Title: The Planck Satallite: First Science Results and Future Prospects

Date: Feb 15, 2011 04:10 PM

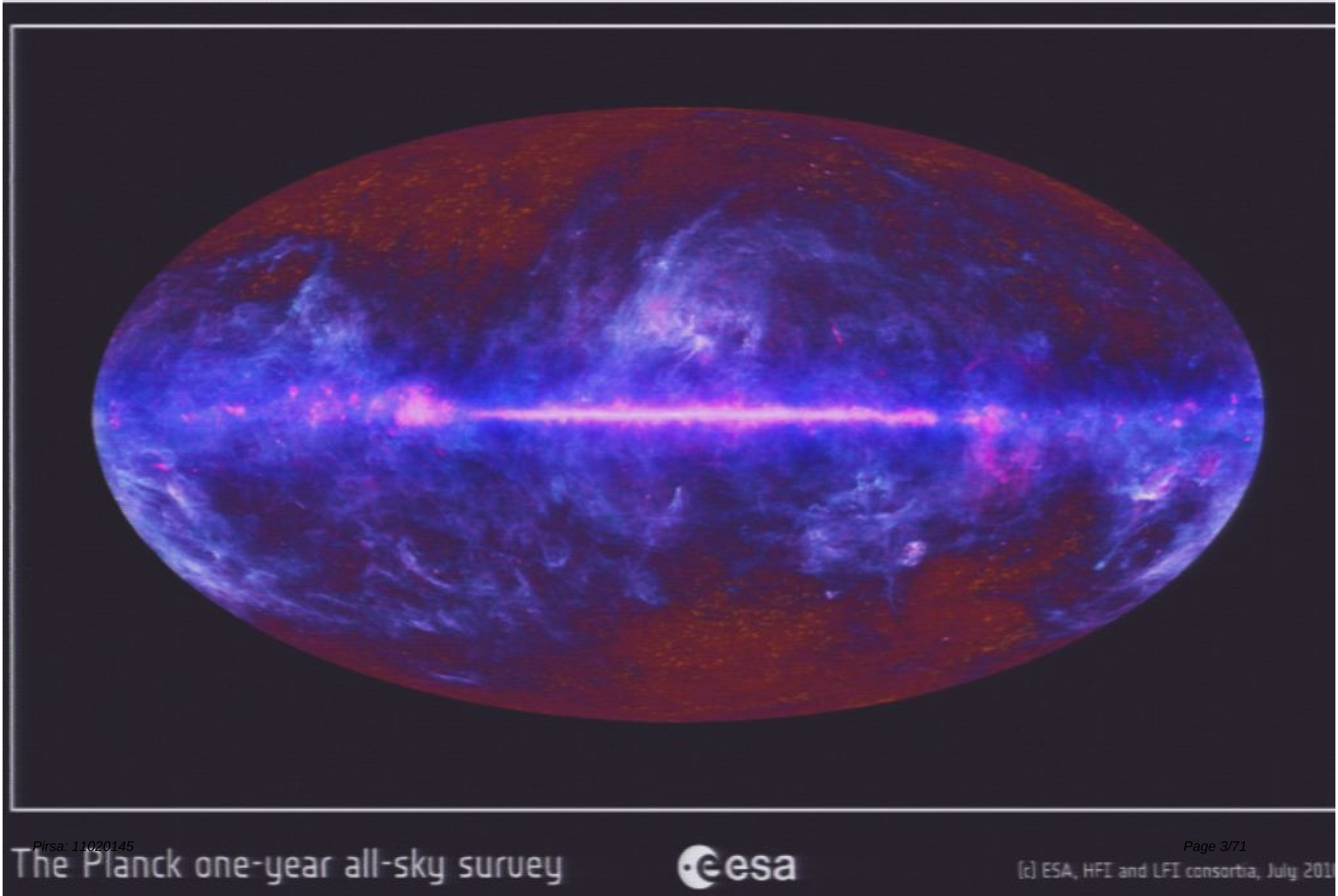
URL: http://pirsa.org/11020145

Abstract:

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

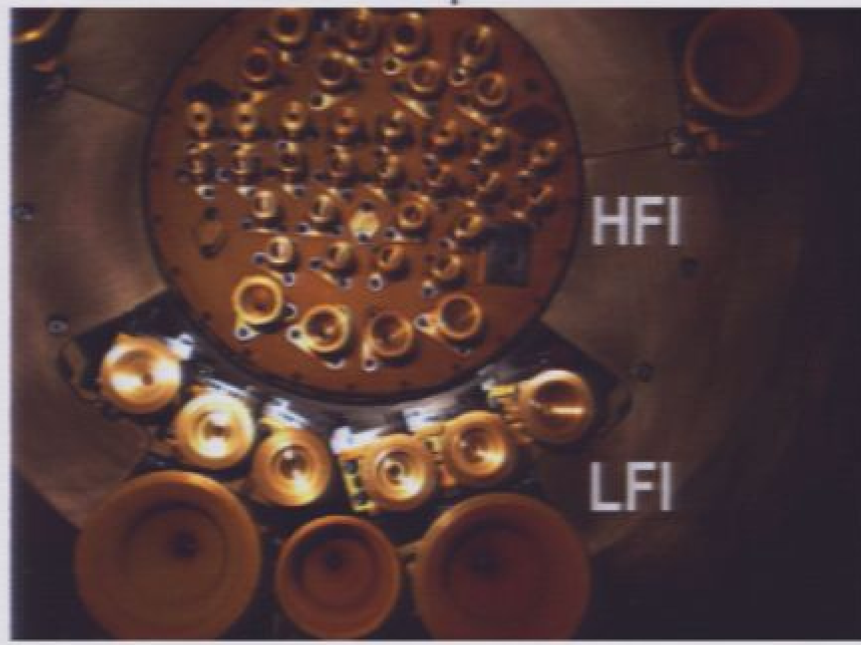
Left earth at ~10 km/s, 1.5 million km in 45 days, cooling on the way (20K, 4K, 1.6K, 0.1K 4 stage).

@L2 on July 2 09 -almost no trajectory correction @operational temp; Survey started on Aug 13 09 at **Planck2011** (Paris, Jan 10-14) & the **AAS** 25 papers & the ERCSC were unveiled

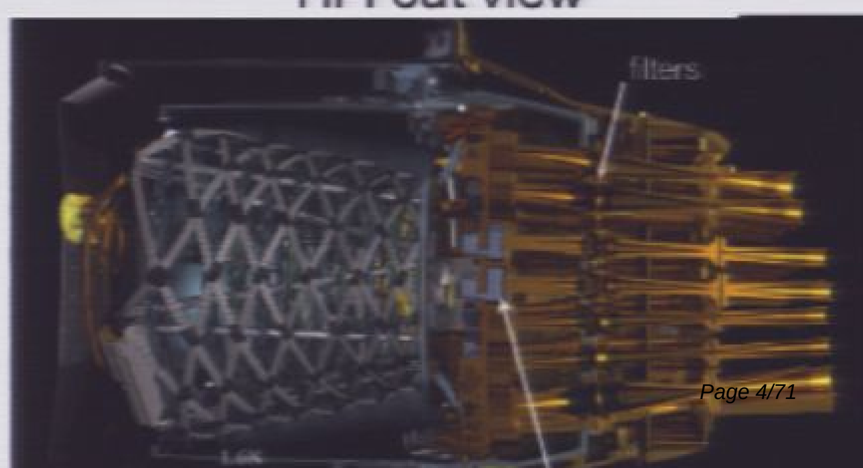


Planck

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 projec
of the European
Space Agency --
ESA -- with
instruments
provided by two
scientific
Consortia funded
by ESA member
states (in
particular the lea
countries: Franc
and Italy) with
contributions fror
NASA (USA), and
telescope
reflectors provide
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

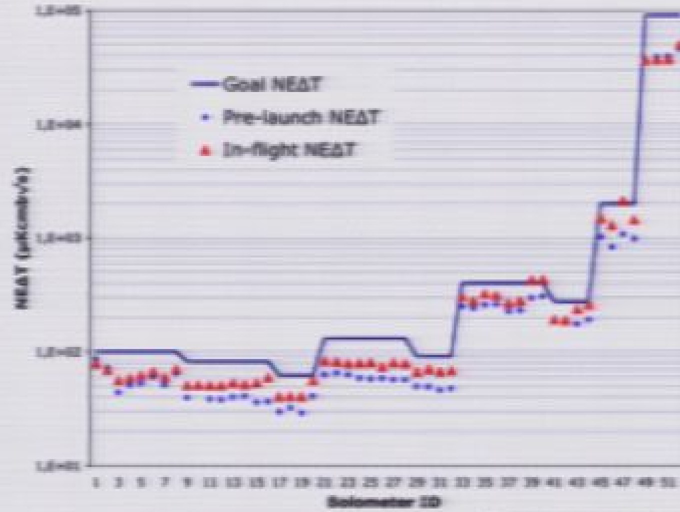
- The scientific analysis is common to both instruments but not the data processing (DPCs in Paris, Trieste)
- Toronto is in Planck-HFI, the higher resolution and higher frequency instrument (52 bolometers, 100-857 GHz
- Project led by Dick Bond with financial support from the Canadian Space Agency
- 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

planck

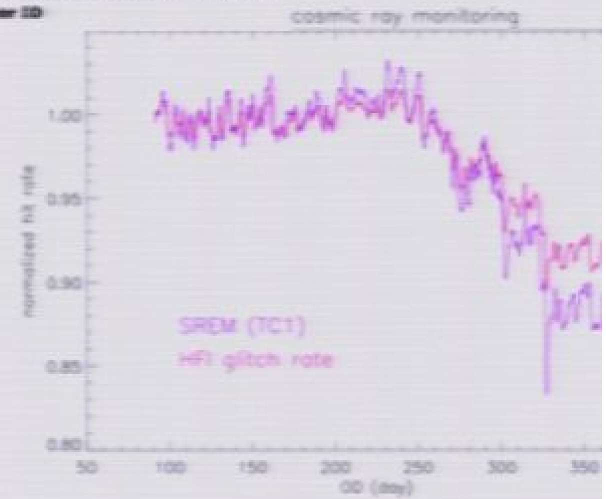
25 papers & a large fraction of the papers at Planck2011 were unveiled for 10 months & 9-freq T data, + a press conference, highlighting: **HFI & LFI work flawlessly** with great results on ERCSC (~15000 sources, 189 SZ clusters), CIB, SZ, AME & the dusty MW, & much more, so many areas, enabled by so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

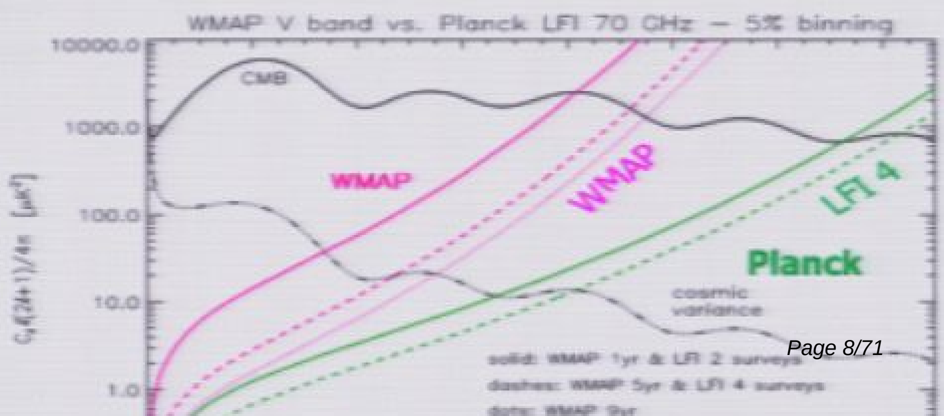


- **CRs: Glitch rate at ~80/min on each bolometer; produces thermal fluctuations**
  - contribute to 1/f noise (significant CSA-HFI role in discovering and characterizing the effect)



- **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: 10% better than Blue Book widely**

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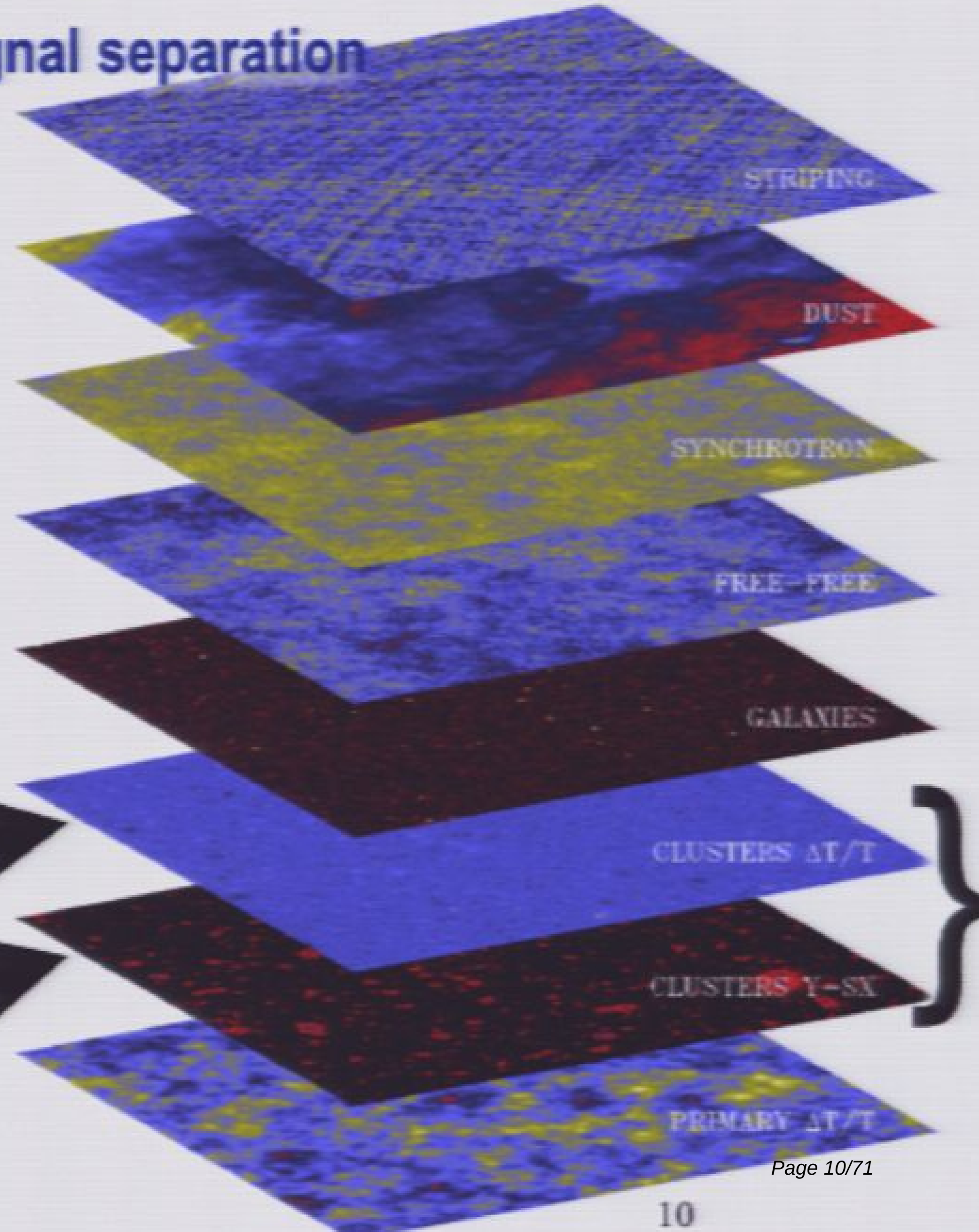
PlanckEXT, EXT=many observatories & expts enabling the astro

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

the quest for the primordial within the primary CMB requires exquisite foreground removal, the ques
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



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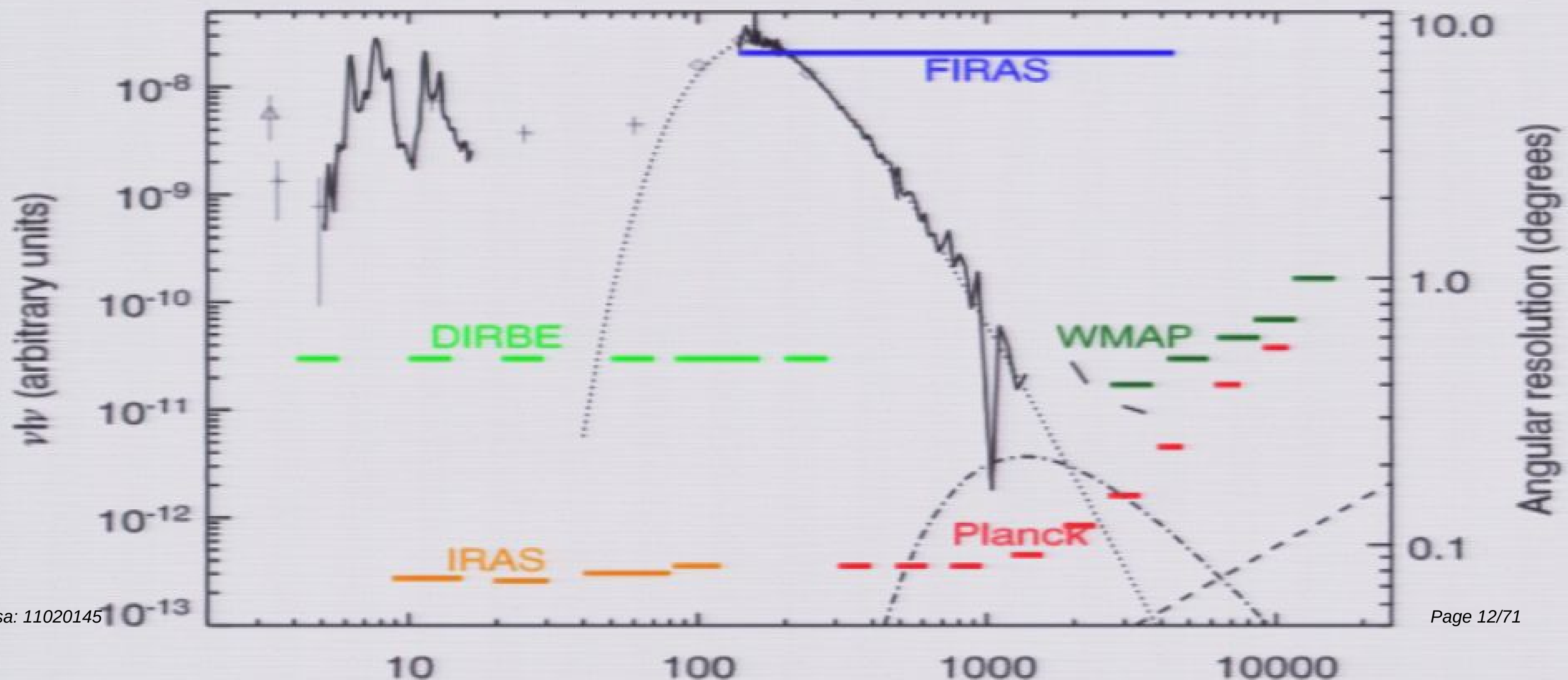

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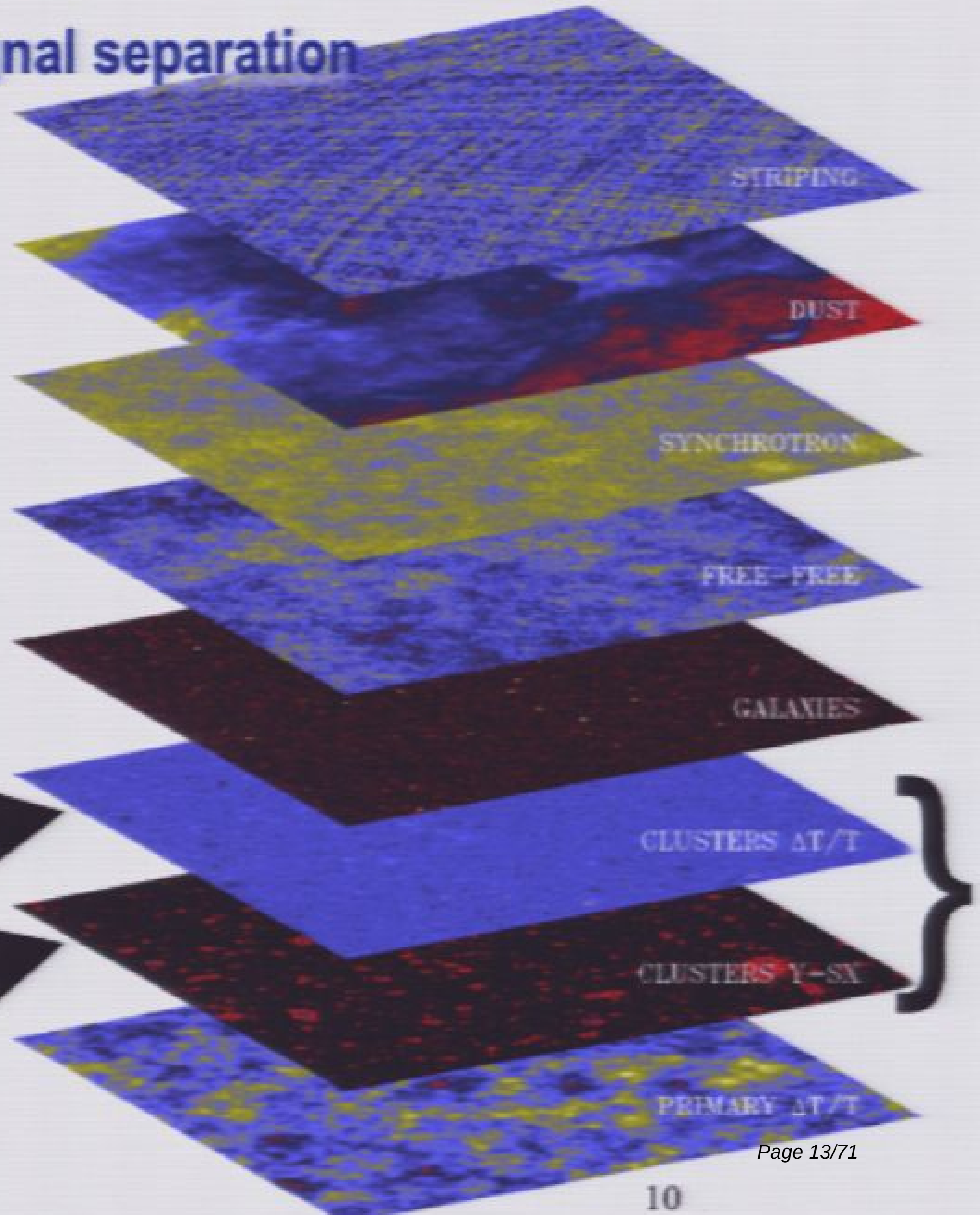
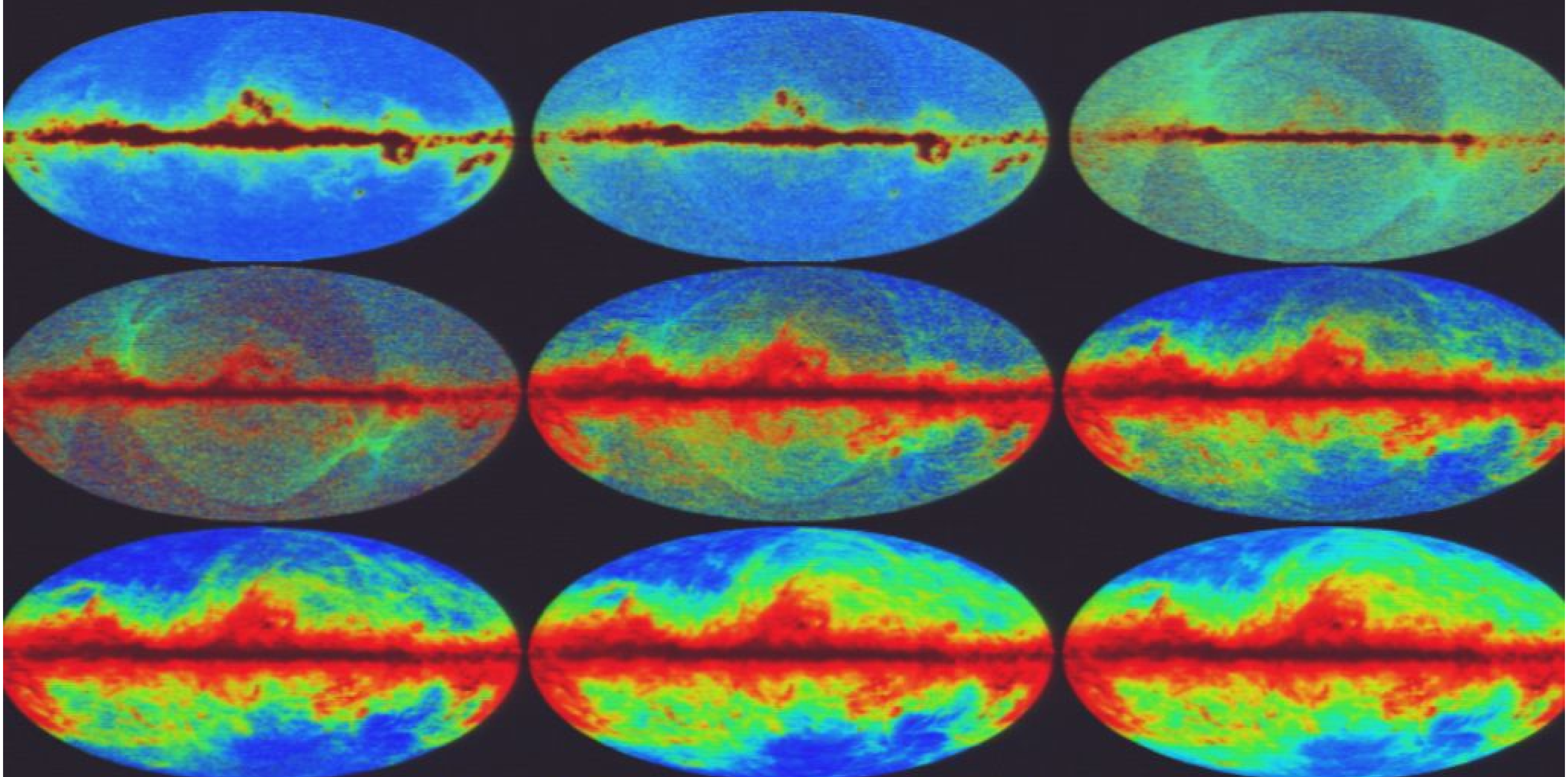


The Planck Foregrounds sky

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?

