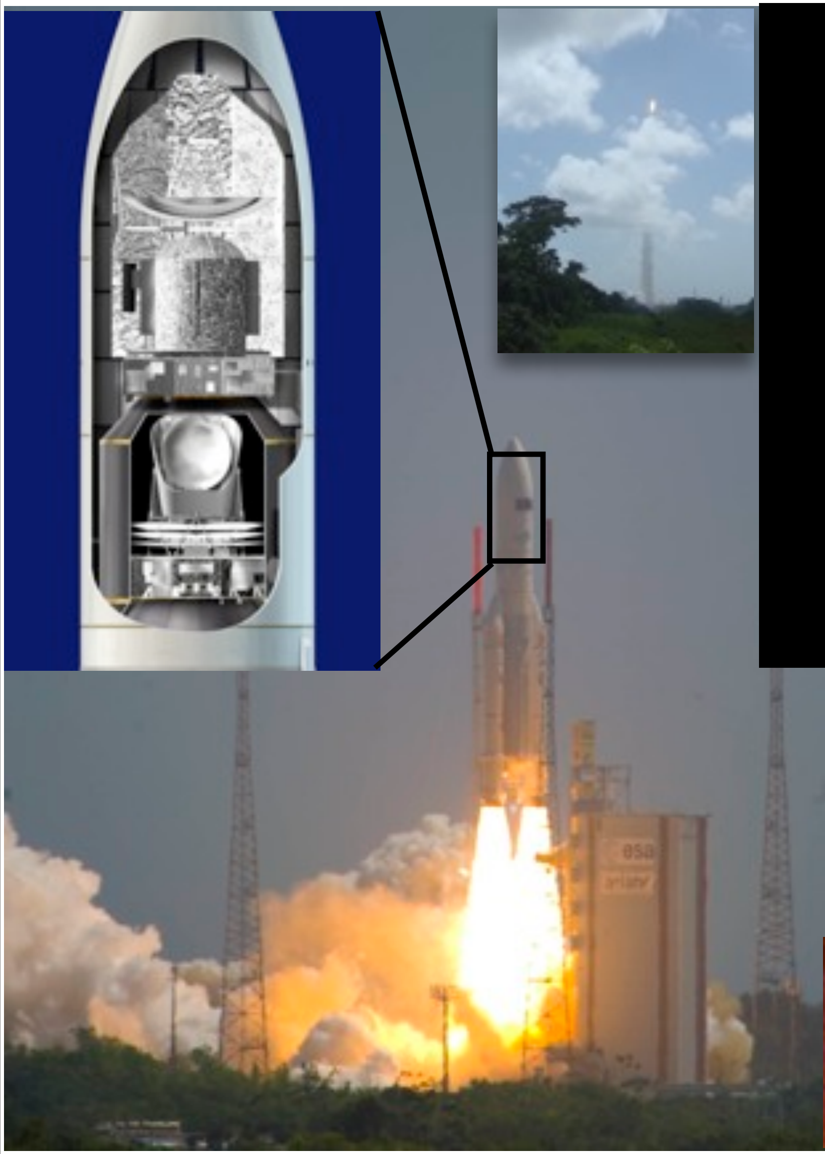
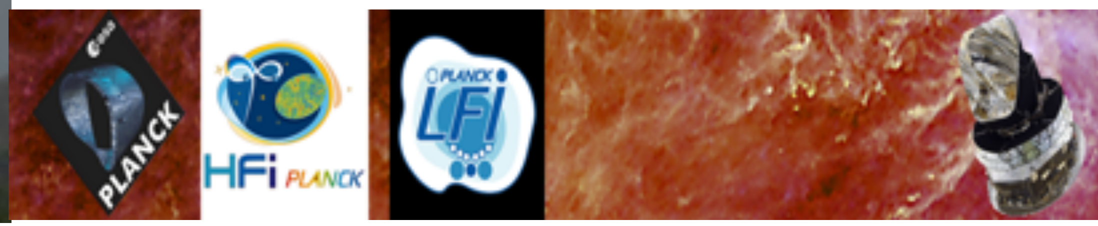
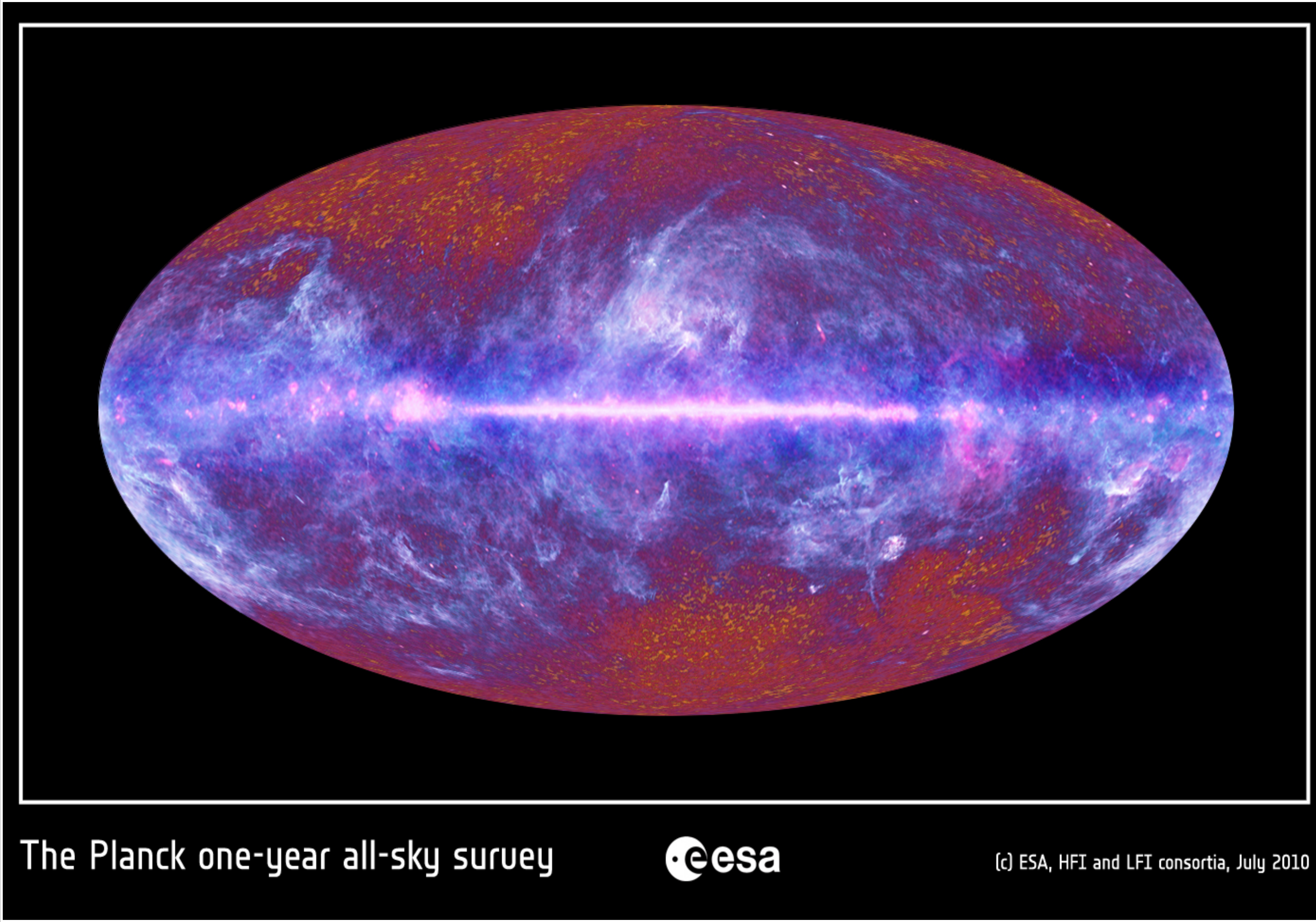
Launch of Planck & Herschel on May 14 2009 from Kourou (Fr. Guiana)





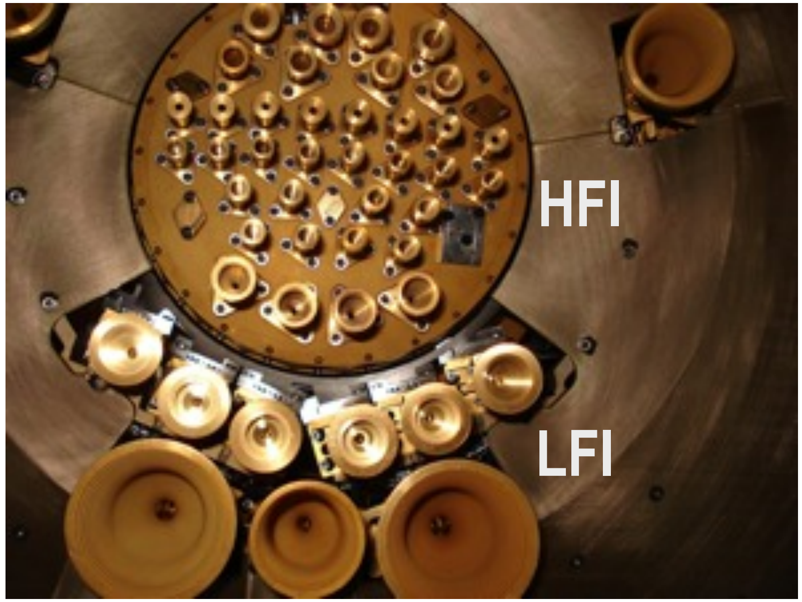
Left earth at ~10 km/s, 1.5 million km in 45 days, cooling on the way (20K, 4K, 1.6K, 0.1K 4 stage).
@L2 on July 2 09 -almost no trajectory correction @operational temp; Survey started on Aug 13 09
spin@1 rpm, 40-50 minutes on the same circle, covers all-sky in ~6 month, ~3 surveys Feb11, ~5 total

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

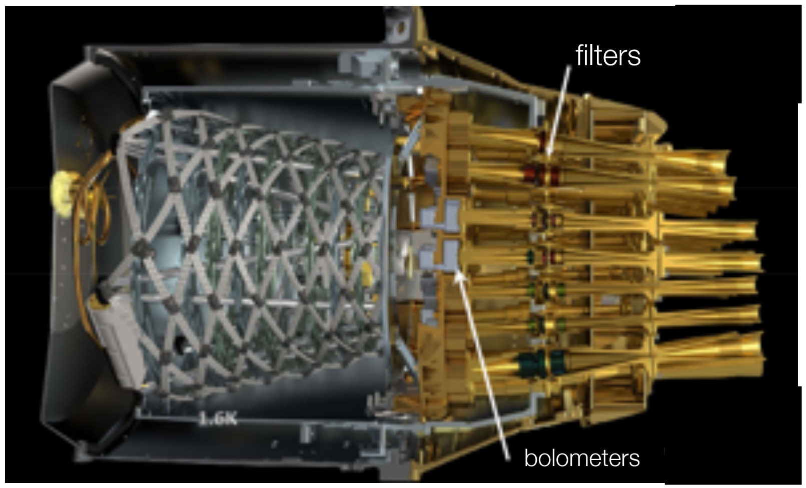


Planck

Focal plane



HFI cut view



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.

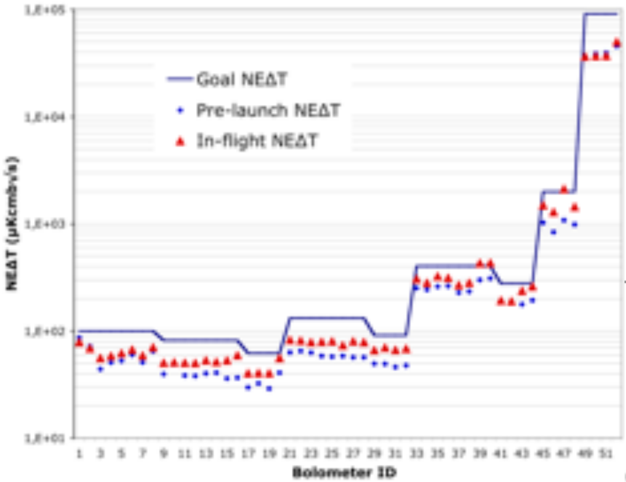
Toronto involvement in Planck: Bond since 1993, Canada since 2001, 1st CSA pre-launch contract 2002-09, post-launch 2010-11, 2011-13

- **The scientific analysis is common to both instruments but not the data processing (DPCs in Paris, Trieste)**
- **Toronto is in Planck-HFI, the higher resolution and higher frequency instrument (52 bolometers, 100-857 GHz)**
- **Project led by Dick Bond with financial support from the Canadian Space Agency**
- **CSA-Planck-HFI: D. Bond (PI), B. Netterfield, P. G. Martin, F. Marleau, M. Nolta, M-A Miville-Deschenes, P. Kummel**, **J. Chluba, D. Pogosyan (UofA),** D. Goncalves, K. Blagrave **(in the past: C. MacTavish, B. Crill, O. Dore & G. Staikos)**
- **CSA-Planck-LFI: D. Scott (UBC), Andrew Walker, Adam Moss,** Jim Zibin, **R. Taylor (UofC)** (in the past: Patanchon)
- **Involvement in science: primary CMB - cosmic parameters, B-mode/GravityWaves, nonGaussianity, sub-dominant elements, anomalies; galaxy clusters; all ISM - dust; Planck+ Herschel, ACT (ACTpol, ABS, Spider)**
- **Involvement in the data processing/analysis:**
  - **In charge of the HFI operation tools: QLA (KST), trend analysis, DailyQualityReport, WeeklyHealthReport to ESA**
  - **Significant contributions to the understanding of the instrument since launch: daily ingestion of data, TOIs, calibration, glitches, thermal fluctuations, dilution lifetime, noise properties,**
  - **Leader of the Galactic Planck Sky Model**

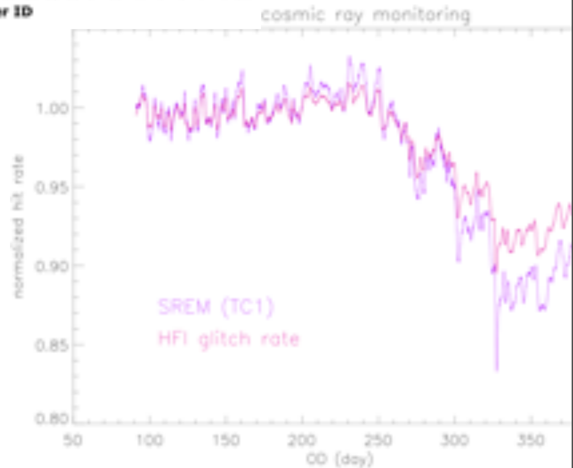
25 papers & a large fraction of the papers at Planck2011 were unveiled for 10 months & 9-freq T data, + a press conference, highlighting: **HFI & LFI work flawlessly** with great results on ERCSC (~15000 sources, 189 SZ clusters), CIB, SZ, AME & the dusty MW, & much more, so many areas, enabled by so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

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)**

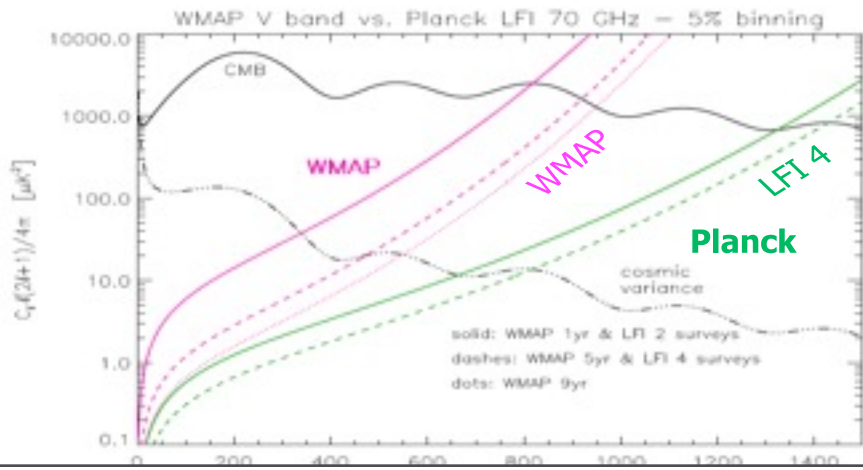


- **CRs: Glitch rate at ~80/min on each bolometer; produces thermal fluctuations**
  - **contribute to 1/f noise (significant CSA-HFI role in discovering and characterizing the effect)**



- **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

- CO 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:** ~ 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, ...

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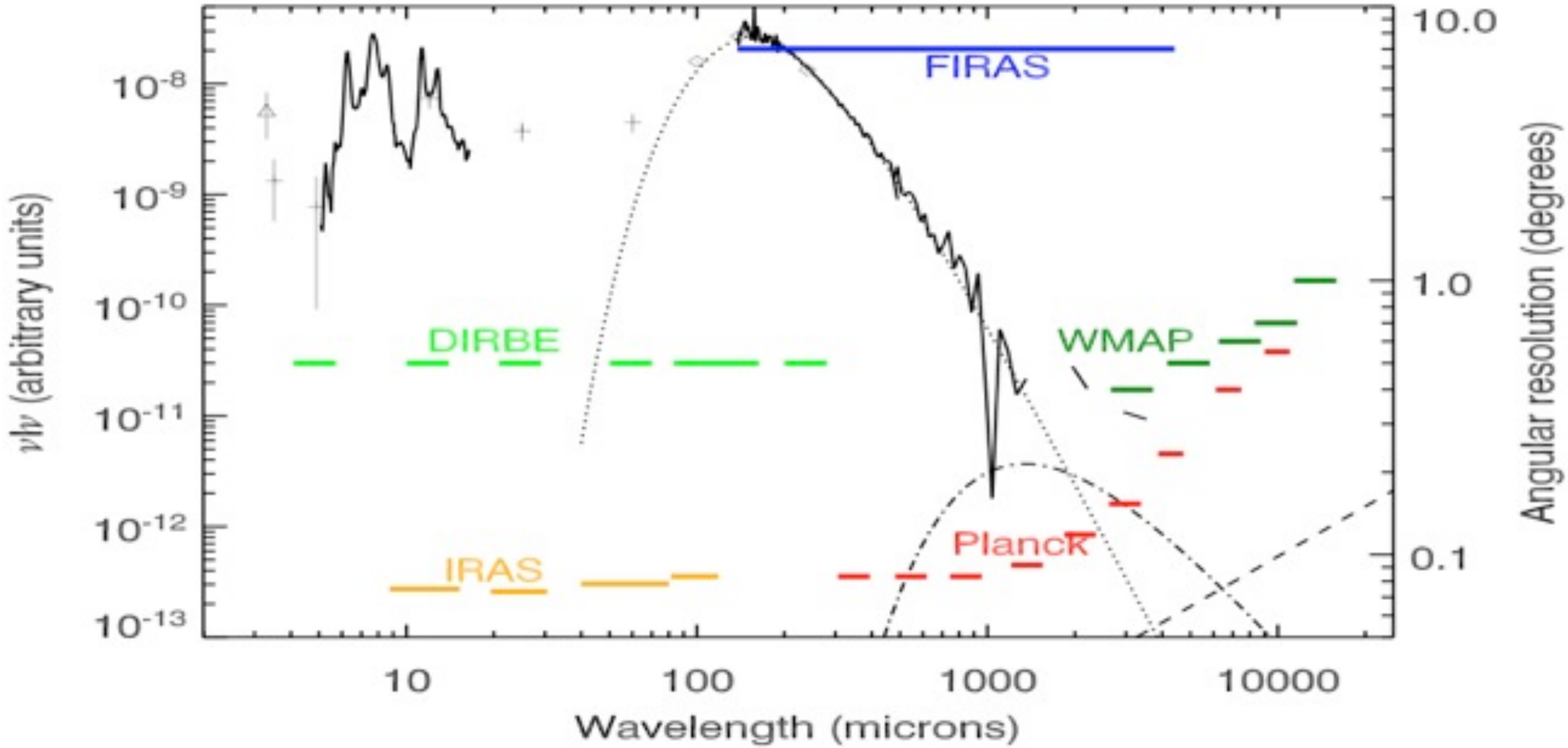


the quest for the primordial within the primary CMB requires exquisite foreground removal, the quest for Milky Way maps & extended source maps requires accurate CMB etal removal

