Russian Physics Journal, Vol. 53, No. 10, March, 2011 (Russian Original No. 10, October, 2010)

ALTERNATIVE ORBITS OF NEW JUPITER SATELLITES

V. A. Avdyushev and M. A. Banshchikova UDC 521.1

A problem of ambiguous determination of orbits for recently discovered unnamed Jupiter satellites of S/2003 family is investigated. Their new alternative orbits, which by analogy with orbits obtained by other authors interpret well the observed data, are presented.

Keywords: orbit determination, numerical integration, Jupiter satellites.

INTRODUCTION

Orbital parameters of celestial bodies are determined from astrometric observations by the least squares method which, as a rule, is reduced to minimization of a certain objective function that expresses a degree of proximity of the observed and modeled positions of an object. At the same time, the Gauss–Newton type iterative methods are conventionally used to minimize the objective function. Meanwhile, mainly due to the fact that the problem being solved is nonlinear, it can have many solutions, in other words, the objective function can have many minima. Formally, the solution which describes the most accurate values of the orbital parameters and provides the least value of the objective function is obviously chosen as the acceptable solution.

It should be noted, however, that in most cases (for example, in the determination of asteroid orbits), the problem of choice of the acceptable solution does not arise at all: the initial approximations necessary for the iterative method that are obtained from preliminary determination of orbits are often so accurate, that the iterative process converges fast to the acceptable solution that yields the absolute minimum of the objective function.

Nevertheless, there are a number of problems for which such a formal choice of solution is not unique, because there are some other alternative solutions for which the objective function takes values very close to the value of the absolute minimum. Uncertainty here is primarily due to the circumstance that observations can involve errors with which the solution providing the absolute minimum of the objective function, that is, representing the observations best of all, will be quite possible far not the best one from the viewpoint of prediction of celestial body motion in future. In [1], for example, it has been demonstrated that the problem of ambiguous orbit determination can arise when solving problems on the dynamics of close planet satellites for low number of observations whose moments are distributed over several groups during a long time period of the order of 10 000 and more object revolutions.

The problem of ambiguous orbit determination can also arise in some other cases, namely, when observations are grouped in a small time interval and cover a short arc of the orbit. It is obvious that almost all new objects have this observation structure. However, this problem can arise only under certain special observation conditions, which though narrow the class of problem objects, are many in number, and the majority of them is presented by far satellites of large planets.

In the present work, the problem of ambiguous orbit determination is investigated on the example of new unnamed Jupiter satellites of S/2003 family, and alternative orbits previously unpublished in the literature are revealed.

Scientific Research Institute of Applied Mathematics and Mechanics at National Research Tomsk State University, Tomsk, Russia, e-mail: sch@niipmm.tsu.ru; scharmn.narod.ru. Translated from Izvestiya Vysshikh Uchebnykh Zavedenii, Fizika, No. 10, pp. 27–30, October, 2010. Original article submitted October 21, 2009.

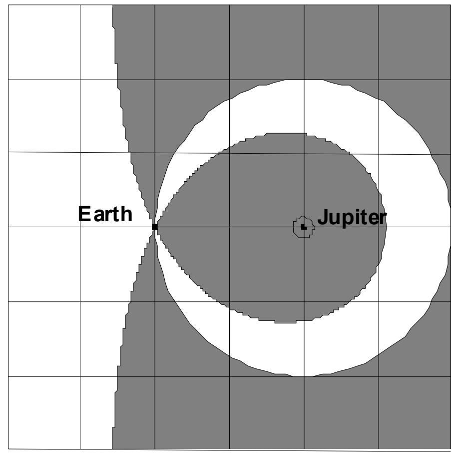

Fig. 1. Region of double solutions (the circle around Jupiter shows the sphere of planet influence).

