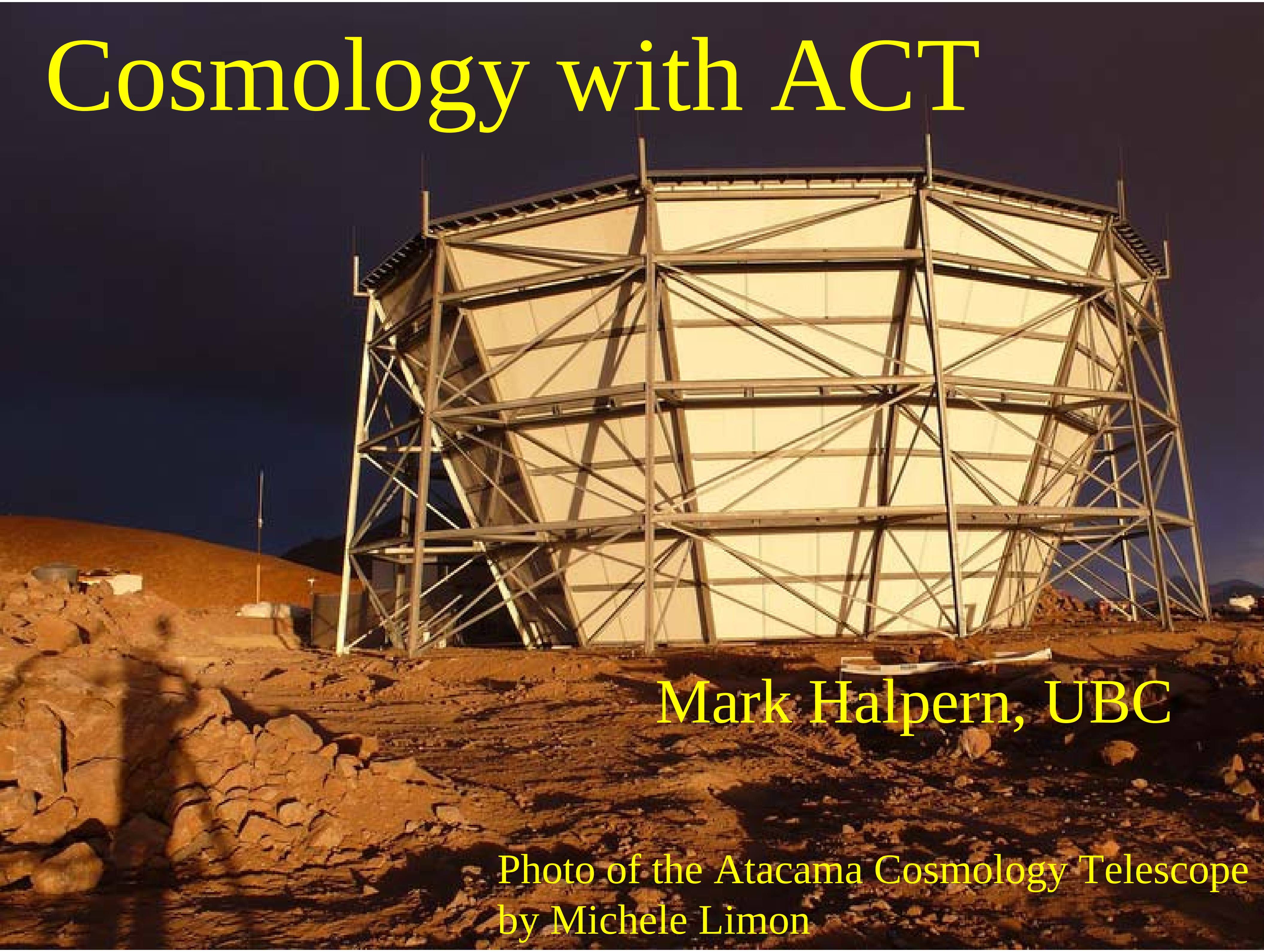
Cosmology with ACT

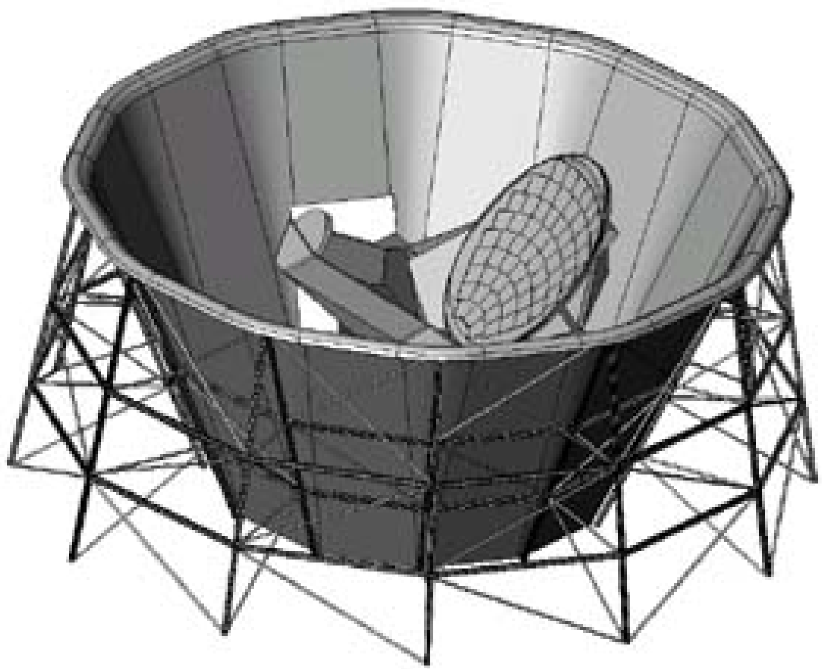


Mark Halpern, UBC

Photo of the Atacama Cosmology Telescope
by Michele Limon

Atacama Cosmology Telescope

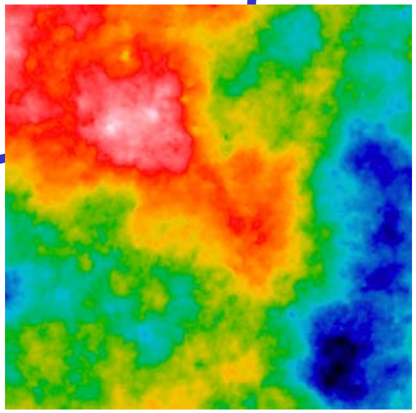
A program designed to measure the high-ℓ features of the CMB



ACT is a 3-color off-axis 6m telescope. Beam sizes are 1-2 arc minutes, corresponding to $400< \ell<7000$

