CMB as a backlight

Part I

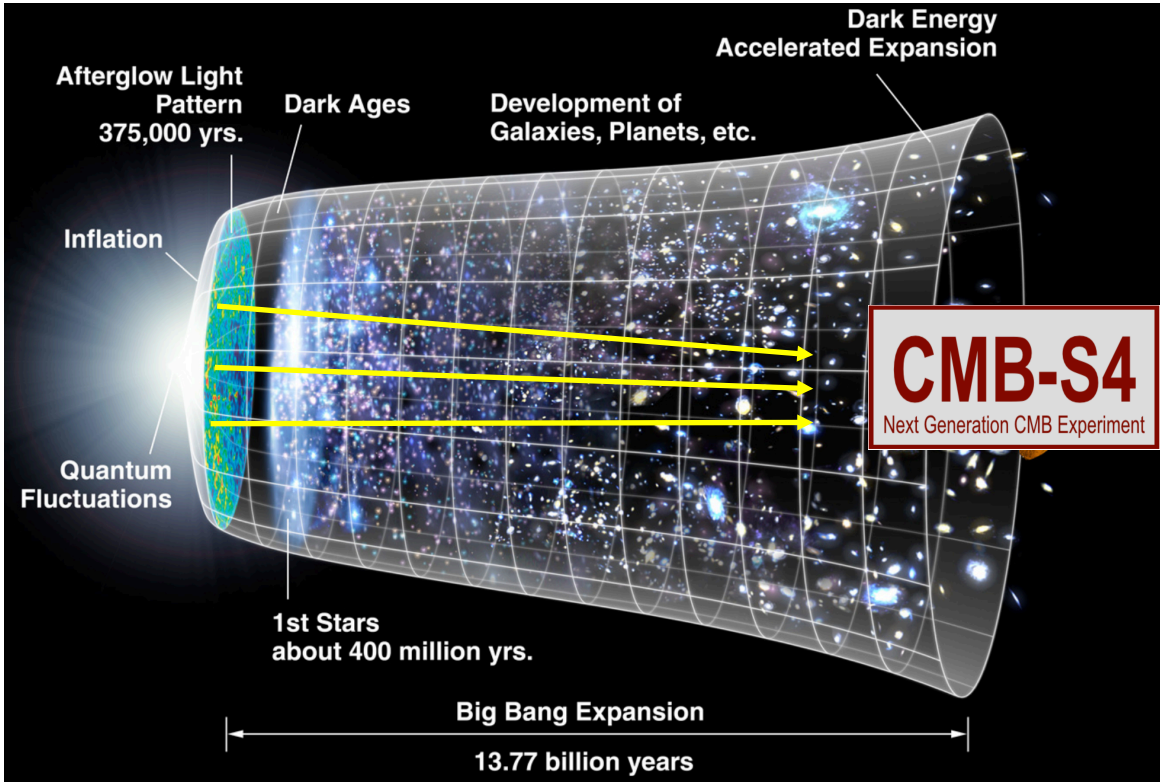
Simone Ferraro

(Lawrence Berkeley National Laboratory)

CMB-S4 collaboration meeting

03/09/2021

A brief history of CMB photons



credit: WMAP

94% of photons don't re-scatter (but are lensed!)

