Overview of the Cosmology program

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BERKELEY CENTER *for*
COSMOLOGICAL PHYSICS

Physics Grad Open House
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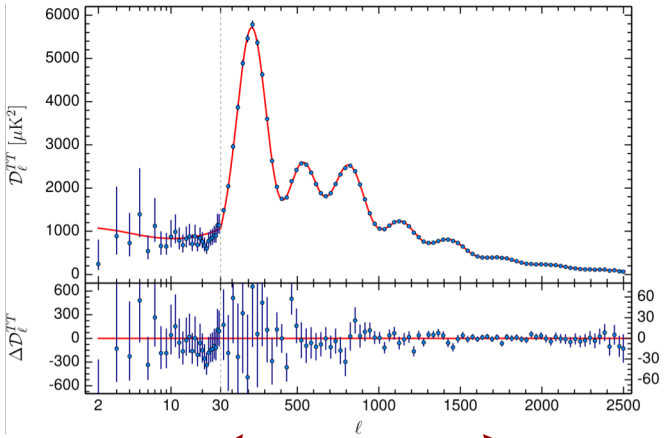
The cosmology group at LBNL

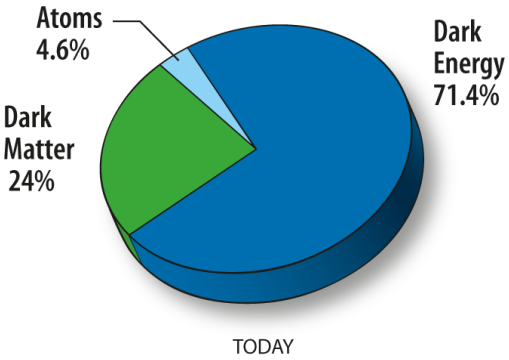
- Over 20 Senior Members. Lots of possible projects and research supervisors.
- Very broad program, from data analysis/modeling/theory to instrumentation, simulations, data management etc.
- Leading major experiments such as DESI and CMB-S4

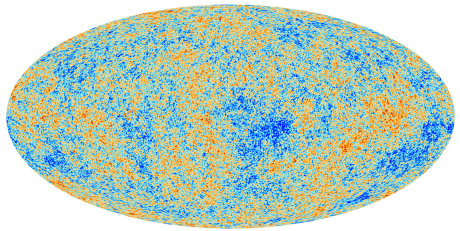
- Very close connection to campus and to BCCP (joint seminars, meetings, weakly pizza, speaker's dinners etc.)
- Campus + LBL → one of the largest and broadest cosmology groups

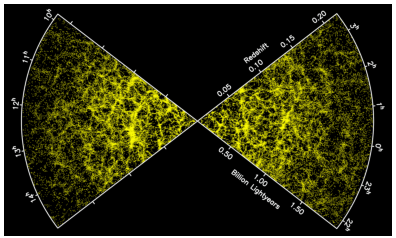
BERKELEY LAB + BERKELEY CENTER *for* COSMOLOGICAL PHYSICS

