ISSN 2409-9066. Sci. innov. 2017, 13(1): 76—80 doi: https://doi.org/10.15407/scine13.01.076

Kulichenko, M.O., Shulga, O.V., Sybiryakova, Ye.S., and Kozyryev, Ye.S.

Research Institute «Mykolaiv Astronomical Observatory», 1, Observatorna St., Mykolaiv, 54030, Ukraine,
tel. +380 512 477 014

DOUBLE STATION OBSERVATIONS OF TELESCOPIC METEORS IN MYKOLAIV

Meteor research using TV CCD unintensified techniques was started in 2011 at RI "MAO". The method of meteor registration is based on the combined observation method developed at RI "MAO". The main accent of the research is made on the precise astrometry and meteoroid orbits calculation. In 2013 first double station meteors with low baseline were observed. Estimation of uncertainties of visible radiant equatorial coordinates, geocentric velocity and heliocentric meteoroid orbit parameters was carried out.

Keywords: meteor, meteoroid, and combined observation method.

The telescopic meteors are the meteors observed by photographic or television systems having a field angle less than 10° (lens focal length is over 50 mm) [2, 3]. The vast majority of researchers around the world (both amateurs and professionals) use systems with a field angle over 20°, which as a rule, are capable of recording meteors with a magnitude of, at least, $(2–3)^m$ [2]. In some cases, image intensifiers that, in addition to raising the system sensitivity, have an option of image scaling and expand the field of view [4] are used. However, such systems have a number of disadvantages (high cost, inertness, low spatial resolution). Therefore, the meteor telescopes of RI «MAO» have no image intensifiers. It has been found that systems with a small field of view and, therefore, with a high spatial resolution are promising in terms of studying the meteors weaker than $(2–3)^m$ [5].

TOOLS AND METHODS OF OBSERVATIONS

The first observations of meteors in test mode commenced at the RI «MAO» in 2011. In 2013—2015, regular observations of meteors by modernized complex of telescopes using CCD television devices (*Watec* cameras) were conducted. The following optical systems were used for observations: *Canon* 85 $f/1{,}8$ ($f = 85$ mm) and *LOMO* $f/2{,}0$ ($f = 100$ mm) lenses [2, 6, 7]. The complex is based on meteor telescope design in a sealed waterproof capsule [6, 7], which enables to make observations without shelter in the automatic mode.

The meteor observations were made using the combined method [1]. The basic principle of the combined method is the separation of imaging the reference stars and the object studied. The first advantage of the method is the possibility of obtaining a more accurate reference system due to summing with shift a large number of frames with stars (750 frames), which is a prerequisite for systems with a small fields of view (<10°). The second advantage is the simultaneous possibility of recording the object with a maximum frame rate (50 half-frames per second in interlaced scan mode), which increases the time resolution of measurements and, as a result, improves the accuracy of kinematic parameters. The mean-square error of the reference system is (3—6)", the maximum of star distribution by magnitude is 10^m.

OBSERVATION RESULTS

In 2011—2016, the RI «MAO» system of TV meteor telescopes recorded 9377 single station meteor trajectories. In 2013, from March till May, a remote base station (telescopes 2 and 4, see Table) was operating at a distance of 5 km from RI «MAO» station (telescopes 1 and 3, see Table).

The MAO station coordinates are $\phi = 46°.9716$N; $\lambda = 31°.9730$E. The remote station coordinates are $\phi = 46°.9550$N; $\lambda = 32°.0394$E.

Since September 2014, a remote base station (telescopes 5, 7, and 9, see Table) was launched at a distance of 11.8 km from the RI «MAO» station (telescopes 6, 8, and 10, see Table). The coordinates of remote station are $\phi = 46°.8716$N; $\lambda = 32°.0183$E.

Table shows the number of meteor trajectories recorded by pairs of base telescopes, number of nights when, at least, one meteor was reported, as well as the number of reference meteors. In 2013—2016, the base observations resulted in 1236 meteor trajectories.

