

DOI: <http://dx.doi.org/10.18524/1810-4215.2017.30.114490>

THE ASTROMETRIC RESULTS OF OBSERVATIONS OF PERIODICAL COMETS AT KT-50 TELESCOPE IN RI “MAO”

A.V.Pomazan, N.V.Maigurova, O.V.Shulga

Research Institute «Mykolaiv Astronomical Observatory», Mykolaiv, Ukraine
antpomaz@gmail.com

ABSTRACT. The astrometric results of the observations of 10 periodical comets in 2017 are presented. The observations were made with telescope KT-50 telescope in RI «Mykolaiv Astronomical Observatory». The differences between the measured from observations (O) and calculated from ephemeris (C) positions and their mean square errors (MSE) were calculated. The ephemeris positions were taken from on-line computation service HORIZONS (JPL NASA, USA). For the measured positions the average MSE values are 0.17" in right ascension and 0.18" in declination respectively. Analysis of the values (O-C) before and after additions of obtained positions to Minor Planet Center (MPC) database revealed a gradual decrease of these differences with respect to the ephemeris. This indicates that the using of the new high-precision positions allows us to refine the calculated ephemeris. As well improvement and lengthening of the astrometric datasets play important role in the modeling of the cometary nongravitational effects.

Keywords: Astrometry, observations, comet, telescope.

1. Introduction

Comets originally formed in the cold outer planetary system and composed mostly of water ice with embedded dust particles. The scientific interest in comets and asteroids is due largely to their status as the relatively unchanged remnant debris from the solar system formation process. These objects may represent potentially catastrophic threats to our planet depending on their size and relative speed. The problem of asteroid-comet hazard is one of the priority tasks in modern astronomy. It is necessary to observe these objects regularly and as long as possible to reliably determine their orbits with better accuracy and produce more precise impact warnings. However, the comets like asteroids that are potentially the most hazardous because they can closely approach the Earth are also the objects that could be most easily exploited for their raw materials.

Comets observations in the Research Institute "Mykolaiv Astronomical Observatory" (RI MAO) have a long history. The earliest positions sent to the Minor Planet Center (MPC) database [<http://www.minorplanetcenter.org/iau/mpc.html>] refer to the observations of comet C/1882 R1-B in 1882. The observations carried out visually using a micrometer.

Table 1 gives statistics data and accuracy of comets observations over whole history of observations at the RI «Mykolaiv Astronomical Observatory».

As can be seen from table 1, there are three main stages of observations of comets in the RI MAO: I) visual observations using a micrometer with average accuracy (mean square error, MSE) 2.566" in RA and 2.094" in Dec; II) photographic observations with average accuracy 0.663" and 0.543" in RA and Dec respectively; III) CCD observation; mean accuracy of 0.230" and 0.217" in RA and Dec respectively.

The modern accuracy of comet positions allows us not only to refine the calculation of ephemerides, but also to make assumptions about the presence and magnitude of non-gravitational effects on the basis of comparison of the calculated and observed positions.

2. Instruments and observations

Newly open and periodic comets were observed at KT-50 telescope of Mobitel complex at RI «Mykolaiv Astronomical Observatory». The ephemerides of the HORIZONS system (JPL NASA, USA) [<http://ssd.jpl.nasa.gov/horizons.cgi>] were used to provide a list of observable comets.

The Mobitel complex was designed at the RI MAO under supervision of Shulga, A.V. (*Shulga et al., 2012*). Currently, the telescope has been equipped with only one optical glass OC-14 (GOST 9411-91) filter. The filter provides a bandwidth close to that of R_c standard filter of the Cousins system.

The specific feature of observations is the use of time delay integration (TDI) mode for all observations. The exposure was selected in such way as to achieve a good signal-to-noise ratio (SNR) based on the apparent magnitude presented in HORIZONS ephemeris system (JPL NASA, USA). The duration of exposure was 120 s for 80% of observations. It corresponds to a frame size of 3056 x 980 pixels and a field of view 42.4'×13.5'.

The 241 observations of 10 comets were obtained at RI MAO during 2017. The comet topocentric positions were sent to MPC database with observatory code 089 (*Kulichenko et al., 2017*).

