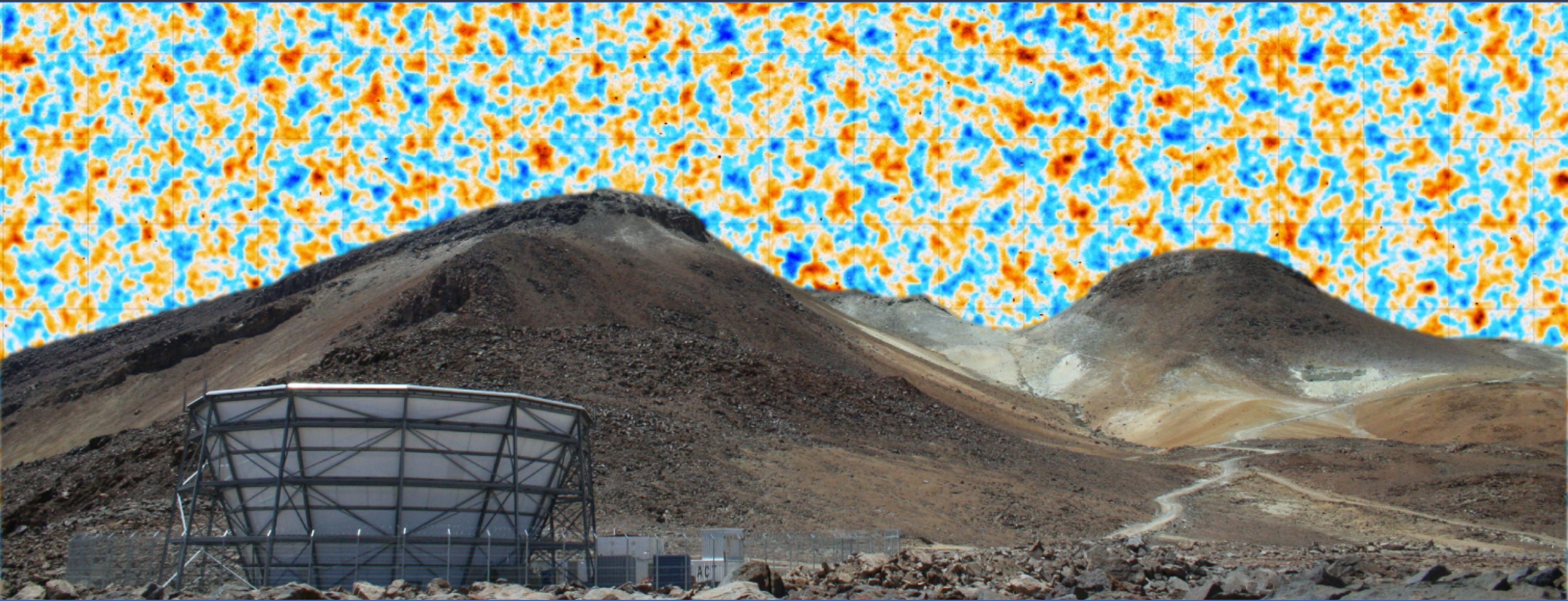


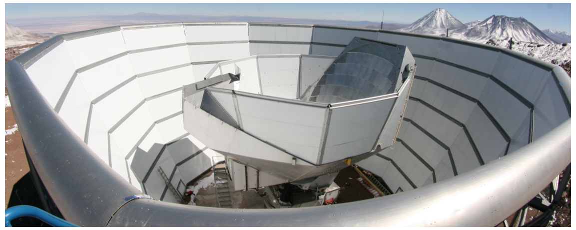
Maximum-likelihood Map-Making for ACTPol/AdvACT

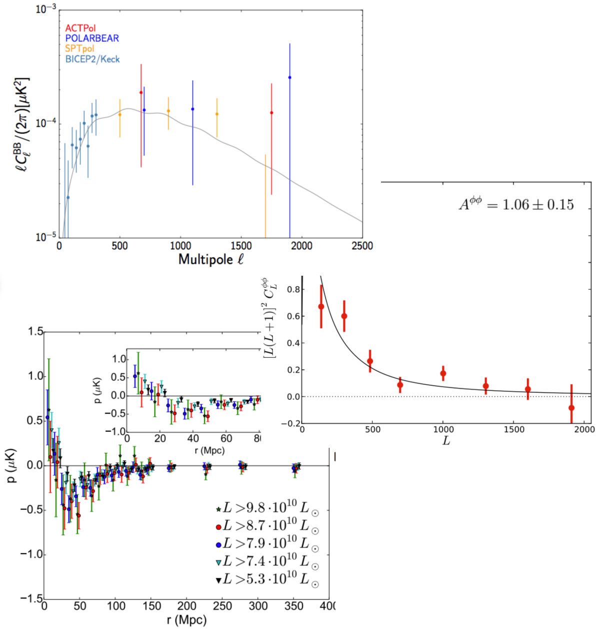
Simone Aiola – Princeton University

19 July 2017 – Nordita

ACTive Team

Outline





1. From time-ordered data to <u>unbiased maximum-likelihood maps</u>

2. Controlling systematics in the map-maker: <u>high-fidelity maps for the community (and the team)</u>

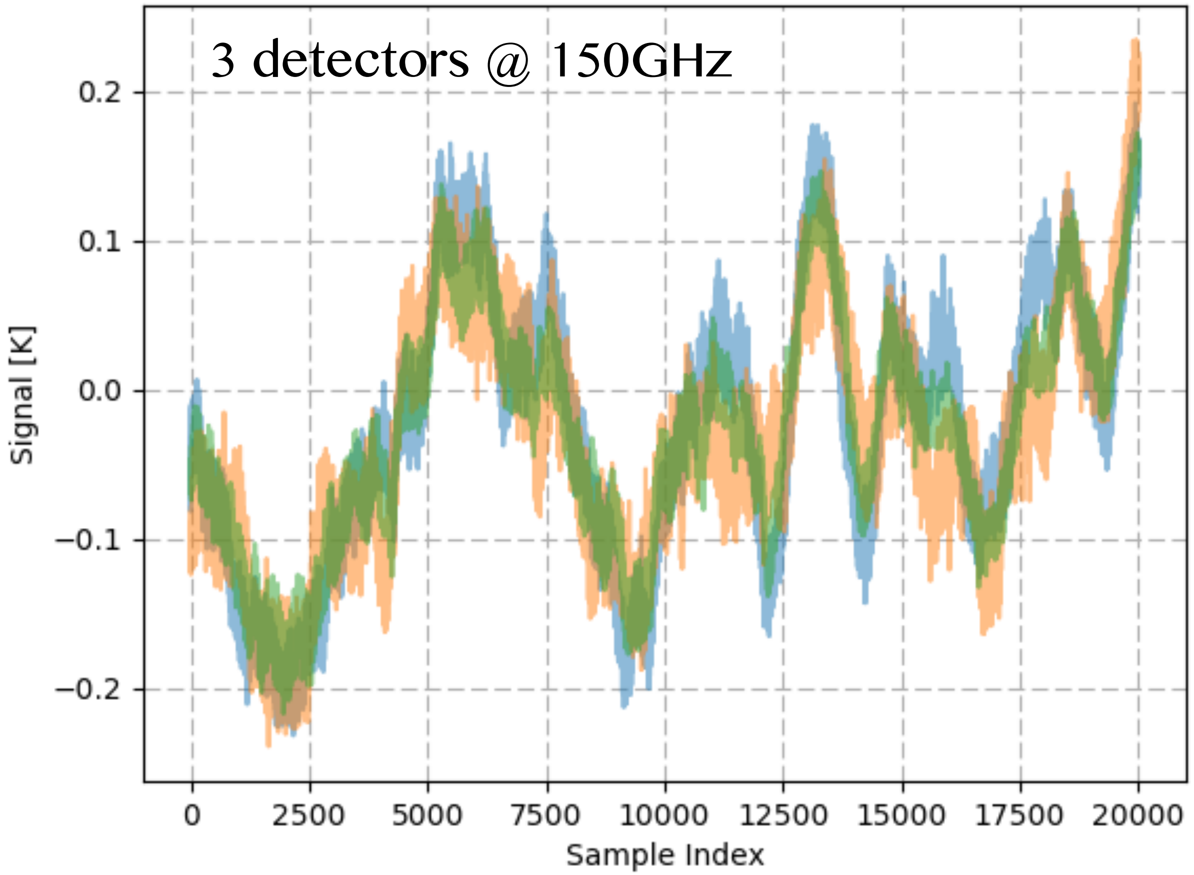
3. <u>From big maps to huge maps</u> → comparison with Planck + map-making challenge for Simons Observatory

