Minutes of the Meeting of the
Astronomy and Astrophysics Advisory Committee
25-26 February 2019

Members attending:

Dieter Hartmann
John O'Meara (Chair)
Ian Dell'Antonio
Scott Dodelson
Eliza Kempton
Andrew Connolly
Constance Rockosi
Mansi Kasliwal
Shane Larson
Petrus Martens

Agency personnel:

Richard Green, NSF-AST
Diana Phan, NSF-AST
Chris Davis, NSF-AST
Elizabeth Pentecost, NSF-AST
Matt Benacquista, NSF-AST
Glen Langston, NSF-AST
Joseph Pesce, NSF-AST
Hans Krimm, NSF-AST
David Boboltz, NSF-AST
Ralph Gaume, NSF-AST
Edward Ajhar, NSF-AST
Luke Sollitt, NSF-AST
Harshal Gupta, NSF-AST
Peter Kurczynski, NSF-AST
Richard Barvainis, NSF-AST
Nigel Sharp, NSF-AST
Jonathan Williams, NSF-AST
Ashley Zauderer, NSF-AST
Allison Farrow, NSF-AST
Randy Phelps, NSF-OIA
Pedro Marronetti, NSF-PHY
Vladimir Papatashvili, NSF-Polar
R. Chris Smith, NSF-MPS OAD
James Whitmore, NSF-PHY
Jean Cottam Allen, NSF-PHY
Paul Hertz, NASA
Rita Sambruna, NASA
Hashima Hasan, NASA
Evan Scannapieco, NASA
Dominic Bedford, NASA
Valerie Connaughton, NASA
Kartik Sheth, NASA
Linda Sparke, NASA
Daniel Evans, NASA
Kathy Turner, DOE
Eric Linder, DOE

Others:

Fiona Harrison, Caltech
Robert Kennicutt, Univ. of Arizona
George Ricker, MIT
Klaus Honscheid, OSU
Adam Bolton, AURA/NOAO
Ashlee Wilkins, AAS
Lindsey Millken, Lewis-Burke
Jeremy Weirich, AURA
Steve Heathcote, NOAO/CTIO
James Lochner, USRA
John Karcz, NASA Ames
Bethany Johns, AIP
Jay Elias, NOAO
Karl Stapelfeldt, JPL
James Murday, USC
Rachel O'Connor
Abigail Sheffer
T. Osborne
David Williams
Joseph Schmitt
Nick Saab
Bill Latter
Greg Mack
Rebecca McNaughton
David Ardila

MEETING CONVENED 9:00 AM, 25 FEBRUARY 2018

The Chair called the meeting to order. Introductions were made.

The minutes from the September 20-21, 2018 and November 6, 2018 meetings were approved by the Committee.

Richard Green reviewed the rules, membership, and duties of the AAAC.

Agency Program Updates

NSF

Richard Green provided an update on AST activities. He presented a few science highlights:

- VLBI observations including the GBT showed that the compact radio source from a neutron star merger showed superluminal motion, consistent with a narrow-angle jet at later times with a viewing angle of ~20°; the sharp inflection in the 0.6-10 GHz light curve suggests an initial cocoon-dominated outflow followed by a jet breakout.
- The most compelling interpretation from ALMA's DSHARP imaging survey of 20 protoplanetary disks is that gas giants form more quickly than expected with some at large distances from host stars; disk perturbations observed in the dust density allow longer accretion growth time for planetesimals. Ten papers have been accepted for publication in ApJ Letters from this research.
- In 2017, using GNIRS on the Gemini telescope, SN2017 was discovered in NGC 6946; ten spectra were obtained over a period spanning 22 and 387 days after the discovery. CO and graphitic dust were clearly detected on Day 124. The CO mass is consistent with a 15 solar mass progenitor which provides clues about dust in the early Universe.

NSF, DOE, and NASA continue to work well together to support the priorities of the astronomy and astrophysics research community, both in collaboration on large managed projects and through coordination of diverse research programs. Current examples of NSF-NASA-DOE coordination include co-sponsorship of the Decadal Survey and joint FACA review panels (e.g. the AAAC). NSF and NASA are collaborating on the exoplanet research program at the WIYN 3.5m telescope; on space weather and solar research programs; on the search for techno-signatures; and on Near Earth Object detection and characterization (with Arecibo and, in the furture, LSST). Semi-annual joint NSF-NASA staff meetings are also being held. Current examples NSF collaboration with DOE include the Dark Energy Camera, Dark Energy Survey data management support, DESI, LSST, the CMB Task Force, and the Gemini-Blanco-SOAR subcommittee of the AAAC.

AST has a high demand in its individual investigator programs. At the same time AST supports a suite of optical/infrared, radio, and solar telescopes. DKIST and LSST construction is being funded through the MREFC line. AST is reorganizing its management of NSF's OIR facilities to optimize time-domain science. AST is also divesting facilities given lower priority by the external review process to accommodate operations of new facilities and to maintain programmatic balance. AST is sponsoring the National Academies decadal survey to set future priorities for scientific direction and facilities development.

The DKIST telescope mount assembly was completed in September 2018. The telescope optics are in place and nighttime alignment has been executed. Current challenges to the project are largely with instrument completion and delivery. The project is still on schedule and within budget contingency. LSST construction is progressing with operations to be begin in 2022.

The National Center for Optical-Infrared Astronomy (NCOA) will integrate the NSF-funded entities, NOAO, Gemini, and LSST operations, under a single organization framework, managed by one management organization. Subject to approval, NCOA initiation will be no later than October 2019 (LSST operations is on track for initial funding in FY2019). Critical milestones have been met with AURA submission of key documents.

There was a very positive outcome for AST in the 2018 budget, with $307M allocated, compared to the FY2017 actual of $252M. Much of the increase went to one-time specific projects (some are dependent on FY2019 availability of funds to complete). MSIP, multi-messenger astrophysics grants, forward funding for DKIST operations for timely completion of the data center, funding of DKIST Level 2 data products, and Center infrastructure upgrades were all supported.

