Multi-frequency power spectra
From the 2008 South Pole Telescope data

Erik Shirokoff

Cosmology in Northern California
Lawrence Berkeley National Laboratory
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KICP
Kavli Institute for Cosmological Physics at the University of Chicago

Berkeley
University of California

ASTRONOMY
University of Illinois at Urbana-Champaign

Case
Case Western Reserve University

McGill

The University of Chicago

Harvard-Smithsonian Center for Astrophysics

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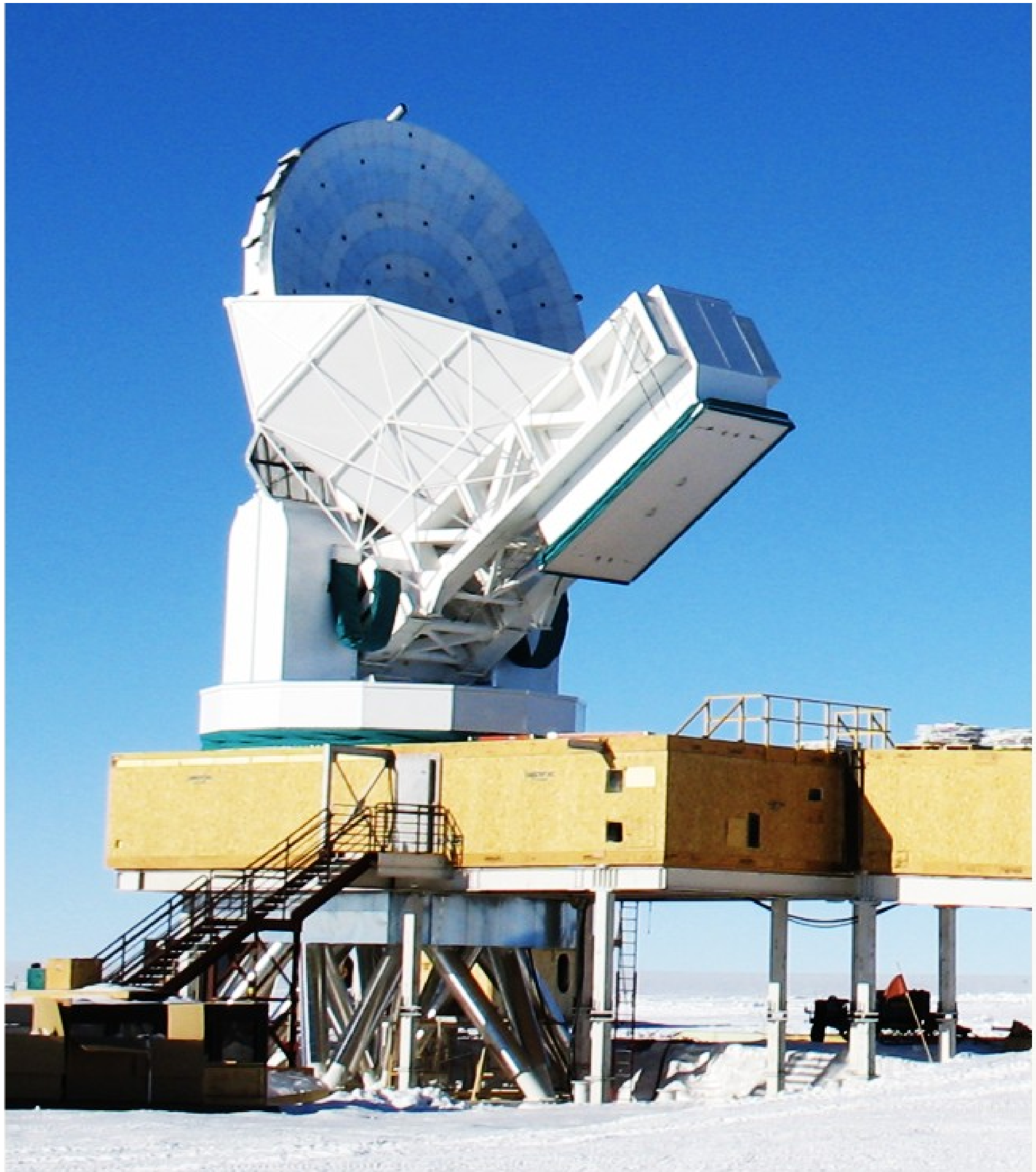
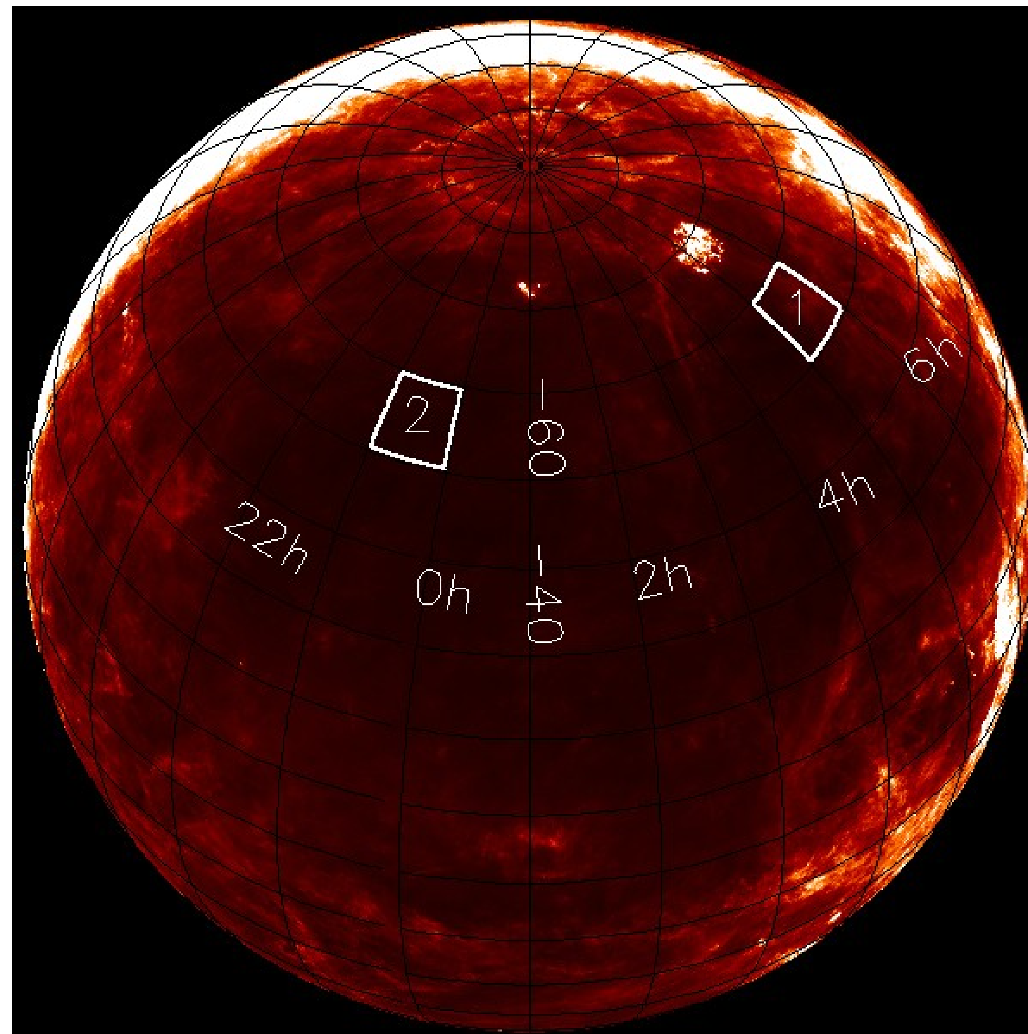


