

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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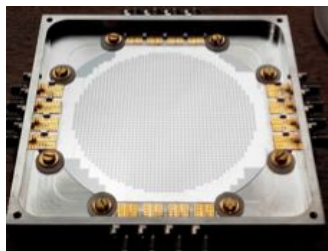
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NIKA2 camera & NIKA Pathfinder

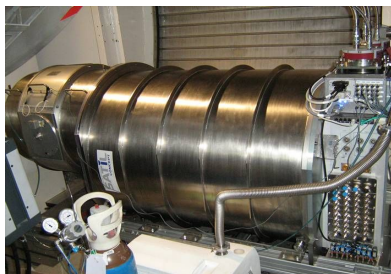
NIKA: New Iram Kinetic inductance detectors Array



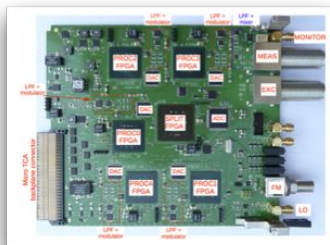
IRAM 30 m telescope



NIKA2 KID ARRAY
~ thousands of pixels



NIKA2 Dilution Cryostat
cooling down the KIDs at
~150 mK



Multiplexing readout electronics
~300 pixels per board

NIKA2 : 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

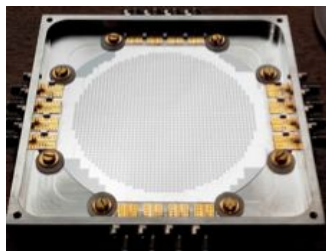
NIKA2 will probe the critical ~ 0.01-0.05 pc scales (~ 10''-60'' in the nearest clouds) at which magnetic field lines may channel the matter of interstellar filaments into growing dense cores.

NIKA2 camera & NIKA Pathfinder

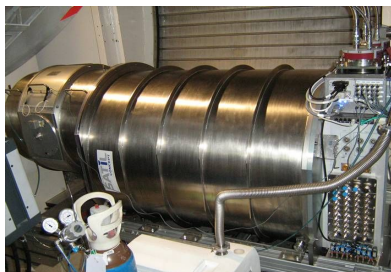
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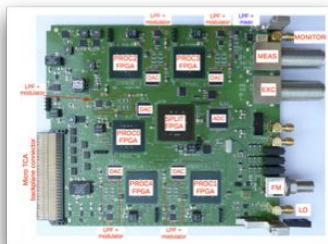
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NIKA

Pathfinder for NIKA2

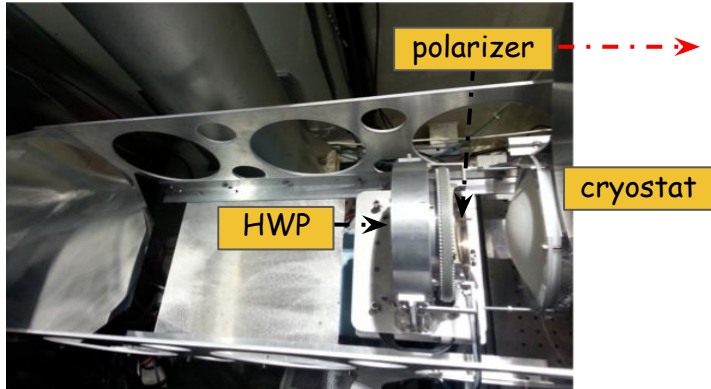
Operated at IRAM 30m telescope from 2012 to 2015

Field of View: 1.8 arcmin (356 valid detectors)

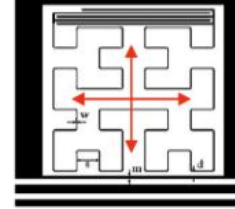
Polarization capability at 260 & 150 GHz

NIKA/NIKA2 Polarimeter

NIKA



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



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

Polarization **totally transmitted** through the HWP+Polarizer.

Polarization efficiency parameters estimated to:

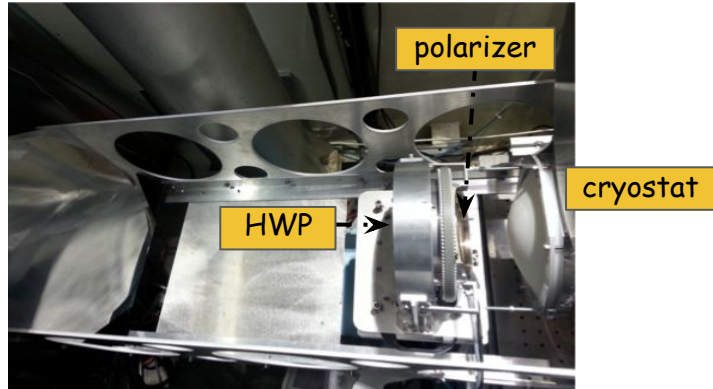
0.9956 \pm 0.0002 @260 GHz band

0.9941 \pm 0.0002 @150 GHz band

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

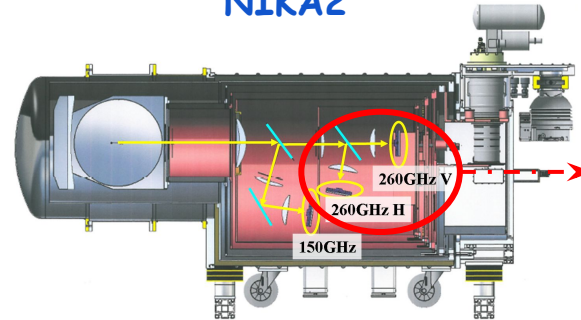
NIKA/NIKA2 Polarimeter

NIKA

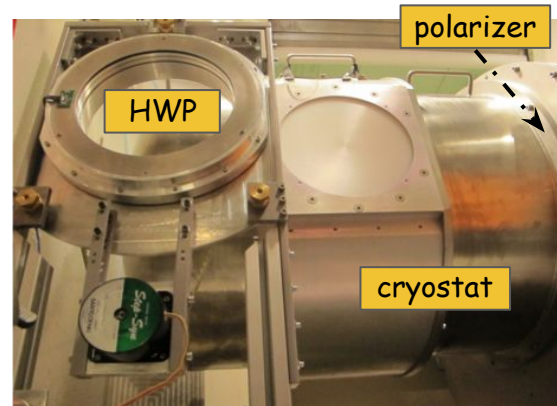


The continuous rotation of the HWP + polarizer + KIDs allows us to get a quasi-simultaneous measurement of the Stokes parameters I, Q, and U.

NIKA2



Two 260 GHz arrays to measure the two linear polarization components



The commissioning of the NIKA2 polarimeter started on June 2017

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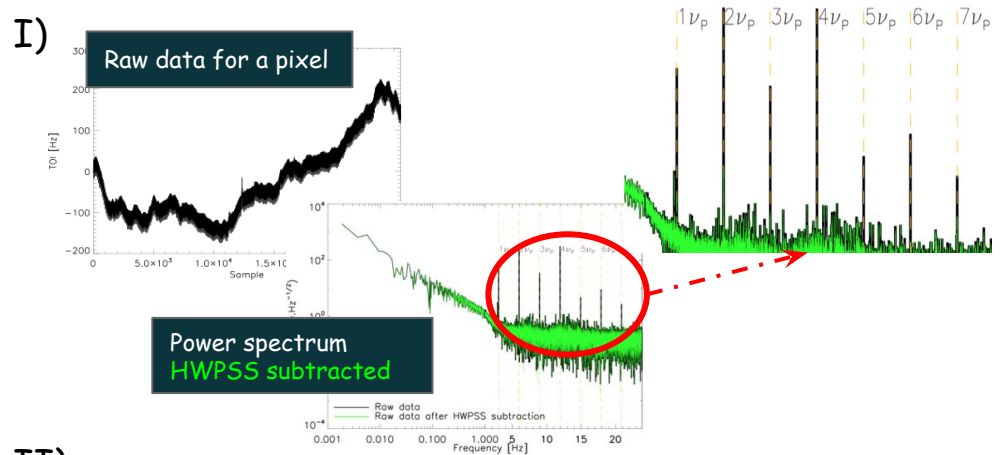
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NIKA polarimeter on the sky

