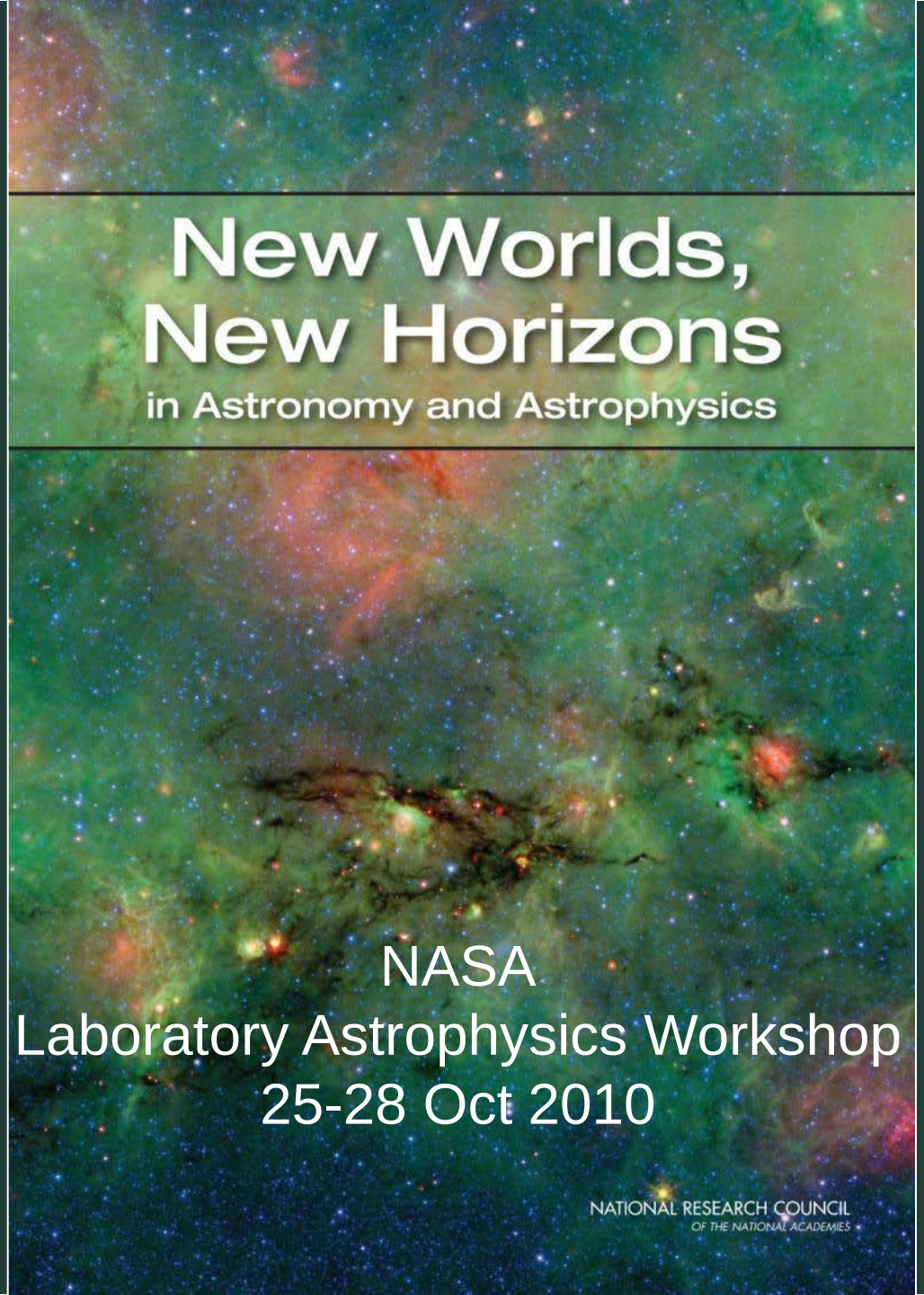
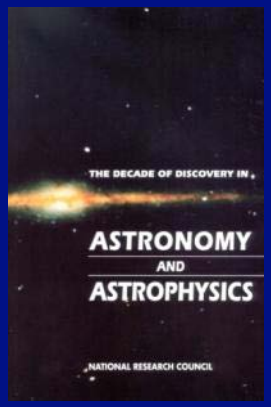
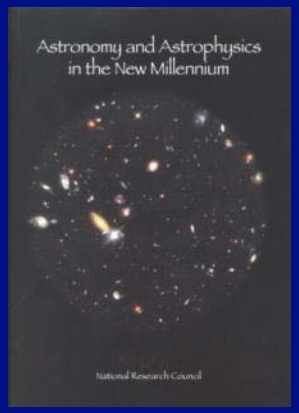