•10 meter, dedicated telescope

•1.1 arcmin beams at 150 GHZ

•960 horn coupled spider-web Transition Edge Sensor bolometers

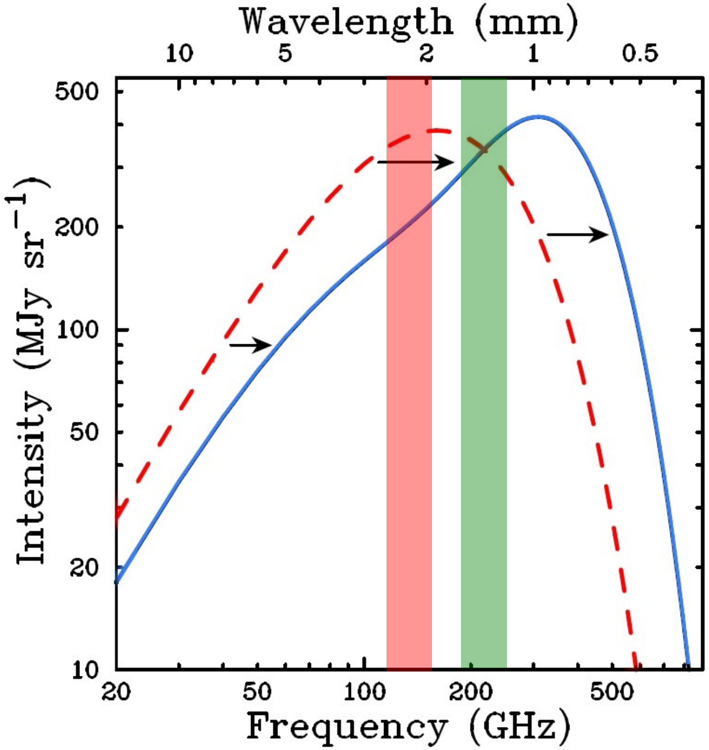
•In 2008, we observed in two bands at 150 and 220 GHz



