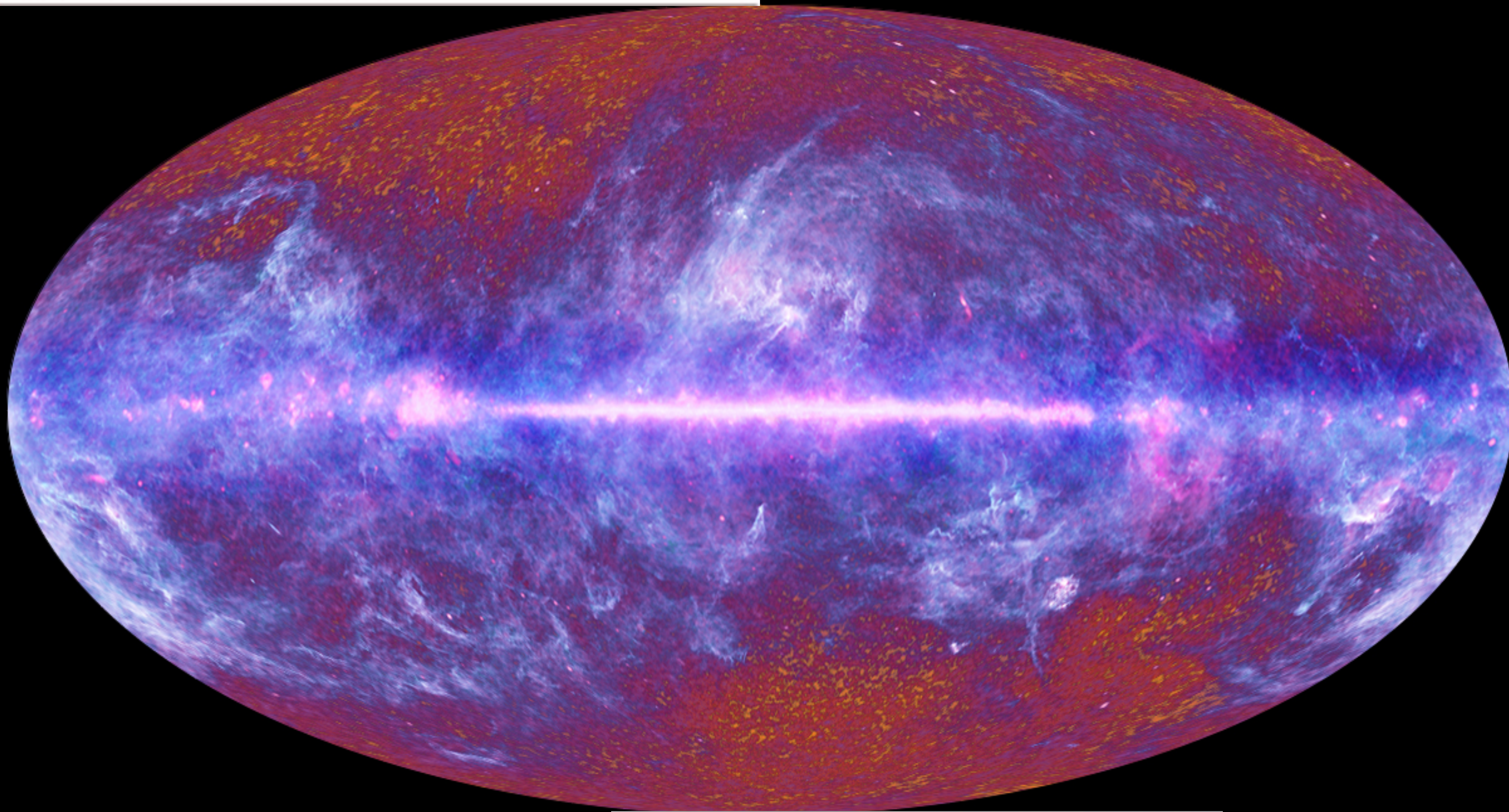
The Cosmic Background Radiation at High Resolution with Planck and ACT

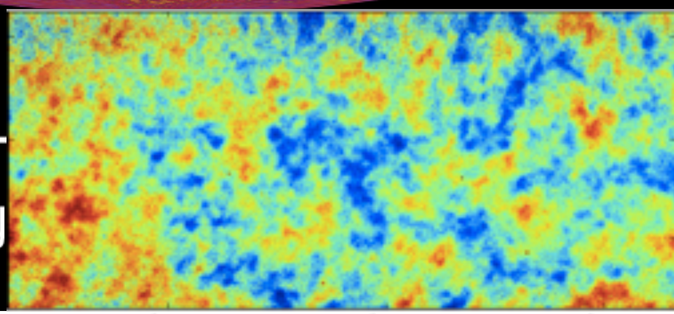
& Foreground

CITA ICAT Canadian Institute for Theoretical Astrophysics L'institut canadien d'astrophysique theorique

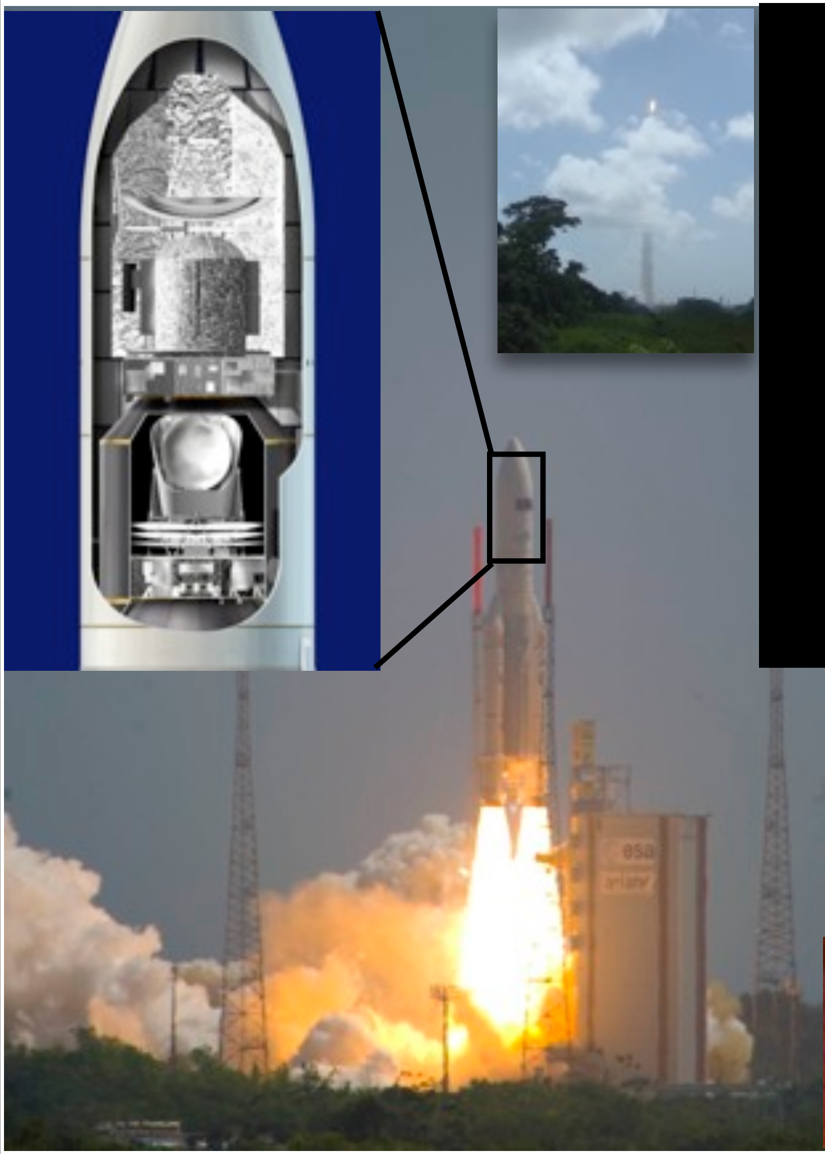
Dick Bond

CIAR

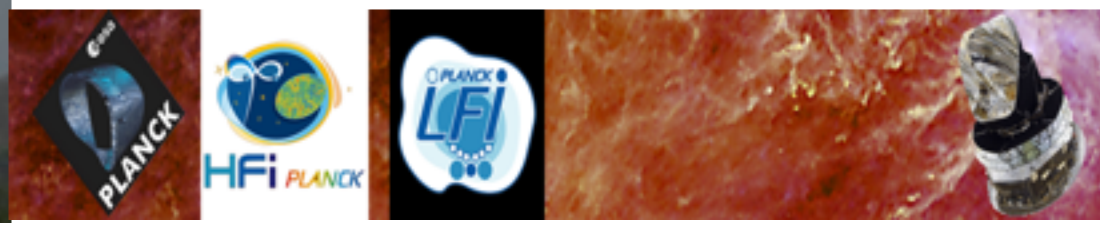




Launch of Planck & Herschel on May 14 2009 from Kourou (Fr. Guiana)



1.5m telescope, HFI bolometers@6freq, LFI HEMTs@3freq,
some bolometers & all HEMTS are polarization sensitive



Left earth at ~10 km/s, 1.5 million km in 45 days, cooling on the way (20K, 4K, 1.6K, 0.1K 4 stage).
@L2 on July 2 09 -almost no trajectory correction @operational temp; Survey started on Aug 13 09
spin@1 rpm, 40-50 minutes on the same circle, covers all-sky in ~6 month, ~3 surveys Feb11, ~5 total

The scientific results that we present today are a product of the Planck Collaboration, including individuals from more than 50 scientific institutes in Europe, the USA and Canada

Planck is a project of the European Space Agency -- ESA -- with instruments provided by two scientific Consortia funded by ESA member states (in particular the lead countries: France and Italy) with contributions from NASA (USA), and telescope reflectors provided in a collaboration between ESA and a scientific Consortium led and funded by Denmark.

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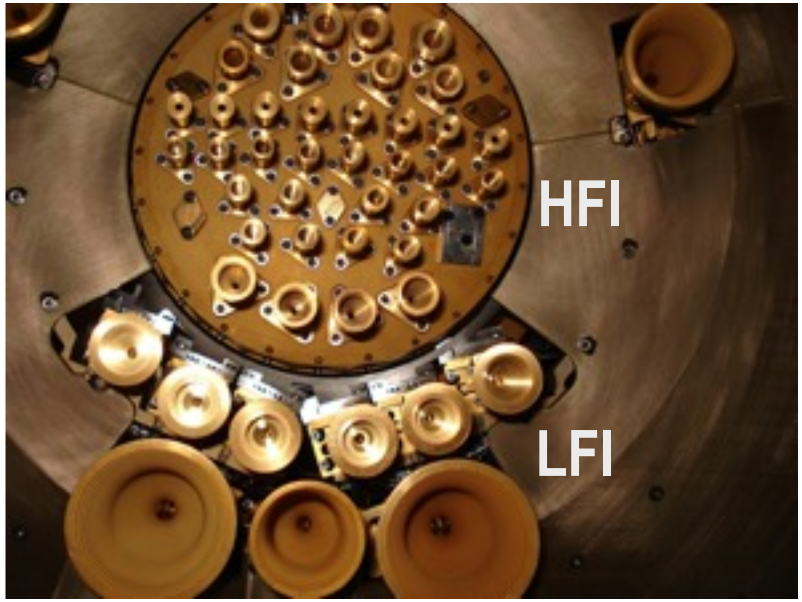
Bond since 1993, Canada since 2001, 1st CSA pre-launch contract 2002-09, post-launch 2010-11, 2011-13

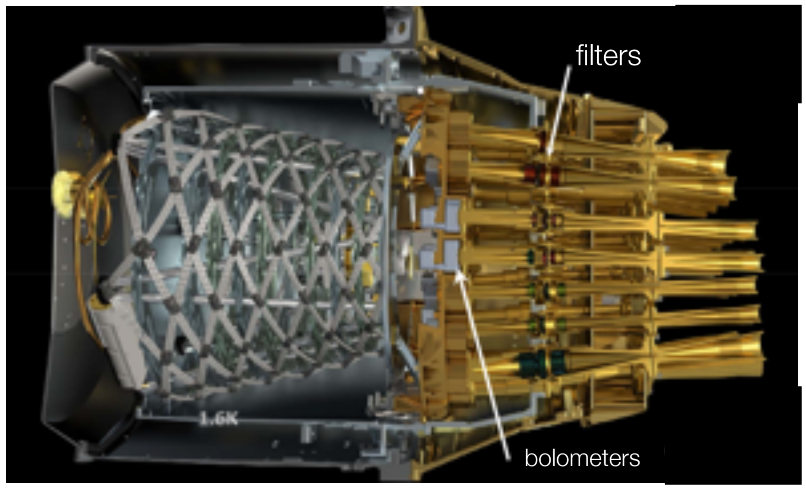
25 papers & a large fraction of the papers at Planck2011 were unveiled for 10 months & 9-freq T data, + a press conference, highlighting: **HFI & LFI work flawlessly** with great results on ERCSC (~15000 sources, 189 SZ clusters), CIB, SZ, AME & the dusty MW, & much more, so many areas, enabled by so many frequencies. more Galaxy Feb 2012, primary CMB & pol TBD, Jan 2013, 14

Planck

Focal plane

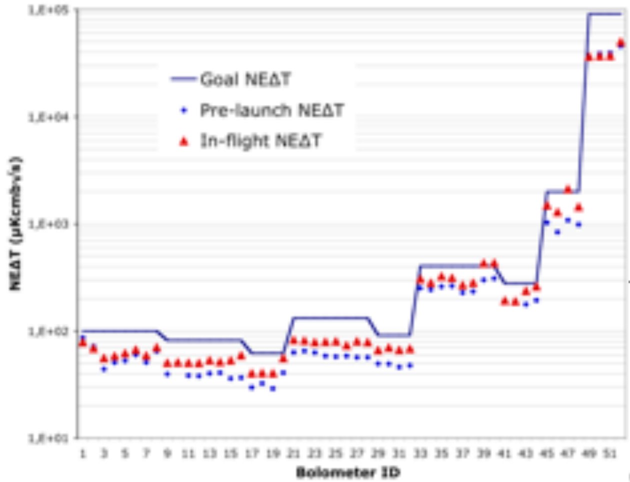


HFI cut view

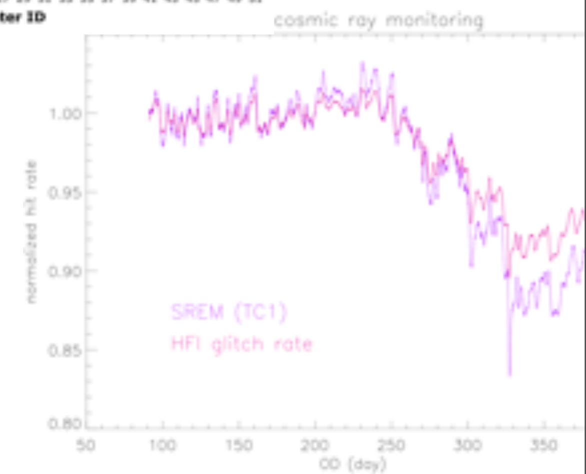


HFI performance

- **Thermal performance**
  - 100 mK HFI detectors behave exactly as during ground tests. Set for minimum Helium flow, enough for 5 sky coverages (until ~Jan 2012 +-x)

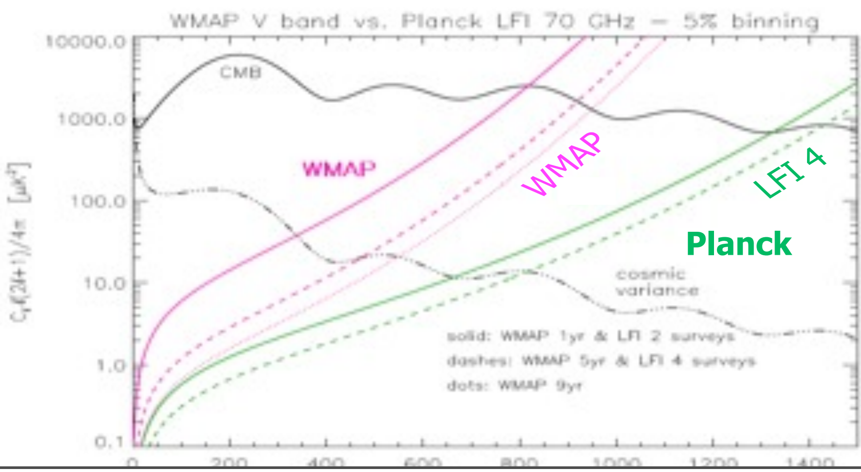


- **CosmicRays: Glitch** rate at ~80/min on each bolometer=>thermal fluctuations
  - contribute to 1/f noise (significant CSA-HFI role in discovering and characterizing the effect)



- **Sensitivity and Beams:** a little better than Blue Book widely used for forecasts. (CR thermal fluctuations make it a little higher than ground measurements). Anticipated "aggregated" sensitivity (100-217 GHz) for 30 months is 0.33 microK-deg ie, **~1000 years of WMAP** *(60-94 GHz = 10.8 microK-deg in 1 yr)* + >2 smaller beam

- **CarbonMonoxide lines** in 100 and 220 GHz complicates modelling, a problem becomes a strength? with separation of components, could get an all-sky CO map



LFI performance

- **Sensitivity and Beams:** ~ Blue Book widely used for forecasts. Beams to - 20 db understood.

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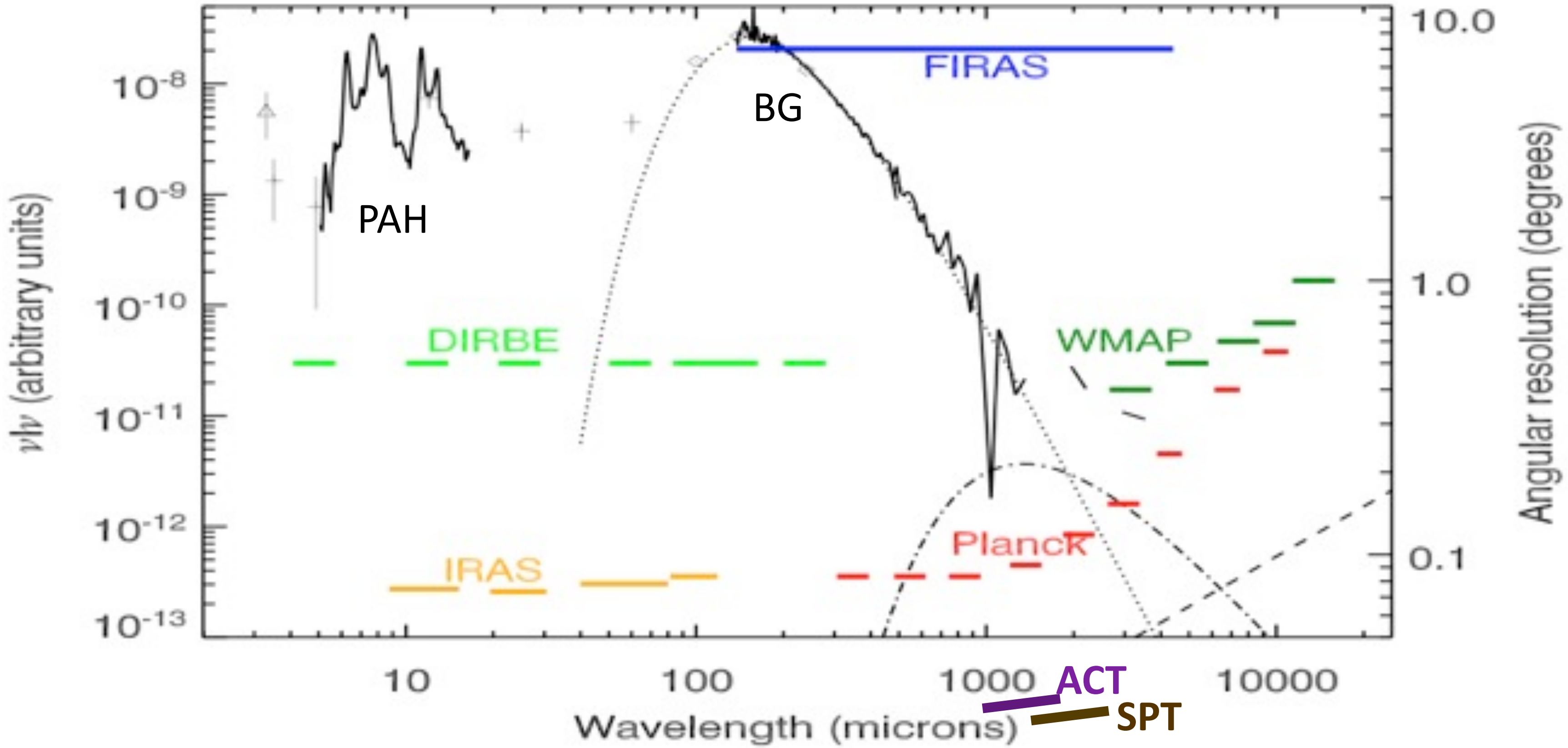
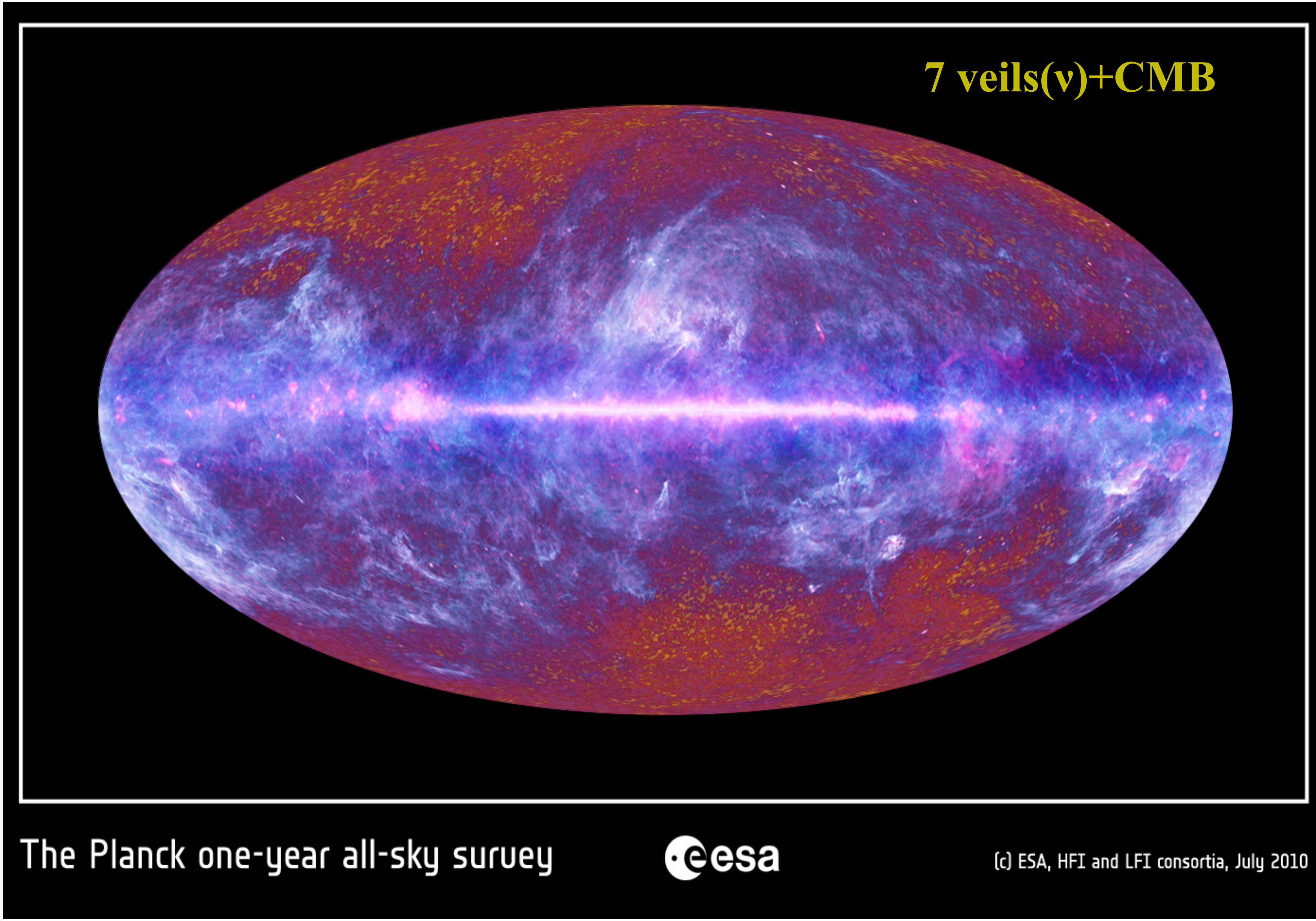
PlanckEXT, EXT=many observatories & expts enabling the astro

