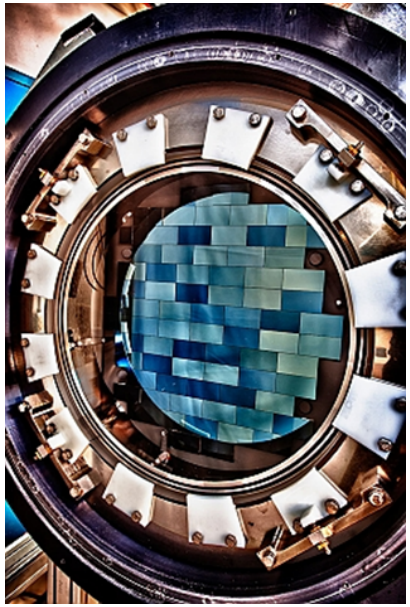
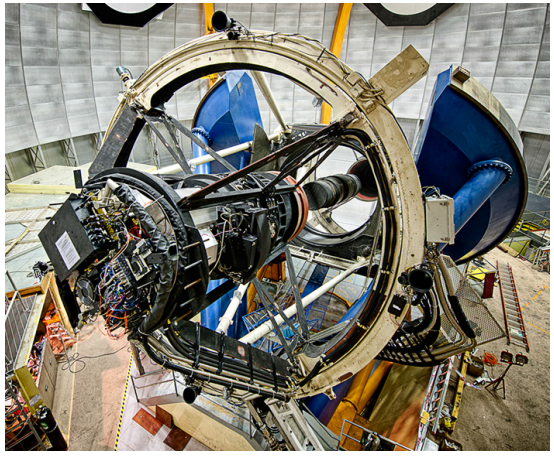
# DOE High Energy Physics (HEP) Cosmic Frontier Subprogram

## Update to HEPAP



Dark Energy Survey's (DES) Camera (DECam) on the Blanco Telescope in Chile



**2 December 2016**
**Kathy Turner**

**HEP Cosmic Frontier Program Managers:**
**Anwar Bhatti (IPA), Eric Linder (IPA), Michael Salamon, Kathy Turner**

# Outline

- **Cosmic Frontier – Mission, Program Areas, Guidance**
- **Program Planning, P5 Implementation**
- **Program Status**
- **Interagency & International Activities**
- **Cosmic Visions (CV) Groups – looking towards the future**
- **Cosmic Microwave Background Stage 4 (CMB-S4) planning & Concept Definition Taskforce (CDT) subpanel**
- **Dark Matter – planning & opportunities**

# Cosmic Frontier Program – Mission, Areas, Guidance


**Cosmic Frontier:** Through ground-based telescopes, space missions, and deep underground detectors, research at the cosmic frontier aims to explore dark energy and dark matter, which together comprise approximately 95% of the universe.

## Program Areas

- Study the nature of **Dark Energy**
- Direct Detection searches for **Dark Matter** particles
  - **CMB –** Inflationary era, Neutrino properties
- **Cosmic-ray & Gamma-ray & Other** studies – particle properties, high energy acceleration mechanisms, indirect searches for dark matter particles, computational cosmology

## Program Guidance

**FACA panels** provide official advice:

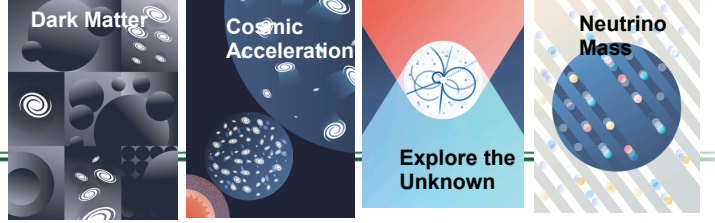
- **HEPAP**– Primary advice for the program
  Subpanels: **P5 2014** (previously P5 2008, PASAG 2009)
- **AAAC (**Astronomy and Astrophysics Advisory Committee) - Advises DOE, NASA, and NSF and Provides Annual Report to Congress et al.
  - Subpanels: **CMB-S4 CDT** starting; (previous w/HEPAP: TFCR 2006, DETF 2006, DMSAG 2007

**National Academy of Sciences (NAS)**

- Reports: New Worlds New Horizons Decadal Review of Astronomy & Astrophysics (2010) “Mid-decade review” (2016)

**Community science studies and input** (e.g. Snowmass, Cosmic Visions groups)

# Cosmic Frontier – Program Guidance




## NAS New Worlds New Horizons 2010 report:

- Recommended that, at the lower funding scenario, DOE participate in **LSST** with NSF ahead of WFIRST with NASA since DOE is making a larger relative $ contribution and its technical role is thought to be relatively more critical.
  - → Moved forward on LSST w/NSF-Astronomy

## P5 Strategic Plan (May 2014) Recommendations:

- **Dark Energy:** Complete **LSST** as planned; Build **DESI**
- **Dark Matter:** Broad Dark Matter Generation 2 (**DM-G2)** program at higher than planned funding; **DM-G3** starting later in P5 decade, guided by DM-G1,G2
- **Cosmic Microwave Background (CMB): support science as part of core program**
  - Stage 4 project **(CMB-S4**) starts mid-way through the P5 decade.
- Cosmic Rays and Gamma Rays - Invest in CTA only if NSF Astronomy moves forward

**2016 AAAC annual report:** see backup for detailed HEP-related guidance & response
**See https://www.nsf.gov/mps/ast/aaac.jsp**

**2014 AAAC - Principles for Access to Federally funded Astrophysics Facilities**
(see https://www.nsf.gov/mps/ast/aaac/aaac_2014_principles_for_access.pdf)

**2016 NAS Mid-Decadal report:** see backup for detailed HEP-related guidance & response
**See https://www.nap.edu/catalog/23560/new-worlds-new-horizons-a-midterm-assessment**

# Cosmic Frontier – Program Planning, P5 Implementation

**P5 Plan: Cosmic Frontier Science Priorities: Advance leadership efforts in the dark matter, dark energy**

→In last few years, moved from operating a broad, diverse suite of experiments to focusing the science & carrying out next generation (i.e. larger) experiments.

**P5 Plan Execution Continues in FY17+**

- Plan successful completion of current operating experiments

- Priority is on executing near-term projects recommended by P5
  - 4 Major Item of Equipment (MIE) Projects in fabrication: **LSSTcam, DESI, LZ, SuperCDMS-SNOLAB**
  - 2 below-MIE projects completing fabrication & moving to operations phase: **SPT-3G, ADMX-G2**
  - Ramp-up on planning for Operations - technical, computing and science operations; quasi-project-like process to develop, review, and monitor a "baseline" experimental ops plan (EOP)

- Laying ground work for future projects (e.g. CMB-S4, DM-G3); R&D support is extremely limited while we focus on the MIE Projects; planning with community and other agencies

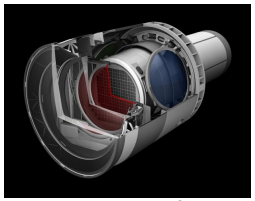
- Ensure the Science Collaboration is in place to adequately carry out all phases of the experiments & projects – leading to best possible science results

Partnerships with NSF-PHY, NSF-AST, NSF-PLR, NASA & International provide opportunities to increase science; Differences in the detailed agency and community practices, programs need to be taken into account to ensure successful project, data and science analysis return.