METEOR TRACK PARAMETERS DETERMINED BY ONE-WAY OBSERVATIONS

For the meteor trajectories obtained by single station observations the following parameters were evaluated: duration in seconds; track angular length in degrees; track angular width in degrees; integral magnitude of the meteor; coordinates of the pole of the large circle of meteor trajectory (PLCMT) and their errors, in degrees. These parameters can be used for single station identification of meteors with streams [3]. Time duration of observed meteors varies within 0.05—0.6 seconds; 70% of meteors has a duration ranging within 0.1—0.2 s. The number of half-frames for the same trajectory varies from 1 to 30, 86% of meteor trajectories has more than 3 half-frames, which enables to determine more reliably the angular and, in the case of the reference meteor, the linear velocity as well as to make analysis of meteor acceleration. The track width of 90% meteor trajectories ranges within (0.01—0.02)°. The meteor distribution by integral magnitude and angular length has maxima at 3^m and 1°, which is interpreted as predominance of faint and short meteor trajectories typical for the telescopic meteors.

Average random error for the PLCMT coordinates is (0.05—0.1)°. The number of processed tracks taken for statistical analysis is 2869. The dependence of random error of PLCMT coordinates on integral meteor magnitude shows an increase in the error for magnitudes fainter than 2^m. Typically, random error of the PLCMT coordinates grows as the length of observed trajectory decreases. The random error of the PLCMT coordinates does not exceed 0.02° for magnitudes over 2^m and angular lengths larger than 1.5° [5, 6].

Statistical Data of Observations for Base Telescope Pairs

Telescope No.	Period	Azimuth, deg.	Altitude, deg.	Field angle, deg.	f, mm	D, mm	Nights	Meteors	Reference meteors
1 2	01.2013—05.2013	6.30 357.7	80.50 80.50	4.2 × 3.2	85	$f/1.8$	67 18	161 66	18
3 4	01.2013—07.2013	10.50 353.5	80.50 80.50	4.2 × 3.2	85	$f/1.8$	101 55	185 167	45
5 6	06.2013—07.2016	1.79 3.74	61.02 65.25	4.2 × 3.2	85	$f/1.8$	317 500	1083 2221	520
7 8	06.2013—07.2016	4.89 10.96	50.74 64.48	4.2 × 3.2	85	$f/1.8$	171 432	605 1434	277
9 10	06.2013—07.2016	355.79 359.71	59.23 66.12	3.6 × 2.7	100	$f/2.0$	240 337	820 1153	376

METEOR PARAMETERS DETERMINED BY DOUBLE STATION OBSERVATIONS

These parameters include the radiant equatorial coordinates, geocentric and heliocentric velocities and elements of the meteoroid heliocentric orbit (semi-major axis, perihelion distance, eccentricity, declination, argument of perihelion, longitude of the ascending node). The radiant position (Fig. 1) is calculated according to the Bolin rule, i.e. as coordinates of «the pole of the large circle of the meteor circle poles» [3]. Average random error of the radiant equatorial coordinates is estimated as 0.5° for right ascension and as 0.4° for declination (Fig. 2). About 80% of meteor trajectories has an error less than 0.2°, which is comparable with the accuracy of radiant calculations published in the Journal of the International Meteor Organization (IMO WGN) [8, 9]. Anomalous errors are also possible (>2° reaching tens of degrees), which has been reported in foreign catalogs. This is caused by spatial arrangement of the actual meteor trajectory in relation to the base line. If the trajectory and the base are in the same plane, then the calculation of the radiant coordinates is impossible, insofar as the trajectory projections observed from the two stations do not have a crossing point that, according to the Olbers principle, is the radiant [3]. About 10% of the observed meteor tracks is oriented at a small angle to the base line and therefore has anomalous error of the radiant equatorial coordinates calculation.

