NIKA: a SZ camera

J.F. MACÍAS-PÉREZ
on behalf of the NIKA collaboration

mm Universe @ NIKA2

Observing the millimeter Universe with the NIKA2 camera

NIKA http://ipag.osug.fr/nika2

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Outline

I. Why high resolution mm cameras for tSZ observations?

II. The NIKA mm camera

III. NIKA SZ pilot sample

IV. Conclusions

Understanding mass-observable relation

- Cluster cosmology requires accurate mass and matter distribution estimates
- Two complementray approaches :

WL masses		baryonic mass proxies
no bias !!?	vs	unknown bias
large scatter		low scatter

Weak lensing provides absolute mass normalisation

Many observational efforts :
CCCP, Weighing the Giants, 400d WL, CFHTLenS, 400d WL, LoCuSS, WISCy

LSST + EUCLID 2021 -->

Y - M_{tot} & P(r)

bias
scatter
evolution

vs

dynamics
z

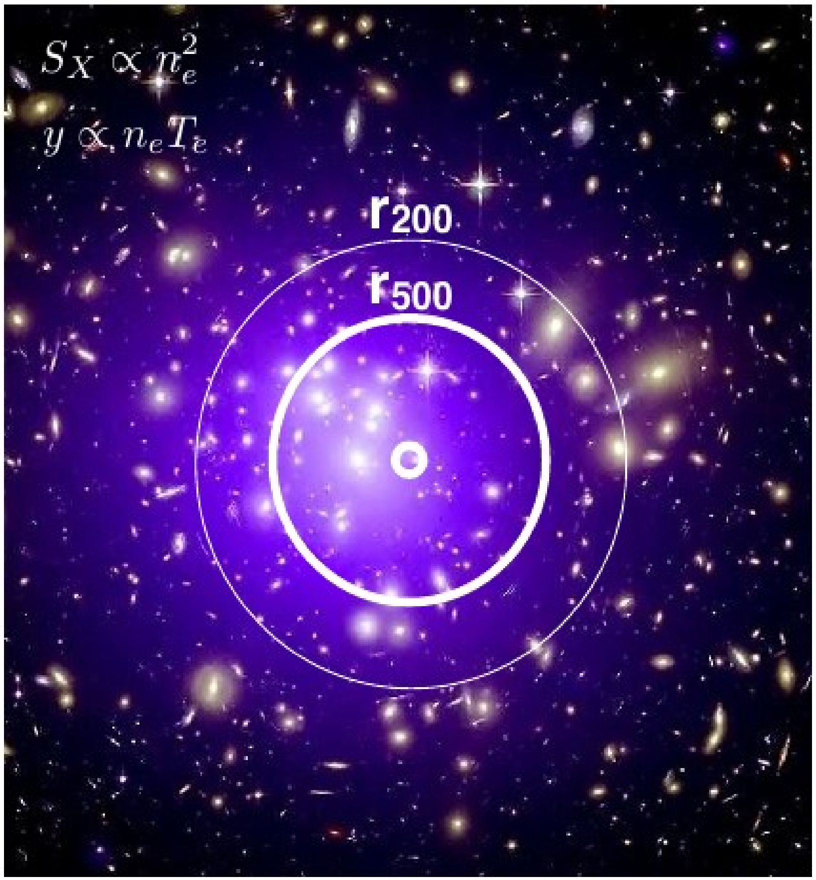
Cluster detection
X-rays : e-ROSITA
SZ : SPT-3G (2016-2019), Advanced ACTPOL

Scaling relations
X-rays : XMM, Chandra
SZ : **NIKA (2009-2014), NIKA2,** MUSTANG2

Mainly low redshift cluster data available, and we expect some evolution with redshift

Multi-wavelength high resolution observations of high redshift clusters are needed

Cluster self-similarity vs radius



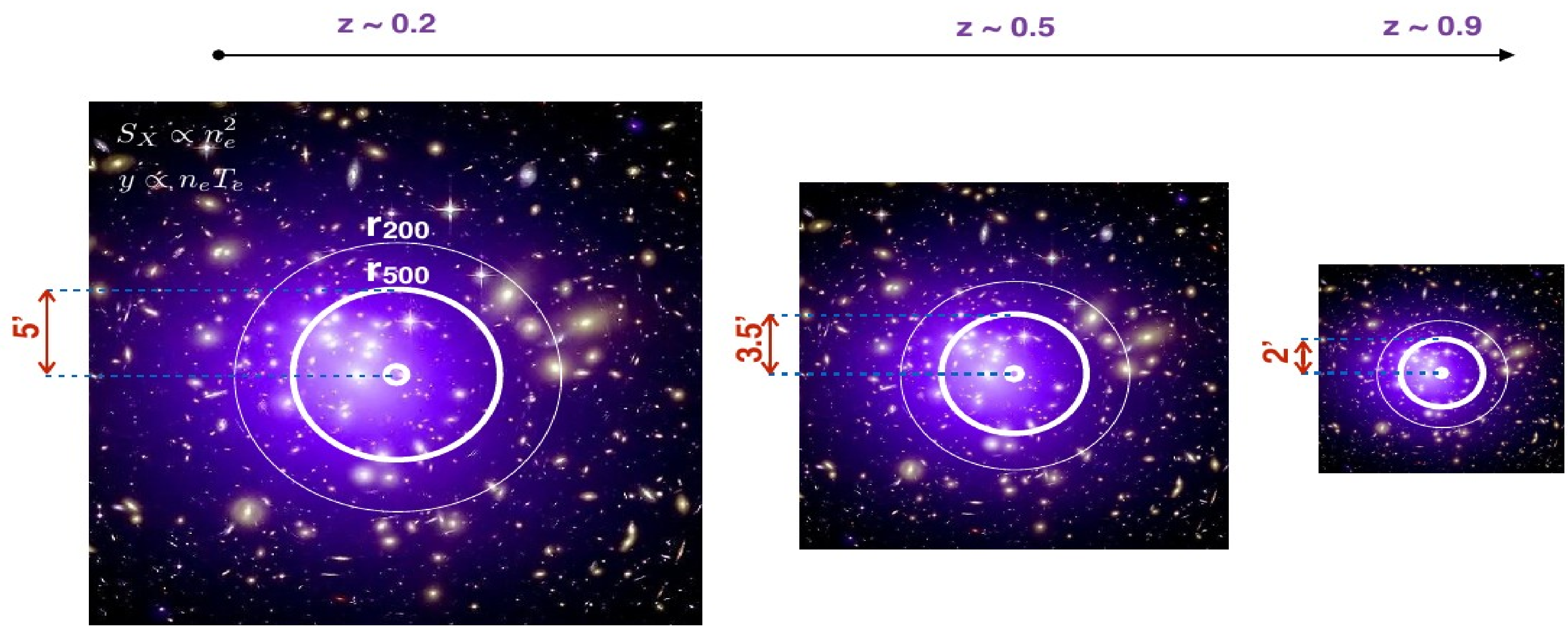
$r \lesssim 0.1 r_{500}$ ⇨ baryonic physics
(e.g. cooling, feedback, affect the normalization)

$0.1 r_{500} \lesssim r \lesssim r_{500}$ ⇨ gravity

$r \gtrsim r_{500}$ ⇨ deviations from equilibrium, on-going formation
(e.g. non-thermal pressure support, affects the normalization)

High redshift clusters

High redshift clusters are at the early stages of formation and may not behave like low redshift ones: merging processes and shocks, undefined outskirts, evolution of scaling relations, non hydrostatic equilibrium, etc



Multi-wavelength high resolution observations of high redshift clusters are needed to identify possible evolution with redshift

Outline

I. Why mm cameras for tSZ observations?

II. The NIKA mm camera

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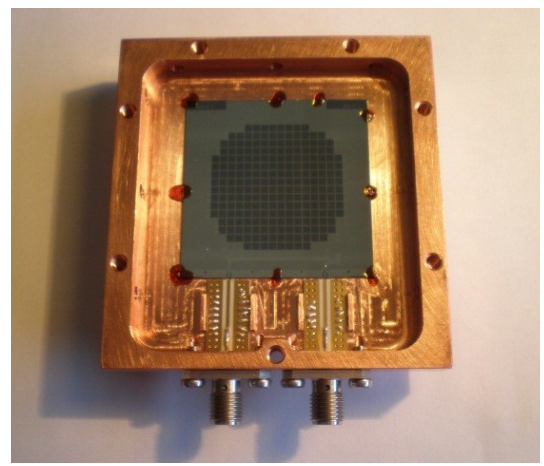
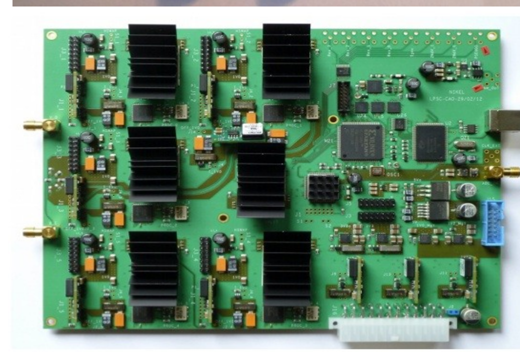
The NIKA camera

