The Cosmic Background Radiation at High Resolution with Planck and ACT

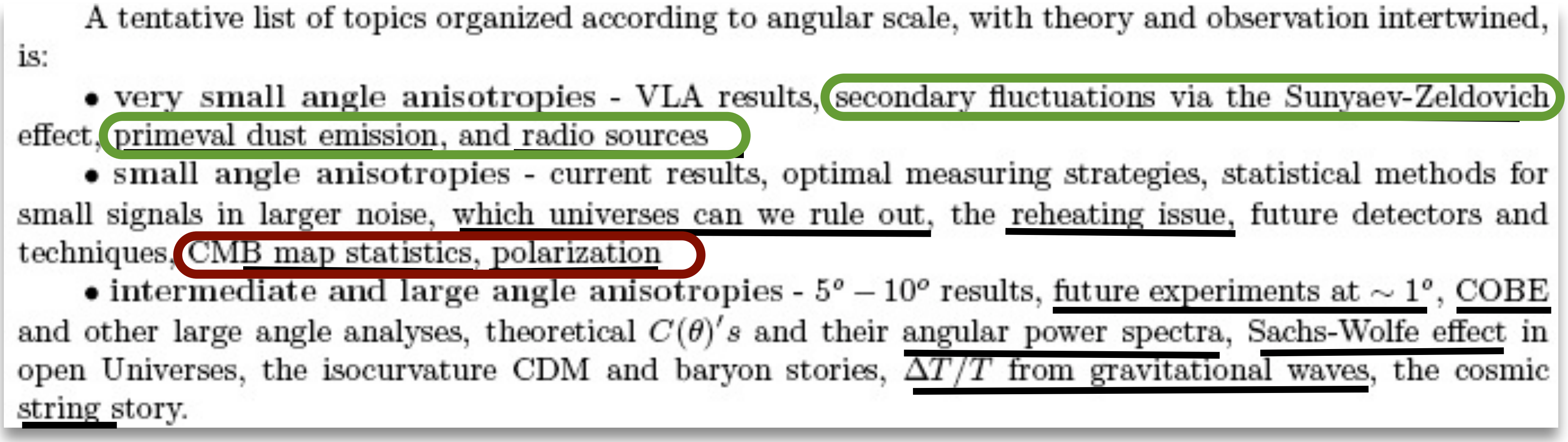
Professor J Richard Bond, Canadian Institute for Theoretical Astrophysics, University of Toronto

We entered the "Planck era" on May 14, 2009 with the successful launch of the Planck satellite which will determine fundamental cosmological parameters to high precision. This talk will describe the status of the instruments and the first burst of (non-cosmological) all-sky results that we released in January, 2011, on topics that include clusters of galaxies, the cosmic infrared background from high redshift galaxies, and dust in the Milky Way. The Atacama Cosmology Telescope probes the CMB to substantially higher resolution and depth than Planck over a few percent of the sky, and its cluster and CIB results complement those of Planck nicely. We have also obtained the best constraints on fundamental cosmological parameters using our ACT data, in conjunction with WMAP7.

Delta T over Tea Toronto May 1987: first dedicated CMB conference, exptalists+theorists, primary+secondary ΔT/T

an early CITA/CIFAR collaboration, 65 participants

e.g., **Bond, Carlberg, Couchman, Efstathiou, Kaiser, Page, Silk, Tremaine, Unruh**; Bennett, **Halpern**, Lange, Mather, **Wilkinson**, ...



A tentative list of topics organized according to angular scale, with theory and observation intertwined, is:

- very small angle anisotropies - VLA results, secondary fluctuations via the Sunyaev-Zeldovich effect, primeval dust emission, and radio sources
- small angle anisotropies - current results, optimal measuring strategies, statistical methods for small signals in larger noise, which universes can we rule out, the reheating issue, future detectors and techniques, CMB map statistics, polarization
- intermediate and large angle anisotropies - $5^o - 10^o$ results, future experiments at $\sim 1^o$, COBE and other large angle analyses, theoretical $C(\theta)'s$ and their angular power spectra, Sachs-Wolfe effect in open Universes, the isocurvature CDM and baryon stories, $\Delta T/T$ from gravitational waves, the cosmic string story.

radio source counts

ambient/blank-field tSZ effect from **clusters & gps** ***dominant Poisson 'self'-clustering*** ***sub-dominant cc-clustering***

dusty gals *gg-clustering term is much more important than for clusters, resolution to see both*

"clustered shots" (peaks aka halos) with pressure/thermal dust emission profiles

effect of energy injection / explosions- a big pre-COBE forecast issue IGM ~ ISM

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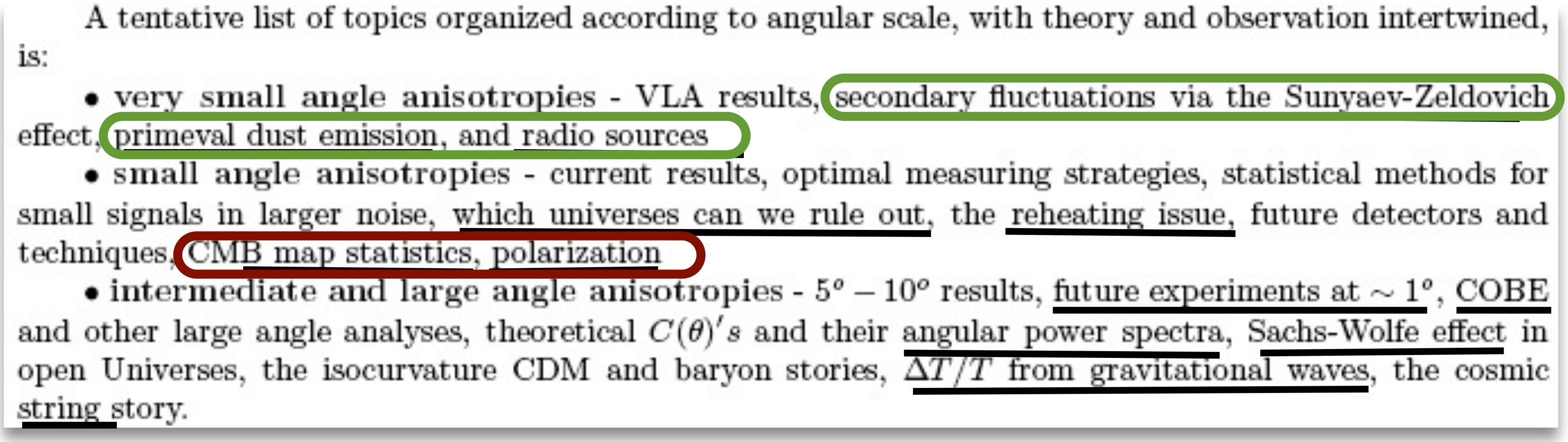

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radio source counts

Planck, ACT, SPT (WMAP) *deZotti model good, but steeper for ν > 70 GHz*

ambient/blank-field tSZ effect from **clusters & gps** ***dominant Poisson*** ***sub-dominant***

Planck, ACT, SPT blind detection; ACT, SPT power ***'self'-clustering*** ***cc-clustering***

dusty gals ***gg-clustering term is much more important than for clusters, resolution to see both***

Planck, ACT, SPT, ACTxBLAST, Herschel

"clustered shots" (peaks for halos) with pressure/thermal dust emission profiles

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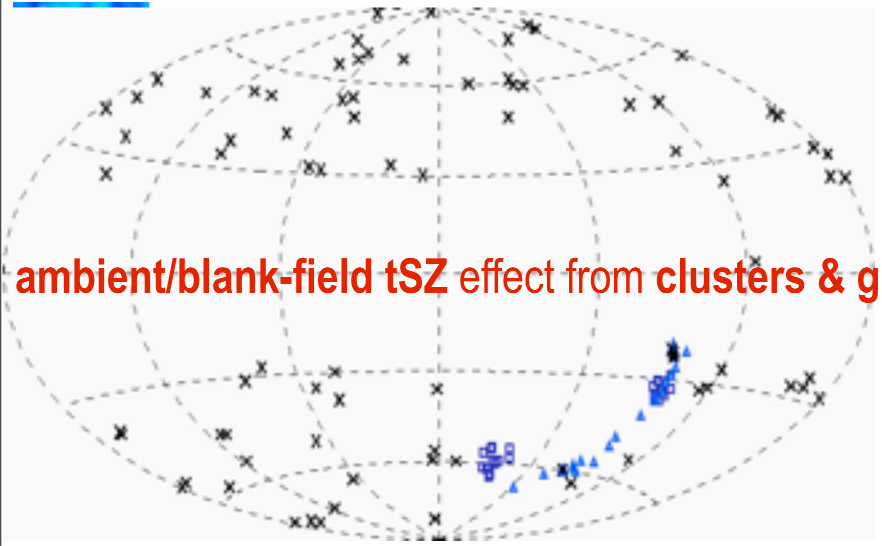
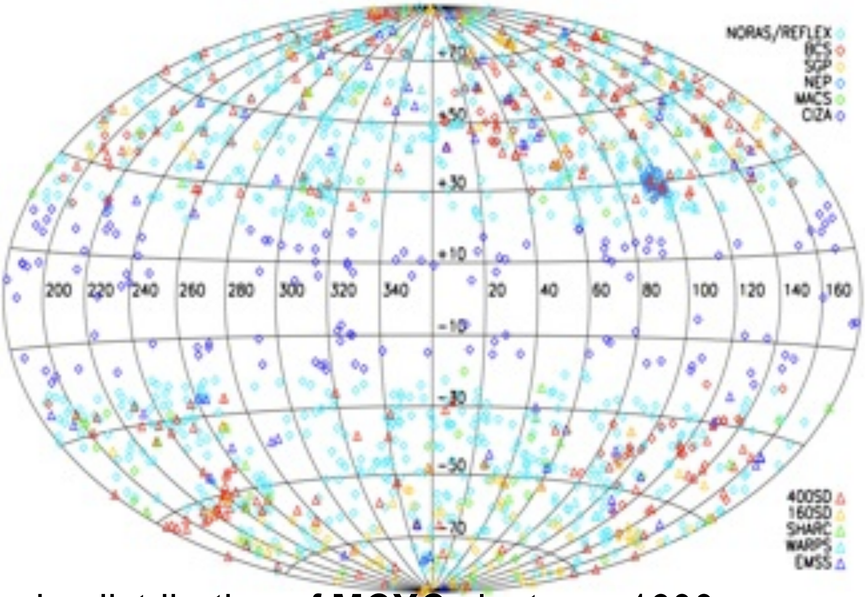
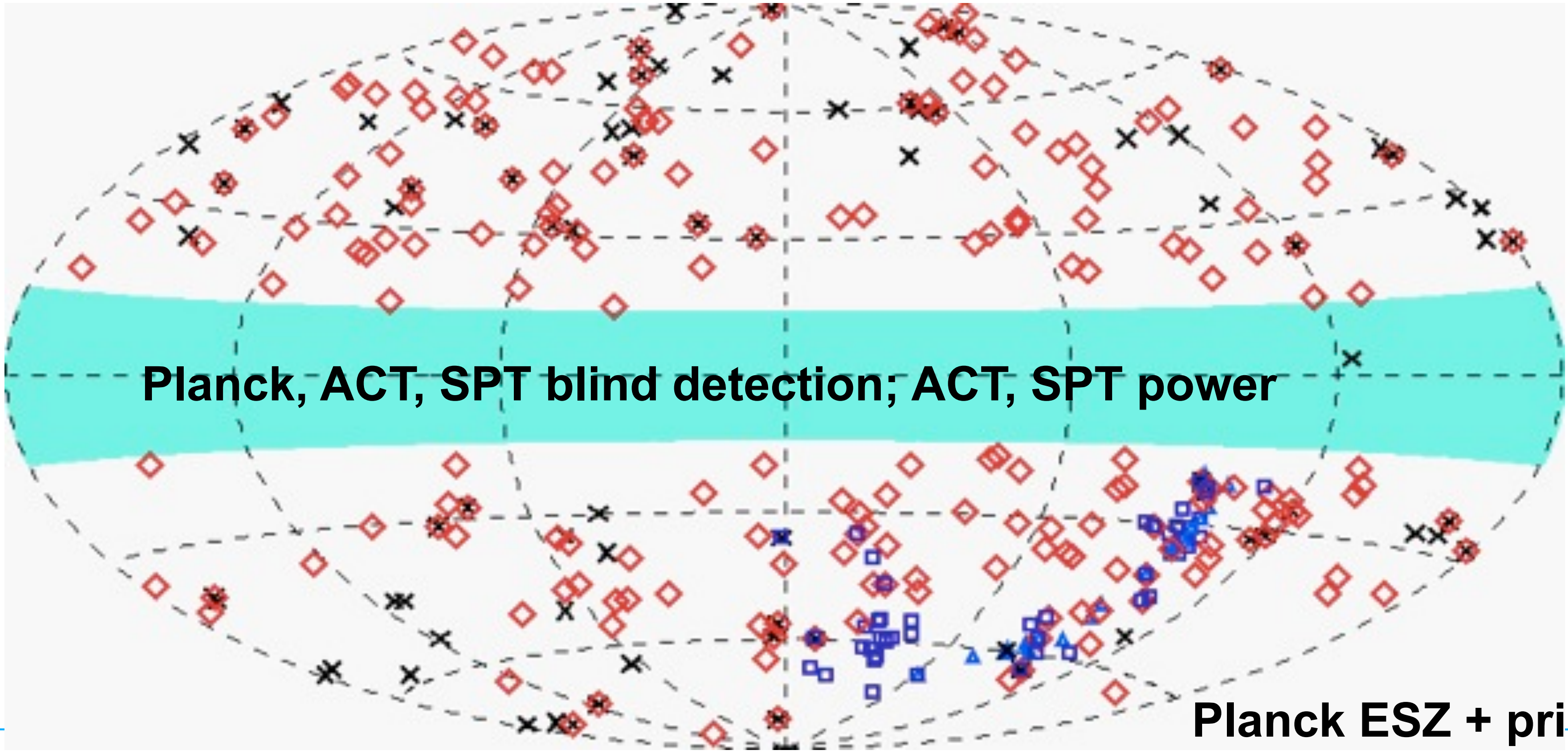


ambient/blank-field tSZ effect from **clusters & gps**

All-sky compilation of first generation SZ clusters *(Douspis et 11)*



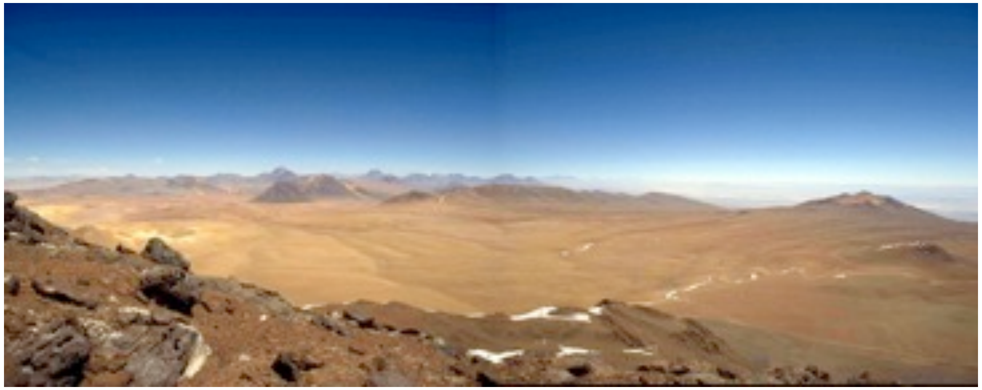
All-sky distribution of **MCXC** clusters ~1600 *(Piffaretti et 10)*



Planck, ACT, SPT blind detection; ACT, SPT power

Planck ESZ + prior-SZ

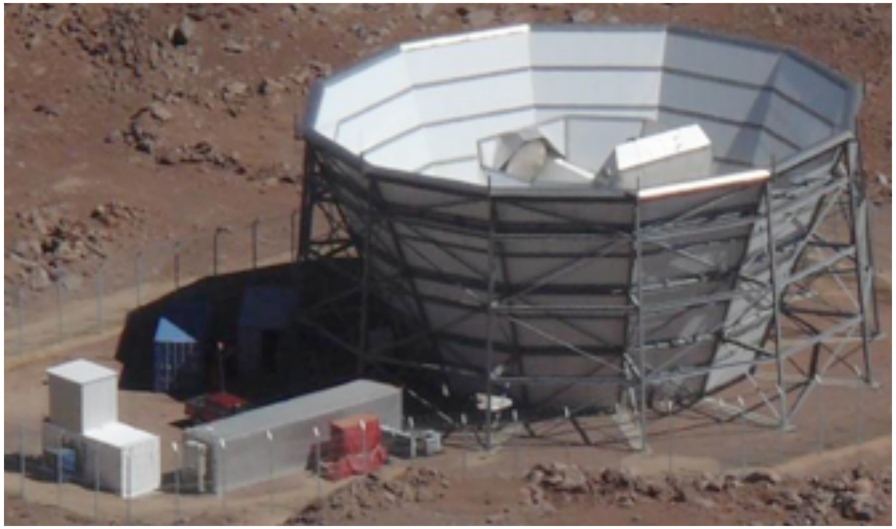
to arcminute scales with bolometer arrays: ACT & SPT



5200 meter elevation, one of driest places on planet

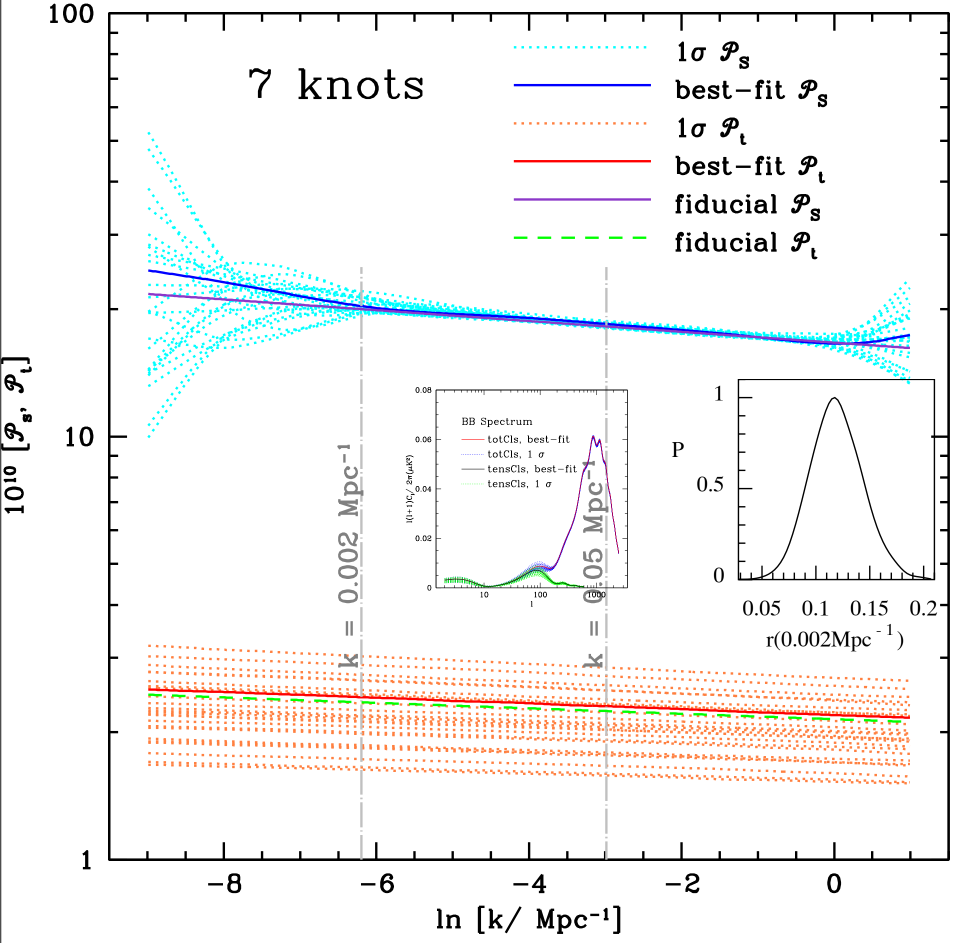
1° field of view, 6-meter primary, 2-meter secondary, 1.4’ resolution

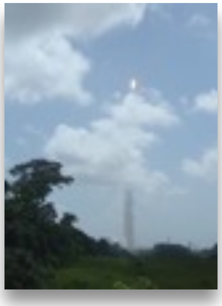
148, 220, (270) GHz, 3000 TES detectors

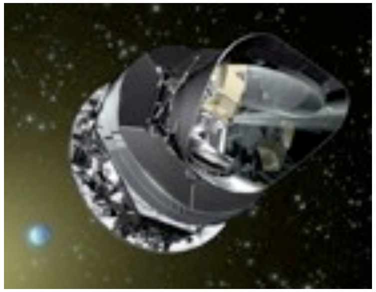


compress data onto non-top-hat k-modes

Planck2.5 7 knot forecast with inflation consistency; input r=0.12 - from $m^2\varphi^2$



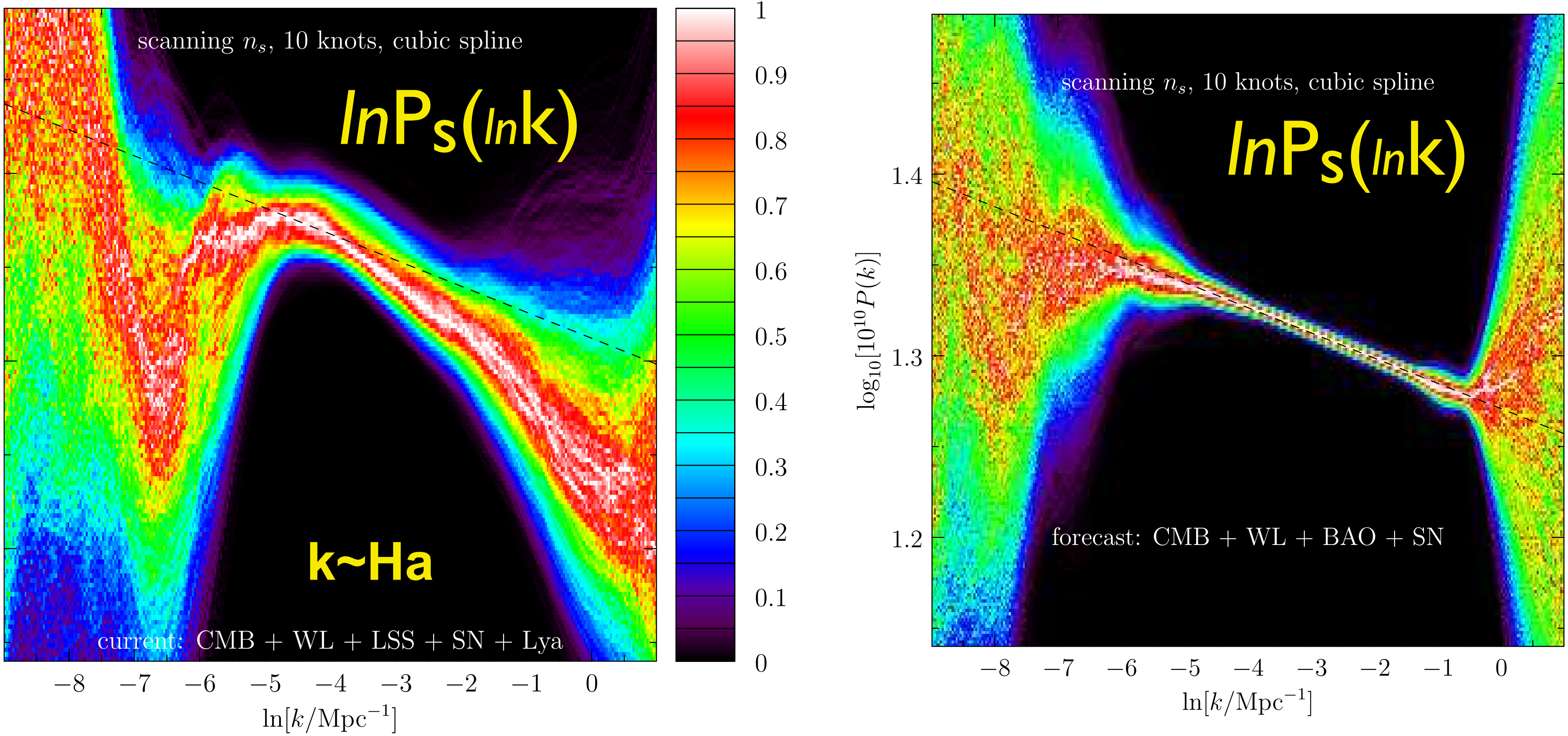




now & future scalar power spectrum trajectories

scan $\mathbf{n_s}(\ln k)$, $\ln \mathbf{A_s} = \ln P_s(k_{pivot,s})$, $\mathbf{r}(k_{pivot,t})$;

consistency => reconstruct $\varepsilon(\ln Ha)$, $V(\psi)$



$$\varepsilon_\psi \approx \varepsilon = -\,d\ln H / d\ln a \;;\; V(\psi) \approx 3M_P^2H^2(1-\varepsilon/3) \;;\; d\psi/ d\ln a = \pm\sqrt{\varepsilon}$$

