March 27 2009

Dear Astro2010 Committee:

Thank-you for the invitation to hold Town Halls in support of the Decadal process. This is a report on the town hall held in Cambridge MA on March 19 2009. The Agenda for the meeting is attached.

Attending from the Decadal committees:
John Huchra, Meg Urry, Deepto Chakrabarty, Jim Moran, Alyssa Goodman, Rob Fesen

Attending from Cambridge area: 102 individuals registered, list is attached.

Summary: As can be seen from the Agenda, after some discussion of the process, the AM was largely devoted to discussion of science opportunities for the next decade, and the PM was largely devoted to discussion of 'State of the Profession' issues and how the Astro2010 report might effect these. Each of the 5 minute talks was accompanied by a single handout, all of which are attached.

Individual discussion/concerns (in roughly the order discussed):

There was concern that the process allow for a connection between the technology and science white papers – ie, that the different groups within Astro2010 do communicate with each other.

Graduate students wanted to be kept informed – some of them in the audience felt that the current efforts by Astro2010 were not sufficient, but there was an email to grad students just the previous day.

There was concern that 'exit ramps' or 'sunset clauses' needed to be included in the Astro2010 writeup, and that not including them in past reports was a mistake.

There was concern that the CAA and AAAC have overlapping and conflicting roles which limit the effectiveness of both. The selection process for the CAA membership was held up as representative of the astronomy community, while the AAAC appointment process [each agency appointing its own members] was not. A related concern was that the Astro2010 report will need a mechanism for maintenance which stays in place until the next Decadal report.

There were several suggestions about ways to increase the role (and funding) for astronomy. These included making connections to:

1) Economic competitiveness – astronomy resonates well with the public, everybody gets excited about the big bang and black holes, this can be used to t each real concepts
2) Green technologies – there is a white paper on this coming
3) Education – The 'U-Teach' undergraduate program, funded partly by Exxon/Mobil and the Gates Foundation, has increased undergrad astro enrollment

at one school by 3x (Fesen/Waller/Zirbel papers) due to its emphasis on a teaching degree.
4)Network connectivity – As evidence by MicroSoftSky and GoogleSky, there is great commercial interest in astronomy. Our data volumes will challenge current networks, and this commercial interest can be exploited to our advantage.

The papers on funding and employment (Garcia, Seth, Waller) generated lengthy discussion. There was agreement that GO funding for the Great Observatories has had a significant impact on the field by allowing open ended but non-tenured soft money positions. There was no value judgment made on this impact, but comments were made that this has allowed an explosion of new science to be done, and that this funding mechanism could cause mid-life career changes. Interestingly, members of the audience in tenured positions held the belief that soft money positions allowed a person to do MORE science than a tenured position, while members in soft money positions felt that tenured positions allowed more science to be done. Both sides of the debate agreed that more science was better! The opinion that support should continue throughout the entire career was voiced. These demographics could change dramatically if the DOE/HEP community gets into Astronomy in a big way – 50% of DOE scientists questioned said that they planned to do astronomy in the next decade, and this community is 10x larger than the current Astronomy community.

Funding in the UK was brought up as a concern and an opportunity. Funding levels there have dropped dramatically, which may be an opportunity for the US to step up and make some beneficial arrangements.

Gender/Minority balance was discussed – while astronomy has made great strides in gender equity, it has not done so on the minority front.

Finally, the structure of the Astro2010 committees was seen as overly complex, and likely to lead to an even more complex Astro2020 process. This concern was allayed to some extent by the comment that the report will be limited to 40+40 pages, and cannot possibly include everything – only the most timely and interesting things.

Respectfully submitted, Michael Garcia, Dan Patnaude,Alicia Soderberg, Deepto Chakrabarty, Jonathan Grindlay.

AGENDA, ASTRO2010 TOWN HALL, MARCH 20, 2009
Hosted by Smithsonian, Harvard, and MIT, and held at
The American Academy for the Arts and Sciences, Cambridge MA.

10:00	10:05	Welcome and Plan for Today	M. Garcia
10:05	10:35	Astro2010 Report	J. Huchra, M. Urry
10:35	10:40	Q/A	
10:40	10:45	Astro2010 CDH Report	Alyssa Goodman
10:45	10:50	How will we cope with the data flood	Doug Burke
10:50	11:45	9 x 5-min talks	
		Ground Based OIR Facilities	Christopher Stubbs
		Magnetic Activity in Low Mass Stars	Andrew West
		Stellar Archaeology in the Next Decade	Cohen et al.
		Cosmic Inflation Probe	Gary Melnick
		Soft X-ray Polarimetry	Herman Marshall
		EXIST	Josh Grindlay
		Relativistic Gravitation	Rainer Weiss
		Structure and Dynamics, MW	Mark Reid
		TESS	David Latham
11:45	12:15	Q/A on 5 min talks	
12:15	1:15	Lunch on site	
1:15	2:10	9 x 5-min talks	
		Astrostats	A. Siemiginowska
		Astrostats, DEM	Vinay Kashyap
		Observatory Class Missions	Michael Garcia
		Employment and Funding	Anil Seth
		Undergraduate Institutions	Frank Winkler
		Public Outreach	Esther Zirbel
		Funding	Thomas Beatty
		Workforce Development	William Waller
2:10	2:40	Q/A on 5 min talks	
2:40	3:10	Open Mic for 30min	
3:10	3:30	Replies to Astro2010 Committees, Wrapup and Adjurn	

REGISTRANTS:

aaccomazzi@cfa.harvard.edu	Alberto	Accomazzi
calcock@cfa.harvard.edu	Charles	Alcock
ballen@cfa.harvard.edu	Branden	Allen
tbeatty@space.mit.edu	Thomas	Beatty
eberger@cfa.harvard.edu	Edo	Berger
jeffb@space.mit.edu	Jeffrey	Blackburne

rblum@noao.edu	Robert	Blum
bodtim@mit.edu	Tim	Bodiya
jbookbinder@cfa.harvard.edu	Jay	Bookbinder
bram.boroson@gmail.com	Bram	Boroson
bradt@mit.edu	Hale	Bradt
dburke@cfa.harvard.edu	Douglas	Burke
bcain@mit.edu	Benjamin	Cain
calzetti@astro.umass.edu	Daniela	Calzetti
ncarleton@cfa.harvard.edu	Nathaniel	Carleton
deepto@space.mit.edu	Deepto	Chakrabarty
jchristi@cfa.harvard.edu	Jessi	Christiansen
aconnors@eurekabayes.com	Alanna	Connors
aconstantin@cfa.harvard.edu	Anca	Constantin
kcovey@cfa.harvard.edu	Kevin	Covey
tdelaney@space.mit.edu	Tracey	DeLaney
rd@cfa.harvard.edu	Rosanne	Di Stefano
dupree@cfa.harvard.edu	Andrea	Dupree
nevans@cfa.harvard.edu	Nancy	Evans
gfazio@cfa.harvard.edu	Giovanni	Fazio
Robert.Fesen@dartmouth.edu	Robert	Fesen
rfoley@cfa.harvard.edu	Ryan	Foley
jfoster@cfa.harvard.edu	Jonathan	Foster
afrebel@cfa.harvard.edu	Anna	Frebel
gaetz@cfa.harvard.edu	Terry	Gaetz
garcia@head.cfa.harvard.edu	Michael	Garcia
mauro@astro.umass.edu	Mauro	Giavalisco
golub@cfa.harvard.edu	Leon	Golub
agoodman@cfa.harvard.edu	Alyssa	Goodman
goren@cfa.harvard.edu	Paul	Gorenstein
alex@qotw.net	Alex	Grant
pgreen@cfa.harvard.edu	Paul	Green
greenhill@cfa.harvard.edu	Lincoln	Greenhill
josh@head.cfa.harvard.edu	Josh	Grindlay
ralf@space.mit.edu	Ralf	Heilmann
jhewitt@mit.edu Jacqueline	Hewitt	
jeroen@space.mit.edu	Jeroen	Homan
huchra@cfa.harvard.edu	John	Huchra
kej@bu.edu	Katie	Jameson
karovska@cfa.harvard.edu	Margarita	Karovska
vkashyap@cfa.harvard.edu	Vinay	Kashyap
jkasper@cfa.harvard.edu	Justin	Kasper
kats@mit.edu	Erik	Katsavounidis
dkeres@cfa.harvard.edu	Dusan	Keres
kkorreck@cfa.harvard.edu	Kelly	Korreck
jmkovac@caltech.edu	John	Kovac
dlatham@cfa.harvard.edu	David	Latham
hlee@cfa.harvard.edu	Hyunsook	Lee
jfliu@cfa.harvard.edu	Jifeng	Liu
hermanm@space.mit.edu	Herman	Marshall
lmatthew@haystack.mit.edu	Lynn	Matthews
jem@cfa.harvard.edu	Jeff	McClintock
gmelnick@cfa.harvard.edu	Gary	Melnick
dmink@cfa.harvard.edu	Doug	Mink
smohanty@cfa.harvard.edu	Subhanjoy	Mohanty
moran@cfa.harvard.edu	James	Moran
gmuench@cfa.harvard.edu	August	Muench
kdmurphy@space.mit.edu	Kendrah	Murphy

ssm@head.cfa.harvard.edu	Stephen	Murray
rmurray-clay@cfa.harvard.edu	Ruth	Murray-Clay
mnowak@space.mit.edu	Michael	Nowak
pnulsen@cfa.harvard.edu	Paul	Nulsen
roleary@cfa.harvard.edu	Ryan	O'Leary
mpahre@cfa.harvard.edu	Michael	Pahre
dpatnaude@cfa.harvard.edu	Dan	Patnaude
pavelmi@bu.edu	Michael	Pavel
jpineda@cfa.harvard.edu	Jaime	Pineda
andreap@head.cfa.harvard.edu	Andrea	Prestwich
jraymond@cfa.harvard.edu	John	Raymond
reid@cfa.harvard.edu	Mark	Reid
sromaine@cfa.harvard.edu	Suzanne	Romaine
aseth@cfa.harvard.edu	Anil	Seth
ishapiro@cfa.harvard.edu	Irwin	Shapiro
asiemiginowska@cfa.harvard.edu	Aneta	Siemiginowska
slane@cfa.harvard.edu	Patrick	Slane
bstalder@cfa.harvard.edu	Brian	Stalder
jsteiner@cfa.harvard.edu	James	Steiner
cstubbs@fas.harvard.edu	Christopher	Stubbs
mengsu@cfa.harvard.edu	Meng	Su
ht@cfa.harvard.edu	Harvey	Tananbaum
matthewt@aavso.org	Matthew	Templeton
vtolls@cfa.harvard.edu	Volker	Tolls
rtuellmann@cfa.harvard.edu	Ralph	Tuellmann
maureen@head.cfa.harvard.edu	Maureen	van den Berg
svrtilek@cfa.harvard.edu	Saeqa	Vrtilek
william.waller@tufts.edu	William	Waller
kwang@cfa.harvard.edu	Ke	Wang
weiss@ligo.mit.edu	Rainer	Weiss
aaw@mit.edu	Andrew	West
dwilner@cfa.harvard.edu	David	Wilner
winkler@middlebury.edu	Frank	Winkler
swolk@cfa.harvard.edu	Scott	Wolk
pwu@bu.edu	Pin	Wu
swuyts@cfa.harvard.edu	Stjin	Wuyts
zhao@cfa.harvard.edu	Ping	Zhao
ezirbel@gmail.com	Esther	Zirbel

Handout re: Alyssa Goodman's short report on the activities of the "Data" side of the **Infrastructure Study Group on "Computation, Simulation and Data Handling,"** to be offered March 20, 2009.