# Cosmic Frontier Status

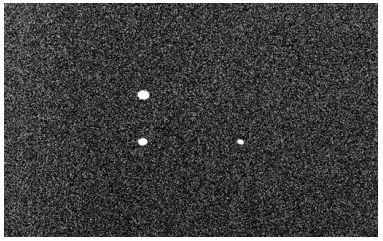
## Dark Energy: Staged program of complementary suite of imaging & spectroscopic surveys

- ***BOSS*** **operations completed 2014, final results out soon;** ***eBOSS*** **&** ***DES*** **continue operations**



- ***Large Synoptic Survey Telescope (LSST) - stage IV imaging***
  - NSF-AST and HEP partnership
  - LSSTcam MIE Project (HEP responsibility) received CD-3 in August 2015
  - Operations planning: LSST commissioning (review Jan. 2016) and facility operations (proposal 2017)
  - Science planning: Dark Energy Science Collaboration (DESC) active, operations review April 2017

- ***Dark Energy Spectroscopic Instrument (DESI) – stage IV spectroscopic***
  - HEP experiment, using NSF's Mayall telescope facility (NSF's NOAO is collaborator)
  - DESI MIE Project received CD-3 in June 2016
  - Operations phase planning w/review ~ summer 2017
  - DESI science collaboration active



Proto-DESI: Fiber Camera Image

- **HEP has research-only activities on** ***Euclid, WFIRST, & supernova surveys***

## Cosmic-ray, Gamma-ray

- **Operations continuing for** ***Fermi/GLAST***, ***AMS***, **and** ***HAWC*** **(started early 2015)**
- **DOE operations funding completed in FY 2016 for** ***VERITAS*** **and** ***Auger***

# Cosmic Frontier Status cont.

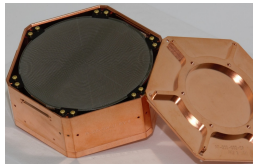
## Dark Matter (direct detection): Staged program w/multiple technologies covering complementary phase space


**- Completed DOE operations support for current DM-G1 experiments in FY 2016.**

**- HEP & NSF-PHY selected suite of 3 DM-G2 Projects in July 2014**

– Collaboration science planning and planning for developing operations also going on

- **ADMX-G2 (below MIE project)**
  - – axion search, build infrastructure (now complete at UW) then carry out series of experiments with dedicated upgrades for each range
  - – Commissioning & Operations started August 2016; Status review Sept. 2016



- ***LZ*** & ***SuperCDMS-SNOLAB (partner w/NSF-PHY) MIE***'s
  - WIMP searches over complementary mass ranges & technologies
  - ***LZ*** received CD-2/3B in August 2016; full fabrication (CD-3) ~ Feb. 2017
  - ***SuperCDMS-SNOLAB*** received CD-1 December 2015; planning towards CD-2/3 in early FY18
- **R&D to optimize science & future directions limited while we focus on fabricating the G2's**

## Cosmic Microwave Background (CMB)

- ***SPT-3G (*****below MIE project) -** partnership with NSF (PLR, AST, PHY)
  - – HEP contributed to detector; Project completing & operations starts ~ Feb. 2017
- **CMB-S4 -** Collaboration has developed a Science Book; significant lab LDRD efforts
  - – AAAC subpanel, Concept, Definition Task force (CDT), formed and starting imminently
- **HEP has research-only activities on a number of the current experiments**

# Cosmic Frontier
# Interagency & International Activities

**Interagency Coordination:** NSF, NASA, DOE interact regularly about planning, overlaps, issues

**Agency Joint Oversight Groups (JOG) & Agency Coordination Groups (ACG)**

- International Finance Board for **FGST** w/NASA-AST, **Auger**
- **DES, LSST:** JOG with NSF-AST
- **HAWC, SuperCDMS, VERITAS**: JOG with NSF-PHY (also CONACYT for HAWC)
- **SPT-3G**: JOG with NSF-PHY, NSF-AST & NSF-PLR
- **DESI**: ACG with NSF-AST

**Tri-Agency Group (TAG) – DOE, NASA, NSF-AST meetings with US-leadership on LSST, WFIRST, Euclid to discuss commonalities, coordination, optimization of data, simulations, software - starting investigation of what needs to be done now to allow Joint Data Processing & share simulations across projects.**

**International:** Making country-level agreements to allow science partnerships to move forward; Hold Agency Bi-lateral meetings

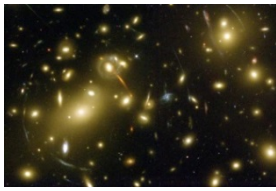
**Astro-Particle International Forum (APIF) – This agency-level group was led by Global Science Forum through 2016; GSF can no longer host and APIF recently accepted a proposal from KIPAC (SLAC/Stanford) to be the host going forward with Roger Blandford as Chair.**

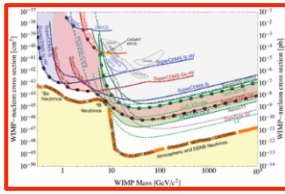
# Cosmic Visions (CV) Groups – looking towards the future

**HEP has started "Cosmic Visions (CV)" groups in several areas**

- Allows interactions with small HEP community groups (~ monthly) as 2-way line of communication for HEP-funded efforts and directions recommended by P5

(NOTE: Of course, any HEP-funded R&D/technology plans need to be in the context of the larger non-HEP and global community)





**CV-CMB**

Coordinate HEP technology R&D and other efforts for future CMB-S4 planning (More broadly, NSF & DOE moving forward with AAAC CDT subpanel)

**CV-DE**

Investigate future HEP directions following the end of fabrication of DESI and LSST; and to complement, build on or extend these experiments in investigating the physics of dark energy.

**CV-DM (Dark Matter Direct Detection)**

- Coordinate and investigate HEP technology R&D to optimize science from DM-G2 experiments and for future DM-G3 planning
- Investigate new avenues for new DM phase space, including investigating science case and possible concepts for new, small dark matter projects

# Planning for CMB-S4 (P5 recommendation)

→Following Snowmass & P5

- Community-based CMB-S4 collaboration has developed a Science Book and a notional array
- HEP labs putting considerable LDRD into developing technology
- In the last year, HEP & NSF have been discussing possible avenues & processes for CMB-S4

**Concept Definition Taskforce (CDT)**

In the October 2016 meeting, NSF and DOE presented plan to charge AAAC to carry out a CDT subpanel study.

- Charge letter (officially signed 11/21/16) by NSF-AST, -PHY,-PLR & DOE-HEP
- AAAC Chair Buell Jannuzi (UArizona) appointed Charles Lawrence (JPL) as Chair
- Membership (21, including Chair) has been selected (letters out last weekend) and most have responded.

# Cosmic Microwave Background Stage 4 (CMB-S4) Concept Definition Taskforce (CDT) Charge Letter Summary (Details in Backup)

**From: HEP, NSF-AST, NSF-PHY, NSF-PLR (signed 11/21/16)**
**To: Buell Jannuzi (AAAC Chair, from U. Arizona)**

**→We request that the AAAC establish a CMB-S4 CDT subcommittee to develop a concept for a CMB-S4 experiment.**

Take as input the CMB-S4 Science Book & further information as appropriate, including global landscape of experiments on the ground, balloons, and space.