XMM Herschel Fermi WMAP GBT BLAST ACT SPT AMI CBI CBASS QUIET SDSS IRAS CO/HI-maps, ...



at **Planck2011** (Paris, Jan 10-14) & the **AAS:** 25 papers & the ERCSC were unveiled



the quest for the primordial within the primary CMB requires exquisite foreground removal, the quest for Milky Way maps & extended source maps requires accurate CMB etal removal

7 veils(ν)+CMB

the TBD of Planck vintage 98: signal separation

striping

dust (thermal+spinning PAH)

synchrotron

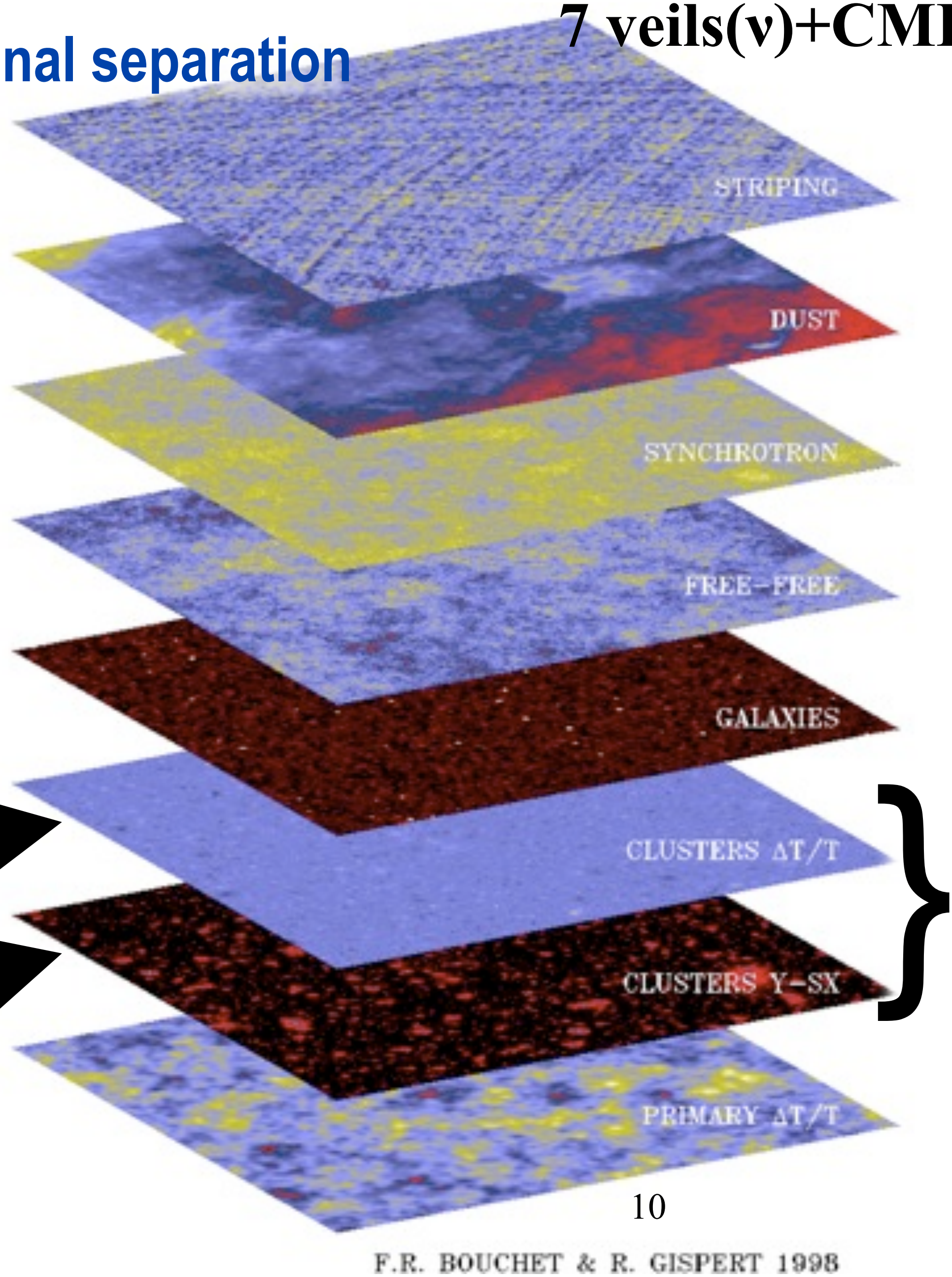
bremsstrahlung

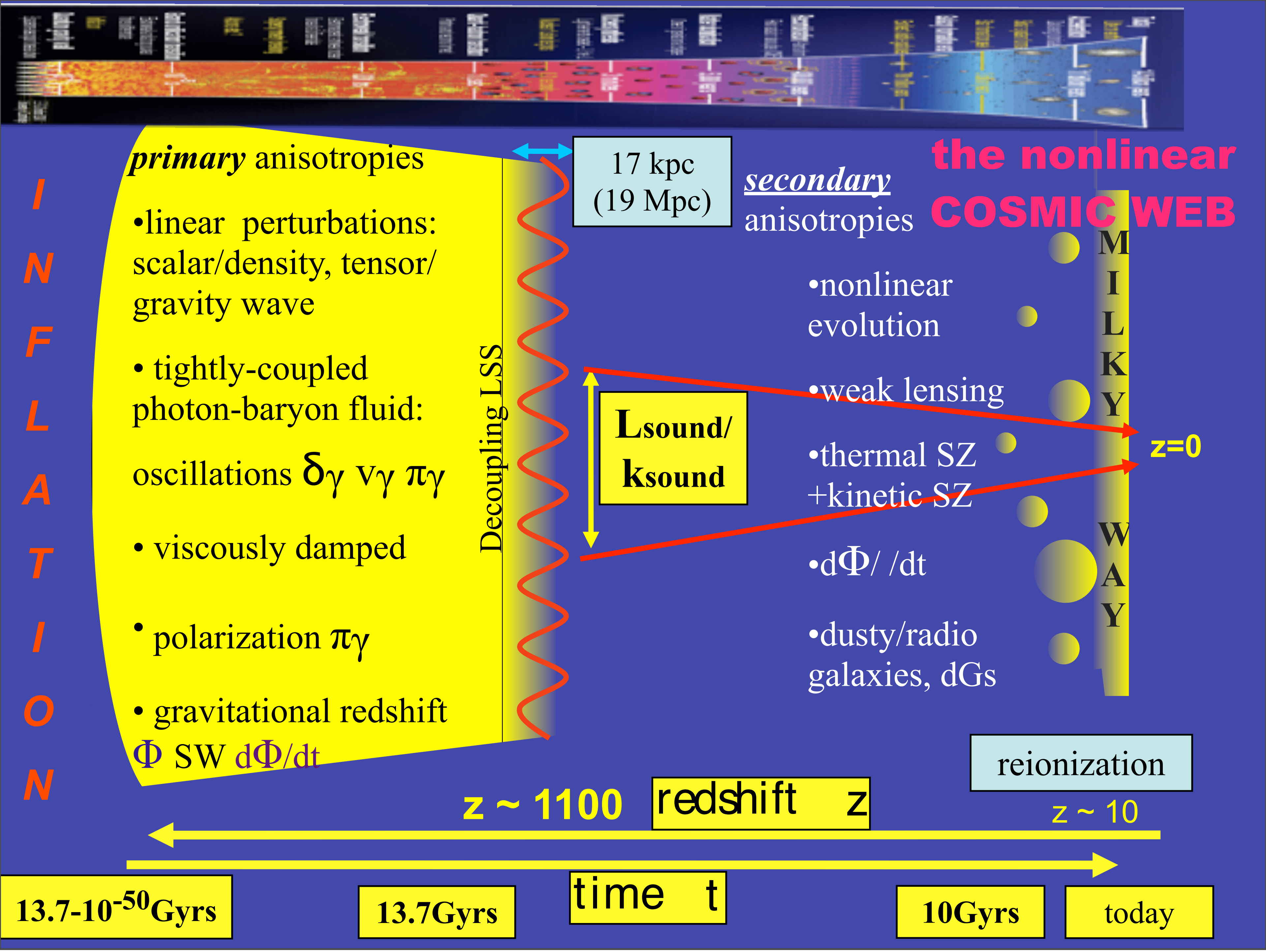
dusty+radio galaxies

kinetic SZ

thermal SZ

PRIMARY

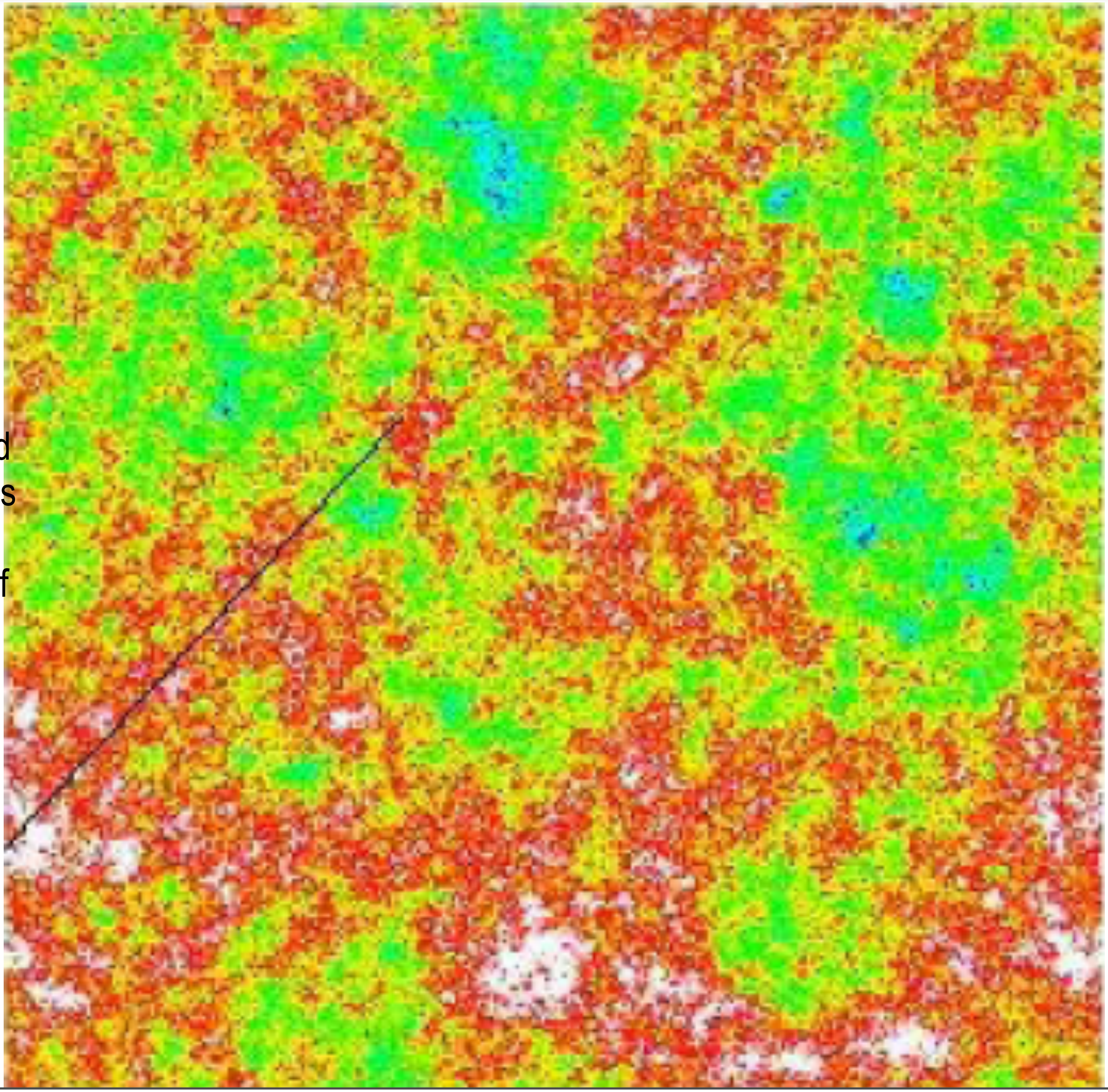




I N F L A T I O N
primary anisotropies
•linear perturbations: scalar/density, tensor/ gravity wave
• tightly-coupled photon-baryon fluid:
oscillations δγ vγ πγ
• viscously damped
• polarization πγ
• gravitational redshift
Φ SW dΦ/dt
Decoupling LSS
17 kpc
(19 Mpc)
Lsound/
ksound
secondary anisotropies
•nonlinear evolution
•weak lensing
•thermal SZ +kinetic SZ
•dΦ/ /dt
•dusty/radio galaxies, dGs
the nonlinear COSMIC WEB
MILKY WAY
z=0
reionization
z ~ 10
z ~ 1100
redshift z
time t
13.7-10-50Gyrs
13.7Gyrs
10Gyrs
today

fluctuations in the **early universe "vacuum" grow** to *all* **structure**

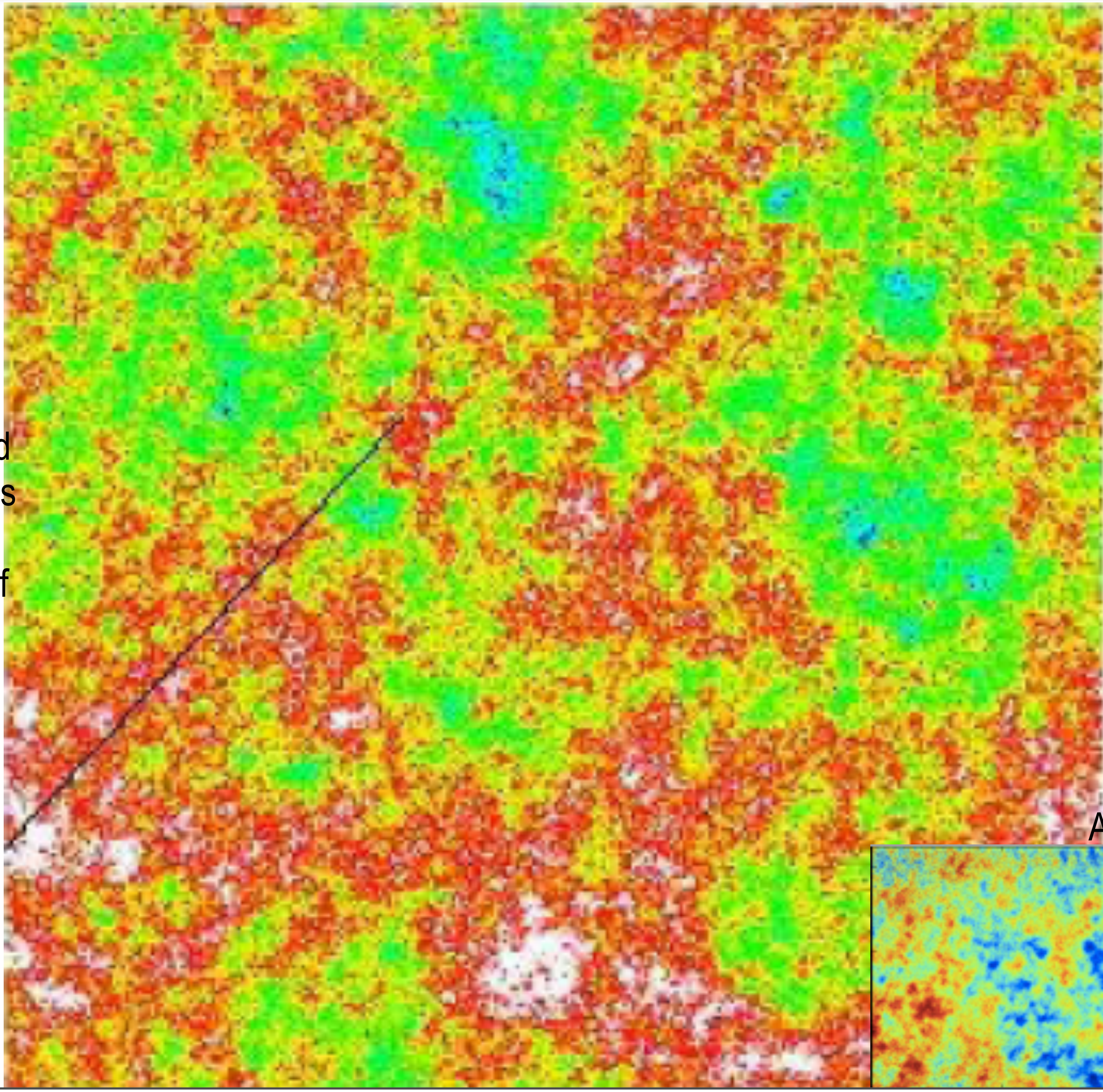
scalar field fluctuations in the vacuum of the ultra-early Universe



evolve from early U vacuum potential and vacuum noise

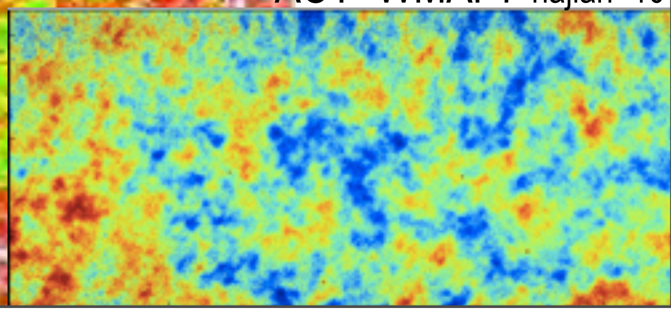
fluctuations in the early universe "vacuum" grow to *all* structure

scalar field fluctuations in the vacuum of the ultra-early Universe



evolve from early U vacuum potential and vacuum noise

ACT+WMAP7 hajian+10



fluctuations in the **early universe “vacuum” grow** to *all* **structure**

400 Mpc

ΛCDM

WMAP5

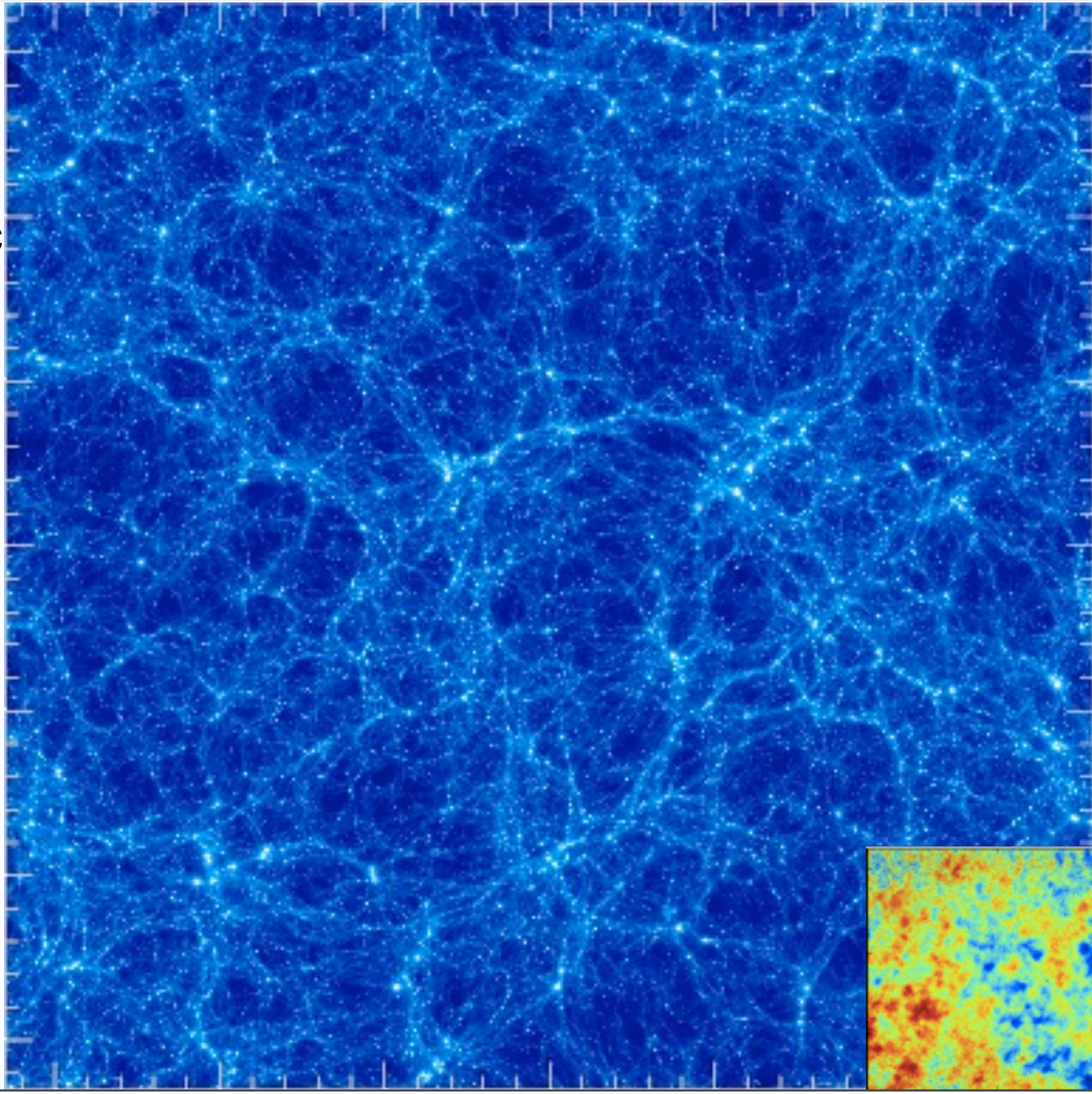
gas density

Gadget-3

SF+ SN E+ winds +CRs

512^3

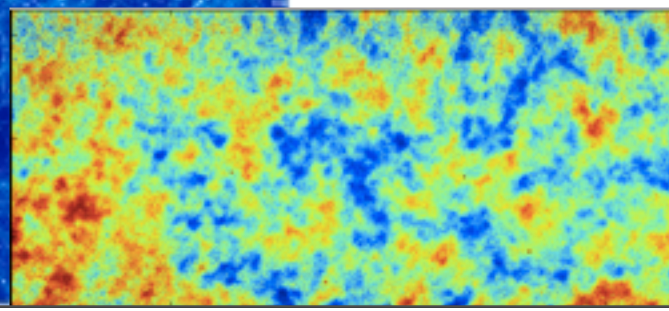
BBPSS10



all this can

evolve from early U vacuum potential and vacuum noise

in the presence of late U vacuum potential aka dark energy



pressure intermittency *in the cosmic web, in cluster-group concentrations probed by* **tSZ**

