Research Summary

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I. LENSING RECONSTRUCTION ON THE CURVED SKY

Cosmic Microwave Background(CMB) photons are gravitationlly lensed by the large scale mass distribution. We can use a first order perturbation to discribe this effect which is called weak gravitationl lensing of CMB. CMB temperature map(T) and polarization map(E,B) are distorted by (what is gravitationl lensing) Weak gravitationl lensing for the microwave background anisotropies (dark matter) in the projected gravtional potential (premodial gravitationl waves)

There are several aspects where we see weak gravitationl lensing effects on CMB. 1.Weak gravitationl lensing modulates CMB temperature and polarization power spectra(2 point power spectrum). Statistical anisotropy is induced. 2.Lensing of CMB fields produces higher-order correlations between the multipole moments. Off-diagonal mode-coupling between map harmonics can be seen. The off-diagonal mode coupling is proportional to lensing potential.[1] 3.It generates B-mode polarization signal which confuses the signal from primordial gravitationl waves.[2]

The lensing signal can help seperate premordial gravitationl waves(delensing) which can generate B-mode before the last scattering surface. It can also be used to help constrain cosmological parameters and lensing mass distribution. Thus, it is important to study weak gravitationl lensing of CMB.

To obtain projected gravitationl potential(lensing potential) and therefor the projected mass, we can take quadratic combinations of CMB fields. This process is called lensing reconstruction which is a story of measuring lensing.

I will outline

Since lensing is most sensitive to the projected potential at $L < 10^2$ or several degrees on the sky, we need consider the curvature of the sky.

In the section, I will present how to treat consisely the effect of gravitationl lensing on CMB temperature and polarization maps by constructing the full sky quadratic estimators of lensing potential and their noise. And I will introduce the simulation of lensed I will give preliminary results of my calcucation

Deriving the full sky minimum variance quadratic estimators of lensing potential from CMB temperature and polarization fields.

My work of this part is mainly about: I am a member of both ACT and Simons

II. INVOLVEMENTS IN THE COLLABORATION

1.understand terms and calculations[3] [4] 2.why the ksz signal due to fluctuations in the ionization fraction during reionization can cause a detectable squeezed limit trispectrum.[5]

In this work, I am investigating a bias to CMB lensing reconstruction from temperature anisotropies due to reionization kinematic Sunyaev-Zel'dovich (kSZ) effect. kSZ effect is a Doppler shift of CMB photons induced by Compton-scattering off moving electrons. Next generation ground-based CMB experiments

? compton scattering and Thomson scattering: Thomson scattering is the elastic scattering of electromagnetic radiation by a free charged particle, as described by classical electromagnetism. It is the low-energy limit of Compton scattering: the particle's kinetic energy and photon frequency do not change as a result of the scattering. This limit is valid as long as the photon energy is much smaller than the mass energy of the particle: , or equivalently, if the wavelength of the light is much greater than the Compton wavelength of the particle.

Reionization: At a redshift of about 10, hydrogen gets ionized again by the ultraviolet radiation of the first structures kSZ:

The kSZ anisotropy can be roughly decomposed into two parts: 1.a "late-time" contribution from redshifts$z <\ 3$ when inhomogeneities are large due to gravitationl growth of structure 2.a "reionization" contribution from z 7, when ionization fraction is inhomogeneous during "patchy" reionization.[3]

tSZ effect: CMB photons interact with electrons that have high energies due to their temperature kSZ effect kSZ anisotropies: are produced in cosmological epochs during which there are large fluctuations in the electron density. ? (physical image) "kSZ" is used to refer to any blackbody temperature fluctuation arising from bulk motion integrated along the line of sight, including the Doppler effect.

? We refer to the Doppler effect as responsible for large-angle kSZ anisotropies. ? bulk velocity

To lowest order (in both optical depth and velocity), the kSZ effect produced only temperature anisotropies, not polarization anisotropies.

late-time kSZ: are present in galaxies and clusters due to the non-linear growth of structure reionization kSZ: fluctuations in the electron density field are due to fluctuations in the ionization fraction, are also expected to be correlated with the matter density field and hence with CMB lensing.

? non-linear growth of structure ? seperation of “late-time” ksz and “reionization ksz” ? addition of “reionization ksz” map and “temperature” map ? how do I tell the difference between “late-time” kSZ and “reionization” kSZ?

? model of reionization kSZ ? CMB unlensed and lensed simulations ? websky reionization kSZ simulation and late-time kSZ(Dr.Trac might ask about this)

CMB-S3 and CMB-S4 lensing for a Stage 4 CMB experiment Their results have neglected the kSZ signal from reionization. kSZ sigunal due to fluctuations in the ionization fraction during reionization can bring a detectable bias(squeezed limit trispectrum) I am working on simulating the bias to lensing reconstruction from reionization kSZ effect.

As a member of both the Atacama Cosmology Telescope (ACT) and the Simons Observatory (SO), I am actively involved in the research and analysis projects in the collaborations. A short summary of each of my involvements is listed below.

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[1] Wayne Hu and Takemi Okamoto. Mass reconstruction with cmb polarization. *Astrophys. J.*, 574:566–574, 2002. doi:10.1086/341110.

[2] Antony Lewis and Anthony Challinor. Weak gravitational lensing of the CMB. *Phys. Rept.*, 429:1–65, 2006. doi:10.1016/j.physrep.2006.03.002.

[3] Simone Ferraro and J. Colin Hill. Bias to CMB Lensing Reconstruction from Temperature Anisotropies due to Large-Scale Galaxy Motions. *Phys. Rev.*, D97(2):023512, 2018. doi:10.1103/PhysRevD.97.023512.

[4] Marcelo A. Alvarez. The Kinetic Sunyaev–Zel’dovich Effect From Reionization: Simulated Full-sky Maps at Arcminute Resolution. *Astrophys. J.*, 824(2):118, 2016. doi:10.3847/0004-637X/824/2/118.

[5] Kendrick M. Smith and Simone Ferraro. Detecting Patchy Reionization in the Cosmic Microwave Background. *Phys. Rev. Lett.*, 119(2):021301, 2017. doi: 10.1103/PhysRevLett.119.021301.