U.S. DEPARTMENT OF ENERGY | Office of Science

Office of High Energy Physics (HEP) Cosmic Frontier

Astronomy & Astrophysics Advisory Committee

January 25, 2022

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Experimental Research at the Cosmic Frontier
Office of High Energy Physics, Office of Science (SC)

OUTLINE

- HEP Program: Intro, Guidance, Budget
- Cosmic Frontier Program Details
- Astro2020 Recommendations

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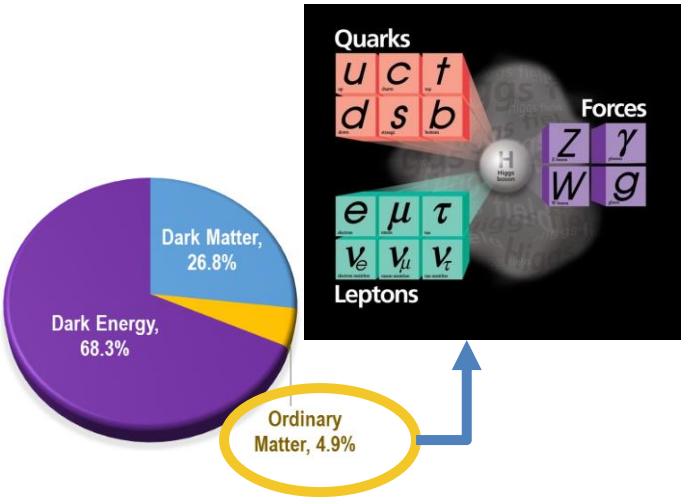
HEP Program:
Intro, Guidance, Budget

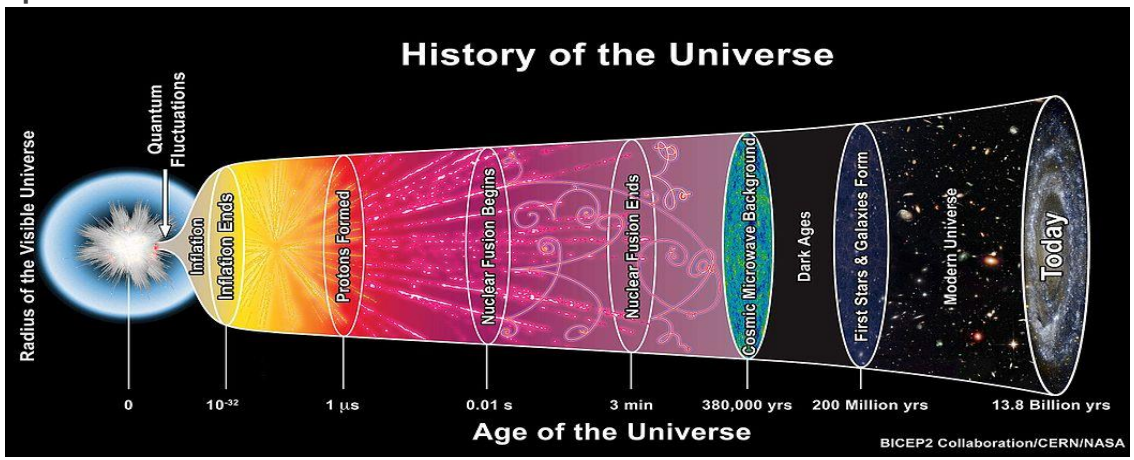
The Office of High Energy Physics (HEP) Program Mission

DOE is a mission-oriented agency → mission includes **maintaining a vibrant U.S. effort in science and engineering as a cornerstone of our economic prosperity with clear leadership in strategic areas.**

HEP's mission is to understand the universe at the most fundamental level:

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

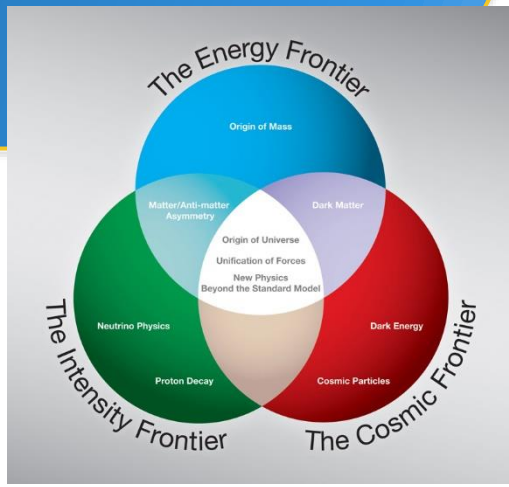




➔Scientific Areas are intertwined: High Energy/Particle Physics, Cosmology, Astrophysics, and Astronomy.

DOE supports ~ 85% of the U.S. HEP effort (in $) at Universities + National Labs

HEP Program Layout



HEP is carried out along 3 Frontiers:
Advancements at all 3 frontiers are needed to achieve the long-term goals of the field.
→HEP is primarily a Particle Accelerator based program: **Energy & Intensity Frontiers**

→Cosmic Frontier is an increasingly important area for discovery. Experiments use naturally occurring data to provide additional input to the Standard Model picture: Cosmic Acceleration (Dark Energy, Inflation), search for Dark Matter particles, Neutrino properties, New Physics (e.g. relic particles, etc)

Crosscutting HEP subprograms:

- Theoretical research, High Performance Computing & Computational HEP, Advanced Detector R&D, Quantum Information Science (QIS).

HEP Program Guidance

FACA panels & subpanels provide official advice:

- **High Energy Physics Advisory Panel (HEPAP)**
  - Advises **DOE & NSF: Provides the primary advice for the HEP program**
  - Subpanels: **The Particle Physics Project Prioritization Panel ("P5") provides the Strategic Plan for HEP**

- **Astronomy and Astrophysics Advisory Committee (AAAC)**
  - Advises **DOE, NASA, & NSF** on issues of overlap, mutual interest and concern
  - Subpanels: CMB-S4 Concept Definition Taskforce (2017), Gemini-Blanco-SOAR Telescopes roles (2019)

Advice Also Provided by: National Academy of Sciences (NAS)

- **Decadal Surveys in Astronomy & Astrophysics (Astro2020)**
- Decadal Survey of Elementary Particle Physics being planned
- Board on Physics & Astronomy (BPA), Committee on Astronomy & Astrophysics (CAA)

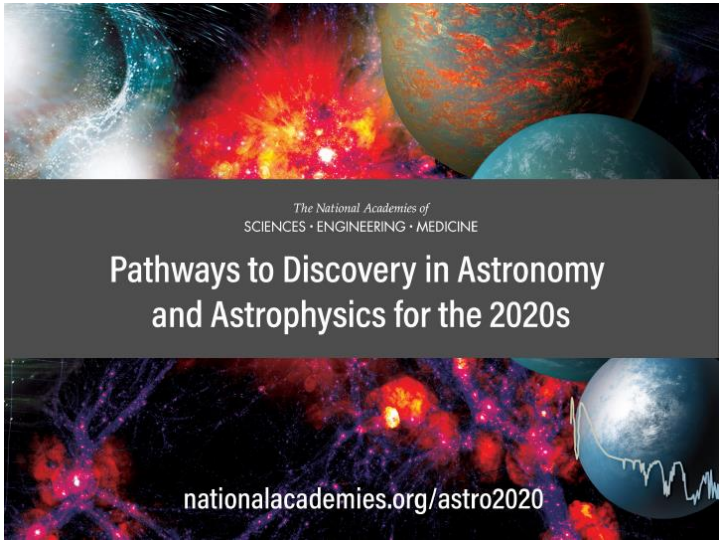
Other Input & Coordination

- Community studies & input, e.g. Snowmass, APS/DPF
  - Basic Research Needs (BRN) studies to start development of new HEP initiatives

Astro2020 – Pathways to Discovery in Astronomy and Astrophysics for the 2020s

National Academies Decadal Survey of Astronomy and Astrophysics released Nov. 4, 2021. Charged & supported by DOE, NSF and NASA

➔DOE appreciates all the hard work the community and the National Academies have done in carrying out the study and providing the report.



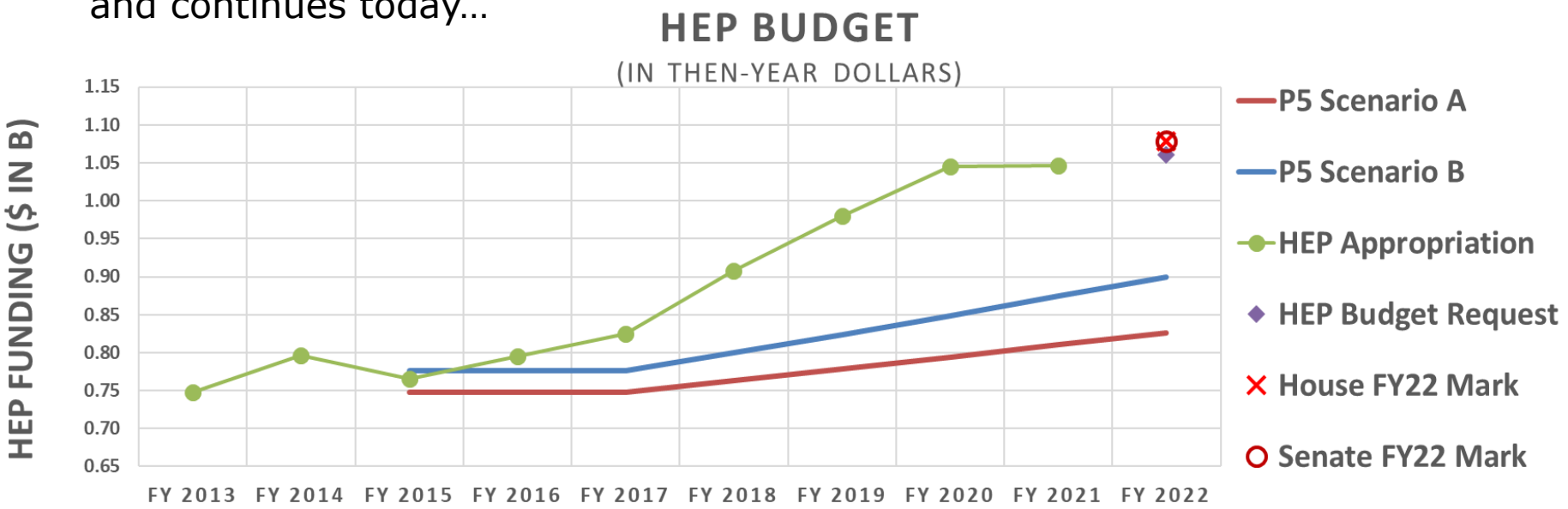
Astro2020 recommended:

- DOE/NSF partnership on CMB-S4
- Efforts on diversity, equity, inclusion, demographics, data, etc. (joint with NSF & NASA)

We have started internal discussions on the recommendations; will engage with NASA and NSF regarding joint recommendations

HEP is continuing to carry out the 2014 P5 Strategic Plan

- The **projects** selected for the P5 strategic plan make significant leaps in addressing HEP science goals.
- U.S. Congress continues to show strong support for executing the P5 strategy, and for accelerating the pace of projects
- When the P5 report was released in May 2014, the FY 2015 budget was already in Congress and the FY 2016 budget was being formulated
- Arguably the first impact (success!) of the P5 report was not seen until FY 2016, and continues today…



