A Brief Review of Pluto Photometry

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Abstract

Photoelectric and photographic photometry of Pluto for 1933-2019 are reviewed. Starting in the 1950s, Hardie discovered that Pluto's brightness changed at different longitudes of the central meridian. He was able to measure Pluto's light curve and discovered a peak-to-valley difference of 0.11 magnitudes. Since then, the light curve has changed. Furthermore Pluto's mean opposition brightness has changed since the 1930s. There are two possible explanations for these changes. One of them is volatile transport caused by the changing Pluto-Sun distance. The other is differences in viewing angle geometry. In addition to this, three other factors affect its brightness by a few percent. These are the phase angle, the distribution of measurements and whether Charon is included with Pluto. It is concluded that more data are needed to determine how much volatile transport and viewing geometry affect Pluto's photometric values.

Viewing geometry

The viewing geometry changed greatly between 1933 and 2019. The table below shows that it rose from 58° S to 56° N between 1933 and 2019. It is not clear how much this will affect the brightness of Pluto; however the map shown in figure 1 shows large albedo changes. Bear in mind that the sub-Earth latitudes and longitudes affect the viewing geometry and may affect Pluto's brightness.

Table 1: Sub-Earth latitudes of Pluto for different years. The sub-Earth latitude is the latitude of the center of Pluto's disk as seen from Earth.

Year	Sub-Earth latitude
1933.9	58° S
1955.3	56° S
1972.3	32° S
1999.5	24° N
2019.5	56° N

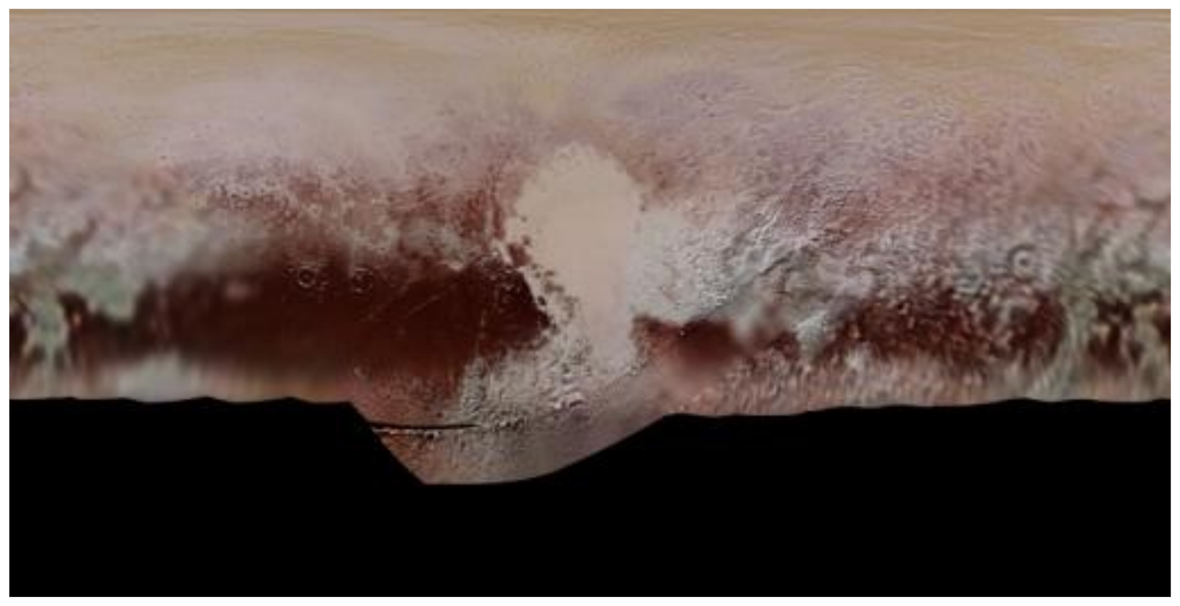

Figure 1: Map of Pluto made by the "Ralph Multispectral Visual Imaging Camera" onboard New Horizons. Note the large dark are near the bottom and the brighter areas near the top. North is at top.

Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute.

Volatile Transport

Pluto's distance from the Sun varies from 30 au near perihelion to 50 au at aphelion. This will cause the surface temperature to changes throughout that planets 249 orbital period. Because of this, some have suggested that some surface ice will sublime when temperatures warm up and the atmosphere will freeze out when temperatures drop.

