Observational Astronomy

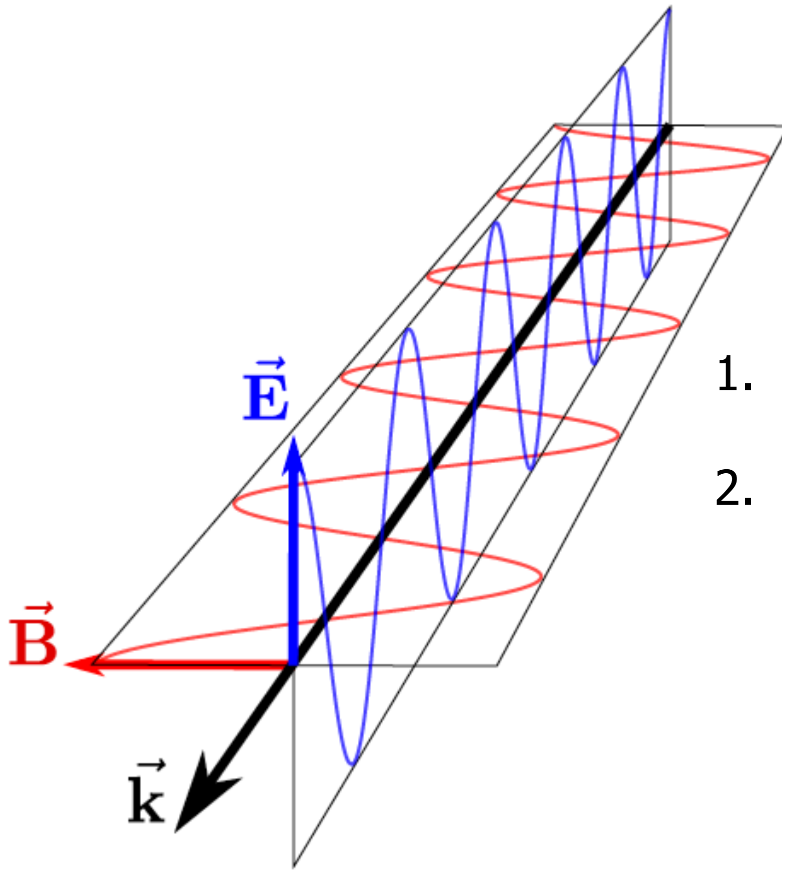
Polarimetry and Polarimeters

Kitchin, pp. 463-487

Polarimetric methods

- Polarized EM radiation
- Polarimetric components
- Imaging polarimetry
- Imaging spectropolarimetry
- Spectropolarimetry of point sources
- Polarimetric data reduction

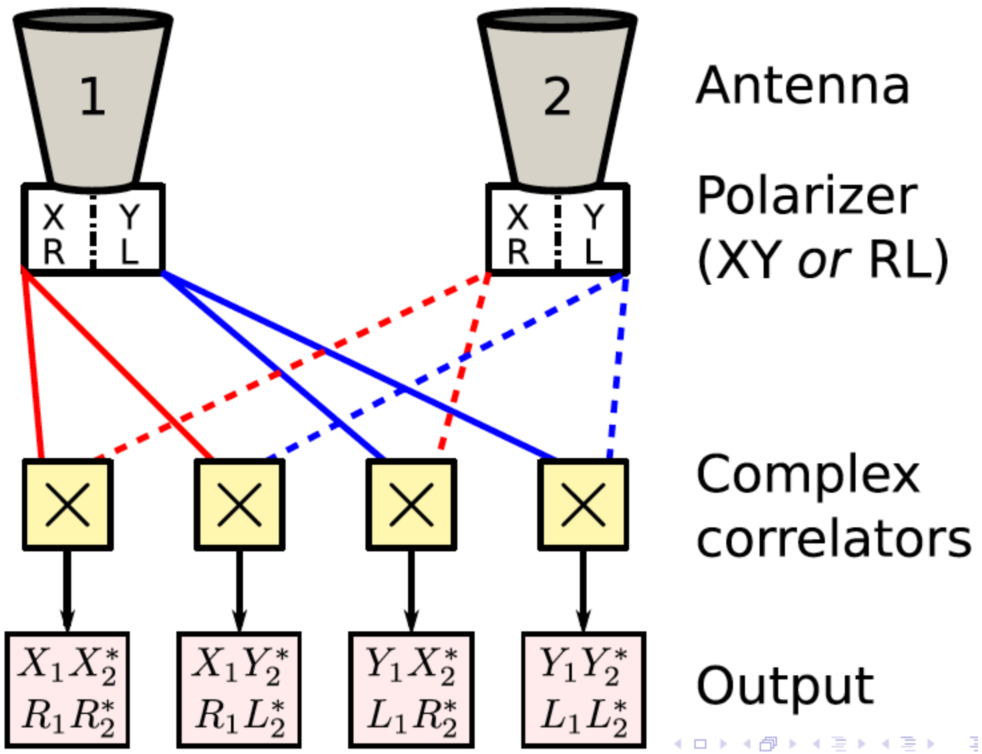
Polarized EM radiation



1. Oscillation plane may be constant for some photons (linear polarization)
2. It may rotate around propagation axis in space and time (circular polarization) for other photons

Radio polarimetry

Wavelengths are long and so are the detector components



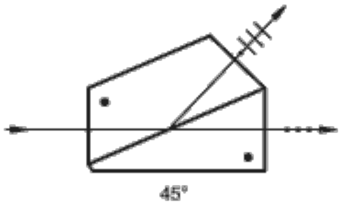
For short wavelengths (mm) the beam is split according to the direction of electric vector oscillations (X or Y) and amplitude+phase are recorded.

