Science Case Beyond the Design Drivers: Report-Back

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On behalf of:

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Science Case beyond the design drivers

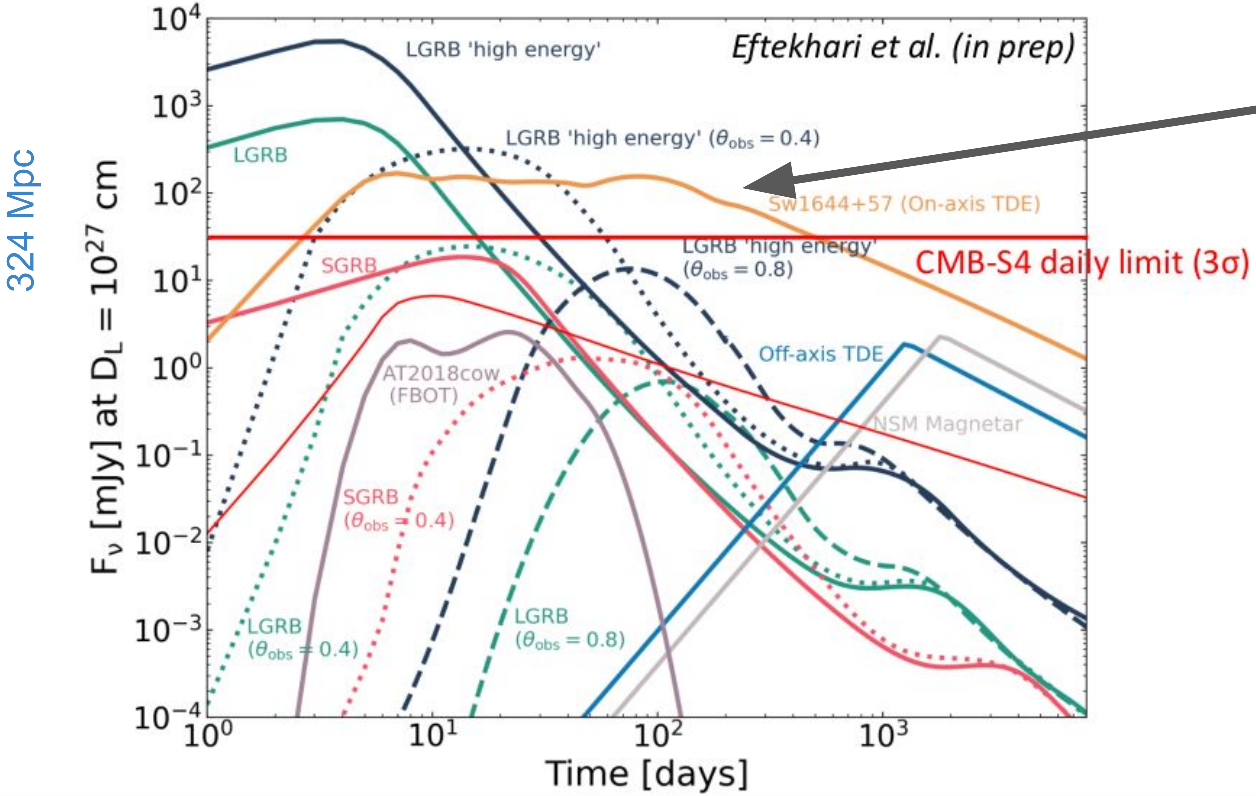
Points for discussion:

- How should we refine the science case for the preliminary baseline design? What to emphasize / de-emphasize compared to the DSR?

- What additions / refinements to the science case should we make looking forward to a Science Book 2 / CMB-S4 Bluebook sometime next year? (All new forecasts based on best estimate performance.)

Jetted TDEs: luminous mm transients

Kate Alexander



More: Tarranah Eftekhari talk Thursday in transient parallel

Peak flux ~10s of mJy, duration ~weeks to months

Summary

- TDEs are exciting targets for CMB-S4 because they can produce luminous mm emission, lasting weeks-months
  - Current work will better constrain rates, radio+mm luminosity function within next few years
- CMB-S4 has great potential for transient science:
  - **Follow up/recovery** of transients discovered by contemporaneous surveys (LSST, eROSITA, Fermi, SKA…)
  - **Blind discovery** of new transients in the mm band (e.g. TDEs in dusty galaxies, obscured AGN, orphan GRB afterglows, ???)
  - **Deep template images** of the mm sky (context for new transient discoveries)
  - See Tarraneh Eftekhari's talk on Thursday for more!