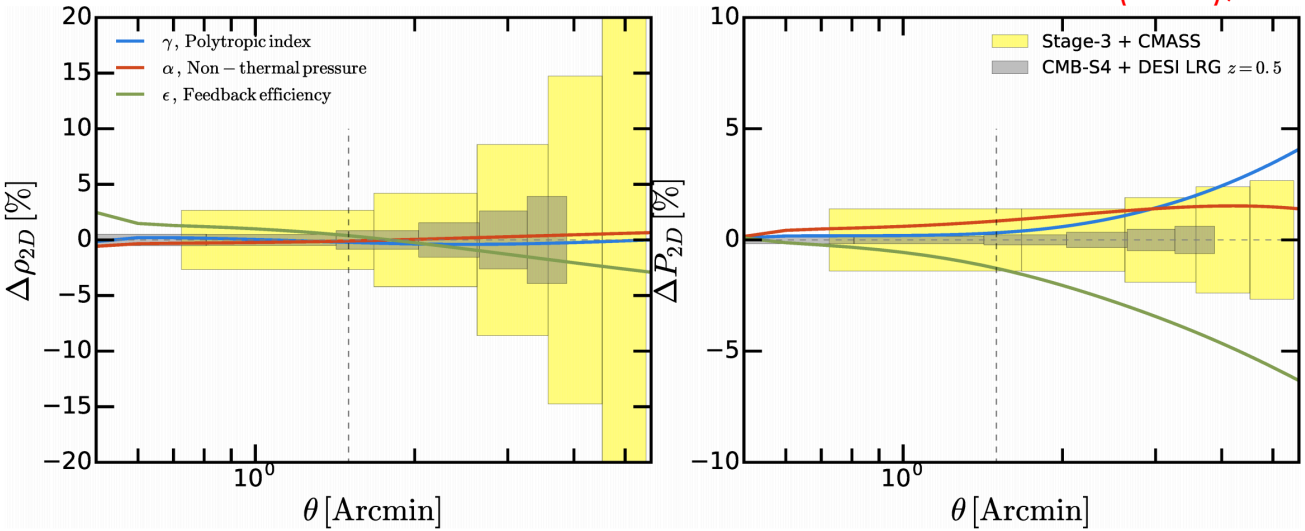
6% scatter with matter

High-resolution CMB experiments are excellent probes of the Large-Scale Structure!

kSZ and tSZ cosmology → Eve Vavagiakis' talk

"Direct" measurement of density, pressure and LOS velocity of the gas in galaxies/clusters

Battaglia, S.F., Schaan, Spergel, 2017
Also: Amodeo et al (2021), Moser et al (2021)



- Halo thermodynamics and feedback as a function of mass, redshift, environment, …

kSZ/tSZ: a 2021 view of CMASS galaxies

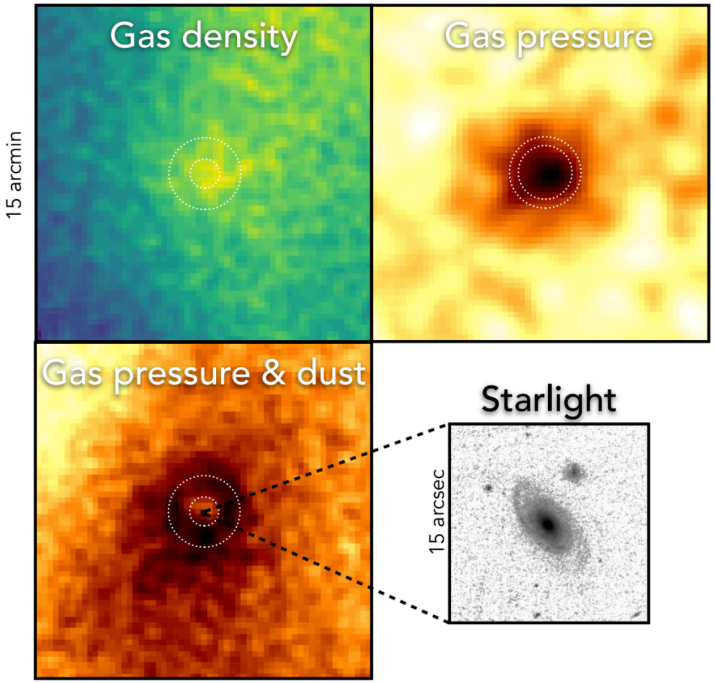
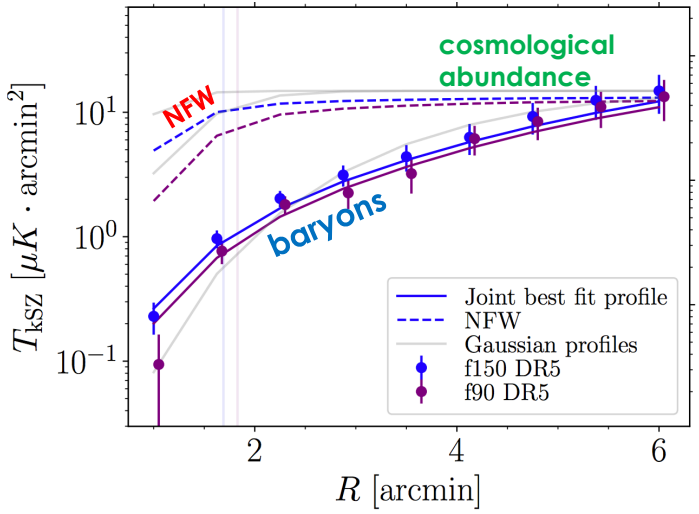
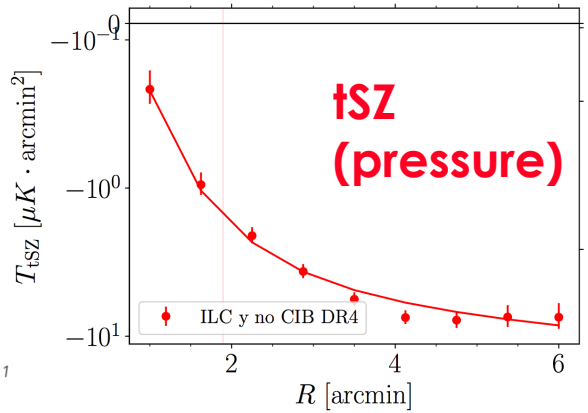


