Comparison of Sunyaev-Zeldovich measurements from *Planck* and from the Arcminute Microkelvin Imager for eleven galaxy clusters

planck

+

AMI

The Planck collaboration & the AMI consortium

Michael Brown,
Jodrell Bank Centre for Astrophysics,
University of Manchester

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

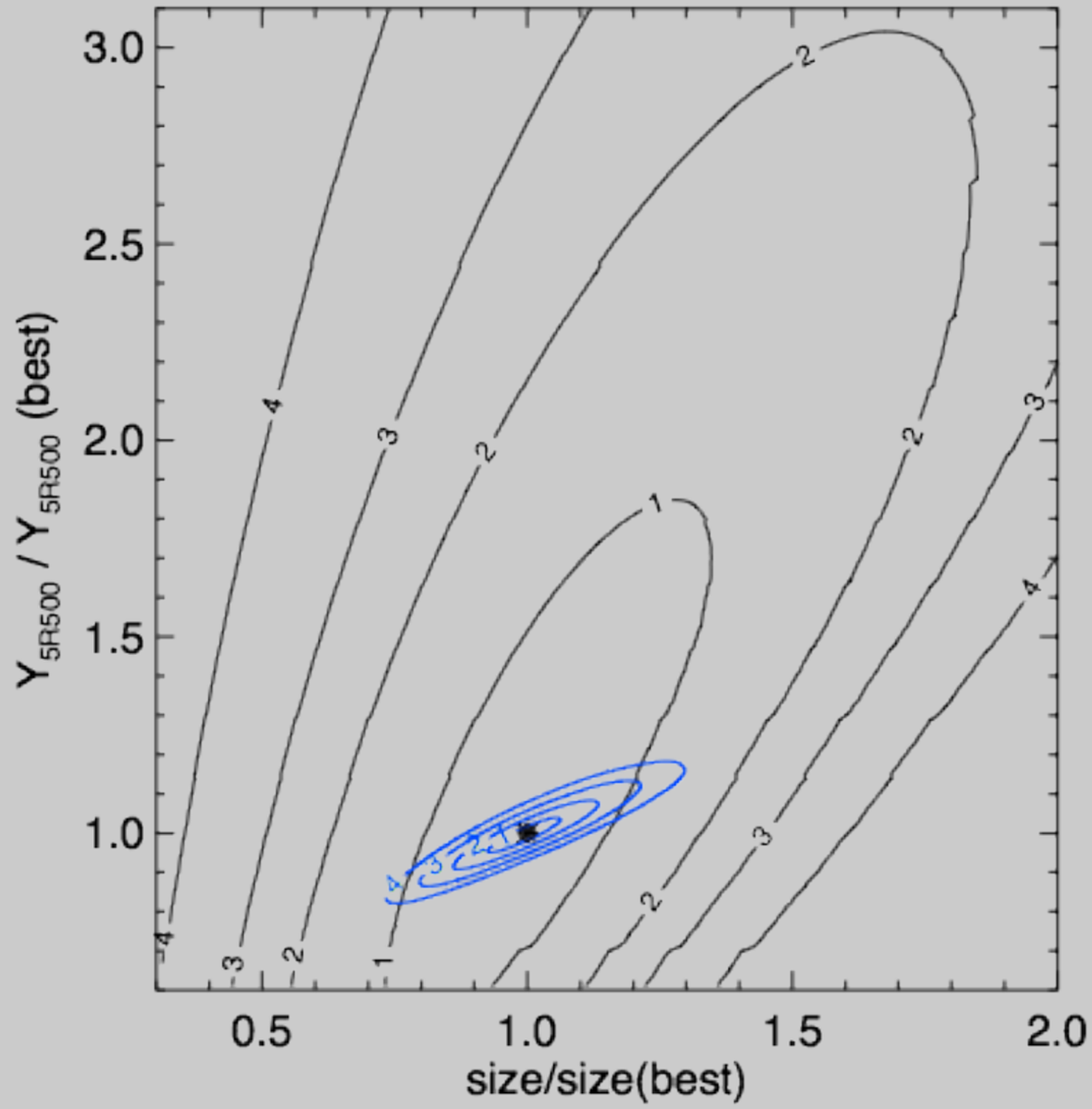
AMI is funded by:

Science & Technology Facilities Council

UNIVERSITY OF CAMBRIDGE

Motivation for this study

- *Planck* SZ constraints exhibit a degeneracy between derived SZ Compton-Y parameter and cluster size.
- AMI's higher resolution can provide more accurate cluster positions & size estimates, and thus break this degeneracy.
- Provide a consistency check on *Planck*'s SZ constraints using different observing frequencies (~15 GHz) & techniques (interferometry).



Planck collaboration (2011) A&A, 536, A8

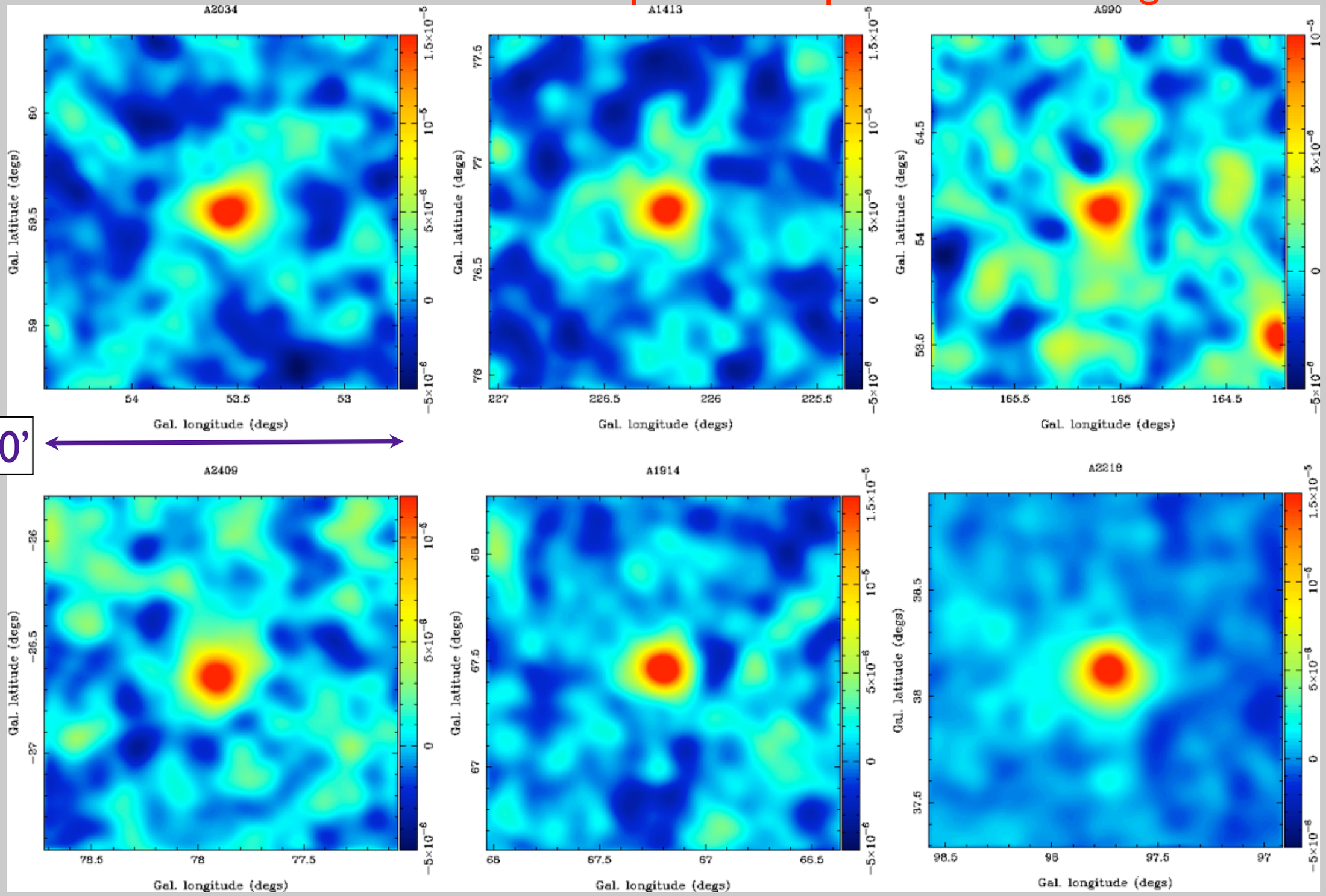
The cluster sample

- Originally identified a sample of 24 clusters which were both present in the *Planck* Early SZ catalogue and had also been "well detected" in previous AMI observations.
- Follow-up AMI observations of two newly discovered *Planck* ESZ clusters added to sample.
- A conservative cut based on radio source environment reduced sample to eleven clusters with benign source environments.
- Sample includes two cool-core clusters, two newly-discovered *Planck* clusters, fairly large spread in redshift ($0.11 < z < 0.55$).
- Not a well-defined or complete sample.
- Some discarded clusters could be recovered with further analysis.

