

Polarisation with New IRAM KID Array (NIKA/NIKA 2)

Groupe: Planck/NIKA

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Séminaire doctorants

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IRAM 30 meter



OVERVIEW

1. Scientific context
2. NIKA2 instrument
3. Polarisation
4. NIKA prototype
5. Perspectives and conclusions

Polarisation at millimetre wavelengths

COSMOLOGY

Measurement of CMB
polarisation B-modes
predicted by inflation

**Next generation of
satellite**

TECHNOLOGY

Reduce photon noise
increasing number of
detectors : **matrix of
detectors**

New technology:
KIDs

ASTROPHYSICS

- Galactic magnetic fields
- Star formation

NIKA/NIKA 2

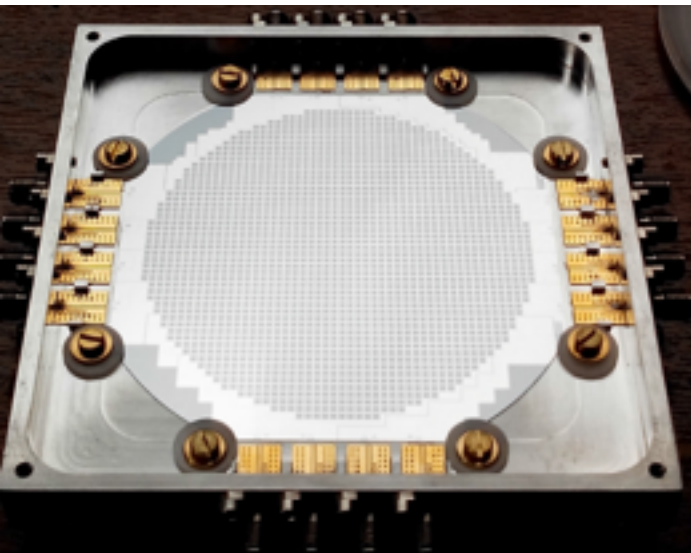
High resolution dual
bands camera installed
at IRAM 30 m
telescope with Kinetic
Inductance Detectors
KIDs

NIKA 2 : dual band camera with Kinetic Inductance detectors



Dilution Cryostat ≈ 100 mK

Bands : 1.25 & 2.14 mm
Beam (FWHM) : 12 '' & 17 ''
Detectors : 2x2000 & 1000
Field of view: 6.5 arc-minutes
Sensitivity : 30 & 20 mJy s^{1/2}



Scientific large program guaranteed :

Clusters of galaxies via the Sunyaev Zel'dovitch effect

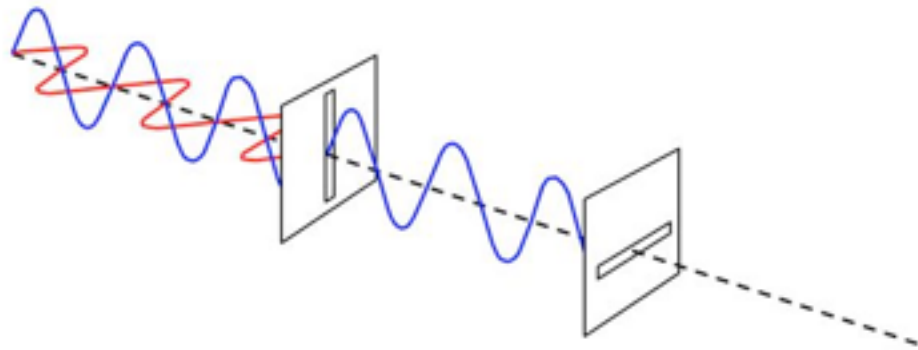
Deep surveys

Mapping the interstellar medium

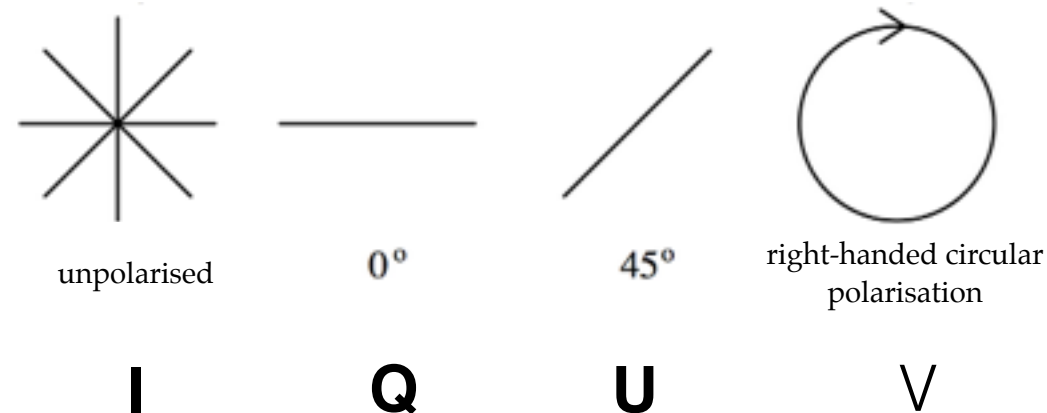
Nearby Galaxies

Polarisation measurements of Galactic regions

Polarisation



Defining the directions of light propagation in terms of electric field using Stokes formalism:



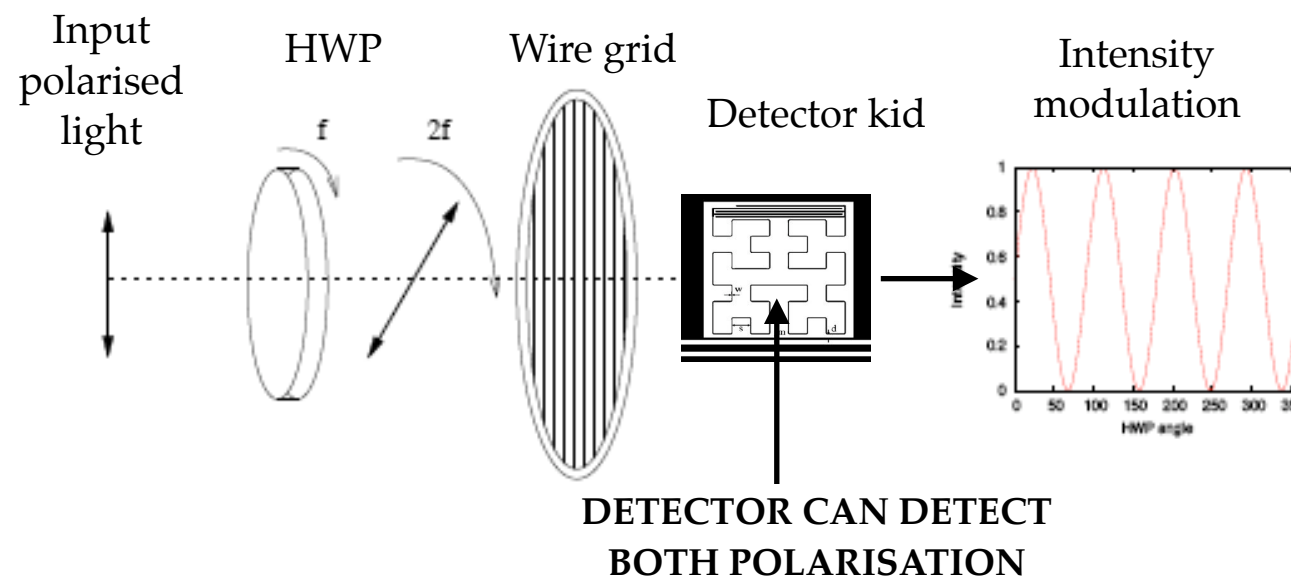
$$\left. \begin{aligned} I &= E_{0x}^2 + E_{0y}^2 \\ Q &= E_{0x}^2 - E_{0y}^2 \\ U &= 2E_{0x}E_{0y}\cos\delta \\ V &= 2E_{0x}E_{0y}\sin\delta \end{aligned} \right\} \begin{array}{l} \text{linear} \\ \text{polarisation} \end{array}$$

δ is phase difference
between $E_{0x}E_{0y}$

NIKA / NIKA 2 - - ► Measurement of I, Q, U

Polarisation with NIKA 2/NIKA

DETECTION STRATEGY : Rotating half wave plate + WIRE GRID



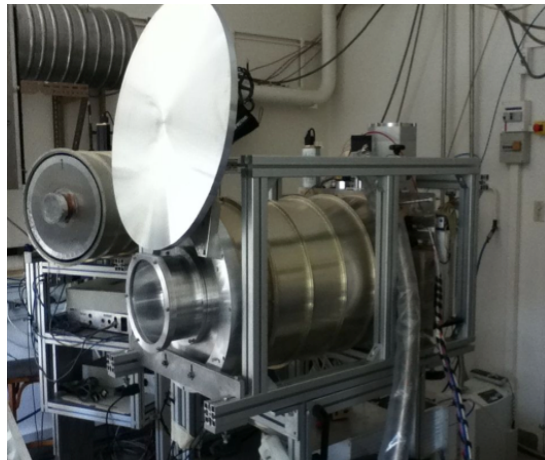
$$S = \frac{1}{2}(I + Q\cos 4\omega t + U\sin 4\omega t)$$

POLARISED SIGNAL MODULATED AT 4
TIMES THE ROTATIONAL FREQUENCY

WIRE- GRID : selects one direction of these
Modulating HWP : simultaneously measurement of I,Q,U

NIKA Prototype

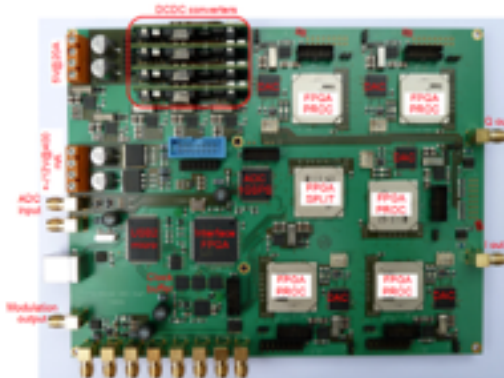
Dilution Cryostat ≈ 100 mK



Built at Néel

[[Monfardini et al 2010](#)]

The dedicated NIKEL
readout electronics



Made in LPSC

[[O. Bourrion et al 2012](#)]

Bands : 1.25 mm & 2.14 mm

Beam (FWHM) : 12 '' & 17''

Detectors : 224 & 132

Field of view: 2.2 arc-minutes

Sensitivity : 40 and 14 mJy s^{1/2}

**3 observational campaigns
open to public observations**

Scientific results :

“First observation of the thermal Sunyaev-Zel'dovich effect with kinetic inductance detectors”

[[Adam, Comis, Macias-Perez et al 2014](#)]

“ Pressure distribution of the high-redshift cluster of galaxies CL J1226.9+3332 with NIKA ”

