MEASURING POLARIZATION OF DISK-INTEGRATED LUNAR REFLECTANCE IN THE MIDDLE ULTRAVIOLET

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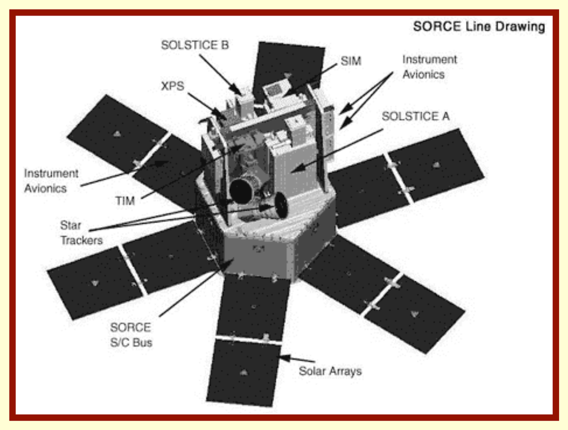
ABSTRACT

It is known that sunlight reflected from the lunar surface is partially polarized. Measurements of the Moon by partially polarizing optical remote sensing instruments may therefore depend on the relative orientation of the instrument axis with the scattering plane. There are circumstances when polarizing effects could become significant, such as when instruments are simultaneously significantly polarizing, at short wavelengths (toward UV), and at phase angles ~100 degrees, when the degree of polarization of light reflected from a surface peaks. At phase angles larger than 100 degrees, polarization decreases.

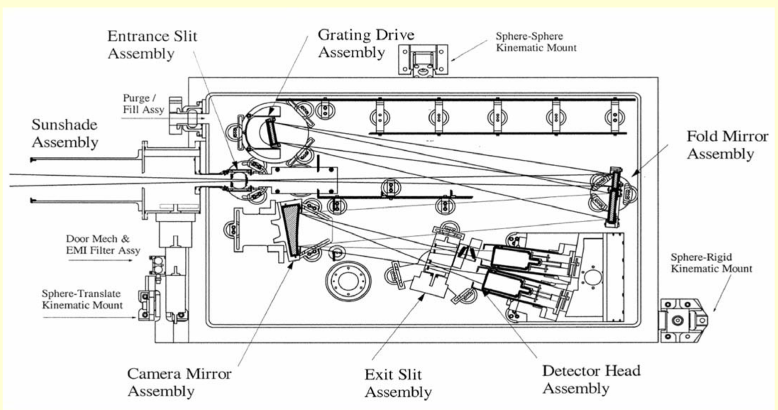
The SOLar-STellar Irradiance Comparison Experiment (SOLSTICE) on the SOLar Radiation and Climate Experiment (SORCE) has been observing the Moon in the ultraviolet (115 – 300 nm) over a wide range of phase angles (0 to ~170°) on a routine basis since June 2006. We have noted a relatively wide distribution of reflectance measurements at any one phase angle and suspect that this may be due to polarization effects. This summer, we searched for correlations between the geometry of the observations collected and measured reflectance. The lunar polarization is poorly characterized at ultraviolet wavelengths, and this effort could lead to a unique measurement.

BACKGROUND

SORCE (SOLar Radiation and Climate Experiment)
NASA-sponsored satellite mission that is providing state-of-the-art measurements of incoming x-ray, ultraviolet, visible, near-infrared, and total solar radiation. The measurements provided by SORCE specifically address long-term climate change, natural variability and enhanced climate prediction, and atmospheric ozone and UV-B radiation.



SOLSTICE A & B
The SOlar Stellar Irradiance Comparison Experiment (SOLSTICE) is one of four solar irradiance measurement experiments that was launched as part of the Solar Radiation and Climate Experiment (SORCE) on January 25, 2003. SORCE SOLSTICE is a follow-on to the very successful SOLSTICE launched aboard the Upper Atmospheric Research Satellite (UARS) in 1991 [Rottman et al., 1993]. The new SOLSTICE makes daily solar ultraviolet (115-320 nm) irradiance measurements and compares them to the irradiance from an ensemble of 18 stable early-type stars.