[Monfardini+ 2011, Bourrion+2012, Calvo+2012]

- prototype of NIKA2
- operated at the IRAM 30 m telescope from 2009-2014
- Dual band camera with 336 KIDs cooled down to 150 mK
- Specific readout electronics





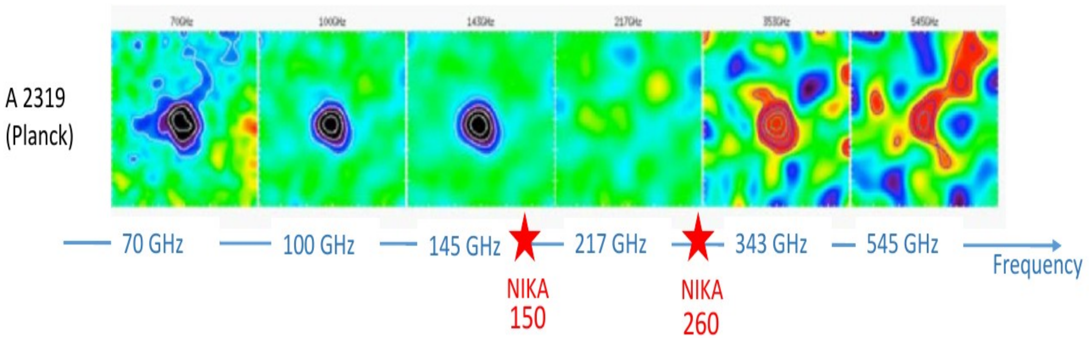
The NIKA camera

- prototype of NIKA2
- operated at the IRAM 30 m telescope from 2009-2014
- Dual band camera with 336 KIDs
- Polarisation capabilities in both bands (see Ritacco's talk)
- First KID based camera to provide scientific grade results

NIKA	150 GHz	260 GHz
# KIDs	132	224
FOV diameter	1.8 arcmin	2.0 arcmin
Sensitivity	14 mJy/s$^{1/2}$	40 mJy/s$^{1/2}$
Angular res.	18 arcsec	12 arcsec

[Adam & NIKA collaboration, 2014, Catalano & NIKA collaboration 2014]

NIKA well adapted for tSZ observations of high z clusters



- Two frequency bands, negative & zero tSZ signal
- High resolution : 17 times better than Planck

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III. **NIKA SZ pilot sample**

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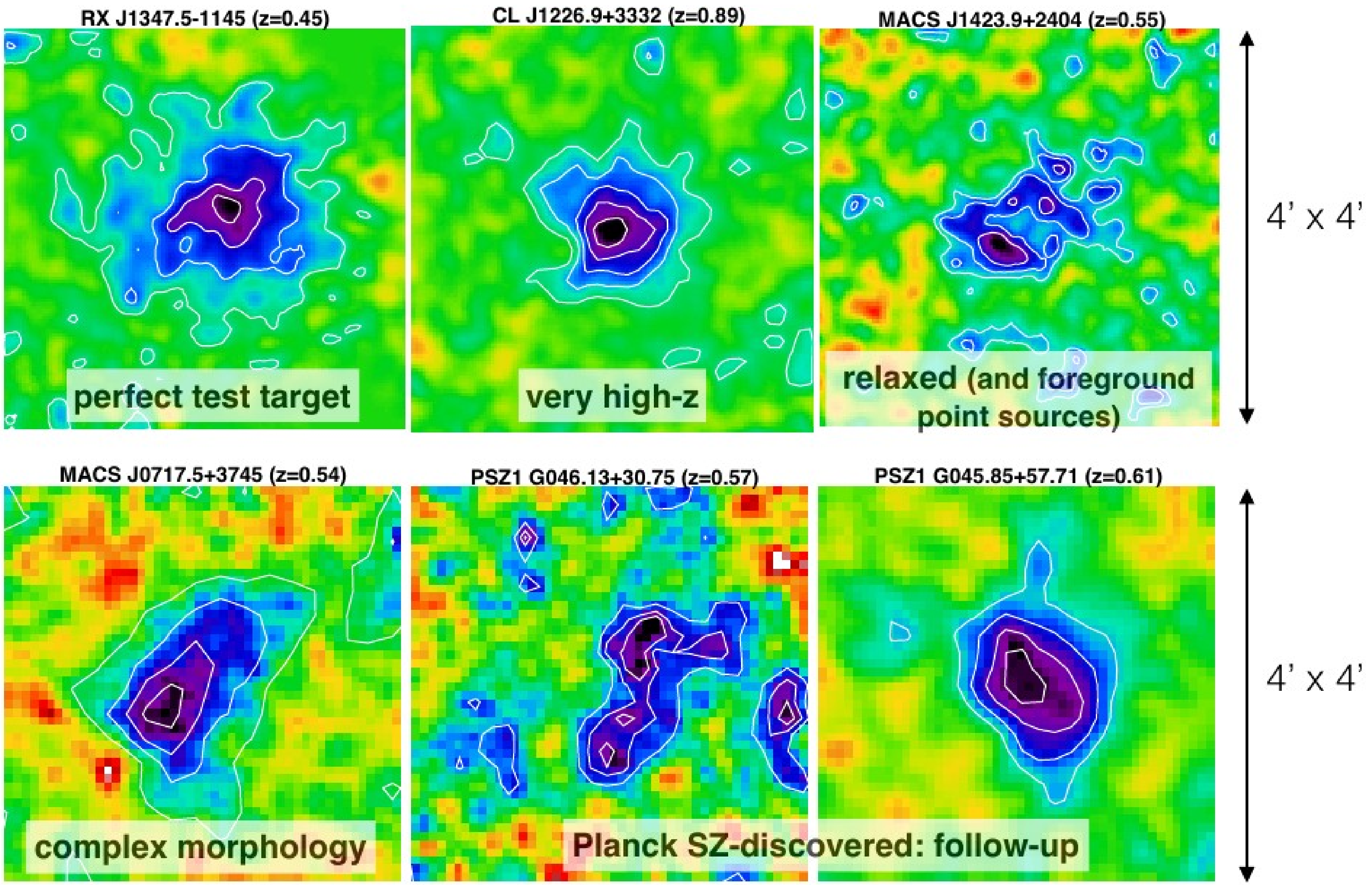
NIKA SZ pilot sample

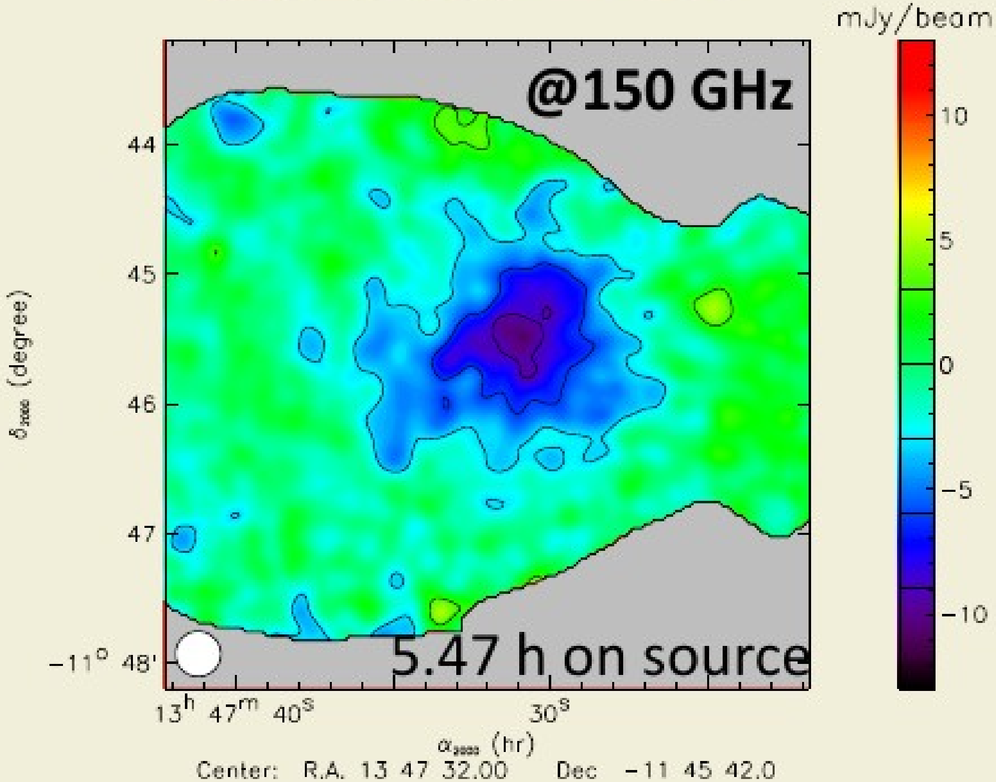


[Adam & NIKA collaboration, 2014, 2015.2016,2017, 2018
Ruppin & NIKA collaboration 2017, Romero & NIKA collaboration 2017]

