BPA – NSF/AST Update

Richard Green

Division Director,
MPS/AST

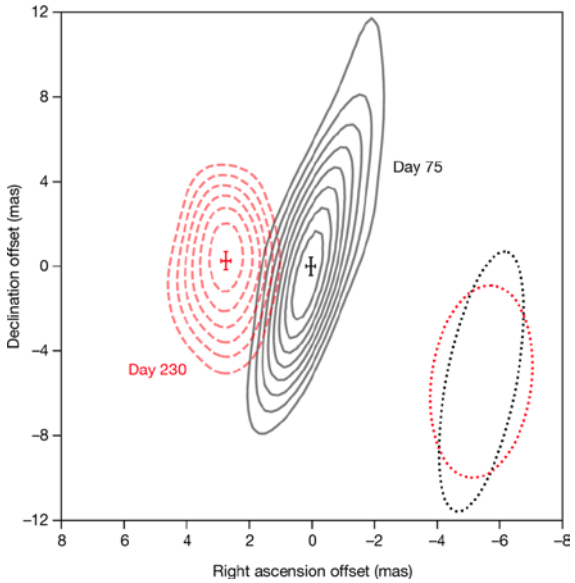
AST Mission: Enable breakthrough science

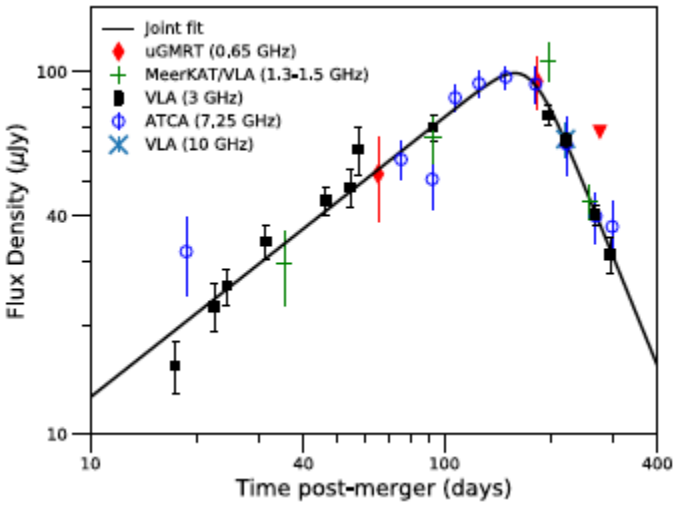
Image of M87 from Event Horizon Telescope

- Doeleman et al. team with 8 telescope VLBI at 1.3 mm.
- Black hole shadow with inferred angular gravitational radius of $3.4 \pm 0.4 \mu as$.
- Assumed distance yields $M=(6.5 \pm 0.7) \times 10^9 M_{\odot}$
- Crescent brightness distribution consistent with Kerr Black Hole.

- NSF (AST) invested some $28M in EHT research over the last two decades, including hardware and algorithm development as well as theoretical modeling (PIRE grant for international collaboration).
- ALMA observations were critical for closing phase; South Pole telescope provided critical baselines.

Jet Breakout from Neutron Star Merger





- VLBI observations including GBT showed that the compact radio source showed superluminal motion, consistent with a narrow-angle jet at later times with viewing angle ~20^{o}.
- The sharp inflection in the 0.6-10 GHz light curve suggests initial cocoon-dominated outflow, followed by jet breakout with power-law slope of $t^{-2.2}$.
- Mooley+ 2018, Nature 561, 355; ApJ 868, L11.

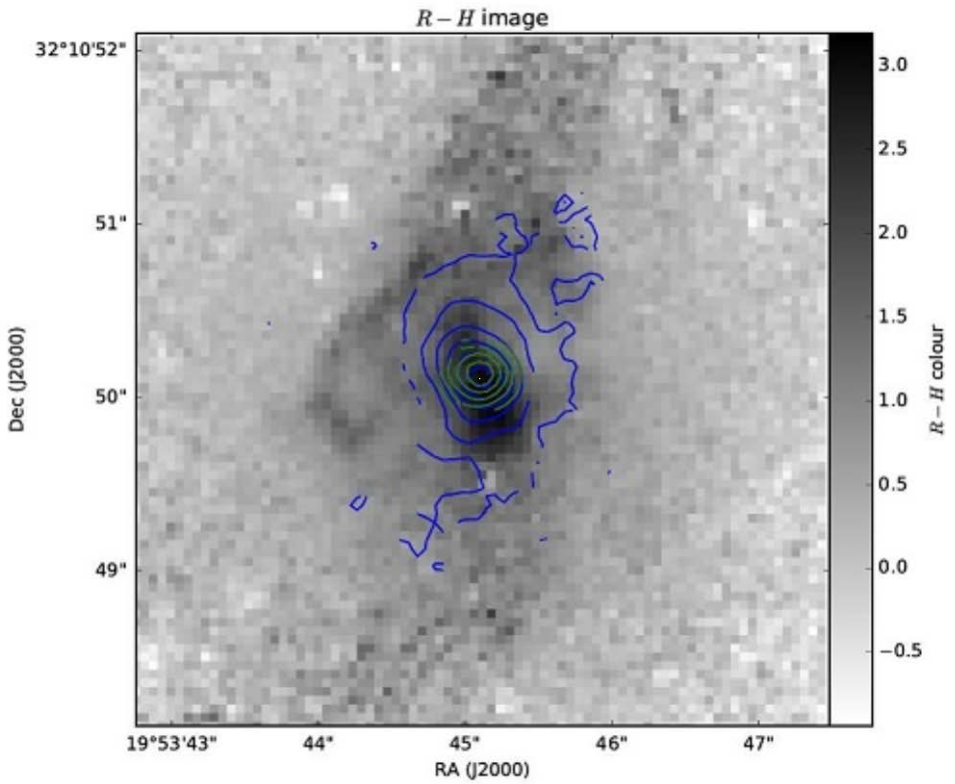
DSHARP is ALMA imaging survey of 20 protoplanetary disks with ~0.035” (5 AU) FWHM in 1.25 mm continuum emission.

