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A consistent model of dusty innermost cometary atmosphere surrounding a non-spherical nucleus

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Physical properties of comets are apparently determined by its formation place and evolution. The primordial differences affect the sublimation occurring when a comet is heated by the Sun. The release of volatiles in turn influences the physical properties of the nucleus, e.g. forming a dust crust on the surface etc. Due to the high porosity and the presence of transparent ice solar light can penetrate to a substantial depth leading to volume energy absorption in the uppermost porous layer of a cometary nucleus [1,2]. As a result, vapor molecules escape from the non-isothermal upper sub-surface layer. Due to intermolecular collisions in the innermost coma the mass, impulse and energy backflows are formed. The nucleus and the innermost coma of an active comet constitute a interacting physical system and their physical properties develop in close symbiosis. Therefore correct thermo physical modelling of a comet cannot be restricted to the nucleus itself - the whole system must be considered simultaneously [3,4]. This motivated us to a revision of the conventional model of a cometary nucleus.

The following important aspects are now included: i) radiative energy transport in porous media; ii) energy transport by sublimation products; iii) heat and mass exchange between the nucleus and the innermost coma, iv) direct simulation Monte Carlo (DSMC) model of dust-gas flow in the innermost coma region [5,6]. The main attention in this work is paid to the investigation of the low density axisymmetric gas-dust flows in the innermost coma region. We consider various types of "activity" both for a spherical and non-spherical nucleus at different heliocentric distances. The corresponding boundary conditions at the nucleus surface are determined from a self-consistent thermal model of a cometary nucleus developed by the authors. Density, different types of temperature and velocity both for the gas and dust are calculated by parallel computer implementation of the kinetic model. The dust grains are simulated by spheres, irregular shaped Gaussian particles, as well as fractal agglomerates. The dynamics of these particles is explored by using the numerical results for the kinetic non-equilibrium gas model.

High porosity leads to a significant decrease of the effective gas flux of volatiles and, as a result, the total dust production decreases. More of the absorbed energy is available to be transferred into the interior of the nucleus. The dependence of the gas production rate on the heliocentric distance is different for comets of different morphology of the uppermost surface layers (e.g. for the comets with surface or layer energy absorption). We show that the spatial structure of inner-most dust-gas coma is sensitive to the nucleus shape as well as to the variations of local gas production rates. In general, spatial structure of the innermost coma (both gas and dust) is a result of interactions of gas flows sublimated from different surface regions. We conclude that the nucleus shape as well as physical properties of nucleus play the major role in formation of innermost coma.

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