ISSI FINAL TEAM REPORT

1. Title of your Team project: Characterization of 67P Cometary Activity

2. Objectives: The goal of this International Team was the characterization of the activity of the 67P/Churyumov-Gerasimenko comet, by combining data acquired from different instruments onboard the ESA's Rosetta mission. Interpretation of data was supported by numerical models and experimental activity. The goal of WP1 (Traceback) was to trace the coma dust motion back to the nucleus surface, in order to retrieve a relation between surface and dust properties. In WP2 (Data Fusion) data from different instruments were merged to identify the main drivers of cometary activity.

3. Dates of meetings: 12-14 February 2020; 22-24 February 2022; 27-29 June 2022

4. Participants: *Team Leader*: A. Longobardo; *Core Team Members*: H. Cottin, C. Güttler, S. Ivanovski, M. Kim, T. Mannel, S. Merouane, G. Rinaldi, M. Rubin, V. Zakharov; *Young Scientists*: F. Dirri, P. Deshapriya, B. Pestoni; *External Collaborators***:** N. Attree, M. Ciarniello, M. Fulle

5. Assessment of the Team activities; highlights: The activity provided a strong advance in understanding issues related to dust ejection from comets. Five papers were published, and other two have been submitted.

6. Outcome in relation to the objectives:

GIADA data analysis. The traceback algorithm developed by Longobardo et al. (2019) was applied to the entire dataset provided from the GIADA dust detector. We found that fluffy and most pristine dust particles are more abundant in rough terrains, according to formation and activity models (Fulle et al., 2020) predicting that they are embedded within voids between cm-sized pebbles (the main responsible for terrains' roughness).

Numerical models. We considered to reconstruct the dust motion also with support of theoretical and numerical models. The assessment of the ejection dust velocity and of the acceleration in a thin layer adjacent to the surface were among the goals of this activity. Firstly, the possibility and correctness of surface representation by homogeneous elements was evaluated, because to consider the real surface topography and morphology would result in a too large computational time. In the case of gas emission from a set of closely located spots with sizes much smaller than the radius of the nucleus, inhomogeneity of the gas production may affect dust acceleration close to the surface. Then, asymptotic values of dust ejection velocity and dust-to-gas mass flux ratio were assessed in the case of the activity model by Fulle et al. (2020).

GIADA vs VIRTIS. Spectral properties of the source regions of the dust particles detected by GIADA were analysed thanks to data obtained from the VIRTIS imaging spectrometer, finding that ice-rich regions are the most dust-emitting ones, according to activity models (Ciarniello et al., 2022).

MIDAS, MIDAS vs GIADA. MIDAS is the atomic force microscope onboard the Rosetta mission. A new version of the catalogue of all dust particles collected and analysed by MIDAS was produced, together with their main statistical properties such as size, height, basic shape descriptors, and collection time. Furthermore, we investigated the scientific results that can be extracted from the catalogue such as size distribution. Then, we analysed the shapes of the cometary dust particles collected by MIDAS and determined which structural properties of the MIDAS dust particles remained pristine.

The GIADA-MIDAS data fusion was aimed at relating 67P dust's morphological and dynamical properties with comet activity and at finding a relation between micro/nano-sized and mm-sized dust. We found that μm-sized particles detected by MIDAS are fragments of larger particles that are broken from the impact on MIDAS instrument and that micro- and nano- particles are not ejected directly from the surface. These results were then confirmed from comparison with COSIMA data (i.e., the mass spectrometer onboard Rosetta). Moreover, dust fragmentation is more efficient when dust speed is larger, while there is no relation between dust properties and ejecting region geomorphology.

ROSINA, ROSINA vs GIADA. We investigated data of the COmet Pressure Sensor (COPS) of the Rosetta/ROSINA instrument suite obtained in the coma of the comet. Specifically, sudden and short increases in the measured gas density were identified as icy grains sublimating in or close to COPS. We investigated the equivalent ice volumes from grains that entered the closed source of COPS and then used the open source of COPS to investigate the overall number of such grains in the coma in comparison to the observed neutral gas activity and ground-based dust brightness.

Then, GIADA and ROSINA-COPS data were related in order to relate ice and dust ejection. A moderate correlation between dust fluffy aggregates and icy particles was found, suggesting that icy particles were released from the fragmentation of fluffy particles.

COSIMA. Beyond the material already published, there is an ongoing very active work to extend the number of particles with an in-depth composition characterization. Currently, no significant link between a specific collection of particles event in COSIMA, a compositional family and a specific region on the nucleus has been established.

Experimental activity. Cometary dust analogs were produced to simulate the photometric behavior of fluffy and compact particles.

Study of cometary activity. Thanks to external collaborators, the temporal variability of 67P activity was studied. This activity concerned the observed seasonal cycle of the 67P's nucleus color, which is linked to the progressive exposure of water ice at smaller heliocentric distances. In this respect, the investigation of the processes driving the seasonal color cycle, within the framework of recent water-driven activity models (Fulle et al., 2020), led to the definition of a new model of the internal structure of a cometary nucleus.

7. Publications resulting from the Team work:

- B. Pestoni et al., ***Multi-instrument analysis of 67P/Churyumov-Gerasimenko coma particles: COPS-GIADA data fusion***, *Submitted to A&A*
- M. Kim et al., ***Cometary dust collected by MIDAS on-board Rosetta, I. Dust particle catalog and statistics***, *Submitted to A&A*
- A. Longobardo et al., ***Combining Rosetta's GIADA and MIDAS data: morphological versus dynamical properties of dust at 67P/Churyumov-Gerasimenko***, *MNRAS*, 516, 4, 5611-5617, 2022
- M. Ciarniello et al., ***Macro and micro structures of pebble-made cometary nuclei reconciled by seasonal evolution***, *Nature Astronomy*, 6, 546-553, 2022.
- B. Pestoni et al., ***Detection of volatiles undergoing sublimation from 67P/Churyumov-Gerasimenko coma particles using ROSINA/COPS. II. The nude gauge***, *A&A*, 651, A26, 2021.
- B. Pestoni et al, ***Detection of volatiles undergoing sublimation from 67P/Churyumov-Gerasimenko coma particles using ROSINA/COPS. I. The ram gauge***, *A&A*, 645, A38, 2021.
- A. Longobardo et al. ***67P/Churyumov–Gerasimenko's dust activity from pre- to post-perihelion as detected by Rosetta/GIADA***, *MNRAS*, 496, 1, 125-137, 2020
- A. Longobardo et al., ***Characterization of 67P/Churyumov-Gerasimenko cometary activity,*** EPSC 2022
- A. Longobardo et al., ***Merging data from Rosetta GIADA and MIDAS dust detectors to characterize 67P's activity***, EPSC 2020