Astrometric and photometric baseline observations of the asteroid 2014 JO25

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Abstract. Ground-based baseline observations of the potentially hazardous asteroid 2014 JO25 were made. The data were processed and the accuracy of the orbital elements of the asteroid was estimated on the basis of the obtained observations and the data from the Minor Planet Center. Also, the estimation of $BVRI$ color indices of the asteroid was made.

1. Introduction
In April 2017, in the frame of the observational campaign organized by the Central (Pulkovo) Astronomical Observatory of the Russian Academy of Sciences (CAO RAS), ground-based baseline observations of the near-Earth object 2014 JO25 were made during its flyby. The aim of the investigation was to construct a precise orbit of the object in question using short-time simultaneous observation of two or more observatories. Also, if possible, the estimation of the axial rotation period of the asteroid as well as the attempt to determine its taxonomical class were planned.

2. Baseline astronomic observations
Ground-based baseline astronomic observations of a celestial body are observations performed simultaneously at two or more observation sites with well-known coordinates located at a certain distance (preferably thousands of kilometers) from each other. This method of observations provides an opportunity to measure by triangulation the distances to the object and to construct a three-dimensional model of its motion [1].

The aim of this investigation was to construct a precise orbit of the asteroid 2014 JO25 based on the data obtained during short-time (1-3 hours) quasi-simultaneous baseline observations.

Six observatories took part in this observational campaign: Pulkovo Observatory of RAS, Mountain Astronomical Station of Pulkovo Observatory (near Kislovodsk), Ussuriisk Astrophysics Observatory of RAS, Zvenigorod Observatory of Institute of Astronomy of RAS, Gissar and Sanglokh observatories of Institute of Astrophysics of Tajikistan. The largest base estimated 6820 km. Parameters of the telescopes and the coordinates of the observation sites are provided in the Table 1.
Table 1. Observatories and telescopes that participated in the campaign of observations of 2014 JO25 in April, 2017.

| Observatory     | MPC code | Coordinates (lat., long.) | Telescope   | Aperture (mm) | Focus (mm) | Scale ("/pix) |
|-----------------|----------|---------------------------|-------------|---------------|------------|---------------|
| Ussuriysk       | С15      | +43°42′ 132°10′           | GAS-250     | 250           | 748        | 3.3           |
| Kislovodsk      | C20      | +43°45′ 42°40′           | MTM-500M    | 500           | 4100       | 1.2           |
| Pulkovo         | 084      | +59°46′ 30°20′           | ZA-320M     | 320           | 3200       | 1.8           |
| Zvenigorod      | 102      | +55°42′ 36°46′           | Zeiss-600   | 600           | 7200       | 0.5           |
| Gissar          | 190      | +38°29′ 68°41′           | AZT-8       | 700           | 2820       | 1.8           |
| Sanglokh        | 192      | +38°16′ 69°13′           | Zeiss-1000  | 1000          | 13000      | 0.3           |

3. Asteroid 2014 JO25

Asteroid 2014 JO25 was discovered in 2014 by A. D. Grauer at the Mt. Lemmon Survey. It belongs to Apollo group of the near-Earth objects and its minimal orbit intersection distance is estimated as 0.0118 AU. 2014 JO25 is classified as a "Potentially Hazardous Asteroid" by the Minor Planet Center [2].

Object's closest approach to Earth (within 4.6 lunar distances or 0.0118 AU) occurred on April 19, 2017. During its flyby, radar observations were made at the Goldstone and Arecibo observatories. The results of these observations showed that the asteroid is in fact a contact-binary object and has a peanut-like shape. The axial rotation period was approximately estimated as 4.5 hours and the largest dimension of the asteroid is at least 650 m [3].

4. Astrometric study

EPOS [4] and APEX-II [5] software systems were used to process the astrometric data and UCAC4 was used as the guide star catalog.

After processing of the data obtained by this campaign, the orbit of 2014 JO25 was constructed and its accuracy was compared to the accuracy of the orbit that can be constructed using the data of not simultaneous observations made by different observatories from 2014 to 2017 (collected on the Minor Planet Center (MPC) web-site). The Table 2 shows comparison of the MPC orbit and the orbit constructed on the base of 1.5-hour simultaneous observations of Ussuriisk and Kislovodsk observatories.

5. Photometric study

APEX-II software package [5] was used to process the photometric data and 2MASS was used in the process of the photometrical reduction.

Observations in BVRI bands of the international photometric system were made to determine color-indices of the asteroid. Based on the data, an attempt to determine the taxonomical class of the asteroid was made. The color-indices of 2014 JO25 asteroid obtained from our observations have best
coincidence with spectra of Q, V or G class (by Tholen classification [6]). The figure 1 illustrates comparison of spectra of 2014 JO25 asteroid and Q class [7].

By this stage of the investigation, the axial rotation period of the asteroid 2014 JO25 has been obtained by means of radar observations in the Goldstone and Arecibo observatories and it was estimated to be approximately 4.5 hours.

The lightcurve obtained from the longest observation series is shown on the figure 2. The Scargle method [8] was used to determine the rotational period from this data. The result shows that the previously estimated axial rotation period is right and is approximately 4.5±0.2 hours. But further investigation is needed.

**Table 2.** Comparison of 2014 JO25 asteroid orbital elements for the epoch JD2458000.5 of MPC orbit and orbit constructed using the short-time base-line observations.

| Elements | MPC | Base-line | Λ |
|----------|-----|-----------|---|
| M, (°)   | 58.788880 | 59.143965 | 0.355085 |
| ω, (°)   | 49.571260 | 49.811066 | 0.239806 |
| Ω, (°)   | 30.652780 | 30.639300 | −0.013480 |
| i, (°)   | 25.269930 | 25.518579 | 0.248649 |
| e        | 0.88543290 | 0.88397329 | −0.00145961 |
| a, (AU)  | 2.068265602 | 2.060720772 | −0.00754483 |
| q, (AU)  | 0.236955192 | 0.239098660 | 0.002143467 |

Where: M — the mean anomaly; ω — the argument of perihelion; Ω — the ascending node; i — the inclination; e — the eccentricity; a — the semi-major axis; q — the perihelion distance; Δ — the differences.

![Figure 1](image_url)

**Figure 1.** Spectrum of 2014 JO25 determined using BVRI observations and spectrum Q-class asteroids.
6. Conclusion
In this study, ground-based quasi-simultaneous baseline observations of 2014 JO25 asteroid were made in April, 2017. Six observatories participated in the campaign. The results of the campaign showed that using short-time (1-2 hours) simultaneous observations from at least two observatories it's possible to construct the orbit of the celestial body in question with the high precision. The accuracy of this constructed orbit is close to the orbit published on the MPC web-site that was constructed with more than 1.5 thousand observations obtained by many observatories from 2014 to 2017.

The taxonomical class (Tholen classification) of 2014 JO25 was presumed to be Q, V or G.

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Figure 2. Lightcurve obtained by processing the observations made in Zvenigorod on April 19, 2017.