White Papers

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Disclaimer:

Direct information almost entirely from being chair of “Planetary Systems and Star Formation”, one of five ”Science Frontier Panels” in Astro 2020

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

Call to the Astronomy & Astrophysics Community for Science White Papers

Submit in PDF via the web form that will be linked to

http://nas.edu/astro2020.html

Submissions must be made between 12:01am EST, Monday 7 January 2019 and 11:59pm Friday 18 January 2019

White papers should identify a primary thematic science area (and, if relevant, a secondary area) from the list below, and should specifically and succinctly identify new science opportunities and compelling science themes, place those in the broader international scientific context, and describe the key advances in observation, experiment, and/or theory necessary to realize those scientific opportunities within the decade 2020-2030.

Planetary systems; Stars and stellar evolution; Formation and evolution of compact objects; Resolved stellar populations and their environments; Galaxy evolution; Cosmology and fundamental physics; Multi-messenger astrophysics

White papers should:

1. Identify scientific opportunities and compelling scientific themes for the coming decade, particularly those that have arisen from recent advances and accomplishments in astronomy and astrophysics;

2. Describe the scientific context of the importance of these opportunities, including connections to other parts of astronomy and astrophysics and, where appropriate, to the advancement of our broader scientific understanding;

3. While focusing on science, not specific missions or projects, describe and quantify the key advances in observation, measurement, theory, and/or computation necessary to realize the scientific opportunities within the decade 2020-2030 and beyond.

- Focus on detailed presentations of important science opportunities rather than broad studies
- Directly identify opportunities and potential observations and/or theory to address them
- *Collaborative efforts are encouraged*
- *A major activity may wish to submit different white papers outlining different scientific opportunities*
- *Warning:* contributing to a white paper may not preclude service for the Survey

Probably the most useful advice I can give is to keep in mind the reader…

- PSF received 86 science white papers
- > 400 over all science areas

Therefore:

- follow instructions (page limit, font size, margins) (use template if possible)
- Focus!

5 pages (reduced from 8 pages in 2010) (I expect much use of web page links)

Skeptic: Is it really worth the effort?

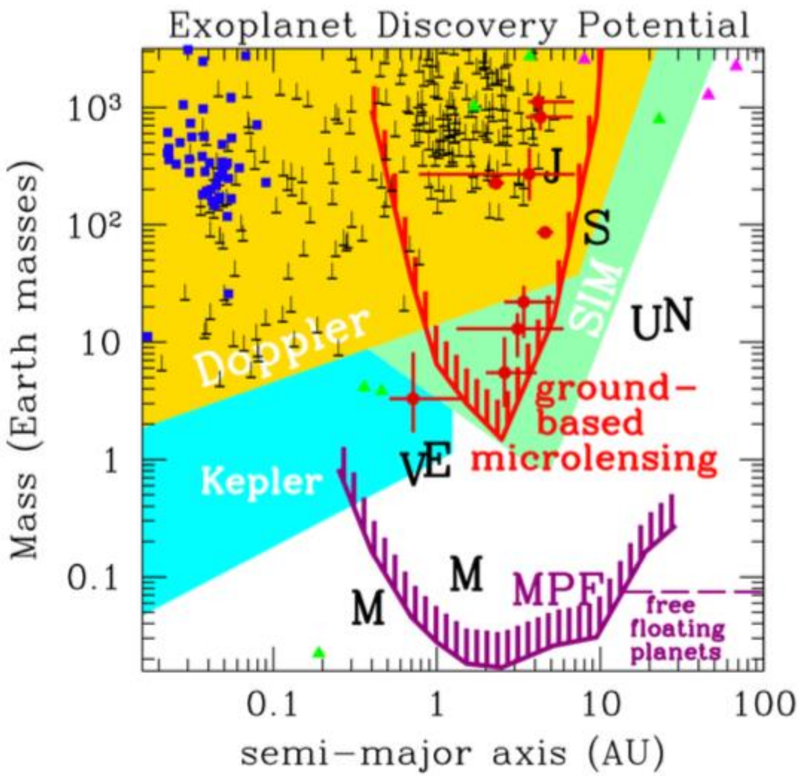
- I found them useful
- Important as any set of committee members may miss something important
- Even if the main large activities/projects are fairly well-known, their relative ranking is not