Atacama Cosmology Telescope

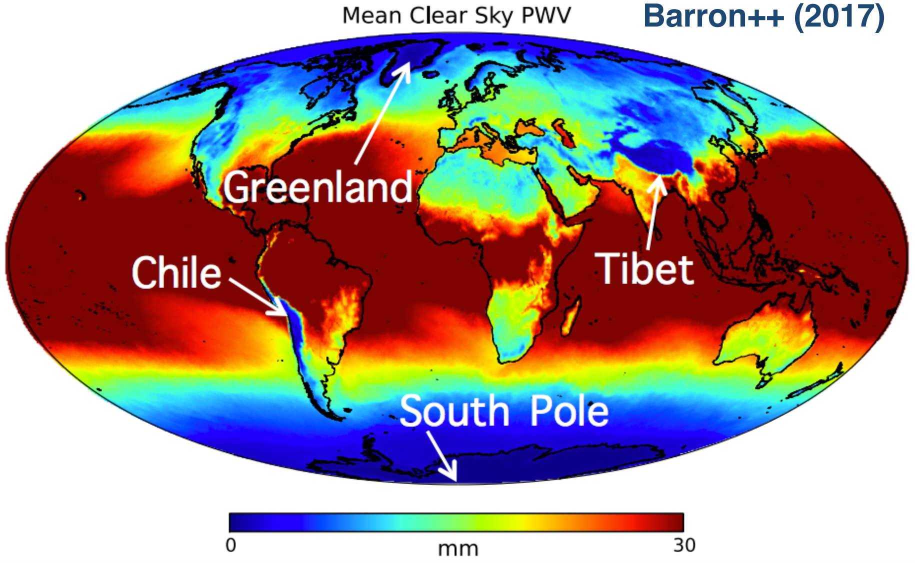
Courtesy of the Simons Foundation

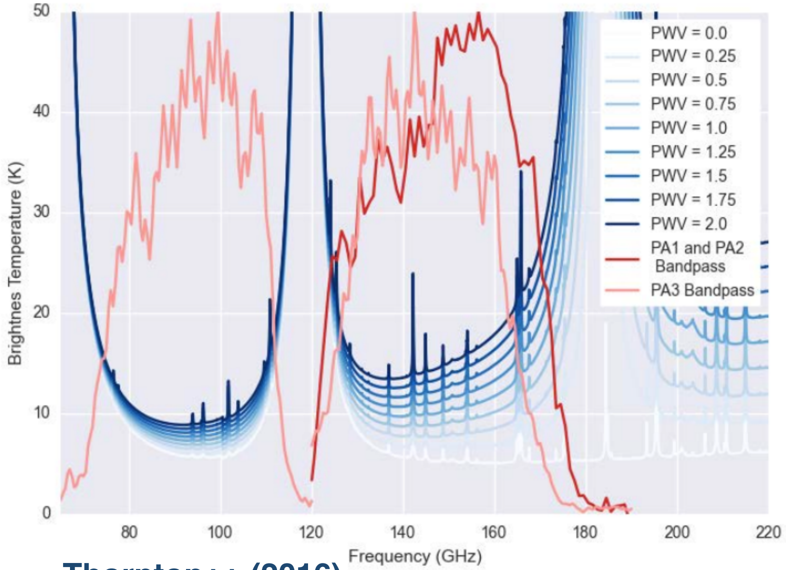
CMB Data for Cosmology (not quite…)

Atmosphere | Foregrounds | TT, EE, BB + Systematics



Barron++ (2017)





Thornton++ (2016)

Map-making (i.e. linear algebra)

- We need to go **from time-ordered data to a sky map**.

Model for the data:

$$d_t = A_{t,p}\, m_p + n_t$$

Basic assumption:

$$\langle d_t \rangle = A_{t,p}\, m_p$$

Requires manipulation of the raw time-streams

- We can write a simple Gaussian likelihood, **noise covariance** matrix needs to be estimated from the data (in Fourier space)

$$\ln \mathcal{L} \propto (d_t - \langle d_t \rangle)^T \boxed{N^{-1}} (d_t - \langle d_t \rangle)$$

$$(A^T N^{-1} A)m = A^T N^{-1} d$$

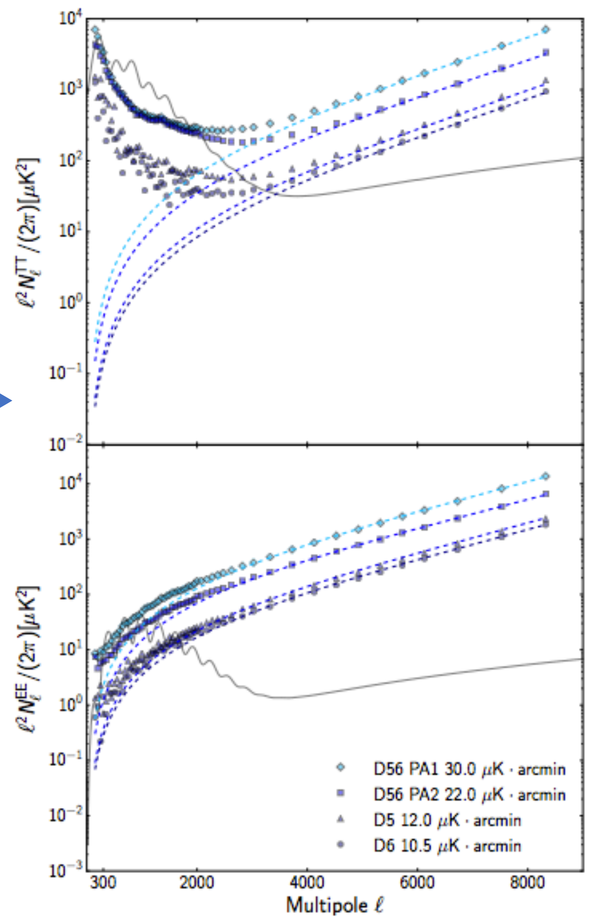
1 TOD

- Some (big) numbers that make a direct inversion impossible.