400 Mpc

ΛCDM

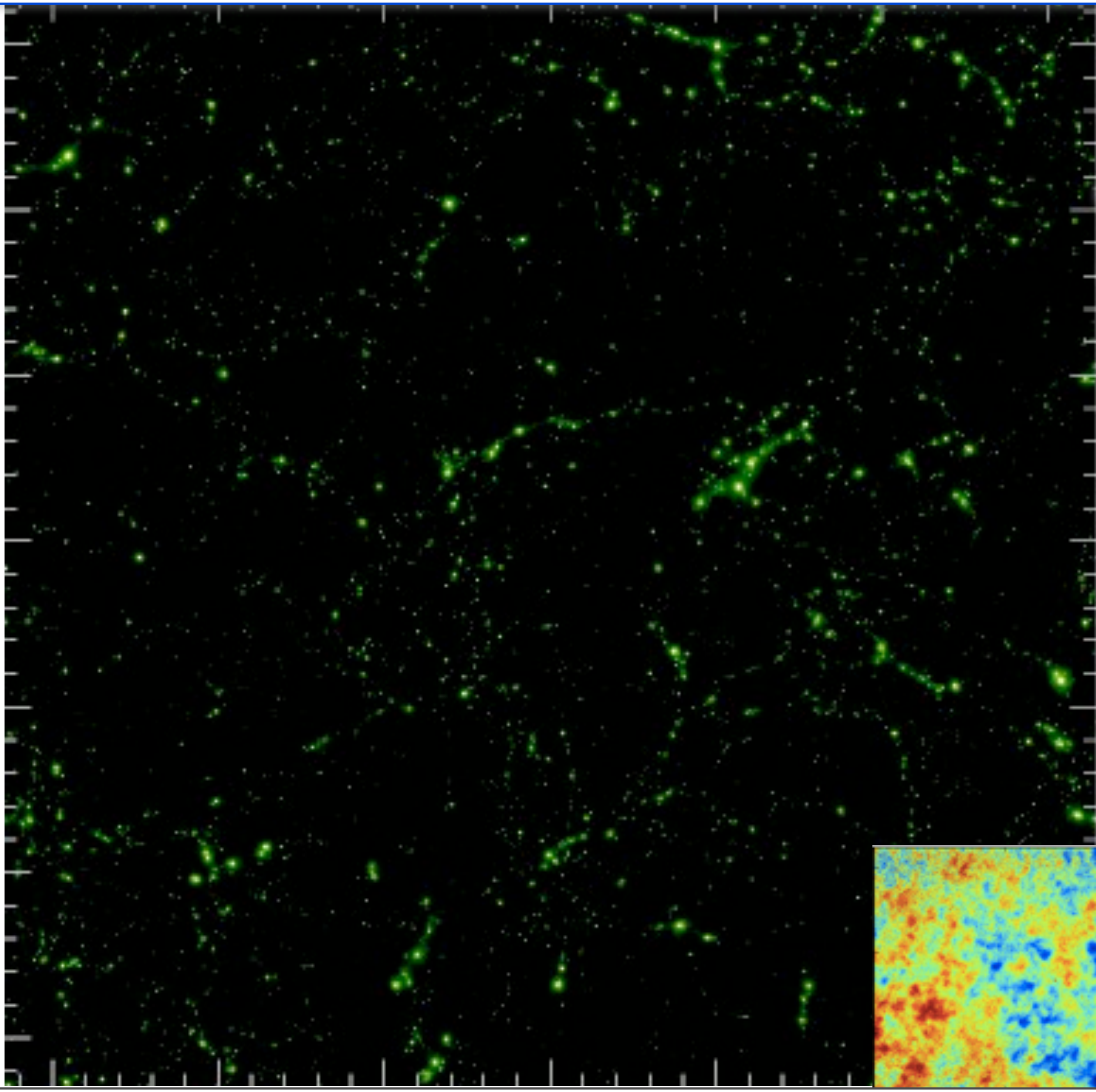
WMAP5

gas pressure

Gadget-3
SF+
SN E+
winds
+CRs

512^3

BBPSS10



CMB gets entangled in the cosmic web

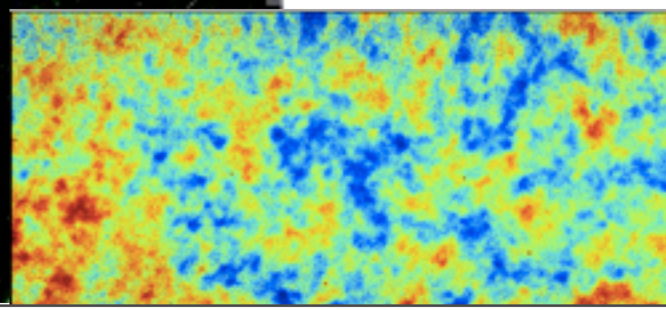
descending into the real gastrophysics

of

cosmic weather

the energetic, turbulent, dissipative, compressive

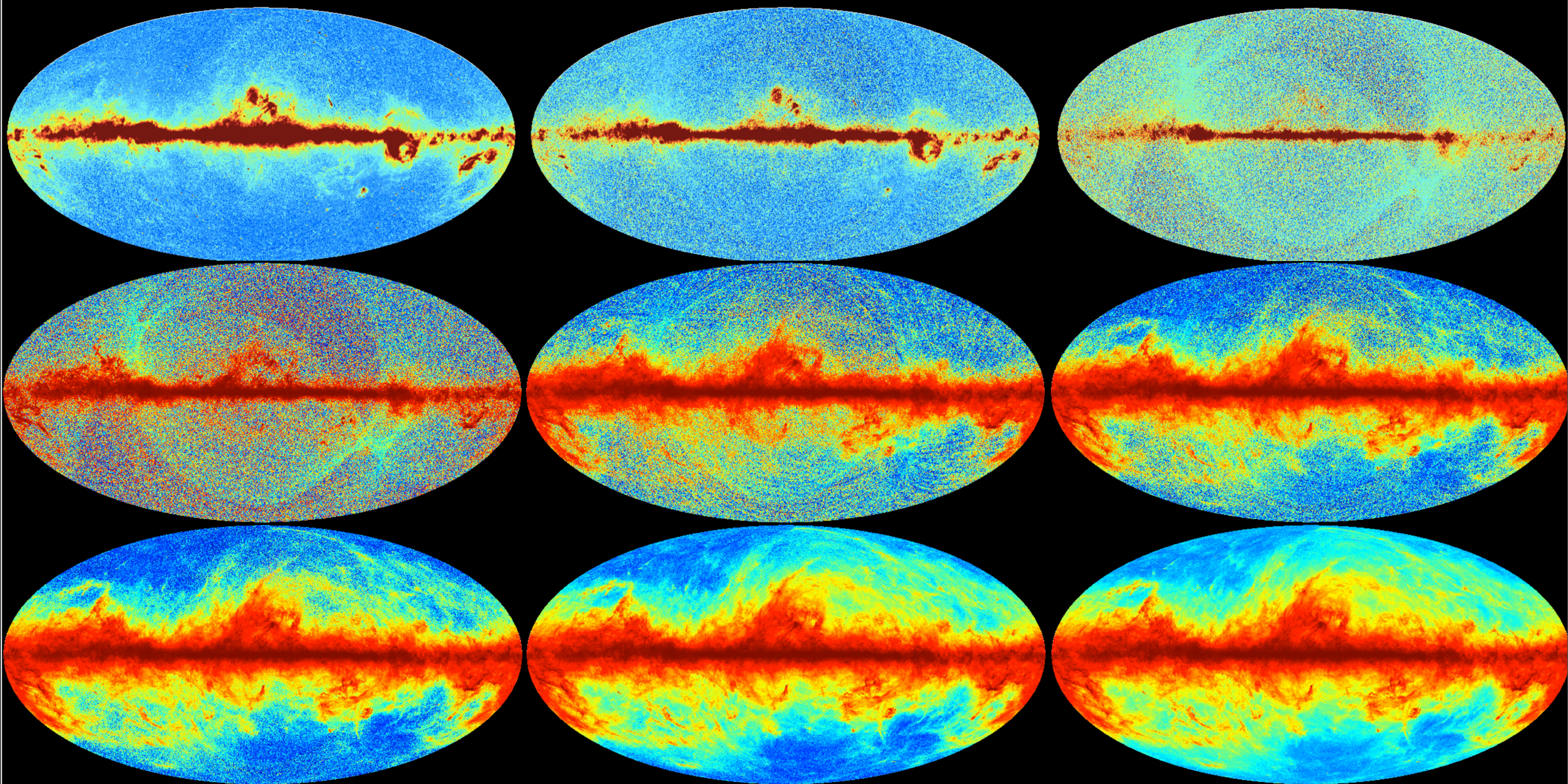
life of the IGM/ICM/ISM



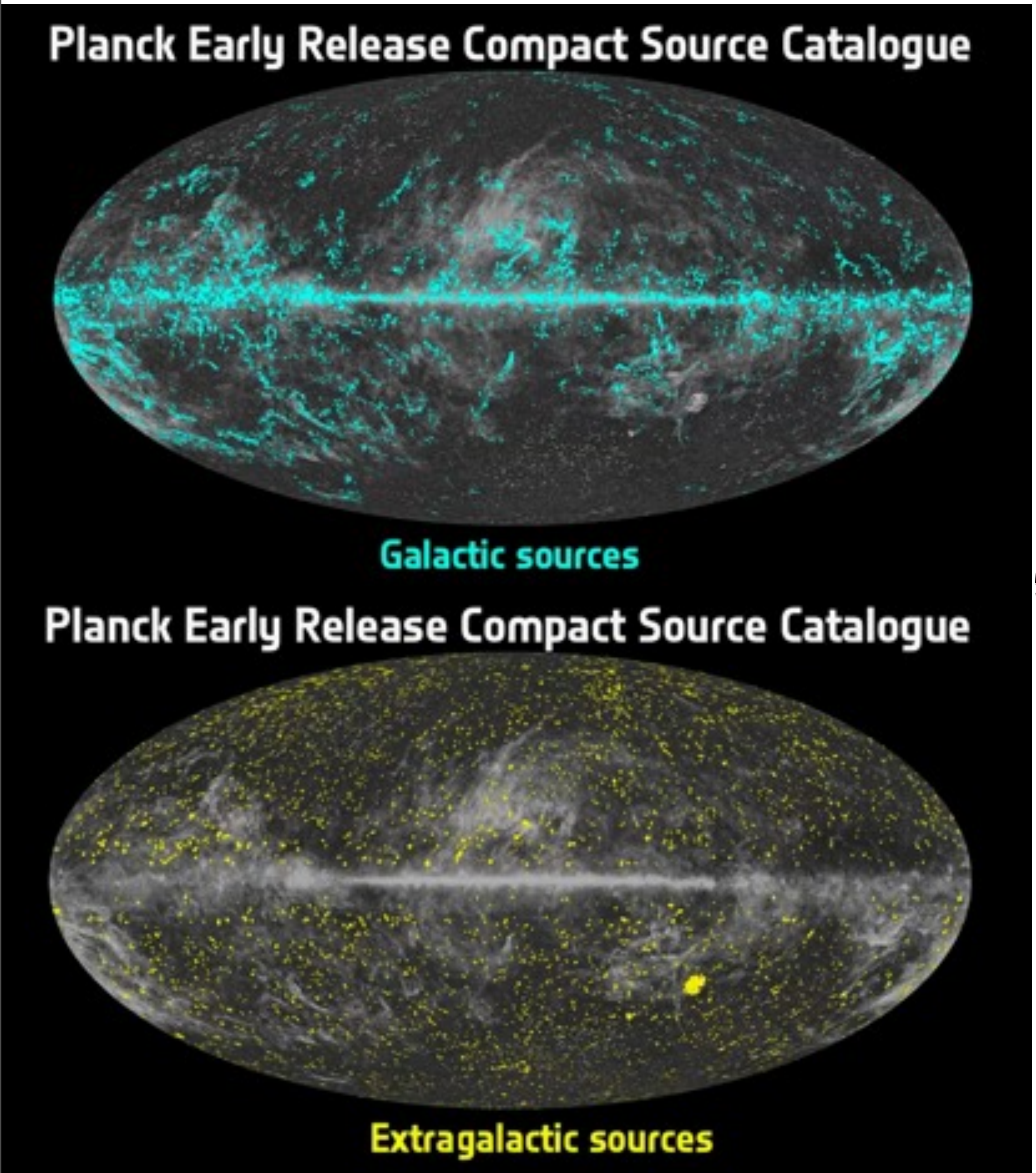
veils(ν) +CMB-CMB

The Planck Foregrounds sky

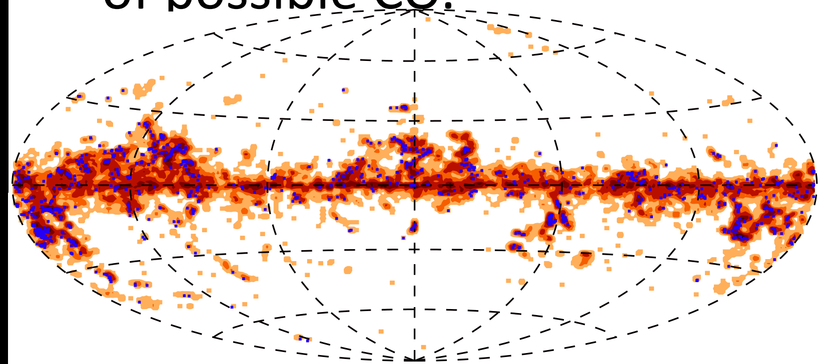
data Aug 13 09 to Jun 7 10: all-9-frequency maps + maps-CMB produced & delivered to consortium Aug 2 10



Needlet ILC method chosen to remove CMB for HFI. so many separation methods - great, so many templates. localized removals won out in some early papers. lessons learned?



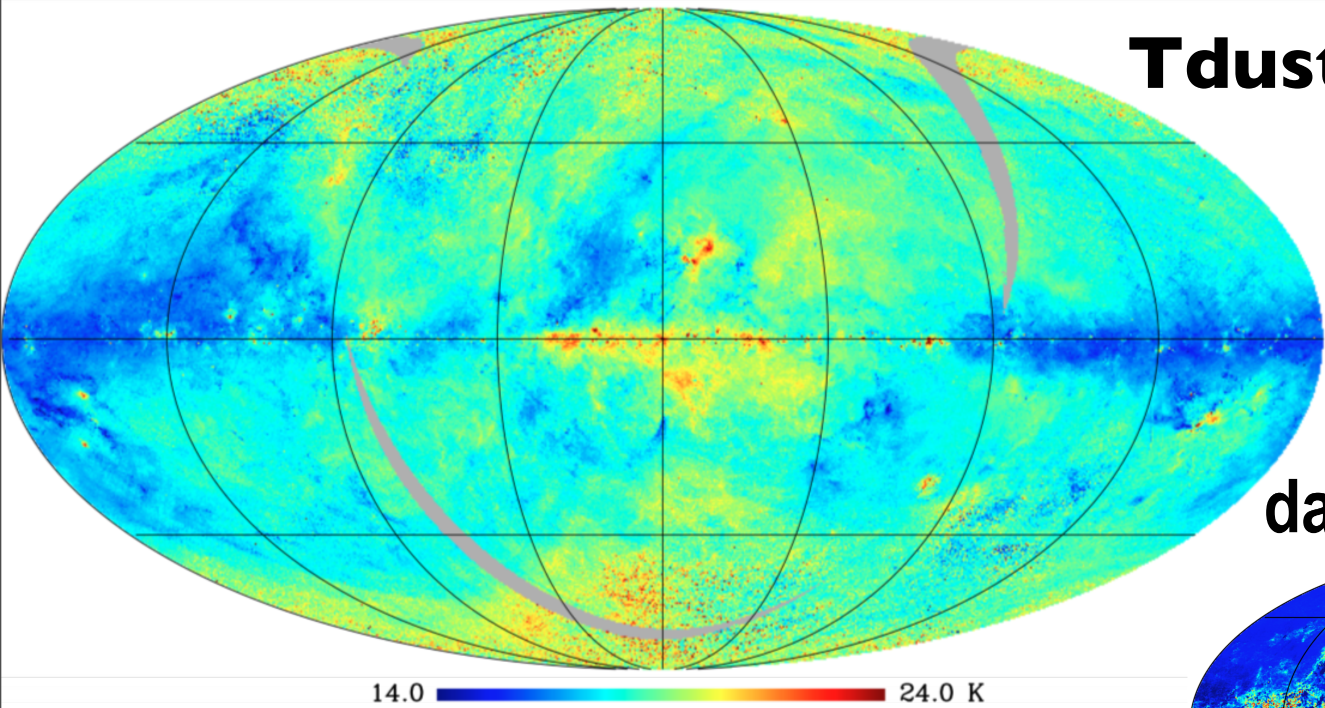
- 15000 sources. Reliability > 90% (using MC) with photometric accuracy <30%, no completeness stats and not flux limited.
- => radio/submm extragalactic sources, Galactic sources, +
- Have to take care at 100 GHz of possible CO.



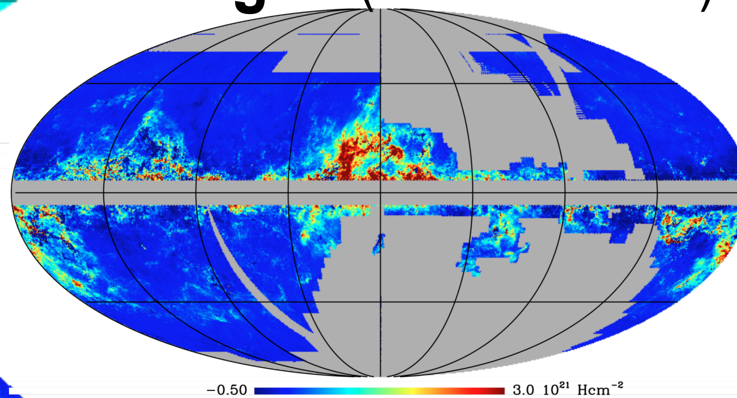
- **915 cold cores** in catalog **ECC** (7-17K, 1.4<beta<2.8), **10783 (C3PO)** seen in maps, most within 2kpc
  Herschel follow-up, some done
- precursors of pre-stellar cores, up to 1e5 Msun
- *Cold Clumps aka cold cores* in groups & filaments, on edges of H1/IRAS loops

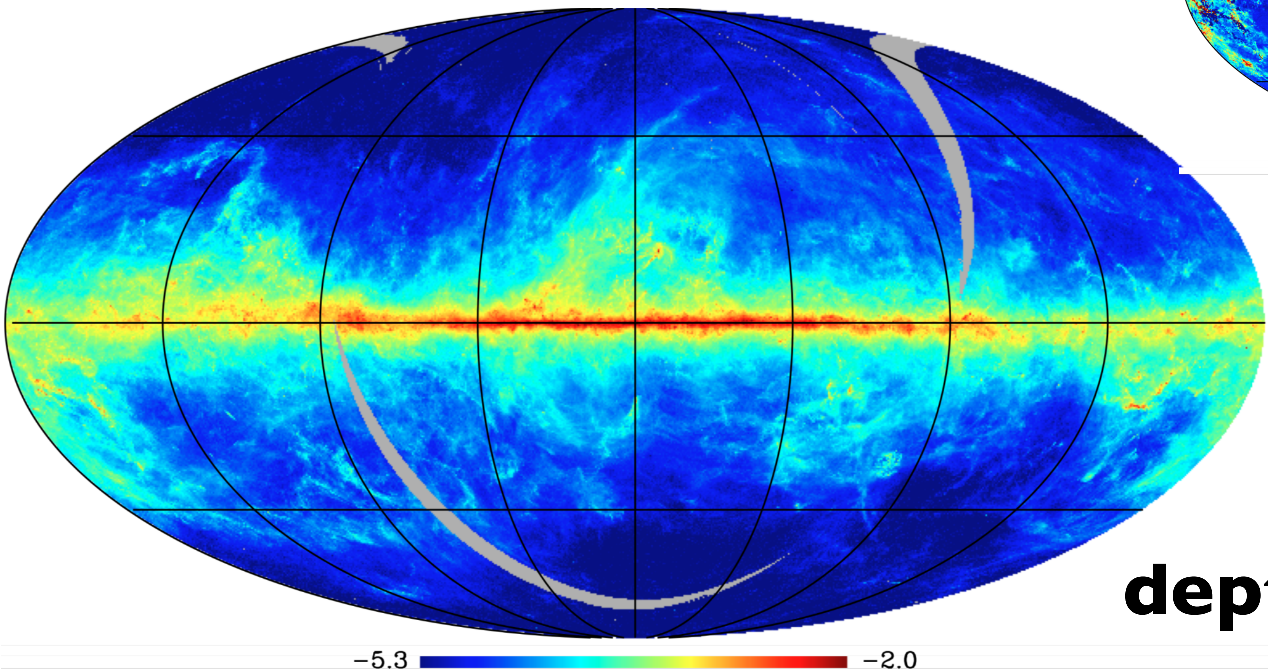
Tdust β fixed @1.8

Planck+IRAS



dark gas (no HI/CO corr)





depth τdust

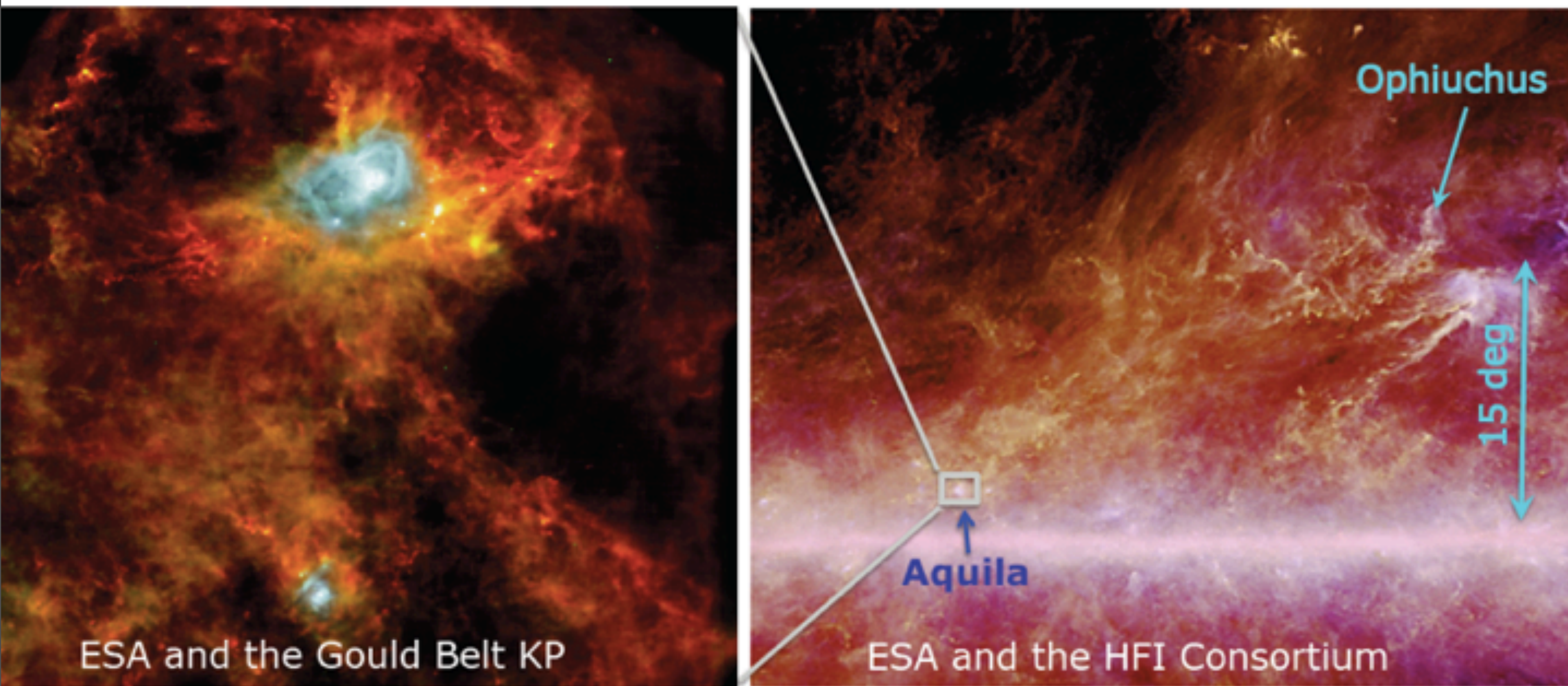
the GALAXY WIDE WEB

Filaments permeate the ISM on all scales

esa

(3.5m telescope) **Herschel**  **Planck** (1.5m telescope)

SPIRE 500 μm +PACS 160/70 μm | **HFI 540/350 μm + IRAS 100 μm**

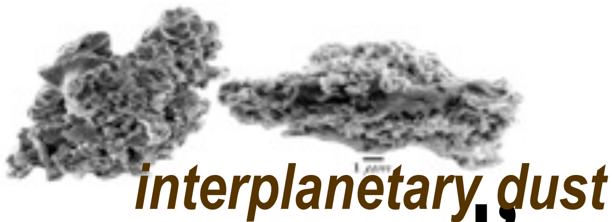


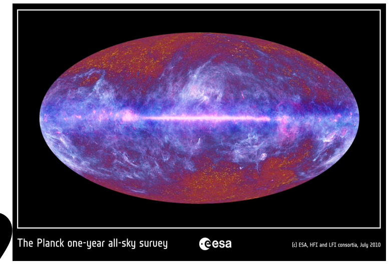
Göran Pilbratt | Planck 2011: The mm & submm sky in the Planck era | Paris | 10 January 2011 | vg #16

Herschel ATLAS is a key legacy survey of 550 sq deg, 300 sq deg & lots of science done

gastrophysics

= gastrointestinal disorder? or



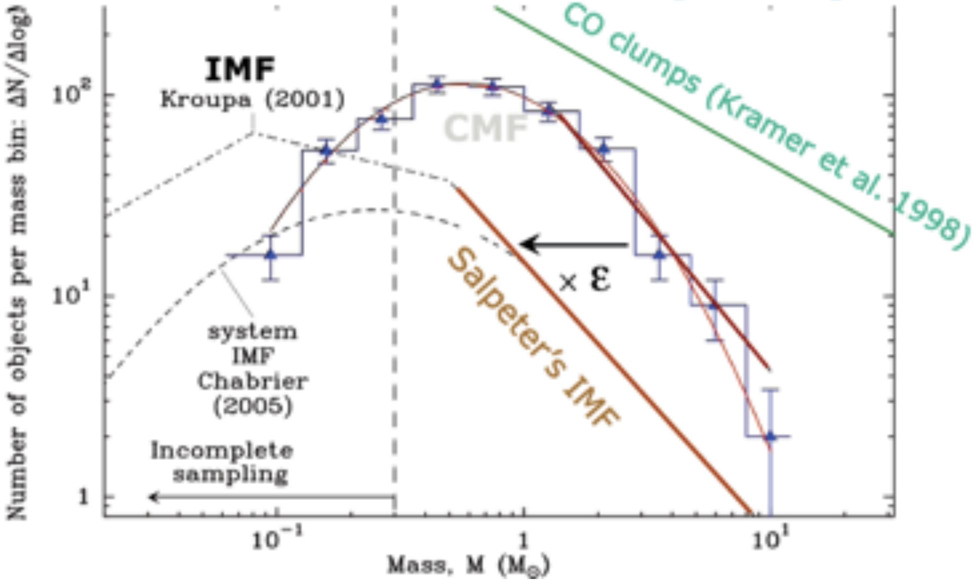


= gourmand's paradise?