The FY2019 PBR was a decrease from the FY2018 request, although the enacted appropriation increased the R&RA budget by 3%. The MREFC line re-incorporated Antarctic infrastructure and provided funding for DKIST and LSST at requested levels. The allocations for the directorates and divisions are in process and will be made public with the approved execution plan. The NSF bill was not under consideration for passage before the end of the fiscal year, so initial operations after October 1 were under a Continuing Resolution (with NSF operating at the FY18 level) until December 21. The major 35-day shutdown was a challenge for AST to keep the flow of funds to the facilities awardees; OMB allowed cash draws for previously allocated funding, unlike the 2013 shutdown. The FY2020 PBR will be released next month.

The FY2019 PBR allocated $30M each for *Windows on the Universe* and *Harnessing the Data Revolution* and $60M for mid-scale projects (all NSF Big Ideas). These programs will support the mix of ground-based data acquisition, development of systems and structures for end-user data science, and the theoretical modeling required for interpretation and prediction. Some solicitations and announcements are already appearing. These "off the top" investments in key future directions result in a ~8% reduction of core funding for AST in the PBR, given the flat top line request. However, astronomers are well positioned to compete and win a larger total of research support than a flat-funded core grants program.

NSF and DOE requested that the AAAC establish an ad hoc subcommittee to consider the scientific utility and US community priorities for the Gemini, Blanco, and SOAR telescopes for the next five years or so, as motivation for agency decisions prior to the Decadal Survey release. The panel examined a wide range of topics from precision cosmology through time domain/multi-messenger astronomy and exoplanets. A preliminary briefing was given to the AAAC last November and the final report will be given at this meeting.

Planning is now underway for input into the next Decadal Survey. NSF/AST and NASA's Astrophysics Division are the primary sponsors of the survey. DOE's Cosmic Frontier in the Office of Science is also a sponsor. NSF is including all ground-based astrophysics (i.e., gravitational wave detection and astro-particle detection) for project prioritization, not limited to AST. AST is supporting development of three major projects, two through activities in national centers, and one through a continuing series of grants; OPP/PHY will support a fourth. NRAO held a series of three Kavli-sponsored and one AUI-sponsored workshops to identify and prioritize the key scientific problems the RMS community would address in the coming decade; many of the scientific goals can be achieved with a concept called Next Generation VLA. NOAO is coordinating with the TMT and GMT projects to develop a community science case requiring time on both telescopes through the new US ELT Program. A new NSB report addresses how to handle lifecycle costs beyond the scope of individual Divisions. The report found that O&M costs for large facilities developed under MREFC can exceed the 'host' Division's capacity to absorb them fully. The NSB recommended Foundation-level ownership of the facilities portfolio with strategic ability to manage support.

Shane Larson asked what the impact of the government shutdown was on the science. Richard Green replied that the group that had the most adverse effect besides the division staff were the postdocs who are independent contractors; the funds are not sent to their host institutions but directly to them and they draw down on those funds and could not do so during the shutdown. This was one of the biggest challenges for the agency. There were also time-critical programs (e.g. AAP, REU) that had to be delayed.

NASA

Paul Hertz provided an update on NASA Astrophysics activities. Engineers and technicians continue critical environmental testing of JWST to prepare it for the rigors of launch.

Some science highlights were presented.

- Voyager 1 has left the heliosphere and has been detecting cosmic rays; it has set an improved upper limit on primodial black holes that contribute to dark matter.
- The New Horizons spacecraft flew by the Kuiper Belt object, Ultima Thule on January 1 within a few thousand kilometers of the surface (surface resolution ~100 meters). It observed smooth cratering of the object which supports some of the models for solar system formation and how bodies in the outer solar system formed.
- TESS is operating and is through half of its survey of the southern hemisphere; data from Sectors 1-5 show supernovae, numerous asteroids, variable stars of great variety, and some comets. During the shutdown, NASA continued to operate the spacecraft.

The partial government shutdown impacted all of NASA Science. The Science Mission Directorate came back from the 35-day shutdown with a focus foremost on supporting post docs, graduate students, and contractors. Due dates for proposals for the research program were shifted; reviews of proposals and grants were suspended and had to be re-scheduled. Processing and payment of funded grants were suspended temporarily and the Spring 2019 balloon campaign in New Zealand was cancelled.

NASA's Astrophysics program is led by strategic missions (in response to decadal surveys) and PI-led missions (Explorer missions) that are supported by research and technology (R&A, suborbitals, CubeSats, ISS). The FY2018 budget for Astrophysics was $1.38B which included mission development, mission operations(including GO), research and technology, and infrastructure and management. WFIRST and JWST have their own program offices within the Astrophysics Division.

The FY19 appropriation provides an increased level of funding for NASA Astrophysics. The total appropriated funding for FY19 (including JWST) is ~$1.496B, an increase of $112M (8%) from the FY18 appropriation. JWST was funded as requested at $305M, a request submitted before the 2018 replan. NASA's plans for accommodating JWST's increased budget requirements will be submitted as part of the FY20 budget request. WFIRST was funded at $312M; the proposed termination was not supported by Congressional appropriation. Hubble and SOFIA received appropriations above the requested levels. The R&A and Science Activation programs were specified at requested levels.

There has been a 26% increase in Research and Analysis (R&A) support since the last Decadal Survey and there is a notionally planned increase of ~28% over the next five years; this includes the CubeSat initiative. The Exoplanet Research Program (XRP) is included within ROSES-19; proposals will be selected jointly by all four divisions in SMD. NASA selected nine Astrophysics Science SmallSat studies in 2018 and will report out at a special session of the AAS meeting in June. A second SmallSat studies solicitation is planned for ROSES-19; NASA is considering holding a workshop later this year focused on technologies and commercial partners in advance of the solicitation.

The Theoretical and Computational Astrophysics Networks (TCAN) supports collaborative cross-institutional networks in theory and computation. The first call for proposals was in 2012 and a second call for proposals was issued in ROSES-2017 with a $1.5M allocation of funds. Proposals were due in January 2018 and selections were made in June; 3 proposals were selected. There has been more than 200% growth over the past six years in technology development funding with over $600M invested since the Decadal Survey. Investment in technologies for future large missions is steadily growing.

JWST is scheduled for launch in March 2021. Progress is being made on vibration and thermal vacuum testing of the repaired spacecraft element sunshield membrane cover assemblies. The science payload will be integrated with the SCE in fall 2019 to form the Observatory; there will be additional mission rehearsals at STScI.

NASA continues work on WFIRST which was funded in the FY19 appropriation ($312M). WFIRST remains on the plan approved at the beginning of Phase B. Significant flight hardware is in production and engineering work is in progress. NASA is proceeding in FY19 toward a Preliminary Design Review and toward Confirmation in FY20.

