New mm-wave instrument ("NIKA") opens for astronomers

Millimetre-wave astronomy is an important tool for studying the cold and the primordial stages of our Universe. This branch of astronomy presents monumental challenges in detector science and technology. At the NEEL Institute, we have pioneered the development of the Lumped Element Kinetic Inductance Detectors (LEKIDs) technology. Our main driver was the construction of a new instrument for the Institut de Radioastronomie Millimétrique (IRAM). This instrument, called "NIKA" (acronym for New IRAM KID Array) was installed at the Sierra Nevada 30-metre radio-telescope in 2010 and is the most sensitive camera in the world using this innovative detection technology. Intense work on completing development of NIKA allowed its opening to the international astronomy community in February 2014.

Modern applications in millimetre and sub-millimetre astronomy require a large number of ultra-sensitive pixels, limited in sensitivity merely by photon counting statistics. This has been achieved in the past by using collections of a few tens of individual low temperature bolometers, cooled down to around 0.1 K (as used e.g. on the Planck satellite launched 2009). In the last few years, the challenge has been to develop monolithic filled arrays satisfying all the sensitivity requirements. But, on increasing the number of pixels, the practical issues associated with multiple electrical feed-throughs reaching into the cold focal plane of the telescope became a limiting factor. The Kinetic Inductance Detector (KID) concept, proposed by Caltech-JPL back in 2002, solves this puzzle in an elegant way.

KIDs are high quality-factor ($Q = 10^4$-10^6) superconducting resonators operated well below their critical temperature *Tc*. In a LEKID, they consist of a single patterned thin film of superconductor sensitive to the incoming radiation via the kinetic-inductance effect. The incoming photons break some of the electron pairs ("Cooper pairs") responsible for superconductivity, perturbing the complex impedance of the superconductor film and thus generating a measurable electrical signal. Many hundreds of KIDs can be multiplexed on a *single readout line* by adjusting their resonance frequencies to different values.

In 2010, our group designed and built an innovative, dual wavelength band, KID camera for the IRAM's 30 metre radiotelescope situated in Spain. Since then, in a highly competitive context, the group has driven the improvement of the NIKA instrument. The original name "Néel IRAM KID Arrays" has become the "New IRAM KID Arrays", reflecting the involvement since 2011 of a number of other groups in France (including LPSC, IPAG and IRAM in Grenoble, the IAS Orsay and CEA Saclay) and abroad (e.g. Cardiff University, IRAM Granada). As a result, this year, NIKA became the first KID-based instrument open to the general astronomical community. Compared to its direct competitor GISMO, based on the more standard bolometer technology and developed by NASA's Goddard Space Flight Center, NIKA has the distinct advantage of mapping the sky simultaneously at two wavelengths: 2.05mm and 1.25mm.

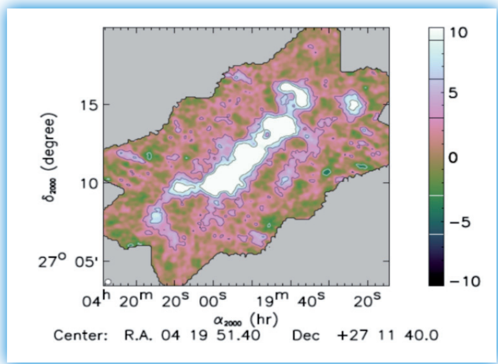

Fig. 1 : The Taurus interstellar dust filament mapped by NIKA at 150GHz (2.00 mm) during the first scientific run.

Fig. 2 : Part of the NIKA team at the Pico Veleta radio-telescope.

From left to right: M. Calvo, A. Catalano, A. Monfardini, J. Macias-Perez, N. Ponthieu.

In the period 14-28/02/2014, the NEEL Institute group leading the NIKA collaboration travelled to the IRAM 30-m telescope located at 2850-meters altitude on the Sierra Nevada, overlooking Granada. In winter the telescope is reached by cableway, followed by a snowcat journey or skiing. Once at the observatory, we worked together with colleagues of the NIKA collaboration in a challenging environment. On location remote from Grenoble, we ensured 24/24 hour support for all the NIKA hardware, ranging from the cryogenics to the detectors and readout electronics and data acquisition. With the astronomers and the IRAM-Spain staff, we checked the quality of the data in real time. We targeted and mapped with unprecedented sensitivity sources ranging from the planet Pluto to small-body disks around nearby stars, remote galaxy clusters, galactic interstellar dust filaments, gamma-ray bursts, etc. About 35% of the observations were done by the NIKA collaborators themselves; the remainder by external astronomers. The preliminary results indicate that NIKA has achieved a record sensitivity, being able to detect extremely faint sources with flux densities incident on the antenna of the order of 10^{-29} W/m^2/Hz (10^{-3} "Jansky units").

Besides providing continuing support to the NIKA exploitation, our group at Institut NEEL is leading the NIKA2 project, based on the same key technologies, namely optical dilution cryostats and kinetic inductance detectors. NIKA2 will incorporate about 5,000 pixels, compared to 350 in NIKA. This will allow linear polarisation measurements at 1.25 mm wavelength, and a 10-fold increase of the mapping speed. The huge NIKA2 instrument is at present being assembled in Grenoble, in G2ELAB's big hall nicknamed "the cathedral". This ongoing work has involved a very large number of participants from the NEEL Institute's entire cryogenics and electronics groups.

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FURTHER READING

Performance and calibration of the NIKA camera at the IRAM 30 m telescope
A. Catalano et al.
Astronomy and Astrophys. 569, A9 (2014)

Improved mm-wave photometry for kinetic inductance detectors
M. Calvo et al.
Astronomy and Astrophys. 511, L12 (2013)