Observations of asteroids with Pulkovo observatory ZA-320M and MTM-500M telescopes for GAIA FUN SSO program

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Introduction

Laboratory of observational astrometry of Pulkovo astronomical observatory of Russian Academy of science takes part in prelaunch training observations of GAIA-FUN-SSO program. Two asteroids were observed for this program after training alerts in 2011–2012.

1. Instruments

Two telescopes of Pulkovo observatory made observations for the GAIA-FUN-SSO program. ZA-320M telescope (Cassegrain system, $D = 32$ cm, $F = 320$ cm, $\mathrm{FoV} \approx 28' \times 28'$) is situated in Pulkovo observatory at the edge of Saint-Petersburg city, Russia. MTM-500M telescope (Maksutov – Cassegrain system, $D = 50$ cm, $F = 410$ cm, $\mathrm{FoV} \approx 21' \times 21'$) is situated in Mountain astronomical station of Pulkovo observatory at Nothern Caucasus near Kislovodsk city, Russia, at 2070 meters above sea level. The telescopes are equipped with CCD-cameras with identical CCD-chips (1024 × 1024 pixels of 24 × 24 μm) and sets of *BVRI* filters.

To make positional and photometrical processing of CCD-observations, we use APEX-II software [1] developed in Pulkovo observatory. The software works automatically and makes following operations:
- Calibration — fitting or synthesis and application of darks and flats
- Sky background smoothing
- Object detection using threshold algorithm
- Deblending
- Object center detection using PSF method
- Flux measurement using aperture or PSF methods
- Noise rejection
- Identification of measured objects with a reference catalogue (USNO-A2, USNO-B1, TYCHO-2, HIPPARCOS, UCAC-3, UCAC-4, XPM, 2MASS, user's catalogues)
- Astrometric reduction using several methods
- Identification of unknown objects using EPOS module (asteroid and comet searching)
- Creation of report in standard format (e.g. MPC).

There is possibility to mark objects and reference stars manually using graphical interface.

To make computations on Solar System bodies' motion, we use the EPOS software [2] developed in Pulkovo observatory too. The software provides a number of kinds of celestial-mechanics calculation and visualization including:
- ephemerides,
- O–C,
- orbit determination and improvement,
- motion of Solar System bodies in various coordinate systems.

2. 2005 YU55 asteroid

2005 YU55 Near Earth Asteroid was observed with ZA-320M and MTM-500M telescopes during its close approach to Earth in November 2012. We observed its light-curves to examine its period of rotation and made observations in *BVRI* filters to determine its color-indices. Most of the observations were used to get the asteroid positions.

The previous value of the asteroid rotational period determined with radar observations is 18 hours (see http://ssd.jpl.nasa.gov/sbdb.cgi?sstr=308635). To determine the period, all our observations that were made without filter were collected and processed. The period was calculated using Scargle's [3] and CLEAN [4] methods. Its value is 16.3 hours. Our observations light-curve with the period is shown in the Figure 1. The black curve is averaged values.

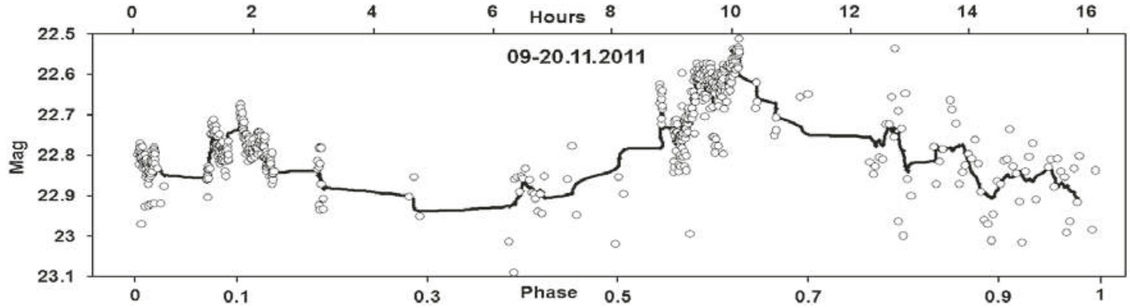

Fig. 1: The light curve of 2005 YU55 asteroid with period of 16.3 hours.