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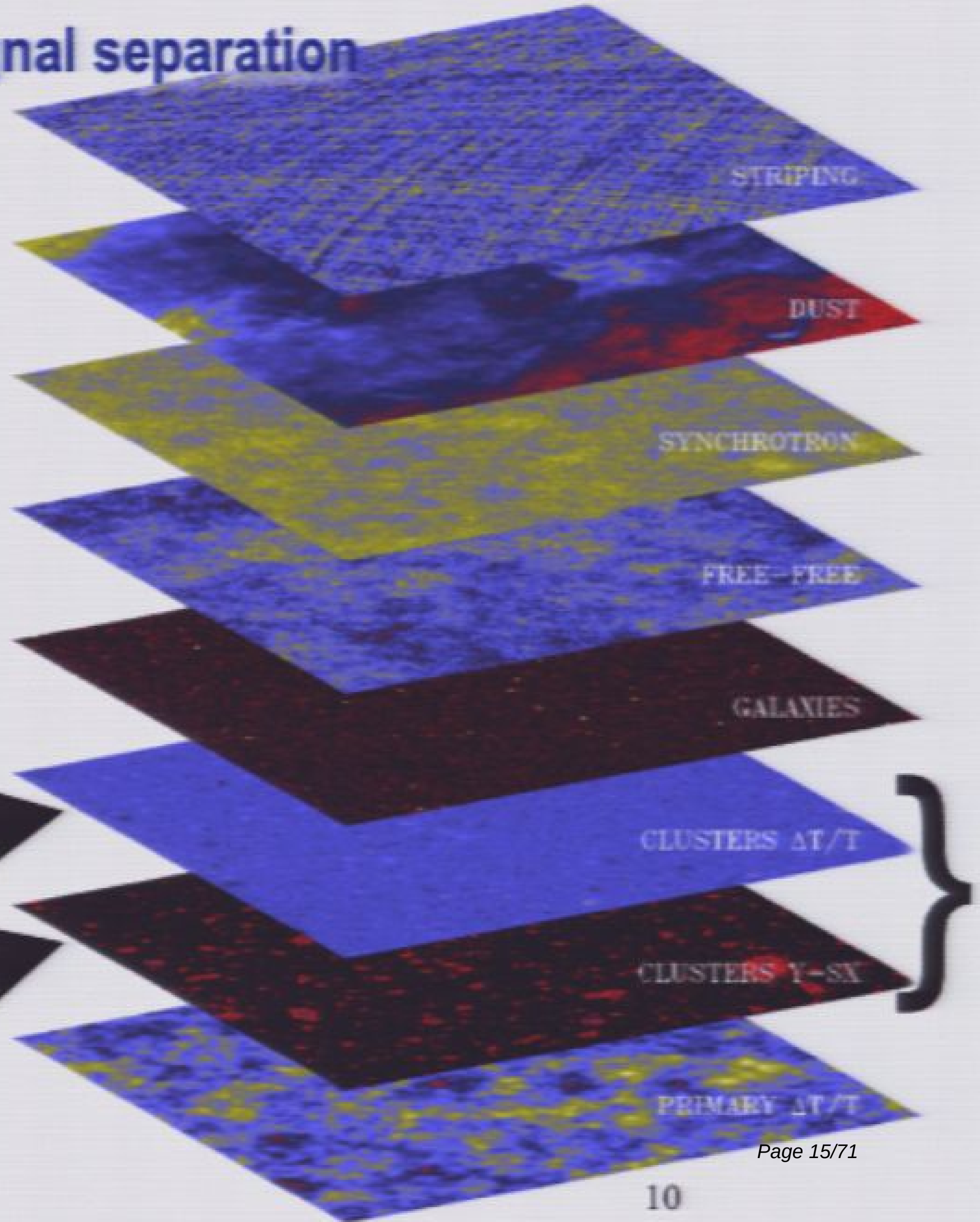

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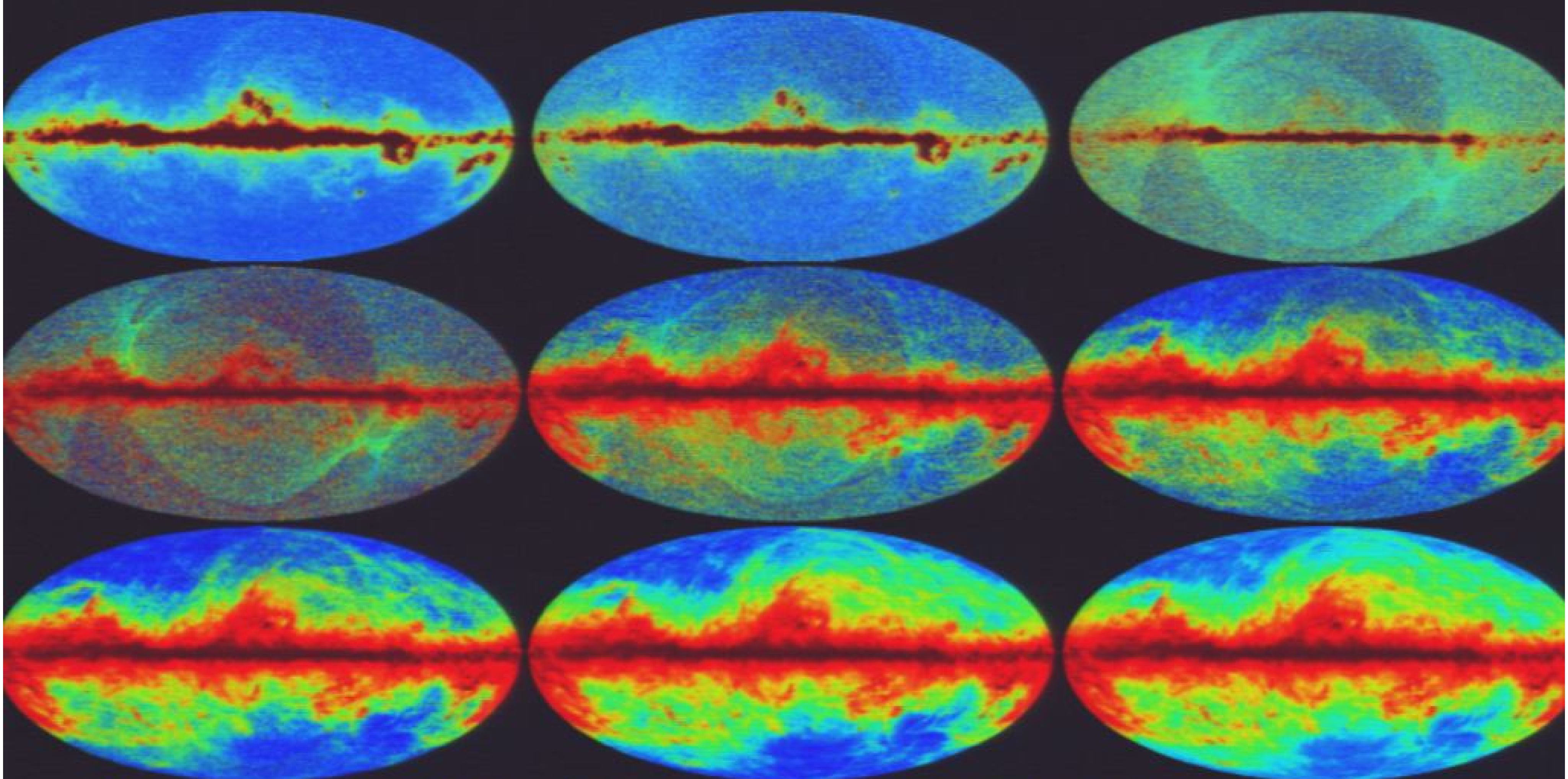

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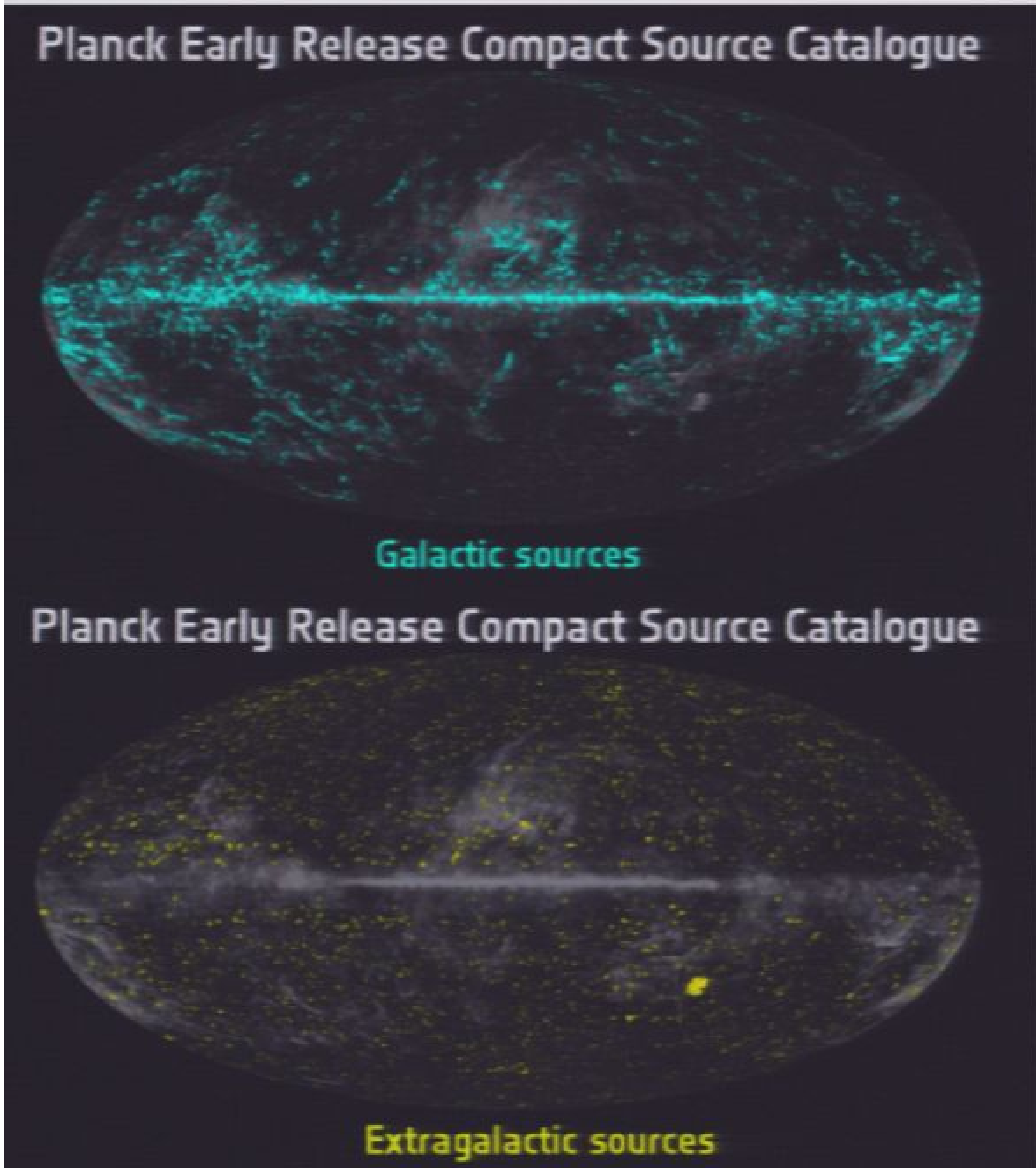
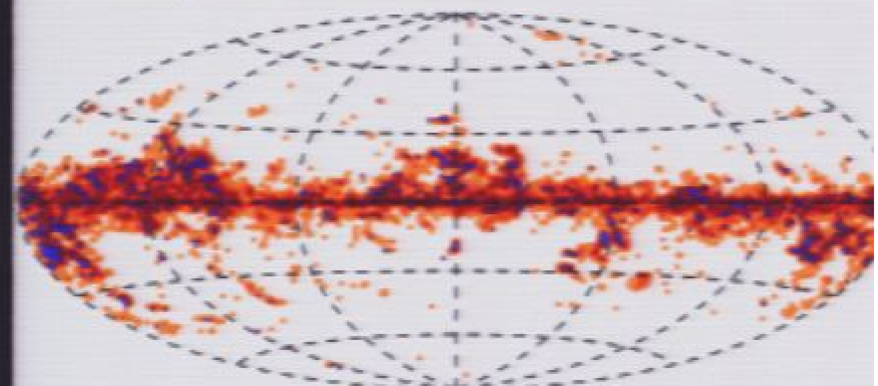


- Reliability > 90% (using MC) with photometric accuracy <30%, no completeness stats and not flux limited.
- => radio/submm extragalacti sources, Galactic sources, +
- Have to take care at 100 GHz of possible CO.



- **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

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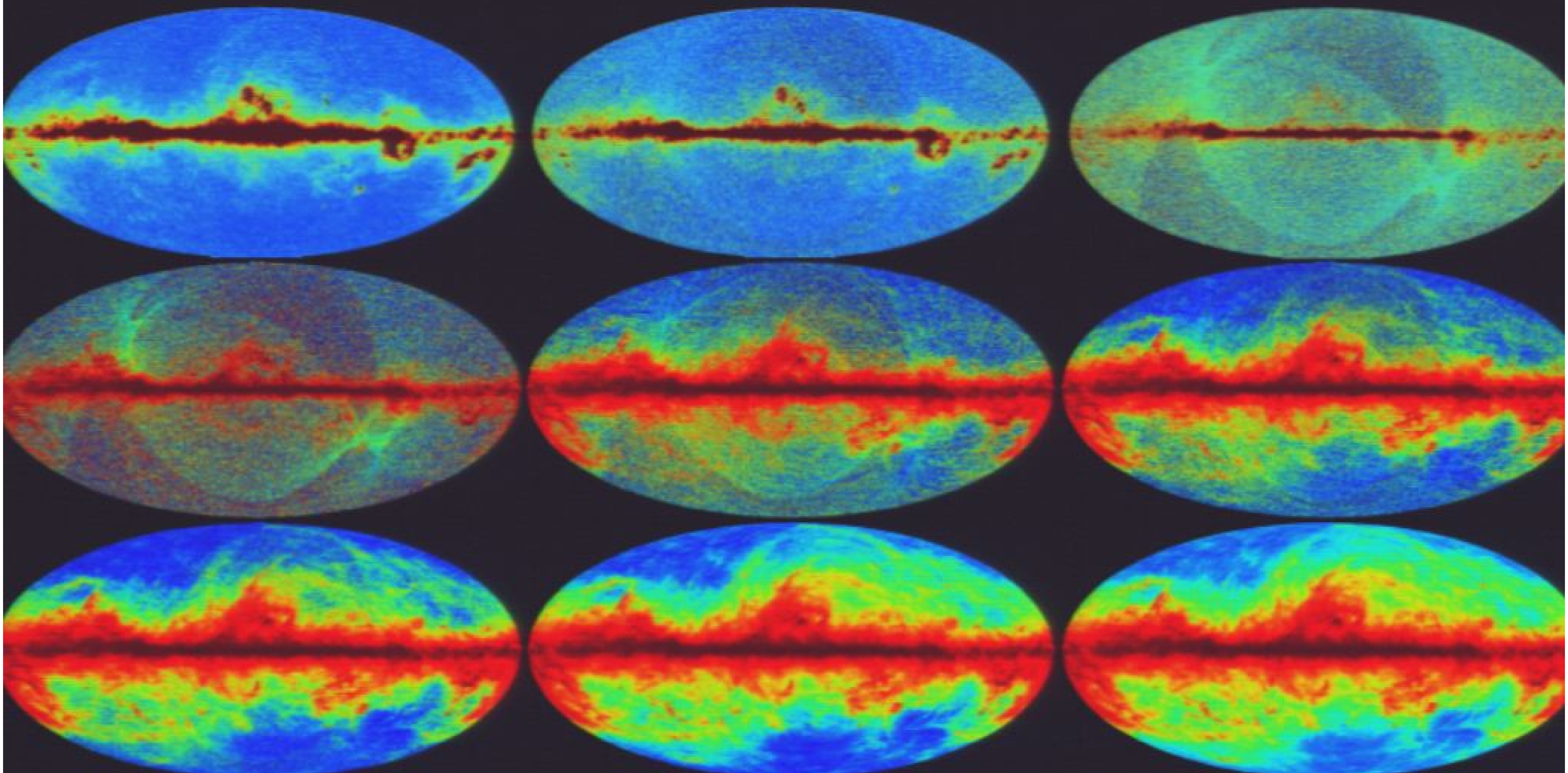

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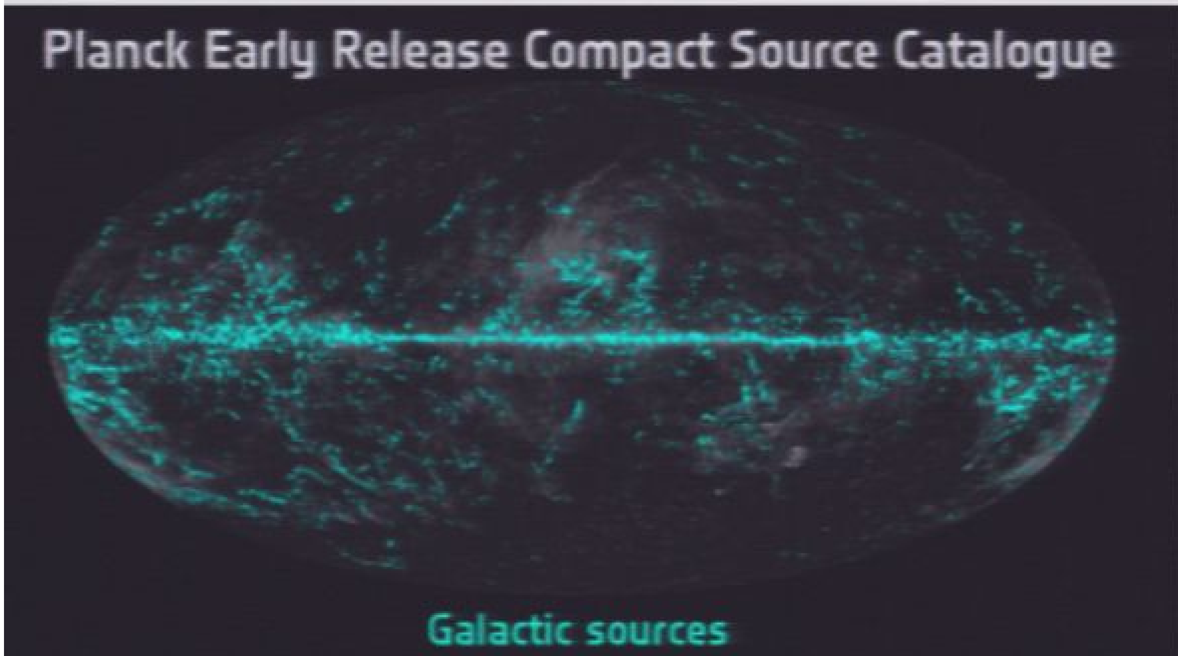

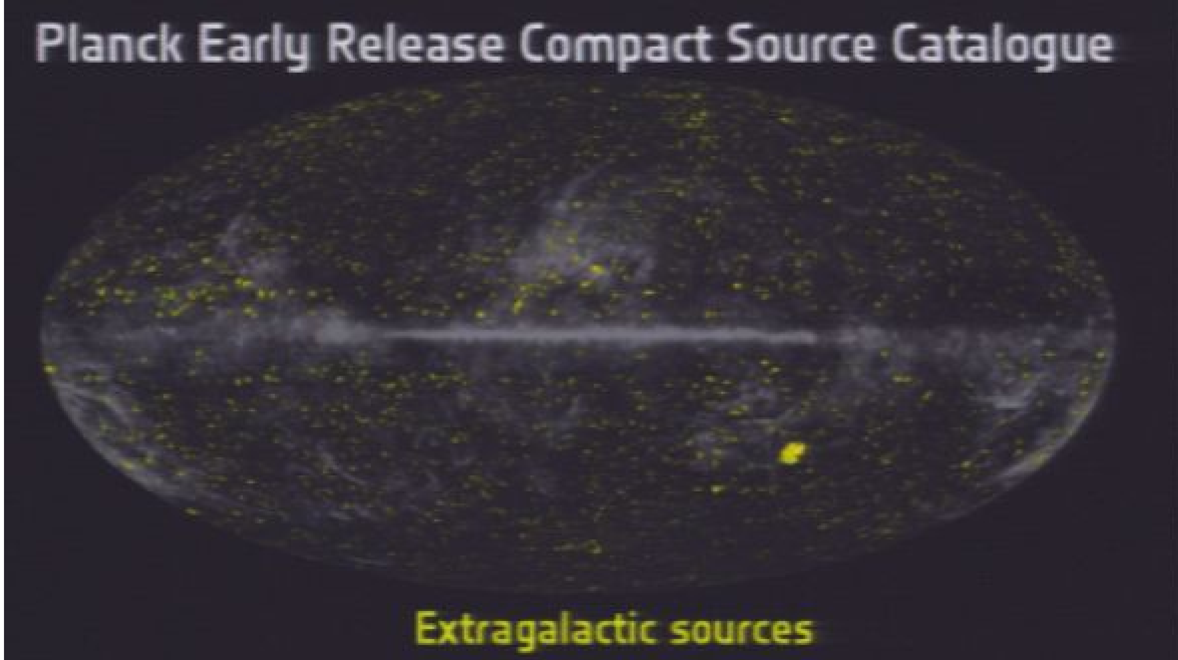

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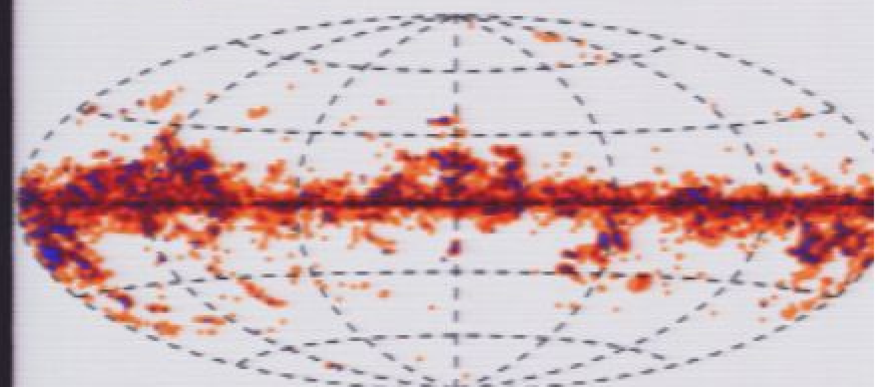

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Delta T over Tea Toronto May 1987: first dedicated CMB conference, exptalists+theorists, primary+secondary ΔT/T

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 - $5^{\circ} - 10^{\circ}$ results, future experiments at $\sim 1^{\circ}$, 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-dominar cc-clusterin*

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

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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-dominan*

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

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Planck, ACT, SPT, ACTxBLAST, Herschel

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- 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

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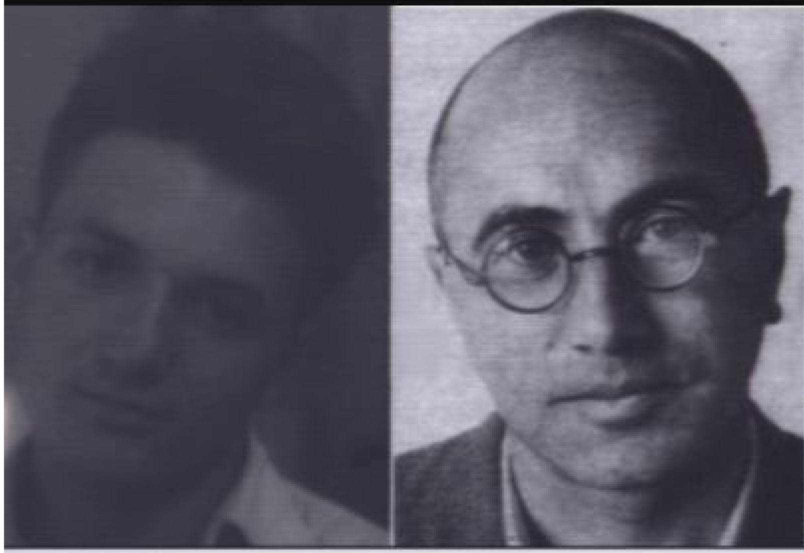
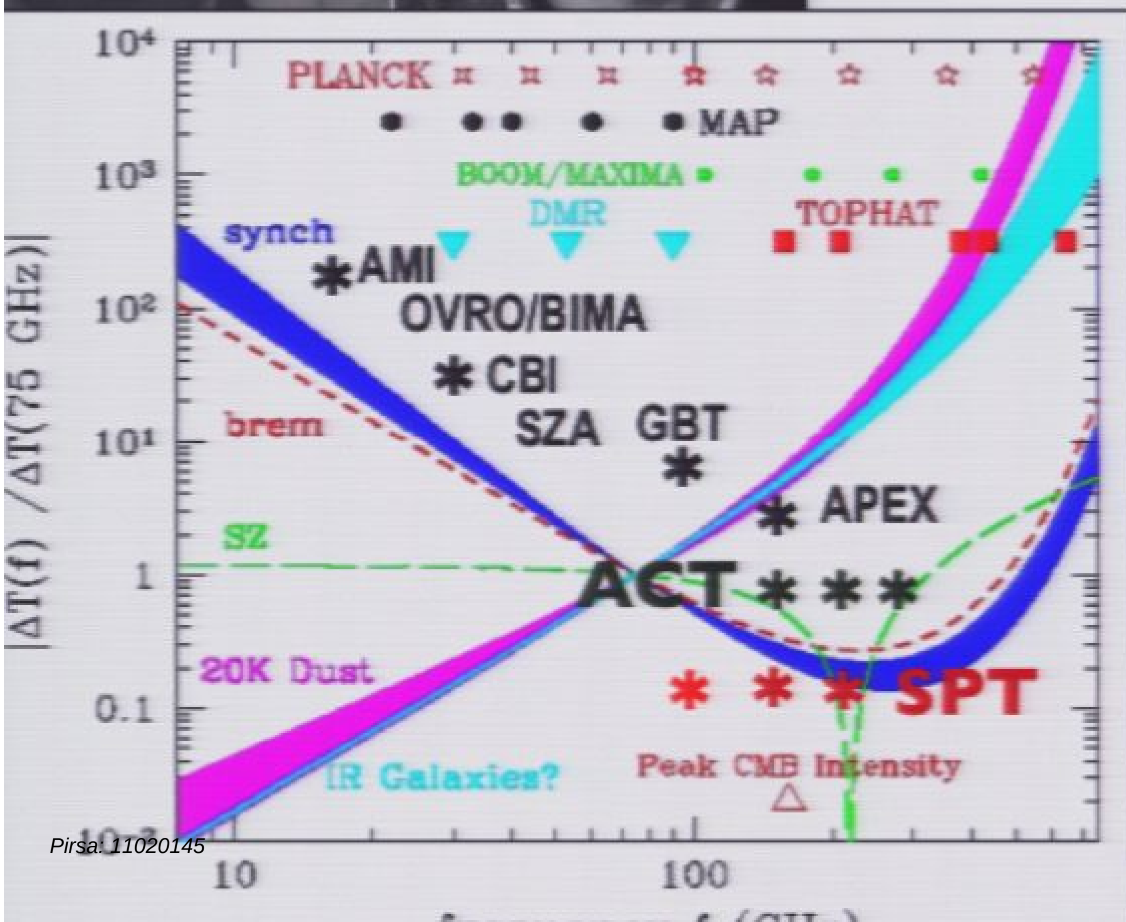


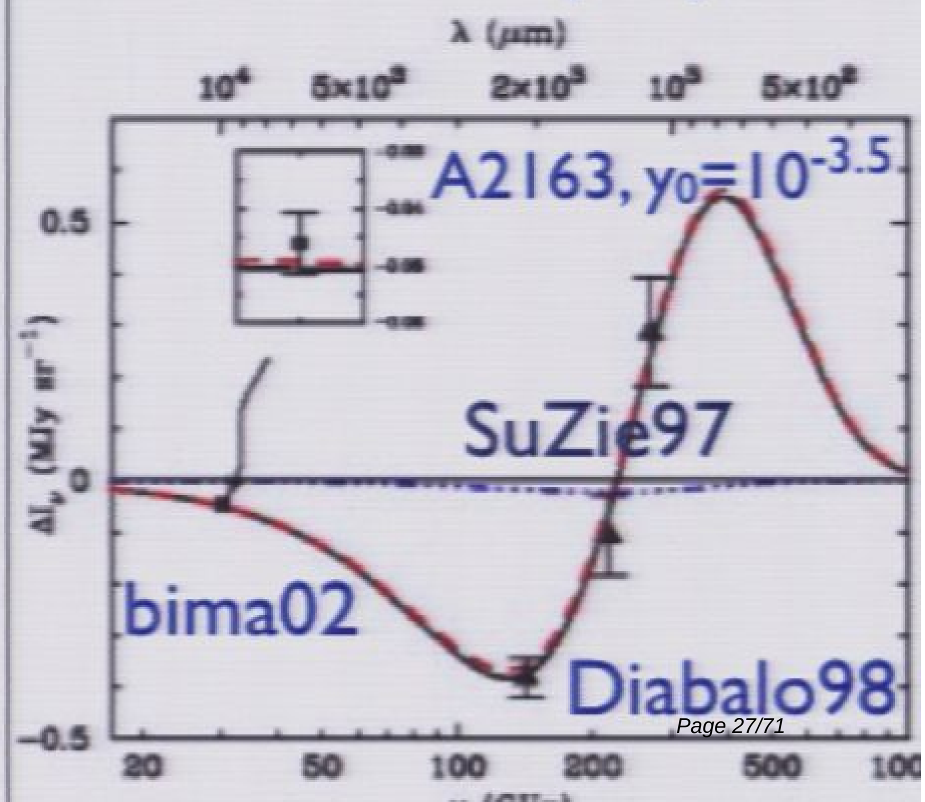
Planck & the thermal Sunyaev-Zeldovich Probe of Gas in the Cosmic Web: $y \sim \int p_e$ dline-of-sight