FY 2022 Budget Request - HEP

HEP Funding Category ($ in K)	FY 2020 Actual	FY 2021 Request	FY 2021 Enacted	FY 2021 Actual	FY 2022 Request	FY 2022 vs. FY 2021
Research	389,646	328,906	398,203	408,163	419,605	21,402
Facilities/Operations	317,310	285,725	314,297	304,337	309,395	-4,902
Projects	338,044	203,500	333,500	333,500	332,000	-1,500
Total	**1,045,000**	**818,131**	**1,046,000**	**1,046,000**	**1,061,000**	**15,000**

FY 2022 President's Request is overlay of Administration, SC, P5 priorities

- SC: interagency partnerships, national laboratories, accelerator R&D, QIS, AI/ML, microelectronics
- HEP: continue successful P5 execution, advance Administration and DOE/SC initiatives

FY 2022 HEP Budget continues support for P5-guided investments

- Research: Continue U.S. leadership in LHC, muon experiments, international neutrino experiments at Fermilab, **dark matter, dark energy,** and a vibrant theory program; QIS; AI/ML; Microelectronics (with ASCR, BES, and FES); Accelerator Science and Technology Initiative; Traineeships in accelerator science, instrumentation, high-performance scientific computing
- Operations: Support HEP user facilities and running P5-recommended experiments
- Projects and Line Item Construction: Project support for HL-LHC Accelerator and ATLAS & CMS Detectors, CMB-S4, and ACORN (new start); LIC support for LBNF/DUNE, PIP-II, mu2e

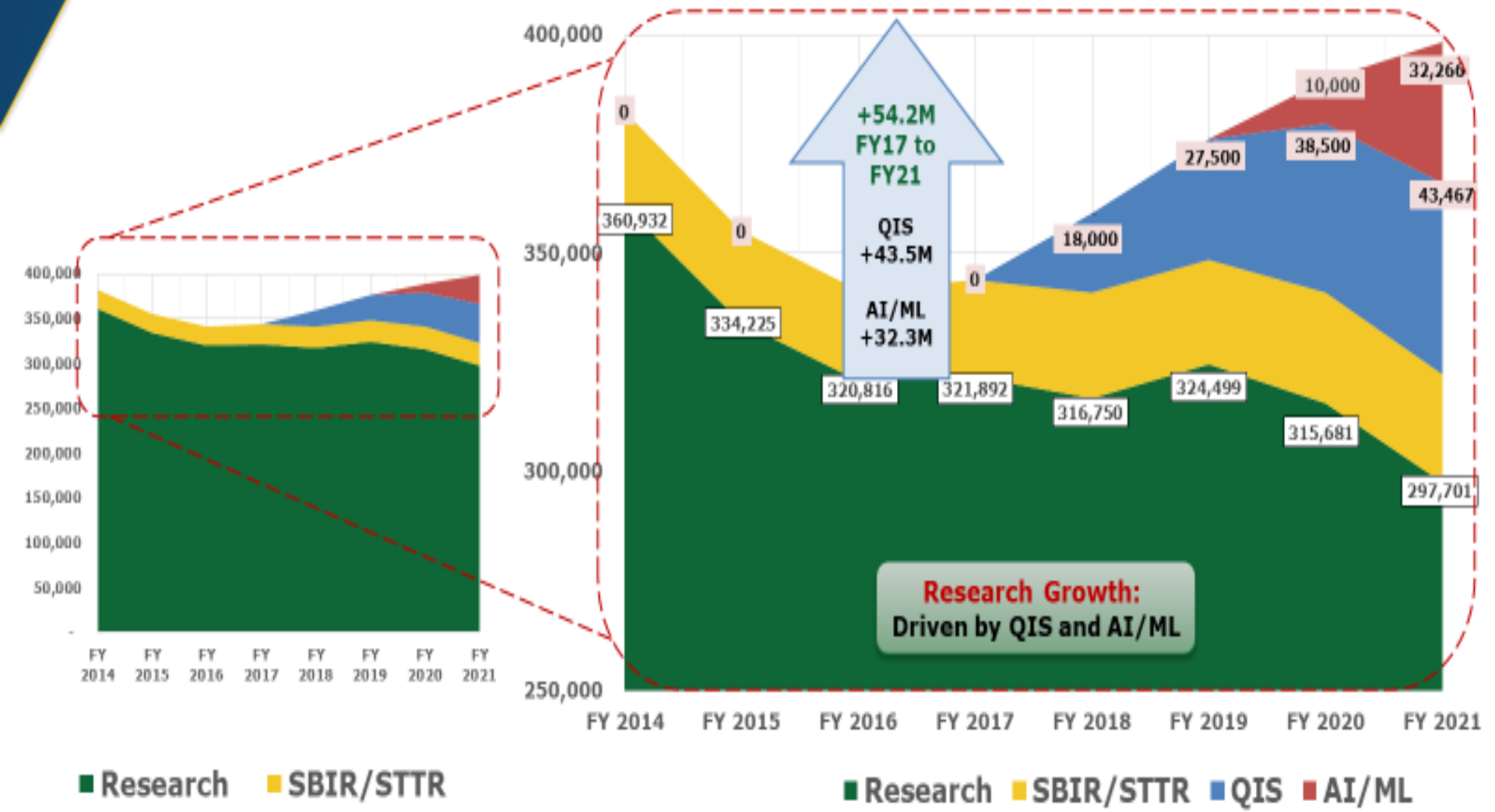
Note: FY 2021 Budget →

- Approved a New Project Start for CMB-S4 as a Major Item of Equipment (MIE)

FY2022 Budget - Some Challenges

- The FY 2022 President's Request Budget for DOE/HEP is down $1.5 million for projects compared to the FY 2021 Appropriation
  - PIP-II accelerator project request is below the approved baseline
  - LBNF/DUNE is below the planned level
  - HL-LHC projects took larger cuts on a percentage basis
- We remain committed to the P5 strategy and its priorities
  - Talking with international partners about our ongoing commitments and plans to successfully carry out HL-LHC and plans for LBNF/DUNE and PIP-II
  - Responding to questions from U.S. Congress on impacts
- Congressional marks are slightly above the FY 2022 budget request for HEP, but final budget language will impact the allocation of any additional resources
  - HEP request: $1.061B
  - House mark $1.078B (+1.6%), Senate mark $1.079B (+1.7%)

HEP Research ($k) FY 2014-2021



Office of Science (SC) - [New] Initiatives

HEP budget (in $K)	FY20 enacted	FY21 enacted	FY22 request
Accelerator Science & Technology		6,411	17,432
Artificial Intelligence & Machine Learning (AI/ML)	15,000	33,488	35,806
Integrated Computational & Data Infrastructure			**4,146**
Microelectronics		5,000	7,000
Quantum Information Science (QIS)	38,500	45,072	51,566
Reaching a New Energy Sciences Workforce			**4,000**
TOTAL	**53,500**	**89,971**	**119,950**

The President has placed a high priority on **American leadership in the Industries of the Future (IOTF):**

- artificial intelligence (AI), quantum information science (QIS), advanced manufacturing, biotechnology, and 5G/advanced wireless technologies

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Cosmic Frontier – Intro, Budget, Guidance

Cosmic Frontier Experimental Research Program

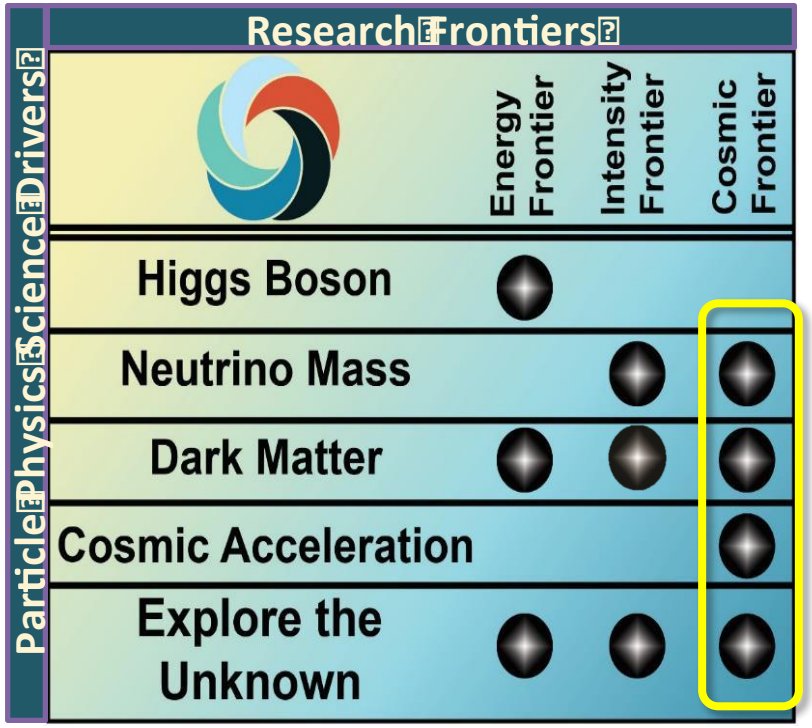
Cosmic Frontier researchers use naturally occurring cosmic particles and phenomena to reveal the nature of dark energy and dark matter, comprising ~95% of the universe, understand the cosmic acceleration caused by dark energy and inflation, infer neutrino properties, and explore the unknown.

→Carrying out program with specific projects recommended by P5:

Cosmic Acceleration:
- Study the nature of **Dark Energy** using imaging & spectroscopic surveys
- Use the **CMB** to study the Inflation

Dark Matter
- Direct Detection searches for **Dark Matter** particles using a variety of methods and technologies

Neutrinos
- Constrain properties using dark energy & CMB measurements



Always interested in **Exploring the Unknown** and New Physics!

