ROTATIONALLY RESOLVED PHOTOMETRY OF THE V-TYPE NEAR-EARTH ASTEROID 4055 MAGELLAN (1985 DO2)

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Abstract:

The Near-Earth Asteroid (NEA) 4055 Magellan was discovered by Glo Helin at Palomar Mountain (IAUC 4638) and was one of the first known minor planets with surface reflectance properties comparable to that of 4 Vesta (Tholen, 1988). Broadband photometry and near-IR spectroscopy revealed strong 0.9 and 1.9 micron proxene bands, suggesting a compositional similarity of 4055 Magellan with that of 4 Vesta and the basaltic achondrite meteorites (Cruikshank et al. 1991). In anticipation of the Dawn mission to 4 Vesta we obtained 5 partial nights of Bessel R photometry of 4055 Magellan at the Jet Propulsion Laboratory Table Mountain Observatory 0.6-m telescope (TMO). We measured a synodic period of 7.488+/-0.001 hr, similar to the 7.475+-0.001 hr period obtained by Pravec et al. (www.asu.cas.cz/~ppravec/newres.txt). Our object exhibited a large lightcurve amplitude (**Δ**M~0.8 mag) implying a highly elongated shape. We used our TMO photometry and the Absolute Magnitude as tabulated by the Minor Planet Center to construct a rudimentary solar phase curve. We derived a phase parameter g = 0.30, similar to the phase behavior as measured by Pravec and colleagues (www.asu.cas.cz/~ppravec/neo.html). Our high g implies a shallow solar phase slope, consistent with the object's high albedo (ρ = 0.31) obtained from thermal measurements (Delbo et al. 2003). The photometric properties of the V-type 4055 Magellan, such as shallow phase slope and high albedo, are consistent with 4 Vesta, giving us confidence in using NEA vestoids as photometric analogs for 4 Vesta.

Methods:

Our goal was to construct a lightcurve for 4055 Magellan giving us insight about its physical characteristics. The observed magnitudes were extracted from photometry collected over a span of 5 nights at TMO (2010 August 9/10/12/13/14). Using the H-G magnitude system (Bowell et al, 1989), Reduced Magnitudes were calculated by

$$\mathbf{V(\alpha) = V_{obs}(\alpha) - 5\log r\Delta}$$

where r is the heliocentric distance, Δ the geocentric distance, both in AU, and α is the solar phase angle. Absolute magnitudes, H, were obtained from equation (Bowell et al, 1989)

$$\mathbf{H(\alpha) = H - 2.5\log[(1 - G)\varphi_1(\alpha) + G\varphi_2(\alpha)]}$$

where H, is the Reduced Magnitude at mean brightness and at solar phase angle 0°. G is the slope parameter. It is scaled in a manner such that G ≈ 0 for low albedo bodies and G > 0.25 for high albedo bodies (Bowell et al,1989). $\varphi_1(\alpha)$ and $\varphi_2(\alpha)$ are specified phase functions given by equation

$$\varphi_i = \exp[-A_i(\tan 0.5\alpha)^{B_i}]\ ;\ i = 1, 2$$
$$A_1 = 3.33\ A_2 = 1.87$$
$$B_1 = 0.63\ B_2 = 1.22$$

Our photometric data was superimposed to generate a composite lightcurve with a complete rotational phase. The key to constructing an accurate lightcurve was determining 4055 Magellan's synodic period. In order to do so, for each test period used, rotational phase values, ψ, were calculated. Rotational phase was found by

$$\psi_{i,k} = (t_k - t_0) / p_i \qquad i,k = 1, 2,...$$

where p_i is the test period, t_k is the time stamp of an exposure in units of Julian Days and t_0 is the data point chosen to be the zero value. Rotational phase was calculated for the time stamp of each exposure. These values were calculated for each test period.