NASA
Laboratory Astrophysics Workshop
25-28 Oct 2010



U.S. Decadal Surveys



- 1964: Ground-based Astronomy: A Ten Year Program (Whitford)
- 1972: Astronomy and Astrophysics for the 1970s (Greenstein)
- 1982: Astronomy and Astrophysics for the 1980s (Field)
- 1991: The Decade of Discovery in Astronomy and Astrophysics (Bahcall)
- 2001: Astronomy and Astrophysics in the New Millennium (McKee-Taylor)
- 2010: New Worlds, New Horizons in Astronomy and Astrophysics

Task and Charge

Negotiated by NRC with Agencies

- NASA, NSF, DOE
- The Committee on Astro2010 will survey the field of space- and ground-based astronomy and astrophysics, recommending priorities for the most important scientific and technical activities of the decade 2010-2020.

Scope

- Remote observing of cosmos, theory, physics, computation and simulation, laboratory astrophysics, solar astronomy (excluding space missions), and technology development
- Activities and infrastructure (broadly defined)
- Balance
- Partnerships: international, private, state …..

Astro2010

Charge led to

- Science First
- Consideration of unstarted projects from previous surveys - no “grandfathering”
- Independent analysis of risk, technical readiness, schedule, and life cycle costs.
- Entire recommended program must fit into a projected budget scenario
- Significant community engagement

Science Frontier Panels

Planetary Systems and Star Formation (PSF) - Lee Hartmann

- **Solar system bodies (other than the Sun) and extrasolar planets, debris disks, exobiology, formation of individual stars, protostellar and protoplanetary disks, molecular clouds and the cold ISM, dust, and astrochemistry.**

Stars and Stellar Evolution (SSE) - Roger Chevalier

- **The Sun as a star, stellar astrophysics, structure and evolution of single and multiple stars, compact objects, supernovae, gamma-ray bursts and solar neutrinos. Extreme physics on stellar scales.**

The Galactic Neighborhood (GAN) - Mike Shull

- **Structure and properties of nearby galaxies including the Milky Way and their stellar populations, interstellar media, star clusters. Evolution of stellar populations.**

Galaxies across Cosmic Time (GCT) - Meg Urry

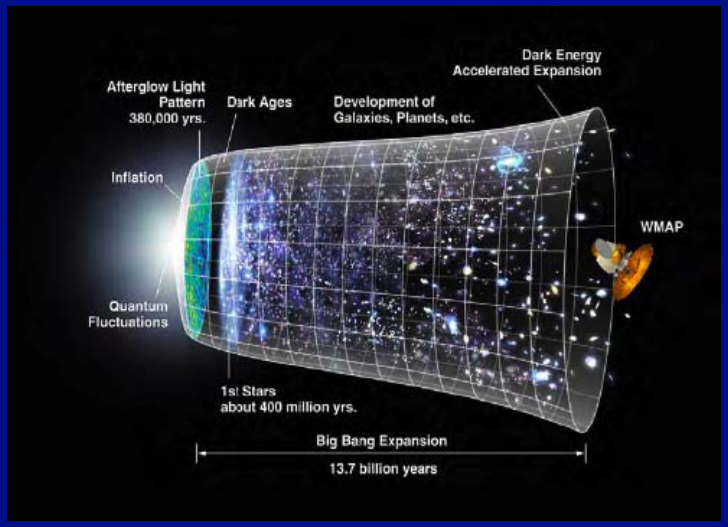
- **Formation and evolution of galaxies and galaxy clusters, active galactic nuclei and QSOs, mergers, star formation rate, gas accretion, global properties of galaxies and galaxy clusters, supermassive black holes.**

