ISW and CMB lensing around superstructures

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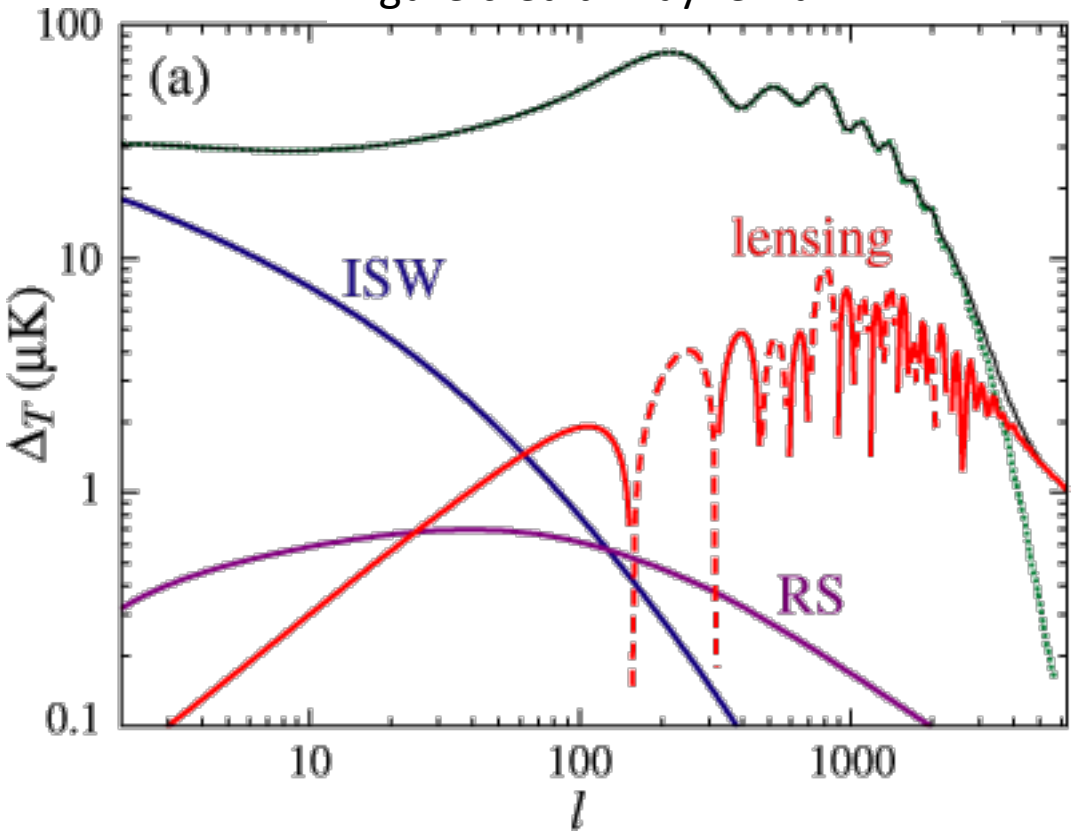
LSS x CMB

Figure credit: Wayne Hu



Lensing convergence

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

Integrated Sachs-Wolfe effect

$$\frac{\Delta T(\hat{\mathbf{n}})}{T_{\rm CMB}} = -\frac{2}{c^2}\int_0^{t_{\rm LS}} \dot{\Phi}(\hat{\mathbf{n}},t)\,dt$$