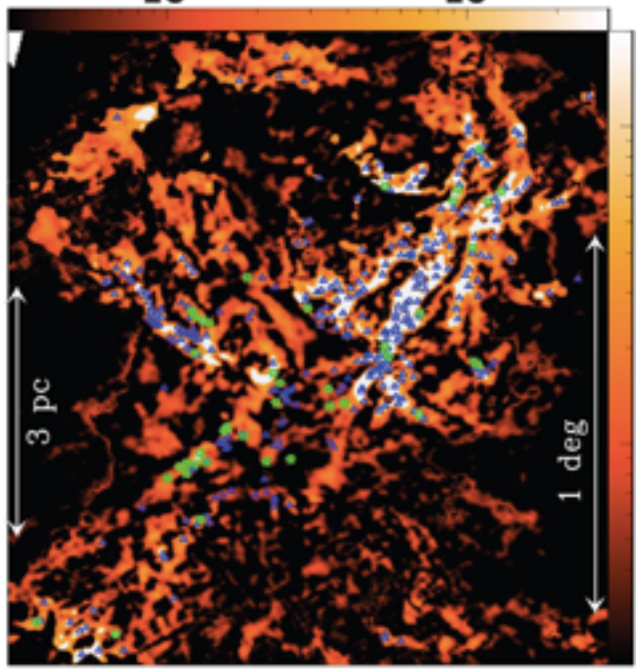
in paris, the latter @planck2011

∃beauty in complex information, but how best to measure it - compress into fewer bits of high Quality (cf. entropy) - what art our science should/must be

Prestellar Core Mass Function (CMF) in Aquila Complex

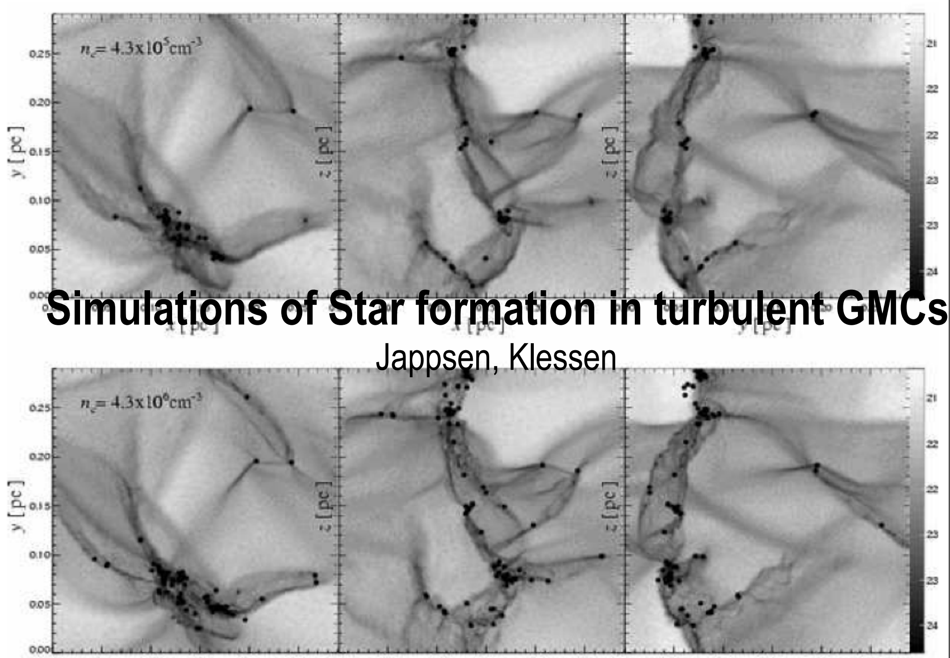


Aquila curvelet N_{H_2} map (cm^{-2})



André et al. 2010, A&A special issue

ISMer-cosmologist cross talk is good and increasing, stimulated by Planck etal



Simulations of Star formation in turbulent GMCs
Jappsen, Klessen

n(M)dM, morphology of filaments, clustering/power spectra, "bulk/turbulent flows"

SIMPLICITY in COMPLEXITY?

but so much chemistry etc

25 papers & a large fraction of the papers at Planck2011 were unveiled for 10 months & 9-freq T data, + a press conference, highlighting: **HFI & LFI work**

- **Galactic dust and templates. MW maps! - see extra emission from 'dark gas' component not in HI or CO, could be H_2 that survives when CO does not. (linear response to templates of all sorts. Planck & Herschel maps beautiful. Tdust vs dust depth/N_H trend) the PlanckEXT extinction model will rule (sometime)**

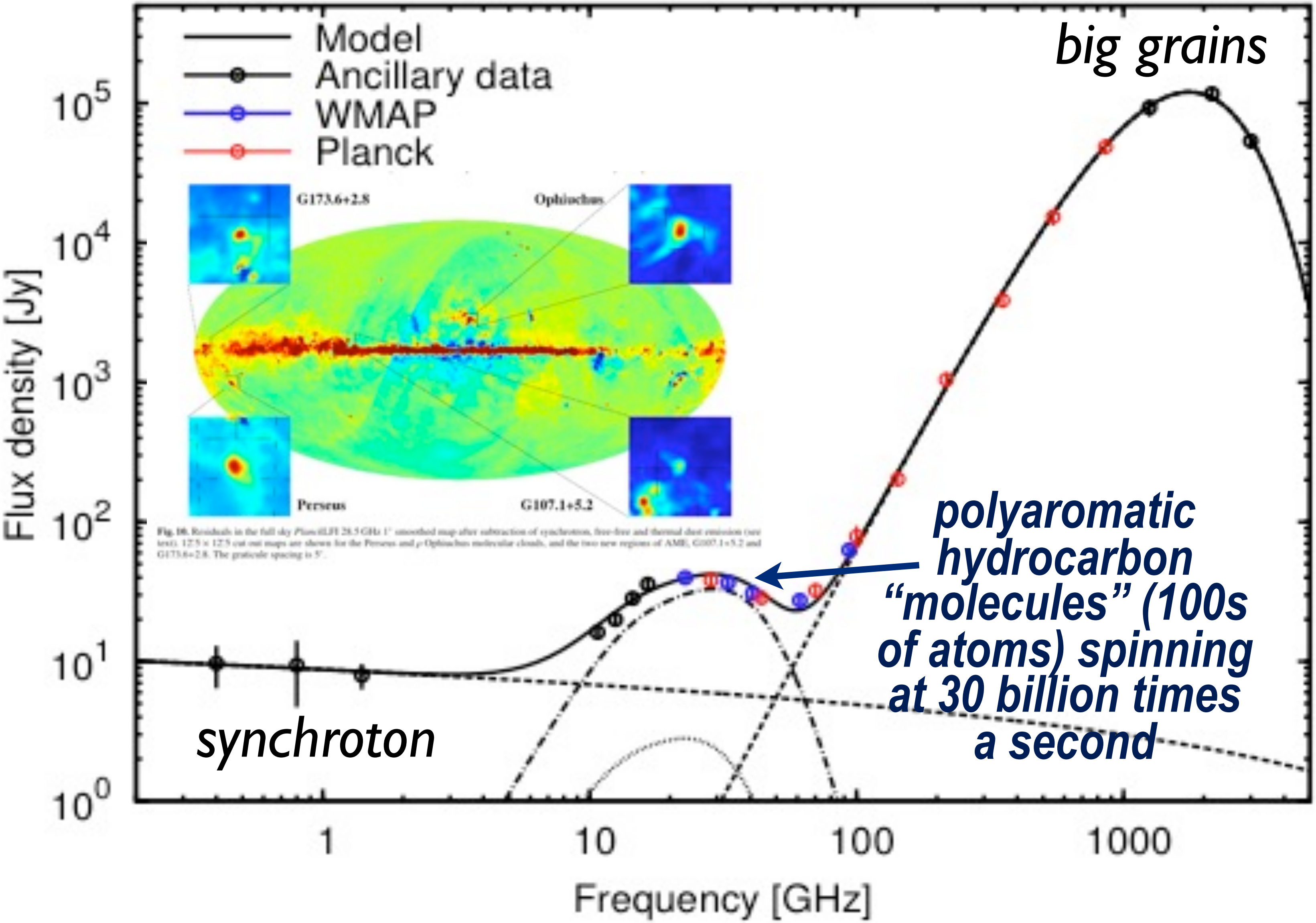


Fig. 4. Spectrum of G160.26-18.62 in the Perseus molecular cloud. The

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- **Spinning dust - AME clearly seen in Perseus and rho-Ophiuchus regions with a spectrum pulled out in excellent agreement with Draine & Lazarian theory from the 90s, a long journey from the OVRO AME discovery & a leap forward**

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.

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radio source counts **Planck, ACT, SPT, WMAP**

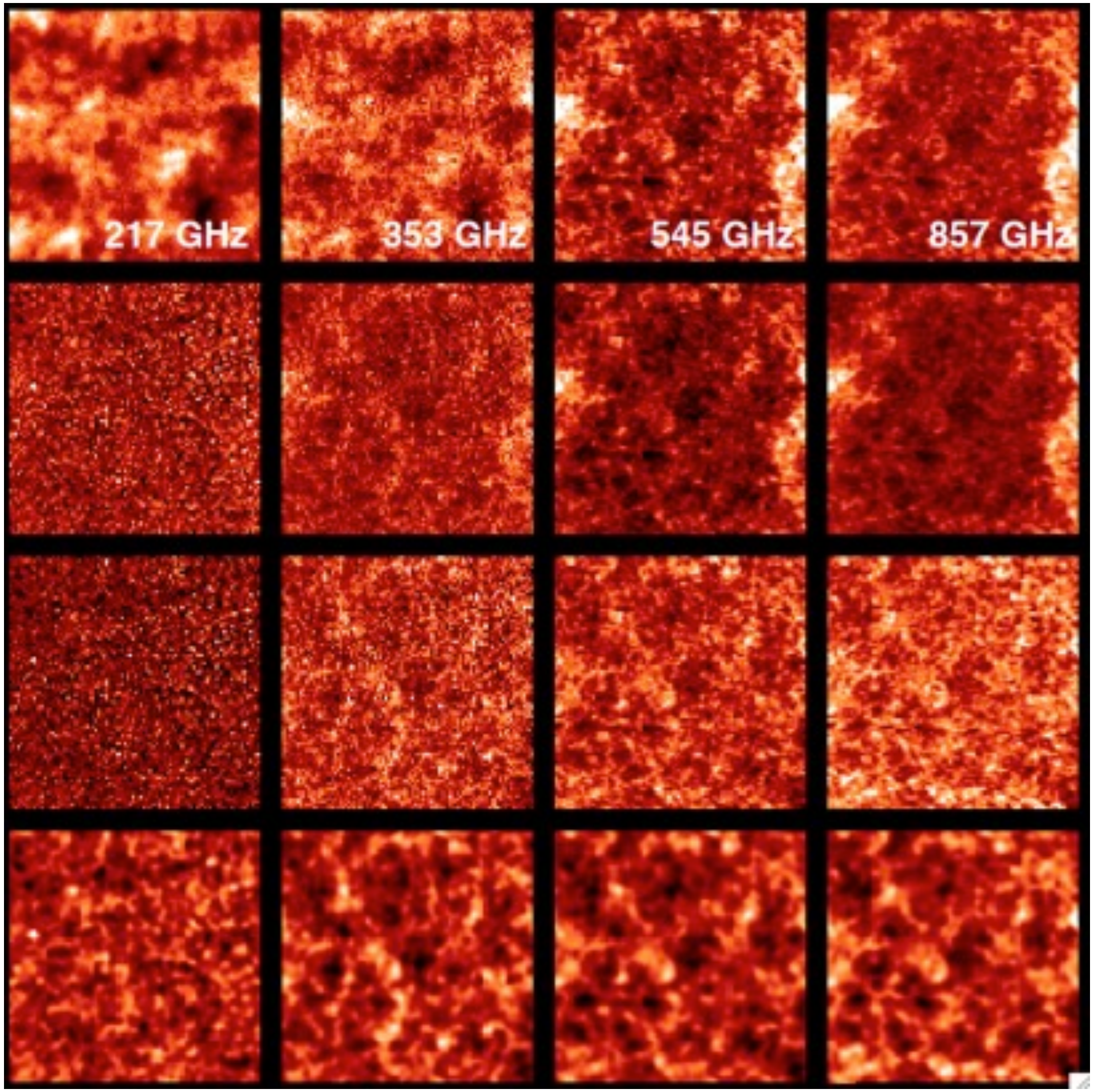
- **Radio src - counts consistent with ACT/SPT (at higher flux range), & WMAP, lower than prior model. there is spectral steepening above 70 GHz.**
- **IR src – possible evidence for cold dust component in local IR galaxies (T<20K).**

dusty gals **Planck, ACT, SPT, ACTxBLAST, Herschel**

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

Planck Early Results: The Power Spectrum Of Cosmic Infrared Background Anisotropies

exquisite information on Galactic foregrounds from the Green Bank telescope (H from 21 cm) & other data, and the Planck point sources +CMB, allows one to dig out an underlying CIB



Planck-HFI Raw maps
26.4 sq. deg.

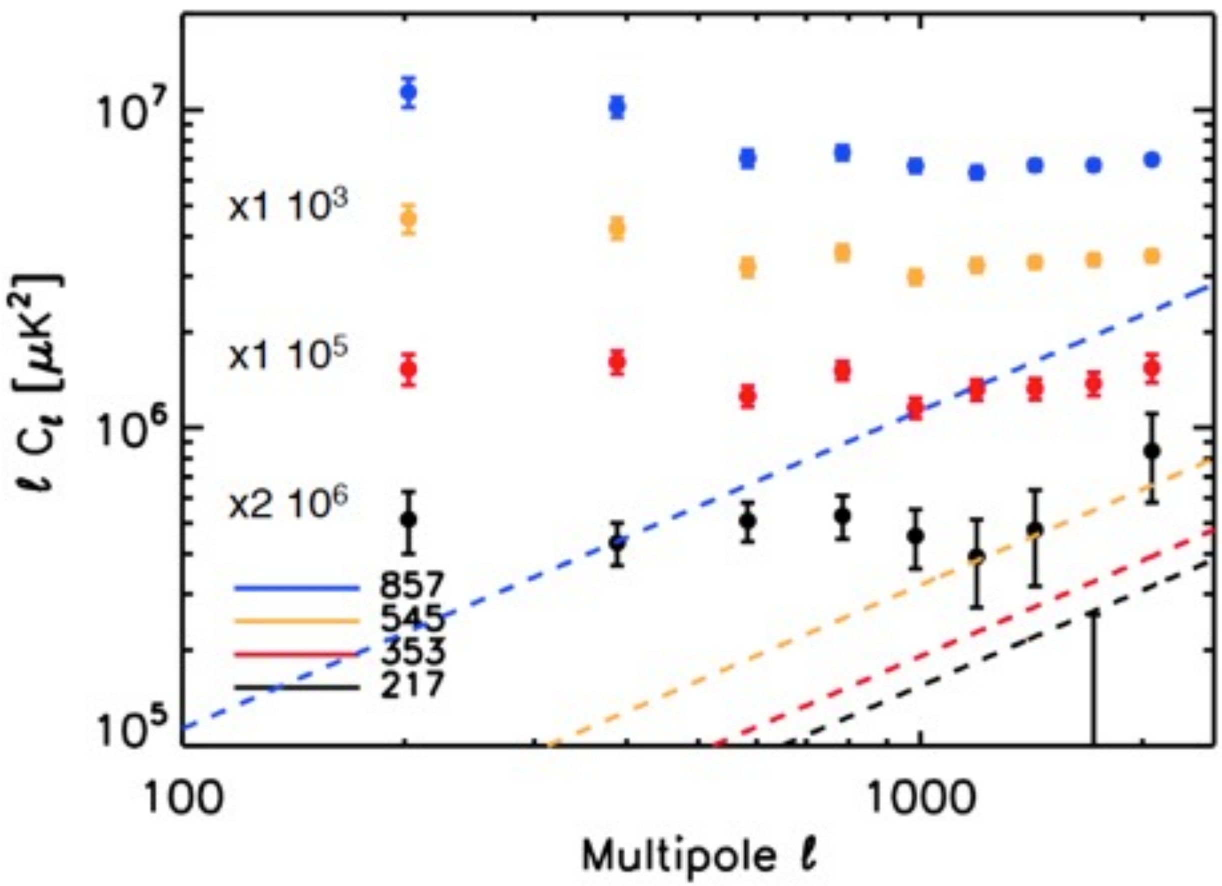
Raw maps
- CMB
- ERCSC point sources

Raw maps
- CMB
- ERCSC point sources
- Galactic dust

CIB maps @ 10 arcmin

Planck Early Results: The Power Spectrum Of Cosmic Infrared Background Anisotropies

clustering of luminous infrared galaxies at high redshift: starbursts, dust-shrouded AGNs, etc



- Planck measures the CIB anisotropies from 10 arcmin to 2 degrees at 217, 353, 545 and 857 GHz
- *Half of power comes from z<0.8 at 857 GHz and z<0.9 at 545 GHz. 1/5 and 2/3 come from z >3.5 at 353 GHz and 217 GHz*
- *Results depends strongly on the HI data & Toronto GBT results*

consistent with $\xi gg \sim r^{-1.8}$ (or even r^{-2}) & linear bias, but halo model with 2-halo dominant, ***sources are exactly what?*** shot noise not (really) measurable with Planck, need higher res expts cf. ***ACTxBLAST, BLASTxBLAST, SPT/ACT CL separation, Herschel (higher)***

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- **CIB - clustering term clearly detected at 217-857 GHz, with diminishing correlation as band separation increases. imaged (BLAST, ACTxBLAST, Planck agree, Herschel a little higher). Source halo model fits the spectra, so does usual galaxy clustering with <bias>. source population is exactly what? => uncertain interpretation**

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

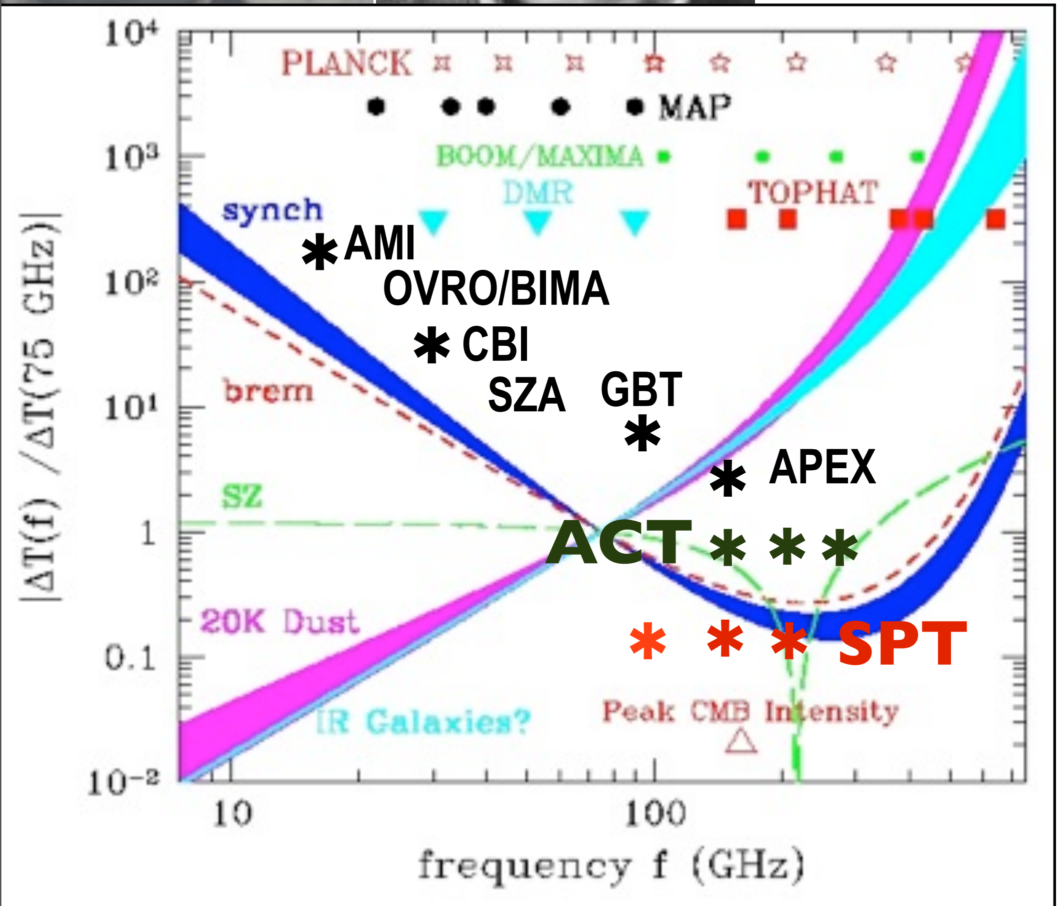
- **SZ - 189 SZ clusters. SZ scaling relations appear as expected for X-ray clusters (no deficit, assuming universal profile), apparent SZ deficit for optical clusters (jury out on cause, but seen in ACTxSDSS-LRGs as well)**

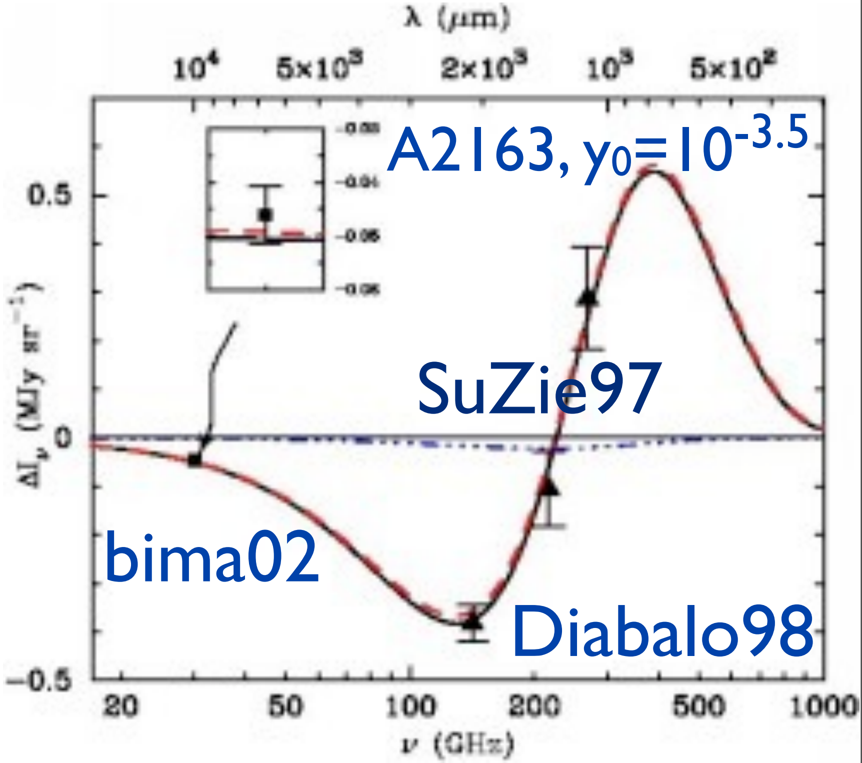
Planck & the thermal *Sunyaev-Zeldovich Probe* of *Gas* in the *Cosmic Web:* $y \sim \int p_e$ dline-of-sight

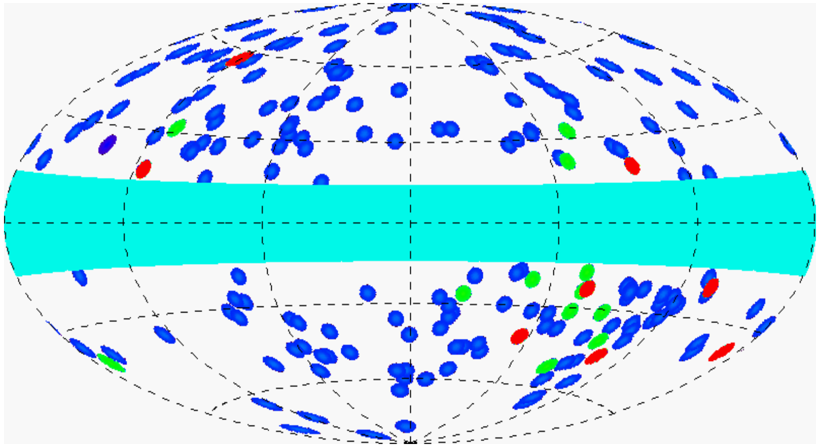
$\Delta T/T = y * (x(e^x+1)/(e^x-1)-4),\ x = h\nu/T_\gamma$