the TBD of Planck vintage 98: signal separation

striping

dust

synchrotron

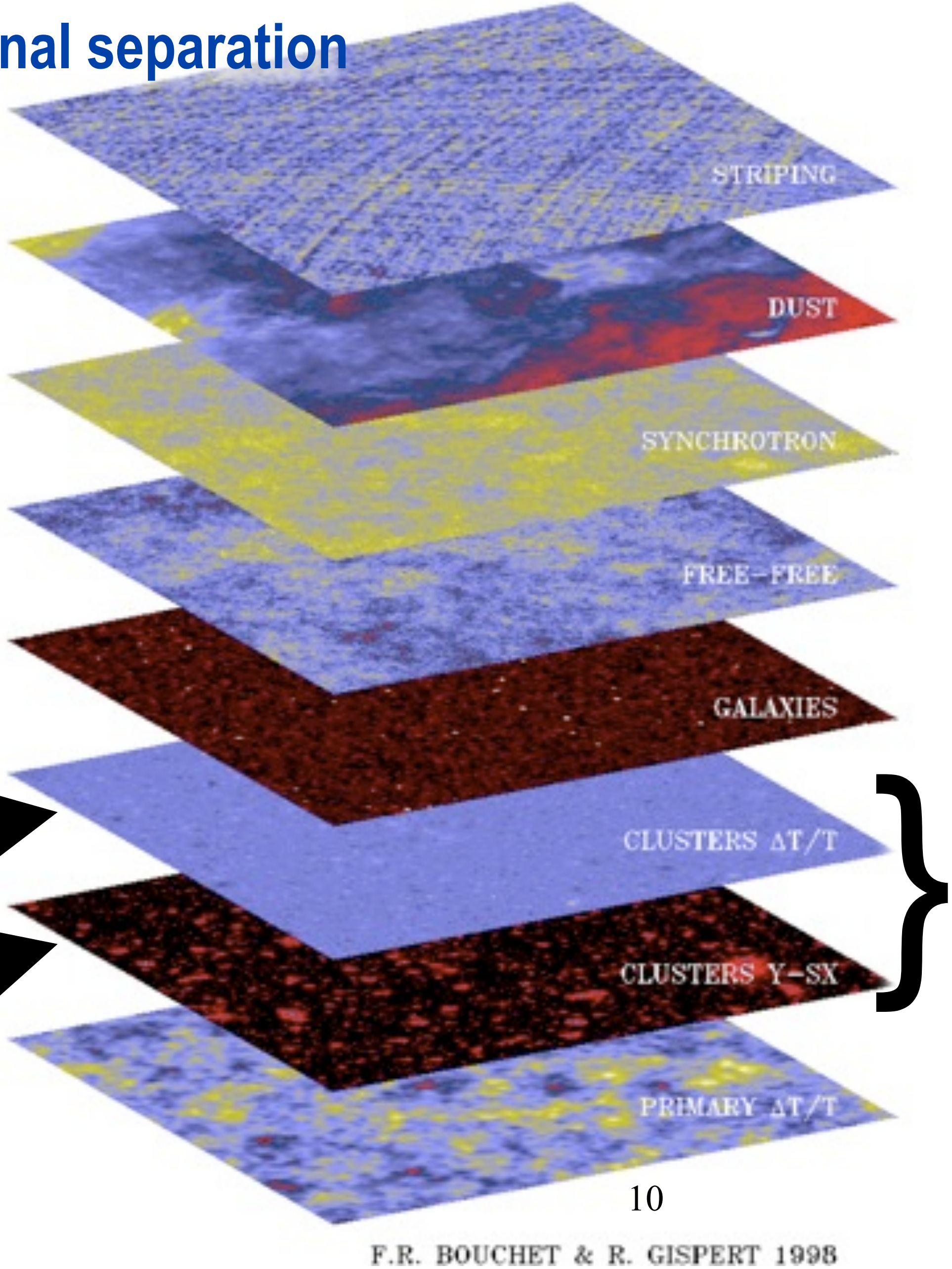
bremsstrahlung

dusty galaxies

kinetic SZ

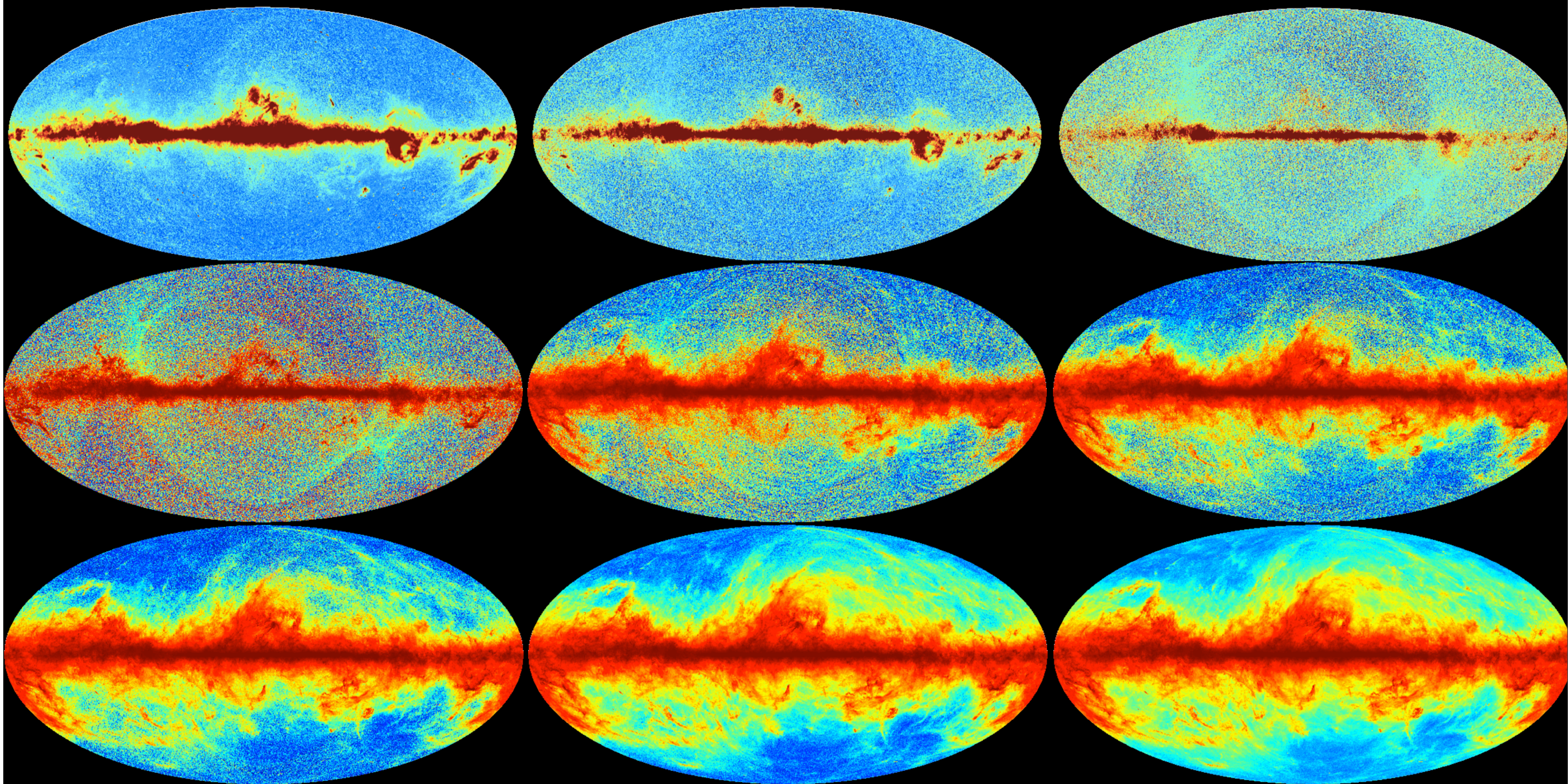
thermal SZ

PRIMARY

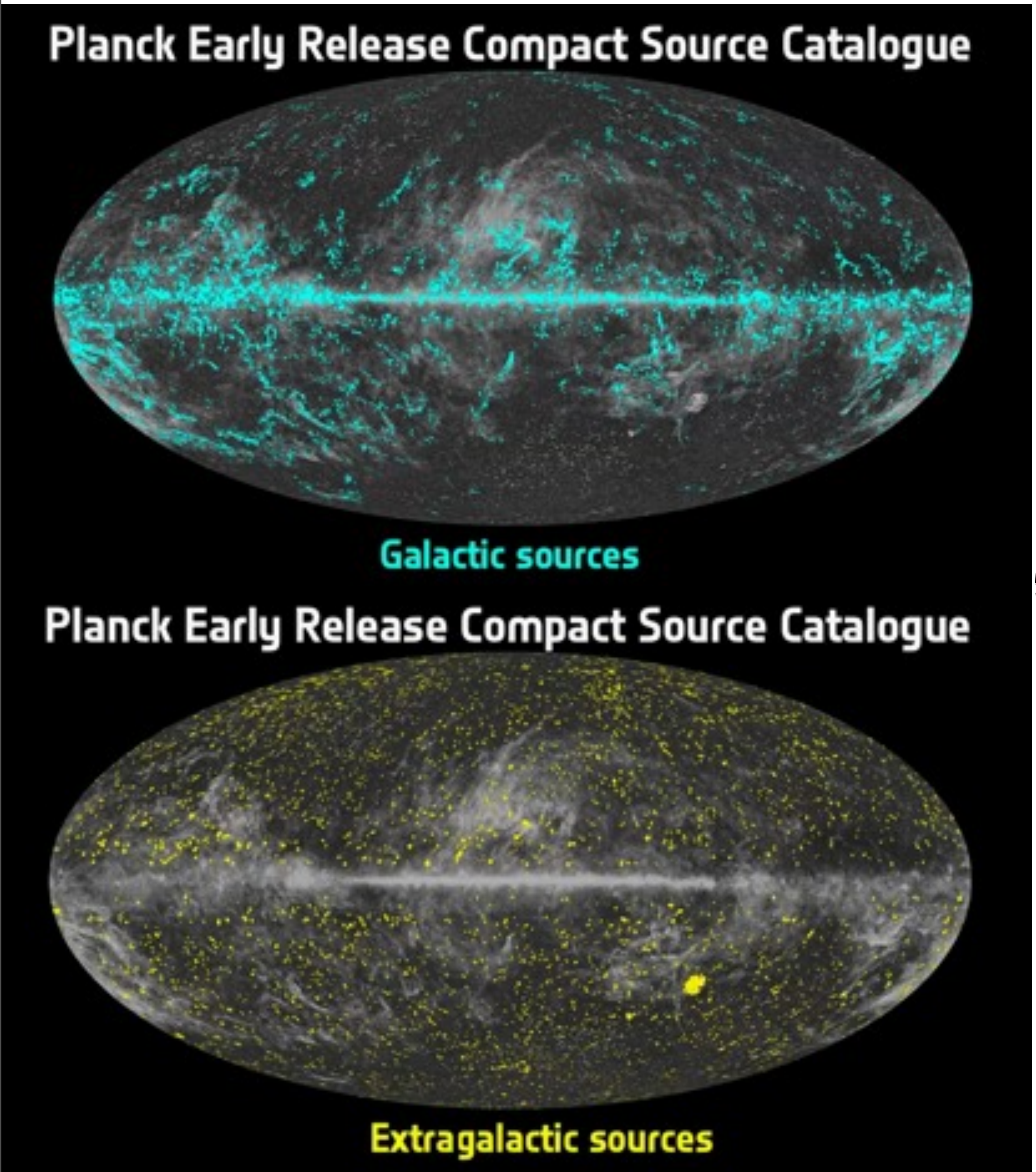


The Planck Foregrounds sky

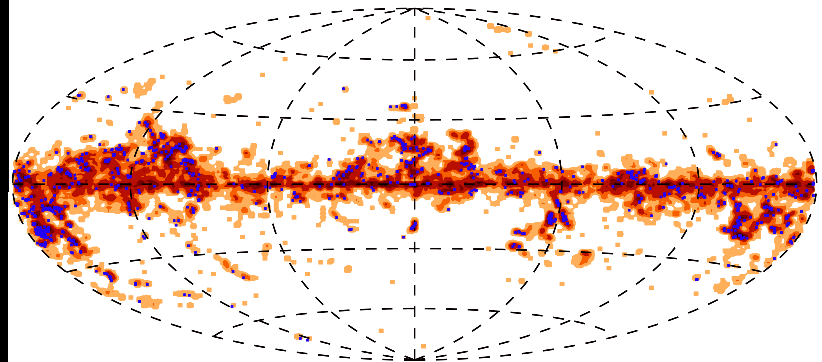
data Aug 13 09 to Jun 7 10: all-9-frequency maps + maps-CMB produced & delivered to consortium Aug 2 10



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?



- 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

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

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

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 for halos) with pressure/thermal dust emission profiles

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

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radio source counts

Planck, ACT, SPT (WMAP) deZotti model good, but steeper for > 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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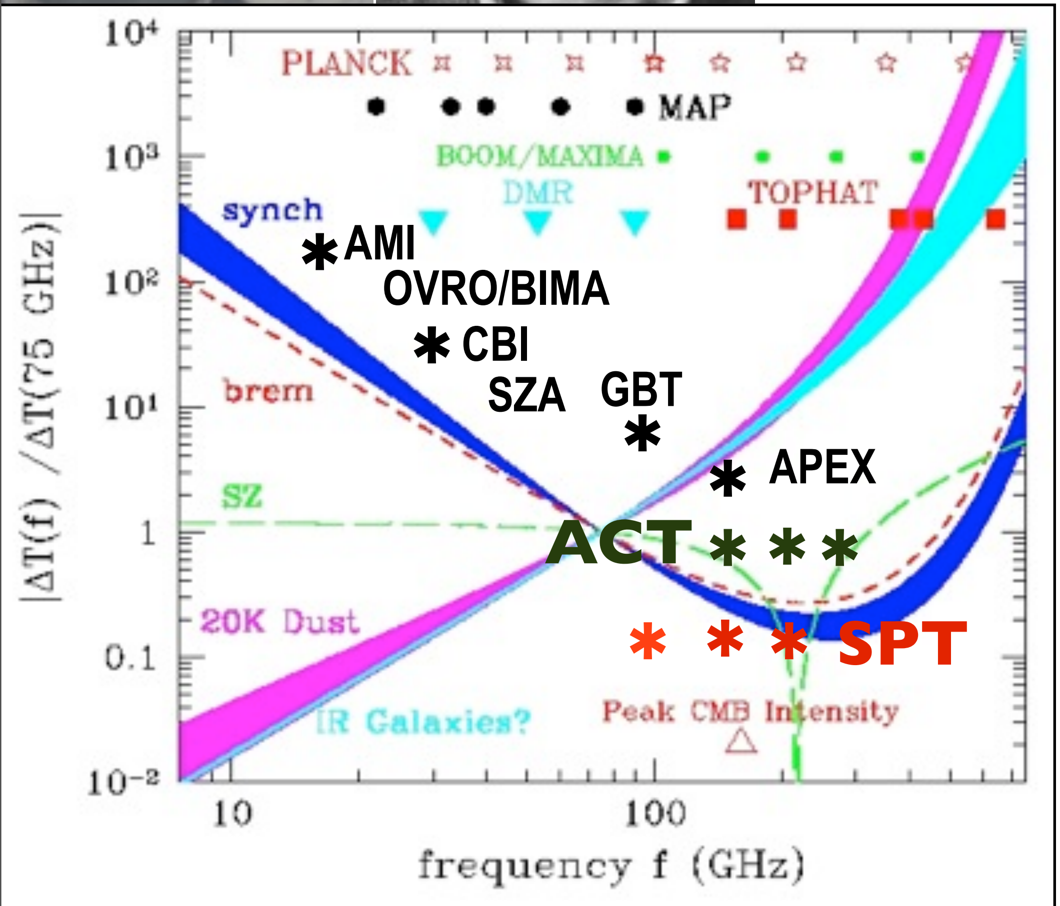
- **SZ - 189 SZ clusters. SZ scaling relations appear as expected for X-ray clusters (no deficit, assuming universal profile), apparent SZ deficit for optical clusters (jury out on cause, but seen in ACTxSDSS-LRGs as well)**
- CIB - clustering clearly detected at 217-857 GHz, with diminishing correlation as band separation increases. imaged Source model with halo model fits the spectra, claim one-halo dominates over Poisson at l=2000. (BLAST, ACTxBLAST, Planck agree, Herschel a little higher, <bias>, source population uncertainty propagates into interpretation uncertainty.)
- Spinning dust - AME clearly seen in Perseus and rho-Ophiuchus regions with a spectrum pulled out in excellent agreement with theory. a long journey with a great leap forward, draine & lazarian will be pleased.
- Radio src - counts consistent with ACT/SPT (at higher flux range), lower than de-Zotti model. Spectral steepening above 70 GHz.
- IR src – possible evidence for cold dust component in local IR galaxies (T<20K).
- 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)**

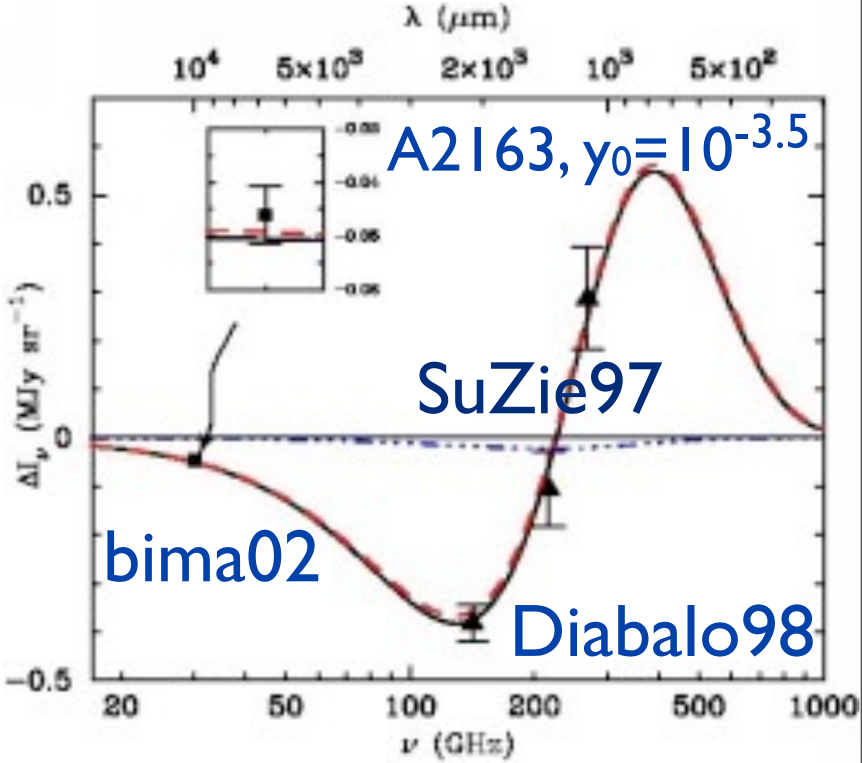
Planck & the thermal Sunyaev-Zeldovich Probe of Gas in the Cosmic Web: $y \sim \int p_e$ *dline-of-sight*

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

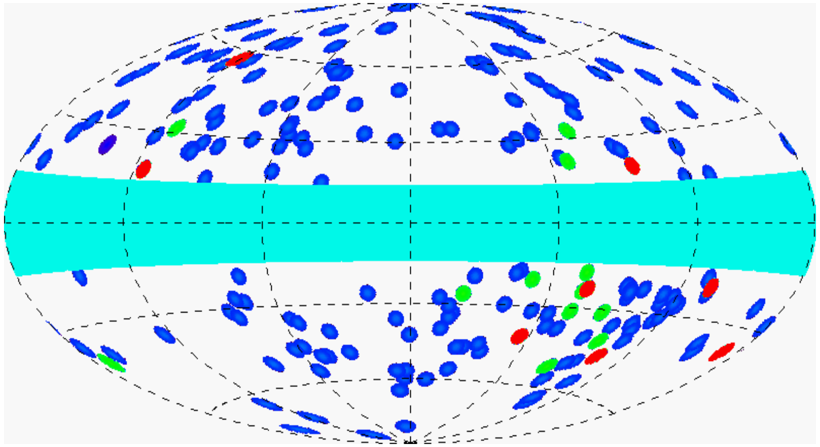
$= -2y$ to xy, **0 @ ν=217 GHz**

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





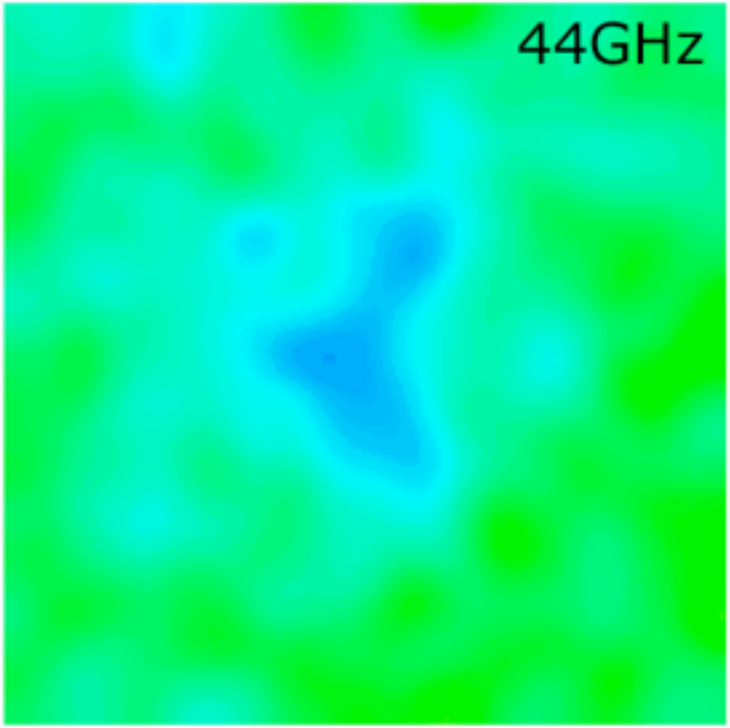
ESZ 20 new + 169 in X/Opt cats

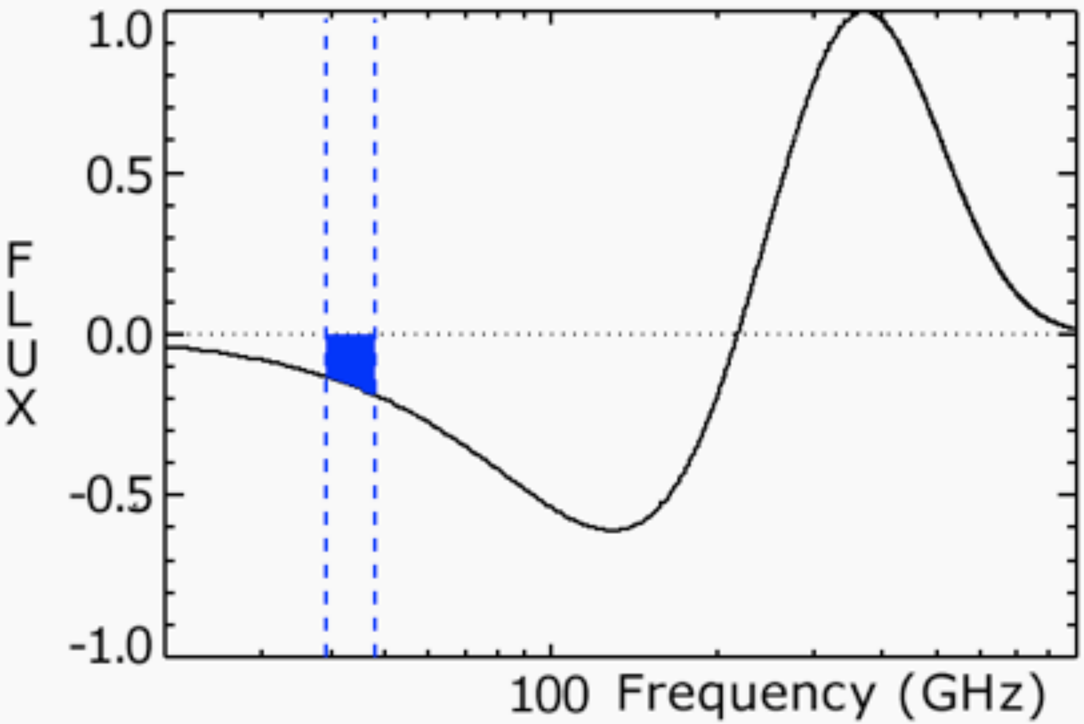


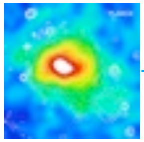
(& ~80% new in SZ, $E_{thermal}$ view)

