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Are fractured cliffs the major source of cometary dust jets ? Evidence from Rosetta at 67P

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Abstract

Dust jets, i.e. fuzzy collimated streams of cometary material arising from the nucleus, have been observed in-situ on all comets since the Giotto mission 30 years ago. Yet their formation mechanism remains unknown. Several solutions have been proposed, from localized physical mechanisms on the surface/subsurface (see review in [1]) to purely dynamical processes involving the focusing of gas flows by the local topography [2]. While the latter seems to be responsible for the larger features, high resolution imagery has shown that broad streams are composed of many smaller features (a few meters wide) that connect directly to the nucleus surface. We show here observational evidence that jets of comet 67P arise from fractured cliffs and describe the physical processes involved, which may explain jet-like activity on all comets.

Sources of fine jets on 67P

The OSIRIS cameras on board ESA's Rosetta give us for the first time the possibility to image these features at a spatial scale better than 30 cm/px, and to monitor their evolution over many months. We summarized here our findings for the epoch August 2014 (3.6 AU) to March 2015 (2.0 AU), when only the Northern hemisphere of comet 67P was illuminated.

Using many images of jets, taken from different angles, we triangulated the position of their footprints on the nucleus. We observed a strong correlation between active sources and sub-solar latitude. Large scale jets sources (a few tens of meters diameter) have been steadily migrating southward since August 2014, always remaining in a latitude band centered on the sub-solar point. This type of activity also seems to start and stop with the terminator crossing the area; the switch on/off time uncertainty is given by our imaging cadence of one observation every 20min. We interpret this as jets being solely driven by solar illumination, with no sub-surface heat source involved.

Jet sources are not evenly distributed within the active latitude band. Detailed inversion of the smallest features shows a clear correlation between jets and fractured cliffs. We do not detect activity arising from smooth surfaces. This is particularly striking in Seth and Ma'at regions where we unambiguously linked dust jets to the fractured walls of active pits and cliffs (Fig. 1) [3].

These active walls show similar morphologic features independently of their location on the nucleus. They are fractured and present signs of ongoing erosion. Large debris fields can be observed below the cliffs, interpreted as blocks falling down from the wall. Cliffs upper edges display mass wasting features, with the upper dust layer seemingly flowing down as the edge of the cliff collapses (Fig. 2). These granular flows expose underneath fractured terrains, indicating that cracks propagates inwards and not only on the surface.

Jet formation and surface evolution

We interpret this morphology as a the signature of a multi steps activity mechanism:

1. Cliffs are first fractured by mechanical or thermal processes [4]

2. Fractures propagate into a matrix of dust and ices

3. Cracks allow the diurnal heat wave to penetrate deeper into the surface, reaching volatiles otherwise insulated

4. Cracks act as nozzles, effectively accelerating and focusing the gas flows to the level needed to lift off dust particles seen in the jets

5. The combination of continued cracking and expanding gas flows weakens the structural in-

tegrity of the cliff, leading to collapse of the wall and mass wasting on the cliff table

6. The cliff continues to retreat until all volatiles are exhausted.

A general mechanism

The process described above is supported by observational evidence on comet 67P, for instance the continued degradation of the cliffs and expansion of granular flows. We believe, however, that it is much more general and apply to all comets. Other authors have linked jest to ragged surfaces on comets 81P/Wild 2 [5], 9P/Tempel 1 [6], and 103P/Hartley 2 [7], but lacked the spatial resolution to describe the smallest jets. Because these regions are very similar to 67P on the large scale (cliffs, pits, no activity from smooth areas) we suspect that their jet activity and surface evolution is driven by the same processes as on 67P.

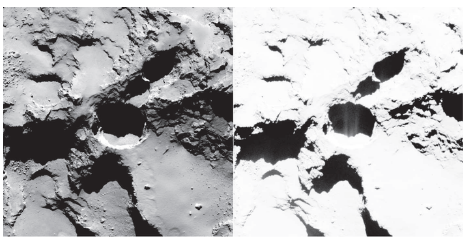

Figure 1: Tiny jets arising from the fractured edge of a 200 m diameter pit.

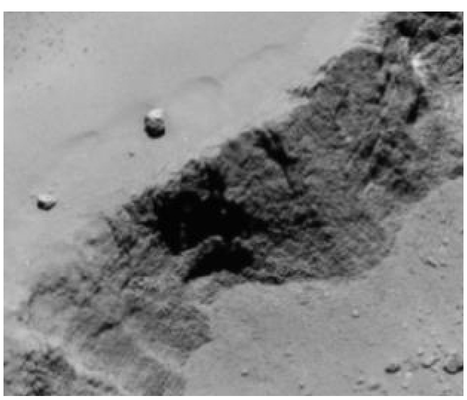

Figure 2: Wall collapse and mass wasting features on an active cliff.

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