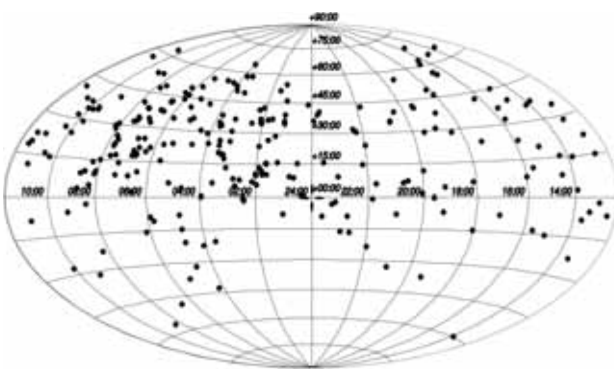

Fig. 1. Map of individual meteor radiant points in the equatorial system

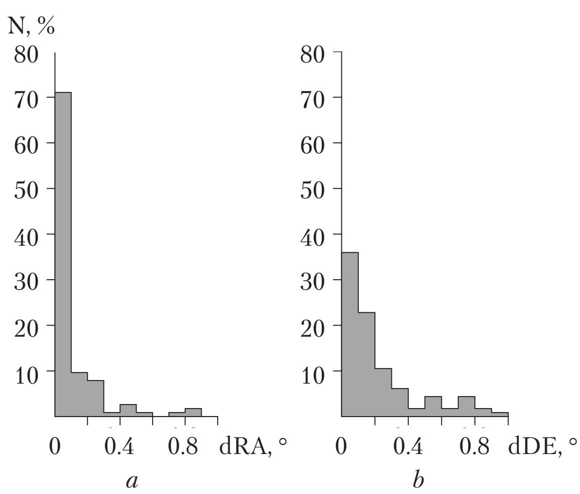

Fig. 2. Distribution of standard deviations of radiant coordinates: *a* – right ascension; *b* – declination

For 347 out of 1236 reference meteors, the basic parameters of the atmospheric path (apparent and geocentric velocities and altitude above sea level) and the elements of heliocentric orbits, as well as the radiant coordinates have been calculated with the radiant coordinates adjusted for diurnal aberration and zenith attraction [3]. The key linear parameters of the atmospheric trajectories are direct range (the perpendicular from the observer to the meteor trajectory) and height. Most of the meteors (>80%) was recorded at a direct range of 70—130 km and at a 70—150 km height of the middle of the track. It should be noted that for small bases (<30 km) and suboptimal angle of intersection of the telescope

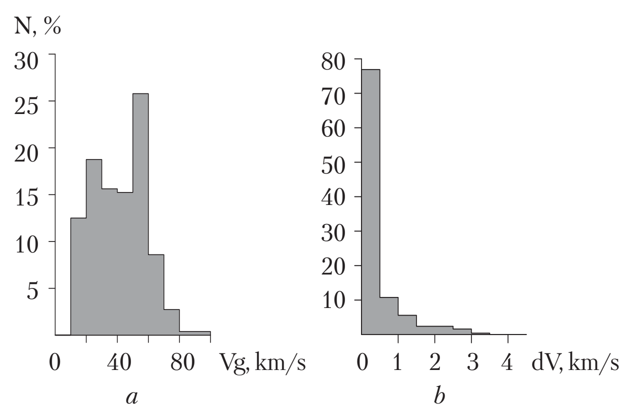

Fig. 3. Distribution of meteor geocentric velocities (*a*) and their standard deviations (*b*)