Galactic Science - questions

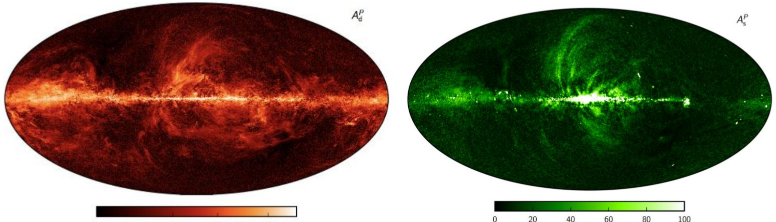
Susan Clark

Spectral Science

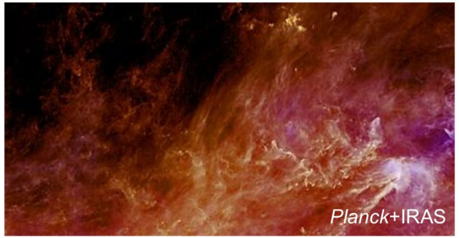
- What is the composition of interstellar dust?
- Is AME polarized?
- How do the combined probes of synchrotron and dust probe the 3D ISM?

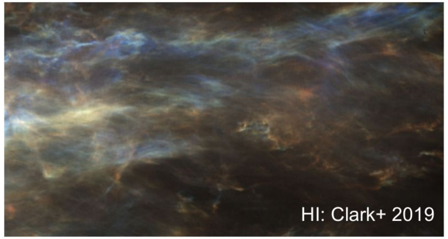
Map-Space Science

- How are dust and gas coupled on small spatial scales?
- How do magnetic fields influence the fragmentation of molecular filaments and the formation of stars?
- What is the nature of magnetohydrodynamic turbulence in the ISM?



Planck 2015 X





Galactic Science - discussion

Susan Clark

The frequency / line-of-sight de-correlation of dust should be important for BB detection. What can CMB-S4 do, given the higher resolution it will have?

- The use of other surveys like PASIPHAE and GAIA, etc. to reconstruct “tomographic” images of the Galaxy.
- Characterizing the 3D structure of the ISM has impacts on both the Galactic science, as well as the foreground modelling.

Theory progress for Galactic Science

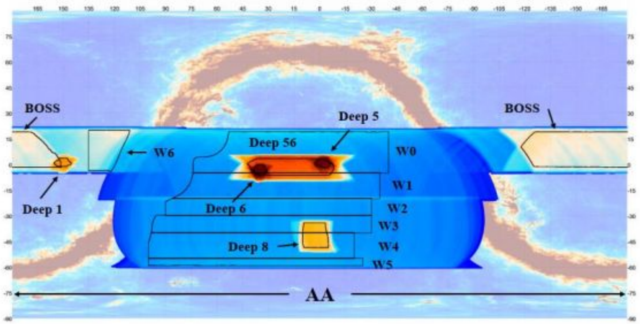
- More work is needed on the on the theory side of ISM/foregrounds. Don't want galactic science theory chasing the data. When we can extend measurements to higher \ell, we want to be ready and have predictions.
- On the cosmology side, all info comes from PS. We know these are NG signals.
- One advantage of galactic science - have other tracers (e.g HI), but we need to quantify and connect to underlying theory.
- Need to pull more info from morphology of the data.
- Statistics such as TB correlation came to galactic science via CMB motivation, but are useful probes of dust and synch. polarization.