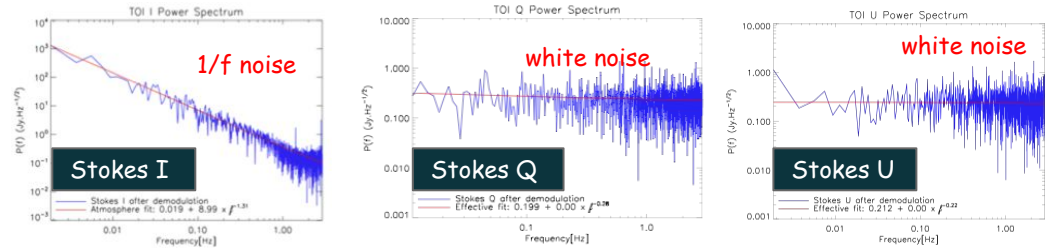
Broad-lines of the data analysis

- 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

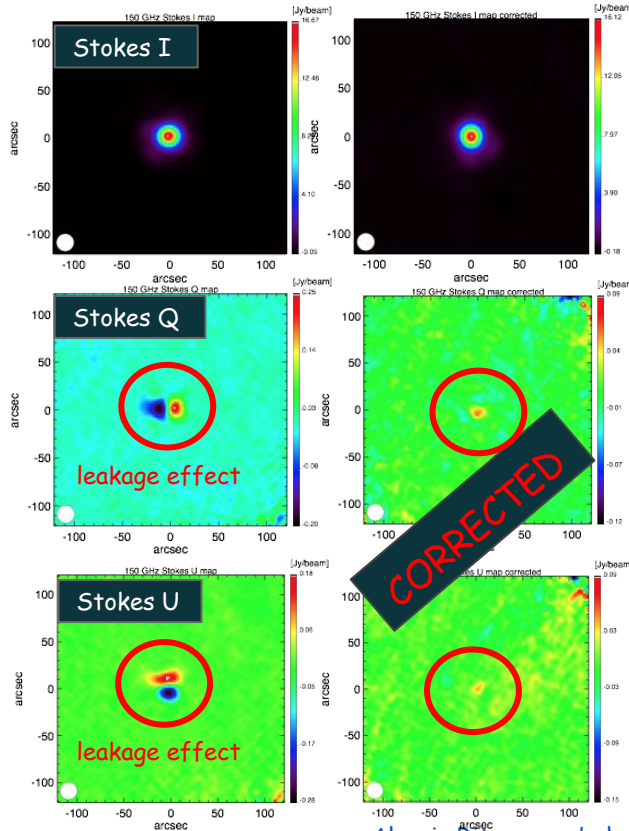


II)



III) + IV) + V)

URANUS



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

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

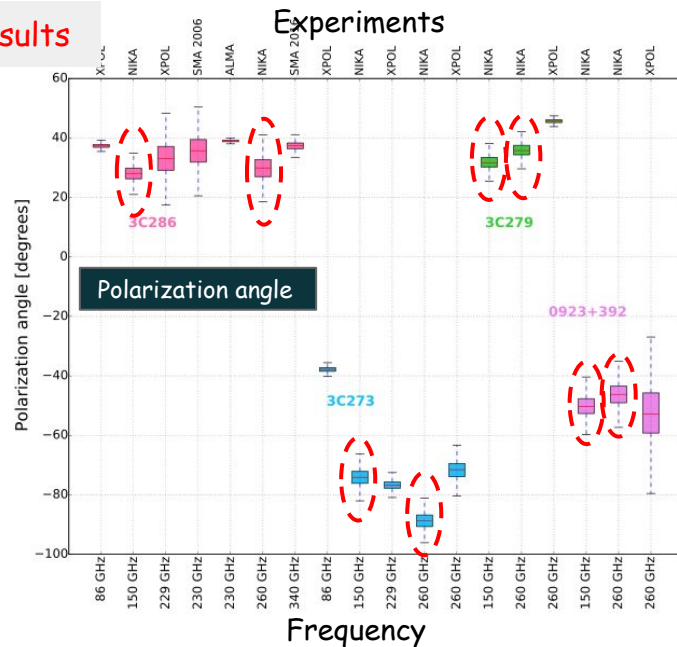
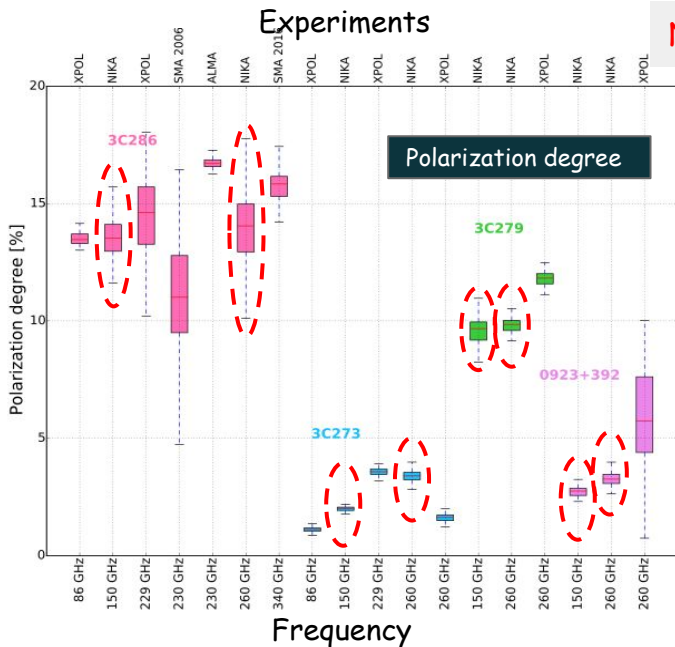
After leakage correction: residual of 0.7%
at 260 GHz and 0.6% at 150 GHz

NIKA sensitivity in polarization measured
on a weak polarized point source

Array	260 GHz	150 GHz
Noise Equivalent flux density (NEFD)	120 mJy.s ^{1/2}	50 mJy.s ^{1/2}

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

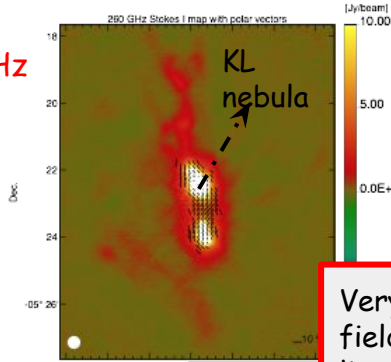
Ritacco et al. 2017
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GALACTIC STAR FORMING REGION: **ORION OMC-1** is the closest site of OB star formation.

