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Manwë -Thorondor: A tertiary system in the Kuiper Belt?

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Abstract

Here we present multi-epoch light-curve observations of the binary Kuiper Belt object (385446) Manwë-Thorondor (aka 2003 QW111). The system is currently undergoing mutual events whereby the two bodies alternately eclipse and occult each other over ~0.5-day periods several times per year. Events are expected until the end of 2019. Our observations reveal a complex light curve with a dominant rotation period of ~12 h and amplitude 0.5 mag, with significant deviations from year to year. We use a preliminary tertiary model to fit the observations, assuming Manwë is a contact binary, and Thorondor is a smaller body with extremely long rotation period (~1 year) and large photometric variability (~1.5 mag).

1. Introduction

Hubble Space Telescope (HST) observations of the 7:4 resonant Kuiper Belt binary object (385446) Manwë-Thorondor (aka 2003 QW111) from 2006 to 2013 reveal a binary orbit with semi-major axis ~ 6700 km and eccentricity ~ 0.6 [1][2]. Mutual events are predicted to recur every period (~110 days) from 2014 to 2019 but with uncertain timing of ~0.5 day. Due to the high eccentricity of the binary orbit and its orientation relative to Earth's line of sight, the events occur in pairs (first inferior, then superior), with the two events separated by ~18 days and occurring over ~0.5 days. The HST photometry suggests asynchronous variability for Manwë and Thorondor, with the two bodies varying by ~0.5 and ~0.7 mag, respectively, but with undetermined periods. Manwë is brighter than Thorondor by 1.2 mag on average. Their estimated mean radii are 80 and 46 km with large uncertainty (~factor 1.5).

2. Light Curve Observations and Modelling

Since 2016 we have been observing the combined light curve of Manwë and Thorondor to detect mutual events and to determine the rotation rates of the two bodies [3][4]. Figure 1 shows our observations to date, where we plot the reduced magnitude versus rotational phase assuming a best-fit, double-peaked rotation period of 11.96 h. The figure also shows several preliminary model fits. The green curve (left) is the nominal prediction for the mutual events assuming no rotational variability (Grundy et al. 2014). The uncertainty in the timing of these events is equivalent to 2 rotation periods. The black curve (left) is a tertiary fit, with Manwë modeled as a contact binary with a rotation period of 11.96 h while Thorondor has no rotational variability. Here the deep excursion in the DCT observations is an inferior mutual event, but this requires a large adjustment to the nominal binary orbit (6° change in inclination). The black curve (right) is a different tertiary model with the binary orbit tweaked so that no mutual events occur at the observed epochs. Again, Manwë is a contact binary with 11.96-h period, but Thorondor has a long rotation period (~8/3 times the binary orbit period) and a large light-curve amplitude (peak---peak 1.5 mag). Here the DCT observations occur when Thorondor is at minimum brightness.

3. Summary and Conclusions

Our observations suggest Manwë may be a contact binary while Thorondor is exceptionally body with high-amplitude variability (~1.5 mag) and very long period (~1 year). This extraordinary rotation rate for Thorondor is required to explain both the regularity we observe for the light curve from day to day and the significant changes we see from year to year. However, this interpretation depends on our assumption that we have not detected any of the expected mutual events. Because of the large uncertainty in the event predictions, this assumption is plausible. Given the complexity of the tertiary system, it is still possible that some of the variability we observe is the result of mutual events. We are currently developing our models further to better predict the mutual event light curves we should see for a tertiary system as a function of the orbit geometry and rotation state of the components. Our goal is to more tightly constrain the rotational state of the bodies in the system and their physical parameters. These results may relate the unusual rotational state of Thorondor to the dynamical history of the system.

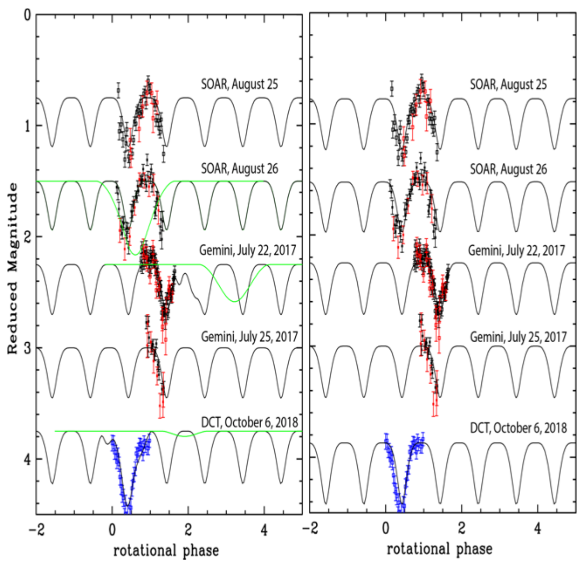

Figure 1: Light Curve observations of Manwë-Thorondor obtained at several different epochs (earliest first), with each dataset offset by 1 magnitude each for ease of interpretation. The rotational phase is computed assuming a double-peaked light curve with period of 11.96 h. Observations were made with the 4.1-m Southern Astrophysical Research telescope (SOAR), the 8.1-m Gemini South telescope, and the 4.3-m Discovery Channel Telescope (DCT) at Lowell Observatory. Red and black points are Sloan g and r, respectively, with g shifted by the mean g-r to show consistency with the r-band observations. Blue points are VR band, calibrated to Sloan r. See text for descriptions of the model fits.

4. References

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