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DETERMINATION OF THE ROTATION PERIOD OF ASTEROIDS FROM A SHORT SERIES OF BRIGHTNESS OBSERVATIONS UNEVENLY SPREAD OVER A LONG TIME INTERVAL

D.Svincicka, I.Eglītis

Institute of Astronomy, University of Latvia,
3 Jelgavas St, Riga, LV-1004, Latvia,
darja.svincicka@gmail.com, ilgmars.eglitis@lu.lv

ABSTRACT. The main belt asteroids, situated between two planets (Jupiter and Mars), are subject to a significant influence from these planets (Mars-crossers by Mars), as well as from other planets. This is particularly concerning in the case of asteroids with small asteroid-Earth minimum orbit intersection distances (MOIDs), as these have the potential to pose a significant hazard to Earth. In this study, we present light curves for 15 main belt and Mars-crossing asteroids with small asteroid-Earth MOIDs, which are smaller than 1.1 AU. These asteroids are particularly likely to become Earth-crossing or near-Earth asteroids. In order to obtain brightness measurements, photometry was performed using CCD images captured by the Baldones Schmit telescope (1.2-metre mirror, equipped with two STX-16803 CCDs). The light curves were obtained by comparing the brightness of the asteroids with the Sun-like colour index of five to six stars, processed with MaxIm DL. The remaining brightness measurements are derived from the Minor Planet Center (MPC) database, based on data from 18 observatories and the Transiting Exoplanet Survey Satellite (TESS). The brightness measurements are only complementary to the asteroid position measurements. Therefore, these brightness measurements are typically not very precise and are separated by different time intervals that may be quite extensive. In order to find the asteroid rotation period, it is sometimes necessary to employ data correction as well as programs that are able to identify the period in unevenly scattered data. Our analysis employed the Lomb–Scargle method, which identified period values for 14 of the asteroids. The method can be used to obtain results for the simple rotations of asteroids, provided that the asteroids are observed in phases within the range of 7 and 40 degrees, that their shape is nearly an elongated ellipsoid, and that their rotation axes are almost perpendicular to their heliocentric orbital planes.

Keywords: photometry, asteroids, Lomb–Scargle method, rotation period.

АНОТАЦІЯ. Астероїди головного поясу, розташовані між двома планетами (Юпітером і Марсом), схильні до значного впливу з боку цих планет (марс-кросери по Марсу), а також з боку інших планет. Це особливо викликає занепокоєння у випадку астероїдів з малими MOID (мінімальними відстанями перетину орбіт астероїдів і Землі), оскільки вони потенційно можуть становити значну небезпеку для Землі. У цій роботі ми представляємо криві блиску для 15 астероїдів головного поясу та астероїдів, що перетинають Марс, з малими MOID астероїд-Земля, меншими за 1,1 а.о. Ці астероїди з великою ймовірністю стануть астероїдами, що перетинають Землю або навколоземні. Для отримання вимірювань яскравості було проведено фотометрію з використанням CCD-зображень, отриманих телескопом Baldones Schmit telescope (1,2 м дзеркало, оснащене двома ПЗЗ-матрицями STX-16803). Криві блиску були отримані шляхом порівняння яскравості астероїдів із сонцеподібним колір-індексом п'яти-шести зір, обробленим за допомогою MaxIm DL. Решта вимірювань яскравості отримані з бази даних Центру малих планет (MPC) на основі даних 18 обсерваторій та супутника Transiting Exoplanet Survey Satellite (TESS). Вимірювання яскравості лише доповнюють вимірювання положення астероїда. Тому ці вимірювання яскравості, як правило, не дуже точні та розділені різними часовими інтервалами, які можуть бути досить великими. Для того, щоб знайти період обертання астероїда, іноді необхідно використовувати корекцію даних, а також програми, які здатні ідентифікувати період у нерівномірно розкиданих даних. У нашому аналізі використовувався метод Ломба–Скаргла, який визначив значення періоду для 14 астероїдів. Цей метод може бути використаний для отримання результатів для простих обертань астероїдів за умови, що астероїди спостерігаються з фазами в діапазоні від 7 до 40 градусів, що їхня форма – майже витягнутий еліпсоїд, і що їхні осі обертання майже перпендикулярні до їхніх геліоцентричних орбітальних площин.