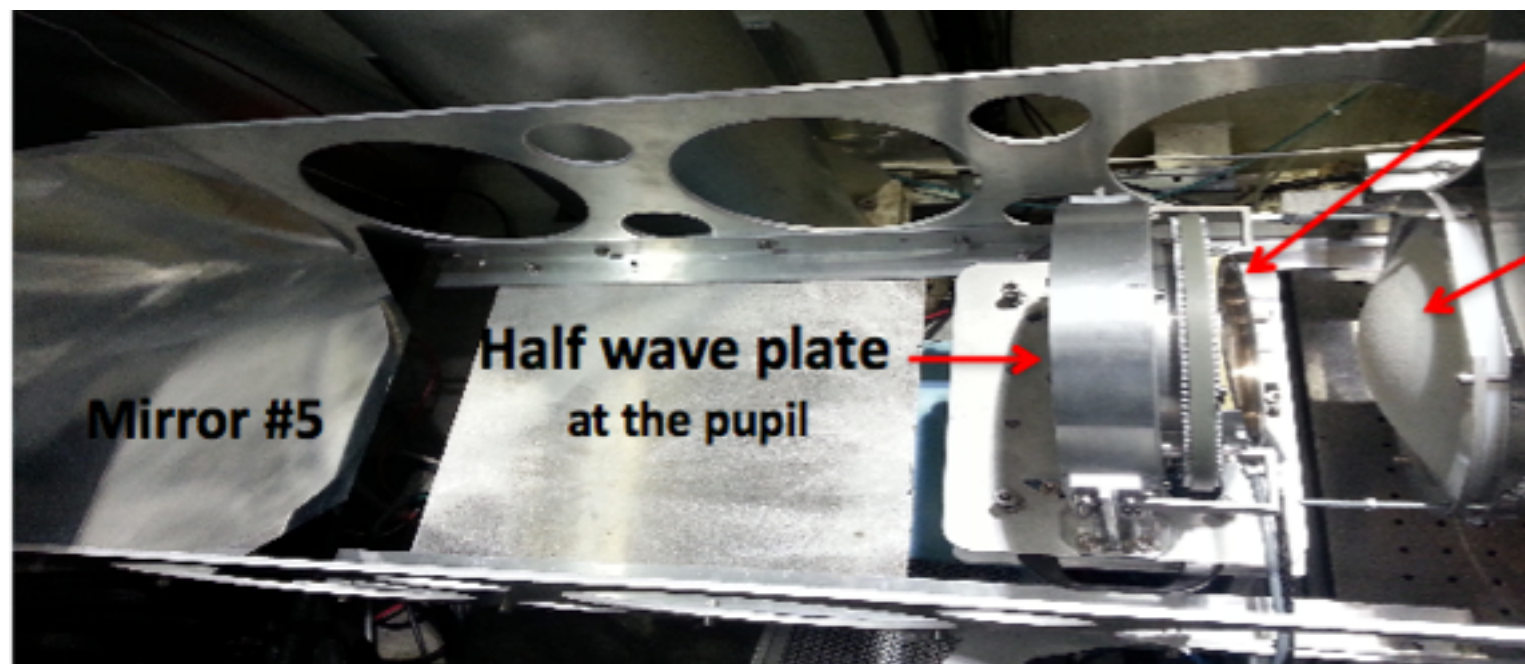
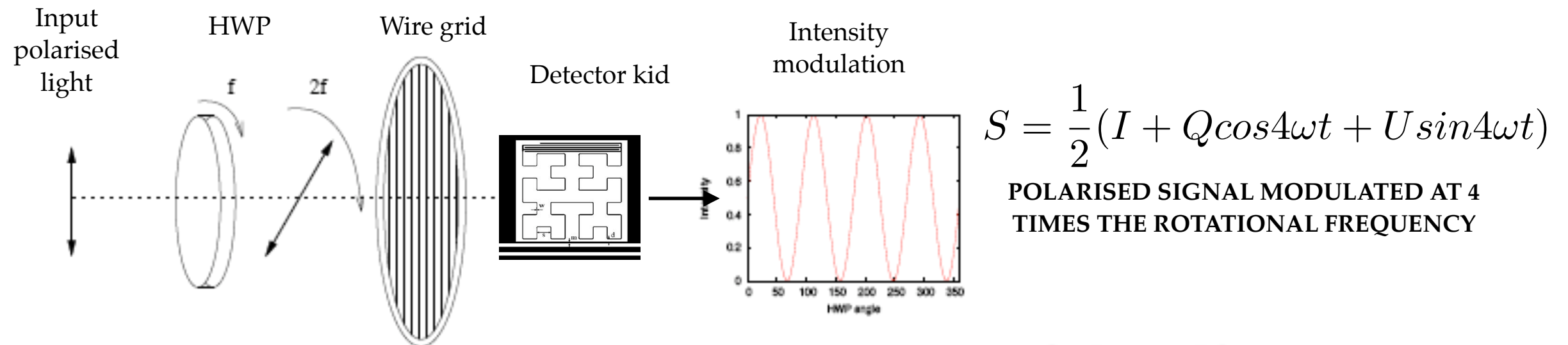
[[Adam, Comis, Macias-Perez, A.Ritacco et al 2014](#)]

“Performance and calibration of the NIKA camera at the IRAM 30 m telescope”

[[Catalano, Calvo, Ponthieu et al 2014](#)]

Polarisation with NIKA prototype

DETECTION STRATEGY: ROTATING HWP + WIRE GRID @ 300 K

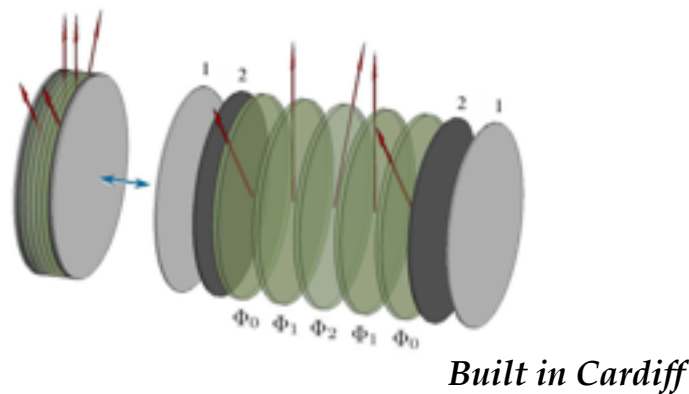


**Polariser grid
at 10 degrees
wrt optical axis**
**Cryostat
window**

First technical campaign January 2014

HWP characterisation

Achromatic HWP

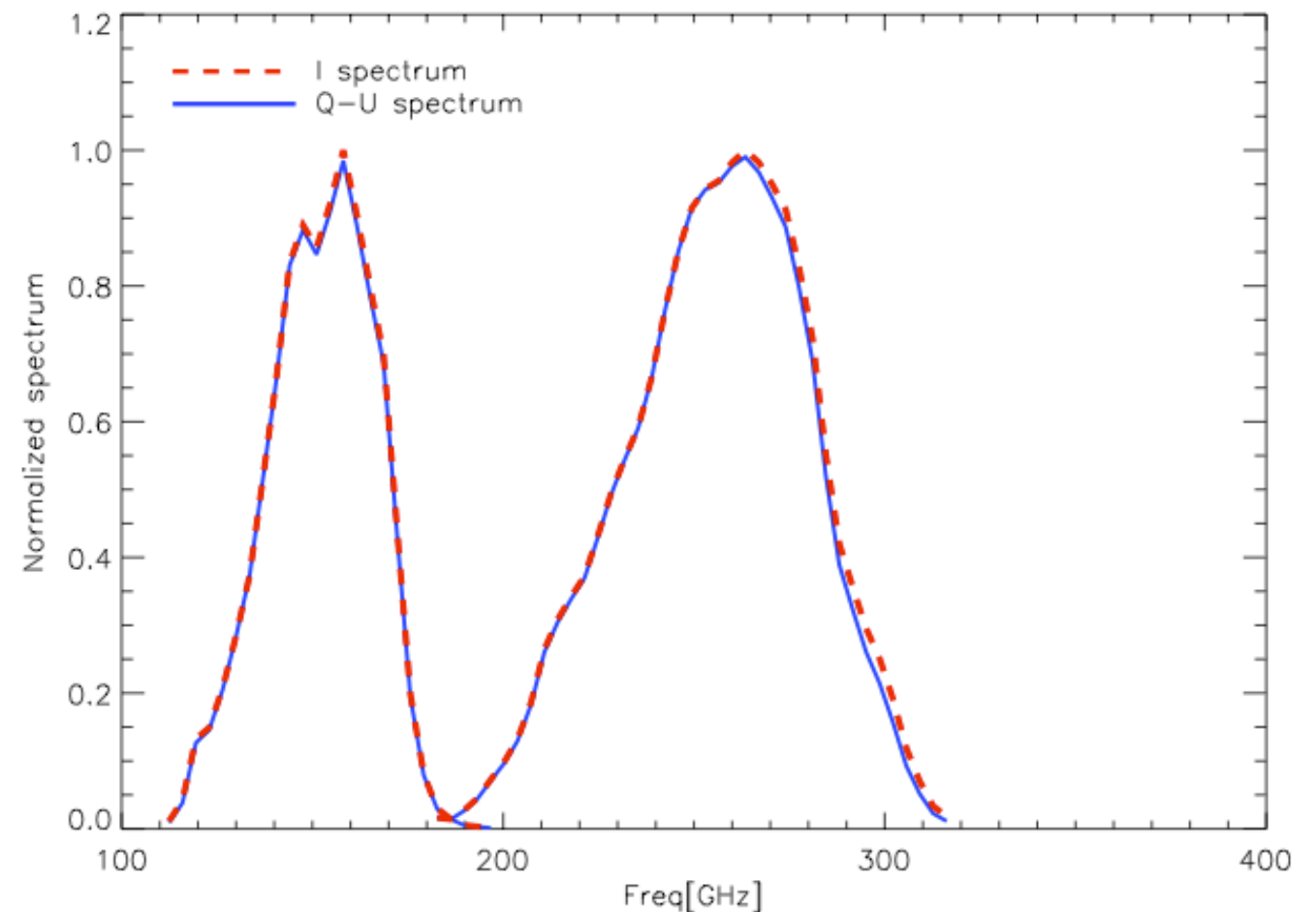


2 transmission axis :

