



Optical Instruments for Solar Eclipse Measurements

Spectro – Polarimeter

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Optical Instrument Projects

- Spectro – Polarimeter: Jon
- Aurora Detector: Kendra
- Solar Radiometer: Logan



Spectro – Polarimeter

- Spectro: range of wavelengths
- Polarimeter: measures the polarization of light
- Hence, measuring polarization as a function of wavelengths

Polarization of Skylight

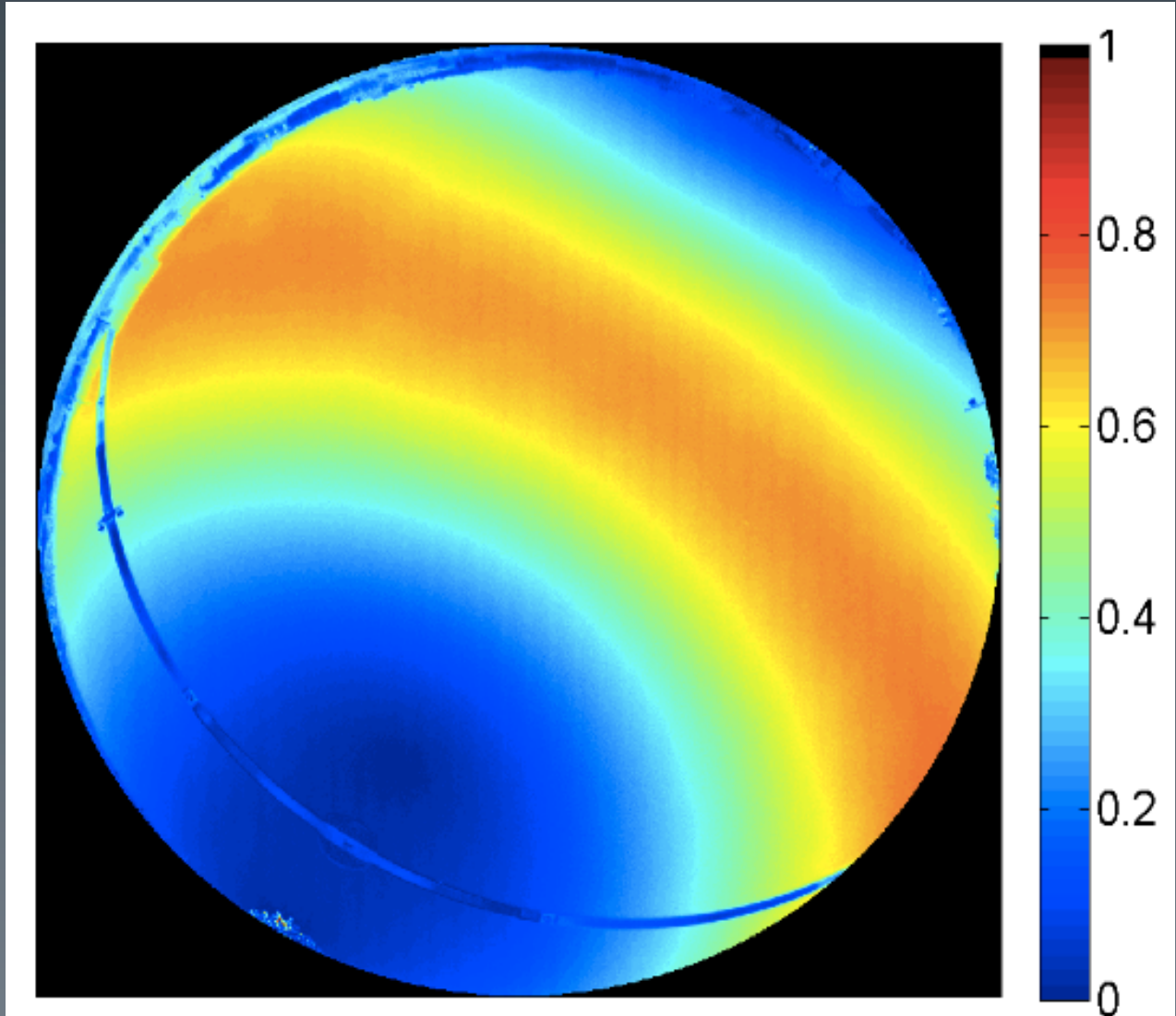


Image by Dr. Joseph Shaw

Stokes Vector & Parameters

The Stokes vector has 4 Stokes parameters

$$\mathcal{S} = \begin{bmatrix} s_0 \\ s_1 \\ s_2 \\ s_3 \end{bmatrix} = \begin{bmatrix} I \\ Q \\ U \\ V \end{bmatrix}$$