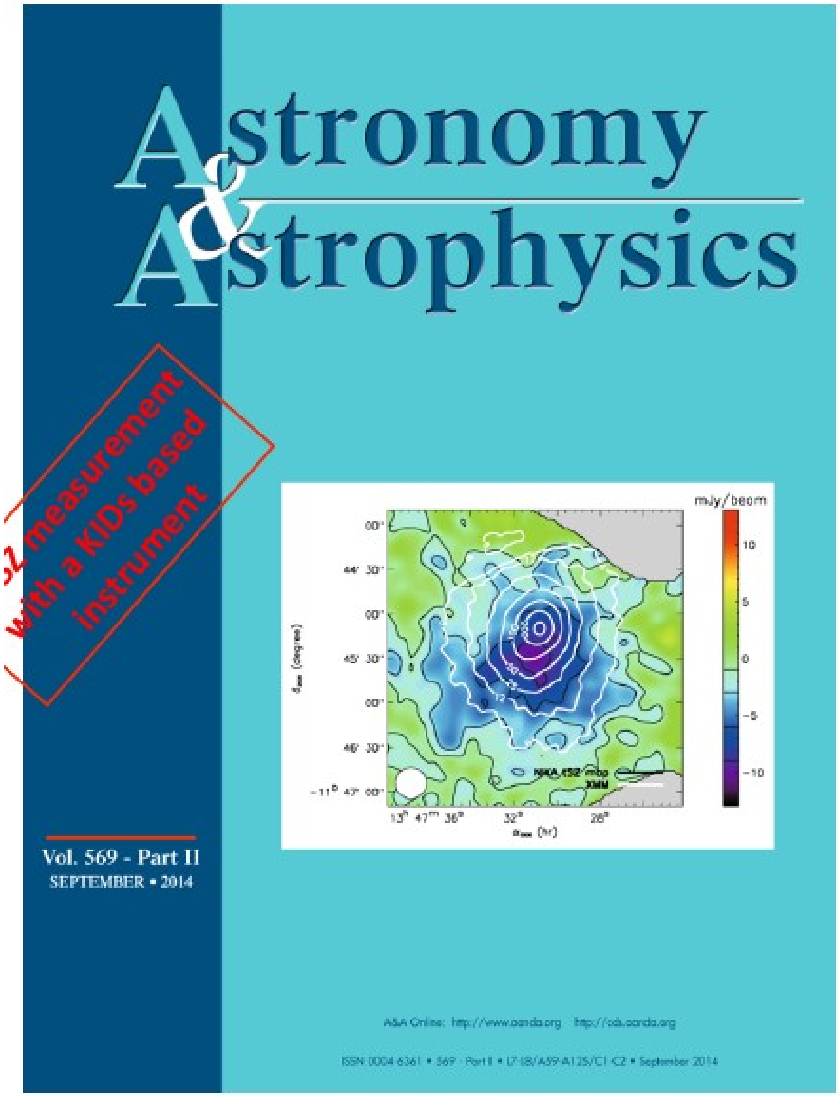
First tSZ measurement with KIDs

intermediate redshift (z = 0.451), compact, strong and well known

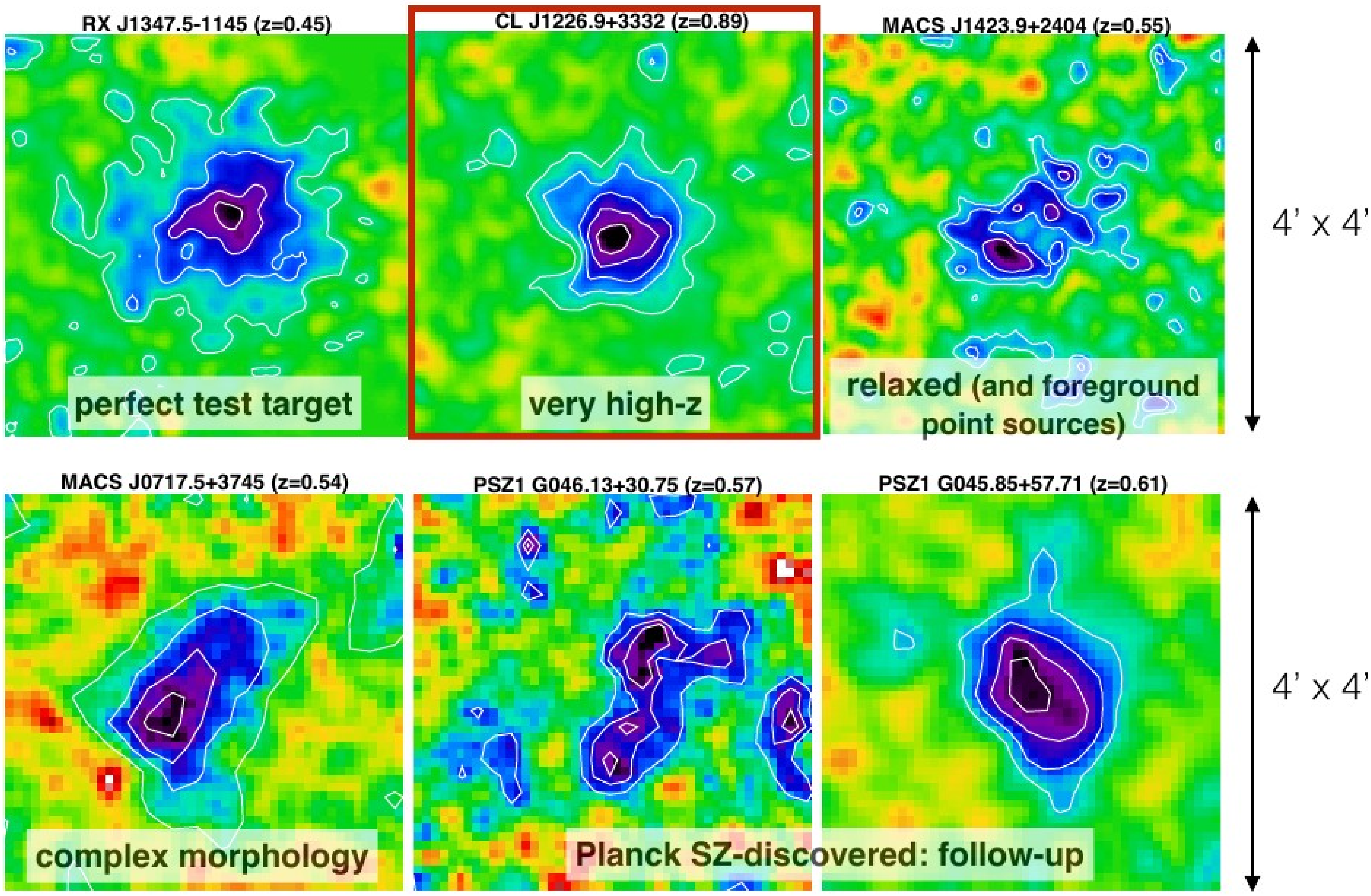
RXJ1347.5-1145:



[Adam, Comis, MP & NIKA collaboration, 2014]



High redshift cluster (z=0.89)



