EPSC Abstracts
Vol. 8, EPSC2013-718, 2013
European Planetary Science Congress 2013

Phaethon as a Rock Comet

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Abstract

Asteroid (3200) Phaethon is dynamically associated with the Geminid stream, and with several other asteroids defining the "Phaethon-Geminid Complex" (PGC). The PGC is likely the result of a past asteroid disruption, of uncertain origin and occurring at an uncertain time, but possibly several $\times 10^6$ yr ago. Geminid meteoroids have a much smaller dynamical age of only $\sim$1000 years, however, suggesting the possibility of a continuing source of mass loss. Observations of Phaethon promise to throw light on the processes by which an asteroid (Phaethon has a Tisserand parameter $T_J = 4.5$) can produce meteoroids.

1. Introduction

We have observed planet-crossing asteroid (3200) Phaethon at three successive perihelia in 2009, 2010 and 2012, using the NASA STEREO spacecraft ([1, 2]). Phaethon is clearly detected in 2009 and 2012, but not in 2010. In both former years, Phaethon brightened unexpectedly by $\sim$1 magnitude at large phase angles, inconsistent with the $\sim$1 magnitude of steady fading expected from a discrete, macroscopic body over the same phase angle range. With a perihelion distance of 0.14 AU and surface temperatures up to $\sim$1000 K, a thermal origin of this anomalous brightening is strongly suspected. However, simple thermal emission from Phaethon is too weak, by a factor $>10^3$, to explain the brightening. Neither can ice survive on this body, ruling out comet-like ice sublimation. Other possible explanations including specular reflection, fluorescence under solar wind impact and forbidden emission from atomic oxygen have been considered and rejected.

Our preferred explanation is that brightening occurs as a result of dust produced and ejected from Phaethon, probably by thermal fracture and/or thermal decomposition of surface minerals when near perihelion. We infer an ejected mass of order $4\times10^8 a_{mm}$ kg per outburst, where a_{mm} is the mean dust radius in millime-

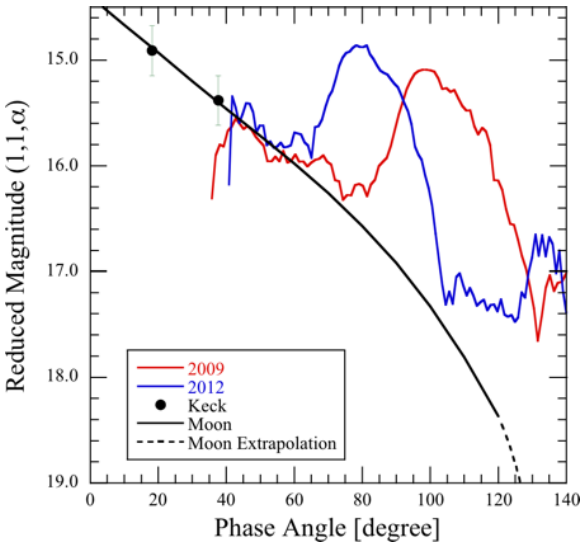

Figure 1: Perihelion lightcurves of Phaethon plotted as a function of phase angle, from 2009 (red) and 2012 (blue). The phase function of the Moon is shown for comparison. The Phaethon phase function is Moon-like in the 0^o to 60^o phase angle range, but shows a brightening at larger phase angles that is unlike the phase function of the Moon or, indeed, any macroscopic solar system body. This brightening indicates repeated activity on Phaethon at perihelion. From reference [2].

ters. For plausible dust radii, this mass is small compared to the estimated mass of Phaethon ($\sim 2 \times 10^{14}$ kg) and to the mass of the Geminid stream (10^{12} kg to 10^{13} kg) with which Phaethon is dynamically associated. If they occur in steady state, perihelion mass-loss events like those observed in 2009 and 2012 contribute to, but do not necessarily account for, the Geminids stream mass.

At the EPSC meeting we will also present new observations of other very-small perihelion asteroids ([3]) and a related search for a comet-like tail on Phaethon.

2. Summary and Conclusions

Phaethon shows activity at perihelion that is best explained as due to the ejection of material in response to very high ($\sim$1000 K) surface temperatures. The object is too hot for water ice to survive. Instead, we interpret the mass loss as caused by thermal fracture and desiccation of hydrated minerals on the surface. With the active ejection of dust and in the absence of sublimating ice, Phaethon is reasonably described as a rock comet.

References

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