Cosmology and Fundamental Physics (CFP) - David Spergel

- **Early universe, microwave background, reionization and galaxy formation up to virialization of protogalaxies. Large scale structure, intergalactic medium, determination of cosmological parameters, dark matter, dark energy. High energy physics using astronomical messengers, tests of gravity, physical constants as determined astronomically.**

Cosmic Dawn

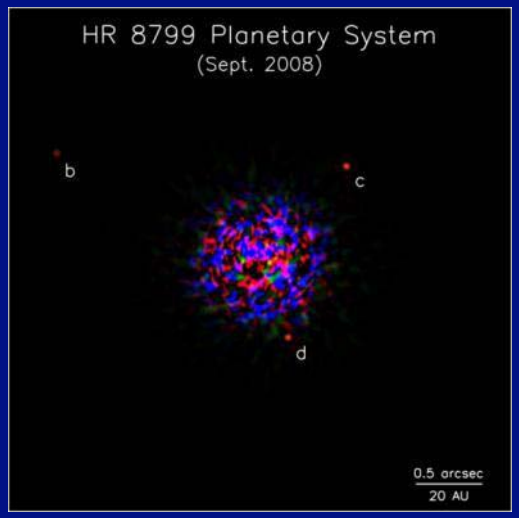
Searching for the first stars, galaxies, and black holes



- We have learned much about the history of the universe, from the Big Bang to today
- A great mystery now confronts us: when and how the first galaxies formed and the earliest stars started to shine - our cosmic dawn
- JWST, ALMA and radio telescopes already under construction will help point the way
- Approaches:
  - Locating “reionization” – finding the epoch ~0.5 billion years, when light from the first stars split interstellar hydrogen atoms into protons and electrons
  - “Cosmic paleontology” – finding the rare stars with the lowest concentrations of heavy elements

New Worlds

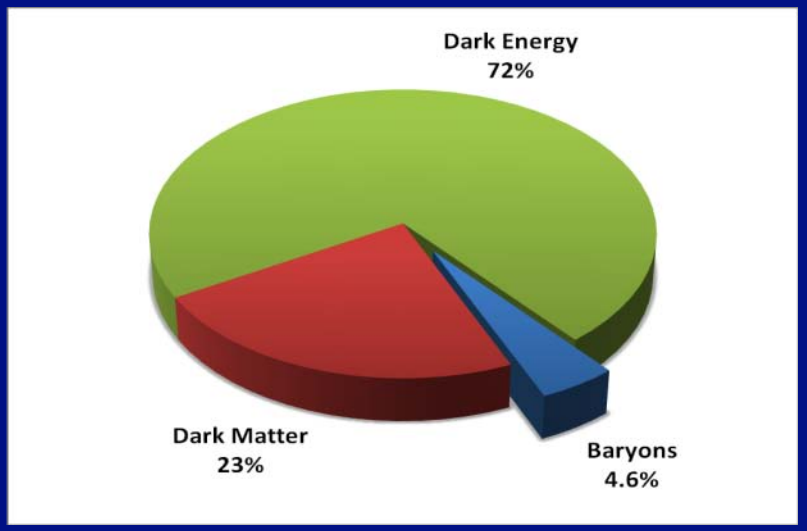
Seeking nearby, habitable planets



- Nearly 500 extrasolar planets now detected - extraordinarily rapid progress
  - Huge range of properties exhibited, surprisingly different from those in our own solar system
  - Many ongoing approaches seek new “Earths” – potentially habitable rocky planets with liquid water and oxygen
  - New techniques being developed
- Kepler data adds over 500 "candidates" to the list, including many less than twice the size of Earth
- Next great step forward: understand frequency of different types of planets and lay scientific and technical groundwork to inform future strategies for detailed study of nearby Earth-like planets