$\mathrm{GW/S} \equiv r \approx 16\varepsilon$

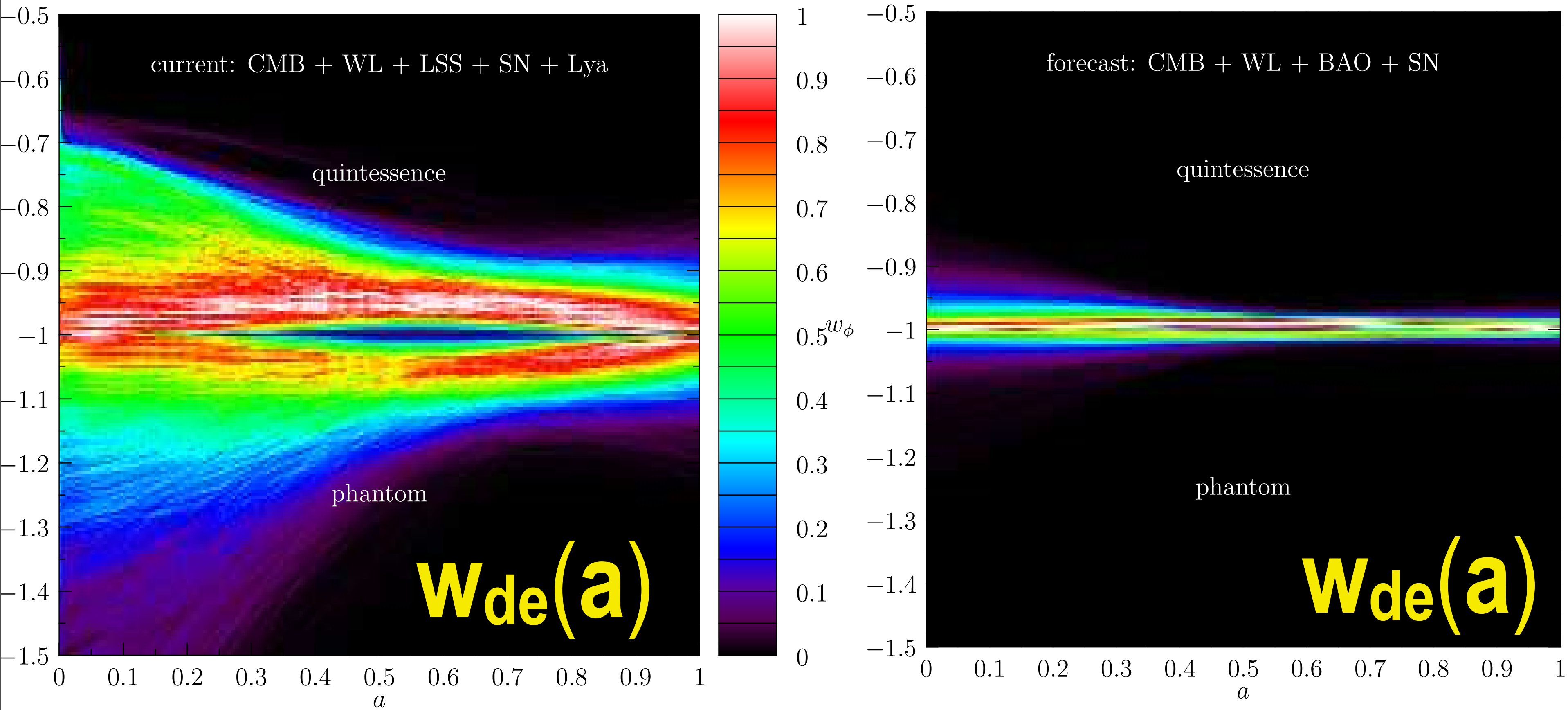
Bond, Contaldi, Huang, Kofman, Vaudrevange 2011

$r \approx 0.1\, V / (10^{16}\,\mathrm{Gev})^4$

NOW & future DE equation of state trajectories

$(1+w_{de}) = - d\ln\rho_{de} / d\ln a^3 = 2/3\ \varepsilon_\psi$ & $\varepsilon=\Omega_\psi\varepsilon_\psi+\Omega_m\varepsilon_m$ & $\varepsilon_m=3/2$

Huang, Bond, Kofman 2010

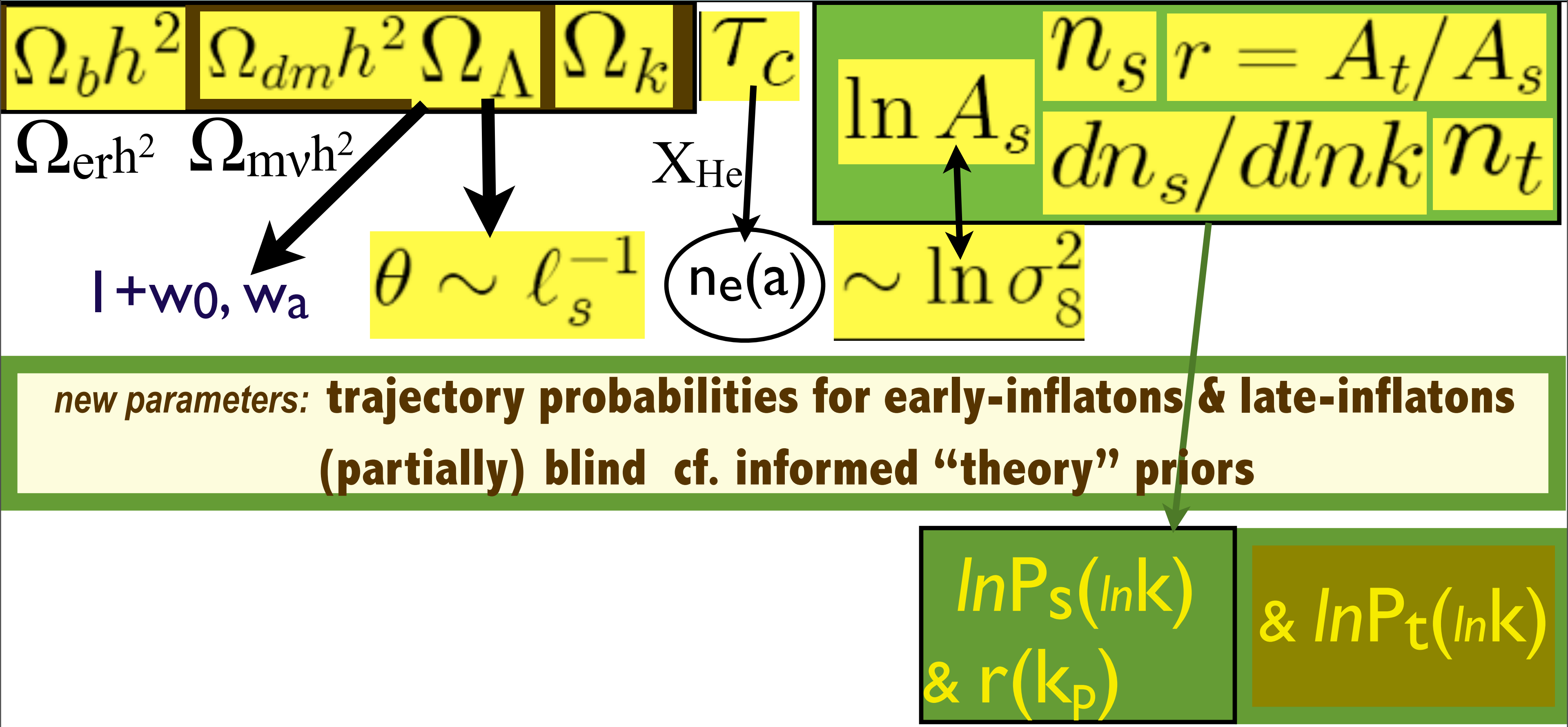


future = Planck2.5+CHIME-BOSS-BAO+"JDEM-SN+Euclid-WL"

3-parameter w_{de} **(z|V(ψ),IC)** paves even wild late-inflaton trajectories

semi-blind w_{de} **(z)** in many z-bands determines only ~2 eigenvalues

Standard Parameters of Cosmic Structure Formation



$\Omega_b h^2$ $\Omega_{dm} h^2$ Ω_Λ Ω_k τ_c

$\Omega_{er} h^2$ $\Omega_{m\nu} h^2$ X_{He}

$1+w_0, w_a$ $\theta \sim \ell_s^{-1}$ $n_e(a)$

$\ln A_s$ n_s $r = A_t/A_s$ $dn_s/d\ln k$ n_t

$\sim \ln \sigma_8^2$

new parameters: **trajectory probabilities for early-inflatons & late-inflatons**

(partially) blind cf. informed “theory” priors

$\ln P_s(\ln k)$ & $r(k_p)$

& $\ln P_t(\ln k)$

$$\varepsilon_\phi \times 2/3 = 1 + w_{de}(a)$$
$$= -\, d\ln\rho_\phi / d\ln \mathbf{a}^3$$

+ subdominant

isocurvature, cosmic string,

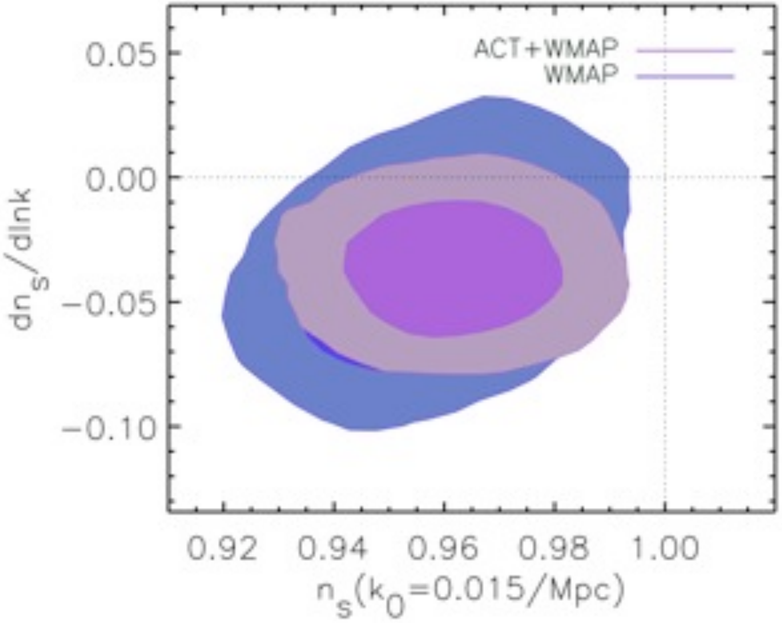
& fgnds, tSZ,kSZ, ...

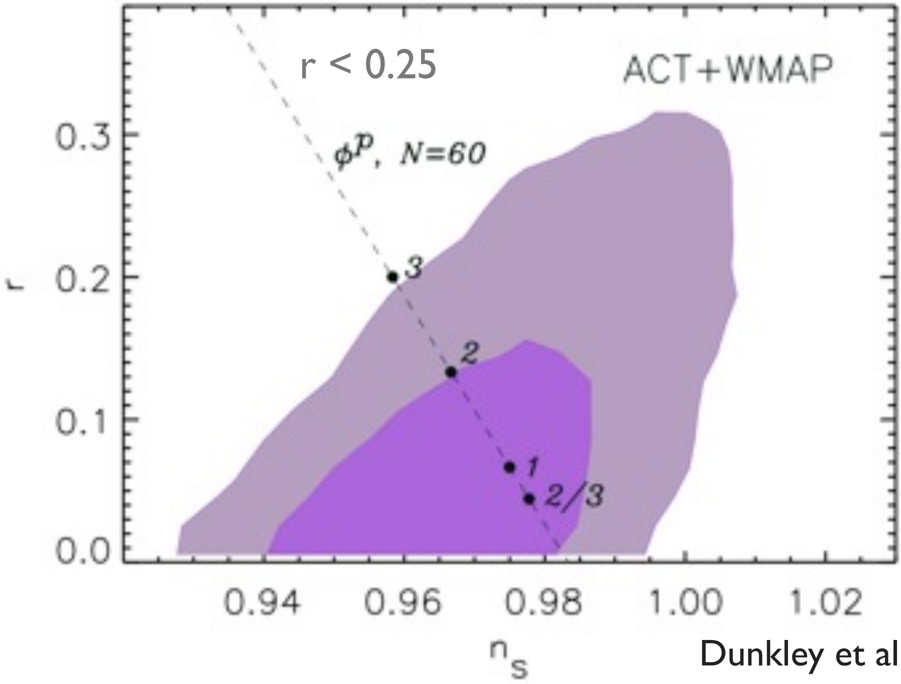
Inflation: limits from spectrum

- Effective field theory, period of exponential expansion for > 60 e-folds.
- Running index, find $dn_s/d\ln k = -0.024 \pm 0.015$

  (ACT+WMAP+BAO+H0)
- New upper limit on tensors, find

  $r < 0.19$ (95% CL, ACT+WMAP+BAO+H0)





Dunkley et al. 2010

Old view: Theory prior = delta function of THE correct one and only theory

New: Theory prior = probability distribution of late-flows on an energy LANDSCAPE

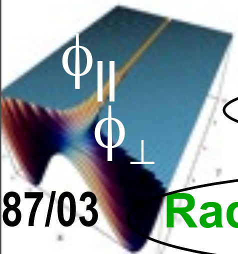
6/7 tiny extra dimensions

1980

R^2-inflation

Old Inflation

Chaotic inflation



New Inflation

Double Inflation

Power-law inflation

SUGRA inflation

87/03

Radical BSI inflation

running (nee variable M_P) inflation

Higgs inflation

Extended inflation

1990

Natural pNGB inflation

Hybrid inflation

KLS94 preheating

SUSY F-term inflation

SUSY D-term inflation

Assisted inflation

Brane inflation

2000

SUSY P-term inflation

Super-natural Inflation

K-flation

N-flation

2003 KKLT

ekpyrotic/ cyclic

D3,D7 brane inflation

DBI inflation

moving brane separations

Racetrack inflation

Tachyon inflation

Warped Brane inflation

moduli fields

monodromy

Higgs inflation

Roulette inflation Kahler moduli/axion

fibre inflation

cosmology forecasts for PlanckEXT

$n_s(k)$, GW $r(k)$, nonG f_{NL}++, $\rho_{de}(t)$, m_ν, strings, isocurvature, ...

current CMB+LSS+WL+SN1a+Lyα **PEXT=**Planck2.5yr + low-z-BOSS + CHIME + Euclid-WL + JDEM-SN

Huang, Bond, Kofman 2010

$n_s = \pm 0.012 \Rightarrow \pm 0.002$ (Pext)

$\ln A_s = \pm 0.03 \Rightarrow \pm 0.008$ (Pext)

Farhang, Bond, Dore, Netterfield 2011 ***forecasting QU not EB***

Spider $2\sigma_r \sim 0.013 \Rightarrow \sim 0.02$ for $0.02 < f_{sky} < 0.15$

Planck2.5yr $2\sigma_r \sim 0.02 \Rightarrow \sim 0.05$ (foregrounds)

quadratic local nonG $-10 < f_{NL} < 74$ (+- 5 Planck)

primordial non-Gaussianity

$$\Phi(x)= \Phi_G(x)+\boxed{f_{NL}}(\Phi_G^2(x)-\langle\Phi_G^2\rangle)$$

local smooth. use optimal pattern estimator

DBI inflation: non-quadratic kinetic energy

cosmic/fundamental strings/defects

from end-of-inflation & preheating

$$\Phi(x)= \Phi_G(x)+ F_{NL}(\chi_b)-\langle F_{NL}\rangle$$

resonant preheating f_{NLeff} + cold spots

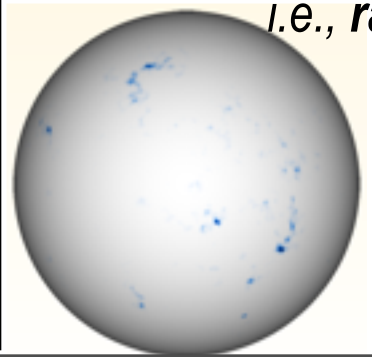
$-10< f_{NL} <74$ (+- 5 Planck)

CMB peaks (hot&cold)

=> the WMAP Cold Spot

clusters are frequency-matched cold/hot spots

*i.e., **rare event nonG tails***



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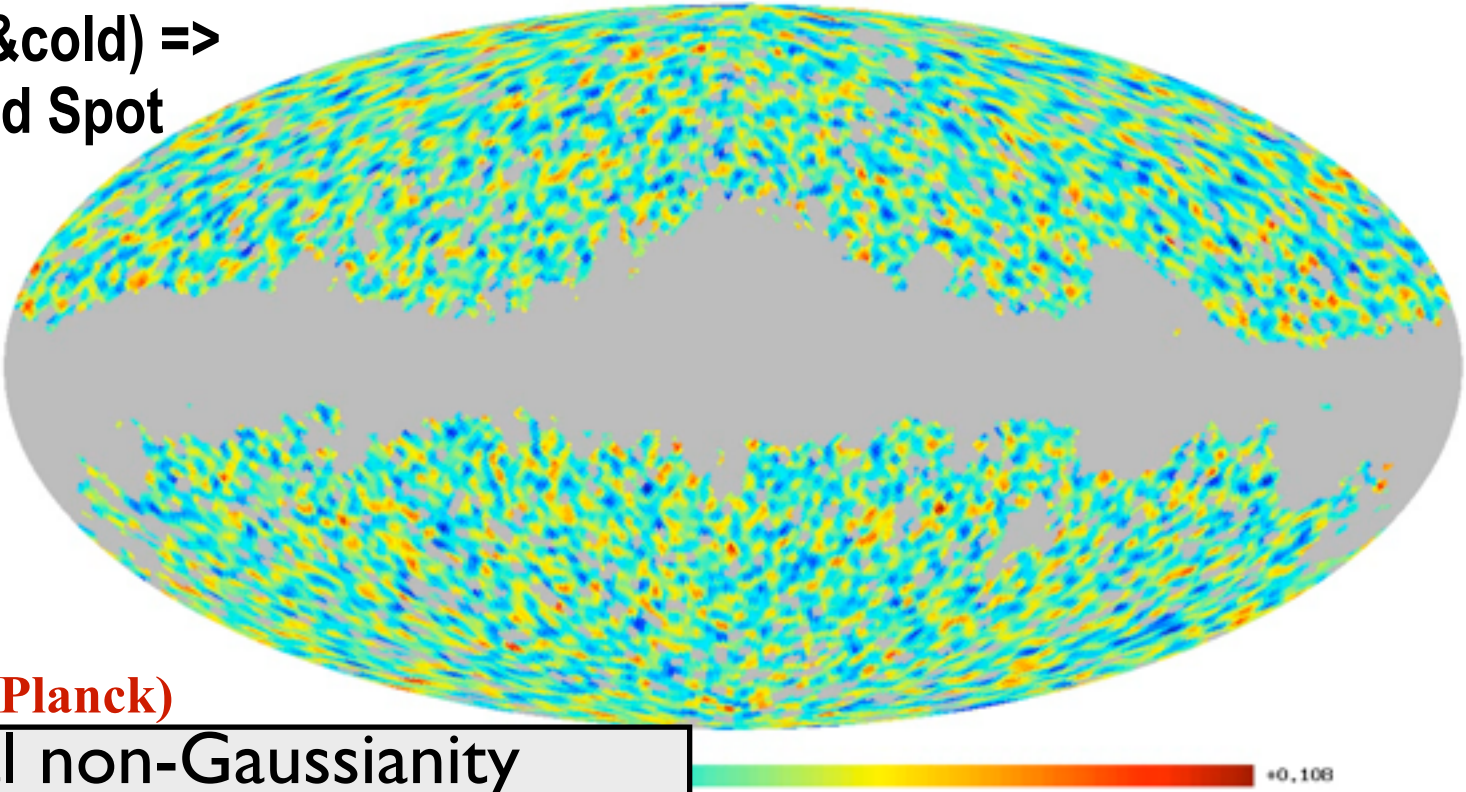
the WMAP Cold Spot



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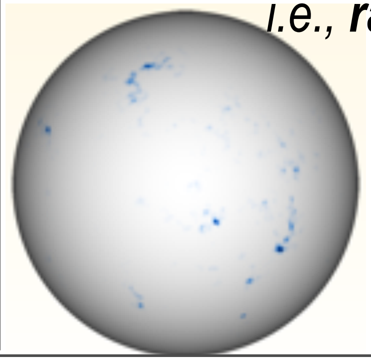

bias modulation with a nearly scale invariant Φ_G out to R_{hor}

primordial non-Gaussianity

$$\Phi(x)= \Phi_G(x)+ \boxed{f_{NL}} (\Phi_G^2(x)-<\Phi_G^2>)$$

local smooth. use optimal pattern estimator

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$$\Phi(x)= \Phi_G(x)+ F_{NL}(\chi_b)-<F_{NL}>$$

