Joint contraints on the galaxy cluster pressure profile from Planck and SPT-SZ

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Observing the millimeter Universe with the NIKA2 camera (June 28 – July 2, 2021)

Motivations

- Only one published study on cluster profiles using the SPT-SZ data (*Plagge et al. 2010*, 15 clusters)
- No statistical SZ profile study based on a large number (hundreds) of clusters

- Both SPT-SZ and Planck data now publicly available (*)
- Excellent complementarity of the two datasets
- **Combining** the two datasets allows for reconstructing better the inner and outer parts of the average cluster profile

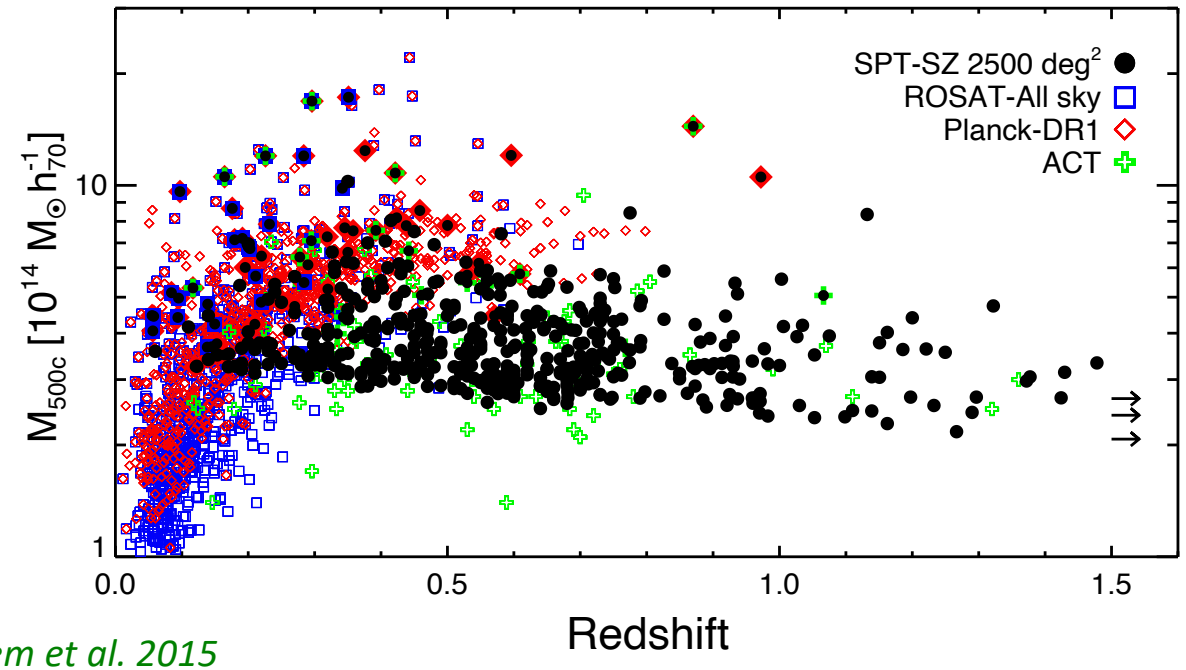
- Combination ACT+Planck (E. Pointecouteau, 31 clusters)
- Combination SPT-SZ+Planck (F. Oppizzi, individual clusters)

(*) SPT-SZ https://lambda.gsfc.nasa.gov/product/spt/spt_prod_table.cfm
Planck https://pla.esac.esa.int/#home

SPT-SZ and Planck complementarity

	SPT	Planck
Spatial resolution	+ (fwhm=1.75arcmin)	- (fwhm>5arcmin)
Instrumental noise	+ (20μKarcmin@150GHz)	- (33μKarcmin@143GHz)
Filter transfer function	- (scales smaller 1/2deg)	+ (all scales)
Frequency range	- (95-220GHz)	+ (100-857GHz)

SPT-SZ cluster catalogue



Bleem et al. 2015

677 candidates (ξ>4.5)

Inside SPT-SZ public footprint
With redshift
SPT flux < 2×10^{-4} arcmin^2

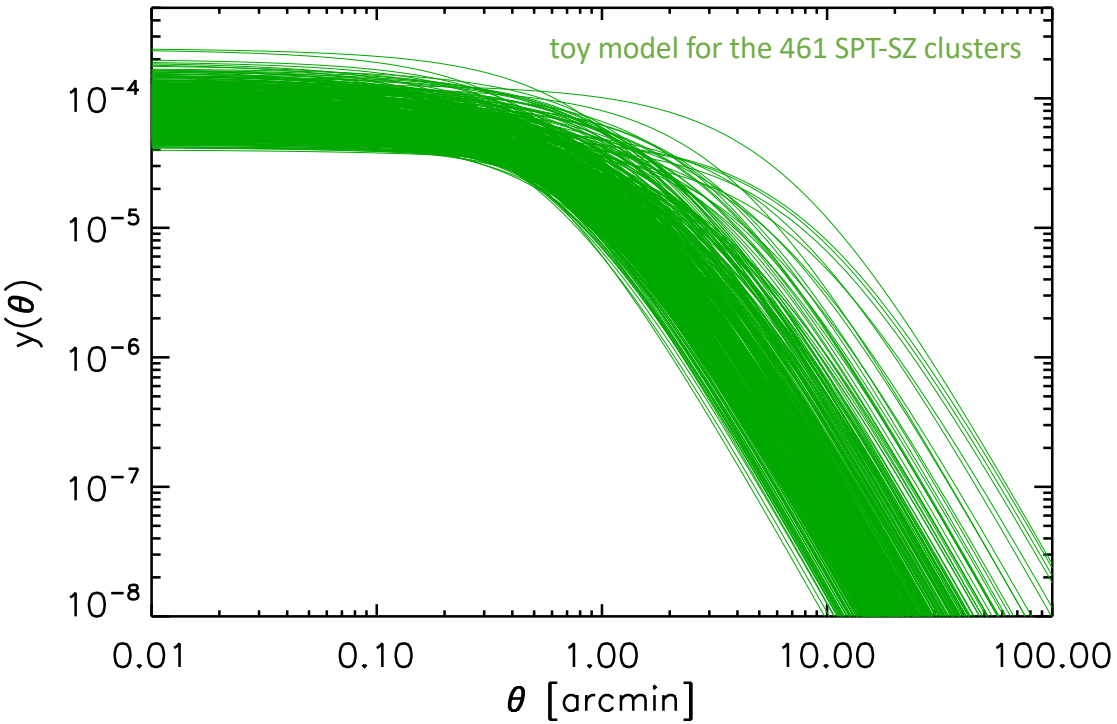
461 clusters

$2\times10^{14}\ M_\odot \leqslant M_{500} \leqslant 10^{15}\ M_\odot$
$0.05 \leqslant z \leqslant 1.7$

