High angular resolution polarization observations of galactic and extragalactic regions with NIKA-NIKA2 camera

Alessia Ritacco
on behalf of the NIKA2 collaboration

SFDE17 - August 7th 2017
Outline

1. NIKA2 camera and NIKA Pathfinder
   - General characteristics and polarization system
2. NIKA polarimeter on the sky
   - Calibration and performance
   - Science verification on compact and extended sources
3. Crab nebula polarization observations at 150 GHz with NIKA
   - Polarization properties
   - Spectral Energy Distribution in polarization
4. Summary and conclusions
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NIKA2 camera & NIKA Pathfinder

NIKA: New IRAM Kinetic inductance detectors Array

NIKA2 : new continuum camera

KIDs: High quality factor superconducting resonators
Dual Band: 150 & 260 GHz (3 arrays)
Wide Field of View: 6.5 arcmin (2896 valid detectors)
High angular resolution: FWHM 17.7 & 11.2 arcsec
Sensitivity: 6 & 20 mJy.s$^{1/2}$ (at null opacity)
Polarization capability at 260 GHz

R. Adam et al. 2017
arXiv:1707.00908

NIKA2 will probe the critical ~ 0.01-0.05 pc scales (~10’’-60’’ in the nearest clouds) at which magnetic field lines may channel the matter of interstellar filaments into growing dense cores.

IRAM 30 m telescope
NIKA2 KID ARRAY ~ thousands of pixels
NIKA2 Dilution Cryostat cooling down the KIDs at ~150 mK
Multiplexing readout electronics ~300 pixels per board
NIKA2 camera & NIKA Pathfinder

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NIKA
- Pathfinder for NIKA2
- Operated at IRAM 30m telescope from 2012 to 2015
- Field of View: 1.8 arcmin (356 valid detectors)
- Polarization capability at 260 & 150 GHz

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NIKA/NIKA2 Polarimeter

NIKA

The continuous rotation of the HWP + polarizer + KIDs allows us to get a quasi-simultaneous measurement of the Stokes parameters I, Q, and U.

Necessary because of the NIKA/NIKA2 KID geometry, sensitive to 2 polarizations.

Polarization totally transmitted through the HWP+Polarizer.

Polarization efficiency parameters estimated to:
- $0.9956 \pm 0.0002$ @260 GHz band
- $0.9941 \pm 0.0002$ @150 GHz band

Ritacco et al. 2017 A&A, 599, A34

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The continuous rotation of the HWP + polarizer + KIDs allows us to get a quasi-simultaneous measurement of the Stokes parameters I, Q, and U.

The commissioning of the NIKA2 polarimeter started on June 2017.

Two 260 GHz arrays to measure the two linear polarization components.
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NIKA polarimeter on the sky

Broad-lines of the data analysis

I. Removal of the HWP induced parasitic signal (HWPSS)

II. Reconstruction of the Stokes I, Q, and U time ordered information (TOI) (Demodulation technique)

III. Subtraction of the atmospheric emission in Stokes I

IV. Correction of the intensity-to-polarization leakage

V. Projection of cleaned TOI into Stokes I, Q, and U maps

Ritacco et al. 2017 A&A, 599, A34
NIKA polarimeter on the sky

Calibration and performance

Before leakage correction: ~3% peak-to-peak of instrumental polarization

After leakage correction: residual of 0.7% at 260 GHz and 0.6% at 150 GHz

NIKA sensitivity in polarization measured on a weak polarized point source

<table>
<thead>
<tr>
<th>Array</th>
<th>260 GHz</th>
<th>150 GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise Equivalent flux density (NEFD)</td>
<td>120 mJy.s$^{1/2}$</td>
<td>50 mJy.s$^{1/2}$</td>
</tr>
</tbody>
</table>
NIKA polarimeter on the sky

Calibration and performance

Selected sample of point sources: comparison with other recent observations and quasi-parallel session of observation with XPOL/30m

Ritacco et al. 2017
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NIKA polarimeter on the sky

GALACTIC STAR FORMING REGION: ORION OMC-1 is the closest site of OB star formation.

260 GHz

Stokes I

KL nebula

Very organized magnetic field topology with field lines mostly oriented to the integral-shaped filament

150 GHz

Stokes I

Stokes Q

Stokes U

Depolarization effect

Ritacco et al. 2017
A&A, 599, A34
NIKA polarimeter on the sky

Science verification

EXTRAGALACTIC OBSERVATIONS: Cygnus A is a typical radio galaxy with twin jets of plasma emanating from its nucleus and forming two extended radio lobes.