Resolution + f_{sky}

$$n_{\text{samp}} \cdot n_{\text{det}} = 10^5 \cdot 10^3$$

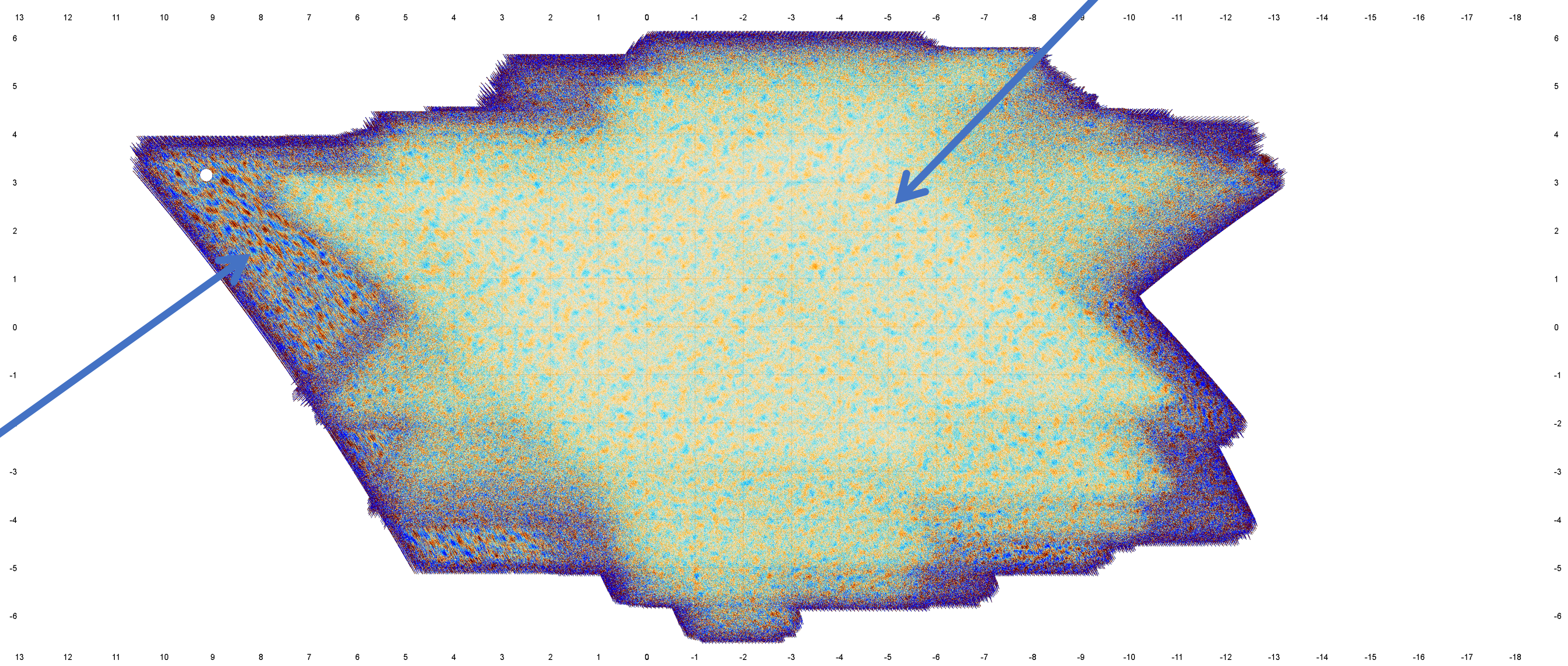
- This linear system can be solved with (preconditioned) conjugate gradient.



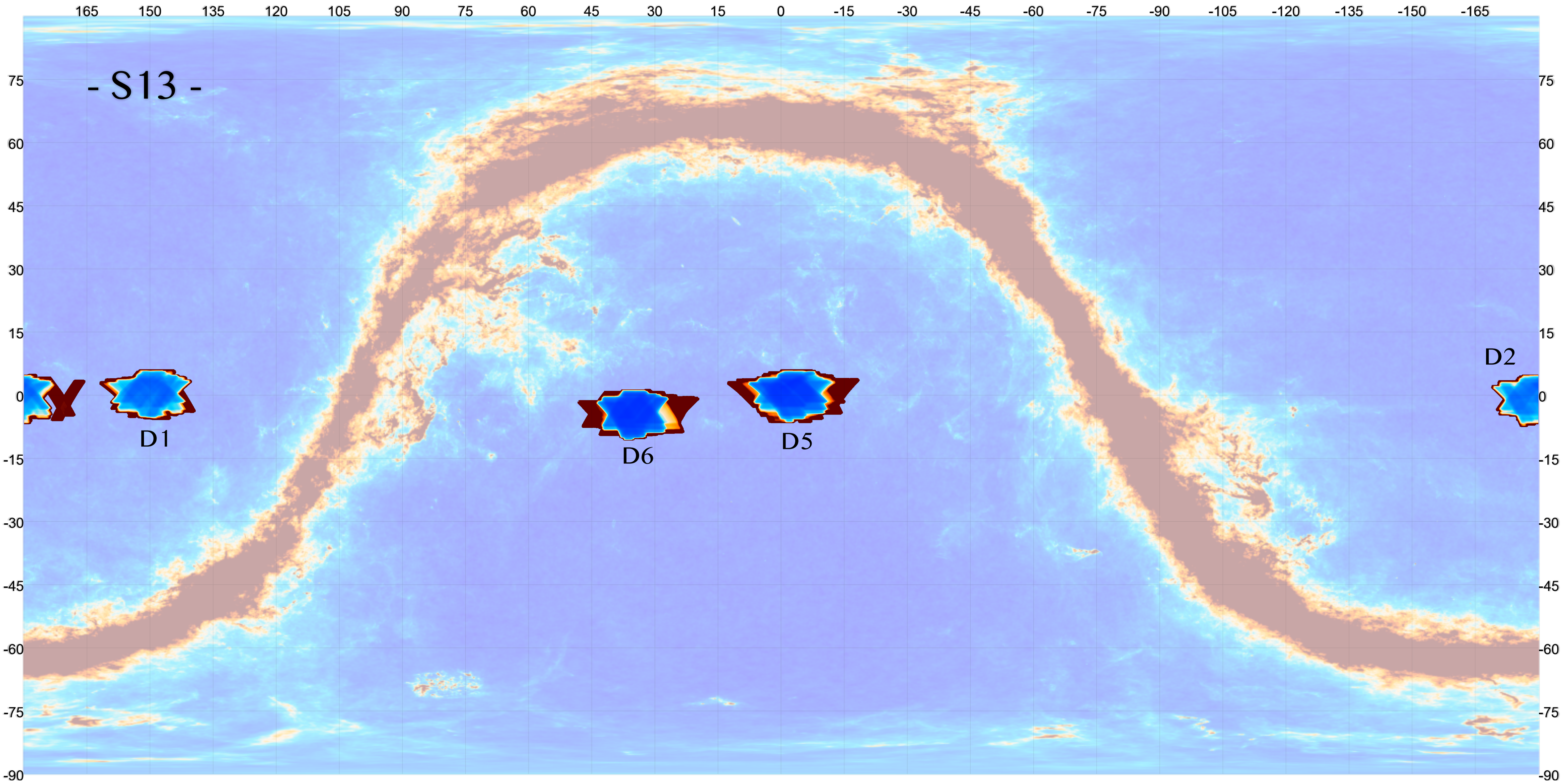
Louis++ (2016)

Go Downhill (with ACT Gods)

