THE ATACAMA COSMOLOGY TELESCOPE
SCIENCE AND ANALYSIS PIPELINE

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Princeton University

On behalf of the ACT collaboration

From Planck to the future of CMB
26-05-2022
Ferrara

ATACAMA COSMOLOGY TELESCOPE

Altitude of 5200 m in the Atacama desert in northern Chile

- Access to ~70% of the sky (ACT maps ~40%)

6 m telescope

- ~5 times Planck resolution

image credit: Mark Devlin

ATACAMA COSMOLOGY TELESCOPE

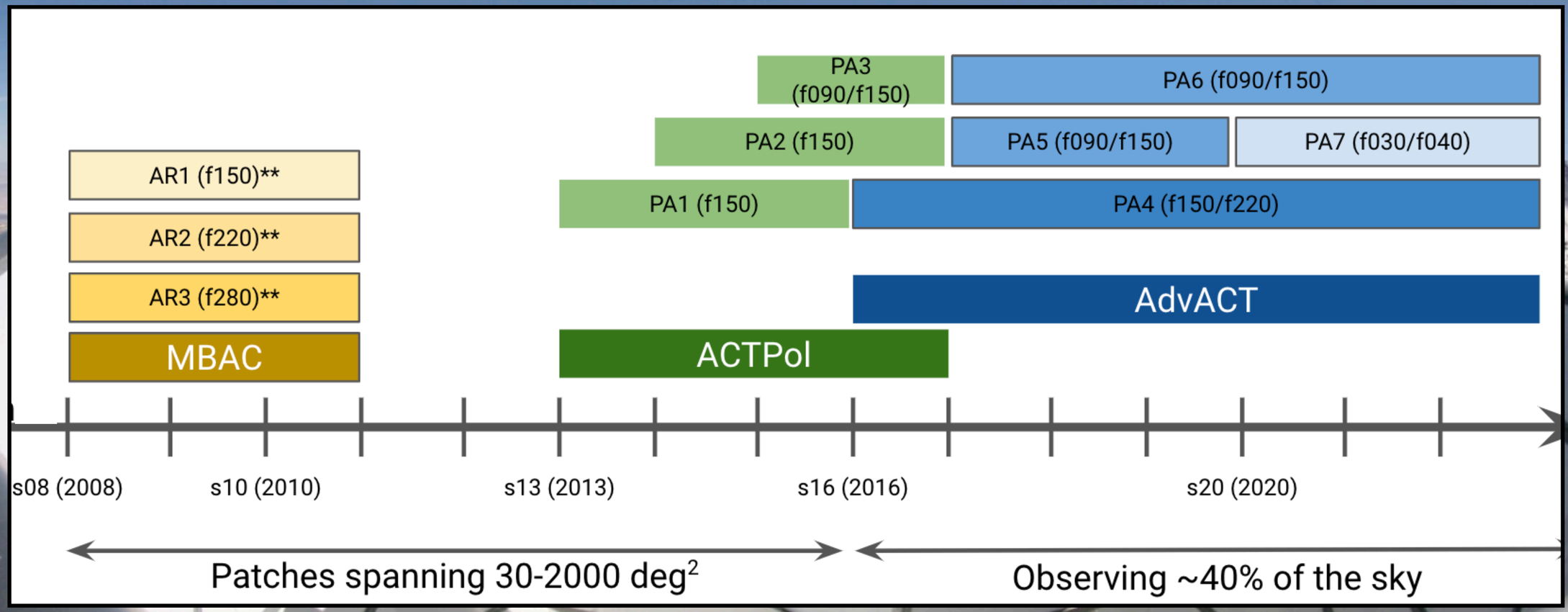

image credit: Mark Devlin

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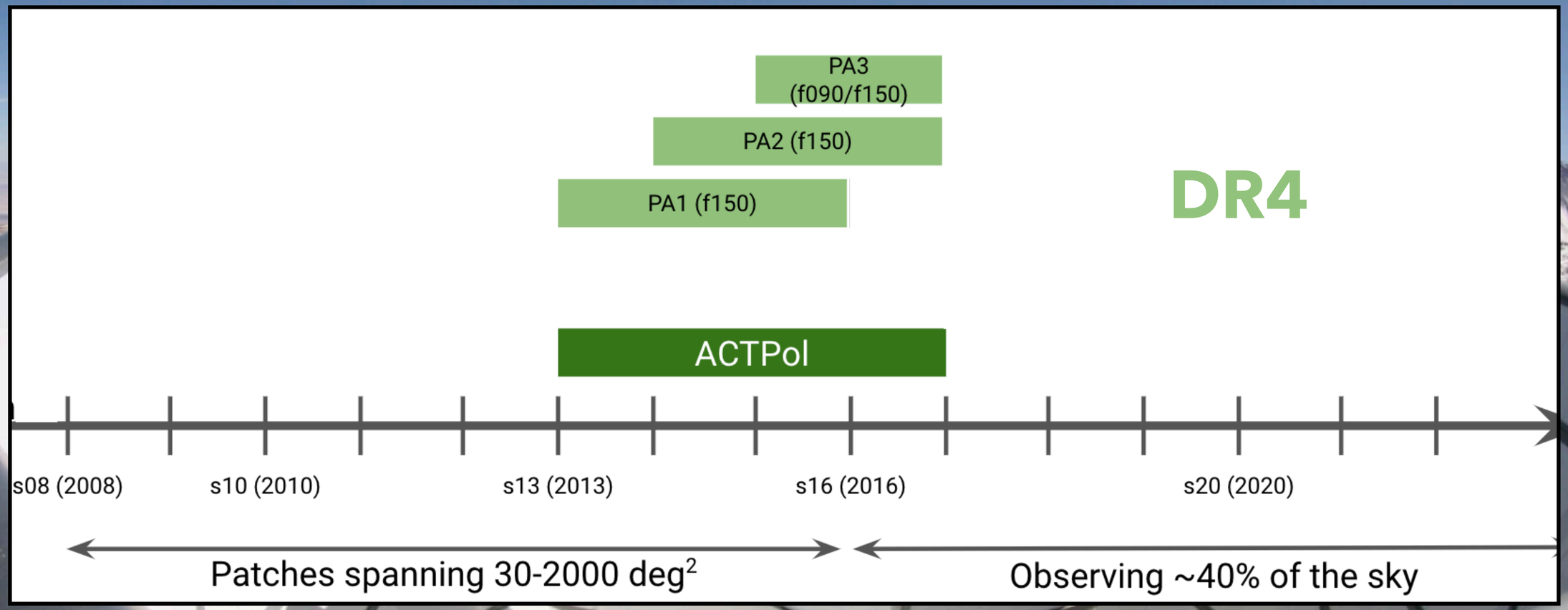

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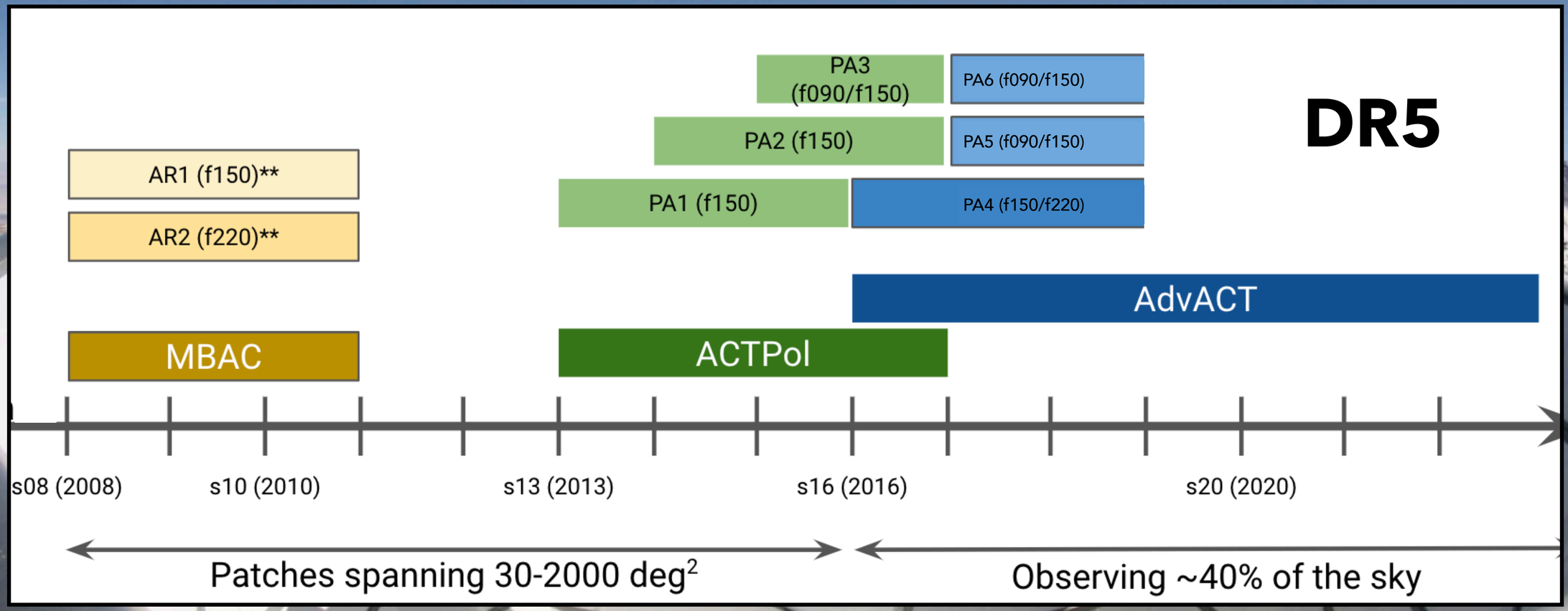

