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

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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.

COSSIM

Over the last 5 years we have developped 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 ([1], [2]) 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.

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, Farnham et al ([3]) and Vincent et al ([2]) 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.

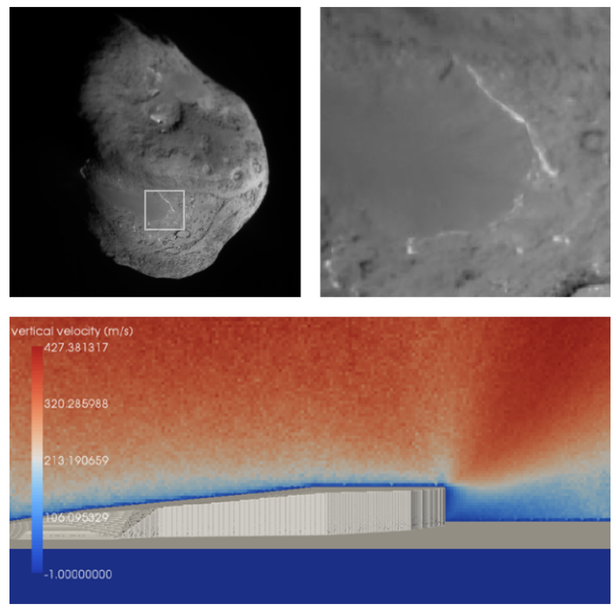

Figure 1: Close view of a cliff on the nucleus of comet 9P/Tempel 1, which is believed to be the source of some of the dust jets and where changes in topography on the order of 20-30m have been observed. Bottom panel shows the simulated cliff, with a 2D slice of the 3D gas flow. Colors from blue to red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

Preliminary results

- A steady gas flow is reached very rapidly, 2 or 3 seconds at most. The changes of solar input and temperature are completely negligible on this time scale.

- Depending on the location with respect to the jet, the gas flow reaches a terminal velocity of 500 to

1000 $m.s^{-1}$. this value is independent form the outgassing rate.

- The common assumption that gas expands perpendicularly to the average local surface is not fully valid here. 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 local normale.
- Dust particles injected in the flow were selected in the size range $10-100\mu m$, following a decreasing power law (exponent = -2.5) and were sphercial in shape. First results indicate a maximum velocity of a few 10s of $m.s^{-1}$ 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.

Conclusion

We have presented several times similar studies for well defined test cases (i.e. activity above fresh impact crater, or cometary ”tiger stripes” model, see [4]) but this simulation describes for the first time a real surface for which there is in situ evidence that activity took place from one orbit to the other. With our model 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.

References

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