Title: ACT DR4

Speakers: Sigurd Naess

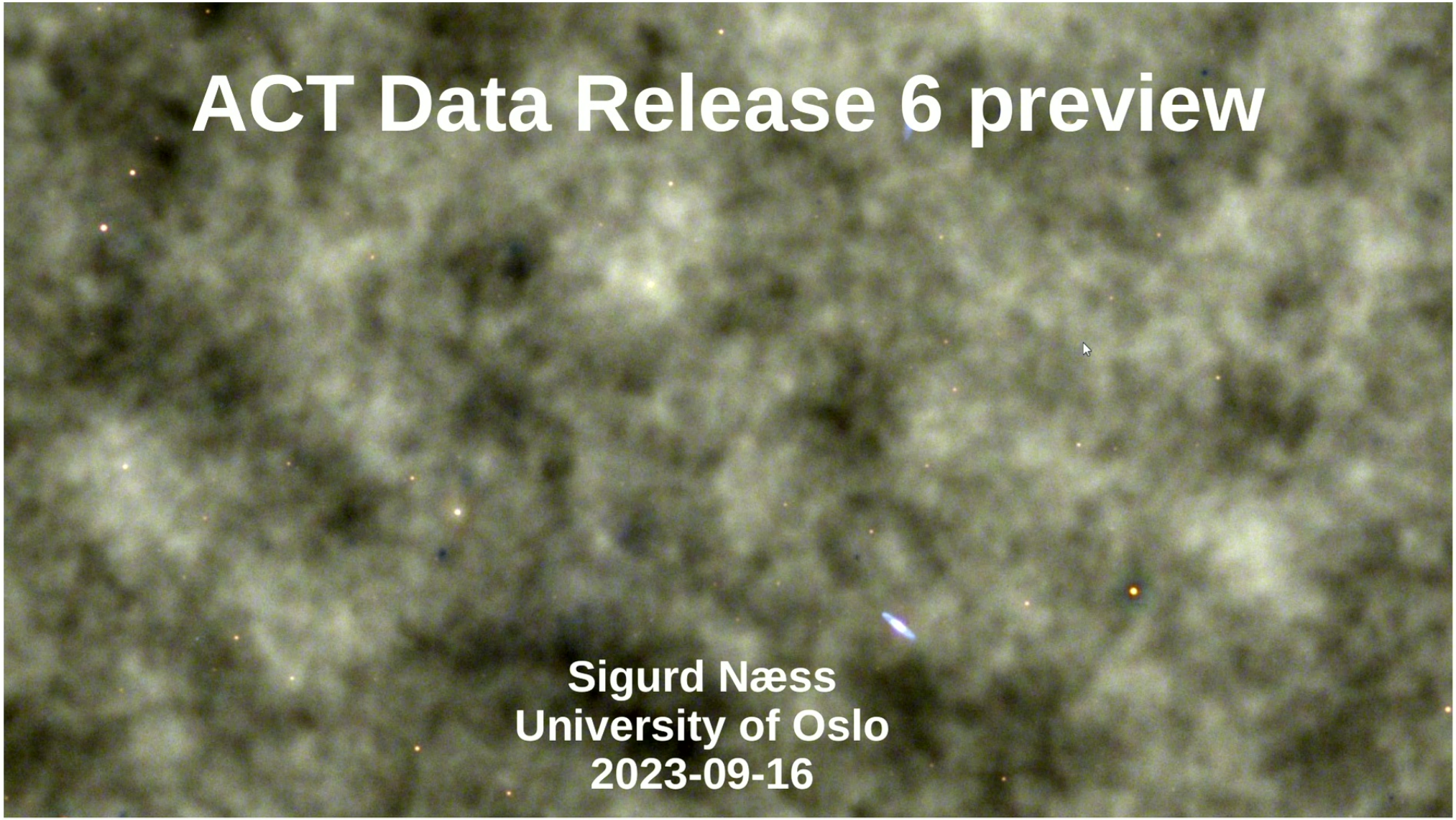
Series: Cosmology & Gravitation

Date: December 05, 2023 - 1:00 PM

URL: https://pirsa.org/23120033

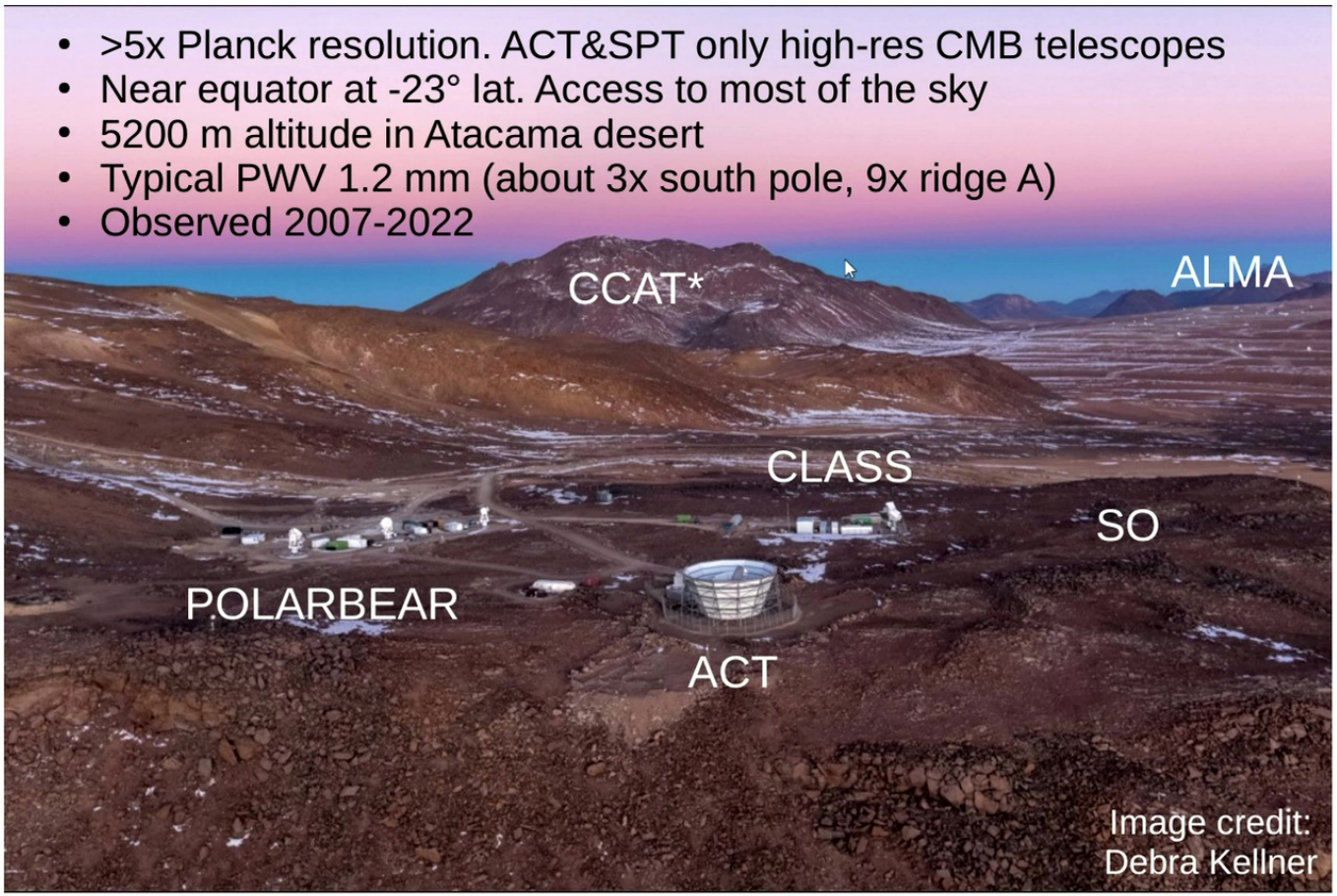
Abstract: Abstract TBA

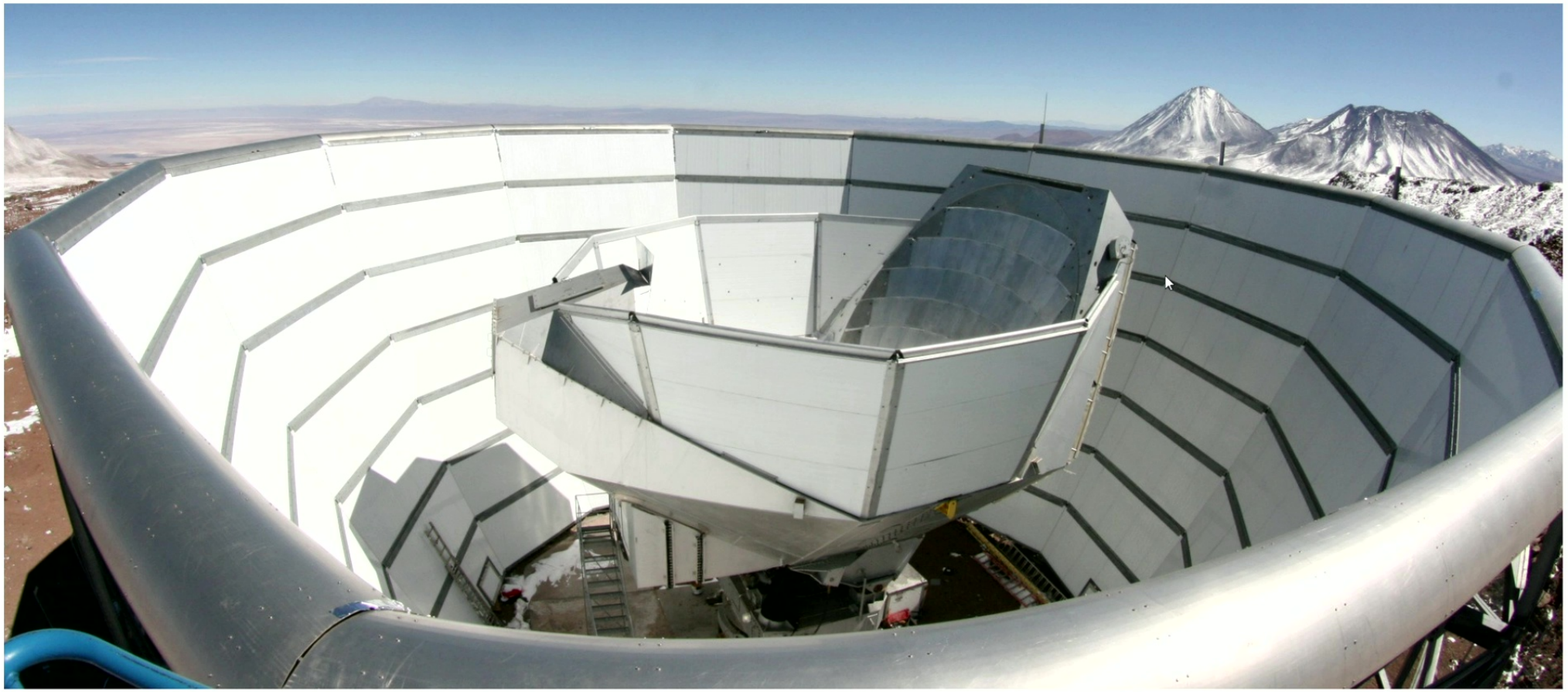
Zoom link https://pitp.zoom.us/j/96982969023?pwd=MjgzaU5mZUVuV3pNVG11dHM2WUd4UT09


ACT Data Release 6 preview
Sigurd Næss
University of Oslo
2023-09-16

The Atacama Cosmology Telescope

- >5x Planck resolution. ACT&SPT only high-res CMB telescopes
- Near equator at -23° lat. Access to most of the sky
- 5200 m altitude in Atacama desert
- Typical PWV 1.2 mm (about 3x south pole, 9x ridge A)
- Observed 2007-2022



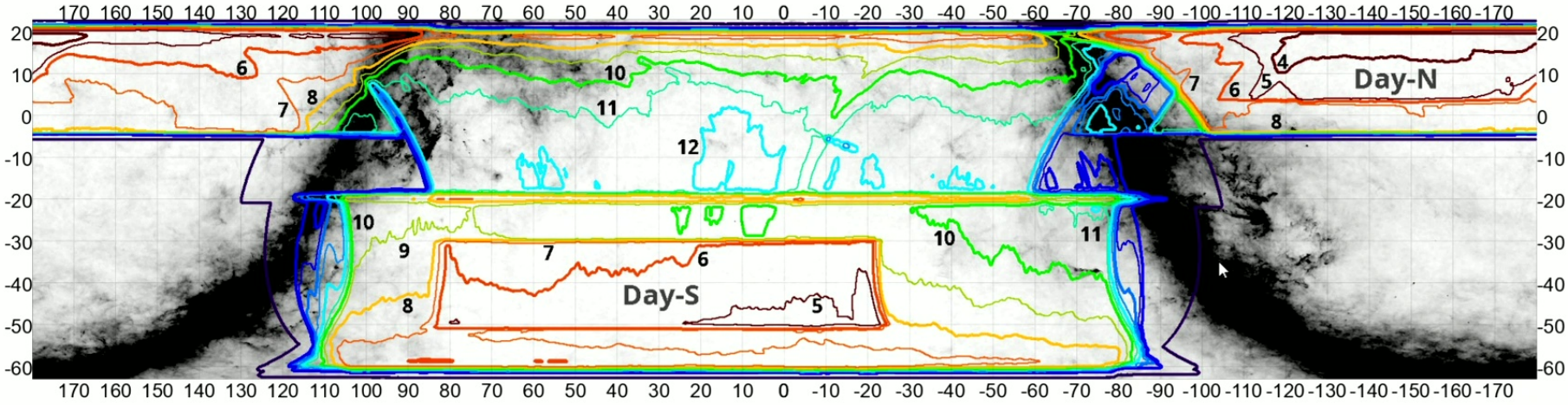


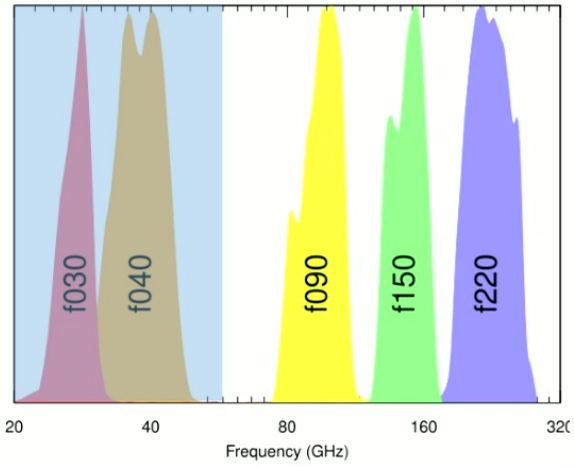
The ACT Collaboration

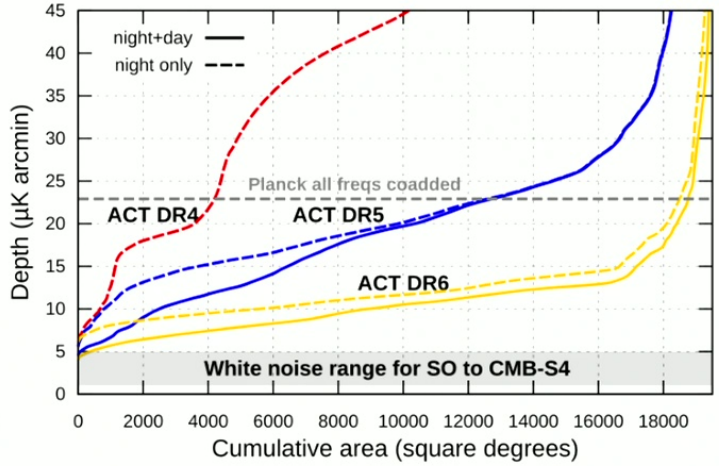
160 collaborators at 45 institutions

PI: Suzanne Staggs (Princeton University)

Advanced ACT survey

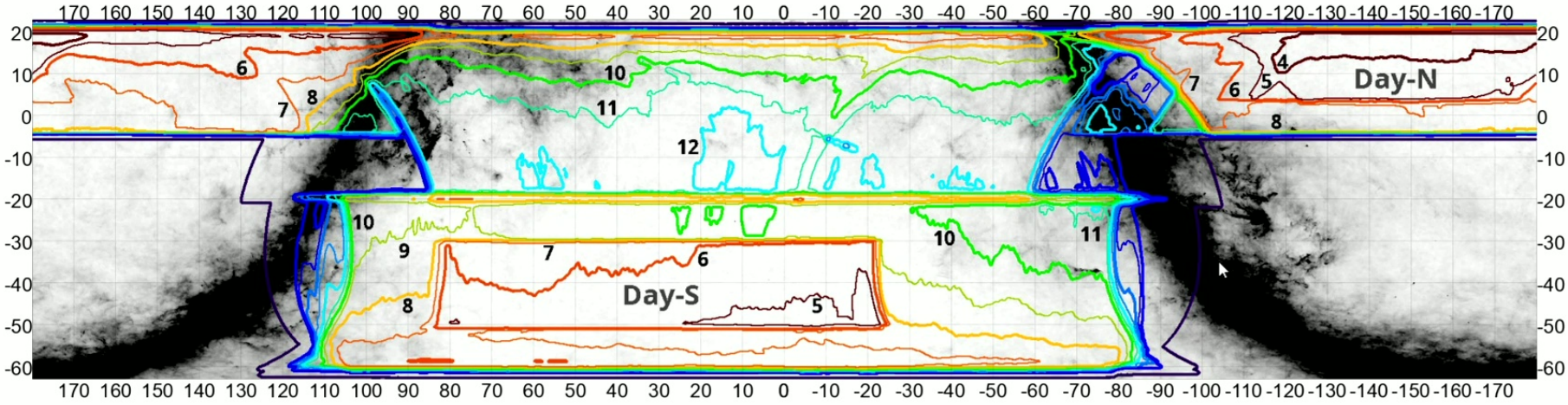


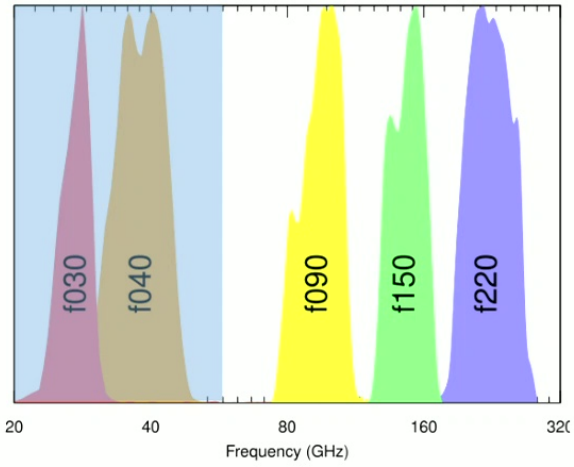


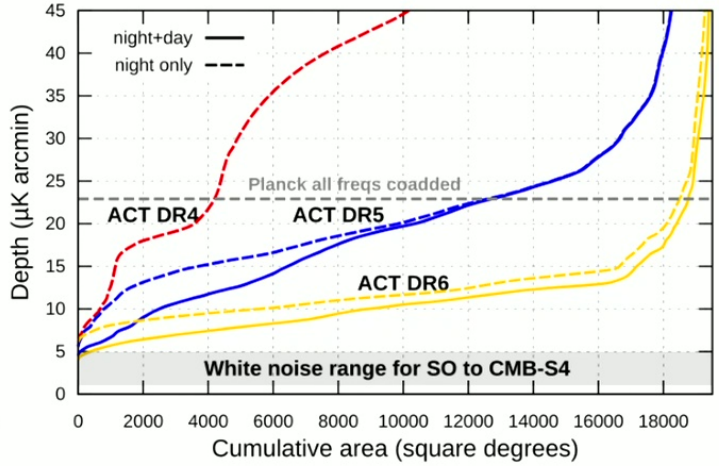


- Observed 2017-2022 in 5 bands
- Combined sensitivity of 6.1 μK√s (mostly in f090 and f150)
- ACT DR6 coming soonish
- Deeper than Planck over 19000°²
- Median depth of 10 μK arcmin
- 10x as much statistical power as DR4 (prev. cosmology release)