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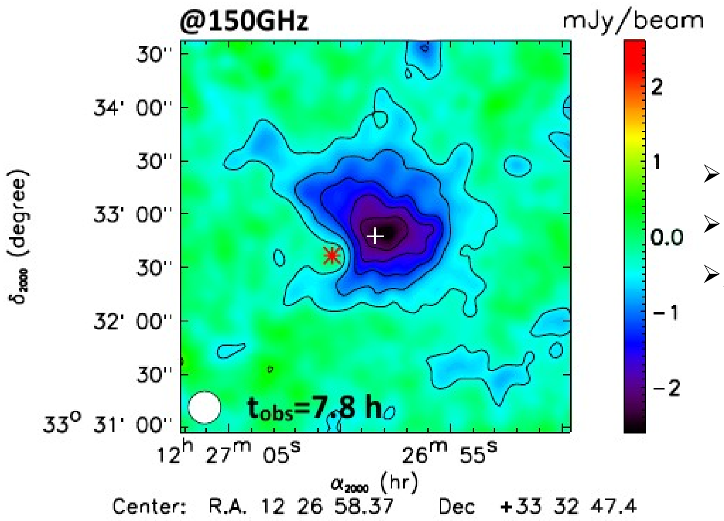
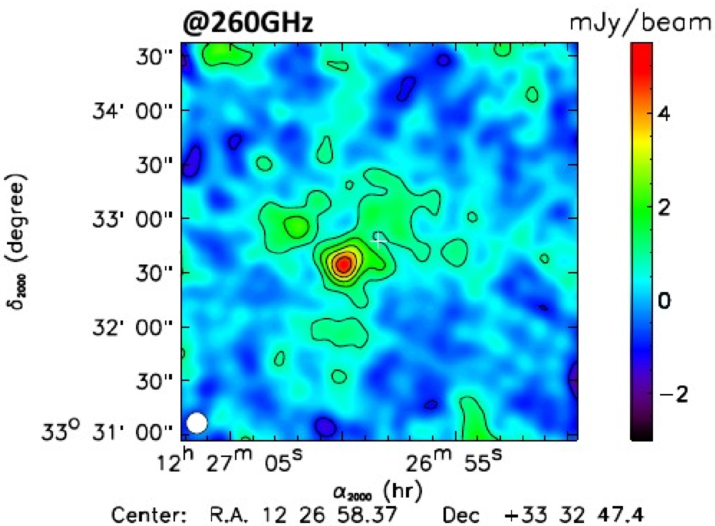
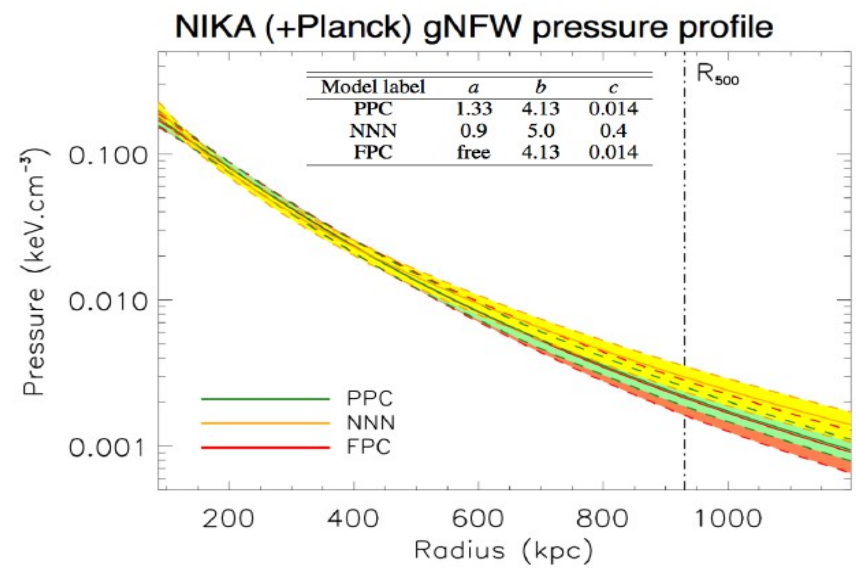


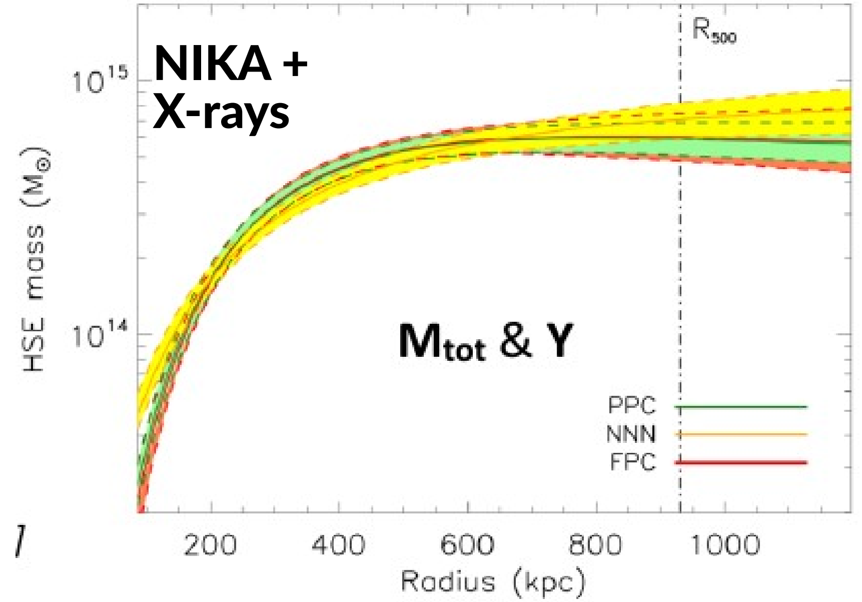


CL1226.8+3332

- Relaxed and massive
- 18-σ peak detection
- Strong point source

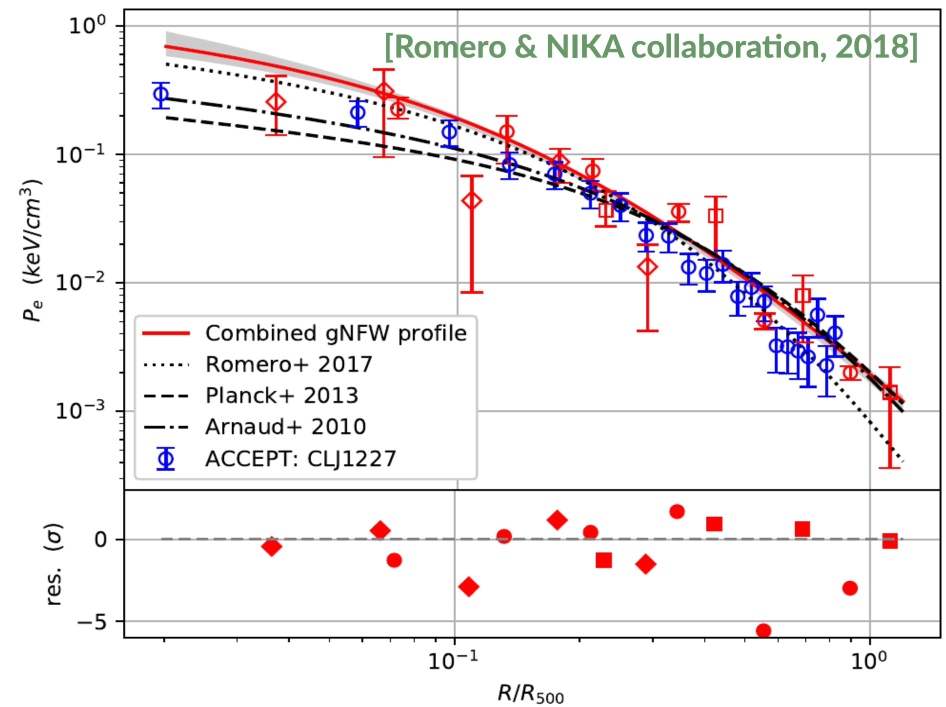
Measure cluster thermodynamic properties and HSE mass





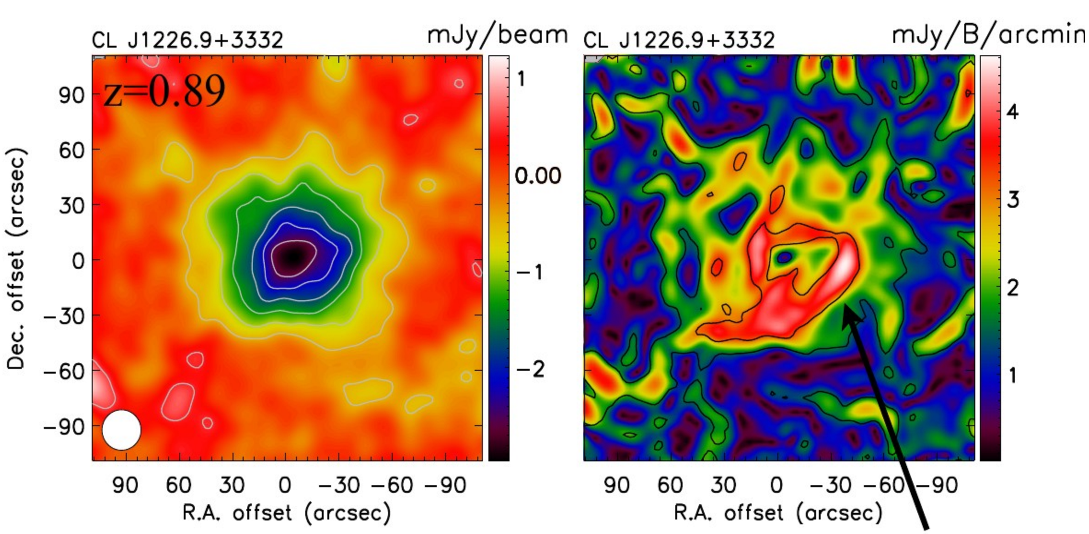
[Adam & NIKA collaboration, 2015]

High redshift cluster (z=0.89)



- **Joint NIKA, MUSTANG, BOLOCAM and PLANCK tSZ analysis** pressure profile from the inner cluster region to the outskirts.

