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67P/Churyumov-Gerasimenko's dust activity from pre- to post- perihelion as detected by Rosetta/GIADA

Andrea Longobardo (1,2), Vincenzo Della Corte (1,2), Alessandra Rotundi (2,1), Giovanna Rinaldi (1,2), Vladimir Zakharov (1,2), Stavro Lambrov Ivanovski (3,2), Michelangelo Formisano (1), Marco Fulle (3), Ernesto Palomba (1,4), Fabrizio Dirri (1)

(1) INAF-IAPS, via Fosso del Cavaliere 100, 0133 Rome, Italy (andrea.longobardo@inaf.it); (2) DIST-Università Parthenope, Centro Direzionale, Isola C4, 80143, Naples, Italy; (3) INAF-OATS, via G.B. Tiepolo 11, 34143 Trieste, Italy; (4) ASI-SSDC, via del Politecnico snc, 00133 Rome, Italy

Abstract

We studied the dust activity of comet 67P/Churyumov-Gerasimenko (67P), by analyzing the detections of the Rosetta/GIADA instrument, obtaining that: 1) fluffy and compact particles are ejected together from the nucleus and separated in the coma due to their different speed; 2) fluffy particles are more abundant in less processed, rough terrains.

1. Introduction

The ESA/Rosetta mission orbited the 67P comet for two years, escorting it through perihelion, occurred on 13th August 2015.

The GIADA (Grain Impact Analyser and Dust Accumulator) dust detector [1] mapped the spatial distributions of the fluffy [2] and compact [3] dust particles in the coma, finding a lack of correlation among them [4]. [5] developed an empirical method to trace back the dust particles detected by GIADA in the coma down to the surface, finding that, inbound to perihelion, fluffy and compact particles are generated from the same source; they are then spread in the coma due to their different speed [6].

In this work, we extended this trace-back procedure to the entire GIADA dataset, in order to define the origin and distribution of fluffy and compact particles in different orbital stages. Moreover, we probed a possible relation between dust particles morphology and the surface geomorphology of the regions from where they are ejected: fluffy agglomerates, more pristine than compact particles [7], could mostly occur in less processed, rough terrains.

2. Methods

We defined six mission periods, each characterized by a spacecraft altitude range (Table 1). For each considered period, we calculated the number of fluffy and compact particles ejected by each geomorphological region of the 67P nucleus [8,9]. To retrieve this number, we applied the trace-back algorithm developed by [5] to the entire GIADA dataset. The algorithm combines the dust velocity (directly or indirectly) measured by GIADA [4], the rotation of the comet, as well as assumptions derived from dust models [10], i.e. a radial trajectory with a constant acceleration up to 11 km from the nucleus surface and then a constant velocity.

Period	Orbital stage	Orbital distance (AU)	Spacecraft height (km)
0	Inbound arc	3.6-2.5	23±17
1	Inbound arc	2.5-2.0	40±30
2	Pre-perihelion	1.9-1.4	150±30
3	Perihelion	1.3-1.6	340±160
4	Post-perihelion	1.6-2.4	300±200
5	Post-perihelion	2.4-3.8	9±9

Table 1. Definition of orbit periods.

Then we compared the spatial distribution of fluffy and compact particles before and after the trace-back, i.e. in the coma and on the nucleus, respectively.

Results were interpreted with the aid of a thermal model (e.g., [11]), consisting in a 3-D finite difference method (FEM) which solves the heat equation coupled with a mass conservation equation that controls the water vapor emission.

3. Results and discussion

3.1 Fluffy vs compact particles

We confirmed the results obtained by [3] for the Period 0, i.e. distributions of fluffy and compact dust particles correlated on the nucleus, but not in the coma. The same results are obtained for the Period 1. For Periods 2, 3 and 4 we did not find any correlation between the two dust populations neither in the coma nor on the nucleus. However, due to the large 67P-spacecraft distance and the deviation of the dust from radial trajectories beyond 40 km [12], retrievals obtained for these periods are affected by a large uncertainty and are poorly reliable. They will be no longer discussed.

On the contrary, we found a correlation both before and after the trace-back for Period 5. This is due to the low spacecraft altitude (i.e. 9 km), not sufficient for the separation of the two dust populations.

3.2 Dust vs surface morphology

For periods 0, 1 and 5, we calculated the fraction of fluffy particles emitted from rough and smooth terrains, respectively (Table 2). With approaching perihelion, fraction of compact particles increases (i.e., fraction of fluffy particles decreases) in smooth terrains, as results of the increasing cometary activity (e.g., [10]). In rough terrains the minimum fraction of fluffy particles is reached after perihelion. We probed two hypotheses to explain this observed behaviour.

% fluffy	0	1	Perihelion	5
Rough terrains	25±4	21±4		14±2
Smooth terrains	24±4	12±3		29±5

Table 2: Fraction of fluffy particles emitted in periods 0, 1 and 5.

Thermal properties. We supposed that different thermal properties of rough terrains could delay their cometary activity. However, thermal simulations evidenced that the temporal temperature behaviour of rough and smooth regions is similar, hence we discarded this hypothesis.

Dust re-deposition. Basing on existing literature (e.g. [14]), we assumed that the dust ejected at orbital distance larger than 3.0 AU is re-deposited dust from previous activity, whereas expulsion of fresh, never ejected dust occurs at lower orbital distances. Thus, we redefined the orbital stages, separating in Period 0 and 5 orbital distances larger than 3 AU (i.e., periods 0A and 5B) and smaller than 3 AU (i.e., periods 0B and 5A), respectively. In order to study the occurrence of fluffy and compact particles in rough and smooth terrains before mixing due to re-deposition, we calculated the relative variation of fraction of fluffy particles in rough and smooth terrains with respect to period 0A (Table 3). When approaching perihelion, the fraction of fluffy particles increases in rough terrains and decreases in smooth regions. After perihelion, it comes back to the initial values in both terrains. We conclude that fluffy particles are more abundant in rough, more pristine terrains.

% fluffy (variation wrt period 0A)	0A	0B	1	Perihelion	5A	5B
Rough Terrains	0	+9%	+7%		-3%	-2%
Smooth Terrains	0	-4%	-16%		+1%	+1%

Table 3. Relative variation of fraction of fluffy particles with respect to period 0A.

4. Conclusions

- Fluffy and compact particles are ejected together from 67P nucleus, then are spread beyond a distance of at least 9 km from the comet surface.
- At distances larger than 70 km from 67P, our traceback procedure is poorly reliable, and 3D+t models are necessary to reproduce the dust particles motion.
- Fluffy particles are more abundant in rough terrains, in line with their pristine nature [2].
- The abundance of fluffy and compact ejected particles is not related to the nucleus surface thermal properties.

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