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Comparative analyses of two Jupiter family comets: dust-rich 67P/Churyumov-Gerasimenko and dust-poor 2P/Encke

Vera Rosenbush (1,2), Nikolai Kiselev (2,3), Oleksandra Ivanova (1,2,4), Olena Shubina (2), Dmitry Petrov (3), Valeriy Kleshchonok (1), and Viktor Afanasiev (5)
(1) Taras Shevchenko National University of Kyiv, Kyiv, Ukraine (vera.rosenbush@gmail.com), (2) Main Astronomical Observatory of the NAS of Ukraine, Kyiv, Ukraine, (3) Crimean Astrophysical Observatory, Nauchnij, Crimea, (4) Astronomical Institute of the SAS, Tatranská Lomnica, Slovak Republic, (5) Special Astrophysical Observatory of the RAS, Nizhnij Arkhyz, Russia

Abstract

The results of imaging photometric, polarimetric, and long-slit spectroscopic observations of comet 67P/Churyumov–Gerasimenko in 2015–2016, which was the target of the ESA's Rosetta mission, and a highly evolved comet 2P/Encke in apparitions of 2013 and 2017 are presented. Similar radial variations of polarization and color over the coma revealed in both comets, dust-poor comet Encke and dust-rich comet 67P/C-G, are discussed.

1. Introduction

Comet 67P/Churyumov–Gerasimenko (hereafter 67P/C-G) was the target of the ESA's Rosetta mission. Combining results of the ground-based observations with the Rosetta studies shed light on the properties of the dust particles as well as processes of their ejection and evolution. Comet 2P/Encke has a number of features that attract the attention of researchers. First of all, comet Encke is a highly evolved comet; an extremely low content of dust which is concentrated in the near-nucleus region of the coma, making Encke one of the gassiest comets; the presence of sunward-oriented fan which is observed near perihelion almost in all apparitions. Accordingly, our researches are aimed at a better understanding of these features and processes occurring in the coma of both comets.

2. Observations

Three sets of photometric, polarimetric, and spectral observations of comet 67P/C-G were carried out on November 8 and December 9 2015 and April 3–5, 2016. Heliocentric distance (r) of the comet was within the range from 1.62 au to 2.72 au, geocentric distances (Δ) from 1.81 au to 1.72 au, and phase angles (α) from 33.2° to 10.4°. Imaging polarimetric, photometric, and long-slit spectroscopic observations of comet Encke were performed at r=0.56 au, Δ=0.65 au, and α=109° on November 4, 2013 and at r=1.052 au, Δ=1.336 au, and α=46.8° on January 23, 2017. In all cases, observations were taken at the 6-m telescope with a multimode focal reducer SCORPIO-2 of the SAO RAS. A 2048×2048 CCD with a full field of view of 6.1'×6.1' and a pixel scale of 0.18 arcsec/px was used as a detector. Observations were acquired using the broad-band filters as well as the narrow-band cometary filters.

3. Results

The spatial distribution of intensity, color, and linear polarization over the coma showed the following features.

3.1 Comet 67P/C-G

The comet was a very active. Two persistent jets and long dust tail were observed during the whole observing period. The radial profiles of surface brightness, color, and polarization significantly differed for the coma, jets, and tail, and changed with increasing heliocentric distance. The dust production $Af\rho$ decreased from 162 cm at $r = 1.62$ au to 51 cm at $r = 2.72$ au. The dust color (g-r) gradually changed from 0.8^m in the innermost coma to ~0.4^m in the outer coma. In November and December, the polarization in the near-nucleus area was ~8%, dropped sharply to 2% at the distance ~5000 km, and then gradually increased with distance from the nucleus, reaching ~8% at 40000 km. In April, at α=10.4°, the polarization varied between –0.6% in the near-nucleus area and –4% in the outer coma.

3.2 Comet Encke

The dust in the comet was concentrated to the near-nucleus area and only a negligible continuum signal was present at distances greater than 2000 km from the nucleus. The low dust production $Af\rho = 32\pm7$ in the BC filter confirmed the status of the comet as optically dust-poor one. The fan/tail structures were detected in the coma in both observational periods. The dust color (BC-RC) decreased from ~1.0^m in the innermost coma up to ~0.1^m at the distance 2500 km. The corrected for gas contamination radial profiles of polarization showed that the polarization in the near-nucleus area was almost 12%, dropped sharply to 6% at the distance ~3000 km, and then gradually increased to the outer coma, reaching 12% at 12000 km.

4. Analysis

Revealed radial variations of polarization and color in both comets, dust-poor comet Encke and dust-rich comet 67P/C-G, suggest a change in the particle properties and, hence, in the mean scattering properties of the grains on a time-of-flight timescale. To calculate the light scattering properties of individual scattering particles, the *Sh*-matrix method [1] for Gaussian particles was used. In the case of comet Encke, we considered cometary dust as a mixture of particles of three types: silicates, organic matter, and water ice. Our simulation allowed us to determine the microphysical parameters of the model particles which demonstrated a good agreement with the observed changes in color and polarization. Contrary, in the case of comet 67P/C-G, cometary dust was presented by particles of single type which decayed with distance from the nucleus. Calculations showed that physical decay of particles can also explain the spatial variations of polarization and color of dust in the comet.

5. Summary and Conclusions

The behavior of polarization and color with the distance from the nucleus of comet Encke *qualitatively* is similar to their behavior observed in comet 67P/C-G [2]. However, the *quantitative* changes in polarization and color with distance from the nucleus of both comets are differed. This may be partly due to different phase angles of comets, 46.8° and 33.2° for Encke and 67P/C-G, respectively. However, most of these differences can be explained by the difference in the properties of dust particles in these two comets. Firstly, the color of Encke's dust in the near-nucleus area of the coma is noticeably redder (reddening is ~15%) than that (8.2%) for comet 67P/C-G. The color change of the dust ("blueing") and the increase of polarization degree toward to the outer part of the coma in comet Encke occur faster than those in comet 67P/C-G. At the nucleocentric distances up to ~3000 km, a decrease in polarization with decreasing particle size is expected when the size of particles decreases from hundreds of microns to some microns. In order to understand how different physical properties of the dust particles affect the behavior of color and polarization, further numerical simulations of light scattering by cometary dust particles are required.

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