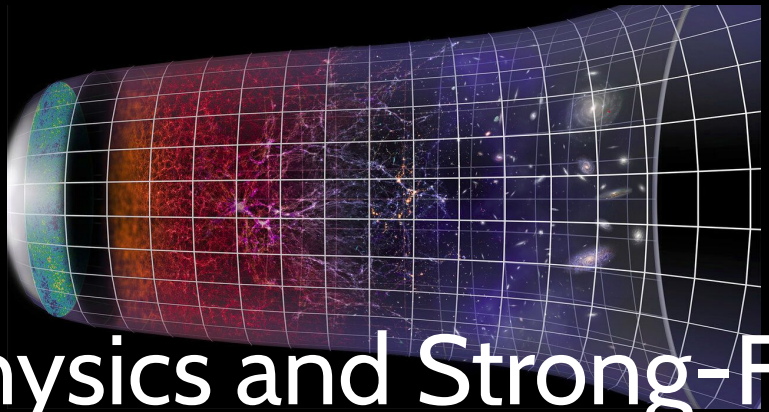
15th Conference on the Intersections of Particle and Nuclear Physics (CIPANP 2025) Madison Wisconsin June 9-13



Cosmic Physics and Strong-Field Gravity: Session Summary

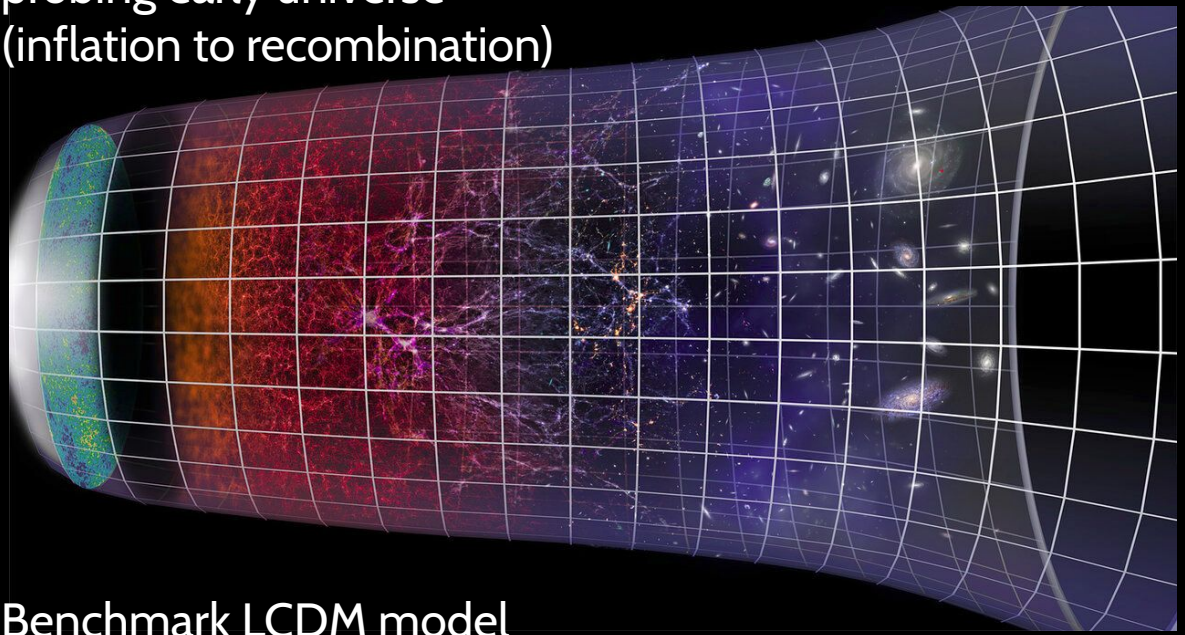
Mathew Madhavacheril (Penn)

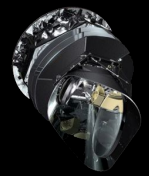
Co-conveners:

Lauren Aldoroty (Duke)

Laura Newburgh (Yale)

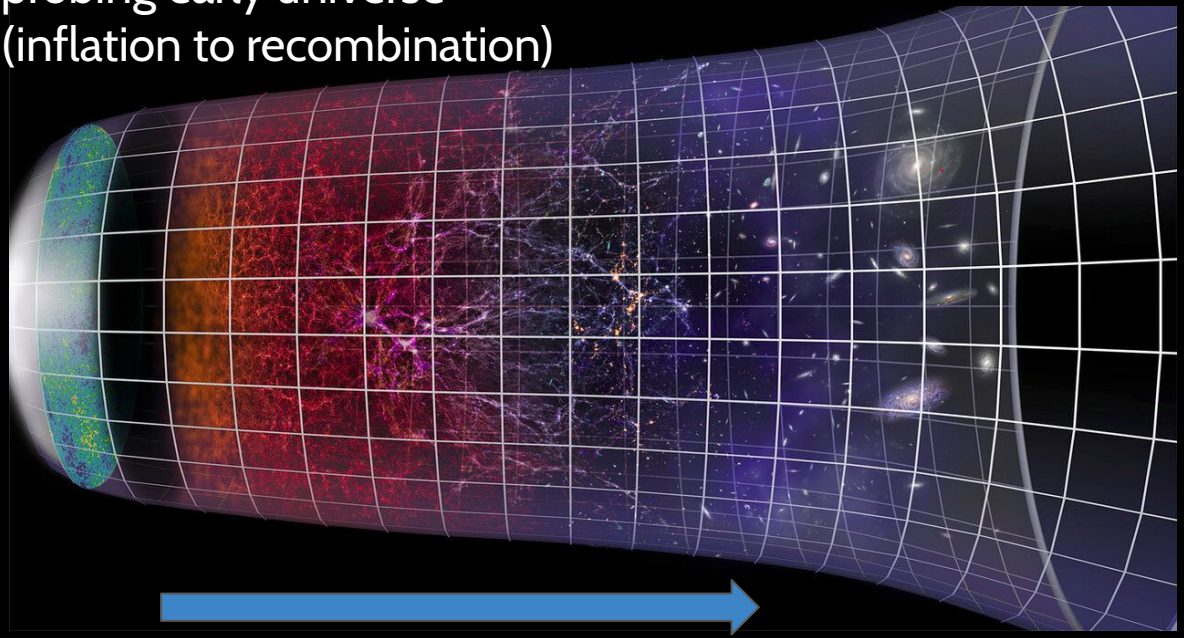
Planck satellite *primarily*
probing early universe
(inflation to recombination)