n_e extraordinary axis

n_o ordinary axis

Optimised in the NIKA range of frequency



red line : NIKA intensity spectral bandpass

blue line : polarisation spectrum

Polarised light transmitted in a large range of frequency

This solution has been adopted for NIKA 2

Data analysis pipeline

Detection of the
signal

Subtraction
parasite signal

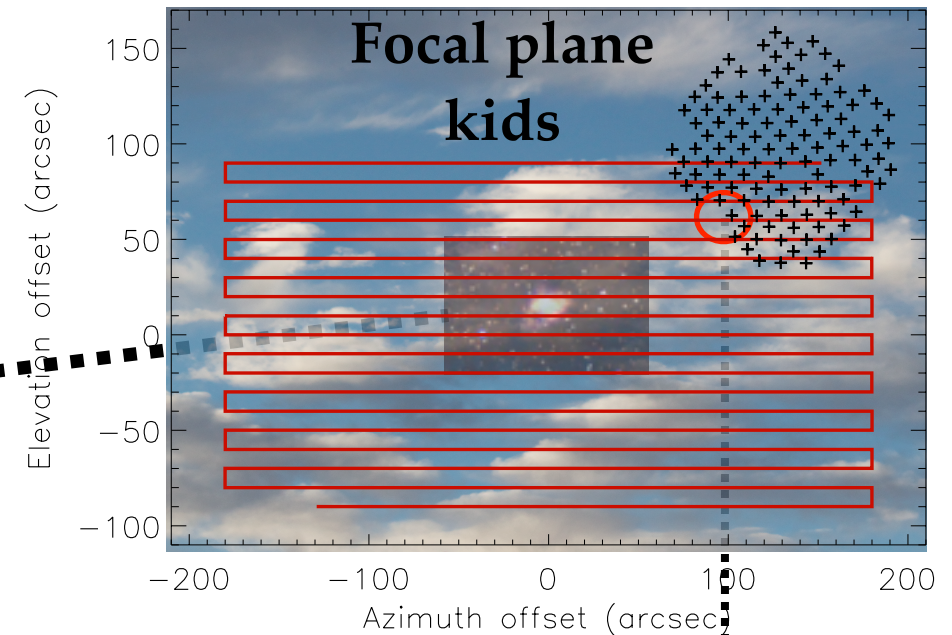
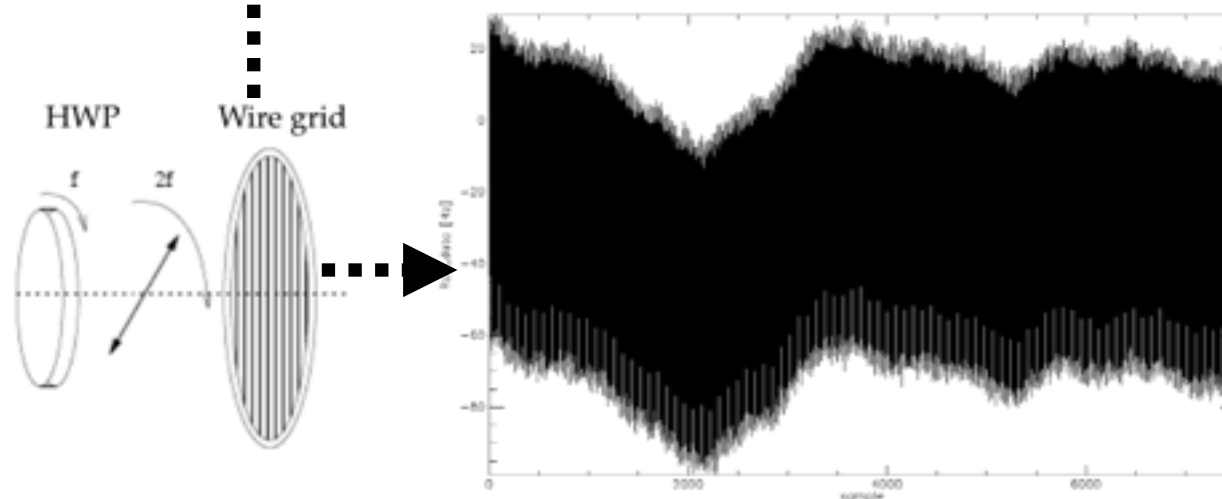
Demodulation
method

Noise de-
correlation

Projection on the
sky



RAW DATA



$$S = \frac{1}{2}(I + Q\cos 4\omega t + U\sin 4\omega t) + \text{parasite signal at HWP harmonics } (\omega t, 2\omega t, 3\omega t \dots)$$

Data analysis pipeline

Detection of the
signal

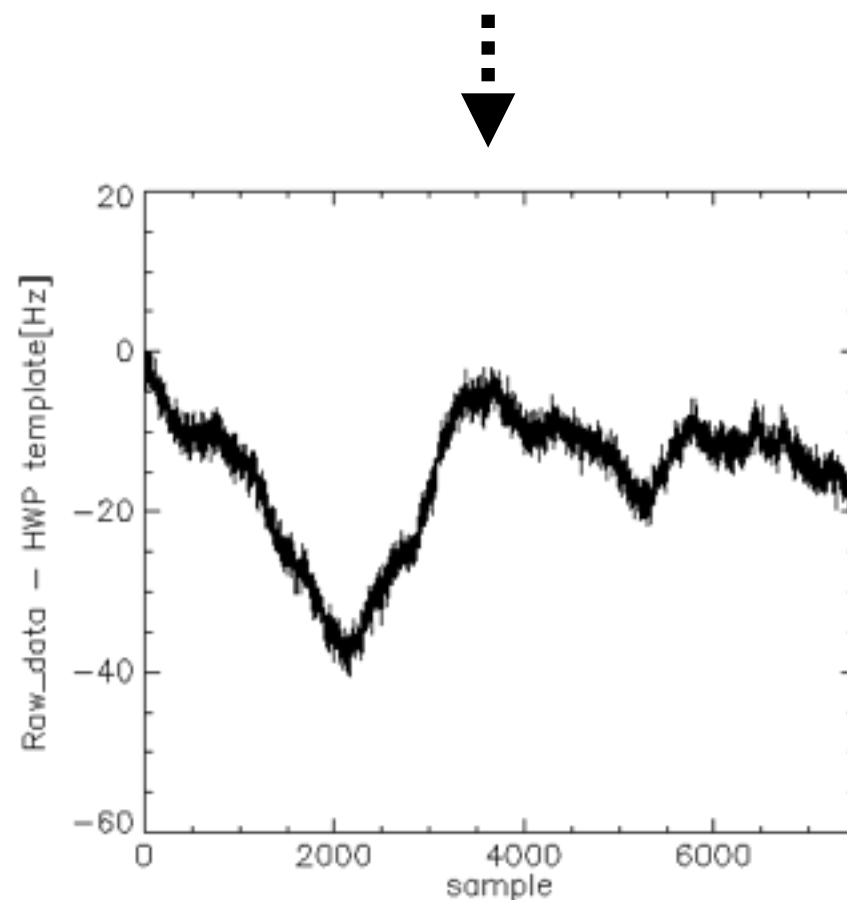
Subtraction
parasite signal

Demodulation
method

Noise de-
correlation

Projection on the
sky

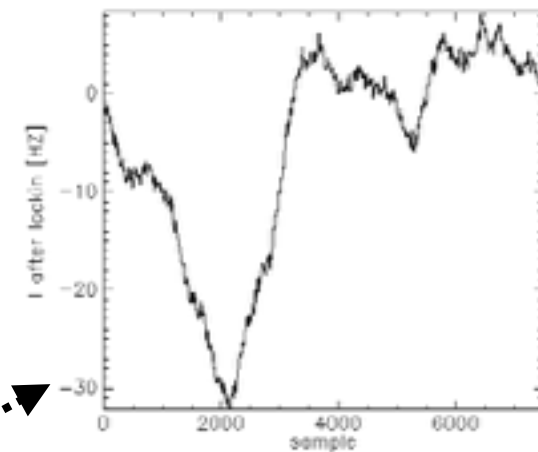
Subtraction parasite signal



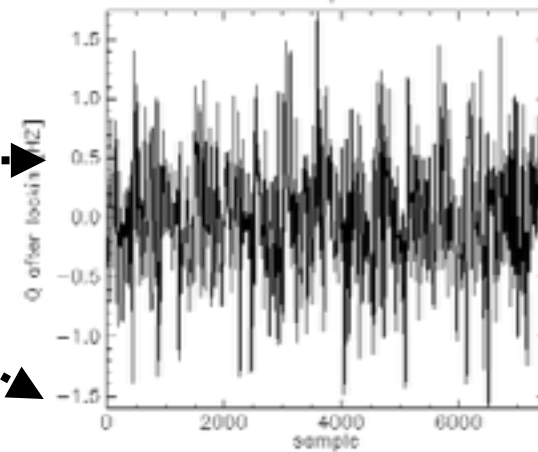
$$S = \frac{1}{2}(I + Q\cos 4\omega t + U\sin 4\omega t) + \text{parasite signal at HWP harmonics} \\ (\omega t, 2\omega t, 3\omega t \dots)$$

Demodulation

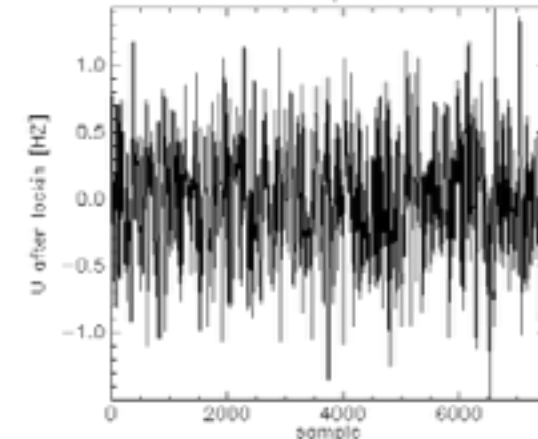
Polarised signal at $4\omega t$



I Stokes
parameter



Q Stokes
parameter



U Stokes
parameter

Data analysis pipeline

Demodulation ... Atmosphere subtraction ...

