Extraterrestrial Dust Flux onto the Earth over Millions of Years

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The main sources of extraterrestrial matter in our solar system are the Kuiper and the Asteroid belt. The dust particles are produced by evaporation of the cometary material and collisions of asteroids induced by the strong gravitational field of the Jupiter in the asteroids belt. Asteroids and comets contribute different fractions of material with different sizes. The size distribution of the dust particles encountering Earth peaks at about 200 μm diameter [1]. The dust grains with less then 10 μm are lost from the solar system by gravitation of the larger planets, such as Saturn and Jupiter, and also due to the solar wind [2,3]. Poynting-Robertson drag [4] causes the dust particles from the asteroid belt and comets to spiral into the Sun. Some of these materials are deposed in the upper Earth's atmosphere and can be accumulated into terrestrial formations like ferromanganese crusts. The measurements of long-lived radioisotopes like ^{10}Be ($T_{1/2} = 1.51$ Myr) [5], and ^{53}Mn ($T_{1/2} = 3.7$ Myr) [6], in these formations have fundamental applications for rather different scientific areas.

These isotopes are produced mainly by the interaction of cosmic radiation with matter (terrestrial or extraterrestrial). They provide information on their actual production parameters as well as in the past. Examples are: (i) possible changes in the intensity of cosmic radiation during the last million years [7]; (ii) flux of extraterrestrial dust in the past; (iii) exposure ages of terrestrial surfaces (exposed to cosmic radiation) [8].

Using the Munich tandem accelerator with the gas-filled analyzing magnetic system (GAMS) it is now possible to measure ^{53}Mn with a very high sensitivity (Fig. 1) [9]. In this study we present for the first time that the measurement of the ^{53}Mn deep profile in hydrogenetic ferromanganese crusts can be used for the determination of extraterrestrial dust flux onto the Earth in the past.

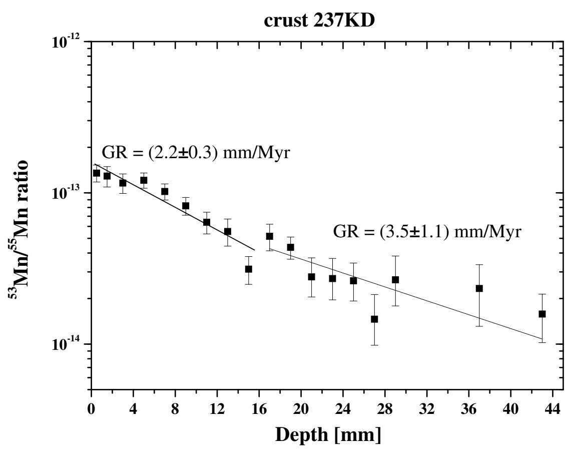

Fig. 1: Depth profile of ^{53}Mn/^{55}Mn ratios in the manganese crust 237 KD. From the exponential fit of the ^{53}Mn data we derive a growth rate (GR) of this crust of (2.2±0.3) mm/Myr for the first 16 mm and (3.5±1.1) mm/Myr at a depth of 16 mm.

This is done by the comparison of two independent measurements, ^{53}Mn data (our data) and ^{10}Be data from Segl et al., 1984 [10] of the same manganese crust (237 KD). ^{10}Be is produced in the Earth's atmosphere by the cosmic radiation. To get the flux we have to take certain assumptions: (i) if one accepts that the Earth's atmosphere providing the "target thickness" was constant during the last million years, then only variations of cosmic radiation can change the production rate of ^{10}Be. These fluctuations are directly proportional to the production of ^{10}Be and ^{53}Mn. (ii) the chondritical composition of extraterrestrial dust averaged over 800 kyr (thickness of our crust layers) was constant (always same target composition). (iii) there was no relative change in the uptake of beryllium and manganese in the crusts over the considered time span. Now we can correct the ^{53}Mn/^{55}Mn and ^{10}Be values by their half-lives and divide the ^{53}Mn/^{55}Mn ratios by the ^{10}Be values. The result delivers a value that is directly proportional to the extraterrestrial dust flux (Fig. 2). From our measurements we can conclude that the flux was almost constant over the last 11 million years.

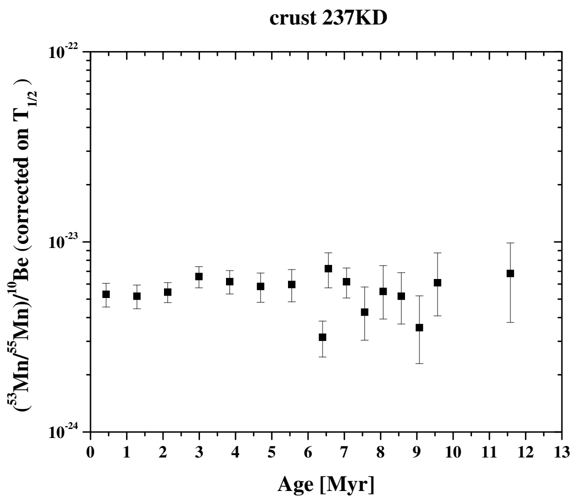

Fig. 2: Decay corrected (^{53}Mn/^{55}Mn)/^{10}Be ratios versus the crust age in the manganese crust 237KD from Central Pacific.

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