POLARIZATION
The fractional linear polarization of a beam of light from a body is defined as:

$$P_b = \frac{I_s - I_p}{I_s + I_p}$$

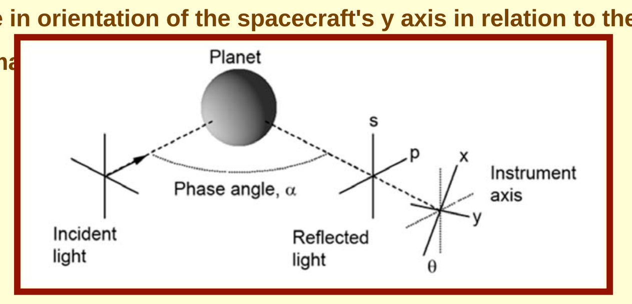
Where Is is the magnitude of the beam which is oriented such that the electric vector is perpendicular to the scattering plane, and Io is the magnitude of the beam which is pointed with the electric vector parallel to the scattering plane. Polarization ranges from +1 to -1, with 0 being unpolarized light.

PHOTOMETRY
The study of the variation in the brightness of a surface or body as a function of the illumination and viewing geometry. Mathematic functions are used to model this variation, and it is essential for comparing the reflectance of one surface to another for different viewing geometries.

PHASE ANGLE
The angle between a light source (in this case, the Sun); what it is reflected off of (the Moon), and the viewer (SOLSTICE on the SORCE spacecraft).

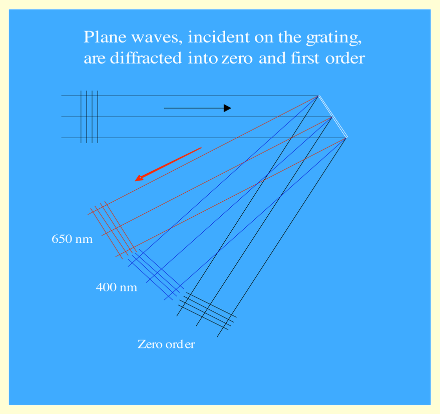
SCATTERING PLANE
The plane defined by SORCE, the Sun, and the Moon. In order to obtain the roll angle (see below), we needed to find the vector normal to the scattering plane.

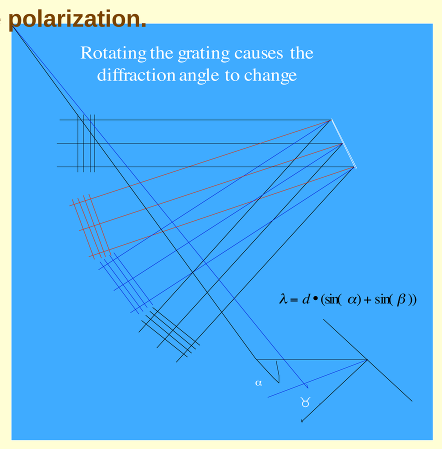
ROLL ANGLE
The change in orientation of the spacecraft's y axis in relation to the vector norma

