EPSC Abstracts
Vol. 11, EPSC2017-784, 2017
European Planetary Science Congress 2017

Seasonal variations of the source regions of the dust jets of comet 67P/Churyumov-Gerasimenko

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Abstract

Because of the gas drag effect, dust grains usually accompany the outgassing process of cometary nuclei. The close-up imaging observations of comet 67P/Churyumov-Gerasimenko showed that the dust coma was filled by numerous narrow jets emanating from the nucleus surface. This means that they can be used to trace the time variation of the gas sublimation regions as the comet moved around the perihelion. Making use of the comprehensive imaging data set provided by the OSIRIS scientific camera, we show in detail how the foot points of the dust jets and hence the outgassing zone would move in consonance with the sunlit belt. Furthermore, a number of source regions characterized by frequent jet activity could be identified which might be the result of local topographical variations or chemical heterogeneities.

1. Introduction

The detailed imaging observations of comet 67P/Churyumov-Gerasimenko showed that its solar radiation driven outgassing behavior was controlled by the its bi-lobate structure of the comertary nucleus and the obliquity of 52° [1]. During the early part of the inbound orbit, only the northern hemisphere was illuminated. The subsolar point gradually shifted from north to south until the equinox on May 10, 2015. Since then the southern hemisphere became more and more active. Even though the time interval of the southern surface heating is short in comparison to the orbital period, the corresponding sublimation process has major effect on the evolution of the geomorphology of the comet itself. This means that the time evolution of the dust coma structure as traced by the total brightness and the fine structures could provide important information to this key process. During the monitoring phase of the Rosetta mission in 2014, the formation and source regions of collimated dust jets from the Hapi region were documented [5],[6],[7]. The OSIRIS observations afterwards until the end of mission in September, 2016 provide a very rich data set to examine the global phenomenon of jet formation and the corresponding time evolution.

2. Method

The standard technique used to identify the narrow dust jets and their footpoints has been applied to the characterization of the jet source distribution in several comets including comet 67P [6],[8]. After finding a jet in an OSIRIS image, the 2D image plane can be transferred to the 3D cometary rotating frame by using SPICE. The jet source should be in the plane perpendicular to the image plane containing the jet. If the same jet was observed in two sequential images taken at different viewing angles, the intersection of the two perpendicular planes to the surface defined by the SHAP5 shape model [9] will give the 3D orientation of the jet and the location of its source region.

3. Result

Figure 1 shows a surface density map of the 1584 jet sources produced by summing up all the data points by assigning a facet to be active if it is within 200 m of a jet foot point. What we see is that the northern part is less active except for the Hapi region and that a number of localized hot spots in the southern part suggesting the higher frequency of dust jet formation. In order to examine the dependence of gas sublimation rate (Z) on the local time (LT) and solar zenith angle (SZA), we have extracted numerically the LT and SZA value of the facets with jet activity. Figure 2 illustrates the LT and SZA distribution of the jet source regions. It is clear that Z follows closely the trends of the local time and solar zenith angle.

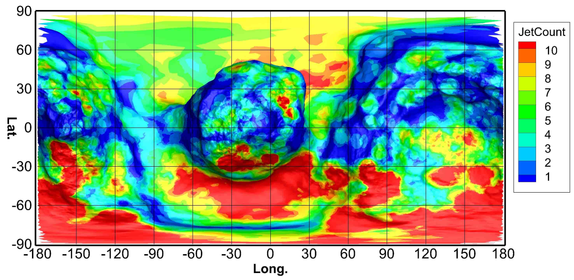

Figure 1: The surface density distribution of the 1584 jet source locations identified in our image analysis and ray-tracing calculation.

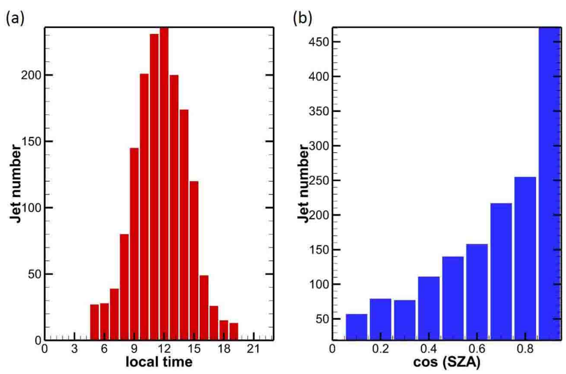

Figure 2: (a) The local time distribution of the jet sources, and (b) solar zenith angle distribution of the jet sources in our study.

4. Conclusions

We have examined the time evolution of the spatial distribution of the dust jet sources from September, 2014, to March, 2016. The observational results are very much in agreement with the idea that the surface sublimation process of comet 67P depended mainly on the local time and, alternatively, the solar zenith angle. It is reasonable to assume that the dust jet activity tracked closely the gas emission. The surface of comet 67P appears to be devoid of intrinsically inactive regions from this point of view. The shape, however, is the main driver for dust jets, as once the gas is released, the flow will be focused by the local topography. This is the main reason why jets footprints tend to fall on cliffs/pits/alcoves.

Acknowledgements

OSIRIS was built by a consortium led by the Max-Planck-Institut fűr Sonnensystemforschung, Göttingen, Germany, in collaboration with CISAS, University of Padova, Italy, the Laboratoire d'Astrophysique de Marseille, France, the Instituto de Astrofísica de Andalucía, CSIC, Granada, Spain, the Scientific Support Oce of the European Space Agency, Noordwijk, Netherlands, the Instituto Nacional de Técnica Aeroespacial, Madrid, Spain, the Universidad Politéchnica de Madrid, Spain, the Department of Physics and Astronomy of Uppsala University, Sweden, and the Institut fűr Datentechnik und Kommunikationsnetze der Technischen Universität Braunschweig, Germany. The support of the national funding agencies of Germany (DLR), France (CNES), Italy (ASI), Spain (MEC), Sweden (SNSB), and the ESA Technical Directorate is gratefully acknowledged. This work was also supported by grant number NSC102-2112-M-008-013-MY3 and NSC 101-2111-M-008-016 from the Ministry of Science and Technology of Taiwan and grant number 017/2014/A1 and 039/2013/A2 of FDCT, Macau. We are indebted to the whole Rosetta mission team, Science Ground Segment, and Rosetta Mission Operation Control for their hard work making this mission possible.

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