NASA Astrophysics Outlook

Presented to the

Board on Physics and Astronomy

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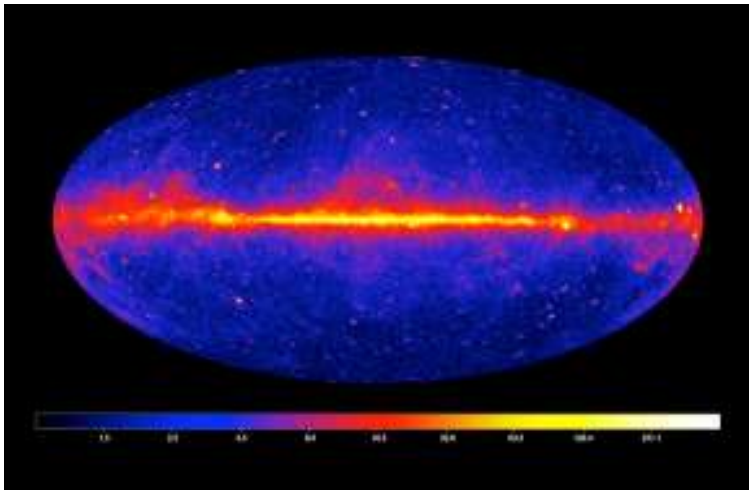
Science Mission Directorate, NASA HQ

November 7, 2011

Astrophysics Division

FY11 Science Highlights



This **Fermi Gamma-ray Space Telescope** all-sky image is the deepest and best-resolved portrait of the gamma-ray sky. The colors map the number of gamma rays above 1 GeV per 0.01 square degree. It clearly shows that the entire sky is filled with gamma-rays with the brightest along the plane of our galaxy (bright yellow “bar” in the middle). Discrete gamma-ray sources include pulsars and supernovae remnants within our galaxy, as well as distant galaxies powered by supermassive black holes.

Scientists using data from NASA's **Wide-field Infrared Survey Explorer** (WISE) have discovered the coldest class of star-like bodies, with temperatures as cool as the human body. Astronomers hunted these dark orbs, termed Y dwarfs, for more than a decade without success. When viewed with a visible-light telescope, they are nearly impossible to see. WISE's infrared vision allowed the telescope to finally spot the faint glow of six Y dwarfs relatively close to our Sun, within a distance of about 40 light-years.

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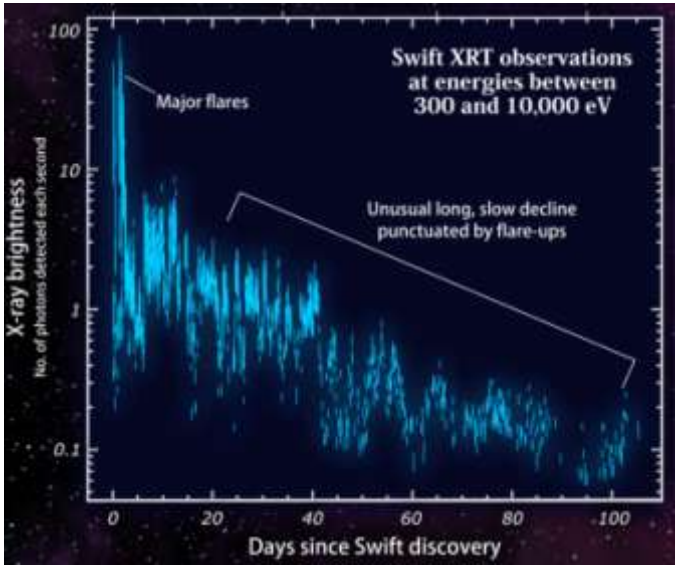
FY11 Science Highlights

VV 340, also known as Arp 302, provides a textbook example of colliding galaxies seen in the early stages of their interaction. Data from NASA's **Chandra X-ray Observatory** (purple) are shown here along with optical data from the **Hubble Space Telescope** (red, green, blue). The edge-on galaxy near the top of the image is VV 340 North and the face-on galaxy at the bottom of the image is VV 340 South. Millions of years later these two spirals will merge - much like the Milky Way and Andromeda will likely do billions of years from now. VV 340 is located about 450 million light years from Earth.



The **Swift X-ray Telescope** continues to record high-energy flares from Swift J1644+57 more than three months after the source's first appearance. Astronomers believe that this behavior represents the slow depletion of gas in an accretion disk around a supermassive black hole. The first flares from the source likely coincided with the disk's creation, thought to have occurred when a star wandering too close to the black hole was torn apart.

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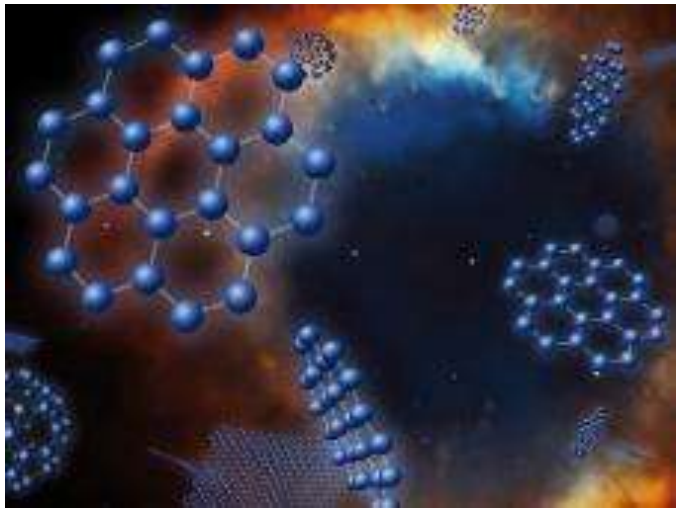
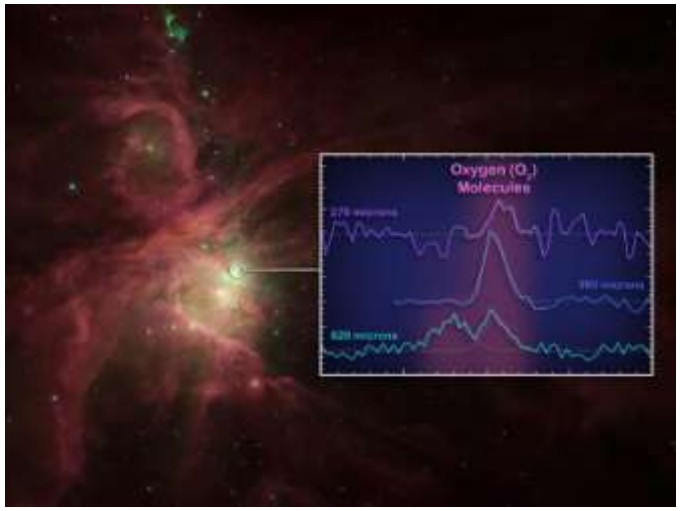
FY11 Science Highlights



