

**REPORT of the COMMITTEE OF VISITORS**  
**Division of Astronomical Sciences**  
**National Science Foundation**  
**February 7-9, 2011**

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**I. Executive Summary**

The 2011 AST Committee of Visitors (COV) is extremely pleased with the discovery and learning outcomes that have resulted from the past 3 years of AST funding awards. As illustrated by the “Highlights” that we enjoyed reviewing, astronomical discoveries that advance our fundamental understanding of the physical universe continue to capture the imagination of the public and generate broad excitement about advances in science. The COV analyzed 52% of the 422 electronic jackets (eJackets) that were provided for our review, as well as many additional major facilities documents. It is clear to us that, across the field, research activities are being well integrated into learning (workforce training) activities. It is also clear that the AST division is continuing to make substantial and wise investments in the design, development, construction and effective operation of major shared resource facilities.

The COV also commends the managerial accomplishments of the AST staff over the past 3 years. Across the board, decisions and recommendations of the staff have been driven by sound scientific objectives, goals set by the community, and with a strong eye toward balance and fairness. The staff has accomplished these things under a tremendously high level of stress resulting from, among other things, (a) a talented and aggressive research community, (b) a funding spike from the American Recovery and Reinvestment Act (ARRA), and (c) insufficient staffing.

The main body of this report – specifically §§IV-VIII – provides further elaboration of the assessment of the COV regarding the actions and accomplishments of the AST division over the past three years. Attention is given especially to the set of issues that were itemized in the charge to the committee and that are repeated in §II of this report. Here we summarize a set of issues and concerns that surfaced during our (sometimes quite lively) discussions of the activities of the AST division over the past three years. Specific recommendations accompany a number of our identified concerns.

**Staffing Issues**

We appreciate the effort that the MPS leadership has made over the past few years to replace vacated positions on the AST staff and especially to appoint Jim Ulvestad and Vernon Pankonin to leadership positions. Nevertheless, the AST division remains critically understaffed. This situation has been particularly glaring in recent years because of ARRA funding. As a result of the additional workload associated with this funding

spike, the time to completion of proposal reviews has been outside the goals normally established by NSF during a significant fraction of this review period. With regard to the ongoing management of major research facilities, staffing is critically low with very little margin for error. Additional management risks on the immediate horizon include: (1) Re-competition of cooperative agreements; (2) increased proposal pressures brought on by more individual investigators seeking funding and the interest in, and expected accessibility of, ALMA; (3) the increased complexity of all future major facilities, involving international sites and partnerships; and (4) the need to implement the results of a portfolio review (see Recommendation-2, below). While it may be possible to gain some efficiency in the processes used to conduct reviews of individual investigator proposals (see §VI.C), there is no avoiding the critical need for additional staffing. In this context our first recommendation is a reiteration of the first recommendation that appeared in the 2008 COV report.

***Recommendation-1:* NSF should thoroughly review the staffing requirements of AST to determine the level required for AST to adequately support its base program while playing a leadership role in the complex, international development of the next generation of world-class observatories.**

### **Portfolio Review**

The COV endorses the goals enumerated by *New Worlds, New Horizons in Astronomy and Astrophysics* (hereafter referred to as the Astro2010 decadal survey). However, a reality check on the federal budget will almost certainly show that few projects recommended in this decadal survey can be afforded over this decade. Moving forward aggressively on plans for the Large Synoptic Survey Telescope (LSST) is wise because this facility alone promises to enhance discoveries in a wide array of astrophysics sub-disciplines. But, as we argue in §V.A of this report, it is extremely important for MPS/AST to conduct a portfolio review as soon as possible to establish a realistic fiscal baseline for the AST division and the community it serves. This review should be conducted soon in order to affect future budget cycles in a timely manner and to set appropriate expectations across the community.

***Recommendation-2:* AST should conduct a thorough and timely review of present and planned programs and activities across the division (a *portfolio review*) in order to establish a realistic fiscal baseline to accompany the community’s scientific aspirations as enumerated in the Astro2010 decadal survey. MPS/AST management should seek community consultation prior to defining the makeup and charge of its portfolio review team.**

The heavily facilities-based aspirations enumerated in the Astro2010 report put pressure on NSF to fund the design & development (D&D), construction, and maintenance & operation (M&O) of additional major research facilities. In a complementary fashion, our review of AST’s activities over the past 3 years makes it clear that the level of oversubscription to AST’s individual investigator program (IIP) is steadily increasing and that there is approximately twice as much outstanding science proposed as NSF is able to fund. A serious discussion of this issue should be part of the portfolio review in order to guard against any tendency for “facilities” funding to inadvertently consume IIP funding, which carries the principal responsibility of all AST-sponsored funding for building intellectual infrastructure. (See §V.B for further elaboration.) AST should construct a means of comparing the relative value of different components of the funding portfolio in order to make responsible decisions about future funding trajectories.

***Recommendation-3:* As it prepares for a portfolio review, AST should consider establishing, with community input, metrics that can be used to measure success – that is, to measure the relative return on investment – of various segments of its portfolio, such as the individual investigator program and major facilities.**

### **Communication with and Participation of the Scientific Community**

There will always be a need for each division of the Foundation to find ways to communicate with the scientific community that are more effective as well as more timely. As a result of our review, the COV recognizes in particular the need for program officers to communicate more effectively with new investigators and with PIs whose proposals are declined or whose award decision is delayed. We strongly encourage AST to make the fullest possible use of the eJacket system to automate contacting PIs and recommend that all automated notifications be enabled. Reiterating a recommendation (#8) from the 2008 COV report, we furthermore think it is important for AST program officers to provide information to PIs regarding the general ranking (e.g., quartile ranking) of their proposal.

Better mechanisms need to be found for raising the community's awareness of new Foundation-wide mandates and requirements, new funding opportunities, and the need for all active members of the research community to participate in proposal review processes. The Foundation should aggressively explore the innovative use of new technologies to facilitate such communication.

***Recommendation-4: The Foundation should aggressively explore the innovative use of new technologies to facilitate effective and timely communication with the research community.***

The COV applauds the efforts of several of NSF's divisions to automate compliance checking and, in so doing, to become less tolerant of the submission of non-compliant proposals. This streamlines the proposal review process and helps ensure that proposal reviews are handled in a fair and equitable manner across all directorates. The AST staff appears to have further streamlined the proposal review process by instructing panels to divide proposals into competitive and non-competitive categories. The COV's discussion of the need to further streamline the IIP proposal review process and to achieve broader participation in panel reviews (see §VI.C) has led to the following recommendation.

***Recommendation-5: AST should consider options to significantly expand the pool of potential panelists, such as: (a) establishing the expectation that past recipients of grants *should* participate in the review process; (b) communicating the benefits of participation to new investigators or those who have been previously unsuccessful; (c) gathering data on the pool of potential panelists earlier than the present practice; and (d) assembling review panels earlier and, perhaps, using a staggered distribution approach.***

### **Major Facilities**

MPS/AST is justifiably proud of the leadership role that AST has played over the years in terms of managing major user facilities. It seems clear, for example, that AST has played a major role in defining the Foundation's approach to management of large facilities, including the establishment and effective operation of major international partnerships. If AST's portfolio review is done well, it will be another example provided by AST of how to manage the Foundation's resources wisely.

Key issues to note regarding individual major facilities are:

Gemini – Gemini presents some of AST's greatest present financial and management challenges. For example, the project has been stressed financially by the United Kingdom's departure from the consortium. The COV endorses the approach that AST has developed to address various issues surrounding the future of Gemini, such as management consolidation and a search for additional partners.

ALMA – It appears as though challenges associated with ALMA construction are being met as a result of strategic decisions implemented by AST and sound management by NRAO. In addition, the AST budget is being managed well to smoothly accommodate ramping up of ALMA operations costs within reasonable budget assumptions. This is being accomplished through the simultaneous ramping down of AST commitments to other facilities. It is gratifying to see that plans are in place to

accommodate ALMA operations costs as this is an issue that has been of concern to the community and, indeed, to many members of this COV.

ATST – To date, ATST has been managed extremely well. Most significantly, the project was well positioned to take advantage of ARRA funding. In addition, thoughtful plans are in place for combining existing solar programs & phasing out existing instruments. However, there is justifiable interest in solar research from a number of NSF Divisions, which creates some ambiguity about the proper home for ATST.

***Recommendation-6: ATST’s ultimate “programmatically home” within NSF should be decided before AST conducts its portfolio review because the portfolio review team will need to know whether or not ATST’s operations cost will be borne by the AST division.***

LSST – With regard to budgeting D&D costs for new facilities, AST is following the Astro2010 recommendations and appropriately assigning highest priority to LSST.

GSMT – Given that it is unclear whether or not AST will be able to afford to move forward this decade with more than one new construction project, and given that the Astro2010 recommendations assign a lower priority to GSMT than to LSST, it is unclear whether or not AST should include D&D costs for GSMT in its near-term budget requests.

***Recommendation-7: A decision regarding whether or not to invest in D&D costs for GSMT should await the results of the portfolio review.***

SKA – AST’s decision to terminate D&D investments in SKA is significant and in line with the Astro2010 recommendations.

### **Finite Lifetimes for Major Facilities**

AST and the MPS directorate as a whole must confront the issue of establishing and implementing finite lifetimes for major facilities. A realistic plan must be developed for decommissioning instruments and phasing out the M&O costs of major research facilities – or at least for removing M&O costs from NSF’s books. Not doing this will severely impact the ability of MPS/AST to afford future operations costs of new facilities.

***Recommendation-8: AST and, more broadly, MPS must develop a realistic plan for decommissioning instruments and phasing out the M&O costs of its current and planned facilities. In particular, AST/MPS should establish and implement finite lifetimes for major research facilities built with NSF funds.***

### **Electromagnetic Spectrum Management (ESM)**

Historically, responsibility for managing the electromagnetic spectrum has been assigned to AST because protecting key “windows” in the spectrum is especially critical to research conducted by the radio astronomy community. ESM has been managed well by AST while its importance to national and international commerce and to the nation’s investment priorities has grown significantly over the past decade. The COV unanimously recognizes the importance of ESM and the need for ESM to achieve and maintain a very high profile within the Foundation.

***Recommendation-9: Given the importance of ESM to the NSF and the growing external pressures that are being placed by international commerce on ESM, a decision needs to be made regarding the proper home for the ESM program. The home for ESM must be chosen to ensure that ESM retains a sufficiently high profile to protect scientifically significant parts of the electromagnetic spectrum for research purposes.***

## **AST Funding Level**

Finally, we would do a disservice to the community if we did not emphasize that with additional funding (for example, a doubling of the AST budget over the decade) AST is well positioned to accomplish great things. The community of researchers is eager, the Astro2010 decadal survey has provided a roadmap, and the AST management team is in place. The Foundation and the Nation can be guaranteed a fabulous return on any additional investment that is made in AST.

## **II. Schedule and Process**

The Committee of Visitors (COV) to the Division of Astronomical Sciences (AST) met at NSF on 7-9 February 2011. The written charge to the COV was provided in a letter dated 4 January 2011 and signed by Dr. Ed Seidel, Assistant Director, Mathematical and Physical Sciences (MPS). The letter charged the COV to address and prepare a report on:

- the integrity and efficacy of processes used to solicit, review, recommend, and document proposal actions;
- the quality and significance of the results of the Division's programmatic investments;
- the relationship between award decisions, program goals, and Foundation-wide programs and strategic goals;
- the Division's balance, priorities, and future directions;
- the Division's response to the prior COV report of 2008; and
- any other issues that the COV feels are relevant to the review.

On Monday, 7 February, AST Director, Dr. James Ulvestad, welcomed the COV and introduced Dr. Seidel who described the committee charge together with the AST elements under review that included the Research Grant programs, Observatory Facility programs, and Electromagnetic Spectrum Management. Dr. Morris Aizenman (Senior Science Associate, MPS) briefed the COV on conflicts of interest, confidentiality, the Government Performance and Results Act, and reporting requirements. Dr. Vernon Pankonin, Deputy AST Director, discussed the meeting procedures and parallel breakout sessions during which members of the COV would conduct a detailed analysis of the eJackets containing proposal actions.

Dr. Ulvestad presented an overview of the AST Division including the organizational structure and responsibilities. Dr. Nigel Sharp presented an orientation to the Individual Investigator Programs (IIP) (including intra-NSF and interagency activities) and briefed the COV on the procedures for accessing and reviewing eJackets.

The COV then moved to a series of parallel breakout sessions and reviewed the details of individual grant programs. At least one AST program officer was available in each session to answer questions. The grant programs reviewed and the respective attending program officers were:

Session 1 (Astronomy & Astrophysics Research Grants Program; AAG):

- Extragalactic Astronomy and Cosmology – Dr. Nigel Sharp
- Stellar Astronomy and Astrophysics – Dr. Donald Terndrup
- Galactic Astronomy – Dr. Katharina Lodders
- Planetary Astronomy – Dr. Tom Statler

Session 2:

- Education & Special Programs (CAREER, REU) – Dr. R. Scott Fisher
- AAPF – Dr. Donald Terndrup (and Dr. Dana Lehr by phone)
- NSF-wide programs, special projects – Dr. Nigel Sharp
- Instrumentation Programs – Drs. Andrew Clegg, Jeff Pier and Gary Schmidt

The review was structured to evaluate proposal and award actions from 2008, 2009 and 2010. COV members reviewed sample eJackets from each program area for a subset of all actions from the three years under consideration. The eJackets were designed to provide members of the COV with as much information as possible about each award, including: the proposal, panel team membership, reviewer comments, NSF Program Officer assessment and recommendation, disposition of the award, feedback provided to the PI, award documentation, and all correspondence between the PI and the NSF Program Officer.

During the second day, the COV was given a series of presentations on the mid-scale and infrastructure programs including EMS, URO and mid-scale and technology programs. Presentations were also provided on the AST Facilities including management and oversight, NOAO, NSO, ATST, Gemini, NAIC, NRAO and ALMA. The COV was then provided with access to eJackets and other review material for the facilities, URO and mid-scale programs.

Time was provided for executive sessions during which the COV formulated a series of initial recommendations and feedback comments. At the close of the meeting in the presence of the COV, the COV Chair, Dr. Joel Tohline, presented the committee's recommendations and feedback to Dr. Seidel and the senior NSF AST staff.

### **III. Science Highlights**

AST supports a wide range of activities through its facilities and grants programs. Since the previous COV report, there has been tremendous progress on a number of fronts, especially with regard to new observatories like EVLA, ALMA, and ATST, but also including results obtained by individual investigators in observational and theoretical domains, and concerning outreach and diversity. The following paragraphs, drawn from a large sample of "science highlights" provided to us by the AST program officers, demonstrate the breadth of these facilities and investigations and the progress that has been made in workforce training, outreach, and broadening participation of traditionally underrepresented groups. We note that the sample of science highlights that were provided to us for review contained relatively few highlights on the theory and computation fronts. Going forward, we recommend that more attention be given to presenting highlights that showcase the full range of AST activities. For a more complete description of scientific endeavors completed during the review period, please see "Part B: Results of NSF Investments" in the supporting documentation for this report.

#### **Expanded Very Large Array (EVLA)**

Dedicated in 1980, the Very Large Array (VLA) has been an extraordinarily productive scientific facility. Astronomers from around the world have used it to study objects as close as within our Solar System, and as distant as the edges of the known Universe. The VLA is now being reborn as a research instrument: by 2012, advanced electronics and software will have completely transformed the VLA into the Expanded Very Large Array (EVLA), a much more capable research tool with more than ten times the sensitivity of the VLA. Reinvigorated by new technologies, the EVLA will probe the frontiers of cosmic radio science for decades to come.

#### **ALMA Prepares for Science Observations**

ALMA is a partnership between North America and Europe to construct 50 antennas of 12m diameter, with an additional four 12m and twelve 7m antennas provided by Japan. ALMA will be the preeminent facility of sub-millimeter and millimeter wavelength radio astronomy for the US and international community. The dramatically improved angular resolution and sensitivity over existing facilities will enable ALMA to open up this wavelength regime to a wide range of astronomical objects, from brown dwarfs to active galactic nuclei. Nine antennas are operating at the 5,000 meter high-altitude site, with an additional 33 antennas at the ALMA mid-altitude station in various stages of assembly and testing. The first science observations – with a subset of the antenna array, frequency bands and operational capabilities – are planned for September 2011.

### **Casting of Primary Mirror for the Advanced Technology Solar Telescope**

The ATST will be the first large US solar telescope accessible to the worldwide solar physics community to be constructed in more than 30 years. The ATST will allow researchers to resolve features of about 20-30 kilometers in size on the Sun, to provide unprecedented observations of solar plasma processes and magnetic fields at a fundamental scale. The ATST observatory is to be built on the summit of Haleakala in Maui, with first light toward the end of this decade. The incident solar energy on the 4.2m-diameter primary mirror will be approximately 14 kilowatts, and this heat must be removed by active cooling to avoid image-blurring air currents. Further, the mirror must be made of a material that resists distortions when heated and cooled. The ATST primary mirror blank was successfully cast at the SCHOTT facility in Mainz, Germany in September of 2010, and slowly cooled in an annealing oven over a three-month period.

### **Multi-Conjugate Adaptive Optics**

In the early morning of January 22, 2011, a new era in high-resolution astronomy began with the successful lighting up of a 5-star sodium laser “constellation” in the skies over Cerro Pachón in Chile. This first demonstration of the Gemini South telescope multiple laser guide star system marks the beginning of on-sky commissioning for the next-generation adaptive optics corrector called GeMS or the Gemini Multi-Conjugate Adaptive Optics (MCAO) System. GeMS will allow relatively wide-field infrared imaging and spectroscopy at extremely high resolution. MCAO is a revolutionary approach to astronomical adaptive optics. The 50-watt laser, split into five beams, causes sodium atoms about 90 kilometers overhead to glow in a distinctive 5-point pattern. The entire GeMS system will be integrated and commissioned in 2011. In 2012 the system should begin providing remarkably sharp images for the study of a wide range of topics ranging from the birth and evolution of stars to the dynamics of distant galaxies.

### **Citizen Scientists Discover Rotating Pulsar**

Three citizen scientists — an American couple and a German – have discovered a new radio pulsar hidden in data gathered by the Arecibo Observatory. This is the first deep-space discovery by Einstein@Home, which uses donated time from home and office computers of 250,000 volunteers from 192 different countries. This is the first genuine astronomical discovery by a public volunteer, distributed computing project. The new pulsar—called PSR J2007+2722—is a neutron star rotating 41 times per second; unlike most other pulsars that spin as quickly and steadily, PSR J2007+2722 sits alone in space, with no binary companion star. Astronomers consider it especially interesting since it is likely a recycled pulsar that lost its companion, or a young pulsar born with a lower-than-usual magnetic field.