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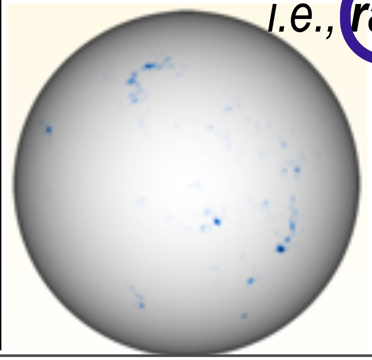
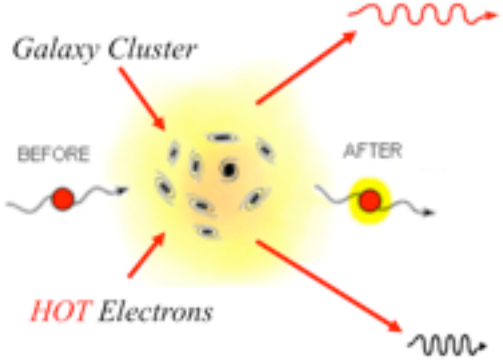
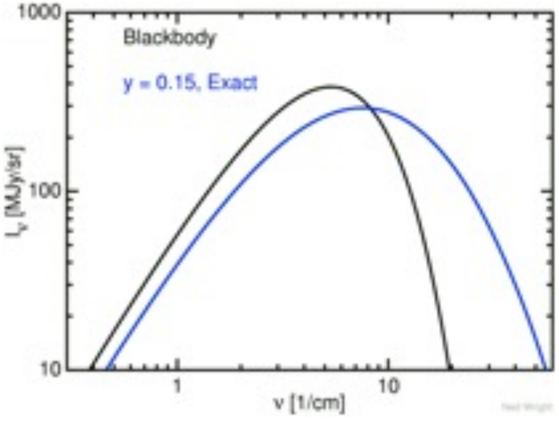
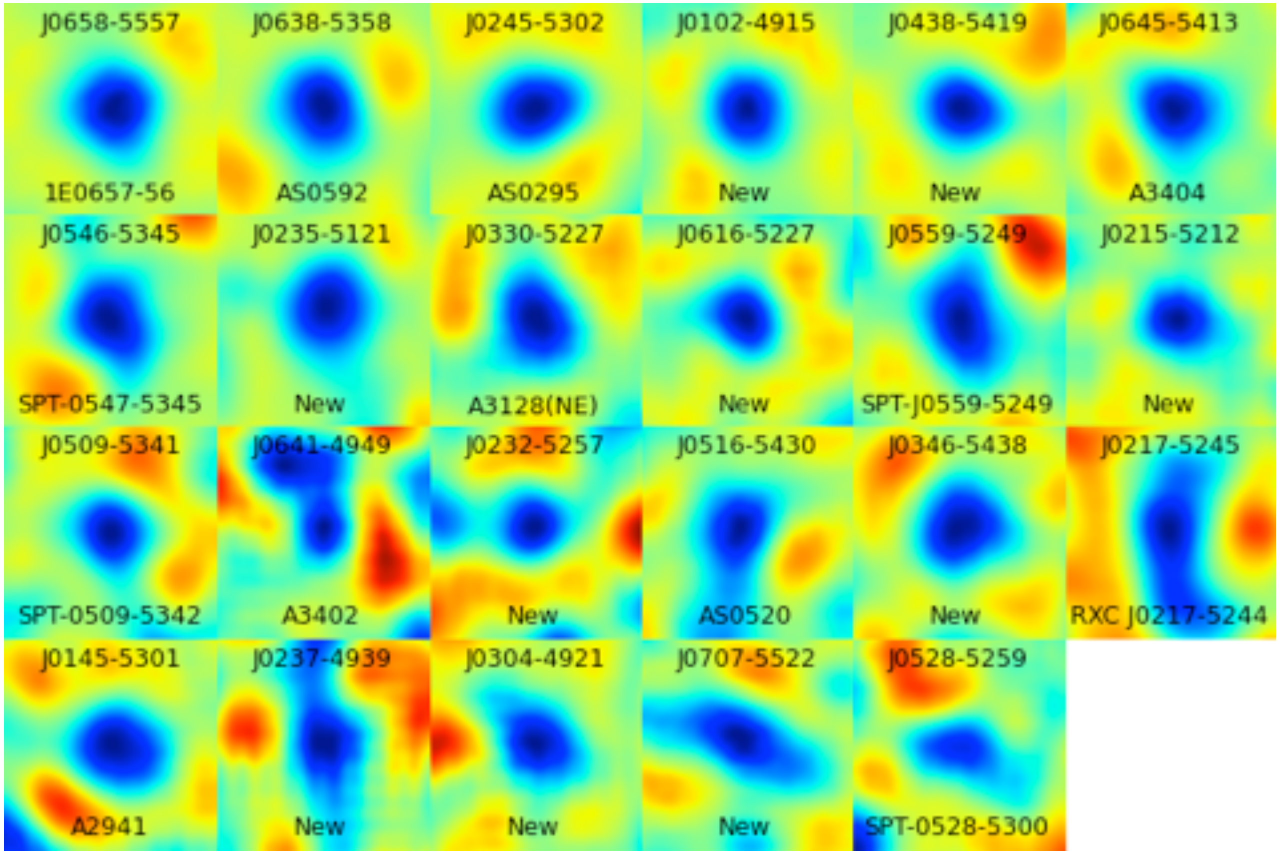


Sunyaev-Zel’dovich clusters in ACT



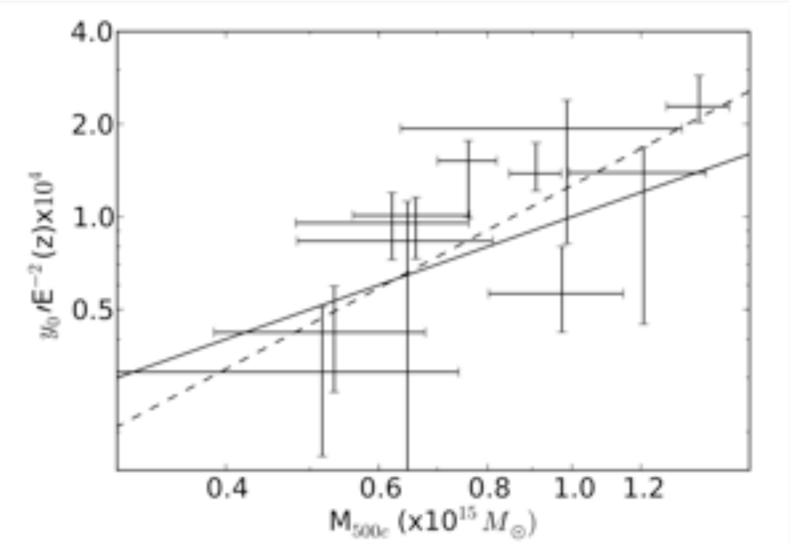


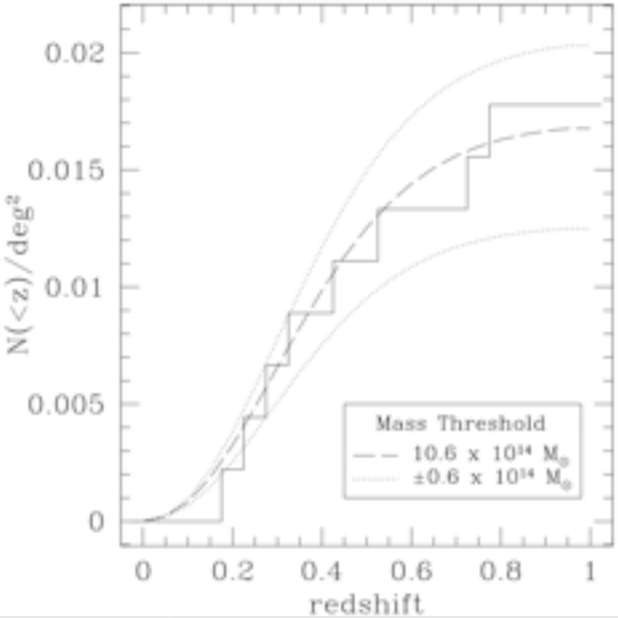


Marriage et al. 2010 in prep

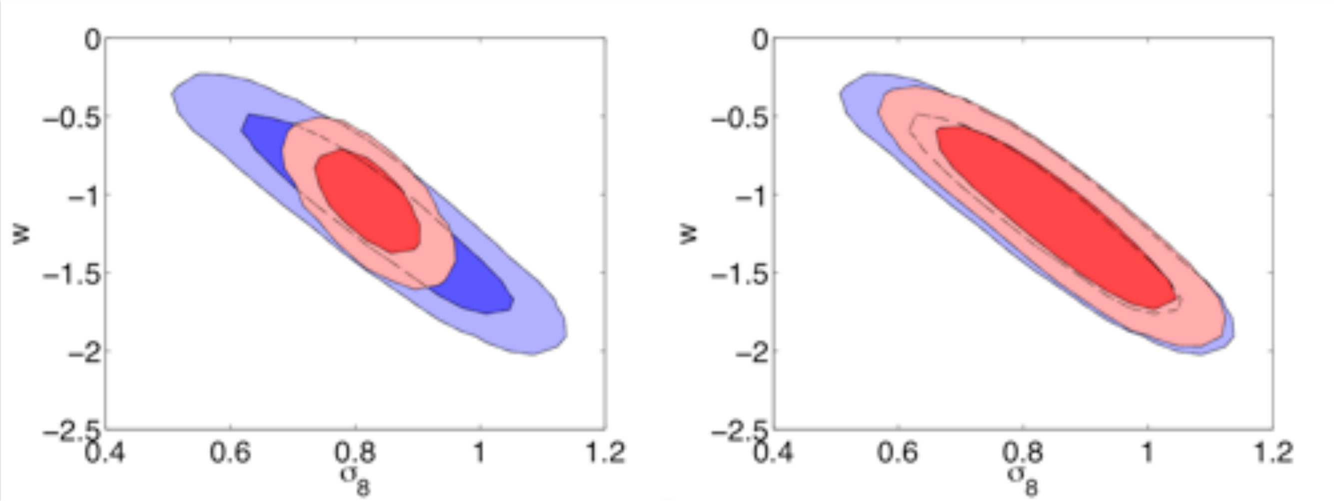
- All been optically followed up (Menanteau et al 2010) and have redshift (out to z~1).

Cluster number counts





For high significance clusters, concordance cosmological model fits the data well for a given mass limit



CBI **pol to Apr'05** @Chile **CBI2**

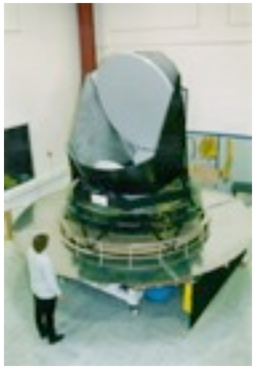
C_L^{SZ}

QUaD @SP

C_L^{SZ}

Planck09.4

52+ bolometers
+ HEMTs @L2
9 frequencies



WMAP @L2 **to 2010**

2004 2005 2006 2007 2008 2009 2011

LHC

Bpol
@L2

C_L^{SZ}

Acbar@SP
~1 blind

>96

OVRO
/BIMA
array

C_L^{SZ}

SZA@Cal

C_L^{SZ}

AMI

GBT

AMIBA

APEX
~400 bolos@Chile

C_L^{SZ}

SPT
1000 bolos
@SPole

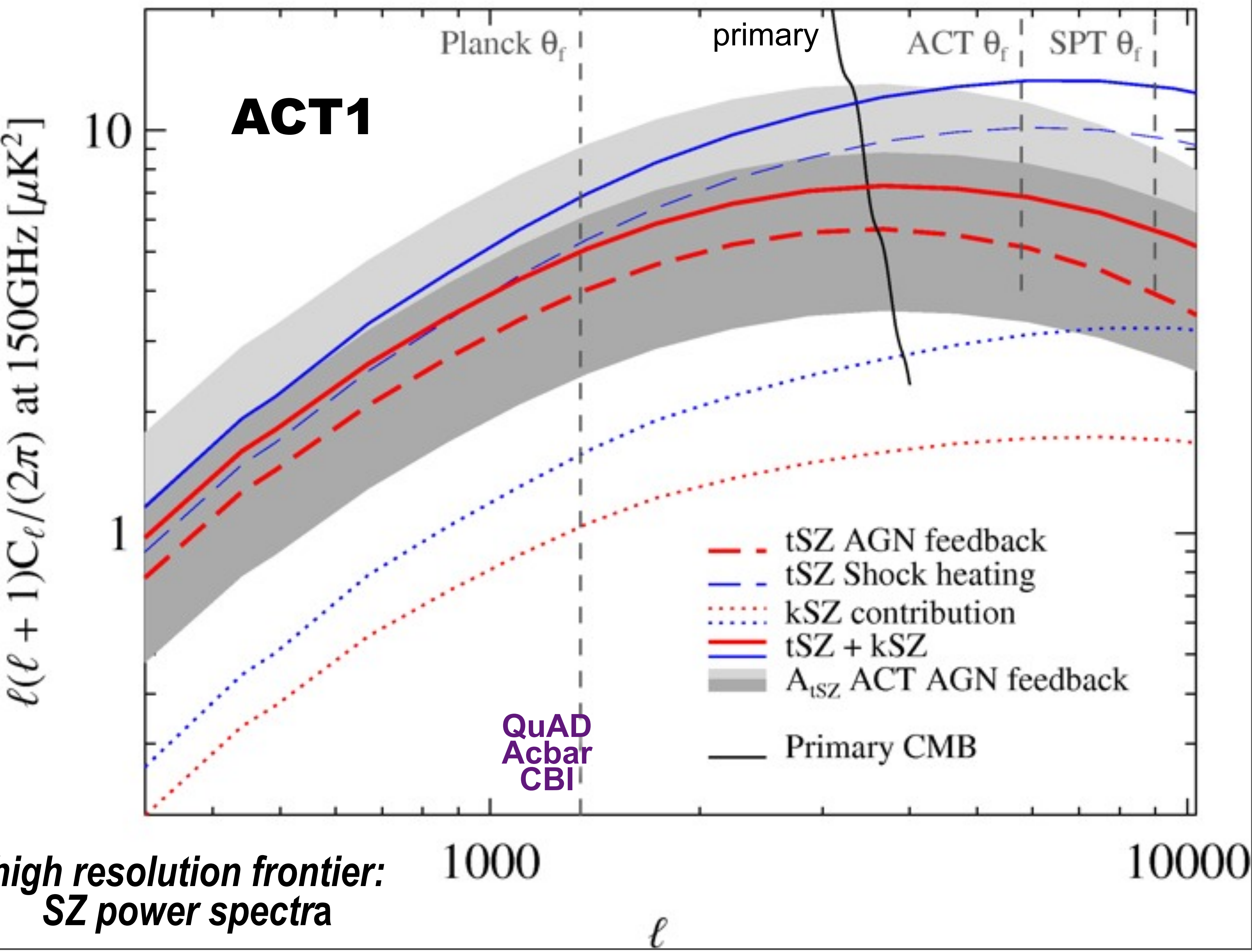
ACT
3000 bolos
3 freqs @Chile

C_L^{SZ}

SCUBA2
12000 bolos
JCMT @Hawaii

80s-90s
Ryle
OVRO

SPTpol
ACTpol
ALMA
CCAT@Chile
LMT@Mexico

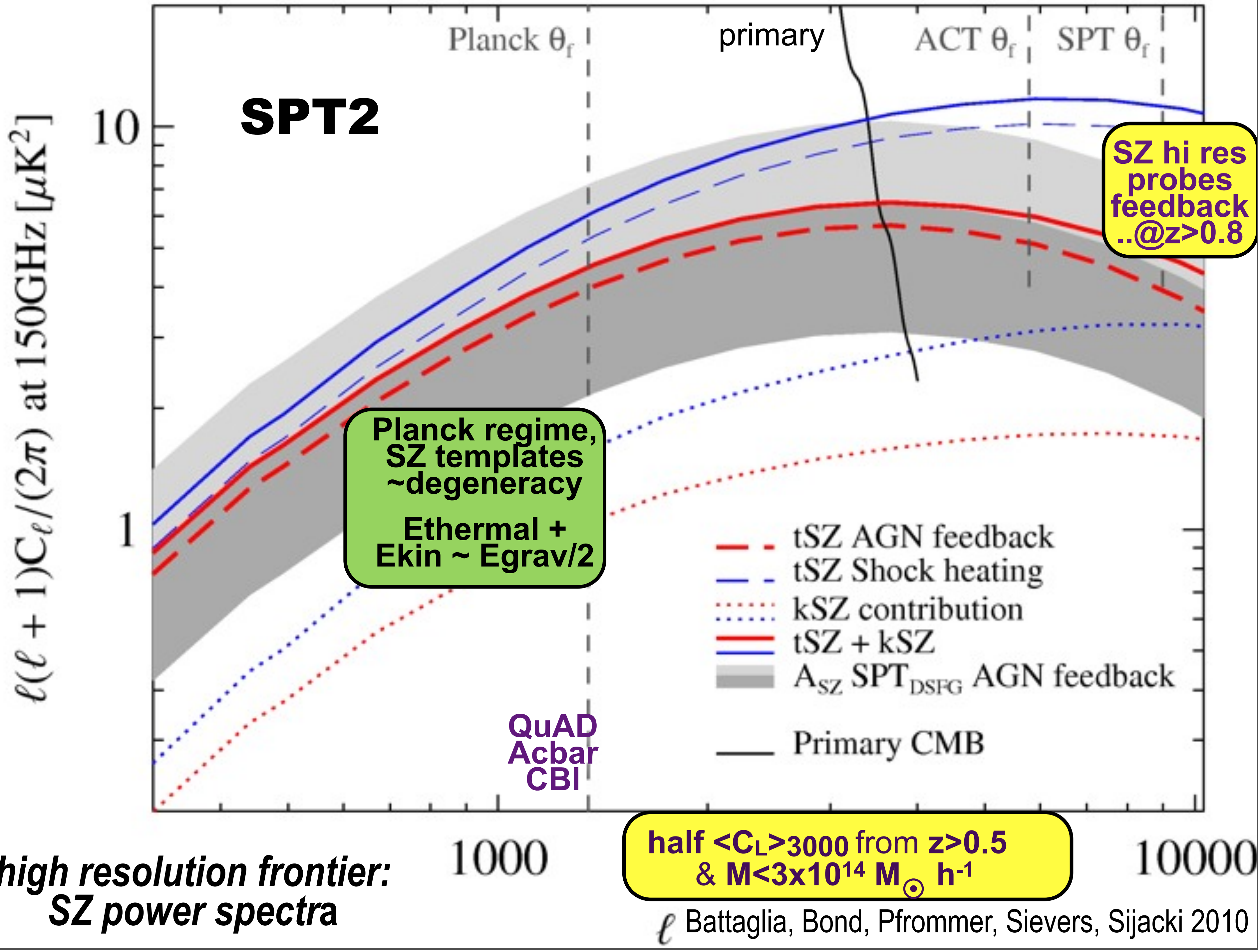


ACT1

primary

QuAD
Acbar
CBI

high resolution frontier:
SZ power spectra



SPT2

SZ hi res probes feedback ..@z>0.8

Planck regime, SZ templates ~degeneracy

Ethermal + Ekin ~ Egrav/2

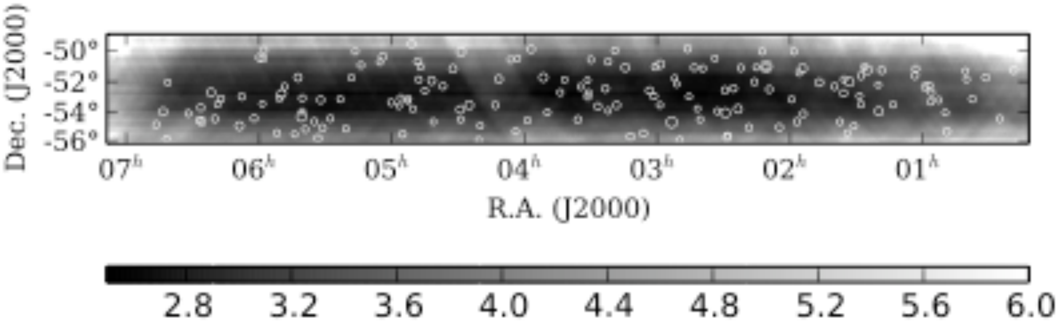
QuAD Acbar CBI

half $\langle C_L \rangle_{3000}$ from z>0.5 & M<3x10^{14} M$_\odot$ h^{-1}

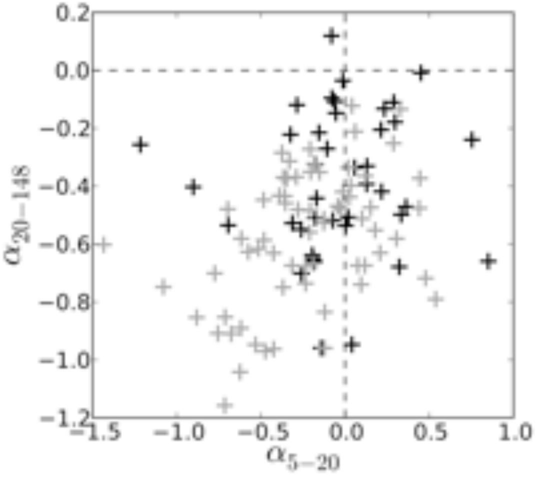
high resolution frontier: SZ power spectra

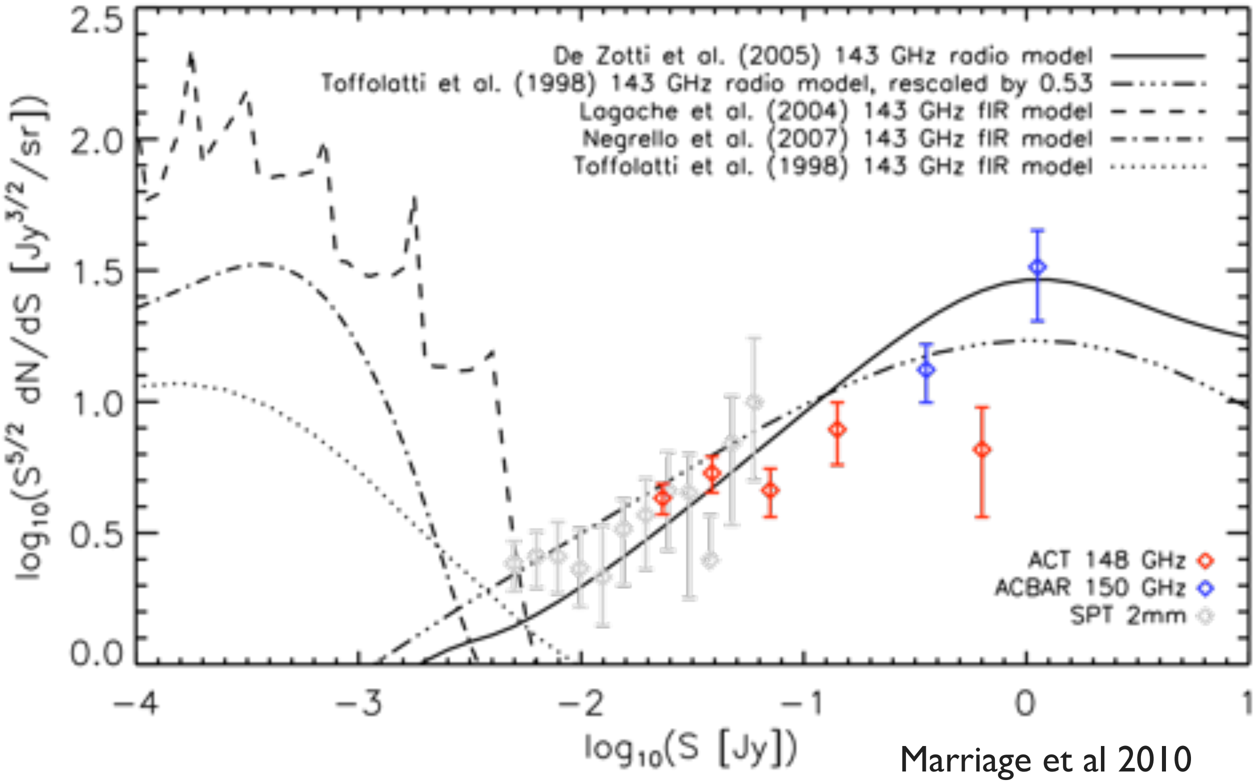
Battaglia, Bond, Pfrommer, Sievers, Sijacki 2010

