Lightcurves of Icy “Dwarf Planets” (Plutoids)

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1. Introduction

The International Astronomical Union has introduced a new category of objects in the Solar System: the “dwarf planets”. The icy “dwarf planets” in the Trans-Neptunian region have been lately designated as “Plutoids”. From the geophysical point of view, the “dwarf planets” are objects in hydrostatic equilibrium. Therefore, the shape and the rotational state can be used to put constraints in some physical properties such as density. Tancredi & Favero (2008) have proposed classification criteria for “dwarf planets” based on their shape and size, mainly considered as the estimates of the shapes from the lightcurves.

Criteria to classify a body as a “dwarf planet”

1. The diameter of the body should be >450 km for icy objects and >800 km for rocky ones. These limits are not precisely determined and they depend on factors such as the composition of the material and the ambient temperature.
2. If there is a direct measurement of the relative roughness of the surface and the shape complies to a figure of equilibrium, the candidate is accepted (Case I).
3. If not, we analyze the observed lightcurve amplitude (Δm).
   - If Δm<0.15 mag, the candidate is accepted as a small departure from a sphere or MacLaurin sphere with small albedo spots (Case III).
   - If Δm>0.25 mag, the candidate can be fitted to a triaxial ellipsoid. We then analyze if this ellipsoid corresponds to the Jaccoby family. We compute the range of possible densities as a function of the assumed aspect angle of the observed lightcurve.
4. If all the solutions correspond to ρ<1 g cm−3, the candidate is accepted. The size might be overestimated due to an assumption of a low albedo (ρ>0.1 g cm−3) (Case IV).
5. If all the solutions correspond to ρ>1 g cm−3, the candidate is not accepted. The size might be underestimated due to an assumption of a high albedo (ρ<0.1 g cm−3) (Case V).

No lightcurves have been published for about half of the possible 39 candidates, which makes it impossible to decide on their status. We have conducted an observational program to obtain lightcurves in the visible spectrum for a set of these candidates. Combined with published spectra and estimates of the size, we can classify these objects according to the proposed scheme, and we can put constraints on their physical properties and geophysical history.

2. Observations

Direct CCD imaging in the visual spectrum was performed in all observing runs and 5 – 7 minute exposures were taken in order to achieve SNR ~ 30 or higher. The first observing run was performed in CASLEO with the 2.15 m telescope during 13, 14, 18 and 19 September 2007. Problems regarding non-uniform parasite illumination in order to achieve SNR ~30 or higher.

3. Results

Overall lightcurves show relative small amplitude and quite scattered data. Here we show lightcurves for each object observed. The observing run is indicated and each night of observations is artificially displaced 1 magnitude up and overlapped in time for ease of visualization.

4. Discussion

Now we are able to compute amplitudes for objects following this method. We generated lightcurves of Tycho’s Ellipsoids according to the equations given by Barucci et al. (1989). The ellipsoids have axis ratios and pole orientation chosen randomly.

We computed the standard deviation (σ) and the maximum amplitude (A) of lightcurves data points. A linear relation between A and σ is obtained in the range 0<σ<0.3 with a slope of 2.8±0.0 as shown in the figure below. Matlab was used to perform calculations.

![Figure. Visualization of linear relation between Amplitude and Standard Deviation](image)

Now we can establish a simple equation (1) to compute TNOs amplitudes as a function of their observed standard deviation:  

$$ A = 2.8\sigma + 1 $$

For a reasonable calculation of A, we implemented a 20 point rejection criteria and made an iteration until no point was rejected.

In the following table we present standard deviations and amplitudes computed with equation 1.

![Table](image)

A selection of objects with amplitudes ≤0.15 mag are listed below and can be classified as Dwarf Planets according to item #4 of the exposed criteria.

5. References