### **Turn and Turn About**

Astronomers at the California Institute of Technology (Caltech) and Ecole Polytechnique Fédérale de Lausanne (EPFL) in Switzerland have discovered the first known case of a distant galaxy being magnified by a quasar acting as a gravitational lens. This provides a novel way to study the host galaxy of a quasar, which is normally hidden in the glare from the quasar itself. Quasars are extraordinarily luminous objects in the distant universe, thought to be powered by supermassive black holes. Observations of the quasar SDSS J0013+1523, found in a search of Sloan Digital Sky Survey quasar spectra, with the W. M. Keck Observatory’s 10-meter telescope confirmed that the quasar, about 1.6 billion light years away, is indeed magnifying a distant galaxy, itself about 7.5 billion light years away. Quasars are valuable probes of galaxy formation and evolution and this discovery demonstrates the continued utility of gravitational lensing as an astrophysical tool. Finding more such systems would help astronomers to understand better the relationship between quasars and the galaxies which contain them, and their co-evolution.

### **Atoms and Ions to Molecules to First Stars**

A few 100 million years after the Big Bang, before the first stars were born, the universe was dark, filled with a hot, thin gas of hydrogen (H) and helium (He) atoms, and negatively charged hydrogen ions (H<sup>-</sup>). The most important cooling mechanism for the gas, which would allow the first stars to form, requires the presence of molecular hydrogen for collisions with H atoms. Measurements in Daniel Savin’s Astrophysics Laboratory at Columbia University determined the speed to make molecular hydrogen from hydrogen atoms (H) and negative ions (H<sup>-</sup>) in the hot primordial soup. Prior to the experiment, there was uncertainty in the models how

quickly the primordial gas was cooled, how quickly the first stars formed and how big they could get. The new measurements by Savin and colleagues significantly lower the uncertainty in the masses of the first stars.

### **Astronomers Discover Most Massive Neutron Star Yet Known**

With all its mass packed into a sphere the size of a small city, a neutron star can be several times more dense than an atomic nucleus. This tremendous density makes neutron stars, the remnants of supernova explosions, a natural “laboratory” for studying the most dense and exotic states of matter known to physics. Astronomers using the Green Bank Telescope (GBT) have discovered the most massive neutron star yet found, a discovery with strong and wide-ranging impacts across several fields of physics and astrophysics. The most massive neutron stars previously known have masses of roughly one and a half times the mass of the Sun, but this one is twice as massive as the Sun. That much mass changes our understanding of a neutron star’s composition, ruling out some theoretical models which postulated that, in addition to neutrons, such stars also would contain certain other exotic subatomic particles called hyperons or condensates of kaons.

### **The Hunt for Dark Energy**

A team of scientists and engineers from NOAO, Lawrence Berkeley National Lab, and Fermilab are nearly finished with the construction of a super-sensitive 570 megapixel camera that will aid in understanding the mysterious dark energy—the force that pulls groups of galaxies apart at ever faster speeds. The red-sensitive, wide-field camera is designed to image 300 million galaxies in the southern sky using the Blanco 4-meter telescope at Cerro Tololo Inter-American Observatory (CTIO) in Chile. The camera and its wide-field survey of the sky rely on special software programs and computing systems that can handle very large amounts of data. The development of the camera has created one of the largest lenses ever made and one of the most sensitive set of CCD detectors to date. More than 120 scientists from 23 institutions in the United States, Brazil, Spain, Germany and the United Kingdom are working on the project. It will generate large amounts of publicly available data that can be used in nearly every field of astronomy.

### **White Dwarf Binary Star System**

For the first time, astronomers have identified two different kinds of white dwarf stars in an eclipsing binary. Finding this very unusual system allowed, for the first time, a direct measurement of the radius of a rare type of white dwarf that is composed of pure helium. White dwarf stars are the very dense remnants of stars like the Sun after they have exhausted their nuclear fuel. What remains is the dense inner core of the original star, typically made of carbon and oxygen. The formation of a binary system of two white dwarf stars is unusual. One of the stars in this newly discovered binary system is a relatively rare helium-core white dwarf with a mass of only 10 to 20 percent that of the sun. Theoretical work predicted that these stars burn hotter and are larger than ordinary white dwarfs, but their size had never been measured. Observations of the star NLTT 11748 by National Optical Astronomy Observatory astronomer Steve Howell, working with astronomers from University of California Santa Barbara, has yielded the first direct radius measurement of this unusual white dwarf and confirms the theory of their formation.

### **Chance of (Comet) Showers? Not So Large, Calculations Suggest**

The Oort cloud is a huge reservoir of icy bodies orbiting the Sun far beyond the realm of the planets. Beyond 20,000 AU, comets are fairly easily disturbed by the gravity of passing stars and deflected into the inner Solar System, where they appear as long-period comets (LPCs). Two University of Washington scientists have discovered that many long-period comets might have originated in a much closer and more populous zone. This implies that the number of comets orbiting in the most distant reaches of the Solar System – the “outer Oort cloud” – may be much smaller than previously thought. In reducing the expected number of comets in the outer Oort cloud, the researchers estimate that only one significant “comet shower” has occurred in the last 530 million years, and suggest that comet showers should be blamed for no more than one mass extinction event on Earth since the emergence of multi-cellular life.

### **Predicting Solar Storms**

A team of scientists has used archived data from the National Solar Observatory (NSO) Global Oscillations Network Group (GONG) to devise what might be a novel way to predict solar storms, in which billions of tons



of ionized gas can be flung from the Sun into interplanetary space at very high speeds by flares and coronal mass ejections. If the matter is directed toward the Earth, it can wreak havoc on terrestrial communications and power systems and endanger astronauts in space and air travelers at high altitudes. A better means to predict such outbursts could provide precious time for preparation of their arrival. NSO's Frank Hill, Irene Gonzalez-Hernandez, and Rudi Komm found that solar active regions do a sort of dance that produces a characteristic pattern; recognizing this pattern might lead to accurate, timely predictions of solar flares a few days in advance. The GONG team currently is studying how to translate their findings into a reliable prediction mechanism.

### **Binary Black Holes**

Astronomers from the National Optical Astronomy Observatory (NOAO) in Tucson have found what looks like two massive black holes orbiting each other in the center of one galaxy. It has been postulated that twin black holes might exist, but it took an innovative, systematic search to find such a rare pair. The newly identified black holes appear to be separated by only a tenth of a parsec, a paltry distance on galactic scales. Since many galaxies are found in clusters, individual galaxies can collide with each other; the mystery is what happens to their central black holes during these events. Theory predicts that the black holes will orbit each other and eventually merge into an even larger black hole. Former NOAO Director Todd Boroson and NOAO Astronomer Tod Lauer used data from the Sloan Digital Sky Survey to look for the characteristic dual black hole spectral signature among 17,500 quasars discovered by the survey. In this pair, the black holes have masses 20 million and one billion times that of the sun.

### **Jets not from hidden ocean on Enceladus**

According to an NSF-supported study led by Nicholas Schneider of the University of Colorado at Boulder's Laboratory for Atmospheric and Space Physics (LASP), water vapor jets that spew from the surface of Enceladus are not really geysers from an underground ocean, as was thought by planetary scientists following a 2005 flyby of the sixth largest moon of Saturn by NASA's Cassini spacecraft. The project was carried out in collaboration with scientists from the University of Maryland and the Institute for Astronomy in Honolulu. Observations using the 10-meter Keck I telescope and the 4-meter Anglo-Australian telescope demonstrated that few if any sodium atoms existed in the water vapor, far fewer than would have been expected from the buried ocean model. Alternatives include water evaporating slowly from deep caverns through small cracks, warm ice vaporizing into space, or friction from tidal motions. Said Schneider, "We have to take them all with, well, a grain of salt".

### **Andromeda Galaxy Cloaked in Debris of Shredded Companions**

As the nearest large spiral, the Andromeda Galaxy is a prime target for some of the world's largest telescopes. An NSF-supported project to map the outer reaches of our Milky Way's big sister is revealing the remains of demolished stellar systems and allowing researchers to probe Andromeda's memory of its own growth. Massive galaxies have the ability to gravitationally shred their smaller neighbors and wrap themselves in the resulting debris. This debris consist of millions of stars, flying in formation – a "tidal stream" that can circle the larger galaxy for billions of years before gradually becoming part of it. These streams are extraordinarily faint and, until recently, have been virtually undetectable. Using the Subaru and Keck II telescopes on the summit of Mauna Kea, Hawaii, the SPLASH (Spectroscopic and Photometric Landscape of Andromeda's Stellar Halo) collaboration has discovered two new tidal streams in Andromeda, 60 to 100 kpc from its center.

### **First Direct Distance Measurement to a Galaxy in the Hubble Flow**

The NRAO Megamaser Cosmology Project has directly measured the distance to a faraway galaxy, providing a valuable yardstick for calibrating large astronomical distances and demonstrating a vital method that could help determine the nature of the mysterious Dark Energy that pervades the Universe. James A. Braatz III and his colleagues employed the Very Long Baseline Array (VLBA), the Robert C. Byrd Green Bank Telescope (GBT), and the Effelsberg Radio Telescope in Germany to determine that the galaxy UGC 3789 is 160 million light years from Earth. They precisely measured both the linear and angular size of a disk of material orbiting

the galaxy's central black hole, exploiting water masers in the disk to provide a bright and stable frequency signal. The observation is part of a major effort to measure the expansion rate of the Universe, the Hubble Constant, with greatly improved precision, and thus constrain the nature of Dark Energy.

### **Astronomical Numbers**

Astronomy is an “observational science,” meaning that astronomers must observe their research objects from afar through telescopes. However, there are also “theoretical” astronomers who try to understand the universe not by observing, but by making mathematical calculations about the physical processes involved. Trying to calculate the mutual gravitational forces acting between more than a few objects requires the help of the modern computer—galaxies contain literally billions of stars, plus dust, gas, and the ever-elusive “dark matter,” and modeling the interiors of stars must be able to account for many complex interactions (gravity, electrical and magnetic forces, chemistry, thermodynamics, fluid dynamics) among a huge number of particles. Thus, the modern supercomputer has become the theoretical astronomer's laboratory. Dr. Stan Woosley and his colleagues at the University of California Santa Cruz, have put together a large NSF-funded “Beowulf” cluster of computers with over 800 fast individual computer “cores” and over 1-1/2 Terabytes of memory (a Terabyte is 1,000 Gigabytes). Dr. Woosley and collaborators have used this computing laboratory to investigate the astrophysics of exploding stars, the dark matter haloes of galaxies, the interior structure of the Sun, and interactions between objects in our solar system.

### **The First Images of an ‘Exo-Solar System’**

Astronomers using the Gemini North telescope and W.M. Keck Observatory on Hawaii's Mauna Kea have obtained the first-ever direct images of a multi-planet system around a normal star, using adaptive optics technology to correct for atmospheric blurring. The Gemini images allowed the international team to make the initial discovery of two planets on October 17, 2007. Using images obtained with the Keck II telescope later in 2007 and in 2008, Christian Marois of Canada's Herzberg Institute of Astrophysics (Victoria B.C., Canada) and members from the U.S. and U.K., confirmed this discovery and found a third planet orbiting even closer to the star. The host star, called HR 8799, is about 130 light years from Earth, and is about 1.5 times the mass of the Sun and significantly younger. The planets, which formed about sixty million years ago, are young enough that they are still glowing from heat released as they continue to contract. Analysis of the brightness and colors of the objects shows that the first two planets are about seven and ten times the mass of Jupiter. As in our solar system, these giant planets orbit in the outer regions of this system - at roughly 25, 40, and 70 times the Earth-Sun separation.

### **PAARE: The Fisk-Vanderbilt Masters-to-PhD Bridge program,**

The Fisk-Vanderbilt Masters-to-PhD Bridge program was established in 2004 with support of a CAREER award to Prof. Keivan Stassun and continues with another CAREER award to Prof. Kelly Holley-Bockelmann. This is a unique collaboration between Fisk and Vanderbilt universities that is poised to become the nation's top source of Ph.D.s in physics and astronomy awarded to underrepresented minorities. This innovative program is funded through the Partnerships in Astronomy & Astrophysics Research and Education (PAARE) program, which seeks to broaden participation in cutting-edge astronomical research. In just five years, the program has attracted 31 underrepresented minority students, 60 percent of whom are women, and has become the nation's top producer of blacks earning master's degrees in physics. Since 2006 Fisk University has awarded about a third of the nation's African American masters in physics.

## **IV. AST Division Management**

### **A. General Impressions**

Overall, the COV is impressed with the management of AST. The organizational structure is appropriate to the task of responsibly managing programs that cover a wide range in scope, intent, and design, from individual proposers (e.g., IIP or CAREER grants) to undergraduate training programs (e.g., REU programs) to major research facilities meant to be accessible to the entire astronomical community (e.g., ALMA).

Program officers are well matched to their assignments. They demonstrate valuable expertise and key awareness of important issues; this statement is true even for those who have joined the staff very recently. AST decision-making processes have been sound during the review period, and the COV finds that management is taking appropriate steps to prioritize, given constrained resources for both funding and staffing. Though arranging backup for staff, especially those program officers for major facilities, remains difficult due to continuing staff shortages (see §IV.B) we commend AST management for taking additional steps to cross-train staff to provide at least partial back up where possible. This foresight will allow AST to alleviate the fallout from an unexpected loss of a program officer who typically corresponds weekly with a facility in some way. AST is at risk because, at current staffing levels, each facility is effectively assigned less than one dedicated Program Officer.

Communication between AST management and staff, and within AST, appears to be direct and clear, and the staff is able to raise issues with management openly on a regular basis. During this review, COV members frequently asked questions and requested further information; the AST staff was open to our requests and suggested related issues for our consideration. There are some indications that communication could be improved between divisions, for projects or programs with cross-division involvement. We encourage AST to identify such programs and emphasize flow of information between program officers.

## **B. Staffing**

### **Accomplishments of AST staff**

The COV is extraordinarily impressed with the managerial accomplishments of the AST staff over the past 3 years. We are very pleased, for example, with the appointment of James Ulvestad as Director of AST, and the recent appointment of Vernon Pankonin as permanent Deputy Director. Across the board, decisions and recommendations of the staff have been driven by scientific objectives, goals of the community, and with a strong eye toward balance and fairness. The staff has accomplished these things under a tremendously high level of stress resulting from, among other things, (a) a talented and aggressive research community, (b) the ARRA funding spike, and (c) insufficient staffing.

### **Staff Workload**

Throughout the COV review it was clear that the AST Division staff are drawn dangerously thin for the enormous workload that is undertaken within the division. While there are a number of steps being undertaken to ensure critical areas are covered by multiple personnel, it is clear that the division is understaffed and that the program officers are overworked. We noted some areas where modest changes may be made to at least partially relieve the burden of the program officers and describe these below. We stress that these suggestions are not going to resolve the workload excess; only the addition of more personnel can truly relieve the situation. The COV noted that 5 program officers are responsible for managing 52% of the AST Division budget yet they are also spread across multiple duties.

### **Specific Issues**

ARRA Funding. The ARRA funding presented a particular challenge to AST staff given the sudden unexpected nature of the stimulus, the magnitude of the funds, constraints on how to properly disburse funds, and the pressure to complete all actions within a very short period. As a result of the additional workload associated with this funding spike, the time to completion of proposal reviews fell outside the 70% in six months goal established by NSF in 2009 and 2010. In our opinion, the AST Division prioritized their work very effectively during this period and ensured that the maximum level of funding was dispersed appropriately to the community. However, the additional load did result in a number of documentation irregularities in 2009 such as unrecorded declination letters in some eJackets. We note that program officers did their best to deal with the volume and PIs would probably have received informal communication in lieu of the formal template email. Work remains to correct and complete actions from 2009 and this will place a continued burden on staff.

Facilities Management. With regard to the ongoing management of major research facilities, staffing is critically low with very little margin for error. Given the scope, complexity and number of programs under AST oversight, we consider this a management risk to be addressed. We expect that the management of the major facilities program portfolio will become more challenging with time due to a number of factors including: (1) the planned re-competition of cooperative agreements; (2) increased proposal pressures brought on by more individual investigators seeking funding and the interest in, and expected accessibility of, ALMA; (3) future major facilities will all be increasingly complex, involving international sites and partnerships; and (4) the need to implement the results of a portfolio review (see Recommendation-2, §V.A). We concur with the practice of assigning a full-time program officer to each of the largest programs and the goal of cross-training program officers to avoid single points of failure, but believe this will not be possible given the current staffing and expected level of activity over the next 3 years.

Process Efficiency. While it may very well be possible to gain some efficiency in the processes used to conduct reviews of individual investigator proposals (see §VI.C), there is no getting around the critical need for additional staffing. In this context our first recommendation is a reiteration of the first recommendation that appeared in the 2008 COV report.

***Recommendation-1: NSF should thoroughly review the staffing requirements of AST to determine the level required for AST to adequately support its base program while playing a leadership role in the complex, international development of the next generation of world-class observatories.***

## **V. Strategic Planning and Implementation**

### **A. Response to Astro 2010**

The COV heard the AST Director's approach to managing the Division's response to the goals outlined in the 2010 *New Worlds New Horizons in Astronomy and Astrophysics* (Astro2010) decade survey. The COV was provided a detailed briefing outlining the Division's interpretation of the Astro2010 recommendations and prioritizations. This included an outline of which components of potential large new facilities (LSST, GSMT) and Mid-Scale programs the Division has begun to phase. The Director clearly articulated that efforts to mature the LSST design and development, and to advance this project within the Agency, had high priority. In addition, the Division intends to develop a process to broadly and openly compete proposals for potential NSF participation in GSMT-like projects, culminating with a possible decision of record in 2012. AST is also working to develop an approach for competing and funding new Mid-Scale Innovations Program (MSIP) in a coordinated fashion. Following Astro2010 recommendations, AST has realigned its D&D and M&O commitments to accommodate operating costs of ALMA and ATST as these facilities begin their scientific utilization. These actions are commensurate with the recommendations in the Astro2010, and indicate that the Division has utilized the survey to appropriately guide its strategic planning.

