

Double station observation of meteors in Nikolaev

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Meteor research using TV CCD unintensified techniques was started in 2011. The facilities and methods of meteor observation and initial processing are described. The initial results from both single and low-base double station observation are described in the article. The main emphasis of the research is precise astrometry and further meteoroid orbit calculations.

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1 Introduction

Meteor observation using video techniques was started at Research Institute Nikolaev astronomical observatory (RI NAO) in 2011. This was the third big meteor research campaign in Ukraine after Odessa (Gorbanev et al., 2006; Gorbanev, 2009) and Kiev (Hajdukova et al., 1995; Kozak et al., 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 to create a completely automated observing set up and to obtain astrometric and kinematic parameters of meteors (radiant point coordinates, velocities, orbit elements) using original software developed in RI NAO.

2 Meteor observation methods and facilities

2.1 Meteor telescopes

Video observations of meteors at the RI NAO are conducted using meteor patrol, which includes 6 optical telescopes (4 lenses: $f = 85$ mm, $f/1.8$; 2 lenses: $f = 100$ mm, $f/2.0$) equipped with a TV CCD cameras WAT-902H2 (768×576 , $8.6 \times 8.3 \mu\text{m}$). The field of view is $3^\circ 2' \times 4^\circ 2'$ for four of the telescopes and is $2^\circ 7' \times 3^\circ 6'$ for the other two telescopes. The system does not include any intensifier. Each video system is contained in a hermetic capsule to protect it from rain and other aggressive meteorological conditions (Figure 1a,b,c). Cameras work in the interlace mode with a rate of 50 half-frames per second.

2.2 Combined observation method

The original combined observation method was developed at RI NAO for observation of objects having high apparent rates on stare telescopes (Shulga et al., 2009; Shulga et al., 2011). Originally it was used for observation of Near Earth Asteroids (NEA), comets, and artificial satellites. The primary aim is to obtain frames with stars and moving object separately in order to allow more accurate coordinate measurement. The automated meteor detection software was designed in 2010, based on the experience with real-time video stream processing.

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Figure 1 – Meteor patrol: a) at RI NAO; b) at station 11.8 km distant; c) meteor telescope inner housing.

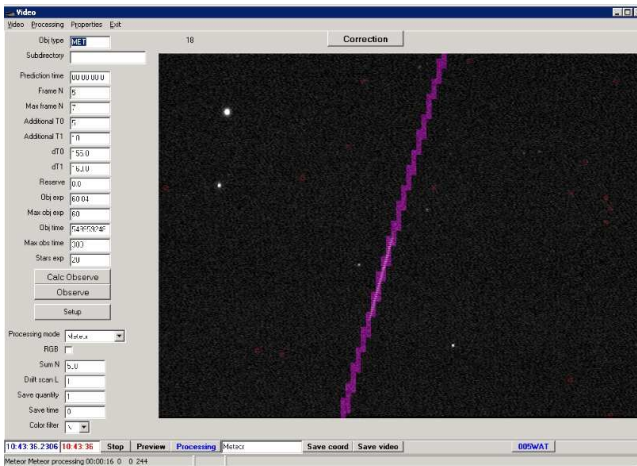


Figure 2 – Software for on-line meteor detection in video stream.

The detection algorithm works as follows:

1. averaging of pixel brightness in cells of 8×8 pixels;
2. calculation of the signal/noise ratio of each cell using the brightness of the same cell in 25 frames before and after the current frame;
3. searching for the lines of the meteor trajectory among the cells that exceed the threshold value of the signal/noise ratio (using the least-square method with exclusion of big deviations);
4. searching for objects which are uniformly moving along the detected line (using the least-square method with exclusion of big deviations);
5. exclusion of objects whose speed is less than 2 deg/s (assumed to be satellites);
6. saving the image sequence.

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 better than 6 arc sec. Limiting magnitude for stars is $(12-13)^m$.

2.3 Time synchronization

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.

