PLANETARY SCIENCE

Cometary spin-down

The rotation rate of a comet more than halved in two months — a much greater change than has previously been observed. This suggests that the comet is in a distinct evolutionary state and might soon reorient itself. SEE LETTER P.186

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Kilometre-sized chunks of ice and dust known as cometary nuclei were left over from the formation of the Solar System[1]. The vast majority of these objects orbit the Sun in one of two cometary reservoirs beyond the orbit of Neptune: the Kuiper belt and the Oort cloud. When an object from one of these reservoirs enters the inner Solar System, it becomes an active comet — its ice is transformed into gas and carries along embedded dust to form a diffuse envelope (coma) and tail. On page 186, Bodewits *et al.*[2] report a dramatic decrease in the rotation rate of comet 41P/Tuttle–Giacobini–Kresák (comet 41P) indicating that this object could soon enter a phase of rotational instability and reorientation that has never before been seen in a comet.

A rotating celestial body that orbits the Sun without being perturbed has a constant spin state — its rotation rate and the orientation of its axis of rotation relative to inertial space (represented approximately by the positions of stars) are fixed. But, in practice, many factors can change a body's spin state. These include the gravitational pull of other objects, collisions, asymmetric emission of thermal radiation from the body[3] and, particularly in the case of comets, the recoil force from the asymmetric release of gas.

Gas that streams from a comet's surface accelerates the region of origin in the opposite direction, like a rocket engine (Fig. 1). If the direction of this acceleration does not cross the body's centre of mass, it will produce a turning effect called a torque. And if the time-averaged torques on all surface elements do not cancel each other out, they will alter the comet's spin state. Outgassing forces will also affect the body's orbit around the Sun[4].

Moderate changes in rotation rate have been observed in several comets — in particular, those visited by spacecraft, for which high-quality data are available. For comet 67P/Churyumov–Gerasimenko, the target of the European Space Agency's Rosetta mission, a clear connection has been established between outgassing-induced torques and changes in rotation rate[5].

If a comet is spun up to a rotation rate at which the centrifugal force near the equator surpasses gravitational and cohesive forces, landslides and partial or even catastrophic fragmentation can occur[6–8]. Such events would be accompanied by strong sublimation (transformation of ice into gas) and dust production from newly exposed areas, which is one possible cause of sudden increases in brightness called outbursts.

Comet 41P is a small (1.4–2.0 km in diameter) body that originated from the Kuiper belt and was pulled into its current orbit in the inner Solar System by the gravity of Jupiter.

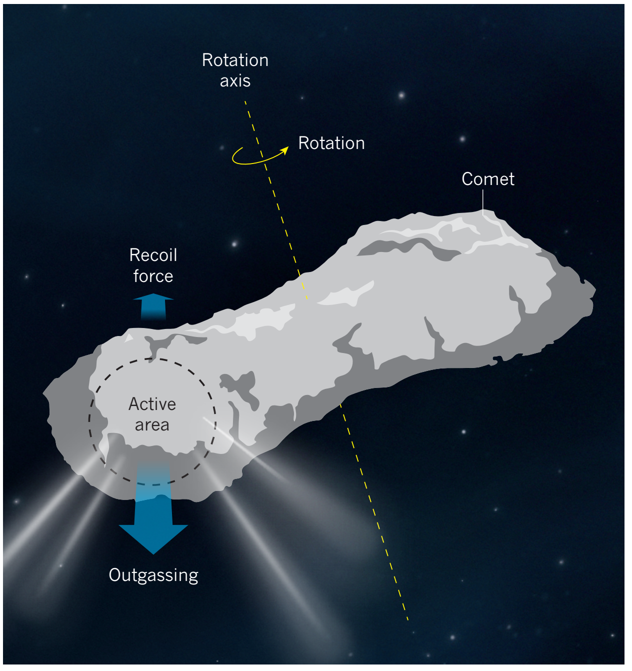

Figure 1 | Asymmetric outgassing from a comet. Bodewits *et al.*[2] report that the rotation rate of comet 41P/Tuttle–Giacobini–Kresák decreased rapidly between March and May 2017. They suggest that this slowdown was caused by the release of gas from a particularly active area far from the comet's rotation axis. Such asymmetric outgassing would have generated a strong recoil force, accelerating the active area in the opposite direction to the comet's rotation and thereby reducing the comet's rotation rate.

During previous passes by the Sun, known as perihelion passages, the comet had a high level of outgassing activity, given its small size[9]. It passed by Earth at only one-seventh of the Earth–Sun distance (an astronomical unit, AU) on 1 April 2017, and had its closest approach to the Sun at a distance of about 1 AU on 12 April.

Bodewits *et al.* observed comet 41P in March 2017 using the Discovery Channel Telescope at the Lowell Observatory in Arizona, and then in May using the UltraViolet–Optical Telescope on board the Swift space observatory. Over the two-month interval between their observations, the authors found that the comet's rotation period increased from an already long 20 hours to more than 46 hours. Such a high rate of change has not been seen in a comet before.

The authors conclude that comet 41P must be subject to an extremely effective torque. They suggest that this feature could be caused by outgassing from a particularly active area far from the body's rotation axis, oriented such that the gas flows in approximately the same direction as the rotation. The efficiency of the torque is enhanced by the comet's comparatively small size, high outgassing rate and slow overall rotation.

Bodewits and colleagues extrapolated the comet's rotation period in time to explore the body's past and future spin states (see Fig. 4 of the paper[2]). Assuming comparable torques during past perihelion passages, the authors found that the comet could have been rotating with a period of about 5 hours, which is near the fragmentation limit, before 2006. They hypothesize that this rapid rotation might be linked to a bright outburst that occurred during the comet's 2001 perihelion passage[9].

For instance, the rotation could have induced a landslide or partial fragmentation in the comet, which would have been visible as an outburst. Alternatively, or in addition, the event behind the outburst might have uncovered an active area that