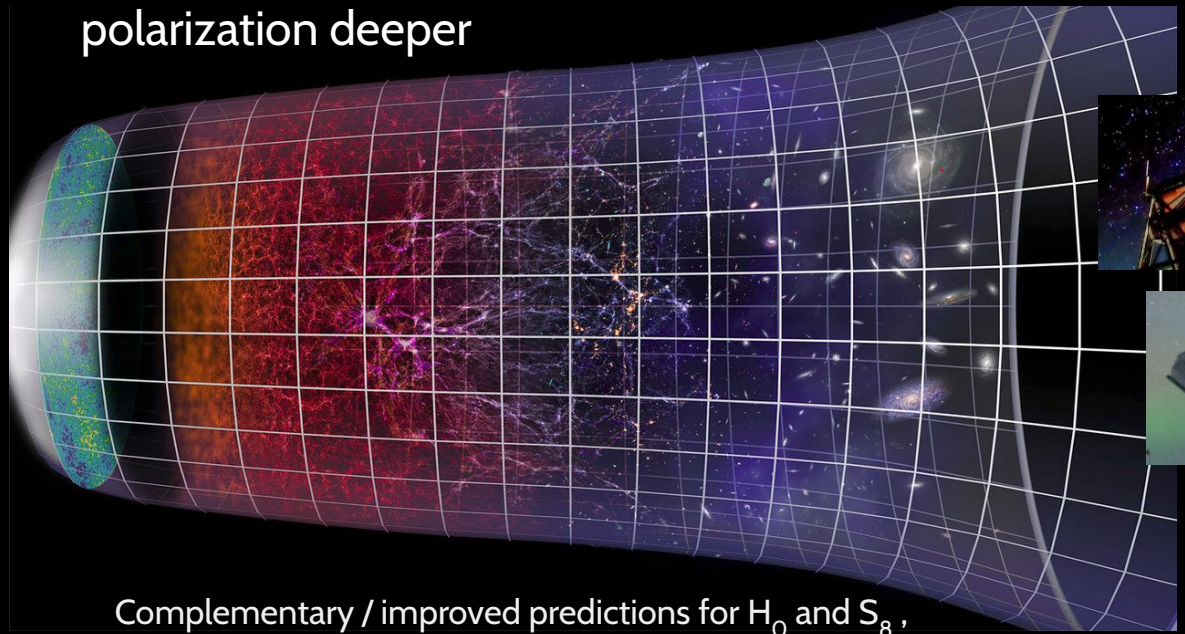
Benchmark LCDM model

Planck satellite *primarily*
probing early universe
(inflation to recombination)



Propagate fit model forward in time
Compare expansion rate H_0
Compare growth S_8

High-resolution ground-based probing polarization deeper



Atacama Cosmology Telescope (ACT)

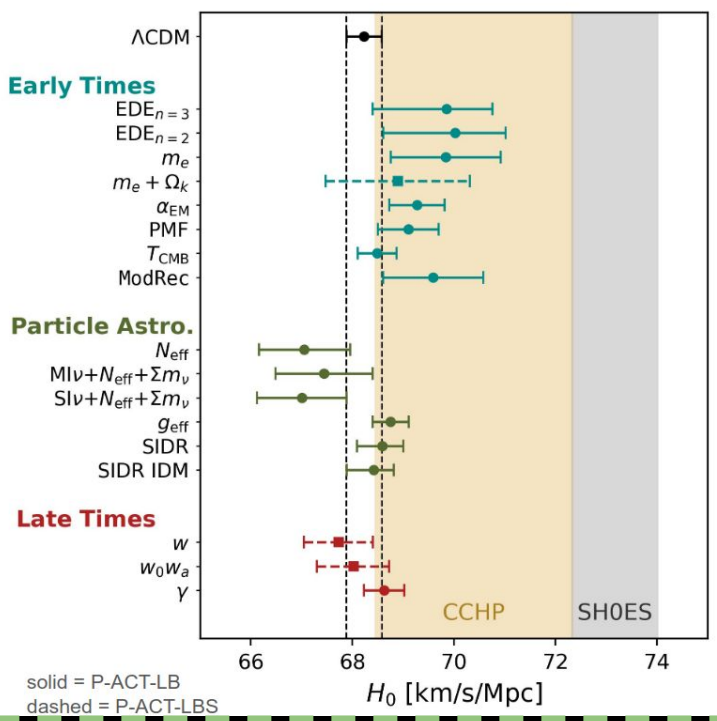
South Pole Telescope (SPT)

Complementary / improved predictions for H_0 and S_8 , explore wider range of new physics

New CMB continues to prefer LCDM : ACT

Zach Atkins (Princeton)

Sam Goldstein (Columbia)