Your future…

Mission-centric example:

A Census of Exoplanets in Orbits Beyond 0.5 AU via Space-based Microlensing

White Paper for the Astro2010 PSF Science Frontier Panel



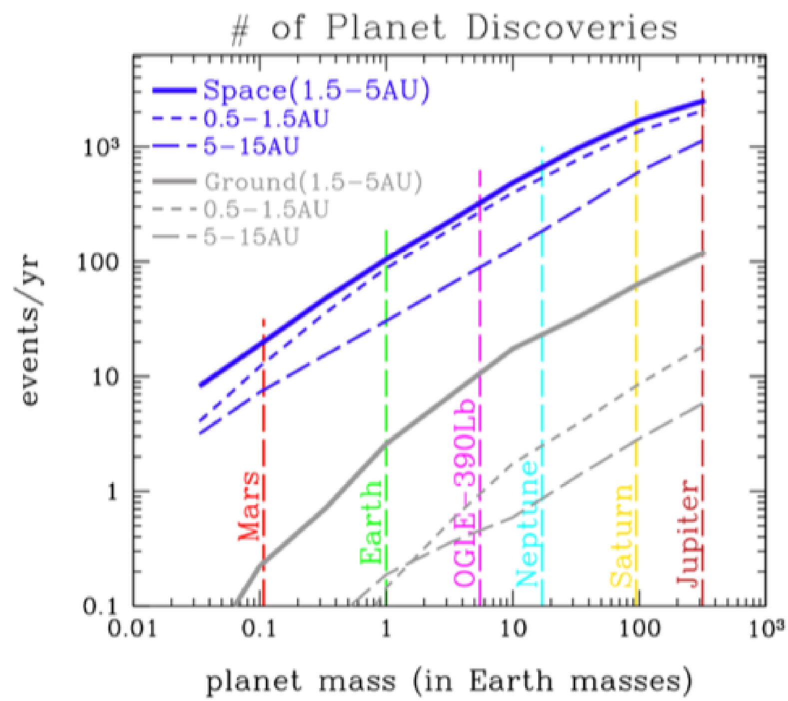


Fig. 4: *The expected number of MPF planet discoveries as a function of the planet mass if every star has a single planet in the given separation of ranges.*

Callouts:

Microlensing light curves yield unambiguous planet parameters. For the great majority of events, the basic planet parameters (planet:star mass ratio, planet-star separation) can be "read off" the planetary deviation (Gould & Loeb 1992; Bennett & Rhie 1996; Wambsganss 1997).

5. Implementation of a Space-based Microlensing Mission

A space-based microlensing mission requires a space telescope of at least 1m-aperture, with a focal plane of > 0.5 sq. deg. in the near IR (or visible) with an orbit with a continuous view the Galactic bulge. It requires no new technology, and can be accomplished with a budget of less than $300 million (excluding the launch vehicle). The Microlensing Planet Finder or MPF (shown on the cover page) is an example of such a mission (Bennett et al. 2004), which has been proposed to NASA's Discovery program. Another, very similar, design known as DUNE (for Dark Universe Explorer) had been proposed to CNES and ESA to study dark energy via the weak lensing method (Refregier et al. 2008). This remarkable similarity between these designs suggests that a joint mission could be even more cost effective.