Characterized by concentric narrow emission rings and depleted gaps, sometimes large-scale spiral patterns & small azimuthal asymmetries.

Most compelling interpretation is that gas giants form more quickly than current theory suggests at large distances from host stars.
Disk perturbations observed in dust density allow longer accretion growth time for planetesimals.
Ten papers accepted for publication in ApJ Letters. Data release at https://bulk.cv.nrao.edu/almadata/lp/DSHARP/.

Imaging AGN Jet-ISM Interaction

- Zovaro et al. (2019) used Gemini-N +NIFS to image the nearby elliptical radio galaxy 4C 31.04 in H and K. The galaxy is 270 Mpc distant, allowing good resolution of the nuclear region.
- The green contours suggest a jet-blown bubble of ionized gas ~400 pc in diameter. The blue contours are consistent with warm molecular gas extending to a kpc.



- Interpretation: “The bubble pushes a forward shock into the interstellar medium, giving rise to the ionized gas. Jet plasma also percolates into the circumnuclear disk, shocking and radially accelerating gas clouds, warming the interstellar medium and giving rise to the molecular emission.”

AST Implementation

- High-demand Individual Investigator programs.
- Suite of forefront ground-based Optical/IR (OIR), Radio-Millimeter-Submillimeter (RMS), and Solar observing facilities plus data holdings supported by AST for merit-based access.
- Construction through the MREFC line of two major new facilities, DKIST and LSST.
- Reorganization of management of NSF OIR facilities to optimize time-domain science.
- Divestment of facilities that were given lower priority by external review process to accommodate operations of new facilities and maintain programmatic balance.
- Sponsoring National Academies decadal survey to set future priorities for scientific direction and facilities development.

AST Division Programs

Individual Investigators
(Lead: James Neff)

- AAG
- CAREER
- AAPF
- ATI
- MRI
- REU
- PAARE

Mid-scale
(Lead: Rich Barvainis)