For long wavelength (m) two detectors can be combined.

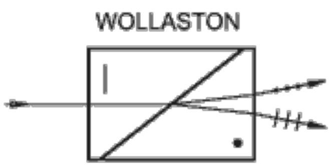
Optical polarimetry
(beam splitting or interference)

Polarizing beam-splitters

- Foster prism

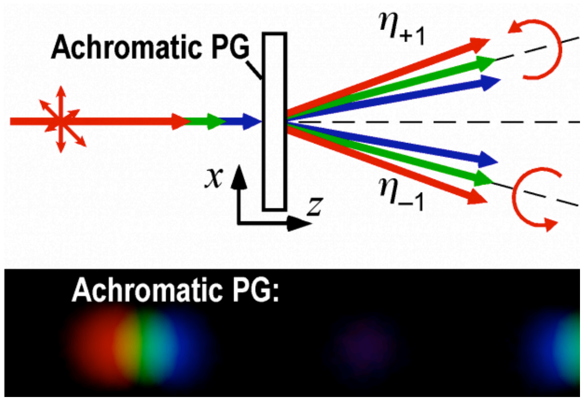


- Wollaston prism

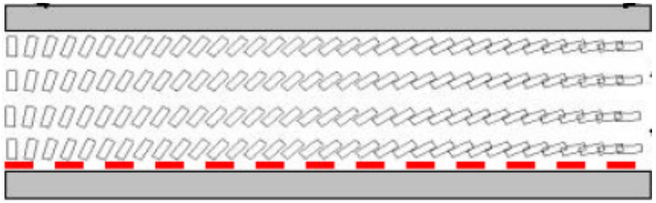


Linear polarization

- Polarizing grating



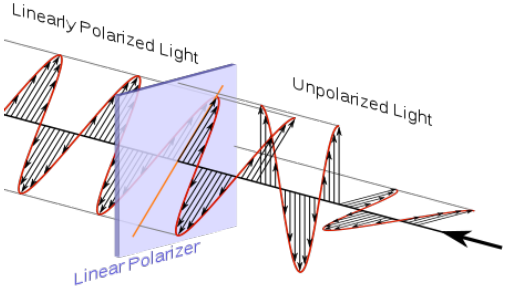
One period of a PG