Redshift z and mass M_{500}
provided in the SPT-SZ catalogue

The average cluster profile

averaging of cluster profiles possible thanks to cluster self-similarity



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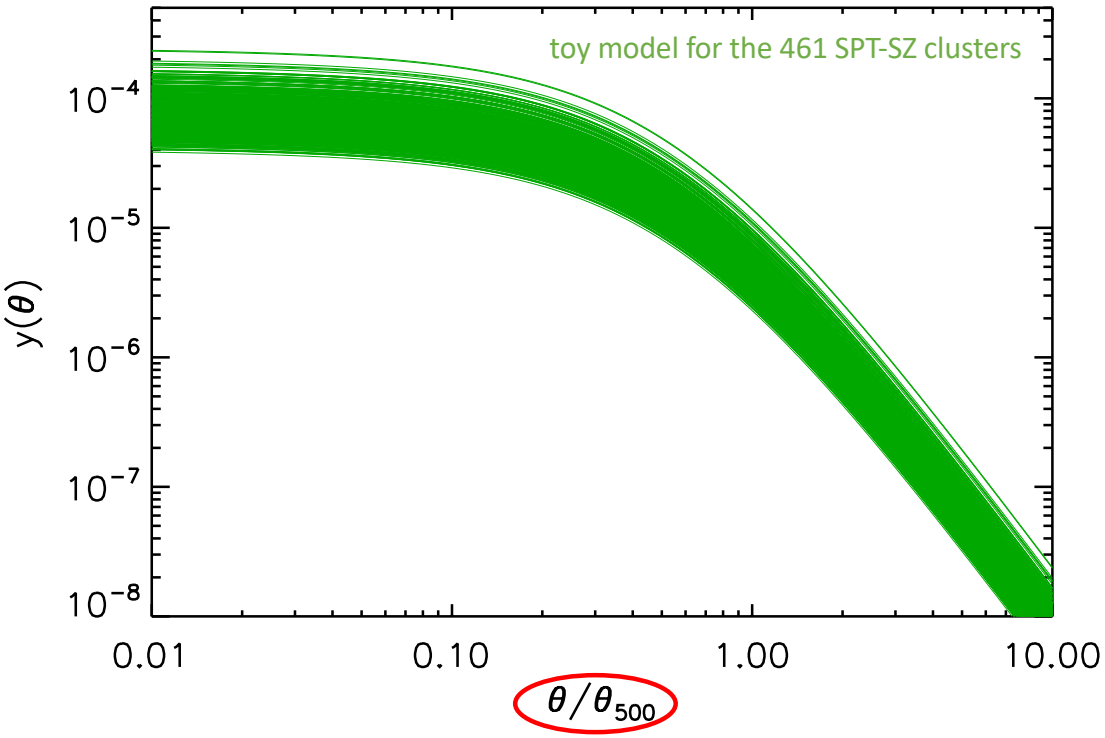
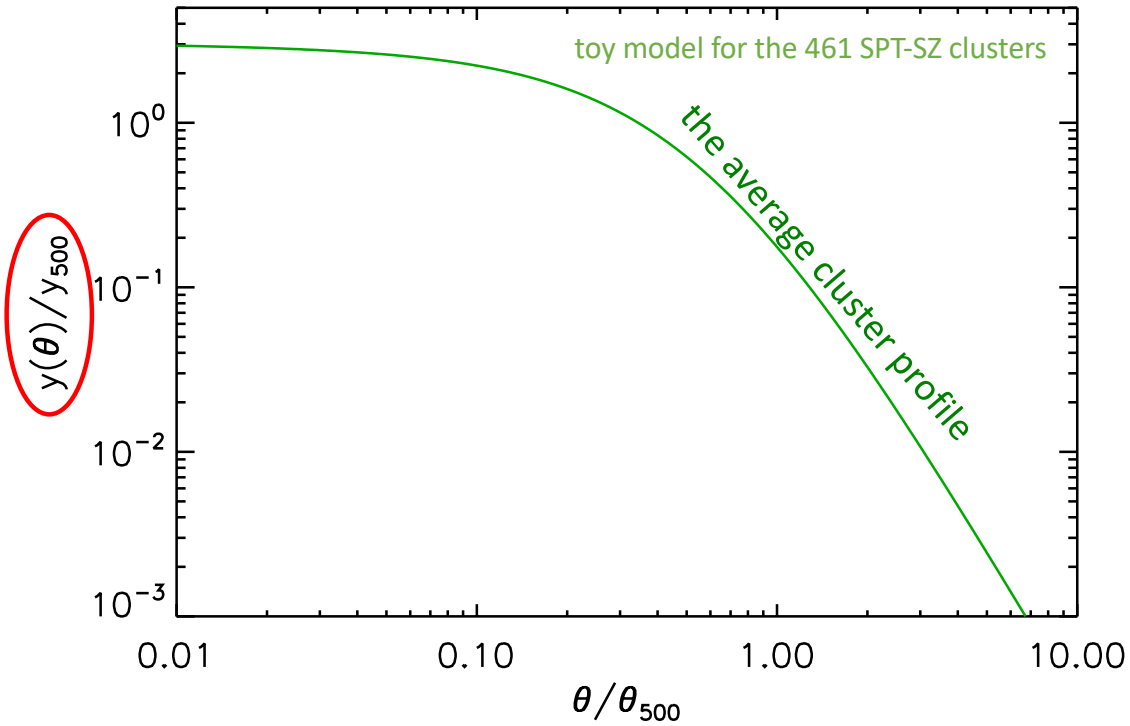