Planck data

- Used *Planck* data taken between 12 Aug 2009 and 27 Nov 2010, ≈ 2.5 full-sky scans.

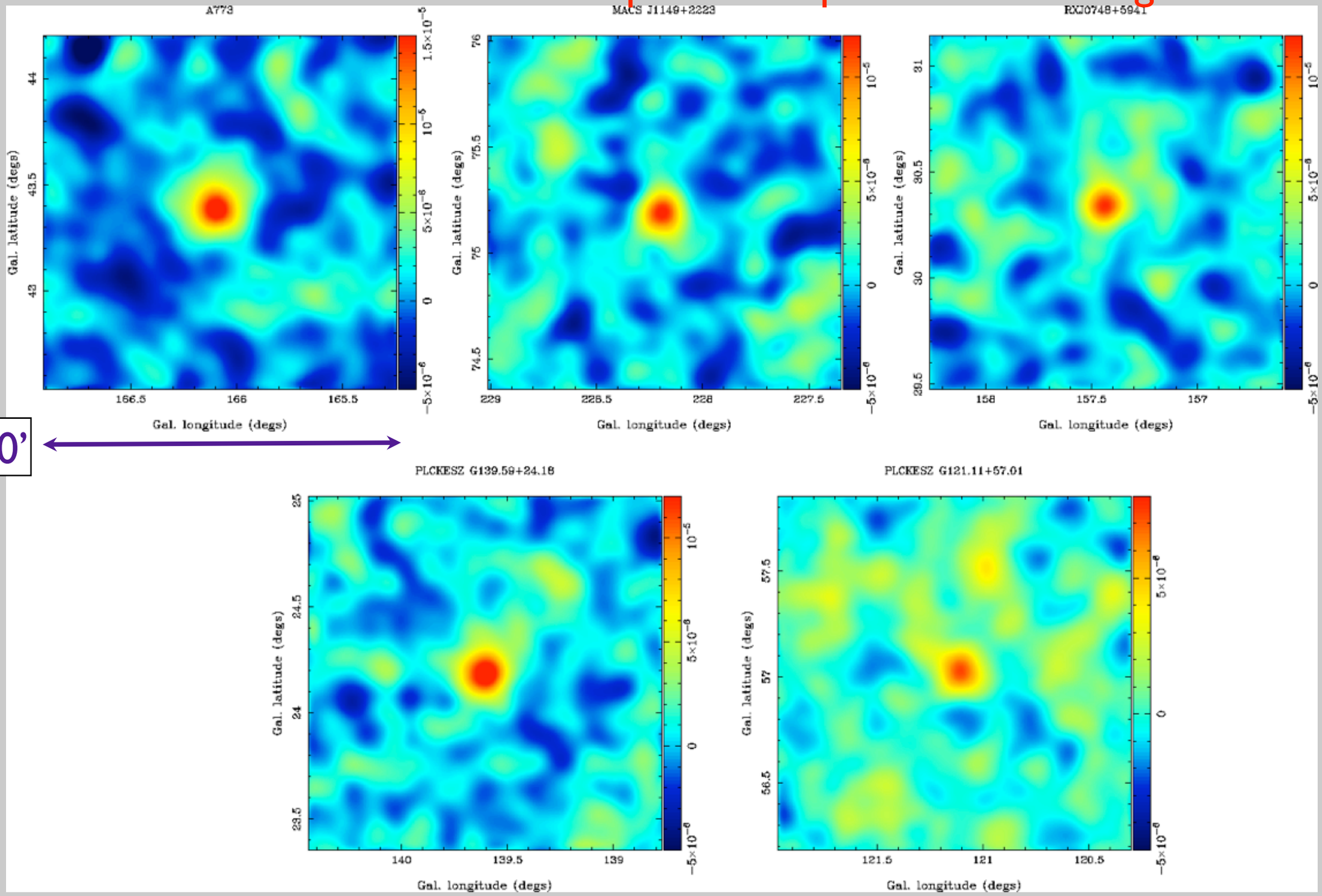
Compton-Y maps extracted using MILCA:



Planck data

- Used *Planck* data taken between 12 Aug 2009 and 27 Nov 2010, ≈ 2.5 full-sky scans.

Compton-Y maps extracted using MILCA:



≈100’

The Arcminute Microkelvin Imager

- A dual-array 15 GHz interferometer located near Cambridge, UK.

AMI Small Array:

⋆ 10 x 3.7m antennas
⋆ "Science array"
⋆ 3' synthesised beam
⋆ 20' primary beam (FOV)

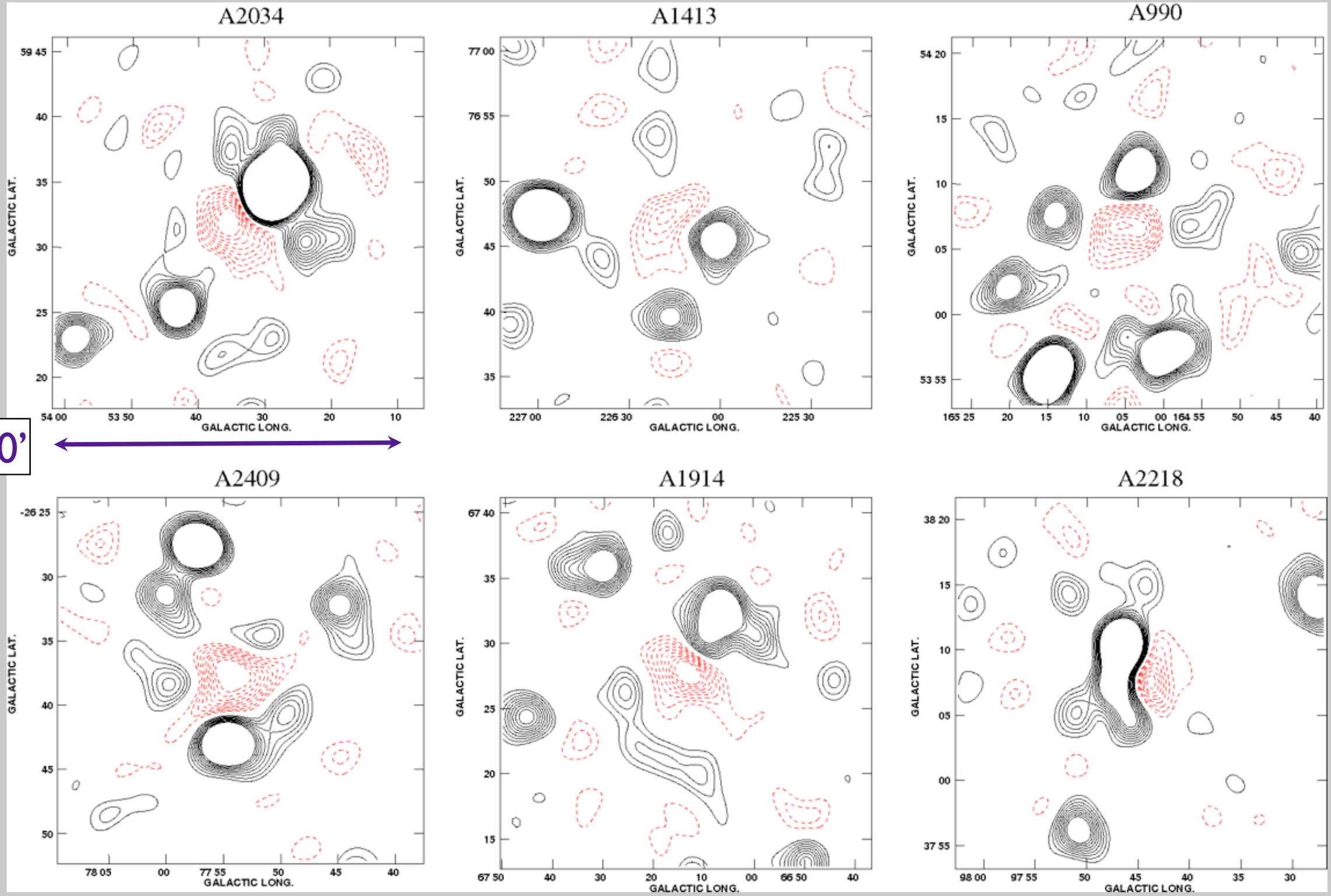
AMI Large Array:

⋆ 8 x 12.6m antennas
⋆ "Source subtractor"
⋆ 0.5' synthesised beam
⋆ 5' primary beam

AMI consortium: Zwart et al. (2008) MNRAS, 391, 1545

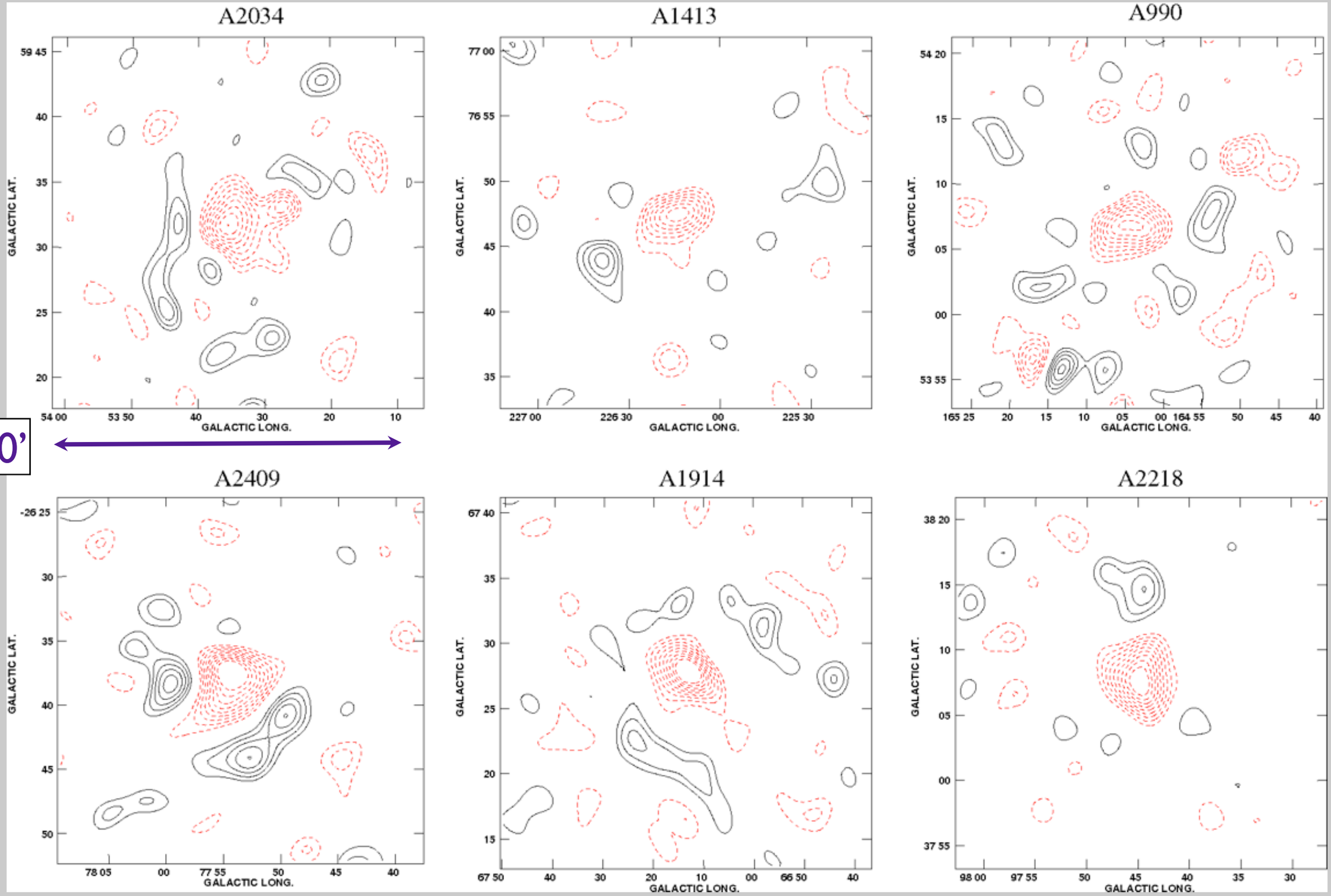
AMI data

- 15 GHz maps before source subtraction...



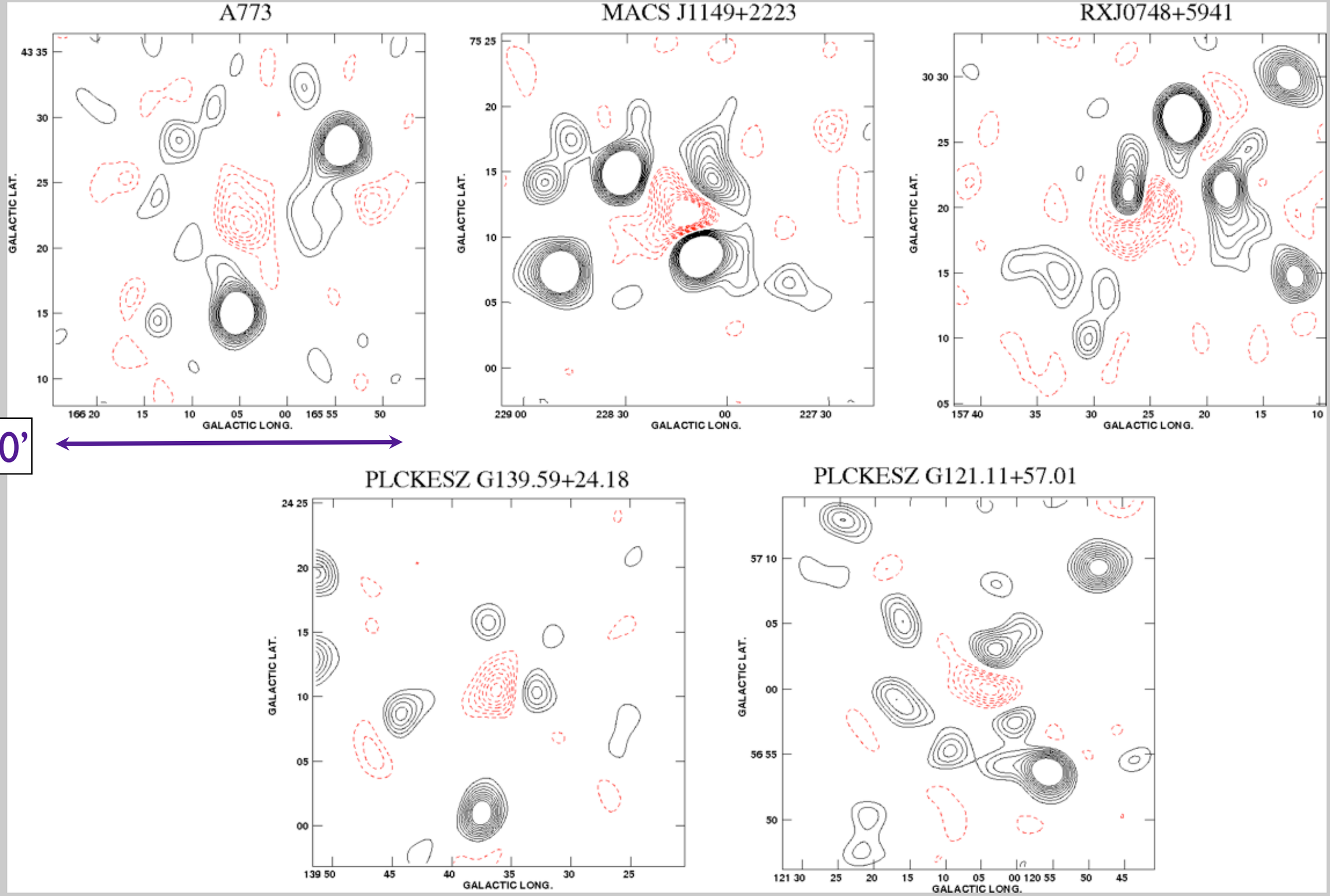
AMI data

- 15 GHz maps after source subtraction...



