**Summary:** Our semi-analytical model shows that Phaethon’s rotation state is close to or above its structural failure condition at present. Such structural sensitivity to failure due to rotation may explain the enhancement of mass shedding events that possibly induced the Geminid meteoroid stream and those observed recently.

**Introduction:** Asteroid (3200) Phaethon, a possible source of the Geminid meteoroid stream [1], has been active during perihelion passages [2, 3]. Taylor et al. [4] reported that Phaethon might be an oblate shape with ~6 km in diameter with an equatorial ridge, or known as a top-shaped asteroid.

Here, we hypothesize that activities of Phaethon may have been further enhanced by fast rotation, which helped structural failure on the surface or in the interior to induce mass shedding that developed the Geminid meteoroid stream and recently observed dust tails.

**Semi-analytical model for structural failure:** We model Phaethon as a triaxial ellipsoid with the same oblateness as Bennu, based on the earlier work [5]. We assume that Phaethon’s structure is uniform as the internal condition is unknown. The bulk density is defined as 1.0 g/cm$^3$, which is within the density range of a B-type asteroid [6]. We compute the minimum cohesive strength that can prevent structural failure of a given element in an asteroid rotating at $P$. We call this strength “critical cohesive strength” and denote it as $Y^*$.  

**Generation of dust tails at present:** At the current rotation period of 3.6 hr, the body is sensitive to structural failure and thus needs cohesive strength to maintain its shape (Fig. 1a). We interpret this sensitivity as a potential enhancement of mass shedding. If there is a trigger of reshaping such as thermal waves, the structure of Phaeton would be perturbed, leading to rotationally driven reshaping at larger scales.

**Possible source of the Geminid meteoroid stream:** Assuming that rotationally induced structural failure helped enhance reshaping, we expect that Phaeton becomes more oblate, i.e., oblateness becomes lower [7]. Therefore, Phaethon may have been less oblate and rotated faster at an earlier stage. If Phaeton is a sphere, the rotation period should become $P = 3.4$ h, which is close to or above the critical rotation period of a spherical body. Figure 1b shows larger $Y^*$ values, indicating higher structural sensitivity. This implies that failure at a shorter spin period is more significant than that at a longer spin period, and thus more materials can be shed [7].

We propose a possible evolution scenario of Phaethon (Fig. 2). Phaethon was originally less oblate and spinning at a shorter spin period than the current period. This stage is before the Geminid meteoroid stream was generated. Because the centrifugal forces may have been severer, the reshaping process caused mass shedding at large scale, which may become a source of the Geminid meteoroid stream. The current oblate shape is a remnant of earlier reshaping activities. Because the oblateness evolved, the rotation of Phaethon slowed down. At this point, the centrifugal effect is less significant, and thus, the magnitude of mass shedding at present is less intense than that in the past.

**References:**  