Dealing w/ Systematics & Foregrounds

Giuseppe Puglisi - UC Berkeley

Systematics simulations with TOAST
(see my poster)
- Beam Side lobe convolution
- Calibration uncertainties
- Gain drifts
- Cosmic Ray glitches
( HWP non-idealties ... )

Radio Source Simulations
- Constrained realizations from Low-Freq. catalogs
- Mock realizations from Websky Halo catalogs

Foregound modelling using Neural Networks

Inpainting Galactic Foreground Intensity and Polarization maps using Convolutional Neural Networks

ForSE: a GAN based algorithm for extending CMB foreground models to sub-degree angular scales
Krachmalnicoff & Puglisi 2020

On-going projects:
- CONet: To improve our CO emission models at High Galactic latitudes
- AMEnet To increase resolution of AME maps

A foreground-immune CMB-cluster lensing estimator

Kevin Levy (MSc student at U. Bonn), Srinivasan Raghunathan, Kaustuv Basu

- Rotate along gradient direction and stack (2% constraint 100k clusters).
- +tSZ (blue) introduces bias but easy to correct (red) at the expense of a slightly larger noise.
- +kSZ (purple) cancels upon stacking, i.e. only adds variance.
- SNR comparison with MLE/QE ongoing.
- Reference: S. Raghunathan et al. 2019, PRL (1907.08605) and Levy et al. in prep.

* rotated cluster stack, ** tSZ estimate (unrotated cluster stack), ***background stack (using random location)
Optimal CMB lensing power spectrum estimation

- Traditional lensing estimators (QE) are known to be sub-optimal for next-gen experiments such as CMB-S4
- New estimators are currently being developed (Carron et al. 2017, Millea et al. 2019)
- Our goal: develop a fast and robust pipeline to get an unbiased CMB lensing power spectrum
- Based on the iterative lensing estimator of Carron et al. 2017

- Reconstruction of lensing power spectra for CMB-S4 like maps
- N0 bias reduced with iterative delensing
- N1 bias doubly reduced
- Currently developing pipeline for iterative RDN0

![Graph showing the comparison between QE and Iterative methods with plots for C^L_\phi and SNR vs Lmax]
Margherita Lembo @ University of Sussex

CMB lensing:
analyzing the impact of masking extragalactic foregrounds (such as CIB, tSZ, radio sources) on both the reconstructed CMB lensing potential and the lensed CMB power spectra.

- Lensed CMB power spectrum biases from masking extragalactic sources

- CMB lensing reconstruction biases from masking extragalactic sources
  ML, G. Fabbian, J. Carron, A. Lewis (in prep.)

Cosmic Microwave Background in view of future experiments:
Which information can be still extracted from the CMB? How to extract this information in a reliable way?

CMB polarization:
working on formalism describing the in-vacuo conversion between polarization states of propagating radiation (GFE), in a cosmological context, which is a powerful tool for constraining new physics beyond the standard model.

Through a dark crystal: CMB polarization as a tool to constrain the optical properties of the Universe

In short...

- “Angelo Della Riccia” Fellowship, University of Sussex (Jan 2021 - Dec 2021)
- Ph.D. in Physics, University of Ferrara (Nov 2017 - Nov 2020)
- Master in Theoretical Physics, University of Bari (Sep 2014 - Sep 2017)
- Bachelor in Physics, University of Bari (Sep 2010 - Sep 2014)
CMB lensing - optimal bias mitigation

- Extragalactic foregrounds (CIB, tSZ, kSZ, radio point sources) in temperature maps significantly bias lensing reconstruction
- Extended a bias-hardening technique (based on Osborne+13) to simultaneously reduce point source, tSZ, and CIB bias at a small noise cost
- What are the optimal ILC weights for bias + noise reduction?

Cross-correlations with future high-z surveys

- Perturbation-theory based Fisher forecasting (github.com/NoahSailer/FishLSS) for 2-point measurements (galaxy and 21 cm clustering, cross-correlations with CMB lensing)
- Self-consistent forecasts for future LSS and CMB surveys (Euclid, MSE, MegaMapper, PUMA, S4, ...)
- Constraints on LCDM and usual extensions, EDE, DM interactions, gravitational slip, etc.