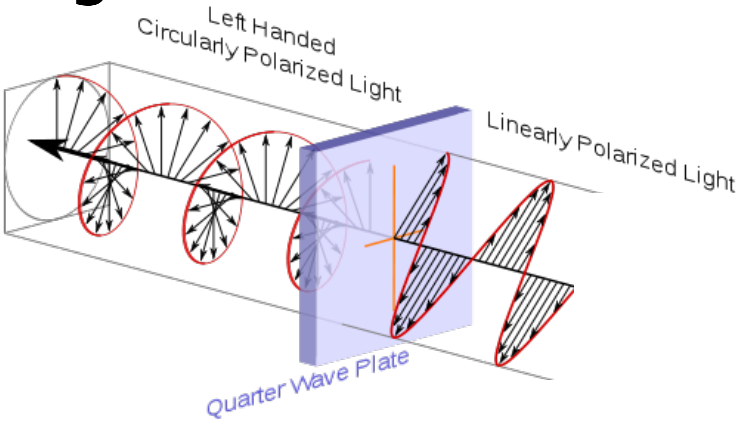
Polarimetric components

Retarder plates and polarizers

- Polarizer

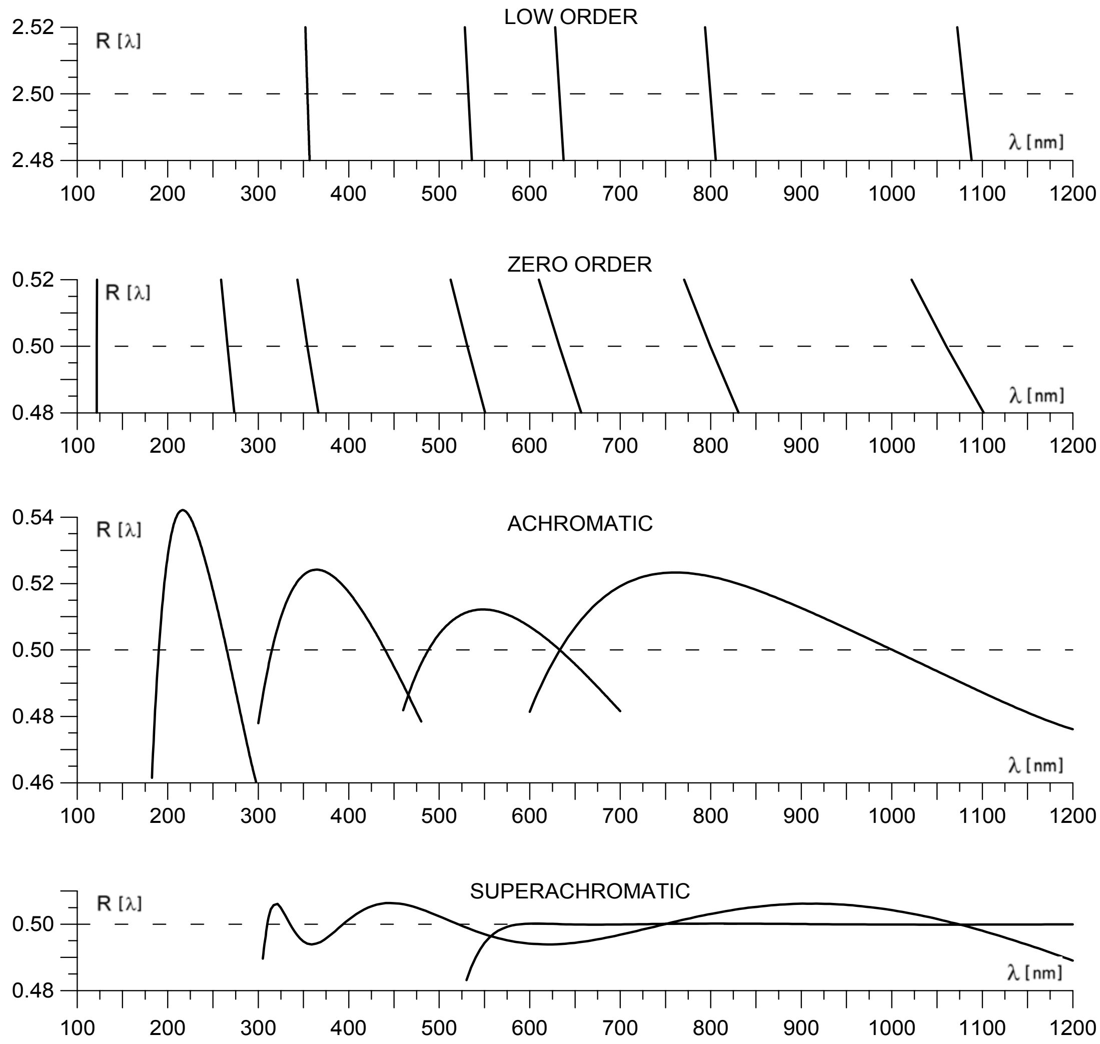


- Quarter-wavelength retarders



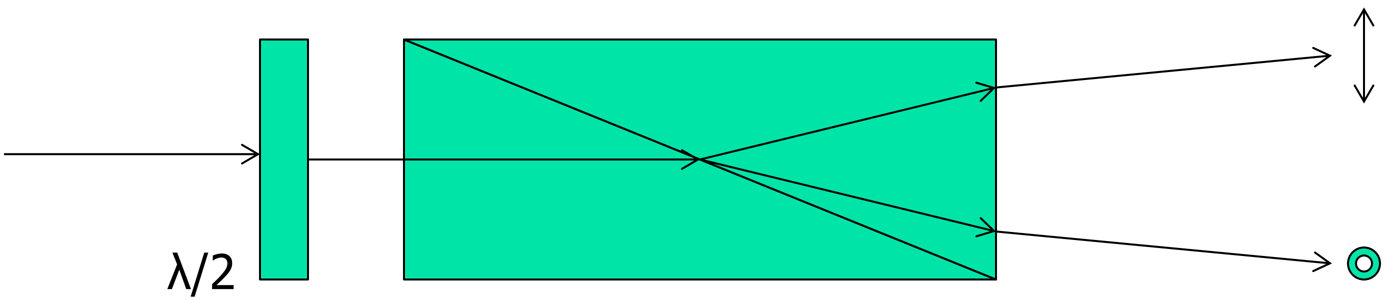
Polarimetric components

Retarder plates wavelength dependence

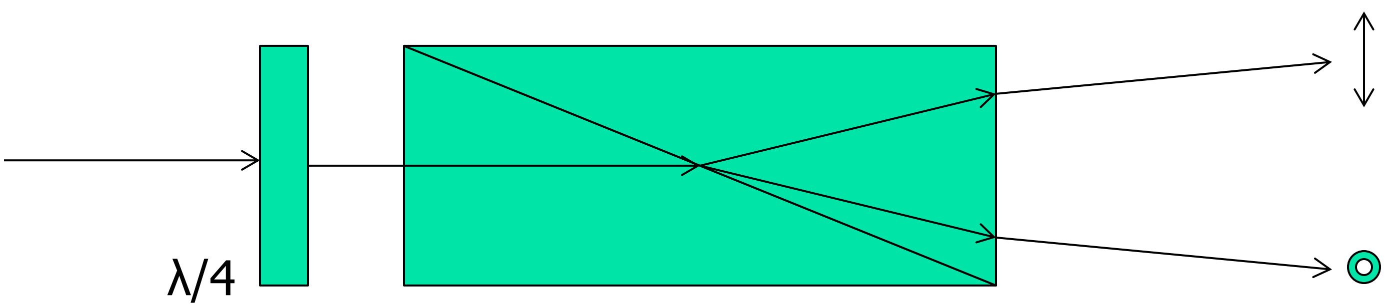


Typical polarimetric units

- Linear polarization:

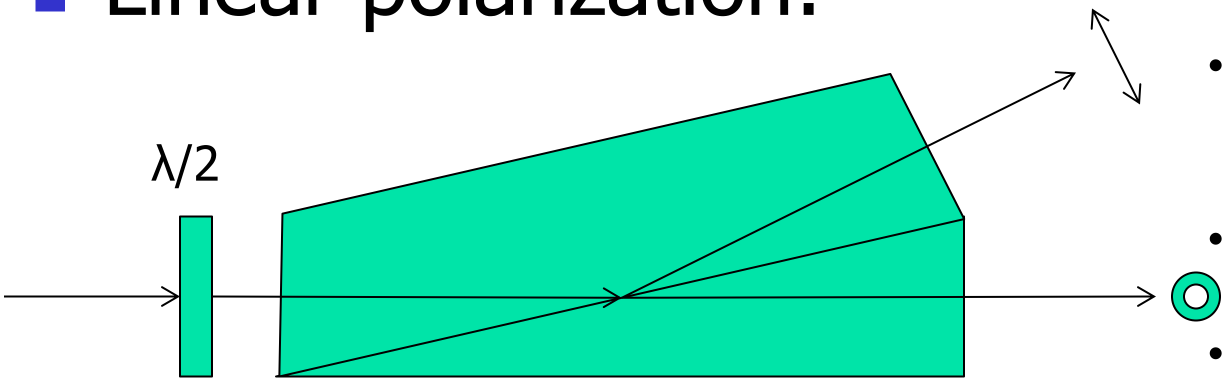


- Circular polarization:



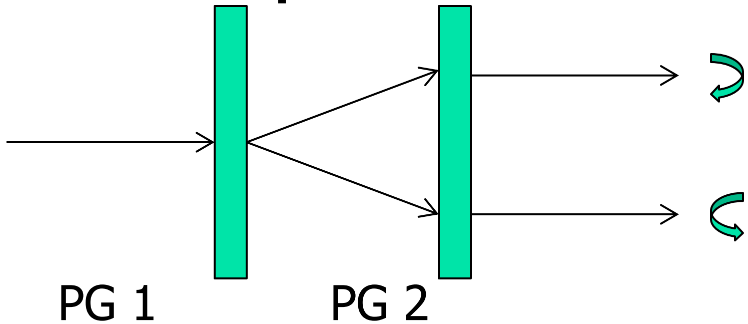
Atypical polarimetric units

- Linear polarization:



- Achromatic
- Good polarization separation
- Works in convergent beam
- Suitable for fiber coupling

- Circular polarization:



- Excellent throughput
- Suitable for slit spectroscopy
- Beam intensity is not affected by the following optics