A simple yet strange Universe









Planck, BOSS

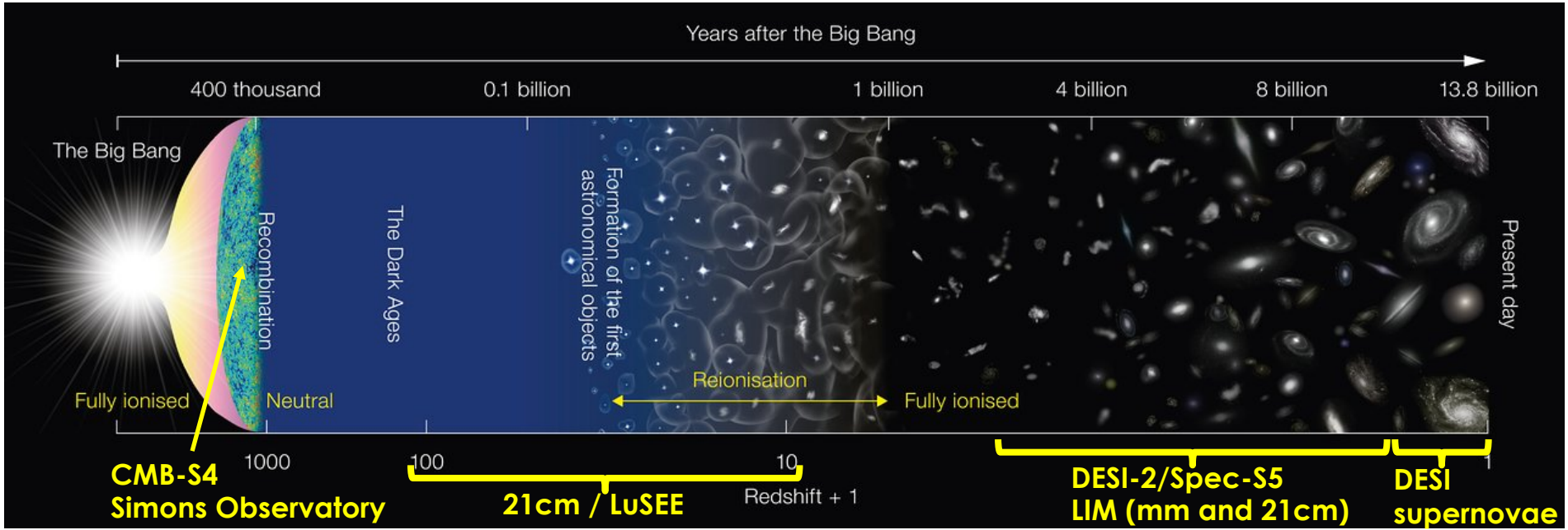
But the model is based on…

- **Dark Matter** (?)
- **Dark Energy** (?)
- **Inflation** (?)
- **Neutrinos and other light particles** (?)

The primary goal of the Cosmology Group program is to understand these "ingredients"!

Brief history of the Universe & our program

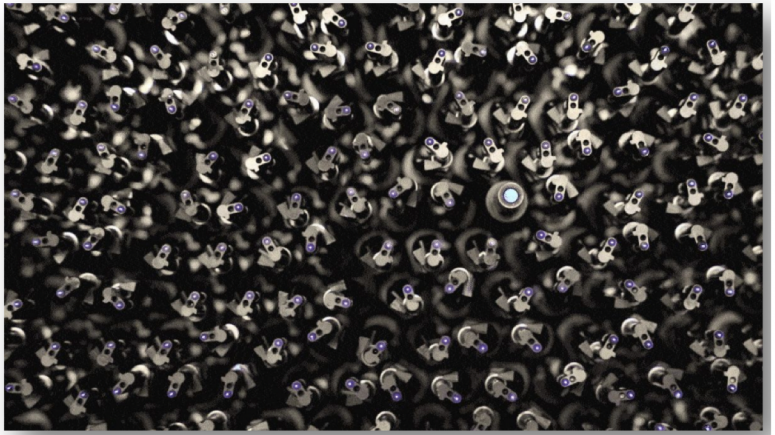
Credit: ESA



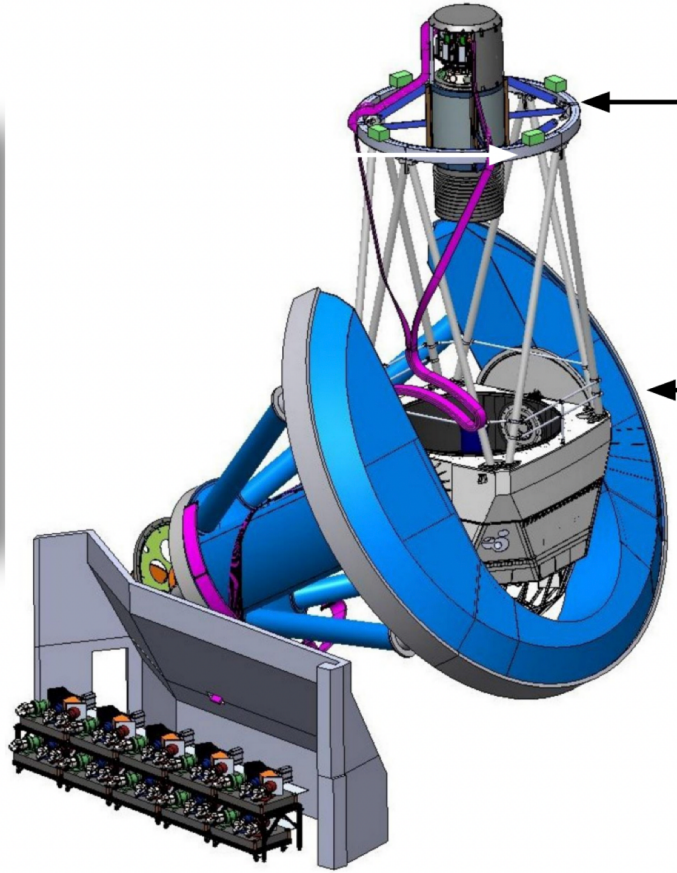
DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

DESI: Massively-multiplexed Spectroscopy



~1 minute to position fibers!



