Initial orbit determinations of NEO-2005 with Pulkovo AMP-method

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Abstract

Pulkovo Apparent Motion Parameters Method (the AMP-method) was proposed by prof. A.A.Kiselev and developed by his colleagues for initial orbit determinations of Artificial Earth Satellites, Space Debris, Asteroids, and Comets on the base of very short observational arc. Observational data for the AMP-method are the celestial body position in a middle moment of its observations, its angular velocity and acceleration for this moment, positional angle of its motion and a curvature of its apparent trajectory. These values are calculated from mathematical processing of crowded accurate coordinat sets of an observed celestial body. The AMP-method is a further development of the Classic Laplace's orbital method. Here the AMP-method was applied for the fast orbit determinations of the NEOs which were discovered in 2005. The first nights positions (1 or 3 dates) from Minor Planet Electronic Circulars were used for this job. Our preliminary osculating orbits were compared with the same orbits published in MPEC.

Detailed results are given in (http://www.nm.neopage.ru and http://www.accuracy.puldb.ru)

Key words:
Astrometric CCD observations. Initial orbit determination. Asteroids.

1. Introduction

In the beginnings of 1970th the method of the fast determination of Artificial Earth Satellites orbits was created and developed by Prof. A.A.kiselev and his colleagues at Pulkovo Astronomical Observatory (A.A. Kiselev, O.P.Bykov., 1973), (A.A. Kiselev, O.P.Bykov., 1976). Method was named Apparent Motion Parameter Method (the AMP-method) and successfully was applied to calculations of osculating AES orbits on the base of their photographic positional observations distributed along a short topocentric arc. But obtaining photographic observations with necessary density and accuracy were very difficult for using AMP-method in practice. Further the AMP-method was applied to determination of asteroid' and comet' orbits (O.P.Bykov., 1989). Now modern CCD positional asteroid and AES observations are resuscitating of the AMP and classical Laplace's methods for the operative orbit determination of observed object in a real time, sometimes directly near observing telescope.

The AMP-method requires a known six observational parameters for a given moment of UT, namely α and δ - usual spherical coordinates of celestial body, μ and $\dot{\mu}$ - its angular topocentric velocity and acceleration, ψ - positional angle of its apparent motions and c - a curvature of its visible trajectory. All these values may be calculated from mathematical processing of crowded accurate positions distributed on a short observational arc. System of equations of AMP-method allows us also to obtain these parameters as an exact function of celestial body oculating elements and topocentric observer's coordinates. Table 1 shows these apparent motion parameters for Numbered asteroid *3317 Paris* for dates of the Workshop meeting. Osculating elements of this asteroid was taken from Bowell's orbital catalog (Lowell Astronomical Observatoty) via Internet. Parameters were calculated with our Pulkovo EPOS Software (L'vov V.N. et. al., 2001).

EPOS (Ephemeris Program for Objects of the Solar system) is the ephemeris program system with wide possibilities for professional and amateur observers of small celestial bodies - from calculation of the objects' ephemerides of various type and for control the accuracy of positional observations of the Solar system's objects, including their identifications with the use of Apparent Motion Parameters. The ephemerides of minor bodies are based on numerical integration of equations of their perturbed motion. The EPOS software package works as a Windows application on the IBM PC compatibles. Table 1 demonstrates a possibility to get new ephemeris data. It is our modern approach to the Ephemeris Service of asteroid and comet observations.

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Table 1
Apparent motion parameters for NMP 3317 Paris

Parameters	Date, DT		
2006 November	16.20000	17.20000	18.20000
α	$12^h23^m54.065^s$	12 24 37.446	12 25 20.529
δ	$14°10'17.60$"	14 09 35.02	14 08 56.81
μ, per day	631.13530"	626.52867	621.84039
$\dot{\mu}$	-36.86803"	-36.76324	-36.65173
ψ	93.95019°	93.58182	93.20344
c	1.831310	1.774134	1.714423

A problem of an identification of observed asteroids may be easy solved with the use of Apparent Motion Parameters.