2.4 Initial processing software

The modified software to process TV observations of low elliptic objects is used for the calculation of the equatorial coordinates of the meteor trajectories. There are three main steps of calculation:

1. star processing (ASTROMETRICA 4.4.1.364 software, USNO-B1.0 reference star catalogue);
2. measuring the meteor trajectory points in frame coordinate system (software developed in RI NAO);
3. calculation of the equatorial coordinates of the meteor trajectories using results of the previous steps (software developed in RI NAO).

3 Results (single station observation)

3.1 Statistics

During 2011–2014, 4135 single station meteors were observed. Due to weather conditions, narrow field and some technical problems the meteor distribution over solar longitude is not representative. The mean duration of observed meteor trajectories was in the range 0.05–0.6 s. The distribution of meteors over meteor magnitude and arc length is shown in Figure 3.

3.2 Astrometry

The main parameter of single station meteor trajectory is the position of the pole of the meteor path's great circle (Gorbanev & Golubaev, 2009). This parameter is used in the subsequent calculation of radiant point coordinates (Astapovich, 1958). The mean accuracy of estimation of the coordinates of the pole is about $(0.05-0.1)^\circ$. The difference in accuracy between systems with different focal lengths is not significant.

4 Visible radiant point estimation

Two double station observation campaigns were conducted at RI NAO: the first one was in spring 2013 (Kulichenko et al., 2014); the second started in September 2013 and it is still working. The first pair of stations observed during March–May 2013 and had a baseline of 5 km. Each station consisted of two meteor telescopes with lenses $f = 85$ mm, $f/1.8$, $FOV = 3^\circ 2' \times 4^\circ 2'$ and unintensified CCD cameras WAT-902H2. Total number of observed meteors was 220, number of simultaneous observed meteor trajectories was 130. The shortness of the baseline led to there being a quite large number of double station meteors, and the fact that one meteor could be observed by both telescopes at one station meant that the number of real observed meteors was about 80. The mean accuracy of visible radiant determination is 0.7 arc sec and more than 60% of radiants have standard deviation of better than 0.2 arc sec. A plot of visual radiants for meteors observed in 2013 is shown in Figure 5.

In summer 2013, the baseline was increased to 11.8 km and a pair of telescopes was added with lenses $f = 100$ mm, $f/2.0$, $FOV = 2^\circ 7' \times 3^\circ 6'$, for more accurate position measurement. During September 2013–September 2014, the total number of observed meteor trajectories was 1757, but due to technical problems two pairs of telescopes only started observing in August 2014. Number of double station meteors 328. The mean accuracy of visible radiant determination is less than 0.5 arc sec, more than 80% of radiants have standard deviation better than 0.2 arc sec. A plot of visual radiants for meteors observed in 2014 is shown in Figure 6.

5 Summary

Regular single station meteor observation in automatic mode began in 2011. The first double station meteors were observed in 2013, using a short baseline. The accuracy of visible radiant estimation is 0.7 arc sec with