However, from the perspective of the COV, the budgetary environment that the AST Division faces differs from the growth profile anticipated in Astro2010. The Division is now challenged with the need to accommodate commitment to operations of facilities and to meet demands of an increased volume of worthy IIP proposals, while at the same time advancing the new starts proposed in Astro2010 within a highly constrained fiscal environment. In response, the Director proposed to conduct a portfolio review wherein all programs, facilities, the individual grants program, and other enterprises supported by the AST division will be reviewed. As explained to the COV, this review will advise AST in developing mechanisms to maintain an appropriate balance among established facilities, new facilities, and intellectual infrastructure. The COV commends the Director for this initiative and recommends that this process be conducted quickly to enable effective strategic planning.

***Recommendation-2: AST should conduct a thorough and timely review of present and planned programs and activities across the division (a portfolio review) in order to establish a realistic fiscal baseline to accompany the community's scientific aspirations as enumerated in the***

**Astro2010 decadal survey. MPS/AST management should seek community consultation prior to defining the makeup and charge of its portfolio review team.**

When conducting this review, the COV argues that the Division should be sensitive to its mandate to sustain an intellectual infrastructure (including theoretical and technology development components) that is sufficiently robust to capitalize on the scientific opportunities afforded by facilities within the portfolio as part of the out year balance. The COV recommends that metrics for assessing science outcomes and returns from facilities (e.g., workforce diversity, publication impact, local economic impact, dissertation utilization, user demographics, etc.) be developed internally by the Division prior to the portfolio review process.

***Recommendation-3: As it prepares for a portfolio review, AST should consider establishing, with community input, metrics that can be used to measure success – that is, to measure the relative return on investment – of various segments of its portfolio, such as the individual investigator program and major facilities.***

In light of the sobering budgetary out-year projections, it seems likely that only a limited number of the innovative activities that push the scientific horizons identified in Astro2010 may be accomplished within the decade. We note that this concern was identified clearly in one key paragraph of the Astro2010 report:<sup>i</sup>

*“If the realized budget is truly flat in FY2010 dollars, the implication is that, given the obligation to provide operational costs for the forthcoming ALMA and ATST, there is no possibility of implementing any of the recommended program this decade — without achieving significant savings through enacting the recommendations of the first 2006 senior review process and/or implementing a second more drastic senior review before mid-decade. Because the termination of programs takes time to implement in practice, it will be difficult to accrue significant new savings before the end of the decade. Thus, in practice, very few new activities could be started within NSF-AST.”*

Should the planned portfolio review bear this out, the AST Director should frankly apprise the community of the limited ability of the Division to execute the Astro2010 recommendations this decade. Given the fiscal stringency that is now extant, the community expectation for a significant infusion of new federal resources to the Division must be constrained and managed by the actions and directives of AST.

The Director conveyed that any MSIP initiative ramp-up, as envisaged by the Astro2010 review, is a challenge without consideration of achieving significant savings elsewhere in the portfolio if the realized budget is flat. As stated in the 2006 Senior Review and echoed in the Astro2010 report, diminishing of the portion of the budget covering facilities may offer a programmatic approach to accomplish the required savings. Termination and closeout costs are now recognized and understood by the Division as an area that requires resources and support within the broader Foundation to achieve. The COV noted that the Director and other staff charged with facilities oversight are sensitive to this issue and, in many cases, are beginning to develop forward-look strategies associated with asset disposal. (See a related discussion accompanying Recommendation-8, §VII.A.) The willingness of AST to actively engage strategically in this exercise is representative of a new best-practice fiscal stewardship philosophy established within the AST Division’s culture.

### **B. Relevance to National priorities**

The COV applauds the Division’s record in supporting programs that are aligned with national priorities, the broader NSF mission, and constituent needs. AST programs have advanced cyberinfrastructure development, workforce training, and international collaborations while addressing environmental concerns and desires to commercialize frontier technologies. For example, in the area of cyberinfrastructure development, the Large Synoptic Survey Telescope (LSST) is estimated to generate ~30 Tb of data per night, with the goal that the data be reduced and freely available to the public within 24 hours of its acquisition. An extensive Data Management System (DMS) is being developed to process and archive data, and to facilitate data distribution and analysis. LSST is likely to catalyze development in tangential areas that further promote

cyberinfrastructure development. Another example is AST's careful administration of electromagnetic spectrum management. (See related discussion accompanying Recommendation-9, §VIII.) There are additional areas of national priority in which AST stands to improve its visibility. These include the nation's policies *vis a vis* energy, environment, global climate change, and defense.

## **VI. Community Interaction and Proposal Management**

### **A. AST Responsiveness to Emerging Research and Education Opportunities**

Over the past decade, AST has oriented itself to be able to better respond to new areas of research. While in the past the four research areas of the Astronomy & Astrophysics Research Grants Program (AAG; as itemized above under Session 1 of §II) were maintained distinctly, that separation has now greatly decreased, with flexibility in funding being provided between the four areas. The COV applauds the funding flexibility that has been built into the AAG program because it accommodates opportunities for emerging science. For example, when one panel receives many highly competitive proposals that would not have been submitted in previous cycles – as happened in the last few years with extra-solar planetary research – those new areas can be accommodated. This is, of course, accompanied by a decrease in funding for other areas since there are no new funds available for emerging research. We encourage the AST to better communicate to the research community its receptiveness to proposals that identify emerging areas of research. Such communication would be particularly important for early career scientists who are not familiar with NSF/AST.

For educational activities there is less ability to be accommodating. Education and outreach activities must specifically be addressed in proposals submitted to the Astronomy & Astrophysics Postdoctoral Fellowships (AAPF) program, and they are covered under the “Broader Impacts” requirement of AAG proposals, so there is some ability within those programs to be responsive to emerging opportunities on education. However, those activities typically make up only a small percentage of the overall program effort and are accordingly limited in their ability to take best advantage of new opportunities. In practice, investigators who are interested in seeking funding to support larger educational activities must submit proposals to NSF's Education and Human Resources (EHR) directorate, where programs are often pre-defined.

### **B. Communication with the Scientific Community**

Effective communication between AST and the scientific community is important for efficient operation within the Division and optimizing the returns on investments, facilities, and programmatic initiatives. Currently, AST communicates broadly to the community and other constituents via special sessions at AAS meetings, announcements in AAS newsletters, formal postings with links on the NSF web site, and automated FastLane emails. Based on discussions with the AST staff, the COV concluded that the communication process could be enhanced at negligible cost by making use of additional email lists and creation of a frequently-updated “announcements” section on the AST web page. In addition, the COV noted that the Division should explore the use of innovative technologies and communication forums (e.g., social media, RSS feeds) that are more frequently used by a growing cohort of the astronomical community, as well as the nation at large, for rapid and effective dissemination of information. The COV recognizes that AST consultation with the broader Agency and other divisions likely is necessary to implement changes, yet there is great benefit to more rapid communication of programmatic issues as well as science highlights to the Division's audience. NSF and AST should consider how best to handle the constraints placed by any federal or NSF requirements for accountability, to streamline the process of securing the permissions to disseminate new information in electronic form and minimize delay in its broadcast to potential award recipients.

***Recommendation-4: The Foundation should aggressively explore the innovative use of new technologies to facilitate effective and timely communication with the research community.***

For developing tracking information and growing the pool of panelists, separate distribution lists could be developed for PIs with existing AST awards, PIs who have pending proposals, and potential PIs. The list of potential PIs could be developed based on prior submissions as well as requests from individuals. The information conveyed in direct email distributions could also be posted on the AST announcements web site,

as well as on RSS feeds and social media outlets. Creating multiple channels of communication is particularly important for early career scientists who are not familiar with NSF/AST and its processes. In addition, broad communication of AST's receptiveness to emerging research is crucial to developing cutting-edge science.

The specific nature of communications will vary depending on the current portfolio of AST awards and planned developments. Communications to active-award PIs could include notices of new reporting requirements and requests for research highlights. Communications to potential PIs (including active-award PIs) could include notices of new funding opportunities, notices of changes to required elements in proposals, notices of changes to review schedules, and advice regarding common failures in compliance to proposal guidelines that will result in mandatory "return without review". Email communications or web forms could also be used in recruiting potential panelists for reviews. The COV's motivation for suggesting a more efficient and innovative use of communication technology is to potentially lower the workload of staff in this area while enhancing the effectiveness and informational clarity of the service provided to the community by the Division staff.

### **C. Proposal Review and Award Process**

#### **The Proposal Oversubscription Dilemma: Under-fund Top Proposals, or Cut Facilities? "Between a rock and a hard place"**

The COV observes that there are approximately twice as many scientific proposals worthy of funding as there is funding to support investigations under the Individual Investigator Programs (IIP) programs. With the number of submissions increasing in the past few years, these numbers are becoming more drastic, with some panels able to accept only the top 2 or 3 proposals in their ranked list. The Committee realizes that the options are limited and unattractive, i.e., to realign funding from Facilities to IIP, to decrease award amounts to the top ranked proposals to be able to give more awards, or to seek greater funding overall for AST.

It is noteworthy that the competition is now so steep within AST panels, that in the year of the stimulus funding, AST was able to double its selections of winning proposals while still selecting all "excellent" or "excellent/very good" proposals. This field is highly competitive and growing. A serious discussion of the issue of proposal oversubscription should be included in the portfolio review, and this fact motivates the COV Recommendation-3; indeed, the portfolio review is in part necessary to prevent funding for facilities from inadvertently consuming the IIP funding. NSF has the responsibility for building, and maintaining, intellectual infrastructure.

#### **Panel Efficiencies**

The COV was shocked to learn that it can take up to 19 potential reviewers being contacted before a single panel slot is filled. When program officers must contact 10-20 potential panelists to get one to agree to participate, it is understandably difficult to form panels that contain the required expertise and yet are acceptably diverse, in addition to consuming inordinate amounts of a program officer's time. This unfortunate situation places substantial additional burden on the AST staff. We feel it is worth quoting from the APS guidelines for professional conduct and the AAS ethics committee:<sup>ii</sup>

*"Peer review can serve its intended function only if the members of the scientific community are prepared to provide thorough, fair, and objective evaluations based on requisite expertise. Although peer review can be difficult and time-consuming, scientists have an obligation to participate in the process."*

In the spirit of this guidance it may be a significant benefit to the NSF review process to consider requesting explicit identification in the PI bio of service on NSF panels during the past 5 years and that this service be included in consideration of the proposals during the panel review.

We hope that the issues that are faced with finding panel members reflect issues of timing rather than a lack of dedication to the peer review process. The AST division maintains a relatively short period of time between

panel member selection and the panel meeting, frequently as short as a few weeks. It is difficult for panelists to have sufficiently free schedules to participate, let alone fully consider all the proposals they are tasked to evaluate, when working on short timescales. The committee understands that part of the scheduling pressure is caused by the stricter NSF rules on conflicts of interest. While no survey has been undertaken to understand the origin of the excessive declinations of requests to participate, it is likely linked to the short lead-time. We have additional concerns that this problem may be contributing to the relatively minimal panel reviews and panel summaries that were observed by the committee members in reviewing panel output and outcomes. We therefore suggest that AST consider the following changes to the panel review process, which affect program officers both pre- and post-review:

We recommend that AST consider options to significantly expand the pool of potential panelists. Past recipients of grants should have an expectation of participating in the system (which should be clearly stated in the call for proposals), and first-time PIs or those who have been unsuccessful can only benefit from learning more about how the review process works. Information about proposers' current institutions, research areas, and grant proposal history could be gathered earlier, which would be useful in assembling panels with minimal conflicts as well as flexibility in emerging research topics. Unfortunately no statistics were available to the COV to investigate what fraction of successful PIs have served on review panels in the past 3-5 years.

We also recommend that AST begin assembling panels earlier, utilizing the advance information gathered to cast a wider net for panelists willing to participate. Distributing those panelists at a date closer to the scheduled date of the panel could still retain the desired (and commendable) flexibility for conflicts of interest and emerging scientific topics. Alternatively AST could identify the majority of panelists in advance and fill in the remaining slots once the panels have been developed. To assist in early panel selection, the COV felt that AST could institute a call for Letters of Intent prior to the proposal deadline, which would have the benefit of allowing for early response to emerging research as well as early identification of panel members and conflicts of interest.

***Recommendation-5: AST should consider options to significantly expand the pool of potential panelists, such as: (a) establishing the expectation that past recipients of grants *should* participate in the review process; (b) communicating the benefits of participation to new investigators or those who have been previously unsuccessful; (c) gathering data on the pool of potential panelists earlier than the present practice; and (d) assembling review panels earlier and, perhaps, using a staggered distribution approach.***

As alluded to above, the committee also noted that the panel summary often simply captures details from the individual reviews and does not reflect details of the panel discussion. There are also instances where the panel summary contains material that is not appropriate to viewing by the PI (e.g., comparison to other similar proposals). Both of these issues place additional burden on the program officers to correct the panel summary and construct a detailed report for the PI. We suggest that AST expand the panel training with well-explained examples of good panel summaries and clear details of the essential components of the panel summary. Discussions with some program officers suggest that they have already developed such materials; it may be most efficient for AST to examine these materials and disseminate them more widely to the other program officers.

### **Contacting PIs**

The COV applauds NSF's efforts of having more automated compliance checking. We also feel that the panel action of dividing proposals into competitive and non-competitive categories is a positive measure to streamline the review process. We strongly encourage AST to make the fullest possible use of the eJacket system to automate contacting PIs and recommend that all automated notifications be enabled. We also reiterate recommendation #8 from the 2008 COV report that all proposers be given their quartile ranking. To further improve the efficiency and effectiveness of grant proposal processing, AST Program Officers should consider (a) including comments extracted from generally insightful PO summary analyses in the written



responses sent to PIs; (b) providing information to PIs regarding the general ranking (e.g., quartile ranking) of their proposal; and (c) becoming less tolerant of non-compliant proposals.

### **Post-Panel Review Process**

The COV examined the individual reviews, panel summaries, and program officer review analyses provided in each eJacket. The COV was impressed with the level of detailed rationale given in the Review Analyses written by the Program Officers and assesses that the decisions are appropriately documented within the eJacket.

The COV flagged some eJackets as missing documentation of the post-decision communication between the Program Officer and PI. In some cases this deficiency was resolved as an eJacket bug that prevented COV logins from accessing the complete documentation within individual eJackets, as Program Officers were able to demonstrate that proper documentation existed within the eJacket system. Of more concern to the COV were cases where the high workload asked of Program Officers prevented them from recording details of phone and email conversations with PIs; in some cases (particularly for declined proposals during the high-workload year of 2009), no information regarding communications after decision was present in the official record. The COV found that a significant number of Panel Summaries for declined proposals provided sufficient justification for the decision, but would ideally have included more significant constructive remarks to the PI for how the proposal might be improved in the future.

Given the high workload on AST staff, the COV was impressed with the achievements of the division relative to the NSF-wide goal of informing 70% of applicants of funding decisions within 6 months. The COV noted that this success rate would be higher if the division were less understaffed. The COV further identified that extenuating one-time circumstances of an influx in ARRA funds in the same year as several key staff departures led to a period with an unreasonably high workload for staff within the Division. The COV compliments AST staff for their performance during this period, but notes that such high levels of over-commitment and workload are unacceptable and unsustainable over longer time periods. Given the current already high workloads, the COV is hesitant to suggest actions that would increase staff workload. However, the COV endorses the goal of quick time to decisions and encourages all efforts to better inform PIs when decisions are delayed. The COV suggests that some efficiencies could be gained by taking advantage of additional automation within the eJacket system, e.g. automatically emailing decline decisions to PIs upon the DD concurrence rather than then waiting for the Program Officer to manually contact the PI. The COV approved of the division effort to encourage panels to ‘triage’ proposals into Highly Competitive, Competitive, and Not Competitive categories as this reduces internal workload on highly overworked staff.

### **Demographics**

An important function of the COV is to determine if the AST Grants Program is balanced in terms of its distribution of awards with respect to underrepresented groups, geographical considerations and size and type of proposing institution. Another important task is to ensure that the proposal reviewers are balanced in terms of these same considerations. The committee received demographic information that was retrieved from the NSF database by AST staff. This information was examined in the context of *award size*, *award success rate*, and *proposal and reviewer demographics*.

There are notable limits to the assessments that could be made by the COV. For instance, no information was provided to assess the median award size with respect to institution size and geographical location, or the PI success rate with respect to institution size. It is also important to note that proposers to NSF and reviewers for NSF are not required to state their gender or to provide their minority status. As a result, any conclusions regarding balance of the proposers or reviewers can only be made based on information available. During the last three-year period, 90% (88%) of the PIs submitting proposals provided information on their gender (minority) status. However, only 36% of reviewers provided demographic information.

### Award Size

We make the following observations about the size of research awards over the last three year period:

- The median AST award size for declared minority PI's is comparable to that for all awards.
- The median award size for declared female PI's is slightly smaller (by ~10%) than that for all awards.
- The median award size has grown above inflation (by ~35%) during the last decade.
- The median award size for "new PI's" is slightly smaller than that for "prior PI's". These categories are defined by whether a PI has held a NSF-AST award in the previous five year period.
- The median award size in the EXC, GAL, and SAA disciplines within the AST AAG Program are comparable in size. The median award size in the PLA discipline is somewhat smaller for relatively well-understood reasons.
- The median award size for the instrumentation program is significantly higher than that for all awards; conversely, the median award size for the postdoctoral fellowship program is lower.

We conclude from this information that AST has an appropriate balance across underrepresented groups and scientific discipline with respect to proposal award size.

### Success Rate

We make the following observations about the proposal success rate:

- The number of PI's receiving AST awards has increased by 45% over the last decade; however, the number of PI's submitting proposals has increased by 80% during this same period. Thus, the success rate has declined significantly.
- During the last three years, the success rates for declared minority and female PI's are comparable to those for all PI's.
- During the last three years, the success rates across the various disciplines of the AST AAG Program are comparable.
- Within statistics, the PI's success rates do not depend on the geographical location (U.S. State) of the PI's institution.

We conclude from this information that AST has an appropriate balance across underrepresented groups, scientific discipline, and geographical location with respect to PI success rates.

### Reviewers and Proposal Processing

We make the following observations regarding proposal reviewers and on the processing of proposals by AST, during the last three year period:

- Most reviewers (both ad hoc and panel) do not address the review criteria in the manner specified by NSF. (That is, the actual boxes intended for the review of the Intellectual Merit and Broader Impacts of the proposal are empty, with the entire review contained in the Summary.) AST has not been enforcing the exact letter of the law in this regard.
- For those reviewers who do correctly complete the review template, more than 90% address both review criteria.
- A relatively small number of proposals were returned without review; these were mostly proposals that were inappropriate in some way or another and/or were withdrawn by the proposers.
- For the reviewers that provide demographic information, the percentage of reviewers from underrepresented groups is comparable to that for the overall distribution of AST PI's.

