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Combining occultation observations with thermal measurements: a powerful technique to characterise Centaurs & TNOs

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Abstract

We present a powerful new tool to combine results from stellar occultation with thermal radiometry to obtain physical properties of TNOs and Centaurs. The new method shows the complementary nature of both techniques and opens up a new road of object characterization in the era of Herschel (about 130 TNOs and Centaurs have been observed at key thermal wavelengths [1]) and at the moment just before Gaia will enable us to observe frequent stellar occultations by TNOs [2, 3].

1. Introduction

Stellar occultations provide an elegant way to determine sizes, shapes and albedos of TNOs [4, 5]. This is a very accurate and powerful method, as it provides diameters with kilometric accuracy, allows determining the shape of the body, and can even reveal the presence of atmospheres with pressures down to an amazing nanobar (nbar) level on the surfaces of these bodies. Predicting and observing occultations by TNOs is extremely difficult and challenging because the angular diameters of the TNOs are very small and neither the stellar catalogues nor the TNOs orbits have the required accuracy to make reliable predictions. However, about 10 stellar occultations by TNOs have so far been recorded and with Gaia in the near future such observations will be possible on a daily basis [2].

Radiometric techniques -first developed for main-belt asteroids- provide an alternative way of deriving reliable size and albedo information for small atmosphereless bodies [6, 7]. Infrared surveys like IRAS [8], AKARI [9], MSX [10], or very recently WISE [11, 12], have demonstrated the fantastic potential of the method for establishing fundamental properties for large samples of near-Earth and main-belt asteroids, Trojans and Centaurs. In addition, observatory missions like ISO [13, 14, 15], Spitzer [16] and Herschel [1] have added high-quality thermal data for individual objects, now also including the most distant Trans-Neptunian objects.

The radiometric modeling techniques have evolved over time to keep up with the wealth of thermal data. This process was starting with the slow-rotator or Standard Thermal Model [6] and the fast-rotating thermal model [17], followed by the near-Earth asteroid thermal model [18] and more sophisticated thermophysical models [19, 20, 21]. The TPM allows to specify shape, rotational and spin-axis properties, as well as thermal properties of the object's surface. The true observing and illumination geometries are taken into account and heat conduction into the surface is considered. This latest generation of TPMs is now capable of handling object constraints related to the occultation measurement(s) -like possible ranges of shape and spin properties- together with radiometric considerations. Typically only a small set of possible occultation constraints are compatible with constraints derived from mid- to far-infrared wavelengths. In this way, the physical characterization of the object improves considerably and fundamental properties like size and density become more reliable.

2. Results

An occultation campaign gives sometimes ambiguous results for the shape, especially when only few chords are usable as often happens with TNOs and Centaurs. The object's extension perpendicular to the observed chords is in many cases not very well constrained. Depending on the object's rotation period and its spin-axis orientation, various elongated shape models are compatible with the observed chords. The derived parameter space for spin-vector obliquity, rotation period and the connected shape of the object is then the starting point for a thermophysical analysis and the radiometric technique can be used to improve the occultation results.

We will present a few representative cases of TNO occultations and the related constraints on size, shape, albedo and possible rotation periods and spin-axis orientations. These parameters are used directly in the TPM code together with the available thermal measurements. The final results are then presented and discussed. Our work includes also prominent cases like Eris [4, 22], Makemake [5, 23], 2002 KX_{14} [24, 25], Quaoar [26, 27], and Varuna [28].

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