Outbursts from cavities in comets

S. Ipatov[1,2]

[1]Vernadsky Institute, Moscow, Russia
[2]Space Research Institute, Moscow, Russia

In 2005 the impact module of the Deep Impact (DI) spacecraft collided with Comet 9P/Tempel 1. Based on analysis of the images made during the first 13 minutes after the collision of the DI impact module with the comet, Ipatov and A'Hearn [1] studied time variations of ejection of material after this impact. Observed brightness of the cloud of ejected material was mainly due to particles with diameters $d < 3$ micron, and so we discussed ejection of such particles. It was shown that, besides the normal ejection of material from the crater, at time t_e after the DI collision between 8 s and 60 s there was a considerable additional ejection (a triggered outburst) of small (micron size) particles. It increased the mean velocities of observed small ejected particles (compared with the normal ejection). It is difficult to explain the time variations in the brightness of the DI cloud at distance $1 < R < 10$ km without considering a triggered outburst of particles with velocities of about 100 m/s.

The outburst could be caused by excavation of a large cavity with dust and gas under pressure. Though the model of a layered target can play some role in an explanation of the variation in brightness of the DI cloud, it cannot explain all details of such variation (for example, at $t_e sim 10$ s there was simultaneously a jump in the direction from the place of ejection to the brightest pixel in an image of the DI cloud by 50 degrees, an increase in the rate of ejection of small particles, and an increase in the brightness of the brightest pixel; at $t_e \approx 60$ s there was a sharp decrease in the rate of ejection of small particles, and at $t_e \approx 60$ s the direction from the place of ejection to the brightest pixel returned to the direction at $1 < t_e < 12$ s; the mean ejection velocities of observed particles were almost the same at t_e about 10–20 s, etc.). In [1] it was concluded that particles could not increase their velocities by more than a few meters per second during those few minutes when they moved from $R = 1$ to 10 km.

The largest cavity excavated after the collision could be relatively deep because a considerable excess ejection lasted during about 50 s. According to Schultz et al. [2], the diameter d_{tc} of the DI transient crater was about 200 m, but some authors support smaller values of d_{tc}. I estimated [3] the depth of the DI crater at $t_e = 8$ s to be about 6 m for $d_{tc} = 200$ m and 4 m for $d_{tc} = 100$ m. The cavity could be located not exactly below the center of the crater (i.e., at a little smaller depth of the crater), but the gas and dust could begin to eject via cracks. The distance between the pre-impact surface of Comet 9P/Tempel 1 and the upper border of the largest excavated cavity of about 4–6 m, and sizes of particles inside the cavities of a few microns are in good agreement with the results obtained by Kossacki and Szutowicz [4]. These authors concluded that the rapid sublimation of the CO ice in a cavity could lead to a rise of gas pressure above the tensile strength of the nucleus. In their models of the explosion of Comet 17P/Holmes, the pressure of CO vapor can rise to the threshold value of 10 kPa only when the nucleus is composed of very fine grains, a few microns in radius. The porous structure of comets provides enough space for sublimation.

The projection of the velocity of the leading edge of the DI cloud (onto the plane perpendicular to the line of sight) was about 100–200 m/s and is typical for outburst particles ejected from comets (references to the papers devoted to natural outbursts can be found in [5]). The similarity of velocities of particles ejected at triggered and natural outbursts shows that these outbursts could be caused by similar internal processes in comets. It is possible that cavities with dust and gas under pressure can be located a few meters below the surfaces of comets. After some time, gas under pressure can make its way from a cavity to the surface of a comet, and the gas formed later can follow this path at a relatively low pressure. Therefore, probably, the more time a comet has spent close to the Sun, the greater are the distances from the surface of the comet to the upper borders of cavities containing dust and gas under considerable pressure.

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