Large cosmology programs with NIKA2

Mapping the SZ effect from galaxy clusters and the dusty-star formation at high redshift

> **Rémi Adam and Guilaine Lagache on behalf of the NIKA collaboration**

> > **PNCG**

15-16/12/2

Outline

1. NIKA2 at the IRAM 30 m telescope: the status

2. High resolution mapping of the SZ effect

- Beyond Planck SZ cluster cosmology
- The NIKA sample as a pilot project for NIKA2

3. NIKA2 deep surveys

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NIKA2: the next generation millimeter wave continuum instrument at the IRAM 30 m telescope



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NIKA2: design of the instrument





NIKA2: kinetic inductance detectors (KID) development

- KID = superconducting LC resonator
- Absorbed photons change the kinetic inductance by breaking Cooper pairs

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

[Monfardini et al. JLTP (2013)]







➡ KIDs are competitive detectors for astronomical observations

[*Catalano et al. A&A (2014), Adam et al. A&A (2014)*]



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NIKA2: first light

- First cool-down and commissioning phase, Oct.-Nov. 2015
- >80% of the 3300 KIDs working well at 150 and 260 GHz
- Calibration tests, observation of faint point sources and diffuse emmission



First characterization of the instrument: preliminary performances in line with specification



30

0

Δ R.A. (orcsec) Center: R.A. 09 18 28.27 Dec +51 42 23.3

-30

HLS091828 at z = 5.24

7/18

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Looking at clusters using the SZ effect



The tSZ effect probes the pressure in clusters



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Beyond Planck SZ observations

- The **pressure** shows a low dispersion among clusters *[Arnaud et al. A&A (2010)]*
- tSZ flux **total mass** calibration required for cosmology *[e.g. Planck XXIX A&A (2013)]*
- **Bias and scatter** to be handled versus cluster properties and redshift

- Need clusters substructure
- ➡ Need high redshift clusters



[Planck intermediate V A&A (2013)]

High resolution tSZ observations are needed (+ multi-wavelength)

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The NIKA2 GT Sunyaev-Zel'dovich large program

Goal: study statistical properties of SZ internal structure



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First SZ observation with KIDs RX J1347.5-1145 (z=0.45)



Sub-structure + large scales recovered



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Resolving clusters thermodynamics at high redshift CL J1226.9+3332 at z = 0.89



ICM thermodynamic reconstruction up to high z



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MACS J1423.8+2404 (z=0.55): a multi-wavelength analysis





SZ structure in the complex merging cluster MACS J0717.5+3745 at z = 0.55



- A triple merger – 4 optical groups with large $v_{\boldsymbol{z}}$ [Ma et al. ApJ (2009)]

- Complex SZ structure mapped

- Many point sources detected



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Probing the gas velocity in MACS J0717.5+3745 at z = 0.55 (work in progress)



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SZ conclusions

- NIKA2 commissioning in progress
- 300 h will be dedicated to Planck/ACT SZ follow-up
- NIKA pilot sample has shown the feasibility and is still in exploitation



A lot of interesting cluster physics to come with NIKA2



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Why deep fields in the mm?

- Dusty star formation at high redshift
- Statistics galaxy populations/formation & evolution of galaxies
 - Number counts, LFs
 - Sources of the Cosmic Infrared Background
 - Physical process of galaxy formation (e.g., SFR)

Individual sources

- Panchromatic SEDs
 - Far-IR/Radio relation
 - SB versus AGN activities
 - SFR, Mdust, Mstars, etc
- High-redshift ISM studies

(eg using ALMA or NOEMA)





Galaxy formation: stellar mass function and SFR

- SAM: fairly well reproduce the local stellar mass functions, but fail to match observations at high redshift (z ≥ 3)
- Cousin+2015 (a,b):
 - From z=8 to z=0 using a no-star-forming gas reservoir
 - This reservoir generates a delay between the accretion of the gas and the star formation process.



Star Formation rate density at high-z?



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Strategies for surveys

Wide & Shallow

- Most extreme sources
- Bright-end #-counts
- Lack the bulk of sources
- Stacking studies

Narrow & Deep

- Standard sources
- "Regular" #-counts
- Most of the sources



Follow Clusters Caustics

- Faint-end sources
- Model dependent #-counts
- Faint (L*) sources

From A. Beelen

Confusion is a serious limitation



The NIKA2 GT survey: narrow and deep

- 300 hours, PIs: Beelen, Lagache & Ponthieu
- GOODS-N (100 hours):
 - 160 Sq. Arcmin (CANDELS) at the confusion
 - 1mm:
 - $5\sigma = 0.45 \text{ mJy}$
 - 32% of the CIB resolved into sources
 - Greve+2008 : $5\sigma = 3.5 \text{ mJy} (\text{in } 300 \text{ arcmin}^2)$
 - 2mm:
 - $5\sigma = 0.28 \text{ mJy}$
 - 23 % of the CIB resolved into sources
 - Staguhn+2014: $5\sigma = 0.68 \text{ mJy} (\text{in } 12.6 \text{ arcmin}^2)$

• COSMOS (200 hours)

- 2000 Sq. Arcmin
- Match SCUBA-2 850 microns sensitivity
- 5 times wider than SCUBA-2 deep surveys, and much deeper than current millimetre surveys (by factor 5 on comparable area at 1.2mm)

The NIKA2 GT survey

	GOODS-N	COSMOS
$1.2 \mathrm{~mm}$ all	278	566
$1.2~\mathrm{mm}~z>2$	199	488
$1.2~\mathrm{mm}~z>3$	95	264
$1.2~\mathrm{mm}~z>5$	14	43
2 mm all	54	76
2 mm z > 2	47	71
2 mm z > 3	28	49
2 mm z > 5	7	15

Predicted number of sources



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The NIKA2 GT survey

- Probe typical star-forming galaxies at z > -3
 - Main sequence of galaxies, SFR/Mdust/Mstar
 - Determine mode of star formation (main sequence vs merger driven starbursts)
- Give the dusty view of SFR at high z (up to z=5-6)
- Measure the clustering of dusty star-forming galaxies
 SFR/dark-matter halo mass
- Measure galaxy number counts and CIB
- Deliver an image in which the instrument and confusion noises are comparable

The NIKA GT blind survey

In GOODS-N, only 9.6/72 hours (6.5 hours on-sky) = we decided to concentrate on a small field centred around a candidate $z\sim6$ galaxie still detected at 1.2mm

- 3

2

0

-1

-2

-3

• $1\sigma=0.6$ and 0.2 mJy at 1.2 and 2mm, respectively (field center)



From R. Adam and N. Ponthieu

- Combined 1.2+2mm NIKA signal to noise map
 - Three $z\sim6$ galaxies (SNR>3.4)?
- one massive dusty main-sequence galaxy (AzGN10)
- one clumpy disk-like below-main- sequence galaxy
- one remarkable case of a 500 microns detected galaxy with no counterpart in neither IRAC nor radio
 - From D. Liu and E. Daddi



And distant galaxies thanks to the magnification

Strong synergy with the galaxy cluster program

CL J1226.9+3332 An amplified galaxy at z=2.26





Herschel 500, 350 and 250 microns



10.0



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NIKA2 is not only about SZ and high redshift star forming galaxies

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

1. Clusters of galaxies via the SZ effect

2. Deep surveys

3. Nearby galaxies

Dust, free-free, synchrotron emission and the galactic environment



4. 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



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