U.S. DEPARTMENT OF ENERGY | Office of Science

Status of the DOE High Energy Physics Program

AAAC meeting

January 25-26, 2018

Kathy Turner - Program Manager, Cosmic Frontier

Office of High Energy Physics

Office of Science, U.S. Department of Energy

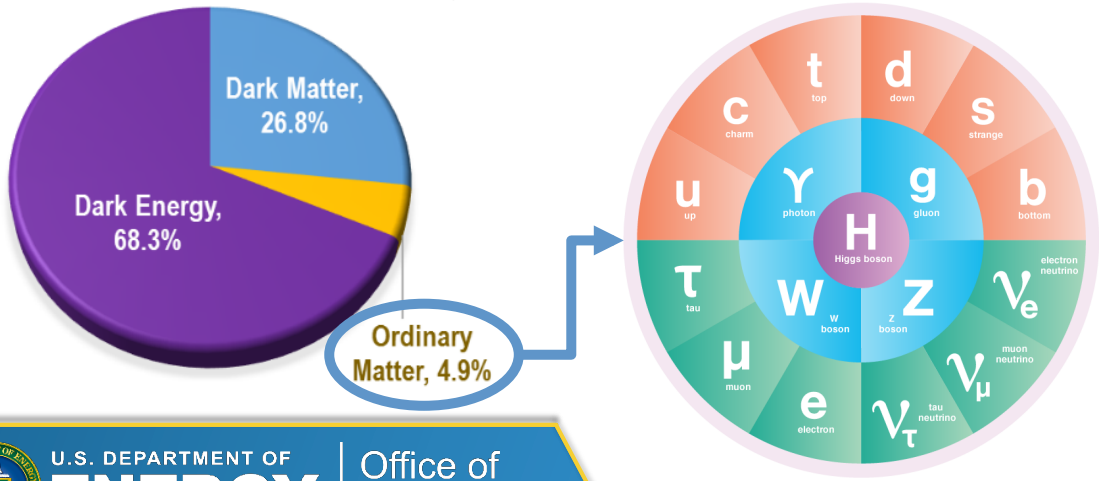
The High Energy Physics Program Mission

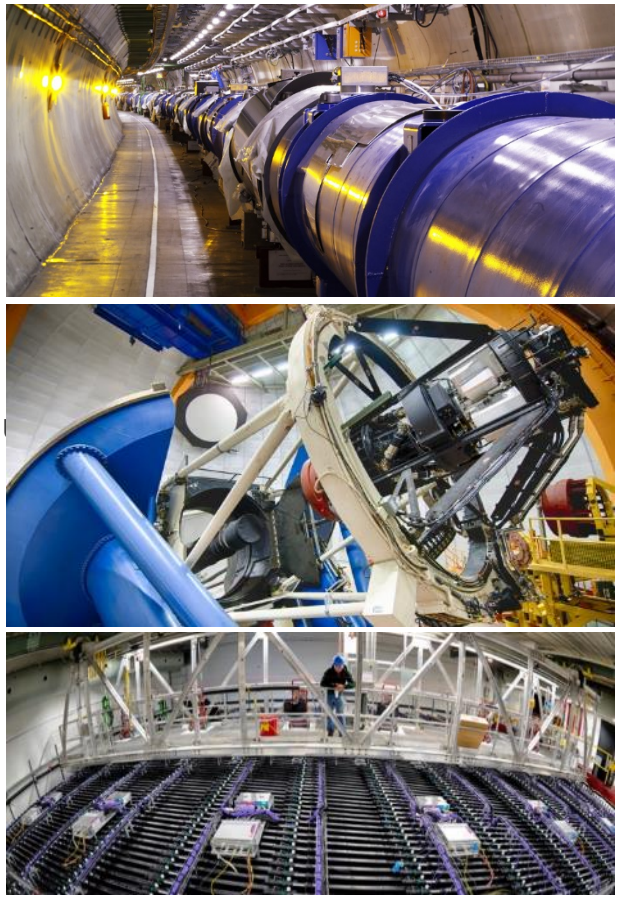
… is to understand how the universe works at its most fundamental level:

- Discover the elementary constituents of matter and energy
- Probe the interactions between them
- Explore the basic nature of space and time

- The DOE Office of High Energy Physics fulfills its mission by:
  - Building **projects** that enable discovery science
  - Operating **facilities** that provide the capability for discoveries
  - Supporting a **research** program that produces discovery science

HEP supports research efforts by scientists on collaborations throu
order to world-leading science.



