Doctoral School of Physics - Eötvös Loránd University (ELTE)

2nd semester report

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PhD Program: **ELTE Astronomy and Space Physics doctoral program**

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Ph.D. Thesis title: **Exploring the physical properties of asteroids with the TESS space telescope**

Introduction

In my research, my primary focus lies in the examination of minor planets within the Solar System in order to understand their characteristics and properties. These bodies hold important information about the origin and evolution of the Solar System, particularly through the in-depth analysis of their light curves. My research builds on data from the Transiting Exoplanet Survey Satellite (TESS), which provides continuous, high-quality photometric time series. In contrast to ground-based observations, these data significantly improve our understanding of these minor planets. We already have high-quality light curves for about 10.000 asteroids from DR1, using data from the first year of TESS's mission (Pál et al. 2020). By using light curve inversion techniques, my aim is to determine the shape, rotational characteristics and surface scattering properties of a vast number of main belt asteroids, Hildas and Jupiter Trojans (Muinonen et al. 2020). This detailed analysis not only reveals their physical properties but also enables the study of their collisional and evolutionary history.

Description of research work carried out in current semester

In my first year of PhD studies, I concentrated on improving and automating a Python code, developed by me, for analyzing light curves from TESS for 43 main belt asteroids. These asteroids were selected based on three criteria. They must have observation in at least three TESS sectors, a brightness of 18th magnitude or brighter, and a shape model in the `DAMIT` (Database of Asteroid Models from Inversion Techniques) database. The code performs rotation period searches and chi-square minimization to determine the direction of the rotational axes and shapes of these selected asteroids. Additionally, we integrated the Lommel-Seeliger scattering model into our analysis, providing more realistic surface scattering and therefore more accurate solutions (Muinonen & Lumme 2015; Muinonen et al. 2015).