Cosmic Birefringence

Yuto Minami

Summary

- Cosmic birefringence: difference of field values with Chern-Simons coupling rotates linear polarization of the CMB photons
  - $\beta = \frac{g_{\phi\gamma}}{2}(\phi_{obs} - \phi_{LSS})$
- Calibration uncertainty on detector rotation α has limited the measurements of β
- When we use the Galactic foreground as a calibrator, we can determine α and β simultaneously
  - $\beta = 0.35 \pm 0.14$
- The measurements with CMB-S4 are highly expected
  - Reducing calibration uncertainty with the ground calibrator
  - Observing FG-dominated regions and channels



we need to observe bright FG region
➢ FG is needed to determine α

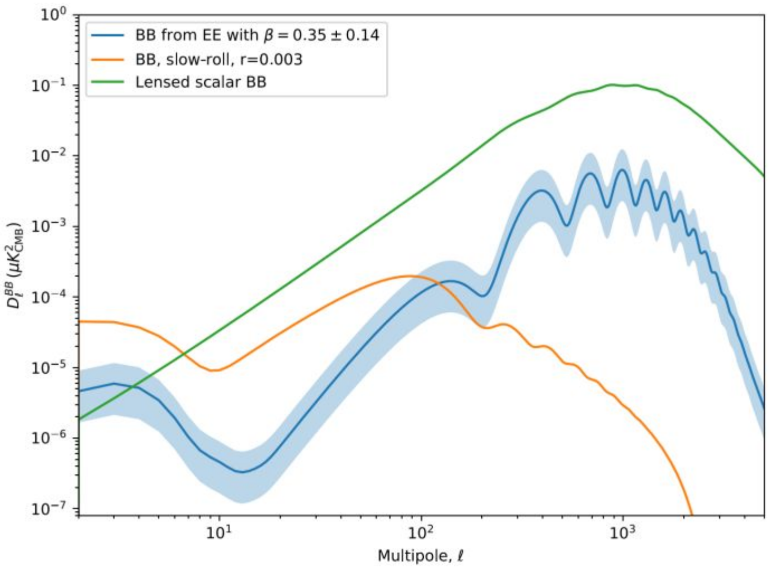
CMB-S4

Cosmic Birefringence

Yuto Minami

Bonus:

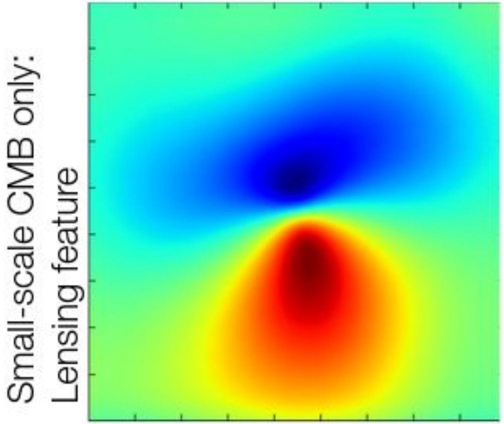
- Does $\beta = 0.35 \pm 0.14$ deg. disturb the measurement of primordial B-mode?

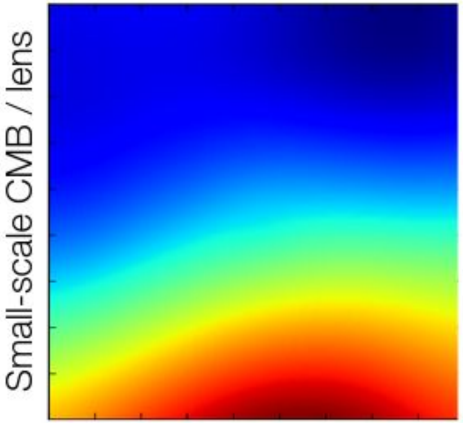


Possibly yes, but it would be revolutionary... would we even be so upset?

Boryana Hadzhiyska

Gradient Inversion Lensing Estimation





~gradient

Refined lensing method for small scales, most precise where the gradient is large

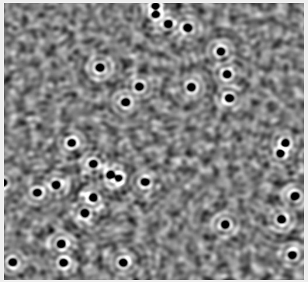
- Suggests simple "gradient inversion" estimator:

$$\hat{d}^{GI}(\mathbf{L}) = \frac{T(\mathbf{L})}{\hat{\mathbf{n}}_{\mathbf{L}} \cdot \nabla T^u}$$

