# Photometric Observations of Pluto

Mark Shiffer
Los Angeles City College
*Los Angeles, CA*

Dr. Bonnie Buratti (Mentor)
Jet Propulsion Laboratory, Cal Tech
*Pasadena, CA*

**Abstract**

*Photometry is the measurement of the output of light. Using photometric methods we were able to gather the data necessary to calculate Pluto's light curves, as well as determine the albedo of Pluto, along with the ability to infer from the data obtained information concerning natural processes of the dwarf planet such as volatile transport. We collected our data using the facilities at JPL's Table Mountain Observatory, using a 0.1 meter refracting telescope, and SI2K CCD camera. This research builds upon previously published research, using the same methods to observe (and refine) characteristics of Pluto, and furthermore will be complimentary to data that is obtained by New Horizons.*

## I. Introduction

In 2003 and 2015, there were two studies published centered on photometry of Pluto, and what could be gleaned from the data received. Both studies, led by Dr. Bonnie Buratti, utilized large time-spans of Pluto observations, using data from 1990 – 1993, 1999, 2000, and in the most recently published paper, data which was obtained between 2008 and 2014. Their data was also contrasted with observations of Pluto as early as the 1950s.

Our data will expand upon these previous findings, and solidify information we have in regards to the dwarf planet. In this respect, our data is a continuation of long-term study of Pluto.

By using photometric methods to observe Pluto, we are able to plot the light curves, albedo, and extrapolate upon said data to make conclusions on natural processes. In both studies by Dr. Buratti, it was found that there is active ongoing transport of seasonal volatiles.

Our ground based observations are also important in that the data we receive will be used complimentary to the data that is received by New Horizons, which made its historic flyby in July of this year.

We collected our data over the summer of 2015, using the facilities at JPL's Table Mountain Observatory. The equipment we used was a 0.6 meter reflecting telescope, and SI2k CCD camera. In our observations, we used a cadence of

*R*, *V*, *B*, respectively at exposure times of 150”, 250”, and 500”.

# II. Methods

We start an evening of observing with an observation plan. A typical plan for observation included the target we were interested in, an integration pattern, ephemeris information of the target, as well as standard stars to observe intermittently throughout the evening.

The first series of pictures we take are bias shots. Biases are taken with a dark exposure setting, and while the dome is closed. Bias frames are taken as they alert the observer to any “live” pixels, which are later corrected by compiling the bias shots together in the data reduction phase.

After we have taken biases, at dusk we prepare to take sky-flats. Sky-flats share a similar responsibility as the bias frames do. These series of pictures are taken at dusk (within a period of ~20 minutes), allowing us an opportunity to take pictures of the sky in which it appears relatively flat. The significance of sky-flats in correcting images is that they allow you to, similarly to biases, recognize any artifacts within your images to later remove for more precise accuracy. We were able to simplify the flat fielding imaging process to a formula which suited our purposes, that is of the following form,

*new time = (wanted/readout) old time*

Within which time relates to exposure, and readout is determined by an average of values as found within the software of our SI2k camera.

Another important aspect of photometric observations is imaging standard stars. Standard stars, or simply standards, are stars which already have well documented outputs of light. In our observations of Pluto, we would intermittently take time to photograph these standards, which we use later in comparison to the output of light measured from Pluto, which allows a more accurate reading.

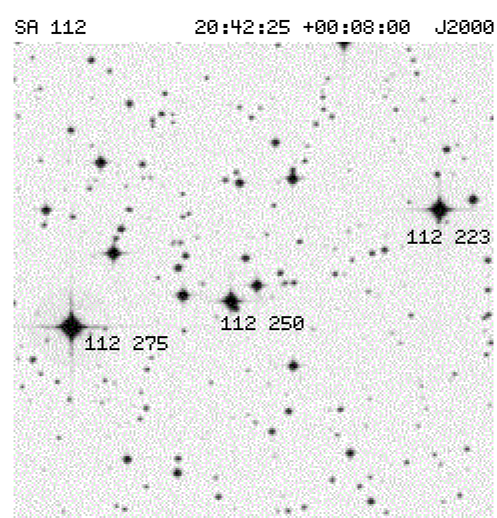


*Figure 1, standard star chart - Wiyn Obs.*

Using our integration pattern of R, V, B, we spend the bulk of an evening using said cadence to observe Pluto. By using a path finder chart, we are able to verify we have located the target.

