Solar Phase Curve of Pluto

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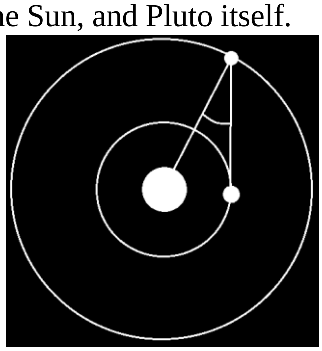
***Abstract*—Pluto has recently been an observation target of interest in both ground and space based astronomy. The *New Horizons* flyby in July 2015 provided new detailed data over a short period of time. Continuous ground based observations of Pluto reveal the long term changes on its surface. We observed Pluto near opposition over eight nights in June, July and August of 2015. Using time-resolved photometry we attempted to resolve an apparent increase in magnitude at successively lower phase angles as well as to contribute to a long-term investigation on volatile transport on the surface of Pluto. Our results were inconclusive.**

1. INTRODUCTION

Pluto is a dwarf planet orbiting the Sun in the Kuiper belt. It was discovered in 1930 by Clyde Tombaugh. Since its discovery, Pluto has been the subject of many studies. Many of these studies consisted of photometric observations of the small body.

Photometry is a measurement of the amount of light given off by an object. Concerning Pluto, photometry is a measurement of the amount of light reflected from the Sun. This magnitude of light changes over the course of time due to a number of effects such as the geometry between the observer, the Sun, and Pluto itself.

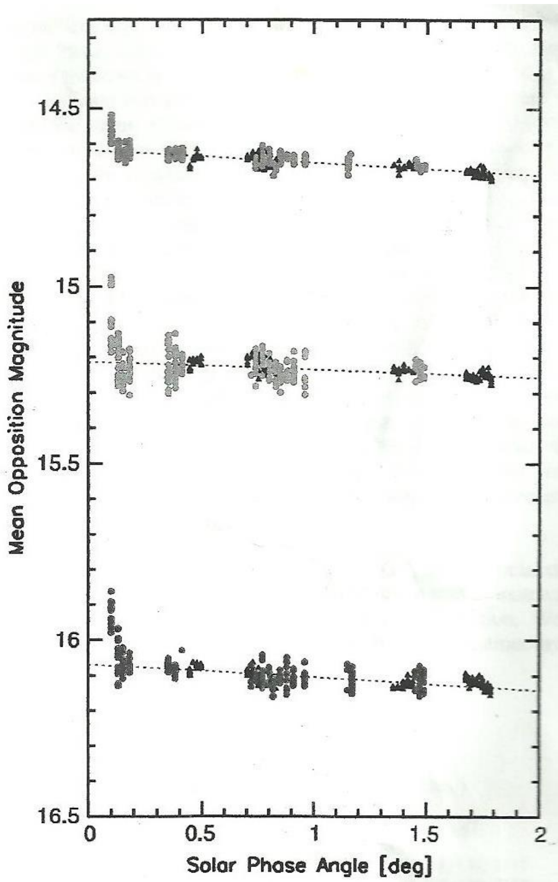


Solar Phase Angle

The alignment of the three objects correlates directly to the proportion of the illuminated surface visible to the observer and is known as the solar phase angle of the object. This illumination is periodic as the objects move into and out of alignment in their respective orbits. Pluto's orbit around the Sun is particularly inclined at ~17.14 degrees. As such the percent illuminated reaches maximums only while Pluto is near alignment with the eight planets. In July 2015, the solar phase curve of Pluto reached a minimum of 0.061 due to the current near alignment.

Another form of periodic light intensity that can be resolved with photometry is due to the objects rotation on its axis. Different features on the objects surface are exhibit differing levels of illumination as well as different colors. The periodic curve can be analyzed to determine surface feature makeup and form. For smaller irregular bodies such as asteroids this is very useful for determining the shape of the object.

A final possible form of periodic intensity in photometry is due to changing features on the surface of an object. These aspects of the light curve are not always due to periodic events but can be caused by singular occurrences. In the case of Pluto, a long-term study of its light curve is seeking to resolve the periodicity of surface feature changes. One such cause of this change could be seasonal changes. From 1999 to the present Buratti et al., have been observing the surface of Pluto to determine the existence of transport of volatiles on the surface.



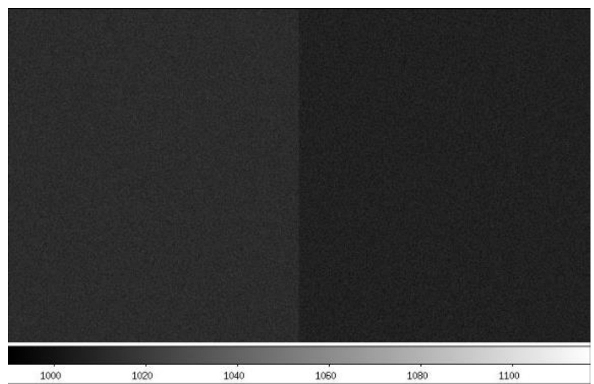
BVR solar phase curves of Pluto (Buratti et al 2015)

We observed Pluto at JPL's Table Mountain Facility (TMO) using the 0.6-meter telescope with Spectral Instruments 2K CCD camera. In order to determine the makeup of the comet, broadband photometry in the Bessel BVR filters was used.

2. METHODS

For any given night of observation, numerous images are taken. The flux of each object can be determined from the relative brightness of each pixel. These images, however, must be corrected for certain errors that can arise in telescope observations.