θ_{500} : characteristic scale

The average cluster profile

averaging of cluster profiles possible thanks to cluster self-similarity

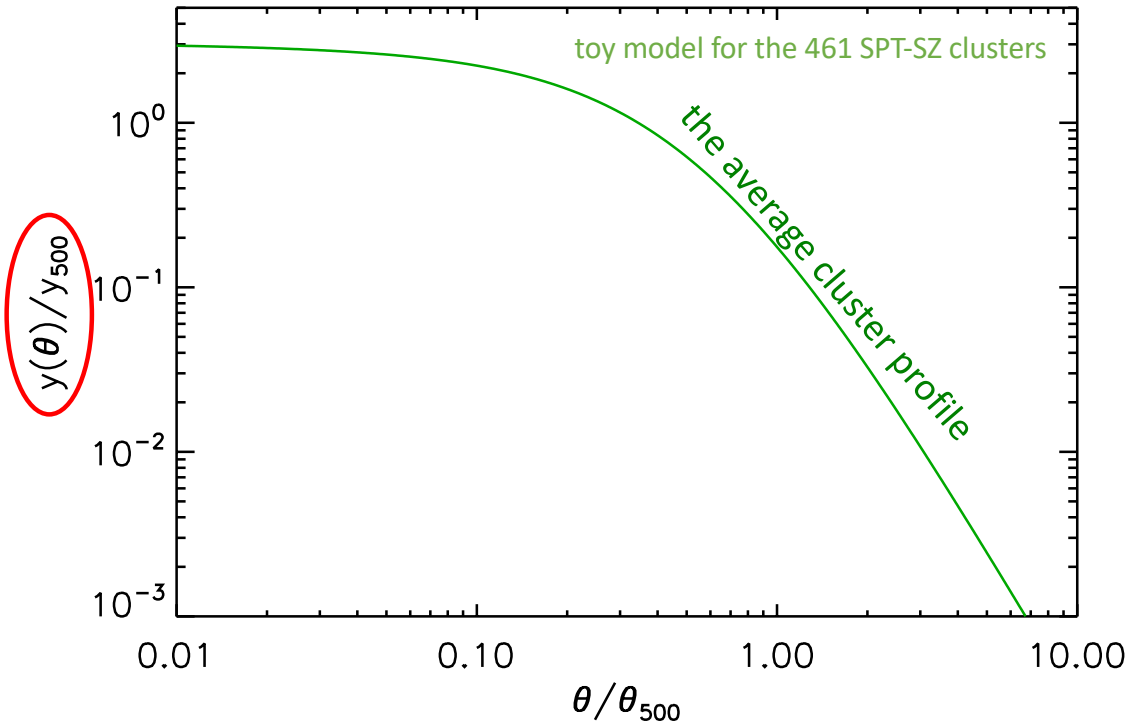


θ_{500} : characteristic scale
y_{500} : characteristic Compton parameter

θ_{500} and y_{500} computed analytically
from redshift z, mass M_{500}
and cosmological parameters

The average cluster profile

averaging of cluster profiles possible thanks to cluster self-similarity



θ_{500} : characteristic scale
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θ_{500} and y_{500} computed analytically
from redshift z, mass M_{500}
and cosmological parameters

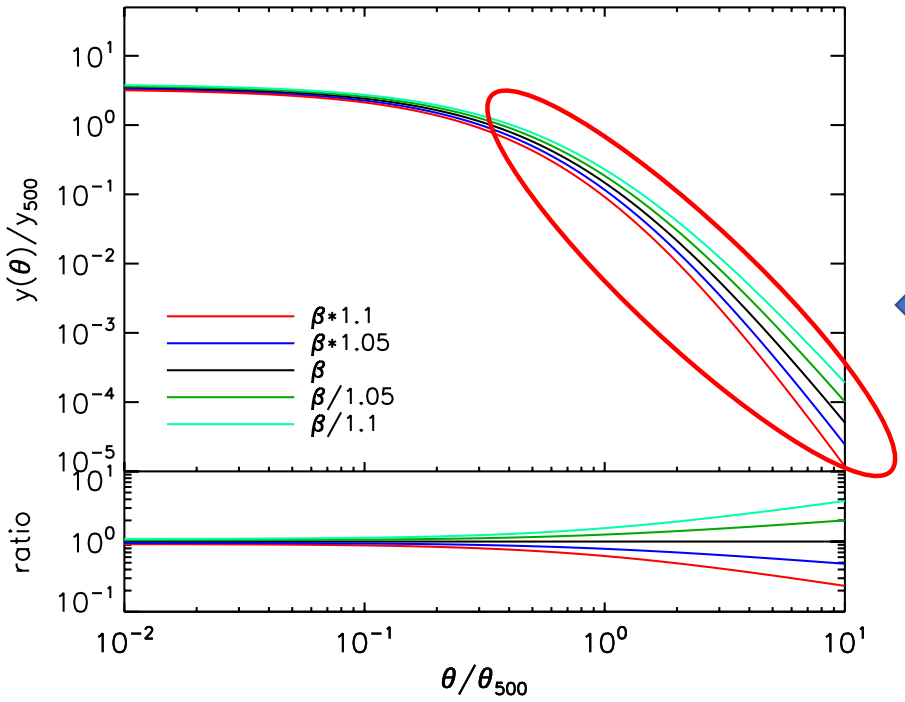
Difficulties
- Instrumental and astrophysical noise
- Beams and θ_{500} rescaling

