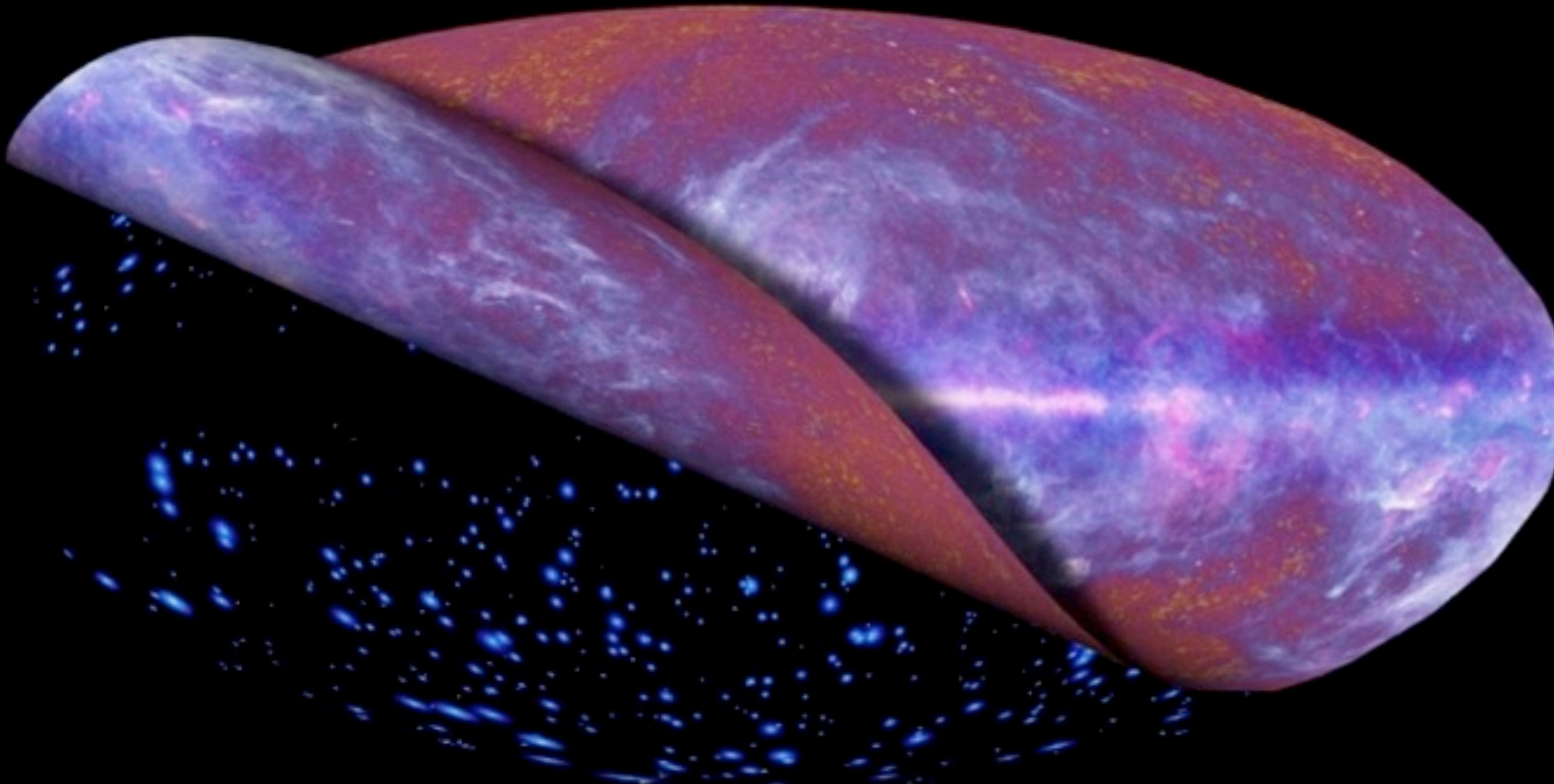
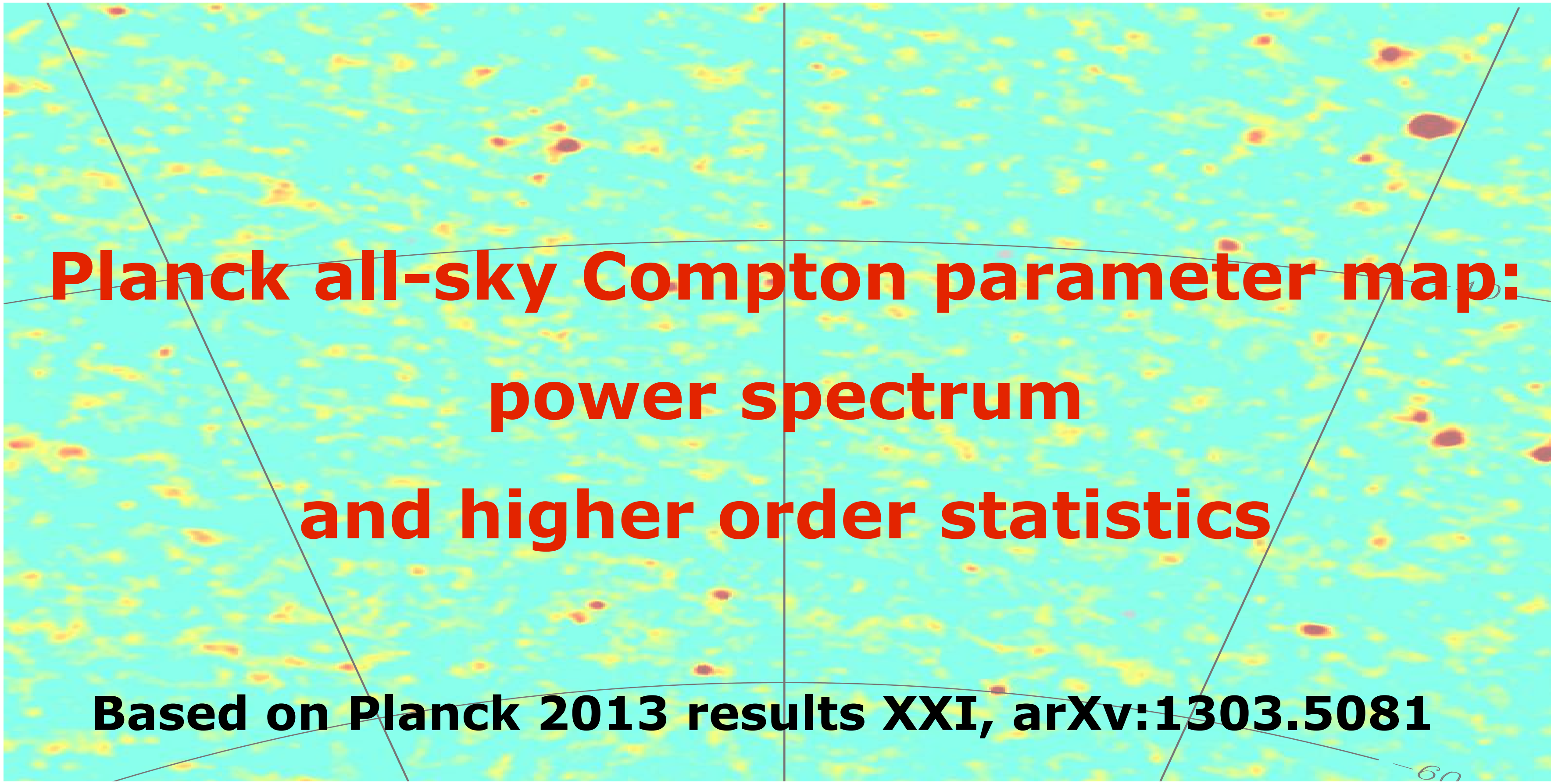


