WIRC-POL: 0.1% polarimetric precision on-sky with the installation of a HWP modulator

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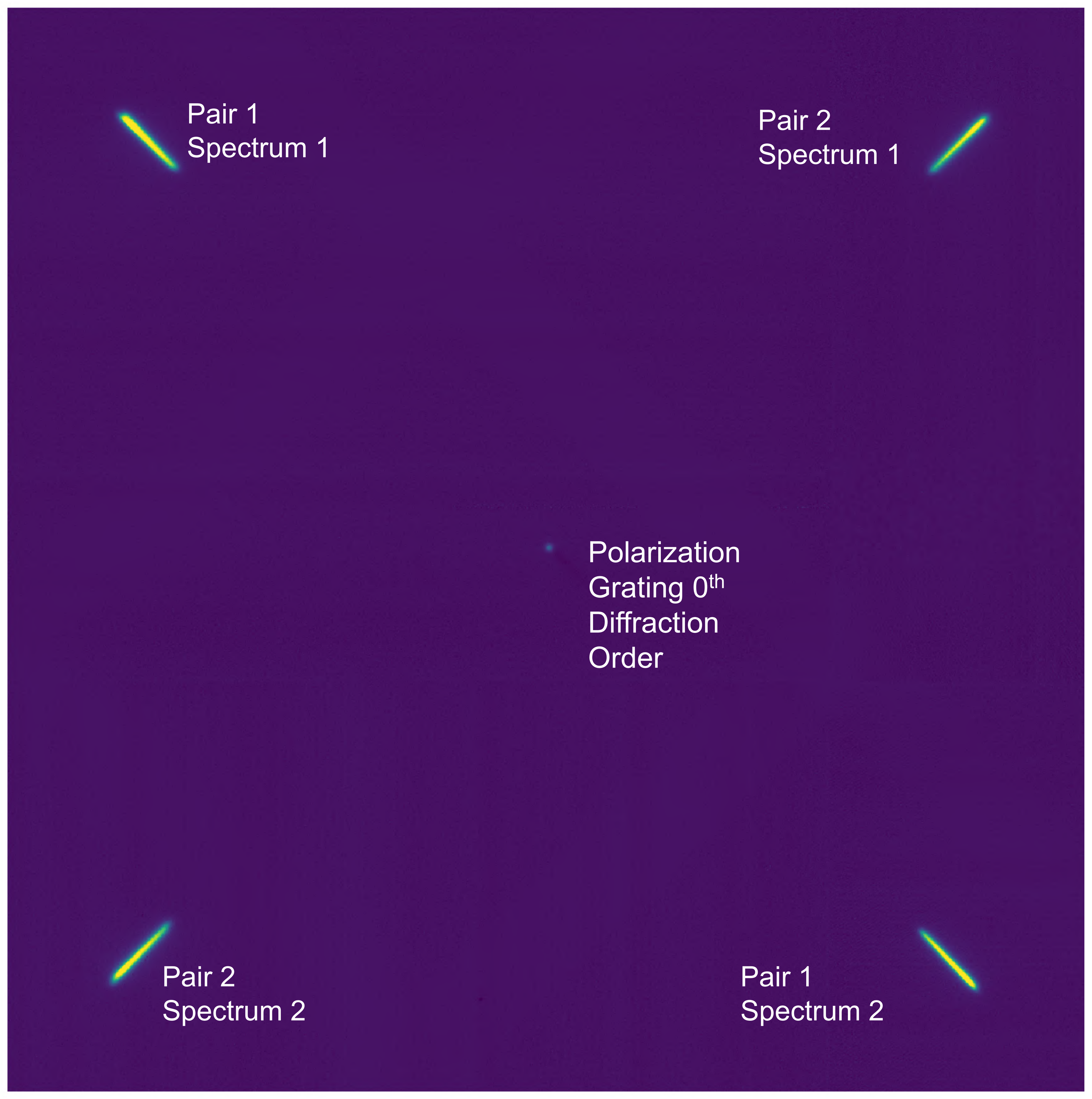
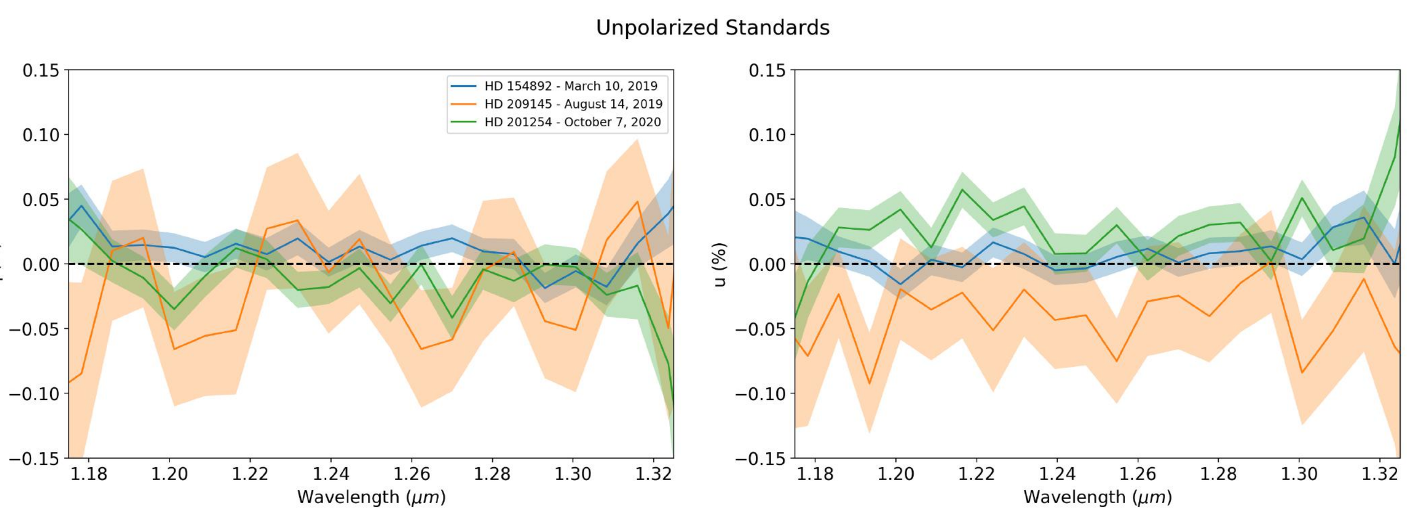
Introduction