Kepler ended its mission in October 2018. Kepler has proven there are more planets than stars in our galaxy. SOFIA's 5-year prime mission will be completed at the end of FY19; there will be separate reviews of the maintenance and operations paradigm and of the science progress and prospects.

TESS launched in April 2018. The TESS sky survey is 25% complete with data having been downloaded for 7 of the 26 sectors planned for the two year primary mission. The first 5 TESS planets were announced at the January AAS meeting; since then at least 4 additional multi-planet systems have been established from the first three survey sectors. Ground-based radial velocity measurements to establish planet masses are in progress for more than 20 additional TESS small planet candidates; 38 selected GI investigations are underway.

NASA will hold a Senior Review in 2019. There will be three panels. These will review Hubble, Chandra, Fermi, NICER, NuSTAR, Swift, TESS, and XMM-Newton. The panels will meet and make their recommendations to the Senior Review Subcommittee, who in turn reports to the Astrophysics Advisory Committee, who in turn make formal recommendations to NASA.

The Astrophysics Division is planning for the next decadal survey. NASA has initiated studies for large (Flagship) and ten medium (Probe) sized mission concepts to inform the Decadal committee. NASA is sponsoring four community-based Science and Technology Definition Teams (STDTs) each partnered with a NASA Center-based engineering team to study large (strategic) mission concept studies selected from the NASA Astrophysics 30-year Visionary Roadmap, a community-based report, and the 2010 Decadal Survey. NASA is supporting 10 PI-led Study Teams for Probe-size mission concept studies, selected competitively and supporting several other planning activities, studies and white papers. NASA is investing in next-generation technologies, including ultrastable telescope technology, starshades, coronagraphs, x-ray mirrors, detectors, etc.

John O'Meara asked both Paul Hertz and Richard Green about the impact of the shutdown on the agency staff; are there staff leaving because this happens too often? Paul Hertz commented that there were staff (specifically aerospace engineers) at some of the centers who did not return after the shutdown; after the 2013 shutdown, there was a bump in the number of retirements but it is too early to tell if there is a bump this year. Richard Green indicated there were some natural changes in staff and AST were looking for several new staff; the shutdown was not good in this respect because it is hard to recruit if there is uncertainty.

Petrus Martens asked about the opportunities to analyze TESS, Kepler, and Gaia data. Paul Hertz indicated that scientists can propose through NASA's Data Analysis program to analyze publicly available data.

Dieter Hartman asked about the independent estimates for the large missions and the Probe missions as related to the Decadal Survey. Paul Hertz indicated that for the large missions, each of the missions is doing a cost assessment using the host NASA center's cost estimating tools; there will be cost and schedule experts on the review team who will review the quality of the cost estimates the project teams have done and whether it is defensible and believable at the level it was done. For the medium projects, NASA did not fund them to do their own cost estimates; they will submit with their notional architectures to NASA as part of the review; NASA will have half of the projects reviewed by the Goddard cost estimation center and the other half by the JPL cost estimation center. Those will be matched with the reports given to the Decadal Survey. Reports for the large missions will be sent to NASA in August with a submission to the Decadal Survey in September.

DOE

Kathy Turner gave an update on DOE activities. The DOE Office of High Energy Physics (HEP) fulfills its mission by building projects that enable discovery science, operate facilities that provide the capability for discoveries, and support a research program that produces discovery science. The 17 DOE laboratories comprise a preeminent federal research system, providing the Nation with strategic scientific and technological capabilities. Through ground-based telescopes and arrays, space missions, and deep underground detectors, research at the Cosmic Frontier aims to explore dark energy and dark matter, which together comprise ~95% of the universe. There is a strong interaction with theory, detector R&D, and computational HEP.

HEP receives advice from several advisory committees including the High Energy Physics Advisory Panel (HEPAP), which is jointly chartered by DOE and NSF to advise both agencies; subpanels such as P5 also provide advice. The AAAC advises DOE, NASA, and NSF on selected issues in astronomy and astrophysics of mutual interest and concern. Formal advice is also provided by the National Academies. There are also community studies such as Snowmass, the CMB-S4 Concept Design Team, the Gemini-Blanco-SOAR telescopes roles subpanel of the AAAC, and tri-agency groups for such projects as LSST, WFIRST, and Euclid. The earliest that a new "Snowmass" process could begin is 2020.

The P5 strategy continues to define the investment in the future of the field. DOE was funded for FY19 in September 2018 when the President signed into law a bipartisan minibus spending package. The FY19 enacted High Energy Physics (HEP) budget provided $980M that included funding for LSST, LHC, DESI, and LZ – an increase of $338.4M above the request. There was also strong support for research and operations funding. Profiles for high-priority projects recommended by P5 contiue to ramp up. The Cosmic Frontier FY19 budget of $101.04M provides funding for scientific research to carry out all phases of an experiment including design, fabrication, and commissioning; it provides funding for commissioning and operations of projects such as LSST, DESI, LZ, and SuperCDMS-SNOLAB; and it provides funding for all Cosmic Frontier projects.

For the Cosmic Frontier, the study of dark energy, dark matter, and cosmic microwave background are supported. DOE, NSF, and NASA partner with DOE on several projects including the Dark Energy Survey (DES), the fabrication of the LSST camera, DESI, and eBOSS. The search for dark matter is done through direct detection experiments over a wide mass range that include LZ, SuperCDMS-SNOLab, and ADMX-G2. The study of cosmic acceleration at energies near the Planck scale and neutrino properties through the cosmic microwave background (CMB) will be done with new generations of the South Pole experiment and next generation CMB.

The Office of Science has several funding opportunities include workforce development programs, science undergraduate laboratory internships, visiting faculty programs, and early career research programs. The 2016 HEP Committee of Visitors recommended that HEP develop a plan for increasing diversity in the programs it supports. HEP is participating with the Office of Science management to develop strategies for improving diversity in its research programs; HEP is participating in a new SC-wide diversity and inclusion working group and is working with the DOE national laboratories to monitor and encourage diversity and inclusion efforts throughs contracts, annual planning processes and budget briefings. HEP participates in workforce development for teachers and scientists programs.