Work in Harmonic (Fourier) space

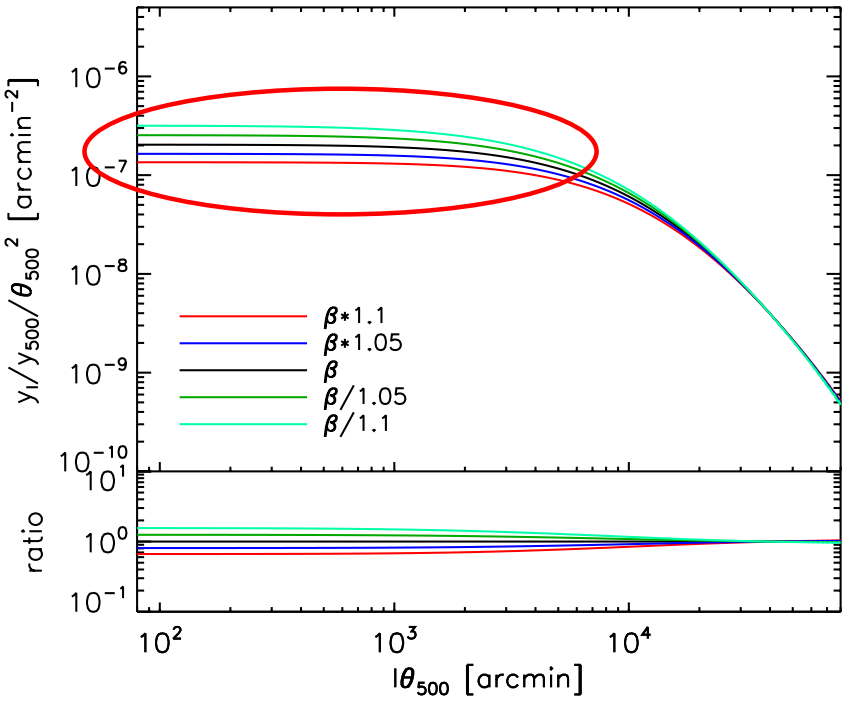
The harmonic space

outer slope β

Real space



Harmonic space



Size θ divided by θ_{500}

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

$$x = r/R_{500}$$

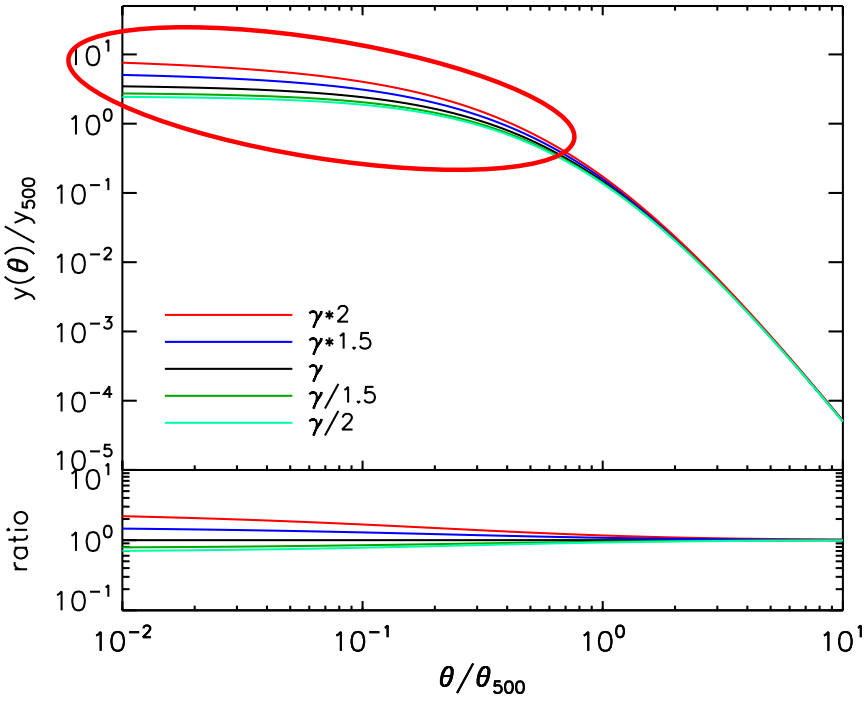
Nagai et al. 2007

Multipole l multiplied by θ_{500}

The harmonic space

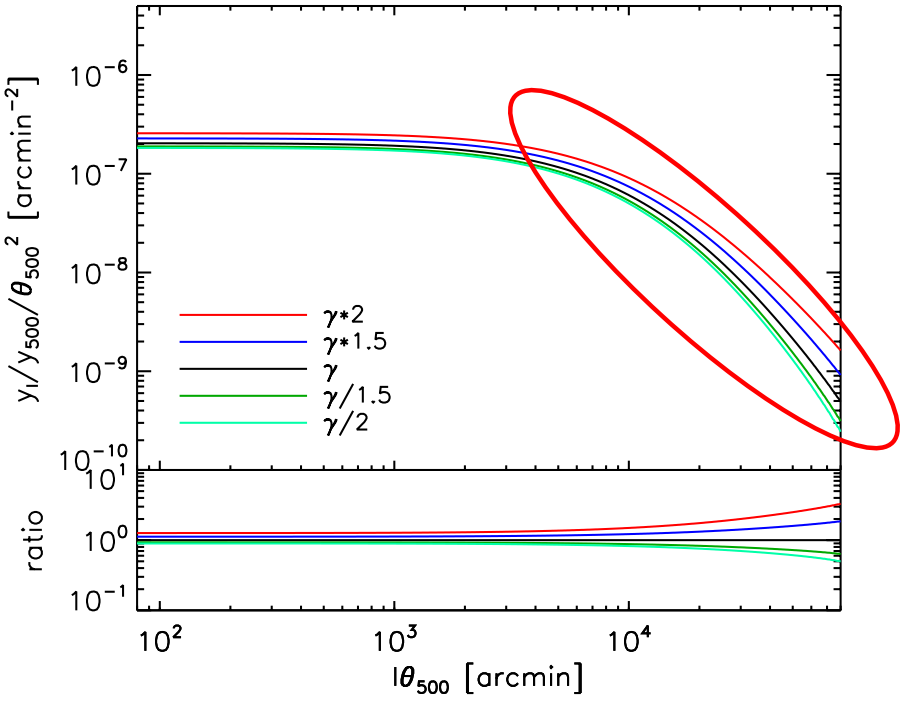
inner slope γ

Real space



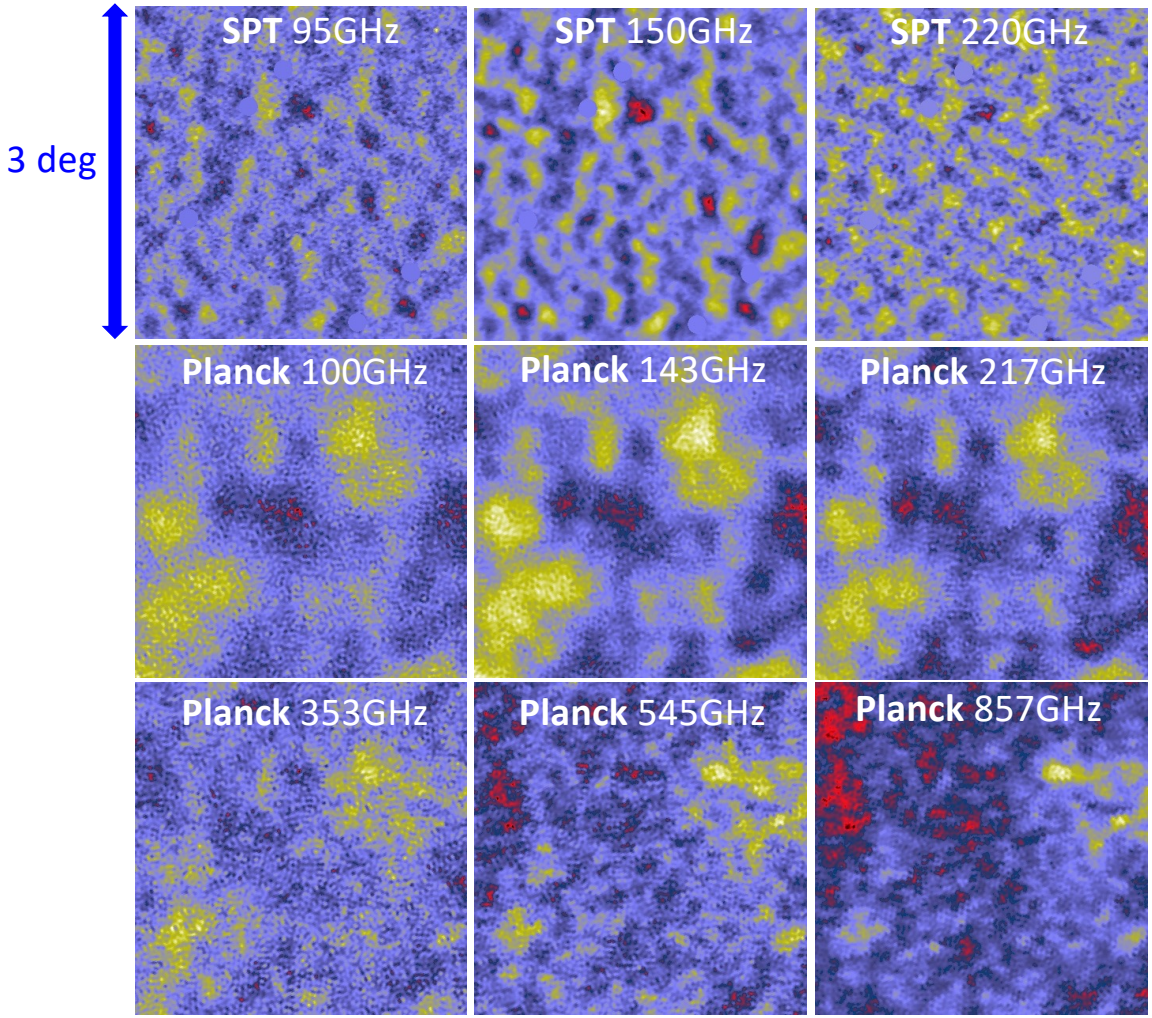
Size θ divided by θ_{500}

Harmonic space



Multipole l multiplied by θ_{500}

SPT-SZ and Planck maps



Method

1 - Internal Linear Combination (ILC)