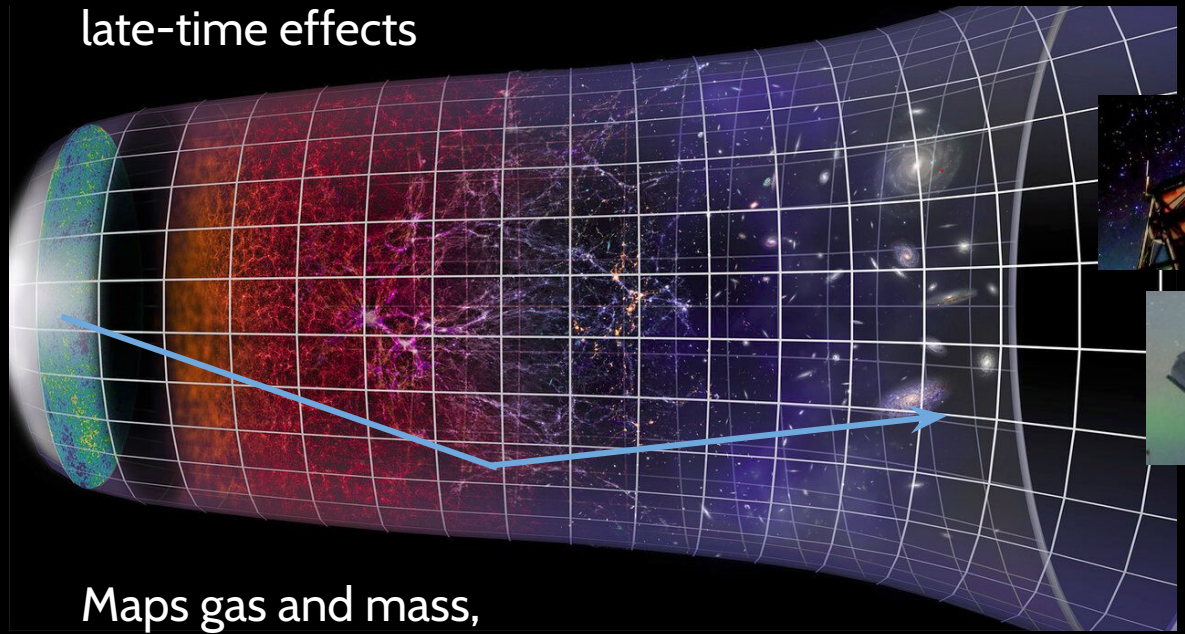


No extensions preferred over ΛCDM

>30 different extensions (not counting different data combos)

Calabrese, Hill, Jense, La Posta et al ACT 2025

High-resolution ground-based probing late-time effects



Atacama Cosmology Telescope (ACT)

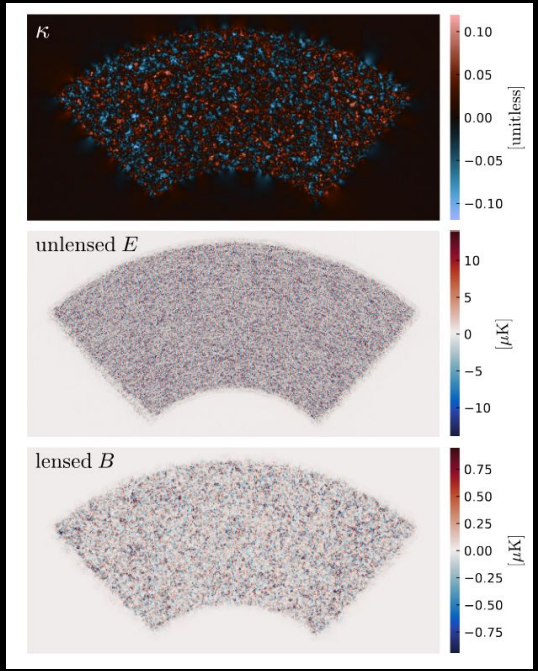
South Pole Telescope (SPT)

Maps gas and mass, growth of structure on linear scales and intermediate times

→ e.g. neutrino mass constraints

New CMB continues to prefer LCDM : SPT

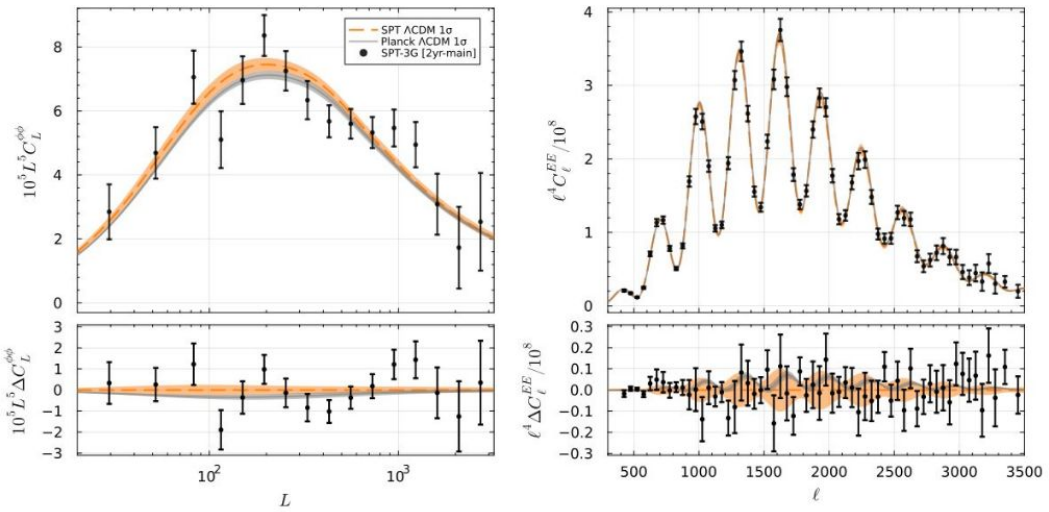
Fei Ge
(KIPAC)



Results – bandpowers

Ge et al SPT 2025

- LCDM model fits SPT data well and in agreement with Planck.



