CCD-OBSERVATIONS OF ASTEROIDS: ACCURACY AND THE NEAREST PERSPECTIVES FOR APPLICATION OF THE LAPLACIAN ORBIT DETERMINATION METHOD

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The modern crowded CCD-observations of the Solar system small bodies are very effective and accurate. They easily provide close positions on a short topocentric arc for any celestial body – from several hours during one night to several successive nights at a single observatory. It is obvious, now, that the informational value of such short arc observations is very high. Statistical treatment of these accurate near positions gives an opportunity to calculate the first ($\dot{\alpha}$, $\dot{\delta}$) and second derivatives ($\ddot{\alpha}$, $\ddot{\delta}$) of spherical asteroid coordinates or an angular topocentric velocity and its positional angle, a topocentric angular acceleration and a curvature of visible trajectory of observed celestial body.

Pulkovo observatory has a long and successful experience of processing short arc observations of Artificial Earth Satellites, Double Stars, Minor Planets and Comets. The classical Laplacian method and the new Apparent Motion Parameters Method developed by Dr.A.A. Kiselev together with colleagues are applied for the orbits determinations.

Practically, the Laplacian method was usually at a disadvantage if compared to the Gaussian initial orbit determination method, in spite of efforts of known scientists – from A.Leuschner to J.Kovalevsky and F.Barlier. The author explains this situation by difficulties of obtaining the first and second derivatives of spherical coordinates from positional observations of celestial body: traditionally these derivatives were calculated from three positions only (it was the common practice in the case of Gaussian orbit determination method). But, at Pulkovo observatory, special parameters of celestial bodies motion were introduced into consideration and special procedures were created for their calculation with the use of crowded accurate sets of positional observations.

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The author continues this tradition of Pulkovo investigations. First of all, it is necessary to compare precisions of new CCD and stable photo positional asteroid observations. Up to day, we have no own CCD-device at Pulkovo and the author was compelled to use the observations published in the Minor Planet Circulars. The CERES software package, created at Institute of Theoretical Astronomy, was applied to calculate residuals $(O - C)$ for near 136 numbered minor planets observed irregularly and quasi-simultaneously in 1993 by CCD, as well as by photo techniques, at 25 observatories (ESO, CERGA, Kitt Peak, Oak Ridge etc.). The accuracy of observations was estimated by means of standard error of average $(O - C)$ for each type of observations obtained by each telescope. As a rule, the CCD-observations of the numbered minor planets are considerably more exact than the photo ones [1]. This conclusion was confirmed later by analysis of an accuracy of the first and the second derivatives obtained from similar sets of CCD and photo observations of unnumbered asteroids.

The high accuracy of the CCD-observations and their efficiency allow to solve the problem of orbit determination for any celestial object moving in the field of reference stars. The Laplacian orbital elements are, of course, preliminary, but they are very close to the real asteroids orbits. The author's practice of orbital calculations with the use of the Laplacian method for the Near Earth Objects, the Main Belt and Kuiper Belt asteroids observed by CCD technique allows to affirm that the Laplacian method can give good results in a direct processing of CCD observations immediately, during their execution on a telescope (for a circular orbit), or several days after (for an elliptical one). The Laplacian method can be successfully applied to solve the problem of faint asteroid identification and detailed study of asteroids population in the Main and Kuiper Belts. For any observer, this method can provide an independent ephemeris service on the basis of the own observations only. The CERES software [2] and LAPLACE software, made at the Pulkovo observatory, are the first steps to realize this purpose in the nearest future.

The algorithms of the Laplacian orbit determination method are published in [3].

References

1. Bykov O.P.: 1994 "On the accuracy of CCD and photo observations of asteroids and their current orbit determinations", *Proceedings of IAU Symp. 167*, p.351, 1994.
2. Babaev I.O., Chernetenko Yu.A., L'vov V.N. et al.: 1994 *CERES - Minor Planets Ephemeris Software Package for IBM PC and Compatibles. User's Guide*,ITA, St.-Petersburg, p.24.
3. Bykov O.P.: 1989 "Determination of celestial bodies orbits by the direct methods", *Problemy postroenia koordinatnykh sistem v astronomii*, GAO, Leningrad, pp. 328-356.