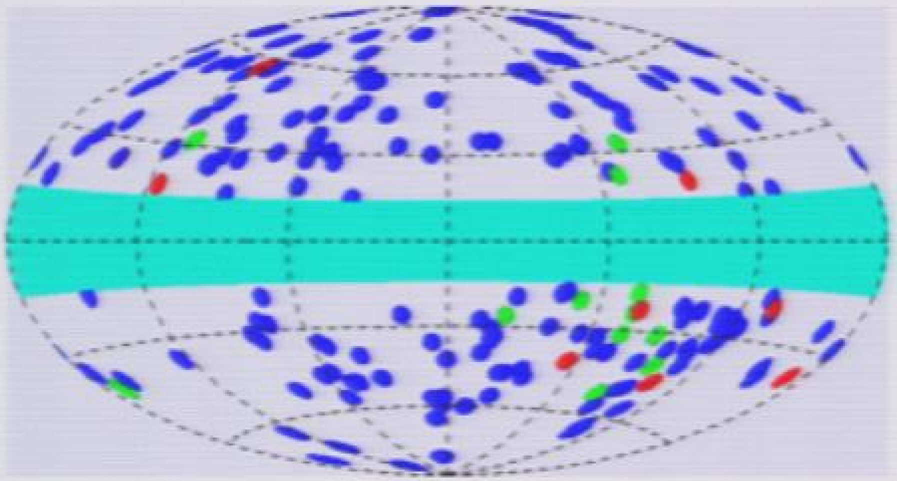
$\Delta T/T = y * (x(e^x+1)/(e^x-1)-4)$, $x = h\nu/T$

$= -2y$ to xy, 0 @ $\nu = 217$ GHz

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







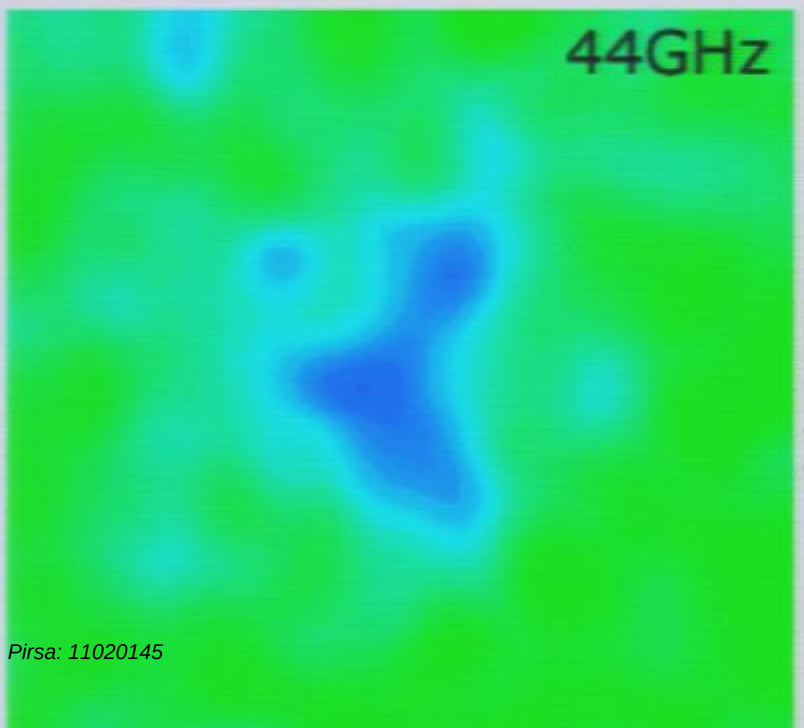
ESZ 20 new + 169 in X/Opt cats

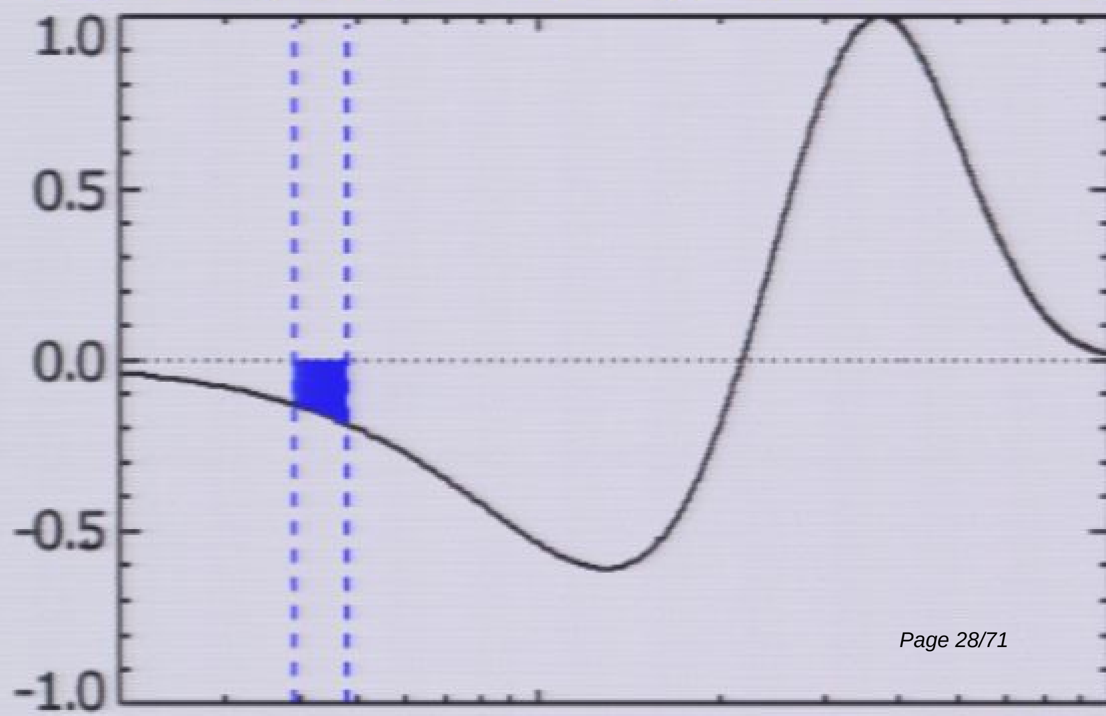
(& ~80% new in SZ, $E_{thermal}$ view)

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





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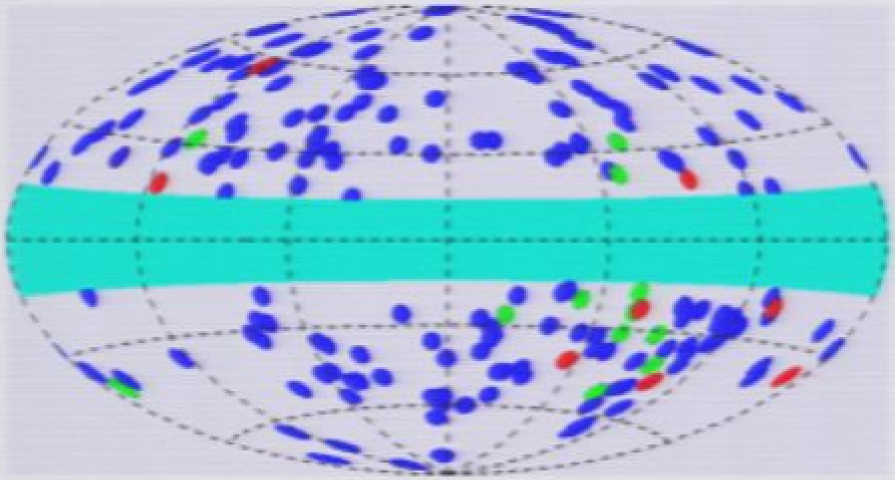

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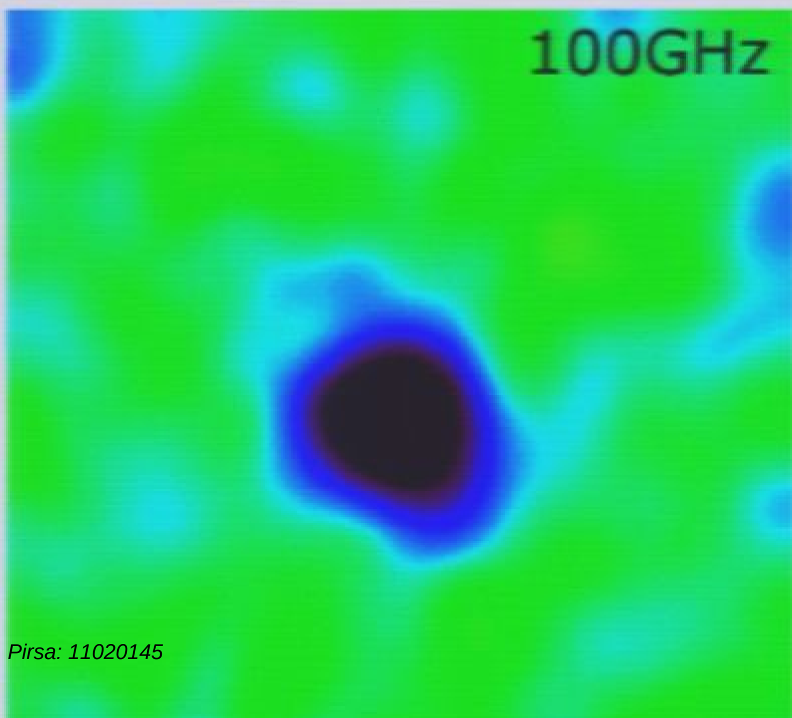

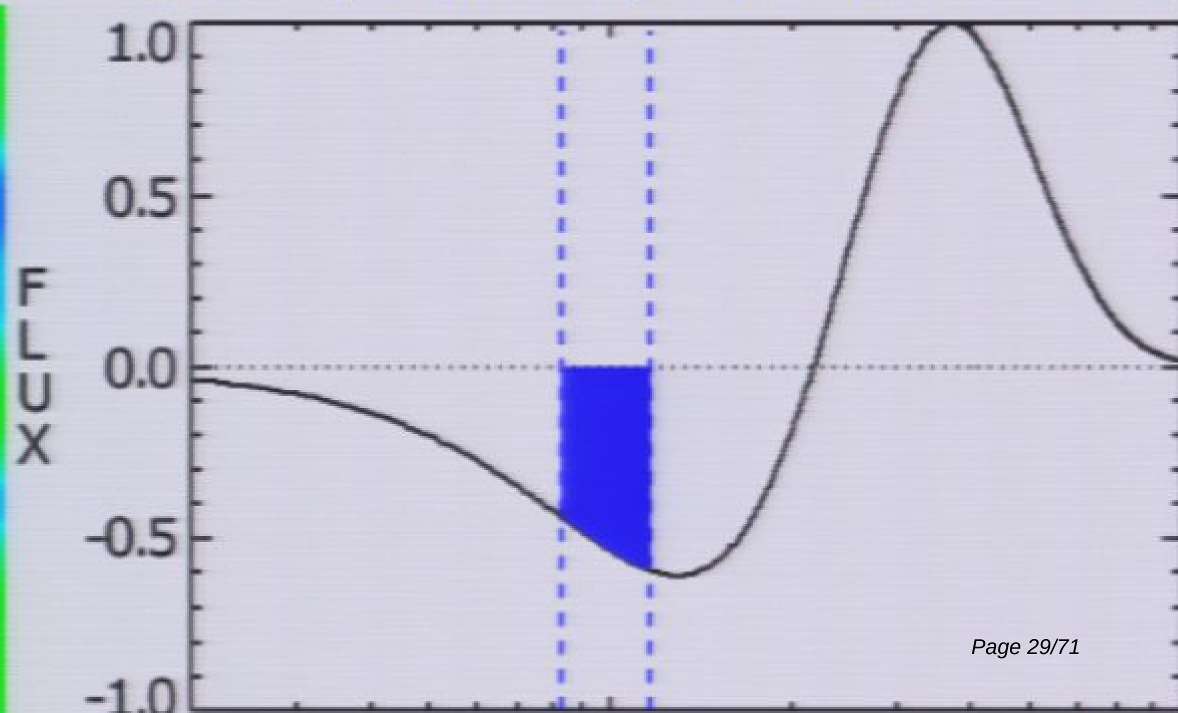

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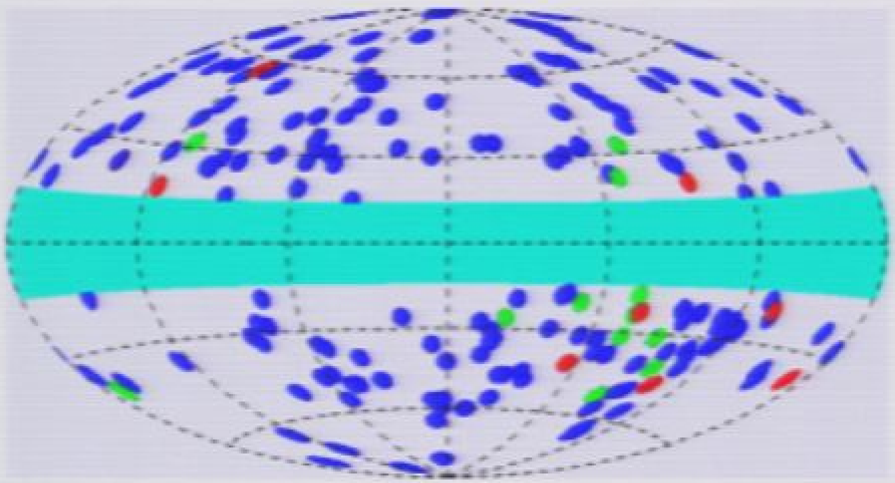

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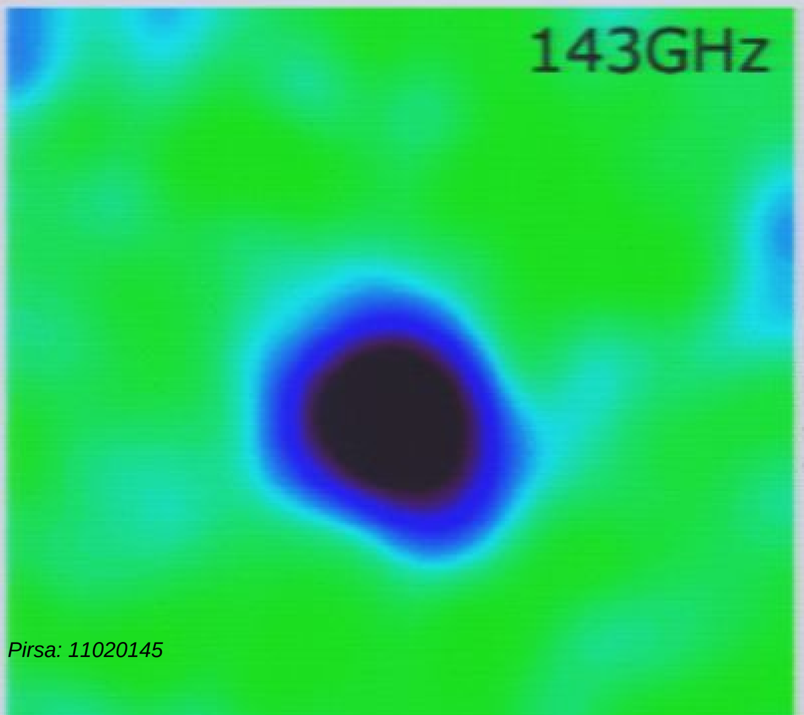
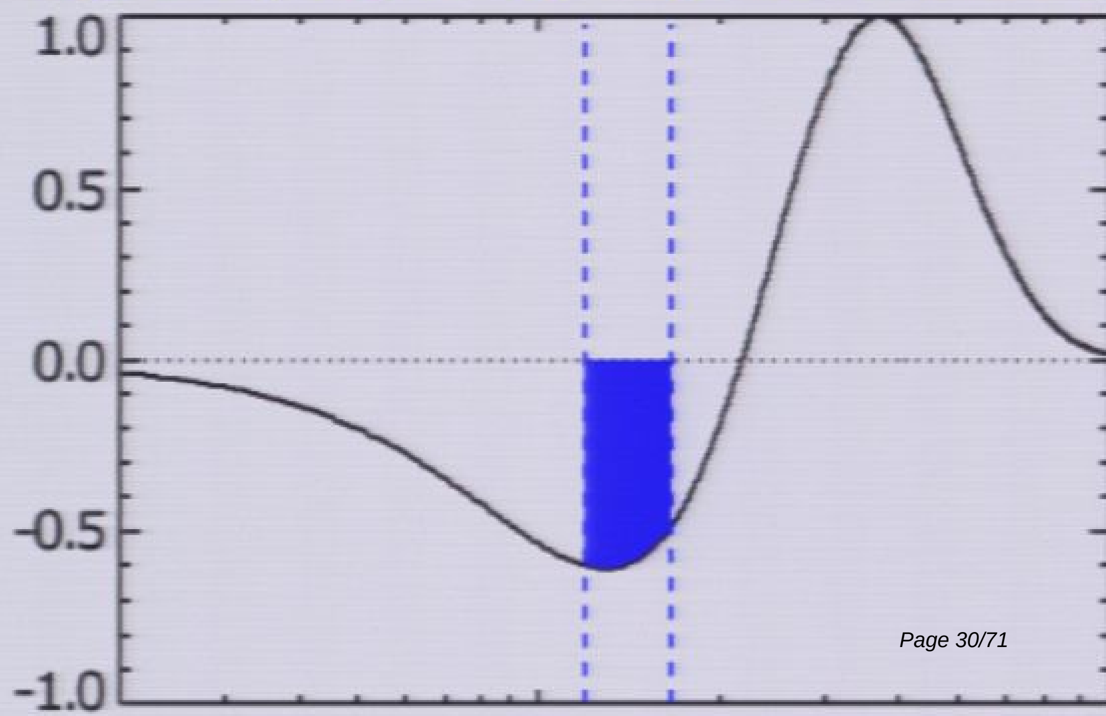
A2319





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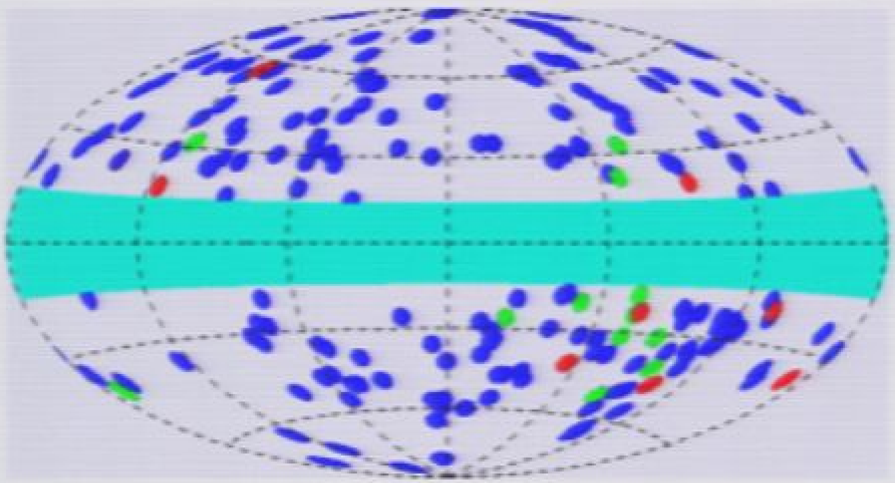

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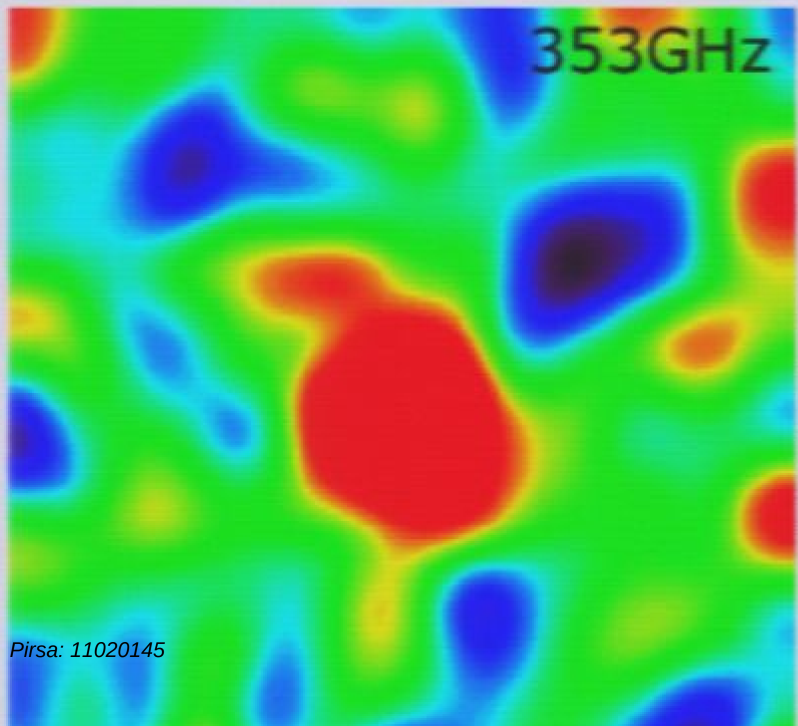

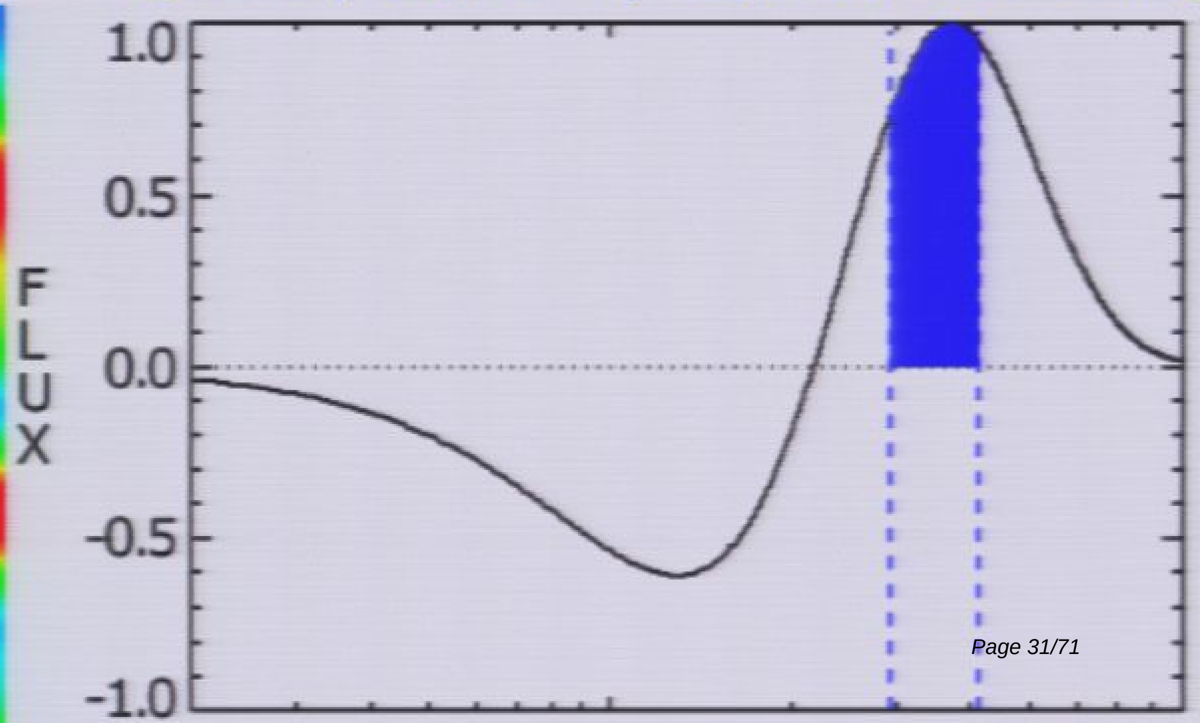

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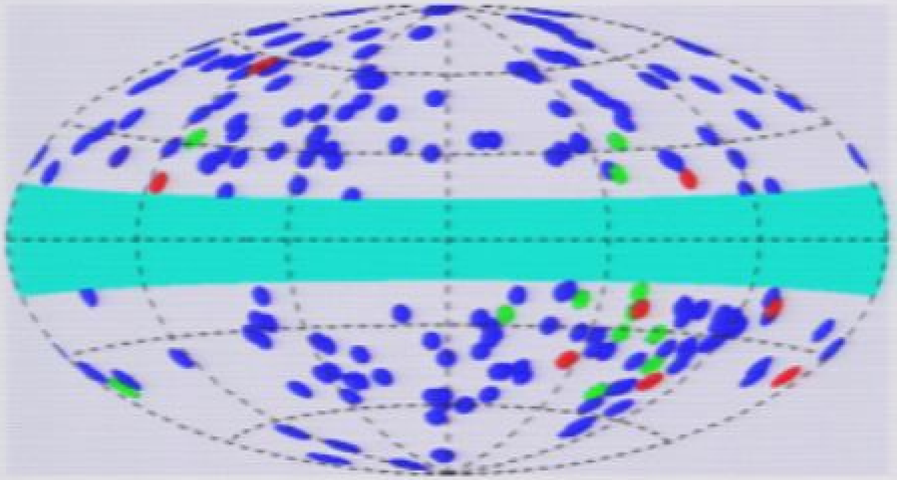

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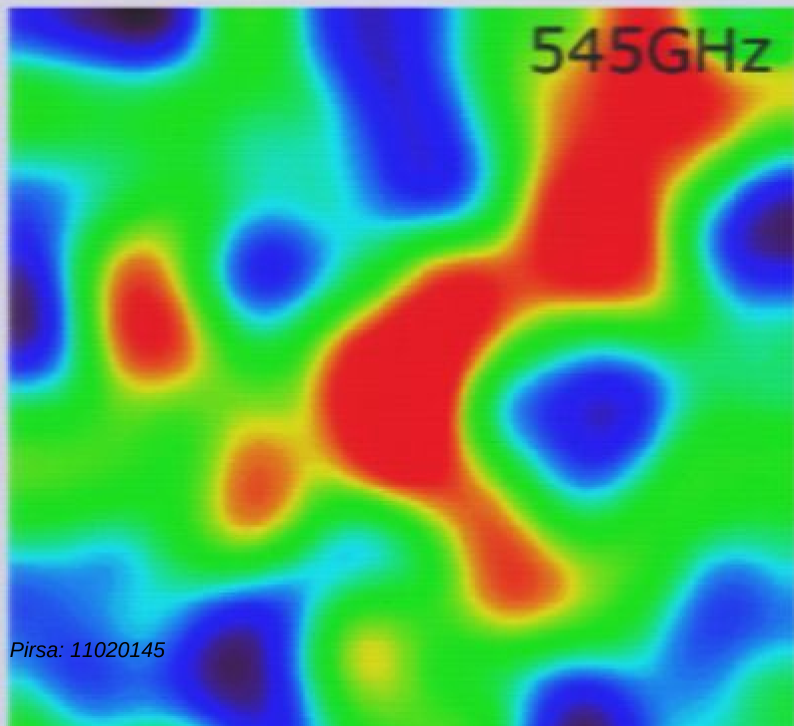
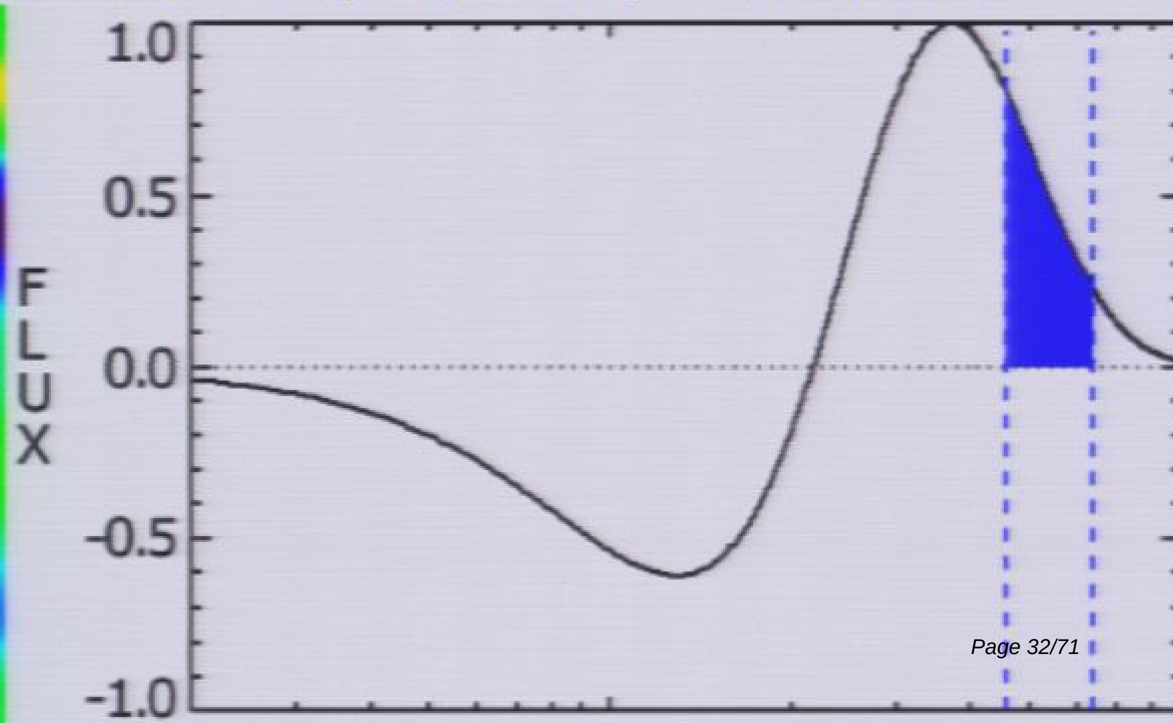