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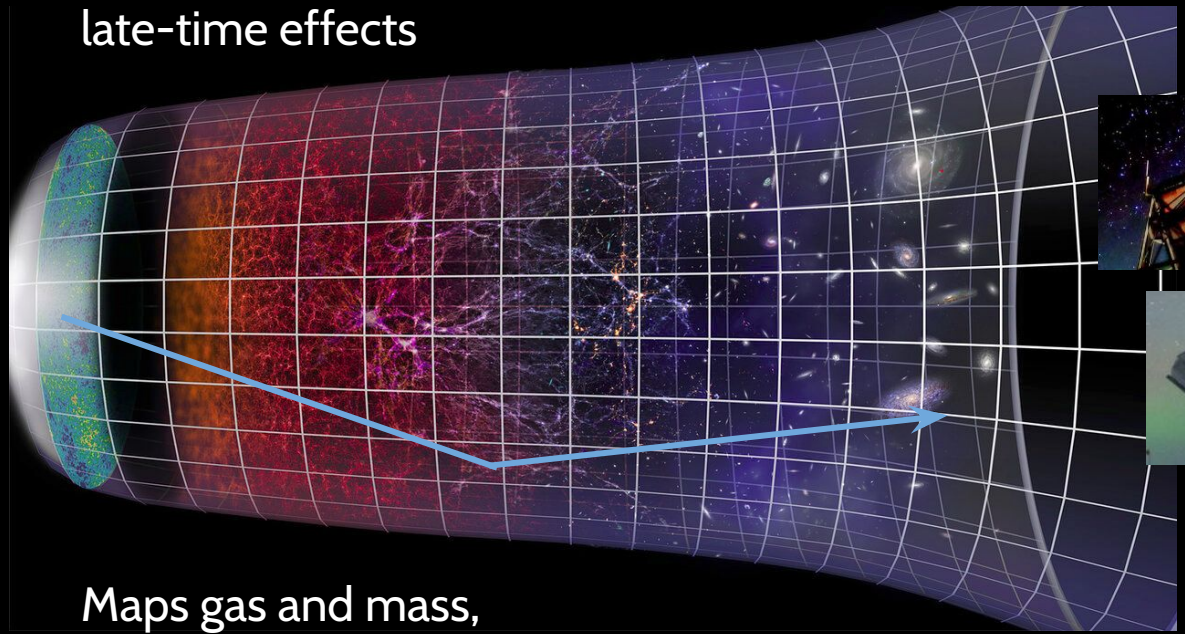
High-resolution ground-based probing late-time effects



Atacama Cosmology Telescope (ACT)

South Pole Telescope (SPT)

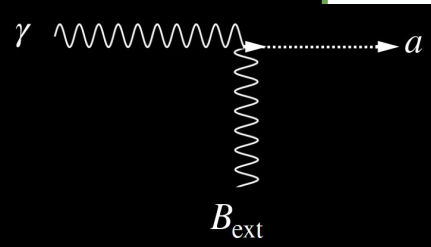
Maps gas and mass, growth of structure on linear scales and intermediate times

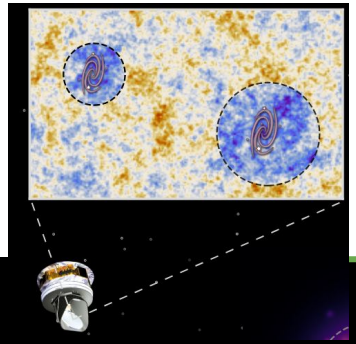
CMB secondary effects as a probe of (new) axion physics

Sam Goldstein (Columbia)

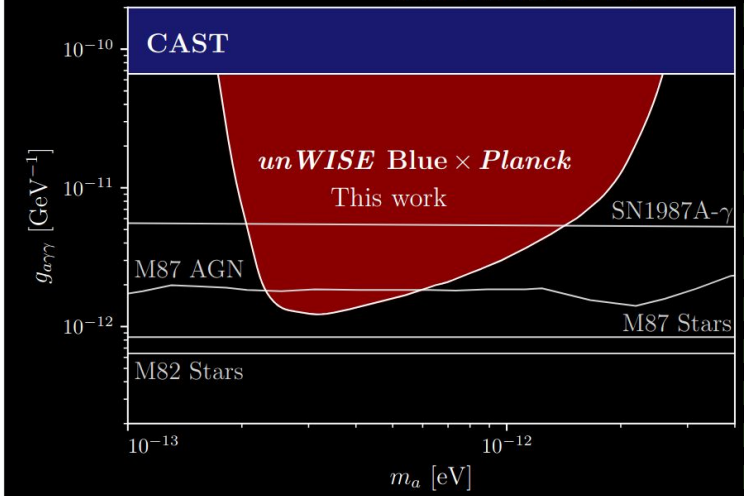
Constraints on axion-photon coupling

- We obtain some of the tightest constraints on $g_{a\gamma\gamma}$ for $m_a \approx 5 \times 10^{-13}$ eV axions
- Highly complementary to existing bounds
  - Existing bounds: **single astrophysical object**
  - Our bounds: ensemble average over **30 million objects**





Goldstein++, *PRL 134.081001*



95% confidence interval on $g_{a\gamma\gamma}$

(https://cajohare.github.io/AxionLimits/)

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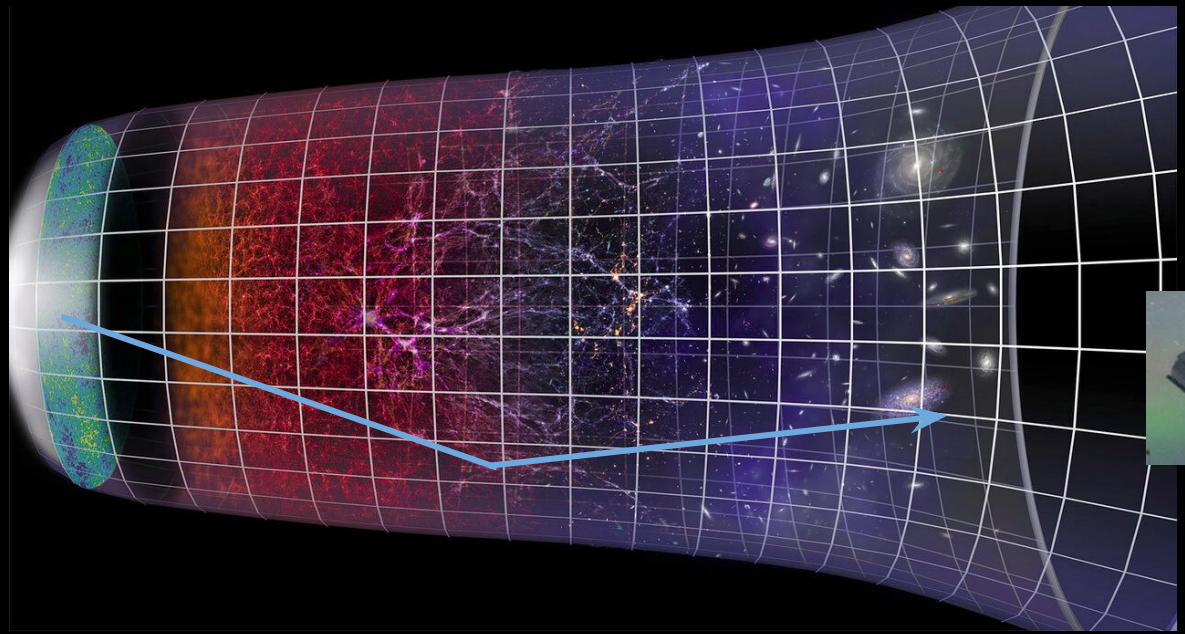
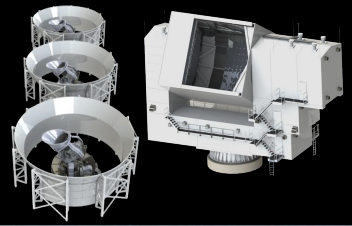
Next generation results rolling in!