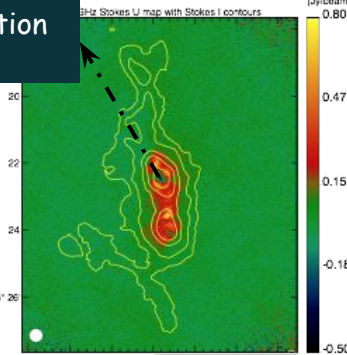
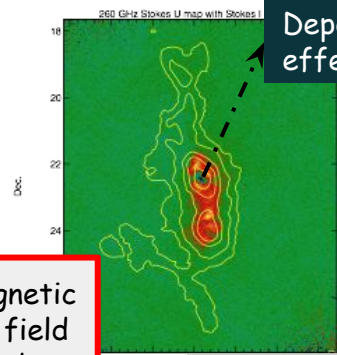
Ritacco et al. 2017
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260 GHz

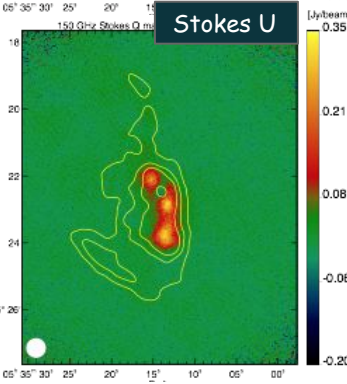
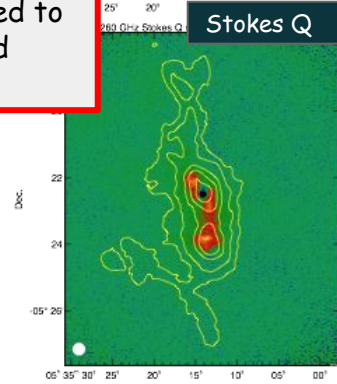
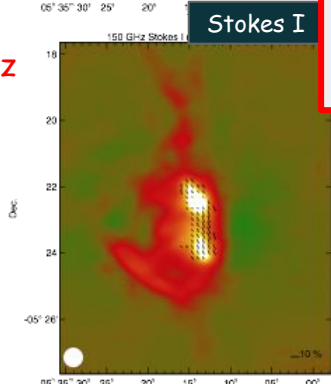


Very organized magnetic field topology with field lines mostly oriented to the integral-shaped filament

Depolarization effect



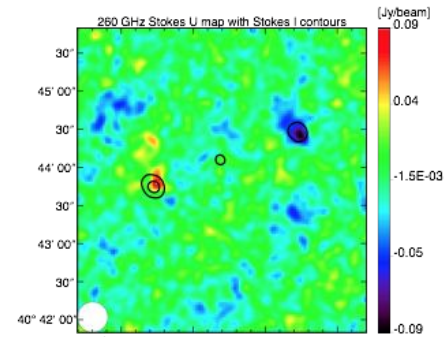
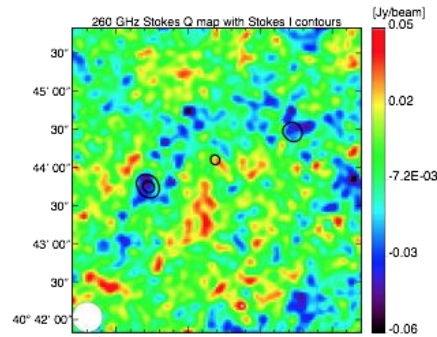
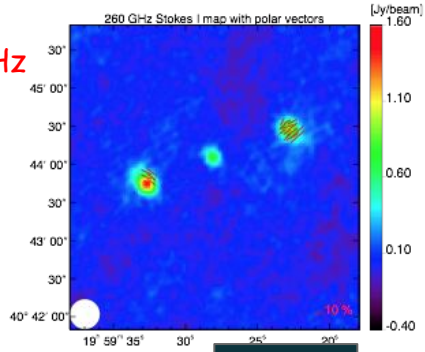
150 GHz