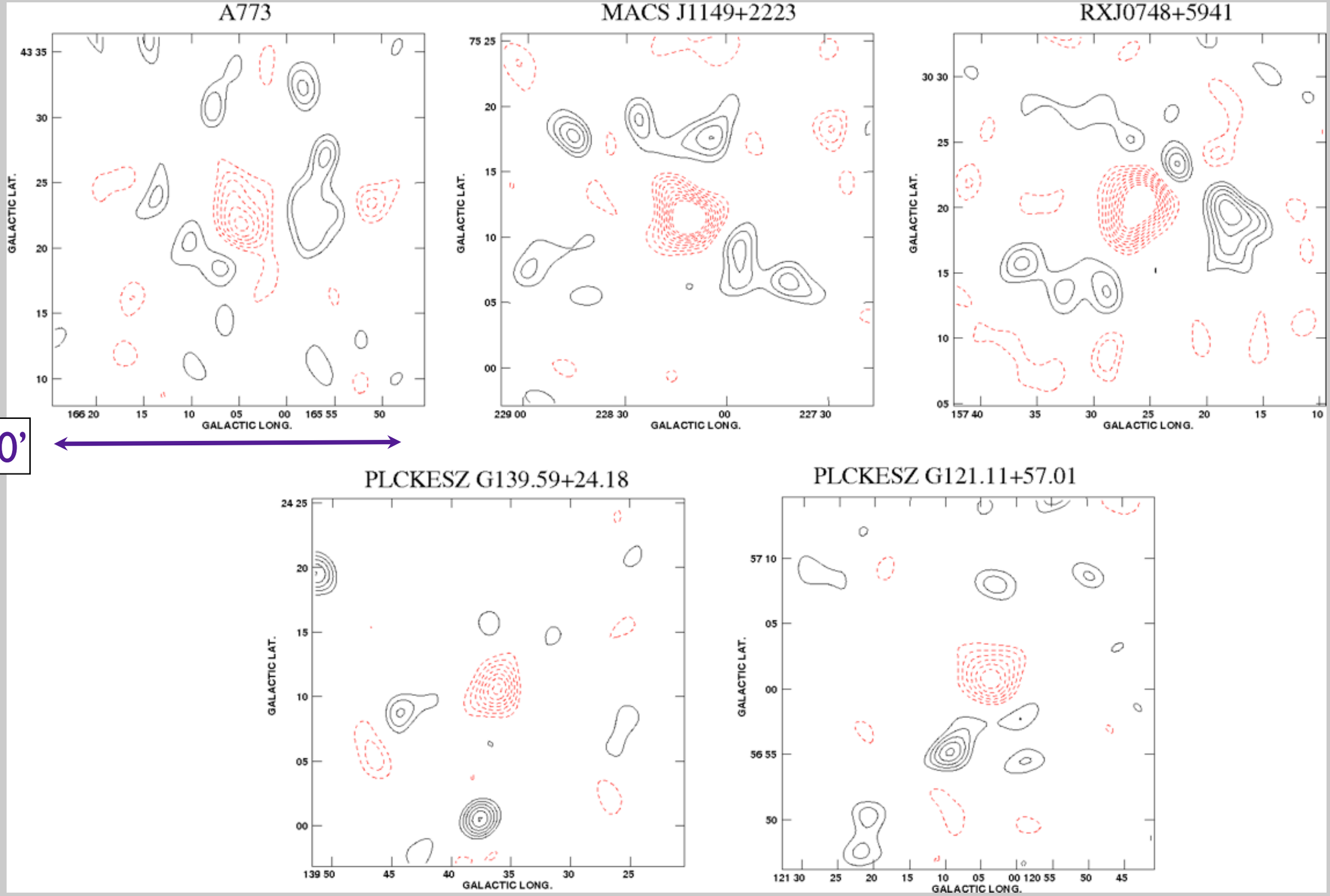
AMI data

- 15 GHz maps before source subtraction...



AMI data

- 15 GHz maps after source subtraction...



Analysing the SZ signal

- Maps for visual examination and qualitative assessment only.
- Quantitative analysis based on fitting data to cluster models.
- Use "Universal Pressure Profile" (Arnaud et al. 2010), a GNFW profile derived from X-ray observations and numerical simulations:

$$P(r) = P_{500}\left(\frac{M_{500}}{3\times10^{14}\,M_{\odot}}\right)^{\alpha_{\rm P}}\frac{P_0}{(c_{500}x)^{\gamma}(1+(c_{500}x)^{\alpha})^{\frac{\beta-\gamma}{\alpha}}}$$

$$\text{with } x = r/R_{500} \text{ and } \alpha_{\rm P} = 1/\alpha_{\rm MY_X} - 5/3.$$

Univeral Pressure Profile concentration & shape parameters:

$\alpha_{\rm MY_X}$	P_0	c_{500}	γ	α	β
0.561	8.403	1.177	0.3081	1.0510	5.4905

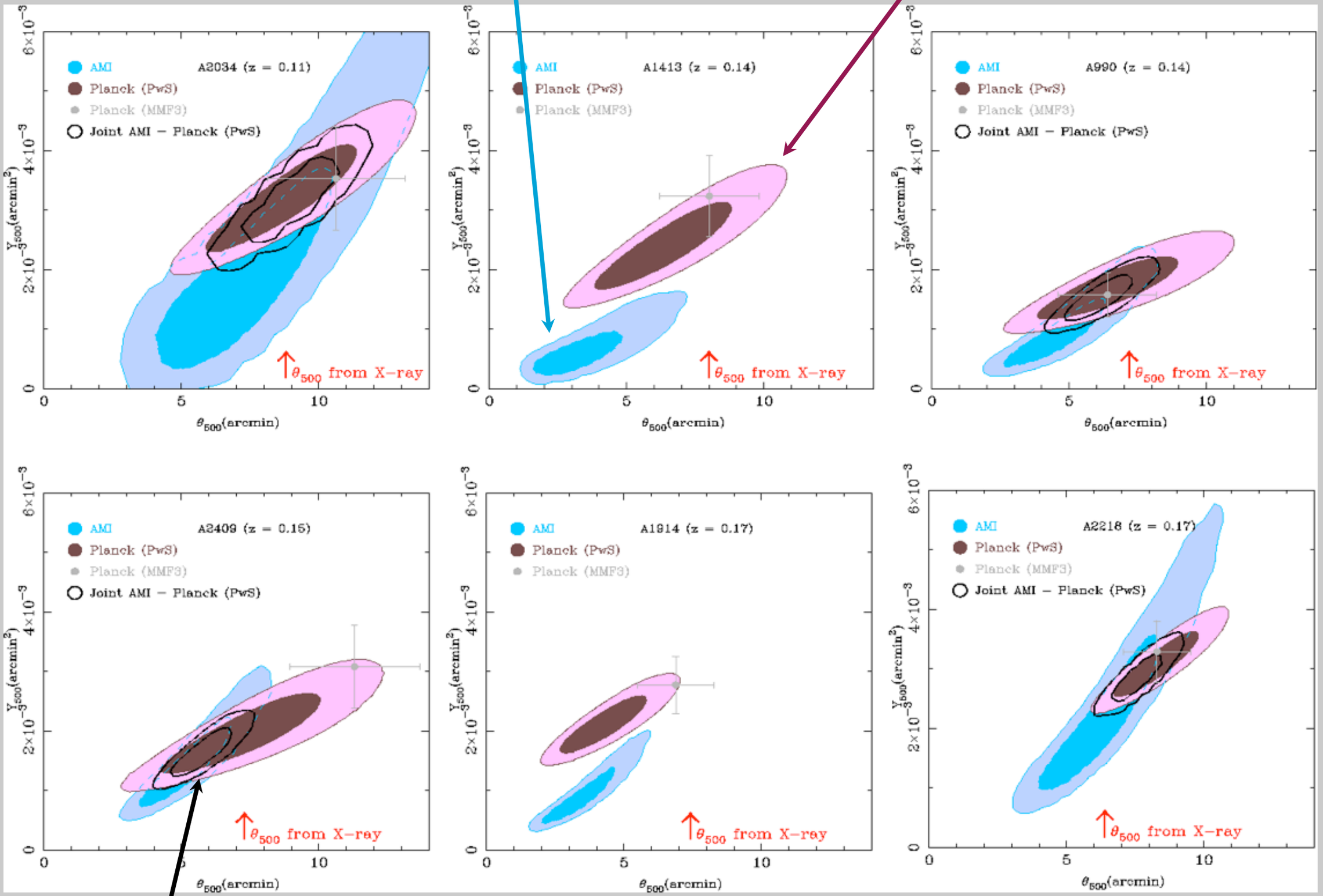
Arnaud et al. (2010) A&A, 517, A92

Results:

AMI constraints

Planck constraints

Y_{500} (arcmin^2)

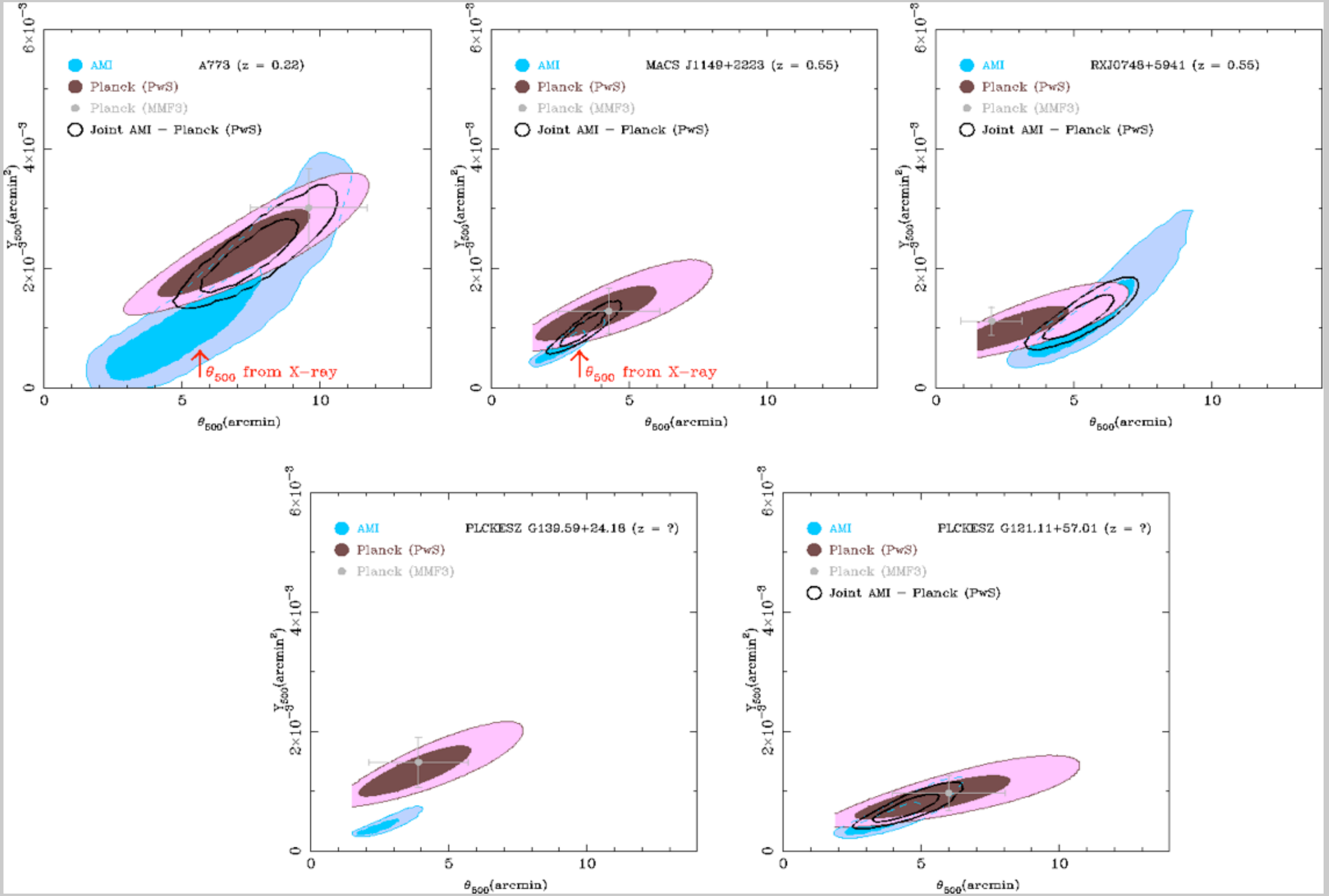


Joint constraints

θ_{500} (arcmin)

Results: AMI constraints *Planck* constraints

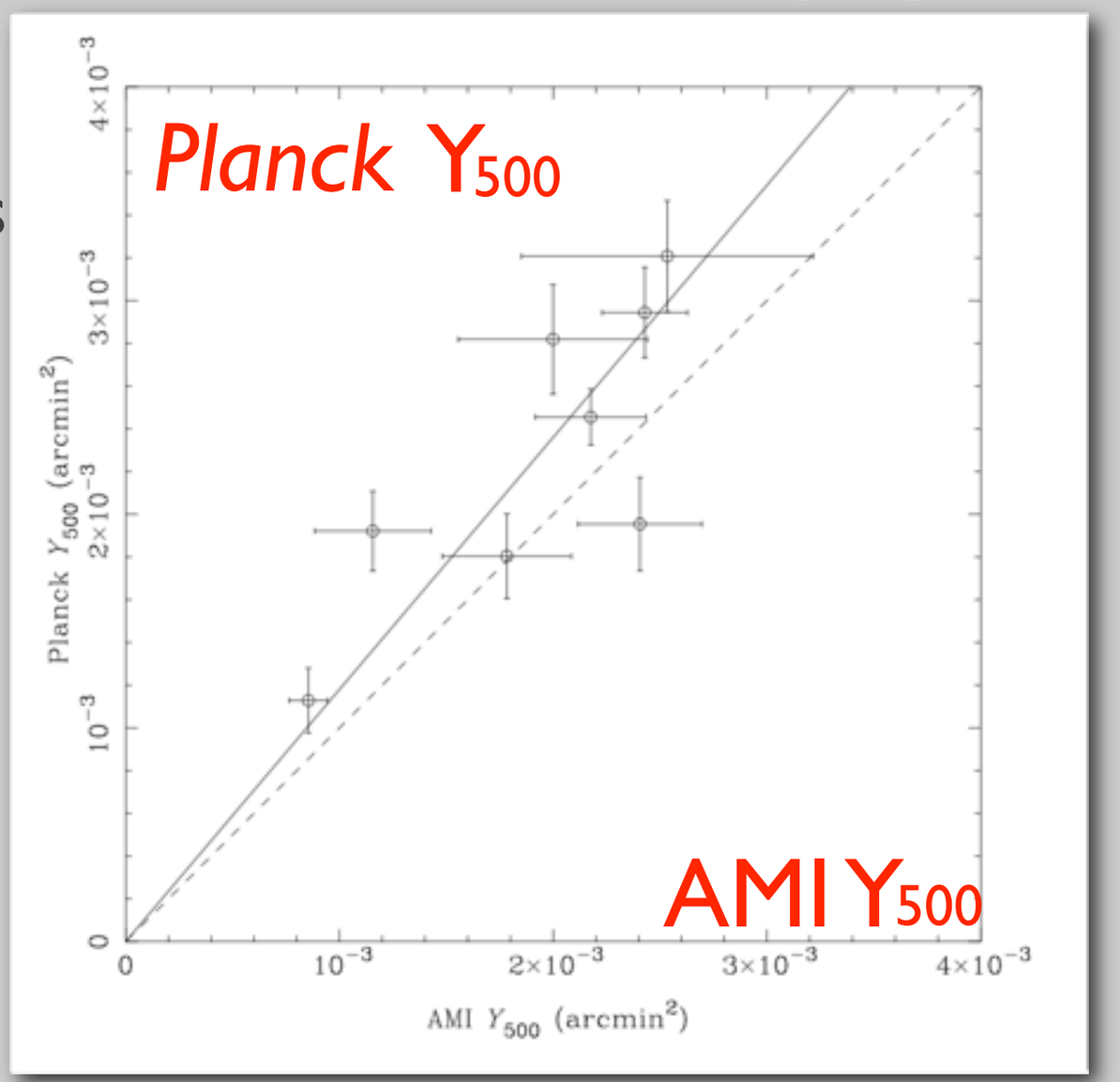
Y_{500} (arcmin^2)