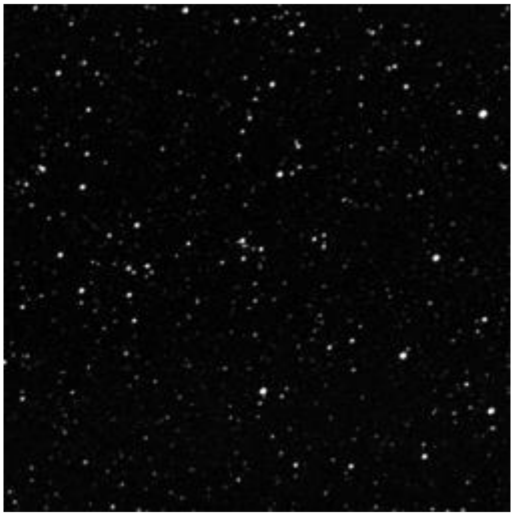

*Figure 2, Pluto pathfinder chart*

# III. Pitfalls

It was unfortunate that we had to experience some difficulties in our time of observations. We lost a significant amount of time due to a wildfire that started within the Pines, and spread far enough to singe utility poles near Wrightwood; blocking out communications for roughly two weeks.

Due to these unforeseen circumstances, and a general lack of time as New Horizons made its flyby, we could not reduce our data in time of this writing.

# IV. Conclusions

Currently our data is being analyzed at JPL by another student, under the direction of Dr. Buratti. However, despite that the data has not yet been fully analyzed, we can predict by previous observations what we expect to find.

What is most important is the light curves we derive from our measurements, which can be plotted from the data obtained. From this alone, we can determine the albedo at R, V, and B wavelengths, colors, and amplitudes of the light curves.

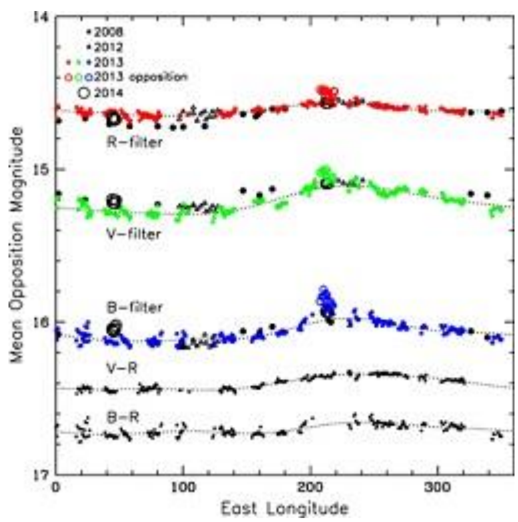


*Figure 3, RVB light curves (Buratti, et al.; 2015)*

In figure 3, we see light curves as Pluto is at opposition. It is also plotted with data that was obtained prior to the publication of the study, which is extremely useful. By comparing the data with what was obtained before, it is possible to extrapolate on natural processes. In both of Dr. Buratti's papers on photometry of Pluto, she, along with other scientists and researchers, were able to conclude from the data evidence of on-going seasonal volatile transport. It is reasonable then to assume, as data becomes available from New Horizons, evidence of active plumes being found on the surface of Pluto.

As mentioned, albedo patterns can also be determined. By looking at the albedos from Pluto, we could meaningfully write of the polar caps, as, of course, albedo is essentially the angle of reflection of light on an ice-covered surface.

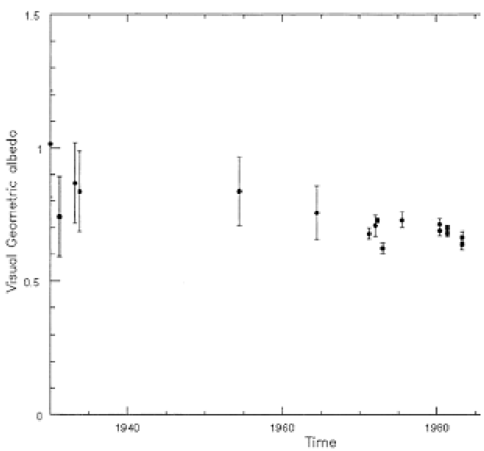


*Figure 4, Pluto's albedo (Buratti, et al.; 2003)*

Indeed, our photometric data of Pluto will further clarify on the dwarf planet that was once artistically rendered purple, and thought of as not having an atmosphere. Our ground based observations will also prove beneficial to the data that comes from the New Horizons space probe. Our data will be used as complimentary data to what is found with New Horizons, and will continue to be used for years to come in long term studies of the dwarf planet.

Our observations of Pluto began in June of 2015, and concluded in August of the same year. During that period of time, we took over 100+ images of Pluto, with the vast majority of observations taking place remotely at the Jet Propulsion Laboratory, with perhaps a fraction of said time spent with on-site observations at JPL’s Table Mountain Observatory.

## V. Acknowledgements

Our work was conducted at the Jet Propulsion Laboratory, supported by National Science Foundation grant #AST-1156756 to Los Angeles City College. I’d also like to acknowledge Dr. Bonnie Buratti, Dr. Michael Hicks, Mr. Paul McCudden, Mr. David Falk, and my colleague James Frederick for their support and guidance.