Astro2010 Infrastructure Study Groups

(Go to Astro2010 main web page)

The Astro2010 survey is being carried out by a survey committee. The committee will be supported by a series of panels and study groups. For information on the structure and work plan of the entire survey, click here.

The infrastructure study groups (ISGs) will assist the Subcommittee on State of the Profession by gathering current information on infrastructure, broadly defined. The ISGs will be a set of community activities comprised of consultants appointed to the survey process and operating under terms of reference provided by the State of the Profession subcommittee. There will be six ISGs.

1. *Computation, Simulation, and Data Handling (CDH).* Summarize existing computational resources and support for acquisition, analysis, and archiving of astronomical data and document needs and schedules for acquiring this capability for future projects for which the data analysis challenges are anticipated to be large. Summarize resources and support available for astrophysical and cosmological simulation and match possible simulation goals to computing capacity. Identify major challenges and changes in computing environments and software and report on expected availability of affordable computing cap ability over the next decade.

   CDH Consultants

   Robert Hanisch, Space Telescope Science Institute, Co-Chair
   Lars Hernquist, Harvard University, Co-Chair
   Thomas Abel, Stanford University
   Keith Arnaud, NASA Goddard Space Flight Center
   David Arnett, University of Arizona
   Tim Axelrod, LSST
   Alyssa Goodman, Harvard-Smithsonian CfA
   Kathryn Johnston, Columbia University
   Andrey Kravtsov, University of Chicago
   Kristen Larson, Western Washington University
   Carol Lonsdale, NRAO
   Mordecai-Mark Mac Low, American Museum of Natural History
   Michael Norman, University of California, San Diego
   Richard Pogge, The Ohio State University
   James Stone, Princeton University

How will we cope with the “data flood”?

Astroinformatics & Astrostatistics

Astroinformatics ⇒ the formalization of data-intensive astronomy and astrophysics for research and education.

The Astronomical Informational Sciences: A Keystone for 21st-Century Astronomy

Thomas Loredo (Dept. of Astronomy, Cornell University)
http://www8.nationalacademies.org/astro2010/DetailFileDisplay.aspx?id=439

> “... vigorous growth of these new disciplines is crucial to the health of twenty-first century astronomy, but that they are poorly served by existing support structures in astronomy and information sciences.”

Astroinformatics: A 21st Century Approach To Astronomy

Kirk Borne (Dept. of Computational and Data Sciences, George Mason University)
http://www8.nationalacademies.org/astro2010/DetailFileDisplay.aspx?id=455

> “Now is the time for the recognition of Astroinformatics as an essential methodology of astronomical research. The future of astronomy depends on it.”

Recommendations from “The Astronomical Informational Sciences” paper

(1) Research funding must involve explicit partnerships between discipline-specific funding sources, all the way down to the level of review panels, which must be interdisciplinary.

(2) Research funding must be sustained, and take an integrated, multi-faceted approach to supporting the variety of Astro/Info research activities.

(3) There must be substantive support for Astro/Info training of young scientists in both astronomy and the information sciences.

(4) Community support mechanisms must be created to foster communication and resource sharing among Astro/Info scientists, between the Astro/Info community and its partner disciplines, and between the Astro/Info community and funding agencies.

http://practicalastroinformatics.org/
http://inference.astro.cornell.edu/Astro2010/

Some Thoughts on Prioritization for Ground-based OIR Facilities.

Christopher Stubbs, Feb 28, 2009.
cstubbs@fas.harvard.edu

- This will be a difficult decade for the nation. Although the new administration's draft budget plan contains generous proposed funding for science, it's imperative that we choose our priorities wisely. Furthermore, in this economic climate we cannot take for granted the historical philanthropic support for large ground-based telescopes.

- Astronomy is a discovery-driven science. An important figure of merit for our field is the number of astronomers on the sky each night, doing science, using a diversity of apertures and an evolving suite of instruments.

- There is however considerable tension between sustaining legacy facilities and building new ones. The ongoing operations cost for the cumulative growth in observing facilities limits our opportunity to fund and operate new telescopes. So we must strike the right balance between the (astronomers*nights) figure of merit and the added capability of expensive new facilities.

- The cost of a telescope grows faster than its collecting area, so photons gathered with a big telescope are more expensive than those collected with a smaller one. For a fixed collecting area, the primary argument for a single filled aperture is achieving improved angular resolution. For a 20-30 m aperture on the ground this requires a working MCAO system, and I claim that to date we have not yet reaped the scientific benefits commensurate with the investment in AO. It's not yet a fully mature technology.

- As a field, astronomy runs the risk of following the trajectory of experimental particle physics, where there is now only one main facility in the world (the LHC) for the entire field. As the costs of large aperture ground-based systems move into the billion-dollar regime, the capital and operating costs of one or two telescopes could consume all our resources. We can and should avoid this fate! Some of today's best astronomy is being done with modest apertures.

The facts and assertions listed above lead me to the following conclusions:

1. In the coming decade we will likely establish at most one major new ground-based OIR system. We should therefore focus our attention on which project is at the top of the survey's list, and we should not shy away from making that choice.

2. Unless the advocates for 20-30 m telescopes can *demonstrate* routinely achieving quantitative exploitation of high angular resolution AND can provide a *compelling* science case (per dollar invested) for this regime, we're better off with more, smaller aperture systems.

3. The sweet spot for the decade ahead is to build and run LSST in conjunction with our legacy observing systems, and to continue the technical and scientific development of AO on existing systems. LSST has a tremendous multiplicative "nonlinear scientific gain" by empowering parallel science (from the solar system to cosmology) with the *same* image stream, and it will usher in an era of time domain astronomy. For example, a 2m telescope can get to the LSST single-frame imaging depth with a 120 second integration, and can easily pounce on LSST alerts.

Some disclaimers: The views expressed here do not represent those of the CfA, Harvard's Department of Physics or Department of Astronomy, the LSST Corporation and management, or any of the various national committees on which I serve. I am right, though.

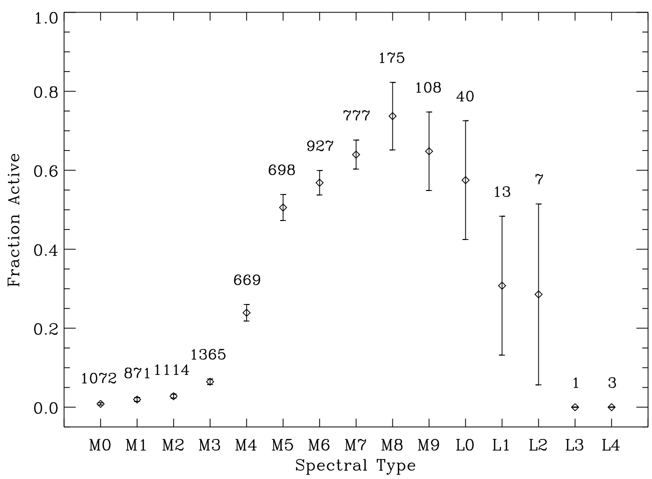
Magnetic Activity in Low–Mass Stars (WP Summary)[1]

Andrew A. West (MIT), Lucianne Walkowicz (UC Berkeley), Matthew K. Browning (CITA) et al.

Low-mass dwarfs (M < 0.6 $M_\odot$; M and L dwarfs) are the most numerous stellar constituents of the Milky Way (∼75% by number; Covey et al. 2008a; Bochanski et al. 2009) and have main sequence lifetimes that exceed the age of the Universe. They are also host to strong magnetic fields that heat the upper atmosphere and create emission or "activity" from the X-ray to the radio. In the optical, we have amassed M dwarf samples that exceed 50 million members photometrically and almost 100,000 spectroscopically (West et al. 2008; Bochanski et al. 2009). With this statistical foothold, we can use low–mass dwarfs to probe the structure, dynamics and evolution of the local Milky Way.

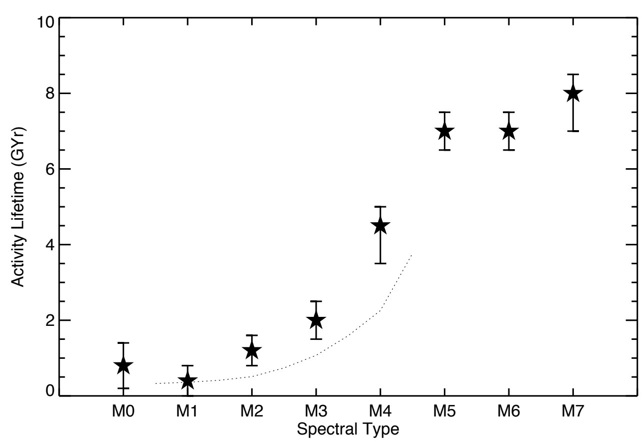
Potential Planet Hosts: Low-mass dwarfs may also represent the largest ensemble of potential planet hosting stars. Their strong magnetic activity may affect the atmospheres and habitability of attendant planets – in particular at the high energy end of the electromagnetic spectrum.

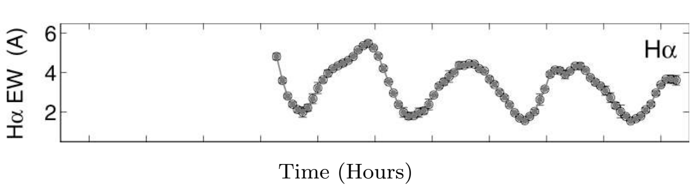
Probes of Stellar Interiors: In addition, low-mass dwarfs probe an interesting transition in the interiors of stars. Like the Sun, early type M dwarfs (M0-M3) have both radiative and convective zones, which have solid body and differential rotation respectively. The transition between these (dubbed the tachocline) is thought to be responsible for setting up a rotational shear and generating the magnetic field (Parker 1993). At around (and later than) a spectral type of M4 (∼ 0.35 $M_\odot$), stars become fully convective.



Despite their different internal structure, late-type M dwarfs are *very* active. In fact, the fraction of active stars (as measured by the Hα emission line) peaks around a spectral type of M7-M8 (see figure to the left; from West et al. 2004). Although a lot of work has focused on understanding the multi-wavelength emission from M dwarfs (e.g. Walkowicz et al. 2008; Berger et al. 2008; Covey et al. 2008b), most studies have concentrated on the easiest-to-observe tracer of M dwarf magnetic activity: Hα.

