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RESULTS OF POSITIONAL AND PHOTOMETRIC MEASUREMENTS OF METEOR TRAJECTORIES OBSERVED IN MYKOLAIV 2017-2018

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ABSTRACT. Regular meteor observation using TV CCD unintensified techniques was started in 2011 in RI «Mykolaiv astronomical observatory» (RI MAO). The method of meteor registration is based on using “track-and-stack” technique for obtaining frames with reference stars and online meteor detection software developed at RI NAO. The main accent of the research is made on precise astrometry and meteoroid orbits calculation. New observational campaign with baselines 11.7 and 100 km was started in 2017-2018 in collaboration with Astronomical Observatory of the I.I. Mechnikov Odessa National University. Eight telescopes with narrow field lens (f=50 mm, f/1.2) were installed in Mykolaiv and Odessa. More than 3000 single station meteors and 221 double station meteors were detected during 2017-2018. Uncertainties of meteor trajectory and orbital parameters are calculated using Monte Carlo method. Catalog of meteor trajectory positions and photometric parameters has created. Standard deviation of approximation of a meteoric trajectory in a large circle is (15-20)". Kinematic parameters of atmospheric meteoric trajectories and elements of heliocentric orbits for 3 meteors were calculated based on the results of television observations with cameras with a field of view <10° at a baseline distance 100 km. The average uncertainty of visible radiant estimation is in (0.3-0.7)º with baseline 100 km. The geocentric velocity estimation uncertainty is 0.5 km/s, elevation uncertainty is 50-150 m.

Keywords: meteors, meteoroid orbits, video observation.

АНОТАЦІЯ. Резулярні спостереження метеорів з використанням непідсиленої телевізійної ПЗЗ техніки було розпочато в 2011 р. в НДІ «Миколаївська астрономічна обсерваторія» (НДІ МАО). Метод спостережень заснований на використанні способу накопичення зі зміщенням для отримання кадрів з опорними зорями і програмному забезпеченні, що реєструє метеори в режимі реального часу, розробленого в НДІ МАО. Головний акцент дослідження робиться на отримання високоточних положень точок метеорної трєкторії та визначенні орбіт метеороїдів. Новий етап спотережень почався в 2017 р. на станціях з базисними відстанями 11.7 та 100 км в співробітництві з астрономічною обсерваторією Одеського національного університету ім. І.І. Мечникова. Вісім телескопів з малими полями зору (f=50 mm, f/1.2) були встановлені в Миколаєві та Одесі. Протягом 2017-2018 зафіксовано більше 3000 однопунктних метеорних реєстрацій та 221 базисний метеор. Невизначеності параметрів атмосферної траєкторії та елементів геліоцентричної орбіти метеороїда були обчислені з використанням методу Монте-Карло. Був створений каталог позиційних та фотометричних параметрів спостережених метеорних траєкторій. Середнє квадратичне відхилення аппроксимації метеорної траєкторії великим колом складає (15-20)". За результатами спостережень камерами з полями зору <10° на базисній відстані 100 км були обчислені параметри атмосферної траєкторії та елементи геліоцентричної орбіти для 3 метеороїдів. Невизначеність в обчисленні видимих екваторіальних координат радіанта на базисній відстані 100 км складає в середньому (0.3-0.7)º. Невизначеність в обчисленні геоцентричної швидкості складає 0.5 км/с, в обчисленні висот – 50-150 м.

Ключові слова: метеори, орбіти метеороїдів, телевізійні спостереження.

1. Introduction

Meteor observation using video techniques was started at Research Institute «Mykolaiv astronomical observatory» (RI MAO) in 2011. This is the third big meteor research campaign in Ukraine after Odessa (Gorbanev, et al., 2006; Gorbanev, 2009) and Kiev (Hajdukova, et al., 1995; Kozak, 2001). The research is based on a system of fixed telescopes equipped with TV CCD cameras for both single and double station observation. The main goals were setting completely automatic observation of meteors, and obtaining astrometric and atmosphere trajectory parameters of meteors (radiant point coordinates, velocities, orbit elements) using original software developed in RI MAO. Results of double station observations in Mykolaiv are in (Kulichenko, et al., 2014; Kulichenko & Shulga, 2018).