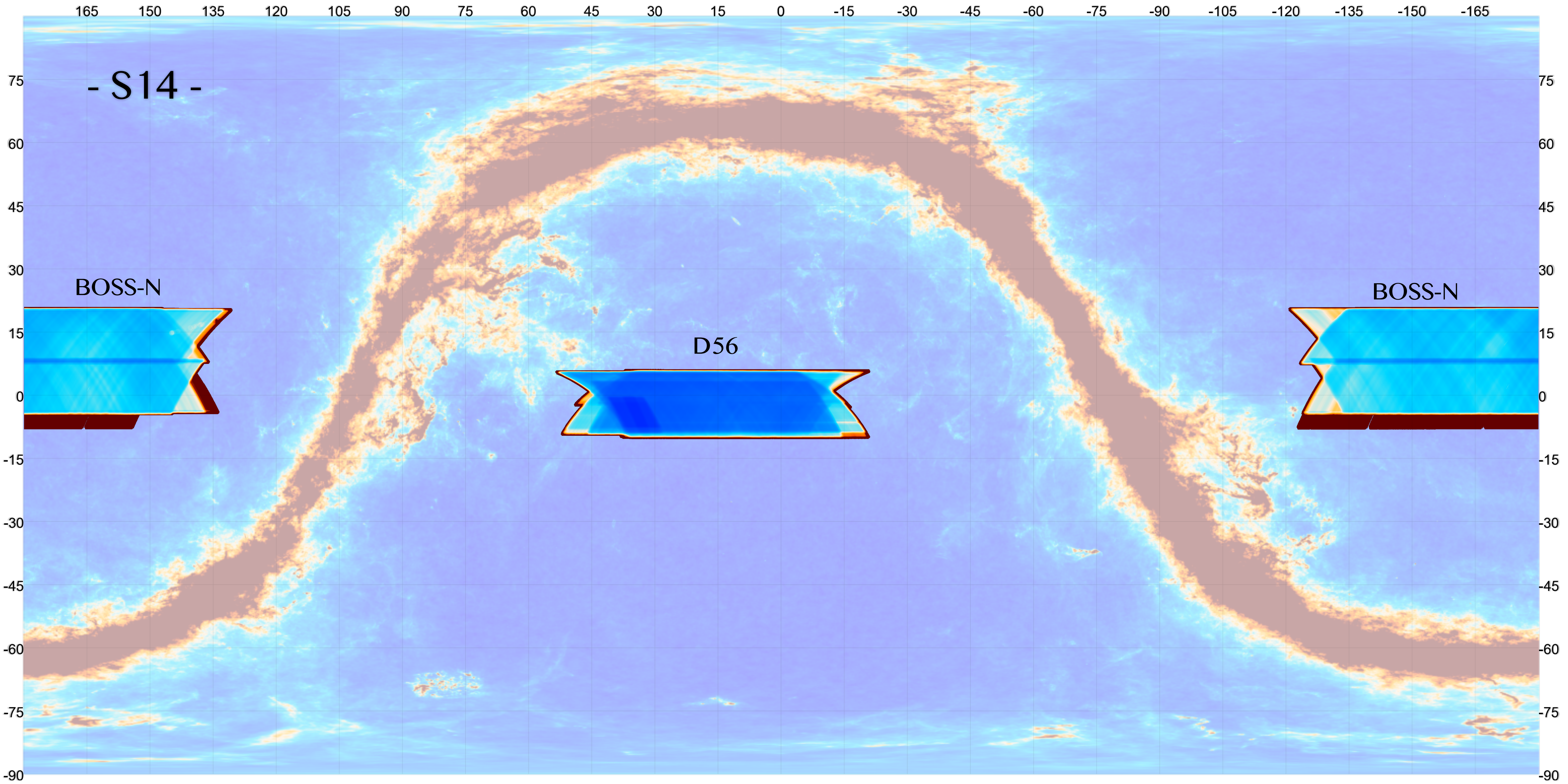
- We start from a biased map, and we converge to the true unbiased solution (small scales first).
- We can recover scales larger than the first acoustic peak (we take spectra $100 < \ell < 9000$).
- We are unbiased for $\ell > 500(350)$ for T(P).
- Straightforward to compute the transfer function.



ACT Footprint

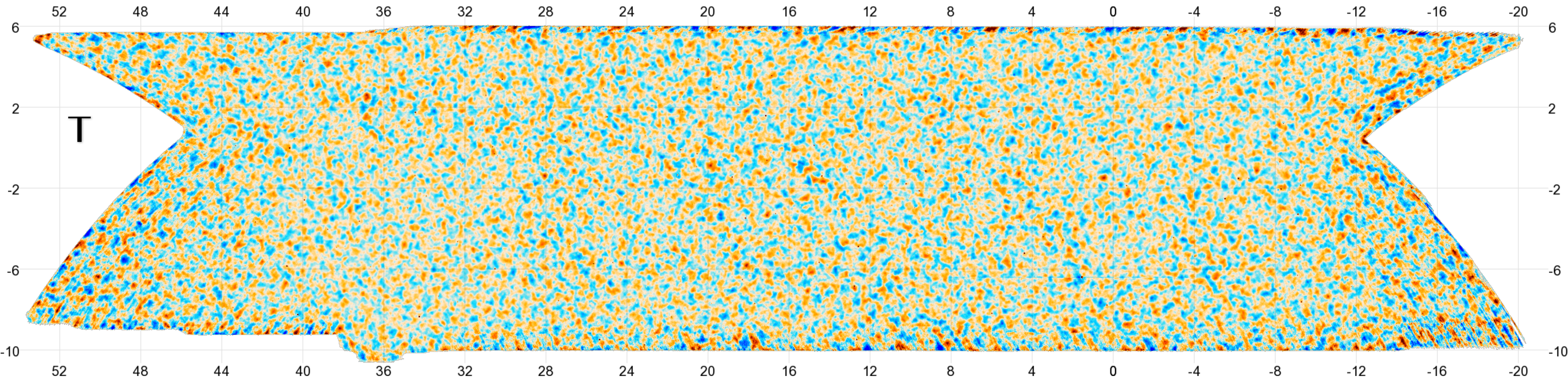


ACT Footprint



CMB D56 Maps

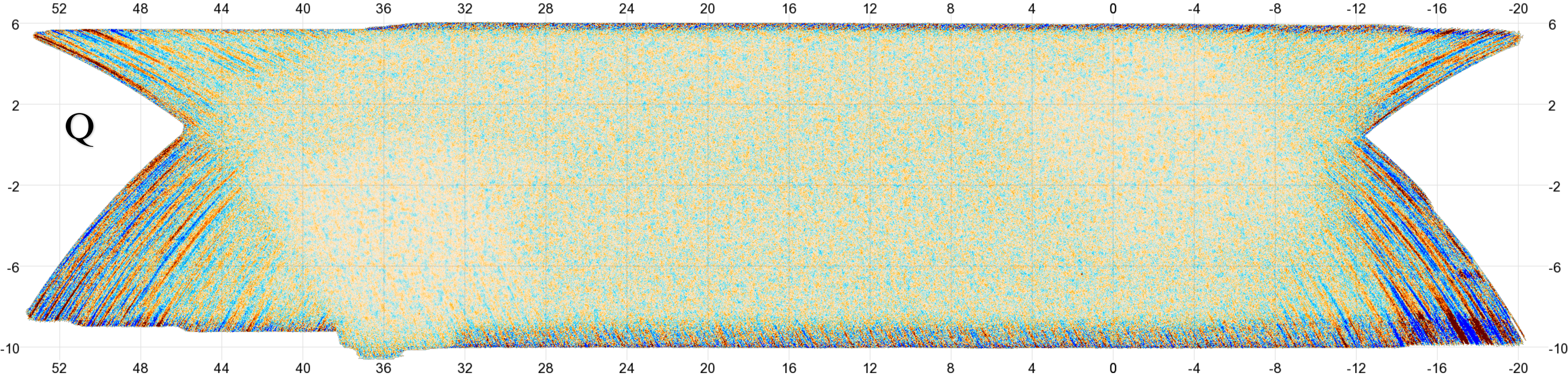
- High signal-to-noise measurement of temperature and polarization fluctuations
- Highlighting only unbiased scales



~ 600 sq-deg mapped on 0.5 arcmin pixels → 18 x 10^6 pixels !