Radio galaxy detections at 148 GHz



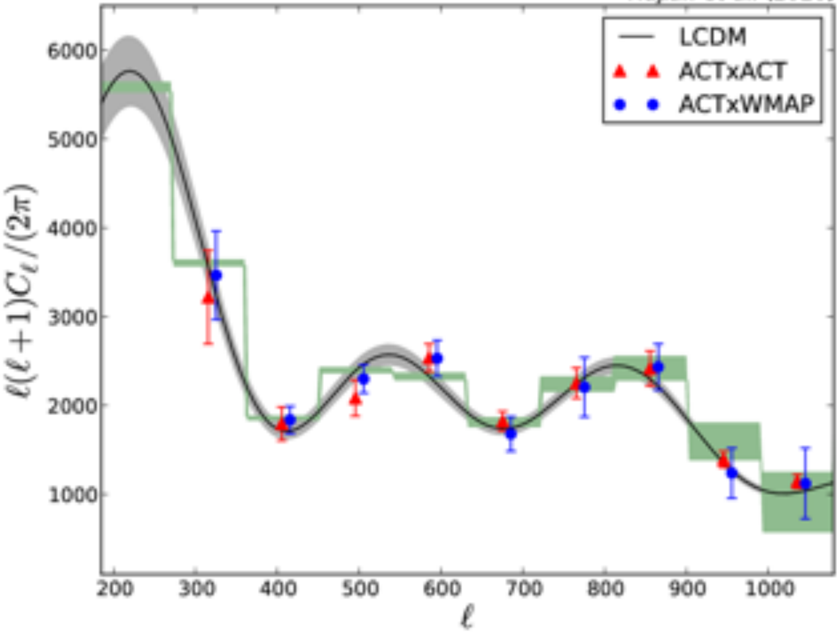
157 sources 15-1500 mJy (5 sigma)
98% known radio sources





Marriage et al 2010

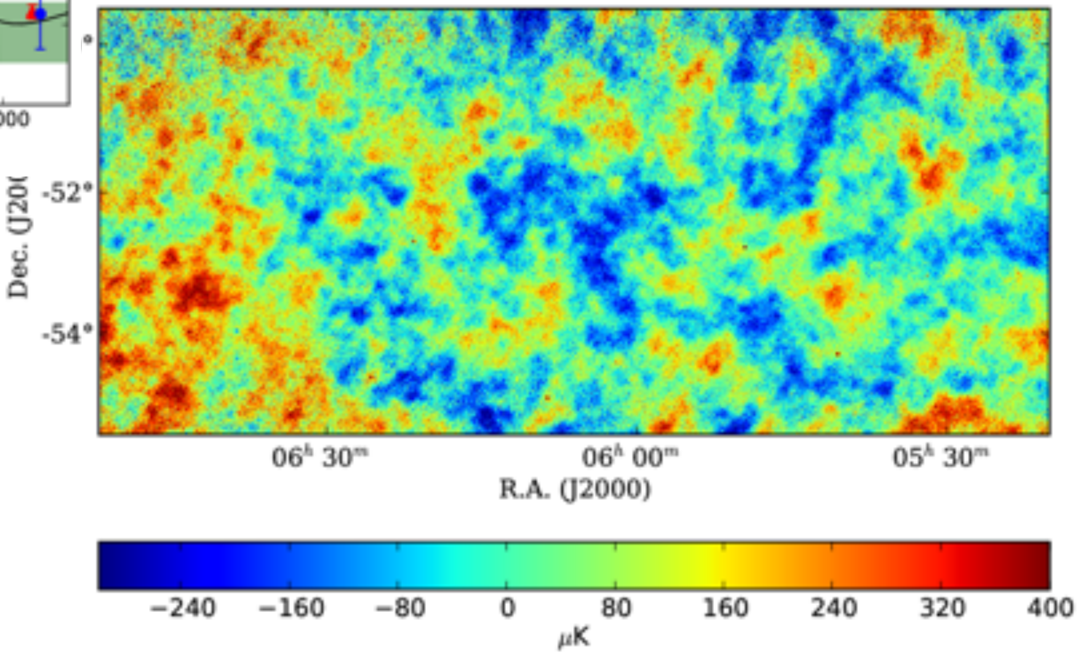
ACT-WMAP cross-spectrum



Hajian et al. (2010)

ACT ‘sees’ same sky as WMAP
Use to calibrate ACT maps, to 2% accuracy

Create a compilation map from two datasets:

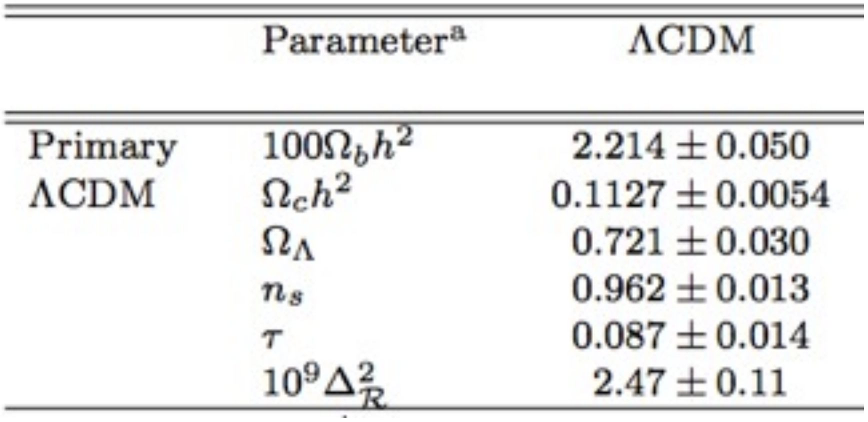


Hajian et al. (2010)

ACT (2008) Parameters

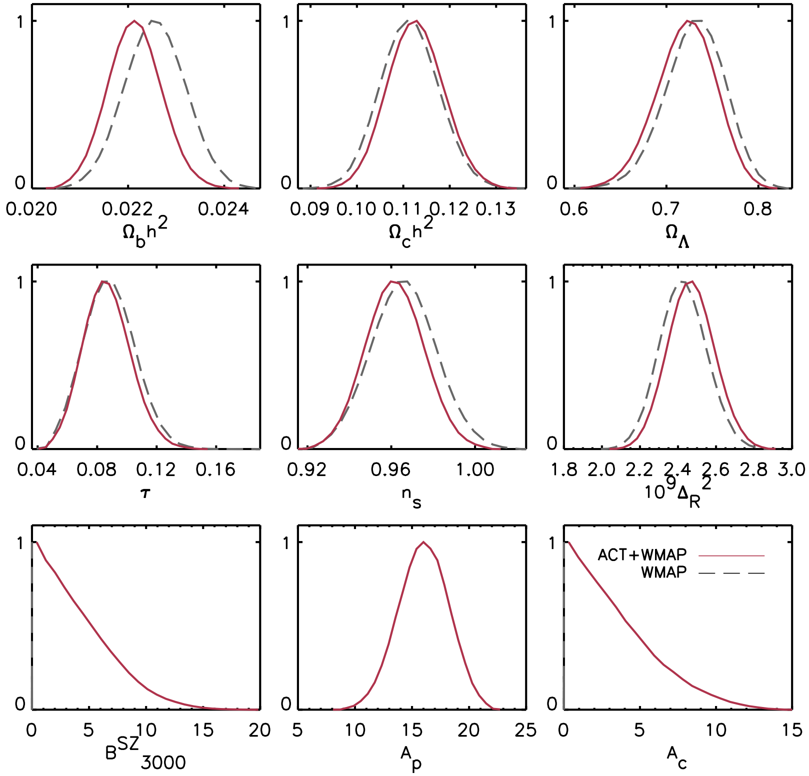
ACT (2008) measures ~10% # of WMAP modes.

So 5-10% improvement on basic params.



	Parameter[a]	ΛCDM
Primary ΛCDM	$100\Omega_b h^2$	2.214 ± 0.050
	$\Omega_c h^2$	0.1127 ± 0.0054
	Ω_Λ	0.721 ± 0.030
	n_s	0.962 ± 0.013
	τ	0.087 ± 0.014
	$10^9 \Delta^2_{\mathcal{R}}$	2.47 ± 0.11

WMAP7+ACT cosmological parameters



Black - WMAP7

Red - +ACT

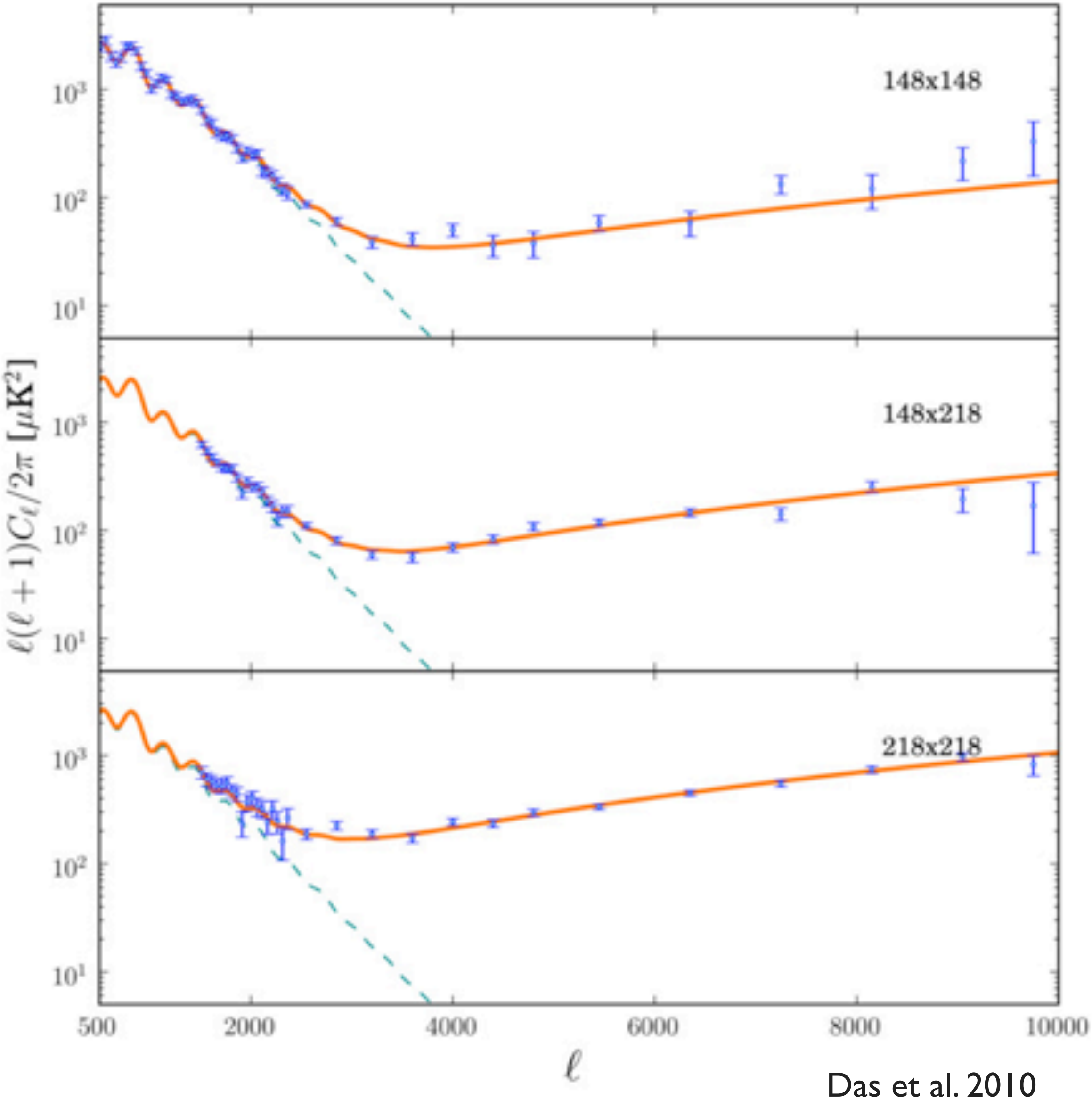
ACT 148-218 GHz spectra

- WMAP extends to l=1000
- ACT:
  500<l<10000 for 148 GHz,
  1500<l<10000 for 218 GHz

- Higher acoustic peaks and Silk damping tail probed

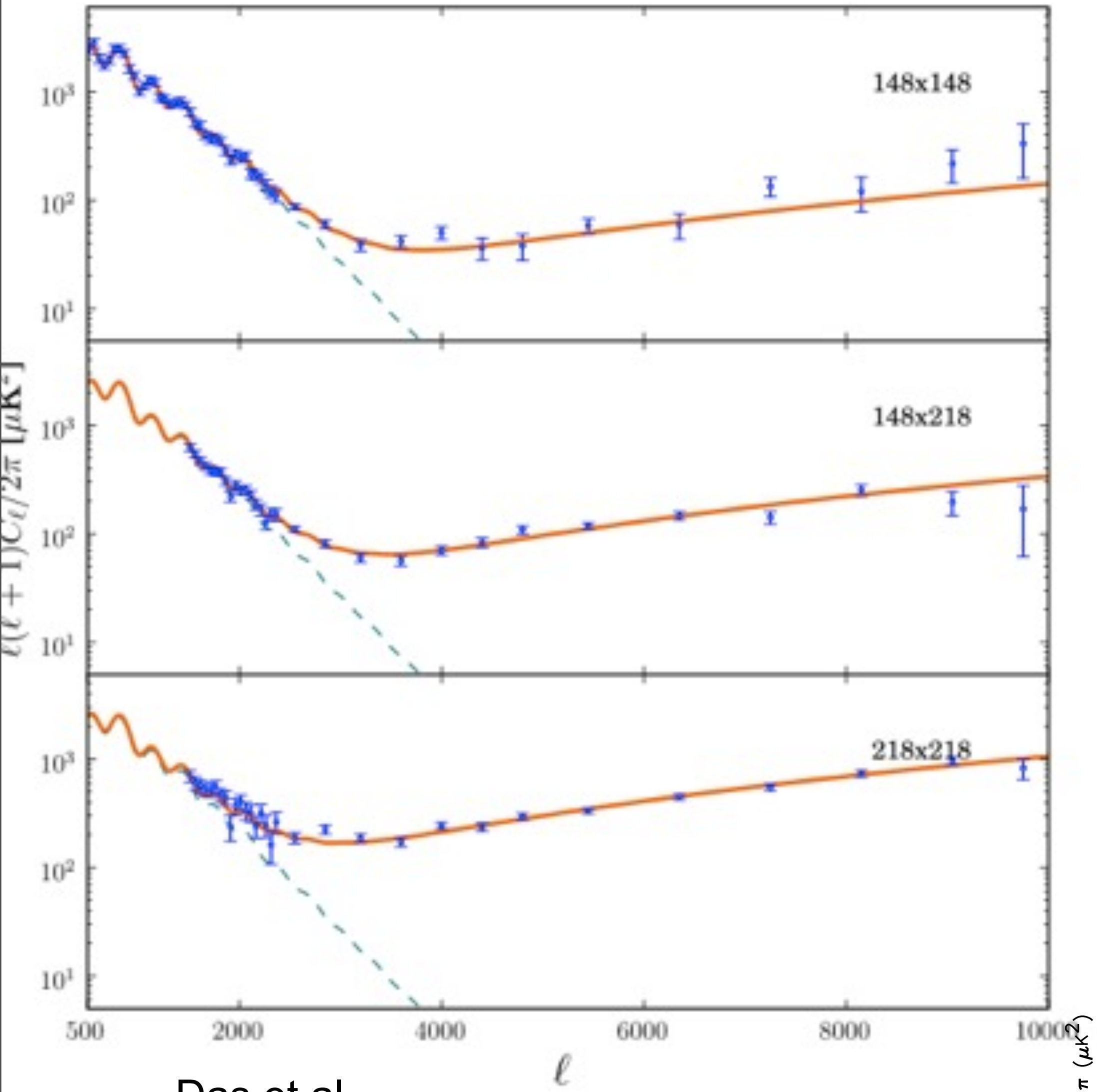
- CMB dominates out to l~3000 for 148 GHz, and l~2000 for 218 GHz

- High ell dominated by point source and SZ.



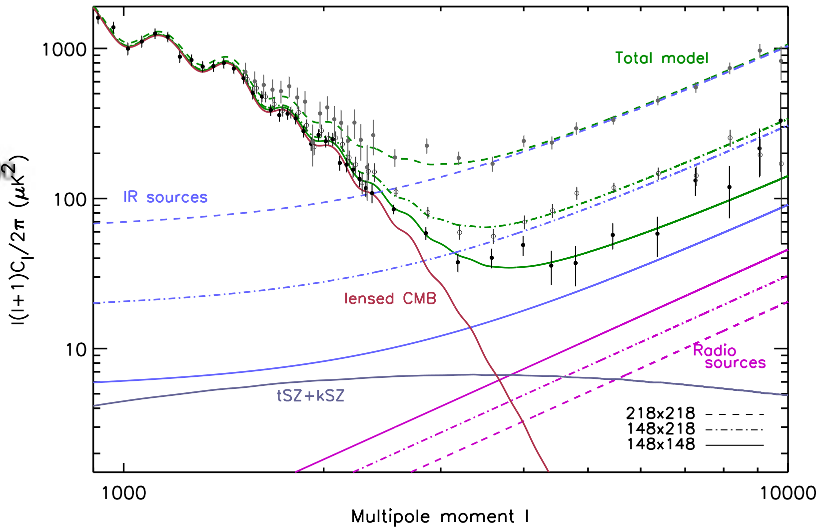
Das et al. 2010

2008 Power Spectra

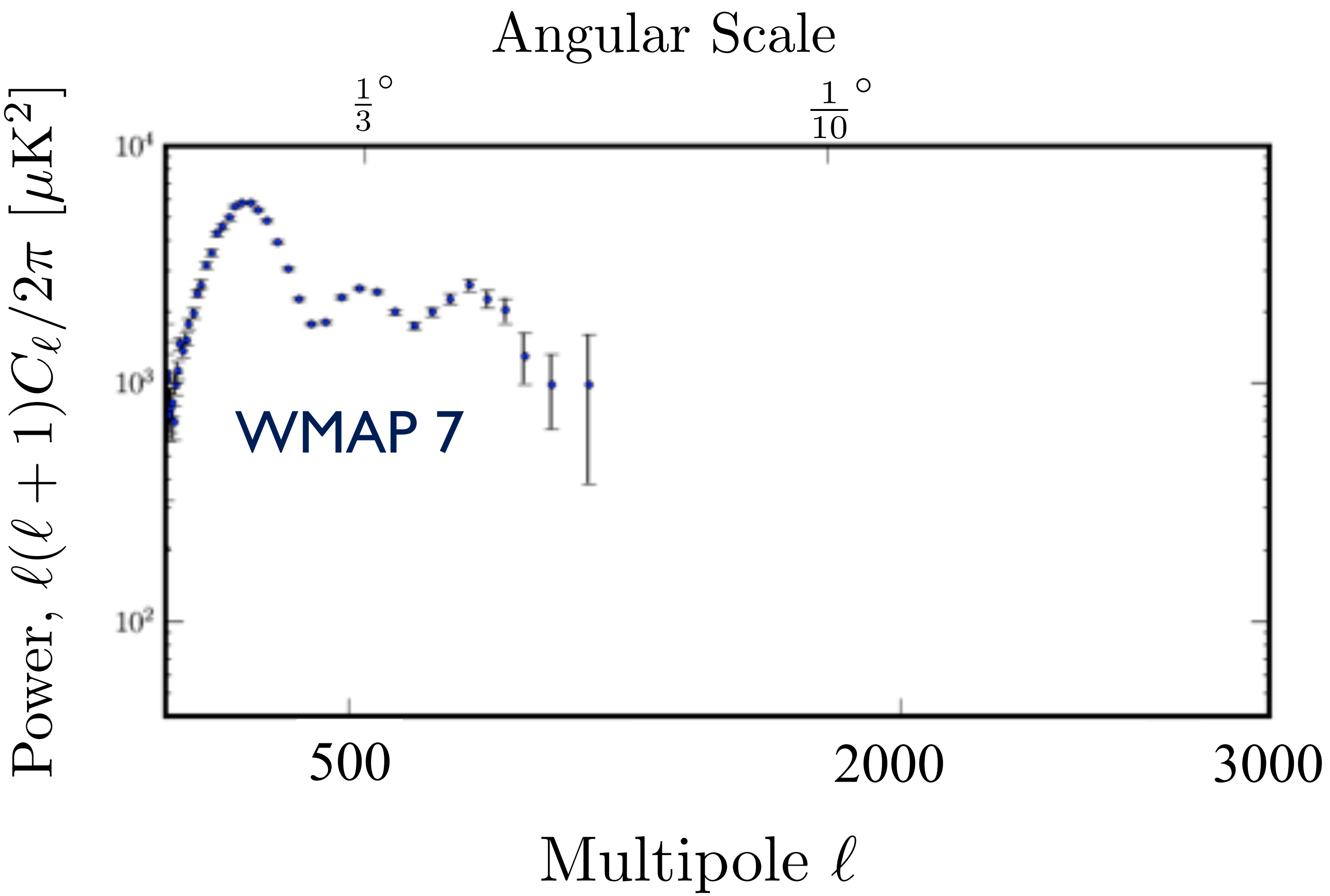


Das et al.

