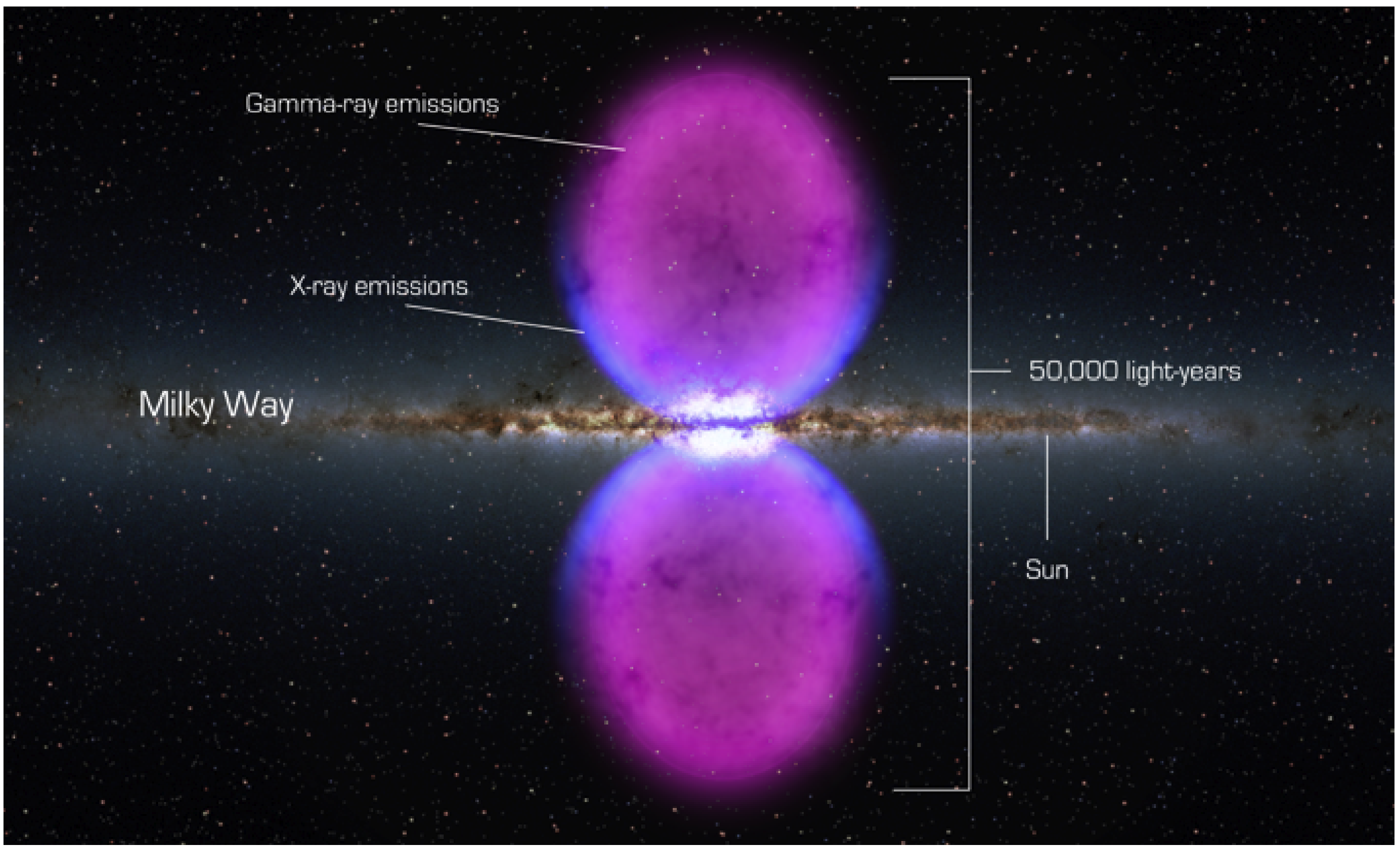
Report of the Astronomy and Astrophysics Advisory Committee

March 15, 2011



The Fermi Gamma-ray Space Telescope, a joint mission of NASA and DOE (with international participation), recently finished two-year's worth of mapping the entire sky every 3 hours using gamma-rays, a form of light radiation more powerful than X-rays. Scientists, after careful removal of obscuring diffuse radiation, unveiled an enormous pair of bubbles of very hot gas centered in the Milky Way. The feature spans 50,000 light-years and may be the remnant of an eruption long ago, perhaps from a super-massive black hole or from an intense burst of star creation near the center of our galaxy. (Credit: NASA Goddard Space Flight Center)

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March 15, 2011

Dr. Subra Suresh., Director
National Science Foundation
4201 Wilson Blvd., Suite 1205
Arlington, VA 22230

Mr. Charles F. Bolden, Jr., Administrator
Office of the Administrator
NASA Headquarters
Washington, DC 20546-0001

Dr. Steven Chu, Secretary of Energy
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585

The Honorable John D. Rockefeller, IV, Chairman
Committee on Commerce, Science and Transportation
United States Senate
Washington, DC 20510

The Honorable Jeff Bingaman, Chairman
Committee on Energy & Natural Resources
United States Senate
Washington, DC 20510

The Honorable Ralph Hall, Chairman
Committee on Science, Space and Technology
United States House of Representatives
Washington, DC 20515

Dear Dr. Suresh, Mr. Bolden, Secretary Chu, Chairman Rockefeller, Chairman Bingaman, and Chairman Hall:

I am pleased to transmit to you the annual report of the Astronomy and Astrophysics Advisory Committee for 2010–2011.

The Astronomy and Astrophysics Advisory Committee was established under the National Science Foundation Authorization Act of 2002 Public Law 107-368 to:

(1) assess, and make recommendations regarding, the status of the activities of the Foundation and the National Aeronautics and Space Administration, and the Department of Energy as they relate to the recommendations contained in the National Research Council's 2001 report entitled *Astronomy and Astrophysics in the New Millenium*, and the recommendations contained in subsequent National Research Council reports of a similar nature;

(2) not later than March 15 of each year, transmit a report to the Director, the Administrator of the National Aeronautics and Space Administration, the Secretary of Energy, the Committee on Commerce, Science and Transportation of the United States Senate, the Committee on Energy and Natural Resources of the United States Senate, and the Committee on Science, Space, and Technology of the United States House of Representatives, on the Advisory Committee's findings and recommendations under paragraphs (1) and (2).

The attached document is the eighth such report. The executive summary is followed by the report, with findings and recommendations for NSF, NASA and DOE regarding their support of the nation's astronomy and astrophysics research enterprise, along with detailed recommendations concerning specific projects and programs.

I would be glad to provide you with a personal briefing if you so desire.

Sincerely yours, on behalf of the Committee,

Kim Griest

Kim Griest
Chair, Astronomy and Astrophysics Advisory Committee

cc: Senator Kay Bailey Hutchison, Ranking Member, Committee on Commerce, Science and Transportation, United States Senate
Senator Lisa Murkowski, Ranking Member, Committee on Energy & Natural Resources United States Senate
Representative Eddie Bernice Johnson, Ranking Member, Committee on Science, Space, and Technology, United States House of Representatives
Senator Bill Nelson, Chairman, Subcommittee on Science and Space, Committee on Commerce, Science and Transportation, United States Senate
Senator John Boozman, Ranking Member, Subcommittee on Science and Space, Committee on Commerce, Science and Transportation, United States Senate
Senator Maria Cantwell, Chairwoman, Subcommittee on Energy, Committee on Energy & Natural Resources, United States Senate
Senator James Risch, Ranking Member, Subcommittee on Energy, Committee on Energy & Natural Resources, United States Senate
Senator Barbara Mikulski, Chairwoman, Subcommittee on Commerce, Justice, Science, and Related Agencies, Committee on Appropriations, United States Senate
Senator Kay Bailey Hutchison, Ranking Member, Subcommittee on Commerce, Justice, Science, and Related Agencies, Committee on Appropriations, United States Senate
Senator Dianne Feinstein, Chairwoman, Subcommittee on Energy and Water Development, Committee on Appropriations, United States Senate
Senator Lamar Alexander, Ranking Member, Subcommittee on Energy and Water Development, Committee on Appropriations, United States Senate

Representative Rodney Frelinghuysen, Chairman, Subcommittee on Energy and Water Development, Committee on Appropriations, United States House of Representatives
Representative Peter J. Visclosky, Ranking Member, Subcommittee on Energy and Water Development, Committee on Appropriations, United States House of Representatives
Representative Frank R. Wolf, Chairman, Subcommittee on Commerce, Justice, Science and Related Agencies, Committee on Appropriations, United States House of Representatives
Representative Chaka Fattah, Ranking Member, Subcommittee on Commerce, Justice, Science and Related Agencies, Committee on Appropriations, United States House of Representatives
Representative Steven Palazzo, Chairman, Subcommittee on Space and Aeronautics, Committee on Science, Space, and Technology, United States House of Representatives
Representative Gabrielle Giffords, Ranking Member, Subcommittee on Space and Aeronautics, Committee on Science, Space, and Technology, United States House of Representatives
Representative Andy Harris, Chairman, Subcommittee on Energy and Environment, Committee on Science, Space, and Technology, United States House of Representatives
Representative Brad Miller, Ranking Member, Subcommittee on Energy and Environment, Committee on Science, Space, and Technology, United States House of Representatives
Representative Mo Brooks, Chairman, Subcommittee on Research and Science Education, Committee on Science, Space and Technology, United States House of Representatives
Representative Daniel Lipinski, Ranking Member, Subcommittee on Research and Science Education, Committee on Science and Technology, United States House of Representatives
Dr. Harry E. Seidel, Assistant Director, Directorate for Mathematical and Physical Sciences, National Science Foundation
Dr. Ed Weiler, Associate Administrator for the Science Mission Directorate, National Aeronautics and Space Administration
Mr. Chuck Gay, Deputy Associate Administrator for the Science Mission Directorate, National Aeronautics and Space Administration
Dr. Paul Hertz, Chief Scientist, Science Mission Directorate, National Aeronautics and Space Administration
Dr. Jon Morse, Director, Astrophysics Division, Science Mission Directorate, National Aeronautics and Space Administration
Dr. Geoffrey Yoder, Deputy Director, Astrophysics Division, Science Mission Directorate, National Aeronautics and Space Administration
Dr. Steven Koonin, Under Secretary, Office of the Under Secretary for Science, U.S. Department of Energy
Dr. William Brinkman, Director, Office of Science, U.S. Department of Energy
Dr. Patricia Dehmer, Deputy Director for Science Programs, Office of Science, U.S. Department of Energy
Dr. Michael Procario, Acting Director, Office of High Energy Physics, U.S. Department of Energy
Dr. Glen Crawford, Head, Research and Technology Division, Office of High Energy Physics, U.S. Department of Energy
Dr. Kathleen Turner, Program Manager, Office of High Energy Physics, U.S. Department of Energy
Dr. Tom Kalil, Deputy Director for Policy, Office of Science and Technology Policy, Executive Office of the President
Dr. Carl Wieman, Associate Director, Science Division, Office of Science and Technology Policy, Executive Office of the President
Dr. James Ulvestad, Director, Division of Astronomical Sciences, National Science Foundation
Dr. Vernon Pankonin, Deputy Director, Division of Astronomical Sciences, National Science Foundation
Dr. Thomas Statler, Program Director, Division of Astronomical Sciences, National Science Foundation

Dr. Sae Woo Nam, Senior Policy Analyst, Office of Science and Technology Policy, Executive Office of the President
Ms. Celinda Marsh, Program Examiner, NASA, Office of Management and Budget
Mr. Brian Dewhurst, Program Examiner, NASA, Office of Management and Budget
Dr. Joel Parriott, Program Examiner, NSF, Office of Management and Budget
Dr. J.D. Kundu, Program Examiner, DOE, Office of Management and Budget

Astronomy and Astrophysics Advisory Committee Members:

Dr. Sarah Church, Stanford University
Dr. Debra Elmegreen, Vassar College
Dr. Joshua Frieman, Fermilab
Dr. Kim Griest, University of California, San Diego
Dr. Martha Haynes, Cornell University
Dr. Jacqueline Hewitt, Massachusetts Institute of Technology
Dr. David Koo, University of California, Santa Cruz
Dr. Gregory Laughlin, University of California, Santa Cruz
Dr. Douglas O. Richstone, University of Michigan
Dr. Paul Vanden Bout, National Radio Astronomy Observatory
Dr. John Wefel, Louisiana State University
Dr. Brian Winer, The Ohio State University
Dr. Charles Woodward, University of Minnesota

Executive Summary

The Astronomy and Astrophysics Advisory Committee (AAAC) advises the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), and the U.S. Department of Energy (DOE) on selected issues within the fields of astronomy and astrophysics that are of mutual interest and concern to the agencies. Established in the NSF Authorization Act of 2002, the AAAC is chartered to assess and make recommendations regarding coordination of astronomy programs of the NSF, DOE, and NASA, to assess and make recommendations regarding the activities of the agencies related to National Research Council Astronomy and Astrophysics Decadal Surveys, and to report their assessments and recommendations annually to the NSF Director, the NASA Administrator, the Secretary of Energy, and relevant committees in the House and Senate.