With EPOS Software we also can calculate full list of ephemerides: for example, a phase angle (8.8°), visual magnitude (16.4^m), elongation (56.2° W), topocentric distance and its the first and the second derivatives. Horizontal coordinates are also available for MPC codes observatories.

We present possibilities of the AMP-method of osculating orbit calculations for the NEOs discovered in the first half of 2005. Forty fast moving asteroids were fixed in this period by MPC. Table 2 presents a list of these NEOs.

Our investigation of these NEOs included also an estimation of accuracy of their CCD observations made by various MPC code' stations. Here we cannot give all our results on this theme (see http://www.mn.neopage.ru) but they are usual, i.e. approximately in two time worse then that of for numbered asteroids.

Table 2
Potentially Hazard Asteroids discovered in the first half of 2005

No	Nomination	No	Nomination
	Jan.-Febr.		*April*
1	2005 AD13	23	2005 GJ8
2	2005 AN26	24	2005 GY8
3	2005 AV27	25	2005 GO21
4	2005 AY28	26	2005 GP21
5	2005 BC	27	2005 GO22
6	2005 BY2	28	2005 GE59
7	2005 BG14	29	2005 GD60
8	2005 CJ	30	2005 GH81
9	2005 CL	31	2005 GC120
10	2005 CZ36		*May*
11	2005 DD	32	2005 JU1
	March	33	2005 JQ5
12	2005 EA	34	2005 JF21
13	2005 EE	35	2005 JE46
14	2005 EO33	36	2005 JU81
15	2005 EK94	37	2005 JS108
16	2005 EY95	38	2005 KJ10
17	2005 EJ225		*June*
18	2005 ED318	39	2005 LW3
19	2005 FH	40	2005 LX36
20	2005 FE3	41	2005 LW39
21	2005 GL	42	2005 LO40
22	2005 GU	43	2005 MO13

2. Problem of the sort arc asteroid' observations

Now a wast expancion of CCD matrices in astronomy allows to elaborate new approach to traditional problem of useing modern observational information obtained from very short arc positions. One can easy get coordinate' sets of any moving celestial object with any dense distribution along short topocentric arc. These data can give us the Apparent Motion Parameters in a middle moment of observations, at least coordinates α, δ, μ, ψ. Several minutes of CCD asteroid' accurate observations are enough for getting these values from mathematical processing of coordinates by means of their linear approximation. Consequently a circular AMP-orbit may be calculated immediately, and it will be suitable to continuation of further observations of fixed object during several close nights by observer himself. Of course, an observer, especially amateur, must inform the Minor Planet Center about his asteroid discovery but he will not wait new ephemerides from MPC for new observations. But Minor Planet Center does not take into consideration one night asteroid positions, up to now only two nights observations are processed in MPC for preliminary orbit determination.

If an accuracy of CCD observations and their distribution along topocentric arc allow to calculate additionally values angular accelerations $\dot{\mu}$ and curvature c of visible trajectory we can obtained preliminary elliptic orbit. For confirmation these possibilities of AMP-orbits we had considerd results of NEOs CCD observations in the first nights of their discoveries for determinations of our orbits as it could be in real time of observations. Initial orbits for these asteroids were taken from Minor Planets Electronic Circulars (MPEC). Our AMP-orbits were compared with the MPC-orbits obtained on the base the same CCD observations. As a rule our data practically coincidence with MPEC elements. In Tables below we give an example of our results.

3. Example of initial orbit determination

Here we present one fragment from our orbital calculations. Original CCD observations were taken from (T.B.Spahr, 20051). Table 3 illustrates a used observational data, namely the Normal Places (NPLs) of asteroid 2005 EE. The NPLs were obtained by polynomial approximation of real CCD observations made by observatories with given MPC codes. Only MPC code 703 is a professional astronomical observatory, other are amateurs of Astronomy with small CCD telescopes. All theire data are given in this Table. Only 25 separate positions were obtained by these telescopes for 3 close nights during 1-3 March. We got Normal Places (NPL) for each observatory by means of linear approximations of spheric coordinate' sets. This procedure are smooth for improvement of observations. Sometimes it is very important for useing the AMP method in a case of many participating observatories with different telescopes and CCD matrices.