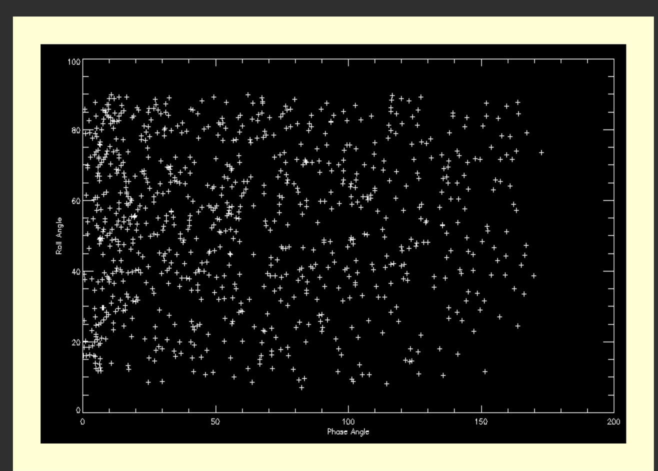


SOLSTICE SET-UP

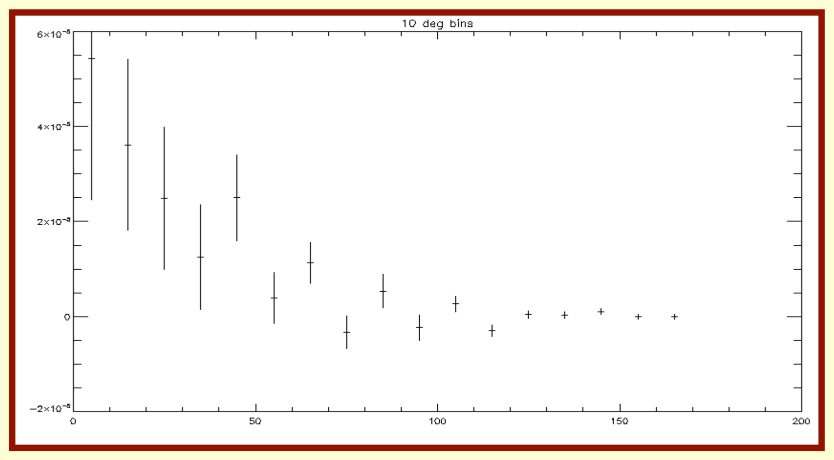
SOLSTICE is a grating spectrometer, with a field of view of about 2 degrees; this means the entire moon is shown in our measurements ("disk-integrated"). The detector is a photomultiplier tube that measures one wavelength at a time by changing the rotation of the grating. Plane waves, incident on the grating, are diffracted into zero and first order. Rotating the grating causes the diffraction angles to change. Since we have a wide range of roll angles for any given phase angle of SOLSTICE data, we are able to determine the polarization.



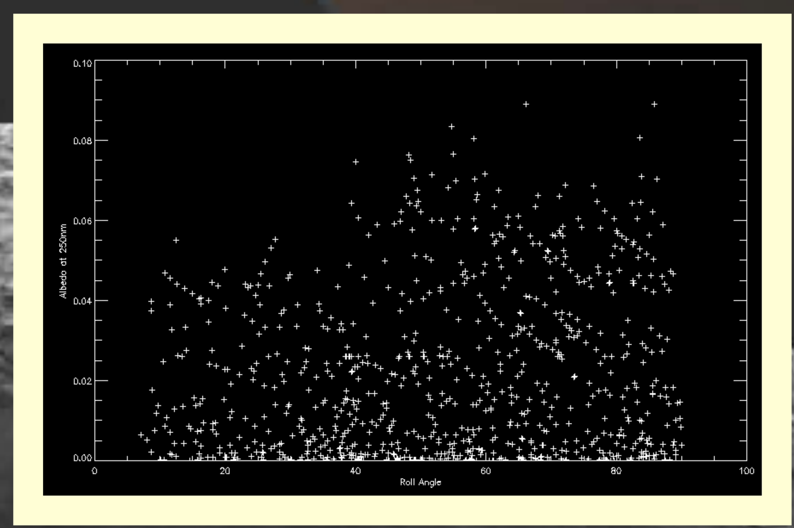


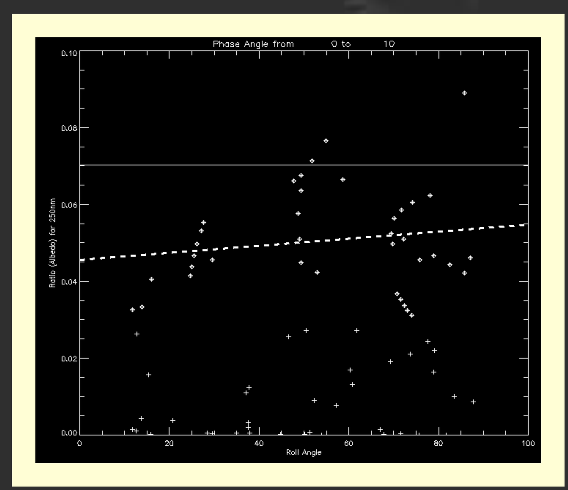


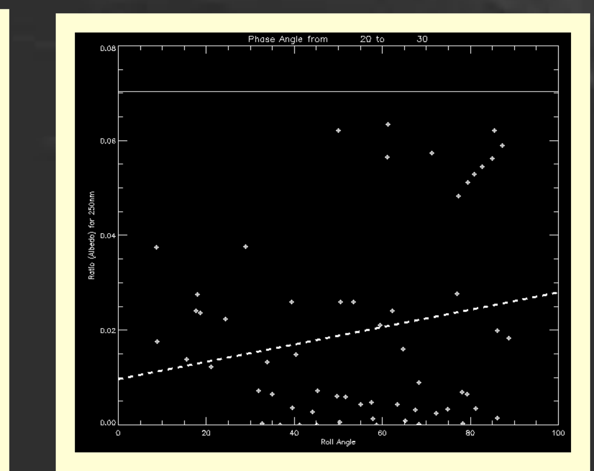
PRELIMINARY RESULTS



DATA CORRECTION
Filtered outliers (points greater than 2 sigma from the mean); filtered obviously suspicious data; tried parsing various intervals of degrees for the x-axis (10 degrees, 20 degrees, 30 degrees, etc.); and altered the y-axis to show the percentage of polarization rather than just the polarization itself.