Andrew Connelly asked how the agencies are going to respond to the White House's Executive Order on Artificial Intelligence (AI) and the data coming from all of the experiments. Kathy Turner indicated that HEP has been asked to collect information on publicly accessible data sets that can be used for AI projects and machine learning studies; considering the interest from the White House there could be an initiative in the future. DOE is only starting on this and has not been coordinating with the other agencies. Richard Green indicated that AST is waiting for direction from the NSF Director's office on this effort.

NSF-Physics Division

Jim Whitmore provided an update on activities in the Physics Division.

The experimental particle astrophysics program supports university research that uses astrophysical sources and particle physics techniques to study fundamental physics. Funding in FY18 for these programs was $18.72M. The Particle Theory program is essential to the success of the entire Particle Physics mission.

The Division supports cutting-edge investigator-driven research in two programs, Theoretical High-Energy Physics and Theoretical Particle Astrophysics and Cosmology. There are regular interactions with other divisions and directorates at NSF. The program supports individuals, RUI's, and special facilities or initiatives (Aspen Center for Physics, TASI summer school, LHC Theory Initiative, etc.). The FY18 budget for these programs is $13.43M.

The Physics Division released in FY19 several solicitations for their investigator-initiated research projects. In addition, NSF released two solicitiations for mid-scale infrastructure projects. Internally, the Division funds midscale proposals through the regular solicitation process and are competitively reviewed; PHY currently has 8 midscale projects in four programs (EPP, NP, Gravitational Physics, and PA) with about $60M invested in the last five years.

A few science highlights were presented.

- The IceCube Collaboration performed its first measurement of the tau neutrino appearance in oscillations of atmospheric muon neutrinos, which excluded the absence of tau neutrino oscillations at a significance of 3.2σ, confirming previous observations by OPERA and Super-Kamiokande. More importantly, this result is also the leading measurement of the tau neutrino "normalization," the ratio of the detected number of tau neutrinos arising from oscillations to the predicted number from the standard neutrino oscillation picture. The measured tau "normalization" is consistent with the standard picture but suggests that future IceCube measurements of this quantity could reveal new physics. These results have just been submitted to the journal *Physical Review D*.

- In a recent publication submitted to *Astronomy and Astrophysics*, the IceCube Collaboration and Pan-STARRS1 scientists have searched for counterpart transient optical emission associated with IceCube high-energy neutrino alerts. Researchers found one supernova worth studying, SN PS16cgx. PS16cgx showed a rising light curve over two days, which is a typical signature of a young supernova, possibly undergoing a potential explosion epoch where very high energy neutrinos could be produced. However, a more detailed analysis showed that it is most likely a Type Ia supernova, i.e., the result of a white dwarf explosion, which is not expected to produce neutrinos. Their findings show that spectroscopic follow-up and multicolor photometric coverage of the light curves of candidate sources are crucial.
- In a new paper by the IceCube Collaboration with the Fermi-LAT collaboration and the ASAS-SN telescopes, researchers went back to eight years of archived IceCube data searching for high-energy neutrino events that could have triggered an alert such as IC-170922A, which culminated with the identification of TXS 0506+056 as its source. A second neutrino, dubbed IC-141209A, was found in spatial coincidence with blazar GB6 J1040+0617, a plausible but unconfirmed source of this neutrino that will be further investigated for flares of lower energy neutrinos. The results of this long-term search of high-energy neutrino emission from blazars also confirm that this type of active galaxy cannot account for the majority of the diffuse neutrino flux seen by IceCube and that the source of most of the high-energy neutrinos is still unknown. These results have recently been submitted to *Astronomy and Astrophysics*.
- Using HAWC, very high energy particle accelerations were found to be powered by the jets of the microquasar SS433; SS 433 is a binary system containing a supergiant star that is overflowing its Roche lobe with matter accreting onto a compact object (either a BH or NS). Two jets of ionized matter with a bulk velocity of $\sim 0.26c$ extend from the binary, perpendicular to the line of sight, and terminate inside W50, a supernova remnant that is being distorted by the jets. At energies > 100 GeV, the particle fluxes of γ rays from X-ray hotspots around SS 433 have been reported as flux upper limits. In this energy regime, it has been unclear whether the emission is dominated by electrons that are interacting with photons from the CMB through inverse-Compton scattering or by protons interacting with the ambient gas. Scientists have measured photon energies of at least 25 TeV, and these are certainly not Doppler boosted, because of the viewing geometry. We conclude that the emission from radio to TeV energies is consistent with a single population of electrons with energies extending to at least hundreds of TeV in a magnetic field of ~16 micro-Gauss.

The 3rd observational (O3) run for LIGO will start in April 2019. In the meantime, commissioning of the instruments has increased the LIGO reach by 20-30%; this would increase the detection rate by a factor of 2. NSF, the United Kingdom, and Australia have awarded ~$35M for the LIGO upgrade known as A+. The upgrade consists of replacing the mirror coatings with new low-absorption materials and incorporating frequency-dependent squeezed light. The upgrade would increase LIGO's sensitivity by 70% of the Advanced LIGO design and its detection rate to about one black hole merger per day. A+ construction would start after O3 (2020) and would be operational in 2024.

The Plasma 2020 Decadal Survey is now underway. It is co-sponsored by NSF, DOE, and DoD. There is some topical scope overalap between Plasma 2020, Astro 2020, and the mid-decadal for Solar and space Physics in the areas of plasma astrophysics and space plasma physics. Currently there is no mechanism for active coordination among NSF, NASA, and DOE in the area of plasma astrophysics, which is undergoing significant expansion with new faculty hires, rapidly advancing numerical modeling capability, as well as better observational and laboratory experimental capabilities.

Dieter Hartmann asked why the growth in the Plasma sector has led to no collaboration among the agencies. Jean Cottam replied that there is a growth in the field but there is no formal mechanism right now for collaborations. Nigel Sharp commented that Physics would like to see more formal collaborations across the field; there is a joint committee with DOE that Nigel is a member of that works with the Fusion Energy people at DOE.

NSF/Polar Programs

Vladimir Papitashvili provided an update on astronomy and astrophysics activities in Antarctica. There are quite a few on-going programs in Antarctica, IceCube, South Pole Telescope (SPT), BICEP, and the long duration balloon program being just a few of them.

