White Papers

Lee Hartmann, University of Michigan
Disclaimer:

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

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**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.
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

Early Career Focus Session for Astro 2020
Table 1. Fundamental questions of neutron star structure and dynamics.

<table>
<thead>
<tr>
<th>Science Questions</th>
<th>Measurements Needed</th>
<th>Implications</th>
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<tbody>
<tr>
<td>What is the nature of ultra-dense matter in the interiors of neutron stars?</td>
<td>The mass-to-radius ratios of several neutron stars to ±5%.</td>
<td>Discriminate among proposed EOSs; constrain a basic unknown of nuclear physics, the nuclear symmetry energy.</td>
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<tr>
<th>Measurement</th>
<th>$M, R$ dependence</th>
<th>Approach</th>
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<tr>
<td>Redshift/compactness</td>
<td>$\beta = GM/Rc^2$</td>
<td>Lightcurves and spectra</td>
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<tr>
<td>Surface gravity</td>
<td>$g = GM/R^2$</td>
<td>Lightcurves and spectra</td>
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<tr>
<td>Light-bending magnified radius</td>
<td>$R_\infty = R \sqrt{1 - 2GM/Rc^2}$</td>
<td>Thermal spectra</td>
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<tr>
<td>Inner edge of accretion disk</td>
<td>$R_{\text{disk}} \geq R$</td>
<td>Broadened Fe lines</td>
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<tr>
<td>kHz QPO frequency (one of several theoretical relations)</td>
<td>$\nu_{QPO} = \sqrt{GM/(4\pi^2R_{\text{disk}}^3)}$</td>
<td>Fast timing of X-ray binaries in outburst</td>
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<tr>
<td>Maximum mass</td>
<td>$M \leq M_{\text{max}}, \text{ for all } R$</td>
<td>Pulse timing</td>
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<td>Minimum spin period</td>
<td>$P_{\min} \propto \sqrt{R^3/M}$</td>
<td>Pulsation searches</td>
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<td>Fractional moment of inertia in crustal superfluid</td>
<td>$\Delta I/I \propto R^4/M^2$</td>
<td>Glitch monitoring</td>
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<td>Seismic vibrations</td>
<td>Mode-dependent</td>
<td>Flux oscillations in flares, bursts</td>
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Early Career Focus Session for Astro 2020
Observational Requirements

The key requirements to realize these opportunities are large collecting area ($\sim$4–8 m$^2$), fast timing ($\leq$100 µsec), and moderate spectral resolution ($E/\Delta E \sim 25$) in the $\sim$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 $\sim$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 $\pm$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.
<table>
<thead>
<tr>
<th>Facilities expected</th>
<th>How do stars form?</th>
<th>How do disks evolve and form planetary systems?</th>
<th>How diverse are planetary systems?</th>
<th>Can we identify the telltale signs of life on an exoplanet?</th>
<th>Can we identify and characterize a habitable, nearby exoplanet?</th>
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<tr>
<td>EVLA</td>
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<td>1 m sec(^{-1}) RV surveys and transit followup; Kepler, JWST, Spitzer transits</td>
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<td>JWST transiting-exoplanet spectroscopy</td>
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<td>8-10m w/ AO</td>
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<td>8-10m w/ AO</td>
<td>UV/vis synoptic surveys</td>
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<td>New facilities needed</td>
<td>30m submm telescope; 8-10m w/ MCAO; GSMT w/ extreme AO</td>
<td>0.1 m sec(^{-1}) RV; microlensing surveys; GSMT w/ extreme AO</td>
<td>Earthlike planet frequency ((\eta_\odot)); 10-Zody limits on exo-zodies; 0.1 (\mu)as astrometry</td>
<td>Census and transit survey, 10^4 nearest M dwarfs; vis/NIR RV followup</td>
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<td>Always needed</td>
<td>Support for theoretical, high-performance computational, and laboratory -molecular astrophysics</td>
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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 $0.7 \leq z \leq 2.0$. 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 $0.7 \leq z \leq 2.0$ 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.
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. The primary recommendations of these papers are:

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