ISW and CMB lensing around superstructures

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LSS x CMB

Lensing convergence

\[ \kappa(\hat{n}) = \frac{1}{c^2} \int_0^{r_{LS}} \frac{r_{LS} - r}{r_{LS}r} \nabla^2 \Phi(\hat{n}, r) \, dr \]

Integrated Sachs-Wolfe effect

\[ \frac{\Delta T(\hat{n})}{T_{CMB}} = -\frac{2}{c^2} \int_0^{t_{LS}} \Phi(\hat{n}, t) \, dt \]
Heating

Cooling

Photons lose energy: cold spot

Photons gain energy: hot spot

Granett et al. (2008)
DESI Legacy survey X Planck lensing & T maps

Why bother looking at superstructures

- Generalization of cluster cosmology / peak counts
- Possibly complementary cosmological information
- Testing theories of gravity
- ...

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50 super-voids/clusters (ZOBV/VOBOZ) from SDSS DR6, LRG Mega-Z catalogue, $z \sim 0.4-0.75$

Stacking of voids/superclusters with CMB

Stacked CMB temperature from WMAP5 V-band, using 50 voids and 50 superclusters positions from SDSS galaxy

Reproducing Granett et al. 2008, see also Planck 2013 results. XIX. The integrated Sachs-Wolfe effect
A 4sigma detection, a problem?

If ISW, the amplitude (~10 muK) is too high compared to LCDM expectation (3-sigma?), e.g.


a tension? what’s missing?

Stacked CMB temperature, filtered by compensated filter of 4-deg radius, R~100 Mpc/h at z~0.5
ISW imprint on the CMB

Kovacs et al. 2019MNRAS.484.5267K
What could be missing

• Point sources, kSZ, tSZ?
• If ISW, how good is linear approximation?
• Sample variance?
• ...

CMB lensing by voids in SDSS

DESI Legacy survey

49 million galaxies covering 17739 \text{deg}^2, \ z < 0.8

0.3 < z \leq 0.45 \text{ voids}

Hang, Alam, Cai & Peacock, 2021MNRAS.tmp.1954H
Lensing imprints by superstructures on CMB

Hang, Alam, Cai & Peacock, 2021MNRAS.tmp.1954H
Temperature imprints by superstructures on CMB

Hang, Alam, Cai & Peacock, 2021MNRAS.tmp.1954H
Summary

• Superstructures leaves imprints on the CMB via lensing and ISW
• Detection of CMB lensing around superstructures: SDSS, DES, Legacy survey
• Possible abnormal ISW signal around super-voids, but lensing is fine
What CMB S4 can do for this?

• Improve S/N for lensing profiles around superstructures
  (e.g. Raghunathan, et al. 2020)

• Measure the projected profiles of density peaks and troughs
  (e.g. Gruen et al. 2016; 2018; Friedrich al.2018; Uhlemann et al. Loverde2020; Paillas, Cai et al. 2021)

Paillas, Cai et al. in prep.