What do we know? Hα activity lifetimes derived from the activity and dynamics of ∼40,000 M dwarfs show a significant increase at the onset of full convection (see figure to the right; from West et al. 2008). We also observe that magnetic activity can be time-variable, producing both large stellar flares (1.3 flares/hr/deg^2; Kowalski et al. 2009) and small-scale variation in the quiescent emission (see figure below; from Berger et al. 2008). *Does emission at other wavelengths have the same time domain behavior (at both the short and long scales)?*





What is needed?

- Large, deep non-optical surveys (particularly in the X-ray and UV)
- Time domain studies of flares and small-scale variability

[1]For references see: http://www8.nationalacademies.org/astro2010/DetailFileDisplay.aspx?id=270

The Role of Stellar Archaeology in the Next Decade

Cohen et al.: Extremely Metal-Poor Stars: The Local High Redshift Universe
Kirby et al.: The Role of Dwarf Galaxies in Building Large Stellar Halos
Mcwilliam et al.: First Stars, Supernovae, Nucleosynthesis and Galactic Evolution

Anna Frebel (CfA, afrebel@cfa.harvard.edu), T. Beers, J. Bullock, J. Cohen, M. Geha, K. Gilbert, J. Kalirai, M. Kaplinghat, E. Kirby, M. Kuhlen, J. Johnson, D. Lai, S. Majewski, A. McWilliam P. Guhathakurta, C. Rockosi, B. Robertson, S. Shectman, J. Simon, C. Sneden, M. Zemp

Extremely Metal-Poor Stars: The Local High Redshift Universe

Extremely metal-poor (EMP) stars can only have formed in the early Galaxy. They represent the local equivalent of the high redshift universe. With them, we can study the first supernovae, the early chemical evolution of the Galaxy, and the history of star formation in the Milky Way ("stellar archaeology"). By analogy we learn about those epochs of early galaxy formation that are currently at such high redshifts that they are beyond the reach of even the largest existing telescopes. By studying the oldest stars we learn about early SN progenitor stars (e.g., initial mass, mass loss history, nucleosynthesis history), the details of the explosion (energy, ejected mass, mixing), the initial mass function or mixing of enriched stellar ejecta from the first stars throughout the gas within a dark matter halo in the early Universe, or both of these. Theoretical simulations have many free or poorly known parameters. They are best guided by observations of metal-poor stars.

The Current Situation

We know that EMP stars (i.e. those with [Fe/H] < -3) are rare and that ultra-metal poor stars with [Fe/H] < -4 are extremely rare. Currently, only three ultra-metal-poor stars are known, two of them are [Fe/H] < -5. Their abundance signatures provide unprecented constraints in theoretical modeling of the first stars and SNe, and early star- and galaxy formation. The hard limit for high-resolution, high-S/N spectroscopy for detailed chemical abundances is currently 16-17th magnitude. This is were the outer halo only begins. Many candidates from the Hamburg/ESO survey and most of SDSS and future Skymapper and LAMOST targets will be in the brightness regime and fainter. Radioactive age dating of the oldest stars is possible if thorium and uranium are dectected in a rare subgroup of metal-poor stars. Despite large efforts only three extremely rare "uranium-stars" have been found by now. This measurement requires very high S/N (> 350 at 4000 Å). Hence, the current hard limit is at $\sim 13th$ mag. The discovery of these rare objects has greatly improved our understanding of nucleosynthesis beyond the Fe-peak, where neutron-capture processes dominate. This provides the a crucial test bed for laboratory spectroscopy and the only empirical constraints on nuclear physics experiments and theories regarding the origin of heavy nuclei. EMP stars are now also found in faint dwarf galaxies (stars with > 17 mag). Comparing their early chemical signature with those of old halo field stars provides crucial observational constraints on λCDM models which are used to simulate the hierarchical formation of galaxies. This observationally addresses the question of whether the surviving dwarf galaxies could potentially be the building blocks of the Mily Way.
All this work requires telescopes which are larger than the current facilities and equipped with a high dispersion spectrograph with high efficiency throughout in the optical wavelength regime.

For the Next Decade, our Main Aim is to

Reach out into the outer Galactic halo and faint dwarf galaxies to find and study more stars at the lowest metallicities, i.e., [Fe/H] < -4 which are currently inaccessible. We may also be able to uncover the signatures of a massive Pop III pair-instability SN in a metal-poor star. Databases from which candidates can be identified for the next decade will come from the SEGUE-1 and SEGUE-2 projects (part of SDSS–II and SDSS–III), and from the LAMOST survey telescope in China, which has a 4000 fiber multi-object spectrograph. The Australian Skymapper survey will also provide numerous metal-poor candidates.

Instrumental Requirements for Stellar Archaeology in the Next Decade

An EMP search in addition to the surveys listed above will need a wide field, highly multiplexed, high throughput, moderate resolution spectroscopic facility to find the most promising candidates in the halo and dwarf galaxies. An extremely large telescope is required with the capability for high-resolution spectroscopy down to the UV atmospheric cutoff since spectroscopic line density increases with decreasing wavelength.

Cosmic Inflation Probe (CIP)

A NASA-Funded Astrophysics Medium-Class Strategic Mission Concept

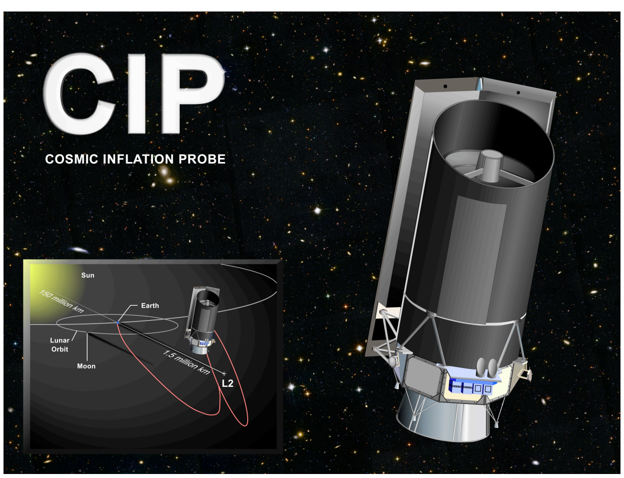
Understanding Inflation is fundamental to understanding the force(s) that shaped the observable Universe. During the interval between about 10^{-36} and 10^{-34} seconds after $t = 0$, Inflation is believed to have driven the Universe into faster-than-light expansion causing its size to grow by a factor of $\sim 10^{43}$ (~ 100 e-foldings). Inflation thus endowed the Universe with many of its most characteristic features, such as the:

- Initial density fluctuations which provided the seeds for galaxy formation and large-scale structure
- Isotropy of the cosmic microwave background (CMB) radiation
- Flatness of space

Inflation saves the Big Bang model by providing a natural explanation for these otherwise unexplained features of our Universe. Yet, despite the indispensable role it plays in our understanding of the Universe, the physics that drove Inflation remains undetermined and largely unconstrained, although models abound.

The Cosmic Inflation Probe (CIP) is a Medium-Class space mission whose focus is the study of the physics that drove the Big Bang. Specifically, CIP is designed to conduct a redshift survey capable of detecting more than 100 million objects between a z of 1.8 and 6.5 and would enable measurement of the galaxy power spectrum, $P(k)$, to better than 1% over length scales of 1 to 100 Mpc. The goal is to use these data to estimate the shape of the primordial power spectrum, convert it to a scalar potential, compare this to the predictions made by various Inflation theories, and thereby significantly constrain Inflation models and, thus, the governing physics at this early time (and very high energies). CIP would achieve this goal by conducting a 1,000 sq. degree galaxy redshift survey toward the North Ecliptic Pole in Hα between 1.8 and 5 μm, limited in sensitivity by only the zodiacal background. In so doing, CIP would determine the angular diameter distance, $D_A(z)$, the Hubble parameter, $H(z)$, and the density parameter, Ω_Λ, to less than 0.42%, 0.44%. and 0.8%, respectively, and tilt and running to $\pm\,0.003$ and $\pm\,0.005$ (2σ), respectively.

In addition to Inflation studies, the CIP survey data can also be used to address many other important science topics, including: determination of the star formation history of the Universe; either detection or improved constraints on the curvature of space, including tests of predictions made by String Theory; measurement of the effects of Dark Energy at high redshift; and determination of the neutrino mass.



CIP is based on an extremely simple and straightforward observatory concept consisting of a 1.5-meter telescope coupled to two wide field-of-view ($18.4' \times 18.9'$) slitless grating spectrographs ($\lambda/\Delta\lambda \sim$600) and two 3$\times$3 arrays of Hawaii-2RG detector arrays. The instrument has no moving parts other than a one-time-use secondary mirror focus adjustment mechanism and a telescope cover eject system. In orbit at L2, all necessary cooling to assure background-limited performance can be obtained exclusively through flight-proven passive cooling techniques – no liquid cryogens or refrigerators are required. CIP will be a high-heritage mission, with much of its design adapted directly from the Spitzer Space Telescope and similar missions. Recently, under a 2008 NASA Astrophysics Strategic Mission Concept Study grant, SAO, its industrial partners, Lockheed-Martin, ITT, and Teledyne, along with JPL, undertook a study that has now enhanced the capability of CIP while reducing the cost and risk of its development.

For further information, contact:

Gary J. Melnick, Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138
gmelnick@cfa.harvard.edu

March 20, 2009

Soft X-ray Polarimetry

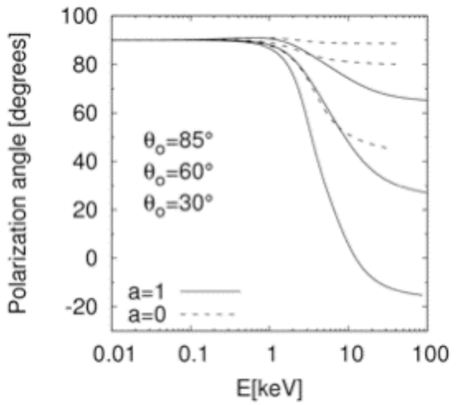
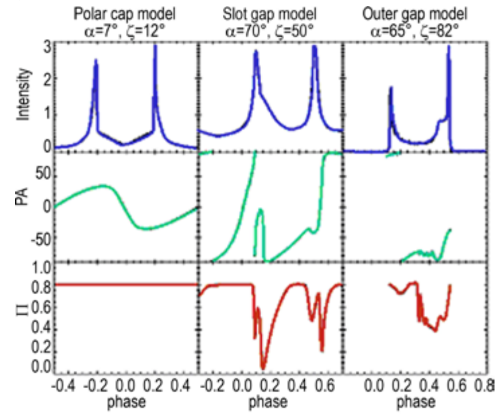
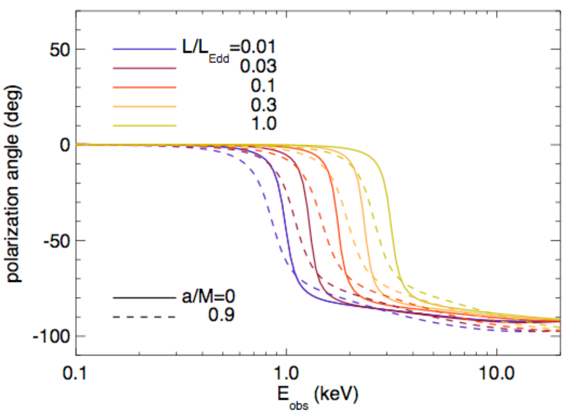