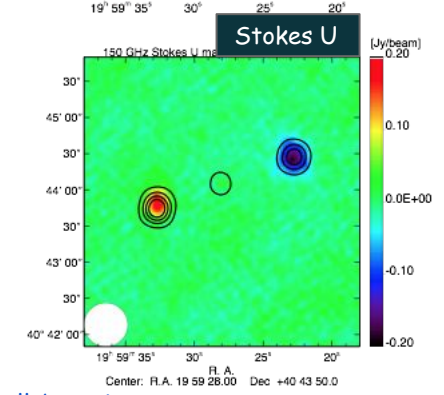
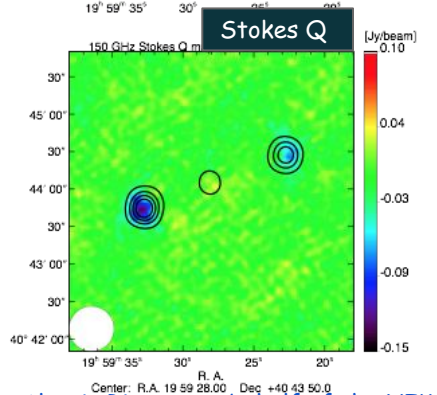
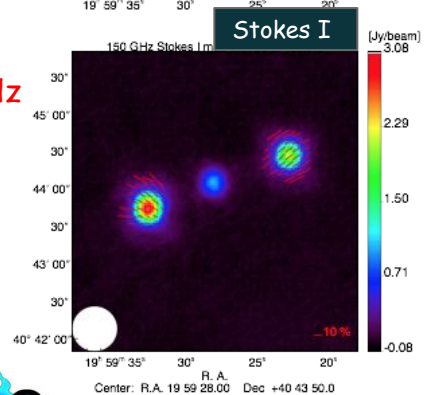
EXTRAGALACTIC OBSERVATIONS: *Cygnus A* is a typical radio galaxy with twin jets of plasma emanating from its nucleus and forming two extended radio lobes.

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

260 GHz



150 GHz



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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

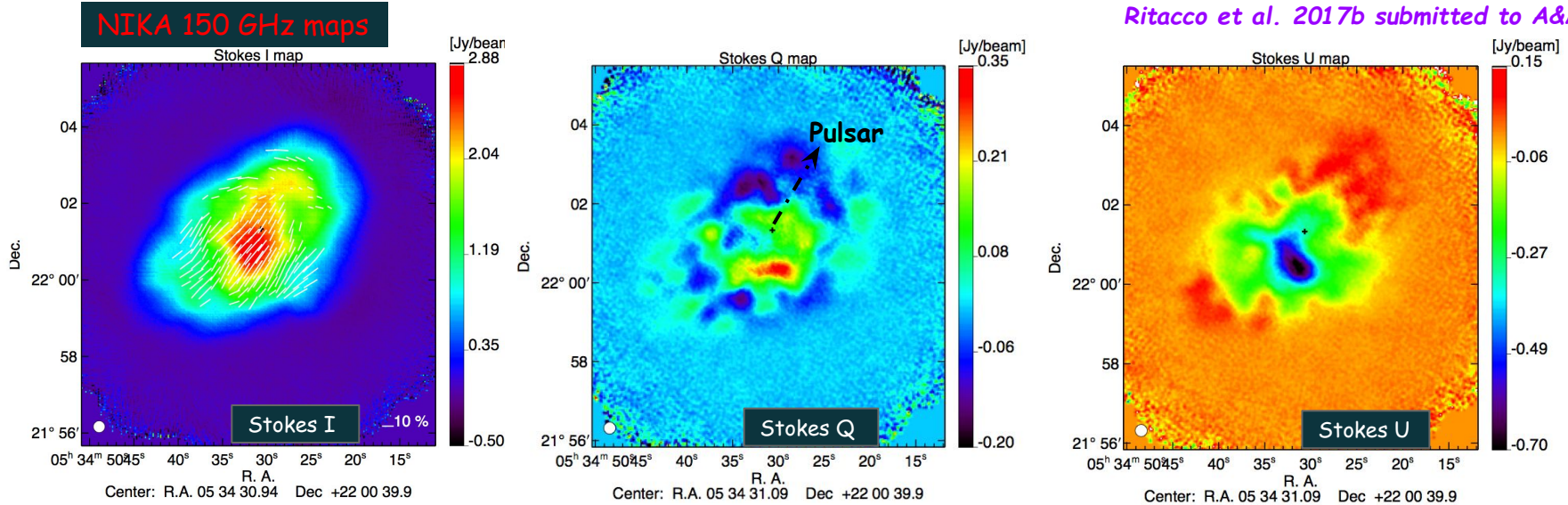
Outstanding questions:

- 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

Ritacco et al. 2016 JLTP, 184, 724
Ritacco et al. 2017b submitted to A&A

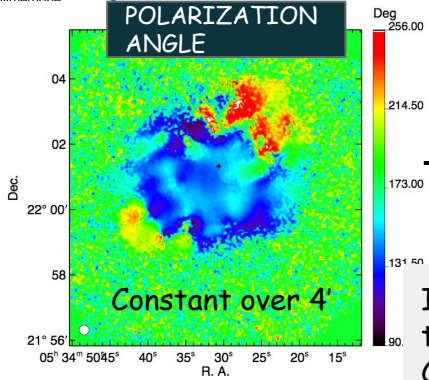


Polarization vectors, indicating both the degree and the orientation, are over-plotted on I map where $I_{POL} > 3\sigma$.