Sailer, Castorina, Ferraro, White (in prep.)
Likelihood methods to infer the optical depth from Planck data

Roger de Belsunce - with: George Efstathiou, Steve, Gratton, Will Coulton (arXiv: in prep.)

Problem
- noise- & systematics-dominated signal
- No exact analytic likelihood (masked sky)

Physical motivation
- $\tau$ relevant for $M_\star$, $A_\nu$, $n_s$, $\sigma_8$
- Constraints on reionization models

Solution
- Improved noise and systematics modelling
- Bayesian frameworks:
  - From likelihood-approximation\textsuperscript{1,2,3} to likelihood-free\textsuperscript{4} schemes
  - First joint TTTEEE likelihood

Consistent results for three likelihoods on systematics dominated signal for $\tau$
1) **Identifying new observables**

2) Extract information from data; **developing different methods**

3) Improve the **detection significance** of upcoming experiments to various cosmological observables

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Delensing the CMB TT,TE,EE
1) Improving measurements of the BAO **peak locations**
2) Better measurement of the damping tail for $N_{\text{eff}}$, $H_0$,++
3) Iterative delensing for B-modes

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**Large-scale velocity** reconstruction from moving lens and kSZ effects

**DETECTION:**
- **SNR~30 for S4**
- **Moving lens:** 1812.03167 and 2006.03060
- **Primordial isocurvature:** $kSZ$: 1908.08953
- **Current CMB only:** $\sigma(A) \sim 500$
- Using kSZ velocities (S4): $\sigma(A) \simeq 0.5$

**SELIM HOTINLI:** shotinl1@jh.edu  
JHU Horizon Fellow

**JOHNS HOPKINS UNIVERSITY**

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First 3 images from Websky simulation
Evidence for line-of-sight frequency decorrelation of polarized dust emission in *Planck* data


**LOS frequency decorrelation:**
If a single line of sight intercepts multiple dust clouds with different SEDs and different magnetic field orientations, the frequency scaling of Stokes $Q$ and $U$ may be different.

We detect this effect in *Planck* data at high significance.

**The key is knowing where to look:** we select sightlines based on their complexity in HI line emission. We use HI-based estimates of the number of clouds per sightline (Panopoulou & Lenz 2020) and the 3D magnetic field geometry (Clark & Hensley 2019).

V. Pelgrims, S.E. Clark, B.S. Hensley, G.V. Panopoulou, V. Pavlidou, K. Tassis, H.K. Eriksen, I.K. Wehus
Connecting KSZ observable with the physics of reionization

Introduction to the KSZ-bias parameter

When it started? How long it continued? Is it driven by massive/lighter halos?

Scaling relation to understand the kSZ power spectrum

Commonly used scaling relation

\[
\frac{l(l+1)}{2\pi} C_{l=3000}^{\text{kSZ}} \approx 2.02 \mu K^2 \left[ \left( \frac{1 + \bar{z}}{11} \right) - 0.12 \right] \left( \frac{\Delta z}{1.05} \right)^{0.47}
\]

New scaling relation

\[
\frac{l(l+1)}{2\pi} C_{l=3000}^{\text{kSZ}} \approx 0.65 \mu K^2 \left( \frac{0.097 + \tau}{0.151} \right) \left( \frac{\Delta z}{1.0} \right)^{0.54} \left( \frac{b_{\text{KSZ}}^2(l = 3000)}{4.0 \times 10^{-7}} \right)^{0.92}
\]
Cosmic Infrared Background (CIB)

- Far infrared of galaxy emission
- Dusty, star-forming galaxies at high redshift
- Theoretical power spectrum
- Cross correlations with CMB lensing, SZ, matter power spectrum, ...
- ACT x Planck
- SFRD
- Constrain $f_{NL}$
Metamaterial Microwave Absorber (MMA)

Presenter: Zhilei Xu; other major contributors: Grace Chesmore, Mark Devlin, Jeff McMahon

- **Injection-molded** for low cost
- Cools down to 1K reliably
- Measured < -30dB reflection/scattering with <45° angle of incidence
- Flat version for more general use

**SO LAT Optics Tube Design**

**MMA Tiles**
- 15°, 30°, 45°
- Black PT 30°, 60°, 65°

**Scattered power (dB)**
- Measured @ 110 GHz

**θ_r [deg]**
- 45°