

User guide for polarimetric observations with NICS

E. Oliva, V. Lorenzi
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1 Standards e choice of position angle

The TNG+NICS system introduces a quite large (several %) instrumental polarization produced by the 45° reflections at M3 and M4. The effect of the latter is constant and can be accurately canceled-out because the mirror is always seen by NICS under the same orientation. The reflection at M3, instead, introduces a variable polarization depending on the angle under which NICS sees the M3 mirror. This angle is given by:

$$\text{Angle_NICS_M3} = \text{constant} + (\text{PosAng} - \text{ParAng})$$

where **PosAng** is the position angle of the frame and **ParAng** is the value of the parallactic angle when the observation are taken.

To measure and correct the instrumental polarization it is always necessary to observe a polarimetric standard (usually a star with a known and, possibly, very small polarization) just before and/or after the object and at values of **Angle_NICS_M3** as close as possible (i.e. within <10 degrees) to those of the object. The easiest approach, therefore, is to perform all observations with **PosAng=ParAng**, i.e. with the position angle as close as possible to the current value of the parallactic angle.

For relatively long integrations the astronomer should monitor the variation of (**PosAng-ParAng**) throughout the observation and make sure that the standard(s) are observed covering the same range of value.

Example:

- First image of object-mosaic taken with **PosAng=113°** and **ParAng=113°**, i.e. (**PosAng-ParAng**)= 0°
- Last image of object-mosaic taken with **PosAng=113°** and **ParAng=133°**, i.e. (**PosAng-ParAng**)= -20°
- Take standard with the following values of position angles:
PosAng=ParAng, **PosAng=ParAng-10°**, **PosAng=ParAng-20°**

This procedure is relatively simple when observing in regions of the sky where **ParAng** does not vary on short time scales, i.e. far from the zenith. Instead, observations in regions where the parallactic angle varies rapidly, i.e. close to the zenith, could be very difficult or even impossible.

The limit on zenith distance for broad-band ima-pol observations is about $z > 15^\circ$ or, equivalently, elevation $< 75^\circ$. Outside of this region the parallactic angle varies by less than 10° in 10 minutes and, therefore, is reasonably constant within the typical integration time of $\text{DIT} \leq 4$ min.

Spectro-pol and narrow band ima-pol observations, instead, require longer integration times (DIT up to 15 min) and, therefore, should be performed at lower altitudes. The practical limit on zenith distance in such a case is about $z > 25^\circ$ or, equivalently, elevation $< 65^\circ$.

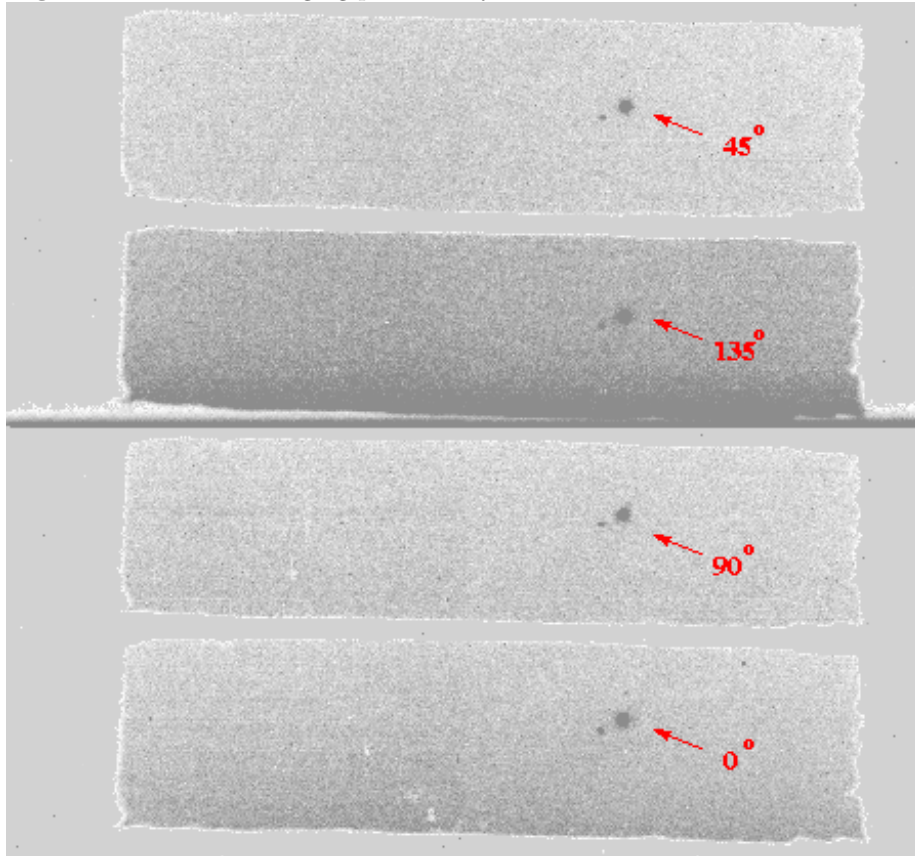
2 Imaging-polarimetry: format and mosaics

The field of view in imaging-polarimetry is about $3' \times 50''$. A MgF_2 double Wollaston on the grism wheel splits the input rectangular image into the four polarization components which are re-imaged at different positions along Y onto the array. Fig. 1 is an example of an image taken in the imaging-polarimetric mode.

