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The stellar occultation by the TNO (174567) Varda of September 10, 2018: size, shape and atmospheric constraints

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Abstract

A stellar occultation by the large Trans-Neptunian object (174567) Varda was registered on September 10, 2018, from three different sites in the United States of America. This technique is being used by our team to characterize these distant small objects of the Solar System. Besides precise measurements of their size and shape, we can also study their surroundings, searching for putative rings/dust, satellites and atmosphere. Varda is a hot-classical object of the Kuiper Belt, having a semi-major axis of 46.1 au, an orbital eccentricity of 0.14 and inclination of 21.5^o. It also has a satellite, Ilmarë, with an estimated size of 361 km and an orbital period of 5.75 days. From the stellar occultation, we derive a surface equivalent diameter for Varda of 757 km and a small oblateness. The presence of an atmosphere around Varda is investigated. It would cause gradual ingress and egress profiles on the occultation light curves. An upper limit, or detection, of such atmosphere, will be presented.

1. Introduction

The Trans-Neptunian Objects (TNOs) are a group of small bodies in orbits beyond that of the giant planet Neptune. It is believed [7] that they are pristine objects remnants of the Solar System formation. During the early ages of the Solar System, the planetary migration would have left signatures on their orbital distribution and physical properties such as sizes, shape, and densities. Therefore, to understand the history and evolution of the outer solar system, it is very important to determine their physical properties.

The stellar occultation technique consists in observing a solar system object crossing the line of sight to a background star. The duration of this event can be used to measure the length of the object at a given location (know as a chord). If at least three chords along different parts of the object are observed during one event, we can precisely determine its size and shape with kilometre accuracy for a TNO. With that, other physical properties such as albedo and density may be obtained. About 26 TNOs have already been observed during a stellar occultation[1] and many interesting features have already been discovered, such as the presence of narrow and dense rings around the centaur Chariklo and the dwarf-planet Haumea [2, 10], the bright surfaces of Eris and Makemake [12, 9], the shape and topographic features of Quaoar, 2003 AZ_{84} and 2007 UK_{126} [1, 4, 11], as well as the evolution of Pluto's atmosphere [8].

(174567) Varda is a large TNO discovered by the Spacewatch project [6] receiving the provisional designation of 2003 MW_{12}. It is considered a hot-classical object of the Küiper Belt. It presents a featureless spectrum, with no clear sign of any volatile on its surface. In 2009 a 321 kilometer satellite, called Ilmarë, was discovered around it, with 5.7 days orbital period and a semi-major axis of about 4809 km [5].

2. Prediction

A stellar occultation was predicted to cross the western USA on September 10, 2018. Predictions were made using Gaia DR2 star position at the epoch of the event and NIMA ephemeris [3], observations made a few weeks before the event obtained from Sierra Nevada and Pico dos Dias Observatories were used to update

[1] see http://occultations.ct.utfpr.edu.br/results/

the orbit and shadow path. The prediction was made available to the observers through the Lucky Star web page[2] and Occult Watcher[3].

3. Observation

Observations were made from eight different sites, using amateur telescopes, ranging from 28 to 60 cm in aperture, and integrating video cameras, with exposures from 0.3 to 4.3 seconds. Images were converted from video to fits and a light curve was obtained for each site, using differential aperture photometry. Three data sets present clear positive occultation light curves and no secondary drop was detected.

From the event times, we could measure Varda's elliptical limb (Fig. 1) with an equatorial diameter of 790 $\pm$ 15 km and oblateness of 0.085, giving an equivalent diameter of 756 km. This size can be compared with the size of 784 $\pm$ 90 km, calculated for the system using Herschel Space Observatory thermal emission observations [13]. Considering the $\Delta_{mag} = 1.734 \pm 0.042$ between Vanda and Ilmarë obtained by Grundy et al., 2015 [5], they derive Varda's equivalent diameter of 722 $\pm$ 80 km.

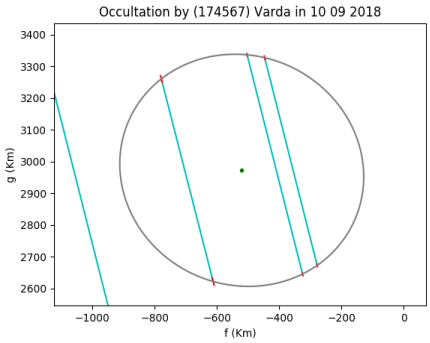

Figure 1: Varda's apparent limb from the stellar occultation detected on September 10, 2018.

4. Summary and Conclusions

In this work, we will present the results from the first detection of a stellar occultation by Varda. From the size and shape determination, and the mass derived thanks to the determination of its satellite, Ilmarë, orbit, we will precisely determine its geometric albedo and density. It will be possible to verify if Varda is in hydrostatic equilibrium, possibly having a Maclaurin shape. We will also be able to constrain Ilmarë's size using photometric and thermal emission observations.

Considering the data quality, investigation of the presence of an atmosphere is possible. It would cause a gradual star flux drop/rise during the ingress/egress of the occultation light curves, and surface pressures up to the nanobar level can be detected.

[2]http://lesia.obspm.fr/lucky-star/
[3]https://www.occultwatcher.net/

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