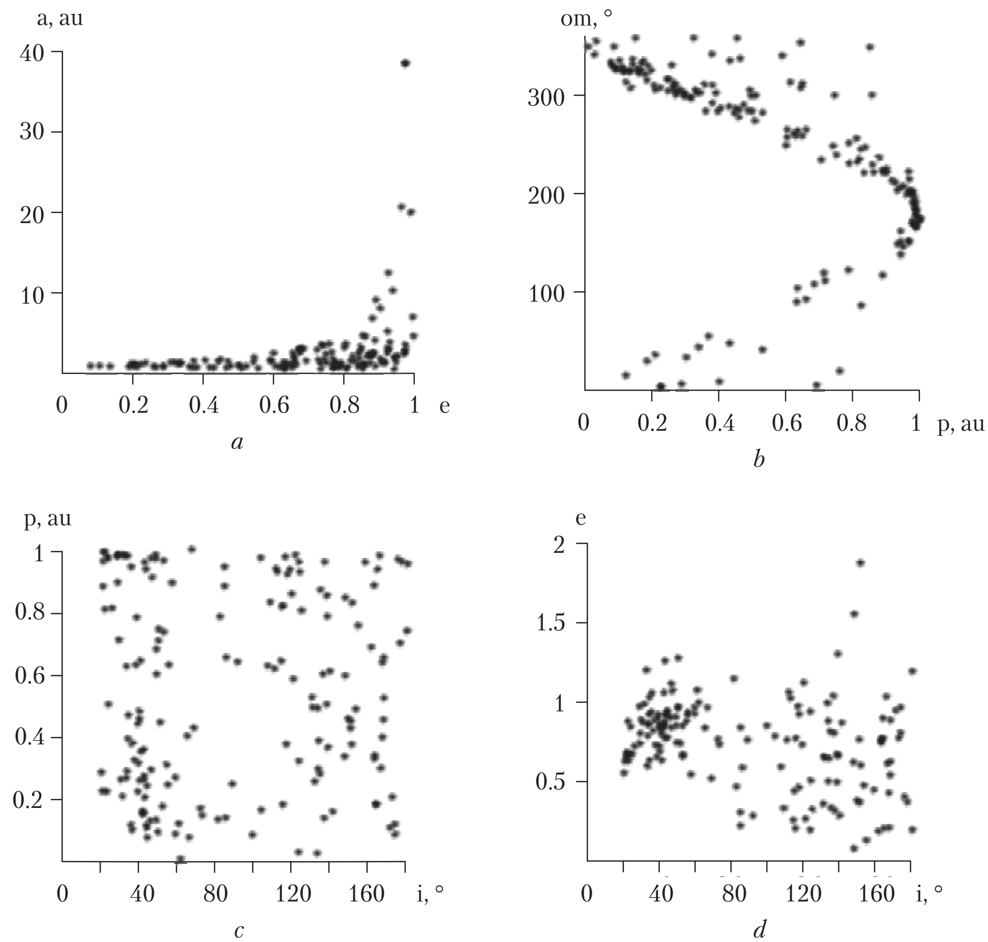

Fig. 4. Meteoroid heliocentric orbit elements, dependences: *a* — semi-major axis on eccentricity; *b* — argument of perihelion on perihelion distance; *c* — perihelion distance on declination; *d* — eccentricity on declination

fields of view the linear parameters are slightly overestimated. That is why out of 481 two-way trajectories observed in 2013—2014, the orbits and atmospheric parameters have been calculated for 347 trajectories only. In the future, the telescopes are expected to be redirected in order to optimize the base and to determine the trajectory more accurately. The distribution of meteors by velocities (Fig. 3) shows a predominance of the meteors of cometary origin (peak at 60 km/s) over that of asteroid one (peak at 10—15 km/s) [10, 11]. Based on the calculation results a catalog of meteoroid heliocentric orbits including the parameters of atmospheric trajectory and equatorial coordinates of adjusted radiants has been being formed. A graphical presentation of the elements of meteoroid orbits is showed in Fig. 4. Standard deviation of velocity averages 0.5 km/s. Random error of heliocentric orbit elements is evaluated by the following standard deviations:

- Semi-major axis — 3.5 A.U.;
- Eccentricity — 0.03;
- Declination — 0.6°;
- Argument of perihelion — 1.4°.

CONCLUSIONS

In 2011—2016, 9377 meteors were observed; 1236 of them by base observations. The coordinates of the pole of large circle of meteor trajectory and the equatorial coordinates of meteor apparent radiants have been estimated with a random error of (0.05—0.1)° and (0.4—0.5)°, respectively. For 347 meteors the heliocentric orbit elements and atmospheric trajectory parameters have been obtained with radiant coordinated corrected. A catalog of heliocentric orbits is under formation.