Here only 4 or 3 positions per night (symbol "j" in the Table) were used for NPLs getting. The NPLs are presented in the Table 3 together with (O-C)s and their errors. The (O-C) values were calculated by EPOS Software with Bowell's orbital elements which were derived from all available observations of 2005 EE (46 positions from March to May). The errors of (O-C)s were obtained as errors of the average meanings for considered night. Naturally, the (O-C) values are reflecting differencies between observed and calculated positions.

As seen an observational set are good for solving orbital task. It would be noted that the seven circular orbits can be calculated for each MPC code observatory with the use of one night observations but these circular orbits (real eccentricity is equal 0.33) may be available for the next observational night only.

Next Table 4 presents the Apparent Motion Parameters calculated from Table 3 data. These AMPs are compared with their meanings calculated by EPOS with the use of Bowell's orbital elements.

Table 4
Apparent Motion Parameters for 2005 EE. Epoch 2005 03 02.19464

	Calculated	Exact
$\alpha = 11^h07^m$	26.650^s	27.253
$\delta = 29°57'$	02.21"	00.57
μ, per day	2425.756"	2425.924
$\dot{\mu}$	−91.634"	−92.818
ψ	283.6160°	283.60982
c	1.838965	1.841095

We can see that NEO 2005 EE had angular velocity near 0.7° per day that is not high for such celestial objects. Our AMPs and their "exact" values are coinciding. But small differencies dive the various elements of orbits which are presented in Table 5.

MPEC elements presented in the last column of Table 5 were calculated by T.B.Sphar (T.B.Spahr, 20051). His orbit is worse than AMP-orbit but he did not use 3 positions obtained with MPC code J95. And Spahr's result is good for 2 nights observations and his method of orbit determination. I don't know what a method was used by Dr.T.Sphar for these orbital calculations.

Table 6 shows a presentation of used NPLs by calculated orbits. Table 7 demonstrates an ephemeris service with elements from Table 5. Our experiense allows us to state that the errors of initial orbital elements have an influence on the AMPs much less than on spherical coordinates. Data presented in Table 7 illustrates this statement. We can

Table 5
Osculating orbit calculated with various methods

Method	AMP	Improvement	MPEC
Positions	25	46	21
Epoch	2005 03	2005 03	2005 02
	02.19464	02.19464	02.00000
a	1.129298	1.130414	1.143650
e	0.326745	0.328254	0.345471
i	6.14621°	6.17246	6.49906
N	110.41971°	110.98637	115.60292
w	284.90132°	284.68501	282.75954
M	90.23289°	89.61010	75.13349

see that the (O-C) values calculated with MPEC orbit are very large in positions α and δ and almost normal in $\dot{\alpha}$, $\dot{\delta}$. These special features are used in our asteroid identification process.

Table 6
Orbital presentations of used observations

No	AMP for α	Impr. for α	AMP for δ	Impr. for δ	code
1	+0.08"	−0.29"	+0.35"	−0.17"	703
2	−0.20	+0.21	−0.17	−0.42	649
3	−0.37	−0.04	+0.20	−0.07	651
4	+0.53	+0.82	−0.40	−0.68	H06
5	+0.71	+0.96	−0.10	−0.34	703
6	−0.61	−0.16	+0.46	+0.28	448
7	−0.04	+0.14	−0.42	−0.24	J95

