Ballisitc landslides from Imhotep depression on Comet 67P/Churyumov–Gerasimenko

L. Czechowski[1,3] and K.J. Kossacki[2].
[1]University of Warsaw, Faculty of Physics, Institute of Geophysics, ul. Pasteura 5, 02-093 Poland (lczech@op.pl).
[2.]University of Warsaw, Faculty of Physics, Institute of Geophysics, ul. Pasteura 5, 02-093 Poland (kjkossac@fuw.edu.pl). [3]Space Research Center PAS, ul. Bartycka18 A, 00-716 Warszawa, POLAND

Introduction

Observations of comets 9P/Tempe 1 and 67P/Churyumov – Gerasimenko revealed existence of different forms of mass motion [1, 2, 3].

In the present paper we consider landslides resulting from ejection of matter from Imhotep depression. It is a depression on the large lobe (Body) of the comet 67P/Churyumov – Gerasimenko.

Gravitational field

The gravitational field of considered comet is complicated [1, 4, 5]. There are several regions of different slopes of the physical surface in respect to the gravity. In our geometrical model the most of the surface (~74%) has the slope in the range $0< \alpha<40^o$. The slope $40^o < \alpha<70^o$ is found on ~17% of the surface. Note also highly non-spherical shape of cometary surface of constant potential (corresponding to terrestrial "geoid") [6].

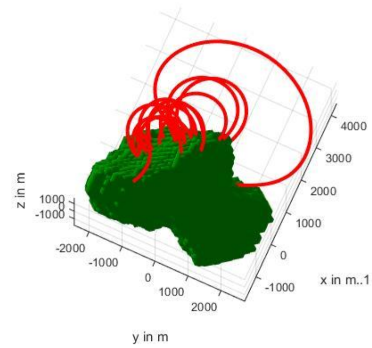
Mechanism of ejection

The slow ejecta (i.e., with the velocity lower than escape velocity) and typical landslides are similar. Both are forms of gravity movement. After landing ejecta can be still moving like a 'regular' landslide. On the other hand, the motion of landslides can include free falling without contact with the ground ('ballistic' landslides).

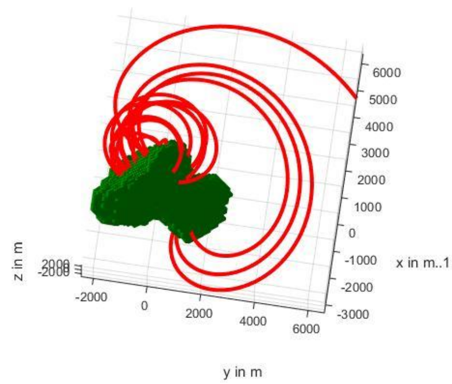
A simple model of processes leading to the formation of slow ejecta is assumed [3, 6]. The phase transition heats a certain underground volume [4, 5]. It leads to vaporization of volatiles. Eventually a cavity is formed. If the pressure in the cavity exceeds some critical value then the crust could be crushed and its fragments will be ejected in space. Some parts of depression in Imhotep region could be a result of such processes. Note that the initial velocity of ejecta are usually approximately perpendicular to the physical surface. This assumption is used successfully in [6].

Results and conclusions

We consider slow ejecta from depression Imhotep. We present results with 12 test particles from Imhotep and results for 145 test particles. We found that ejecta with the velocity 0.3 m s^{-1} (or lower) land close to the starting point. Ejecta faster than 0.5 m s^{-1} have complex trajectories and could land far from the starting point. For the velocity 0.7 m s^{-1} (and higher) some of ejecta did not landed during modeling.



A



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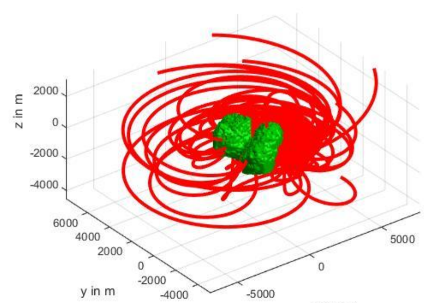

C

Fig. 1 A (upper) - Trajectories of 12 test particles (red lines) and assumed mass distribution in the comet (green volume). Test particles are ejected vertically (relative to the physical surface) from 12 positions inside the Imhotep (on the large lobe, the upper left) at the speed of 0.5 m s^{-1}. Note that all ejected particles landed on the comet. B: The same for the speed of 0.7 m s^{-1}. C : The same for 145 test particles ejected vertically at the speed of 0.7 m s^{-1}. Note that some ejecta did not land during time of modelling. The large lobe (and Imhoteb) is here in the right lower part of the figure..

In [6] we have found that ejecta from Hathemit depression (on the small lobe Head) fall in a wide belt on one comet's hemisphere. These results are confirmed by observations: southern and northern hemisphere's surfaces are clearly different [6]. For ejecta from Imhotep there are no such pattern.

Ejecta landing on the highly inclined surface could trigger another landslide - Fig. 2. It depend on angles of landing and the properties of the material of the comet [6, 7].

Determining the places of deposition of the material ejected from Imhoteb or Hatmelib will allow to determine the composition of the comet's interior under these regions without the need for drilling. This would be particularly important if the CEASAR mission will be launched. It will return a sample from the nucleus.

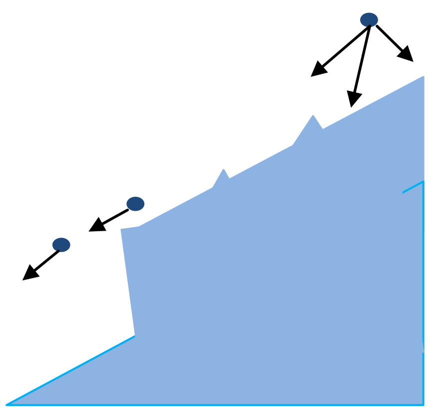

Fig. 2 The fate of ejecta after landing depends on many factors: friction coefficient, inclination of the place of landing, the vector of velocity, etc. However often the motion is determined by small scale details of the comet's surface. Note that sliding grain must overcome the worst obstacle on a given face.

Acknowledgements

The research is partly supported by Polish National Science Centre (decision 2018/31/B/ST10/00169)

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