X-ray

Optical

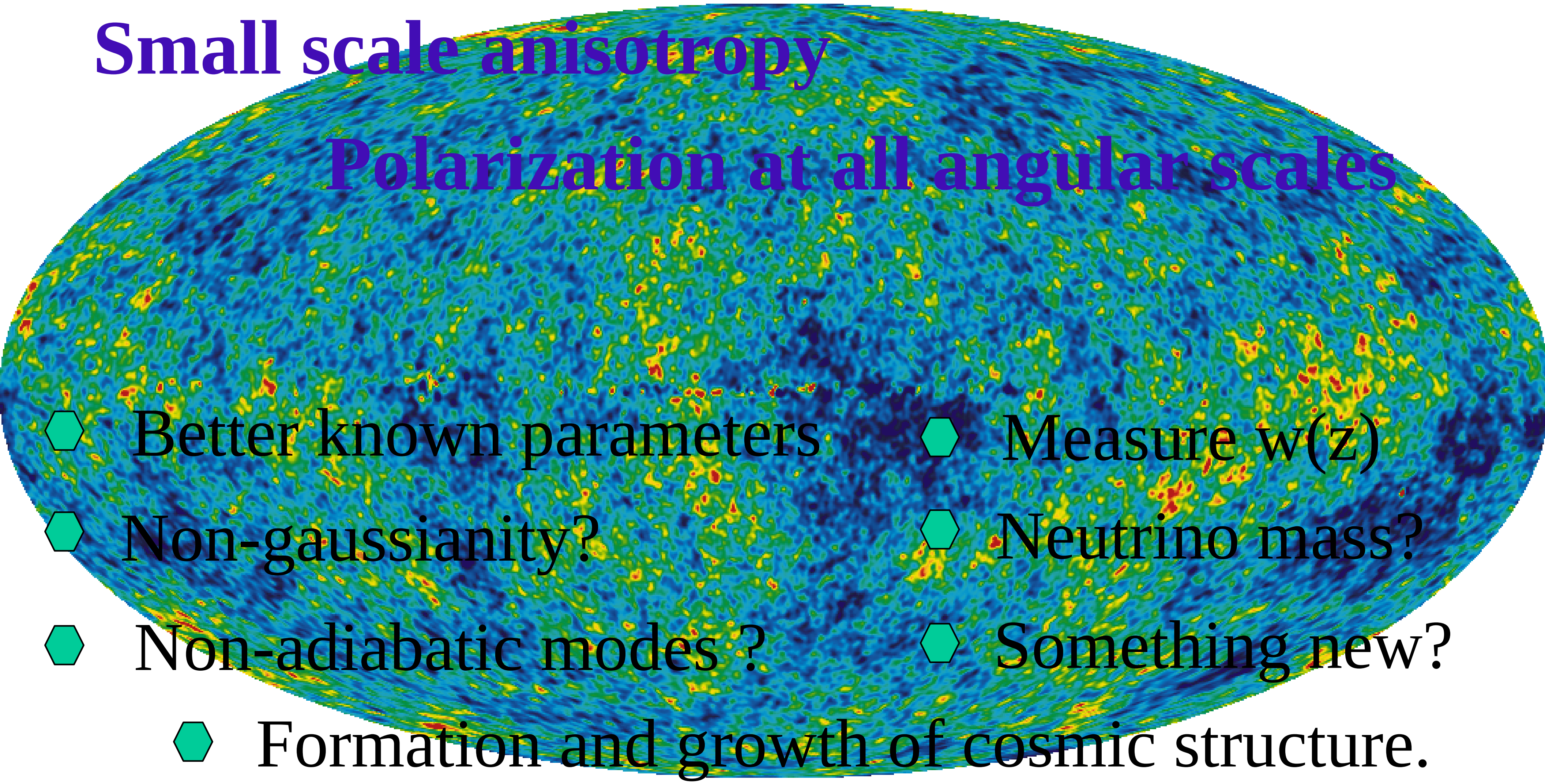


Theory

Collaboration:

Cardiff	Columbia	CUNY	Haverford	INAOE	NASA/GSFC	NIST	Princeton
Rutgers	UBC	U. Catolica	U. KwaZulu-Natal	UMass	UPenn	U. Pittsburgh	U. Toronto

The CMB is still a scientific gold mine.

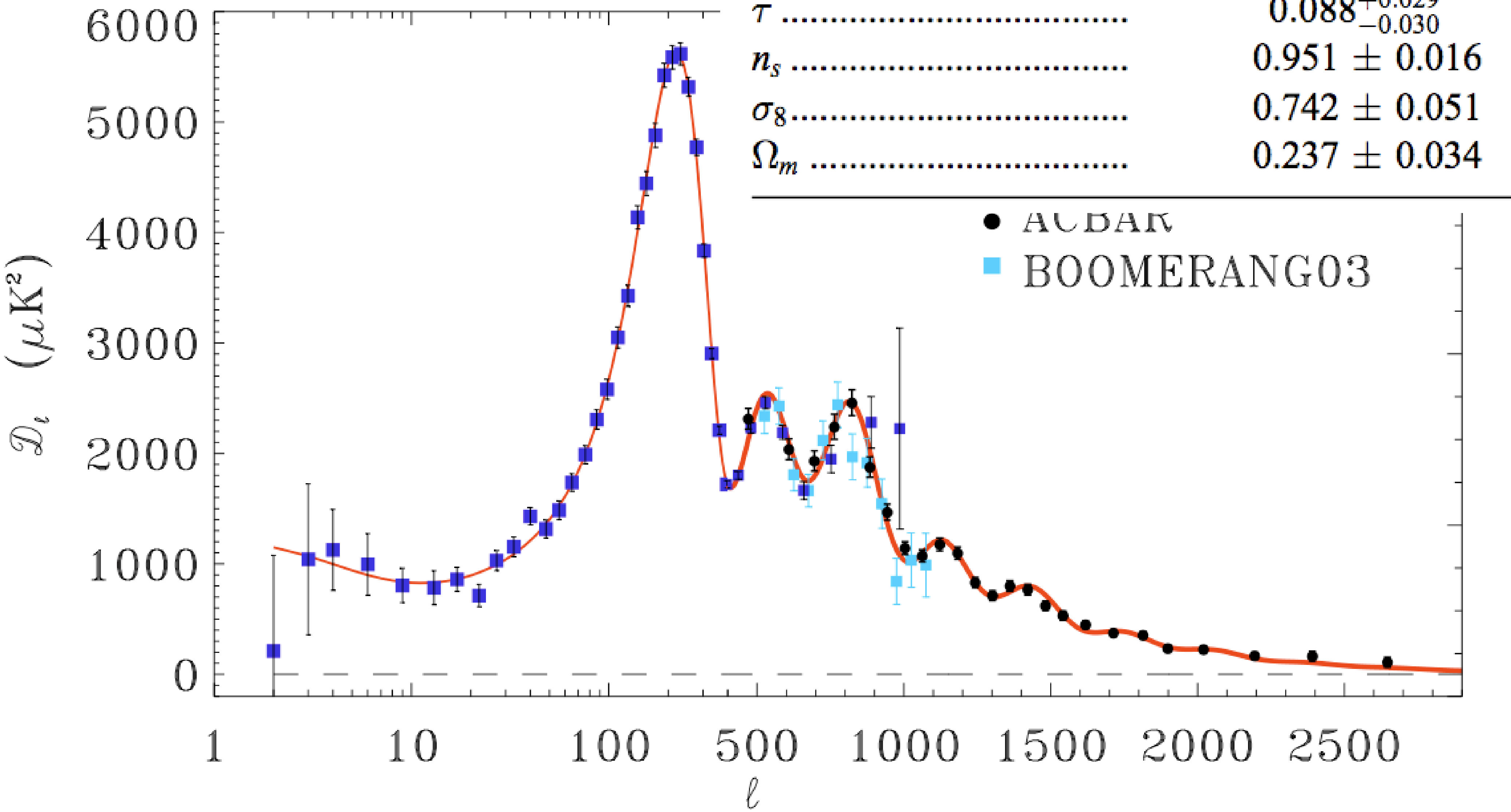


Small scale anisotropy

Polarization at all angular scales

- Better known parameters
- Measure w(z)
- Non-gaussianity?
- Neutrino mass?
- Non-adiabatic modes ?
- Something new?
- Formation and growth of cosmic structure.
- **Tests of field theories at 10^{-35} s.**

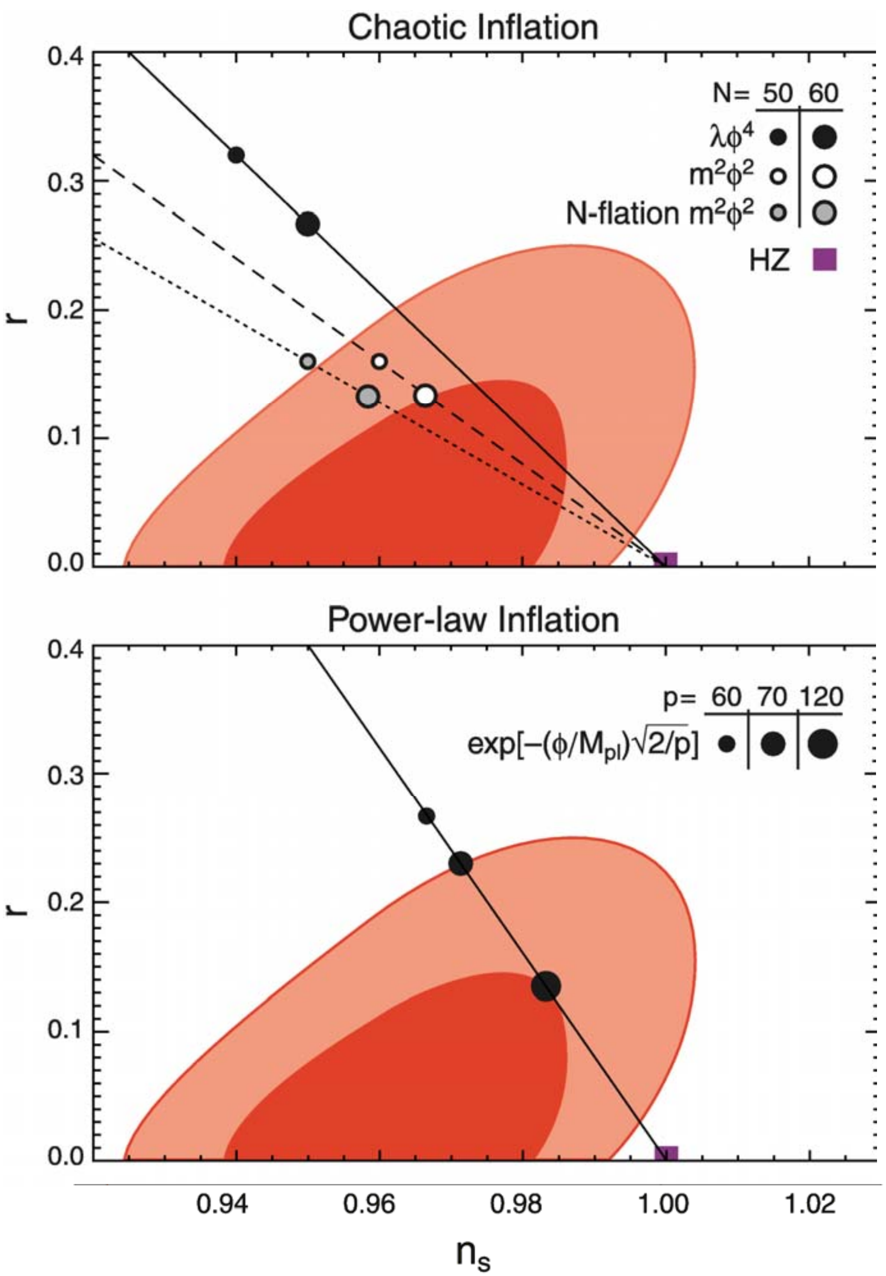
Parameter	*WMAP* Only
$100\Omega_b h^2$	$2.230^{+0.075}_{-0.073}$
$\Omega_m h^2$	$0.1265^{+0.0081}_{-0.0080}$
h	0.735 ± 0.032
τ	$0.088^{+0.029}_{-0.030}$
n_s	0.951 ± 0.016
σ_8	0.742 ± 0.051
Ω_m	0.237 ± 0.034