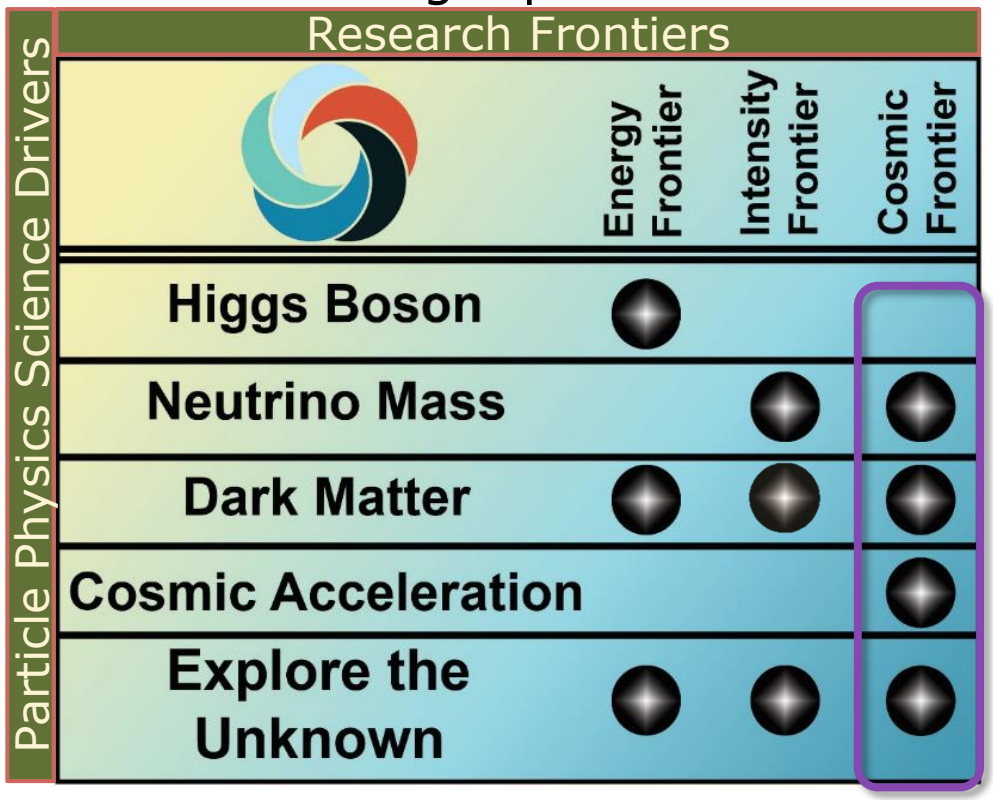


Enabling the Next Discovery

HEP Program is guided by the 2014 "P5" Strategic Plan

- P5 (U.S. Particle Physics Project Prioritization Panel) identified 5 Science Drivers to address the scientific motivation of particle physics
- Research Frontiers are useful categorization of experimental techniques and serve as the basis of the budget process

- Research Frontiers are complementary
  - No one Frontier addresses all science drivers
  - Each Frontier provides a different approach to address science driver
  - Enables cross-checking scientific results



HEP Budget: Status of FY 2018 Budget

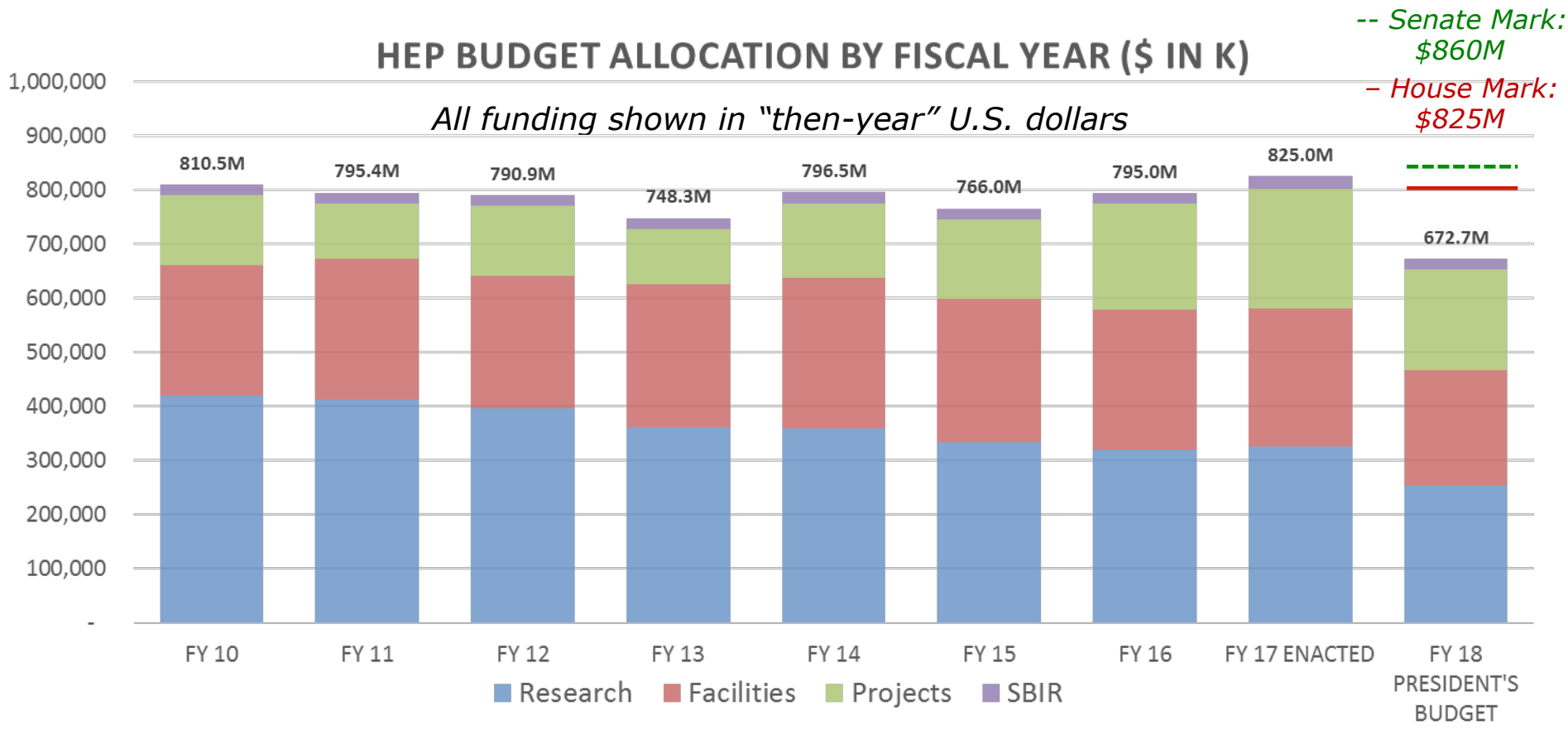
➔**FY17:** HEP received $825M in the FY 2017 Congressional Appropriation, about $7M above the FY 2017 President's Request

➔**FY18:** President's Request for HEP of $672.7M is guided by priorities of Administration, Office of Science, & 2014 P5 plan

- U.S. House of Representatives released draft language for the FY 2018 budget in June 2017; U.S. Senate in mid-July 2017
  - Language is supportive of HL-LHC Accelerator Project, HL-LHC ATLAS and CMS Upgrade projects, LBNF/DUNE, and **Cosmic Frontier projects**
  - Research funding will by necessity continue to be constrained, but efforts critical to executing the P5 recommendations remain a priority
- Congressional Marks are budget indicators, but final appropriation bill and report language directs program implementation
- Another Continuing Resolution (CR) was passed earlier this week; through February 8.

