD ENABLE MANY KINDS OF ASTROPHYSICS INVESTIGATIONS as well as investigations in heliophysics, earth science, and planetary science.

Anticipated Sponsor: NASA

Participating Individuals or Institutions: The following astrophysicists are members of the Scientific Ballooning Assessment Group, which has laid out a roadmap for scientific ballooning. These are all people who have had an active involvement in the balloon program; however, this list represents only a small fraction of the astrophysicists who are and would be involved in the program in the future: Steven Boggs (University of California, Berkeley), Michael Cherry (Louisiana State University), Mark Devlin (University of Pennsylvania), Jonathan Grindlay (Harvard University), Martin Israel (Washington University in St. Louis), Jonathan Ormes (University of Denver), Eun-Suk Seo (University of Maryland, College Park), Eliot Young (Southwest Research Institute, Boulder), Vernon Jones (NASA Headquarters), John Mitchell (NASA GSFC), Jack Tueller (NASA GSFC). In addition to astrophysicists, the scientific balloon program is of value to scientists studying heliophysics, earth science, and planetary science; scientists from those disciplines also participated in the Scientific Ballooning Assessment Group.

Current Status: The balloon program with CONVENTIONAL AND LONG-DURATION ZERO-PRESSURE BALLOONS IS HIGHLY SUCCESSFUL AND FULLY OPERATIONAL; however, the program is in jeopardy because of limited funding for increasingly sophisticated scientific instruments, resulting in fewer flights. Without an adequate number of flights each year the capability of the balloon manufacturer and the NASA Columbia Scientific Balloon Facility could be lost. The program's NEW SUPER-PRESSURE BALLOON CAPABILITY IS IN DEVELOPMENT and a successful flight of a scaled prototype 7-million-cubic-foot (Mcuft) balloon has been carried out. Larger prototypes are under development leading to a production super-pressure balloon of about 22 Mcuft capable of carrying a one-ton science instrument to an altitude of about 33.5 km, but the program will require expansion if it is to reach the objective of carrying one-ton science instruments to altitudes of about 38 km. Super-pressure balloons, augmented with modest capability for trajectory modification, would enable ultra-long-duration flights exceeding 100 days.

Additional Information: Please see the link to "2009 Report of the Scientific Ballooning Assessment Group" on the left side of the NASA Balloon Program Office home page http://sites.wff.nasa.gov/balloons/

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114. Semiconducting Compton Imager and Polarimeter (SCIP)

Point of Contact: Eric Wulf, Naval Research Laboratory

Summary Description: Space-based gamma-ray nuclear line science in the energy range from 100s of keV to 10s of MeV requires state of the art instrumentation to detect the background dominated signals necessary for spectrometry, polarimetry, and imagery of astrophysical sources. A Compton instrument offers the best gamma-ray and polarization sensitivity in this energy range while providing excellent energy and image resolution. Semiconducting detectors have the best combined energy and position resolution in the range of interest and therefore offer the best existing technology to enable a space-based Compton instrument. Power on a space-based mission is limited, therefore the readout electronics for the semiconducting detectors must not only be low-

power but also low-noise to maintain the energy resolution of the detectors. The Semiconducting Compton Imager and Polarimeter (SCIP) program will focus on detector and electronic development and demonstrations of a laboratory scale instrument.
Anticipated Sponsor: NASA, Other
Homeland Security applications funding
Participating Individuals or Institutions: Eric Wulf (Naval Research Laboratory), Neil Johnson (Naval Research Laboratory), Eric Grove (Naval Research Laboratory), Bernard Phlips (Naval Research Laboratory), James Kurfess (Praxis, Inc.), R. Marc Kippen (Los Alamos National Laboratory), Steve Boggs (UC Berkeley), Henric Krawczynski (Washington University in St Louis)
Current Status: Current NASA Astronomy and Physics Research and Analysis funding for work on thick silicon detectors and readout electronics. Balloon flights for both germanium and thin silicon Compton telescopes.
Additional Information:
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115. SIM Lite Astrometric Observatory

Point of Contact: James C Marr or Michael Shao, NASA JPL
Summary Description: The SIM Lite is a micro-arcsecond (µas) Astrometric Observatory that responds directly to the recommendations in the previous three Astronomy and Astrophysics Decadal Surveys (Field 1980; Bahcall 2000; McKee/Taylor 2000) and the AAAC Exoplanet Task Force report (Lunine 2008), accomplishing the full range of exoplanet discovery & characterization and astrophysics envisioned at the "goal-level" of performance in those reports. SIM Lite is a pointed observatory that achieves global astrometry at 4 µas mission accuracy from V = -1.5 to 20 mag and, in the narrow angle mode, is capable of 1 µas precision in ~1000 sec and, with 100's of repeated measurements over 5 years, can detect a planetary signature as small as 0.2 µas with a SNR of 5.8. SIM Lite's science objectives are described in the URL links below.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Jet Propulsion Laboratory; Northrop Grumman Space Technology; Caltech; Multiple universities and other institutions that are home to the current and future SIM Lite science team PIs and supporting science members.
Current Status: NASA Phase B. Technology development completed in 2005 and signed off by NASA HQ after extensive external review.
Additional Information: http://planetquest.jpl.nasa.gov/SIM/index.cfm see especially the subheadings "Science Objectives" and "Technical Readiness".
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116. South Pole Telescope

Point of Contact: Tom Crawford, University of Chicago
Summary Description: The 10-meter South Pole Telescope was built to conduct sensitive, large area surveys at millimeter through submillimeter wavelengths. The current goal is to complete a survey covering of order 4000 square degrees at wavelengths of 1.4mm, 2mm and 3mm to search for galaxy clusters via the Sunyaev-Zel'dovich (SZ) effect, and to characterize the fine angular scale CMB anisotropy. These measurements are being pursued to investigate dark energy through its effect on the growth of structure, and to constrain inflationary parameters through the effect on the spectrum of primordial fluctuations. The next goal starting in 2011 is to deploy a polarimeter and survey approximately 1000 square degrees to characterize the CMB polarization (and foregrounds) on scales of degrees to arcminutes (the resolution of the

SPT at 2mm is 1 arc minute). The goal of this program is to detect or set meaningful limits on the level of inflationary B-modes in the CMB polarization on large angular scales, and to characterize the B-mode lensing signal on intermediate angular scales. The next large survey is expected to start mid-decade. The survey and instrumentation is not fully defined at this time. It will most likely be a large survey of the submm sky from 2mm to 0.3mm, i.e., spanning the submillimeter atmospheric window. The broad wavelength coverage, high resolution (10 arcsecs at 300 um), and large survey area will be used to fully characterize the high redshift universe, in particular the first epoch of galaxy formation and the star formation history of the universe. The survey will provide information on scales and objects from nearby stellar disks to seeds of large scale structure. The large area systematically searched by the SPT survey provide the rare objects for follow-up by ALMA and JWST. All of the SPT surveys will be provided to the general community for decades to come. The development of large format, multichroic, polarization-sensitive, detector focal plane arrays is critical to accomplish the goals of the upcoming SPT surveys.

Anticipated Sponsor: NSF, Other

Primary funding for development and operations is from NSF-Office of Polar Funding. DOE and NASA funding is desired for detector development and science analysis.

Participating Individuals or Institutions: University of Chicago (lead institution), U.C. Berkeley, U.C. Davis, U. Colorado at Boulder, U.I. Urbana-Champaign, Case Western Reserve Univ, Harvard U., Smithsonian Astrophysical Observatory, McGill University, Cardiff University

Current Status: Operating. Taking data for SZ survey project. Funding for development and deployment of polarimeter is secure. Operations funding secure through 2011. Next survey receiver, i.e., after polarimeter, is not designed or funded. It should be ready in 2014. It is not currently funded.

Additional Information: http://spt.uchicago.edu for general description of ongoing project.

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117. Space-based Microlensing Survey of Extrasolar Planets

Point of Contact: David Bennett, Univ. of Notre Dame

Summary Description: A space-based microlensing survey for extra-solar planets will provide a statistical census of exoplanets with masses down to 0.1 Earth-masses and orbital separations ranging from 0.5AU to infinity. This includes analogs to all the Solar System's planets except for Mercury, as well as most types of planets predicted by planet formation theories. Such a survey will provide results on the frequency of planets around all types of stars except those with short lifetimes. Close-in planets with separations < 0.5 AU are invisible to a space-based microlensing survey, but these can be found by Kepler. This mission can be done within the cost constraints of NASA's Discovery Program, and the ExoPlanet Task Force gave a (qualified) recommendation that such a mission be done. However, NASA currently plans to discontinue exoplanet missions under the Discovery Program. The telescope needed is also quite similar to some of the telescopes for proposed JDEM concepts and their European counterparts. So, it might be possible to combine a microlensing planet search mission with a dark energy mission at a substantially lower cost than doing both missions separately. But NASA has no mechanism for proposing such a mission.

Anticipated Sponsor: NASA, Other

A joint mission between NASA and ESA or CNES is a possibility.

Participating Individuals or Institutions: David Bennett (PI, Univ. of Notre Dame), Ed Cheng (Deputy PI, Conceptual Analytics), John Mather, Randy Kimble; Lockheed Martin: Domenick Tenerelli (NASA/GSFC), J. Anderson, S. Friedman, K. Sahu; J.-P. Beaulieu, I. Bond, K. Cook, B.S. Gaudi, A. Gould, J. Jenkins, D. Lin, M. Rich, A. Udalski, P. Yock

(STScI)
Current Status: Pre-phase A
Additional Information: A white paper to the ExoPlanet Task Force is available here: http://arxiv.org/abs/0704.0454

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118. SPICA Participation through a US-built science instrument: BLISS, the Background-Limited Infrared Submillimeter Spectrograph.

Point of Contact: Charles M. (Matt) Bradford, NASA JPL
Summary Description: We outline a plan for US participation in the Japanese-led Space Infrared Telescope for Cosmology and Astrophysics (SPICA) mission currently under development with launch envisioned in 2017. SPICA features a 3.5-meter telescope actively cooled to below 5K, operated at L2 with a 5-year lifetime. The large cold aperture offers the potential for mid-IR to submillimeter observations which are limited only by the zodiacal dust emission and other natural backgrounds. If equipped with suitable instrumentation, SPICA can enable sensitivities comparable to JWST and ALMA but in the crucial but still relatively unexplored far-IR regime spectral range. SPICA has a strong following in Europe, and telescope and instrument contributions are under Phase-A study by ESA and its member states.
We have been working with the SPICA principals in a study of a sensitive US-built spectrometer called BLISS which would be one of the 3 or 4 science instruments. The collaboration is compelling because US detectors for far-IR / submm wavelengths are world-leading, and our provision of BLISS has the potential to dramatically enhance the capabilities of SPICA. An instrumental contribution to SPICA would allow US scientific access to all the capabilities of SPICA, a great-observatories-class facility, at relatively moderate cost. A similar approach of low-cost but crucial and scientifically enabling technological contributions led to US scientific participation in ESA's Herschel and Planck missions.
BLISS is envisioned to cover the 38 to 430 micron regime with grating spectrometer modules using sensitive superconducting bolometers. The result will be an optimized spectroscopic follow-up capability, and BLISS / SPICA will be 3-6 orders of magnitude faster than currently-planned facilities for spectroscopy. Throughout the lifetime of the mission, BLISS will obtain thousands of complete far-IR spectra of galaxies ranging from the local universe to redshift 6. In aggregate, these spectra will chart the history of stars, black hole activity, and organic element production from 1 BY after the Big Bang to the present.
A timely if modest investment by NASA is required in order to enable this unique opportunity. Participation in SPICA with an instrument such as BLISS is the top priority of the US far-IR astrophysics community for the coming decade, outlined in a notice to the Survey by Martin Harwit et al. In addition to the scientific value, SPICA participation also provides a platform for advancing low-background far-IR focal-plane technologies, the key technical hurdle for our community's long-term plans: US-led cryogenic far-IR missions CALISTO/SAFIR and SPIRIT.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: C. Matt Bradford (JPL), James J. Bock (JPL), Martin Harwit (Cornell), George Helou (Caltech), Lee Armus (Caltech), Daniel F. Lester (U. Texas, Austin), George Rieke (U. Arizona), Matt Malkan (UCLA), Gordon Stacey (Cornell), Michael Werner (JPL), J. D. Smith (U. Toledo), Takao Nakagawa (ISAS, Japan), Hideo Matsuhara (ISAS, Japan)
Current Status: The schedule for SPICA is very tight. On July 8, 2008, SPICA entered a "pre-project phase", corresponding to a NASA Phase-A study; and European astronomers are currently studying a contribution of the SPICA telescope and an instrument through ESA's Cosmic Visions program. Instrument resource allocations

(volume, mass, power) are currently underway, and to keep US options open, NASA should soon initiate steps for formal US participation with consent of the Decadal Review. A US Background-Limited Infrared Spectrometer for SPICA, BLISS, has been under pre-phase-A study in the US for more than 4 years. The effort was initiated with a NASA award as part of the Origins Probe studies in 2003, and has also received 3 years of modest detector development funds through the ROSES program. The anticipated end-to-end cost to NASA for participation on SPICA, from inception through instrument delivery, mission operations, data archiving and processing support for the mission, and grant support for participating US astronomers is expected to be in the range of $250--300 M, approximately half of which will be devoted to construction and testing of instrument hardware. In return for this investment, the US scientific community will obtain access to all of SPICA's instruments on a competitive basis, an arrangement paralleling NASA's agreement with ESA on Herschel, where the US community is reaping similar benefits in return for a comparable investment of NASA funds.

Additional Information: more information at http://www.submm.caltech.edu/BLISS/

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119. SPIRIT - The Space Infrared Interferometric Telescope

Point of Contact: David Leisawitz, NASA GSFC

Summary Description: SPIRIT is a two-telescope Michelson interferometer operating over the far-infrared wavelength range 25 to 400 microns and offering a powerful combination of spectroscopy (R ~ 3000) and sub-arcsecond angular resolution imaging (integral field spectroscopy) in every arcminute-sized field observed. With angular resolution two orders of magnitude better than that of the Spitzer Space Telescope (like JWST), and with comparable sensitivity, SPIRIT will:

(a) revolutionize our understanding of the formation of planetary systems by resolving protoplanetary disks and mapping their continuum and line emission, enabling us to "follow the water" in developing planetary systems;

(b) discover otherwise-undetectable planets through their gravitational perturbations of debris disks by providing sensitive, high-contrast images of the warm dust in many such systems;

(c) spectroscopically probe the atmospheres of extrasolar giant planets in orbits typical of the planets in our solar system to learn about their chemistry and physical conditions; and

(d) make unique and profound contributions to our understanding of the formation, merger history, and star formation history of galaxies using well-understood spectral line diagnostics and probing the unconfused far-IR emissions of individual sources throughout the redshift range $0 < z < 3$.

These are the subjects of white papers planned for submission to the science panels of the Decadal Survey. Measurement capabilities like those offered by SPIRIT are called for in the science papers.

The SPIRIT mission concept has deep roots in the astrophysics community's strategic plans. The 2000 Decadal Report said: "A rational coordinated program for space optical and infrared astronomy would build on the experience gained with [JWST] to construct SAFIR, and then ultimately, in the decade 2010 to 2020, build on the SAFIR, TPF, and SIM experience to assemble a space-based, far-infrared interferometer." The kilometer baseline far-IR interferometer included in NASA's long-range plan for astrophysics, widely known as the Submillimeter Probe of the Evolution of Cosmic Structure (SPECS), was the subject of a NASA "vision mission" study, as was the Single Aperture Far-IR (SAFIR) Telescope. In 2003, the Community Plan for Far-IR/Submillimeter Space Astronomy expressed the consensus view of the far-IR community and offered practical advice: in addition to the flagship missions SAFIR and SPECS, the Community Plan recommended two smaller missions, SPIRIT and a far-IR sky survey mission, identified key technologies, and recommended international collaboration. Unlike SPECS, SPIRIT does not require formation flying, and it was considered to be the logical way to embark on the interferometry path if its cost would be much less than that of a flagship mission. SPIRIT was selected by NASA for study as a candidate Origins Probe mission, its science potential was assessed, and its cost was estimated. The cost did prove to be less than that of a typical flagship mission, and SPIRIT was again recently recommended by consensus of the far-IR community in the updated Community Plan, a document called “Far-Infrared/Submillimeter Astronomy from Space: Tracking an Evolving Universe and the Emergence of Life,” which is the subject of a parallel Notice of Interest submitted by Martin Harwit. Particularly pertinent to SPIRIT, the updated far-IR Community Plan recommends significant investment in the coming decade in SPIRIT mission-enabling technology, and SPIRIT and SAFIR Phase A studies by the end of the decade to prepare for a “which-goes-first” decision by the 2020 Decadal Survey Committee to be based on scientific merit, technical readiness, and affordability. With a suitable investment in far-IR detector technology – the pacing item – SPIRIT could enter Phase B shortly after 2020 and be prepared for launch by 2028.

SPIRIT has two afocal, off-axis telescopes with 1 m diameter primary mirrors. Its single scientific instrument serves a dual purpose: it combines the telescope beams and provides variable optical delay for Fourier transform spectroscopy, a technique now advancing in the lab toward TRL 6 with NASA funding through the ROSES/APRA program. The SPIRIT telescopes are moveable across the length of a rotating 36 m long structure and are thus capable of densely sampling the uv plane for high-quality imaging. Cryocoolers similar to the one developed for JWST are used to cool the optics to 4 K, cold baffles reject stray thermal radiation, and next-generation detectors cooled to ~50 mK will enable measurements limited by astrophysical background photon noise. Metrology tolerances are coarser than those applicable to interferometers or segmented mirror telescopes designed to operate at shorter wavelengths; alignment and pathlength control are well within reach of current technical capability, leaving only subsystem details to be proven in a flight-like environment. Japan is preparing a balloon-borne far-IR interferometer for flight in 2009, and the US could fly a SPIRIT pathfinding far-IR interferometer during the next decade. SPIRIT was designed to fit into an Atlas V launch vehicle with a medium-length fairing.

