LIGHTCURVE BASED DETERMINATION OF 10 HYGIEA'S ROTATIONAL PERIOD WITH TRAPPIST-NORTH AND -SOUTH

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A densely-sampled lightcurve of the large main-belt asteroid 10 Hygiea was obtained with the TRAPPIST-South (TS) and TRAPPIST-North (TN) telescopes in 2018 September and October. We found its synodic rotation period and amplitude to be 13.8224 ± 0.0005 h and 0.27 mag. The data have been submitted to the ALCDEF database.

Observations of the large main-belt asteroid (MBA) 10 Hygiea were acquired with the robotic telescopes TRAPPIST-North (TN, Z53) and TRAPPIST-South (TS, I40) of the Liège University (Jehin et al., 2011). They are located, respectively, at the Oukaïmeden Observatory in Morocco and the ESO La Silla Observatory in Chile. Both are 0.6-m Ritchey-Chrétien telescopes operating at *f*/8 on German Equatorial mounts. TN camera is an Andor IKONL BEX2 DD (0.60 arcsec/pixel) and the one of TS is a FLI ProLine 3041-BB (0.64 arcsec/pixel).

The raw images were calibrated with corresponding flat fields, bias and dark frames and photometric measurements were obtained using *IRAF* (Tody, 1986) scripts. The differential photometry and lightcurves were made with Python scripts. For the differential photometry, all the stars with a high enough SNR were used and checked to discard the variable stars. Various apertures were tested to maximize the SNR. In the composite lightcurve below, the normalized relative flux is plotted against the rotational phase. The rotation period was determined with the software *Peranso* (Vanmunster, 2018), which implements the FALC algorithm (Harris et al., 1989). The reported amplitude is from the Fourier model curve.

10 Hygiea is the fourth largest MBA with a diameter of 434 ± 14 km (Vernazza et al., 2019). Since 1991, all of Hygiea's reported rotation periods agreed with a value close to 27.6 h (LCBD, Warner et al., 2009) but were each time built from sparsely sampled lightcurves. In support of the ESO Large Programme 199.C-0074 (Vernazza et al., 2018) aiming to determine precise volumes and densities of the 40 largest MBAs, we started extensive photometric observations of Hygiea to refine its rotation period and help in the shape and spin axis determination. Such a long period is challenging to cover, especially when it is close to 24 h (the 27.6 h period translates in a phase shift of only 13% of the rotation each night), explaining the lack of dense lightcurves for this large and bright asteroid. To tackle this challenge, the complementarity of the two TRAPPIST telescopes at two different longitudes was decisive to acquire long and continuous photometric series as illustrated in Ferrais et al. (2020).

We observed Hygiea in 2018 from September 10 to October 17 with TN and TS using the Johnson-Cousins broad band Rc filter, no binning, and an exposure time of 8 seconds. As more data were gathered, the phased lightcurve started to show a classic double-sinusoidal shape with the previously reported period but with the high quality of the data, we noticed it was perfectly symmetric (see Fig. 1 for the final lightcurve phased with P = 27.6 h). Therefore, we produced the split halves plot which showed two identical halves and a very convincing fit (Fig. 2). From the final data set rich of 9490 images split in 13 long photometric series for a total of 73 h, a new synodic period of 13.8224 ± 0.0005 h was derived and confirmed by the converging 3D model built with the VLT/SPHERE adaptive optics images (Vernazza et al., 2019). These images revealed the spherical shape of Hygiea and albedo features at its surface, explaining the single-peak shape of its lightcurve.

Following the publication of the new period in Vernazza et al. (2019), Pilcher (2020) derived a similar synodic period of 13.828 ± 0.001 h from photometric observations obtained in 2019. We stress with this example the importance of high-quality photometric data to derive asteroid rotation periods, especially for those having a period close to a multiple of a day and to be careful with symmetric double-peak lightcurves which might have in reality half the period due to an albedo feature rather than due to their shape.

