Season-Driven Surface Evolution in Comets

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Physics of comets after the Rosetta mission: Unresolved problems
5 Sep 2018 / Stará Lesná, Slovakia

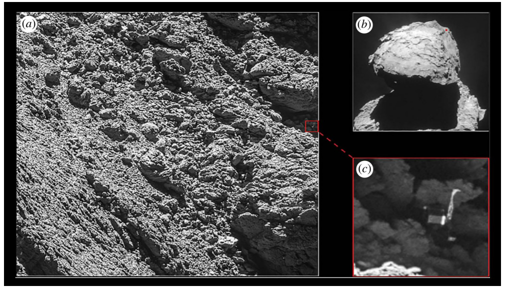
67P: Surface dichotomy

Rosetta images of comet 67P/Churyumov-Gerasimenko show a remarkable surface texture difference between the two hemispheres: smooth northern latitudes versus rough southern latitudes (Thomas et al. 2015, El Maarry et al. 2016).

Thomas et al. 2015:
Smooth terrain.

Fig. 7. High-resolution image of smooth terrain in the Ash region. The image scale is around 14 cm/px (nominal scale ≈17 cm/px when calcu-

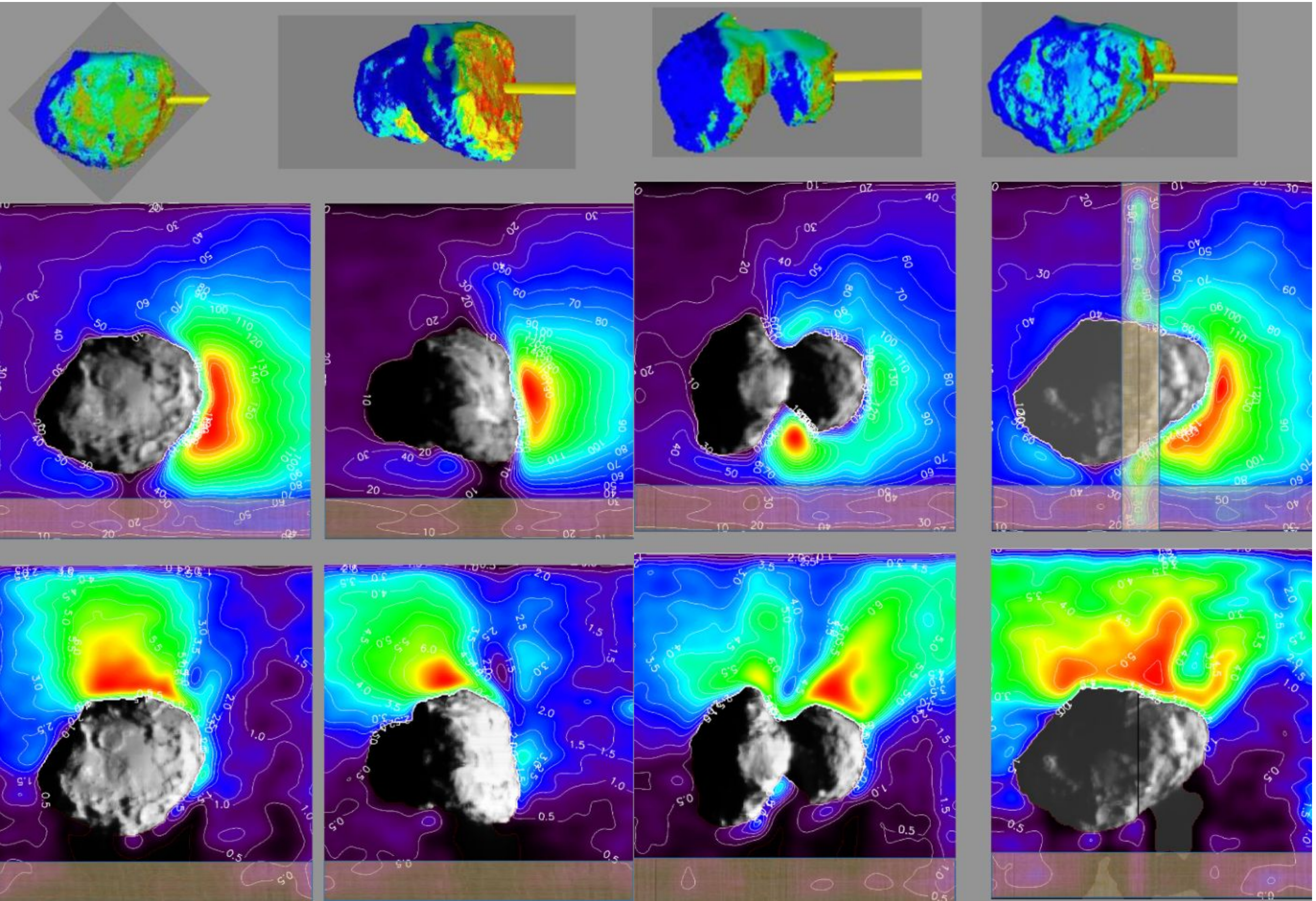
Boehnhardt et al. 2017:
Rough terrain.



