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On figure of a sublimating cometary nucleus

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The problem of the change of the figure of a cometary nucleus when its matter is sublimating from the nucleus surface is considered. The sublimation intensity is taken to be proportional to the solar ray energy falling onto the nucleus surface facets in the unit of time. For the case when the axis of rotation of the nucleus is normal to the plane of the cometary orbit and the initial figure of the nucleus has a rotational symmetry the averaged equations in partial derivatives describing the changes of the form of the nucleus have been derived both for the cartesian and the polar coordinates. In the cartesian coordinates with x–y plane laying in the plane of the cometary orbit this equation is

$$\frac{\partial x(z,t)}{\partial t} = -A. \tag{1}$$

For the polar coordinates it looks as

$$\frac{\partial R(\alpha,t)}{\partial t} = -A \left(\cos\alpha + \sin\alpha \frac{1}{R}\frac{\partial R}{\partial t}\right). \tag{2}$$

In (1) and (2) A is the constant which depends on the properties of the sublimated material and the cometary orbital elements, x(z,t) is the distance of the point of the nucleus surface from the axis of the nucleus rotation (z-axis), R and α are the cometocentric distance and latitude of the point of the nucleus surface, correspondingly. The equation (1) has the unique solution satisfying the boundary conditions,

$$x(z,t) = x_0(z) - A(t - t_0), \tag{3}$$

where $x_0(z)$ is the function representing the figure of the initial meridian of the nucleus. Any initial figures of the cometary nucleus with rotational symmetry are admissible in (3) if for any permissible z exists only one (there must not be the selfshadowing effects).

Equation (2) is convenient to use when the initial nucleus has the spherical figure.

Its solution for this case is

$$R = \sqrt{R_0^2 - A^2(t - t_0)\sin^2\alpha} - A(t - t_0)\cos\alpha. \tag{4}$$

Using (3), (4) the estimates have been obtained for the time of life of the nuclei of comets moving in different orbits about the Sun.

The detailed numerical model describing the sublimation of matter from the cometary nucleus having general figure and rotation is developed and realized as well [1]. The numerical simulation of evolution of the dynamic state and some physical parameters has been done for the sublimating cometary nucleus. The evolution of the nucleus figure and rotational parameters is considered taking into account the dust component in the cometary matter.

The cometary nucleus is approximated by cones with the top in the centre of inertia of nucleus and bases on the cometary surface. Area, S, vector of orientation, $\mathbf{n}$, and thickness of dust layer, γ, are determined for each base. Two frames of reference have been used for orientation of these bases in space: the nonrotating Kenig's frame, OXYZ, with the origin in the center of inertia of the nucleus and rotating one, oxyz, rigidly connected with the nucleus and with the axes directed along the main axes of inertia. To connect these frames the matrix of rotation $\mathbf{P}$ is used.

Due to sublimation the nucleus loses matter mainly in the equatorial areas. When the polar areas of the nucleus contain a dense dust crust the equatorial ravine arises as a consequence of sublimation. The wideness of this ravine depends on the dust component distribution in the nucleus. The more dust is maintained by the nucleus, the narrower ravine appears. The nucleus gets the dumb–bell shape [2]. During the evolution this ravine becomes more and more deep and at last the nucleus disintegrates being broken along the ravine.

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References

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