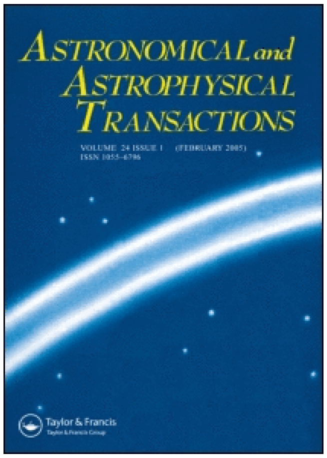

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Information technology for visualization of a dynamic evolution of meteoroid complexes

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INFORMATION TECHNOLOGY FOR VISUALIZATION OF A DYNAMIC EVOLUTION OF METEOROID COMPLEXES

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A computer technology is presented to visualize the results of a probability–stochastic model of the parent-body disintegration and to develop the space model of a meteoroid complex formed by disintegration fragments at different ejection rates in a given range of the true anomaly variations. Three-dimensional images of fragment orbits are constructed from a simulation result.

KEYWORDS: information technology, dynamic evolution, meteoroid complexes

Probability models of the disintegration of small bodies in the Solar System are applied to study the dynamic evolution of meteoroid complexes. Stochastic methods used for simulating such problems generate enormous data files difficult to analyse without extra transformations. One of the ways to solve this problem is visual representation of simulation results and it is widely used in conceptual studies of the behaviour of celestial objects in a long time series (Tajima and Takano, 2001).

The paper presents computer technology to visualize the results of a probability–stochastic model of the parent-body disintegration and to develop the space model of a meteoroid complex formed by orbits of disintegration fragments at different ejection rates within a given range of the true anomaly variations. The process of disintegration is considered to be the isotropic ejection of a solid nucleus component at any orbital point of a body under investigation. Input model parameters are the Keplerian orbital parameters of a studied body, the expected range of ejection rates of substances, and the point of ejection of a substance in an orbit specified by the true anomaly. Simulation results present orbital element deviations of ejection fragments from the parent-body orbit at discrete points. The algorithm of disintegration has been published previously (Kulikova, 1971, 1988).

The technology for studying the behaviour of the disintegration fragments of a space body has been developed on the basis of this algorithm. It includes the following programs: probability–statistical simulation of data on object disintegration; sampling and rearrangement of simulation results; calculation of maximum and minimum deviations for fragment orbital elements at every ejection point; construction of different plots of the orbital parameter

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dependence on the true anomaly and the substance ejection rates from several appearances of a celestial object. The above aspects of the technology have been considered in more detail by Kulikova and Tischenko (2003). The present paper is devoted mainly to three-dimensional visualization of simulation results which allows space filling with fragments having expected elliptical orbits to be qualitatively studied within a united technology.

The input data for a visualization system are prescribed by the Keplerian orbital parameters a, e, I, Ω and ω of the parent body and deviations δa, δe, δI, $\delta\Omega$ and $\delta\omega$ of ejection fragment orbital elements for the specific substance ejection rate and the true anomaly *Color*, where substance ejection is simulated, as well as the parameter specifying the colour of the orbit representation. The position of an orbital plane relative to the ecliptic and the coordinate axis is shown in Figure 1.

An image is constructed in a heliocentric coordinate system. The x axis is in the direction of the vernal equinox γ, the $x\mathrm{S}y$ plane is aligned with the ecliptic. The frame of reference chosen and the input data orient the plane elliptic orbit in space so that the Sun is always at the focus of the ellipse. The form of a fragment orbit is defined as $a + \delta a$, $e - \delta e$ or $a - \delta a$, $e + \delta e$ for the stable Sun's position in the focus of the ellipse. Orbits of all fragments as well as orbits obtained only in maximum and minimum deviations of the Keplerian elements can be represented by visualization. Extra elements for investigation, i.e. the line of nodes NN_1, the celestial sphere, the orbits of the planets of the Solar System and the coordinate axes, may appear in a three-dimensional scene when desired by the user and the intersecting planes of the ecliptic and osculating orbits may be used for convenience when studying a set of orbits.