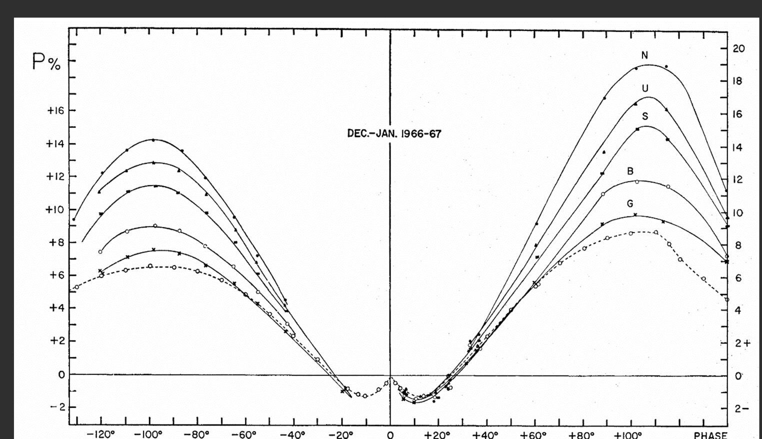


FIG. 2. Percentage polarization of moon as a function of wavelength and phase angle. Dashed curve is taken from Lyot (1929).

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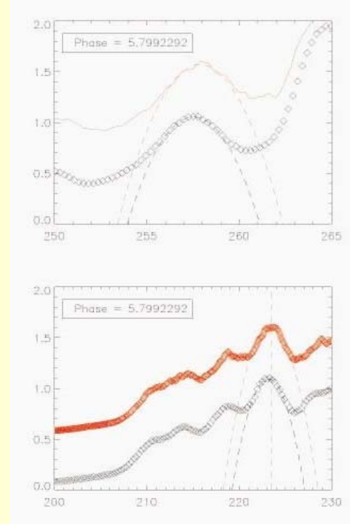
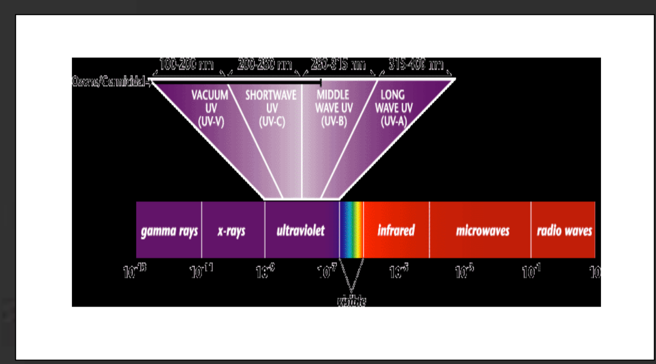
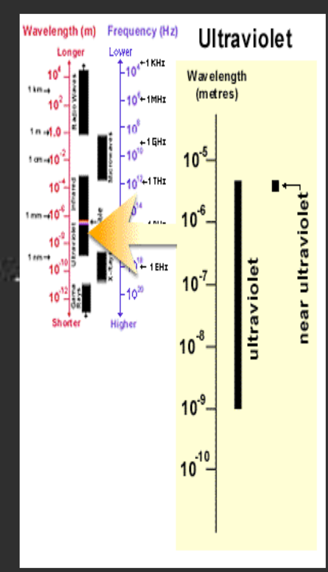
Huge thanks to Erin and Marty for coordinating this experience, and to all of my fellow REU students for making 2010 an awesome summer.

REASON WHY WAVELENGTHS WERE CHOSEN



SOLSTICE is sensitive to polarization at 250 nm and not at 195 nm (which we used to check our data collection). The Sun's spectrum is normalized, and both the Sun and the Moon have been given a Gaussian fit. The ratio of the Sun's fit to the moon's is the reflectance.





CONCLUSIONS

When making a plot of phase angle vs. percentage of polarization, we were able to extrapolate a curve between the data from SOLSTICE at 250 nm and the curve of percent polarization of the moon at visible wavelengths.

This correlation is much lower than expected, however, and there is still a great deal of noise in the data. Further steps could be to determine why the measurements in the middle ultraviolet (MUV) are not congruous with our predictions, and to suggest possible solutions for more data correction.