Focus on needed capabilities:

Fragmentation in Molecular Clouds and the Origin of the Stellar Initial Mass Function

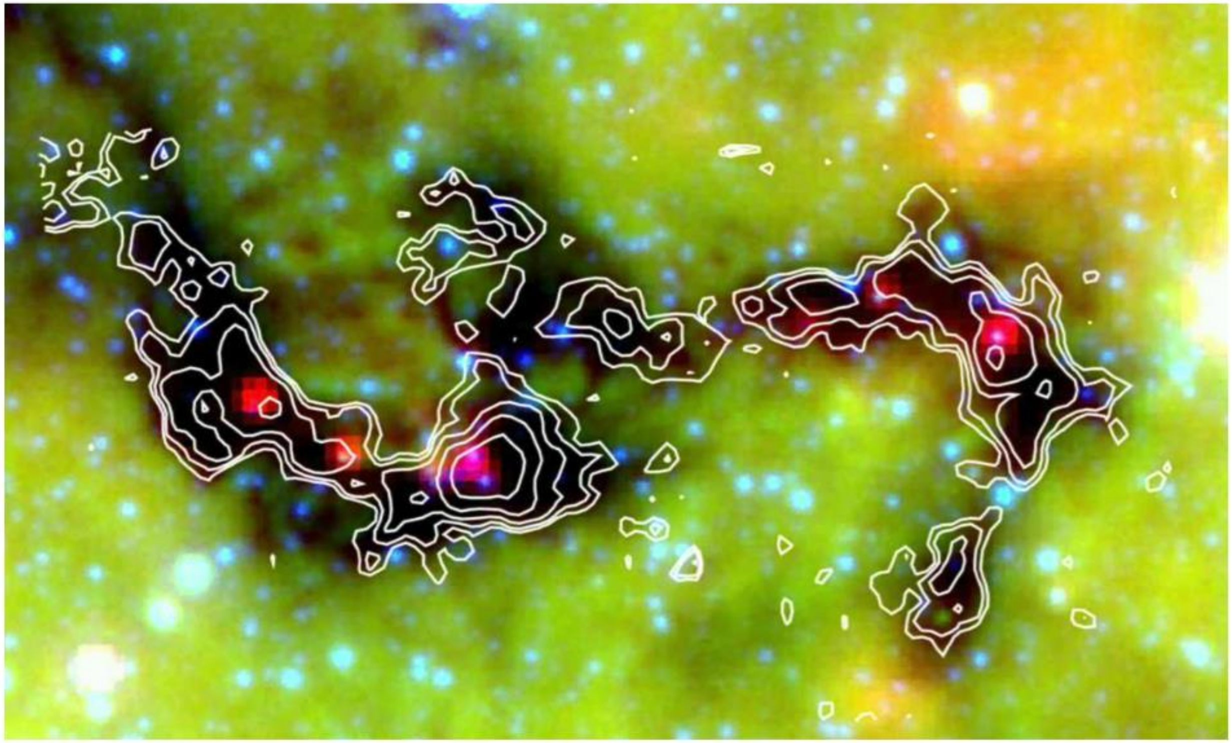


Image courtesy of C. Brogan, R. Indebetouw, & T. Hunter (NRAO)