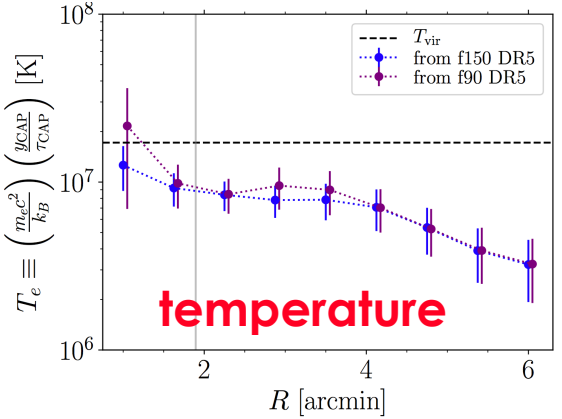
Figure: Emmanuel Schaan
ACT+Planck microwave images: Schaan et al 2020. HST ACS I band image: Masters et al 2011



kSZ (density)



tSZ (pressure)



temperature

Schaan, S.F., Amodeo, Battaglia + ACT (2021)
Amodeo, Battaglia, Schaan, S.F. Moser + ACT (2021)

Also (not shown here): Vavagiakis et al + ACT (2021), Calafut et al + ACT (2021), Kusiak et al (2021) + previous literature!

kSZ and tSZ cosmology

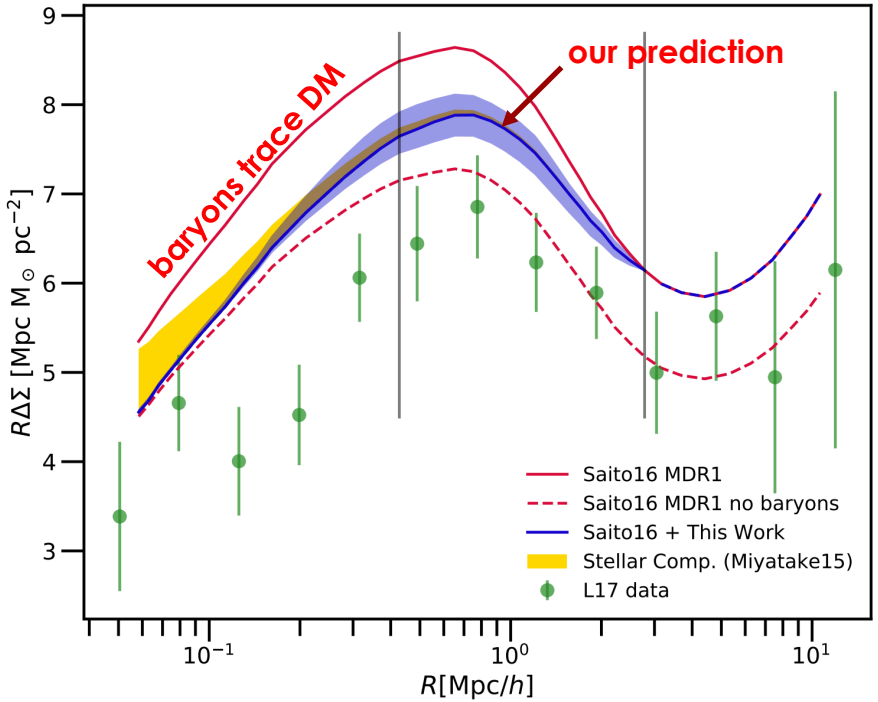
→ Eve Vavagiakis' talk

Calibration of baryon effects in weak lensing:

- Baryons are ~16% of the mass: statistically "large" effect on weak lensing
- Galaxy lensing amplitude typically "lower" than expected (also, CMB lensing will check this!)
- Direct calibration with kSZ (gas density measurement)

