

# Jet activity on the cliffs of comet 9P/Tempel 1

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## 1. Motivation

Understanding how the activity of comets develops and how gas and dust flows are linked to the topography is one of the main challenges of cometary research. The dust coma is known for being anisotropic, displaying many jet-like structures, and in situ missions have revealed that these features can often be associated to specific regions on the surface of the nucleus. A good model of these areas is necessary to understand not only the activity itself, but also how the morphological features of the surface are affecting the physical processes taking place, and inversely constrain the effects of the activity on the local surface.

## 2. COSSIM

Over the last 5 years we have developed and presented the numerical code COSSIM (COma Structures SIMulator), a tool which aims to reproduce the gas and dust jets at all scales, from ground based observations to detailed in-situ images ([2, 4]). In the context of the Rosetta mission, en route to comet 67P/Churyumov-Gerasimenko, we have upgraded the code to be able to take into account the full 3D description of the gas flows above active areas. The OSIRIS camera system on board the spacecraft will track the jets and observe the surface with a spatial resolution as good as a few cm/px; we need to be able to describe the gas/dust interaction at this resolution. The new model can handle 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.

## 3. The cliff of 9P/Tempel 1

The current work focusses on simulating at high resolution the activity seen on a peculiar terrain of 9P/Tempel 1. From in-situ and ground based observations, [1] and [4] have linked some the coma structures 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.

The simulated domain is a cube of 400x400x400 meters size, with a 3D topographic model of the region at the bottom, reconstructed from in situ images. The outgassing rate is modulated by the solar input, through a thermal model of the surface. We allow the vertical cliff to emit up to 10 times more gas molecules than its surroundings, for the same solar flux received. We model first the expansion of the gas until we reach a steady flow. We inject dust particles with zero velocity in the gas flow and follow their acceleration in the jet.

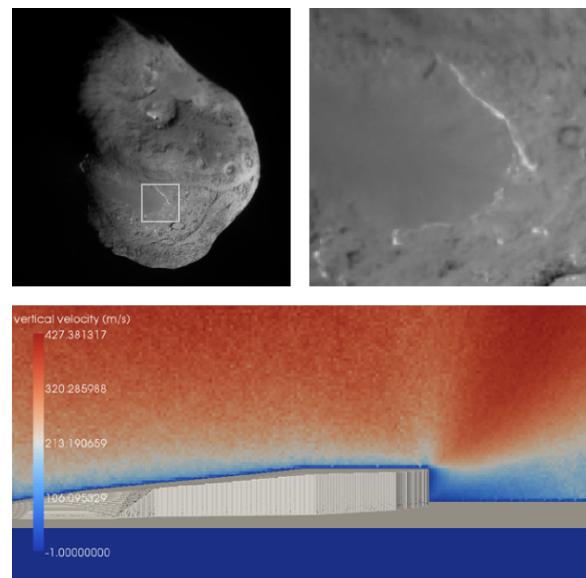


Figure 1: Close view of a cliff on the nucleus of comet 9P/Tempel 1, which is believed to be the source of some of the dust jets and where changes in topography on the order of 20-30m have been observed. Bottom panel shows the simulated cliff, with a 2D slice of the 3D gas flow. Colors from blue to red represent the velocity of gas molecules.

## 4. Preliminary results

- Even when starting from vacuum, a steady gas flow is reached very rapidly, in 25 seconds at most. The changes of solar input and temperature are negligible on this time scale.
- The gas flow is accelerated until it reaches a terminal velocity of about  $1000 \text{ m.s}^{-1}$  which seems to be independent from the outgassing rate.
- The common assumption that gas expands perpendicularly to the average local surface is not verified in that case. The strong change of topography induces a shock front at the top edge of the cliff and we measure a deviation of up to 20 degrees from the average local surface normal.
- Dust particles injected in the flow were selected in the size range  $10 - 100 \mu\text{m}$ , following a decreasing power law (exponent = -2.5) and were spherical in shape. First results indicate a maximum velocity of a few 10s of  $\text{m.s}^{-1}$  at a distance of 1 nucleus radius. So far only a simple drag force model, local gravity, and radiation pressure were considered to calculate the acceleration of the grains. We are refining the simulations to include fractal aggregates.

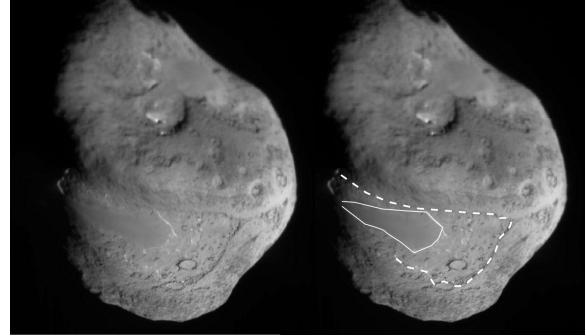


Figure 2: Is the dotted line showing the former extent of the smooth area (solid line) ? By studying the activity we try to constrain the evolution of the surface in this region of 9P/Tempel 1.

## References

- [1] Farnham, T. et al, Dust coma morphology in the Deep Impact images of Comet 9P/Tempel 1, 2007, *Icarus* 187
- [2] Vincent, J.-B. et al, A numerical model of cometary dust coma structures: application to comet 9P/Tempel 1, 2010, *A&A*, 512, A60
- [3] Vincent, J.-B. et al, 3D modeling of cometary dust jets, from the nucleus surface to infinity, European Planetary Science Congress, Madrid, Spain, Sep 23-28, 2012
- [4] Vincent, J.-B. et al, Spin and activity of comet 67P/Churyumov-Gerasimenko, 2012, *A&A*, January 2013, 549, A121

## 5. Conclusion

This work is a continuation of what we presented at EPSC 2012, where we have shown several simulations for well defined test cases (i.e. activity above fresh impact crater, or cometary "tiger stripes" model, see [3]). We focus now for the first time on a real surface for which there is in situ evidence that activity took place from one orbit to the other. We can bring important constraints on the physics of this region, and understand which parameters rule the formation of the observed dust and gas structures. We will discuss as well the implications on the surface: the activity is modulated by the topography, but at the same time the topography evolves due to the activity and our model supports the understanding of the processes involved.