Polarimetry

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Polarimetry Issues

- Polarimetry requirements (recap)
- Mueller matrices for telescope
- Instrumental polarization of telescope
- Location of polarization modulator(s)

Polarimetry Requirements

- Polarization sensitivity: amount of fractional polarization that can be detected above a (spatially and/or spectrally) constant background. It refers to a relative measurement. ATST sensitivity requirement: **10^{-5}**
- Polarization accuracy: absolute error in measured fractional polarization, an absolute measurement. ATST accuracy requirement: **$5 \cdot 10^{-4}$**
- Instrumental polarization requirements:
  - **< 1% instrumentally induced polarization** at all wavelengths and all points in FOV before polarization modulation
  - **Instrumental polarization calibration**: should be known to an accuracy of **at least $5 \cdot 10^{-4}$**
  - **Instrumental polarization stability: change no more than $5 \cdot 10^{-4}$ within 15 min**

f/2 Mueller Matrices

- Aluminum coating at 400 nm in prime focus

$$\begin{pmatrix} 1.0 & 0.002387 & 0.0 & 0.0 \\ 0.002387 & 0.999902 & 0.0 & 0.0 \\ 0.0 & 0.0 & -0.99955 & -0.02666 \\ 0.0 & 0.0 & 0.02666 & -0.999452 \end{pmatrix}$$

- The same in Gregorian focus (after M2)

$$\begin{pmatrix} 1.0 & 0.004472 & 0.0 & 0.0 \\ 0.004472 & 0.999998 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.998424 & 0.049914 \\ 0.0 & 0.0 & -0.049915 & 0.998422 \end{pmatrix}$$

- No polarimetry equipment in prime focus
- Instrumental polarization fixed with respect to telescope
- Instrumental polarization rotates with respect to image

FOV Dependence

- Center

$$\begin{pmatrix} 1.0 & 0.004369 & 0.0 & 0.0 \\ 0.004369 & 0.999999 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.998455 & 0.048772 \\ 0.0 & 0.0 & -0.048772 & 0.998454 \end{pmatrix}$$

- Y=2.5 arcmin

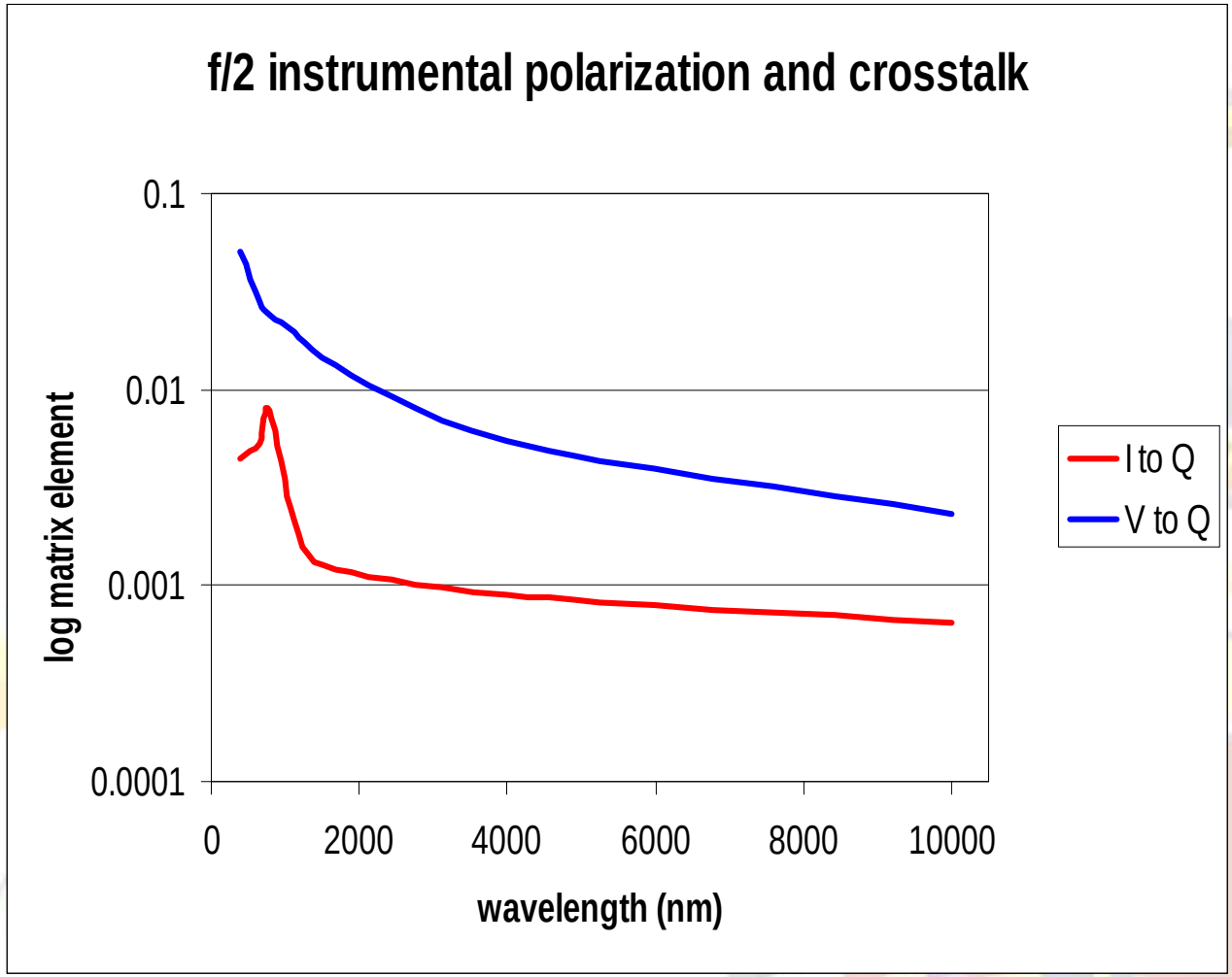
$$\begin{pmatrix} 1.0 & 0.004472 & 0.0 & 0.0 \\ 0.004472 & 0.999998 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.998424 & 0.049914 \\ 0.0 & 0.0 & 0.049915 & 0.998422 \end{pmatrix}$$