- No demographic information was provided to assess whether reviewers are distributed geographically or by size of institution in a reasonable manner.
- In FY08, AST processed 75% of the received proposals within six months of receipt. In FY09 and FY10, the percentages were much lower.

We conclude that most reviewers are not providing demographic information and are not correctly completing the NSF review template. For reviewers providing demographic information, AST has the appropriate balance of reviewers from underrepresented groups. During the last two years, AST has not processed the majority of submitted proposals by the time of six months from the proposal submission. In FY09, the stated problem was that most of the declinations were completed in the fiscal year because of short-staffing of AST and because of a much larger number of awards due to ARRA funds. In FY10, the spillover from FY09 caused a late start in the processing of the FY10 proposals.

## **VII. National Observatories and Large Facilities**

### **A. AST Oversight of Facilities**

The AST Division of NSF oversees an impressive array of national observatories and large facilities (collectively, large programs) through cooperative agreements with the respective managing organizations. It was clear to the COV from the presentations and interactions with AST management and the program officers, that the staff is dedicated and highly skilled, and that they are providing high quality and efficient oversight of the public funds expended on these important national assets. The AST model for overseeing large facility programs is an acknowledged success within the agency and has been adopted as the standard for use by other divisions.

### **Staff Success and Challenges**

Given the scale and duration of the large programs, AST has assigned permanent staff as program officers to ensure continuity of oversight, and has assigned a backup program officer for the largest or most complex programs. We endorse the Director's plan to try and arrange staff loads so that every large program has a primary and backup program officer, however we are concerned about the level of staffing available. Specifically we note the following.

- Only five persons are tasked with the oversight of all the AST large programs. Given the number, scale and increasing complexity of the programs, we consider this level of staffing to be low by approximately a factor of two.
- The present staffing level has resulted in a very heavy workload for the program officers. It is notable that there have been no significant problems in NSF oversight during 2008-2010. However, due to a number of factors including increasing program complexity and the new requirement derived from National Science Board policy that all cooperative agreements be openly competed at each renewal, we expect workloads to increase further and this to be a source of risk to NSF.
- The effective management of 52% of AST annual budget (plus additional MREFC funding) by only 5 FTEs is made possible only by the highly efficient program officers, and the excellent work of the managing organizations (AURA, AUI, etc) and the associated oversight committees for the facilities.

The COV wishes to commend the quality and professionalism of the NSF program officers assigned to facility oversight. Credit for successes in development of the ATST and ALMA facilities should be shared with the NSF staff that has shown skill and perseverance in overseeing these programs. The COV also commends the tactful and successful management of partnerships with many other countries. Most of the AST facilities now involve international collaboration and the interactions and process for inclusion appear to be working well.

### **Future Facility Priorities**

With regard to budgeting D&D costs for new facilities, AST is following the Astro2010 recommendations and appropriately assigning highest priority to LSST. The AST decision to terminate D&D investments in SKA is significant and also in line with the Astro2010 recommendations. However, given that it is unclear whether or not AST will be able to afford to move forward this decade with more than one new construction project, and given that the Astro2010 recommendations assign a lower priority to GSMT than to LSST, it is unclear whether or not AST should include D&D costs for GSMT in its near-term budget requests.

***Recommendation-7: A decision regarding whether or not to invest in D&D costs for GSMT should await the results of the portfolio review.***

### **Challenge of Increasing Operations Costs for Facilities**

The coming decade will see a number of important facilities milestones for AST. ALMA will move into full operations, the ATST construction is expected to be completed and the telescope made operational, and the LSST, if funded in a timely fashion through the MREFC, will also be constructed and commence operations. If all of these facilities become scientifically productive, it will be a very successful decade for facility development in the AST Division, and U.S. astronomers will be world leaders in the science enabled by these facilities. However, these facilities, which are more expensive and complex than previous AST facilities, will have correspondingly larger operations budgets. At present, there is not a clear path towards accommodating all the operations budgets while maintaining the present facilities, much less for taking on the suite of additional priorities put forth by the Astro2010 decadal review.

We reiterate the point made by the AST “Senior Review” Committee, that the AST Division must consider carefully the relative priorities of continuing to operate its older facilities and transitioning to the increased cost of operating the new facilities. AST has scoped and assessed closure plans for a number of the older facilities and faces the issue that closure costs can be significant. For example, closing the Arecibo radio telescope could cost an estimated \$88M, more than eight times the annual operating cost. Despite the challenge, the budget and facilities planning process must identify and take such costs into account.

AST and the MPS directorate as a whole must confront the issue of establishing and implementing finite lifetimes for major facilities. A realistic plan must be developed for decommissioning instruments and phasing out the M&O costs of major research facilities – or at least for removing M&O costs from NSF’s books. Not doing this will severely impact the ability of MPS/AST to afford future operations costs of new facilities.

***Recommendation-8: AST and, more broadly, MPS must develop a realistic plan for decommissioning instruments and phasing out the M&O costs of its current and planned facilities. In particular, AST/MPS should establish and implement finite lifetimes for major research facilities built with NSF funds.***

## **B. National Optical Astronomy Observatories (NOAO)**

NOAO is operated under a cooperative agreement between NSF and AURA in place through March 31, 2014. Prior to expiration, NSF will re-compete the management award. In addition to a base budget to cover Observatory operations and maintenance, development and Education and Public Outreach, funding is also provided to NOAO for the ReSTAR and Telescope System Instrumentation (TSIP) programs. The present agreement also serves as a conduit for LSST design and development funding. In FY10 the base budget was \$27.5M, TSIP was funded at \$4M and ReSTAR at \$3.9M.

The COV was impressed with the accomplishments of the NOAO staff, its service to the community and the scientific productivity of the instruments and observing programs. During 2008-2010 the telescopes at Kitt Peak National Observatory and Cerro Tololo Inter-American Observatory supported nearly 500 observing programs per year involving some 1,000 scientists from over 150 U.S. institutions, including more than 150

Ph.D. thesis and other graduate student observers, in total resulting in 1,100 publications based on new observations or archival data. NOAO's System Technology Center includes five technology programs: System Instrumentation, ReSTAR Instrumentation, TSIP, LSST and GSMT/ELT technology programs. Progress and technical accomplishments were sound in all these programs. NOAO is providing effective support to the community through the NOAO System Science Center.

### **C. Gemini**

NSF fulfills the role of "Executive Agency" for the six-country international Gemini partnership and provides oversight of AURA in its role as the selected Managing Organization under a cooperative agreement. AURA is responsible for the Gemini International Observatory that operates the Gemini North (Mauna Kea, Hawaii) and South (Cerro Pachon, Chile) telescopes.

Gemini has been scientifically productive since 2008, pursuing observations including the first images of extrasolar Jovian planets and key observations to show that GRB 090423 is one of the most distant objects in the universe ( $z = 8.3$ ). Observations from Gemini yield ~150 refereed papers per year. Also of note was first light of the 5 spot laser of the Multi-Conjugate Adaptive Optics (MCAO) system at Gemini South, and the leadership role Gemini is playing in developing the next generation of AO systems that are required for the GSMT era and wider field of view AO instrumentation.

However, of all the AST facilities, Gemini faces the greatest financial and management challenges. With the recent withdrawal of the United Kingdom from the six-country partnership, Gemini's annual budget will decrease from \$31.9M in 2010 to \$24.3M in 2012. The impact of the reduction is magnified due to the difficulties being experienced in operating facilities on two different continents in a distributed model of engineering and community user support, and with a multiple instrument, queue observing mode of operation. Gemini's present operational model likely is unsustainable given the new, post-UK, operational baseline budget. The level of satisfaction in the user community with support for Gemini appears low and there seems to be a lack of community advocacy for the facility. Additionally, the Astro2010 review recommended the NSF "should consider consolidating the National Optical Astronomy Observatory and Gemini under a single operational structure, both to maximize cost-effectiveness and be more responsive to the needs of the U.S. astronomical community."

The NSF is addressing these issues with a team led by the AST Director to develop a plan for the consolidation of management and to address operational issues. The team will also consider alternative configurations with partners that would bring additional aperture assets from the partners into the US system. The COV endorses the approach that the NSF has developed to address the Gemini issues.

### **D. National Solar Observatory (NSO) and Advanced Technology Solar Telescope (ATST)**

The NSO is operated by AURA through a cooperative agreement with NSF. Facilities include observatories at Kitt Peak in Arizona and at Sacramento Peak in New Mexico, and the world-wide GONG network. In addition to base funding of \$9.1M in FY10 for Operations and Maintenance and Education and Public Outreach, funding was also provided through the MREFC line (\$13M in FY10) and from ARRA (\$146M) for the construction of the ATST on Mauna Kea, Hawaii.

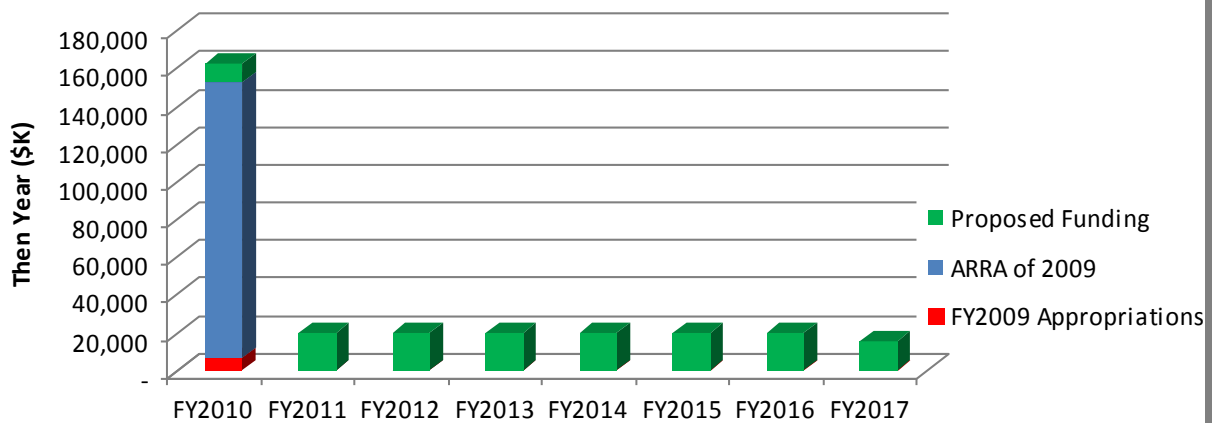
The NSO facilities have been scientifically productive over the last three years with an average of 75 observing programs per year involving 110 observers and 20 PhD thesis observers, yielding 150 publications per year based on NSO telescope and archive data.

With a 3-times improvement in resolution and 8-times improvement in light grasp over present state of the art, ATST promises to be the world's flagship facility for ground-based solar physics observations, and the first large public-access solar telescope constructed in the past 30-years. The telescope will achieve the spatial

resolution on the Sun that is required to image the fundamental scales of photospheric magnetic fields well below the photospheric pressure scale height (~ 100 km).

A total of \$298M will be awarded for construction, almost half of which (\$146M) came from the ARRA stimulus Construction funding in FY09 as shown in the figure below. Progress on the design and planning for ATST has proceeded well with the program passing its final design review and MREFC panel readiness review in 2009 leading to the authorization for funding AURA by the NSB. Building permits are in hand but we note that a related lawsuit and administrative challenge has been filed that has the potential to impact schedule. We commend NSF, AURA and the ATST team for maintaining the core skills within the team during more than a decade of planning and reviews, and we have confidence in the team moving forward with construction towards an operational date later this decade.

### Proposed ATST Funding Plan (includes contingency)



In the past three years, AST has done an excellent job in overseeing NSO and the oversight of the planning phase of the ATST. Most significantly, the ATST project was well positioned to take advantage of ARRA funding. In addition, thoughtful plans are in place for combining existing solar programs & phasing out existing instruments. However, there is justifiable interest in solar research from a number of NSF Divisions, which creates some ambiguity about the proper home for ATST. Given the possibility that solar physics may be moved from the AST Division, we recommend that such a determination be made prior to the portfolio review in order to provide budget clarity.

***Recommendation-6: ATST’s ultimate “programmatic home” within NSF should be decided before AST conducts its portfolio review because the portfolio review team will need to know whether or not ATST’s operations cost will be borne by the AST division.***

#### E. National Atmospheric and Ionospheric Center (NAIC)

The AST Division provides oversight of the NAIC in coordination with the Division of Atmospheric and Geospace Sciences (AGS) through a cooperative agreement with Cornell University. The present agreement covers operations and maintenance of the 305-m fixed, spherical reflector located in Arecibo, Puerto Rico, and

expires September 30, 2011. NSF has solicited proposals for a new five-year cooperative agreement as required by NSB policy.

The AST Senior Review assessed the NAIC astronomy program as very strong but lower priority relative to other AST programs and recommended reduced AST investment to FY10 with a further decrease thereafter. AST responded appropriately to the recommendation by ramping the budget from \$10.5M in FY08 to \$8.4M in FY10 and has requested \$6M in FY11. The GEO/AGS contribution has remained steady at ~\$2M through FY10 with a request for \$3M in FY11. Investments of supplemental funding such as \$3.1M from ARRA in FY09 have emphasized risk reduction, long-term viability and partnership building consistent with the Senior Review recommendations. The long-term budget plan does appear viable, particularly if planned funds from NASA are forthcoming for planetary radar activities. The COV commends NSF on the steps it has taken to respond to the Senior Review recommendations regarding the NAIC.

## **F. National Radio Astronomy Observatories (NRAO)**

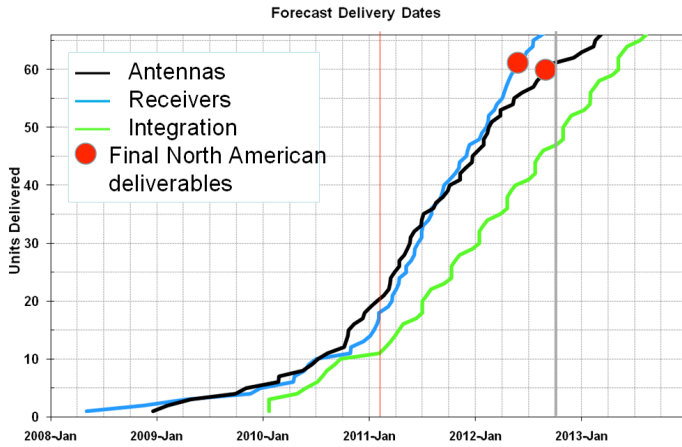
The AST Division provides oversight of NRAO through a cooperative agreement with Associated Universities Inc. (AUI). Funds are provided through separate sub-agreements for NRAO base maintenance and operations, and ALMA construction. In FY10, the base operations budget was funded at \$67.1M and covered the operation of the Very Large Array (VLA), Green Bank Telescope (GBT), Very Long Baseline Array (VLBA) and Expanded VLA (EVLA) construction; ALMA construction was funded at \$64.3M. The cooperative agreement with AUI was renewed in October 2009 for five years. NSF plans to solicit proposals for the maintenance and operation of NRAO, including ALMA, from October 1, 2016.

The COV was impressed by the productivity of the NRAO facilities and with the progress of its two major development projects, EVLA and ALMA. The transition from the VLA correlator to the new EVLA correlator in early 2010 marked a watershed milestone for NRAO: the VLA ceased to exist and EVLA commissioning and early science commenced. The VLA has been one of the (if not the) most productive ground-based scientific instruments – ever, and the upgrade to the EVLA with an improvement in performance by a factor of ten and complete frequency coverage from 1 to 50 GHz provides a new and powerful capability for U.S. and international astronomers. The final EVLA construction funds will be expended in FY11 and the project milestones have been met on or ahead of schedule and on budget, representing a major achievement for NRAO and NSF. Such an increase in capability does however present challenges including dealing with data sets that are an order of magnitude larger than for the VLA, more complex processing and analysis challenges, and training the community to take full advantage of the instrument. NRAO has correctly identified this as a high priority and NSF should monitor progress in this area with care since the productivity of the instrument depends critically on its usability by the community.

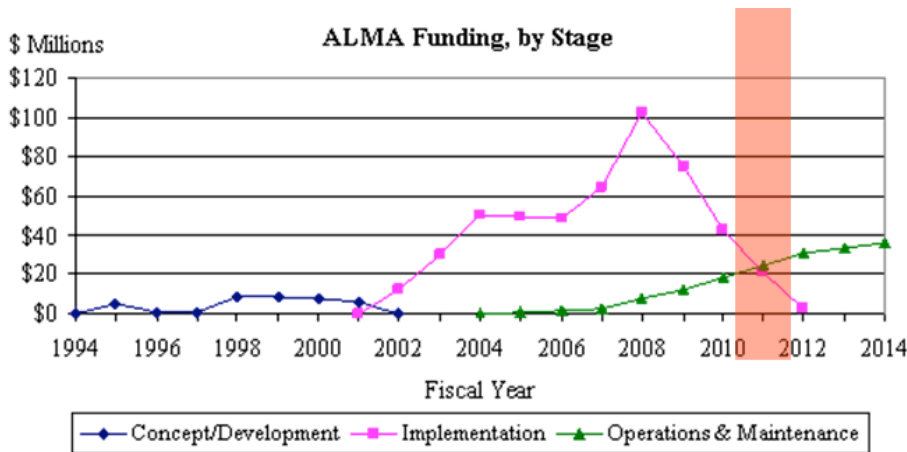
Following the Senior Review recommendation to significantly scale back the investment in the VLBA operations, NRAO with support from AST has been active in seeking partnerships to provide sufficient funding to continue operations at half the present cost to AST. NRAO has made very good progress in establishing agreements with both domestic and international partners and is close to securing commitments for the required \$3M/year. NRAO should be commended for their efforts and creativity in developing a plan to continue the operation of the VLBA with its capability of 0.1mas resolution over frequency intervals in the range of 0.3 GHz – 50 GHz.

With a total program cost of \$1.3B, ALMA represents the largest undertaking in radio astronomy to date. In partnership with the Europe Southern Observatory, NSF AST through AUI and NRAO is nearing completion of construction of more than fifty 12-meter telescopes situated in Northern Chile. The construction phase for ALMA is over 80% complete (see figure below) with \$22M remaining in contingency (33% of uncommitted budget) and is presently ~ 5% behind the baseline schedule. Once liens and pending change requests are accounted for, the effective contingency is \$10M (15%). The program is entering a critical integration phase, with 33 antennas now installed in Chile, mm and sub-mm receivers in production and science commissioning

underway. The project appears well managed and in a healthy state. ALMA funding is transitioning from construction to operations in FY11 (see figure below).