2 - Renormalize

3 - Rescale & azimutal average

4 – Sample average

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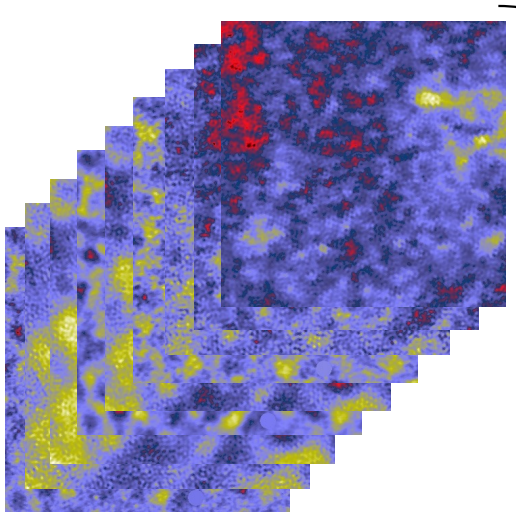
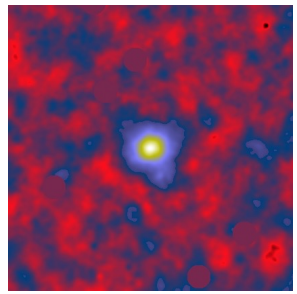


SPT-SZ and/or **Planck** maps

e.g. Remazeilles, Delabrouille & Cardoso 2011

assumes
- SZ frequency spectrum
(including relativistic SZ corrections)
- filter transfer function



Compton y map
(Fourier space)

Method

1 - Internal Linear Combination (ILC) ⟶ **Compton y** map in Fourier space = **FT(y)**

2 - Renormalize

3 - Rescale & azimutal average

4 – Sample average

Method

1 - Internal Linear Combination (ILC) → **Compton y** map in Fourier space = **FT(y)**

2 - Renormalize → **FT(y)** map divided by $\mathbf{y_{500}}$

3 - Rescale & azimutal average

4 – Sample average

Method

1 - Internal Linear Combination (ILC) → **Compton y** map in Fourier space = **FT(y)**

2 - Renormalize → **FT(y)** map divided by $\mathbf{y_{500}}$

3 - Rescale & azimutal average → **FT(y/y_{500})** weighted averaged in $\mathbf{l*\theta_{500}}$ bins

4 – Sample average

Method

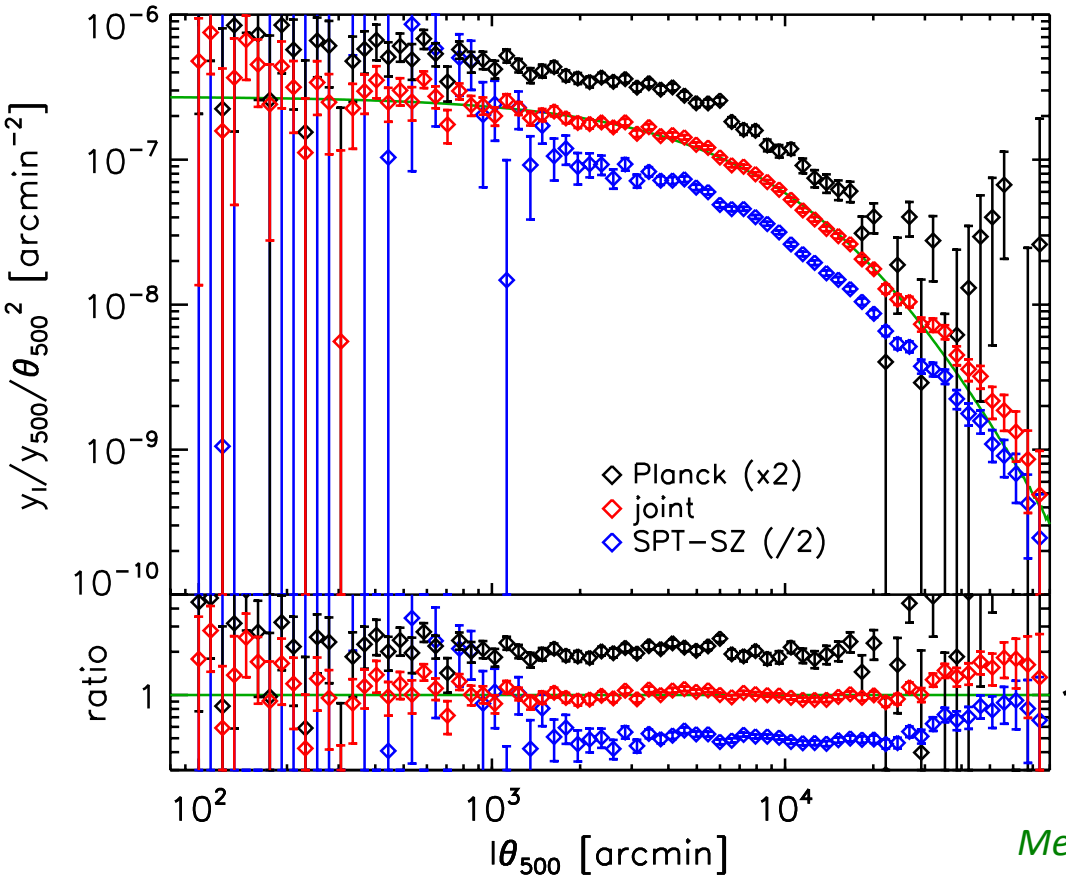
1 - Internal Linear Combination (ILC) → **Compton y** map in Fourier space = **FT(y)**

2 - Renormalize → **FT(y)** map divided by $\mathbf{y_{500}}$

3 - Rescale & azimutal average → $\mathbf{FT(y/y_{500})}$ weighted averaged in $\mathbf{l*\theta_{500}}$ bins