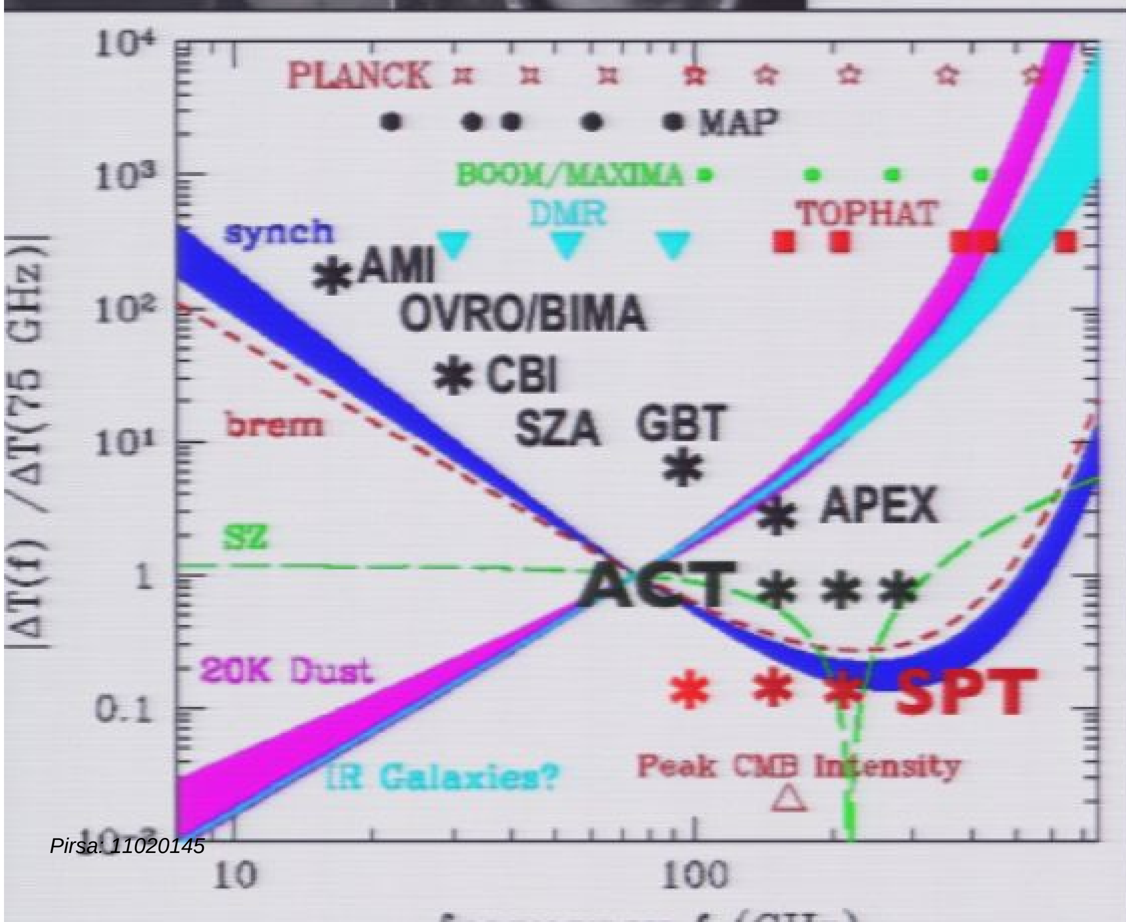


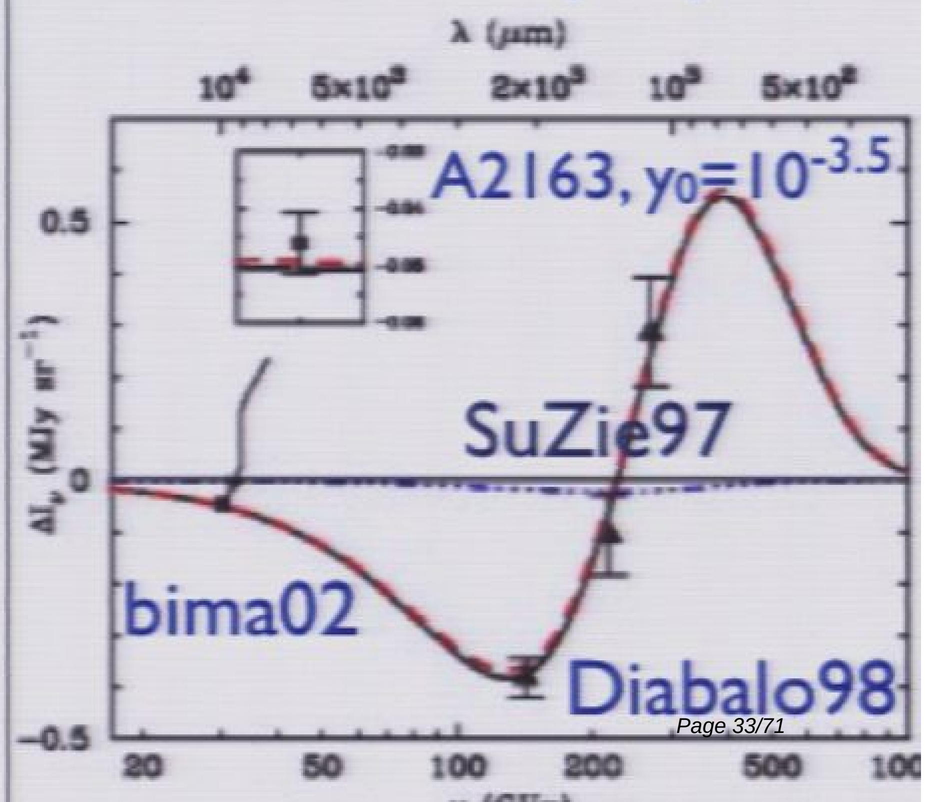
Planck & the thermal Sunyaev-Zeldovich Probe of Gas in the Cosmic Web: $y \sim \int p_e$ dline-of-sight

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

$= -2y$ to xy, 0 @ $\nu = 217$ GHz

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





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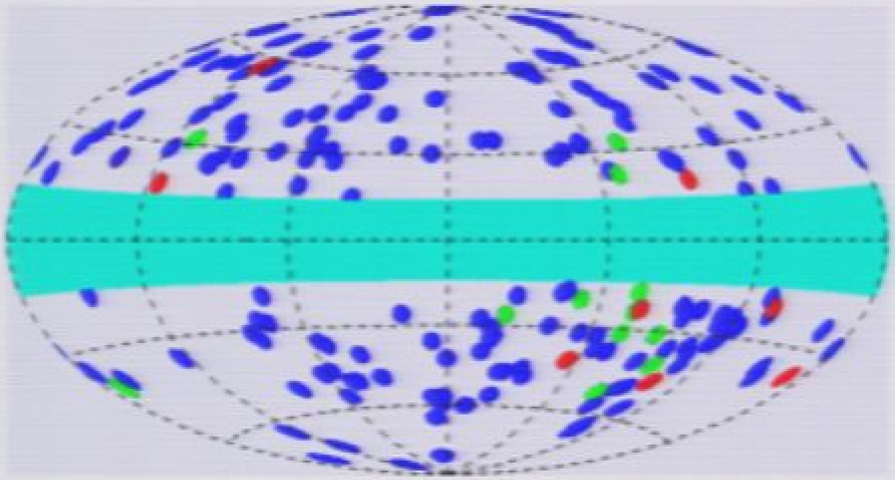

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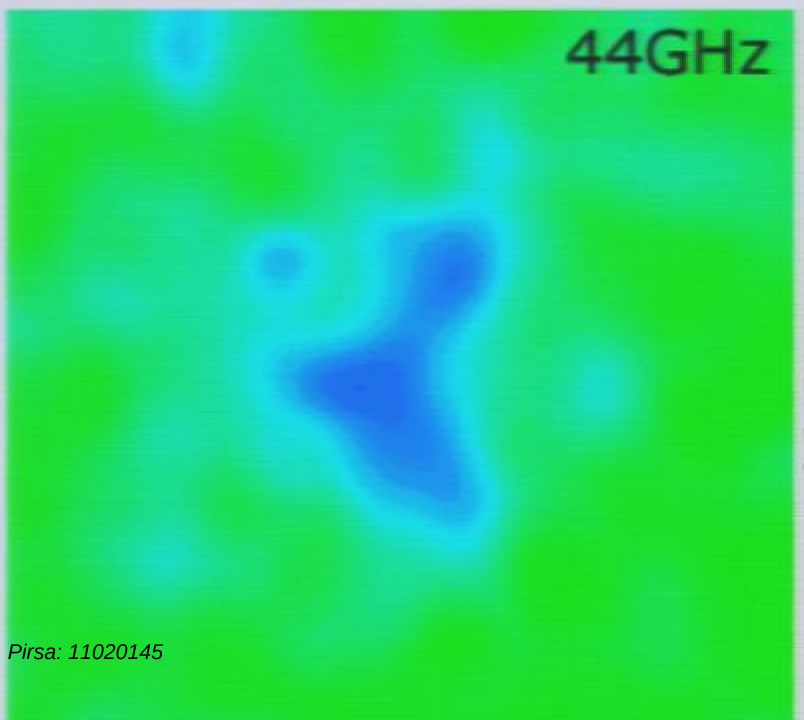

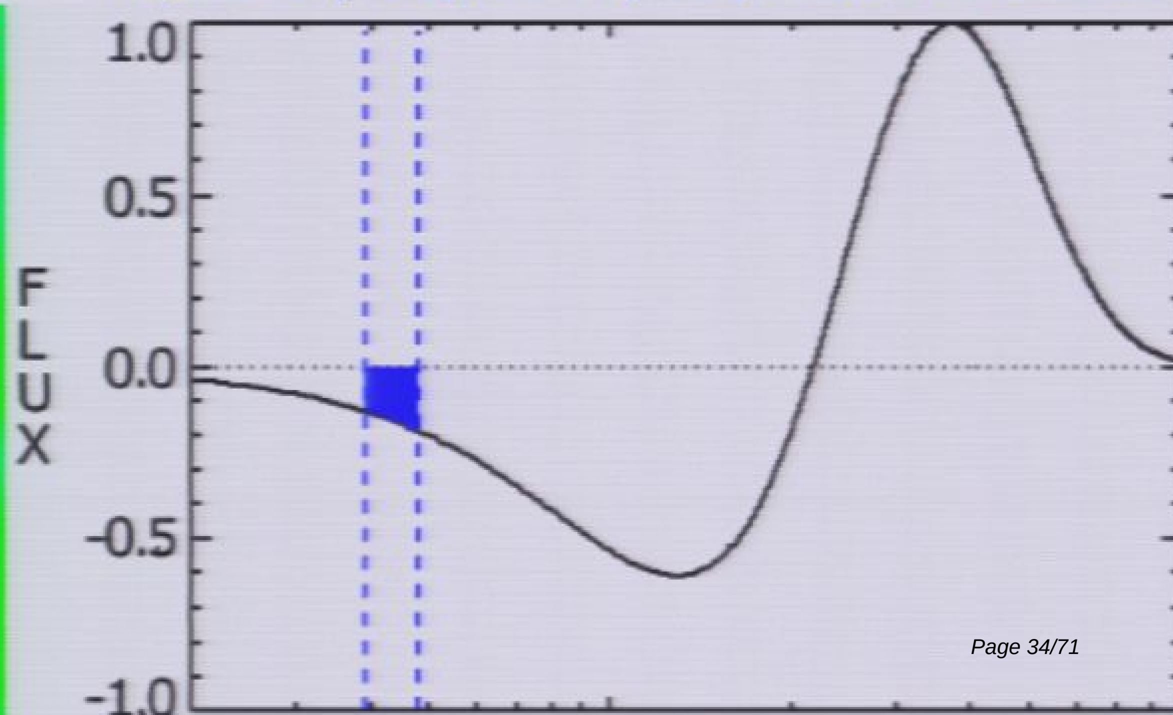

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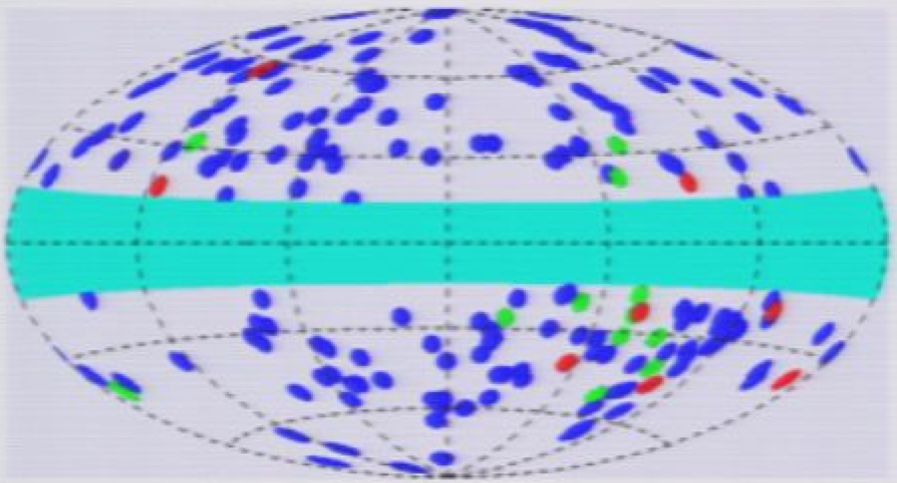

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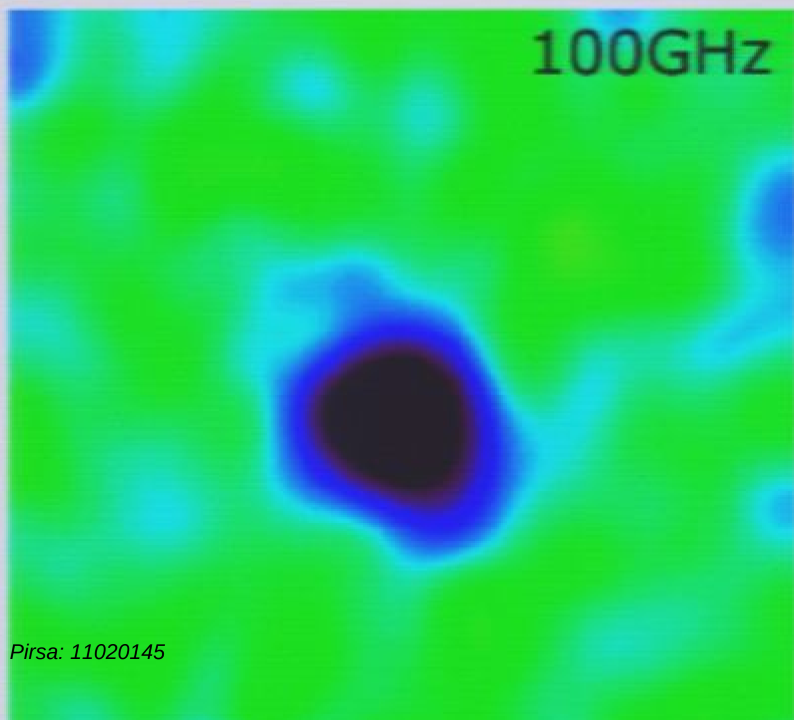

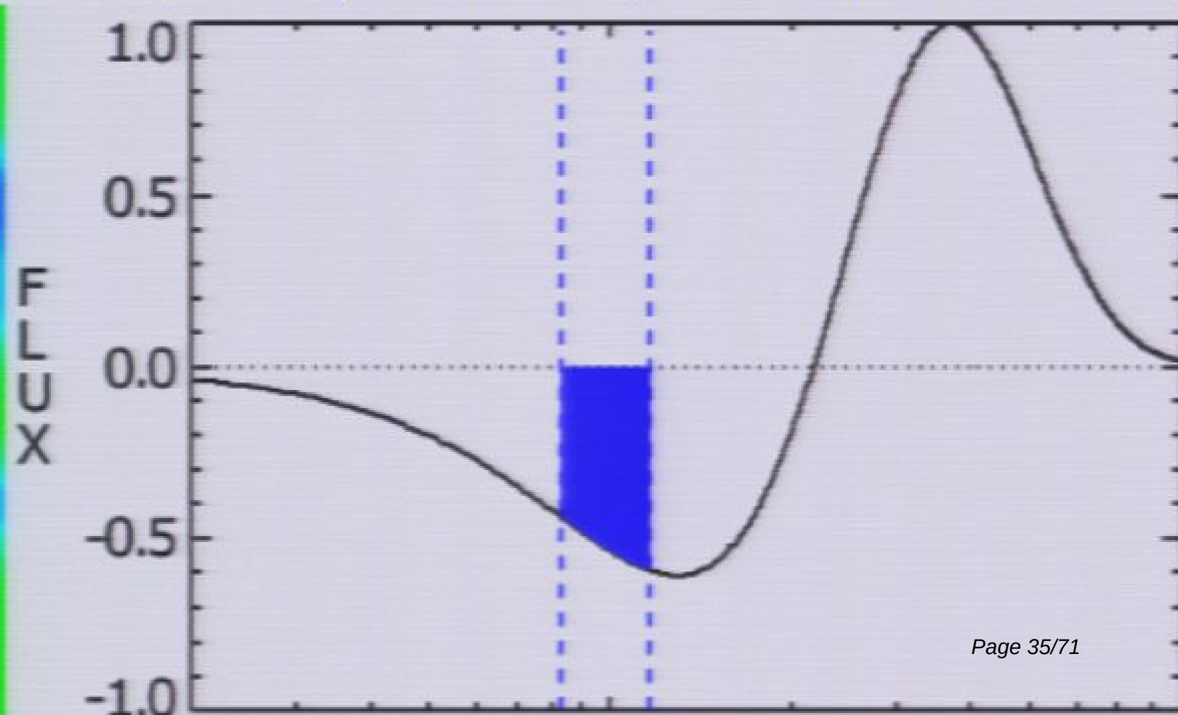

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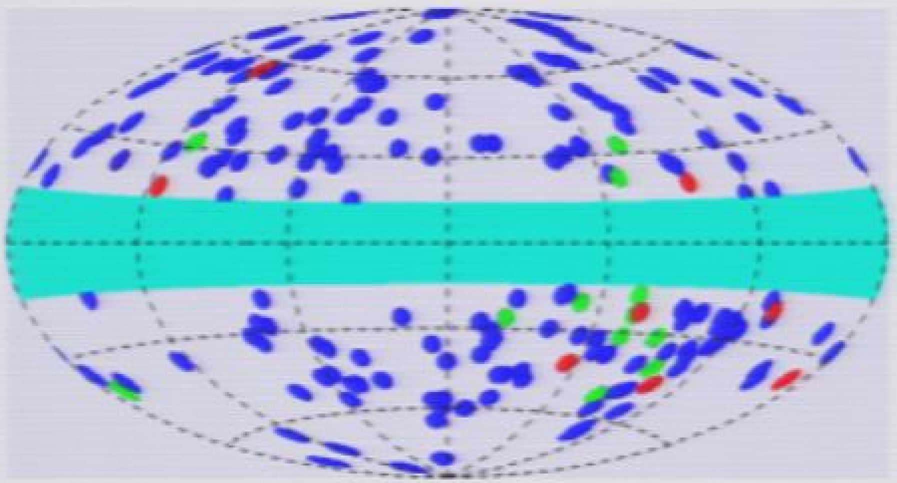

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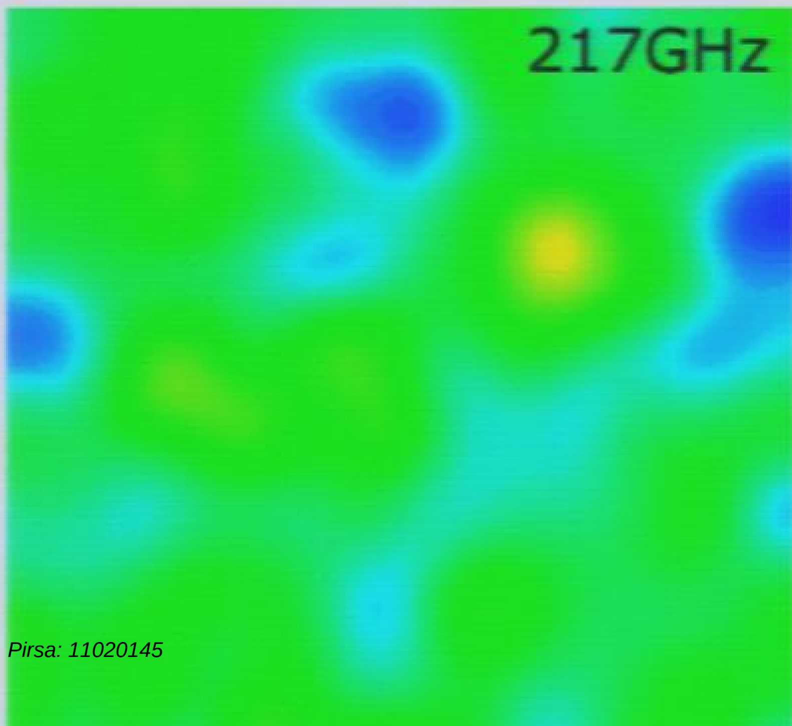

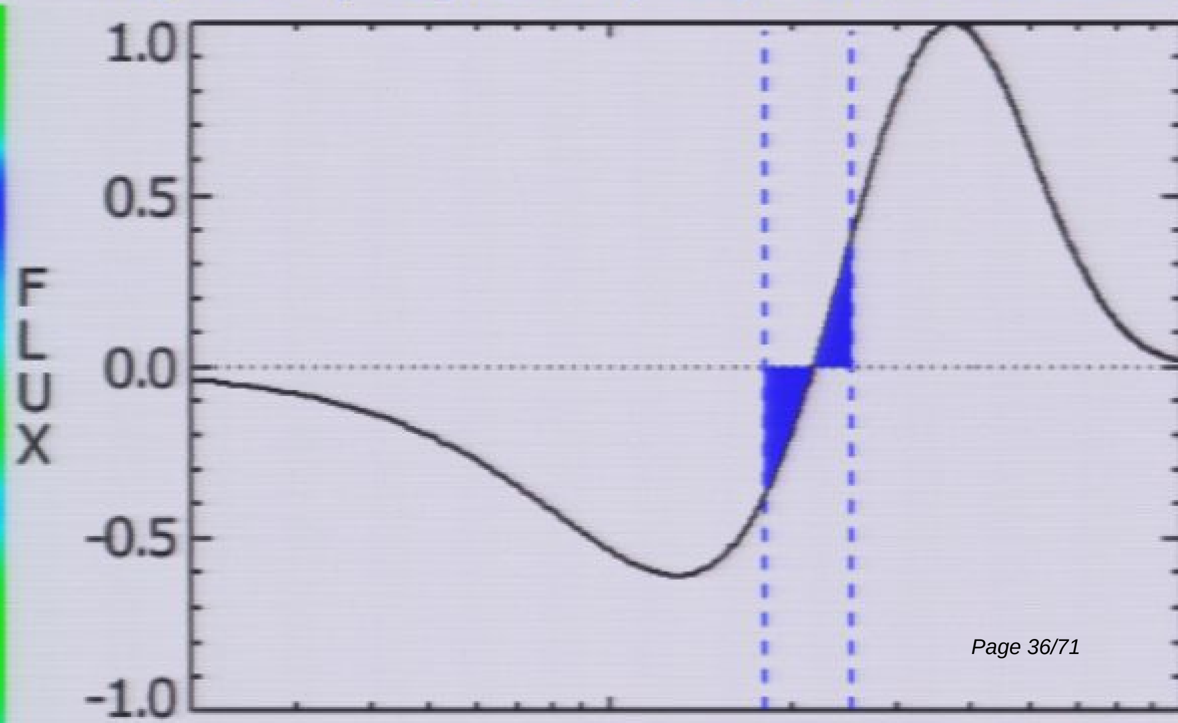

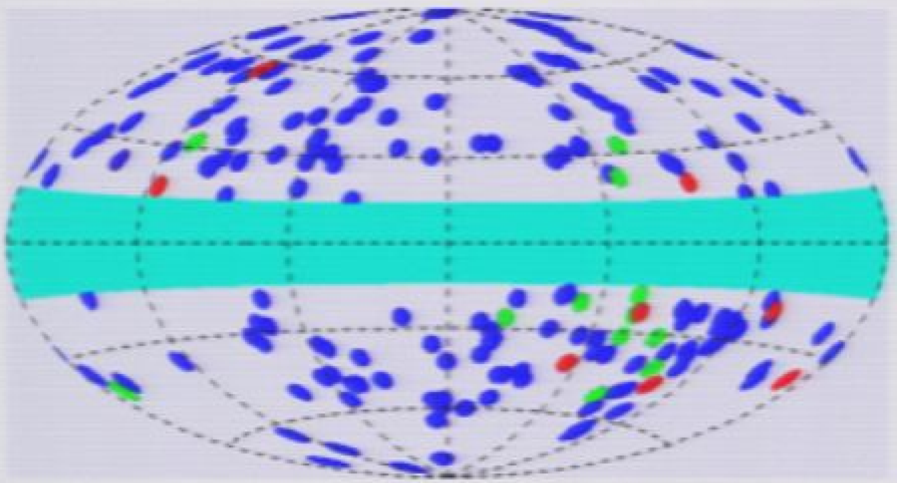

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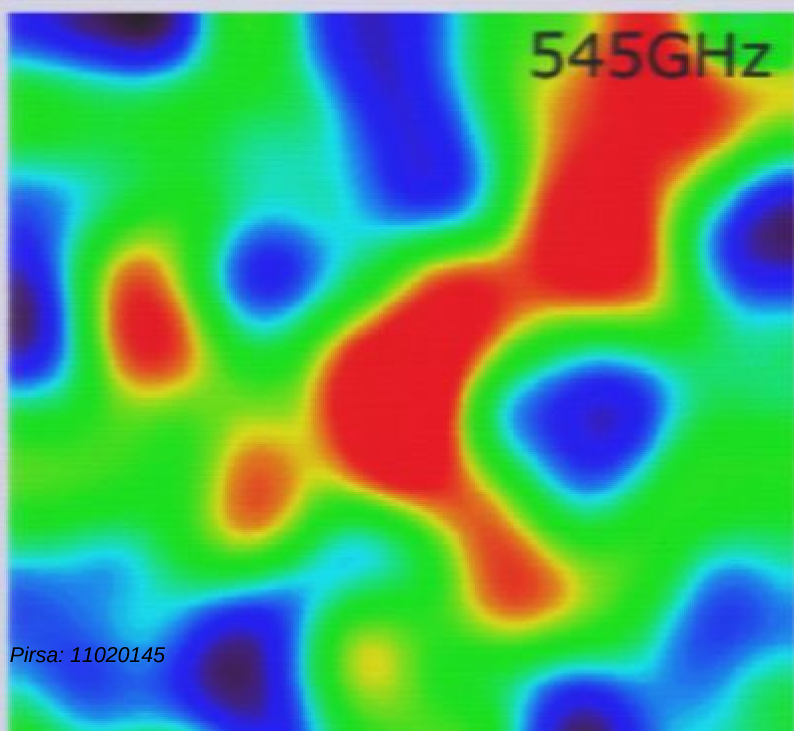
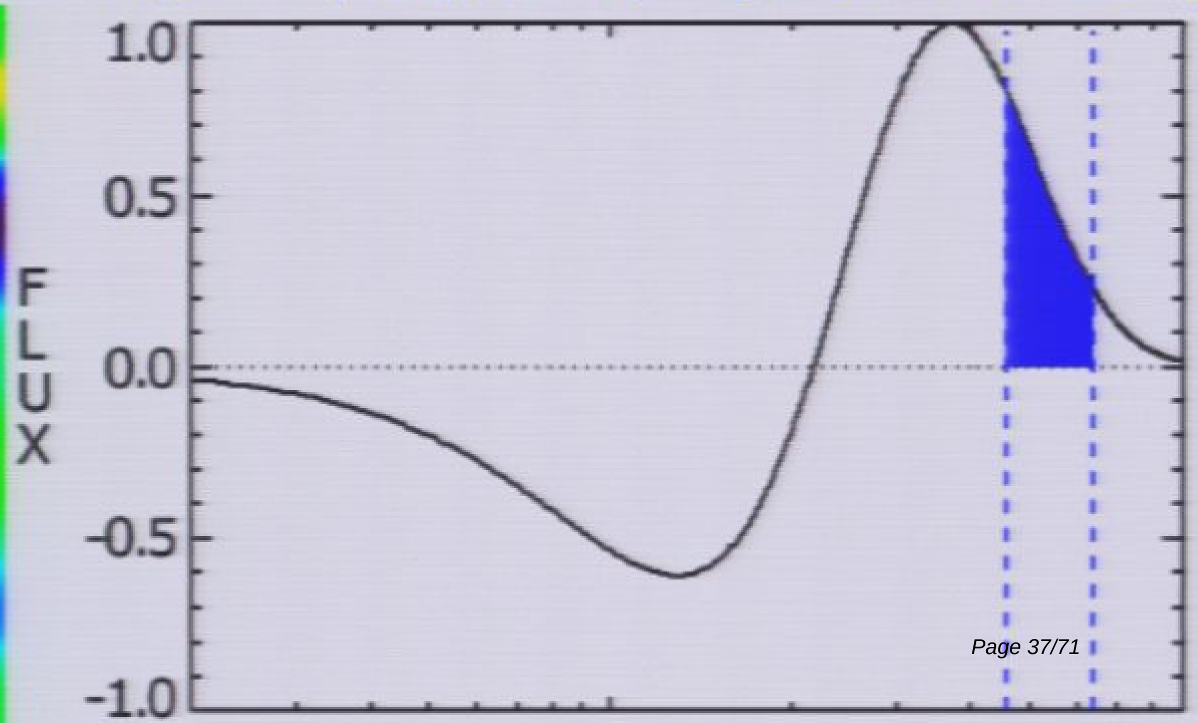
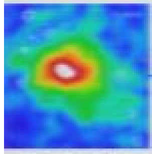
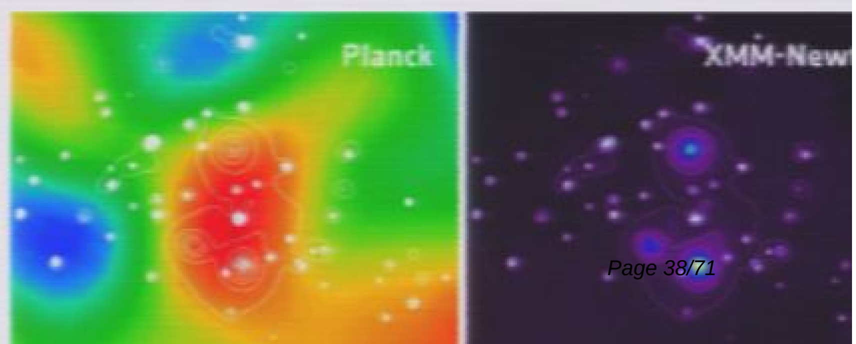
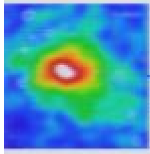