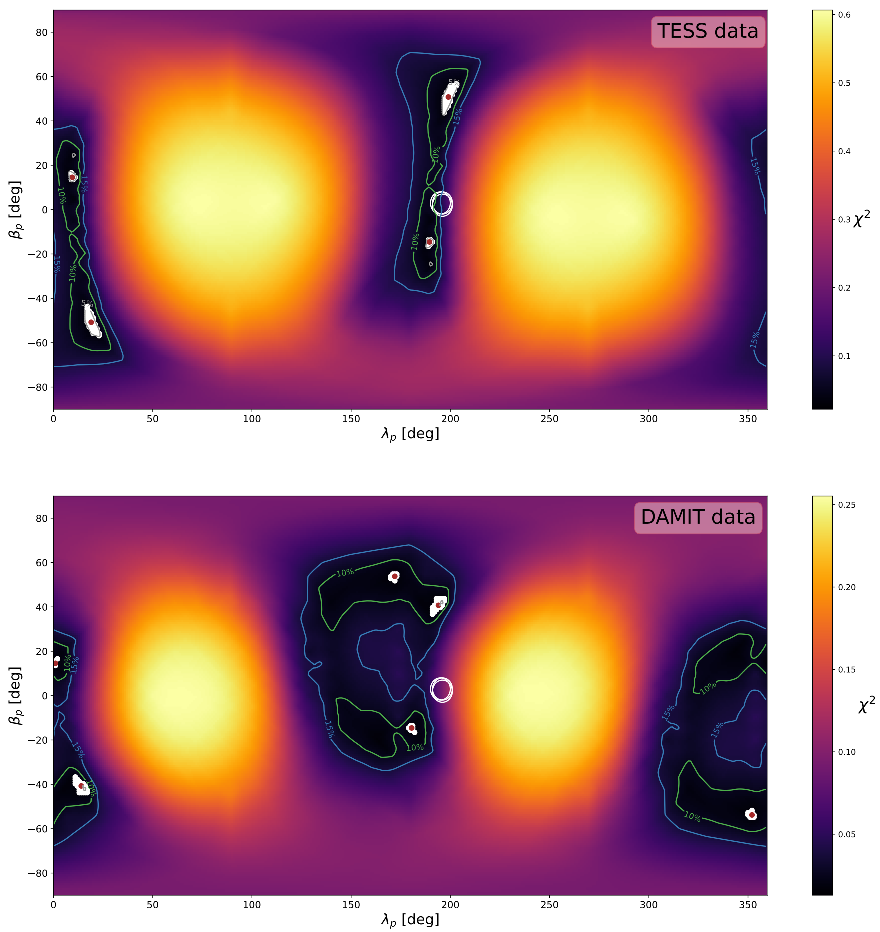

Figure 1: Possible axis of rotation solutions for asteroid (22) Kalliope. The top panel shows the results obtained using TESS data, while the panel on the bottom uses the same procedure but for DAMIT data. The dark areas indicate the possible directions of the axis of rotation. The white dots show the smallest 100 chi^2 values. The three contour levels show the 1, 2 and 3% of the maximum value. The red dots in the middle of the minimum areas show the median of those. And the white circles represent the DAMIT coordinates for the axis of rotation.

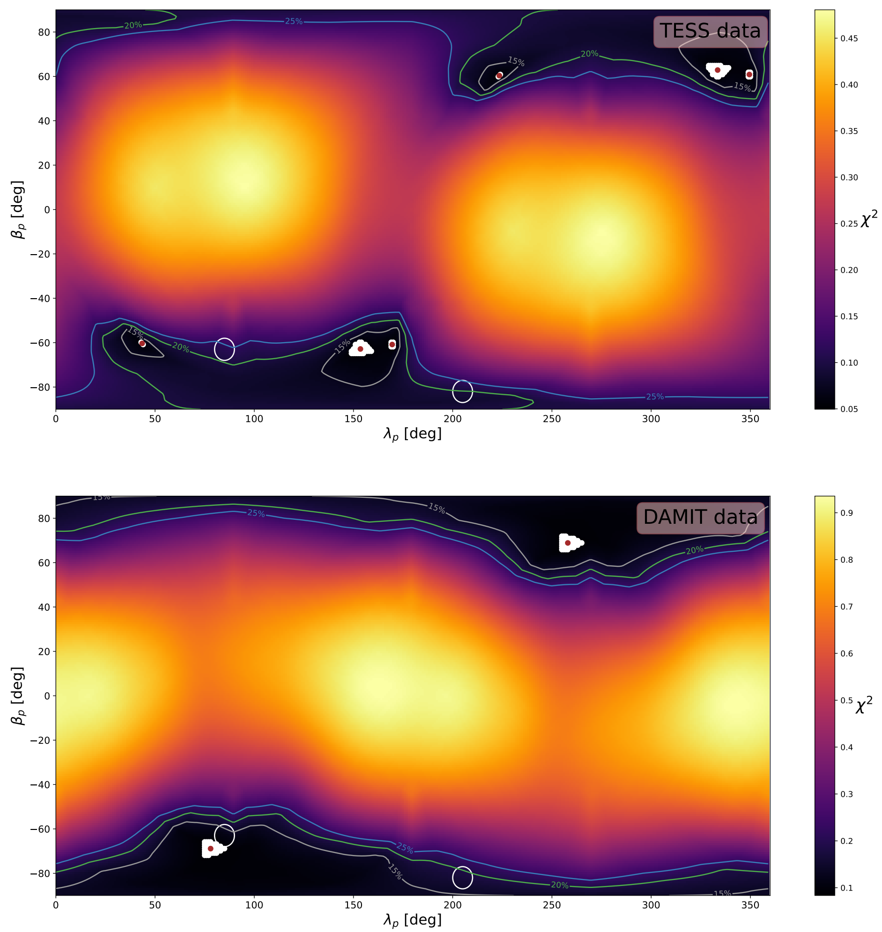

Figure 2: Same as before, but for the asteroid (1572) Posnania.

