Commissioning of the polarization capabilities of NIKA2

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Abstract

This document aims at giving a guideline for the incoming NIKA2 polarization capabilities commissioning campaigns taking advantage of NIKA polarimeter characterization. NIKA2 polarization system consists of an ambient rotating half-wave-plate (HWP hereafter) and a polarizer mounted inside the cryostat into the 100 mK stage, which is needed to split the two orientations of the linear polarization onto two 1 mm detector arrays. A similar setup has been tested using the previous NIKA camera. The gained experience with NIKA give us an idea of the polarization tests that should be done with NIKA2, which will be discussed here.

1 First tests to check the instrumentation

June 9th-13th, 2017

The NIKA2 polarization system has been tested during few commissioning campaigns last year. Since then few things in the data acquisition software are changed.

- The first step should be to check the proper functioning of the system.
- The step forward is to fix the HWP rotation frequency and consequently the scanning speed of the telescope.

Indeed, analyzing the data from these few polarization tests performed last year we noticed that pushing up to 3 Hz the HWP rotation frequency ω causes a not trivial parasitic signal due to the background signal modulation and peaked at harmonics of ω, which appears worse than what observed with NIKA. [3] describes this parasitic signal and how we correct for it in NIKA polarization data. During the next campaign that we will have in June 9th-13th we should try different options and find the right balance between scanning fast and reduce the systematic effects. For NIKA we used an acquisition rate of 47.68 Hz, a HWP rotation frequency of 2.98 Hz and consequently we had a maximum scanning speed of 26.23 arcsec/s. These parameters could be set up as starting point.

With these parameters we had the polarization signal located at $\sim$ 12 Hz, far enough from the atmospheric noise contribution. A total of 8 harmonics of the parasitic signal have been observed and subtracted from the data. We should verify, also, that we are able to correct for this systematic effect with any weather condition.

2 Intensity to polarization leakage effect characterization

June and/or October, 2017

- Characterization of the instrumental polarization observing unpolarized sources, *e.g.* planets: Uranus, Mars.

NIKA polarimeter characterization showed a systematic effect consisting of a bipolar pattern identified as an intensity to polarization leakage effect and observed on polarization maps of Uranus, which is expected to be unpolarized. The signal observed on Q and U maps consists of a positive and negative component and it has been observed fixed in NASMYTH coordinates (*i.e* cabin coordinates). The derived instrumental polarization reached a level of 3% of the total intensity. We still have not a good understanding of the instrumental origin of this effect but we developed an algorithm to subtract it to polarized observations. More details can be found in [3].

In order to have a proper estimation of the polarization with NIKA2 we should investigate this effect and understand how to reduce it instrumentally. A good way should be observing unpolarized sources, like planets, at different elevations and weather conditions. We need to understand if the effect is only related to the optics in the cabin or there is anything else contributing to it, e.g. atmosphere.

A quick analysis on NIKA2 polarization observations of Uranus carried out last year (2016) have shown (see Fig. 1) a different shape of such a systematic effect in Q and U compared to what observed with NIKA [3]. Such an instrumental polarization reaches a level of 1.2 % of the total intensity. This observation has been performed in March 5th, 2016. After that, the optics has been modified. The characterization of this systematic effect should be a priority.

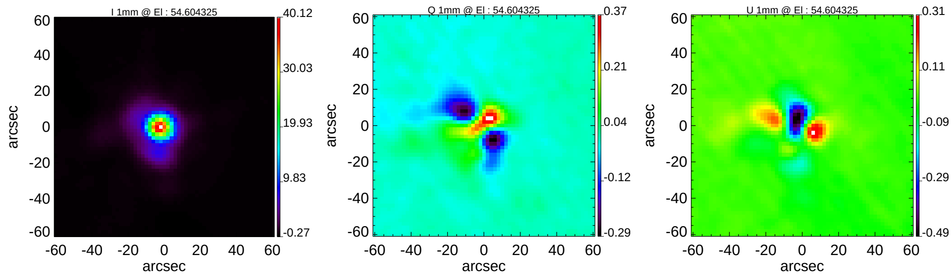


Figure 1: From left to right: Uranus Stokes maps I, Q, and U of NIKA2 observations performed in March 5th, 2016.

3 Calibration of the polarization angle and degree

The final step before the science verification is the calibration of the polarization degree and angle. For this we should plan observations of well known polarized sources together with a parallel session of observations with XPOL [4]. Tab. 1 lists few quasars with the expected values of total intensity and polarization. Even if they have been previously observed, quasars are in general variable in time scales from years to hours. A parallel session of observations is preferable to get the calibration of the polarization properties, *i.e.* angle and degree.

The Crab nebula is a supernova remnant that is indicated as a calibration source at millimeter wavelengths. It has been observed with NIKA and the values indicated in Tab. 1 will be reported in an ongoing NIKA paper.

3.1 Early science verification

After the calibration of the polarization angle and degree we could move on an early science verification using observations of CasA, NGC7538 [1], Orion molecular cloud and so on.