- X=2.5 arcmin

$$\begin{pmatrix} 1.0 & 0.004318 & -0.000836 & -0.00002 \\ 0.004318 & 0.999946 & -0.000382 & 0.009329 \\ -0.000837 & -0.000163 & 0.998507 & 0.048196 \\ -0.00002 & -0.009336 & -0.048196 & 0.998453 \end{pmatrix}$$

Wavelength Dependence

wavelength	I to Q	V to Q
400	0.004472	0.049914
650	0.005241	0.027803
800	0.007916	0.023909
1130	0.002123	0.019822
1500	0.001296	0.014471
4000	0.000889	0.005502
10000	0.000653	0.002318



Coude focus (vertical)

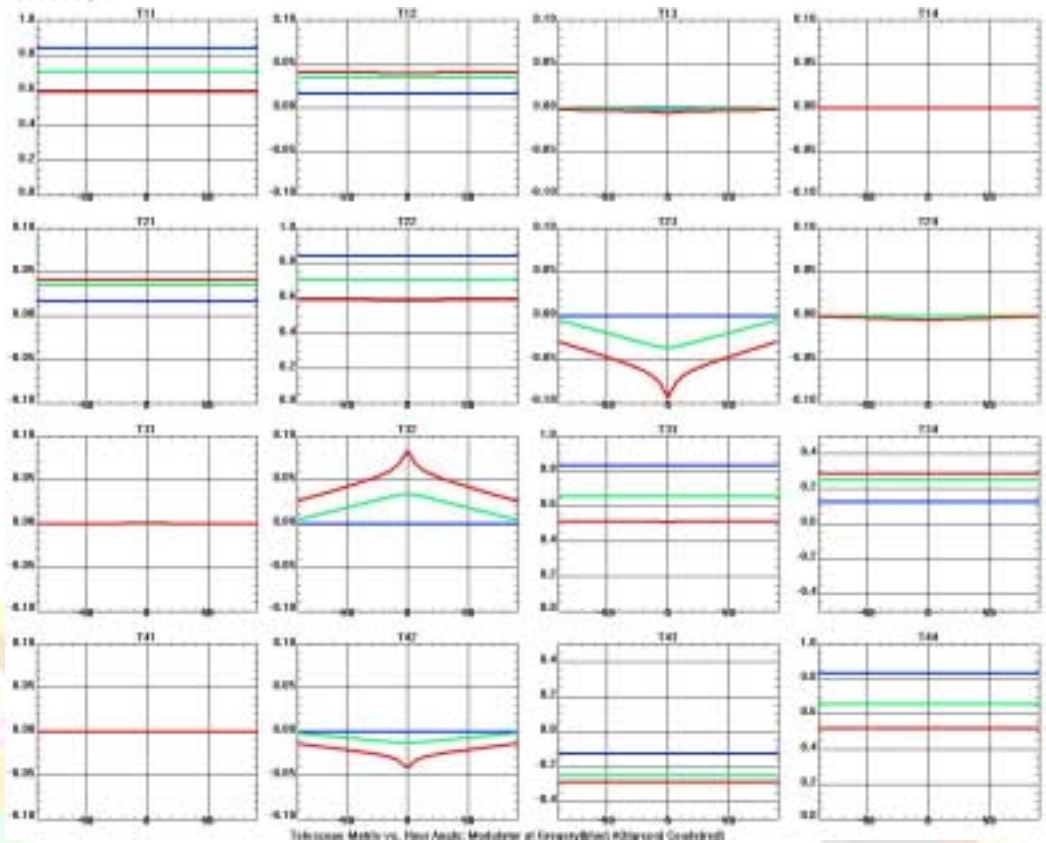
- Zenith pointing

$$\begin{pmatrix} 1.0 & -0.038994 & 0.004329 & 0.001342 \\ -0.038865 & 0.997303 & 0.028529 & -0.064338 \\ 0.005407 & -0.053469 & 0.898747 & -0.432341 \\ 0.001317 & 0.045585 & 0.434772 & 0.89783 \end{pmatrix}$$

- Horizon pointing

$$\begin{pmatrix} 1.0 & -0.005469 & 0.005274 & -0.000824 \\ 0.005251 & -0.997338 & -0.028629 & 0.064156 \\ -0.005494 & 0.03718 & -0.996776 & 0.066728 \\ -0.000796 & 0.06208 & 0.068652 & 0.995058 \end{pmatrix}$$