One way to measure the thickness of Pluto's atmosphere is to analyze occultation data. For example Elliot et al (2007) suggest that atmospheric extinction has fallen between 1988 and 2006. Pluto was about as close to the sun as possible (29.7 au) for its June 9, 1988 occultation but was 31.1 au from the Sun on its June 12, 2006 occultation. This group also reports a temperature drop from 114 K in 1988 to 97 K in 2006 at the half-light radius. Therefore, there is evidence that Pluto is cooling as it moves away from its 1989 perihelion point. Figure 2 shows the changing Pluto-Sun distances.

The Measurements

Two kinds of measurements for Pluto + Charon are summarized here. The brightness of this system in the Johnson B and V filters are presented first. These measurements are normalized to the Mean opposition distance which is 39.5 and 38.5 au for the Pluto-Sun and Pluto-Earth distances. These are designated by the symbols B_o and V_o respectively. The peak-to-valley magnitude differences in the rotational light curve of Pluto + Charon are then summarized.

In recent years it has been possible to measure the photometric constants of Pluto and Charon. For the sake of historical consistency, I have decided to report the Pluto + Charon values.

Mean B_o and V_o values

The mean B_o and V_o values increased between 1933.9 and 1999.5. The V_o value continued to increase during the early 21st century. This is consistent with Pluto + Charon getting darker since the 1930s. Mean B_o and V_o measurements are shown in Figures 2 and 3.

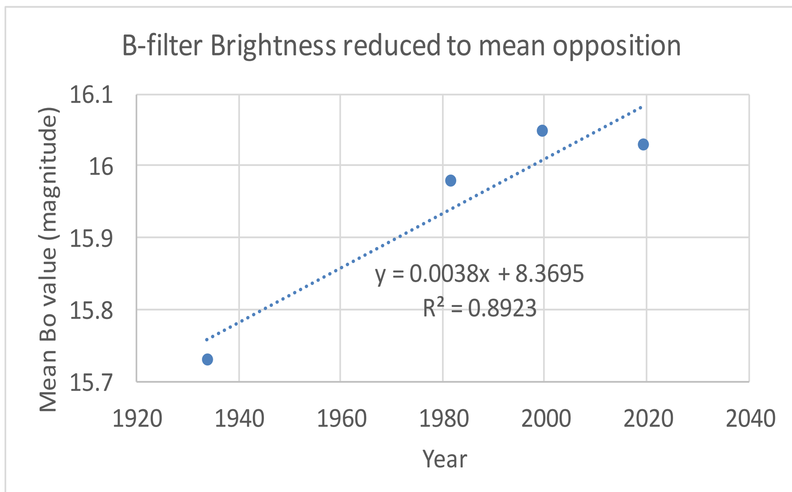

Figure 2: Mean B_o values measured since 1933.

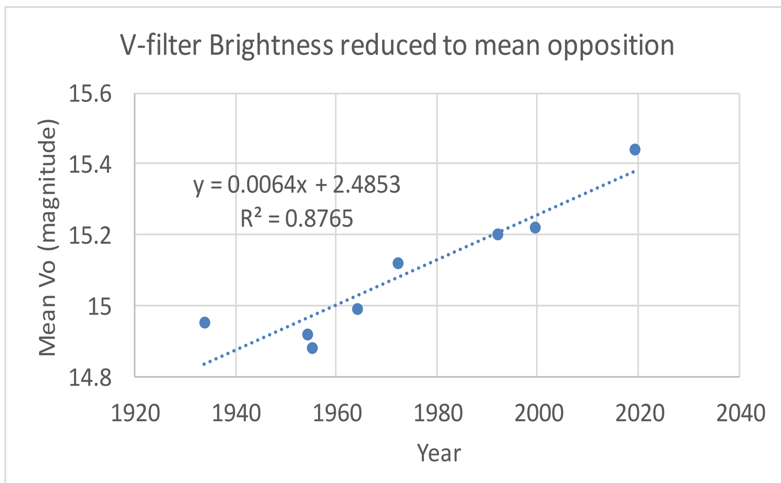

Figure 3: Mean V_o values measured since 1933.

