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Constraints on Charon's orbit from the stellar occultation of 22 June 2008

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Abstract

A stellar occultation involving both Pluto and Charon was observed on 22 June 2008. This unique event is used to put constraints on the Plutocentric Charon's orbital elements. Our observation is marginally consistent with the current PLU017 Charon's ephemeris ($a = 19606$ km, $e = 0.022$, $\omega = 156.5°$). It is not consistent with the recent solution derived by Tholen et al in 2008 (see [2]): $a = 19570.45$ km, $e = 0.03484$, $\omega = 157.9°$, but it is fully consistent with that solution, provided that a scaling factor is applied so that $a = 19636$ km, as in Tholen and Buie, 1997 (see [3]) all other orbital elements remaining the same.

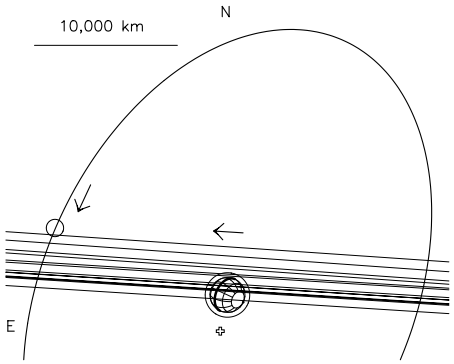

Figure 1: Geometry of the 22 June 2008 stellar occultation. Charon's position along its orbit is shown at the moment of the satellite occultation. Arrows indicate Charon's orbital motion, and the stellar motion relative to the system.

Observations

On 22 June 2008, the same star was occulted by Pluto, as seen from Australia, and then by its main satellite, Charon, twelve minutes later or so, as seen from Indian Ocean and southern Africa.

Nine observations were attempted from various stations in Australia, five of them yielding light curves for the Pluto event. The Charon occultation detection was attempted from two sites in South Africa, one site in Namibia and one site in La Réunion Island, yielding one positive detection at the latter site. All the stellar trajectories relative to Pluto are shown in Fig. 1.

It was a unique opportunity to obtain a direct measurement of Pluto–Charon distance at a specific moment, avoiding the possible biases associated with imaging, such as systematic pixel scale errors or photocenter displacements caused by albedo features on the planet surface or its satellite. As such, this observation may discriminate between various orbital solutions currently used for Charon.

A fit to the five Pluto occultation light curves obtained in Australia, using a ray tracing method and a standard atmospheric model for the planet, provides – among others – Pluto's offset with respect to it expected DE413 ephemeris position. The same method, applied to the Charon event (assuming a radius between 602–608 km) in La Réunion, provides the satellite offset with respect to the DE413 + PLU017 ephemeris ([1]), and thus, Charon's position relative to Pluto.

Fig. 2 shows Charon's limb projected in the sky plane, as derived from the occultation, along the expected position as derived from the orbital parameters

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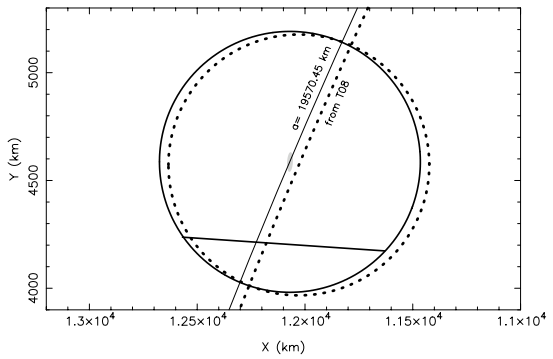

Figure 2: Fit of Charon's limb (solid circle) to the occultation chord (almost horizontal solid line). The dotted circle and line are Charon's position and orbital motion, respectively, as expected from [2], see text. The solid, inclined line is the projected semi-major axis trace according to [2]. The small shaded area is the 3-σ error ellipse for Charon's center, from our observation.

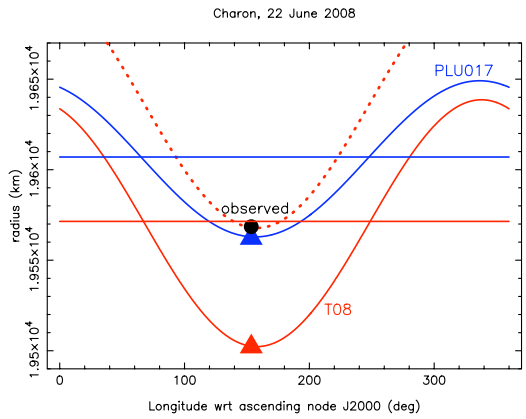

Figure 3: Blue: orbital solution of PLU017 ([1]), with the blue straight line showing the corresponding semi-major axis value, see abstract. The blue triangle is the expected Charon's position at the moment of occultation. Red, solid: the same as before, but for the T08 orbital solution ([2]), see abstract. Red, dotted: the T08 solution scaled to the orbital semi-major axis of [3], see abstract and text. Black dot: observed Charon's position during the occultation. The formal 1-σ error bar on that point is roughty the size of the dot.

recently published by Tholen et al. ([2]) referred to as "T08" hereafter. There is a small but significant mismatch between the two positions, amounting to a radial discrepancy of about 43 km.

This radial discrepancy is better shown in Fig. 3, where Charon's position is plotted in radial Plutocentric distance vs. longitude with respect its J2000 ascending node. This projection was made using the orbital solution of [2]. Note that the Charon occultation was observed very near (about 4 deg. in longitude) its periapsis. We see that the radial mismatch with T08 now amounts to 66 km or so. We have also plotted in Fig. 3 the orbital solution used in the PLU017 ephemeris ([1]), which appears to lie closer to the observed point.

Discussion

Note that the observed and predicted longitudes agree well (to within 0.1 deg or so), indicating that Charon's orbital period is robustly determined.

On the other hand, since we have only one occultation measurement of Charon's distance to Pluto, there is no unique solution to derive new orbital elements for the satellite. However, we note that the T08 solution is not consistent with our observation. A possibility exists that the latter solution is correct, except for a scaling factor. In fact, the orbital solution of Tholen and Buie, 1997 (see[3]), or "TB97", gives a semi-major axis $a = 19636$ km for Charon's Plutocentric orbit, vs. $a = 19570.45$ km for T08. Scaling the T08 solution by a factor of 19636/19570.45 actually put Charon's position right on top of the observed point, see Fig. 3.

In conclusion, our observation is consistent with the PLU017 solution, or with the T08 solution scaled to the orbital semi-major axis published in [3], see abstract for numerical values. Those scaling factors appear to be one of limiting parameters when deriving orbital elements from images of the system. More occultation measurements involving both Pluto and Charon are encouraged, although they remain rare events.

References

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