WIRC+Pol[1] is an R~100 J and H-band spectropolarimetry mode for the seeing-limited Wide-field InfraRed Camera (WIRC[2]) at the Palomar 200-inch Hale telescope. It's enabled through a split-pupil polarization grating and the insertion of a rotatable Half-wave plate. (HWP), installed in 2019[3]. The split-pupil design results in two pairs of orthogonally polarized spectra per target, allowing for Q and U to be measured simultaneously. Here we present the results of an extensive calibration campaign in the J-band. H-band calibration is ongoing and expected to yield similar results. WIRC+Pol is being used for observations of brown dwarfs, supernova, asteroids, stellar ISM dust and young stellar objects.

Example Data



<0.1% Instrumental Polarization



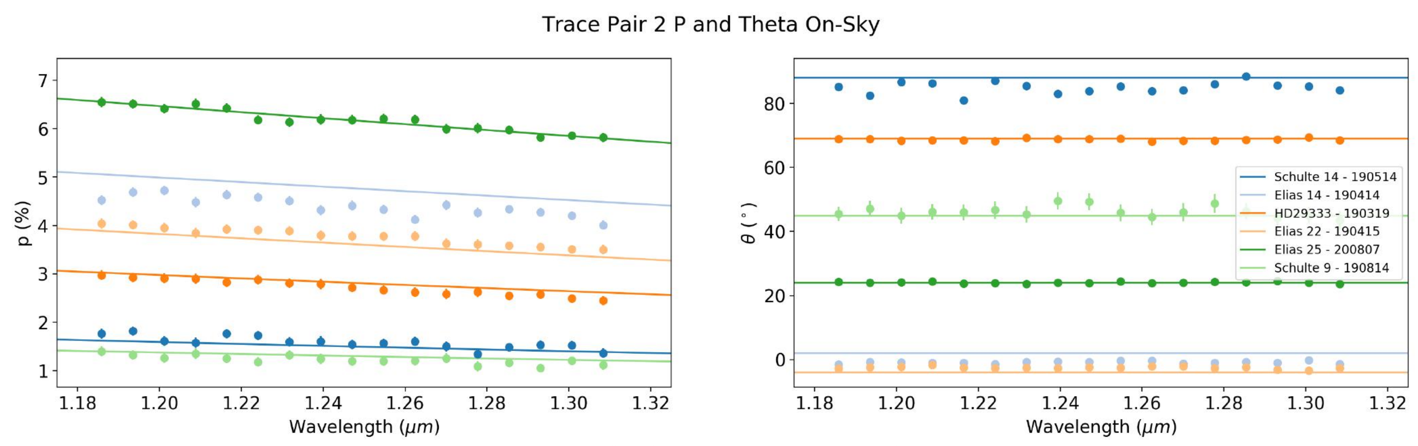
- The instrumental polarization is consistently below 0.05% in both q and u.
- The source of the residual variation in the instrumental polarization remains unknown but may be due to instrumental or data analysis effects

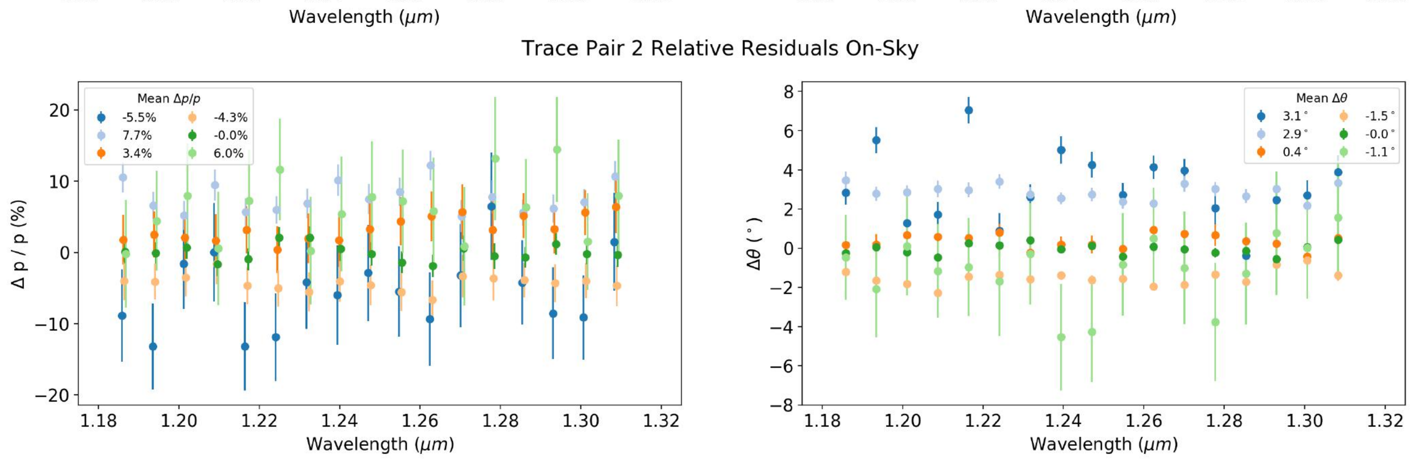
Instrument Calibration Model

We assume a simple instrument calibration model, relating the measured Q and U values to the on-sky values through Q and U efficiency and crosstalk terms:

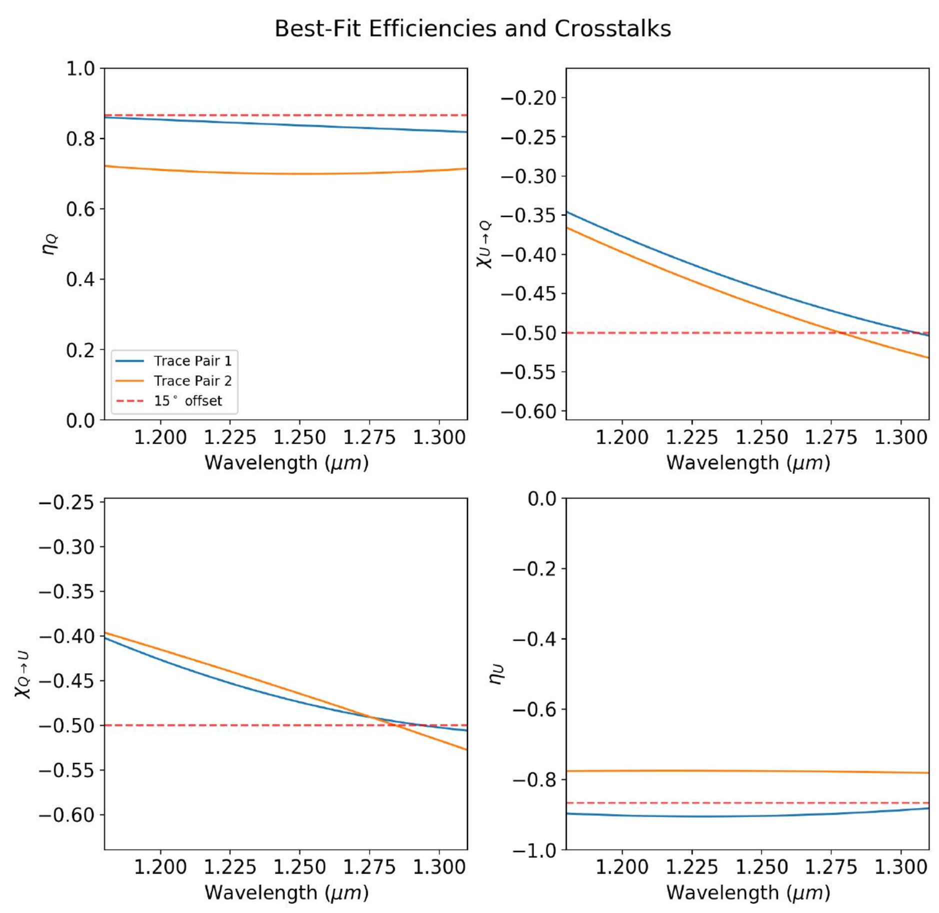
$$Q_{Measured} = Q_{Sky} \cdot \eta_Q + U_{Sky} \cdot \chi_{U \to Q}$$
$$U_{Measured} = U_{Sky} \cdot \eta_U + Q_{Sky} \cdot \chi_{Q \to U}$$

where η and χ are the efficiencies and crosstalks. We treat each pair of orthogonally polarized spectra as an independent polarimeter and find value of η and χ for each pair. We assume the crosstalks and efficiencies to be second-order polynomials as a function of wavelength and fit for the polynomial coefficients using observations of polarization standards, assuming the Serkowski law fits from Whittet et al. 1992[4].