NIKA map — Gradient filtered map

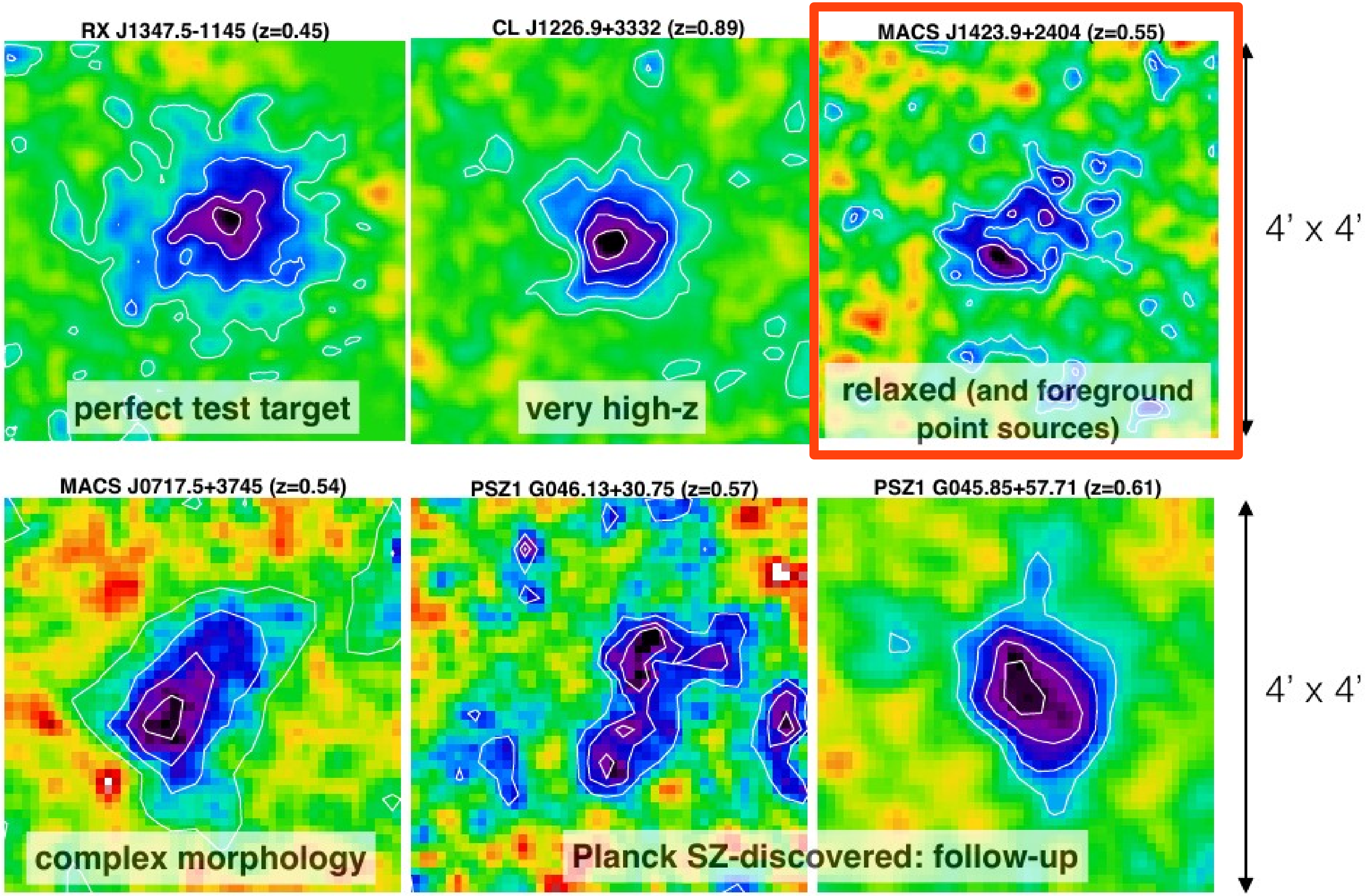


Pressure jump caused by merger

- ICM physical state determination: Direct detection of pressure jump induced by merging events

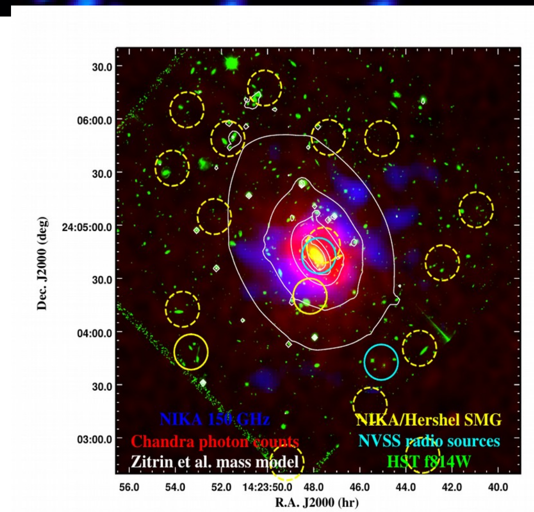
[Adam & NIKA collaboration, 2017]