- Short, focused introduction
- Short, focused state of field

3. Observational Goals

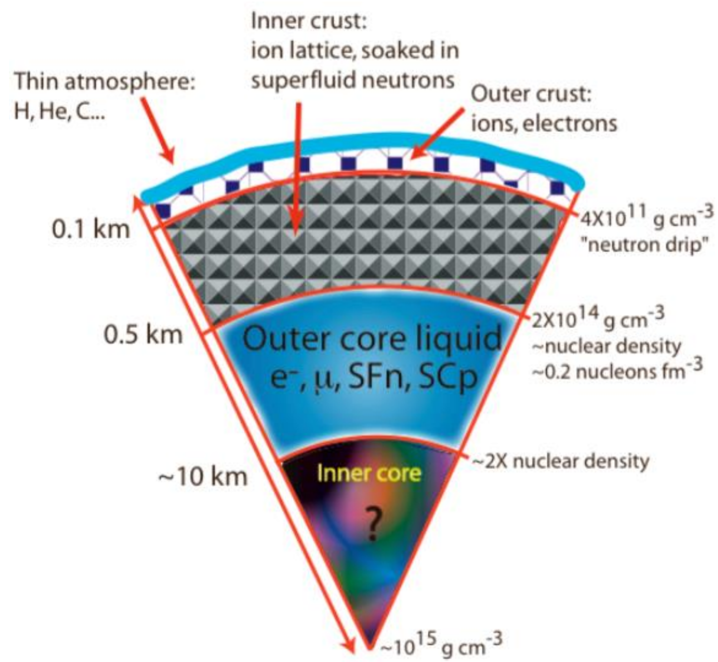
- *Sensitivity to clumps capable of forming a 0.01* $M_{\odot}$ *brown dwarf*
- *Observations of the dust continuum and molecular lines*
- *Angular resolution* $< 5''$ *to resolve 0.05 pc diameter clumps to 1 kpc*
- *Surveys over tens of square degrees to image molecular clouds*
- *Multi-wavelength observations to measure dust temperatures and emissivity*

4. Recommendations

No single instrument or telescope can satisfy all of the goals outlined in Section 3, and observations on multiple platforms will be required. Our specific recommendations are:

- **Development of next-generation, large-format bolometer cameras**
- **Continued development of heterodyne focal plane arrays**
- **Support for 25-50 m class millimeter/submillimeter telescopes**
- **Support for millimeter-wave interferometry**

X-ray Timing of Neutron Stars, Astrophysical Probes of Extreme Physics



Related Astro2010 white papers:

J. Cordes et al., *Tests of Gravity and Neutron Star Properties from Precision Pulsar Timing and Interferometry*

P. Freire et al., *Constraining the Bulk Properties of Dense Matter by Measuring Millisecond Pulsar Masses*

D. Lai et al., *Extreme Astrophysics with Neutron Stars*

F. Paerels et al., *The Behavior of Matter Under Extreme Conditions*

J. Tomsick et al., *X-ray Timing of Stellar Mass Black Holes*

Table 1. Fundamental questions of neutron star structure and dynamics.

Science Questions	Measurements Needed	Implications
What is the nature of ultra-dense matter in the interiors of neutron stars?	The mass-to-radius ratios of several neutron stars to ±5%.	Discriminate among proposed EOSs; constrain a basic unknown of nuclear physics, the nuclear symmetry energy.
What is the physics responsible for the dynamic behavior of neutron stars?	Characterization of outbursts, oscillations, and rotational irregularities.	Constrain the bulk properties of dense matter. Probe quantum phenomena in neutron stars.

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Measurement	*M*, *R* dependence	Approach
Redshift/compactness	$\beta = GM/Rc^2$	Lightcurves and spectra
Surface gravity	$g = GM/R^2$	Lightcurves and spectra
Light-bending magnified radius	$R_\infty = R \big/ \sqrt{1-2GM/Rc^2}$	Thermal spectra
Inner edge of accretion disk	$R_{\text{disk}} \geq R$	Broadened Fe lines
kHz QPO frequency (one of several theoretical relations)	$\nu_{\text{QPO}} = \sqrt{GM/4\pi^2 R_{\text{disk}}^3}$	Fast timing of X-ray binaries in outburst
Maximum mass	$M \leq M_{\max}$, for all R	Pulse timing
Minimum spin period	$P_{\min} \propto \sqrt{R^3/M}$	Pulsation searches
Fractional moment of inertia in crustal superfluid	$\Delta I/I \propto R^4/M^2$	Glitch monitoring
Seismic vibrations	Mode-dependent	Flux oscillations in flares, bursts

Observational Requirements

The key requirements to realize these opportunities are large collecting area (~4–8 m^2), fast timing ($\leq$100 μsec), and moderate spectral resolution ($E/\Delta E \sim 25$) in the ~0.2–20 keV X-ray band. The Advanced X-ray Timing Array (AXTAR), currently being studied as a MIDEX-class mission, would provide sufficient collecting area to achieve ~5% radius constraints based on the burst oscillation technique [28]. A low-cost SMEX Mission of Opportunity, the Neutron star Interior Composition Explorer (NICE) has also been proposed, providing an excellent match to the softer spectra of MSPs, to achieve ±5% radius measurements for 2–3 targets. The High Time Resolution Spectrometer detector planned for IXO will revolutionize the field by providing radius estimates for a large number of accreting and rotation-powered neutron stars.