- Total Irradiance
- Vertical or horizontal component
- 45° or 135° component
- Circular component

Spectro – Polarimeter Goals

- Measure the Stokes vector
- Compare to atmospheric parameters

$$S = \begin{bmatrix} s_0 \\ s_1 \\ s_2 \\ s_3 \end{bmatrix} = \begin{bmatrix} I \\ Q \\ U \\ V \end{bmatrix}$$

Spectro – Polarimeter Instrument

- ASD Spectroradiometer with range of 350-2500 nm
- Linear polarizer attached to a rotation stage
- Equatorial mount

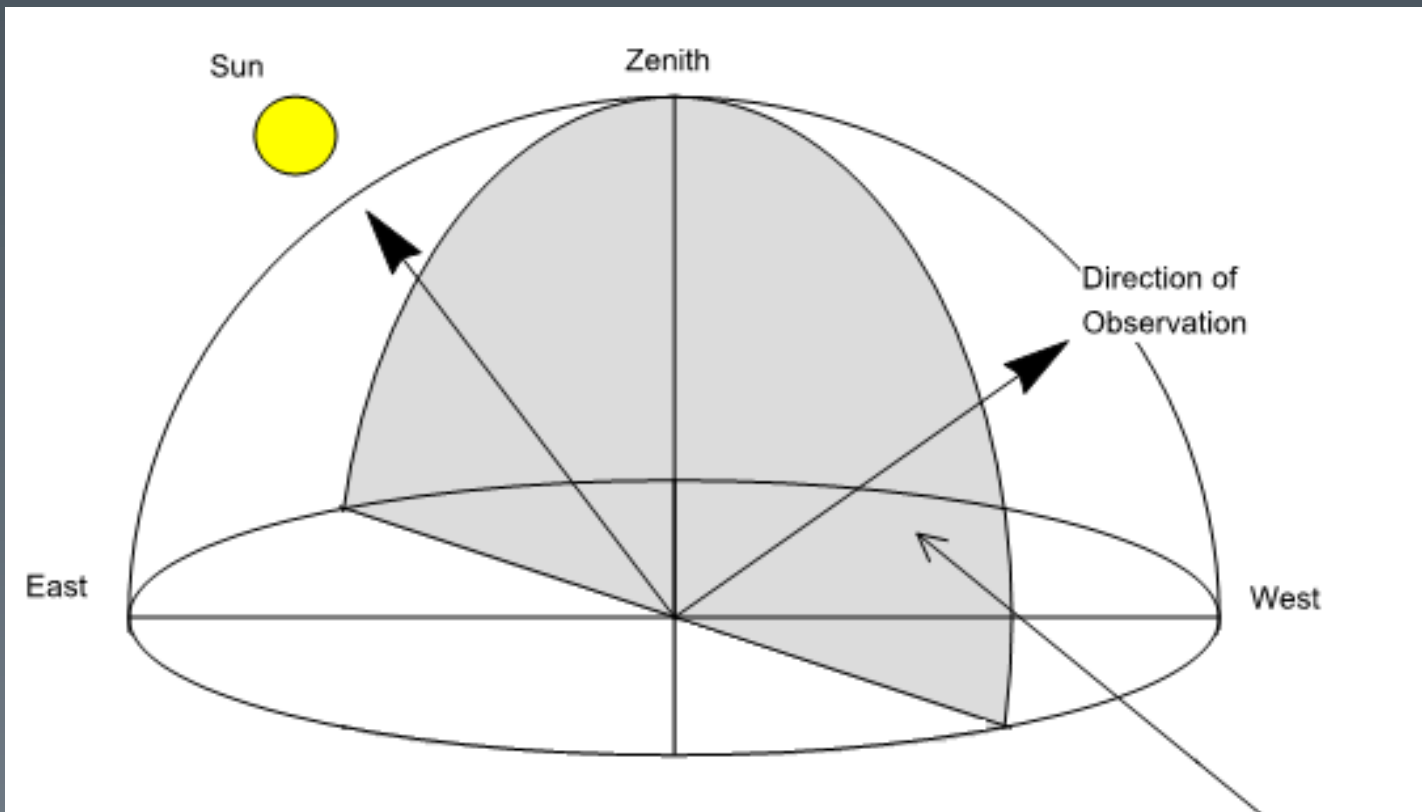


Spectro – Polarimeter Procedure

- Calibration of the mount
- Current azimuth and elevation of the sun
- Locating a position 90° away from the sun
- Take measurements for 2 minute intervals