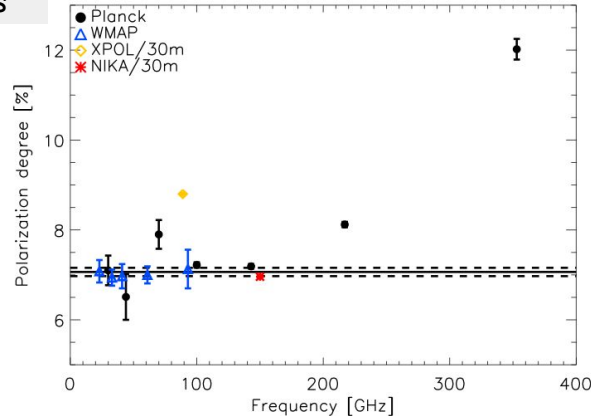
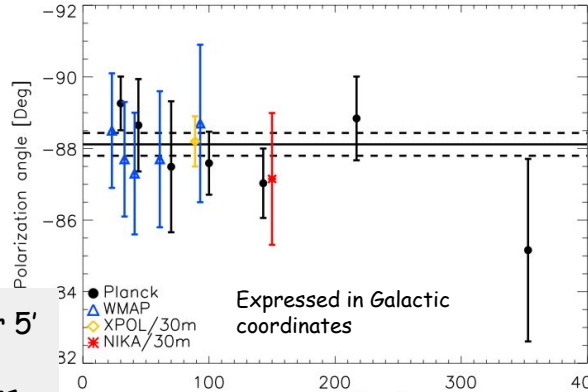
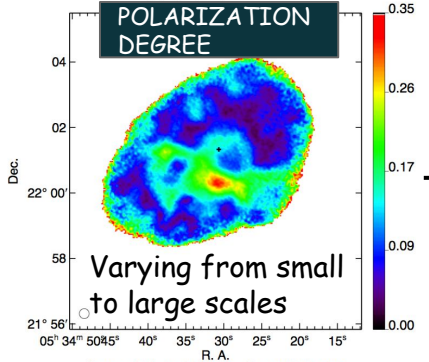
~ 2.7 hours of observation - sky opacity τ : 0.1-0.3

Crab nebula observations

A calibrator for CMB experiments

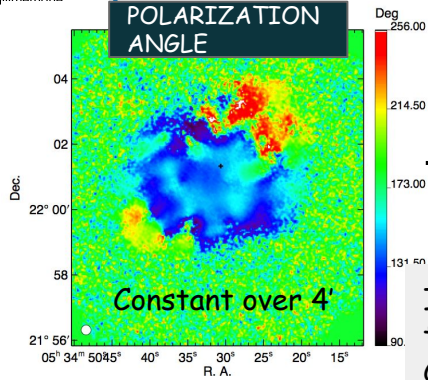


Integrating over 5' to compare with CMB experiments

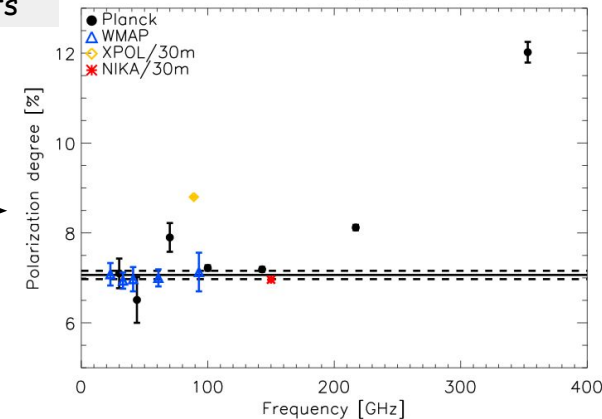
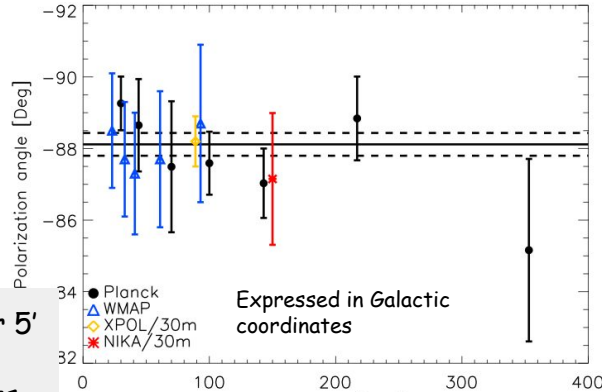
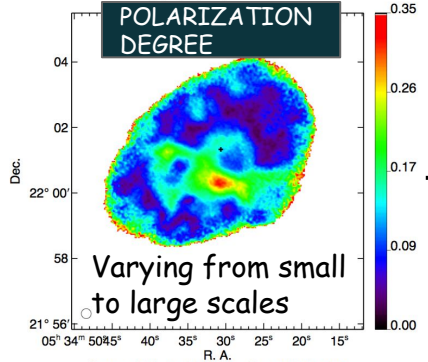