One example…

Tilt of the Angular Power Spectrum.

The overall tilt of the spectrum--- encoded in the "scalar spectral index" n_s--- is a new handle on inflation.



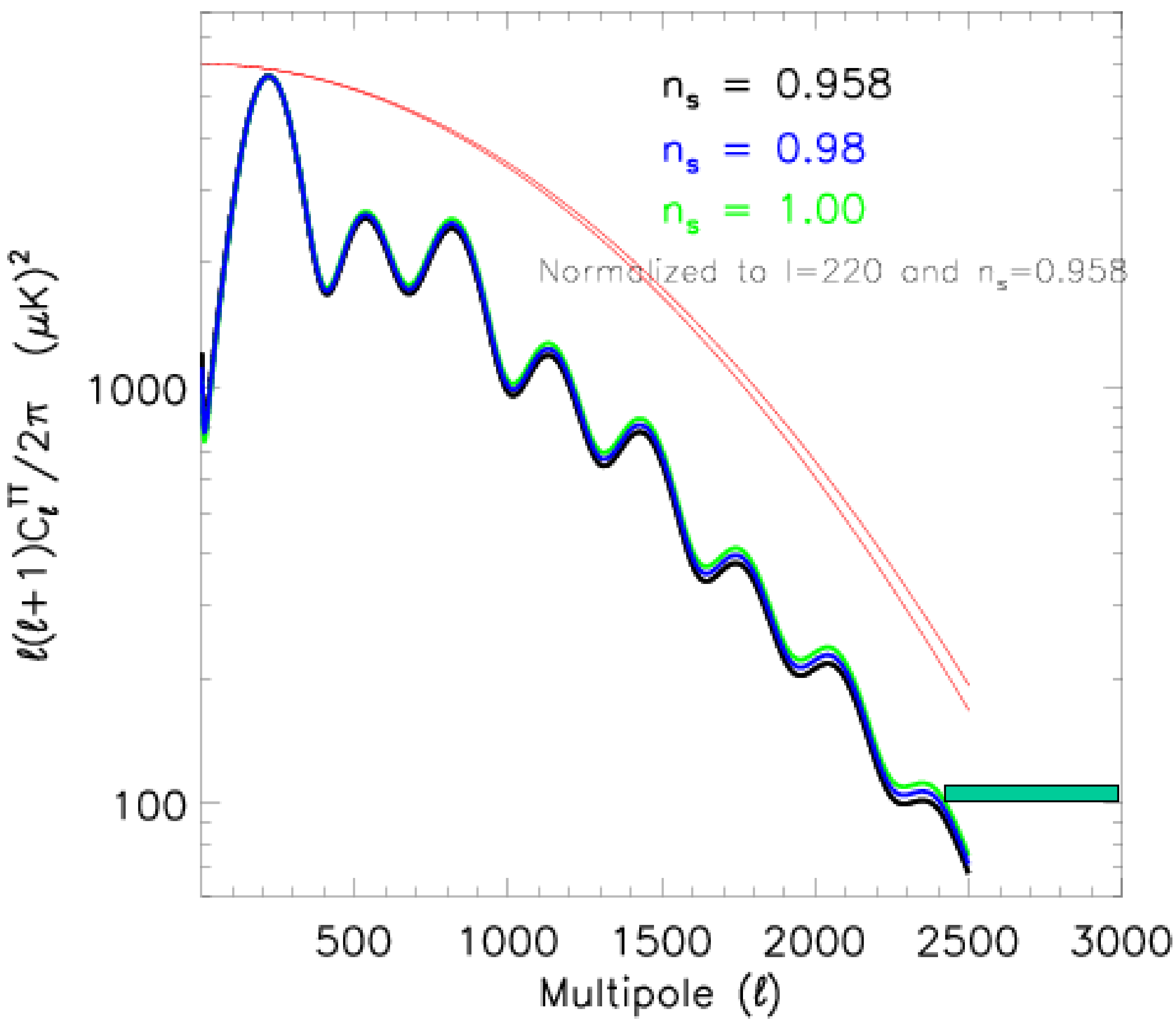
ACT and other small scale measurements will resolve n_s.

Polarization experiments will help resolve *r*.

Expect results from Planck, Clover, Spider, Ebex, Spud, Bicep, Poincare, bPol, CMB-pol. This is an active field.

Expts in red use UBC TES electronics and NIST-style multiplexors.

Comparison of WMAP and ACT spectra will provide a useful measurement of n_s.



A 2% variation in n_s produces a 5% variation in primary anisotropy at $l = 2500$.

The relative calibration of WMAP and ACT must be known to <1% to provide useful data. This is easier than knowing the WMAP beam shape well enough.

ACT will also probe secondary anisotropies which arise during the epoch of structure formation

Sunyaev Zeldovich effect from clusters	Epoch of cluster formation
Gravitational Lensing of the CMB	Measure w(z)
Vishniac Effect and Kinetic SZ	Measure mass spectrum
Foreground point sources	Star formation history