Table 1: Statistics of comet's observations in RI «Mykolaiv Astronomical Observatory»

Year	Number of comets	Number of positions	O – C, "		MSE, "	
			RA	Dec	RA	Dec
1882	1	2	-1.769	0.550	-	-
1890	1	9	1.458	-0.189	1.895	1.735
1898	2	9	-4.174	-1.000	1.957	2.847
1900	1	10	-0.166	-0.620	3.847	1.701
Visual observations		30	-1.163	-0.315	2.566	2.094
1968	1	1	-0.869	-1.700	-	-
1974	1	9	-0.178	0.092	1.053	0.519
1985	2	131	-0.238	-0.189	0.602	0.562
1986	2	46	-0.634	-0.162	0.660	0.586
1990	1	5	-0.099	0.460	0.618	0.321
1996	2	50	-0.096	-0.232	0.241	0.660
1997	1	28	-0.343	-0.069	0.802	0.612
Photographic observations		270	-0.265	-0.017	0.663	0.543
2005	1	27	0.264	0.555	0.149	0.316
2011	5	163	-0.129	0.045	0.272	0.170
2012	14	222	0.235	0.064	0.402	0.244
2013	2	32	0.129	-0.025	0.112	0.212
2014	5	312	0.041	0.155	0.165	0.285
2015	2	30	0.626	-0.532	0.280	0.077
CCD observations		786	0.194	0.044	0.230	0.217

3. Processing and astrometric reductions

Accurate astrometric observations of comets are possible only during their approach to the Earth and the Sun. Unfortunately most comets have a large coma or areole at that time. This leads to an erroneous identification of the photometric center of brightness with the center of mass. According to research performed by Chesley *et al.* (2001) the true nucleus position of the comet was more accurately defined if the brightest pixel were used rather than positions based upon a best-fitting two-dimensional Gaussian fit to the photometric image. Based on this assumption, we have used brightest pixels only for measuring of comet's positions on images.

The "Astrometrica" software has been used for processing of obtained observations. Radially symmetric Gaussian function was used to getting instrumental coordinates of the reference stars in the system matrix. The 4-th order polynomial with GAIA DR1 (*Gaia collaboration, 2016*) as reference star catalog was chosen to connection model between the tangential and the measured coordinates. Astrometric reductions were made without bias, dark and flat corrections.

To compare such two measuring method we have made a test measuring of positions of the comet JOHNSON (C/2015 V2) observed on May 30, 2017. Measured positions presented in Table 2.

Presented *MSE* values of residuals between ephemerid (C) and measured (O) positions show better accuracy for those positions measured by picked up brightest pixels with aperture around 2 FWHM (it is correspond line with 8 pixels aperture). Such aperture was selected to measure of positions of all observed comets.

Table 2: Accuracy of positions measured by two different methods

Aperture, px	O – C, "		MSE, "	
	RA	Dec	RA	Dec
5	0.062	0.021	0.192	0.269
12	0.062	0.028	0.207	0.285
*5	0.048	-0.029	0.122	0.224
*8	0.075	-0.094	0.087	0.187

* The brightest pixels only were picked up for measuring the positions of comet.

4. Analysis of measured positions of comets

We have made the comparison of observed positions (O) with the calculated ephemeris (C) provided by on-line service HORIZONS (JPL NASA, USA) and have calculated the residuals (O – C) in both coordinates, which are listed in Table 3.

The Table 3 contains the date of observation, the number of frames, magnitude of the object, (O – C) differences and their standard errors (*MSE*) in both coordinates. The mean internal accuracy of single position is 0.169" in right ascension and 0.184" in declination. It was calculated using standard deviations (O – C) in positions for each series of observations.

The comparison of observed and calculated positions is given by distribution of single values of (O – C) and mean of the series of observations on Fig. 1 a) and b). On Fig. 1 b) each point represents the mean of the series of measurements of each comet per night. So, one can find points there which correspond to the same comet, but obtained in different observational periods. The error bars correspond to one-sigma interval.

