LPSC Grenoble
Laboratoire de Physique Subatomique et de Cosmologie

Enigmass
The enigma of mass

NIKA

Sunyaev-Zel'dovich observations at high-redshift with NIKA

Rémi Adam
on behalf of the NIKA collaboration

PNCG
Paris - 25/11/2014

Towards high-angular resolution Sunyaev-Zel'dovich observations

What can we learn from clusters: Astrophysical and Cosmological interplay

Improved masses determination

Cluster Cosmology

Growth of structures + Universe expansion

Unbiased low scatter mass needed from observable proxies (e.g. SZ flux)

Cluster Astrophysics

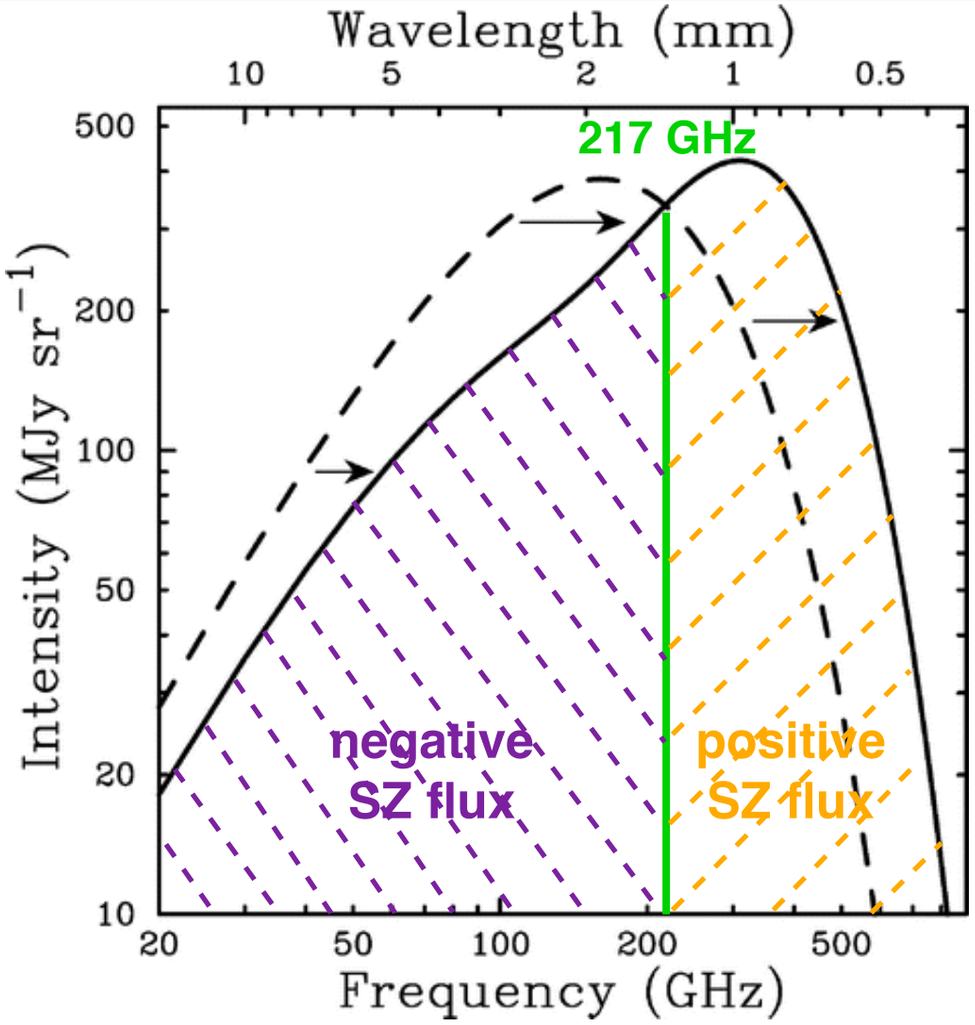
Shocks heating, MHD turbulence
Dynamical/thermodynamical state
Feedback from compact sources (AGN)
Clumping
...

[e.g. S. Allen et al. (2011)]

Improved constraints on astrophysical models

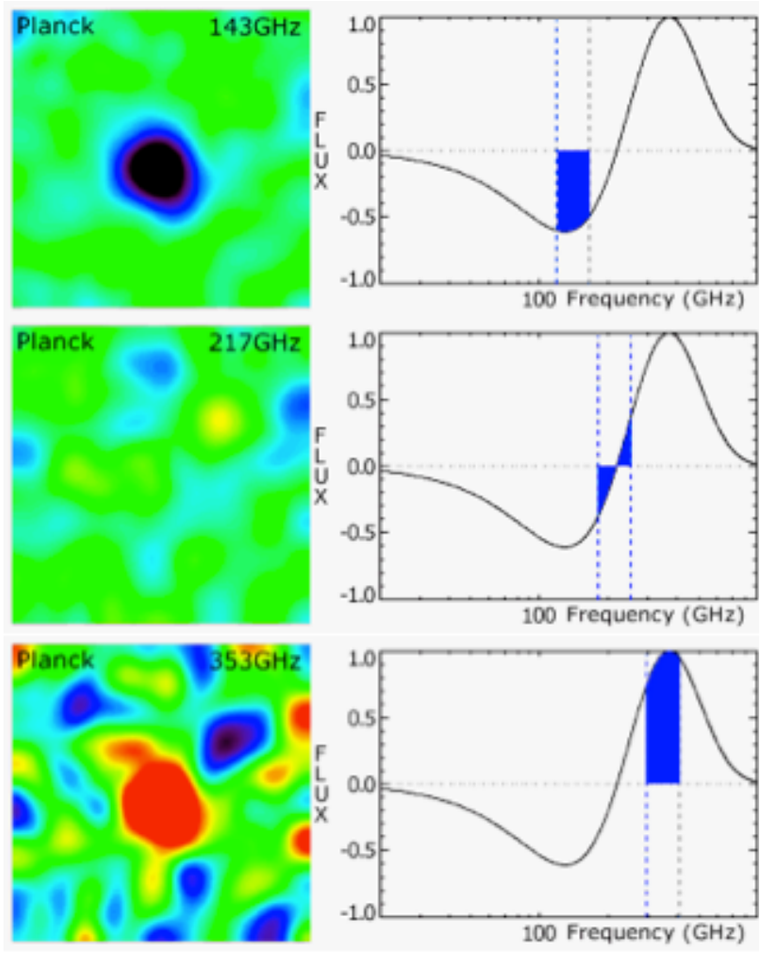
➡ **Deep astrophysical understanding of cluster is necessary for cosmology**

Probing pressure with the thermal Sunyaev-Zel'dovich effect (tSZ)



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

- tSZ = CMB spectral distortion caused by electronic pressure
- No redshift dependence



[ESA HFI/LFI consortia]

$$\frac{\Delta I_{tSZ}}{I_0} = (f(\nu) + \delta_{tSZ}(T_e, \nu)) \frac{\sigma_T}{m_e c^2} \int P_e dl$$

Compton parameter
y: tSZ amplitude

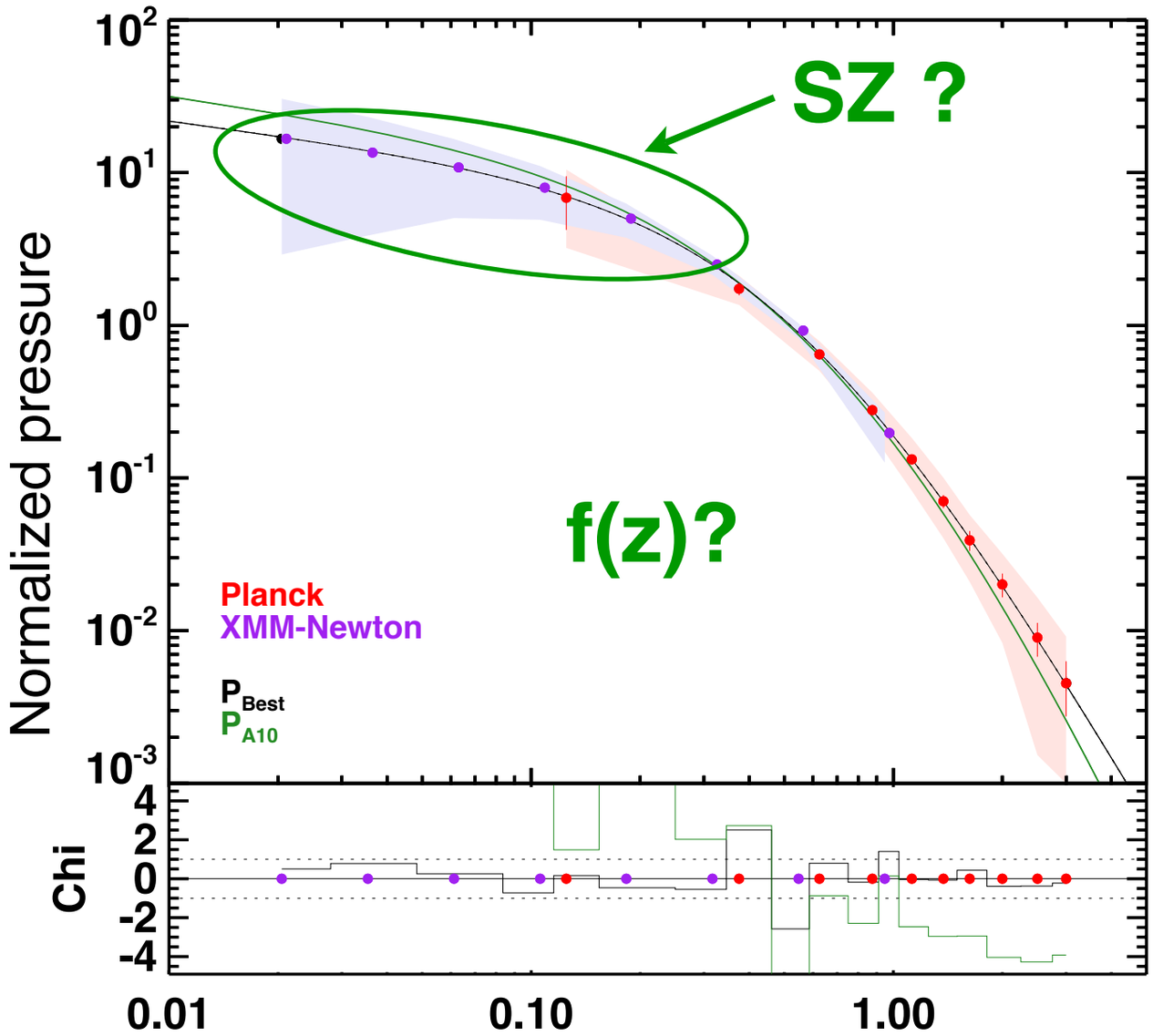
➡ **The tSZ effect probes the pressure in clusters**

The need for high-angular resolution SZ observations

- **Bias** due to departure from equilibrium to be handled

- Need to look at clusters in **details** to calibrate the pressure (*i.e.* mass) distribution at small scales

- Need to look at **high-z** clusters to calibrate the pressure profile as a function of redshift



[Planck intermediate V (2013)]

➡ **High-resolution SZ observations are required (+ multi-wavelength)**

NIKA: a KID-based camera at the IRAM 30m telescope

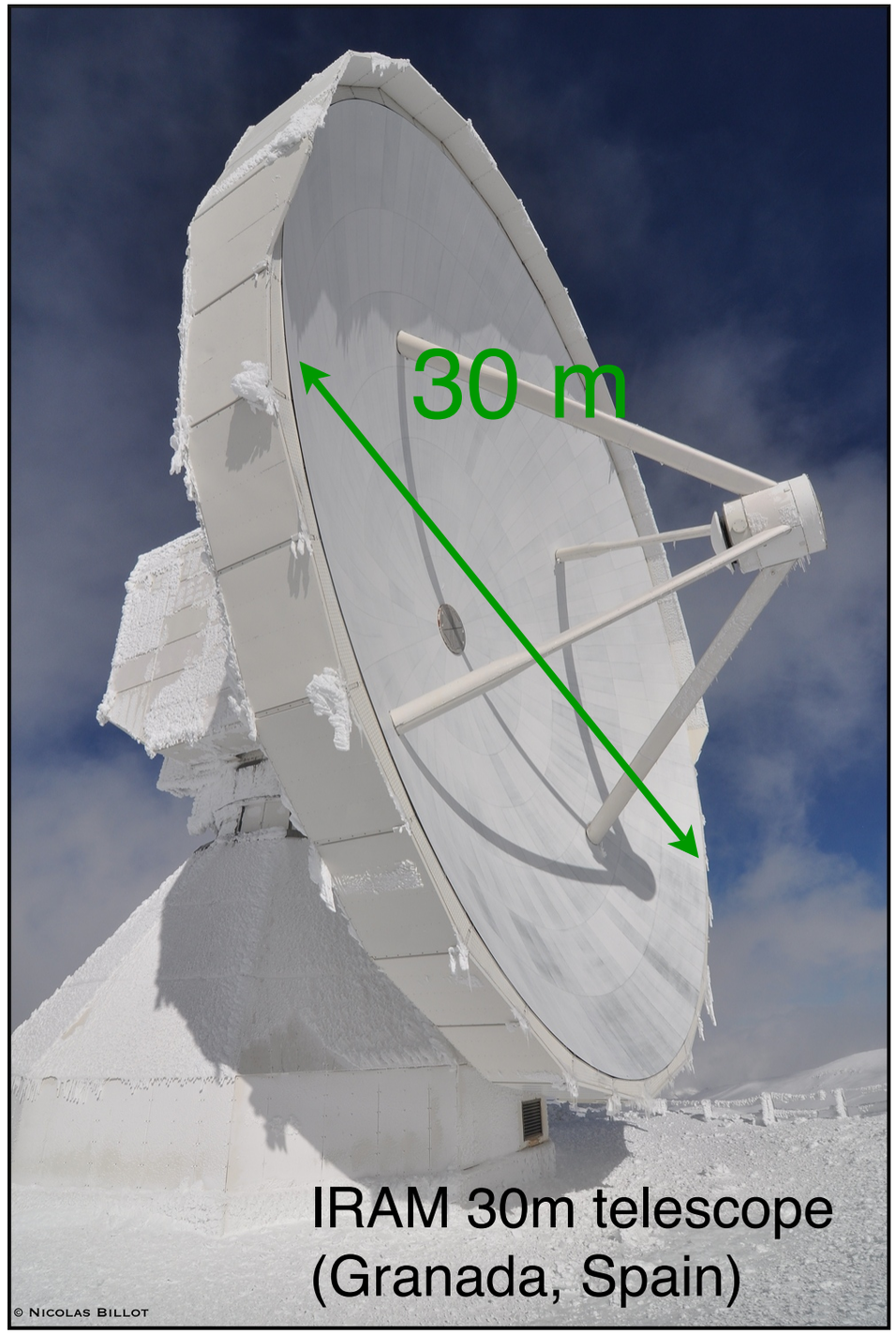
Towards the next generation of mm-wavelength instruments

How to improve high-resolution SZ observations?

- Large dish telescope (high-resolution)
- 100 - 300 GHz observations
- Many detectors
- Large instantaneous field-of-view

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

The New IRAM KID Arrays (*NIKA*):
➡ Developed in Grenoble (+ Cardiff, Paris)



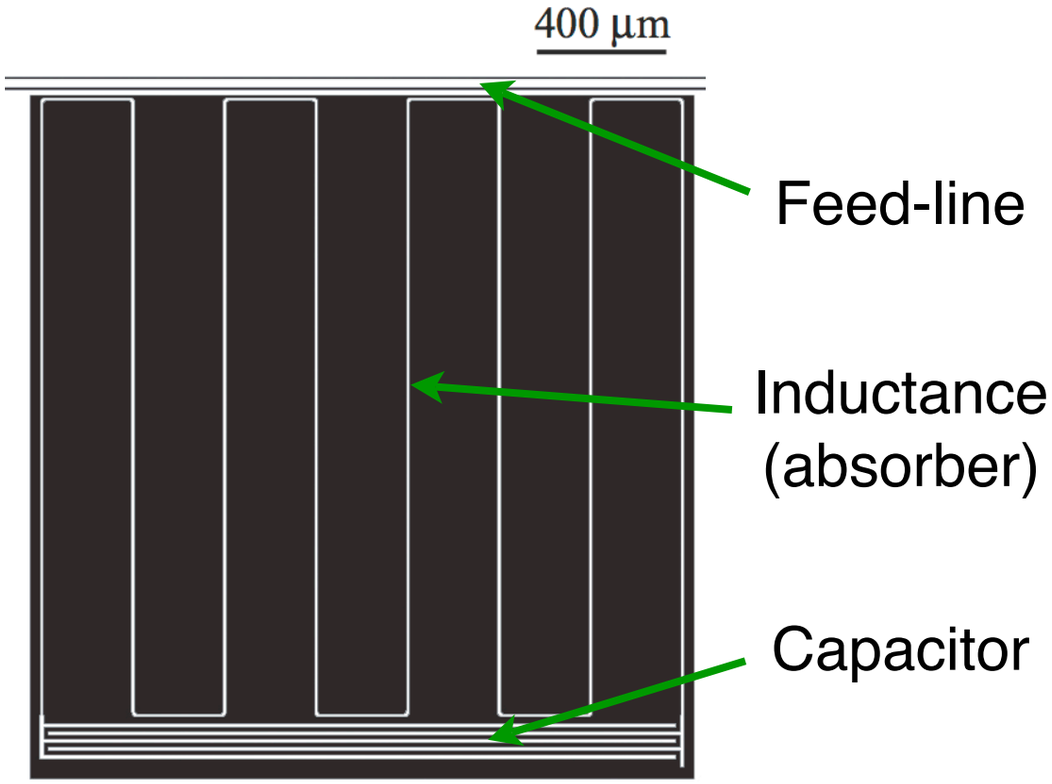
IRAM 30m telescope (Granada, Spain)

[N. Billot]

The Kinetic Inductance Detectors (KIDs)

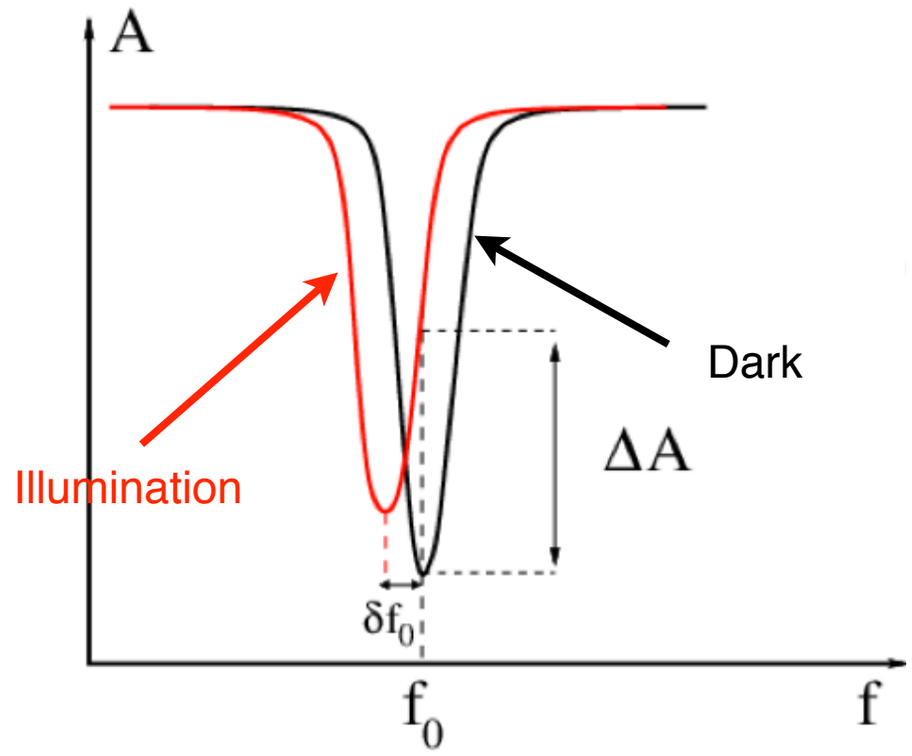
- KIDs are high-Q superconducting RLC **resonators**
- Absorbed photons change the kinetic inductance by breaking **Cooper pairs** (charge carriers)

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



Single KID (aluminum on silicon wafer)

[A. Monfardini et al. (2010)]



Transfer function of a single KID

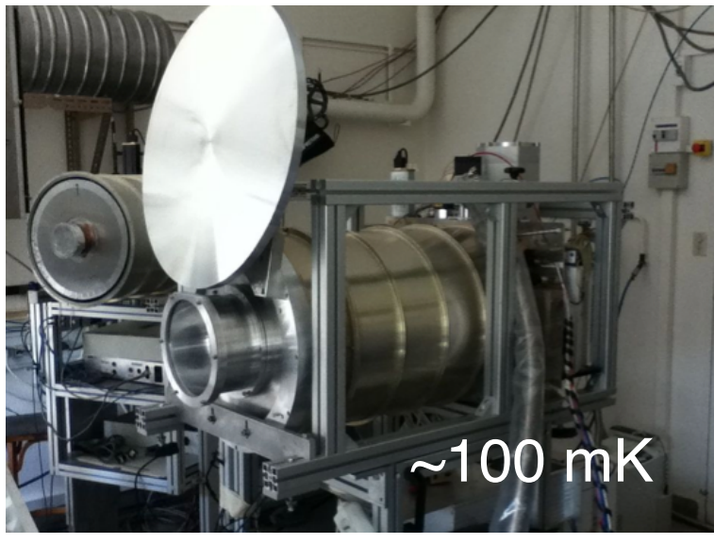
➡ **KIDs probe optical power via the shift of their resonance frequencies**

The NIKA and NIKA2 projects

The IRAM 30m telescope:

- **12”** resolution at 260 GHz
- **17.5”** resolution at 150 GHz

The dilution cryostat:

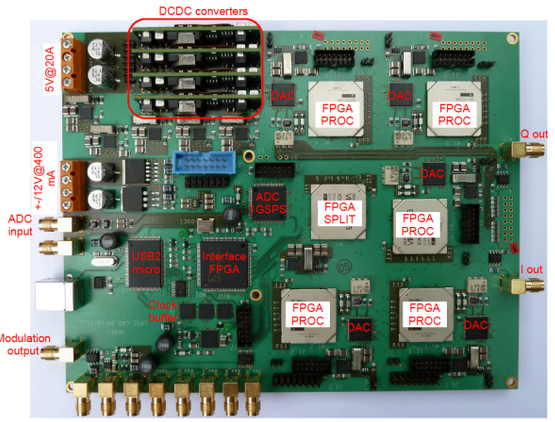


The dedicated optics:

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

The dedicated NIKEL readout electronics

[O. Bourrion et al. (2012)]



The two KID arrays:

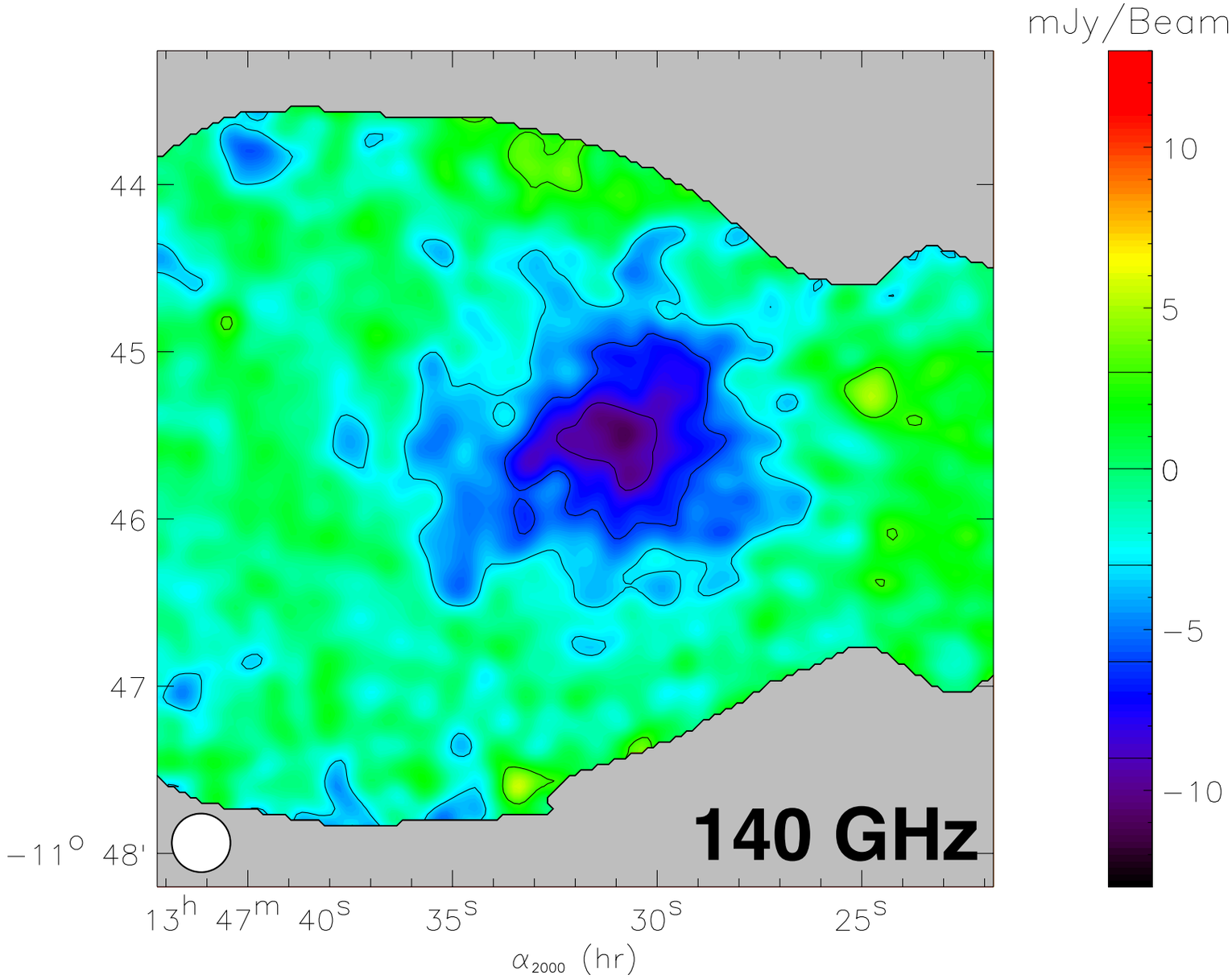
- **2x2000 (224)** KIDs at 260 GHz
- **1000 (132)** KIDs at 150 GHz
- State-of-the-art sensitivity

NIKA2 (NIKA prototype)

➡ **The NIKA prototype is opened to the community since February 2014**

Towards a first NIKA cluster sample as a NIKA2 pilot study

The first NIKA tSZ observations
RX J1347.5+3745 (z=0.45)



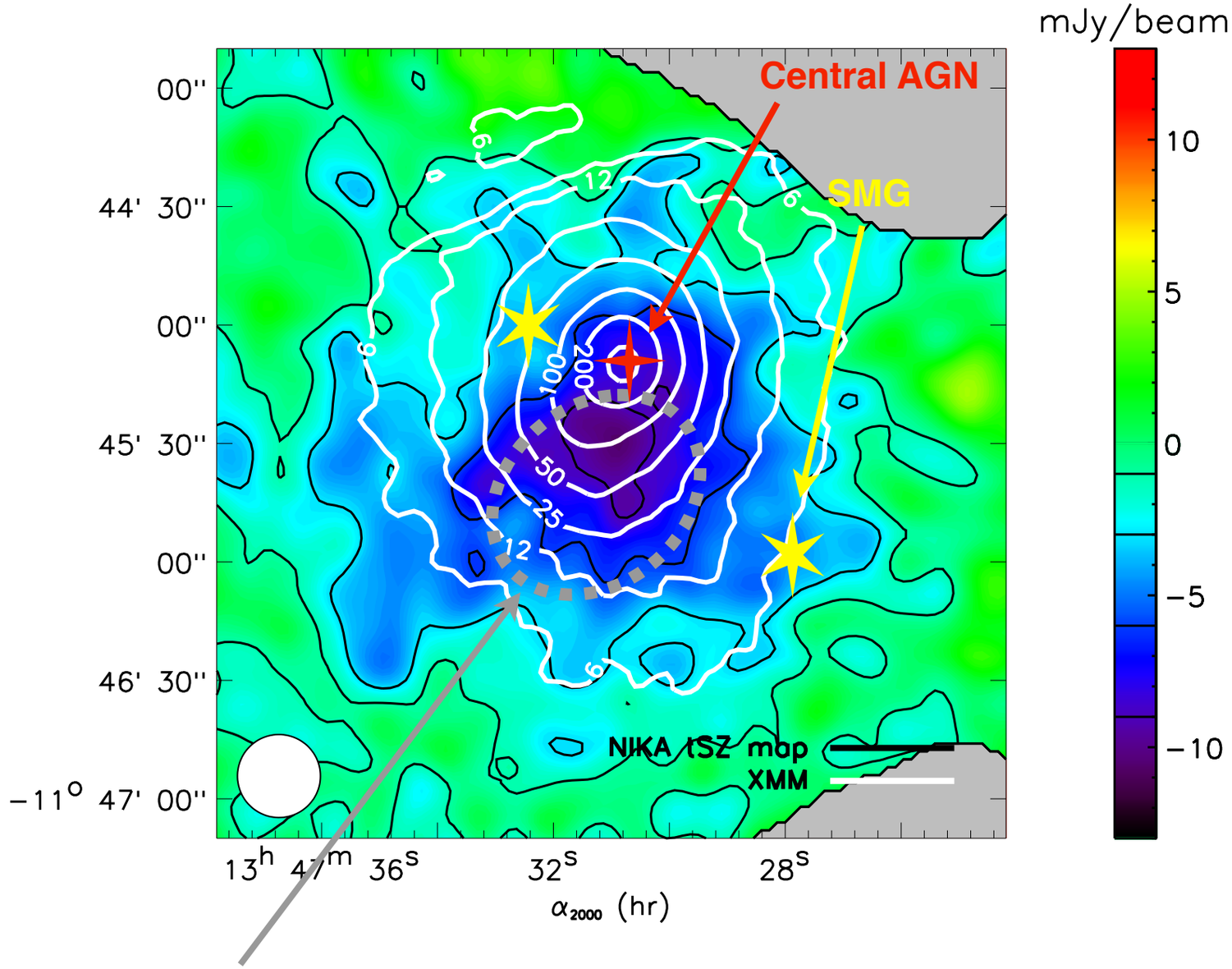
- The ideal test cluster: **RXJ1347.5+3745**, well known, compact and bright
- Technical time observation of November 2012
- Integration time: 5h47min
- Atmospheric removal using the 240 GHz channel as a template

➡ **The first tSZ observation with KIDs, using the *NIKA* prototype**

[R. Adam, B. Comis, J. F. Macías-Pérez et al. (2013)]

The first NIKA tSZ observations

Complementarity of resolved (sub)millimeter, X-ray, radio and optical data



Radio halo at the shock location

[C. Ferrari et al. (2011)]

- The X-ray emission is due to bremsstrahlung from hot electrons

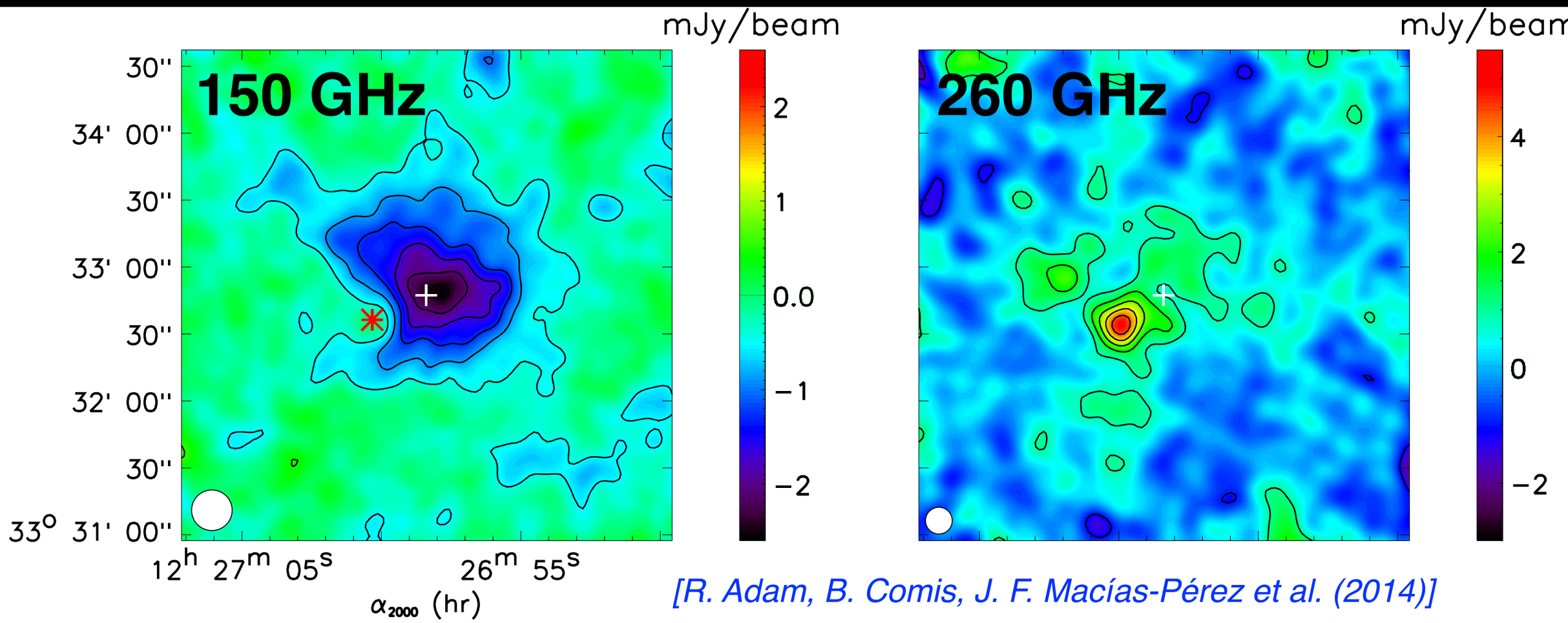
$$\mathrm{X\ ray} \propto n_e^2 \sqrt{T_e}$$

$$\mathrm{SZ} \propto P_e \propto n_e T_e$$

- tSZ is well adapted for the **measurement of shocks**
- RX J1347.5-1145 is an ongoing merger (strong SE extension)
- Multiwavelength observations provide a complete picture of the cluster

➡ **Detection and SZ mapping achieved**

Looking at high redshift clusters
CL J1226.9+3332 (z=0.89)

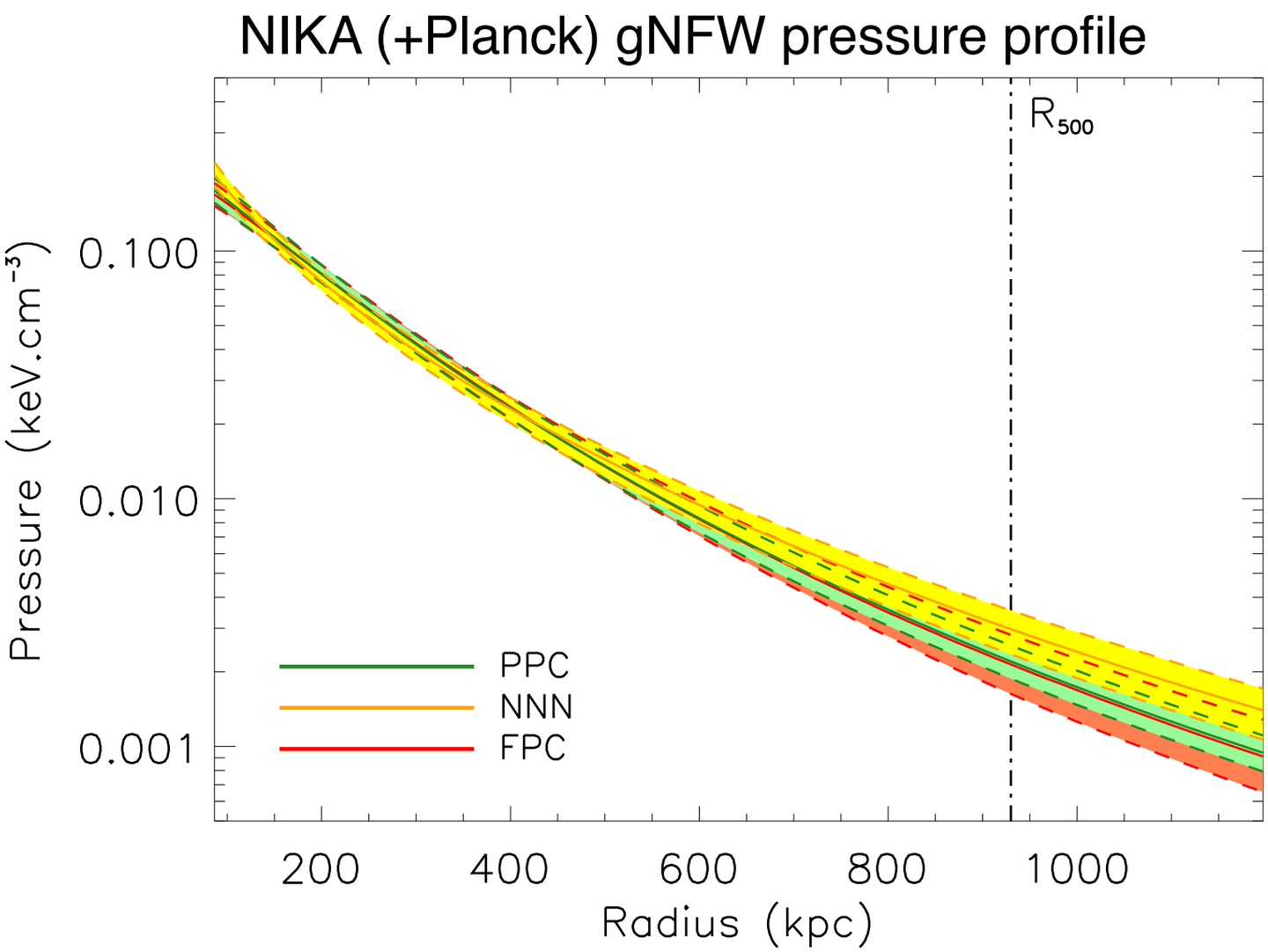


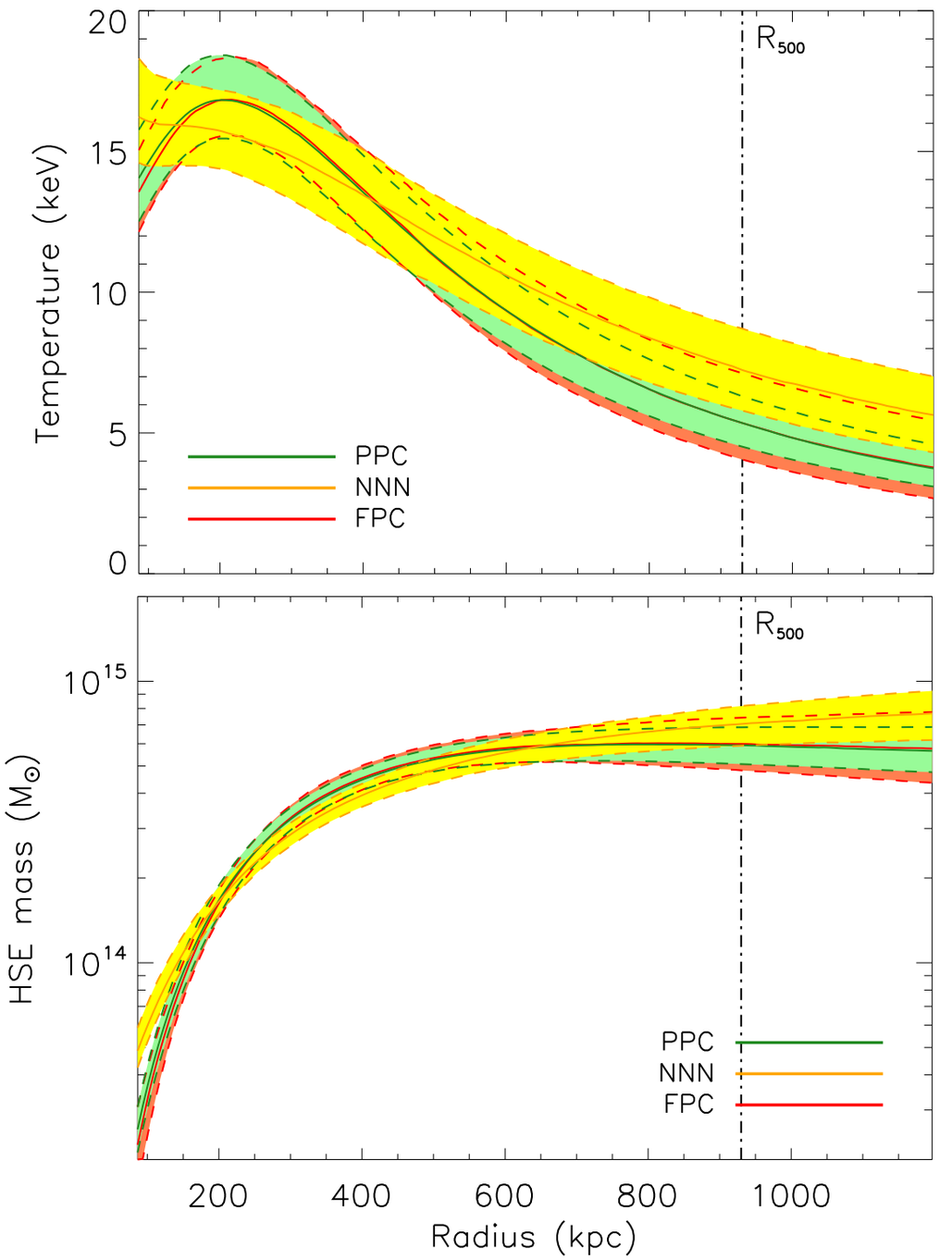
[R. Adam, B. Comis, J. F. Macías-Pérez et al. (2014)]

- First NIKA Open Pool (February 2014): 7.8 hours
- Sub-mm point source identification with the 260 GHz band
- SZ detection within the two bands
- Accurate signal mapping at ~ 20” - 3’ (0.1 - 1 R_{500} at z ~ 0.9)
- NIKA + Planck (pressure) + X-ray (ACCEPT, density) give temperature and mass profiles

➡ **NIKA provides accurate pressure profile reconstruction up to high z**

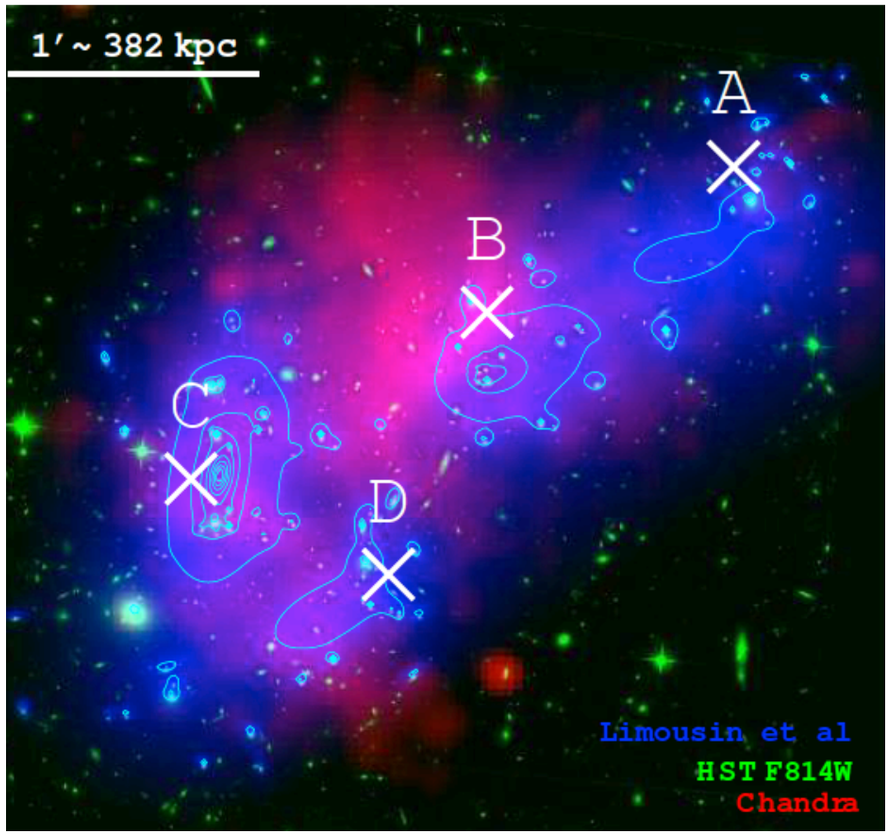
Looking at high redshift clusters
CL J1226.9+3332 (z=0.89)



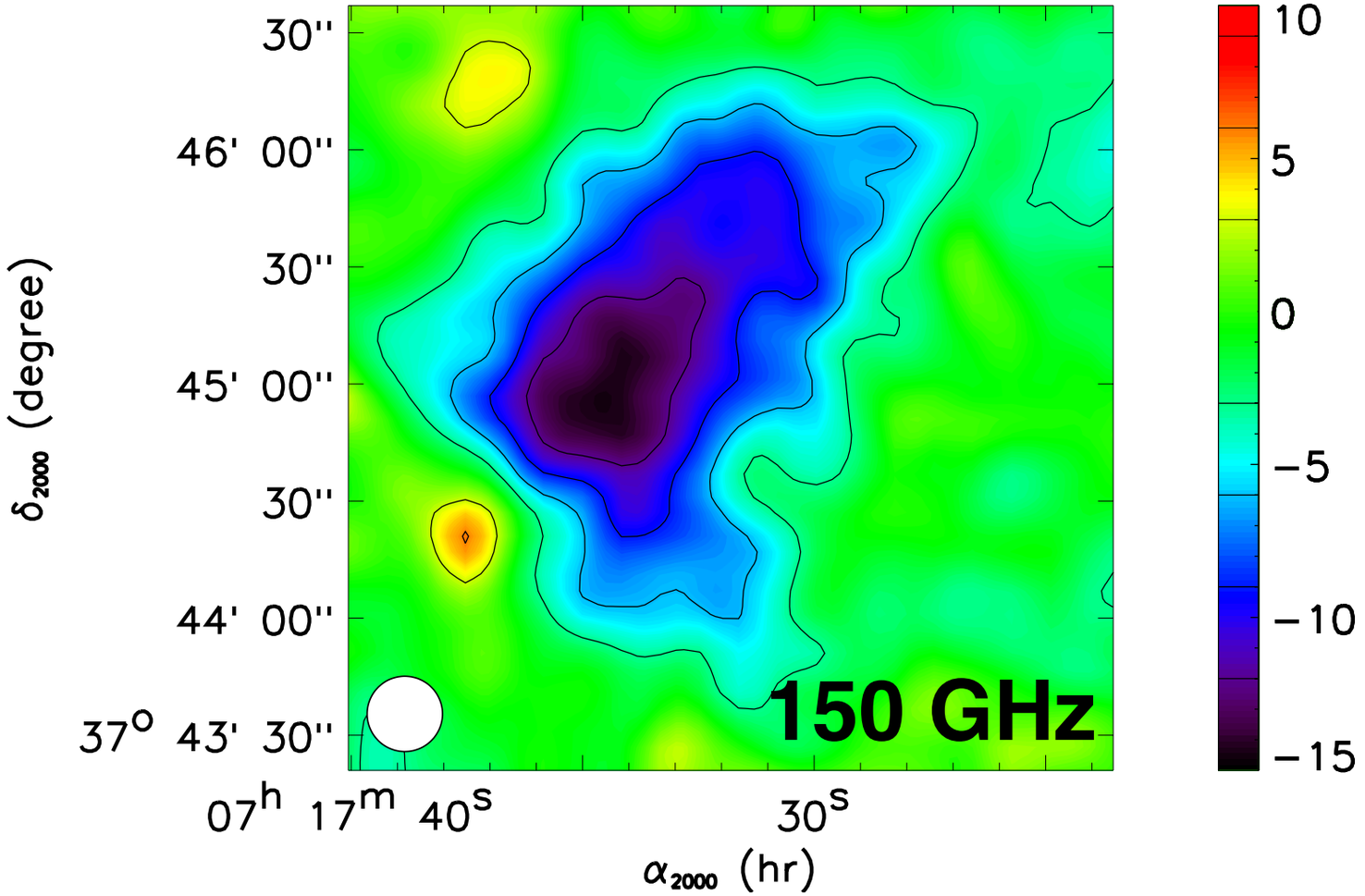


➡ **NIKA provides accurate pressure profile reconstruction up to high z**

Looking at spectacular mergers
MACS J0717.5+3745 (z=0.55), work in progress



[J. Sayers, T. Mroczkowski et al. (2013)]



An exceptionally disturbed cluster

- Triple merger
- 4 optically identified groups
- Temperature up to 30 keV

NIKA data

- First NIKA Open Pool (February 2014)
- 5.3h on source shown here (signal/noise)

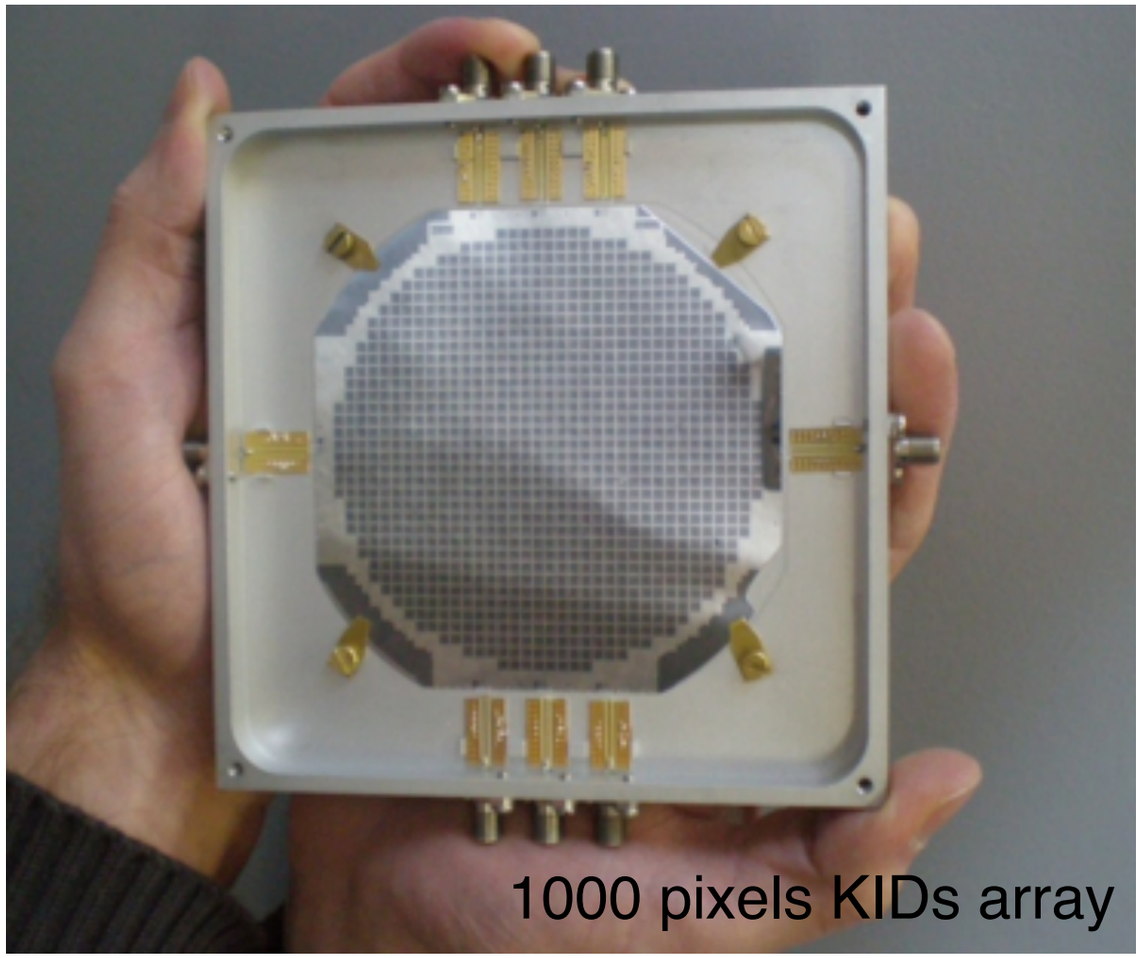
➡ **SZ mapping of (one of?) the most complex system**

Conclusions, perspectives and NIKA2

NIKA2: the status

NIKA2 ***(NIKA prototype)***

- 5000 (300) detectors at SZ frequencies: 150 and 260 GHz (similar)
- 6.5 (2) arcmin instantaneous field-of-view
- State-of-the-art sensitivities (similar)
- High angular resolution: 17.5” and 12” (similar)



- The *NIKA2* cryostat has arrived!
- The assembling of optics and wireing is ongoing
- The >1000 pixels arrays are currently tested

➡ ***NIKA2*** **will be commissioned by 2015**

NIKA2
Large Sunyaev-Zel'dovich programs

SZ large program

- **300 hours** dedicated for SZ
- Observe ~ **50 clusters** in the range **z = 0.5 - 1.5**
- Planck/ACT clusters are a working basis to define a **representative sample**
- Combine SZ with **multi-wavelength** data

SZ goal

- Calibrating the **SZ flux** as a **mass** proxy and its **evolution** with redshift
- Characterize the **structural properties** and clusters dynamical state
- Measure the **kinematic SZ** effect, related to the gas velocity, in individual clusters

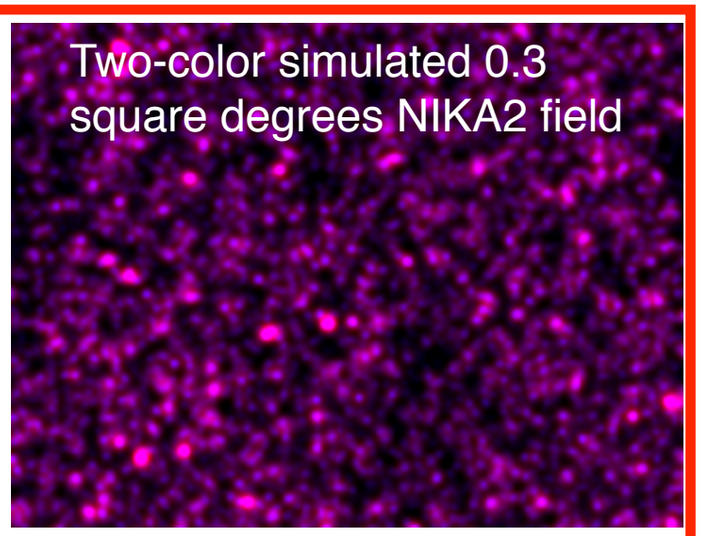
NIKA2 is not only about SZ
Large programs in preparation

- NIKA2 will be opened to the IRAM community in early 2016
- A total of **1300 hours** have been alocated as **guaranteed time** for building the NIKA2

1. Clusters of galaxies via the SZ effect

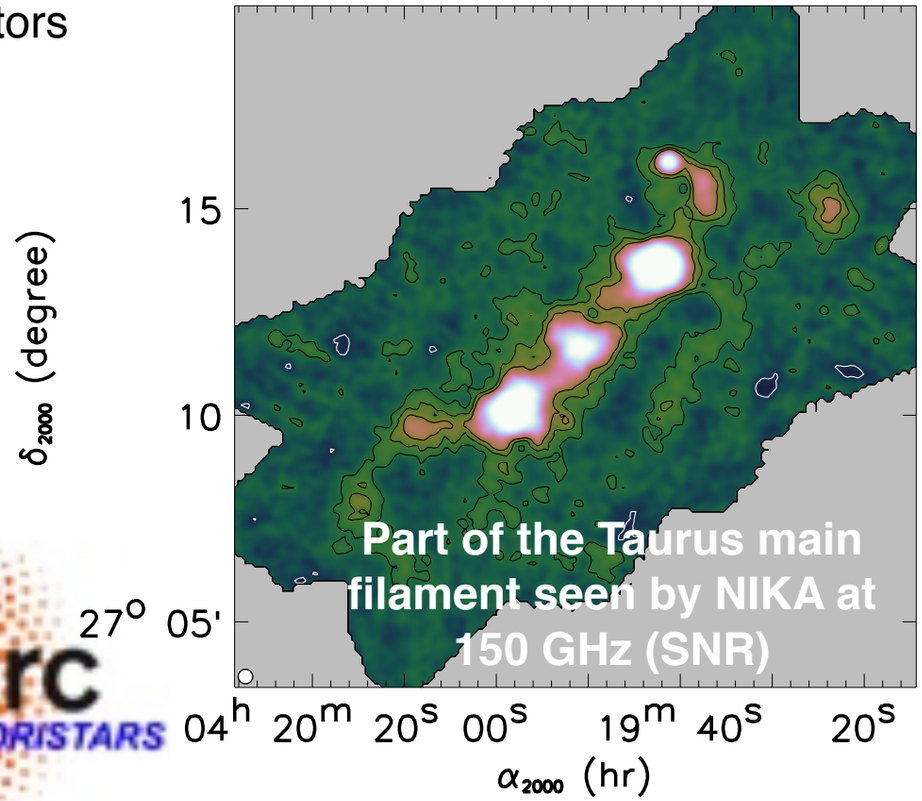
2. Deep surveys

- Complete view of SFR at high redshift
- New insight into galaxy formation/evolution
- Star formation - dark matter halo connection



3. Mapping the interstellar medium

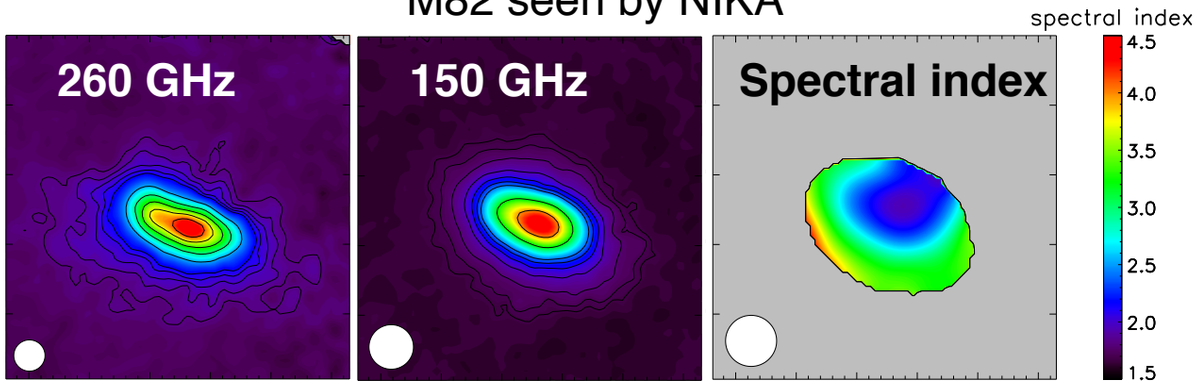
- Characterizing the dust properties
- Origin of the low-mass end of the IMF
- Characterizing the mass reservoirs of massive star progenitors



4. Nearby galaxies

Study of the dust, free-free and synchrotron emission and the galactic environment

M82 seen by NIKA



5. Polarization of galactic regions

- NIKA2 will have polarization capabilities at 260 GHz
- Study the role of magnetic fields in shaping the interconnected network of filaments and pre-stellar cores

http://ipag.osug.fr/nika2

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

+ NIKA SZ involved people: N. Aghanim, M. Arnaud, H. Aussel, B. Comis, H. Dole, M. Douspis, G. Lagache, J.-B. Melin, M. De Petris, E. Pointecouteau, G. Pratt