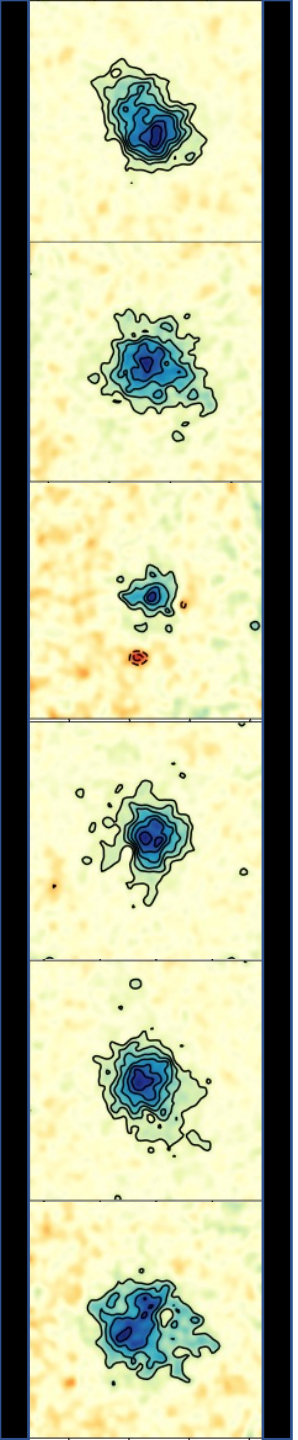


NIKA2

Laurence Perotto

Conseil Scientifique de l'IN2P3 | 3-4 July 2023 | Paris

NIKA2 collaboration

NIKA2 Worldwide

- 163 scientists from 33 Institutes in 9 countries (France, Spain, Italy, Ireland, Belgium, Greece, UK, Iran & USA).
- specialists in instrumentation, data analysis, and scientific interpretation in astrophysics and cosmology

NIKA2 France

- 112 specialists from 13 laboratories affiliated with IN2P3, INSU, INP, CEA and IRAM
- Origin: Synergy IN2P3-INSU-INP that has proven its efficiency since 20 yrs (Archeops, Planck, NIKA, KISS, NIKA2, Concerto)
- Leading position: Principal Investigator: A. Monfardini I. Néel, INP; Project Scientist: J.F. Macías-Pérez LPSC/IN2P3

NIKA2 IN2P3

- 23 scientists at LPSC and IP2I-Lyon (~2-3 FTE/yrs since 15 yrs)
- Leading responsabilities : Project Scientist (J.F. Macías-Pérez), President of the Editorial Board (L. Perotto) …
- Major contributions to the construction: Readout electronics (O. Bourrion) + strong involvement of the services
- Key role in the scientific exploitation (PI of a Large Program)

NIKA2 MoU

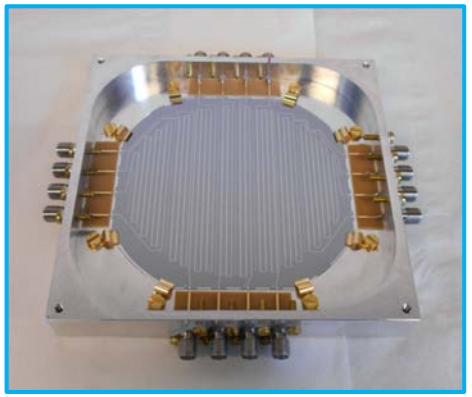
- Responsability of the construction, commissioning, maintenance & upgrades until ~2030
- 1300 hours of Guaranteed Time at the IRAM 30-m telescope distributed in 5 *Large Programs, one of which led by IN2P3*

NIKA2 in a nutshell

A millimetric continuum camera of 2 900 Kinetic Inductance Detectors (KID), operating at 150 and 260 GHz, installed at the IRAM 30-meter telescope, and operating since 2017

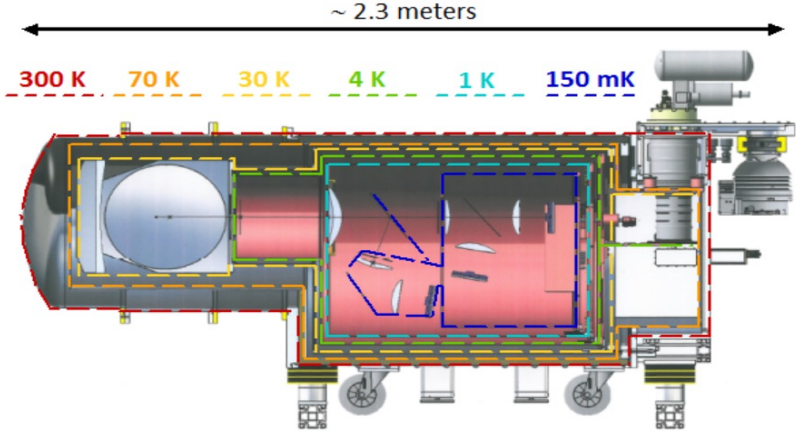
Bourrion et al. (2016) Jinst, 11, 11
Adam et al. (2018) A&A 609, A115
Perotto et al. (2020) A&A 637, A71