CMB D56 Maps

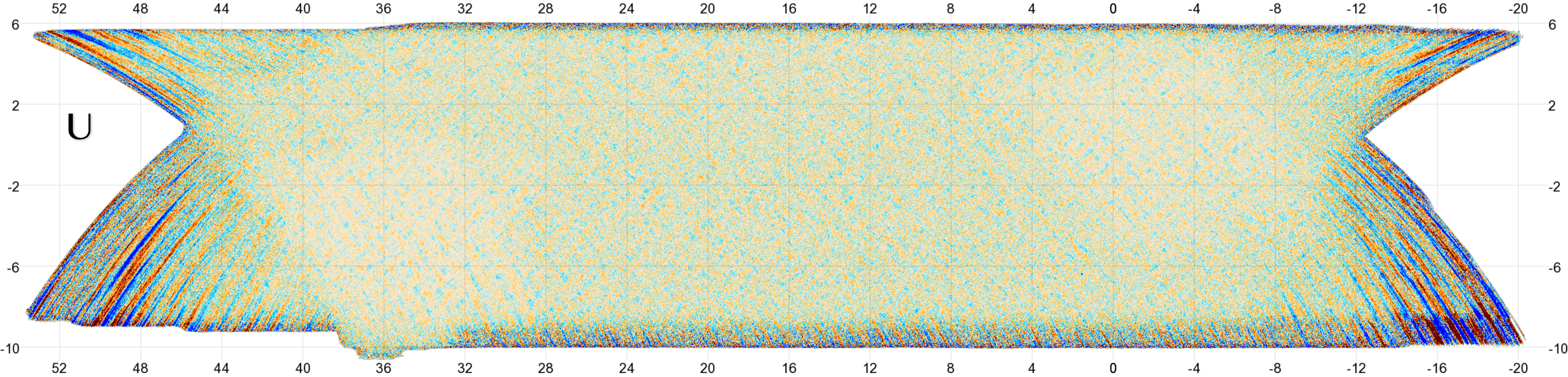
- High signal-to-noise measurement of temperature and polarization fluctuations
- Highlighting only unbiased scales



~ 600 sq-deg mapped on 0.5 arcmin pixels → 18 x 10^6 pixels !

CMB D56 Maps

- High signal-to-noise measurement of temperature and polarization fluctuations
- Highlighting only unbiased scales

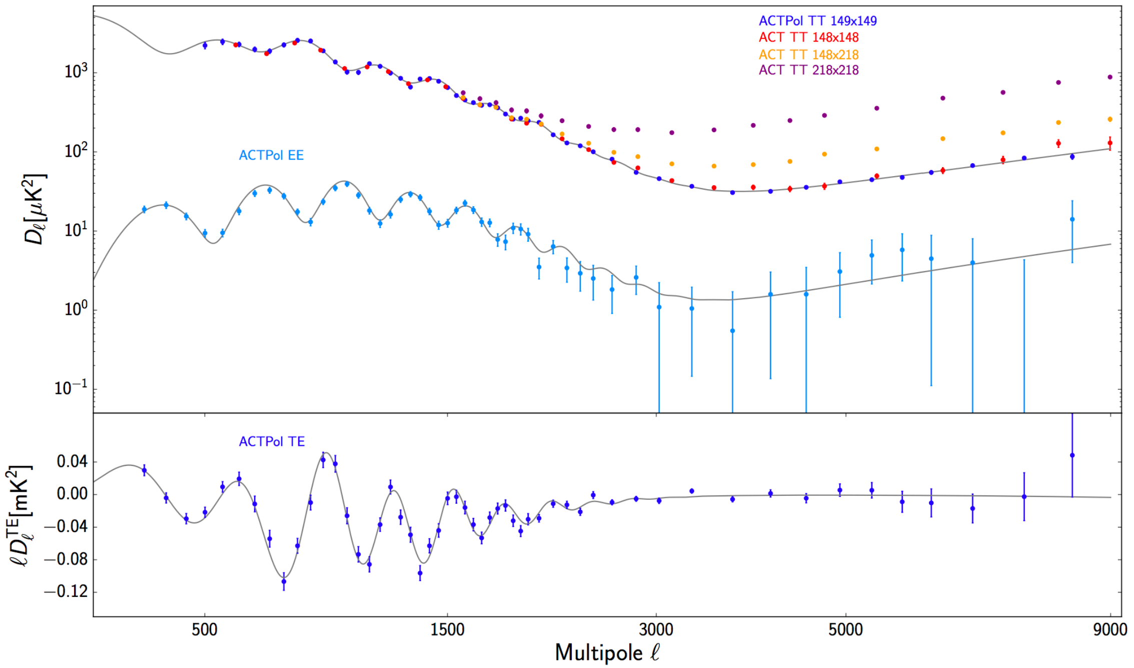


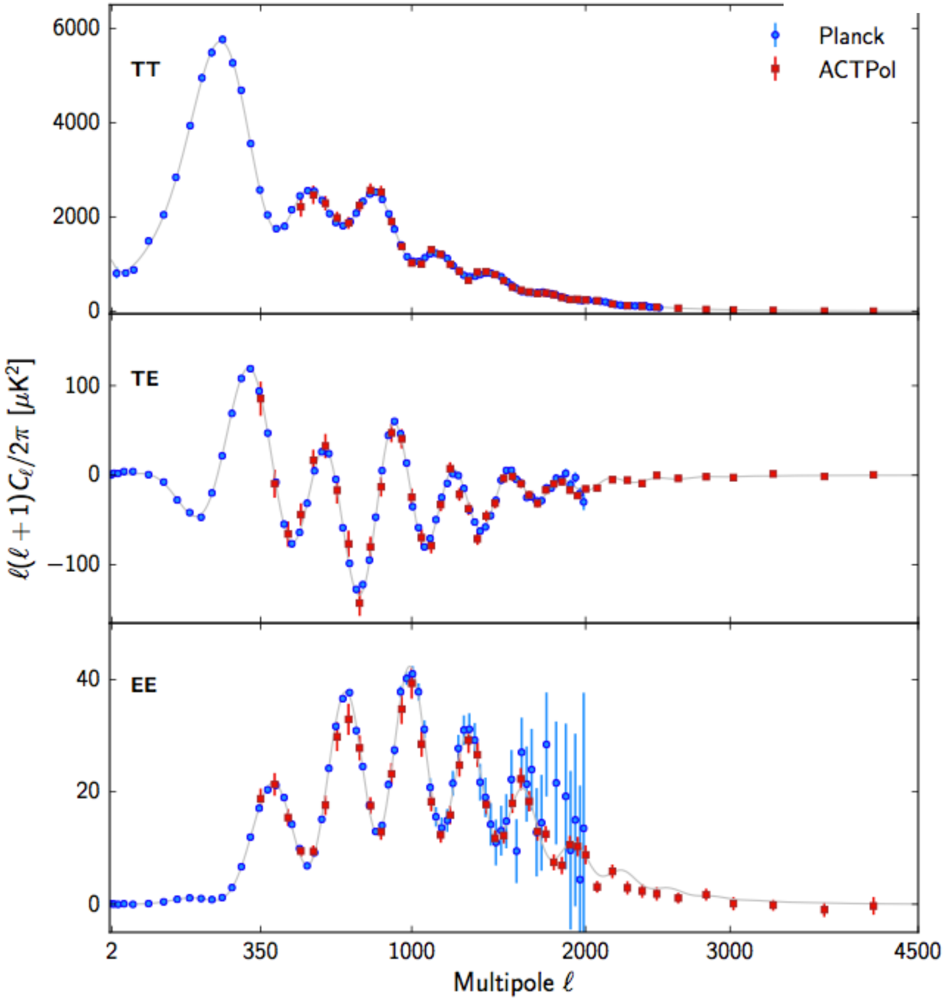
~ 600 sq-deg mapped on 0.5 arcmin pixels → 18 x 10^6 pixels !