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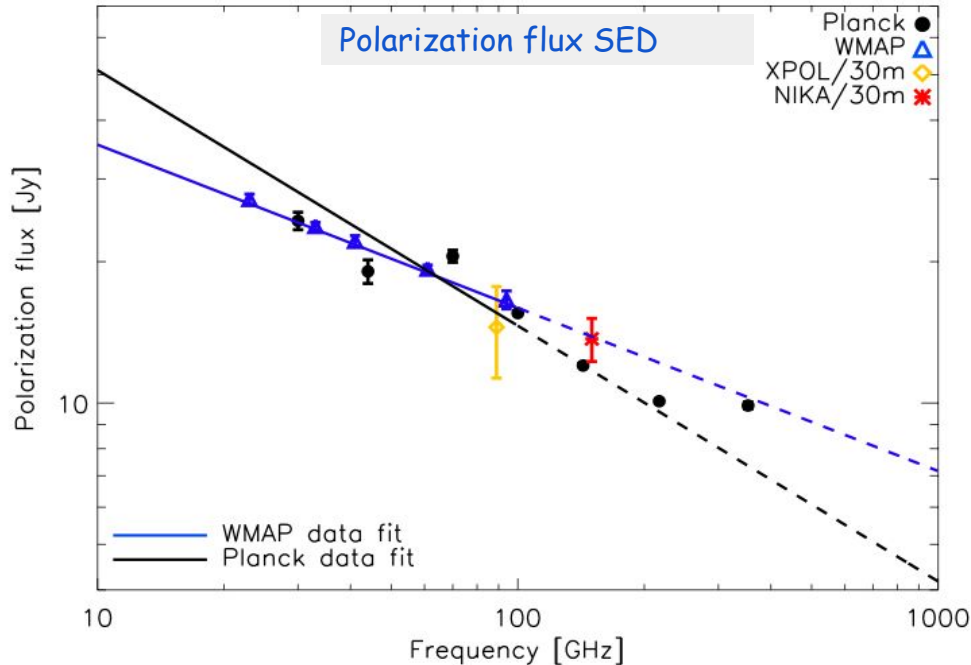


Integrating over 5' to compare with CMB experiments



- Polarization angle constant at arcmin scales between 23-217 GHz with a value of $\psi = -88.1 \pm 0.3 \text{ deg}$
- 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 1σ error with high angular resolution experiments as XPOL, SCUPOL and POLKA.

Ritacco et al. 2017b submitted to A&A



Planck data: oscillating behavior

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

- best-fit parameters for WMAP only data:

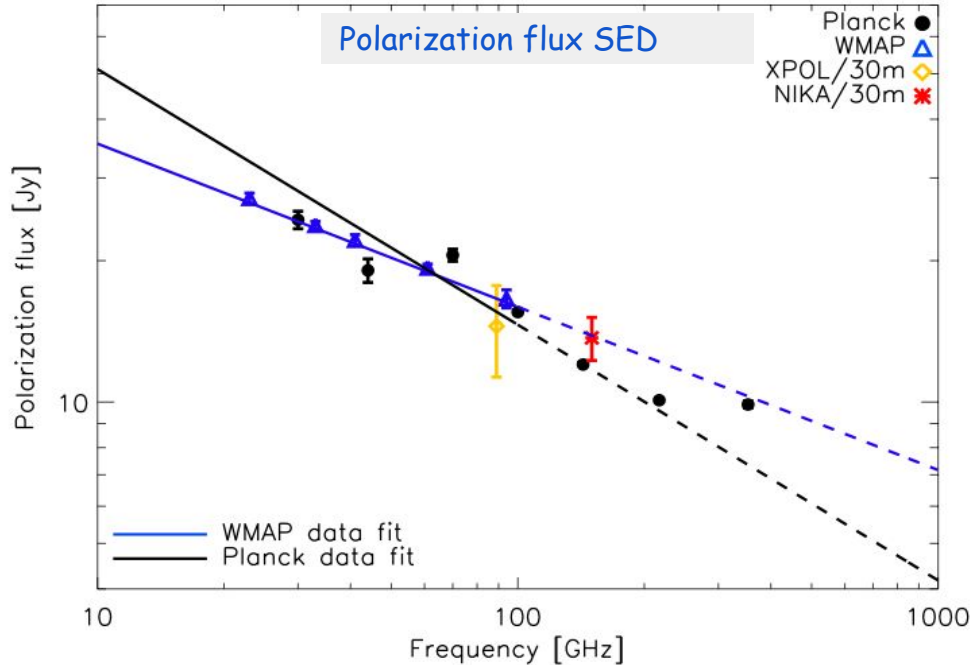
$A = 78.9 \pm 7.8$, $\beta_p = -0.35 \pm 0.03$, Spectral index in polarization