**Specifically, the CDT is asked to deliver:**

- **The Science Requirements and their rationale**
- **Measurement and Technical Requirements derived from Science Requirements**
- **Project Strawman Concept**
- **Options and Alternatives (prioritized to the extent possible) for:**
  - Concept design (e.g. sites, telescopes, detectors)
  - Concept staging and schedule
  - Collaboration and Data models and interfaces
- **R&D development needed, with priorities, to demonstrate technical readiness**
- **Cost ranges for strawman concept, including explanations for how developed**

# CMB-S4 CDT Charge Letter cont.

**The CDT should provide a report on the Science and Measurement Requirements to the AAAC by June 2017 and a final report to AAAC by October 2017 for consideration.**

**[The CDT's] deliberations and recommendations will inform the agencies on a concept for the CMB-S4 and contribute to the agencies' planning activities. The formation of the CDT does not imply any commitment by the agencies to specific funding or project status for CMB-S4.**

Signed (completed 11/21/16)

Denise Caldwell, NSF-PHY
Eric Saltzman, NSF-PLR
James Siegrist, DOE-HEP
James Ulvestad, NSF-AST

Agency Points of Contact:

Richard Barvainis, NSF-AST
Kathleen Turner, DOE-HEP

# Dark Matter Searches

**P5 Recommendations**

- **Search for dark matter (DM) particles is a high science priority**

- **Broad program of DM-G2 experiments**
  - HEP is committed to supporting current G2 projects as a priority.

- **R&D and planning for DM-G3**
  - While we focus on the DM-G2 experiments, limited funds are available for R&D to optimize DM-G2 science, or to continue or develop technologies for the future; Have proposals in for consideration

- **Maintain diversity of project scales (i.e. ensuring we also have small projects in program)**

**Program Status**

- It is important to cover all relevant phase space to the extent feasible.
- Majority of effort and funding is currently aimed at WIMP/axion searches in Cosmic Frontier
- Experiments using accelerator beams to search for particles that connect Standard Model particles to dark sector are supported in the Intensity Frontier.
- LHC data & other data are also used to search for DM candidates (but aren't dedicated dark matter search experiments). There are also considerable theoretical studies of dark matter.

# HEP Investigating Dark Matter Future Opportunities

**To respond to the P5 recommendations, HEP is interested in identifying new, small project(s) designed for dark matter searches in areas of parameter space (i.e. mass ranges or types of particles) not currently being explored**

**➔In order to move forward and to understand the possibilities, we need community input**

**Asked the CV-DM group to spearhead organizing a workshop ~ March/April 2017**

- **CV-DM group expanded to include people involved in accelerator-based searches**

**The workshop should examine the next step(s):**

- **Detail the science case for unexplored areas of parameter space**
- **Describe concepts for small (up to ~ $10M) projects designed for dark matter searches that could address these science goals -** can be non-accelerator or accelerator based
- **Provide White Paper by ~ June 1, 2017 for use as input to HEP for FY19 planning**

**If there is a strong science case and possibility for project(s) to address science goals, HEP could then move forward with R&D to determine feasibility and process to select concepts to develop (as always, depending on funding availability!)**

# Summary

**P5 developed compelling, realistic strategic plan with a community consensus vision**
**→The HEP FY 2017 Budget Request continues the implementation of the P5 vision**

- Close coordination with the other agencies; significant partnerships.

**Cosmic Frontier Program – Exciting Time!**

- **4 MIE Projects in Fabrication Phase**
- **2 small Projects Fabrication → Moving to Operations**

- **Need to ensure Science work force to adequately carry out all phases of the Experiments (design, fabrication, operations, science analysis)**
- **Significant ramp-up in effort for Experiment Operations & Science -- Planning with other agencies & projects**

**Future Planning:**

- **Cosmic Visions Groups**
- **Dark Matter – small project to investigate other areas of phase space**
- **CMB - AAAC subpanel to carry out a CMB-S4 Concept Definition Taskforce**

# Cosmic Microwave Background Stage 4 (CMB-S4) Concept Definition Taskforce (CDT) Charge Letter

**From: HEP, NSF-AST, NSF-PHY, NSF-PLR (signed 11/21/16)**
**To: Buell Jannuzi (AAAC Chair, from U. Arizona)**

**We request that the AAAC establish a CMB-S4 CDT subcommittee to develop a concept for a CMB-S4 experiment.**

Ground-based CMB generally falls under the purview of NSF and DOE, while NASA supports CMB projects within its long-duration balloon program and space missions. In its 2016 report, the interagency AAAC recommended the following: "We encourage DOE, NSF, and the university community to continue working toward a plan for a future (Stage 4) ground based CMB experiment." Following that recommendation and other community input, NSF and DOE are requesting that the AAAC establish this CDT. The creation of the CDT also is in response to the favorable comments or recommendations on CMB science that have been made by community advisory groups over the past decade:

- 2010, Astronomy and Astrophysics Decadal Survey (charged by NASA Astrophysics, NSF-AST, and DOE-HEP): CMB projects are among the "projects thought compelling for a [competed] Mid-Scale Innovations Program" in NSF and "The committee recommends… continuing steps consistent with the DOE mission"
- 2014, Particle Physics Project Prioritization Panel (P5) of the High Energy Physics Advisory Panel (HEPAP) (charged by DOE-HEP and NSF Directorate for Mathematical and Physical Sciences, which includes NSF-PHY and NSF-AST): "Support CMB experiments as part of the core particle physics program. The multidisciplinary nature of the science warrants continued multi-agency support"
- 2015, National Academies report on "A Strategic Vision for NSF Investments in Antarctic and Southern Ocean Research" (charged by NSF-PLR): Identified continuation of studies of the Cosmic Microwave Background as one out of three strategic priorities

These community reports identify CMB as an important scientific priority for consideration by DOE-HEP, NSF-AST, NSF-PHY, and NSF-PLR, hence providing additional rationale for the CDT activity.

# CMB-S4 CDT Charge Letter cont.

The Snowmass 2013 process (http://science.energy.gov/hep/research/snowmass-p5-process/) brought together the U.S.-based CMB community, including many of the current experimental teams, and began to define a coordinated next generation experiment which was termed CMB-S4. The CMB-S4 community-based collaboration has held semiannual meetings and produced a substantial CMB Science Book (see arXiv:1610.02743 [pdf, other]) justifying the CMB-S4 science case. DOE-HEP national laboratories and some university groups are already actively engaged in technology development for CMB-S4.

**The CMB-S4 CDT is asked to develop a concept for implementing a ground-based CMB-S4 experiment. The CDT will take as input the community CMB-S4 Science Book and any further community information as appropriate, and will consider the global landscape of CMB experiments (including ground, balloons, and space).**

**Specifically, the CDT is asked to deliver:**

- **The Science Requirements and their rationale**
- **Measurement and Technical Requirements derived from the Science Requirements**
- **Project Strawman Concept**
- **Options and Alternatives (prioritized to the extent possible) for:**
  - **Concept design (e.g. sites, telescopes, detectors)**
  - **Concept staging and schedule**
  - **Collaboration and Data models and interfaces**
- **R&D development needed, with priorities, to demonstrate technical readiness**
- **Cost ranges for strawman concept, including explanations for how they were developed**

# CMB-S4 CDT Charge Letter cont.

**The CDT should provide a report on the Science and Measurement Requirements to the AAAC by June 2017 and a final report to AAAC by October 2017 for consideration. In accordance with Federal Advisory Committee Act (FACA) rules, the reports will be discussed and approved by the AAAC before formal transmittal to the agencies.**

**We appreciate your effort in establishing this subcommittee. Its deliberations and recommendations will inform the agencies on a concept for the CMB-S4 and contribute to the agencies' planning activities. The formation of the CDT does not imply any commitment by the agencies to specific funding or project status for CMB-S4.**

We look forward to working with you in this important endeavor. The point of contact for each of the agency participants are listed below.

