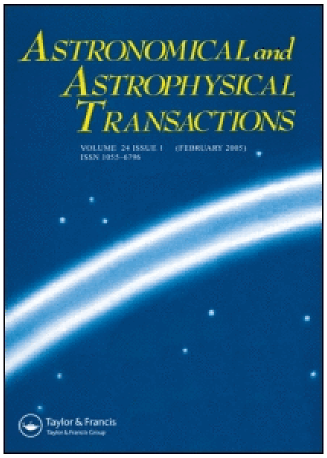

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Numerical algorithms and programs for investigation of motion of asteroids and comets closely approaching major planets

V. A. Shefer [a]
[a] Research Institute of Applied Mathematics and Mechanics, Tomsk

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NUMERICAL ALGORITHMS AND PROGRAMS FOR INVESTIGATION OF MOTION OF ASTEROIDS AND COMETS CLOSELY APPROACHING MAJOR PLANETS

V. A. SHEFER

Research Institute of Applied Mathematics and Mechanics, Tomsk

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Numerical algorithms and programs for investigation of motion of asteroids and comets closely approaching major planets based on the equations of motion in a regularized and stabilized form are described.

KEY WORDS Motion of asteroids and comets

Among the problems connected with the investigation of the motion of small bodies in the Solar system, the problem of the prediction of the motion of asteroids and comets closely approaching major planets is the most complicated one. Alongside with the fact that the objects considered have close approaches with major planets, many of them (unusual minor planets and most of comets) move in the orbits with great eccentricities. The application of traditional methods of investigation in these cases runs against a number of difficulties. Classical Newtonian equations of motion used for the calculation of space locations of investigated small bodies, as is known (Stiefel and Scheifele, 1971), are singular in the neighbourhood of collisions of gravitating masses but the solutions of these equations are unstable in the Lyapunov sense. In numerical solution of the prediction problem for the motion of asteroids and comets closely approaching major planets, these singularities of the equations of the motion lead to an irrational decrease of the magnitude of the investigation step in the neighbourhood of the perihelion and in the zones of close approaches, and to the loss of the accuracy of the calculation.

A complex of algorithms and programs constructed by us for the investigation of the motion of asteroids and comets closely approaching major planets is developed basing on the equations of motion free of the above singularities.

The software developed consists of a data file and application packages. The complex of algorithms and programs is designed for solving the following problems:

- numerical integration of the equations of motion of a small body with taking into account perturbations from nine major planets and the Moon as well as relativistic and non-gravitational effects in the motion of the body;

- comparison of the theory with observations;
- correction of the initial parameters of the motion;
- investigation of the evolution of elements of the orbits of small bodies and peculiarities of their motion.

The data file includes a search for coordinates and velocities of nine major planets and the Moon covering the interval of 100 years (1900–2000), a catalogue of reduced observations of the small body considered and information on observatories.

The following main programs form a part of the application packages:

1. programs of numerical integration of differential equations of motion in a regularized and stabilized form by the Everhart method;
2. programs of simultaneous numerical integration of differential equations of motion and equations in variations in a regularized and stabilized form by the Everhart method;
3. programs for comparison of the theory with observations and the construction of conditional equations;
4. a program for solution of a system of conditional equations by the method of least squares;
5. programs for computation of coordinates and velocities of major planets and the Moon;
6. programs for determination of osculatory elements of the orbits of small bodies and finding out the peculiarities of their motion.

The complex of programs developed is characterized by a certain independence and flexibility in changing one group of programs by another. The control programs carry out the function of forming a software package for a solution of a concrete problem. The possibility of using various programs of numerical integration and the confrontation of the theory with observations in the problem of investigation of motion of a concrete object serves as a foundation for a reliable mutual control of the results.

All the programs are developed in FORTRAN for a digital computer.

The developed complex of programs was successfully used by us for the construction of a numerical theory of motion of the unusual minor planet Icarus, the investigation of the evolution of its orbit and peculiarities of its motion (Shefer, 1984). A high efficiency of the algorithms and programs is also shown on the example of motion of such complex objects as comets Halley, Honda-Mrkos-Pajdusakova and Gehrels 3 (Shefer, 1990).

The results obtained allow us to draw a conclusion about the fact that the complex of programs together with the foundation of coordinates and velocities of major planets and the Moon makes it possible to develop, with a sufficiently high accuracy, numerical theories of the motion of asteroids and comets closely approaching major planets with account for perturbations during the whole period of their observation and to investigate the peculiarities of motion of the object considered even in the most complicated cases when exceedingly close approaches with major planets take place in the investigated interval of time.

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