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On the near space population from simulation results

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A new computer technology module for studying meteoroid complexes is proposed. Space structure is represented by orbital fragments with their visualization from simulated cometary nucleus disintegration. The modelled section in the ecliptic is shown which presents the complex form and its inner structure. This representation can be used for analysing space filling to establish potentially dangerous regions near the complex and the concrete planet's orbits or other object routes. Main results for specific comets are given.

Keywords: Meteoroid complexes; Computer simulations

A computer technology based on mathematical simulation of small body disintegration [1–3] followed by data visualization has been developed to study meteoroid complexes formed in the process of cometary nuclei evolution. 3D representation of a modelled meteoroid complex above the ecliptic [2] does not give deep insight into the boundaries of its intersection region with the ecliptic (Fig. 1*a*) and a module is developed for graphic representation of this region as a plane image. The obtained pattern

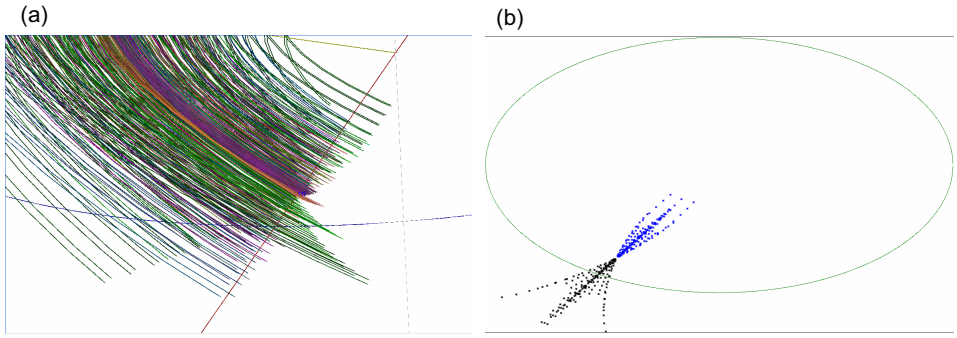


Figure 1 Expected 3D-image of the comet Halley complex (*a*) and its intersection region with the ecliptic (*b*) for $120° \leq U \leq 180°$; magnification ratio is 10.

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presents a meteoroid complex structure and its section form (Fig. 1*b*). It possibly involves extra elements in the form of planet's orbits or other object trajectory.

The problem is reduced to the following: the intersection axes of the ecliptic and the fragment orbit are found from known parameters of the cometary fragment motion. The intersection points of the orbit and the ecliptic are calculated as follows. Fragment position coordinates in the ecliptic are found by the iteration method with a δt step. Of a set of points found, chosen are two adjacent ones for which z-coordinate changes its sign. The procedure is repeated untill δt exceeds the required accuracy (in this case 0.000001). The distance between the points obtained is very small, the curvature of an elliptical line is negligible and the section of this elliptical orbit can be identified with a straight line connecting two points. Then intersection coordinates of the straight line and the ecliptic are calculated. This algorithm has been used for all fragments the orbits of which are calculated within the parent body disintegration. The intersection region of a simulated complex and the ecliptic is plotted from the coordinates.

The usability of a given complex is provided by service buttons, realized in a control window. Their design and admissibility correspond to the principles common to this technology. Display options control the following operations:

- displaying of ascending and (or) discending nodes;
- displaying of planetary orbits;
- selection of the data obtained in simulating comet disintegration in the form of substance ejection rates and points which are to be used for icon generation;
- grid set up;
- prescription of the magnification ratio K for deviations in angular parameters of a fragment orbit ($\delta\Omega$, $\delta\omega$, δi) from a parent body orbit;
- displayng the coordinate at any orbital point in the graphic or table form by a database cursor;
- plotting the intersection regions for several returns of a parent body in one figure.

Figures 1–3 demonstrate some results for specific comets. Figure 1*a* shows a 3D image of the meteoroid complex formed in comet Halley disintegration in 1986 with ejection rates $0 < V < 1$ (km/s) at different orbital points of a parent body. Plotting is realized in the module "Visualization" with orbit imaging (above the ecliptic) of fragments ejected at the true anomaly U points from 120° to 180° at different rates. The Earth's orbit and the nodal line of a parent pody are also displayed.