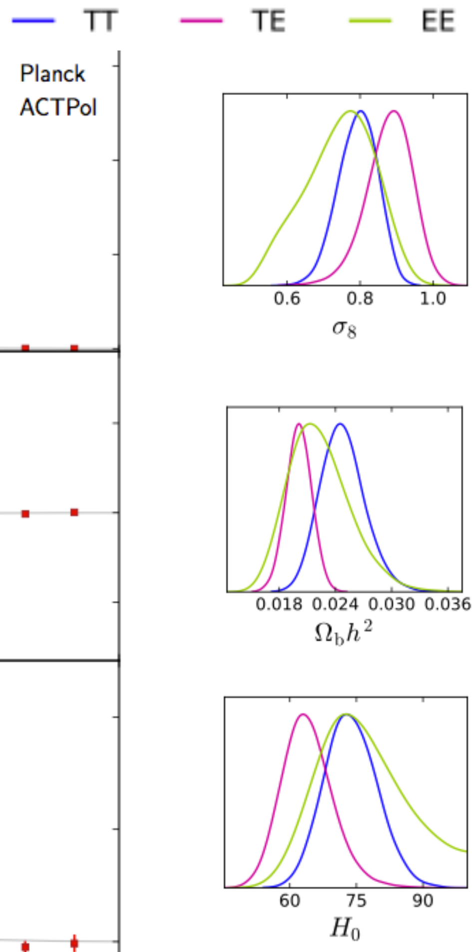
CMB D56 Spectra

Polarization is starting to dominate the constraints on some cosmological parameters

Louis++ (2016)



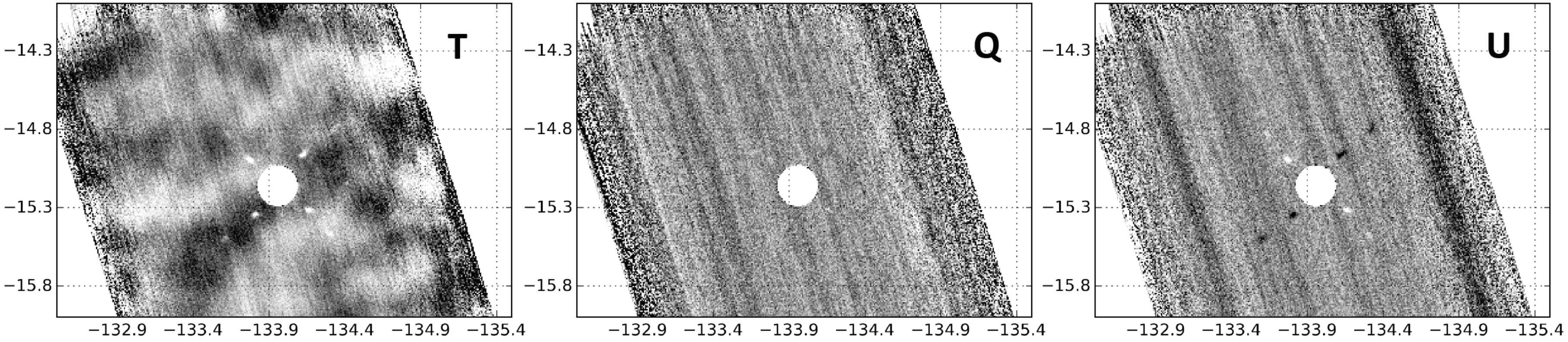


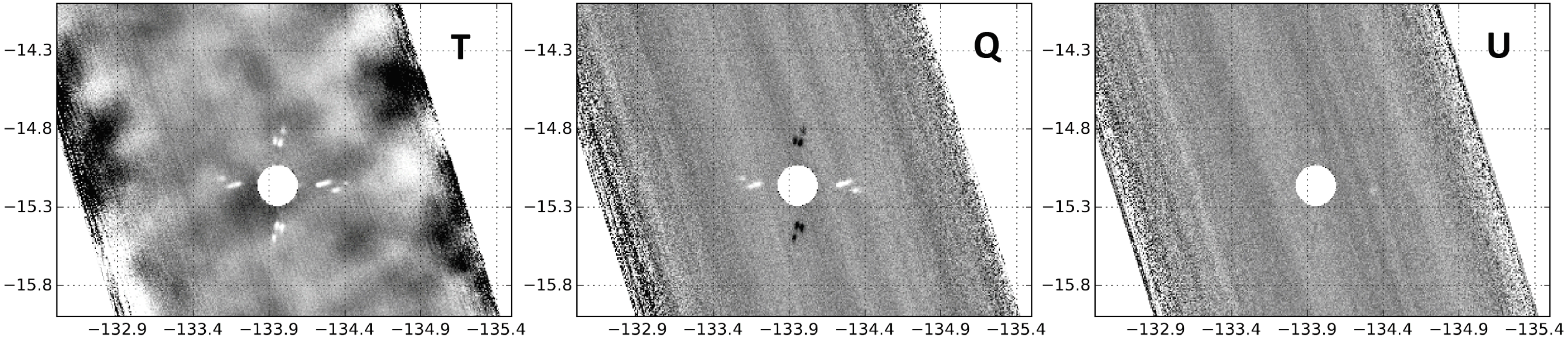


Raw cross-spectra → FG-marginalized spectra → Parameters

Sidelobes Removal

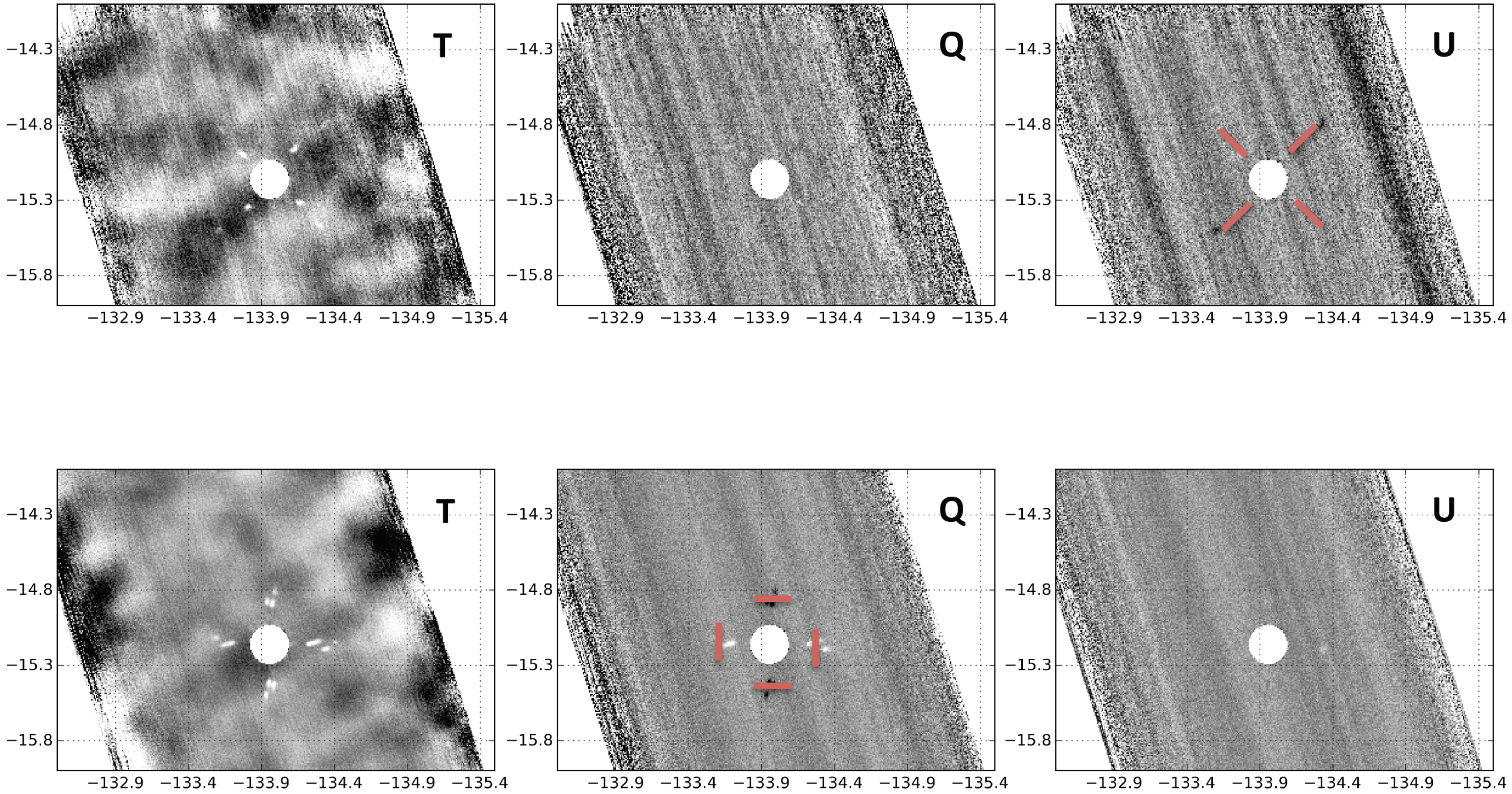
- Atmospheric noise (T) leaking into E polarization noise → signal must do the same.
- Observations of bright planets allowed us to model and remove this leakage effect.