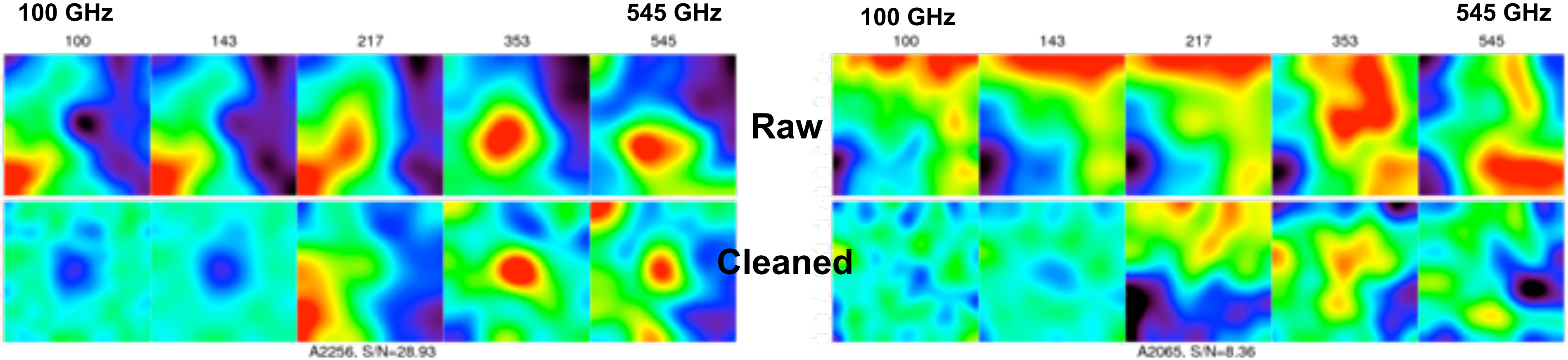
Planck**XMM** dedicated time on newbies
~95% reliable, validation, S/N ~ 6 cut
+ cross-correlate with X/SDSS cats, Y-"M"
scaling OK in shape, puzzle in amp for
optical maxBCG/LRG
new SZ reported
by ACT (~50), SPT (~50), AMI, .. more coming

A2319

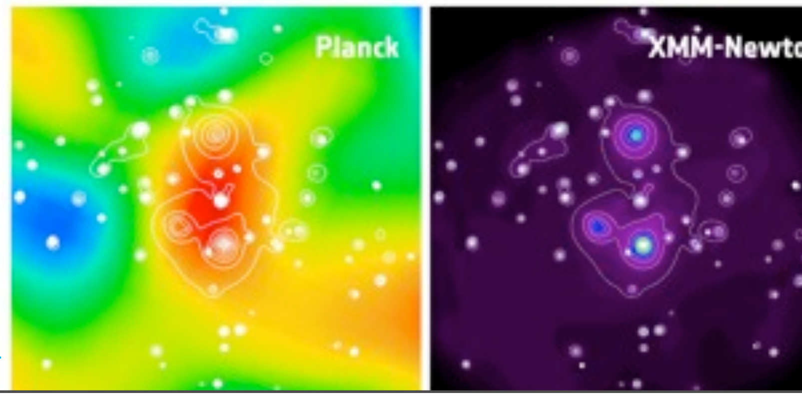


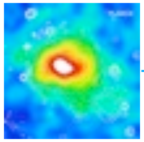






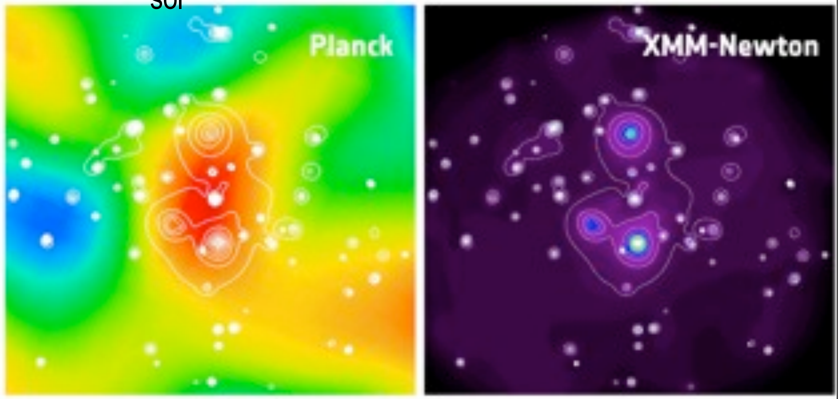
Frequency range from 30 to 857 GHz Sept09 1st clusters detected FLS (A2163, ...); Jan10 1st reliable blind candidates; typical SZ sources are barely visible in raw frequency maps, ~1-2 sigma sources in cleaned frequency maps => Planck-internal QA: 2 methods MMF3 + e.g., PowellSnakes. **MMF3 output: position, 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.

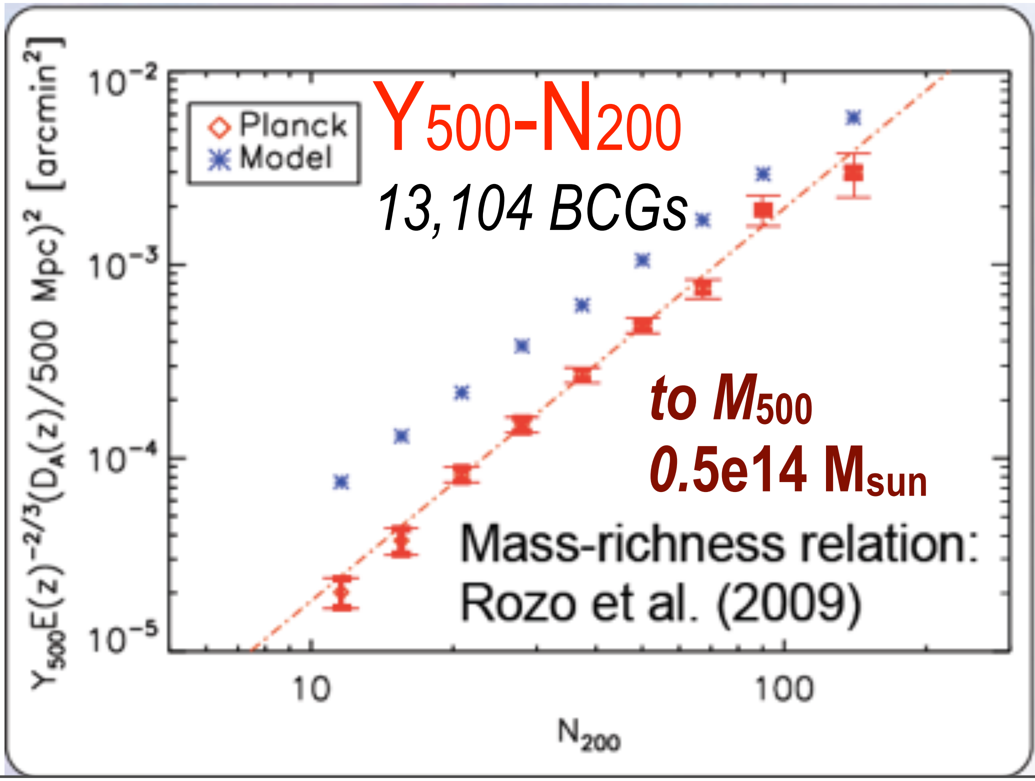


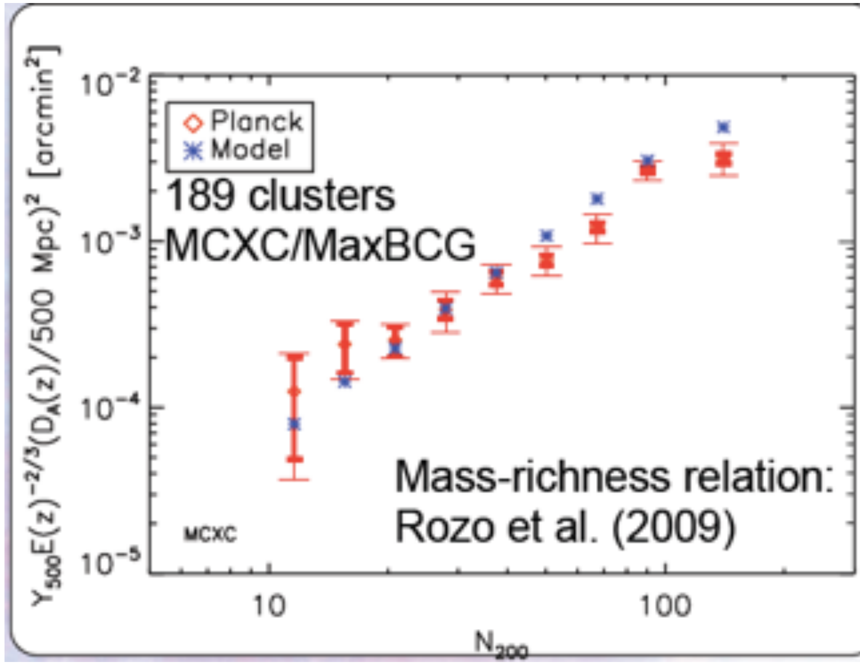


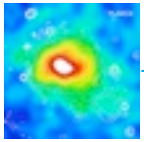
Planck sees the rarest and most massive clusters over the whole sky: small/moderate redshifts (86% with z<0.3); masses to 1.5 × 10^{15} M_{sol}. 90% of the RASS above M > 9 × 10^{14} M_{sol} detected by blind ESZ, 5/21 of new Planck > 9 × 10^{14} M_{sol}.

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 triples (super-clusters) systems; 0.09 < z < 0.54









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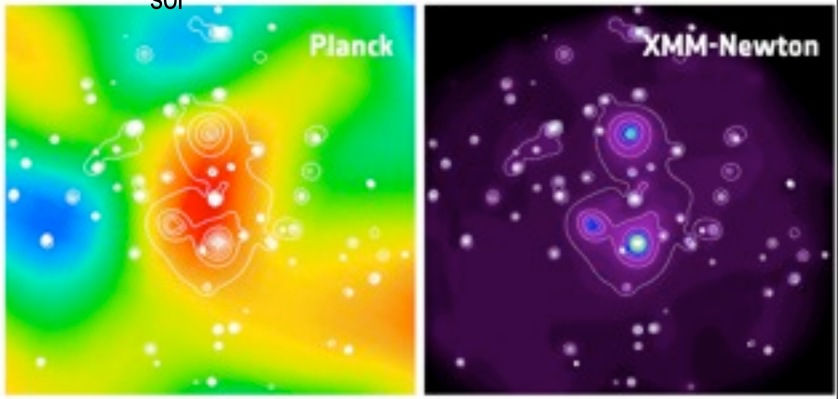
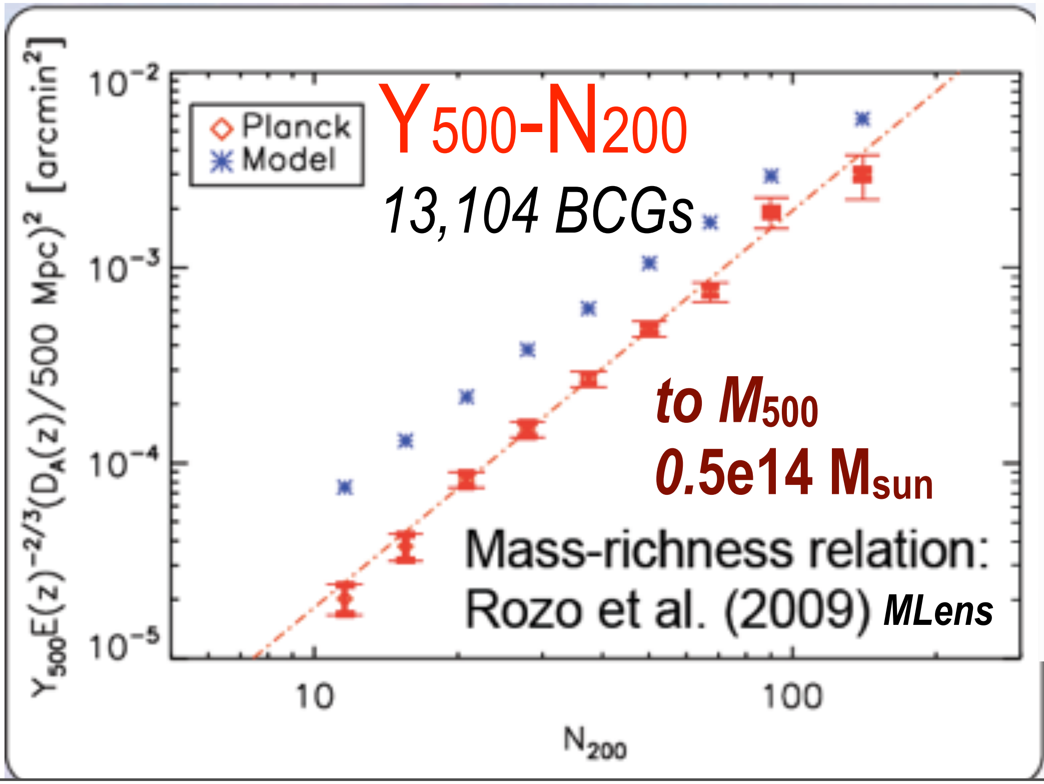
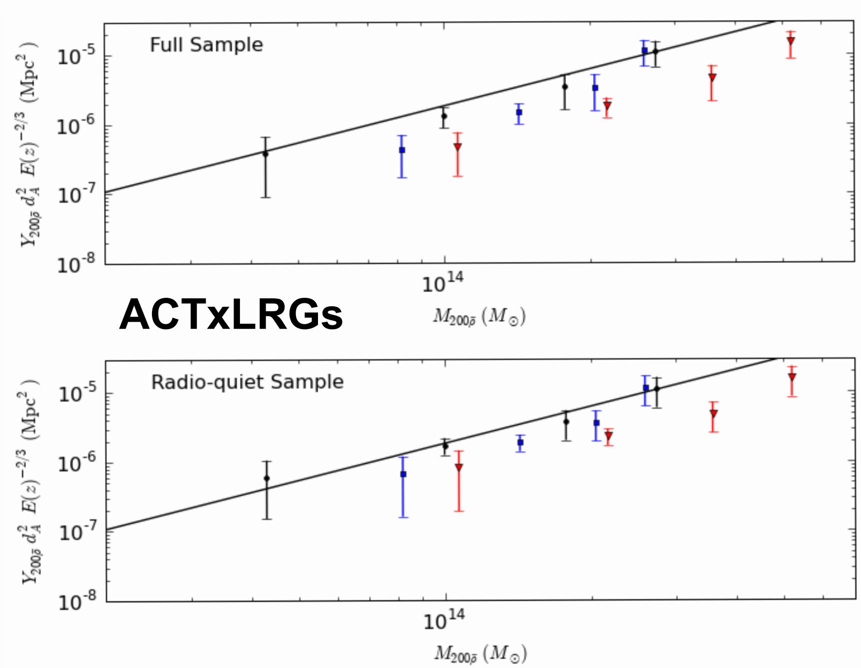
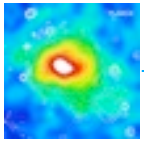






Hint for sub-populations? Optical selection effects? Difference between Mx & MLens & Mbias?...

Tuesday, February 22, 2011



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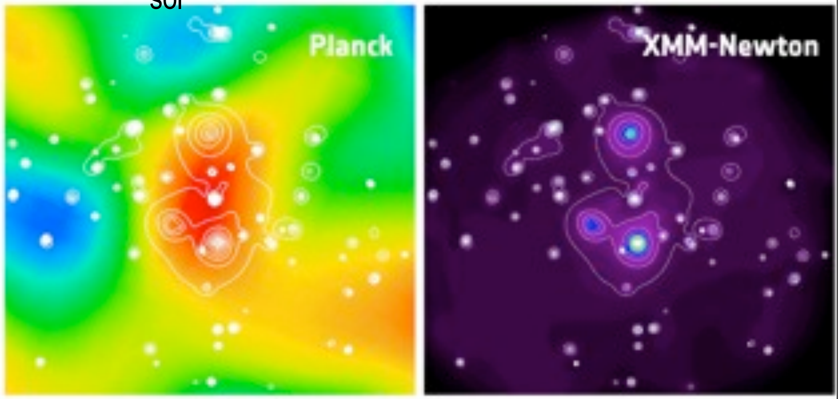
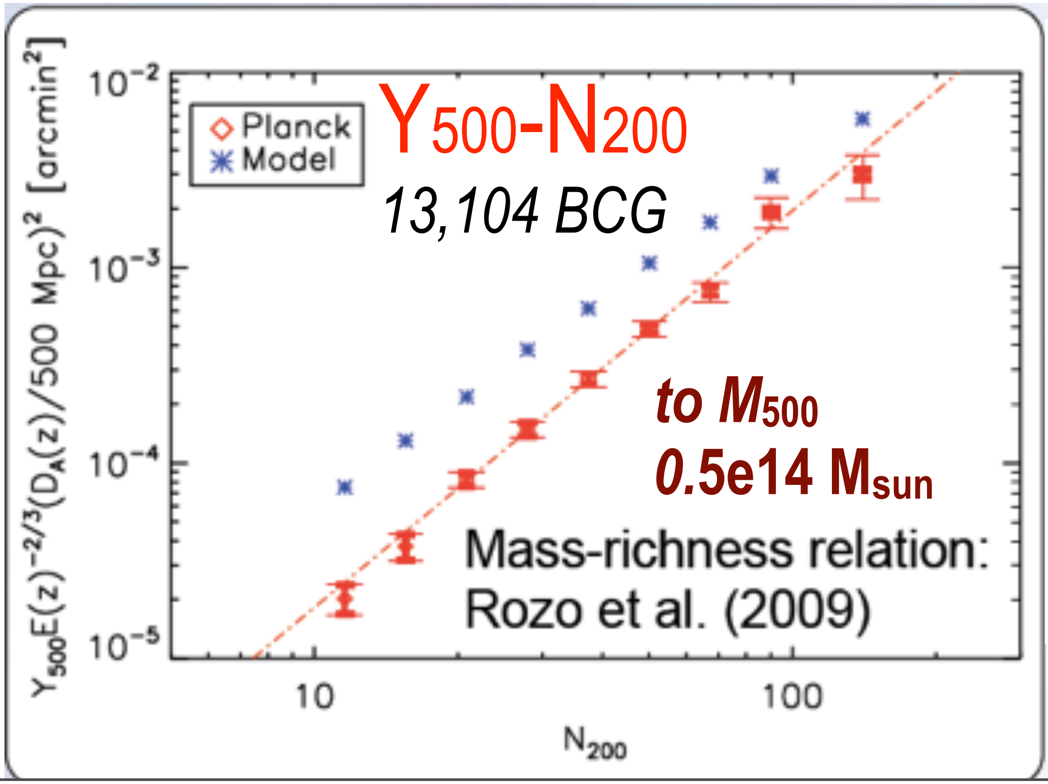
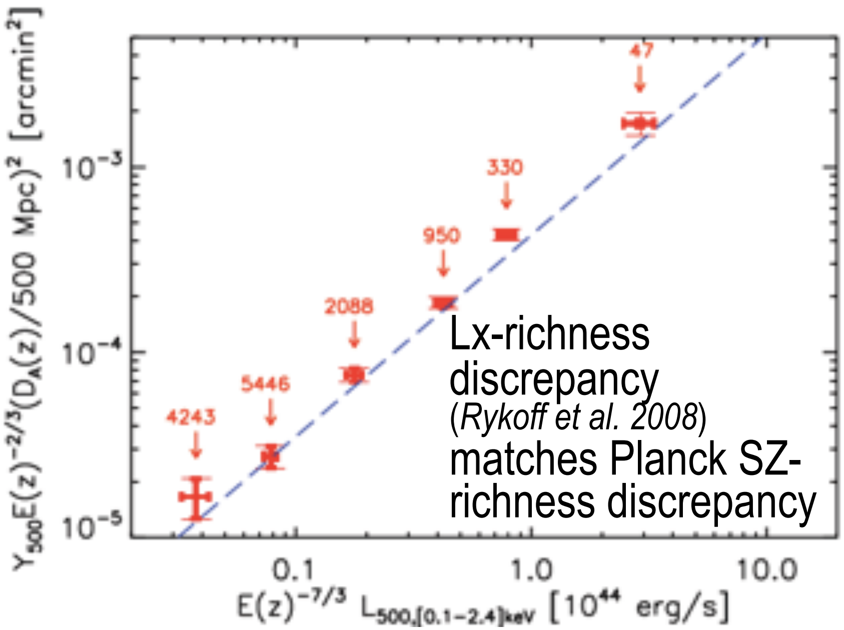
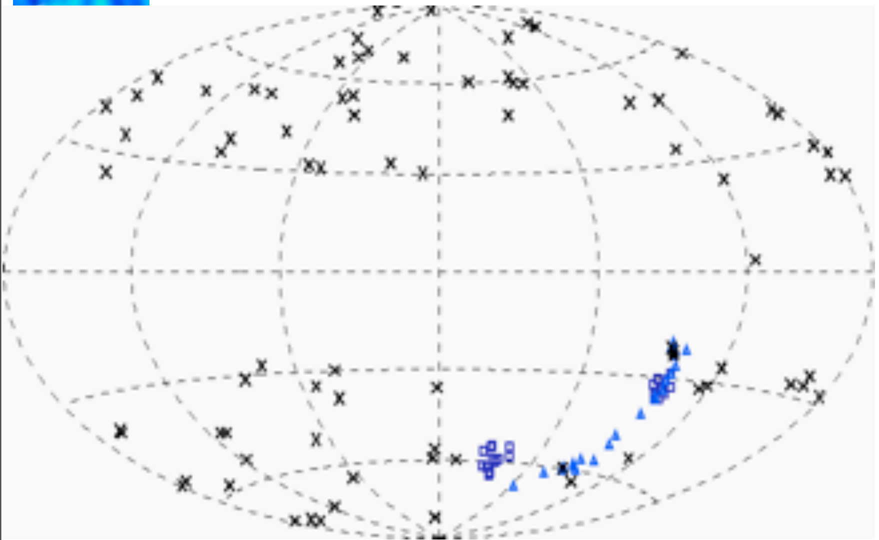
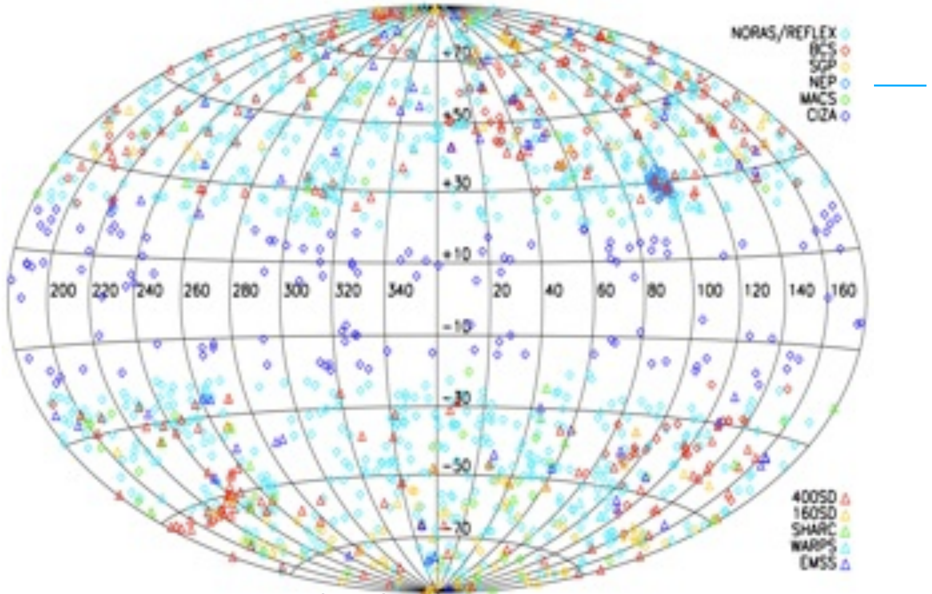