During the SPIRIT Origins Probe mission concept study, both grass-roots and independent parametric cost analyses were conducted by experienced engineers and cost modelers. The “basis of estimate” assumptions and the detailed Master Equipment List used in these cost analyses will be provided if the Decadal Survey’s independent cost contractor desires such information.

Anticipated Sponsor: NASA, Other

Potential international partners include ESA and its European member nations, Canada, and Japan.

Participating Individuals or Institutions: Peter Ade (U. Cardiff), Amy Barger (UWisc), Dominic Benford (NASA GSFC), Andrew Blain (Caltech), John Carpenter (Caltech), John Carr (NRL), Drake Deming (NASA GSFC), Nicholas Elias (U. Heidelberg), Michel Fich (U. Waterloo), Jacqueline Fischer (NRL), Jonathan Gardner (NASA GSFC), Paul Goldsmith (Caltech/JPL), Jane Greaves (U. St. Andrews), Martin Harwit (Cornell), Makoto Hattori (Tohoku U.), Frank Helmich (SRON), George Helou (Caltech/IPAC), Lynne Hillenbrand (Caltech), Rob Ivison (ROE), Alan Kogut (NASA GSFC), Marc Kuchner (NASA GSFC), John Lacy (UT Austin), William Langer (Caltech/JPL), Richard Lyon (NASA GSFC), Amy Mainzer (Caltech/JPL), John Mather (NASA GSFC), Hiroshi Matsuo (NAO Japan), Margaret Meixner (STScI), Harvey Moseley (NASA GSFC), Lee Mundy (UMD), Stephen Rinehart (NASA GSFC), Aki Roberge (NASA GSFC), Eugene Serabyn (Caltech/JPL), Hiroshi Shibai (Nagoya U.), Robert Silverberg (NASA GSFC), Michael Skrutskie (U. Colorado), Gordon Stacey (Cornell), Johannes Staguhn (UMD), Stephen Unwin (Caltech/JPL), Alycia Weinberger (Carnegie DTM), David Wilner (SAO), Alwyn Wootten (NRAO), Ned Wright (UCLA), Harold Yorke (Caltech/JPL), and Jonas Zmuidzinas (Caltech)

Current Status: An intensive, year-long pre-phase A study was conducted under NASA's Origins Probe Mission Concept Study Program, with supplementary systems and discipline engineering and cost analysis support provided by NASA's Goddard Space Flight Center.
Additional Information: Within 30 days of 01-13-2009, five SPIRIT papers will be available from the following URL:
https://webdrive.gsfc.nasa.gov/longauth/600/David.T.Leisawitz.1/SW1NgIC. Please use the following to login: username = SPIRITDecadal, password = SPIRITDecadal
(If the URL expires, please contact the Activity PoC, who will gladly supply copies of the SPIRIT papers.)

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120. Starshade for JWST

Point of Contact: Webster Cash, University of Colorado
Summary Description: It is generally agreed that direct imaging and spectroscopy of Earth-like planets is among the highest priority goals in all of the sciences. Discovery of habitable planets and strong biosignatures would literally change the way we, as a people, view the night sky. The New Worlds Observer and THEIA are completing ASMCS studies, funded at the full level, indicating they are considered viable flagship missions for the coming decade. Our studies have shown the great bulk of the cost resides in the telescope half, while the starshade half falls in the medium cost category, well under one billion dollars. This reopens the potential for NASA to leverage an existing asset to lower the price and accelerate the schedule in the search for habitable planets and life signatures. Our study has also shown that a starshade can be flown to rendezvous and work with JWST but requires zero technical redesign or operations changes for the observatory. A starshade can be designed to remotely align itself between the observatory and the target star so that JWST need only point at the target when ready. It can deliver the contrast and inner working angle (60mas) necessary to study habitable zones around nearby stars even though the JWST telescope has a segmented aperture with modest wavefront quality at short wavelengths. The observations would primarily occur at the short wavelength end of the JWST bandpass, between 0.65 and 1.5microns, and can reach 3microns at the expense of some inner working angle. A starshade can "visit" over 100 planetary systems in a five year period without refueling and will probably be able to study dozens of habitable zone planets and many more colder ones. Follow-up photometry and spectroscopy using JWST's instruments (R=100 spectroscopy with NIRSpec) can reveal the true nature of each planet and start the serious search for biomarkers. It is estimated that these observations will require less than 10% of JWST's observing time. A starshade for JWST may provide the only opportunity to detect and address the habitability of terrestrial exoplanets with a medium mission budget.
Anticipated Sponsor: NASA, Other
Likely interest from ESA as well.
Participating Individuals or Institutions: W. Cash (U. Colorado), D. Spergel, (Princeton U.), R. Soummer (STScI), R. Polidan (NGST), Other institutions include GSFC, USNO, GRC and Ball
Current Status: Pre-Phase A, ASMCS studies completed
Additional Information: http://newworlds.colorado.edu/, ASMCS study reports from NWO and THEIA to be available shortly

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121. Starshade Technology Development

Point of Contact: Amy S. Lo, Northrop Grumman Corporation

Summary Description: Since the development of a high-performance, technically feasible, external occulter, known as a starshade (Cash 2006), a variety of missions have proposed pairing a starshade with a space telescope to enable high-contrast imaging. The most notable of these is the New Worlds Observer mission concept, which uses a starshade with a diffraction-limited telescope to perform terrestrial planet finding. Beyond TPF, starshades have been proposed to accomplish many science goals including planet formation, AGN composition analysis, and exo-zodiacal light characterization. The NWO team and others have been studying the incorporation of starshades into a wide range of mission concepts such as ACCESS, ATLAST, and JWST. While the NWO team has largely used existing technology for these starshades, we have identified several areas of technology development that will enable us to rapidly demonstrate and implement starshades for the missions under study. In order to meet a 2010-to-2020-era implementation, we propose the following activities: 1) Creation of a robust optical testbed to demonstrate the performance of the starshade and validate the predictions of our starshade optical models. 2) Development of starshade hardware including precision thin-edge treatments, large-scale deployment, and opaque membranes. 3) Development of astrometric sensors for starshade positioning. While each of these technologies exists, they need to be integrated for adequate starshade performance. We envision the launch of an engineering starshade unit on a suborbital or other ultra-low cost vehicle to validate the technology and perform some limited science. This Starshade Technology Development program will provide a fundamental stepping stone for the implementation of not only the New Worlds Observer mission, but also probe class and future missions that call for the use of a starshade.
Anticipated Sponsor: NASA, ESA
Participating Individuals or Institutions: A large consortium of institutions and individuals are contributing to this effort: NASA Goddard Space Flight Center, NASA Glenn Research Center, United States Naval Observatory, University of Colorado, Boulder, Space Telescope Science Institute, Northrop Grumman Aerospace Systems, Ball Aerospace & Technologies Corporation
Current Status: Pre-phase A, concept study.
Additional Information: http://newworlds.colorado.edu/

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122. Stellar Imager (SI) – A UV/Optical Interferometer (UVOI) Viewing the Universe in High Definition

Point of Contact: Dr. Kenneth G. Carpenter, NASA GSFC
Summary Description: The Stellar Imager (SI) Vision Mission (see http://hires.gsfc.nasa.gov/si/) is a UV-optical aperture-synthesis spectral imager with separated apertures, each at least one meter in diameter, spread over baselines up to a km across, and a central beam-combing hub with focal-plane instrumentation that provides an angular resolution (0.1 milli-arcsec) more than 200x that of Hubble Space Telescope (HST). It will provide heretofore unattainable views of the surfaces and interiors (via spatially-resolved asteroseismology) of other solar-type stars, of the inner regions and winds of Active Galactic Nuclei (AGN), and of the dynamics of many systems and processes throughout the Universe. The primary goal of this mission is to revolutionize our understanding of: 1) Solar and Stellar Magnetic Activity and their impact on Space Weather, Planetary Climates, and Life, 2) Magnetic and Accretion Processes and their roles in the Origin & Evolution of Structure and in the Transport of Matter throughout the Universe, 3) the close-in structure of AGN and their winds, and 4) Exo-solar planet transits and disks. It is critical that technology development (e.g., precision formation flying and closed-loop control phasing control of large arrays) for this mission occur during the 2010 decade to enable a launch in the ~2025 era. SI is a potential implementation of the UVOI in the 2006 Science Program for NASA's Astronomy &

Physics Division and a Flagship "Landmark Discovery" Mission in the 2005 Heliophysics Roadmap. The NRC has also recommended that this concept be studied further in the context of being enhanced by the Constellation architecture, although there are versions of the mission that do not require the Ares V as a launch vehicle.

Anticipated Sponsor: NASA, Other

plus possibly ESA

Participating Individuals or Institutions: PI: GSFC/K. Carpenter. Partial list of collaborators includes: Industrial Partners: LMATC/C. Schrijver/R. Woodruff, BATC/S. Kilston/C. Noecker, NGST/A. Lo/C. Lillie, Seabrook Eng./D. Mozurkewich; NASA Centers: GSFC/W. Danchi/R. Lyon/J. Leitner/E. Stoneking, MSFC/P. Stahl, JPL/J. Breckinridge, STScI/R. Allen; University Partners: SAO/M. Karovska, ASU/R. Windhorst, CUA/F. Bruhweiler, MIT/D. Miller, SUNY/F. Walter, UCO/A. Brown/G. Harper, NOAO/K. Mighell; International Partners: College de France/A. Labeyrie, AI-Potsdam/K. Strassmeier, U. Aarhus/ J. Christensen-Dalsgaard

Current Status: Pre-Phase A

Additional Information: http://hires.gsfc.nasa.gov/si/

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123. Study of Large-Telescope Verification and Testing Strategies and Issues

Point of Contact: Julie Crooke, NASA HQ

Summary Description: NASA's astrophysics observatories continue to grow in size, performance requirements and sensitivity. NASA's mantra, "test as you fly" has become increasingly challenging and difficult. As with JWST, future flight hardware system verification may become a pivotal make-or-break serial process combination of sub-system tests, with modeling and simulation tool analyses not having proven until orbit. This study for the 2010 Decadal Review will investigate the full range of issues and potential solutions to test and verify the performance of future astrophysical observatories, including issues related to technical (size, sensitivity, etc.) and non-technical root causes of project cost and schedule growth (i.e., thermal vacuum testing options, its associated potential consequences, conflicts and solutions; transportation limitations, asset sharing among projects (contamination, project schedule delays, etc.), and augmenting institutional capabilities), to name a few. It is vital that, as the astrophysics community identifies and prioritizes future astrophysics missions, it also addresses the ability to verify mission performance prior to launch. The consequences and impacts of decisions, if made early enough, can benefit the success of future missions and their associated costs and schedules.

Anticipated Sponsor: NASA, Other;

NASA, DoD, NRO, Aerospace Corporation

Participating Individuals or Institutions: Sponsoring institutions, NASA Centers

Current Status: Limited work on this topic

Additional Information: Please contact Activity POC @ Julie.A.Crooke@nasa.gov for a copy of the NASA HQ Final Report, December 2006, "Agency Verification Strategies and Issues Study". (The report can not be posted to an open FTP site.)

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124. Technology Development for Automated Rendezvous and Docking and Robotic Servicing of Future Astrophysics Missions

Point of Contact: Linda L. Brewster, NASA MSFC

Summary Description: Future Astrophysics Missions will be enhanced by a robotic servicing capability to allow replacement or upgrading of science instruments and spacecraft components and the resupply of consumables such as cryogens or fuel. Such a capability would significantly increase the long term science return on the taxpayer's investment. The value of this potential capability has been made evident by numerous human servicing missions to Hubble, and the recent Orbital Express mission demonstrated many of the capabilities needed to allow robotic servicing and resupply to occur. Therefore, technology development is required to mature, demonstrate and standardize this capability for inclusion in future space missions. For example, the ability to autonomously acquire, track, and rendezvous with a spacecraft at L2; a standardized interface for docking between spacecraft (and once docked, the servicing spacecraft could reboost or otherwise adjust the orbit of the science spacecraft); interfaces to facilitate exchange of science instruments and spacecraft components; standardized interfaces to allow refueling; cryogenic interfaces to allow transfer of coolants. An example of a mission which could benefit from this capability is a large UV/Optical space telescope (e.g., ATLAST).

Anticipated Sponsor: NASA

Participating Individuals or Institutions: Phil Stahl, Randy Hopkins, Tom Bryan, and Ricky Howard of MSFC; Chuck Lillie of NGST; Harley Thronson of GSFC; and Marc Postman of STScI

Current Status: Design and development phase: There are many individual components that make up an AR&D and robotic servicing system; a first generation of some components have been flown on Orbital Express.

Additional Information: The Orbital Express mission demonstrated many of the concepts (AR&D, automated fuel transfer, and installing/removing electronic boxes or components.) http://www.darpa.mil/orbitalexpress/index.html

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125. Technology Development for Future Sparse Aperture Telescopes and Interferometers in Space

Point of Contact: Dr. Kenneth G. Carpenter, NASA GSFC

Summary Description: The most critical technology-development needs on the roadmap toward future high-angular-resolution, space-based observatories (long-baseline sparse aperture telescopes and imaging interferometers) are those needed to position and control the mirror surfaces and the spacecraft on which they rest with very high precision. This will be done via autonomous staged-control systems which combine precision formation flying of spacecraft (the “mirrorsats” and the beam-combiner spacecraft) with precision active optical control of the mirror surfaces (i.e., their tip, tilt, piston, and translation). These control technologies must be developed during the next decade to enable numerous missions being considered by NASA for flight in the next two decades, including the Stellar Imager (SI), Space Infrared Interferometric Telescope (SPIRIT), Sub-Millimeter Probe of the Evolution of Cosmic Structure (SPECS), Life Finder (LF), Black Hole Imager (BHI/MAXIM), and Planet Imager (PI), and smaller precursor missions, which may fly in the later part of the 2010 decade.

Anticipated Sponsor: NASA, Other
with possible ESA contribution

Participating Individuals or Institutions: PI: GSFC/K. Carpenter. Partial list of collaborators includes: Industrial Partners: NGST/A. Lo/C. Lillie, Seabrook Eng./D. Mozurkewich, Aurora Flight Systems/J. Parrish, LMATC/C. Schrijver/R. Woodruff; NASA Centers: GSFC/R. Lyon/J. Leitner/E. Stoneking, MSFC/P. Stahl; University Partners: SAO/M. Karovska/J. Phillips, MIT/D. Miller

Current Status: Pre-Phase A

Additional Information: http://hires.gsfc.nasa.gov/si/

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126. Technology Development for Lightweight Low Cost Space Optics

Point of Contact: Greg Hickey, NASA JPL
Summary Description: New technologies have emerged that will make possible large, lightweight, low cost primary mirrors for future NASA space telescopes. One example is the Actuated Hybrid Mirror (AHM), developed by a team of Northrup Grumman Xinetics, LLNL, and JPL, which has achieved 10-15 kg per square meter areal densities for mirrors up to 1.4 m in diameter. AHMs use nanolaminate metal foils bonded to SiC substrates, together with many embedded small ceramic actuators, to achieve low mass and high optical quality, together with low cost and short fabrication time cycle. Another example is the ITT light weight ULE mirror process first demonstrated on the AMSD program at the 1.4 m size, and further developed more recently in cooperation with JPL. This approach uses ultra-light weighted glass substrates supported by force actuators to achieve the same result. Other approaches have been proposed in the past, such as hybrid structures utilizing composite materials, or electrostatically suspended reflective membranes. Continued progress in lowering areal density while providing diffraction-limited optical performance, is necessary if the most ambitious visions for NASA space telescopes are to be realized. Lightweight active optics for cryogenic applications will also be important to future NASA infrared and far-infrared missions. SiC (as used for the Herschel Space Observatory) or innovative glass solutions may offer lower-cost, higher-performance alternatives to conventional approaches. JPL is interested in pursuing advanced lightweight optics technology developments that will enable the missions of the next 2 decades. We anticipate proposing specific areas of investigation including large (2.5 m diameter) Actuated Hybrid Mirrors (with Northrup Grumman Xinetics); large, extremely lightweight glass mirrors (with ITT); composite-based hybrid mirrors; and cryogenic lightweight mirrors.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Greg Hickey (JPL), Dave Redding (JPL), Dave Van Buren (JPL), Gary Parks (JPL), Robert Laskin (JPL), Mark Ealey (Northrup Grumman Xinetics), Troy Barbee (LLNL), Cal Abplanap (ITT)
Current Status: Design and Development
Additional Information:

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127. Technology Development for Precision Spacecraft Formations

Point of Contact: Dr. Fred Hadaegh, NASA JPL
Summary Description: Many future astrophysical science missions, such as extrasolar terrestrial planet interferometer missions, x-ray interferometer missions, and optical/UV deep space imagers, call for instrument apertures or baselines beyond the scope of deployable structures. The only practical approach for providing the measurement capability required by the science community's goals is precision formation flying (PFF) of distributed instruments. In effect, PFF synthesizes a virtual structure, thereby enabling apertures and baselines orders-of-magnitude greater than the largest monolithic spacecraft instrument dimension.