$= -2y$ to xy, **0 @ ν=217 GHz**

$\Delta I_\nu = \Delta T/T * x^4 e^x/(e^x-1)^2$







ESZ 20 new + 169 in X/Opt cats

(& ~80% new in SZ, $E_{thermal}$ view)

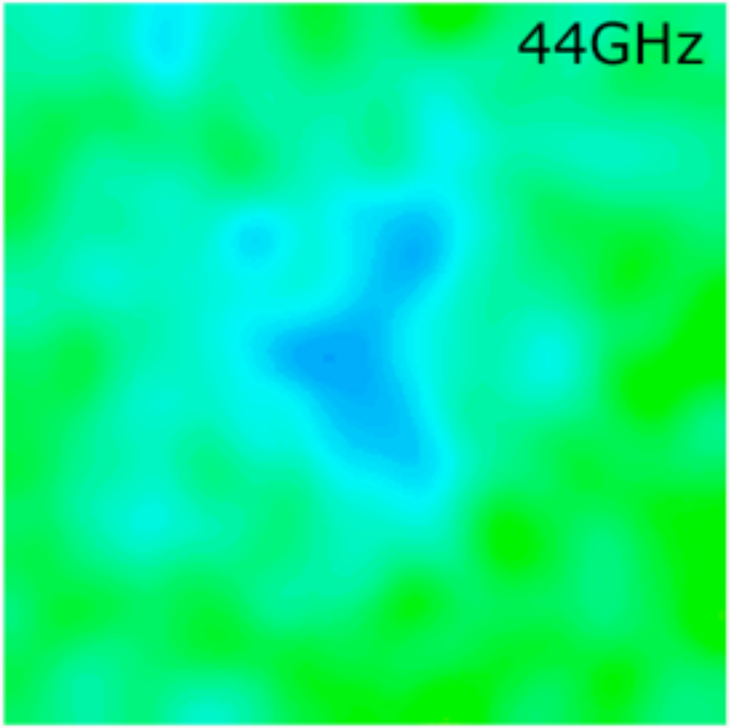
Planck**XMM** dedicated time on newbies

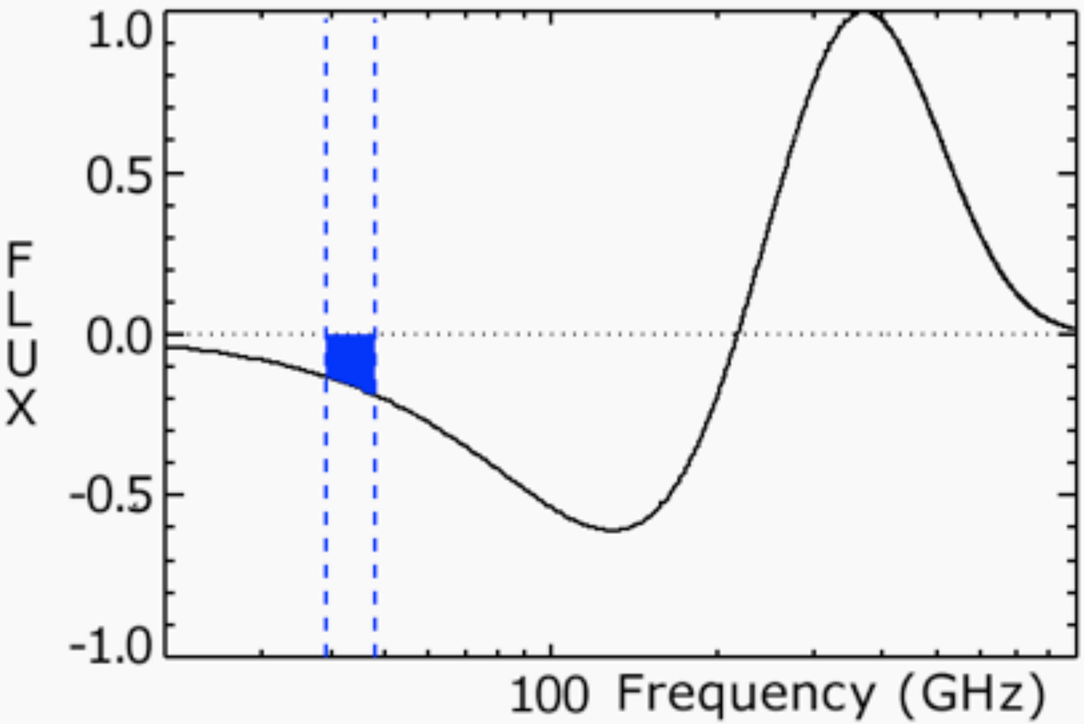
~95% reliable, validation, S/N ~ 6 cut

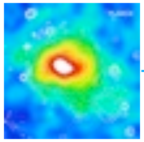
+ cross-correlate with X/SDSS cats, Y-”M” scaling OK in shape, puzzle in amp for optical maxBCG/LRG

new SZ cluster detections reported by ACT (~50), SPT (~50), AMI, .. more coming

A2319







Planck sees the rarest & most massive clusters over the whole sky:

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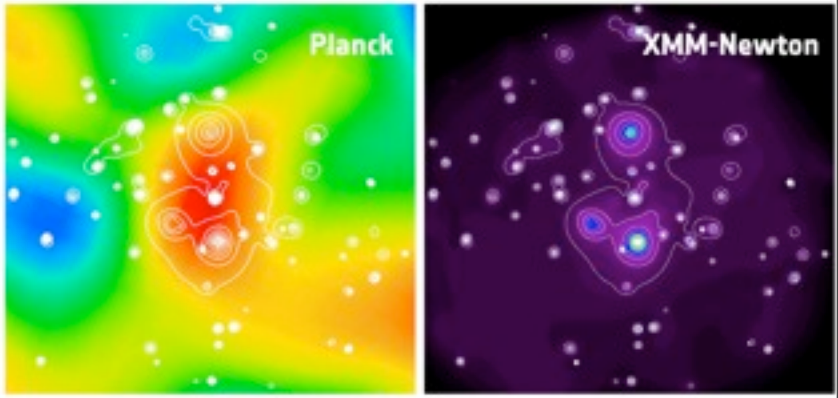
Feb10 targets for XMM-*Newton* - **25 candidates observed:** DDT time, eg, pilot 10 targets from 62% of sky coverage, in 4 < S/N < 6 range (EZ > 6); high S/N (>5) programme 15 targets. **21 confirmed** → ***~85% success rate; 17 single clusters, most disturbed; 2 double systems; 2 triple (super-cluster) systems; 0.09 < z < 0.54***



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

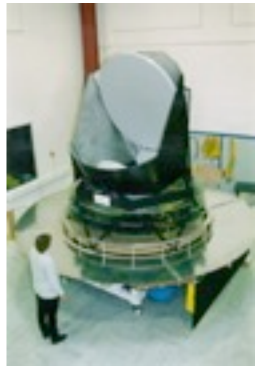
53+35 cls **(>=40)**

QUaD @SP

189 +10 **cls (>=1000)**

Planck09.4

52+ bolometers
+ HEMTs @L2
9 frequencies



WMAP @L2 **to 2010**

2004 — 2005 — 2006 — 2007 — 2008 — **LHC** — 2009 — 2011

Bpol @L2

21+26~50 (>=750)

>96

OVRO /BIMA array

38 cls

80s-90s
Ryle
OVRO

Acbar@SP
~1 blind

SZA@Cal

3 cls (z>1), x?

AMI

7+1 cls >=50+25

GBT

4 cls (~25 CLASH)

AMIBA

6 cls

APEX
~400 bolos@Chile

~25 cls

SPT
1000 bolos
@SPole

ACT **23+27~50 cls**

3000 bolos
3 freqs @Chile

SCUBA2
12000 bolos
JCMT @Hawaii

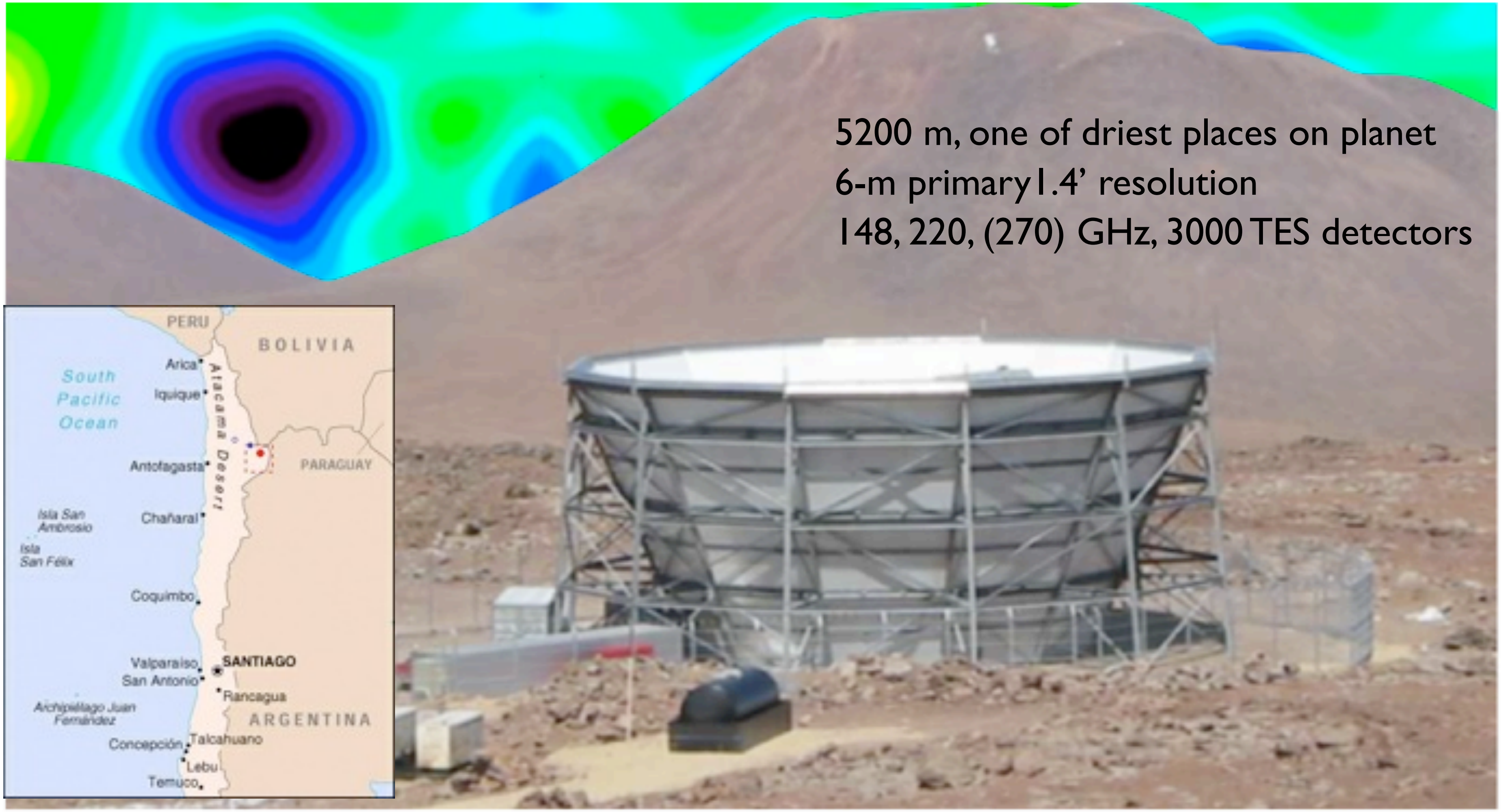
SPTpol
ACTpol

ALMA

CCAT@Chile

LMT@Mexico

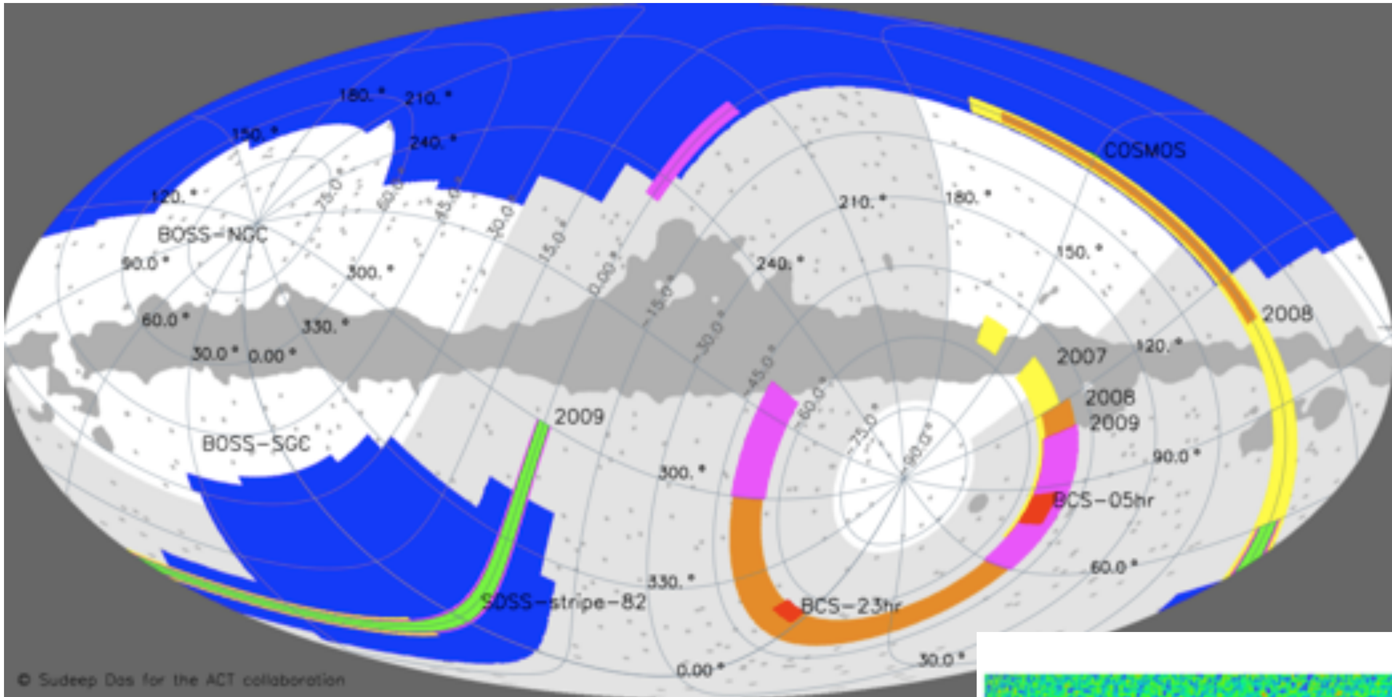
Cosmology From 17,000 Feet:
Results From the Atacama Cosmology Telescope



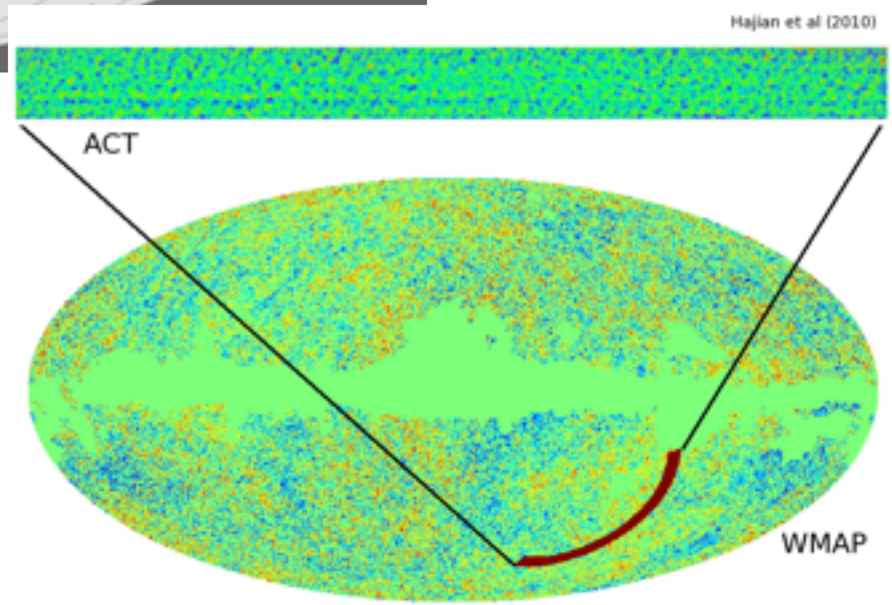
V. Acquaviva [1,2]
P. Ade [3]
P. Aguirre [4]
M. Amiri [5]
J. Appel [6]
E. Battistelli [7,5]
J. R. Bond [8]
B. Brown [9]
B. Burger [5]
J. Chervenak [10]
S. Das [29,6,1]
M. Devlin [2]
S. Dicker [2]
W. B. Doriese [11]
J. Dunkley [12,6,1]
R. Dunner [4]
T. Essinger-Hileman [6]
R.P. Fisher [6]
J.W. Fowler [6]
A. Hajian [6]
M. Halpern [5]
M. Hasselfield [5]
C. Hernandez-Monteagudo [13,2]
G. Hilton [11]
M. Hilton [14, 15]
A. D. Hincks [6]
R. Hlozek [12]
K. Huffenberger [16,6]
D. Hughes [17]
J. P. Hughes [18]
L. Infante [4]
K.D. Irwin [11]
N. Jarosik [6]
R. Jimenez [19]
J.B. Juin [4]
M. Kaul [2]
J. Klein [2]
A. Kosowsky [9]
J.M. Lau [20,6]
M. Limon [21]
Y.T. Lin [22,1,4]
R. Lupton [1]
T.A. Marriage [1,6]
D. Marsden [2]
K. Martocci [23,6]
P. Mauskopf [3]
F. Menanteau [18]
K. Moodley [14]
H. Moseley [10]
B. Netterfield [24]
M.D. Niemack [11,6]
M.R. Nolta [8]
L.A. Page (PI) [6]
L. Parker [6]
B. Partridge [25]
H. Quintana [4]
B. Reid [19,1]
N. Sehgal [20,18]
J. Sievers [8]
D. Spergel [1]
S.T. Staggs [6]
O. Stryzak [6]
D. Swetz [2]
E. Switzer [23,6]
R. Thornton [26,2]
H. Trac [27,1]
C. Tucker [3]
L. Verde [19]
R. Warne [14]
G. Wilson [28]
E. Wollack [10]
Y. Zhao [6]

[1] Princeton University Astrophysics (USA)
[2] University of Pennsylvania (USA)
[3] Cardiff University (UK)
[4] Pontifica Universidad Catolica de Chile (Chile)
[5] University of British Columbia (Canada)
[6] Princeton University Physics (USA)
[7] University of Rome "La Sapienza" (Italy)
[8] CITA, University of Toronto (Canada)
[9] University of Pittsburgh (USA)
[10] NASA Goddard Space Flight Center (USA)
[11] NIST Boulder (USA)
[12] Oxford University (UK)
[13] Max Planck Institut fur Astrophysik (Germany)
[14] University of KwaZulu-Natal (South Africa)
[15] South African Astronomical Observatory
[16] University of Miami (USA)
[17] INAOE (Mexico)
[18] Rutgers (USA)
[19] Institute de Ciencies de L'Espai (Spain)
[20] KIPAC, Stanford (USA)
[21] Columbia University (USA)
[22] IPMU (Japan)
[23] KICP, Chicago (USA)
[24] University of Toronto (Canada)
[25] Haverford College (USA)
[26] West Chester University of Pennsylvania (USA)
[27] Harvard-Smithsonian CfA (USA)
[28] University of Massachusetts, Amherst (USA)
[29] BCCP UC Berkeley and LBL (USA)

ACT equatorial data (2008-10)



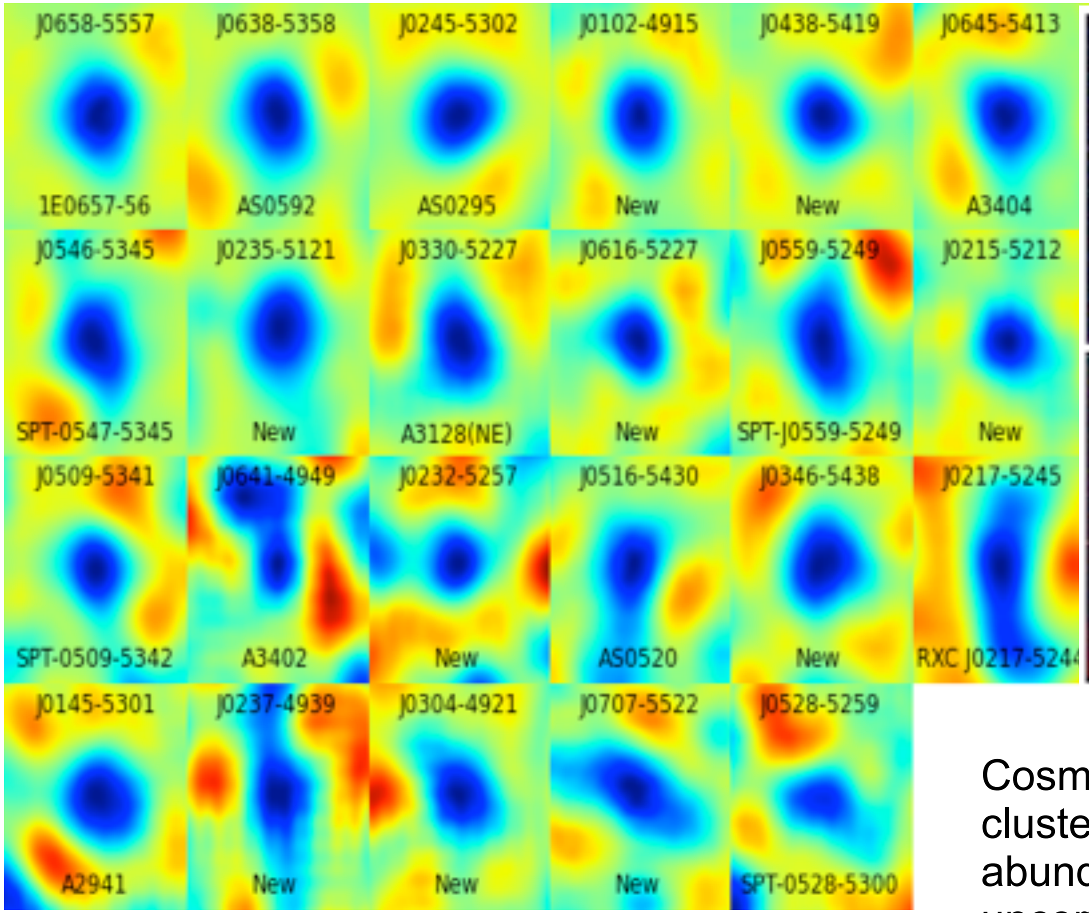
325 sq degrees, 23uK/arcmin, maps@CITA



23 Galaxy Clusters Found by ACT via SZ Signal

Marriage et al 2010 (1010.1065)

Optical Observations Menanteau et al 2010 (1006.5126)



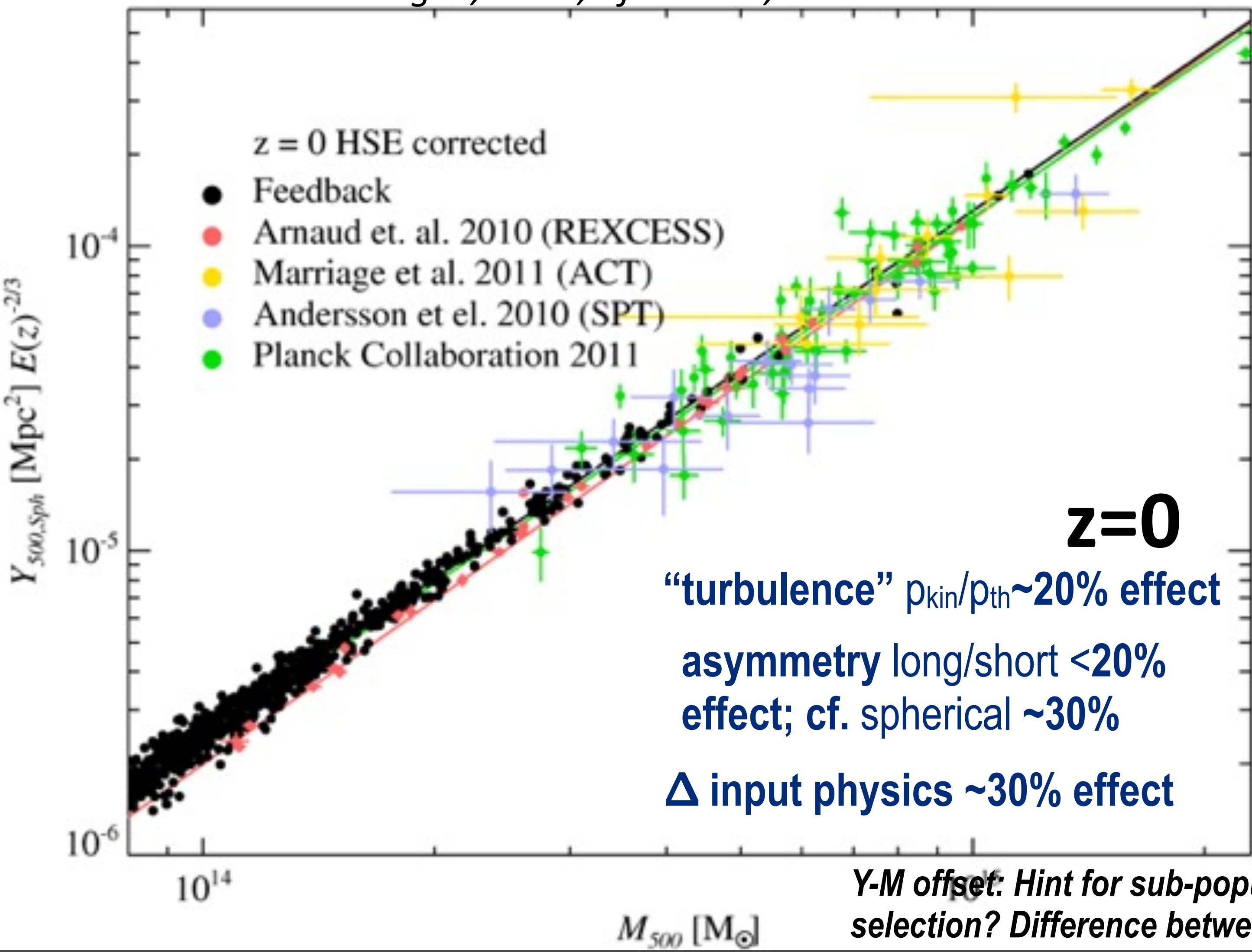
Cosmic Parameters from 9 confirmed clusters (Sehgal et al.2010) using cluster abundances => mass calibration still too uncertain (e.g. σ_8=0.82±0.05 to 0.85±0.12). attempt at Dark Energy equation of state, little leverage

With the ACT equatorial strip, >50 clusters.