Planck unveils the Sunyaev-Zeldovich effect



Planck all-sky Compton parameter map: power spectrum and higher order statistics

Based on Planck 2013 results XXI, arXv:1303.5081

J.F. Macías-Pérez

LPSC Grenoble

on behalf of the ***Planck Collaboration***

Outline

-Reconstruction and characterization of the *Planck* y-map

-Power spectrum analysis

-High order statistics

- -1D-PDF analysis
- - Bispectrum

-Cosmological implications

From Planck channel maps to a y-map

- Adapted component separation algorithms:

  NILC and MILCA [Remazeilles et al 2011/2012; Hurier et al 2010/2012]

  ➡ constraints on electromagnetic spectra: preserve tSZ effect and remove CMB

  ➡ simultaneous spatial (pixel domain) and spectral (multipole domain) localisation

- Use HFI channels from 100 to 857 GHz

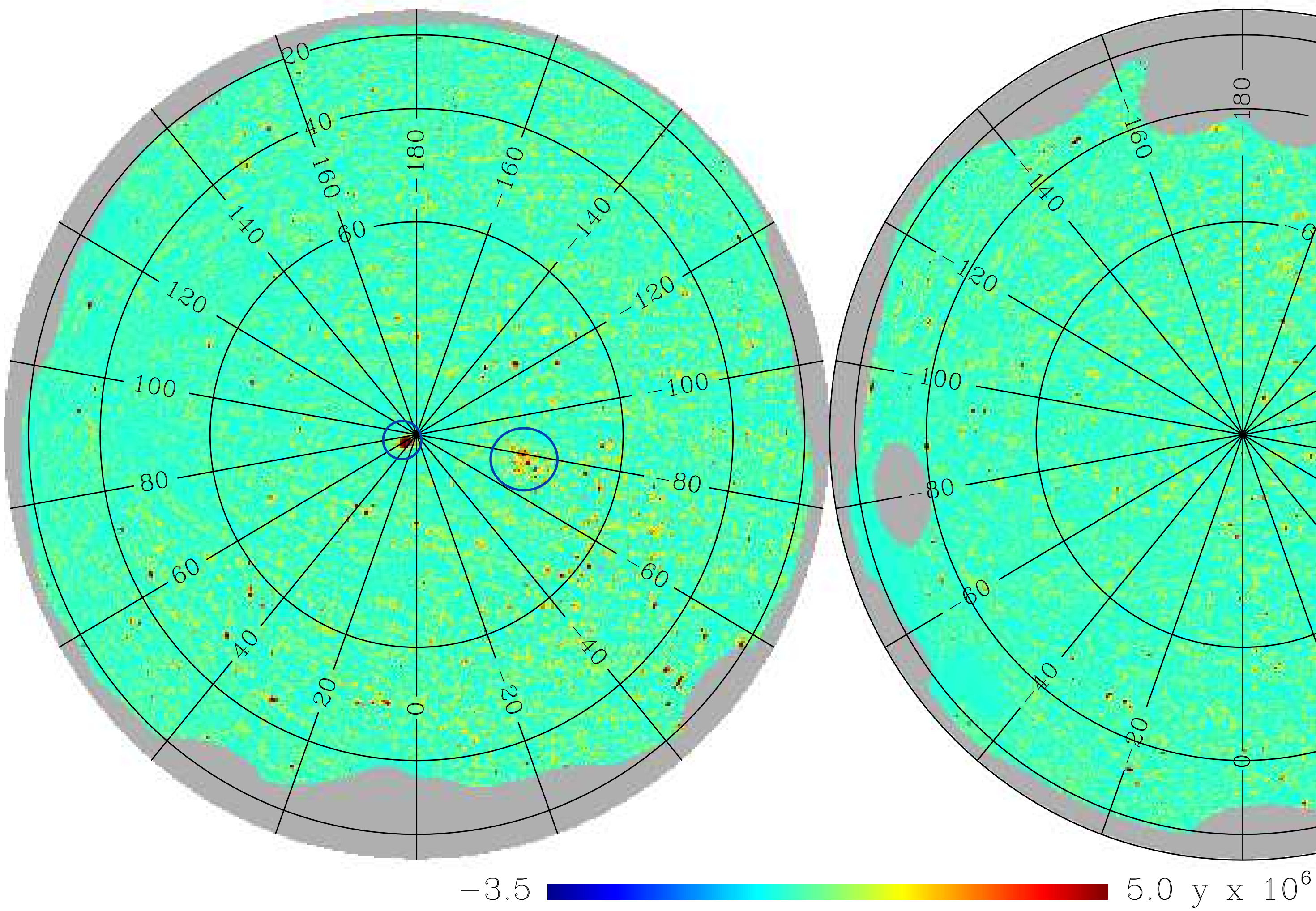
  ➡ the 857 used only for ell < 300

- Common resolution of 10 arcmin

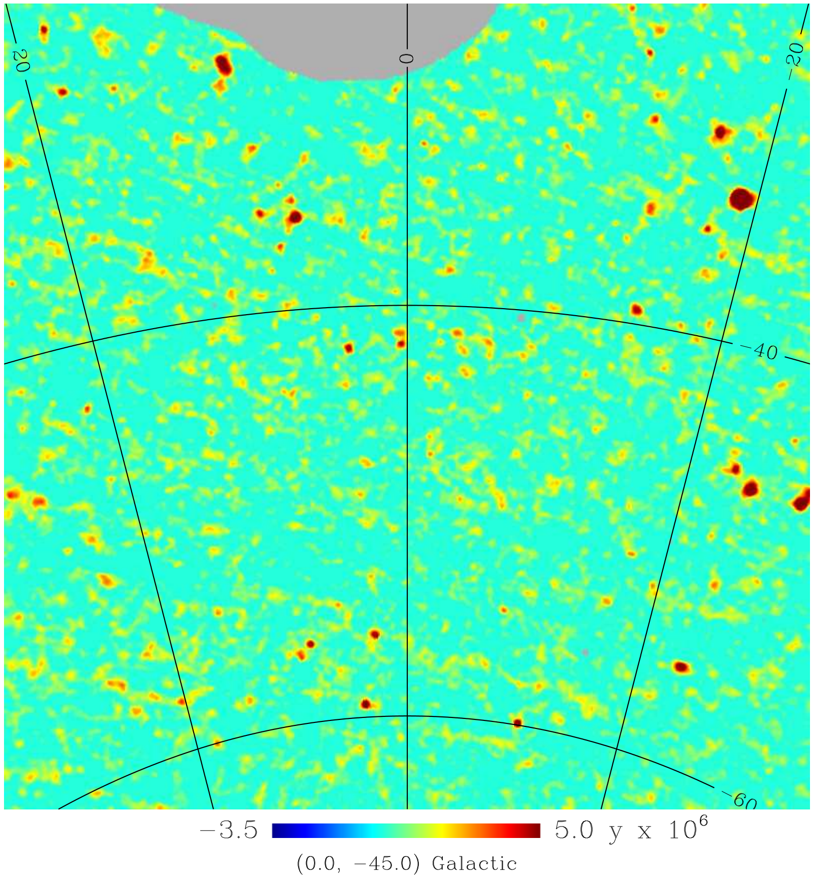
-Validation on FFP6 simulations

-Same algorithms as for the PIP (for example COMA and cluster merger analysis - Barbara's talk!