Thousands KID-based camera…



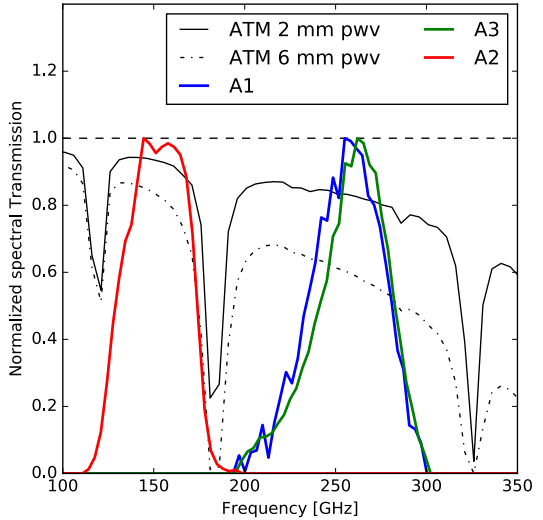
One of the two 1140 KID arrays at 260 GHz

…cooled at 150 mK…



Design of the cryogenic stages

… operating at 150 and 260 GHz …



Measured spectral transmission

IRAM 30-meter telescope at Pico Veleta, 2870m, Spain

…with an angular resolution < 20″ and an instantaneous field of view of 6.5′ in diameter…

…and sensible to polarization at 260 GHz

Commissioning & Performance in intensity

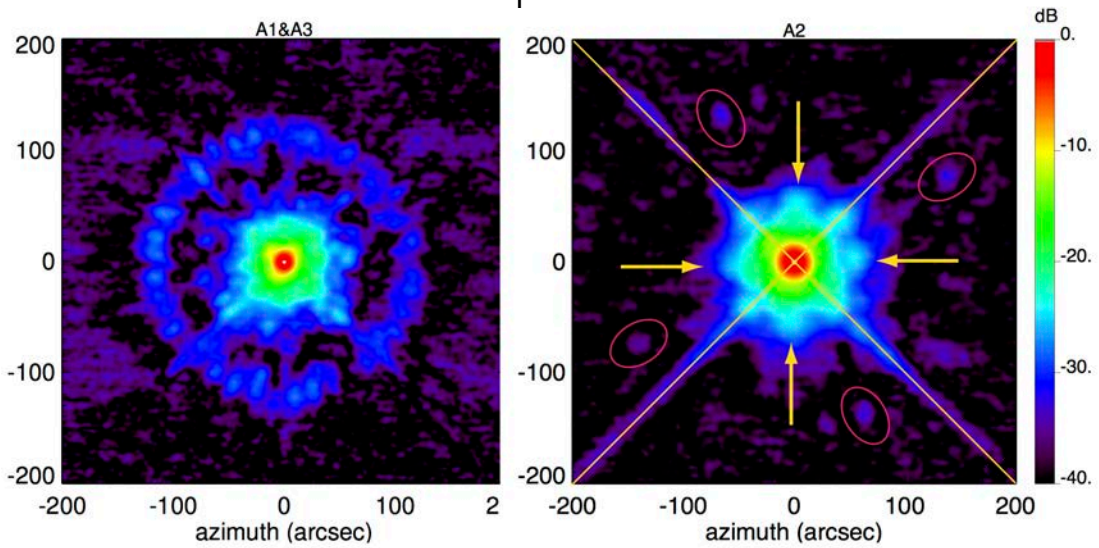
Responsability LPSC/IN2P3

In depth characterization of the performance using a large amount of calibration data over a year

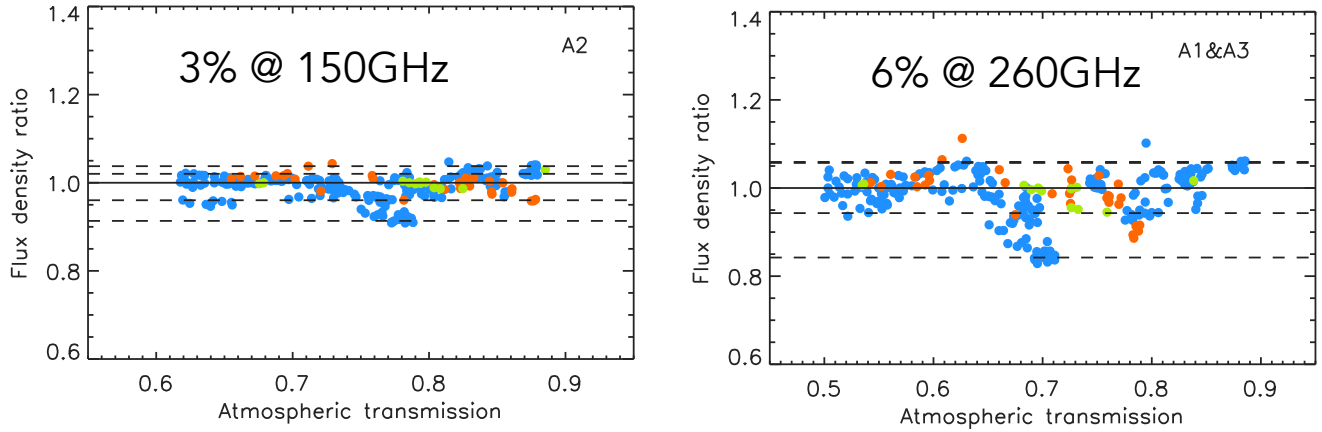
	150 GHz	260 GHz
FOV diameter	6.5′	6.5′
Angular resolution: FWHM	17.6″ ± 0.1″	11.1″ ± 0.2″
Sensitivity mJy.s$^{1/2}$	9 ± 1	30 ± 3
Mapping speed arcmin^2 /mJy^2 / hours	1388 ± 174	111 ± 11

Perotto et al. (2020) A&A 637, A71

Stack map of the beam



Rms calibration uncertainties



Performances better than the specifications (except for the sensitivity at 260GHz, affected by the dichroic effect)
Exceptional stability and sensitivity at 150GHz!

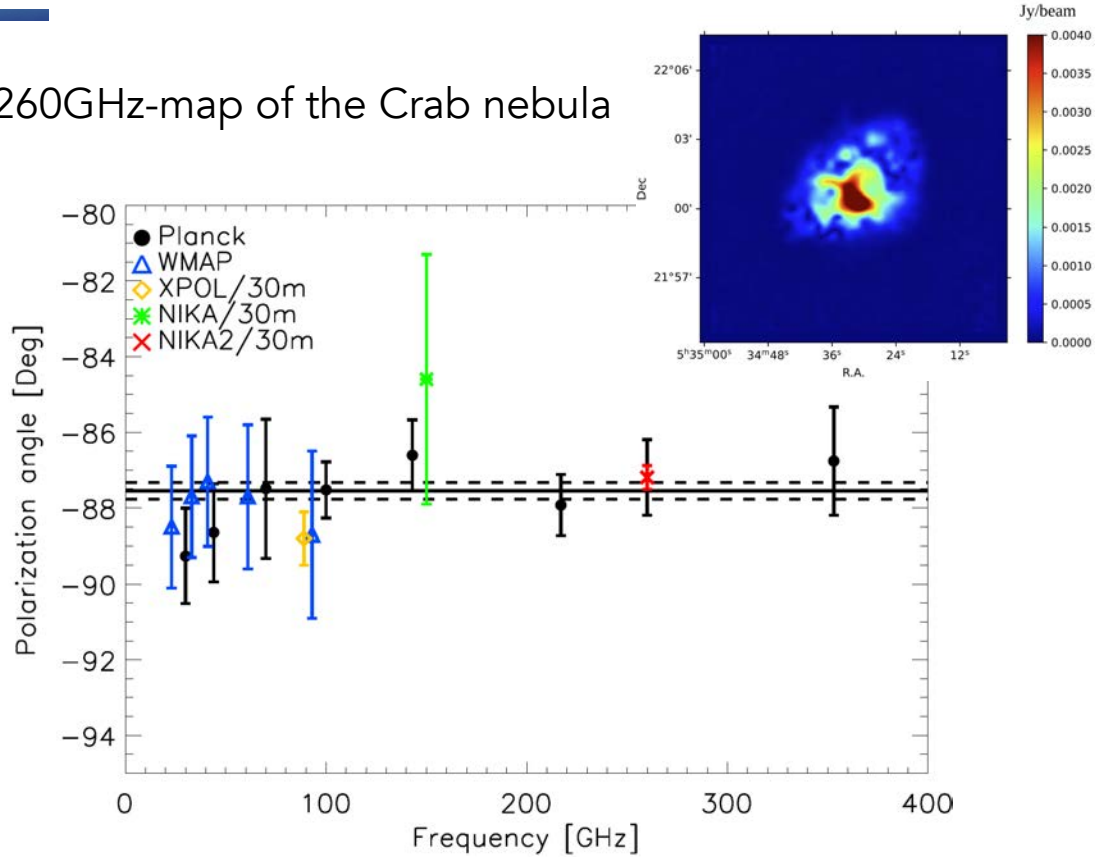
NIKA2 -- high angular resolution combined with a wide field of view in 2 frequency bands -- A unique combination of performances!

Performance & Science verification in polarization

Very good performance in polarization

- Residual instrumental polarisation ~1 %
- Absolute orientation uncertainty ~ 1 deg
- Sensitivity:
  - 33 mJy.s$^{1/2}$ (Stokes I)
  - 22 mJy.s$^{1/2}$ (Stokes Q & U)

NIKA2pol 260GHz-map of the Crab nebula



Crab Nebula is used as a primary calibrator for CMB polarisation

Improving the measure of the mean polarisation angle translates into
Improving the sensitivity to tensor-to-scalar ratio of future CMB

NIKA2 timeline

NIKA Pathfinder (2009-2015)

- 2009: 70-detector prototype, first light at the IRAM 30-m telescope
- 2012: 356-detector dual-band instrument
- 2014: First resolved SZ mapping using KID technology + First direct measurement of the kinetic SZ effect

NIKA2 (2015-2030)

- 2015: 2900-detector dual-band: installation & commissioning
- 2017: opening to the community
- 2017-2022: uninterrupted observation : ~10 campaigns/yr → 53 science campaigns
- 2023: end of the LP in intensity / opening the polarization to community
- 2023-2030: maintenance and upgrades of NIKA2 at the IRAM 30-m telescope

Scientific production & international visibility

- 22 articles + 22 referred proceedings of the NIKA2 collaboration
  - 16 articles have the first author affiliated to IN2P3
- 104 articles referring to NIKA2 in the abstract
- NIKA2 has been granted a sizeable ANR twice:
  - Construction, 980 keuros, P.I. A. Benoit, Néel/INP
  - Scientific exploitation, 410 keuros, P.I. F. Mayet, LPSC/IN2P3

- Millimeter Universe Conference series

June 2019 | Grenoble

June 2021 | Roma

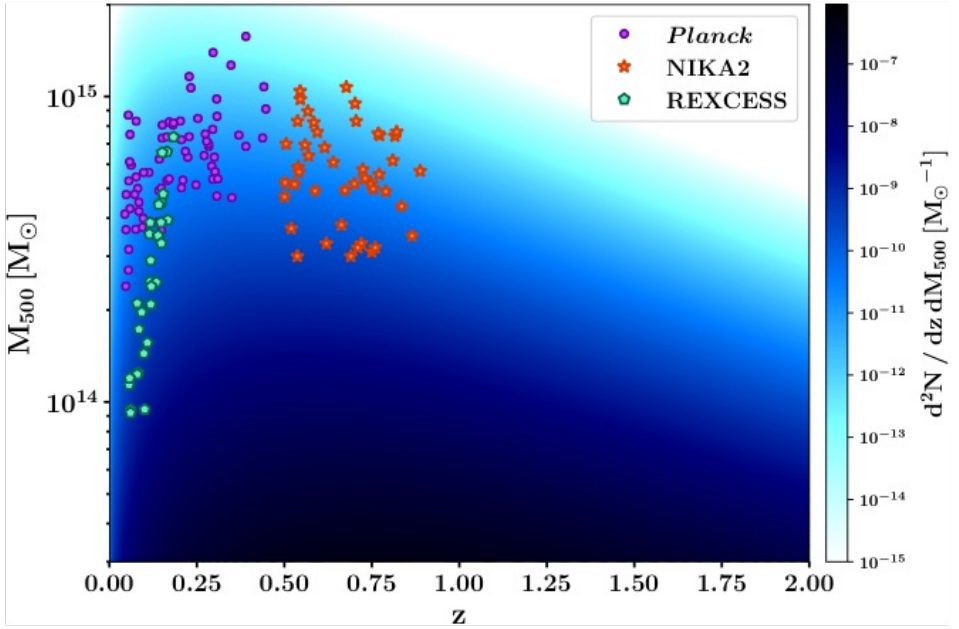
26-30 June 2023 | Grenoble

2025 | Chicago ?

NIKA2 Sunyaev-Zel'dovich Large Program

- SZ cosmology requires the calibration of 1. a scaling relation between the mass and the SZ observable and 2. a mean electronic pressure profile using spatially resolved observation of galaxy clusters.
- Biases in the estimation of these quatities is a possible explanation of the tension between CMB-angular power spectrum and CMB-SZ cosmological results
- Main objectives of the NIKA2 SZ Large Program is to improve the accuracy of their measurements

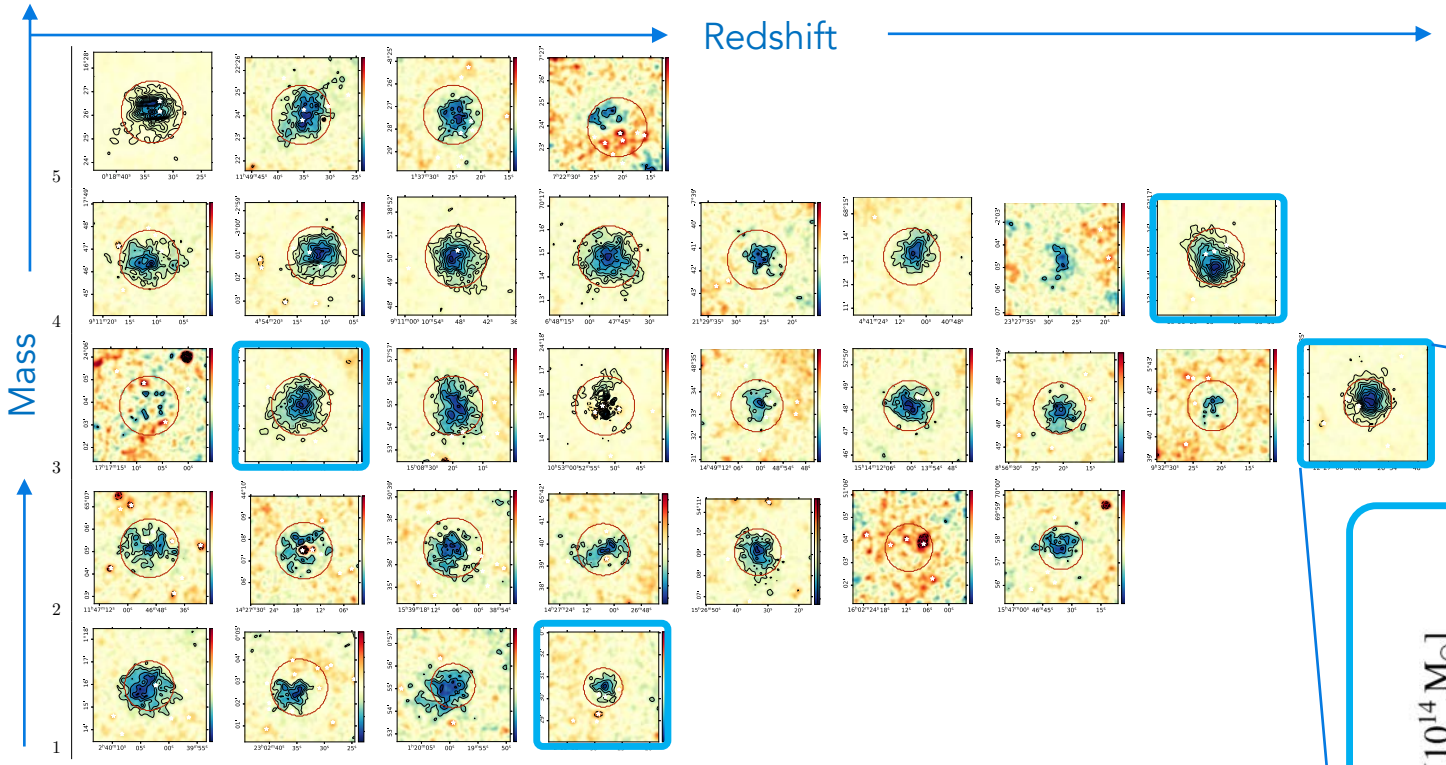
  - P.I. Mayet & Perotto (both affiliated to IN2P3)
  - 300 hours of Guaranteed Time at the IRAM 30-m telescope
  - Representative: selected in mass and redshift in the Planck and ACT catalogues
  - Spanning mid and high-redshift / including low-mass clusters
  - Multi-lambda analysis: X-ray observation available for all clusters



Provide the community with tools to improve the Cosmology with SZ effect

NIKA2 SZ Large Program first results

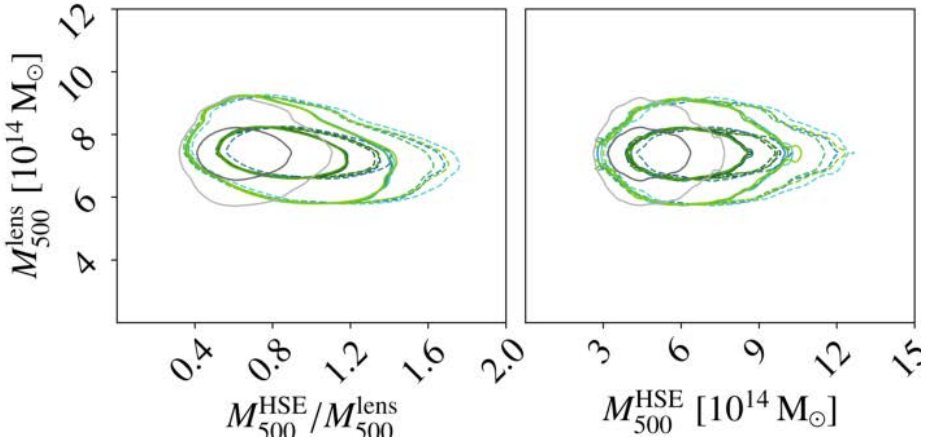
- The observations have been completed in January 2023 → 35 clusters are mapped to the expected sensitivity



Published individual analysis

Ruppin et al. (2018) A&A 615 A112
Kéruzoré et al. (2020) A&A 644 A93
Artis et al. (2023) in prep.

Muñoz-Echeverría et al. (2023) A&A 671, A28



- First single-cluster analyses show the power of resolved SZ observations to obtain accurate mass measurements

NIKA2 SZ Large Program upcoming data release

NIKA2 LPSZ main products and associated key papers

- NIKA2 LPSZ sample characterization

  For each cluster, we will provide:
  - The maps at 150 & 260 GHz, and the related products (pixel-to-pixel covariance, transfer function, …)
  - The thermodynamical profiles (P_e, M_{HSE}, $T_{e,}$ …) and integrated quantities: Y500, M500, P500

- NIKA2 LPSZ point source catalogues

  From the sample, we will estimate the products of interest for Cosmology

- NIKA2 LPSZ mean pressure profile

- NIKA2 LPSZ mass-observable scaling relation

- NIKA2 LPSZ implication for SZ cosmology
  - Reanalyse of the Planck SZ results using NIKA2 LPSZ calibration tools
  - Provide data-driven feedback to improve the Hydrodynamical simulation

NIKA2 LPSZ additional papers

- Probing the origin of the hydrostatic mass bias
- Improving the knowledge of Cluster's Physics (AGN feedback, …)
- Constraining evolution with mass/redshift
- …

Summary & Perspectives

NIKA2 is an international collaboration gathered around the construction and the scientific exploitation of the NIKA2 camera

NIKA2@IN2P3: leading responsabilities, major role in the construction (strong involvement from the services@LPSC), key role in the science exploitation

Characterization of the performance in intensity: resp. IN2P3, thorough study of the systematics: NIKA2 has unique capabilities

Polarization: Very good performance → implication for future CMB primordial B-mode oriented experiment

NIKA2 LPSZ, a IN2P3-led Large Program, 300h of Guaranteed Time
→ First 4 published analysis
→ Science exploitation and preparation of the data release is deeply ongoing
→ Main goal: improve the accuracy of SZ-based cosmology

Science observation flawlessly conducted from 2017 to 2023, and will continue until ~2030

Current refurbishment of the 30-m telescope, followed in 2023-2024, by an upgrade of NIKA2 (better sensitivity at 260GHz)

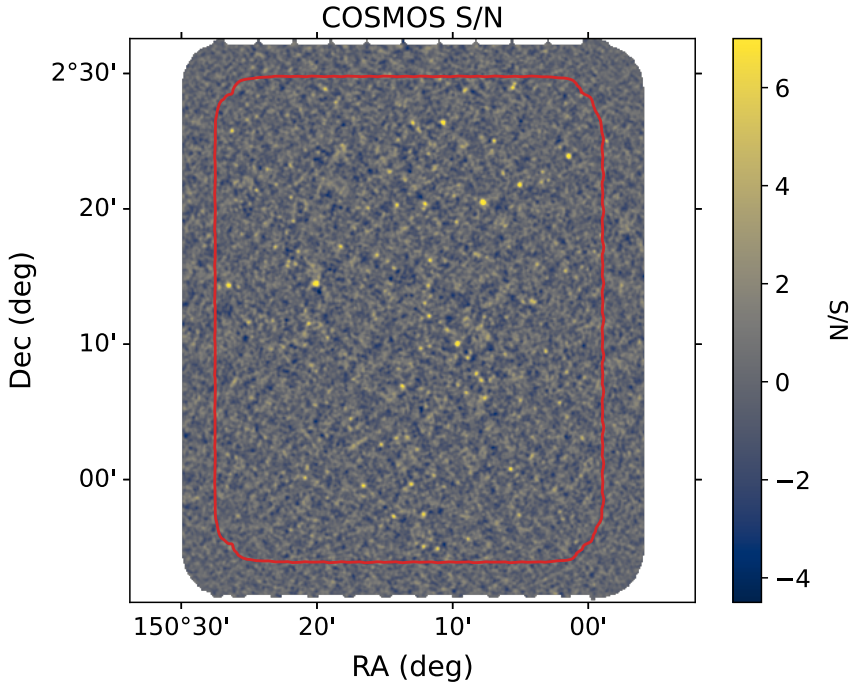
BACK UP

NIKA2 Large Programs

Cosmology (600h GT)

The NIKA2 Cosmological Legacy Survey (N2CLS)
PIs: Guilaine Lagache, Alexandre Beelen, Nicolas Ponthieu, INSU

High-resolution tSZ observations of a large sample of clusters of galaxies (LPSZ)
PIs: Frédéric Mayet, Laurence Perotto, IN2P3

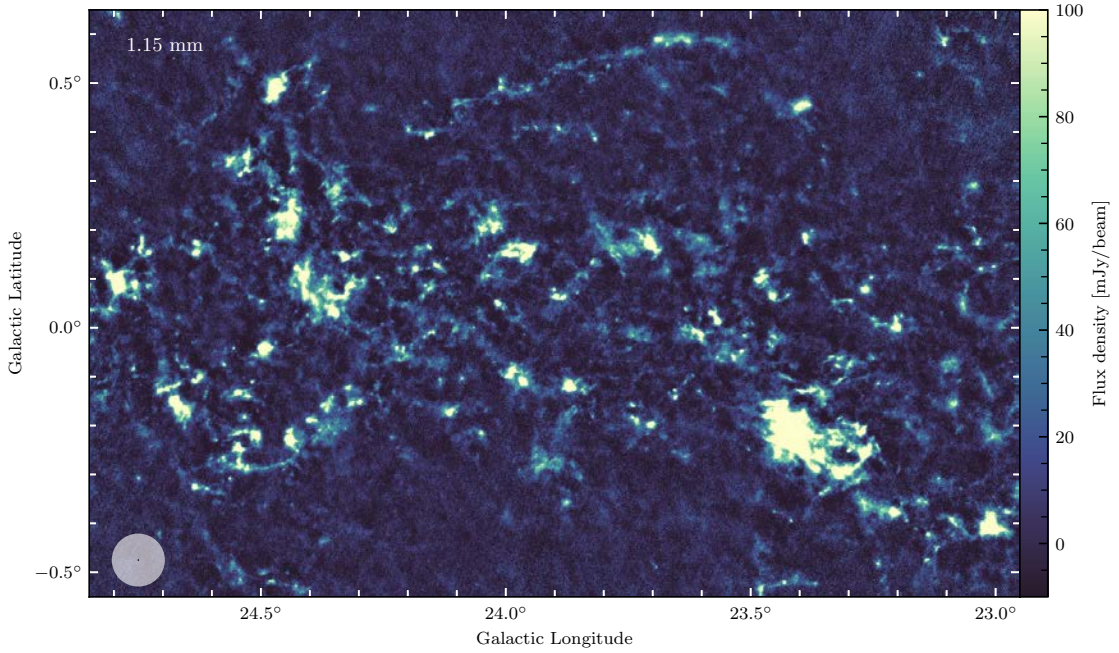


Galactic Astrophysics (700h GT)

Galactic Star Formation with NIKA2
GASTON
PI: Nicolas Peretto, Cardiff University

Interpreting the Millimetre Emission of Galaxies with IRAM and NIKA2 -- IMEGIN
PI: Suzanne Madden, CEA

Probing the B-Field in star-forming Filaments Using NIKA2-Pol
B-FUN
PI: Philippe André, CEA



NIKA2 upgrades

Improvement of optics, detector arrays, readout electronics and software

Two-steps strategy

First round

- Improvement of the cold optical elements (thermal filters, dichroic + lenses?)
- 1 mm arrays replacement
- Improved electronic control system (synchronization cryogenic stages / DAQ)

Second round

- Readout electronics replacement: new broader bandwidth boards developped for CONCERTO
  - Requirement 1: production of 20 boards
  - Requirement 2: development and test of the acquisition software

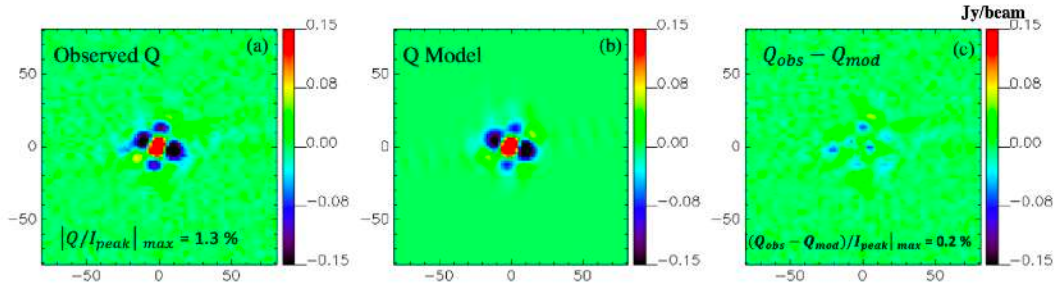
- in case, further changes to fix problems introduced by the first intervention

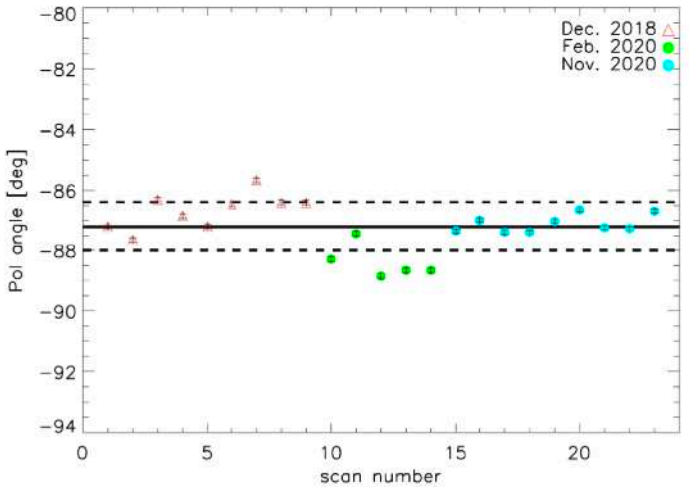
Performance & Science verification in polarization

Very good performance in polarization

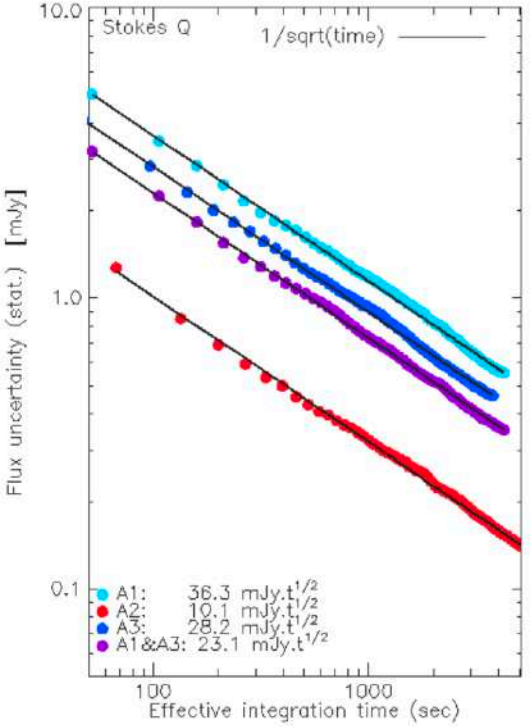
- Residual instrumental polarisation ~1 %
- Absolute orientation uncertainty ~ 1 deg
- Sensitivity:
  - 33 mJy.s$^{1/2}$ (Stokes I)
  - 22 mJy.s$^{1/2}$ (Stokes Q & U)

Residual instrumental polarization: Stokes I → Stokes Q, U leakage
After subtraction of a model from observation of unpolarized source at various angles





Stability of the polarization angle measured from a polarized quasar



Rms noise as a function of the integration time $\sigma = NEFD/\sqrt{t}$

NIKA2@IN2P3

- 23 specialists at LPSC and IP2I-Lyon (~2-3 FTE/yrs since 15 yrs)

Name Last	First	Laboratory	Current Position	Role & responsabilities
Current NIKA2@IN2P3 Cosmology Team				
Catalano	Andrea	LPSC	researcher (CR)	Core Team
Chérouvrier	Damien	LPSC	PhD student	Collaborator
Hanser	Corentin	LPSC	PhD student	Core Team
Macías Pérez	Juan	LPSC	senior researcher (DR)	Project Scientist
Mayet	Frédéric	LPSC	full professor (PR)	P.I. of the LPSZ
Moyer	Alice	LPSC	PhD student	Collaborator
Muñoz-Echeverría	Miren	LPSC	PhD student	Core Team
Perotto	Laurence	LPSC	researcher (CR)	Editorial Board Chair
Savorgnano	Sofia	LPSC	PhD student	Collaborator
Ruppin	Florian	IP2I	associate professor (MdC)	Core Team
Past NIKA2@IN2P3 Cosmology Team				
Adam	Rémi	OCA (INSU)	researcher (CR)	Core Team
Artis	Emmanuel	MPE Garshing (Deutchland)	post-doc	Core Team
Comis	Barbara	non-academic		
Kéruzoré	Florian	Argonne (USA)	post-doc	Core Team
Ritacco	Alessia	INAF (Italy), ENS	post-doc	Core Team
Electronics team				
Bounmy	Julien	LPSC	research engineer (IR)	Collaborator
Bourrion	Olivier	LPSC	research engineer (IR)	Core Team
Hoarau	Christophe	LPSC	engineer (IE)	Collaborator
Vescovi	Christophe	LPSC	research engineer (IR)	Collaborator
Mechanics team : Servive Étude et Réalisation Mécanique (SERM)				
Angot	Julien	LPSC	research engineer (IR)	Collaborator
Menu	Johan	LPSC	engineer (IE)	Collaborator
Roni	Samuel	LPSC	engineer (IE)	Collaborator
Roudier	Sébastien	LPSC	engineer (IE)	Collaborator
Detector team : Service Détecteurs et Instrumentation (SDI)				
Marpaud	Julien	LPSC	engineer (IE)	Collaborator
Software team				
Dargaud	Guillaume	LPSC	research engineer (IR)	Collaborator
Fulachier	Jérôme	LPSC	research engineer (IR)	Collaborator
Lambert	Fabian	LPSC	research engineer (IR)	Collaborator
Odier	Jérôme	LPSC	research engineer (IR)	Collaborator

TABLE 1 – NIKA2 team at IN2P3