Physics of the Universe

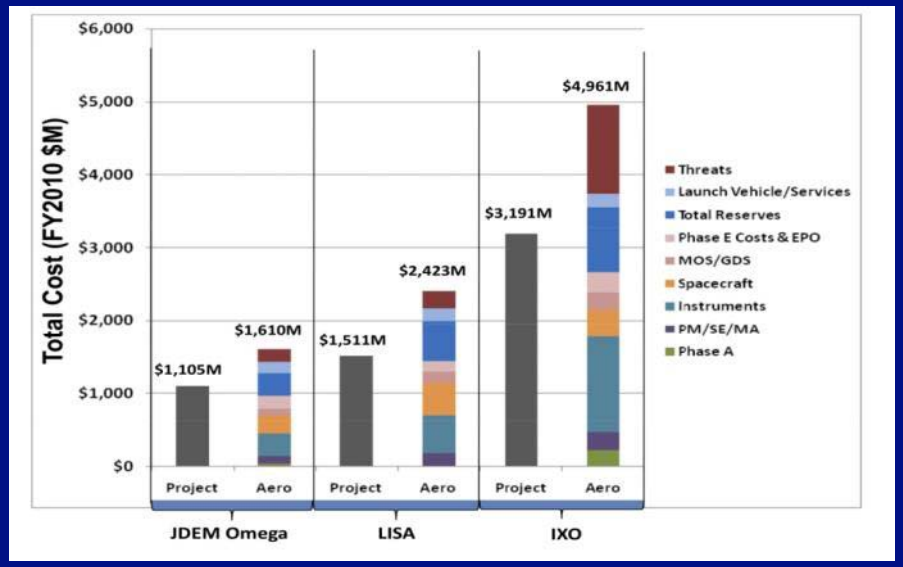
Understanding Scientific Principles



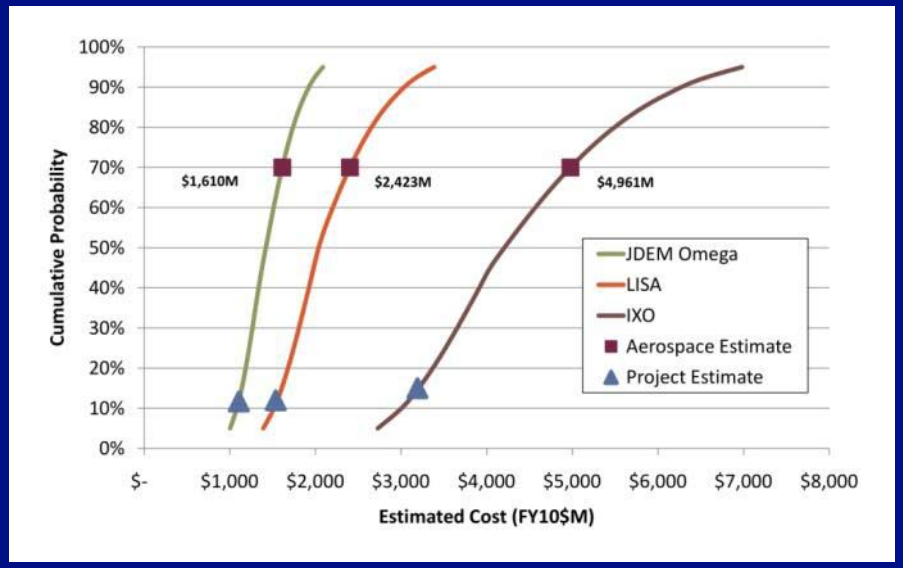
- Determine properties of dark energy, responsible for perplexing acceleration of present-day universe
- Reveal nature of mysterious dark matter, likely composed of new types of elementary particles
- Explore epoch of inflation, earliest instants when seeds of structure in the universe were sown
- Test Einstein's general theory of relativity in new important ways by observing black hole systems and detecting mergers