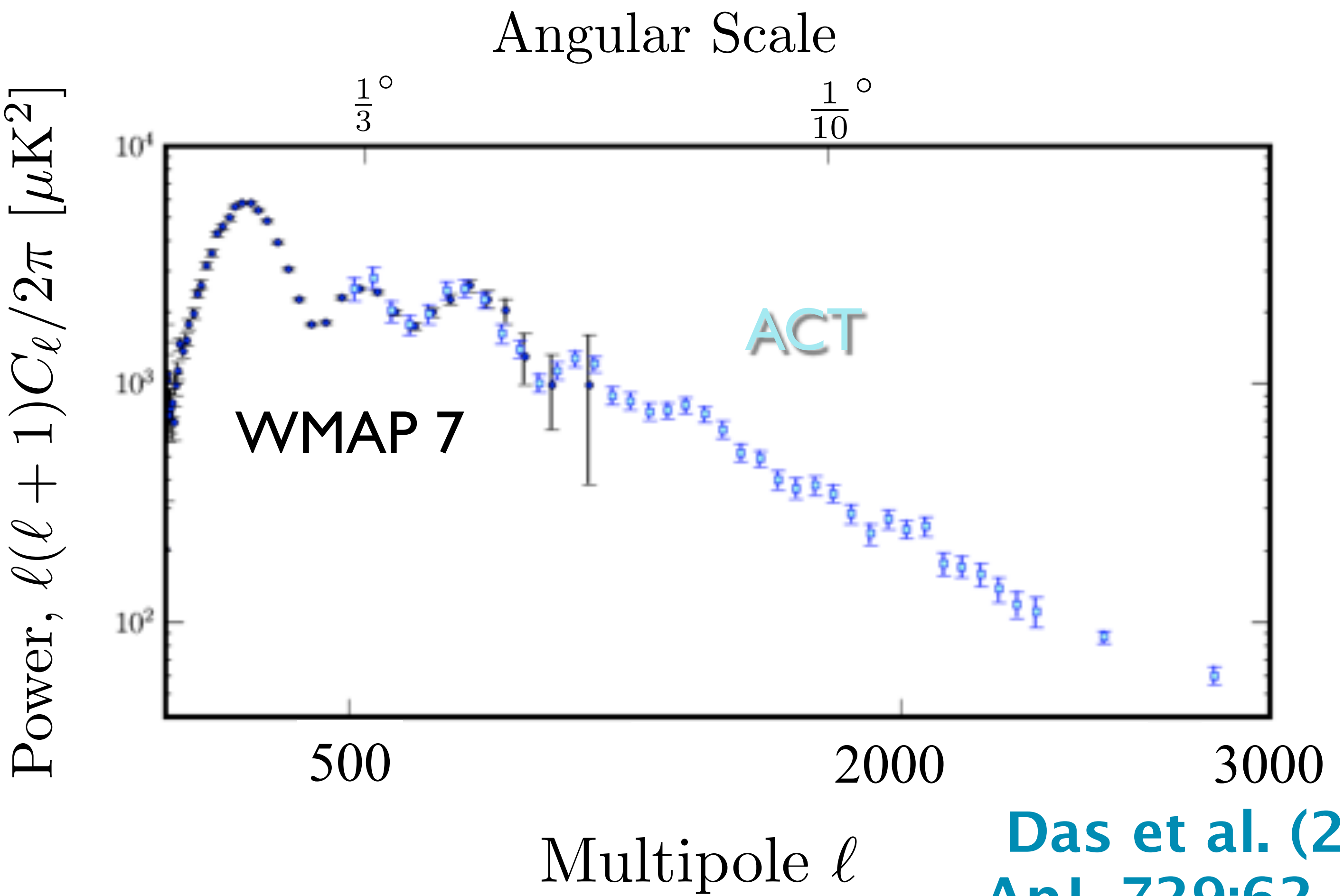
Spectra fit models quite well (148 chi^2=29/46 DOF), atmosphere/instrument noise worse at 220, limits low-l. High-l tail rising quickly with frequency, implies IR/dusty sources (vs. AGN).



HIGH RESOLUTION POWER SPECTRUM FROM ACT

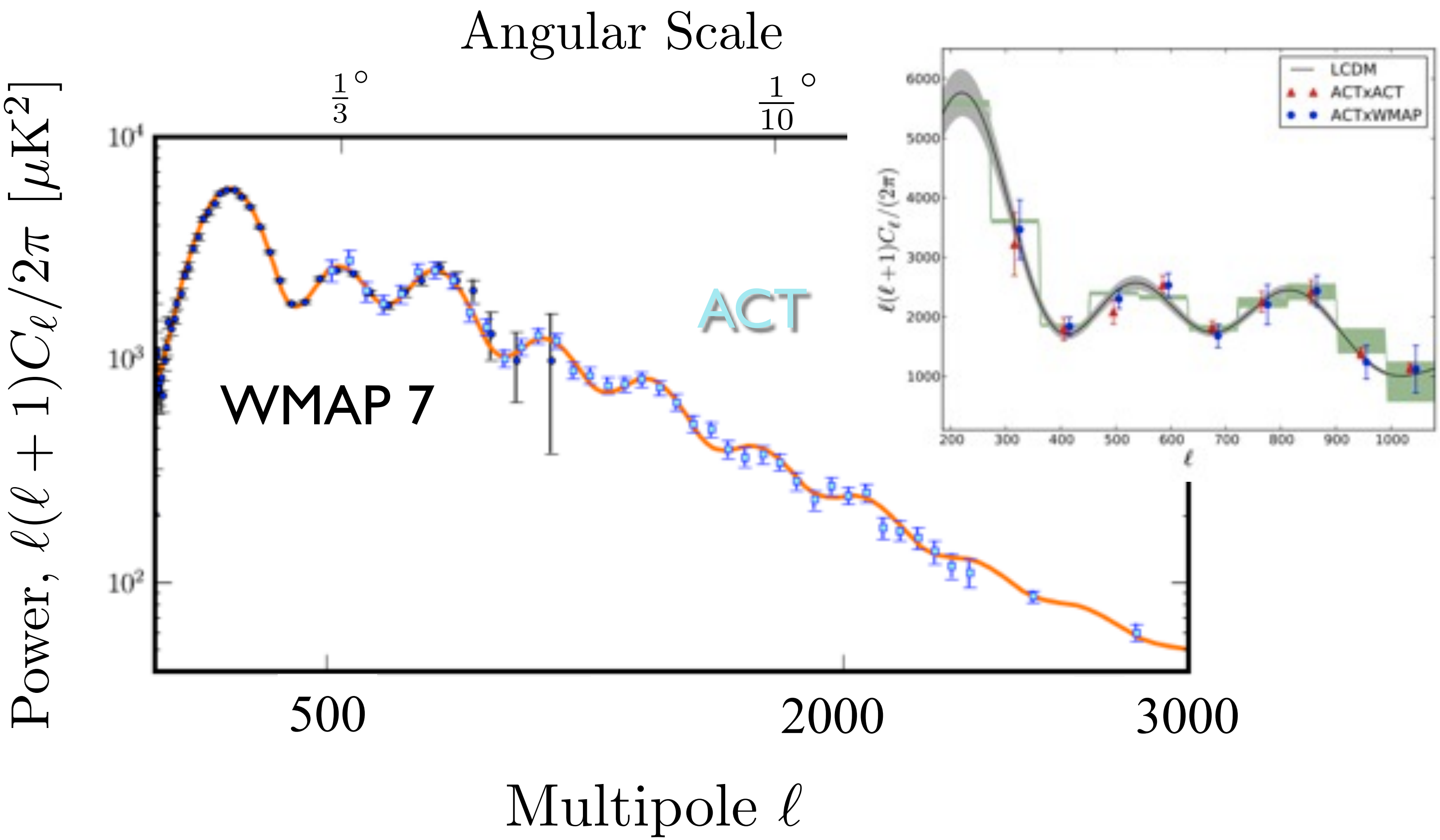


HIGH RESOLUTION POWER SPECTRUM FROM ACT

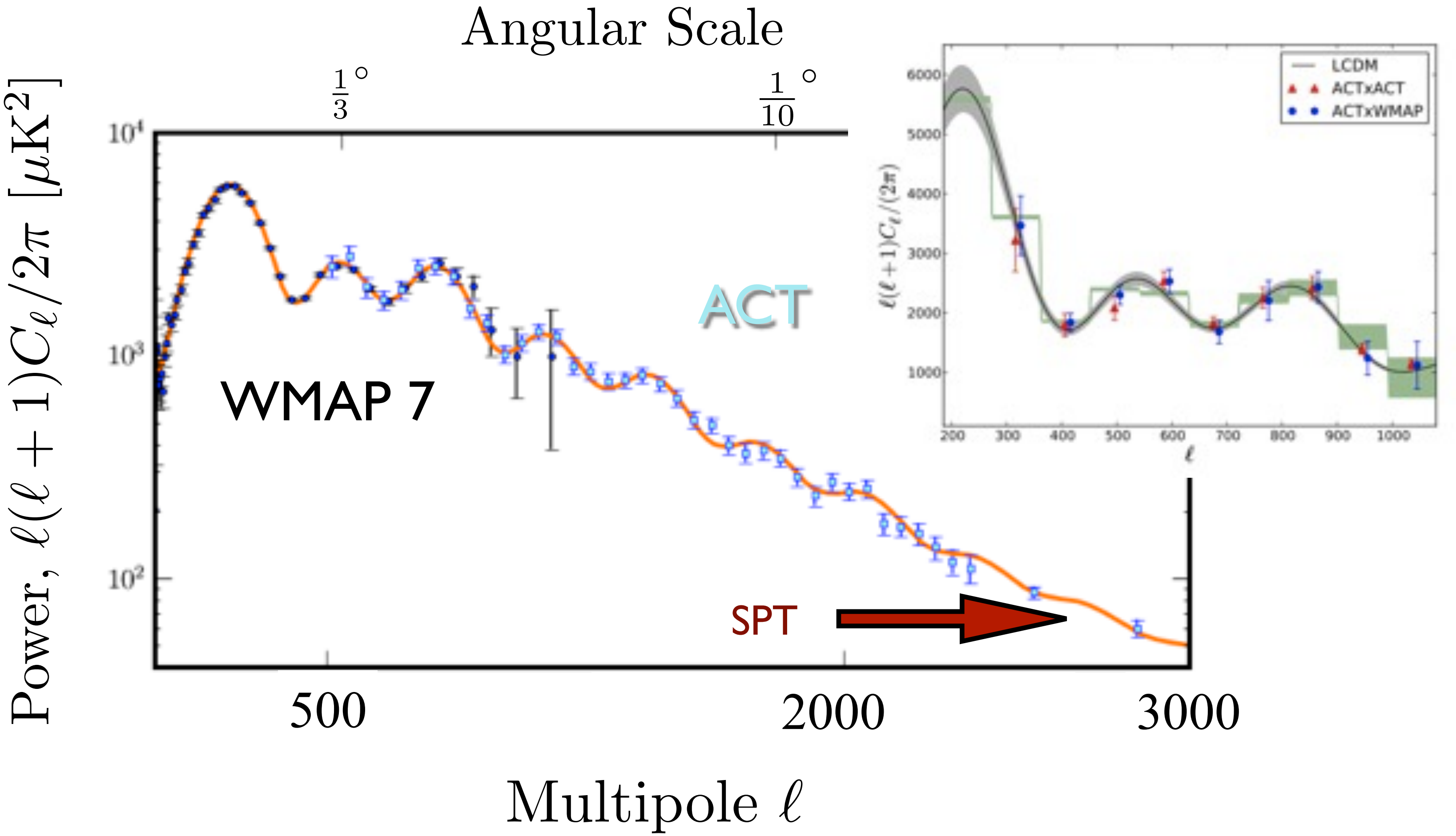


Das et al. (2011), ApJ, 729:62 , 2011

HIGH RESOLUTION POWER SPECTRUM FROM ACT



HIGH RESOLUTION POWER SPECTRUM FROM ACT



ACT - Moving Past Standard Parameters

- ACT 2008 high-res spectrum really helps constrain parameters past standard 6 in LCDM.

- Factor of ~50% improvement on running of the spectral index.

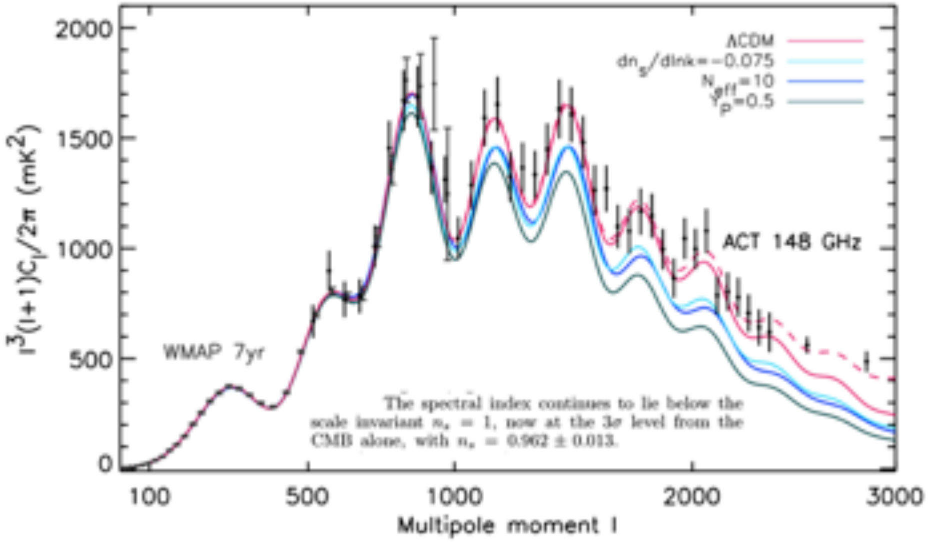
- 60% improvement on cosmic string constraints.

- >40% improvement on r.

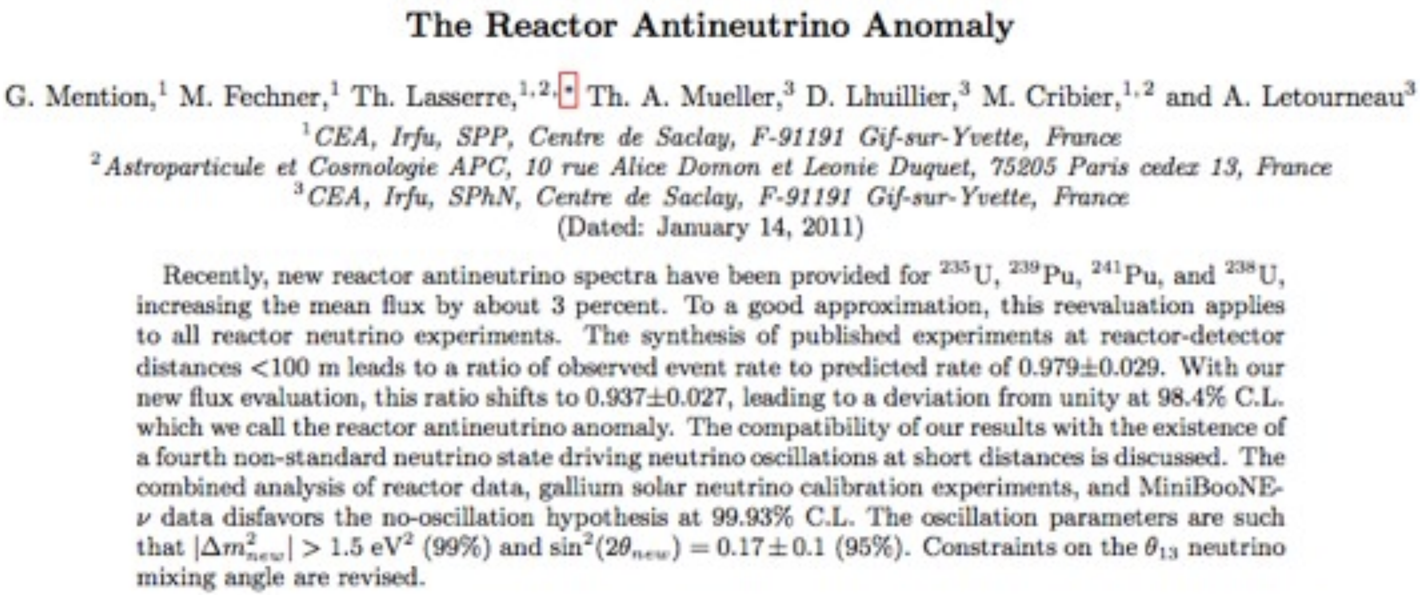
- Constraint on n_{rel}, unlike WMAP7 alone.

- Measurement of primordial He abundance (pre-star)

Model PS for extended cosmology models, several times



The spectral index continues to lie below the scale invariant $n_s = 1$, now at the 3σ level from the CMB alone, with $n_s = 0.962 \pm 0.013$.

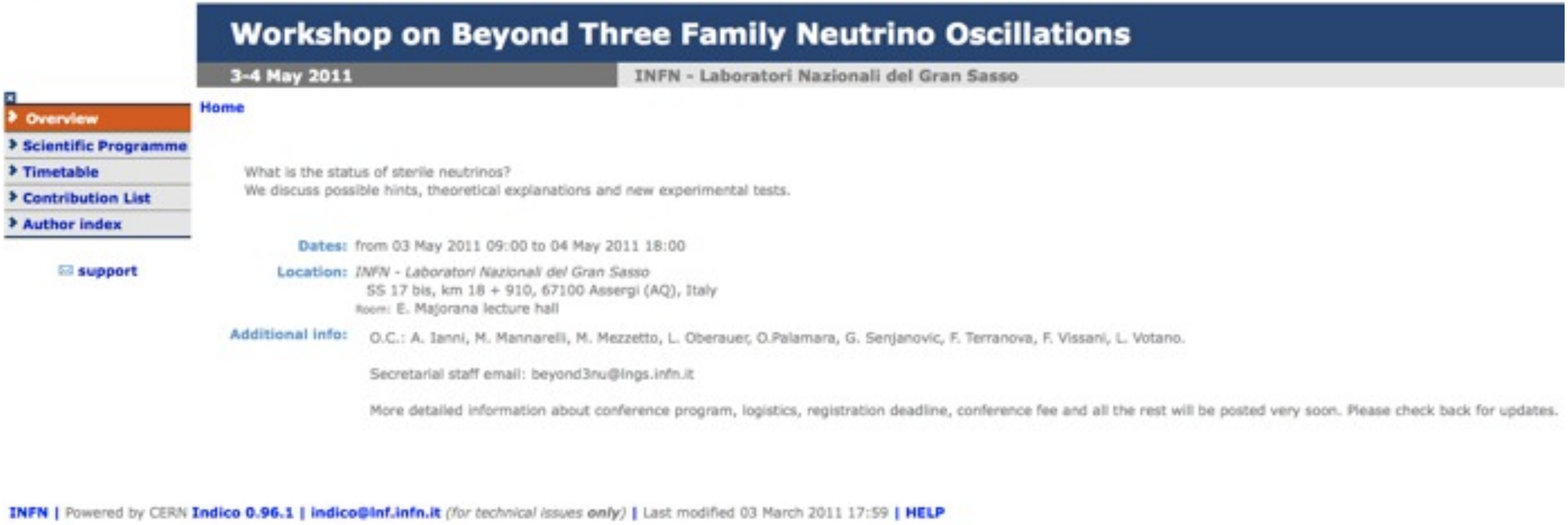


The Reactor Antineutrino Anomaly

G. Mention,[1] M. Fechner,[1] Th. Lasserre,[1,2,*] Th. A. Mueller,[3] D. Lhuillier,[3] M. Cribier,[1,2] and A. Letourneau[3]

[1]*CEA, Irfu, SPP, Centre de Saclay, F-91191 Gif-sur-Yvette, France*
[2]*Astroparticule et Cosmologie APC, 10 rue Alice Domon et Leonie Duquet, 75205 Paris cedex 13, France*
[3]*CEA, Irfu, SPhN, Centre de Saclay, F-91191 Gif-sur-Yvette, France*
(Dated: January 14, 2011)

Recently, new reactor antineutrino spectra have been provided for ^{235}U, ^{239}Pu, ^{241}Pu, and ^{238}U, increasing the mean flux by about 3 percent. To a good approximation, this reevaluation applies to all reactor neutrino experiments. The synthesis of published experiments at reactor-detector distances <100 m leads to a ratio of observed event rate to predicted rate of 0.979±0.029. With our new flux evaluation, this ratio shifts to 0.937±0.027, leading to a deviation from unity at 98.4% C.L. which we call the reactor antineutrino anomaly. The compatibility of our results with the existence of a fourth non-standard neutrino state driving neutrino oscillations at short distances is discussed. The combined analysis of reactor data, gallium solar neutrino calibration experiments, and MiniBooNE-ν data disfavors the no-oscillation hypothesis at 99.93% C.L. The oscillation parameters are such that $|\Delta m^2_{new}| > 1.5$ eV^2 (99%) and $\sin^2(2\theta_{new}) = 0.17 \pm 0.1$ (95%). Constraints on the θ_{13} neutrino mixing angle are revised.



What is the status of sterile neutrinos?
We discuss possible hints, theoretical explanations and new experimental tests.

Dates: from 03 May 2011 09:00 to 04 May 2011 18:00

Location: *INFN - Laboratori Nazionali del Gran Sasso*
SS 17 bis, km 18 + 910, 67100 Assergi (AQ), Italy
Room: E. Majorana lecture hall

Additional info: O.C.: A. Ianni, M. Mannarelli, M. Mezzetto, L. Oberauer, O.Palamara, G. Senjanovic, F. Terranova, F. Vissani, L. Votano.

Secretarial staff email: beyond3nu@lngs.infn.it

More detailed information about conference program, logistics, registration deadline, conference fee and all the rest will be posted very soon. Please check back for updates.

