EPSC Abstracts
Vol. 13, EPSC-DPS2019-1022-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

On the constraints from the spin state and global shape of comet 67P/Churyumov-Gerasimenko on its material strength.

Raphael Marschall (1), David Nesvorný (1), Joel Parker (1), Derek C. Richardson (2)
(1) Southwest Research Institute, 1050 Walnut St, Suite 300 Boulder, CO 80302, USA, marschall@boulder.swri.edu, (2) University of Maryland, Department of Astronomy, College Park, MD 20742-2421, USA

Abstract

The strength of cometary material has been determined with various methods as described by [1]. Previous methods to estimate the tensile strength of comet 67P/Churyumov-Gerasimenko (hereafter 67P) included inferences from overhangs, cliff heights, and collapsed features. In this study we have focused on a different method by estimating the frictional and cohesive properties of the cometary material needed to preserve the observed complex shape at the current rotation period.

1 Introduction

ESA's Rosetta mission escorted comet 67P from August 2014 to September 2016. With the OSIRIS (Optical, Spectroscopic, and Infrared Remote Imaging System) cameras a detailed high-resolution shape model [3] was constructed and the rotation state was determined. The comet revealed itself to have a bi-lobate shape with a diverse morphology [2]. A deep "neck" and the tall Hathor cliff in the northern hemisphere dominate the overall shape. The OSIRIS data also allowed for estimates of the tensile strength. By means of systematically quantifying overhangs [4] the tensile strength was estimated to be 1 Pa and less. Other measurements on cliffs by [5, 6, 7] come to similar conclusions. Furthermore, for other comets estimates from breakups due to close planetary encounters [9] and sun-grazing comets [8] arrived at values of 5 Pa and 100 Pa respectively. The low strength of cometary bodies is therefore well established.

The extreme shape of 67P gives a further constraint on the bulk strength of the body, which we will explain in this work.

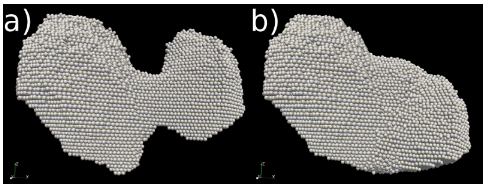

Figure 1: a) The shape of 67P filled with spheres with a radius of 40 m; b) the evolved shape after 24h of assuming cohesion- and friction-less particles.

2 Method

The bi-lobate shape of 67P with its deep "neck" especially in the northern hemisphere provides in conjunction with the rotation of the body a constraint on the material strength. Because the global shape has not significantly changed over the course of the 2015 apparition we can explore conditions under which material properties the shape remains unaltered. Besides self-gravity and the centrifugal forces due to the 12h period, the material properties can determine the shape. To study the behaviour of different material properties of 67P we explore parameter space with the Soft-Sphere Discrete Element Method (SSDEM) version of the code `pkdgrav` [10, 11]. `pkdgrav` can efficiently treat the interaction of many thousands of spheres including mutual gravity as well as friction and cohesive forces. The code has most recently successfully been applied to study the breakup of rubble-pile bodies due to spin-up [12]. That study showed how cohesion and friction can decrease the critical spin period and increase the size of fragments once the body disrupts.

In our case we are interested in finding the material properties that preserve the global shape of the comet. Figure 1 shows in panel a) the shape of comet 67P filled with spheres of radius 40 m while panel

b) shows the result of the shape change under the assumption of cohesion- and friction-less spheres. The particles in this case only interact gravitationally and due to their initial motion resulting from the bulk rotation of the body. The observed shape change illustrates how far the current shape is away from fluid equilibrium. The bi-lobate shape of 67P with its deep "neck" especially in the northern hemisphere provides in conjunction with the rotation of the body a constraint on the material strength. Because the global shape has not significantly changed over the course of the 2015 apparition we can explore conditions under which material properties the shape remains unaltered. Besides self-gravity and the centrifugal

We will present results for the final shape assuming different material parameters, internal configurations, and particle sizes.

Acknowledgements

Raphael Marschall acknowledges the support from the Swiss National Science Foundation grant 184482.
Derek C. Richardson acknowledges support from NASA grant NNX15AH90G from the Solar System Workings program.
We would also like to acknowledge the support from NASA via the Jet Propulsion Laboratory contract 1336850 to the Southwest Research Institute.

References

[1] Groussin, O., Attree, N., Brouet, Y., et al., The Thermal, Mechanical, Structural, and Dielectric Properties of Cometary Nuclei After Rosetta, 2019, Space Science Reviews, 215, 4, 29

[2] N. Thomas, M.R. El Maarry, P. Theologou et al., Regional unit definition for the nucleus of comet 67P/Churyumov-Gerasimenko on the SHAP7 model, 2018, Planetary and Space Science, 0032-0633

[3] Preusker, F., Scholten, F., Matz, K.-D., et al., The global meter-level shape model of comet 67P/Churyumov-Gerasimenko 2017, A&A, 607, L1.

[4] Attree, N., and 54 colleagues 2018. Tensile strength of 67P/Churyumov-Gerasimenko nucleus material from overhangs. Astronomy and Astrophysics 611, A33.

[5] Groussin, O., and 51 colleagues 2015. Gravitational slopes, geomorphology, and material strengths of the nucleus of comet 67P/Churyumov-Gerasimenko from OSIRIS observations. Astronomy and Astrophysics 583, A32.

[6] Basilevsky, A. T., and 7 colleagues 2016. Estimating the strength of the nucleus material of comet 67P Churyumov-Gerasimenko. Solar System Research 50, 225.

[7] Vincent, J.-B., and 53 colleagues 2017. Constraints on cometary surface evolution derived from a statistical analysis of 67P's topography. Monthly Notices of the Royal Astronomical Society 469, S329.

[8] Klinger, J., Espinasse, S., Schmidt, B. 1989. Some considerations on cohesive forces in sun-grazing comets.. Physics and Mechanics of Cometary Materials 197.

[9] Asphaug, E., Benz, W. 1996. Size, Density, and Structure of Comet Shoemaker-Levy 9 Inferred from the Physics of Tidal Breakup. Icarus 121, 225.

[10] Richardson, D. C., Quinn, T., Stadel, J., Lake, G. 2000. Direct Large-Scale N-Body Simulations of Planetesimal Dynamics. Icarus 143, 45.

[11] Schwartz, S. R., Richardson, D. C., Michel, P., An implementation of the soft-sphere discrete element method in a high-performance parallel gravity tree-code, 2012, Granular Matter, 14, 3, 363–380

[12] Zhang, Y., Richardson, D. C., Barnouin, O. S., Michel, P., Schwartz, S. R., Ballouz, R.-L. 2018. Rotational Failure of Rubble-pile Bodies: Influences of Shear and Cohesive Strengths. The Astrophysical Journal 857, 15.