

# **NIKA as a new instrument for high resolution Sunyaev-Zel'dovich observations**

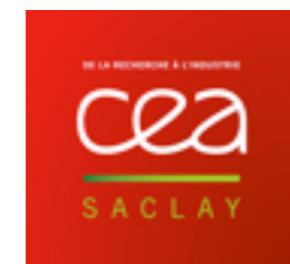
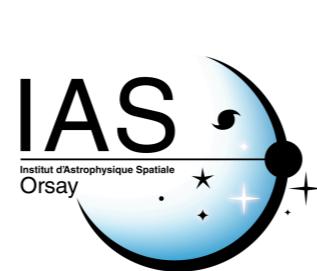
Rémi Adam

JRJC 2013 - 6 Dec. 2013 - Barbaste



<http://ipag.osug.fr/nika2>

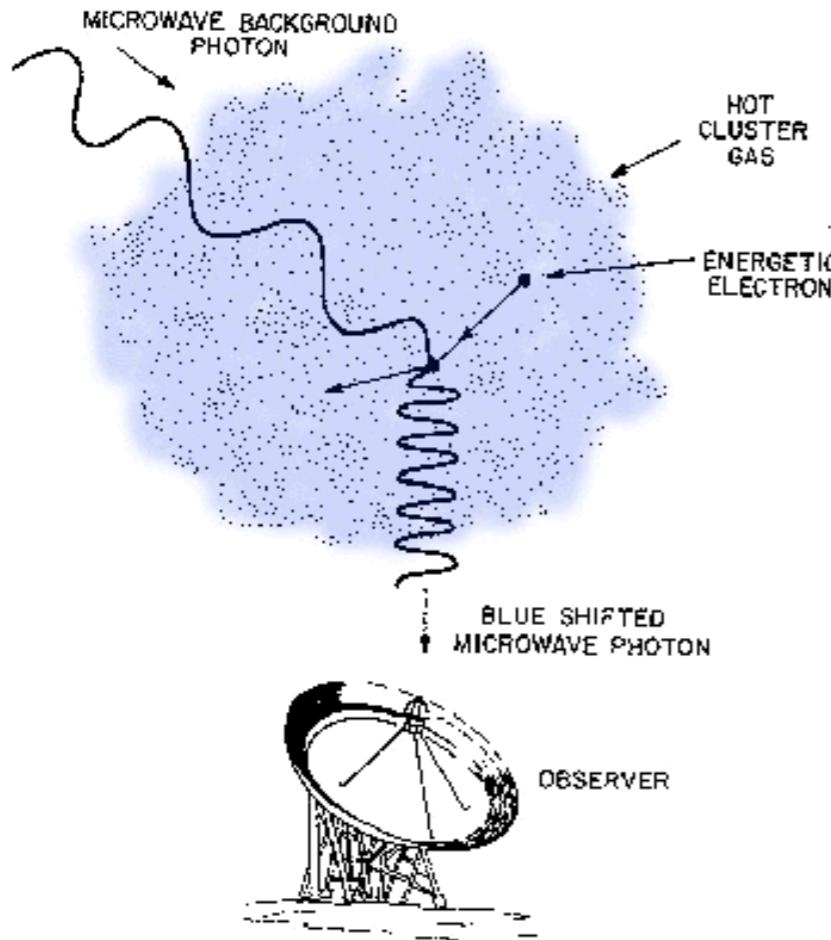
R. Adam, A. Adane, P. Ade, P. André, A. Beelen, B. Belier, A. Benoît, A. Bideaud, N. Billot, N. Boudou, O. Bourrion, M. Calvo, A. Catalano, G. Coiffard, B. Comis, A. D'Addabbo, F.-X. Désert, S. Doyle, J. Goupy, C. Kramer, S. Leclercq, J. F. Macias-Perez, J. Martino, P. Mauskopf, F. Mayet, A. Monfardini, F. Pajot, E. Pascale, L. Perotto, E. Pointecouteau, N. Ponthieu, V. Revéret, L. Rodriguez, G. Savini, K. Schuster, A. Sievers, C. Tucker, R. Zylka



# Outline

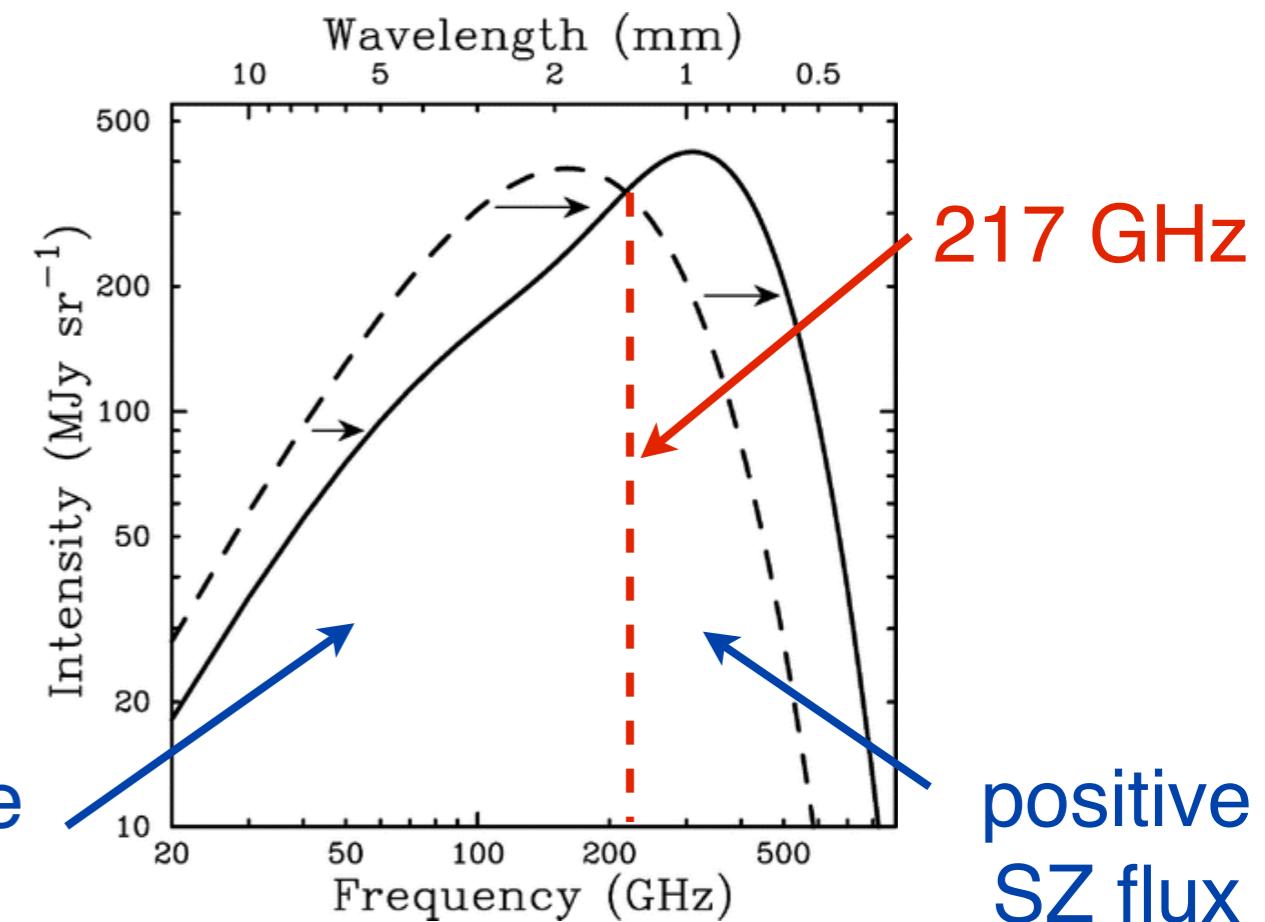
1. The Sunyaev-Zel'Dovich effect (SZ)
2. The Kinetic Inductance Detectors (KIDs)
3. The New IRAM KIDs Array (**NIKA**)
4. First SZ results with the *NIKA* prototype

# The Sunyaev-Zel'Dovich effect (SZ)



[L. Van Speybroeck]

