Indication for Supernova Produced ^{60}Fe Activity on Earth

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From the number of supernova explosions observed in spiral galaxies one can conclude, that such an event near to the solar system within a distance < 30 pc ($\approx 10^{18}$ m) has a probability of only a few in 100 My. However, the observation of radioactivities on earth, which cannot be produced by other processes, would be a clear indication for such an event [1,2].

Severeal long lived radioisotopes are possible diagnostic tools to identify their origin from supernovae. We believe that the most promising isotope for this purpose is ^{60}Fe ($T_{1/2} = 1.5$ My), which is predicted to be produced in significant amounts in supernovae [3]. For heavier isotopes the production yield is relatively low, for isotopes lighter than iron there is too much cosmogenic background due to cosmic ray induced spallation of nuclei in the atmosphere and in extraterrestrial matter. Additionally, it can be shown that all other production channels for ^{60}Fe (e.g. production on krypton in the atmosphere, production in extraterrestrial matter, double neutron capture of ^{58}Fe or fission neutron induced reactions) can be neglected [4].

For our search we have chosen a hydrogenetic deep sea ferromanganese crust from the South Pacific. It can be dated and has the advantage of an extremely low growth rate of only 1–2 mm/My. Roughly 1 % of the iron released into the ocean finally is built into the crust. From three layers, corresponding to time spans of 0–2.8 My, 3.7–5.9 My, and 5.9–13.4 My, iron was chemically extracted. In these samples ^{60}Fe/Fe ratios have been measured by means of accelerator mass spectrometry with the gas-filled analyzing magnet system GAMS [5]. The results are shown in fig. 1 (a). In the two younger layers an ^{60}Fe signal clearly above our detection limit of $^{60}\mathrm{Fe/Fe} = 2 \times 10^{-16}$ has been measured.

Converted into ^{60}Fe fluxes and decay corrected, the signal of the intermediate layer is significantly higher than that for the youngest layer (fig. 1 (b)). This enhancement could be explained by an intake in the order of 10^7 ^{60}Fe cm^{-2} about 5 My ago (see fig. 1 (c)). If one takes into account the reduced iron uptake of the crust, this corresponds to an ^{60}Fe pulse of about 10^9 atoms cm^{-2}. These values are far to high to be explained by other sources of ^{60}Fe, which yield fluxes of at most a few times 10^5 ^{60}Fe cm^{-2}.

In addition, ^{53}Mn ($T_{1/2} = 3.7$ My) was measured in the same crust samples [6]. The ^{60}Fe/^{53}Mn ratios of a few % strongly disfavour solar system origin of the observed ^{60}Fe, too. Estimations, based on measurements of cosmogenic ^{60}Fe in meteorites [7] yield ^{60}Fe/^{53}Mn ratios in the order of only 10^{-4} in matter with solar system composition.

According to [3] a supernova of 20 solar masses ejects 1.12×10^{-5} solar masses of ^{60}Fe. Assuming isotropic expansion, this leads to a surface density of 2×10^9 ^{60}Fe cm^{-2} at a distance of 30 pc. Using an expansion velocity of 10 km/s this number will be reduced to $\approx 5 \times 10^8$ due to radioactive decay.

These estimations suggest a supernova explosion near to the solar system, which occured about 5 My ago, as the most probable explanation for our findings.

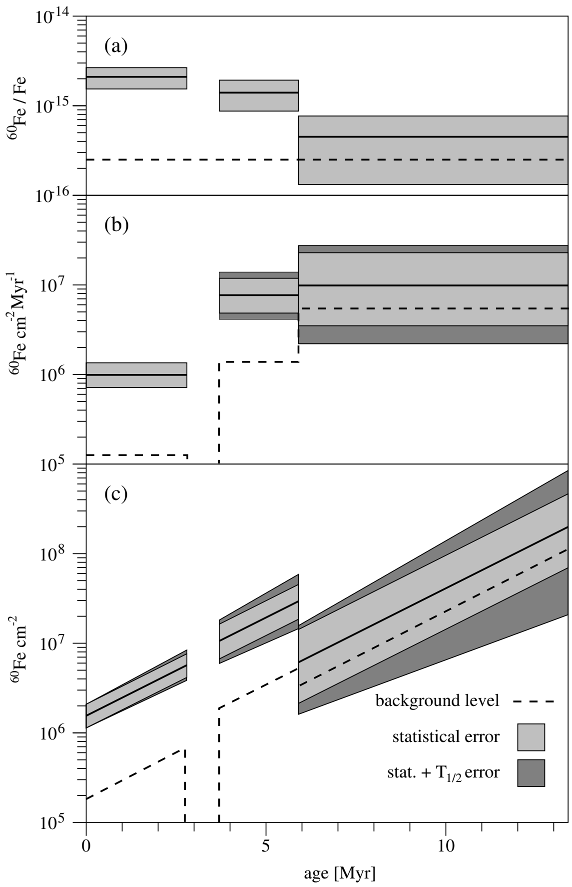

Fig. 1: ^{60}Fe/Fe ratios observed in the ferromanganese crust and resulting fluxes and fluences *into the crust*. The fluxes on earth can be assumed to be about two orders of magnitude higher
(a) ^{60}Fe/Fe ratios as measured from the different layers corresponding to different time spans. The signal of the first two layers is clearly above the detection limit (dashed line)
(b) ^{60}Fe flux (^{60}Fe cm^{-2} My^{-1}) into the crust. Here a constant flux during the respective time interval is assumed. The decay of ^{60}Fe is taken into account. The additional error is due to the error in the half-life of ^{60}Fe.
(c) In case of a pulse the fluence (^{60}Fe cm^{-2}) has been decay corrected for the time when the pulse reached the earth. Therefore the fluence has to increase with the age.

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