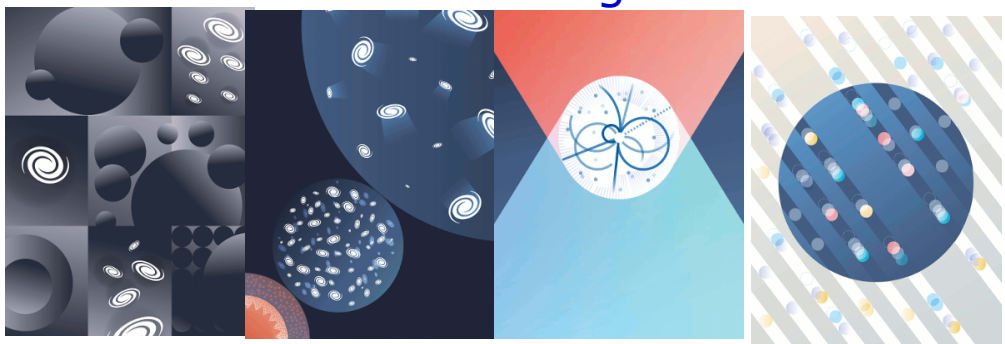
→Planning the HEP program is challenging due to the significant differences in the Request, House & Senate marks, and short term CRs.

HEP Budget Status



Cosmic Frontier Experimental Program

→Pursues 4 of the 5 science drivers from the 2014 P5 Strategic Plan



Dark Matter | Cosmic Acceleration | Explore the Unknown | Neutrino Mass

Science priorities are aligned with the 2014 P5 strategic plan:

- P5 recommended a complementary suite of projects to advance understanding of the nature of dark matter and dark energy, and to support CMB experiments as part of core program

Program Areas:

Dark Energy, Dark Matter, CMB, Cosmic-ray & Gamma-ray experiments

- HEP-related efforts in Theory, Detector R&D, accelerator-based experiments

Cosmic Frontier – FY18

FY18 Status & Outlook

- **Operating experiments** continue to advance & produce science results

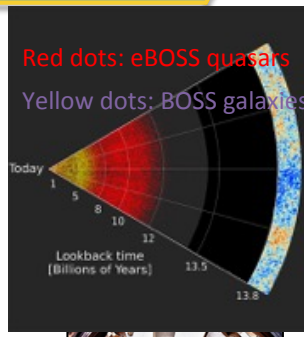
- **Projects:** Priority is on executing the 4 P5-recommended Major Item of Equipment (MIE) projects, currently in fabrication phase: **LSSTcam, DESI, LZ, SuperCDMS-SNOLAB**
  - FY18 Request prioritizes efforts on LZ, slows DESI and SuperCDMS-SNOLAB
  - House and Senate FY18 Marks address these issues.

  Efforts are also underway to plan the next phase
  - Develop and review each project's experimental operations plan
  - Task force to investigate optimizing computing needs across Cosmic Frontier

- **Future Planning**: Laying ground work for the future
  - These are mainly science studies; R&D funds are VERY limited.

Dark Energy

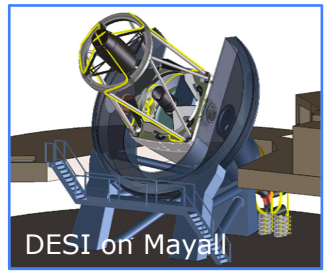
Staged, complementary suite of imaging and spectroscopic surveys (in partnership with NSF-AST)
-- Will enable precision measurements to differentiate between: cosmological constant and/or new fields; or modification to General Relativity



Operating:
– ***eBOSS*** – Stage III spectroscopic in New Mexico started in 2015 with current HEP grant through mid-FY18
– ***Dark energy Survey –*** *Stage III* imaging in Chile started 5-year survey in late FY13

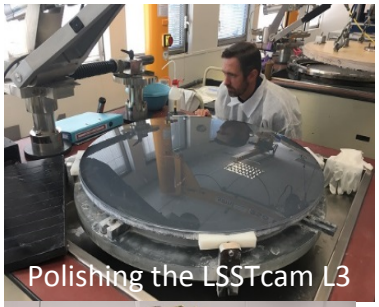
In Fabrication phase:
– **Large Synoptic Survey Telescope (LSST)** - Stage IV imaging
***Dark Energy Spectroscopic Instrument* (DESI)** - Stage IV spectroscopic

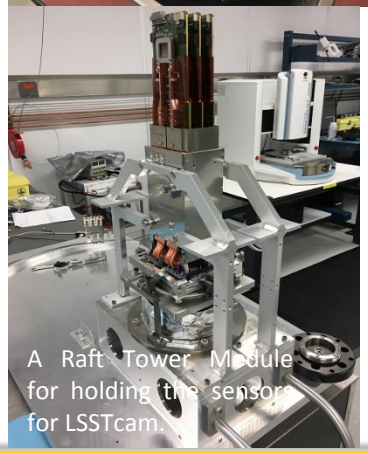
Future Planning: Dark Energy future directions community workshops held; Investigate optimizing science in DESI/LSST era and/or follow-on projects; will produce a White Paper



Large Synoptic Survey Telescope (LSST)


The finished cryostat grid protected by a Plexiglas shield


Polishing the LSSTcam L3


A Raft Tower Module for holding the sensors for LSSTcam.

The Stage IV, next-generation, wide-field LSST facility in Chile is designed to provide deep images of half the sky every few nights, enabling study of the nature of dark energy using multiple cosmological probes.

DOE-HEP & NSF-AST partnership:

- NSF leads the LSST project and is responsible for the 8.4m telescope facility and data management system.
- DOE is responsible for providing the LSSTcam: CD-3 approval 2015; early delivery planned in FY20, followed by commissioning.

Status

- LSST Project Status review Sept. 2017; next July 2018
- LSST Facility Operations phase being planned
  – DOE & NSF proposal review in Dec. 2017; full science operations planned to start FY23
- Dark Energy Science Collaboration (DESC) operations plan review spring 2017; next one 2018

Dark Energy Spectroscopic Instrument (DESI)

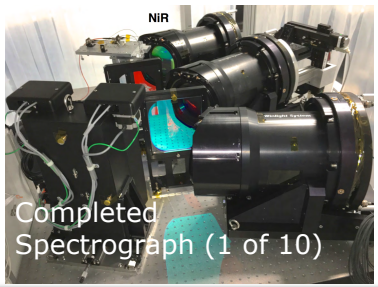
DESI's Stage IV spectroscopic survey will measure 30 million spectra of galaxies & quasars to map their 3-D positions and determine the growth of cosmic structure over 10 billion years; uses Baryon Acoustic Oscillation and Redshift Space Distortion growth and other methods

DOE leads the DESI experiment. The DESI project will provide the new spectrographs and associated systems to be mounted and operated on the Mayall telescope at Kitt Peak.

