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Mixing region over a surface of cometary nucleus with small-scale inhomogeneities. II Active spots on a less active background surface.

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Contemporary missions to comets allow reconstruction of the nucleus shape in a very high resolution. The real surface of cometary nucleus has complex topography and morphology which results in highly nonuniform gas emission even on a small spatial scale. Numerical simulation from the real surface considering all details is either impossible or excessively computationally expensive. In practice, the real surface is substituted by some ``effective" shape model suitable for numerical simulations but with less number of surface facets (i.e. with less resolution). Each of the surface facets, constituting the shape model separately is assumed to be homogeneous and having the averaged properties of the real surface, which it covers. The correctness of such representation (degradation) of the real surface was studied previously in [1] for the case of active spots on an inactive surface. The present study considers the active spots on the less active background surface.

In the present work we consider a pedagogic case – a spherical surface with surface gas production formed by (1) the gas emission q_i from a set of closely located (with interval L) spots (see Fig.1) with sizes l_i much smaller than the radius of the sphere R_n, and (2) the gas emission q_b from the surface outside the spots (i.e. the background).

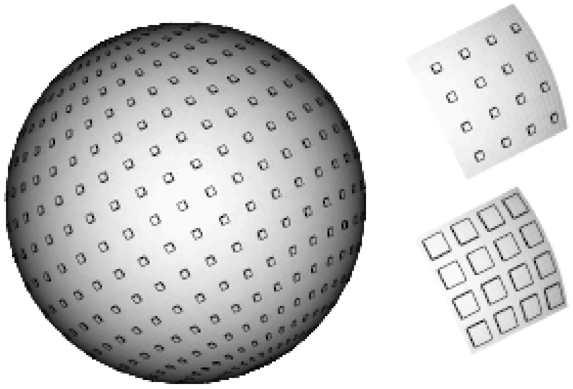

Fig.1. Distribution of active spots over the surface (two cases of active area are shown on the right)

Conventionally the flow from an inhomogeneous surface can be divided into two regions: (1) a mixing region; and (2) a uniform flow. The flow in the mixing region is multidimensional i.e. with variation of parameters not only along the radial direction. The uniform flow is a result of viscous dissipation of the flow in the mixing region and it is one dimensional with variation of parameters along the radial direction only (as it would be in the case for the expansion from a homogeneous sphere). We study the structure of the flow in the mixing region for different combinations of l_i, L, q_i, q_b and define parameters of the resulting uniform flow. Due to a large number of spots it is possible with sufficient precision to restrict the computational domain as shown in Fig.2.

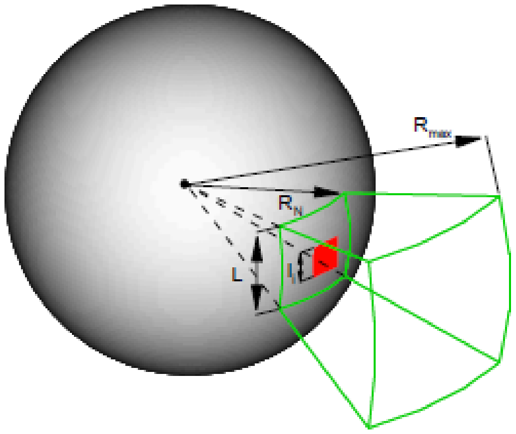

Fig.2. Computational domain (the layout is made not to scale): green lines show the boundaries, the active spot is shown in red.

In the present study the postulated production rates and relative activity of the background are $10^{21}<q_i<1.5\cdot10^{22}$ [$m^{-2}s^{-1}$] and $0.01<q_b/q_i<0.3$ respectively. A specific model of gas production is not critical in this study since it serves only to determine realistic values of q_i and q_b.

Results of the simulation show that for the production rates q_i under consideration have the flow rarefaction in the vicinity to the spots corresponds to Kn_L=0.03-0.0002. The flow in the vicinity of the surface has complex spatial structure -- it contains multiple shocks leading to the non-monotonous and periodic variation of flow parameters (see example in Fig.3). The dispersion of the flow parameters in cross-sections perpendicular to the radial direction is evaluated to define the distance when the flow from an inhomogeneous surface can be considered homogeneous.