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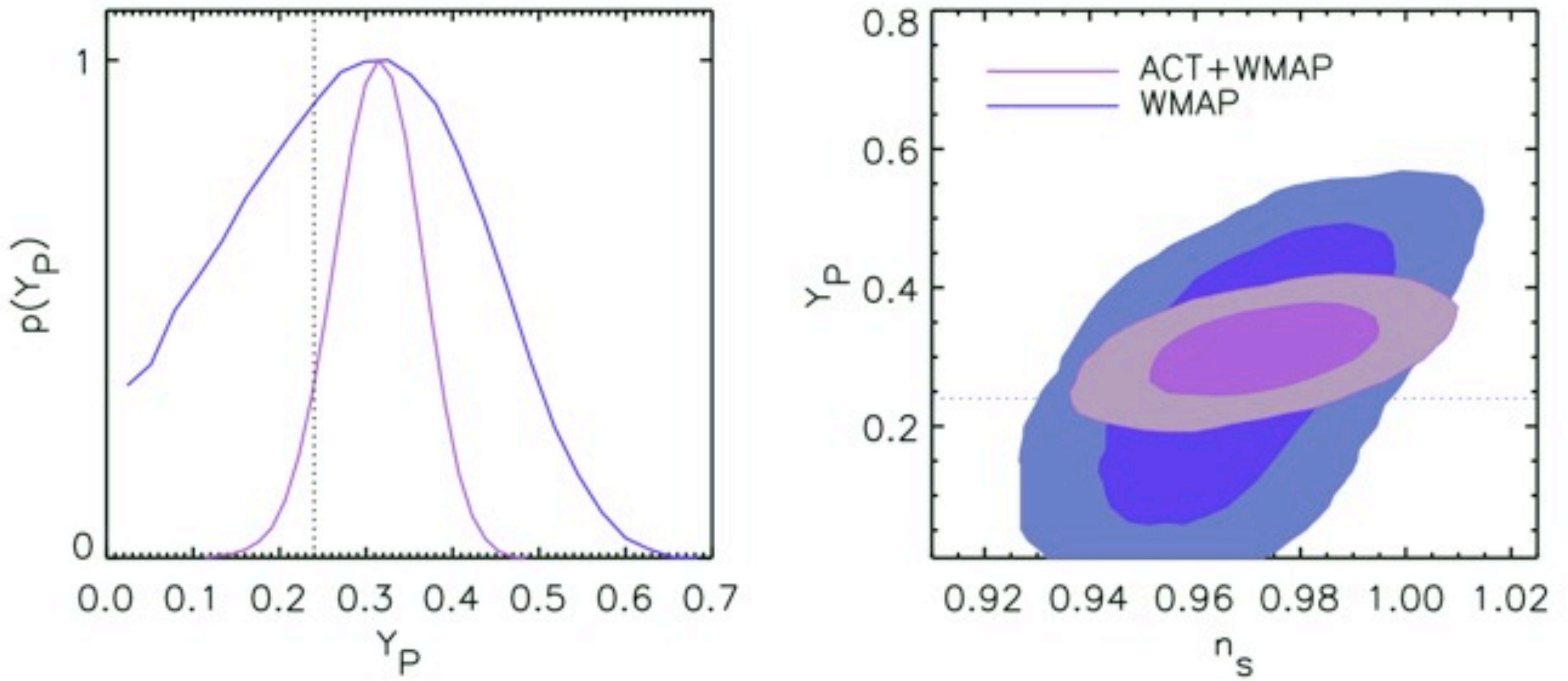
Primordial helium



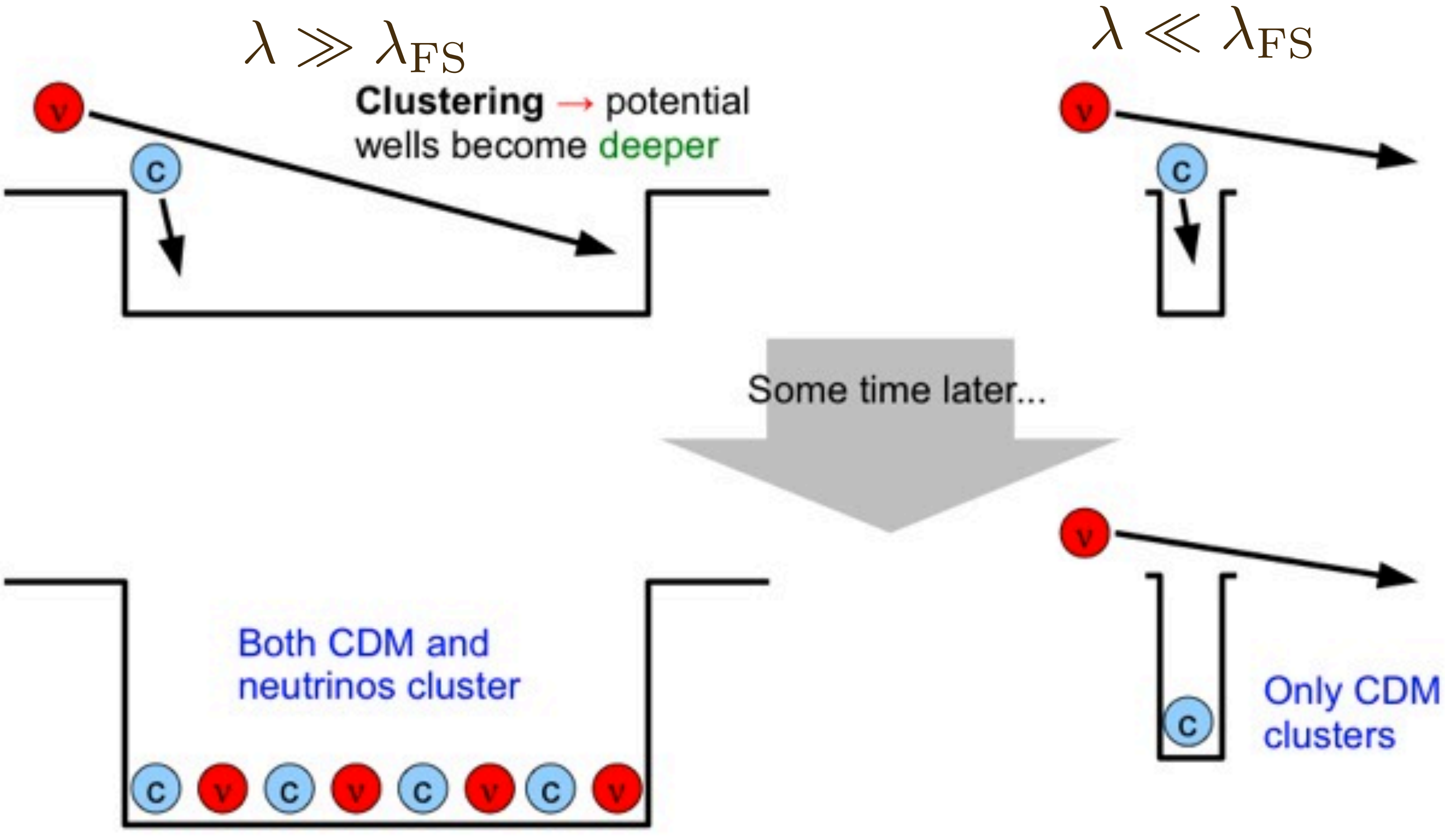
Usually assume $Y_P=0.24$*, predicted by BBN:* $Y_P = 0.2485+0.0016[(273.9\Omega_b h^2-6)+100\,(S-1)]$

More helium decreases electron density, increasing Silk damping.

We find $Y_p = 0.313 \pm 0.044$ (68% CL, ACT+WMAP)

A universe with no helium is now ruled out at 6 sigma from CMB – it would produce too much small scale power. Provides test of BBN epoch.

MASSIVE NEUTRINOS SUPPRESS STRUCTURE FORMATION ON SMALL SCALES



$\lambda \gg \lambda_{\rm FS}$

Clustering → potential wells become deeper

$\lambda \ll \lambda_{\rm FS}$

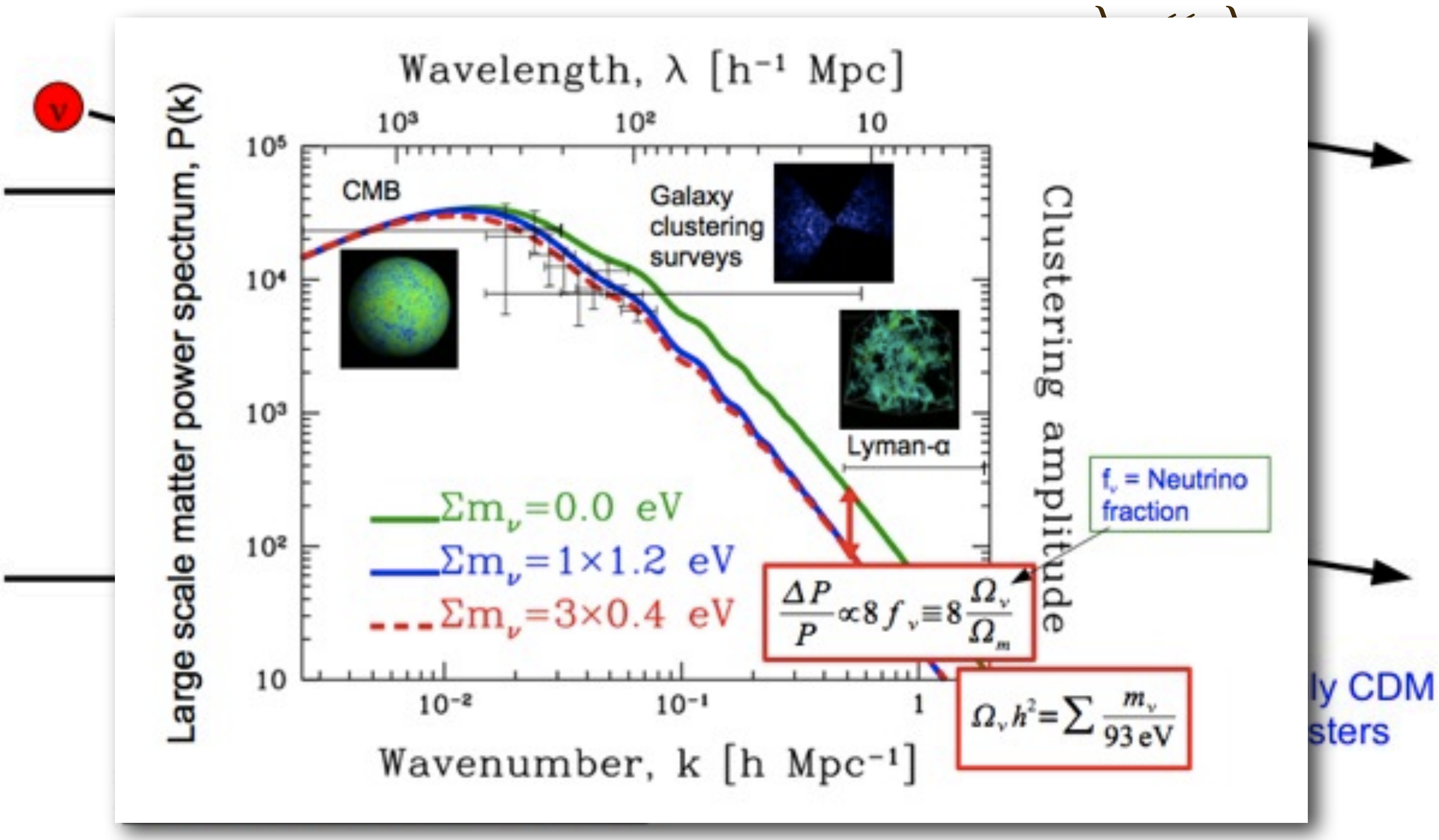
Some time later...

Both CDM and neutrinos cluster

Only CDM clusters

Graphics from Y. Wong

MASSIVE NEUTRINOS SUPPRESS STRUCTURE FORMATION ON SMALL SCALES



$$\frac{\Delta P}{P} \propto 8 f_\nu \equiv 8 \frac{\Omega_\nu}{\Omega_m}$$

$$\Omega_\nu h^2 = \sum \frac{m_\nu}{93\,\mathrm{eV}}$$

Graphics from Y. Wong

Relativistic species

'Assume' N=3 neutrino species.

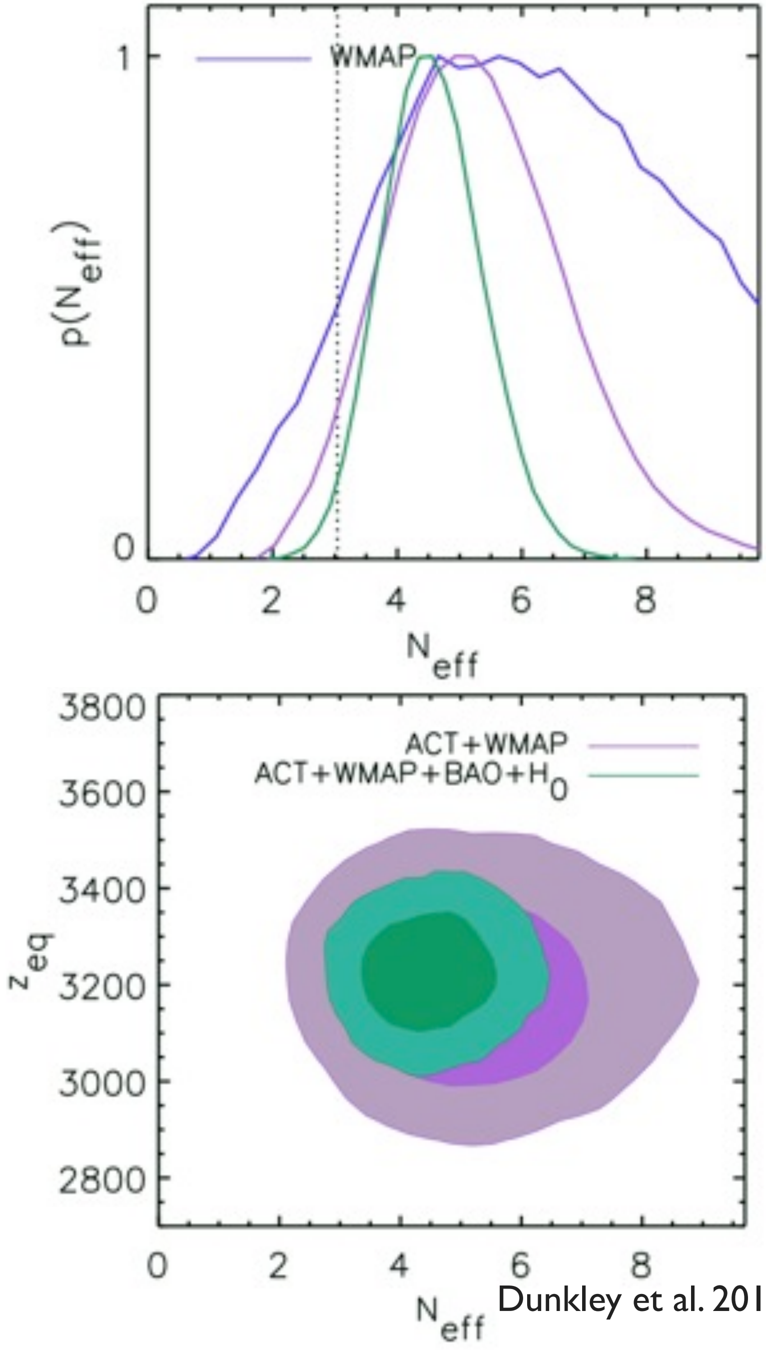
$$\rho_{rel} = \left[\frac{7}{8}\left(\frac{4}{11}\right)^{4/3} N_{eff}\right]\rho_{\gamma}$$

More species, longer radiation domination.
Changing Neff changes equality redshift.

Also - species suppress early acoustic oscillations in primary CMB, and phase shift in primary CMB. Distinct to zeq.

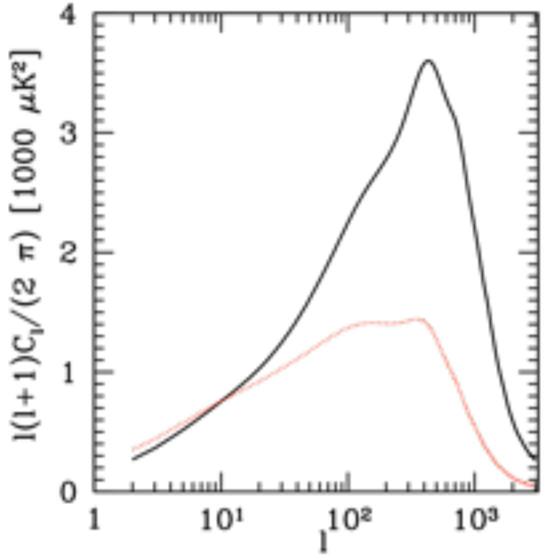
For ACT+WMAP we find $N_{eff} = 5.3 \pm 1.3$
(CMB now constrains it from above)

Error reduced to ± 0.75 with BAO and H_0 measures. Mean value higher than 3.04 but N=3 still fits data well!



Dunkley et al. 2010

Bounds on cosmic strings



From shape of spectrum, cosmic strings cannot be dominant source of anisotropy.

May be sub-dominant. Expected spectrum is uncertain.

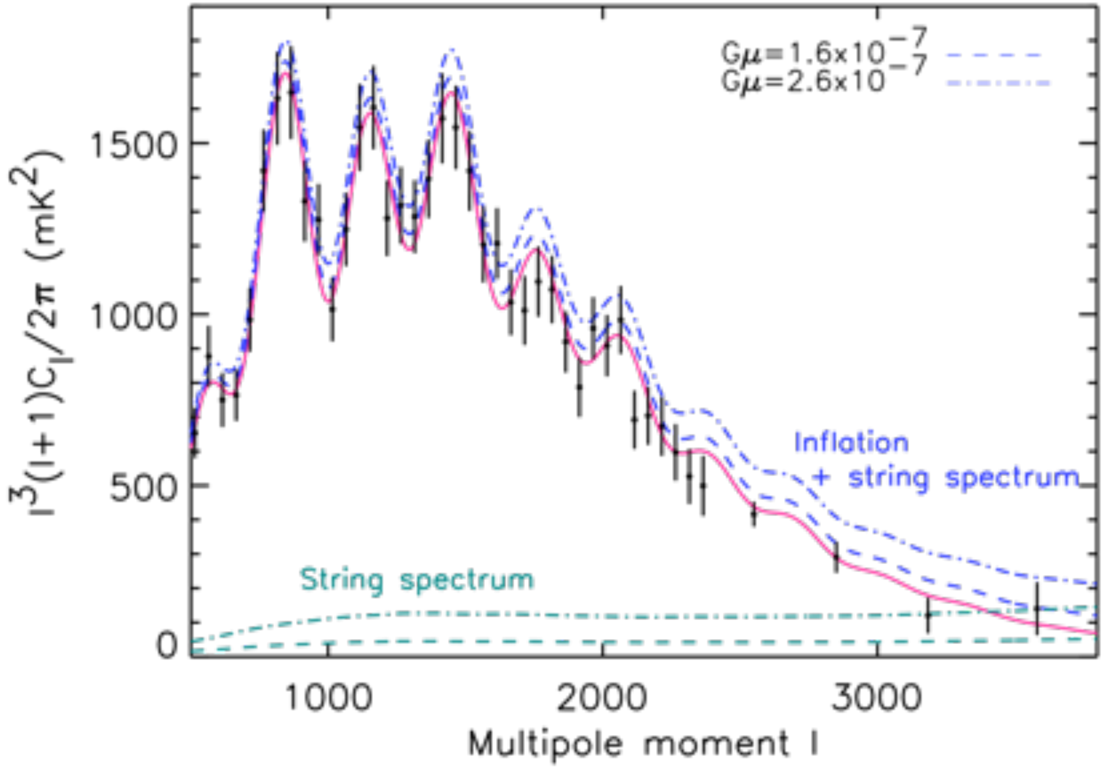
We take Nambu string sims as in Battye & Moss 2010. At small scales expect ell^{-1} scaling.

Find upper limits for ACT+WMAP:

$G\mu < 1.6 \times 10^{-7}$ (95%)

(pre-ACT was 2.6×10^{-7})

Spectral index prefers to be less than unity (0.963±0.013), disfavoring hybrid inflation models predicting n~1



Dunkley et al. 2010

Summary

- There are multiple physical components in small-scale microwave sky. A simple model fits the ACT 148 and 218 GHz data.

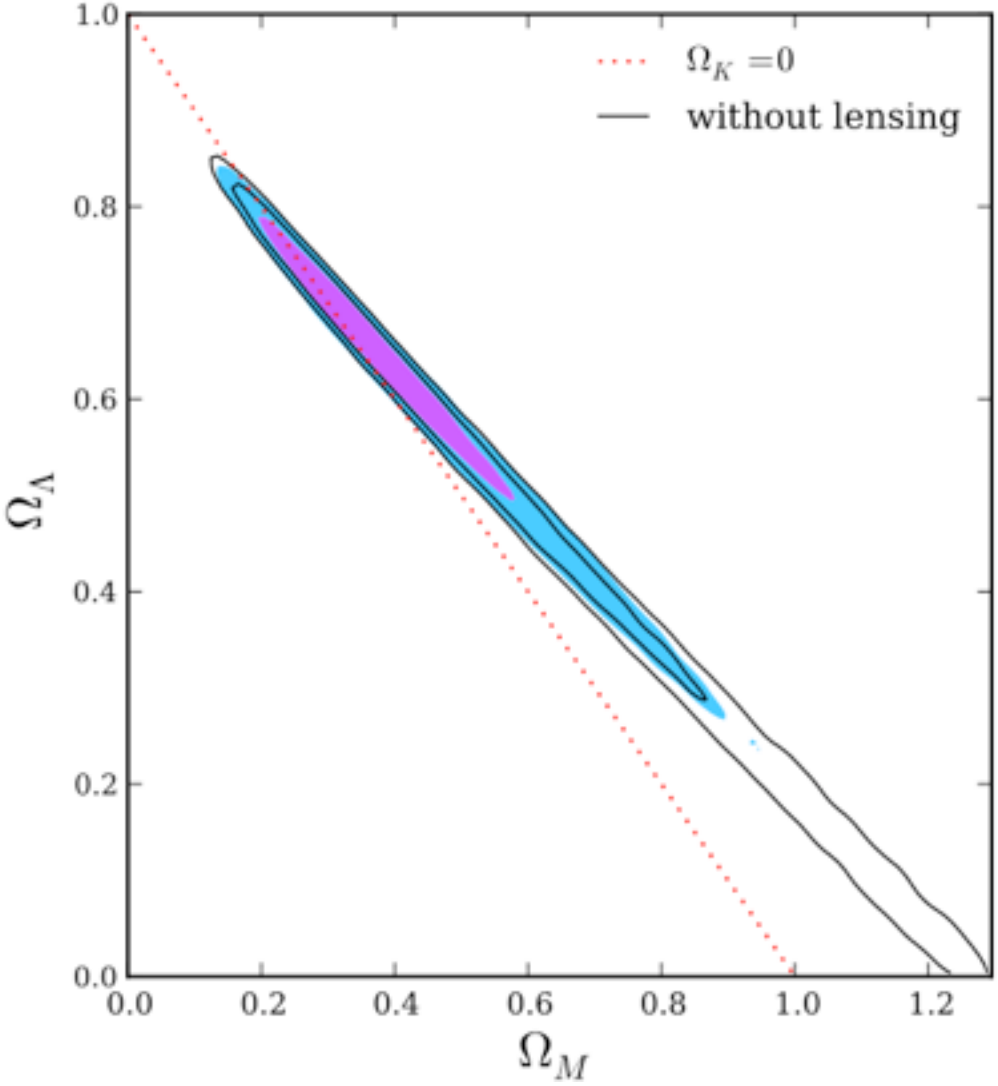
- Clustering of unresolved IR sources is needed; and a preference for non-zero SZ power from galaxy clusters, consistent with expectations.

- The ΛCDM model continues to fit the data, and lensing of the CMB is preferred at almost 3σ; ACT's longer level arm gives stronger new constraints on inflationary parameters, and probes non-standard physics through testing relativistic species, detecting primordial helium at 6σ, and constraining cosmic string contributions.

- ACT continues to work with 1000s detectors on the sky. Taken ~18 months of data over ~1300 sq deg, and will run to end of 2010 to make way for the funded ACTPol.

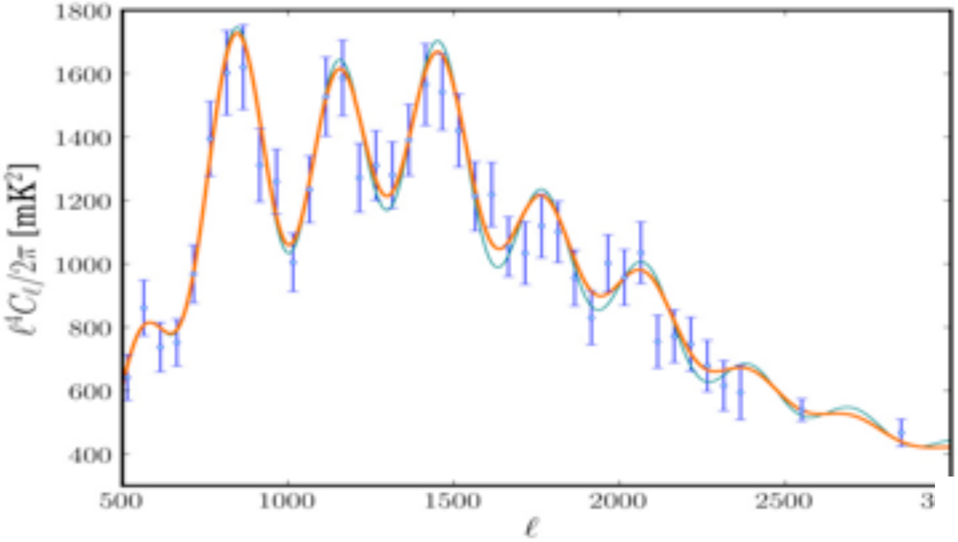
CMB-only evidence for Λ

ACT lensing data breaks geometric degeneracy!