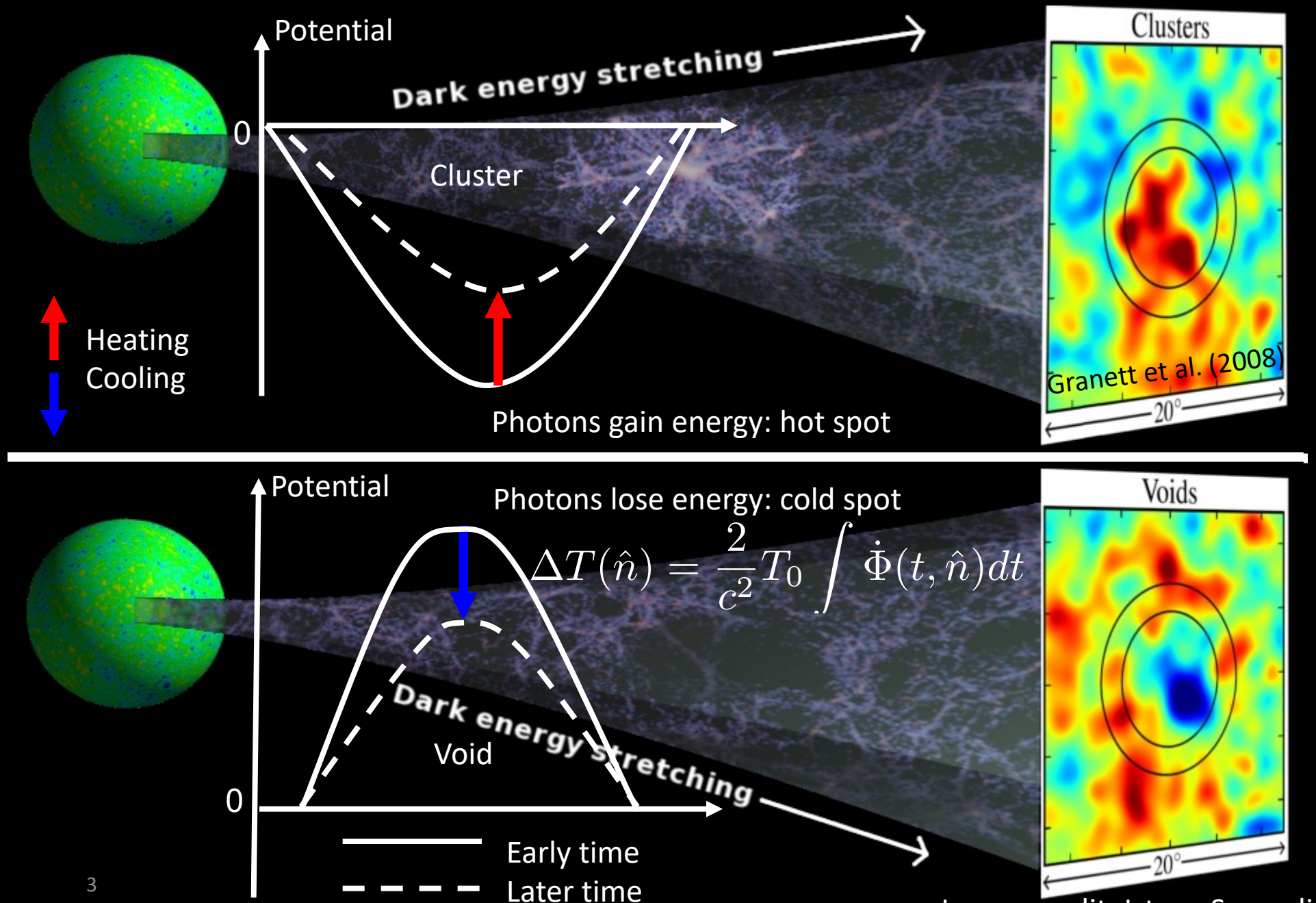
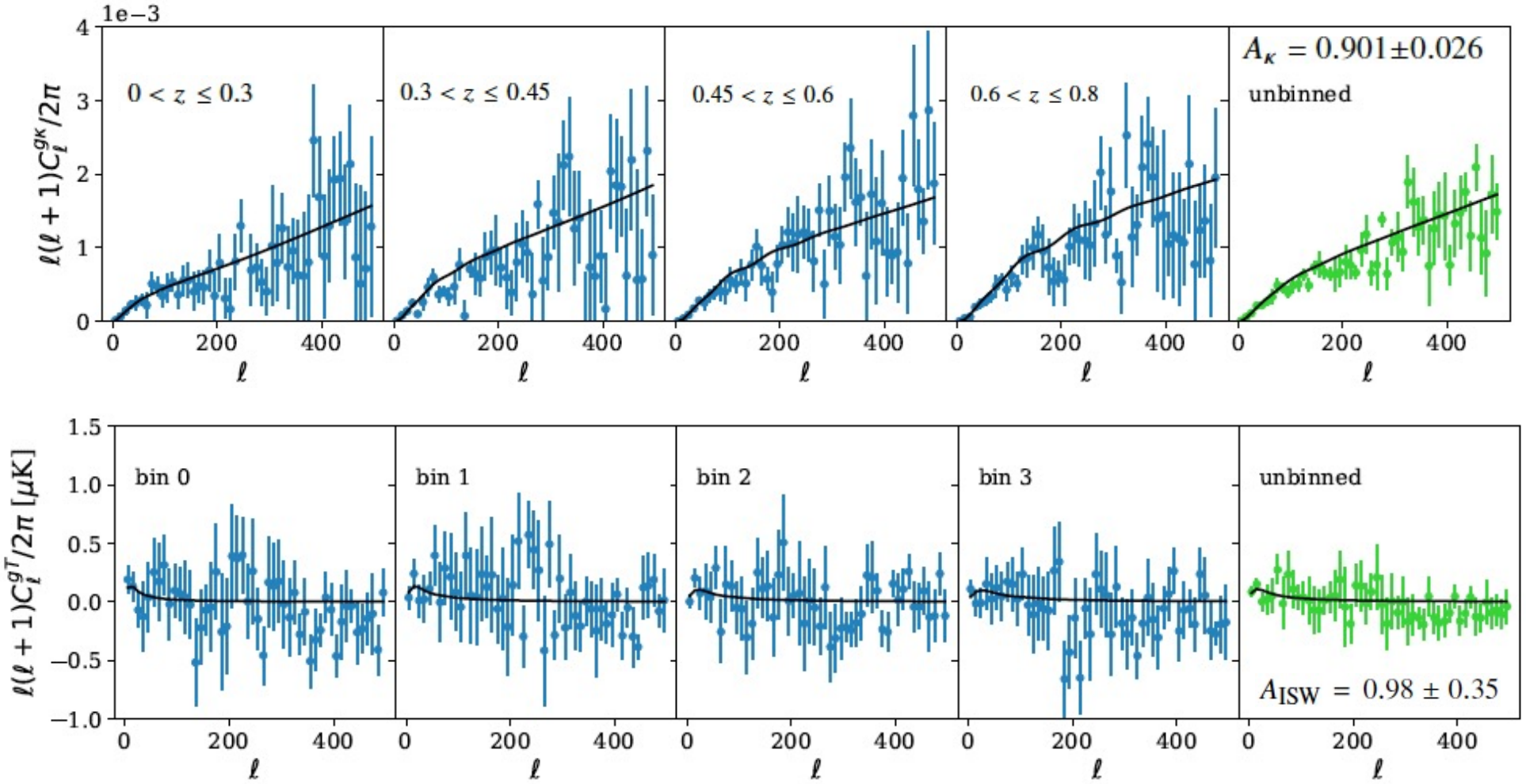