4 – Sample average → $\mathbf{FT(y/y_{500})_i}$ **(i=1,461)** weighted averaged

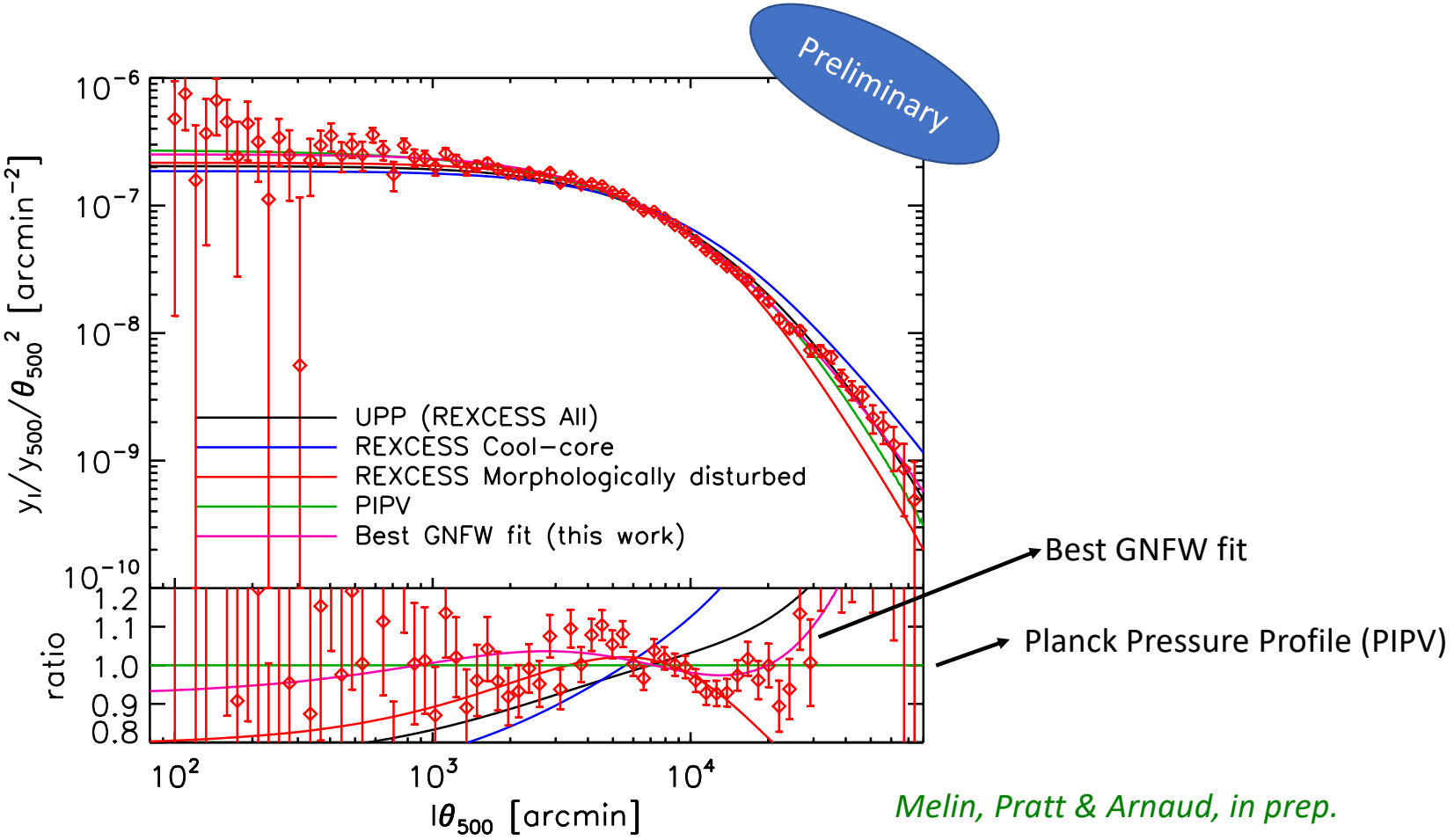
SPT-SZ and Planck profiles



Planck Pressure Profile (PIPV)

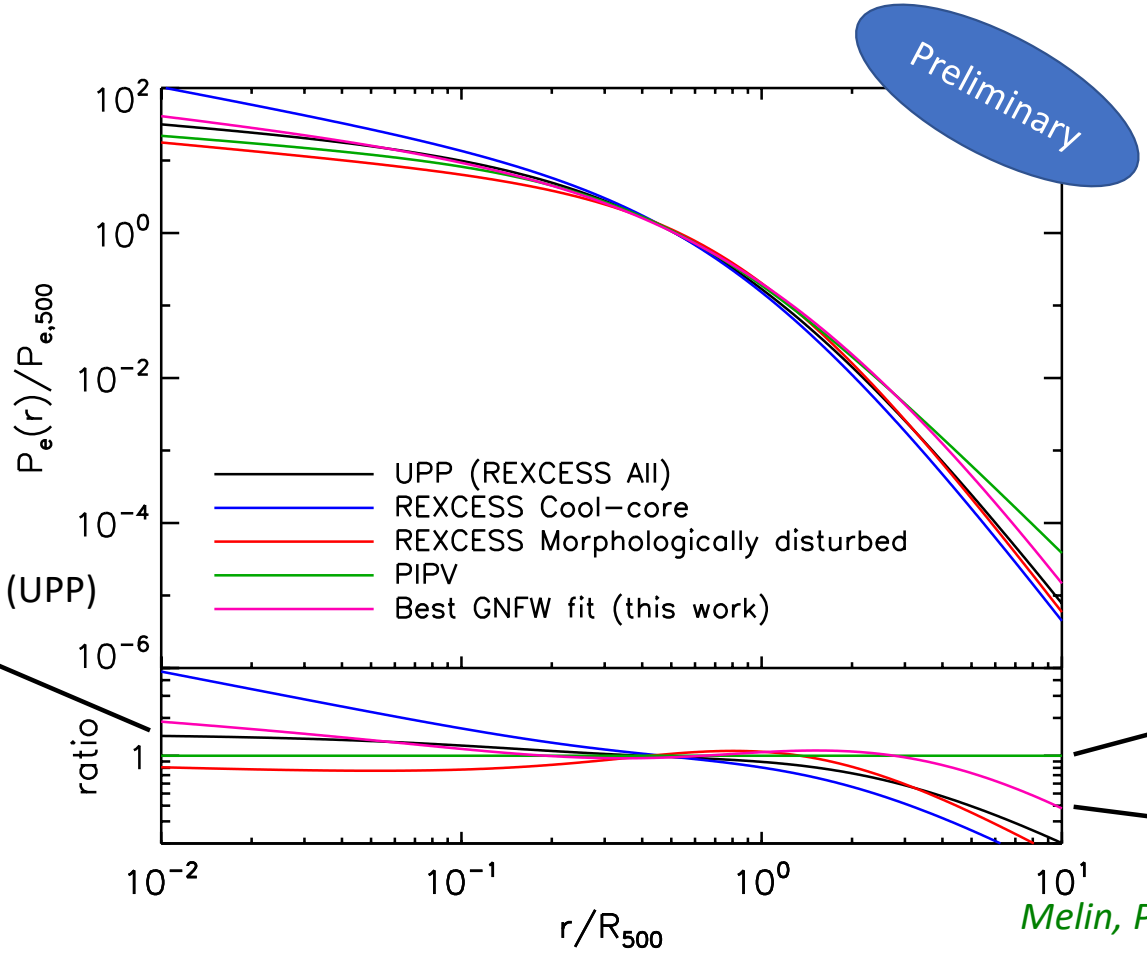
Melin, Pratt & Arnaud, in prep.

Joint profile



Melin, Pratt & Arnaud, in prep.