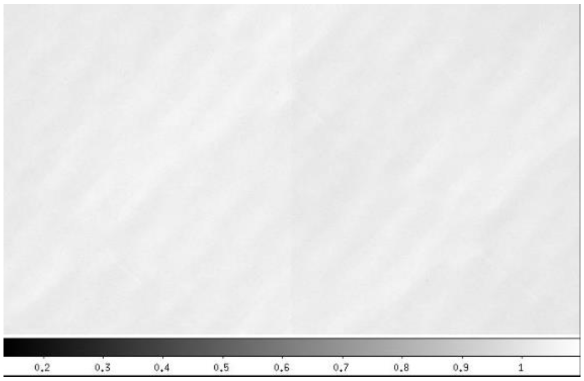
The first correctional step required is to take number of bias or dark frames. These images are of the telescope while closed. The series of dark frames is averaged together producing a single frame. Ideally, this frame is completely uniform, but occasionally individual pixels can remain charged. Only these pixels will be aparent on the averaged frame. The pixels in question will not provide accurate data and are discarded from the remaining images.



Bias Frame

After biases, the night sky near sunset is imaged also known as sky flats. The sky near twilight is relatively uniform in the field of view. Errors in the images will occur due to slightly differing sensitivities of the pixels in the CCD. Sky flats seek to correct those errors. Knowing that an image should be completely flat and uniform corrections can be made on the sky flat images to adjust to uniformity. Sky flats are taken in each filter to adjust for any differences between each.

Further corrections to images include the process of taking flat images, or in this case sky flats. Light reflected in a curved mirror does not reflect uniformly. An image of a purported flat object provides the offset that the telescope is producing. With sky flats images of the sky at twilight is near uniform brightness with little to no visible stars. Sky flats require careful tracking along the sky to coincide with the changing brightness of the sky as the sun sets. Images are taken in all filters being used as different filters can produce different aberrations. Each image is corrected to a flat field.



B-Filter Skyflat

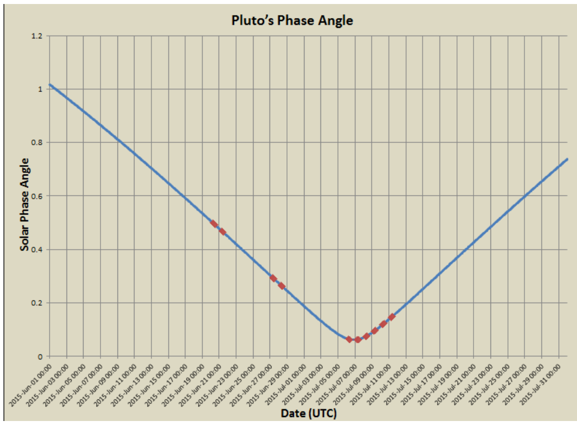
The atmosphere can also change over the course of the night. Air density and moisture have a dramatic effect on the apparent brightness of the same object. To correct for changes in atmospheric conditions there are a number of stars that are well catalogued. The magnitudes of these stars in each filter are known with a high degree of accuracy. Periodically throughout the night images of these stars are taken for later correction due to atmospheric conditions.

PG1633+099,etc

The telescope can also change focus over the course of the night due to changes in temperature. There are controls to maintain near uniformity but occasional variances do occur. This is particularly noticeable each night. As such, each night requires a number of focus frames from which the best focus is determined. If images later appear to be out of focus, further focus frames may be necessary.

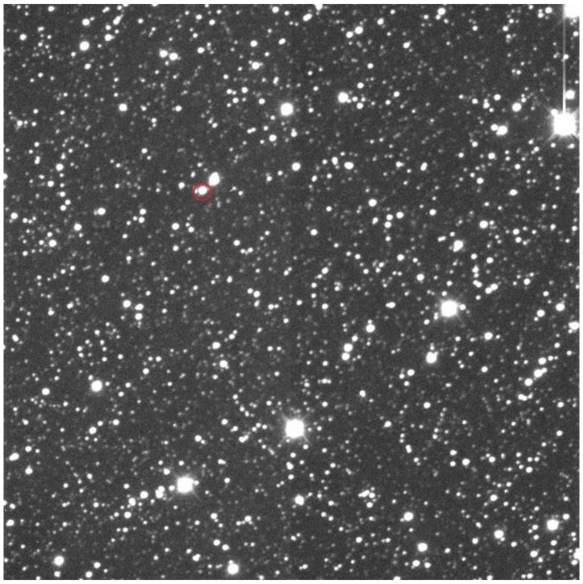
3. RESULTS

We observed Pluto over 10 nights during the summer of 2015. The data has not yet been processed due to some serious setbacks throughout the project. Weather was not good on many nights preventing any observation. There were network connection issues on a few evenings preventing any control of the telescope. The telescope one night moved beyond a hardware limit preventing any further observation. Perhaps the biggest setback was a forest fire at Table Mountain which prevented all observation and any access to the site. The network at the time was also disabled preventing any transfer of data to JPL until the fire was out. This kept us from being able to access the data in the final weeks of the summer.



Observation Nights with Phase Angle

When this data is processed we hope to see the flux curve of Pluto near opposition. When these data points are included with prior work we hope to see if there is evidence of seasonal pattern on Pluto or possible other motions of material on its surface. Further work can always be done each year as Pluto approaches opposition at lower phase angles.



Pluto – July 9, 2015

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