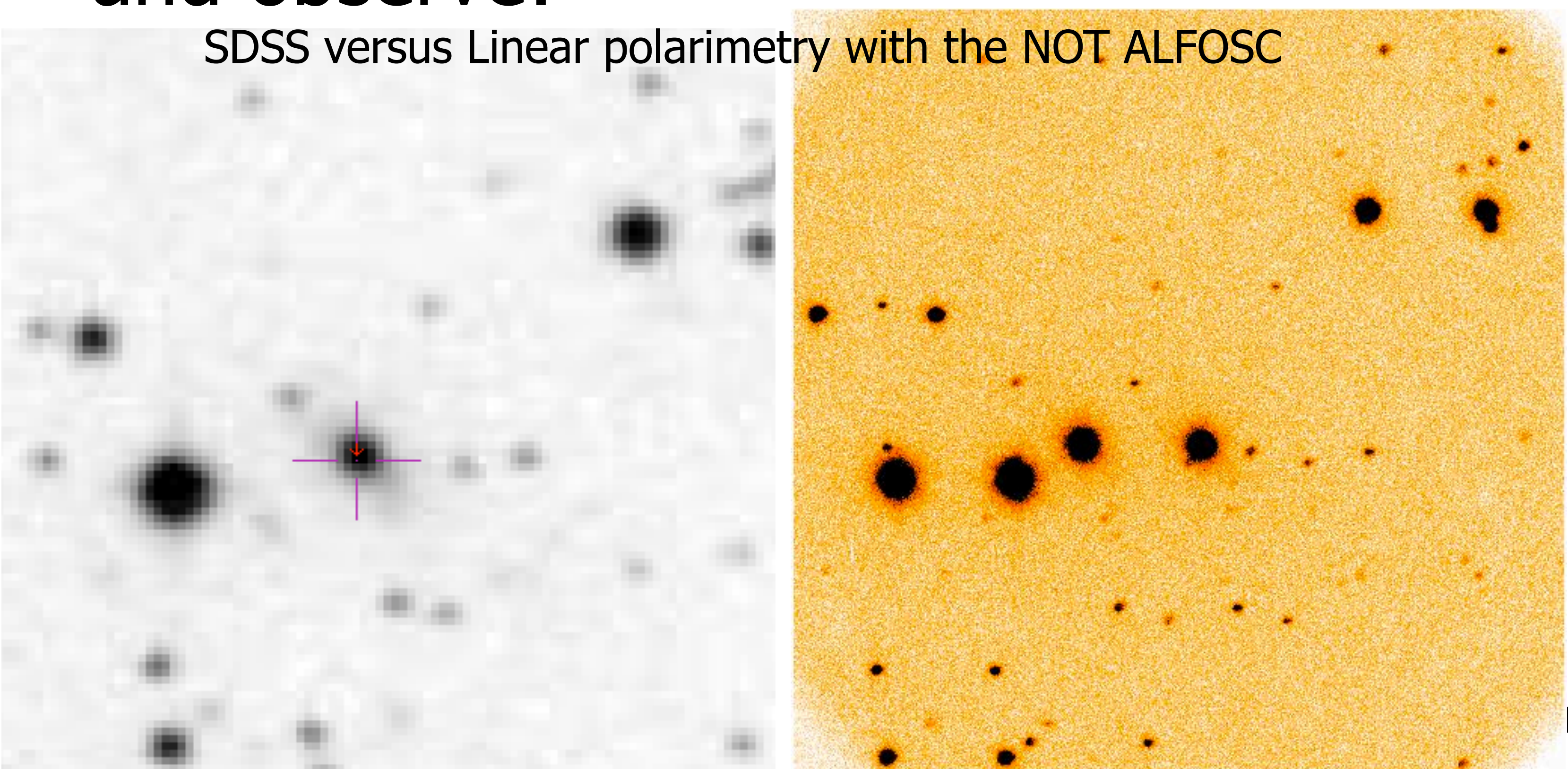
Polarimetric measurements

- What comes out of a beam-splitter (in theory) in a single beam is $(I \pm Q)/2$ or $(I \pm U)/2$ for linear and $(I \pm V)/2$ for circular polarization
- The simplest way to get Stokes parameters is to subtract the two beams
- This only works if the optical paths for the two beams are identical

Imaging polarimetry

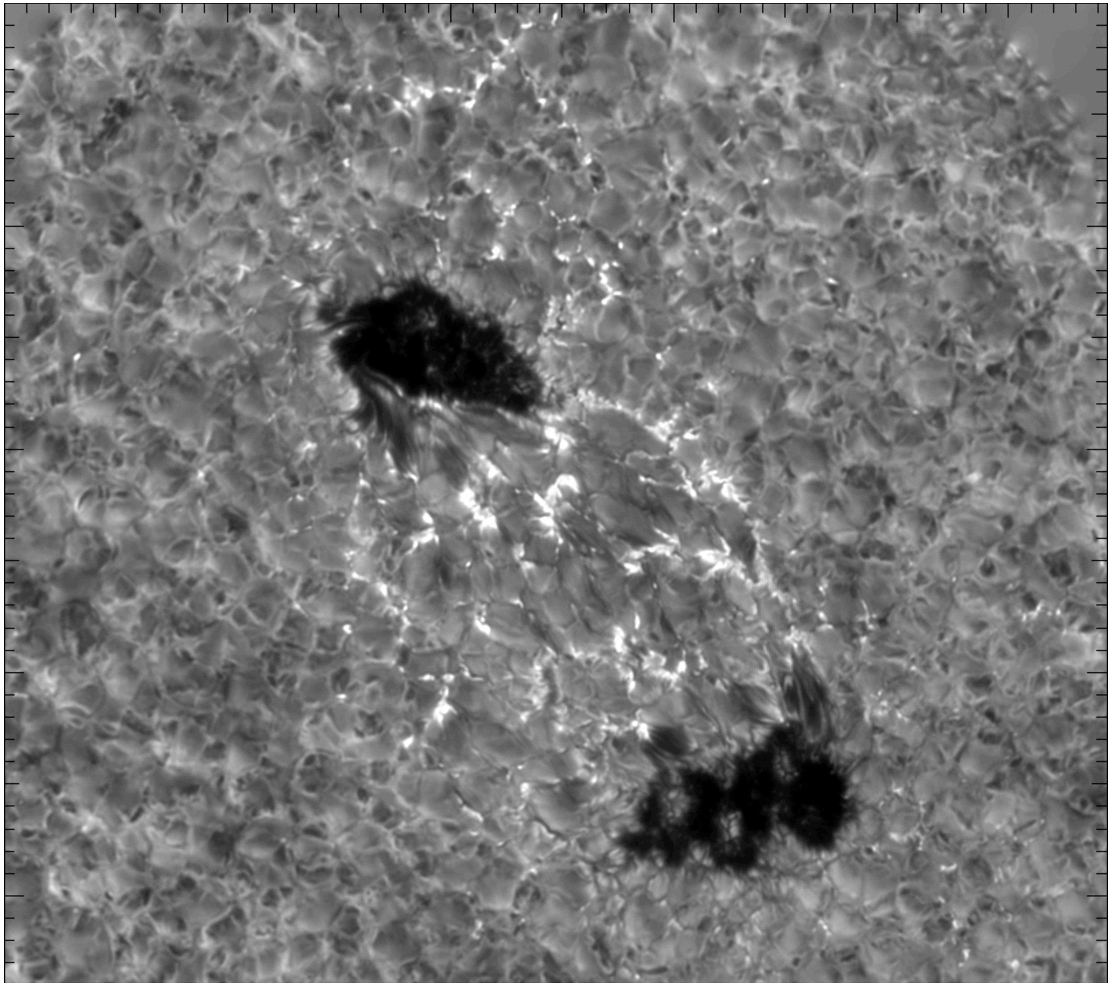
Insert a Wollaston in your focal reducer and observe:

SDSS versus Linear polarimetry with the NOT ALFOSC



Spatially-resolved spectropolarimetry

SST image of a solar active region in Stokes V in the wing of Fe I 6302 Å line



Spatially-resolved spectropolarimetry

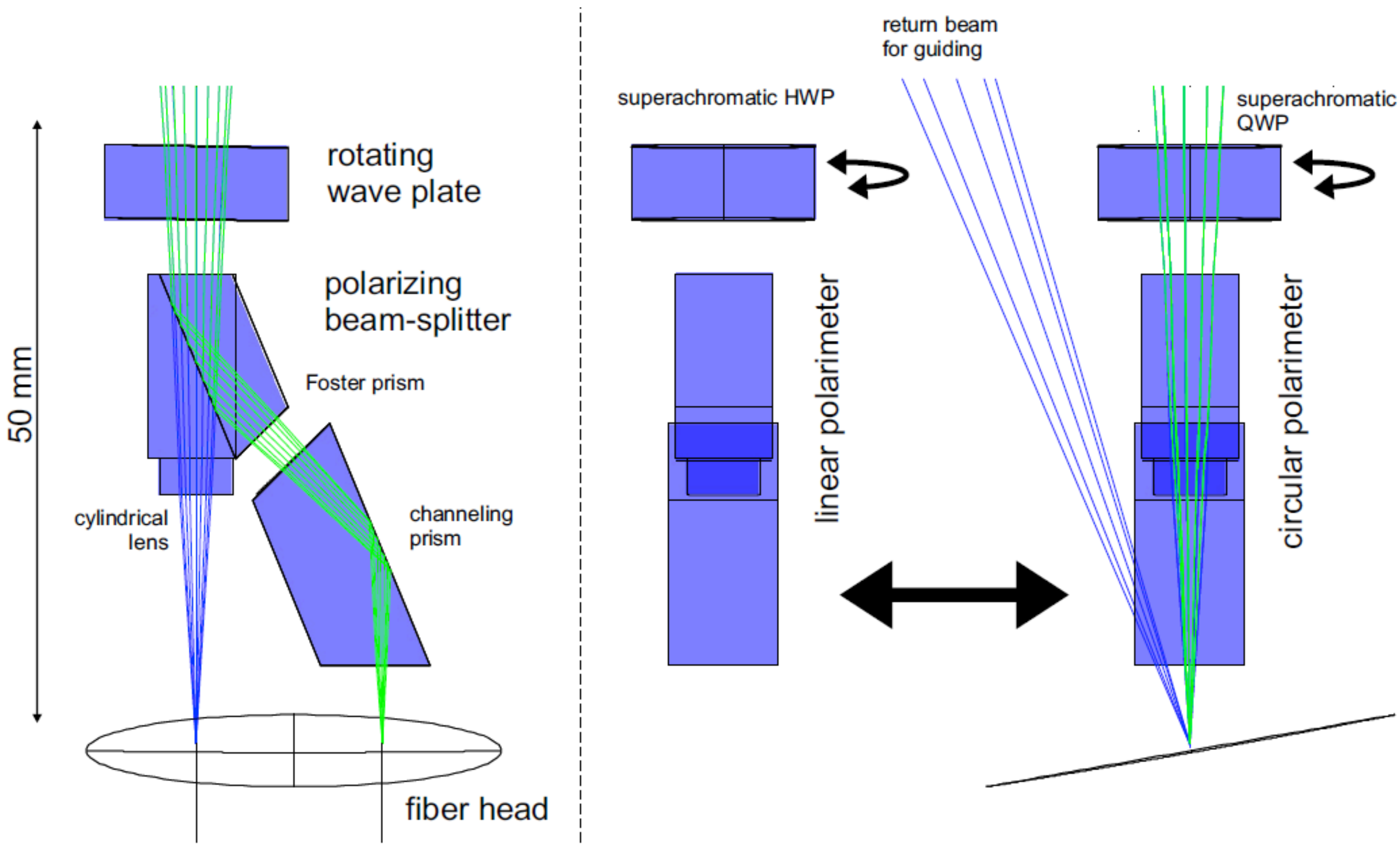
Solar image was taken with the CRISP instrument at SST. It combines beam-splitter with a tunable filter capable of scanning short spectral regions.

Spectropolarimetry of point sources

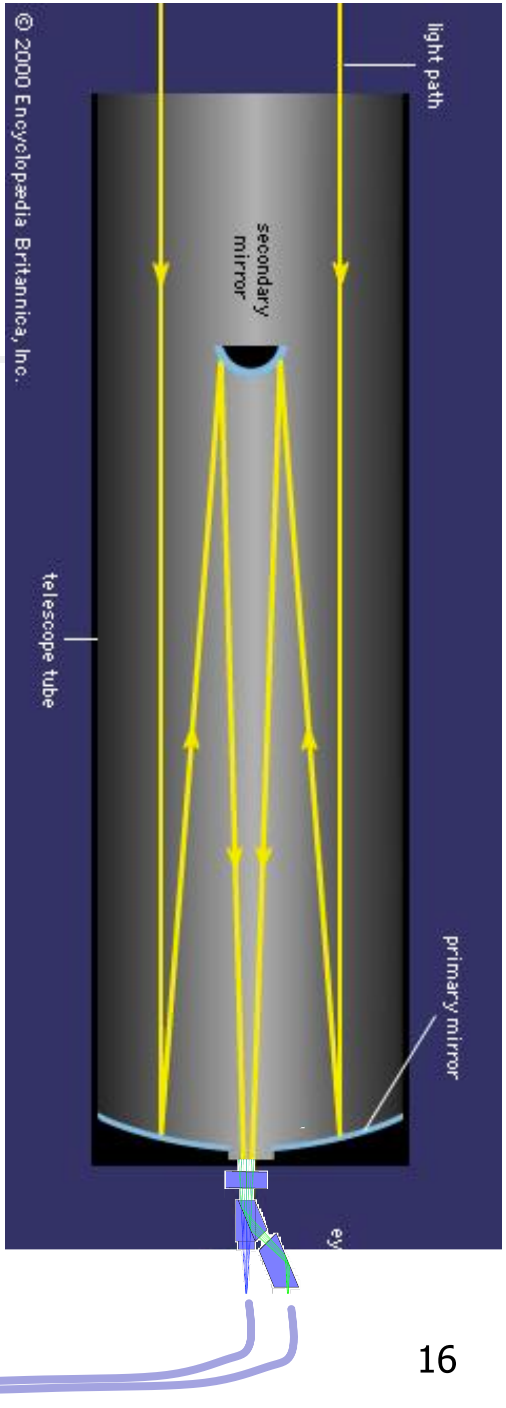
Main idea: a polarimeter feeding a spectrometer