Since most observations are taken at position angles different than zero (see Sect. 1), the mosaic should be always defined in X-Y coordinates, i.e. with the command `REL2SOURCE.XY` at the beginning of the mosaic file. For on-source mosaics the offsets in Y must be limited to less than 100 pixels while those in X can extend to about ± 400 pixels.

A “standard” mosaic file, called `ima_pol_standard.txt`, is available in the dedicated directory of PC-NICS.

Fig. 1 Raw frame in imaging polarimetry.



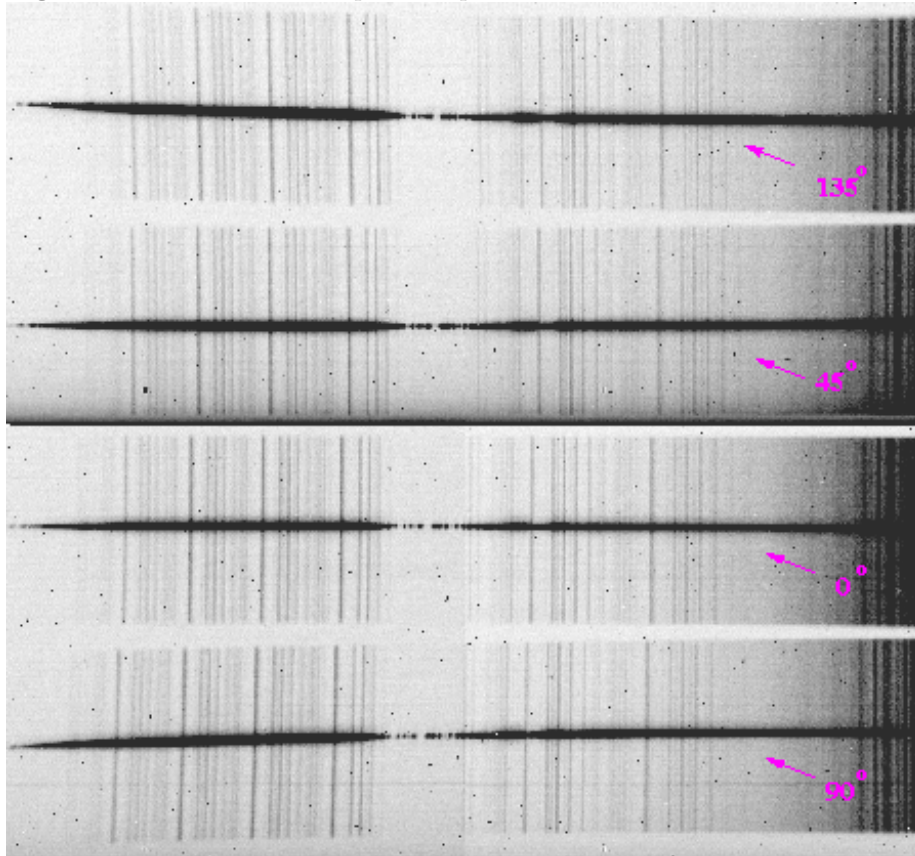
3 Spectro-polarimetry: format and mosaics

The slit length in spectro-polarimetry is $50''$, the choice of slit widths is the same as in normal spectroscopy. A LiNbO_3 double Wollaston on the filter wheel splits the input slit image into the four polarization components which are dispersed by the grism/prism. The resulting spectra are re-imaged at different positions along Y onto the array. Fig. 2 is an example of a spectrum taken in the spectro-polarimetric mode.

The mosaics should be defined in X,Y and are similar to those used for normal spectroscopy. For on-source mosaics the offsets in Y should be always limited to ± 90 pixels to maintain the object within the length of the slit.

A “standard” mosaic file, called `spe_pol_standard.txt`, is available in the dedicated directory of PC-NICS.

Fig. 2 Raw frame of an HK spectrum-polarimetric observation of a star.



4 Expected performances and e.t.c.

Taking into account the light losses at the Wollaston, each of the four sub-images (or sub-spectrum) receives about 21% of the flux entering the instrument. Consequently, the expected performances can be obtained using the NICS exposure time calculator (e.t.c.) and decreasing by a factor of 4.8 the flux of both object and sky – i.e. increasing by 1.7 the magnitudes of both object and sky.

Each of Stoke parameters necessary for determining the amount and direction of linear polarization, i.e. Q and U , is the result of a combination of measurements extracted from two sub-images:

$$Q = \frac{I(0^\circ) - I(90^\circ)}{I(0^\circ) + I(90^\circ)}$$

$$U = \frac{I(45^\circ) - I(135^\circ)}{I(45^\circ) + I(135^\circ)}$$

$$P = \sqrt{Q^2 + U^2}$$

Consequently, to achieve a given accuracy on the polarization degree P one needs to reach a s/n ratio of at least a factor of $\sqrt{2}$ larger in each sub-image.

As a guideline, below is a list of the magnitudes necessary to obtain a $1\text{-}\sigma$ accuracy of 1% on the amount of linear polarization with 30 minutes integration time and 1" seeing.

Band	Limiting Magnitude
J	16.8
H	16.2
K'	15.6

The limiting magnitudes scale with integration time (t), seeing (θ) and polarimetric accuracy (σ) as follows

$$m_{lim}(t) = m_{lim}(30 \text{ min}) + 1.25 \log_{10} \left(\frac{t}{30 \text{ min}} \right) - 2.5 \log_{10} \left(\frac{\theta}{1''} \right) + 2.5 \log_{10} \left(\frac{\sigma}{1\%} \right)$$