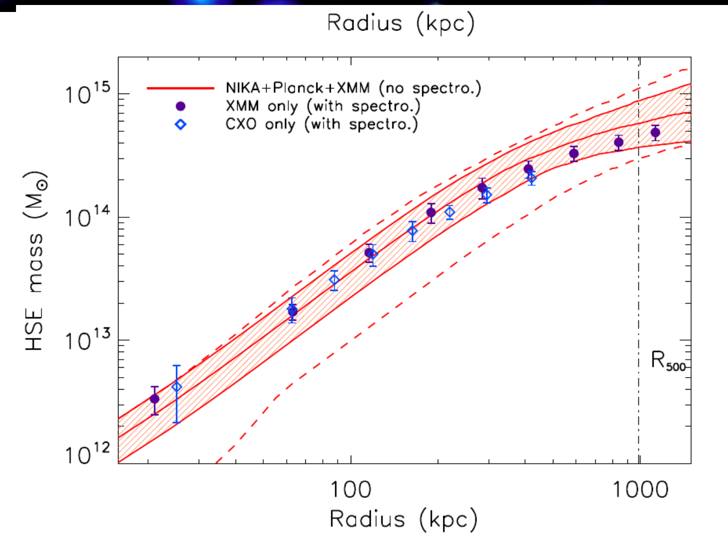
Rich environment

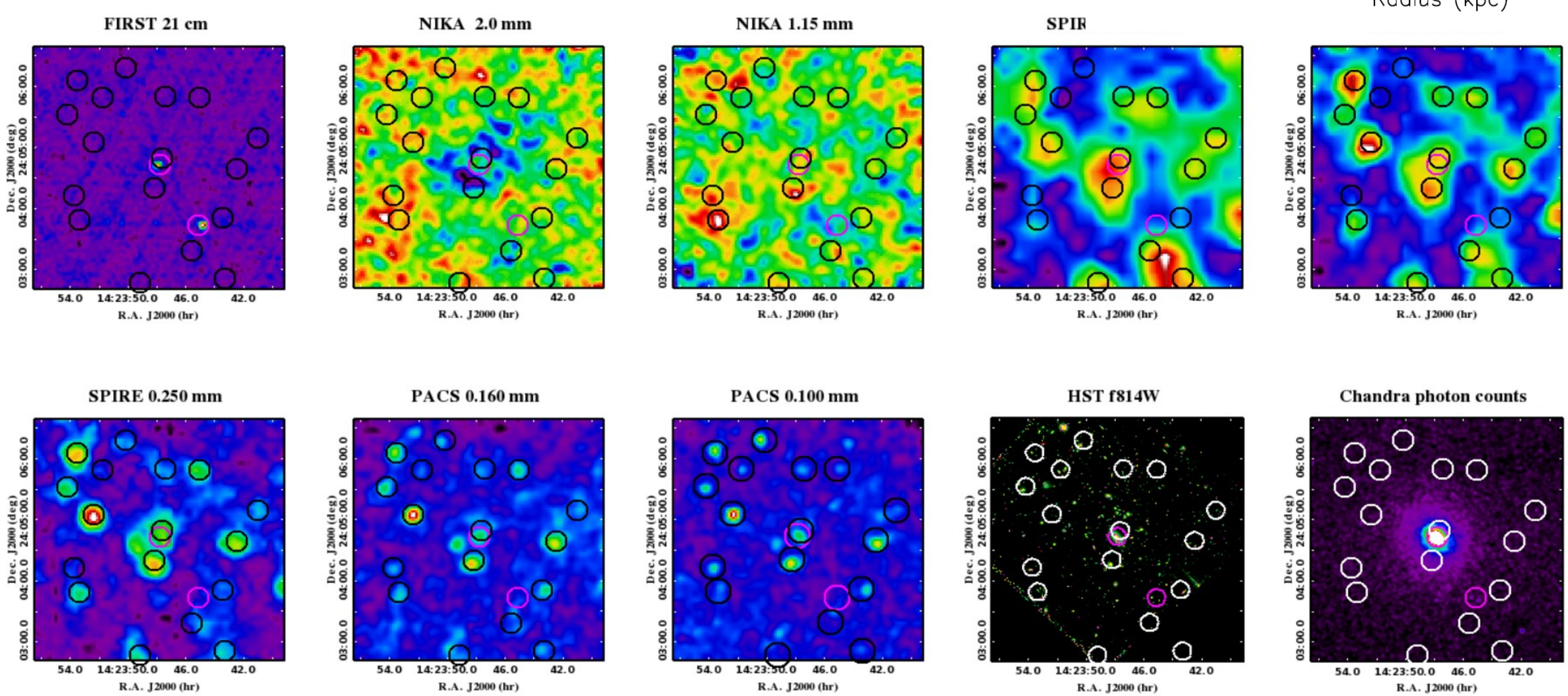


Rich environment

- 17 SMG + 2 RS but still possible to reconstruct thermodynamics properties and mass
- Multi-wavelength analysis

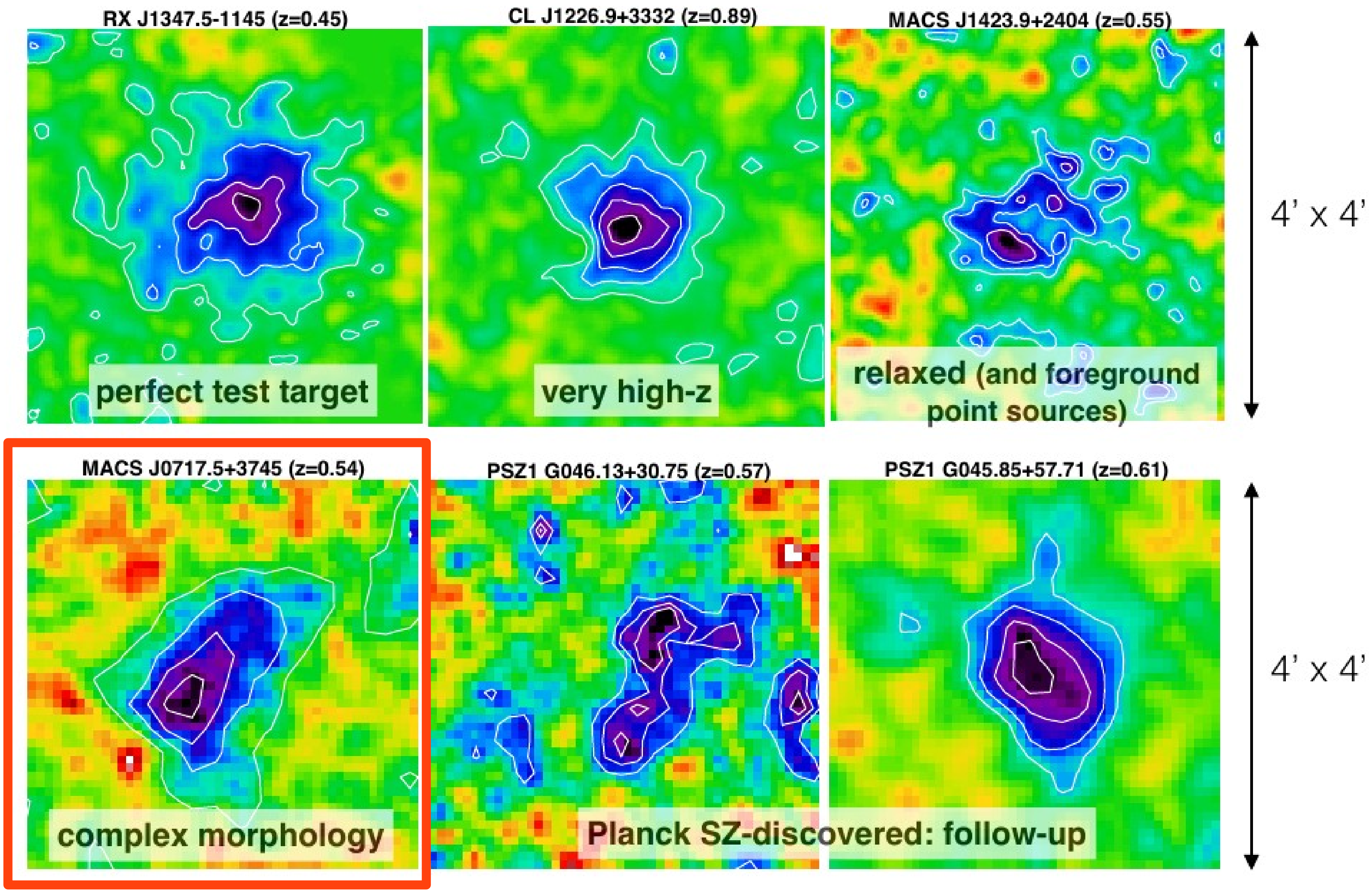






J.