Pluto's Rotational Light curve

Pluto rotates about every 6.39 days. As a result, all longitudes face the Earth during the 6.39 day period. Pluto is brighter at some longitudes than at others. The difference is called the peak-to-valley brightness difference. Figure 4 shows how the peak-to-valley brightness difference (in magnitudes) has changed since 1954. In all cases, the brightness changes are for the V filter. The Peak-to-valley brightness difference increased from 1954 to 1999 but appears to have dropped a little during the early 21st century.

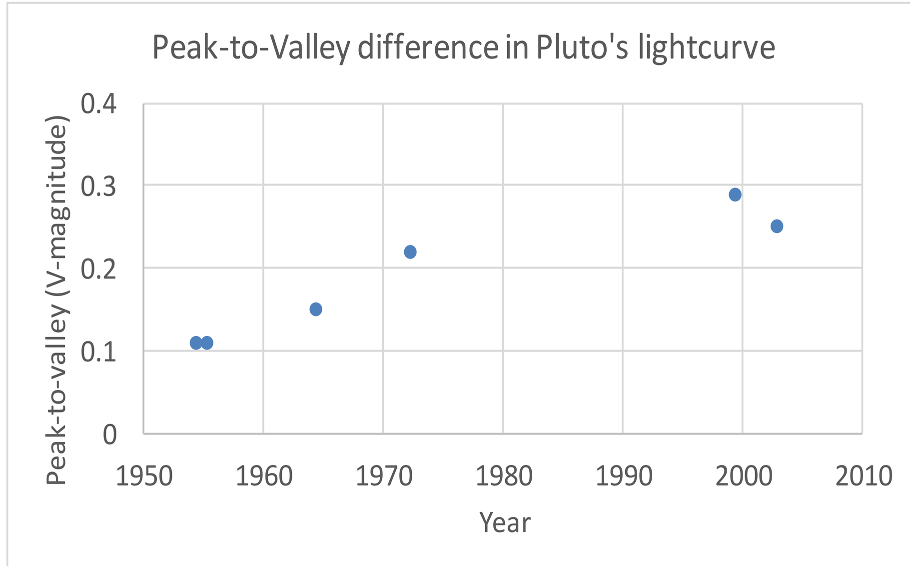

Figure 4: A graph of the peak-to-valley difference in Pluto's light curve (V filter) for different years.

There seems to be a correlation between the peak-to-valley difference and the V_o value. Essentially, as the Pluto + Charon system darkens (higher V_o value), the peak-to-valley difference in the light curve increases. This can be seen in Figure 5.

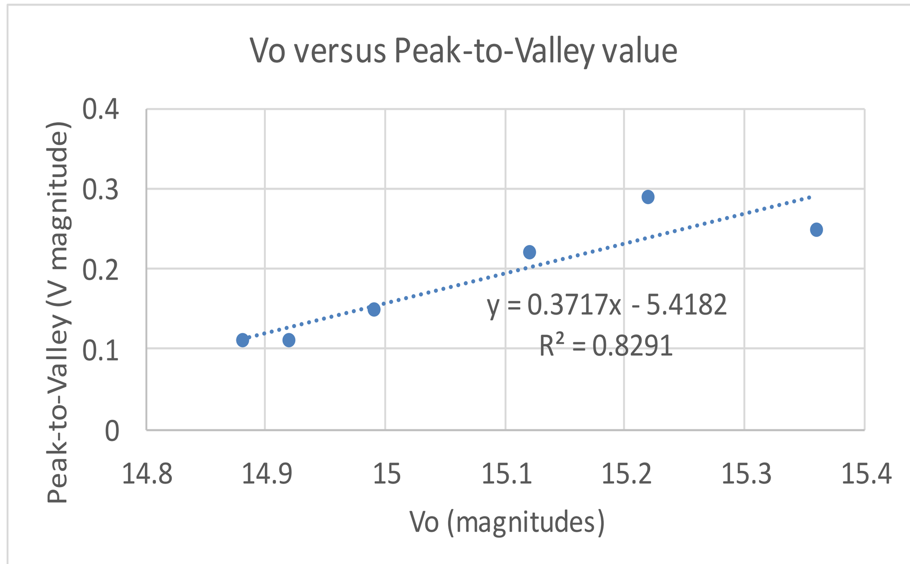

Figure 5: A graph of the peak-to-valley difference in brightness versus the V_o value.

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