Table 3: Astrometric accuracy of measured positions of observed comets

Comet	Number of positions	Date of observations	mag*, N-mag	RA		Dec	
				O – C, "	MSE, "	O – C, "	MSE, "
29P	3	27-06-2017	14.6**	-0.095	0.210	0.215	0.224
29P	9	30-07-2017	14.5**	0.104	0.085	0.057	0.147
29P	2	01-08-2017	14.5**	0.115	0.086	0.160	0.063
29P	9	13-09-2017	14.5**	0.465	0.174	0.084	0.256
29P	9	14-09-2017	14.5**	0.603	0.158	0.031	0.204
29P	9	17-09-2017	14.6**	-0.425	0.308	-0.072	0.328
29P	8	18-09-2017	14.6**	-0.322	0.158	0.060	0.168
41P	9	02-06-2017	14.3**	0.381	0.062	-0.017	0.072
41P	9	06-06-2017	14.5**	0.388	0.072	0.048	0.159
41P	9	26-06-2017	16.1**	-0.172	0.106	0.059	0.104
41P	8	30-06-2017	16.4**	-0.113	0.110	-0.066	0.177
65P	5	26-06-2017	16.2	-0.062	0.311	-0.952	0.368
65P	3	30-06-2017	16.3	-0.115	0.402	-0.565	0.372
C/2015 ER61	6	18-09-2017	16.5	0.380	0.186	0.053	0.200
C/2015 O1	9	01-06-2017	16.2	0.048	0.139	0.014	0.131
C/2015 O1	10	02-06-2017	16.2	0.090	0.060	-0.029	0.082
C/2015 O1	8	06-06-2017	16.2	0.023	0.111	0.230	0.214
C/2015 V2	10	30-05-2017	8.8**	0.158	0.091	-0.012	0.174
C/2015 V2	15	01-06-2017	8.8**	0.059	0.073	0.019	0.087
C/2015 V2	5	02-06-2017	8.8**	0.030	0.058	-0.151	0.071
C/2015 V2	9	06-06-2017	8.8**	0.040	0.087	-0.006	0.132
C/2015 VL62	6	13-09-2017	16.0	-0.463	0.392	0.191	0.180
C/2015 VL62	9	14-09-2017	16.0	0.022	0.335	0.029	0.573
C/2015 VL62	9	17-09-2017	16.1	-0.352	0.262	0.462	0.239
C/2015 VL62	9	18-09-2017	16.1	-0.124	0.513	0.133	0.232
C/2016 M1	6	14-07-2017	16.9	-0.003	0.094	-0.009	0.146
C/2016 M1	9	17-07-2017	16.9	0.018	0.092	0.128	0.089
C/2016 M1	5	18-07-2017	16.9	0.020	0.088	0.106	0.058
C/2016 M1	9	19-07-2017	16.9	0.006	0.135	0.151	0.157
C/2016 R2	6	03-10-2017	16.0	0.233	0.157	-0.235	0.123
C/2017 O1	9	03-10-2017	15.6	-0.171	0.115	-0.020	0.177

* Comet's approximate apparent visual nuclear magnitude.

** Comet's approximate apparent visual total magnitude (T-mag).

The comparison of observed and calculated positions is given by distribution of single values of (O – C) and mean of the series of observations on Fig. 1 a) and b). On Fig. 1 b) each point represents the mean of the series of measurements of each comet per night. So, one can find points there which correspond to the same comet, but obtained in different observational periods. The error bars correspond to one-sigma interval.

To estimate external accuracy of our observations and to compare our results with other observatories we have made analysis of “residuals.txt” file presented on IAU MPC site. We have selected two lists of observatories: I) those one have least (O – C) and their errors; II) those one have the largest number of observations. For analysis were selected only data since 2010. The observations of 10 comets observed in RI MAO in 2017 were taken for each observatory from those lists. Table 4 and 5 represent the (O – C) values and their errors for list I and II respectively.

5. Conclusions

The 241 positions of the 10 periodic comets were obtained from observations at KT-50 telescope in RI “MAO” in 2017.

The accuracy of obtained positions were analyzed to respect to ephemerides calculated by service HORIZONS (JPL NASA, USA). The mean values of (O – C) and MSE are $0.042'' \pm 0.200''$ in RA and $-0.087'' \pm 0.353''$ in Dec respectively.

Analysis of the values (O – C) before and after additions of obtained positions to Minor Planet Center (MPC) database revealed a gradual decrease of these differences with respect to the ephemeris. This indicates that the using of the new high-precision positions allows us to refine the calculated ephemeris. As well improvement and lengthening of the astrometric datasets play important role in the modeling of the cometary nongravitational effects.