Variation with Hour Angle

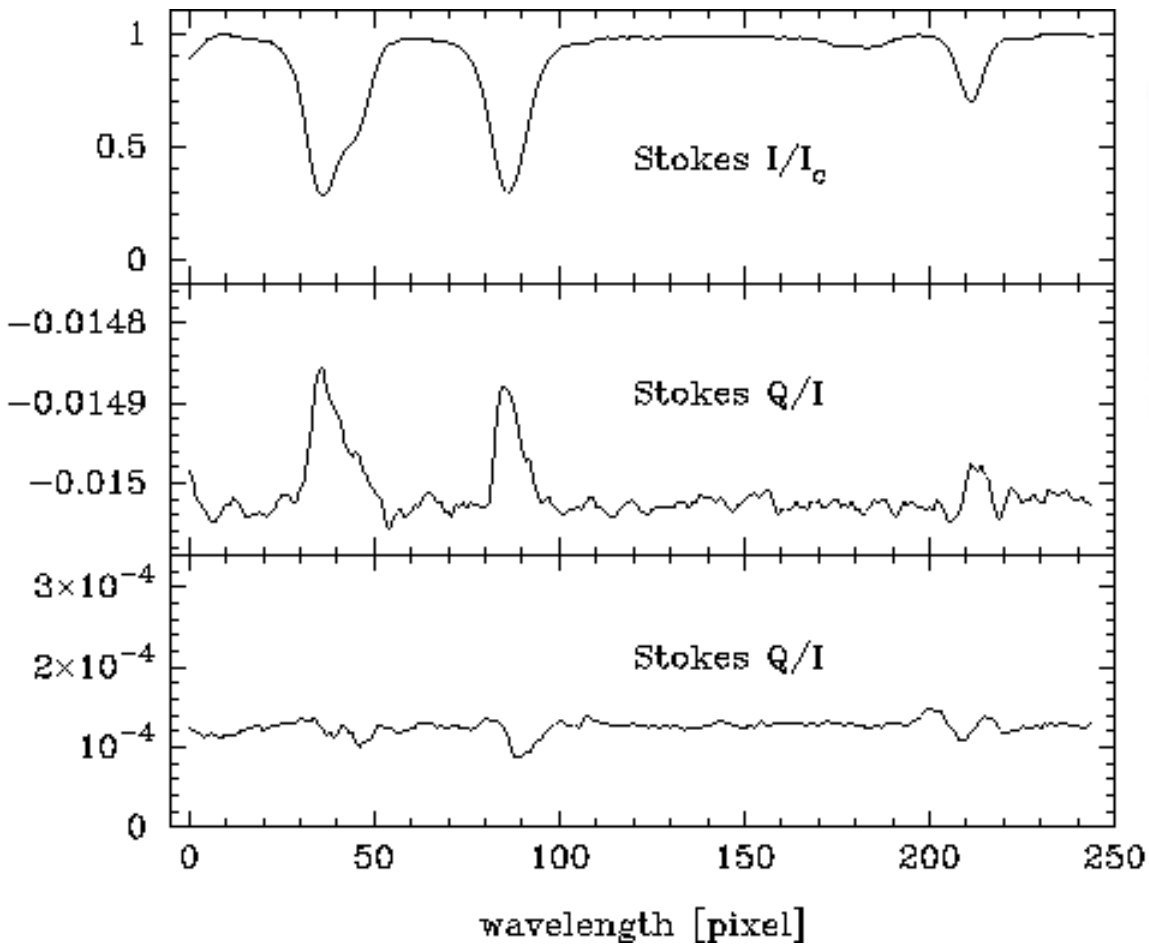


Telescope matrix vs hour angle for optics preceding modulator at **Gregory**, **AO (middle curves)**, and **Coudé**. X_{11} shows transmission preceding modulator. All other elements normalized to X_{11}. Only modulator at **Gregory** location (top blue curve) is constant over the day.

Instrumental Polarization

- How do we measure instrumental polarization?
  - Sun (profiles symmetries), sky, artificial light source?
  - Develop and verify at existing telescopes
- How do we compensate for it?
  - Active compensation with optics
  - Physical model of instrumental polarization combined with compensation during data reduction
- Instrumental polarization budget

