The Photometric Light Curves and the Rotation Period of the Asteroid 3122 Florence

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Abstract. This study presents our results of the 3122 Florence asteroid photometric observations. We focused on the light curve construction and on the subsequent rotation period determination. Duration of our observations spanned four nights during which we obtained three relatively high-quality light curves. Observational data have been combined into one file and by using the MOP Canopus software we have determined the value of the rotation period to be $P = 2.352 \pm 0.210$ hours.
Key words: minor planets – near Earth objects – 3122 Florence – photometry – periods

Introduction

In the scope of our astrometric program, we have decided to observe the asteroid number 3122 Florence during the time of its near-Earth flyby in the year 2017. Our primary objective was to perform astrometry measurements of the asteroid in the context of the Target Asteroids project of NASA (Target Asteroids 2017). For the observations, we have used our telescope Celestron 9.25" (Schmidt-Cassegrain) on the NEQ6/Pro mounting, equipped with the Moravian Instrument camera MI G2-1600. The SIPS (Scientific Image Processing System, 2016) system had been used for the exposures, camera movements and for the initial processing of the images. Even though we do have the filter wheel with the B, V, R and I filters inside the camera, we have observed the asteroid in the integral light only. Instead of doing short individual observations, we have decided to perform long observations during as many nights as possible. With this approach, we saw a possibility to accurately determine the rotation period of the asteroid. Our access in the rotation period determination had been based on the work of Apostolovska et al. (2017).

2. Observations and data reduction

We managed to observe the object successfully during four nights. The meteorological conditions on the first night of the August 28, 2017 allowed us to observe for approximately 40 minutes. Even if these observations do

Table 1. The basic data of our observations and conditions.

Day		28.8.2017	31.8.2017	7.9.2017	8.9.2017
Start (UT)	hour:min:sec	20:57:19	20:05:49	20:04:40	19:34:41
End (UT)	hour:min:sec	21:39:44	23:03:50	22:54:44	21:23:01
Rectascension	hour:min:sec	21:32:09	21:04:39	19:59:53	19:50:58
Declination	deg:min:sec	−27:29:17	−03:10:36	+46:37:38	+50:27:24
Altitude	deg	8	37	82	84
SNR		~ 700	~ 1000	~ 600	~ 550
Weather cond.		Poor, high clouds	Excellent	Very well	Excellent

certainly have some value we consider them as trials only. The asteroid had been rather low over our horizon but it had been bright and clearly visible in the telescope. The brightness can be explained by the fact that it was approaching the closest position to the Earth. The weather conditions were very good with clear sky. The next suitable night had been on August 31, 2017 when we managed to observe for more than two hours. Comparing with the previous night, the asteroid had been much higher over the horizon and the weather conditions have been excellent, again with clear sky. A week later, during the night of the September 07, we observed for three hours while the next night of September 08 for more than two hours. The asteroid had been rather high over the horizon but its brightness had gone down. The weather conditions were again excellent during the aforementioned 2 nights. However, subsequent nights did not provide favorable meteorological conditions and after that the asteroid had not been reachable for our telescope. Nevertheless, we have obtained three complete light curves. As we were doing exposures, the data were split into individual files in the Flexible Image Transport System (FITS) format which we have then processed with the Astrometrica system (Raab, 2011). The MPO Canopus system (Warner, 2011) was subsequently used to determine the rotation period of the asteroid. Initially, we have tried to determine the rotation period individually for each of the three sets of data. As these results were not scientifically acceptable, we decided to merge the data into one large file with the Julian date as an independent variable and with the observed magnitude as the dependent variable. This new combined file then served as an input into the MPO Canopus software system. Comparing our results with those of other observers of the asteroid 3122 Florence around the world as well as with the NASA radar observations of this object, we have not identified any significant discrepancy (NASA Press Rel., 2017).

We have arranged the basic information on the times, positions and on the weather conditions of our observations into the Table 1. We hope that it will expound the system and the results of our observations will be more clear.

3. Results

As stated above, we have observed the asteroid 3122 Florence during four nights and we have obtained around 1 500 exposures of this object. The exposure time was set to 20 seconds for the first two nights and to 30 seconds for the remaining two nights. Even if we later excluded the measurements made on August 28 from our subsequent analysis we have anyway decided to publish them here just as a raw data on the basis that no observation is repeatable.