Ключові слова: фотометрія, астероїди, метод Ломба–Скаргла, період обертання.

1. Introduction

The influence of planets on asteroids can result in significant alterations to their orbits. These influences include gravitational perturbations (Nesvorný et al., 2002; Morbidelli et al., 2002) and orbital resonances (Nesvorný et al., 2002). The Yarkovsky (and YORP) effect (Bottke, 2006) can assist in this process, exerting a particularly strong influence on asteroids with a diameter of less than 40 km. It is of great importance to study those asteroids with small asteroid-Earth MOIDs, since they are particularly unstable and the most likely to evolve into Earth crossers and near-Earth asteroids (NEAs) over time.

We present a method for analysing asteroids using brightness measurements, that are available alongside positional measurements. The principal objective of these observations is to obtain position measurements. These observations are typically conducted on several occasions throughout the night, over the course of several nights, with an inter-measurement interval of approximately 5–30 minutes. It should be noted that observations are frequently separated by a considerable interval of time, even spanning years and may be lacking sufficient precision due to external factors such as weather conditions or overexposure.

Subsequently, the data are corrected so that the resulting light curves are dependent solely on the rotation period (Zeigler & Hanshaw, 2016). Moreover, when constructing phase-magnitude diagrams, any brightness values that deviate by more than three standard deviations per night are removed, as they are likely to be the result of an error.

A period search was conducted using the Lomb Scargle program from the astropy package in Python (Astropy Collaboration, 2024), which was incorporated into the Python script written at the Institute of Astronomy. The Lomb Scragle method was selected due to its capacity to analyse unevenly sampled data and to perform an analytical analysis of white noise, thereby highlighting only those spikes that are significant. It is possible that erroneous strikes may be observed as a result of factors such as observation periodicity, alliance frequencies, or other effects (VanderPlas, 2018). In order to ascertain the correct period, a Gaussian shape spike exceeding a significant power of 0.2 was sought.

The final period was calculated using the results from all observatories, weighted according to the number of observations, peak power, and deviation from the linear phase-magnitude diagram relationship.

2. Results

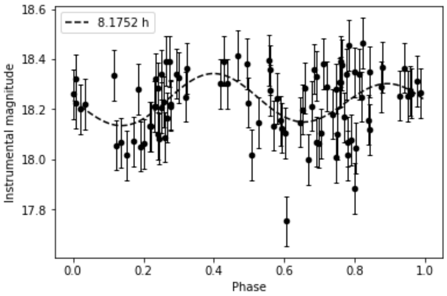

Figure 1: The light curve of asteroid 1205, observed at observatory W68 in the O-band.

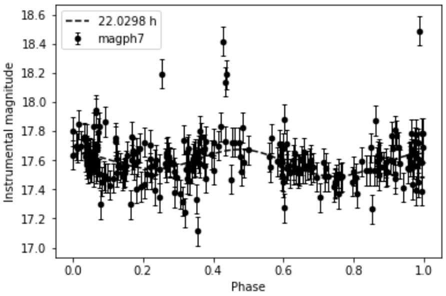

Figure 2: The light curve of asteroid 1779, observed at observatory T05 in the O-band. P_w= 22.071 ± 0.072 h

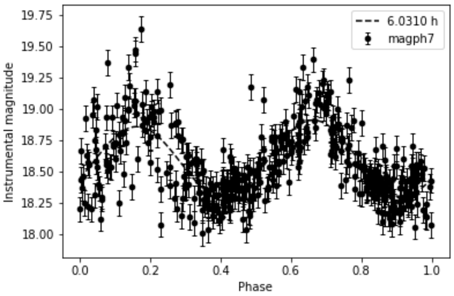

Figure 3: The light curve of asteroid 1818, observed at observatory T08 in the O-band. P_w= 6.031 ± 0.001 h