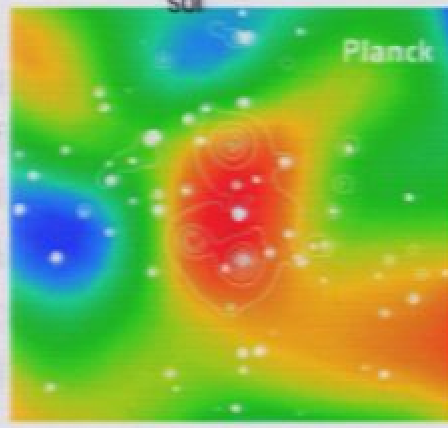
Frequency range from 30 to 857 GHz Sept09 1st clusters detected FLS (A2163, ...); Jan10 1st reliable blind candidates; typical SZ sources are barely visible in raw frequency maps, ~1-2 sigma sources in cleaned frequency maps => Planck-internal QA: 2 methods MMF3 + e.g., PowellSnakes. **MMF3 output: position,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

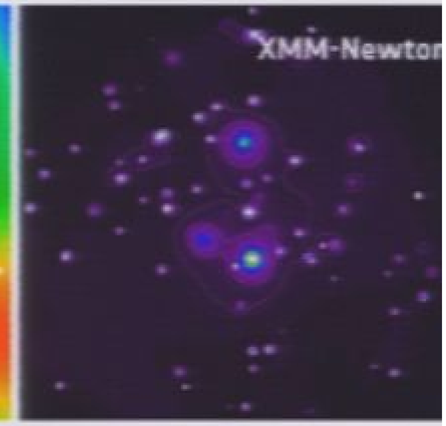


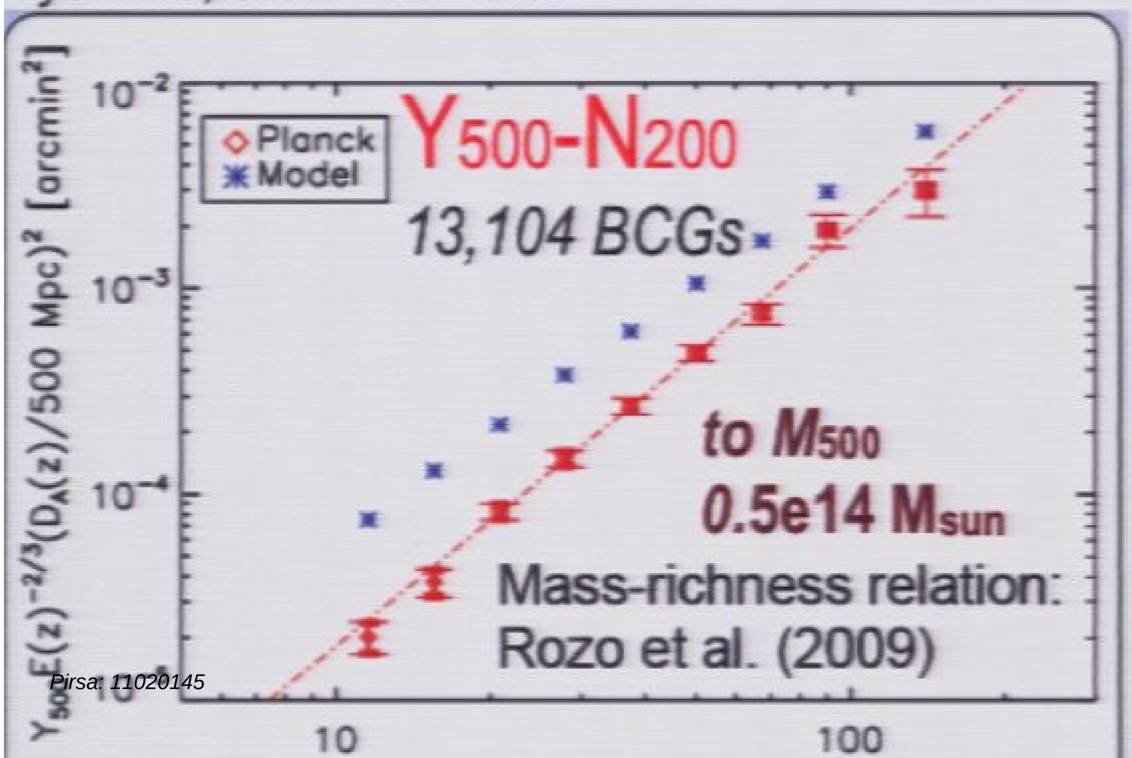


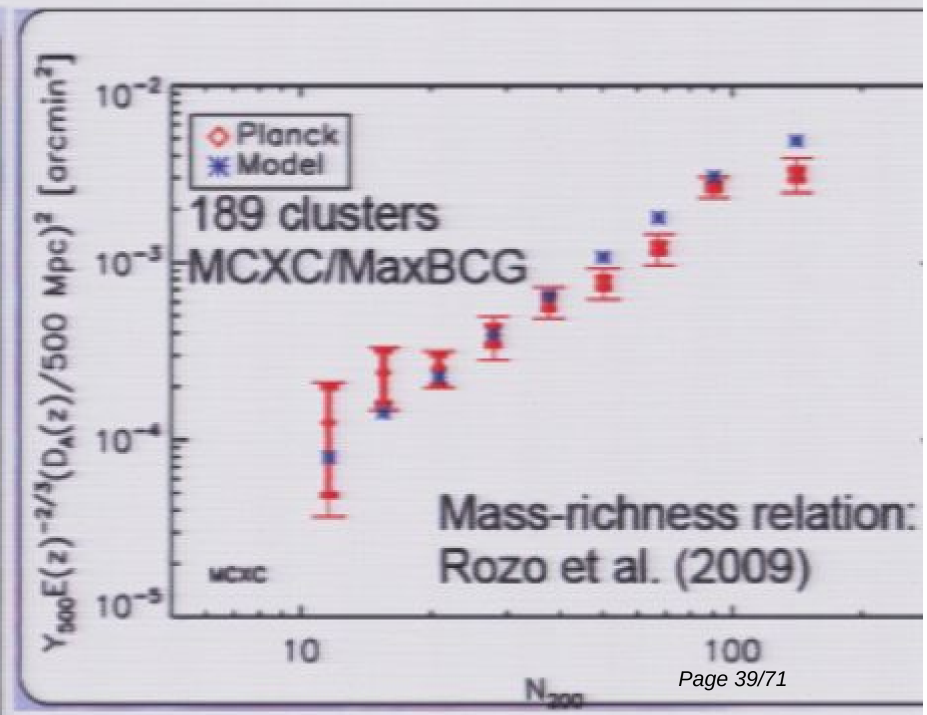
Planck sees the rarest and most massive clusters over the whole sky: small/moderate redshifts (86% with z<0.3); masses to 1.5×10^{15} M_{sol}. 90% of the RASS above $M > 9 \times 10^{14}$ M_{sol} detected by blind ESZ, 5/21 of new Planck $> 9 \times 10^{14}$ M_{sol}.

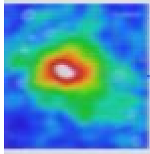
Feb10 targets for XMM-*Newton* - **25 candidates observed:** DDT time, eg, pilot 10 targets from 62% of sky coverage, in 4 < S/N < 6 range (EZ > 6); high S/N (>5) programme 15 targets. **21 confirmed** → **~85% success rate;** 17 single clusters, most disturbed; 2 double systems; 2 triples (super-clusters)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











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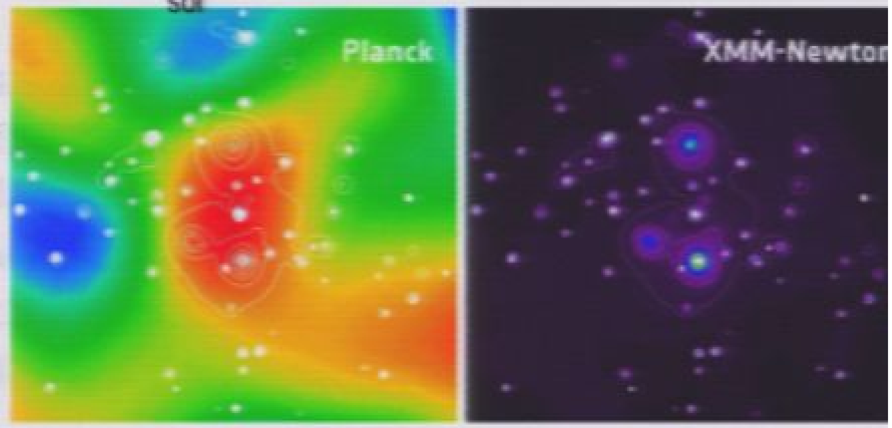
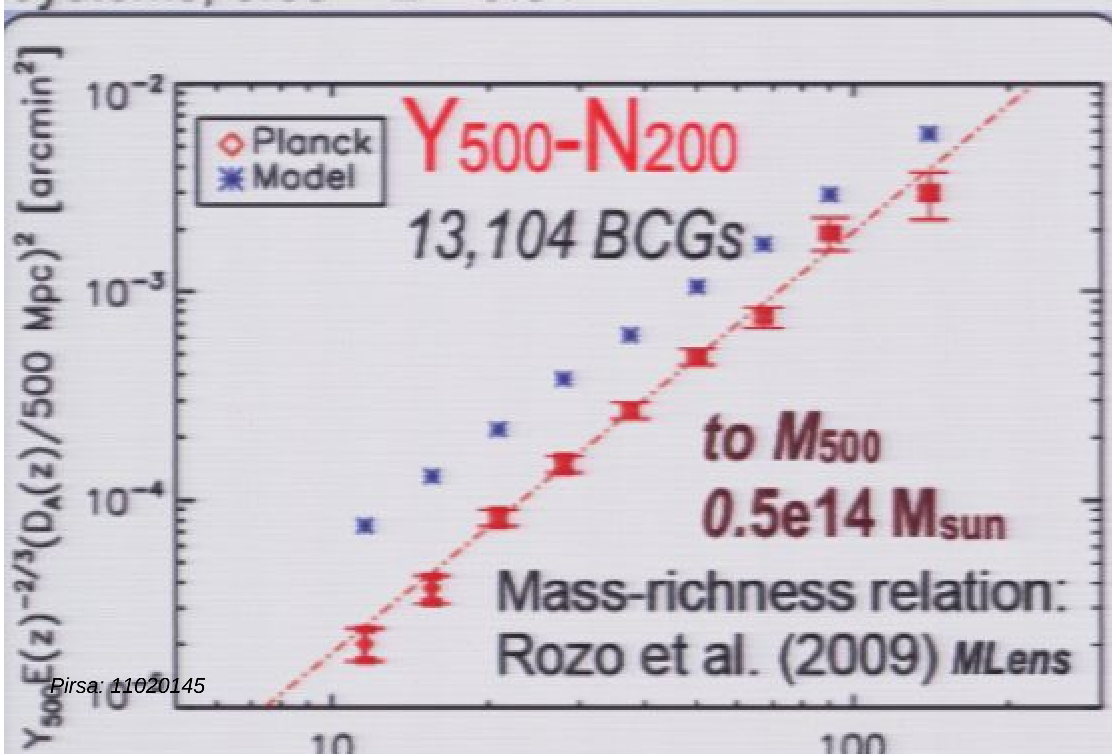
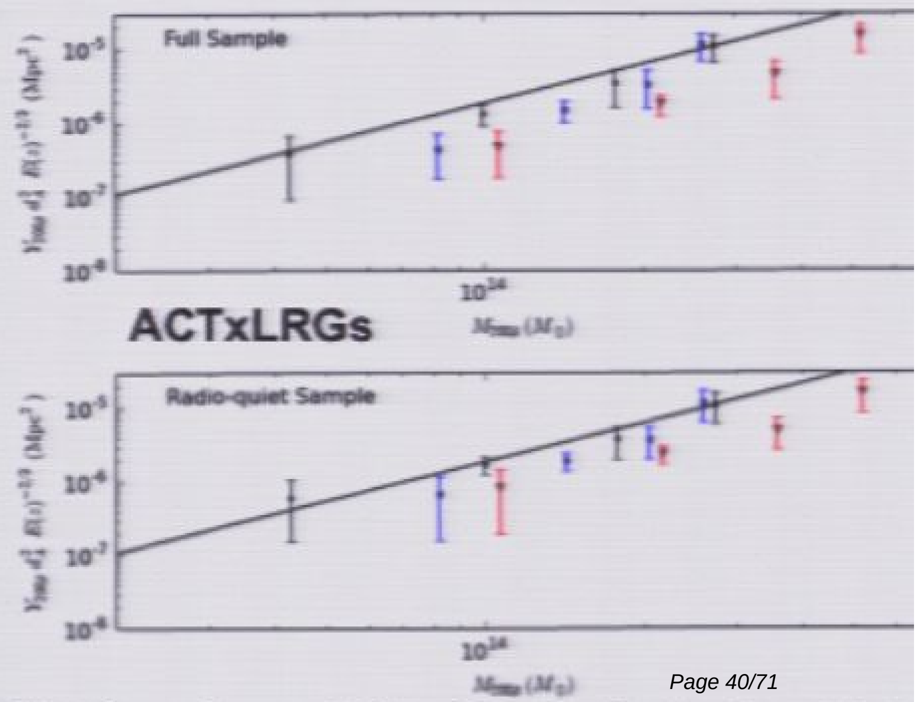
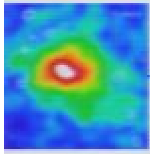






Hint for sub-populations? Optical selection effects



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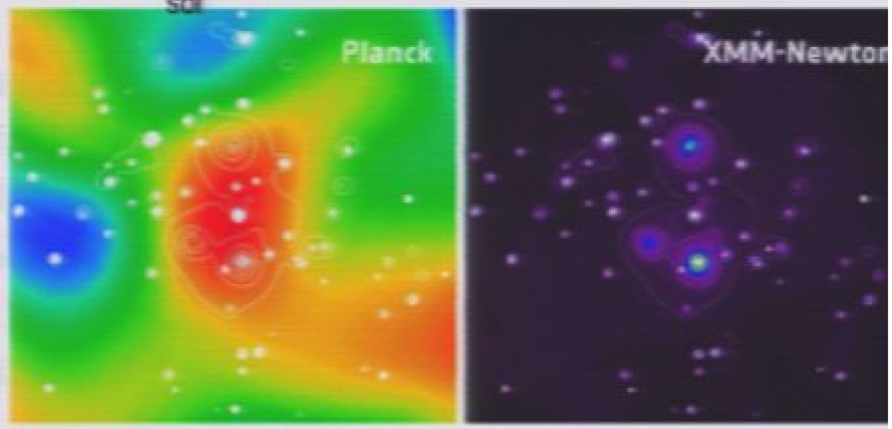
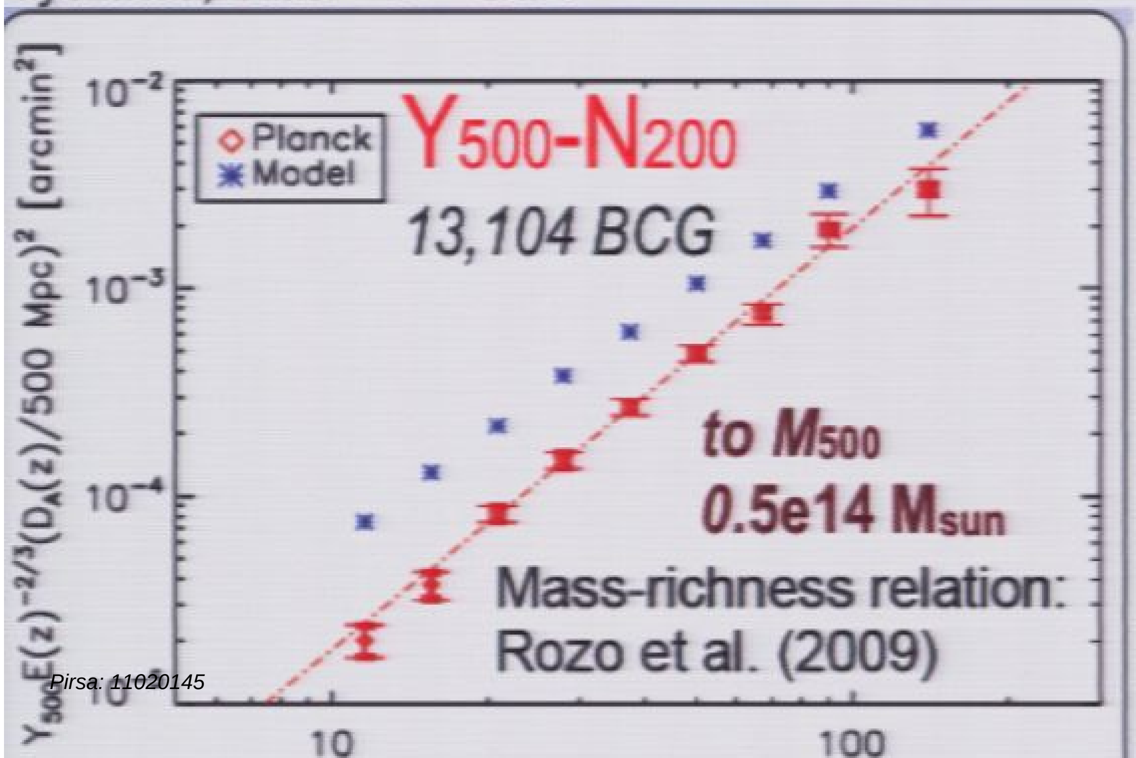
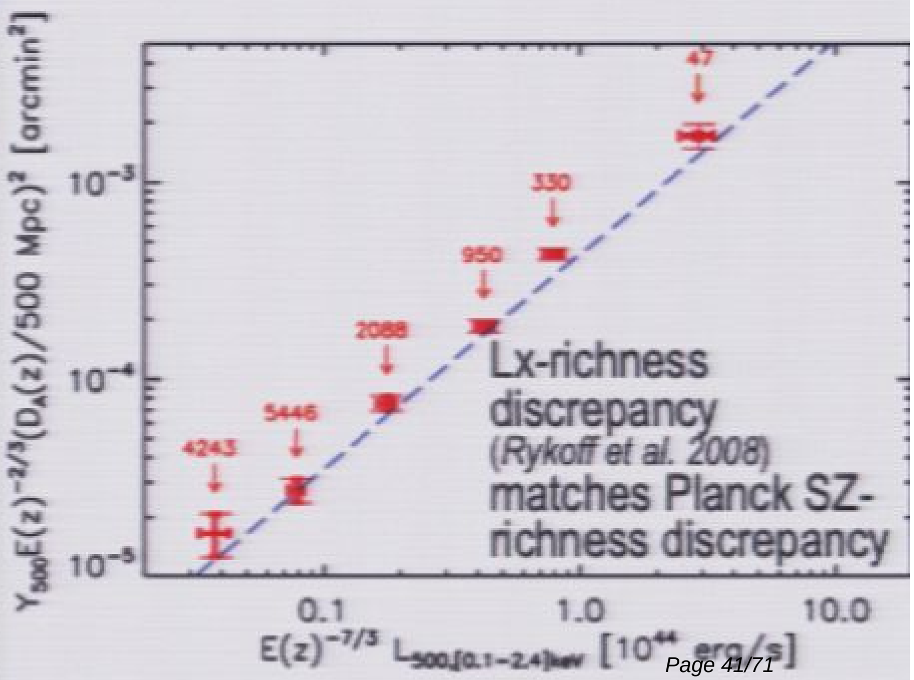
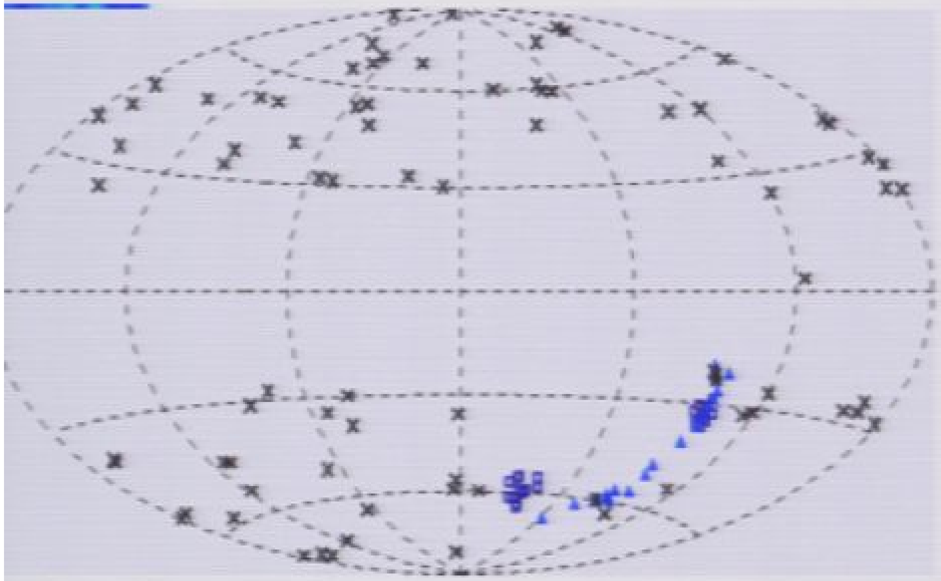
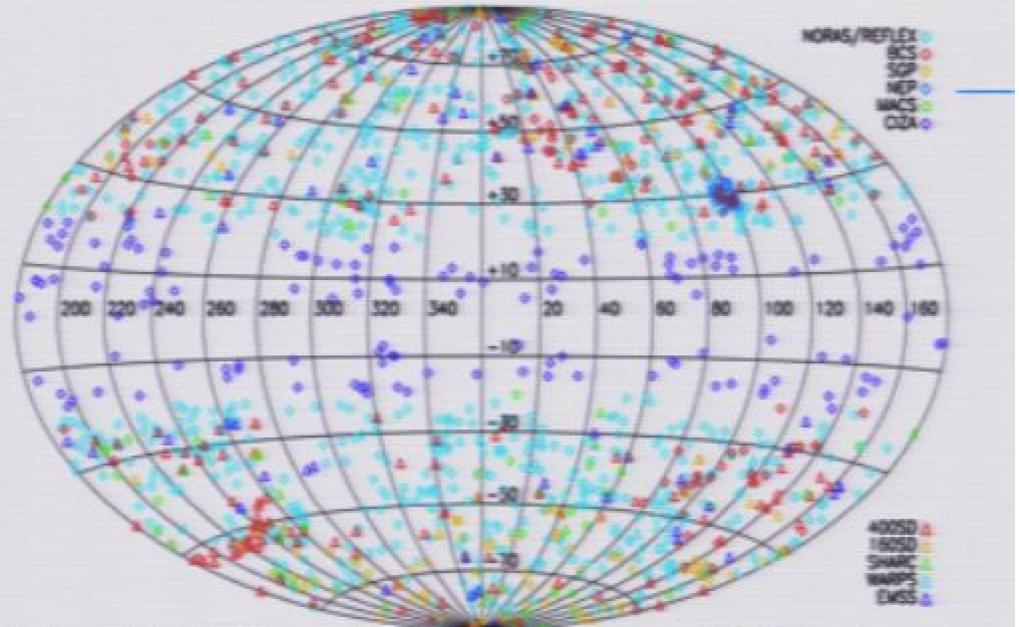