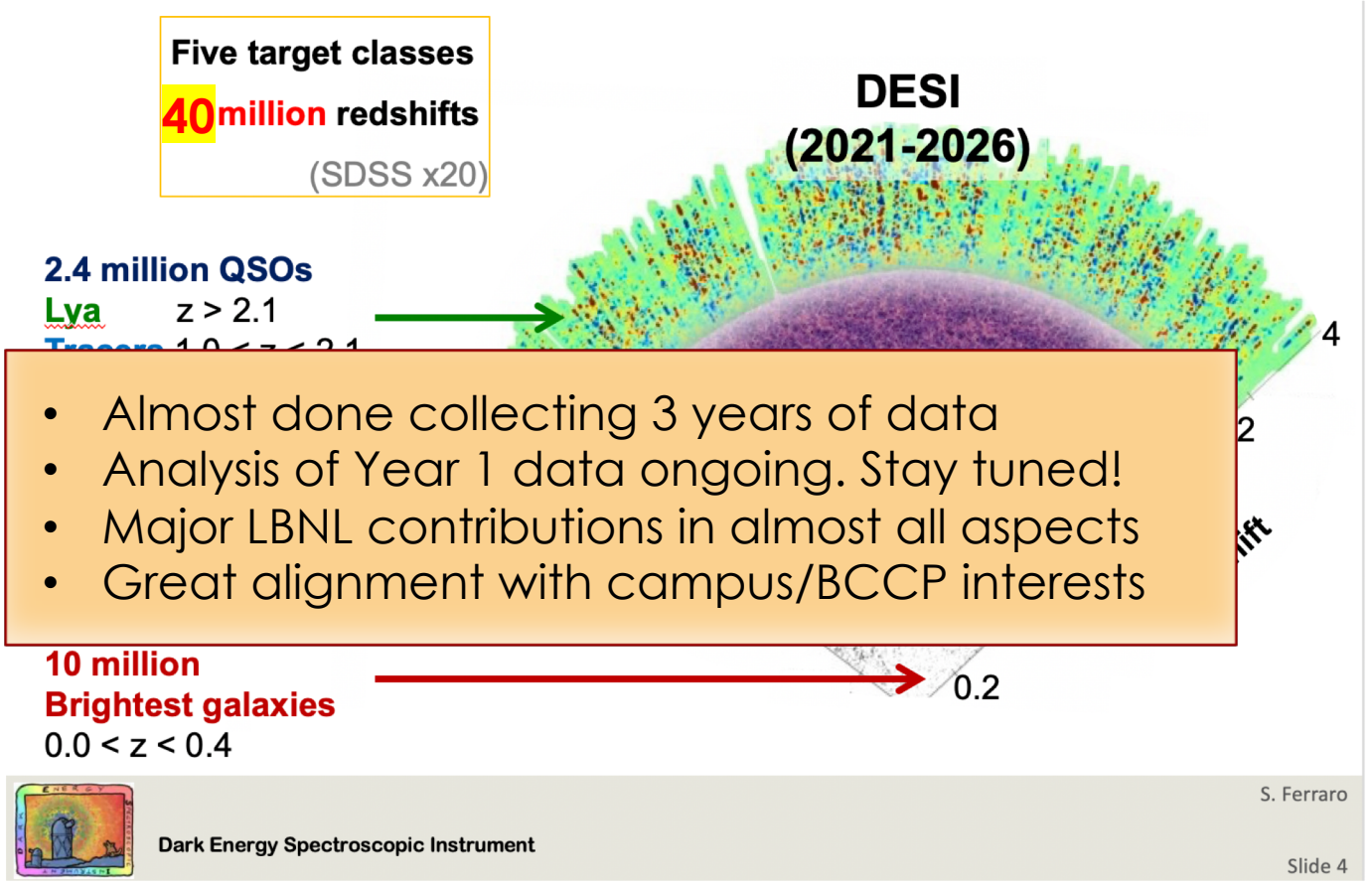
Focal plane assembly with 5000 fiber positioners

Mayall 4m telescope

10 spectrographs (360-980nm)