IceCube was completed in 2010 to search for very high energy neutrinos created in the most extreme cosmic environments. In 2013 there was a discovery of the first high energy (100 TeV - 10 PeV) cosmic neutrinos; in 2017 IceCube issued an alert (170922A) upon pinpointing an extragalactic neutrino (~0.3 PeV) source within 0.1 degree of the flaring blazar TXS 0506-056. It was #4 in the Top 10 stories of 2018 in *Science News*. The neutrino observation points to one source of high-energy cosmic rays.

A proposal has been submitted for IceCube Gen2 Phase 1, an extension for precision netrino physics and astrophysics. This would provide 7 additional strings (each 100+ DOMs) in the center for the DeepCore Array. The main science objective is to look at a new window on the PeV universe.

The radio detection of neutrinos (using the Askaryan Radio Array, or ARA) complements optical techniques at very high energies. The Office of Polar Programs (OPP) and the Physics Division are deploying an array of 37 stations that will reach required sensitivity at energies above 100 PeV. Radio signals from secondary particles generated by an ultra-high energy (GZK, > 10^{18} eV) neutrino interaction within the ice.

The concept for ARIANNA is an array of ~1000 autonomous stations in Antarctica to measure the flux of ultra-high energy (GZK) neutrinos from astrophysical sources; the same as ARA's radio detection method that additionally includes measurements of a signal reflected from the water surface under the Ross Ice Shelf. Two ARIANNA stations are currently being tested at the South Pole Station to compare with ARA data.

Discoveries with the SPT include some of the most extreme objects in the Universe and have had lasting impacts on the fields of cosmology, galaxy clusters, and high-redshift galaxies, with over 200 papers published and over 10,000 citations. There have been 2 generations of cameras on the telescope with a third proposed that will be an order of magnitude improvement over the other cameras. The team is currently surveying the final target sky field, a 1500 deg^2 region fully overlapping the BICEP Array survey field (for de-lensing the B-mode signal); the final target map depth (2.2 μk-arcmin at 150 GHz) and observing strategy will enable breakthrough science in many areas, including new windows on the transient Universe and multi-messenger astrophysics. SPT uncovered the distant protocluster SPT2349-56, located approximately 12.4 billion light-years away and it was first discovered as a faint smudge of the mm-wavelength light in 2010 with the SPT and subsequently studied with ALMA.

Hardware upgrades to BICEP include optics and a new 270 GHz frequency band.

The 0.6m aperture High Elevation Antarctic Terahertz telescope (HEAT), operated robotically at Ridge A summit, is delivering spectroscopic data from 150 to 500 microns. This was a joint project between U.S. and Australian scientists. The HEAT and PLATO-R telescopes were removed from Ridge A in January

2019. HEAT's deep spectroscopic surveys found pervasive, diffuse molecular clouds not seen in existing surveys of CO and HI.

There have been a total of 56 long duration balloon and super pressure balloon payloads flown from McMurdo Station over the past 29 years. In the 2018/2019 austral summer season only two payloads were flown, and both were terminated after being launched due to equipment failures. BLAST-TNG was stored on-site and will be launched in 2019-2020.

Current annual spending for Antarctic Astrophysics is ~$9.0M, where ~$5.0M goes to support neutrino astrophysics and ~$4.0M to support astronomy and CMB-related projects. Antarctic astrophysics research projects are co-funded with PHY and AST. OPP spent jointly with AST and PHY ~$100M between 2004-2018.

Decadal Survey Planning

Robert Kennicutt and Fiona Harrison provided an update on Decadal Survey activities. A proposal was funded by the three Agencies for the Decadal Survey. The scope for the Survey will include ground and space-based observations, theory, computation, lab astrophysics, ground-based solar astronomy, gravitational-wave observations, multi-messenger astronomy and astrophysics, exoplanets, and the implementation and scope of WFIRST, Athena, and LISA. The time for completing the Survey process through to report release is around 2 years. The plan is to review the current state of astronomy and astrophysics, identify compelling science challenges for the future, develop a research strategy to advance scientific frontiers in the next decade, develop a set of decision rules for robust programs, and assess the state of the profession.

The Survey committee is now being identified and appointed. Panels will be formed in late Spring 2019 and the panels will deliberate in late 2019. The report writing will begin in Spring 2020 with the report released in late 2020. The deadline for science white papers is March 11 to accommodate those affected by the government shutdown. There is very strong community interest and the Survey expects hundreds of papers to be submitted. It is important that the plan for the science be laid out in the white papers. The emphasis of the science white papers is future science. The Survey will also be accepting State of the Profession white papers. The Survey Committee will be coordinating with the AAS to engage directly with early career and under-represented communities. There will be a series of Town Hall sessions at the AAS meetings and the web site will be updated regularly with FAQs.

Ground-based TESS Follow-up Observing Program

George Ricker provided an update on TESS, the Transiting Exoplanet Survey Satellite. TESS is an all-sky survey to identify the nearest systems of transiting planet candidates. Follow-up work includes characterizing planet masses from precise radial velocities, spectroscopy of planetary atmospheres, and astroseismology.

The satellite was launched April 18, 2018 on a SpaceX F9 rocket. TESS is now on-orbit and the sky survey is underway. TESS is the highest etendue optical space mission yet flown, ~6 times greater than Kepler. The commissioning of the satellite and science instruments was fully successful: camera focus and stability of the satellite/instruments is excellent; readout noise and crosstalk are very low; and scattered light mitigation is effective. Science Survey sectors 1-7 have been completed; sector 8 is in progress. For comparison, the Kepler search area extended 3000 light years and covered 25% of the sky, whereas TESS extends out to 200 light years and is all-sky. It is expected that TESS will fill in the region that was not detected by Kepler. The initial data release was on December 6, six weeks earlier than originally planned; the data was posted at MAST. Publications from TESS are trending upwards

TESS is doing more than imaging exoplanets. TESS is imaging solar system objects like comets and asteroids; explosive and variable extragalactic sources such as supernovae, AGNs, and gamma ray bursts; and variable stars such as eclipsing binaries, white dwarfs, and flare stars. TESS is also going deep: in one hour achieving 1% photometry on 16^{th} magnitude sources, in tweleve hours 10% photometry at 19.5 magnitude. All TESS data products are archived a STScI.