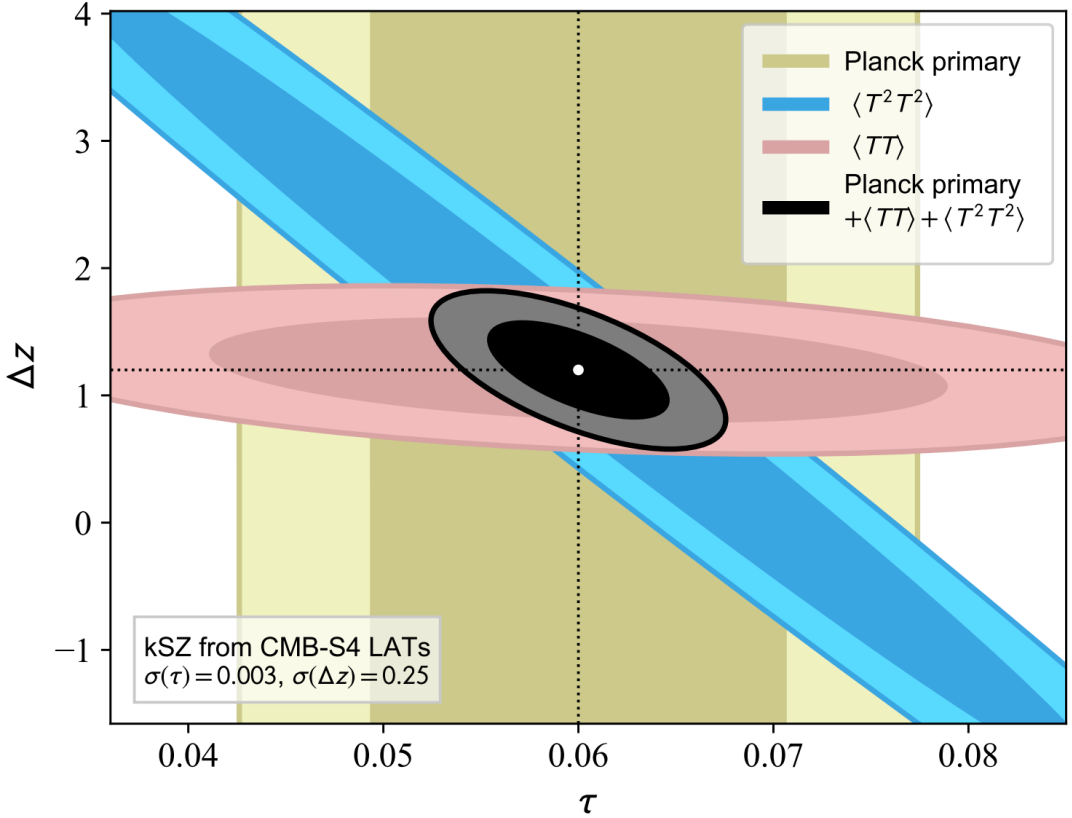
Measuring velocities:

- Tests of gravity / scale dependence of growth
- Sample variance cancellation and ~50% improvement on f_{NL}
- Access to very large-scale modes: "no shot noise"



Amodeo, Battaglia, Schaan, Ferraro, Moser + ACT (2021)

Patchy reionization with kSZ



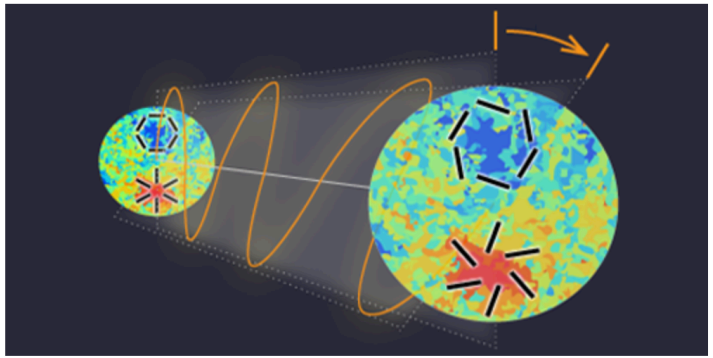
- kSZ: large imprint on high-ell T power, and largest non-Gaussianity.
- Use 4-pt (Smith&Ferraro) to separate reionization from late-time component.
- 2-pt + 4-pt very effective at breaking degeneracies!

Alvarez, Ferraro, Hill, Hlozek, Ikape (2021)

Cosmic birefringence

→ Yuto Minami's talk

- Birefringence: rotation of plane of linear polarization.
- E.g. a pseudo-scalar (such as axion) coupled to electromagnetic tensor.
- **Breaks parity!** Generates <EB> & <TB>.



