

1. Moon Polarization

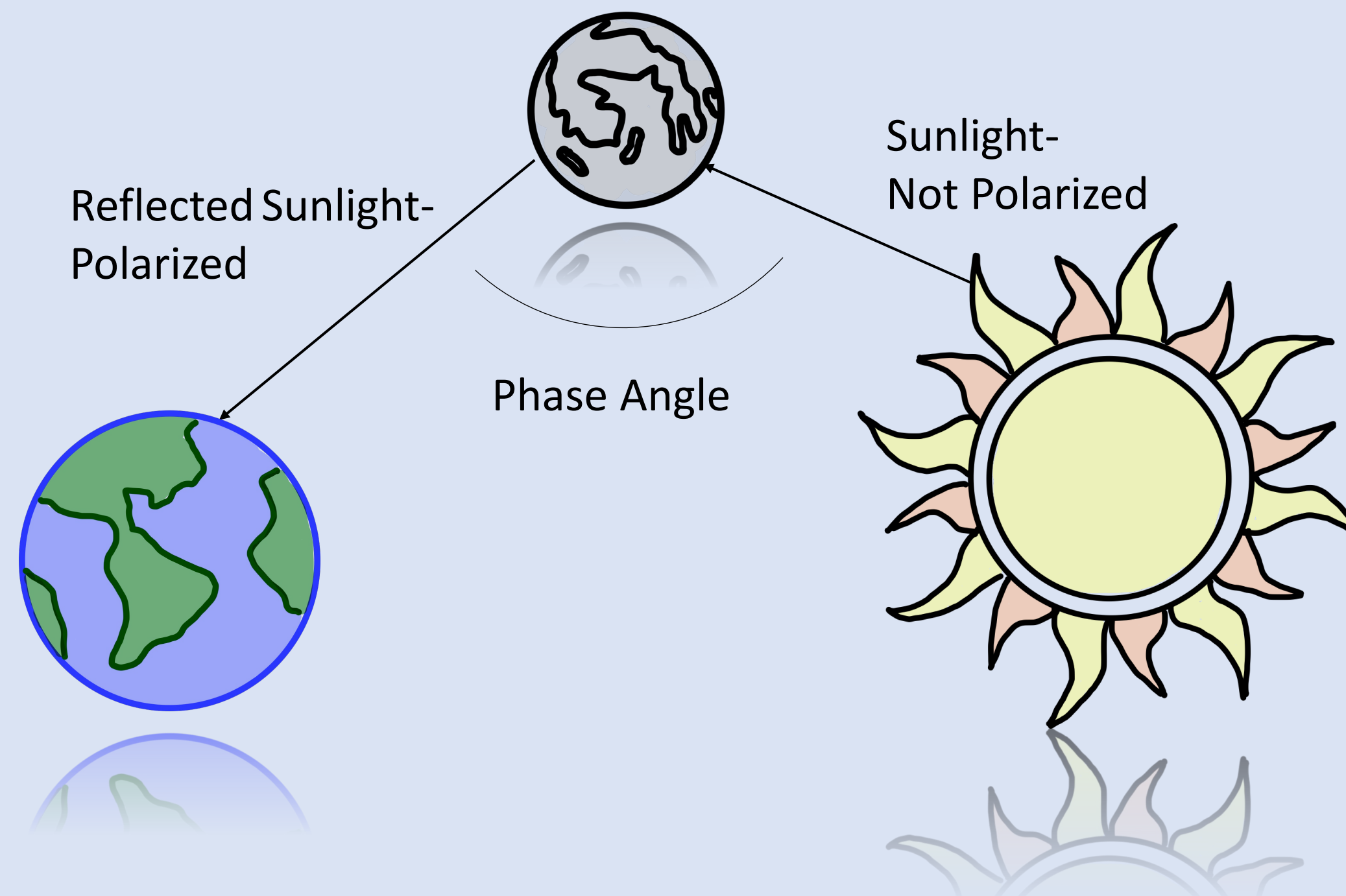
Polarization is the tendency of electric fields to oscillate directionally, which can be caused by:

- Reflections
- Scattering
- Polarizing Materials

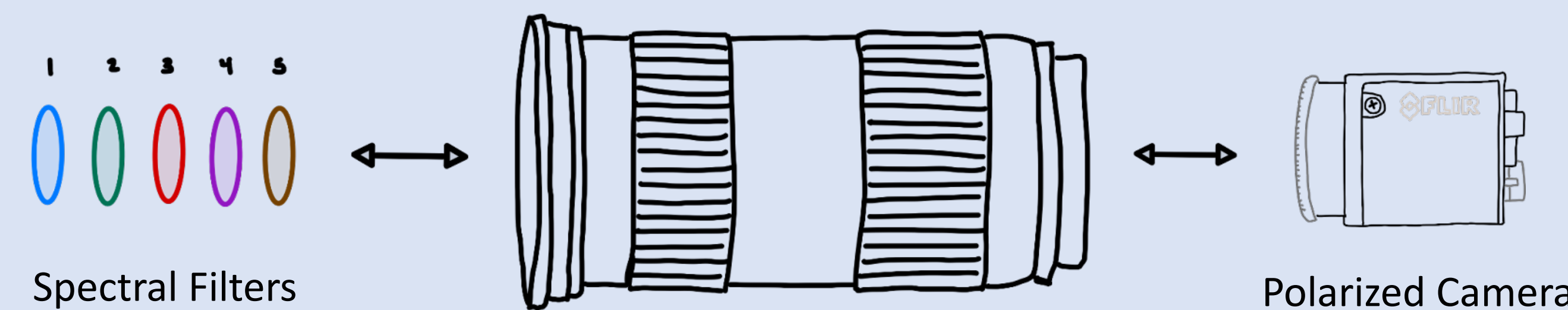
Sunlight is reflected off the Moon's surface, which causes the reflected sunlight (i.e., moonlight) to be polarized.

Research Question: How does the lunar polarization versus phase angle curve change as a function of wavelength?

Objective: Take polarization images of the Moon and see how filters in the visible and near-IR change the degree of polarization and how it varies with phase angle.

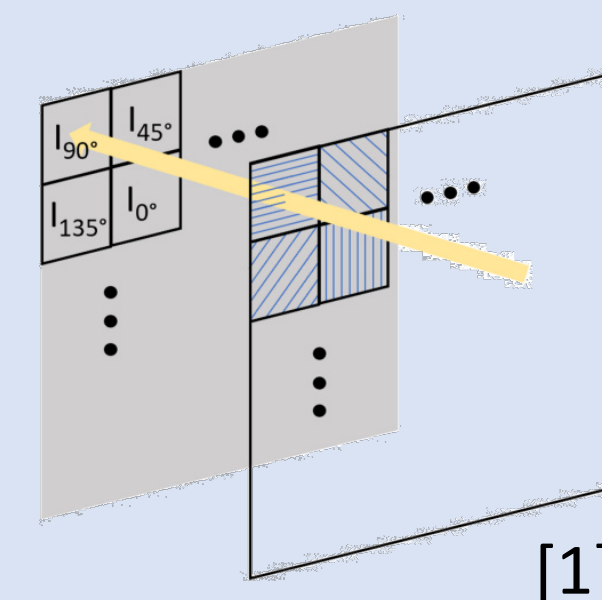


2. Instrumentation



Polarization Camera

Instead of rotating a polarizer externally, we used a camera with polarization states built into pixel groups, so we can take an image with different polarization states at the same instant.



[1]

Stokes Parameters

$$S_0 = I = I_{0^\circ} + I_{90^\circ}$$

$$S_1 = Q = I_{0^\circ} - I_{90^\circ}$$

$$S_2 = U = I_{45^\circ} - I_{135^\circ}$$

Degree of Linear Polarization

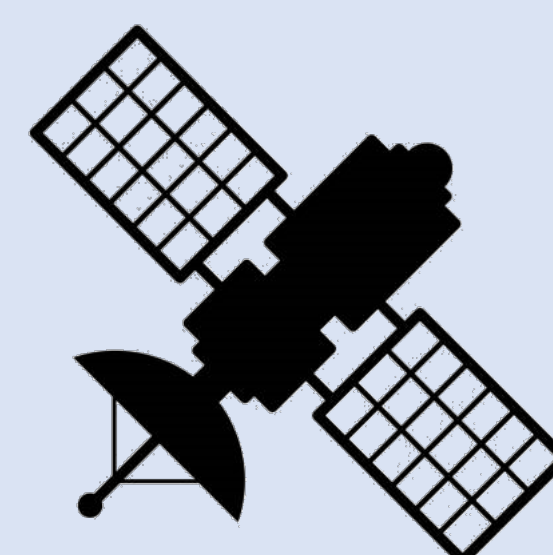
$$DoLP = \sqrt{(S_1^2 + S_2^2)} / S_0^2$$