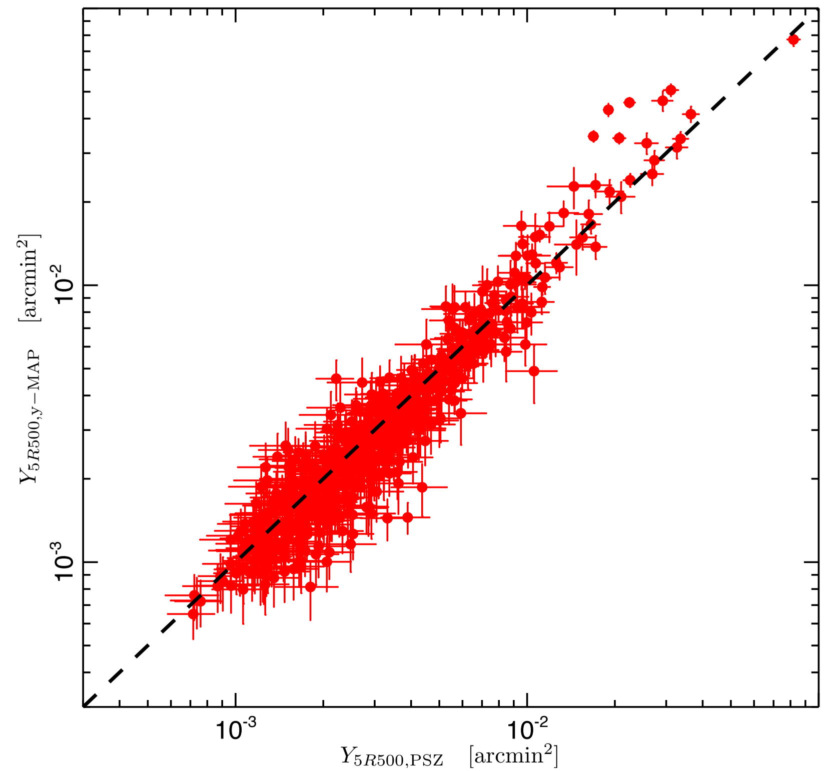
Planck Compton parameter map I



Planck Compton parameter map II



614 out of 790 common clusters at S/N > 4.5
outside a 33% Galactic mask

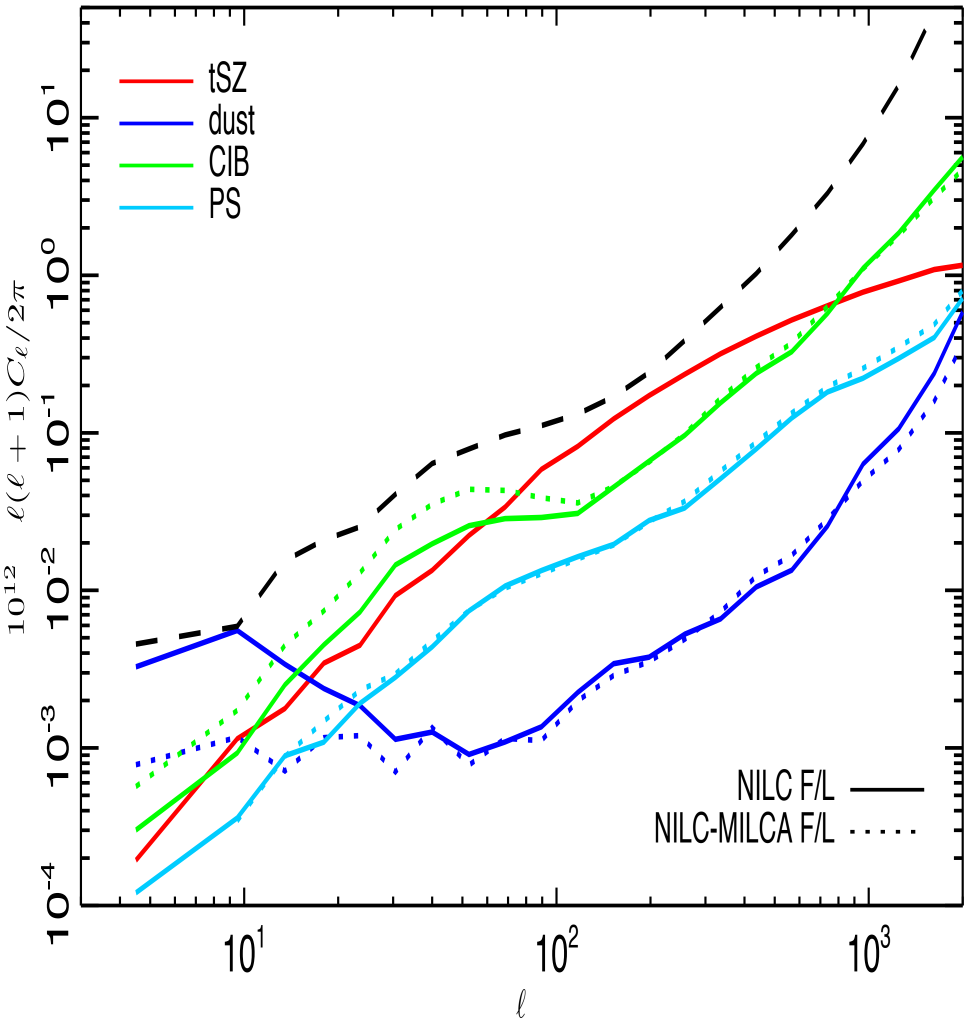


Use two independent methods to detect clusters on the y-map:

SEXtractor + MMF and MHW + SEXtractor **[Melin et al 2006; Lopez-Caniego et al 2006; Gonzalez-Nuevo et al 2006; Bertin & Arnouts 1996]**

➡ number of detected clusters and measured flux consistent with Planck SZ catalogue

Power spectrum analysis I : foregrounds



- Apply same component separation algorithms to the FFP6 simulations
- Compute cross-power spectrum of the FIRST and LAST maps

[Tristram et al 2005]

Main foreground contributions

➡ Galactic thermal dust at large angular scales - mask galactic emission on 50% of the sky

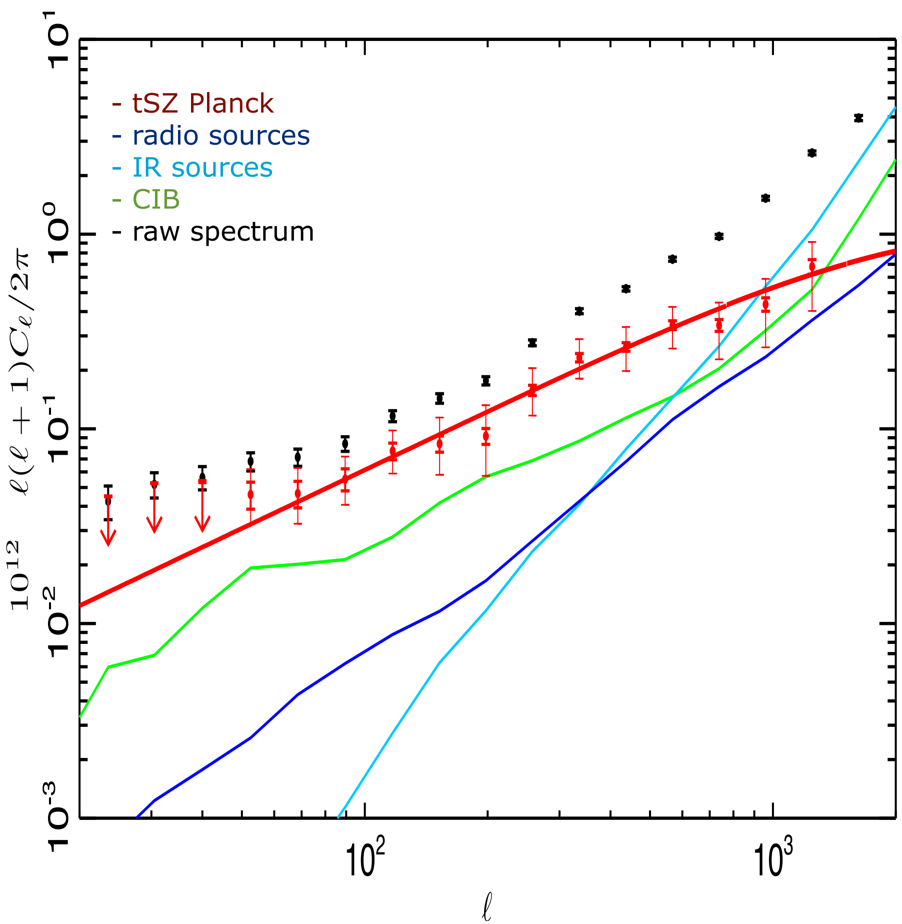
➡ cosmic infrared background and point sources at small angular scales - use physically motivated model + mask strong sources