DESI

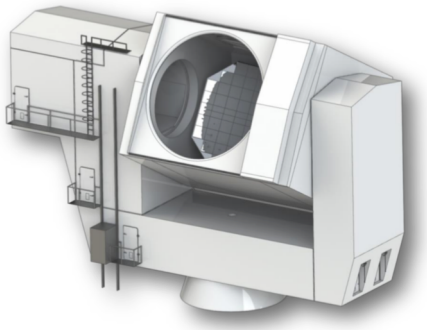
Dark **E**nergy **S**pectroscopic **I**nstrument: Massively multiplexed spectroscopic survey with 5000 robotic fibers, over ~14,000 sq. deg

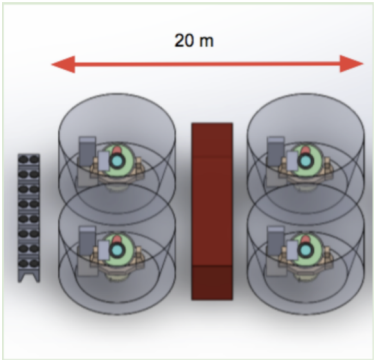


- Almost done collecting 3 years of data
- Analysis of Year 1 data ongoing. Stay tuned!
- Major LBNL contributions in almost all aspects
- Great alignment with campus/BCCP interests

DESI is so successful that we are proposing DESI x 10 (Stage-5 spectroscopy!) two 6 meter telescopes with 26,000 fibers!

The CMB landscape – 2024-2030?





Large Aperture Telescope
one 6 meter in diameter

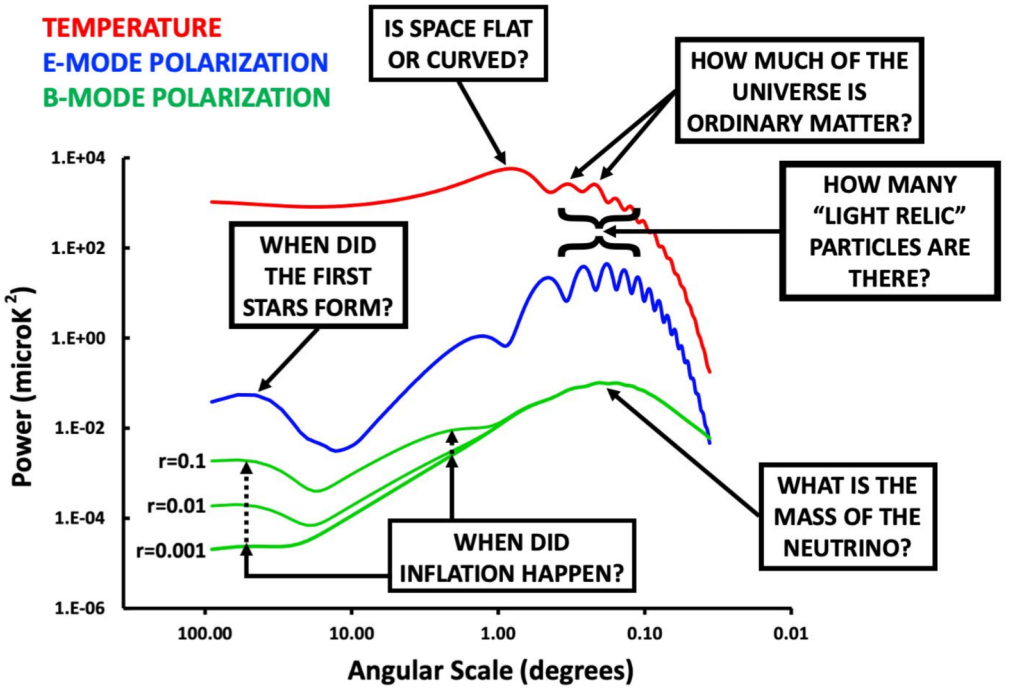
Small Aperture Telescopes
42 cm refractors

Large frequency coverage (30 – 270 GHz)

Funded
6-year program
First light in 2024!

CMB-S4 (2032? – 10 year survey)

	Sensitivity (μK^2)	$\sigma(r)$	$\sigma(N_{eff})$	$\sigma(\Sigma m_\nu)$	Dark Energy F.O.M
Stage 2 1000 detectors	$\geq 10^{-5}$	0.035	0.14	0.15eV (Boss BAO prior)	~180 (DES+BOSS SPT clusters)
Stage 3 10,000 detectors	10^{-6}	0.006	0.06	0.06eV (Boss BAO prior)	~300-600 (DES + DESI SZ Clusters)
Stage 4 CMB-S4 ~500,000 detectors	10^{-8}	0.0005	0.027	0.015eV (DESI BAO +T_e prior)	1250 (DESI +LSST S4 Clusters)