This communication represents our annual report. Our findings and recommendations related to our charter are given below.

Findings:

**The new NRC Astro2010 decadal survey report: New Worlds, New Horizons (NWNH), is a culmination of unprecedented community effort. The report represents the nationwide consensus of the most critical and promising future directions in astrophysics and astronomy. For the first time independent assessment of cost and technical maturity of all proposed projects was included in the decision making process.*

**The many ongoing NASA, NSF and DOE science breakthroughs and successes in astrophysics and astronomy are the result of successful agency stewardship of previous decadal surveys. That is, the decadal process really works, and it is important to maintain the priorities and balance given in NWNH.*

**Budgetary constraints may severely delay the implementation of many of the NWNH recommended projects. Continued budgetary constraints have the potential to damage current U.S. worldwide leadership in astronomy and astrophysics.*

**We highly commend the initial response of the agencies to NWNH, given the budgetary constraints. Especially welcome are NASA's plans for the midscale Explorer program, NSF's plan for midscale innovation projects, the NASA Tech Fellows program, and NASA's Wide-Field Infrared Survey Telescope (WFIRST) plans.*

**We commend the interagency actions by the NSF and DOE with respect to the Large Synoptic Survey Telescope (LSST), which we find to be consistent with the recommendations of NWNH.*

**"Rising Above the Gathering Storm" warns that the Nation must do a better job in training the next generation of scientists and engineers in order to remain competitive. Astronomy has a role to play in this regard, because it is a mind-opening field, a gateway, in which exciting* *discoveries can attract young people to STEM (science, technology, engineering, and mathematics) careers.*

**As noted in the AAAC letter of October 22, 2010, the Committee remains concerned about the potential impacts of the anticipated* James Webb Space Telescope *(JWST) cost increases and schedule delays on the NWNH recommended major space activities for the decade.*

**NWNH called for the formulation of a Decadal Survey Implementation Advisory Committee (DSIAC) to provide strategic advice on decadal report-related issues and to monitor the progress on achieving the recommendations. While the AAAC has a role as shepherd over the decadal results, its charge is primarily to be a tactical committee, whose role is to advise on issues related to project development, particularly projects that cut across more than one agency. AAAC is available to work with a newly formed DSIAC as needed.*

**The Committee finds that interagency cooperation plays a key role in the astronomy research program and will continue to do so through the next decade. The agencies have identified opportunities for joint activities from the priorities recommended in the NWNH program, but the Committee notes that in many cases activities may be limited by the tight fiscal environment.*

Astronomy and Astrophysics Advisory Committee Report
March 15, 2011

The following constitutes the annual report of the Astronomy and Astrophysics Advisory Committee (AAAC) for 2010-2011. The role of the AAAC is 1) to monitor the coordination of astronomy and astrophysics across three agencies: DOE, NASA and NSF, 2) to monitor the status of activities contained in the relevant National Research Council (NRC) decadal survey reports, and 3) to report on our findings by March 15 each year.

The AAAC met four times during 2010/2011 and was briefed on the status of astronomically related projects by the NSF, DOE, and NASA. The Committee also heard from OSTP and OMB. The Committee, representing the astrophysics community, had extensive back and forth discussion of many projects with the agencies. Our task was to understand and evaluate the agencies' progress and approaches towards the various projects. One of our main tasks this year was to understand and evaluate the agencies' responses to the new NRC decadal survey on astrophysics, *New Worlds, New Horizons in Astronomy and Astrophysics* (NWNH). To help us understand this survey we were extensively briefed by Roger Blandford, chair of the Astro2010 survey, as well as other members of the Astro2010 committee. We carefully questioned Blandford and others on the methods and conclusions detailed in NWNH. We then asked the agencies detailed questions on their responses to the survey. The Committee's findings and recommendations are based upon these briefings, our discussions, as well the Committee's knowledge of the fields of astronomy and astrophysics under discussion.

Science Highlights

Below we provide a sampling of some of the scientific breakthroughs made this year by past NASA, NSF, and DOE investments in Astronomy and Astrophysics. In the interest of brevity, we mention here only a few examples of the many exciting discoveries and scientific advancements in the field of astronomy and astrophysics made over the last year.

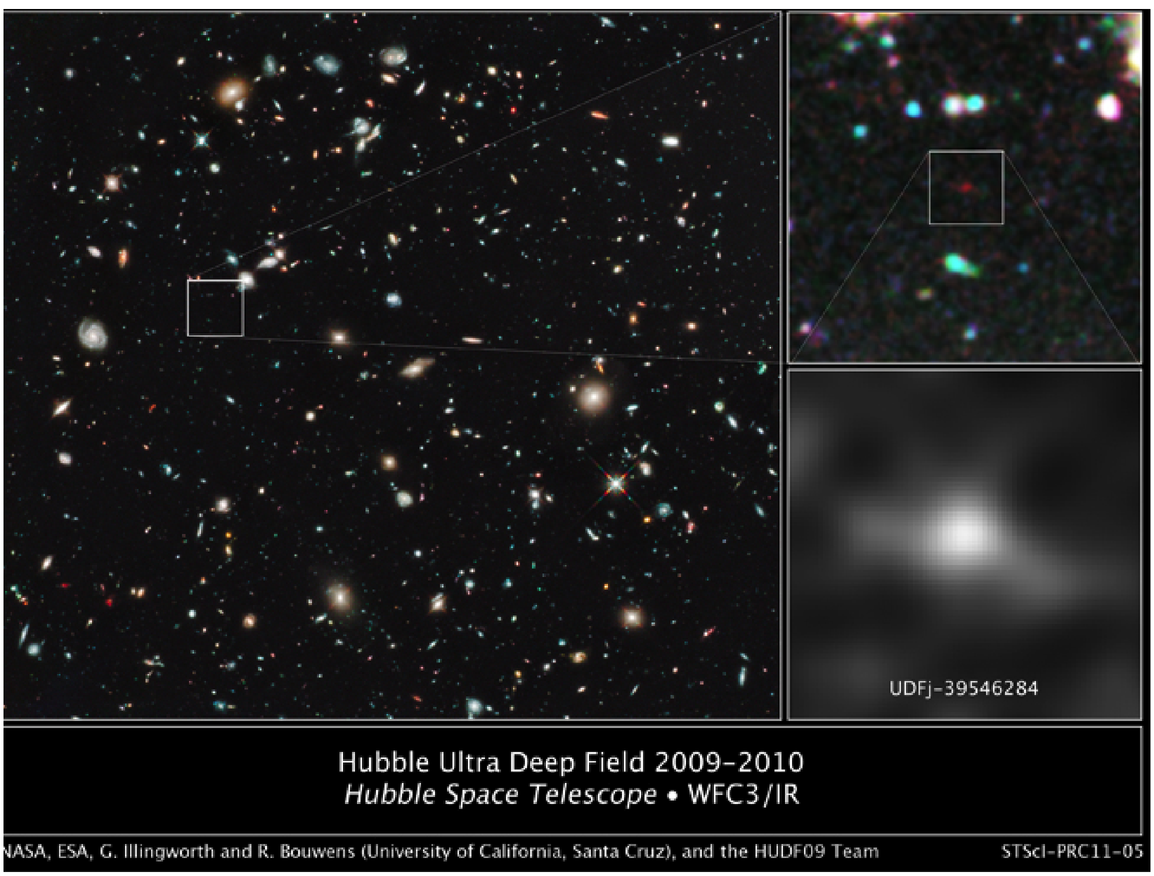
2a. Planets from Kepler

NASA's Kepler Mission, which was launched in March of 2009, is producing extraordinary discoveries. The Kepler spacecraft continuously monitors 156,000 stars in the plane of the Milky Way and watches for transits – the slight, repeated, characteristic dimming that occurs when a planet passes in front of its parent star. Kepler's initial performance demonstrates that it has the sensitivity to detect Earth-size planets on Earth-like orbits, which will give us the first genuine accounting of the frequency of potentially Earth-like worlds in the Cosmos.

Kepler's full mission will unfold over the next several years, but the initial results have been stunning. In February of 2011, it produced 1,235 high-quality extrasolar planet candidates, including several that are potentially Earth-like. With a single announcement, the census of known planets (accumulated over the past 15 years) was more than doubled. Many of the new worlds can be classified as "Super Earths", a heretofore completely unstudied realm of planets with masses lying between those of Earth and Neptune. Other highlights included a system with six individually transiting planets, and another in which two planets execute an uneasy gravitational dance as they share a single orbital period.

2b. Oldest Galaxies yet seen from HST

Besides searching for new planets, astronomers extract clues to our origins by using telescopes as time machines to peer billions of years back in time. With the successful refurbishment mission of the NASA/ESA Hubble Space Telescope (HST) in mid-2009, this powerful time machine was enhanced with a new infrared camera that has found the most distant galaxy that humans have ever seen. Announced in early 2011, this galaxy appears as a tiny red "blob" amidst 1000's of galaxies (see Figure) seen in the deepest picture of the sky ever taken, requiring weeks of staring at a single tiny patch of sky. More than 100 of these young galaxies would be needed to form our home galaxy, the Milky Way. Astronomers estimate that the red "blob" formed less than 500 million years after the Big Bang, which is equivalent to seeing our Universe, if it were a 50 year old man today, when it was still only a 2 year old toddler. To search the Universe at even earlier times, at its crawling infant stage, scientists will require Hubble's successor, the James Webb Space Telescope (JWST), currently the last of the major missions to be launched by NASA this decade.