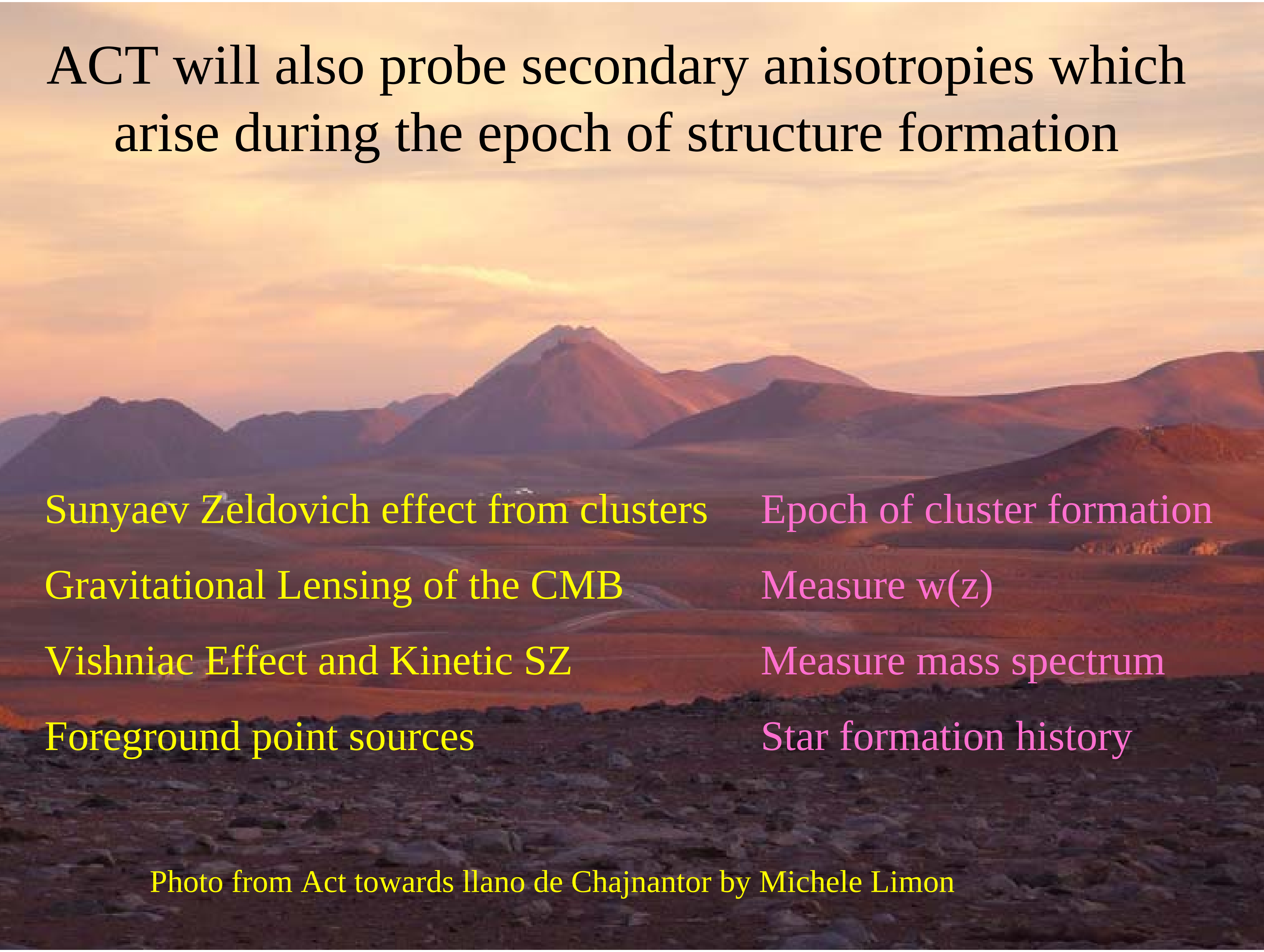
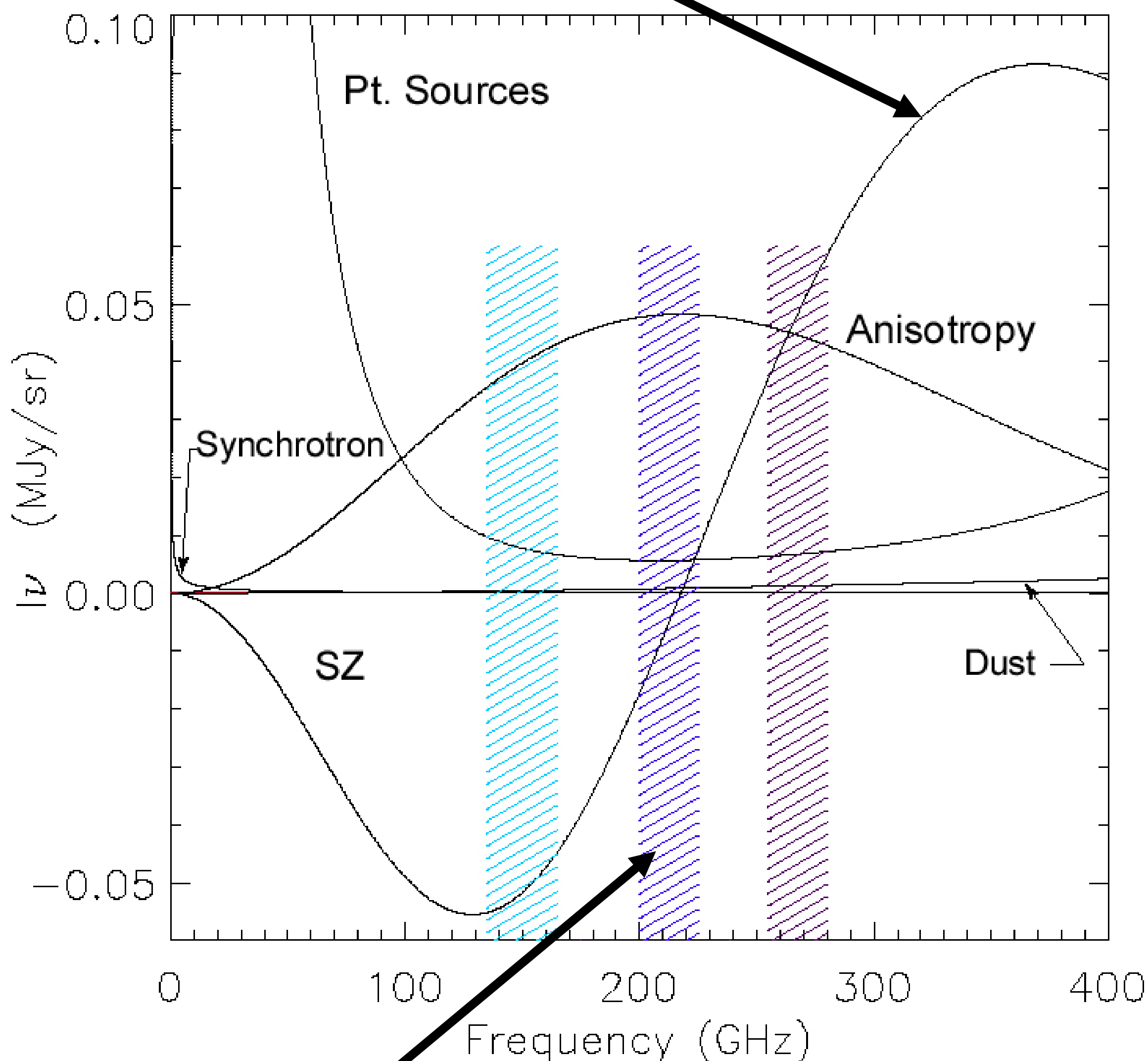


Photo from Act towards llano de Chajnantor by Michele Limon

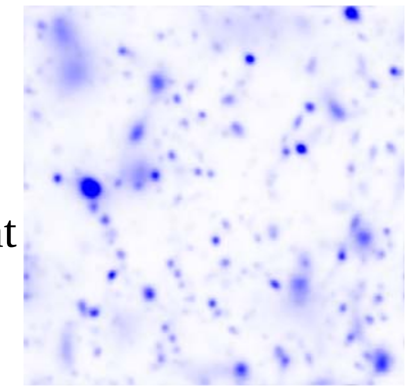
SZ Signature: Non-CMB spectrum

Hot electron gas imposes a unique spectral signature:
photon number is preserved while photons scatter to higher energy



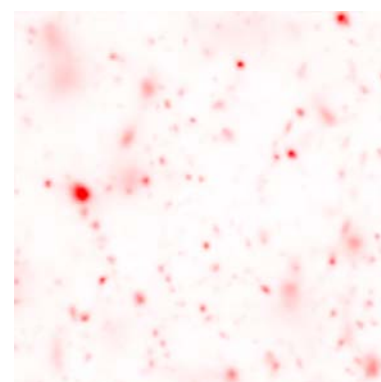
NO SZ Contribution in Central Band

145 GHz
decrement



220 GHz
null

270 GHz
increment



1.4°x 1.4°

Thomson Scattering and structure in either the velocity or the density of free electrons produce a secondary anisotropy.

The frequency spectrum (color) of the anisotropy matches the CMB.

$$\Delta_T(\hat{\gamma}) = -\int \mathrm{d}\mathbf{l}.\frac{\mathbf{v}}{c}\,\sigma_T n_{e,\mathrm{f}} e^{-\tau} = -\frac{\sigma_T c}{H_0}\int \frac{\mathrm{d}\chi}{1+z}\,\frac{\hat{\gamma}.\mathbf{v}}{c} n_{e,\mathrm{f}} \tag{1}$$

where σ_T is the Thomson cross-section, $n_{e,\mathrm{f}}$ the number density of free electrons, $\mathbf{v}$ the peculiar velocity and l the coordinate along the line of sight, all in physical units.

Valageas, Balbi &Silk Astro-ph 0009040

ACT will measure the matter power spectrum in both linear (Ostriker-Vishniac) and non-linear (kinetic Sunyaev-Zel'dovich) growth regimes.