Image credit: Istvan Szapudi

DESI Legacy survey X Planck lensing & T maps

Lensing

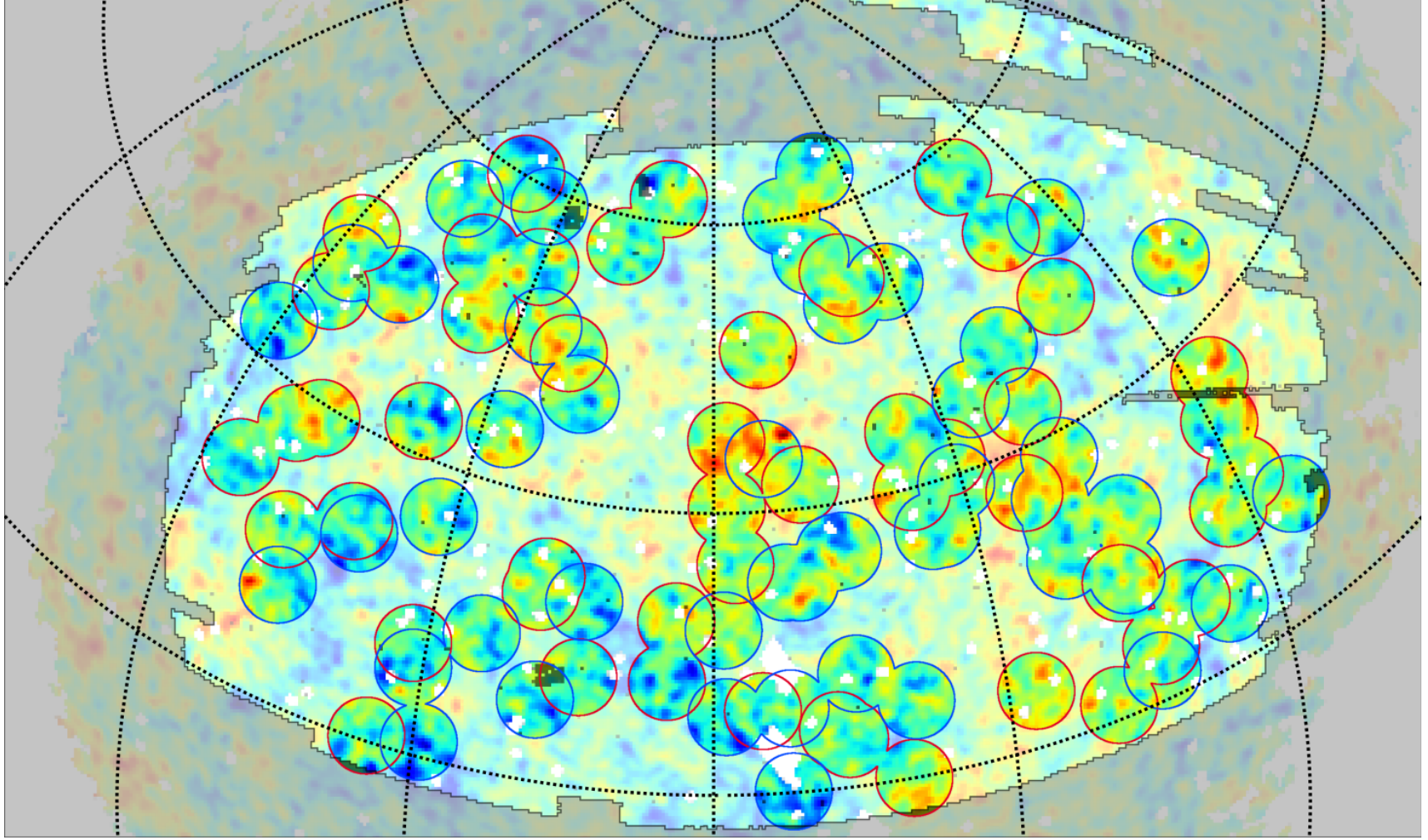
ISW



Hang, Alam, Peacock & Cai, 2021MNRAS.501.1481H, see also Krolewski, Ferraro & White, arXiv:2105.03421