The surface differences are correlated with coma composition, indicating the different terrains have different compositions: e.g., the smooth terrain is depleted in CO2 and CO (Fink et al. 2016, Fougere et al. 2016).

The surface and coma dichotomy is the product of mass transfer. Large particles lifted from the southern hemisphere during its intense summer season may fall back onto the northern hemisphere in deep winter.

Surface dichotomy → coma heterogeneity



Rosetta/VIRTIS-M coma maps,
April 2015, 1.8 au

Illumination

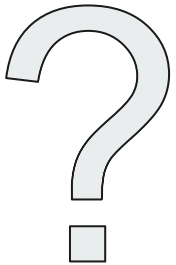
Water: sunward

Carbon Dioxide: produced from a specific surface area

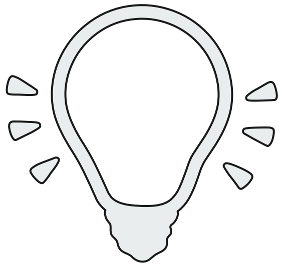
Fink et al. 2016

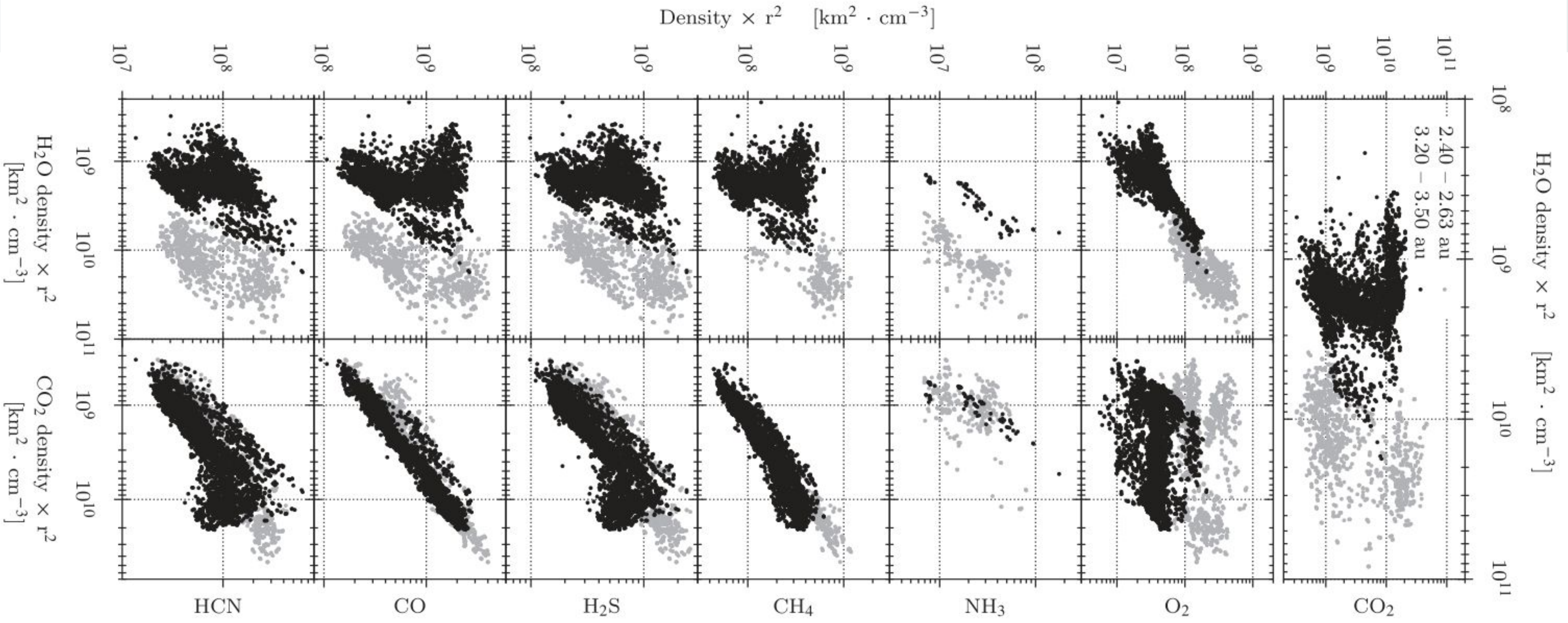
Coma heterogeneity and surface evolution