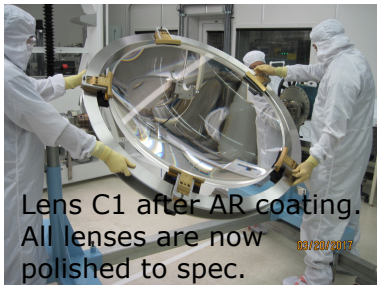
- HEP has MOU's w/NSF-AST to "lease" the Mayall telescope; ramping up partial support in FY16-18; full support for dark energy ops starting FY19

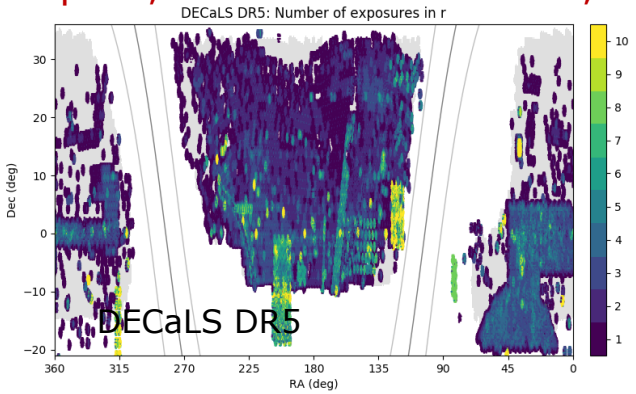
Status

- DESI project CD-3 approval June 2016
- Review of Project status & Operations plan in Feb. 2018
- Mayall shutdown in Feb. 2018; Full dark energy survey operations starting FY20
  - All lenses polished and coated, all petals manufactured
  - DECaLS: DECam Legacy Survey, covering 2/3 of DESI footprint, had DR5 in Oct. 2017; now 75% complete



Completed Spectrograph (1 of 10)


Lens C1 after AR coating. All lenses are now polished to spec.



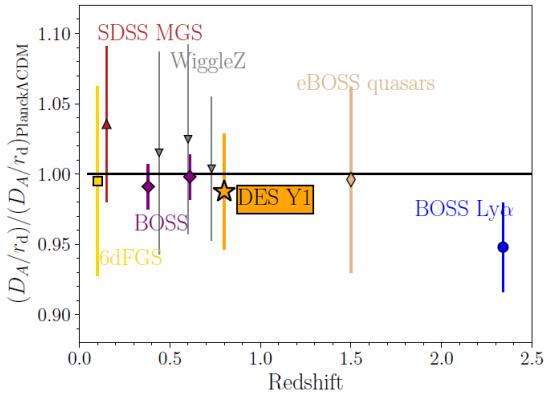
Science Highlight – Dark Energy Survey (DES)

- DES probes Dark Energy via survey of 300 million galaxies & 3000 supernovae, using 570-megapixel Dark Energy Camera on Blanco 4-meter telescope in Chile
  - Operations started August 2013; now in 5th year (of 5) of observing. Collaboration proposing to extend operations through Dec. 2018.

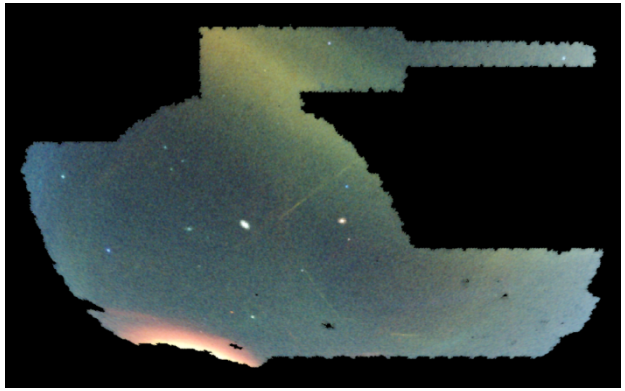
Results:

- Aug. 2017: Year 1 Cosmology results from galaxy clustering & weak lensing; constraints competitive with Planck CMB
- Dec. 2017: Year 1 Cosmology results from BAO to z=1; results competitive with WiggleZ, BOSS BAO measurements
- Jan. 2018: Data Release 1; first 3 years of survey data for full 5000 sq. deg. now public
- Well over 100 papers submitted and accepted; e.g., most distant supernova, new Milky Way dwarf satellites to constrain dark matter, 11 new Milky Way stellar streams

Year 1 BAO measurements vs. Planck ΛCDM predictions. Consistent with previous BOA measurements.



DES DR1 5000 sq. deg. spatial density of stars. (Blue is closer, red is more distant.) Streaks are stellar streams.

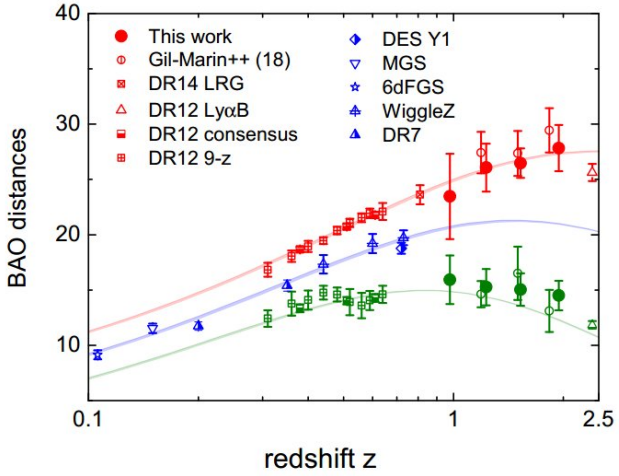


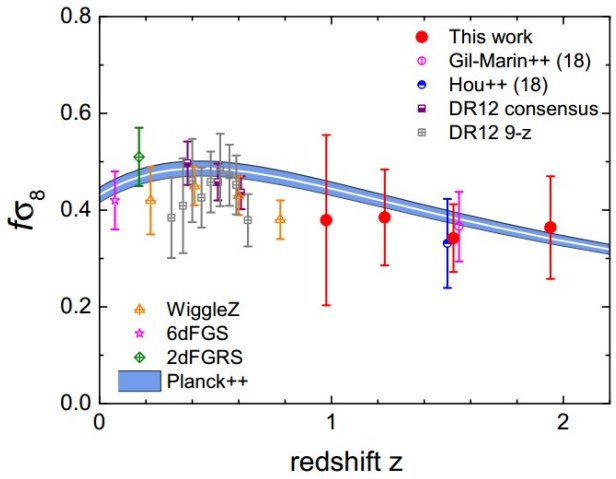
Science Highlight – eBOSS

- Extended Baryon Oscillation Spectroscopic Survey (eBOSS) is a cosmological spectroscopic survey on the 4th generation of the Sloan Digital Sky Survey (SDSS-IV) at Apache Point Observatory
  - DOE funded a spectrograph upgrade for SDSS-III (BOSS)
  - HEP grant to support eBOSS operations goes through mid-FY18

Results:

- May 2017: First measurement of BAO between z = 0.8 and 2.2
- Jan. 2018: First measurement of Redshift Space Distortions (RSD) using Quasars between z = 0.8 and 2.2
- Both consistent with Planck ΛCDM





eBOSS Quasar measurements of BOA parameters (left) and RSD (right) are filled circles, compared to other results. Bands are based on Planck ΛCDM parameters.