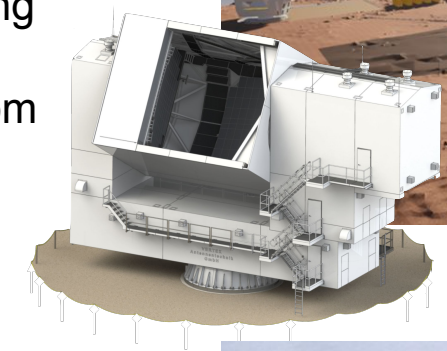
CMB-S4 Project In A Nutshell

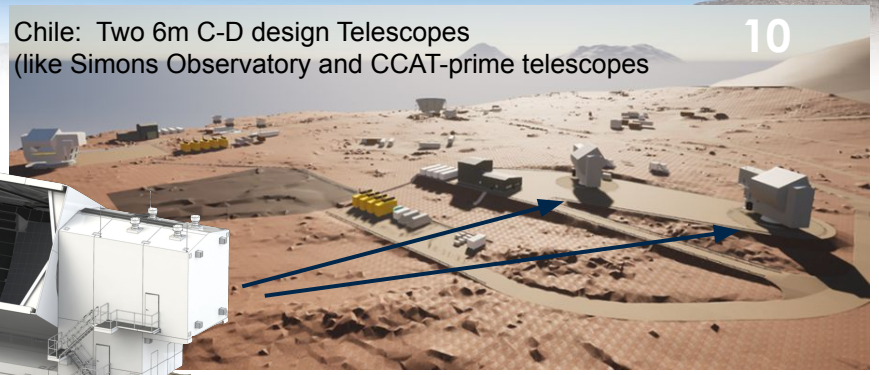
A deep-wide N_{eff} and Legacy Survey using **2 x 6m telescopes** targeting 60% of sky with **274,760 detectors** over 6 bands from Chile, over 7 years.

An ultra-deep “r” survey targeting 3% of sky using **9 x 0.6m small refractor telescopes** with **90,336 detectors** over 8 bands and a **5m telescope** with **128,448 detectors** over 7 bands from South Pole, over 10 years.

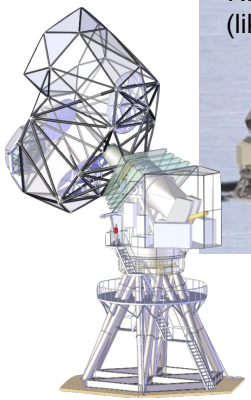
The degree angular scale B-mode sensitivity is provided by both the small and large telescopes; the arcm delensing sensitivity by the large telescope.

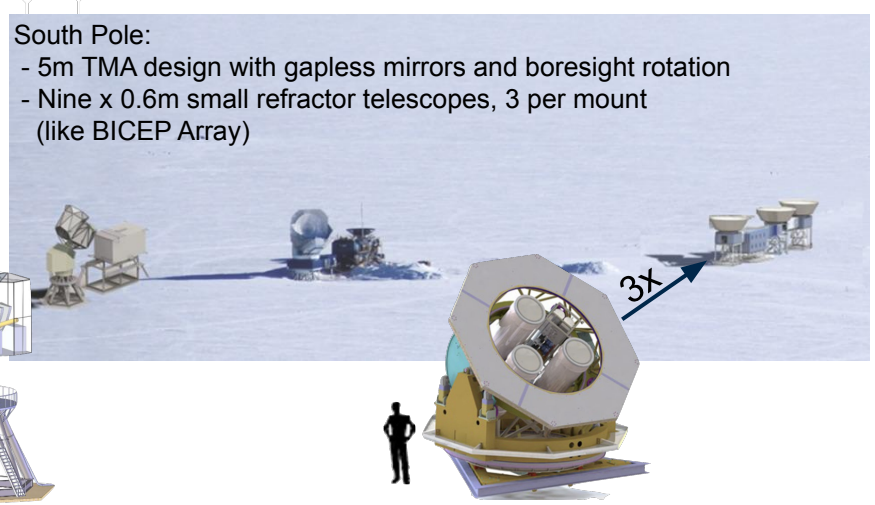
Chile: Two 6m C-D design Telescopes
(like Simons Observatory and CCAT-prime telescopes