Signed (completed 11/21/16)

Denise Caldwell, NSF-PHY
Eric Saltzman, NSF-PLR
James Siegrist, DOE-HEP
James Ulvestad, NSF-AST

Agency Points of Contact:

Richard Barvainis, NSF-AST
Kathleen Turner, DOE-HEP

# CMB-S4 CDT Membership

| | | |
|---|---|---|
| Julian | Borrill | LBNL/NERSC |
| John | Carlstrom | Chicago/ANL |
| Tom | Crawford | Chicago |
| Mark | Devlin | Penn |
| Jo | Dunkley | Princeton |
| Raphael | Flauger | UT Austin |
| Brenna | Flaugher | FNAL |
| Shaul | Hanany | Minnesota |
| Kent | Irwin | Stanford/SLAC |
| Bill | Jones | Princeton |
| Brian | Keating | UCSD |
| John | Kovac | Harvard |
| Akito | Kusaka | LBNL |
| **Charles** | **Lawrence (Chair)** | **JPL** |
| Adrian | Lee | Berkeley/LBNL |
| Jeff | McMahon | Michigan |
| Mike | Niemack | Cornell |
| Steve | Padin | ANL/Chicago |
| Clem | Pryke | Minnesota |
| Suzanne | Staggs | Princeton |
| Ed | Wollack | GSFC |

# AAAC Annual Report (March 2016)
## Summary of Cosmic Frontier Major Recommendations & HEP comments

- **See more details in Backup & https://www.nsf.gov/mps/ast/aaac.jsp**

***Where it can improve overall science productivity and efficiency, cooperation in database design and data sharing is encouraged among US agencies, international agencies, and scientific collaborations.***

- TriAgency/TriProject (TAG) Group meetings; Knowledge transfer from current to next-generation

***We encourage DOE, NSF, and the university community to continue working toward a plan for a future ground-based CMB-S4 experiment.***

- HEP is planning to participate in a CMB-S4 project following P5 plan. With NSF (PHY, AST & PLR), charged AAAC to carry out Concept Definition Taskforce (starting now)

***The agencies should continue to pursue international partnerships in order to further accomplish the goals of the NAS NWNH 2010 report. The AAAC's "Principles for Access to Large Federally Funded Astrophysics Projects and Facilities" should guide the process.***

- Continuing & building further international cooperation and partnerships is important theme of our program the P5 Strategic Plan. We adhere and plan according to the AAAC 2014 "Principles" document, with the understanding that reciprocity is an important factor.

***Community based groups, such as the AAS and the APS, should study the recent and projected growth of the leading US astronomy & astrophysics research community for the next decadal survey planning exercise of the end of this decade.***

- We understand this recommendation to be directed mainly to AAS & APS
- For HEP Cosmic, the grant approval rate is ~ 55%; Note that funding is typically < requested & people are expected to have roles and responsibilities on the project/experiment, i.e. not only data analysis

See https://www.nsf.gov/mps/ast/aaac.jsp

# AAAC Annual Report (March 2016) Findings & Recommendations

**Section 2**

***FINDING: Thanks to US investment in basic research at NSF, NASA, and DOE, the US program in Astronomy and Astrophysics has achieved spectacular breakthroughs over the past year.***

**Section 3**

***FINDING: US agencies work well together to support the priorities of the scientific community, both in collaboration on large managed projects and in coordination of diverse research programs.***

***FINDING: Some unique information in the high quality data that will be obtained in several future surveys— particularly LSST, Euclid, and WFIRST— will be significantly enhanced by combining their analysis at an early "pixel" stage, rather than a more highly reduced catalog stage.***

***RECOMMENDATION: Where it can improve overall science productivity and efficiency, cooperation in database design and data sharing is encouraged among US agencies, international agencies, and scientific collaborations.***

**DOE-HEP comments:**

- TriAgency/TriProject (TAG) Group (Agency plus Project people) meets monthly to discuss DOE/NASA/NSF cooperation on Euclid/LSST/WFIRST, in particular Joint Data Processing & Simulations.
- DES collaboration has had meetings with LSST to help in knowledge transfer (HEP labs have gotten recommendations in reviews to ensure this is happening for their roles & responsibilities)
- DESI collaboration has many people that were on BOSS, so knowledge transfers automatically.

# AAAC Annual Report (March 2016) - Findings & Recommendations

**Section 3 cont.**

***FINDING: With its history of successes funded by NASA, NSF, and DOE, CMB science crosses the boundaries of agencies. Third generation ground-based efforts and suborbital payloads are now reaching the sensitivity that could enable ground-breaking discoveries of CMB B-modes.***

***FINDING: The scientific community studying the cosmic microwave background has made significant progress on a unified strategy for a fourth generation, ground-based survey of the Universe ("CMBS4"), orders of magnitude more capable than current experiments, with enormous potential for new scientific discovery. A larger role of DOE coordinated with NSF is important to realize the great scientific potential of CMB-S4.***

***RECOMMENDATION: We encourage DOE, NSF, and the university community to continue working toward a plan for a future (Stage 4) ground-based CMB experiment.***

**DOE-HEP comments:**

As recommended by P5 (HEPAP subpanel which reported in May 2014; this is our Strategic Plan), HEP is planning to participate in a CMB-S4 project as part of our program plan. The community-based CMB-S4 collaboration has developed a Science Book and a notional array of several telescopes in Chile and the South Pole with approximately half a million detectors. HEP is working with NSF (PHY, AST, and Polar offices) to coordinate planning for a path forward. We are charging AAAC to carry out a subpanel study to develop the Science requirements → Technical requirements, and to develop a Strawman concept.

# AAAC Annual Report (March 2016) - Findings & Recommendations

**Section 4.8**

***FINDING: The agencies are working together to ensure that the highest priorities of NWNH, WFIRST and LSST, are moving forward. WFIRST has recently successfully moved into the formulation phase under the guidance of NASA, and LSST is well into the construction phase, with the camera under construction under DOE support and facility construction in the MREFC line at NSF led by AST.***

***RECOMMENDATION: The agencies should continue to pursue international partnerships in order to further accomplish the goals of NWNH. The AAAC's "Principles for Access to Large Federally Funded Astrophysics Projects and Facilities" should guide the process.***

**DOE-HEP comments:**

- Building further international cooperation and partnerships was an important theme of the P5 Strategic Plan.
- Most of our projects and experiments are international collaborations & many couldn't be done optimally (or sometimes at all) otherwise.
- We have been a member of the Global Science Forum's Astro-Particle International Forum (GSF APIF) since its start; GSF can no longer host and APIF recently accepted a proposal from KIPAC (SLAC/ Stanford) to be the host going forward.
- We adhere to the AAAC 2014 "Principles" document, with the understanding that reciprocity is an important factor. The arrangement for contributing to building and operating the experiment and data access (open, after an appropriate proprietary period) is part of the plan from the beginning.

# AAAC Annual Report (March 2016) - Findings & Recommendations

**Section 5**

***FINDING: Spending for astronomy and astrophysics research continues to lag the optimistic scenarios included in NWNH. Lack of a consistent funding stream puts some of the agency programs at risk and does not support the long term planning needed to execute the decadal survey plan.***

***RECOMMENDATION: We urge that the full programmatic funding required by the three agencies to execute their FY 2017 plans, as described in their budget requests, be provided.***

**DOE-HEP comments:**

- We understand this recommendation to be directed mainly to Congress.
- For DOE-HEP, the FY17 President's Request provides a slight increase (~ $1M) for Cosmic Frontier; We are awaiting the approved budget to develop the plan for the year.