Angle of Polarization

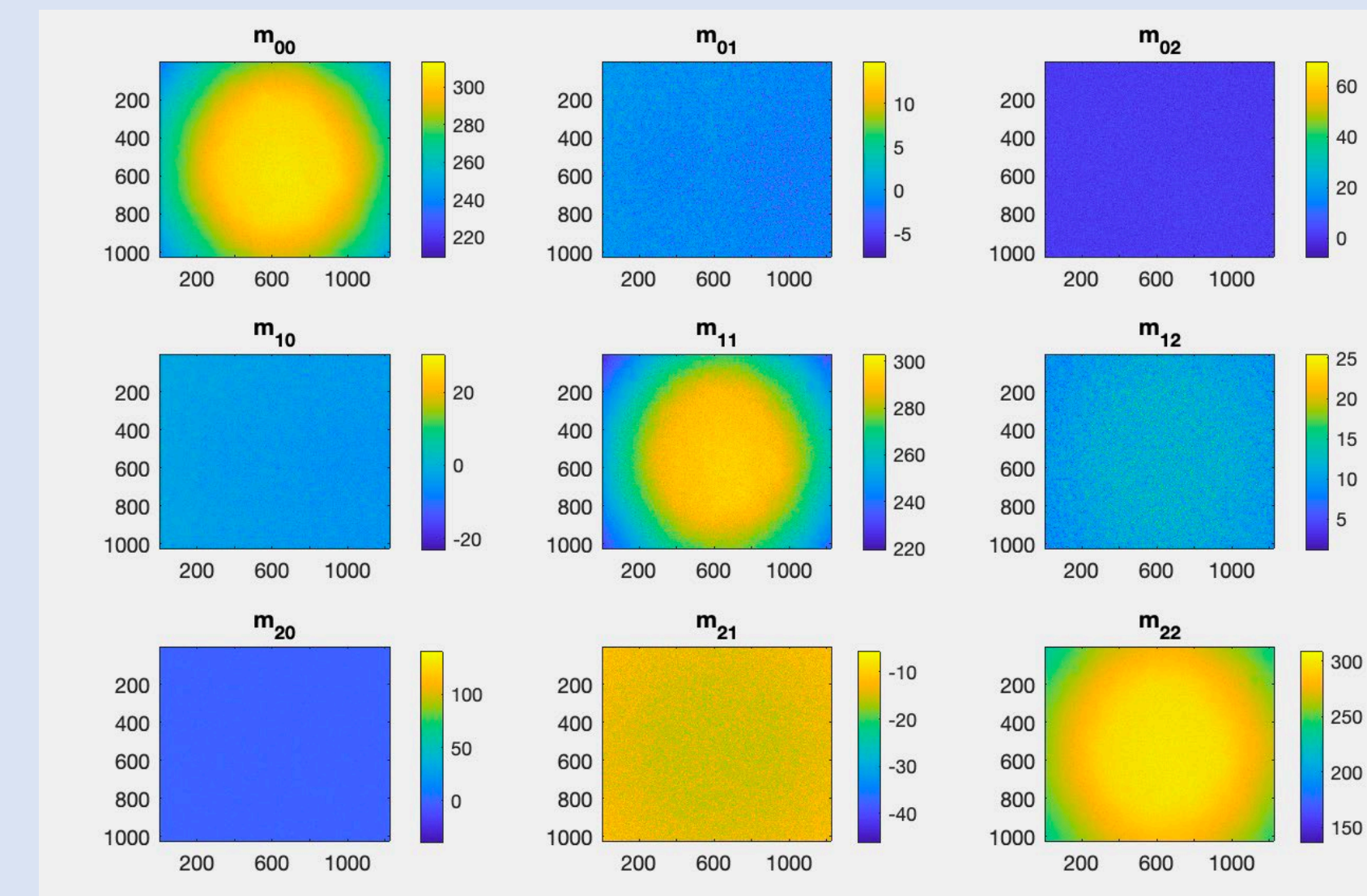
$$AoP = \frac{1}{2} \arctan \frac{S_2}{S_1}$$

What does this help with?