Figure 1*b* presents intersection of the complex and the ecliptic for similar disintegration data. One node and two complex branches formed in comet disintegration are given. One branch corresponds to positive deviation values of fragment orbit parameters, another − to negative values. Every ejection point in the comet's orbit is in line with ten points in the ecliptic (one for each fragment orbit) obtained at different ejection rates. Longitude of the ascending node has the geatest impact on the complex structure in the ecliptic as it evidences the angle between a nodal line

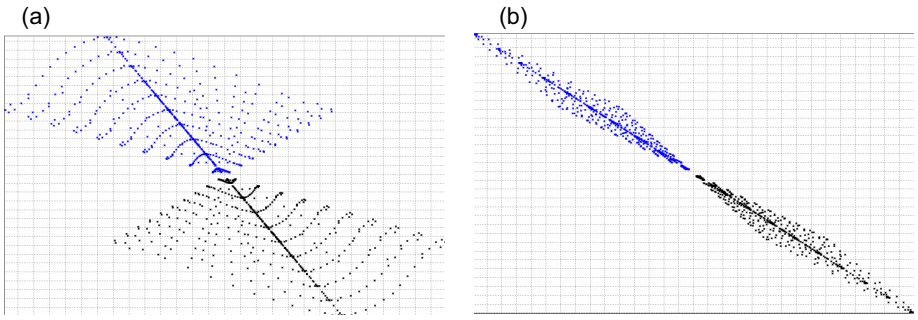


Figure 2 Expected intersection region of comet Pons–Winnicke meteoroid complex with the ecliptic throughout the orbit ($0^\circ \leq U \leq 360^\circ$): ($a$) magnification ratio K is 10; (b) magnification ratio K is 1.

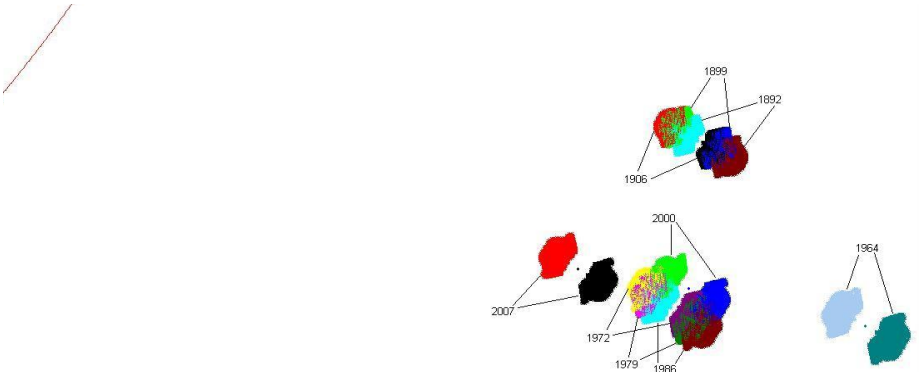


Figure 3 Intersection regions of simulated meteoroid complexes for nine Holme's comet returns.

and a direction to vernal equinox. Variations in longitude deviations of the ascending node $\delta\Omega$ of ejected fragments depend on true anomaly values at the ejection point. Most significant displacements in orbits are expected for the fragments formed when a parent body approaches the aphelion. Displacement in the lines of intersection (Fig. 1b) is in agreement with variations in $\delta\Omega$ values. This fact confirms the validity of plotted intersection regions. Figure 2 demonstrates the possibility of image scaling by increasing deviations in angular parameters of the fragment orbit. Here applied are the data obtained in simulating Pons–Winnicke comet disintegration throughout the orbit at ejection rates up to 10 m/s. The rate range is divided into 10 intervals. It is clear that Fig. 2a depicts the intersection point distribution of fragment orbits more obviously as compared to Fig. 2b and it is more suitable for the complex structure analysis. The ejection rate dependence of an orbit position is clearly followed (10 rate intervals are also used here).

The possibility of plotting several intersection regions in one figure is illustrated by nine returns of Holme's comet as an example; nucleus disintergation for these returns has been simulated from available data (Fig. 3).

This figure shows descending nodes located near the Mars's orbit. Two expected branches of a complex are presented for each return. This visual pattern allows one to analyze the expected movements of a comet and its simulated complex in some space region. In conclusion, the presented graphical form of a meteoroid complex structure may help in visual identification of potentially dangerous space regions where some meteoroid complex may approach the concrete planet's orbit or other object route.

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