**Section 6**

***FINDING: Over the last decade proposal success rates in Astronomy and Astrophysics have dropped significantly. This is not principally the result of a decline in proposal merit, changing demographics, or an increase in the average funding request per proposal (beyond inflation). Rather this is a consequence of flat or declining budgets for individual investigator grants, more investigators, and a larger proportion of multiple and resubmitted proposals. In the absence of facility divestment by NSF/AST over the coming years, proposal success rate is expected to decline even further.***

# AAAC Annual Report (March 2016) - Findings & Recommendations

**Section 6 cont.**

***FINDING: A very low proposal success rate impacts both researchers and the agencies. Researchers spend more time resubmitting meritorious but unfunded proposals and serving on review panels. Some researchers may elect to leave the field or decide not to pursue original and potentially transformative research. Agencies must manage the increased workload, staffing problems, and increased costs associated with reviewing more proposals.***

***RECOMMENDATION: Community based groups, such as the AAS and the APS, should study the recent and projected growth of the leading US astronomy and astrophysics research community for the next decadal survey planning exercise of the end of this decade.***

**DOE-HEP comments:**

- We understand this recommendation to be directed mainly to AAS & APS.
- For HEP Cosmic Frontier, the grant approval rate was 52%/58% in FY15/16 (PI approval rate 48%/45% in FY15/16); with low statistics, the changes shouldn't be taken as significant.
  - Note that HEP typically provides less funding than requested and also our community expects people to have roles and responsibilities on all phases of an experiment, i.e. not data analysis alone.

# NAS Mid-Decadal Report (Aug. 2016)
# Summary of Cosmic Frontier Major Report Findings & HEP Comments

**For details, see backup and**
**https://www.nap.edu/catalog/23560/new-worlds-new-horizons-a-midterm-assessment**

**FINDING 3-2: Current projections for LSST performance and data products promise transformational scientific impact, as envisioned by NWNH. To realize the full scientific potential of this great new facility, funding that enables individual investigators and groups of investigators to deliver the scientific results will be critical.**

**- HEP is supporting efforts on the LSST Dark Energy Science Collaboration to carry out planning, simulations and data challenges to be ready for precision dark energy studies.**

**p. 3.8 NWNH additionally recommended DOE and NSF funding of Theoretical and Computational Astrophysics Networks (TCAN)**

**- DOE HEP has a broad Theory program which supports a number of theory & computation cosmology efforts. We did not break out a piece of this to fund TCAN separately**

# NAS Mid-Decadal Report (Aug. 2016)
# → HEP Comments

see https://www.nap.edu/catalog/23560/new-worlds-new-horizons-a-midterm-assessment

**FINDING 2-3: At the Department of Energy (DOE), support for astrophysics has been strong, and the budget reality has been close to the baseline plan presented in NWNH.**
**DOE-HEP Cosmic Frontier program following the NWNH and the P5 strategic plan is moving forward on the next phase of priority projects and experiments.**

**FINDING 3-1: LSST planning and construction have progressed well and are on schedule and within budget, successfully bringing together NSF funding, DOE funding, and private funding.**
**Agencies have worked hard to line up funding, activities and review schedules; planning for operations is ramping up now.**

**FINDING 3-2: Current projections for LSST performance and data products promise transformational scientific impact, as envisioned by NWNH. To realize the full scientific potential of this great new facility, funding that enables individual investigators and groups of investigators to deliver the scientific results will be critical.**
**HEP is supporting efforts on the LSST Dark Energy Science Collaboration to carry out planning, simulations and data challenges to be ready for precision dark energy studies when the data comes.**

# NAS Mid-Decadal Report (Aug. 2016)
## → HEP Comments cont.

**FINDING 3-4: Despite limited resources for MSIP, NSF-AST has funded an exciting set of highly ranked proposals in a heavily oversubscribed competition. Some mid-scale programs recommended by NWNH have also moved forward with funding from DOE and from the NSF Physics and Polar Programs. The scientific promise of these projects confirms the NWNH expectation that a mid-scale program would enable major advances that respond nimbly to opportunities on a diverse range of science topics.**

**DOE-HEP Cosmic Frontier program includes a suite of imaging and spectroscopic surveys moving from Stage 3 to 4; a suite of direct detection dark matter experiments using multiple technologies moving from Generation 1 to 2; small efforts in CMB moving towards planning for a CMB-S4.**

**p. 3.8 NWNH additionally recommended DOE and NSF funding of Theoretical and Computational Astrophysics Networks (TCAN)**

- DOE HEP has a broad Theory program which supports a number of theory & computation cosmology efforts. We did not break out a piece of this to fund TCAN separately.

# HEP Program Guidance

**FACA panels & subpanels provide official advice:**

- **High Energy Physics Advisory Panel (HEPAP)**
  - Jointly chartered by DOE and NSF to advise both agencies
    - **Provides the primary advice for the program**
  - Subpanels for detailed studies (e.g. Particle Astrophysics Science Assessment Group "PASAG" in 2009, **Particle Physics Project Prioritization Panel ("P5")** in 2008, 2014

- **Astronomy and Astrophysics Advisory Committee (AAAC)**
  - Advises DOE, NASA, and NSF on selected issues in astronomy & astrophysics of overlap, mutual interest and concern
  - Subpanels:
    - These were joint AAAC & HEPAP: TFCR (2006), DETF (2006), DMSAG (2007)
    - AAAC only: CMB-S4 CDT (now formed & starting imminently)

**Formal Advice Also Provided by:**

- **National Academy of Sciences (NAS)**
  - Reports: New Worlds New Horizons (2010) Decadal Review of Astronomy & Astrophysics, "Mid-decade review" (2016)
  - Ongoing: Board on Physics & Astronomy (BPA), Committee on Astronomy & Astrophysics (CAA)

**Other**:

- Community science studies and input (e.g. Snowmass)

# Cosmic Frontier
# Guidance from Astro2010 "New Worlds New Horizons" Report (August 2010)

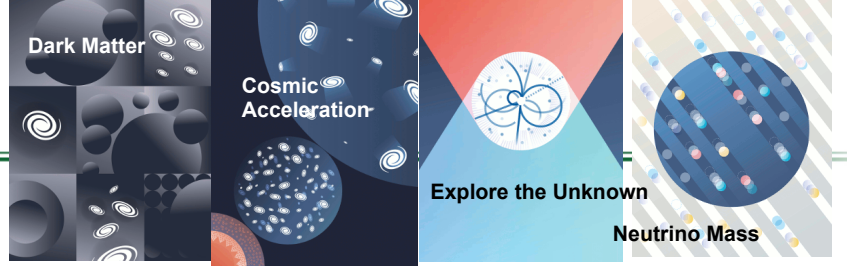
**Specific Recommendations to DOE :**

A program fitted under the **DOE budget doubling scenario** means that roughly $40 million per year would be available by the end of the decade, after due allowance for an underground dark matter detection program as recommended by HEPAP-PASAG. This amount will be sufficient to allow participation in LSST, WFIRST, and ACTA as well as some of the smaller astrophysical initiatives recommended by HEPAP-PASAG under Scenario C. In addition, a $2 million per year Theory and Computation Networks program is recommended.

However, **if the budget is lower**, the HEPAP-PASAG recommended investment in dark matter detection will be reduced and the available funds will decrease to $15 million under Scenario A. DOE is a minor partner in the two largest projects that the survey committee has recommended—LSST and WFIRST—and it is likely that the phasing will involve choices by NSF and NASA, respectively. Other considerations being equal, the recommended priority order is to collaborate first on LSST because DOE will have a larger fractional participation in that project, and its technical contribution is thought to be relatively more critical. ACTA, Theory and Computation Networks, and the smaller initiatives have lower priority.

**Summary:** In lower scenarios, DOE should participate in LSST ahead of WFIRST since DOE is making a larger relative $ contribution and its technical role is thought to be relatively more critical. DOE may have opportunities to contribute to mid-scale ground-based projects with NSF (ground priority #2), and should contribute to ACTA with NSF and to the Theory & Computation Network (TCN). These smaller programs and ACTA have lower priority than LSST & WFIRST.