3D pressure profile



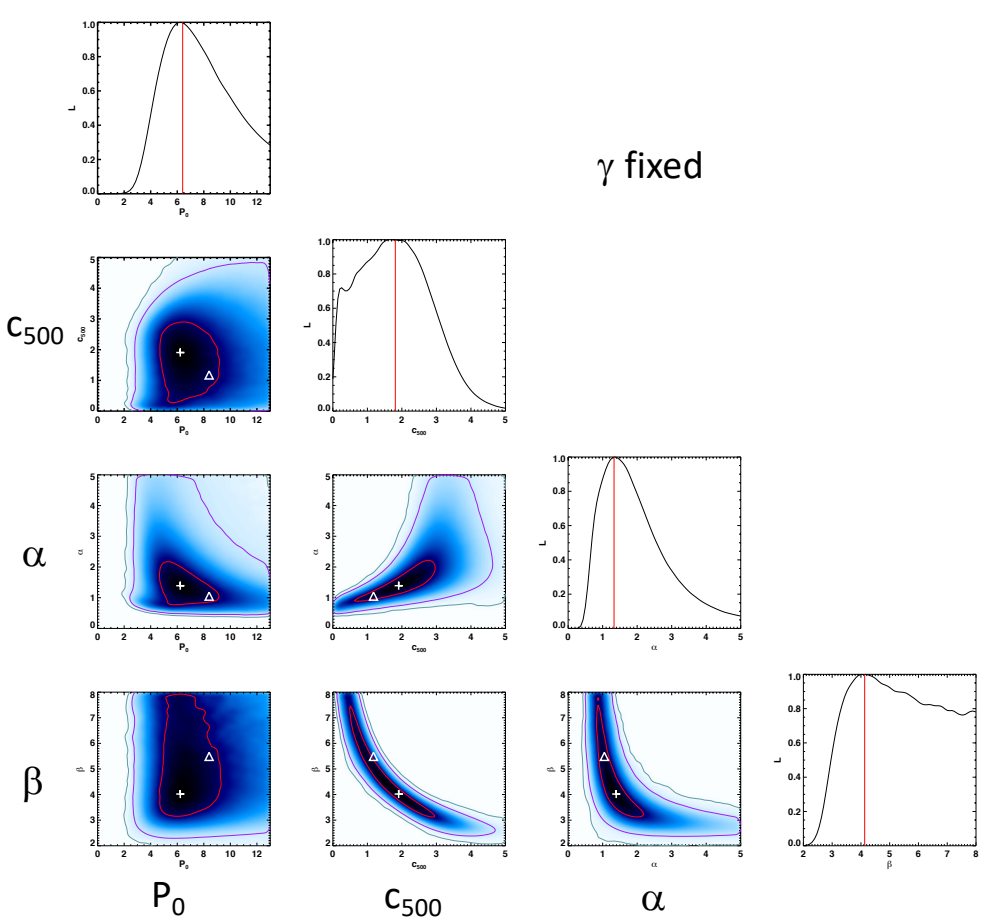
Universal Pressure Profile (UPP)
(Arnaud et al. 2010)

Planck Pressure Profile (PIPV)

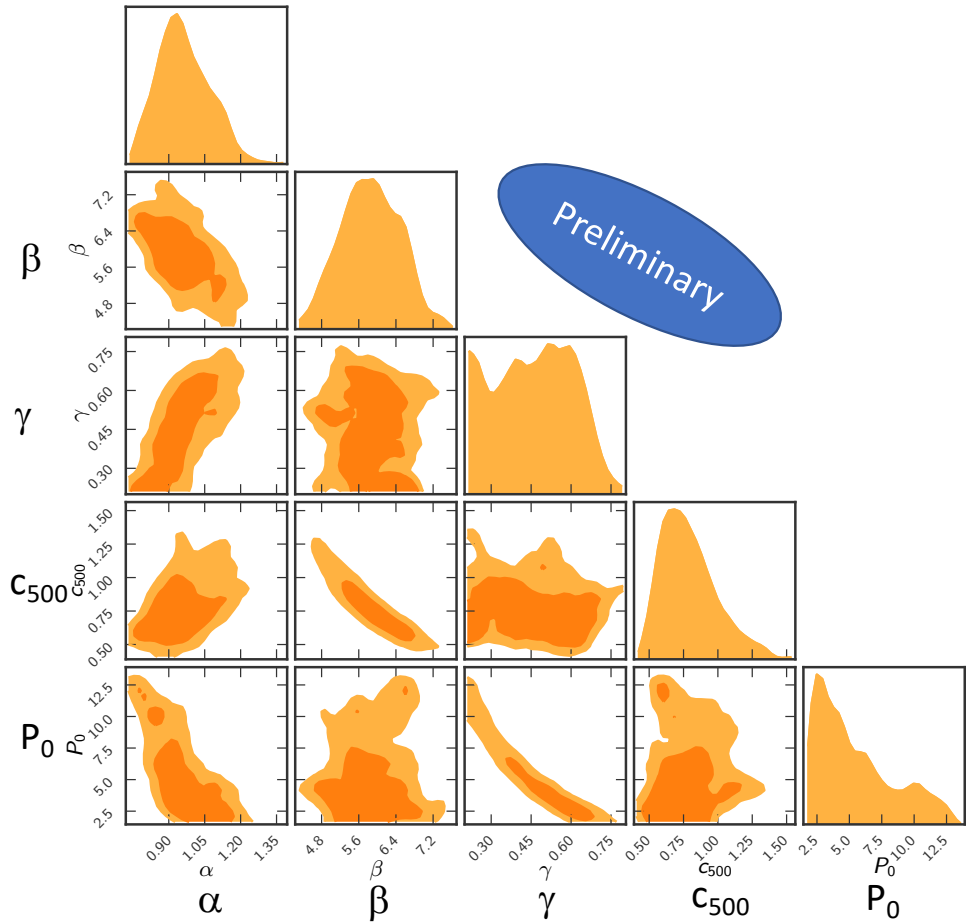
Best GNFW fit

Melin, Pratt & Arnaud, in prep.