2. Meteor observation methods and facilities

2.1. Meteor telescopes

In 2017-2018 Video observations of meteors at the RI MAO are conducted using meteor patrol, which includes 8 optical telescopes (f = 50 mm, f/1.2) equipped with a TV CCD cameras WAT-902H2 (768×576, 8.6×8.3μ). The field of view of each telescope is 5.6°×7.4°. Comparing with previous work (Kulichenko, et al 2015) such optical systems allow to increase amount of detected meteors and average angular length of observed meteor trajectory. System doesn't have any intensifier. Each video system is contained in a hermetic capsule to prevent it from rain and other aggressive meteorological conditions (Figure 1). Cameras work in the interlace mode with rate 50 half-frames per second. Three stations with baselines 11.7 and 100 km were set: 1) Mykolaiv, RI MAO, consists of 4 telescopes (φ=46.972667, λ=31.972055); Mykolaiv, Vitovka, consists of 2 telescopes (φ=46.871598, λ=32.018309); Kryzhanovka, Astronomical Observatory of the I.I. Mechnikov Odessa National University (AO ONU), consists of 2 telescopes (φ=46.560722, λ=30.806500).

2.2. Observation method

The original observation method was developed at RI MAO for observation of objects having high apparent rates on stare telescopes (Shulga, et al., 2009, 2011). Firstly it was used for observation of artificial satellites. The main idea of the method is obtaining frames with stars and moving object separately for more accurate coordinate measurement. The automated meteor detection software was designed in 2010, based on the experience with real-time video stream processing.

Parallel to the real-time detection process the star images are accumulated with a 30 s exposure using the «track-and-stack» technique. Accuracy of the reference system is less than 6 arc sec. Limiting magnitude for stars $(12\text{-}13)^m$.

The method of double station synchronization is based on using PPS-impulse from GPS receiver Resolution-T as reference impulse. Accuracy of time synchronization is 10^{-4} s.

2.3. Software

The modified software is used for the calculation of the equatorial coordinates of the meteor trajectories. There are four main steps of calculation:

1) stars processing (software – TraEx (written in Python, developed in RI MAO), reference star catalogue – Tycho2;
2) extracting and measuring the meteor trajectory points in frame coordinate system (software – TraEx);
3) calculation of the equatorial coordinates of the meteor trajectories using results of the previous steps (software – TraEx);
4) searching for meteors observed simultaneously from two stations and calculation of parameters of atmosphere trajectories and elements of heliocentric orbits (software developed in RI MAO).

Uncertainties of meteor trajectory and orbital parameters are calculated using Monte Carlo method (Albin, et al. 2016). The Monte Carlo method is based on the generation of random numbers in accordance with the statistical distributions of the measured equatorial coordinates of the meteor and, as a consequence, the corresponding distributions for all the kinematic and orbital parameters of the meteor body. This approach allows us to estimate the standard deviation of the desired quantities, as well as to specify their mathematical expectation.

3. Results

3.1. Single station observation

During 2017-2018 more than 3000 single station meteors were observed. The mean duration of observed meteor trajectories is in 0.04-1.2 s. Mean amount of frames is about 8-10. The distribution of meteors over meteor magnitude has two maxima at 0^m and 2^m. Arc length of meteor trajecrories is in (0.08-7.5)°.

The main parameter of single station meteor trajectory is the position of meteor's path big circle pole (Gorbanev & Golubaev, 2009). This parameter is used for further calculating of radiant point coordinates and heights (Astapovich, 1958). The mean accuracy of pole coordinates estimation is about (0.05-0.1)°.

3.2. Meteoroid orbits

Due to large amount of detected phenomena only short period of observation for two stations with baseline 100 km (4 telescopes) is completely processed. Total number of observed meteors was 220, number of simultaneous observed meteor trajectories – 130. In the period from April 2018 to July 2018 213 single station meteors were detected, but only 3 meteors (Table 1) were observed simultaneously because of difficulty with correct pointing of narrow field telescopes on distance 100 km. After pointing correction in August 2018 preliminary searching for double station meteors in the period of next 4 months gave result of 218 meteors. The velocity estimation uncertainty is 0.5 km/s, elevation uncertainty is 50-150 m. Uncertainties of heliocentric orbital elemets calculation are shown in the table 1.