θ_{500} (arcmin)

Observations

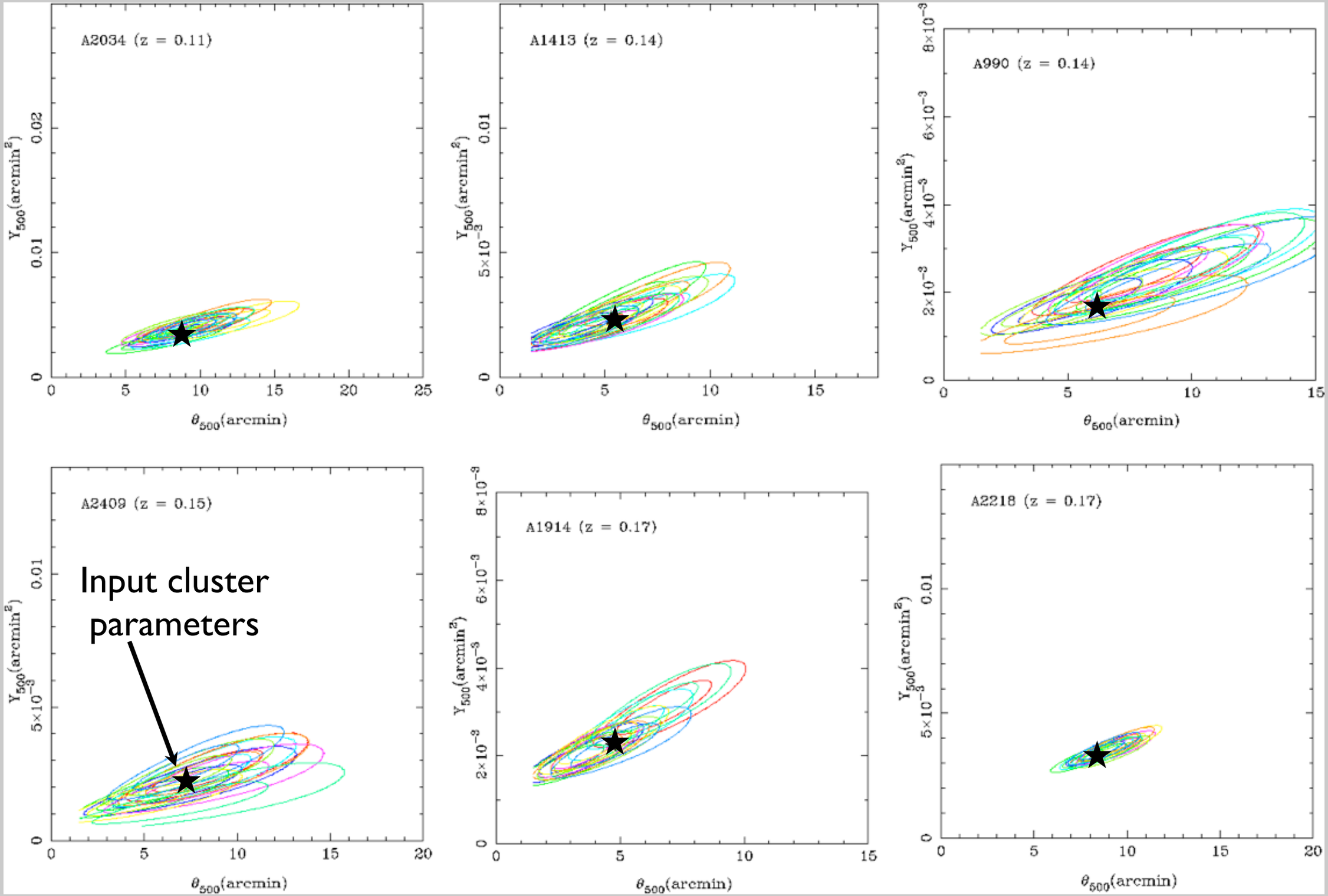
- For three clusters (A1413, A1914 and PLCKESZ G139.59+24.18), *Planck* and AMI constraints are clearly discrepant.
- Significant overlap in posterior distributions for remaining eight clusters.
- Taken as an ensemble, AMI finds SZ signal to be, on average, smaller in extent and fainter than *Planck* finds.
- Where results are consistent overlap region provides tighter combined constraint.



(adopting X-ray determined cluster size)