Projection
on the sky

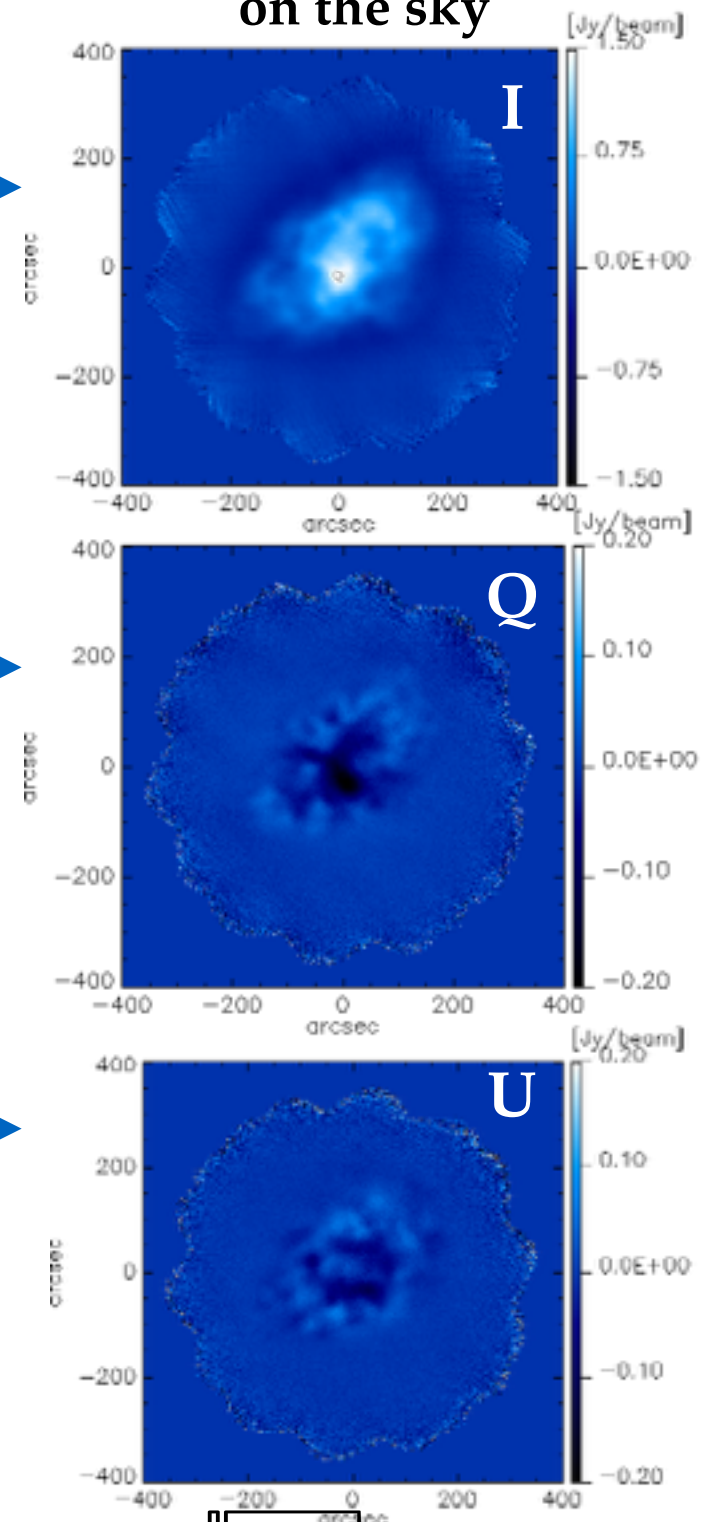
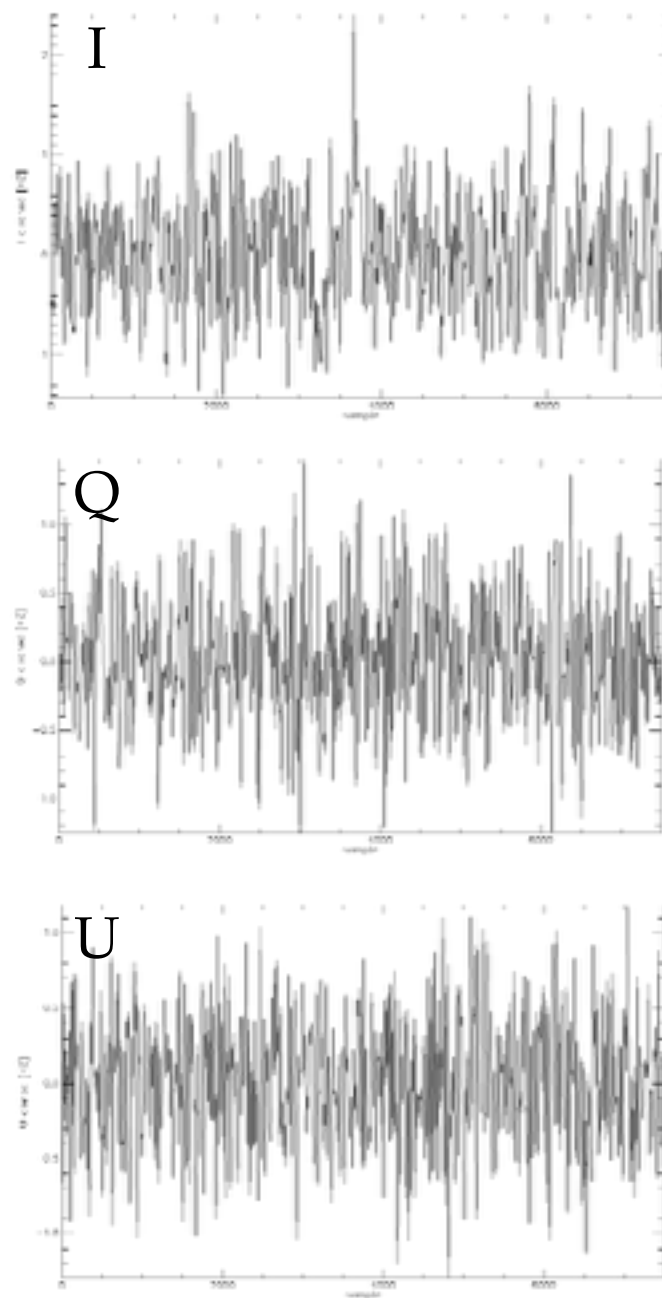
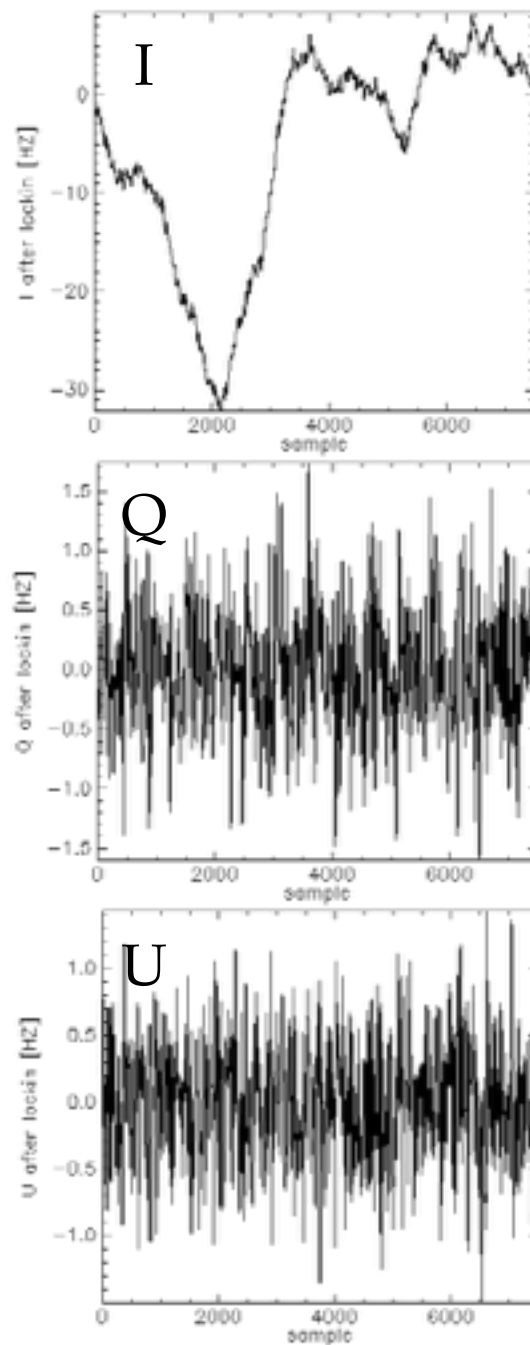
Detection of the
signal

Subtraction
parasite signal

Demodulation
method

Noise de-
correlation

Projection on the
sky



Goals:

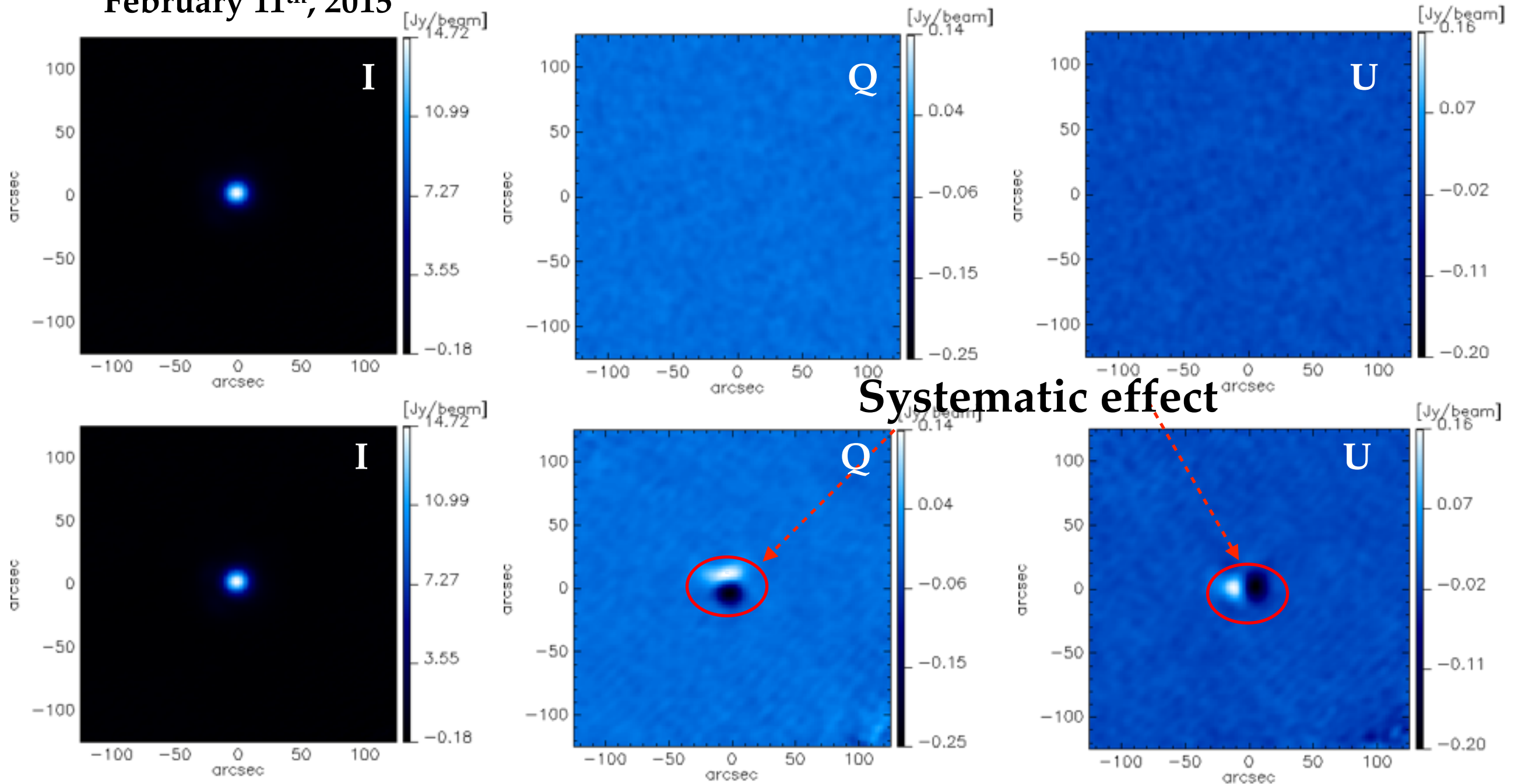
1. Study instrumental polarisation
2. Calibration in polarisation angle

HOW?