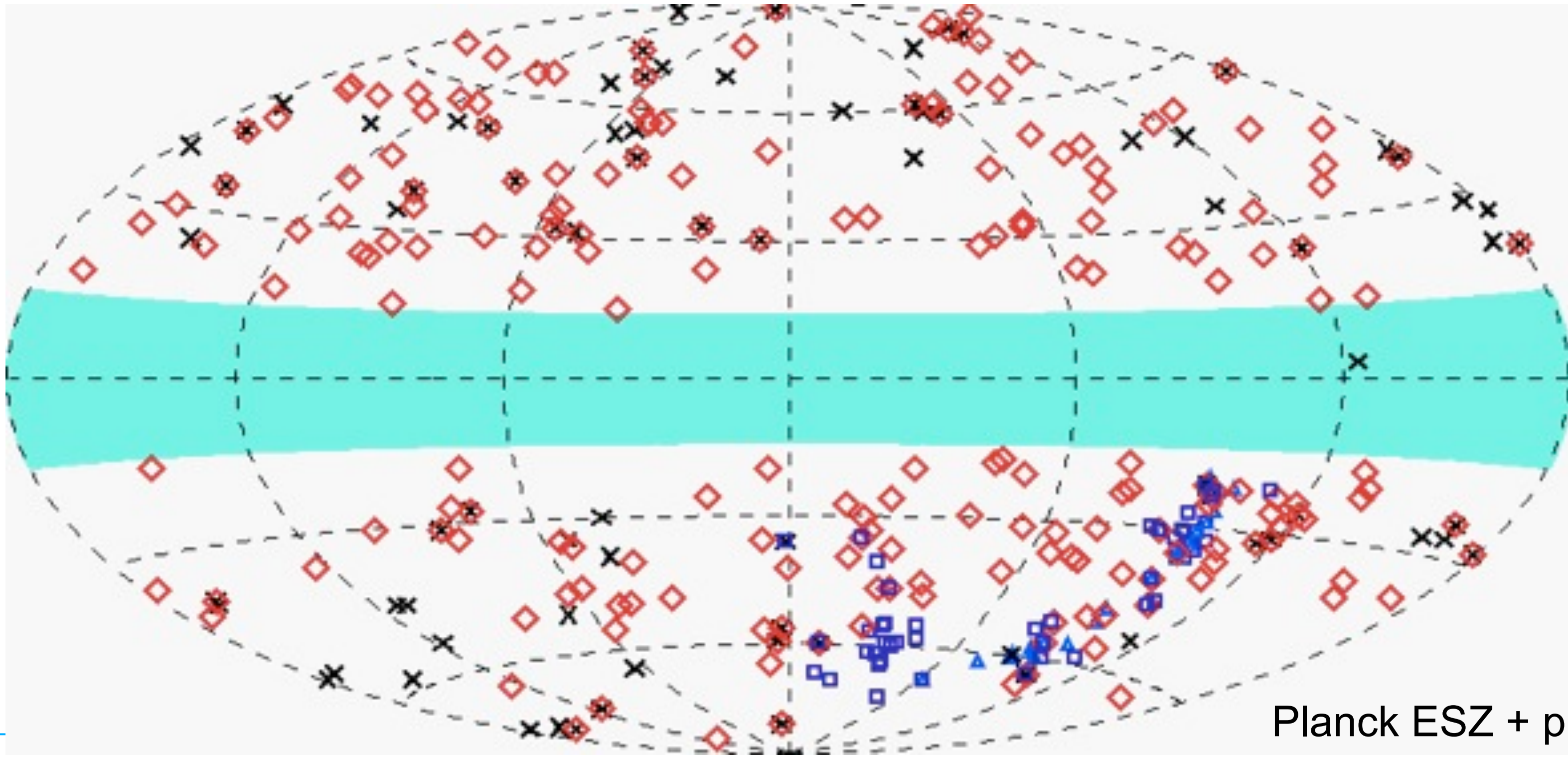
Lx-richness discrepancy (*Rykoff et al. 2008*) matches Planck SZ-richness discrepancy





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

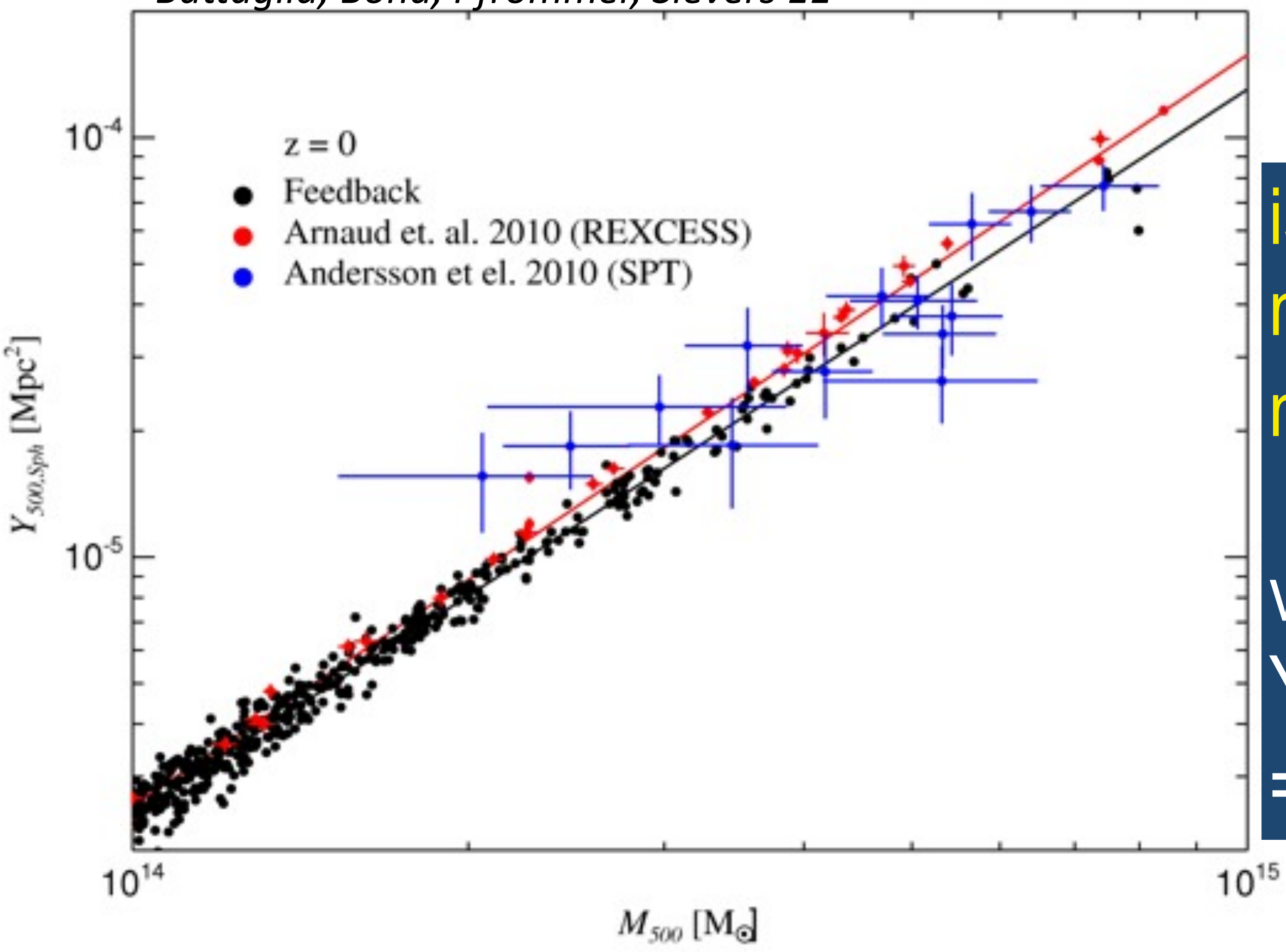
All-sky distribution of MCXC clusters ~1600 *(Piffaretti et 10)*



$Y(<r_\Delta)$-$M(<r_\Delta)$ relation, *where*

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

Battaglia, Bond, Pfrommer, Sievers 11



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

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

$Y(<r_\Delta)$-$M(<r_\Delta)$ relation, *where*

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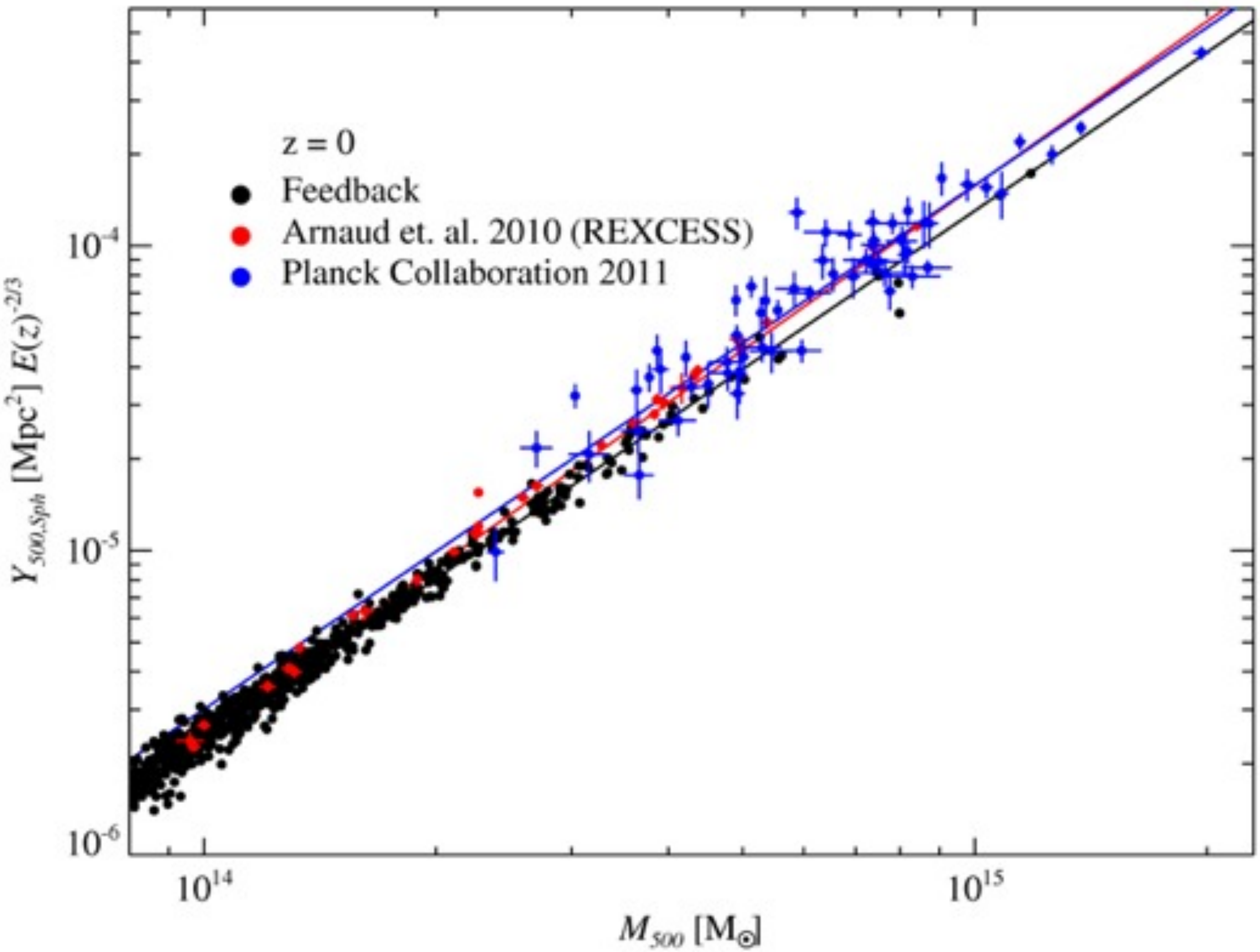
Battaglia, Bond, Pfrommer, Sievers 11



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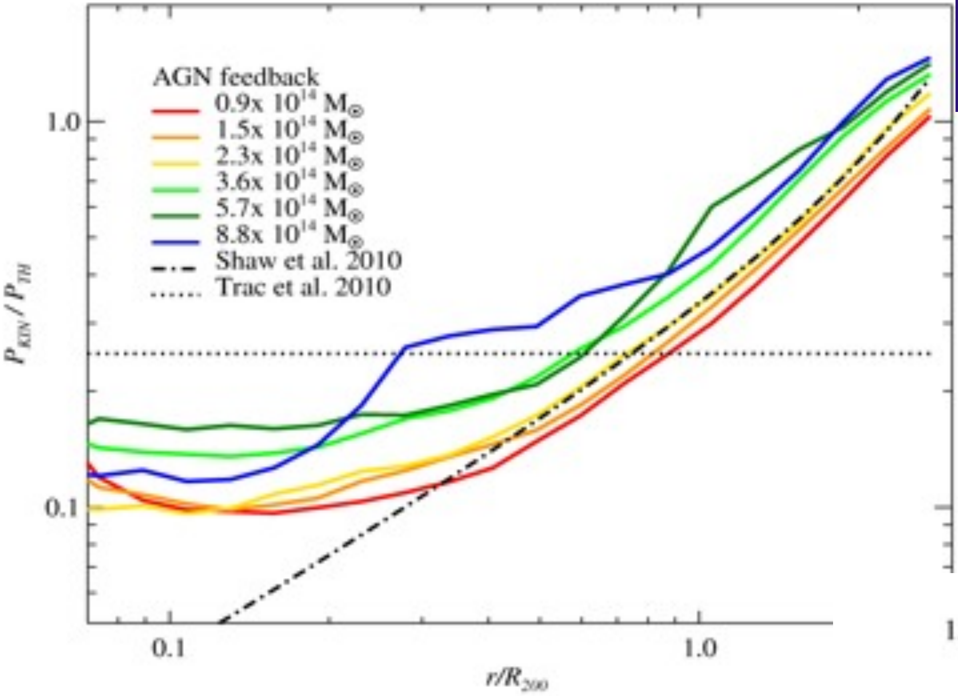
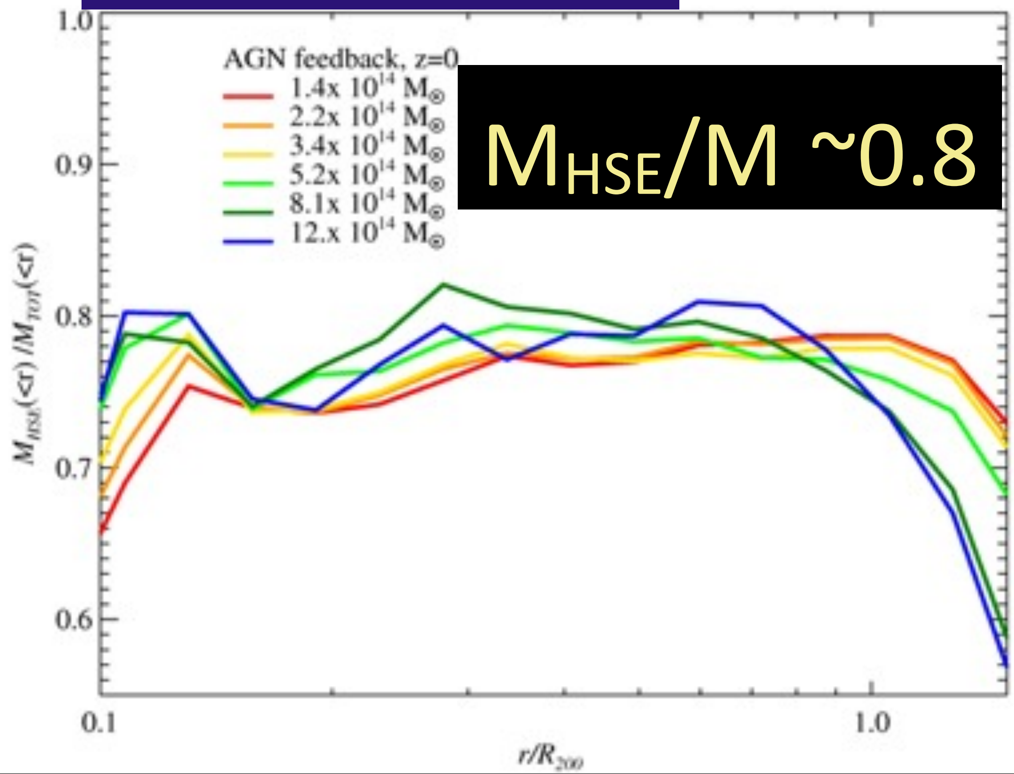


P_{kin}/P_{th}~0.1-0.6!

$<(\Delta v)^2>/c_s^2$ cannot be ignored in HSE $\nabla p_{g,tot}=\rho_g g$

Hydro Sims include all effects
(except of course for those not included).

Analytic and semi-analytic treatments must be fully calibrated with sims to give a useful phenomenology.