Example: HARPSpol

HARPSpol optical design

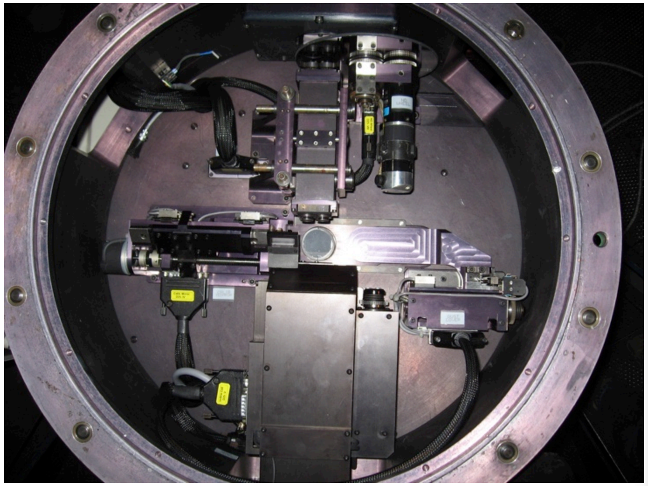


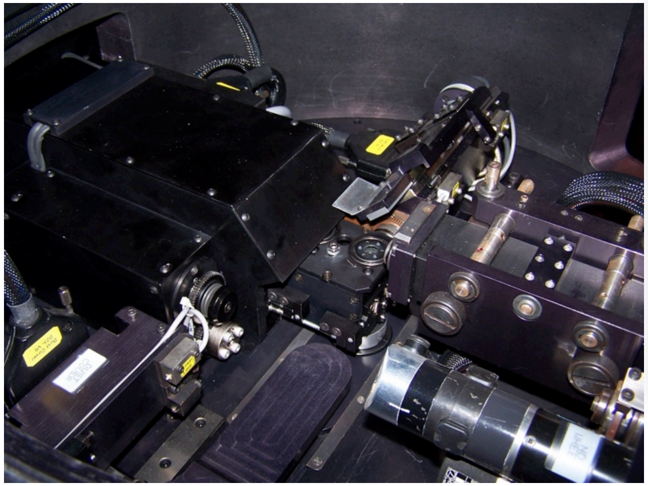
HARPSpol location

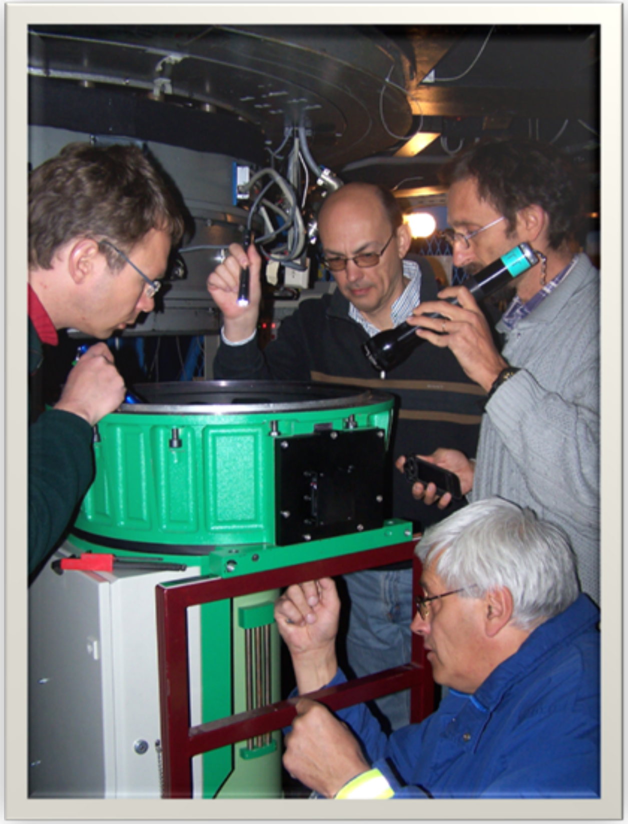


HARPSpol location

Cassegrain adapter



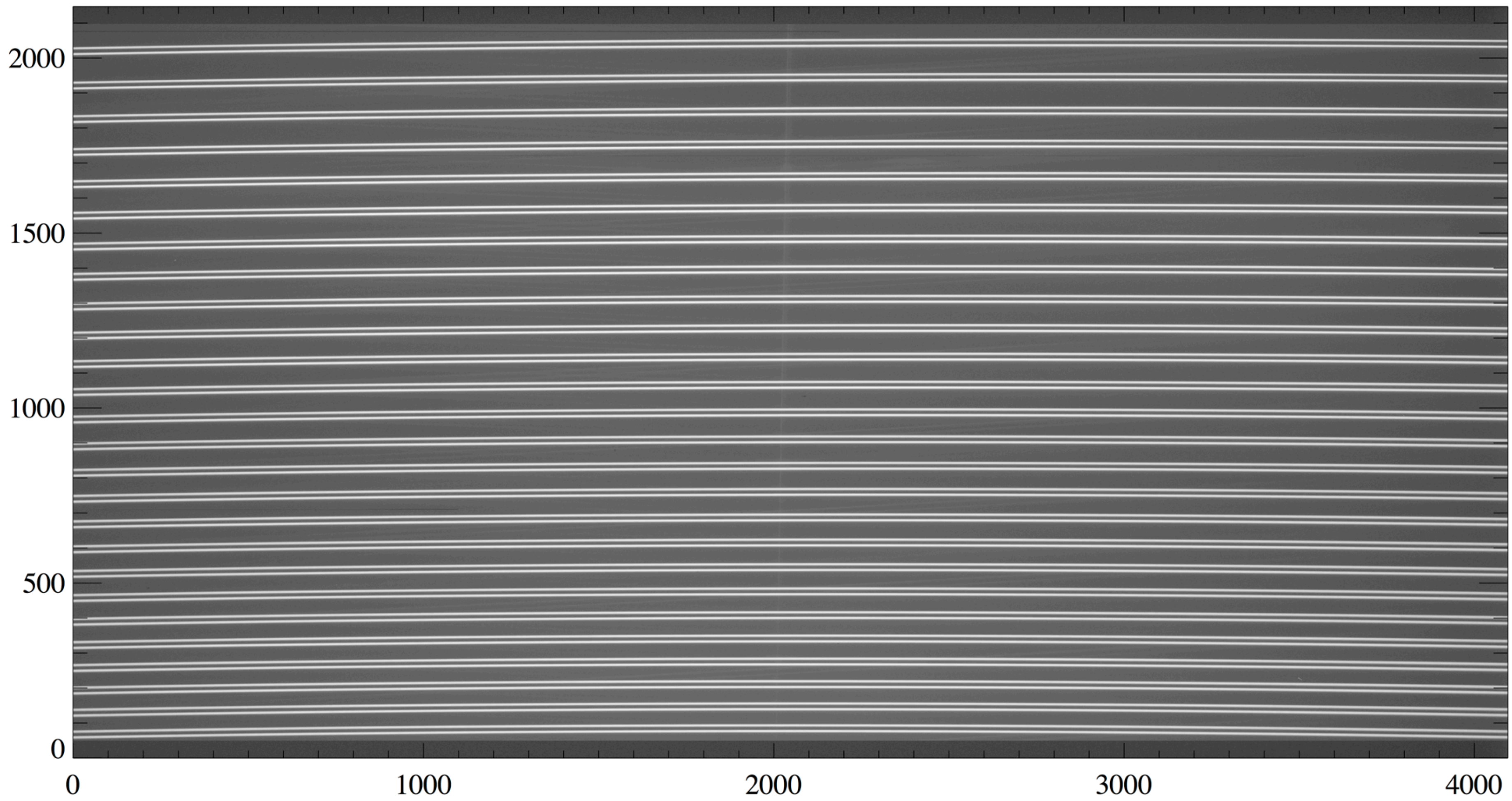




Why the location is important?

- Oblique reflections by conducting surfaces (read *mirrors*) introduce broad-band linear polarization
- Stresses in surface coatings act as retarder plates converting linear polarization to circular and back
- HARPSpol has none of these problems

HARPSpol spectral format



What about the difference between the fibers?

- We split every exposure into four sub-exposures switching polarization between beams
- Then we will compare intensities registered from sequential sub-exposures by the same pixels
- This process is the final step in data reduction and is called *demodulation*

Demodulation