Fig.1. Rotation of the polarization angle of th ermal emission in GBHB. From Dovciak et al. (2008)

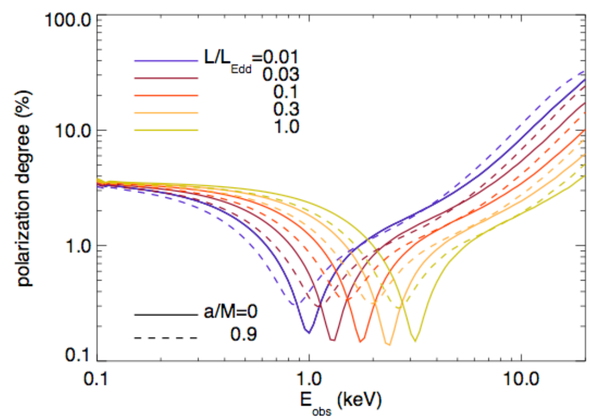
Possible scientific Investigations include pulsar B-field modeling (right), QED effects in strong magnetic fields, tests of General Relativity near Galactic black hole binaries (GBHBs, left), modeling structure in quasar and BL Lac jets, and modeling atmospheres of AGN accretion disks (below left and right). In the cases of AGN and GBHBs, polarization angles rotate significantly below 1-2 keV, arguing that low energy measurements will complement those at higher energies.



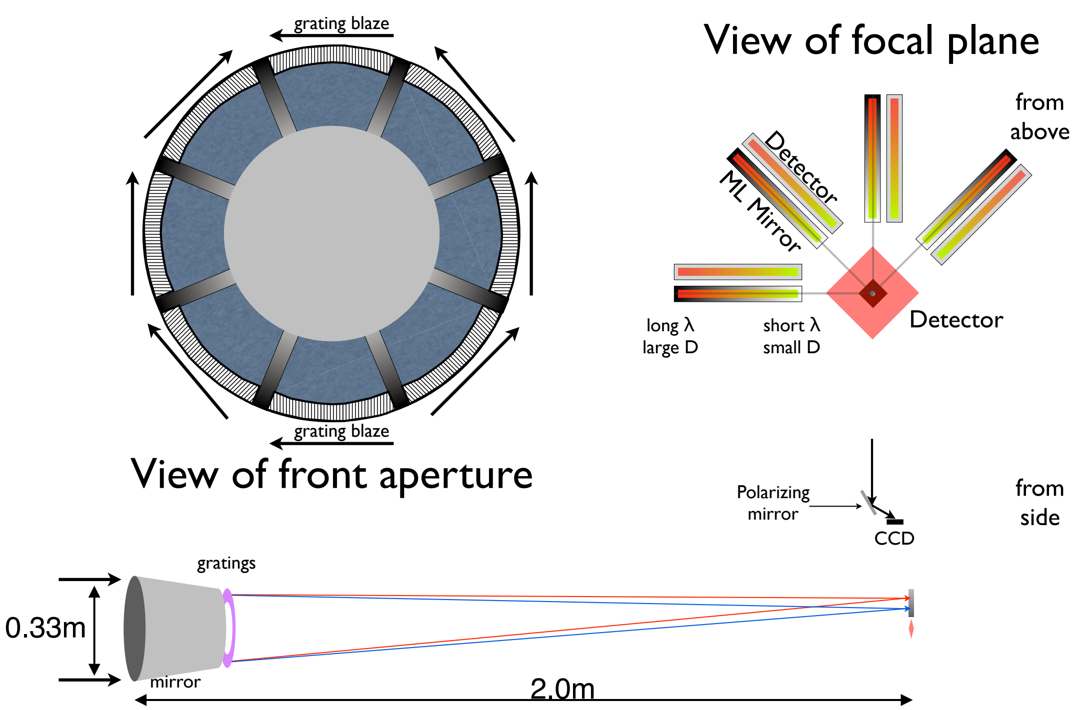
: Intensity and predicted polarization position angle and degree of polarization for the polar cap (left; Daugherty & H arding); outer gap (middle; Romani & Yadigaroglu), and slot gap (right; Dyks et al. 2004) models.



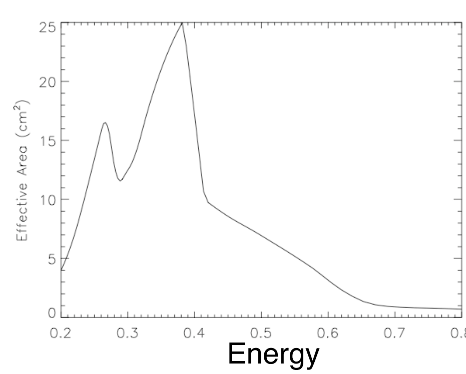
Models of AGN accretion disk polarization parameters from Schnittmann & Krolik (2009). The position angle (left) sweeps through 90° between 0.5 and 5 keV, depending on the Eddington ratio while the percentage polarization goes through a minimum (left).



A Soft X-ray Spectropolarimeter



A design of a soft X-ray polarimeter (left) that uses blazed transmission gratings to disperse X-rays to multilayer coated flat mirrors. The coating thickness, D, varies so that the peak reflectivity matches the wavelength of the spectrum. A small mission (EA below) can measure 15% polarization of a BL Lac or a pulsar in several bands in 1-2 days.

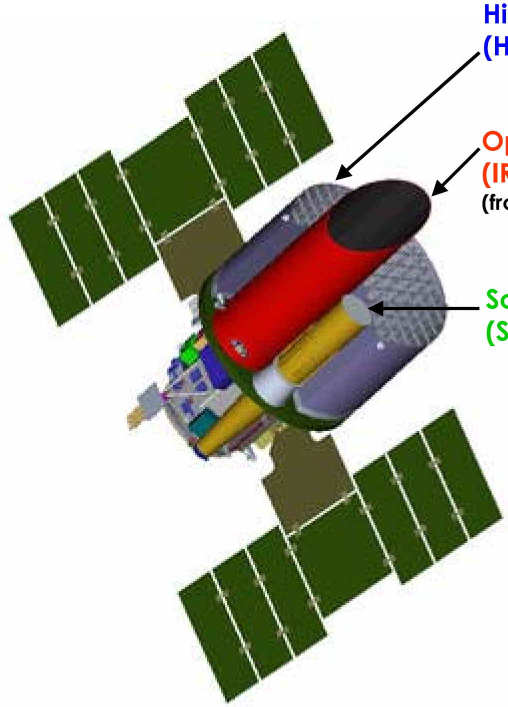


Energetic X-ray Imaging Survey Telescope: *EXIST*

Hard X-ray (5–600keV) all-sky imaging survey every 3 orbits (3h) **to measure, as *Primary Objectives*:**

- **The birth of stellar BHs from cosmic GRBs & *measure redshifts on board* to probe cosmic structure/evol. out to z >7-15**
- **Obscured or dormant SMBHs to probe SMBH properties & evolution, CXB origin & accretion luminosity of the universe**
- **Measuring the Transient Universe to probe stars, BHs, IMBHs in Local Group; magnetars, SNe(breakout), AIC to 300Mpc**

Plus Secondary Objectives*: 511keV from BHs & novae; ^{44}Ti survey & SN rate in Galaxy; Galaxy Cluster survey; *& more…



High Energy Telescope (HET): 4.5m^2 CZT/mask

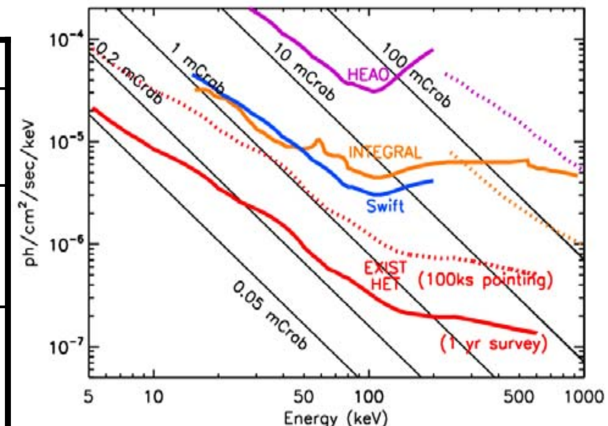
Optical-IR Telescope (IRT): 1.1m Cassegrain
(from *GeoEye/NextView*)

Soft X-ray Imager (SXI): 0.6m Wolter I

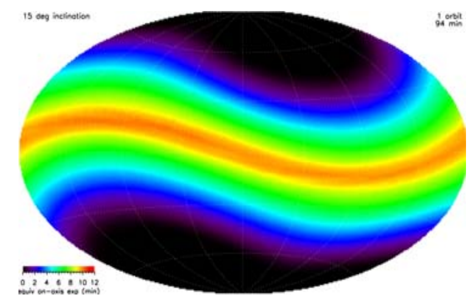
(proposed contrib.from Italy/ASI)

http://exist.gsfc.nasa.gov/

HET Survey	Properties
Survey AGN GRBs	No. Obj >>3. E4 700/y
Flux lim dE=E/2 in: 5-100 keV 100-600 keV	Full sky 1y (cgs) 7 E-13 5 E-12
Time Res. ea. Photon GRB pos. Mission dur	Units 0.1msec 10sec 5y
En. Resol. 20-600 keV	dE/E (%) 2 – 6%
IRT Followup	**Properties**
Imaging 4 bands, 0.3-2.3 m	AB =24 in 100sec!
Spectra (ea. Band)	R = 30, 3000
SXI Followup	**Properties**
CCD imaging Spectra 0.1 – 10 keV	20' FoV, 15" psf
Sensitivity (10ksec)	2E-15 cgs



***EXIST* 1yr full sky survey sensitivity (5σ)**



***EXIST/HET* sky coverage, 1 orbit**

- **All-sky image ea. 3h with 2' (5-600 keV) resol. & ≤20" positions,10 sec timing, ~10% duty cycle**
- **Two narrow-field telescopes: IRT: 0.3-2.2 m (1.1m Cass) & SXI: 0.1-10keV (950cm^2); 6Mbs total all 3 instruments**
- **Recommended by 2000 Decadal Survey; synergy with Fermi, JWST, LSST, IXO & LISA if launched in 2017; $900M 5y mission**

Town Hall Meeting of the Decadal Astrophysics Survey
American Academy of Arts and Sciences Cambridge, Mass March 20, 2009

Opportunities to understand relativistic gravitation in the next decade

Rainer Weiss , MIT 617-253-3527 weiss@ligo.mit.edu

The coming decade will be a transition in studies of gravitational physics. There is a high probability that gravitational waves from compact binary coalescences will be observed by ground based detectors. By the middle of the decade the laser interferometric detectors in the United States (LIGO) and in Italy (VIRGO) will be detecting the gravitational wave chirps from neutron star - neutron star coalescences at a rate between one a week to one a month. If black holes of mass 10 to 1000 solar masses exist in nature, the characteristic gravitational radiation emitted by their formation and that from the collision and merger of the black holes will be observed. The black hole radiation, and to a lesser extent the neutron star emission, will provide our first direct evidence of the behaviour of gravitation in strong fields. Fields where GM/Rc^2 has significant values approaching unity. The field strengths and dynamics at the sources can no longer be approximated by Newtonian gravitation and a fully relativistic Einstein formulation is required.