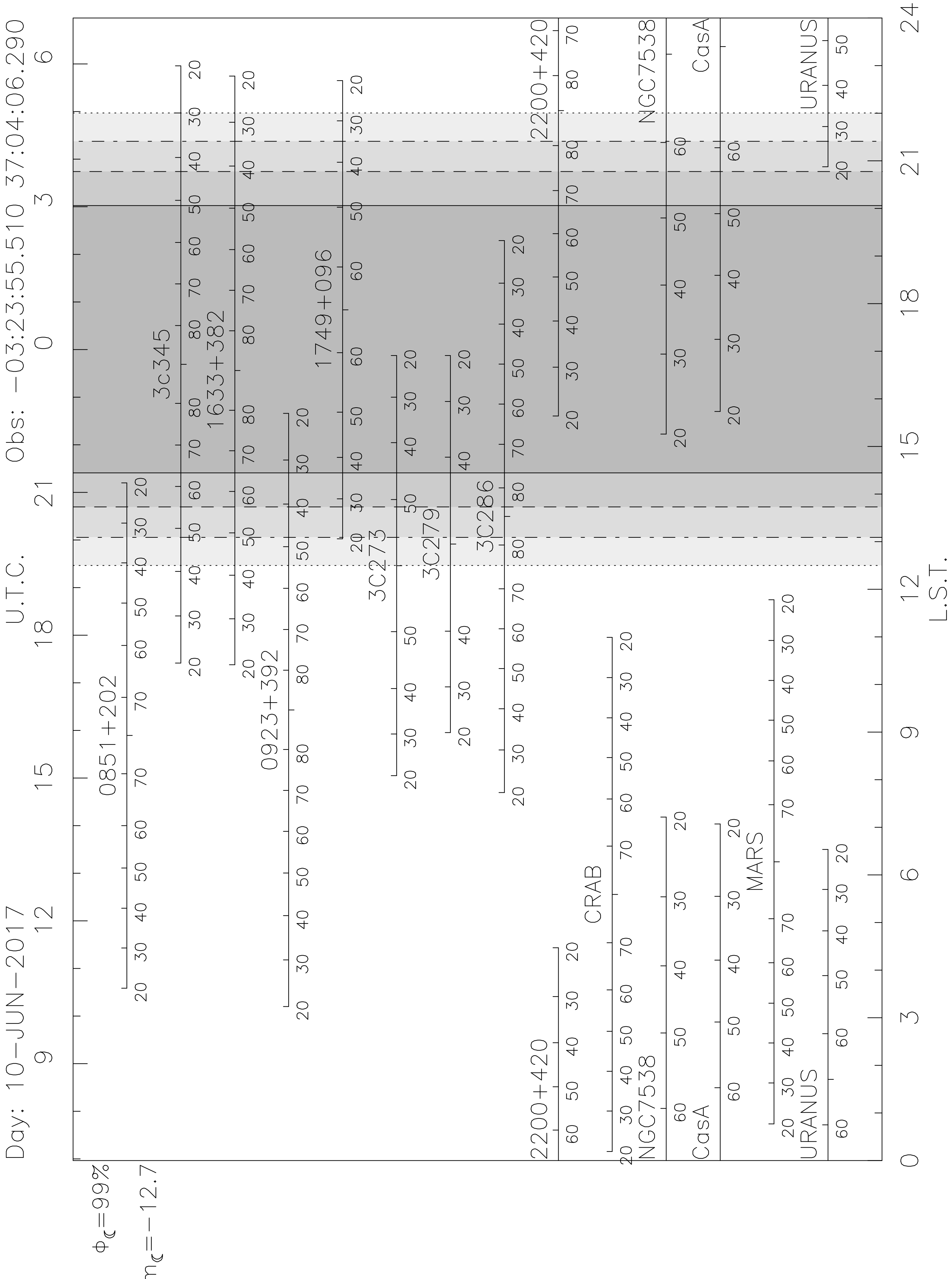
The visibility of the sources discussed above during next June is represented in Fig. 4.

3.2 NEFD in polarization

The Noise-Equivalent-Flux-density in polarization should be estimated on a weak source for which we can have long integration time on source. For NIKA we used for example the primary calibrator 3C286, which has about 0.3 Jy of intensity flux at 260 GHz and a degree of polarization of 14% of the total intensity.

4 Conclusions

This document represents a starting point for incoming polarization capabilities commissioning campaigns of NIKA2. Here the discussion benefits from previous observations with the NIKA camera. To summarize the main points are: fix the rotation frequency of the HWP and consequently the scanning speed of the telescope; characterize the instrumental polarization observing planets expected to be unpolarized; calibrate the polarization angle and degree thanks to a parallel session of quasars observations with XPOL and observe well known and highly polarized extended sources; characterize the sensitivity of the instrument on a weak source.



Day: 10−JUN−2017
Obs: −03:23:55.510 37:04:06.290
U.T.C.
L.S.T.
Φ☾=99%
m☾=−12.7
0851+202
0923+392
3c345
1633+382
1749+096
3C273
3C279
3C286
2200+420
CRAB
NGC7538
CasA
MARS
URANUS

Source	Exp. Flux	Exp. Polar at 1mm
	Jy	%
3C 286 *	0.3	14.4
0003-066	1.2	16.7
3C345	2.6	7.1
2200+420	5.5	12
0851+202	2.42	5.2
0923+392	2.52	5.4
1749+096	1.3	3.3
1222+216	0.6	6.5
1633+382	1.7	2.4
3C354.3	6	8
3C273	3.6	1.1
3C279	8.5	10
Crab nebula +	204.4±7.9±10.2	7.1±0.1

Table 1: * Primary calibrator. The expected values of total intensity and polarization indicated here for all the quasars except 3C 286 refer to [2]. However quasars are in general variable in intensity and polarization, for that reason these survey of quasars should be observed in a parallel session with XPOL [4]. + The Crab nebula is a well known calibration source already observed with NIKA; the values here refer a NIKA paper to be submitted. The intensity flux has been estimated (150 GHz) using standard aperture photometry techniques and the polarization value, estimated in a region of $5'$, is the mean value obtained comparing different observations at millimeter wavelengths.

References

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