The constancy of the galactic cosmic-rays: the contribution of cosmogenic nuclides in iron meteorites

Thomas Smith[1,2], Ingo Leya[1], Silke Merchel[3], Georg Rugel[3], Stefan Pavetich[3,4], and Andreas Scharf[3]
[1]*Physics Institute, University of Bern, Sidlerstrasse 5, CH-3012 Bern, Switzerland*
[2]*Present address: Sate Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, 19 Beitucheng Western Road, Box 9825, 100029 Beijing, People's Republic of China*
[3]*Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany*
[4]*Present address: Department of Nuclear Physics, The Australian National University, Canberra, ACT 2601, Australia*

Introduction: The long-term variation of the galactic cosmic-rays (hereafter labelled GCRs) is a long-standing question. Meteorites represent the best candidates to study whether such periodic variations have occurred [1]. During their travel in space, meteoroids are exposed to GCRs, which induces nuclear interactions producing (among others) stable (noble gases) and radioactive cosmogenic nuclides. Being interested in the long-term variation of the GCRs, we focus on iron meteorites because they typically have cosmic-ray exposure (CRE) ages in the range of a few Ma and – for some – even up to 2Ga [2]. It has been demonstrated previously that periodic GCR flux variations can induce peaks in CRE age histograms, which is due to the fact that during periods of high fluency the "apparent" time seems to run faster and *vice-versa*.
Shaviv et al. (2002) [3] suggested a link exists between the occurrence of ice-age epochs and our Solar System crossing the spiral-arms of our galaxy, with a periodicity of ~140 million years (Ma); he proposed that such a periodicity would as well be identified in the CRE histogram for iron meteorites. Therefore, we wanted in this study to set up a consistent exposure age histogram and then search for periodic peaks, which would indicate whether periodic GCR flux variations exist or not.

Materials and Methods: In this work, we studied 56 iron meteorites, mainly from group IIIAB (n = 42); we measured the He, Ne, and Ar isotopic concentrations by noble gas mass spectrometry at the University of Bern, following procedures described in [4,5]. The ^{10}Be, ^{26}Al, ^{36}Cl, and ^{41}Ca activities have been measured at the DREsden Accelerator Mass Spectrometry (DREAMS) facility using chemical procedures previously described in [6].

Results and Discussion: The CRE ages have been calculated using the well-adopted ^{36}Cl-^{36}Ar dating systematic [1]. We corrected the data for radioactive decay on Earth, i.e., we determined the terrestrial age for each studied meteorite. To avoid problems with ^{10}Be and ^{26}Al production from inhomogeneous distribution of sulfur- and phosphorous-rich inclusions (i.e. troilite and schreibersite, respectively), we preferred to use the ^{41}Ca-^{36}Cl system to determine terrestrial ages, based on new Monte-Carlo calculations [7].
The calculated CRE ages range between ~12 and ~652 Ma, which is in the expected range for iron meteorites [2,8]. In addition to our data, we used the data of the big Twannberg iron meteorite [9] as well as data from [1] and [10]. We were able to establish a consistent histogram of 68 iron meteorites. The examination of the CRE histogram revealed, after correction for pairing, 40 individual ejection events, without evidence for any periodic structures. This is consistent with earlier studies arguing that the CRE histogram do not show any periodic features (*e.g.* [11,12]). Nevertheless, the ^{36}Cl-^{36}Ar CRE ages are systematically lower by ~40% than the published ^{41}K-K CRE ages (*e.g.* [13]); we propose that a possible explanation for such a difference could be an offset in the ^{41}K-K dating system, which needs to be improved to safely conclude about whether there were GCR intensity periodic variations or not.

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