M_{HSE}/M ~0.8

Battaglia, Bond, Pfrommer, Sievers 11

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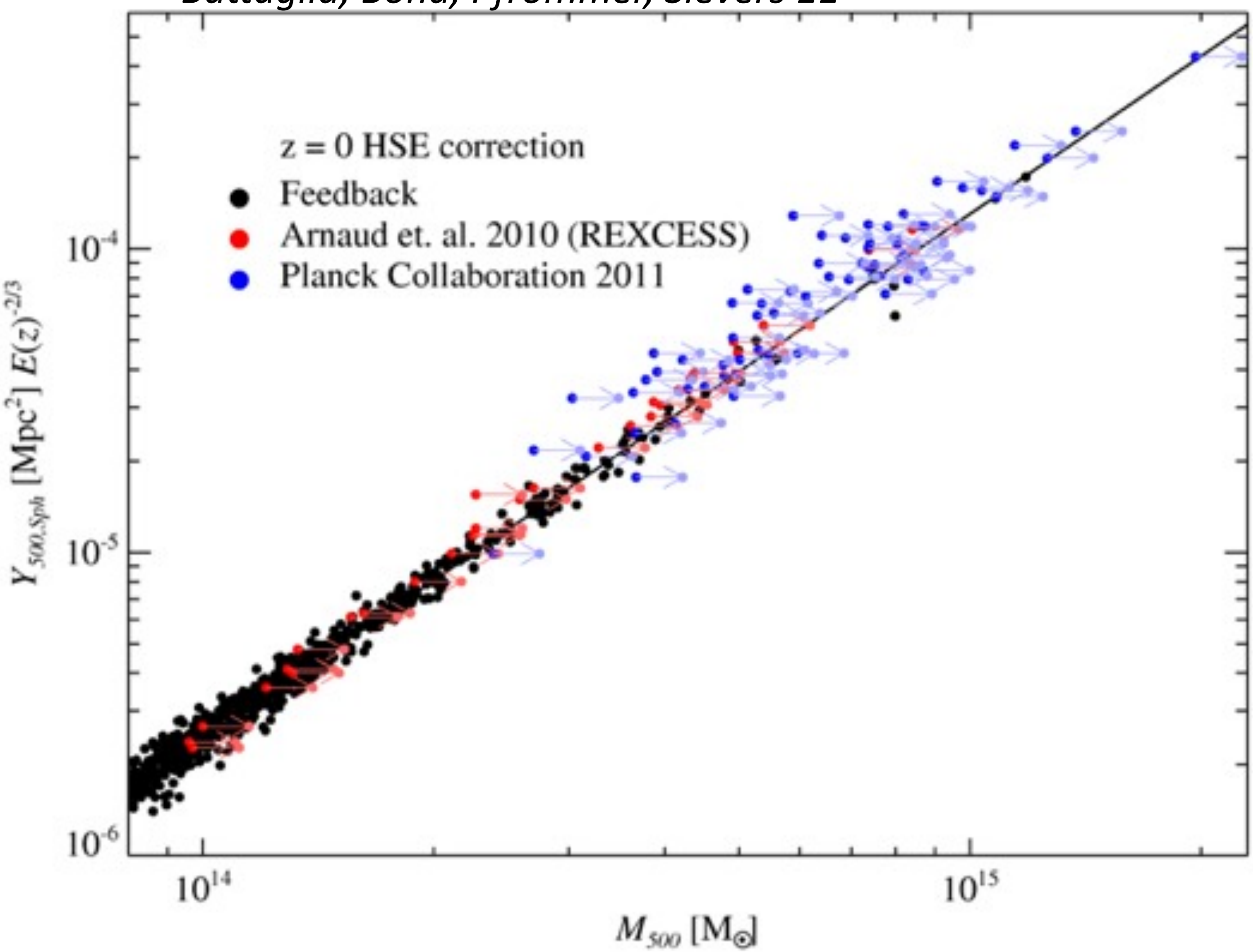
Battaglia, Bond, Pfrommer, Sievers 11



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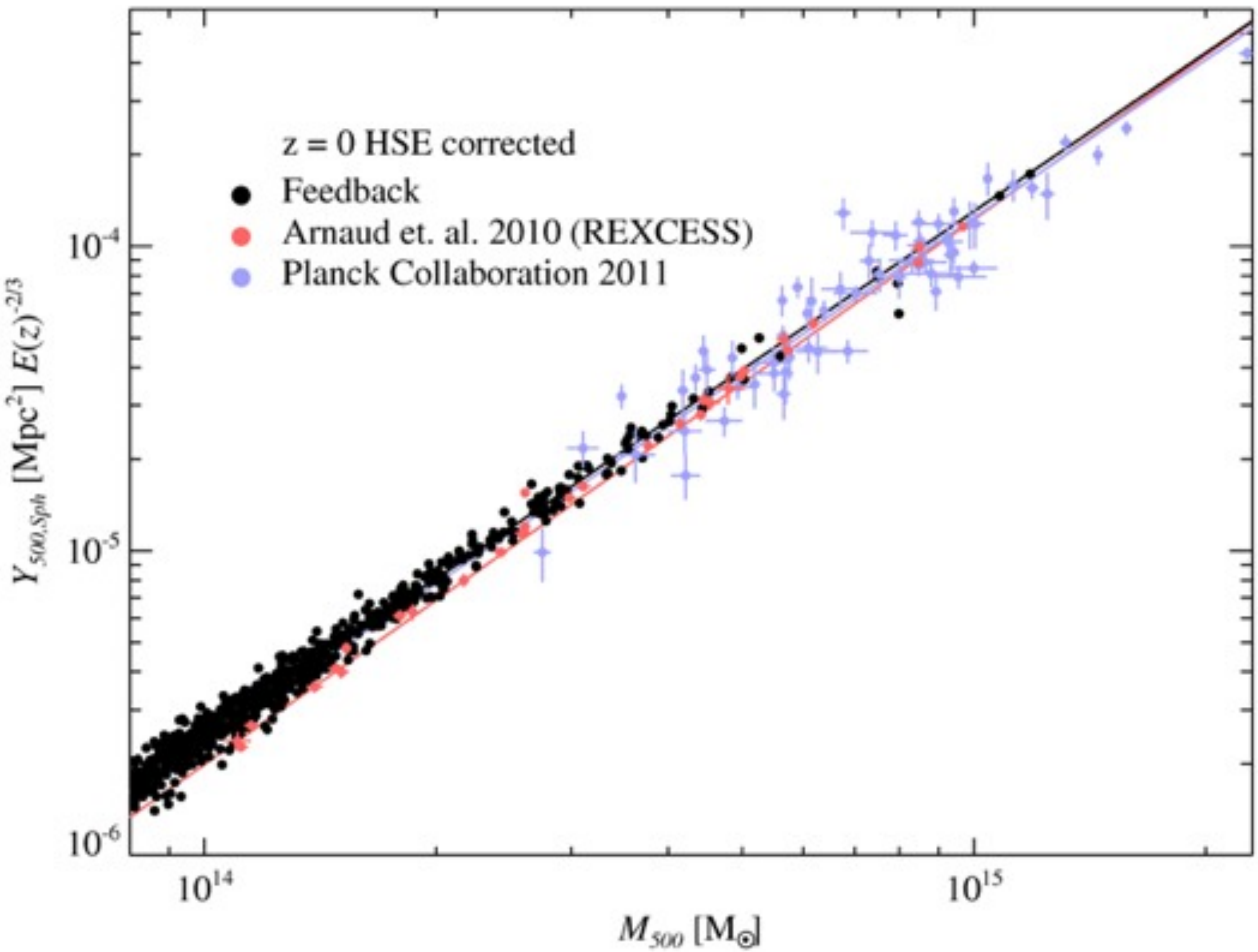

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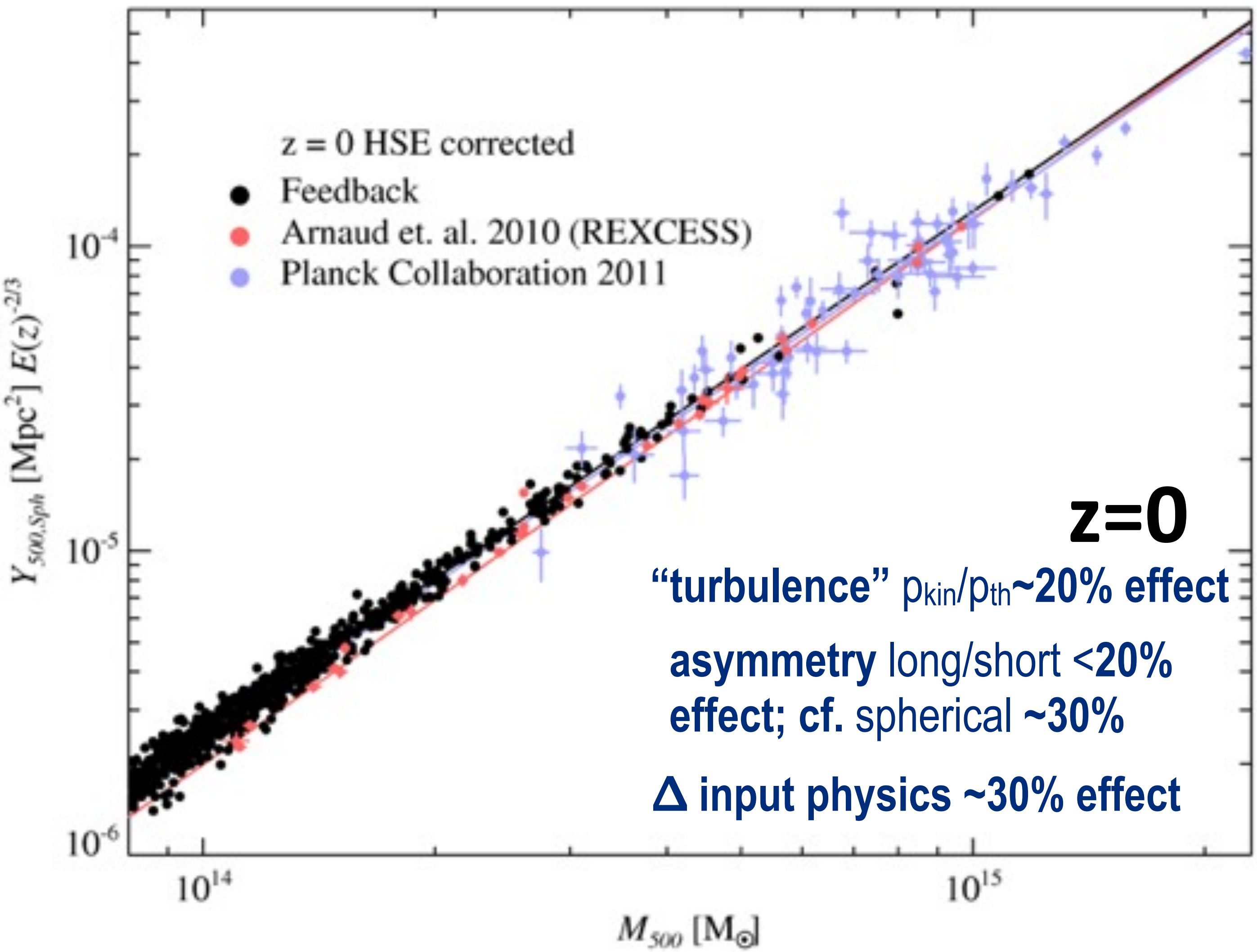

z=0

"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)
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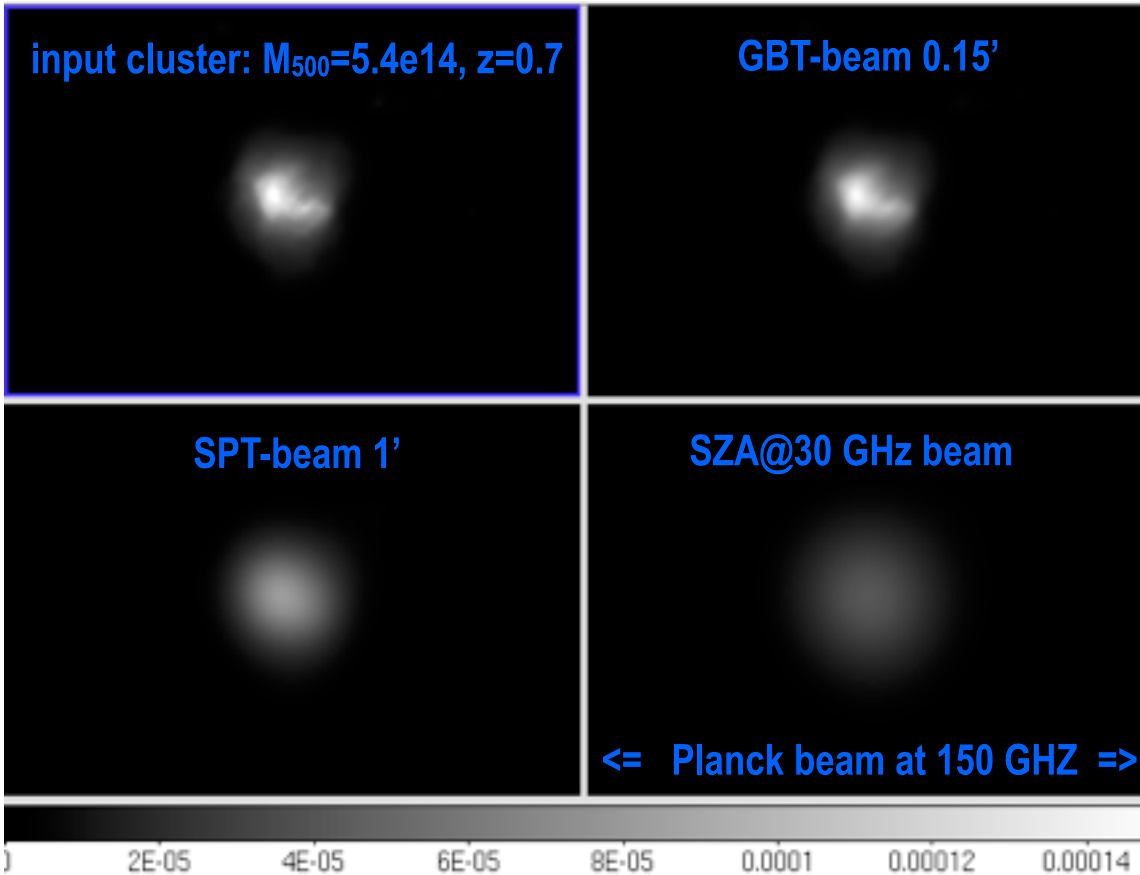
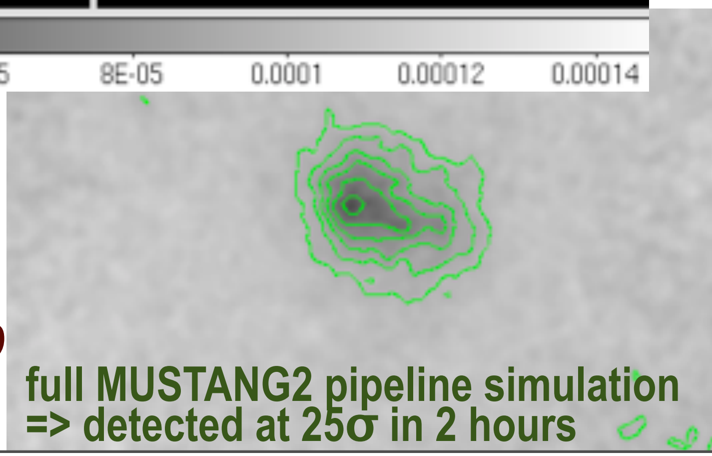
Mustang on GBT 90 GHz 64 bolometer array Imaging SZ @~10” res 4 cls 2010, ~25 Hubble CLASH cls to come Devlin, Mason, ...

future: High-Res SZ sim for MUSTANG2

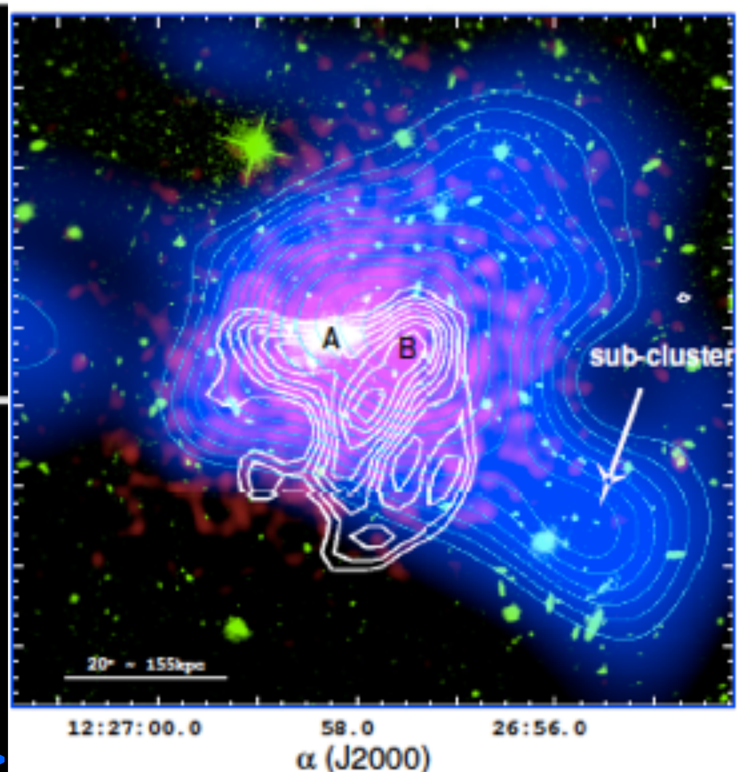


100x mapping speed!
160 cf. 64 pixels, over larger area (5’ vs. 40”)

=> Planck followup to 35σ in 1hr



now: CL1226 z=0.89



Red Chandra
Blue/cyan weak lens Σ
Green optical
White MUSTANG SZ >3σ

A BCG ~ X-ray peak
B Dark Matter peak
~ lobe of SZ ridge

$n_{cluster}$

$(Y_{SZ}, M_{lens}, Y_X, L_X, T_X, L_{cl,opt}, R_{ich}, \ldots$

$|$ gold-sample, thresholds)

$+ C_L^{SZ}$(cuts) will deliver valuable

cosmic gastrophysics for sure.

Will it deliver fundamental physics

e.g., the dark energy EOS, primordial

non-Gaussianity??? σ_8 even?

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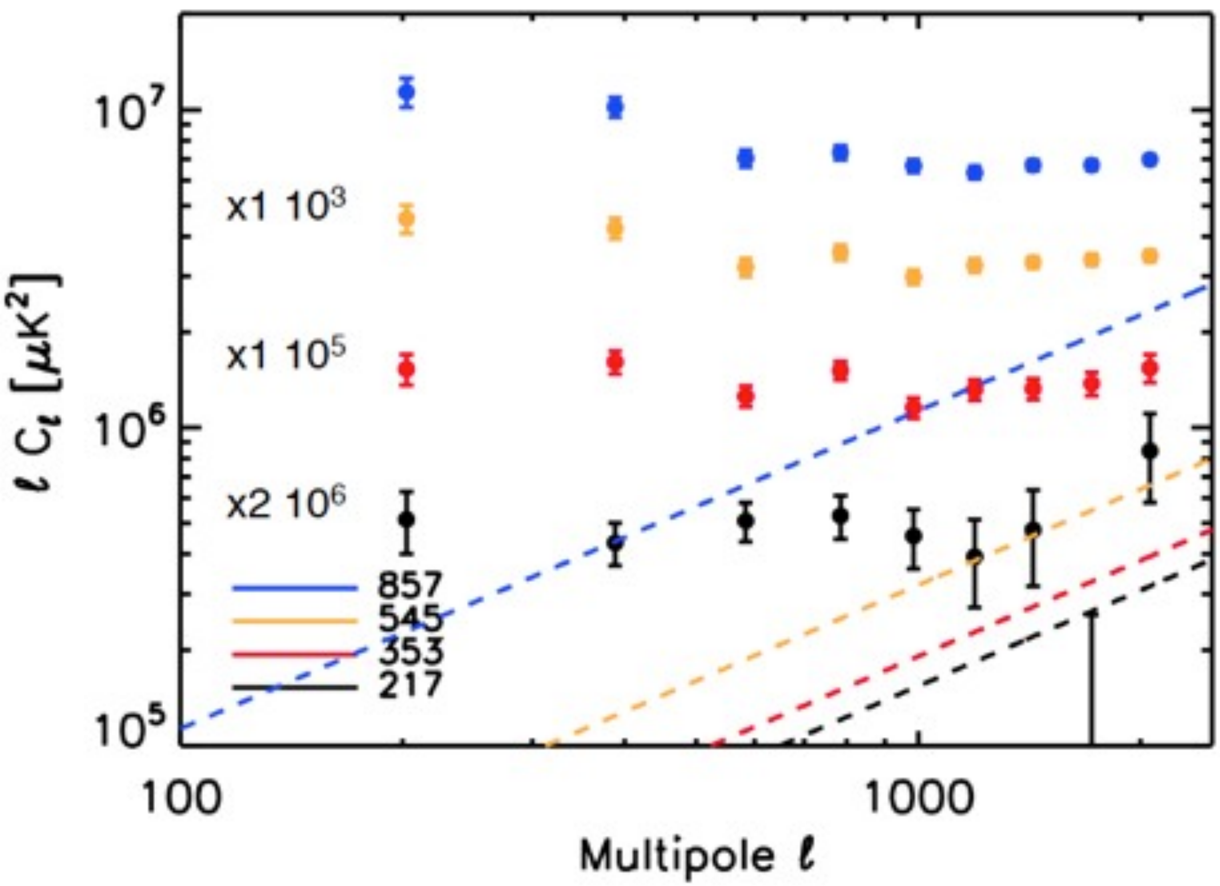
Planck Early Results: The Power Spectrum Of Cosmic Infrared Background Anisotropies



- 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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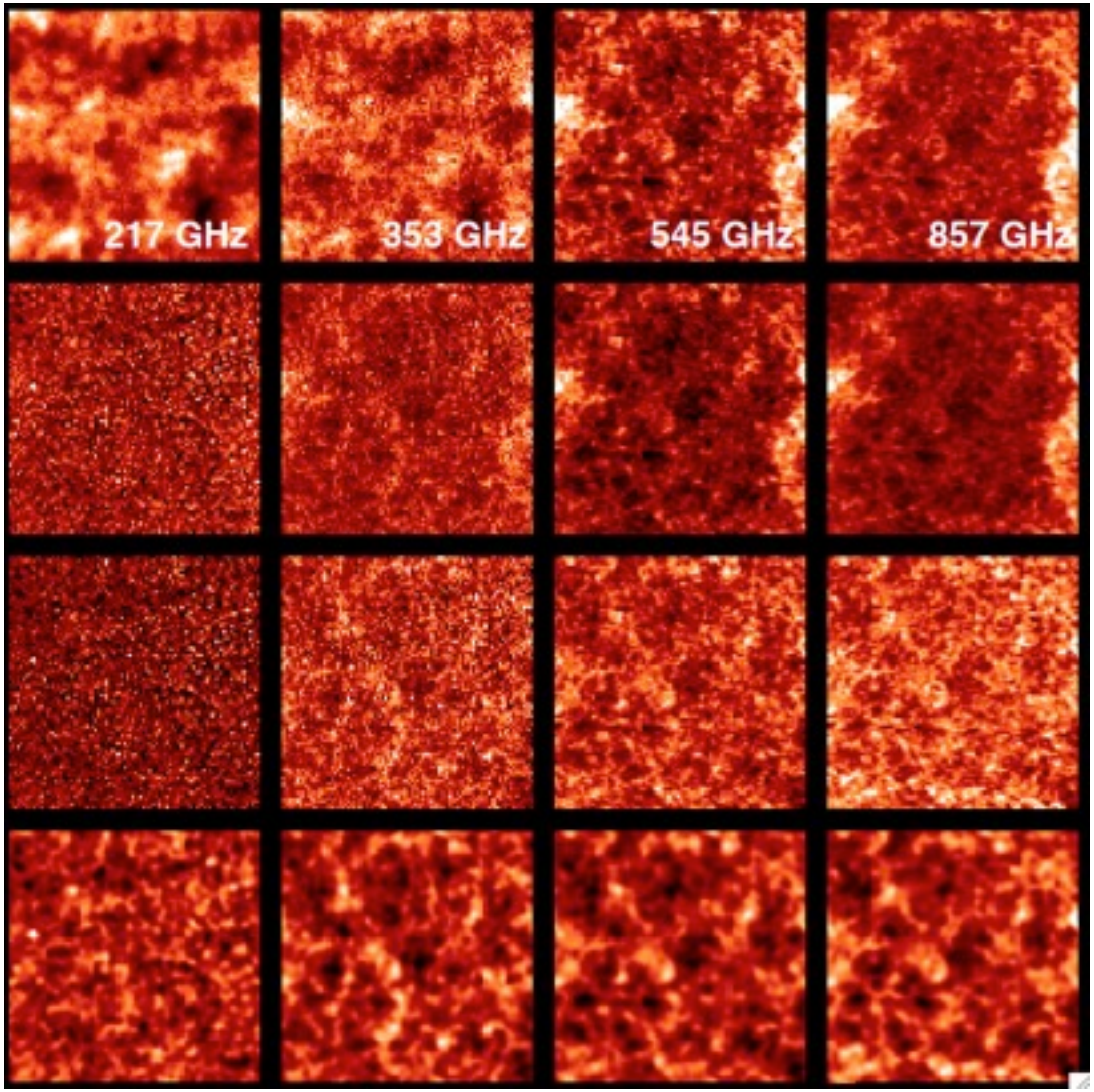

Planck-HFI Raw maps
26.4 sq. deg.