[Sherwin, Dunkley, Das in prep.]

The CMB appears to be lensed



$$\underbrace{\Theta(\hat{n})}_{\text{Lensed}} = \underbrace{\tilde{\Theta}}_{\text{Unlensed}}(\hat{n} + \underbrace{\nabla\phi}_{\text{Deflection Field}})$$

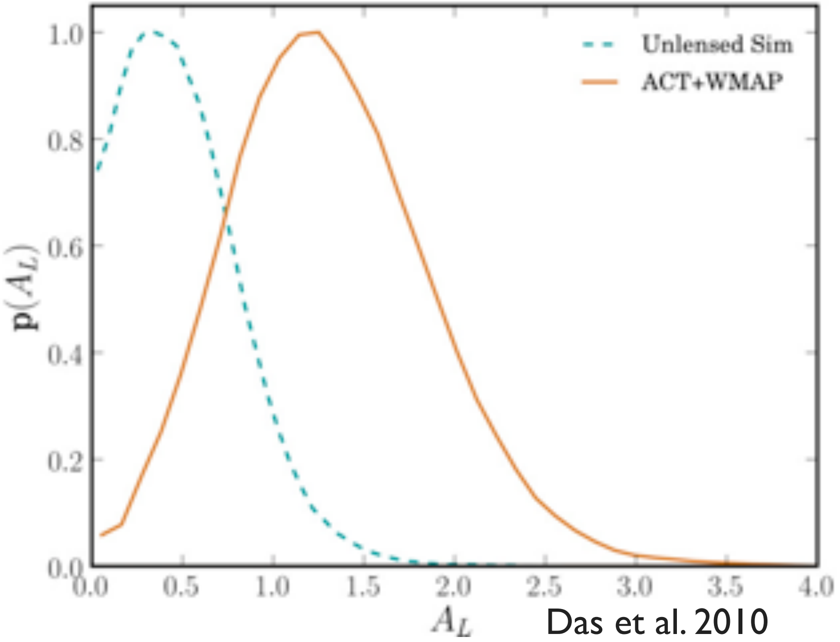
$$\phi = -2\int \underbrace{\boxed{\frac{d_A(\eta_0-\eta)}{d_A(\eta)d_A(\eta_0)}}}_{\text{Geometry}} \underbrace{\boxed{\Phi(\eta\hat{n},\eta)}}_{\text{Matter potential}}$$

- An unlensed spectrum would have sharper features

- Test for lensing in spectrum by marginalizing over (unphysical) parameter A_L, scaling lensing potential. [Calabrese et al 2008]

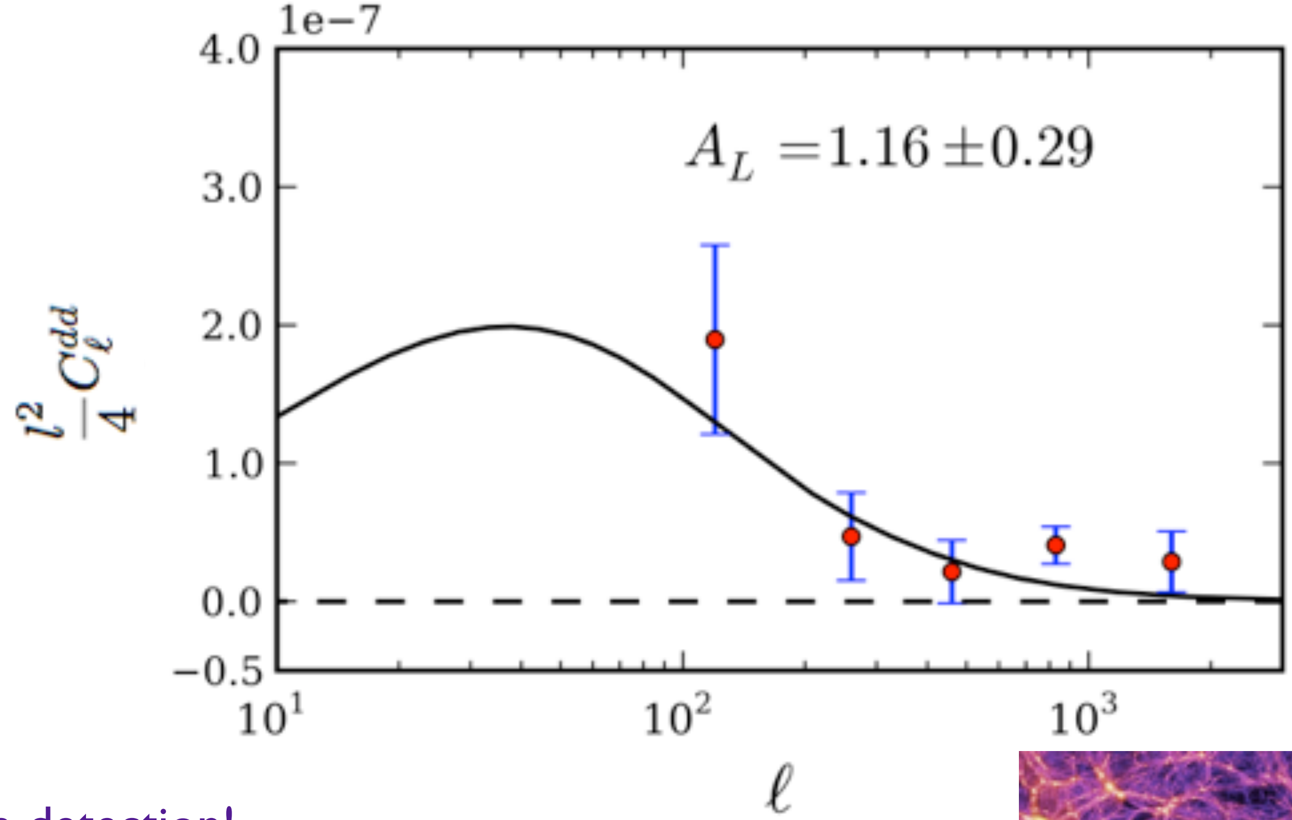
- Expect A_L=1, and unlensed has A_L=0. See lensing at almost 3σ level:

$$A_L = 1.3 \pm 0.5^{+1.2}_{-1.0} \text{ (68, 95\% CL)}$$

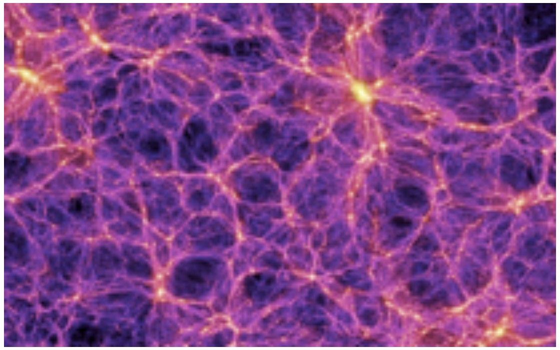


Das et al. 2010

ACT detection of the lensing power spectrum

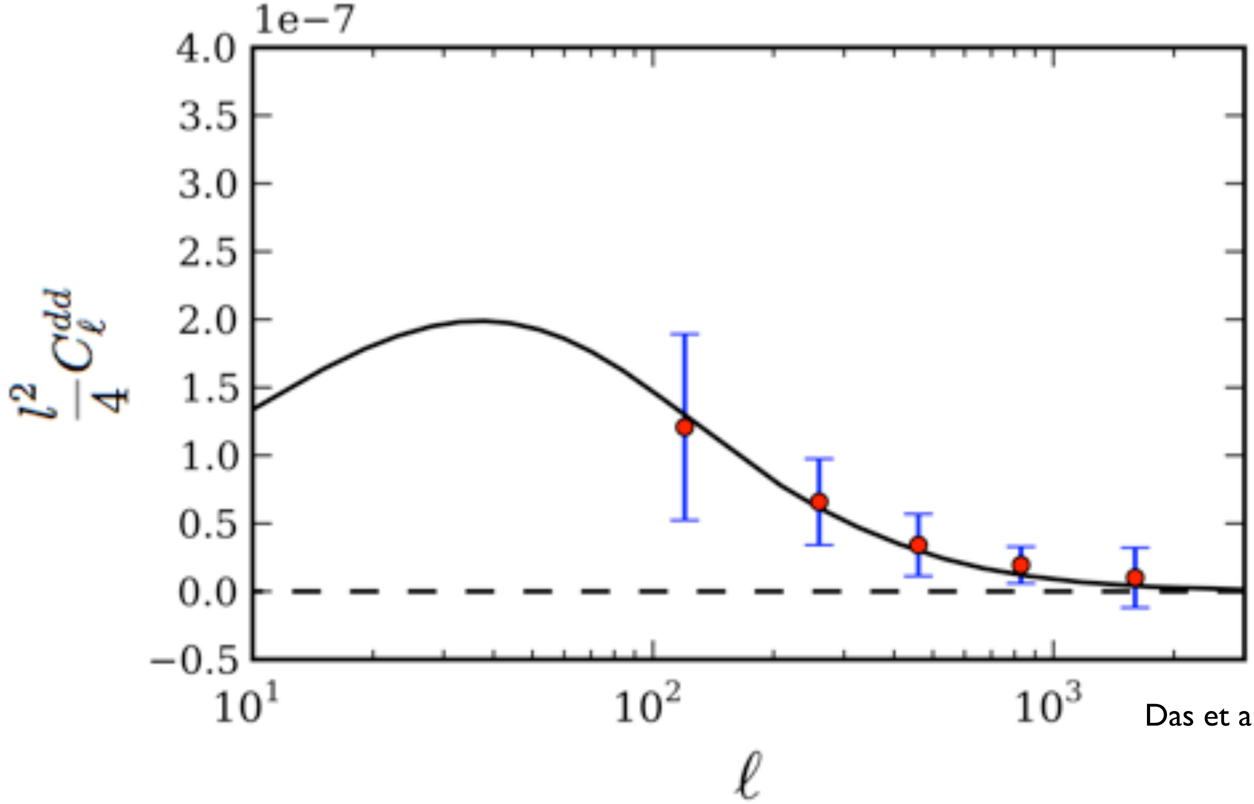


- 4-sigma detection!
- Constrains amplitude of matter fluctuations at z~0.5-3 to 12%.
- Direct gravitational probe of dark matter to z~1100



[Das, Sherwin et al. 2011, arXiv:1103.2124]

Do we trust? – test with simulations



Das et al 2011

Issues: Correlated atmospheric noise at low l can contaminate signal

Filter out modes below l=500

Unresolved IR point sources and SZ dominate power at high l

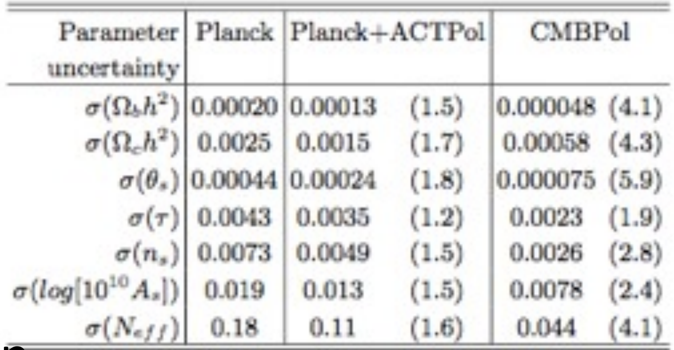
Only use modes below l=2300

Point sources can add spurious power

Remove using template subtraction method

ACTpol Summary

- Mapping speed ~25 times ACT.
- Cover 4000 square degrees to 20 uK-arcmin, 150 to 5 uK-arcmin.
- Planck+ACTpol measures sum of neutrino masses to ~0.06 eV - detection expected.
- Planck+ACTpol measures # of relativistic species to 0.11
- Expect to measure 1,000 clusters with ACTpol, large fraction of which will be ACTpol discoveries.



Parameter uncertainty	Planck	Planck+ACTPol		CMBPol	
$\sigma(\Omega_b h^2)$	0.00020	0.00013	(1.5)	0.000048	(4.1)
$\sigma(\Omega_c h^2)$	0.0025	0.0015	(1.7)	0.00058	(4.3)
$\sigma(\theta_s)$	0.00044	0.00024	(1.8)	0.000075	(5.9)
$\sigma(\tau)$	0.0043	0.0035	(1.2)	0.0023	(1.9)
$\sigma(n_s)$	0.0073	0.0049	(1.5)	0.0026	(2.8)
$\sigma(log[10^{10} A_s])$	0.019	0.013	(1.5)	0.0078	(2.4)
$\sigma(N_{eff})$	0.18	0.11	(1.6)	0.044	(4.1)

TABLE IV. 68% c.l. errors on cosmological parameters in the case of extra background of relativistic particles N_{eff}. The numbers in brackets show the improvement factor σ_{Planck}/σ respect to the Planck experiment.

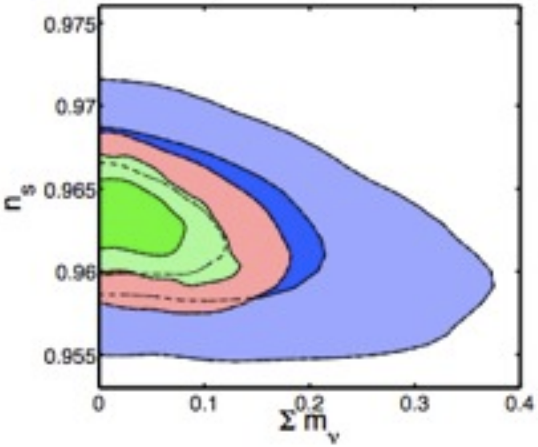
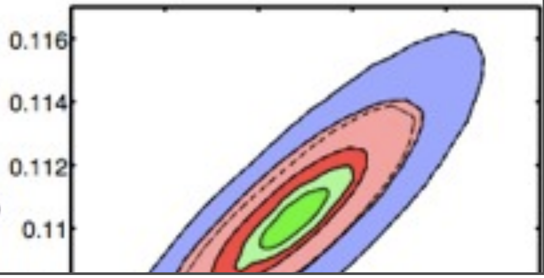


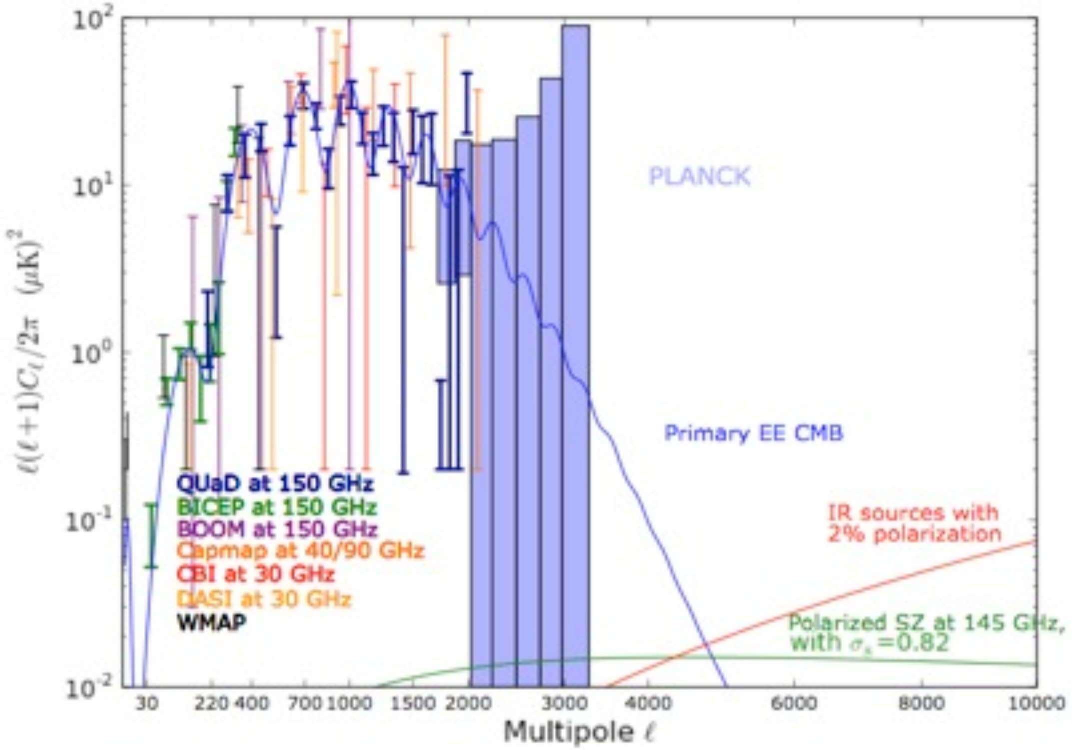
FIG. 2. 68% and 95% likelihood contour plots on the $\sum m_\nu$ - n_s plane fo
CMBPol (gree

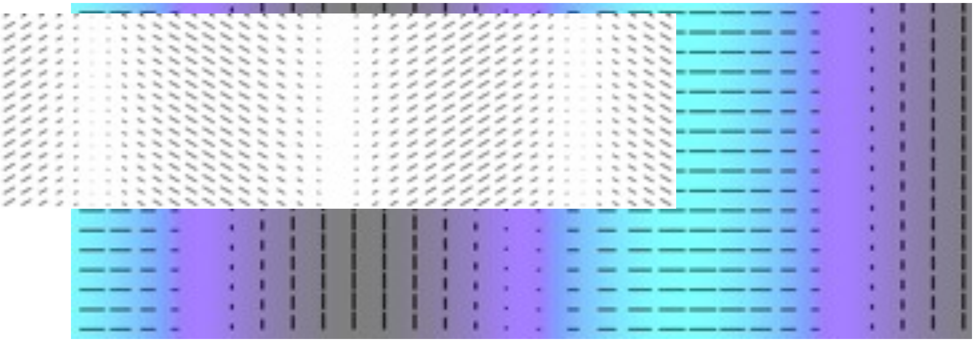


Parameter forecasts from Galli et al.
Blue=Planck, Red=ACTpol,
Green=CMBpol (far future, unfunded).

Next Step For ACT: ACTPol

M. Niemack et al. 2010 (1006.5049)





E and B modes. Scalar fluctuations make E only.

Next generation of CMB science will require higher precision on small scales.

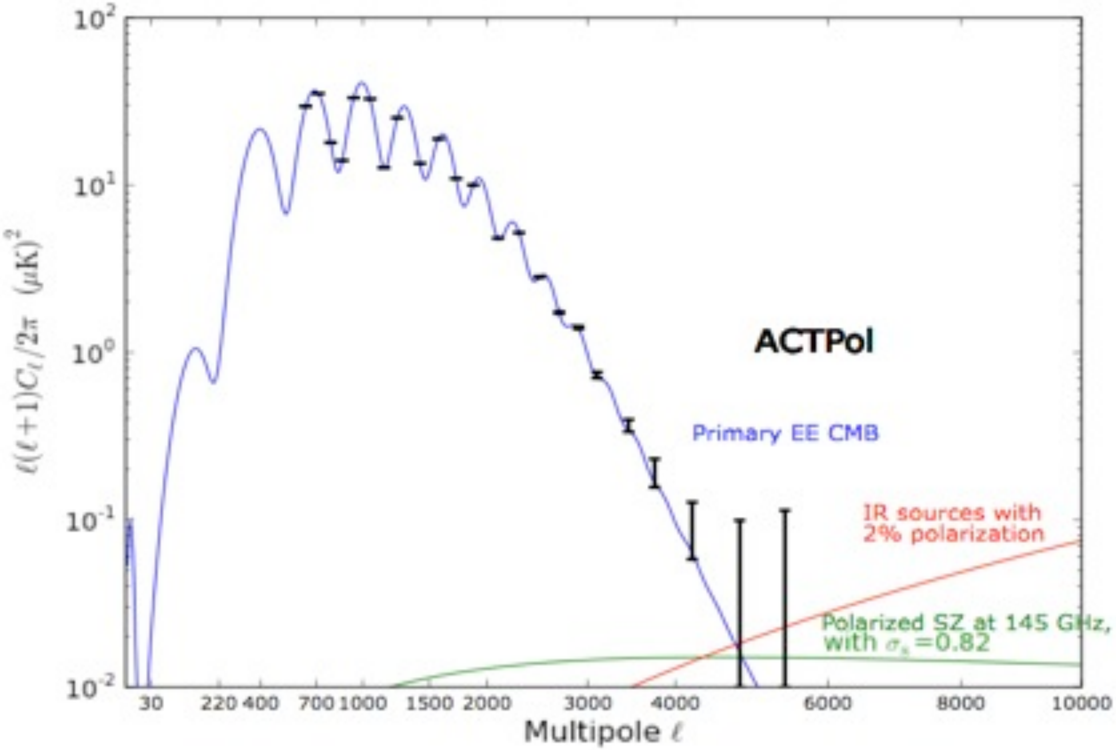
CMB far more polarized (17%) than astrophysical foregrounds (few %), pol’n will be cleaner than intensity.

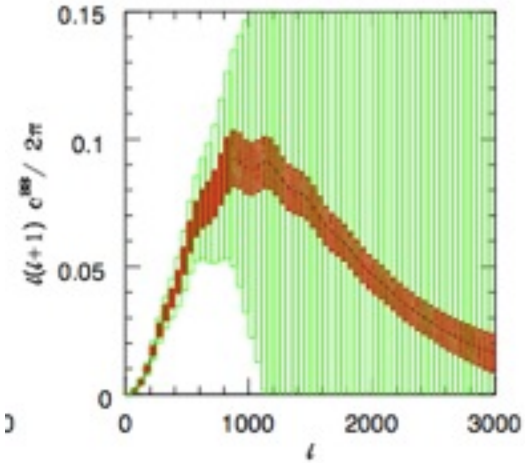
We have been funded to upgrade ACT to polarization, expect 16-25x increase in mapping speed vs. current ACT (maybe another 2 also)

First camera goes on in 2012, full camera (>3000 detectors) in 2013.