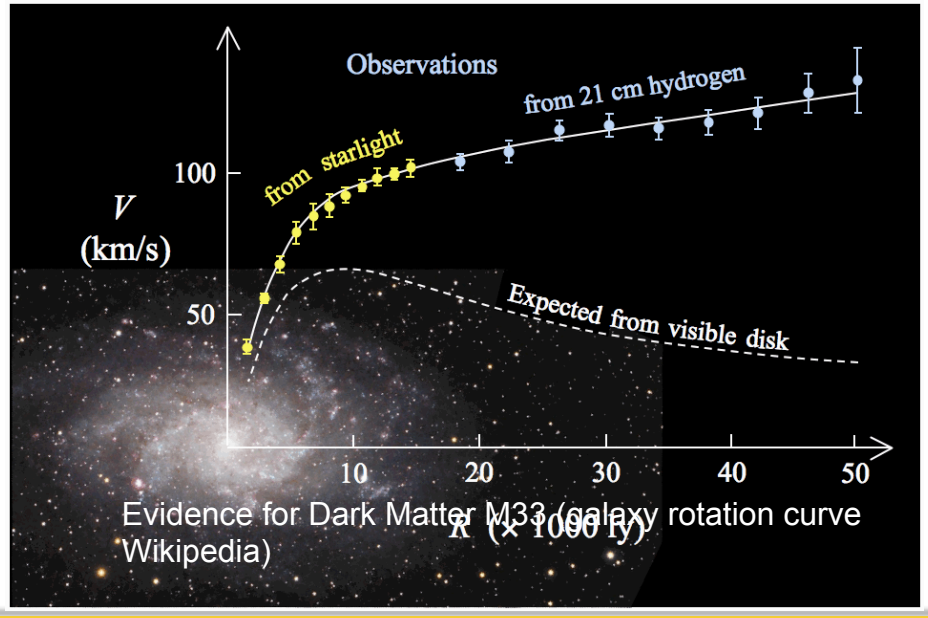
Direct Detection Searches for Dark Matter (DM)

Staged suite of complementary direct detection experiments with multiple technologies to search for dark matter particles

- 3 Generation-two projects were selected by HEP & NSF-PHY in July 2014 following P5 report: **ADMX-G2, LZ, SuperCDMS-SNOLAB**
- High- and low-mass WIMP sensitivity; Axion (very low mass) searches

Operating/Completed:

- Completed HEP support for operations on current DM-Generation 1 (DM- G1) experiments in FY16/17: ADMX-II, LUX, CDMS-Soudan, DarkSide-50, COUPP/PICO, DAMIC -- some continue with other funding sources
- **ADMX-G2** axion search at UWash (HEP); Science ops started Jan 2017 & goes through FY20



Evidence for Dark Matter M33 (galaxy rotation curve Wikipedia)

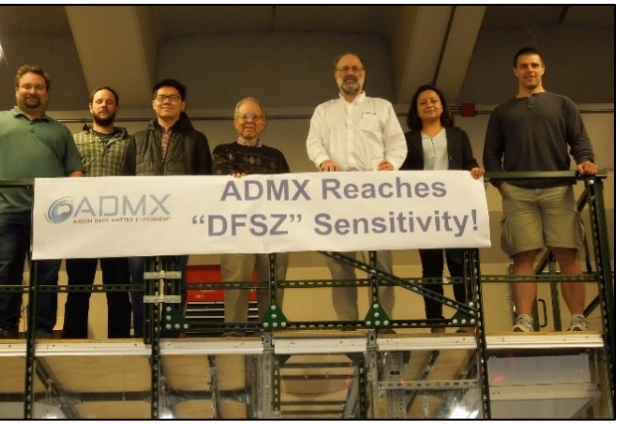
Science Highlight – ADMX-G2

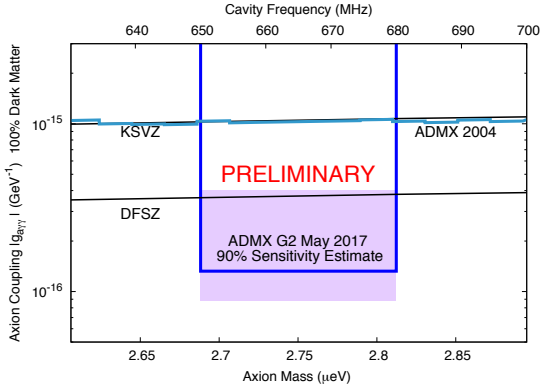
Axion Dark-Matter eXperiment Generation 2 at Univ of Washington

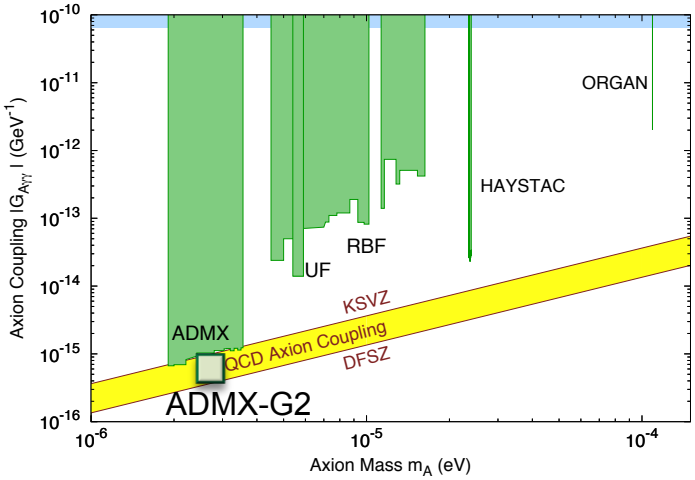
- Uses a strong magnetic field and resonant cavity to convert dark matter axions into detectable microwave photons
- Selected as one of three G2 dark matter experiments following P5
  - Currently stepping through range 0.5 to 2 GHz (~ 2 to 8 micro-eV)
  - Dec. 2017 review of operations status (now led by Fermilab)

Results:

- May 2017: ADMX reaches DFSZ sensitivity limit at 650 – 680 MHz. First time this limit reach for any axion mass range!





