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# The first stellar occultations by irregular satellites

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## Abstract

## 1. Introduction

The irregular satellites are objects that orbit the Giant Planets from great distances, with highly inclined, eccentric orbits and mostly retrograde. It is believed that these satellites were captured by their host planets during the Solar System evolution. Thus, studying them may give us hints about their region of origin.

In order to estimate their dimensions with great accuracy, [1] predicted stellar occultations by the 8 largest irregular satellites of Jupiter (Himalia, Elara, Pasiphae, Carme, Lysithea, Leda, Ananke and Sinope) and 1 of Saturn (Phoebe) up to 2020. Due to the passage of the satellites in front of the Galactic Plane in 2018, for Phoebe, and 2019-2020 for the Jovian ones, a large number of events were predicted. Until now, 5 stellar occultations were observed involving Phoebe and 2 with Himalia.

## 2. The Stellar Occultations of Phoebe

The first stellar occultation by Phoebe ever to be observed happened at 06 July 2017. This occultation was observed in Japan by two observers. In 2018, other four occultations were observed, in South America (19 June 2018) and Australia (26 June, 03 July and 13 August 2018). Unfortunately, each event had only one positive chord.

The Cassini spacecraft allowed many studies to be developed about Phoebe. However, some regions of the object were not observed by the spacecraft, mainly in the latitudes higher than 60°, while other regions were observed only with low resolution. It is important to note that, by 2017/2018, it is the north region of Phoebe that is observed from Earth. The technique of stellar occultation, whose results can achieve kilometre accuracy can be used to constrain the shape of Phoebe in the regions that were not observed by Cassini.

Since Phoebe already has a known shape from Cassini observations, we used the 3D shape model of [2][1] to fit our chords. This is important because Phoebe is highly cratered so it is likely that the chords may have passed through topographical features.

### 2.1. New rotational period for Phoebe

Firstly, the model is rotated to the configuration of the epoch of occultation, given the orientation model of [3]. By comparing with the chords of the 2017 event, we notice that both chords could not fit well the 3D shape model. One of the chords was located very far from the projected limb.

However, the chord could fit very well the 3D model if we considered another longitude. This is expected from the error associated with the rotational period of Phoebe. The difference between this result and the expected longitude suggested us two possible solutions for the rotational period for the satellite: P1 = 9.274401 h ± 0.02 s or P2 = 9.273651 h ± 0.02 s.

Since the 2018 events had only one chord each, they could not univocally be used in the determination of a longitude. Instead we projected the solutions found to the epoch of these events and analyzed them.

We found that, using P1, the longitude for the 19 June 2018 event would be close, about 1.5° of difference, to a longitude interval where the only chord of the event is larger than the shape model given its direction and the uncertainty of the chord, creating a region of improbability.

Also, for the 26 June occultation, the ephemeris offset obtained is farther from the 19 June and 03 July events using P1 than P2. It is not expected they to be

[1]Gaskell (2013): https://space.frieger.com/asteroids/moons/S9-Phoebe

far from each other since the observations are only 2 weeks apart. Given these facts and that the P2 solution is closer to those published by [4], P2 is our favorite solution.

## 3. The Stellar Occultation of Himalia

Himalia is the largest irregular satellite of Jupiter and it is the main satellite of the group that bears its name. Its radius is known from low resolution Cassini observations as $75 \pm 10 \times 60 \pm 10$ km [5], giving the satellite an ellipsoidal shape.

Himalia was the first Jovian irregular satellite ever observed by an occultation, at 12 May 2018 in the USA. This provided two positive chords. The second one happened in 20 May 2018, a week later, observed in Europe and providing six positive chords.

By fitting the 20 May chords with a elliptical shape, we find a size which is larger than those provided by Cassini, with an equatorial radius larger than 100 km. As expected from objects with these dimensions, Himalia must have craters with significant sizes compared to the satellites'. By using chords that could be located in craters, the determination of the size could be affected.

Because of this we compare the chords with the shape given by [5]. This comparison can be seen in Figure 1. The straight line is an ellipsoid with radius of 75x60 km and the dashed lines considering an error of 10 km.

It is possible to note that the chords suggest Himalia has a larger shape than that provided by Cassini. It also suggests Himalia has craters that could be larger than 10 km.

## 4. Summary and Conclusions

Stellar occultations of irregular satellites has provided us new informations about these interesting objects. The new rotational period of Phoebe can be used to better fit new occultations. This is important to better constraint the shape of Phoebe if chords close to the north pole of the satellite is observed.

For Himalia, the preliminary results show a probable cratered shape and a equatorial radius larger than those obtained by Cassini.

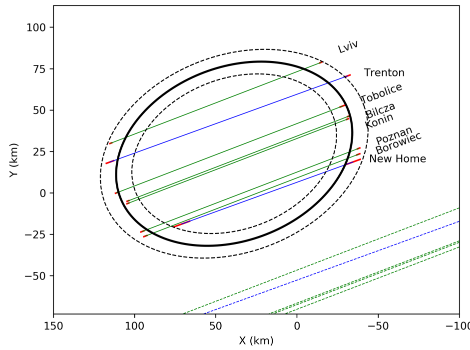


Figure 1: Chords of Himalia from 2 stellar occultations compared to the estimated shape obtained by Cassini. Black straight and dashed lines gives the ellipse from Cassini observations and error bars, respectively. Blue and green lines are the chords from 12 May and 20 May events, respectively, where the straight ones are the positive chords and dashed ones are the negative chords.

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