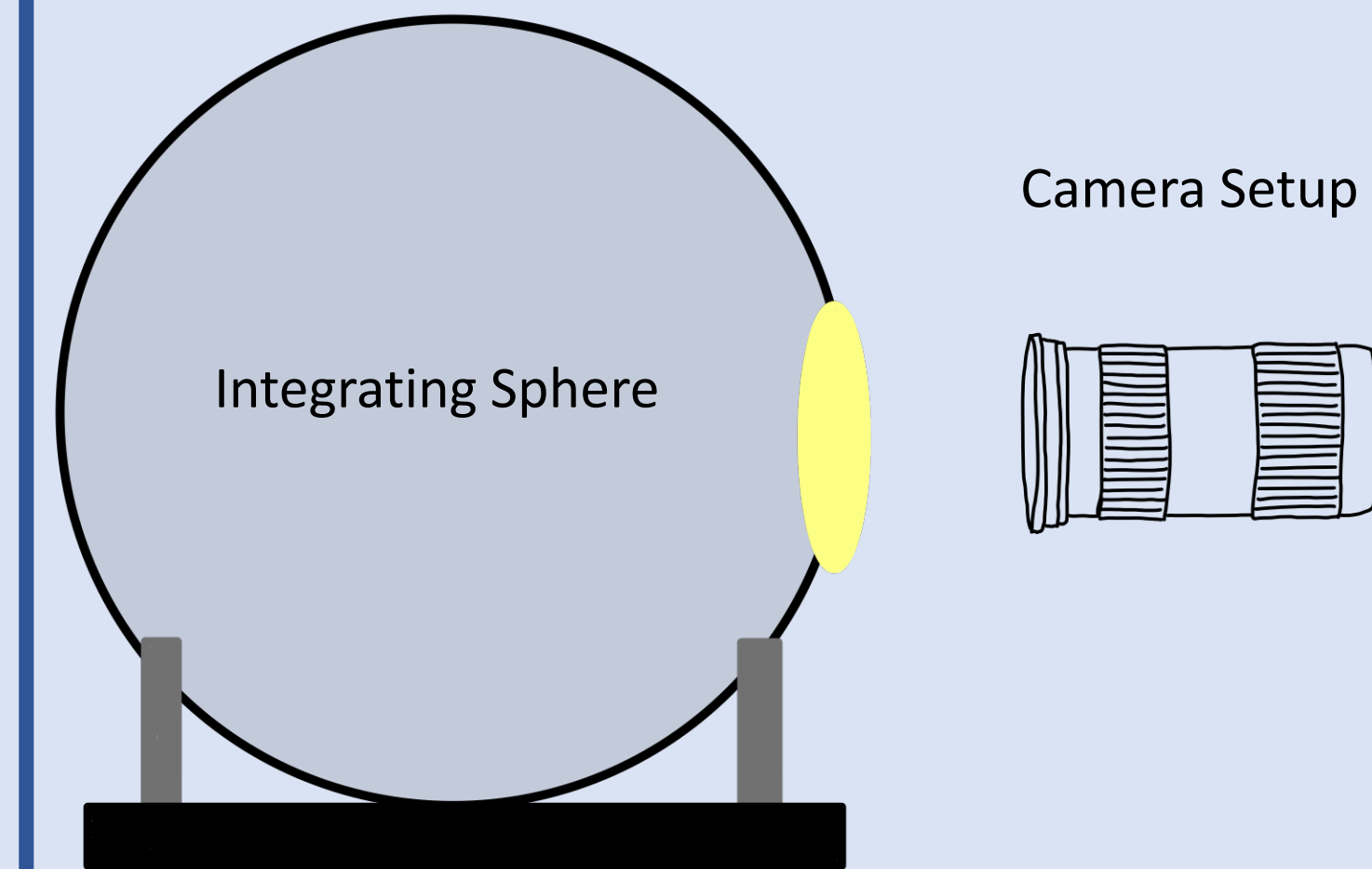
- Satellites instruments may have some intentional or unintentional polarization sensitivity
- Many radiometric models for the Moon but almost no polarimetric models!
- Satellites can use the Moon as a calibration source if a polarimetric Moon model is refined