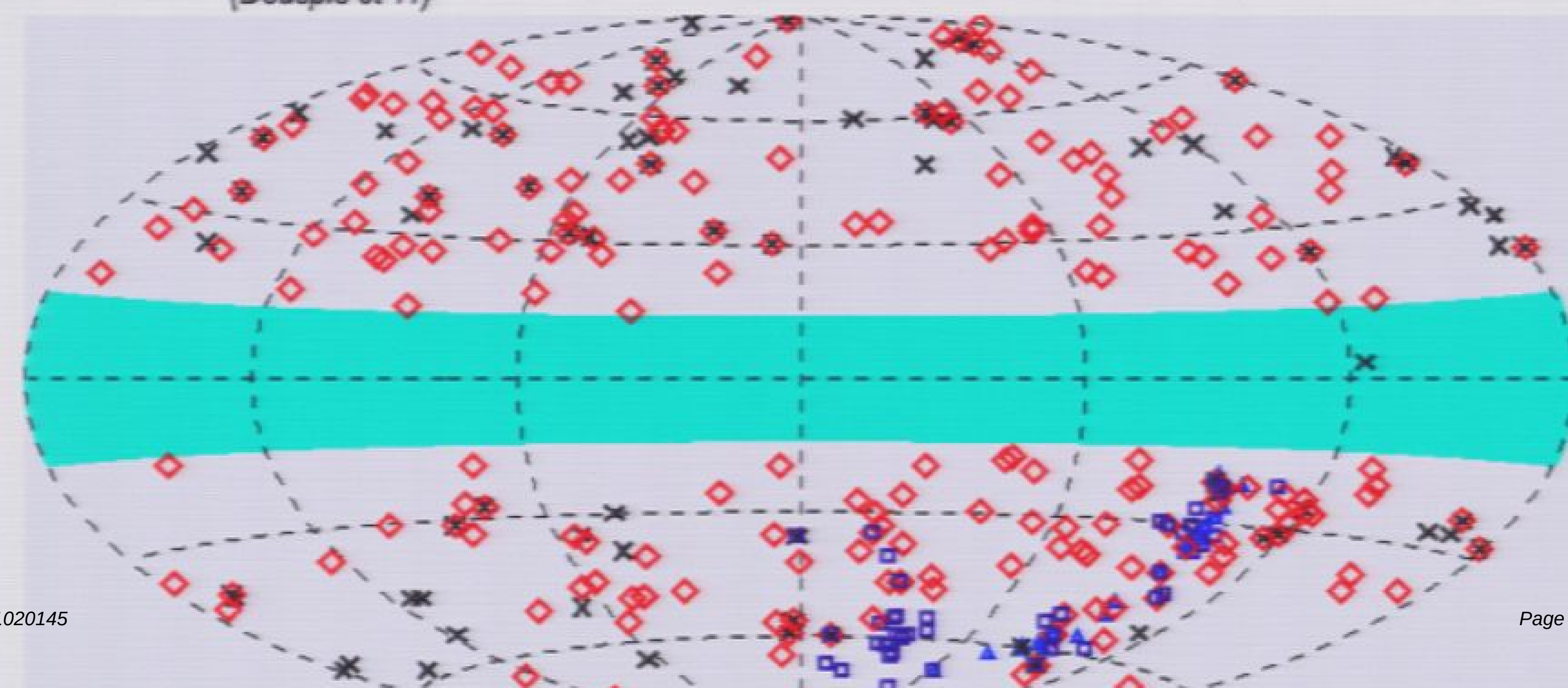






All-sky compilation of first generation SZ clusters *(Douspis et 11)*

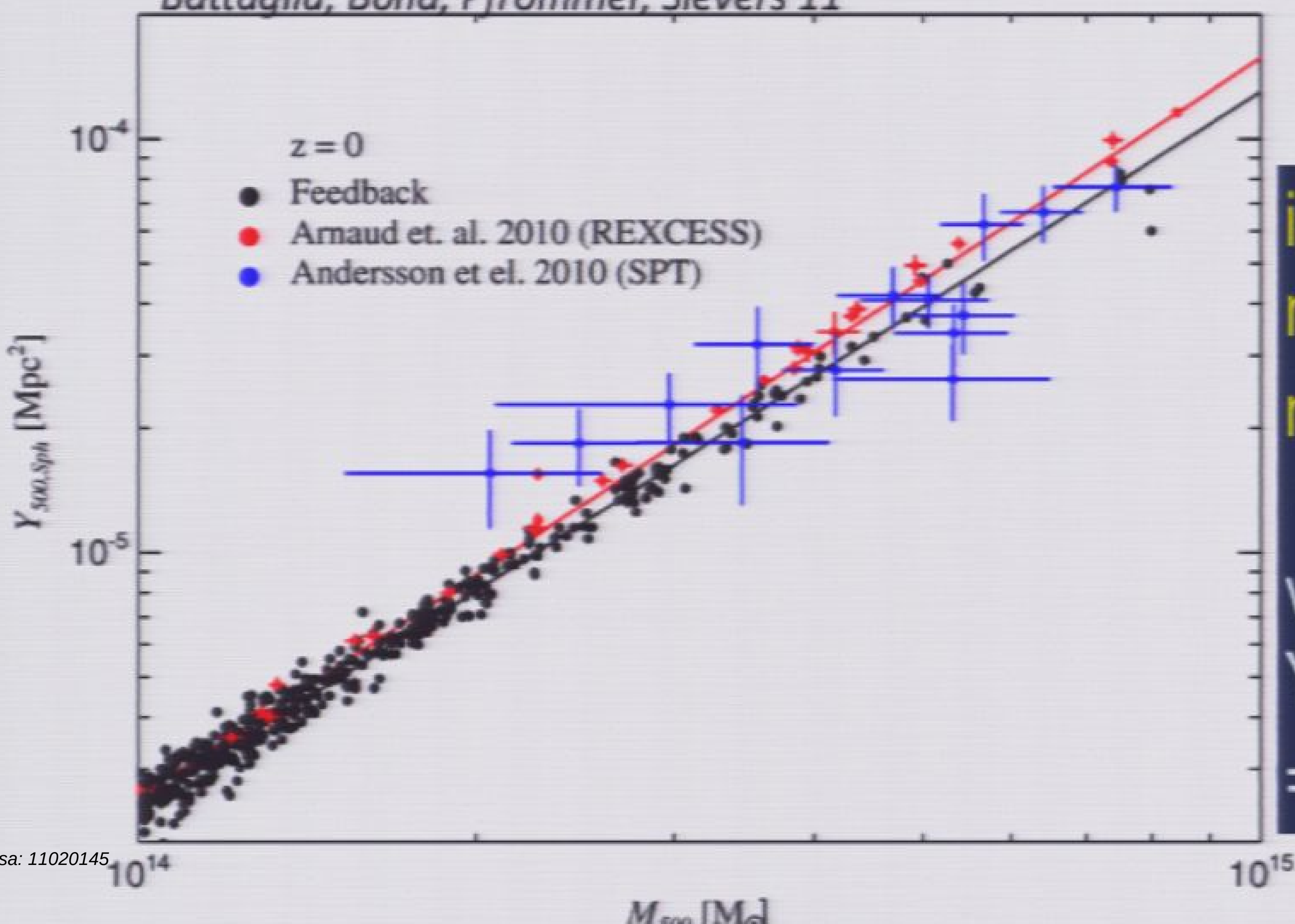
All-sky distribution of MCXC clusters ~1600 *(Piffaretti et 10*



Y(<r_Δ)-M(<r_Δ) relation, *where*

M(<R_Δ)/V(<R_Δ)=$\Delta\ \rho_{crit}$, 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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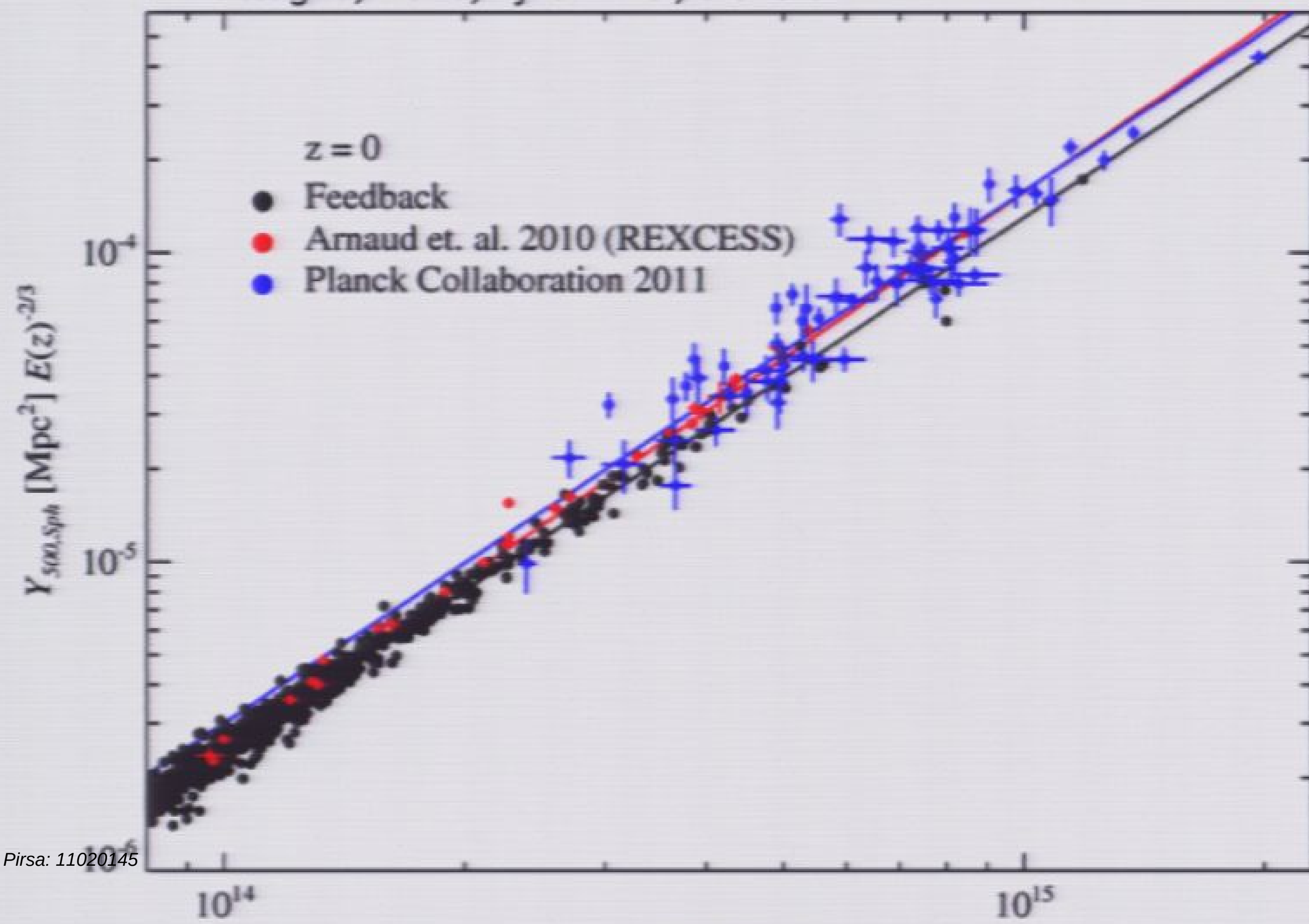

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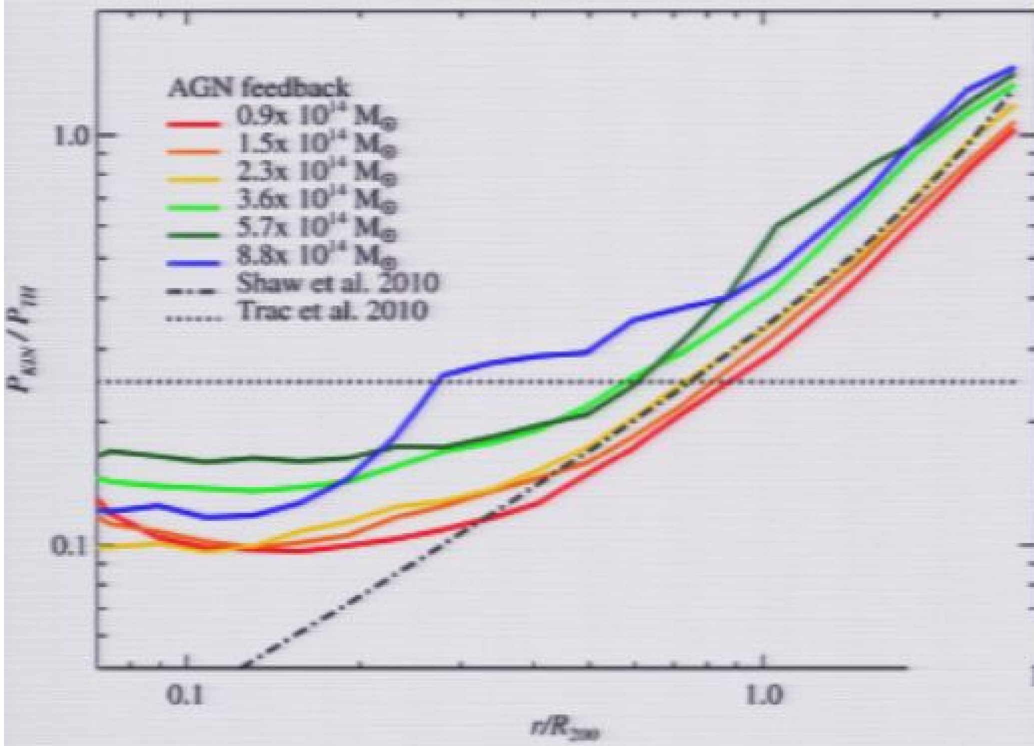
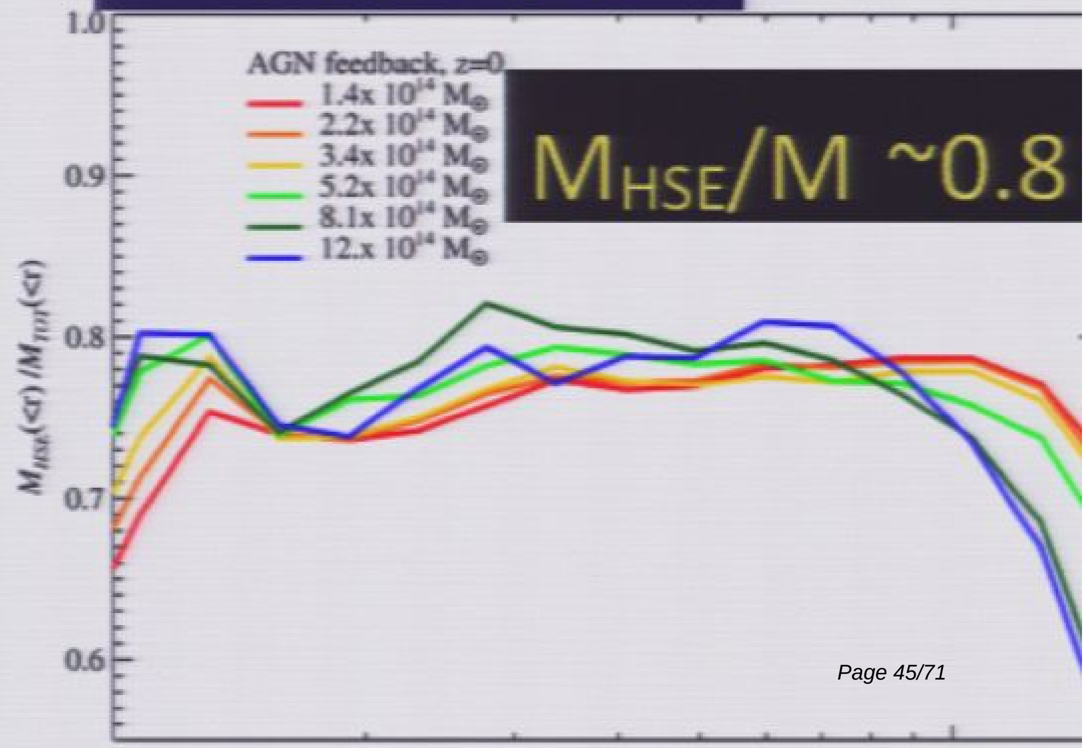


$P_{kin} / P_{th} \sim 0.1\text{-}0.6!$

$<(\Delta v)^2>/c_s^2$ cannot be ignored in HSE

$\nabla p_{g,tot} = \rho_g g$



$M_{HSE}/M \sim 0.8$

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.

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

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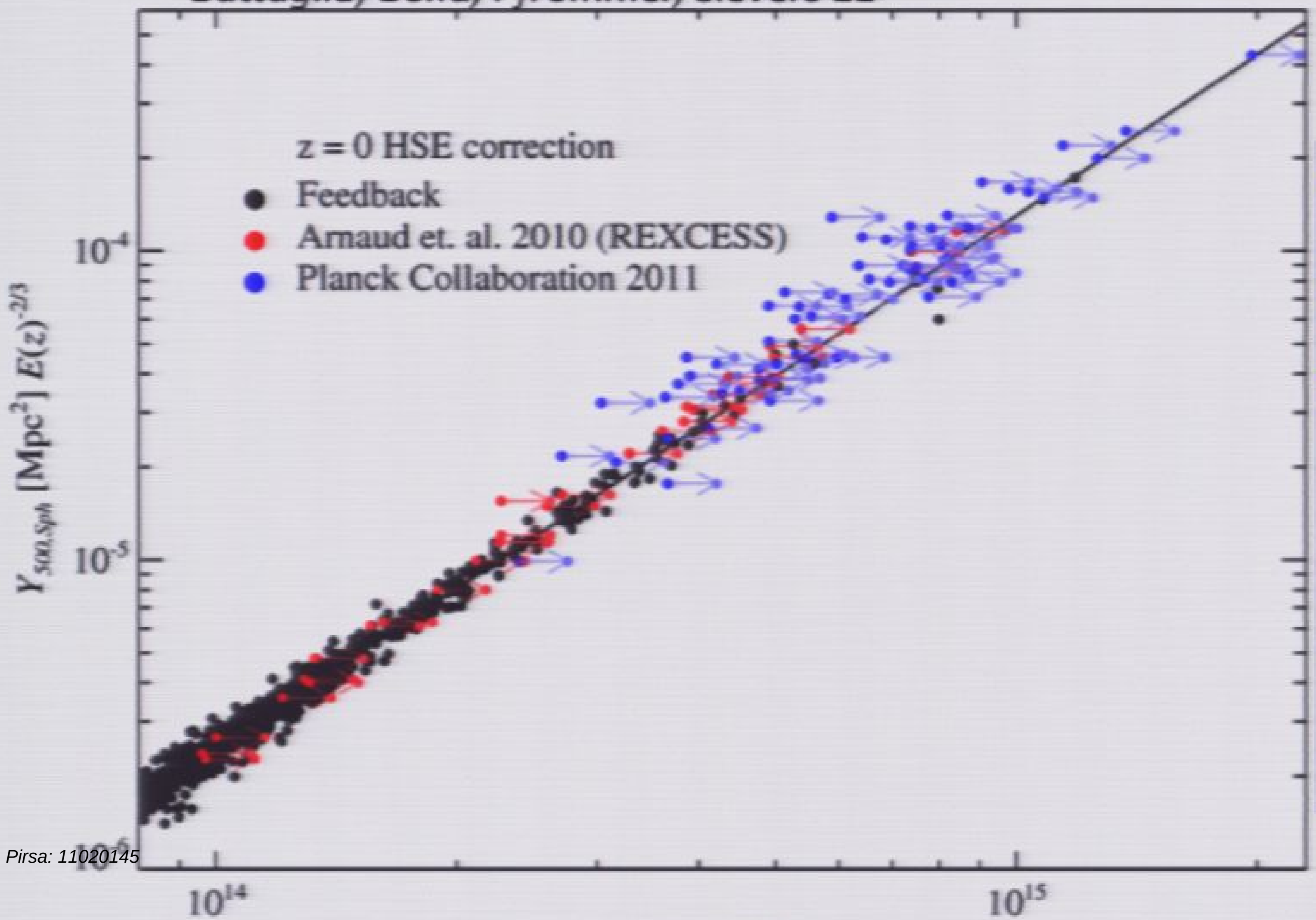

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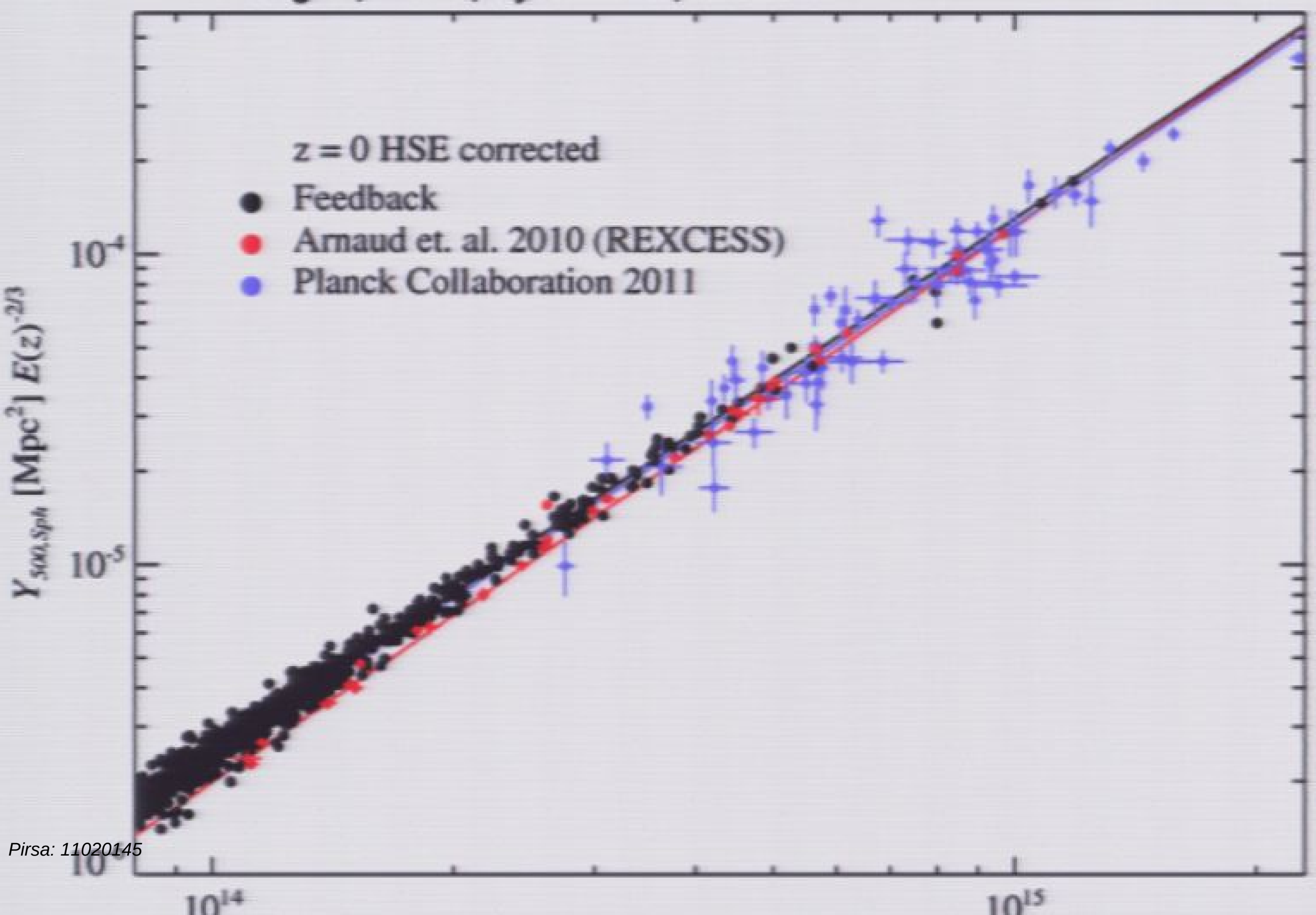

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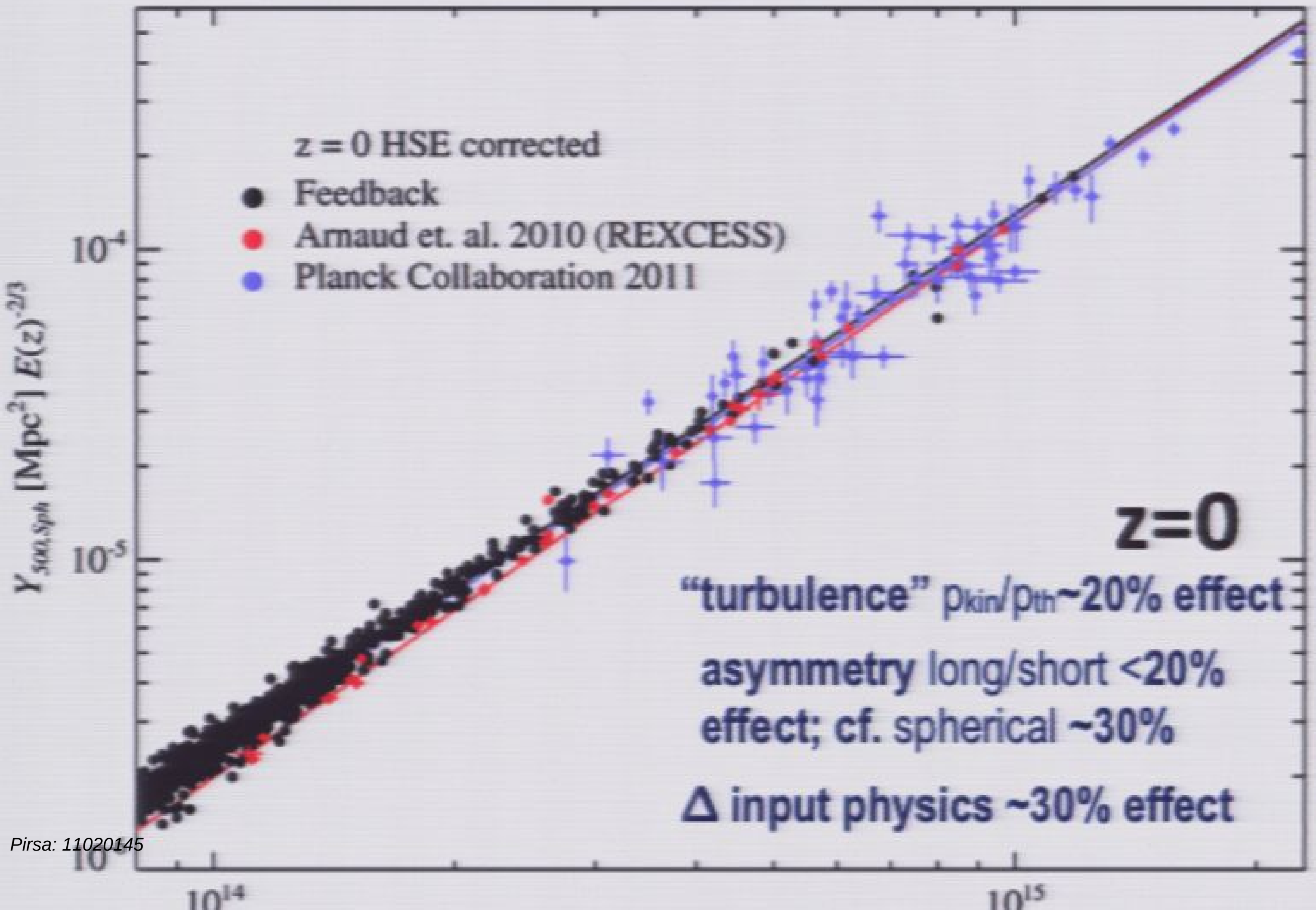

Planck-ESZ gives **Y_{5R500}**

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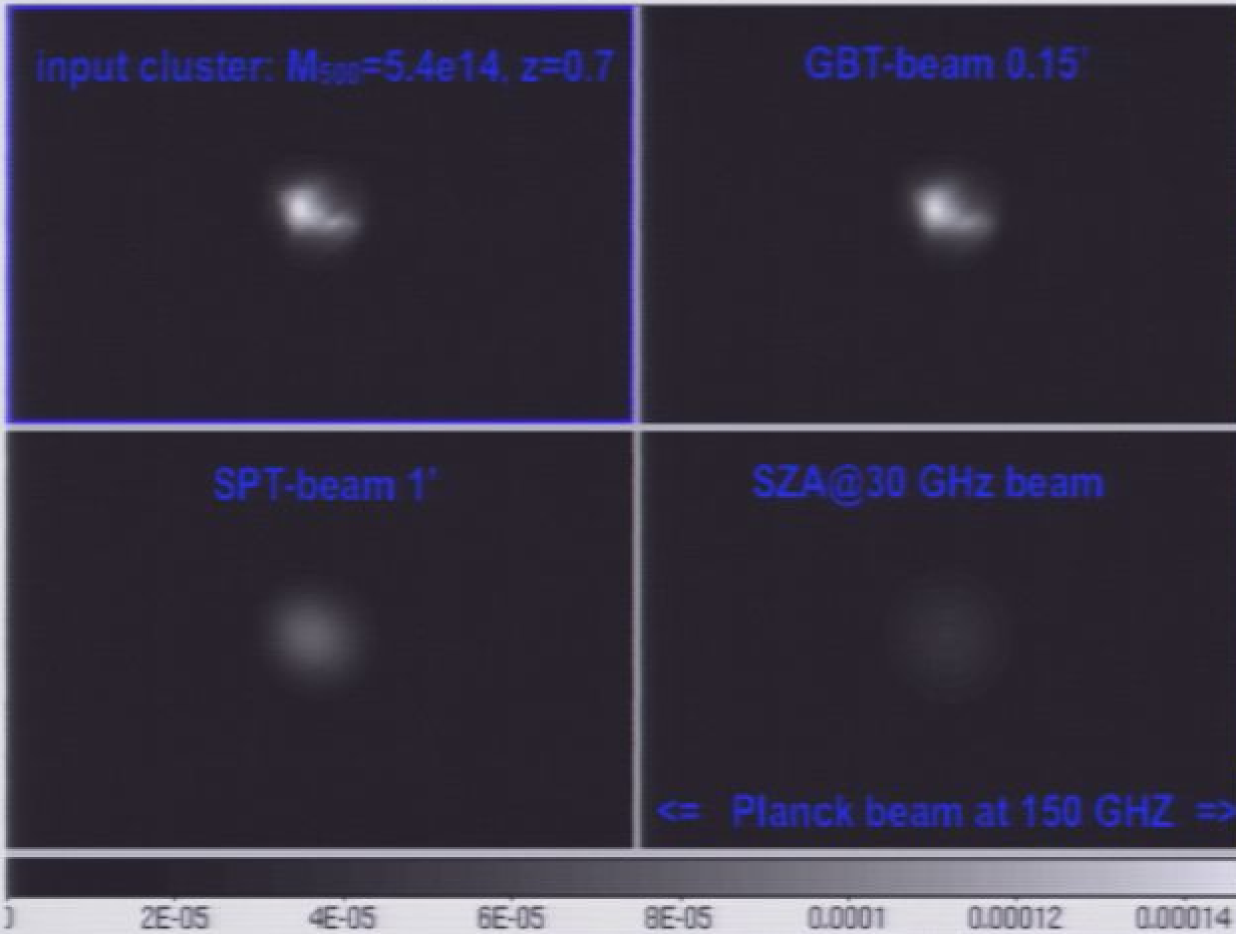
=> $n_{cl}(Y, z)$

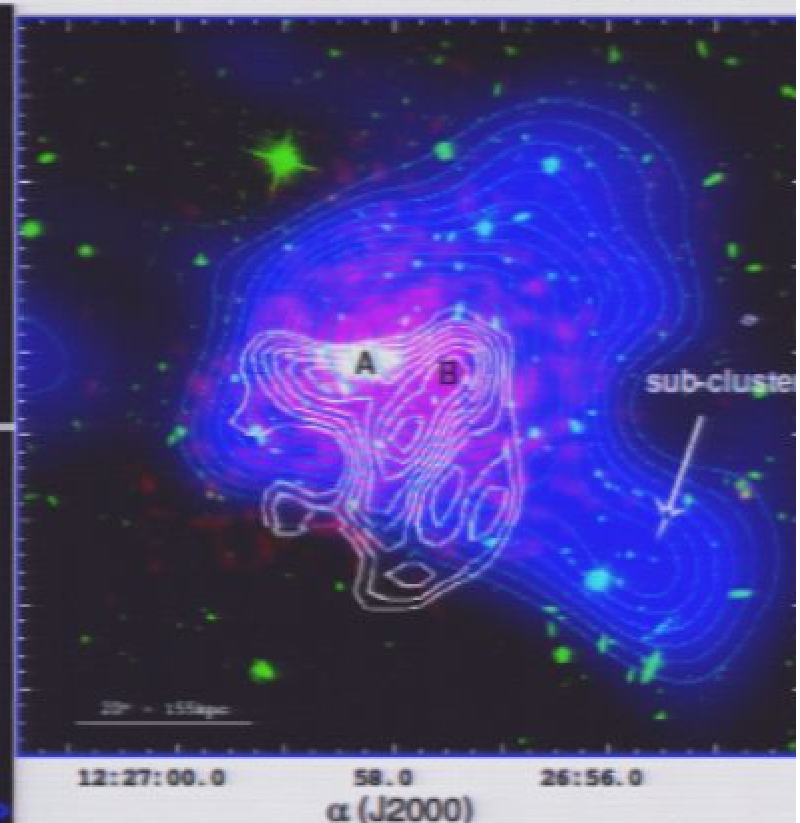
Mustang on GBT 90 GHz 64 bolometer array Imaging SZ

@~10" res 4 cls 2010, ~25 Hubble CLASH cls to come Devlin, Mason, ...

future: High-Res SZ sim for MUSTANG2



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

100x mapping speed!