Formation flying missions create unique technology needs and their architectures are fundamentally different from single spacecraft architectures. They require the combination of distributed sensor measurements, path-planning, and control capabilities, subject to communication capacity to guarantee formation performance. Distributed architectures must also ensure collision avoidance, allow for the allocation and balancing of fuel consumption, and allow for graceful degradation with failures. New, scalable and robust classes of distributed multi-spacecraft system architectures need to be developed that integrate formation sensing, communication & control. To function as a formation, the spacecraft must be coupled through autonomous control. Such control requires inter-spacecraft range and bearing information to determine the present formation configuration, and optimal, desired trajectories that achieve science goals. For astrophysical interferometry, inter-spacecraft range and bearing knowledge requirements are on the nanometer and subarcsecond-levels, respectively. Improved wide field-of-view (FOV) sensors and high-fidelity simulation tools are essential for operating these missions and validating system performance prior to launch. Precision formation controls require micro, non-contaminating propulsion systems. Current astrophysical science missions such as stellar imagers and x-ray interferometers, plan on having formations of twenty-plus spacecraft. These missions will require high-bandwidth, low-latency, and robust inter-spacecraft communication systems and distributed command and sensing architectures for coordinating these complex and precise formations. High-throughput, low-latency multi-point (cross-linking) communication with adaptable routing and robustness to fading is necessary to support these missions. Throughput and latency directly impact inter-spacecraft control and knowledge performance and payload operational efficiency. Real-time control quality of service must be maintained over large dynamic ranges and varying number of spacecraft and formation geometries. Payloads will require 10's-1000's Mbps for target recognition/science-in-the-loop applications. Coordinating multiple spacecraft requires distributing locally available information (e.g., a local inter-spacecraft sensor measurement) throughout a formation. Health and high-level coordination information must also be disseminated (e.g., a spacecraft's readiness to perform a certain maneuver). For these reasons, and unlike any single-spacecraft application, formations require closing control loops over a distributed wireless data bus. Hence, the overall precision performance of the formation is limited by the ability of the inter-spacecraft communications. While technologies such as cellular towers are fine for terrestrial voice applications, formations require highly reliable systems free of single-point-failures having high-bandwidth and guaranteed low-latency. For the precision-levels envisaged, dropped packets can cause a synthesized instrument to stop functioning, severely reducing observational efficiency. Finally, the range of over which formations operate means that the communication system must simultaneously be able to talk to a spacecraft tens of kilometers away without deafening a spacecraft ten meters away, a problem area referred to as cross-linking.

Anticipated Sponsor: NASA

Participating Individuals or Institutions: F. Hadaegh (JPL), J. Breckinridge (JPL), S. Dubovitsky (JPL), J. Mueller (JPL), M. Ortiz (Caltech), S. Pellegrino (Caltech), J. Marsden (Caltech), D. Miller (MIT), R. Smith (UCSB), R. Mehra (Scientific Systems), G. Cameron (Orbital Sciences)

Current Status: N/A

Additional Information:

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128. Technology Development for Space Telescope Wavefront Sensing and Control

Point of Contact: Dave Redding, NASA JPL

Summary Description: Future large space telescopes will likely utilize actively controlled mirrors to achieve large aperture and high wavefront quality in a low-mass, low-cost package. These mirrors may be segmented so they can be folded into a compact form for launch, and deployed when on orbit. Active mirrors require Wavefront Sensing and Control (WFS&C) systems, to measure and correct post-launch figure and alignment errors. WFS&C is used on JWST, for example, to establish diffraction-limited performance. Future missions will require improvements in WFS&C performance to reduce cost and complexity, increase performance, or provide near-continuous WF control. Very large segmented mirror telescopes as well as telescopes requiring extreme precision such as Exoplanet imaging systems will require Metrology systems. Examples are being studied by the ATLAST group (http://www.stsci.edu/institute/atlast). Metrology offers full-time, high bandwidth sensing for maintaining high optical quality during science observations. It has important advantages that will make it the preferred solution for some missions. A prototype laser system can measure 6 degrees of freedom of mirror segments at a 1 kHz rate. Control systems based on wavefront measurements or other techniques are extremely important for making cryogenic space telescopes affordable. If actuators and sensors can encompass the range of deformations of the overall structure, then there is no need to test the entire telescope performance when cold. Verifying the cold performance of individual segments together with the operation of the WFS&C system can guarantee proper optical performance when cold, with dramatic reduction in test complexity and cost. This will be significant for future mission such SAFIR/CALISTO, which employs a 10m class telescope cooled to 4 K (http://safir.jpl.nasa.gov/whatIs.shtml). We are interested in pursuing advanced WFS&C technology developments that will enable the missions of the next 2 decades. Some specific areas of investigation that we feel should be pursued are Wavefront Sensing (including continuous WFS and multi-color WFS), Wavefront Control (Advanced Deformable Mirrors), Metrology Systems (Laser Truss elements; Edge Sensors; Photogrammetry), and Testbed and Ground-Based Telescope Demonstrations.

Anticipated Sponsor: NASA

Participating Individuals or Institutions: S. Basinger (JPL), S. Bikkannavar (JPL), D. Coulter (JPL), M. Dragovan (JPL), J. Green (JPL), C. Lawrence (JPL), O. Lay (JPL), D. Lester (Univ. Texas), C. Ohara (JPL), M. Postman (STScI), D. Redding (JPL), F. Shi (JPL), F. Zhao (JPL); NASA Jet Propulsion Laboratory, Space Telescope Science Institute, NASA Goddard Space Flight Center, Northrop Grumman Aerospace Systems, Ball Aerospace & Technologies Corporation, ITT Space Systems, Xinetics, Inc.

Current Status: Pre-Phase A

Additional Information: http://www.stsci.edu/institute/atlast, http://planetquest.jpl.nasa.gov/SIM/index.cfm

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129. Technology Development in the Area of Modeling and Simulation

Point of Contact: Claus Hoff, NASA JPL

Summary Description: In the area of large space and ground based apertures, it is generally recognized that commercially-available tools, though mature and feature-rich, do not adequately address the unique requirements of current and proposed NASA missions given anticipated thermal, structural, and optical stability requirements (milli-Kelvin thermal gradient stability, controlled wave front errors to nanometer levels) and physical effects. Considering that it will be impossible to ground-test large space based systems in their deployed configurations prior to launch, it becomes clear that meaningful advancement of the state-of-the-art is required in order to be capable of placing a greater reliance on and confidence in computer-aided modeling and simulation. In addition, for the quantification of margins and uncertainties (QMU), a common integrated model and an efficient analysis tool are required to make such investigations feasible.

JPL has developed the computational platform Cielo, which provides for a single model finite element transient simulation for the thermal, structural, and optical response predictions of complex structures functioning in extreme operating environments. Cielo is an open and extendable platform for interrogating the interrelationship of new technologies, for resolving limitations in the features of commercial off the shelf tools (COTS), and for independent verification and validation regarding simulations and designs. We propose to extend Cielo to develop an integrated modeling tool which includes the action of any thermal, structural, optical, and electro-mechanical feedback and control systems on the simulation and design. This capability will enable the simulation and design of an optical system incorporating adaptive optics, real-time wave front error minimization, and thermal-structural flexures resulting from time and temperature dependent boundary conditions.

QMU on large models requires a high performance analysis engine that takes advantage of parallel processing, includes all relevant multi physics, and may include feedback control systems. To supplement the compute engine, a coherent framework for parameter variation must be provided. We propose to use the solution capabilities in Cielo and integrate them with the public domain QMU tool Dakota from Sandia National Laboratories. In addition, we propose to develop a numerically-efficient, parametric, semi-analytic sensitivity capability that can be used to compute response changes for changes in given parameter sets.

Anticipated Sponsor: NASA

Participating Individuals or Institutions: Mike Chainyk (JPL), Claus Hoff (JPL), Greg Moore (JPL), Lee Peterson (JPL), Marco Quadrelli (JPL), Paul von Allmen (JPL), Prof. Michael Ortiz (Caltech), Prof. Paul Dimotakis (Caltech), Prof. Jerold Marsden (Caltech)

Current Status: N/A

Additional Information:

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130. Technology Investments to Meet the Needs of Astronomy at Ultraviolet Wavelengths in the 21st Century

Point of Contact: Kenneth Sembach, Space Telescope Science Institute

Summary Description: Our team of academic, government, and industrial partners is producing an ultraviolet technology roadmap as part of a NASA Astrophysics Strategic Mission Concept Study for a future large Ultraviolet/Optical telescope in space. A primary goal of this study is to identify technologies that could be matured within the next decade to provide a cost-effective way to revolutionize ultraviolet (100-300 nm) observations of the Universe, either by diversifying and extending the science capabilities of large (4-16m class) UV/optical telescopes, or by increasing the science potential of smaller (SMEX, MIDEX, Probe-class) missions within their cost-constrained envelopes. Examples of future large mission concepts that would benefit from this development include ATLAST, MUST, THEIA, and NWO. We will provide the Decadal Committee with a clear articulation and prioritization of the technology investments needed to meet the needs of ultraviolet astronomy in the 21st century. Key focus areas include new generations of UV-sensitive CCD and microchannel plate detectors, efficient optical coatings shortward of 300 nm, improvements in grating efficiency and aberration correction, and optimized optical designs for slit spectrographs, all-reflective integral field units, and wide-field spectral imagers. We would be pleased to present a summary of our study to the Decadal Committee.

Anticipated Sponsor: NASA

Participating Individuals or Institutions: An extended group of individuals has expressed interest in helping our core team with this effort. That group includes individuals at the following institutions and is listed below.

Space Telescope Science Institute, Ball Aerospace and Technologies Corporation, Northrup Grumman Corporation, NASA/GSFC, NASA/JPL, NASA/MSFC, Arizona State University, Boston University, Northwestern University, Princeton University, University of California – Berkeley, University of California - Santa Cruz, University of Colorado – Boulder, University of Massachusetts – Amherst, University of Virginia

Bala Balasubramanian, Matthew Beasley, Morley Blouke, Webster Cash, Supriya Chakrabarti, Tim Cook, Dennis Ebbets, James Green, Tupper Hyde, Rolf Jansen,

Edward Jenkins, Ian Jordan, N. Jeremy Kasdin, <Chuck Lillie, John MacKenty, Shouleh Nikzad, Robert O'Conell, Bill Oegerle, Marc Postman, Xavier Prochaska, Aki Roberge, Paul Scowen, Ken Sembach, Oswald Siegmund, George Sonneborn, Nathan Smith, Philip Stahl, Todd Tripp, Melville Ulmer, John Vallerga, Barry Welsh, Bruce Woodgate
Current Status: Astrophysics Strategic Mission Concept Study (ongoing)
Additional Information:

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131. Telescope Array Project

Point of Contact: Gordon Thomson, Rutgers University
Summary Description: The Telescope Array Project aims to study cosmic rays of the highest energies, covering the range in energy from the "knee" of the cosmic ray spectrum at 3x10^15 eV to above the "GZK cutoff" which occurs at 6x10^19 eV. To do this a series of detectors will be co-located at the Telescope Array site in Millard County, Utah, which include fluorescence detectors, scintillation counter arrays on the desert floor, underground muon detectors, shower Cerenkov light detectors, and radio detectors. We plan to extend our coverage beyond the usual definition of cosmic rays (protons and nuclei) to include neutrinos, and to do neutrino astronomy.
Anticipated Sponsor: NSF, Japanese funding agencies, Korean funding agencies, Russian funding agencies
Participating Individuals or Institutions: 5 institutions in the United States, 15 institutions in Japan, 7 institutions in Korea, 1 institution in Russia, 1 institution in Belgium
Current Status: The first phase of the experiment, to cover from 10^18 eV up, has been deployed and is collecting data. The second phase, to reach down to 3x10^16 eV is called the Telescope Array Low Energy Extension (TALE), and has been proposed to funding agencies in the U.S., Korea, and Japan. Two future phases of the experiment are in the planning stage.
Additional Information: See http://www.telescopearray.org for further information. Click on "TALE Program Overview" as well.

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132. Telescope for Habitable Exoplanets and Interstellar/Intergalactic Astronomy

Point of Contact: N. Jeremy Kasdin, Princeton University
Summary Description: THEIA is a concept for a powerful 4-meter telescope capable of detecting and characterizing Earth-like planets around nearby stars. With its advancedinstrument suite, THEIA is also capable of conducting a broad program of astronomical observation and having a major impact on our understanding of star formation, galaxy evolution and the intergalactic medium. THEIA is the combination of 3 NASA mission concept studies: (1) XPC: the eXtrasolar Planet Characterizer, a proposal to build a hybrid occulter/coronagraph to study exoplanets; (2) SFC: Star Formation Camera, a wide field near-IR/optical/UV camera optimized to study star formation and galaxy evolution; and (3) UVS: Ultraviolet Spectrograph, a highly efficient spectrographdesigned to study the intergalactic medium and probe the chemical evolution of the universe. THEIA is an occulter/telescope system. When the occulter is “on target”, it searches for and characterizes planets around nearby stars. While the occulter is moving, the telescope will carry out several key science investigations and will conduct a diverse and exciting general astrophysics program.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Industry Partners: Lockheed Martin, ITT, Ball

Aerospace, Goodrich, ATK; NASA Centers: JPL, GSFC, Ames, Marshall'; University Partners: Arizona State, Caltech, Carnegie, Case Western, Colorado, JHU, Massachusetts, Michigan, MIT, Penn State, Princeton, STScI, UCSB, UCB, Virginia, Wisconsin, Yale; Team Members: Paul Atcheson, Matt Beasley, Rus Belikov, Morley Blouke, Eric Cady, Daniela Calzetti, Craig Copi, Steve Desch, Alan Dressler, Dennis Ebbets, Rob Egerman, Alex Fullerton, Jay Gallagher, Jim Green, Olivier Guyon, Sally Heap, Rolf Jansen, Ed Jenkins, N. Jeremy Kasdin, Jim Kasting, Ritva Keski-Kuha, Marc Kuchner, Roger Lee, Don J. Lindler, Roger Linfield, Doug Lisman, Rick Lyon, John MacKenty, Sangeeta Malhotra, Mark McCaughrean, Gary Mathews, Matt Mountain, Shouleh Nikzad, Bob O'Connell, William Oegerle, Sally Oey, Debbie Padgett, Behzad A Parvin, Xavier Prochaska, I. Neill Reid, James Rhoads, Aki Roberge, Babak Saif, Dmitry Savransky, Paul Scowen, Sara Seager, Bernie Seery, Kenneth Sembach, Stuart Shaklan, Mike Shull, Oswald Siegmund, Nathan Smith, Remi Soummer, David Spergel, Phil Stahl, Glenn Starkman, Daniel K Stern, Dominick Tenerelli, Wesley A Traub, John Trauger, Todd Tripp, Jason Tumlinson, Ed Turner, Bob Vanderbei, Rogier Windhorst, Bruce Woodgate, Bob Woodruff

Current Status: Astrophysics Strategic Mission Concepts Studies Completed March 2009

Additional Information: ASMCS study reports to be available shortly

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133. Terrestrial Planet Finder Coronagraph and Exoplanet Coronagraph Technology

Point of Contact: Marie Levine, NASA JPL

Summary Description: From 2004-2006 NASA funded an in-depth study for a flagship exoplanet imaging mission, Terrestrial Planet Finder Coronagraph (TPF-C), with the expectation of a new mission start in 2007. The resulting concept, known as Flight Baseline-1 (FB1), exemplifies the largest possible flagship coronagraph mission (8x3.5m telescope) for Earth-size exoplanet characterization in the visible using existing EELV launch vehicles. FB1 is designed with an internal Lyot band-limited coronagraph operating at 4 lambda/D, for which a detailed Technology Development plan was established, reviewed and approved with no identified show-stoppers (TPF-C Technology Plan (2005), TPF-C Flight Baseline-1 Report (2005)). Since then, TPF-C has been re-staged by NASA as the Exoplanet Coronagraph Technology program. The technology needs for visible exoplanet coronagraphs of any scale and approach have benefited from many inputs and reviews over the last 3 years and are becoming well understood: TPF-C Science and Technology Definition Team Report (2006), TPF-C Workshop (2006), Navigator Program Forum (2007), Exoplanet Community Report (2008), ASMCS Exoplanet Mission Concept Studies (2009). The identified enabling visible exoplanet coronagraph technologies are: starlight suppression, wavefront sensing and control including deformable mirrors, precision structures, light-weight optics, and modeling and simulation. On-going demonstrations in the Jet Propulsion Laboratory High Contrast Imaging Testbed (HCIT) achieved contrast to earth-imaging milestone levels (5x10-10 contrast) in 10% bandwidth in the visible using an FB1 type Lyot band-limited coronagraph. Other coronagraph starlight suppression methods have also been tested. Presentations, if requested, will report on the TPF-C FB1 mission concept as well as the visible internal coronagraph technology state-of-the-art, including promising developments in high efficiency coronagraphs operating down to 2lambda/D, such as the Phase Induced Amplitude Apodization (PIAA) and possibly others, which would enable a single-spacecraft 4m telescope mission with essentially the same exoplanet science as the original FB1, realizing significant cost savings to the program.

