Bouncing boulders on comet 67P

Jean-Baptiste Vincent (1), Samuel Birch (2), Alex Hayes (2), Kris Zacny (3), Nilda Oklay (1), Pamela Cambianica (4)
(1) DLR Institute for Planetary Research, Berlin, Germany (jean-baptiste.vincent@dlr.de), (2) Cornell Center for Astrophysics and Planetary Science, Cornell University, Ithaca, NY, USA, (3) Honeybee Robotics Ltd., (4) Center of Studies and Activities for Space (CISAS) "G. Colombo", University of Padova, Padova, Italy

Boulders are ubiquitous on comet 67P [1]. Most are found in taluses and probably created by rockfall events from nearby cliffs; isolated boulders are sometimes detected in smooth terrains, partially embedded in airfall deposits.

While escorting the comet for over two years around perihelion, ESA's Rosetta observed many changes on the surface in relation to these boulders [2], for instance: burial (partial or total); uncovering (partial or total); displacement over a short distance (slide, roll); large distance transport (jump, fall); fragmentation.

These changes provide natural experiments from which we can derive the mechanical properties of the cometary material associated to boulders and their surrounding terrains, with only few free parameters. For instance, we can use reliable estimations of mass and gravity from other studies ([3] + [4]) to derive the impact speed and calculate the compressive strength of a falling block depending on its survival, potential fragmentation, size of impact print in the regolith...

Such approach has been used with Rosetta's lander. Biele et al (2015) derived the mechanical properties of the soil in the Agilkia region, where Philae touched down and bounced on 12 November 2014 [5]. From measures of the velocity change and the size of footprints on the surface, they calculated that Agilkia's surface is rather soft: a thick layer (20 cm) of dust with low compressive strength (1 kPa).

Studying the displacement of boulders across several regions of 67P allows us to repeat this experiment with different terrains and test a wider range of physical parameters. We can for example derive shear stress from rock slides, or regolith cohesion from craters created at various impact speeds. This is particularly relevant for future cometary missions like CAESAR (NASA New Frontiers proposal) which aim to acquire and return a cometary sample, and therefore need accurate determination of mechanical properties of the surface in potential regions of interest.

We will show at this conference the first results of our analysis of several surface changes related to boulders, combining observations and numerical modeling. We focus particularly on the case of bouncing objects, such as the one presented in Figure 1. Here, this object of about 10 m diameter appears to have fallen from a nearby cliff and bounced several times on the regolith without breaking. We use this observation, and other similar events, to derive the cohesion and compressive strength of both consolidated (boulder) and loose material (regolith) in several regions of the nucleus.
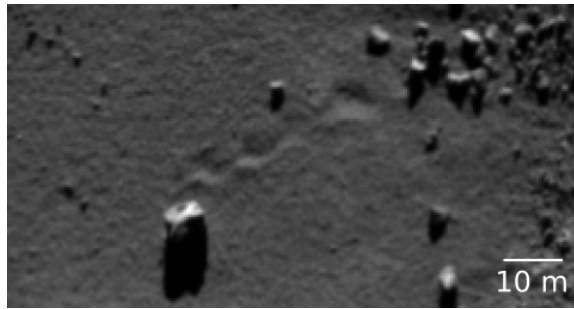

Figure 1: Example of a 10 m boulder which bounced several times on 67P's regolith, observed by the OSIRIS narrow angle camera on Rosetta.

References

[1] M. Pajola et al, Size-frequency distribution of boulders ≥7 m on comet 67P, A&A (2015)

[2] J.-B. Vincent et al, Meter scale changes on comet 67P, EPSC (2018)

[3] M. Pätzold et al, A homogeneous nucleus for comet 67P from its gravity field, Nature (2016)

[4] F. Preusker et al, The global meter-level shape model of comet 67P, A&A (2017)

[5] J. Biele et al, The landing(s) of Philae and inferences about comet surface mechanical properties, Science (2017)

Acknowledgements