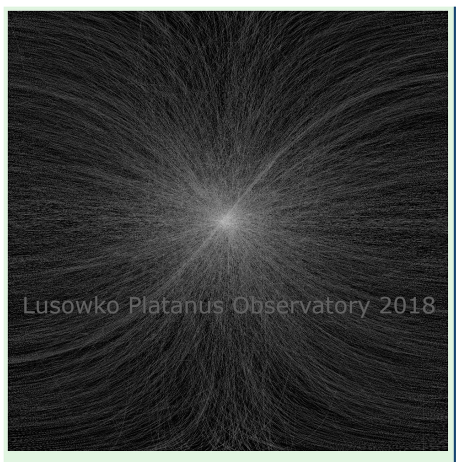

Photometric observations of asteroids - in support of Gaia Mission

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1. Introduction

Photometric observations of asteroids have been the main source of our knowledge about asteroids' surface physical properties for more than 100 years. Even if significant progress has been achieved in the last decade due to spacecraft explorations, the groud based observations still remain important because of their ammount and coverage. Combination of spacecraft observations with groud-based ones enhances reliability of the Solar system science (see Santana-Ros et al., 2015).

In this paper I focus on asteroid photometry in amateur practices. First, I present my involvement in Gaia-GOSA programme: I have observed 4 asteroids simultaneously with the Gaia spacecraft. Second, I present the photometry of (1627) Ivar. Ivar is one of the well-examined asteroids with a rotation period P_{sid} = 4.7951689 ± 0.0000026 h and shape models available (Crowell et al., 2016). Future observations could improve the model and help detect YORP effect (Warner, 2015). Finaly I show how high precision photometry can be achieved using amateur, inexpensive setup and how quality can be laveraged with the use of dense sampling and statistics methods.

2. Telescopes

I made observations in two locations: Nerpio (Spain) and Lusowko (Poland).

In Nerpio I used a remote Corrected Dall-Kirkham (PlanWave) 12.5" (f/8) telescope with Finger Lakes Instrumentation ProLine 16803 cooled camera (front-iluminated KAF-16803, diam. 52.1 mm, pixel 9.0 µm) and Astrodon L, Ha, SLOAN i', r', g' filters.

In Lusowko I used Celestron Rowe-Ackermann-Schmidt Astrograph 11" (f/2.2) with high sensitive ZWO ASI290MM (pixel 2.9 µm) and ZWO ASI1600MM (pixel 3.8 µm) cooled CMOS mono cameras with the 12bit A/D converter. This system takes advantage of speed, sensitivity and low read-noise of the CMOS to collect high frequency frames for better astrometry and photometry reduction. The site is registered in IAU as K80 "Lusowko Platanus Observatory".

3. Observations for Gaia-GOSA

In 2017 following observations have been submitted to Gaia-GOSA:

Object	Night	Vmag
774 Armor	May 22nd/23rd, 2017	13.90
409 Aspasia	May 23rd/24th, 2017	11.64
409 Aspasia	May 24th/25th, 2017	11.66
387 Aquitania	June 5th/6th, 2017	11.78
387 Aquitania	June 6th/7th, 2017	11.79
387 Aquitania	June 7th/8th, 2017	11.80
704 Interamnia	July 23rd/24th, 2017	10.99

Table 1: Asteroids observed in 2017

All observations have been performed in the observatory in Nerpio. All frames have been calibrated with bias, dark and flat field frames. In Gaia-GOSA programme professional astronomers perform full photometry reduction and final result comes from observations received from many observers around the world. This cooperative work produces quality lightcurve of an asteroid hence its period and other properties.

4. (1627) Ivar Photometry

4.1. Observations

I observed Ivar during 3 successing nights in May 2018, at Lusowko Platanus Observatory. Frames were taken using ASI290MM CMOS camera, with no filter. Single frame exposure time was 2 seconds. In total 27900 frames were collected in series of 450.