During processing of the data, one more period was noticed in observations with both the telescopes in several nights. Its value varies in different nights from 0.9 to 1.2 hours. The magnitude span is about zero-point-fifteen here. As an example, light-curve with this small period from one night observations is shown on the Figure 2. Durations of the observations were long (ten hours) and included several period durations. We are not sure about reality of this period. But if it is real this may mean that the asteroid is binary.

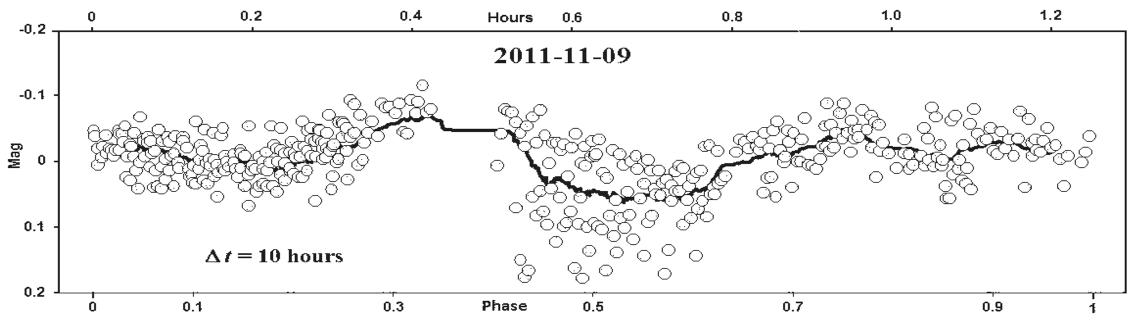

Fig. 2: The light curve of 2005 YU55 asteroid with period of 0.9 hours (one night observations).

The weighted means of color-indices from our observations are following:

$$B–V = 0.67^m \pm 0.07^m, \quad V–R = 0.34^m \pm 0.09^m, \quad R–I = 0.30^m \pm 0.07^m.$$

The effective color measured from spectrum of the asteroid in [5, 6] is $V–R = 0.37^m$. Our value is in agreement with it.

Authors of article [5] have classified 2005 YU55 asteroid by its spectral observations. They have fitted analogues asteroid spectra: C_{gh}, C, C_h (Bus), G (Tholen). These reflectance spectra are flat in visible wavelength range.

We have tried to classify 2005 YU55 asteroid using our wide-band photometry. The authors of article [7] classify asteroids on Tholen's classification using wide-band photometry: *BVRI* and additional *Z* band at 0.91 μm. We have no *Z* filter. But using their method in this narrower (0.44–0.83 μm) spectral diapason, the spectrum form of the asteroid is close to B, F, C, G (Tholen) classes — the classes with flat spectra in visible range too. B class is closest.

Authors of article [6] have built phase curve for 2005 YU55 asteroid in *R* band and determined its absolute magnitude and slope parameter. Figure 3 is sketch from the article [6] containing the phase curve. We put our *R* band observations into the sketch. And the observations lay on the same phase curve but have greater scattering. They are made with lower phase angles than in [6] and this confirms the values of absolute magnitude and slope parameter of the asteroid.

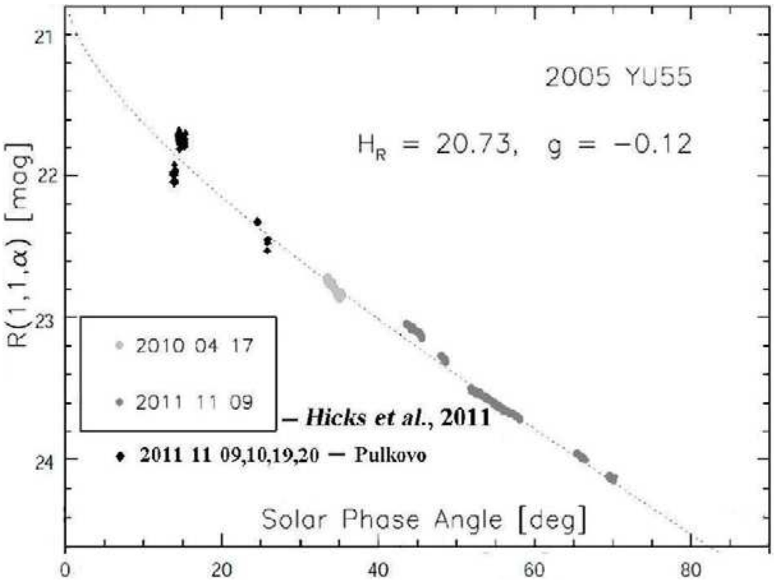

Fig. 3: The graph of phase curve of 2005 YU55 asteroid from [6]. The results of Pulkovo *R*-band observations are added to the graph — black dots.