Table 1: Results of meteoroid orbit determination for 3 meteoroids observed in April-May 2018 with baseline 100 km

Parameter	20180413_2739090_A3K1	20180413_2804334_A3K1	20180502_2746108_A3K1
Radiant equatorial coordinates, °	276.4±0.03 -32.3±0.08	322.1±0.9 0.5±1.7	333.8±0.3 5.3±0.8
Geocentric velocity Vg, km/s	66.4±0.06	41.8±0.2	65.7±0.6
Height H1, km	117.2±0.06	118.8±0.09	115±0.6
1/a, au-1	0.22±0.006	1.32±0.02	-0.07±0.06
a, au	4.43	0.75	--
Perihelion distance q, au	0.72±0.001	0.08±0.02	0.59±0.02
Eccentricity e	0.83±0.004	0.89±0.02	1.04±0.04
Inclination i, °	156±0.1	152±3	175±1
Argument of perihelion om, °	247±0.3	18±2	100±3
Longitude of ascending node Om, °	23.77	23.79	42.30

4. Conclusion

Since 2011 regular automatic monitoring of meteors with the use of "track and stack" technique is conducted. In 2017-2018 eight meteor telescopes worked, located at tree stations at a distances of 11.7 km and 100 km. An array of data containing more than 3000 single station meteor trajectories has been obtained. Catalog of meteor trajectory positions and photometric parameters has created. Standard deviation of approximation of a meteoric trajectory in a large circle – (15-20)". Kinematic parameters of atmospheric meteoric trajectories and elements of heliocentric orbits for 3 meteors were calculated based on the results of television observations with cameras with a field of view <10° at a baseline distance 100 km. The velocity estimation uncertainty is 0.5 km/s, elevation uncertainty is 50-150 m.

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References

Albin T., D. Koschny, R. Soja, et al.: 2016, in *Proc. of the International Meteor Conference, Egmond, the Netherlands*, 2-5 June 2016, Eds.: Roggemans, A., Roggemans, 20.

Astapovich I.S.: 1958, Meteor phenomena in Earth atmosphere. (Fizmatgiz, Moscow).

Gorbanev Y. M., Golubaev A. V., Zhukov V. V., et al.: 2006, *Solar System Research*, **40**, 5, 412.

Gorbanev Y. M.: 2009, Odessa Astron. Publ., **22**, 60.

Gorbanev Y. M., Golubaev A. V.: 2009, *Odessa Astron. Publ.*, **22**, 4.

Hajdukova M., Kruchinenko V. G., Kazantsev A. M., et al.: 1995, *Earth, Moon, and Planets*, **68**, 1-3, 297.

Kozak P. M., Rozhilo A. A., & Taranukha Y. G.: 2001, in *Proc. of the Meteoroids 2001 Conference, 6 - 10 August 2001, Kiruna, Sweden*. Ed.: Barbara Warmbein. ESA SP-495, Noordwijk: ESA Publications Division, ISBN 92-9092-805-0, 337.

Kulichenko N., Shulga O., Kozyryev Y., et al.: 2014, in *Proc. of the International Meteor Conference, Poznan, Poland, 22-25 August 2013*. Eds.: Gyssens, M.; Roggemans, P.; Zoladek, P. International Meteor Organization, 2014, ISBN 978-2-87355-025-7, 50.

Kulichenko N., Shulga O., Kozyryev Y., et al.: 2015, WGN, **43**, 3, 81.

Kulichenko M.O., Shulga A.V.: 2018, *Odessa Astron. Publ.*, **31**, 186.

Shulga O., Kozyryev Y., and Sybiryakova Y.: 2009, in *Proc. of IAU Symposium № 248 "A Giant Step: From Milli- to Micro-arcsecond Astrometry", Shanghai*, 2007, 128.

Shulga O., Kozyryev Y., and Sybiryakova Y.: 2011, in *Proc. Of Gaia follow up network for solar system objects workshop held at IMCCE, Paris observatory, France*, 2011, 97.