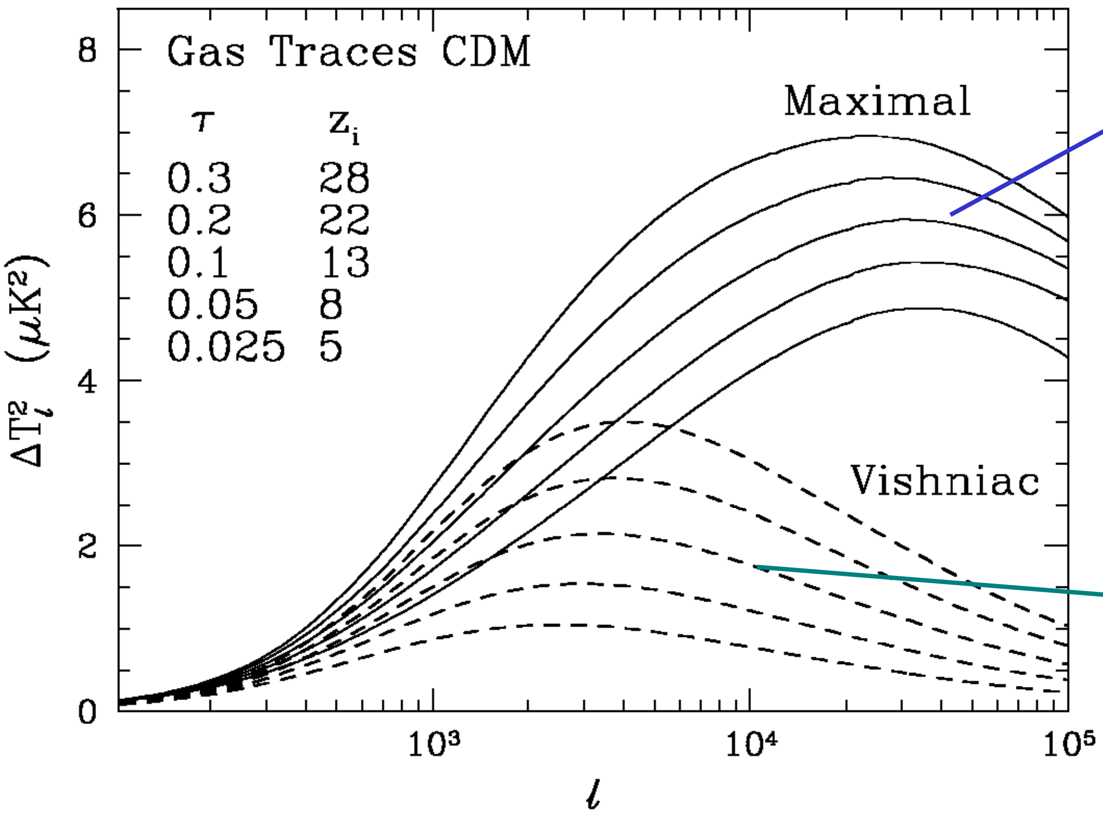


Fig. 5.— Maximal nonlinear enhancement of the Vishniac effect. Under the assumption that the gas density traces the dark matter density into the deeply nonlinear regime the Vishniac effect is significantly enhanced by nonlinearities at $\ell \gtrsim 1000$ especially in the late reionization scenarios.

Non-linear: kSZ

Clusters have formed. Cluster velocity produces signal

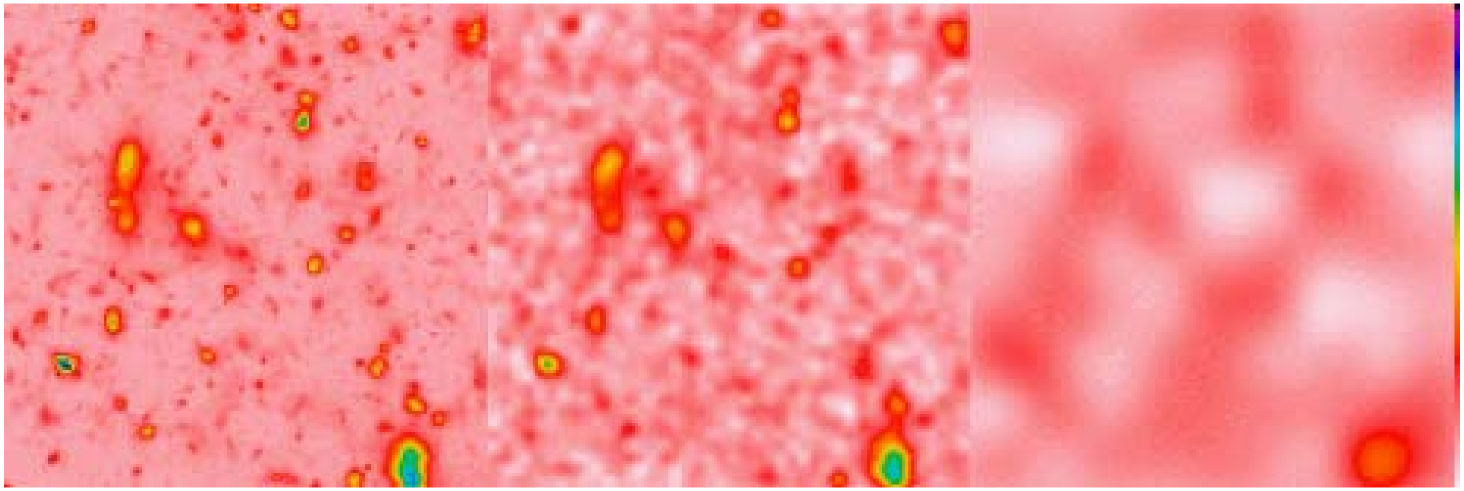
Linear Effects: OV

Structure in n_e not correlated with bulk **v**.

From Wayne Hu, Astro-ph 9907103

The ACT angular resolution is needed to study SZ.

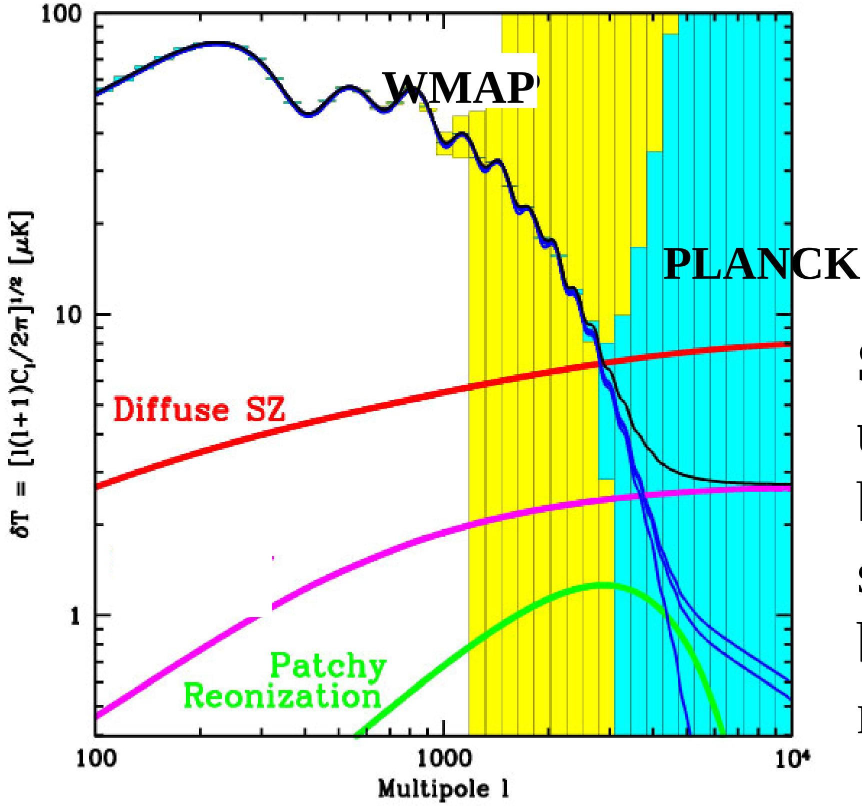
1.4^0



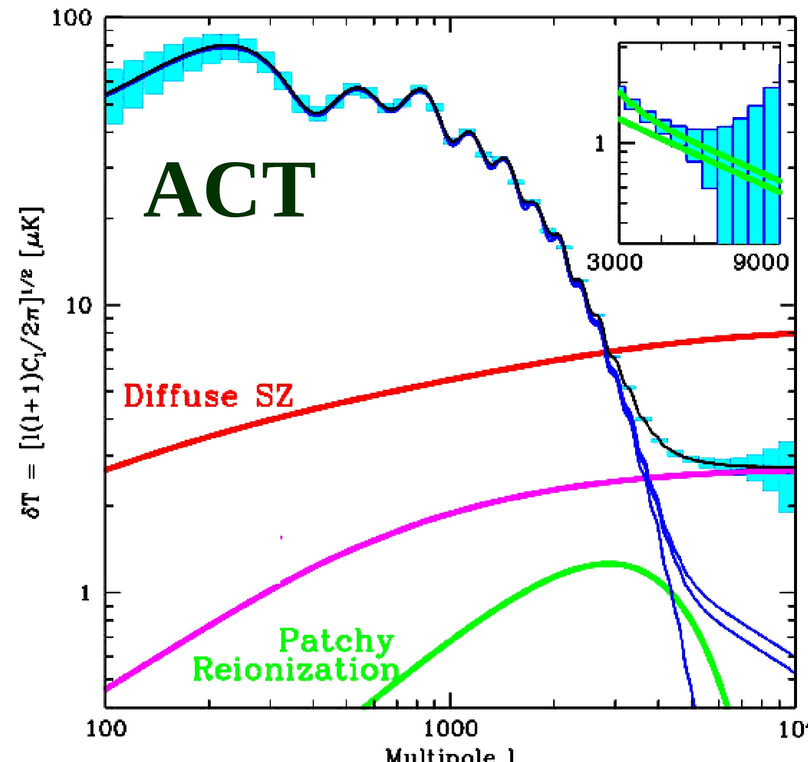
150 GHz

SZ Simulation | **MBAC on ACT** | *Planck* | Burwell/Seljak

2X noise
1.7’ beam



Statistical uncertainties based on 1 season with best measured noise.