200 square degrees

18 μK arcmin at 150 GHz

40 μK arcmin at 220 GHz

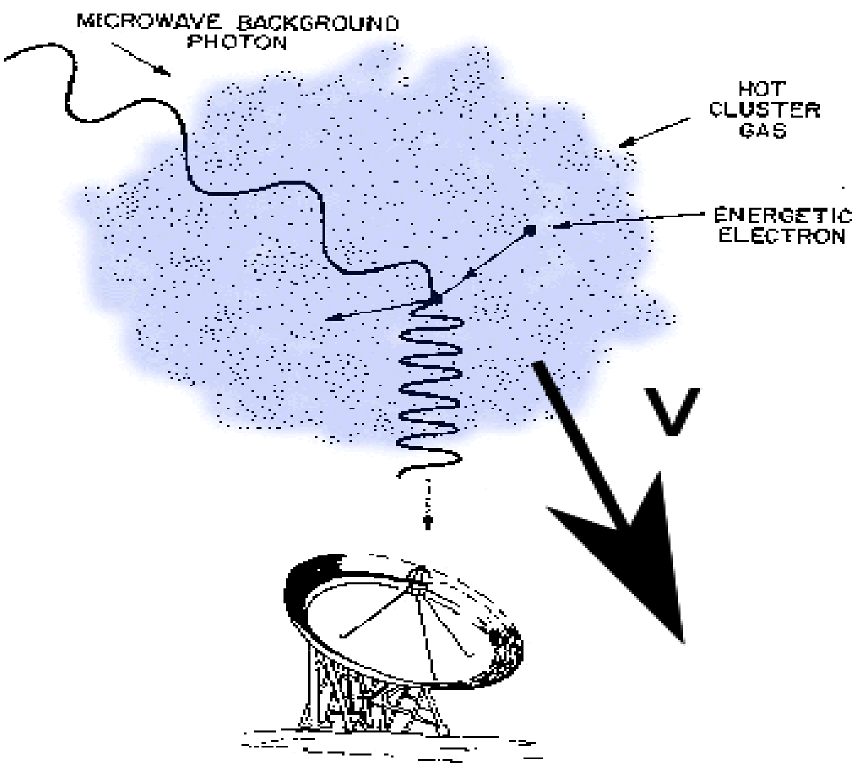


Thermal Sunaev-Zel'dovich effect

CMB photons inverse Compton scatter off hot electrons in galaxy clusters.

$$\Delta T \propto f(h\nu/kT_{CMB}) \cdot y$$

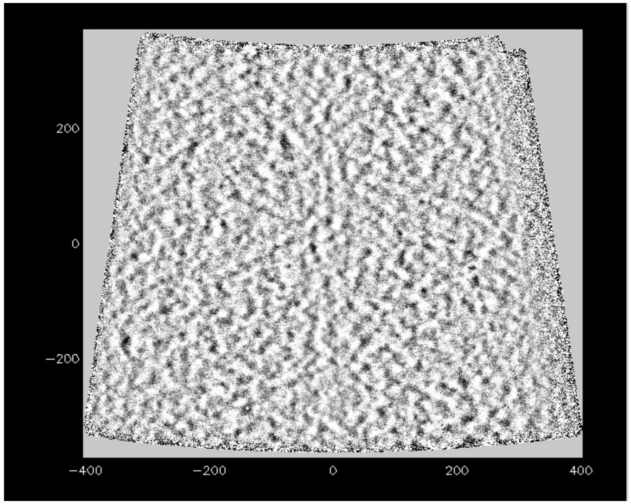
$$y = \sigma_{\mathrm{T}} \int dl \; n_e \frac{kT_e}{m_e c^2}$$