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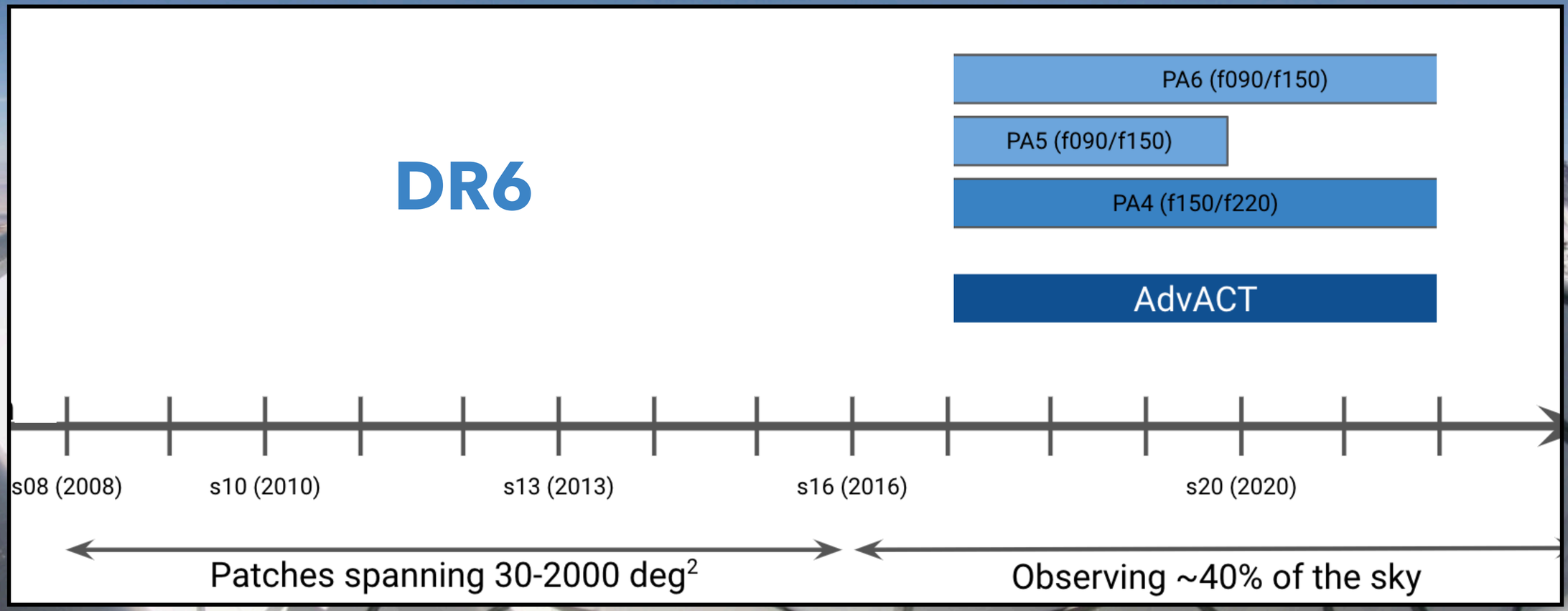
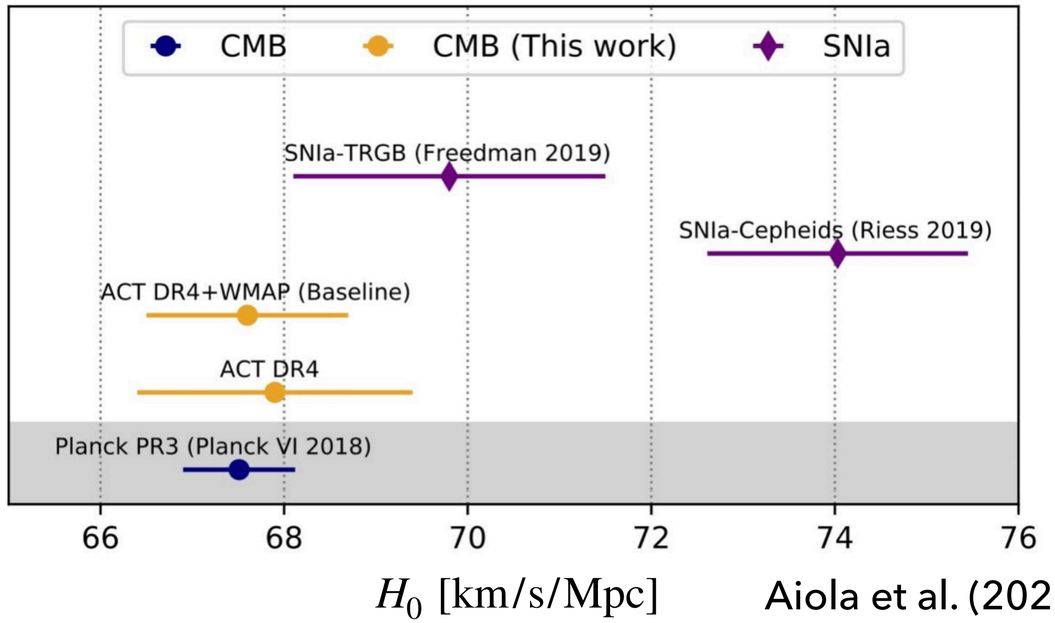


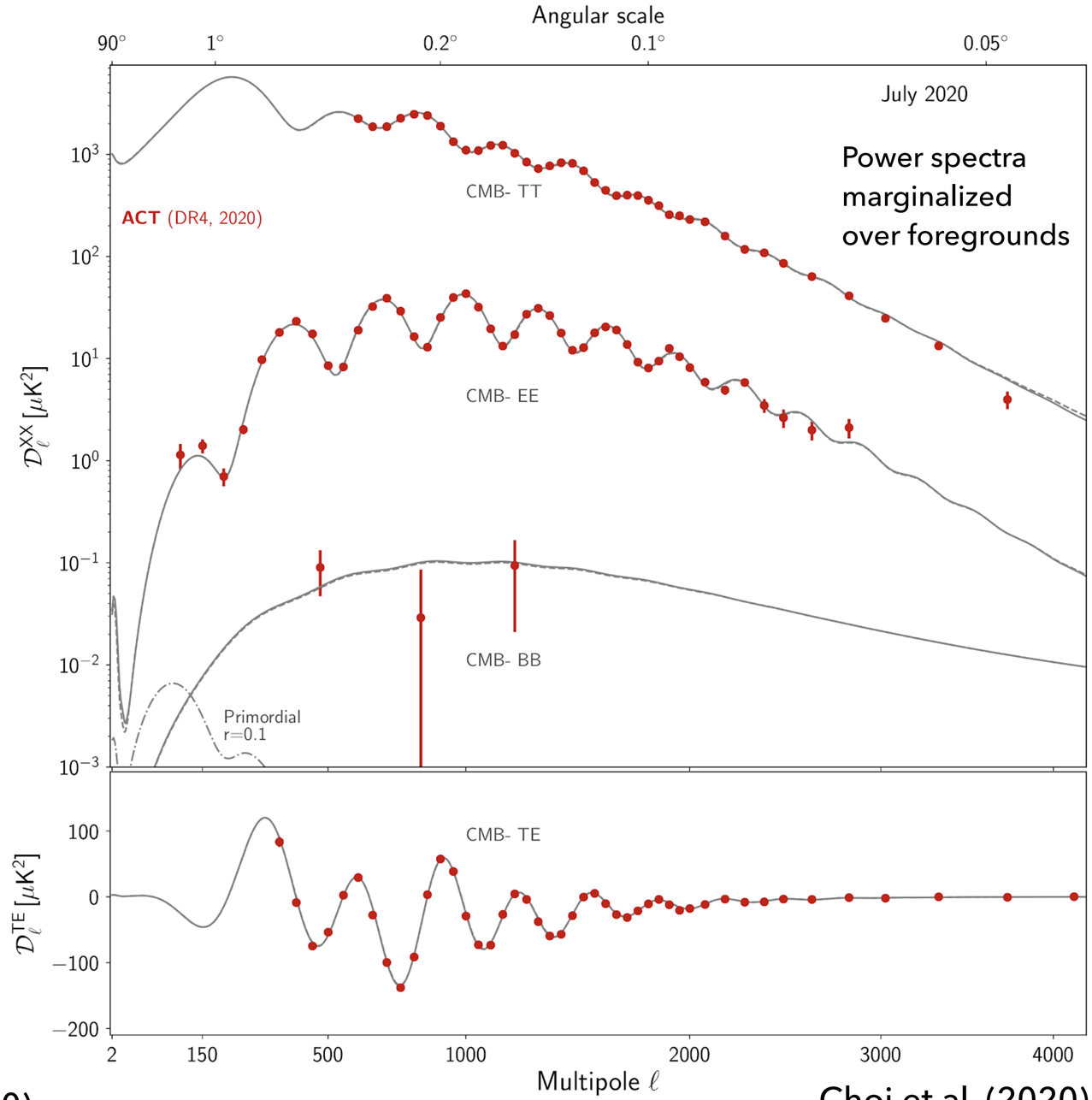
image credit: Mark Devlin

ACT DR4

- **Choi *et al.* (2020)** : spectra, null tests, likelihood. **Aiola *et al.* (2020)** : maps and cosmological parameters. Maps and likelihood are public
- H_0 from ACT consistent with Planck

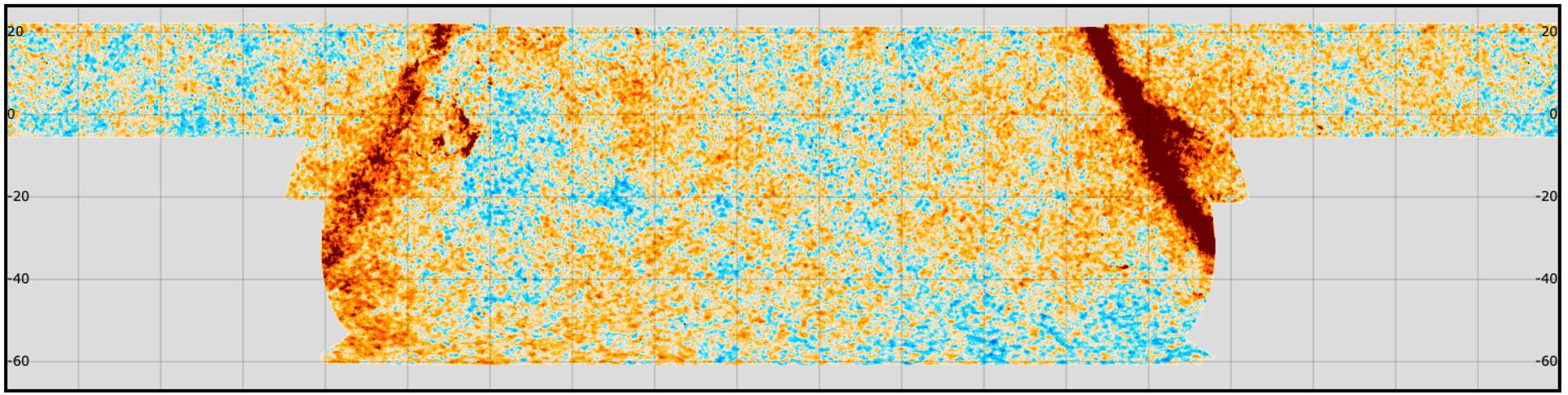


Aiola et al. (2020)