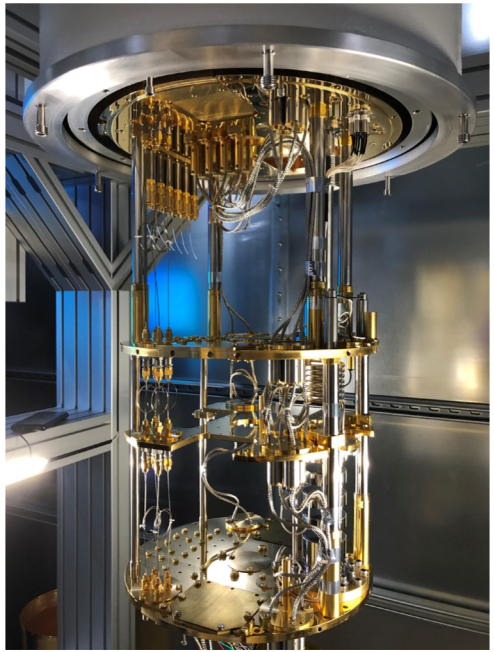


South Pole:
- 5m TMA design with gapless mirrors and boresight rotation
- Nine x 0.6m small refractor telescopes, 3 per mount
(like BICEP Array)

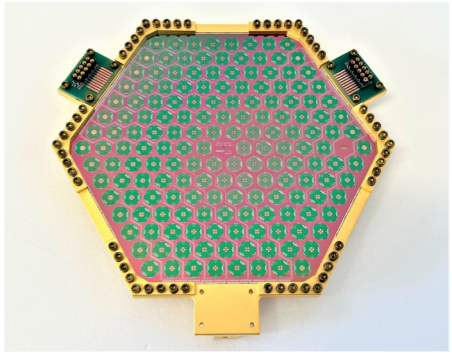




CMB Instrumentation



one of several 100 mK testing systems @ LBNL



prototype sensor array for CMB-S4

telescope site in the Chilean Atacama desert

telescope site at the geographic South Pole

- Exciting CMB instrumentation program at LBNL
  - Superconducting detector & readout development
  - Cryogenic receiver development, integration, and testing
  - Data analysis
- Contact
  - John Groh
  - Akito Kusaka
  - Adrian Lee
  - Aritoki Suzuki