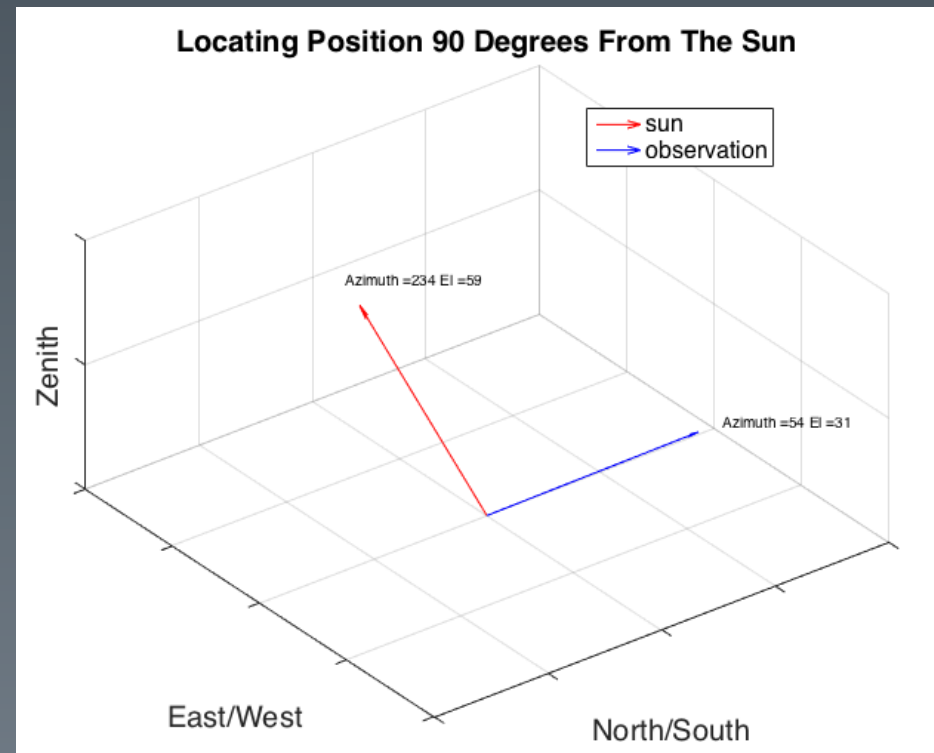


Principal Plane



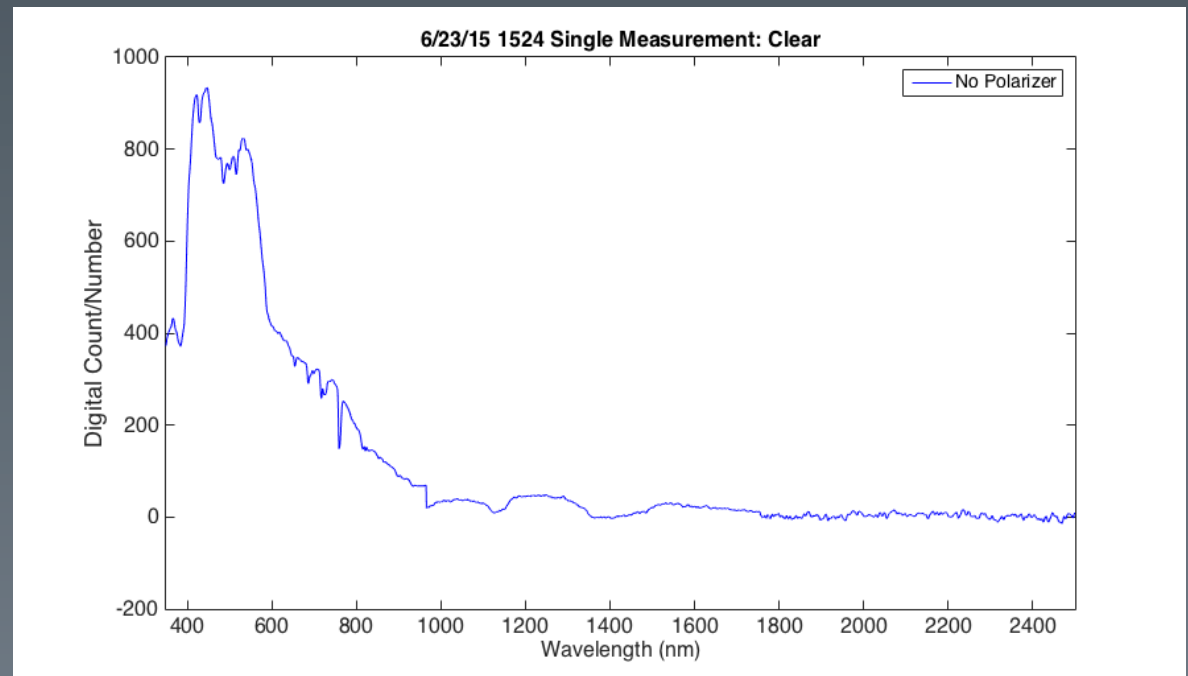
Programming & Analysis

- Locating 90° from the sun:
- Example:
 - Sun's Location –
Az: 234.0 and El: 59.0
 - Observation –
Az: 54.0 and El: 31.0