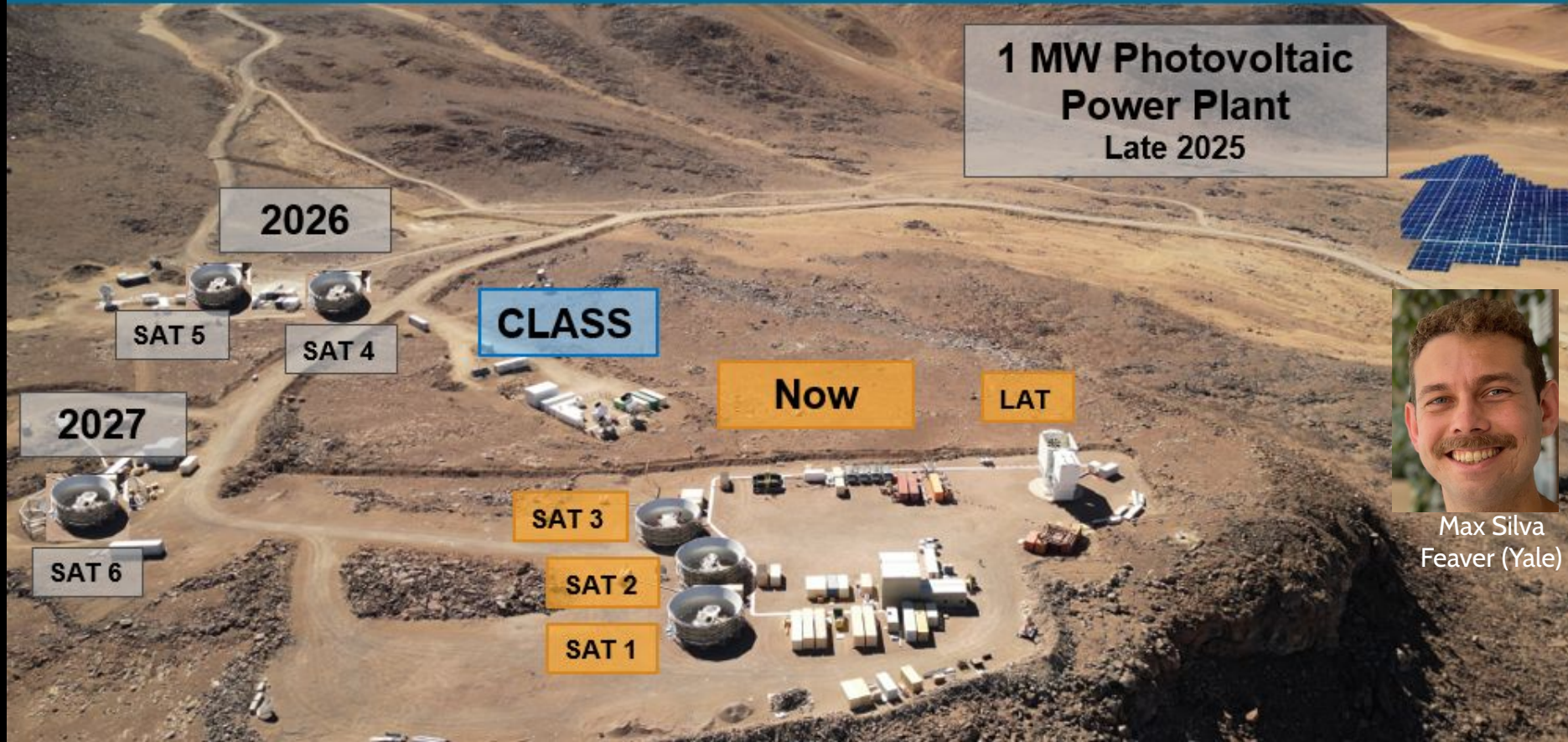


Simons Observatory



SPT3G

Timeline for SO expansions



Max Silva Feaver (Yale)

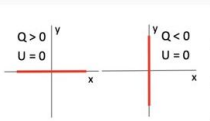
Timeline for SO expansions

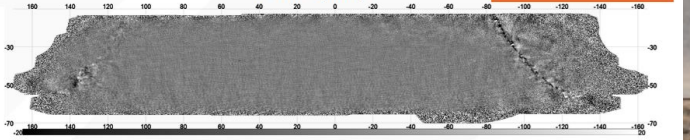
Preliminary

First Light Mars Map (LAT)

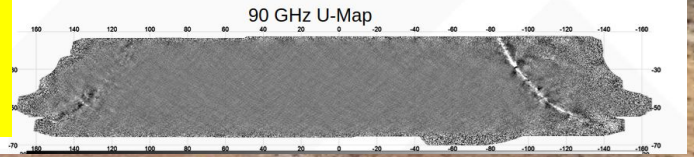
First maps made within ~1 month of data taken

Preliminary





Early polarization maps (SAT)