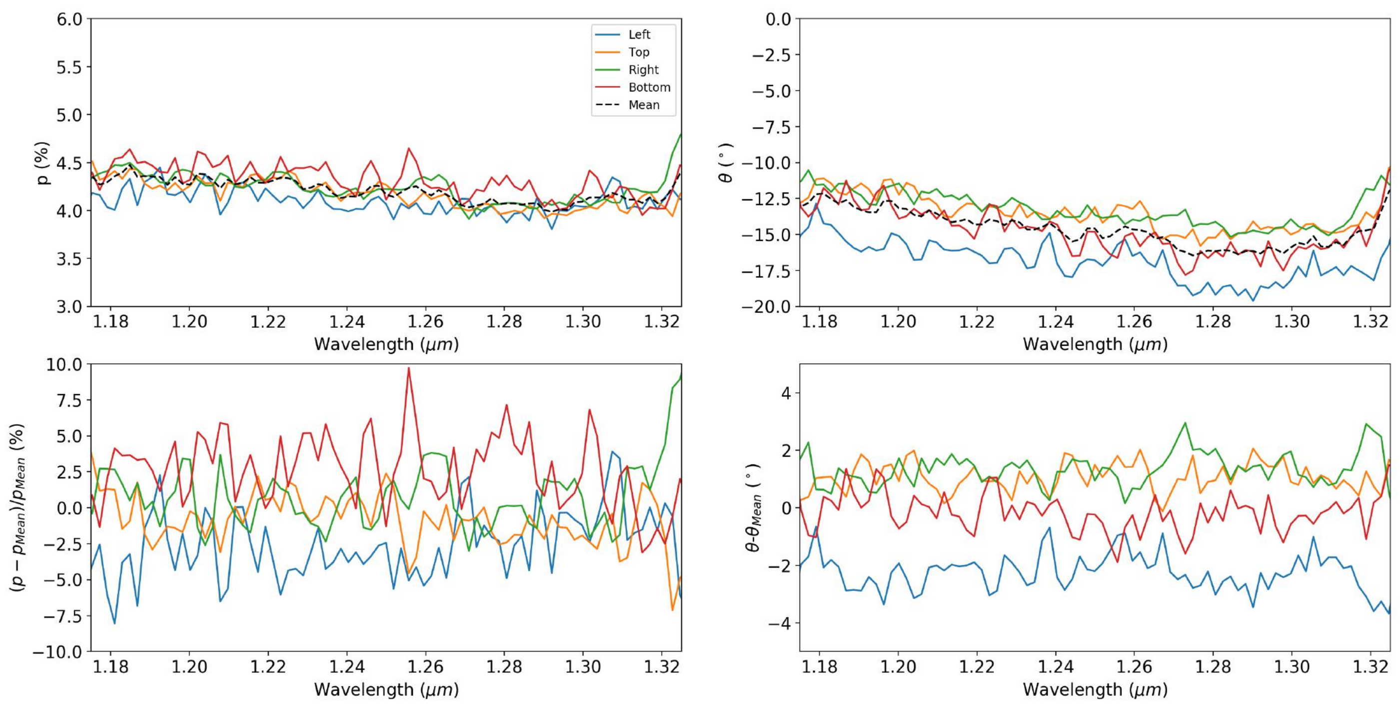
- The fit yields average residuals of less than 10% relative to the expected *p* values, and under 3 degrees difference from the expected position angles. Slightly better results were obtained for Trace Pair 1 (not pictured here).



- The best fit ηs and χs may be approximately explained by a position angle offset (~15°) plus a wavelength dependent crosstalk and a slightly different modulation efficiency for each pair