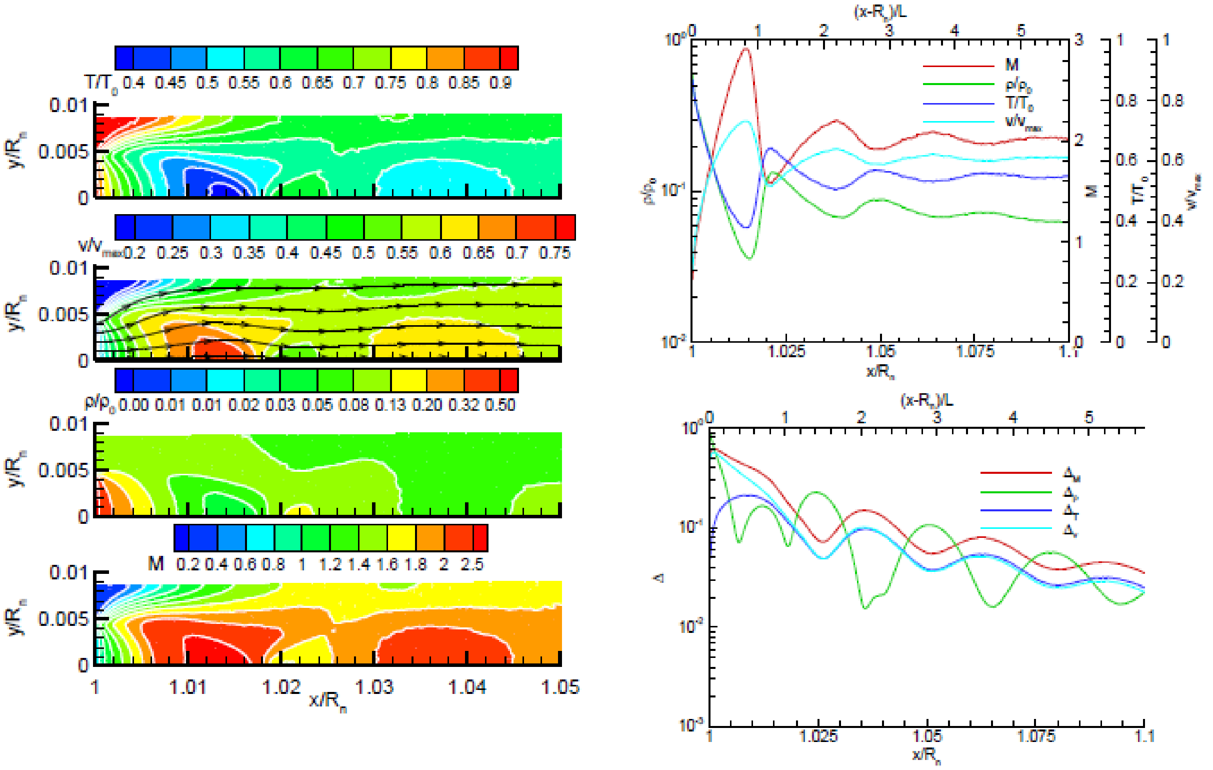

Fig.3 Case l_i/L=0.5, q_b/q_i=0.07, Kn_L=0.001: the distribution of flow parameters (temperature, velocity, density, Mach number) in the plane of symmetry (left) and along the radial direction (top right). Dispersion of the Mach number (ΔM), density ($\Delta\rho$), velocity (Δv) and temperature (ΔT) in cross-sections perpendicular to the radial direction (bottom left).

In comparison with previously studied cases with a completely inactive background (see [1]), the presence of the background gas production prevents free expansion of the flow from the spot and decreases the rarefaction of the flow.

Conclusions:

Introducing the background gas production does not change significantly the scales and conditions when the flow from an inhomogeneous surface becomes effectively homogeneous found for the case with an inactive background.

The altitude above the surface *h*, where the flow becomes practically uniform (dispersion <5%), is between 1 and 10·*L* (depending on the rarefaction). This puts a limit on the spatial resolution of the effective surface.

The flows from inhomogeneous and homogeneous surfaces with the same surface temperature and total gas production rates are not equivalent (i.e. parameters of the resulting uniform flow are not the same as parameters in the flow from homogeneous surface at the same distance). This non-equivalence is more pronounced for the less rarefied flows.

For the substitution of the flow from an inhomogeneous surface by the flow from effective surface we provide the position of the sonic surface and the distribution of parameters on it for a broad range of conditions.

In the mixing region, the gas flux from active spots accelerates very fast to the velocities significantly higher than in the flow from a homogeneous surface. In the range of the background relative activity $0.01<q_b/q_i<0.3$ the flow has a strong lateral component of the velocity in the vicinity to the surface. This has an important impact on the dust velocity (radial and transverse), systematically larger than usually computed, due to a ``kick’’ (i.e. intensive acceleration on a short scale) in the mixing region.

Acknowledgments

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References

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