Cost, Risk, and Technical Evaluation

- Early call for Notices of Intent followed by open Request for Information
  - Activities selected by PPPs and committee for a 2nd Request for Information



- Subset selected by PPPs and committee for CATE review
  - Independent cost appraisals
  - Evaluations of technical readiness schedule and risk assessment



Budgetary Context

- Agency Guidelines
  - NSF and DOE – constant budgets in fixed dollars ($FY2010)
  - NASA – constant real year dollars (declining budget in $FY2010)
- Survey Budgets (the optimistic scenario)
  - NSF and DOE – “doubling” = 4% per year growth in $FY2010
  - NASA – constant in $FY2010 dollars
- Notional “sand charts”
  - Exhibit possible spending profiles consistent with committee budgets and the recommended program, i.e. phasing
  - Allowed the committee to examine possible programmatic scenarios
  - Provide advice in less optimistic budget scenarios

Community Input

An unprecedented response

- 324 Science White Papers (a unique snapshot of the field)
- 69 State Of The Profession Position Papers
- 70 White Papers on Technology Development, Theory, Computation, and Laboratory Astrophysics
- 108 Community Responses to a Request for Information on Research Activity Proposals
- Email Inputs to the Committee
- Community-organized Town Halls

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/

Laboratory Astrophysics in the U.S.
J. Lawler et al.

Roles, Current Status, Opportunities, Future Trends, and Funding Issues for Laboratory Plasma Astrophysics
A State of the Profession Position Paper Submitted to the Astro2010 Decadal Survey
Hantao Ji et al.

Some Examples of Laboratory Astrophysics in Support of Ground Based Astronomy — J. Lawler et al.

The Need for Plasma Astrophysics in Understanding Life Cycles of Active Galaxies
H. Li et. al

Infrastructure Study Groups

Computation, Simulation, & Data Handling (CDH) – Robert Hanisch & Lars Hernquist

- Computational resources and support for analysis and archiving of astronomical data; resources and support available for astrophysical and cosmological simulation; major challenges and changes in computing environments and software; expected availability of computing capability over the next decade.

Demographics (DEM) – James Ulvestad

- Numbers of astronomers and astrophysicists working in different environments and subfields; diversity, geography and student populations; breakdown of resource allocation by field, discipline and cost category where possible; subscription rates for programs; publication rates.

Facilities, Funding and Programs (FFP) – J. Craig Wheeler

- List major operational public and private facilities, their capabilities, ages, and proposal pressure; budgets for all agency programs; infrastructure issues such as support for laboratory astrophysics and technology development and theory.

International and Private Partnerships (IPP) – Robert Dickman

- Lessons learned; scope and current status of relevant major projects in development; summarize lessons learned to promote successful collaborations.

Education & Public Outreach (EPO) – Lucy Fortson & Chris Impey

- Public communication programs; astronomy in K-12 and college education; professional education for astronomers, journalists and science policy experts.

Astronomy & Public Policy (APP) – Daniel Lester

- Benefits to the nation that accrue from federal investment; contributions made to important research of societal importance; current structure of committees and reporting lines that are used to provide advice to the federal government.

Facilities, Funding, and Programs:

J. Craig Wheeler, University of Texas at Austin, *Chair;*
Rebecca A. Bernstein, University of California, Santa Cruz;
David Burrows, Pennsylvania State University;
Webster Cash, University of Colorado;
R. Paul Drake, University of Michigan;
Jeremy Goodman, Princeton University;
W. Miller Goss, National Radio Astronomy Observatory;
Kate Kirby, Harvard-Smithsonian Center for Astrophysics;
Anthony Mezzacappa, Oak Ridge National Laboratory;
Robert Millis, Lowell Observatory;
Catherine Pilachowski, Indiana University;
Farid Salama, NASA Ames Research Center; and
Ellen Zweibel, University of Wisconsin.