Y. Minami/KEK

- Can reconstruct both a constant rotation and rotation fluctuations.
- Possible sources: axion string network, axion dark matter, Lorentz-violating physics beyond the Standard Model, primordial magnetic fields, …
- Recent progress on internal calibration of polarization angle (Minami&Komatsu 2020).

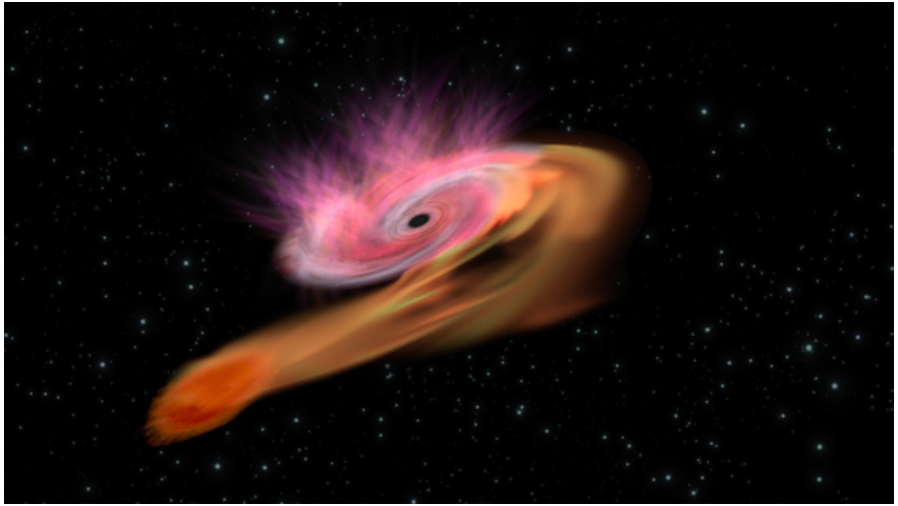
A detection of parity violation would transform our understanding of the dark sector!

Carroll, Field & Jackiw (1990); Harari & Sikivie (1992); Carroll (1998)

Tidal Disruption Events

- Disruption of stars by supermassive black holes (SMBHs).
- Probe of accretion on SMBHs.
- Probes of jets and their full life-cycle
- Study the environment (eg. density). around quiescent SMBHs.
- Detected in Planck.

- Future surveys (inc. CMB-S4) will greatly expand the TDE sample and allows for early detection.
- Great for multi-messenger studies!



Credit: ESA/C. Carreau

→ **Kate Alexander's talk**

External Collaboration Committee Parallel

On Friday at 10:30am Pacific

10:30 → 11:15 **External Collaboration Committee Parallel** 45m

Speakers: Lloyd Knox (UC Davis) , Rachel Bean (Cornell University;) , Dr Simone Ferraro (Lawrence Berkeley National Laboratory)

Goal: provide the necessary link to external follow-up observations or survey data that are required to maximize the science return from CMB-S4.

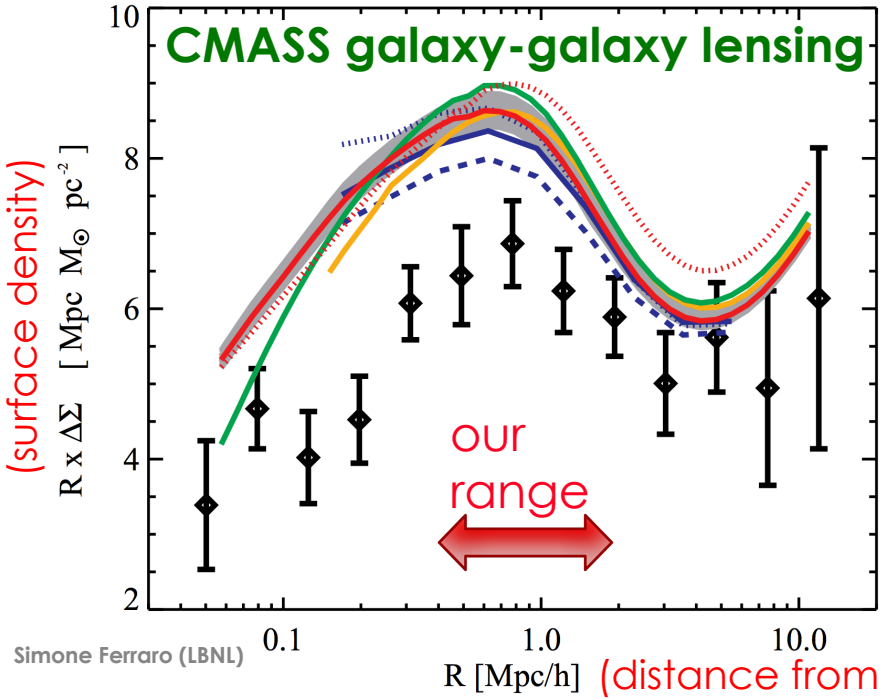
In the near term: facilitate science forecasting/simulations that requires external collaboration (e.g., with VRO/LSST), and that could impact CMB-S4 design.