Cosmic Frontier – Program Planning & Execution

- **Astro2010 recommended DOE/NSF partnership on LSST (Rubin)**

- **P5 (2014) recommended Cosmic Frontier science & project priorities in Dark Energy, Dark Matter (direct detection) & CMB**
  - Dark Energy: build **LSST (Rubin) & DESI**
  - Dark Matter: suite of "generation 2" direct detection experiments – **ADMX-G2, LZ, SuperCDMS SNOLAB**
  - CMB: support as part of the core program within multi-agency context; carry out multi-agency **CMB-S4** project later in the decade
  - Maintain a portfolio of small projects: e.g. we are carrying out **ADMX-G2, SPT-3G, Dark Matter New Initiatives**

Notes:
- Most Experiments are done in partnership with NSF-PHY, NSF-AST, NSF-OPP, NASA, and/or International agencies/institutions.
- Significant contributions & support from other HEP areas, e.g. Theory, Advanced Detector Development, Computational HEP, QIS, AI/ML
- Contributions from other SC areas → ASCR Supercomputing resources

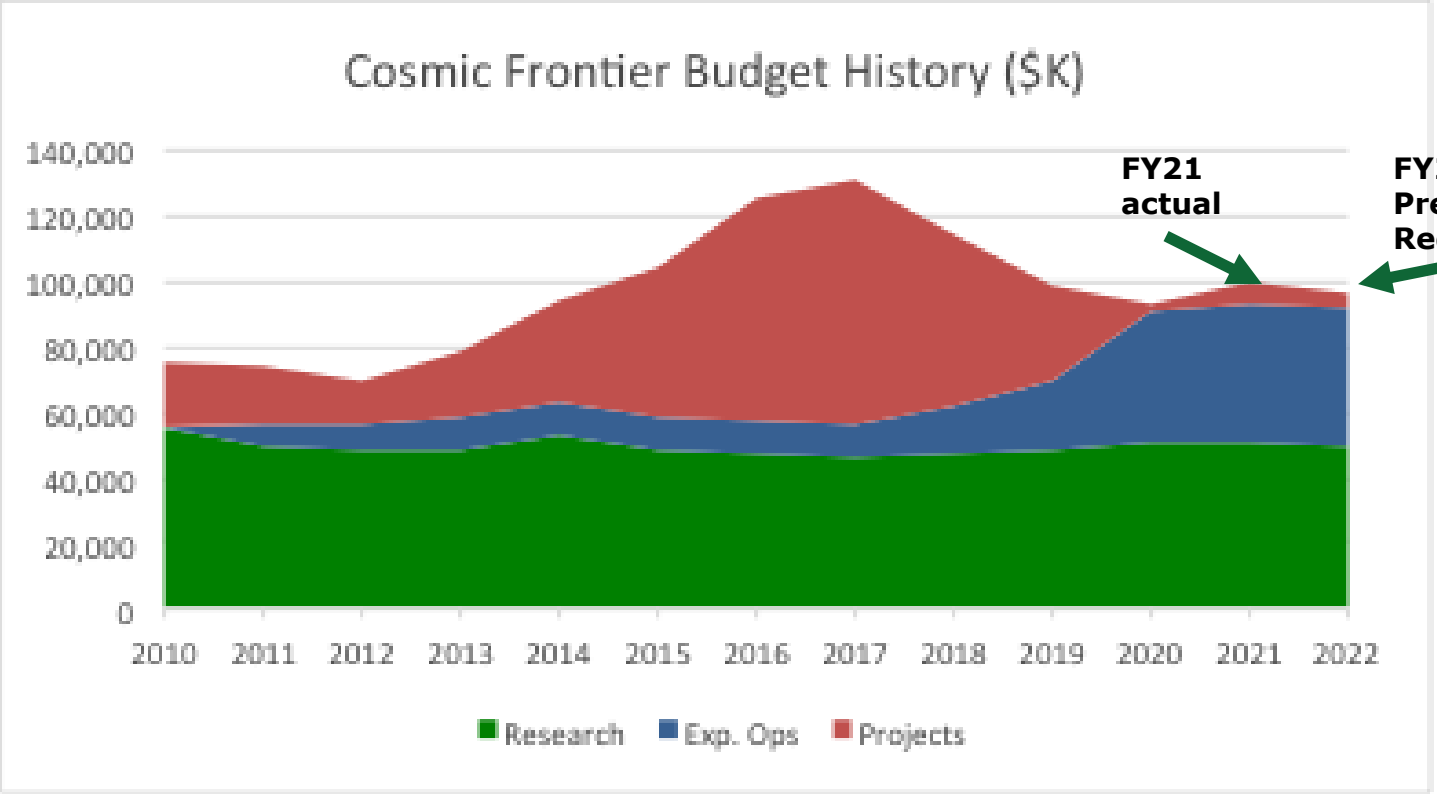
FY 2019-2022 Budget – Cosmic Frontier

Cosmic Frontier ($K)	FY2019 Actual	FY2020 Actual	FY2021 Approp.	FY2021 Actual	FY2022 Pres. Req.
Research (Univ+Lab)	48,053	44,264	39,634	43,901	42,012
Research AI/ML		3,351	3,920	4,920	5,106
Future R&D	3,265	2,480	2,000	1,700	2,000
Exp. Operations	20,957	40,235	43,897	42,880	42,500
Projects	26,350	2,450	6,000	6,000	5,000
DESI	*9,350*	*0*	*0*	*0*	*0*
LZ	*14,450*	*0*	*0*	*0*	*0*
SuperCDMS SNOLAB	*2,550*	*0*	*0*	*0*	*0*
CMB-S4	-	*2,450*	*6,000*	*6,000*	*5,000*
Total	**98,625**	**92,780**	**95,451**	**99,401**	**96,618**
Office support	3,667	4,181	4,436	4,970	*
SBIR/STTR	2,869	3,524		1,624	*
Total Full	**105,161**	**100,485**	**99,887**	**105,995**	

- **Research: Scientist support for world-leading efforts in design and optimization in their planning, fabrication, commissioning, operations and data production/analysis.**
- **Operations:** Commissioning and facility operations planning for LSST/Rubin; operations of FGST/LAT, SPT-3G, ADMX-G2, DESI, LZ; pre-operations activities for SuperCDMS-SNOLAB.
- **Projects:** CMB-S4

* These costs have not yet been applied for FY22

Cosmic Frontier Budget History



Projections:

- **Experimental Operations**: As the current Projects complete, estimated needs ramps up to ~ $55M to $60M by FY2024; levels to ~ $40M by FY2030.
- **Future opportunities**: Compelling Cosmic Frontier Projects will be considered and supported within available overall HEP Project funds. Guidance from Astro2020, next P5

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Cosmic Frontier – Cosmic Acceleration

- Dark Energy
- CMB-S4

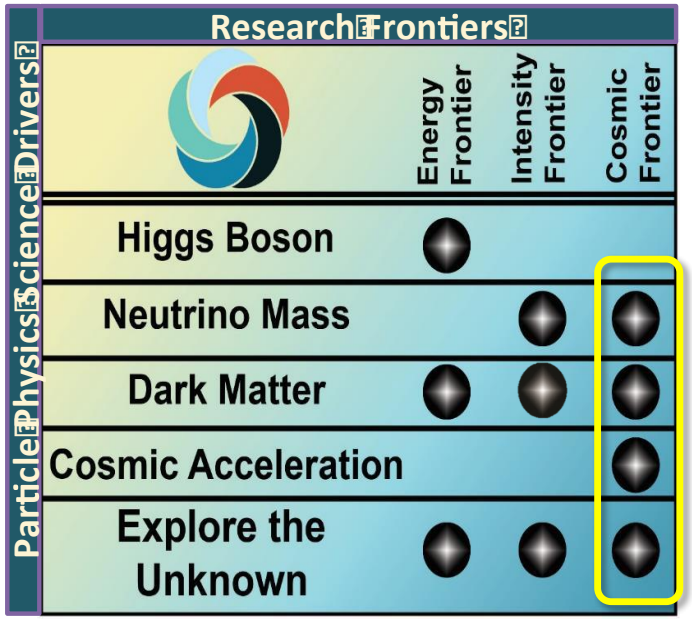
Cosmic Frontier – Cosmic Acceleration

Cosmic Acceleration:

- Imaging & Spectroscopic surveys to determine the nature of **Dark Energy**

  Stage 3
  - extended Baryon Oscillation Spectroscopic Survey (***eBOSS***), Dark Energy Survey **(*DES*)**

  Stage 4
  - Dark Energy Spectroscopic Instrument (***DESI***)
  - ***Vera C. Rubin Observatory,*** w/DOE's ***LSST Camera*** MIE project, ***Rubin Facility Operations***, & the Dark Energy Science Collaboration **(*DESC*)**



- Study the Inflationary era using its imprint on the cosmic microwave background (**CMB**) at energies near the Planck scale (with NSF)
  - South Pole Telescope 3rd Generation (***SPT-3G***)
  - CMB-stage 4 *(**CMB-S4**)*

Dark Energy Survey (DES)

DARK ENERGY SURVEY

DOE and NSF partnership

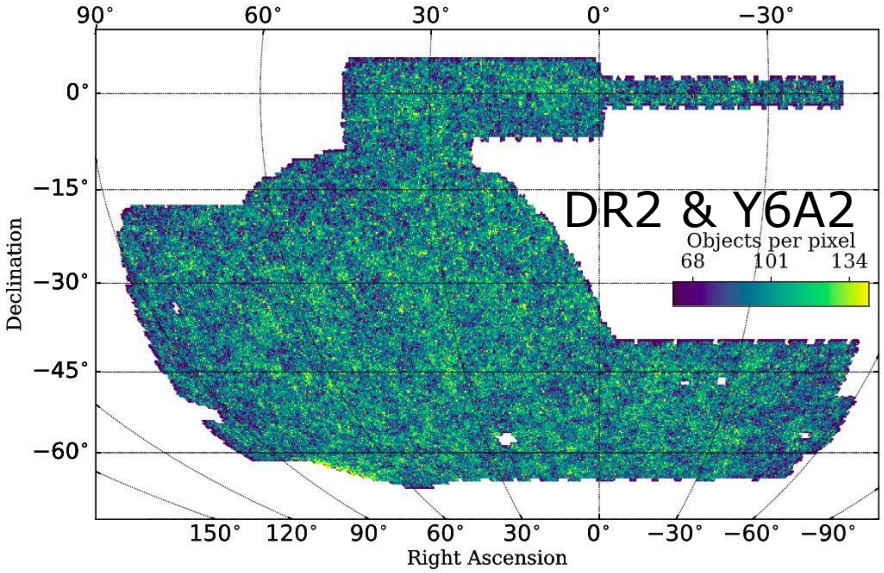
- Fermilab led fabrication of 570Mpix Dark Energy Camera (DECam); NSF led telescope upgrades, data man. system
- Both agencies supported operations on NSF's Blanco telescope at CTIO in Chile.
- 6-year imaging survey of 5100 sq-deg completed Jan. 2019
- **Priority is now Y6 Cosmology Analyses**

- *Collaboration > 400 scientists from 25 institutions in 7 countries*
- **Over 370 publications; > 90 PhD's**

Cosmology 7 ways:

Growth rate of structure and Expansion History: Weak Gravitational Lensing, Galaxy Clustering, & Galaxy Cluster Abundance

Expansion History: BAO (standard rulers), SNIa (standard candles), Gravitational Wave Follow up (standard sirens), Strongly-Lensed Transients.



DES Highlight: Weak Lensing Cosmology

Y3 Cosmology Catalogs were released Jan 2022.