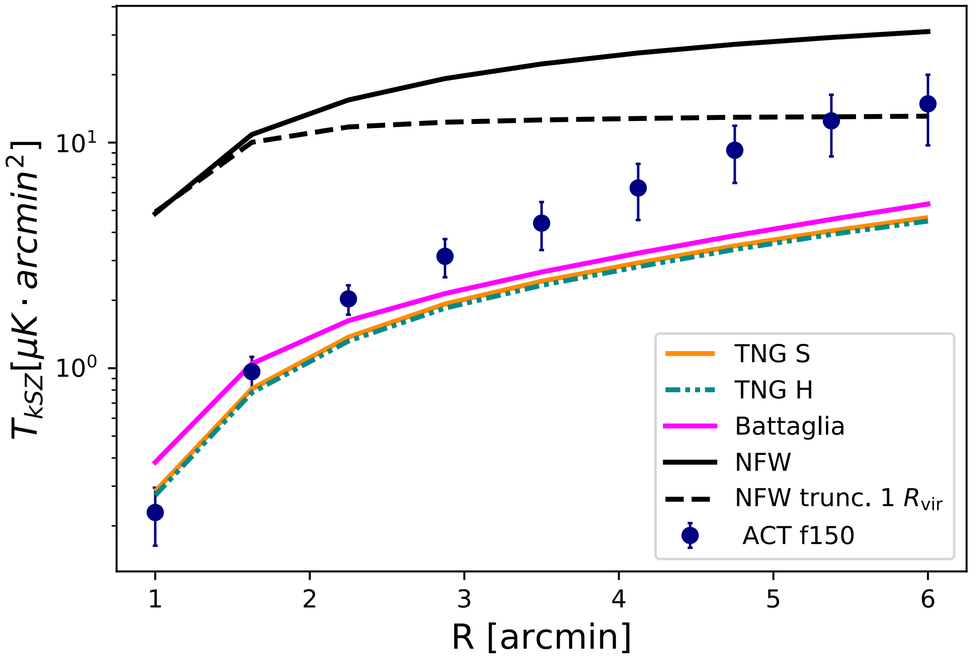
Choi et al. (2020)

ACT DR5



Interactive map viewer : phy-act1.princeton.edu/public/snaess/actpol/dr5/atlas/ Naess *et al.* (2020)

- Co-added all ACT data up to 2018 with Planck HFI
- Suitable for "high-ℓ" science
- Caveats for "precision" cosmology: only one map per frequency (90, 150, 220 GHz), no simulations



Amodea++ (2020), Schaan++ (2020)

- DR5+ : Galactic center, see talk by Brandon Hensley from yesterday

ACT DR6

- Jointly map seasons 17-21
  - Allows for an 8-way split of the data
- 90, 150, 220 GHz (30, 40 GHz TBD)
- Data volume ~190TB, ~10x DR4

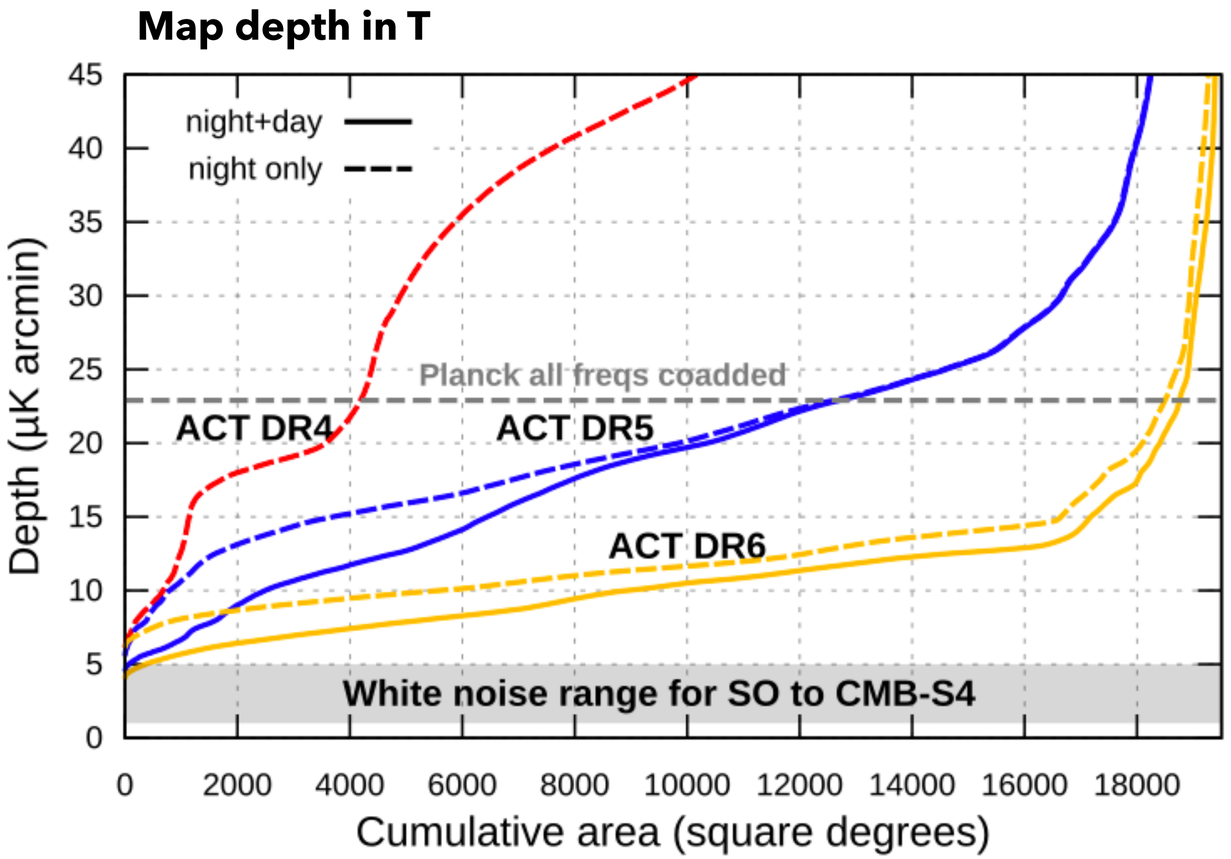


figure credit: Sigurd Næss

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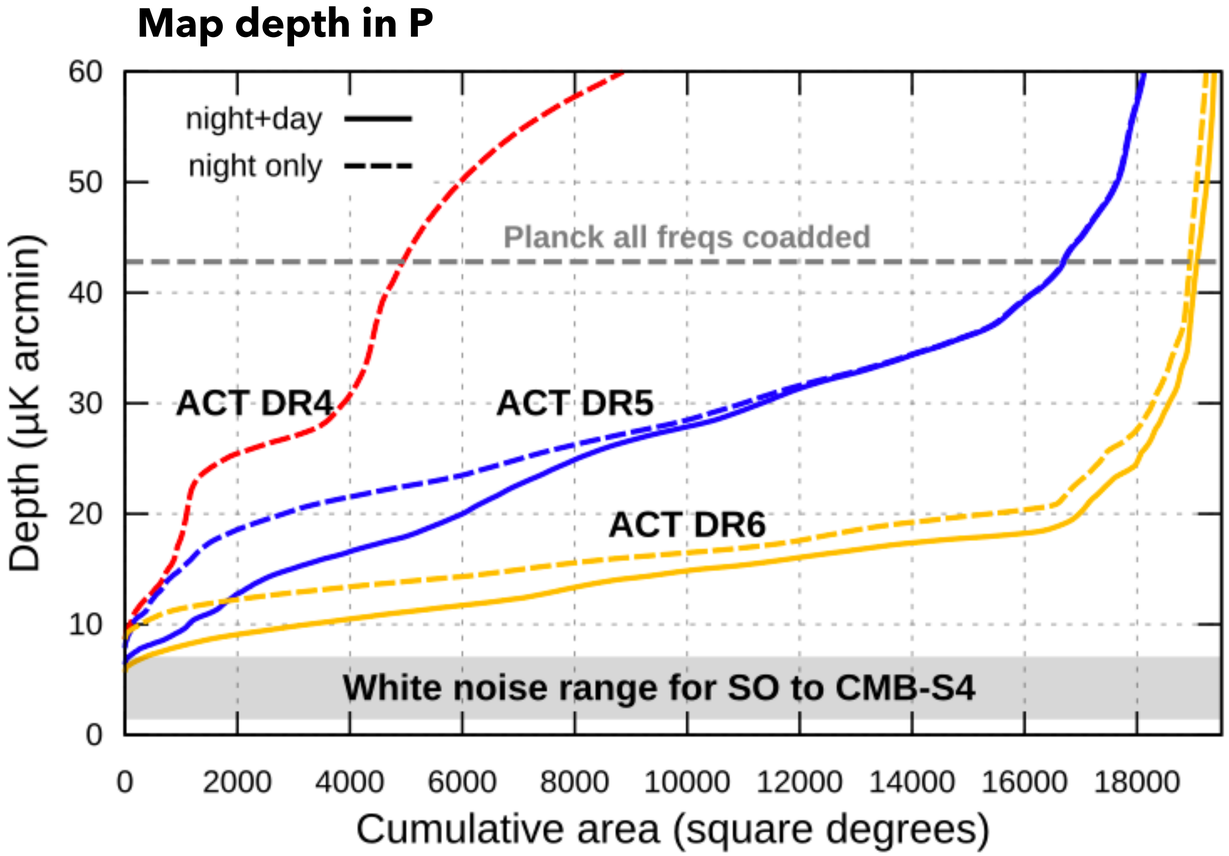


