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Observing and modeling the near-nucleus coma structure around terminators on 67P/Churyumov-Gerasimenko

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Abstract

We present analysis on the structure of near-nucleus coma of comet 67P/Churyumov-Gerasimenko using imaging data from OSIRIS camera on-board Rosetta spacecraft. The emergence and cease of dust jets on diurnal time scale show that dust emission starts instantly upon sunrise, while diminishes gradually after sunset. Local gas field around terminators are modeled using 3-D Direct Simulation Monte Carlo with boundary condition provided by thermal models. Simulation results reveal that fine structures in the water gas coma form immediately upon local sunrise, that correlates well with jet-like features in the dust field. Modeling the trajectories of dust particles provide further insight into the ejection scenario, initial velocity and collimation of dust ejecta.

1. Introduction

Observing and studying the inner gas- and dust-comae of comets is the key to understanding cometary activity. The inner comae are the link between the sources of cometary activity on the nucleus and the outer-coma or tail structures that are extensively observed via ground-based and space-borne telescopes from afar. Analyzing the dynamics of gas and dust in the near-nucleus regime sheds light on the nucleus properties, the mechanisms of volatile sublimation as well as dust release. However, the cometary nuclei and their ambient dust coma structures could not be resolved until 1986, when spacecraft Giotto, Vega 1 and 2, observed comet 1P/Halley during the close flybys. Since then, spacecraft data of increasing spatial resolution and time coverage have been gathered of several comets, with the most recent and most comprehensive dataset acquired by Rosetta, the European Space Agency's rendezvous and landing mission to the Jupiter Family Comet 67P/Churyumov-Gerasimenko (hereafter 67P).

As observed by various Rosetta instruments, the near-nucleus comae of 67P exhibit complex visual structures that may reflect local variations of number densities of gas molecules and dust ejecta [1, 2, 3]. However, given the odd shape of the nucleus and uncertainty in physical properties, it is often difficult to connect coma structure directly with distribution of activity on the nucleus. Significant effort has been put into modeling the global gas and dust comae via state-of-the-art 3-D Direct Simulation Monte Carlo (DSMC), for interpreting in situ and remote sensing observations [4, 5].

In this work, we concentrate on localized near-nucleus coma by modeling gas and dust emission around terminators. It has been discovered that a diurnal water cycle is at work on the nucleus that brings subsurface water upwards at night to form a layer of frost on the surface, which sublimates at local sunrise [6]. While at sunset, dust activity tends to lag into night side as jets beyond dusk terminator were observed [7]. Taking advantage of the high spatial and temporal resolution of OSIRIS images, we try to link this diurnal water cycle with the onset and end of local dust activity on 67P, and investigate the formation and evolution of complex structures in the observed inner coma.

2. Analysis and results

We present and analyze a selection of OSIRIS images where prominent dust jets are observed close to terminators. Local shape model of the nucleus with resolution of approximately 30 m is used to simulate the condition of insolation at the epoch of observation. Thermal models are applied to generate temperature and mass flux of water outgassing from the nucleus, which provide the boundary conditions for 3-D DSMC simulations of the gas field.

Fig.1 shows an OSIRIS observation of fine structures of the inner dust coma along the terminator, in contrast with the shadowed nucleus background. We modeled gas emission from the terminator by simulating temperature and outgasing rate considering sublimation of dusty ice. The modeled gas field exhibits fine structures comparable to those in OSIRIS observations. Although the exact mechanisms of dust ejection are thus far little understood, the correlation indicates that the motions of the dust ejecta are likely coupled with the gas field of water molecules. In addition, our results suggest that water outgassing and the induced dust activity along terminators may play a distinct role in shaping the visual pattern of the inner coma of comets. The contributions of terminator activity are probably most pronounced on such irregular-shaped nuclei as 67P, where abrupt topography gives rise to complex and prevalent shadowing effect.

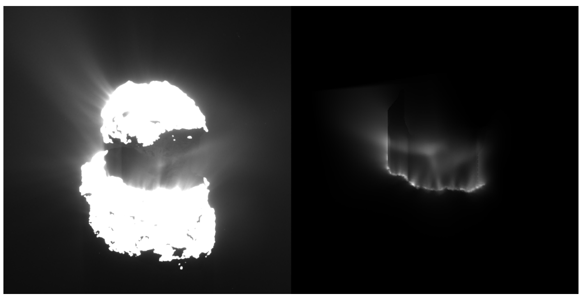

Figure 1: Left: Contrast-stretched OSIRIS image of comet 67P taken in February 2015. The sun is towards top of the image. The "neck" of the nucleus is in the shadow cast by the small lobe. Filaments of dust, or so called "jets", are seen against the shadowed neck region. Right: DSMC modeled local water gas field around the neck region. Brightness refelects column density calculated by taking into consideration shadowing effects.

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References

[1] Sierks, H. et al.: On the nucleus structure and activity of comet 67P/Churyumov-Gerasimenko, Science, Vol. 347, pp. aaa1044, 2015.

[2] Biver, N. et al.: Distribution of water around the nucleus of comet 67P/Churyumov-Gerasimenko at 3.4 AU from the Sun as seen by the MIRO instrument on Rosetta, Astronomy and Astrophysics, Vol. 583, pp.A3, 2015.

[3] Migliorini, A. et al.: Water and carbon dioxide distribution in the 67P/Churyumov-Gerasimenko coma from VIRTIS-M infrared observations, Astronomy and Astrophysics, Vol. 589, pp. A45, 2016.

[4] Fougere, N. et al.: Three-dimensional direct simulation Monte-Carlo modeling of the coma of comet 67P/Churyumov-Gerasimenko observed by the VIRTIS and ROSINA instruments on board Rosetta, Astronomy and Astrophysics, Vol. 588, pp. A134, 2016.

[5] Marschall, R. et al.: Modelling observations of the inner gas and dust coma of comet 67P/Churyumov-Gerasimenko using ROSINA/COPS and OSIRIS data: First results, Astronomy and Astrophysics, Vol. 589, pp. A90, 2016.

[6] De Sanctis, M. et al.: The diurnal cycle of water ice on comet 67P/Churyumov-Gerasimenko, Nature, Vol. 525, pp. 500-503, 2015.

[7] Shi, X. et al.: Sunset jets observed on comet 67P/Churyumov-Gerasimenko sustained by subsurface thermal lag, Astronomy and Astrophysics, Vol. 586, pp. A7, 2016.