Anticipated Sponsor: NASA

Participating Individuals or Institutions: Remi Soummer (Space Telescope Science

Institute), James Kasting (Penn State University), Wesley Traub (Jet Propulsion Laboratory), Michael E. Brown (California Institute of Technology), Robert A. Brown (Space Telescope Science Institute), Mark Clampin (NASA Goddard Space Flight Center), Henry C. Ferguson (Space Telescope Science Institute), Olivier Guyon (University of Arizona), Heidi B. Hammel (Space Science Institute), Sara R. Heap (NASA Goddard Space Flight Center), Scott D. Horner (Lockheed-Martin), N. Jeremy Kasdin (Princeton University), Mark J. Kuchner (NASA Goddard Space Flight Center), Douglas Lin (University of California, Santa Cruz), Mark S. Marley (NASA Ames Research Center), Victoria Meadows (Spitzer Science Center), M. C. Noecker (Ball Aerospace & Technology Corp.), Ben R. Oppenheimer (American Museum of Natural History), Stephen Ridgway (National Optical Astronomy Observatories), Sara Seager (Carnegie Institution of Washington), Karl R. Stapelfeldt (NASA Jet Propulsion Laboratory), John Trauger (Jet Propulsion Laboratory), Robert Vanderbei (Princeton University)
Current Status: TPF-C mission was in pre-Phase A until 2006 when it was postponed indefinitely by NASA. The activity has now been re-scoped into the Exoplanet Exploration Coronagraph Technology Program which oversees visible exoplanet coronagraph technology development, performs continued starlight suppression technology demonstrations, and currently provides technical support to the Principal Investigators of the Exoplanet Astrophysics Strategic Mission Concept Studies (ASMCS) exoplanet concepts.
Additional Information: Exoplanet Community Report (draft, Nov 2008): http://exep.jpl.nasa.gov/documents/Forum2008_268_small.pdf, Navigator Program Forum (May 2007) http://planetquest.jpl.nasa.gov/NavigatorForum/agenda.cfm, Terrestrial Planet Finder Coronagraph Workshop (Sept 2006) http://planetquest/TPF/tpf-c_workshopDocs.cfm, Terrestrial Planet Finder Coronagraph, Science and Technology Definition Team (STDT) Report (June 2006) http://planetquest.jpl.nasa.gov/TPF/STDT_Report_Final_Ex2FF86A.pdf, Terrestrial Planet Finder Coronagraph, Flight Baseline #1 Report (July 2005) http://planetquest.jpl.nasa.gov/documents/TPFC-FB1_Report.pdf, Terrestrial Planet Finder Coronagraph Technology Plan (March 2005) http://planetquest.jpl.nasa.gov/TPF/TPF-CTechPlan.pdf

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134. Terrestrial Planet Finder Interferometer

Point of Contact: Peter R. Lawson, NASA JPL
Summary Description: The Terrestrial Planet Finder Interferometer is a mission concept to survey ~150 nearby stars for the presence of Earth-like planets, to detect signs of life or habitability, and to enable revolutionary advances in high angular resolution astrophysics. TPF (Interferometer) received a high ranking amongst the major initiatives that were reviewed in the 2000 Decadal Survey; the committee recommended that $200M be invested to advance technology development in the Decade of 2000-2010. We propose that this successful work be continued to further advance the technology to system-level readiness at TRL 6 before the end of the Decade 2010-2020.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: C. A. Beichman, W. C. Danchi, K. J. Johnston, A. Léger, T. Herbst, F. Malbet, O. Absil, R. Akeson, J. Bally, A. Belu, M. Boyce, J. Breckinridge, A. Burrows, C. Chen, D. Cole, D. Crisp, R. Danner, P. Deroo, V. Coudé du Foresto, D. Defrère, D. Ebbets, P. Falkowski, R. Gappinger, C. Hanot, I. Haugabook, T. Henning, Ph. Hinz, J. Hollis, S. Hunyadi, D. Hyland, L. Kaltenegger, J. Kasting, M. Kenworthy, A. Ksendzov, B. Lane, G. Laughlin, O. Lay, R. Liseau, B. Lopez, R. Millan-Gabet, S. Martin, D. Mawet, B. Mennesson, J. Monnier, M. C. Noecker, J. Nishikawa, M. Pesesen, R. Peters, A. Quillen, S. Ragland, S. Rinehart, H. Rottgering, D. Scharf, E. Serabyn, M. Tehrani, W. Traub, S. Unwin, D. Wilner, J. Woillez, N. Woolf, and M. Zhao

Current Status: The Terrestrial Planet Finder Interferometer has been in Pre-phase A of development. Most of its major milestones planned for the 2000-2010 Decade have been accomplished, bringing the technology now to TRL 4-5.
Additional Information: http://planetquest.jpl.nasa.gov/TPF-I/tpf-I_index.cfm

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135. The Advanced X-ray Timing Array (AXTAR)

Point of Contact: Paul S. Ray, NRL
Summary Description: AXTAR is a NASA MIDEX mission concept for X-ray timing of compact objects that combines very large collecting area, broadband spectral coverage, high time resolution, highly flexible scheduling, and an ability to respond promptly to time-critical targets of opportunity. It is optimized for submillisecond timing of bright Galactic X-ray sources in order to study phenomena at the natural time scales of neutron star surfaces and black hole event horizons, thus probing the physics of ultradense matter, strongly curved spacetimes, and intense magnetic fields. AXTAR's main instrument is a collimated, thick Si pixel detector with 2-50 keV coverage and over 3 square meters effective area. For timing observations of accreting neutron stars and black holes, AXTAR provides at least factor of five improvement in sensitivity over the RXTE PCA. AXTAR also carries a sensitive sky monitor that acts as a trigger for pointed observations of X-ray transients and also provides high duty cycle monitoring of the X-ray sky with 20 times the sensitivity of the RXTE ASM. AXTAR builds on detector and electronics technology previously developed for other applications (for sponsors including NASA, DARPA, and DHS) and thus combines high technical readiness and well understood cost.
Anticipated Sponsor: NASA, Other
A significant amount of the technology development has come from DOD and DHS sponsorship.
Participating Individuals or Institutions: Paul S. Ray (NRL), Deepto Chakrabarty (MIT), Tod E. Strohmayer (GSFC), Bernard F. Phlips (NRL), and a large science working group from many institutions.
Current Status: Pre-phase A concept study with ongoing technology development.
Additional Information: http://xte.mit.edu/AXTAR

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136. The Arecibo Telescope: Frontiers in Astronomy and Fundamental Physics

Point of Contact: Donald B. Campbell, Cornell University
Summary Description: The proposed activity builds on the very high sensitivity at mid-cm wavelengths of the 305 m Arecibo telescope; it has five times the sensitivity of the next largest single-dish radio telescope and five times smaller beam area. New instrumentation can further exploit this large collecting area to keep Arecibo as a forefront telescope for the next decade. When equipped with focal plane arrays, Arecibo is uniquely capable of large scale cm-wavelength surveys. Ongoing and imminent surveys, many of which will extend beyond the next five years, utilize the recently installed ALFA receiving system, a 20 cm wavelength 7-feed focal plane array, and the associated 300 MHz bandwidth spectrometers. The surveys include; 1) pulsar and transient searches; 2) blind surveys of HI in external galaxies out to red-shifts of 0.25; 3) a targeted survey to measure the HI content of massive galaxies selected from the SDSS and GALEX surveys; 4) a survey of HI in our Galaxy at very high spectral resolution and covering the full Arecibo sky; 5) measurement of Galactic and extragalactic magnetic fields via Faraday rotation measurements of continuum sources; 6) SETI searches. The pulsar

search is aimed at discovering objects that will elucidate the equation of state of ultra-dense matter and provide additional objects for which high timing precision can be obtained for inclusion in the global pulsar timing array. Decade term pulsar timing measurements with Arecibo are crucial to detecting the background energy density in gravitational waves at nanohertz frequencies. Arecibo's sensitivity also makes it the premier instrument to search for radio counterparts of Fermi (GLAST) pulsed sources. Planning and definition work has begun on a 40-beam focal plane phased array as a next generation instrument that will greatly enhance Arecibo's survey capabilities. This is a cutting-edge project that will draw on current multi-nation efforts to develop such devices for use with the SKA. Installation on the Arecibo telescope is planned for about four years from now and will give Arecibo a survey speed comparable to the SKA pathfinders currently under construction such as ASKAP. Major objectives are an ultra-high sensitivity survey of HI in the low red-shift universe and a deep search for pulsars and transients. Not all surveys with Arecibo are at 20 cm. Arecibo is an important component of the High Sensitivity VLBI Array and the European VLBI Network enhancing the sensitivity of these arrays by up to a factor of four. This enables such programs as high precision astrometry of pulsars out to five or more kilo-parsecs from the Sun, an important input to supernova mechanisms and to improving the precision of pulsar timing measurements. Arecibo's recent detection of cm-wavelength molecular lines from Arp 220 is galvanizing the formation of consortia to carry out Galactic and extra-galactic surveys for such lines. A survey of near-Earth asteroids using the Arecibo S-band radar system, including precision ranging to many of them, will continue through the next decade. Results of this work will contribute to our understanding of planetary system formation and evolution.

Anticipated Sponsor: NASA, NSF

Participating Individuals or Institutions: Donald Campbell (NAIC, Cornell University), James Cordes (Cornell University), Jonathan Davies (University of Cardiff, United Kingdom), Wolfram Freudling (ESO, Munich, Germany), Tapasi Ghosh (National Astronomy and Ionosphere Center (NAIC)), Carl Heiles (UC Berkeley), Ellen Howell (NAIC), B. Murray Lewis (NAIC), Jean-Luc Margot (UCLA), Robert Minchin (NAIC), Michael Nolan (NAIC), Chris Salter (NAIC), David Schiminovich (Columbia University), Russell Taylor (University of Calgary, Canada), Yervant Terzian (Cornell University); Participants in NANOGrav: The North American Nanohertz Observatory of Gravitational Waves

Current Status: The Arecibo telescope is an existing instrument that requires operating funds. A major instrumentation development is the 40-beam Focal Plane Phased Array. This is currently at the planning and definition stage - i.e pre-Phase A. Its expected cost is less than ten million dollars.

Additional Information: http://www.naic.edu, http://www.naic.edu/alfa/ - the NAIC ALFA web site, http://egg.astro.cornell.edu/alfalfa/ - the ALFALFA web site, http://www.nanograv.org - the NANOGrav web site

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137. The Astrobiology Space Infrared Explorer Mission

Point of Contact: Scott Sandford, NASA Ames

Summary Description: ASPIRE is an infrared space observatory optimized to investigate issues of key importance to astrobiology, astrochemistry, and astrophysics by spectroscopically detecting and identifying solid and gas phase organic compounds and related materials in a wide variety of environments in space using the mid- and far-infrared spectral windows. This information will be used to establish how and where these materials are formed, how they evolve, and how they find their way to planetary surfaces.

Anticipated Sponsor: NASA

Participating Individuals or Institutions: NASA-Ames Research Center, Jet Propulsion

Laboratory, Ball Aerospace (Science CoIs come from many institutions, including NASA-Ames, JPL, NASA-GSFC, UC Berkeley, CalTech/IPAC, Univeristy of Hong Kong, and Service d'Astrophysique,C.E.A)
Current Status: The ASPIRE mission has been selected for two Concept Studies (Origins Probes Concept Studies and the current Strategic Astrophysics Missions Concept Studies. This mission also builds on the Astrobiology Explorer (ABE) MIDEX mission, which received Pahse A funds during the last MIDEX round. The current status of this mission concept is therefore a VERY mature Pre-phase A.
Additional Information: NONE

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138. The Baryonic Structure Probe: A Probe-Class Mission to Revolutionize Observations of the Cosmic Web

Point of Contact: Kenneth Sembach, Space Telescope Science Institute
Summary Description: Most of the mass in the Universe is located outside galaxies in the intergalactic medium. The evolution of the cosmic web and the circulation of gas into and out of galaxies are key ingredients in recipes for how galaxies form and change with time. Yet, observations of the organization and physics of the intergalactic medium, and by association its accompanying dark matter, are difficult owing to the extreme faintness of the emission fluxes and the limited sensitivity of current observatories at ultraviolet and X-ray wavelengths. To ameliorate this deficiency, we have defined a dedicated observatory located at L2 that is capable of simultaneously observing both the faint ultraviolet emissions from the cosmic web and the absorption produced along the intergalactic paths to distant QSO. This Baryonic Structure Probe consists of a 2m-class telescope outfitted with a high-resolution UV absorption-line spectrometer, co-aligned with two smaller (~0.5m) "outrigger" spectrographs optimized for high sensitivity UV emission-line imaging of the cosmic web. Such a mission is scientifically compelling, feasible with modest technology investments, and commensurate with a Probe-class cost envelope of $600-700M. We would be pleased to present this mission concept to the Decadal Committee.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Submitted on behalf of the Baryonic Structure Probe Concept Study Team
Current Status: NASA Origins Probe Concept study completed
Additional Information:

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139. The Combined Array for Research in Millimeter-wave Astronomy – CARMA

Point of Contact: Lee Mundy, University of Maryland
Summary Description: The Combined Array for Research in Millimeter-wave Astronomy (CARMA) is a university-based observatory developing technology and techniques, and enabling new science. The operating array of 23 antennas provides resolutions ranging from 6" to 0.15" at 230 GHz and supports science ranging from measurements of cosmological parameters to molecular gas content of galaxies over cosmic time to the structure and chemistry of nearby planet-forming circumstellar disks. In the next 5-10 years CARMA will be collaborating in the development of very broadband digital signal processing,flexible correlators, multi-frequency receivers, coherent detector focal plane arrays, and atmospheric phase corrections. Implementation of these technologies on CARMA will enable: (1) ultra-broad bandwidth (40-80 GHz)for deep chemical studies and

red-shift searches; (2) fast, wide-field mapping at resolutions from 5" to 0.5" for broad studies of star and galaxy formation, and (3) precision measurements of cosmological parameters through studies of the structure of cluster gas and cluster evolution. CARMA complements ALMA by providing a broad survey capability and a platform for technical development throughout the decade.

Anticipated Sponsor: NSF

Participating Individuals or Institutions: Lee Mundy (U. Maryland), Douglas Bock (CARMA), John Carpenter (Caltech), Carl Heiles (UC Berkeley),Richard Crutcher (U. Illinois), David Hawkins (Caltech), James Lamb (Caltech), Richard Plambeck (UC Berkeley), and David Woody (Caltech)

Current Status: Design and Development

Additional Information: http://www.mmarray.org/

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140. The Event Horizon Telescope

Point of Contact: Sheperd Doeleman, MIT

Summary Description: A long standing goal in astrophysics is to directly observe the immediate environment of a putative black hole with angular resolution comparable to the event horizon. Realizing this goal would open a new window on the study of General Relativity in the strong field regime, accretion and outflow processes at the edge of a black hole, the existence of an event horizon, and fundamental black hole physics. Steady long-term progress on improving the capability of Very Long Baseline Interferometry (VLBI) at short wavelengths has now made it extremely likely that this goal will be achieved within the next decade. The most compelling evidence for this is the recent observation by 1.3mm VLBI of Schwarzschild radius scale structure in SgrA*, the compact source of radio, submm, NIR and xrays at the center of the Milky Way. SgrA* is thought to mark the position of a ~4 million solar mass black hole, and because of its proximity and estimated mass presents the largest apparent event horizon size of any black hole candidate in the Universe. This new 1.3mm VLBI detection confirms that short wavelength VLBI of SgrA* can and will be used to directly probe the Event Horizon of this black hole candidate: in short, SgrA* is the right object, VLBI is the right technique, and this decade is the right time. Over the next decade, our group proposes to combine existing and planned mm/submm facilities into a high sensitivity, high angular resolution "Event Horizon Telescope" that will bring us as close to the edge of black hole as we will ever come. This effort will include development and deployment of submm dual polarization receivers, highly stable frequency standards to enable VLBI at 230-450GHz, higher bandwidth VLBI backends and recorders, as well as commissioning of new submm VLBI sites. We emphasize that while there is development and procurement involved, the path forward is clear and the recent successful observations have removed much of the risk that would normally be associated with such an ambitious project.

Anticipated Sponsor: NSF, With international contributions.