Picture of the Hubble Ultra Deep Field shows thousand's of tiny colored dots of light, each a galaxy seen as it existed several billions of years ago. The blowup of the inset square in the large picture is shown in the upper right; the magnified image shows a red "blob" that astronomers measure to have formed less than 500 million years after the big bang, the earliest stage of a young galaxy ever seen. The further-magnified image shown in the lower right panel reveals the shape of this budding galaxy. (Credit: see image)

2c. New Heavy Neutron Star Discovered by Robert C. Byrd Radio Telescope

Observations of a white dwarf – neutron star binary system using the Robert C. Byrd Green Bank Telescope (GBT), an NSF facility, show the neutron star to have a mass of nearly twice that of the sun. The stars' orbits are seen edge-on, and measurement of the delay in pulses from the neutron star pulsar (PSR J1614-2230) as the pulsar passes the white dwarf (the Shapiro Delay) allows the masses of both stars to be determined. The unexpectedly large mass (1.97 M_{sun}) of the neutron star has implications for the state of matter at ultra-high densities, ruling out some theoretical models and putting limits on others. The observations exploited the large collecting area of the GBT and the power of a recently developed high-speed digital signal processor. In general, such measurements depend critically on access to wide swaths of the electromagnetic spectrum free of interference.

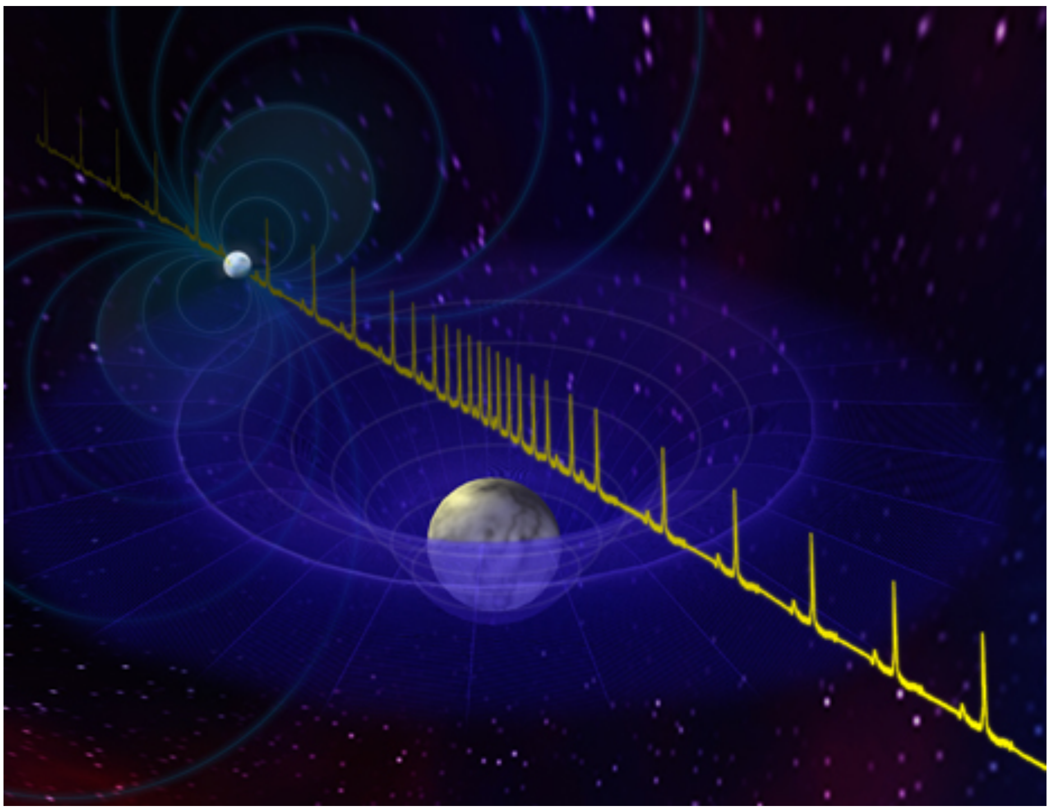
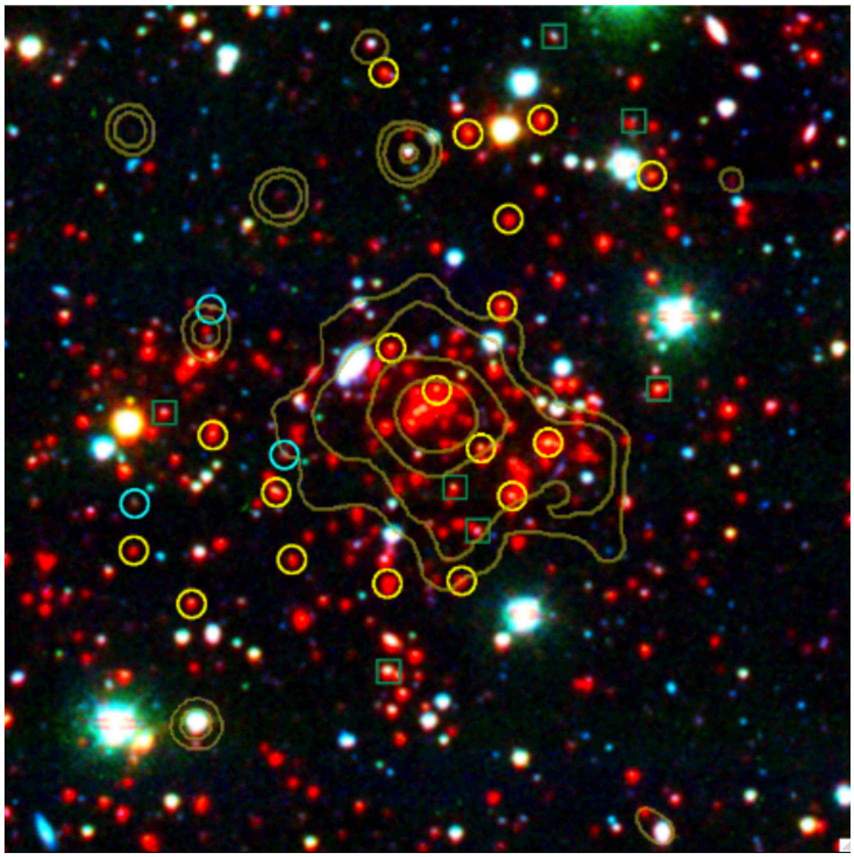


Image shows pulses from the neutron star pulsar being slowed down (pulses become closer together) as they pass near the white dwarf. This effect, known as the Shapiro Delay, is caused by the gravitational field of the white dwarf, as predicted by Einstein's Theory of General Relativity (Credit: Bill Saxton NRAO/AUI/NSF)

2d. Largest Cluster of Galaxies Discovered by NSF South Pole Telescope

The 10-meter South Pole Telescope (SPT), operating at the NSF Amundsen-Scott South Pole Station, discovered the two most massive clusters of galaxies at large distances, each with a mass of about a quadrillion (a thousand trillion) times the mass of the Sun. They were detected via the Sunyaev-Zel'dovich effect: a small fraction of the radiation coming from the cosmic microwave background through the cluster is scattered by the very hot cluster gas (temperature of about 100 million degrees), resulting in a characteristic deficit in the microwave intensity (at long wavelengths) in the direction of the cluster. Optical images taken with the 4-meter Blanco telescope at the NSF-supported Cerro Tololo Interamerican Observatory (CTIO) in Chile, along with measurements from NASA's Spitzer and Chandra observatories and the Magellan telescope, show that one of the clusters, which is seen when the Universe was only 5.7 billion years old, contains many old, red galaxies. The census of clusters being carried out by the SPT, in combination with the DOE- and NSF-supported Dark Energy Survey that will begin operations at CTIO in 2012, will help illuminate the nature of dark energy driving the acceleration of cosmic expansion.



Optical+near-infrared image of distant, massive cluster discovered by the South Pole Telescope, with Chandra X-ray contours, revealing the very hot cluster gas, overlaid. Old galaxies in the cluster are indicated by yellow circles. (Credit: Brodwin, etal, ApJ, 721, 90 (2010).)

2e. Lasers Used by NSF-supported Gemini Telescope to Make Space Resolution Images from the Ground

Major discoveries in astronomy are almost always due in part to technological advances, often in computing, optics, and ever-larger detectors sensitive to new energies. Culminating a 10-year effort in one such advance, the international Gemini South Telescope opened up a new era in high-resolution astronomy with the successful propagation of a 5-star sodium laser guide star system in the skies over Cerro Pachón in Chile in the early morning of 22 January 2011 (see Figure).

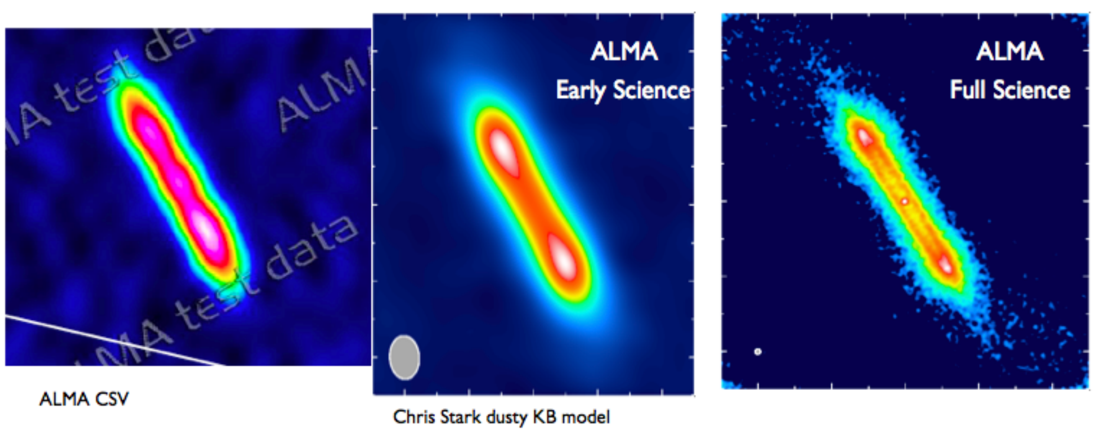
This next-generation system called GeMS uses a 50-watt laser developed in partnership with Lockheed Martin Coherent Technologies, split into five beams, each activating sodium atoms about 90 kilometers overhead to glow as an artificial star. These 5 laser stars enable a revolutionary approach to astronomical imaging, called multi-conjugate adaptive optics (MCAO). MCAO samples the complex turbulence of the atmosphere at several altitudes and then applies software used for medical tomography to reconstruct a 3-D map of how the atmosphere is distorting starlight. High speed computing and electronics are then used to continually adjust a deformable mirror to cancel out this atmospheric blur at about 1000 times a second. The resultant pin-sharp images are superb, equaling that normally only possible in space, and equivalent to a 100-fold improvement in image contrast or a 10-fold gain in faintness, covering an area of sky over 10 times larger than that possible with the first generation of adaptive optics. In 2012, the system should begin providing remarkably sharp and large images for studying topics ranging from newly discovered exo-planets to super-massive black holes.

Main image is a fish-eye interior view of the NSF supported Gemini South 8-meter Telescope (located at Cerro Pachon in Chile) with its dome slit open to the night sky and showing the first shooting on 22 January 2011 of its Multi-Conjugate Adaptive Optics (MCAO) laser guide star system. The thin line emanating from the center of the telescope is actually comprised of 5 sodium laser beams that create 5 artificial stars in a thin layer 90 km up in the atmosphere. The upper left inset shows a highly magnified image of these 5 laser stars spread over a region roughly 1/20th of the diameter of the full moon, formed at the very tip of the thin line. Having access to these artificial stars, astronomers using large telescopes from the Earth's surface are able to overcome *the blur ("seeing") due to turbulence of the atmosphere and view the universe full of newly discovered planets and super-massive black holes with the nearly pin-point sharpness normally possible only by expensive space borne telescopes (Credit: Gemini Observatory/AURA)*

2f. NSF Supported ALMA Radio Telescope Coming On Line

Construction of the international Atacama Large Millimeter Array (ALMA) is proceeding, with much progress in the last year. As of February 2011, there are 17 U.S. antennas in Chile, 8 of which are installed at the high site at 5000 meters elevation. These eight, along with one Japanese antenna are now functioning as an array, producing the first ALMA images (see Figure). A first call for proposals for early science will be issued on March 31st, with the first observations with an array of 16 antennas scheduled for fall 2011.