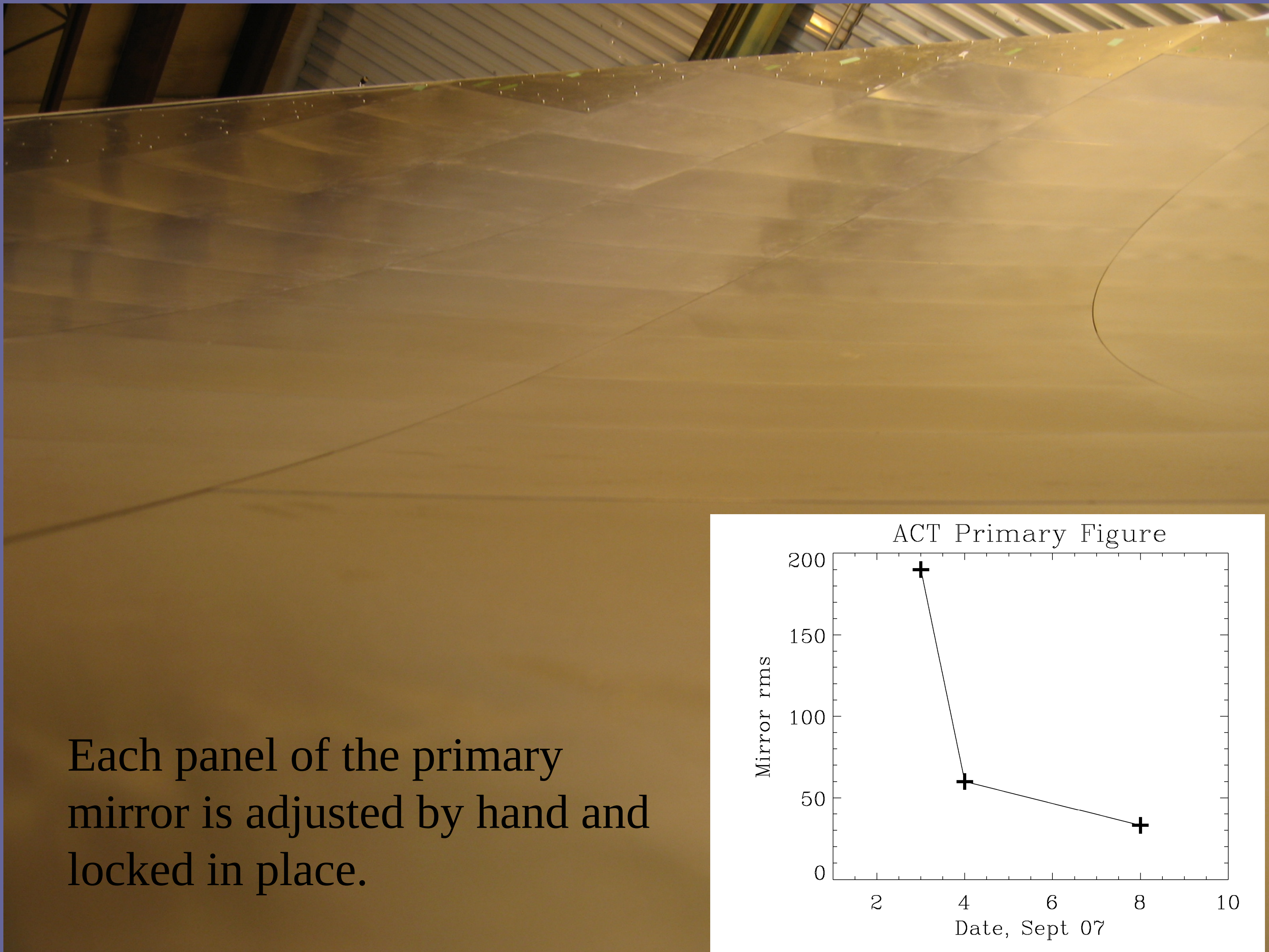
de Oliveira-Costa

The ground screen is bigger than the telescope.

Photo by Michele Limon


A view looking down the face of the
primary, before the panels were installed

Panels Installed



Each panel of the primary mirror is adjusted by hand and locked in place.

Large sensitive arrays of superconducting Transition Edge Sensor bolometers are at the heart of ACT.

We build the control and readout electronics for these arrays.

(UBC electronics are in use or planned for ACT, Bicep, CCAT, Clover,, Poincare, SCUBA2, Spider, SPT, Spud, Z-spec…)

The ACT 145 GHz array, fully assembled.