Is the 67P scenario common or rare in the comet population? To address this question, we first consider coma heterogeneity and find that there are opportunities to identify heterogeneous comet surfaces via the near-infrared.



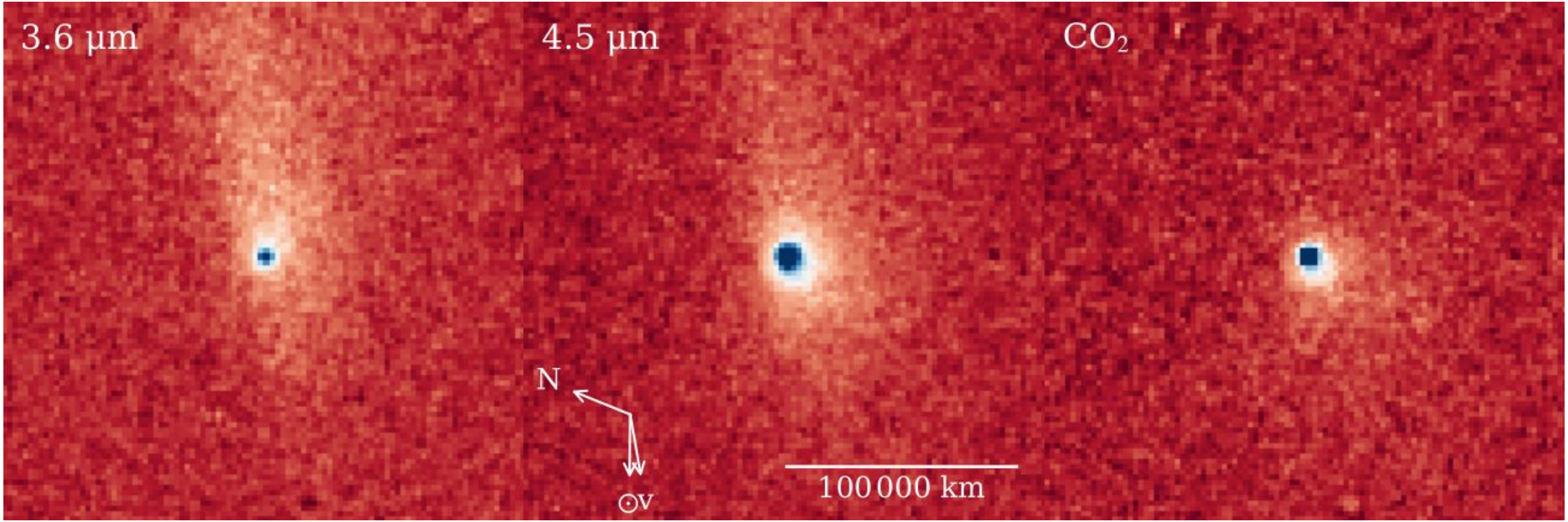
We compared compositional results from ROSINA and VIRTIS (e.g., Bockeleé-Movan et al. 2016; Gasc et al. 2017) with those from other comets as observed with ground-based telescopes (e.g., Dello Russo et al. 2016).





ROSINA/DFMS gas correlations around equinox (Gasc et al. 2017), 1 Jan to 1 Aug 2016, 2.0 to 3.5 au.

Ground-based near-IR taxonomies and the coma heterogeneity of 67P are compatible with each other. This suggests that the correlations of 67P's minor species with H2O and CO2 are common in the comet population.



3.6 µm = dust

4.5 µm = dust+CO2

4.5 - 3.6 µm = CO2

Spitzer Space Telescope images of comet 67P showing CO2 asymmetry at 3 au (Snodgrass et al. 2017). These data are part of an imaging survey of CO2 in comets (Kelley et al. in prep).