SIMONS ARRAY

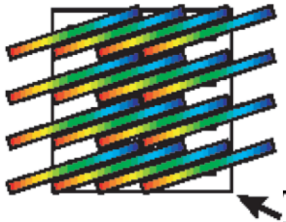
SIMONS OBSERVATORY

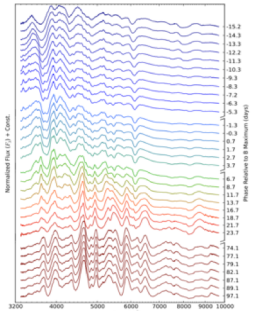
CMB-S4
Next Generation CMB Experiment

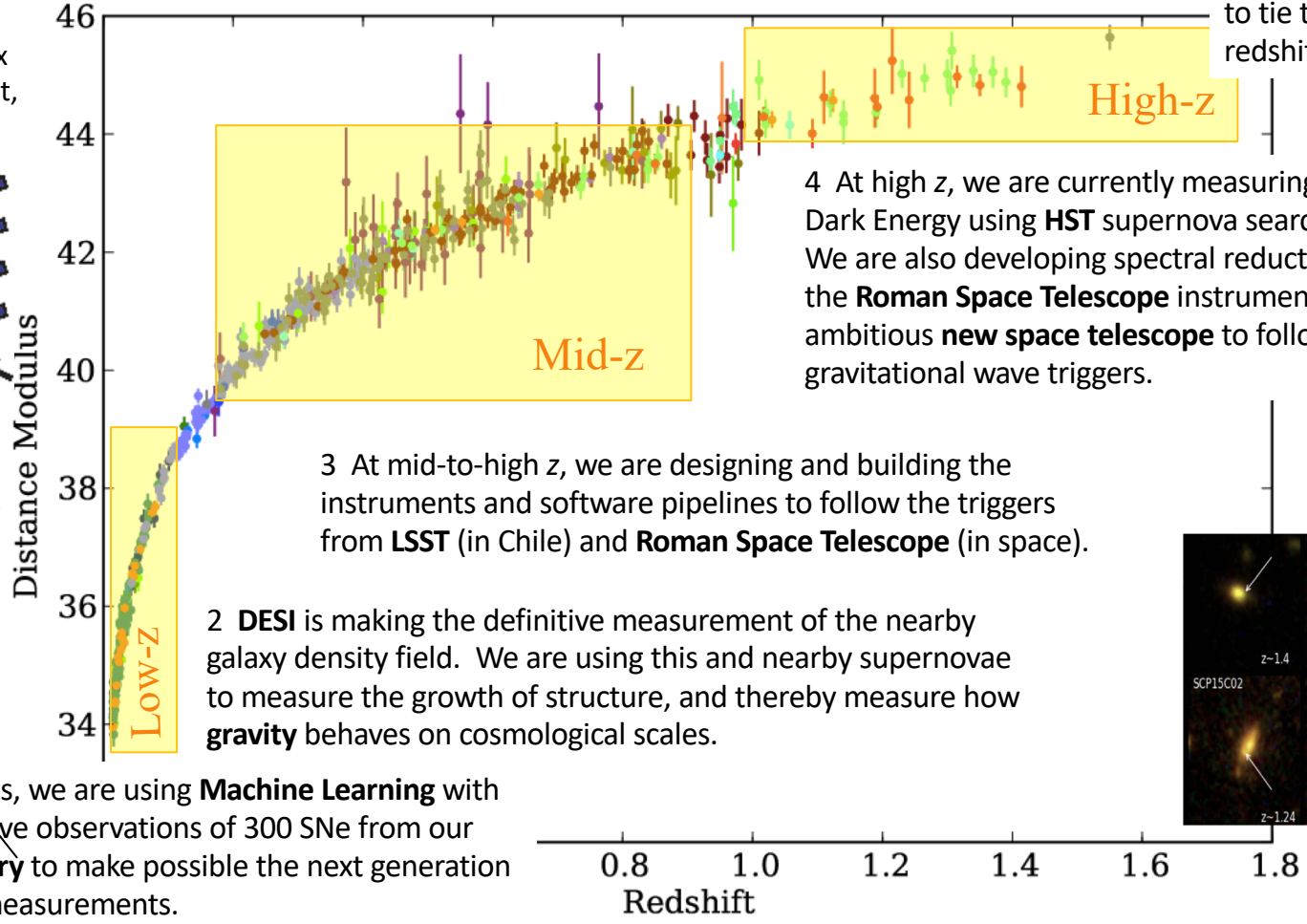
LiteBIRD

Studying Dark Energy & Gravity with Supernovae

Saul Perlmutter,
Greg Aldering, Alex Kim + Peter Nugent, Rob Knop in C[3]





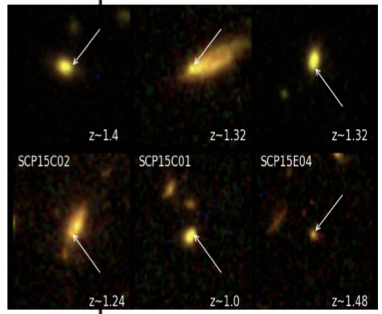


5 We are determining SI-traceable flux calibration to tie together SNe at all redshifts.

4 At high *z*, we are currently measuring time-variability of Dark Energy using **HST** supernova searches and follow-up. We are also developing spectral reduction techniques for the **Roman Space Telescope** instruments, and propose an ambitious **new space telescope** to follow SNe and LIGO gravitational wave triggers.

3 At mid-to-high *z*, we are designing and building the instruments and software pipelines to follow the triggers from **LSST** (in Chile) and **Roman Space Telescope** (in space).

2 **DESI** is making the definitive measurement of the nearby galaxy density field. We are using this and nearby supernovae to measure the growth of structure, and thereby measure how **gravity** behaves on cosmological scales.

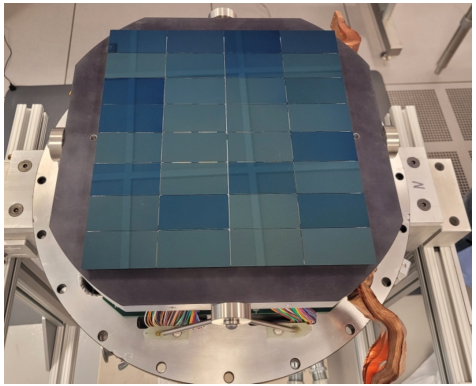


1 At low redshifts, we are using **Machine Learning** with the comprehensive observations of 300 SNe from our **Nearby SN Factory** to make possible the next generation of Dark Energy measurements.

La Silla Schmidt Southern Survey (LS4)

Why consider a shallow, optical survey in the south at a time during which it will not only overlap with the Rubin observatory, but also with the BlackGEM and DECam facilities?