Eliza Kempton asked about funding for the ground-based follow-up observations. George Ricker replied that there are other facilities that are participating in the PRB work, mainly in the South and in Hawai'i; these are devoting large blocks of time for TESS follow-up. There was funding for some follow-up in the TESS mission but there has been more effort on the part of the community to bring their resources to the team. A majority of the facilities doing the follow-up are not ones that the US has funded or has access to, and this is an issue that needs to be discussed for the future.

Gemini-Blanco-SOAR (GBS) Subcommittee Report

Klaus Honscheid, Chair of the GBS Subcommittee, presented the committee's final report to the AAAC. The GBS Subcommittee was requested to develop an assessment of the scientific utility and priorities for the US community for the Gemini Telescopes and the complementary Blanco and SOAR 4-meter telescopes for the first half of the upcoming decade. The purpose was to provide NSF with timely advice on the renewal of agreements for two of the facilities and DOE with advice on whether there was need and priority for use of these facilities to enhance dark energy science investigations. Specifically, the ad hoc subcommittee was asked to deliver:

- An assessment of the degree to which each of the telescopes provides critical complementary data for the Large Synoptic Survey Telescope (LSST), multi-messenger/time domain science, and dark energy science.
- A short list with description and evaluation of the highest impact science in other areas enabled for US observers by the facilities (separately or in combination), given the planned instrument complements.
- An assessment of whether the current share is adequate to accomplish the highest impact scientific programs identified in the two activities above.
- Evaluation of modes of multi-facility use that could be further enhanced or have competitive access streamlines (e.g., GRB follow-up).
- Point out missing instrumental and adaptive optics capabilities needed for the highest priority programs.

The charge was received in August 2018 and a preliminary report was presented to the AAAC in November 2018. This was a strong committee with expertise covering a wide range of GBS science. The committee was split into sub-groups to address science cases for small bodies and exoplanets, star formation and stellar astrophysics, supernovae and transients and variable stars, galaxies and multi-messenger astronomy, and dark energy and matter. There was insufficient time to solicit community input but the subcommittee did request and receive information from all three observatories; at their in-person meeting, there were presentations from the observatory directors.

Klaus Honscheid provided an example of the multi-messenger science that could be done with the GBS system. The advanced detectors on the Laser Interferometer Gravitational-Wave Observatory (LIGO) and on Virgo will start their next run with increased sensitivity. Both instruments will be observing/detecting numerous binary black hole, neutron star-neutron star, and neutron star-black hole mergers. However, localization is uncertain on the sky over 10-100 deg^2. Follow-up requires same-night optical and near-IR imaging and high cadence spectroscopy. DECam on Blanco is unsurpassed for localization, while Flamingos-2 on Gemini can be used for pure red kilonovae work; Gemini is well set up for intense optical and near-IR imaging and spectroscopy at high cadence; SOAR can do the same for brighter objects.

Multi-messenger astronomy and time domain science are supported by all three telescopes. Development of the necessary software tools is underway. Discussions on coordinated observations and data sharing policies have started. The DOE's focus on dark energy science was also supported by all three telescopes; the Alert Broker is critical for this. GBS spectroscopy supports probes of dark matter physics using dwarf galaxies and stellar streams. Spectroscopy of cluster galaxies provides critical calibration of photo-z's to enable cluster cosmology. Gemini Adaptive Optics (AO)-assisted imaging and spectroscopy will be needed so that hundreds of LSST time delay gravitational lenses can be used for cosmology.

Exciting scientific opportunities warrant the extension of the Gemini and SOAR agreements. A particularly strong case is using GBS as a coordinated LSST follow-up system. It will rely on facilities being secured and optimized together rather than separately. NSF should renew both the Gemini and SOAR agreements at the current level. The Gemini, Blanco and SOAR observatories should continue to optimize and coordinate their position for follow-up observations in the LSST and MMA era while maintaining a strong PI based program covering a broad range of science.

To take full advantage of the scientific opportunities afforded by these telescopes, continuing cooperation among the observatories and coordinated development of the required tools and policies to support an OIR system will be required. NSF should continue to implement the OIR system-related recommendations from the 2015 NRC report and support development of OIR system tools and policies; engage the community in both process and development; encourage community contributions to the requirements, interfaces and functionality of software tools like the Astronomical Event Observation Network (AEON), Event Brokers like ANTARES, and Target and Observation Managers (TOMs); ensure that all interfaces are open and provide the options to accept inputs from 3rd party (i.e. user) applications and alert streams; consider organizing a series of workshops on OIR system tools; and coordinate efforts in software development for OIR system operation (Brokers, TOMs, Schedulers, etc) to ensure cooperation, particularly between institutions and with international partners.

In order to secure the long term future of the Gemini, Blanco and SOAR (GBS) system, a science plan or roadmap is needed for these facilities. NSF needs to: start development of a coordinated scientific program for GBS for the second half of the next decade (2025-2030); continue to evolve the OIR system and define the role of the GBS system for the era of extremely large telescopes; develop an instrumentation concept for the Blanco telescope for the time following the 5-year (public) DECam period, i.e. beyond 2024; develop an instrumentation concept for the SOAR telescope that builds SOAR's strength in time domain science and fast-and-flexible follow-up of targets of opportunities; continue to invest in AO capabilities for Gemini North and South, including wide-field and high contrast imaging, spectroscopic capabilities, and long and broad wavelength coverage; and, while outside the scope set by the charge, include the Mayall telescope on Kitt Peak in future planning efforts

The subcommittee commented on the instrumentation that would be needed. Gemini instrumentation continues to improve; the continuation of this program and expeditious commissioning of new facility instruments has to remain a high priority. Gemini needs to find a way to strengthen support for its Visitor Instrument program. The subcommittee also suggested that NSF consider enhancing NIR imaging capabilities by supporting a smaller field-of-view instrument for targeted followup observations with SOAR and a wide field-of-view instrument for the Blanco.

The subcommittee suggested establishing a joint university-observatory R&D program on instrumentation, detectors and adaptive optics capabilities for the next decade. A highly-multiplexed, multi-object, wide field-of-view spectrograph on an 8-10 m class telescope in the southern hemisphere remains missing from the US OIR portfolio. The science case for such a facility is very strong, as detailed in many recent studies including the 2015 NRC report and the 2016 Kavli Report on Maximizing Science in the Era of LSST. NSF should explore options with international partners to provide access to such a facility, preferably in the Southern hemisphere for the second half of the next decade, such as access to the Prime Focus Spectrograph (PFS) on Subaru and/or contributing to the Mauna Kea Spectroscopic Explorer (MSE) project at the CFHT site.