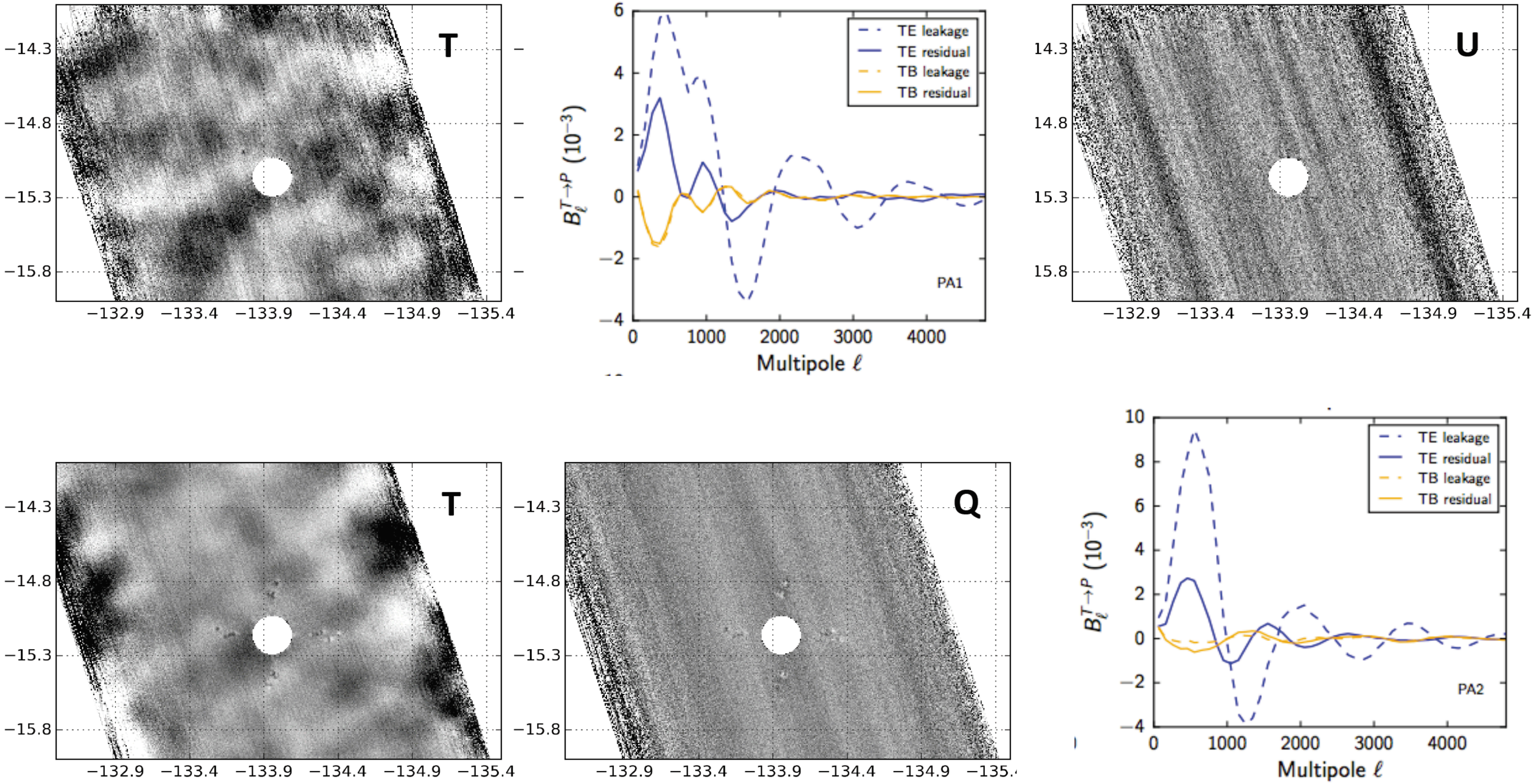
Sidelobes Removal

- Atmospheric noise (T) leaking into E polarization noise → signal must do the same.
- Observations of bright planets allowed us to model and remove this leakage effect.



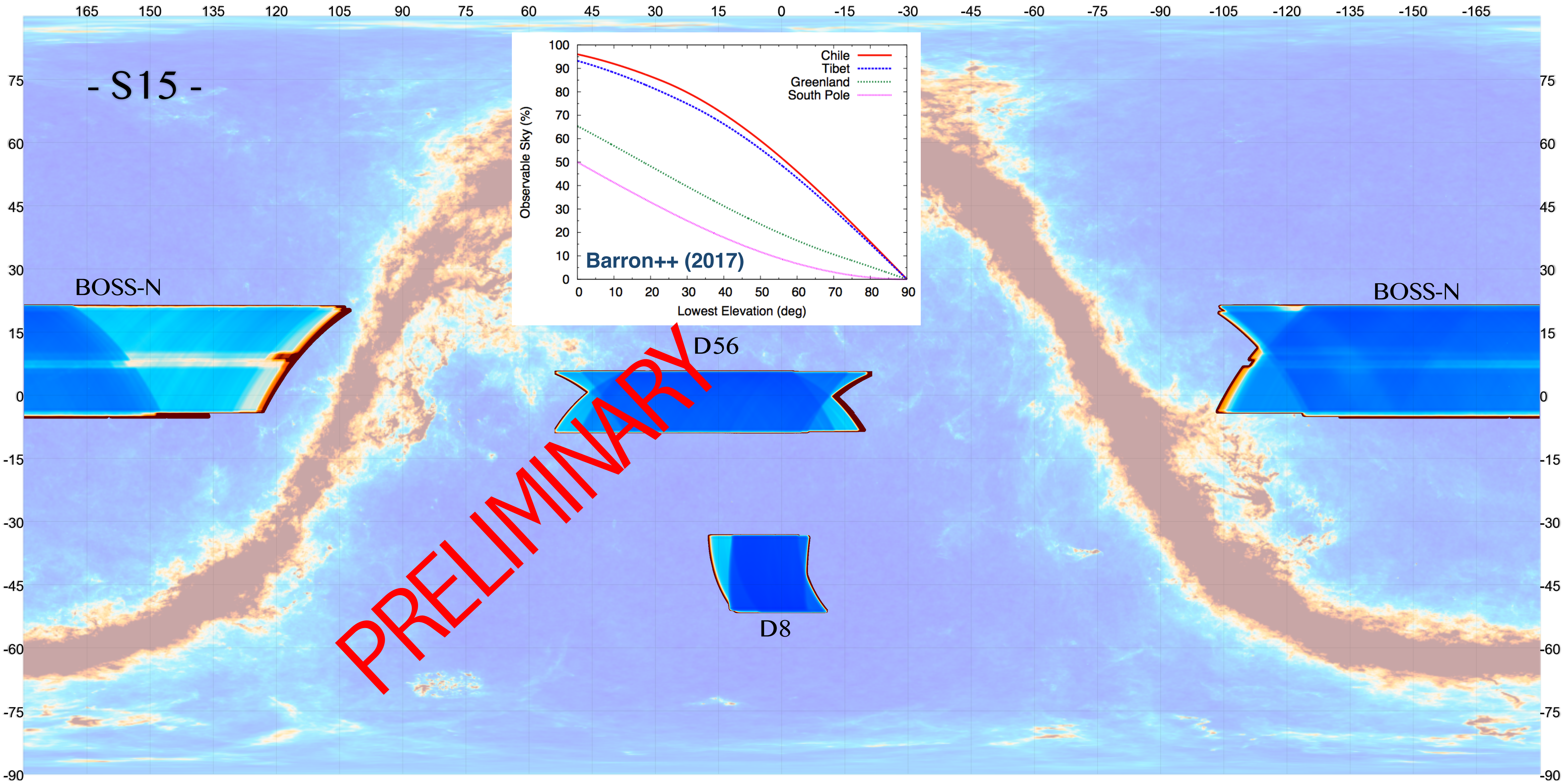
Sidelobes Removal

- Atmospheric noise (T) leaking into E polarization noise → signal must do the same.
- Observations of bright planets allowed us to model and remove this leakage effect.