1. Planets: unpolarised sources
2. Quasars: polarised radiogalaxies
Extended known sources

Instrumental polarisation? Planets

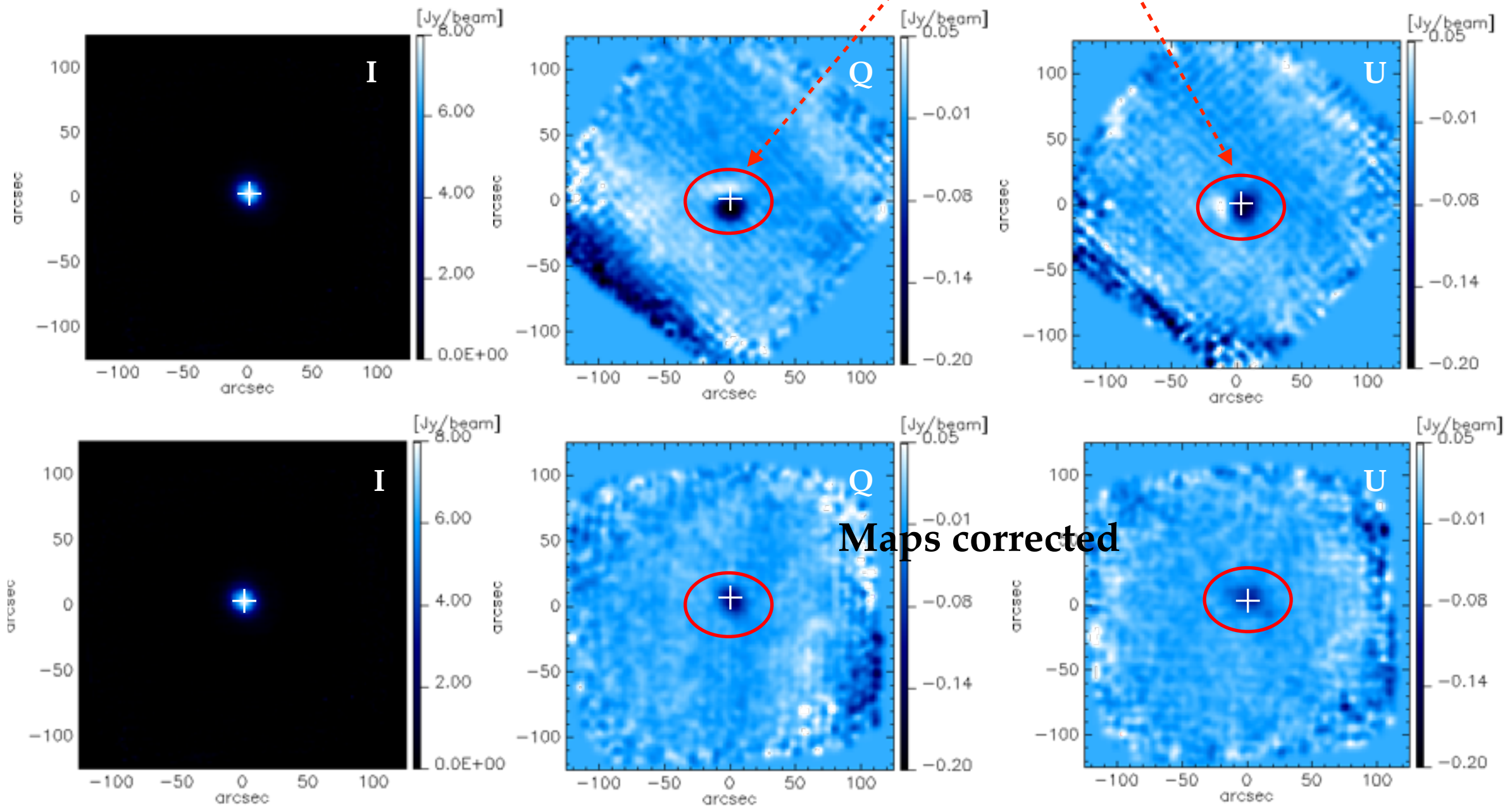
Uranus @ 2mm
February 11th, 2015



Template of the $I \rightarrow P$ leakage effect

Systematic effect correction: quasar example

3C273 @ 2mm
February 17th, 2015



Good subtraction of the systematic signal

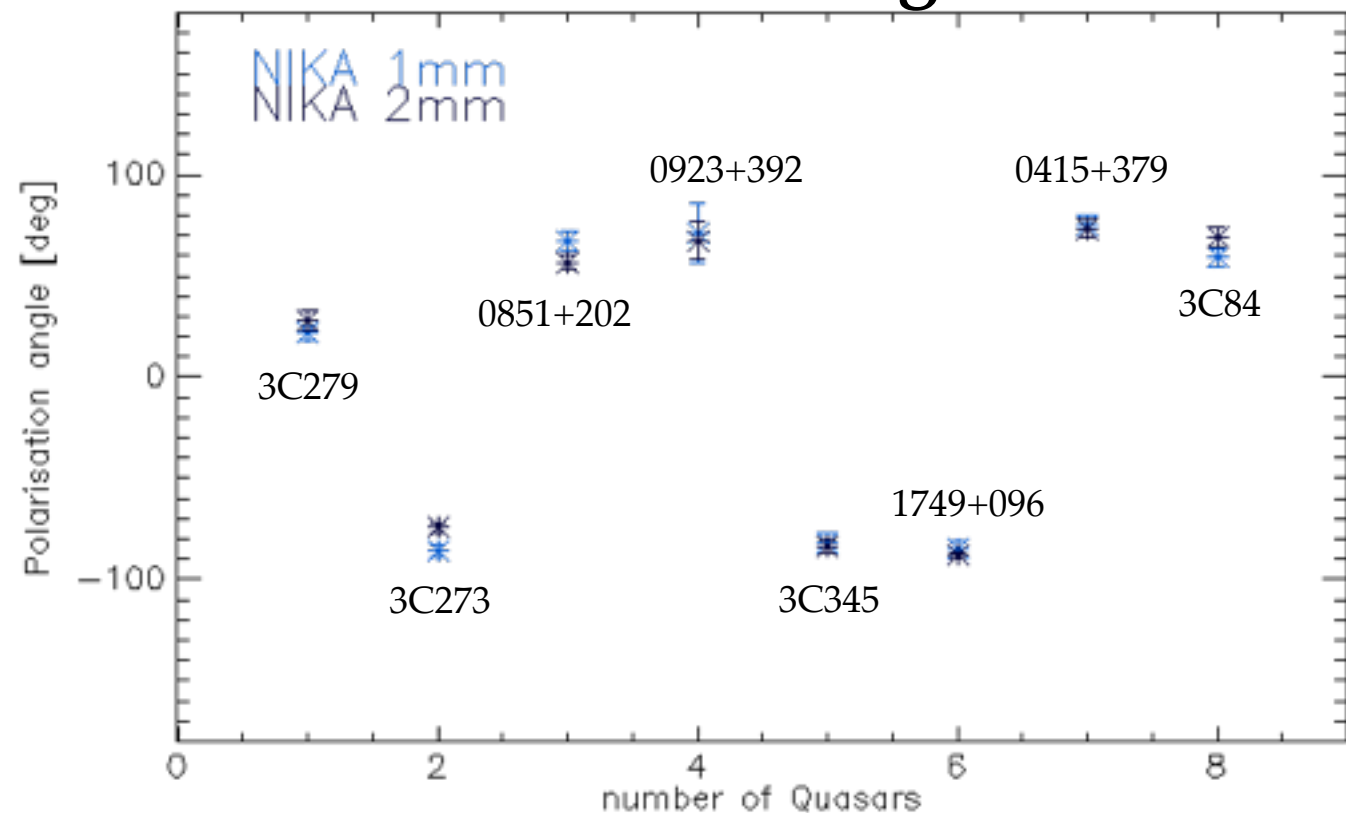
Results of last observational campaign: February 2015

