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3D modeling of cometary dust jets, from the nucleus surface to infinity

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Abstract

Cometary dust comae are not isotropic but often display narrow features extending radially away from the nucleus or appearing as arcs, spirals, or shell patterns. These features detected in ground based observations have generally been interpreted as signatures of dust emitting sources on the surface of the rotating nucleus ([1]). This was later confirmed by in-situ observations by several missions which described in details the dust features and in some cases could link them to specific regions of the surface (see [2] for a review).

The mechanism leading to the formation of the jets can be divided in two phases. First, sublimation of ices in the subsurface or on the surface creates gas which expands in the vacuum and drags along the dust grains. This acceleration zone expands for at most a few nucleus radii. In the second phase, the gas density becomes too low to allow efficient acceleration of the dust, and the motion of the grains is totally decoupled from the gas. Dust particles are then mostly affected by the solar gravity and radiation pressure, and follow a ballistic trajectory.

This second phase of jet creation is well understood and several authors have proposed models that reproduce well the geometry and dynamics of the jets in ground based images, and allow to derive important physical parameters for the dust out of the acceleration zone. On the other hand, the physics of jets formation close to the surface are still poorly constrained. The link between the two phases is done through empirical laws giving an estimate of the size and velocities distribution at the end of the acceleration layer, but very little is known about the mechanisms leading to these distributions.

In support of the Rosetta mission, which will orbit comet 67P/Churyumov-Gerasimenko in 2014/2015, we are developing a numerical model describing the formation and evolution of dust jets from the nucleus surface to infinity. The OSIRIS camera system on board Rosetta will track the jets and observe the active regions with a spatial resolution as good as a few cm/px and we need to be able to describe the gas/dust interaction at this resolution. Several versions of our code COSSIM (COma Structures SIMulator) have been presented and published over the last years ([3], [4], [5]), and we have shown that we can describe accurately the ballistic phase of the jets. We are now upgrading the model to simulate the earliest phase of jet formation. For this purpose we develop a full 3D description of the gas flows in the active regions. The model is able to take into account all kind of complex topography, from craters to cliffs, or subsurface reservoirs, at different scales. We consider as well the surface temperature, the dust and ice layers porosity, the presence of several different ices species, and different gas flows in the same regions.

We will present the first results from our model, mainly focusing on three test cases that could possibly form a jet:

1. Farnham et al ([6]) and Vincent et al ([3]) have linked some the Tempel 1 jets to the edge of one of the smooth regions, where a cliff has been seen to recede from 2005 to 2011. We propose a 3D model of the jet starting from the cliff (Fig. 1 & Fig. 2).

2. An impact can excavate the dust layer and reveal ice underneath. We model the sublimation starting at the bottom of the crater (Fig. 3).

3. We discuss the possibility that sublimation takes place below the surface and gas escapes through cracks. Many small jets can be formed this way and later merge into a larger collimated structure.