- MSIP

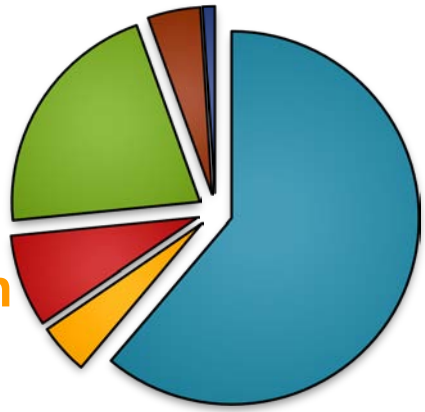
Facilities

- ALMA
- NRAO
- Gemini
- NOAO
- LSST
- Arecibo
- NSO
- GBO

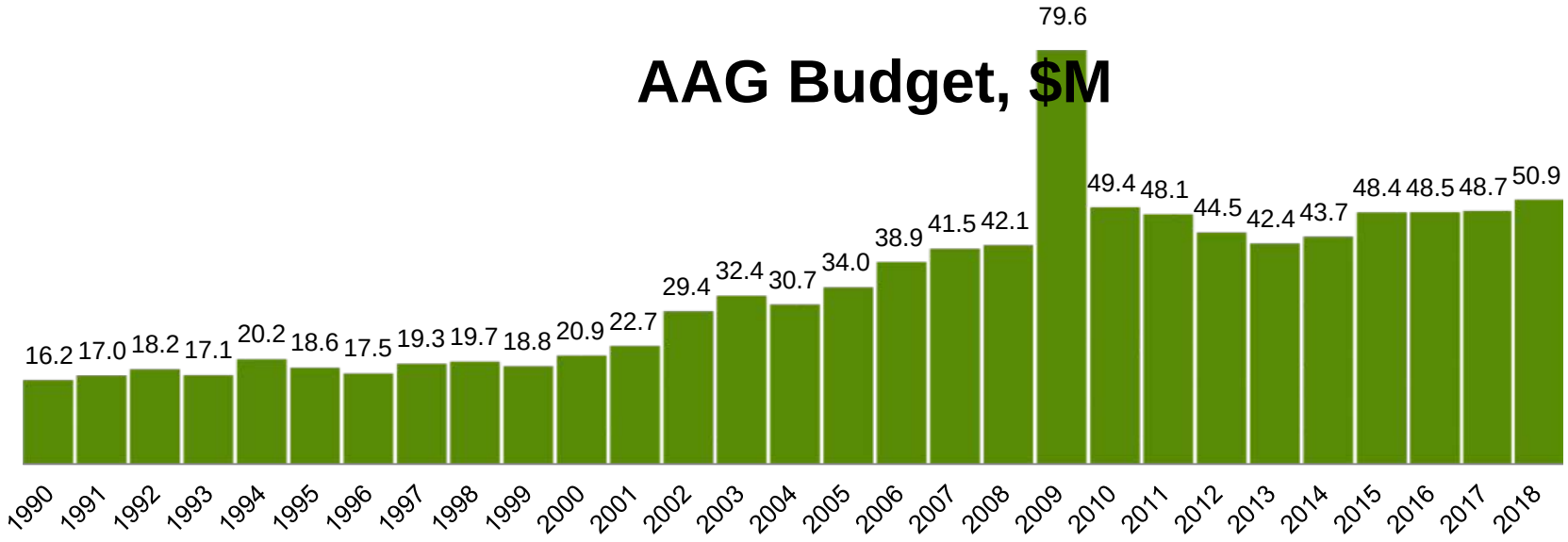
Research

Technology/ Instrumentation

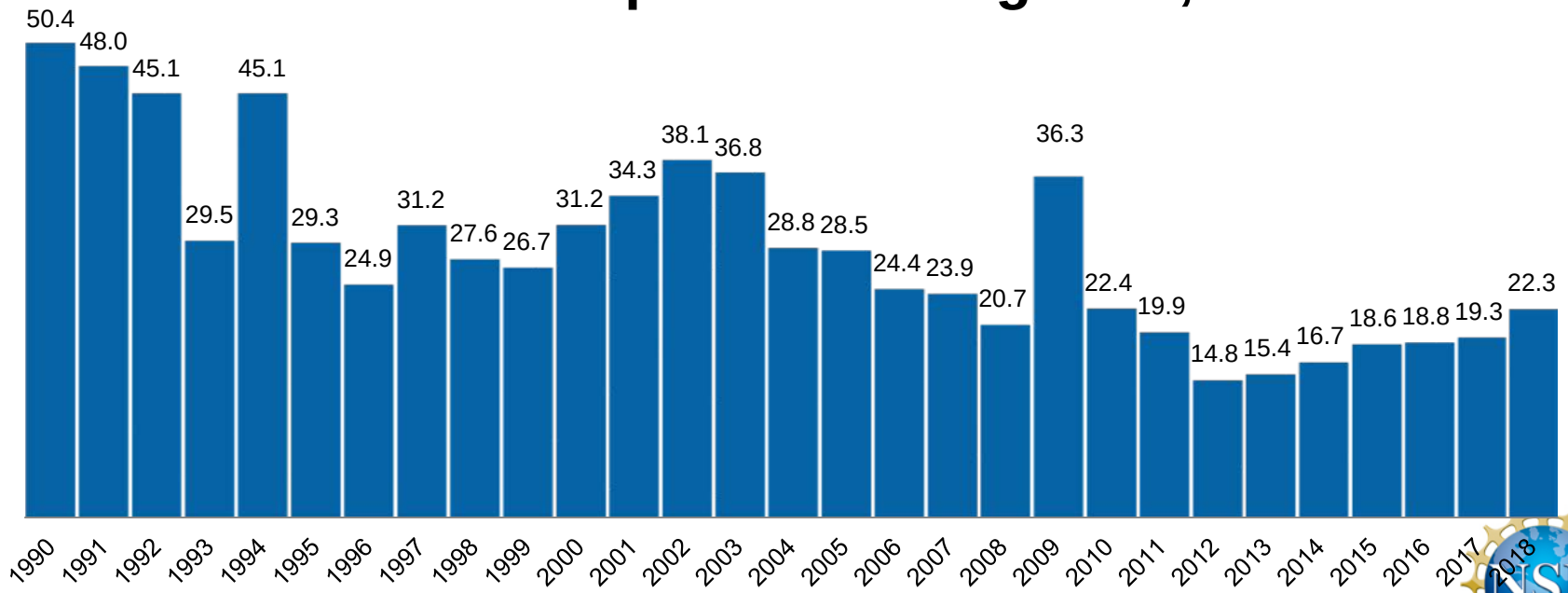
Education and Special Programs



AAG Budget, $M



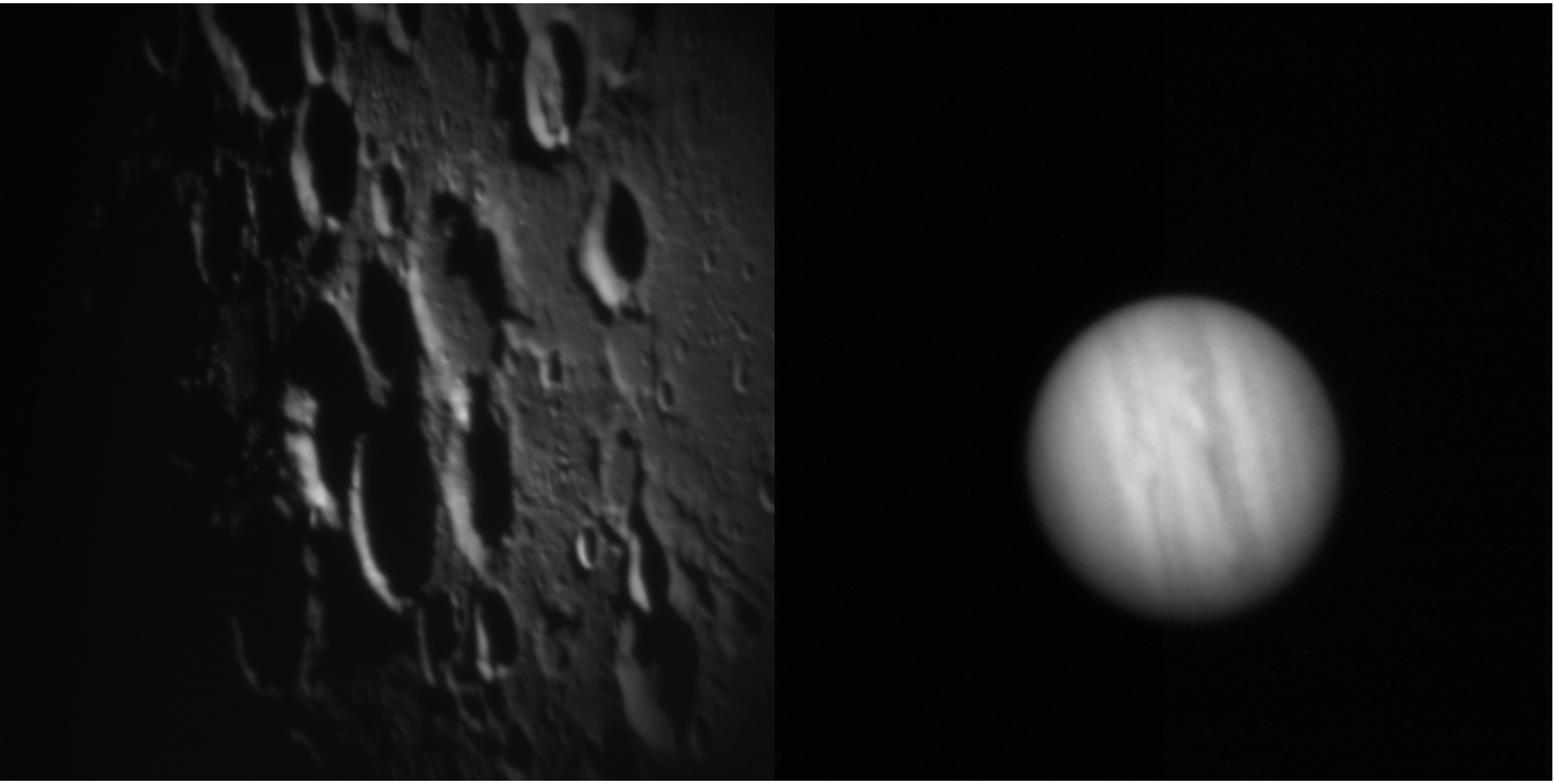
Proposal Funding Rate, %



DKIST Telescope Mount, Sept. 2018

- Telescope optics in place, M1 & M2 aligned.
- Current challenges largely with instrument completion and delivery, as well as data policy.
- Commissioning of thermal control loops also a significant task.
- Still on schedule and within budget contingency.

DKIST Images, March 2019

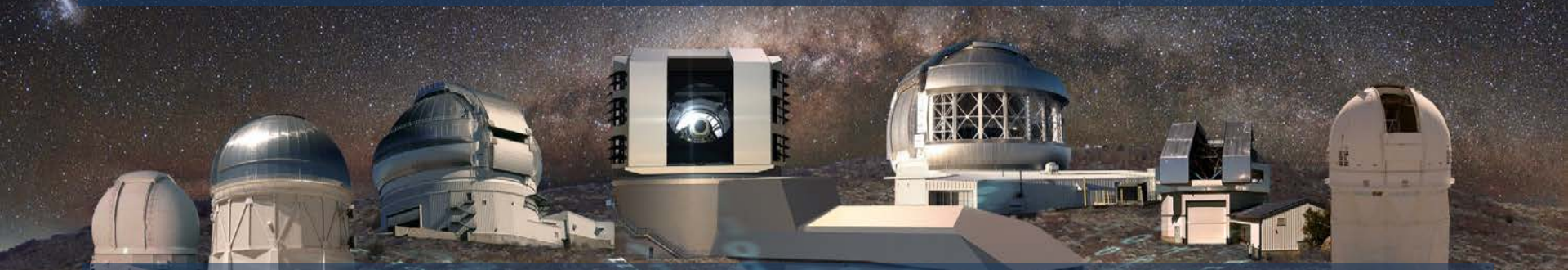


- Images using M1 and M2 final optics, taken as part of nighttime optics commissioning.

LSST Current Construction Site

On budget and on schedule for operations in 2022.

NSF's National Center for Optical-Infrared Astronomy (NCOA) integrates the NSF-funded entities -- National Optical Astronomy Observatory (NOAO), Gemini Observatory, and Large Synoptic Survey Telescope (LSST) operations -- under a single organizational framework, managed by one management organization as an FFRDC.



- **NCOA initiation no later than 1 Oct 2019. Approved by National Science Board to proceed.**
- **LSST operations received initial funding in FY 2019.**

Background is a montage of major facilities under NCOA.

Critical milestones met with AURA submission of several key documents.

NOAO-NCOA Reviews

- Three-pronged review in February
  1. Review of NOAO Program and Operations Plan for current FY.
  2. Review of NCOA transition Program and Operations Plan.
  3. 'Comprehensive performance review' of AURA/NOAO management during the period of the current Cooperative Agreement.
- Important potential outcomes from report
  - Positive report on NCOA Program and Operations Plan, combined with positive review of submitted Cost Model by BFA would serve as a basis for go-ahead to launch by Director's Watch List Council.
  - Report on NOAO retrospective evaluation would form the basis for the recommendation in mandatory extend/compete process; if renewed, terms would then align with those of AURA awards for Gemini and LSST, for recompetition of the package for 2026. (Note change in philosophy for size of attractive enterprise.)
- AURA is currently recruiting for NCOA Director.