Raw maps
- CMB
- ERCSC point sources

Raw maps
- CMB
- ERCSC point sources
- Galactic dust

CIB maps @ 10 arcmin

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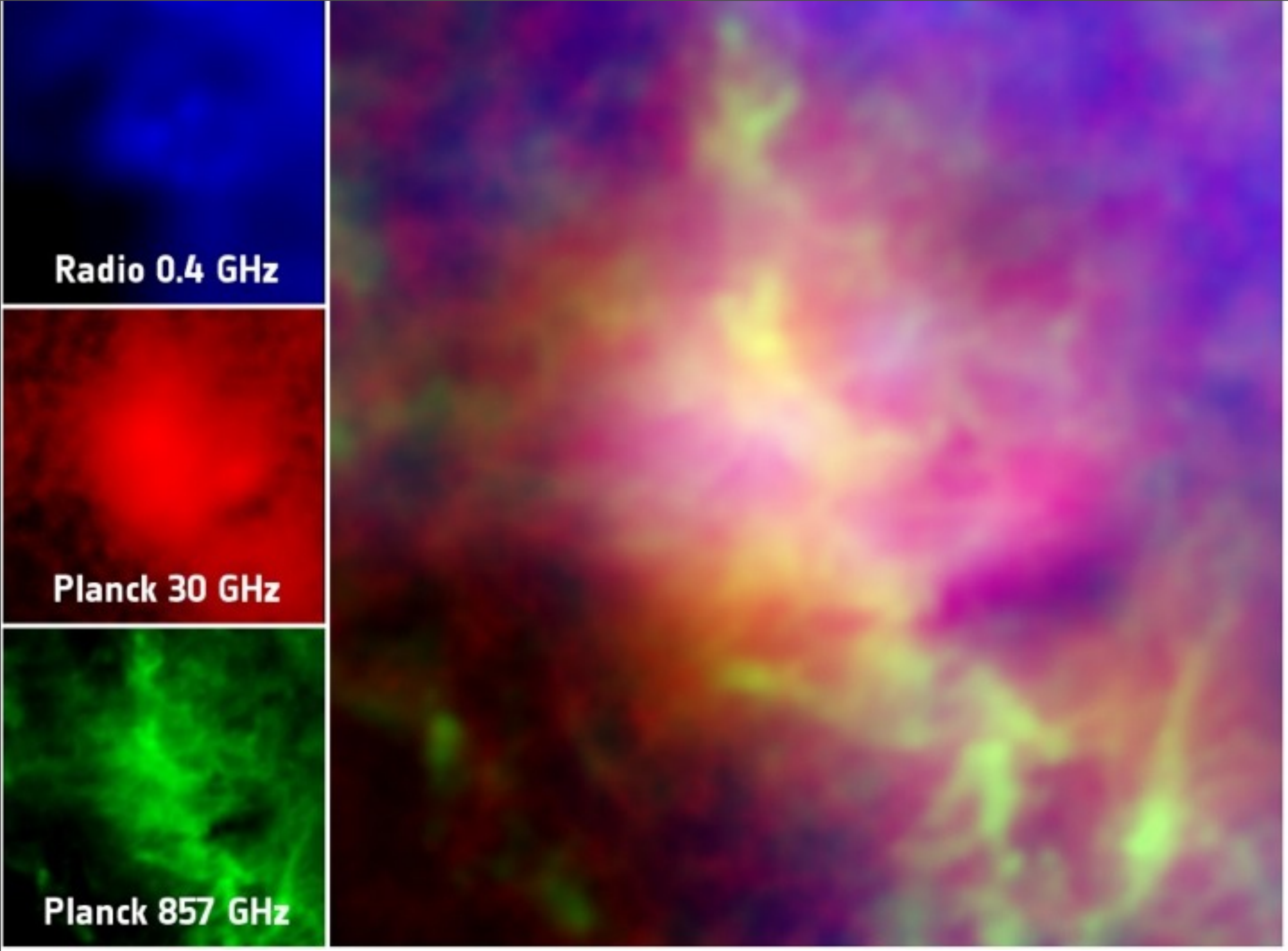
Radio 0.4 GHz
Planck 30 GHz
Planck 857 GHz

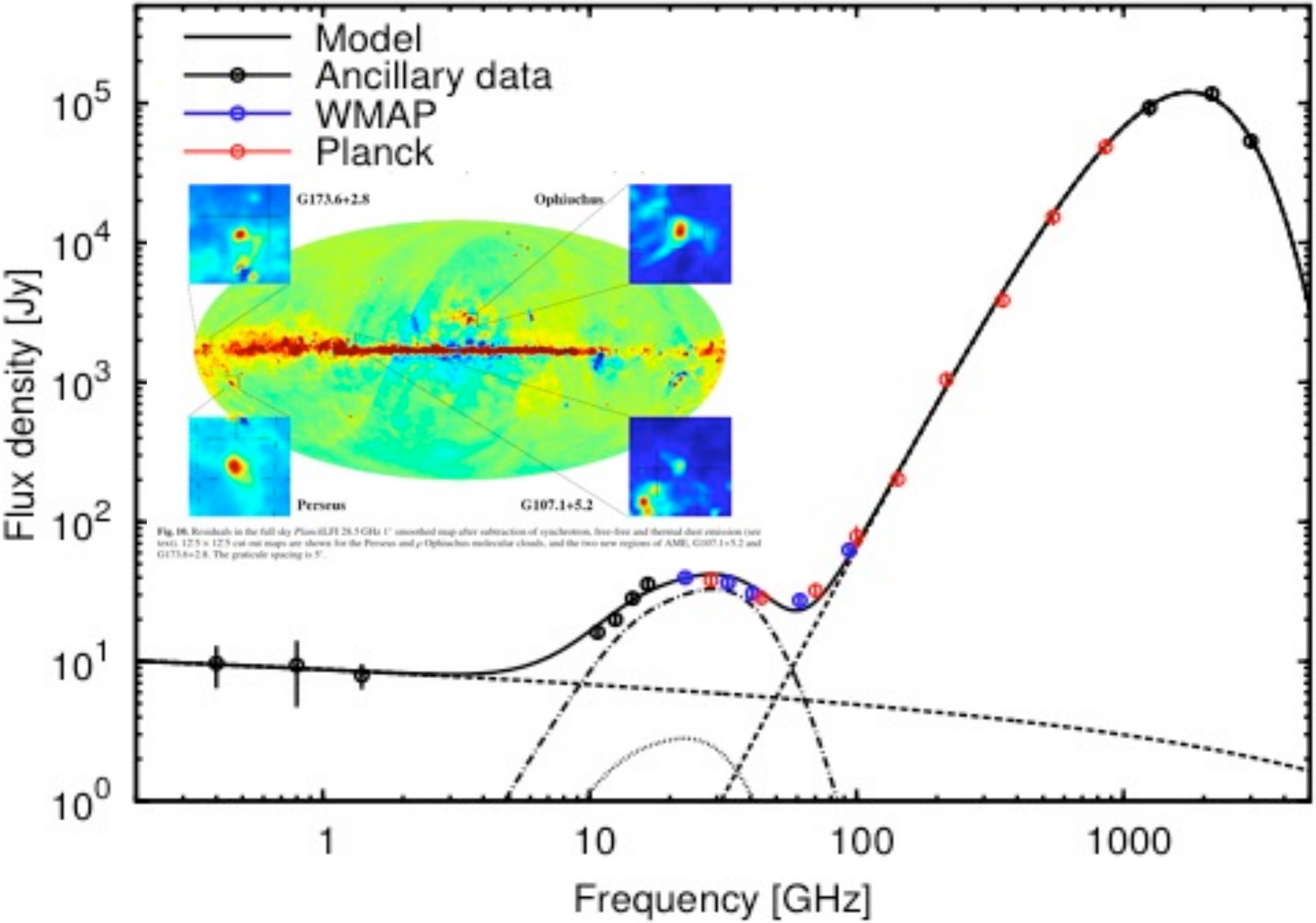

Fig. 4. Spectrum of G160.26-18.62 in the Perseus molecular cloud. The

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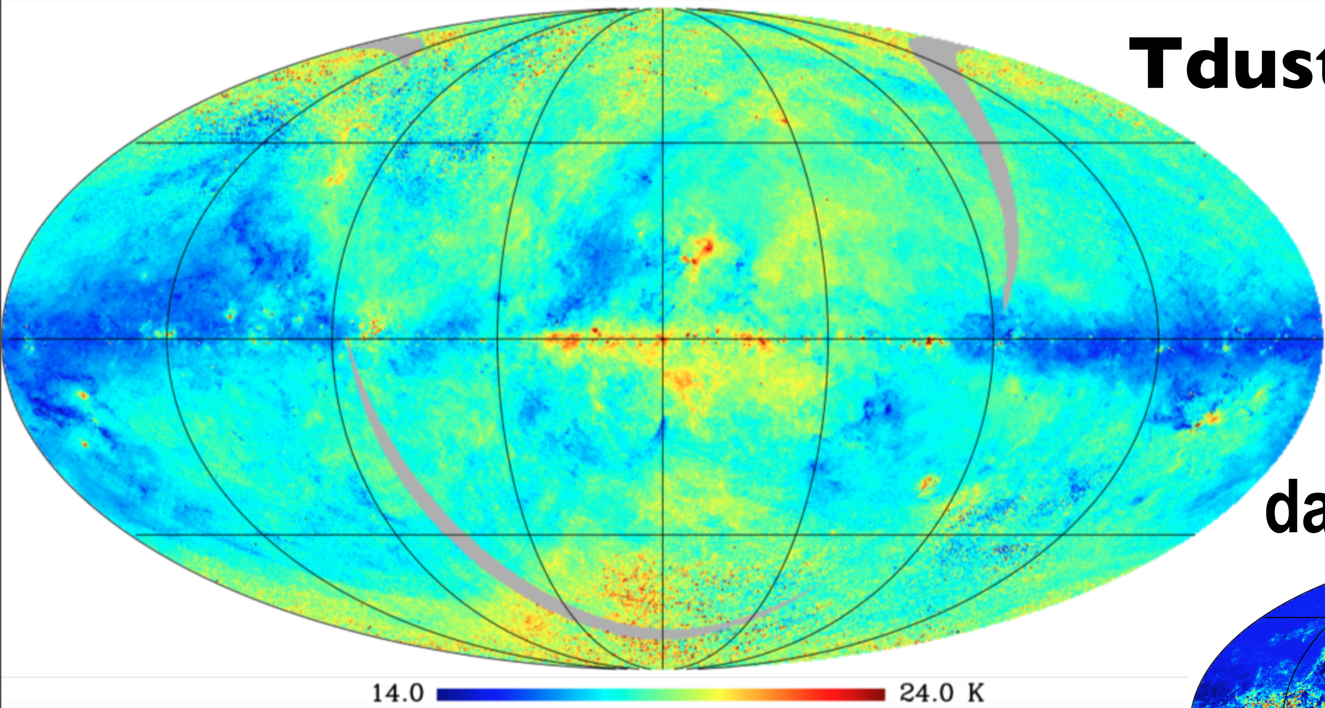
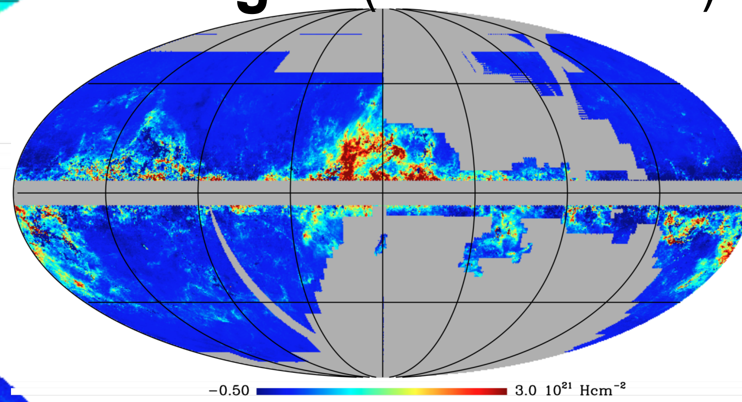
-

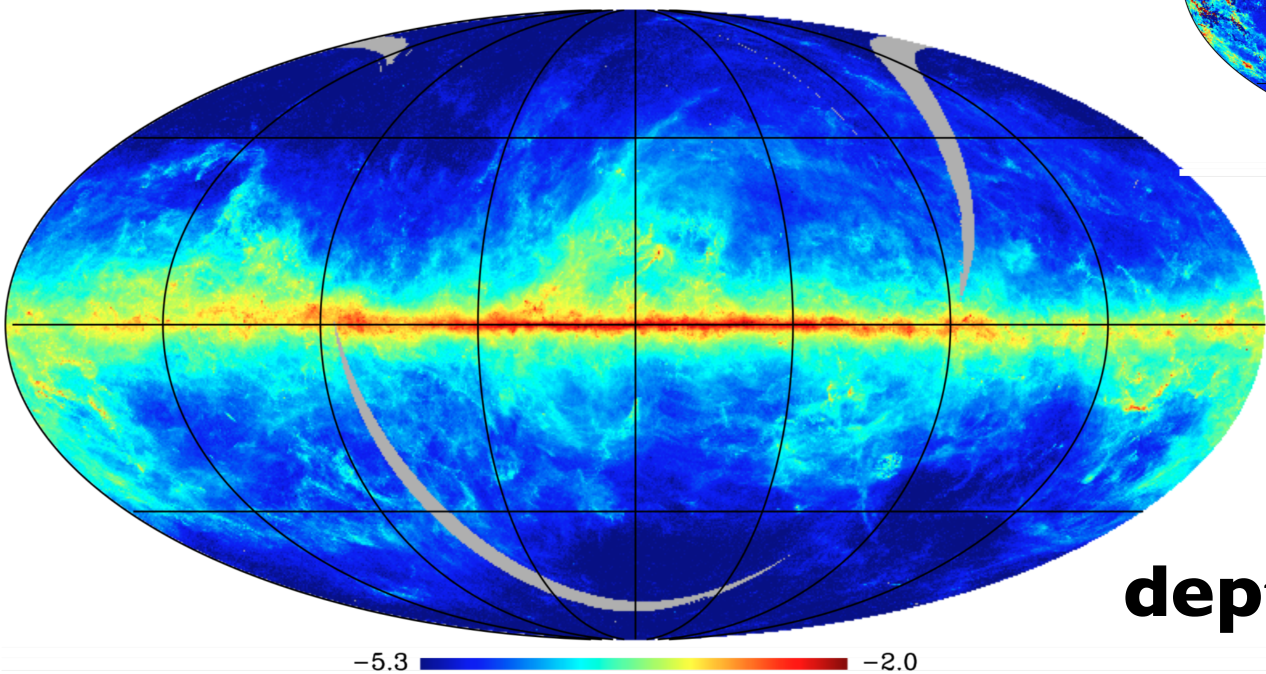
Tdust β fixed @1.8

Planck+*IRAS*

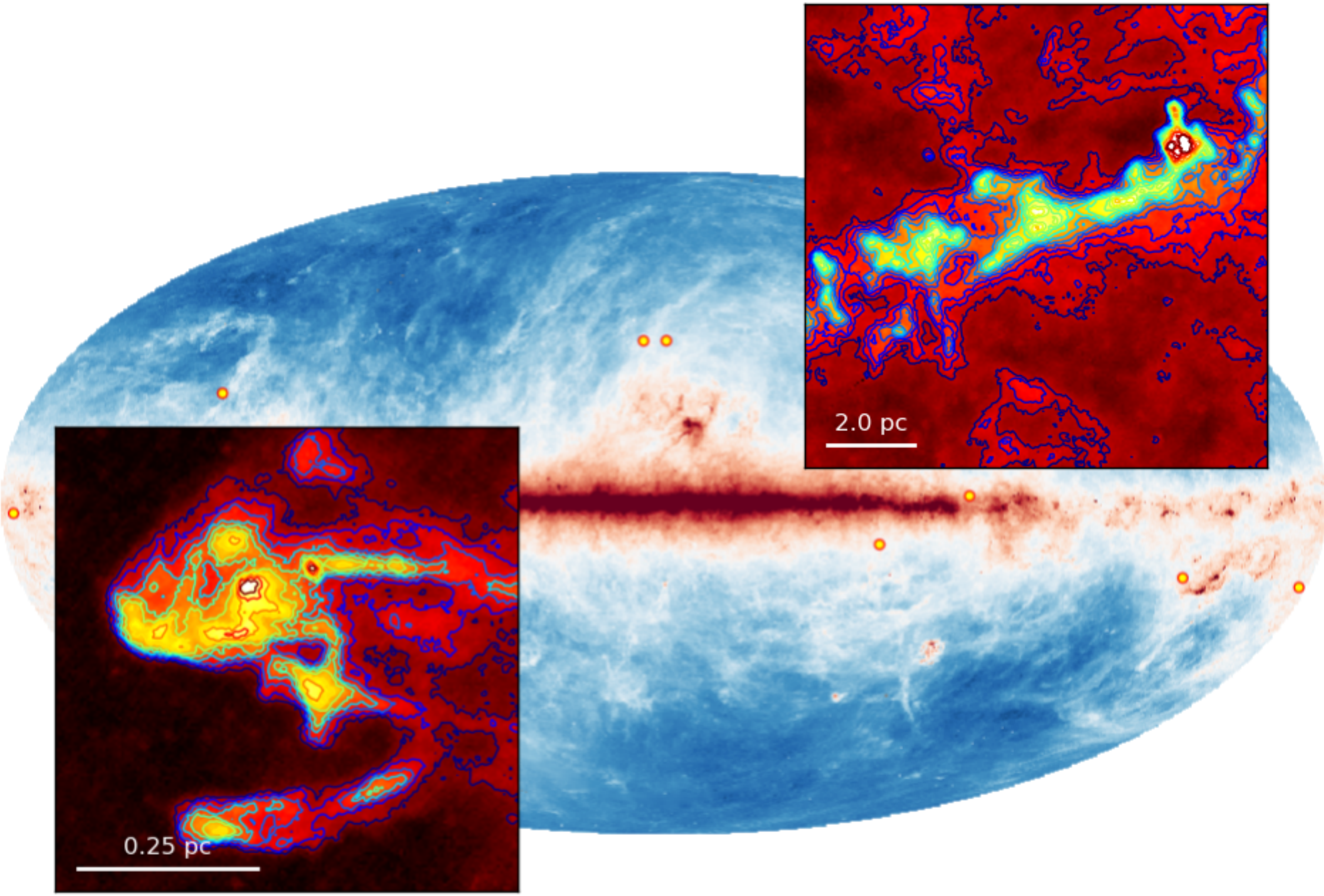


dark gas (no HI/CO corr)





