The PolCor "Lucky" Polarimeter/coronagraph

PolCor is a combined "Lucky" imager, polarimeter, and coronagraph
built for NOT by Göran Olofsson and Hans-Gustav Florén, Stockholm.

Summary

Compared to a general purpose instrument like ALFOSC, PolCor has the following advantages

1. Sharper images (typically 0.7 -> 0.4 arcsec without wasting frames and -> 0.2-0.3 arcsec with frame selection)
2. Much higher time resolution (milliseconds, if needed)
3. Much better PSF (higher image contrast)
4. Much better coronagraphic performance
5. Much less interference fringes
6. More accurate sky subtraction
7. More accurate colour index measurements
8. No time loss for reading out

The disadvantage is a small field (1 arcmin) and no spectroscopic mode. The data volume is also much larger and the data reduction more time consuming.

Image quality

The all-mirror re-imaging optics is (with good margin) diffraction limited and the reflectivity of the 4 mirrors in the light path is 99.5% each (over the sensitivity range of the detector) resulting in only 2% losses. The relay optics has a 1:1 imaging which results in a pixel scale of 0.12 arcsec/pixel. Only shift-and-add (i.e. correcting for image motion) typically improves the seeing from 0.7" in staring mode to 0.4". If one uses frame selection ("Lucky imaging") and deconvolution, the resolution will improve to 0.2 – 0.3 ", but at the expense of the limiting magnitude. Barlow lenses with x2 and x3 are available, which would be needed for speckle interferometry. The all-mirror optics (except for filter and cryostat window) minimizes the risk for ghosts (we have so far not detected any ghosts). In order to limit the extent of diffraction stripes, PolCor has a computer controlled Lyot stop that masks the secondary mirror support blades. This mask is slightly undersized to block the diffraction rings caused by the coronagraphic disks (and thereby lower the PSF wings by 1-2 orders of magnitude).

The detector

The EMCCD camera (Andor IXON) uses a thinned 512x512 CCD array with 16 micron pixels, giving a full field of 1 arcminute. It can be used both in classical mode (with a read-out noise of 6 e- rms) and EM mode with an on-chip gain up to 1000. For low light levels it can be used in a photon counting mode (fastest full-frame readout rate 33 Hz), which is in principle noise-less, but in practice limited by clock induced pulses, which occur typically once for 200 readouts. With broad band filters the sky emission is too high for photon counting, but it has been found that the EM mode is linear over a wide range and this is the normal mode of operation. In practice, all frames are stored, so the mode of operation is a post-processing decision.

Th QE is not particularily high (around 30%) in the UV, but on the other hand, the AR coating is efficient at longer wavelengths and we have seen no interference fringes caused by the OH sky emission.

Very high time resolution can be achieved by limiting the readout area of the chip, making

speckle interferomerty possible.

Coronagraphy

There is a choice of 3 sizes (1.5, 3 and 6 arcseconds in diameter) coronagraphic disks each size with a choice of 3 different optical densities (2, 3.5 and 5 equivalent to 5, 8.75 and 12.5 magnitudes). The reason for not using totally opaque disks is to allow centering and monitoring the star. The Lyot mask is rotating in the same sense (but opposite direction) as the field rotator in order to cancel the effect of spider deffraction.

Polarization measurements

The polarizing element is a high-quality polarizer which is designed for the 410 – 750 nm region). It is rapidly turned to the 4 positions (0, 45, 90 and 135 degrees) and "dark" repeatedly many cycles to average atmospheric variations.

Filters

PolCor is equipped with Bessel U, B, V, R and I filters. In addition very narrow-band filters (0.3-0.5 nm) are also available for the lines FeI 386 nm, CaII 393, NaI 589, KI 767, and CaII 854. The purpose of these filters is observations of circumstellar resonance scattering. The filter holder can take 2 filters at a time and in order to cancel sky variation in filter ratio measurements, Polcor has a mode of operation that repeatedly change between the two filters. It is a relatively simple matter to change filter holder, and other filters out of the NOT list with diameter 50 or 60 mm can be used.

Beam-switching mode

A beam switching mode is being prepared in order to make it possible to measure low surface brightness objects without the usual difficulties in determining the sky level.