Table 8
Verification of AMP-orbits of NEOs-2005

Nomin. 2005	Obs. arc	Δc	Δa (a.e)	Δe	Δi (deg.)	ΔN (deg.)
AD13	7.4	0.000	−0.001	−0.000	0.0	0.0
AN26	1.3	0.004	−0.082	−0.022	−0.3	1.7
AV27	1.4	0.001	−0.117	−0.022	−0.1	−0.4
AY28	2.3	0.000	−0.001	0.013	0.3	−0.0
BG14	0.2	0.001	0.080	0.006	2.9	4.8
CL	4.0	−0.000	0.157	0.030	0.4	−0.5
DD	1.3	−0.000	0.001	0.000	0.0	0.0
EA	1.6	−0.000	0.002	0.002	0.0	−0.0
EE	1.2	−0.002	0.001	0.001	0.0	−0.5
EK94	1.3	0.011	−0.079	−0.015	−0.4	−2.2
EY95	1.4	0.000	0.034	0.043	0.3	−1.7
EJ225	1.1	−0.011	−0.054	−0.005	0.2	−0.3
ED318	1.1	0.089	−0.075	−0.023	−0.1	−0.4
FH	1.3	0.017	−0.071	−0.009	−0.3	−0.3

Table 3
Normal places and (O-C)s for PHA 2005 EE and their errors

No	Date 2005	α	(O-C)	δ	(O-C)	MPC code	Posit.	Telescopes
1	03 01.32761	11 10 05.970	−0.29"	+29 48 17.06	−0.17"	703	4	Catalina Sky Survey, Arizona, USA
			±0.54		±0.09			D=0.4, FL=1.2, FOV=175x175', Scale=2.6"
2	03 02.17446	11 07 30.305	+0.21	+29 56 50.53	−0.42	649	4	Powell Observatory, Louisburg, USA
			±0.21		±0.10			D=0.3, FL=3.8, FOV=30x30', Scale=1.8"
3	03 02.17765	11 07 29.707	−0.04	+29 56 52.71	−0.07	651	4	Grasslands Observatory, Tucson, USA
			±0.28		±0.15			D=0.6, FL=3.1, No data
4	03 02.20918	11 07 24.054	+0.82	+29 57 10.10	−0.68	H06	3	New Mexico Skies Observatory, Germany
			±0.39		±0.09			D=0.25, FL=0.8, FOV=56x37', Scale=2.2"
5	03 02.28467	11 07 10.390	+0.96	+29 57 53.20	−0.34	703	4	Catalina Sky Survey, Arizona, USA
			±0.64		±0.24			D=0.4, FL=1.2, FOV=175x175', Scale=2.6"
6	03 02.29397	11 07 08.622	−0.16	+29 57 59.05	+0.28	448	3	Desert Moon Observatory, Las Cruces, USA
			±0.22		±0.28			D=0.3, FL=2.0, FOV=21x21', Scale=2.4"
7	03 03.06168	11 04 51.454	+0.14	+30 04 47.19	−0.24	J95	3	Great Shefford, Berkshire, England
			±0.38		±0.11			D=0.3, FL=1.8, FOV=25x25', Scale=1.5"

Table 7
Ephemerides with initial orbits from Epoch 2005 03 02.19464 to Epoch 2005 04 15.01153

	MPC code	Date	α	δ	$\dot{\alpha}$	$\dot{\delta}$	Orbit
Observations	J50	Apr. 15.01153	$10^h23^m18.9^s$	+25°27′31"	29.7^s	−774"	Improv.
Calculations		Apr. 15.01153	10 22 57.7	+25 28 54	29.3	−770	AMP
(O-C)			21.2	− 83"	0.4^s	−4"	
Calculations		Apr. 15.01153	10 25 40.7	+25 29 59	31.0	−758	MPEC
			− 141.8	− 148"	-1.3^s	−16"	

Table 8 summarizes results of our job. It consists columns of "absolute" errors of observational and calculational values of curvatures and orbital elements. These meanings were obtained with formulae: ""AMP elements" minus "Improve elements"". If an accuracy of CCD used observations and topocentric arc are optimal for applying of AMP method, these tabular errors are small or close to zero. As a hole our initial AMP-orbits give a good ephemeris prognosis during one or two week. It makes them practically important.

4. Conclusion

We are sure that Pulkovo Apparent Motion Parameters Method may be recommended for initial orbit determinations to observers especially amateurs of Astronomy. The matter is only in expansion of according SOFT for example, Pulkovo EPOS.

It seems to us the circular orbits may be used for identification of moving objects in Gaia observational campaign. But this question requares special investigation.

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