$E_{e,th}(<r_\Delta)-M(<r_\Delta)$ relation, *where*

$M(<R_\Delta)/V(<R_\Delta)=\Delta\,\rho_{crit}$, Δ=2500, **500**, 200

Battaglia, Bond, Pfrommer, Sievers 11



z=0

"turbulence" p_{kin}/p_{th}**~20% effect**

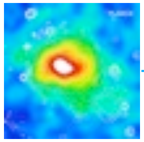
asymmetry long/short <**20% effect; cf.** spherical **~30%**

Δ input physics ~30% effect

Planck-ESZ gives $\mathbf{Y_{5R500}}$

is Y_{SZ} a good mass proxy in $n_{cl}(M, z)$?
even though virial theorem
Y(e,K/U,...|M)
=> $n_{cl}(Y, z)$

Y-M offset: Hint for sub-populations? Optical selection? Difference between Mx & MLens & Mbias?...



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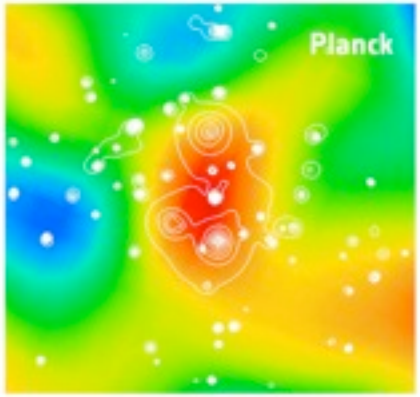
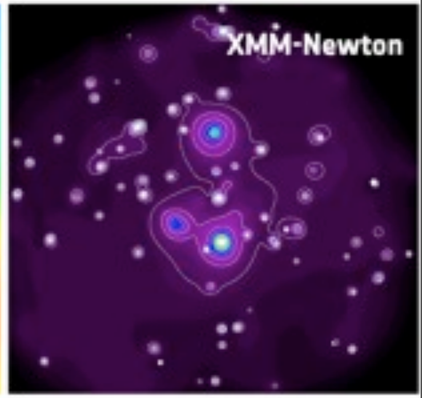
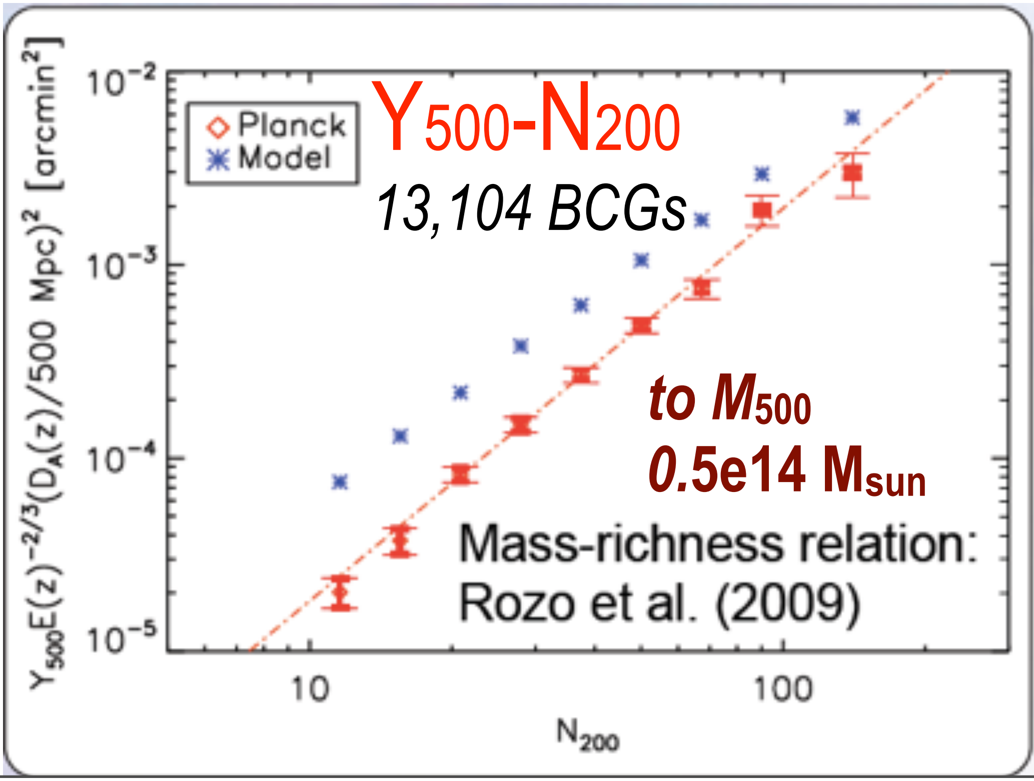
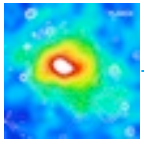
cross-correlate with the *13,104* optical "brightest cluster galaxies" from the Sloan Digital Sky Survey, estimate cluster size and mass by richness = number of galaxies in the cluster

Mass-richness from stacked gravitational lensing observations. Ee,th-"M" disagrees, lower Ee,th. Why?









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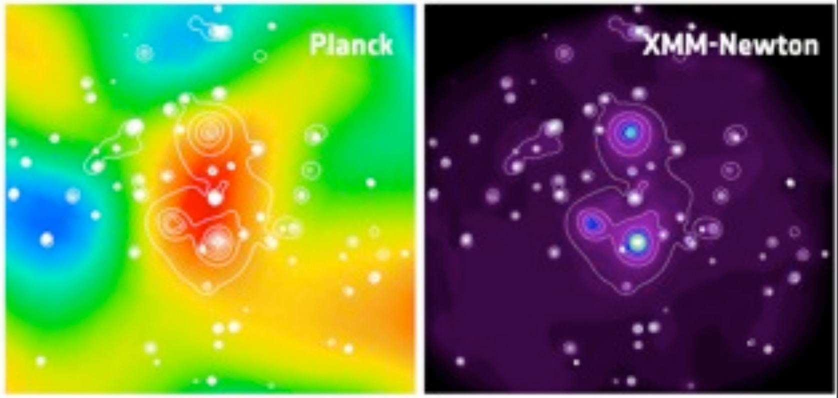

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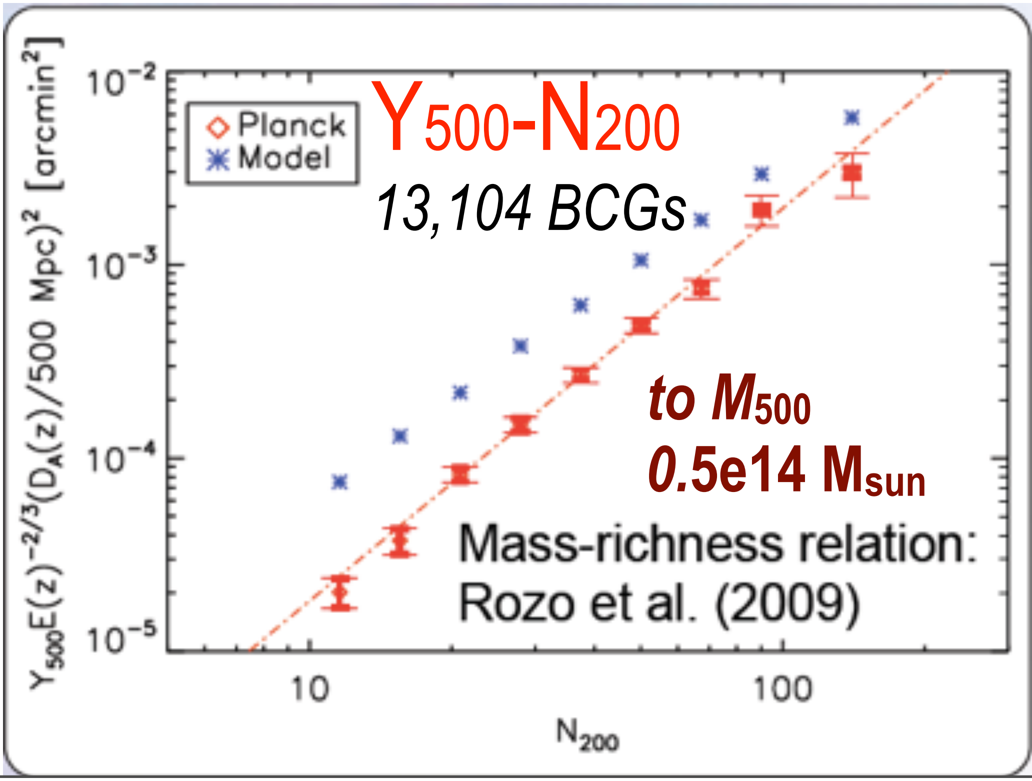

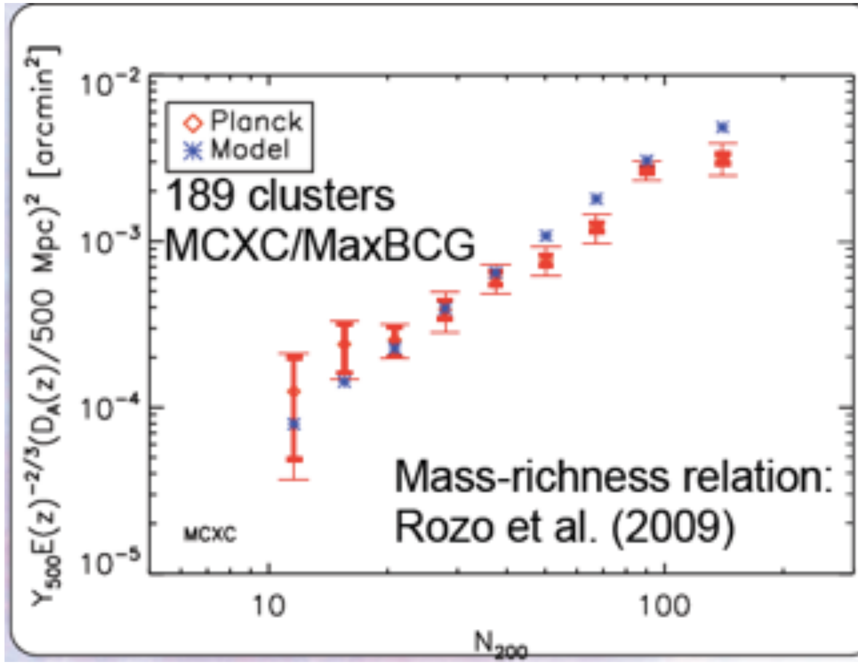

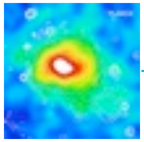

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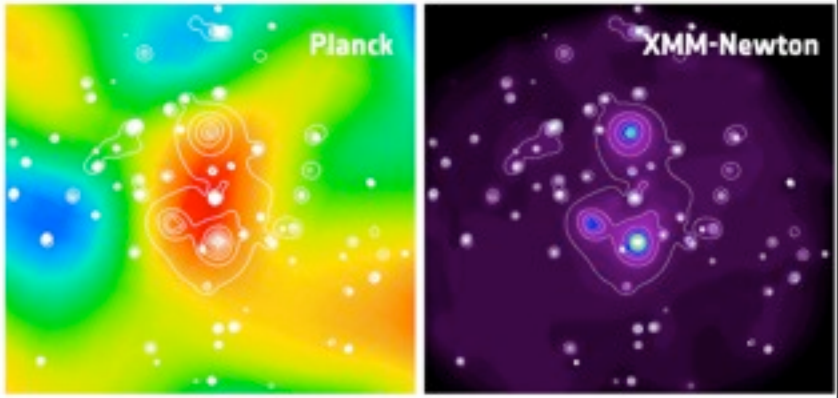

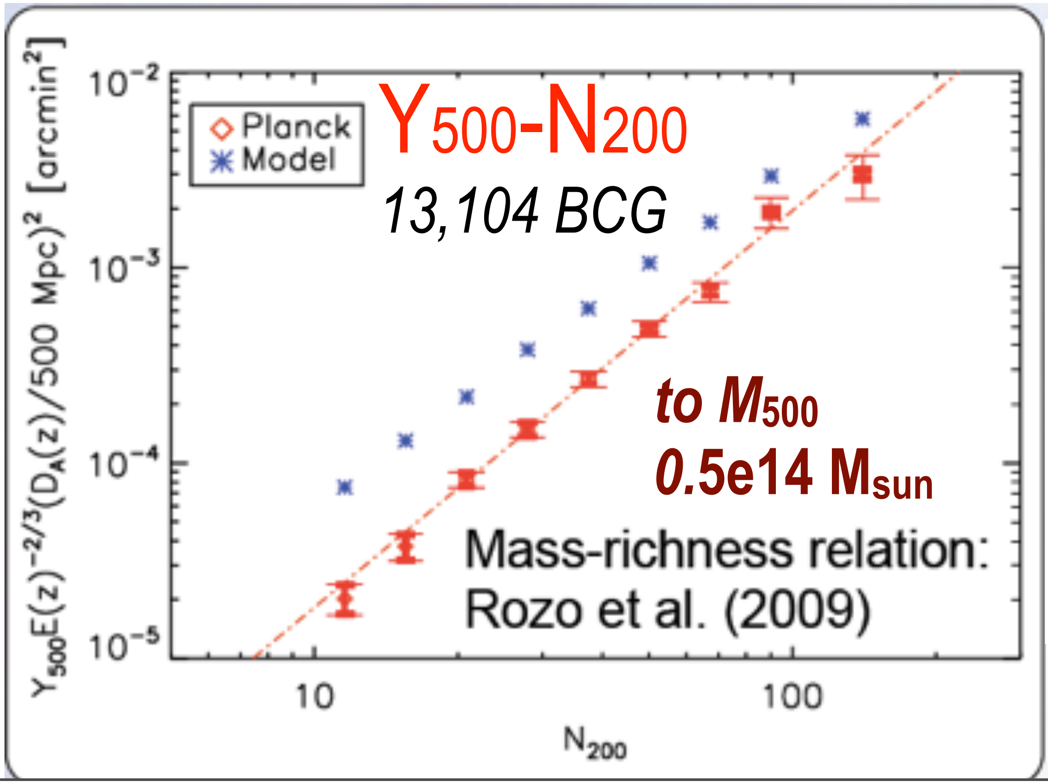

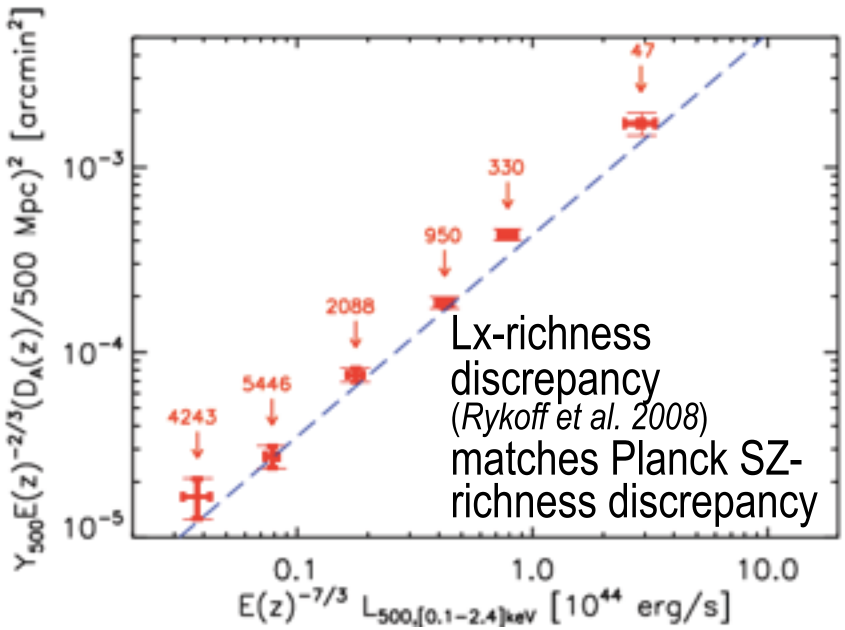

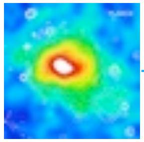

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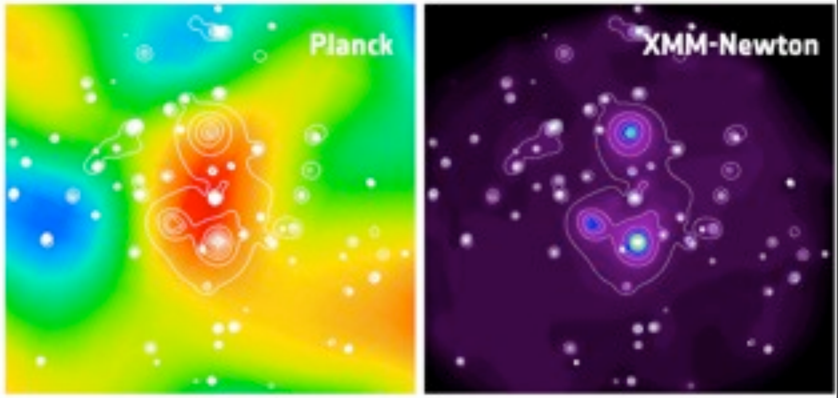
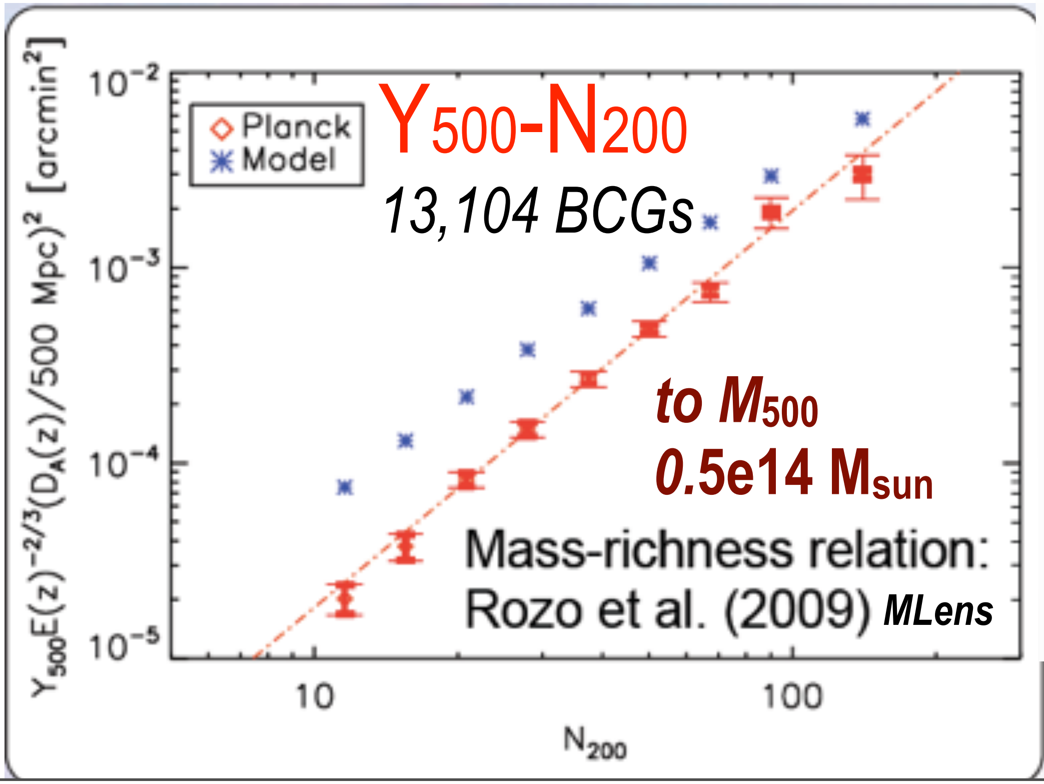
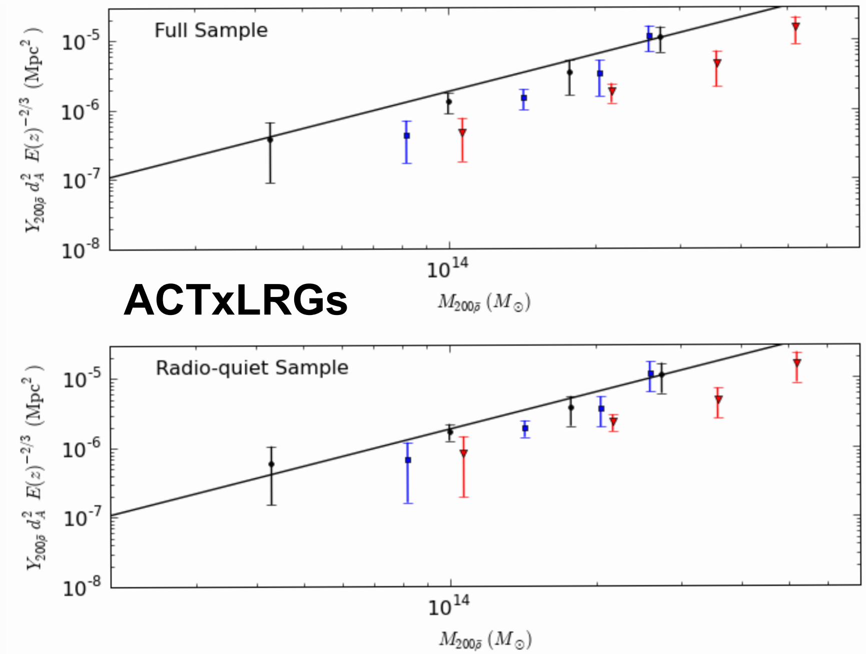






Hint for sub-populations? Optical selection effects? Difference between Mx & MLens & Mbias?...

$n_{cluster}$

$(Y_{SZ}, M_{lens}, Y_X, L_X, T_X, L_{cl,opt}, R_{ich}, \ldots$ | z, gold-sample, thresholds)

+ C_L^{SZ}(cuts) + $\xi_{cc}(r|n_{cl})$ will deliver valuable cosmic gastrophysics for sure.

Will it deliver **fundamental physics** e.g., the dark energy EOS, primordial non-Gaussianity??? σ_8 even?

cluster/gp system used since 80s: Xtra power ξ_{cc} ξ_{cg} => xCDM

$P_{\rho\rho}$(.25h/Mpc) aka σ_8 via n_{cl} *are we really ready for prime time? mock-ing!!*

25 papers & a large fraction of the papers at Planck2011 were unveiled for 10 months & 9-freq T data, + a press conference, highlighting: **HFI & LFI work**

near-future cosmology => PlanckEXT

EXT=many observatories & expts enabling the cosmology/astro

XMM **Herschel** Fermi **WMAP GBT BLAST ACT** SPT AMI **CBI** CBASS QUIET **SDSS** IRAS CO/HI-maps,...