figure credit: Sigurd Næss

DR6 COMPARED TO DR4

Preliminary DR6 **EE** error bars on top of fiducial spectrum

DR4 data

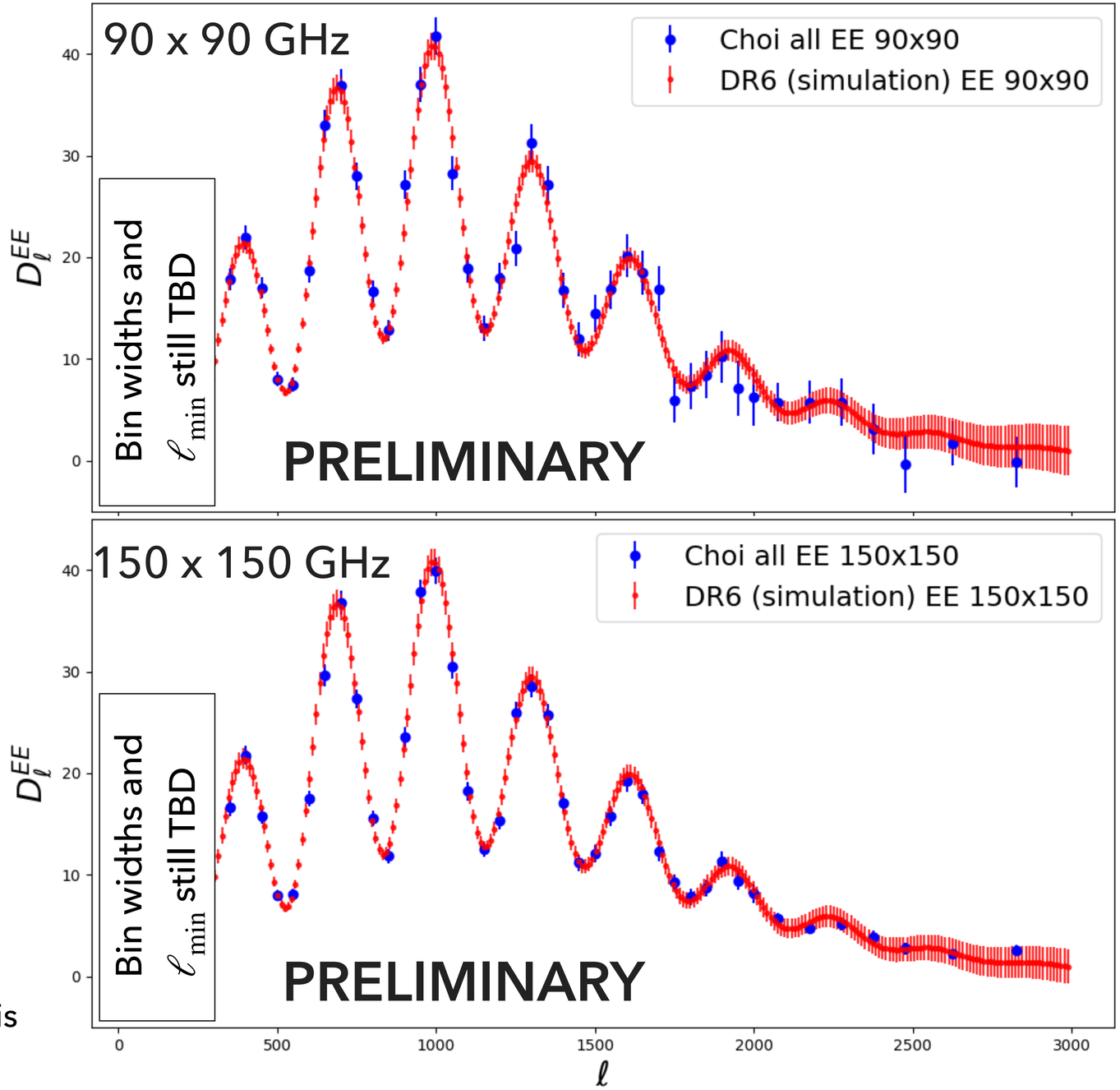


figure credit: Thibaut Louis

DR6 COMPARED TO DR4

Preliminary DR6 **TE** error bars on top of fiducial spectrum

DR4 data

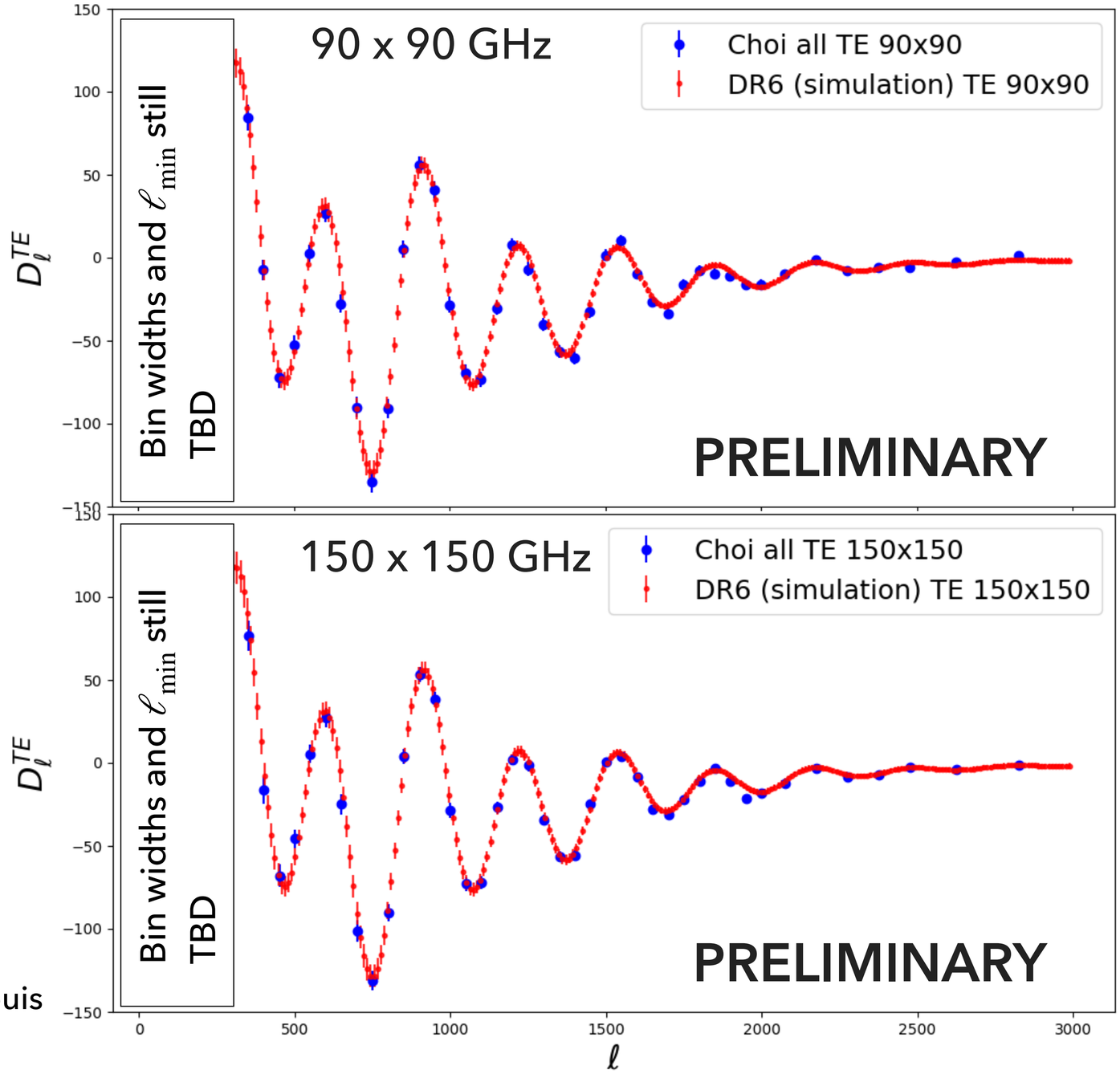


figure credit: Thibaut Louis

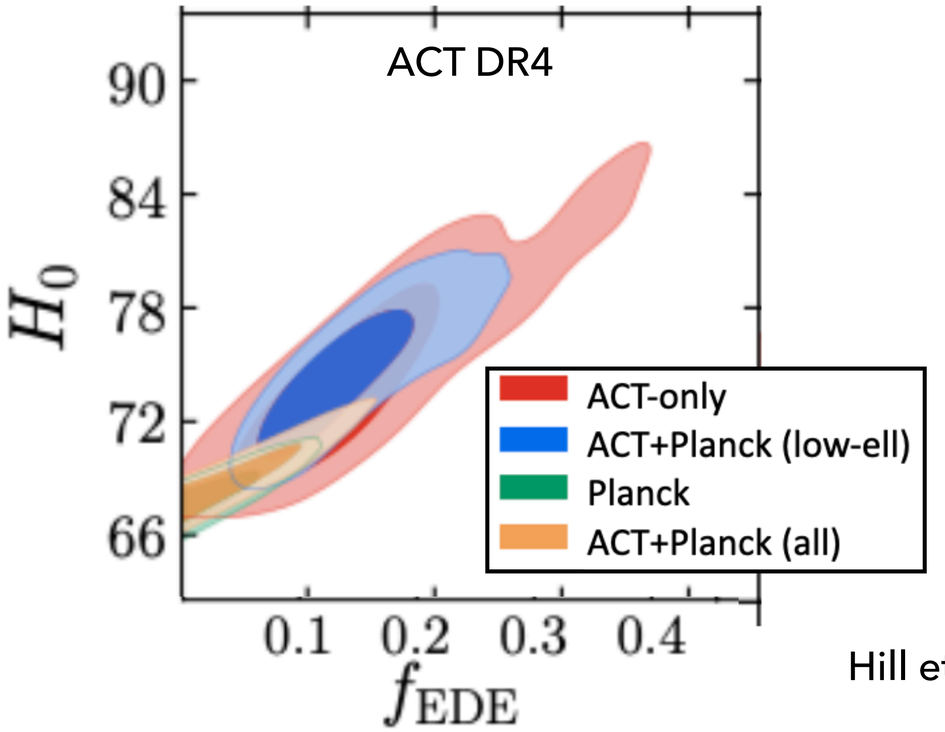
CONSTRAINTS FROM TT, TE, EE

- DR6: power spectrum constraints move beyond Planck

	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**

Forecast

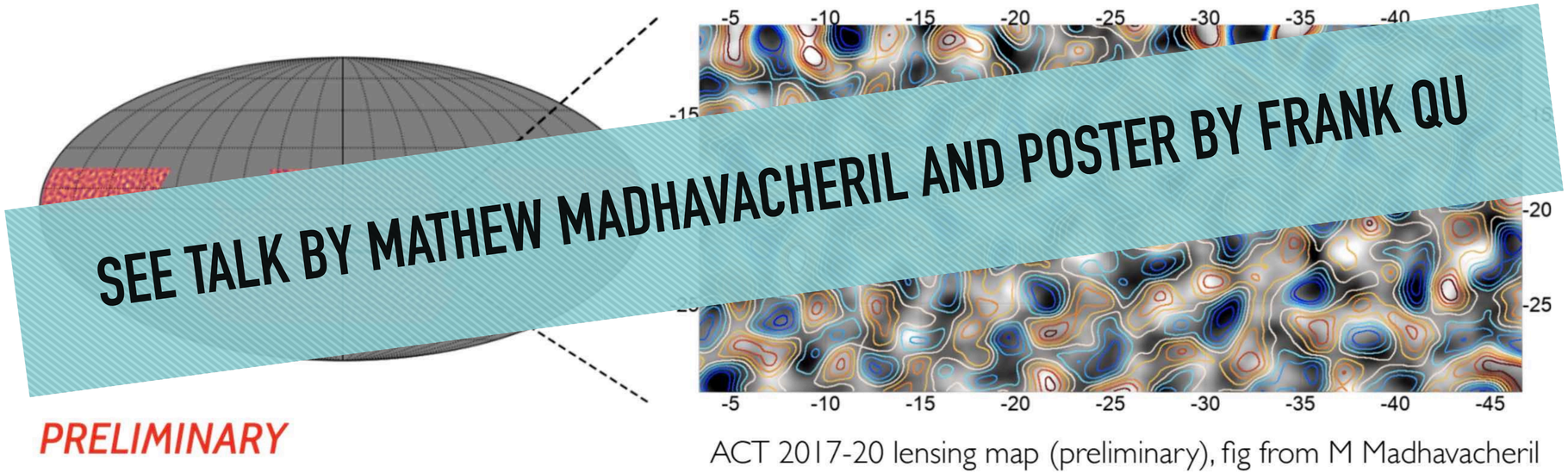
- Early Dark Energy (Poulin++ (2019), Smith++ (2022), Agrawal++ 1904.01016)