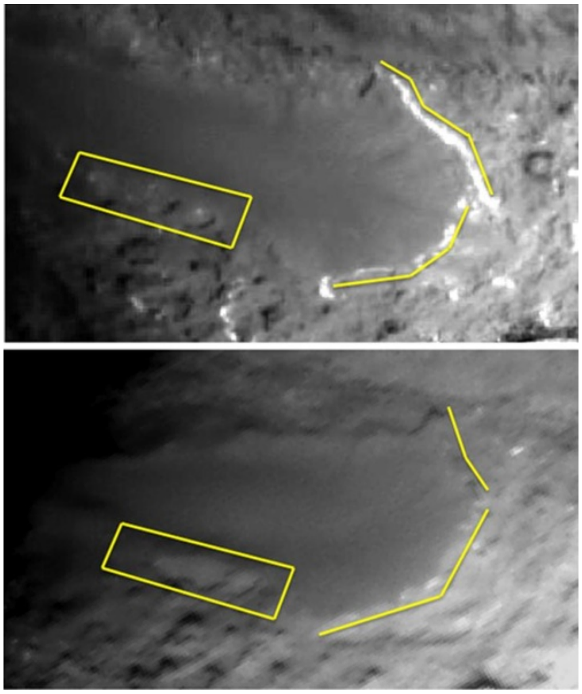

Figure 1: Close view of a cliff on the nucleus of comet 9P/Tempel 1, which is believed to be the source of some of the dust jets. Top panel is an image from Deep Impact acquired in 2005, bottom panel shows the same area observed by Stardust-NeXT in 2011. Changes in topography on the order of 20-30m have been observed in this region. Source: Deep Impact/Stardust-NeXT teams

References

[1] Sekanina, Z. et al, Anisotropic emission from comets: Fans versus Jets. I. Concept and modelling, 1987, ESA SP-278.

[2] Belton, M., Cometary activity, active areas, and a mechanism for collimated outflows on 1P, 9P, 19P, and 81P, 2010, Icarus 210.

[3] Vincent, J.-B. et al, A numerical model of cometary dust coma structures: application to comet 9P/Tempel 1, 2010, A&A, 512, A60

[4] Lin, Z.-Y. et al, Physical studies of 81P/Wild 2 from the last two apparitions, 2012, A&A, 537, A101

[5] Vincent, J.-B. et al, Spin and activity of comet 67P/Churyumov-Gerasimenko, 2012, A&A, submitted

[6] Farnham, T. et al, Dust coma morphology in the Deep Impact images of Comet 9P/Tempel 1, 2007, Icarus 187.

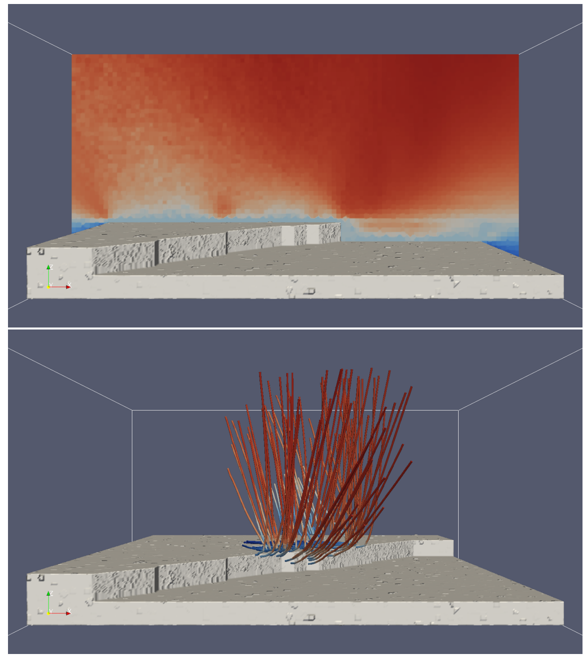

Figure 2: Top panel: simulated cliff, with a 2D slice of the 3D gas flow. Colors from blue to red represent the velocity of gas molecules. Bottom panel: same view with stream lines indicating the 3D trajectories of molecules in the gas flow.

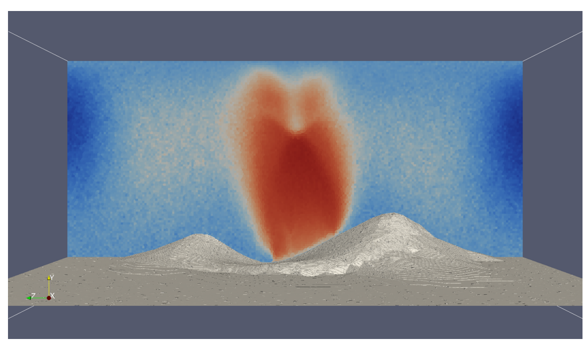

Figure 3: 3D view of a crater with an active gas-emitting floor. The 2D slice shows the distribution of gas velocities at the onset of the jet.