FY 2018 Budget

- Very good outcome in the end for AST – total $307M, compared to FY17 actual of $252M.
- Much of the increase went to one-time specific projects (some dependent on FY19 availability of funds to complete):
  - MSIP, for total funding close to aspirations in NWNH
  - Multi-messenger astrophysics grants
  - Major upgrade to Gemini N Adaptive Optics system in service of time domain follow-up, stellar populations studies
  - Forward funding DKIST operations for timely completion of data center, supplement for Level 2 data products.
  - Forward funding LSST operations pending NCOA initiation

FY 2018 Budget

Several MSIP projects received awards:

- Keck All-Sky Adaptive Optics – Wizinowich @ CARA
- Facility IFU Spectrograph for Magellan – Simcoe @ MIT
- HERA Project for low-frequency – Parsons @UCB
- MMT Adaptive Optics System – Hinz @ Arizona
- BICEP upgrade to Stage 3 – Kuo @ Stanford
- Dedicated FRB localization – Hallinan @ Caltech
- Long Wavelength Array – Taylor @ UNM
- GBT Metrology – Lockman @ NRAO (won kudos from WVa Congressional staff…)
- ALPACA L-Band Phased Array for Arecibo – Jeffs @ BYU

FY 2019 Budget

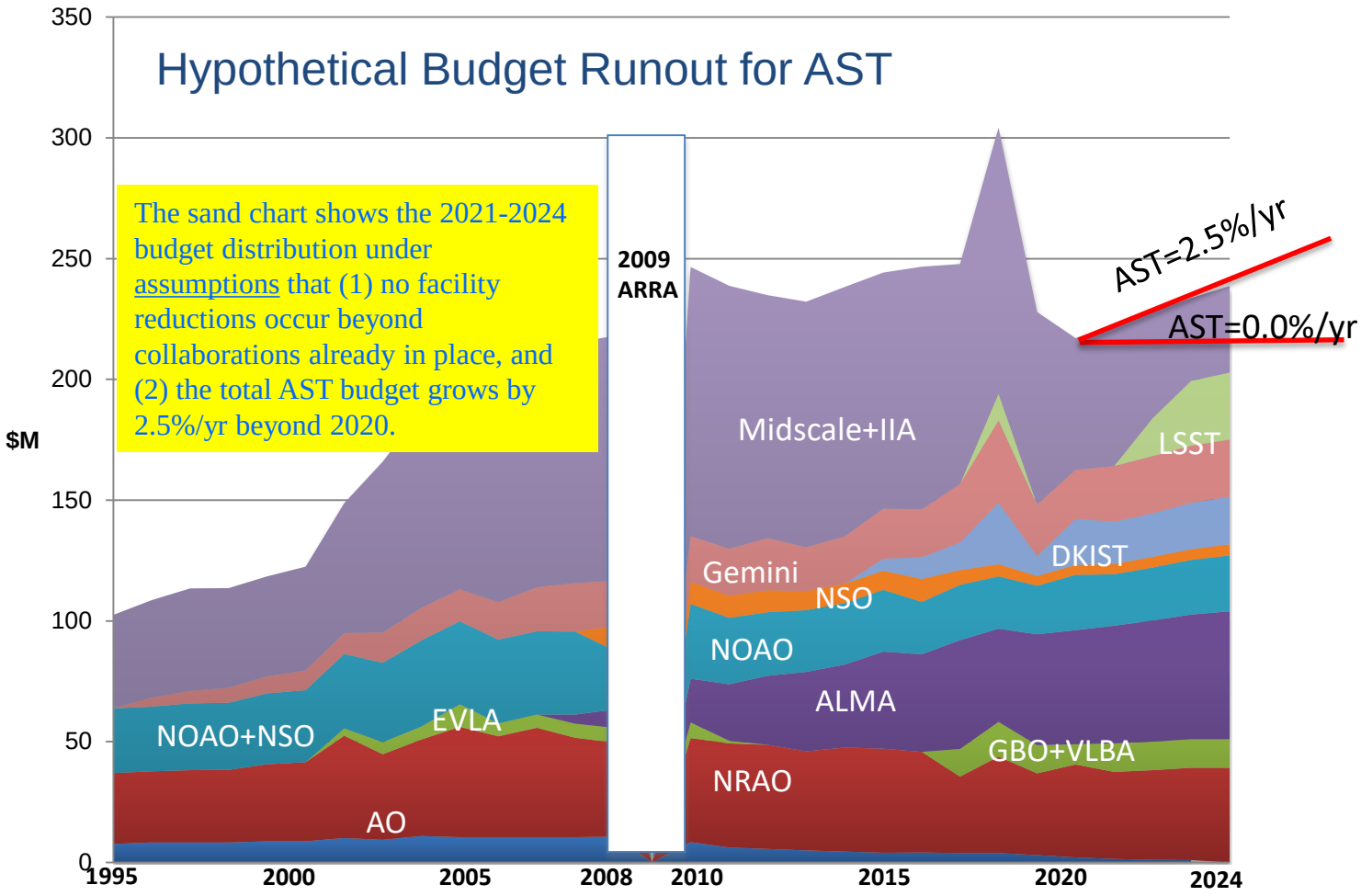
- Enacted appropriation increases R&RA by 3%.
- MREFC line re-incorporates Antarctic infrastructure; DKIST and LSST at requested levels.
- Directorate and Divisional allocations completed. Will be made pubic with approved Execution Plan.
- NSF's bill was not under consideration for passage before the end of FY 18, so operations after Oct 1 were under a Continuing Resolution until Dec 21st.
- Major 35-day shutdown challenge for AST was maintaining flow of funds to facilities awardees, particularly those with Chilean labor contracts. OMB allowed cash draws for previously allocated funding, unlike the 2013 shutdown.
- FY 20 President's Budget Request has been released.