It appears as though challenges associated with ALMA construction are being met as a result of strategic decisions implemented by AST and sound management by NRAO. In addition, the AST budget is being managed well to smoothly accommodate ramping up of ALMA operations costs within reasonable budget assumptions. This is being accomplished through the simultaneous ramping down of AST commitments to other facilities. It is gratifying to see that plans are in place to accommodate ALMA operations costs as this is an issue that has been of concern to the community and, indeed, to many members of this COV.



### VIII. Electromagnetic Spectrum Management (ESM)

Historically, responsibility for managing the electromagnetic spectrum has been assigned to AST because protecting key “windows” in the spectrum is especially critical to research conducted by the radio astronomy community—being able to detect and monitor natural radio emission from the Earth and other astronomical objects enables us to understand better a wide variety of scientific topics including weather conditions and climate change on Earth, the building blocks of stars and planets, and the cosmic radiation from the Big Bang and conditions in the early universe. ESM has been managed well by AST while its importance to national and international commerce, and thus to the nation’s investment priorities, has grown significantly over the past decade. This statement has always been true in a country driven increasingly by technology, but the radio spectrum will feel increasing pressure due to new economic drivers, such as the growing number of smart phones, the recent Presidential Memorandum on Unleashing the Wireless Broadband Revolution, and the National Broadband Plan to accelerate the delivery of high-speed broadband connections across the country. In this context, the COV unanimously recognizes the importance of ESM and the need for ESM to achieve and maintain a very high profile across the Foundation.

There was some division among COV members about the best mechanism for maintaining a high profile for ESM. The staff responsible for ESM has been proactive and effective in their efforts to protect scientifically important frequencies, but the workload required to prepare for international conferences is significant and



nearly continuous; for instance, World Radiocommunication Conferences are held every 3-4 years, and current ESM staff estimate it takes them approximately three years to prepare for the complex discussions and negotiations that will occur. In addition, ESM staff members deal increasingly with pressures from economic drivers such as the interest in cellphones and the interest in the development of unmanned aircraft, which may require continuous, high-speed communication with the ground. In some respects, more resources might be available to ESM were it housed at a higher level in the NSF, and it is appropriate that NSF-wide funds should be used for this. In addition, as the COV was inform even NSF's spectrum related interests go beyond those related to radio astronomy.

However, extracting ESM from AST might result in an undesirable rebalance of the priorities of national technology initiatives against the needs of radio astronomy research. In the last decade, the British equivalent of the FCC, Ofcom, has switched from a "Command and Control" mode of regulating the electromagnetic spectrum, in which radio astronomy received direct regulated protection in scientifically relevant wavebands, to a mode known as "Market Based", in which interested parties must compete for desired spectrum. While radio astronomy was provided some funds for effectively buying back the protected spectral windows, such funds are unlikely to be sufficient to compete with significant commercial interests. Furthermore, though such agreements can in principle be renegotiated in the future, they are in practice virtually irreversible—once the construction of radio transmitters has been allowed in a radio astronomy band they are nearly impossible to remove. Such is the case for the K-band window (~20-40 GHz) near one of the telescopes in the MERLIN array, a UK radio telescope array with capabilities complementary to that of the NSF-funded VLBA and EVLA. In addition, UK astronomers are slated to lose access to the 606-614 MHz band in 2012, and the band near 2.7 GHz will no longer be protected from stray transmissions in nearby regions of the spectrum; these changes will affect radio astronomy at all UK radio astronomy sites and, even more worrisome, have the potential to be a model for spectrum management across Europe. Some of these same issues are also relevant in the U.S. In a recent report by the Committee on Scientific Use of the Radio Spectrum, NSF and NASA have received recommendations to "support research and development for unilateral RFI mitigation technology", as current regulations provide insufficient protection from out-of-band and spurious interference from sources like communications satellites.

In these difficult economic times, the lure of sacrifice of U.S. radio astronomy for perceived technological and economic improvement could be large without responsible and high-profile management by the NSF. Were commercial sources to be allowed access to currently protected frequency bands, the research community would be effectively blinded in the radio regime. The COV recommends that NSF consider carefully the best means to support a high profile for ESM to ensure the continued protection of scientifically important bands of the radio spectrum.

***Recommendation-9: Given the importance of ESM to the NSF and the growing external pressures that are being placed by international commerce on ESM, a decision needs to be made regarding the proper home for the ESM program. The home for ESM must be chosen to ensure that ESM retains a sufficiently high profile to protect scientifically significant parts of the electromagnetic spectrum for research purposes.***

## **IX. Response to 2008 COV**

Sixteen recommendations were highlighted in the 2008 COV report. Over the past three years, the AST leadership has made a concerted effort to address all of the recommendations that touched on issues under the AST division's control. For example, in making budgetary decisions necessary to pave the way for the operation of new major facilities, AST has implemented key recommendations from the mid-decade *Senior Review* as urged by the 2008 COV (see 2008 recommendations #3, 4, and 14).

When called upon to do so during the recent decadal review, the AST staff provided valuable input to the community which allowed the Astro2010 review team to make informed decisions regarding, for example, reprioritization of projects identified in the previous decadal survey (see 2008 recommendation #5). Concerns

related to instrumentation development and mid-scale infrastructure programs that were explicitly identified by the 2008 COV (see recommendations #10, 11, and 12) also surfaced in the Astro2010 report. As is discussed in earlier sections of this 2011 COV report, AST has taken specific actions to address these concerns.

As is also discussed elsewhere in this report, with the assistance of ARRA funding, AST has made extraordinary progress toward bringing the ATST project into its construction phase (2008 recommendation #15). At the same time, the ARRA funding spike added stress to the system especially in the context of reviews carried out in connection with individual investigator programs (IIP). Nevertheless, the AST staff remained mindful of the COV report and made an effort to address the 2008 COV's concerns and recommendations regarding management of the IIP (see recommendations #7, 8, and 9).

Five of the 16 recommendations that were highlighted in the 2008 COV report addressed issues that fell outside the immediate control of the AST leadership. In response to recommendations #1 and 2, NSF/MPS made additional travel funds available to the AST division and facilitated the hiring of new staff within AST including the appointment of James Ulvestad as AST Director and Vernon Pankonin as AST Deputy Director. Despite these gains, as our report makes clear, AST remains critically understaffed. Recommendation #1 of this 2011 COV report therefore restates recommendation #1 from the 2008 COV report.

It is not obvious to what extent the National Science Board or the Foundation has considered recommendations #6 and 13 from the 2008 COV report which deal with (#6) building flexibility into MREFC processes to better facilitate partnerships with private or public entities, and (#13) not forcing a routine, five-year re-competition of all facilities management contracts. These are both concerns that need to be further considered even though this 2011 COV did not raise either issue to the level of a formal recommendation.

Finally, in §VIII of this 2011 COV report we have once again expressed concern about the Foundation assigning proper visibility to the issue of electromagnetic spectrum management (ESM). It is our understanding that, in response to the 2008 COV's recommendation #16, the MPS directorate has discussed with the Foundation director whether or not ESM should be moved to a higher level within the organization. We note that no such reorganization has taken place while the importance of ESM to AST – and, in fact, to the nation – has increased over the past few years.

**FY 2010 REPORT TEMPLATE FOR  
NSF COMMITTEES OF VISITORS (COVs)**

<b>Date of COV: February 7-9, 2011</b>
<b>Program/Cluster/Section: All Division programs and activities</b>
<b>Division: AST</b>
<b>Directorate: MPS</b>
<b>Number of actions reviewed: 257</b>  <b>Awards: 109</b>  <b>Declinations: 143</b>  <b>Other: 5</b>
<b>Total number of actions within Program/Cluster/Division during period under review:</b>  <b>Awards: 715</b>  <b>Declinations: 1811</b>  <b>Other: 70</b>
<b>Manner in which reviewed actions were selected:</b>  <b>COV members individually selected from list of 422 e-jackets provided by AST.</b>

**PART A. INTEGRITY AND EFFICIENCY OF THE PROGRAM'S PROCESSES AND MANAGEMENT**

Briefly discuss and provide comments for *each* relevant aspect of the program's review process and management. Comments should be based on a review of proposal actions (awards, declinations, and withdrawals) that were *completed within the past three fiscal years*. Provide comments for *each* program being reviewed and for those questions that are relevant to the program under review. Quantitative information may be required for some questions. Constructive comments noting areas in need of improvement are encouraged.

**A.1 Questions about the quality and effectiveness of the program's use of merit review process.** Provide comments in the space below the question. Discuss areas of concern in the space provided.

QUALITY AND EFFECTIVENESS OF MERIT REVIEW PROCESS	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE <sup>iii</sup>
<p>1. Are the review methods (for example, panel, ad hoc, site visits) appropriate?</p> <p>Comments: See discussion in main text of the report.</p> <p>Source: Jackets and the EIS. Select the "Type of Review" module.</p>	YES
<p>2. Are both merit review criteria addressed</p> <p>a) In individual reviews? YES</p> <p>b) In panel summaries? YES</p> <p>c) In Program Officer review analyses? YES</p> <p>Comments:</p> <p>Source: Jackets</p>	YES
<p>3. Do the individual reviewers provide substantive comments to explain their assessment of the proposals?</p>	YES

<p>Comments:</p> <p>Source: Jackets</p>	
<p>4. Do the panel summaries provide the rationale for the panel consensus (or reasons consensus was not reached)?</p> <p>Comments:</p> <p>Source: Jackets</p>	<p>YES</p>
<p>5. Does the documentation in the jacket provide the rationale for the award/decline decision?</p> <p>(Note: Documentation in jacket usually includes context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), program officer review analysis, and staff diary notes.)</p> <p>Comments: The COV reviewed the individual reviews, panel summaries, and program officer review analyses. The COV was impressed with the level of detailed rationale given in the Review Analyses written by the Program Officers.</p> <p>Source: Jackets</p>	<p>YES</p>

<p>6. Does the documentation to PI provide the rationale for the award/decline decision?</p> <p>(Note: Documentation to PI usually includes context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), and, if not otherwise provided in the panel summary, an explanation from the program officer (written or telephoned with diary note in jacket) of the basis for a declination.)</p> <p>Comments: The COV flagged some e-jackets as missing documentation of the post-decision communication between the Program Officer and PI. In some cases this deficiency was resolved as an e-jacket bug that prevent COV logins from accessing the complete documentation within individual e-jackets. In those cases Program Officers were able to demonstrate that proper documentation existed within the e-jacket system. Of more concern to the COV were cases where the high workload asked of Program Officers prevented them from recording details of phone and email conversations with PI. The COV found that a significant number of Panel Summaries for declined proposals provided sufficient justification for the decision, but would ideally have included more significant constructive remarks to the PI for how the proposal might be improved in the future.</p> <p>Source: Jackets</p>	<p>YES</p>
<p>7. Is the time to decision appropriate?</p> <p>Note: Time to Decision – NSF Annual Performance Goal: <b>For 70 percent of proposals, inform applicants about funding decisions within six months of proposal receipt or deadline or target date, whichever is later.</b> The date of Division Director concurrence is used in determining the time to decision. Once the Division Director concurs, applicants may be informed that their proposals have been declined or recommended for funding. The NSF-wide goal of 70 percent recognizes that the time to decision is appropriately greater than six months for some programs or some individual proposals.</p> <p>Comments: Given the high workload on AST staff, the COV was impressed with the achievements of the division relative to the NSF-wide goal of informing 70% of applicants of funding decisions within 6 months. The COV noted that this success rate would be higher if the division were less understaffed. The COV further identified that extenuating one-time circumstances of ARRA funds in one year coincided with several key staff departures led to an unreasonably high workload for staff within the Division. The COV compliments AST staff for their performance during this period, but notes that such high levels of over-commitment and workload are unacceptable and unsustainable over longer time periods. rather than then waiting for the Program Officer to manually contact the PI. The COV approved of the division effort to encourage panels to ‘triage’ proposals into Highly Competitive, Competitive, and Not Competitive categories as this reduces internal workload on highly overworked staff.</p>	<p>No</p>

<p>Source: Jackets and EIS-Web COV module. Select “Report View”, then select “Average Dwell Time,” and select any combination of programs or program solicitations that apply.</p>	
<p>8. Additional comments on the quality and effectiveness of the program’s use of merit review process:</p>	

**A.2 Questions concerning the selection of reviewers.** Provide comments in the space below the question. Discuss areas of concern in the space provided.

<p><b>SELECTION OF REVIEWERS</b></p>	<p><b>YES , NO, DATA NOT AVAILABLE, or NOT APPLICABLE<sup>iv</sup></b></p>
<p>1. Did the program make use of reviewers having appropriate expertise and/or qualifications?</p> <p>Comments:</p> <p>Source: Jackets</p>	<p>YES</p>
<p>2. Did the program use reviewers balanced with respect to characteristics such as geography, type of institution, and underrepresented groups?</p> <p>Comments: The COV ability to address this question was limited by the fact that demographic data for reviewers is self-reported, with only about 25% of reviewers reporting this information.</p> <p>Source: Jackets and EIS-Web COV module. The “Report View” has reviewers by state, institution type, minority status, disability status, and gender</p>	<p>YES</p>

<p>3. Did the program recognize and resolve conflicts of interest when appropriate?</p> <p>Comments:</p>   <p>Source: Jackets</p>	
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<p>4. Additional comments on reviewer selection:</p>          
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**A.3 Questions concerning the resulting portfolio of awards under review.** Provide comments in the space below the question. Discuss areas of concern in the space provided.

<b>RESULTING PORTFOLIO OF AWARDS</b>	<b>APPROPRIATE, NOT APPROPRIATE<sup>v</sup>, OR DATA NOT AVAILABLE</b>
<p>1. Overall quality of the research and/or education projects supported by the program.</p> <p>Comments:</p>   <p>Source: Jackets and program information</p>	<p>APPROPRIATE</p>



<p>2. Does the program portfolio promote the integration of research and education?</p> <p>Comments:</p> <p>Source: Jackets and program information</p>	<p>APPROPRIATE</p>
<p>3. Are awards appropriate in size and duration for the scope of the projects?</p> <p>Comments:</p> <p>Source: Jackets and EIS-Web COV module has a “Report View” that gives average award size and duration for any set of programs or program solicitations you specify.</p>	<p>APPROPRIATE</p>
<p>4. Does the program portfolio have an appropriate balance of:</p> <ul style="list-style-type: none"> <li>• Innovative/potentially transformative projects?</li> </ul> <p>Comments:</p> <p>Source: Jackets and program information.</p>	<p>APPROPRIATE</p>
<p>5. Does the program portfolio have an appropriate balance of:</p> <ul style="list-style-type: none"> <li>• Inter- and Multi- disciplinary projects?</li> </ul> <p>Comments:</p> <p>Source: Jackets, program information, and some people use as a proxy data on jointly funded projects. See EIS-Web COV module, “Report Review” and select “co-funding from” and “co-funding contributed to” to find jointly supported awards.</p>	<p>APPROPRIATE</p>

<p>6. Does the program portfolio have an appropriate balance considering, for example, award size, single and multiple investigator awards, or other characteristics as appropriate for the program?</p> <p>Comments:</p> <p>Source: Jackets, program information, and EIS-Web COV module for information on award size.</p>	<p>APPROPRIATE</p>
<p>7. Does the program portfolio have an appropriate balance of:</p> <ul style="list-style-type: none"> <li>• Awards to new investigators?</li> </ul> <p>NOTE: A new investigator is an investigator who has not been a PI on a previously funded NSF grant.</p> <p>Comments:</p> <p>Source: EIS-Web COV module on "Funding Rate," filtered by PI Characteristic (use the pop-up filter).</p>	<p>APPROPRIATE</p>
<p>8. Does the program portfolio have an appropriate balance of:</p> <ul style="list-style-type: none"> <li>• Geographical distribution of Principal Investigators?</li> </ul> <p>Comments:</p> <p>Source: EIS-Web COV module, using "Proposals by State"</p>	<p>APPROPRIATE</p>
<p>9. Does the program portfolio have an appropriate balance of:</p> <ul style="list-style-type: none"> <li>• Institutional types?</li> </ul> <p>Comments:</p> <p>Source : EIS-Web COV module, using " Proposals by Institution Type"</p>	<p>APPROPRIATE</p>

<p>10. Does the program portfolio have an appropriate balance:</p> <ul style="list-style-type: none"> <li>• Across disciplines and subdisciplines of the activity?</li> </ul> <p>Comments:</p> <p>Source: Jackets and program information</p>	<p>APPROPRIATE</p>
<p>11. Does the program portfolio have appropriate participation of underrepresented groups?</p> <p>Comments: See text of the report.</p> <p>Source: EIS-Web COV module, using “Funding Rate” with the pop-up filter (this allows you to see female and minority involvement, where involvement means being PI or co-PI).</p>	<p>APPROPRIATE</p>
<p>12. Is the program relevant to national priorities, agency mission, relevant fields and other constituent needs? Include citations of relevant external reports.</p> <p>Comments:</p> <p>Source: Program information</p>	<p>APPROPRIATE</p>
<p>13. Additional comments on the quality of the projects or the balance of the portfolio:</p>	

**A.4 Management of the program under review.** Please comment on:

1. Management of the program.

**Comments:** The 2011 COV finds AST to be well managed, balancing the needs of a range of programs, including individual grants programs, undergraduate training programs, and large facilities projects that are both in operation and under construction. The management of AST is a model for the agency, and their successes are particularly commendable given insufficient staffing. See §IV of the report for more information.

2. Responsiveness of the program to emerging research and education opportunities.

**Comments:** The COV applauds the funding flexibility that has been built into the AAG program because it accommodates opportunities for emerging science. The COV finds less flexibility in the existing structure to accommodate emergent educational opportunities. See §VI of the report for more information.

3. Program planning and prioritization process (internal and external) that guided the development of the portfolio.

**Comments:** The COV finds that AST has been careful in planning, and responsive to the ever-changing balance of available resources and demand in its developing portfolio. We commend the Director's immediate plans for a full portfolio review to help balance the expectations of the Astro2010 report and the fiscal reality of the current economic environment. See §§V,VII.A of the report for more information.

4. Responsiveness of program to previous COV comments and recommendations.

**Comments:** AST has addressed all of the recommendations of the COV that were under its direct control, to the degree allowed by the available resources. See §IX of the report for more information.