Participating Individuals or Institutions: MIT Haystack Observatory, Arizona Radio Observatory - University of Arizona, Smithsonian Astrophysical Observatory-Center for Astrophysics, UC Berkeley Radio Astronomy Laboratory, Joint Astronomy Centre - James Clerk Maxwell Telescope, Caltech Submillimeter Observatory, Combined Array for Research in Millimeter-wave Astronomy, Max Planck Institut fuer Radioastronomie, National Astronomical Observatory of Japan, Institut de Radio Astronomie Millimetrique, National Radio Astronomy Observatory, Academia Sinica Institute for Astronomy and Astrophysics

Current Status: 230GHz VLBI observations of SgrA* confirm Schwarzschild radius structure, and the necessary development and deployment is low risk, so our project is now in a design and costing analysis phase that should be complete before the end of the

year.
Additional Information: www.haystack.mit.edu/ast/uvlbi/mm/eht.html
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141. The Fourier-Kelvin Stellar Interferometer (FKSI): A Probe-class Infrared Space Mission for the Spectroscopic Characterization of Exoplanets, Exozodiacal Levels, Debris Disks, and High Angular Resolution Astrophysics

Point of Contact: William C. Danchi, NASA GSFC
Summary Description: The Fourier-Kelvin Stellar Interferometer (FKSI) mission is a two-telescope infrared space interferometer with 0.5 meter aperture telescopes on a 12.5 meter baseline on a boom, operating in the spectral range 3 to 8 (or 10) microns, and passively cooled to about 60 K. The main goals for the mission are the measurement and characterization of the exozodiacal emission around nearby stars, debris disks, spectroscopic characterization of the atmospheres of known exoplanets, and the search for and characterization of Super Earths around nearby stars. The FKSI mission has been reviewed in the context of the Exoplanet Community Forum 2008 and has been included in the notional timeline developed for the area of "Direct Infrared Imaging of Exoplanets," as a candidate for a mid-sized or Probe-class strategic mission (see the Exoplanet Community Forum Report Chapter 4: http://exep.jpl.nasa.gov/documents/Forum2008_268_small.pdf). Most of the technical risks have been retired through technology investments for JWST, SIM, and TPF-I/Darwin, and most technologies are at a Technical Readiness Level (TRL) sufficient for advancement to Phase A. This mission could receive a Phase A start in the next 2-5 years with only modest technology investments.
Anticipated Sponsor: NASA, Other
Also funding for European collaborations via CNES and ESA may be possible.
Participating Individuals or Institutions: W. C. Danchi (PI), C. A. Beichman, K. J. Johnston, A. Léger, T. Herbst, F. Malbet, O. Absil, R. Akeson, J. Bally, R.K. Barry, A. Belu, M. Boyce, J. Breckinridge, G. Bryden, A. Burrows, K. Carpenter, C. Chen, D. Cole, D. Crisp, R. Danner, L. D. Deming, P. Deroo, V. Coudé du Foresto, D. Defrère, D. Ebbets, P. Falkowski, M. Fridlund, R. Gappinger, I. Haugabook, L. Kaltenegger, J. Kasting, M. Kenworthy, M. Kuchner, A. Ksendzov, B. Lane, G. Laughlin, O. Lay, R. Liseau, B. Lopez, R. Millan-Gabet, S. Martin, D. Mawet, B. Mennesson, J. Monnier, M. Muterspaugh, M. C. Noecker, J. Nishikawa, M. Pesesen, R. Peters, R. Petrov, A. Quillen, S. Ragland, J. Rajagopal, A. Roberge, S. Rinehart, H. Rottgering, D. Scharf, F.-X. Schmider, E. Serabyn, M. Tehrani, W. Traub, S. Unwin, F. Vakhili, D. Wilner, J. Woillez, N. Woolf, and M. Zhao
Current Status: Pre-phase A.
Additional Information: http://exep.jpl.nasa.gov/exep_exfSOC-LOC.cfm, http://exep.jpl.nasa.gov/documents/Forum2008_268_small.pdf
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142. The Frequency Agile Solar Radiotelescope

Point of Contact: Tim Bastian, National Radio Astronomy Observatory
Summary Description: The Frequency Agile Solar Radiotelescope (FASR) is a solar-dedicated radio telescope that provides a unique combination of superior imaging capability and broad instantaneous frequency coverage to address a wide range of science goals. These include 1) the nature and evolution of coronal magnetic fields; 2) the physics of flares; 3) drivers of space weather; 4) physics of the quiet solar

atmosphere. FASR will enable wholly new observing techniques (the quantitative measurement of coronal magnetic fields) and will address a number of outstanding and fundamental physics problems: magnetic energy storage and release, particle accleration and transport, shock formation and propagation, nonradiative heating, and more. The major advance offered by FASR over previous generations of solar radio instrumentation is its unique ability to perform time-resolved imaging spectroscopy of the Sun using combination of ultra-wide frequency coverage (50 MHz to 21 GHz), high spectral resolution (as high as <0.1%), high time resolution (as high as 20 ms), and high image quality. Radiation from this wavelength range probes the solar atmosphere from the middle chromosphere through to the middle corona and above, an environment in which a wealth of fundamental astrophysical processes occurs. The value of such a facility to the solar, heliospheric, and astrophysical communities has been recognized previously by the 2001 AASC decadal survey as a moderate initiative and by the 2002 CSSP decadal survey as the top-ranked small initiative. The project, currently in its design and development phase, seeks reaffirmation of the project to help ensure eventual funding.
Anticipated Sponsor: NSF, Other
While it is anticipated that NSF will provide the bulk of the funds necessary for FASR construction and operations, the French may provide one subsystem and additional operations funds will be sought from other agencies in support of certain activities (e.g., space weather).
Participating Individuals or Institutions: National Radio Astronomy Observatory, AUI, University of California, Berkeley, Caltech, Owens Valley Radio Observatory, New Jersey Institute of Technology, University of Michigan, University of Maryland, Paris Observatory
Current Status: Design and development, proposal for pathfinder instrument in preparation for NSF/ATM
Additional Information: http://www.fasr.org
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143. The Giant Magellan Telescope Project

Point of Contact: Patrick J. McCarthy, Acting Director, GMT project
Summary Description: The GMT partners aim to construct and operate a 30m-class giant segmented mirror telescope to realize the top priority for ground-based astronomy in the 2000 decadal survey. The telescope will use state of the art adaptive optics and its great collecting area to address fundamental questions in the study of exoplanets, black hole growth, dark matter and dark energy, galaxy evolution, first light and reionization. The project expects to commence operations before the end of the next decade.
Anticipated Sponsor: NSF
Participating Individuals or Institutions: The Carnegie Institution of Washington, Harvard University, Smithsonian Institution, University of Texas at Austin, Texas A&M University, University of Arizona, Astronomy Australia Limited, The Australian National University, Korean Astronomy and Space Science Institute.
Current Status: Design and Development Phase
Additional Information: http://www.gmto.org
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144. The HORUS Origins Science Mission: To Study the Formation of Planetary Systems, Stars, and Galaxies

Point of Contact: Paul Scowen, ASU
Summary Description: The High-ORbit Ultraviolet-visible Satellite (HORUS) is a 2.4-meter class space telescope that will help to accomplish NASA's Vision for Space

Exploration (VSE). To do so, HORUS will provide 100 times greater imaging efficiency and more than 10 times greater UV spectroscopic sensitivity than has existed on the Hubble Space Telescope (HST). The HORUS mission will address the VSE goal of robotically exploring the solar system and beyond, contributing vital information on how solar systems form and whether habitable planets should be common or rare. It also will investigate the structure, evolution, and destiny of galaxies and universe. This program relies on focused capabilities unique to space and that no other planned NASA mission will provide: near-UV/visible (200-1100nm) wide-field, diffraction-limited imaging; and high-sensitivity, low- and high-resolution UV (100-320nm) spectroscopy. Our implementation offers ample opportunity for international participation in order to accomplish VSE goals and provides an appealing complementary capability to JWST for the forthcoming decade of astronomy.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Paul Scowen (Arizona State U.), Rolf Jason (Arizona State U.), Matthew Beasley (U. Colorado – Boulder), Patrick Hartigan (Rice U.), Steven Desch (Arizona State U.), Aki Roberge (NASA – GSFC), Alex Fullerton (STScI), Debbie Padgett (IPAC / Caltech), Mark McCaughrean (U. Exeter), Nathan Smith (UC Berkeley), Sally Oey (U. Michigan), Daniela Calzetti (U. Massachusetts), Jason Tumlinson (STScI), John Gallagher (U. Wisconsin – Madison), Robert O'Connell (U. Virginia), Rogier Windhorst (Arizona State U.), Sangeeta Malhotra (Arizona State U.), James Rhoads (Arizona State U.), Daniel Stern (JPL), Oswald Siegmund (UC Berkeley – SSL), Bob Woodruff (LMCO), Shouleh Nikzad (JPL), Jeff Hester (Arizona State U.), John Bally (U. Colorado – Boulder), Rob Kennicutt (U. Cambridge), Tod Lauer (NOAO), Jill Bechtold (U. Arizona), Chris Johns-Krull (Rice U.)
Current Status: Design & Development
Additional Information: http://horus.asu.edu

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145. The Large Array Synoptic Survey Telescope

Point of Contact: James N. Heasley, University of Hawaii
Summary Description: We propose a vision for wide-field optical/NIR survey observations in the decade 2010-2020 that builds organically on the Pan-STARRS development to meet the goals for synoptic survey science on an 8-m class telescope such as those proposed in the "Astronomy and Astrophysics in the New Millennium" (AANM) report and in the forthcoming Astro2010 report. The Pan-STARRS project has made substantial investments in the designs for the wide-field telescope, billion pixel CCD focal plane arrays, the image-processing pipeline software and hardware systems, and the software for data catalogs and image distribution. These are now all well-developed technologies, with low risk and well-defined costs. We propose the extension of the Pan-STARRS surveys to greater depth and improved time sampling through the development of a global network of systems with capability similar to the PS4 system. This network would make observations in a coordinated manner, and its data would be combined with those from PS4. This expanded data collection will provide the community with a significant resource to begin meeting the science goals of AANM and Astro2010 in this decade. We envision this network as a public-private entity. As such, data release policies would be timely but coordinated, allowing for some propriety period for federation members. The PS4 facility will be the first component of the expansible network and the hub for the global scheduling of observations and data processing/distribution. The federation will have a single director reporting to a board of directors of the member institutions and agencies.
Anticipated Sponsor: DOE, NASA, NSF, Other
The approach we advocate for synoptic surveying consists of a federated network of survey telescopes that will be operated by an international public-private partnership

based on the proven engineering and costs of the successful Pan-STARRS prototype system (PS1). A global network of such telescopes could be built to specification by an institution, agency, nation, or any collaboration thereof, either by contracting with the Pan-STARRS project or from Pan-STARRS blueprints as a franchise with each members own resources. The benefits of such a federation are that

* The costs of these systems are well established and the risks are low.
* The construction timescale is short, and the extensibility of such a network allows the exploitation of technological developments.
* The software infrastructure exists.
* As the data accumulate and size of the network increases, the attraction to new potential partners increases.

Participating Individuals or Institutions: The Pan-STARRS development team at the Institute for Astronomy: W. Burgett, K. Chambers, J. Heasley, N. Kaiser, E. Magnier, J. Morgan, P. Onaka, J. Tonry
Current Status: Design and Development
Additional Information: http://lasst.ifa.hawaii.edu/lasst
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146. The Large Millimeter Telescope

Point of Contact: F. Peter Schloerb, University of Massachusetts
Summary Description: The Large Millimeter Telescope (LMT) is a 50m diameter, millimeter-wave, single dish, telescope that is being built by a collaboration between the country of Mexico and the University of Massachusetts at Amherst. The lead Mexican institution in the collaboration is the Instituto Nacional de Astrofisica, Optica, y Electronica (INAOE). This telescope is being constructed at an excellent millimeter-wave site in Mexico and will operate primarily in the 1-4 mm wavelength range. With 2000 square meters of collecting area in the single dish, the telescope will be a significant complementary instrument to ALMA and, thereby, provide additional scientific opportunities that will enhance ALMA's productivity and enable exciting new scientific programs. We seek to gain funding to support the US portion of this binational project. Specifically, since the telescope is nearing completion, we seek: (1) funding to support the telescope commissioning; (2) funding to support equipment, software development, and commissioning work needed to bring the telescope from its initial operation at 3mm to final operation at 1mm wavelength; (3) funding to complete and field the full initial set of scientific instrumentation now planned; (4) funding to develop and field at least two "next generation" scientific instruments in the next decade; and (5) funding to support the US share of the telescope operations during the next decade to enable use by the US community. At this time, the US (through UMass-Amherst) participation in the telescope is at approximately the 1/3 level, subject to final negotiation with our Mexican partners. UMass seeks, though gaining additional US funding for the project, to increase this share.
Anticipated Sponsor: NSF
Participating Individuals or Institutions: University of Massachusetts at Amherst (USA), Instituto Nacional de Astrofisica, Optica, y Electronica (Mexico)
Current Status: Telescope is under construction. The current plan, which is being funded primarily by the Mexican government, calls for first light and initial scientific work with the inner 32m diameter of the antenna surface sometime in late 2009 or early 2010. The completion of the remaining antenna surface is expected to follow this milestone in about one year's time.
Additional Information: Project Web Site: www.lmtgtm.org
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147. The Modern Universe Space Telescope

Point of Contact: James C. Green, University of Colorado
Summary Description: The Modern Universe Space Telescope (MUST) was a NASA Vision Mission study for a large (10m) UV-Optical space telescope that was intended to advance the frontiers of astrophysics without incoporating terrestrial planet finding/imaging into its science case. Most of the current UV-optical mission concepts have planet finding as their primary science goal, and the technical requirements for this activity have the potential to limit the astrophysical capabilities of such a mission. MUST has been conceived to provide the maximum capability for observations relevant to cosmology, galactic evolution, stellar astrophysics and solar system science. The MUST concept has been updated to be compatible with the Costellation architecture. James Green was the Pricipal Investigator of the Vision Mission study.
Anticipated Sponsor: NASA
Participating Individuals or Institutions:
Current Status: Pre-phase A
Additional Information:
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148. The Near-Infrared Sky Surveyor (NIRSS)

Point of Contact: Daniel Stern, NASA JPL, Caltech
Summary Description: Operating beyond the reaches of the Earth's atmosphere, free of its limiting absorption and thermal background, the Near-Infrared Sky Surveyor (NIRSS) will deeply map the entire sky at near-infrared wavelengths, thereby enabling new and fundamental discoveries that will directly address the NASA scientific objective of studying cosmic origins. NIRSS will (i) fundamentally alter early universe studies by identifying large samples of quasars emitting in the first billion years after the Big Bang, (ii) probe the first generation of star formation by measuring the diffuse infrared background, (iii) test theories of structure and galaxy formation by measuring the spectral energy distributions of billions of galaxies over a wide redshift range, and (iv) find the coolest Galactic sources, thereby probing both the star-planet boundary and the origins and age of the Milky Way Galaxy. NIRSS, a medium-class mission, will use a 1.4-meter class telescope to reach full-sky micro-Jansky sensitivities in four passbands from 1 to 4 microns in a 2 year mission. At the three shorter passbands (1-2.5 microns), the proposed depth is comparable to the deepest pencil-beam surveys done to date and is ~500 times more sensitive than the only previous all-sky near-infrared survey, 2MASS. At the longest passband (~3.5 microns), which is not feasible from the ground, NIRSS will be ~100 times more sensitive than WISE. NIRSS fills a pivotal gap in our knowledge of the celestial sphere and is a natural complement to WISE, which will provide shallow, full-sky, mid-infrared (3-24 micron) images, and is well matched to the next generation of deep, wide-area (>2 ster), ground-based optical surveys (e.g., LSST and Pan-Starrs). With the high thermal backgrounds of ground-based infrared observations, a full-sky, microJy-depth, near-infrared survey is only feasible from space.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Mark Brodwin (Harvard/CfA), Asantha Cooray (UC-Irvine), Roc Cutri (IPAC/Caltech), Arjun Dey (NOAO), Peter Eisenhardt (JPL/Caltech), Anthony Gonzalez (Univ. Florida), Jason Kalirai (STScI), Amy Mainzer (JPL/Caltech), Leonidas Moustakas (JPL/Caltech), Jason Rhodes (JPL/Caltech), S. Adam Stanford (UC-Davis/LLNL), & Edward L. Wright (UCLA)
Current Status: Pre-phase A
Additional Information: https://zwolfkinder.jpl.nasa.gov/~stern/NIRSS_09jan.pdf
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149. The New Worlds Observer

Point of Contact: Webster Cash, University of Colorado
Summary Description: Direct imaging and spectroscopy of Earth-like planets is among the highest priority goals in all of the sciences. Discovery of habitable water planets and strong biosignatures would literally change the way we, as a people, view the night sky. Perhaps the most effective approach to finding and studying habitable planets is embodied in the New Worlds Observer mission concept. NWO is completing an ASMCS study, funded at the full level indicating it is considered a viable flagship mission for the coming decade. The concept as studied features a 50m diameter starshade (external occulter) and an HST quality 4m observatory. The study shows that all needed technologies exist, but that a short development/demonstration program is advisable. NWO will be able to find planets with greater efficiency than any other proposed approach, so it does not need a precursor mission to produce a target list. NWO will provide detailed maps (images) of entire planetary systems from the habitable zone outward. It will perform immediate, follow-up spectroscopy of all the interesting exoplanets discovered with the sensitivity needed to seriously begin the search for life. Whole planetary systems can be efficiently surveyed by this method. Seventy percent of the time the starshade will be in transit to the next target, leaving a 4m telescope free for other astrophysics. This large space telescope would be capable of a broad range of science from high resolution ultraviolet spectroscopy of nearby stellar coronae to wide field, deep surveys in pursuit of dark energy.
Anticipated Sponsor: NASA, Other
Likely ESA interest
Participating Individuals or Institutions: W. Cash (U. Colorado), R. Polidan (NGST), the New Worlds Team. Other institutions include GSFC, USNO, GRC, and Ball
Current Status: Pre-Phase A. ASMCS Study Completed
Additional Information: http://newworlds.colorado.edu/ ASMCS study reports from NWO to be available shortly

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150. The North America Array: a continent-wide radio telescope for the 2020s and beyond

Point of Contact: Jim Ulvestad, Assistant Director, National Radio Astronomy Observatory (Head of New Initiatives Office)
Summary Description: Three of the primary scientific frontiers in centimeter wavelength radio astronomy are

1. Elucidation of the structure of the galaxy and the universe through precision astrometry.
2. Imaging the gas in thermal radio sources in the universe at resolutions of a few milliarcseconds.
3. Imaging distant galaxies to explore the evolutionary relationship between active and "non-active" galaxies.

The first goal requires a substantial increase in sensitivity on continent-scale interferometric baselines, the second requires a significant increase in collecting area from within the Expanded Very Large Array (EVLA, maximum baseline of 35 km) out to several hundred kilometers, while the third requires a combination of those two developments. Thus, these key science areas lead naturally to the desire for a continent-wide radio telescope which we call the North America Array. The expansion of the EVLA to larger spatial scales (and hence higher resolution) was recommended by the 2000 decadal survey as part of the EVLA program, while the total increase in collecting area provides access to numerous of the science goals that have been presented in the context of the international Square Kilometer Array (SKA) Program. In the next decade, our activity is focused on the development and prototyping of the North America Array, as well as delivering key astrometric science; primary activities are:

1. Improve the sensitivity of the Very Long Baseline Array by more than a factor of 10 over its original design by increasing the bandwidth to at least 4 GHz per polarization, comparable to EVLA.
2. Prototype the new observing stations of the North America Array, based on the antenna systems developed as part of the Technology Development Project of the US SKA Consortium.
3. Connect the Pie Town VLBA antenna, and possibly 1-2 other VLBA antennas to the EVLA in order to deliver science and prototype the delivery of ultra-wide bandwidth data over commercial networks.