# Cosmic Frontier: P5 Strategic Plan (May 2014) Recommendations




- **Dark Energy**
  - **Complete LSST** as planned
  - **Build DESI** as a major step forward in dark energy science
- **Dark Matter**
  - Proceed immediately with a broad second-generation (G2) dark matter direct detection program **(DM-G2)** with capabilities described in the text
    - Invest in this program at a level significantly above that called for in the 2012 joint agency announcement of opportunity
  - Support one or more third-generation (G3) direct detection experiments
    - Guide G3 by the results of the preceding (G1, G2) searches
    - Seek a globally complementary program and increased international partnership in G3 experiments (DM-G3 Project is in the P5 plan in later part of their 10 year plan)
- **Cosmic Microwave Background (CMB)**
  - Support CMB experiments as part of the core particle physics program
  - The multidisciplinary nature of the science warrants continued multi-agency support **(CMB-S4 Project** is in the P5 plan, starting about mid-way through their 10 year plan)
- Cosmic Rays and Gamma Rays
  - Invest in CTA only if the critical NSF Astronomy funding can be obtained
    - CTA has a broad science reach that transcends fields, with the dark matter detection capabilities of direct importance to particle physics; Using P5 Criteria, a de-scoped US component should be shared by NSF-AST, NSF-PHY and DOE.

# P5 Report – Program & Project Criteria


**HEP will use P5 criteria to develop the program and determine which projects, and at what level, to invest in.**

- **Program optimization criteria**

– **Science**: based on the Drivers, assess where we want to go and how to get there, with a portfolio of the most promising approaches.
– **International context**: pursue the most important opportunities wherever they are, and host world-leading facilities that attract the worldwide scientific community; duplication should only occur when significant value is added or when competition helps propel the field in important directions.
– **Sustained productivity**: maintain a stream of science results while investing in future capabilities, which implies a balance of project sizes; maintain and develop critical technical and scientific expertise and infrastructure to enable future discoveries.

- **Individual project criteria**

– **Science:** how the project addresses key questions in particle physics, the size and relevance of the discovery reach, how the experiment might change the direction of the field, and the value of null results.
– **Timing**: when the project is needed, and how it fits into the larger picture.
– **Uniqueness**: what the experiment adds that is unique and/or definitive, and where it might lead. Consider the alternatives.
– **Cost vs. value**: the scope should be well defined and match the physics case. For multidisciplinary/agency projects, distribution of support should match the distribution of science.
– **History and dependencies**: previous prioritization, existing commitments, and the impacts of changes in direction.
– **Feasibility**: consider the main technical, cost, and schedule risks of the proposed project.
– **Roles**: U.S. particle physics leadership

# Cosmic Frontier – Program Planning & Implementation

**Partners:**
Form partnerships or use other agency's facilities when needed → We have significant planning & coordination with multiple offices in other agencies: NSF-PHY, NSF-AST, NSF-PLR, NASA

**Plan Funding:**
- Long-term support for our responsibilities in designing, building and operating projects
- **Support for HEP-style science collaboration in all stages, to get the best possible science results**

**Implementation: Work proactively with our labs & community to carry out the program**

**Move Forward to Execute P5 Plan**
- Science & project priorities in Dark Energy, Dark Matter (direct detection), CMB
- Plan successful completion of current operating experiments
- Move forward on planning & fabrication for near-term projects recommended by P5
- Support for future projects later in P5 plan (e.g. CMB-S4, DM-G3) is extremely limited
    - **Planning path forward with NSF and community to determine possible future paths**
- Ensure **the** science team is in place to adequately carry out the experiments **&** projects

**Planning starting for next National Academies' Astronomy & Astrophysics Decadal Survey (starts ~2018)**
- HEP's primary advice comes from HEPAP & we are following the P5 Strategic Plan (May 2014)
- For the next Decadal we are interested in science & project opportunities that overlap with our program.
- Use the P5 Plan & P5 criteria to develop the program & determine projects & levels for investment

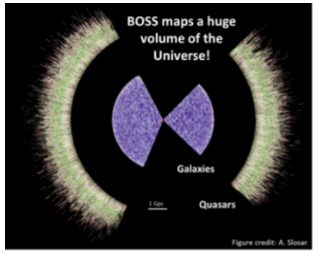
# Cosmic Frontier – Program Planning, P5 Implementation Considerations

**Develop Program following the P5 Plan & considering P5 Criteria:**

- Science goals and how it will address DOE-HEP goals
- Make unique, significant, coherent contributions to facilities/experiments selected for the program at a level commensurate with expected science return on HEP physics goals
    - Roles & responsibilities in line with our contributions/expertise
    - **What does HEP community bring to the table?**

      Need to bring unique, visible, leadership contributions, especially if it's an area usually supported by another agency. Typically this is expertise in developing & delivering state-of-the art instrumentation, lab infrastructure & project management, "big data" computing facilities and expertise, and having a cohesive science collaboration to carry out all phases of the project/experiment and deliver precision results.
- For facilities with broader science program (e.g. astronomy facilities) than the interests of the HEP program, make project contributions at appropriate level & support research efforts for our science interests
- Balance & Stages: Staged implementation, results; varying project size; complementary and varying methods/technologies; balance between science areas and speculative/ guaranteed results

# Cosmic Frontier – Dark Energy




**Precision measurements to differentiate between Cosmological Constant and new fields or modification to General Relativity**

- staged, complementary suite of imaging, spectroscopy and supernova survey experiments

**Operating/Completed:**

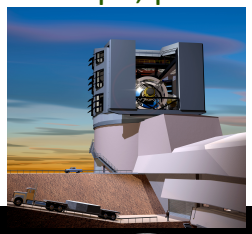
– ***BOSS* (spectroscopic)** ended in FY14; **eBOSS (spectroscopic)** started in FY15

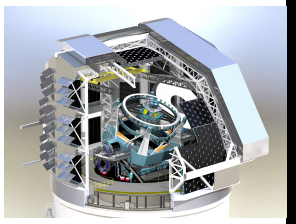
– ***DES* (imaging)** started 5-year survey in late FY13; HEP built the camera which operates on the Blanco telescope; partner w/NSF-AST

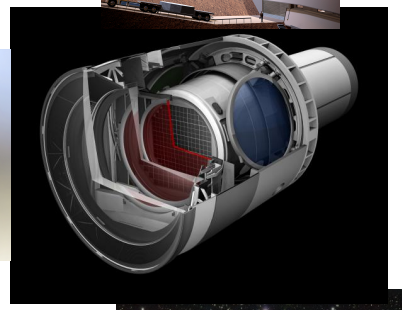
**Design, Fabrication:**

– ***Large Synoptic Survey Telescope* (LSST, Stage IV imaging)**

- HEP and NSF-AST (lead agency) partnership; HEP responsible for the LSST camera (SLAC)
- LSSTcam CD-3 (full fabrication approved) Aug. 2015
- LSST Project Status review Aug 2016; Commissioning phase review Jan. 2017
- LSST Facility Operations phase planning started; proposal in spring 2017
- LSST Dark Energy Science Collaboration (DESC) Ops review ~ March 2017