3D pressure profile – best fit

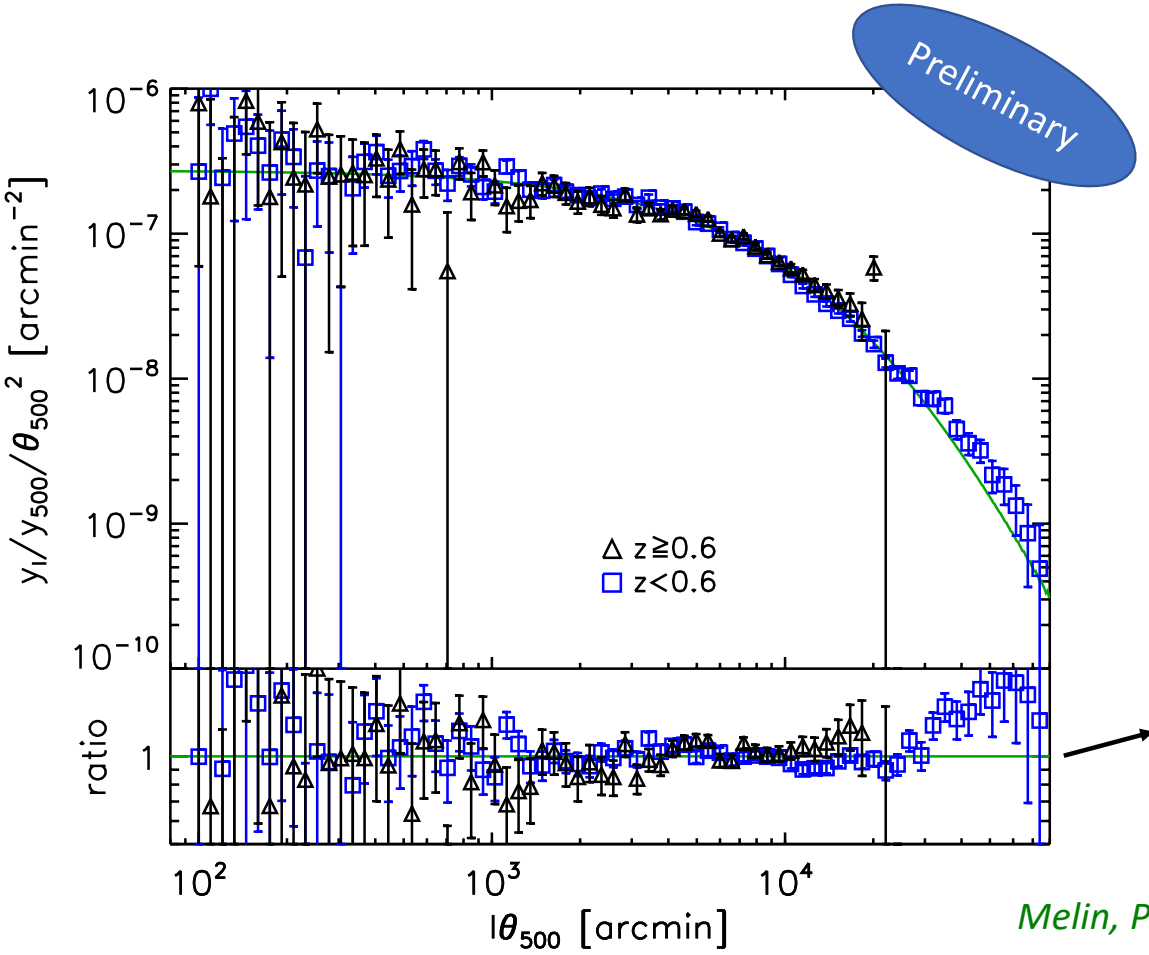


Planck Intermediate Results V, 2012



Melin, Pratt & Arnaud, in prep.

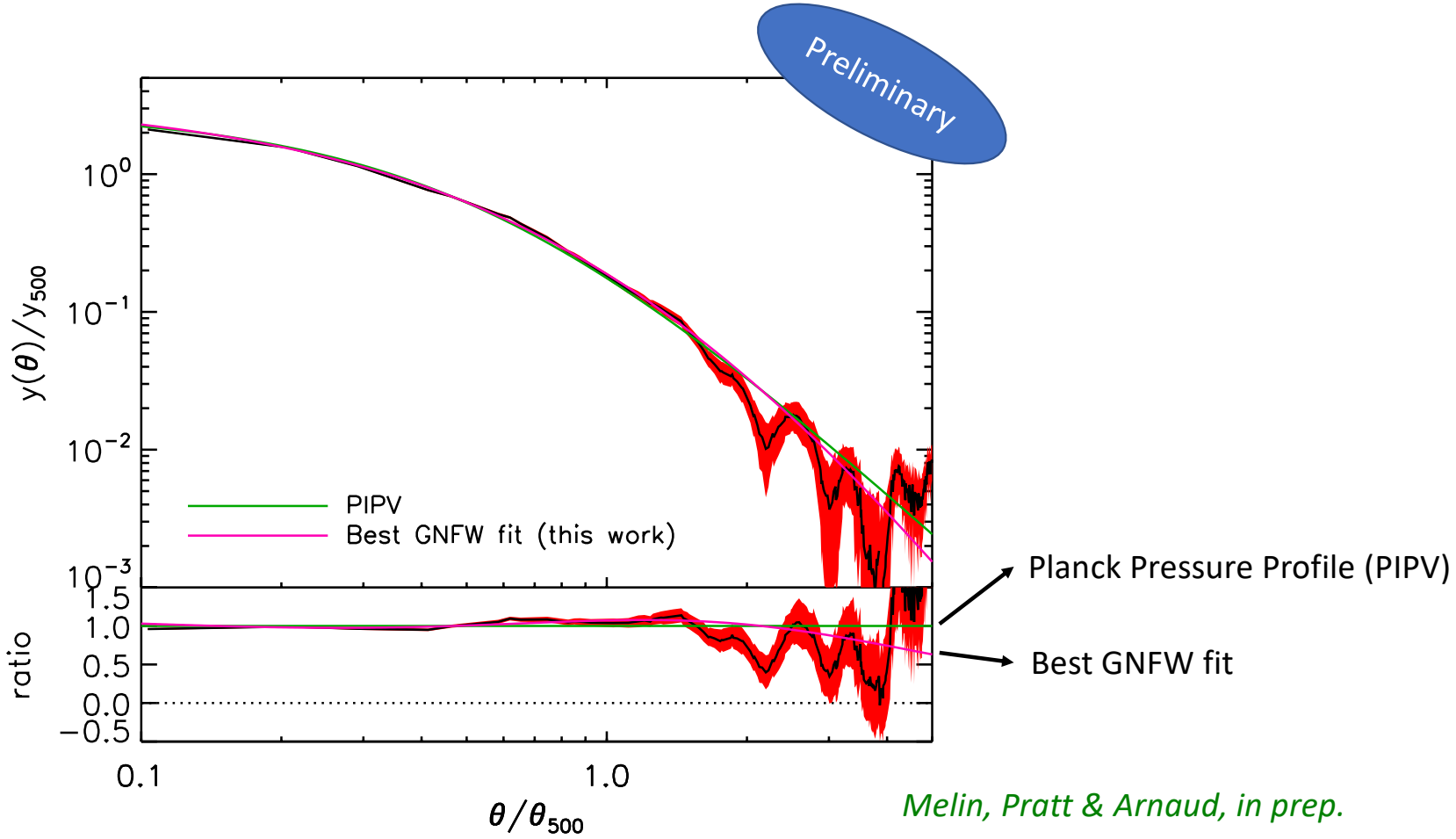
Redshift evolution of the joint profile



Planck Pressure Profile (PIPV)

Melin, Pratt & Arnaud, in prep.

A look at the outskirts: 2D Compton profile



Melin, Pratt & Arnaud, in prep.

Summary & Future steps

- Average cluster pressure profile measured for 461 clusters of the SPT-SZ catalogue
- Takes advantage of both Planck and SPT-SZ data
- Average profile close to Arnaud et al. 2010 in the inner part, and to Planck pressure profile 2013 in the outer part
- Significant improvement on the precision of the parameters of the GNFW fit with respect to Planck pressure profile
- Additional fittings possible with subsamples (e.g. high/low redshift)
- Outskirts : pressure variations at $\theta > 2\theta_{500}$ (shocks ?), no clear single feature

- Future steps : GNFW fits for low/high redshift subsamples, average pressure profile scaled in θ_{200m}