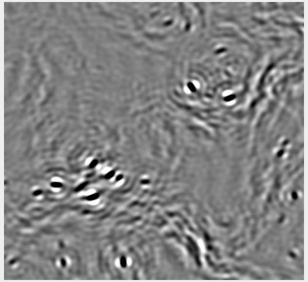
Not limited by cosmic variance;
SNR ~ local gradient

- Quadratic estimator: divides out <grad^2> – extra error!

$$\hat{d}^{QE}(\mathbf{L}) = \hat{d}^{GI}(\mathbf{L}) \frac{(\hat{\mathbf{n}}_{\mathbf{L}} \cdot \nabla T^u)^2}{\langle(\hat{\mathbf{n}}_{\mathbf{L}} \cdot \nabla T^u)^2\rangle}$$



True small-scale lens map



GI reconstruction

Small-scale lensing

Boryana Hadzhiyska

- Significant improvement compared to QE (on L>4000):

SNR	UL	S4-like	SO-like
Auto QE	205	100	7
Auto GI	1515	360	30

C_L^{dd}

Factor of 4 improvement!

Advantages of small-scale lensing:

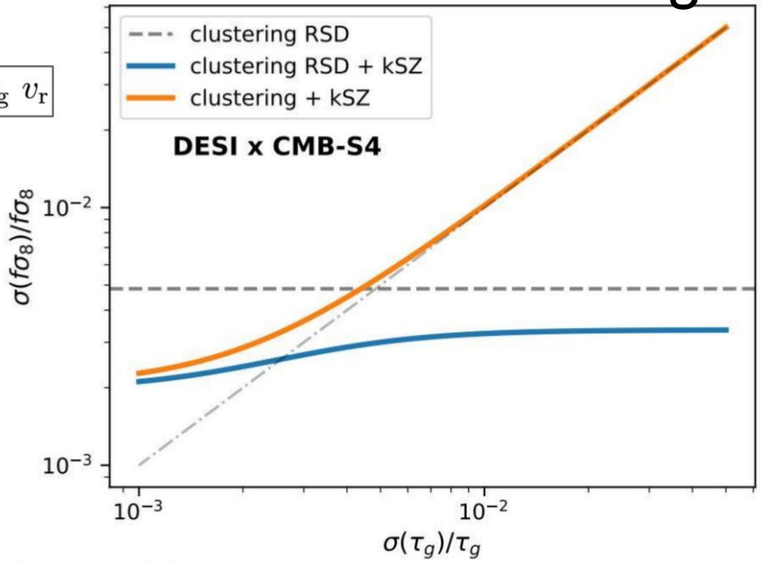
a. axion physics, warm dark matter (WDM)
b. cross-correlations with galaxies, polarization
c. assembly bias (one-halo term)

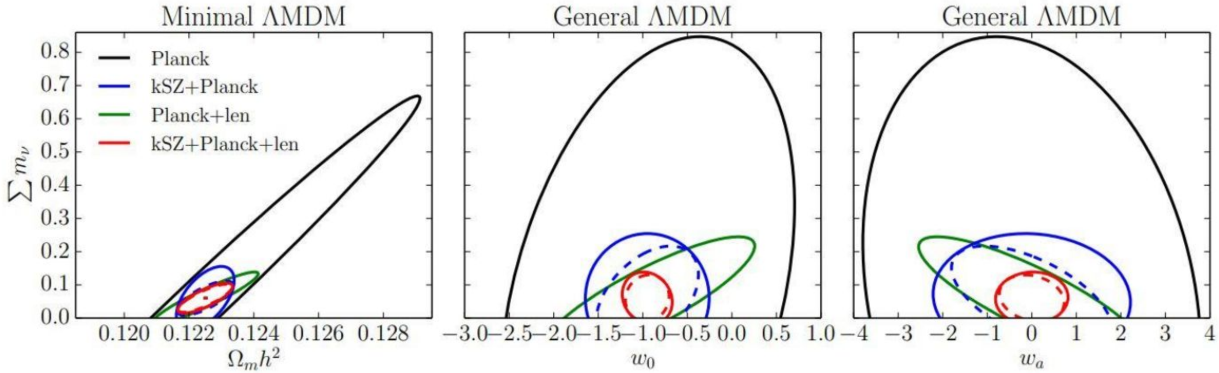
Into the regime where non-linear effects are important for interpretation