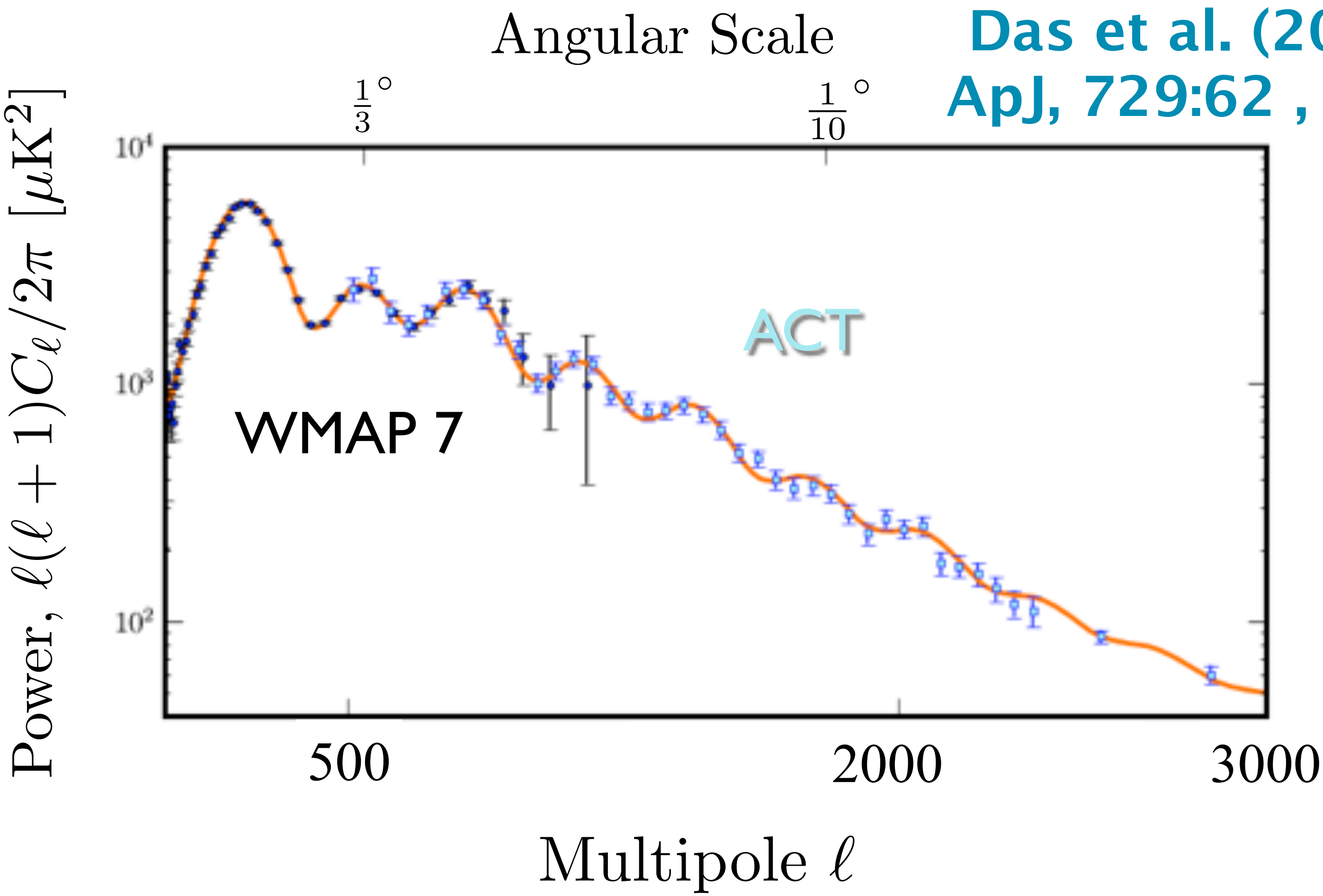
cosmology: **$n_s(k)$, GW $r(k)$, nonG f_{NL}++, $\rho_{de}(t)$, m_ν, strings, isocurvature,... $n_e(t)$**

ACTpol, SPTpol, eRosita, PanStarrs, DES, LSST, **GBT**, **CCAT**,

ABS, Spider, *EBEX, Keck,* ***CHIME****, EUCLID, ...* $\subset$ **EXT**

HIGH RESOLUTION POWER SPECTRUM FROM ACT

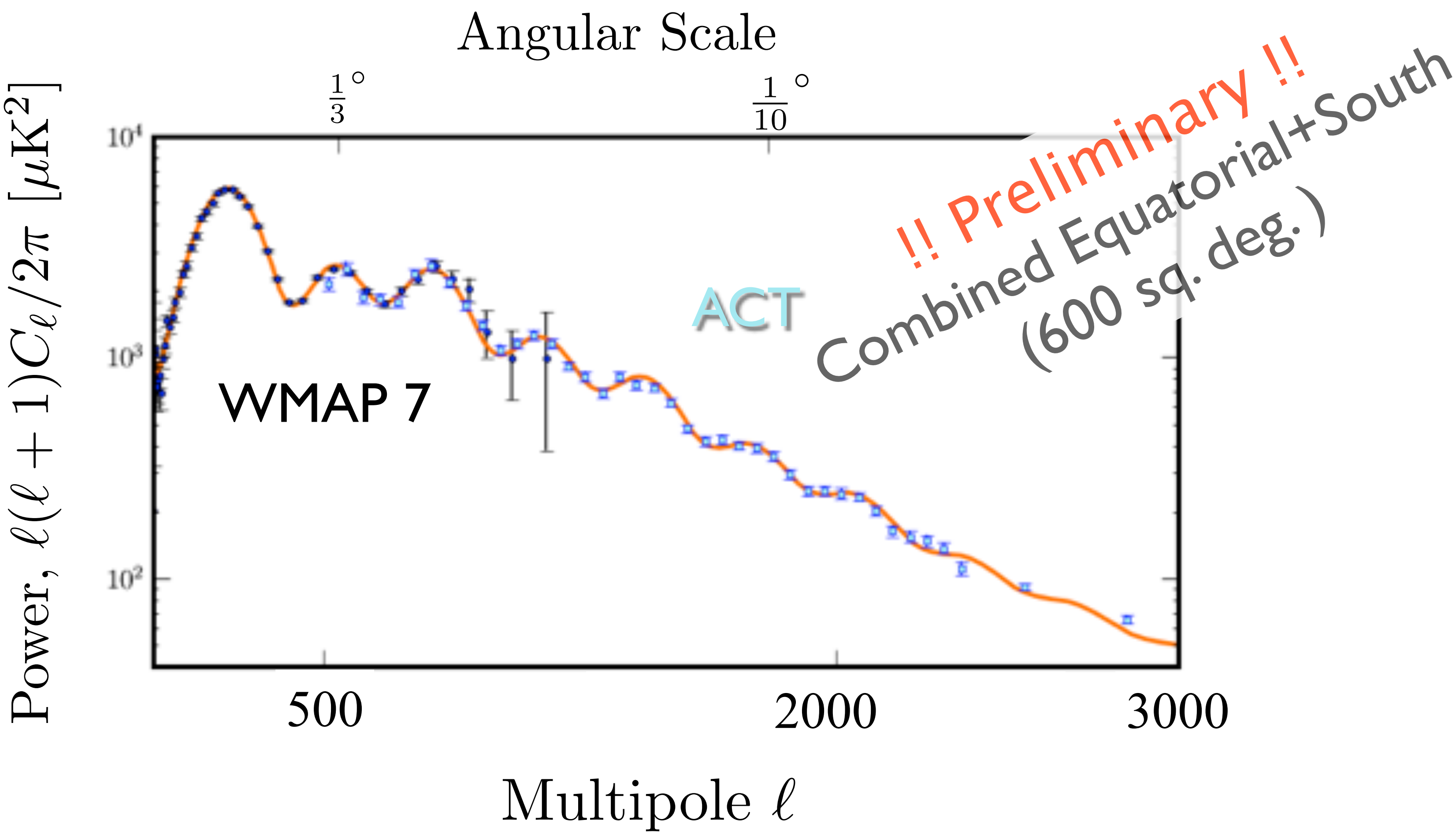
Das et al. (2011), ApJ, 729:62 , 2011



tilted ΛCDM a very good fit (n_s constant); but data are good enough to search for subdominant cosmic parameters

Dunkley+. 2010

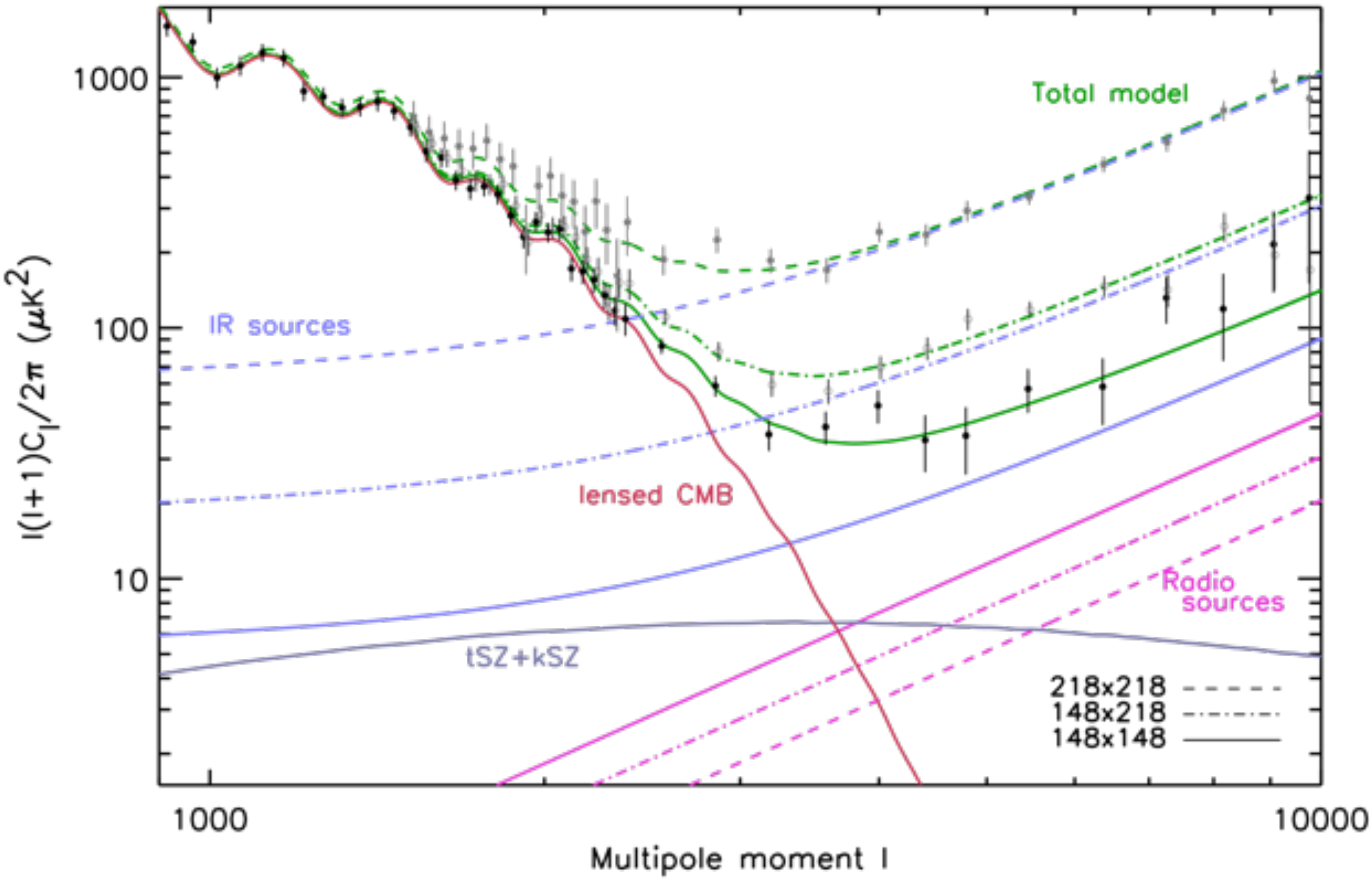
HIGH RESOLUTION POWER SPECTRUM FROM ACT: NEW RESULT!



tilted ΛCDM a very good fit (n_s constant); but data are good enough to search for subdominant cosmic parameters

Sievers+. 2011

primordial (lensed) CMB + veils, ***the veils = radio sources, the CIB, tSZ and kSZ (& Milky Way dust and synchrotron at lower multipoles)***



Dunkley+. 2010

Standard Parameters of Cosmic Structure Formation

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

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

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

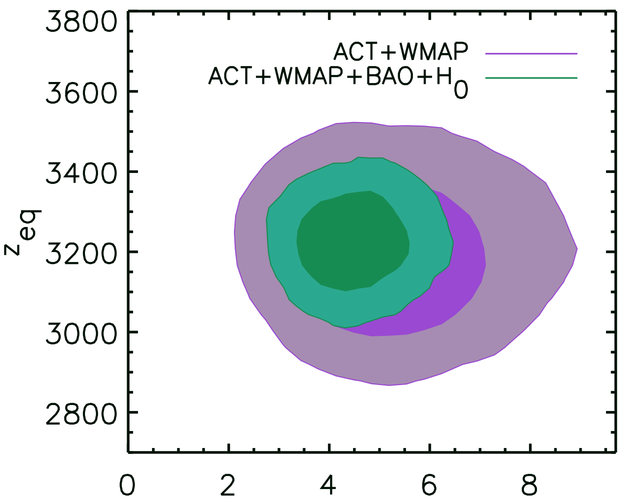
$1 + w_0, w_a$ $\theta \sim \ell_s^{-1}$ $n_e(a)$ $\sim \ln \sigma_8^2$

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

(partially) blind cf. informed "theory" priors

$\Omega_{er} h^2$ Number of Relativistic Species

WMAP7+ACT08+BAO+HO =4.56±0.75; 3 still OK

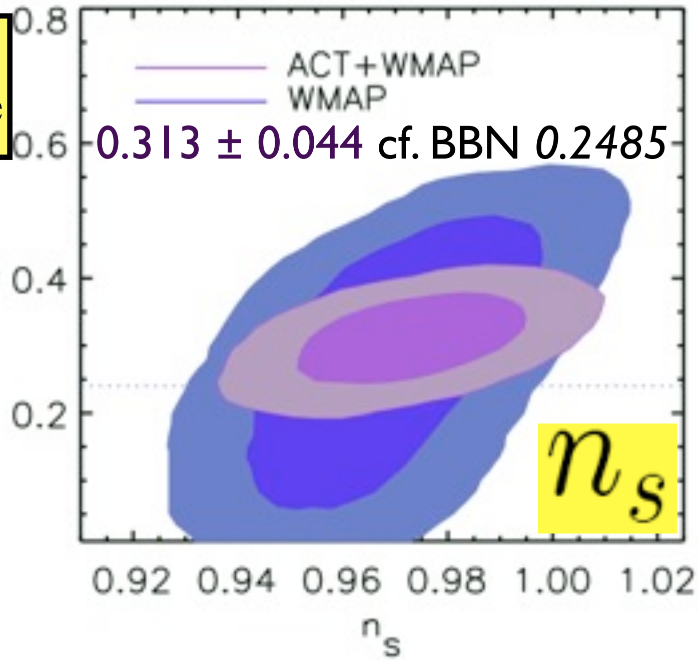


to ±0.11 Planck+ACTpol

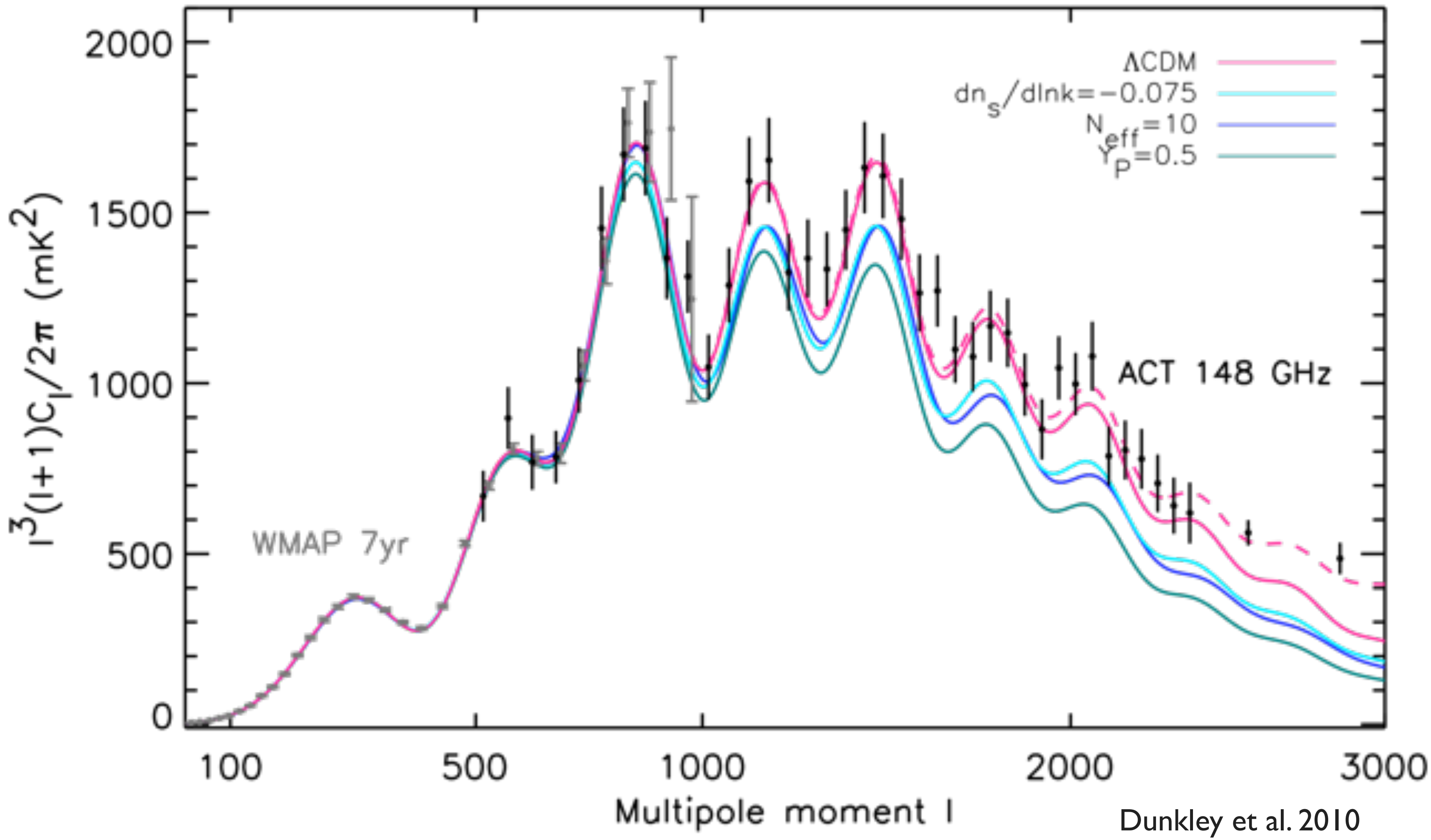
$N_{\nu,effective}$

Abundance of Primordial Helium

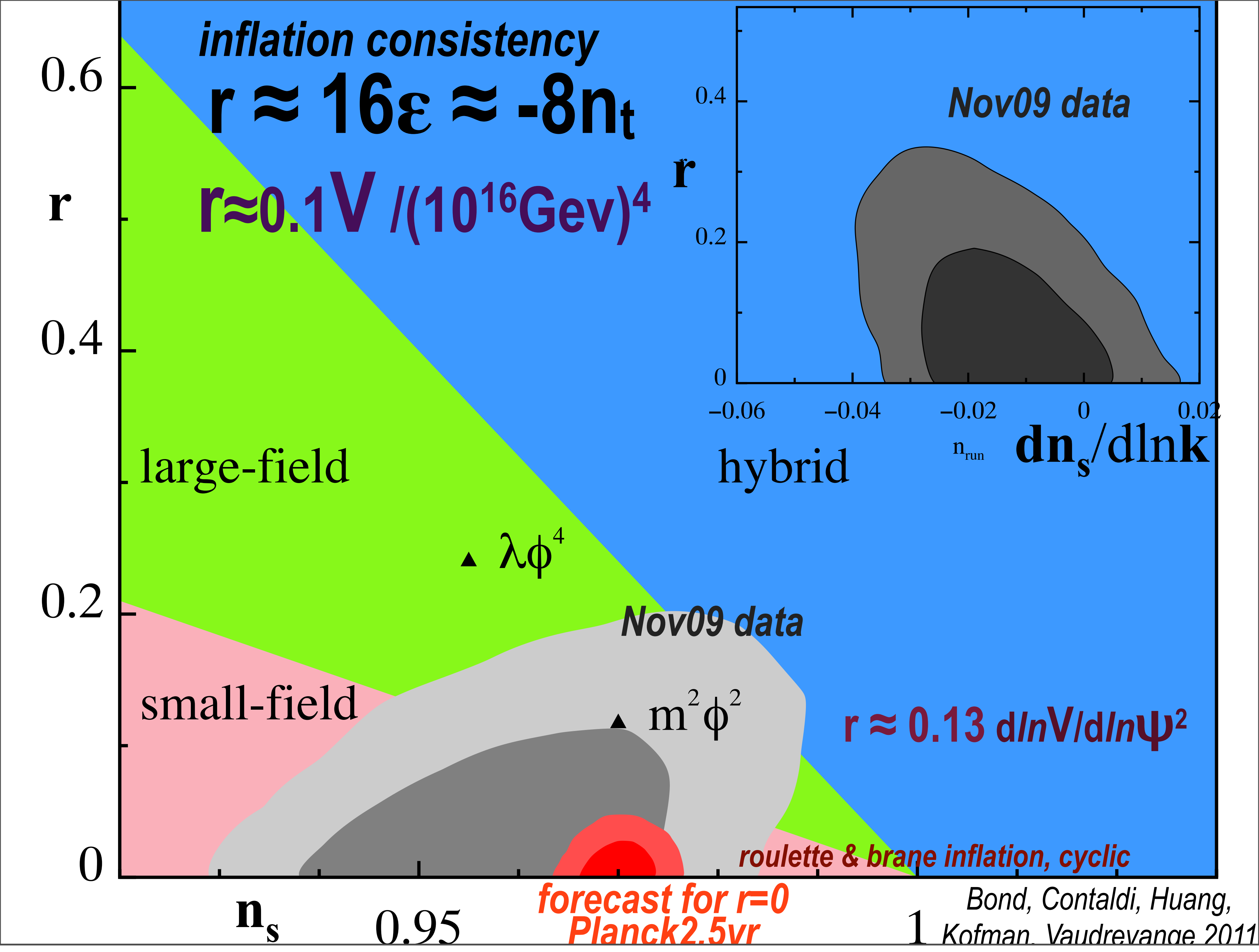
X_{He}



‘low-L’ part of ACT’s power spectrum



Dunkley et al. 2010



Wednesday, May 11, 2011

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

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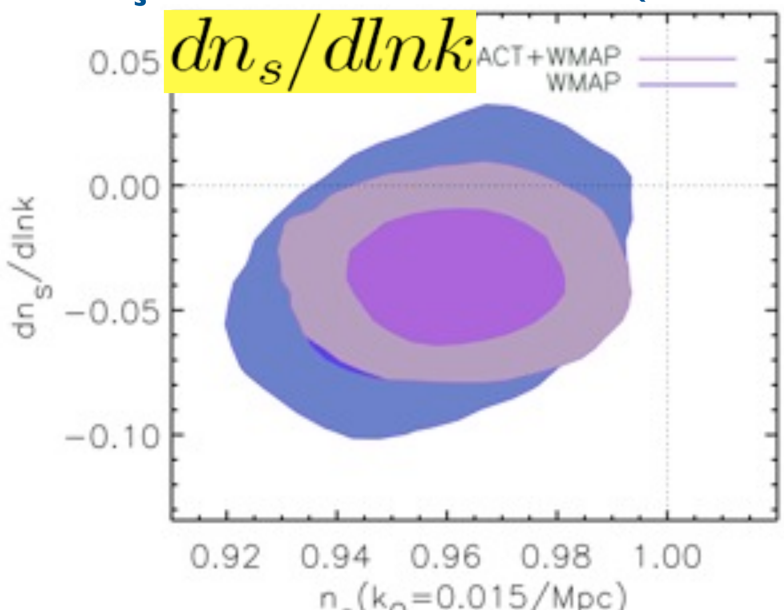
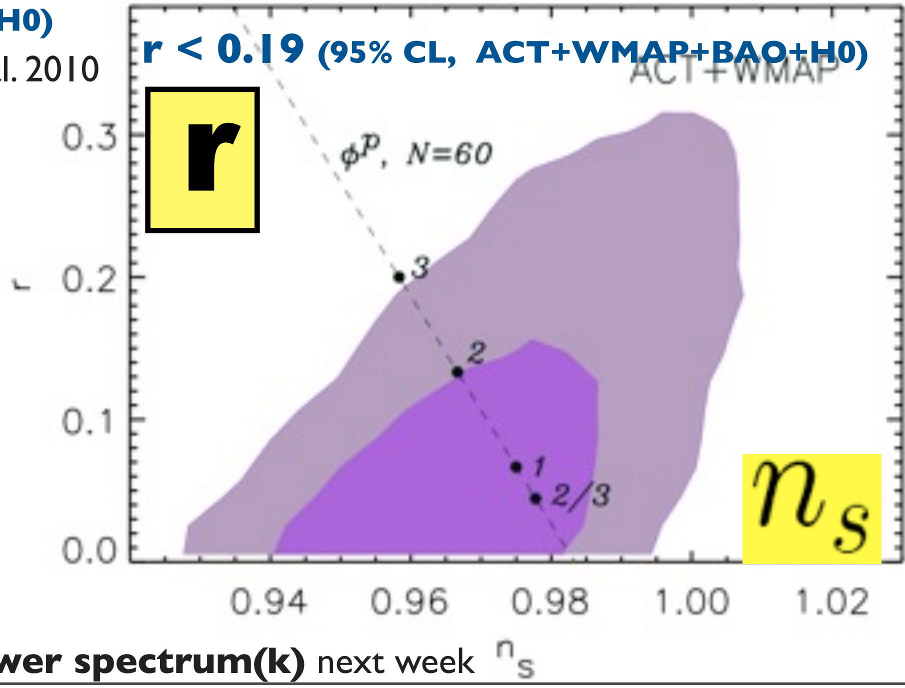
$dn_s/d\ln k$ = -0.024 ± 0.015 (ACT+WMAP+BAO+H0)