The AAAC officially received the report from the GBS Subcommittee; the charge was met by the subcommittee. John O'Meara thanked Klaus Honscheid and the subcommittee for their hard work. Richard Green also thanked Klaus Honscheid and the subcommittee; he noted that it was a comprehensive look at the science of the facilities with a clear set of recommendations to the agencies.

Electromagnetic Spectrum Management

Ashley Zauderer and Jonathan Williams gave a presentation on electromagnetic spectrum management (ESM). NSF funds a wide variety of programs that require usage of the radio spectrum across divisions. NSF-funded astronomy research relies on access to the electromagnetic spectrum. The ESM program resides in MPS/AST because historically spectrum usage has been focused primarily around the needs of a few large facilities and the National Radio Quiet Zone. Many measurements depend critically on access to wide swaths of the electromagnetic spectrum being free of interference.

Protected frequency bands include most important identified spectral lines for studying the local universe (e.g. HI, CO, OH masers), but Doppler-shifted lines from sources further away in the Universe fall into non-protected bands. Frequencies used for observation are often non-interchangeable, and much observation is done opportunistically. It is imperative that the increasing demands for spectrum take into consideration the challenges to scientific progress and NSF appreciates efforts to coordinate and to limit out-of-band emissions; astronomy observations also include continuum emission (thermal, non-thermal).

The United States has significant scientific assets/large facilities outside of its national borders. Observatories tend be in geographically remote sites, but radio emission from moving emitters such as car radars, satellites, and high altitude delivery systems will be an increasing challenge.

There are national, regional, and international radio regulations that govern the radio spectrum. NSF's position on radio spectrum is brought before several committees including the Committee on Radio Frequencies (CORF) and the International Committee on the Allocation of Frequencies (IUCAF). NSF also works with the spectrum managers at its radio telescopes. NSF participates alongside other federal agencies in the Interdepartment Radio Advisory Committee (IRAC). NSF has representations on official US delegations to the Inter-American Telecommunications Commission (CITEL) of the Organization of American States (OAS). Every four years, over 160 International Telecommunication Union (ITU) members participate in treaty-based modifications to the ITU radio regulations; NSF leads Group 7D-Radio Astronomy. NSF works with other directorates and divisions within NSF that have spectrum needs as well as other agencies such as NASA, DOE, NOAA, and NTIA.

Large Ground-based Astrophysics Projects

Ralph Gaume, Joseph Pesce, Nigel Sharp, and Jim Whitmore provided an update on several large ground-based projects that will be considered by the upcoming Decadal Survey, US-ELTs, ngVLA, IceCube

Gen2, and CMB S-4. NSF expects to receive Design and Development proposals for US-ELT and ngVLA.

Ralph Gaume noted that ELTs were included in the last decadal survey; giant telescopes were #3 for ground-based projects; the survey recommended that NSF invest in one of the two projects underway; NSF did not fund either TMT or GMT. The aspiration now is a bi-hemispheric ELT (2 telescopes, 2 hemispheres, 1 system) that provides all-sky coverage, a broad suite of instruments, key science programs, open access for ≥25% at both facilities, and strengthened US scientific leadership. It is envisioned that 80% of public time will be allocated annually to key science projects (KSPs) with 20% for PI-class projects. NSF has asked NOAO to lead development of the KSPs; they issued a call last year for community participation in KSP development with over 250 respondees (66% unaffiliated with GMT/TMT partners) in 8 topical groups. The science case for the telescopes has been made for well over a decade, but now the question is; what is the justification for two telescopes? Greater science and all-sky access. NSF investments will be needed to realize US open access to the ELTs, on the order of ~$1B.

Joe Pesce provided information on ngVLA, the Next Generation Very Large Array. This would be the next ground based radio facility. The ngVLA is not designed to be a survey telescope, rather a proposal-driven telescope that will be flexible in response to user requirements as the decades progress. The ngVLA will have 1.2-116GHz frequency coverage. The main array would be 214x18m offset Gregorian antennas with locations across NM, TX, AZ, and Mexico; the short baseline array would be 19x6m offset Gregorian antennas and the long baseline array would be 30x18m antennas located across the continent for baselines up to 8000km. The project is working on partnership development; there have been a number of science conferences with a Science Book with 88 peer-reviewed contributions from 286 authors. The project is preparing a D&D proposal to submit to NSF and is preparing for the Decadal Survey. Overall construction costs in 2018 risk-adjusted base-year dollars are estimated at $2.3B with contributions from the US at $1.75B. Operations costs are estimated at $80M per year.

Jim Whitmore provided information on the IceCube-Gen2 project, a multi-messenger astrophysics with high energy neutrinos project. The goal is to provide ~4x the significance to the September 22, 2017/TXS 0506+056 type event, study fundamental physics at some of the most extreme energies measured, study neutrino properties, test symmetries in nature, and search for dark matter. The upgrade to the observatory would be an additional array of 120 strings of sensors sensitive to neutrinos up to ~100PeV. The concepts are mature and developed from expertise and knowledge gained from IceCube. Preliminary Gen2 design work is currently underway by the IceCube collaboration. The primary deep-ice optical detector array is anticipated to be similar in scope to the IceCube MREFC at ~$300M. Preliminary design activities include improvements in logistical efficiencies, transportation via traverse, lower power requirements for sensors, etc. The expected operations costs are somewhat higher than the current program ($7M/year from NSF and similar amount from non-US).

Nigel Sharp provided information on the CMB Stage-4 project. The S4 experiment will provide a dramatic leap forward in understsnding, space, time, and the evolution of the Universe. CMB-S4 will cross critical thresholds in testing inflation, determining the number and masses of neutrinos, constraining possible new light relic particles, providing precise constraints on the nature of dark energy, and testing general relativity on large scales. The project is well underway in terms of definition; the groups involved in the project are coming together in various technical ways which are collaborative, building on existing investments such as ACT, BICEP, POLARBEAR and SPT. The Cosmic Microwave Background Stage-4 Concept Definition Task Force (CDT) reported to the AAAC in October 2017. The CDT strawperson estimate was $9M for D&D, $412M for construction (options ranging from $354M to $470M) with an annual operations budget of $18M and $14M for science. Significant private investment has already been made by the Simons Foundation primarily; international partners are engaged and are expressing more interest in the project and DOE has already put in funding through its Laboratory Directed R&D and through the preProject Development Group. Also, DOE has already invested significantly in SPT and NSF has significant investment in SPT and the Atacama high site.