Night	Start (UTC)	End (UTC)	Frames collected	Quality frames
May 4th/5th, 2018	20:57:13.5	02:16:38.2	8550	8227
May 5th/6th, 2018	20:12:19.7	02:13:41.1	9450	8842
May 6th/7th, 2018	19:59:18.8	02:00:09.0	9900	7480

Table 2: Observation arc

Parameter	Conditions
Ecliptic coordinates	λ: 223.48 – 224.82 °, *β*: 8.45 °
Phase	18.35 – 19.01 °
Brightness (as predicted by JPL Horisons)	12.87 – 12.82 mag
Speed	0.883 – 0.874 ″/min
Apparent altitude	33.8 – 48.1 °
Airmass	1.341 – 1.792

Table 3: Observation conditions

4.2. Reduction

Due to number of frames I have built a kind of pipeline. Dark and bias frames have been applied. Then a routine found plate solution for each frame, identified reference stars and the asteroid. Differential photometry of each object has been performed using AUTOPHOTOM program from STARLINK package. Next, set of reference stars has been chosen, based on their brightness stability:

Night	Nbr of ref. stars	Magnitudes (Gaia G-band)	Colors (Gaia BP-RP)
May 4th/5th, 2018	8	10.9225 – 12.7095	0.7782 – 1.1674
May 5th/6th, 2018	16	12.0442 – 14.0463	0.7087 – 1.8267
May 6th/7th, 2018	11	11.5691 – 13.2281	0.7087 – 1.3152

Table 4: Reference stars

For each frame Ivar's differential magnitude and its uncertainty has been calculated. Brightness correction for geometry (phase angle, Earth and Sun distance) has been applied (assuming G=0.60 as in MPC 17262). Geometry data have been taken from JPL Horizons service and LT corrected.

4.3. Results

Synodic period has been determined using 20th-order weighted fourier series as 4.79562 ± 0.00003 h. Uncertainty has been designated using Monte Carlo method. Amplitude was estimated as ~ 1.2 mag.

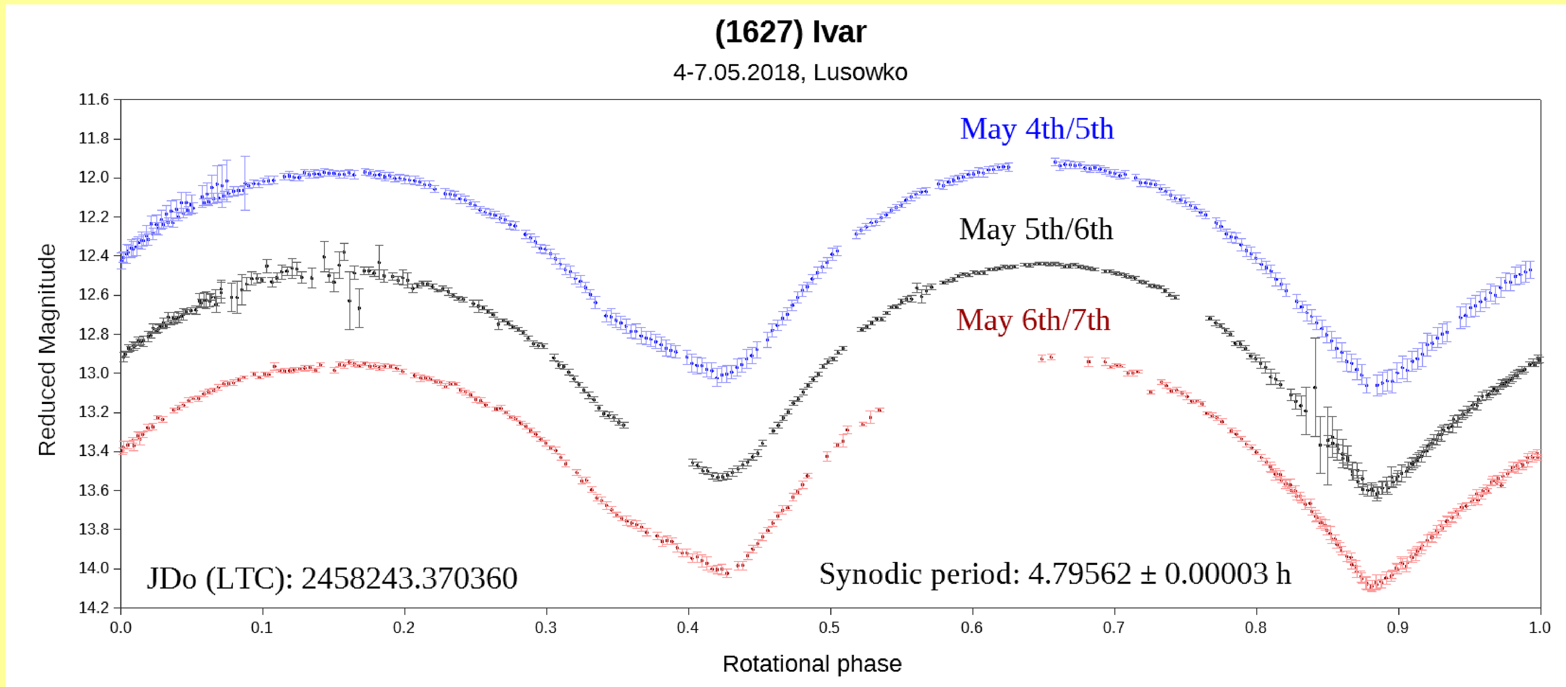

Figure 1: Observations of Ivar night by night. Magnitude shift applied to reveal details.