These steps will provide noteworthy science results in the coming decade, as well as preparing us for a substantial increase in science capability in the frequency range of 5-50 GHz in the post-2020 decade.

Anticipated Sponsor: NSF, Other

The international SKA Program plan envisions a high-frequency SKA (frequencies of a few GHz to 25 GHz or higher) in the decade beginning in 2020, with international funding. The North America Array is a possible realization of SKA-high, and hence might attract substantial international funding.

Participating Individuals or Institutions: Activity led by NRAO. NRAO has many partners in technology development, sensitivity enhancement, and science programs that are on the road to the North America Array, although there are no explicit partnering agreements for the North America Array. The most relevant partners are: CASPER lab of UC Berkeley; South African SKA Project; MIT Haystack Observatory; Max Planck Institut fuer Radioastronomie; CONACyT (Mexico); University of New Mexico; Harvard-Smithsonian Center for Astrophysics; US SKA Consortium (via their NSF-funded Technology Development Project); European-led PrepSKA consortium for SKA Design and Development

Current Status: Some aspects in technology development, some in prototyping. Expansion of VLBA to 500 MHz bandwidth under way, to be completed by 2011. EVLA Phase 1 to be completed in 2012.

Additional Information: http://www.nrao.edu/nio/naa/

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151. The Observatory for Multi-Epoch Gravitational Lens Astrophysics (OMEGA)

Point of Contact: Leonidas A Moustakas, NASA JPL, Caltech

Summary Description: Dark matter in a universe dominated by a cosmological constant seeds the formation of structure and is the scaffolding for galaxy formation. The nature of dark matter remains one of the fundamental unsolved problems in astrophysics and physics even though it represents 85% of the mass in the universe, and nearly one quarter of its total mass-energy budget. The mass function of dark matter “substructure” on sub-galactic scales may be enormously sensitive to the mass and properties of the dark matter particle. On astrophysical scales, especially at cosmological distances, dark matter substructure may only be detected through its gravitational influence on light from distant varying sources. Specifically, these are largely active galactic nuclei (AGN), which are accreting super-massive black holes in the centers of galaxies, some of the most extreme objects ever found. With enough measurements of the flux from AGN at different wavelengths, and their variability over time, the detailed structure around AGN, and even the mass of the super-massive black hole can be measured. The Observatory for Multi-Epoch Gravitational Lens Astrophysics (OMEGA) is a mission concept for a 1.5-m near-

UV through near-IR space observatory that will be dedicated to frequent imaging and spectroscopic monitoring of ~100 multiply-imaged active galactic nuclei over the whole sky. Using wavelength-tailored dichroics with extremely high transmittance, efficient imaging in six channels will be done simultaneously during each visit to each target. The separate spectroscopic mode, engaged through a flip-in mirror, uses an image slicer spectrograph. After a period of many visits to all targets, the resulting multidimensional movies can then be analyzed to a) measure the mass function of dark matter substructure; b) measure precise masses of the accreting black holes as well as the structure of their accretion disks and their environments over several decades of physical scale; and c) measure a combination of Hubble's local expansion constant and cosmological distances to unprecedented precision. We present the novel OMEGA instrumentation suite, and how its integrated design is ideal for opening the time domain of known cosmologically-distant variable sources, to achieve the stated scientific goals.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: The current list of participants follows. There are several others that will be included by the time of the white paper submission, whose participation role is being negotiated currently. I am happy to provide more details as necessary. Leonidas Moustakas (JPL/Caltech), Adam Bolton (IfA, Hawaii), Jeffrey Booth (JPL/Caltech), James Bullock (UC Irvine), Edward Cheng (Conceptual Analytics), Dan Coe (JPL/Caltech), Christopher Fassnacht (UC Davis), Varoujan Gorjian (JPL/Caltech), Charles Keeton (Rutgers), Christopher Kochanek (Ohio State University), Charles Lawrence (JPL/Caltech), Philip Marshall (UC Santa Barbara), Benton Metcalf (MPIA, Germany), Priyamvada Natarajan (Yale), Shouleh Nikzad (JPL/Caltech), Bradley Peterson (Ohio State University), Joachim Wambsganss (Heidelberg, Germany)
Current Status: Pre-phase A
Additional Information: SPIE-published white paper: http://arxiv.org/abs/0806.1884, Webpage: http://www.its.caltech.edu/~leonidas/OMEGA

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152. The ORION Widefield UV/Optical Imager

Point of Contact: Paul Scowen, ASU
Summary Description: Orion is a 1.1-meter class space telescope that will conduct the first-ever high spatial resolution survey of a statistically significant sample of massive star-forming environments in the Solar neighborhood to answer the question "how frequently do solar systems form and survive" in such environments. Within the Mid-Sized Explorer (MIDEX) cost envelope of $240M (FY07), Orion will provide 100 times greater imaging efficiency than currently exists on HST. The Orion mission has a well-defined scientific program at its heart: a statistically significant survey of local, and intermediate sites and indicators of star for-mation to investigate and understand the range of envi-ronments, feedback mechanisms, and other factors that most affect the outcome of the star and planet formation process. This program relies on focused capabilities unique to space and that no other planned NASA mis-sion will provide: near-UV/visible (200-1100nm) wide-field, diffraction-limited imaging. The Orion imager has a field of view (FOV) of ~200 square-arcminutes, uses a di-chroic to create optimized UV/blue and red/near-IR channels for simultaneous observing in 2 bandpasses, and employs modern detectors with substantial quan-tum efficiency gains, especially at red wavelengths, over the CCDs used in HST's cameras. We estimate discovery efficiency gains of factors of 100 for imaging with Orion relative to HST based on our design and assuming an Earth-Sun L2 orbit that provides long tar-get visibility. To deliver the performance cited for this mission, a new class of CCD detector is being developed with our partners at JPL to deliver DQE levels down to the blue edge of Silicon that will match the DQE performance in the red, allowing us to build the Observatory with a dichroic splitter to simultaneously observe in the red and blue without taking a hit in observing efficiency or the quality of the

images produced.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Paul Scowen (Arizona State U.), Rolf Jansen (Arizona State U.), Matthew Beasley (U. Colorado – Boulder), Steven Desch (Arizona State U.), Debbie Padgett (IPAC / Caltech), Mark McCaughrean (U. Exeter), Nathan Smith (UC Berkeley), Sally Oey (U. Michigan), Daniela Calzetti (U. Massachusetts), John Gallagher (U. Wisconsin – Madison), Robert O'Connell (U. Virginia), Rogier Windhorst (Arizona State U.)
Current Status: Design & Development
Additional Information: http://orion.asu.edu
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153. The Square Kilometer Array

Point of Contact: James M. Cordes, Cornell University
Summary Description: The activity next decade includes development, design and construction of the SKA. The SKA will provide radio-astronomy capabilities necessary for understanding key topics in fundamental physics, cosmology, and astrobiology. These include:
(1) Understanding galaxy assembly and evolution using the 21-cm atomic hydrogen line and non-thermal synchrotron radiation as dynamical and star-formation tracers;
(2) Testing theories of gravity using binary pulsars (including those orbiting Sgr A*), probing the equation of state through precise determination of neutron-star masses, and detecting nano-Hertz gravitational waves from inspiraling supermassive black-holes (and other sources) using precision timing of pulsars;
(3) Probing cosmology and dark energy using large-volume surveys of the hyperfine 21-cm hydrogen line;
(4) Determining the evolution of cosmic magnetic fields from comprehensive Faraday-rotation and Zeeman-splitting surveys;
(5) Surveying the origins and manifestations of life by inventorying molecules and conducting searches for extraterrestrial intelligence (SETI); and
(6) Sampling the transient radio sky comprehensively as part of a multiwavelength campaign for discovery, for understanding the demography and physics of transient sources, and exploiting them to study intervening media.
Science goals will be accomplished through a combination of large-scale surveys and detailed follow-up observations using the same instrument.
For this NoI, the primary focus for activity next decade is construction of the mid-frequency-range instrument (approximately 0.3 to 10 GHz), preceded by science pathfinding, design and development, and engineering design. Efforts in the U.S. are coordinated with the international SKA Program Development Office (Manchester, UK) through the US SKA Consortium and through individuals' participation in international committees, working groups, and task forces. A site either in Western Australia or the Karoo desert, South Africa will be selected early in the decade. Construction will follow on a time scale determined by technology development now taking place and also by the availability of funding from international partners. Related activities next decade follow from, firstly, the likely co-siting of a low-frequency-band SKA for studying the Epoch of Reionization (and preceding eras) using the highly redshifted 21-cm atomic hydrogen line and, secondly, technology development of antennas and receivers extendable for use in a high-frequency SKA that targets high-resolution and thermal science, including active galactic nuclei at high redshifts, precision determination of the Hubble constant, and synoptic mapping of planetary disks. These activities are described in separate Notices of Interest from other, related groups and reflect the programmatic aspect of the SKA.
The first phase of the mid-frequency SKA will exploit the ability to do science as the array is built. A key milestone during the buildout is an array with sensitivity ten times greater

than any current instrumentation in the southern hemisphere accompanied by more than one hundred times the survey speed. While providing the platform for developing operations and data management, this first phase of the SKA will also deliver results in key science areas, particularly in gravity science, galaxy evolution, cosmic magnetism, and the transient radio sky. The eventual sensitivity of the full instrument is aimed to be about ten times that of Arecibo and 50 times that of the VLA.

Anticipated Sponsor: NSF, Other

Funding agencies in Australia, Canada, Europe, South Africa and other countries

Participating Individuals or Institutions: US SKA Consortium: Chair: James M. Cordes (Cornell), Vice-Chair: Patricia Henning (U. New Mexico), Secretary: Dayton Jones (JPL), Treasurer: Jill C. Tarter (SETI Institute); Member Institutions: California Institute of Technology, Cornell University, Harvard-Smithsonian Center for Astrophysics, Haystack Observatory (with MIT), Jet Propulsion Laboratory (with CIT), Massachusetts Institute of Technology, National Astronomy and Ionosphere Center (with Cornell), National Radio Astronomy Observatory, Naval Research Lab, SETI Institute, University of California, Berkeley, University of Illinois, University of New Mexico, University of Wisconsin; SKA Program Development Office (SPDO, Univ. of Manchester, UK): Director: Richard Schilizzi, Project Engineer: Peter Dewdney, Project Scientist: Joseph Lazio (Naval Research Laboratory, USA); SKA Science and Engineering Committee (SSEC): There are 24 members of the SSEC, one third from the U.S. and who are members of the US SKA Consortium (G. Bower, UCB; J. Cordes, Cornell; T. Henning, UNM; D. Jones, JPL; K. Kellermann, NRAO; R. Preston, JPL; Y. Terzian, Cornell; and J. Ulvestad, NRAO). Other members of the SSEC are from Australia, Canada, China, Europe, India and South Africa.; SSEC Executive Members: Chair: K. Kellermann (NRAO, USA), Vice Chair: M. Garrett (ASTRON, Netherlands), Past-Chair: B. Boyle (ATNF-CSIRO, Australia), Secretary: C. Greenwood (SPDO), Member: J. Jonas (Rhodes U., South Africa), SPDO Director: R. Schilizzi (SPDO), Chair, European SKA Consortium: T. van der Hulst (U. Groningen, Netherlands); Preparatory SKA Project (Funded by the European Commission and European national agencies):

Coordinator: P. Diamond (U. Manchester)

Current Status: The SKA's current phase as an international project is design and development leading to a costed system design by 2012. Activities are coordinated by the SKA Program Development Office (Manchester, UK), funded in the U.S. by the NSF under the SKA Technology Development Project (TDP) to the U.S. SKA Consortium, in Europe by the EC and national agencies under the Preparatory SKA Project (PrepSKA), and by agencies in Australia, Canada and South Africa. D&D under this funding continues to 2012, after which an engineering-design phase will lead to the inititation of construction of the first phase toward the middle of the next decade.

This broad plan has received high rankings in both Australia and Europe in their prioritization of astronomy projects over 10-20 year periods (Australia: "New Horizons: A Decadal Plan for Australian Astronomy 2006-2015"; Europe: "Astronet: Towards a Strategic Plan for European Astronomy". South Africa ranks the SKA to be a key part of its strategic plan for astronomy and education in science and engineering. See URLs below.

Additional Information: US SKA Consortium web site: http://usskac.astro.cornell.edu or http://www.astro.cornell.edu/ska/, International SKA web site: http://www.skatelescope.org, Australian Astronomy Decadal Plan 2006-2015: http://www.aao.gov.au/nca/decadalplan.html, European Astronet Stragetic Plan: http://www.astronet-eu.org/,South African SKA Web Site: http://www.ska.ac.za/

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154. The Star Formation Camera: a wide-field, high-resolution camera to map star formation near and far

Point of Contact: Paul Scowen, ASU
Summary Description: The Star Formation Camera (SFC) is a concept for a wide-field (~15'x19', >~280 arcmin^2), high-resolution (18x18 mas pixels) UV/optical dichroic camera for a 4-m class space-based telescope. SFC will deliver diffraction-limited images at lambda > 300 nm in both a Blue (190--517nm) and a Red (517--1075nm) Channel simultaneously. SFC is designed to efficiently conduct a comprehensive and systematic study of the astrophysical processes and environments relevant for the births and life cycles of stars and their planetary systems, and to investigate and understand the range of environments, feedback mechanisms, and other factors that most affect the outcome of the star and planet formation process. We present the design and performance specifications resulting from an implementation study of the camera. The result is a lightweight, low-cost instrument that will provide deep, high-resolution imaging across a wide field enabling a wide variety of community science as well as the core science that drives the design of the camera. The technology associated with the camera is next generation but still relatively high TRL (above 4-5), allowing a low-risk solution with moderate technology development investment over the next 10 years. New technology development is needed for the production, assembly, characterization, and flight-verification of large focal plane arrays.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Paul Scowen (Arizona State U.), Rolf Jansen (Arizona State U.), Matthew Beasley (U. Colorado – Boulder), Steven Desch (Arizona State U.), Aki Roberge (NASA – GSFC), Alex Fullerton (STScI), Debbie Padgett (IPAC / Caltech), Mark McCaughrean (U. Exeter), Nathan Smith (UC Berkeley), Sally Oey (U. Michigan), Daniela Calzetti (U. Massachusetts), Jason Tumlinson (STScI), John Gallagher (U. Wisconsin – Madison), Robert O'Connell (U. Virginia), Rogier Windhorst (Arizona State U.), Sangeeta Malhotra (Arizona State U.), James Rhoads (Arizona State U.), Daniel Stern (JPL), Oswald Siegmund (UC Berkeley – SSL), Bob Woodruff (LMCO), Shouleh Nikzad (JPL), Doug Lisman (JPL), Stuart Shaklan (JPL), Steve Macenka (JPL)
Current Status: In Design & Development under NASA Astrophysics Mission Concept Studies
Additional Information: http://sfc.asu.edu

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155. The Star Formation Observatory

Point of Contact: Paul Scowen (ASU)
Summary Description: We propose the 1.65m Star Formation Observatory, a space telescope that will address pivotal components in the 2007 NASA Science Plan, with a primary focus on Cosmic Origins. The design under consideration will provide 100 times greater imaging efficiency and >10 times greater spectroscopic efficiency below 115 nm than existed on previous missions. We will present the requirements, technical implementation, management, cost, and technology roadmap of this mission for conducting critical observations of the formation of planets, stars, and galaxies. The mission has a well-defined Origins scientific program at its heart: a statistically significant survey of local, intermediate, and high-redshift sites and indicators of star formation, to investigate and understand the range of environments, feedback mechanisms, and other factors that most affect the outcome of the star and planet formation process and the path from the Big Bang to people. This program relies on focused capabilities unique to space and that no other planned NASA mission will provide: near-UV/visible (200–1100 nm) wide-field, diffraction-limited imaging; and high-efficiency, low- and high resolution (R

40,000) UV (100–320 nm) spectroscopy using far-UV optimized LiF/Al coatings and recent advances in Micro-Channel Plate (MCP) detector technology. The Observatory imager has a field of view in excess of 17x17; (>250 arcmin^2) and will use a dichroic to create optimized UV/blue and red/near-IR channels for simultaneous observations in 2 bandpasses. It employs detectors that offer substantial quantum efficiency gains and that suffer lower losses due to cosmic rays. Both multi-band imaging and UV spectroscopy contribute essential information that will revolutionize our understanding of the star formation process.