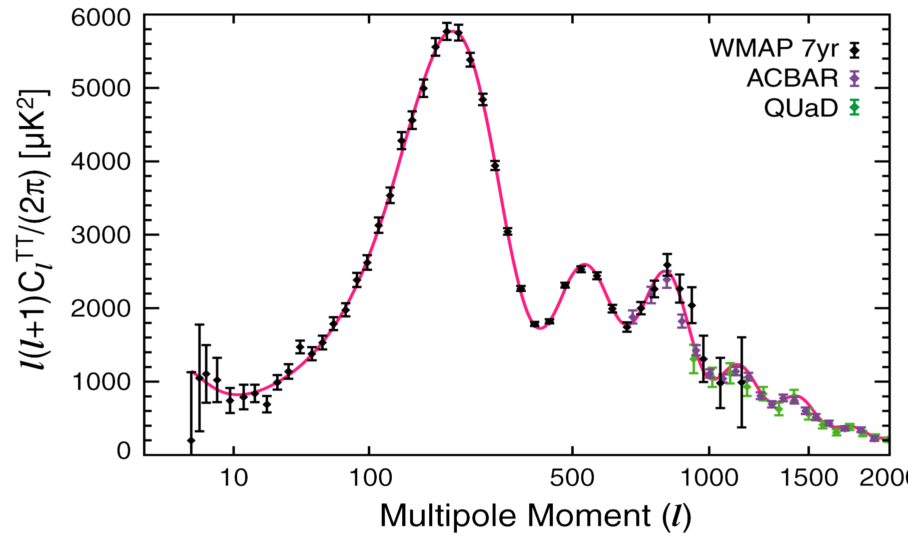


Kinetic Sunaev-Zel'dovich effect

Doppler shift due to proper motion of ionized gas

$$\Delta T \propto \sigma_{\mathrm{T}} \int dl n_e \frac{v_{\|}}{c}$$





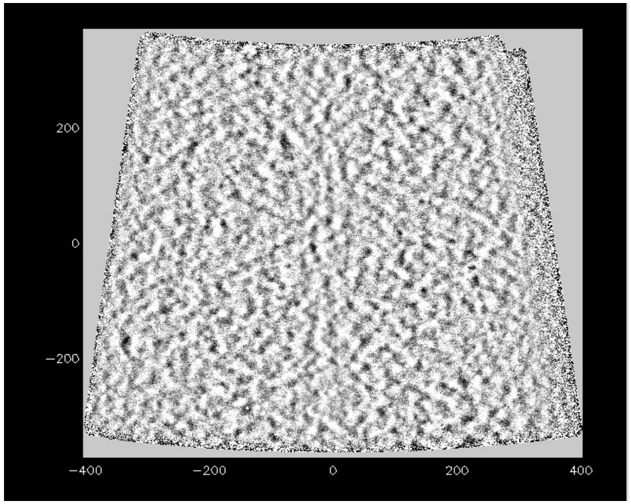
$$T(\hat{n}) = \sum a_{\ell m} Y_{\ell m}(\hat{n}) \qquad C_\ell = \frac{1}{2\ell+1} \sum_{m=-\ell}^{\ell} < a_{\ell m} a^*_{\ell m} >$$

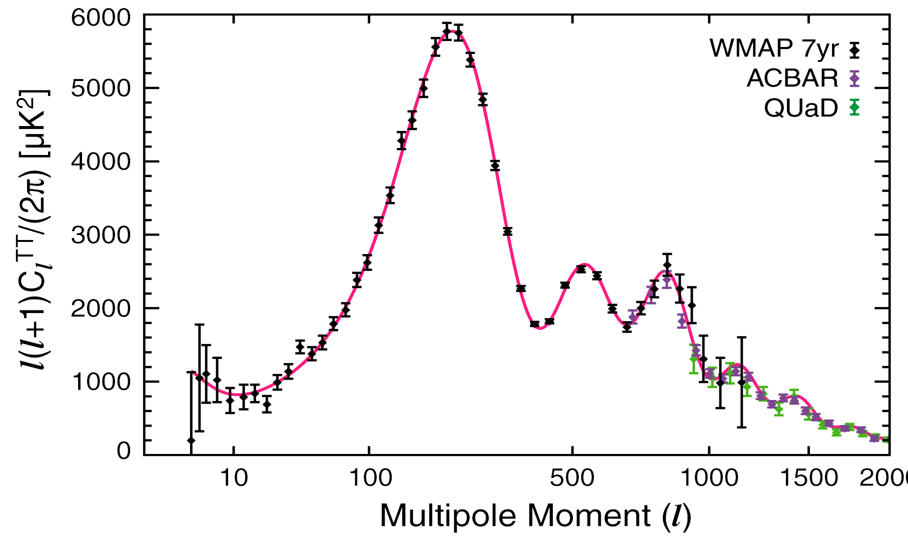
$\mathrm{Psuedo} - C_\ell$ analysis: Calculate FFT of maps, then include

- Beams
- TOD Filtering
- Map area
- Source masking

$$< \tilde{C}^{ii}_\ell > = \sum_{\ell'} M_{\ell \ell'}[W] F_{\ell'} B^2_{\ell'} < C_{\ell'} > + < N_\ell >$$

(using formalism from Hivon 2002)





Cross Spectrum analysis:

- Use a single two-hour observation as a map unit.
- Calculate cross spectra between all maps of a given field.

  Average contains no noise bias.

  Measure instrumental noise directly.