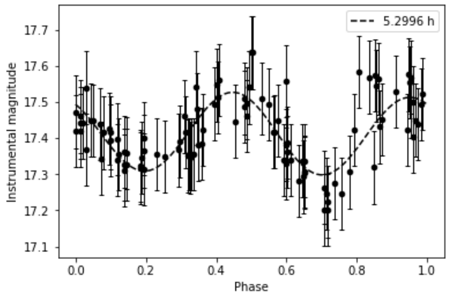

Figure 4: The light curve of asteroid 1951, observed at observatory I41 in the R-band. P_w=5.306 ± 0.007 h

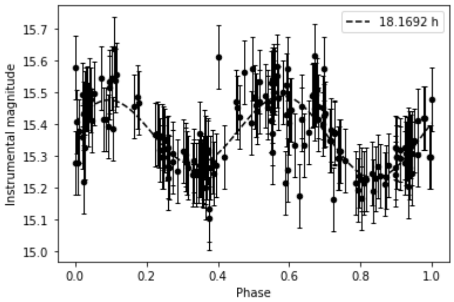

Figure 5: The light curve of asteroid 1963, observed at observatory M22 in the O-band. P_w= 18.181 ± 0.012 h

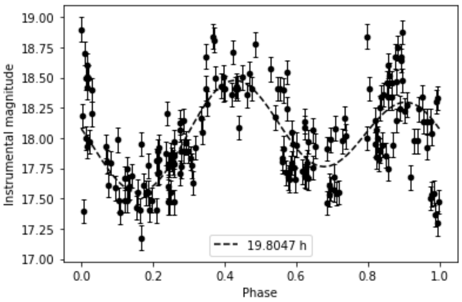

Figure 6: The light curve of asteroid 2128, observed at observatory T05 without the use of a filter. P_w= 19.777 ± 0.097 h

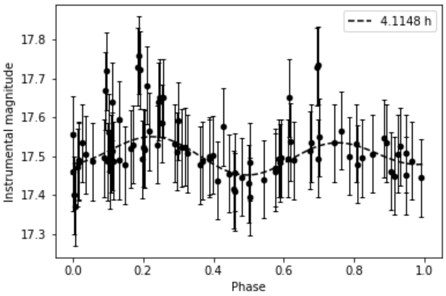

Figure 7: The light curve of asteroid 2134, observed at observatory I41 in the R-band. P_w= 4.113 ± 0.003 h

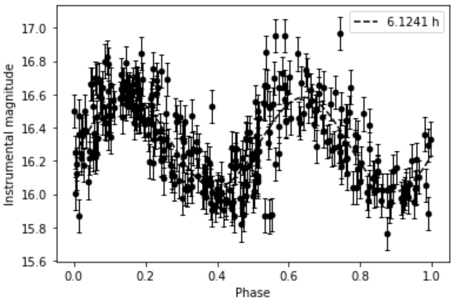

Figure 8: The light curve of asteroid 2150, observed at observatory T05 in the O-band. P_w=6.125 ± 0.005 h

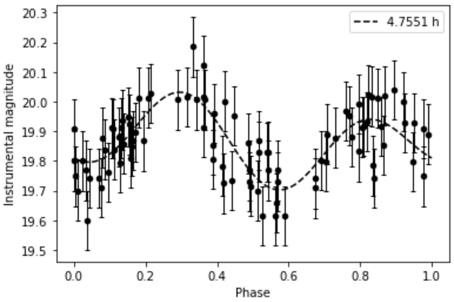

Figure 9: The light curve of asteroid 2174, observed at observatory G96 in the G-band. P_w= 4.785 ± 0.006 h

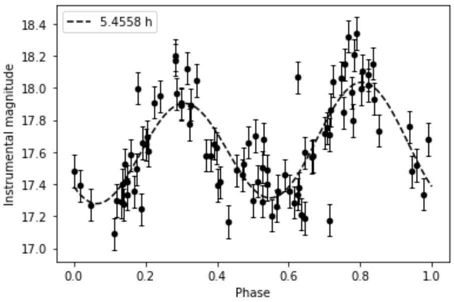

Figure 10: The light curve of asteroid 2318, observed at observatory W68 in the O-band. P_w= 5.458 ± 0.002 h