Hill et al. (2021)

- With **DR6** the current best-fit ACT EDE model would be discriminated at **~20 sigma** from the current best-fit Planck model

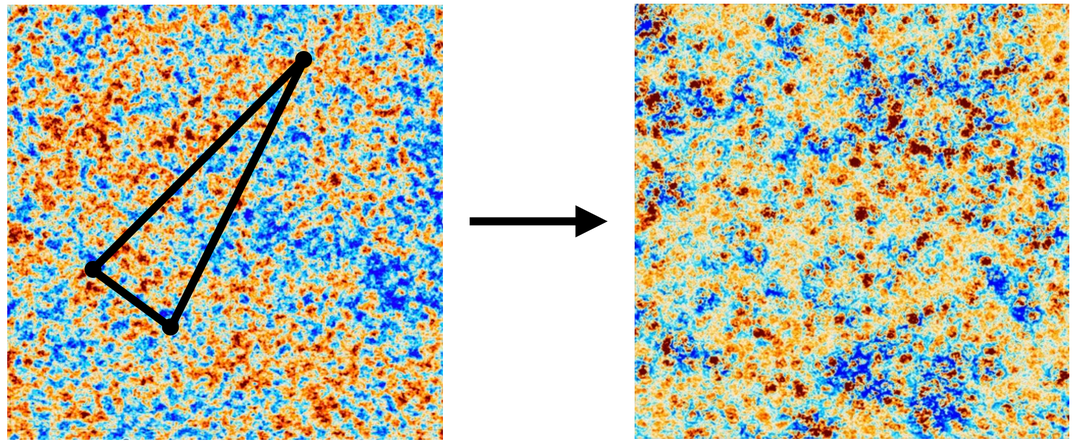
LENSING



ACT 2017-20 lensing map (preliminary), fig from M Madhavacheril

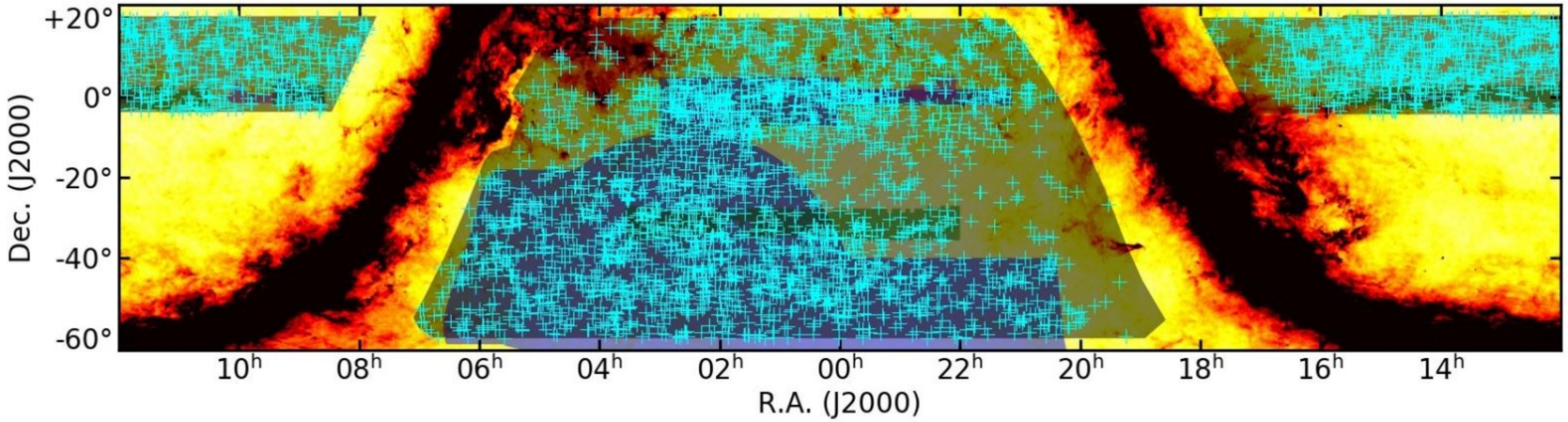
BISPECTRUM ($f_{\rm NL}$)

- Joint DR6 ACT + Planck primordial $f_{\rm NL}$ search
  - Needlet-ILC CMB maps with optional CIB/ tSZ deprojection
  - Optimal C^{-1} filtering of signal + noise to combine Planck and ACT in the map-domain

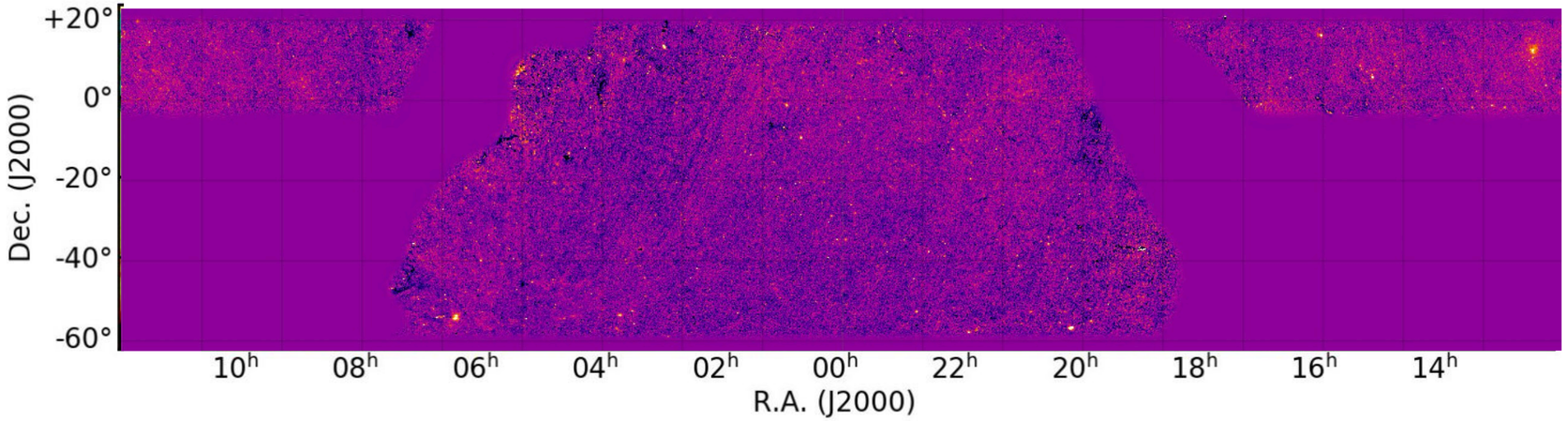


$f_{\rm NL}^{\rm local} \neq 0$ sim

CLUSTERS



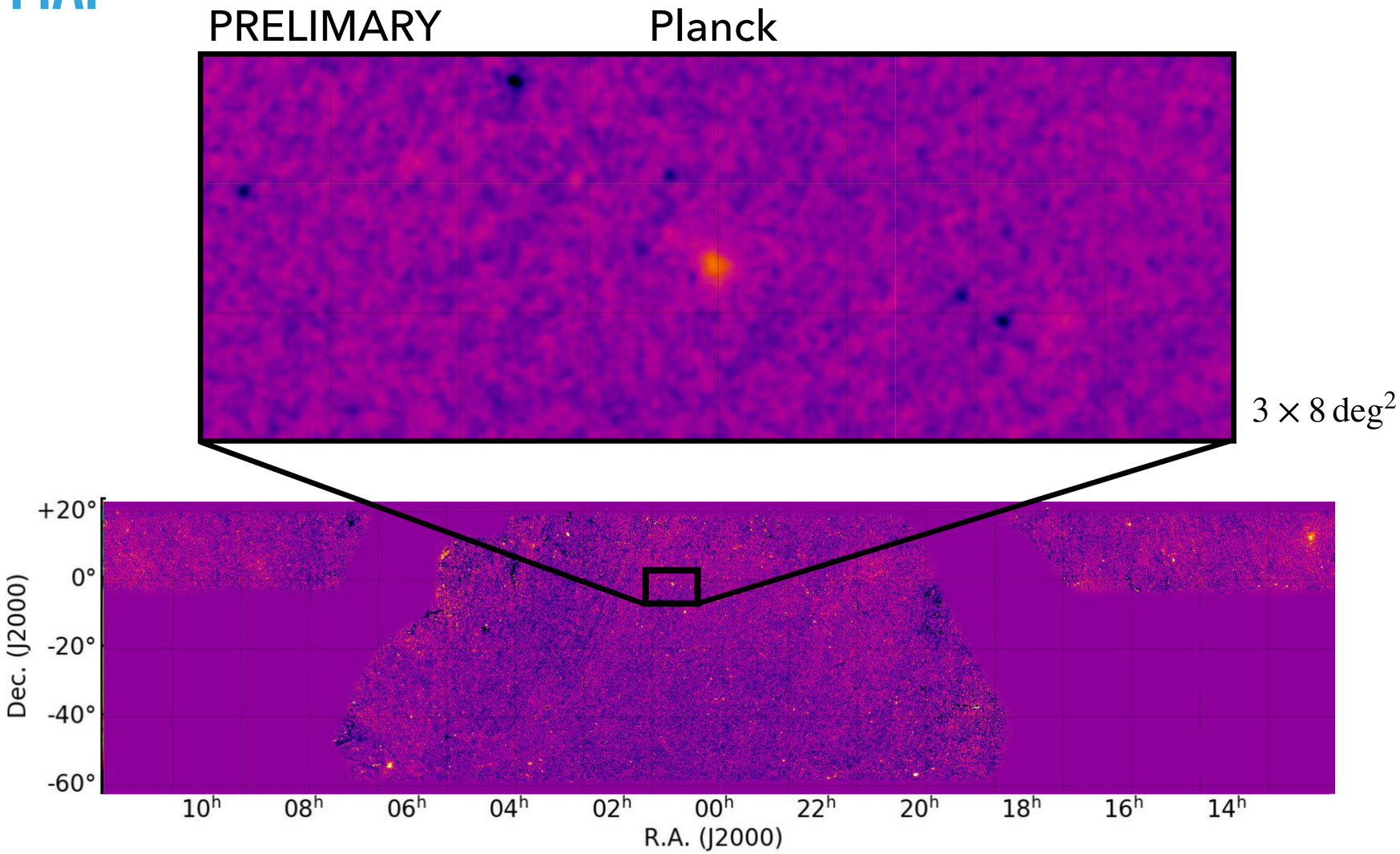
- DR5 SZ cluster catalog from Hilton *et al.* (2021) (>**4000** SNR>4 clusters, DR6 adds >**1000**)