- NILC y-map is less contaminated by foregrounds but slightly noisier than MILCA

Power spectrum analysis III : modelling

Three component model : **tSZ** + clustered **CIB** + **Point sources**

$$C_l = C_l^{tSZ} + A^{CIB} \times C_l^{CIB} + A^{PS} \times (C_l^{RS} + C_l^{IRS})$$



- **tSZ**: 2-halo model; ***Tinker et al 2008*** mass function; ***Arnaud et al 2010*** pressure profile; 20% mass bias - same as for cluster number count analysis (Marian's talk)

[Taburet et al 2009,2010,2011]

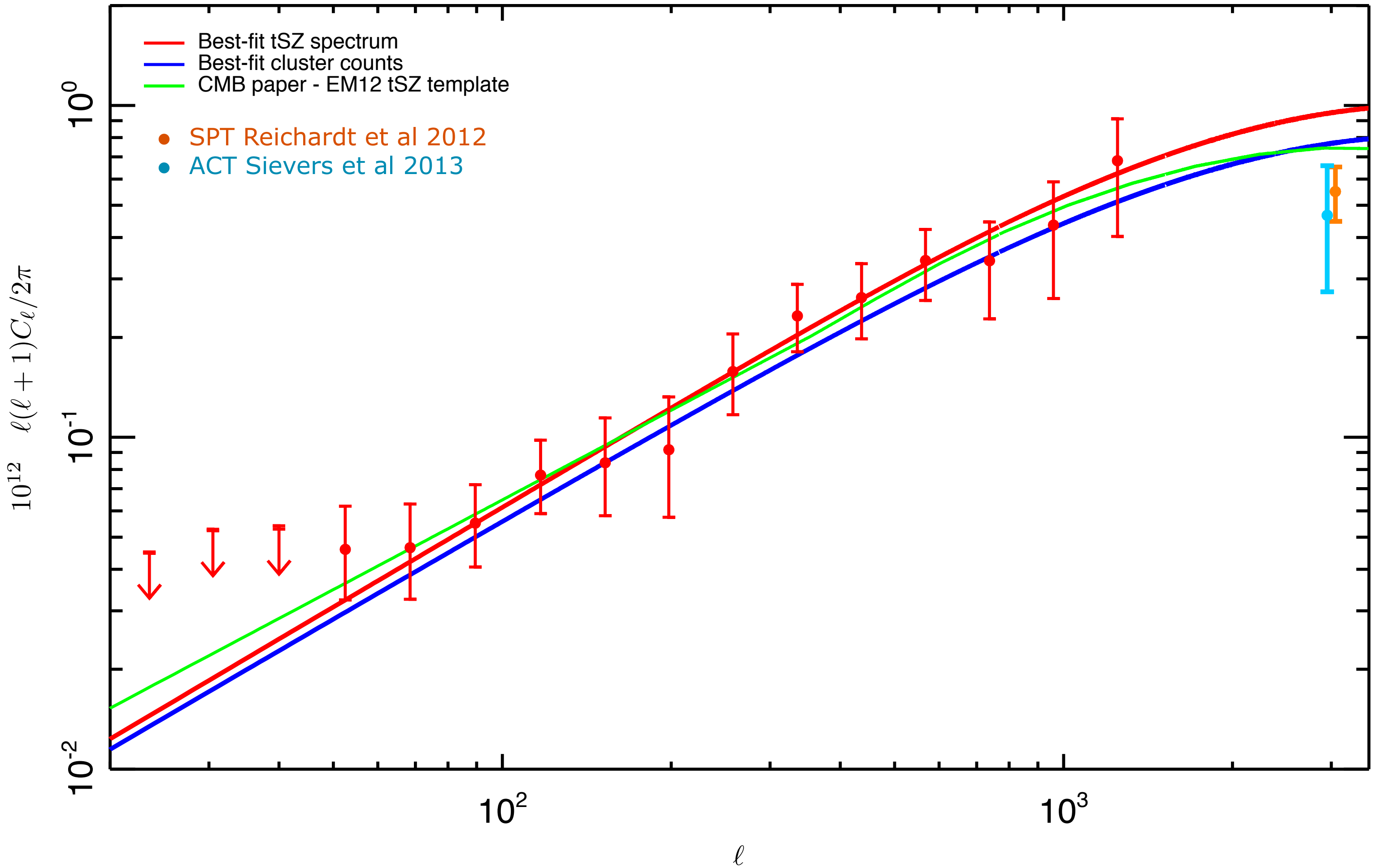
- clustered ***CIB***: best-fit frequency auto and cross-power spectra for the 6 HFI bands (Guilaine's talk) - 5% uncertainties on cross correlation coefficients accounted for

- ***Point sources***: number count models for the radio (Tucci et al 2011) and infrared (Bethermin et al 2012) sources - same as for CIB analysis (Guilaine's talk)

We assume Gaussian priors for $\mathbf{A^{PS}}$ and $\mathbf{A^{CIB}}$ (1±0.5)

Planck tSZ power spectrum

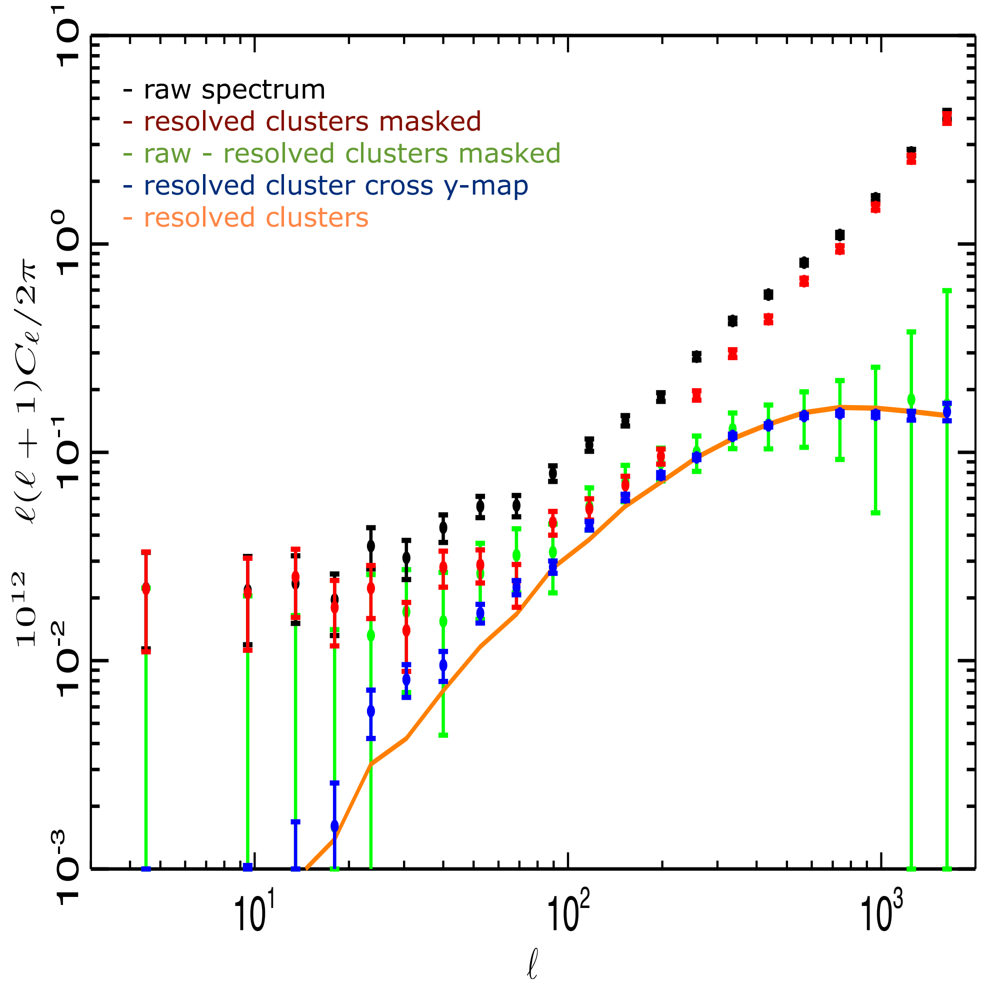
First tSZ power spectrum measurement on angular scales from *3 degrees to 10 arcmin*