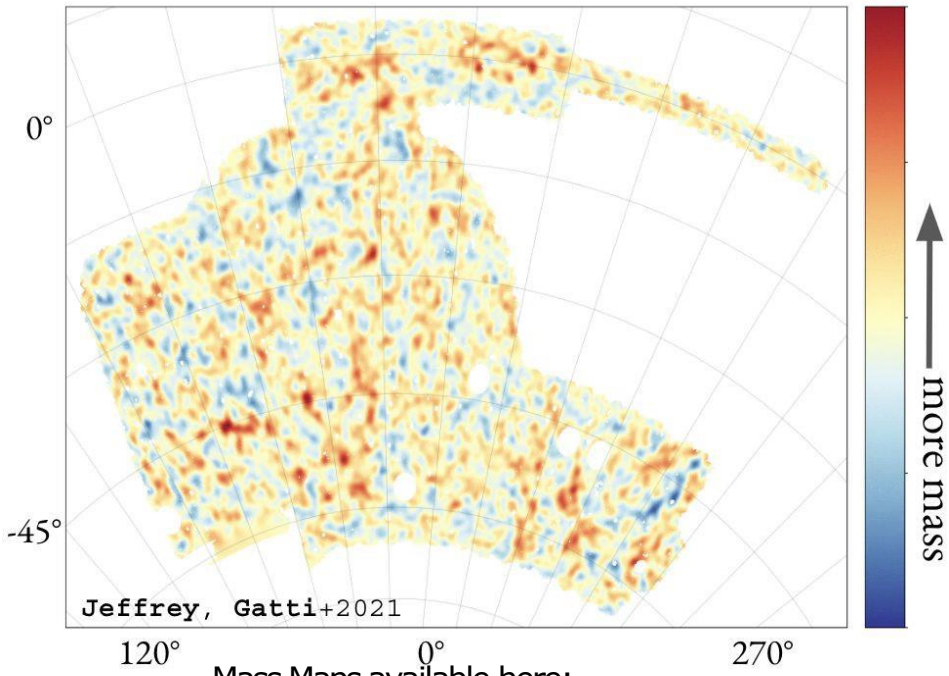
- **Expect Y6 catalogs ~ end 2023.**

Y3 Weak Lensing Cosmology Results from Y1-Y3 data: largest ever sample of galaxies (226 million) over an enormous piece of the sky was used to produce the most precise measurements of the universe's composition and growth to date. DES cosmology results from the 3 by 2 point (3x2pt) correlation functions that provided the world's best cosmology results (was previously shown)

→ **PRD 105, 023520 (2022).**

Shown at Cosmopalooza (held in lieu of AAS: DES collaboration is now working on using the mass map to carry out 3-pt "shear-shear-shear" correlation information & shear "peak statistics" to extract cosmology. These are sensitive to different spatial and frequency scales and complementary to the 3x2pt Y3 results & will improve on the 2pt correlations analysis. See:

Gatti et al, submitted, https://arxiv.org/abs/2110.10141 (Y3 Moments)
Gatti et al, MNRAS, 2021 https://arxiv.org/abs/1911.05568 (Y3Sim Moments)
Zuercher et al, submitted 2021 https://arxiv.org/abs/2110.10135 (Peaks)



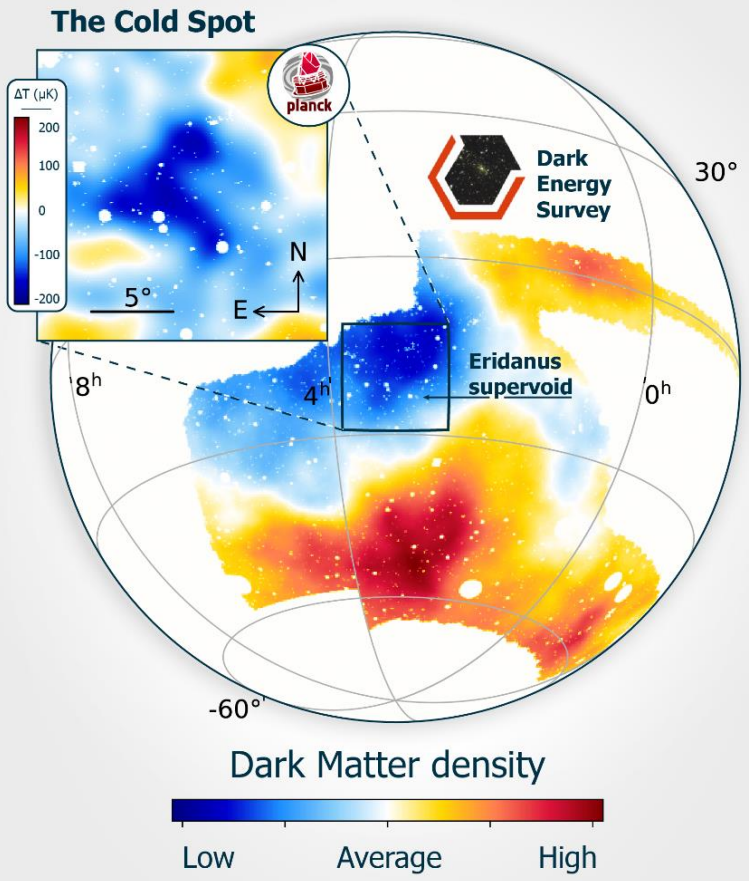
Mass Maps available here:
https://des.ncsa.illinois.edu/releases/y3a2

DES Highlight: Growth of Structure from Cosmic Voids

- Association of a foreground "supervoid" is evident in the DES weak-lensing mass map, aligned with the so-called Cold Spot in the CMB.
- Using the DES Y3 galaxy catalog to study the supervoid's characteristics
- Underdensity of matter at $z < 0.2$ has been confirmed. It is the largest underdensity in the WL mass maps.
- The WL signal is also 30% lower than expected from simulations, suggesting a causal connection between the CMB and DES measurements.

→ Will investigate cosmology implications in the future.

A. Kovács, MNRAS 510, 216 (2022)



The Cold Spot resides in the constellation Eridanus in the southern galactic hemisphere. The inset shows the microwave temperature map of this patch of the sky as mapped by the Planck satellite. The main figure depicts the dark matter mass map created by the DES team. Graphics by Gergő Kránicz and András Kovács.

Dark Energy Spectroscopic Instrument (DESI) Experiment

DOE's DESI started its 5-year suvey in May 2021!

- World's premier multi-object spectrograph w/5,000 fibers, positioned robotically

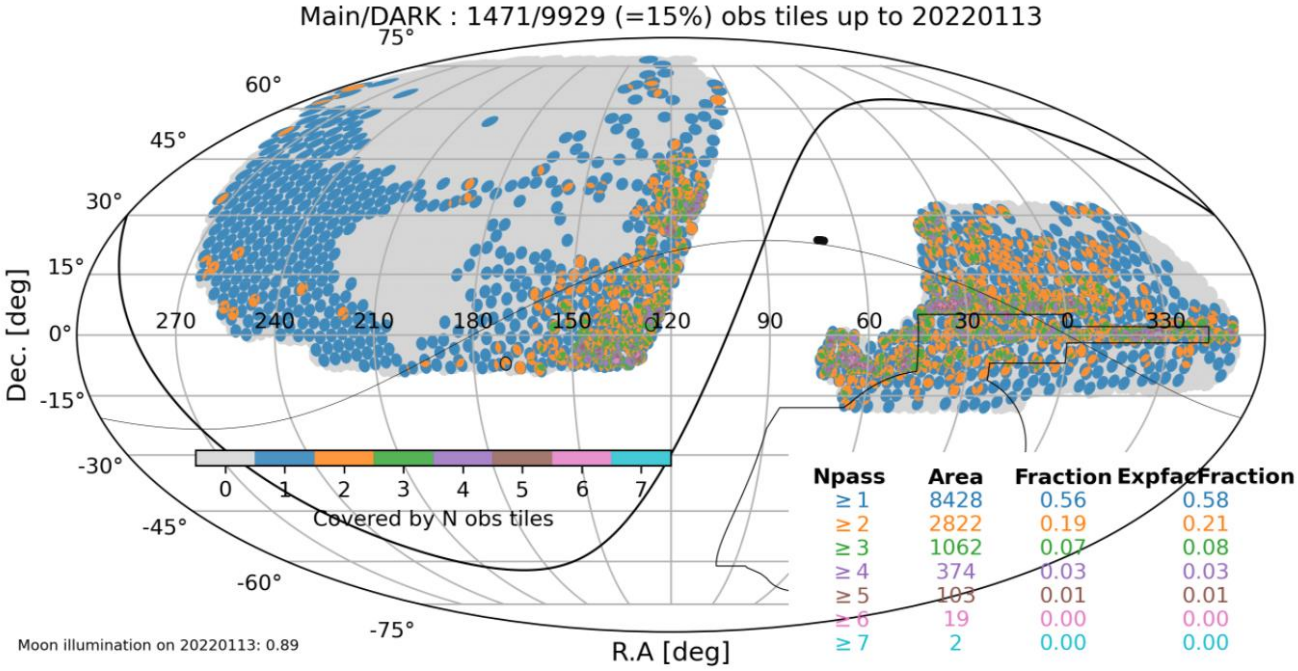
First **Stage IV dark energy** → Will measure spectra of > 40 million galaxies

Running at full steam → 8,000 square degrees surveyed already:

- 8,000 in single pass of an eventual seven passes of 14,000 sq.deg.
- Expect five or more passes on 2,000 sq.deg. by summer

DOE/LBNL Project: Instrumentation, Data Management System, & Upgrades of NSF's Kitt Peak Mayall telescope (including MOSAIC camera).

Operations: DOE provides full support for NSF's Mayall telescope.



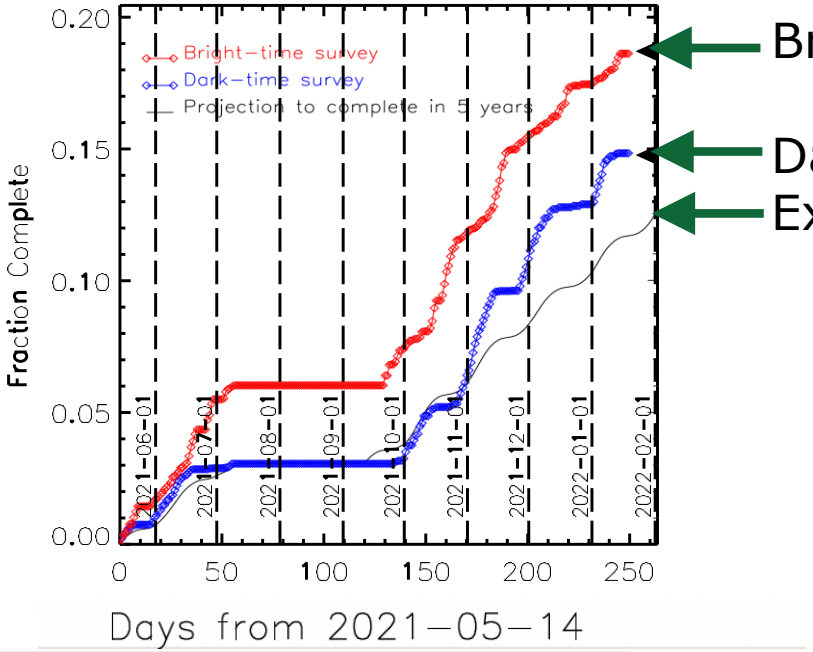
Credit: D. Schlegel (LBNL)