Dunkley et al. 2010

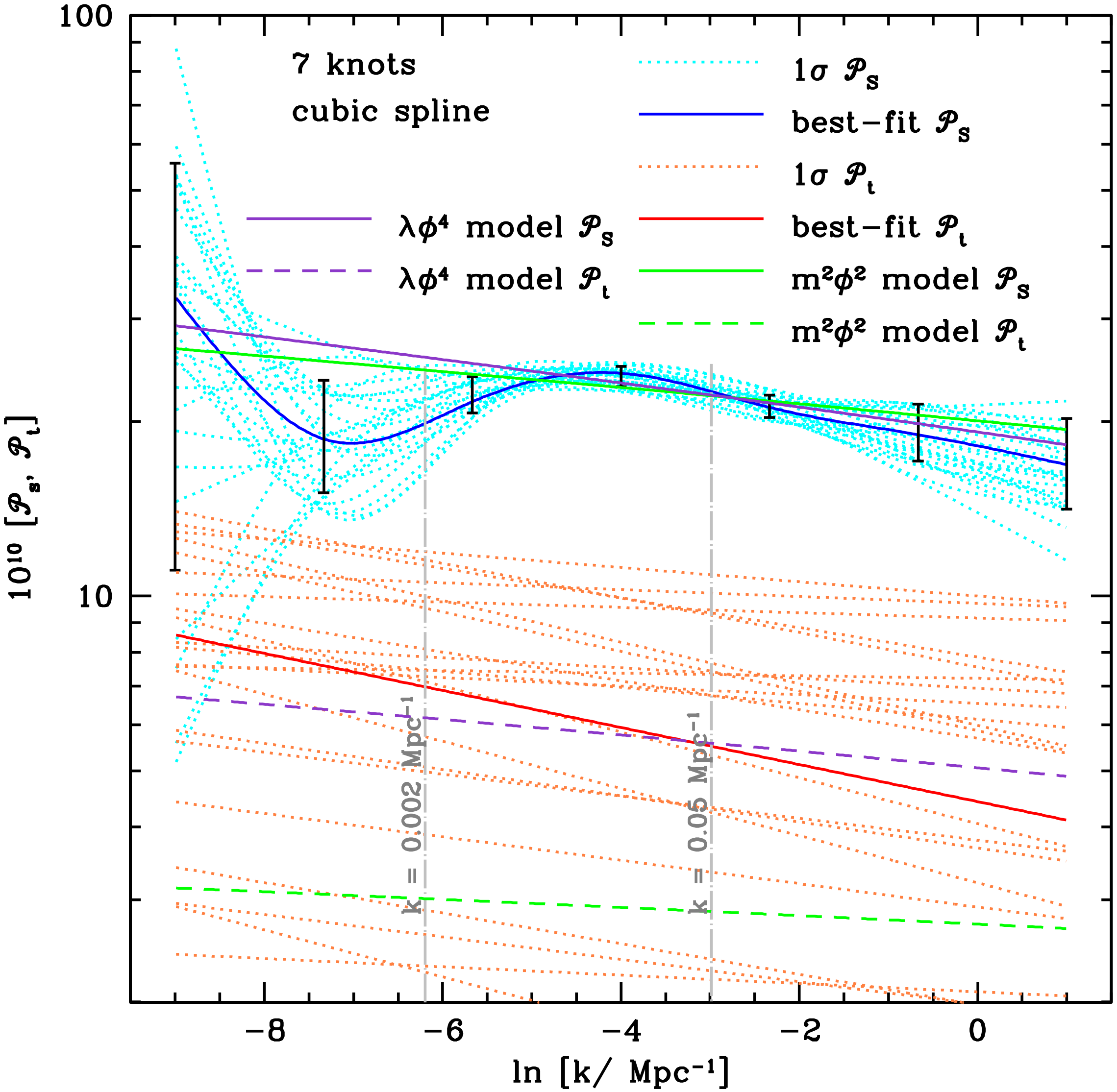
r < 0.19 (95% CL, ACT+WMAP+BAO+H0)

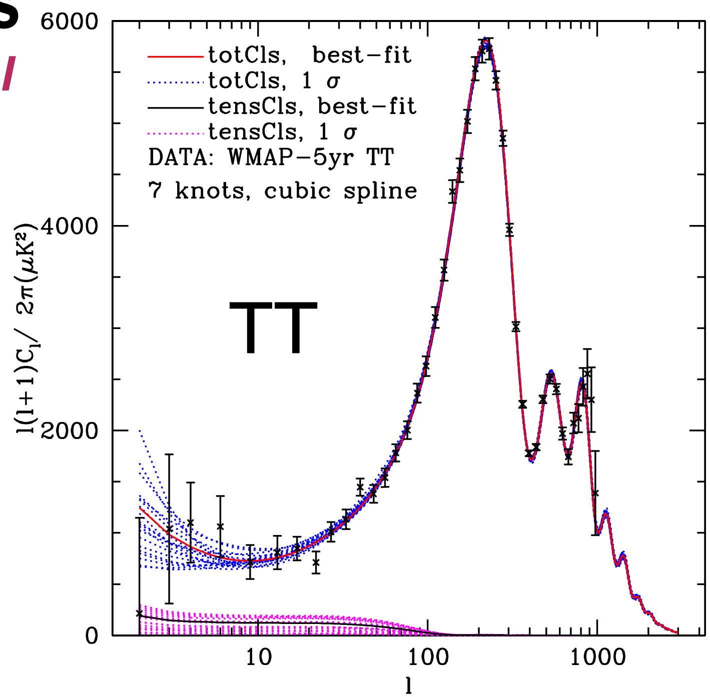


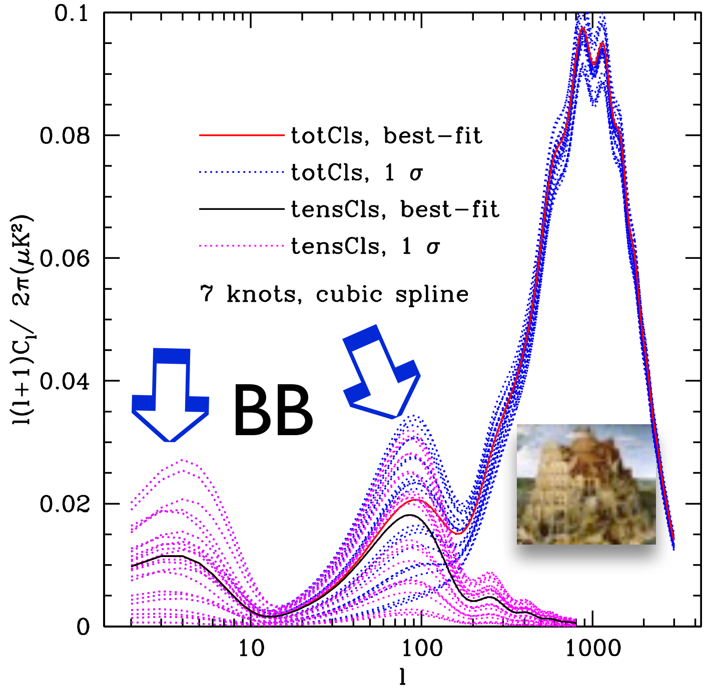
Hlozek et al. 2011 **Primordial power spectrum(k)** next week

compress data onto non-top-hat k-modes

partially-blind scalar ln-power trajecteries & usual r-n_t tensor - no consistency relation. Nov09 data





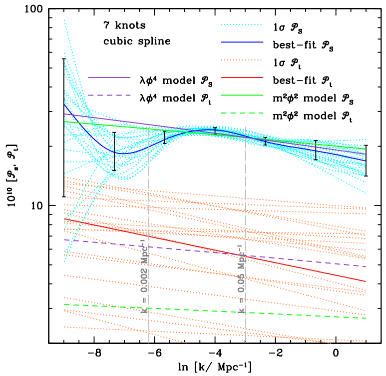


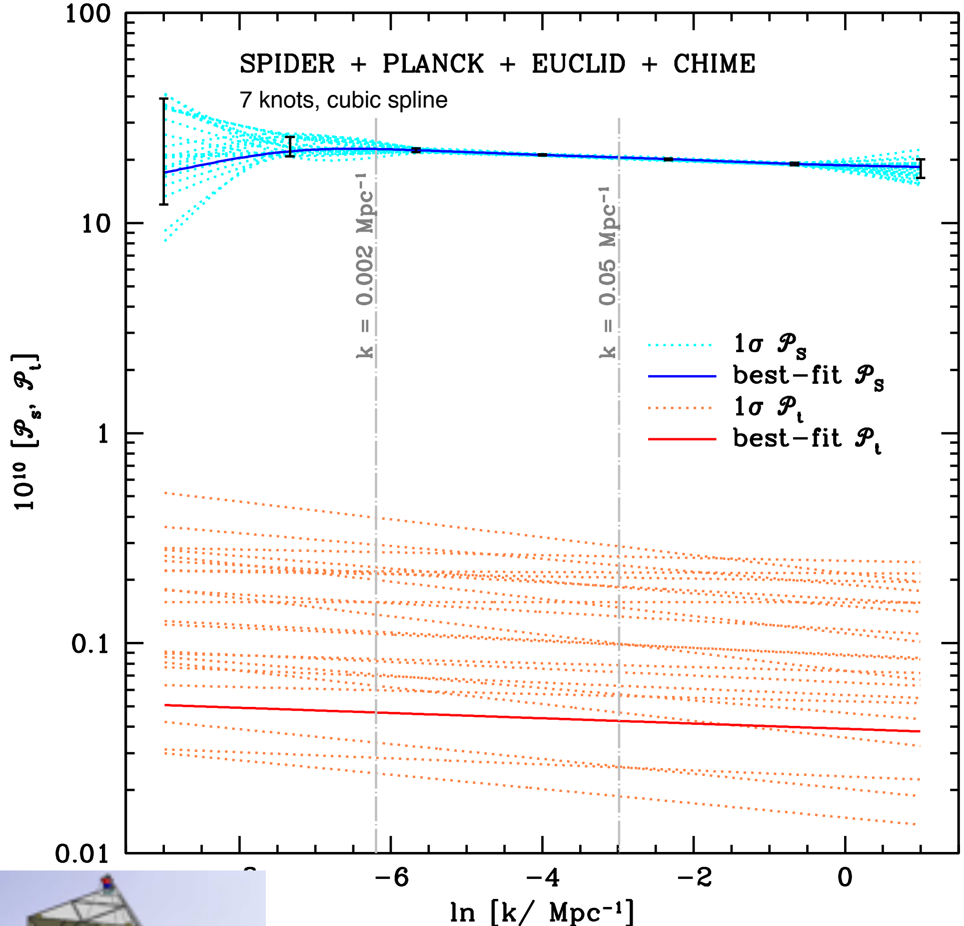
Bond, Contaldi, Huang, Kofman, Vaudrevange 2011

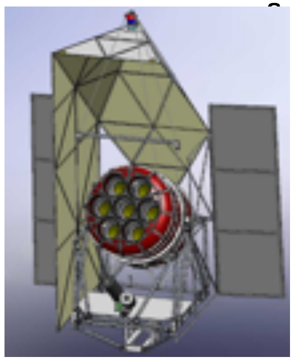
Wednesday, May 11, 2011

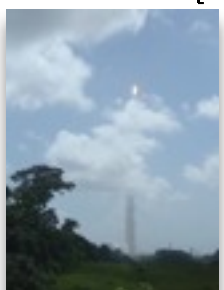
compress data onto non-top-hat k-modes

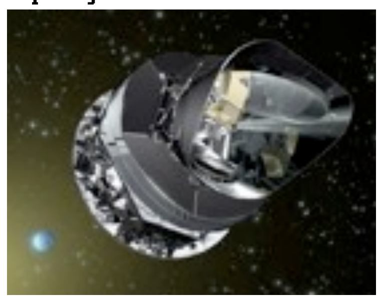
Spider-24days + Planck-2.5yr + ... 7 knot $\ln P_s$ $+r$-n_t forecast for r=0 (+ fgnds)



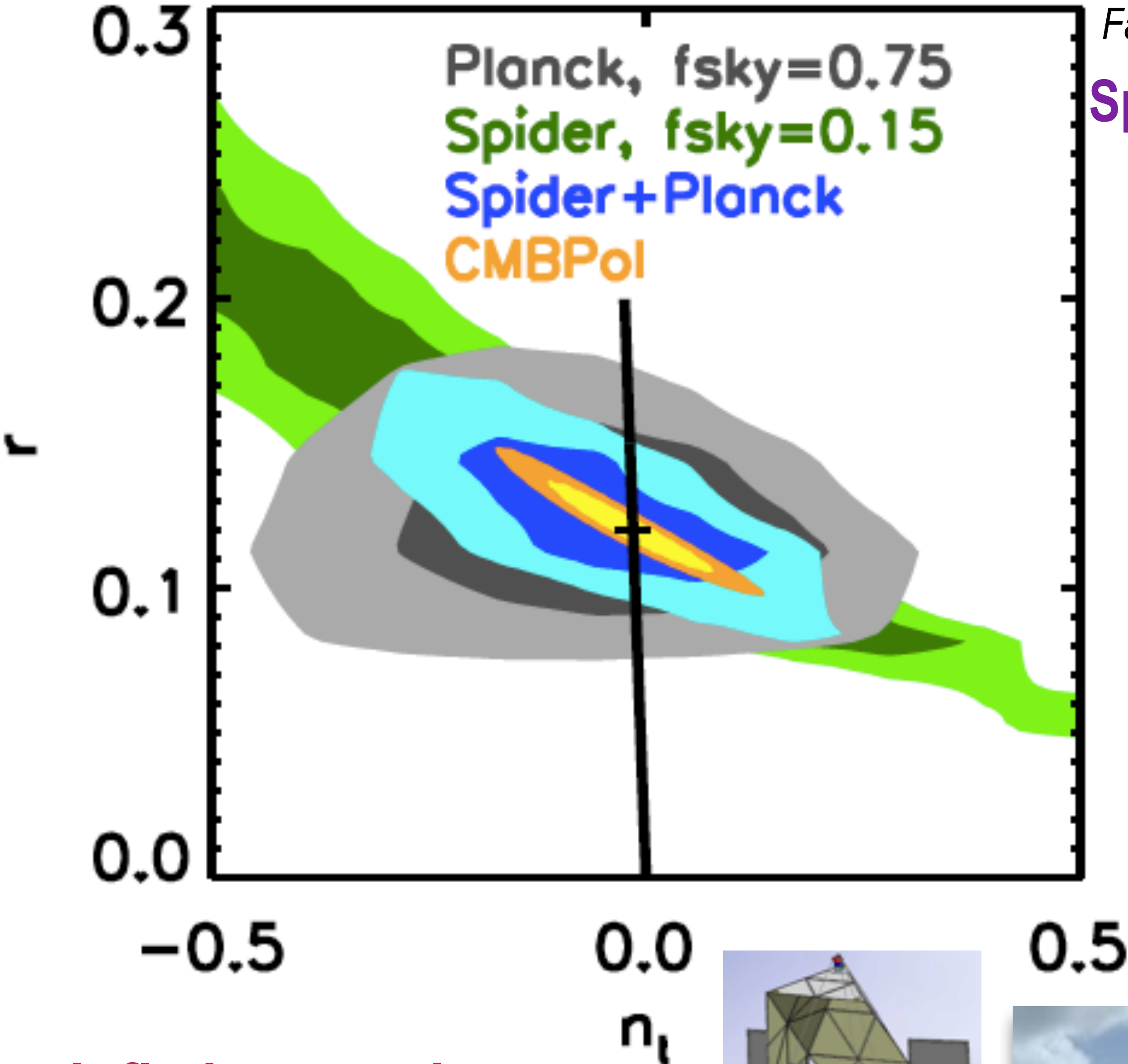








Farhang, Bond, Dore, Netterfield 2011



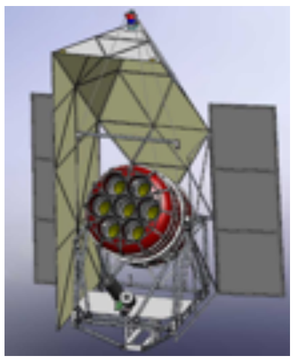
Spider-24days+Planck-2.5yr
r-n_t forecast
for r=0.12 input for $m^2\varphi^2$
(including fgnds)

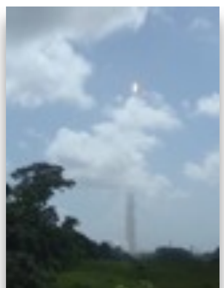
r to ± 0.02

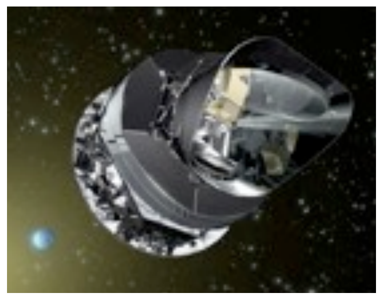
inflation consistency

$$-n_t \approx r/8 \approx 2\varepsilon(k)$$

$$1-n_s \approx 2\varepsilon + d\ln\varepsilon/d\ln Ha$$







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** => **± 0.002 (Pext)**

$\ln A_s = \pm$ **0.03** => **± 0.008 (Pext)**

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

Spider $2\sigma_r$ ~0.013 => ~0.02 *for* ***0.02 < f_{sky} < 0.15***

Planck2.5yr $2\sigma_r$ ~0.02 => ~0.05 (foregrounds)

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

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)

$\Omega_m = \pm 0.012 \Rightarrow \pm 0.001$ (Pext) $1-\Omega_{\Lambda de}$ ie, V_{de}

$w_0 = \pm 0.06 \Rightarrow \pm 0.01$ (Pext) if $w_a = 0$ $\pm 0.14 \Rightarrow \pm 0.03$ $w_a \neq 0$

DEslope $(d\ln V/d\psi)^2/4$ @pivot a_{eq} $= 0.0 \pm 0.18 \Rightarrow \pm 0.03$ (Pext)

$z_{re} = \pm 1.2 \Rightarrow \pm 0.3$ (Pext)

$\sigma_8 = \pm 0.016 \Rightarrow \pm 0.002$ (Pext)

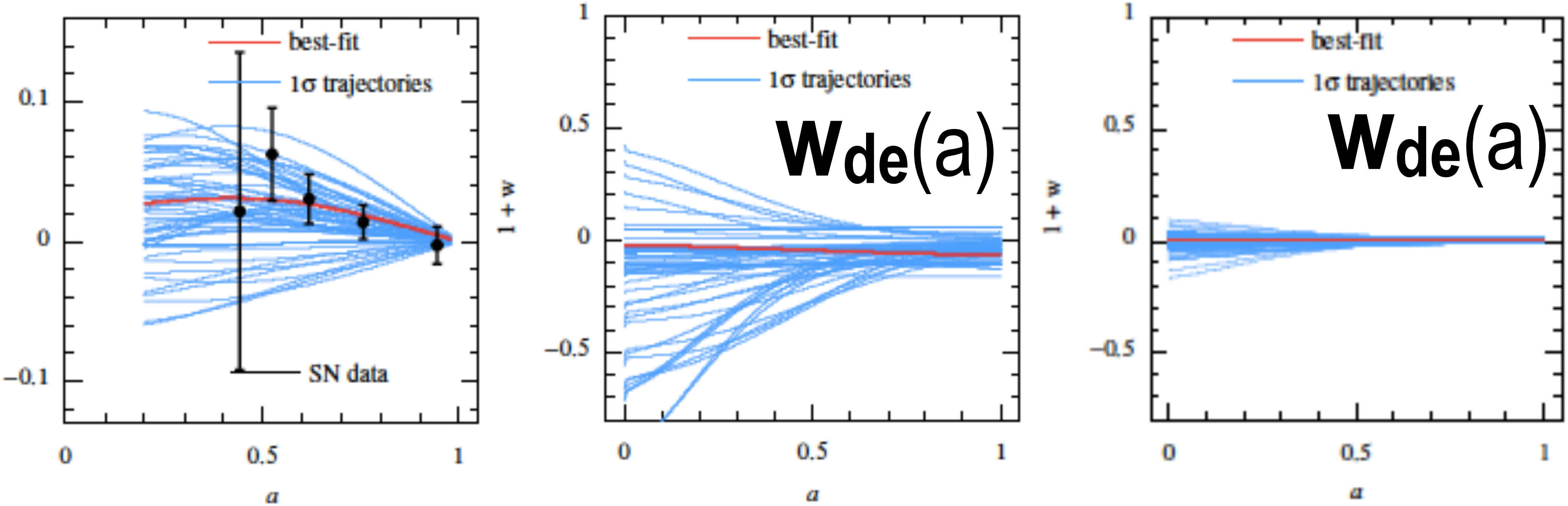
$\Delta \sum m_\nu \sim 0.06$ eV

Planck + ACTPol

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; Huang, Bond 2011



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 ~3 eigenvalues

25 papers & a large fraction of the papers at Planck2011 were unveiled for 10 months & 9-freq T data, + a press conference, highlighting: **HFI & LFI work flawlessly** with great results on ERCSC (~15000 sources, 189 SZ clusters), CIB, SZ, AME & the dusty MW, & much more, so many areas, enabled by so many frequencies. more **Veils Feb 2012**, **primary CMB & pol TBD, Jan 2013, 14, .**

- **SZ - 189 SZ clusters. SZ scaling relations appear as expected for X-ray clusters , apparent SZ deficit for optical clusters (jury out on cause, ACTxSDSS-LRGs too}**
- **CIB - clustering clearly detected at 217-857 GHz, in power spectrum & images Sources in halo model fits the spectra. BLAST, ACTxBLAST, Planck agree, Herschel a little higher, still an interpretation uncertainty.)**
- **Spinning dust - clearly seen in Perseus and rho-Ophiuchus regions with a spectrum in excellent agreement with spinning PAH theory.**
- **Radio sources: Planck counts consistent with ACT/SPT; local IR galaxies: cold dust component.**
- **beautiful Milky Way dust maps, all sky and for selected regions - see extra emission from 'dark gas' not in HI or CO, could be H_2 that survives when CO does not.**

ACT+WMAP7: tilted ΛCDM still works well, modest basic 6 parameter improvement, separated power components CIB, tSZ+kSZ; 7+ peaks seen; **running =-0.024±0.015; r <0.19 40%** stronger, **cosmic strings 60%** more constrained, primordial **Helium** (electron number/baryon) **0.313±0.044 cf. ~*0.25* BBN, $N_{\nu,eff}$ =4.56±0.75, so 3 OK;** CMB lensing @4σ via 4pt function Das+11 => Ω_{de} @3.3σ via just CMB Sherwin+11

ACTpol+**Planck2.5**+SPTpol+**ABS+Spider**+..**$n_s(k)$**, GW **r(k)**, nonG **f_{NL}++, ρ_{de}(t), m_ν,..**
~25x ACT&Pol, ~1000clusters, CMB lens for DE isocurvature, strings,..

END