5. Additional comments on program management:

## **PART B. RESULTS OF NSF INVESTMENTS**

The NSF mission is to promote the progress of science; advance national health, prosperity, and welfare; and secure the national defense (NSF Act of 1950).

In this Section, the COV is asked to comment on (1) noteworthy achievements based on NSF awards in the portfolio under discussion; (2) ways in which funded projects have collectively affected progress toward NSF’s mission and the strategic outcome goals of Discovery, Learning, and Research Infrastructure; and (3) expectations for future performance based on the current set of awards.

NSF investments produce results that appear over time. Consequently, the COV review may include consideration of significant impacts and advances that have developed since the previous COV review and are demonstrably linked to NSF investments, regardless of when the investments were made.

In addition to identifying particularly noteworthy accomplishments or “highlights,” the COV is encouraged to comment on the impact of NSF supported contributions to the field. For example, the COV report may include comments on NSF supported work in context of contributions to advance a field, impact of NSF investments to stimulate emerging new areas, and potential for transformative impact in research or education.

To assist the COV, NSF staff will provide award “highlights” as well as information about the program and its award portfolio. The COV is asked to use this information, members’ own knowledge of the field, and other appropriate information to develop its comments for this section.

**B. Please provide comments on the activity as it relates to NSF’s Strategic Outcome Goals. Provide examples of outcomes (“highlights”) as appropriate. Examples should reference the NSF award number, the Principal Investigator(s) names, and their institutions.**

**B.1 OUTCOME GOAL for Discovery: “Foster research that will advance the frontier of knowledge, emphasizing areas of greatest opportunity and potential benefit and establishing the nation as a global leader in fundamental and transformational science and engineering.”**

This category includes NSF’s disciplinary and interdisciplinary research in science and engineering, education research, and centers.

Comments: See the “Science Highlights” section of the main text together with the selection of awards below.

**B.2 OUTCOME GOAL for Learning: “Cultivate a world-class, broadly inclusive science and engineering workforce, and expand the scientific literacy of all citizens.”**

This category includes K-12, undergraduate, graduate, and postdoctoral education and training; public understanding of science; and lifelong learning.

Comments: See the “Science Highlights” section of the main text together with the selection of awards below.

**B.3 OUTCOME GOAL for Research Infrastructure: “Build the nation’s research capability through critical investments in advanced instrumentation, facilities, cyberinfrastructure and experimental tools.”**

This category includes facilities, research instrumentation, and cyberinfrastructure.

Comments: See the “Science Highlights” section of the main text together with the selection of awards below.

**B1 : Outcomes in the area of Discovery**

**Turn and Turn About**

*Outcome:* Astronomers at the California Institute of Technology (Caltech) and Ecole Polytechnique Fédérale de Lausanne (EPFL) in Switzerland have discovered the first known case of a distant galaxy being magnified by a quasar acting as a gravitational lens. This provides a novel way to study the host galaxy of a quasar, which is normally hidden in the glare from the quasar itself.

*Impact:* Quasars are extraordinarily luminous objects in the distant universe, thought to be powered by supermassive black holes in the cores of galaxies. A single quasar can be a thousand times brighter than the entire galaxy surrounding it, making studies of those hosts “a bit like staring into bright car headlights and

trying to discern the color of their rims”, according to Frederic Courbin, lead author on the research paper describing the discovery.

*Significance:* Using gravitational lensing to measure the masses of distant galaxies independent of their brightness was suggested in 1936 by Caltech astrophysicist Fritz Zwicky, and it has been used effectively for this purpose in recent years. Until now, the technique had never been applied to measure the masses of quasar hosts themselves - usually, galaxies or galaxy clusters are found to be lensing quasars. To find the cosmic lens, astronomers searched a large database of quasar spectra obtained by the Sloan Digital Sky Survey to select candidates, and follow-up observations of the best candidate using the W. M. Keck Observatory’s 10-meter telescope confirmed that quasar SDSS J0013+1523 at about 1.6 billion light years away is indeed magnifying a distant galaxy, itself about 7.5 billion light years away.

Quasars are valuable probes of galaxy formation and evolution and this discovery demonstrates the continued utility of gravitational lensing as an astrophysical tool. Finding more such systems would really help astronomers to understand better the relationship between quasars and the galaxies which contain them, and their co-evolution.

***NSF Award Numbers:***

**0407448**

**Award Title: Collaborative Research: The Palomar-QUEST Survey**

**PI: Stanislav Djorgovski**

**Institution Name: California Institute of Technology**

**0909182**

**Award Title: The Catalina Real-Time Transient Survey (CRTS)**

**PI: Stanislav Djorgovski**

**Institution Name: California Institute of Technology**

**0443905**

**Award Title: An Extension to the Sloan Digital Sky Survey**

**PI: Richard Kron**

**Institution Name: Astrophysical Research Consortium**

**Atoms and Ions to Molecules to First Stars**

*Outcome:* Lab measurements determined the speed to make molecular hydrogen, H<sub>2</sub>, from hydrogen atoms (H) and negative ions (H<sup>-</sup>) out of the hot primordial soup. This reaction speed determines how quickly the soup cooled before any stars could form after the Big Bang.

*Impact:* Prior to the experiment, there was uncertainty in the models how quickly the primordial was cooled by forming molecular hydrogen. This time scale determined how quickly the first stars formed and how big they could get. The new measurement by Dr. Savin and his colleagues lowers the uncertainty in the masses of the first stars by about 20%. The nature of the first stars set the stage for the cosmic structure and development of everything that followed - primordial galaxies and the stars in the Universe we see today.

*Significance:* A few 100 million years after the big bang the dark universe was filled with hydrogen (H) and helium (He) atoms, and negatively charged hydrogen ions (H<sup>-</sup>). Before the first stars could form, the hot primordial gas had to cool. Collisions of H atoms transferred kinetic energy to molecular hydrogen (H<sub>2</sub>). The internal energy gained by H<sub>2</sub> was then radiated away through photon emission. However, before the gas could cool this way, molecular hydrogen had to be present too.

The researchers studied the major H<sub>2</sub> forming reaction from the initially present H and H<sup>-</sup>, which proceeds via an intermediate step of a negatively charged H<sub>2</sub> molecule, which leaves H<sub>2</sub> and an electron behind:

$H + H^- = H_2^- = H_2 + e^-$ . The speed of this reaction controls the cooling speed, which was measured in Dr. Savin's Astrophysics Laboratory at Columbia University.

***NSF Award Numbers:***

**0807436**

**Award Title:**

**Improved Understanding of Molecular Clouds and Emission Line Objects with Laboratory Astrophysics Studies at the Heidelberg Ion Storage Ring**

**PI: Daniel Wolf Savin**

**Institution Name: Columbia University**

**0606960**

**Award Title: Further Measurements of Thermal Energy Charge Transfer in Support of Ground-Based Astronomy**

**PI: Daniel Wolf Savin**

**Institution Name: Columbia University**

**0520990**

**Award Title: MRI:Acquisition of Instrumentation for Biometric Authentication Research: Collaborative Research**

**PI: Michael Schuckers**

**Institution Name: Saint Lawrence University**

**Chance of (Comet) Showers? Not So Large, Calculations Suggest**

*Outcome:* Two University of Washington scientists have discovered that many long-period comets, coming from a region more than 4 trillion miles from the Sun, may have originated in a much closer and more populous zone. This implies that the number of comets orbiting in the most distant reaches of the Solar System – the “outer Oort cloud” – may be much smaller than previously thought.

*Impact:* Reducing the number of comets in the outer Oort cloud may resolve a long-standing puzzle concerning the amount of mass involved in the formation of the planets. It also means that “comet showers” in the inner Solar System may have been less frequent and less severe than previously thought. The researchers estimate that only one significant shower has occurred in the last 530 million years, and suggest that comet showers should be blamed for no more than one mass extinction event on Earth since the emergence of multi-cellular life.

*Significance:* The Oort cloud is a huge reservoir of icy bodies orbiting the Sun far beyond the region of the planets. Beyond 20,000 Astronomical Units (AU, the mean Earth-Sun distance), comets are fairly easily disturbed by the gravity of passing stars and deflected into the inner Solar System, where they become observable long-period comets (LPCs). Inside 20,000 AU, the Sun's gravity is more dominant, and comets are less easily disturbed; moreover, comets from this region are prevented from crossing the orbits of Jupiter and Saturn by the gravitational influence of these giant planets. For these reasons the inner Oort cloud has not been regarded as a source for LPCs. But the researching team, using sophisticated computer simulations, identified a new mechanism by which the gravity of the outer planets can kick an inner Oort cloud comet temporarily into the outer cloud, where it can be fairly quickly diverted and become an observable LPC. This new pathway can account for a significant fraction of LPCs, making a huge outer Oort cloud population unnecessary.

***NSF Award Numbers:***

**0709191**

**Award Title: The Oort Cloud in the Galactic Context**

**PI: Thomas Quinn**

**Institution Name: University of Washington**



### **Jets not from hidden ocean on Enceladus**

*Outcome:* According to this study led by Prof. Nicholas Schneider of the University of Colorado at Boulder's Laboratory for Atmospheric and Space Physics (LASP), water vapor jets that spew from the surface of Enceladus are not really geysers from an underground ocean, as was thought by planetary scientists following a 2005 flyby of the sixth largest moon of Saturn by NASA's Cassini spacecraft. The project was carried out in collaboration with scientists from the University of Maryland and the Institute for Astronomy in Honolulu.

First observed in 2005 when Cassini made its then closest flyby of the small moon, the jets were found to consist of both water vapor and icy particles, and inspired speculation by planetary scientists that they were geysers, that is, violent explosions of water out of a vent caused by expanding bubbles of water vapor emanating from an ocean beneath the icy crust of Enceladus. Schneider and colleagues wondered if there was an ocean underneath that crust which was just spraying out through cracks like a geyser boiling away into space. If such an ocean did exist, it might provide a suitable environment for primitive life forms.

Testing the theory required experiments to find the relative content of sodium in the water vapor component of the jets. If the jets were geysers originating from an underground ocean, then the sodium content in the water vapor should be high. Such sodium should give off the same yellow light seen in street lights, and fortunately the world's best telescopes can detect even a small number of sodium atoms orbiting Saturn. Observations using the 10-meter Keck 1 telescope and the 4-meter Anglo-Australian telescope, however, demonstrated that few if any sodium atoms existed in the water vapor. "It would have been very exciting to support the geyser hypothesis. But it is not what Mother Nature is telling us," said Schneider. However, an additional study by a different group of researchers analyzed the icy grains that also make up the expelled jets, and did find some salt in the particles in the plume, suggesting they have come from an ocean. Thus, not finding salt in the vapor speaks to the conditions of that possible ocean.

One suggestion is that deep caverns may exist where water evaporates slowly.

When the evaporation process is slow the vapor contains little sodium, just like water evaporating from the ocean. The vapor turns into a jet as it leaks out of small cracks in the crust into the vacuum of space. It would only contain more salt if the evaporation is more explosive. The idea of slow evaporation from a deep cavernous ocean is not as dramatic, but it is supported by the results so far. Other explanations for the jets are, however, equally plausible, such as warm ice vaporizing away into space. It could even be places where the crust rubs against itself from tidal motions and the friction creates liquid water that would then evaporate into space.

*Impact:* The wide-spread collaboration across US institutions involves significant training of junior researchers.

*Significance:* Understanding the satellites of planets in the outer solar system remains of critical interest, and progress is still possible from ground-based facilities as well as from space probes.

#### ***NSF Award Numbers:***

**0709343**

**Award Title: Collaborative Research: A Comparative Study of Escaping Atmospheres using AEOS/HiVIS**

**PI: Nicholas Schneider**

**Institution Name: University of Colorado at Boulder**

### **Andromeda Galaxy Cloaked in Debris of Shredded Companions**

*Outcome:* It's the most distant object visible to the unaided eye. But the Andromeda Galaxy is also a prime target for some of the world's largest telescopes. This NSF-supported project to map the outer reaches of our

Milky Way's big sister is revealing the remains of demolished stellar systems and allowing researchers to probe Andromeda's memory of its own growth.

Massive galaxies have the ability to gravitationally shred their smaller neighbors and wrap themselves in the resulting debris. That debris consists of millions of stars, flying in formation---a "tidal stream" that can circle the larger galaxy for billions of years before gradually becoming part of it. These streams are extraordinarily faint and, until recently, have been virtually undetectable.

Using the Subaru and Keck II telescopes on the summit of Mauna Kea, Hawaii, the SPLASH ("Spectroscopic and Photometric Landscape of Andromeda's Stellar Halo") collaboration has discovered two new tidal streams in Andromeda, 60 to 100 kiloparsecs (200,000 to 300,000 light years) from the galaxy's center. Puragra Guhathakurta of the University of California at Santa Cruz, who leads the international project, says that Andromeda is an ideal test case for studying how large galaxies grow over time. "Our external vantage point gives us a global perspective, and yet it's close enough for us to obtain detailed measurements of individual stars," he says.

Far from being a bland dumping ground for the galaxy's oldest stars, Andromeda's halo is a colorful tangle of stellar populations stripped from different dwarf galaxies, each with its own story of star formation and chemical evolution. The SPLASH observations add to a growing body of data that, in the coming decade, will lead to a complete rewrite of the history of galaxy halos.

*Impact:* Of the total personnel involved in this project, 4 of the 7 undergraduates, 8 of the 16 graduate students, and 2 of the 8 postdocs, and 5 of the approximately 20 faculty/senior researchers are women. Two graduate students are minority women who have overcome substantial personal and/or family obstacles. Three of the undergraduates are Hispanic, one is a native Hawaiian. Two junior personnel were recipients of the Hubble postdoctoral fellowships offered by NASA/STScI, and subsequently obtained positions at STScI and Yale. An undergraduate from Univ of Hawaii Hilo and a Masters student from Fisk University (both minority women) secured summer internships at the NSF-funded Center for Adaptive Optics at UCSC. Two PIs on this collaborative research program, one female, received NSF CAREER grants.

*Significance:* This project is revealing, in unprecedented detail, a view of the structures and compositions of the first galactic halo outside of our own Galaxy. Comparison with the Milky Way will lead to a greater understanding of the formation of both galaxies, as well as galaxy evolution in general.

***NSF Award Numbers:***  
**0607852**

**Award Title: Collaborative Research: The Assembly History of the Andromeda Spiral Galaxy**  
**PI: Puragra Guhathakurta Institution Name: University of California-Santa Cruz**

### **Astronomical Numbers**

*Outcome:* Dr. Stan Woosley and his colleagues at the University of California Santa Cruz, have put together a large "Beowulf" cluster of computers with over 800 fast individual computer "cores" and over 1-1/2 Terabytes of memory (a Terabyte is 1,000 Gigabytes). The computer purchase was funded by the NSF's Major Research Instrumentation (MRI) program through the Division of Astronomical Sciences. Dr. Woosley and collaborators have used this computing laboratory to investigate important problems in (1) High Energy Astrophysics (e.g. what happens when stars explode); (2) Cosmology (modeling the dark matter haloes of galaxies and also making a detailed model of the outer part of our own Milky Way Galaxy); and (3) Planetary Sciences and our Sun (convection layers inside our sun; interactions and collisions among objects in our solar system).

*Impact:* In addition to allowing the development of sophisticated and advanced computer code that will address problems of interest through the astronomical community, the team will involve and train graduate students and postdocs in the techniques of sophisticated supercomputer modeling.

*Significance:* This new computer cluster provides the necessary supercomputing resources to study over ten major grand-challenge problems in astrophysics, planetary science, and telescope instrument design. The science and engineering it enables will make significant contributions to the field of astronomy.

***NSF Award Numbers:***

**0521566**

**Award Title: Acquisition of Beowulf Cluster for a Center for Computational Astrophysics at the University of California, Santa Cruz**

**PI: Stanford Woosley**

**Institution Name: University of California-Santa Cruz**

**PAARE: The Fisk-Vanderbilt Masters-to-PhD Bridge program**

*Outcome:* Ms. Fabienne Bastien, a student in the bridge program, is the first author of a discovery presented in the *Astrophysical Journal* that the young eruptive star V1647 Orionis is ringing like a bell due to a recent episode of massive accretion from its protoplanetary disk. The star, with an age of just one million years, is an example of a newly formed star similar to our Sun very early in its evolution. The star is ringed by a disk of gas and dust from which planets may eventually form. The material in this protoplanetary disk normally spirals in onto the star, like water going down a drain. However, like a river held back by a dam, the material can be held back from falling onto the star by the star's strong magnetic field. Occasionally, dammed-up material builds to a critical mass and crashes violently onto the star, leading to a dramatic brightening of the star which has been observed in V1647 Orionis at least twice in the past few years, once in 2003 and again in 2009. The high cadence measurements of the star's brightness variations during these two eruptions, obtained with the 0.9m telescope at NSF's Kitt Peak National Observatory and the 1.0m telescope at NSF's Cerro Tololo Interamerican Observatory, reveal that the star began to "ring like a bell", oscillating with a period of 3.1 hours. Like a bell or tuning fork vibrating at its "fundamental frequency", the detected period of the star's oscillation is consistent with the value found by theoretical calculation.

*Impact:* The Fisk-Vanderbilt Masters-to-PhD Bridge program was established in 2004 with support of a CAREER award to Prof. Keivan Stassun and continues with another CAREER award to Prof. Kelly Holley-Bockelmann. This is a unique collaboration between Fisk and Vanderbilt universities that is poised to become the nation's top source of Ph.D.s in physics and astronomy awarded to underrepresented minorities. In just five years the program has attracted 31 underrepresented minority students, 60 percent of whom are women, and has become the nation's top producer of blacks earning master's degrees in physics. Each year for the past seven years, U.S. universities have awarded an average of 333 master's degrees in physics, astronomy and astrophysics to women and underrepresented ethnic minorities and 25 Ph.D.s in astronomy and astrophysics. That averages out to one woman or minority Ph.D. degree every two years for the 53 institutions that grant these degrees. For underrepresented ethnic minorities alone, the average is one Ph.D. every 10 years. Since 2006 Fisk University has awarded about a third of the nation's African American masters in physics. Such small numbers mean that a single program, like the Bridge Program, can have a significant impact. Ms. Bastien, lead author of the above study of V1647 Orionis, has been honored with selection to attend the upcoming Lindau Meeting of Nobel Laureates.

*Significance:* This innovative program is funded through the Partnerships in Astronomy & Astrophysics Research and Education (PAARE) program. This is a program that has the goal of broadening participation in cutting-edge astronomical research.