1. AMBIGUOUS PROBLEM OF PRELIMINARY ORBIT DETERMINATION

Planet satellites, as a rule, are observed in the angular coordinates, and the problem of ambiguous determination of orbits for new far satellites is actually reduced to the well-known problem of preliminary orbit determination from three angular positions, when under certain observation conditions, there exist two acceptable solutions of the Lagrange eighth-degree equation for the distance that yield two preliminary Kepler orbits [2]. Conditions for double solutions are satisfied when the observable object is located in the region shown in Fig. 1 by grey color with Jupiter as a central body. From the figure it can be seen that this region covers the sphere of Jupiter influence. Therefore, for any planetary satellite whose orbit is preliminary determined, two solutions will always exist that will describe the observations equally well. If there is no additional information about the geocentric distance to the satellite, it appears absolutely impossible to choose the orbit which corresponds to the actual one.

2. AMBIGUITY PROBLEM OF ORBIT DETERMINATION FOR NEW SATELLITES

Nevertheless, the ambiguity problem is solved in the stage of orbit refinement based on additional observations which, as a rule, are available. When solving the inverse problem using an excessive sample of observations, a reasonable criterion for the acceptable solution corresponding to the actual orbit is the minimal root-mean-square (rms) error: from the two solutions it is necessary to choose that for which the rms error is considerably smaller. However, if in both cases the rms errors are comparable, the choice of the solution without additional information on the orbit is problematic. Such a situation is quite possible for objects observed on a very short arc, which is characteristic of the new unnamed Jupiter satellites of S/2003 family that we considered as having double solutions.

Based on preliminary knowledge of satellite observation periods shown in Fig. 2, we can state with confidence that for objects observed less than 100 days, alternative solutions that are equally applicable for representation of the observations must exist.

3. ALTERNATIVE ORBITS OF THE NEW JUPITER SATELLITES

The orbits of the S/2003-family satellites were determined from the available astrometric observations [3] based on high-accuracy numerical modeling of satellite motion [1] by solving the nonlinear least-squares problem. As

TABLE 1. Alternative Estimates of Orbital Elements

Satellite	a, a.u.	e	i, °	σ, "	a^*, a.u.	e^*	i^*, °	σ^*, "
S/2003 J02	$1.81 \cdot 10^{-1}$	0.34	174	0.14	$8.04 \cdot 10^{-2}$	0.74	123	0.20
S/2003 J03	$1.29 \cdot 10^{-1}$	0.23	129	0.22	–1.89	1.05	121	0.30
S/2003 J04	$1.23 \cdot 10^{-1}$	0.43	119	0.20	$1.53 \cdot 10^{-1}$	0.27	120	0.17
S/2003 J05	$1.63 \cdot 10^{-1}$	0.21	142	0.25	$-1.31 \cdot 10^{-2}$	12.29	141	1.10
S/2003 J09	$1.58 \cdot 10^{-1}$	0.21	159	0.32	$-1.17 \cdot 10^{-2}$	8.96	164	4.22
S/2003 J12	$1.17 \cdot 10^{-1}$	0.49	146	0.20	$1.92 \cdot 10^{-1}$	0.40	165	0.21
S/2003 J14	$1.68 \cdot 10^{-1}$	0.28	160	0.19	$1.33 \cdot 10^{-1}$	0.08	46	5.45
S/2003 J15	$1.52 \cdot 10^{-1}$	0.13	127	0.24	$-2.35 \cdot 10^{-2}$	4.73	87	3.78
S/2003 J16	$1.38 \cdot 10^{-1}$	0.24	167	0.16	$-3.44 \cdot 10^{-2}$	4.35	149	0.92
S/2003 J17	$1.53 \cdot 10^{-1}$	0.19	161	0.15	$-3.97 \cdot 10^{-1}$	1.26	20	2.21
S/2003 J19	$1.59 \cdot 10^{-1}$	0.30	166	0.20	$-3.64 \cdot 10^{-2}$	1.71	106	1.28
S/2003 J23	$1.56 \cdot 10^{-1}$	0.36	156	0.35	$8.08 \cdot 10^{-2}$	0.42	58	0.85