Cluster number counts best-fit model and re-scaled CMB tSZ temp are consistent the measured tSZ power spectrum; a power law is also a good fit to the data.

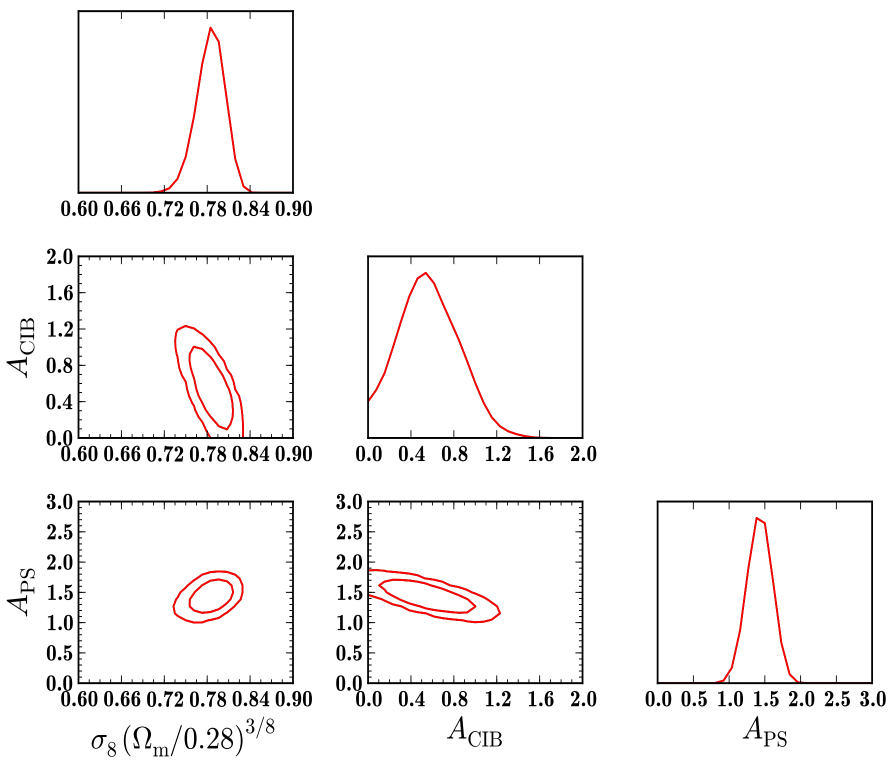
Power spectrum analysis IV: resolved clusters

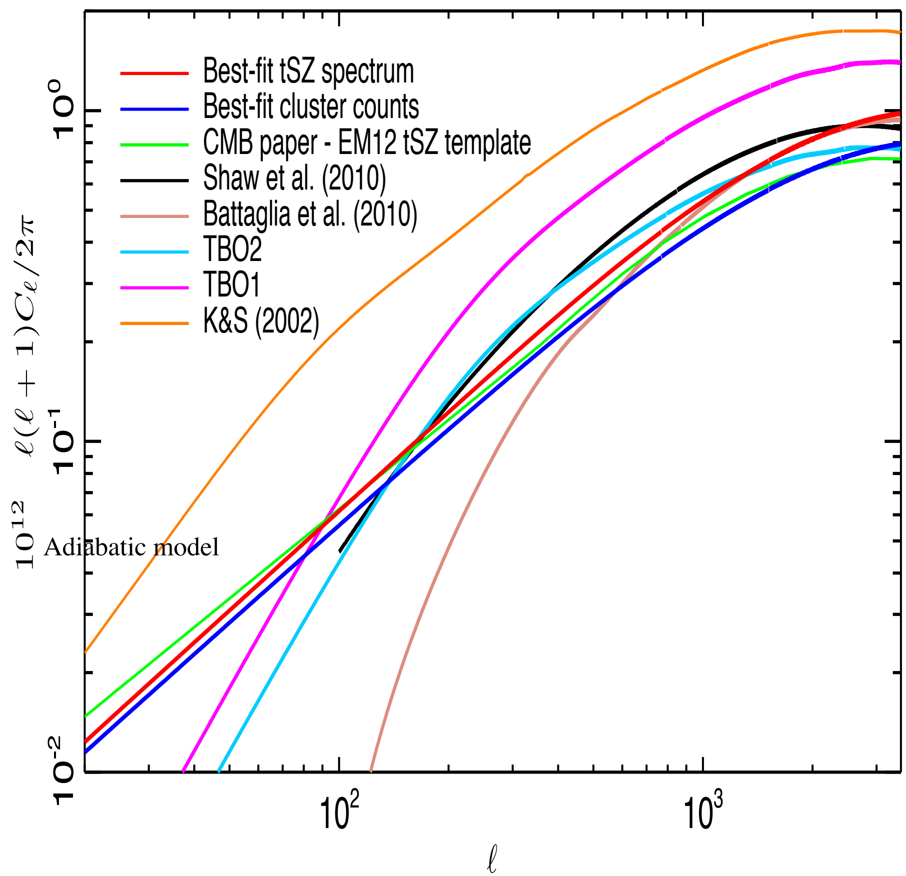
- Simulate detected clusters
- Mask all *Planck* detected point sources from 100-857 GHz
- A significant fraction of the observed signal is due to resolved clusters of galaxies
- Clear indication of signal from unresolved clusters and diffuse structures