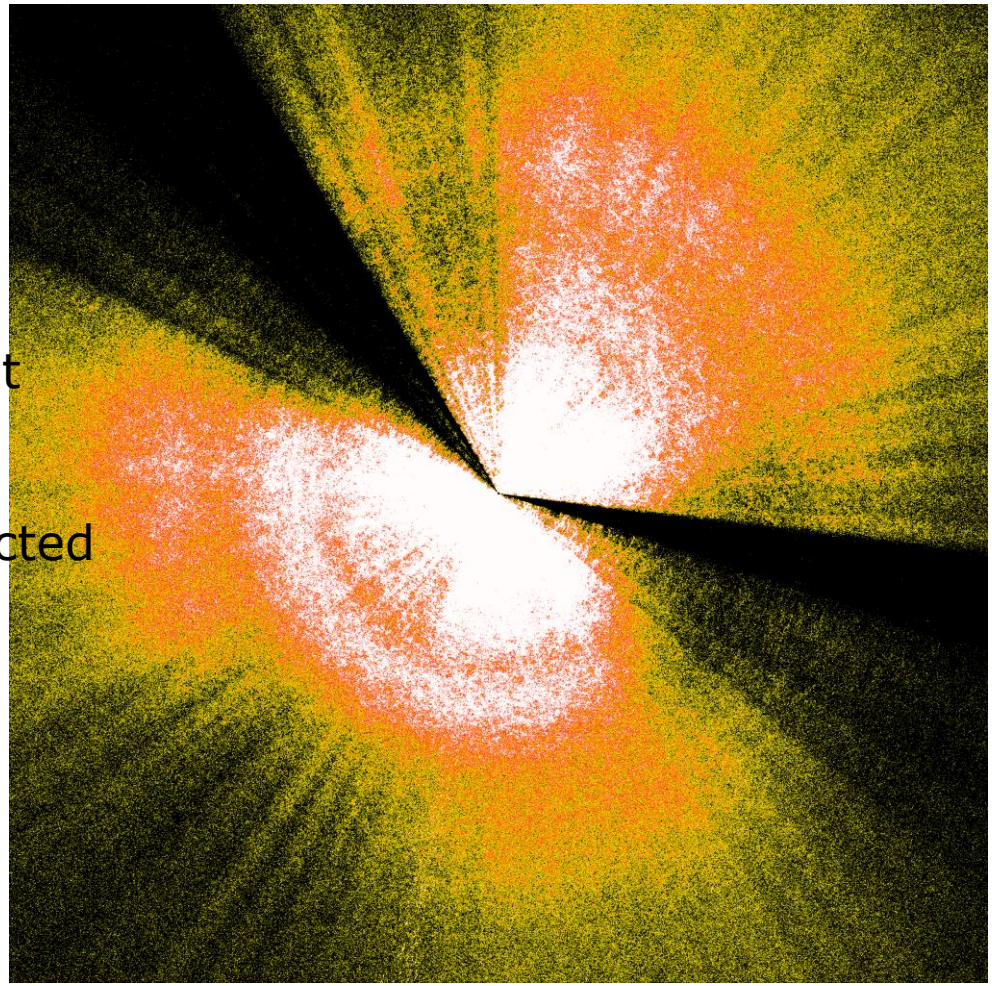
DESI has surveyed 7.5 million galaxies to date

Survey is running at high efficiency (and slightly ahead of schedule)

- **Already surpassed the sum of all prior largest redshift surveys**

January 6: DESI broke its own record for the most redshifts recorded, 157,641 unique redshifts in a single night.





Credit: D. Schlegel (LBNL)

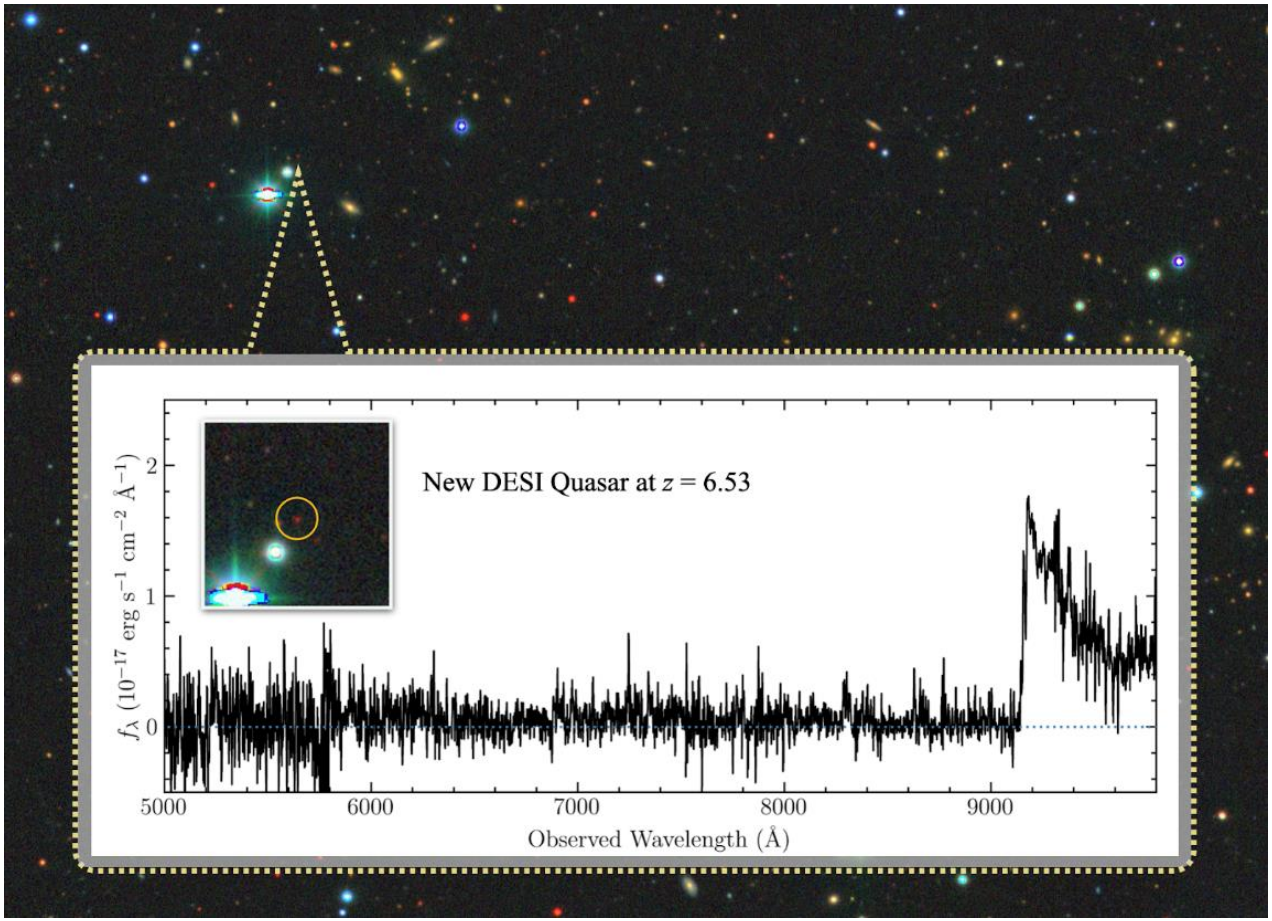
DESI: Survey Validation (SV) Phase Data

- Survey validation (SV) data going through final data processing, expected to finish in February 2022
- Two million object redshifts in 20 (3 deg. diameter) deep, high-completeness fields within this data assembly
- SV public data release by end of this year or early next year
  - 144 unique target selection fields
  - 20 complete "rosette" fields (3 deg. diam.)
  - 21 spare fiber secondary programs
  - 9 secondary programs on dedicated fields

Field	Field Center	
	α (deg)	δ (deg)
COSMOS	150.10	2.18
GAMA G12 #1	179.60	0.00
GAMA G12 #2	183.10	0.00
GOODS-North	189.90	61.80
Coma cluster	194.75	28.20
VVDS-F14	210.00	5.00
DEEP2 CFHTLS-D3/W3	215.50	52.50
Bootes NDWFS/AGES	217.80	34.40
GAMA G15 #1	216.30	-0.60
GAMA G15 #2	219.80	-0.60
GAMA G15 #3	218.05	2.43
ELAIS N1	242.75	54.98
HSC DR2 #1	241.05	43.45
HSC DR2 #2	245.88	43.45
XDEEP2	252.50	34.50
Euclid Deep Field	269.73	66.02
Coma outskirts	194.75	24.70
GAMMA G15 #4	212.80	-0.60
Near ecliptic pole	269.73	62.52
HSC DR2	236.10	43.45

DESI at Cosmopalooza

- First DESI scientific results presented at Cosmopalooza (replacement for cancelled AAS meeting) in January.



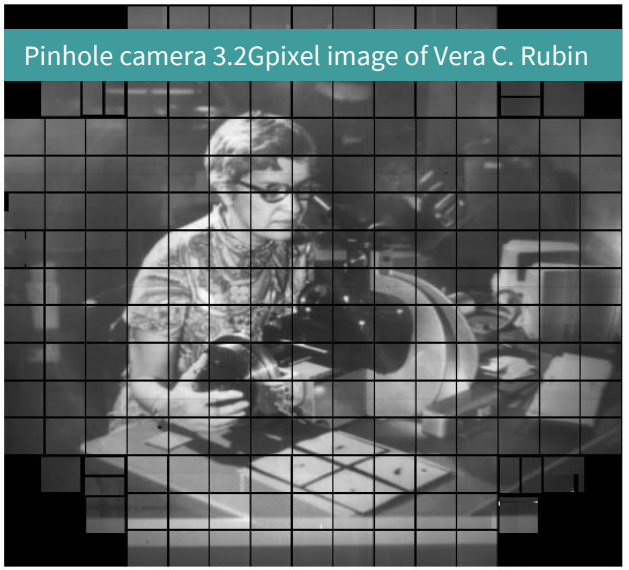
Example of the throughput of DESI's near-infrared spectroscopy in finding DESI's highest redshift, z=6.53, quasar

Vera C. Rubin Observatory

A next-generation, ground-based facility, providing time-lapse imaging of faint astronomical objects across the entire visible sky every few nights.

Discovery Science! 4 primary themes:

- Probing Dark matter and **Dark Energy**
- Mapping the Milky Way
- An Inventory of the Solar System
- The Transient Optical Sky



NSF (AURA) and DOE (SLAC) partnership, with private, international contributions

- Project: DOE responsible for the Camera fabrication & commissioning
- Facility Operations: 50/50 DOE & NSF split

For the first ten years of operations (prime survey), the **Vera C. Rubin Observatory** will carry out the **Legacy Survey of Space and Time (LSST)**, using the **DOE's LSST Camera** and the **NSF's Simonyi Survey Telescope**.

Due to covid-19, expect delay of about ~ 22 months for overall Observatory completion & data-taking start (now mid 2024)

DOE's LSST Camera – Project Complete!

HEP Camera Project Fabrication:

- Due to covid-19 delays & uncertainties, the MIE was restructured to complete at the subsystem level
  - Got CD-4 approval at end of Sept. 2021 (Project Complete)
  - All key performance parameters demonstrated.

3.2 Giga Pixel Focal Plane

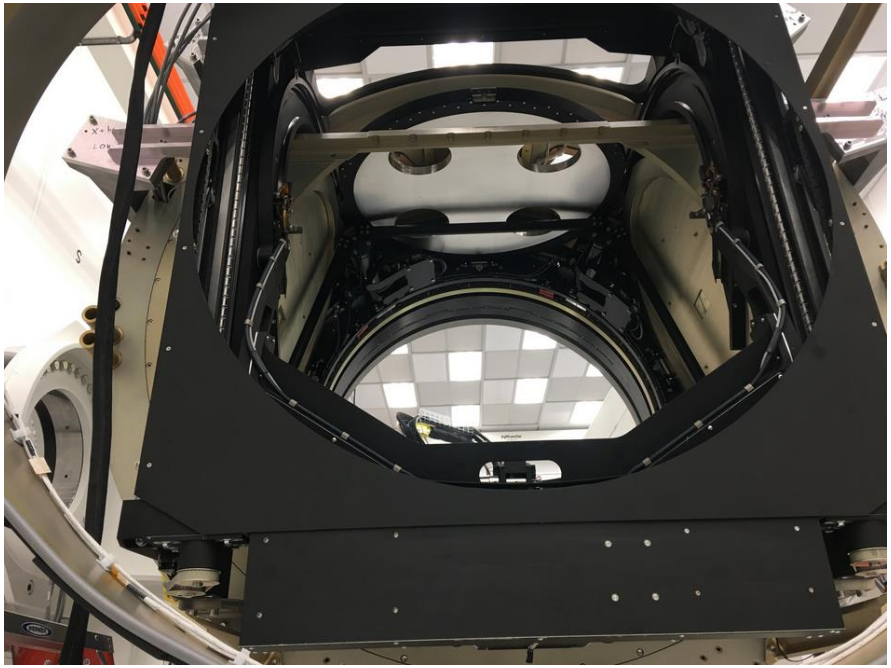
- Delivery of all the filters to SLAC completed the scope of the LSST Camera project.