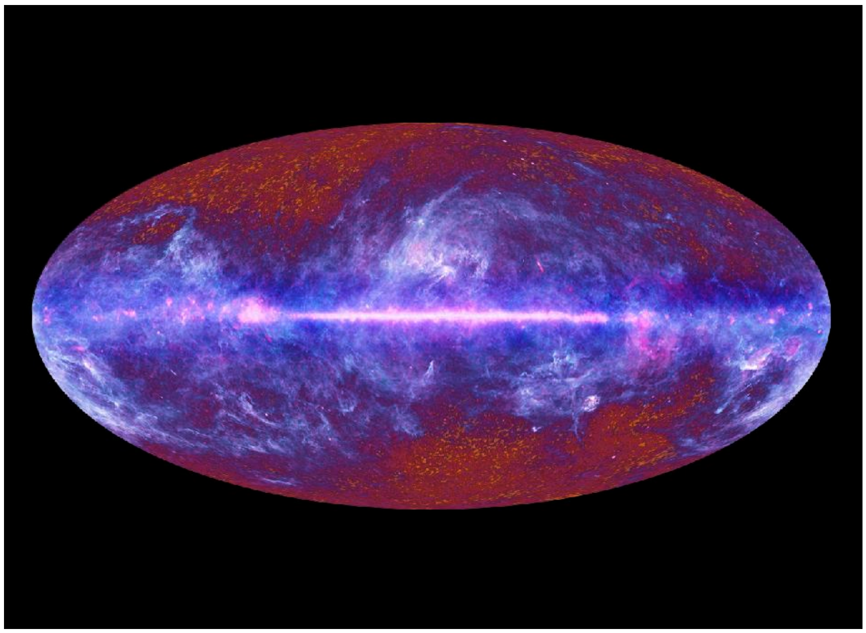
The 8-element array of ALMA antennas currently operating on the ALMA site.



Left panel – an image of the debris disk left over from the formation of the star β Pic, taken with the array of 8 ALMA antennas shown above; center panel – a simulation of the image expected with the ALMA Early Science Array; right panel – same expected with the full ALMA array (Credit: ALMA (ESO/NAQ/NRAO))

2g. ESA/NASA Planck Satellite Steps Forward as Leader in Cosmic Microwave Background Measurement

The Planck satellite, built by the European Space Agency (ESA) with significant contributions to instrument development and data analysis by NASA, has since its launch in 2009 returned spectacular images of the coldest regions in the universe and our own galaxy. The figure below shows a map of the entire sky made by combining maps from nine different frequency bands between 30 and 857 GHz. The science highlights from this mission include a catalog of thousands of previously unknown microwave sources including the nurseries in which stars form in our own galaxy, and distant, giant clusters of galaxies that are the largest known objects in the universe. Planck is continuing to survey the sky in order to provide precise maps of the Cosmic Microwave Background radiation which is the relic of the hot big bang that occurred approximately 13.7 billion years ago.

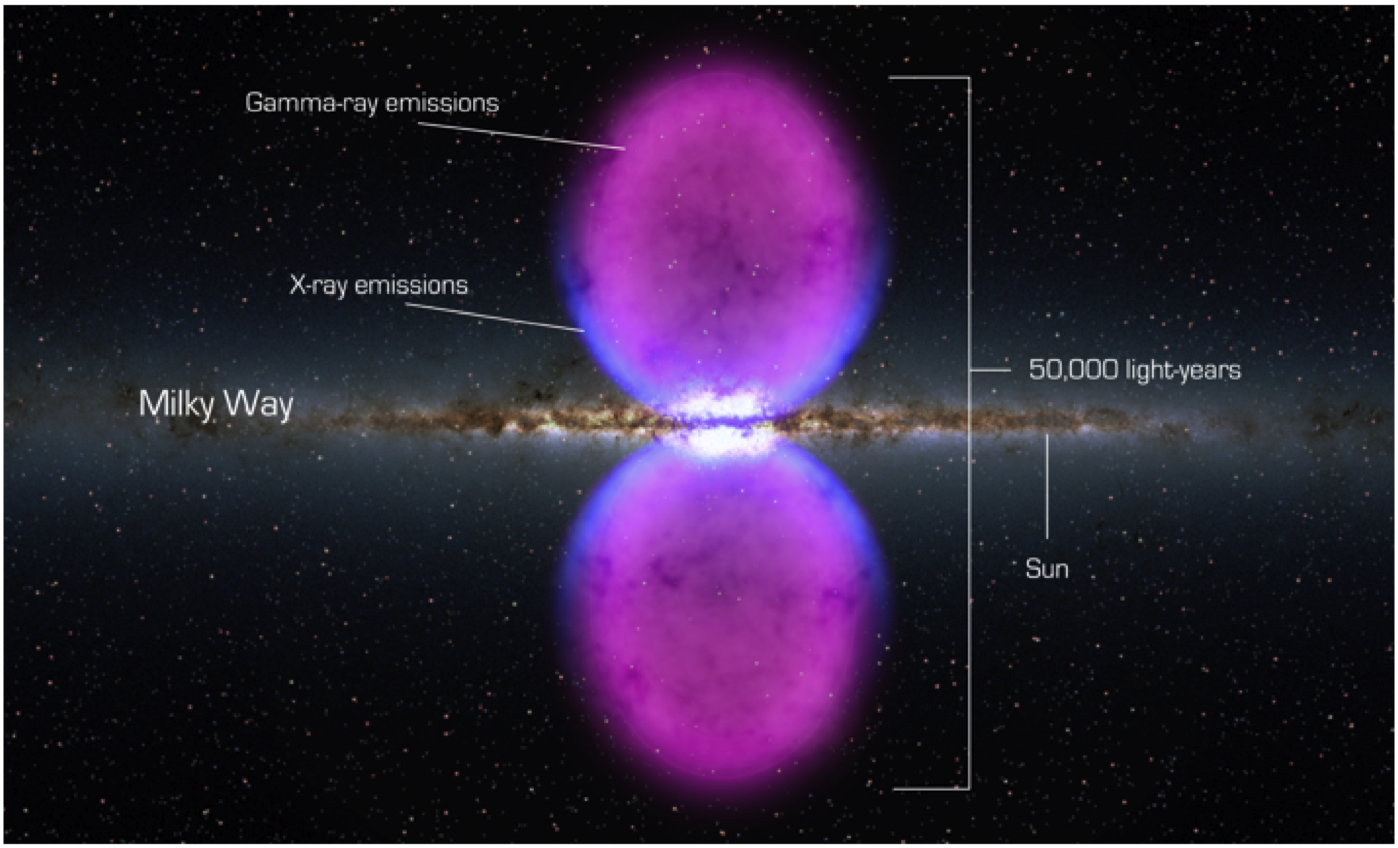


The sky as viewed in microwaves after a one-year survey by the Planck satellite. The wisps and bubbles of gas and dust in our own Milky Way galaxy (the purple and blue regions) are clearly visible and are relatively close-by in our cosmic neighborhood. The much fainter and finer-scale structures visible at the top and bottom of the map are the earliest visible signs of formation of the galaxies and other structures in the universe. Because of the finite speed of light, we see these structures as they were 13.7 billion years ago, a mere 400,000 years after the Big Bang. (Credit: ESA, HFI & LFI consortia (2010))

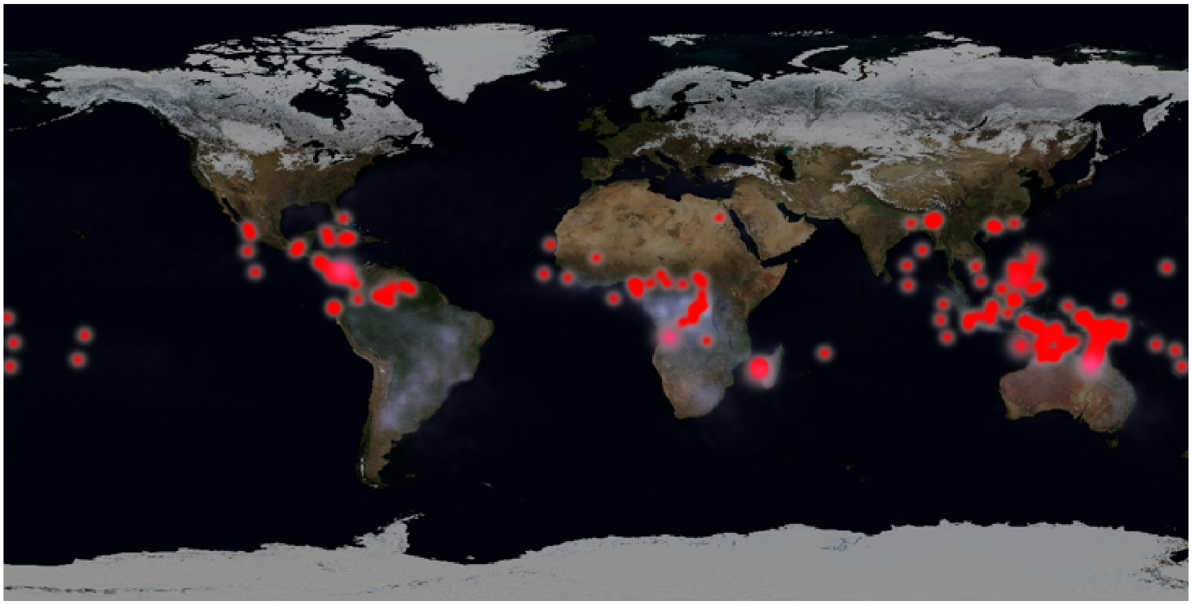
2h. Joint NASA/DOE Fermi Gamma-ray Space Telescope Discovers Enormous Bubbles Blown out of the Galactic Center; Gives New View of Thunderstorms From Above

Besides clues to our origins, astronomers continue to reveal new mysteries, especially when the Universe is viewed through "eyes" or cameras that reach previously inaccessible sensitivities, sharpness of detail, or energies. For example, one recent mystery was revealed using the Fermi Gamma-Ray Space Telescope, an extraordinarily successful inter-agency mission that mapped the sky every 3 hours using gamma-rays, a form of light that is the highest energy, even more energetic than X-rays. Combining the resources of NASA and DOE, as well as contributions from 90 national and international institutions, Fermi was launched in mid-2008. Among a plethora of discoveries, Fermi revealed a surprise about our own Milky Way: its center is sandwiched between two enormous bubbles (see Figure). These were unveiled by astronomers only after careful removal of diffuse gamma-rays that pervade the whole sky. Their origins remain unknown, but are speculated to arise from powerful jets emanating from a supermassive black hole (mass of several million suns) that resides at the center of our galaxy or perhaps from high speed winds blown by a massive burst of new star creation.

Fermi even had a surprise much closer to home, from our own planet Earth. As reported in Jan 2011 by the Fermi team, the tops of thunderstorms and lightning on Earth, known for years to produce gamma-ray flashes, have now been directly observed to launch beams of electrons and its anti-matter form (positrons) beyond our atmosphere into space (see Figure).