Following the quasar movement on the sky

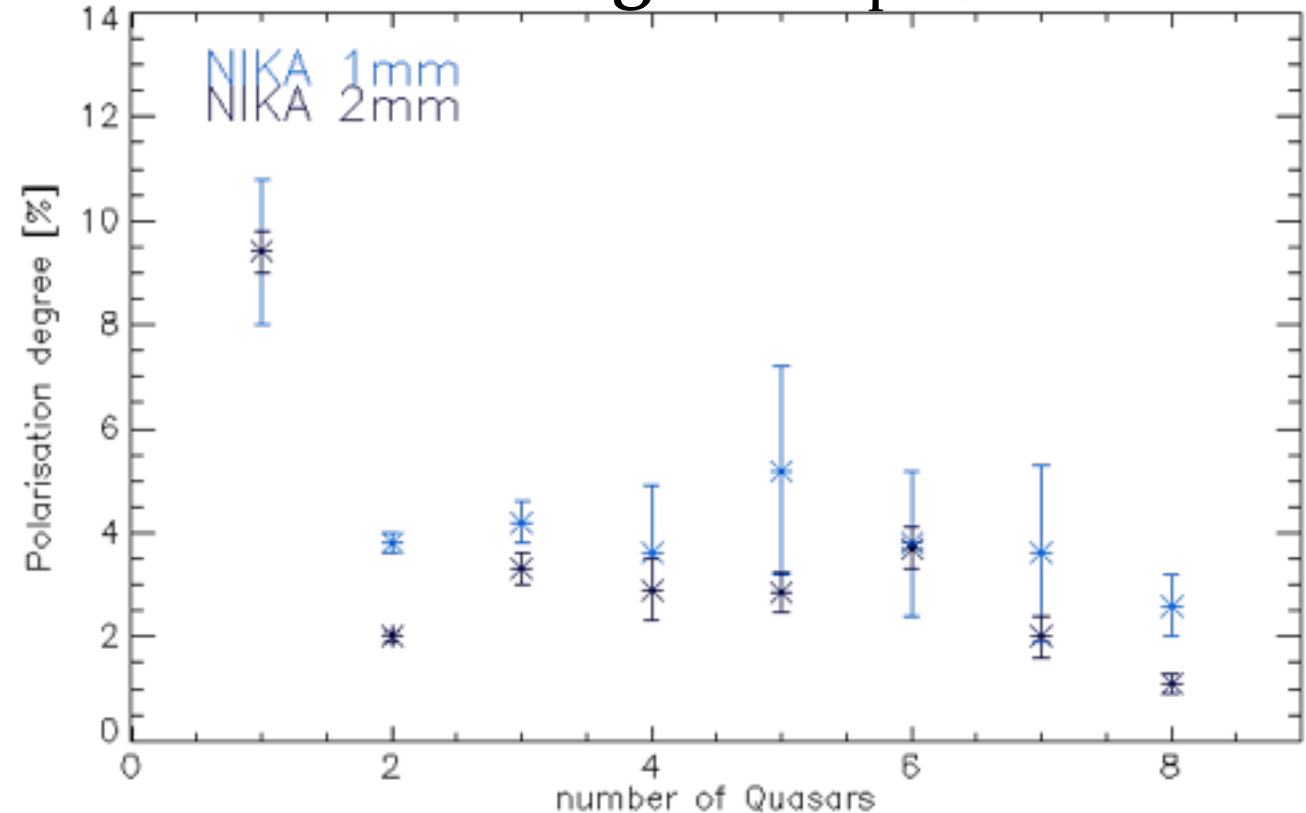


We expect unchanged values of polarisation intensity and angle

Polarisation angle



Pol degree = I_{pol} / I

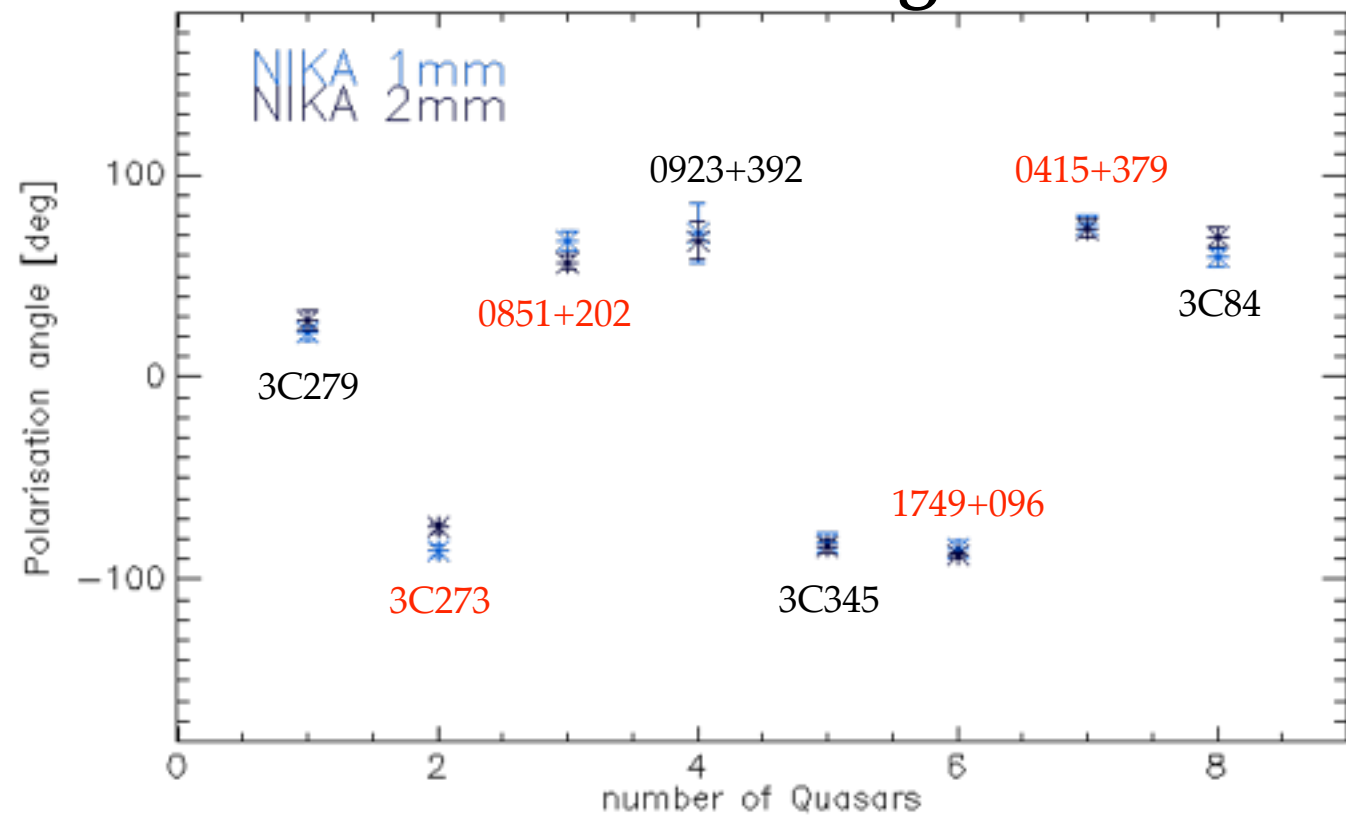


Agreement between the two NIKA bands

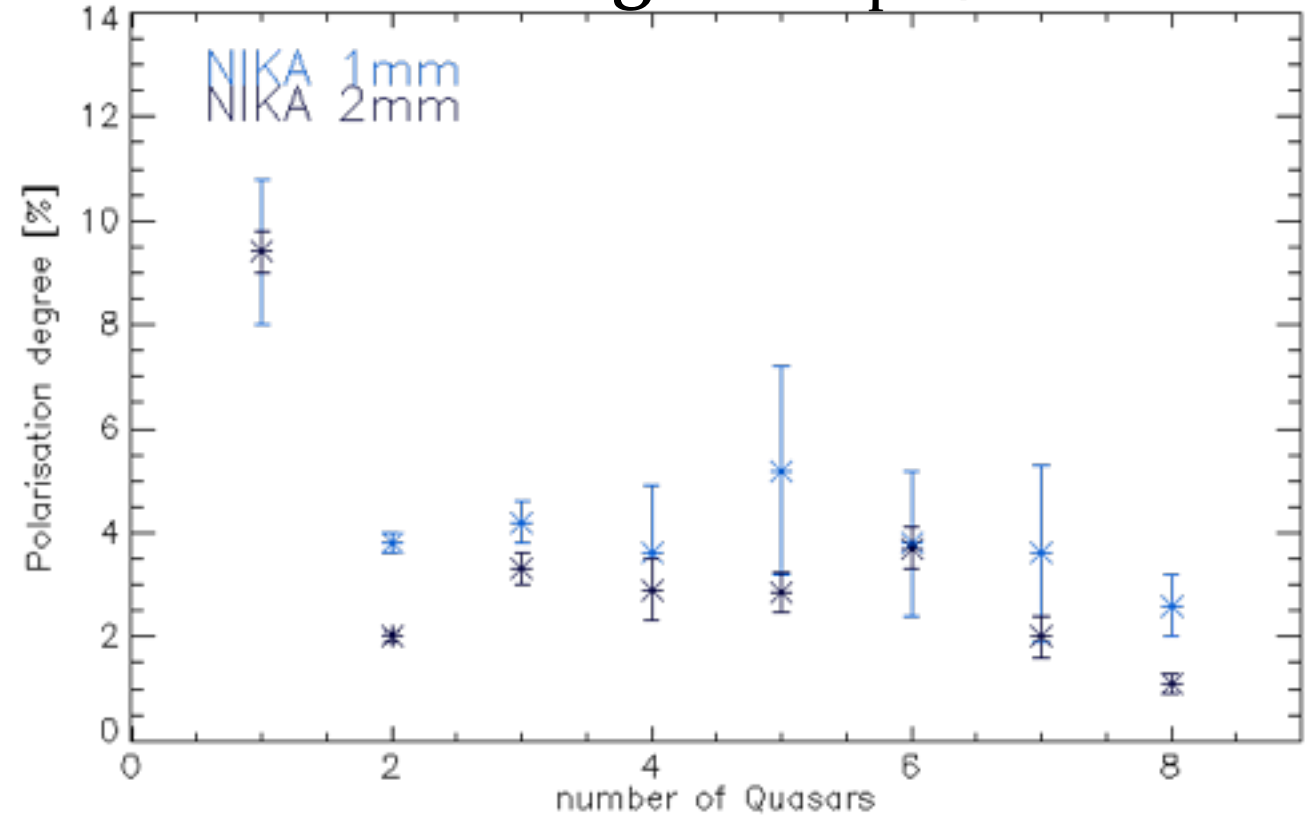
Results of last observational campaign: February 2015

NIKA - XPOL cross calibration

Polarisation angle



Pol degree = I_{pol} / I

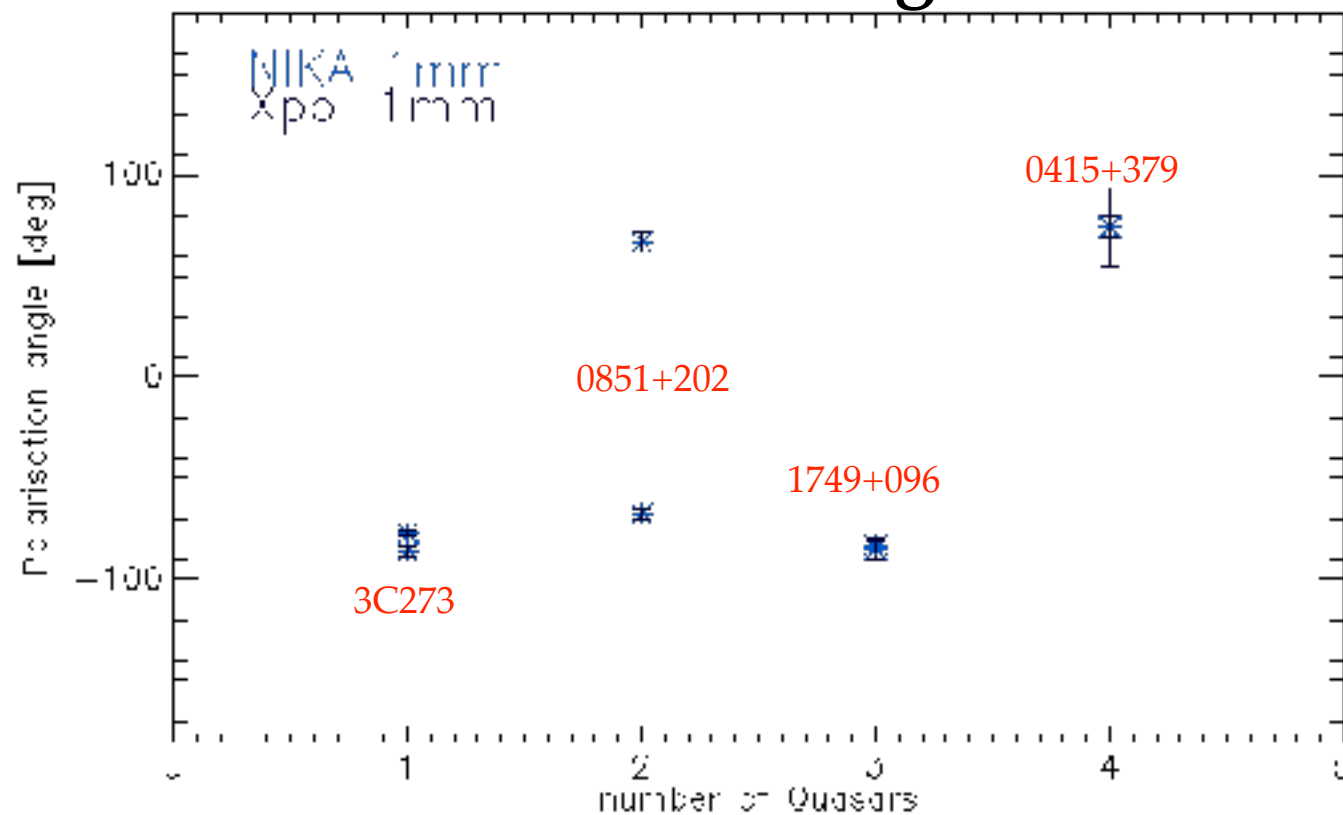


Agreement between the two NIKA bands

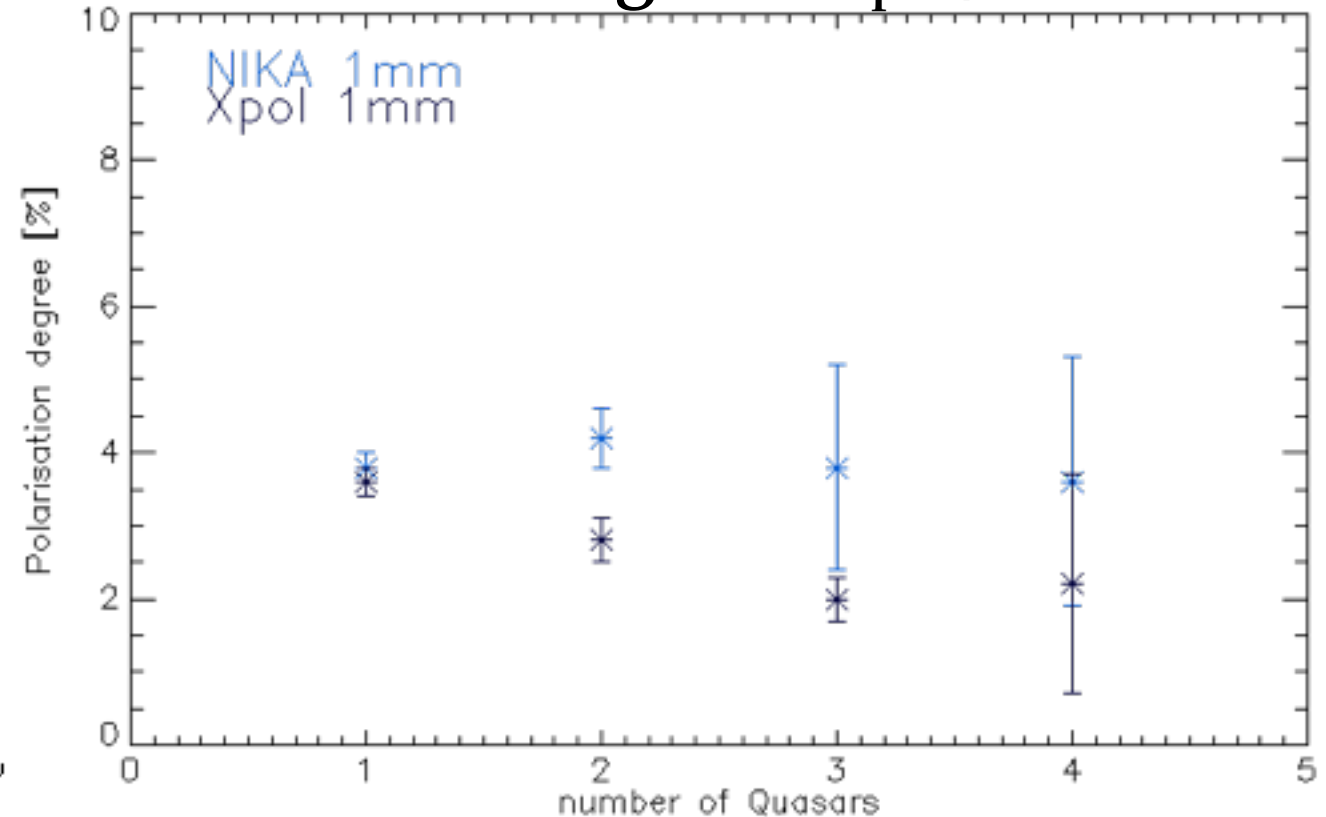
Results of last observational campaign: February 2015