Using our observations, we calculated 926 positions of the asteroid with mean accuracies of 0″.1–0″.4. The results were sent to Minor Planet Center.

This asteroid has approaches to Venus, Earth and Mars. During a close approach to a planet, it changes its orbit sharply. The modeling of the changes was made using EPOS software. Figure 4 shows the orbit changes during two close approaches of the asteroid to planets — to Earth and to Venus. Large changes in the node line position are clearly seen. And graphs of Figure 5 show changes of the orbital elements during the approach to the Earth in November of 2012. One can see that value changes of some elements are not monotonous.

3. TP3522 = 2012 BS67 asteroid

After discovery of TP3522 asteroid on Royal Observatory of Belgium on 17-th of January 2012, we got an alert about it. On 20-th of January, we made 24 observations of the asteroid with MTM-500M telescope. This amount is about 1/3 of all observations of the object in MPC database (77 observations). Mean accuracy of our observations is 0″.2 on each coordinate. These observations (along with observations of other observatories) allowed confirmation of discovery of the asteroid and its orbit improvement.

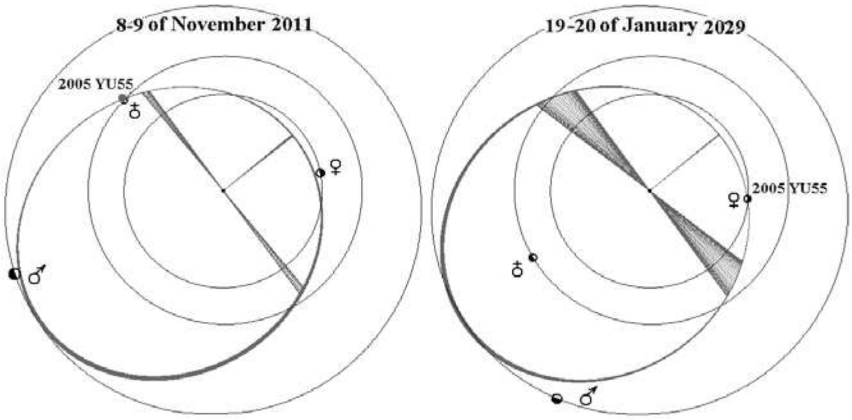

Fig. 4: Changes of 2005 YU55 orbit during close approaches to Earth and Venus.

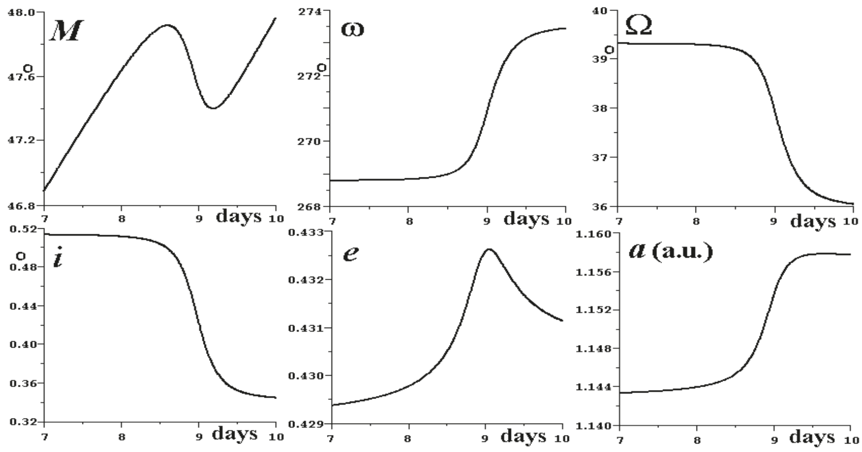

Fig. 5: Changes of 2005 YU55 orbital elements during close approaches to Earth on 8-9 of November 2012.

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