DIVISION OF ASTRONOMICAL SCIENCES (AST)

$217,080,000
-$94,080,000 / -30.2%

AST Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$311.16**	**-**	**$217.08**	**-$94.08**	**-30.2%**
Research	**65.35**	**-**	**43.44**	**-21.91**	**-33.5%**
CAREER	4.17	-	5.00	0.83	19.9%
Education	**4.73**	**-**	**4.70**	**-0.03**	**-0.6%**
Infrastructure	**241.08**	**-**	**168.94**	**-72.14**	**-29.9%**
Arecibo Observatory[1]	8.10	-	2.13	-5.97	-73.7%
ALMA	38.55	-	47.26	8.71	22.6%
AST Portfolio Review Implementation	0.24	-	-	-0.24	-100.0%
DKIST[2]	24.00	-	19.01	-4.99	-20.8%
Gemini Observatory[3]	34.02	-	20.28	-13.74	-40.4%
LSST[4]	11.10	-	-	-11.10	-100.0%
Midscale Research Infrastructure	32.98	-	5.00	-27.98	-84.8%
NOAO[3]	25.09	-	22.91	-2.18	-8.7%
NRAO[3,5,6]	44.46	-	38.40	-6.06	-13.6%
NSO[3]	8.82	-	4.13	-4.69	-53.2%
Other AST Facilities	11.91	-	8.42	-3.49	-29.3%
LBO[6]	*3.49*	-	-	*-3.49*	*-100.0%*
GBO	*8.42*	-	*8.42*	-	-
Research Resources	1.81	-	1.40	-0.41	-22.5%


Hypothetical Budget Runout for AST
The sand chart shows the 2021-2024 budget distribution under assumptions that (1) no facility reductions occur beyond collaborations already in place, and (2) the total AST budget grows by 2.5%/yr beyond 2020.
$M
350
300
250
200
150
100
50
0
1995
2000
2005
2008
2009 ARRA
2010
2015
2020
2024
AST=2.5%/yr
AST=0.0%/yr
Midscale+IIA
LSST
Gemini
DKIST
NSO
NOAO
ALMA
GBO+VLBA
NRAO
NOAO+NSO
EVLA
AO

Issues Illustrated by Sand Chart

- Individual Investigator Program is progressively squeezed by addition of new facilities operations costs, and by attempts to hold constant level of effort for existing facilities.
- FY19 President's Budget Request level may serve as worst case, given Congressional appropriations that have been more favorable.
- AST's tactic is to hold facilities support constant for PBR and to use grants success rate as the capacitor to accommodate final appropriation; facilities operators must otherwise take immediate action to reduce costs = staff.
- Challenge is to make the case that support of individual investigators is the sowing of seeds for the next generation of critical discoveries. Funding stakeholders understand the mission and development of facilities much more clearly.

New Solicitations / Dear Colleague Letters

- The FY 2019 President's Budget request allocates $30M each for Windows on the Universe and Harnessing the Data Revolution and $60M for mid-scale projects.
- These programs can support the rich mix of ground-based data acquisition, development of systems and structures for end-user data science (search for lower σ GW events in the data stream post facto), and the theoretical modeling required for interpretation and prediction. Intended to be funded at this level for several years.
- 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. Astronomers are well positioned to compete and win a larger total of research support than a flat-funded core grants program. (Pie chart showed ~1/4 for grants, sand chart showed typical level of ~$240M, so 8% of $60M is ~$5M. If astronomers get even ¼ of the Windows funding, total grants $ go up.)

Divestment Summary

Telescope	Status
KPNO 2.1m	Caltech-led consortium operating for FY 2016-2020.
Mayall 4m	Slated for DESI; bridge from NSF to DOE; NSF/DOE MOU for transition.
WIYN 3.5m	NOAO share to NASA-NSF Exoplanet Observational Research Program; NSF/NASA MOU in place; NASA instrument under development.
GBO	Separation from NRAO in FY 2017; ~30% collaboration for basic scope; Final Environmental Impact Statement (FEIS) issued in Feb; NSB approval pending. MOA in work for new partner; more new partners desired.
LBO/VLBA	Reintegrated into NRAO in FY 2019; MOA with US Navy in place for 50%.
McMath-Pierce	Funding for utilization as science outreach center.
GONG/SOLIS	GONG refurbishment; Interagency Agreement with NOAA signed to share GONG operations costs. SOLIS moved from Kitt Peak to Big Bear.
Sacramento Pk.	Initial NSF and State funding for consortium led by NMSU; NSO to provide continuing site support; NSB approval for ROD.
Arecibo	UCF new operator, with plans for increasing share; hurricane recovery funding being deployed; challenges with science staff & morale.
SOAR	Post-2020 status to be reviewed.