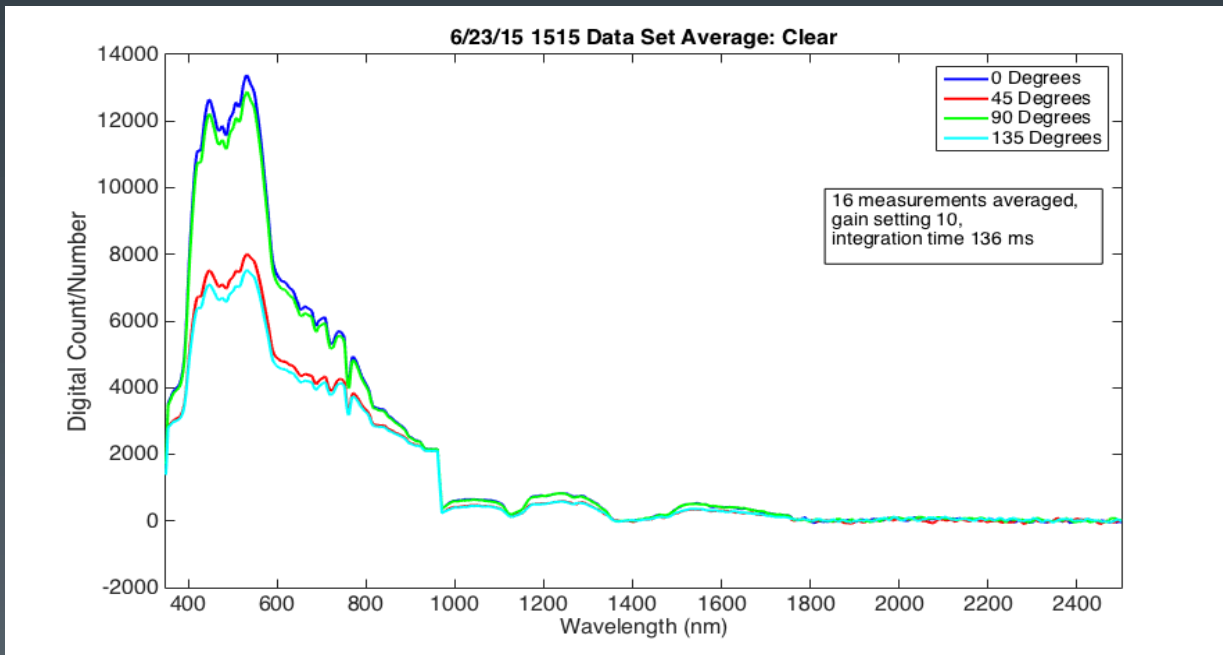
Programming & Analysis

- Averaging multiple measurements
- Smoothing the data



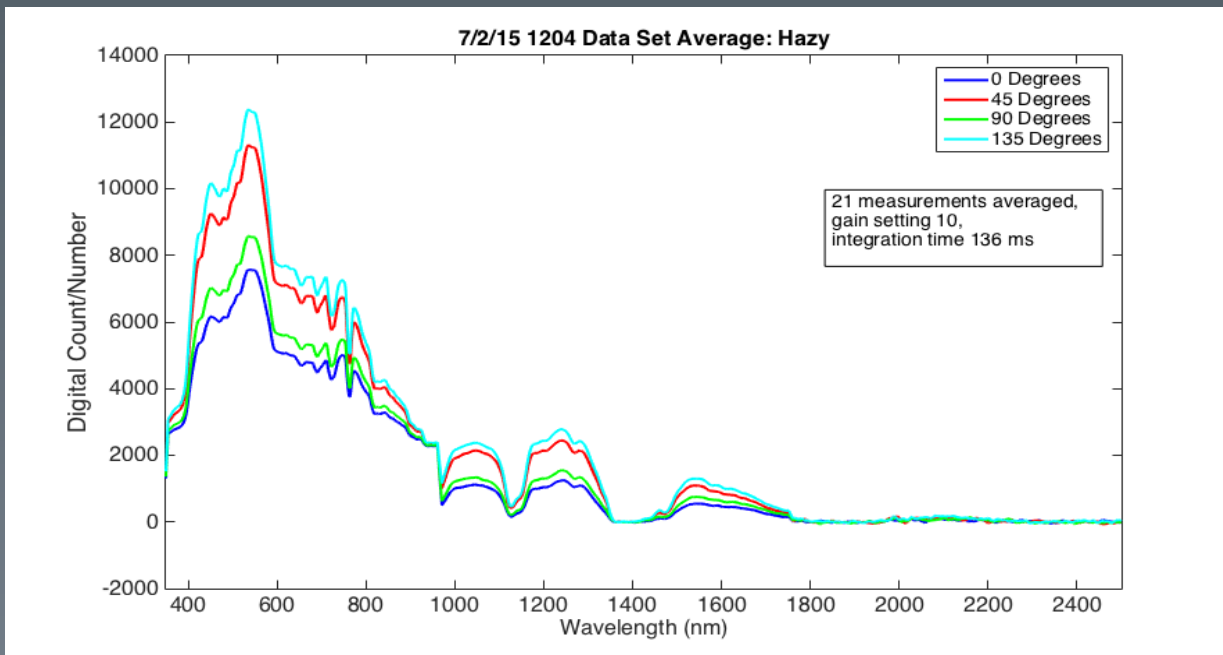