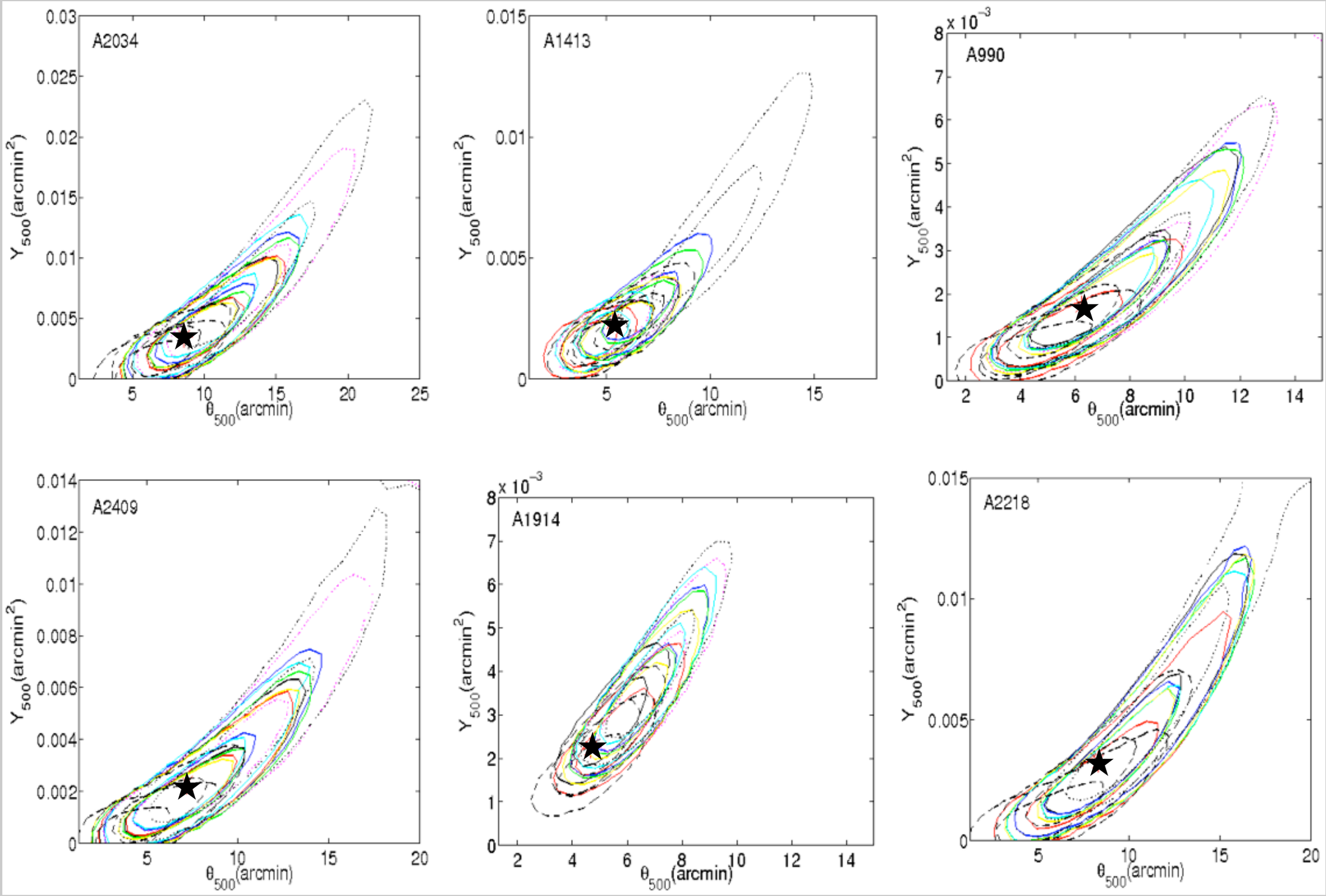
Tests for systematics

- Simulations reveal no obvious instrumental or astrophysical systematics.... simulated *Planck* recovery:



Tests for systematics

- Simulations reveal no obvious instrumental or astrophysical systematics.... simulated AMI recovery:



Including information from X-ray observations

$$P(r) = P_{500}\left(\frac{M_{500}}{3\times10^{14}\,M_{\odot}}\right)^{\alpha_{\rm P}}\frac{P_0}{(c_{500}x)^{\gamma}(1+(c_{500}x)^{\alpha})^{\frac{\beta-\gamma}{\alpha}}}$$

$$\text{with } x = r/R_{500} \text{ and } \alpha_{\rm P} = 1/\alpha_{\rm MY_X} - 5/3.$$

UPP concentration & shape parameters:

$\alpha_{\rm MY_X}$	P_0	c_{500}	γ	α	β
0.561	8.403	1.177	0.3081	1.0510	5.4905

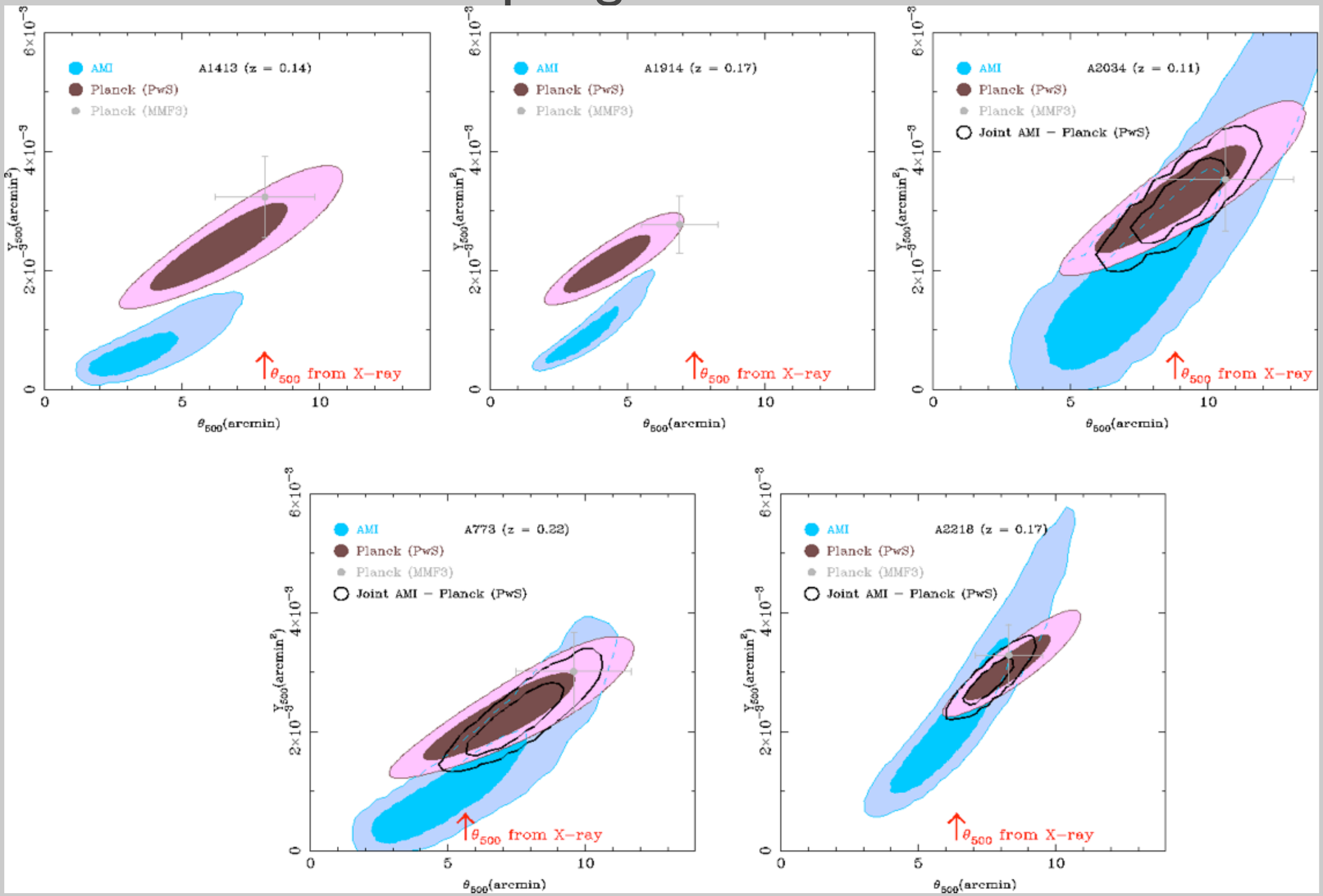
Arnaud et al. (2010) A&A, 517, A92

- In place of Universal Pressure Profile, use individual GNFW profiles fitted to high-quality X-ray observations (Pratt et al. in prep):

Cluster	R_{500} (Mpc)	P_{500}	P_0	c_{500}	α	γ
A1413	1.240	3.229	31.08	0.90	0.69	0.191
A1914	1.348	4.045	49.94	1.88	0.95	0.000
A2034	1.211	2.899	9.14	1.84	1.72	0.000
A2218	1.169	3.039	40.92	1.02	0.74	0.000
A773	1.232	3.724	20.61	1.25	0.96	0.000

Previous results adopting UPP:

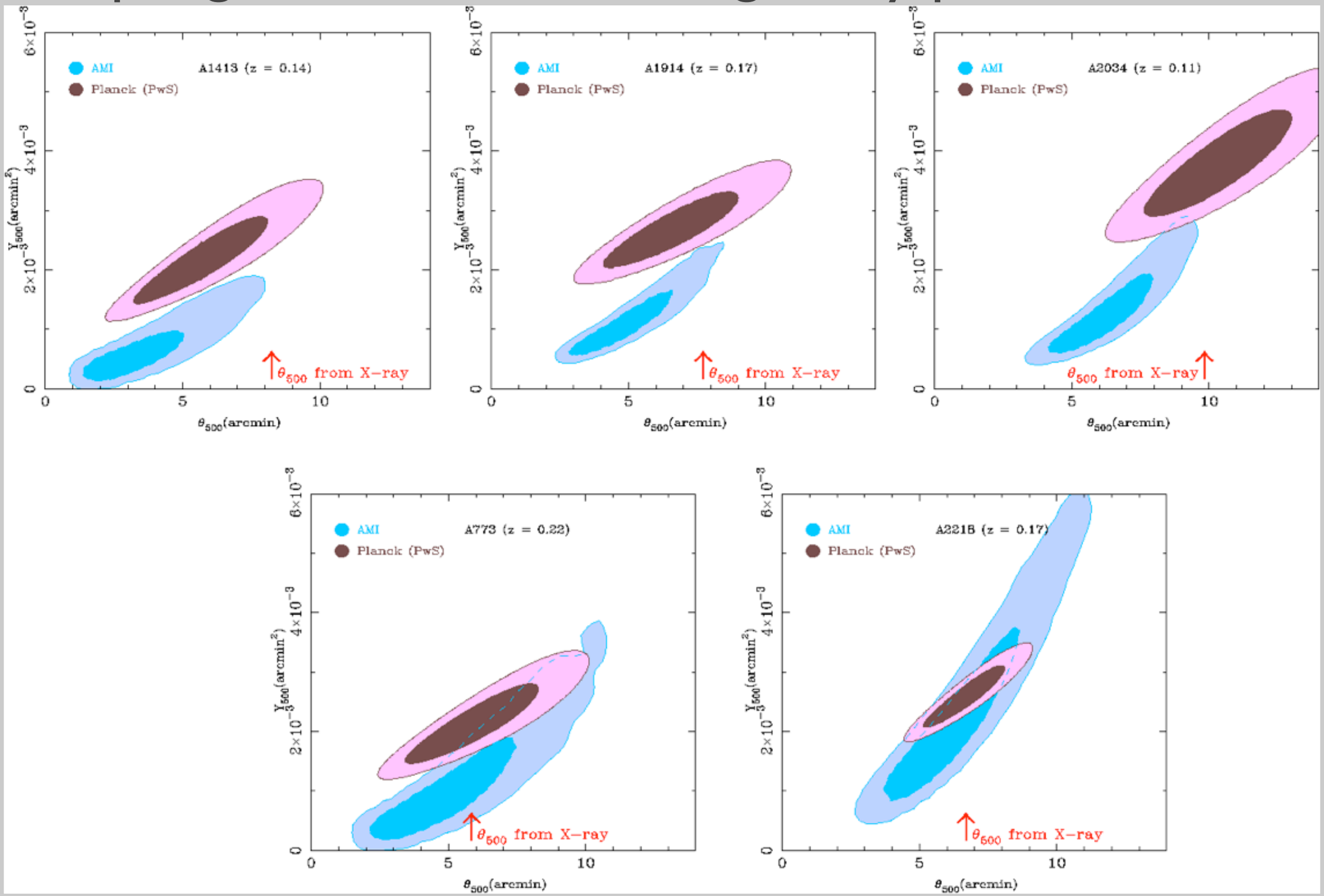
Y_{500} (arcmin^2)



AMI constraints *Planck* constraints ⟶ θ_{500} (arcmin)

Adopting individual best-fitting X-ray profiles:

Y_{500} (arcmin^2)



AMI constraints *Planck* constraints → θ_{500} (arcmin)

Conclusions

- Good agreement on many individual clusters but on average, AMI finds clusters to be fainter and smaller than *Planck*.
- For clusters where *Planck* & AMI are consistent, combining constraints is powerful.
- 3 out of 11 clusters show quite large discrepancy.
- Simulations don't show up any problems due to either foregrounds or analysis methodologies.
- Adopting X-ray best-fitting GNFW shape parameters does not appear to resolve discrepancies in general.
- Future work will involve larger cluster sample and fitting of GNFW parameters simultaneously to *Planck*, AMI and X-ray data.

Analysing the SZ signal

- Have enforced cluster position to be the same in *Planck* & AMI analyses (so we are comparing integrated SZ signal centred on identical sky coordinates).

- Compare and combine constraints from *Planck* and AMI in the 2D parameter space of θ_{500} and Y_{500}.

- To analyse the *Planck* data, we use PowellSnakes algorithm as this returns the full likelihood distribution.

  Carvalho et al. (2011) arXiv:1112.4886
  Planck collaboration (2011) A&A, 536, A7 & A8

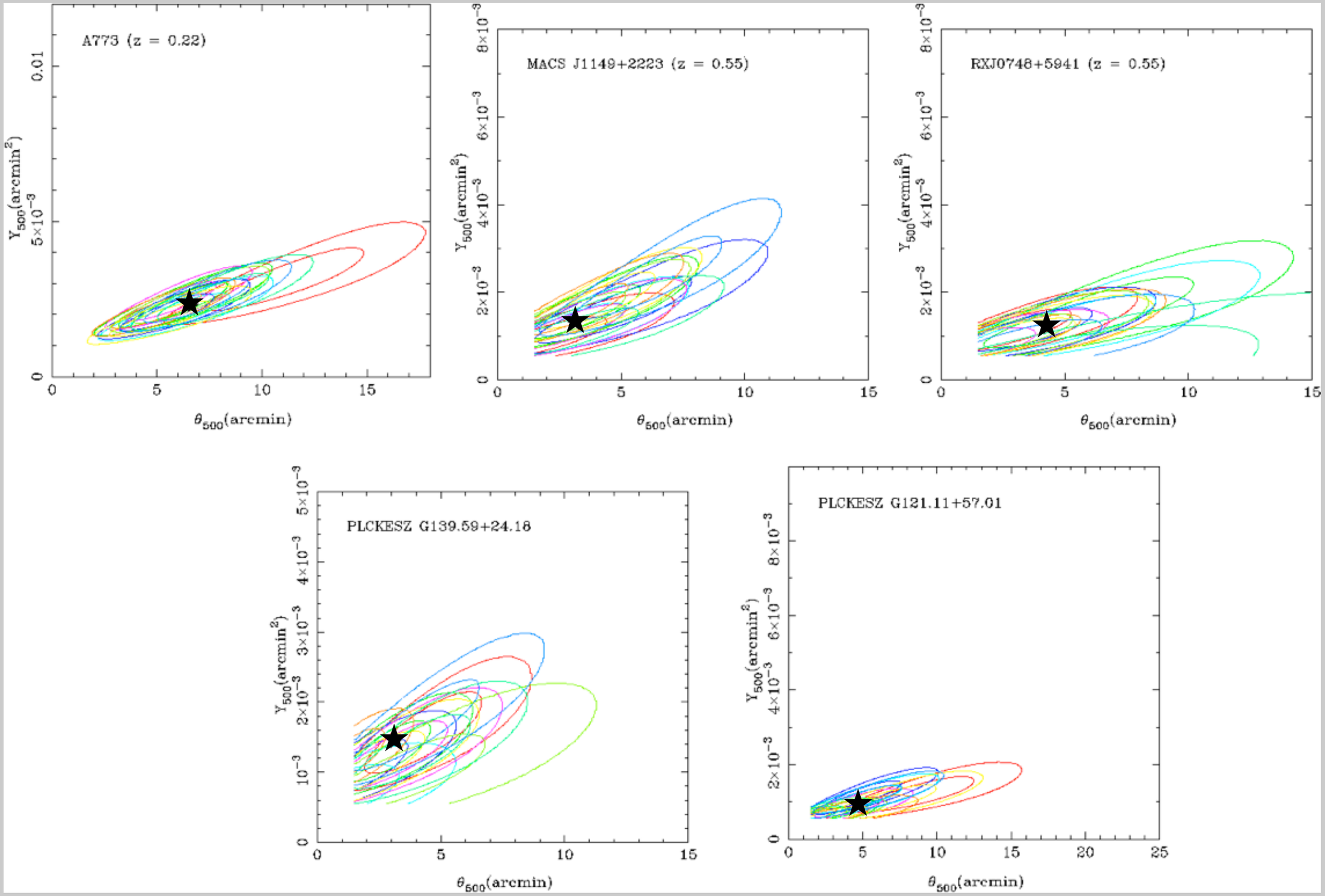
  ⋆ Different to Matched Multi-Filter algorithm used for Early SZ catalogue (but very good agreement between the two).

- To analyse the AMI data, we use the McAdam software for Bayesian analysis of interferometric data.

  Feroz et al. (2009) MNRAS, 398, 1601& 2049

Tests for systematics

- Simulations reveal no obvious instrumental or astrophysical systematics.... simulated *Planck* recovery:



Tests for systematics

- Simulations reveal no obvious instrumental or astrophysical systematics.... simulated AMI recovery: