

## NIKA2, A DUAL-BAND MILLIMETRE CAMERA ON THE IRAM 30 M TELESCOPE TO MAP THE COLD UNIVERSE

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**Abstract.** A consortium led by Institut N el (Grenoble) has just finished installing a new powerful millimetre camera NIKA2 on the IRAM 30 m telescope. It has an instantaneous field-of-view of 6.5 arcminutes at both 1.2 and 2.0 mm with polarimetric capabilities at 1.2 mm. NIKA2 provides a near diffraction-limited angular resolution (resp. 12 and 18 arcseconds). The 3 detector arrays are made of more than 1000 KIDs each. KIDs are new superconducting devices emerging as an alternative to bolometers. The commissioning is ongoing in 2016 with a likely opening to the IRAM community in early 2017. NIKA2 is a very promising multi-purpose instrument which will enable many scientific discoveries in the coming decade.

Keywords: Camera, millimetre astronomy, cosmology, galaxies, star formation, interstellar dust

### 1 Introduction

The golden age of (sub)millimetre astronomy started with the two flagship space missions Herschel and Planck. It is now ongoing with the two world-class (sub)millimetre interferometers ALMA and NOEMA. Whereas Herschel and Planck provided surveys of a large portion or all of the sky at medium angular resolution (35 arcsec. at 500 micron for Herschel and 5 arcmin at 1 mm for Planck), the ground-based interferometers can dig deeply at high angular resolution (sub-arcsecond), but only on very tiny spots (around 20 arcseconds at 1 mm) of the sky. The IRAM 30 m radiotelescope, a leading millimetre facility in Spain, near Granada, can fill the angular scale gap. For that purpose, a wide-field camera is necessary. A consortium of laboratories in France and UK, along with IRAM, has just built and installed such a camera called NIKA2 (more details given in Catalano et al. 2016, see also <http://ipag.osug.fr/nika2>).

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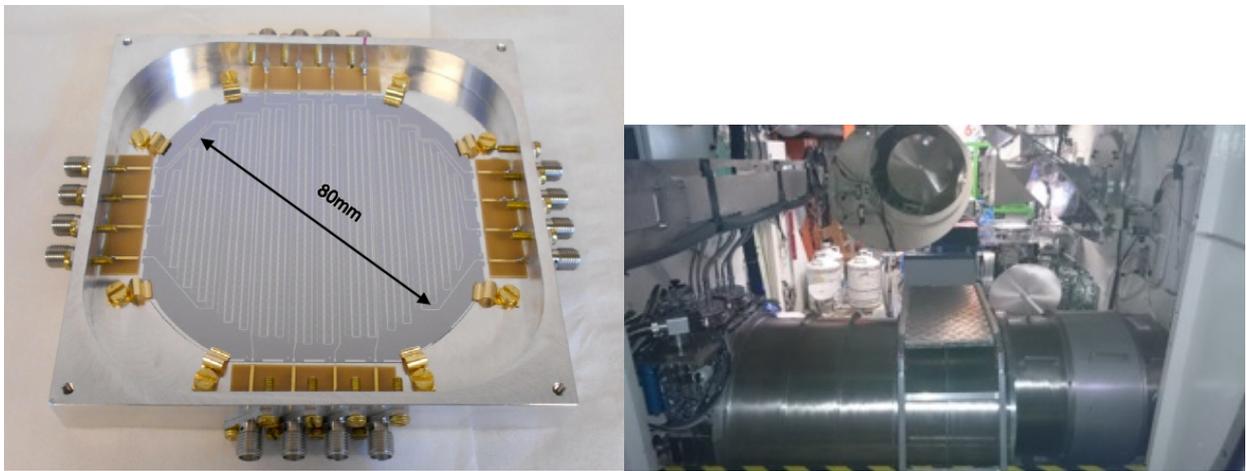
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## 2 A description of NIKA2

The camera is based on novel detectors. Kinetic Inductance Detectors (KIDs) are supraconducting devices (Day et al. 2003; Doyle et al. 2006) that see their electrical properties change with incoming light. The kinetic inductance is modified when Cooper pairs are broken by photons of sufficient energy. KIDs are proving to be an alternative to bolometers with specific advantages: time constant (less than a millisecond), low sensitivity to the cooler temperature (a thousand times less than for a bolometer), and ease to manufacture (a single aluminum layer on a silicon wafer). Each detector is wired to be a high-efficiency RLC resonator coupled by a linefeed to the readout. The signal can thus be frequency-multiplexed by a factor of at least 150, each KID having its own resonant frequency. Moreover the detector resonance frequency is linearly dependent on the incoming photon flux. A complex readout system is required to simultaneously measure all the detectors at a sampling rate of up to 100 Hz (Bourrion et al. 2011). Since 2009, these properties have been checked on the sky with the NIKA prototype camera (Monfardini et al. 2010, 2011; Calvo et al. 2013; Catalano et al. 2014) at the IRAM 30 m telescope. Figure 1 (left panel) shows one of the two NIKA2 1 mm arrays. The sampling of the sky by each planar array is of  $F.\lambda \simeq 0.7 - 1$ .



**Fig. 1. Left:** NIKA2 1 mm array containing more than 1000 KIDs. It is made of a single layer of aluminum on a silicon wafer. Aluminum is a superconductor below 1 K. Feedlines are seen meandering around the detectors. The readout connectors can be seen on the sides: a pair of connectors correspond to the input and output of one feedline and there are 8 readouts needed to read that array. **Right:** The NIKA2 cryostat in the Nasmyth cabin of the IRAM 30 m radiotelescope.

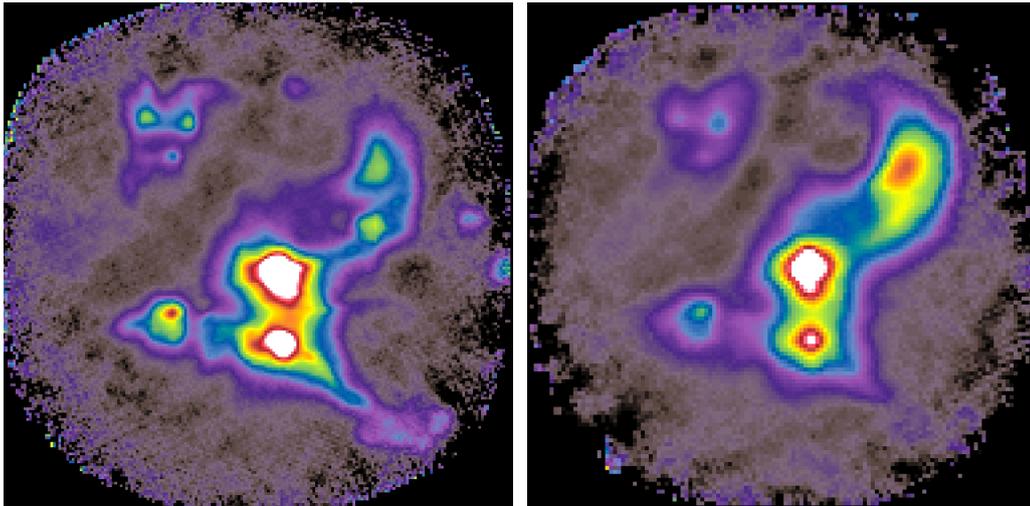
Most of NIKA2 is made of two 4 K pulse-tube cryocoolers and a closed-cycle  $^3\text{He}$ - $^4\text{He}$  dilution fridge so that these detectors can function at typically 150 mK. The NIKA2 cryostat provides a continuous cooling (no duty cycles) for the whole duration of each observing campaign (up to several months). The optics is made of polyethylene lenses with a near-telecentric system that focuses light on the plane detectors. Filtering (high-frequency cut-off, bandpass) is done via mesh filters (Ade et al. 2006). A dichroic splits the 1 and 2 mm light. Then, a polarizing capability is obtained by having a cold polarizing grid at 45 deg. from the incoming 1 mm light splitting the two linear polarizations onto the two 1 mm arrays. When one wishes NIKA2 to be in the polarization observing mode, a removable half-wave plate can be slid in front of the cryostat. This system was used with NIKA (Ritacco et al. 2016) and provides a continuous rotation of the polarization axis so that Stokes parameters for the linear polarization can be retrieved. Figure 1 (right panel) shows how the heavy cryostat (more than 1.3 tons) fits into the Nasmyth cabin of the IRAM 30 m radiotelescope. A new optical system (M3 and M4 mirrors) had to be designed to accommodate the NIKA2 field-of-view.

## 3 The performance of NIKA2

NIKA2 provides an instantaneous circular field of view with a 6.5 arcmin. diameter on the sky in a simultaneous way in the two broad atmospheric bands at 260 GHz (1.2 mm) and 150 GHz (2.0 mm). The angular resolution is better than 12 and 18 arcsec at resp. 1.2 and 2 mm. The goal sensitivities are resp. 15 and 10 mJy rms

for a point-source in one second of integration on average across the whole focal plane. The total number of detectors is about 1100 per array and there are three arrays (two at 1.2 mm and one at 2 mm). The percentage of valid detectors is above 80 % (some detectors cannot be used as their resonant frequencies happen to be too close to each other). The on-going commissioning is assessing these values with thorough calibration campaigns and there are no signs that they cannot be reached.

Maps of the sky can be obtained with a size of up to several degrees by raster scans: the whole telescope is moving with respect to the map center in a zig-zag pattern. The secondary mirror is not wobbling. To illustrate NIKA2 early capabilities, we show the maps obtained at 1 and 2 mm in Fig. 2 around the ultracompact HII region NGC 7538, a secondary calibrator.



**Fig. 2.** RA-Dec maps centered on the ultracompact HII regions NGC 7538 at **Left:** 1.2 mm and **Right:** 2 mm. The maps were obtained by using the standard NIKA2 IDL-based pipeline and an adaptation of the Scanamorphos map-making algorithm (Roussel 2013) to NIKA2. The integration time was 12 minutes. The size of the mapped square is 10 arcmin. The brightness scale is linear and the maximum is at several Jy per beam. The central calibrator is clearly surrounded by many other bright regions.

## 4 Conclusions

The NIKA2 commissioning is ongoing at the end of 2016. The final configuration of the instrument, which includes improvements in optical elements, filtering, readout electronics and the 2 mm array, still has to be characterised. A science verification phase will begin in early 2017 and the instrument could then be opened to the IRAM community. Five large programs of guaranteed time will be pursued (along with open time proposals): 1) mapping of the hot gas in fifty clusters of galaxies, as already performed on 6 clusters with the prototype camera (Adam et al. 2014, 2015, 2016; Ruppin et al. 2016), 2) a deep survey down to the confusion limit, 3) mapping of nearby galaxies, 4) galactic observations of star formation and dust properties, and 5) polarization of star-forming regions. The observations with NIKA2 will provide several lists of relevant targets to be explored by NOEMA.

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