***NSF Award Numbers:***

**0849736**

**Award Title: Graduate Opportunities at Fisk in Astronomy and Astrophysics Research (GO-FAAR)**

**PI: Keivan Stassun**

**Institution Name: Fisk University**

**B2: Outcomes in the area of Learning**

**Undergraduate Student Research Activities**

**Andromeda Galaxy Cloaked in Debris of Shredded Companions**

*Outcome:* It's the most distant object visible to the unaided eye. But the Andromeda Galaxy is also a prime target for some of the world's largest telescopes. An NSF-supported project to map the outer reaches of our Milky Way's big sister is revealing the remains of demolished stellar systems and allowing researchers to probe Andromeda's memory of its own growth.

Massive galaxies have the ability to gravitationally shred their smaller neighbors and wrap themselves in the resulting debris. That debris consists of millions of stars, flying in formation---a "tidal stream" that can circle the larger galaxy for billions of years before gradually becoming part of it. These streams are extraordinarily faint and, until recently, have been virtually undetectable.

Using the Subaru and Keck II telescopes on the summit of Mauna Kea, Hawaii, the SPLASH ("Spectroscopic and Photometric Landscape of Andromeda's Stellar Halo") collaboration has discovered two new tidal streams in Andromeda, 60 to 100 kiloparsecs (200,000 to 300,000 light years) from the galaxy's center. Puragra Guhathakurta of the University of California at Santa Cruz, who leads the international project, says that Andromeda is an ideal test case for studying how large galaxies grow over time. "Our external vantage point gives us a global perspective, and yet it's close enough for us to obtain detailed measurements of individual stars," he says.

Far from being a bland dumping ground for the galaxy's oldest stars, Andromeda's halo is a colorful tangle of stellar populations stripped from different dwarf galaxies, each with its own story of star formation and chemical evolution. The SPLASH observations add to a growing body of data that, in the coming decade, will lead to a complete rewrite of the history of galaxy halos.

*Impact:* Of the total personnel involved in this project, 4 of the 7 undergraduates, 8 of the 16 graduate students, and 2 of the 8 postdocs, and 5 of the approximately 20 faculty/senior researchers are women. Two graduate students are minority women who have overcome substantial personal and/or family obstacles. Three of the undergraduates are Hispanic, one is a native Hawaiian. Two junior personnel were recipients of the Hubble postdoctoral fellowships offered by NASA/STScI, and subsequently obtained positions at STScI and Yale. An undergraduate from Univ of Hawaii Hilo and a Masters student from Fisk University (both minority women) secured summer internships at the NSF-funded Center for Adaptive Optics at UCSC. Two PIs on this collaborative research program, one female, received NSF CAREER grants.

*Significance:* This project is revealing, in unprecedented detail, a view of the structures and compositions of the first galactic halo outside of our own Galaxy. Comparison with the Milky Way will lead to a greater understanding of the formation of both galaxies, as well as galaxy evolution in general.

**NSF Award Numbers:**

**0607852**

**Award Title: Collaborative Research: The Assembly History of the Andromeda Spiral Galaxy**

**PI: Puragra Guhathakurta**

**Institution Name: University of California-Santa Cruz**

**0607377**

**Award Title: Collaborative Research: The Assembly History of the Andromeda Spiral Galaxy**

**PI: James Bullock**

**Institution Name: University of California-Irvine**

**0607630**

**Award Title: Collaborative Research: The Assembly History of the Andromeda Spiral Galaxy**

**PI: Kathryn Johnston**

**Institution Name: Wesleyan University**

**Astronomy REU Students Delve Into Antarctic Meteorites**

*Outcome:* Every year meteorites are recovered from the blue ice sheets of Antarctica. On a poor year there may be 200. On a good year there may be over 1000. Over 20,000 total have now been recovered, with collection funded by NSF, sample curation handled by NASA, and the Smithsonian ultimately adding them to its collections. Why so many, and how come they are there, is basically understood. They fall off the ice sheets that carry them either to the sea or to the mountains. At the mountains their path is blocked, and the ice yields its meteorites as the ice evaporates and ablates.

So what can be learned from this treasure chest of solar system materials? Lunar meteorites and Martian meteorites have been identified among them – making meteorites the “poor man’s space probes” - and primitive solar system condensates have been discovered that provide a wealth of details about the early solar system. But of their histories, little is known. For 14 years NSF funded the systematic measurement of thermoluminescence levels (TL) of Antarctic meteorites, literally the light emitted when they were heated in the dark. The phenomenon is well known to archeological pottery dating and to health physics where we need to monitor radiation exposure in the laboratory. The intensity of the TL, when suitably calibrated, provides a measure of radiation exposure, and if dose rate can be estimated, the measurement can provide an estimate of age.

Christina Ragland and Jordan Yozzo, two REU students supported by the Division of Astronomical Sciences, recently measured the natural TL levels of 40 Antarctic meteorites and they looked at the 14-year database and came up with new insights into their history. Christina is a biochemistry major at the University of Arkansas, and Jordan is a geology major at the University of Tulsa. They were part of the REU program in astronomy, space, and planetary science at the Arkansas Center for Space and Planetary Science at the University of Arkansas. Their work was recently submitted to the journal *Meteoritics and Planetary Science*.

Christina and Jordan compared the TL data with the level of  $^{26}\text{Al}$  (radioactive aluminum) activity, which was measured as part of a smaller systematic study of returned Antarctic meteorites by researchers at Battelle Northwest. By comparing data obtained in the two laboratories, including the measurements they made in a hectic summer, Christina and Jordan were able to deduce information on the orbits of the meteorites when they encountered the Earth and the time since the meteorites fell to Earth. It is a complicated deduction, but the breakthrough was when it was realized that the natural TL of a group of meteorites thought to have passed close to the Sun, say within 0.6 AU, was decaying more rapidly than “normal” meteorites which had an orbit that kept them at about 1 AU from the Sun. (An astronomical unit, AU, is the average distance between Earth and the Sun.)

*Impact:* REU programs naturally broaden participation and almost by definition produce broad impacts in science due to the fact that students are doing most, if not all, of the research for each program. A large part of this comes from the built-in teaching and mentoring component in every REU program.

*Significance:* The study of meteorites is in many ways a proxy for studying the Earth. By researching the composition and age of these “poor man’s space probes” we can learn about the conditions present when our home planet formed. We can also learn about the differences and similarities between Earth and the other rocky bodies in the solar system. This type of research has a real multi-disciplinary aspect to it since the students are working at the interface of astronomy, polar research, and chemistry.

***NSF Award Numbers:***

**0851150**

**Award Title: REU site: Interdisciplinary Research Experiences in the Astronomical, Space and Planetary Sciences**

**PI: Julia Kenefick**

**Institution Name: University of Arkansas**

**B3: Outcomes in the Research Infrastructure**

The AST Division allocates 56% of its annual budget to the operation and maintenance of facilities. The staffs of the national facilities represent a valuable investment and continue to provide excellent service to the community and be scientifically highly productive. A selection of scientific and facilities-related highlights is provided below.

**National Optical Astronomy Observatories (NOAO)**

**Casting of Primary Mirror for the Advanced Technology Solar Telescope**

*Outcome:* When it becomes operational in 2018, the Advanced Technology Solar Telescope will give solar scientists the most detailed images of the sun ever taken. The telescope will shed new light on the processes that drive solar activity and the creation, interaction, and annihilation of magnetic fields in the solar atmosphere.

*Impact:* The ATST will be the first large US solar telescope accessible to the worldwide solar physics community to be constructed in more than 30 years. With a light grasp more than seven times greater than any existing instrument, and an angular resolution of better than 0.03 arc-seconds, it will allow researchers to resolve features of about 20-30 kilometers in size on the Sun, to provide unprecedented observations of solar plasma processes and magnetic fields.

*Significance:* The ATST’s primary mirror will have a diameter of 4.2 meters (165 inches). The ability of a telescope to discern detail is proportional to the diameter of the primary light-collecting element. The ATST primary will be a factor of more than 2.5 larger than the collecting optic of any solar telescope worldwide. There are a number of technical challenges that this optic must overcome:

1. It will be an off-axis mirror. The polishing of this mirror to its off-axis paraboloidal shape will be more complex than for a typical on-axis primary mirror.
2. The incident solar energy on the primary will be approximately 20 kilowatts. While most of this energy will be reflected, the mirror will be heated and will be actively cooled.

The second of these challenges requires that the mirror be constructed of a material that has a very low coefficient of thermal expansion (CTE). That is, it must not change its size when heated or cooled. Since it is difficult to ensure uniform cooling of the mirror, a material with a non-negligible CTE would change its shape when in use and would distort the images that the telescope produces.

Of the possible zero-expansion materials that can be cast in the requisite size, the project has chosen Zerodur (TM), a glass-ceramic fabricated by the German firm SCHOTT AG. The ATST primary mirror blank was successfully cast at the SCHOTT facility in Mainz, Germany in September of 2010. In October 2010, the still-hot blank was placed in an annealing oven where it will be slowly cooled over a three month period.

Following fabrication of the primary blank, it will be shipped to a polishing facility for the grinding and polishing of the final optical surface. The final shape of the mirror will be accurate to less than a millionth of an inch.

***NSF Award Numbers:***

**1011851**

**Award Title: Advanced Technology Solar Telescope (ATST) Construction under the Major Research Equipment and Facilities Construction (MREFC) Account**

**PI: Stephen Keil**

**Institution Name: AURA/National Optical Astronomy Observatories**

**The Hunt for Dark Energy**

*Outcome:* An extra-sensitive 570 megapixel camera designed to detect red-shifted light in a hunt for dark energy will be installed at the southern sky facility Cerro Tololo Inter-American Observatory (CTIO) in Chile. CTIO is operated for NSF by the National Optical Astronomy Observatory (NOAO).

*Impact:* The development of the camera and the wide-field survey of the sky aid the development of special software programs and computing systems that can handle very large amounts of data. The development of the camera has created one of the largest lenses ever made and one of the most sensitive set of CCD detectors. This has applications for a wide-variety of scientific and medical instruments.

*Significance:* More than 120 scientists from 23 institutions in the United States, Brazil, Spain, Germany and the United Kingdom are working on the project. A team of scientists and engineers from NOAO, Lawrence Berkeley National Lab and Fermilab are nearly finished with the construction of a special camera that will aid in understanding dark energy-the force that pulls groups of galaxies apart at ever faster speeds. The red-sensitive, wide-field camera is designed to image 300 million galaxies in the southern sky using the Blanco 4-meter telescope at CTIO. It will generate large amounts of publicly available data that can be used in nearly every field of astronomy.

***NSF Award Numbers:***

**0950945**

**Award Title: Management and Operations of the National Optical Astronomy Observatory**

**PI: William Smith**

**Institution Name: AURA/National Optical Astronomy Observatories**

**0809409**

**Award Title: Management, Operations, and Associated Projects for the National Optical Astronomy Observatory**

**PI: William Smith**

**Institution Name: AURA/National Optical Astronomy Observatories**

**White Dwarf Binary Star System**

*Outcome:* For the first time, astronomers have identified two different kinds of white dwarf stars in an eclipsing binary system.

*Impact:* Finding this very unusual system allowed for the first time a direct measurement of the radius of a rare type of white dwarf star that is composed of pure helium.

*Significance:* Stars end their lives in many ways. White dwarf stars are the very dense remnants of stars like the sun after they have exhausted their nuclear fuel. At this point they are about the size of the Earth. What remains is the dense inner core of the original star, typically made of carbon and oxygen. The formation of a binary system of two white dwarf stars is unusual.

One of the stars in this newly discovered binary system is a relatively rare helium-core white dwarf with a mass of only 10 to 20 percent that of the sun. Theoretical work predicted that these stars burn hotter and are larger than ordinary white dwarfs. Until now, their size had never been measured. Observations of the star NLTT 11748 by National Optical Astronomy Observatory (an NSF-funded FFRDC) astronomer Steve Howell working with a astronomers from University of California Santa Barbara has yielded the first direct radius measurement of this unusual white dwarf and confirms the theory of these objects.

The other star in the binary star system is a more ordinary white dwarf, composed of mostly carbon and oxygen. It has about 70 percent of the mass of the sun. This “ordinary” white dwarf star is more massive and also much smaller than the other white dwarf.

***NSF Award Numbers:***

**0950945**

**Award Title: Management and Operations of the National Optical Astronomy Observatory**

**PI: William Smith**

**Institution Name: AURA/National Optical Astronomy Observatories**

**0809409**

**Award Title: Management, Operations, and Associated Projects for the National Optical Astronomy Observatory**

**PI: William Smith**

**Institution Name: AURA/National Optical Astronomy Observatories**

**Binary Black Holes**

*Outcome:* Finding a needle in a haystack might be easy compared to finding two very similar black holes closely orbiting each other in a distant galaxy. Astronomers from the National Optical Astronomy Observatory (NOAO) in Tucson have found what looks like two massive black holes orbiting each other in the center of one galaxy. It has been postulated that twin black holes might exist, but it took an innovative, systematic search to find such a rare pair.

The newly identified black holes appear to be separated by only a tenth of a parsec - less than a tenth of the distance from Earth to the nearest star. This discovery of the most plausible binary black hole candidate ever found may lead to a greater understanding of how massive black holes form and evolve at the center of galaxies, and was published in the journal *Nature* in March 2009.

The signature of a black hole in a galaxy has been known for many years. The material falling into a black hole emits light in narrow wavelength regions forming emission lines which can be seen when the light is dispersed into a spectrum. These emission lines carry the information about the speed and direction of the black hole and the material falling into it. If two black holes are present, they would orbit each other before merging and would have a characteristic dual signature in their emission lines. This signature has now been found.

Former NOAO Director Todd Boroson and NOAO Astronomer Tod Lauer used data from the Sloan Digital Sky Survey, a 2.5-meter diameter telescope at Apache Point in southern New Mexico, to look for this



characteristic dual black hole signature among 17,500 quasars discovered by the survey. More than 100,000 quasars are known, with most being found in the Sloan Digital Sky Survey and at distances that are billions of light-years away.

*Impacts:* These results are of significant interest to the physics and astronomy communities, and have been widely publicized in magazines like *Discover* and *Scientific American*.

*Significance:* This study provides convincing observational evidence for the existence of binary black holes and will help us understand how black holes are formed and how they evolve.

***NSF Award Numbers:***

**0244680**

**Award Title: Cooperative Agreement for the Management, Operation and the Maintenance of the National Optical Astronomy Observatories (NOAO)**

**PI: William Smith**

**Institution Name: AURA/National Optical Astronomy Observatories**

**Gemini Observatory**

**The First Images of an ‘Exo-Solar System’**

*Outcome:* Astronomers using the Gemini North telescope and W.M. Keck Observatory on Hawaii’s Mauna Kea have obtained the first-ever direct images identifying a multi-planet system around a normal star.

The Gemini images allowed the international team to make the initial discovery of two of the planets in the confirmed planetary system with data obtained on October 17, 2007. Then, on October 25, 2007, and in the summer of 2008, the team, led by Christian Marois of the National Research Council of Canada’s Herzberg Institute of Astrophysics (Victoria B.C., Canada) and members from the U.S. and U.K., confirmed this discovery and found a third planet orbiting even closer to the star with images obtained at the Keck II telescope. In both cases, adaptive optics technology was used to correct in real-time for atmospheric blurring to obtain these historic infrared images of an extra-solar multiple-planet system.

According Dr. Marois, this discovery is the first time we have directly imaged a family of planets around a normal star outside of our solar system.

The host star (a young, massive star called HR 8799) is about 130 light years away from Earth. Comparison of data taken at different epochs show that the three planets are all moving with, and orbiting around, the star, proving that they are associated with it rather than just being unrelated background objects coincidentally aligned in the image. The planets, which formed about sixty million years ago, are young enough that they are still glowing from heat released as they contracted. Analysis of the brightness and colors of the objects (at multiple wavelengths) shows that these objects are about seven and ten times the mass of Jupiter. As in our solar system, these giant planets orbit in the outer regions of this system - at roughly 25, 40, and 70 times the Earth-Sun separation. The furthest planet orbits just inside a disk of dusty debris, similar to that produced by the comets of the Kuiper Belt objects of our solar system (just beyond the orbit of Neptune at 30 times the Earth-Sun distance). In some ways, this planetary system seems to be a scaled-up version of our solar system orbiting a larger and brighter star.

The parent star HR 8799 has about 1.5 times the mass of the Sun and is 5 times more luminous but is significantly younger. Infrared observations by satellites have shown evidence for a massive disk of cold dust orbiting the star. According to Benjamin Zuckerman (a UCLA professor of physics and astronomy in the Physics & Astronomy Dept. and a co-author on the paper) who has been studying dust disks orbiting nearby stars for decades, “HR 8799’s dust disk stands out as one of the most massive in orbit around any star within 300 light years of Earth.”

*Impact:* This will prove to be a historic investigation and the images result may appear in every new astronomy textbook.

*Significance:* This is the first system of exo-planets ever imaged. Nearly all of the 300+ known exoplanets have been discovered by spectroscopic means.

***NSF Award Numbers:***

**0647970**

**Award Title: Management and Operations of the Gemini Observatory**

**PI: William Smith**

**Institution Name: AURA/National Optical Astronomy Observatories**

### **National Solar Observatory**

#### **Predicting Solar Storms**

*Outcome:* A team of scientists have used archived data from the NSF's National Solar Observatory (NSO) Global Oscillations Network Group (GONG) to devise what may be a more accurate way to predict solar storms.

*Impact:* Solar storms (flares and coronal mass ejections) can spew billions of tons of ionized gas into inter-planetary space at high speeds. If the matter is directed towards the Earth, it can wreak havoc on terrestrial communications and power systems and present dangers to astronauts in space and air travelers at high elevation. A better means to predict such outbursts would provide precious time for preparation of their arrival.

*Significance:* Solar active regions do a sort of twist that may lead to accurate, timely predictions of solar flares few days in advance. Using the Global Oscillation Network Group (GONG), a chain of six stations around the world, NSO's Frank Hill, Irene Gonzalez-Hernandez, and Rudi Komm found that hot gas flowing from the interior of the Sun to the surface induces a subsurface vorticity pattern, akin to a whirlpool. GONG measures oscillations in the solar surface through the red and blue shift of light as gas parcels rise and fall at the solar surface. The flow of hot gas from the interior naturally means a flow of cold gas must return to the interior, especially as massive, intense bundles of magnetic field lines are pushed from the interior. The collision between flows pushes part of the gas sideways into other material, and sets up two immense donuts of hot gas, like two smoke rings swirling atop each other. The structures are on the order of 16,000 km deep (about a third more than the diameter of Earth) and 180,000 km wide (about 14 times Earth's diameter). The GONG team is studying how to translate their findings into a prediction mechanism and a better understanding of the "smoke ring" mechanism. Other areas of study by the GONG team include details of the meridional flow, a conveyor belt the moves from the equator to high latitudes and then descends to the solar interior, and other features related to the 11-year sunspot and solar activity cycle.