Now

LAT

SAT 3

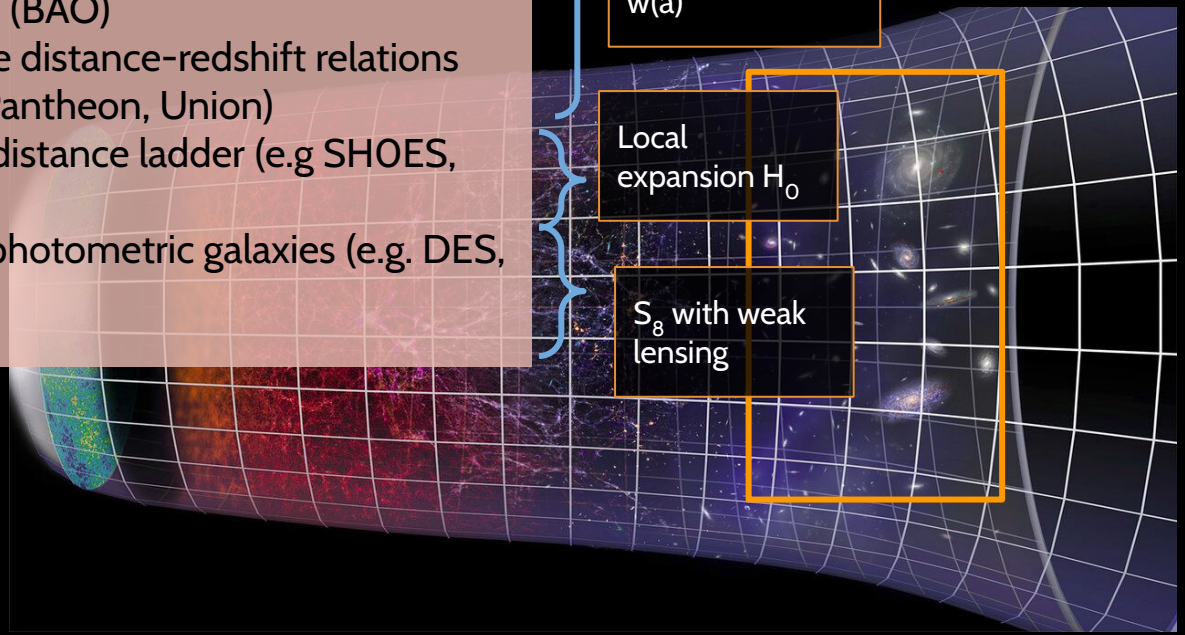
SAT 2

SAT 1

SAT 6

Max Silva Feaver (Yale)

- 3d mapping of galaxies with spectroscopic surveys (e.g. DESI) measure imprint of acoustic oscillations in galaxy distribution (BAO)
- Supernovae distance-redshift relations (e.g. DES, Pantheon, Union)
- Calibrated distance ladder (e.g SHOES, CCHP)
- Shapes of photometric galaxies (e.g. DES, LSST)



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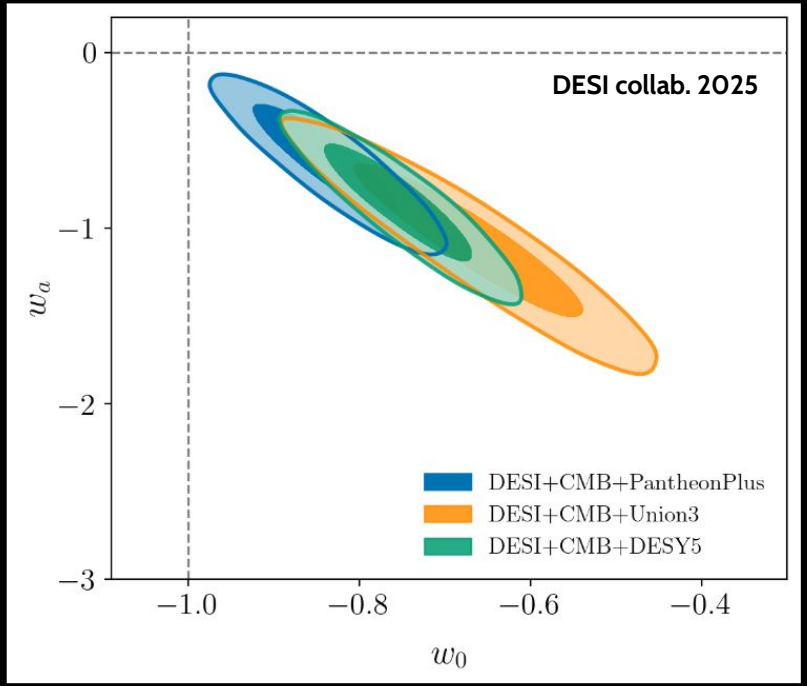
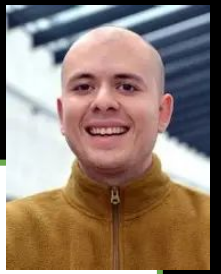
Evolving dark energy?

- 4.2σ
- Unless there is an **unknown systematic** error associated with one or more datasets, it is clear that ΛCDM is being challenged by the combination of DESI BAO with other measurements and that dynamical dark energy offers a possible solution

Uendert Andrade (Michigan)