$$\frac{V}{I}=\frac{\left[\frac{f^{\circlearrowright}(45)}{f^{\circlearrowleft}(135)}\cdot\frac{f^{\circlearrowright}(135)}{f^{\circlearrowleft}(45)}\cdot\frac{f^{\circlearrowright}(225)}{f^{\circlearrowleft}(315)}\cdot\frac{f^{\circlearrowright}(315)}{f^{\circlearrowleft}(225)}\right]^{1/4}-1}{\left[\frac{f^{\circlearrowright}(45)}{f^{\circlearrowleft}(135)}\cdot\frac{f^{\circlearrowright}(135)}{f^{\circlearrowleft}(45)}\cdot\frac{f^{\circlearrowright}(225)}{f^{\circlearrowleft}(315)}\cdot\frac{f^{\circlearrowright}(315)}{f^{\circlearrowleft}(225)}\right]^{1/4}+1}$$

$$\frac{V}{I}=\frac{\left[\frac{0.5\cdot(I+V)}{0.5\cdot(I-V)}\cdot\frac{0.5\cdot(I+V)}{0.5\cdot(I-V)}\cdot\frac{0.5\cdot(I+V)}{0.5\cdot(I-V)}\cdot\frac{0.5\cdot(I+V)}{0.5\cdot(I-V)}\right]^{1/4}-1}{\left[\frac{0.5\cdot(I+V)}{0.5\cdot(I-V)}\cdot\frac{0.5\cdot(I+V)}{0.5\cdot(I-V)}\cdot\frac{0.5\cdot(I+V)}{0.5\cdot(I-V)}\cdot\frac{0.5\cdot(I+V)}{0.5\cdot(I-V)}\right]^{1/4}+1}$$

$$\frac{V}{I}=\frac{(I+V)-(I-V)}{(I+V)+(I-V)}\equiv\frac{V}{I}$$

Next time

ALMA data reduction as your final lab!