Why bother looking at superstructures

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



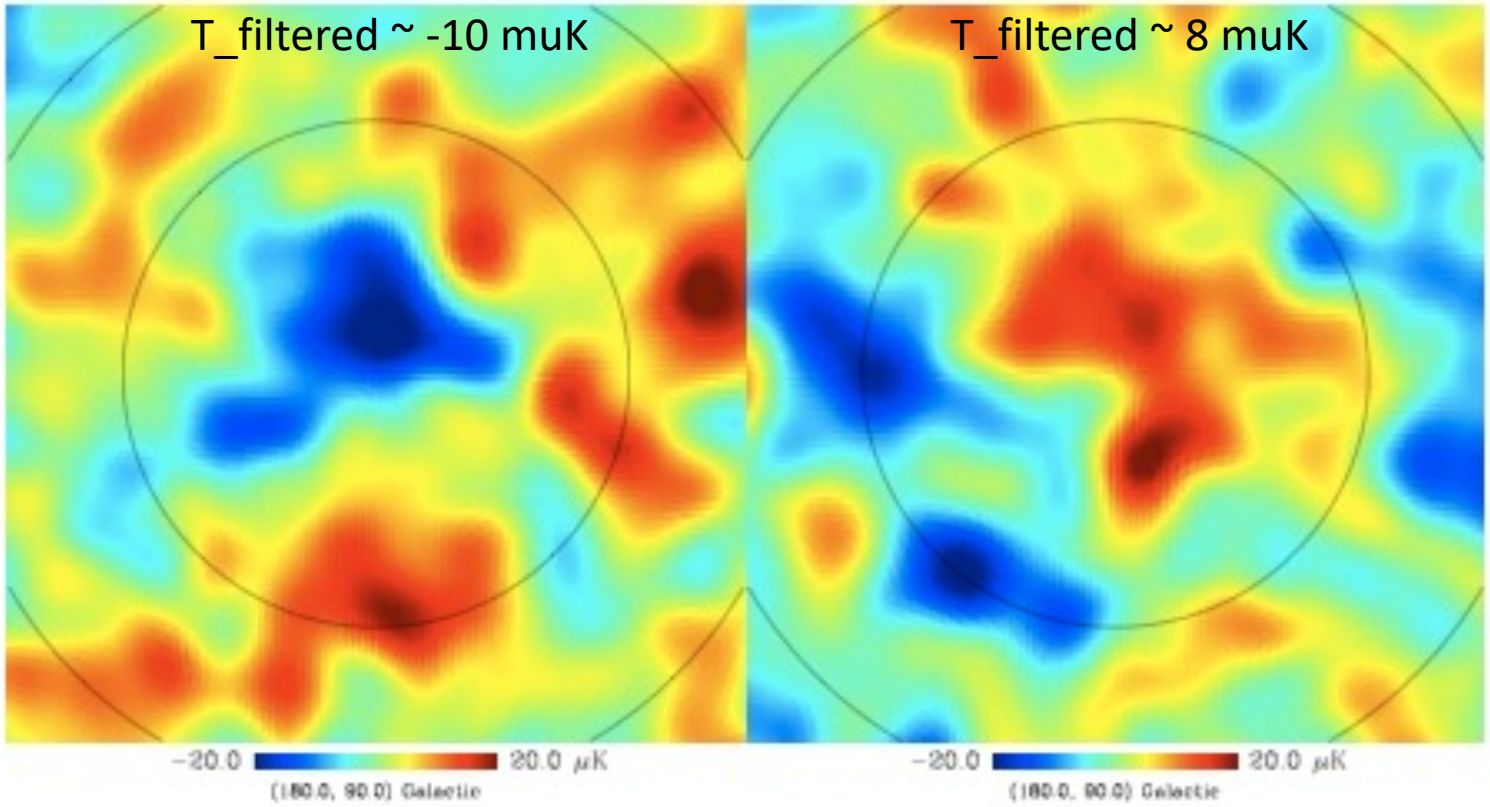
50 super-voids/clusters (ZOBOV/VOBOZ) from SDSS DR6, LRG Mega-Z catalogue, z ~ 0.4-0.75