Ritacco et al. 2017
A&A, 599, A34

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Crab nebula polarization observations

First high angular resolution observation in polarization at 150 GHz

- Supernova remnant, synchrotron emission powered by the central pulsar through its jet
- Most intense polarized source in the microwave sky at angular scales of few arc-minutes
- Polarization angle expected to be constant over a frequency range 30-300 GHz

Outstanding questions:

- Polarization Spectral Energy Distribution (SED) not defined at high and intermediate frequencies
- Previous polarization observations at 90 GHz (Aumont et al. 2010) have shown that the polarization properties vary from small to large angular scales
Crab nebula polarization observations

High angular resolution observations at high frequencies are needed to understand the variation of the polarization properties

Polarization vectors, indicating both the degree and the orientation, are over-plotted on I map where $I_{POI} > 3\sigma$.

~ 2.7 hours of observation - sky opacity $\tau$: 0.1-0.3
Crab nebula observations

Varying from small to large scales

Integrating over 5' to compare with CMB experiments

Expressed in Galactic coordinates

A calibrator for CMB experiments
Crab nebula observations

A calibrator for CMB experiments

- Polarization angle constant at arcmin scales between 23-217 GHz with a value of $\psi = -88.1 \pm 0.3$ deg
- Strong case for a constant polarization degree below 217 GHz. Averaged value: $p = 6.96 \pm 0.02\%$
- Polarization angle and degree at the pulsar position and peak position consistent within $1\sigma$ error with high angular resolution experiments as XPOL, SCUPOL and POLKA.

Ritacco et al. 2017b submitted to A&A
Crab nebula observations

Spectral Energy Distribution

Planck data: oscillating behavior

WMAP data: consistent with a single power law model $I_v = A(v/1\text{GHz})^{\beta}$.

- best-fit parameters for WMAP only data:
  \[ A = 78.9 \pm 7.8, \quad \beta_p = -0.35 \pm 0.03 \]

Spectral index in polarization consistent with the one found in total intensity flux.

Ref:
Macias et. al 2010
Ritacco et al. 2017b submitted to A&A
Crab nebula observations

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Spectral index in polarization

More data at mm wavelengths at higher frequencies are needed to better understand the trend showed by Planck data (e.g. NIKA2 @260 GHz)

Macias et al. 2010

Ritacco et al. 2017b submitted to A&A
Summary and Conclusions

1. NIKA Pathfinder polarization tests allowed us to choose the best configuration to transmit ~100% of the polarization through the NIKA2 polarimeter as well.

2. The science verification on extragalactic and galactic sources highlighted the potentiality of such a polarimeter.
   - Cygnus-A 1st observation in polarization at these wavelengths. Opposite directions of polarization vectors onto radio lobes as predicted by the literature;
   - Orion OMC-1 magnetic field lines morphology oriented to the filament. B dragged by large-scales converging material accreting along the filament onto the core.

3. CRAB nebula first high angular resolution polarization observations at 150 GHz.
   - Polarization angle constant (23-217 GHz) at arcmin scales with $-88.1 \pm 0.3$ deg;
   - First estimation of the spectral index in polarization $\beta_p = -0.35 \pm 0.03$. 
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NIKA2 POLARIMETER HAS JUST STARTED THE COMMISSIONING PHASE

Stay Tuned!
THANK YOU FOR YOUR ATTENTION!
Planck data (Planck collaboration 2016a) show a break at ~100 GHz neither consistent with previous results nor with an extra dust component.

Assuming a single power law of the form: $I_\nu = A(\nu/1\text{GHz})^\beta$

Best-fit model (cyan line) to the data ($\nu<100$ GHz) computed by $\chi^2$-minimization:

- $A = 980.6 \pm 0.7$, $\beta = -0.3151 \pm 0.0002$

Planck error bars very small.

Archeops - GISMO/30m - NIKA/30m consistent @ ~150 GHz within 1σ with a single power law model.

A break in the SED showing a extra dust component has been identified for $\nu>1000$ GHz (Macias et al. 2010; Gomez et al. 2012)

More data at mm wavelengths are needed to better understand the observed break of the SED (e.g. NIKA2 @260 GHz)