6/23/15

Clear



7/2/15

Hazy



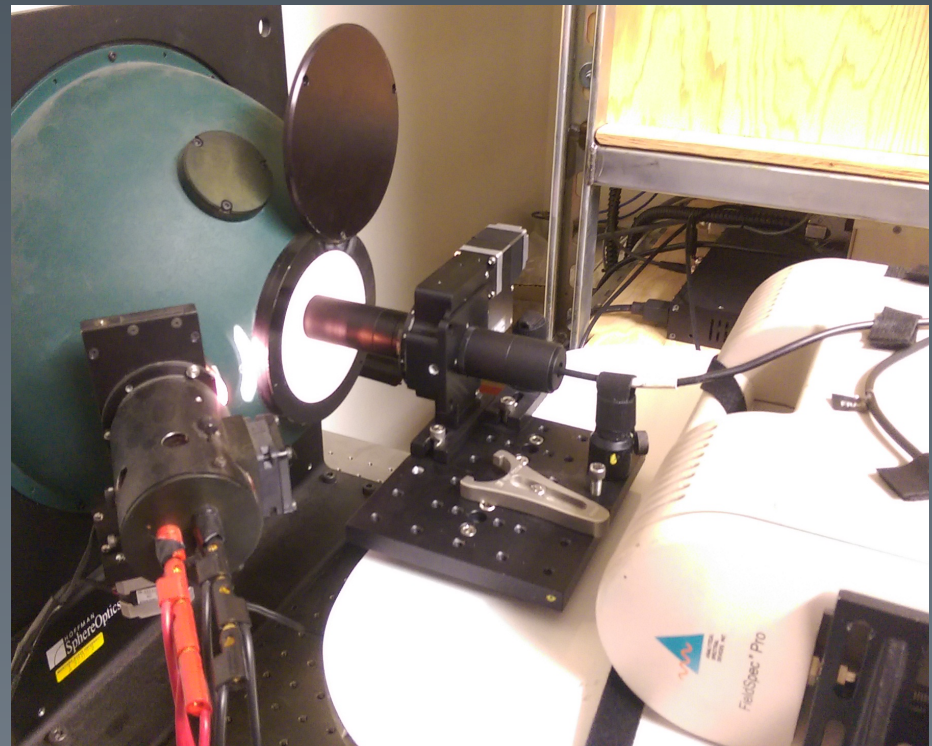
Calibration Techniques

Integrating Sphere

- Source with random polarization