Granett B. R., Neyrinck M. C., Szapudi I., 2008, ApJL, 683, L99

Stacking of voids/superclusters with CMB

cold spot surrounded by hot ring

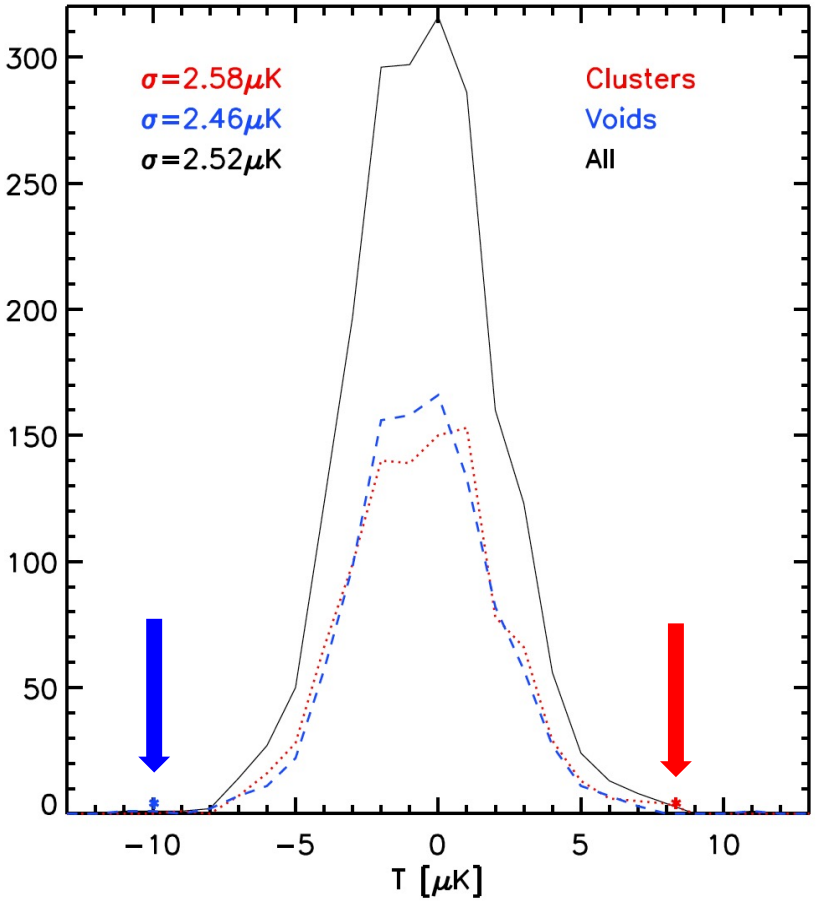
hot spot surrounded by cold ring



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?



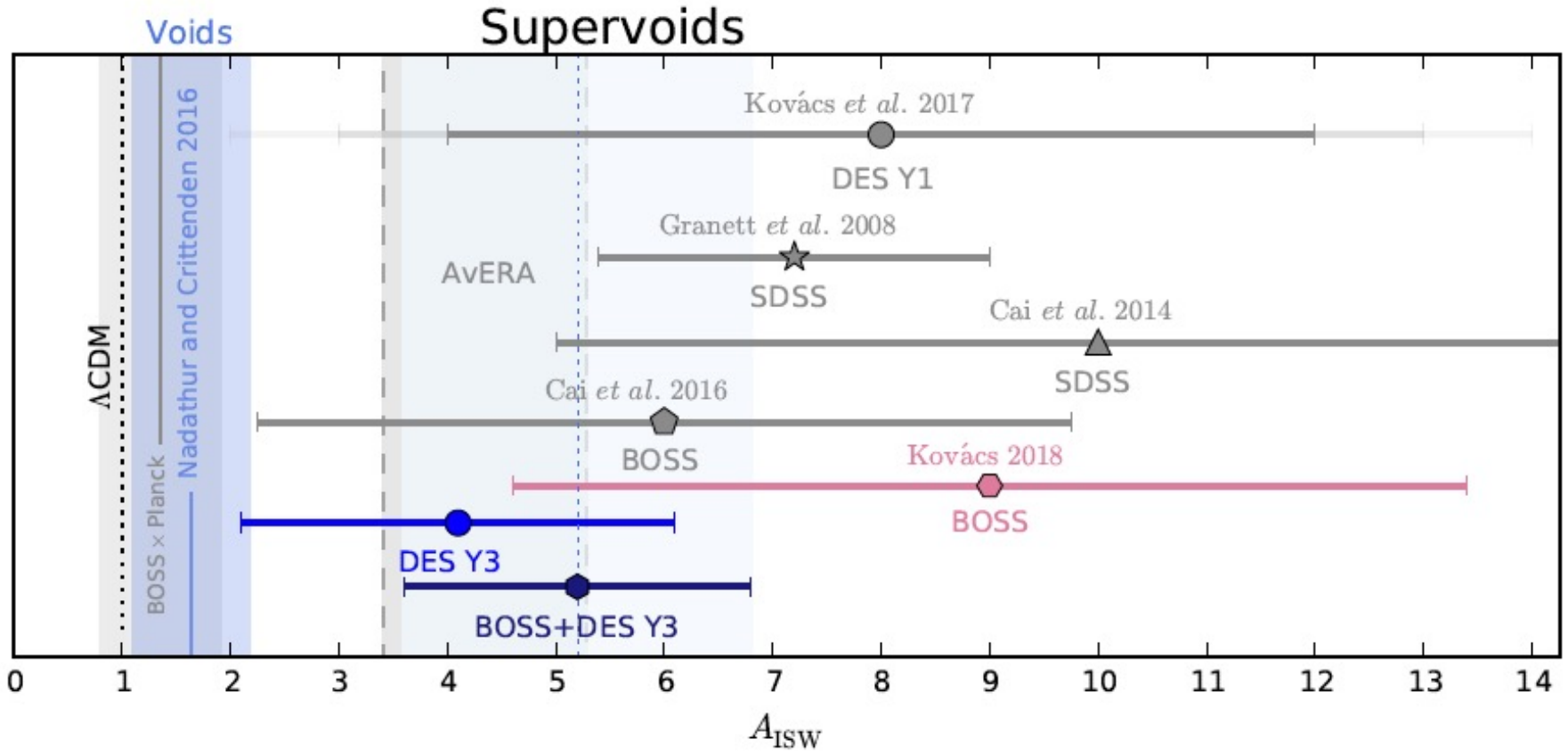
Stacked CMB temperature, filtered by compensated filter of 4-deg radius, R~100 Mpc/h at z~0.5

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

Granett et al. (2008), Papai et al. (2011), Nadathur et al. (2012), Flender et al. (2013), Hernandez-Monteagudo & Smith (2013), Aiola et al. 2015, Cai et al. 2017; Kovacs et al. 2018, 2019, 2021

a tension? what's missing?