The technology is realized with the help of an applied program interface API OpenGL (Krasnov, 2000). The process of image formation proceeds as follows: a model matrix is

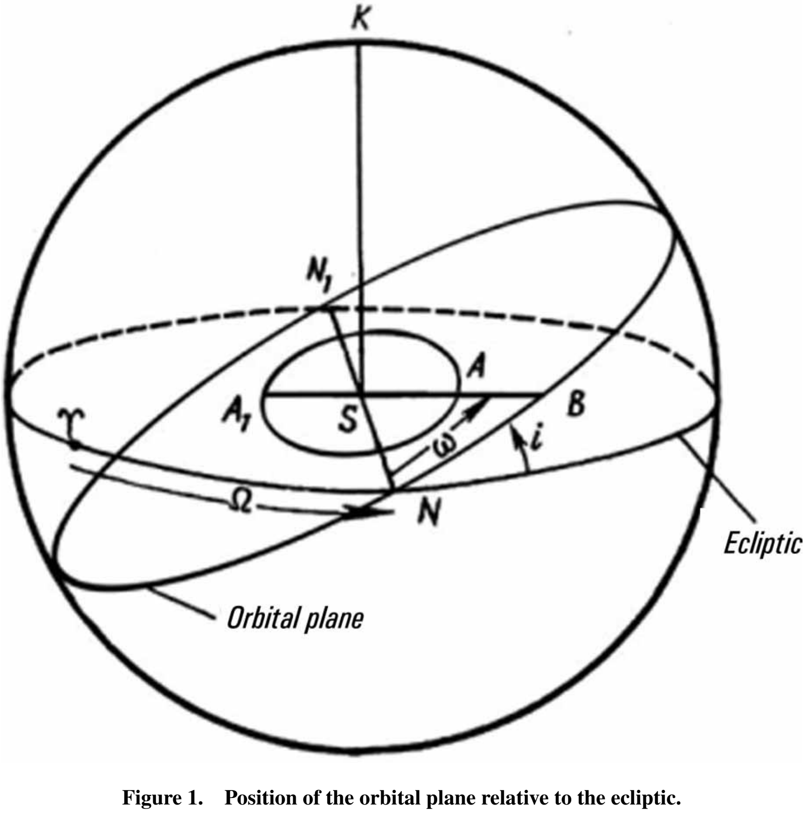

Figure 1. Position of the orbital plane relative to the ecliptic.

formed from the OpenGl object coordinates obtained and the coordinates of the observer are calculated. Then the projection matrix where the scene space is formed undergoes a transition. Everything that is outside the scene is cut. All coordinates are normalized and an image is reduced to the output window sizes. The volume of the represented space and the form of angle and distance transformation are determined in the projection matrix. The technology makes use of the orthographic projection where real angles and object dimensions are represented; this is considered important for analysis of the drawings obtained. In a perspective projection the angles and the distances between the objects are distorted depending on the distance. The distortion coefficient depends on the angle of view given in the projection and this makes the perception of the space orbit distribution worse. A smoothing function is used to improve the quality of the three-dimensional representation.

To form the required three-dimensional scene on screen, the ranges of true anomaly variations and the substance ejection rates are presented using a standard window interface OC Windows. When the parameters requried are installed, a window ‘Universal’ is formed. Here the following image elements may be controlled: shift and rotation of coordinate axes with the help of a ‘mouse’; the notation of the celestial sphere and celestial equator; plotting of coordinate axes and alteration of their sizes; redeifinition of the image background colour; application of intersecting planes of the osculating orbit and ecliptic; image printing; images of the planets of the Solar System planets and the line of nodes.

Published data on the objects observed during long time intervals have been used to illustrate the opportunities attained with this technology. Among these were comets Halley, Giacobini–Zinner, Tempel–Tuttle II and Pons–Winnicke, meteoroid complexes which can result in dangerous situations in the Earth’s biosphere. Computer simulation of disintegration has been performed for all their appearances. Demonstration drawings are based on observations of comet Halley in 1986. The orbital orientation of comet Halley in space is realized according to the orbit presentation given by Belyaev and Churyumov (1985). Figure 2 shows the technology window which represents a general view of the meteoroid complex of comet Halley with the planetany orbits indicated.