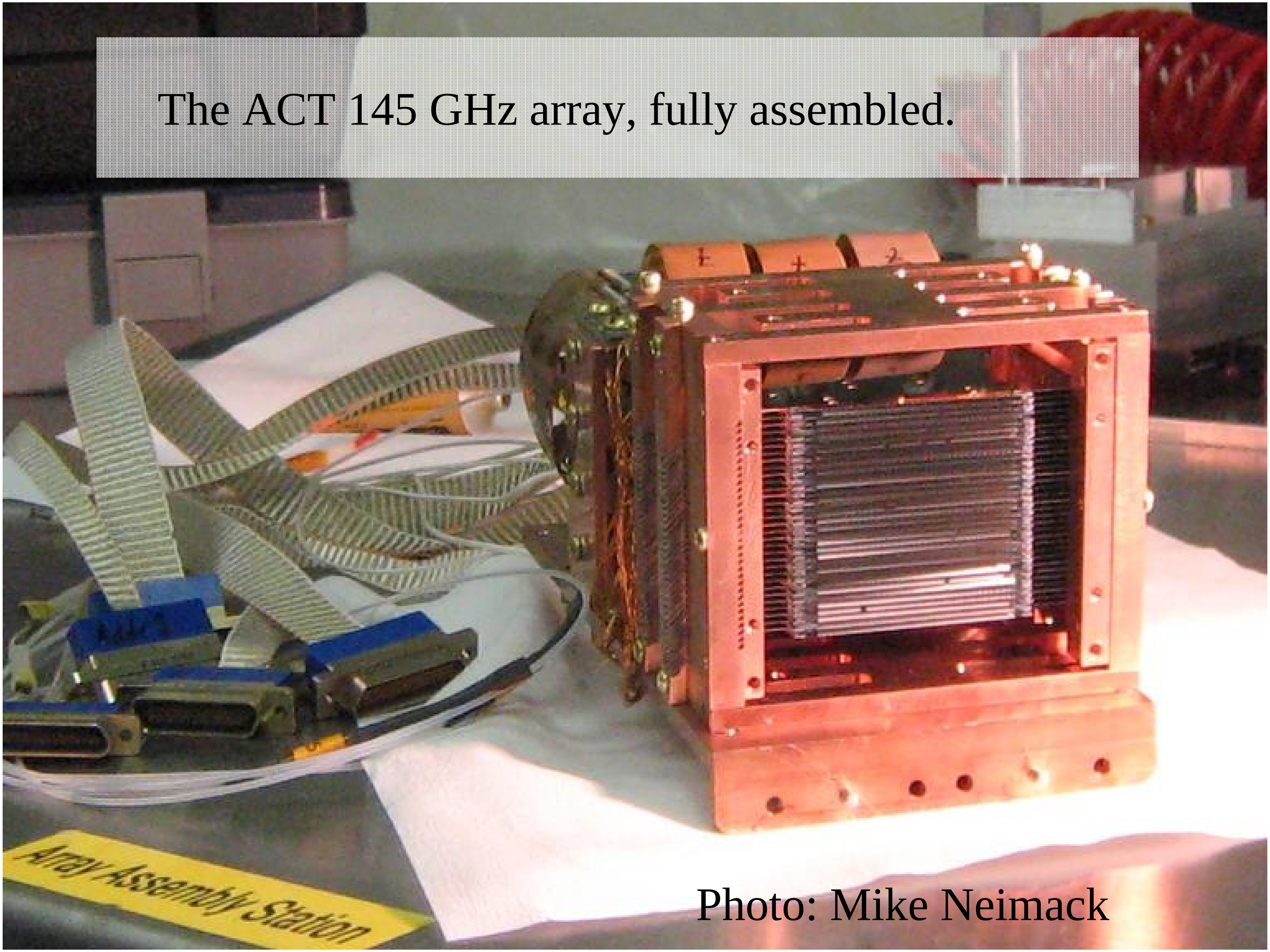


Photo: Mike Neimack

UBC and ACT

Mandana Amari

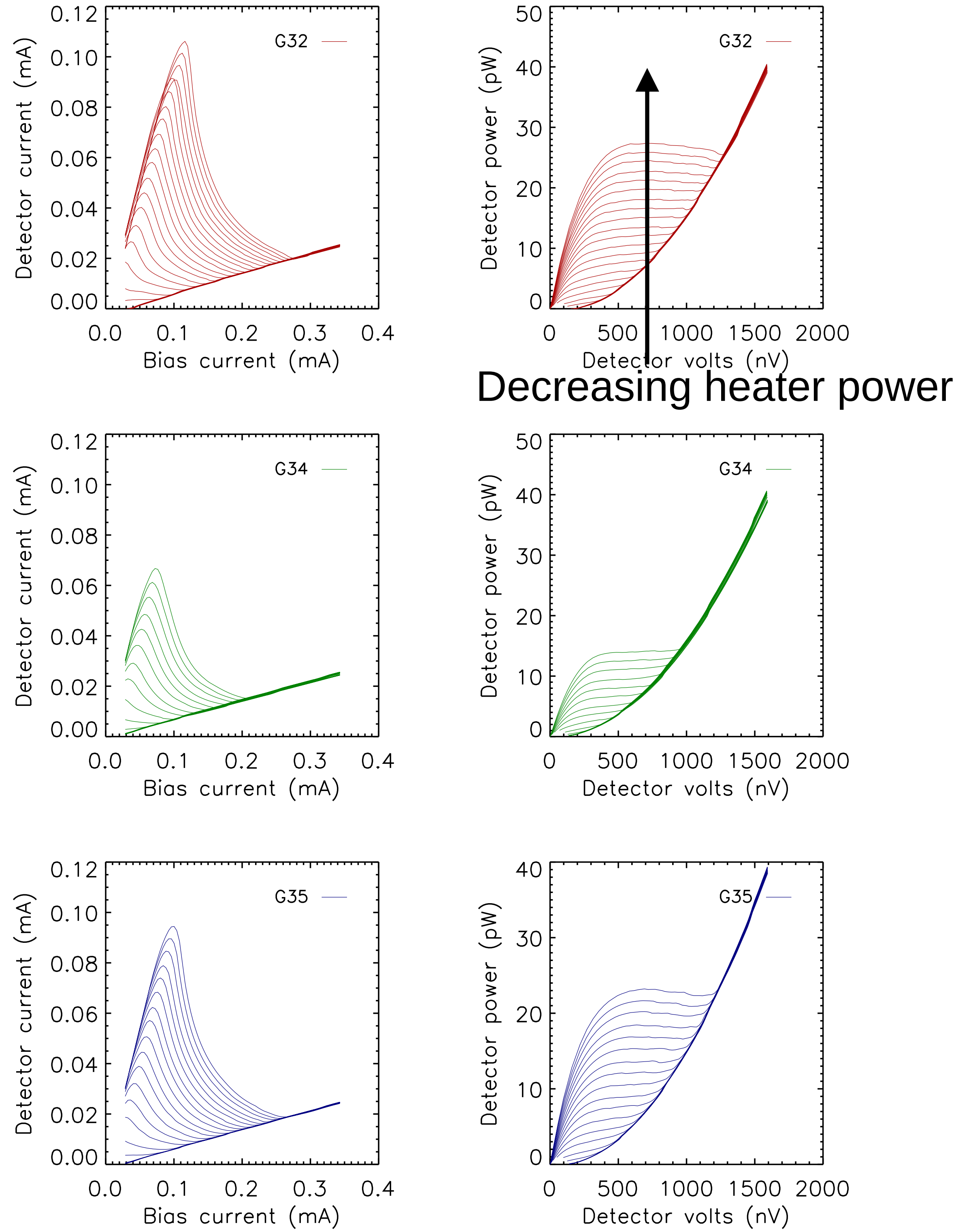
Elia Batastelli

Bryce Burger

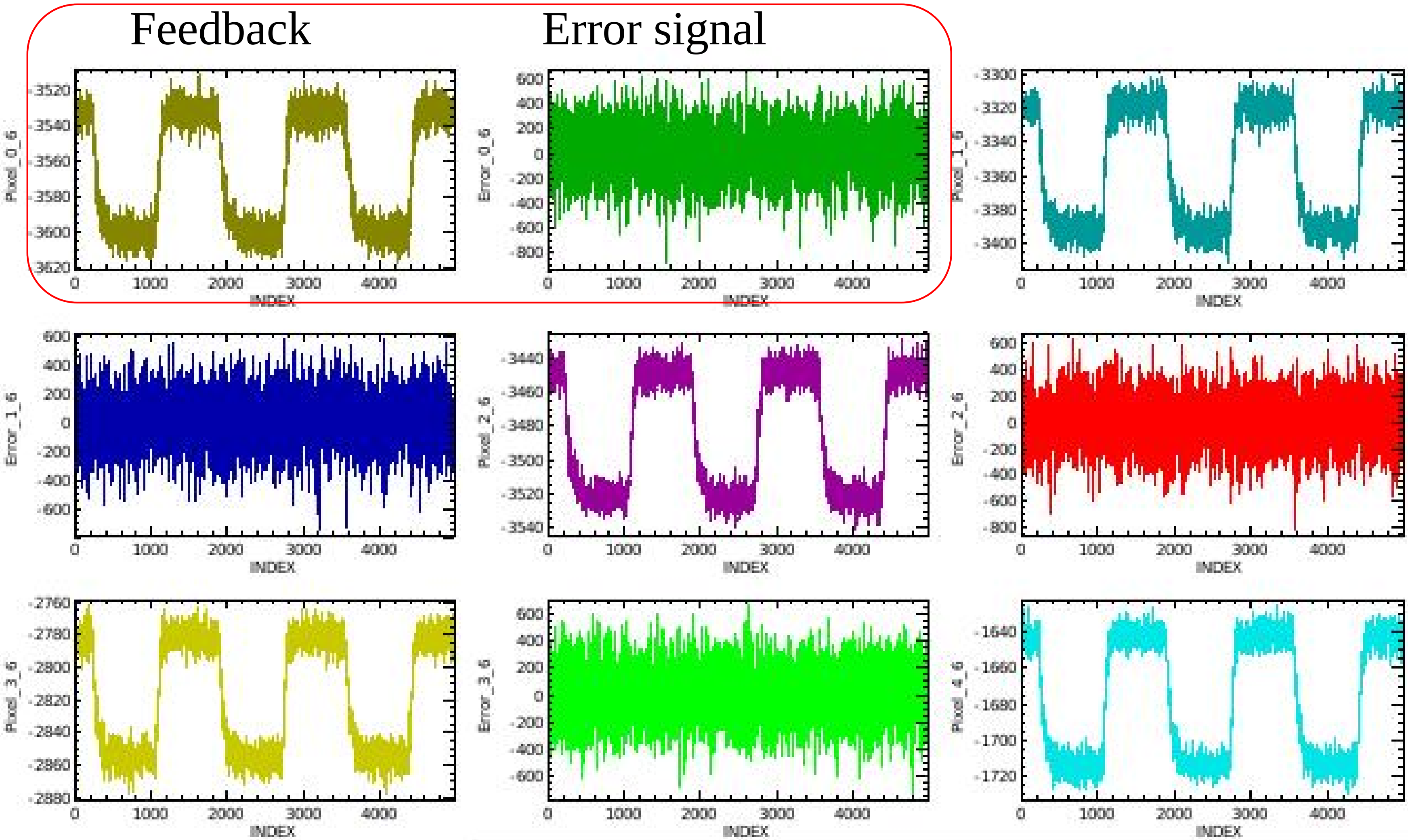
Matthew Hasselfield

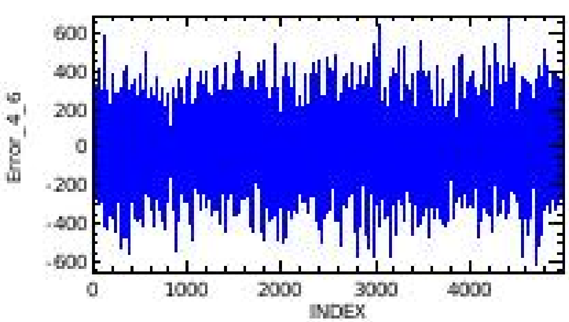
Load curves

- Also plot as power in detector vs voltage
- Power constant in superconducting transition
- Power proportional to V^2 in normal state
- Responsivity (S) in transition proportional to 1/V