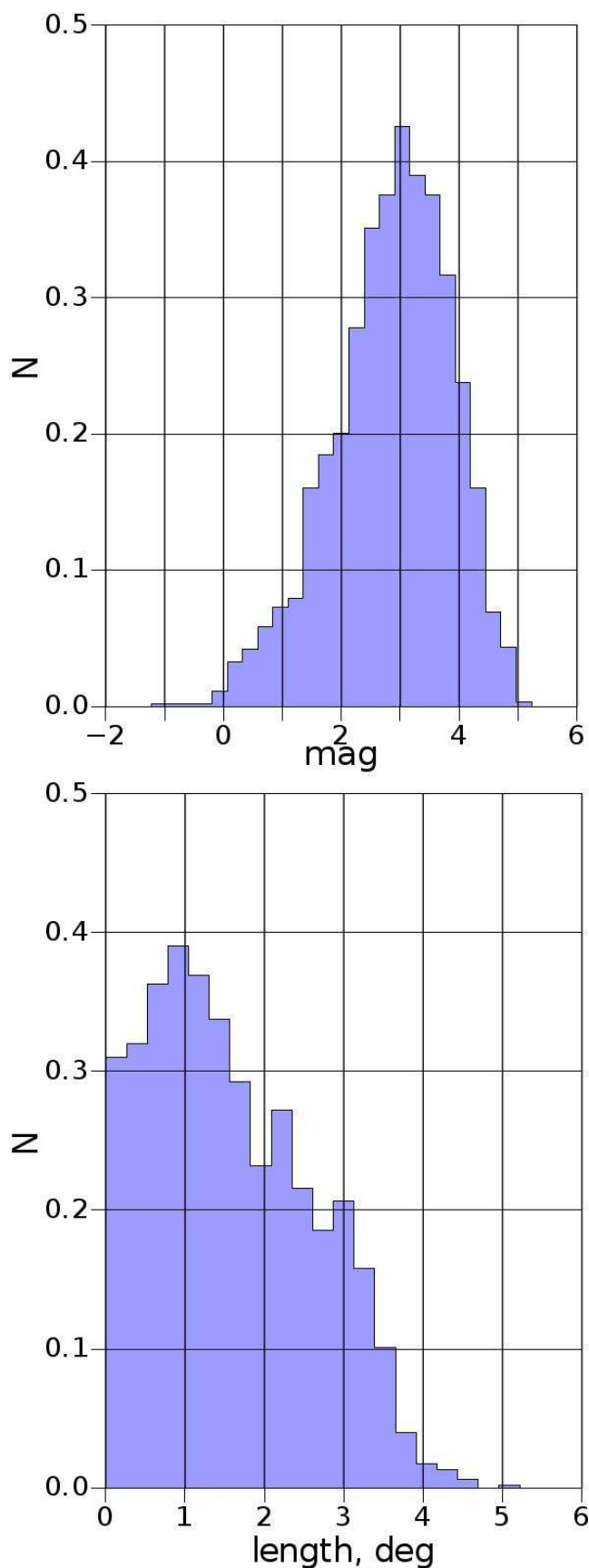


Figure 3 – a) Meteor magnitude distribution; b) meteor arc length distribution.

baseline 5 km, and better than 0.5 arc sec with baseline 11.8 km. Software for the calculation of double station meteor parameters is under construction.

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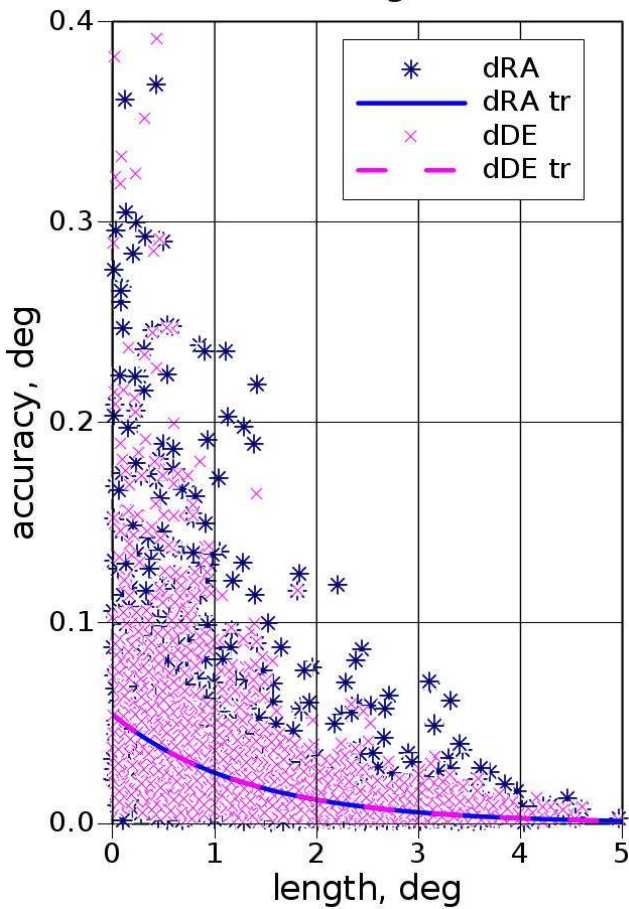
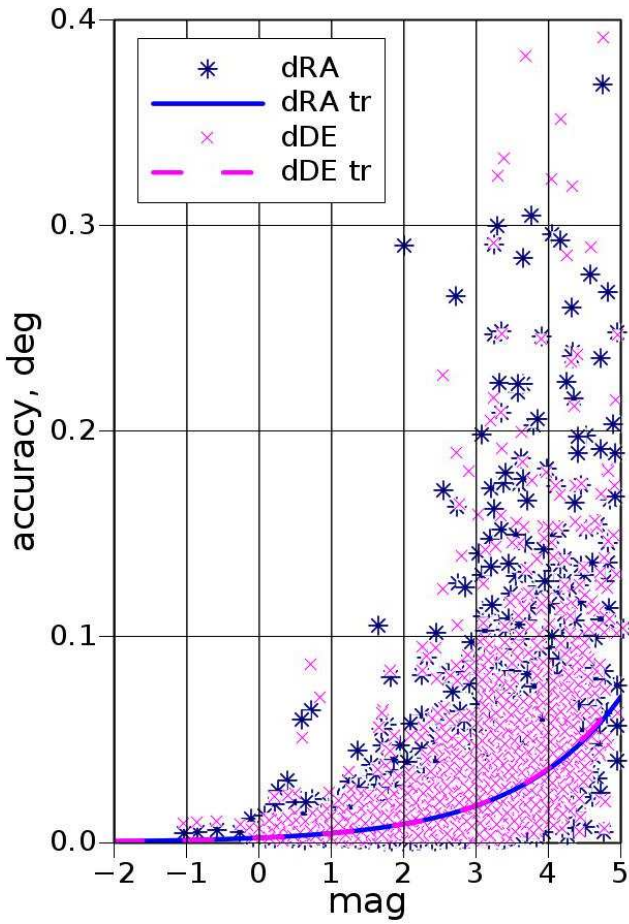