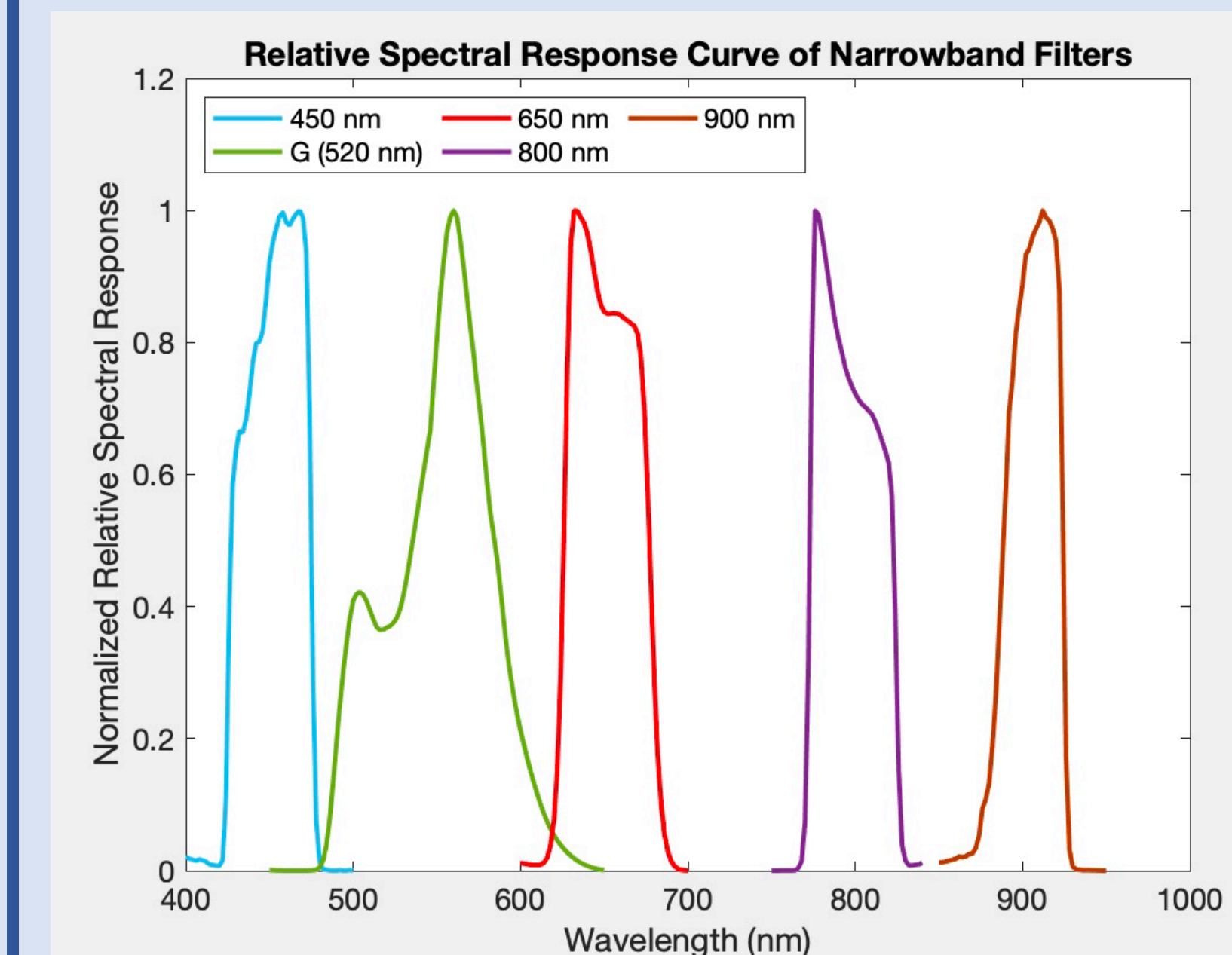
3. Calibration Procedures



1. Polarimetric Calibration: Applied to raw images to obtain Stokes parameters (example shown for 900 nm filter).



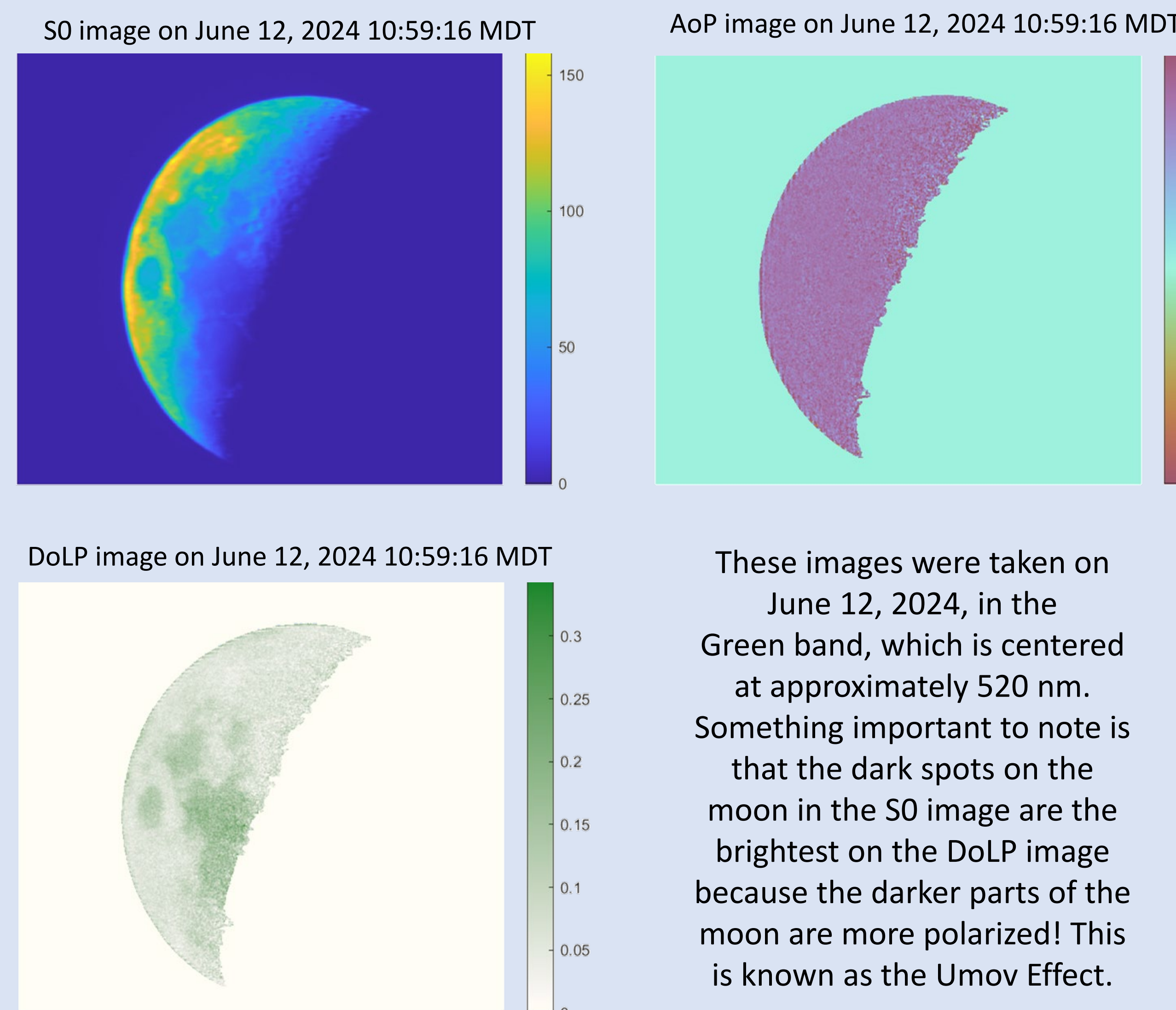
2. Radiometric Calibration: Performed with an integrating sphere to achieve a flat-fielding effect and to convert digital number to radiance $\frac{W}{m^2 Sr}$.



3. Spectral Calibration: Performed with a monochromator to determine the relative spectral response, which quantifies the imaging system's peak-normalized response versus wavelength. This is measured separately for each filter.