The natural questions once observing the physics in strong fields will include: scaling with mass and size, the effects of intrinsic spin, the interactions with electromagnetism. The behaviour in these highly curved spaces will certainly be new physics.

The LISA (Laser Interferometer Space Antenna) will provide information of the scaling with exquisite signal to noise. LISA will observe low frequency (milliHertz to 0.1Hz) gravitational waves originating from the dynamics associated with 10^6 to 10^5 solar mass black holes. The black holes are known to exist in the centers of galaxies. The radiation would come from the black holes in colliding galaxies observable to a distance encompassing the bulk of the universe. The detectable black hole - black hole collision rate is 10 to 100's per year.

Gravitational waves from the origins of the universe may be observed by measuring the electromagnetic polarization patterns of the cosmic background radiation (CBR). Gravitational waves originating from the acceleration during the inflationary epoch have imprinted density fluctuations in the primeaval plasma at the decoupling time and in the plasma at the time of "reignition", the epoch of the formation of the first stars. These gravitational wave induced density fluctuations, coupled to the temperature anisotropy, cause large scale CBR polarization patterns through Thomson scattering. This indirect but critical measurement would provide unique information about strong field gravitation at the earliest instants of the universe.

Ground based and balloon borne measurements are currently in progress to measure the polarization patterns. The logical next step would be a satellite (CMBPOL) to offer full sky coverage over a large range of wavelengths to deal with polarized foreground emission and with sufficient observing time to handle systematics and provide integration time.

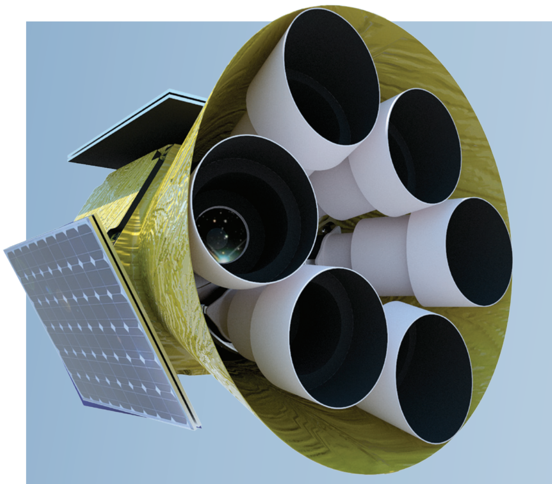
Structure and Dynamics of the Milky Way and the Local Group

M. J. Reid (Harvard-Smithsonian CfA), K. M. Menten (MPIfR), A. Brunthaler (MPIfR)
G. A. Moellenbrock (NRAO), L. Loinard (UNAM), J. Wrobel (NRAO)

Recent advances in radio astrometry with the VLBA have resulted in near microarcsecond accurate trigonometric parallax and proper motion measurements for masers in star forming regions. We are now poised to directly measure the full 3-dimensional locations and motions of *every* massive star forming region in the Milky Way and for the first time to map its spiral structure. Such measurements would also yield the full kinematics of the Milky Way and determine its fundamental parameters (R_0 and Θ_0) with 1% accuracy. Coupled with other observations this would yield the distribution of mass among the various components (including dark matter) of the Milky Way.

The VLBA has already been used to measure the proper motions of the galaxies M33 and IC10, which are satellites of Andromeda at nearly 1 Mpc distance. With improved telescopes and equipment, we could greatly improve upon and expand these measurements, including a measurement of the proper motion of the Andromeda galaxy, which is key to understanding the history and fate of the Local Group. The combination of optical velocities and radio astrometric data would allow detailed modeling of the mass distributions of the disks, bulges, and dark matter halos of galaxies in clusters.

Telescope Advance	Scientific Impact
6.7 GHz receivers for VLBA	Expand number of parallax targets by $\times 10$ to map spiral structure and dynamics of the (northern) Milky Way.
High (32 Gbps) data recording rate and/or additional telescopes/collecting area	Background calibrators a factor of > 6 nearer to targets, enabling sub-μas astrometry.
	Proper motions of weak (~ 10 μJyAGNs in Local Group and beyond (e.g., Andromeda, M81, Virgo Cluster).
Improved southern hemisphere VLBI capability (e.g. partial SKA)	Map southern portion of Milky Way; trigonometic parallaxes of LMC & SMC.



MISSION OVERVIEW

INNOVATIVE, $105M SMEX EXOPLANET FINDER

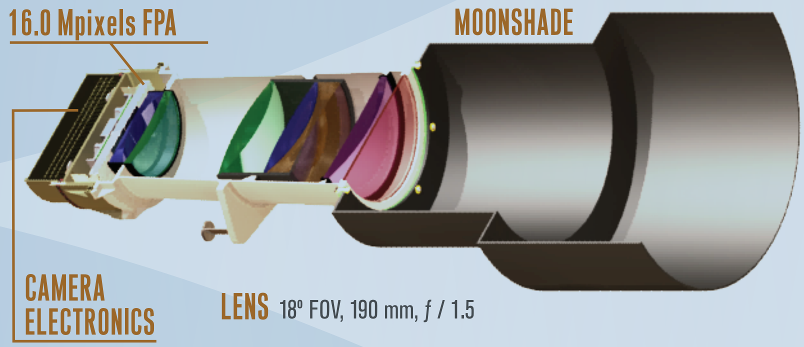
- Experienced team MIT, CfA, NASA & ATK
- All-sky, bright star, 2 year survey
- Launch, Kwajalein Atoll, December 2012
- 2.1° inclination (600 km), low radiation orbit
- Uses existing ground stations operated by MIT
- Provides “Special Interest” targets for JWST
- Strong Exoplanet Science Team
- Contributed telescope time for ground follow up

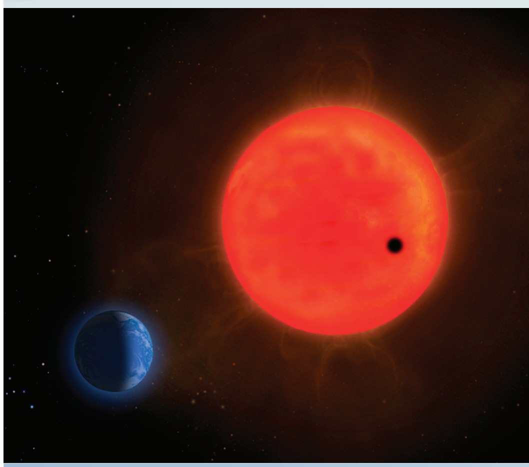
SCIENCE OBJECTIVES

IDENTIFY 1000+ EXOPLANETS

- Primarily around bright stars
- Stellar types FO to M7
- Rocky planets to gas giants
- Detect planets smaller than 2 earth radii

TESS PAYLOAD, SIX IDENTICAL WIDE FOV CCD CAMERAS





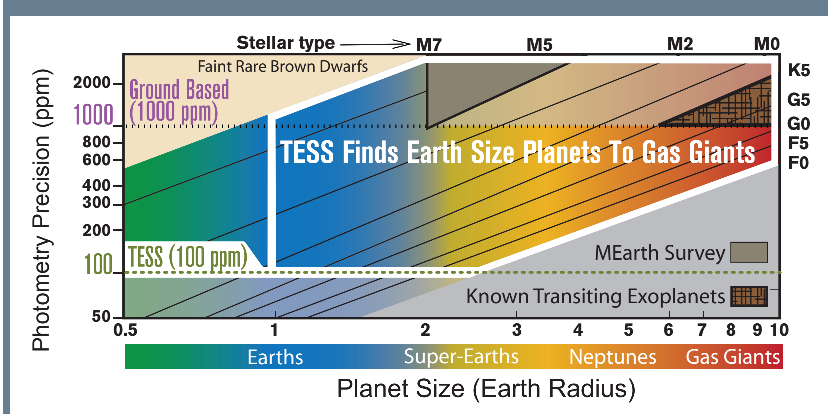
Cool star with water world and transiting exoplanet

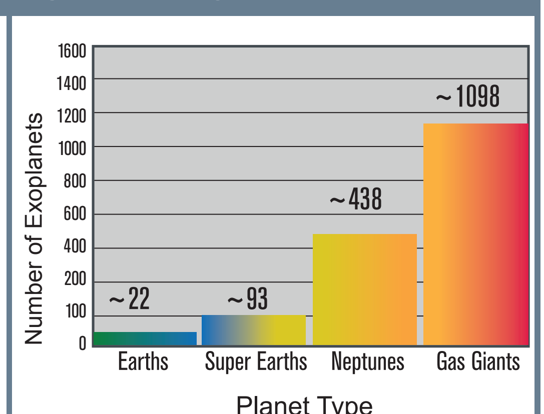
NASA STRATEGIC GOALS

TESS ADDRESSES NASA’S STRATEGIC GOALS 2006 TO 2016

- “Conduct advanced telescope searches for earth-like planets and other habitable environments around nearby stars”
- Value mission that provides “...a wide shallow equivalent of Kepler using a small satellite with a very large instantaneous field of view.”
- Search the entire sky for transiting planets around “...the brightest possible host stars, down to at least 10th magnitude.”