AAAC Subcommittee on Gemini, Blanco, & SOAR

- The Gemini international agreement is up for renewal in 2021; assessment point this year and all current partners announced intentions to re-up at the Board meeting last Nov.
- SOAR international agreement up in 2020.
- AST and DOE jointly requested AAAC to form an ad hoc subcommittee to evaluate the scientific utility and US community priorities for the telescopes for the next five or so years, as motivation for agency decisions prior to Decadal Survey release.
- Chair was Klaus Honscheid (OSU); the panel examined a wide range of topics from precision cosmology through time domain/multi-messenger and exoplanets.
- Preliminary briefing to AAAC in early November; final report presented to the AAAC in Feb. They found high value for US community science for all facilities.

- Findings

The sub-committee reviewed the science opportunities afforded by Gemini, Blanco, and SOAR over the next 5 years and found them to be strong.

All three telescopes are important and valuable assets to the US OIR program.

- Preparations are well underway to support time domain science in the LSST.
- The GBS system provides strong support for multi-messenger astronomy.
- The traditional science areas reviewed by the sub-committee can be done excellently with the GBS system.
- New instruments and extended AO support are under development.

- Findings

  The NSF focus on multi-messenger astronomy and time domain science is supported by all three telescopes.

  The DOE focus on dark energy science is supported by all three telescopes.

Recommendations

- 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.
- **Recommendation 1**
- NSF should renew the Gemini agreement at the current level.
- **Recommendation 2**
- NSF should renew the SOAR agreement at the current level.
- **Recommendation 3**
- 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.

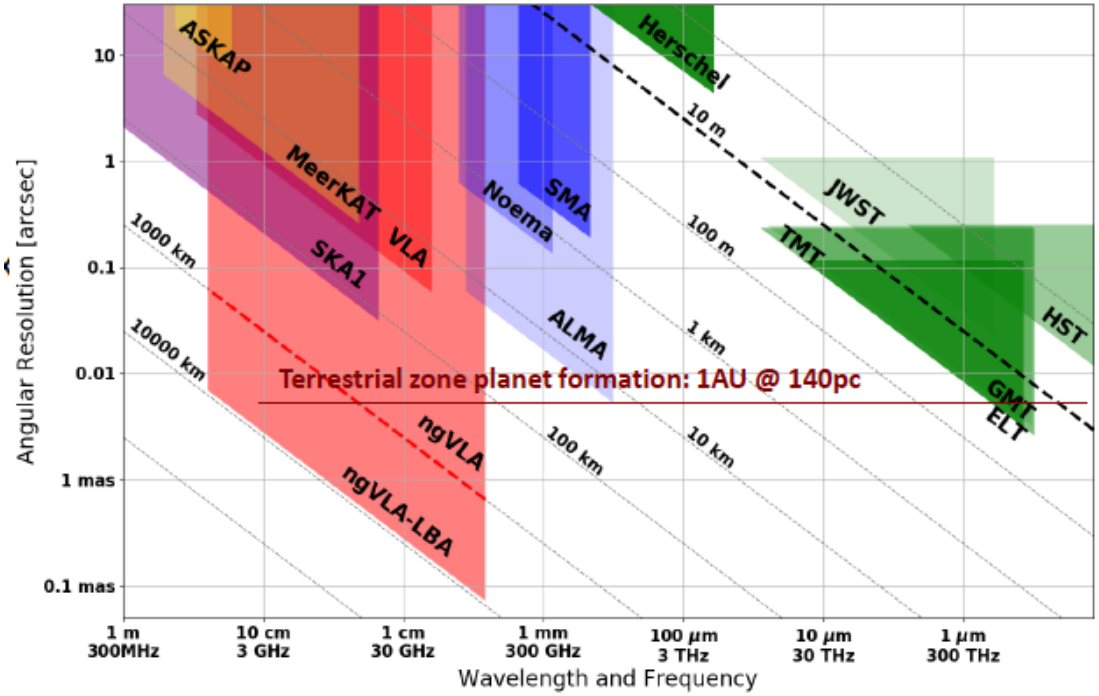
- **Recommendation 4**
- Continue to implement the OIR system related recommendations from the 2015 NRC report and support development of OIR system tools and policies.
- **Recommendation 5**
- Start development of a coordinated scientific program for GBS for the second half of the next decade (2025 - 2030).
- **Recommendation 6**
- Continue to develop the GBS system, and more broadly the entire US OIR system, by adding capabilities currently lacking from the portfolio.

Decadal Survey

- Planning is now well underway for input to the next Astronomy & Astrophysics Decadal Survey.
- NSF/AST and NASA Astrophysics Division are the primary sponsors of the survey. DOE 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 scientific consideration, 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 support a fourth.
- AST does not explicitly support preparation of mid-scale proposals for Decadal submission; these are community-initiated, so the scope and breadth of topics are known only informally to AST.

