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Size, density, albedo and atmosphere limit of dwarf planet Eris from a stellar occultation

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Abstract

We report the observation of a multi-chord stellar occultation by the dwarf planet (136199) Eris. The event was observed on November 6, 2010 UT, from two sites in Chile. Our observation is consistent with a spherical Eris with radius R_E=1163±6 km, density ρ=2.52±0.05 g cm^{-3}, and visible geometric albedo p_V=$0.96^{+0.09}_{-0.04}$. Besides being remarkably similar in size to Pluto, Eris appears as one of the intrinsically brightest objects of the solar system, with a density suggesting a mainly rocky interior. Upper limits of about 1 nbar are derived for the surface pressure of possible nitrogen, argon or methane atmospheres of the dwarf planet.

1. Introduction

The dwarf planet Eris pertains to the so-called scattered Trans-Neptunian disk objects, with a high orbital eccentricity (e=0.44) and inclination (i=44°) above the ecliptic plane. Eris is now near its aphelion (at 97.6 AU), and is the most remote body presently observed in the solar system. With an orbital period of almost 560 years, it will take more than 240 years from now to reach its perihelion, at 37.8 AU. Its radius has been estimated to 1200±100 km based on direct imaging [1], while its thermal flux detection provided another estimation of 1500±200 km [2], significantly larger than Pluto, whose minimum radius is estimated to 1169±10 km [3]. Moreover, the motion of Dysnomia (Eris' satellite) provides the mass of the dwarf planet, M_E=(1.66±0.02)×10^{22} kg, 27% larger than Pluto's mass [4].

Here we present the results derived from the occultation of a faint star (V ∼17.1) by Eris that was observed from Chile on November 6, 2010. It improves the size, density, albedo determinations for the dwarf planet, and places an upper limit for a putative atmosphere.

2. Observations

The occultation observation was attempted from 25 sites, 2 of them in Chile provided positive detections of the event, at San Pedro de Atacama and La Silla, using telescopes of modest sizes (40 to 60 cm, see [5]).

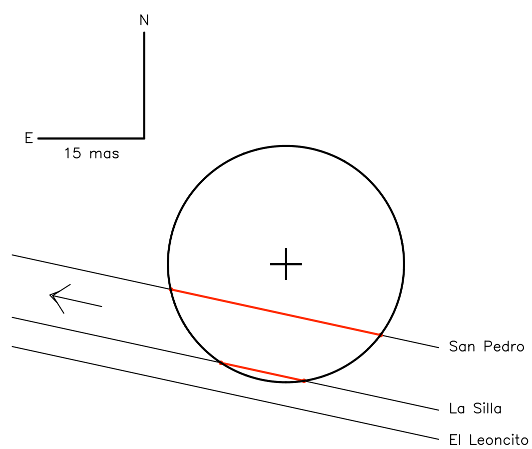

Figure 1: The circle of radius 1163 km is the best fit to the two occultations chords (red) obtained in Chile at the San Pedro de Atacama and La Silla stations. A third station at El Leoncito grazed Eris' limb and was negative. North (N) and east (E) J2000 celestial directions are shown, as well as the scale in milli-arcsec (mas), with 1 mas corresponding to 69.436 km at Eris.

3. Results

The positive detections yields two occultation chords that are consistent with a spherical body, and provide an Eris' radius of R_E=1163±6 km, assuming a spherical body, see Fig. 1. This is very close to the lower limit of Pluto's radius derived from stellar occultations [3]. This implies a density of ρ=2.5±0.05 g cm^{-3}, and indicates that Eris is mainly composed of rocky material, with a relatively thin ice mantle. This is a surprising result, as in situ formation scenarii favor icy bodies with low density. Actually, a large rocky fraction migth imply an impact that scooped away the ice mantle, leaving a mainly rocky body [6]

Using current estimations of Eris magnitude, we infer a geometric albedo of p_V=0.96$^{+0.09}_{-0.04}$ for the dwarf planet [5]. This makes Eris one of the brightest body of the solar system after the Saturnian icy satellites Tethys and Enceladus [7]. For the latter bodies, the bright surface is thought to be associated with a geologically active surface or surface bombardment by Saturn's ring ice particles.

In Eris case, the bright surface could be due to the collapse of a nitrogen or methane atmosphere that is activated at perihelion through sublimation, and that condensates as the temperature drops at perihelion. The occultation light curves observed during the November 6, 2010 stellar occultation actually place an upper limit of 1-4 nbar for possible nitrogen, methane or argon atmosphere [5].

4. Summary and Conclusions

The stellar occultation of November 6, 2010, shows that, if circular, Eris has a radius of R_E=1163±6 km, smaller that previously estimated. This implies a very bright surface with a geometric albedo of p_V=0.96$^{+0.09}_{-0.04}$ and a density of ρ=2.5 ± 0.05 g cm^{-3}, indicating a high rock fraction. The high albedo can be caused by a collapsed nitrogen, methane or argon atmosphere that is presently condensed on the surface, and sublimated only near perihelion. The high rock fraction could be on the other hand be associated with a collision that blasted away Eris' volatiles.

Furthermore, this observation demonstrates that occulations of faint stars (here $V \sim$17.1) can be detected through modest instruments. This is made possible as sensitive cameras and better astrometric predictions are available. This opens up a new era of discoveries because faint stars are far more numerous than bright ones. This allows us to determine the size of remote (e.g. trans-neptunian) objects at kilometric accuracy, with associated accurate values for their albedo and density. Finally, we have demonstrated that we can detect (or place upper limits) of very tenous atmospheres at a few nbar level.

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