TESS WILL FIND ~1600 EXOPLANETS





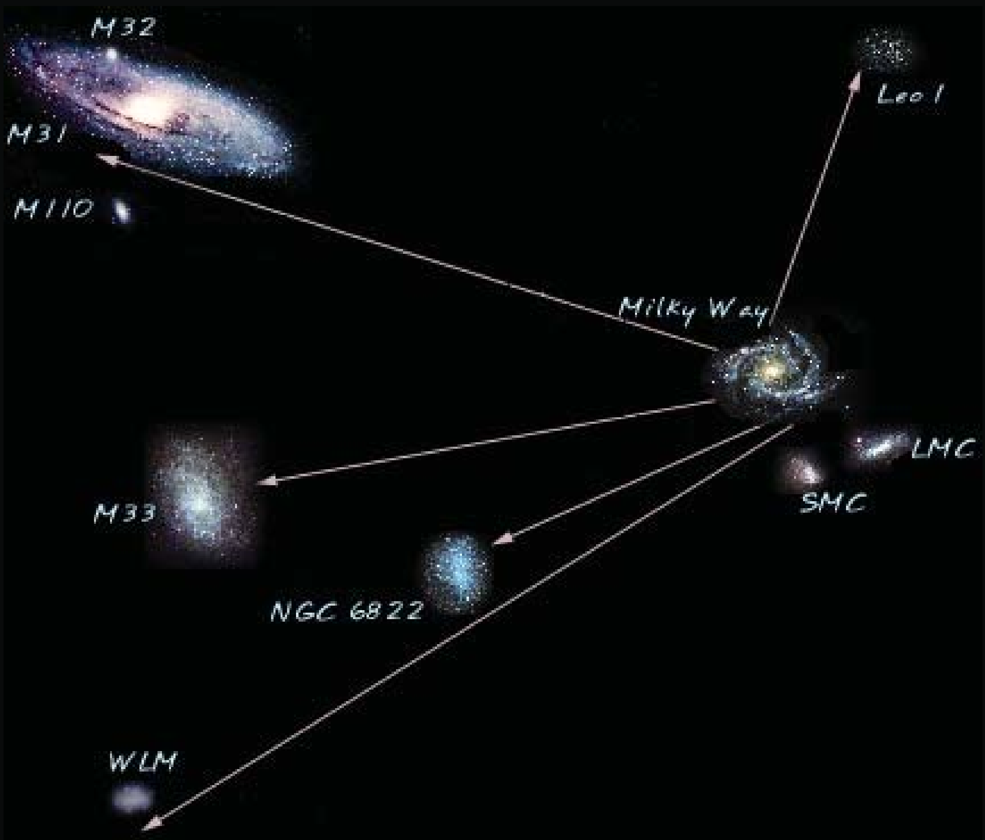
Microlensing

ROSANNE DI STEFANO, KEM H. COOK, PRZEMYSLAW WOZNIAK CHARLES ALCOCK, ANDREW C.BECKER, ANN ESIN, FRANK PRIMINI, KAILASH C. SAHU, BRANIMIR SESAR

Projects of the past have been very successful at discovering the most obvious types of events and establishing the efficacy of wide-field monitoring.
Microlensing monitoring programs paved the way for Pan-STARRS and LSST.

The scientific goals of the microlensing monitoring programs have been only partially realized: Do MACHOs contribute to dark matter? Will lensing discover a significant fraction of exoplanets? Can we learn about distant stellar populations?
While progress has been made on each front, much more remains to be done.
To achieve the science goals more completely and convincingly, we can do better with ongoing and future projects.

We know that specially tailored projects, such as OGLE, MOA, and the new South Korean project (to monitor with 10-minute cadence) can do well. Pan-STARRS and LSST will also be important.



Pan-STARRS and LSST will find thousands of events per year.

1. These look through all directions of the Galactic Halo.
They can provide the definitive result on the contribution of MACHOs and will also be sensitive to the stellar remnants in the Halo.

2. They will measure the mass distribution and explore the binary and planetary-system fraction in several external galaxies.

3. They will discover many "mesolenses", and will thereby explore the region within a kpc of Earth.
(Over...)

Mesolensing

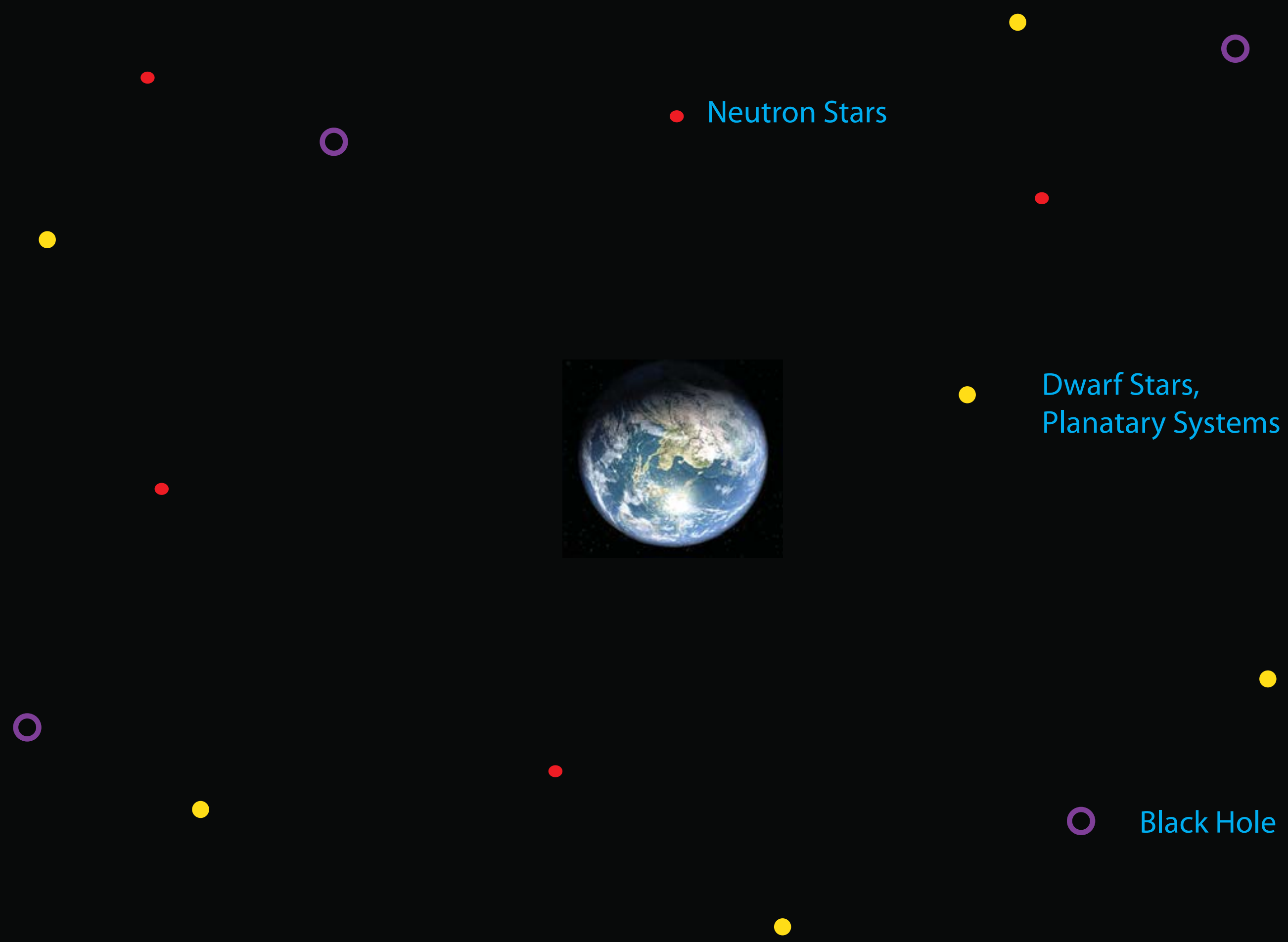
Lenses near the Earth (closer than roughly a kpc) have large Einstein rings and large angular motion.

Nearby lenses have been called mesolenses because they

(1) generate events at a higher rate per lens.

(2) have a better chance to produce astrometric as well as photometrc results. ("Meso" expresses the mix of properties typically seen in microlensing with those typically seen at cosmological scales.)

(3) often can be detected directly. This tends to break the degeneracy inherent in lensing and also makes it possible to predict and plan for future lensing events. **Targeted lensing is a new frontier.**



These results will not be obtained without significant effort.
The first generation of lensing events made only a fraction of the discoveries that would have been possible, given the impressive data collection effort. After-the-fact analyses have proved difficult.

Ongoing and new projects may also fail to extract the rich science results that will be possible, given their data sets.
The community must make it a priority to make a significant investment in theory, planning special features of the software, and in result-directed data analysis. It is modest (a few percent of the money directed toward equipment and data collection), but it is essential and should be specified as an important part of the packages from day one.

Astrostatistics: Data Analysis Challenges

Aneta Siemiginowska (SAO), Vinay Kashyap (SAO) & Alanna Connors for CHASC

- Future => **new challenges** to data analysis techniques and methods.
- Mathematically and statistically sound methods have been developed in other sciences, e.g. geophysics, medicine or biology, and some of these methods can be translated to apply to astronomical data.
- Methods developed to disentangle the complex thermal structures of solar and stellar coronae. These techniques are widely used in the analysis of X-ray bright stars, and similar methods may be necessary for the analysis of X-ray clusters expected to be observed with IXO.
- Other examples include joint spatial-spectral-temporal analysis, the importance of choosing the correct likelihood, the advent of sophisticated and powerful (but also highly targeted) numerical methods, a better understanding of systematic errors, inclusion of model incompleteness (e.g., atomic databases), etc.
- **Inter-disciplinary Collaborations**

  ∗ astronomers, statisticians and computer scientists.
- Collaborations have been emerging during the last decade to address data challenges.
- Our local group: *CHASC Astrostatistics* - `http://hea-www.harvard.edu/AstroStat/` initially focused on *Chandra* X-ray Observatory data challenges, now the work also includes challenges in the optical, Solar and γ-ray data.
- FUTURE:
  - Development of Algorithms, Methods and Techniques to address issues in advanced instrumentation.
  - Dissemination of the new methods.
  - Guidance for Astronomers to use and apply the methods in their work.
  - Career path in Astrostatistics.

Astrostatistics: Data Analysis Challenges: DEM
Vinay Kashyap and Aneta Siemiginowska for CHASC SAO, Cambridge, MA

An Emission Measure Distribution (EMD) characterizes the temperature structure of a volume of optically thin thermal plasma. It allows the contribution to the observed line flux to be separated into two distinct components, a source-dependent term (the EMD, and the composition), and an atomic-physics dependent term (the intrinsic emissivity and the ion balance in the plasma). In general, the flux due to a transition $j : u \to l$ can be written as

$$f_j = \frac{1}{4\pi d^2}\frac{hc}{\lambda_j}\sum_t \mathcal{E}_{jt}(n_e, T_t, Z, I)\iota_t(T_t, Z, I)A_Z\frac{n_H}{n_e}n_e^2(n_e, T_t)\delta V_t(n_e, T_t)$$

where d is the distance to the source, λ_j is the wavelength of the transition, n_e is the electron number density of the plasma at a temperature T_t occupying a volume δV_t, A_Z is the abundance of element Z, ι is the fraction of the ionic species I relative to its elemental abundance, $\mathcal{E}$ is the intrinsic atomic emissivity, and the summation is taken over the temperature range. The last two terms are strictly source dependent, and are identified with a measure of the source emission characteristics, viz., $EMD(T_t) \equiv n_e^2(T_t)\ \delta V(T_t)$. Note that when multiple line transitions j are considered, this is in the form of a matrix equation,

$$\mathbf{f}_j = \mathbf{G}_{jt} \cdot \mathbf{EMD}_t\,,$$

where $EMD_t \equiv n_e(T_t)^2\delta\,(T_t)V$ is a vector defined over temperature space, and G_{jt} encompasses all the other terms. Thus, in principle, the EMD can be obtained by first measuring a number of line fluxes and inverting the above equation. Once EMD_t is computed over a certain range of temperatures with any set of line fluxes and any detector, that same EMD_t can then be used to predict or compare with other line fluxes in any other detector, and thus provides an extraordinarily powerful diagnostic of the structure of the source.