Challenges:

- Currently calibrated up to $1.1 \mu\text{m}$



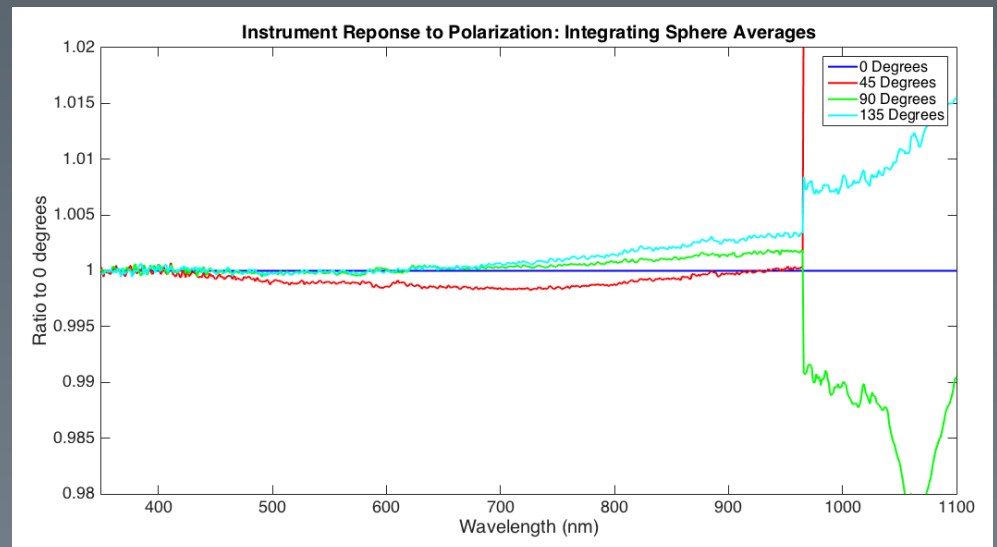
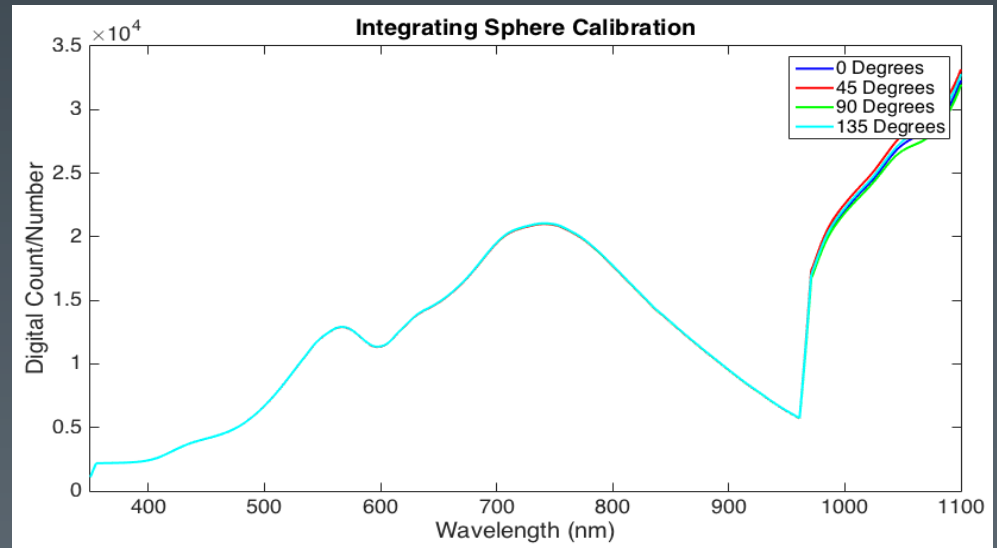
Instrument Response