PSF report, Astro2010

Summary of Requirements

	How do stars form?	*How do disks evolve and form planetary systems?*	*How diverse are planetary systems?*	*Can we identify the telltale signs of life on an exoplanet?*	*Can we identify and characterize a habitable, nearby exoplanet?*
Facilities expected	EVLA ALMA *Herschel* SOFIA JWST 8-10m w/AO	EVLA ALMA *Herschel* JWST 8-10m w/AO UV/vis synoptic surveys	1 m sec^{-1} RV surveys and transit followup; *Kepler*, JWST, *Spitzer* transits	1 m sec^{-1} RV surveys and transit followup; *Kepler*, JWST, *Spitzer* transits	JWST transiting-exoplanet spectroscopy
New facilities needed	30m submm telescope; 8-10m w/ MCAO; GSMT w/ extreme AO	GSMT w/ extreme AO; NIR synoptic surveys	0.1 m sec^{-1} RV; microlensing surveys ; GSMT w/ extreme AO	Earthlike planet frequency ($\eta_{\oplus}$); 10-Zody limits on exo-zodies; 0.1 μas astrometry	Census and transit survey, 10^4 nearest M dwarfs; vis/NIR RV followup
Always needed	Support for theoretical, high-performance computational, and laboratory -molecular astrophysics				

Dark Energy from a Space-Based Platform

BAO, SNIa, weak lensing

Baryon Acoustic Oscillations: JDEM offers the opportunity to measure BAO over the full sky to about the cosmic-variance limit in the range $0.7 \lesssim z \lesssim 2.0$. The challenge for an aggressive BAO survey is to acquire an unprecedented precision spectroscopic survey of ~200 million galaxies over a large effective cosmic volume. The key to achieving the requisite survey speed is to take advantage of wide field slitless spectroscopy of the bright Hα line enabled by a space mission. For $0.7 \lesssim z \lesssim 2.0$ this line falls in the NIR; a space mission evades the bright infrared glow of the Earth's atmosphere and thus makes this approach possible.

Type Ia Supernovae: Ground-based surveys in the coming decade will detect thousands of $z<1$ Type Ia supernovae. However, a space observatory is the only feasible route to obtaining ~1000 high-precision light curves in the NIR and rest-frame V band for z>0.8. At lower z the space-based calibration and NIR data will enable lower systematic errors than can be achieved from the ground.

Weak Gravitational Lensing: The weak gravitational lensing measurement is made by obtaining shear and redshift estimates for each element of the source population. The CMB or

Wide Field Imager in Space for Dark Energy and Planets

Andrew Gould

A wide-field imager in space could make remarkable progress in two very different frontiers of astronomy: dark energy and extra-solar planets. Embedding such an imager on a much larger and more complicated DE mission would be a poor science-approach under any circumstances and is a prescription for disaster in the present fiscal climate. The 2010 Decadal Committee must not lead the lemming stampede that is driving toward a DE mega-mission, but should stand clearly in its path.

While the science goals of these 3 experiments are complementary, the instrumentation is not, and hence the costs and engineering complexity are bound to spiral out of control. Moreover, we are entering an era of severe financial crisis when such exponentiating costs simply will not be tolerated.