However, the inversion is not an easy problem (see Kashyap & Drake (1998ApJ, 503, 450; Judge et al. 1997Ap, 475. 275J for details). Because the transformation matrix $\mathbf{G}$ determines the coverage of the solution space, and because its form is usually quite broad, the solutions are subject to high-frequency oscillations and indeterminacy. In fact, the integral form of the equation is a Fredholm Equation of the First Kind, with $\mathbf{G}$ acting as the kernel function transforming between wavelength and temperature space. In order to obtain a reasonable solution, it is necessary to first obtain a sample of lines that have good coverage in temperature space, and then to impose a smoothness condition that eliminates high-frequency oscillations in the solutions. The problem is compounded by the high dynamic ranges that often exist in the solutions. The selection of appropriate lines is a non-trivial task, since care must be taken that the selected lines have well-calculated emissivities and are uncontaminated by other lines nearby or by continuum flux. Furthermore, abundance anomalies can significantly affect the solutions and great care must be taken to minimize their effects, e.g., by carrying out multiple iterations of the solution using only lines from one element at a time, or by using abundance independent ratios of H-like and He-like lines, etc. In this context, it is important to note that instrument calibration plays a critical role in the analysis, since systematic calibration uncertainties tend to mimic abundance anomalies.

Despite the mathematical, statistical, and astrophysical problems, EMDs are an enormously useful tool in understanding the structure of solar and stellar coronal plasma. Numerous efforts are underway to better characterize the solutions, to obtain realistic uncertainty ranges, and to extend their applicability to decipher even the spatial structure. The algorithms developed to solve this problem in the context of stellar coronal astrophysics have wide applicability because of the mathematical similarity to a diverse variety of problems (e.g. outflows with several velocity components, multi-component absorbers).

Astronomy Community support by Observatory Class Missions

A note to the ASTRO2010 Committees at the Cambridge Town Hall, March 20 2009

Michael Garcia, Smithsonian Astrophysical Observatory, Garcia@head.cfa.harvard.edu

THESIS: Observatory/Flagship class missions are used by, and support, a very large fraction of the astronomy community. Observatory class missions are typically designed for a 5-year life and an additional 5-year extended operations phase. The proper mix of small, medium, and Observatory class missions should therefore include at least one Observatory class mission per decade.

SUPPORTING DATA, NUMBER OF USERS:

- Number of Chandra Users: (ie, successfully proposing)
  PIs: 794
  Co-Is: 2519
  Either PI or Co-I: 2640

- Number of XMM-Newton Users:
  PIs: 767
  Co-Is: 2805
  Either PI or Co-I: 3000

Number of AAS Members: <8000, approximated from AAS Phone book. Urban legend: approximately half of these are currently engaged in research. Therefore approximately half the active astronomy researchers use and are supported by either Chandra or XMM-Newton. Caveats: 2640/4000 is more than half (66%), but the European users of Chandra may not be AAS members.

A few comments from the State of the Profession Paper: 'The Value of Observatory-Class Missions', from HST, Chandra, and Spitzer

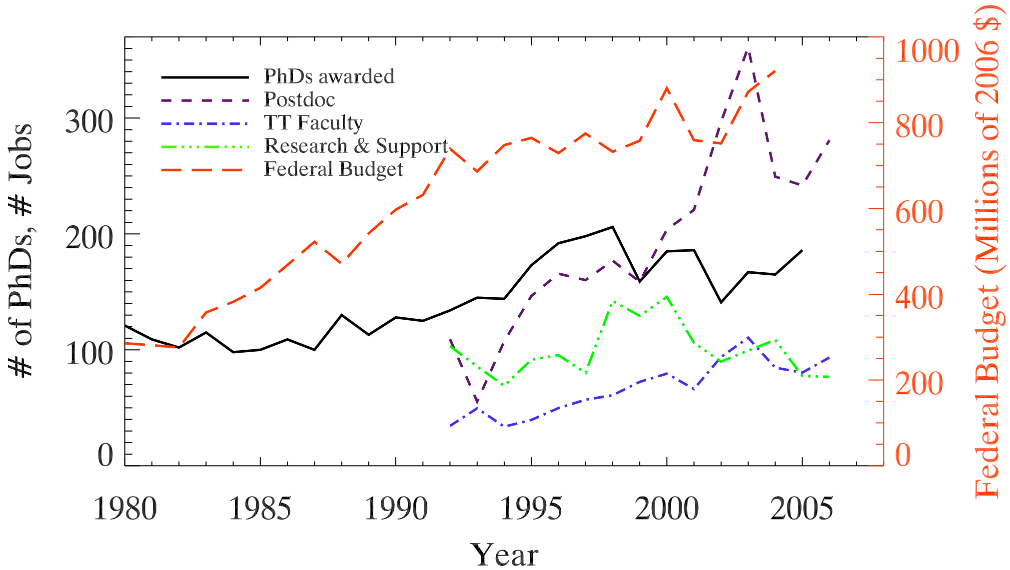
PUBLICATION RATE: Over the last 3 years, these three observatories account for ~20% of all publications and ~27% of all citations. These rates are increasing.

COMMUNITY FUNDING LEVEL: These three observatories provide 35% to 40% of all NASA astrophysics research grant funding. These funds go to individual PIs, Co-Is, postdocs and grad students.

Observing programs for Observatory class missions are open to the entire community, allocated by peer reviews annually, and therefore can react to possible changes in research priorities. Observatory class missions (for example JWST and IXO) are designed for a 5 year life, and with an additional 5 year extended operations phase (if warranted). At least one such mission per decade is therefore the right number to maintain the current high level of support to the astronomy community, and ensure the continued high scientific output of the large community using these facilities.

Employment & Funding in Astronomy

Primary Author: Anil Seth (aseth@cfa.harvard.edu)



Primary Goal: to advocate for a discussion of the astronomical employment picture in the current decadal survey. This requires (1) collecting employment and funding data and (2) deciding what jobs are needed to sustain and improve the field.

Current Employment & Funding Picture:

- The # of PhDs produced correlates with federal funding. Both now and in the past, permanent jobs exist for half or less of current astronomy PhDs.
- The number of postdocs have risen steeply (more than doubled) in the last 20 years, while the number of long-term research positions has not changed.
- For NASA centers, out of a total budget of $206 million about 5% gets spent on research positions.
- The funding of graduate students and postdocs is about $130 million/year, similar to the total NASA+NSF grant funding.

Suggestions:

- Data on employment in astronomy and how it is funded should be collected and published by the decadal survey.
- We should improve the availability and acceptability of graduate training in areas outside of research and consider Master's degree programs.
- To improve the lifestyle and efficiency of postdoctoral researchers we should make an effort to move to a single 5-year postdoc as the normal path.
- We should invest in longer-term research positions instead of continuing to increase funding for younger researchers.

Astronomy Priorities for Undergraduate Institutions

P. Frank Winkler, Middlebury College

Comments for Astro2010 Panel, Cambridge, MA Town Hall, 20 Mar 2009

Primarily Undergraduate Institutions (PUIs) produce a substantial fraction (~35%) of the nation's scientists, including astronomers. Experience doing meaningful research as an undergraduate can be crucially important in setting career paths. For the future of our discipline, we need to maintain and expand research opportunities for undergraduate students and their faculty mentors. Astronomers at PUIs most need:

(1) Reasonable prospects for obtaining individual, stable research funding. Previous reviews have consistently recognized this need:

> *The highest priority of the survey committee* for ground-based astronomy is the strengthening of the infrastructure for research, that is, increased support for individual research grants and for the maintenance and refurbishment of existing frontier equipment at the national observatories. — DDAA, p.2
>
> Adequate funding for unrestricted grants that provide broad support for research, students, and postdoctoral associates is required to ensure the future vitality of the field; *therefore new initiatives should not be undertaken at the expense of the unrestricted grants program*. — AANM, p. 5
>
> NSF-AST should anticipate that pressure on the grants program will intensify over the next five years and should be prepared to increase its level of support to reflect the quality and quantity of proposals. — Recommendation No. 1, SR, p. 5

The Astro2010 Committee should affirm the importance of individual grants in the strongest possible terms; nothing should be be assumed.

(2) Reasonable (competitive) access to high-quality public facilities with modern instrumentation: NOAO, NRAO, NSO, NASA. Healthy national observatories are vital to astronomers at PUIs, and to US astronomy in general.

NOAO is especially crucial for PUI astronomers because ground-based O/IR observers represent the largest segment of the PUI community, and because undergraduates, who typically gain some experience with optical telescopes on their home campuses, find these more approachable than radio arrays or space-based instruments. They will readily accept responsibility on their first trip to a professional observatory. Yet NOAO is vulnerable because the vast majority of US glass is at the independent observatories. Astronomers at PUIs generally have little access to private telescopes; for us NOAO is the only game available.

For a variety of reasons, including contracting budgets and the bifurcation of NSF-sponsored ground-based astronomy into NOAO and Gemini as separate, sometimes competing institutions, NOAO suffered serious decay in both infrastructure and morale in the early 1990's. Divestiture of shares in several NOAO telescopes led to fewer opportunities for astronomers whose sole access to ground-based facilities is through NOAO.

The 2006 Senior Review set NOAO on a new course:

> The O/IR Base program should be led by NOAO. It should deliver community access to an optimized suite of high performance telescopes of all apertures through Gemini time allocation, management of the TSIP program, and operation of existing and possibly new telescopes at CTIO and KPNO. … — SR, p.55

NOAO followed up by forming first the ReSTAR and then the ALTAIR committees to assess community needs and make strong positive recommendations regarding access to small-to-medium (<6m) and large (6.5-10m) telescopes and instrumentation. Under strong new leadership, NOAO has developed a clear sense of mission to be the US center of R&D for ground-based O/IR astronomy. It is expanding access to 2-4m telescopes at KPNO and CTIO, coordinating public access to a wide-range of public and private observatories, and participating in development of exciting new instruments like LSST and the Dark Energy Camera.

This revitalized NOAO holds great promise to serve the entire US astronomical community, including astronomers at PUI institutions. It is essential that the broad goals defined by the Senior Review and strategies proposed by the community-based ReSTAR and ALTAIR committees be given the time and dollars to develop their full potential. I urge the Committee to give a high priority to continuing renewal and modernization of NOAO facilities, together with expanding open access to independent observatories through the TSIP program, as parts of an integrated system for ground-based O/IR astronomy.

Statistics: Where do Physics and Astronomy PhD students receive their undergraduate degree?
(~50% of PhD students are US nationals; of these, 85-90% of entering grad students in PH/AST received their undergrad degree in PH. The table below gives stats for these.)

AIP Survey of US BA/BS degree recipients in PH or AST in their first year after graduation, classes of 2005 & 2006 combined:

Type undergrad Institution	No. Degree Recipients	% in grad school	No. in grad school	% of grad-school population
Bachelor's-only	2300	29%	670	34%
Master's- Granting	350	39%	140	7%
PhD-Granting	2700	44%	1190	59%
Total	5350		2000	100%

(from Patrick Mulvey, AIP Statistics Department, 18 Mar 2009)
More comprehensive but less recent statistics show a similar pattern: *Baccalaureate Origins of Doctoral Recipients*, Higher Education Data-Sharing Consortium, 1998.