160 cf. 64 pixels, over larger area (5' vs. 40")

=> Planck followup

$n_{cluster}$

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

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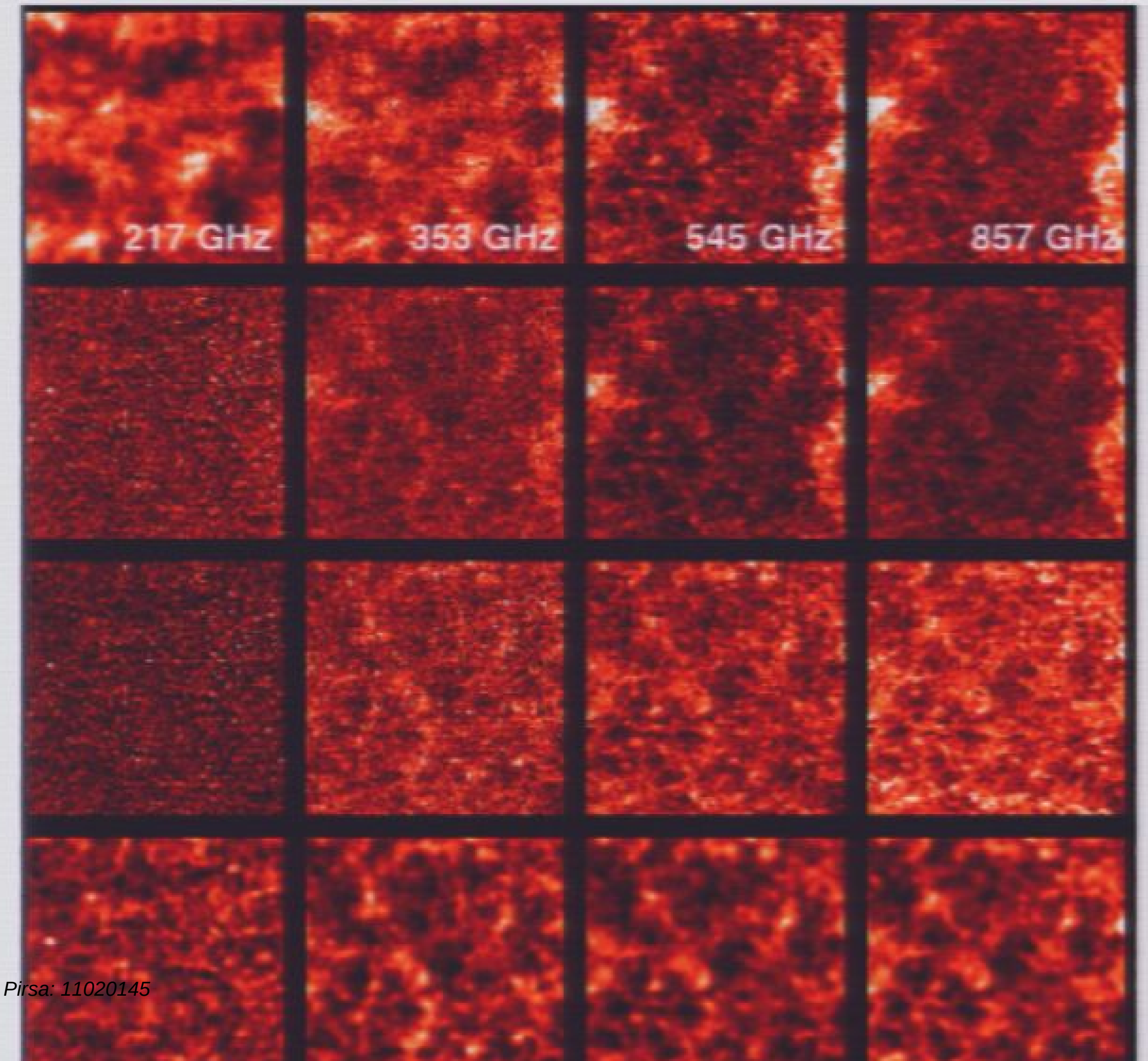
Planck Early Results: The Power Spectrum Of Cosmic Infrared Background Anisotropies

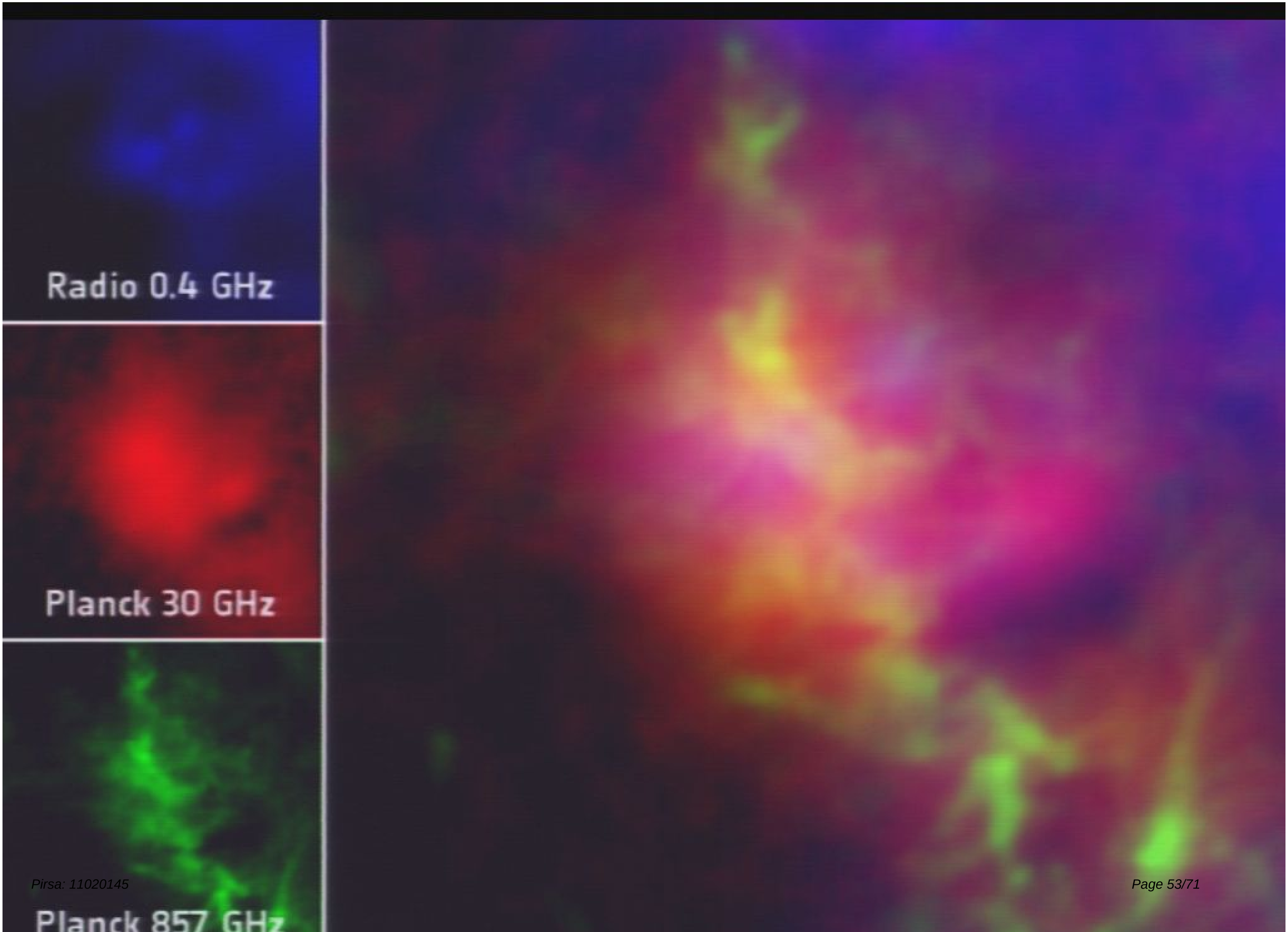


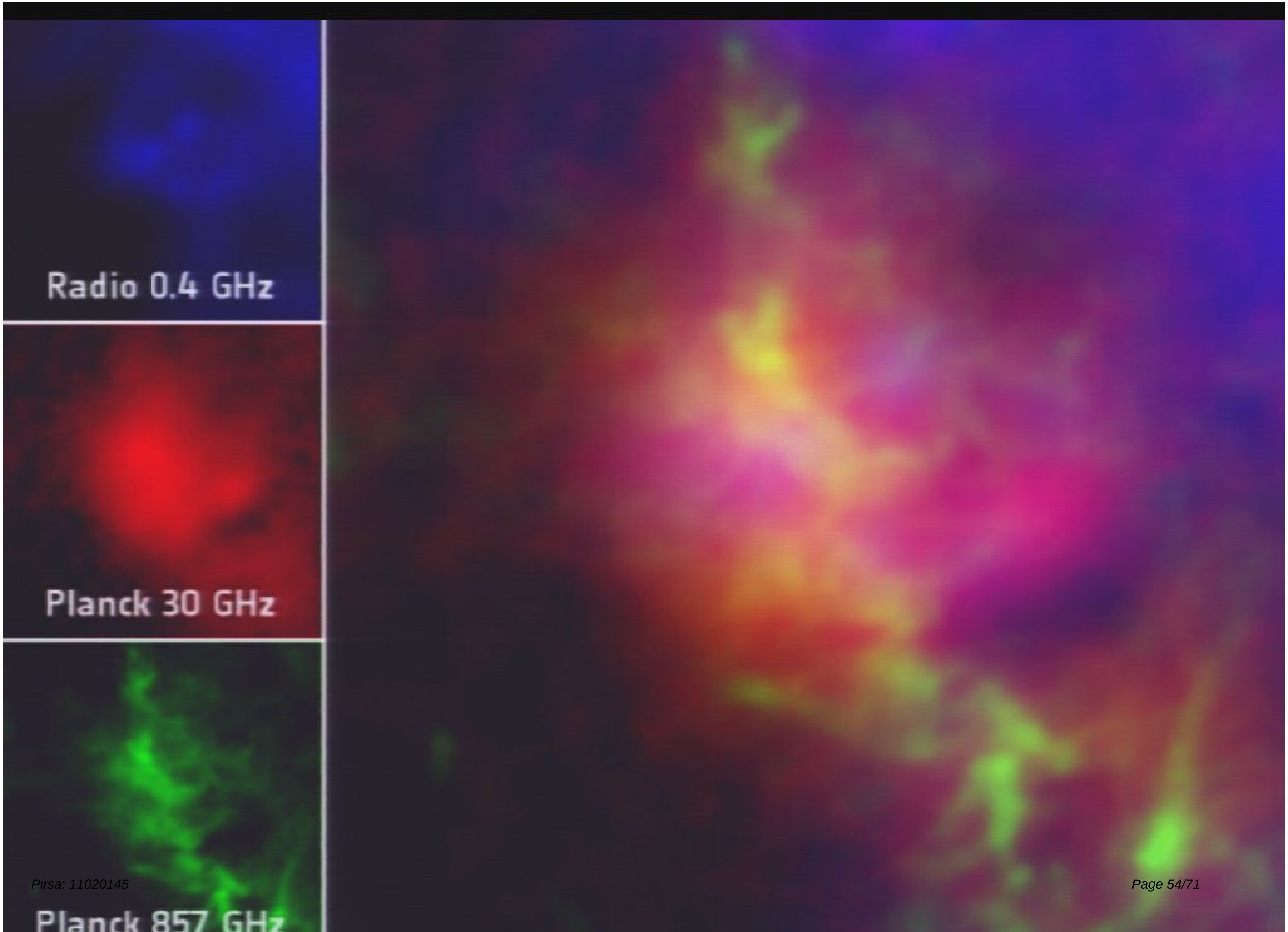
Planck-HFI Raw maps
26.4 sq. deg.

Raw maps
- CMB
- ERCSC point sources

Raw maps
- CMB
- ERCSC point sources
- Galactic dust

CIB maps @ 10 arcmin


Radio 0.4 GHz
Planck 30 GHz
Planck 857 GHz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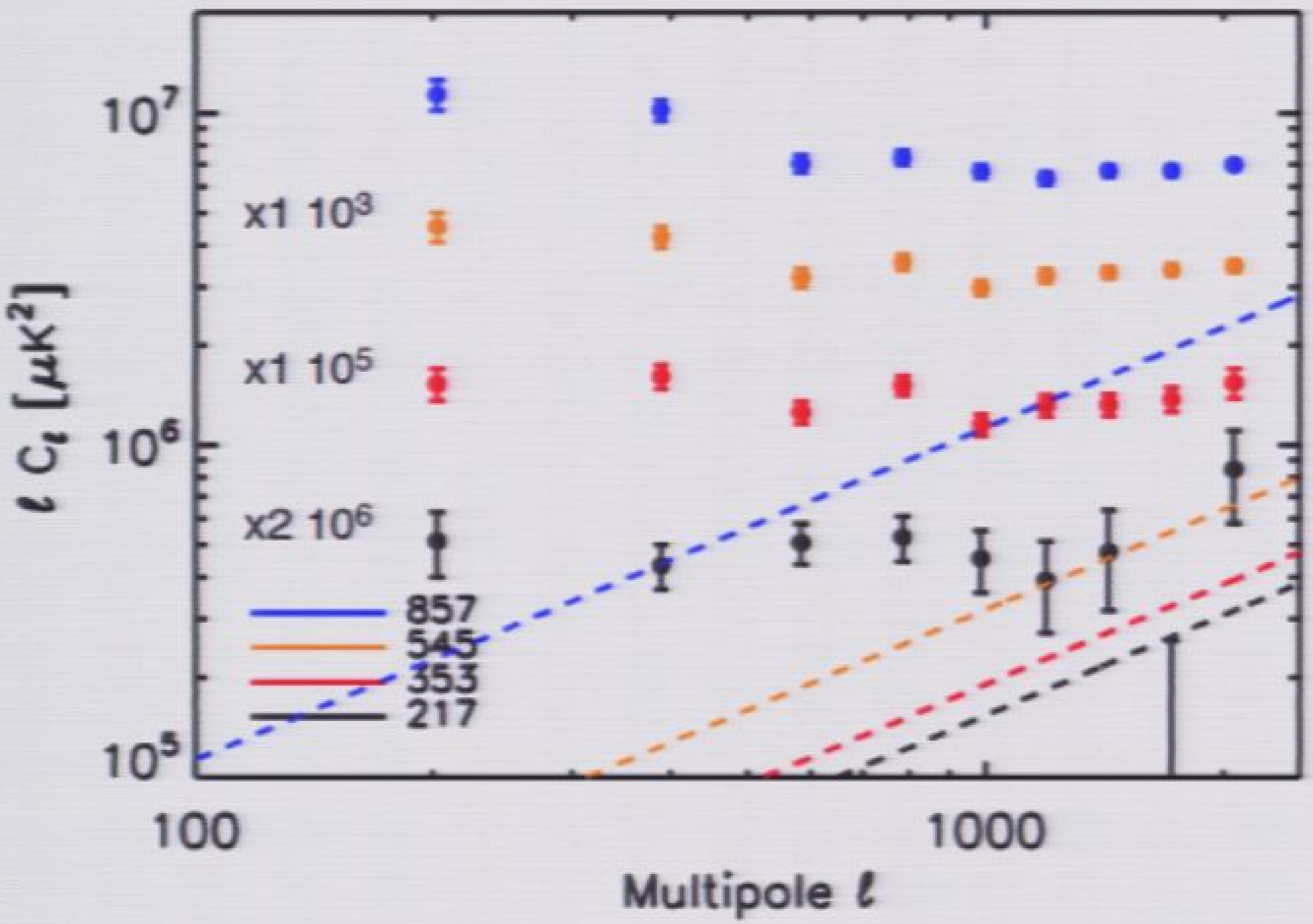

- Planck measures the CIB anisotropies from 10 arcmin to 2 degrees at 217, 353, 545 and 857 GHz
- *Half of power comes from z<0.8 at 857 GHz and z<0.9 at 545 GHz. 1/5 and 2/3 come from z >3.5 at 353 GHz and 217 GHz*
- *Results depends strongly on the HI data, & Toronto GBT results*

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

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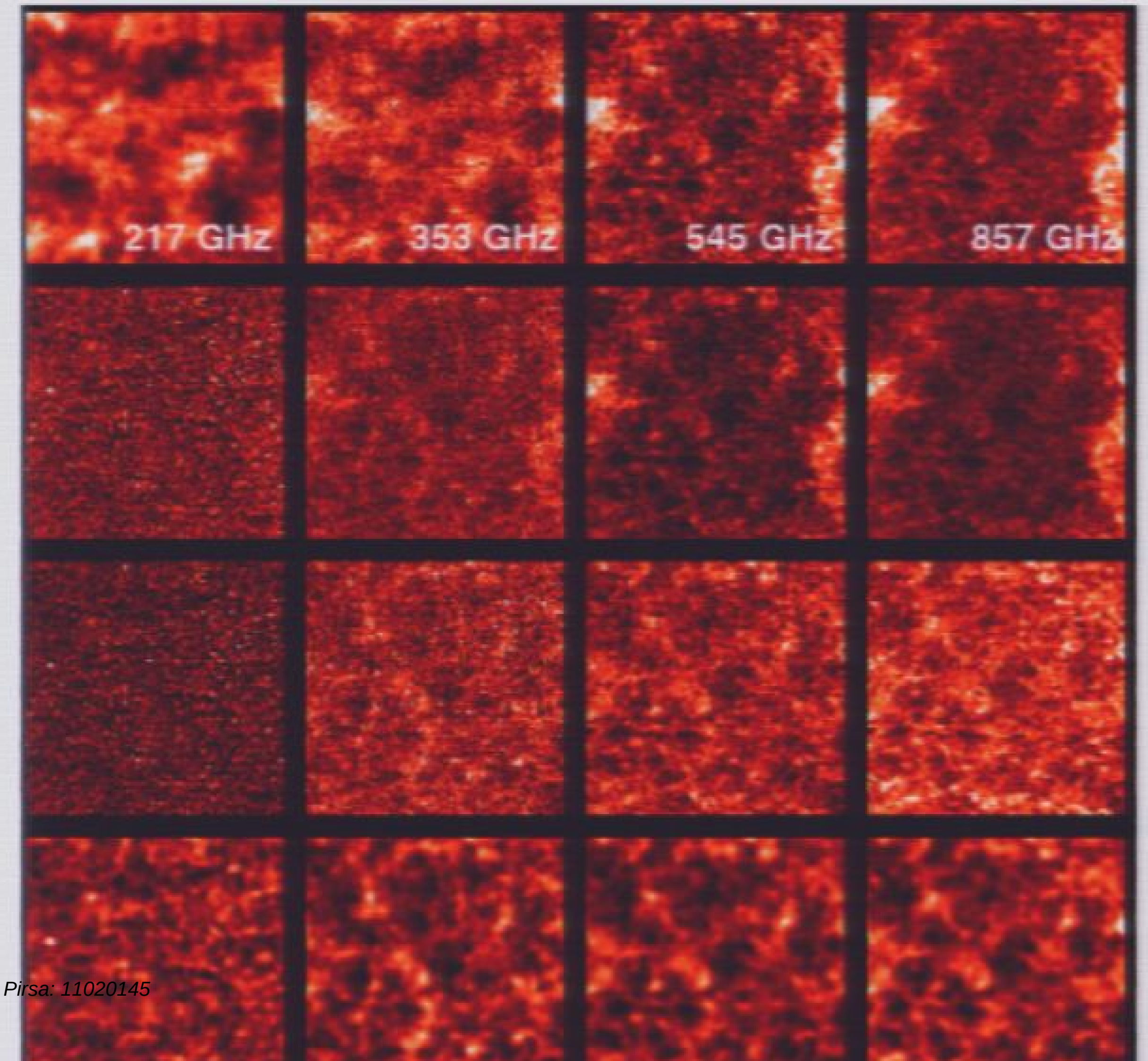

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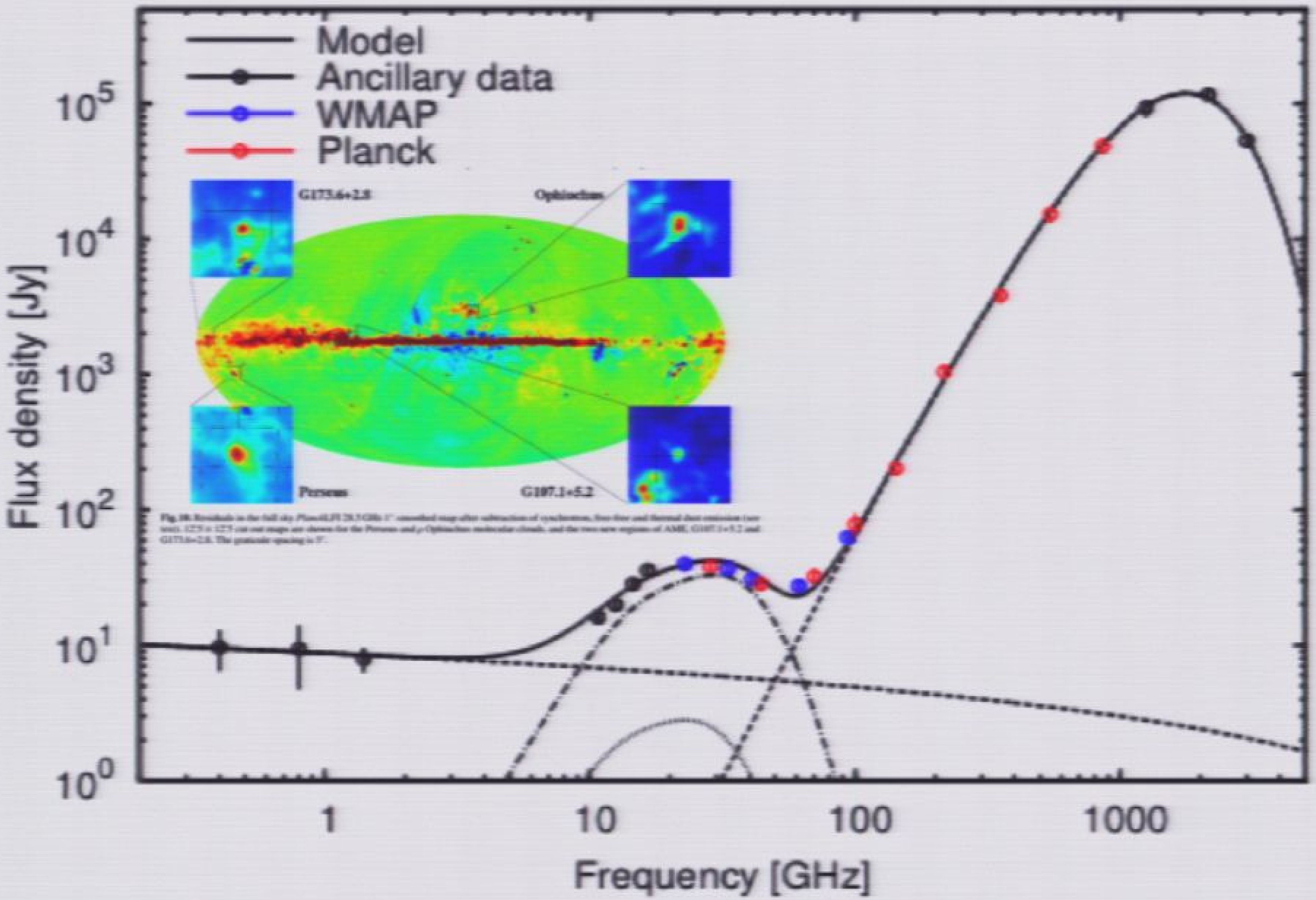

