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Motion of landslides on 67P/Churyumov-Gerasimenko

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Abstract

We investigate motion of landslides on 67P/ Churyumov-Gerasimenko. Even a small meteorite could trigger the landslide – see [3]. Presently, we concentrate on the dynamics of the moving mass. The motion of the landslide could last several hours depending on many factors. We include realistic shape of the comet's surface and realistic shape of the gravity field to find the trajectory and the final position of the moving mass.

1. Introduction

Landslides were observed on a few comet's nuclei, e.g. [1], [2] and Fig. 1. We considered beginning of the motion in [3] – see some summary in the present and the next sections.

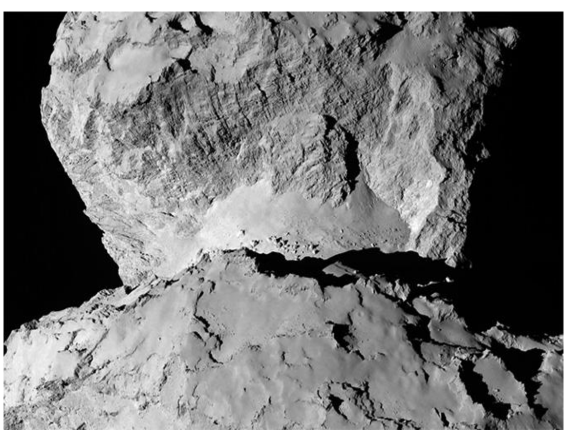

Fig. 1 An example of landslide on the 67P/ Churyumov-Gerasimenko comet.

The motion could be triggered by many factors, e.g. by increasing the surface activity of the comet resulting from intensive heating near perihelion, by meteoroids impacts, by the tidal forces, etc. Some of these factors depend on properties of the nucleus. Comets nuclei are believed to be built of soft materials like snow and dust. However, the lander Philae indicates a different situation. According to [5]: "thermal probe did not fully penetrate the near-surface layers, suggesting a local resistance of the ground […] equivalent to >2 MPa of uniaxial compressive strength". We assume here that elastic properties of the comet's nuclei could be similar to elastic properties of dry snow, namely Young modulus is assumed to be 1 – 100 MPa, see [4] and [2].

2. Impact as triggering

The nature of triggering the motion is not critical for later motion of the landslide therefore simplified model of the comet is satisfying. In [3] we found that impact of 1 kg meteoroid could lead to comet's vibrations with acceleration of the ground higher than local gravity resulting in triggering the mass motion. The three modes of vibrations are considered – see [3] and Fig. 2.

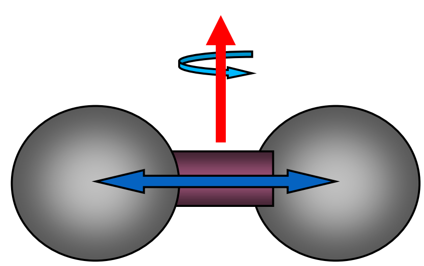

Fig. 2 One of the possible modes of vibration of simple model of irregular comet. The red arrow is the angular velocity, while the blue arrow indicates the mode of oscillation. Other modes are: bending and twisting.

The impact or tidal forces result in changing of rotation of the comet. In general, the vector of angular velocity will be a subject to nutation and consequently could be an additional factor triggering the landslides.

3. Coefficient of friction

After triggering, the later motion depends on other parameters. For near spherical comets the problem of coefficient of friction is critical because of low angle of the normal to the surface in respect to the gravity field. The mechanism of low friction is not unique. According to [2] fluidization and multiphase transport of cometary material could be an explanation.

4. Gravity and the surface of comet

We investigate motion of landslides on a comet of irregular shape. The mechanism of low friction is not critical here. In fact, mass motion often occurs without contact with the surface. However, for such motion the shape of the comet and its gravity must be realistic. We consider nucleus of the 67P/Churyumov- Gerasimenko comet with density 470 kg/m^3.

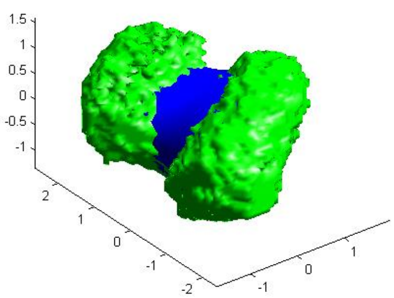

Fig. 3 The surface of the comet (green) and the surface of constant value of the gravitational potential of low value (blue).

Note that nucleus' shape does not resemble the shape of surface of constant value of gravitational potential (i.e. 'geoid'). The differences between the 'geoid' and physical shape of the nuclei could be dramatic. It is an important difference comparing to terrestrial geoid where the physical surface and geoid are close one to another.

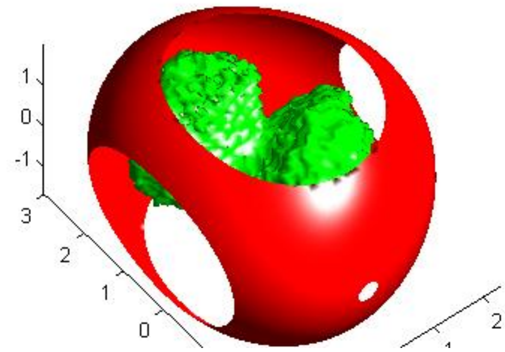

Fig. 4 The surface of the comet (green) and the surface of the constant value of the gravitational potential of high value (red). For visualization some parts of the red surface are cut and removed.

5. Summary and Conclusions

Our numerical models indicate the parts of the nucleus where landslides start, the trajectory of motion and the parts where landslides stop. The motion of the mass is often complicated because of complicated distribution of the gravity and complicated shape of the nucleus. We performed several simulations to find the most probable source of the matter of landslides seen in Fig. 1.

Acknowledgements

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