I carried out a thorough analysis of the results by cross-referencing them with the data available in the DAMIT database. These measurements are ground-based measurements, therefore their duration is much shorter and their coverage is much worse than in TESS measurements, but they provide a greater quantity of data from various viewing directions and their pole orientation results are obtained with much more complex shape models (Durech et al. 2010). I was able to perform this comparison for 4 objects. For the others, unfortunately, there were not enough observations that met the criteria.

(22) Kalliope and (1572) Posnania are two examples of the four objects mentioned above. The results for these two objects are shown on Figure 1. and on Figure 2. For both asteroids, we used TESS data from three sectors, while for the DAMIT data, we used light curves from which we could extract meaningful amplitudes. This gave us 4 measurements in the case of (22) Kalliope. For (1572) Posnania we tested whether we get a closer solution to the DAMIT coordinates if we used all the measurements that met the criteria. This gave us 16 measurements. Since, these are much shorter and more incomplete measurements compared to the TESS data, plus since different parts of the orbit are sampled by the two techniques, we got a small difference in the results. Apart from this, however, our results for the TESS data are close to the solutions in DAMIT.

In the future, I plan to apply this entire procedure to the whole TESS minor planet database. This approach will go beyond the initial requirement for a corresponding solution in the DAMIT database, and will include an extensive sample of light curves for potentially hundreds of thousands of minor planets.

In addition to my work on main-belt asteroids, I have analysed the rotational properties of Hilda and Jupiter Trojan asteroids, once again using data from the TESS mission. Ground-based measurements often suffer from observational limitations that can distort the data. Space telescopes such as TESS can overcome many of these limitations. For example, ground-based observations often underestimate the number of slow-rotating asteroids, leading to biased rotational period and amplitude distributions. For instance, a large sample of Hilda light curves from the K2 mission demonstrated an excess of long rotation periods (Szabó et al. 2020). This phenomenon has also been observed in other solar system asteroid populations from the main belt (Pál et al. 2020).

I have been able to obtain several week-long, uninterrupted light curves for a substantial number of Hildas and Jupiter Trojans. These data sets often span multiple sectors, providing a much more comprehensive view than what ground-based methods or even the K2 mission could offer.

For this analysis, I have used a Python code, written by Attila Bódi, which can determine periodicities using photometric data. It can filter out the noise using the LOWESS Smoother algorithm, thus increasing the chance of distinguishing the true signal. We first defined the periods for Hildas up to 19 magnitude, but since then I have reviewed measurements in the fainter region and found a number of useful light curves. The faintest object (2011_WA52), for example, drops down to 23.88 magnitude in one of its sectors.

In the future, I plan to investigate the variations in rotation between the 'red' and 'less red' groups within these populations, as well as the distinctions among different collisional families. These analyses are important for understanding the diverse evolutionary paths and collisional histories of Hildas and Jupiter Trojans.

1 Studies in current semester

During my second semester, I completed the following subjects, all with excellent grades,

- At the edge of the Solar System 2 (FIZ/5/048)
- Radio astronomy II. (FIZ/5/010)
- The structure of compact stars (FIZ/5/025)

2 Further activities

- From 4 to 16 February 2024, I participated in the 2023 NEON Observing School programme, during which I had the opportunity to learn how to use local instruments, telescopes and systems and to carry out the reductionof my own measurements. On 6 March, with Zsófia Bora, we had the opportunity to give an astronomical demonstration to a group of high school students in the ELTE planetarium.
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- Since 2021, I have been carrying out astronomical observations and scientific measurements at the Observatory of the HUN-REN Centre for Astronomy and Earth Sciences, Miklós Konkoly Thege Institute of Astronomy in Piskéstető, for an average of one week per month.

3 Conferences in current semester

- I have applied for and was accepted to the TESS Science Conference III held in Boston from July 29 to August 2, 2024, with a 15-minute presentation and a poster on the topics described above.
- I have applied for and was accepted to the Europlanet Science Congress 2024, held in Berlin from 8 to 13 September 2024, by contributing a 15-minute presentation and a poster on the topics described above.

References

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