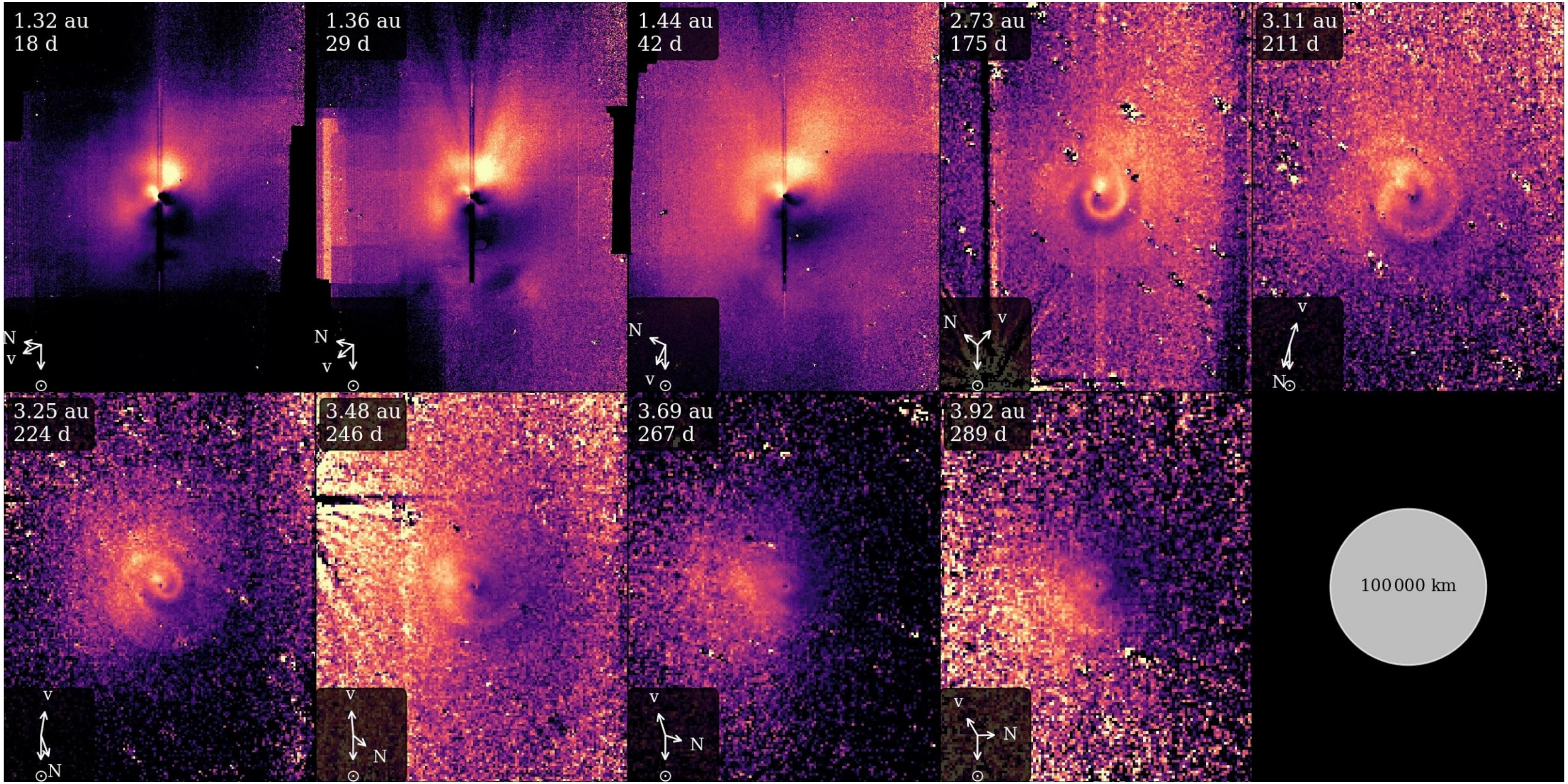
The asymmetry is not sunward, indicating nucleus active area (the southern hemisphere) is an important aspect of coma appearance in telescopes (cf. Fink et al. 2016). Such coma asymmetries are common in our data set.

Find comets with strong seasons

67P's high obliquity and the approximate alignment of the rotational pole with perihelion conspire to produce a strong southern summer. This effect, in turn, evolves the surface. We performed a literature search for all comet pole orientations: 18 moderately precise estimates (30° uncertainty or better).