L1-L2 lens assembly (L1 lens on top at 1.57m diameter)

LSST Camera Commissioning

HEP Commissioning roles – LSST Camera

- Assembly and verification at SLAC
- Ready to ship to Chile (~ late fall FY2022)
- Ready for for installation & commissioning on telescope (~ spring 2023)

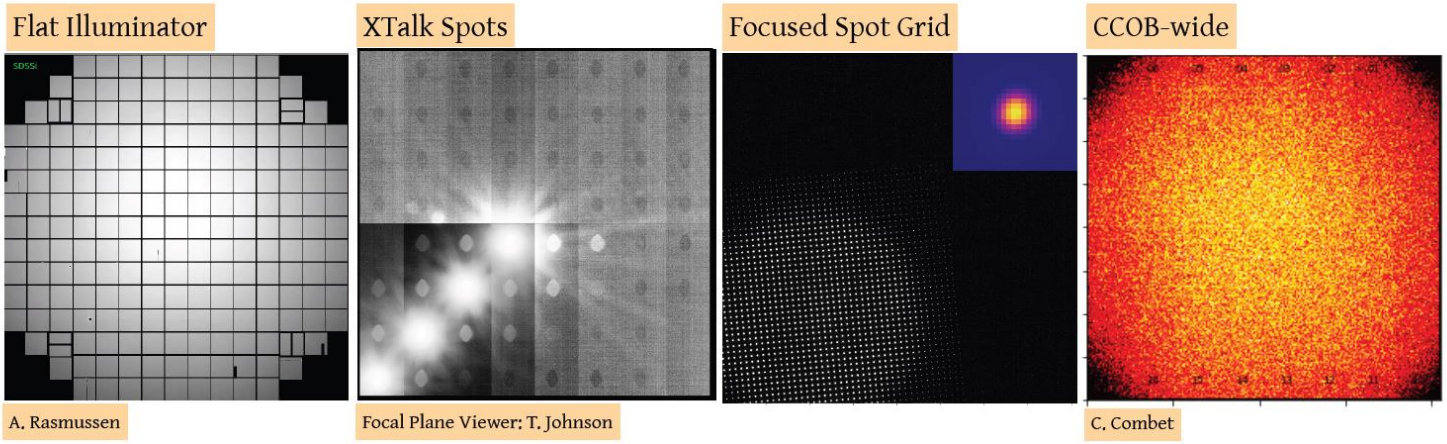


Commissioning of the filter exchange system by the IN2P3 team at SLAC has resulted in compliant filter exchange time below the 90sec requirement to the camera

All filters received from the LSSTCam project have been transferred to the clean room at SLAC

LSST Camera Commissioning at SLAC

Comprehensive set of images was collected w/standard Calibration Images: Bias, Dark, Flats plus structured images with several moveable projectors



Electro-optical testing in progress

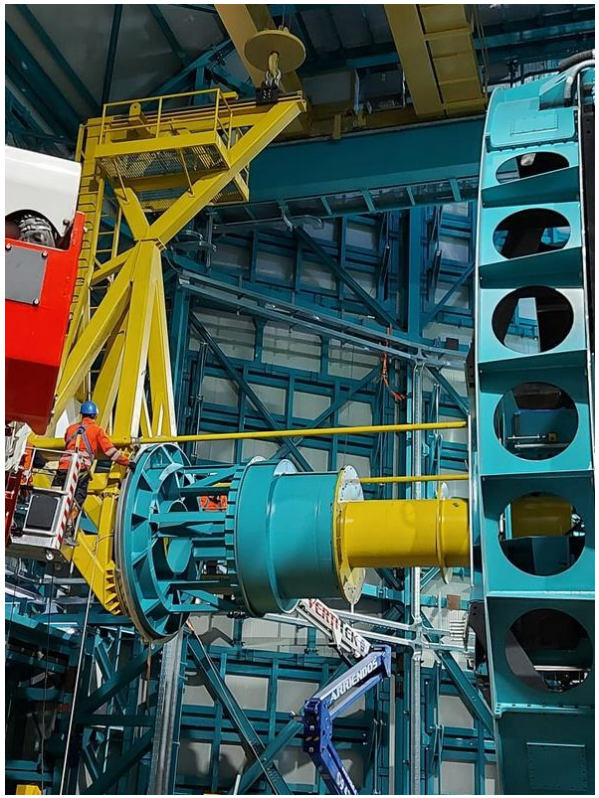
- More than 15K full focal plane images and more than 42K single raft image collected
- ONLY 3 non-useable out of 3024 focal plane channels. No degradation over time to date
- The Data Management Team was engaged: Data copied to NCSA & SLAC data facility

LSST Camera Commissioning in Chile

The **Commissioning Camera** has undergone critical testing to verify the interface with the rotator and cable wrap and the 9-CCD focal plane has been operated extensively (9800 exposures recorded to date)

The refrigeration pathfinder, part of the commissioning camera assembly has been turned on to assess performance on the summit

Camera Team supported the vendor demonstration of the camera installation on the telescope in November using a mass simulator.



Rubin Observatory: Facility Operations Planning

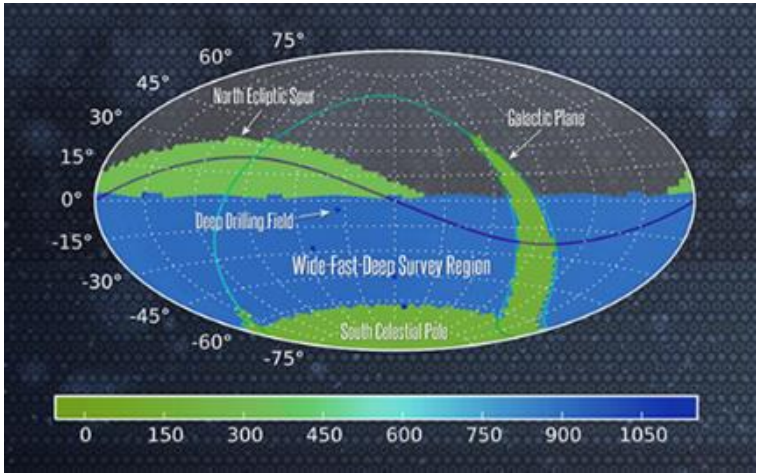
The Rubin Observatory will conduct a 10-year deep, wide, fast, optical imaging Legacy Survey of Space and Time (LSST) using DOE's LSST Camera & the Simonyi Survey Telescope

DOE & NSF will provide 50/50 support for operations
- Joint review of Ops plan scheduled for Feb. 2022

DOE-supported operations efforts are primarily:

- Camera maintenance and operations
- US Data Facility → SLAC selected to be the managing organization
  - Will carry out the full data facility efforts & deliver all the data products to all researchers and collaborations

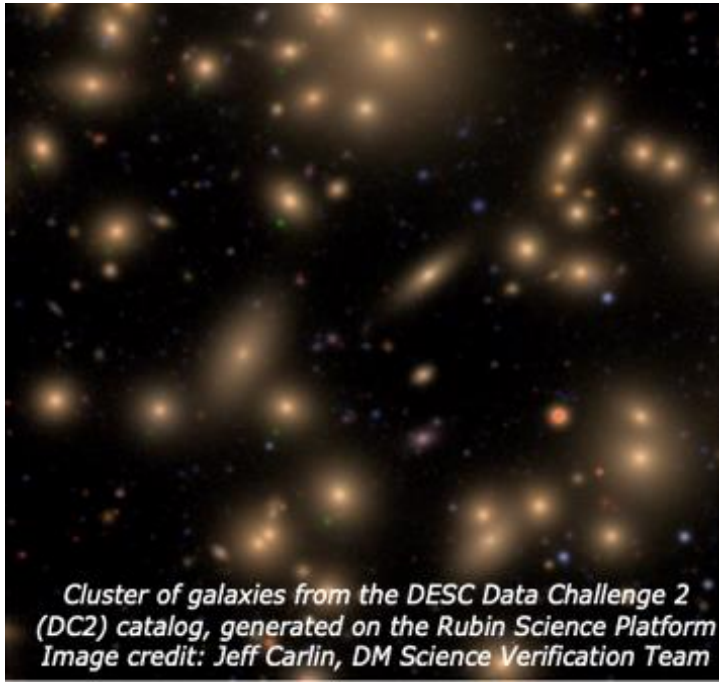
International in-kind contributions
- in exchange for early access to data.
- Agreements are being drafted.



Rubin Observatory Legacy Survey of Space and Time → Dark Energy Science Collaboration (DESC)

Scientific Research - Both NSF and DOE will support community efforts

- **DOE's research efforts are organized through DESC**; planning and readiness activities are continuing.



Cluster of galaxies from the DESC Data Challenge 2 (DC2) catalog, generated on the Rubin Science Platform Image credit: Jeff Carlin, DM Science Verification Team

Data enable study of the nature of Dark Energy via complementary probes: SNe, BAO, Weak Lensing, Galaxy Clusters

These tests also provide constraints on the nature of inflation, modifications to GR, the masses of neutrinos, the nature of dark matter.