Eve Vavagiakis

The Sunyaev-Zel'dovich Effects

- kSZ effect probes peculiar velocities $(\Delta T/T)_{\mathrm{kSZ}} = -\tau_{\mathrm{g}}\ v_{\mathrm{r}}$
- Constrain neutrino mass sum, σ_8, *f*, dark energy, models of modified gravity
- tSZ effect: sensitive to integrated line-of-sight pressure profile, can break optical depth degeneracy
- Measure ionized gas profiles, constrain feedback mechanisms, trace baryons: Amodeo et al. 2020, arXiv:2009.05558, Schaan et al. 2020, arXiv:2009.05557
- Pairwise correlation statistic: temperature differences average out contamination





Top: CMB-S4 Science Case,

arXiv:1907.04473

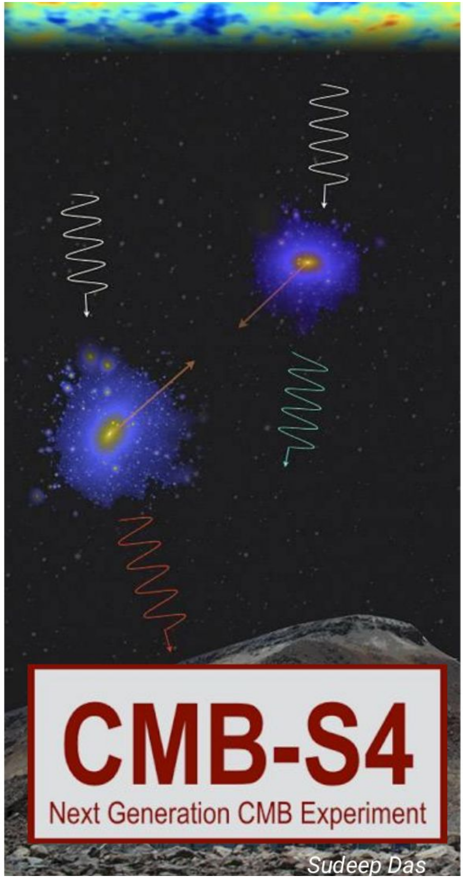
Left: Mueller, de Bernardis, Bean, Niemack, arXiv:1412.0592

CMB-S4

kSZ/tSZ

Eve Vavagiakis

- 5.4σ measurement of pairwise kSZ in ACT+*Planck* data with SDSS DR15 (arXiv:2101.08374)
- Check models with empirical y-tau relationship from tSZ and kSZ measurements (arXiv:2101.08373)
- Step towards extracting mean pairwise velocity from pairwise momentum measurements
- Complementary kSZ and tSZ analysis from ACT with different methodology: Amodeo et al. 2020, arXiv:2009.05558, Schaan et al. 2020, arXiv:2009.05557
- Higher S/N with improved data: constrain $\sum m_\nu$, σ_8, *f*, dark energy, models of modified gravity
- Learn about baryon distribution, evolution of galaxies