Probing axion dark matter with CMB and LSS



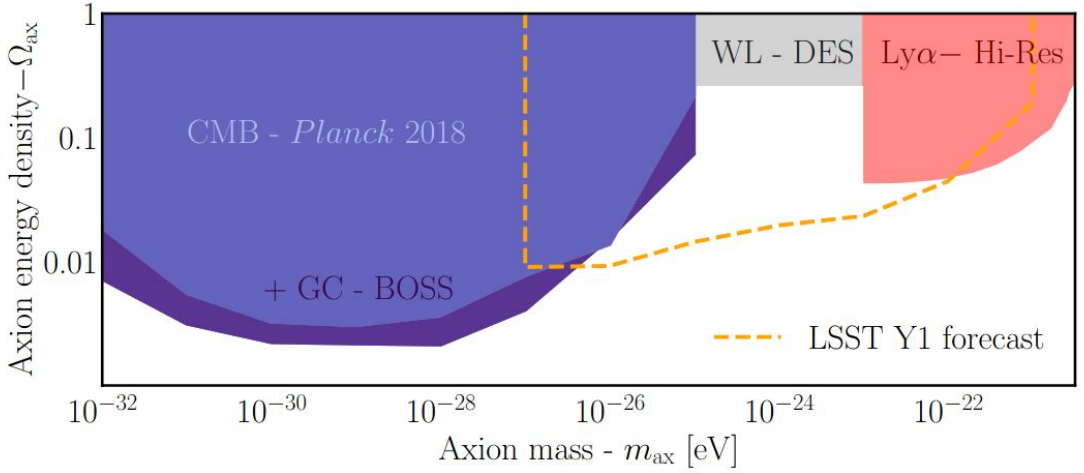
Keir Rogers (Imperial)

Some probes (e.g. some galaxy weak lensing) find low S_8

Could this be axion dark matter? Or complex gastrophysics on small scales?

Rubin LSST weak lensing + CMB gas observables will tell us!

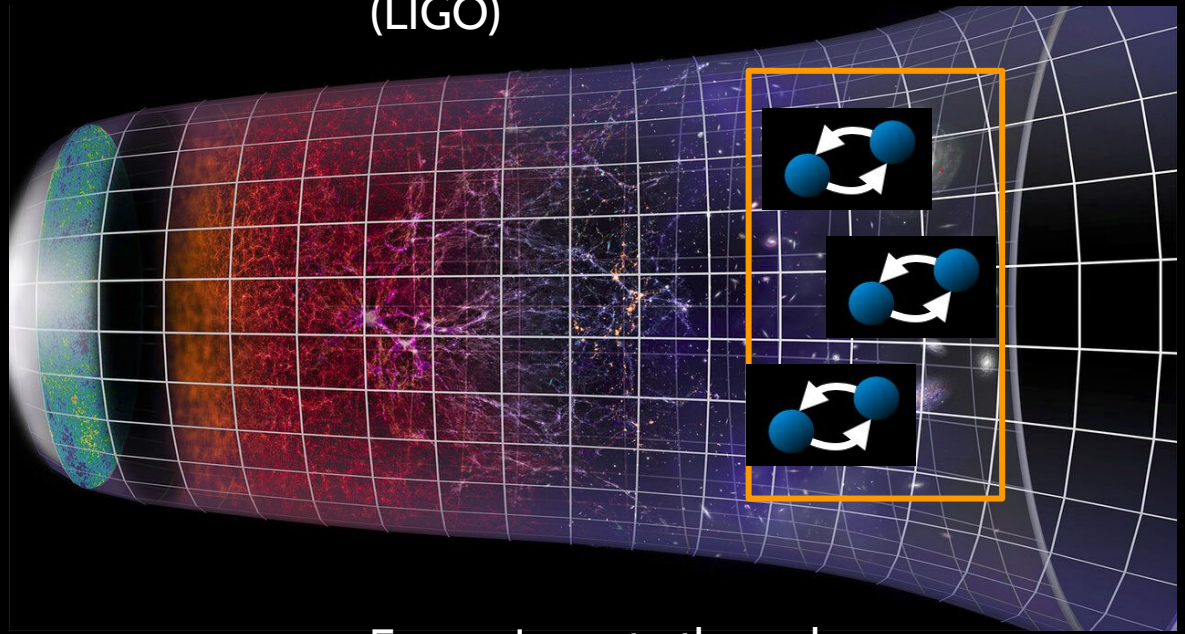
LSST Y1 weak lensing as a dark matter probe: strongest limits & discovery potential



Kobayashi+ (2017); Rogers+ (2021); Dentler+ (inc. Rogers, 2022); Preston, Rogers+ (2025)

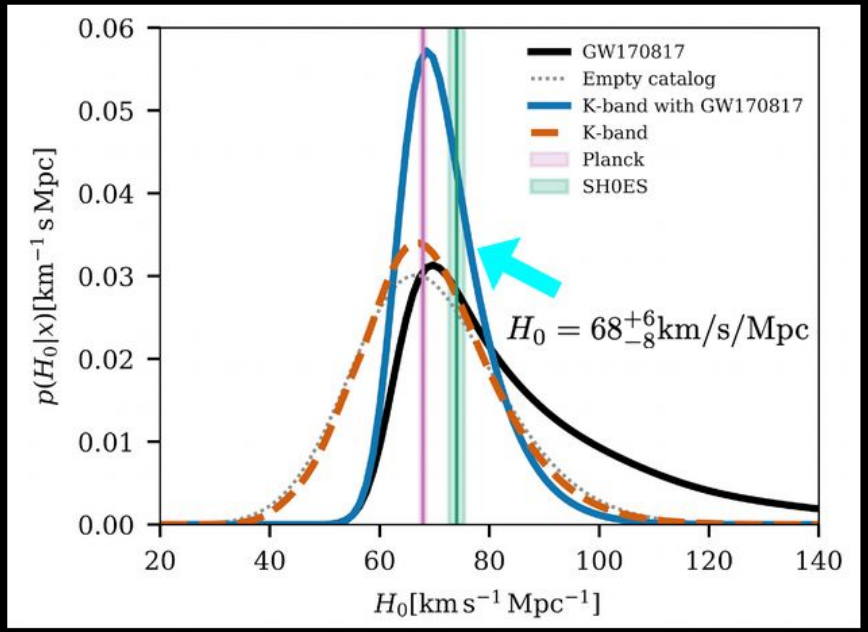
quoted from talk

Gravitational waves from compact object mergers (LIGO)



Expansion rate through standard siren

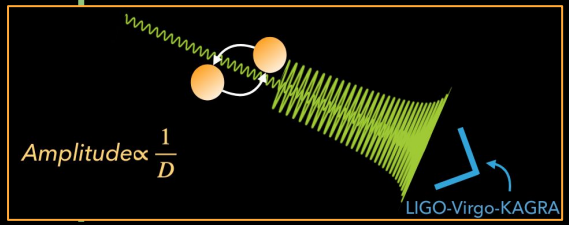
LIGO-Virgo-KAGRA standard siren measurement from GWTC-3



LVK, 2111.03604

Hsin Yu-Chen
(UT Austin)

$$cz = H_0 D$$



42 binary black hole mergers + 2 binary neutron star mergers
+ 2 neutron star-black hole mergers +GW190814

Results for O4a will be available in late August.