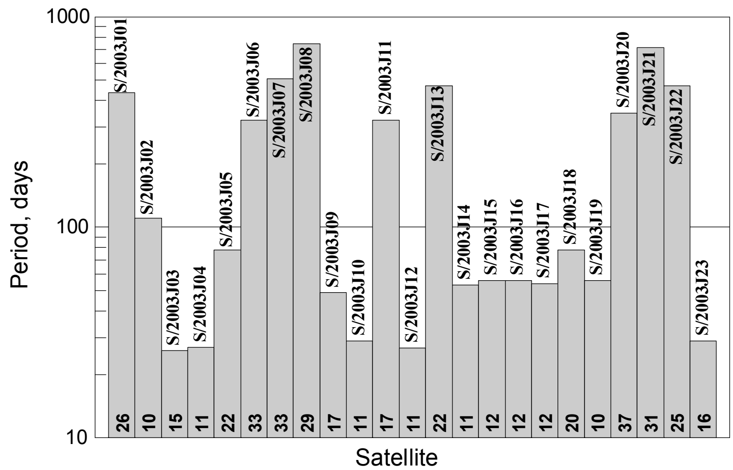

Fig. 2. Periods of observations of new far Jupiter satellites discovered in 2003. At the bottom of the figure, the number of observations is specified for each satellite.

initial approximations for each satellite, the pair of solutions obtained from preliminary orbit determination by the Laplace method was taken [2].

As a result, we obtained pairs of orbits only for 12 satellites of 23; their elements are presented in Table 1. For each of the remaining 11 satellites, only one or another initial approximation provided convergence of the iterative process. In Table 1, a is the major semiaxis, e is the eccentricity, i specifies the inclination to the geo-equator in the J2000 epoch, σ is the rms error, and the asterisk designates the alternative orbital elements previously unpublished in the literature. It is interesting that among 24 orbits of 12 pairs, 7 alternative orbits are hyperbolic, that is, 7 objects can be asteroids temporarily captured by Jupiter. However, from the alternative solutions we can take only those whose rms errors are sufficiently small. Thus, only 4 objects deserve attention: S/2003J02, S/2003J03, S/2003J04, and S/2003J12, one of which (S/2003J03) has a hyperbolic orbit.

Figure 3 shows their perturbed orbits around Jupiter (with coordinates α_J, δ_J) in the system of geocentric angular coordinates (α, δ). From the figure it can be seen that both orbits determined from observations for each satellite are tangential to each other in the initial epoch and interpret observations equally well (within the accuracy of ground-based observations; see Table 1).