Advanced ACT survey







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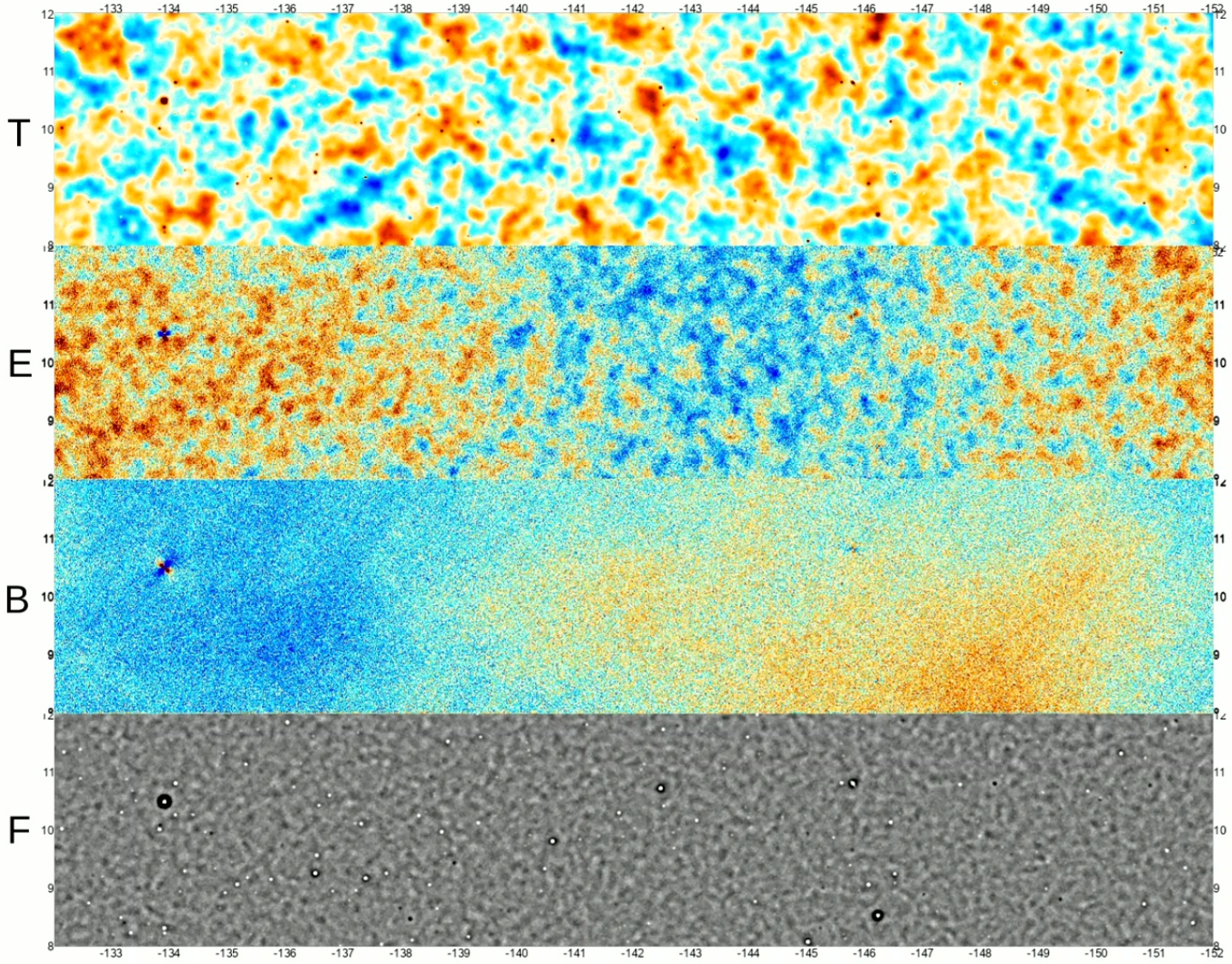
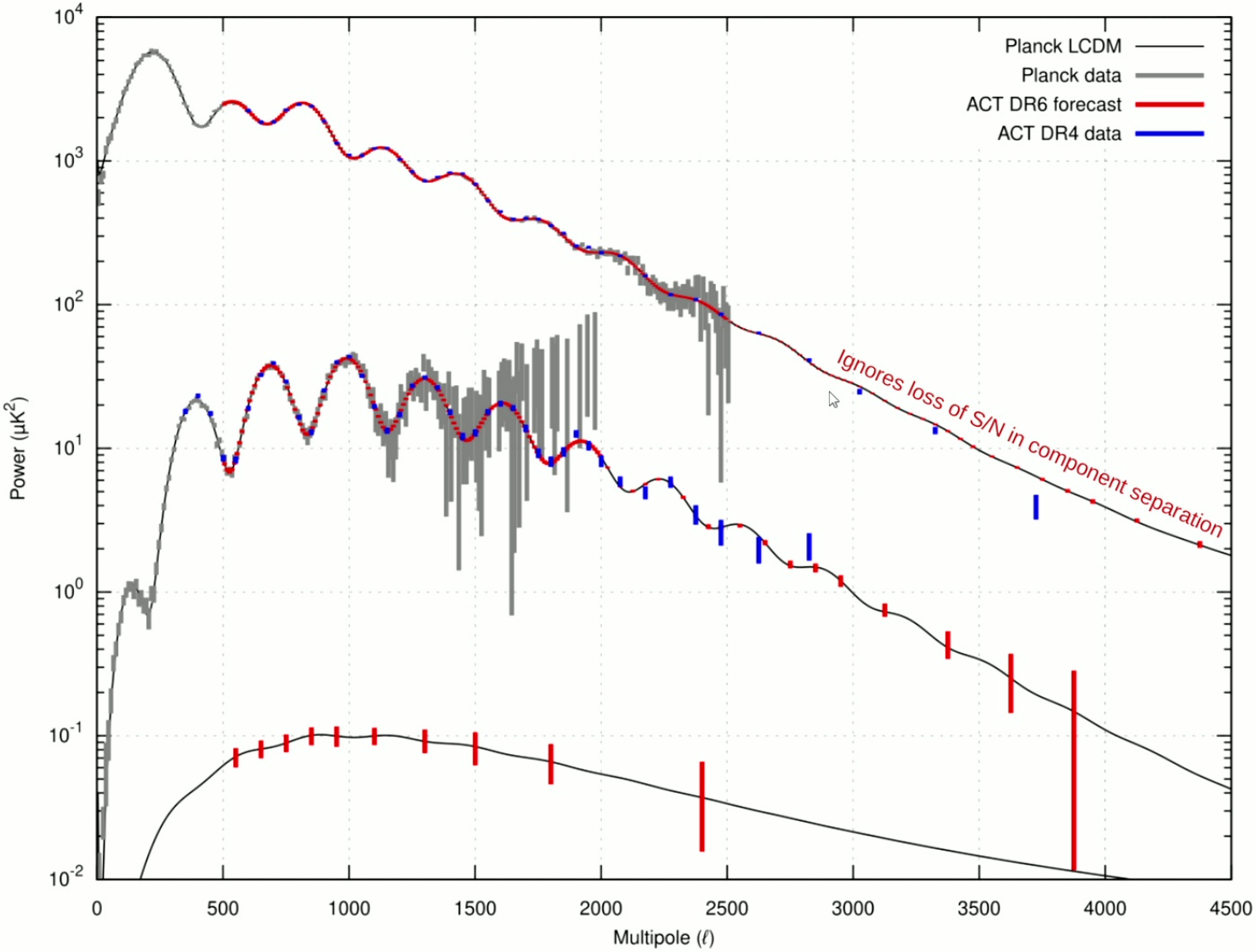


DR6 map example (from 4-5 μK arcmin region)

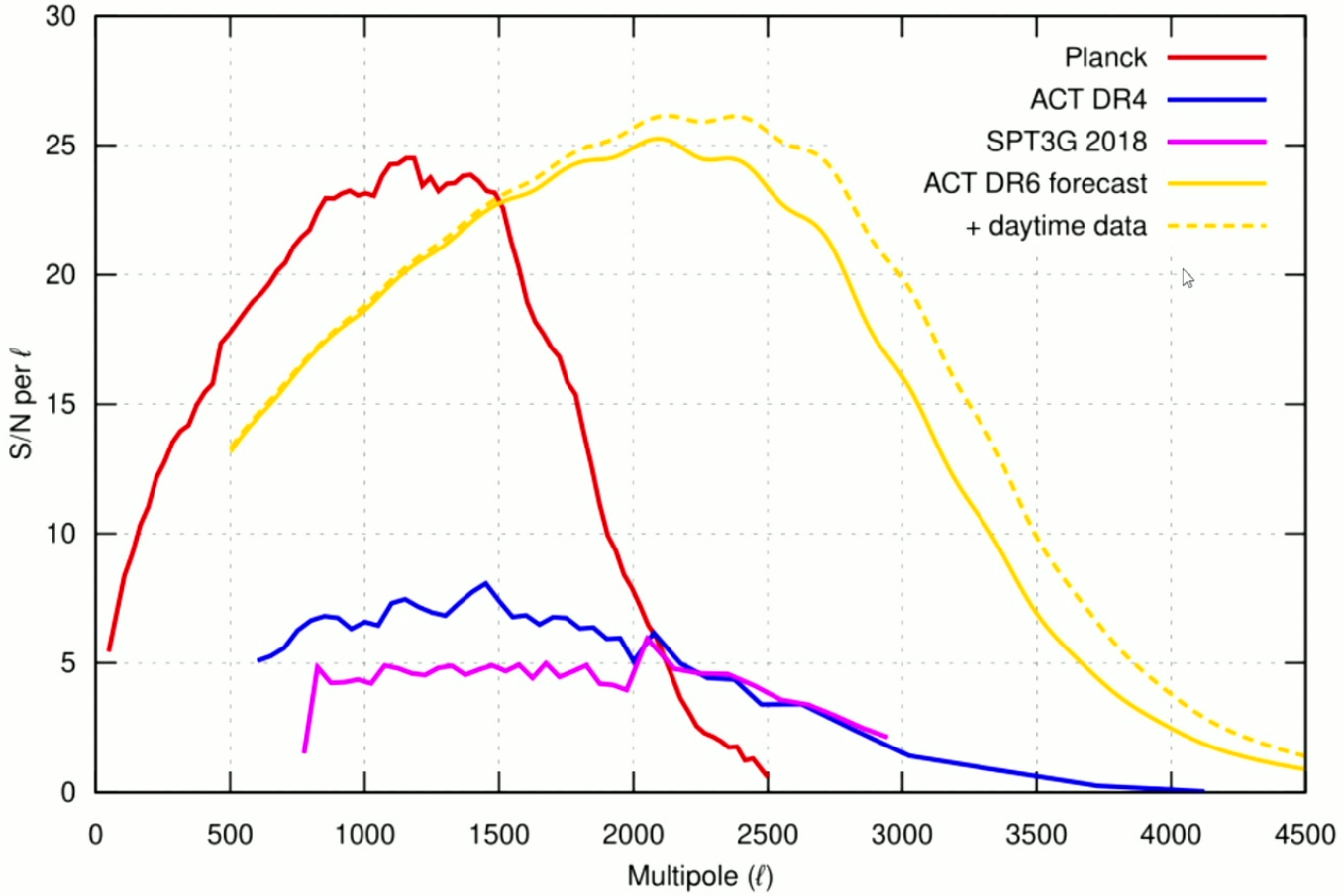
CMB power spectrum forecast

- Data not quite ready yet :(But we have a preliminary forecast
- Same bin size for Planck and DR6
- Larger bins for DR4
- Hard to see the error bars!



Better comparison: S/N per ℓ

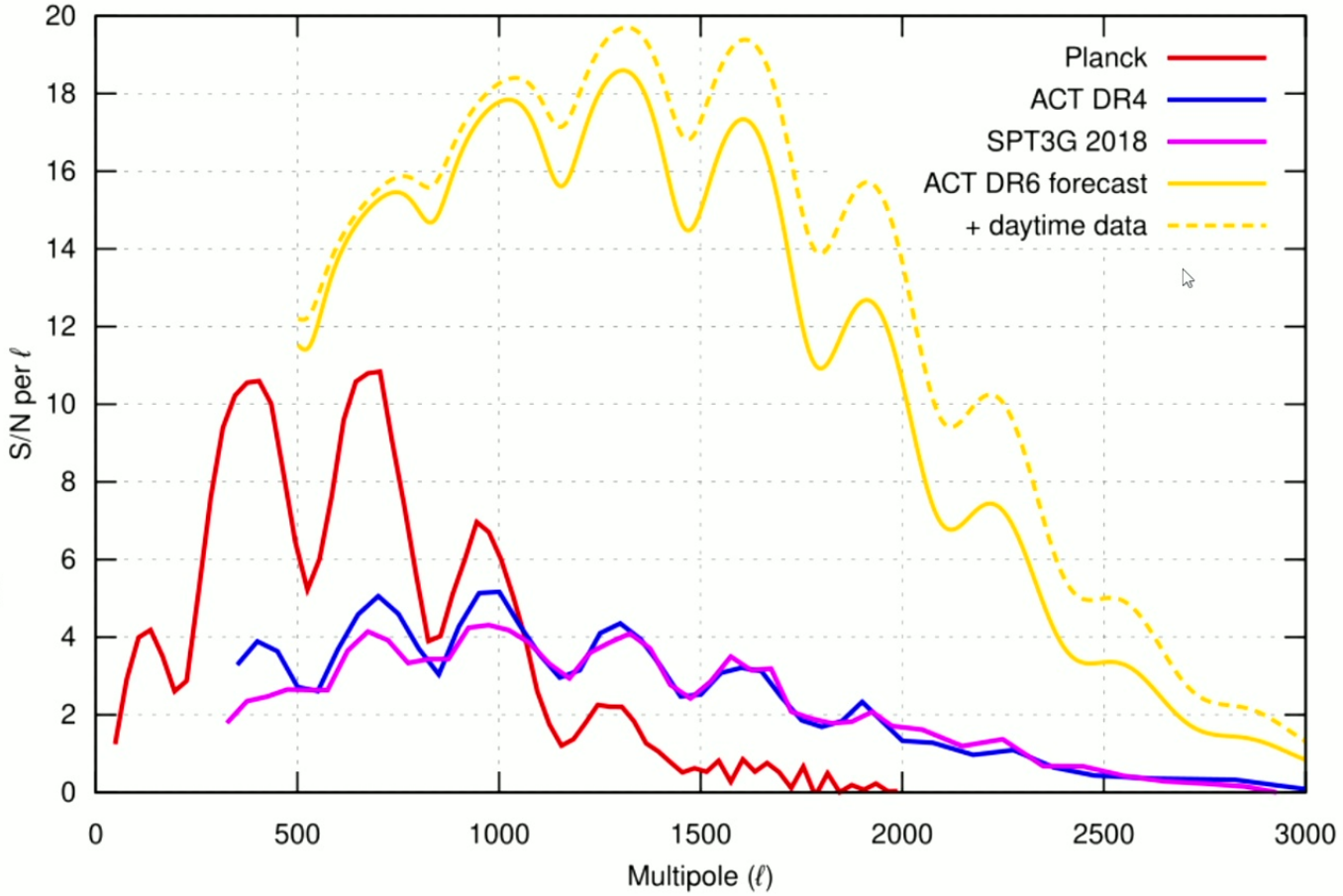
Preliminary!



TT

Better comparison: S/N per ℓ

Preliminary!



EE

Big step up from both DR4 and Planck!

Forecast for cosmological parameters

(Hopefully the real measurements will be out soon!)

	DR4 + WMAP	Planck	DR6 + Planck
$\sigma(H_0)$	1.1	0.5	**0.4**
$\sigma(n_s)$	0.006	0.004	**0.003**
$\sigma(N_{\rm eff})$	0.3	0.2	**0.1**

Preliminary Forecast

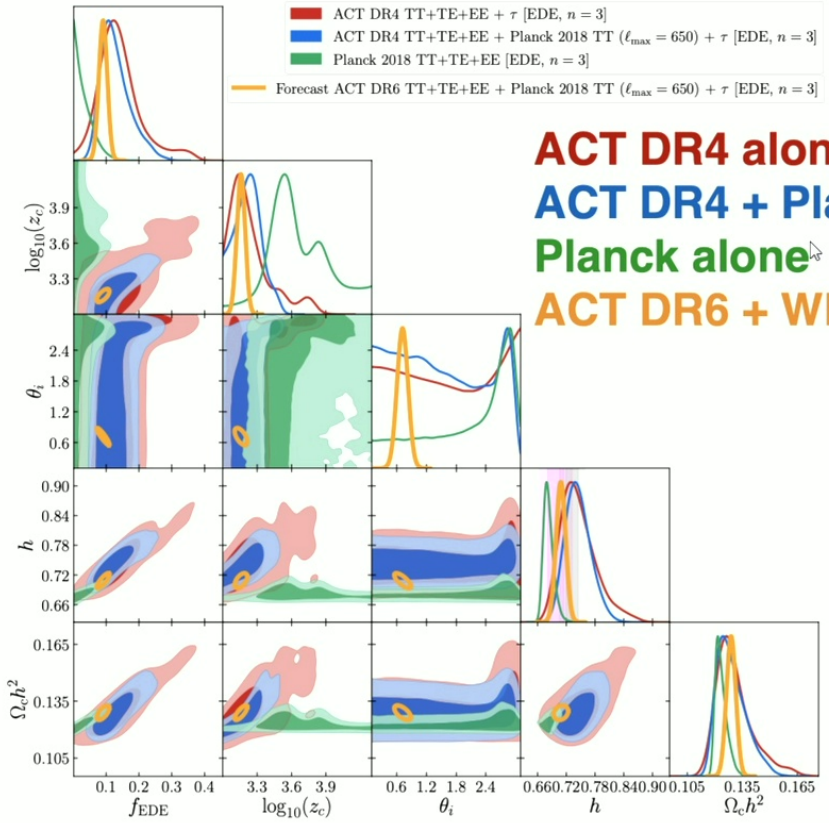
2x improvement in sensitivity to new light relic particles (N_{eff})

Early Dark Energy

Colin Hill
Columbia

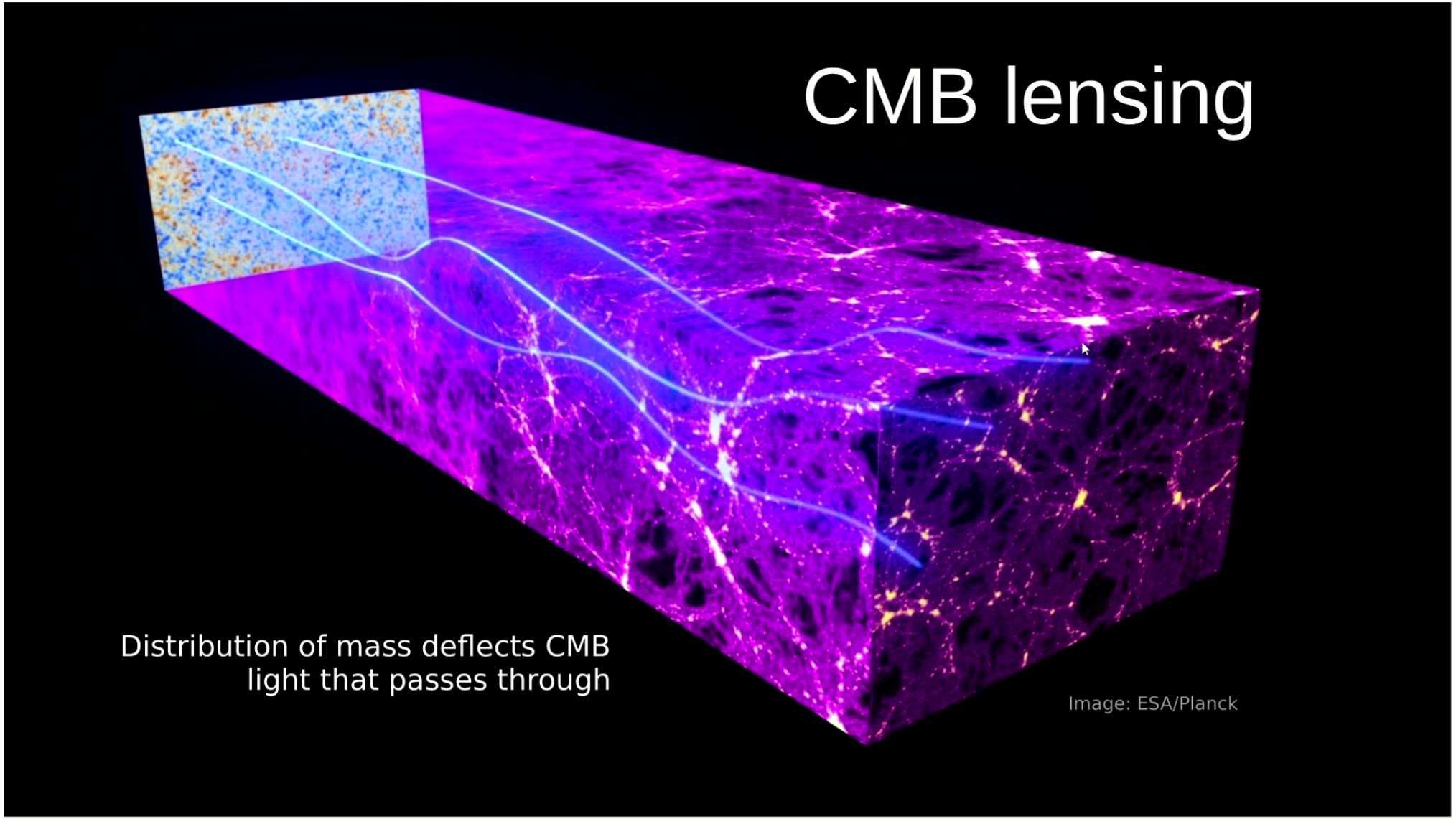
ACT DR6 Forecast (very simple + likely too optimistic)

In general LCDM extensions benefit more from ACT DR6 than the basic 5-parameter version



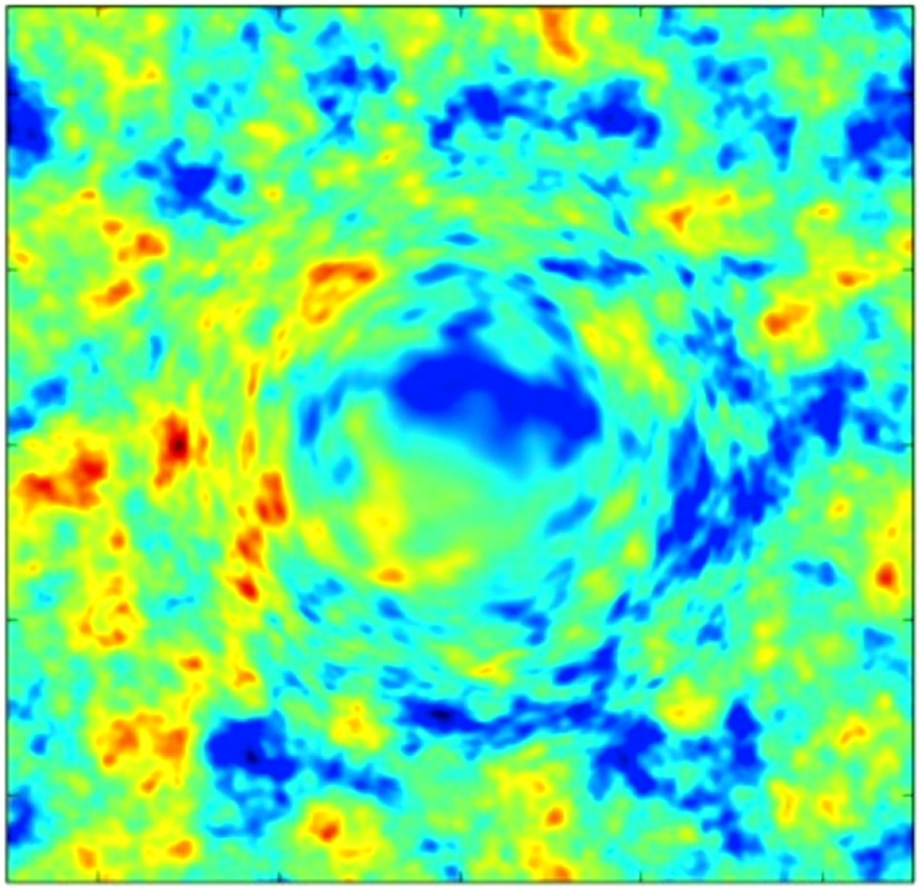
forecast assumes CV-limited TT on 2<ell<2500, TE on 350<ell<1800, EE on 350<ell<1000 w/ fsky=0.3

CMB lensing

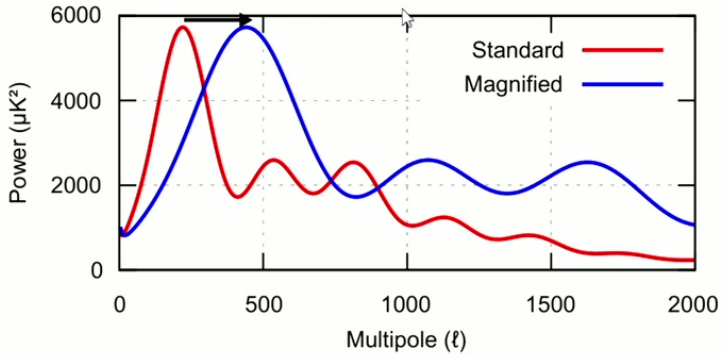


Distribution of mass deflects CMB light that passes through

Image: ESA/Planck



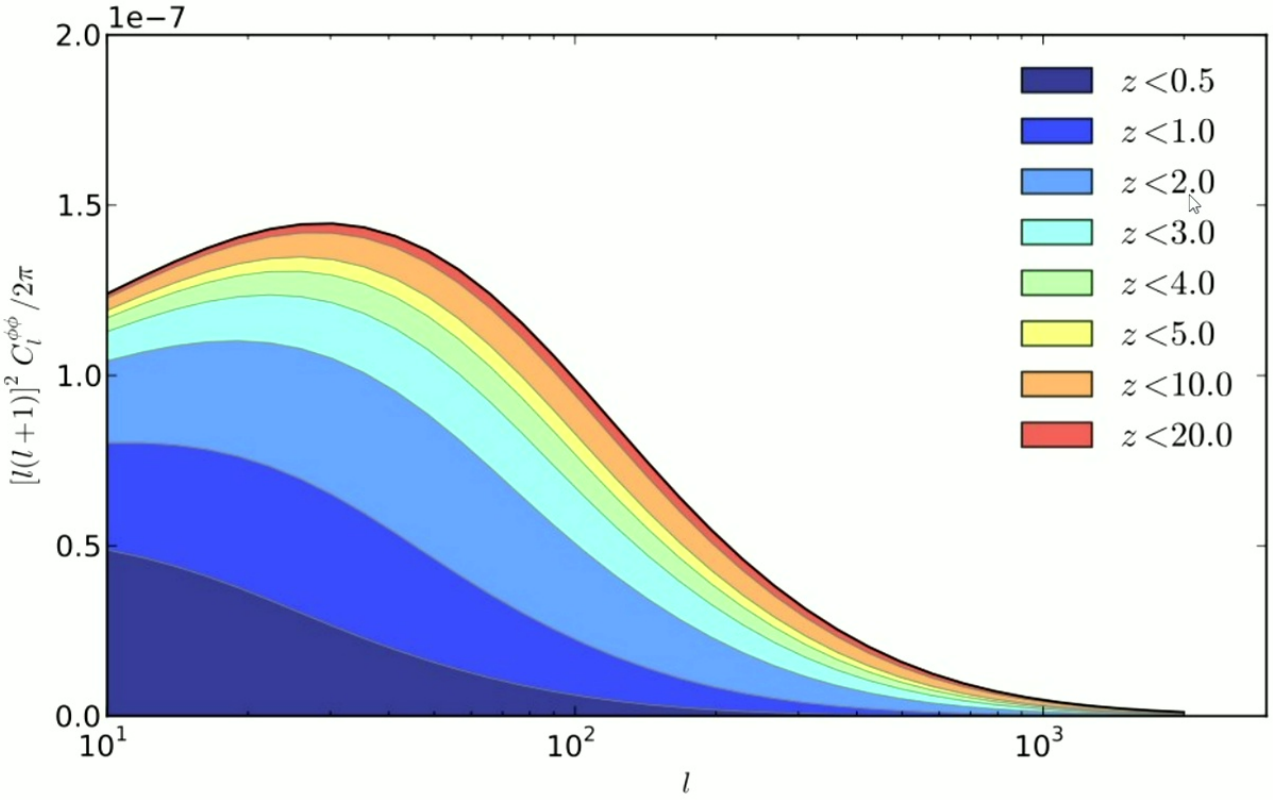
- Exaggerated example of lensing of CMB by a point mass
- More mass ⇒ more magnification
- Can recover mass distribution by comparing power spectra in different areas of the map



- In practice a fancier algorithm is used, but principle is the same

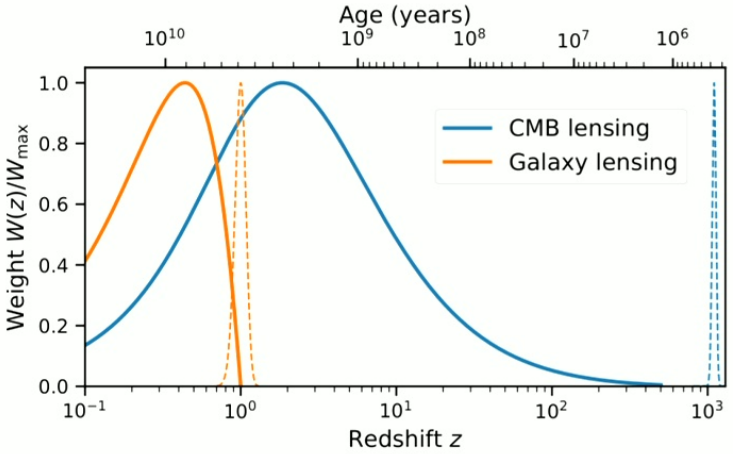
What does CMB lensing tell us?

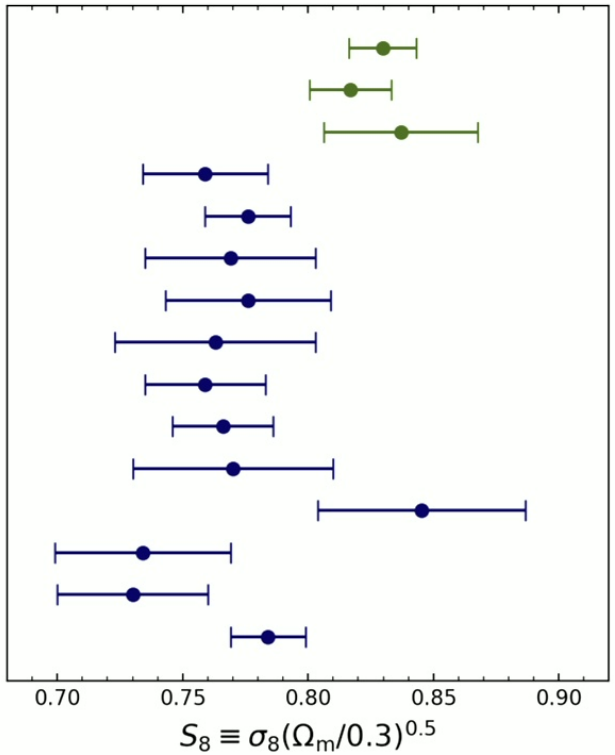
Sensitive to integral of matter power spectrum over all redshifts
Probes higher redshifts than galaxy surveys, but lower than the CMB



Motivation: is something wrong with large-scale structure growth? ”S_8 tension”

- CMB itself probes high-reshift linear scales
- Galaxy lensing probes low-redshift, non-linear scales
- Many galaxy lensing surveys consistently low by about 1.5σ
- CMB lensing probes intermediate redshift, mostly linear. Does it see a discrepancy?





CMB: Planck CMB aniso.
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CMB: WMAP+ACT CMB aniso.
WL: DES-Y3 galaxy lensing
WL: DES-Y3 3x2
WL: HSC-Y3 galaxy lensing (Real)
WL: HSC-Y3 galaxy lensing (Fourier)
WL: HSC-Y3 3x2
WL: KiDS-1000 galaxy lensing
WL: KiDS-1000 3x2
GC: BOSS EFT 2-pt + 3-pt
GC: eBOSS BAO+RSD
CX: SPT/Planck CMB lensing x DES
CX: Planck CMB lensing x DESI LRG
CX: Planck CMB lensing x unWISE

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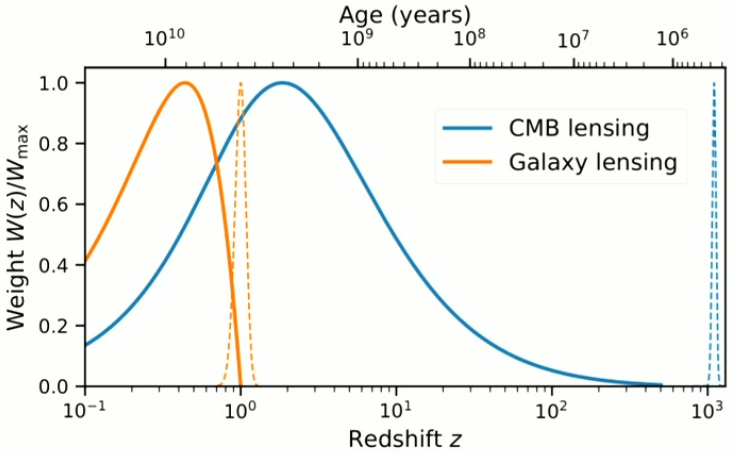

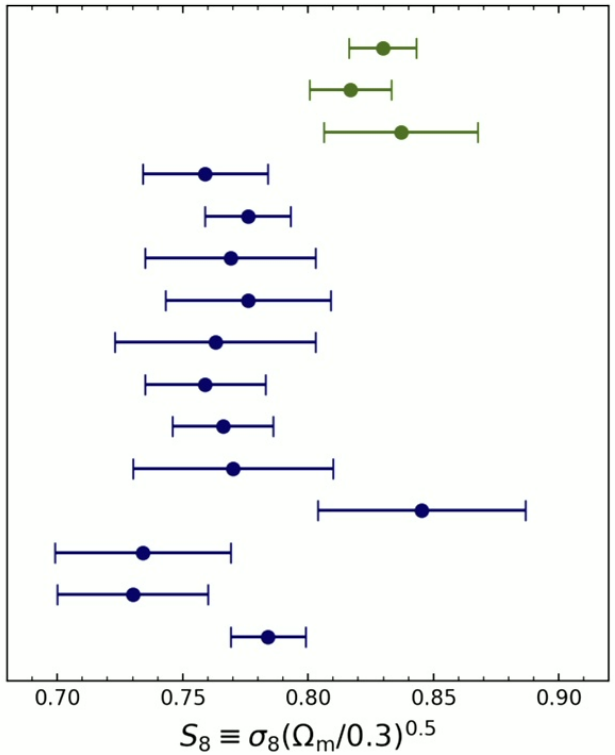

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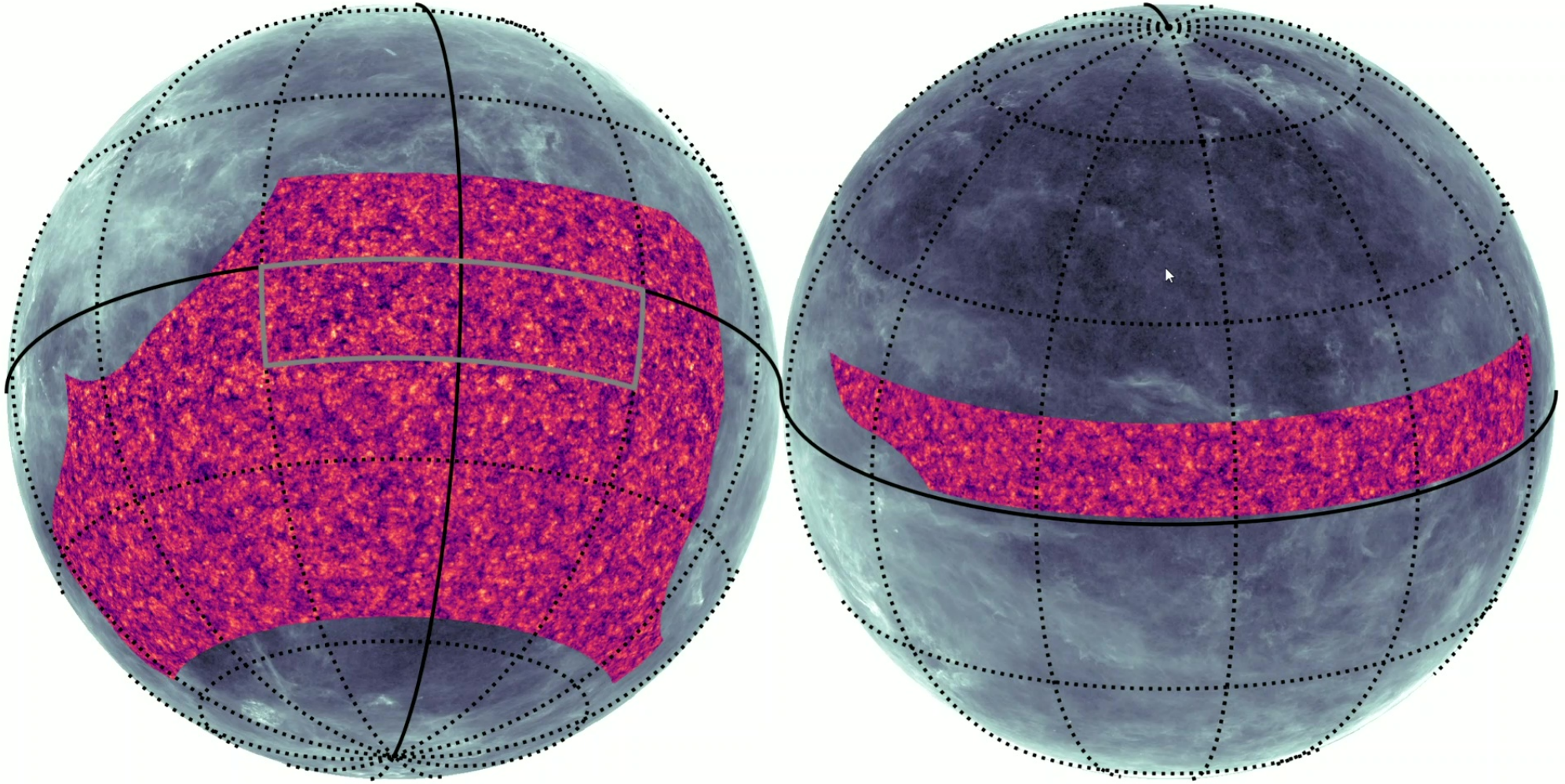
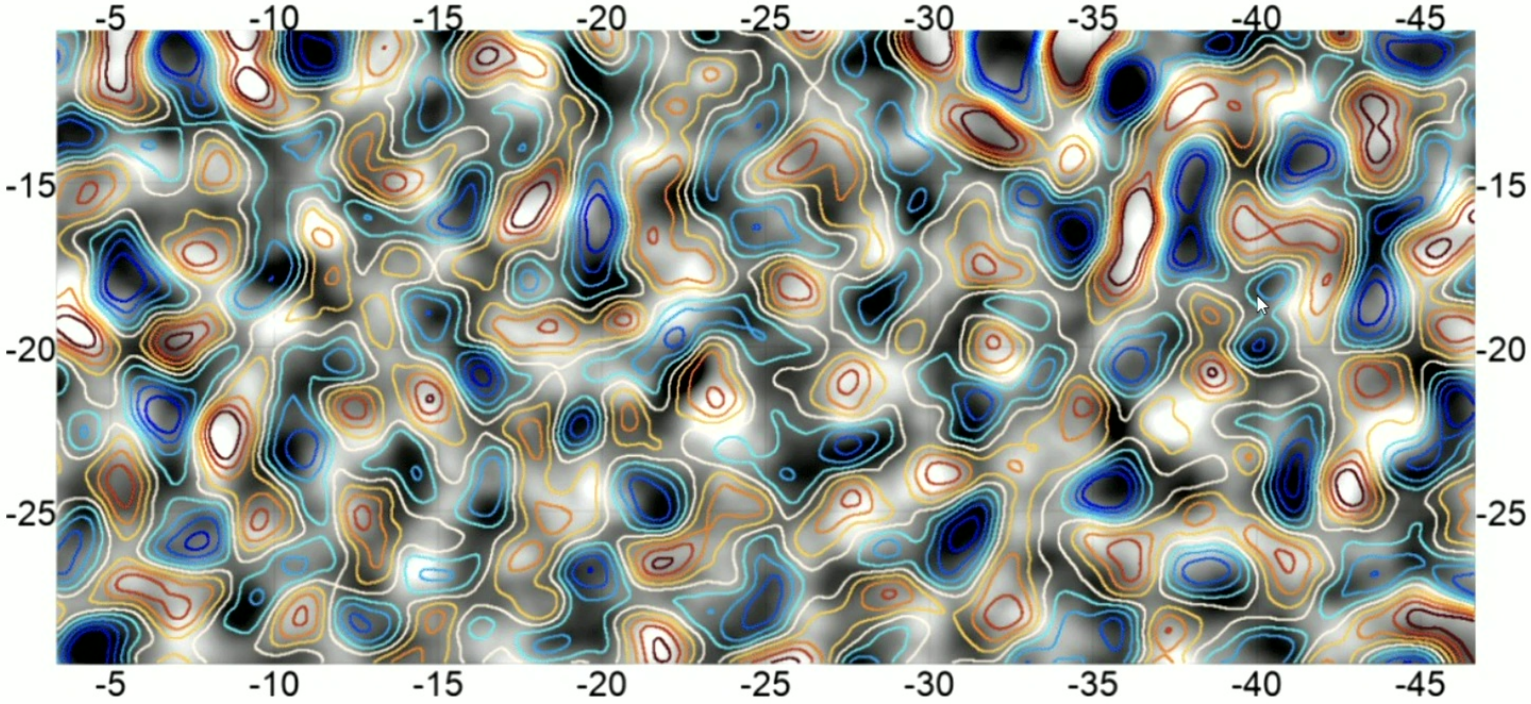
ACT DR6 CMB lensing map



Great consistency with CIB!



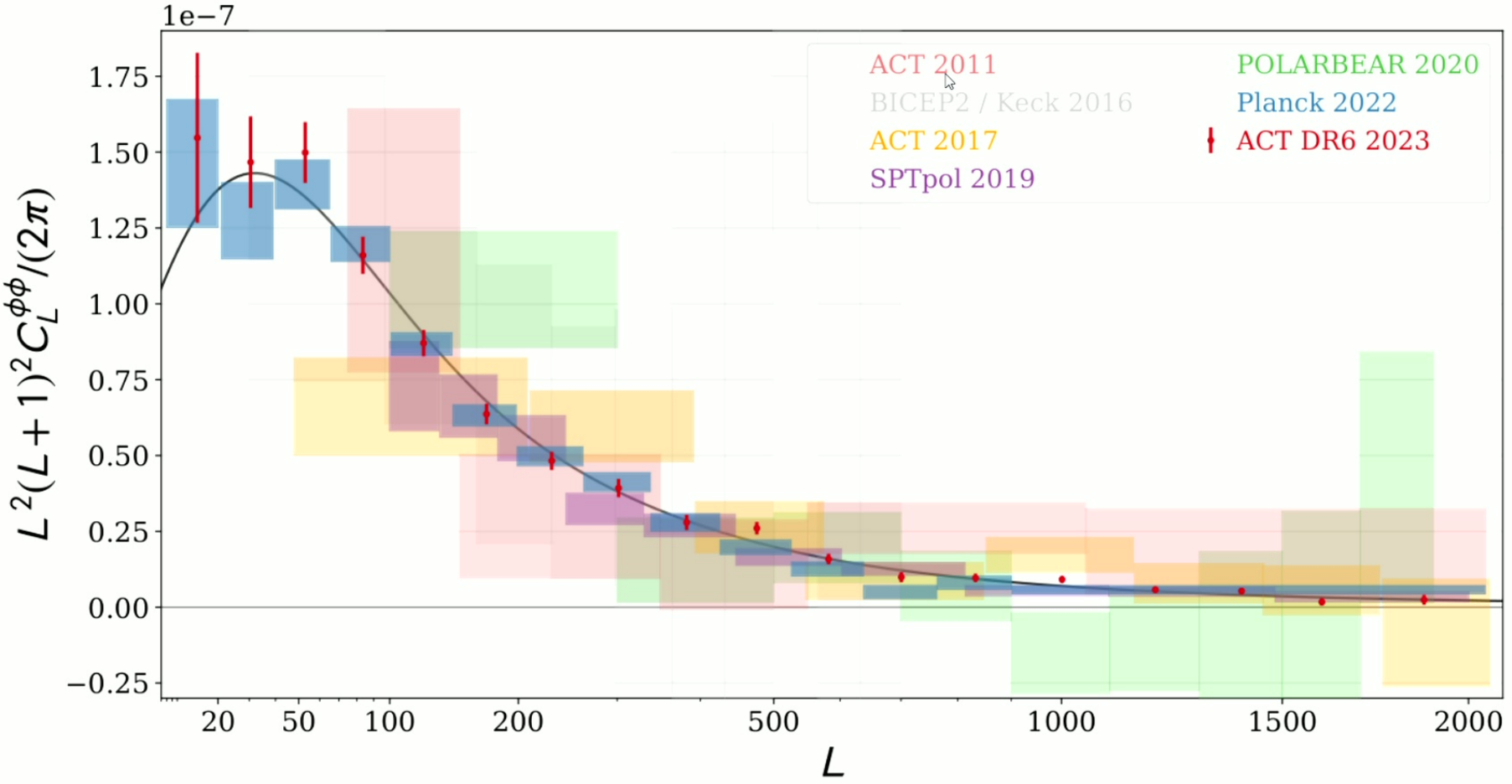
Background: ACT lensing map

Contours: Planck Cosmic Infrared Background (CIB) map

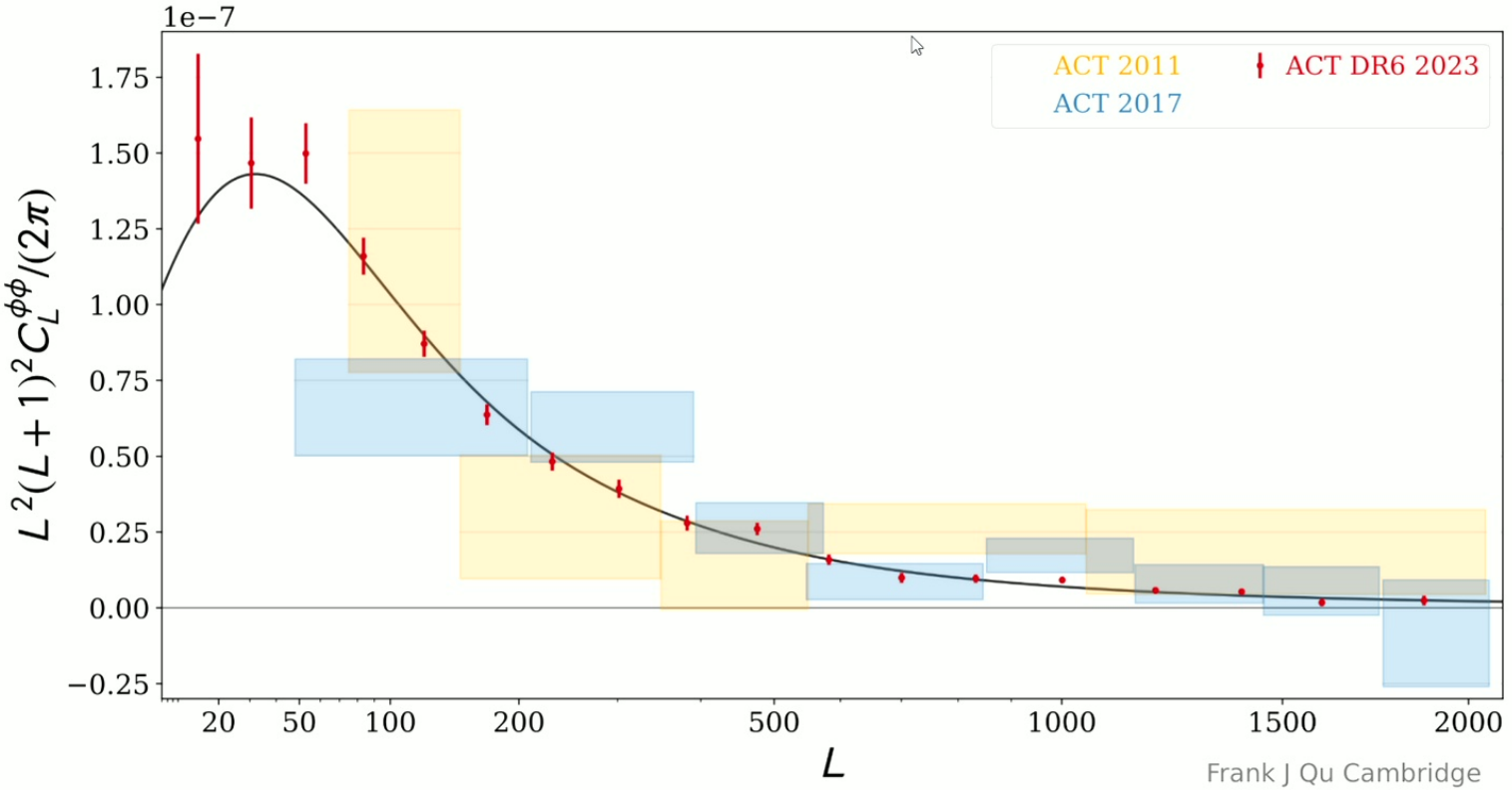
High correlation because both are sensitive broad redshift range around z = 2

ACT DR6 lensing power spectrum

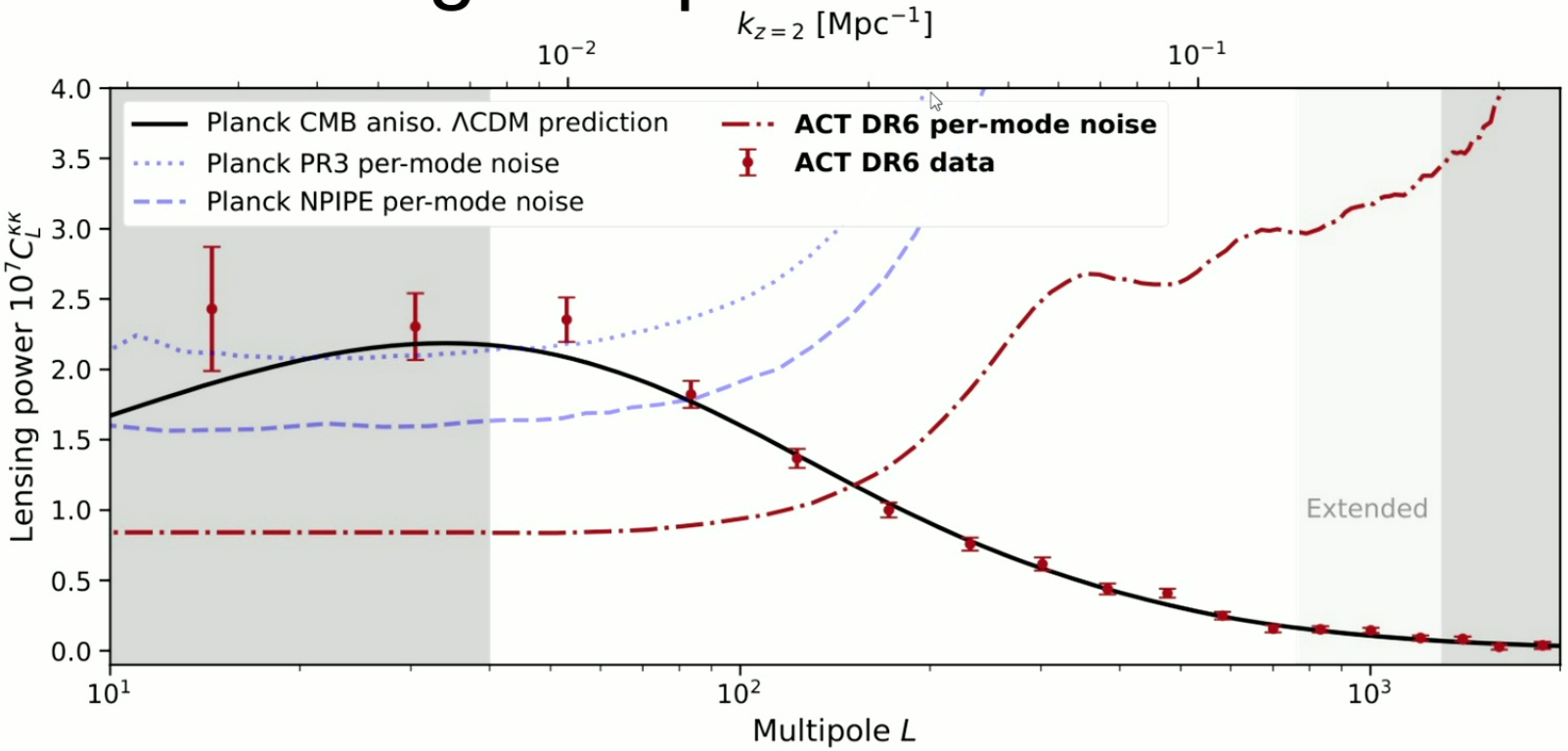
https://arxiv.org/abs/2304.05203, https://arxiv.org/abs/2304.05202



Rapid progress over the last decade with ACT



Lensing S/N per mode vs Planck



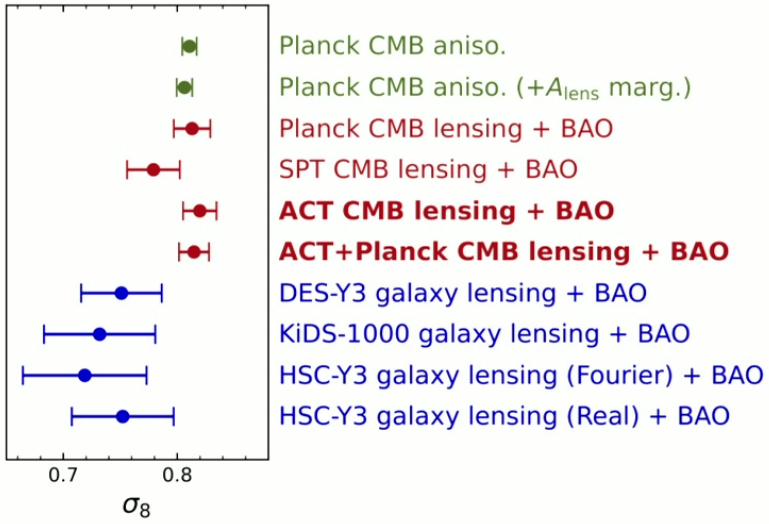
ACT is deeper but covers less sky than Planck
Overall very similar sensitivity: 43σ for ACT and 42σ for Planck

Both ACT and Planck CMB lensing agree with CMB anisotropies

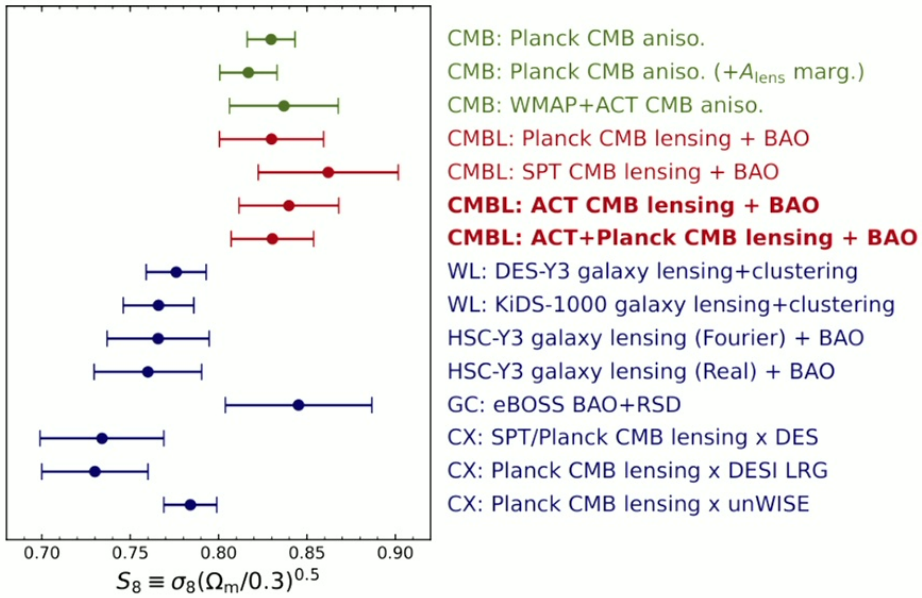
ACT lensing (z~2): $\sigma_8 = 0.819 \pm 0.015$
ACT+Planck lensing (z~2): $\sigma_8 = 0.815 \pm 0.013$
Planck CMB aniso (z≈1000): $\sigma_8 = 0.811 \pm 0.006$

No sign of the low σ_8 (or equivalently S_8) seen in galaxy lensing! Problem with non-linear scales?

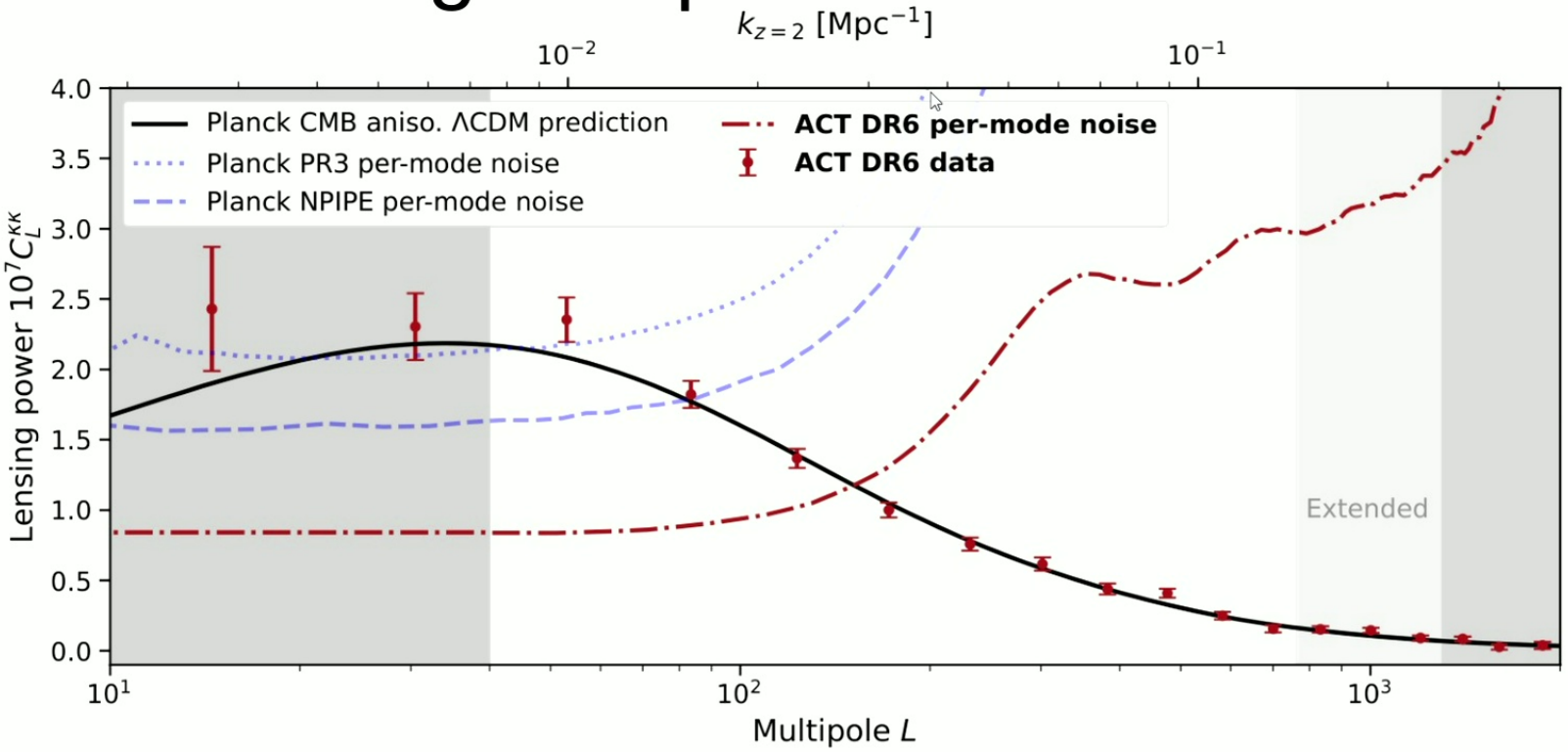
σ_8



S_8



Lensing S/N per mode vs Planck



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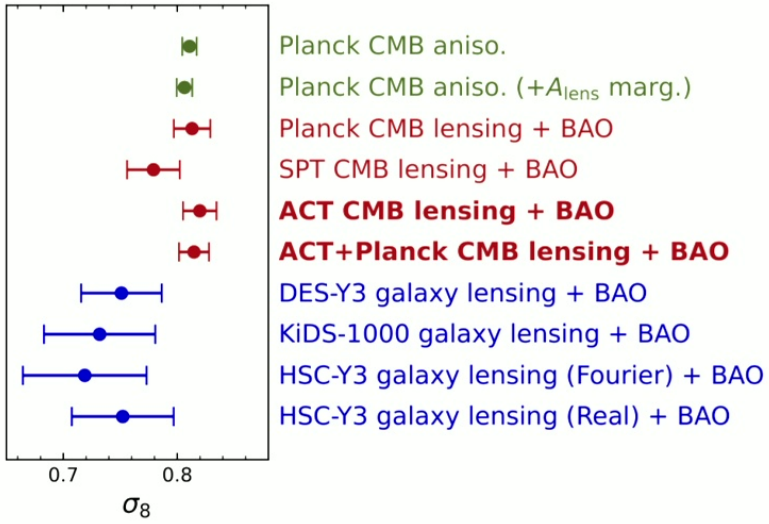
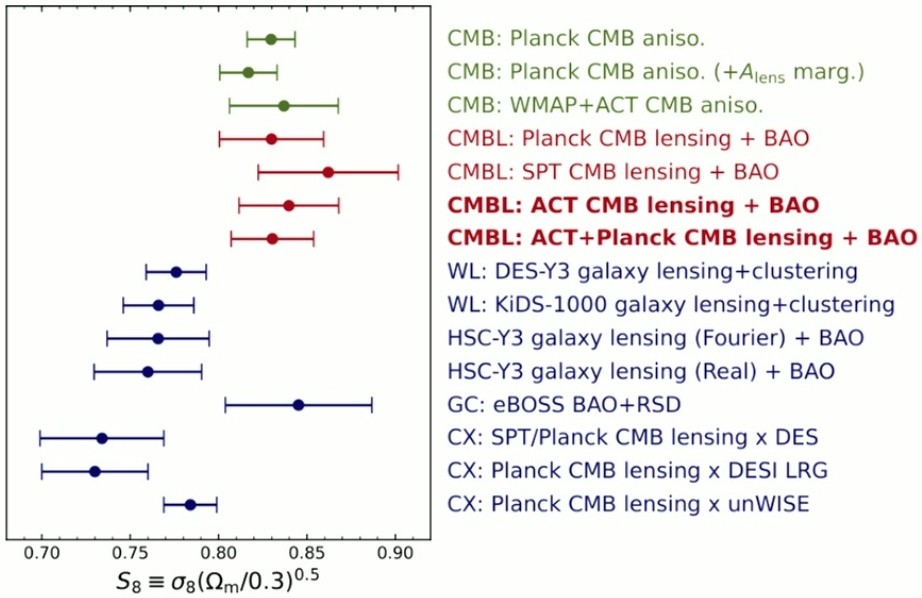


S_8



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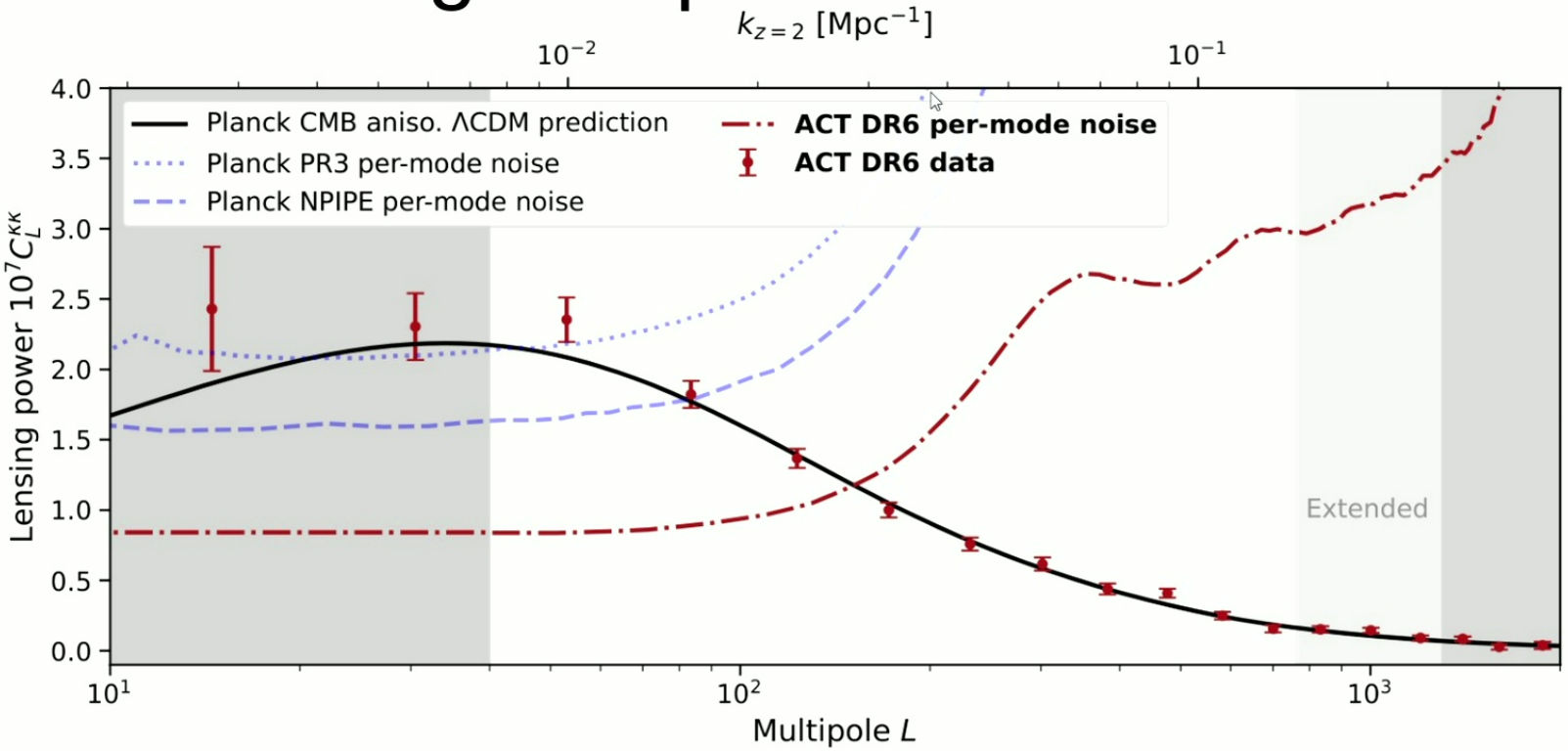

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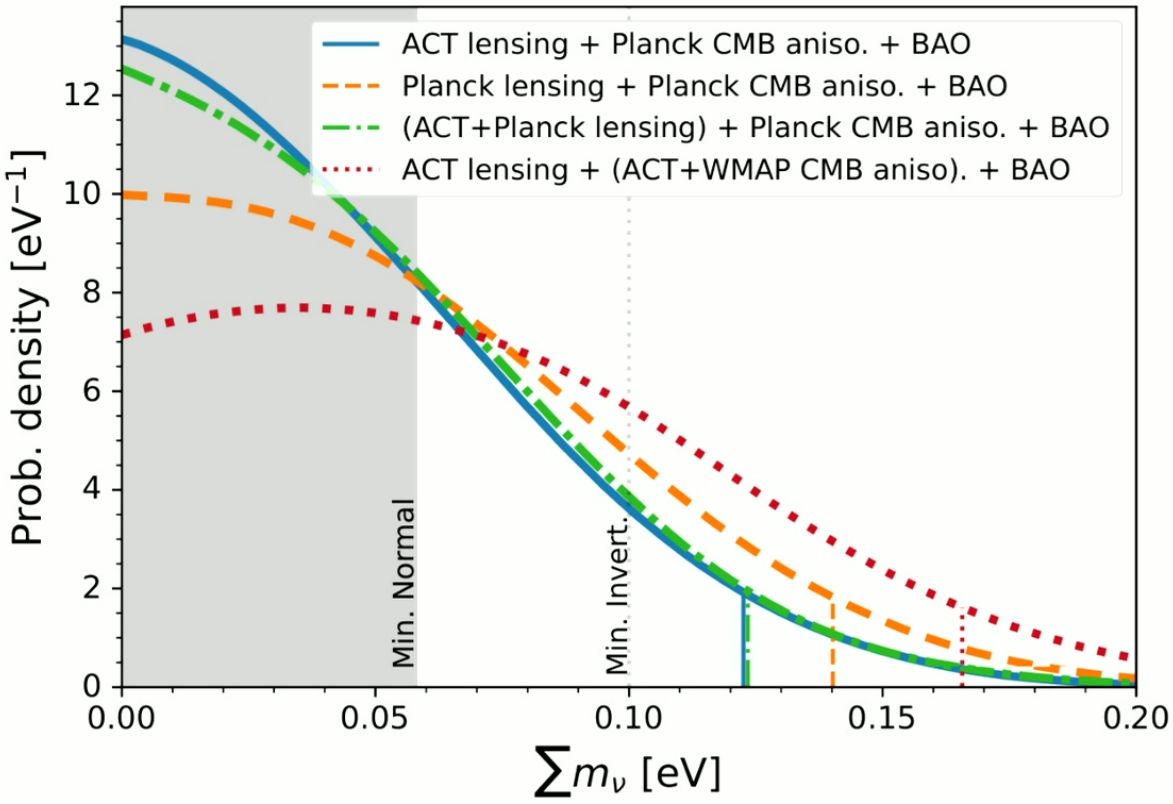
Neutrino mass



Planck lensing + Planck CMB

$$\sum m_\nu < 0.14\,\mathrm{eV};\ \ 95\%\ \ \mathrm{c.l.}$$

ACT lensing + Planck CMB

$$\sum m_\nu < 0.12\,\mathrm{eV};\ \ 95\%\ \ \mathrm{c.l.}$$

Combined

$$\sum m_\nu < 0.12\,\mathrm{eV};\ \ 95\%\ \ \mathrm{c.l.}$$

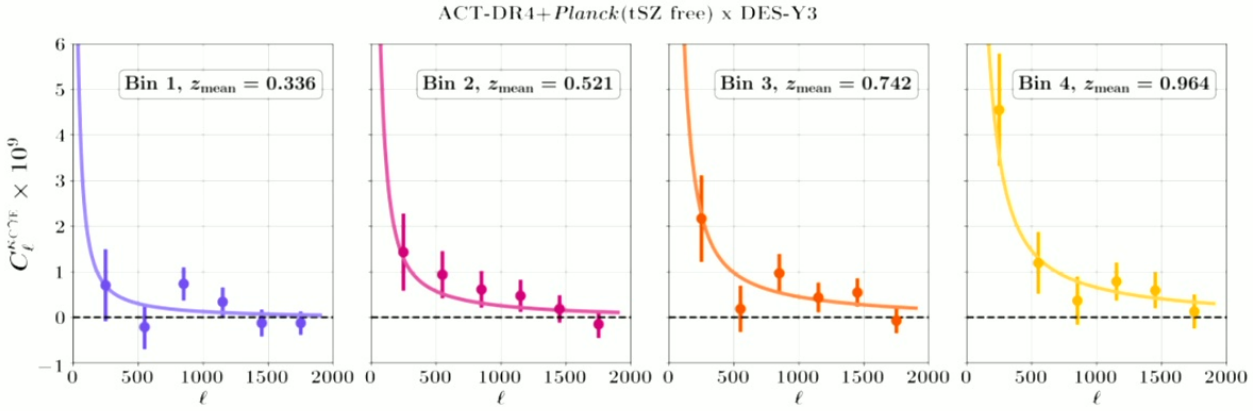
* ACT CMB aniso. not used in these bounds because they weren't ready yet

** PR3 has a stronger neutino bound (0.12) than PR4 that we use here despite PR4 being more sensitive, due to a negative noise fluctuation

Lensing tomography

- CMB lensing integrates matter power spectrum over all redshifts. No redshift resolution
- Can probe redshift evolution by cross-correlating with optical galaxy surveys
- Several papers in progress for DR6

Example plot from DR4: https://arxiv.org/abs/2309.04412



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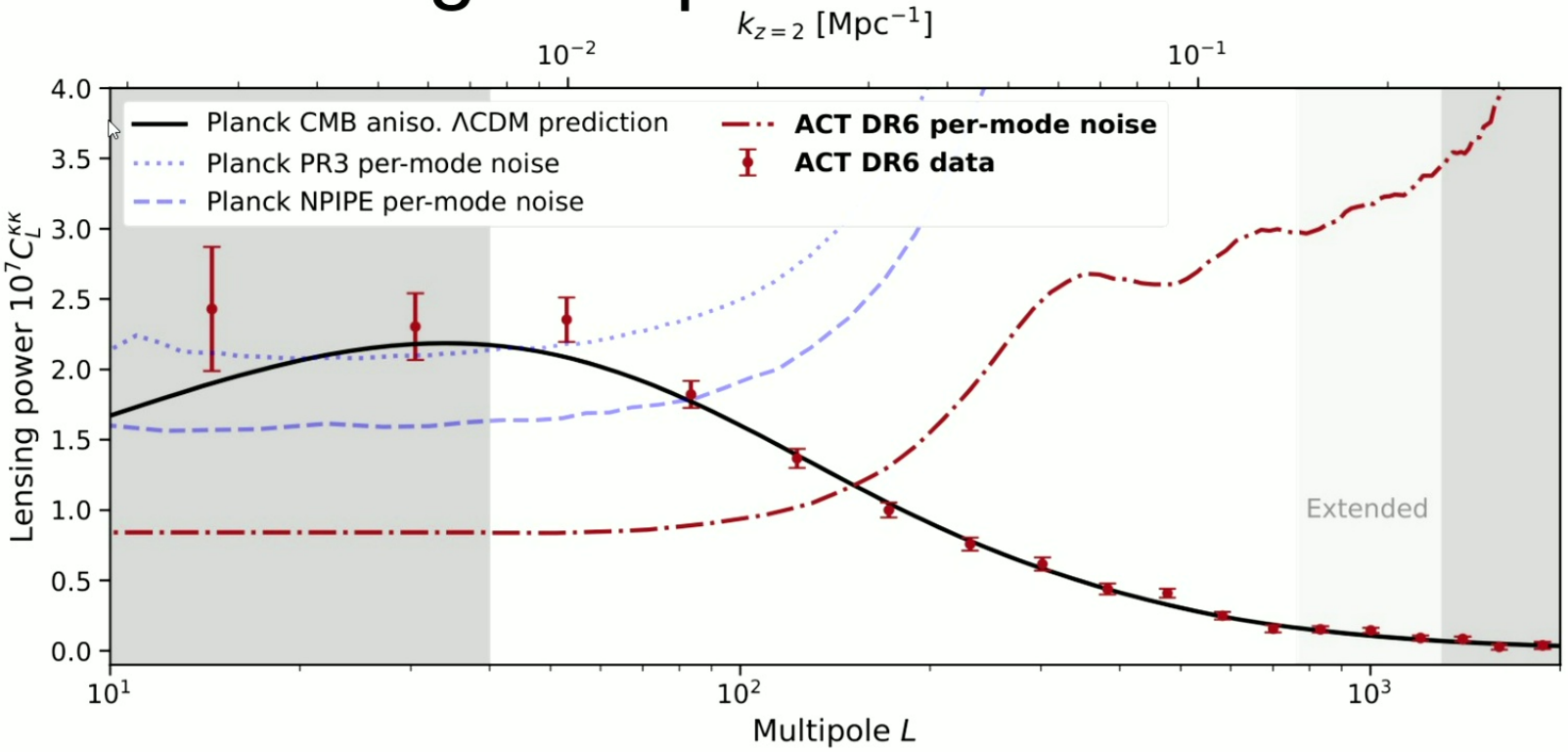

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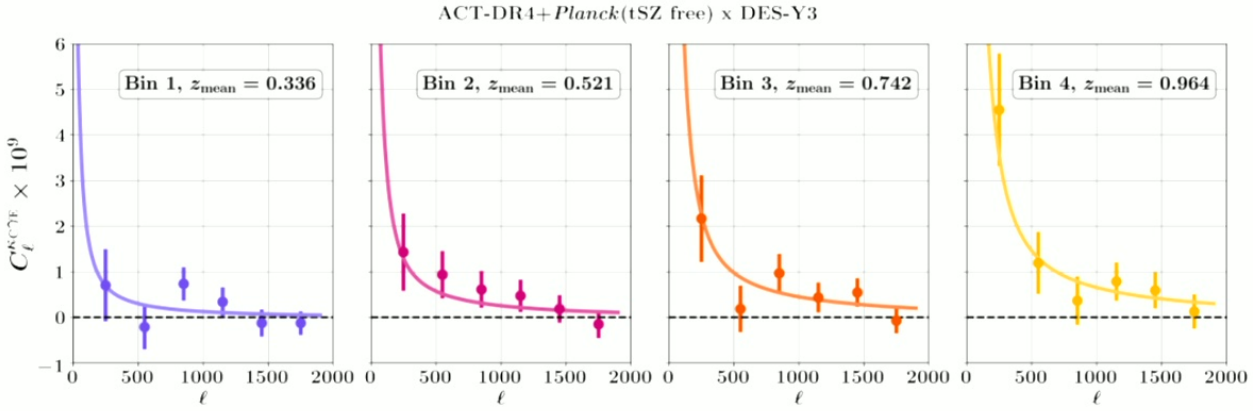
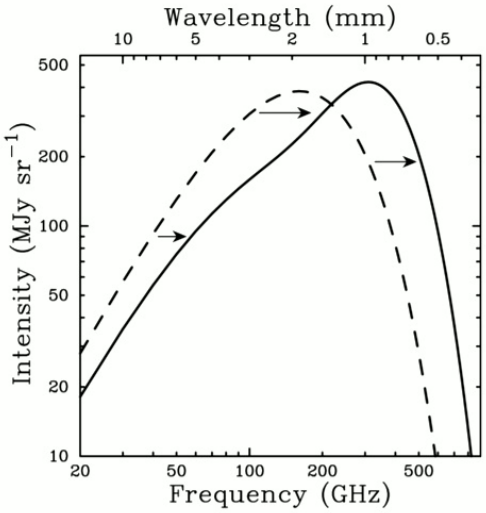
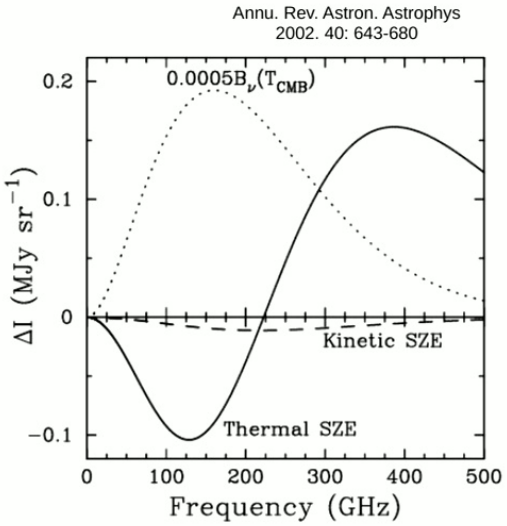
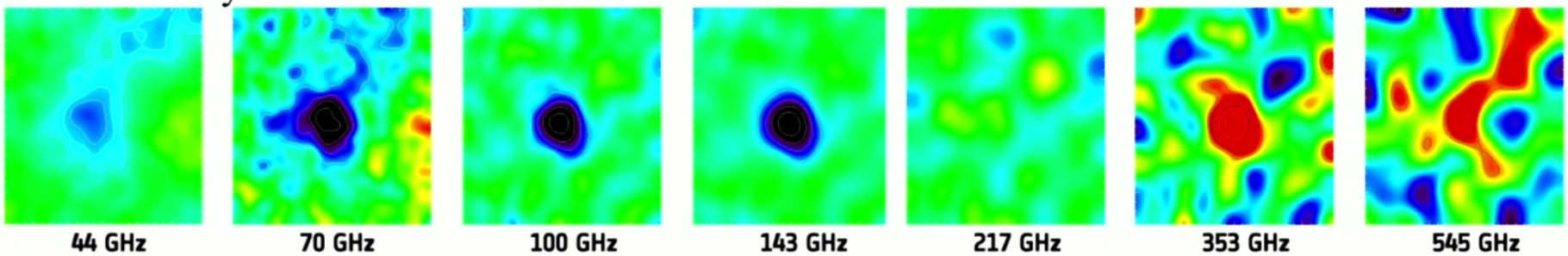


Hot gas leaves imprint in CMB via the thermal Sunyaev-Zel'dovich effect

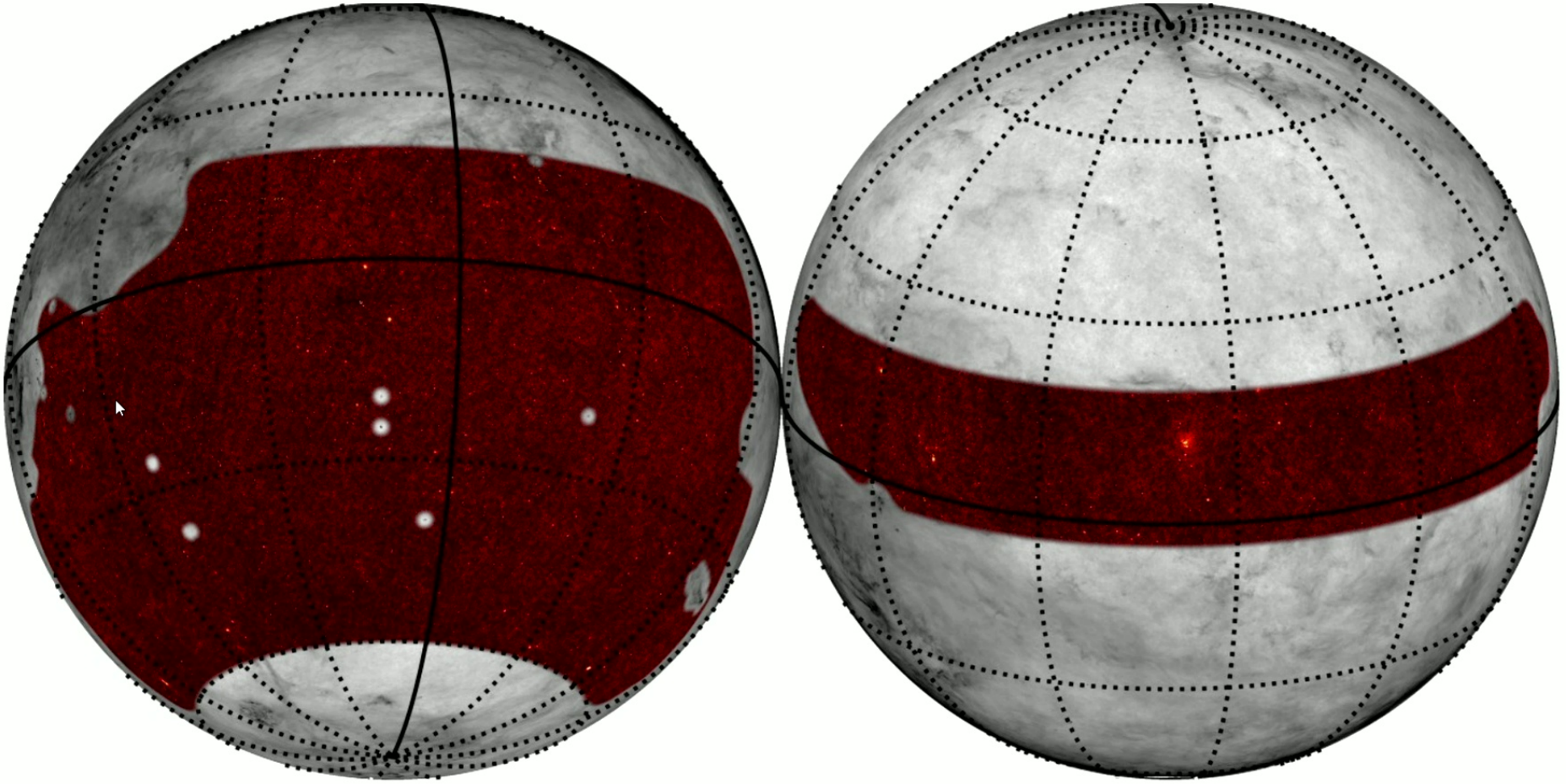




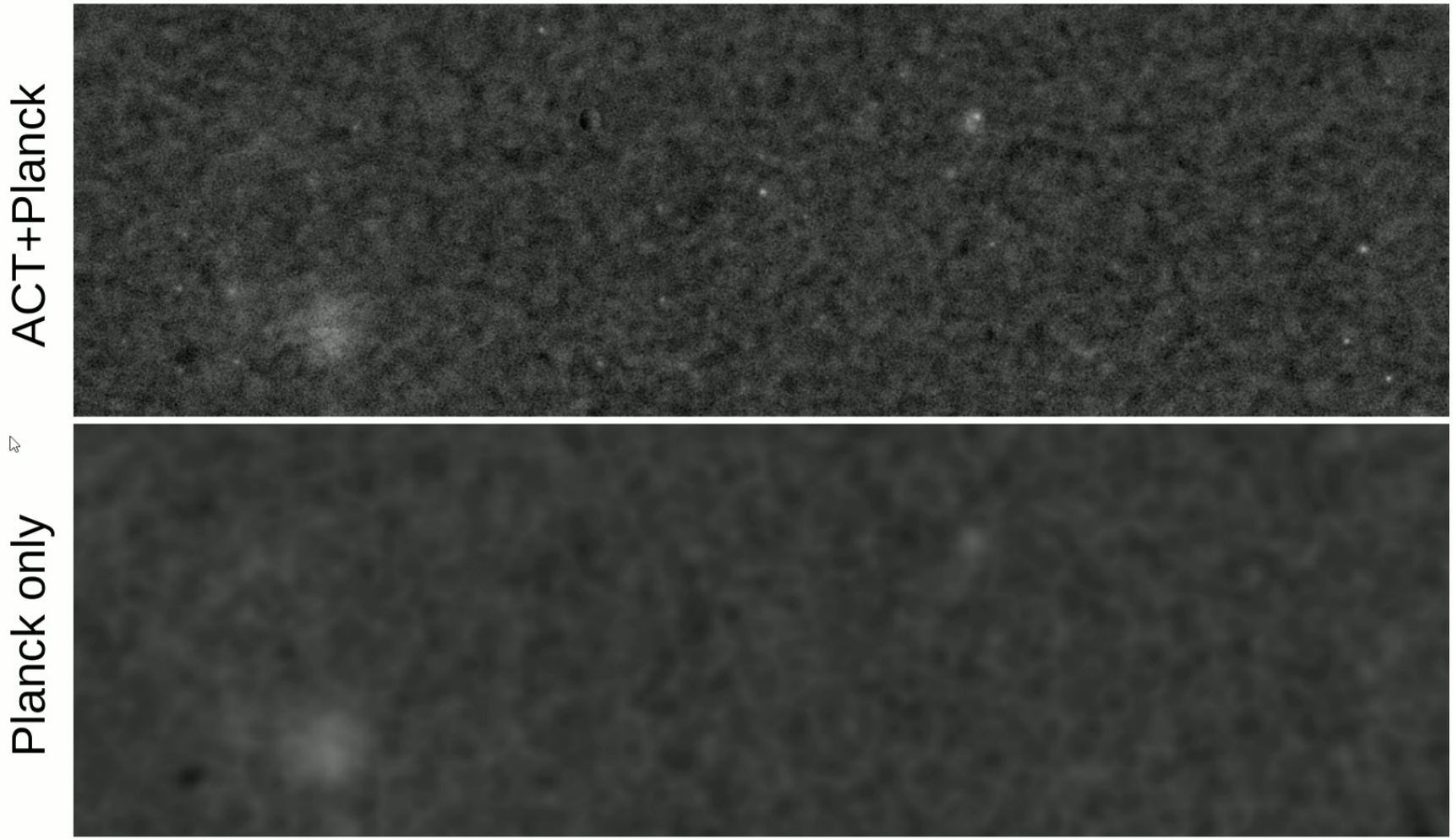
A2319 seen by PLANCK



ACT DR6 + Planck compton y map

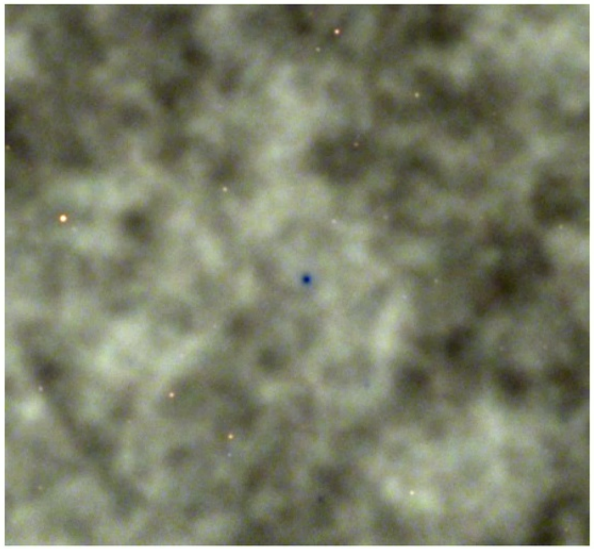


Zoom on 45°² area

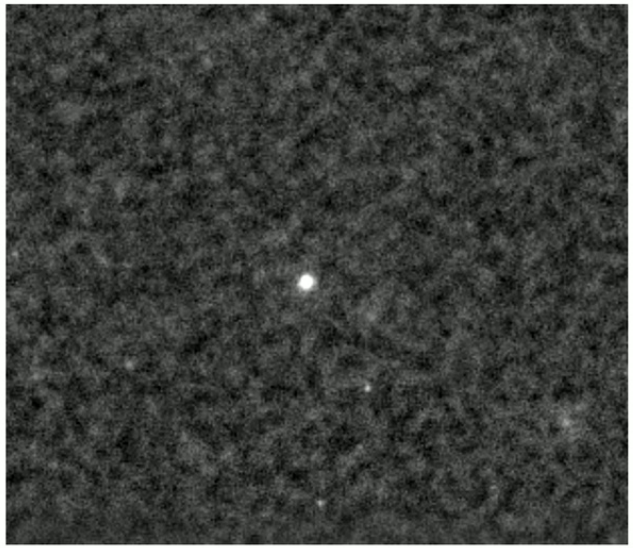


Galaxy clusters appear as dark spots in CMB map below 230 GHz

Intensity map
R:f090,G:f150,B:f220



Compton y map

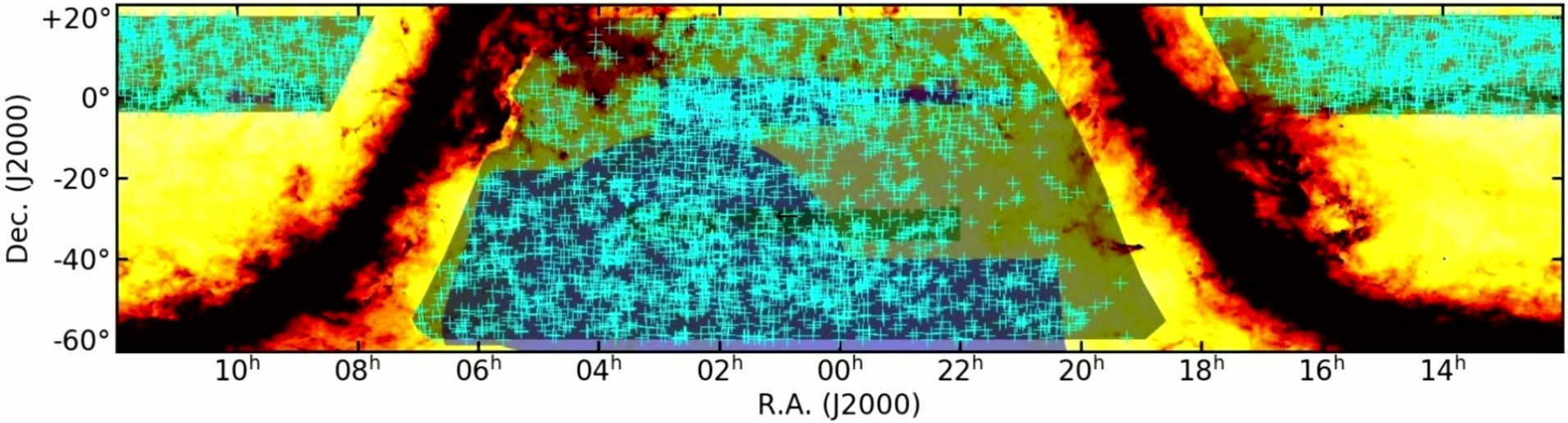


DES optical image
(zoom)

Detect by looking for negative point sources in the CMB map
(or positive point sources in the y map)

Cluster catalog

DR5 SZ cluster catalog from Hilton et al. (2021) (>4000 confirmed SNR>4 clusters)



Preliminary number for DR6 catalog: 6800 SNR>4 clusters!
Comparison: Planck has 1203 confirmed clusters

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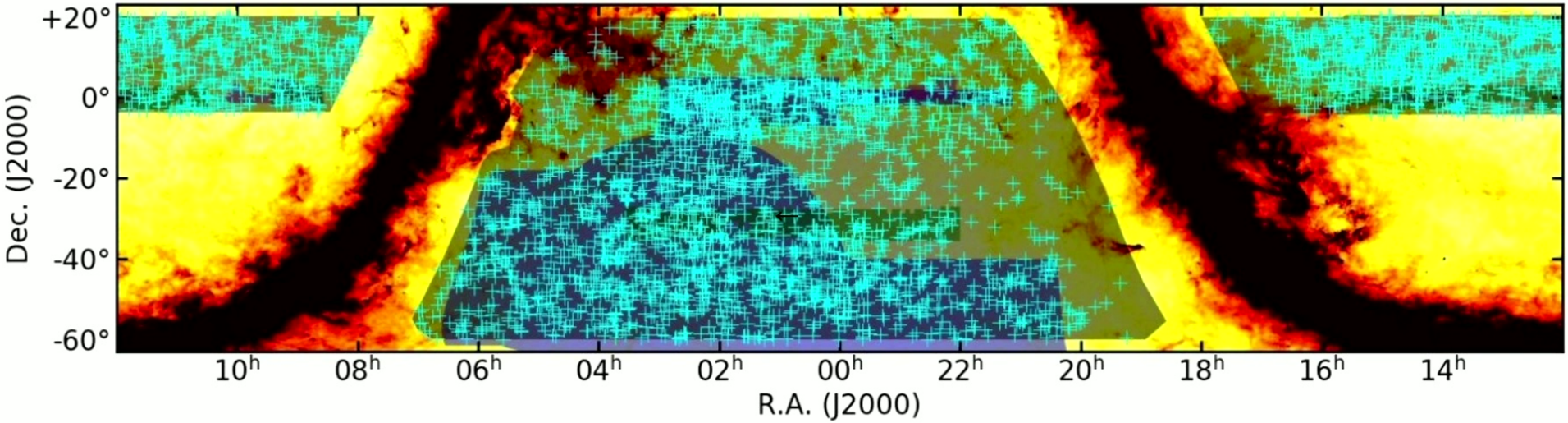

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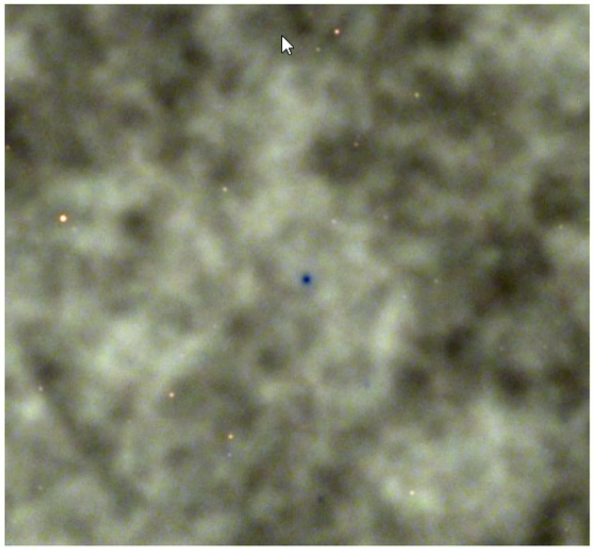
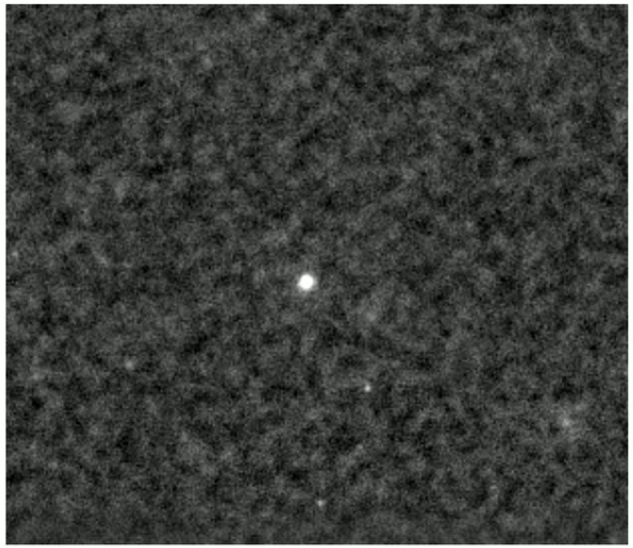
Galaxy clusters appear as dark spots in CMB map below 230 GHz

Intensity map
R:f090,G:f150,B:f220



Compton y map



DES optical image
(zoom)

Detect by looking for negative point sources in the CMB map
(or positive point sources in the y map)

Cluster catalog

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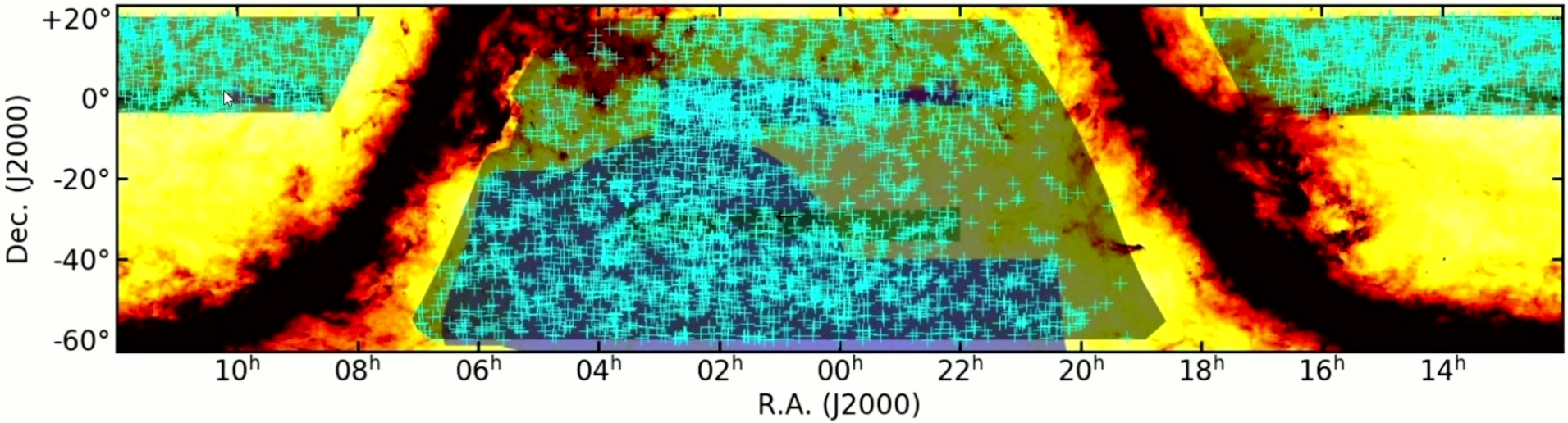
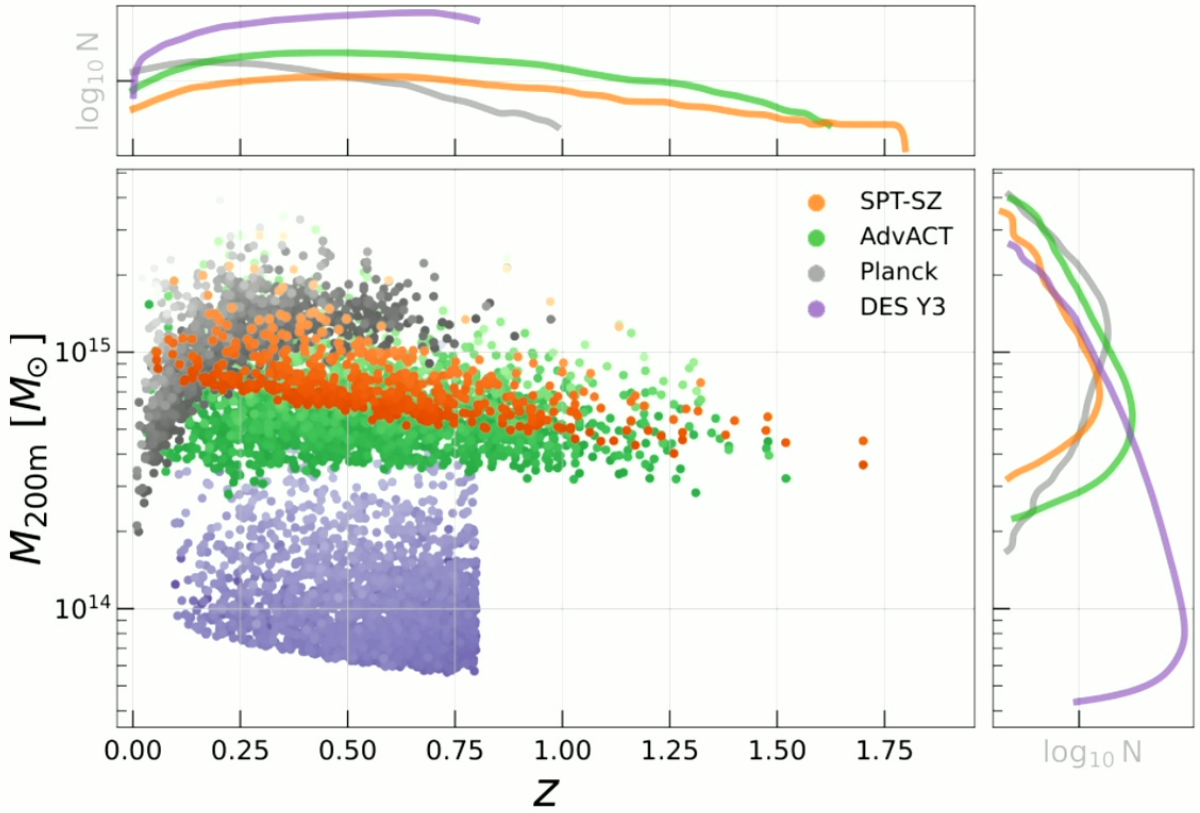
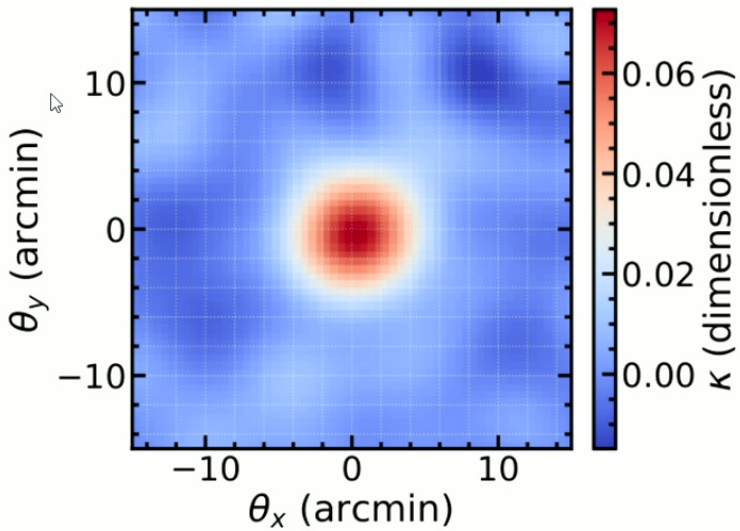


Preliminary number for DR6 catalog: 6800 SNR>4 clusters!
Comparison: Planck has 1203 confirmed clusters

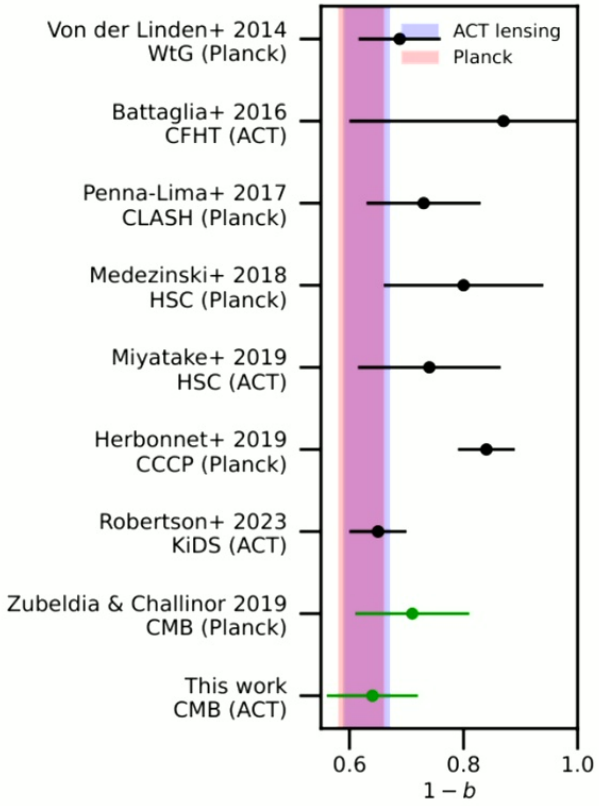
tSZ gives almost redshift-independent selection function
Very different from optical surveys like DES!



Need to calibrate tSZ-mass relationship to do cosmology with clusters. Solution: Cluster lensing!



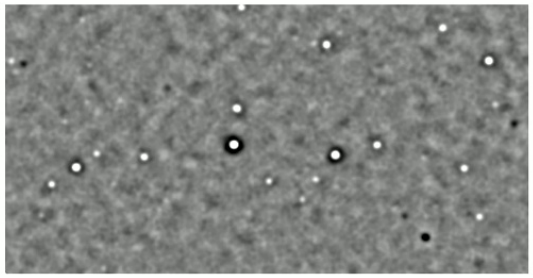
Stack of lensing maps from 3958 clusters. 15σ detection!



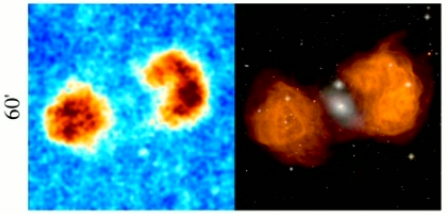
Preliminary! Eunsong Lee at al. (in prep)

Much more than just CMB and clusters in the maps!

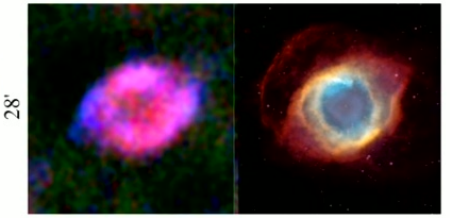
Point sources & clusters



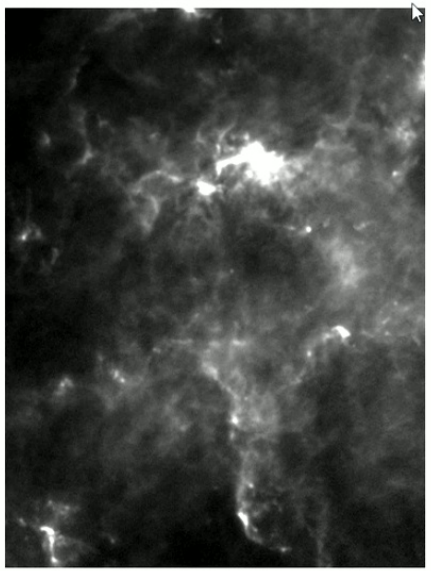
Fornax A



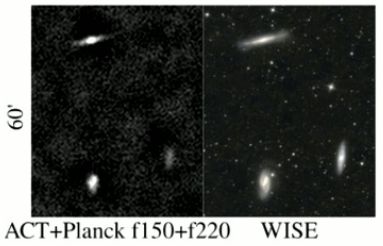
Helix Nebula



Galactic dust



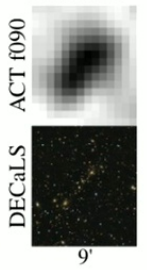
Leo Triplet



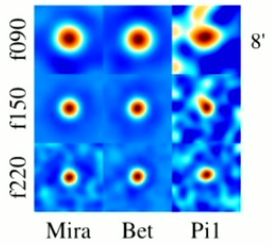
NGC 55

NGC 253

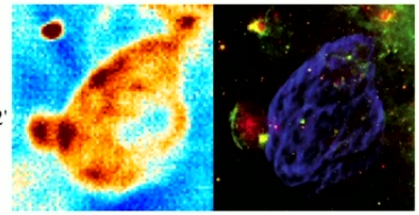
Merging clusters



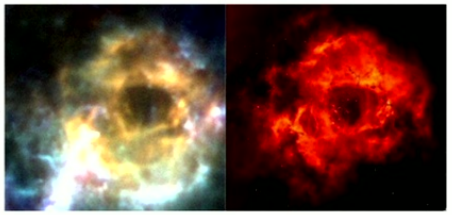
Stars



Supernova remnant W44

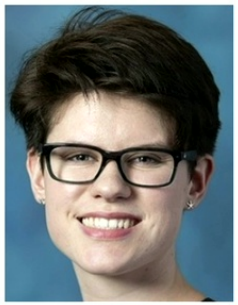


Rosette nebula



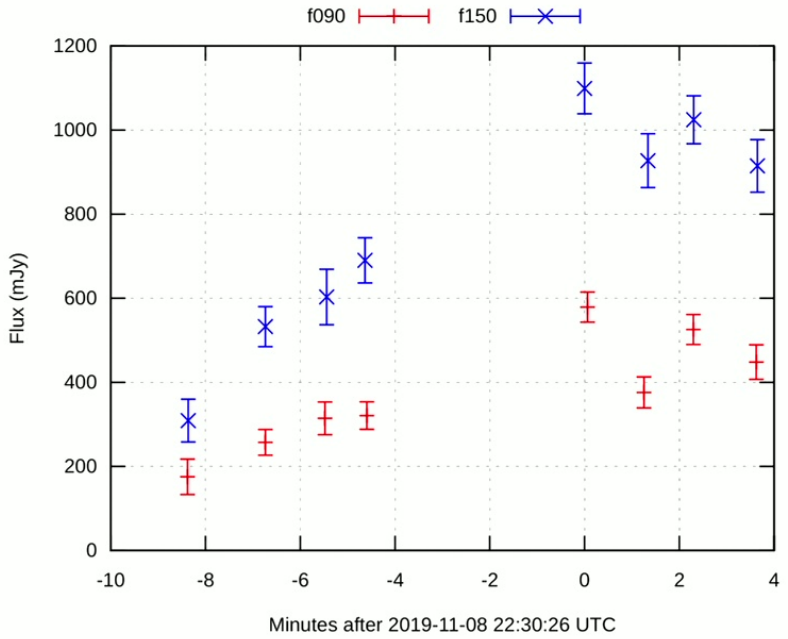
Blind transient search





We found 11 transients using old maps meant for Planet 9 search - mostly flaring stars: https://arxiv.org/abs/2303.04767

New search in progress with better maps



Rapid stellar flare from the star 2MASS J18151564-4927472, 62 pc away.
Corresponds to an X5000000 flare!
8 minute rise time!