Power spectrum: cosmological implications

Use a MCMC analysis to fit σ_8, Ω_m, A^{CIB} and A^{PS}



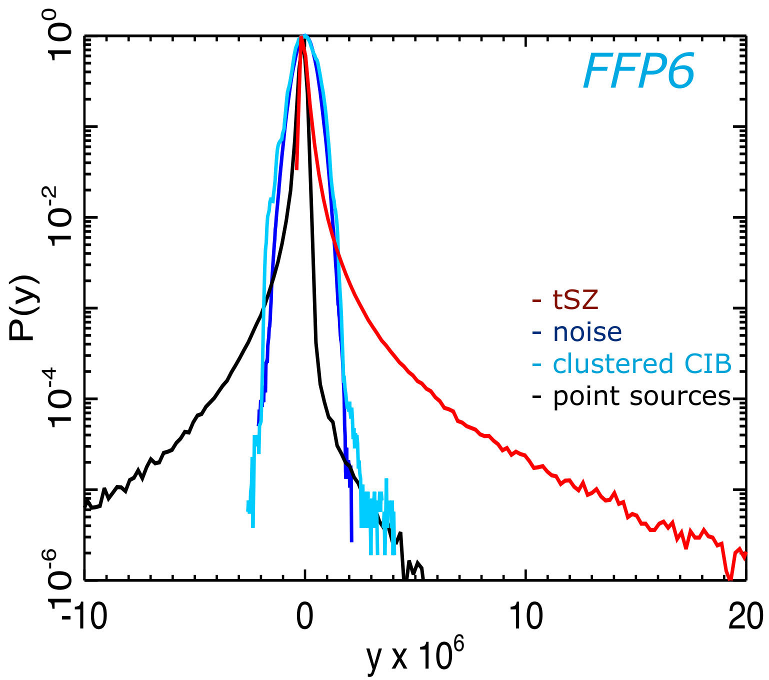


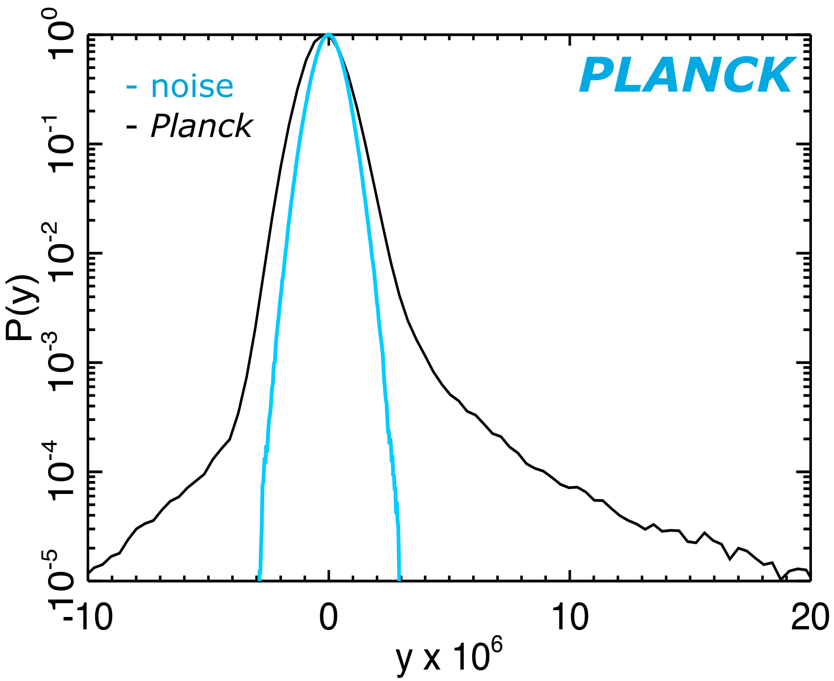
$\sigma_8(\Omega_m)^{3.2/8.1} = 0.784 \pm 0.016$ (68% C.L.)

Physical model dependent:
mass function, pressure profile, mass bias, gas physics, ...

1D-PDF analysis: asymmetry of the distribution

Use a signal-to-noise filter in harmonic space to enhance tSZ signal



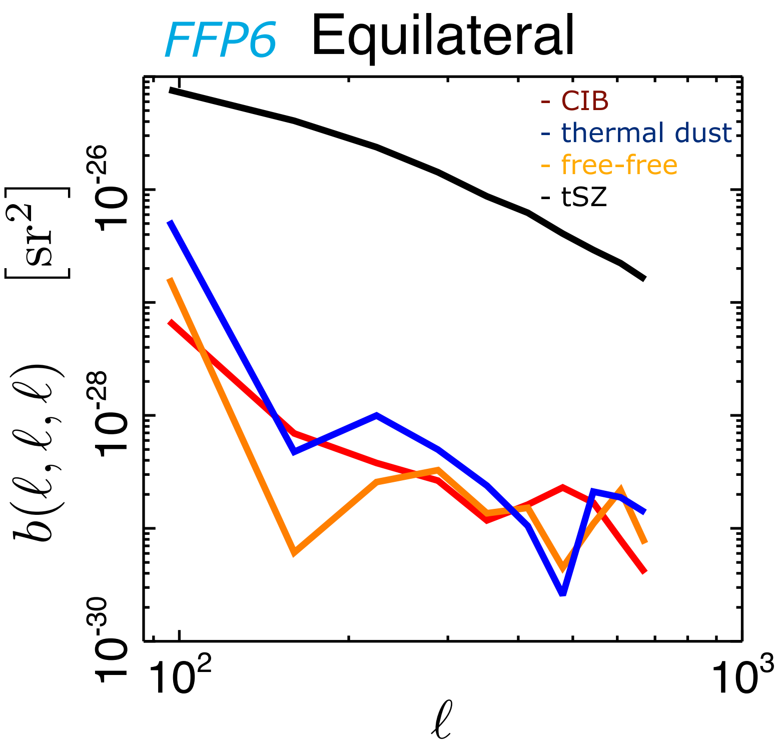


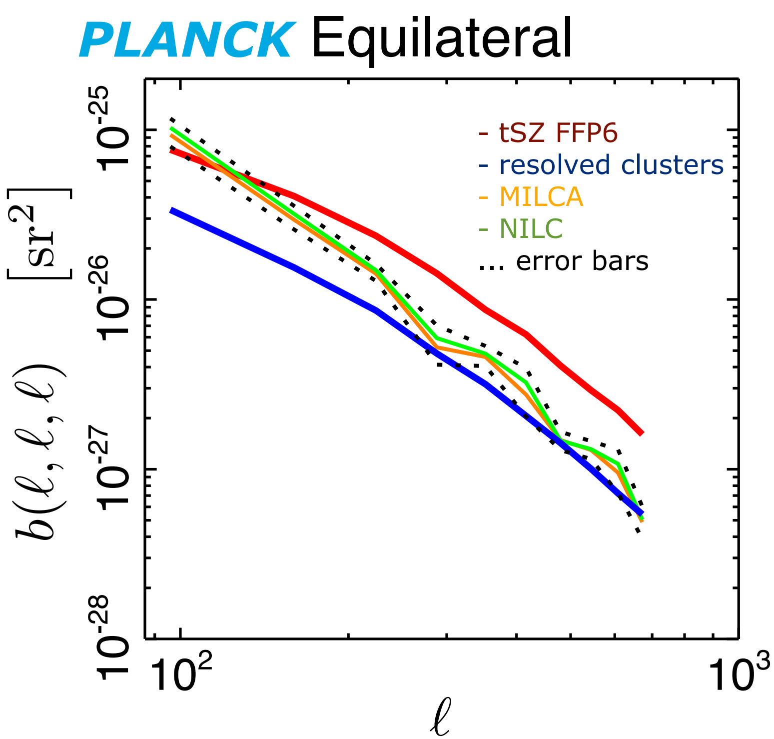
After filtering tSZ effect dominates:

- 1D-PDF shows a positive tail consistent with tSZ effect
- skewness is not significantly affected by foreground emission
- unnormalized skewness scales as σ_8^{10-11} so $\sigma_8 = 0.779 \pm 0.015$ (68% C.L.)

Bispectrum analysis

Compute bispectrum for various configurations





- the bispectrum of the y-map is dominated by the tSZ signal **[Lacasa et al 2012]**
- Planck provides first measurement of the tSZ effect bispectrum
- clear indications of unresolved clusters and diffuse tSZ emission
- bispectrum amplitude scales as σ_8^{10-12} and so $\sigma_8 = 0.74 \pm 0.04$ (68% C.L.)

Conclusions

planck

-*Planck* has obtained the first all-sky y-map

-cluster properties in the y-map are consistent with those in the *Planck* SZ catalogue

-tSZ power spectrum has been measured on angular scales from 3 degrees to 10 arcmin

- power spectrum and high-order statistics of the y-map are consistent with tSZ origin for the signal

-power spectrum and high order statistic analyses set consistent and tight constraints on the matter content of the universe

-constraints on σ_8 are consistent with cluster number counts

- but at the 2.7 σ level with respect to the *Planck* CMB analysis: uncertainties on physics of clusters need to be accounted for

The scientific results that we present today are a product of the Planck Collaboration, including individuals from more than 100 scientific institutes in Europe, the USA and Canada

Planck is a project of the European Space Agency, 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.