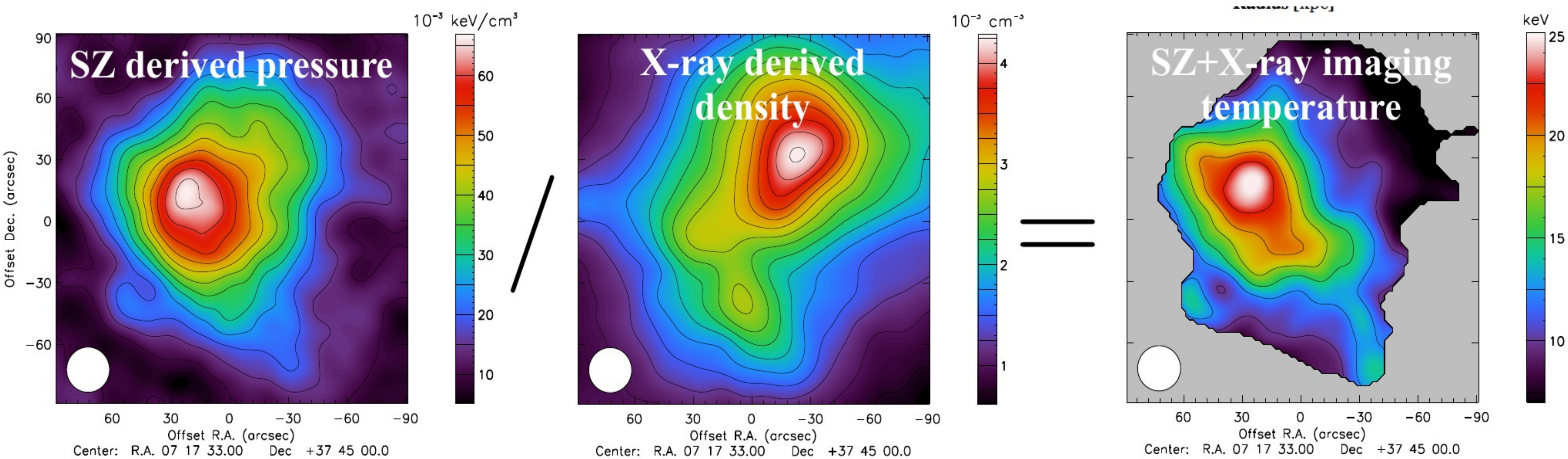
Complex physics

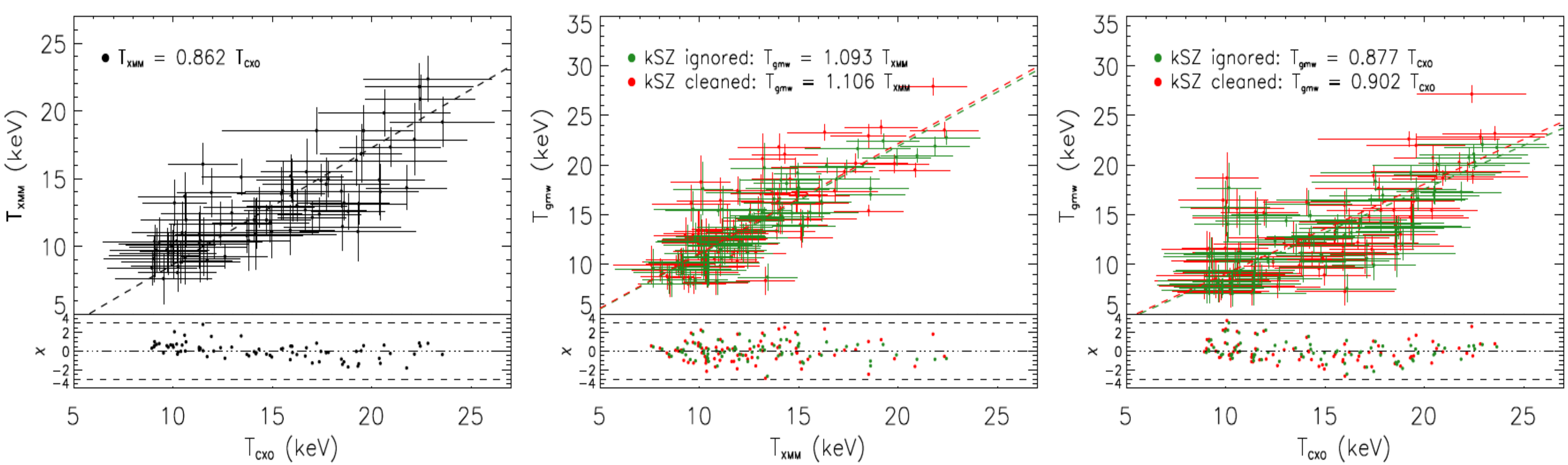


Temperature map from tSZ + X-rays

[Adam & NIKA collaboration, 2017]

$P_e = n_e T_e$ ➡ *First 2D temperature map from combined tSZ and X-ray imaging*





MACS J0717-3745 and kSZ

- High sensitivity NIKA data (12 hours on source)
  + High quality X-ray, optical and IR data

- However, mapping kSZ is very challenging:

  Complex system (5 subclusters
  Foreground emission
  Degeneracy relativistic tSZ and kSZ

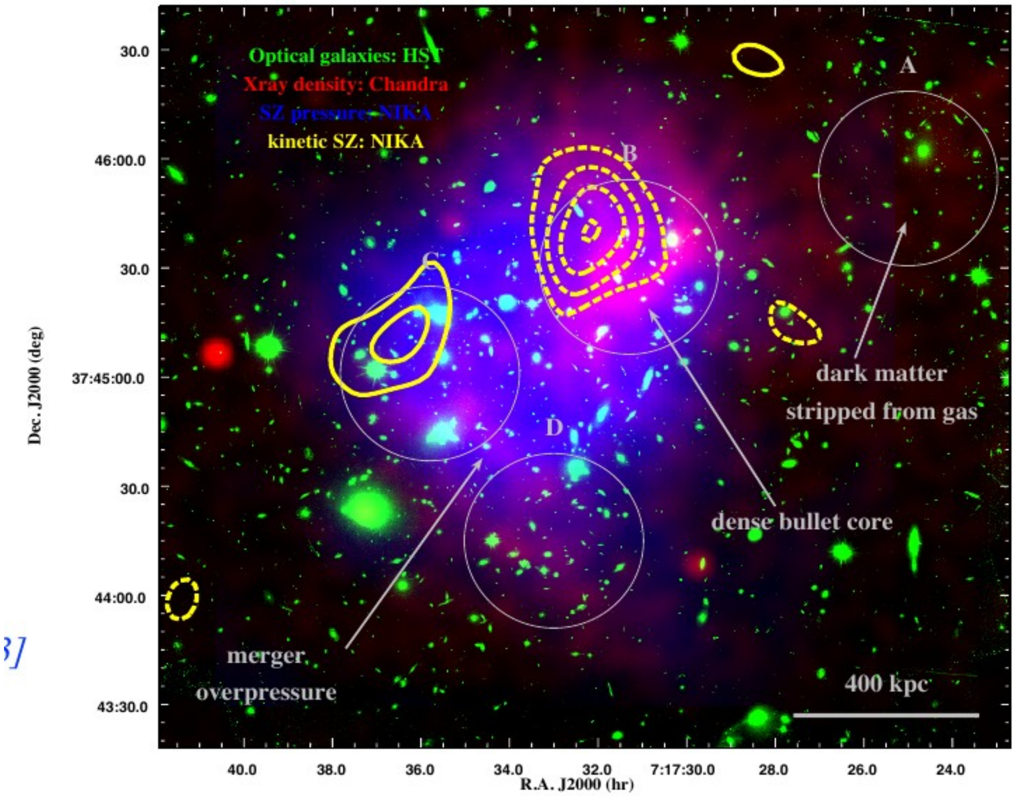
- Use the two NIKA channel maps
  + temperature map from X-rays

spectral dependencies

$$\frac{\Delta I_\nu}{I_0} = f_\nu \; y_{\mathrm{tSZ}} + g_\nu \; y_{\mathrm{kSZ}}$$

gas pressure — *gas velocity and density*

MACS J0717-3745



[Adam & NIKA collaboration, 2016]

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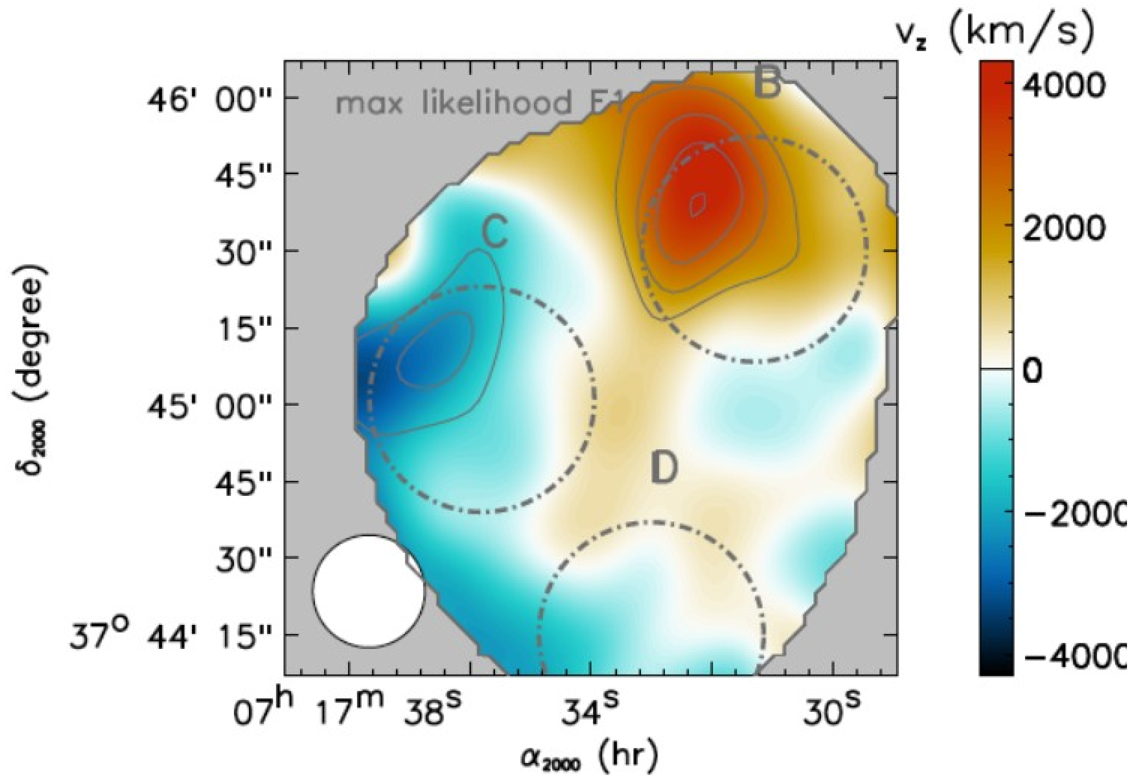
[Adam & NIKA collaboration, 2016]