AMOLA (atomic and molecular lab astro) grants from the NSF Divisions of Physics and Chemistry.

Original Award Date	Total Awards	AMOLA Awards	AMOLA/Total %	AMOLA/year
1989-1993	186	29	16	5.8
1994-1998	255	26	10	5.2
1999-2003	251	11	4.4	2.2
2004-2008	264	8	3.0	1.6

AMOLA grants from the NSF Division of Astronomical Sciences.

Original Award Date	Total Awards	AMOLA Awards	AMOLA/Total A %	MOLA/year
1989-1993	701	12	1.7	3.2
1994-1998	686	12	1.7	2.4
1999-2003	906	11	1.2	2.2
2004-2008	1038	19	1.7	3.8

wavelength	mission	collision cross-sec.	rate coeff.	nuclear masses	nuclear decays	nuc. Matter equation of state	line transitions	grain properties (opacities, etc.)	grain photoelectric yields	x-ray absorption	photoionization and recombination rates	magnetzed and high energy density plasmas	HCI cross-sections
OIR	HST	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	
	ground-based	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	
	(VLT, Keck, Subaru)	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	
	JSWT	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	
	Spitzer	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	
	Sofia	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	
radio, submm	ALMA, etc.	✔	✔	✔	✔		✔	✔	✔		✔	✔	
x-ray	Chandra	✔	✔	✔	✔		✔			✔	✔	✔	✔
	XMM	✔	✔	✔	✔		✔			✔	✔	✔	✔
uv	HST	✔	✔	✔	✔		✔	✔	✔		✔	✔	✔

Program Prioritization Panels

Radio, Millimeter and Submillimeter from the Ground (RMS) - Neal Evans

- **Observatories and telescopes that observe primarily in these wavebands**

Optical and Infrared Astronomy from the Ground (OIR) - Pat Osmer

- **Observatories and telescopes that observe primarily in these wavebands**

Electromagnetic Observations from Space (EOS) - Alan Dressler

- **All space-based astronomical projects observing the electromagnetic spectrum.**

Particle Astrophysics and Gravitation (PAG) - Jackie Hewitt

- **All projects exploring areas at the interface of physics and astronomy such as gravitational radiation, TeV gamma-ray astronomy, and free-flying space missions testing fundamental gravitational physics.**

Optimizing the Recommended Program

- Prioritizing based on science objectives
- Building upon existing astronomical enterprise
- Evaluating cost risk and technical readiness
- Maximizing scientific return under highly constrained budget guidelines
- Choosing most urgently needed activities from long list of compelling ideas and concepts
- Considering international and private partnerships

Balancing the Program

- Large *and* small/medium activities
- Existing *and* new facilities
- Known science objectives *and* discovery space
- Promise *vs.* risk
- Ground *and* Space
- 2020 *and* 2030