***NSF Award Numbers:***

**0950946**

**Award Title: Management and Operations of the National Solar Observatory**

**PI: William Smith**

**Institution Name: AURA/National Optical Astronomy Observatories**

### **NAIC Arecibo Observatory**

#### **Citizen Scientists Discover Rotating Pulsar**

*Outcome:* Idle computers are the astronomers' playground: Three citizen scientists—an American couple and a German--have discovered a new radio pulsar hidden in data gathered by the Arecibo Observatory. This is the first deep-space discovery by Einstein@Home, which uses donated time from the home and office computers

of 250,000 volunteers from 192 different countries. This is the first genuine astronomical discovery by a public volunteer distributed computing project.

*Impact:* The discovery highlights the importance of citizen science, as well as the partnerships and discoveries that arise when scientific data are shared. The new pulsar--called PSR J2007+2722--is a neutron star, rotating 41 times per second, that is located approximately 17,000 light years from Earth. Unlike most other pulsars that spin as quickly and steadily, PSR J2007+2722 sits alone in space, and has no orbiting companion star. Astronomers consider it especially interesting since it is likely a recycled pulsar that lost its companion. However they cannot rule out that it may be a young pulsar born with an lower-than-usual magnetic field.

*Significance:* Chris and Helen Colvin, of Ames, Iowa, and Daniel Gebhardt, of Universität Mainz, Musikinformatik, Germany, are credited with this discovery. Their computers, along with half a million others from around the world, are harnessed to analyze data for Einstein@Home (volunteers contribute about two computers each). Starting in March of 2009, Einstein@Home also began searching for signals from radio pulsars in astronomical observations from the Arecibo Observatory in Puerto Rico. Arecibo, a National Science Foundation (NSF) facility operated by Cornell University, is the world's largest and most sensitive radio telescope. About one-third of Einstein@Home's computing capacity is used to search Arecibo data.

***NSF Award Numbers:***

**0431904**

**Award Title: Management and Operation of the National Astronomy and Inosphere Center (NAIC), Arecibo Observatory (AO) 2005-2010**

**PI: Donald Campbell**

**Institution Name: Cornell University**

**PI: Robert Brown**

**Institution Name: Cornell University**

**0630534**

**Award Title: AST Cooperative Support Agreement PY 2006**

**PI: Donald Campbell**

**Institution Name: Cornell University**

**PI: Robert Brown**

**Institution Name: Cornell University**

**NRAO ALMA**

**ALMA Prepares for Science Observations**

*Outcome:* ALMA antennas and other equipment continued to be delivered at a steady pace to the operating site in Northern Chile. A total of 33 antennas, including 17 from Vertex RSI, the North American antenna vendor, and one half of the full complement, are at the ALMA site in various stages of assembly and test. Nine antennas have been transported to the 16,500 ft high altitude site and are obtaining commissioning data.

Following a series of operational readiness reviews in 2010, ALMA was declared ready to begin science observing, initially with a subset of the antenna array, frequency bands and operational capabilities. The first science observations are planned for September 2011.

*Impact:* The North American ALMA Science Center (NAASC), the gateway to the ALMA Observatory in the U.S., will hold schools, workshops and courses in the techniques and science of (sub)millimeter astronomy and support student and postdoctoral fellowship programs. The NAASC will implement an aggressive Education and Public Outreach program to communicate the excitement of ALMA to the astronomy community and general public.

*Significance:* Under construction since 2002, ALMA is a partnership between North America and Europe to each construct 25 antennas of 12 m diameter, with an additional four 12m and twelve 7m antennas provided by Japan. Processing the signal from each antenna with that measured by every other antenna allows a radio image of the sky to be constructed in a process called interferometry that has angular resolution equivalent to a single dish the size of the entire array.

ALMA will be the preeminent facility of sub-mm and mm wavelength radio astronomy for the US and international community. The dramatically improved angular resolution and sensitivity over existing facilities will enable ALMA to open up the sub-mm/mm wavelength regime to a wide range of astronomical objects and their researchers.

***NSF Award Numbers:***

**0244577**

**Award Title: Atacama Large Millimeter Array (ALMA)**

**PI: Riccardo Giacconi**

**Institution Name: Associated Universities Inc/National Radio Astronomy Observatory**

**1007566**

**Award Title: Operations and Maintenance of the Atacama Large Millimeter Array (ALMA)**

**PI: Ethan Schreier**

**Institution Name: Associated Universities Inc/National Radio Astronomy Observatory**

**NRAO Green Bank Telescope**

**Astronomers Discover Most Massive Neutron Star Yet Known**

*Outcome:* Astronomers using the National Science Foundation's Green Bank Telescope (GBT) have discovered the most massive neutron star yet found, a discovery with strong and wide-ranging impacts across several fields of physics and astrophysics.

*Impact:* The most massive neutron stars previously known have masses of roughly one and a half times the mass of the Sun. Instead, the new observations revealed a neutron star twice as massive as the Sun. That much mass changes our understanding of a neutron star's composition. Some theoretical models postulated that, in addition to neutrons, such stars also would contain certain other exotic subatomic particles called hyperons or condensates of kaons. The new results rule out those ideas. If any quarks are present in a neutron star core, they cannot be "free," but rather must be strongly interacting with each other as they do in normal atomic nuclei. There remain several viable hypotheses for the internal composition of neutron stars, but the new results put limits on those, as well as on the maximum possible density of cold matter.

*Significance:* Neutron stars are the superdense "corpses" of massive stars that have exploded as supernovae. With all their mass packed into a sphere the size of a small city, their protons and electrons are crushed together into neutrons. A neutron star can be several times more dense than an atomic nucleus, and a thimbleful of neutron-star material would weigh more than 500 million tons. This tremendous density makes neutron stars an ideal natural "laboratory" for studying the most dense and exotic states of matter known to physics.

The scientists used an effect of Albert Einstein's theory of General Relativity to measure the mass of the neutron star and its orbiting companion, a white dwarf star. The neutron star is a pulsar, emitting lighthouse-like beams of radio waves that sweep through space as it rotates. This pulsar, called PSR J1614-2230, spins 317 times per second, and the companion completes an orbit in just under nine days. The pair, some 3,000 light-years distant, are in an orbit seen almost exactly edge-on from Earth. That orientation was the key to making the mass measurement.

As the orbit carries the white dwarf directly in front of the pulsar, the radio waves from the pulsar that reach Earth must travel very close to the white dwarf. This close passage causes them to be delayed in their arrival by the distortion of spacetime produced by the white dwarf's gravitation. This effect, called the Shapiro Delay, allowed the scientists to precisely measure the masses of both stars.

**NSF Award Numbers:**

**0956545**

**Award Title: Management and Operations of the National Radio Astronomy Observatory**

**PI: Ethan Schreier**

**Institution Name: Associated Universities Inc/National Radio Astronomy Observatory**

### **NRAO Very Long Baseline Array**

#### **First Direct Distance Measurement to a Galaxy in the Hubble Flow**

*Outcome:* The NRAO Megamaser Cosmology Project has directly measured the distance to a faraway galaxy, providing a valuable yardstick for calibrating large astronomical distances and demonstrating a vital method that could help determine the nature of the mysterious Dark Energy that pervades the Universe. James A. Braatz III and his colleagues employed the Very Long Baseline Array (VLBA), the Robert C. Byrd Green Bank Telescope (GBT), and the Effelsberg Radio Telescope in Germany to determine that the galaxy UGC 3789 is 160 million light years from Earth. They precisely measured both the linear and angular size of a disk of material orbiting the galaxy's central black hole. Water molecules in the disk act as masers to amplify radio waves the way lasers amplify light waves.

The observation is part of a major effort to measure the expansion rate of the Universe, the Hubble Constant, with greatly improved precision, and thus constrain the nature of Dark Energy. The new measurement demonstrates a one-step, geometric technique for establishing distances to galaxies far enough away to infer the expansion rate of the Universe. The work on UGC 3789 follows an earlier landmark measure done with the VLBA in which the distance to the galaxy NGC 4258 was directly measured by observing water masers in a disk of material orbiting its central black hole. The measurement to UGC 3789 adds a new milepost seven times more distant than NGC 4258, which is too close to measure the Hubble Constant directly.

The NRAO Megamaser Cosmology Project is using the GBT to search for other galaxies with similar water-molecule masers in disks orbiting their central black holes. As candidates are identified, the VLBA, the GBT, and the Effelsberg telescope engage in multi-year campaigns to image the galaxies and measure their rotational structure, as required for the distance measurements. UGC 3789 is the first galaxy in the program to yield such a precise distance.

*Impact:* The results will be broadly disseminated to other researchers in the field and to the general public.

*Significance:* This research is part of an effort to measure the expansion rate of the Universe with greatly improved precision. This work should constrain the nature of Dark Energy.

**NSF Award Numbers:**

**0226933**

**Award Title: NRAO Management, Operations and Maintenance**

**PI: Ethan Schreier**

**Institution Name: Associated Universities Inc/National Radio Astronomy Observatory**

### **University Radio Observatory: CARMA**

#### **Imaging Protoplanetary Disks with CARMA**

*Outcome:* When a star is "born", it is often surrounded by a rotating disk of gas and dust. These disks will likely form planetary systems analogous to our own Solar System. One of the main goals in astronomy today

is to understand how planets form in these disks. An important clue to understanding this process is to measure the location and amount of gas and dust. CARMA, the Combined Array for Research in Millimeter-wave Astronomy, is an observatory consisting of 23 radio dishes that work together as an interferometer to produce images of the sky at millimeter radio wavelengths.

CARMA has imaged the dust emission in 14 disks surrounding young stars. These stars formed only about one million years ago, and any planets in their disks are in the very early phases of development. These disks tend to be larger in size than our solar system, and contain enough material to form Jupiter-size planets. Interestingly, the disks have quite a variety of morphologies. In some disks, the dust is smoothly distributed, while in others, the dust is “missing” from the inner part of the disk close to the star. The differences in the morphology may reflect various stages of planet formation in these disks. (Work led by Laura Perez, Andrea Isella, and John Carpenter at Caltech).

*Impact:* Graduate students are active participants in this work and are thereby learning the techniques of millimeter wavelength astronomy. NSF’s new Atacama Large Millimeter/submillimeter Array (ALMA) observatory, currently under construction, will use very similar methods. Training the workforce for ALMA is an important goal of this program.

*Significance:* The work helps astronomers better understand the formation of planets around stars, and the origins of our own solar system.

***NSF Award Numbers:***

**0838260**

**Award Title: Collaborative Research: Astronomy with CARMA**

**PI: John Carpenter**

**Institution Name: California Institute of Technology**

**0838178**

**Award Title: Collaborative Research: Astronomy with CARMA**

**PI: Lee Mundy**

**Institution Name: University of Maryland College Park**

**Cyberinfrastructure**

**Black hole appearance refined**

*Outcome:* Black holes are at the basis of many models proposed to explain observations of astronomical objects. Theoretical calculations and, increasingly, numerical simulations, show that including black holes is often the only way to explain detailed observations and the complex behaviors they imply. Of course, since the black hole itself is a one-way trip from which nothing escapes, the photons that reach to distant observers are generated by infalling material before it gets swallowed, primarily from rotating accretion disks. High temperatures and intense radiation mean that most accretion disks contain highly ionized plasma, so studying accretion dynamics in detail requires not just complex fluid dynamics but also consideration of strong magnetic fields – magnetohydrodynamics (MHD). However, it takes special care to connect the dynamics of the inward flow of matter, which depends mostly on how rotational motion couples across the disk, moving angular momentum in and out, with the details of the emitted radiation, which depends much more on thermodynamics and the way that photons diffuse through the accreting material.

The present work started with an existing numerical approach, capable of conserving energy and radiation flux throughout while still being fully consistent with general relativity, but which worked only in the special two-dimensional case of axisymmetry (symmetric around the rotation axis of the spinning black hole). The technique was first extended to work properly in three spatial dimensions. It was critically important to use an energy-conserving algorithm in order to allow the energy dissipated in the course of relativistic accretion to be captured as heat. In addition, to make sure the geometric thickness of the simulated disk was explicitly

controlled by the simulation, the algorithm needed to include a cooling function for the optically thin regions (where light can escape), as well as a direct calculation of both the amplitude and location of the radiative cooling associated with the accretion stresses. Finally, a fully relativistic ray-tracing method, following light photons as they pass through the simulation, had to be developed to calculate the luminosity received by distant observers, and thus the appearance of the disk at a distance.

Now that the full physical situation can be properly modeled by simulation, it turns out that there is significant extra energy released, over and above that predicted by classical accretion theory, which necessarily had to include simplifications. However, much of this extra heat is released deep in the potential well closer to the black hole, where photon capture and gravitational redshifting strongly limit how much energy can escape. Thus, significant thermal and magnetic energy remains with the gas and is swallowed by the black hole. Thus, the final luminosity reaching a far-distant observer is only 6% greater than previously predicted: had the full dissipated energy been able to escape, it would have been 20% brighter. Interestingly, we see that a combination of effects working in opposite directions means that the over-simplified initial calculations were not that far off. Nevertheless, the ability to include more detailed, more realistic, physics in simulations of black hole accretion, and to make detailed predictions of accretion disk appearance, will be critical for continued work to understand these power sources, ubiquitous throughout astrophysics.

*Significance:* Including more comprehensive and more realistic physics in accretion studies provides more insight and more believable conclusions about the astrophysical objects these models explain.

*Impact:* Techniques developed for this visualization will aid many other fields trying to comprehend complex simulations through visual analytics.

***NSF Award Numbers:***

**0313031**

**Award Title: ITR-MHD Turbulence in Black Hole Accretion: A Testbed for Interactive Visualization of Large 3-D Datasets**

**PI: Julian Krolik**

**Institution Name: Johns Hopkins University**

PART C. OTHER TOPICS

**C.1. Please comment on any program areas in need of improvement or gaps (if any) within program areas.**

The COV identified no gaps in the scientific programs.

**C.2. Please provide comments as appropriate on the program's performance in meeting program-specific goals and objectives that are not covered by the above questions.**

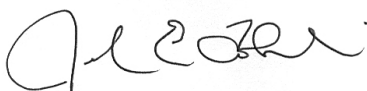
**C.3. Please identify agency-wide issues that should be addressed by NSF to help improve the program's performance.**

**C.4. Please provide comments on any other issues the COV feels are relevant.**

**C.5. NSF would appreciate your comments on how to improve the COV review process, format and report template.**

It would be helpful to provide more information in advance about the structure of the eJacket system, particularly for first-time members of a COV. This would ensure that the short time available to review individual eJackets would be most efficiently used during the COV meeting. It would also be helpful to have all relevant demographic information (regarding both proposers and reviewers) assembled before the meeting, given that there are standard questions the COV is asked each period regarding demographics.

**SIGNATURE BLOCK:**



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For the COV for the NFS/MPS Division of Astronomical Sciences  
Joel E. Tohline, Chair



## Commonly Used Acronyms

AAG	Astronomy & Astrophysics Research Grants Program
AAPF	Astronomy & Astrophysics Postdoctoral Fellowships
AAS	American Astronomical Society
ALMA	Atacama Large Millimeter Array
ARRA	American Recovery and Reinvestment Act
APS	American Physical Society
AST	Division of Astronomical Sciences
ATST	Advanced Technology Solar Telescope
AUI	Associated Universities Incorporated
AURA	Association of Universities for Research in Astronomy
CAREER	Faculty Early Career Development
COV	Committee Of Visitors
CTIO	Cerro Tololo Inter-American Observatory
D&D	Design and Development
DD	Division Director
EHR	Education and Human Resources
ELT	Extremely Large Telescope
EPFL	Ecole Polytechnique Fédérale de Lausanne
ESM	Electromagnetic Spectrum Management
EVLA	Expanded Very Large Array
EXC	Extragalactic Astronomy and Cosmology
FCC	Federal Communications Commission
FTE	Full Time Equivalent
GAL	Galactic Astronomy
GBT	Robert C. Byrd Green Bank Telescope
GONG	Global Oscillations Network Group
GSMT	Giant Segmented Mirror Telescope
GeMS	Gemini Multi-Conjugate Adaptive Optics System
IIP	Individual Investigator Programs
LASP	Laboratory for Atmospheric and Space Physics
LSST	Large Synoptic Survey Telescope
M&O	Maintenance and Operations
MCAO	Multi-Conjugate Adaptive Optics
MERLIN	Multi-Element Radio-Linked Interferometer Network
MPS	Mathematical and Physical Sciences
MREFC	Major Research Equipment and Facilities Construction
MSIP	Mid-Scale Innovations Program
NAIC	National Astronomy and Ionosphere Center
NASA	National Aeronautics and Space Administration
NOAO	National Optical Astronomy Observatories
NRAO	National Radio Astronomy Observatories
NSB	National Science Board
NSF	National Science Foundation
NSO	National Solar Observatory
PAARE	Partnerships in Astronomy & Astrophysics Research and Education
PI	Principal Investigator
PLA	Planetary Astronomy
PO	Program Officer
REU	Research Experience for Undergraduates
RFI	Radio Frequency Interference
SAA	Stellar Astronomy and Astrophysics

SKA	Square Kilometer Array
TSIP	Telescope System Instrumentation
URO	Universities Radio Observatories Program
VLA	Very Large Array
VLBA	Very Long Baseline Array

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<sup>i</sup> *New Worlds, New Horizons in Astronomy and Astrophysics*, Committee for a Decadal Survey in Astronomy and Astrophysics; National Research Council, The National Academies Press (2010), p. 240.

<sup>ii</sup> American Physical Society (APS) Guidelines for Professional Conduct, adopted 10 November 2002 [[http://www.aps.org/policy/statements/02\\_2.cfm](http://www.aps.org/policy/statements/02_2.cfm)]; and American Astronomical Society (AAS) *Ethics Statement*, adopted 8 January 2010 [[http://aas.org/about/ethics\\_statement](http://aas.org/about/ethics_statement)].

<sup>iii</sup> If “Not Applicable” please explain why in the “Comments” section.

<sup>iv</sup> If “Not Applicable” please explain why in the “Comments” section.

<sup>v</sup> If “Not Appropriate” please explain why in the “Comments” section.