From William Coulton (see poster)

- Preliminary Planck + ACT DR6 Compton Y map showing the thermal SZ effect

COMPTON Y-MAP



Needlet-ILC from William Coulton (see poster)

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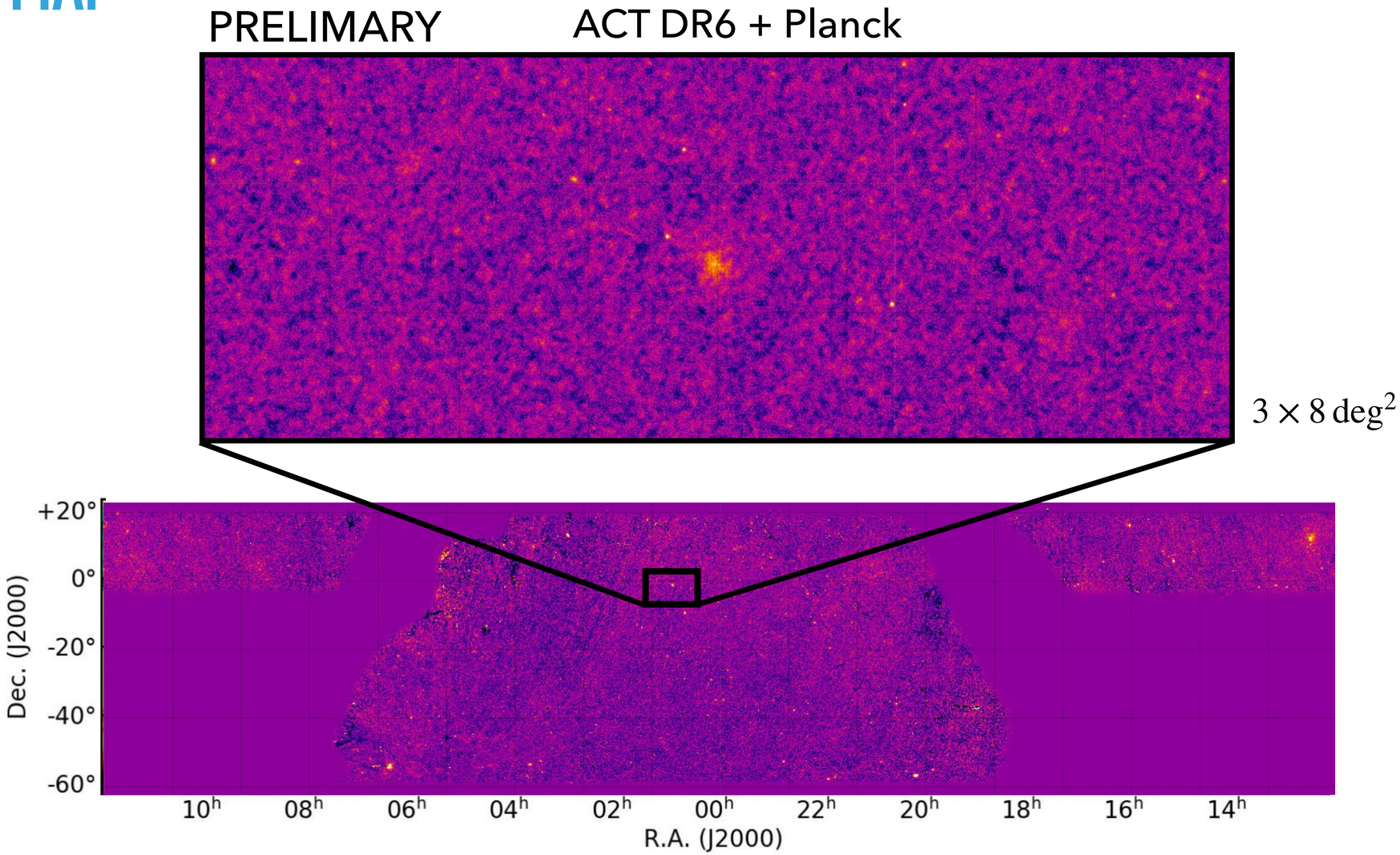
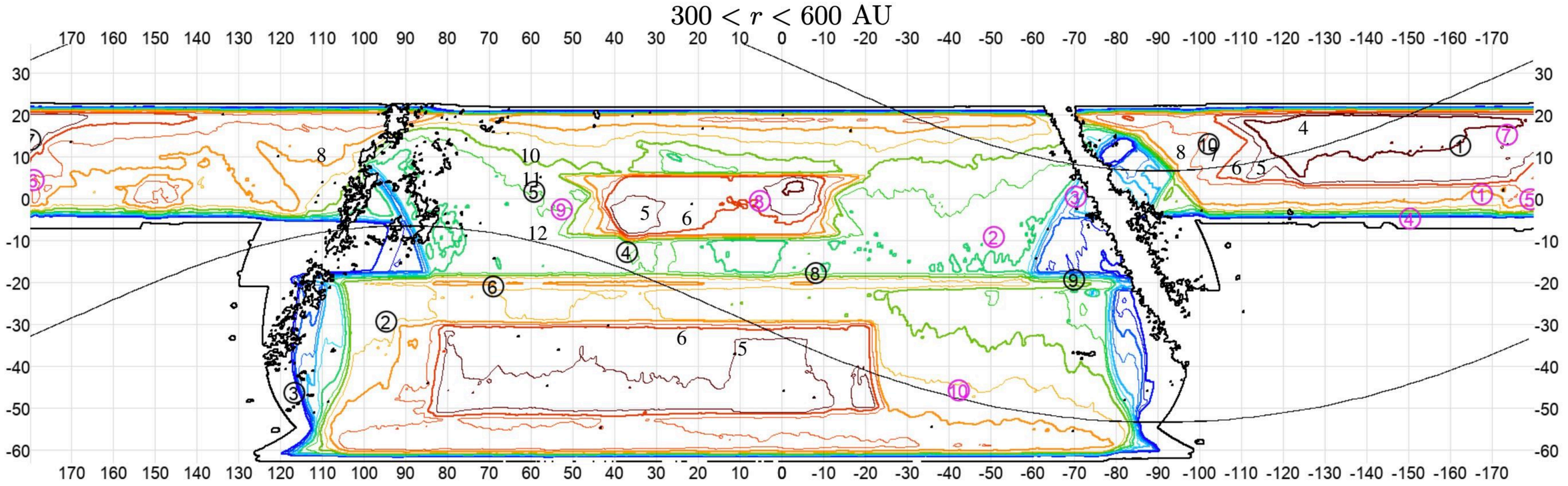


Needlet-ILC from William Coulton (see poster)

