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Chariklo's body and ring system: three multi-chord stellar occultations in 2017

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Abstract

We present the results obtained in 2017 during three multi-chord occultations by the Centaur (10199) Chariklo and its rings. Two of the occultations were predicted using pre-released Gaia's DR2 stellar positions. This allowed predictions at the milli-arcsec (mas) level accuracy, corresponding to about 10 km projected at Chariklo's distance. These multi-chord occultations permit the refinement of shape models for the main body. They confirm the W-shape structure of the main ring C1R, and show virtually opaque and sharp edges for that ring. A simultaneous detection at two different wavelengths (450-650 nm and 700-1000 nm) show no difference in the profiles, suggesting ring particles larger than several μm.

1. Introduction

Two dense and narrow rings around Chariklo (the largest Centaur object known to date with a diameter of ~260 km) were discovered in 2013 using a stellar occultation [1]. From 2013 to 2016, 16 other occultations by Chariklo were observed, refining the physical parameters of Chariklo's system [2, 3, 4]. Here, we focus on three occultations observed in 2017.

Rings subtend about 80 mas projected in the sky and are only resolved by using stellar occultations. Until Sept. 2016, the prediction accuracy (~40 mas), was the main limitation for organizing efficient and successful campaigns. The Gaia DR1 catalogue reduced the uncertainties on star positions to ~10 mas (~100 km at Chariklo), due to the still unknown star proper motions. This is solved in the DR2 catalog, which provides sub-mas accuracies (a few km at Chariklo).

2. DR1 and DR2-based predictions

Gaia DR1 [5] contains the astrometry of one billion stars (with no proper motions). It allowed us to improve the accuracy of our predictions by a factor of about 5. We then used various methods to improve stellar proper motions (UCAC5, TGAS, UCAC4-DR1), while reducing our previous Chariklo occultation and astrometric observations against DR1. This was used to feed NIMA (Numerical Integration of the Motion of an Asteroid, see [6]).

The April 9, 2017 occultation was predicted using the NIMAv11 ephemeris and DR1 + UCAC5 stellar proper motion. The 1σ accuracy of the event was about 20 mas in right ascension (ra) and declination (dec), mostly dominated by the ephemeris and stellar proper motion uncertainties.

In May 2017, the Gaia project released two preliminary DR2 stellar positions for the June 22 and July 23[1]. This included the proper motion and yielded accuracy to 0.2 mas in ra and dec, while NIMAv11 ephemeris provided typical accuracies of 10 mas in ra and dec.

Finally, the positive detection of the June 22 event provided the NIMAv13 ephemeris, that has a accuracy of 2 mas both in ra and dec (Fig.1). This is much smaller than the ring angular span (80 mas) and Chariklo diameter (25 mas). This clearly illustrates the quantum leap brought by Gaia concerning stellar occultation predictions, as it permits an efficient and optimized coverage of the occultations.

[1] https://www.cosmos.esa.int/web/gaia/news_20170523

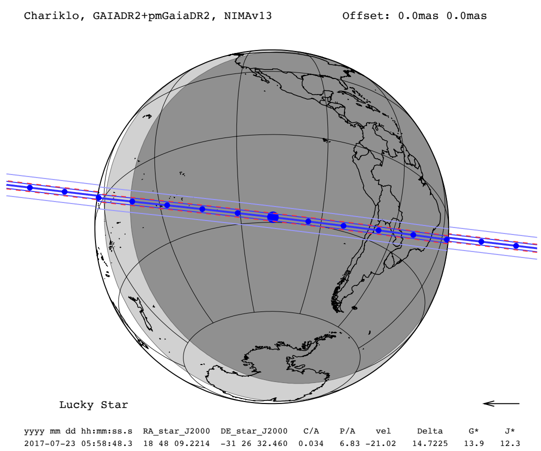

Figure 1: Prediction map of the July 23, 2017 event using the NIMAv13 ephemeris and the pre-released Gaia DR2 star position + proper motion. Blue dots are spaced by 1 min (the larger dot corresponding to closest geocentric approach), the arrow (bottom right) indicating the direction of the shadow motion. Dark blue lines represent main body shadow limits, whereas light blue lines represent rings shadow boundaries. Red dotted lines represents the 1σ uncertainty on prediction.

3. Results

The refinement of the Chariklo's orbit and the Gaia DR2 positions have allowed multichord observations for the three events. The April 9 event was observed at 3 different stations, the June 22 event, from 6 stations and the July 23 from 14 stations. The July 23 post-occultation residual shows a difference of 10 km (about 1 mas) compared to our prediction.

We will present updated results on refined shape models for Chariklo, the orbital elements of the ring system, and the width variation of the main ring C1R. Finally, the dual Lucky Imager of the Danish telescope provides simultaneous profiles of Chariklo's main ring C1R, see Fig. 2 for details.

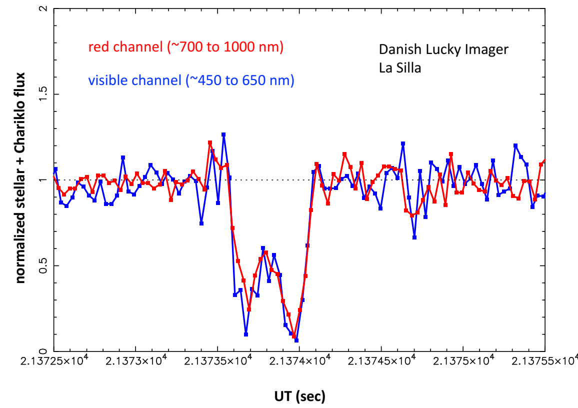

Figure 2: The simultaneous profiles of Chariklo's main ring C1R obtained during the July 23, 2017 stellar occultation in two channels (as indicated in the figure). Note (1) the conspicuous W-shape of the ring optical depth profile, (2) its almost opaque edges and (3) the similarity of the profiles in the two channels, indicating that the optical depth is dominated by particles larger than several μm.

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