negative  
SZ flux

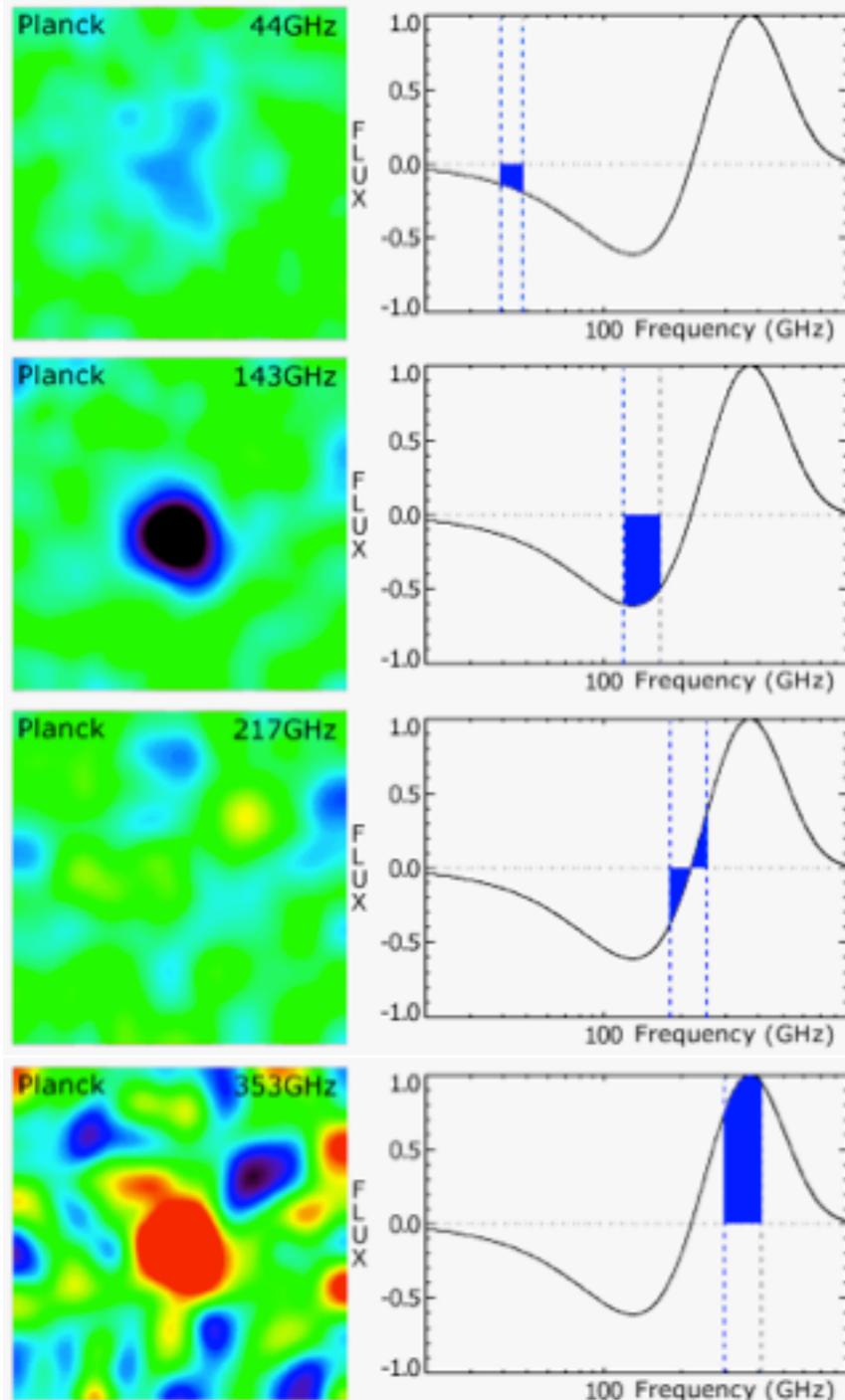


[J. E. Carlstrom et al. (2002)]

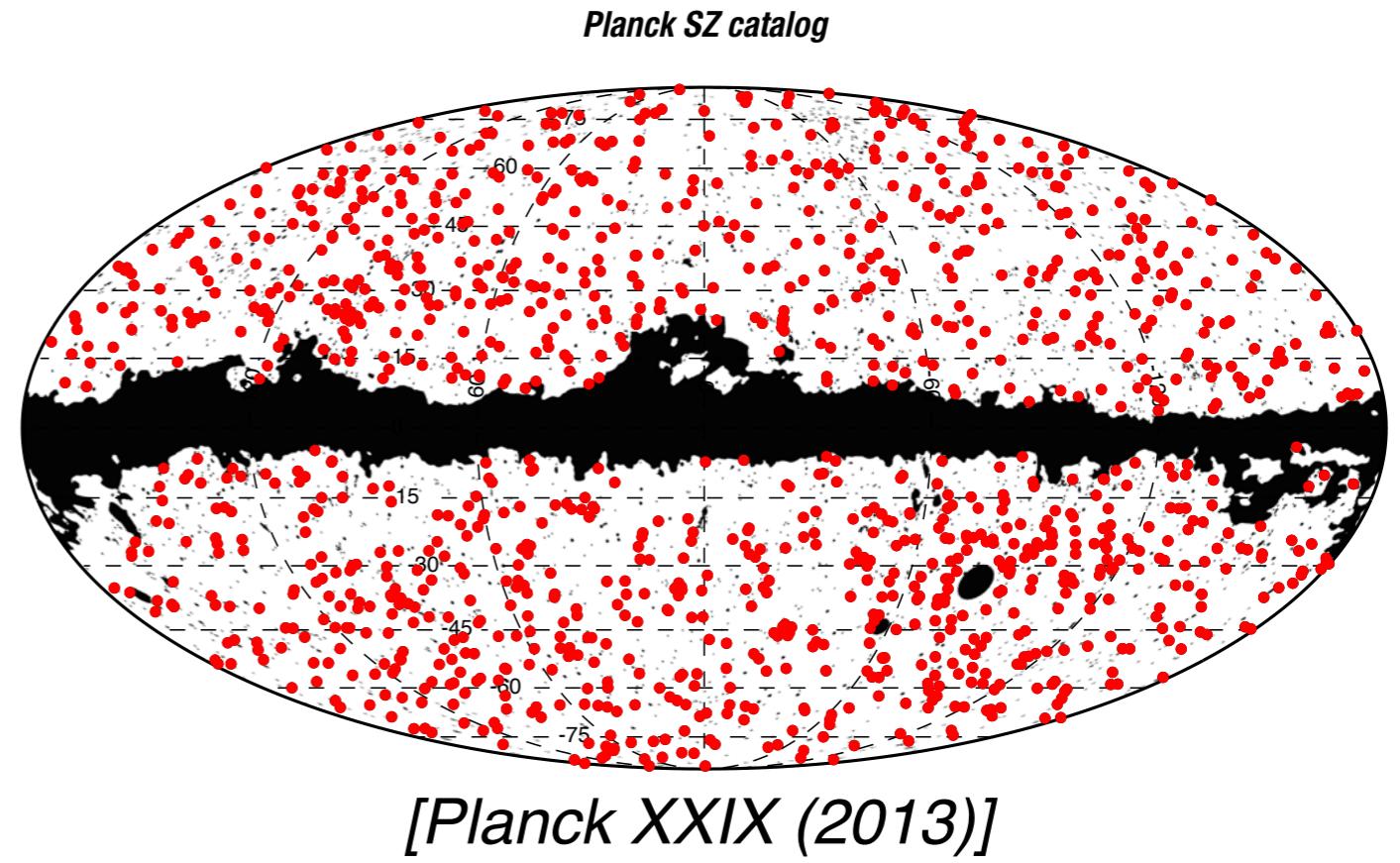
$$\text{SZ}_{\text{flux}} \propto \int P_e dl$$

- The SZ effect is the distortion of the CMB spectrum via the inverse Compton scattering of hot electrons in the intra-cluster medium

# State-of-the-art SZ science: the Planck results



[ESA HFI/LFI consortia]



[Planck XXIX (2013)]

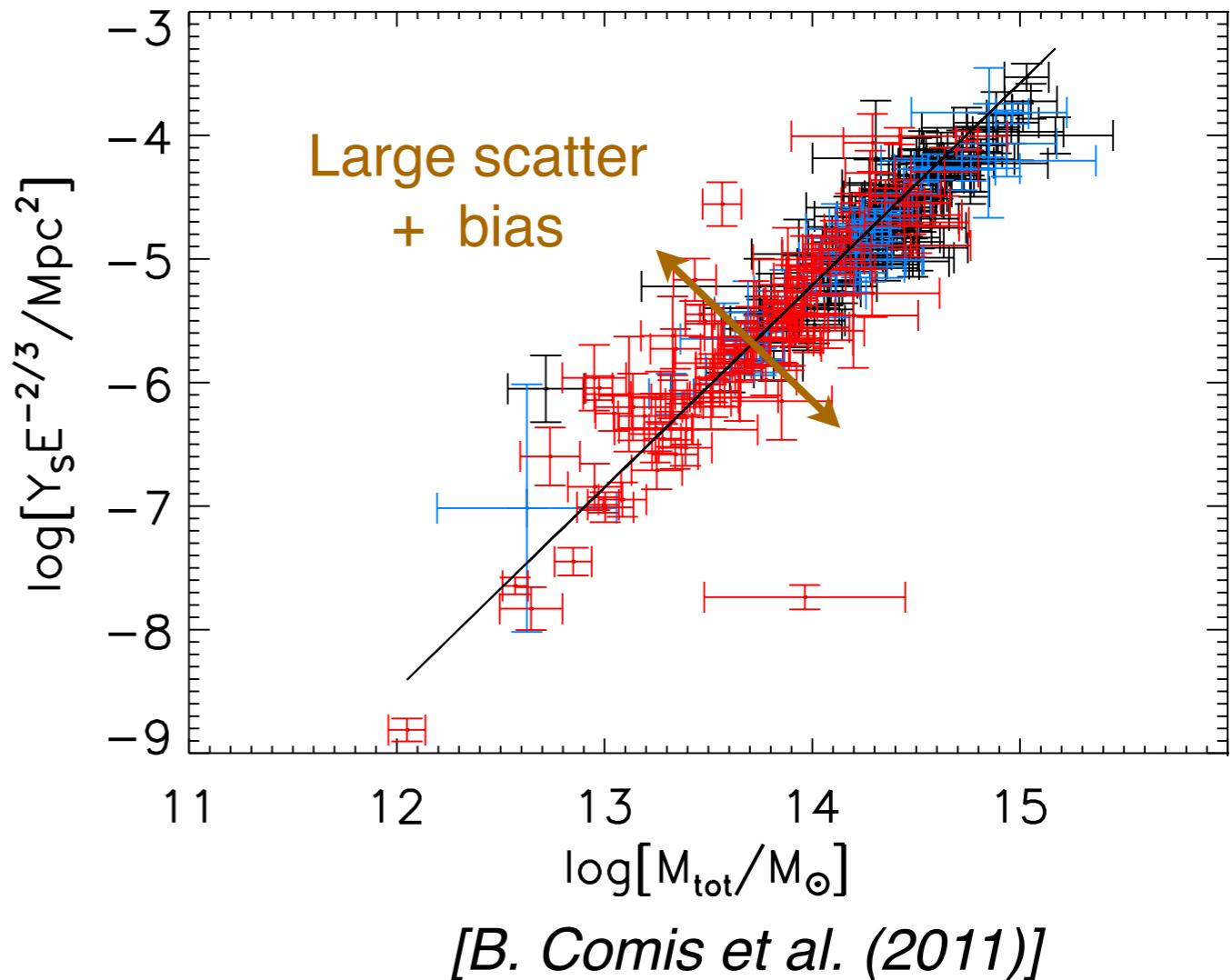
- Full sky
- 9 frequency band (30 - 857 GHz)
- Angular resolution of 33 - 4.5 arcmin
- 1227 clusters in the catalog

→ **Planck provides the largest SZ sample but high-z clusters are unresolved**

# The SZ effect as a mass proxy

$Y_S = \text{SZ}_{\text{flux}} \rightarrow \text{thermal pressure} \rightarrow \text{thermal energy} \rightarrow \text{hydrostatic mass}$

- SZ flux - total mass calibration is required for cosmology
- Bias due to non gravitational processes (e.g. non virialized structures)
- Need to look in details in clusters: projection effects, shocks, ...