TIME-DOMAIN ASTRONOMY

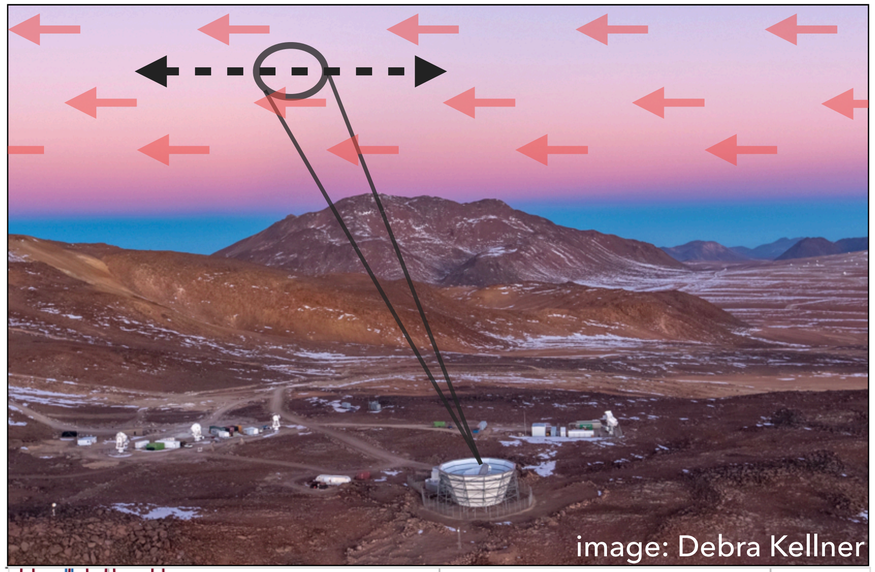


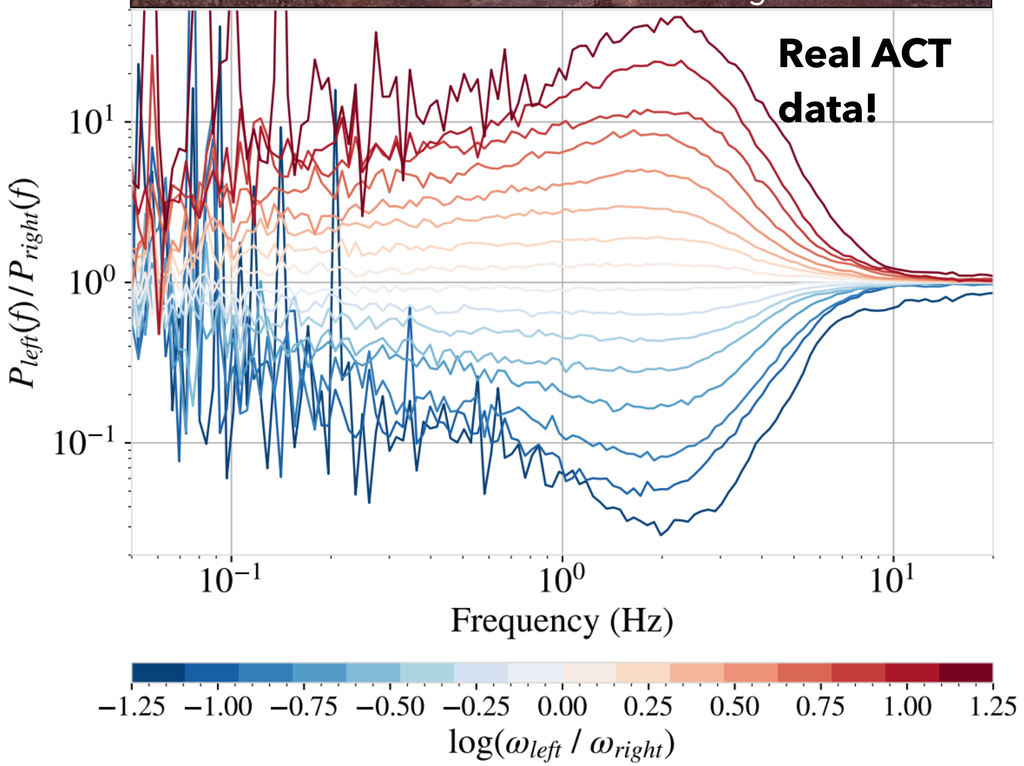
- Flux limit in mJy for Planet 9 & top candidates from Naess *et al.* (2021)

- Mapped data per **3-days**. Used in searches for:
  - Planet 9 with "shift-and-stack" search (Naess *et al.* (2021)
  - Flaring stars (Naess *et al.* (2021), AGN

MODELING OF ATMOSPHERE

- Max likelihood mapmaking models atmosphere as stationary noise in time-domain (assume stationary over ~10 min)
- Crucial to include correlations between detectors in noise model
  - Possible improvement from Morris *et al.* (2022): **incorporate wind direction in noise model**





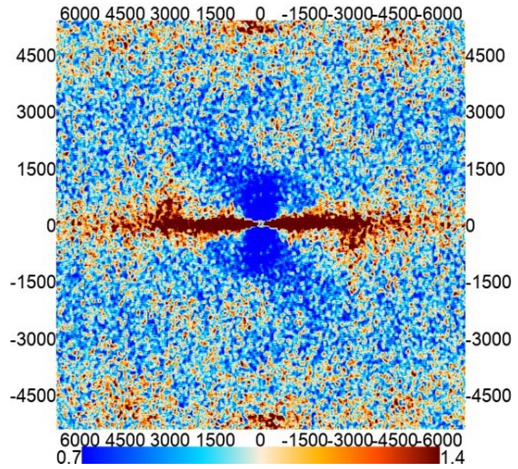
Morris *et al.* (2022)

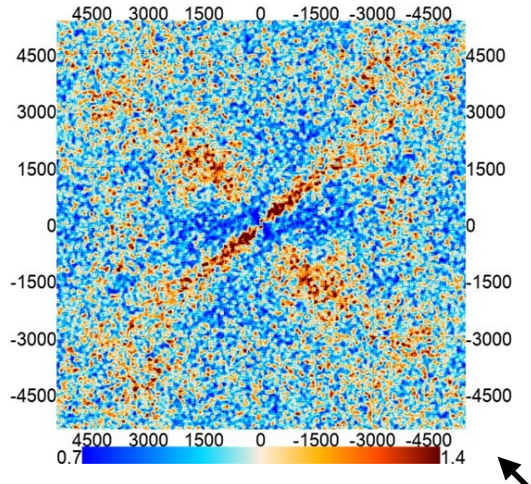
NOISE PROPERTIES OF THE ACT MAPS

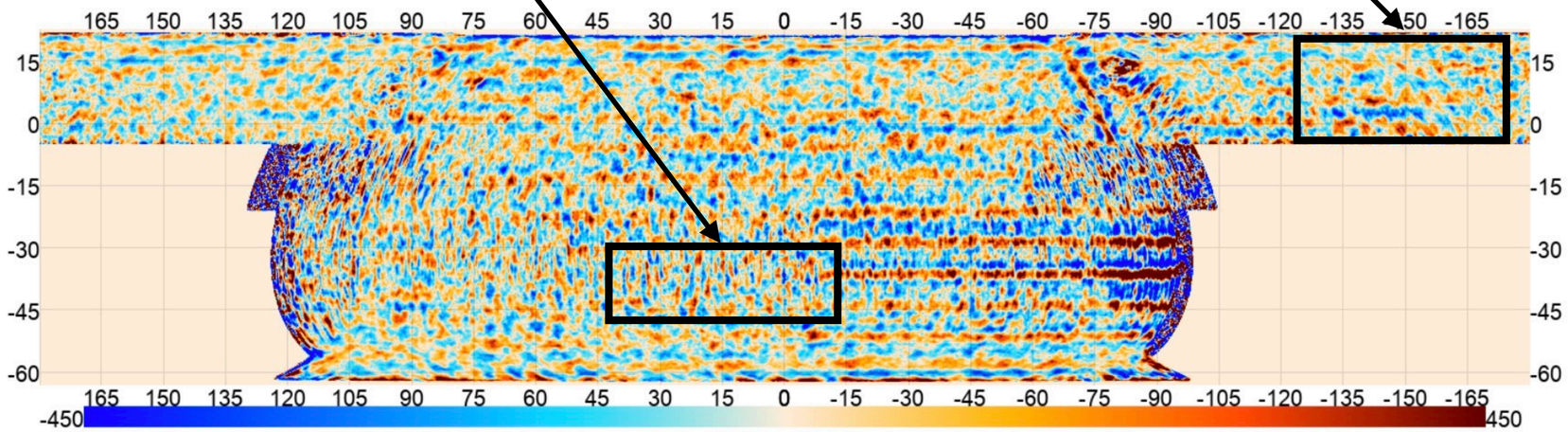
Max likelihood mapmaking puts focus on quantifying the noise in the map (instead of bias in the map)

- Noise spectrum N_ℓ is very red
- Correlated noise with varying directions
- Map depth that varies with pixel and angular scale

2D Fourier spectra. Azimuthally symmetric part has been subtracted







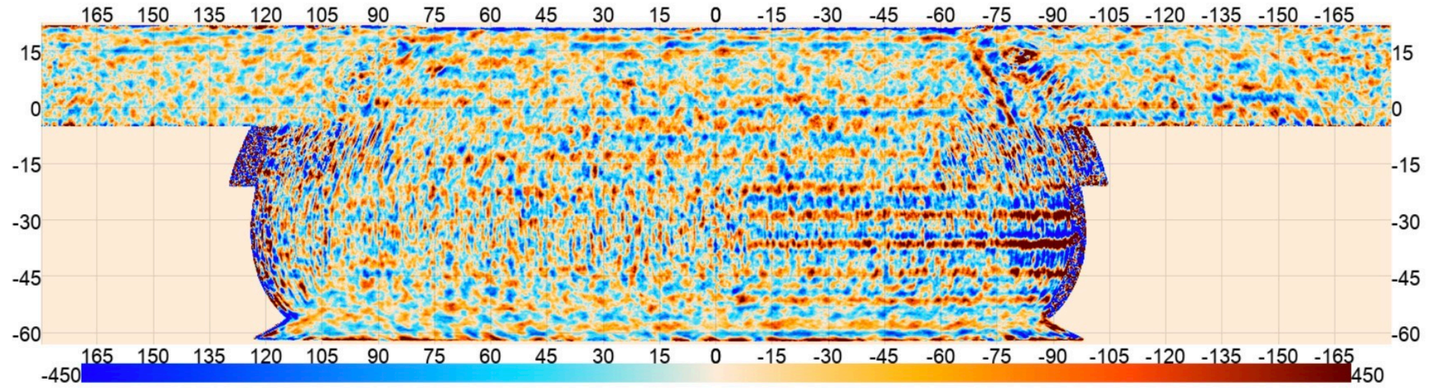
Differenced data for split 1/8 PA5 f090. Stokes I

image credit: Zach Atkins

MAP-BASED NOISE SIMS

Zach Atkins, Princeton
PhD student

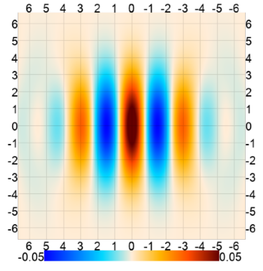
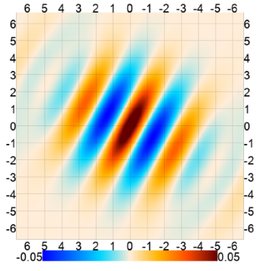
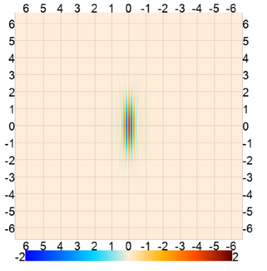
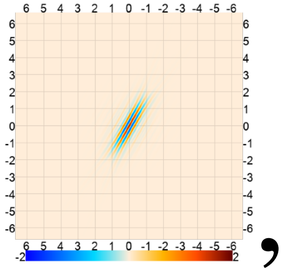
- (directional) wavelets to capture spatial and directional deviations from noise power spectrum N_ℓ
- github.com/ACTCollaboration/mnms



$$\circledast$$

$$N_\ell^{-1/2}$$

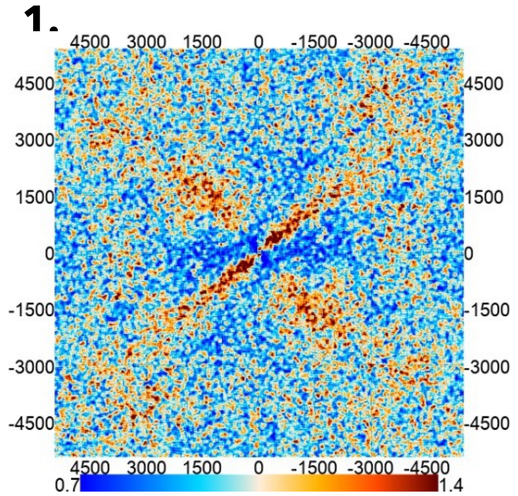
$$\circledast$$

$$\left(\dots, \; \text{  }, \; \text{  }, \; \dots, \; \text{  }, \; \text{  }, \; \dots \right)$$