depth τdust



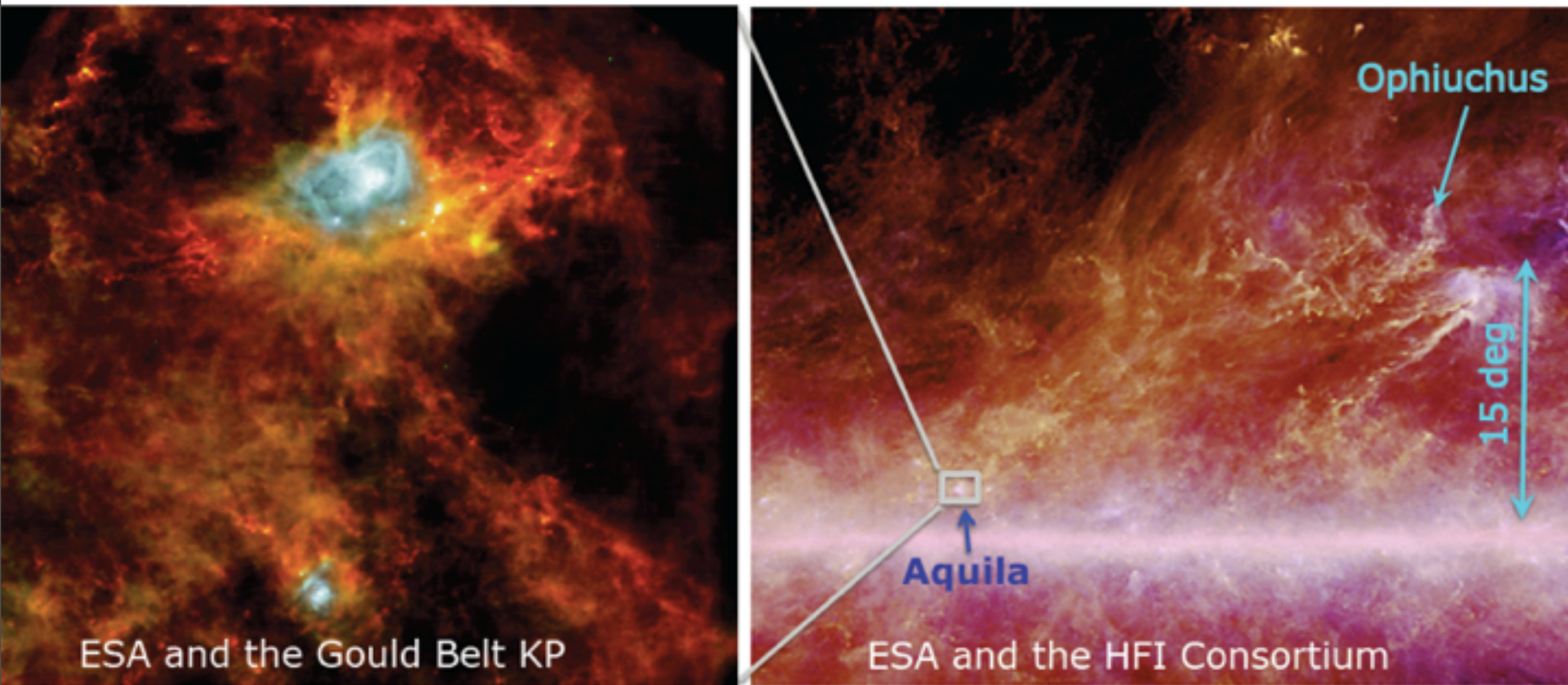
IRAS **Planck** **Herschel**

the GALAXY WIDE WEB

Filaments permeate the ISM on all scales

Herschel | **Planck**

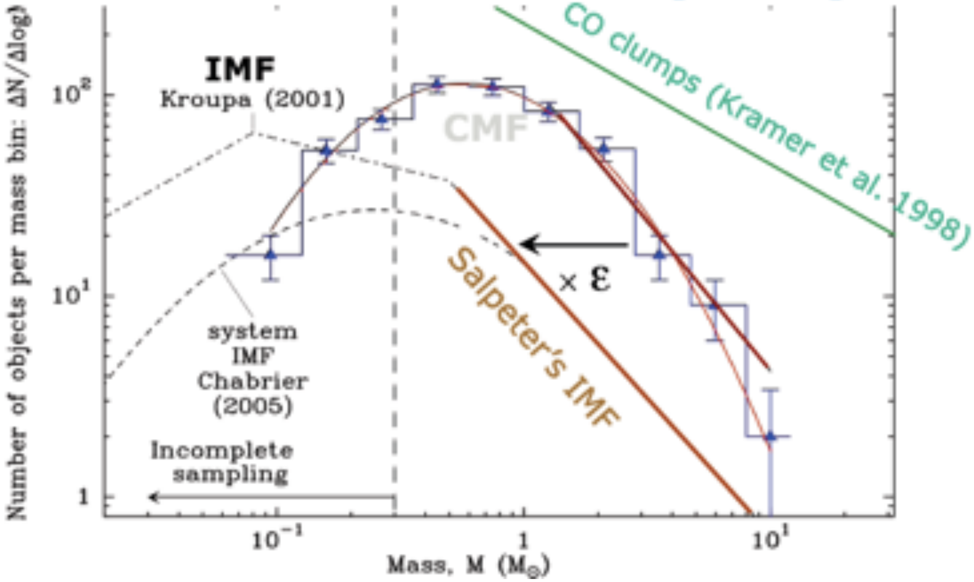
SPIRE 500 μm +PACS 160/70 μm | **HFI 540/350 μm + IRAS 100 μm**



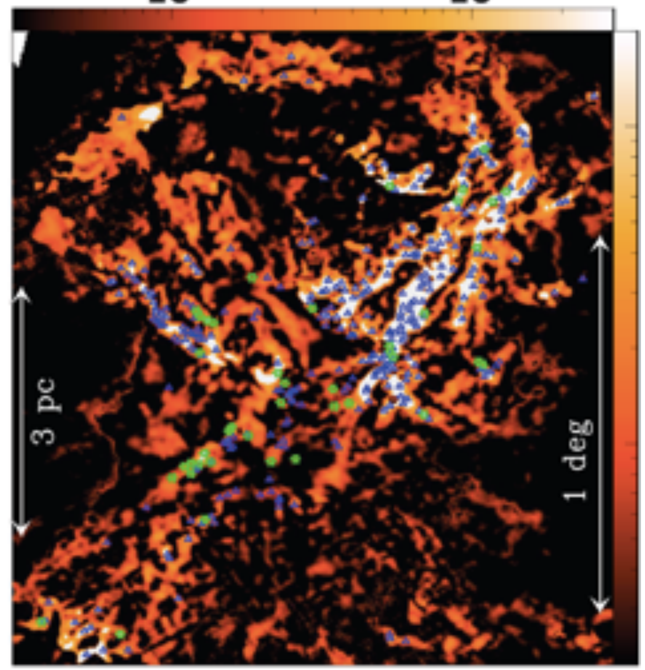
Göran Pilbratt | Planck 2011: The mm & submm sky in the Planck era | Paris | 10 January 2011 | vg #16

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

Prestellar Core Mass Function (CMF) in Aquila Complex



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



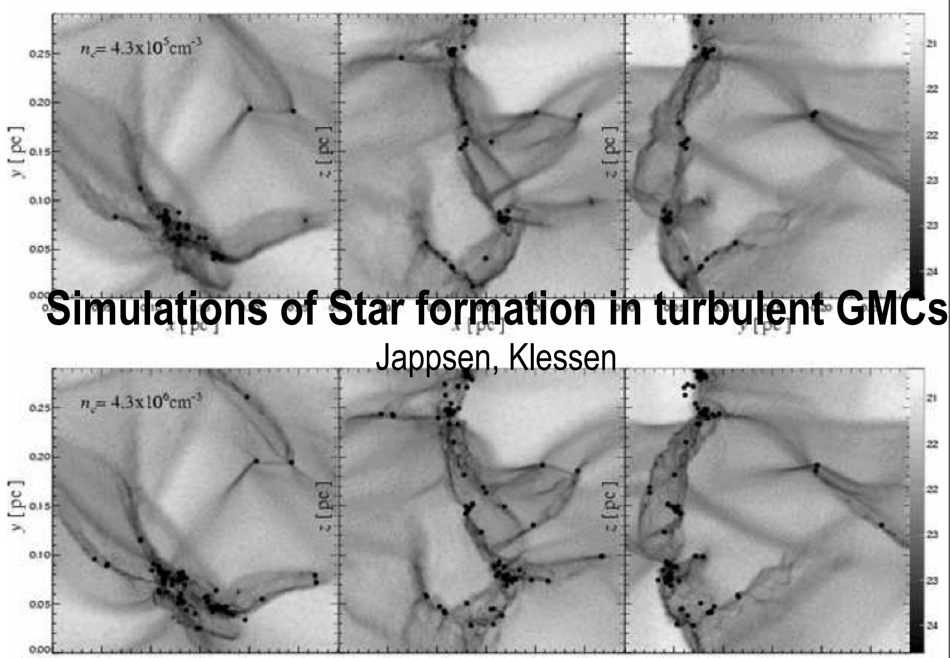
André et al. 2010, A&A special issue

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

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

SIMPLICITY in COMPLEXITY?

but so much chemistry etc



Simulations of Star formation in turbulent GMCs

Jappsen, Klessen

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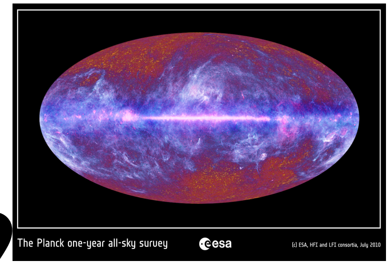
gastrophysics

= gastrointestinal disorder? or

interplanetary dust



= gourmand's paradise?

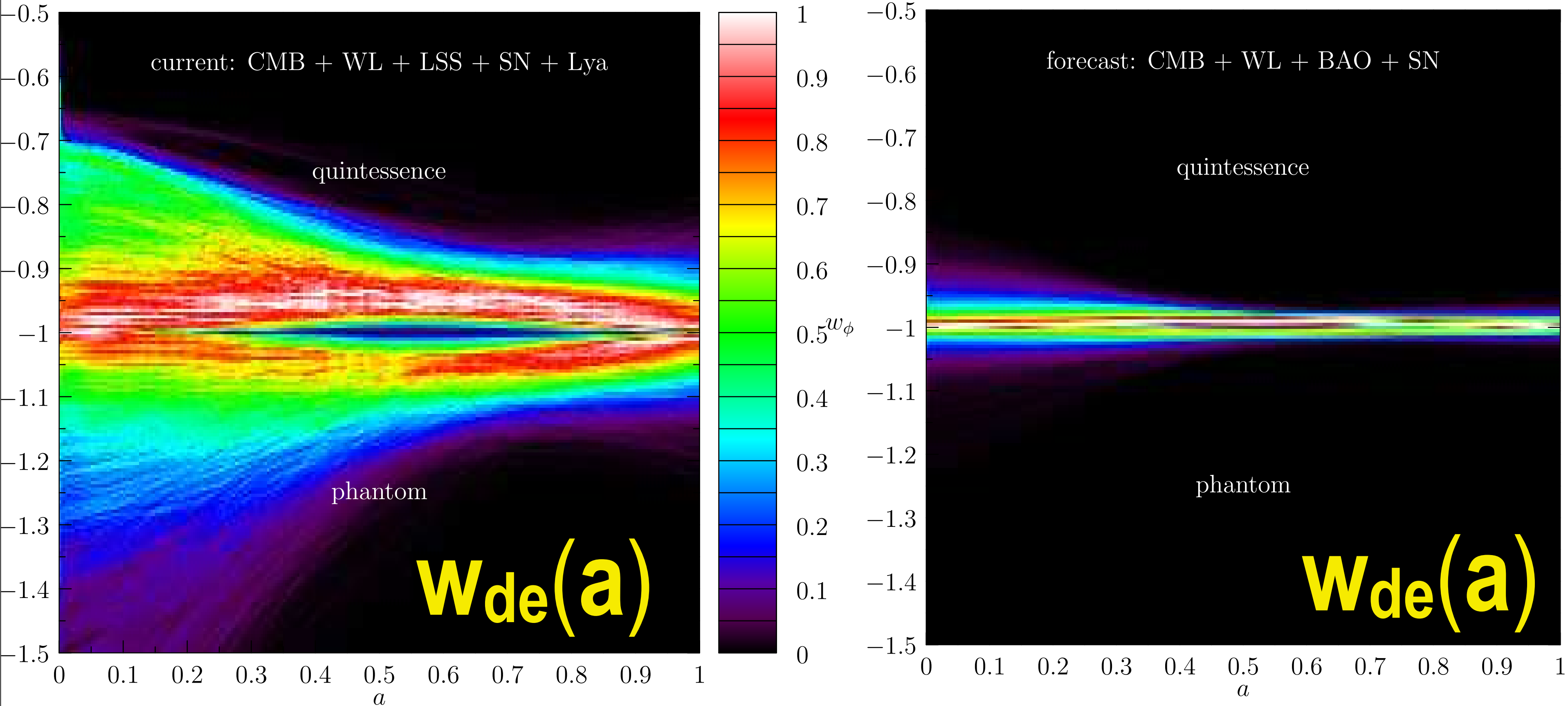
in paris, the latter @planck2011

∃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 cosmology forecasts for PlanckEXT

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

future DE equation of state trajectories NOW

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



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

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

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

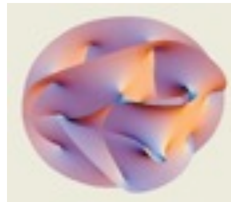
standard inflation space: n_s $dn_s/d\ln k$ r =T/S @k-pivots

WHAT IS PREDICTED?

Smoothly broken scale invariance by nearly uniform braking (standard of 80s/90s/00s) r~0.03-0.5

large field inflation (field moves > Planck mass)

or highly variable braking r tiny (stringy cosmology) $r<10^{-10}$



small field inflation (field moves <Planck mass ⇒ r<.007)

Bond, Kofman, Prokushkin,Vaudrevange 07, **Roulette Inflation with Kahler Moduli and their Axions**

Barnaby, Bond, Zhiqi Huang, Kofman 09, **Preheating after Modular Inflation**

monodromy (V=cosine+linear) & fibre inflation give larger r~.03

current r constraints (95%CL) - **prior sensitive**

r < 0.16 (no running, all data sets)

r < 0.32 (no running, CMB-only data sets)

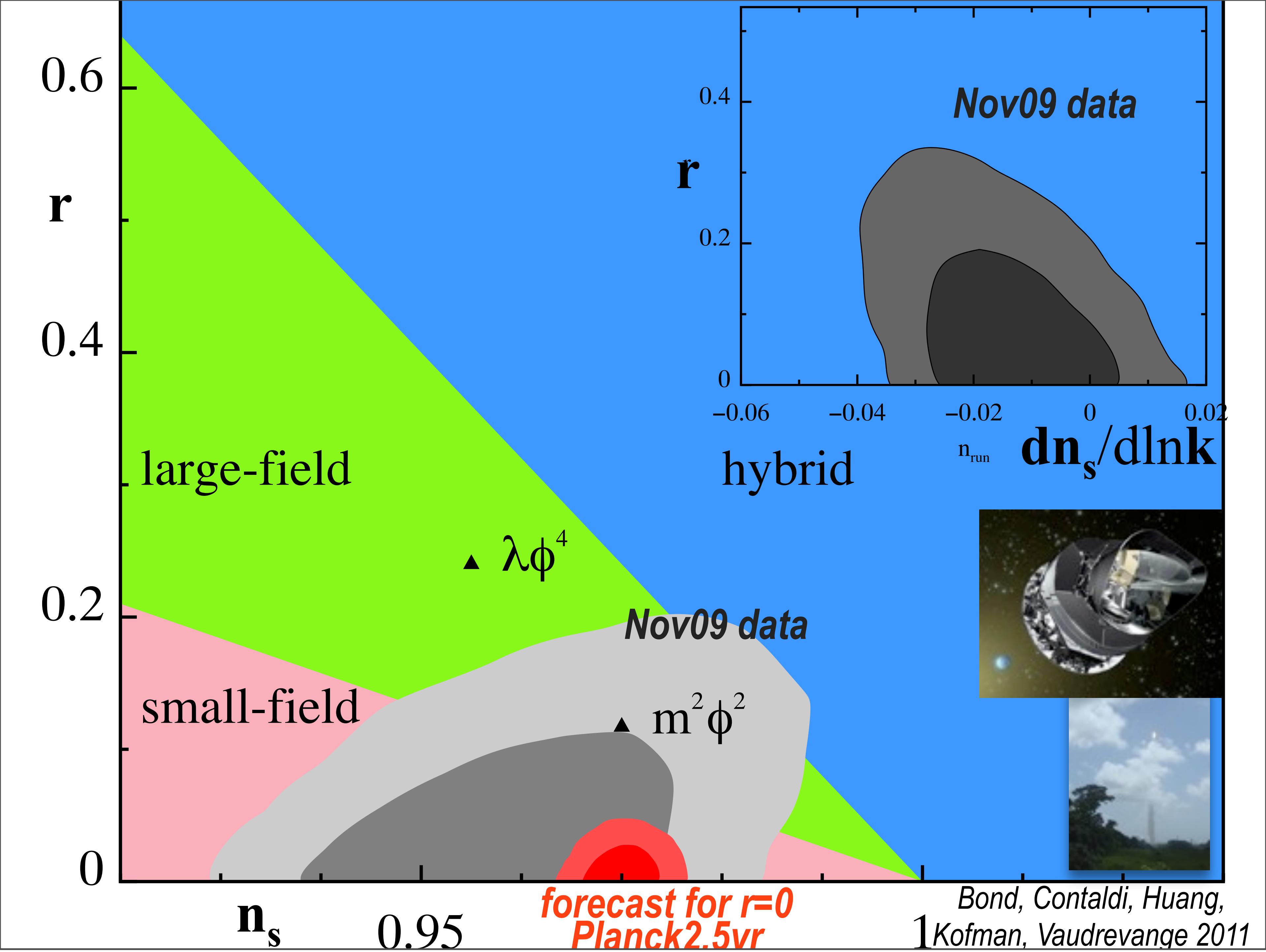
r < 0.27 (with running, all data sets)

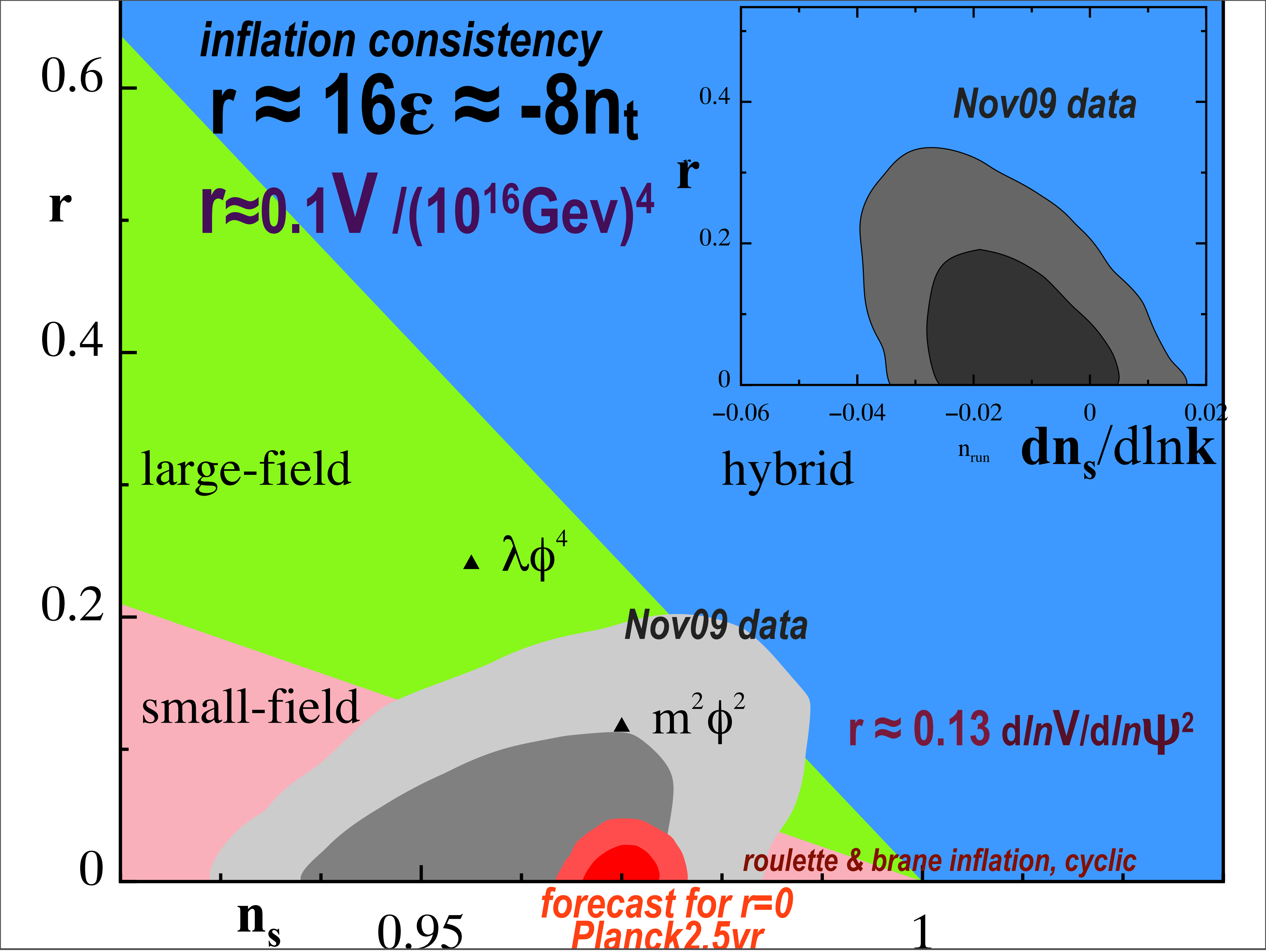
& f_{NL}<1 typical cf. $-4< f_{NL} <80$ (+- 5 Planck)

inflation consistency

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

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

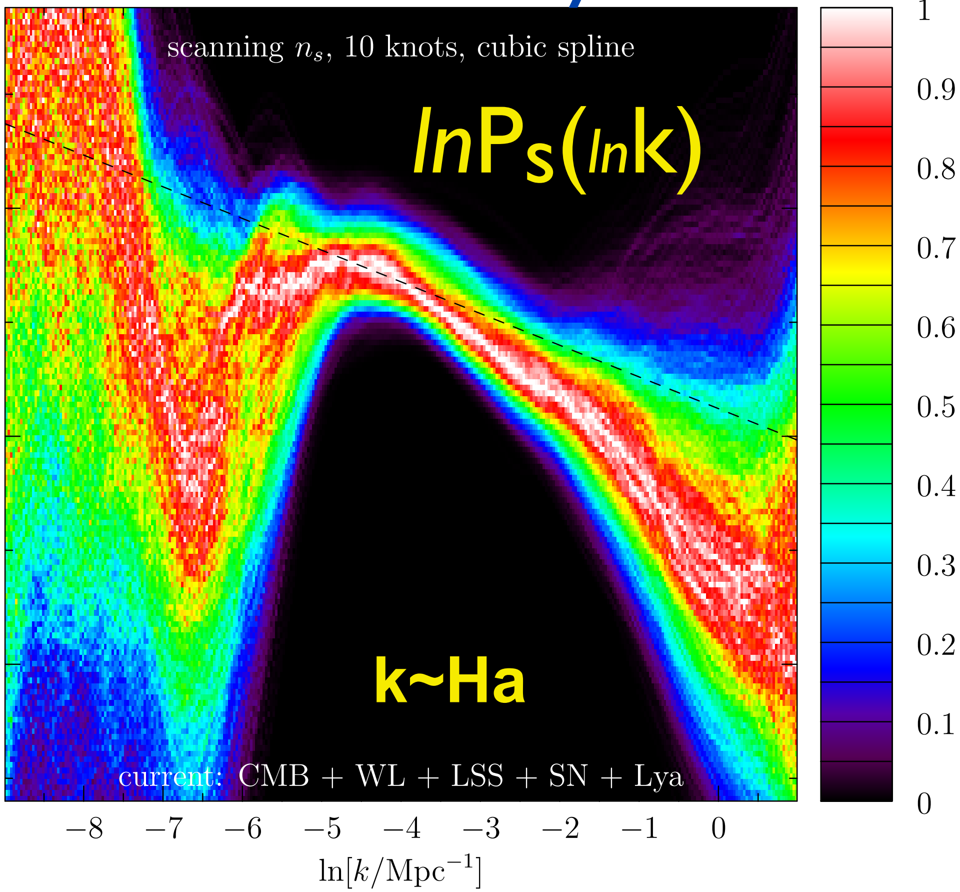

0.6
r
0.4
0.2
0
large-field
small-field
λφ^4
m^2φ^2
Nov09 data
n_s
0.95
1
hybrid
r
0.4
0.2
0
Nov09 data
−0.06
−0.04
−0.02
0
0.02
n_run
dn_s/dlnk
forecast for r=0
Planck2.5yr
Bond, Contaldi, Huang,
Kofman, Vaudrevange 2011