4a. Processed Image Data

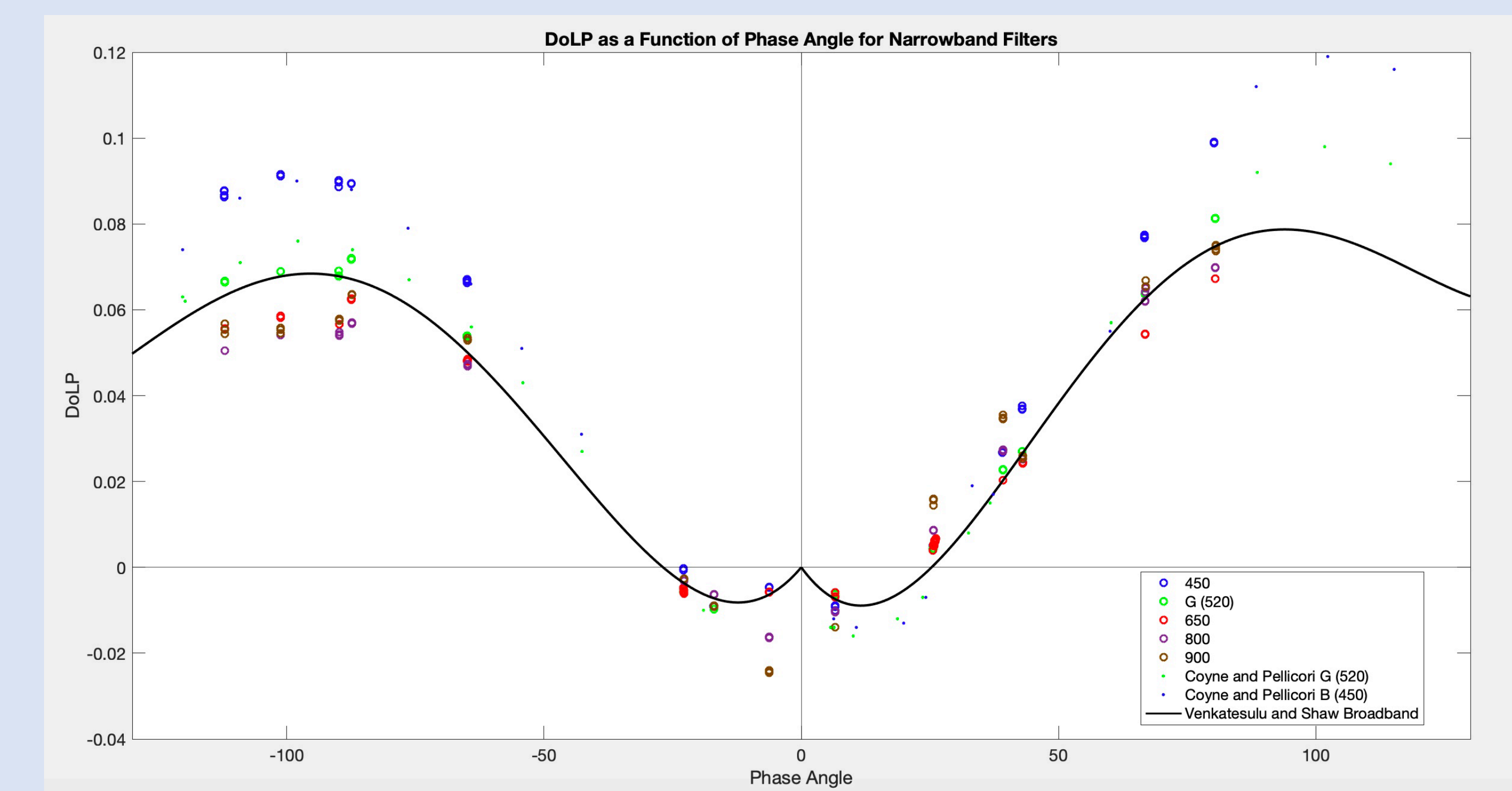
Three Polarization Parameters



These images were taken on June 12, 2024, in the Green band, which is centered at approximately 520 nm. Something important to note is that the dark spots on the moon in the S0 image are the brightest on the DoLP image because the darker parts of the moon are more polarized! This is known as the Umov Effect.

4b. DoLP Curve Data

Summary of data recorded on seven days



The figure above shows DoLP as a function of phase angle in degrees as well as how DoLP varies with wavelength. The signature S curve follows that of previous data recorded in the ORSL lab as well as data from Coyne and Pellicori (small green and blue dots) [3]. We observed that DoLP decreases as wavelength increases.

5. Conclusions

- The DoLP of the Moon increases with wavelength
- DoLP maximum (~5 to 9%) occurs near 90-degree lunar phase angle (quarter moon) and minimum (0 to ~2%) occurs for 0 degrees (full moon)
- **Future work:** Continue recording images to more completely fill in the plot, possibly with more filters at wavelengths used for satellite calibration, and publish results