REFERENCES

1. Shulga O., Kozyryev Y., and Sybiryakova Y. *Observation of NEO having high apparent rates with Mobitel telescope.* In: Proc. Of Gaia follow up network for solar system objects workshop held at IMCCE, Paris observatory, France, 2011, pp. 97-100.
2. Kulichenko N.A., Shulga A.V., Kozyryev Y.S., Sibiryakova Y.S. Ispoljzovanie TV-kamer dlja nabljudenij meteorov. *Kosmichna nauka i tehnologija* (Space science and technology). 2012. 18(6): 67—72 [in Russian].
3. Astapovich I.S. *Meteor phenomena in Earth atmosphere.* Moscow: Fizmatgiz, 1958 [in Russian].
4. Kozak P.M., Rozhilo A.A., Taranukha Y.G. *Some features of digital kinematic and photometrical processing of faint TV meteors.* In: Proceedings of the Meteoroids 2001 Conference, Kiruna, Sweden, 2001, pp. 337—342
5. Gorbanev Y.M. Odessa Television Meteor Patrol. *Odessa Astronomical Publications.* 2009. 22: 60—67 [in Russian].
6. Kulichenko N.A., Shulga A.V., Kozyryev Y.S., Sibiryakova Y.S. Televizionnye nabljudenija meteorov v NII NAO. *Visnyk Astronomichnoji Shkoly* (Astronomical School's Report). 2013. 9(1—2): 107—110 [in Russian].
7. Kulichenko N., Shulga O., Kozyryev Y., and Sybiryakova Y. Double station observation of meteors in Nikolaev. *WGN, Journal of the International Meteor Organization.* 2015. 43(3): 81—84.
8. Johannink C. Results of the CAMS project in 2012. *WGN, Journal of the International Meteor Organization.* 2013. 41(6): 184—189.
9. Korlevic K., Segon D., Andreic Z., Novoselnik F., Vida D., Skokic I. Croatian Meteor Network Catalogues of Orbits for 2008 and 2009. *WGN, Journal of the International Meteor Organization.* 2013. 41(2): 48—51.
10. Ueda M., Fujiwara Y. Television Meteor Radiant Mapping. *Earth, Moon, and Planets.* 1995. 68(1—3): 585—603.
11. Steel D. Meteoroid Orbits. *Space Science Reviews.* 1996. 78(3—4): 507—553.

Received 17.10.16

М.О. Куліченко, О.В. Шульга,
Є.С. Сибірякова, Є.С. Козирєв

Науково-дослідний інститут
«Миколаївська астрономічна обсерваторія»,
вул. Обсерваторна, 1, Миколаїв, 54030 Україна,
тел. +380 512 477 014

БАЗИСНІ СПОСТЕРЕЖЕННЯ ТЕЛЕСКОПІЧНИХ МЕТЕОРІВ У м. МИКОЛАЄВІ

У 2011 р. в НДІ «Миколаївська астрономічна обсерваторія» (НДІ «МАО») розпочато дослідження метеорів з використанням телевізійної техніки. Метод реєстрації метеорів заснований на комбінованому методі спостережень, розробленому в НДІ «МАО» [1]. Особливу увагу зосереджено на високоточній астрометрії та розрахунку елементів орбіт метеороїдів. У 2013 р. розпочато перші одночасні спостереження двома станціями з малою базою (< 20 км). Проведена оцінка величин випадкових похибок у розрахунку екваторіальних координат видимого радіанта, геоцентричної швидкості та параметрів геліоцентричної орбіти метеороїда.

Ключові слова: метеор, метеороїд, комбінований метод спостережень.

Н.А. Куличенко, А.В. Шульга,
Е.С. Сибирякова, Е.С. Козырев

Научно-исследовательский институт
«Николаевская астрономическая обсерватория»,
ул. Обсерваторная, 1, Николаев, 54030, Украина,
тел. +380 512 477 014

БАЗИСНЫЕ НАБЛЮДЕНИЯ ТЕЛЕСКОПИЧЕСКИХ МЕТЕОРОВ В г. НИКОЛАЕВЕ

В 2011 г. в НИИ «Николаевская астрономическая обсерватория» (НИИ «НАО») начаты наблюдения метеоров с использованием телевизионной техники. Метод регистрации метеоров основан на комбинированном методе наблюдений, разработанном в НИИ «НАО» [1]. Особое внимание уделено высокоточной астрометрии и расчету элементов орбит метеороидов. В 2013 г. запущены первые одновременные наблюдения метеоров двумя станциями с малой базой (< 20 км). Проведена оценка величин случайных погрешностей в вычислении экваториальных координат видимого радианта, геоцентрической скорости и элементов гелиоцентрической орбиты метеороида.

Ключевые слова: метеор, метеороид, комбинированный метод наблюдений.