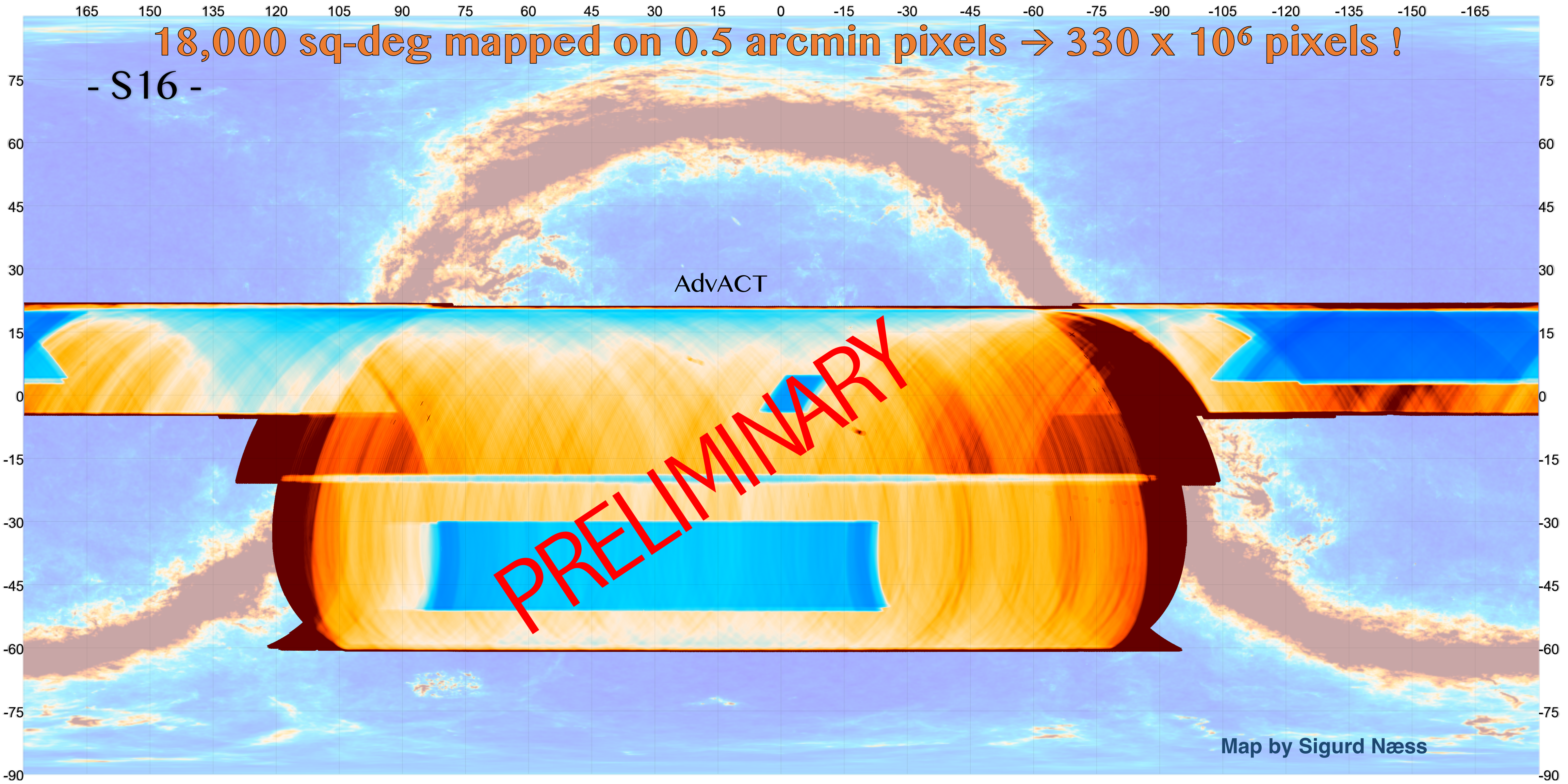


Louis++ (2016)

ACT Footprint

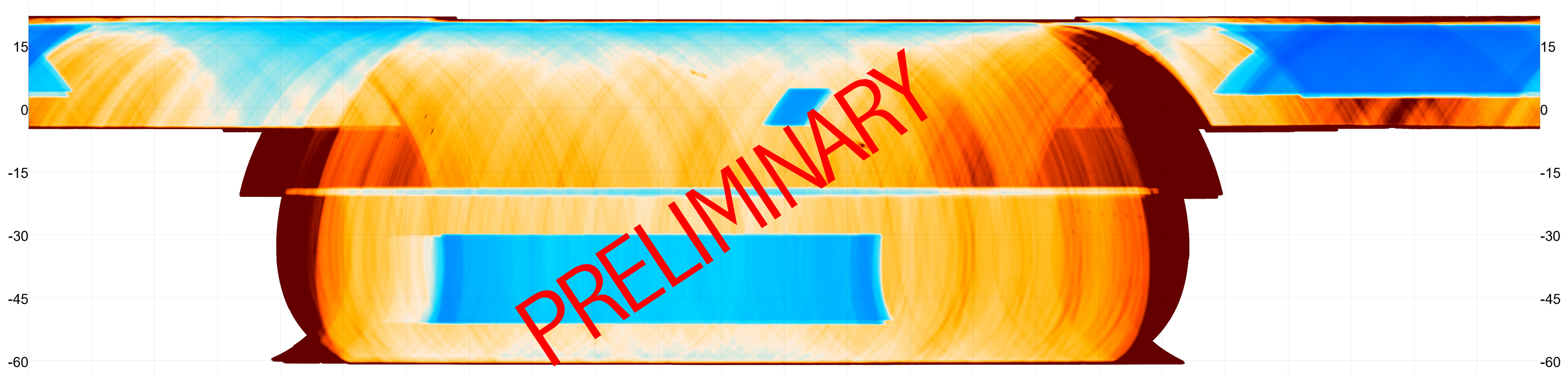


ACT Footprint



Temperature Map @ 150GHz

18,000 sq-deg mapped on 0.5 arcmin pixels → 330 x 10^6 pixels !



<u>S16</u>

PA2 @ 150 GHz
PA3 @ 90 / 150 GHz
HF @ 150 / 220 GHz

<u>S17</u>

MF @ 90 / 150 GHz
MF @ 90 / 150 GHz
HF @ 150 / 220 GHz

<u>S18</u>

LF @ 28 / 41 GHz
MF @ 90 / 150 GHz
HF @ 150 / 220 GHz

Conclusions

- We produce maximum-likelihood temperature and polarization maps:
  - Two independent pipelines working on several computing clusters
  - Unbiased at multipoles bigger than 350(500) for P(T)
  - Systematics are treated in the map-making step
  - Easy to interpret, to work with, and to share with the community (go online !)
- We cover roughly 18,000 sq-deg at different frequencies:
  - Non-trivial cross-check of Planck results
  - Small-scale foregrounds (of interest especially for lensing)
  - Neutrino science via lensing and high-ell
  - Clusters, tSZ, kSZ and tons of cross-correlations
  - SO/CMB-S4 target such large areas → feasible to work with 330 million pixels