Results:

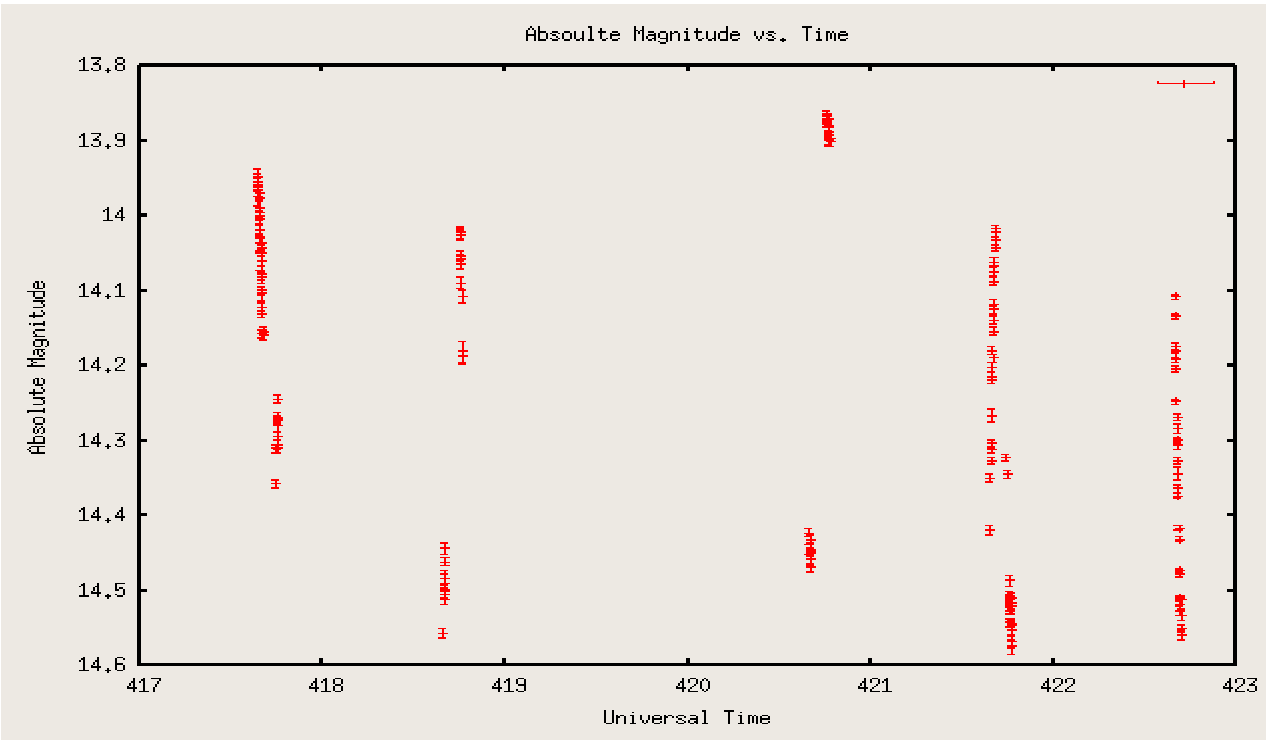
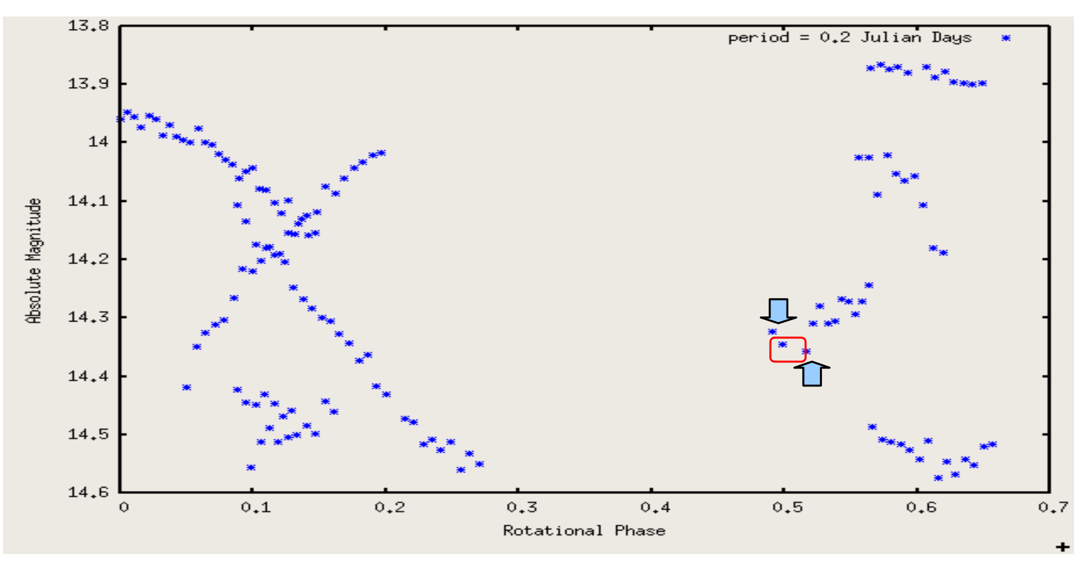