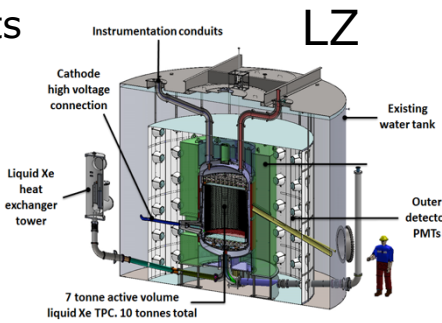


Direct Detection Searches for Dark Matter (DM) cont.

In Design, Fabrication:

LZ at Homestake Mine in South Dakota (HEP)

- WIMP search through dual phase liquid Xe over ~10-1000 GeV mass
- In fabrication phase; CD-3 approved Feb 2017; science operations starts FY21
- Review of Project status & Operations plan in Jan. 2018



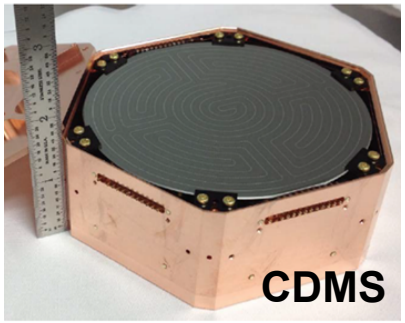
SuperCDMS-SNOLab in Canada (HEP+NSF-PHY partnership)

- WIMP search using cryogenic solid-state crystals over ~1-10 GeV mass
- In final design phase; CD-1 approved Dec. 2015; science operations starts FY21
- CD2/3a review Jan. 2018; Review of operations planning spring 2018

Future Planning:

→P5 recommendation to include small projects in the program

- Now Laying groundwork for small DM projects
- Dark Matter Community workshop held March 2017 to update identification of scientifically compelling areas to search, see https://arxiv.org/abs/1707.04591
- Next step, starting later in FY2018, is to determine which science areas DOE-HEP should focus on and whether there are concepts for small projects to investigate these.



Cosmic Microwave Background (CMB)

Study cosmic acceleration (inflationary epoch) at energies near the Planck scale and dark energy and neutrino properties using the CMB, the oldest visible light (with NSF)

Operating

- ***SPT-3G*: HEP support towards major upgrade of camera; Operations started Jan. 2017**
- Research-only activities on a number of the current experiments; Lab involvement via LDRD

Future planning

As recommended by P5, HEP is planning to participate in a next-generation, 10x more sensitive array, the **CMB Stage 4 (CMB-S4)**

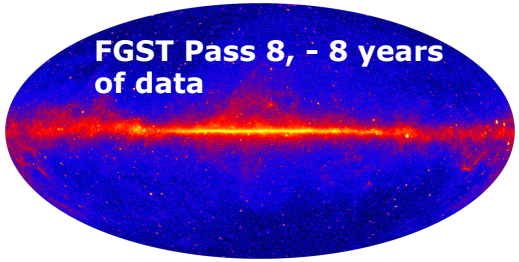
- AAAC approved the CMB-S4 Concept Definition Taskforce (CDT) report in Oct. 2017
  - describes science goals, technical requirements, and a strawman concept(
  - https://www.nsf.gov/mps/ast/aaac/cmb_s4/report/CMBS4_final_report_NL.pdf
  - https://science.energy.gov/~/media/hep/hepap/pdf/201712/Day2/Lawrence_CMB-S4_CDT_for_HEPAP_12-01-2017.pdf
- DOE/HEP and NSF meetings to coordinate
- HEP lab groups have set up a pre-Project Design Group (pPDG) in coordination with the CMB-S4 collaboration, for pre-conceptual planning,

Cosmic-ray & Gamma-ray physics

- Use ground-based arrays, space telescopes, and an experiment on the International Space Station (ISS) to perform indirect searches for dark matter, fundamental physics & high energy acceleration mechanisms
  - Many significant inter-agency & international partnerships

Operations - HEP Roles Completed:

- VERITAS (2017), Pierre Auger (2016)



Operations - HEP Roles Continue:

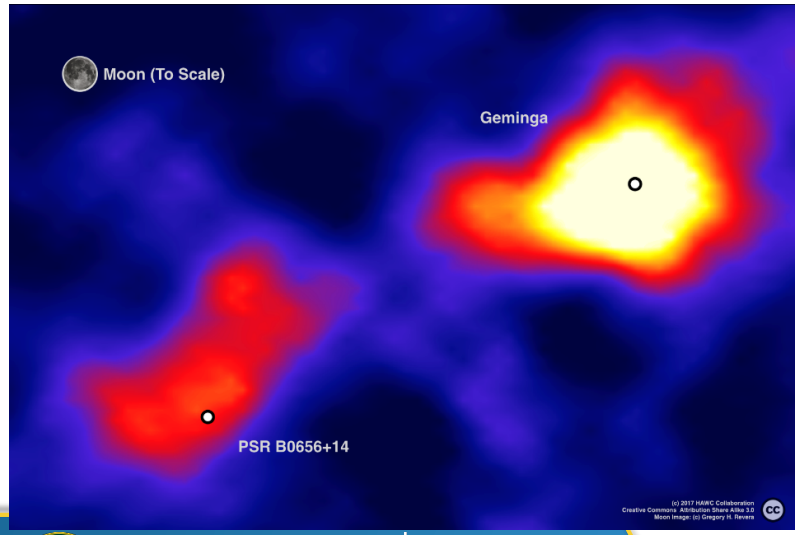
- *Fermi/GLAST (w/NASA); launched June 2008*
  - HEP is supporting the Instrument Science Ops Center at SLAC;
  - In coordination with NASA, HEP is planning to continue support of critical efforts at SLAC if operations > 10 years
- *AMS (w/NASA) on the ISS; started 2011*
- *HAWC (w/NSF) in Mexico;* 5 year operations started early 2015

Science Highlight – High Altitude Water Cherenkov (HAWC)

- 100 GeV to > 100 TeV γ-rays, in Mexico
  - Indirect dark matter search from γ-ray annihilation & decay; Quantum gravity effects on propagation of γ-rays; Particle acceleration in extreme conditions
- 5 year all-sky survey started March 2015

Results:

- Nov. 2017: ruled out two pulsars as the source of positron excess at Earth.
- detected gamma-ray haloes that would not exist if positrons were travelling as fast as needed. Other explanations, such as dark matter, may be needed to account for positrons.