Backup slides

Halo model for the tSZ effect power spectrum

$$C_l^{tSZ} = C_l^{1halo} + C_l^{2halo}$$

$$C_\ell^{1\text{halo}} = \int_0^{z_{\max}} dz \frac{dV_c}{dz d\Omega} \int_{M_{\min}}^{M_{\max}} dM \frac{dn(M,z)}{dM} |\tilde{y}_\ell(M,z)|^2$$

Tinker et al 2008
mass function

$$C_\ell^{2\text{halos}} = \int_0^{z_{\max}} dz \frac{dV_c}{dz d\Omega} \times \left(\int_{M_{\min}}^{M_{\max}} dM \frac{dn(M,z)}{dM} |\tilde{y}_\ell(M,z)| \; B(M,z) \right)^2 P(k,z)$$

Arnaud et al 2010
pressure profile

$$\frac{dn}{dM} = f(\sigma) \frac{\bar{\rho}_m}{M} \frac{d \ln \sigma^{-1}}{dM}$$

$$f(\sigma) = A\left[\left(\frac{\sigma}{b}\right)^{-a} + 1\right] e^{-c/\sigma^2}$$

$$\sigma^2 = \int P(k) \hat{W}(kR) k^2 \, dk,$$

$$\tilde{y}_\ell(M,z) = \frac{4\pi r_s}{l_s^2} \left(\frac{\sigma_T}{m_e c^2}\right) \int_0^\infty dx\, x^2 P_e(M,z,x) \frac{\sin(\ell_x/\ell_s)}{\ell_x/\ell_s}$$

$$\begin{aligned} P(r) &= P_{500} \left[\frac{M_{500}}{3\times 10^{14}\, h_{70}^{-1}\, M_\odot}\right]^{\alpha_P + \alpha'_P(x)} \mathbb{p}(x) \\ &= 1.65\times 10^{-3}\, h(z)^{8/3} \left[\frac{M_{500}}{3\times 10^{14}\, h_{70}^{-1}\, M_\odot}\right]^{2/3+\alpha_P+\alpha'_P(x)} \\ &\quad \times \mathbb{p}(x) \;\; h_{70}^2\, \text{keV cm}^{-3} \end{aligned}$$

$$\mathbb{p}(x) = \frac{P_0}{(c_{500}x)^\gamma \left[1 + (c_{500}x)^\alpha\right]^{(\beta-\gamma)/\alpha}}$$

$[P_0, c_{500}, \Upsilon, \alpha, \beta, \alpha_P] = [3.130 h_{70}^{-3/2}, 1.156, 0.3292, 1.0620, 5.4807, 0.12]$ $x = r/R_{500}$

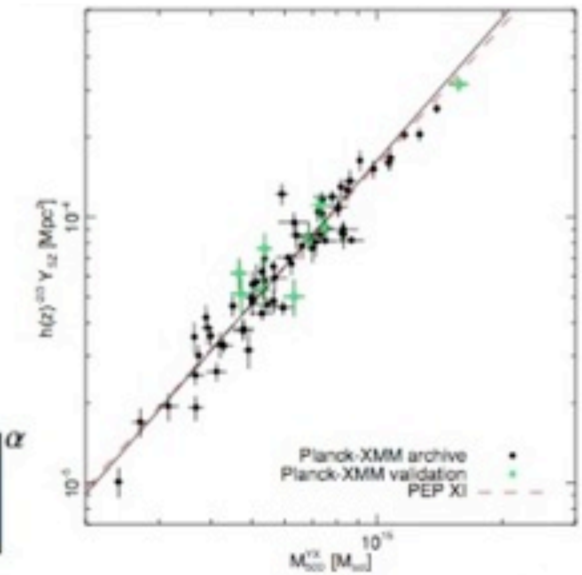
From Marian's talk:

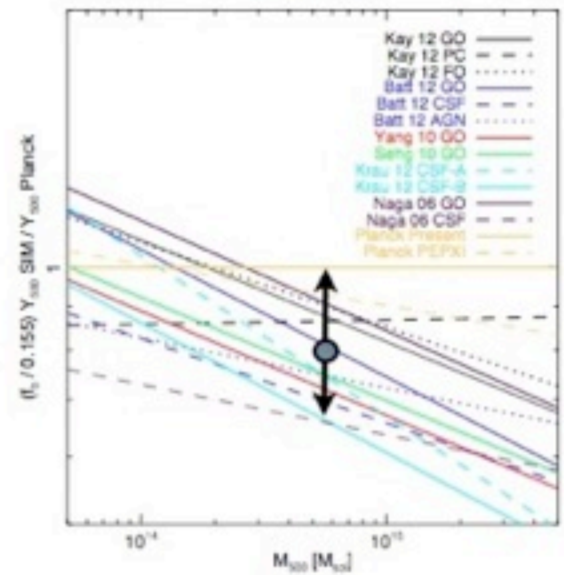
- From 71 clusters in the sample with good XMM data
- Scaling Y_{SZ} re-extracted with Xray size&position vs M^{YX}

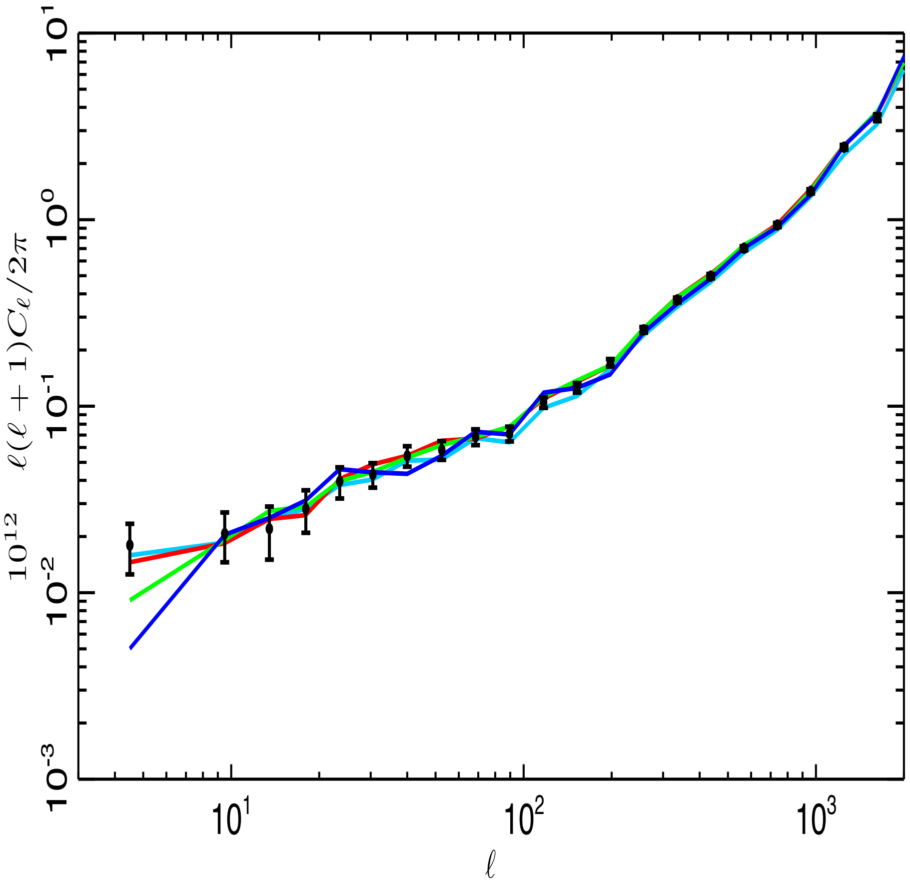
$$E^{-\beta}(z)\left[\frac{D_A^2(z)\,\bar{Y}_{500}}{10^{-4}\,\mathrm{Mpc}^2}\right] = Y_*\left[\frac{h}{0.7}\right]^{-2+\alpha}\left[\frac{(1-b)\,M_{500}}{6\times10^{14}\,\mathrm{M_{sol}}}\right]^{\alpha}$$