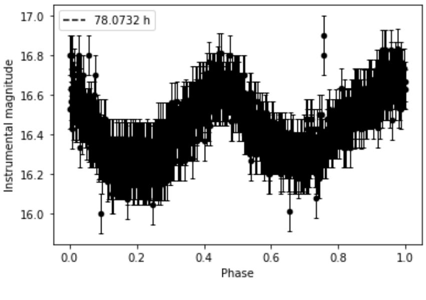

Figure 11: The light curve of asteroid 2497, observed at observatory TESS in the G-band. P_w= 77.760 ± 0.065 h

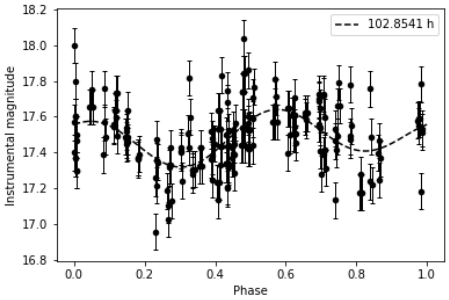

Figure 12: The light curve of asteroid 2503, observed at observatory T05 in the O-band. P_w= 102.984 ± 0.101 h

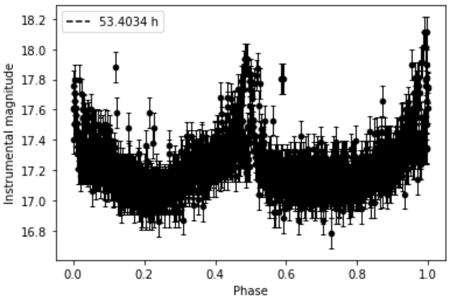

Figure 13: The light curve of asteroid 2538, observed at observatory TESS in the G-band. P_w= 53.401 ± 0.033 h

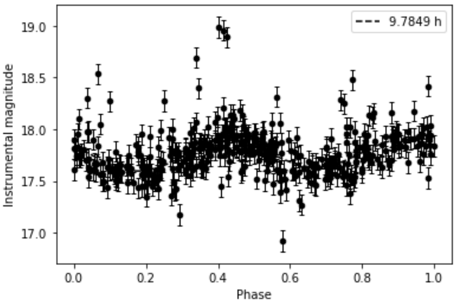

Figure 14: The light curve of asteroid 2539, observed at observatory T08 in the O-band. P_w= 9.789 ± 0.008 h

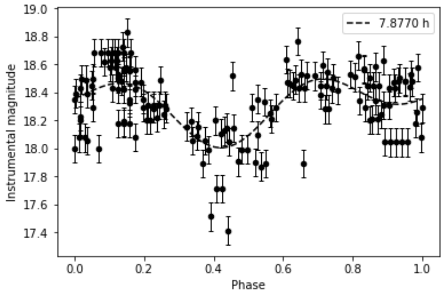

Figure 15: The light curve of asteroid 2583, observed at observatory 703 in the G-band. P_w= 7.790 ± 0.001 h

3. Conclusion

We employed a combination of CCD photometry and MPC brightness data to obtain brightness measurements, which were subsequently corrected and used to derive light curves for 15 asteroids. Subsequently, the Lomb–Scargle method was employed, resulting in the determination of a period for fourteen asteroids. However, insufficient data was available for asteroid 1205 to yield a reliable result. Our findings were compared with those of other authors. The periods were known for five of the asteroids, four of which were in agreement, but the period of one 2174 asteroid was inconsistent with our value. This may be due to limitations in our methodology. The rotational periods of asteroids can be determined using this approach, provided they exhibit simple rotation, are observed during phases within 7 to 40 degrees, are elongated ellipsoids, and have nearly perpendicular rotation axes to their heliocentric plane.

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