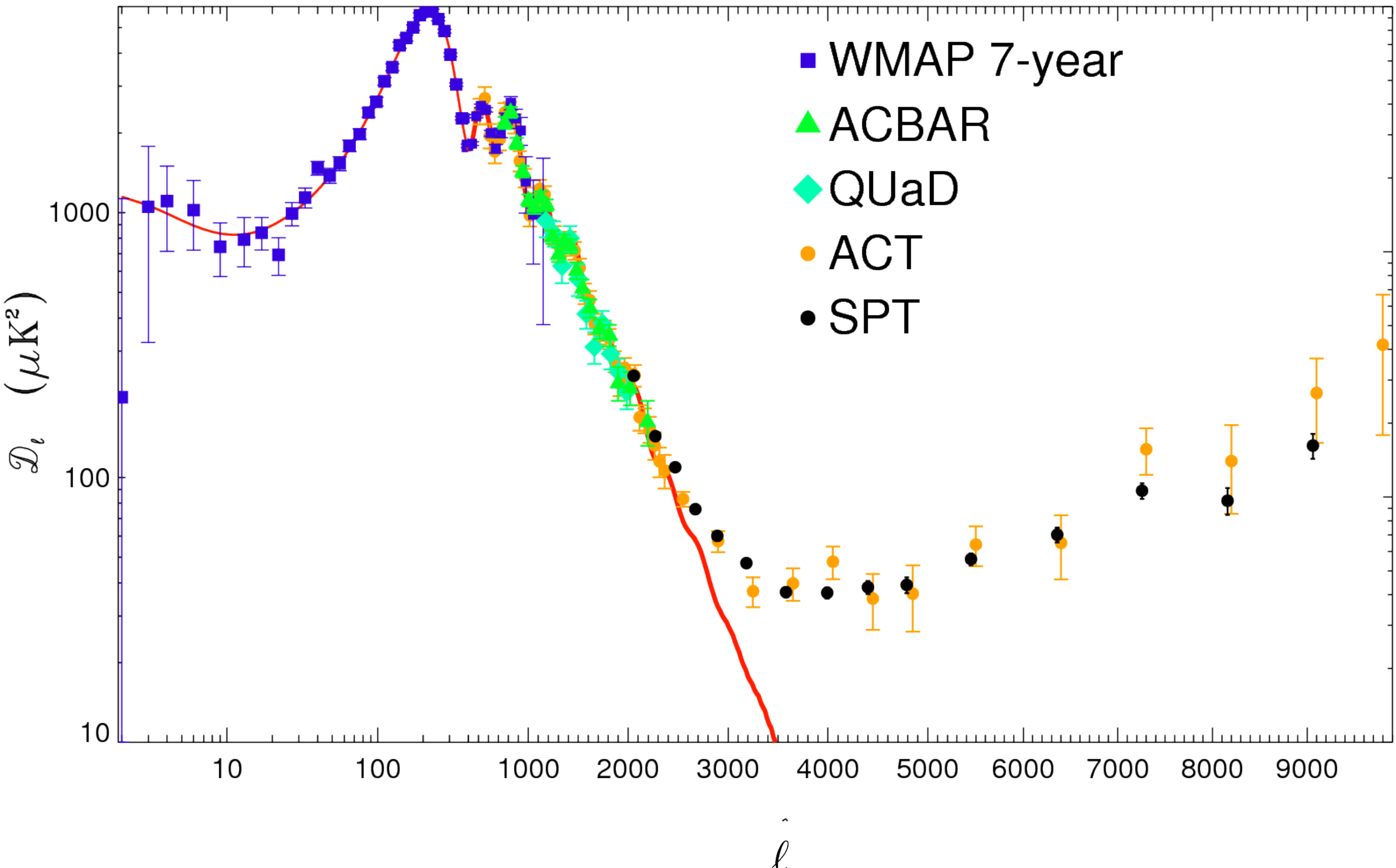
- Need to account for sample variance:

  Generate hundreds of signal-only simulated maps.

(see Polenta 2005; Tristram 2005)