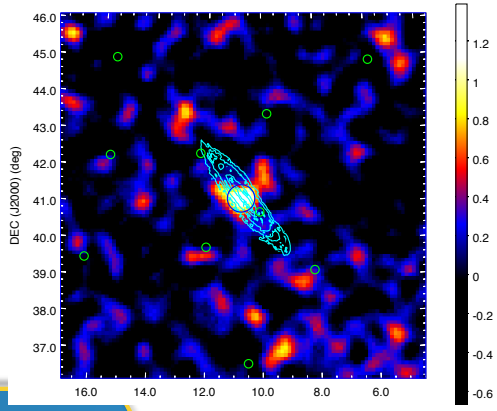


HAWC with its wide field of view sees the pulsars Geminga and PSR B0656+14 as broad beacons of gamma rays that appear much larger in angular extent than Earth's moon (which is shown for scale). Extended emission indicates positron diffusion is slow.

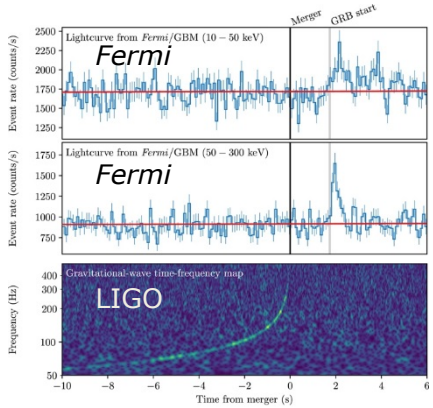
Science Highlight: Fermi Gamma-ray Space Telescope

- Study high-energy (~20 MeV->300 GeV) gamma-rays using particle physics detector technology in space. Indirect Dark Matter (DM) detection; high-energy acceleration mechanisms
  - Launched June 2008 for 5-year mission with 10-year goal; NASA Senior Review Panel (SRP) in 2016 recommended continuation of the Fermi science mission through FY18. SRP will review again in 2019 (SRPs now occur every 3 years).
- Results
  - May 2017: Gamma-ray emission of M31 (nearest large spiral galaxy) is correlated with its center. Competing interpretations are: unresolved pulsars or dark matter annihilation (would be in tension with dSph satellite limits)
  - Aug. 2017: Fermi GBM triggered on a GRB 1.7s after the LIGO merger. The GRB lasted about 2 seconds. (Also detected by INTEGRAL)

LAT gamma-ray excess toward center of M31 (>1 GeV, foreground subtracted)



GBM detection of GRB170817A 1.7s after GW170817



SCIENCE PORTFOLIO REVIEW

DOE HEP Portfolio Review

HEPAP was charged (Oct. 2017) to carry out a Portfolio Review

-- Modeled on NSF Portfolio Review and NASA Science Reviews

Why:

- Given the current budget outlook, we think it is imperative to take a close and critical look at currently operating HEP experiments and how effectively they are advancing the P5 plan
  - Portfolio Review is the process we have created to implement this
  - Overarching goal is to maintain and optimally execute the P5 plan

Note: The Cosmic Frontier has had reviews of operating experiments in the past; what's new is it is now in the context of the entire program.

What:

- Independent peer review of currently operating experiments supported by HEP
- Will focus on scientific impact and productivity of HEP-supported contributions
- HEP will use the results to define a detailed implementation plan for P5 strategic vision in the FY19 to FY22 timeframe
- HEP management will ensure that key officials in institutions or agencies that are partners in operating experiments are apprised of the plans for the HEP Portfolio Review as well as resulting decisions.

DOE HEP Portfolio Review

Experiments being reviewed:

- Includes all currently-supported HEP experiments that have taken physics data for at least two years, and are expected to request significant DOE support for operations or related activities (e.g., computing) beyond FY 2018
- There are 2 separate subpanels:
  1. LHC subpanel is chaired by Hugh Montgomery & covers ATLAS and CMS
  2. "Main" subpanel is chaired by Paul Grannis covers **AMS, Fermi-GLAST, HAWC, DES, eBOSS in the Cosmic Frontier**, along with 8 Intensity Frontier experiments (Daya Bay, K0TO, MicroBooNE, Minerva, NA61/ SHINE, NOvA, SuperK, T2K)

Schedule

- HEPAP charged Oct. 2017
- Proposals and materials are due Feb. 1, 2018
- Subpanels will meet F2F at the end of February & end of March.
- Reports will be provided to HEPAP for approval in May 2018

More information →

- *See Glen Crawford's HEPAP Dec. 2017 Presentation at:*

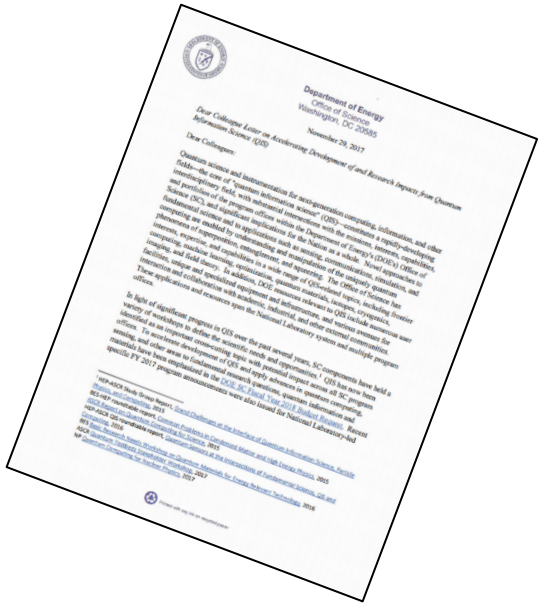
https://science.energy.gov/~/media/hep/hepap/pdf/201712/Day1/Crawford_2017-11-30_DOE_Portfolio_Review.pdf

