

### Forming Carbonaceous Chondrites in Near-Earth Space

P.M. Shober<sup>1,4</sup>, M.W. Caffee<sup>2,3</sup>, P.A. Bland<sup>4</sup>

<sup>1</sup>Institut Mécanique Céleste et de Calcul des Éphémérides, Observatoire de Paris, PSL, 75014, 5 Paris, France (planetarypat@gmail.com), <sup>2</sup>Department of Physics and Astronomy, Purdue University, Indiana, 47907, West Lafayette, USA, <sup>3</sup>Department of Earth, Atmospheric and Planetary Sciences, Purdue University, Indiana, 47907, 9 West Lafayette, USA, <sup>4</sup>Space Science & Technology Centre, School of Earth and Planetary Sciences, Curtin University, 11 GPO Box U1987, Western Australia, 6845, Perth, Australia.

**Introduction:** Carbonaceous chondrites are chemically the most primitive material available from our solar system, and they comprise ~4% of all meteorites deposited on Earth. For decades meteoriticists speculated whether they originated from comets or asteroids [1]. However, based on meteorite falls recorded by dedicated fireball networks, they all seem to come from hydrated low-albedo asteroids in the main asteroid belt [2][3][4][5]. The most common groups of carbonaceous chondrites are the CI and CMs.

CI and CM chondrites share one very peculiar feature that stands out amongst all meteorites: they nearly always have very short cosmic-ray exposure (CRE) ages [6][7]. Impact derived meteorites from the main belt are generally quite agreeable with the exposure ages of most ordinary chondrites (H, L, and LL), representing over 85% of all meteorites. Yet, the short CRE timescales (<2 Myrs) of CI/CM chondrites provide very little time for the transfer of meteoroids from the main asteroid belt. The average dynamical lifetime of debris in near-Earth space alone is around ~10 Myrs. Additionally, other features within CI/CM chondrites place significant constraints on the histories of these samples.

The peculiar CRE ages and irradiation histories raise the question: are CI/CM chondrites better explained through an active formation occurring in near-Earth space? And what CRE ages would you expect from meteoroids ejected in near-Earth space?

**Results:** We developed an impact rate and orbital distribution model to help answer these questions. The model created was derived from data<sup>1</sup> of low-albedo asteroids in near-Earth space. In order to estimate the impact rate, we needed to test several ejection scaling relationships and physical lifetime constraints for the carbonaceous

meteoroids being generated. As seen in Figure 1, we found that an ejection mechanism with little influence due to solar distance and strong physical lifetime constraints produce the most likely orbit distributions according to the five carbonaceous falls. Moreover, the expected dynamical lifetimes found from the model correspond nicely with the CRE ages of the carbonaceous falls, providing strong evidence of an active formation and ejection occurring in near-Earth space.

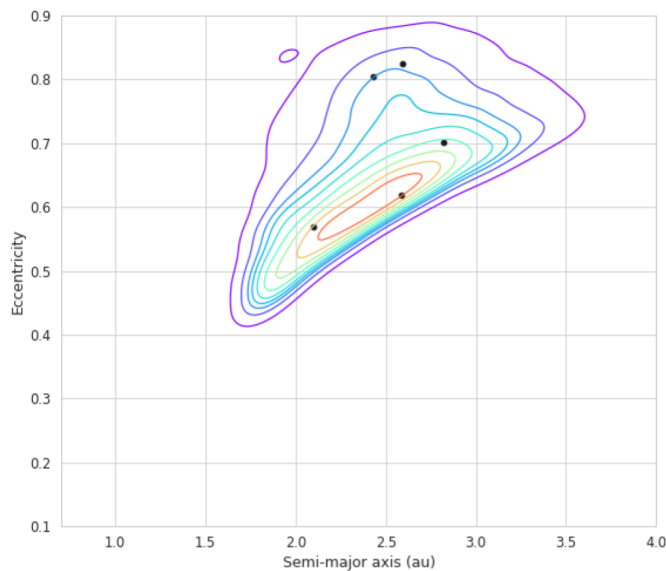


Figure 1. Orbit distribution of recovered carbonaceous chondrite falls (black) compared to the orbital distribution expected from a near-Earth ejection mechanism with physical lifetime constraints applied. The model disregards meteoroid ejections from highly evolved orbits.

**References:** [1] McSween Jr, H. Y. (1979). *Reviews of Geophysics* 17(5):1059-1078. [3] Brown, P.G. et al. (2000). *Science* 290(5490): 320-325. [4] Haack, H. et al. (2012). *Meteoritics & Planetary Science* 47(1):30-50. [5] Jenniskens, P. (2012). *Science* 338(6114):1583-1587. [6] Borovička et al. (2021). *Meteoritics & Planetary Science* 56(3):425-439. [7] Herzog, G. F. and Caffee, M. W. (2014). *Meteorites and cosmochemical processes* 1:419-454. [8] Zolensky, M. E. et al. (2021). *Meteoritics & Planetary Science* 56(1):49-55.

<sup>1</sup> <https://ssd.jpl.nasa.gov/horizons/>