NASA's **Spitzer Space Telescope** has spotted the signature of graphene in space. If confirmed, this would be the first-ever cosmic detection of the material -- which is arranged like chicken wire in flat sheets that are one atom thick. Graphene was first synthesized in a lab in 2004, and subsequent research on its unique properties garnered the Nobel Prize in 2010. It is as strong as it is thin, and conducts electricity as well as copper. Some think it is the "material of the future," with applications in computers, screens on electrical devices, solar panels and more.



The **Herschel Space Observatory**, an ESA mission with important NASA contributions, definitely confirmed oxygen molecules in space near the star-forming core of the Orion nebula. The molecules, whose presence had been hinted at in space before, were detected by Herschel. The heterodyne instrument for the far infrared was used to split light from a specific region of the Orion nebula into its different submillimeter wavelengths. Astronomers recognized three distinct fingerprints of oxygen molecules. The three lines show different ranges of wavelengths, with the signatures of oxygen molecules highlighted in pink.

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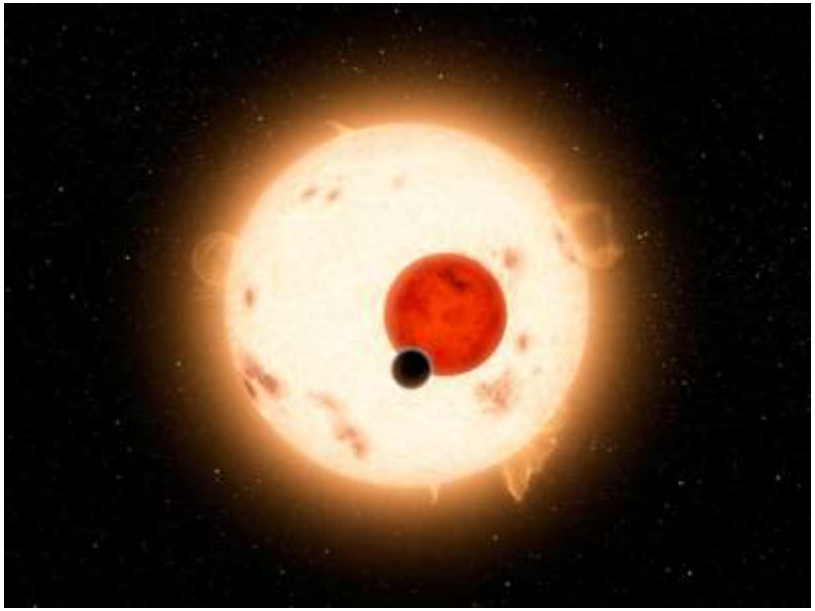
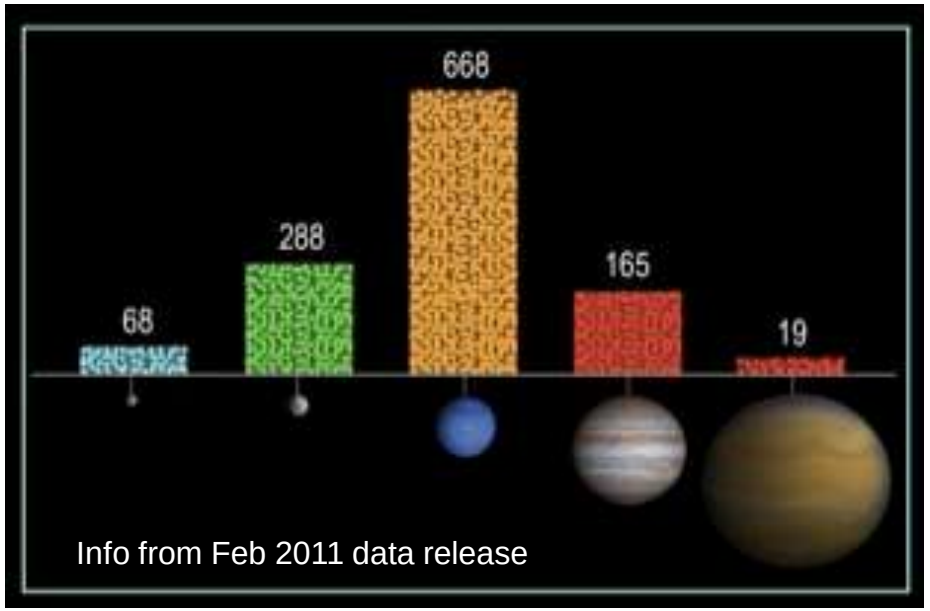
Kepler Mission

The First Circumbinary Planet



- The Kepler mission has made the first unambiguous detection of a circumbinary planet -- a planet orbiting two stars -- 200 light-years from Earth.
- The planet, called Kepler-16b, is a cold world, with a gaseous surface, and not thought to harbor life.
- Kepler-16b orbits around both stars every 229 days, similar to Venus' 225-day orbit.
- The parent stars are smaller than our sun. One is 69 percent the mass of the sun and the other only 20 percent.
- Kepler-16b lies outside the system's habitable zone, where liquid water could exist on the surface, because the stars are cooler than our sun.