ISW imprint on the CMB

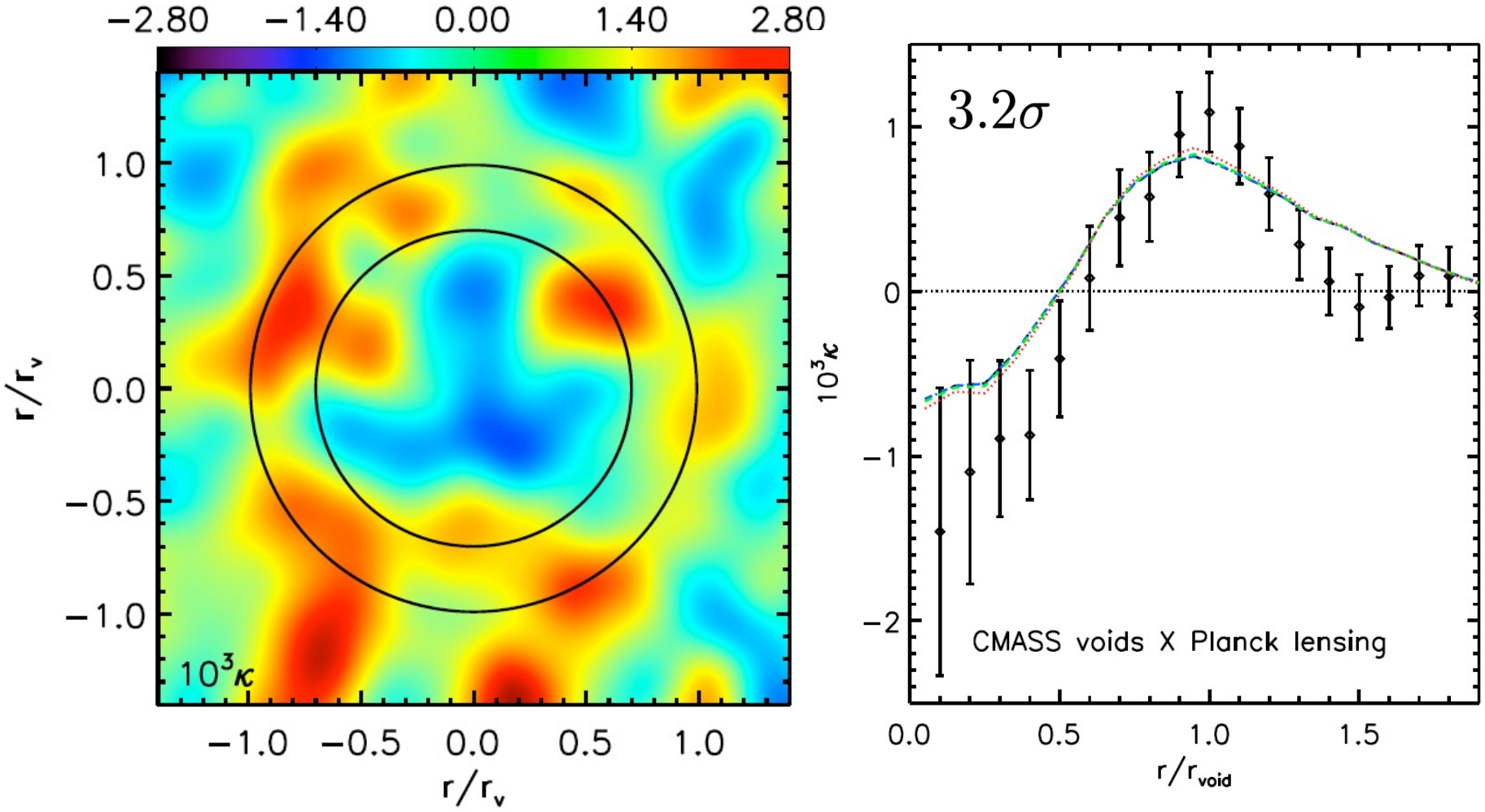


Kovacs et al. 2019MNRAS.484.5267K

What could be missing

- Point sources, kSZ, tSZ?
- If ISW, how good is linear approximation?
- Sample variance?
- …