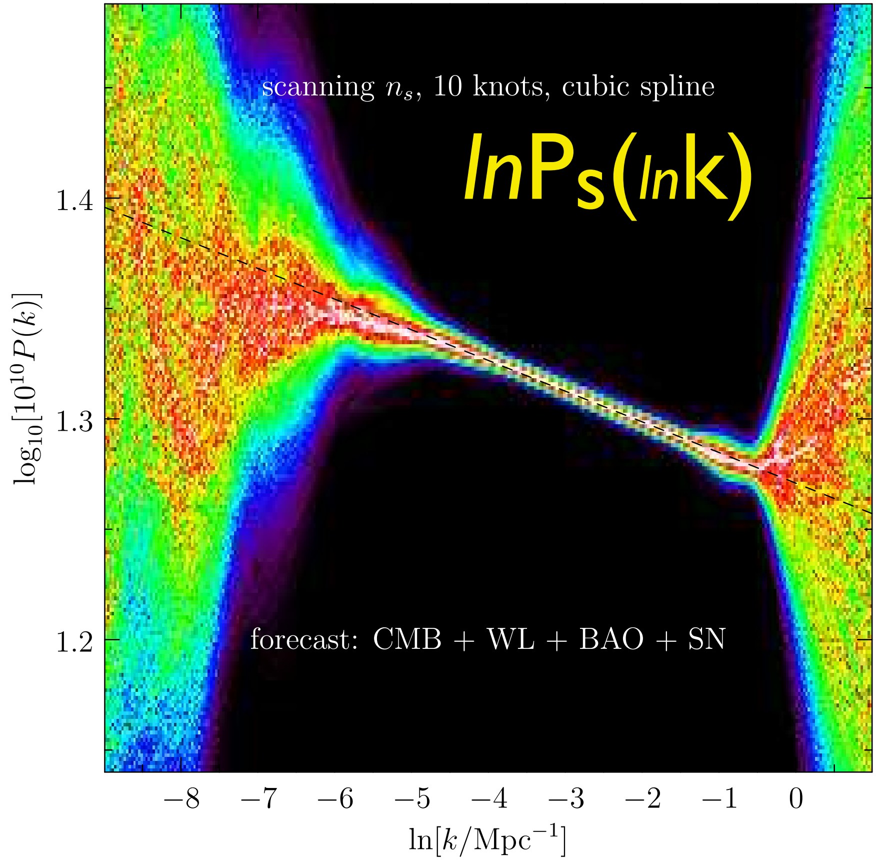

inflation consistency
r ≈ 16ε ≈ -8n_t
r≈0.1V /(10^16Gev)^4
r
0.6
0.4
0.2
0
large-field
hybrid
λφ^4
Nov09 data
small-field
m^2φ^2
r ≈ 0.13 dlnV/dlnψ^2
roulette & brane inflation, cyclic
forecast for r=0
Planck2.5yr
n_s
0.95
1
Nov09 data
0.4
0.2
0
−0.06
−0.04
−0.02
0
0.02
n_run
dn_s/dlnk

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 $\varepsilon(\ln Ha)$, $V(\psi)$



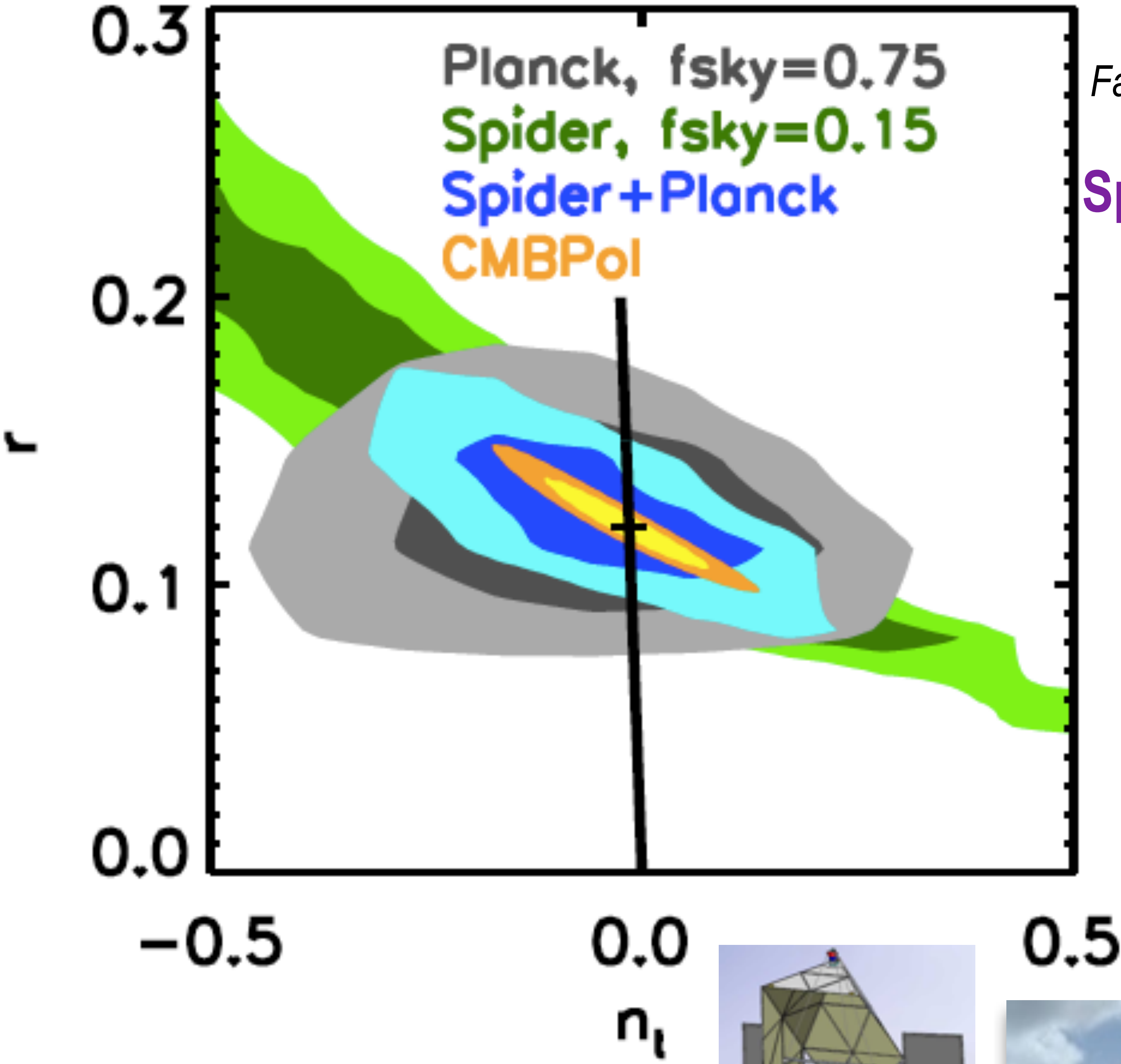


$\varepsilon_\psi \approx \varepsilon = -\,d\ln H / d\ln a$; $V(\psi) \approx 3M_P^2H^2(1-\varepsilon/3)$; $d\psi / d\ln a = \pm\sqrt{\varepsilon}$

GW/S≡r ≈16ε

Bond, Contaldi, Huang, Kofman, Vaudrevange 2011

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



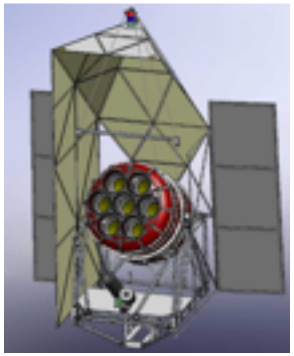
Farhang, Bond, Dore, Netterfield 2011

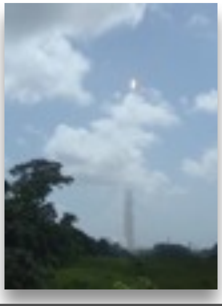
Spider-24days+Planck-2.5yr r-n_t forecast

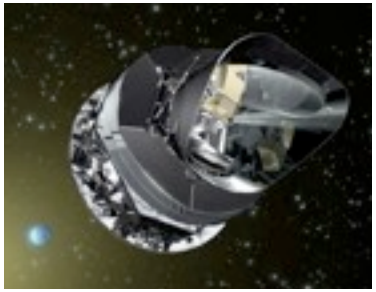
for r=0.12 input for $m^2\varphi^2$

(including fgnds)

r to ± 0.02

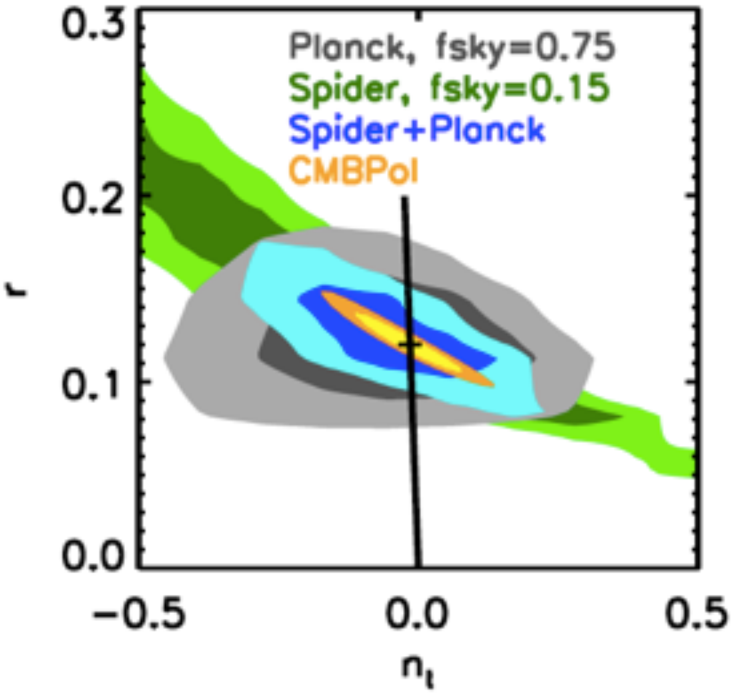




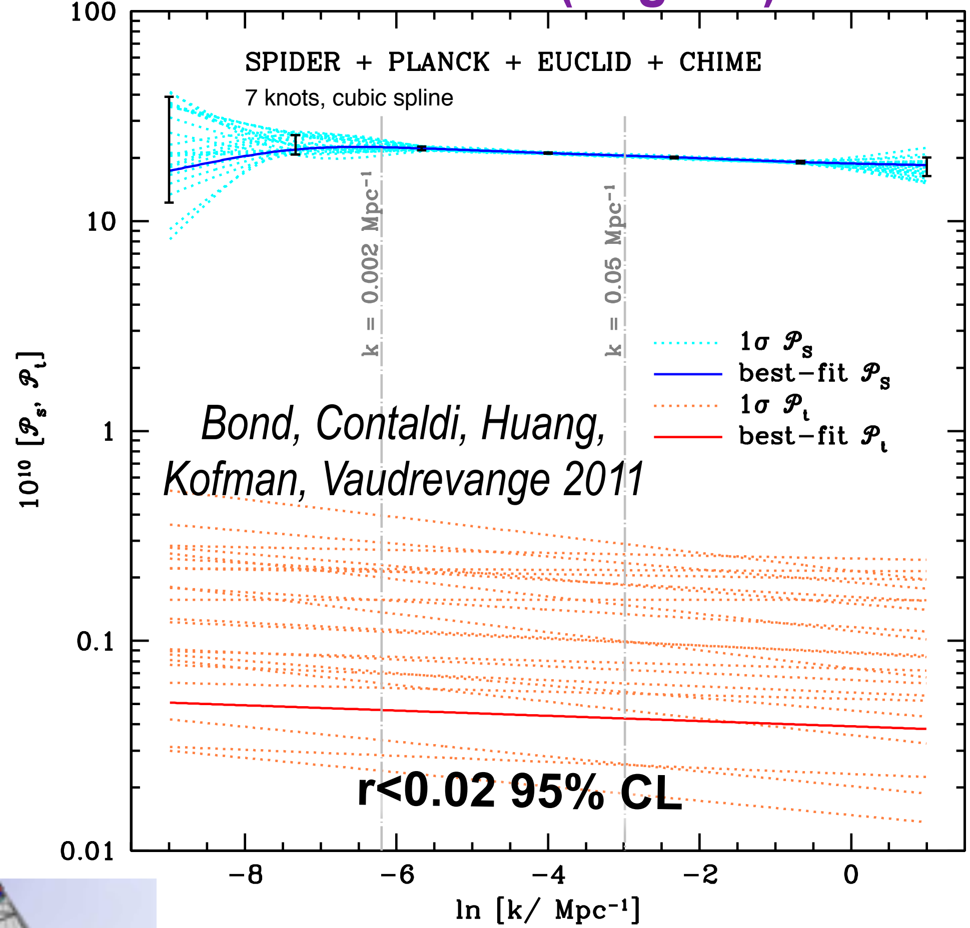


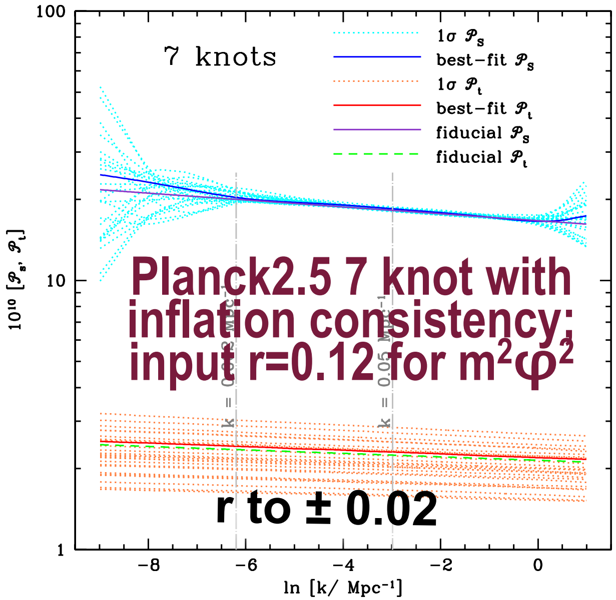
compress data onto non-top-hat k-modes

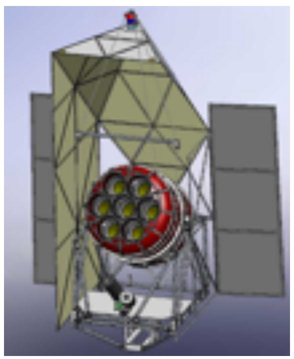
Farhang, Bond, Dore, Netterfield 2011

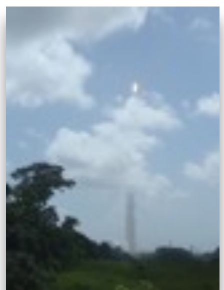


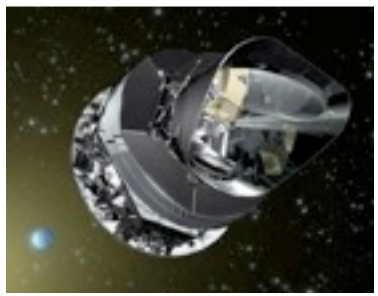
Spider-24days + Planck-2.5yr + ... 7 knot $\ln P_s$ +r-n_t forecast for r=0 (+ fgnds)











CMB peaks (hot&cold) => the WMAP Cold Spot

primordial non-Gaussianity

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

local smooth. use optimal pattern estimator

DBI inflation: non-quadratic kinetic energy

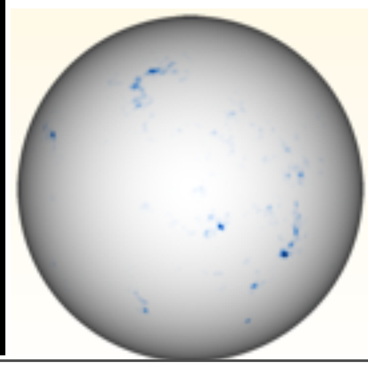
cosmic/fundamental strings/defects

from end-of-inflation & preheating

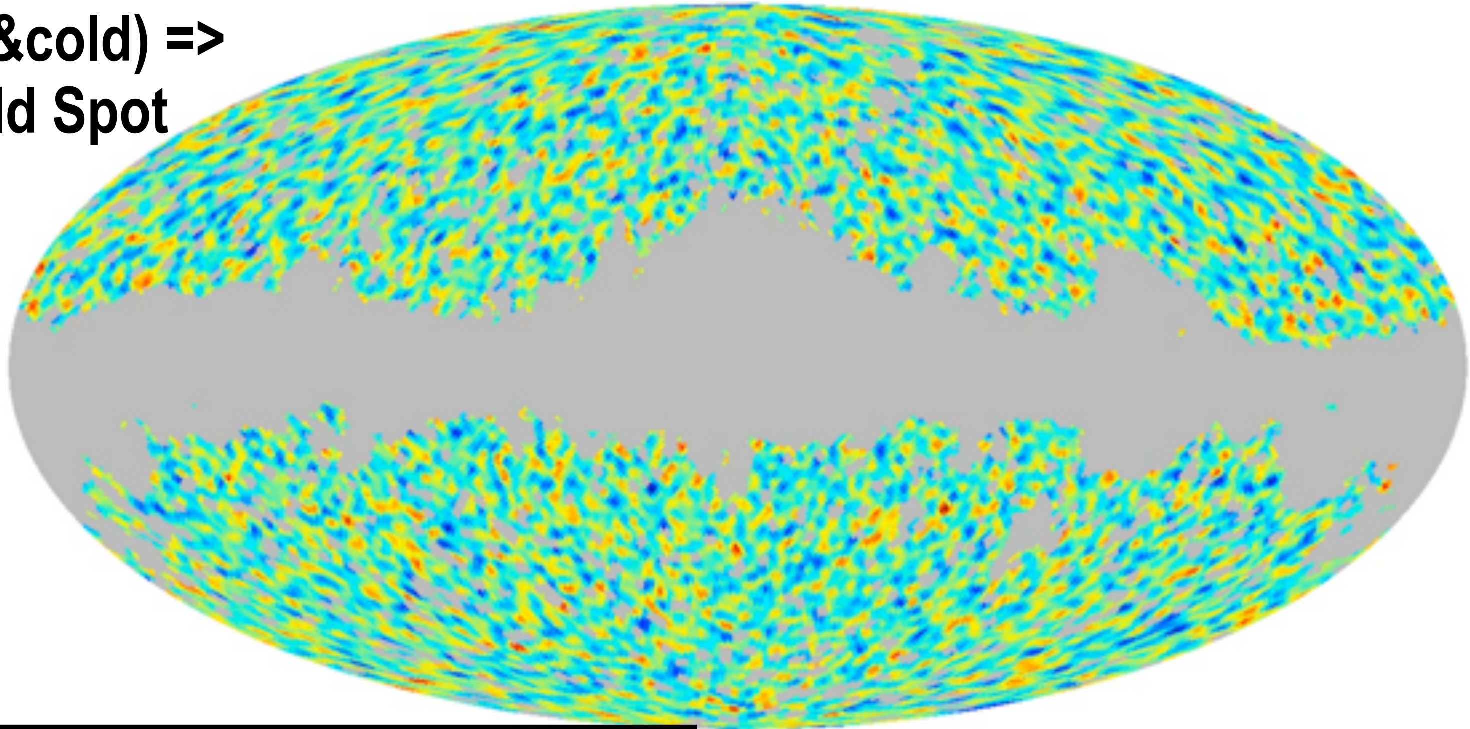
$$\Phi(x)= \Phi_G(x)+ F_{NL}(\chi_b)-<F_{NL}>$$

resonant preheating f_{NLeff} + cold spots

$-4< f_{NL} <80$ (+- 5 Planck)



CMB peaks (hot&cold) =>
the WMAP Cold Spot



primordial non-Gaussianity

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

local smooth. use optimal pattern estimator

DBI inflation: non-quadratic kinetic energy

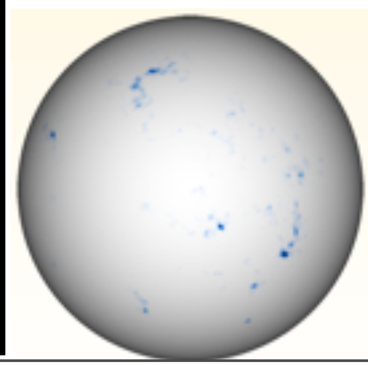
cosmic/fundamental strings/defects

from end-of-inflation & preheating

$-4 < f_{NL} < 80$ (+- 5 Planck)

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

resonant preheating $\mathbf{f_{NLeff}}$ **+ cold spots**



end 2