Your participation and input will be greatly appreciated!

BACKUP SLIDES

Lensing is Low: Cosmology, Galaxy Formation, or New Physics?

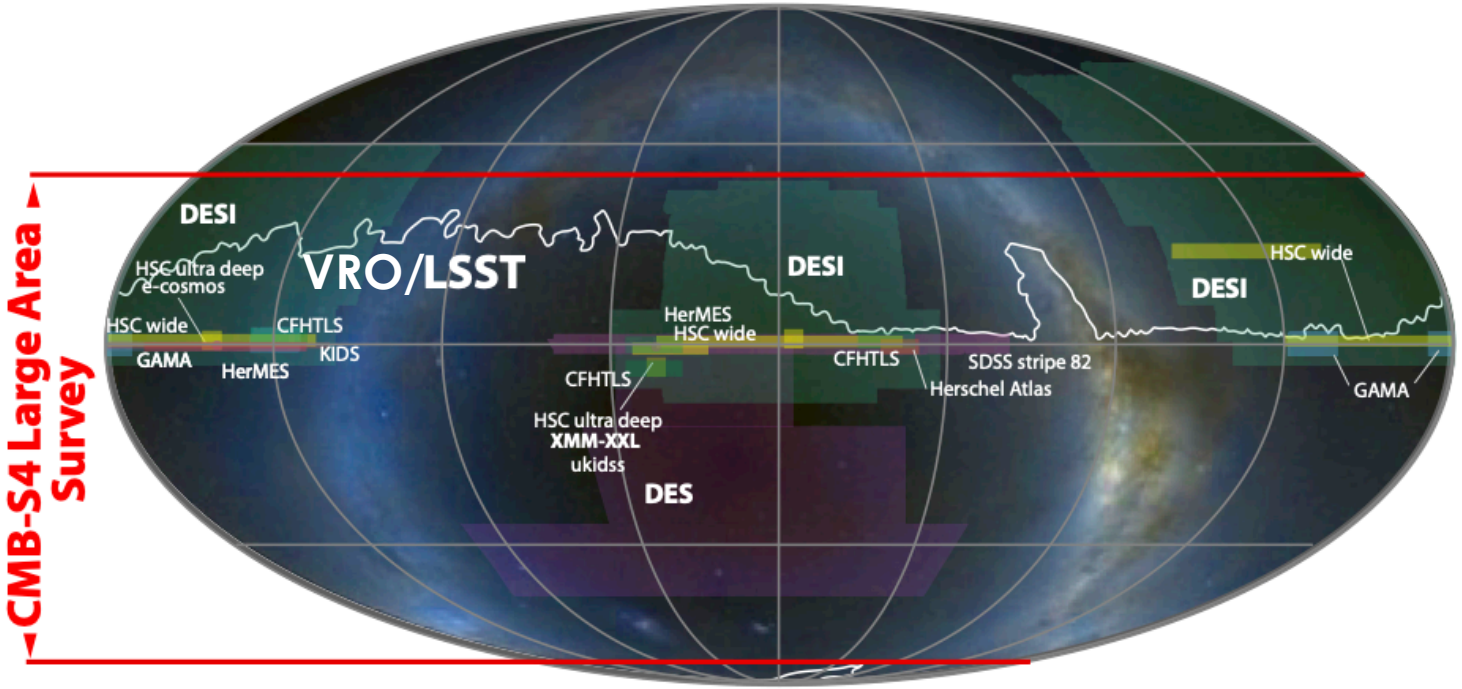
Alexie Leauthaud[1,2], Shun Saito[3], Stefan Hilbert[4,5], Alexandre Barreira[3], Surhud More[2], ++



Can this be explained (at least in part) by baryon effects?

CMB-S4 Large Area Survey

The Large Area Survey will cover ~70% of the sky to unprecedented depth, ensuring overlap with the majority of current and planned surveys



CMB-S4 collaboration