Andrew Connolly asked about the ELTs: Is the expectation that the funding would come from an MREFC proposal if it was recommended by the 2020 Decadal Survey? Ralph Gaume responded that yes, a proposal would be supported by the MREFC program for funding. This would also apply to IceCube Gen2, ngVLA, and CMB-S4. Connolly noted that the MREFC current envelope is not commensurate with any of the projects going through MREFC, and one would have to couple the Decadal's science urgency and the benefit to all of the science community with the knowledge that MREFC needs to be fixed. The AAAC might want to think about this as it puts together its recommendations in its report. Ralph Gaume commented that in the FY2019 PBR the MREFC line is trailing off, but one should look at the recent appropriation that Richard Green provided in his talk where the MREFC line is in a different direction than the PBR.

Mid-Scale Programs MSIP, MSRI 1&2, and ATI

Richard Barvainis provided an update on the Mid-scale Innovations Program (MSIP) and the Mid-Scale Research Infrastructure (MSRI) Program. MSIP has been run biennially since 2014 with a program budget of ~$15-20M per year (the plus-up in FY18 provided additional funding). AST will be running a solicitation this summer for funding in FY20. The program supports both construction and operations/science projects with twenty-three awards made so far. There are stand-alone science programs as well as community access programs with the potential to support design programs and long-term facilities. To date there have been 15 science awards and 8 access awards with proposal funding between $600K and $10M. Proposal topics range from the nearby universe to CMB and everything in between. Funded proposals include the ZTF (a LSST pathfinder), EHT (radio imaging of black holes), HERA, NANOGrav, TolTEC, ACT, POLARBEAR, CLASS, BICEP, and two adaptive optics projects, MAPS (MMT) and KAPA (Keck), CHARA, ALPACA, and Las Cumbres Observatory (optical telescope network).

Ralph Gaume noted that AST was able to fund more than the $15-20M level; proposals were funded for 2 years using FY18 and FY19 funds. It is anticipated that the awards will be supported using FY19 appropriated funds as indicated in congressional language.

John O'Meara inquired about the term "community access." Rich Barvanis replied that community access could mean buying time on telescopes. It could also, for example, be sharing data with the community like the SuMIRE survey project with Subaru that is using funds from MSIP; TolTEC is also partially community access.

Scott Dodelson asked if the projects are funded using existing funds. Barvainis replied that projects are funded through several sources. For example, ACT has basically been funded through MSIP over the past few years but previously was funded through the Division's mid-scale program. Almost all of the programs have other sources of funding, though many are dominated by MSIP, like HERA and CLASS; the ZTF is receiving funds from NSF and partner organizations.

Connie Rockosi asked about the NSF oversight for these projects. Barvainis replied that the review process for submission involves pre-proposals reviewed by panels and then down selected invitations to submit full proposals that are evaluated by panels. For oversight of these projects, quarterly reports are required from each project and there are visits to the PI's institutions; reverse site visits are also done. External panels are also used.

Nigel Sharp provided an update on the Mid-Scale Research Infrastructure (MSRI) program, one of NSF's

10 “Big Ideas.” MSRI is a new NSF Program that is being offered for the first time in FY19. There are two lines of funding for MSRI, one at the $6-20M range (MSRI-1), and the other at the $20-$70M range (MSRI-2). Both allow for upgrades to existing infrastructure, but no operations and maintenance support or science research support is allowed. Proposals require a strong scientific merit case and must respond to identified needs of the community. NSF-sponsored FFRDCs such as the AST observatories and NCAR may submit proposals in response to either solicitation. For MSRI-1, 246 pre-proposals were received and were reviewed internally; full proposals are by invitation only and are due May 20, with funding support from FY19 funds. For MSRI-2, 64 Letters of Intent were received and preliminary proposals are due March 11; full proposals are by invitation only and are due August 2, with funding support from FY20 funds.

John O’Meara asked whether NSF received proposals from other divisions besides AST. Nigel Sharp replied that NSF received proposals from virtually every division at NSF, including SBE; it has been truly NSF-wide. Most of the proposals did come in to Engineering and MPS. The opportunity was open to NSF’s observatories and centers. About 100 proposals were received for implementation and about 90 for design. Both MSRI-1 and MSRI-2 received $30M each annually; by running them every other year, there is ~$60M to spend on each program. The solicitation allows a division or directorate to choose a proposal from those submitted and fund it themselves. The proposals can also include software development which is critical to all projects. Oversight for MSRI-2 awards will require more oversight, such as annual reviews.

Peter Kurczynski provided an update on the Advanced Technologies and Instrumentation (ATI) programs. ATI has been around since the 1980s and has provided funding for technologies and instrumentation for radio and sub-millimeter astronomy, adaptive optics, IR detectors, and instrumentation for KPNO, Palomar, CSO, Keck and other observatories. The ATI has made 496 awards over the past 30 years or so; the literature impact is comparable to pure science programs. The first ATI award for LSST was made in 2004 and enabled the development of the camera. Instrumentation has been developed for many of the optical telescopes in existence, including Gemini, Subaru, Keck, Magellan, LBT, VLT, and MMT. NSF has invested $29M in science being investigated with the Event Horizon Telescope, with 8 ATI awards totaling $8M. ATI currently has an active solicitation.

John O’Meara asked what the annual budget is for ATI. Peter Kurczynski replied that it is around $8M, but he has not done a historical analysis to see if that has been a steady number throughout the years of the program. There was no solicitation last year, but typically it is offered annually.

Other Discussions

The next meeting of the AAAC is scheduled for June 3; this will be a telecon. The Chair would like to have a meeting of the AAAC before the annual report is delivered to the Agencies and Congress. The shutdown made it impossible for the AAAC to deliver its annual report by March 15; the report will be delivered in late April and the Chair will send a letter to the agencies and Congress informing them of the delay. The focus of the March meeting will be a brief update on the FY19 and FY20 agency budgets and discussion of the annual report.

The Committee spent the remainder of the time discussing the annual report and writing assignments. The Chair plans to follow the same format and structure as previous reports.

MEETING ADJOURNED AT 12:00 PM, 26 FEBRUARY 2019