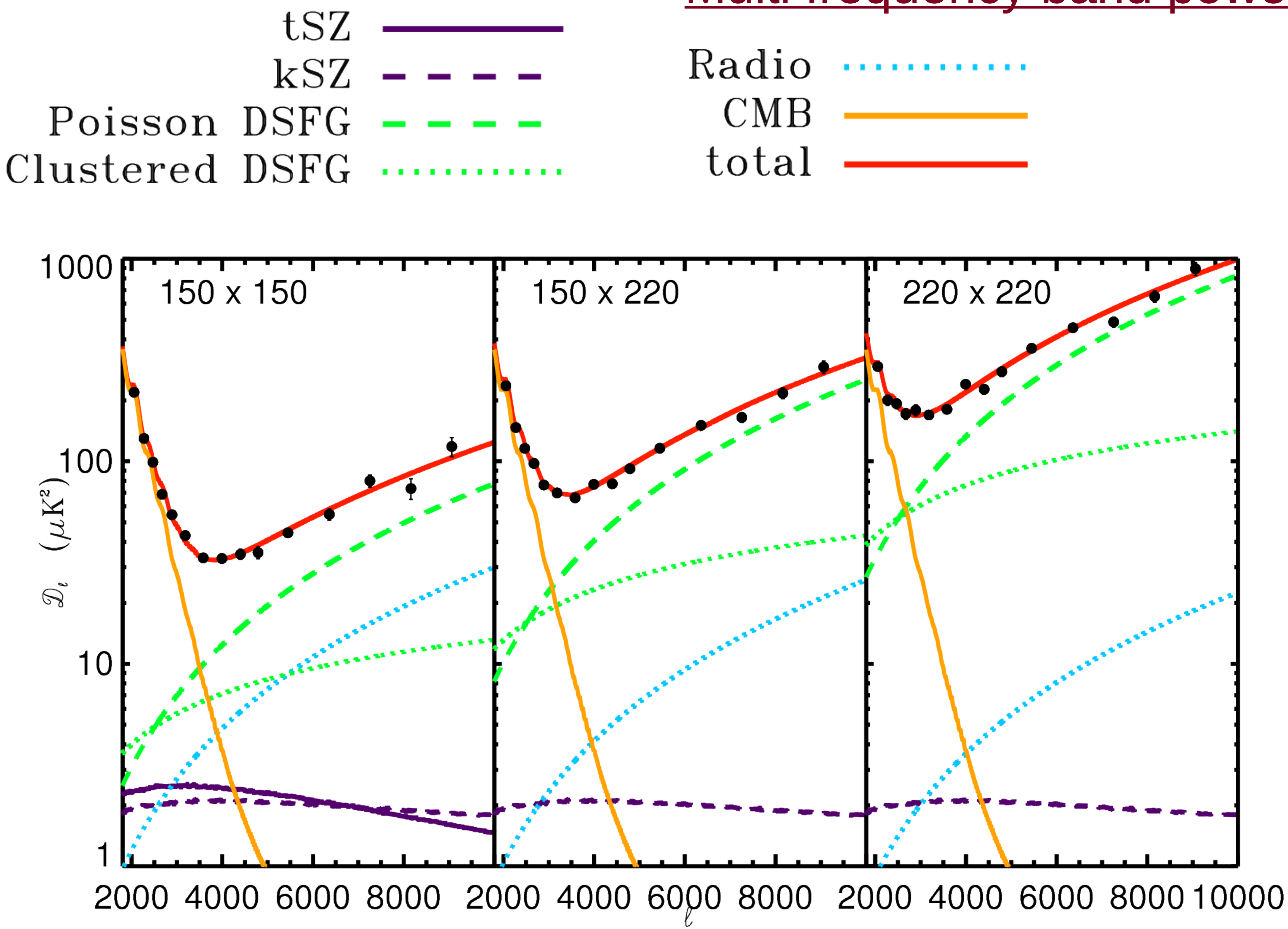
150 GHz

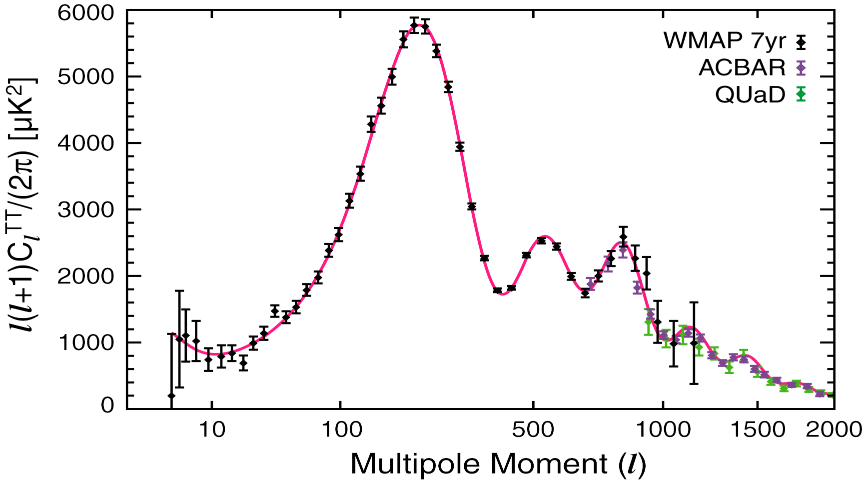
$$D_\ell = C_\ell\, \ell\, (\ell + 1)/2\pi$$

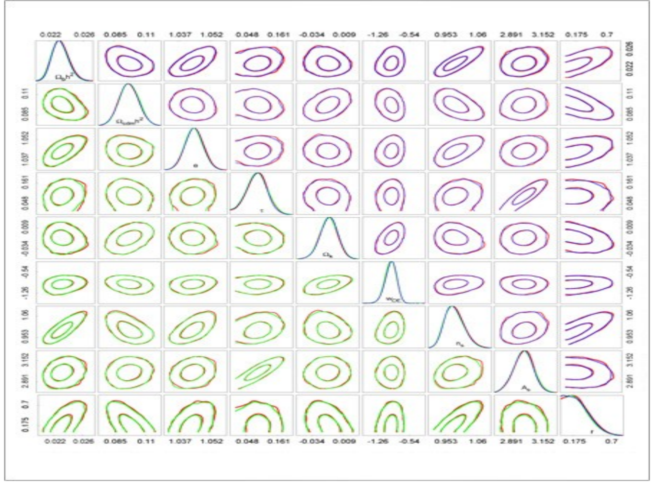


(ACT results from Das 2010)

Multi frequency band powers







DSFG-Subtracted bandpower fitting (Lueker '10 method):

•Choose a linear combination of band-powers to minimize one component.

•MCMC fits to the resulting differenced spectrum

•Constrain a linear combination of tSZ + kSZ, and residual foregrounds.

Multi-frequency fitting:

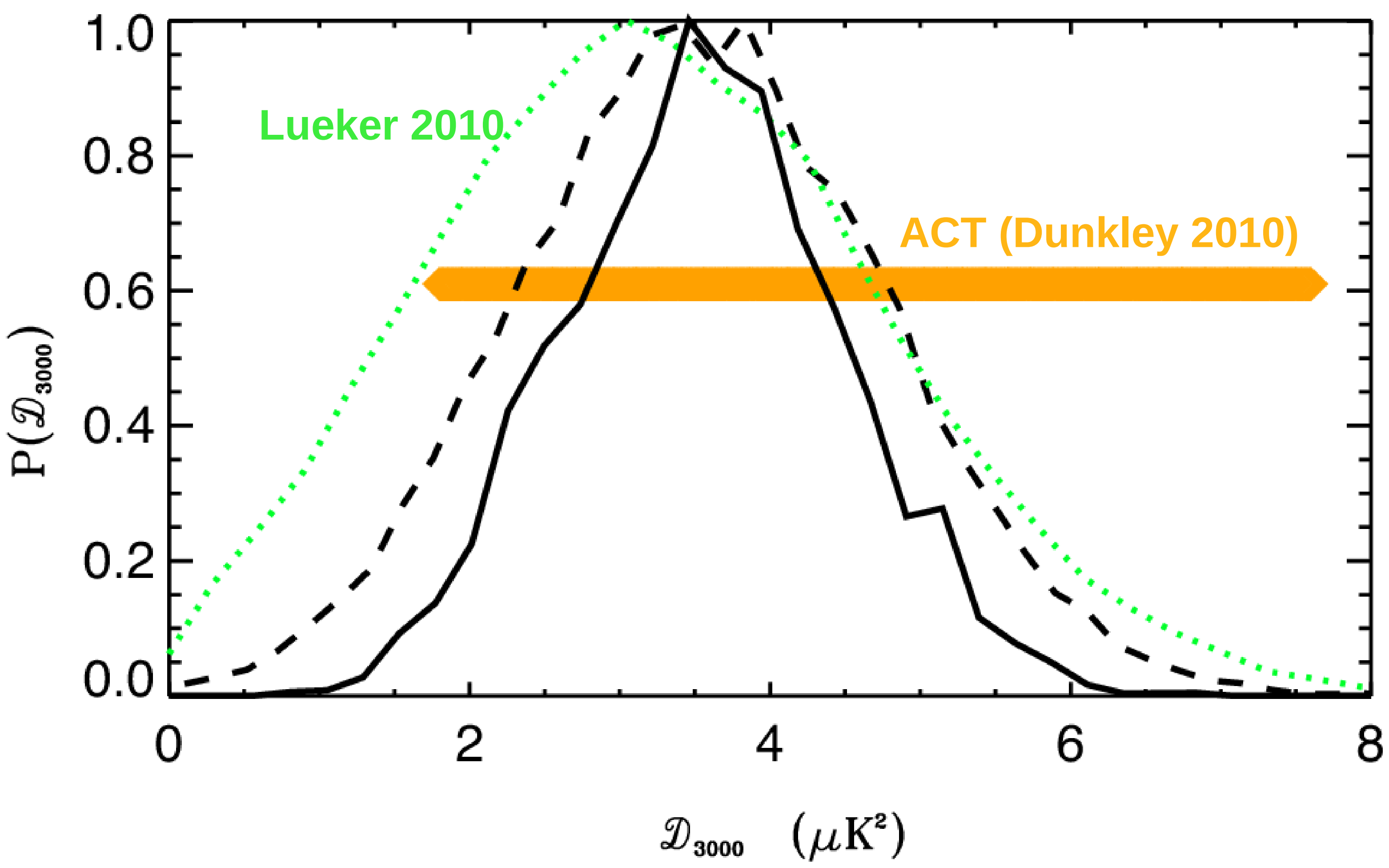
•Modified CosmoMC code *(see M. Millea's talk)*

•Simultaneous fit to all 3 cross spectra + WMAP7 + QUAD + ACBAR

•Basic model includes tSZ, kSZ, and two DSFG components with a common spectral index