NIKA - XPOL cross calibration

Polarisation angle



Pol degree = I_{pol} / I



Promising @ 1mm between NIKA & XPOL

EXTENDED SOURCES OBSERVED

1. Study the systematic effect
2. Apply the correction and complete the calibration

WORK IN PROGRESS

Observations:

ORION OMC -1

GALAXY M87

DR21OH

CYGNUS-A

CRAB NEBULA

KNOWN CALIBRATION SOURCE



CRAB NEBULA
visible light

SUPERNOVA REMNANT THAT EMITS
A HIGHLY POLARISED SIGNAL



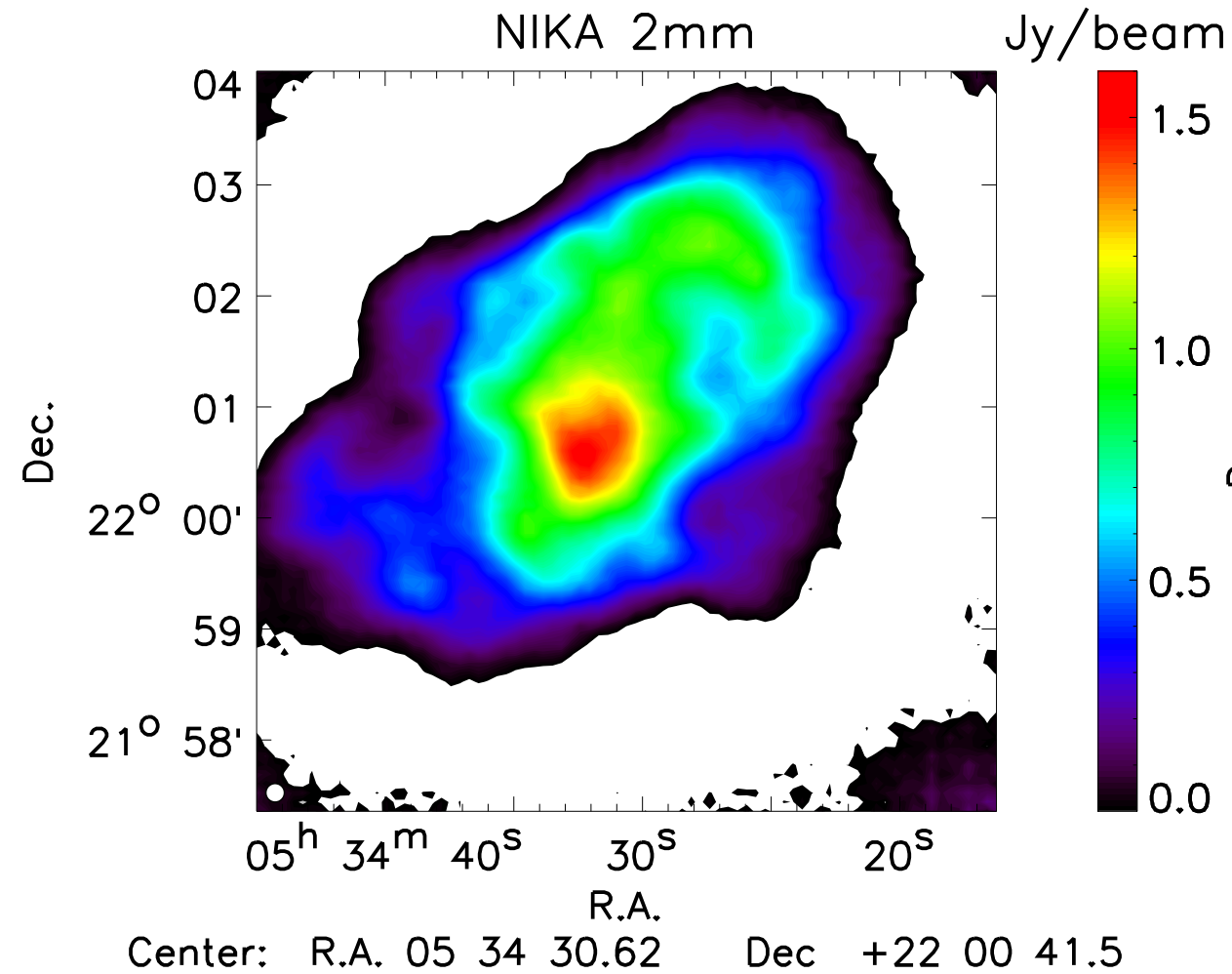
Synchrotron emission of the central pulsar
Its interaction with the surrounding gas

KNOWN CALIBRATION SOURCE

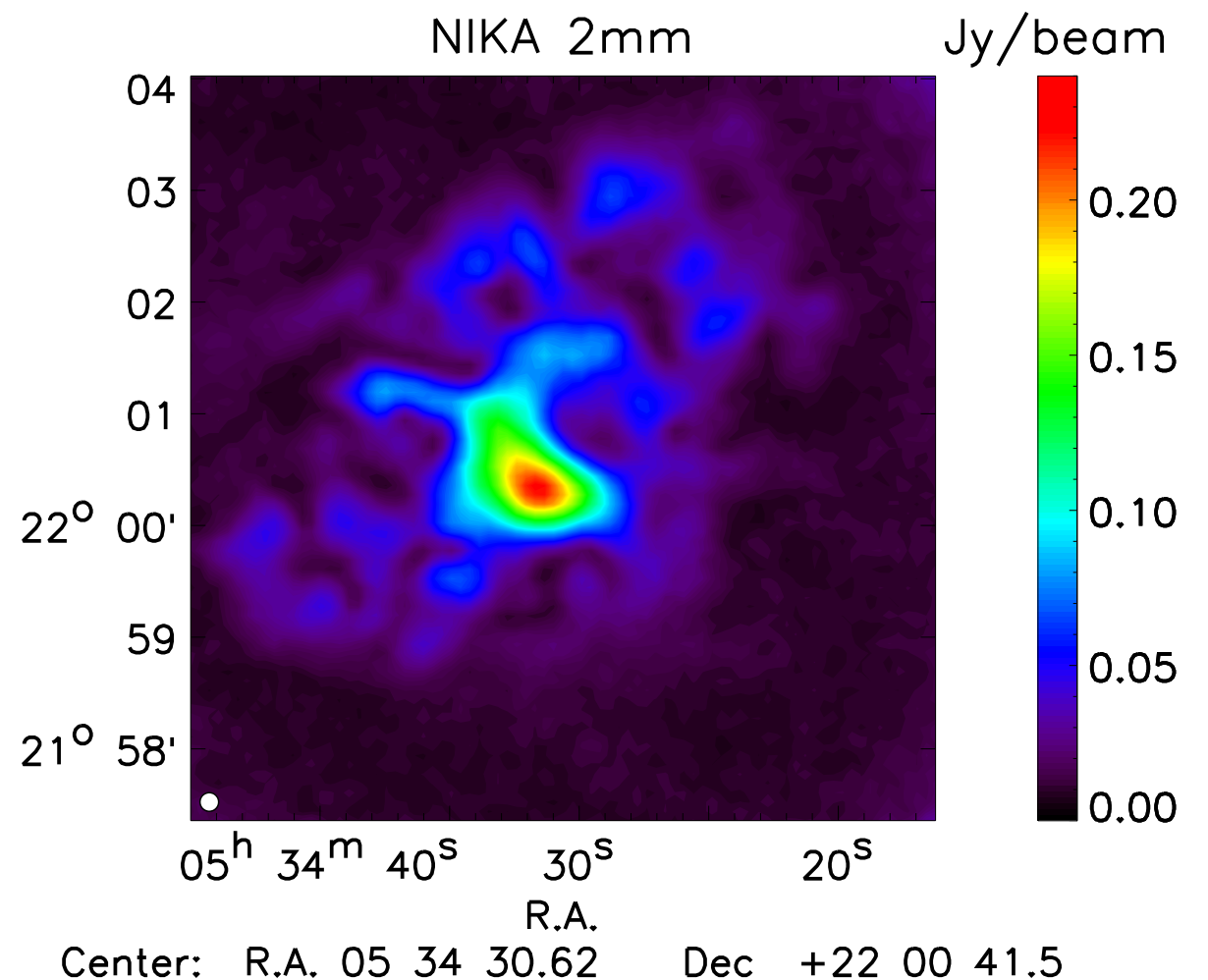
CRAB NEBULA

radio light

Intensity I



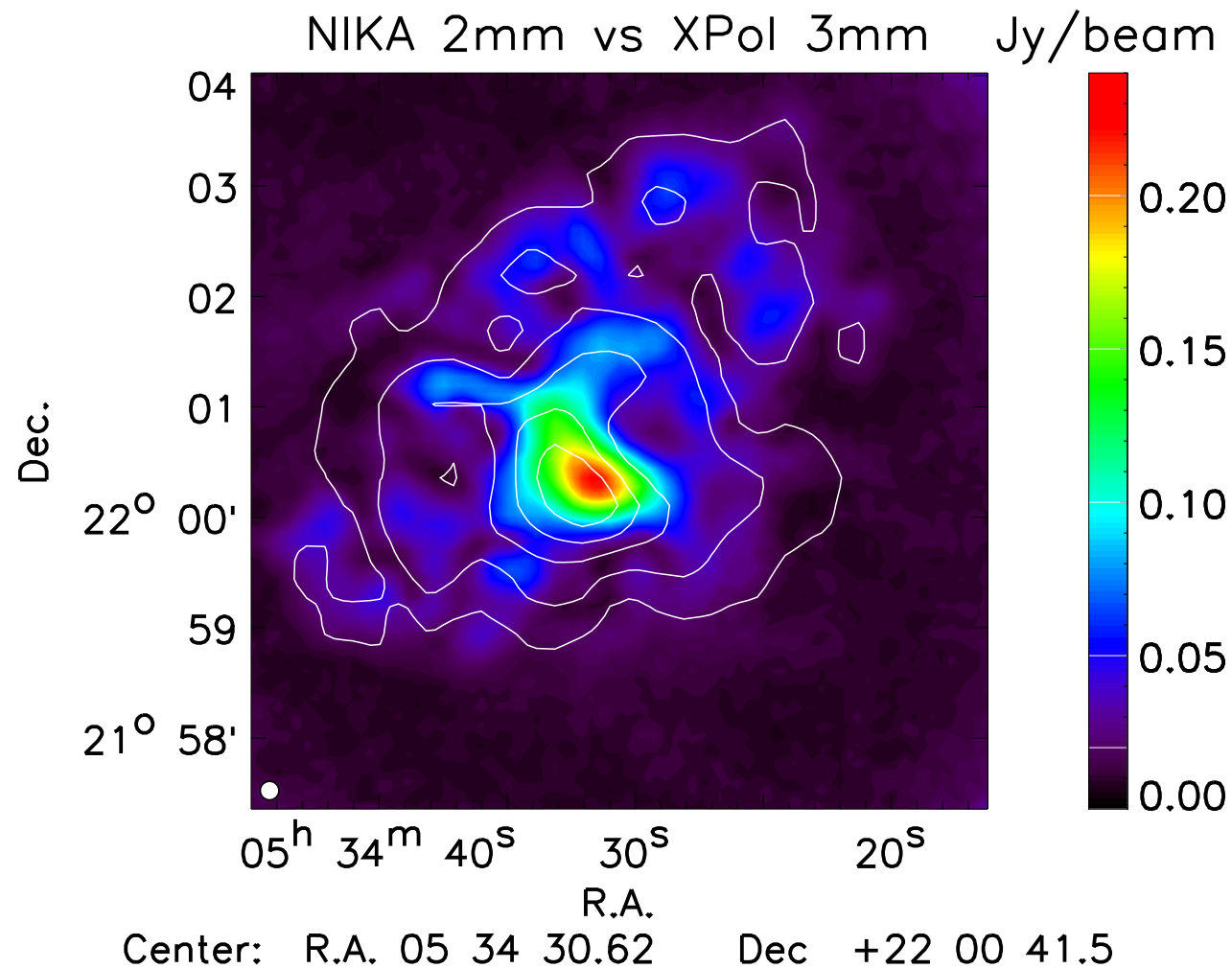
*Polarised intensity =
 $\text{sqrt}(Q^2 + U^2)$*