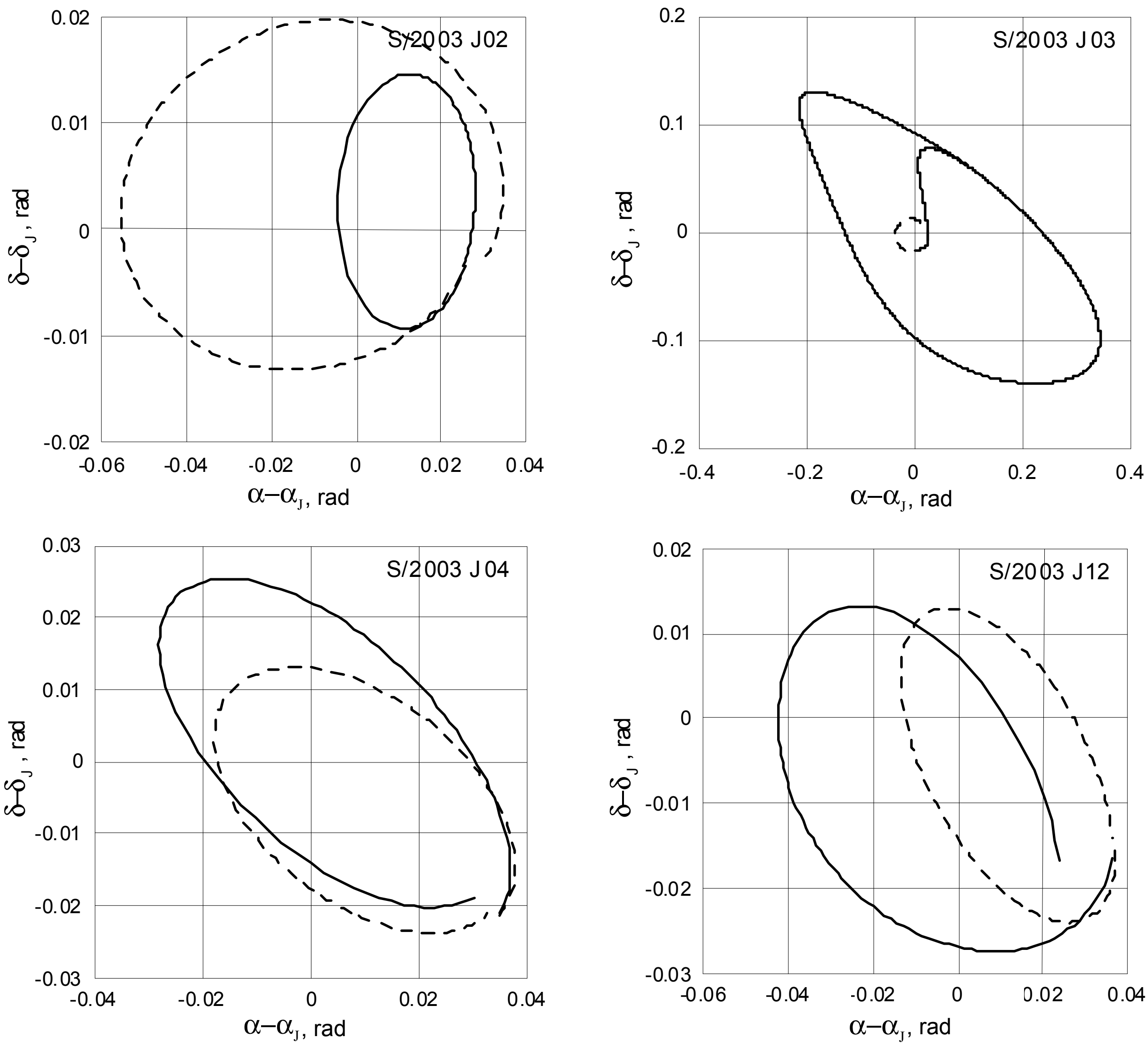

Fig. 3. Alternative orbits of S/2003 J02, S/2003 J03, S/2003 J04, and S/2003 J12 satellites (the dashed curves show the orbits determined in [4–6]).

CONCLUSIONS

Thus, the problem of ambiguous orbit determination has been considered in this work on the example of the new unnamed Jupiter satellites of S/2003 family, and their alternative orbits previously unpublished in the literature have been obtained. Only four alternative orbits of S/2003J02, S/2003J03, S/2003J04, and S/2003J12 satellites deserve attention, since they represent the satellite observations as well as the orbits obtained previously. Therefore, for these satellites it is actually impossible to choose the orbit which would correspond to the actual satellite orbit, that is, which would adequately describe the satellite motion. To solve this problem, additional observations are necessary.

This work was supported in part by the Special Federal Program "Scientific and Pedagogical Personnel of Innovative Russia."

REFERENCES

1. V. A. Avdyushev and M. A. Banshchikova, Astron. Vestn., **42**, No. 5, 156–195 (2008).
2. C. V. L. Charlier, Assoc. R.A.S., 120–122 (1910).
3. J. E. Arlot and N. V. Emelyanov, Astron. Astrophys., **503**, 631–638 (2009).
4. S. S. Sheppard, D. C. Jewitt, J. Kleyna, *et al*., IAU Circ., No. 7900, 1 (2002).
5. N. V. Emelyanov, Astron. Astrophys., **435**, No. 3, 1173–1179 (2005).
6. V. A. Avdyushev and M. A. Banshchikova, Astron. Vestn., **41**, No. 5, 446–452 (2007).