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



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

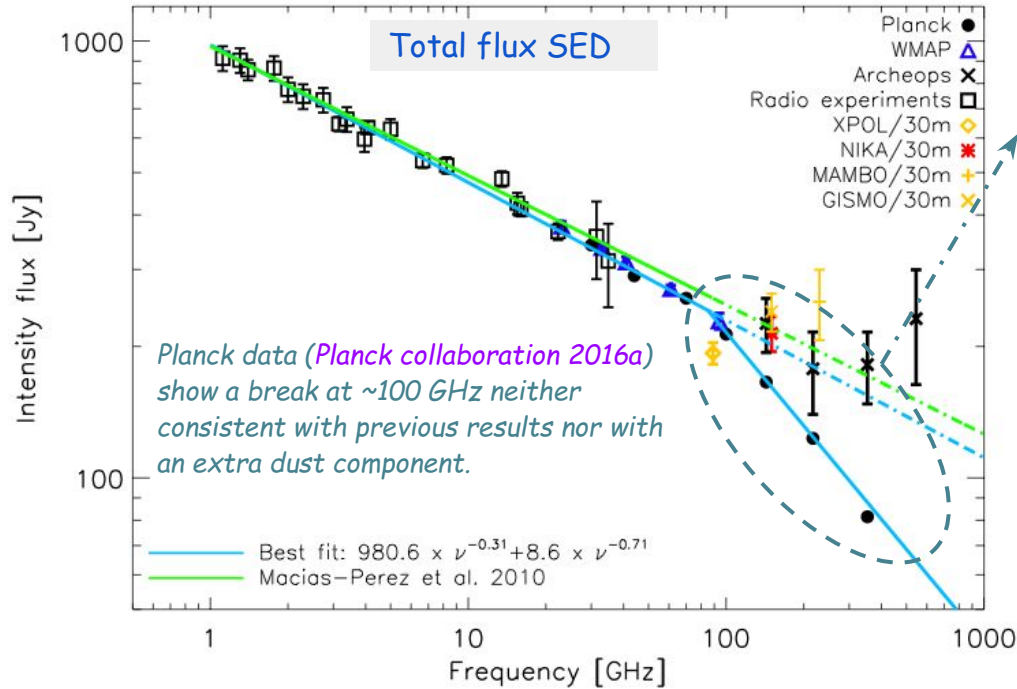
Stay Tuned!

THANK YOU FOR YOUR ATTENTION!



R. Adam, A. Adane, P. Ade, P. André, A. Andrianasolo, M. Arnaud, H. Aussel, I. Bartalucci, A. Beelen, B. Belier, A. Benoît, A. Bideaud, N. Billot, G. Blanquer, N. Boudou, H. Bourdin, O. Bourrion, A. Bracco, M. Calvo, A. Catalano, G. Coiffard, B. Comis, A. Cruciani, A. D'Addabbo, M. De Petris, J. Démoclès, F.-X. Désert, S. Doyle, E. Driessen, E. Egami, R. Evans, C. Ferrari, J. Goupy, O. Hahn, B. Hasnoun, I. Hermelo, C. Kramer, G. Lagache, S. Leclercq, J. P. Leggeri, J. F. Lestrade, J.-F. Macías-Pérez, G. Martínez-Aviles, J. Martino, D. Martizzi, A. Maury, S. Maurogordato, P. Mauskopf, F. Mayet, A. Monfardini, T. Mroczkowski, S. Navarro, F. Pajot, E. Pascale, L. Perotto, G. Pisano, E. Pointecouteau, N. Ponthieu, G. W. Pratt, V. Revéret, M. Ricci, A. Rigby, A. Ritacco, L. Rodriguez, C. Romero, H. Roussel, F. Ruppin, G. Savini, K. Schuster, A. Sievers, S. Triqueneaux, C. Tucker, H.-Y. Wu, M. Zemcov, R. Zylka





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 an extra dust component has been identified for $\nu > 1000$ GHz (Macias et. 2010; Gomez et al. 2012)

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 χ^2 -minimization:

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

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

Ritacco et al. 2017b submitted to A&A