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Characterization of material around (2060) Chiron from a 2011 stellar occultation

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Abstract

A stellar occultation by Chiron was observed in 2011, the data from which have been interpreted as detecting a ring system similar to that around Chariklo. We present a detailed re-examination of that optical dataset, with a focus on significant light-curve features, and we additionally analyze the near-infrared spectra. This work has been submitted for publication in [1].

1. Introduction

Centaurs are particularly interesting bodies, transitioning in their orbits from the outer Solar System to other fates, including becoming short-period comets, moving farther inward, or being ejected. They exhibit a color bimodality and some centaurs are known to have comas or outgassing. A better characterization of individual centaurs can allow more accurate comparison with possible kindred populations as well as an increased understanding of planetary surface processes.

Stellar occultations are one of the most accurate methods to study centaurs. Successful stellar occultation observations in 1993 and 1994 indicated that Chiron's nucleus is greater than 180 km in diameter and revealed an asymmetric dust coma as well as discrete jet-like features around Chiron's nucleus [1–2]. Such activity is notable, given Chiron's relatively distant orbit and large nucleus size relative to comets.

2. Observations

In 2011 November 29, Chiron occulted a fairly bright star (*R*~15 mag) as observed from the 3-m NASA Infrared Telescope Facility (IRTF) on Mauna Kea and the 2-m Faulkes Telescope North (FTN) at Haleakala. Unfiltered, visible-wavelength images were taken at 4.98 Hz from FTN and 0.5 Hz from the IRTF. Simultaneous, low-resolution, near-infrared (NIR) spectra were obtained at ~0.1 Hz from the IRTF. The NIR data have 474 distinct wavelength channels. To exclude noisy channels, and allow the widest wavelength coverage possible, only channels 10 through 453 (1.02–2.50 μm) were used in these analyses.

3. Analyses

Differential light curves were derived for each of the three datasets. Sn occultation by Chiron's nucleus was detected from the IRTF while the FTN detected short-timescale dips before and after the predicted midtime but no solid-body occultation. Poor weather prevented data collection before and after the predicted midtime when Chiron and the star were well separated. Therefore, the geometry of the event is not accurately established. We thus consider the limiting cases of the IRTF being a central chord (minimum nucleus size) or a graze (maximum nucleus size).

A square-well model is employed to measure the size of the nucleus. For all light-curve features that are more than a 4-σ variation from the baselines (shown in Fig. 1), the location, equivalent width, and optical depth are calculated. We searched for trends between significant light-curve features in the visible and NIR data, as well as in spectral data at each time step.

4. Summary and Conclusions

We place a lower limit on the diameter of Chiron's nucleus of 160.2±1.3 km, which is consistent with previous measurements. Symmetric dips were

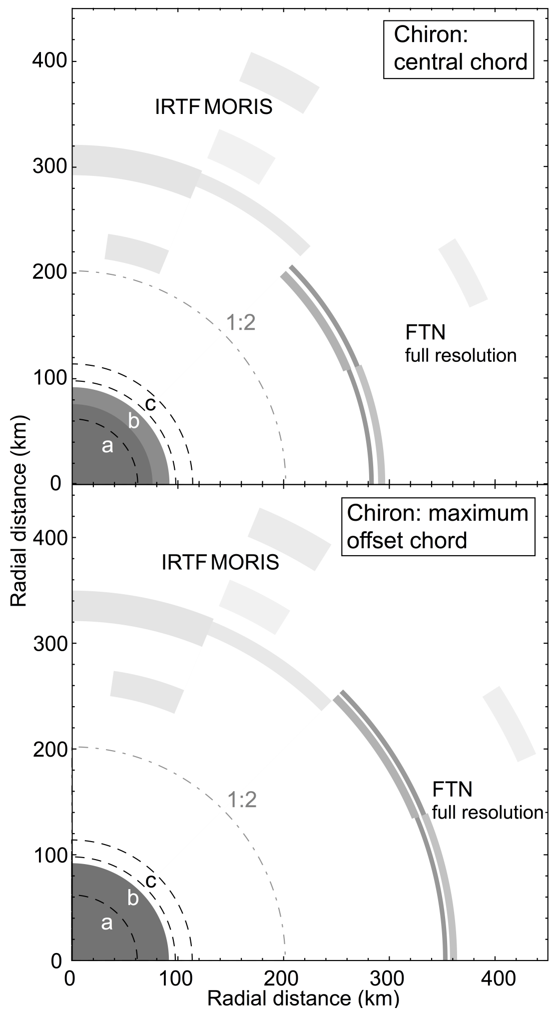

Figure 1: Schematic diagrams of the Chiron system. Two limiting geometries for the occultation are shown. Dotted lines indicate ellipsoidal semi-axes *a*, *b*, and *c* for Chiron's nucleus from ALMA data [4]. Significant features in the light curves are plotted at their measured locations (including error bars), and the grayscale corresponds to optical depth. Moving clockwise from the top left in each panel, each dataset is displayed from immersion to emersion. Asymmetric features appear as partial arcs. Note that the distance scale for Chiron is in the sky plane: there are no assumptions about pole orientation. For reference, the location of the 1:2 resonance is marked as a gray dot-dashed line.

observed between 280–360 km from the center (depending on event geometry) and there is a gap between them of 10.2±1.8 km. Each of these features varies azimuthally in width from ~2–3 and 4–6 km and in line-of-sight optical depth from ~0.55 to 0.95 (normal optical depth ~0.3–0.5 for the proposed ring-pole orientation). These features are similar in equivalent depth to Chariklo's more symmetric, inner ring. Increased transmission near the nucleus suggests that these features are more likely to be planar rings than a shell of material. Note that features similar to Chariklo's outer ring are below the detection threshold for this dataset.

The increased-transmission region is within the 1:2 spin-orbit resonance (roughly 200 km from the surface), which is consistent with the proposed clearing pattern for a non-axisymmetric nucleus [5]. Characteristics of additional, asymmetric features are presented, which are likely to be transient, as well as detection of an extended shell or diffuse ring from ~900–1480 km with line-of-sight optical depth ~0.04. There are no significant features in the NIR light curves, nor any correlation between optical features and NIR spectral slopes.

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