Anticipated Sponsor: NASA

Participating Individuals or Institutions: Paul Scowen (Arizona State U.), Rolf Jansen (Arizona State U.), Matthew Beasley (U. Colorado – Boulder), Steven Desch (Arizona State U.), Aki Roberge (NASA – GSFC), Alex Fullerton (STScI), Debbie Padgett (IPAC / Caltech), Mark McCaughrean (U. Exeter), Nathan Smith (UC Berkeley), Sally Oey (U. Michigan), Daniela Calzetti (U. Massachusetts), Jason Tumlinson (STScI), John Gallagher (U. Wisconsin – Madison), Robert O'Connell (U. Virginia), Rogier Windhorst (Arizona State U.), Sangeeta Malhotra (Arizona State U.), James Rhoads (Arizona State U.), Daniel Stern (JPL), Oswald Siegmund (UC Berkeley – SSL), Bob Woodruff (LMCO), Shouleh Nikzad (JPL)

Current Status: Design & Development

Additional Information: http://sfo.asu.edu

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156. The Synoptic All-Sky Infrared (SASIR) Survey

Point of Contact: Joshua Bloom, UC Berkeley

Summary Description: We are proposing to conduct a wide-field (~1 square degree), multicolor (1 - 2.2 micron) synoptic infrared imaging survey with a new dedicated 6.5 meter telescope to be built at San Pedro Martir Observatory, Mexico. This initiative is being developed in partnership with astronomy institutions in Mexico and the University of California. The 4-year SASIR Survey will reach more than 100 times deeper than 2MASS, increasing the effective detection volume by more than one million and revealing the entire missing sample of faint red dwarf stars in the local solar neighborhood to at least 25 parsec. The unprecedented depths will yield discovery of hundreds of quasars beyond redshift of 7, allowing detailed study of the timing and the origin(s) of reionization in the early universe. The synoptic study will provide observations of over one million supernovae and variable stars, providing better distance measures than comparable optical observations to date and reveal the dynamic infrared universe as never seen before. The wide field will enable a connection of the gravitational wave and neutrino universe -- with events otherwise poorly localized to ~1 deg on the sky -- to transient electromagnetic phenomena.

Anticipated Sponsor: NSF

1. Consejo Nacional de Ciencia y Tecnologia (CONACyT) in Mexico
2. private foundation support

We expect the US National support to be less than 50% of the total design and construction of the survey and likely less than 50% of the operations budget.

Participating Individuals or Institutions: US: The University of California, Andrew Szentgyorgyi (Harvard/CfA), MEXICO: Instituto de Astronomia at Universidad Nacional Autonoma de Mexico (IAUNAM), Instituto Nacional de Astrofisica, Optica y Electronica (INAOE)

Current Status: Pre-phase A. No significant funding has been secured for this project to date. Funds for the detailed design of the survey have been solicited (in late 2008) from the NSF and CONACyT. Partial funding for a pathfinder survey ("RATIR"; first light Jan 2010) on the 1.5m at San Pedro Martir has been secured.

Additional Information: * The public portal for SASIR is at: http://www.sasir.org

* A public link to science and technical talks generated during a 1 week workshop among SASIR participants is at: http://www.inaoep.mx/~progharo/gh2008/

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157. THESIS

Point of Contact: Mark R. Swain, NASA JPL

Summary Description: THESIS, the Transiting Habitable-zone Exoplanet Spectroscopy Infrared Spacecraft, is a concept for a MIDEX/Discovery class exoplanet mission. Building on the recent Spitzer and Hubble successes in exoplanet characterization via molecular spectroscopy, THESIS would extend these types of measurements to a large population of planets including non-transiting planets and super-Earths. The ability to acquire high-stability, contemporaneous, spectroscopic data from the near-visible to the mid-infrared are important and unique aspects of the THESIS mission concept. Broad spectral coverage (near-infrared to mid-infrared) is especially important for exoplanet emission spectra, sometimes called emergent spectra, to resolve the ambiguity between temperature and composition. Contemporaneous spectral coverage is important because detectable variability in exoplanet atmospheres makes it difficult to assemble a meaningful spectrum from non-contemporaneous data. Because the signal-to-noise of "combined light" measurements scales as the ratio of telescope diameter, there is an enormous discovery space for a ~1 m class, purpose-built, exoplanet spectroscopy mission (including spectroscopy of non-transiting planets). A strength of the THESIS concept is simplicity low technical risk, and modest cost. By enabling molecular spectroscopy of exoplanet atmospheres, THESIS mission has the potential to dramatically advance our understanding of conditions on extrasolar worlds while serving as a scientific stepping stone to more ambitious future missions.

Anticipated Sponsor: NASA, Other

The possibility of foreign contributions is being explored.

Participating Individuals or Institutions: Mark Swain (NASA JPL), Drake Deming (NASA GSFC), Carl Grillmair (Caltech SSC), Thomas Henning (Max-Planck Institute for Astronomy)

Current Status: pre-phase A

Additional Information:

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158. Thirty Meter Telescope

Point of Contact: Edward C. Stone, Caltech

Summary Description: Design, construct and operate a ground-based optical-infrared telescope with a 30 meter diameter aperture to observe in seeing-limited mode and in diffraction-limited mode employing integral adaptive optics systems. The telescope will employ large Nasmyth platforms to flexibly accommodate a broad array of instruments.

Anticipated Sponsor: NSF, Other

In addition to NSF, sponsors will include the California Institute of Technology, the University of California, the Gordon and Betty Moore Foundation, the Association of Canadian Universities for Research in Astronomy (ACURA) and their funding sponsors, the National Astronomical Observatory of Japan (NAOJ) and their sponsors, and other private and international sponsors.

Participating Individuals or Institutions: Association of Canadian Universities for Research in Astronomy (ACURA), University of California, California Institute of Technology, National Astronomical Observatory of Japan (NAOJ) and other participants engaged in discussions with TMT. With NSF support, participation of the NSF-funded US astronomy community will be significant.

Current Status: Design and Development will conclude in March 2009. Early Construction phase activities will commence April 2009. On-site construction is planned by October 2011.
Additional Information: http://www.tmt.org TMT website, http://www.tmt.org/foundation-docs/index.html TMT Foundation science and design documents
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159. Tinsley Space Telescope (new mission concept)

Point of Contact: Sara R. Heap, NASA's Goddard Space Flight Center
Summary Description: The Tinsley Space Telescope (TST) is a mission concept employing a 4-m, diffraction-limited telescope to study the evolution of galaxies, although its capabilities will be useful for other studies such as dark energy. At 1 micron, the wide-field imager will have a resolution of ~0.4 kpc over the redshift range, z=0.8-2.5, so the structure and color distribution of an L* galaxy (Re~2-4 kpc) can be mapped in detail. TST's spectrograph consists of TBD multi-object spectrographs each having a digital micro-mirror device (DMD) to isolate galaxies for spectroscopy, and each DMD consisting of a 2Kx1K array of micromirrors. The spectrograph concept is similar but more compact than the spectrograph being developed for ESA's EUCLID mission. When provided with an external occulter, TST becomes a powerful mission to find and characterize Earth-like planets orbiting nearby stars, similar to NASA's ASMCS study concepts, New Worlds Observer or THEIA. TST also has two integral-field spectrographs (with CCD detectors) that can be used to obtain spectra of galaxies or planetary systems. It is expected that TST would devote 85% of its observing time to extragalactic research and 15% to exoplanet research.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: The science and engineering teams are being formed. Although the core group is mainly at Goddard (lead center) and the STScI, the full team will include scientists at other NASA centers, universities, and industry. There will be foreign participation.
Current Status: study
Additional Information: http://sites.google.com/site/TinsleySpaceTelescope (under construction)
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160. U.S. Participation in Gemini

Point of Contact: William S. Smith Jr., AURA
Summary Description: The US is now a nominal 50 percent partner in the Gemini program. The present International Agreement is set to expire in 2012. In 2009, the Agreement has set an "Assessment Point" to begin the discussions towards a renegotiated agreement, decide whether to close the facilies, or extend the present agreement until 2015.
It has been suggested that the US seek a greater partnership share in Gemini as a part of any renegotiated agreement. This would have budgetary implications.
Anticipated Sponsor: NSF
Participating Individuals or Institutions:
Current Status:
Additional Information:
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161. US Participation to the ESA Euclid Near-Infrared Spectrograph (former SPACE project)

Point of Contact: Massimo Robberto, Space Telescope Science Institute
Summary Description: Dr. Robberto, STScI scientist, has envisioned a novel space mission able to obtain the first 3-d map of the Universe and study Dark Energy through BAO taking ~500 million spectra in the near-IR, in slit mode at R~400. The mission, conceived as a joint ESA/NASA mission, has been proposed to ESA under the name SPACE (SPectroscopic All Sky Cosmic Explorer) with A. Cimatti (Bologna) and M. Robberto as co-PIs. SPACE has won the selection for the Cosmic Vision 2015-2025 planning cycle and is now incorporated into the EUCLID study (EUCLID Near-Infrared Spectrograph, E-NIS). SPACE/ENIS is expected to outperform any other planned project or mission for BAO studies. A team of 23 US scientist supported the preparation of the original SPACE proposal.
Anticipated Sponsor: NASA, Other
ESA and the Space Agencies of ESA Member States are funding study/design activities.
Participating Individuals or Institutions: The US team of co-investigator of the orignal SPACE proposal is made by: M. Robberto (co-PI), Y. Wang (U. Oklahoma), X. Fan (U. Arizona), P. Madau (UCSC), M. Stiavelli , I. N. Reid, M. Postman, R. White, S. Casertano, J. MacKenty (STScI), J. Gardner, M. Clampin, R. Kimble (GSFC), A. Szalay, R. Wyse (JHU), A. Shapley (Princeton), N. Wright (UCLA), M. Strauss (Princeton), M. Urry (Yale), A. Burgasser (MIT), J. Rayner (Hawaii), B. Mobasher (UC Riverside), M. Di Capua (UMD), L. Hillenbrand (Caltech), M. Meyer (Steward), S. Beckwith (UC). The European SPACE/E-NIS team includes about 100 scientists from Austria, France, Germany, Italy, the Netherlands, Romania, Spain, Switzerland, United Kingdom, and ESO. The collaboration is led by A. Cimatti (Univ. Bologna)
Current Status: The ESA internal assessment phase, or phase 0, for Euclid and other candidate mission began in November 2007. Up to end of May 2008, a basic feasibility study was carried-out by ESA leading to a very preliminary design for the Euclid mission and its payload.
In May 2008 the Invitation to Tender was issued to Industry. The preliminary design is used by industry for a more thorough assessment lasting about a year. The report of this assessment study will be presented to the scientific community in late 2009. A parallel competitive contract was awarded to EADS Astrium (Germany) and Thales Alenia Space (Italy).
Additional Information: With a letter dated Jun-8-2007, NASA (A. Stern) acknowledged that the science objectives of SPACE are aligned with Science Plan for NASA's Science Mission Directorate 2007-1016. NASA is not currently funding the US participation to E-NIS study phase. It is expected ESA and NASA to enter soon into discussions about common development and support of a joint Dark Energy Mission.
ESA EUCLID web site: http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=42266
Paper on Space mission proposal http://arxiv.org/abs/0804.4433

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162. VERITAS Upgrade

Point of Contact: Rene Ong, UCLA
Summary Description: The VERITAS array, consisting of four 12m diameter atmospheric Cherenkov telescopes, has been observing the Northern sky at TeV gamma-ray energies for two years with high sensitivity (< 1% Crab Nebula flux in ~40 hours) and with excellent energy and angular resolution. Exciting new results on a variety of TeV gamma-ray sources, both galactic and extra-galactic, have already been obtained. Technical developments and Monte Carlo simulation results now suggest that substantial

further improvements to the array performnce are possible and that a moderate-scope upgrade is timely and very worthwhile.
Anticipated Sponsor: DOE, NSF, SAO
Participating Individuals or Institutions: Please see http://veritas.sao.arizona.edu/ for a list of the participating institutions from the U.S., Canada, the U.K. and Ireland.
Current Status: We are in the Design and Development phase at this point. There is technical work associated with higher-performance cameras and electronics taking place, along with detailed simulation studies.
Additional Information: A web page describing the upgrade will be set up and linked the main VERITAS page at http://veritas.sao.arizona.edu/.
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163. W. M. Keck Observatory

Point of Contact: Taft Armandroff, W.M. Keck Observatory
Summary Description: The W. M. Keck Observatory (WMKO) operates two 10-meter telescopes on an excellent site with a highly capable suite of advanced instrumentation for both optical and near-infrared wavelengths. WMKO has developed and operates an advanced laser-guide-star adaptive optics system and related instrumentation. The Observatory also operates the only large-aperture OIR interferometer in the U.S. In order to assure WMKO's continued high scientific productivity over the coming decade, a number of initiatives are planned. These were developed as part of a community-based strategic planning process and include: a) a next-generation adaptive optics system (NGAO); b) a new highly efficient optical integral-field spectrograph(Keck Cosmic Web Imager, KCWI); c) an initiative to enhance our multi-object optical spectroscopy capability; d) optical and infrared detector upgrades; e) enhancements to our precision radial velocity capability for exoplanet studies; f) continued operation of the Keck Inteferometer, with its scientific scope broadened by incorporating laser-guide-star adaptive optics, resulting in unprecedented astrometric capability (ASTRA). WMKO plans to continue to play a leading role in the U.S. ground-based optical/infrared system.
Anticipated Sponsor: NASA, NSF, Other
Other is checked to reference Keck's support from non-federal sources, e.g., private philanthropy, that provides leverage to federal investment. NASA is a 1/6 partner in WMKO, and NSF participates via TSIP, ATI and MRI.
Participating Individuals or Institutions: The partners in the operation of Keck Observatory are Caltech, the University of California and NASA. The University of Hawaii participates in Keck observing by providing access to Mauna Kea. Yale University and the Swinburne Institute of Technology participate in observing via a partnership with Caltech. The broad U.S. community gains peer-reviewed access to the Keck telescopes via NASA and the NSF/NOAO Telescope System Instrumentation Program (TSIP).
Current Status: The Observatory is in routine operation. The initiatives referred to above are largely in Pre-phase A or design.
Additional Information: http://www.keckobservatory.org/
A link for Astro 2010 materials will be added.
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164. Warm Spitzer Operations - Years 3-5

Point of Contact: B.T. Soifer, Caltech
Summary Description: After its cryogen is depleted Spitzer will still have unsurpassed imaging capability at 3.6 and 4.5um, achieving 100 nJy sensitivity, and 100 micro-magnitude precision photometry. At these wavelengths "Warm Spitzer" will be 3 orders of magnitude faster than any ground-based facility, and will not be surpassed until the

launch of JWST. NASA has approved two years (13,000 - 14,000 hrs of science observations) of post-cryogen operations for Warm Spitzer with the opportunity for extension based on recommendation by the 2010 Senior Review of operating missions. Warm Spitzer can operate for an additional 2.5 - 3 years until the end of 2013 or early 2014 (an additional 19,000 - 21,000 hours of science observations) when changes in the orbital geometry prevent further communication with the satellite. Warm Spitzer will execute many vital surveys, ranging from cosmological searches for the youngest galaxies to probing time-scales of variability of forming stars. In addition, Warm Spitzer will probe physical characteristics of newly discovered exoplanets, and potentially detect exo-superearths. All of the science executed by Warm Spitzer will be based on peer-reviewed proposals. 75% of the observing time is allocated to Exploration Science programs (>500 hrs) with the rest allocated to small projects and DDT science. The science of Warm Spitzer is strongly synergistic with Kepler and WISE and will be important preparation for JWST.
It is our belief that an additional 2.5-3 years of Warm Spitzer operations will provide an outstanding science resource to the community in return for a relatively modest investment of NASA science operations funding.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Mission operations are conducted at JPL. Science operations are conducted by the Spitzer Science Center on the Caltech campus. The science executed is selected by peer-reviewed competitions.
Current Status: Approved for 2 years of operations. Can operate for 4.5 - 5 years.
Additional Information: http://ssc.spitzer.caltech.edu/mtgs/warm/wp.html

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165. Wavefront Sensing and Control for Advanced Telescope Architectures

Point of Contact: Bruce H. Dean, NASA GSFC
Summary Description: Future light-weighted telescope architectures supporting coronagraph-imaging systems such as the 16-m ATLAS-T enable terrestrial planet discovery as well as ultraviolet-to-near infrared astronomy. Such missions require active optical control to maintain element positioning and dynamic figure adjustment to sub-nanometer tolerances. An image-based wavefront sensing approach offers the necessary accuracy along with simplifications in the telescope architecture that replace optical hardware with a computational approach using the science camera as the wavefront sensor in a coronagraph-imaging configuration. The performance capabilities enabled by such systems dovetail with cost reductions and reduced opto-mechanical risk resulting from reduced hardware requirements. Prior state-of-the-art wavefront sensing has been demonstrated to TRL-6 for JWST and relies on multi-scale phase retrieval techniques as well as data post-processing to return sensing accuracies to about the 10 nanometer level and at a quasi-static update rate. But the lag-times between wavefront sensing, and then control, which are characteristic of the post-processing approach, are often prohibitive for missions requiring frequent optical monitoring and correction, when compared with the JWST quasi-static environmental requirements. In addition, precision control of segmented mirror systems are required at about a 10X compared to the JWST levels. Recent developments in wavefront sensing approaches, including white light amplitude, phase, and polarization phase control, must be matured to at least TRL-6 to enable these missions. These developments have reached preliminary technology readiness levels through testbed work at GSFC and we propose to further refine and develop these technologies in combination with the 64 bit DSP super-computing architectures utilized for JWST TRL-6, which were utilized to overcome dynamic disturbances that were present for the JWST TRL-6 data collection. Recent testbed work at GSFC has achieved stability to < 2 nm rms and at a multi-Hz update and control rate.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: NASA Goddard Space Flight Center, NASA Jet Propulsion Laboratory, Ball Aerospace
Current Status: Technology Readiness Level (TRL) 4

Additional Information: http://www.stsci.edu/institute/atlast, http://istd.gsfc.nasa.gov/index.php?mymenu1=mymenu1&img=Code551.jpg&branch=branch&newID=1

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166. Wide Field X-ray Telescope Mission