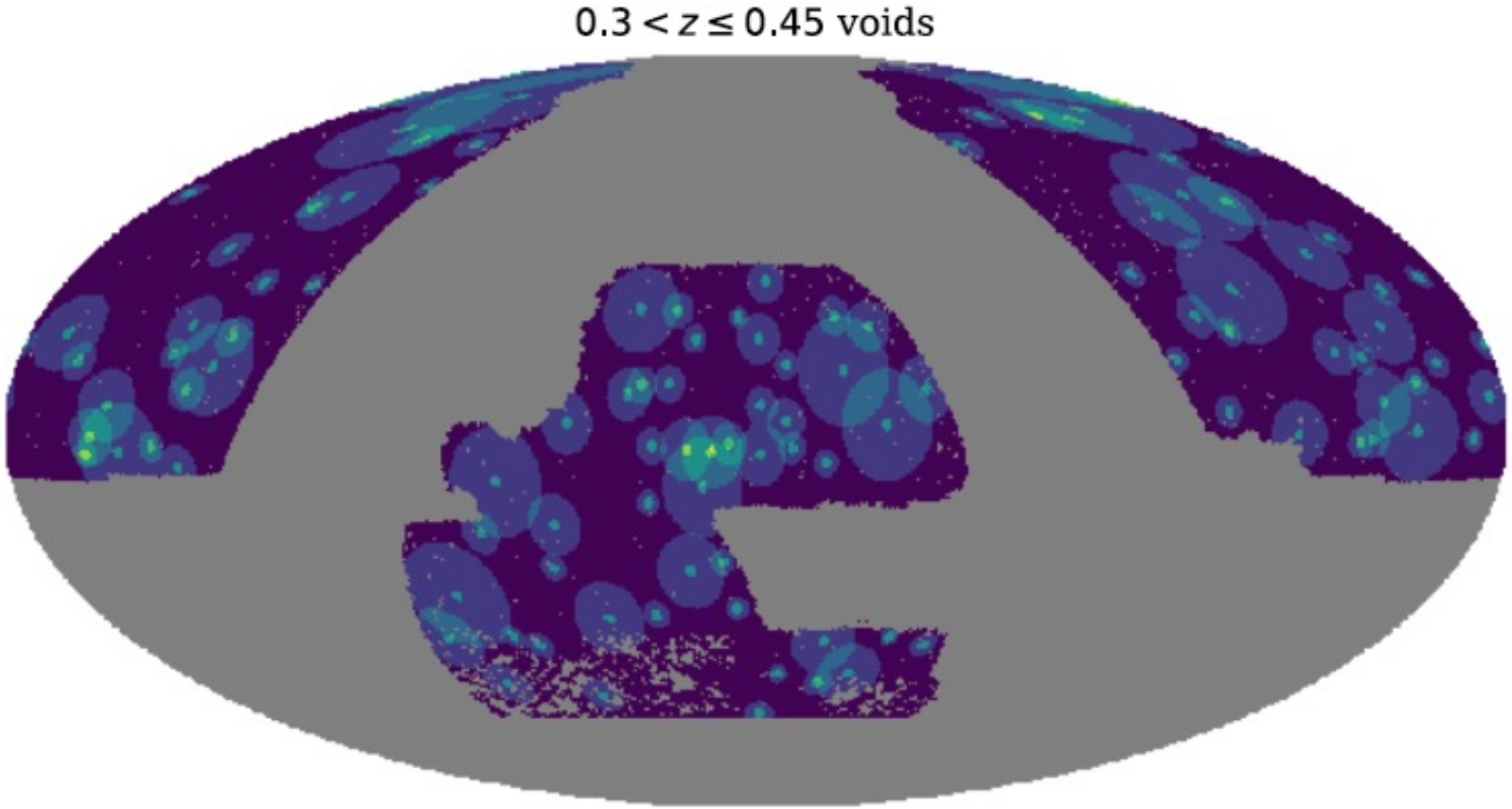
CMB lensing by voids in SDSS



Cai et al. 2017, see also Raghunathan, et al. 2020 ApJ...890..168R, Vielzeuf et al. 2021MNRAS.500..464V

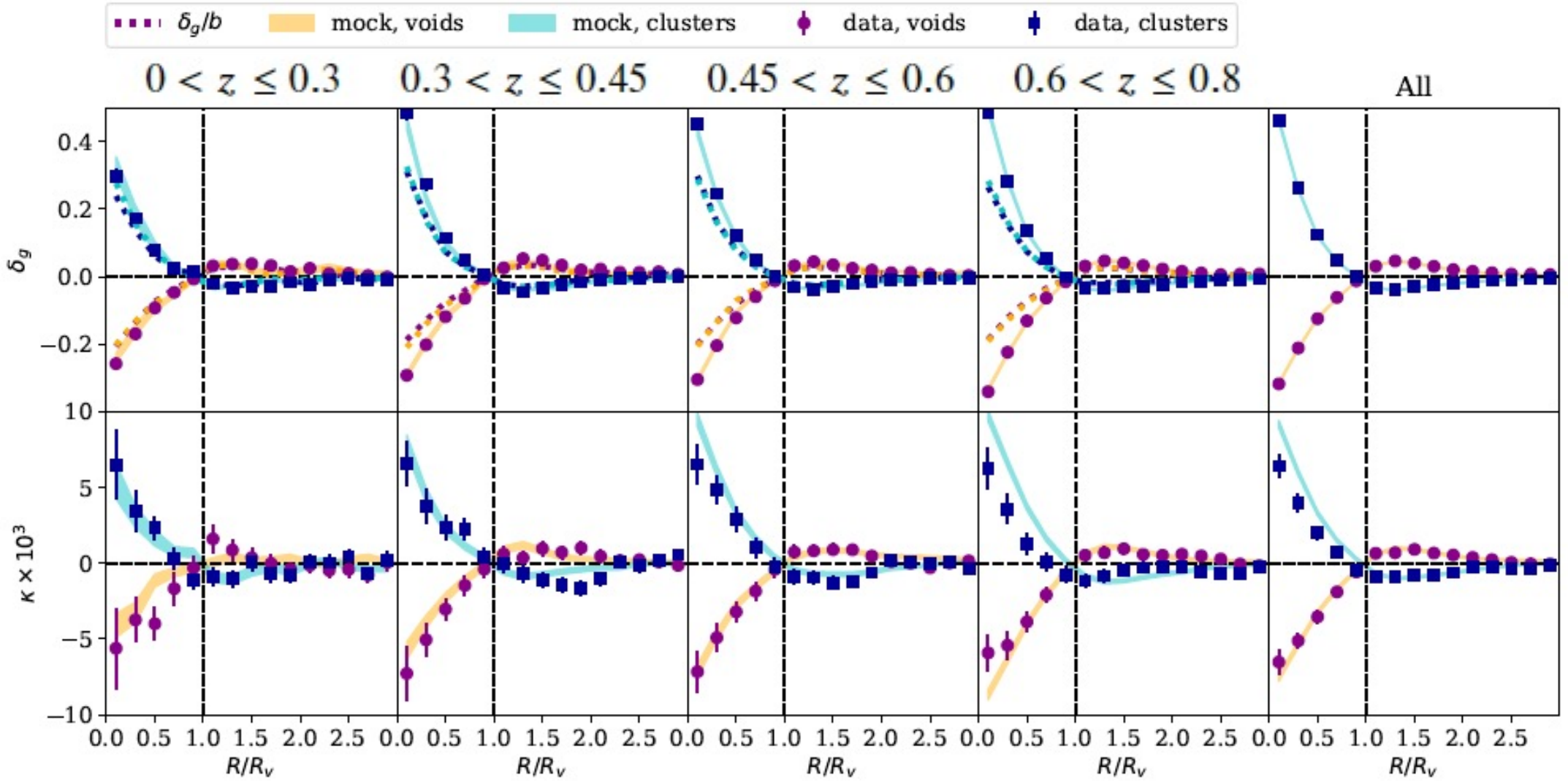
DESI Legacy survey

49 million galaxies covering 17739 deg^2, $z < 0.8$



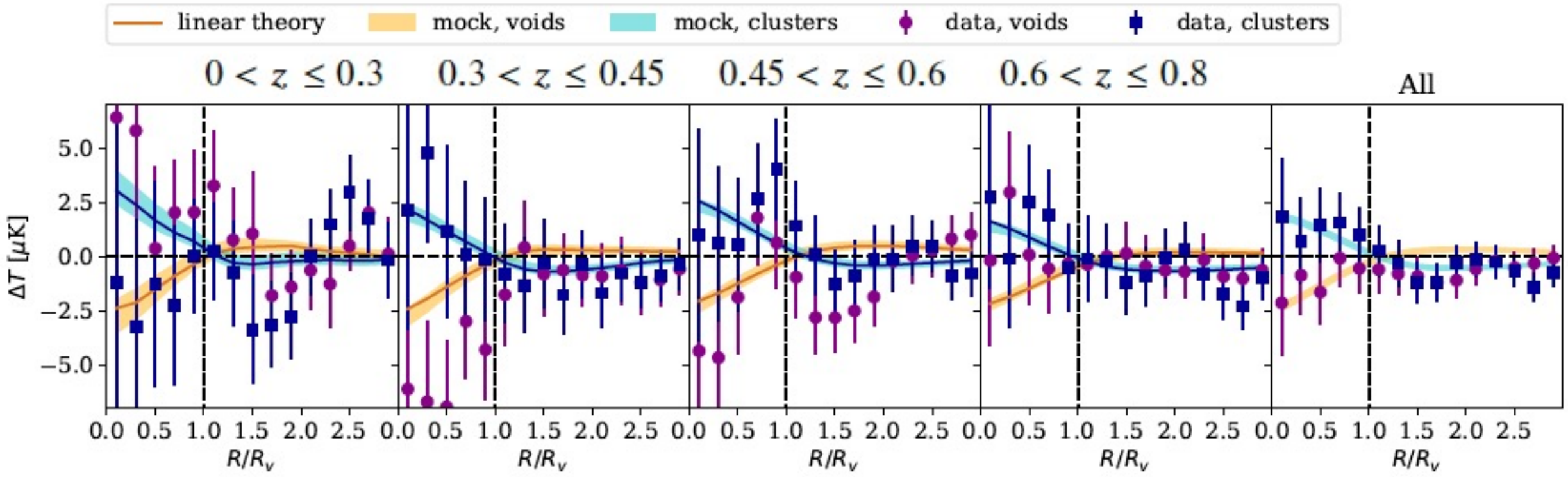
Hang, Alam, Cai & Peacock, 2021MNRAS.tmp.1954H

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 densit

  (e.g. Gruen et al. 2016; 2018; Friedrich al.2018; Uhlemann et al. Loverde2020; Paillas, Cai et al. 2021)