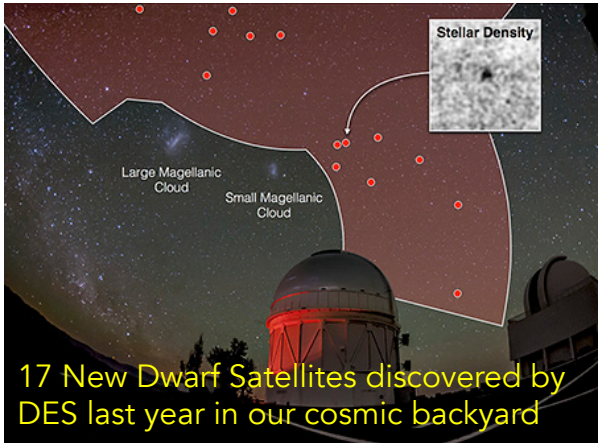
– ***Dark Energy Spectroscopic Instrument* (DESI, Stage IV spectroscopic)**

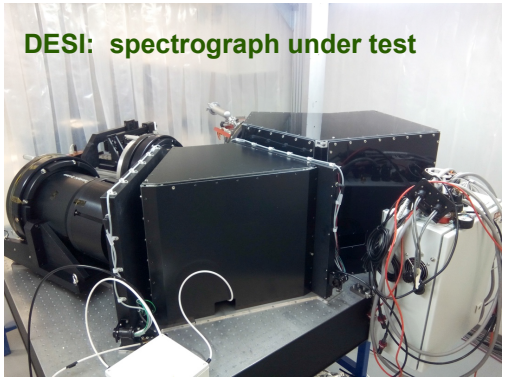
- "HEP experiment" with LBNL managing; CD-3 (full fabrication approved) June 2016
  - build DESI instrumentation & data management system for use on Mayall telescope with HEP providing partial support in FY16-18; full support starting in FY19
- DESI Operations phase planning started; Project and Operations plan reviews in summer 2017

**Research:** In addition to above, HEP has research-only activities on **Euclid, WFIRST,** & **supernova surveys**

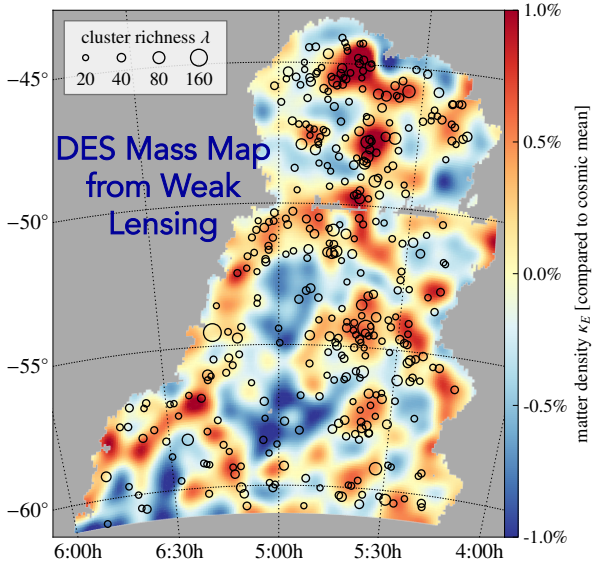
# Understanding Dark Energy

## A suite of imaging and spectroscopic surveys aim to address the question of what drives cosmic acceleration

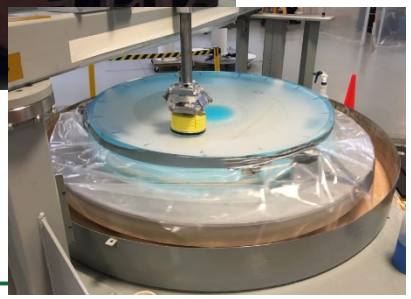






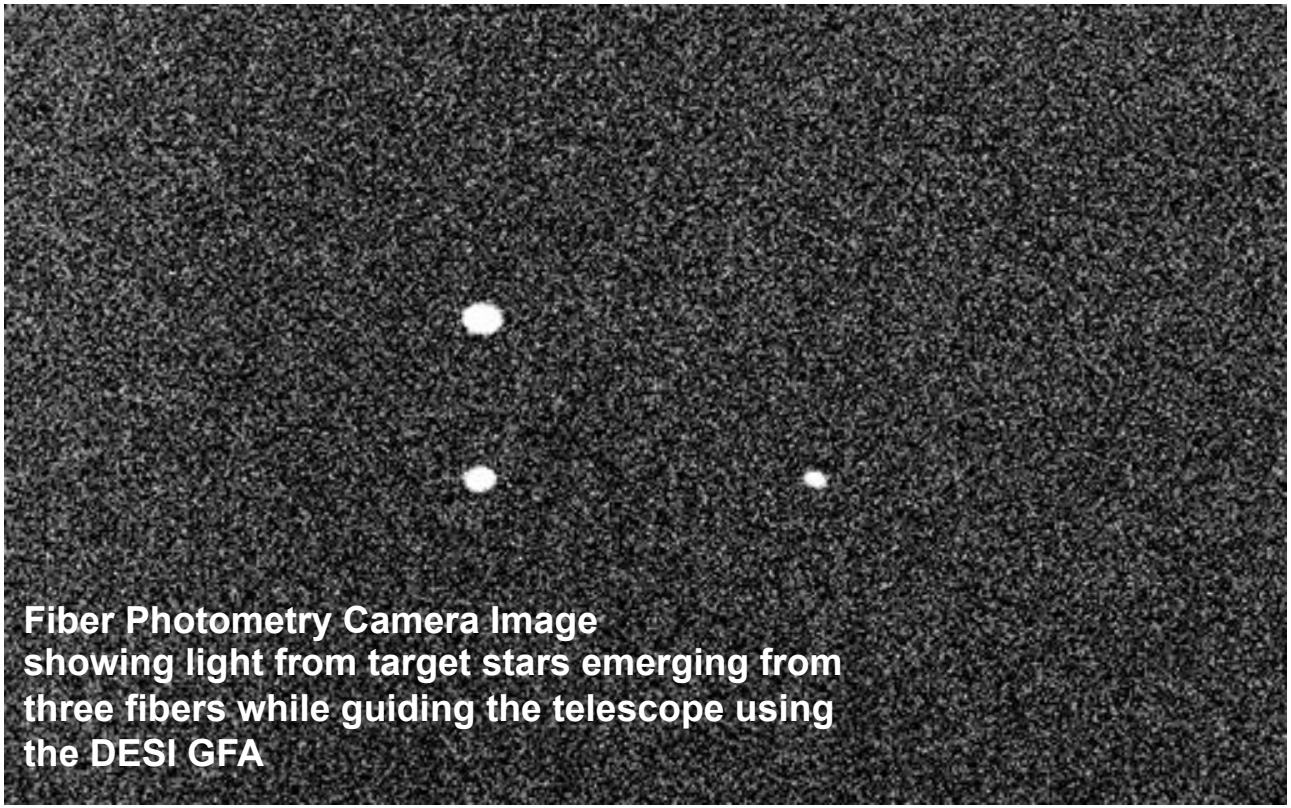




# ProtoDESI a Success !!

**Mid- September 2016: Completed, all goals accomplished!**

**"**ProtoDESI completed its primary mission of demonstrating placing stars on fibers. We targeted three stars and all three were found. The image below is the record of the observed light from the three fibers. With this accomplishment we have demonstrated that we can guide the Mayall telescope into position and then move the fibers onto specific targets".