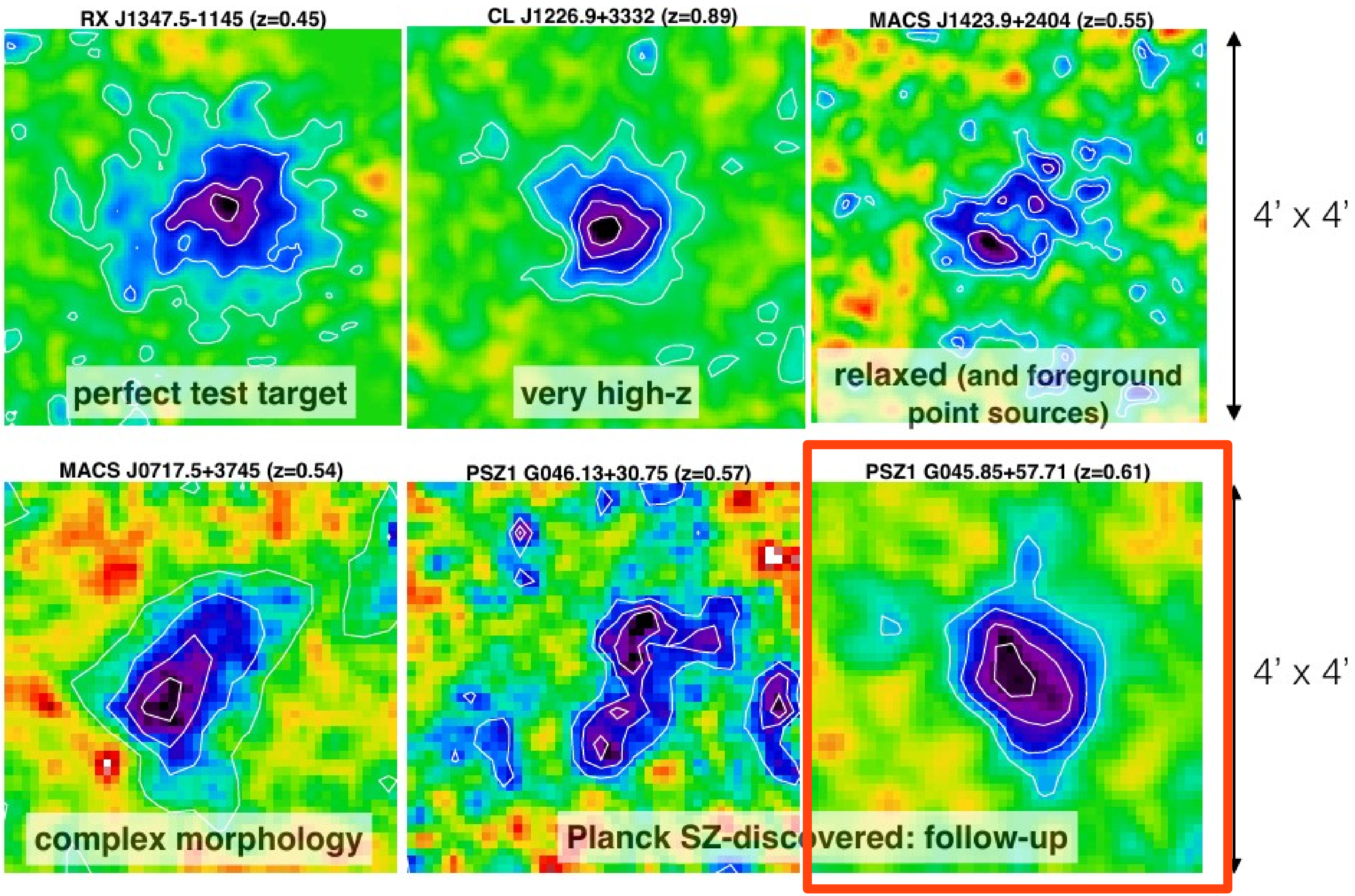
MACS J0717-3745 velocity map



First direct mapping of kSZ emission

[Adam & NIKA collaboration, 2016]

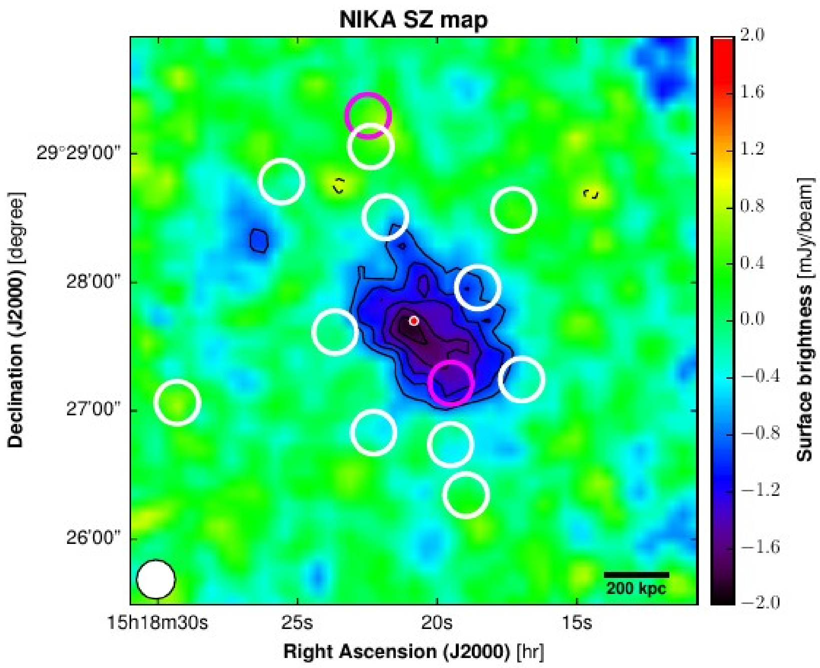
Follow-up of Planck clusters

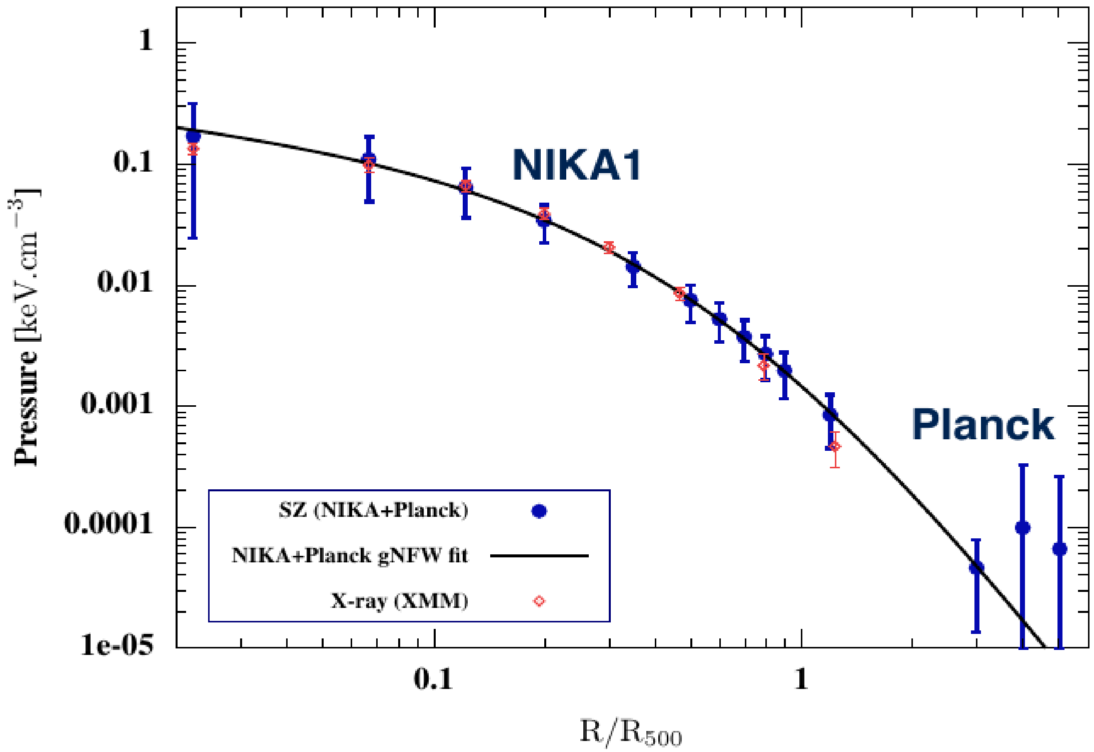


Follow-up of Planck clusters

PSZ1 G045.85+57.71

- Planck tSZ detected cluster at high redshift, z = 0.61
- 5h41m observations with NIKA1 in moderate weather conditions





[Ruppin & NIKA collaboration, 2017]

First non-parametric reconstruction of the pressure profile for high redshift cluster

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IV. **Conclusions**

Conclusions

- NIKA has been the first KID based camera able to produce scientific grade results
- High resolution SZ resolution observations of high redshift clusters are needed to check possible redshift evolution of cluster properties
- NIKA high resolution tSZ observations has been extremely successful covering a large number of scientific cases
- Observational strategy as well as analysis tools have been developed using NIKA observations and are now currently used for NIKA2
- NIKA has provided first direct mapping of the kSZ effect opening a new window in cluster physics and cosmology
- Joint NIKA-XMM temperature map has demonstrated the power of adding X-rays and tSZ observations for replacing costly spectroscopy observations
- NIKA have paved the way for NIKA2