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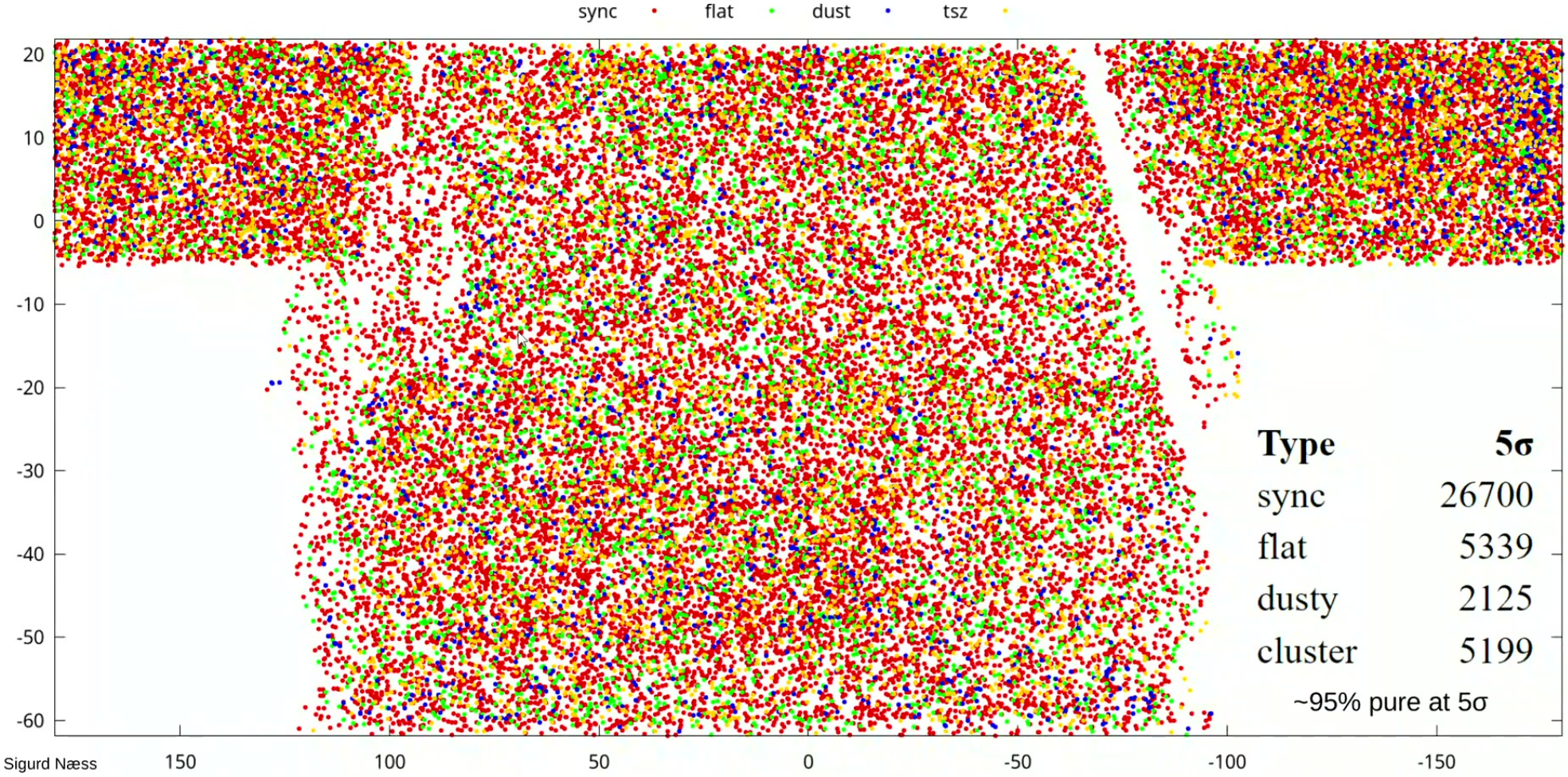
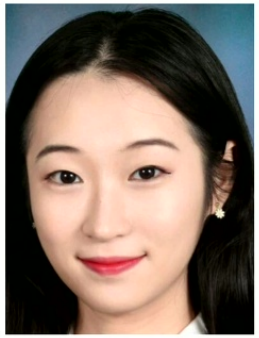
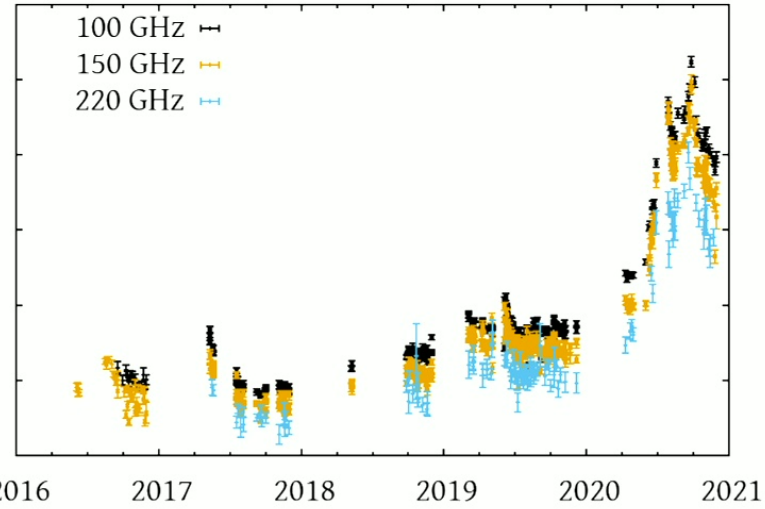
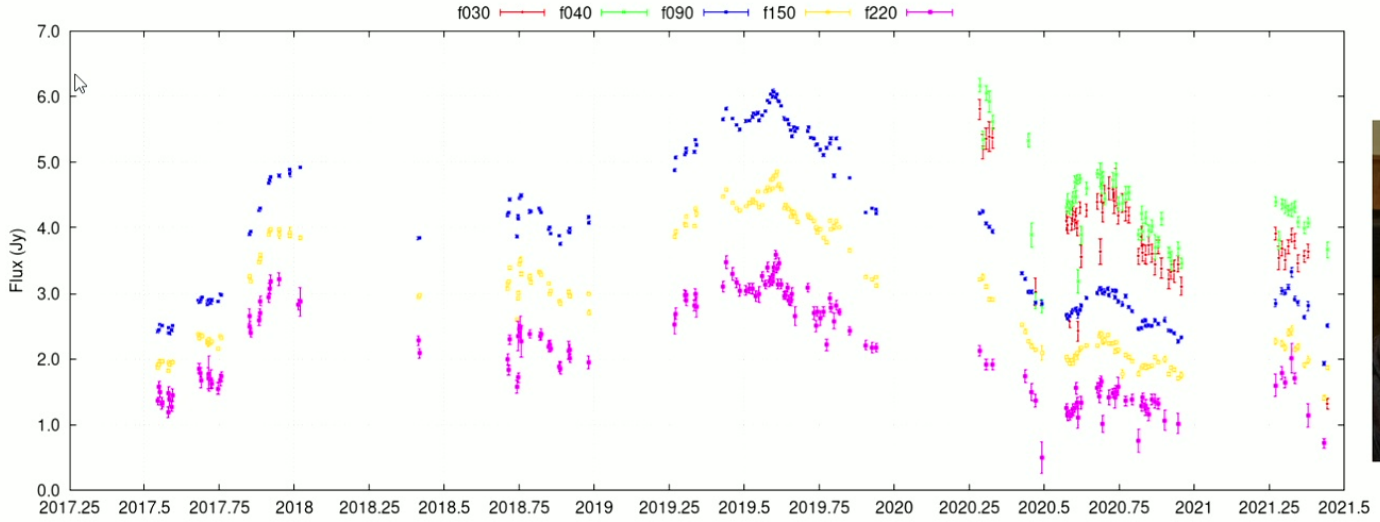
>30000 point sources in ACT DR6, most of them AGNs
By far the biggest catalog in this frequency range (Planck has 2000)



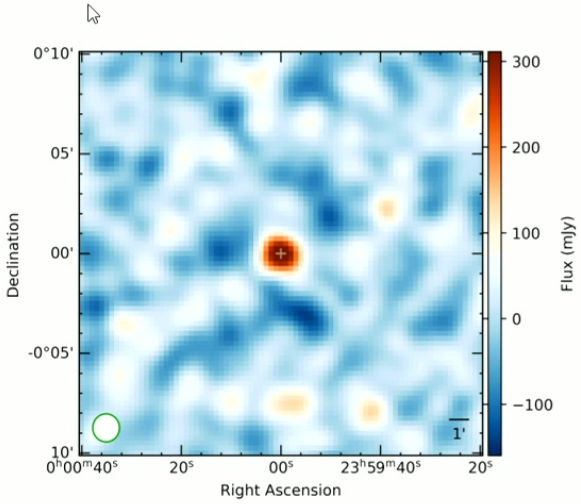
Working on light curves for thousands of AGNs

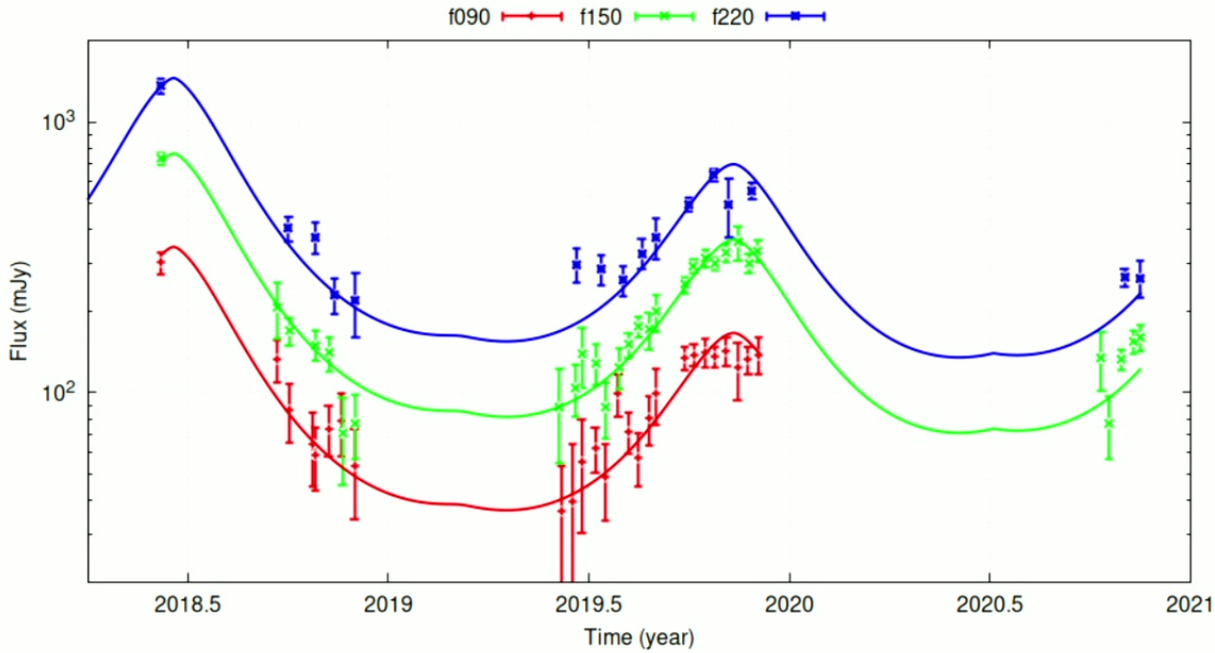






Asteroid light curves and modelling





Vesta from ACT DR6 short-cadence maps. mm observations probe subsurface properties of asteroid regolith

https://arxiv.org/abs/2306.05468

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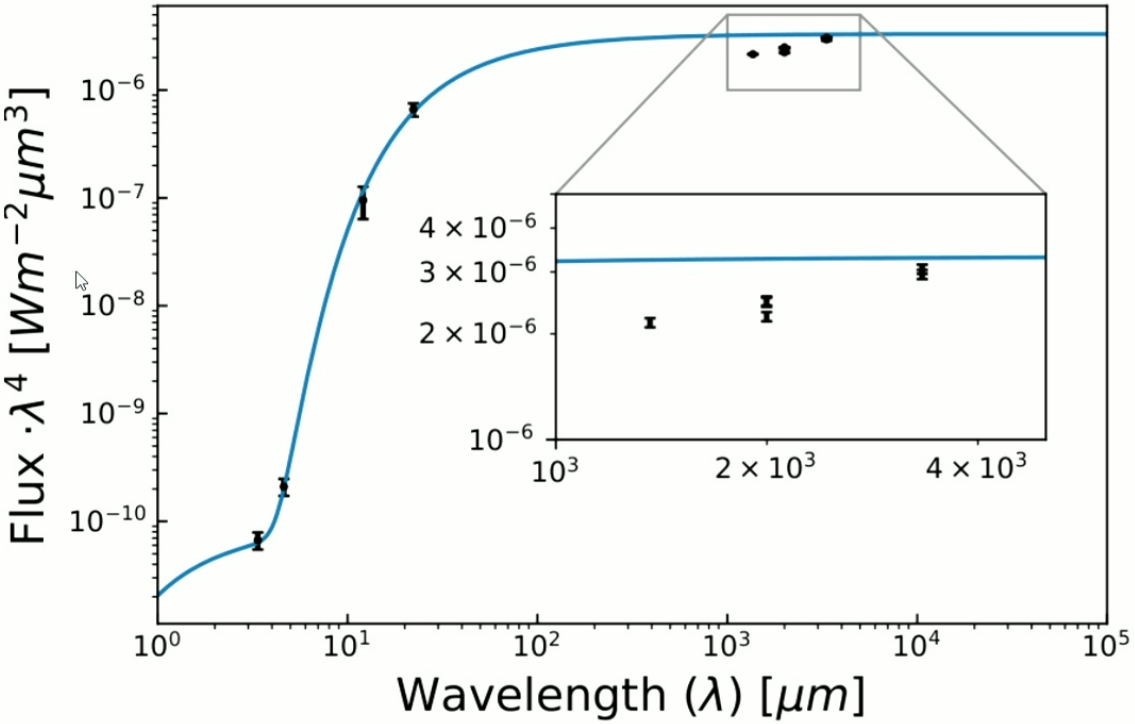
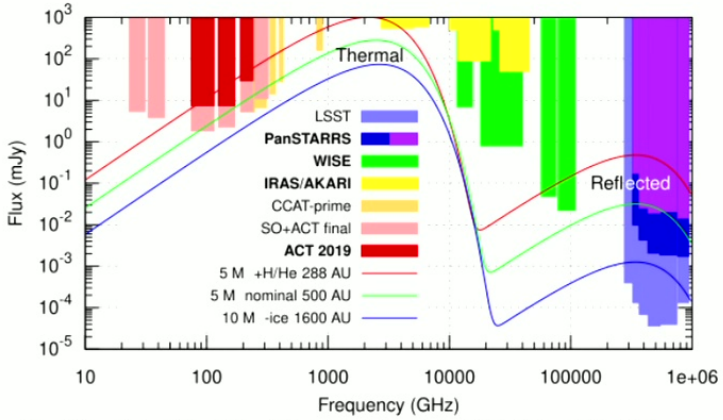
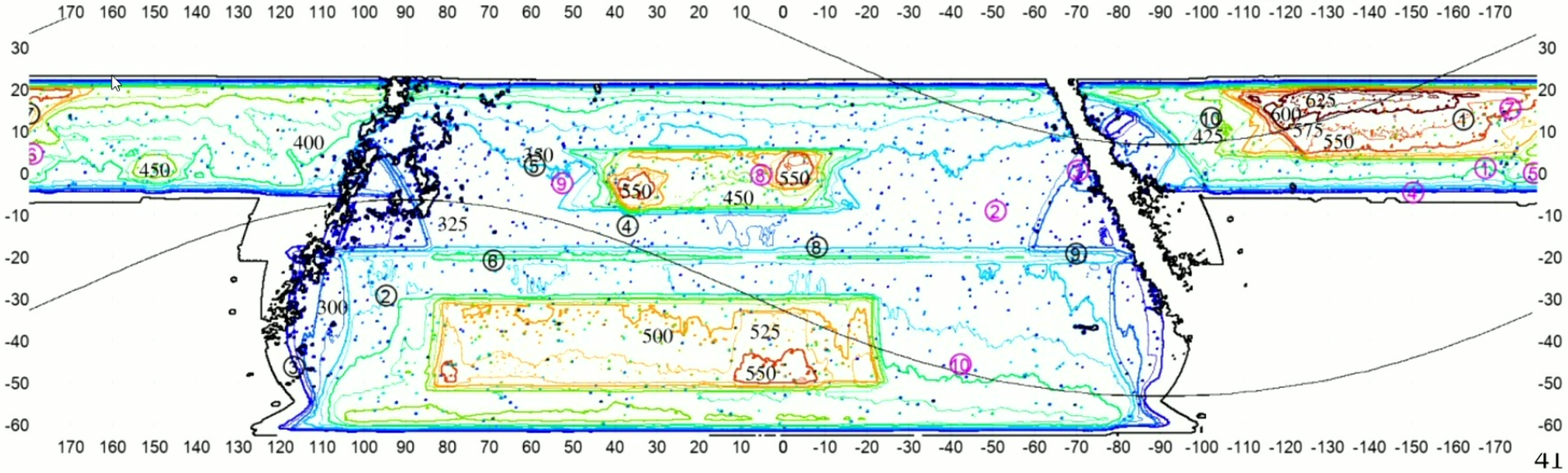
Asteroid microwave flux deficit



- Microwaves probe few mm sub-sufrace
- We confirm earlier findings that asteroids microwave flux is about 25% less than expected from the most popular model (NEATM)
- Sub-surface colder than expected?

Constrained Planet 9 to be >325-625 AU distant over much of its expected orbit using ACT DR5 data





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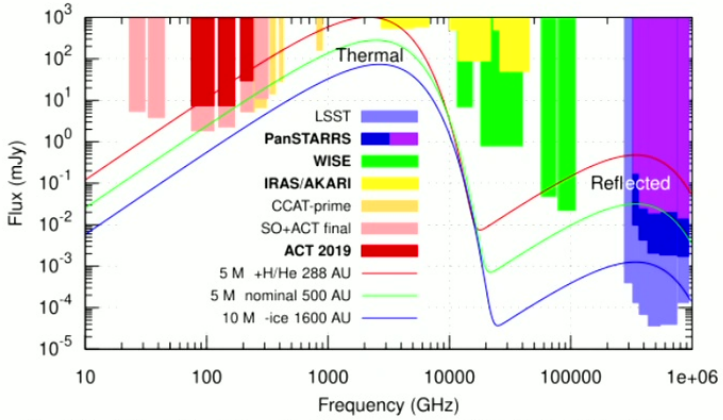

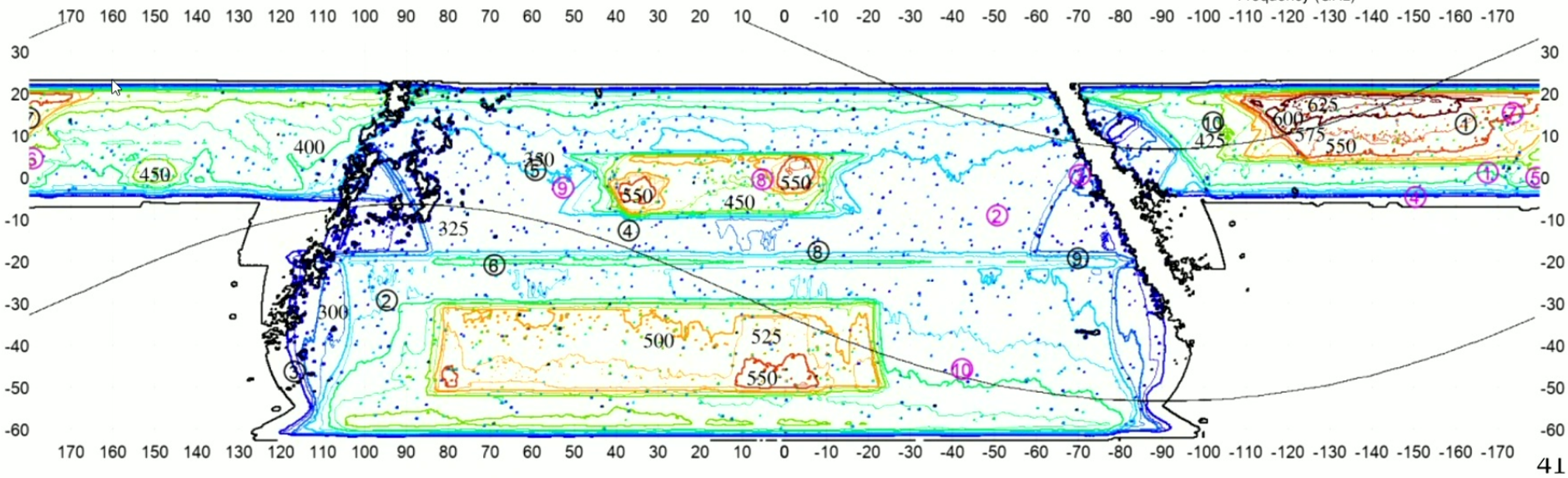

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When's it coming out?!

- Hoped it would be out by now, but systematics were more work than expected (as usual)
- Power spectrum unblinding in a few weeks(?)
- Data release by end of winter, maybe?
- At least some of it's already out (e.g. lensing)

What's next?

- ACT was dismantled in 2022, and will be replaced by Simons Observatory
- SO will consist of 1 large telescope (ACT-sized) and 6 small telescopes (similar to POLARbear/bicep - targeting B-modes)
- Where ACT had ~5k detectors, SO will have ~60k detectors (half in the large telescope)
- Advanced SO will later double this to around 110k detectors!
- First light expected late spring 2024