Point of Contact: Stephen S. Murray, Harvard Smithsonian CfA
Summary Description: Science Objectives are to study: a) the Relation of clusters of galaxies with cosmology and the growth of structure, and the astrophysics of the intracluster medium (ICM); b) AGN and the growth and evolution of supermassive black holes, primordial black holes, black hole fueling, and time variability of black holes; c) Normal galaxies and the correlation of x-ray luminosity with other galaxy properties; and d) Synergies of a flux limited large area x-ray survey with similar surveys in other bands.To achieve these goals this medium class mission will consist of several (3 or 4) co-aligned X-ray telescope modules, each with an independent CCD focal plane. The novel feature of WFXT is the wide filed design of the X-ray optic that permits a 1 degree field of view with a 5 arcsecond HEW angular resolution across this wide field. The combination of large solid angle, large effective area (~7500 square cm at 1 keV) and high angualr resolution allows WFXT to survey a large area of the sky (20,000 square degrees) to a sensitivity ~100 times fainter than the ROSAT All Sky Survey. Extended X-ray sources (all clusters and many groups) will be easily distigushed from point-like sources (AGN and galaxies) so that samples of various classes of these objects can be studied. Two additional surveys of increasing depth will cover ~3000 square degrees and ~100 square degrees to probe fainter or lower luminoisty sources, and to provide larger numbers of clusters with high quality spatially resolved X-ray spectra.
Anticipated Sponsor: NASA
Participating Individuals or Institutions: Riccardo Giacconi (Johns Hopkins University), Andy Ptak (Johns Hopkins University), Colin Norman (Johns Hopkins University), Niel Brandt (Penn State University), Martin Weisskopf (MSFC), Mark Bautz (MIT), Chris Burrows (SolutionsIQ), Michael Paul (Applied Physics Laboratory), Alexey Vikhlinin (Harvard-Smithsonian Center for Astrophysics), Paolo Tozzi (INAF/Trieste), Roberto Gilli (INAF/Bologna), Stephen Murray (Harvard-Smithsonian Center for Astrophysics), Steve Allen (Stanford University), Kathryn Flanagan (Space Telescope Science Institute), Piero Rosatii (ESO), Stefano Borgani (INAF/Trieste), Giovanni Pareschi (INAF/Brera), Brian Ramsey (MSFC), Gianpiero Tagliaferri (INAF/Brera), Ron Elsner (MSFC)
Current Status: Pre-Phase A
Additional Information: Web Site: http://wfxt.jhu.edu

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167. Wide field, multi-pixel camera development for the Robert C. Byrd Green Bank Telescope

Point of Contact: Karen O'Neil, NRAO Assistant Director for Green Bank Operations
Summary Description: The NRAO plans the development of a set of wide field multi-pixel cameras for the Robert C. Byrd Green Bank Telescope (GBT). These instruments will include traditional feed-horn focal plane arrays of 60 – 100 elements, or more, to cover frequencies from 10 – 115 GHz, a 1,000 pixel bolometer array at 90 GHz, and beam-forming phased arrays at frequencies near 1 GHz. These instruments will increase the astronomical capabilities of the GBT by two or more orders of magnitude, provide an essential complement to ALMA and the EVLA, and enable new science in many areas of interest, including star formation, cosmology, and astrochemistry. These instruments will

be built in partnership with the US astronomical community, and all costs associated with these projects will be in their research, development, and one-time construction. Ongoing operational costs of the instruments will be provided by the NRAO operations budget.
Anticipated Sponsor: NSF, Other
We will seek partial funding for the construction of the instruments through a number of private organizations. All costs involved in these projects are research, development, and manufacturing – the operation costs of the instrument will be born by the NRAO operations budget.
Participating Individuals or Institutions: The project is still in the early planning phase. We anticipate significant community involvement in all aspects of the projects, from research through development and manufacturing, and including the hardware and software components of the project.
Below we provide a list of institutions which have already expressed interest in participating in the project. We plan an open call for participants combined with a workshop to lay out the path forward for community involvement in 2009, which should result in a significant increase in this list.
University of Maryland, Stanford University, California Institute of Technology, University of California, Berkeley, University of Pennsylvania, West Virginia University, National Institute of Standards and Technology
Current Status: Pre-phase – We have begun development of a three prototype instruments - 7-pixel array at 18-26 GHz, an uncooled beam forming array at 1.4 GHz, and a 64-pixel bolometer array at 90 GHz. In addition to being scientifically useful instruments in their own right, the prototype instruments will identify some of the technical issues needed to be resolved for the other arrays. Planning for the much larger (100-1000+) pixel arrays is in the early planning phase. We are in the process of bringing together members from the community who may be interested in the research, development, and/or manufacturing part of the components. We have also just begun identifying possible sources of funding for the project.
Additional Information: http://www.gb.nrao.edu/program
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168. Wide-field Fiber Multi-Object Spectrometer (WFMOS)

Point of Contact: Douglas Simons, Director Gemini Observatory
Summary Description: WFMOS will be developed collaboratively by the Gemini and Subaru Observatories. It is to be deployed on the Subaru telescope for the shared use of both astronomical communities. WFMOS is expected to provide spectroscopic observations of ~4500 targets simultaneously across a 1.5-degree field of view to explore the nature of Dark Energy and to map the formation history of the Galaxy. The basic instrument concept relies on the use of a prime focus array of remotely positioned fibers that feed a large bank of spectrometers located off the telescope. WFMOS will share critical infrastructure with the new HyperSuprime Cam wide-field imager being built by Subaru. The preliminary baseline performance requirements for WFMOS on Subaru include:
* Wavelength Range: 0.39 – 1.0 µm
* Field of View: 1.5 deg
* Spatial Sampling: 1 arcsec fiber entrance
* Spectral Resolution: R = 1800 - 3500 (3000 fibers) and R = 40,000 (1500 fibers)
* Simultaneous wavelength coverage: 0.39 – 1.0 µm (low resolution spectrographs), >100 Å (high resolution)
* Simultaneous Targets: ~4500
* Detector operating modes: Standard readout or Nod and shuffle.

Anticipated Sponsor: NSF, Other
WFMOS is a joint venture of the Gemini and Subaru observatories. The Gemini

Observatory is operated by the Association of Universities for Research in Astronomy, Inc., under a cooperative agreement with the NSF on behalf of the Gemini partnership: the National Science Foundation (United States), the Science and Technology Facilities Council (United Kingdom), the National Research Council (Canada), CONICYT (Chile), the Australian Research Council (Australia), Ministério da Ciência e Tecnologia (Brazil), and SECYT (Argentina). The Subaru Telescope is operated on behalf of the Japanese astronomical community by the National Astronomical Observatory of Japan (NAOJ).
Participating Individuals or Institutions: The institutions and organizations that will construct WFMOS have not been selected. Conceptual Design studies are currently being conducted by: The Anglo Australian Observatory (Australia), NOAO (US), Johns Hopkins University (US), U. Durham (UK), U. Portsmouth (UK), U. Oxford (UK), RAL (UK), Caltech (US), Penn State (US), Jet Propulsion Lab (US), ATC (UK), Cambridge IofA (UK), U. College London (UK), and LNA (Brazil).
Current Status: Two competitive Conceptual Design Studies (similar to Pre-phase A) were funded by Gemini in 2008, with technical support from Subaru. Those studies will conclude in Feb. 2009.
Additional Information: A 2004 Feasibility Study for WFMOS was conducted by the AAO. The report can be found at
http://www.gemini.edu/files/docman/science/aspen/WFMOS_feasibility_report_public.pdf
The RfP for the WMFOS Conceptual Design Studies can be found at:
http://www.gemini.edu/node/148

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169. Working Group on Laboratory Astrophysics (WGLA)

Point of Contact: Farid Salama, NASA Ames
Summary Description: The Working Group on Laboratory Astrophysics was created by the American Astronomical Society (AAS) with the endorsement of the Astronomy and Astrophysics Advisory Committee (AAAC), which advises the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA) and the U.S. Department of Energy (DOE) on selected issues within the fields of astronomy and astrophysics that are of mutual interest and concern to the agencies. The Working Group is charged with improving the interaction between the data users (astronomers, astrophysicists, and astrochemists) and the data providers (laboratory astrophysicists and astrochemists). The providers include experimentalists and theorists carrying out research motivated by problems in astrophysics and astrochemistry. The Working Group includes prominent members of the user community, yet has been kept small for efficiency. The activities of the Working Group are guided by advancing space- and ground-based astronomy through the promotion of laboratory astrophysics and astrochemistry. Since astronomy is primarily an observational science detecting photons, atomic, molecular, and solid state processes that produce the observed photons are a main focus. Because our understanding of the Universe also relies on knowledge of the evolution of matter (nuclear and particle physics) and of the dynamical processes shaping it (plasma physics), the focus also incorporates work in these areas as well. The Working Group discusses policies with other academic, international, or governmental organizations, as appropriate to advance its activities. The Working Group also acts on behalf of the AAS to seek out possible sources of funding for support of the discipline from local and national sources, public and private.
Anticipated Sponsor: DOE, NASA, NSF, Office of Naval Research, Air Force Office of Scientific Research
Participating Individuals or Institutions: The WGLA represents all researchers nationally working in the area of Laboratory Astrophysics.
Current Status: Like missions and facilities, laboratory astrophysics critically depends on the maintenance of infrastructure, both hardware and personnel. The current funding

model of 1 to 3 year grants barely provides the necessary maintenance especially given the nature and duration of many laboratory programs. A longer term view, tied to key science efforts, needs to be developed. The Decadal Survey is the ideal instrument for this.

Well-attended sessions on laboratory astrophysics at AAS and APS meetings, which were organized by the Working Group and its members, highlighted the contributions of laboratory work to all of astronomy. At a recent Town Hall Meeting, the ongoing needs of the astronomical community were brought to the fore. Plans are being made to continue these interactions, but long-term efforts such as the Survey are required to bring everything into focus.

At present there is an extensive range of ongoing research activities in laboratory astrophysics. In the absence of a global plan for the field these have arisen in a somewhat random fashion reflecting the entrepreneurial efforts of various investigators. We will discuss the scope, specifics, and potential of these activities in our white paper. Laboratory astrophysics has not yet benefited from a broad assessment of its sensible intellectual roles within the broad scope of astronomy and astrophysics as a whole. We would hope to see the Committee recommend that the NRC undertake such a study.

Additional Information: http://www.aas.org/labastro/

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170. Xenia: A Probe of Cosmic Chemical Evolution

Point of Contact: Chryssa Kouveliotou, NASA MSFC

Summary Description: Xenia is planned as a medium-size cosmology mission. It addresses objectives of two Science Frontier Panels of the 2010 Astronomy and Astrophysics Decadal Survey: the Cosmology and Fundamental Physics (CFP) and the Galaxies across Cosmic Time (GCT) Panels. The mission's primary goal is to understand the formation and evolution of structures on various scales from the early Universe to the present (stars, galaxies and the cosmic web). Xenia will use X- and gamma-ray monitoring, wide-field X-ray imaging and high-resolution spectroscopy to collect essential information from three major tracers of these cosmic structures: the Warm Hot Intergalactic Medium (WHIM), Galaxy Clusters, and Gamma Ray Bursts (GRBs). Our goals are to trace the chemo-dynamical history of the ubiquitous warm hot diffuse baryon component in the Universe residing in cosmic filaments and clusters of galaxies up to its formation epoch (at z =0-2) and to map star formation and galaxy metal enrichment into the re-ionization era beyond z ~ 6. The concept of Xenia (Greek for "hospitality") evolved in parallel with the Explorer of Diffuse Emission and GRB Explosions (EDGE), a mission proposed by a multinational collaboration to the ESA Cosmic Vision 2015. Xenia, planned for launch by an ESA-Vega launch vehicle, incorporates the European and Japanese collaborators and instrumentation of EDGE and Swift into a U.S. led mission. We combined the scientific objectives and preliminary design efforts of EDGE (cryogenic imaging spectrometers and wide field X-ray optics) and built upon the technological readiness demonstrated by Swift (fast re-pointing), to enable our goals be achieved within the cost envelope of a medium-size mission.

Anticipated Sponsor: NASA, Other

Our international collaborators are being funded by their national agencies to continue instrument development for Xenia. More specifically funding has been allocated by: ASI (Italian Space Agency), SRON (Dutch Space Agency), JAXA (Japanese Space Agency)

Participating Individuals or Institutions: US Institutions: C. Kouveliotou (PI), J. Fishman, M. Weisskopf, B. Ramsey, S. O'Dell, J. Kolodziejczak, C. Wilson-Hodge, A. van der Horst (NASA/MSFC), N. Gehrels, R. Kelley, S. Barthelmy, R. Mushotzky (NASA/GSFC), R. Kippen (LANL), D. Burrows (lead of the instrument teams), P. Meszaros, L. Townsley (Penn State University) D. Hartmann (lead of the science teams, Clemson University), S. Woosley, E. Ramirez-Ruiz, J. Prochaska (University of California

Santa Cruz), M. Briggs, M. Bonamente (University of Alabama, Huntsville), M. Galeazzi (University of Miami), J. Bregman (University of Michigan), F. Paerels (Columbia University), A. Rasmussen (SLAC), J. Hughes (Rutgers University), J. Bloom (University of California, Berkeley), J. Grindlay (Harvard University), A. Kusenko (University of California, Los Angeles), D. McCammon (University of Wisconsin); Foreign Institutions: L. Piro, P. Ubertini, L. Natalucci, G. Pareschi, G. Tagliaferri, G. Ghisellini, G. Ghirlanda, S. Campana, L. Amati, S. Ettori, T. Mineo, S. Molendi (INAF (Institutes and Observatories in Rome, Bologna, Milano, Palermo)), E. Branchini (University of Rome), J-W. Den Herder, W. Hermsen, J. Kaastra (SRON), J. Schaye (Leiden University), R. Wijers (University of Amsterdam), T. Ohashi (Tokyo Metropolitan University), K. Mitsuda, Y. Takei, N. Yamasaki (JAXA/ISAS), Y. Tawara (Nagoya University), N. Kawai (Tokyo Institute of Technology), Y. Suto (University of Tokyo), A. Holland (Open University), P. O' Brien, J. Osborne (Leicester University), G. Branduardi-Raymont (University College London)

Current Status: Pre-Phase A

Additional Information: We provide below the link to the EDGE mission, while the Xenia link is being under construction. The link will change shortly. http://projects.iasf-roma.inaf.it/edge/

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171. Xian--eXtreme Imaging Antarctic Network

Point of Contact: Don York, The University of Chicago

Summary Description: A large array (400) of 50 cm telescopes is proposed to survey the sky continuously, in drift scan CCD mode from Dome A during Antarctic night. Images of 8000 sq. degree at 1 arcsec resolution every 10 to 20 seconds will be recorded. The design parameters are based on detailed study of GRB afterglows, orphan afterglows and SNe blueflashes, but numerous other types of research can be pursued with the design (astroseismology, SNe, asteroids, comets, flare stars, gravitational lensing of QSOs, etc.). Apart from the variable character of individual objects, the aggregate studies are relevant to stellar interiors and a number of cosmological parameters. The effective survey power is thousands of times greater than previous surveys to this depth for short-term transients. By co-adding frames, timescales of up to days can be explored, thus including LSST and PANSTARRS scales, but covering uniquely faster timescales than can be seen, all-sky, with those projects. The data will be processed in small CCD read out segments, on line, to search for transient objects at the level of 10% or greater at effective V magnitude of 20 (more significance for brighter objects). False positives will be eliminated by on-line evaluation of image structure (cosmics) and by comparison with previous frames of the same part of the sky, depending on the interests of the investigators. An all- sky map to 25th magnitude will be constructed in the first 24-hours of full operations so that flares of Galactic stars can be readily identified, then updated to keep track of slow changes with time (comets, asteroids, Earth orbiting satellites) which might cause false positives in the main pipeline. The array is to be operated in conjunction with a 4 meter class telescope, dedicated to follow-up of transients triggered by the on-line software and international alerts of all transients (at threshold) will be provided.

Anticipated Sponsor: DOE, NASA, NSF

Possible international partnership with China and Australia, France and Italy.

Participating Individuals or Institutions: Lifan Wang (Texas A&M), Xiangqun Cui (NIAOT), Don Lamb (U. Chicago), Michael Ashley, John Storey (USNW), Morley Blouke (Ball Aerospace), Al Harper (U. Chicago), Alexei Khokolov (U. Chicago), John Lawrence (AAT/Macquerie Univ.), Xiangyan Yuan (NIAOT), Xu Zhou (NAOC) and others (see url below)

Current Status: The design is a concept. Key elements are being or have been tested.

a) The Polar Research Institute of China has made three traverses to Dome A, between 2004 and 2009. Equipment has been left there, unmanned. A manned station is being built.
b) Four, fourteen centimeter, co-pointed telescopes operated through the winter of 2008, unmanned, powered by a generator (USNW) and controlled by satellite transmissions. They are pointed at the South Pole and the sky drifts by, giving continuous coverage to search for variable objects. No real-time processing is provided, but data are archived.
c) A prototype 50-cm Schmidt is being constructed (NAIOT) for use in winter 2010, with minimal moving parts, operating from -90 C to room temperature without focus change.
d) Full CCD arrays (20 sq. degree, 16,000 x 16,000 pixels, with more frequent readout (~100 CCD lines)) have been studied by Ball Aerospace, which must be optimized for low power operation and produced in large quantities.
e) NAOC is purchasing a 10K by 10K chip with less frequent readout for the 50-cm prototype (underfilled focal plane).
f) Key elements of the real time pipeline have been conceptualized for false positive removal (see url below).
Studies of 4-meter class telescopes, that could be adapted for follow-up of triggers from Xian at Dome-A have been done (PILOT-USNW) or are under way (KDUST-NAOC).
Additional Information: Relevant papers at http://astro.uchicago.edu/~don/xian