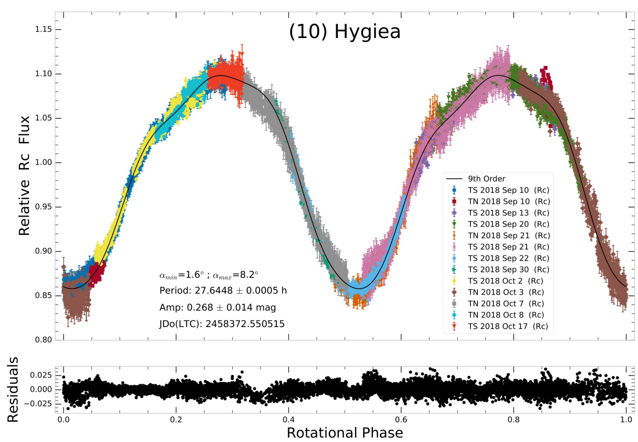

Figure 1. Phased lightcurve using the previously reported rotation period of 27.6 h.

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
10	Hygiea	09/10-11/17	9490	*4.8,8.2	0.6	4.6	13.8224	0.0005	0.27	0.01	MB-O

Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date and reached a minimum during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner *et al.*, 2009).

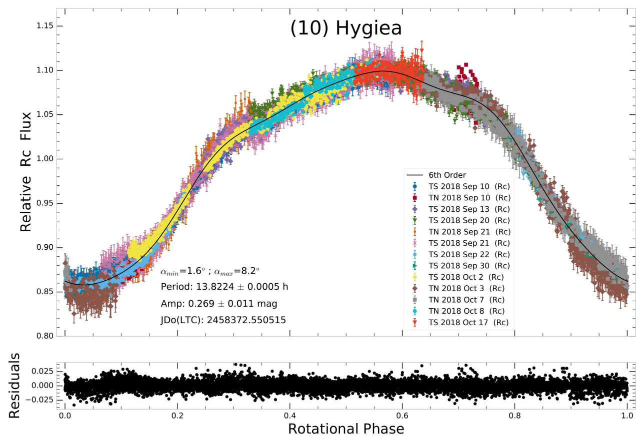

Figure 2. The lightcurve phased using the new period of 13.8224 h.

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LIGHTCURVE ANALYSIS OF L4 TROJAN ASTERIODS AT THE CENTER FOR SOLAR SYSTEM STUDIES: 2020 OCTOBER TO DECEMBER

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Lightcurves for six L4 Jovian Trojan asteroids were obtained at the Center for Solar System Studies (CS3) from 2020 October to December.

CCD photometric observations of six Trojan asteroids from the L_4 (Greek) Lagrange point were obtained at the Center for Solar System Studies (CS3, MPC U81). For several years, CS3 has been conducting a study of Jovian Trojan asteroids. This is another in a series of papers reporting data analysis being accumulated for family pole and shape model studies. It is anticipated that for most Jovian Trojans, two to five dense lightcurves per target at oppositions well distributed in ecliptic longitudes will be needed and can be supplemented with reliable sparse data for the brighter Trojan asteroids. For two of these targets we were able to get preliminary pole positions and create shape models from sparse data and the dense lightcurves obtained to date. These preliminary models will be improved as more data are acquired at future oppositions and will be published at a later date.

Table I lists the telescopes and CCD cameras that were used to make the observations. Images were unbinned with no filter and had master flats and darks applied. The exposures depended upon various factors including magnitude of the target, sky motion, and Moon illumination.

Telescope	Camera
0.40-m f/10 Schmidt-Cass	FLI Proline 1001E
0.40-m f/10 Schmidt-Cass	Fli Microline 1001E
0.35-m f/10 Schmidt-Cass	Fli Microline 1001E

Table I. List of telescopes and CCD cameras used at CS3.

Image processing, measurement, and period analysis were done using *MPO Canopus* (Bdw Publishing), which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris et al., 1989). The Comp Star Selector feature in *MPO Canopus* was used to limit the comparison stars to near solar color. Night-to-night calibration was done using field stars from the ATLAS catalog (Tonry et al., 2018), which has Sloan *griz* magnitudes that were derived from the GAIA and Pan-STARR catalogs and are the "native" magnitudes of the catalog.

To reduce the resetting nightly zero points, we use the ATLAS r′ (SR) magnitudes. Those adjustments are mostly ≤ 0.03 mag. The occasions where larger corrections were required may have been related in part to using unfiltered observations, poor centroiding of the reference stars, and not correcting for second-order extinction terms.