The Promise of Low-Frequency Gravitational Wave Astronomy

Lead Author: Tom Prince (Caltech/JPL)
for
Members of the LISA International Science Team

Finding and Using Electromagnetic Counterparts of Gravitational Wave Sources

E. Sterl Phinney

Abstract

The principal goal of this whitepaper is not so much to demonstrate that gravitational wave detectors like LIGO and LISA will help answer many central questions in astronomy and astrophysics, but to make the case that they can help answer **a far greater range of questions** *if we prepare to make the (sometimes substantial) effort to identify electromagnetic counterparts to the gravitational wave sources.*

TECHNOLOGY DEVELOPMENT FOR COMPUTATIONAL RADIO ASTRONOMY: 2010-2020

Common issues in processing and computation across all wave-bands for the observational projects of the coming decade include:

i) large-scale data management,
ii) distributed, massive storage and federated databases,
iii) high-speed network connections,
iv) long-term data curation support,
v) community software development,
vi) data mining, reduction and analysis tools,
vii) common data access protocols (e.g. Virtual Observatory); and
viii) open and equitable community scientific access.

Astro2010 Technology White Paper:

Coherent Detector Arrays for Millimeter and Submillimeter Astronomy

Abstract

Progress in many areas of astronomy requires large-area surveys and observations of extended objects. This includes the cosmic microwave background, nearby galaxies, the Milky Way, and regions of star-forming regions within our galaxy. The ability to carry out such studies is critically dependent on the development of affordable high-sensitivity focal plane arrays, for both spectral line and continuum observations. We discuss a program for the next decade to develop such technology for ground-based and space-based millimeter and submillimeter astronomy. Appropriate technologies exist, but significant effort is required to make the transition from simply replicating individual pixels to approaching focal plane array design in an integrated fashion from feeds to spectrometers for spectral analysis. This advance is essential to realize the full potential of major new ground-based, suborbital, and future space facilities, and is relevant to the RMS and EOS panels. The recommended budget for this activity is $65M.

Laboratory Astrophysics and the State of Astronomy and Astrophysics

Submitted by the

American Astronomical Society Working Group on Laboratory Astrophysics
http://www.aas.org/labastro/

The last decade, however, has seen the funding reality change drastically. A number of programs that previously supported laboratory astrophysics research are no longer doing so, particularly in the critically important areas of atomic, molecular, and solid matter physics. The astronomy and astrophysics benefited from laboratory astrophysics research in these six areas without having to support them at a level anywhere close to that required to meet the actual need.

From a funding perspective, laboratory astrophysics now lies on the boundary between fields and as a result, its support is now insufficient to keep up with the demands of astronomy and astrophysics.

Increasing the Number of Underrepresented Minorities in Astronomy
Executive Summary

An Astro2010 State of the Profession Position Paper

2. <u>The primary recommendations of these papers are:</u>

For Colleges, Universities, and National Centers/Observatories:

- Commit to engaging local under-served minority communities, to encourage interest in and appreciation of math and science, and retain their interest in astronomy.
- Develop "horizontal" and "vertical" partnerships with MSIs. Form equal-stakes partnerships in research, funding, and development that reflect the mutual synergies of intellectual contribution.
- Develop internship programs that connect minority students to mentored research engagement with scientific and/or engineering staff.

For Funding Agencies:

- Substantially expand funding for programs that specifically forge linkages between MSIs and research universities.
- Provide funding incentives for broadening participation of underrepresented minorities in mission critical ways by including this in the funding criteria (e.g., NSF's "broader impacts" criterion).
- Provide opportunities for continuity of funding for astronomy education programs by establishing Federal funding cycles in the same way that research is funded.

For Professional Societies:

- Play a lead role in aggressively identifying exceptionally effective K-12 outreach programs and work to see them adopted widely, particularly in under-served communities.

Conclusions?

- there is no one style of effective white paper – groups/individuals, missions/broad applications

- *All of these are useful inputs.*

- Important as any set of committee members may miss something important
- Even if the main large activities/projects are fairly well-known, their relative ranking is not
- small-scale initiatives could be important to the futures of many early career scientists