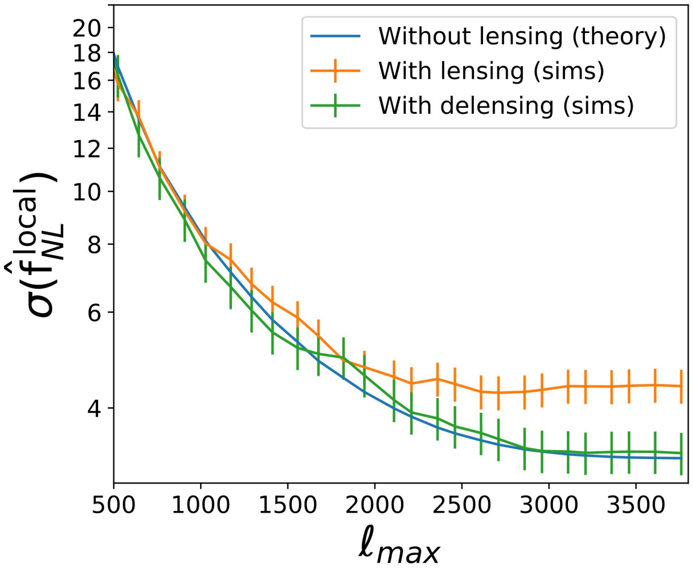
CMB Bispectrum

Will Coulton

$\sigma(f_{NL})$

Shape ($\zeta\zeta\zeta$)	Current	S4 constraint
Local	-0.9 ± 5.1	1.9
Equilateral	-26 ± 47	22.1
Orthogonal	-38 ± 23	9
Shape ($\zeta\zeta h$)	**Constraint**	
Local	-48 ± 28	0.79
Equilateral	-	16
Orthogonal	-	4.4

Local non-Gaussianity SNR for measurements with ~8uk' noise with delensing!



Nearly optimal!
With no biases

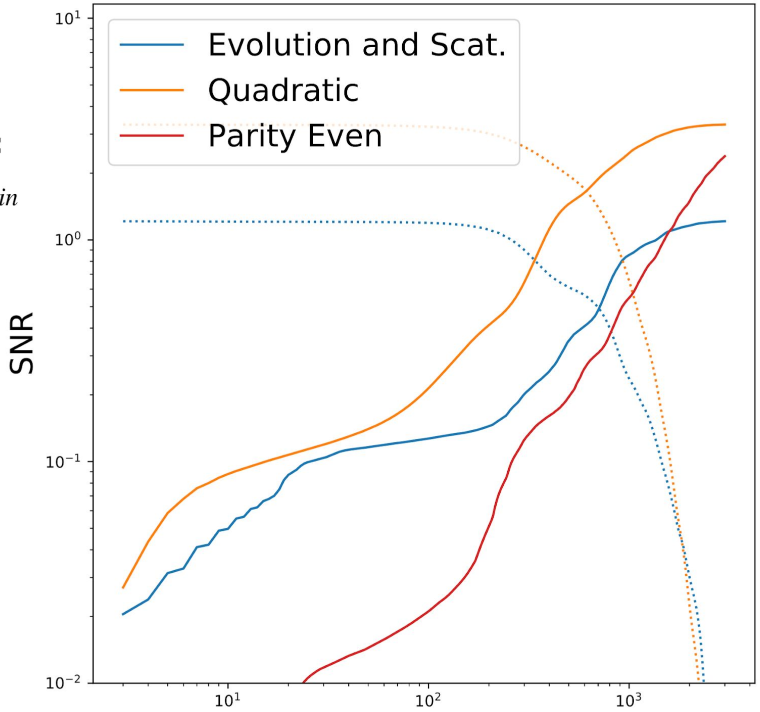
Theoretical target for scalar non-Gaussianity: $\sigma(f_{NL})$~1

CMB Bispectrum

Will Coulton

Parity odd SNR for S4
(assuming 80% of lensing B mode power removed)

Dotted Lines:
SNR wrt to ℓ_{min}



Solid Lines:
SNR wrt to ℓ_{max}

Intrinsic Bispectrum - Non-primordial, non-scalar non-Gaussianity

SNR~O(1) with CMB-S4

CMB-S4

ECC Parallel Session

What is the External Collaborations Committee?

- Mandated in bylaws
- Just created two weeks ago
- Raison d'etre: provide the necessary link to external follow-up observations or survey data that are required to maximize the science return from CMB-S4.
- Near-term goal: facilitate science forecasting that requires external collaboration (e.g., with LSST), and that could impact CMB-S4 design.

We are looking to the Science Council to establish priorities for such forecasting projects, and to take the lead on planning any such forecasting exercises. We will then work with external collaborations to develop any necessary publication agreements and resource-sharing agreements.

We expect our membership to expand, to include people with strong links to simulation and forecasting activities in external collaborations.

ECC Parallel Session is 10:30 am to 11:15 am Pacific Friday

We will discuss potential forecasting projects and their prioritization and challenges to their execution -- in particular looking for challenges that can be solved with coordination with external collaborations. We expect attendance by Colin Hill and potentially other members of an SO body similar to the ECC, so we can learn from their experience and avoid duplication of effort.