Second-Order Effects

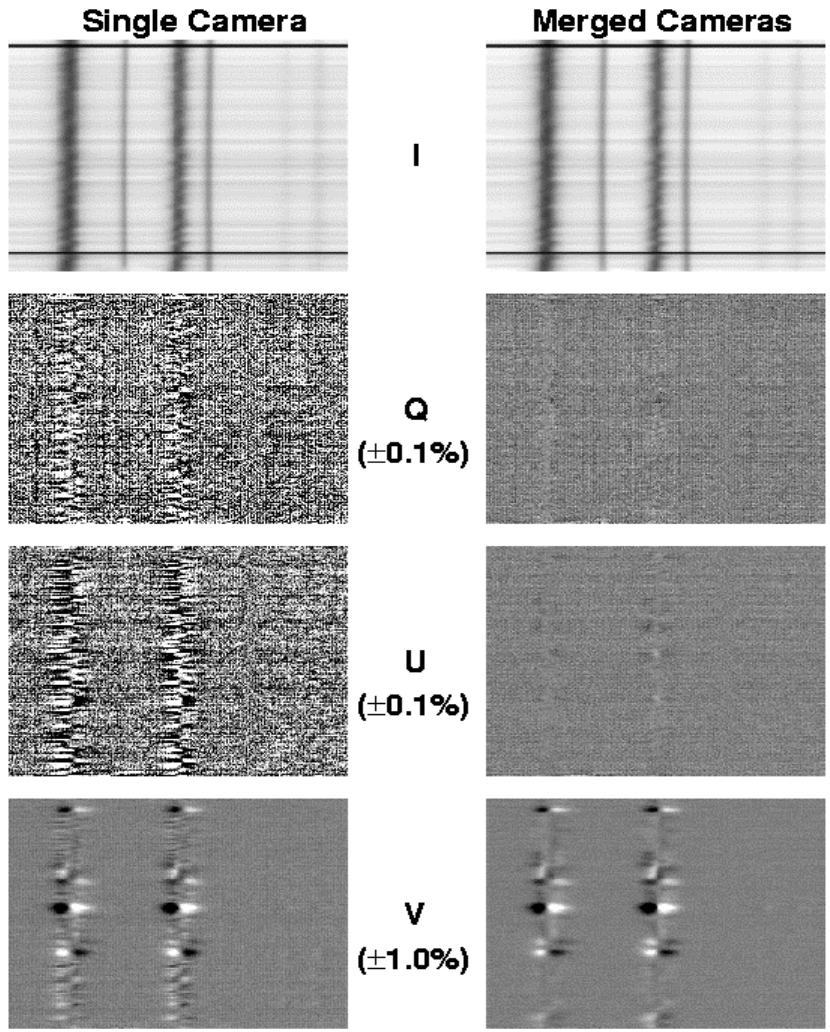


- Two 1% effects (e.g. instrumental polarization, non-linearity) couple to give a 0.01% effect
- Non-linearity in CCD cameras, influence of seeing in dual-beam polarimeter are typically 1%
- Need to remove instrumental polarization to at least the 10^{-3} level

Doppler Shift + Image Motion (DSIM)

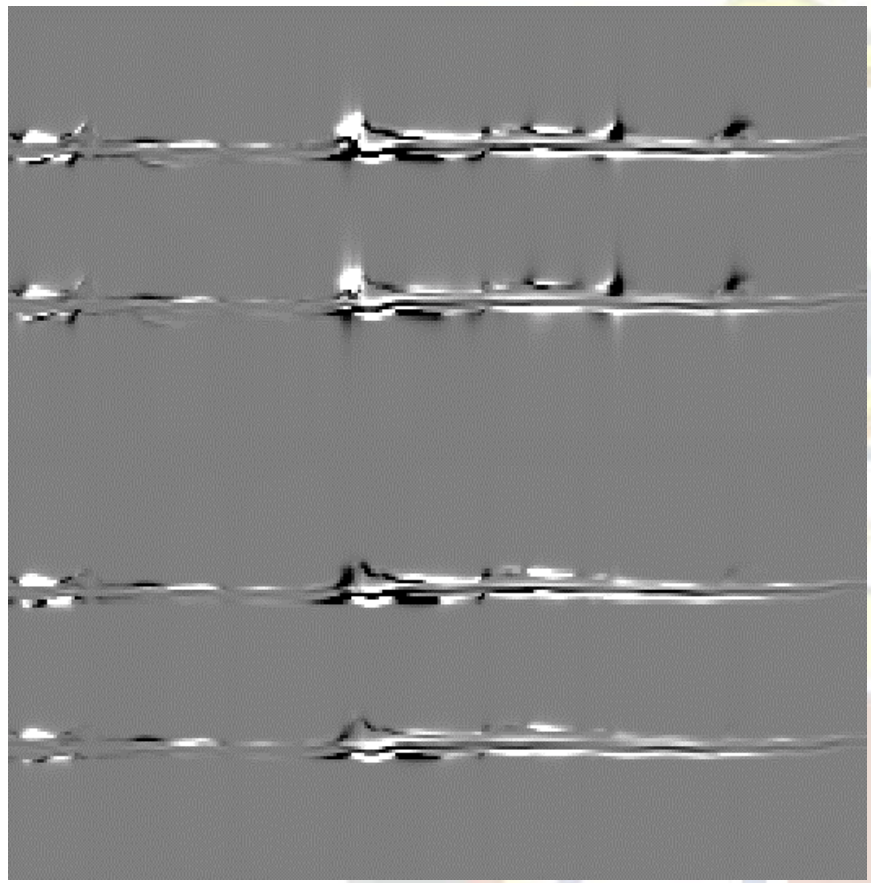
- ASP Single Camera demodulation: spurious Stokes V-like signals in lines due to variable Doppler shifts of spectrum lines
- If telescope polarization significant, spectral lines and DSIM show up in QUV
- Dual-beam polarimeter minimizes the DSIM I→QUV crosstalk
- Dual-beam system does not reduce DSIM crosstalk among QUV; to achieve 10^{-4} polarimetric precision, telescope polarization should be $\leq 10^{-2}$

Picture and text courtesy Bruce Lites



Transfer Optics Problem

- Dual-beam system with modulator at Gregorian and analyzer at Coude
- Transfer optics coupled with seeing introduces cross-talk among QUV
- Simulation: top is with polarizing transfer optics, bottom is without
- Calibration is not trivial



Gregorian Focus Area