Figures 3a and 3b represent part of the meteoroid complex of comet Halley above the ecliptic. Orbital parameters of fragments are obtained in comet disintegration at ejection rates up to 1 km s^{-1}; visualization is realized for four ranges of ejection rates. In Figure 3a the substance ejection points are equal to 10°, 20°, 30°, 40° and 50° of the true anomaly; each

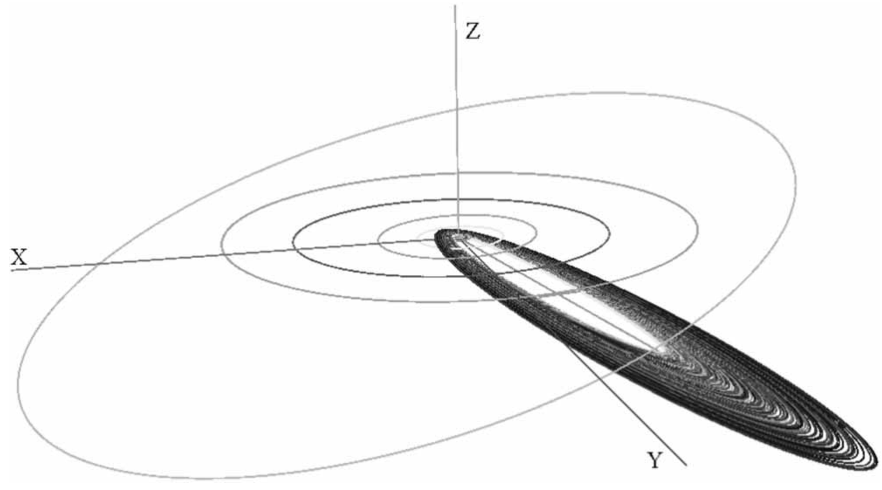

Figure 2. **General view of the expected meteoroid complex of comet Halley in the Solar System.**

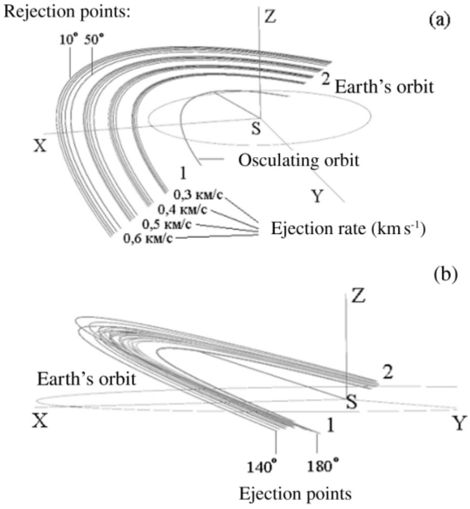

Figure 3. Part of the expected meteoroid complex of comet Halley above the ecliptic illustrating its layered structure for different distributions of substance ejection points in the simulation (a) near the perihelion and (b) near the aphelion.

angle is depicted by the respective colour, and ejection rates for one angle have different colour shades. The layered structure of a complex is clearly seen, and each layer consists of fragment orbits corresponding to one ejection rate range. Figure 3b shows the orbits of fragments ejected near the aphelion ($U = 140$–$180°$). In Figure 3a all orbits in node 2 are outside the Earth's orbit and in Figure 3b some orbits intersect it.

Figure 4 illustrates a layered structure analogous to that shown in Figure 3 but, in this case, disintegration is simulated for a narrower range of ejection rates (0.4–0.6 $\mathrm{km\,s^{-1}}$) by dividing it into a similar number of rate subintervals and, as a result, the layers formed by disintegration fragments at the same point can be represented more accurately.

Figure 5 presents the fragment orbits above the ecliptic obtained in disintegration at ejection rates up to 0.4 $\mathrm{km\,s^{-1}}$ at all ejection points from 0° to 180°. It is clear that intersection with the Earth's orbit is possible at low substance ejection rates.

Figure 6a shows the fragment orbits which specify the boundaries of the meteoroid complex and allow its width to be estimated. In Figure 6b an image at the perihelion is enlarged to provide a better view.

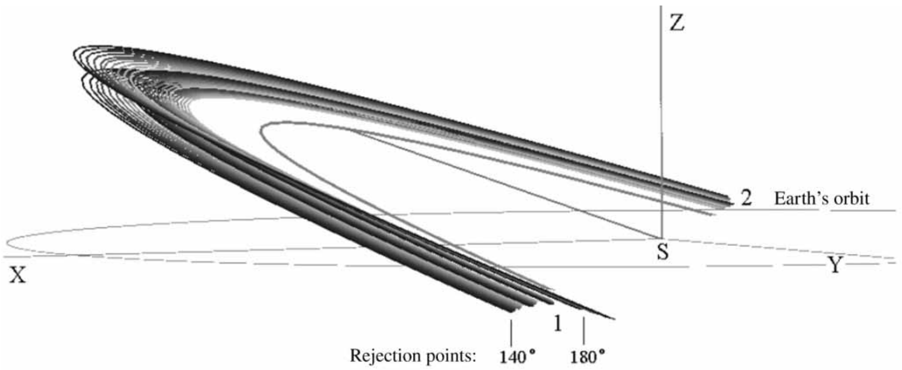

Figure 4. Layered structure of the expected complex analogous to Figure 3b in a simulation for narrower rate variations.