Additional Data Released to Public Sept. 27

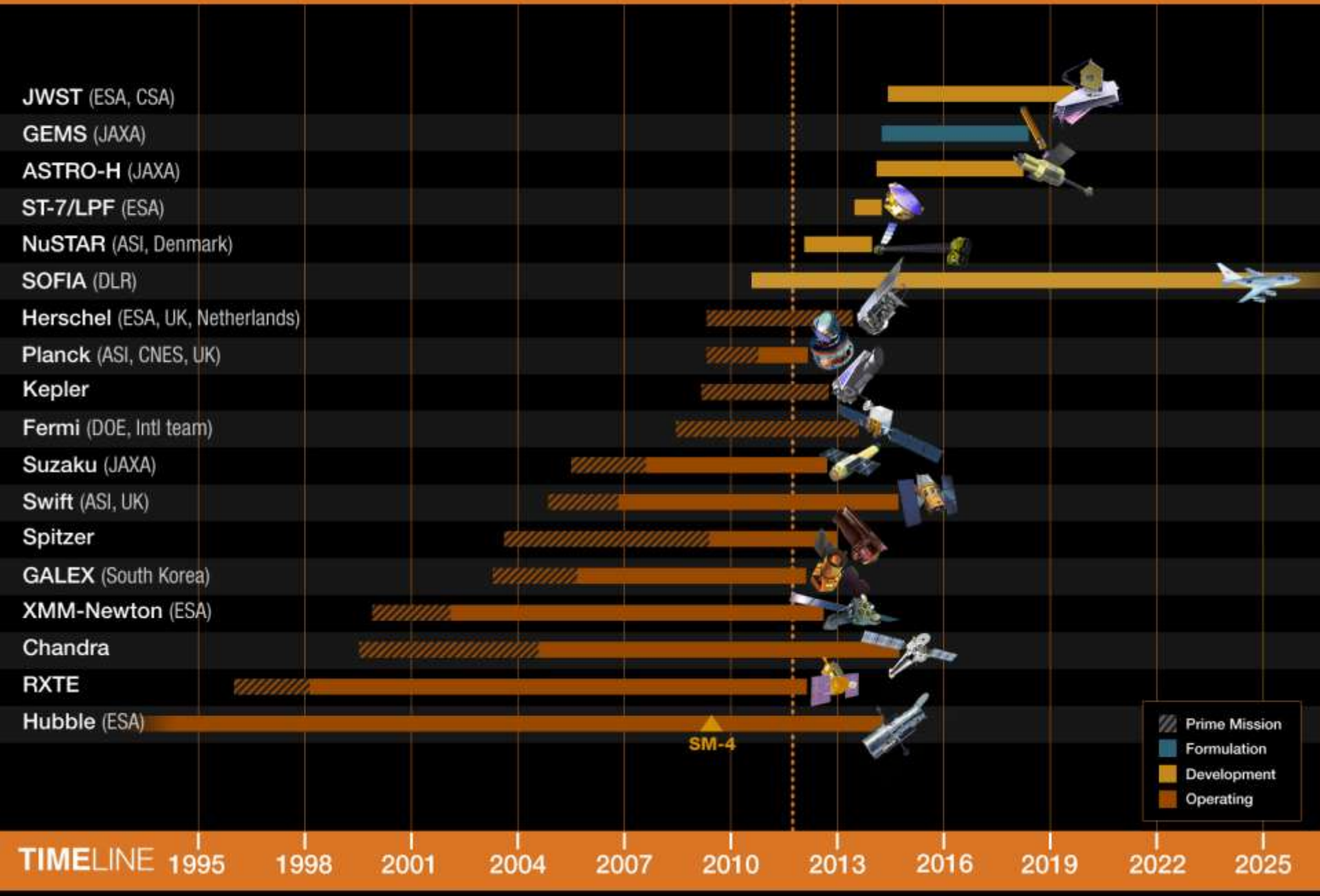


- The planetary candidates include: 68 of Earth-size, 288 of super-Earth-size, 662 of Neptune-size, 165 of Jupiter-size, and 19 larger than Jupiter as of January 2011.
- Kepler has released data on 155,453 stars and on the 1,235 planetary candidates that it has discovered in the first 4 months of science operations.
- 54 planetary candidates are in the habitable zone of their host stars, a region where liquid water could exist on a planet's surface. The 5 smallest of these range in size from 0.9 to twice the size of the Earth.
- 170 stars show evidence of multiple planetary candidates.
- Confirmed 20 exoplanets. Remaining planet candidates still require follow-up observations to verify they are actual planets.

On September 12, 2011, at the Extreme Solar System Conference, it was reported that Kepler has now identified: 1781 candidates, 121 in habitable zone, 123 are less than 1.25 as wide as the Earth, and 27 confirmed exoplanets.