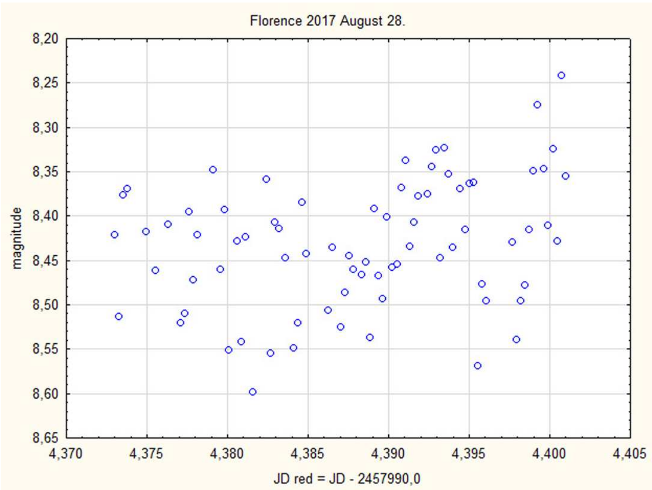

Fig. 1. The photometric data from August 28, 2017. The magnitudes are the true magnitudes of the asteroid in accordance with the Pogson's law.

Based on the data from the night of August 28, the standard deviation has been calculated at 0.07 mag. This value reflects the fact that for us the asteroid was relatively low on our visible horizon. During the following nights however, the standard deviation of our determined magnitudes of the asteroid was calculated to be slightly lower. According to the MuniWin software package (Motl, 2010) the standard deviation is around 0.003 mag.

By looking at the determined, fairly disparate, individual light curves presented on Fig. 2, we concluded that the rotation of the asteroid is not simple. Despite that, we have identified an approach to calculate the common period of its rotation. First we standardized the magnitude values using formula

$$u = (m - \bar{m})/\sigma, \tag{1}$$

where m is the magnitude, $\bar{m}$ is the value of the mean magnitude for the whole night and σ is the dispersion or standard deviation of the magnitudes computed from the data for the given or corresponding night. This approach allows us to make the data scalable. Then, applying a small shift on the x-axis we were able to obtain the data as they are presented in Fig. 3 without any a priori (by definition) given value of period into them.

With this refined data we were able to use the MPO Canopus system to determine the common value of the rotation period of the asteroid based on our observations from the three nights. We calculated the period to have the value of $P = 0.098 \pm 0.01$ day $= 2.352 \pm 0.21$ hours. This value is presented

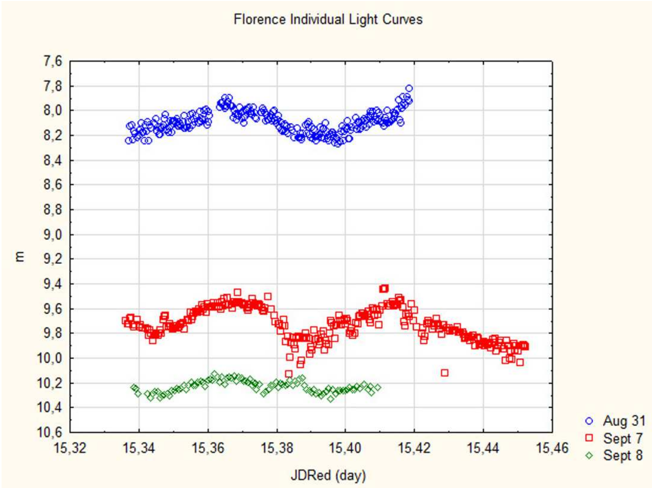

Fig. 2. Our photometric data in common. The magnitudes are the true magnitudes of the asteroid in accordance with the Pogson's law.

in Fig. 4 as one of the direct outputs from the MPO Canopus system. Next, the Fig. 5 shows corresponding periodogram of the asteroid.

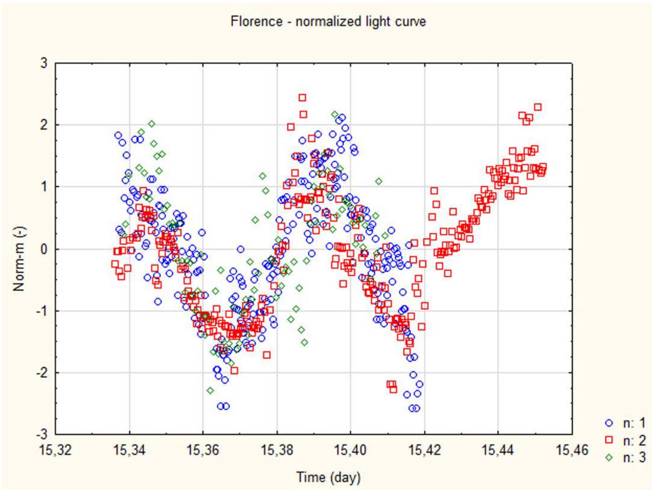

Fig. 3. Our standardized measurements. The magnitudes are dimensionless values computed in accordance with the Eq. 1.