→ **High angular resolution SZ observations are needed in order to break degeneracies and understand biases**

# Towards the next generation of mm wavelength instruments

## How to improve high resolution SZ observations ?

Reduce the noise

~~1. Space/ballon experiments~~  
(Low resolution)

Increase statistics

~~2. Observe longer~~  
(Life is short)

Increase statistics

3. Use more detectors

Kinetic Inductance Detectors (KIDs) offer an alternative to bolometers for large array instruments

- **The New IRAM KIDs Array (*NIKA*) is a dual-band KIDs camera being developed in Grenoble and observing at the IRAM 30m telescope (Granada)**

# The Kinetic Inductance Detectors (KIDs)

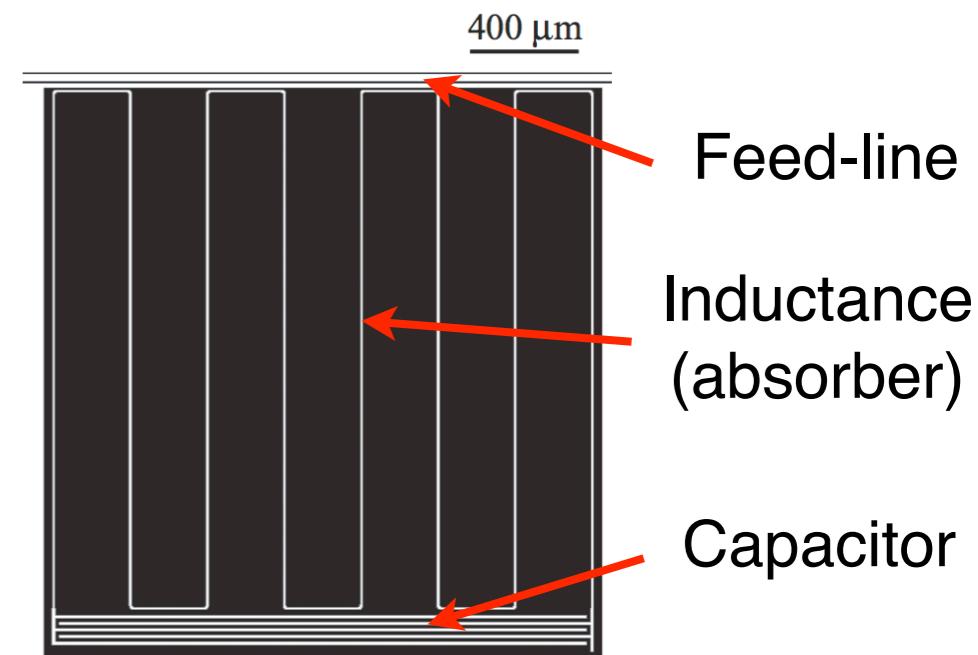
- KIDs are high-Q superconducting RLC resonators

$$T \sim 100 \text{ mK} \ll T_c \simeq 1.2 \text{ K}$$

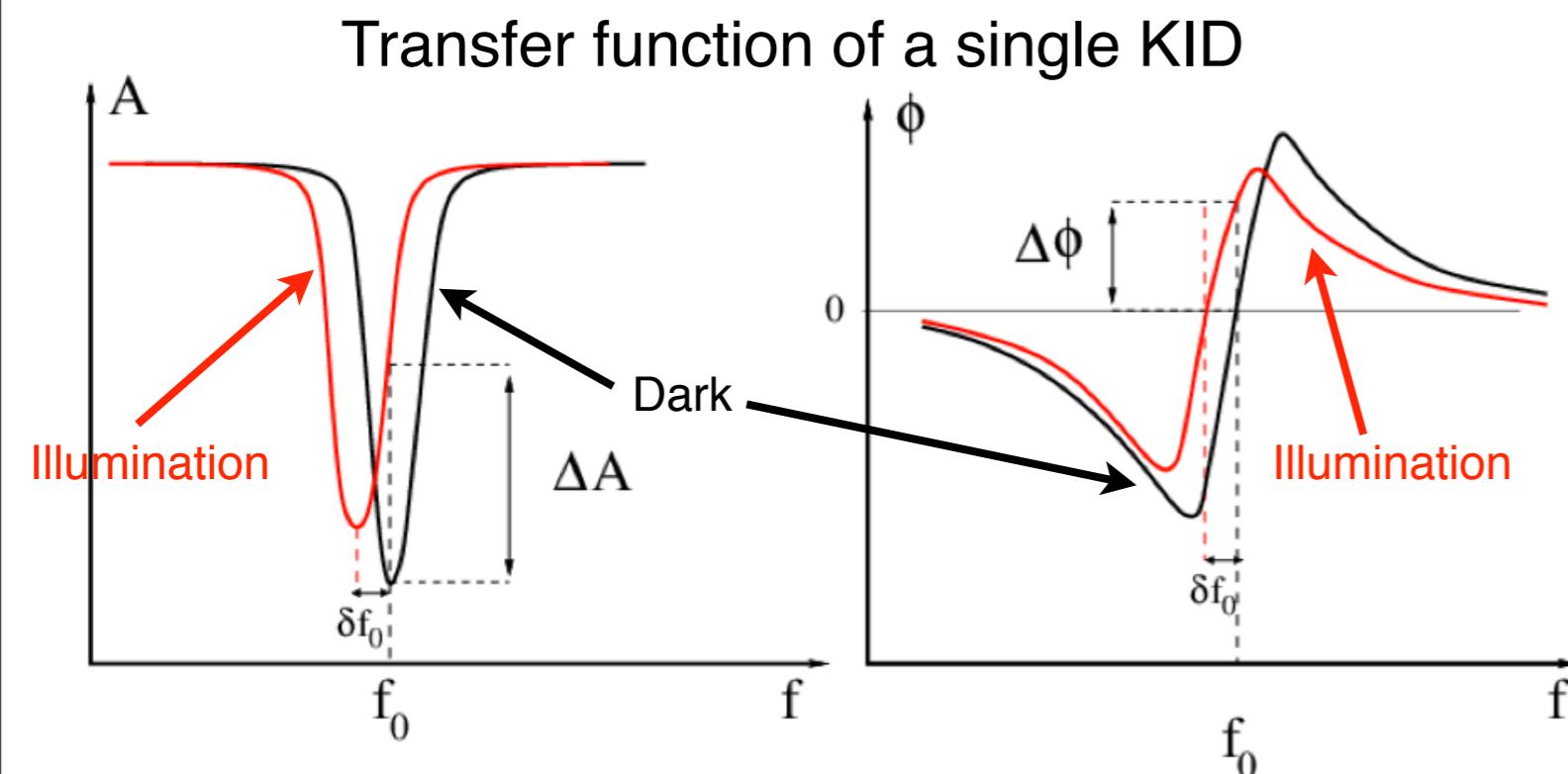
- Absorbed photons change the kinetic inductance by breaking Cooper pairs (charge carriers)

$$\delta f_0 \propto \delta L_k \propto P_{opt}$$

Single KID:  
Aluminum on silicon wafer



[A. Monfardini et al. (2010)]

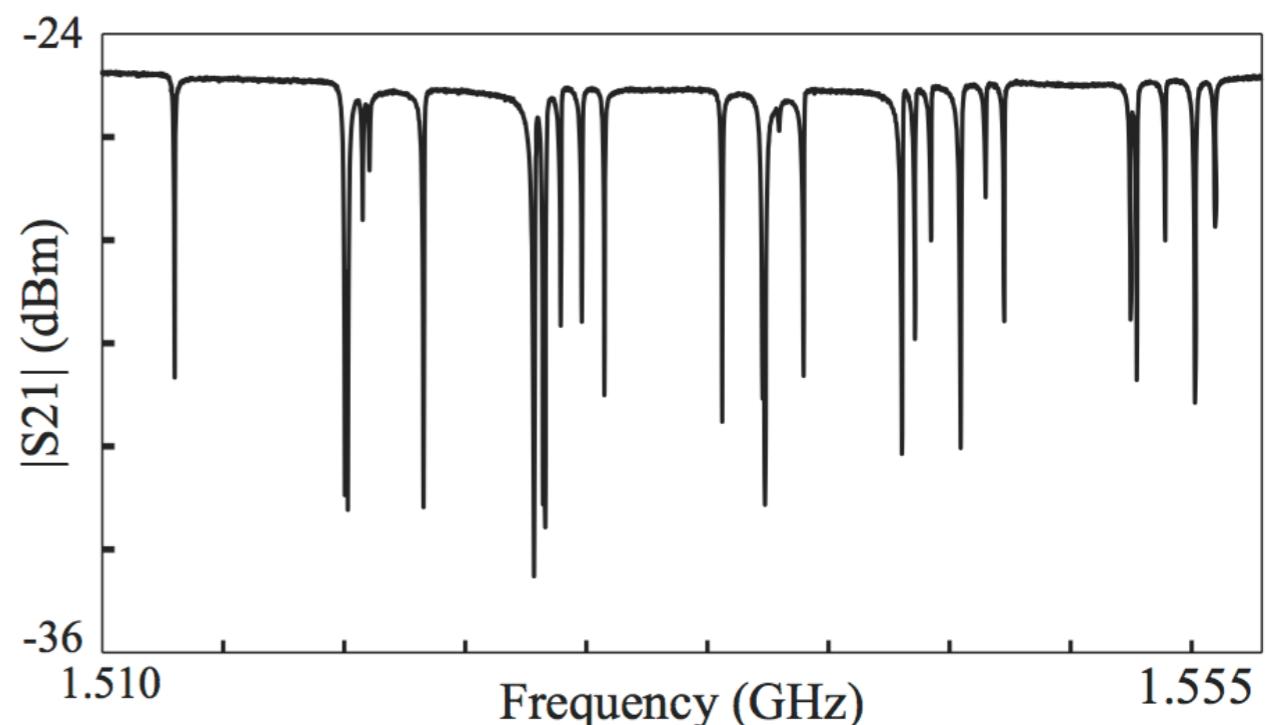
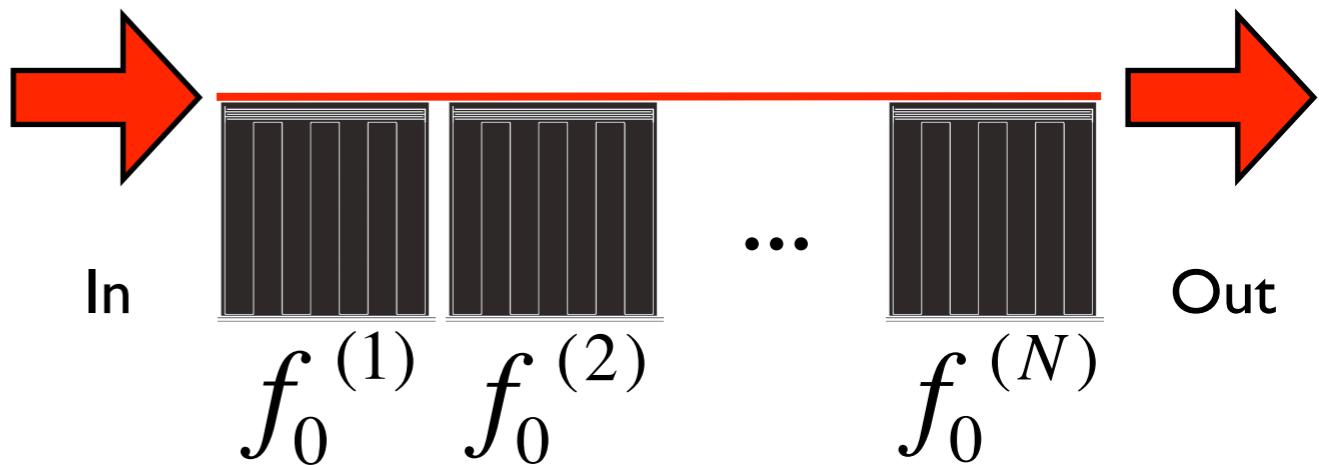
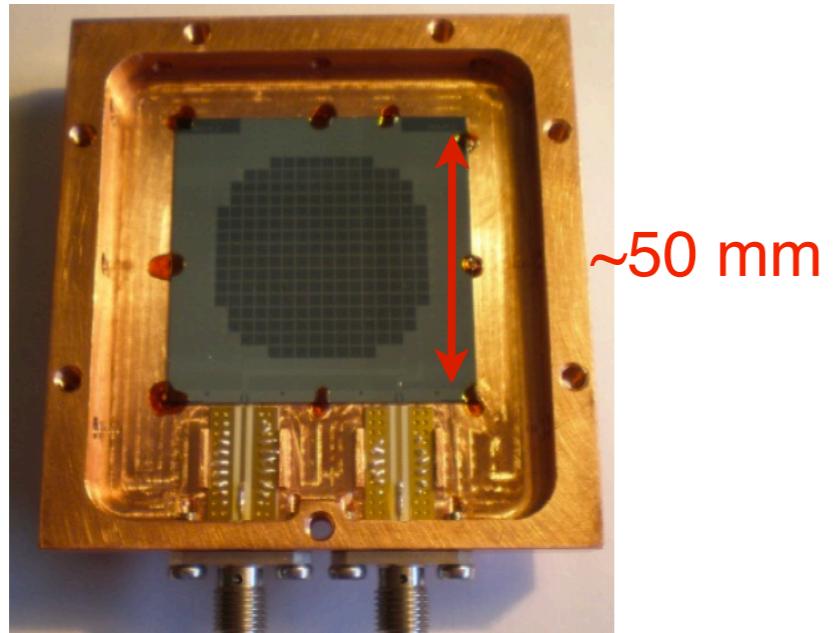


→ KIDs probe optical power via the shift of their resonance frequencies

# Frequency multiplexing with KIDs

- KIDs arrays are pixels connected to a single transmission line
- Cheap and easy to make
- Not sensitive to temperature fluctuations

Example of a 132 KIDs array (140 GHz)



[A. Monfardini et al. (2010)]

→ KIDs are intrinsically frequency-multiplexed

# The NIKA2 project and the NIKA prototype

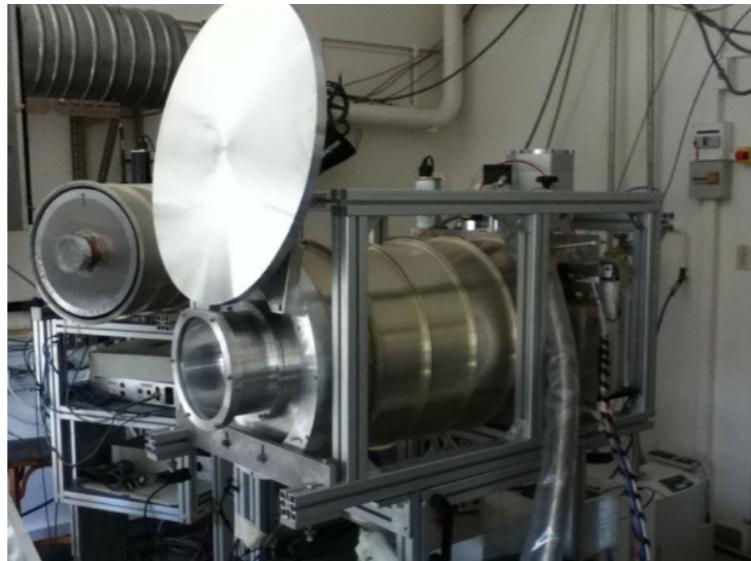
## *The IRAM 30m telescope:*



- 12" resolution at 240 GHz
- 17" resolution at 140 GHz

## *The dilution cryostat:*

- operates at ~100 mK

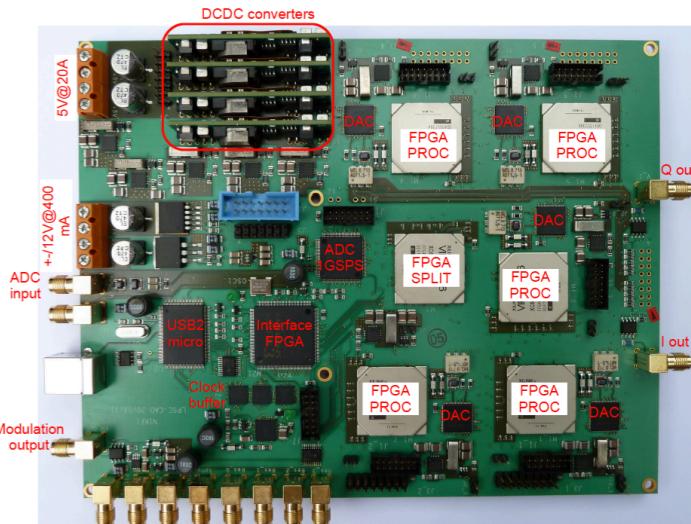


## *The dedicated optics:*

- 6.5' (1.8') field of view
- Beam splitting in two bands
- Filters + mirrors + lenses

## *The NIKEL readout electronics*

[O. Bourrion et al. (2012)]



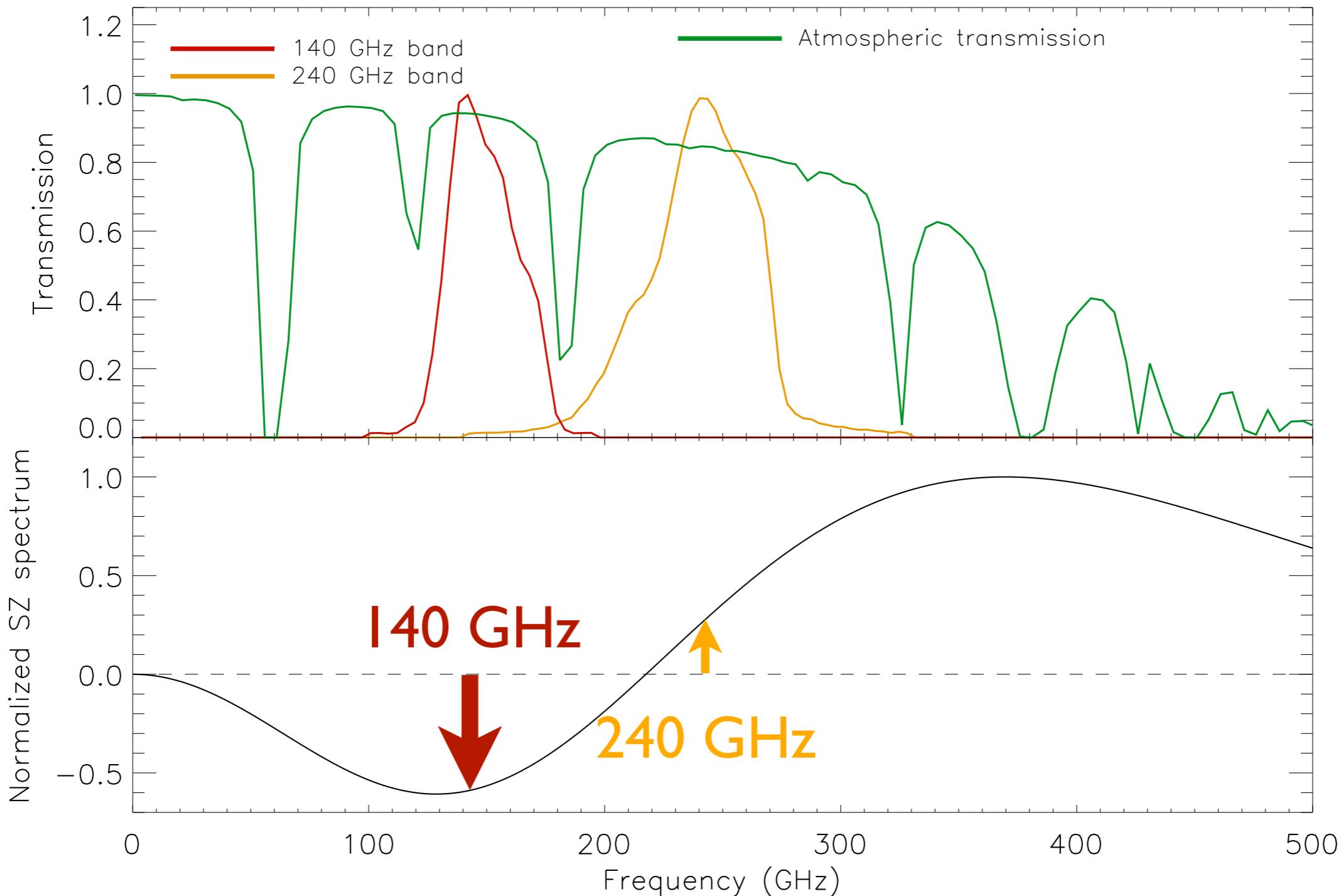
## *NIKA2 and its prototype*

## *The two KID arrays:*

- 2x2000 (224) KIDs at 240 GHz
- 1000 (132) KIDs at 140 GHz
- State-of-the-art sensitivity

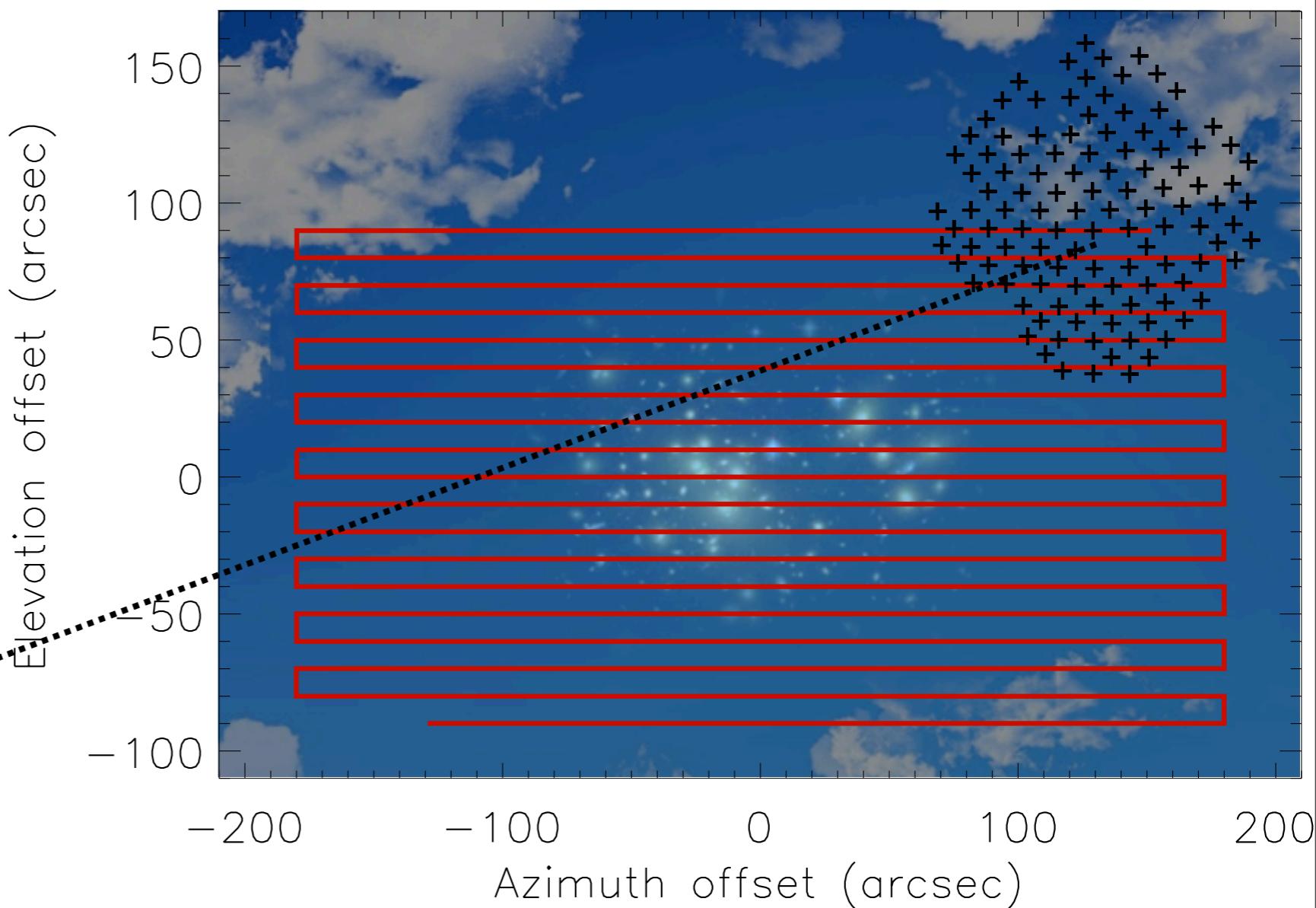
→ The NIKA prototype is currently working and NIKA2 will be commissioned by 2015

# NIKA, a well adapted instrument for SZ observations



→ SZ science is at the core of the *NIKA* project

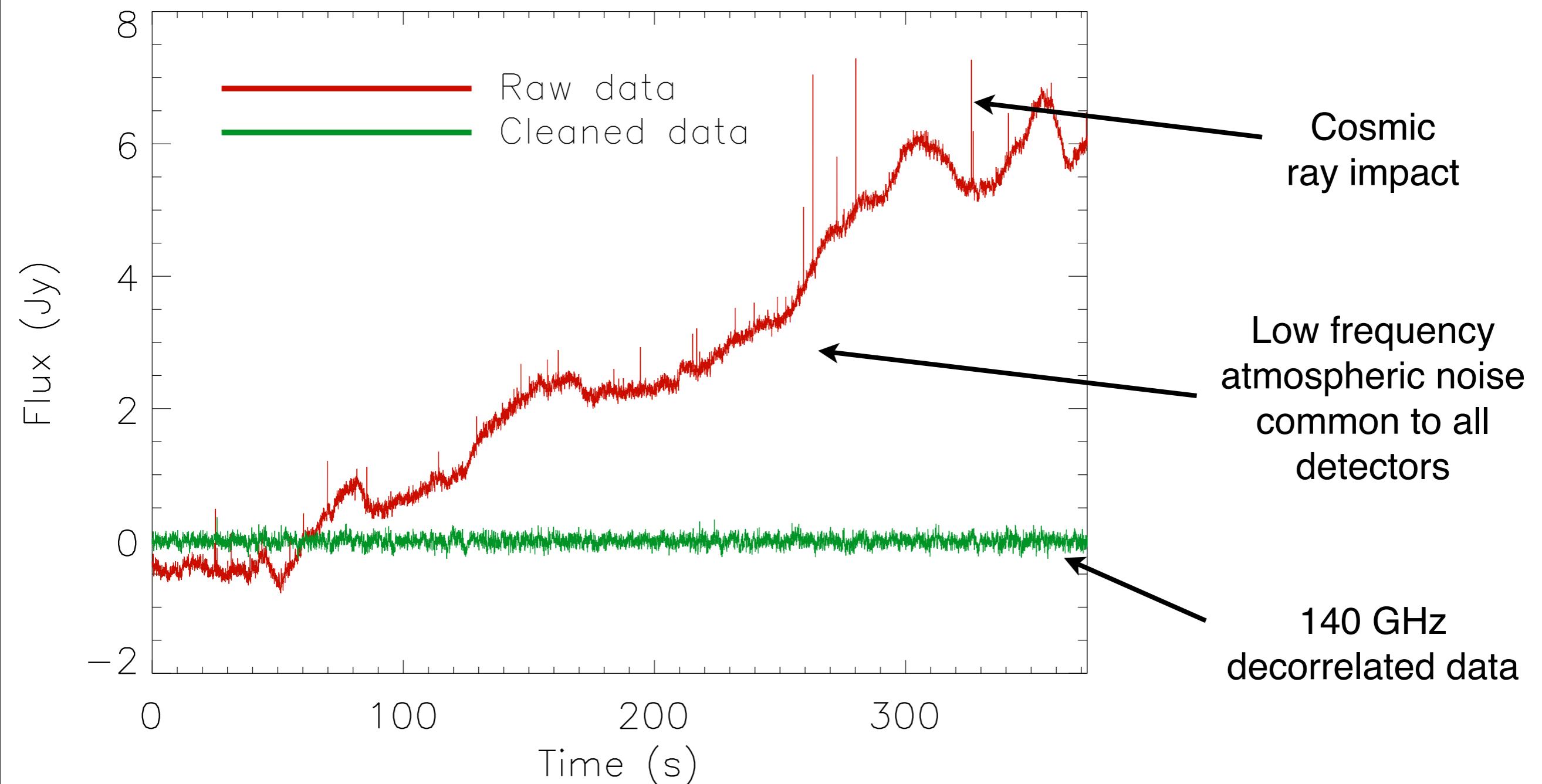
# The NIKA data analysis pipeline in a nutshell: scanning strategy



→ The signal is modulated by the scanning strategy

# The NIKA data analysis pipeline in a nutshell: dual-band decorrelation

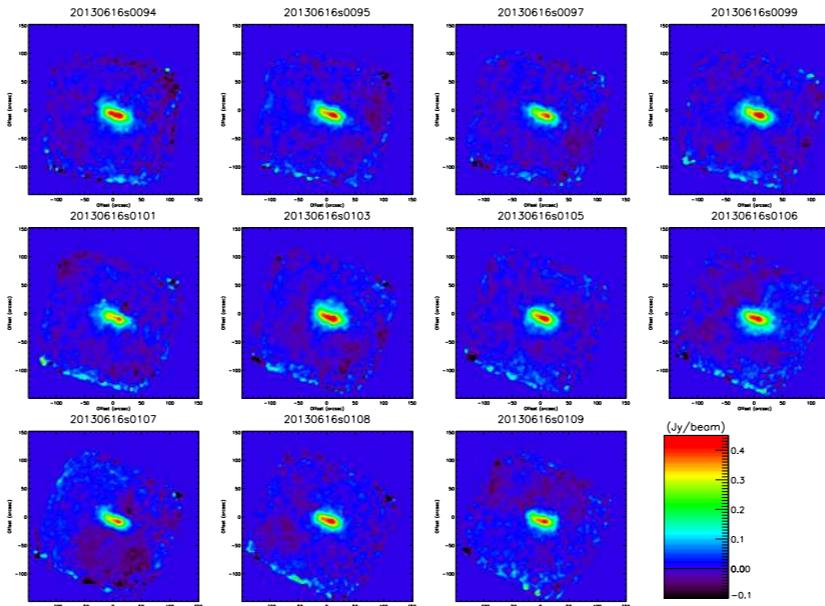
1. Low frequency common-mode at 240 GHz (atmospheric noise but no SZ)
2. Template fitting at 140 GHz



# The NIKA data analysis pipeline in a nutshell: mapmaking

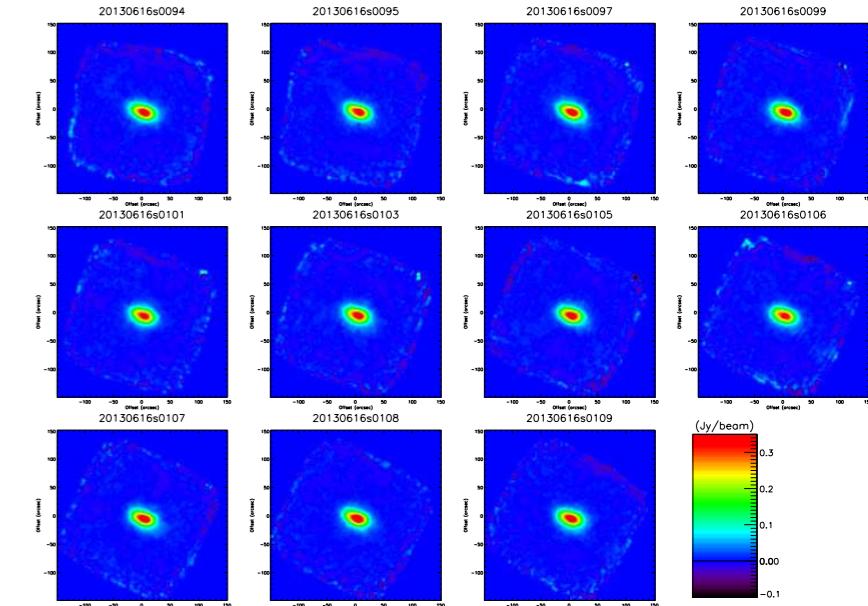
1. Inverse variance  
weighting

Scan maps 240 GHz



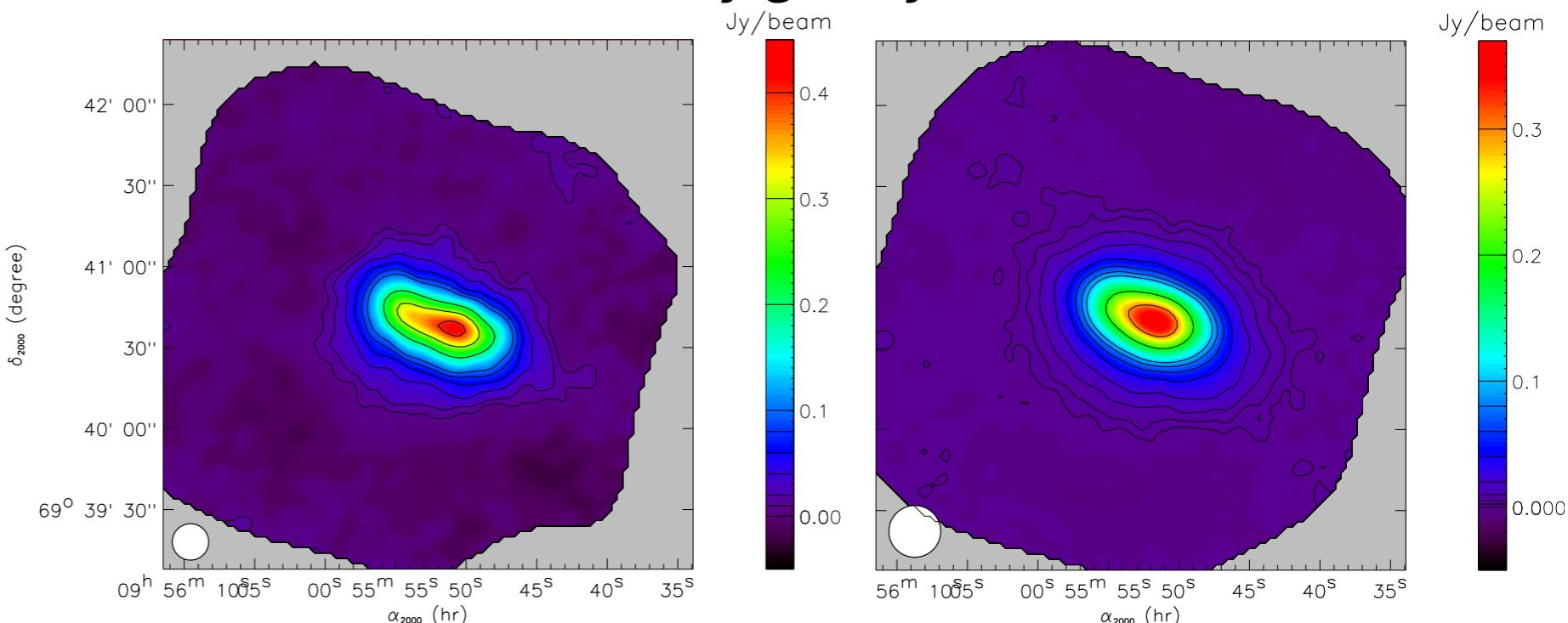
2. Valid data are  
projected onto  
pixelized map

Scan maps 140 GHz

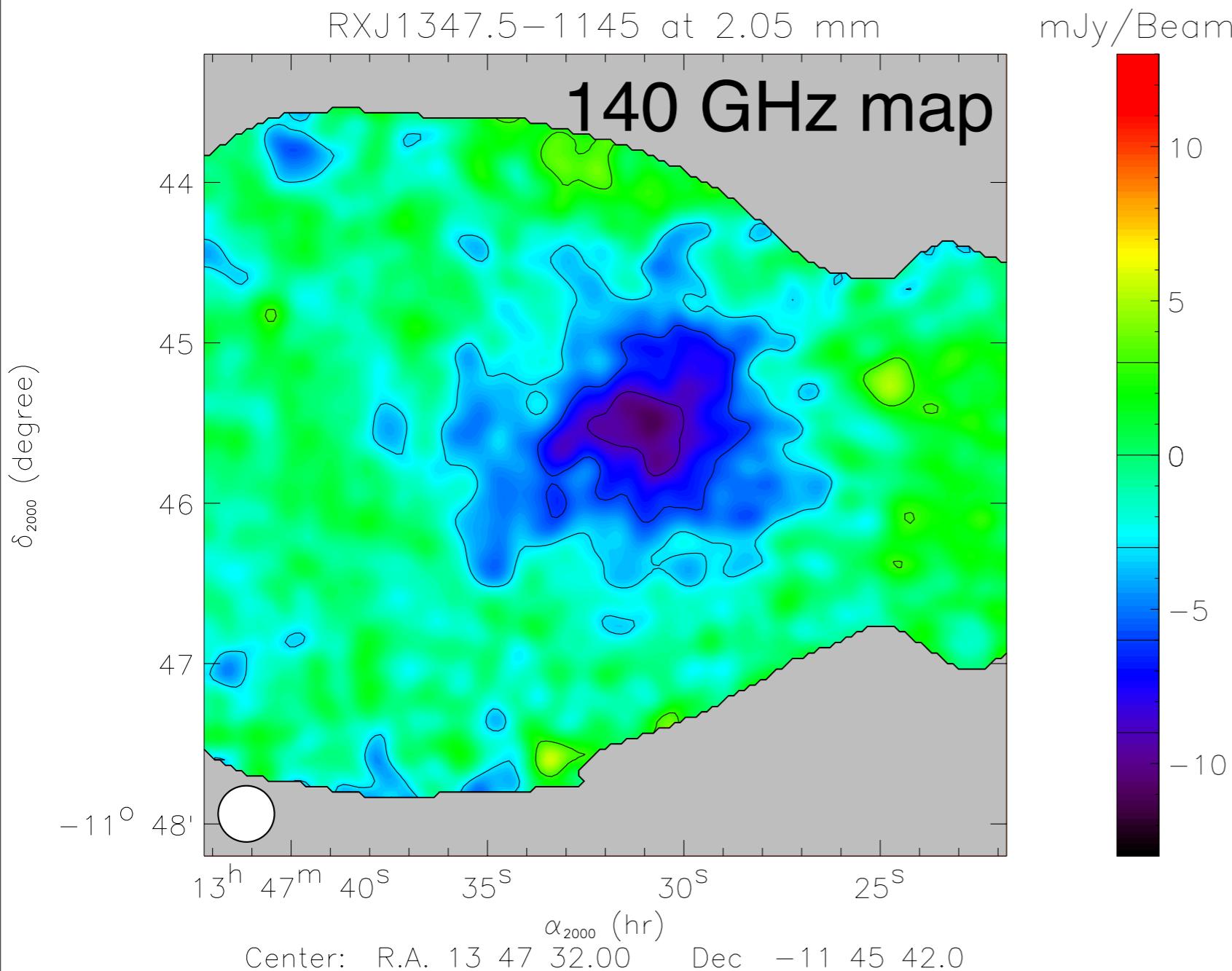


3. Individual scan  
maps are combined

*Example of the  
nearby galaxy M82*



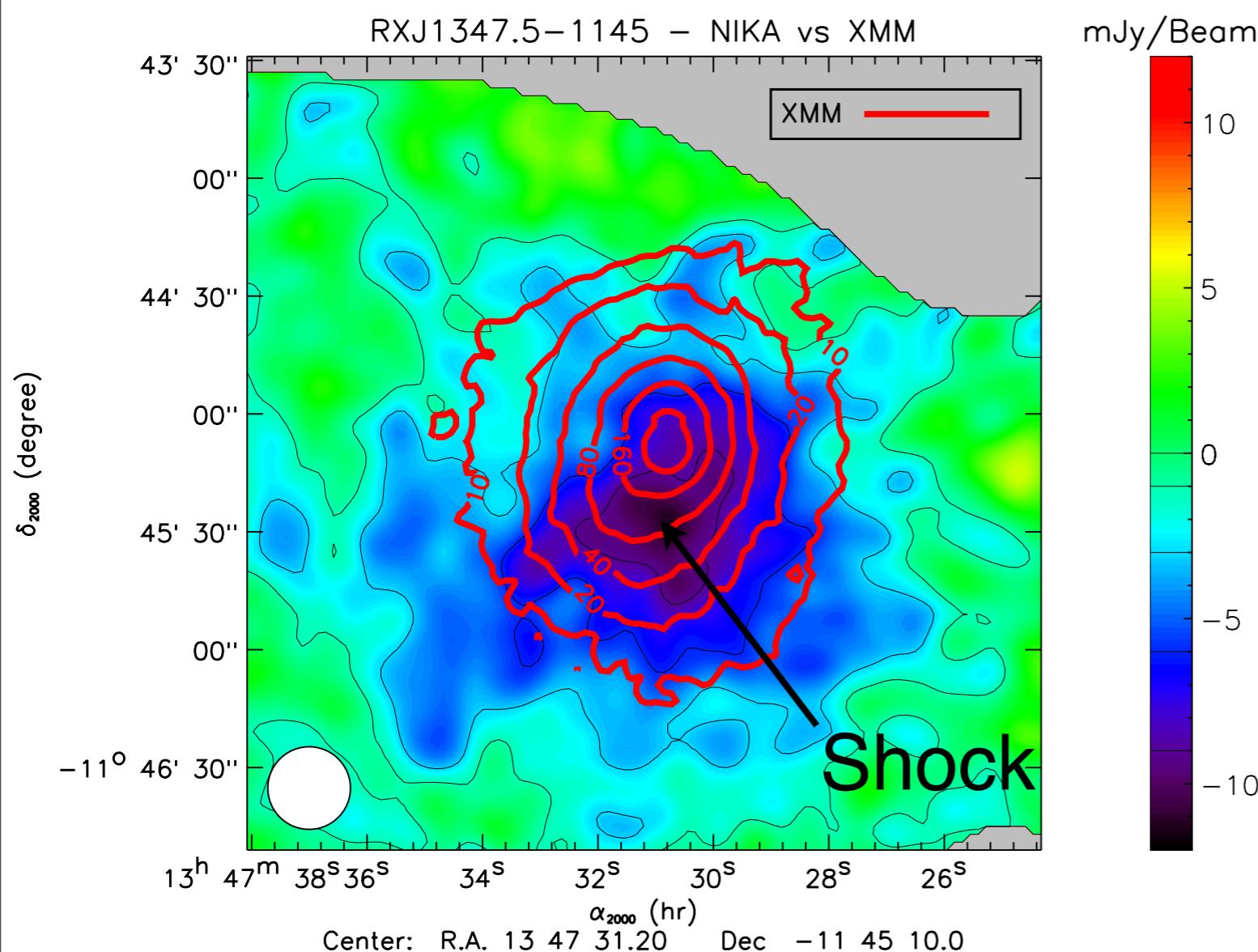
# First results with the NIKA prototype: RX J1347.5-1145 ( $z=0.45$ )



- Observations performed in November 2012
- Dual-band common-mode decorrelation from the 240 GHz band
- Large scales are recovered
- Integration time: **5h47min**

→ The first SZ observation with KIDs, using the NIKA prototype  
[R. Adam, B. Comis, J. F. Macías-Pérez et al. (2013) - accepted]

# SZ results: RX J1347.5-1145 complementarity with X-ray data

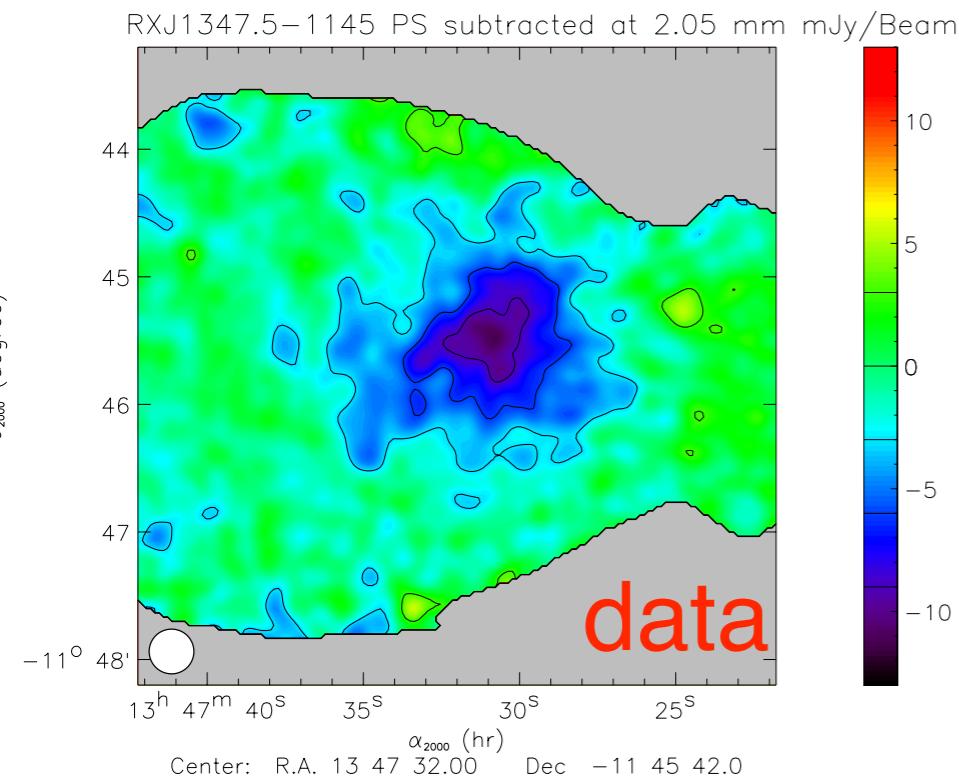


- The X-ray emission is due to bremsstrahlung from hot electrons
- $$X \text{ ray} \propto n_e^2 \sqrt{T_e}$$
- $$\text{SZ} \propto P_e \propto n_e T_e$$
- SZ is well adapted for the measurement of shocks
  - RX J1347.5-1145 is an ongoing merger (strong south extension)

→ Detection and SZ mapping achieved

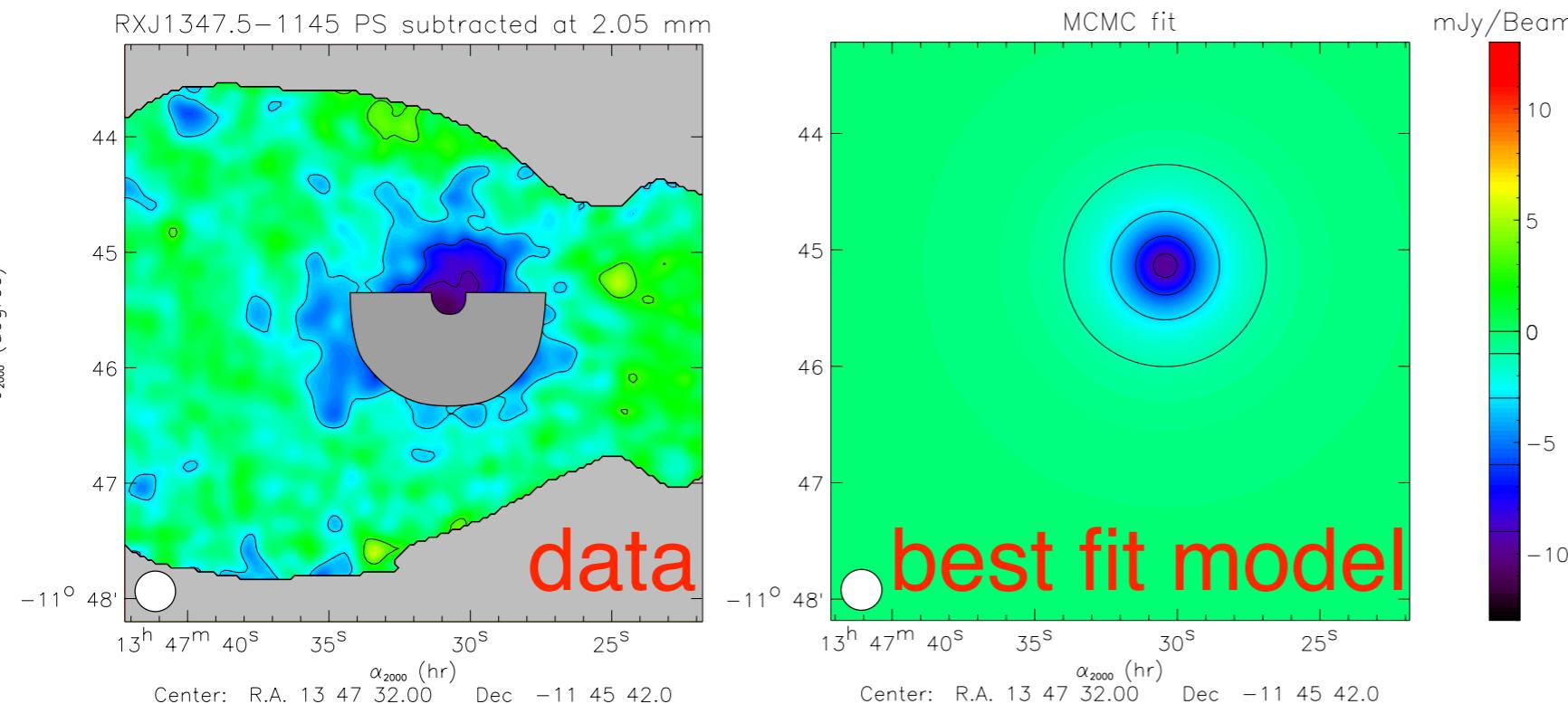
# SZ results: RX J1347.5-1145 pressure distribution

- We fit the relaxed North region of RX J1347.5-1145 using a gNFW pressure profile parametrization [D. Nagai et al. (2007)]



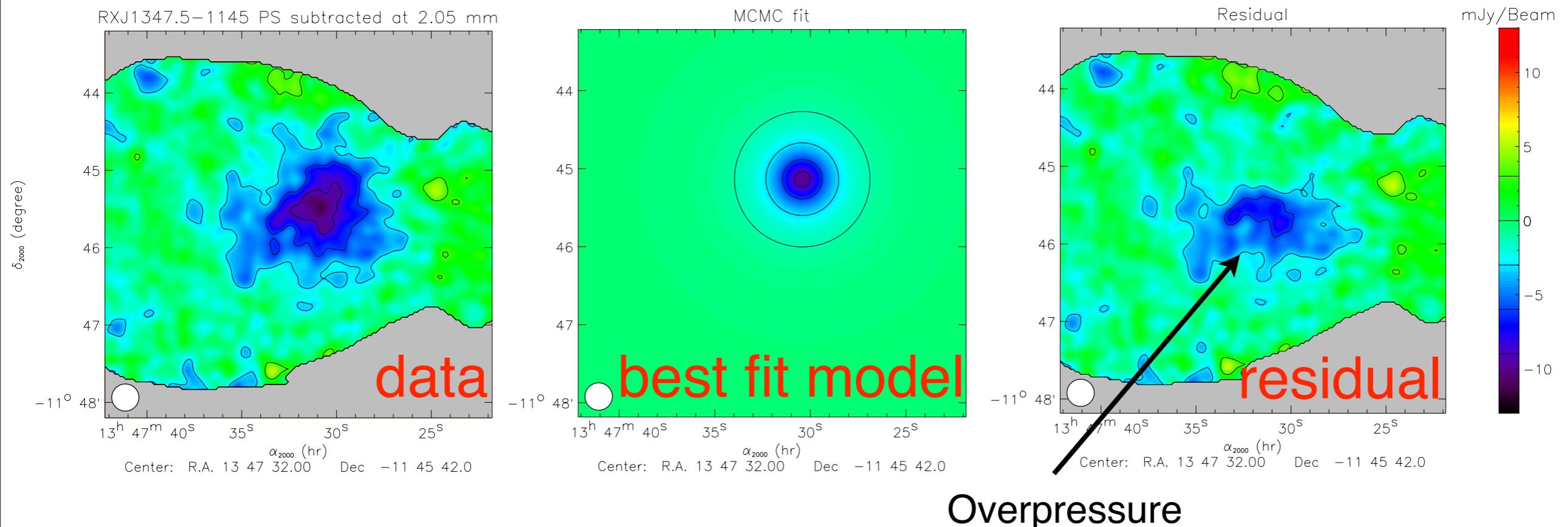
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→ We confirm that RX J1347.5-1145 appears as a relaxed cool core subject to a merging on its South-East part

# SZ results: RX J1347.5-1145 pressure profile

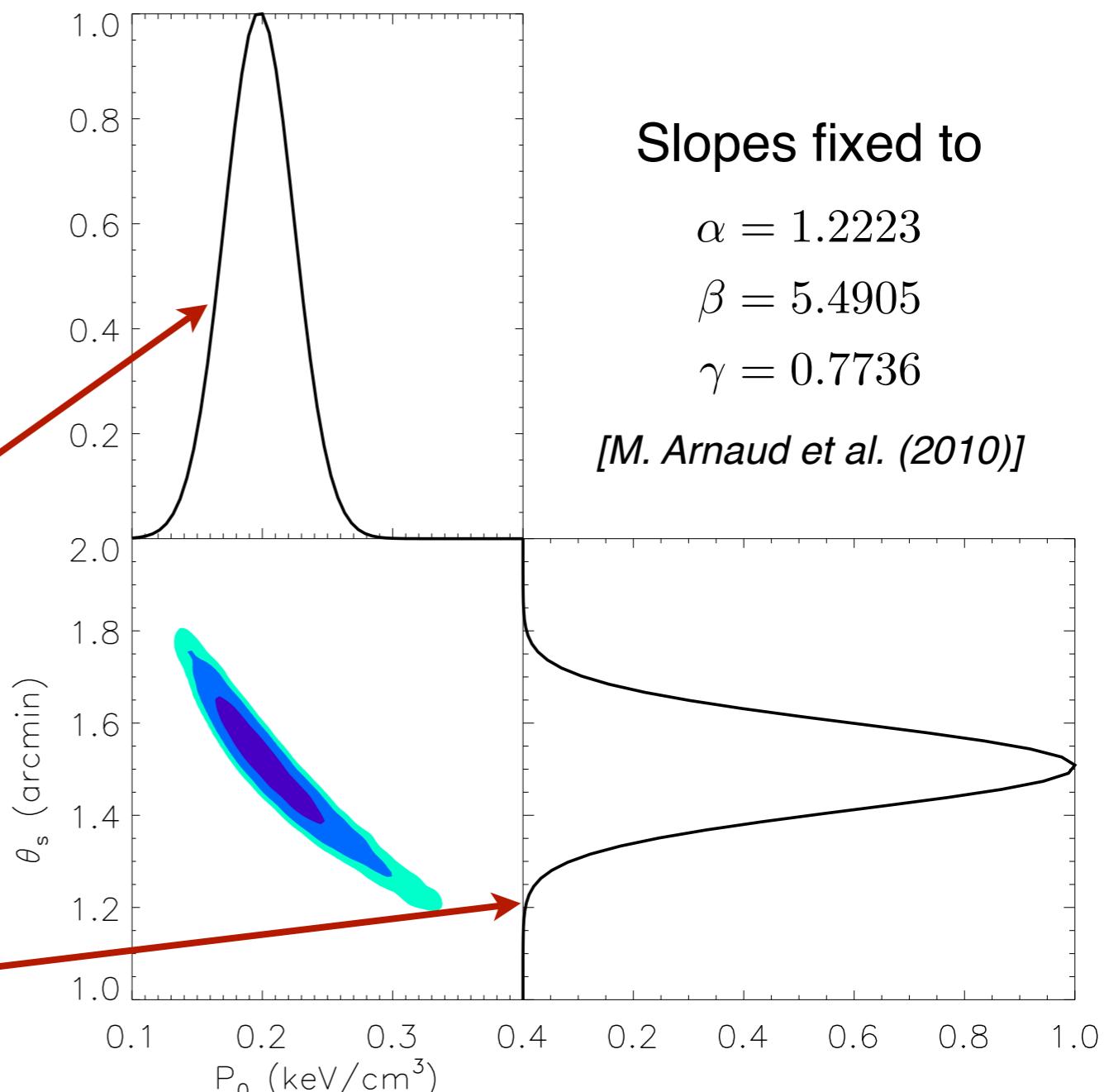
- The SZ effect probes the pressure:

$$\frac{\delta I}{I} = f(\nu) \times \frac{\sigma_T}{m_e c^2} \int P(r) dl$$

- We use the generalized Navarro Frenk and White pressure profile (originally for Dark Matter)

$$P(r) = \frac{P_0}{\left(\frac{r}{r_s}\right)^\gamma \left(1 + \left(\frac{r}{r_s}\right)^\alpha\right)^{\frac{\beta-\gamma}{\alpha}}}$$

[D. Nagai et al. (2007)]



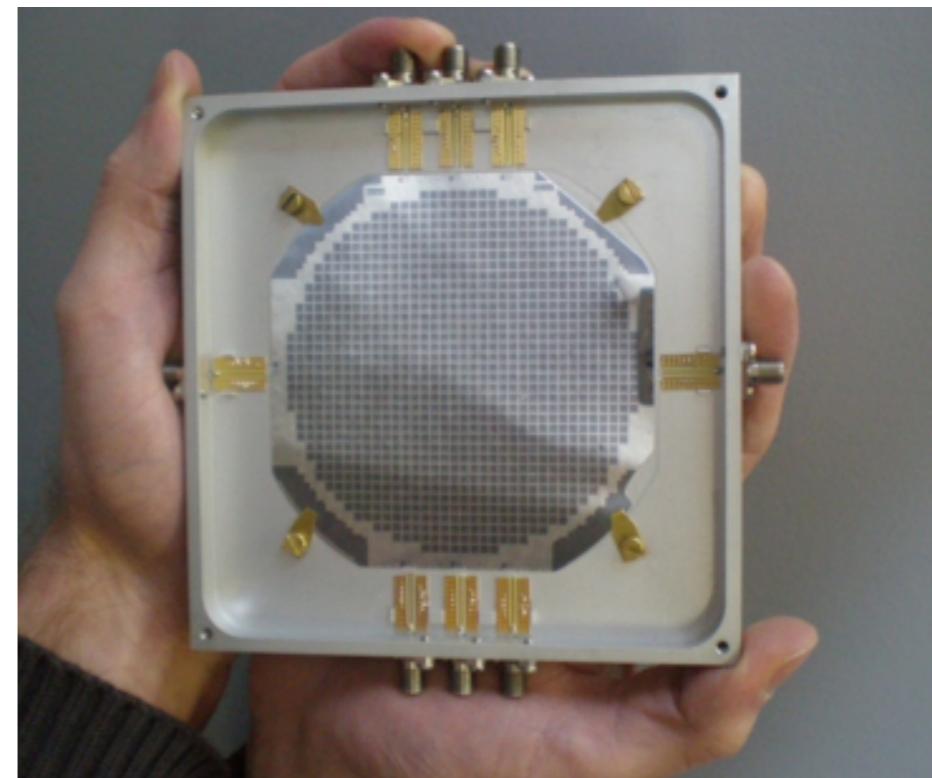
→ **Nika is able to measure pressure profiles up to high redshift ( $z = 0.45$  here) thanks to its high angular resolution**

# Conclusions

- SZ observations provide valuable information concerning galaxy clusters
- KIDs are a promising alternative to bolometers for large array instruments
- We show for the first time the capability of KIDs for SZ observations with the *NIKA* prototype
- *NIKA2* will be a well-suited instrument for in-depth studies of the ICM from local to distant clusters (e.g. follow up of PLANCK's clusters at high redshift)

## ***NIKA2* project milestones:**

- Cryostat and electronics in construction
- Commissioning by 2015



1000 pixels KIDs array