The Fermi Gamma-ray Space Telescope, a joint mission of NASA and DOE (with international participation), recently finished two-year's worth of mapping the entire sky every 3 hours using gamma-rays, a form of light radiation more powerful than X-rays. Scientists, after careful removal of obscuring diffuse radiation, unveiled an enormous pair of bubbles of very hot gas centered in the Milky Way. The feature spans 50,000 light-years and may be the remnant of an eruption long ago, perhaps from a super-massive black hole or from an intense burst of star creation near the center of our galaxy. (Credit: NASA Goddard Space Flight Center)

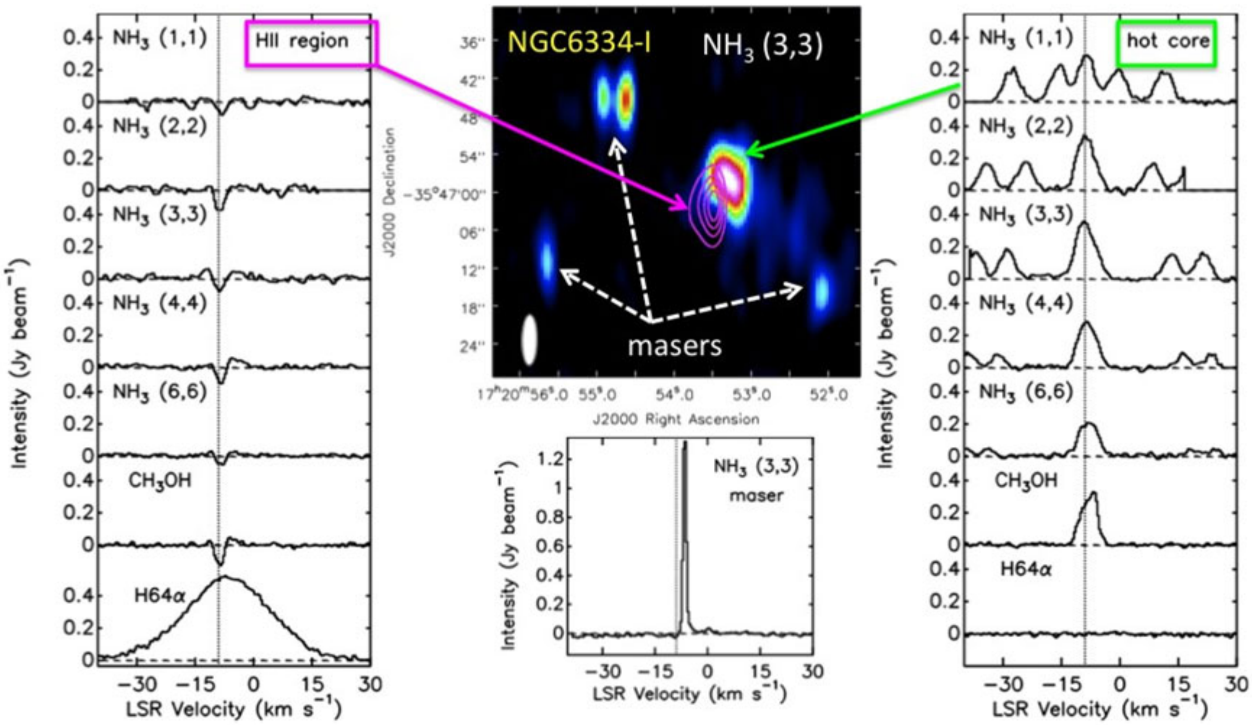


Map of gamma-ray flashes detected by Fermi in 2010, showing Fermi's scientific versatility. These flashes are linked to the creation of anti-matter particle beams that are ejected from lightning events on the top of thunderstorms. (Credit: NASA)

2i. The Expanded Very Large Area (ELVA) Radio Interferometer

During the last year, the Expanded Very Large Array (EVLA), and NSF facility, has "turned on" providing vast new capabilities in sensitivity, bandwidth and correlator capacity, funded through NSF-AST. In January, the old VLA correlator was turned off, replaced by the new WIDAR correlator. Commissioning and early science observations have demonstrated the success of the EVLA project, giving the first hints of the kinds of results we can expect over the next decade. Of particular note, the WIDAR correlator enables simultaneous spectral imaging observations of multiple subbands centered on different spectral lines, and hence the physical conditions in regions of massive star formation (see Figure). Further commissioning of the EVLA will expand these capabilities even further to a wide range of science applications in cm-wave synthesis imaging.

Finding: The many ongoing NASA, NSF and DOE science breakthroughs and successes in astrophysics and astronomy are the result of successful agency stewardship of previous decadal surveys. That is, the decadal process really works, and it is important to maintain the priorities and balance given in NWNH.



Composite of EVLA WIDAR test results toward the massive protocluster NGC6334I. Middle Top: False color image of NH3 (3,3) integrated intensity. Left: Spectra from the ultracompact HII region (magenta contours in the NH3 (3,3) image). Right: Spectra from the hot cores. Middle Bottom: Example NH3 (3,3) maser spectrum. Credit: Crystal Brogan and Todd Hunter, http://science.nrao.edu/enews/3.6/index.shtml

3. The Decadal Process

3a. Effort

The Astro2010 report, *New Worlds, New Horizons in Astronomy and Astrophysics (NWNH)*, is the culmination of an unprecedented community effort for a decadal report. The main committee of 23 people represented diverse institutions, research expertise, project development, and mission management experience. There were 9 sub-panels reporting to the main committee: 5 Science Frontier Panels (SFP) that covered the full range of topics for astronomy and astrophysics research, and 4 Program Prioritization Panels (PPP) that considered both ground and space-based missions across the electromagnetic and gravitational spectrum. There were also 6 Infrastructure Study Groups (ISG) that provided data on the state of the profession including demographics, international and private partnerships, public policy, computation facilities, and education and outreach. These panels and groups comprised some 200 astronomers and astrophysicists. There were multiple public meetings held across the country, and calls for White Papers and Requests for Information resulted in over 400 submissions detailing science opportunities, proposed projects, infrastructure issues, technology development, theory, and laboratory astrophysics.

For two years, Astro2010 met in person 6 times and held more than 100 teleconferences in an iterative process to develop its recommendations. The SFPs and ISGs provided summaries and information to the whole panel that led to the key science goals and state of the profession recommendations; these goals in turn helped inform the project selections by the main committee once the PPPs provided their summaries.

3b. Consensus

Like previous decadal reports, which have been widely regarded as models for other scientific communities to emulate, NWNH represents a consensus vision that provides Congress, OSTP, and the agencies a clear picture of the intent of the community regarding priorities for federal funding. The American Astronomical Society (AAS) has endorsed the report and its recommendations. Following the report's release in August, numerous public meetings were held nationwide so that the details could be explained and questions answered, culminating in a town hall at the AAS winter meeting in Seattle in January 2011. The community recognizes that, while not all projects and ideas submitted to Astro2010 could be supported (their total cost exceeded predicted optimistic budgets by 10:1), it is important to be united in support of the balanced program of high priority projects selected by Astro2010. Moreover, the NWNH report defined a well balanced program of truly exciting science that, when implemented and complemented by projects already underway such as the JWST and ALMA, will continue the leadership role of the United States in Astronomy and Astrophysics.

3c. Budgetary Restraint, Costing Effort

NWNH took special efforts to present a fiscally realistic set of recommendations. The agencies all provided budget guidelines, and the Committee adhered to them in developing its report. For NASA, the Committee assumed both a pessimistic budget that was flat in real dollars (the guideline given by NASA), and a more optimistic one that was flat in 2010 dollars. For NSF and DOE, the Committee assumed both a pessimistic budget that was flat in 2010 dollars (the guideline given by these agencies), and an optimistic one that represented a doubling over the decade. For the NSF, the Committee understood that the recommendations made under the assumption of the optimistic scenario could be implemented in a flat budget only if NSF/AST reduced funding for existing activities or if additional funding were found for AST. Within these constraints, the Committee considered the most compelling science, and selected the most promising projects and missions for further consideration. An independent outside consulting firm provided an assessment of cost appraisal and technical evaluation (CATE) along with consideration of risk. This CATE process helped the Committee develop realistic budgets for different projects, which could then be compared against the budget envelopes in the final selection of projects. The result was a set of recommendations that fit the optimistic budgets, along with more modest goals in the case of pessimistic budgets.

3d. Examples of Transformative Potential of NWNH Projects

The list of small, medium, and large projects presented in the recommendations of NWNH provides many opportunities for transformative science. The number one large ground-based project, the Large Synoptic Survey Telescope (LSST), is transformative in the time domain. By observing half the sky in several filters every few days for a decade, this large field-of-view telescope will enable studies of time and position variability, from supernovae that will help us understand the acceleration of the universe, to a study of near-Earth asteroids (a Congressionally mandated study) in greater depth than ever before. LSST will map billions of galaxies to reveal the structure of baryonic matter, which in turn yields clues about dark energy, and LSST will also complete a census of stars in our Milky Way galaxy. The acquisition plan provides a robust data processing and management infrastructure that allows quick alerts, sorting, and archiving of tens of terabytes of data every night. Besides data access for professional astronomers and for use in training, education, and outreach, such technological data-intensive development will help in numerous areas reaching far beyond astronomical endeavors.

The Wide-Field Infrared Survey Telescope (WFIRST), the number one ranked large space recommendation, will transform our large scale view of the universe through images and spectra of billions of galaxies, as well as provide a census of exoplanets for future dedicated studies, and map stars in our galaxy; its guest investigator mode will provide important access to all U.S. astronomers. Its infrared capabilities will complement the large-scale optical view of the universe that LSST will provide.

Transformative science at short radio wavelengths will be achieved through CCAT, a 25-m sub-millimeter and millimeter telescope designed to complement ALMA by providing wide field surveys of all major astronomical classes of objects, ranging from those in the outer solar system, planet-forming regions, nearby galaxies, clusters of galaxies, and even the most distant, earliest galaxies to form in the Universe. CCAT is being built by a private consortium of universities and foreign partners. NSF participation opens to the U.S. astronomical community not only the telescope but also, and most importantly, the database gathered by CCAT surveys.

Some transformative science to be harvested in the next decade cannot yet be imagined; that's why NWNH recommends, as its second priority both in space and on the ground, mechanisms for funding projects that individually would fall into a medium category. Some of our most spectacular transformations in science have come previously through such medium-scale missions, such as WMAP. The recommended Explorer program enhancement would restore the capabilities of NASA to launch several MIDEX and SMEX missions and Missions of Opportunity over the decade. Similarly, a Mid-Scale Innovation Program at NSF would compete projects midway between the MRI and MREFC funding levels in order to encourage rapid development of medium-scale projects. In addition to CCAT, several proposals were called out in NWNH as examples of worthy mid-scale efforts, ranging from a solar radio telescope (FASR) to advanced adaptive optics, from hydrogen epoch of recombination radio arrays (HERA) to an optical spectrograph designed to image 3000 spectra simultaneously from a 4-m telescope (BigBOSS), to detection of gravitational waves from colliding black holes (Nanograv).

3e. December Implementation Report

At the fall AAAC meeting, Jon Morse reported that NASA had been considering an opportunity to join ESA's Euclid mission (if it is selected for an M-class mission) at a 20% investment level as a way of getting a start on some of the dark energy studies highlighted in NWNH. The OSTP recognized that such a level of collaboration was not noted in NWNH, and called for a Panel on Implementing Recommendations from the New Worlds, New Horizons Survey to address the issue and write a report. The panel, organized by directors of the National Academies' Board of Physics and Astronomy and the Space Studies Board, consisted of members of those committees, some of whom also served on Astro2010. The report, released in December, considered 4 options: (A) proceed with a WFIRST launch this decade, (B) collaborate on a joint mission with ESA that included all 3 components of WFIRST (exoplanet census via microlensing; dark energy science via baryon acoustic oscillations, weak lensing, and Supernova Ia studies; and a survey/guest investigator mode) and kept the US in a leadership position, (C) proceed with a 20% investment in Euclid, and (D) do no WFIRST and no collaboration, if necessary in order that the small and medium recommendations of NWNH were not lost. Options (A), (B), and (D) were the ones that were deemed to be consistent with NWNH.

Finding: The new NRC Astro2010 decadal survey report: New Worlds, New Horizons (NWNH), is a culmination of unprecedented community effort. The report represents the nationwide consensus of the most critical and promising future directions in astrophysics and astronomy. For the first time independent assessment of cost and technical maturity of all proposed projects was included in the decision making process.

4. Agency Response to New Worlds, New Horizons in the Context of Budgetary Constraints

One of the duties of the AAAC is to assess the progress of DOE, NASA and NSF in implementing the NRC Decadal Report (NWNH). Each agency has prioritized the top-level recommendations of NWNH. DOE and NSF have prioritized the LSST in accordance with the top ground-based recommendation, and NASA has prioritized WFIRST. At the same time, budget uncertainties force the agencies to be very cautious. With a flat NASA astrophysics budget, WFIRST cannot start until a suitable budget wedge opens up, which depends on the revised JWST plan, but seems unlikely to occur before JWST is launched. At a flat budget, NSF cannot start LSST without canceling or re-scoping current activities. DOE's projected funding for dark energy allows participation in only one major experiment. DOE is planning participation in LSST since that was recommended as the priority for DOE, due to its critical role. DOE is not considering a role in WFIRST at this time, though is supporting scientists that are working on the Science Definition Team.

Given that the prospects for starting these two highly ranked projects before late in the decade seem limited, the Committee was pleased to find that the agencies are committed to trying to incorporate them into their portfolios. This intention was clear from the agency presentations that described future budget planning, interagency management structures for LSST, and the formation of the science definition team for WFIRST. The Committee also commends the agencies for following a number of other recommendations from the NWNH. These include augmentations to the Explorer line by NASA and to technology development for new projects by NASA and NSF, and maintaining other grants programs by NSF.

4a. NASA Explorer Program and Sub-orbital Program

NASA's Explorer Program has been very successful over the past decades in developing low-cost, scientifically focused space missions that have provided discovery-rich new data for the Astrophysics community. Recognizing the need for such medium-cost missions, NWNH recommended that Explorers for astrophysics investigation be increased by about 2 new astrophysics MIDEX missions, 2 new astrophysics SMEX missions, and at least 4 astrophysics Missions of Opportunity (MoO) per decade. The Committee was pleased to hear NASA's plans for augmenting the Explorers. Historically the Explorer line has been held in Heliophysics, with the community submitting proposals in response to an Announcement of Opportunity. When an astrophysics mission is selected, funds for the mission are transferred from Heliophysics to Astrophysics. NASA has now split the Explorer line, transferring half to astrophysics to initiate a series of Astrophysics Explorer Missions. Moreover, within the FY2012 budget request, and continuing into the out years, the budget for the new Astrophysics Explorers is planned to be augmented to bring the mission frequency to about four new starts per decade. The AAAC commends NASA on implementing this very exciting new program.

One of the recommendations from NWNH in the small category was an augmentation in support for sub-orbital – particularly balloon – payload development. The sub-orbital program provides a test bed for new technology, a very effective training ground for young researchers and graduate students and the opportunity to obtain exciting new data that can form the basis of, and rationale for, a larger space mission. Many of NASA's current PI's received their initial training as part of the sub-orbital program. The Committee was, therefore, very pleased to hear that NASA plans to augment the level of funds available to develop these sub-orbital payloads. Moreover, in the balloon program, NASA reported the recent successful launch and flight of a 14 million cubic foot (MCF) superpressure balloon, the last step before scaling this new technology to ~26 MCF which will enable flights of several thousand pound payloads for durations of up to ~100 days. After many years of development, the Ultra-Long Duration Balloon capability is close to becoming a reality and an important new scientific tool for astrophysics investigations.

NASA's responses to the recommendations of Astro2010 have been quite supportive of the goals outlined by the NWNH report, to within the available resources. The FY2012 budget request was the first one that could be attuned to the recommendations of the decadal survey, and, overall, the AAAC was satisfied with the Agency's efforts. The Committee realizes, however, that we are immersed in difficult financial times and appropriated funds may not be the same as the budget requests upon which much of our discussion was based. We anticipate the need for re-alignment of priorities as the budget process unfolds, and providing such advice will be the work of the AAAC (and a DSIAC) over the next several years.

4b. **NSF Mid-scale Program Augmentation**

The Astro2010 recommendations included, as second priority (following LSST) in the category of large ground-based programs, an augmentation of the NSF mid-scale innovation program. This recommendation recognizes the "funding gap" that currently exists between the top of the MRI funding bracket ($4M) and the bottom of the MREFC funding bracket (about $135M). It also recognizes the need for smaller investments in instrumentation and infrastructure that can respond quickly to new scientific priorities in an innovative manner. Furthermore, it recognizes the important role that such mid-scale projects, often university-based, play in training students and young scientists in instrumentation. Without an increase in the NSF/AST division's funding level, or a reprogramming of existing NSF/AST funds, the recommendation for an augmented mid-scale program within AST cannot be implemented.

In the current climate of restricted funding, it is particularly important to identify a portion of the portfolio that will enable activity that can respond to new scientific initiatives in a timely manner. We therefore commend NSF/AST for its plans to initiate a portfolio review in the coming year with the goal of balancing support for existing programs and for new initiatives, such as a mid-scale innovation and infrastructure program. We are encouraged that NSF is also considering a Foundation-wide mid-scale initiative, which may provide a funding mechanism outside of AST lines.

4c. **Large Synoptic Survey Telescope (LSST)**
The Large Synoptic Survey Telescope (LSST) is the lead ground-based facilities priority emerging from the community deliberation and consensus summarized in NWNH. The NWNH outlined an implementation strategy for an LSST facility involving a cooperative partnership between federal agencies (the National Science Foundation as lead agency through its Division of Astronomical Sciences (NSF/AST), working with the Department of Energy Office of High Energy Physics (DOE/HEP)), the public-private sector, and international partners. The genesis of the LSST concept can be traced to a high-priority recommendation of the 2000 Decadal Survey (Astronomy and Astrophysics in the New Millennium) that articulated the need for a large-aperture, very-wide-field, synoptic survey telescope to observe the entire sky visible from a selected site repeatedly over many years of effort. Over the last decade that project concept has matured into the LSST. Many key areas of technical performance (including fabrication of telescope optics), instrumentation capabilities (e.g., large format sensor development), data archiving and management approach (e.g., data farm model builds engaging commercial enterprises), cyber infrastructure, scientific rationale, and citizen-scientist interaction are already well defined.

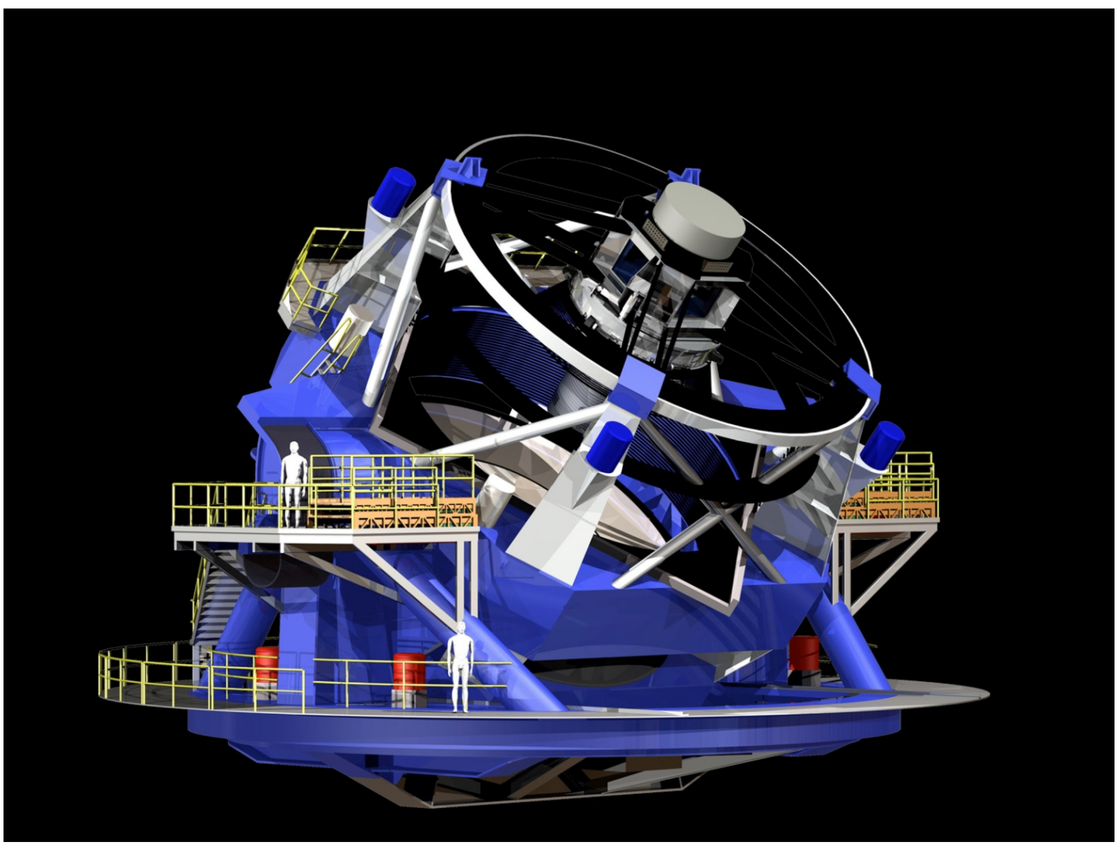
Currently, the LSST project is a broad consortium (overseen by the LSST Corporation) comprising over 30 universities, research institutions, non-profit foundations, and international partners that plans to build a survey telescope with an 8.4-m primary mirror and a 6.7-m effective aperture on Cerro Pachon, Chile (see Figure). This peak in Chile also is home to one of the twin Gemini 8-m telescopes, part of the International Gemini Observatory, funded in part by the NSF. Operationally, the LSST facility is designed for "wide-fast-deep" surveys, with images of the entire available sky being obtained with an advanced 3.2 Gigapixel camera (Illustrated below) covering a 9.6 square degrees to depths of 24th magnitude at optical wavelengths over a 10-year baseline operational period. During this period, each field will be observed 1000 times in six filter bands and produce 30 Terabytes of data per night. The LSST project has four motivating science goals: the study of dark energy and dark matter, an inventory of the solar system, the study of optical transients, and investigating galactic structure. Time-domain science, encompassing the measurement of millions of celestial sources on any given night, is a largely unexplored area of observational astrophysics. LSST plans to have a rapid response alert system of less than 1 minute for transient events. The LSST discovery space related to time-domain phenomena has great promise to yield new discoveries that broaden our understanding of the universe, from the solar system to the deepest reaches of space.

The LSST was deemed to be in an advanced state of technical readiness by the NWNH study, and pending the outcomes from a future request to the Major Research Equipment and Facilities Construction line, initiated within the NSF/AST, and approval by the National Science Board, could proceed to implementation during this decade. DOE/HEP is planning LSST as its priority for a next-generation ground-based experiment for the study of dark energy and has indicated a serious interest in providing expertise and leading fabrication of the camera via the SLAC National Accelerator Laboratory. Further, DOE/HEP is considering whether to assist in some part of the development of data-related processing, archiving, data-management metrics and facilities. Both agencies have assigned program managers to track development of the LSST. Despite unknown out-year budgetary guidance post FY2012, the AAAC also was apprised that the NSF/AST has initiated processes to further refine the LSST schedule and life-cycle costs as a prelude to possible MREFC construction funding.

The AAAC notes that both NSF/AST and DOE/HEP have made progress on their LSST plans. NSF/AST and DOE/HEP have established a joint oversight group (JOG) for LSST designed to facilitate communication, planning, and schedule discussion related to LSST development. Challenges include proper timing of project–related development milestones and project assessment points.

LSST provides not only an opportunity for interagency collaboration, but also a chance for the agencies to align themselves with national strategic plans to enhance advanced technology development, investment and innovation in cyber infrastructure, and workforce development. The enormous data produced each night have cross-cutting interest for automatic event detection in large data streams, data visualization, and data-mining. The public's access to LSST data enables expansive citizen-science, outreach, and infusion of science into the K-12 education.

The AAAC notes the NSF/AST intention to advance the LSST project's visibility within the Foundation, as the Mathematical and Physical Science Directorate matures the LSST for potential introduction into the MREFC process this decade.



The 8.4-meter LSST will use a special three-mirror design, creating an exceptionally wide field of view and will have the ability to survey the entire sky available at any given time of year in a single filter in only three nights. (Image credit: LSST Corporation)

The LSST focal plane array scale model. The arrays diameter is 64 cm, and this mosaic will provide over 3 Gigapixels per image. The image of the full moon (30 arc minutes in angular extent) is placed upon the array for visually representing the field of view of the LSST camera. (Image credit: LSST Corporation).

4d. NASA Tech Fellows

Research endeavors supported by the federal investment in astronomy attract participation from some of the brightest and most technically able individuals within the nation. The NWNH assessment notes that this workforce of talent provides broad benefits to the nation and society. Participants in the enterprise develop skills and high levels of competency in disciplines with applicability beyond the confines of astronomy and astrophysics, and such engagement provides a vehicle to develop a science literate and technically adroit 21st century workforce. The complexity and depth of the engineering challenges arising from today's new astronomical facilities, balloon, sub-orbital, and space missions require transformative approaches at fundamental levels. To sustain the ability of the nation and agencies such as NASA to develop innovative solutions over the next decade requires investment in workforce development in areas of critical technologies. Such investments serve to strengthen the core capabilities and skills necessary to advance national scientific and programmatic goals and objectives in an ever more competitive international arena. The Science Mission Directorate at NASA presented a new 2012 initiative, known as the NASA Tech Fellow Program, to address workforce development that will benefit future mission development, technology readiness and responsiveness, and foster innovation. These fellowships are envisaged to be similar in impact and scope as the successful Hubble fellowships, but instead of being dedicated to advancing the frontiers of science, they are focused on advancing technology. The AAAC was enthusiastic about the Directorate's approach to responding to the NWNH conclusions regarding the role of the astronomy enterprise in serving as a gateway for new technology development, stimulating American competitiveness, and addressing national challenges of the 21st century.

The AAAC was impressed by the creativity demonstrated by the Science Mission Directorate at NASA in the establishment of a technical fellows' opportunity, and endorses this approach as a way to address a critical need to maintain core workforce competencies and to drive innovation, by drawing on a younger demographic pool within the field of astronomy and astrophysics.

Finding: Budgetary constraints may severely delay the implementation of many of the NWNH recommended projects. Continued budgetary constraints have the potential to damage current U.S. worldwide leadership in astronomy and astrophysics.

Finding: We highly commend the initial response of the agencies to NWNH, given the budgetary constraints. Especially welcome are NASA's plans for the midscale Explorer program, NSF's plan for midscale innovation projects, the NASA Tech Fellows program, and NASA's Wide-Field Infrared Survey Telescope (WFIRST) plans.

Finding: We commend the interagency actions by the NSF and DOE with respect to the Large Synoptic Survey Telescope (LSST), which we find to be consistent with the recommendations of NWNH.

5. JWST Issues

NASA's James Webb Space Telescope (JWST) is a 6.5-meter, infrared-optimized space telescope planned for launch later this decade. It was the highest-priority large space mission recommended by the 2000 Decadal Survey of Astronomy & Astrophysics, *Astronomy and Astrophysics in the New Millenium* (AANM), and has been envisioned as a Great Observatory successor to the Hubble Space Telescope. As described in the Astro 2010 Decadal Survey report *New Worlds, New Horizons* (NWNH), which reaffirmed its importance, JWST is expected to make profound discoveries in several areas of astronomy, particularly in probing the epoch of Cosmic Dawn, when the first galaxies formed in the early Universe, a few hundred million years after the Big Bang. With its infrared sensitivity, it will also be able to penetrate into dust clouds and help illuminate how stars are forming new planetary systems.

JWST uses innovative, cutting-edge technologies that have been developed after its inception, resulting in escalated costs from the ~$1B given in the AANM report in 2000 to $5B at the time of the JWST Project Confirmation Review in July 2008. In the last three years, the project has experienced further delays and cost growth. In late October, 2010, the JWST Independent Comprehensive Review Panel, formed at the request of Senator Mikulski and chaired by John Casani, issued its final report. The Casani report found that the recent cost growth and schedule delays were due primarily to problems in budgeting and program management at Goddard Space Flight Center and NASA Headquarters: the project failed to develop a reasonable cost and schedule baseline at the time of Confirmation, and the reserves provided were too low. It estimated that the minimum life cycle cost of the project would be an additional $1.5B over the NASA estimate of $5B and that the launch date would slip from June 2014 to at least September 2015, even assuming a substantial increase in project funding starting in FY2011.

The Casani report made a number of recommendations to restructure the management of the project at Goddard and at NASA Headquarters, and NASA has moved quickly to implement or begin to implement the key recommendations. At Headquarters, the JWST office and its associated budget have been moved from the Astrophysics Division to its own office within the Science Mission Directorate (SMD) and now reports directly to the SMD Associate Administrator and to the NASA Associate Administrator. At Goddard, the project office now reports directly to the Goddard Director. A re-planning program is underway and is expected to lead to a new launch date and re-baselined life cycle cost estimate by Summer of 2011; this re-planning could lead to a launch date later than 2015. On the hardware side, the segments of the primary mirror and the major instruments are expected to be delivered in the Summer-Fall 2011 timeframe.

The cost overrun and schedule delay of JWST is expected to have a substantial impact on the implementation of the program of large astronomy space missions recommended in NWNH, particularly the top-ranked WFIRST mission. The scale of the impact will depend on the JWST launch date, on the design and scale of the WFIRST mission, and on whether WFIRST goes forward as a stand-alone mission or is ultimately merged with the ESA Euclid mission.

Finding: As noted in the AAAC letter of October 22, 2010, the Committee remains concerned about the potential impacts of the anticipated James Webb Space Telescope *(JWST) cost increases and schedule delays on the NWNH recommended major space activities for the decade.*

6. Specific Issues

6a. Euclid/WFIRST

As discussed by the AAAC in a letter last year, NASA and ESA had discussed a possible 20% NASA participation in the ESA-led Euclid mission. Jon Morse outlined a plan to continue discussions with ESA while also beginning to build a WFIRST Science Definition Team (SDT). In October, the NAC Science Committee recommended that WFIRST implementation should continue, SDT nominations should be solicited, and a partnership with ESA on Euclid should continue to be discussed with the goal of a joint mission or complementary missions if they met all the WFIRST goals along with the Euclid goals. AAAC advised NASA that they agreed with the recommendations. Subsequently, the NRC Implementation Panel was formed to study the Euclid/WFIRST issue, and reported on its findings. Jon Morse reported to the AAAC that NASA's FY2012 budget request most resembles the Implementation Panel's option (D) (No FY2012 funding request for a WFIRST project, but support for near-term mission concept development activities (see Section 3c for definitions of the options). He also stated that options (A) and (B) (missions encompassing all the science of WFIRST: planet microlensing, 3 avenues of dark energy research, and a survey guest investigator mode) are still under consideration for future budget requests. Morse also described the selection of the WFIRST Science Definition Team (SDT), co-chaired by Jim Green and Paul Schechter, with broad representation; their first meeting took place in January. We applaud Morse and NASA for pursuing paths to either implement WFIRST or to play a leadership role in a joint mission that accomplishes its goals.

6b. Plutonium-238

The manmade radioactive isotope Pu-238 can be used to generate electricity due to the heat emitted by its radioactive decay. Encapsulated in a radioisotope thermoelectric generator (RTG), this vital element is necessary for powering probes sent to the outer reaches of the solar system, a research area where the U.S. can clearly claim significant international leadership. AAAC remains concerned that delays in the restart of this production effort hinder not only the ability for the US to conduct NASA planetary missions to the outer solar system, but may well impede development and implementation of future astrophysics missions requiring significant power resources operating in deep space beyond Earth orbit.

Prompt action is required to begin producing Pu-238 as it will take about 8 years from initiation to full production of the required 5 kg/year. Cooperation between the DOE and NASA, with support from the President and funding from Congress, would be required to fulfill this vital need. The AAAC notes that the NASA Administrator, in the 2011 NASA Strategic Plan - p.15ff, has recognized the import of this national production capability asset and the challenge presented by the lack of availability.

The AAAC urges that, in consultation with Congress, prompt action be taken and appropriate budgetary resources be identified through cooperative coordination between DOE, NASA, and, if applicable, other federal agencies (i.e., NSA, Dept. Homeland Security), to enable the Pu-238 project production restart for deep space mission applications.

6c. The DSIAC

NWNH called for the formulation of a Decadal Survey Implementation Advisory Committee (DSIAC) to provide strategic advice on decadal report-related issues and to monitor the progress in achieving the recommendations. Over the years, the distinction between the AAAC and agency-independent panels such as the NRC Committee on Astronomy and Astrophysics (CAA) has become blurred. We understand from discussions at the February meeting that the agencies and the National Academies are considering how best to constitute a DSIAC. Such a committee might resemble the CAA. Its advice may be needed soon, since the budget conditions have already changed considerably since NWNH was issued. It is important that the role of such a committee be distinct from that of the AAAC.

Finding: While the AAAC has a role as shepherd over the decadal results, its charge is primarily to be a tactical committee, whose role is to advise on issues related to project development, particularly projects that cut across more than one agency. AAAC is available to work with a newly formed DSIAC as needed.

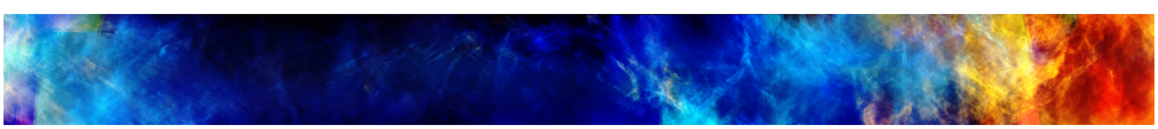
6d. Interagency Cooperation

The Committee received briefing from agencies on interagency activities both in the implementation of existing projects, and in the planning for the new starts recommended in NWNH. The following are some examples of current interagency projects:

a) The Fermi Telescope (see section 2h) is just one example of an existing interagency project in which the complementary talents of the DOE-funded and NASA-funded communities were key to its ultimate success.