Optical response of five bolometers:





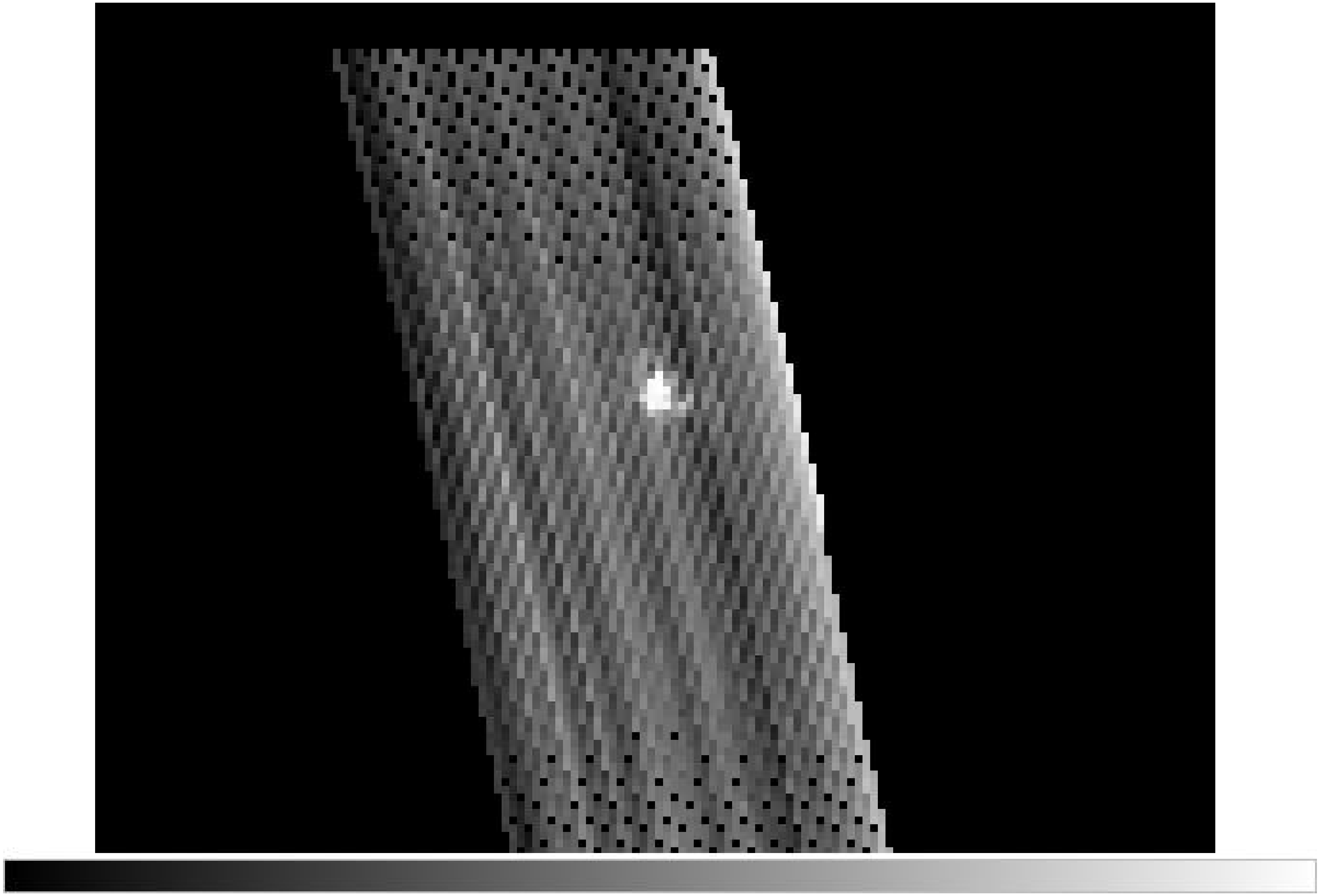
This is 10 kHz readout of a sub-pW optical signal.

(Data collected at UBC on a cryostat in New Jersey. by Elia Batastelli.)

Cross Linked Scan Strategy is Crucial to Making Maps on Degree Angular Scales

- 240 square degrees in circle
- 100 square degrees for CMB

QuickTime™ and a
BMP decompressor
are needed to see this picture.



An image of Jupiter taken in drift scan with an 8x32 camera, taken before primary surface alignment, in fact taken before the ladder was removed from in front of the primary!

observing

- 2007 Season Complete:
  30 Days with 1000-element 145 GHz detector array

- 2008 Season to commence in June for 6 months with 145, 215, (and 280) GHz arrays

- 2009 Season: Another 6 months with three arrays

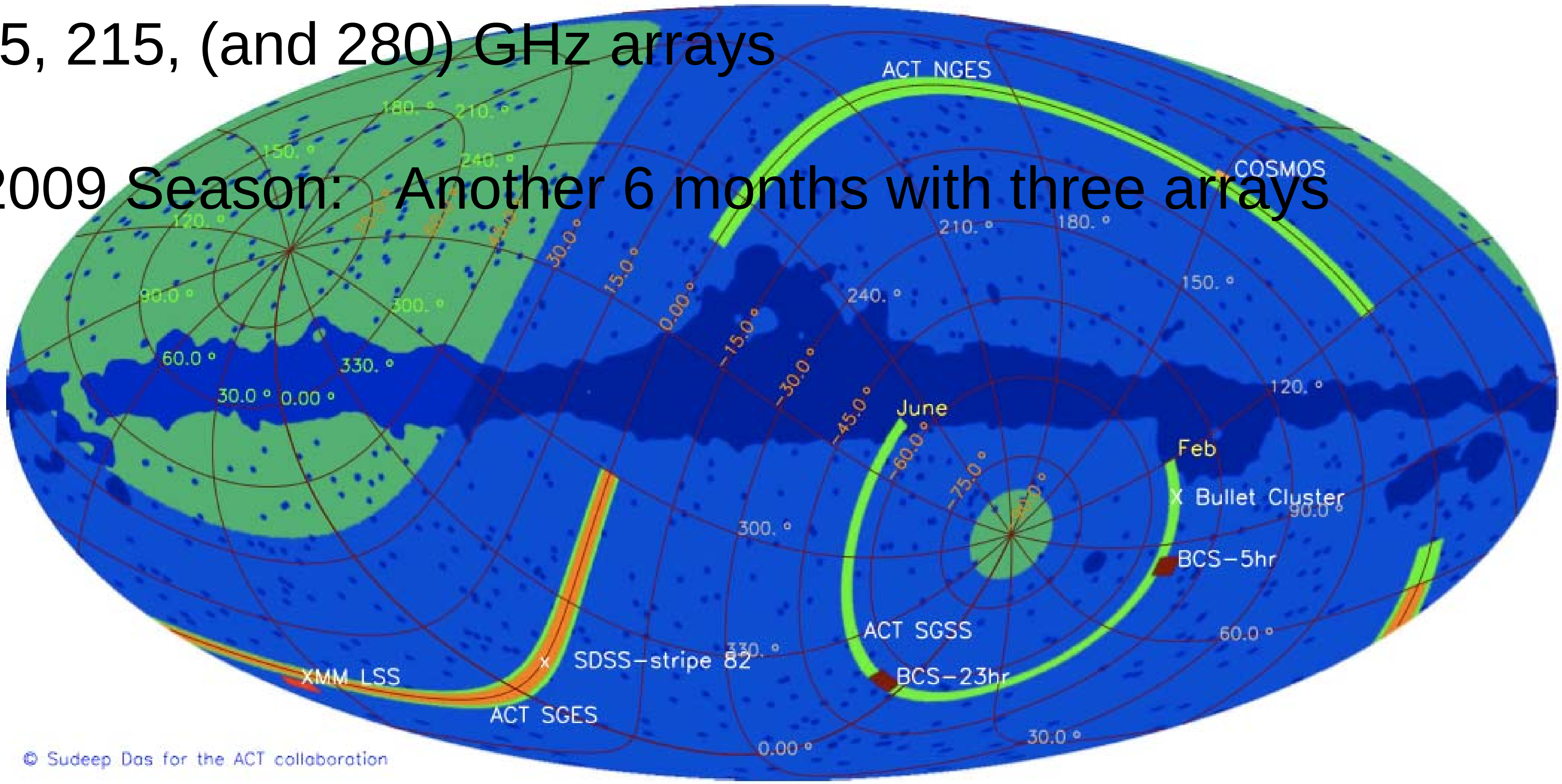


Photo by Elia Batastelli, 7 Oct. 2007.