- The cadence of the LSST is not optimal for many transients. While the reach of this experiment is impressive, most science cases are focused on high-precision photometry and astrometry over long periods of time for the optically brighter end of the transients (e.g., variable stars, high-proper motion stars, etc.), while on the fainter end the focus is on transients with slower evolution (e.g., high-redshift type Ia supernovae for cosmology). Some transients (NEOs and KBOs) require frequent paving across the entire sky.
- Not all volumes are created equally. The follow-up capabilities of most of the world's telescopes can only handle the brighter sources discovered by the Rubin Observatory and there is a large swath of transient science in which a timely spectrum is the only path forward for new science. In addition, much of the local universe is inaccessible to the Rubin Observatory due to saturation.
- One survey is not the path forward for transient astrophysics. What has become increasingly apparent in astronomy is the power of two or more overlapping surveys. This now forms the backbone of multi-messenger astronomy as well as the desire to initiate collaborations between such surveys as Euclid and WFIRST with the LSST, or the DES and DECaLS imaging surveys paving the way for a spectroscopic survey like DESI.

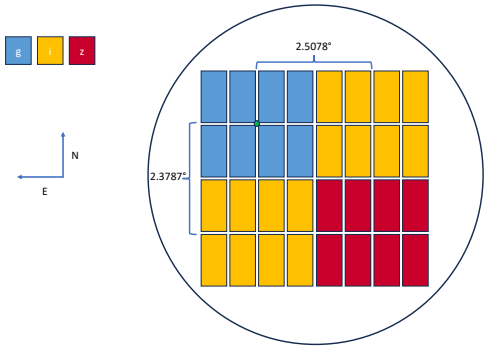


32 fully depleted LBNL CCD's comprise the 20 sq. deg. focal plane. Camera has been assembled and is being tested now.

Quick facts:

- **20 sq. deg. fov**
- **3 fixed filters to start (g+i+i+z)**
- **45s exp; 15s read+slew**
- **g-band: 21.0+/- 0.5**
- **I-band: 20.8 +/- 0.2**
- **z-band: 20.0**
- **2k-4k sq.deg./night**
- **90% Survey mode**
- **10% MMA ToO's and special projects**
- **Real-time public data**
- **On Sky April 2024**

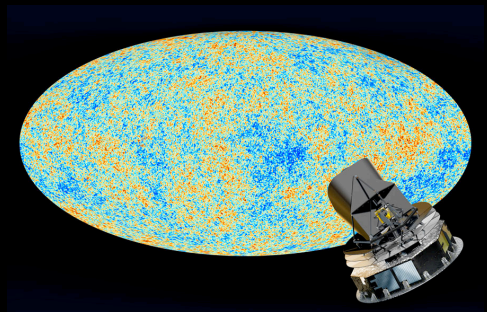
Overall science goal: Fill in the Rubin Observatory's LSST cadence to increase the scientific potential of nearby/fast evolving transients with a particular focus on SN Ia / SN II-P cosmology & peculiar velocities, and standard sirens with NS - NS/BH mergers. Stack images over a week's time to search for strong gravitationally lensed supernovae.

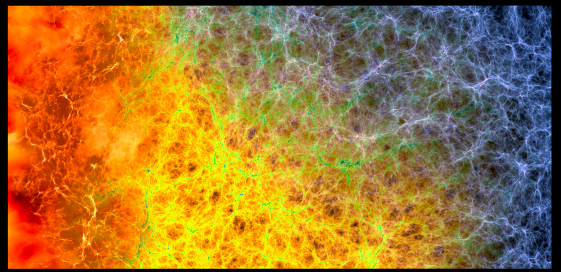


Fixed filters allow for a rapid search in multiple colors quickly over several hundred sq. deg.

Computational Cosmology Center

- A multi-disciplinary center combining people, expertise, and projects from physical sciences, CS, and applied math
- Three major cosmology directions: CMB, supernovae & transients, and large-scale structure of the universe
- Computational directions: instrumental pipelines and data processing, numerical simulations, ML/AI
- Participation in major observational surveys: DESI (LBL-lead), Simons Observatory, Rubin/LSST, La Silla Schmidt Southern Survey, CMB-S4 (LBL-lead)
- Access to world-leading supercomputer centers including NERSC, Oakridge and Argonne Leadership Facilities
- For more info, people working at the center, and contacts, see: https://crd.lbl.gov/divisions/scidata/c3/





R&D efforts

LuSEE-Night
antenna

CMB
detector &
readout

LIM
detector &
readout

Spectroscopy
CCDs
positioners
spectrographs

Supernovae