AST Decadal Survey Preparations

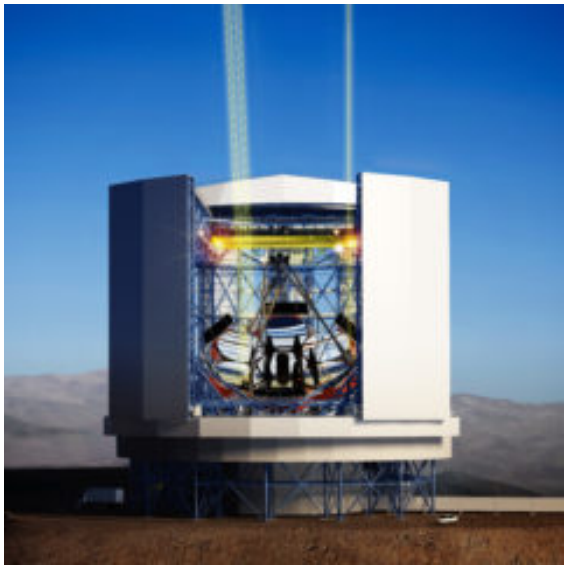
- NRAO held a series of three Kavli-sponsored workshops and one AUI-sponsored to identify and prioritize the key scientific problems the RMS community would address in the coming decade.
- Many of the scientific goals can be achieved with a concept called Next Generation VLA, including
  - Unveiling the Formation of Solar System Analogues
  - Probing the Initial Conditions for Planetary Systems and Life with Astrochemistry



•Funded technical concept studies are underway within NRAO, and science book is linked as ASP Conference 517, with 830 pages and 285 authors.

AST Decadal Survey Preparations

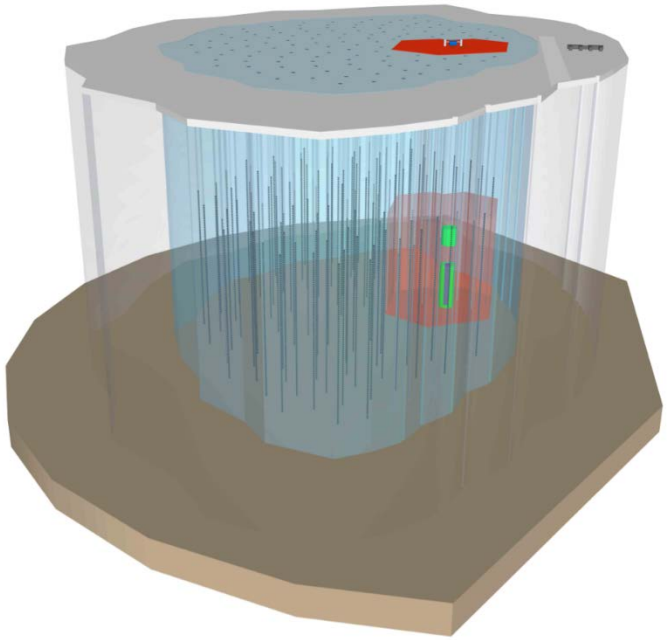
- NOAO is coordinating with the TMT and GMT projects to develop a community science case requiring time on both telescopes through the new US ELT Program. AURA seeking Dave Silva replacement.
- The approach will be based on key science programs, requiring substantial allocations of time.
- Over 250 community scientists working on defining the case, 2/3 unaffiliated with GMT/TMT partner institutions.
- USELTP November workshop with 86 participants, 8 KSP groups with 2 conveners each.
- Anticipating D&D, MREFC proposals this year.



Cosmic Microwave Background (CMB)

- CMB Stage 4 goals: testing inflation, determining the number and masses of the neutrinos, constraining possible new light relic particles, providing precise constraints on the nature of dark energy, and testing general relativity on large scales.
- Two sites: South Pole and Atacama
- Fourteen small (0.5m) telescopes and three large (6m) telescopes, with 512K total detectors
- Report released to AAAC by its subcommittee on 10/23/17.
- Prioritized for DOE support in P5 report.

IceCube-Gen2



- Purpose is in-depth exploration of neutrino Universe in the PeV to EeV range with hundreds of detections above 100 TeV.
- Double the current spacing of photometer strings detecting Cherenkov flashes from 125 to 250 meters and doubling the deployed instrumentation will extend volume to ten cubic kilometers.

- Precision IceCube Next Generation Upgrade (PINGU) denser subarray (shown in green) targets precision measurements of the atmospheric oscillation parameters and the determination of the neutrino mass hierarchy as well as the search for dark matter.
- Proposed surface radio array will detect air showers to allow for vetoing to enhance sensitivity.
- Development supported by OPP and PHY, but part of Decadal considerations for NSF astrophysics.

NSB Report to Congress on Operations Costs

- Linked to NSB website: https://www.nsf.gov/nsb/publications/2018/NSB-2018-17-Operations-and-Maintenance-Report-to-Congress.pdf
- Finds that O&M costs for large facilities developed under MREFC can exceed the 'host' Division's capacity to absorb them fully, in analogy to the original reasons to establish the MREFC line for construction in the first place.
- Recommends Foundation-level ownership of the facilities portfolio with strategic ability to manage support.
- Foundation-level allocation of O&M funds could be possible as supplement to Division-level funding for initial cost sharing (5-10 years max at <50%).
- Foundation-level O&M funding could be used to smooth the transition from construction to operations.
- It could also be used when a Division needed to divest but the Foundation had strategic interest in continuation.

Valuable Recommendations from Decadal Survey

- Scientific priorities!
  - Broadening of scope to include multi-messenger ground-based observations is primarily to understand how investigations fit into overall discovery potential for the next decade.
- Broader scope unlikely to change internal Divisional structure with respect to program homes – GW in Physics, CMB in Polar, etc.
- In optimistic scenario, prioritizing of large programs defines order of entry into MREFC queue.
- For NSF, Decadal Survey recommendations are similar to those of (FACA) review panels – extremely valuable, well informed advice in the assembly and management of investments in the overall program.