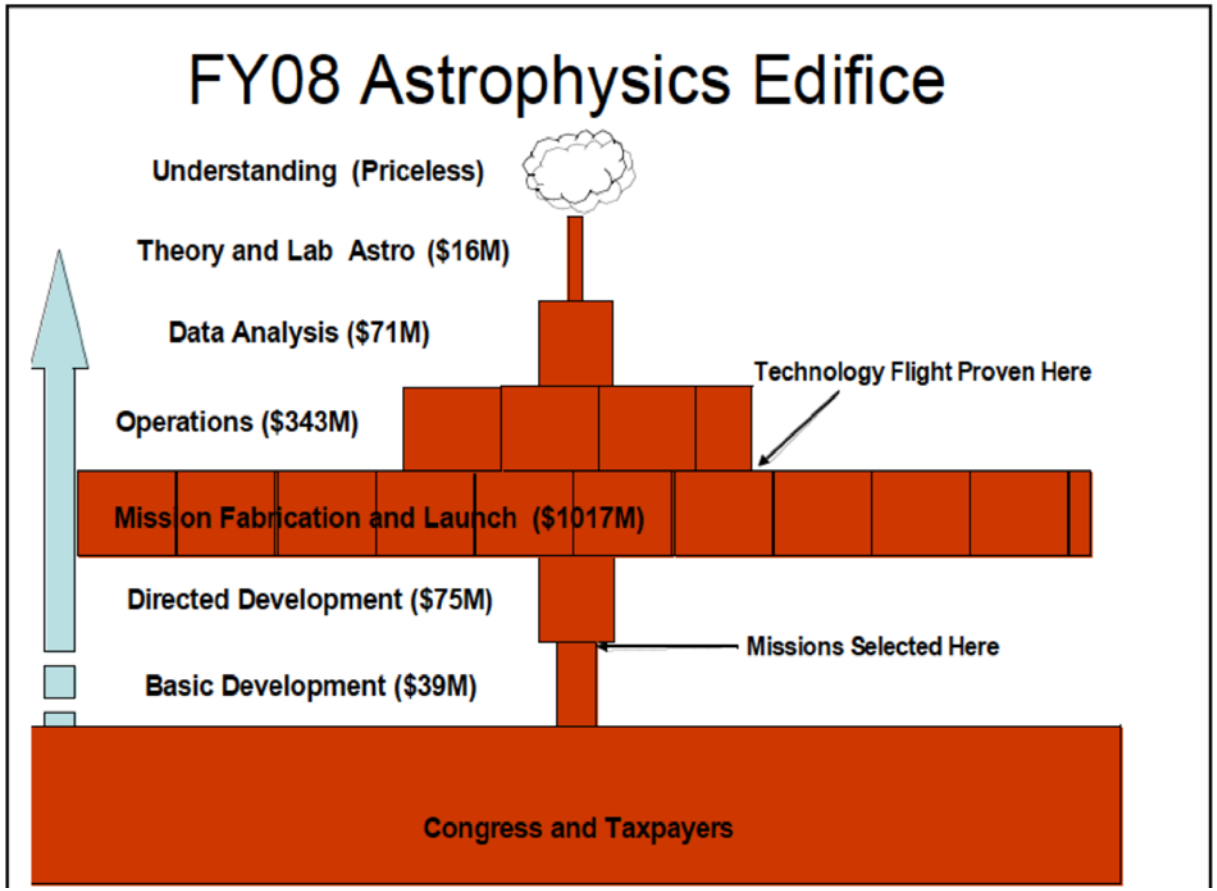


Fig. mm. Graphical view of breakdown of NASA Astrophysics Division funding for 2008. Division of the $39M Ņbasic developmentÓ between mission-specific and long-range technology development is not shown.

Large Scale Space Program - Prioritized

1. Wide Field InfraRed Survey Telescope (WFIRST)

1. Explorer Program Augmentation

2. Laser Interferometer Space Antenna (LISA)

3. International X-ray Observatory (IXO)

Medium-Scale Space Program - Prioritized

1. New Worlds Technology Development Program

2. Inflation Technology Development Program

Small Category: SPICA

- US Instrument contribution to JAXA-ESA SPICA mission
  - Far-infrared telescope; successor to Spitzer
  - Birth of galaxies, stars, planets; cycling of gas through interstellar medium
  - 3.5m aperture
  - Launch date 2018
- Will address many of this survey's science priorities, including understanding the birth of galaxies, stars, and planets, as well as the motion of matter through our own interstellar medium.