As the period determination is the crucial point of our work we have

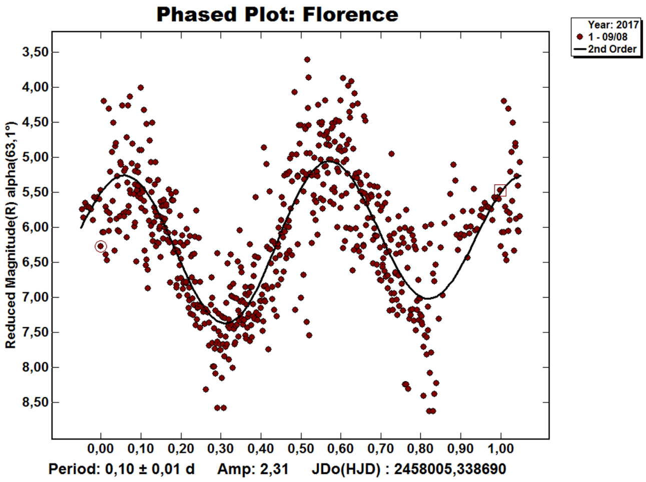

Fig. 4. The result from the MPO Canopus system.

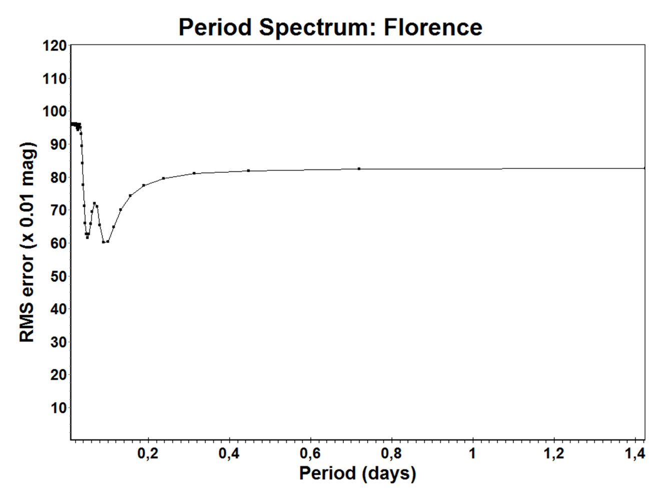

Fig. 5. The corresponding periodogram from the MPO Canopus system.

input our data into the NASA Exoplanet Archive system too. The obtained value of period is almost the same as from the MPO Canopus system. The corresponding periodogram is in Fig. 6. Even if the computed values of the period are almost equal we allow us to express our opinion that the periodogram in Fig. 6 is nicer.

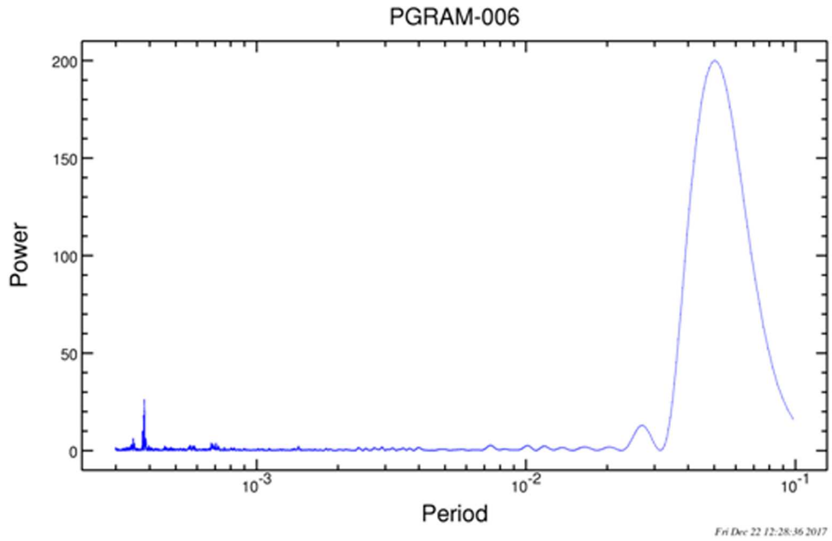

Fig. 6. The NASA Exoplanet Archive system periodogram for our data.

4. Conclusion

According to the NASA press release information, based on their observations from five nights, the period of the Florence asteroid rotation is 2.358 ± 0.001 hours. Part of these observations from the night of September 08 between 22:46 UT and 23:09 UT is overlapping with ours from the same night. Our result of $P = 2.352 \pm 0.21$ hours corresponds very closely to the official NASA value. To be honest, we should also mention that if we would have tried to work with our individual light curves we would have obtained the value of the period around 2.7 hours. We would like to stress here that if we have not had deep knowledge in the mathematical statistics we would have not been able to give the data into one file as it is depicted in Fig. 3 and in the final result we would have not been able to determine the true value of the rotation period of the asteroid Florence too. From this and from the official NASA press release data, we concluded that our approach to normalize the data and the construction of the unified light curve has been correct and appropriate. Of course, it is very important to compare our results with the results of the other observers of the asteroid Florence. The common results are given on the web page of the JPL. We can easily conclude that our results are in excellent accordance with the results which are published on this web page.

The next approach of this asteroid to the Earth will be in the year 2057. We believe that our results will assist our future colleagues as they are complementary to the NASA ones because they were measured from another location.

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