Astrophysics Missions timeline

Last updated: October 17, 2011



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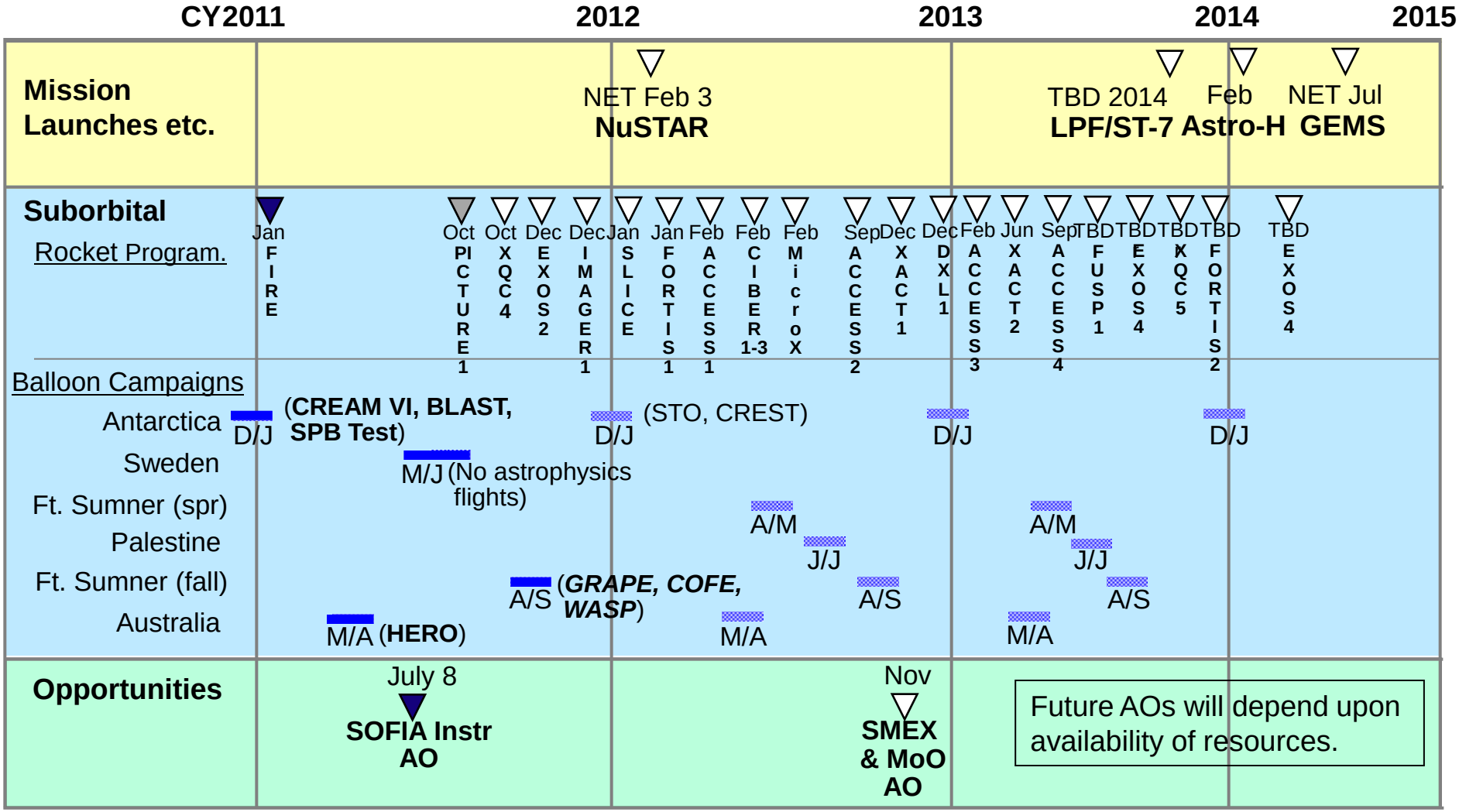
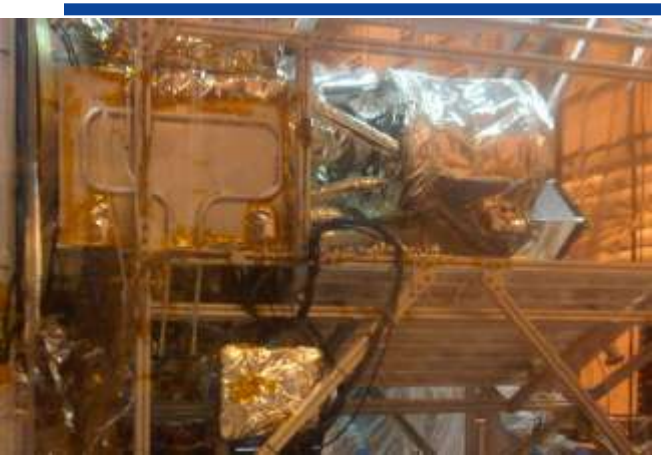
Astrophysics Mission Events