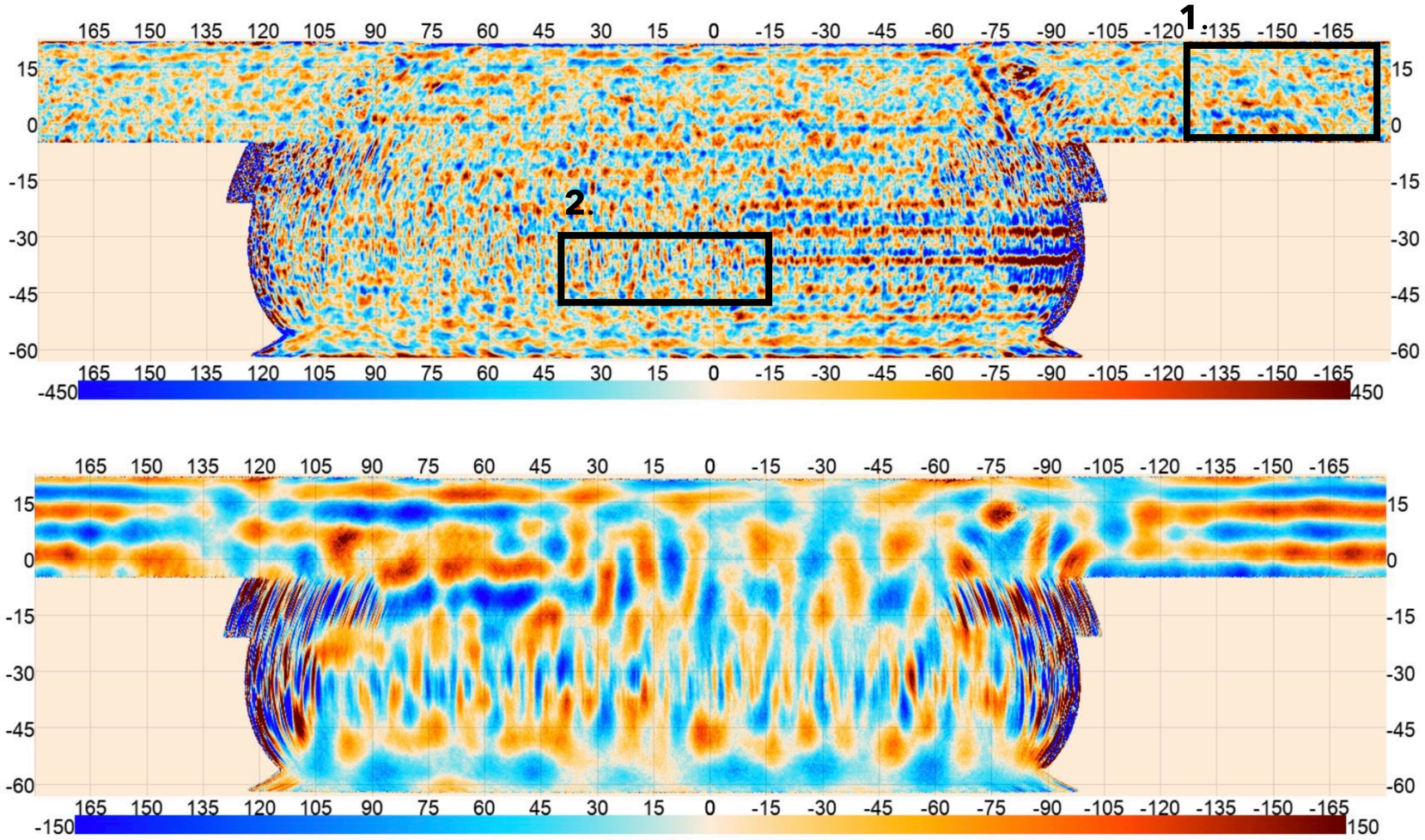
$$\downarrow$$

For each convolved map, estimate noise variance per pixel

MAP-BASED NOISE SIMS



Azimuthally symmetric part has been subtracted



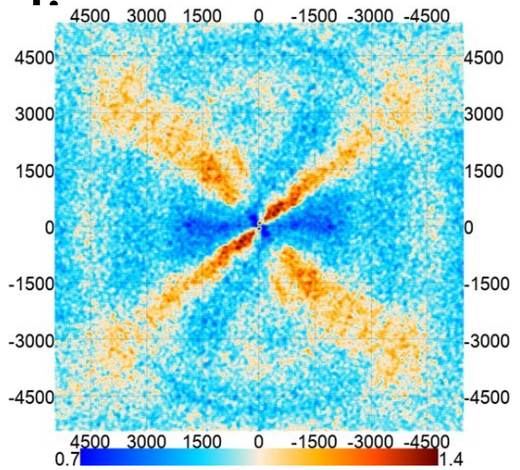
Differenced **data** for split 1/8 PA5 f090. Stokes I and Q

image credit: Zach Atkins

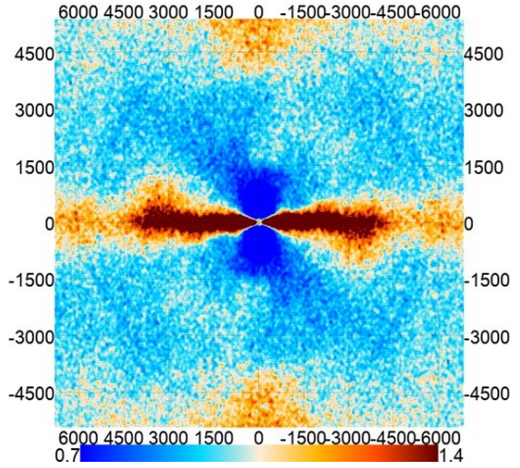
MAP-BASED NOISE SIMS

Mean of 10 sims

1.



2.



Azimuthally symmetric
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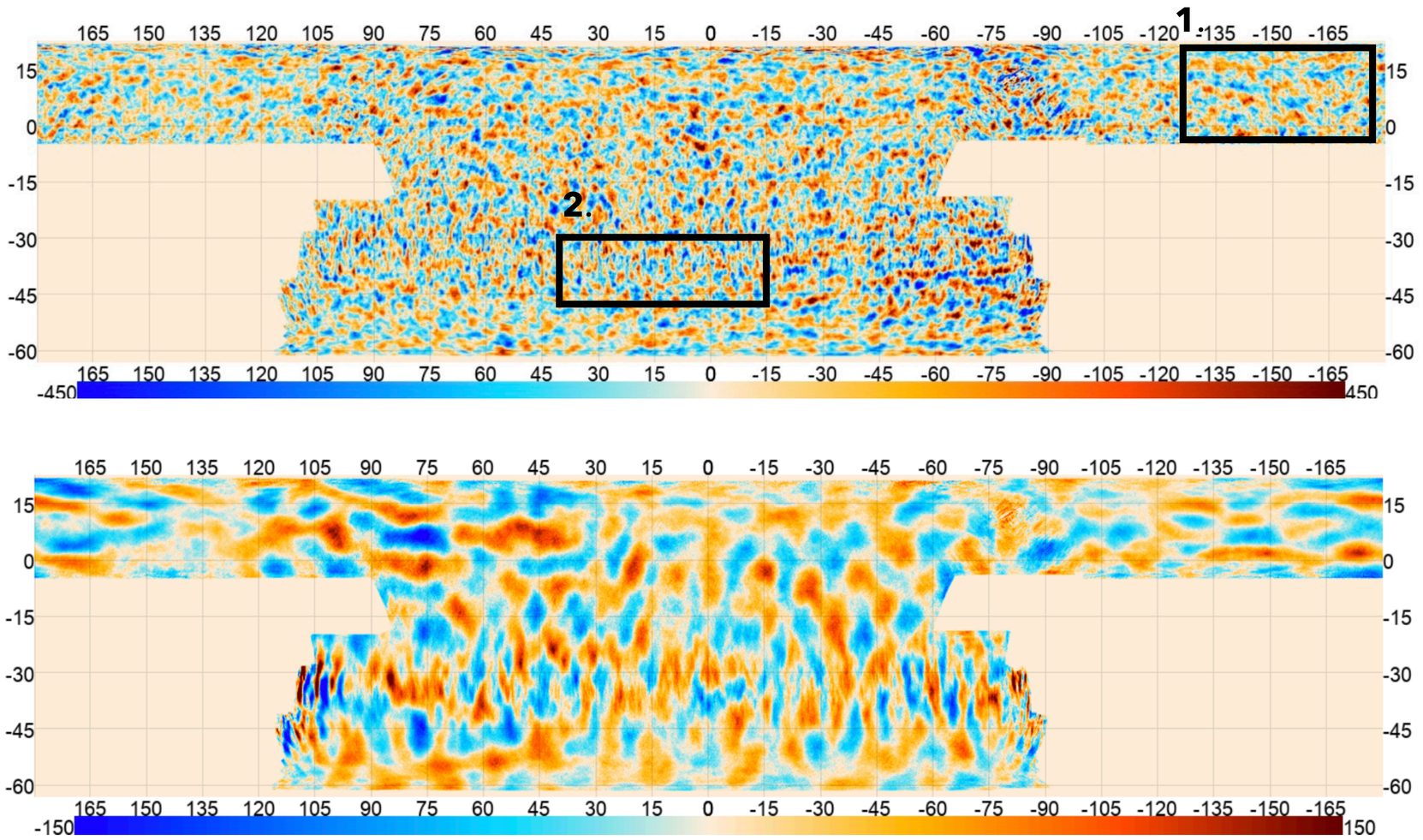

Sim for split 1/8 PA5 f090. Stokes I and Q

image credit: Zach Atkins

SUMMARY

- ACT DR4 & DR5 data available, DR6 analysis is underway
  - Wide range of science, inc. lensing, cluster science (tSZ, kSZ), time-domain astronomy, bispectrum, cross-correlations with galaxy surveys
  - DR6 lensing power spectrum results coming soon
  - DR6 power spectrum analysis + data release coming later (hoping end of 2022)
- ACT pipeline
  - Influence of wind speed/direction on atmospheric noise contribution
  - Map-based noise simulations: wavelet-based noise model