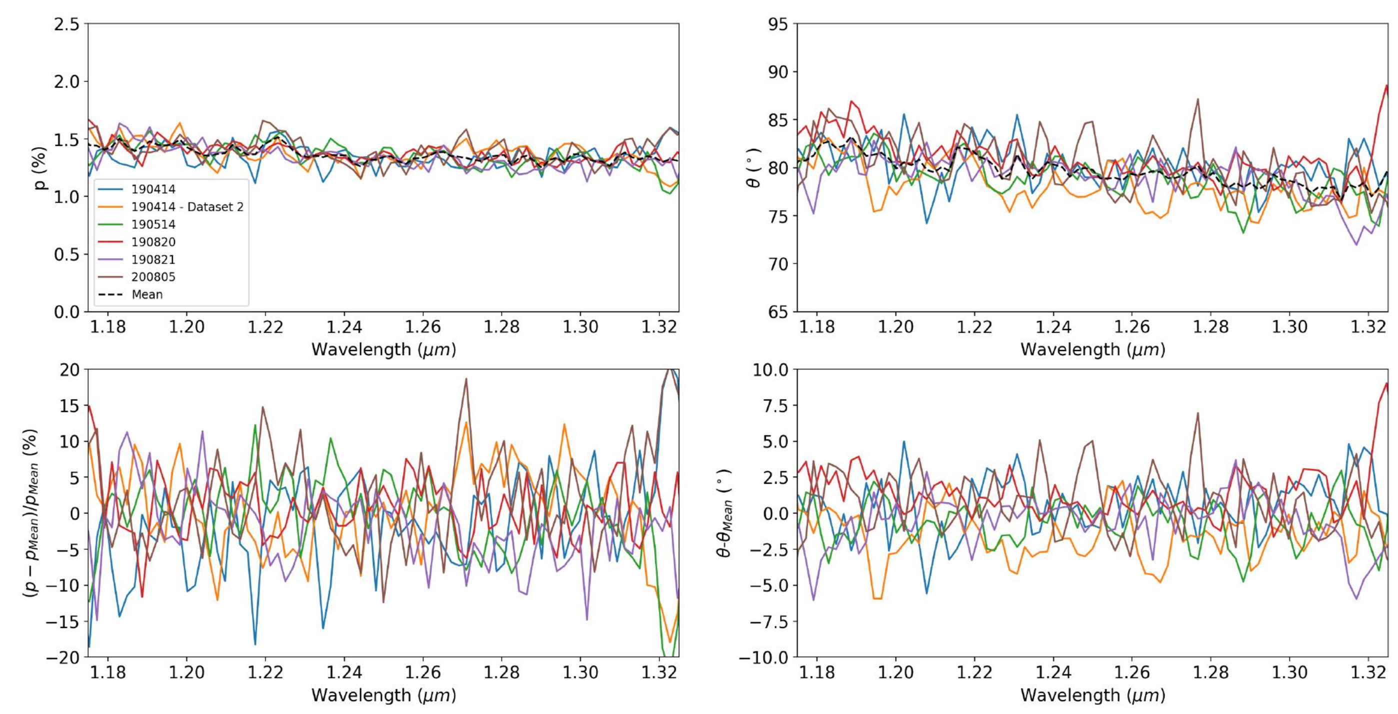
Spatial and Temporal Stability

The polarized standard Elias 2-14 was observed at four locations centered in each quadrant of the WIRC+Pol 4.3"x4.3" field of view.



- The polarimetric efficiencies and/or crosstalks appear to be slightly variable with location on the detector
- The relative change in *p* value is < +/- 10% of the mean value
- The change in linear polarization angle is < 3°
- For the highest precision, users should obtain polarized standard observations at the same detector location(s) as their science target(s)

The polarized standard Schulte 14 (Cyg. OB2 No. 14) was observed multiple times between Apr. 14, 2019 and Aug. 5, 2020. During this time, the instrument was mounted and dismounted many times.



- The polarimetric efficiencies and crosstalks appear to be stable at the <10% level over periods of 16 months.
- Instrumental position angle offsets appear to be stable to within ~3° over periods of 16 months and multiple instrument mountings

Conclusions

1. **WIRC+Pol's instrumental polarization is < 0.05%**
2. **Our instrumental calibration model can reproduce polarized standard measurements to within Δp/p=10% and Δθ=3 (available now in the DRP)**
3. **The polarimetric efficiencies and crosstalks appear to be spatially and temporally stable to within the calibration model's errors**

REFERENCES

1. Tinyanont, S. et al. 2019, *PASP*
2. Wilson, J.C. et al. 2003, *SPIE*
3. Tinyanont, S et al. 2019, *SPIE*
4. Whittet, D.C.B. et al. 1992, *ApJ*

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