- lognormal scatter on Y
- Ratio between our scaling and numerical simulation scalings from litterature

$\longrightarrow$ $(1-b) = 0.8\ in\ [0.7-1.0]$

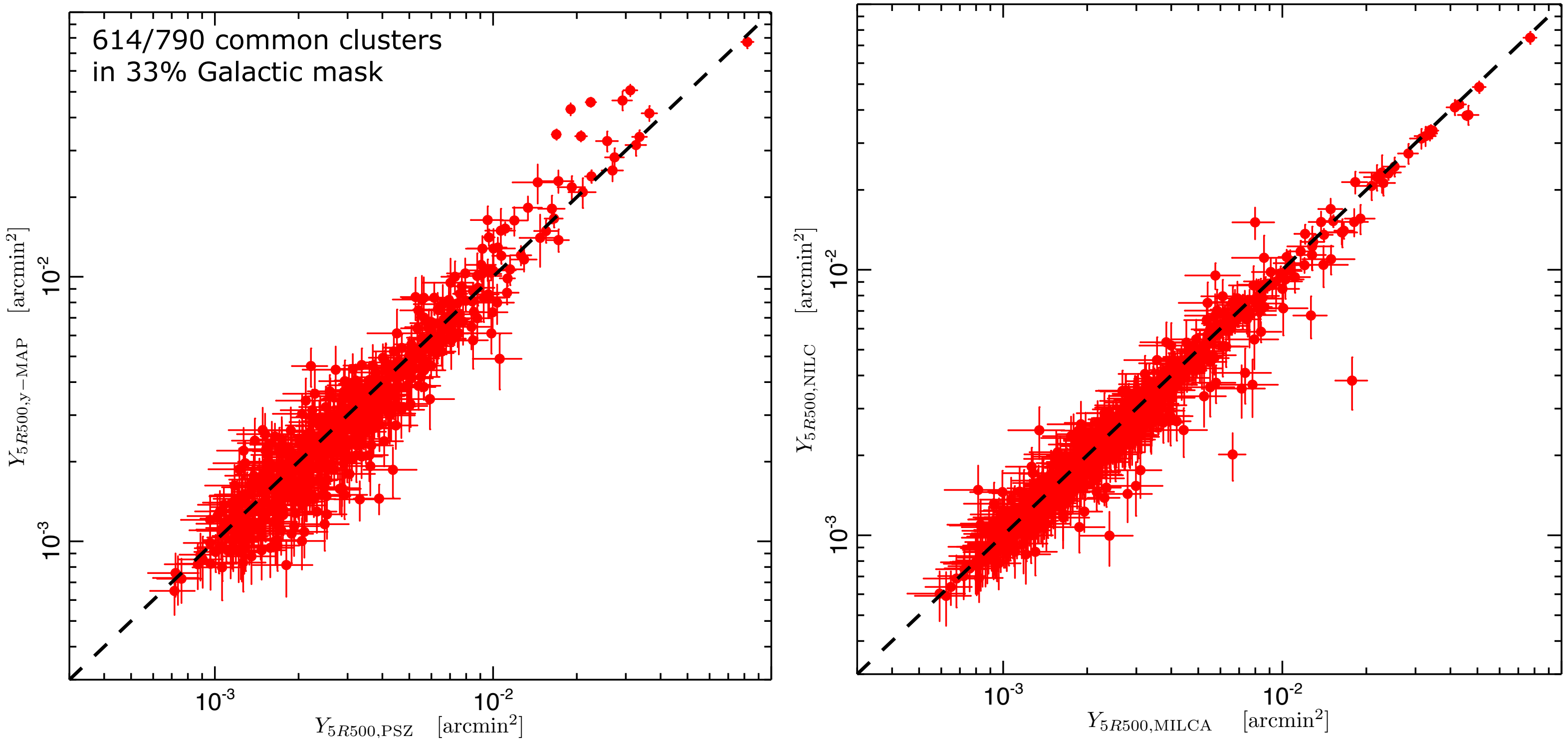






- Mask 50% of the sky using the 857 GHz map to avoid thermal dust emission contamination
- Mask all *Planck* detected point sources from 100-857 GHz
- As radio sources show up as negative spikes we cross check there are not resolved sources left in the y-map after masking

y-map characterisation: detecting clusters



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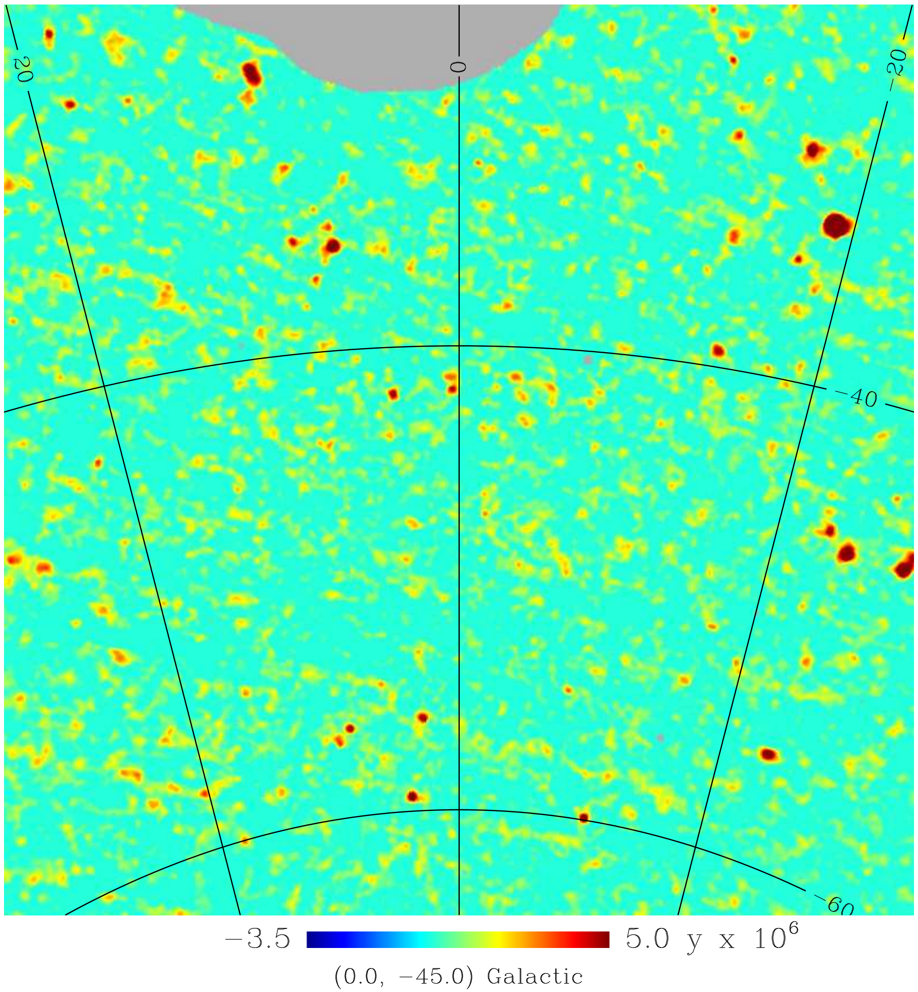
Planck Compton parameter map II

NILC tSZ map



MILCA tSZ map