Hsin-Yu Chen / UT Austin

quoted from talk

Future cosmology

Principled ML techniques to unlock more information

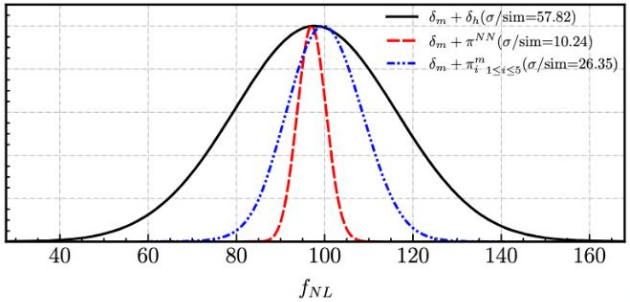
Moritz Munchmeyer (UW-Madison)

Testing primordial non-Gaussianity (e.g. fNL) better than Planck is a goal for many galaxy surveys

Neural network method that could allow marginalization over training simulation assumptions gives large improvement

Result: Strong improvement in sensitivity to f_{NL}

Under simulation conditions, **the new method is several times more sensitive than the "old" analytic method.**



Black: analytic method without NN
Red: new NN method

Using Quijote-PNG simulations with $f_{NL} = 100$.

Caveat: In this analysis, the neural network gets to see the matter field, which is not directly observable.

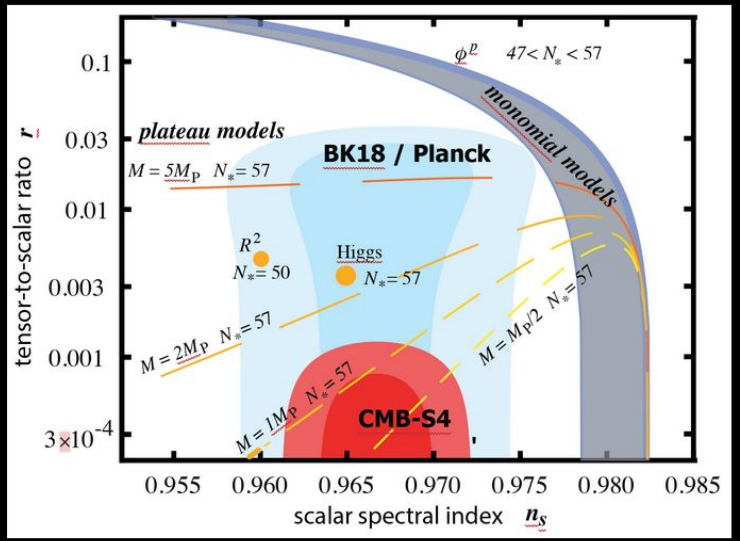
quoted from talk

Future science with CMB-S4

Jeff McMahon (Chicago)

The new plan achieves the CMB-S4 goals with:

- Continued operations with the completed **Simons Observatory**
- Continued operations with **SPO** with the proposed SPT-3G+ camera and upgrades to BICEP/Keck
- **CMB-S4** hardware in Chile (one large and six small aperture telescopes) more the doubling the mapping speed of SO.



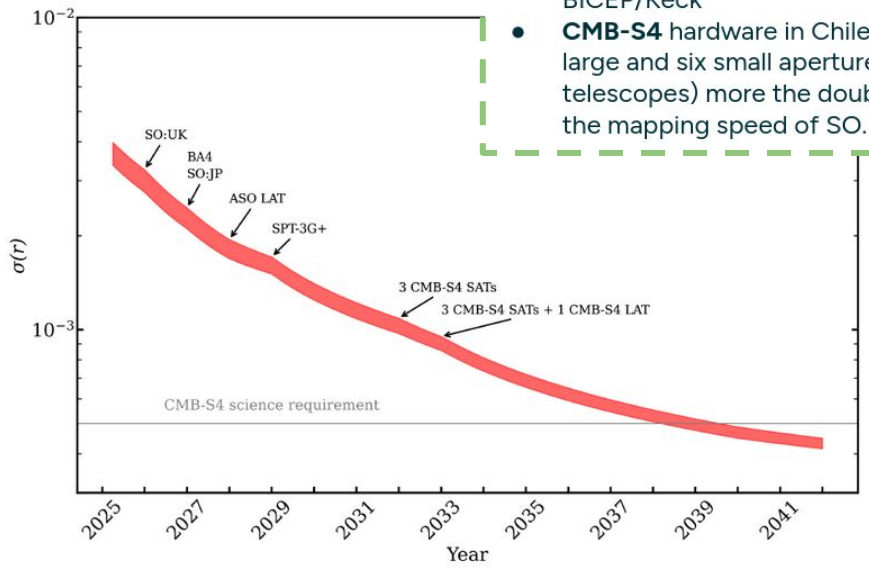


Figure 4.1: Forecast for $\sigma(r) = f(t)$ for combined observations by SPO, SO, and CMB-S4 with six SATs and one LAT. The years when additional instrumentation are assumed to be brought online are indicated.

quoted from talk

Summary

- Precision measurements are already uncovering disagreements (esp. late times)
  - Local expansion rate (H_0)
  - Dynamical dark energy (w_0, w_a)
  - Matter clustering amplitude (S_8)
- Unclear if these are due to new physics, systematics or fluctuations
- Neutrino mass and axion dark matter, for example, need more clarity on these systematics and/or LCDM extensions
- New generation of CMB and galaxy surveys are now pushing fast to clarify this through joint probes
- New ways of analyzing LIGO events may help with the Hubble tension