Figure 1: Plot of Absolute Magnitudes for observed nights

Figure 1 is a graph of Absolute Magnitude as a function of time. A G value of 0.15 was assumed. Comparing the time stamp on our images to the time stamp on 4055 Magellan's ephemeris generated by JPL's Horizons database, provided values for r, α, and Δ that were used to calculate Reduced Magnitudes and Absolute Magnitudes. We wrote C programs to obtain these magnitudes.

Figure 2: Plot of unphased lightcurve using a period of 0.2 days



The range for rotational values was such that $0 < \psi < 1$. We assumed different synodic periods such that $0.0001 < p < 0.5$ where period p has units of Julian Days. We wrote a C program that, for each individual rotational phase value, illustrated in Figure 2 as the boxed point, given by a test period, 0.2 Julian Days in Figure 2, calculated the error in Absolute Magnitude between two data points closest in value to rotational phase. The arrows in Figure 2 indicate the values closest to the boxed rotational phase point. Our goal was to find a period that would produce a small error in magnitude and thus a phased lightcurve. The period used in Figure 2, was too small and therefore produced an unphased lightcurve

Figure 3: H Vs. Rotational Phase

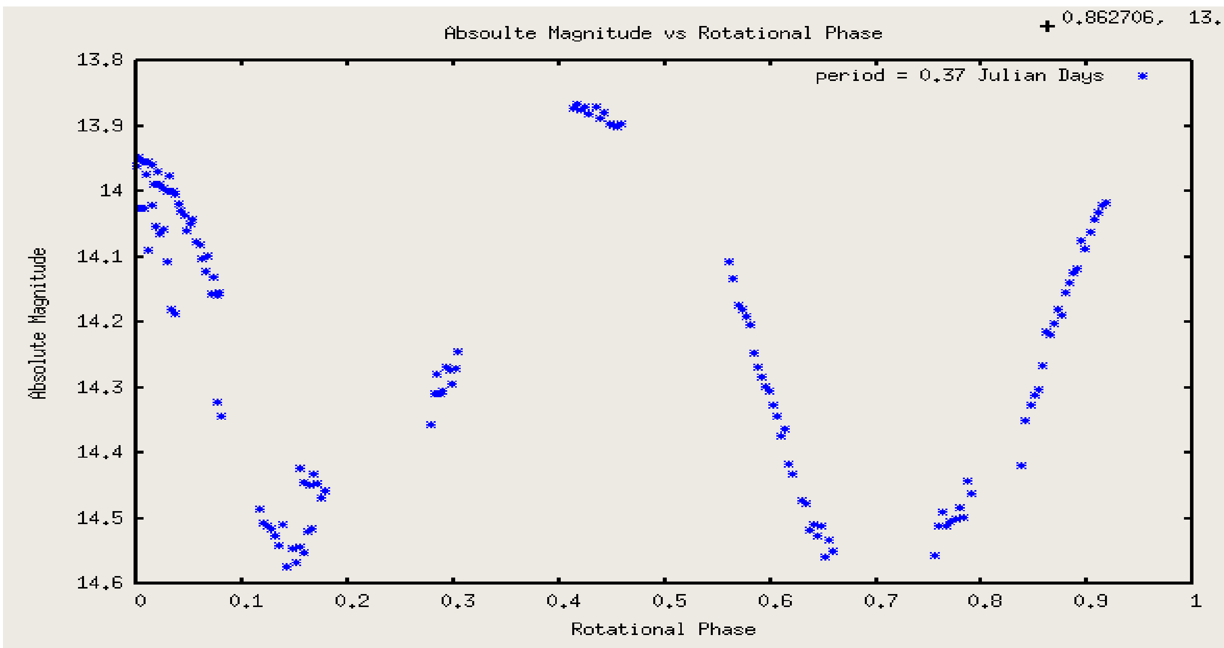


Figure 4: H Vs. Time

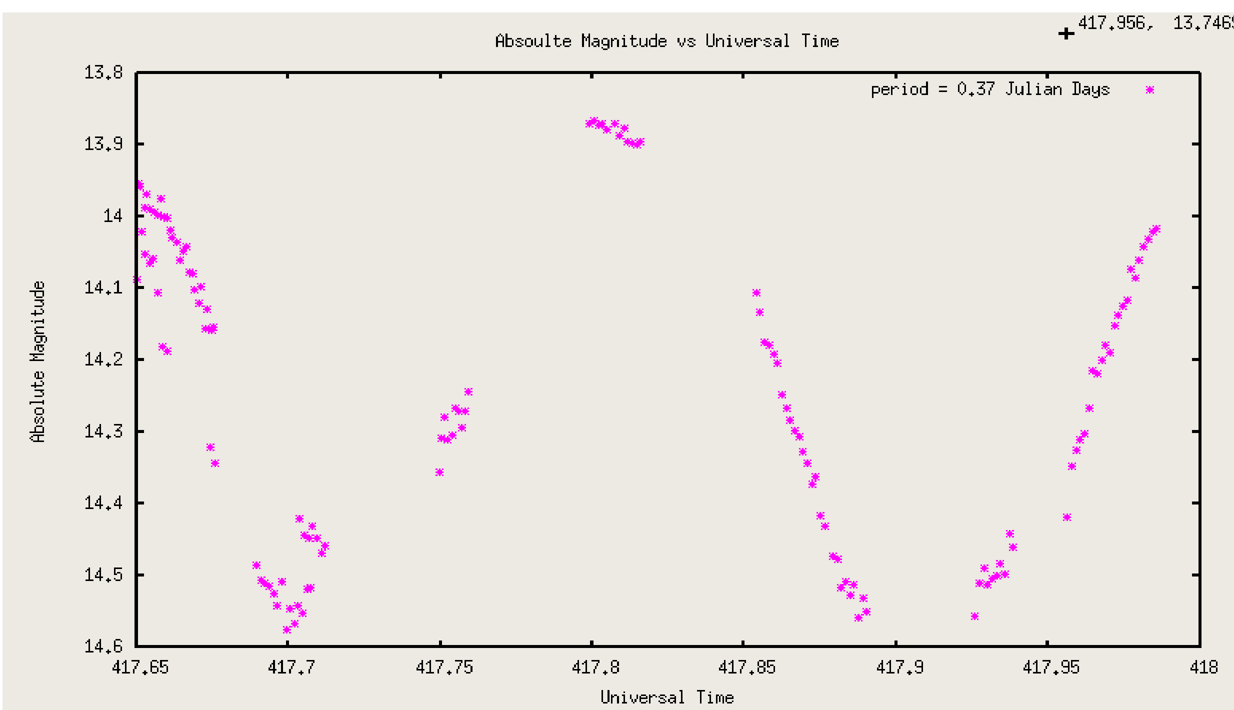


Figure 5: Solar Phase Curve

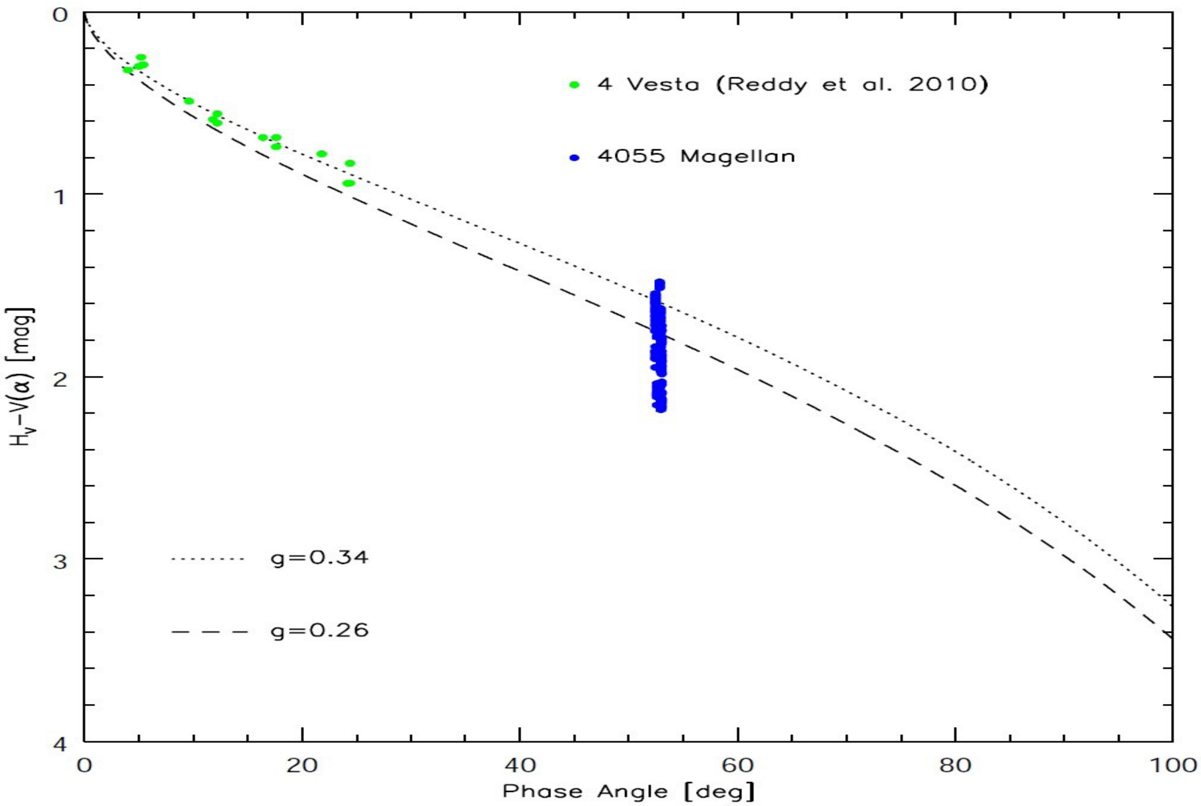


Figure 3 plots the rotational phase values obtained from the synodic period 0.037 days. Figure 4 is the phased lightcurve that was produced once rotational phase was converted to units of time. Our lightcurve exhibits a large amplitude implying a highly elongated shape. From figure 5, which compares 4055 Magellan Solar Phase Curve with Vesta's Solar Phase curve, we derived a phase parameter, g = 0.30 suggesting a shallow solar phase slope. This agrees with the its high albedo. Based on the similarity between the two solar phase curves and the spectrum in Figure 1 we determined that 4055 Magellan's composition is similar to that of 4 Vesta.

Conclusion:

Our lightcurve, through which we determined a synodic period of 0.37 Days, implies that there are photometric similarities between 4 Vesta and 4055 Magellan. Our lightcurve's large amplitude and our g value derived from our Solar Phase curve are consistent with physical characteristics of 4 Vesta. Based on these results we are confident that we can use NEA vestoids as photometric analogs for 4 Vesta.

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