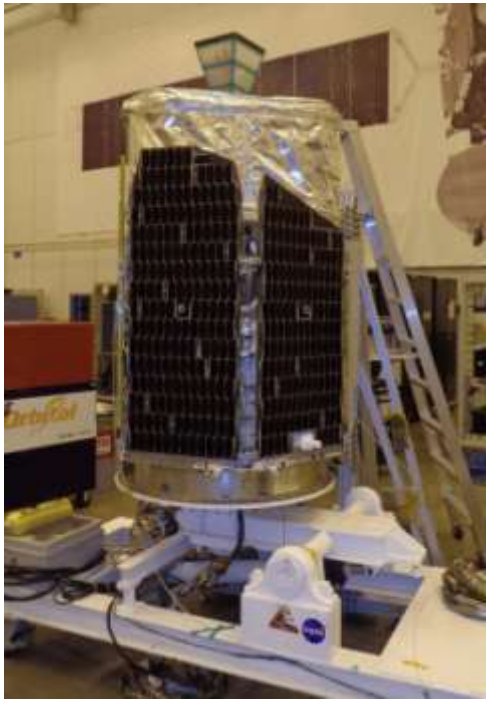


Last Updated: October 18, 2011

Accomplishments & Significant Events



NuSTAR Observatory removal from TVAC chamber at OSC

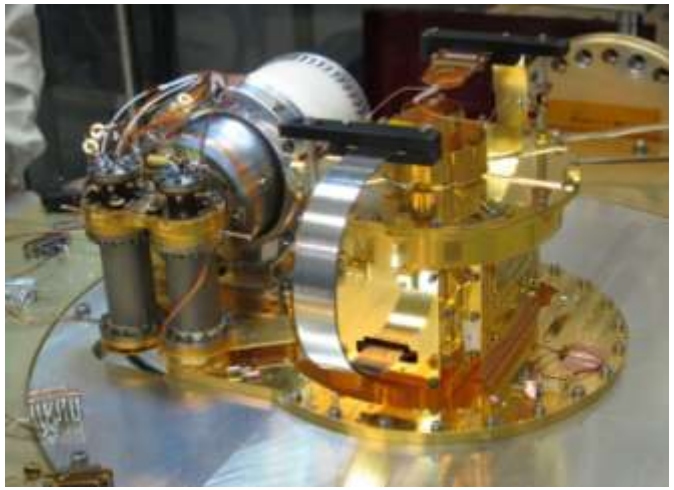


NuSTAR Observatory

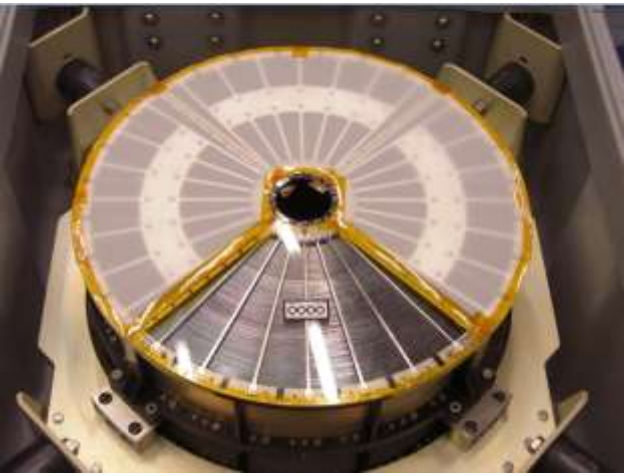
NuSTAR

- Thermal Vacuum Chamber testing successfully completed July 31 with no major issues.
- Solar Array attached to NuSTAR spacecraft, and successfully deployed on August 17, 2011.
- Vibration testing was underway when the east coast earthquake occurred. No damage. Vib test successfully completed September 8.
- Observatory acoustics test successfully completed September 14.
- Observatory shock test successfully completed September 19.
- NuSTAR launch scheduled for early 2012.

Accomplishments & Significant Events (cont.)



EM CSI: Detector assembly and ADR's #1 and 2 on right, ADR's #3 on left.



Astro-H EM soft X-ray mirror shipped to JAXA.

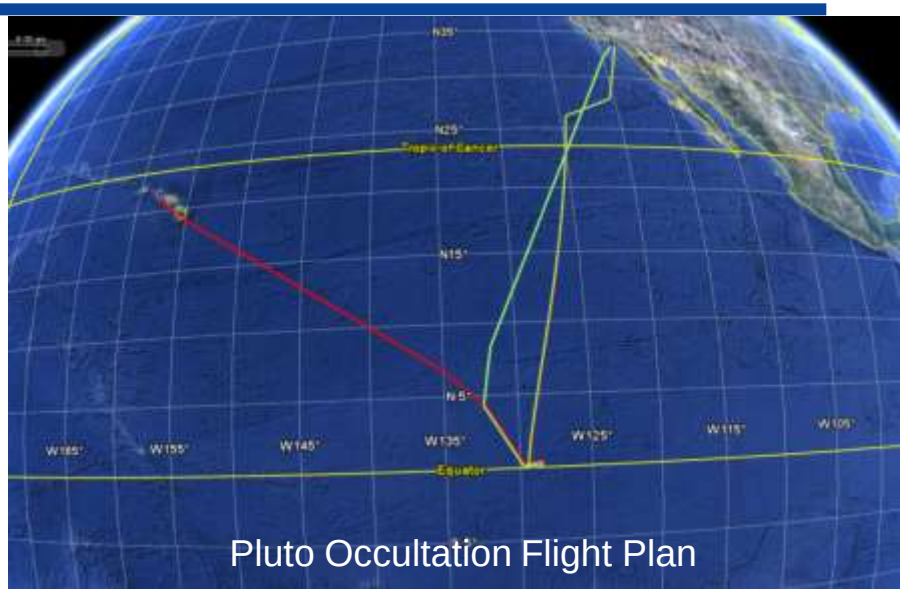
Astro-H

- Engineering Model (EM) model Calorimeter Spectrometer Insert (CSI) has been completed. The CSI includes the detector and three Adiabatic Demagnetization Refrigerators (ADR's). The CSI is the primary NASA deliverable to JAXA for this mission.
  - Performance testing at cryogenic temperatures completed. Performance is nominal. The CSI cooled to operating temperature of 50 mK and X-rays were detected on all pixels.
  - Cold vibration testing completed in September. Post-vibe performance testing beginning week of October 10.
- The EM mirror quadrant for the soft X-ray telescope has been completed and was shipped to Japan October 7. The flight model (FM) mirror is in fabrication.
- The FM detector array is complete. The flight spare is in fabrication.

Accomplishments & Significant Events (cont.)

SOFIA

- Pluto Occultation successfully completed June 23, including 150-mile repositioning with in-flight replan.
- Released AO for second Generation Instruments on July 8. Proposals received Oct 7.
- Completed 9 (of 11 planned) Basic Science #2 flights with the GREAT instrument. Final two flight will be completed in early Nov.
- Completed mirror damage risk assessment and primary mirror repairs allowing completion of segment 2 flight schedule.
- First International Deployment to Germany (Sept 15-21) and Joint Base Andrews AFB stopover (Sept 22-23).