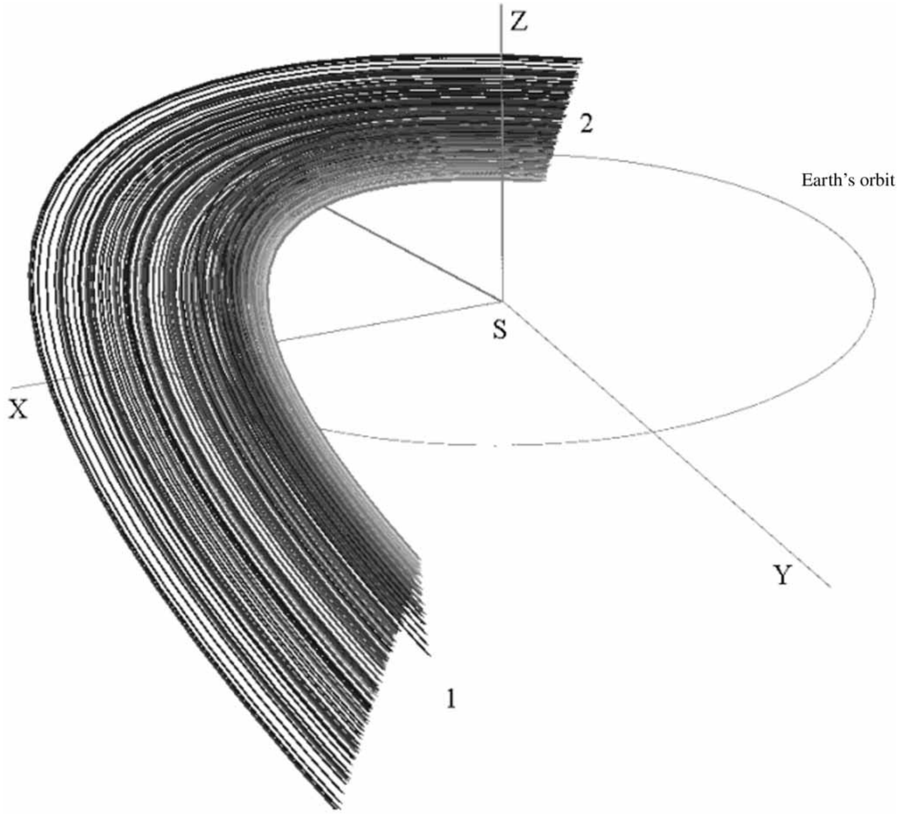

Figure 5. Intersection of the expected meteoroid complex with the Earth's orbit.

Figure 7 illustrates the complex structure of the meteoroid complex in space: orbit positions at the perihelion and aphelion differ. All deviations in the fragment orbital elements are enlarged tenfold to allow visualization.

Figure 8 demonstrates the opportunities of the technology for analysing object behaviour during long time intervals. Meteoroid complexes, possibly formed in the disintegration of comet Halley in its five previous appearances are represented. Lines of nodes exhibit the displacement of fragment orbits in the years in which the comet appeared.

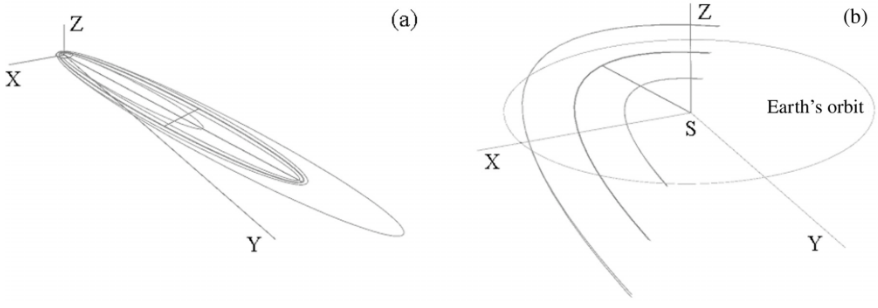

Figure 6. (a) Expected width of the meteoroid complex along the whole orbit; (b) enlarged image of one part of the complex above the ecliptic.

