EPSC Abstracts
Vol. 12, EPSC2018-930, 2018
European Planetary Science Congress 2018

The meteorite flux of the last 2 Myr recorded in Atacama

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Abstract

The delivery of meteoroids to the Earth is controlled by the complex dynamical evolution of the Solar System bodies. Although the intensity of the current flux of meteoroids to the Earth can be estimated by meteor observations [1], the characterization of the longer term flux and its possible variability in intensity and composition requires the study of meteorites. Large meteorite collection recovered from deserts are particularly suited for this purpose, as they terrestrial age can be estimated from cosmonogenic nuclides measurements. In this work, we show that meteorites from the Atacama desert allow studying the meteorite flux variability over the last 2 Myr.

The Atacama desert is an important meteorite reservoir with very high number of meteorites per surface units [2, 3]. Terrestrial ages of 54 ordinary chondrites from this desert were determined by measuring the ^{36}Cl content of their metallic fraction. These meteorites (25 H, 26 L, and 3 LL) were randomly selected among the 385 meteorites found in the El Médano dense collection area. Care was taken to discard possibly paired meteorites to avoid overrepresentation of large fall events that can produce hundreds of meteorites. The protocol used to extract the chlorine was inspired by the works of [4] and [5]. Typically, the samples were crushed, washed in hydrochloridric and fluoridric acids and dried in order to magnetically separate the metal fraction. These fractions were then dissolved, spiked with ^{35}Cl, and silver chloride precipitates were formed. The isotopic ratio measurements were performed at ASTER AMS facility. Finally, terrestrial ages T_{age} were derived from the measured activity in the samples A_{mes}:

$$T_{\mathrm{age}} = \frac{1}{\lambda} \ln\left(\frac{A_{\mathrm{sat}}}{A_{\mathrm{mes}}}\right) \quad (1)$$

where λ is the ^{36}Cl half-life (λ = (301 $\pm$ 0.01) kyr [6]) and A_{sat} the saturated activity in chondritic meteorites exposed to cosmic rays (A_{sat} = (22.8 $\pm$ 3.1) dpm kg^{-1} [7]).

The cumulative distribution distribution of these terrestrial ages is displayed in Fig. 1. About 30% of the samples are older than 1 Myr, and that the oldest are older than 2 Myr. The distribution can be fitted as an exponential decrease, with an half-life of 568 kyr. The uncertainties on the ages range from 60 to 100 kyr. For comparison, meteorites from other hot deserts and Antarctica have an average terrestrial age of only ∼20 kyr and ∼50 kyr respectively [8]. These results are consistent with the old surface ages of the Atacama desert surfaces and the long-standing hyperarid climate [9, 10] and offer an explanation for the unusually high number of meteorites that were found in the El Médano area (∼160 meteorites per km^2 [3]).

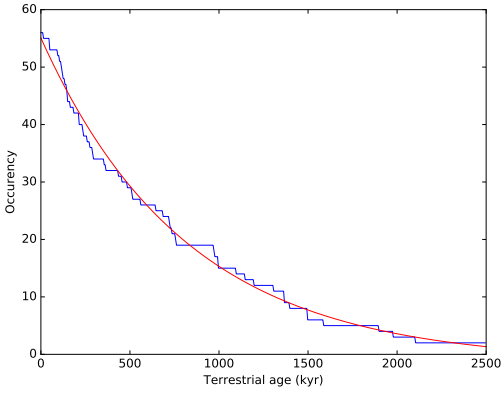

Figure 1: Cumulative terrestrial age distribution measured by ^{36}Cl (blue) and the exponential best-fit (red).

We then studied the flux variability between H and L chondrites over the last million years, statically more representative. The H chondrite fraction with respect to the total (H+L) chondrites is presented in Fig. 2. Our results show a variability over the last million years, where H are dominant within the 600-1400 kyr and L are dominant within the 200-600 kyr.

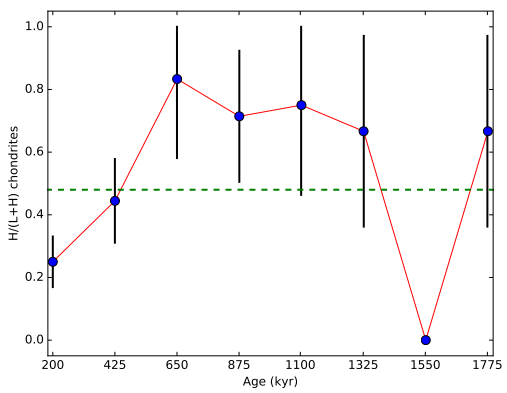

Figure 2: H chondrite fraction (with respect to the total H+L chondrite) for bins of 225 kyr. The green dotted line is the current ratio computed from the meteorite fall population (800 over the last two centuries)

Because we took care to select meteorites that were not paired, we rule out the hypothesis of a large meteorite shower that could bias the statistics. We have started to investigate dynamically the possibilities for the encounter between Earth and a meteorite swarm. The low probability to keep a stable swarm after ejection from resonant orbits within the main belt is probably not consistent with catastrophic collision in the main-belt, but periodic encounters between Earth and Near-Earth-Objects due to precession cycles could be investigated. Further work should be done, especially measurement of cosmic ray exposure ages (i.e., the transfer time to the Earth under the form of a meteoroid), in order to investigate this potential link. Also, this result will need to be confirmed by conducting the same type of study in a different area of the Atacama desert.

The El Médano meteorite collection from the Atacama meteorite collection is exceptionally old and allows for the first time a statistical approach to study the possible variations of the flux of meteoroids to the Earth over the last million years.

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