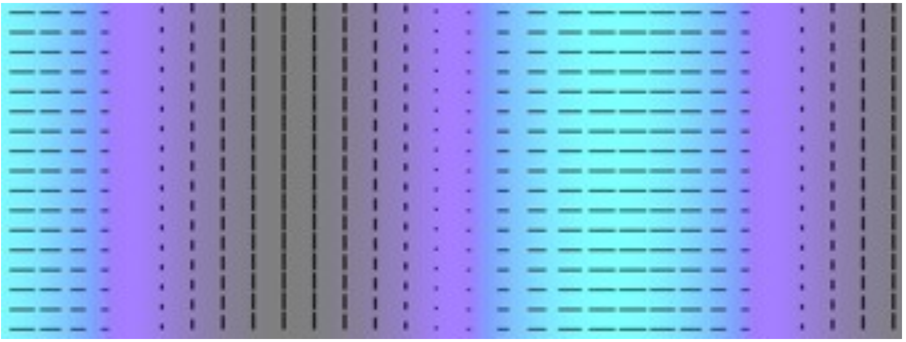
Next Step For ACT: ACTPol

M. Niemack et al. 2010 (1006.5049)





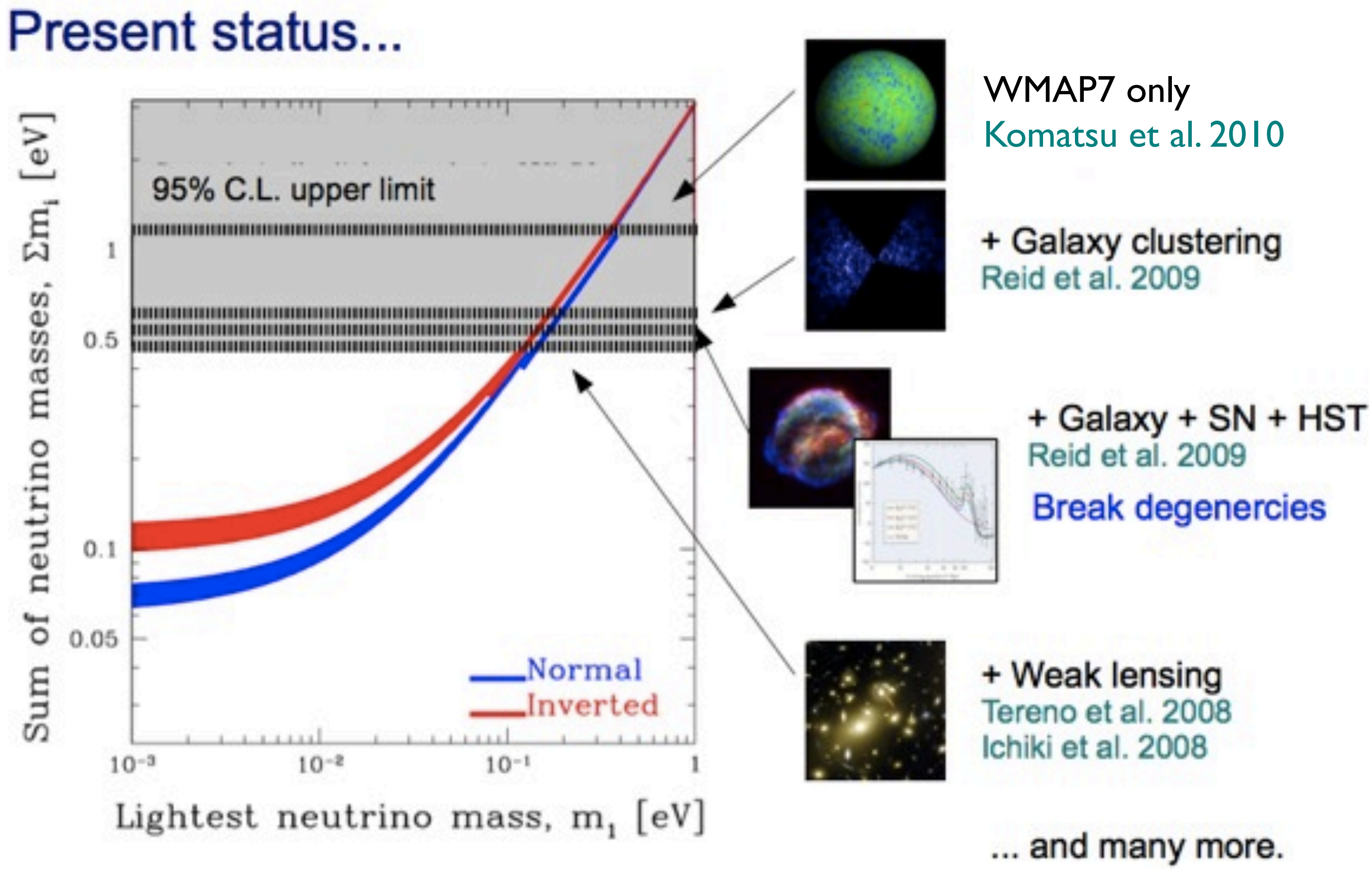
Green - Planck B-mode, brown, ACTpol



Summary

- Central goal is understanding nature of Dark Energy and Dark Matter
- Primordial CMB is powerful probe, but has geometric degeneracy
  - CMB lensing directly probes dark matter distribution.
- With ACT, make measurement of lensing power spectrum – robust 4-sigma detection
  - evidence for Lambda at 3.5 sigma from the CMB alone
- To come: higher S/N spectra, cross-correlations, polarization lensing… the beginning of an exciting research program

ACTPOL CAN HELP CONSTRAIN NEUTRINO HIERARCHIES!



Present status...

WMAP7 only
Komatsu et al. 2010

+ Galaxy clustering
Reid et al. 2009

+ Galaxy + SN + HST
Reid et al. 2009

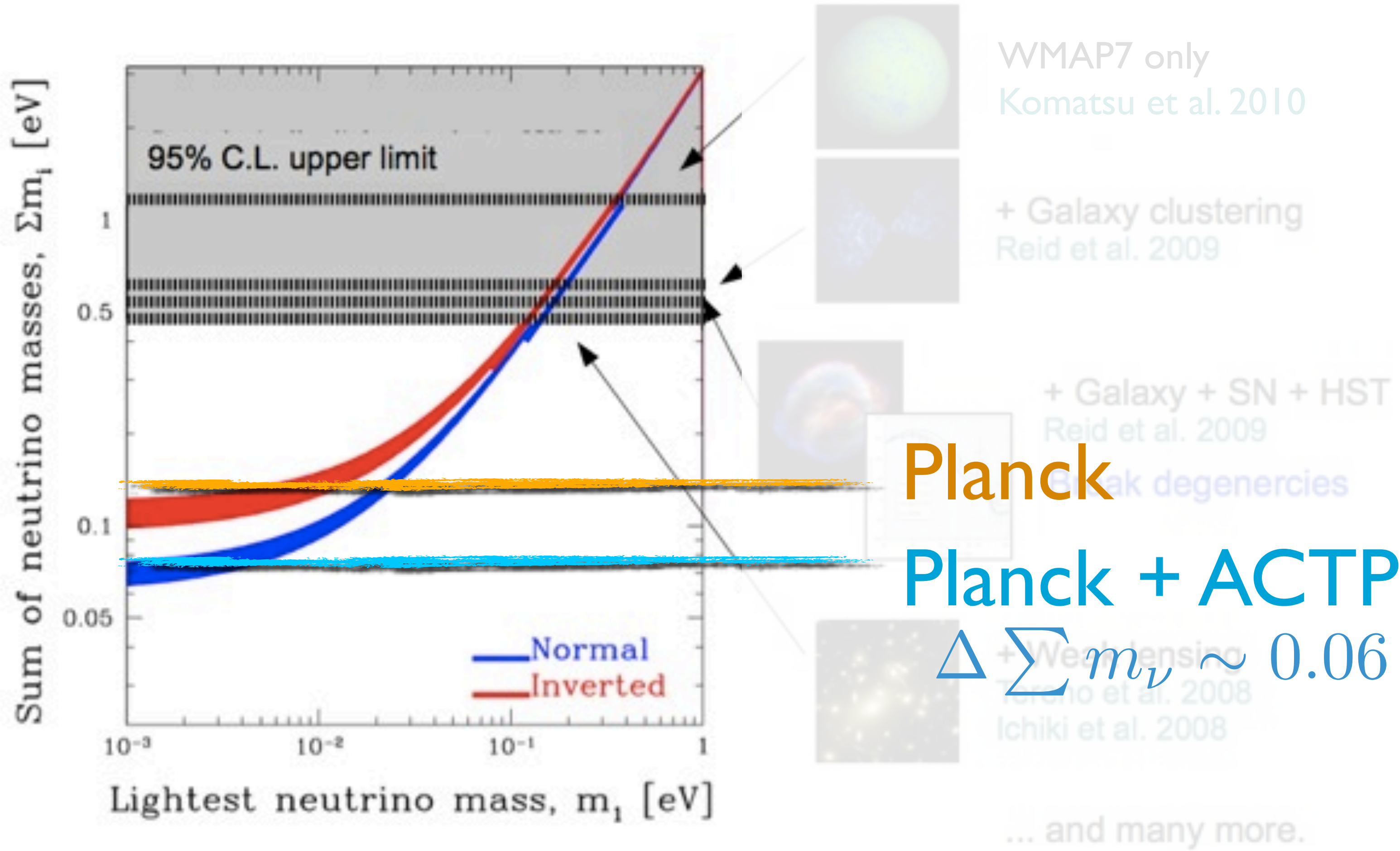
Break degenercies

+ Weak lensing
Tereno et al. 2008
Ichiki et al. 2008

... and many more.

Graphic from Y. Wong

ACTPOL CAN HELP CONSTRAIN NEUTRINO HIERARCHIES!

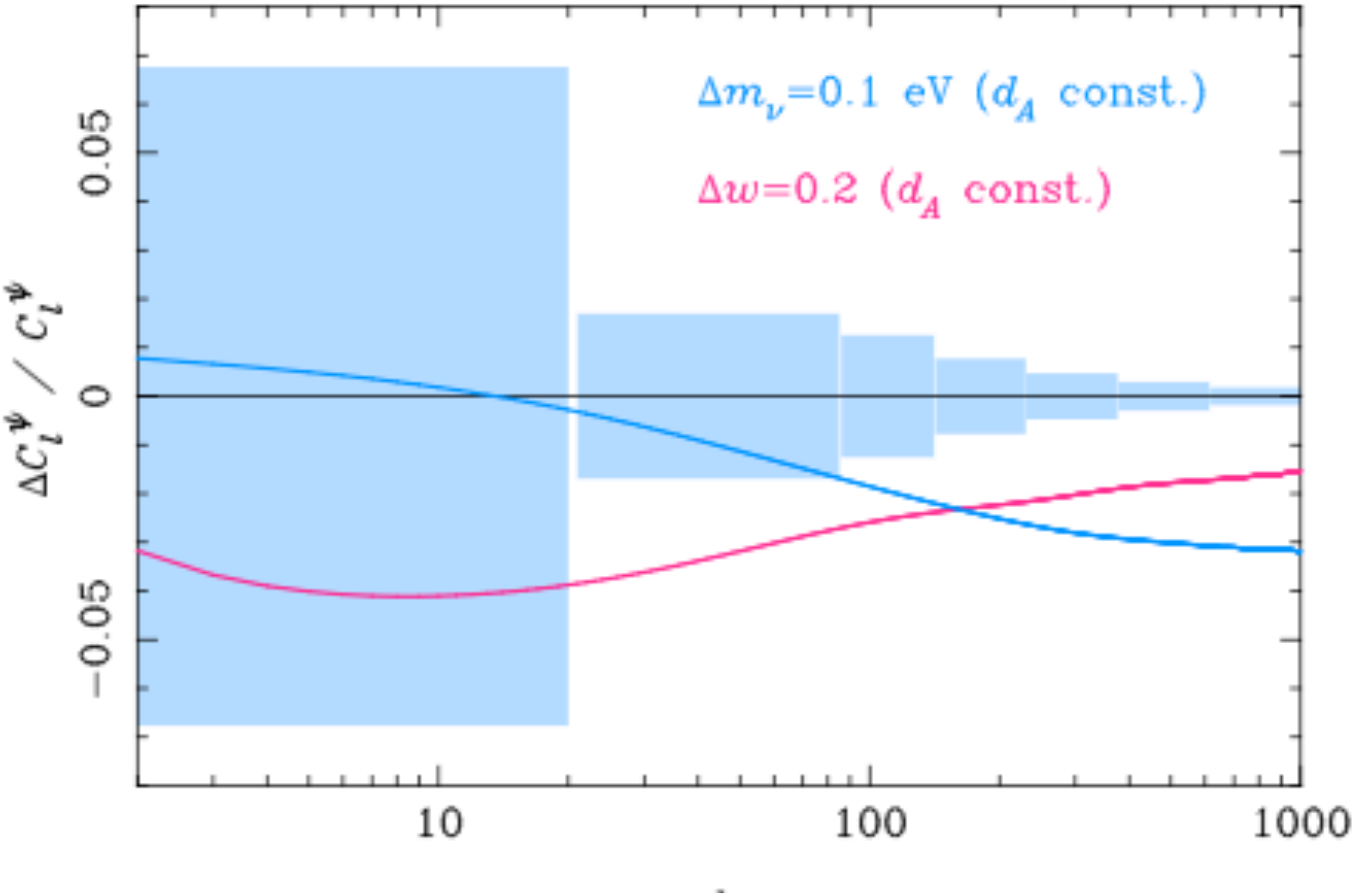


Planck

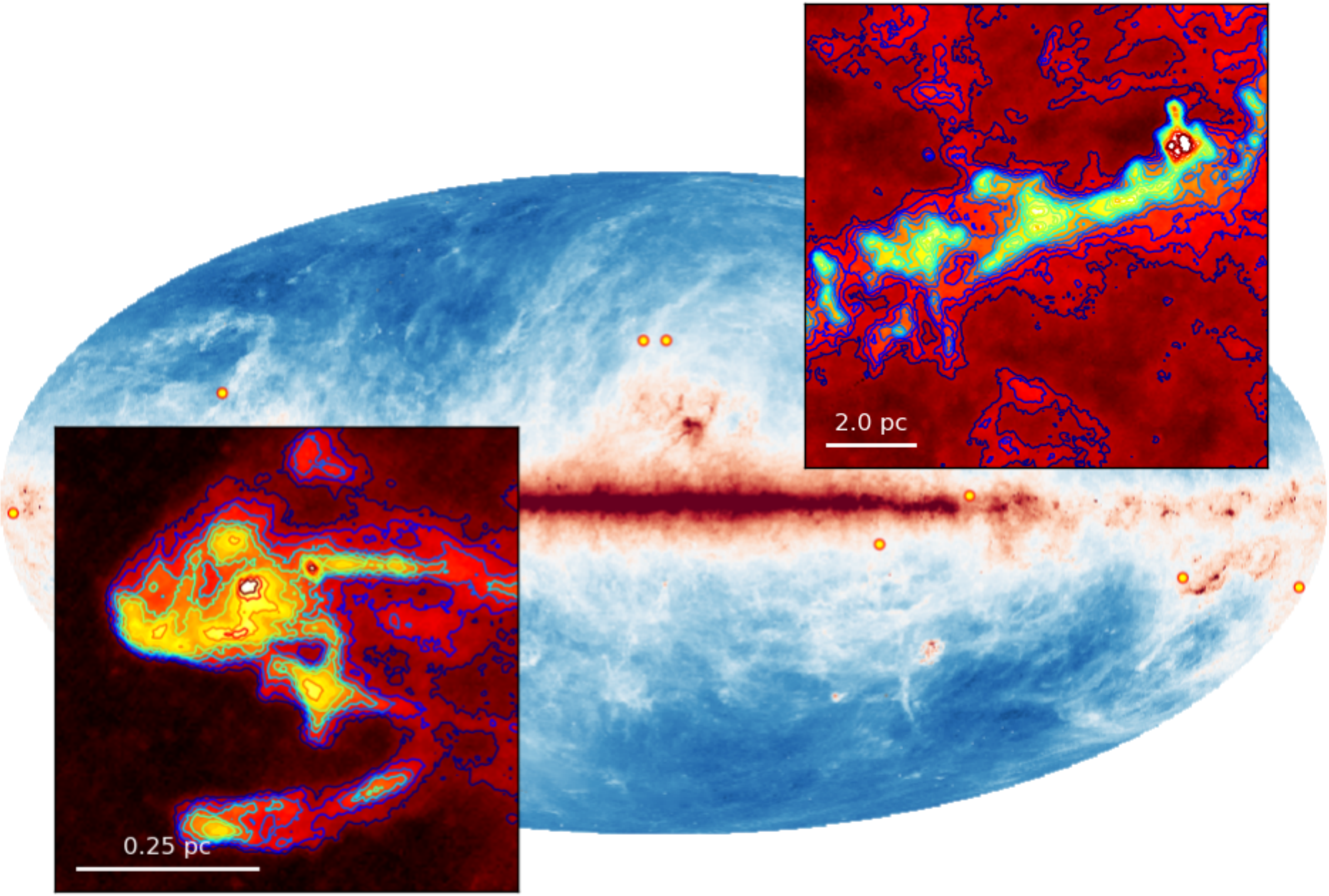
Planck + ACTPol

$$\Delta \sum m_\nu \sim 0.06 \text{ eV}$$

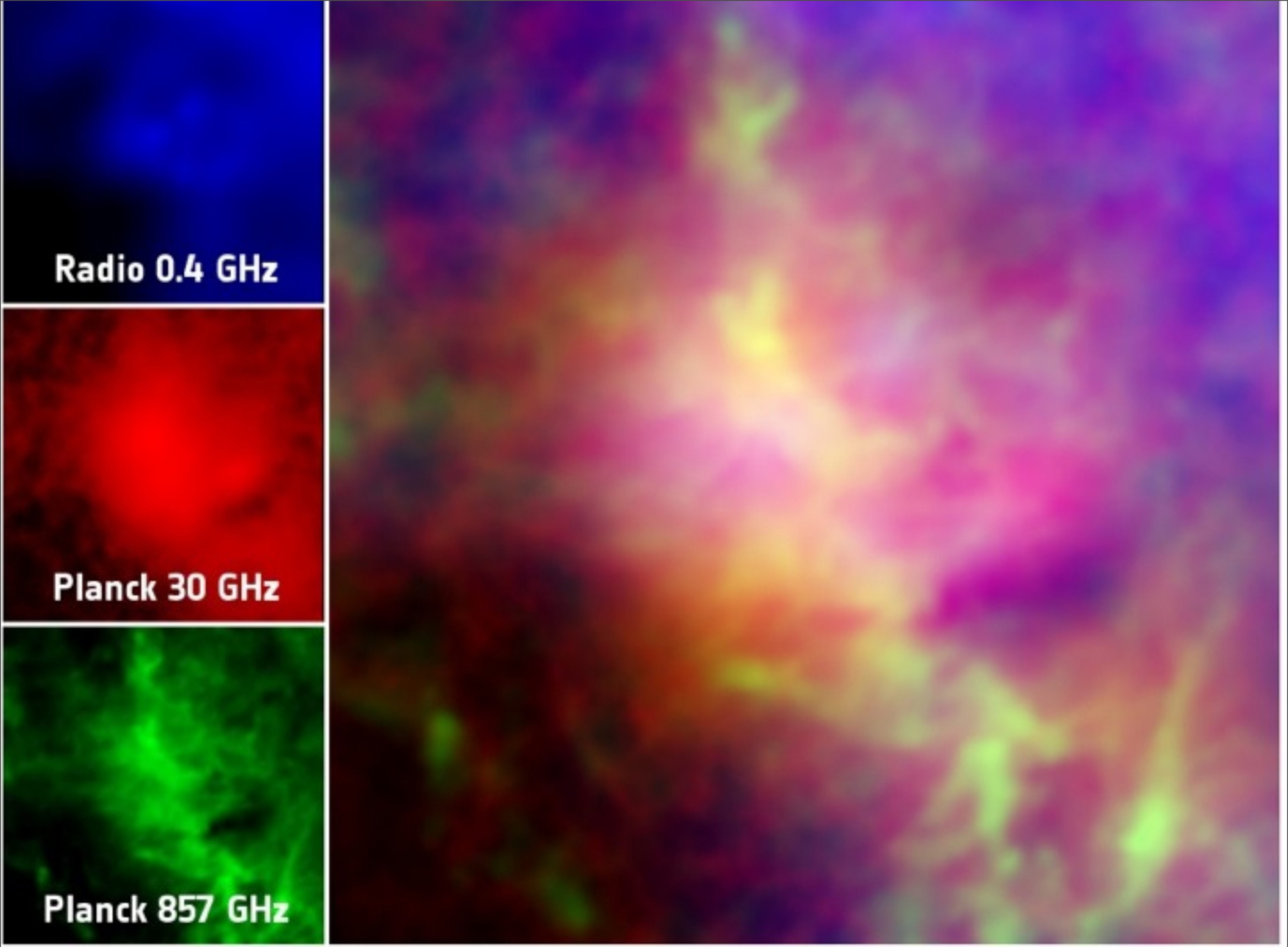
Graphic from Y. Wong

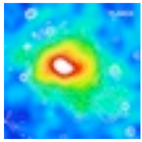


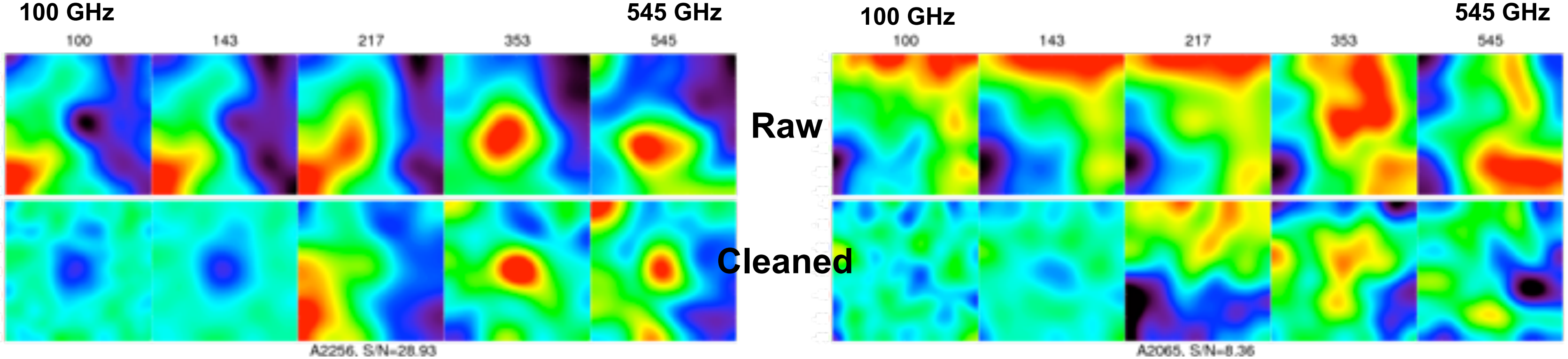
Δm_ν=0.1 eV (d_A const.)
Δw=0.2 (d_A const.)
ΔC_l^ψ / C_l^ψ
0.05
0
−0.05
10
100
1000



IRAS **Planck** **Herschel** (6.5m telescope)


Radio 0.4 GHz
Planck 30 GHz
Planck 857 GHz





Frequency range from 30 to 857 GHz Sept09 1st clusters detected FLS (A2163, ...); Jan10 1st reliable blind candidates; typical SZ sources are barely visible in raw frequency maps, ~1-2 sigma sources in cleaned frequency maps => Planck-internal QA: 2 methods MMF3 + e.g., PowellSnakes. **MMF3 output: position, size estimate, and integrated-y,** Position: accuracy ~2 arcmin. Cluster size & integrated-y measure are degenerate → Prior on cluster size reduces the scatter in Y estimate Cluster size from X-ray taken as best estimate.