•Provides tighter constraints -or- more freedom to vary parameters

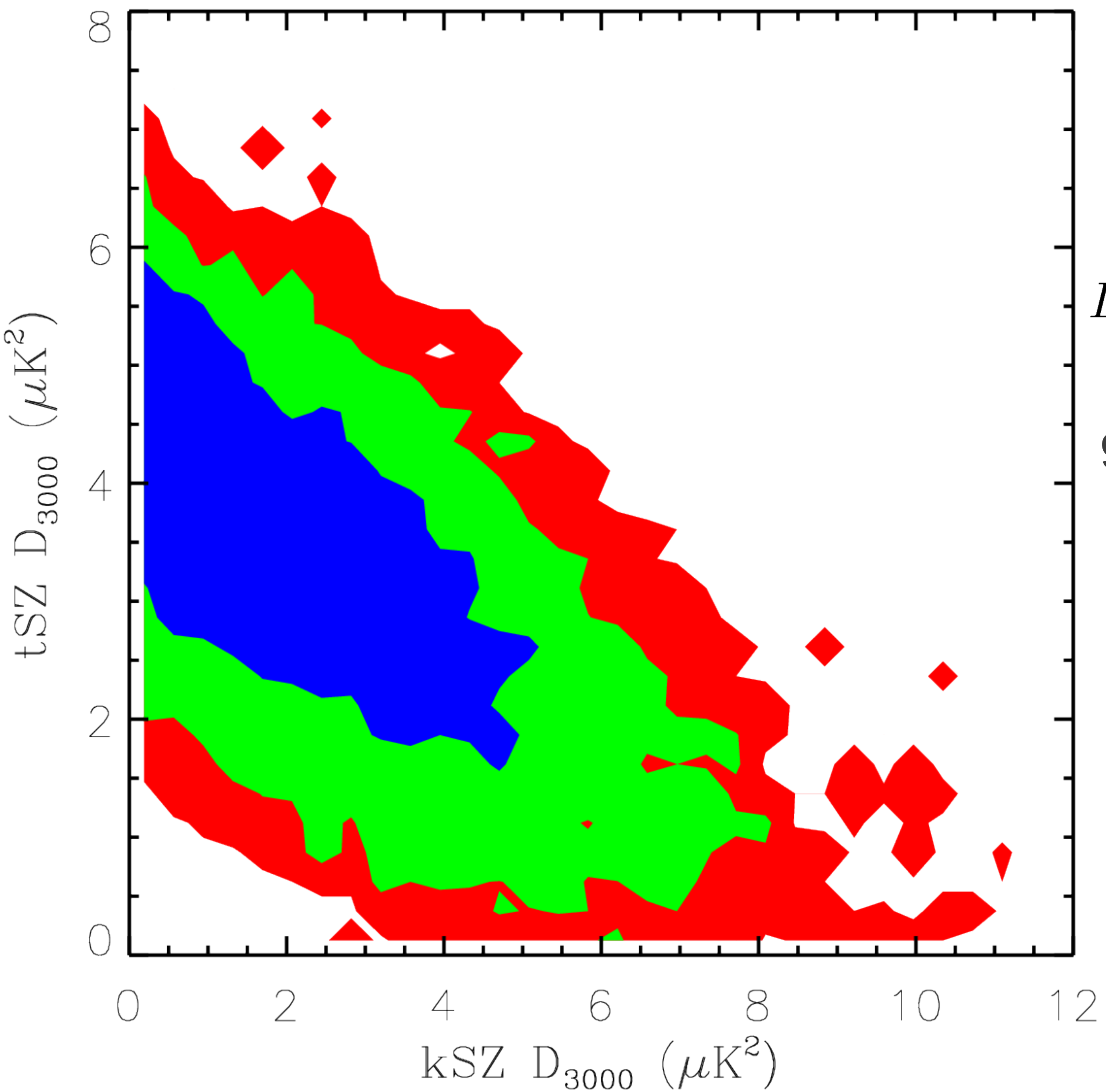
Results: tSZ power



$$D_{3000}^{tSZ} = 3.60 \pm 1.00\,\mu\mathrm{K}^2$$

With a fixed homogeneous kSZ model (Sehgal et al 2010)

Results: tSZ and kSZ power when kSZ is allowed to vary



$$D_{3000}^{tSZ} = 3.34 \pm 1.27\,\mu\mathrm{K}^2$$

95% confidence limits:

$$D_{3000}^{tSZ} < 5.0\mu\mathrm{K}^2$$

$$D_{3000}^{kSZ} < 7.3\mu\mathrm{K}^2$$

The End

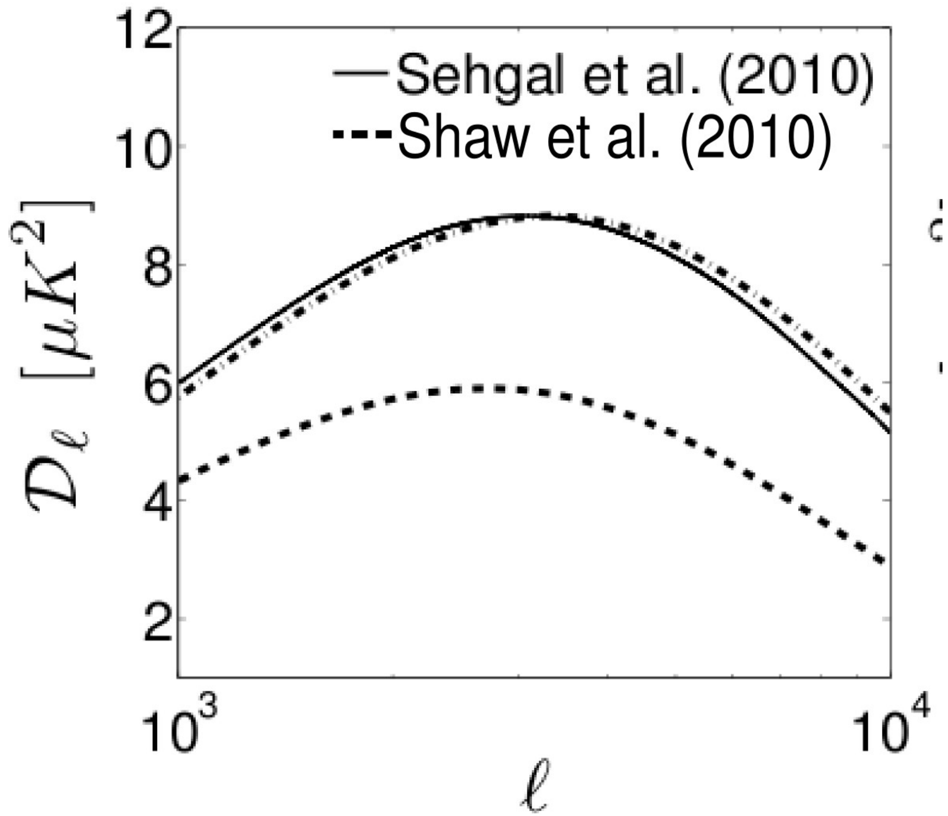
What about the angular power spectrum?

- tSZ probes late, dense structure

$$C_\ell^{tSZ} \propto \sigma_8^7 (\Omega_b h)^2$$

Sounds good. . . but

- ½ of tSZ power from z>1
- ½ of tSZ power from clusters with $M < 10^{14} M_\odot$
- Models disagree at 50%
- Fit to a scaled template.



Shaw et al. astro-ph/1006.1945