$$R^{0^\circ}(\lambda) = \frac{I_{rp}^{0^\circ}(\lambda)}{I_{rp}^{0^\circ}(\lambda)}$$

$$R^{45^\circ}(\lambda) = \frac{I_{rp}^{45^\circ}(\lambda)}{I_{rp}^{0^\circ}(\lambda)}$$

$$R^{90^\circ}(\lambda) = \frac{I_{rp}^{90^\circ}(\lambda)}{I_{rp}^{0^\circ}(\lambda)}$$

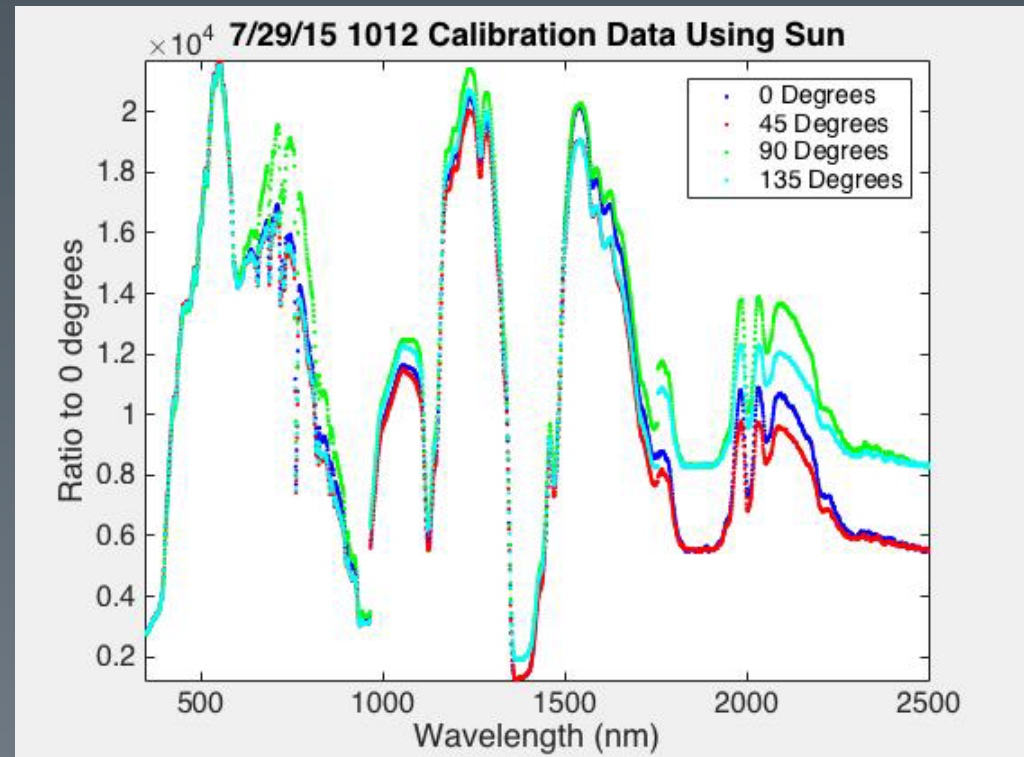
$$R^{135^\circ}(\lambda) = \frac{I_{rp}^{135^\circ}(\lambda)}{I_{rp}^{0^\circ}(\lambda)}$$