Acronyms for Reports and Committees

DDAA: *The Decade of Discovery in Astronomy and Astrophysics*, 1991
AANM: *Astronomy and Astrophysics in the New Millennium,* 2001
SR: *From the Ground Up: Balancing the NSF Astronomy Program*, Senior Review Report, 2006
ALTAIR: Access to Large Telescopes fro Astronomical Instruction and Research, Committee Report 2009
ReSTAR: Renewing Small Telescopes fro Astronomical Research, Committee Report, 2007
AIP: American Institute of Physics

Incorporating Astronomy Education & Public Outreach

Esther Zirbel
Tufts & Walden
ezirbel@gmail.com

Outline

- Why relevant?
- Astronomy in K-12 Schools
- Teacher Education Programs
- Astronomy in Undergraduate Institutions
- Informal Astronomy Education
- Astronomy Education Research
- Conclusion

Why Relevant?

- Educate the public
  → Want their support for our programs
- Train the future STEM workforce
  → Astronomy is a marketable degree
- Enhance the scientific literacy
  → Most people are already curious about astronomy and have questions
  → Use people's interest as a hook to teach complex science concepts

Astronomy in K-12 Schools

- Teach more astronomy in schools
  - Children have burning questions about black holes, planets, galaxies, the big bang, etc
  - Kids want answers from their teachers
  - Can use kid's curiosity as a hook for other science concepts
  - Teach process of science through the lens of astronomy
- Teach modern topics in schools
  - Newtonian physics can be rather dry and counter-intuitive
  - Basics of Einstein's work is more exciting (e.g. space time travel) and not that much more difficult

→ Call for more astronomy in K-12 curricula
→ Incorporate astronomy into the standards

Teacher Education Programs

- In-service programs
  - Bring teachers up to date with modern astronomy concepts so that the can answer their own students' questions
  - Create an assessment system to assure that astronomy professional development programs and field experiences have a high standard
- Pre-service programs
  - Collaborate with education faculty to design "astronomy-and-pedagogy" courses
  - Next slide: Improve AST-101 courses

Undergraduate Education

- Enhance STEM workforce
  - Make astronomy to be a "marketable" degree at the bachelors level
  - Introduce more "terminal masters" level courses for students not wanting to do a PhD
- Educate non-science majors
  - Revise survey course philosophy
  - Design multidisciplinary courses
  - Teach process of scientific inquiry

Informal Astronomy Education

- Involve Parents in Kid's Programs
- Outreach in Museums
- Offer programs in adult education centers and community learning centers (e.g. Weston Center; Cambridge Adult Education)

Astronomy Education Research

- Research
  - How students learn astronomy concepts
  - Alternate and innovative modes of teaching
  - Effective professional development models
- Curricula and Materials
  - Develop research based curricula that are aligned with how students learn
- Assessment
  - Incorporate assessment loops into educational programs and curricula

Conclusion

- Astronomy education programs are very important
  - Stakeholders need to be convinced to provide funding for astronomy research and exploration
- Teachers, K-12 & college students, and the public need to be (and want to be) educated about astronomy
  - Astronomy provides a great hook to explain other complex science concepts
- Research on effective models needs to be conducted and assessment methods need to be integrated
- Ultimate aim is to enhance both the science literacy and the STEM workforce

Funding Astronomical Programs

Thomas G. Beatty – MIT Department of Physics
tbeatty@space.mit.edu

To secure funding for astronomy in the coming decade, the astronomical community needs to demonstrate the gains in economic competiveness, international cooperation, and national prestige generated by funding astronomical research. This will present the case for astronomy to members of Congress in terms that they easily understand, and also allow astronomy to differentiate itself from other science programs that are competing for the same federal funding.

Funding for astronomical programs, and the grants provided by NSF and NASA, is decided upon by the House Committee on Science and Technology. Due to the budget process, this means that astronomy is only competing against other scientific programs for federal funding. To provide for adequate funding in the coming decade, the astronomical community needs to therefore demonstrate to the Committee that astronomical research programs provide more benefits than other scientific programs.

To do this, the community must demonstrate the non-scientific benefits that funding astronomy provides; members of Congress are often indifferent to scientific arguments. In general, these benefits can be grouped into three categories:

Economic Competitiveness

- Astronomical programs help create and maintain a highly educated and technically literate workforce.
- Astronomy spurs the development of a range of technologies, such as imaging devices, precision machinery, and supercomputers, which have applications in both national security and consumer products.

International Cooperation

- Similar to what has been done with the space program, astronomy offers many opportunities for other nations to contribute to joint scientific projects, such as observatories located outside the United States or collaborative research.
- Astronomy therefore may be used as a foreign policy tool to generate international goodwill towards the United States.
- The prospects for international cooperation are particularly relevant given President Obama's desire for a more multilateral foreign policy.

National Prestige

- Many of the discoveries that can be made in the next decade, such as the discovery of habitable Earth-like planets, the identification of dark matter and dark energy, or even the discovery of life on an exoplanet, will be historic events.
- The United States has already devoted considerable resources towards laying the foundations for these discoveries.
- Other nations, in particular the Europeans, are well positioned to build on this foundation themselves.
- The United States should therefore "go the last mile" and see these projects through to their completion.

BRIEF ON WORKFORCE DEVELOPMENT IN ASTRONOMY

William H. Waller (Tufts University and MA Space Grant Consortium)
Susana Deustua (Space Telescope Science Institute)
Others in Space Science E/PO (Pending)

Executive Summary:

This brief calls for a broadening of the astronomical profession, so that it serves a greater cross-section of American society and so attains greater relevance and value among the US citizenry. This will require significant reform of undergraduate and graduate Astronomy education programs, so that students can prepare for a greater variety of Astronomy-related careers. We also recommend additional support for mid-career professionals who are looking to make transitions into new types of Astronomy-related employment. In these ways, more people can develop and sustain their identity within the profession of Astronomy, as they contribute to a more astronomically attuned society.

Introduction:

Although Astronomy deals with the entire Universe and all that it contains, the profession itself is relatively small – with less than 10,000 practitioners within the United States. Worldwide, we are little more than one in a million. Despite these low numbers, Astronomy – and astronomers – have an enormous impact on society. Our almost daily discoveries are the stuff of news stories, radio shows, television productions, museum exhibits, planetarium presentations, and casual conversations among friends and strangers alike. Moreover, astronomers serve the needs and interests of much larger professions, most notably in Physics, Aerospace, Instrumentation Engineering, Computer Science, and Education. Even the legal, insurance, and entertainment industries have been known to hire astronomers from time to time. To ensure that Astronomy remains a viable and growing profession, it is necessary to prepare future astronomers and to support current astronomers with these larger connections in mind.

Recommendations:

1. Advocate and support early Astronomy education in America's K-12 schools.
2. Through targeted seminar courses, introduce undergraduate students to a wider range of Astronomy-related topics (journalism, education, instrumentation).
3. Provide career experiences for undergraduate students in a broader array of Astronomy-related venues (museums, publishers, instrument developers, etc.)
4. Foster and support interdisciplinary Masters degree programs in Astronomy education, instrumentation, and other Astronomy-related professions.
5. Provide fellowships for mid-career astronomers wishing to pursue new opportunities at Astronomy-related venues (research institutions, aerospace companies, museums, media outlets, school districts, minority education centers).

Astro-Statistics, Astro-Informatics and the Importance of Cross-Discipline Work

A. Connors, V. Kashyap A. Siemiginowska, and P. Protopapas for CHASC

1. Cross-Disciplinary Work: Takes Time As Eric Feigelson (Penn State, Astronomy) is fond of telling us, ``Real Interdisciplinary collaboration takes time... a minimum of about a year to get started on a good problem..''

2. Awareness of Problems Astrophysicists Culturally Don't See. One recent example: Xiao Li Meng, Chair, Harvard Statistics, Mar 3 Stat 310, discussing problems with physicist's standard procedure for systematic uncertainties: ``You mean they think if you put enough systematic errors together, it will end up Gauss-Normal?'' An older, more famous example: misusing χ^2 (Protassov et. al. 2002, Ap.J., 571, 545).

3. Awareness of New Methods: EE, Geo, Medical, ... One example: wavelets and related multi-scale, non-parametrics go beyond Fourier transforms. Ingrid Daubechies: ``But I looked at it differently... A change ... A way of paying attention.''

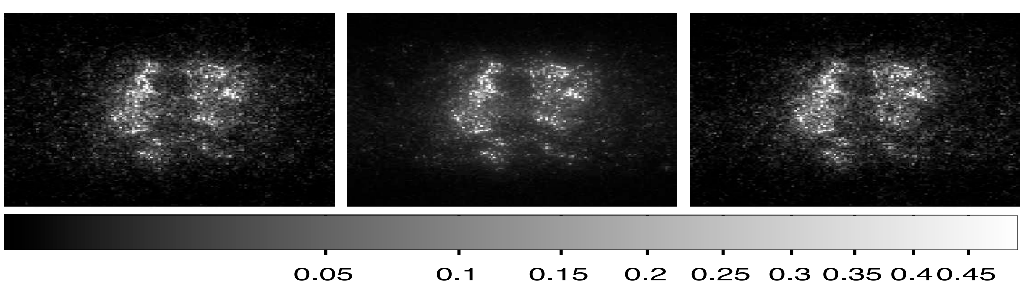
4. Statistics gives Structure, and hence the error bars From Dixon, Hartman, Kolaczyk, et al 1998 New Astronomy 3, 539: `... quantification of object-wise significance (e.g., "this blob is significant at the nσ level") are difficult.' From John Rice, UCB, Statistics [paraphrased remarks from SCMA IV]: "You want ... some kind of likelihood based structure, to have even some hope of understanding the total errors."

5. Computer Science gives Structure, Speed, Practicality: From Computer Science e,g, Alex Gray (AAS Jan 2009) ``Statisticians tell me what to calculate; My job is to speed up the calculation''

6. Other Information Science: Visualization, Representing Results See, for example, IIC, AstroMed, etc.

7 What do we need: Process for encouraging long-term, open, interdisciplinary research.

8. What benefits: **1)** Better astronomy - grasping essence of science from complicated data; **2)** Keeping up with the instruments (old quote) **3)** Learning and experience, particularly for young people, in how to do cross-discipline work **4)** The Unexpected - medicine, earth/atmosphere science, ...



9. Example: Using EMC2 to find $\pm 5\%$ bounds on shape of faint gas structure along Galactic Plane (Simulation): These three show the $\pm 5\%$ uncertainty limits on the *shape* of the 'unknown'. (d) Mean of images with summary statistic (total extra counts) in *Lower 5%* (Connors and van Dyk, SCMA IV). (e) Mean of all images; (f) Mean of images of upper 5%.