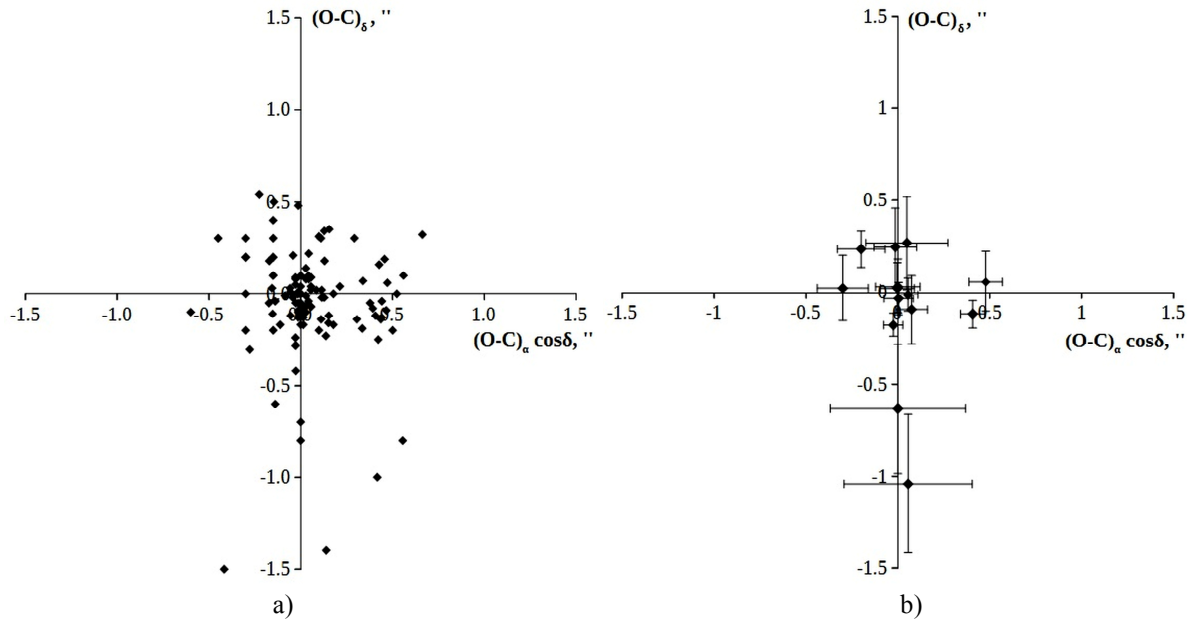


Figure 1: Distribution of: a) single values of $(O - C)$; b) mean values of $(O - C)$ for series.

Table 4: Comparison of $O - C$ values and their errors for list of selected observatories with good accuracy of asteroids observations

Obs. code	Num of positions	RA		Dec	
		$O - C$, ''	MSE, ''	$O - C$, ''	MSE, ''
089*	241	0.025	0.169	0.003	0.184
168	33	-0.208	0.197	0.086	0.176
213	96	0.140	0.519	0.179	0.295
215*	63	0.166	0.302	0.000	0.237
987	36	-0.086	0.232	0.120	0.173
A71	47	0.002	0.290	0.362	0.385
B74	24	-0.013	0.395	0.046	0.152
C47	196	0.012	0.204	0.046	0.180
D95*	74	0.068	0.232	0.072	0.332
F51	34	0.056	0.144	-0.585	0.471
G40*	98	0.095	0.255	-0.044	0.217
I72	54	-0.088	1.476	0.478	1.504
J01	143	0.126	0.361	0.128	0.359

* The observatories which have the observations of 10 comets observed in RI MAO in 2017.

Acknowledgements. This research has made use of the on-line service JPL HORIZONS and database MPC. The authors are grateful to colleagues who have taken part in observations of comets: N. Kulichenko, M. Kaliuzny, V. Kryuchkovskiy, D. Bodryagin.

References

Astrometrica, [online]. Available at: <http://www.astrometrica.at>
 Chesley S. R., Chodas P. W., Keesey M. S. et al.: 2001, *Bull. Am. Astron. Soc.*, **33**, 1090.
 Gaia collaboration: 2016, *A&A*, **595**, A1-A7, A133.

Table 5: Comparison of $O - C$ values and their errors for list of selected observatories with a large number of asteroids observations

Obs. code	Num of positions	RA		Dec	
		$O - C$, ''	MSE, ''	$O - C$, ''	MSE, ''
160	297	0.017	0.294	0.037	0.213
585	477	0.070	0.210	0.192	0.308
703	32	-0.493	2.294	1.369	1.192
A77	302	0.117	0.962	-0.027	0.612
C23	300	0.007	0.256	0.101	0.179
F51	34	0.056	0.144	-0.585	0.471
H45	267	-0.023	0.174	-0.012	0.150
I81	211	0.008	0.422	0.133	0.472
J22	246	0.099	0.366	-0.083	0.517
K02	195	0.126	0.209	-0.042	0.173
Q11	138	0.134	0.247	0.035	0.273
T05	150	-0.107	0.212	0.018	0.257
T08	133	-0.081	0.204	-0.150	0.214

JPL's On-Line Solar System Data Service, [online]. Available at: <http://ssd.jpl.nasa.gov/horizons.cgi>.
 Minor Planet Center, [online]. Available at: <http://www.minorplanetcenter.org/iau/mpc.html>.
 Minor Planet Circulars [online] Available at: http://www.minorplanetcenter.net/iau/ECS/MPCArchive/2017/MPC_20171005.pdf, [MPC_20170709.pdf](http://www.minorplanetcenter.net/iau/ECS/MPCArchive/2017/MPC_20170709.pdf), [MPC_20170609.pdf](http://www.minorplanetcenter.net/iau/ECS/MPCArchive/2017/MPC_20170609.pdf).
 Minor Planet Electronic Circ., [online]. Available at: <http://www.minorplanetcenter.net/mpec/K17/K17N58.html>
 Shulga A.V., Kozyrev E.S., Sibiryakova E.S. et al.: 2012, *Space science and technology*, **18(4)**, 70 [in Russian].