Collaboration ~ 1180 members;

- 235 full members; from 20+ countries
- Since 2018, more than 40 journal publications

Connections with Rubin Observatory

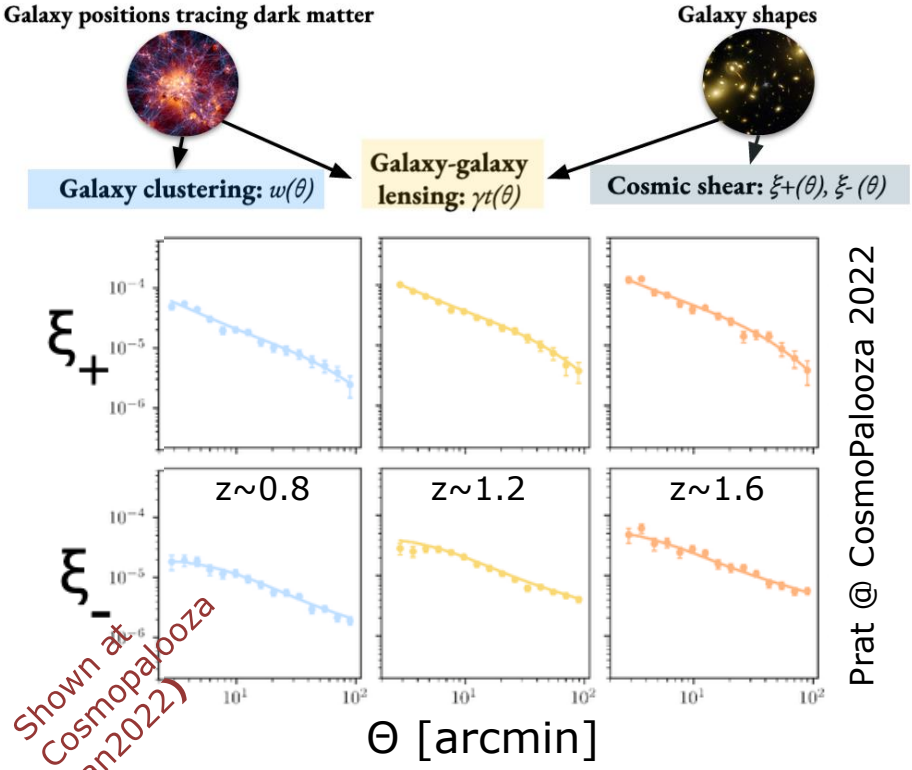
- Provided DESC Data Challenge 2 simulations for use in Rubin Data Preview 0, which is enabling 'delegates' from all LSST Science Collabs to test analyses
- Proposals involving ~50 DESC members have been accepted by Rubin Observatory for participation in technical validation of the observatory

LSST DESC: Recent Highlights

Science Highlights from DC2 Analysis – Validating analysis tools

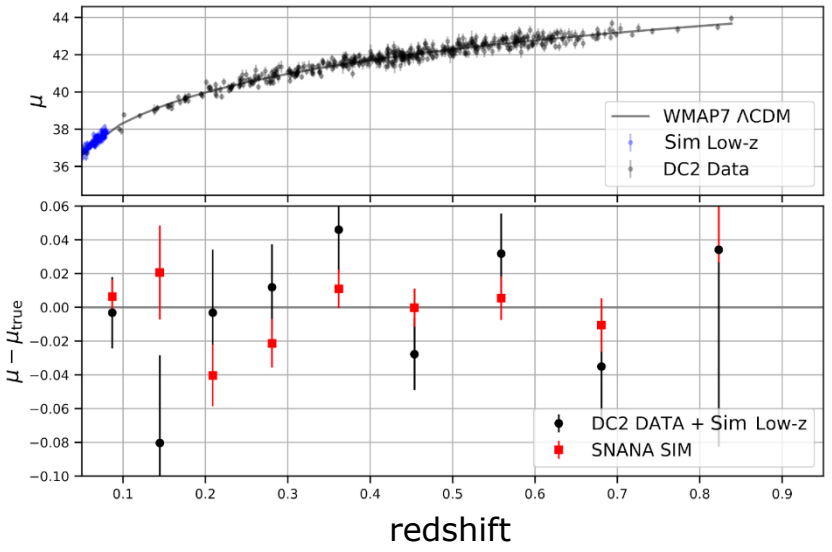
Static cosmology probes: 3x2pt analysis

Validating 3x2pt pipeline (TXPipe): Can we recover 3 angular two-point correlation functions? **YES**



Time domain probe: Type Ia Supernovae

End-to-end test of SN analysis pipeline: Can we recover input cosmological parameters, individual light curves over full redshift range from DC2 image simulations using the LSST pipeline and literature codes: **YES**
→First-ever simulated pixels-to-cosmology analysis! (Submitted)



Astro2020 Science Theme: New Messengers and New Physics

Scientific questions associated with inquiries ranging from astronomical constraints on the nature of dark matter and dark energy, to the new astrophysics enabled by combined observations with particles, neutrinos, gravitational waves, and light.

The needed capabilities include:

- Facilities to discover and characterize the brightness and spectra of transient sources as they appear and fade away
- Ground-based ELTs to see light coincident with mergers
- A next-generation radio observatory to detect the relativistic jets produced by neutron stars & black holes
- **Next generation CMB telescopes to search for the polarization produced by gravitational waves in the infant universe**
- Upgrades to current ground-based gravitational wave detectors, and development of next generation technologies
- Improvements in the sensitivity and angular resolution of high energy neutrino observatories

Astro2020 recommended DOE/NSF partnership on CMB-S4 (p. 7-26)

NSF & DOE should jointly pursue the design & implementation of the next generation ground-based cosmic microwave background experiment.

HEP is having internal discussions & will talk with NSF at the appropriate time.

Astro2020 Report: Realizing the Opportunities

CMB-S4 builds on the foundation of decades of CMB measurements to take a major leap, pushing CMB science to the next level, with scientific goals:

- B-mode CMB polarization signatures of primordial gravitational waves and inflation
- Maps 50% sky, every other day from 0.1-1 cm with unprecedented sensitivity
- Broad science including systematic time domain science

Key Attributes

- Balanced program between DOE (60%) and NSF (40%) for all phases
- Brings wide range of technical & scientific expertise from community & national labs
- Total design, development and construction cost: $660M
- First observations could begin by 2030

"**An important requirement for our strong endorsement is that the project broadly engage astronomers beyond the traditional CMB community.** CMB-S4 will produce data sets of unprecedented sensitivity, cadence and spectral coverage that will advance general astrophysics and open discovery space opportunities for diverse scientific communities. Previous CMB experiments have not had the charge or funding to make data rapidly available and generally usable."

"Because of its great potential to advance general astrophysics and open discovery space, it is essential that CMB-S4 produce transient alerts, as well as calibrated maps in all bands and on all angular scales that are openly usable and accessible on as rapid a cadence as practical"

CMB-S4 Planning & Status

2014 HEPAP/P5 strategic plan recommended CMB-S4 as a joint DOE/NSF project
2016-2017 AAAC subpanel: CMB-S4 Concept Definition Taskforce study
2019 – DOE approved CD-0; **HEP Cosmic Frontier's next Flagship Project**
2020 – LBNL chosen as DOE's lead lab
FY2021 - Congress approved as an MIE "project start"

Goal: cross critical science thresholds, including definitive tests of Inflation

Science	Stage 2	Stage 3	Stage 4	Top Level goal for CMB-S4
Inflation "r"	≤0.1	≤0.01	**≤0.001**	Detect/rule out classes of inflationary models
s(Neff)	0.14	0.06	**0.03**	Detect/rule out light relic particles w/ spin
s(Mn)	0.15eV	0.06eV	**0.02eV**	3s detection
# detectors	~1000	~10,000	**~500,000**	Deployed on multiple telescopes
Sensitivity (mK^{-2})	10^5	10^8	**10^8**	2° to 1' angular scales

In planning phase as a joint DOE & NSF project:

21 telescopes, in 2 aperture scales, at 2 sites:

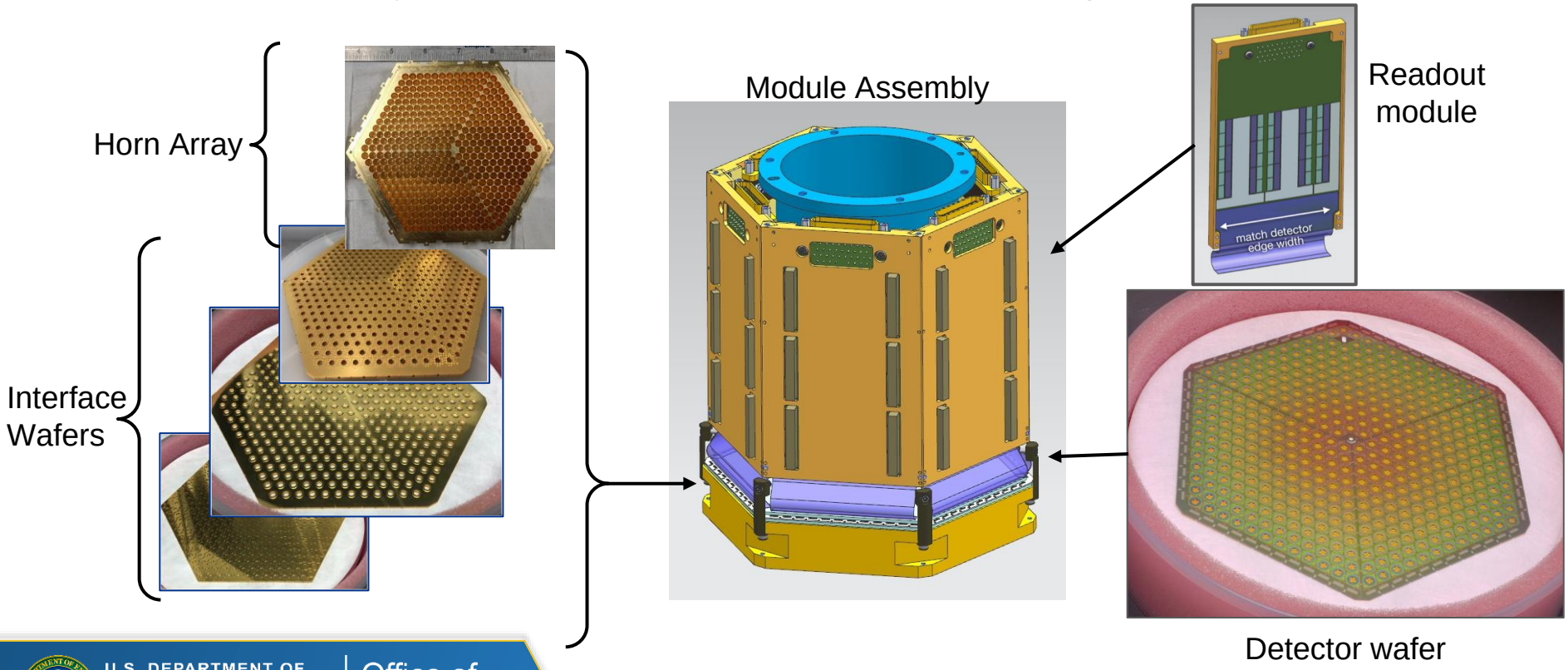
- 2 large aperture (6m) in **Chile**
  - Deep & wide N_{eff} & Legacy Survey ~60% of sky
- 1 large (5m), 18 small (0.5m) at **South Pole**
  - Ultra-deep survey ≥ 3% of sky + delensing

Total 500,000 cryogenic sensors, superconducting readout; scale up of over x10 from all stage 3.

Collaboration > 300 members!

CMB-S4 Planning & Status

- Short-term funding gap is limiting progress, particularly for Detectors, Readout, and Modules which require continued R&D before production can start
- Strong recommendation from Astro2020 for DOE and NSF to partner in CMB-S4 development.
- Status and plans updated and presented at the Director's Review November 2021; DOE Office of Project Assessment status review in February 2022



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Astro2020 – Other Recommendations

Astro2020 Chapter 3: The Profession & its Societal Impacts

Recommendation (p. 3-14): Funding agencies should increase incentives for improving diversity among the college/university astronomy and astrophysics faculty, for example by increasing the number of awards that invest in the development and retention of early-career faculty and other activities for members of under-represented groups.

Recommendation (p. 3-22): NASA, NSF, and DOE should reinvest in professional workforce diversity programs at the division/directorate levels with purview over astronomy and astrophysics. Because academic pipeline transitions are loss points in general, supporting the creation and continued operation of "bridge" type programs across junctures in the higher-education pipeline and into the professional ranks appear especially promising.