Pluto Occultation Flight Plan

Segment aired July 4

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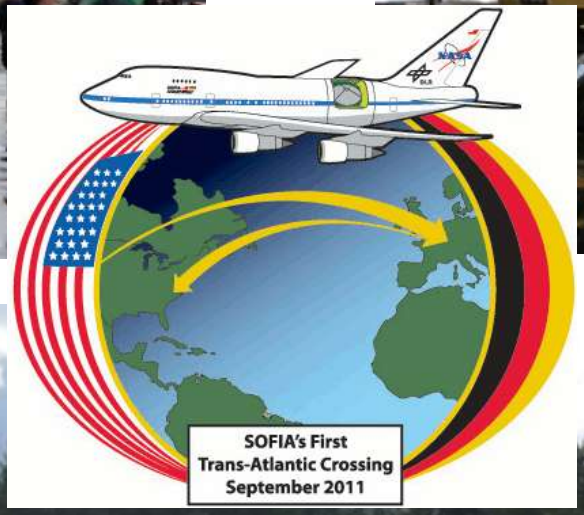
SOFIA Deployment to Germany September 2011



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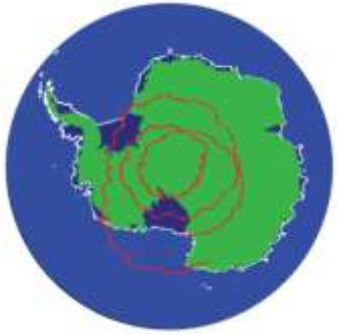
Balloon Program

Antarctica is center piece of the Balloon Program

- NASA-NSF/OPP Long-Duration Balloon (LDB) Program provides:
  - NASA's lowest cost access to space (>= stratosphere)
  - Spacecraft-scale payloads (1000 - 2000 kg science instruments)
  - Exposures comparable to short-duration spacecraft
  - Recoverable / Re-usable payloads: Increase the exposure at low cost
- The Balloon Program has focused on expanding the highly successful LDB flights **around** Antarctica.
  - Flight durations of up to 4-6 weeks
  - Flight support to 3 payload flights every year



42-day CREAM flight Dec - Jan 2004-05

Scientific Opportunities in the coming decade

- Frontier Astrophysics on Super-Pressure Balloons (SPB) launched **<u>from</u>** Antarctica enable Ultra-Long Duration Balloon (ULDB) flights.
- ULDB flights from Antarctica yield long exposure: 60 days now; 100 days soon.
  - Would like increased flight operations window in Antarctica
  - Work with NSF/OPP to enable flights to leave Antarctica and be recovered in South America, New Zealand, Australia, etc., thereby increasing science.

Record 54-day SPB flight Dec - Feb 2008-09

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2012 Senior Review of Operating Missions

Invited Missions	
Planck	Hubble
Chandra	Fermi
Warm Spitzer	Kepler
Swift	
XMM-Newton	
Suzaku	

2012 Senior Review Schedule	
Draft Call for proposals	Jul 1, 2011
Call for Proposals	Aug 10, 2011
EPO SR Proposals Due	Dec 15, 2011
SR Proposals Due	Jan 15, 2012
EPO Section Review	Jan 23 - 25, 2012
SRC Meets	Feb 28 - Mar 2, 2012
Final Report	Mar 30, 2012

Changes to the 2012 Senior Review

- Better defined process for inviting missions into the Senior Review.
- EPO review part of Senior Review 2012.
  - In 2010, the EPO review was performed separately, after the Senior Review.

New Projects in the Senior Review

- Kepler and Fermi were invited to participate in the Senior Review - completed Level 1 requirements review.
- In 2009, the Astrophysics Subcommittee had recommended that Hubble be invited to the 2012 Senior Review.

http://science.nasa.gov/astrophysics/2012-senior-review/

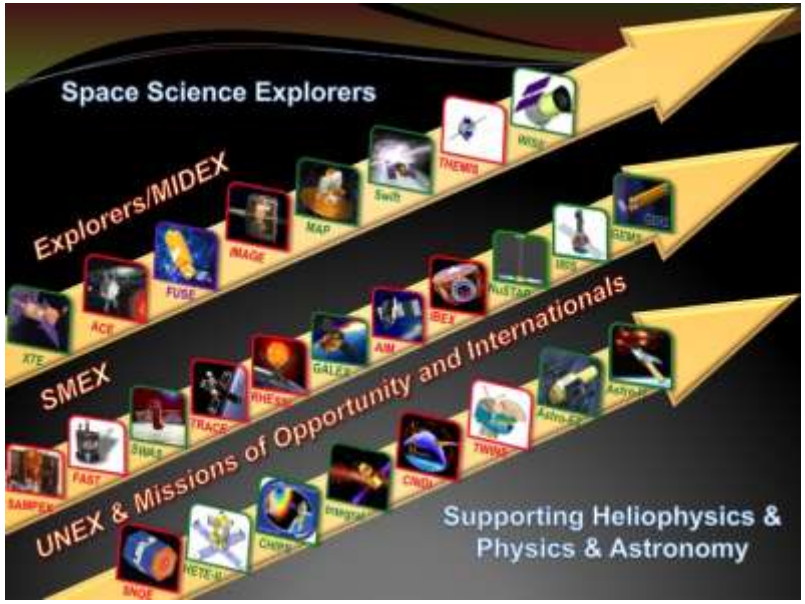
Explorers Summary

- NWNH Recommendation:

  The committee therefore recommends, as its second priority in the large category of space-based projects, that NASA should support the selection of two new astrophysics MIDEX missions, two new astrophysics SMEX missions, and at least four astrophysics MoOs over the coming decade. AOs should be released on a predictable basis as close to annually as possible, to facilitate Missions of Opportunity. Further, the committee encourages inclusion of suborbital payload selections, if they offer compelling scientific returns.

- A Future Astrophysics Explorer missions budget was created to increase the flight rate to achieve the recommended four missions and four missions of opportunity selected by the end of the decade.

- Notional Mission Selection Dates:
  - ✓ September 2011 Step 1 Explorer and MoO selection (current AO)
  - February 2013 Step 2 Explorer selection and MoO (current AO)
  - September 2013 Step 1 Explorer and MoO selection (next AO)
  - February 2015 Step 2 Explorer selection and MoO (next AO)



The September 2011 selection had:

- 15 Astrophysics EX mission proposals - $200M plus launch costs
- 11 Astrophysics SALMON/Missions of Opportunity proposals - $55M includes both Partner MOs and Small Complete Missions

Astrophysics Explorer Selections September 2011

Step 1 Explorer Selections

Fast Infrared Exoplanet Spectroscopy Survey Explorer (FINESSE) Mark Swain, PI, JPL
FINESSE would use a space telescope to survey more than 200 planets around other stars. This would be the first mission dedicated to finding out what comprises exoplanet atmospheres, what conditions or processes are responsible for their composition, and how our solar system fits into the larger family of planets.