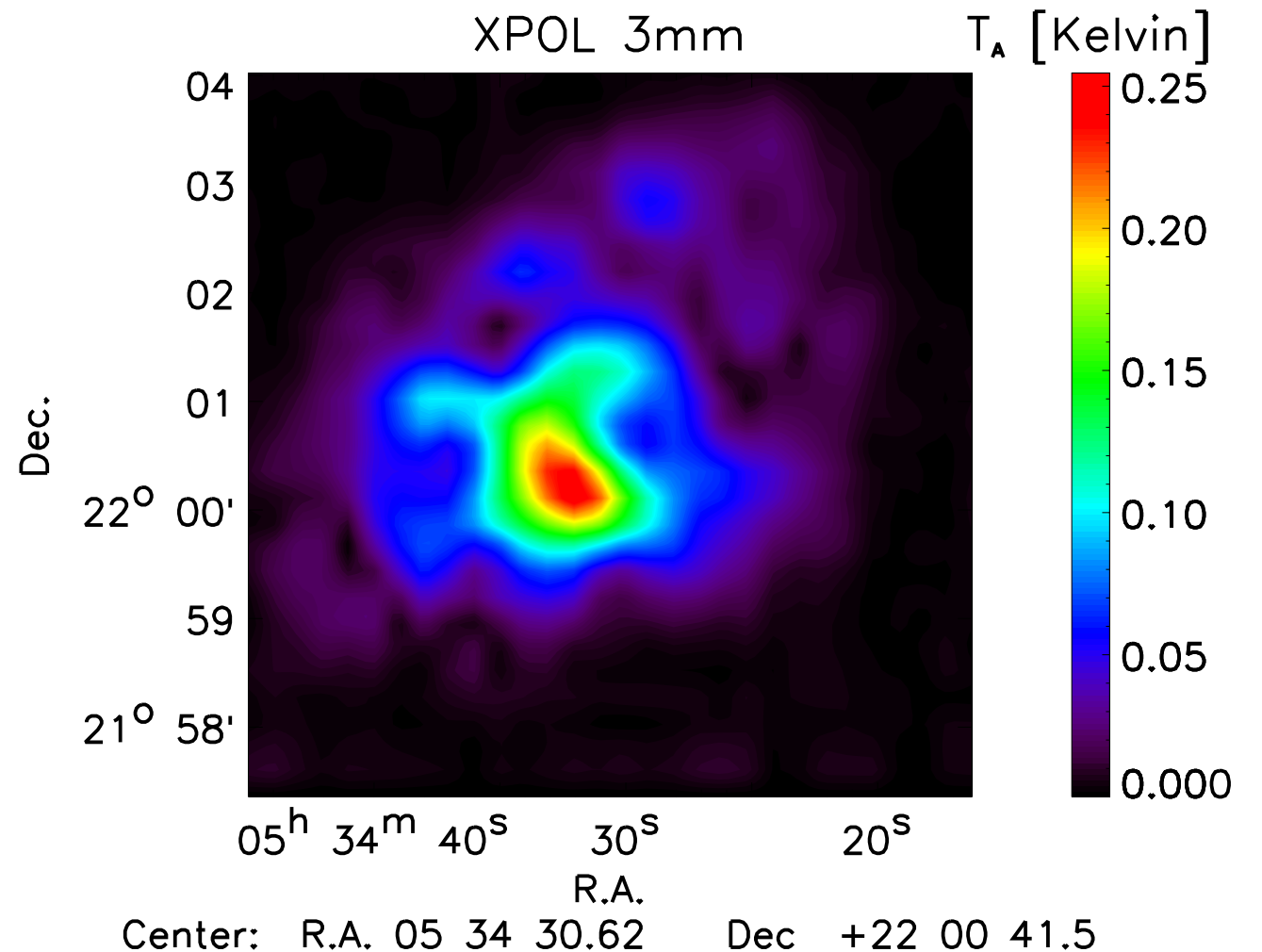
KNOWN CALIBRATION SOURCE

CRAB NEBULA

Polarised intensity = $\sqrt{Q^2 + U^2}$



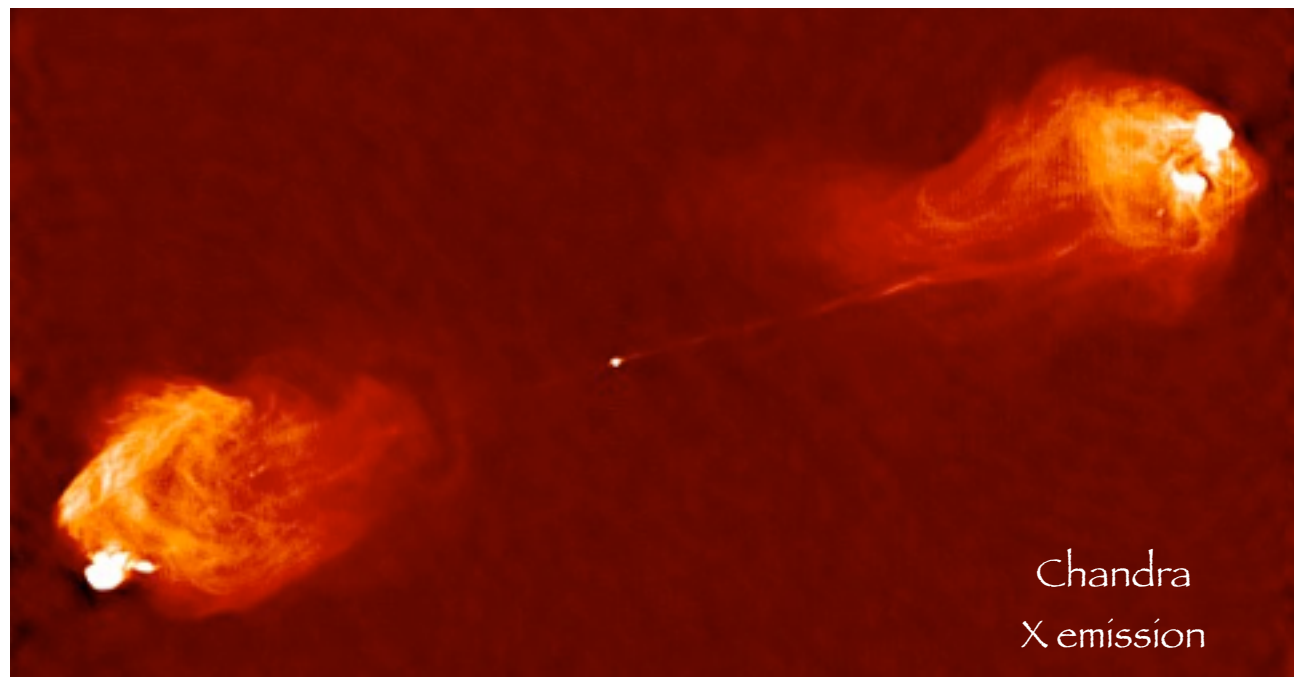
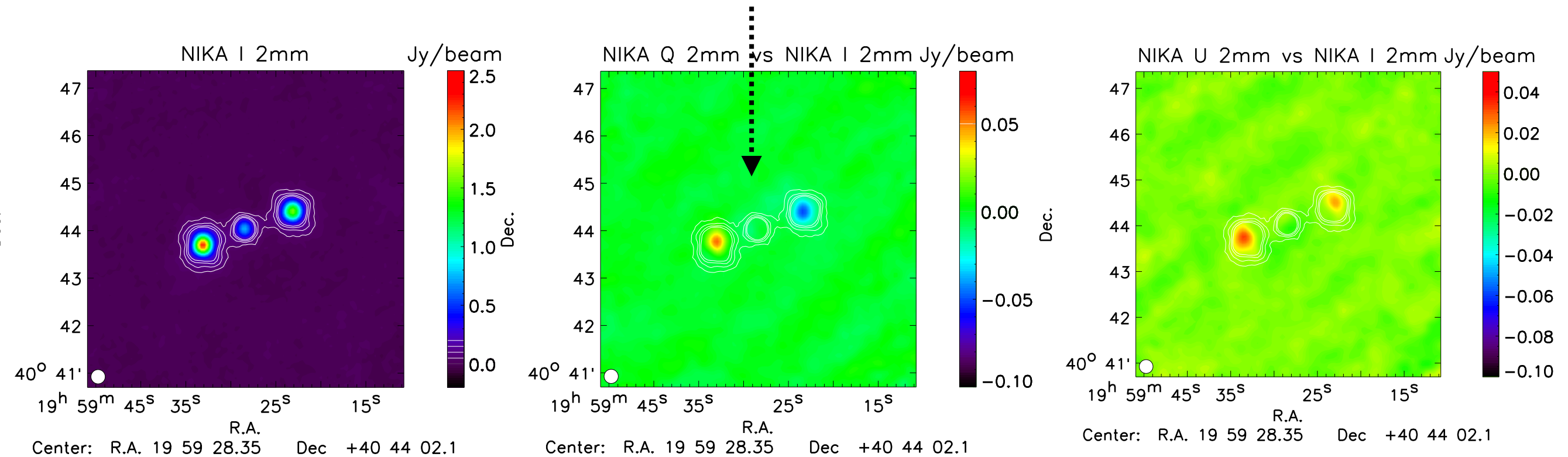
NIKA experiment



XPol experiment

Cygnus-A - preliminary results

Galaxy in the centre is not expected to be polarised



Cygnus A

One of the strongest radio sources in the sky.
Radio observations show two jets emitted in opposite directions from the galaxy's centre

Conclusions & perspectives

Characterisation of instrumental setup

Validation of data analysis software

First polarised light with kinetic inductance detectors (NIKA)

Perspectives:

Finalise data analysis and production of first NIKA polarimetry paper

NIKA 2 to be installed next June

First light January 2016

MERCI



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FOCUS
Focal Plane Array for Universe Sensing