Fig. 4. Spectrum of G160.26-18.62 in the Perseus molecular cloud. The

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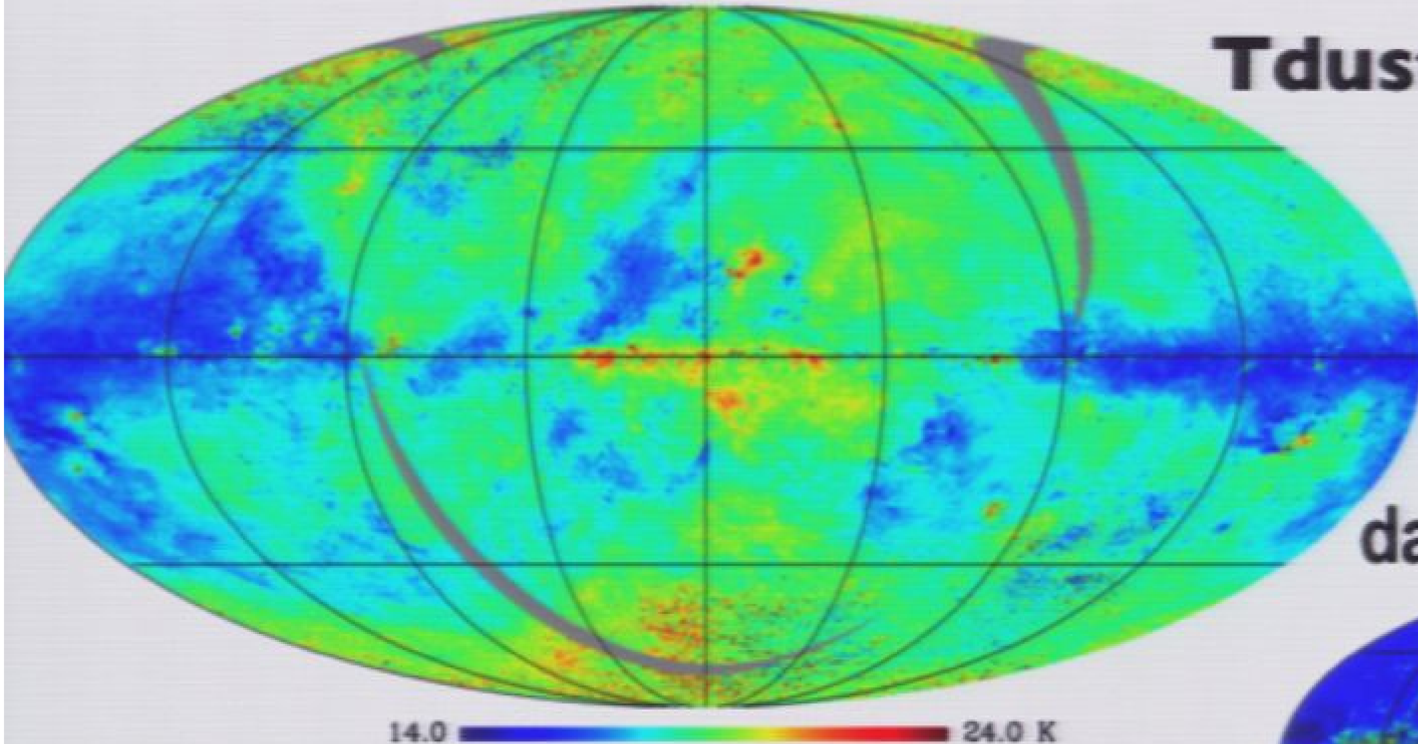
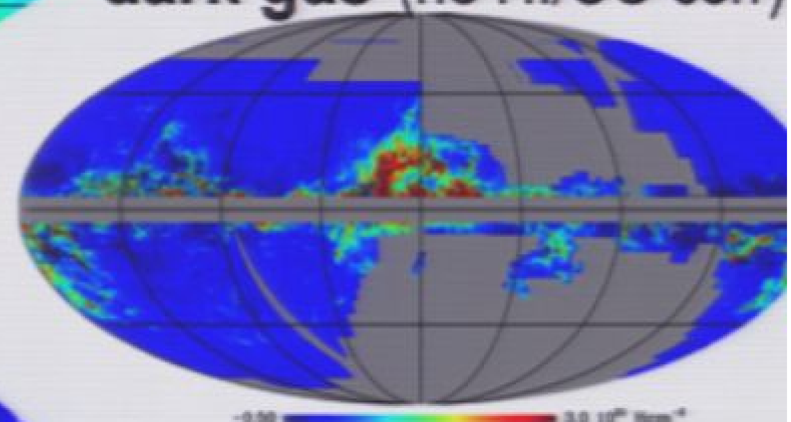
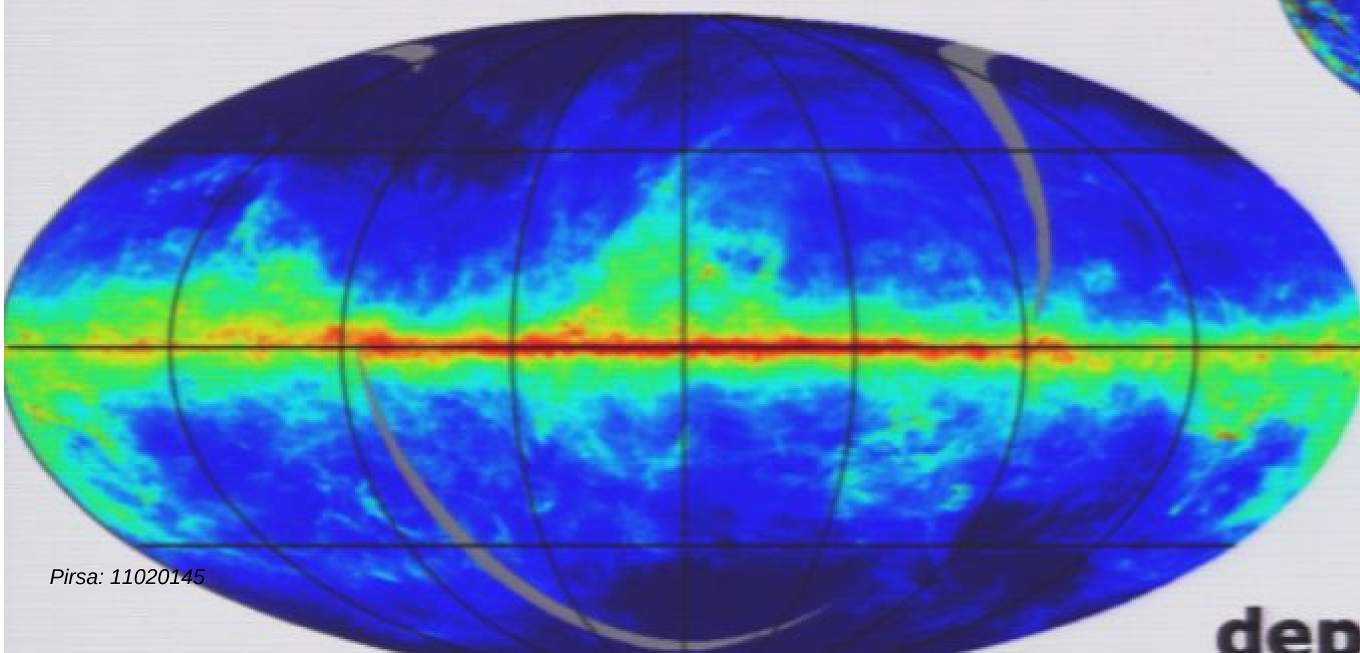
Tdust β fixed @1.8

Planck+*IRAS*

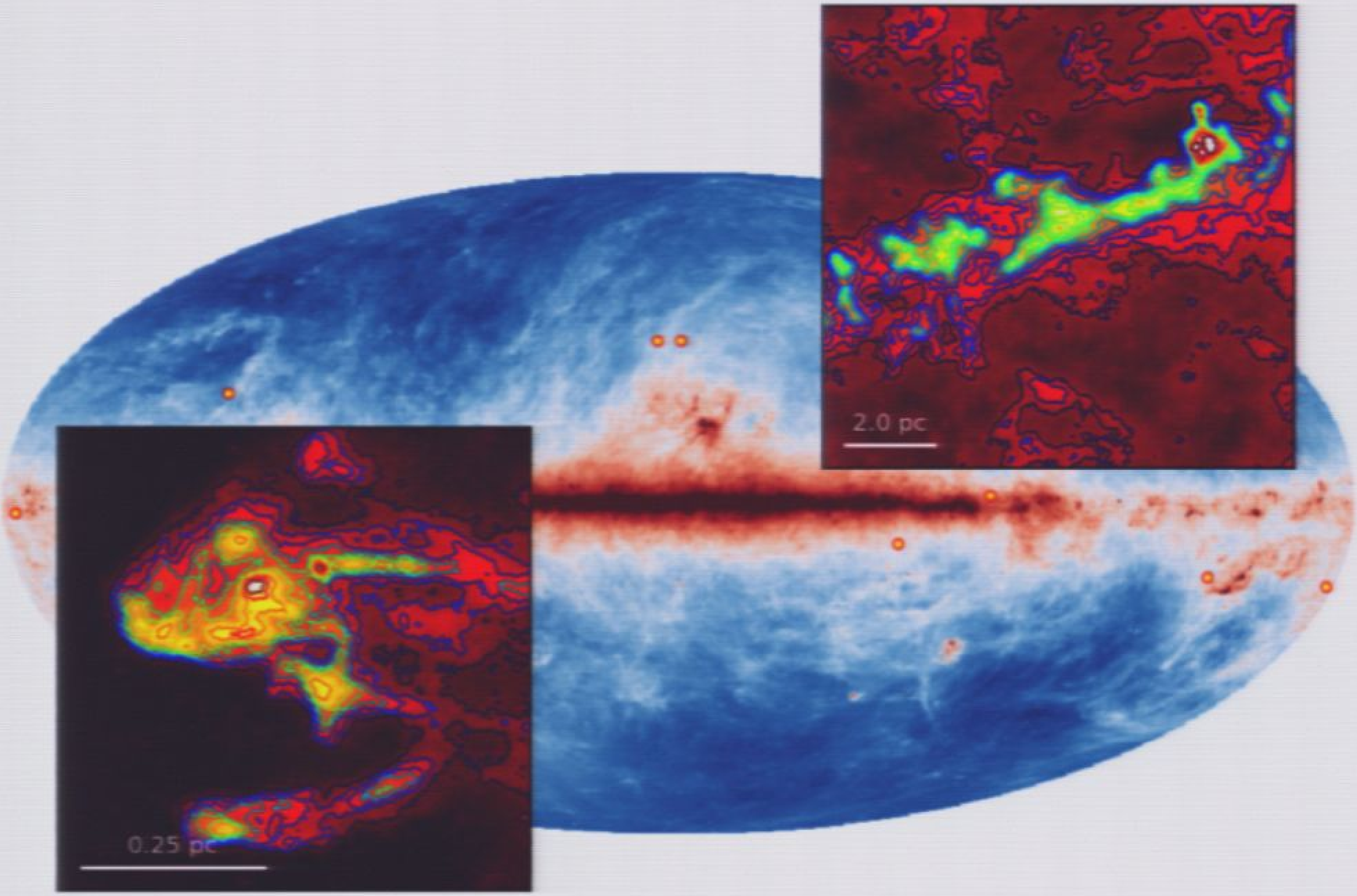


dark gas (no HI/CO corr)





depth τdust


2.0 pc
0.25 pc

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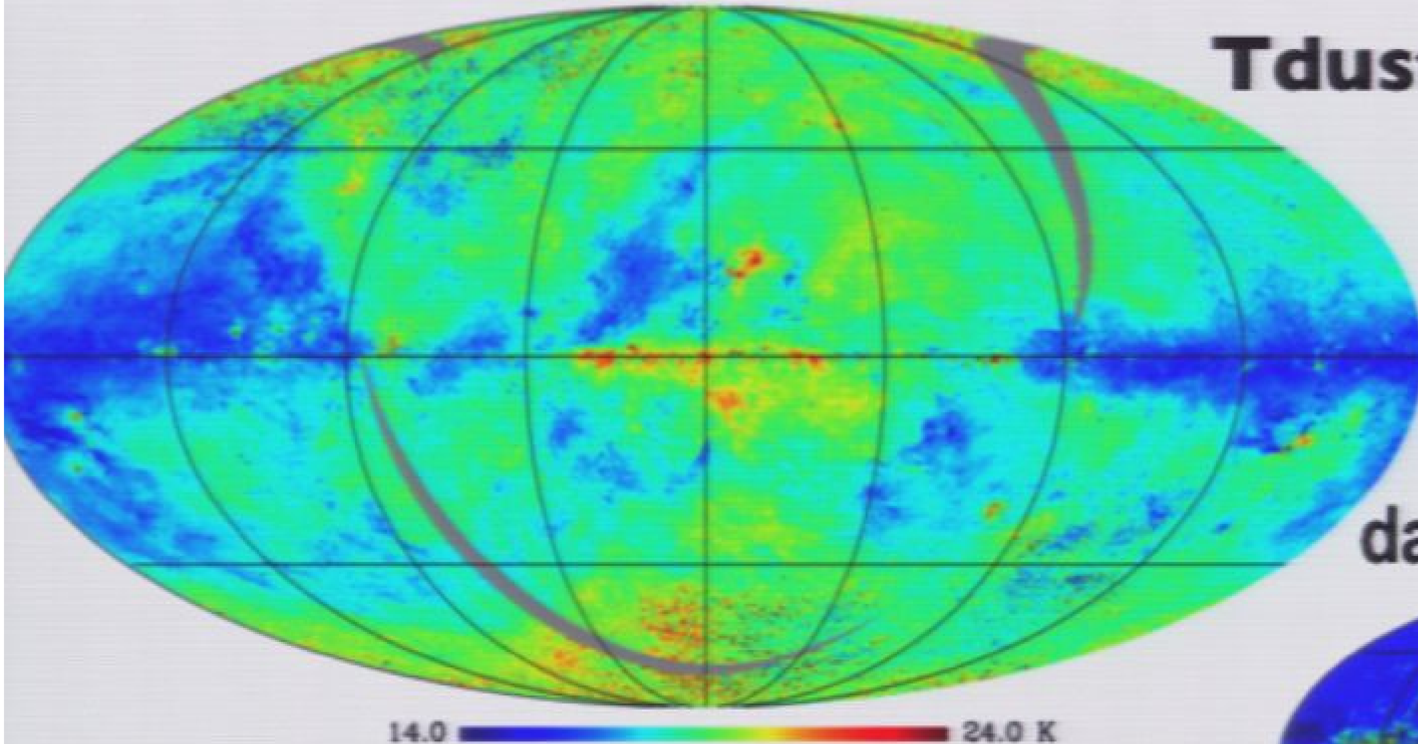

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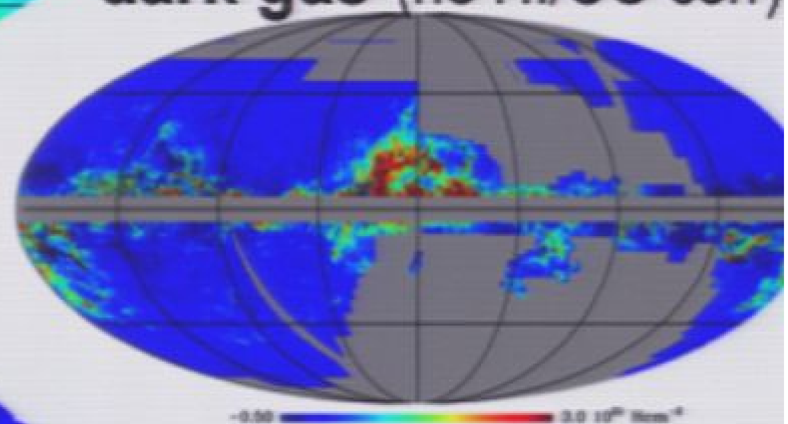

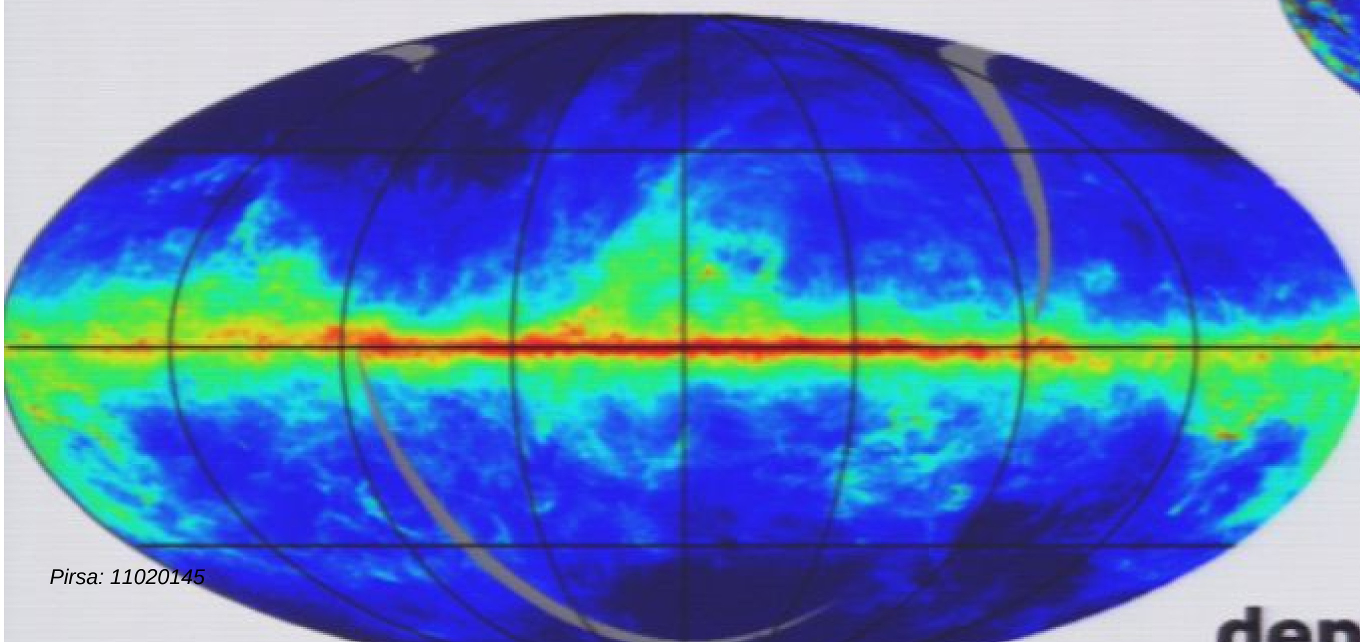

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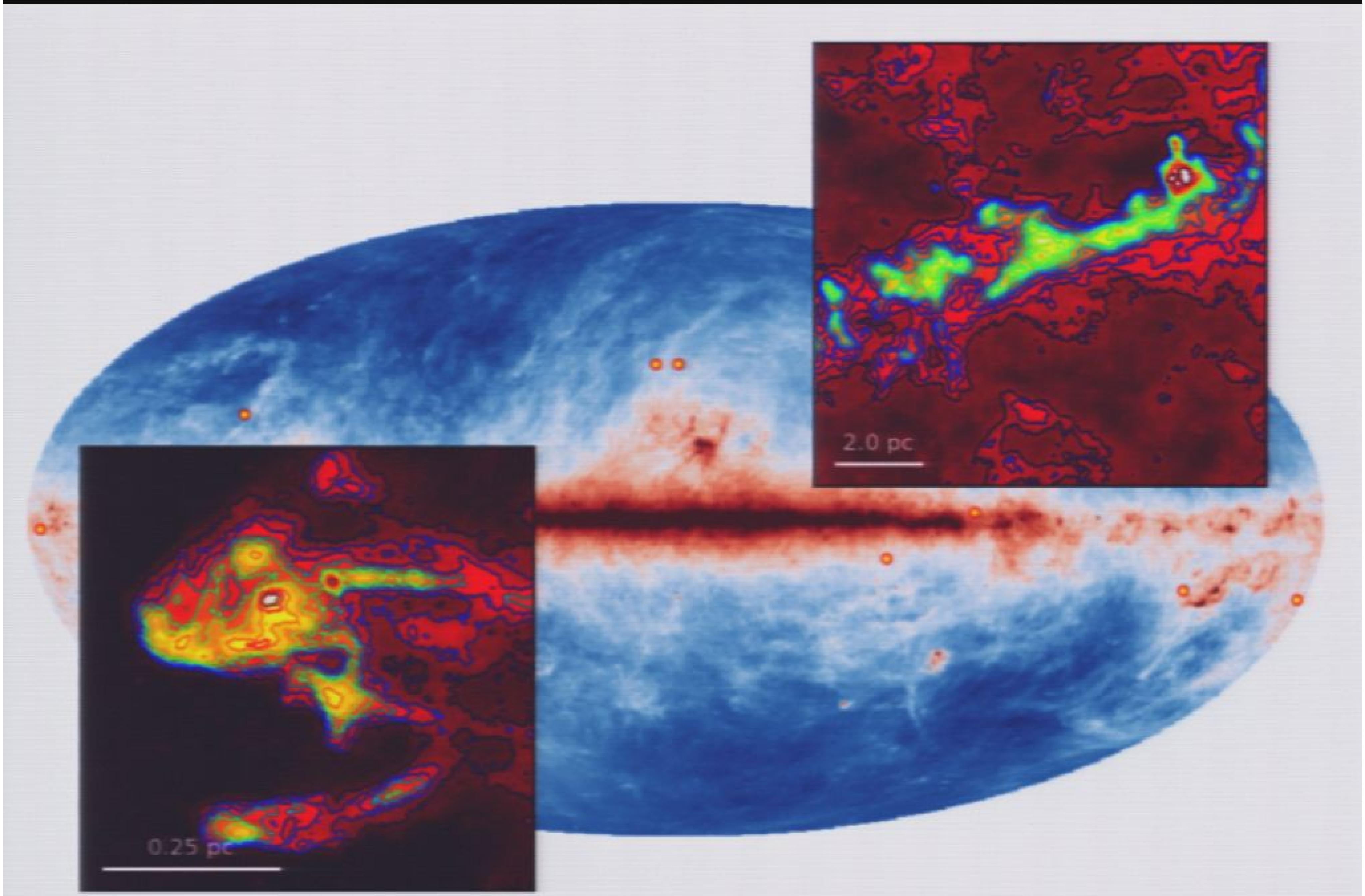

2.0 pc
0.25 pc

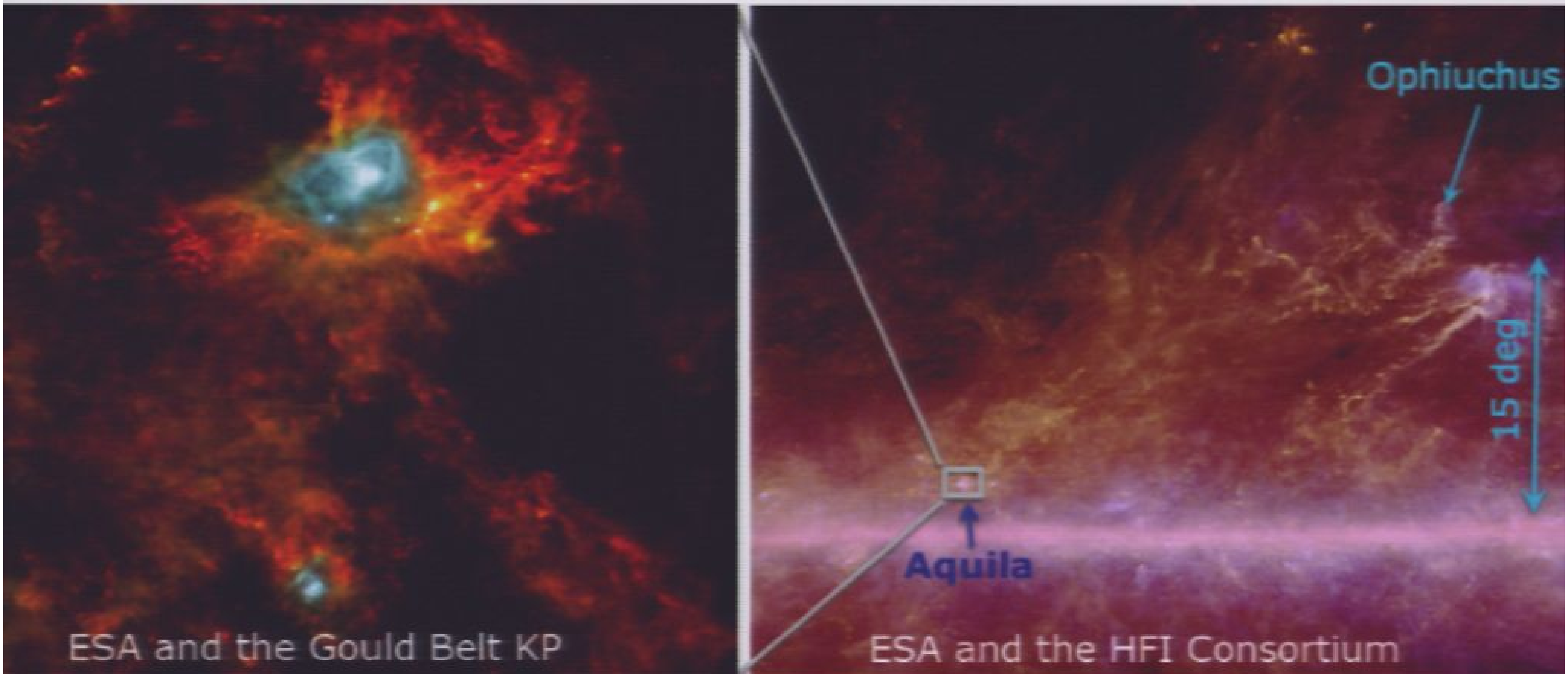
the GALAXY WIDE WEB

Filaments permeate the ISM on all scales

esa

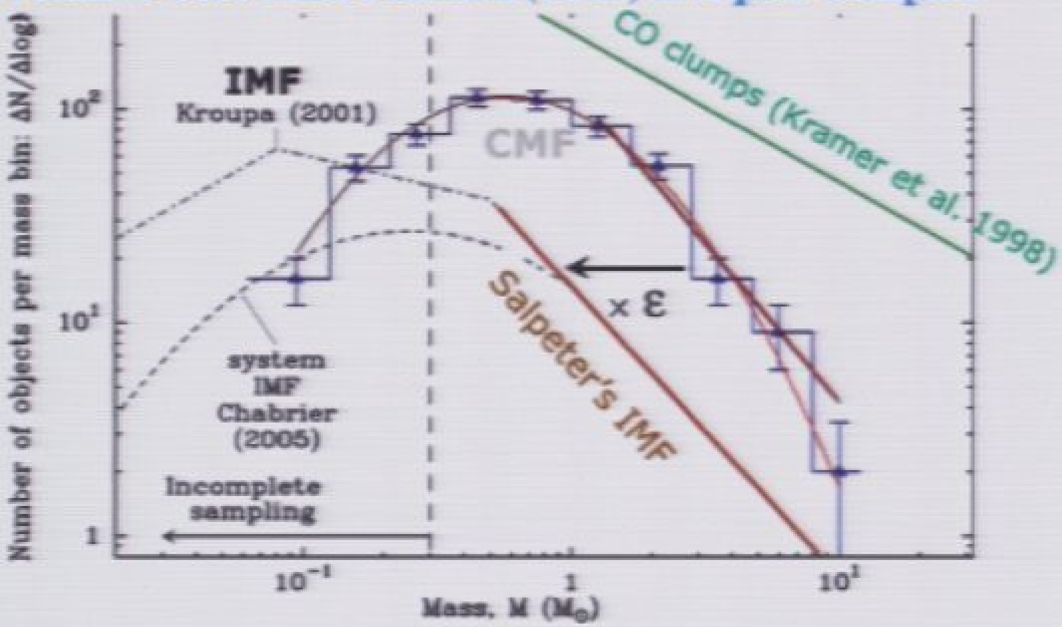
Herschel — SPIRE 500 μm +PACS 160/70 μm

Planck — HFI 540/350 μm + IRAS 100 μm

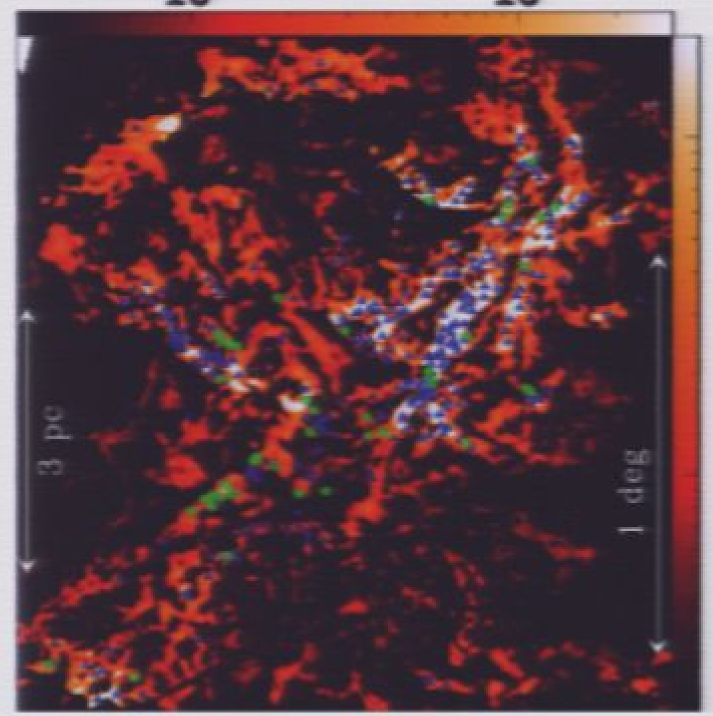


Göran Pilbratt | Planck 2011: The mm & submm sky in the Planck era | Paris | 10 January 2011

Prestellar Core Mass Function (CMF) in Aquila Complex

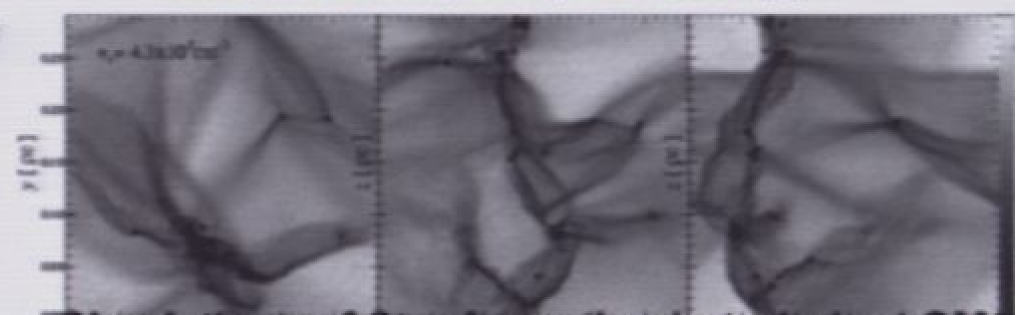


Aquila curvelet N_{H_2} map (cm^{-2})
10^{21} 10^{22}



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 GMC
Jappsen, Klessen

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

SIMPLICITY in COMPLEXITY?

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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