Transiting Exoplanet Survey Satellite (TESS) George Ricker, PI, MIT
Using an array of telescopes, TESS would perform an all-sky survey to discover transiting exoplanets, ranging from Earth-sized to gas giants, in orbit around the nearest and brightest stars in the sky. The mission's primary goal would be to identify terrestrial planets in the habitable zones of nearby stars.

MoO Selections

Gal/Xgal U/LDB Spectroscopic/Stratospheric THz Observatory (GUSSTO) Christopher Walker, PI, University of Arizona, Tucson -- This mission would launch a high altitude balloon with a one-meter telescope to provide a comprehensive understanding of the inner workings of our Milky Way galaxy and one of our galaxy's companion galaxies, the Large Magellanic Cloud.

Neutron star Interior Composition ExploreR (NICER) Keith Gendreau, PI, Goddard -- This mission would place an X-ray timing instrument on the International Space Station (ISS) to explore the exotic states of matter within neutron stars and reveal their interior and surface compositions.

ESA Cosmic Vision Status Astrophysics

M-Class Missions (M1 and M2)

- ✓ September 19, 2011, the Astrophysics Working Group (AWG) sent its recommendations to the Space Science Advisory Committee (SSAC).
- ✓ AWG recommended that Solar Orbiter and Euclid be selected as M1 and M2, respectively, and proposed that PLATO continue in the competitive process for the M3 mission.
- ✓ October 4, 2011, the SSAC accepted the recommendations of the AWG.
- November 2011, the Science Programme Committee (SPC) meets to consider the SSAC decision on two missions for the invitation to Tender release.
- July 2012, following 'consolidation' of partners, Science Programme Committee will consider adoption of missions (Cost-at-Completion and Payload Formal Agreement).
- September 2012 , M2 mission enters Implementation Phase.

M-Class Mission M3

- ✓ EChO, LOFT, MarcoPolo-R and STE-QUEST selected for Assessment Phase and further downselect for launch in 2022. (PLATO may be included if the mission re-proposes per AWG recommendation)

Timeline for selection of M-Class missions from: http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=42370

ESA Cosmic Vision Status Astrophysics

L-Class Missions (L1 & L2)

- ✓ October 2007: EJSM-Laplace, IXO & LISA selected for study, with NASA in a key role in all three.
- ✓ February 2011: Assessment phase completed, but NWNH and NASA budget preclude proceeding
- ✓ April 2011: ESA defined new approach – European-led teams to define affordable European-led missions with limited international participation for launch in early 2020s
  - ✓ Athena (replacing IXO), LISA, and EJSM-Laplace studies are underway
  - Technical studies to be completed in November 2011
  - Review by ESA advisory bodies in December 2011 – January 2012
- February 2012: Recommendation to SPC for one or two missions to enter phase A/B1
- L1 target launch date 2020.

WFIRST

- Science Definition Team (SDT) has delivered its interim report in July 2011.
  - Copy of the report can be found at: *http://wfirst.gsfc.nasa.gov/science/WFIRST_IDRM_Report_Final_signed_Rev2.pdf*
  - The Interim Design Reference Mission (IDRM) is a proof of concept that a mission can be constructed that is compliant with the NWNH recommendation for groundbreaking observations in Dark Energy, Exoplanet and NIR sky surveys.
- Final SDT report to be delivered NLT December 2012.

New Technology Fellowship
Nancy Grace Roman Technology Fellowship in Astrophysics

- The Roman Fellowship is structured into three components with specific gates for entering the next phase.
  - A one-year Concept Study to generate the detailed plans and commitments for developing the proposed astrophysics technology. A final report is due nine-months after the start of the award, which will be peer reviewed.
  - A subset of the Technology Fellows will be selected to continue the fellowship and implement the plans conceived during the Concept Study. This Development Effort is for an additional four-years.
  - Fellows in the four-year Development Effort may apply for start-up funds when they obtain a tenure-track, permanent civil service, or equivalent position.
- The Roman Fellowship will:
  - Provide early career researchers the opportunity to develop the skills necessary to lead astrophysics flight instruments/projects and become principal investigators of future astrophysics missions.
  - Develop innovative technologies that have the potential to enable major scientific breakthroughs.
  - Foster new talent by putting early-career instrument builders on a trajectory towards long-term positions.

https://science.nasa.gov/researchers/sara/student-programs/nancy-grace-roman-technology-fellowships-astrophysics-early-career-researchers/