Calibration Techniques

Using the Sun:

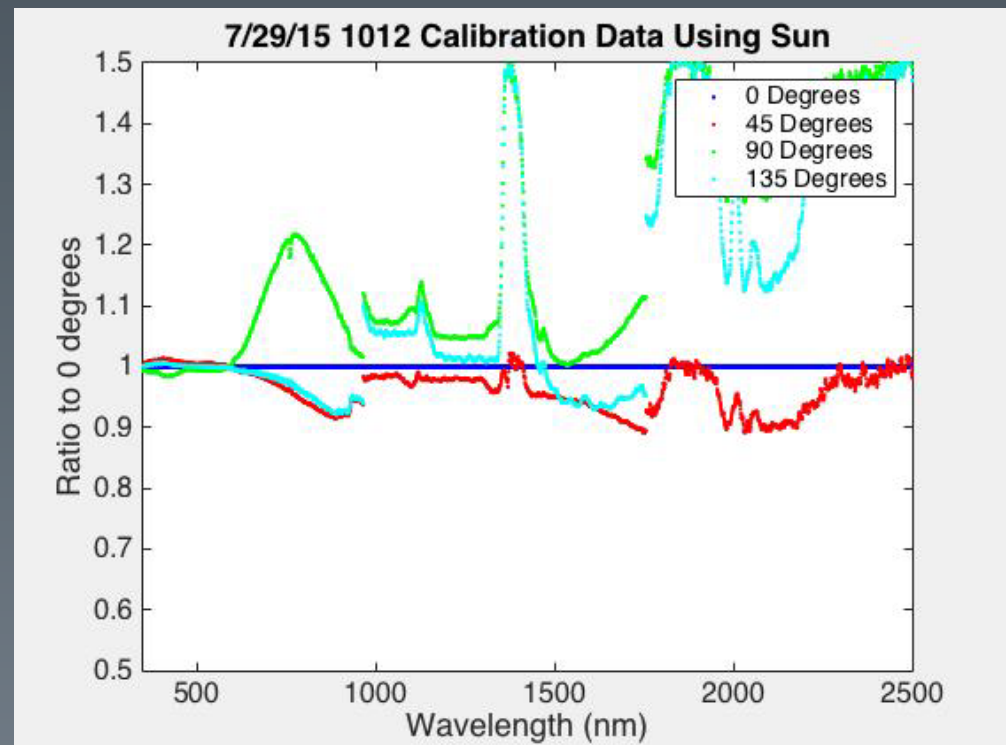
- 20 measurements in a 2 minute interval
- Significant instrument response



Instrument Response

Using the Sun:

- 20 measurements in a 2 minute interval
- Significant instrument response



Stokes Parameters

$$S_0 = I(0^\circ) + I(90^\circ)$$

$$S_1 = I(0^\circ) - I(90^\circ)$$

$$S_2 = 2 \cdot I(45^\circ) - I(0^\circ) - I(90^\circ)$$

$$S_3$$

Equatorial Mount Problem



Rotation Matrix

$$M_R = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos(2\theta) & -\sin(2\theta) & 0 \\ 0 & \sin(2\theta) & \cos(2\theta) & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$S' = M_R(2\theta) \cdot S$$

Normalized Stokes Vector

7/31/15, clear conditions

500 nm light:

$$S = \begin{bmatrix} 1.000 \\ 0.642 \\ 0.167 \\ 0 \end{bmatrix}$$

$$DoLP = \frac{\sqrt{S_1^2 + S_2^2}}{S_0}$$

$$DoLP = 0.663$$



Future Adjustments

Instrument Response

- Fixed Polarizer and Wave Plate

Apply studies to future instrumentation

for the 2017 solar eclipse



References

Collett, E. (1993). *Polarized Light: Fundamentals and Applications*. New York, NY: Marcel Dekker, Inc.

Hecht, E. (2002). *Optics*. San Francisco, CA: Addison Wesley.