Compute **obliquity**: obliquity closer to 90 makes stronger seasons.

Compute **true anomaly of solstice** for the positive pole: closer to 0° / 180° makes for stronger seasons.



In addition, our Spitzer survey of comets should allow us to derive 7 more pole orientations. Above, enhanced images of C/2014 Q2 (Lovejoy) show CO2-gas spirals that will be used to derive the pole (Kelley et al. 2017, Kelley et al. in prep).

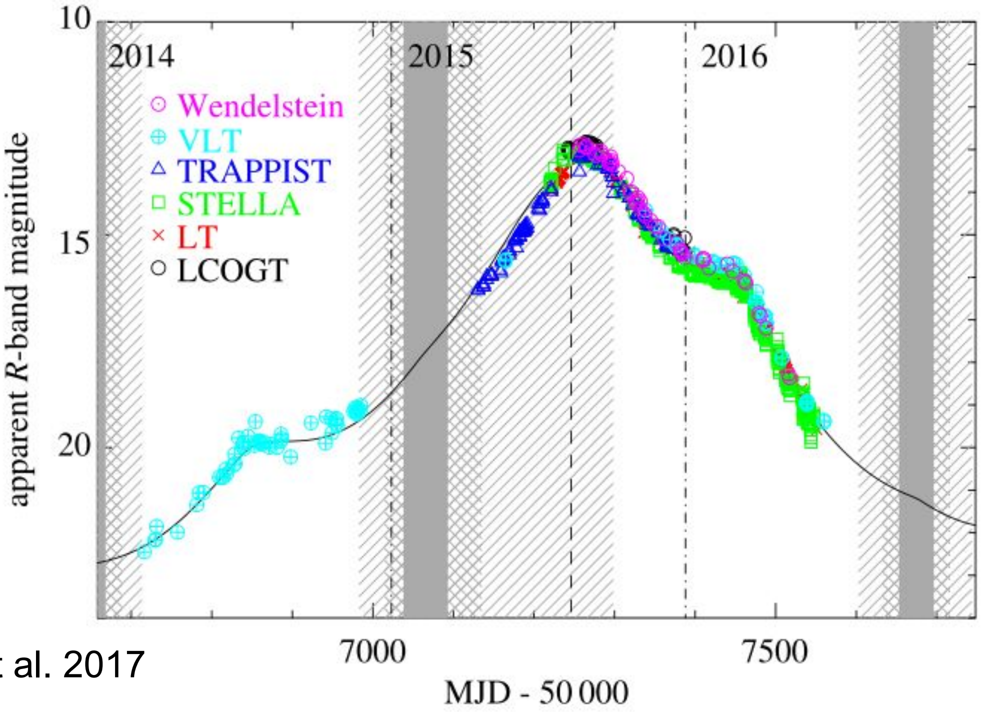
Requirement: Large particle fallback

67P's smooth terrain is composed of large particle fallback, millimeter-sized and larger (Mattola et al. 2015).

For comets that may have strong seasons, we estimate a_{crit}, (Meech and Svoren 2004) the largest sized particle that can be ejected (idealized comet nuclei!). Comets that can lift similar sized particles as 67P might produce similar smooth terrains.

Indirect method: Perihelion activity offsets

Activity or non-gravitational forces do not always peak at perihelion. This is a potential consequence of strong seasons.



Snodgrass et al. 2017

67P has an offset of +35 days in the non-gravitational forces (NASA JPL) and Seiichi Yoshida's lightcurve offset is +40 days. Snodgrass et al. (2017) put the peak of activity at +14 days.

We searched the JPL orbit database for comets with non-gravitational forces offset from perihelion and with perihelion insize of 2 au: 11 comets without estimated poles.

Figure 10. Total *R*-band magnitude of the comet, compared with prediction from previous orbits (solid line). Solar elongation is indicated with hatching as in figure 1. (Online version in colour.)

Conclusions

After considering pole orientation and/or non-gravitational offsets, and estimating the a_{crit} parameter, we have a preliminary list of 10 comets that should be examined more closely for strong cometary seasons and coma heterogeneity.

Improving or verifying the rotational poles will determine if the seasons are 67P-like.

Measuring the coma composition of these comets and its potential correlation with hemisphere is a first test for 67P-like mass transport in the comet population.