Awards

- **Saul Perlmutter, Brian P. Schmidt, and Adam G. Riess** received the 2011 Nobel Prize in Physics for the "discovery of the accelerating expansion of the Universe through observations of distant supernovae."
- **W. Vernon Jones**, senior scientist, Astrophysics Division, NASA HQ received the:
  - 2011 AIAA Otto Winzen Lifetime Achievement Award, which honors outstanding contributions and achievements in the advancement of free-flight balloon systems or related technologies. Jones is honored for applying the vision of long-duration balloons to a better understanding of cosmology and the fundamental origins of our universe.
  - 2011 IUPAP Yodh Prize for his outstanding contributions to balloon-borne cosmic ray and particle astrophysics experiments
- **William Atwood** (UC Santa Cruz) received the American Physical Society's 2012 W.K.H. Panofsky Prize in Experimental Particle Physics for his leading work on the design, construction, and use of the Large Area Telescope on the Fermi Gamma-ray Satellite, enabling numerous new results in gamma-ray astrophysics and fundamental physics.
- **Gerald Fishman** (MSFC) and **Enrico Costa** (Institute of Space Astrophysics and Cosmic Physics) shared the 2011 Shaw Prize in Astronomy for their leadership of space missions that enabled the demonstration of the cosmological origin of gamma ray bursts, the brightest sources known in the universe. Fishman was the principal investigator of the BATSE experiment aboard the Compton Gamma Ray Observatory, while Costa led the development of the Dutch-Italian satellite BeppoSAX.
- **Benjamin A. Mazin**, University of California, Santa Barbara, received the 2010 PECASE award. He was recognized for outstanding contributions to the development of ultra-sensitive, low-temperature detector arrays that provide energy resolution and arrival timing for photons from X-rays to the near infrared.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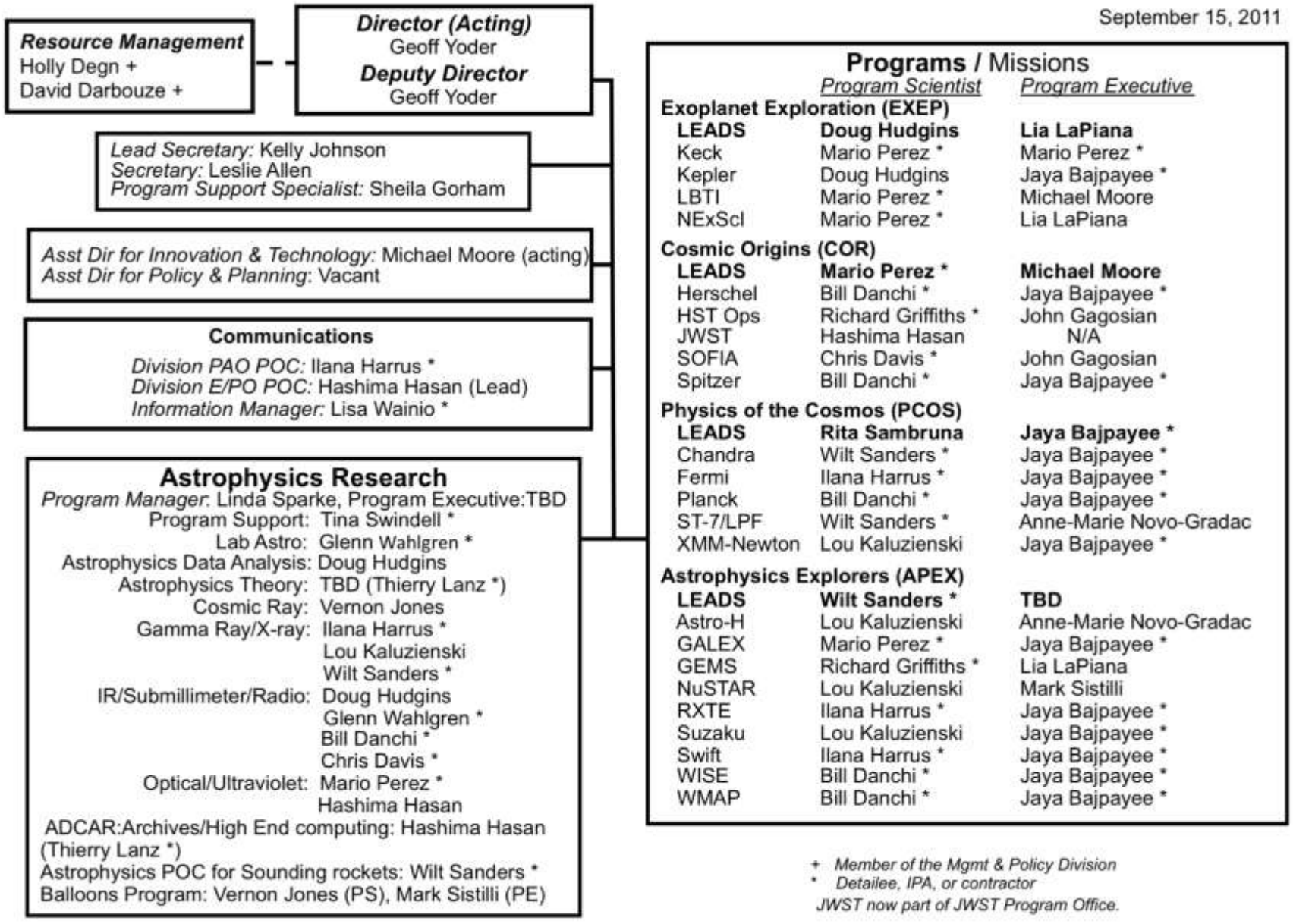
Astrophysics Division Organization Chart



Programmatic Special Topics
Astrophysics Division

- **Improving Communications**
  - New Astrophysics Division Communication Plan created.
    - Concise, accurate, and timely communication to internal and external stakeholders is critical.
    - Improve communication with the scientific community and the public.
    - SMD Astrophysics website will evolve to provide additional info.
  - New Quarterly Program Office meeting will:
    - Improve communication between the Program Offices.
    - Use the Program expertise.
    - Build outreach.
  - Astrophysics Division Website:
    - *http://science.nasa.gov/astrophysics/*

Astrophysics Division

Top 10+1 Science Highlights of the Year

- **Fermi** Discovers Giant Structure in Our Galaxy (November 9, 2010)
- **Chandra** Finds Youngest Nearby Black Hole (November 15, 2010)
- **Kepler** Mission Discovers Its First Rocky Planet (January 10, 2011)
- **Fermi** Catches Thunderstorms Hurling Antimatter into Space (January 10, 2011)
- **Gravity Probe B** Confirms Two Einstein Space-Time Theories (May 4, 2011)
- **GALEX** Helps Confirm Nature of Dark Energy (May 19, 2011)
- **Hubble/Spitzer** Telescopes Discover Surprisingly Young Galaxy (April 12, 2011)
- **Herschel** Helps Solve Mystery of Cosmic Dust Origins (July 7, 2011)
- **WISE** Earth's First Trojan Asteroid Discovered – Neo-WISE Planetary (July 27, 2011)
- **Swift** Spots Black Hole Devouring a Star (August 24, 2011)
- **Kepler** Discovers First Planet Orbiting Two Stars (September 15, 2011)