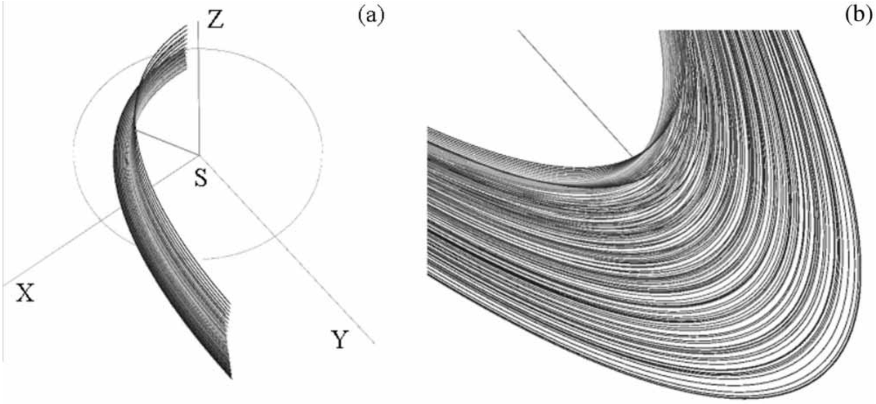

Figure 7. **Orbit distribution of the expected meteoroid complex (a) at the perihelion and (b) at the aphelion.**

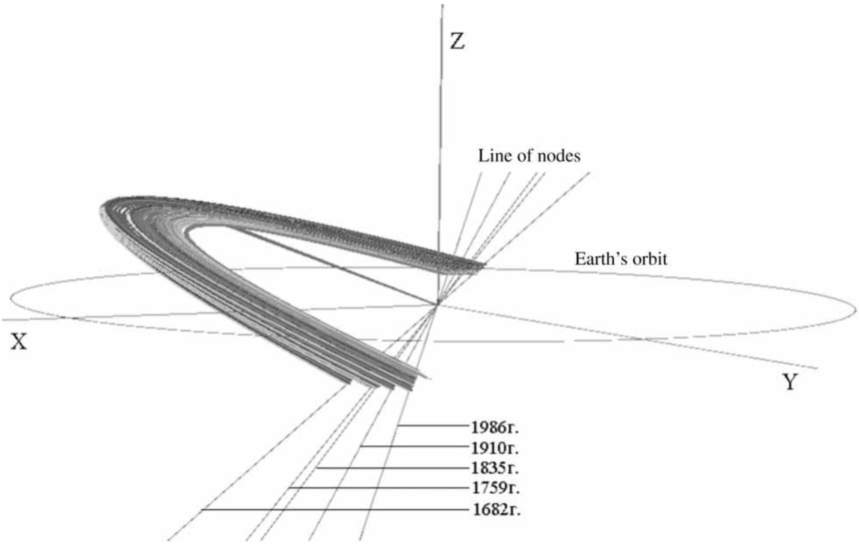

Figure 8. **Expected fragment orbits of comet Halley formed in several comet rotations.**

It should be pointed out that the technology presented enables us to analyse the dynamic evolution of one or several objects at different appearances in a drawing. It will make it possible to study the expected formations of meteoroid complexes and to reveal the regions where encounters with their disintegration fragments both near the Earth's orbit and in distant space missions are most probable.

References

Belyaev, N. A., and Churyumov, K. I. (1985) *Comet Halley and its Observations*. Nauka, Moscow.
Krasnov, M. (2000) Graphics in Delphi Designs, BXV, St Peterburg.
Kulikova, N. V. (1971) *Astron. Vest.* **5**, 181.
Kulikova, N. V. (1988) Doctor's Thesis, Institute of Nuclear Power Engineering, Obninsk.
Kulikova, N. V., and Tischenko, V. I. (2003) *Astron. Astrophys. Trans.* **22**, 535.
Tajima, T., and Takano, A. (2001) *Proceedings of the 3rd Europen Conference on Space Debris*, European Space Operations Centre, Darmstadt, Germany, 2001, Vol. 1, pp. 133–138.