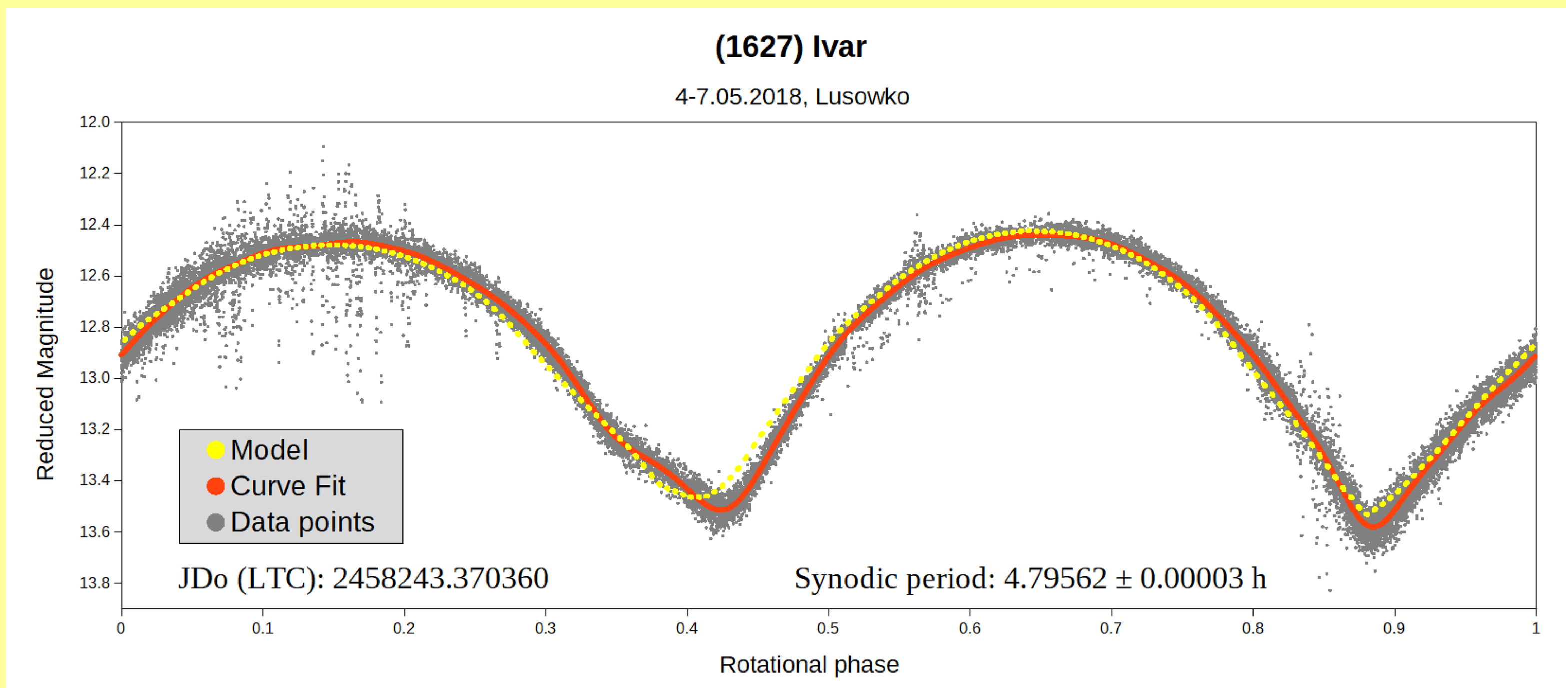

Figure 2: Dense observations (gray) with uncertainty for every data point makes possible fitting smooth light curve (red), manifesting details not present in current models (yellow; Hanus et al., 2015). Lightcurve of the model was obtained from ISAM service (Marciniak et al., 2012).

5. Summary and Conclusions

Photometric observations will remain main source of information about asteroids properties for a long time yet. "More data" eternal demand can be fulfilled due to modern, quick CMOS cameras. Increased computer performance deals with complex problems of huge datasets processing. In this paper I have proven that all of this can be exploited in amateur practice which may result in quality input for researchers and improvement of existing models.

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