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The near-Earth asteroid (3200) Phaethon as the source of heated CM meteorites

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Abstract

For the most abundant meteorites falling on Earth, the ordinary and the carbonaceous chondrites, which are broadly associated with asteroids of the spectroscopic S-complex and C-complex respectively, there is no convincing link to specific parent bodies. Here we show that the thermal infrared emissivity of CV, CK and thermally metamorphosed (a.k.a. heated) CM carbonaceous chondrites is well matched with that of the near-Earth asteroid (3200) Phaethon. When the dynamical link of Phaethon with the main-belt asteroid (2) Pallas is taken into account, the connection between Phaethon and the heated CM meteorites becomes the most favorable scenario. Phaethon is regularly exposed to temperatures up to 1000 Kelvin when passing through its perihelion, and these extreme perihelion heat pulses offer the mechanism to explain the thermal metamorphism of CM meteorites. Considering that Phaethon is so far the only identified dehydrated and heated CM-like object on a potentially collisional orbit with the Earth, we suggest it is a significant source of heated CM meteorites. Moreover, we predict that the Geminids, one of the most prominent early meteor stream, associated with Phaethon, are heated CM carbonaceous chondrites and that the heated CM in our meteorite collections are Geminids or former pieces of Phaethon.

Data

Our analysis is based on the unique Spitzer spectral data (Fig. 1) of Phaethon from January 14, 2005 that cover the wavelength range of 5–38 μm. To obtain the emissivity from the Spitzer spectra, we used results from our previous study of [H16], where we applied the thermophysical model to the Spitzer thermal infrared data. Specifically, we divided the observed fluxes by the modeled spectrum that we computed by the thermophysical model.

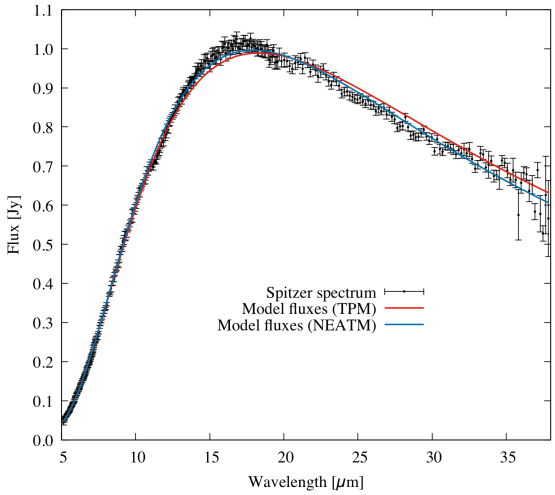

Figure 1: The Spitzer (IRS) spectral data of Phaethon from January 14, 2005: The observed spectra and the best-fitting NEATM and TPM models for the preferred pole solution of [H16].

Methods

We developed a simple fitting routine to quantify an agreement between two spectral datasets. The fitted (laboratory) spectrum is re-sampled using the linear interpolation to match the data point distribution of our Spitzer spectrum of Phaethon and then the fitted (laboratory) spectrum is scaled to best fit the Phaethon

spectrum using the least-squares method.

To identify a suitable spectral analog for Phaethon, we compared its emissivity spectra to laboratory mid-infrared emissivity and transmission spectra of known meteorites and minerals. We downloaded all available spectra from Relab[1] and ASU[2] spectral libraries. Moreover, we also digitized the mid-infrared transmission spectra for all meteorites of the carbonaceous chondrite group studied in [B14].

Results and conclusions

The absorption features in Phaethon's mid-infrared emissivity spectra are most likely related to olivine, and consistent with the spectral signatures of CV, CK, or heated/dehydrated carbonaceous chondrites.

Considering that Phaethon is so far the only identified dehydrated [T18] and heated CM-like object on a potentially collisional orbit with the Earth, we suggest it is a significant source of heated CM meteorites. Moreover, we propose that the Geminids, one of the most prominent early meteor stream, associated with Phaethon, are heated CM carbonaceous chondrites and that the heated CM in meteorite collections (such as PCA 02010 or PCA 91008) are likely Geminids/fragments of Phaethon (and Pallas).

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[T18] Takir, D., Reddy, V., Hanus, J., et al. 2018, in Lunar and Planetary Science Conference, Vol. 49, Lunar and Planetary Science Conference, 2624

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[2] http://speclib.asu.edu/