Large-scale Ground-based Program - Prioritized

1. Large Synoptic Survey Telescope (LSST)
2. Mid-Scale Innovations Program
3. Giant Segmented Mirror Telescope (GSMT)
4. Atmospheric Cerenkov Telescope Array (ACTA)

Mid-Scale Innovations Program

- Large number of exciting and viable projects addressing survey goals are in ~$10-$100M range: Possible exemplars include: BigBOSS, CMB, ExoPlanet initiatives, FASR, HAWC, HERA, Adaptive Optics, NanoGRAV
- **RECOMMEND creation of competed program at NSF that will meet this need, like NASA Explorer program**
- Funding increase from ~$18M currently to competed $40M per year
- CCAT (33% share) recommended for early start

Small-scale Investments

- Target work-force development
  (TSIP, Sub-orbital, AAG, ATP)
- Develop technology for future
  (NSF ATI, NASA Tech. Dev.)
- Support current/upcoming facilities
  (Lab Astro, Theory)
- Address changing role of computation and theory
  (Theory Computational Networks)

Lab Astrophysics in the Survey Report

- “Laboratory astrophysics” is called out on 21 different pages
- All chapters and sections except chapter 2
- Total of 44 references

Where to find it:

- Ch 1: summary of recommendations
- Ch 4: Demographics
- Ch 5: Core program description
- Ch 7: Budget plans

MONEY

NASA:

Laboratory Astrophysics:

Herschel, JWST, SPICA, and IXO, with their fine spectral capabilities, will place new demands on basic nuclear, ionic, plasma, atomic, and molecular astrophysics. Care should be taken to ensure that these needs are met. An increase by $2 million per year in the funding of the present program is recommended.

(p1-9)

It is recommended that NASA, in coordination with DOE, assess the level of funding available for laboratory astrophysics through the APRA program relative to the requirements of its current and future spectroscopic missions. Funding through APRA that is aimed at mission-enabling laboratory astrophysics should be augmented at a level recommended by this scientific assessment. While the costs of obtaining the data that will be needed in the coming decade are difficult to estimate, an increase of 25 percent over the current budget, or a notional budget increment of $20 million over the decade, may be required. (p 7-27)

NSF:

Astronomy and Astrophysics Grants Program (AAG)

Individual investigator grants provide critical support for astronomers to conduct the research for which the observatories and instruments are built. The current funding level has fluctuated, especially due to the welcome injection of ARRA5 funding, but the rough baseline is $46 million. An increase of $8 million to bring the baseline to $54 million is recommended. This increase should include the support of new opportunities in Laboratory Astrophysics. (p1-12)

Astronomy and Astrophysics Grants Program

Competed individual investigator grants, as described in Chapter 5, provide critical support for astronomers to conduct the research for which the observatories and instruments are built. The current funding level has fluctuated, especially because of the welcome injection of ARRA funding, but the rough baseline is $46 million per year. An increase of $8 million to $54 million per year is recommended. This increment should include the support of new opportunities in Laboratory Astrophysics.

(p7-39)

CONCLUSION: DOE national laboratories, including those funded by the Office of Science and the National Nuclear Security Administration, have many unique facilities that can provide basic astrophysical data.

The committee believes that NASA, NSF, and DOE will need to include funding for laboratory astrophysics in support of new missions and facilities and supports this conclusion in its proposed program. Other funding models should be considered if it is deemed necessary and cost-effective.

RECOMMENDATION: NASA and NSF support for laboratory astrophysics under the Astronomy and Physics Research and Analysis and the Astronomy and Astrophysics Research Grants programs, respectively, should continue at current or higher levels over the coming decade because these programs are vital for optimizing the scientific return from current and planned facilities. Missions and facilities, including DOE projects, that will require significant amounts of new laboratory data to reach their science goals should include within their program budgets adequate funding for the necessary experimental and theoretical investigations.

(pp 1-17; 5-23,24)

A2010 Survey Summary

- This is an extraordinary time in the study of the cosmos, but also a time of serious constraints on federal discretionary budgets.
- The recommended program is science-driven and will enable progress across a large swath of research and open up more discovery space.
- A balanced program should be maintained throughout the decade. Effective international, public-private and inter-agency collaboration is required for success of the program.
- A serious effort has been made to appraise activity cost, risk and technical readiness.
- Mid-decade decisions should be made based on recommendations from an independent, strategic advisory committee.
- Astro2010 has had unprecedented involvement and support by the astronomical community and immense effort by the committee, panels and consultants, as well as the strong cooperation of the agencies and professional societies.