Recommendation (p. 3-23): NSF, DOE and NASA should implement undergraduate and graduate "traineeship" funding, akin to the NIH MARC and NIH "T" training grant programs, to incentivize department/institution-level commitment to professional workforce development, and prioritize interdisciplinary training, diversity, and preparation for a variety of career outcomes.

Recommendation (p. 3-27): NASA, NSF, DOE, and professional societies should ensure that their scientific integrity policies address harassment and discrimination by individuals as forms of research/scientific misconduct.

Astro2020 Chapter 3: The Profession & its Societal Impacts

Assessment of equity in review and awarding of grants and projects is difficult because of disparity of available data on proposers, awards

Recommendation (p. 3-29): NASA, NSF, and DOE should implement a cross-agency committee or working group tasked with establishing a consistent format and policy for regularly collecting, evaluating, and publicly reporting demographic data and indicators pertaining at a minimum to outcomes of proposal competitions.

- **Although gender parity overall has improved steadily over the decade, imbalances persist in leadership ranks of missions and projects on all scales. The representation of URMs remains almost non-existent**

Recommendation (p. 3-30): NASA, DOE, and NSF should consider including diversity—of project teams and participants—in the evaluation of funding awards to individual investigators, project and mission teams, and third-party organizations that manage facilities. Approaches would be agency specific, and appropriate to the scale of the projects.

Recommendation (p. 3-35): The astronomy community should, through the American Astronomical Society in partnership with other major professional societies (e.g., American Physical Society, American Geophysical Union, International Astronomical Union), work with experts from other experienced disciplines (such as archaeology and social sciences) and representatives from local communities to define a Community Astronomy model of engagement that advances scientific research while respecting, empowering and benefiting local communities.

Astro2020 Chapter 4: Optimizing the Science - Foundations

➔Enabling Science Through a Healthy Individual Investigator Grants Program

Recommendation (p. 4-3): The National Science Foundation, NASA, and the Department of Energy should release data on proposal success rates on an annual basis and should track metrics that allow them to analyze statistically what is being supported.

➔The data revolution enables much of modern astrophysics. Large surveys, accessible public datasets, and computation require strategic investments in archiving, reduction, and analysis

Recommendation (p. 4-20): NASA and the National Science Foundation should explore mechanisms to improve coordination among U.S. archive centers and to create a centralized nexus for interacting with the international archive communities. The goals of this effort should be informed by the broad scientific needs of the astronomical community.

Recommendation (p. 4-21): The National Science Foundation and stakeholders should develop a plan to address how to design, build, deploy, and sustain pipelines for producing science- ready data across all general-purpose ground-based observatories (both federally and privately funded), providing funding in exchange for ensuring that all pipelined observations are archived in a standard format for eventual public use.

- Though DOE isn't listed, we do have an interest and effort in this area.

DOE's SC and HEP already have efforts addressing a number of the Astro2020 recommendations

The DOE **Office of Science (SC)** is fully committed to fostering safe, diverse, equitable, and inclusive work, research, and funding environments that value mutual respect and personal integrity.
https://www.energy.gov/science/diversity-equity-inclusion

DOE **SC**-wide effort to implement DEI 2019 Report Recommendations. See report to Nov. 2021 HEPAP by Dr. Julie Carruthers, head of DOE SC Office of Diversity, Inclusion & Research Integrity.
https://science.osti.gov/-/media/hep/hepap/pdf/202111/SC_DEI_Initiatives-Carruthers_HEPAP_202111.pdf

SC has added language to its Funding Opportunity Announcement's (FOA) to remind the community of prohibition of harassment & discrimination by awardees and recipient institutions.

SC now includes diversity-promoting program policy factors in all of its FOA's which allow the selection official to make award decisions based on other factors when all other things such as merit are considered equal, including e.g. promoting diversity of PI's, institutions, etc.

DOE's SC and HEP already have efforts addressing a number of the Astro2020 recommendations

A FOA is in progress for **SC**-wide **Reaching a New Energy Sciences Workforce (RENEW)** program to support undergrad and graduate student fellowships targeted at MSI/URG

- Program was piloted in the Officed of Nuclear Physics (NP) in FY21
- **HEP** jointly supported some of NP awards at institutions which had adjacent HEP programs
- Plan to implement an **HEP** version in FY22 at the $4M/year level ($30M SC overall)

To support this:

- Office of Workforce Development for Teachers and Scientists (WDTS) has been conducting "Listening Sessions" with MSI/URG administrators, faculty, students & professional societies to boost participation in SC programs

- SC has also been increasing its outreach efforts to individual and institutions underrepresented in the SC portfolio, bringing broader awareness of SC opportunities through a more coordinated SC-wide effort.

DOE's SC and HEP already have efforts addressing a number of the Astro2020 recommendations

Some other **SC Office of Workforce Development for Teachers and Scientists (WDTS)** programs: https://science.osti.gov/wdts

SC Graduate Student Research fellowships (SCSGR)
- Supports grad student research at a DOE lab, 3 to 12 months
- Two calls per year, usually Feb/Aug
- Applications typically due May/Nov for following Fall or Summer start

Science Undergraduate Laboratory Internships (SULI)
- Supports undergraduate research at a DOE lab, 10 to 16 weeks
- Three calls per year, for following Spring/Summer/Fall terms

Visiting Faculty Program
- Summer research support for faculty/students from historically underrepresented institutions
- One call per year, usually in Oct. Applications due in Jan.

Available funds have been increasing!

DOE's SC and HEP already have efforts addressing a number of the Astro2020 recommendations

SC Early Career Program (PI's within 10 yrs of PhD and awards are for 5 years) continues to promote diversity of PI's and Institutions. Program supports over 80 PI's/year.

- The recently-closed 2022 (FOA) strengthened review criteria consideration of promotion of diversity of PI's and Institutions.

SC conducts regular external reviews of its awards management business practices of all of the offices' research programs through Committee of Visitors reviews every 3-4 years.

- This includes an evaluation of demographics of applicants and awardees and provides an assessment of diversity efforts.
- In the 2020 HEP CoV, the URG and gender fund rate was found to be equivalent to the full rate, but the participation was poor.

DOE's SC and HEP already have efforts addressing a number of the Astro2020 recommendations

HEP Research Opportunities FOA (our primary research FOA) for FY2022 added an appendix on the PI's Recruitment and Mentoring Plan:

> Included in research efforts is training of junior scientists (students & postdocs) to enable them successfully complete their research and move to next career step.

Further, we want to broaden and diversify the HEP research community and increase opportunities for everyone to contribute.

- A new merit criterion was added for proposal evaluation:
  Quality and Efficacy of Recruitment and Mentoring Plan

➔HEP specifically considers diversity when setting up review panels for proposals as well as projects, experimental operations and facilities.

HEP has graduate student traineeships in Instrumentation, Accelerator R&D and Computing, e.g. see https://science.osti.gov/-/media/grants/pdf/foas/2021/SC_FOA_0002496.pdf

DOE's SC and HEP already have efforts addressing a number of the Astro2020 recommendations

HEP holds an annual PI meeting geared towards university PI's, and specifically to help junior PI's to navigate the program and have direct contact with DOE program managers.

- Talks by HEP staff on overall program, budget, new initiatives, DEI, funding opportunities, and details of each area, e.g. Cosmic Frontier.
- We encourage you to read over these talks and contact the relevant program manager regarding program details and opportunities.
- See https://www.orau.gov/heppi2021 -- go to agenda and the linked talks

➔**HEP** will continue to provide info on proposal success rates for Cosmic Frontier in the AAAC meetings.

➔Most of the **HEP Cosmic Frontier** projects and collaborations have developed Codes-of-Conduct. This is a promising practice within the community

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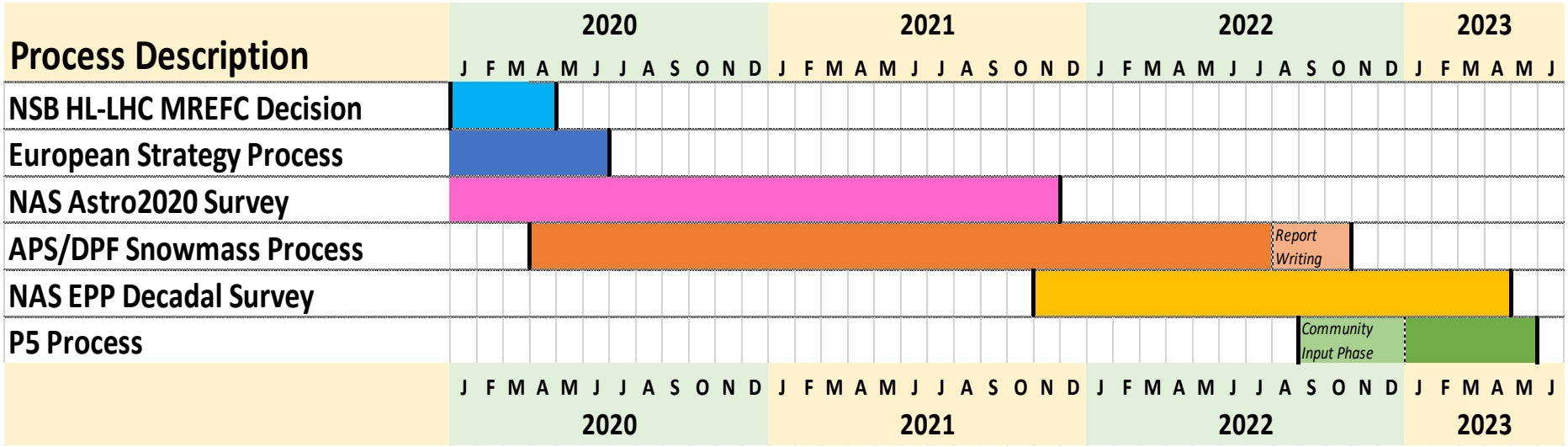
Planning, Summary

Strategic Planning Timeline

- HEP community-wide "Snowmass" study process organized by the Division of Particles and Fields (DPF) of the American Physical Society (APS) has restarted (https://snowmass21.org/start)
  - Paused due to the COVID; resumed full activities as of September 2021
  - "Community Summer Study" will take place July 17–27, 2022 at UW-Seattle.
  - Full Snowmass reports will be available by the end of October 2022
- New National Academy of Sciences (NAS) Elementary Particle Physics (EPP) Decadal Survey will run concurrently with and complement the Snowmass process
- Next P5 process to begin after Snowmass and NAS Decadal Survey, circa late 2022: **P5 report by May 2023 will inform FY 2024 Congressional actions & FY 2025 U.S. budget formulation**



Summary

HEP continues to carry out the 2014 P5 strategic plan; Strong support from the scientific community and the Hill

→Cosmic Frontier continues to produce excellent, world-leading science results

- **DES** completing data analyses
- **DESI** has started it science survey operations (May 2021)

- **LSST Camera** complete, Commissioning ongoing
- **Rubin Observatory** Facility Ops planning to be ready for data in 2024.
- **DESC** planning dark energy studies

- **CMB-S4** – LBNL selected as lead DOE lab; Approved as a fabrication project for DOE in the FY2021 budget; working towards planning for CD-1 and beyond. Recommendation by Astro2020

- **Future Planning** – Astro2020, Snowmass → P5

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