- Charge letter, instructions and FAQ at: https://science.energy.gov/hep/hepap/reports/

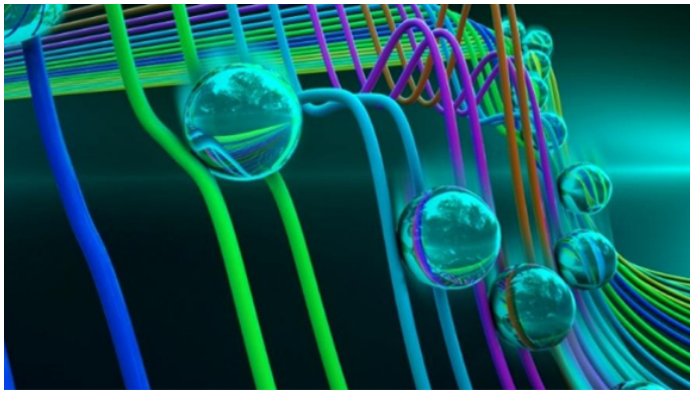
QUANTUM INFORMATION SCIENCE (QIS)

SC Dear Colleague Letter on QIS

- Office of Science (SC) Dear Colleague Letter (DCL) released Nov. 29, 2017
- Quantum Information Science (QIS) identified as an important cross-cutting topic with potential impact across all SC program offices
- Should be taken as a statement of interest in encouraging activity in this field
- Encourages submission of innovative research ideas in QIS via any appropriate existing mechanism
- The DCL is not a solicitation and does not add to the scope of, or change the review criteria of, any published announcement

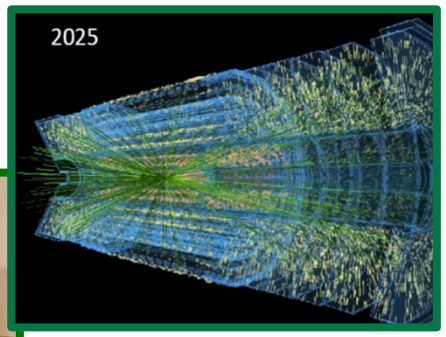


For full text, see "What's New" at: https://science.energy.gov/sc-2



QIS in the HEP program

- Emphasis is on HEP mission, science drivers, and advancement of QIS in the context of the broader SC initiative
- Program Manager for QIS at HEP: Lali Chatterjee
- FY 2018 Request includes **~$15M for QIS**, prioritized as:
  - Fundamental HEP and QIS research
    - Foundational concepts of quantum information
    - Field theory and analog simulations
    - Experiments and emulators
  - Supporting technology for HEP
    - Quantum computing
    - Quantum controls and sensors



- **Funding Opportunity Announcement** (FOA) and Lab Program Announcement in development for potential release after appropriations
- **HEP has posted a RFI** seeking input on the intersection of HEP and QIS. It is linked from the HEP home page (science.doe.gov/hep) and closes Feb. 12, 2018.

Grants, Awards

DOE Office of Science Early Career Awards

HEP had 11 awards in FY17
→ Winners in the Cosmic Frontier

Anja von der Linden
Stony Brook University
Galaxy clusters – for Dark Energy

Michael Schneider
Livermore National Lab
Weak lensing – for DE

... and Cosmic Frontier-related Detector R&D and Theory awards

Zeeshan Ahmed
SLAC
Expert in CMB detectors

Marilena LoVerde
Stony Brook University
Expert in cosmological neutrinos

Cosmic Frontier – Statistics on Comparative Review Research Grants

		FY12	FY13	FY14	FY15	FY16	FY17
Cosmic $M request Y1-3		$3.3	$7.7	$7.5	$6.8	$7.8	$24.6
Cosmic $M request Y1		$3.3	$7.7	$7.5	$6.8	$7.8	$7.6
Cosmic $M funded Y1		$1.6	$3.4	$4.4 w/FFF	$3.3 w/FFF	$4.3M w/FFF	$4.7M w/FFF
Cosmic - proposal counts							
	received	11	33	29	27	43	31
	reviewed	10	28	28	27	36	26
	funded	6	18	19	14	21	18
	success rate	60%	64%	68%	52%	58%	69%
Cosmic CR - PI counts							
	received	21	61	40	43	65	49
	reviewed	20	54	38	43	55	43
	funded	13	27	25	21	25	26
	success rate	65%	50%	66%	48%	45%	60%

Notes:

- FFF = Fully Forward Funding required if grant < $1M
- Typically the total of all requests is for ~2-3X the funds we have available.
- We typically fund the grants at less than their request; Reduced research scope is negotiated with PI(s) if needed
- FY18 grants are in process; funding very constrained while waiting for an approved budget

Cosmic Frontier – Statistics on Early Career Awards (universities & labs)

	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17
# received - Univ	11	8	12	16	6	7	7	8
# received - Lab	10	4	7	9	7	5	6	5
# funded - Univ	**2**	**1**	**2**	**1**	**1**	**0**	**1**	**1**
# funded - Lab	**0**	**2**	**1**	**1**	**0**	**0**	**0**	**1**

Awards (5-year):

FY10
Newman (Pitt)
Mahapatra (TAMU)

FY11
Chou (FNAL)
Slosar (BNL)
Hall (Maryland)

FY12
Mandelbaum (CMU)
Padmanabhan (Yale)
Carosi (LLNL)

FY13
Bolton (Utah)
Chang (ANL)

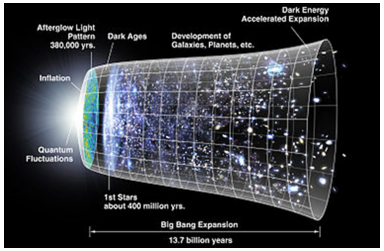
FY14
Dahl (Northwestern)

FY15: none

FY16
Rozo (Arizona)

FY17
von der Linden (SUNY-SB)
Schneider (LLNL)

Summary & Conclusion



- HEP is maintaining the core of the DOE Science Mission
  - HEP is delivering exciting discoveries, important scientific knowledge, and technological advances
  - Program priorities will continue to be driven by the P5's compelling, realistic strategic plan
    - Cosmic Frontier has staged program of currently operating experiments, projects in fabrication and planning for the future, to make significant advances aligned with the P5 science drivers.
    - HEP looking forward to participation in the National Academy of Science's 2020 Astronomy & Astrophysics Decadal Survey

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