**Fiber Photometry Camera Image showing light from target stars emerging from three fibers while guiding the telescope using the DESI GFA**

# Cosmic Frontier:
# Direct Detection Dark Matter (DDDM)

**→Learn the identity and nature of Dark Matter with staged program of experiments with multiple technologies & methods**

**Operating:**
Completing Operations on current DM-Generation 1 (DM-G1) experiments in FY16/17: **ADMX-II, LUX, CDMS-Soudan, DarkSide-50, COUPP/PICO, DAMIC**

**Design, Fabrication:**
Progress continues on DM-G2's selected by HEP & NSF-PHY in July 2014

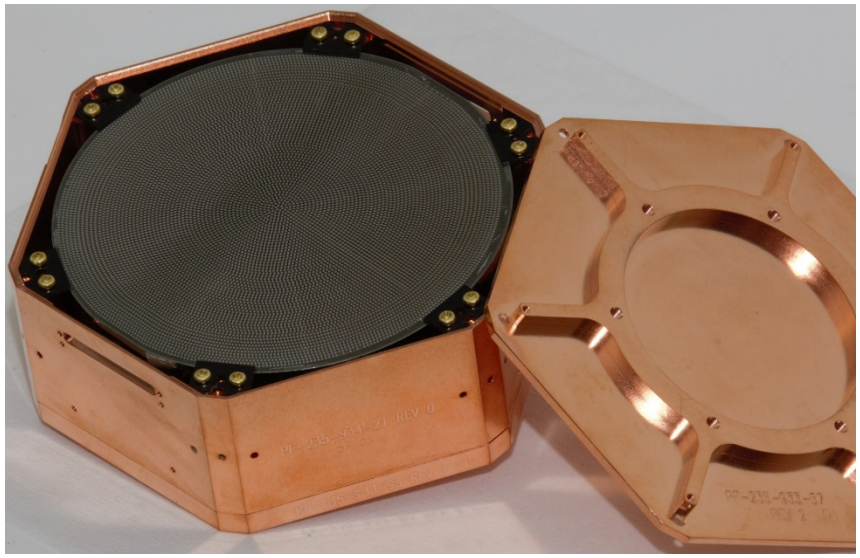
- **ADMX-G2** axion search at U.Wash. (HEP)
  - operations starting; status review Sept. 2016

- **LZ** at Homestake Mine in South Dakota (HEP, LBNL project office)
  - WIMP dark matter search through dual phase liquid Xe – higher mass range
  - Fabrication start (CD-1/3a) in FY15; CD-2/3a approval Aug. 2016

- **SuperCDMS-SNOLab** at Sudbury Neutrino Observatory in Canada
  - WIMP search using cryogenic solid-state crystals – lower mass range
  - HEP+NSF-PHY partnership, SLAC Project Office
    - CD-1 approval in Dec. 2015; Status review held July 2016

# Cosmic Frontier: Direct Detection Dark Matter (DDDM)

LZ: Large-scale prototype testing using liquid Xenon is underway at SLAC



SuperCDMS SNOLAB: first 100mm HV prototype detector

Flange sections for the LZ cryostat manufactured from ultra-low radioactivity Titanium

# Cosmic Frontier: CMB

Gain insight into **inflationary epoch** at the beginning of the universe, **dark energy & neutrino properties** by studying oldest visible light.


**Current Experiments:**

- ***SPT-3G*** **– HEP provided support towards major upgrade of the camera to greatly increase sensitivity; Operations starting early 2017 (NSF-led)**


➔**CMB-S4 Community-based Collaboration brought together ground based community to plan future**

- **Notional array of several telescopes in Chile & South Pole with on the order of 0.5 M detectors**
- **Needs scale-up of detector fabrication, testing, and readout**

***CMB-S4 Collaboration*** **Science Book:**
**https://arxiv.org/abs/1610.02743**


**Future Planning:**

**As recommended by P5, HEP is planning to participate in a CMB Stage 4**

- **HEP labs already heavily involved in R&D to align with P5**
- **HEP will coordinate efforts & roles within HEP program**

- **Working with NSF to coordinate planning and a path forward**
- **Have charged the AAAC to hold a CMB-S4 Concept Definition Taskforce (CDT)**
  - **Will be set up in the next few weeks**

# Cosmic Frontier – Cosmic-ray, Gamma-ray

**Use ground-based arrays, space telescopes, and an experiment on the International Space Station to perform indirect searches for dark matter, fundamental physics**

→ **Significant inter-agency & international partnerships**

**HEP Operations Roles Completing in FY16:**

***VERITAS*** *(w/NSF)*

– HEP operations support completed; finalizing HEP-supported analysis

***Auger*** *(w/NSF-PHY)*

– HEP participation in operations & research ramping down in FY16; no participation planned on upgrade

**Operations continuing:**

***Fermi/GLAST*** *(w/NASA)*

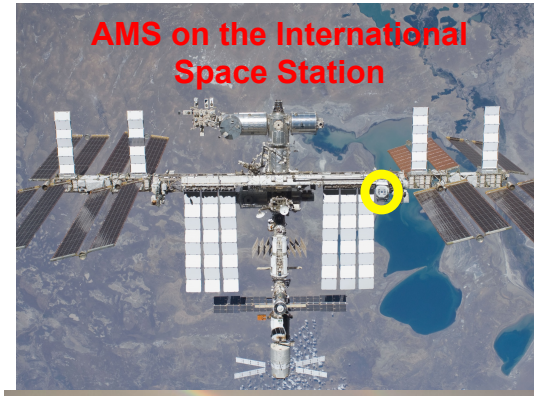
– HEP is supporting the Large Area Telescope Instrument Science Ops Center at SLAC; In coordination with NASA, HEP is planning to continue support of critical efforts at SLAC if operations go past 10 years

***AMS*** *(w/NASA)*

– operations continuing

***HAWC*** *(w/NSF)*

– 5 year HEP-supported operations started early 2015





# FY 2014-2017 HEP Program - Budget Status

| HEP Budget History ($K) | FY14 PRB | FY14 Actual | FY15 PRB | FY15 Enacted | FY16 PRB | FY16 Enacted | FY17 PRB |
|---|---|---|---|---|---|---|---|
| Energy Frontier | 154,687 | 152,386 | 153,639 | 147,584 | 154,555 | 150,723 | 150,998 |
| Intensity Frontier | 271,043 | 250,987 | 251,245 | 264,224 | 247,196 | 243,121 | 234,144 |
| **Cosmic Frontier** | **99,080** | **96,927** | **101,245** | **106,870** | **119,325** | **130,582** | **130,069** |
| Theory & Comp. Physics | 62,870 | 64,275 | 58,850 | 59,274 | 60,317 | 59,083 | 59,656 |
| Advanced Tech R&D | 122,453 | 150,270 | 114,242 | 120,254 | 115,369 | 115,494 | 118,285 |
| Accelerator Stewardship | 9,931 | 9,075 | 19,184 | 10,000 | 14,000 | 9,000 | 13,744 |
| SBIR/STTR | 21,457 | 0 | 20,595 | 20,794 | 21,138 | 20,897 | 22,580 |
| HEP Subtotal | 741,521 | 723,920 | 719,000 | 729,000 | 731,900 | 728,900 | 729,476 |
| Construction, Line Item | 35,000 | 51,000 | 25,000 | 37,000 | 56,100 | 66,100 | 88,521 |
| **HEP TOTAL** | **776,521** | **774,920** | **744,000** | **766,000** | **788,000** | **795,000** | **817,997** |
| Office of Science TOTAL | 5,152,752 | 5,066,372 | 5,111,155 | 5,067,738 | 5,339,794 | 5,350,200 | 5,672,069 |

*FY14 SBIR/STTR was ~ $21M, so FY2014 actual was ~ $796M.
PRB = President's Request Budget

FY16: The enacted budget was above the Request and squarely in P5's Scenario B.
FY17: We are currently in a Continuing Resolution (CR) until Congress passes a budget → have to plan a budget to spend at last year's rate.

…Planning is difficult… We typically have plans for a full-year CR, the PRB and then the enacted budget.