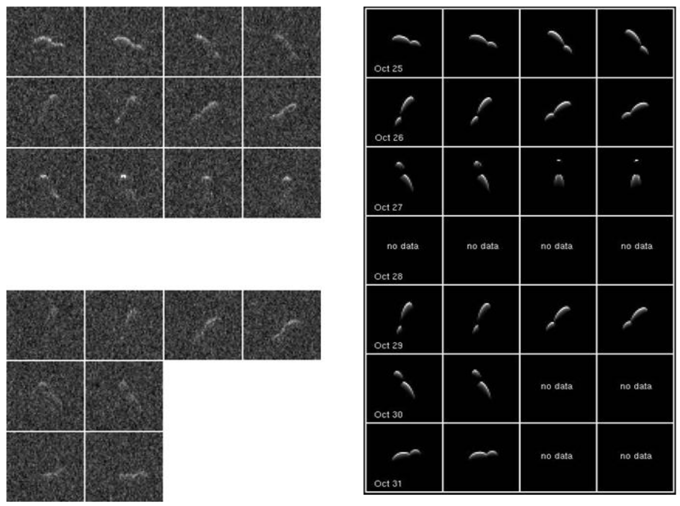
b) The Virtual Astronomical Observatory (VAO) is proceeding with joint NASA/NSF funding. The VAO Interagency Oversight Group meets regularly, and is initiating meetings with project managers. The Virtual Astrophysical Observatory fosters the development and public dissemination of protocols and tools that enable data mining and analysis of large astronomical datasets. Examples of images obtained using the Montage image mosaic tool, funded by the National Aeronautics and Space Administration's Earth Science Technology Office, Computation Technologies Project, under Cooperative Agreement Number NCC5-626 between NASA and the California Institute of Technology. Montage is maintained by the NASA/IPAC Infrared Science Archive. The Montage package, which includes an adaptation of the MOPEX algorithm developed at the Spitzer Science Center, can be applied to many public datasets as well as original ones.

Wide area mosaic of a section of the Galactic plane measured with the Spitzer Space Telescope and constructed using the Montage package. In this four-color composite, blue is 3.6 microns, green is 4.5 microns, orange is 5.8 microns, and red is 8.0 microns. (Credit: NASA/JPL-Caltech/E. Churchwell) (University of Wisconsin). From http://montage.ipac.caltech.edu/gallery.html



Wide area mosaic of high galactic latitude ((b > 20 degrees) 21 cm HI line detected with the Arecibo L-band Feed Array (ALFA) by the Arecibo Legacy Fast ALFA (ALFALFA) survey. The Montage package distribution provided through the VAO allows for the quick combination and re-projection of over 1200 ALFALFA HI line images in dual polarization, here over 1500 square degrees of sky. (Credit: B. Kent (NRAO), NAIC/Cornell and the ALFALFA team. From http://montageblog.wordpress.com/)

c) NASA is providing support for the S-band radar program at the National Astronomy and Ionosphere Center's Arecibo Observatory which is principally funded by NSF. In October, the Arecibo planetary radar system was used to make images of comet 103P/Hartley, the target of the EPOXI spacecraft mission (see Figure). The precision of the radar observations allowed mission control to update its navigation of the spacecraft, as it approached the comet.



This pair of mosaics shows twenty radar delay-Doppler images (left) obtained with the Arecibo S-band radar system and model images (right) of the nucleus on (from top to bottom) Oct 25-27 and 29-31.(Credit: J. K. Harmon, M. C. Nolan, E. S. Howell (Arecibo Observatory) and J. D. Giorgini (Jet Propulsion Laboratory)). From: http://www.naic.edu/science/ao_hartley.html

Interagency cooperation will continue to play a key role as the agencies move to implement the NWNH recommendations. In our 2009-2010 report, this Committee stated "where interagency cooperation or coordination is required, we recommend that, upon receipt of the [NWNH] report, the relevant agencies should identify a lead agency and the structure(s) necessary for the execution of relevant projects." The Committee is pleased to note that this process is underway. For example, an LSST Interagency NSF-DOE Joint Oversight Group has formed that meets bi-weekly, and a WFIRST Science Definition Team has been formed with members drawn from communities traditionally supported by both NASA and DOE.

We note that there will be other opportunities for interagency cooperation as other recommendations from the NWNH report are implemented, most of which have been identified by the agencies. These include potential DOE contributions to mid-scale experiments for areas such as Dark Energy and Cosmic Microwave Background for which NSF and/or NASA are likely to be the lead agencies. The 4th ranked project in the NWNH report, the European-led CTA ground-based gamma-ray observatory, is also an example of a project in which DOE and NSF could potentially both be involved in funding US participation.

Funding constraints will likely dictate the extent of future interagency cooperation. For instance, DOE is supporting members of the WFIRST science definition team, but its participation in the mission itself will depend on future funding profiles as well as defining a distinct contribution that can be made by DOE researchers.

Finding: The Committee finds that interagency cooperation plays a key role in the astronomy research program and will continue to do so through the next decade. The agencies have identified opportunities for joint activities from the priorities recommended in the NWNH program, but the Committee notes that in many cases activities may be limited by the tight fiscal environment.

6e. GSMT

The Giant Segmented Mirror Telescope (GSMT), a large (30-m class aperture) optical and near-infrared telescope with advanced adaptive optics was identified in NWNH as the third ranked ground-based project. Science operations for this facility were envisioned to commence mid-2020 and a 25% federal share and investment in a GSMT was strongly recommended to provide access for the entire US astronomy and astrophysics community. Such a facility would have roughly 10 times the collecting area and up to 80 times the near-infrared sensitivity of current facilities leading to transformative advances that would address many of the key scientific questions identified in NWNH including: studies of the earliest galaxies, galactic evolution, and the detection and characterization of planetary systems. Federal investment in a GSMT facility was deemed essential to maintain US competitiveness in ground-based astronomy over the next 20 year period.

NWNH identified two US-led design approaches that are in concept development with established private consortia comprised of international partner countries, public and private US universities, and various non-profit foundations. In part, the NWNH survey committee recommended that the NSF Division of Astronomical Science (NSF/AST) initiate an immediate process to choose a GSMT-concept partner for federal investment. In part, the NWNH motivated the need for such action as soon as possible due to the complex partnership arrangements regarding share and governance, the evolving technical readiness of the projects, and the long project lead times to identify critical technologies that would then advance to fabrication and facility integration. The NWNH assumed that the federal cost share for construction would be borne by the NSF MREFC line, while the federal share of the operations costs were to be carried by the NSF/AST.

The AAAC was apprised of the strategy that the NSF/AST was advancing to understand the portfolio impact of a GSMT, at a time when other new, large facility commitments such as Atacama Millimeter Array (ALMA) and the Advanced Technology Solar Telescope (ATST), occupy a significant portion of the out year funding projections. Given the current possibility of flat or even declining budgets, the AAAC was informed by the NSF/AST that a decision, leading to a competitive selection process associated with GSMT concepts as envisioned by the NWNH recommendation, would not be made until after the FY2011 budget is resolved. NSF conversations with the AAAC indicated that the ability of the NSF/AST to consider incorporation of any GSMT investment in out-year budgets must await the outcomes of the complete division portfolio review; such a review was also recommended by NWNH to take place before mid-decade. The Division Director remarked to the AAAC that this process would assess all programs, including facilities, the individual investigator programs, and other programmatic initiatives such as the Telescope System Instrumentation Program (TSIP), with an objective of ascertaining the proper portfolio balance to potentially initiate new NWNH initiatives, by shedding or re-budgeting lesser programmatic priorities in an era of tightly constrained budgetary growth.

Although the NSF/AST articulated interest in potential federal involvement in a US-led GSMT project, the consequences of the current fiscal environment are clear to the AAAC. Potential significant federal investment in a GSMT project could be significantly delayed, perhaps to the end of the decade, if at all.

The AAAC notes the desire of the NSF/AST to maintain momentum regarding opportunities for federal investment in a GSMT facility. The AAAC concurs with the current Division assessment that significant federal investment, at the level of approximately 25% envisaged by the NWNH, within this decade is a major challenge, barring a change in the projected budgetary environment or a marked rebalancing of the Division's portfolio following the portfolio review.

7. Investment in Astronomy as a National Priority

Astronomy is driven by human curiosity. The field of astronomy and astrophysics, and the associated missions, facilities, and technologies provide tantalizing clues to deciphering fundamental questions regarding our universe and the role of humanity within the cosmos. The discipline has long been recognized as sparking wonder for the natural world, inspiring the imaginations of generations of the public, and firing the aspirations of our nation's science, technology, engineering, and mathematics workforce. The NWNH outlined an exciting future roadmap to understand our "cosmic dawn," the search for the first stars, galaxies, and black holes, to characterize the growing multitude of new worlds extant around other stars, seeking nearby, habitable planets, and to explore the fundamental physics of the universe, by better developing our understanding of dark matter and dark energy, and the veracity of Einstein's theory of gravity (general relativity) in the environs of merging black holes.

The vision of the NWNH was to compound the success of the past federal, international and private investment in astronomy infrastructure, education outreach, knowledge base, workforce skills, and technology innovation by outlining a balanced program of new activities, mindful of expectations imposed on our community by national budgetary priorities and restraints, to provide an ever-deepening knowledge of our universe. The benefit to the nation and society by federal investment in the astronomy enterprise is aligned with our nation's desire to innovate, educate, and build to enhance international competitiveness and cooperation, economic security, and world leadership in science, engineering, and technology. Astronomy research and education is very well aligned with two of the four top-level recommendations of *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (National Academies Press 2007).

Example science highlights enumerated within this report illustrate the dividends of past federal investment in the discipline, from advances in sensors, adaptive optics, laser technologies, super pressure balloon payload capabilities, to revolutions in computational methodologies, large scale data-mining techniques and theoretical algorithms, as well as international collaboration and participation. NASA missions such as FERMI and SOFIA are now returning new discoveries in the gamma-ray and the infrared regimes, Kepler is unveiling hundreds of possible Earth-like planets, while the currently-being-commissioned international facility ALMA, supported in part by the NSF, is poised to revolutionize our understanding of the first stars and galaxies and newly forming planetary systems through its millimeter/sub-millimeter views. These examples serve to demonstrate the broad impact of the discipline and the benefits of public support of astronomy and astrophysics and demonstrate the leadership role that the United States commands on the international scientific, engineering, and technical stage.

During our deliberations, the AAAC was informed that all agencies are finding it challenging to respond to the priorities and recommendation in the NWNH report that promote a vigorous and balanced research program in the coming decade, because of programmatic and budgetary constraints. Clearly, the breadth of portfolio in the NASA's Science Mission Directorate (SMD) is shrinking, the Division of Astronomical Science within the NSF struggles to identify out year funding wedges to enable new investment, while the DOE has been forced to review the set of interagency astronomy and astrophysics initiatives they can support. This current environment is juxtaposed with the urgency and strategic national importance of enhancing federal investment in STEM fields and initiatives to enhance basic research, such as the American Competes Act. The globalization of astronomy, and its associated innovative technologies, infrastructure, cyber management, and workforce skills, have the potential to erode and eventually eclipse the current world leadership role in astrophysical science held by the America. International cooperation and partnerships have enumerable benefits, including leveraging of resources, technology transfer, commerce, work-force development, and inter-governmental cooperation.

The AAAC notes that judicious federal investment in astronomy is necessary to achieve the programmatic objectives over the decade of the NWNH decadal survey, maintain the core capabilities required to realize the scientific return of past investment, and to sustain the national commitment to discovery and innovation. Investment in advanced research is key to building America's future.

Finding: The 2007 NAS-NAE-IOM report, "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future" warns that the Nation must do a better job in training the next generation of scientists and engineers in order to remain competitive. Astronomy has a role to play in this regard, because it is a mind-opening field, a gateway, in which exciting discoveries can attract young people to STEM (science, technology, engineering, and mathematics) careers.