Figure 4 – Accuracy of calculation of the pole position of the meteor's great circle pole: a) dependence on meteor magnitude; b) dependence on meteor arc length.

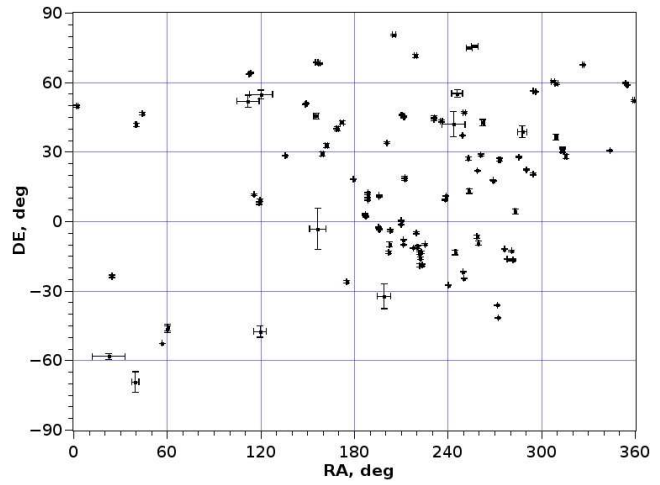


Figure 5 – Radiant plot, with uncertainties, of meteors observed in 2013.

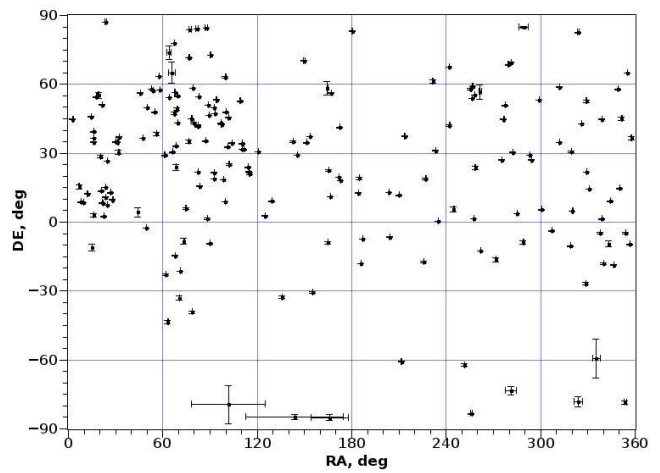


Figure 6 – Radiant plot, with uncertainties, of meteors observed in 2014.