EFFECTS OF THE SOLAR SYSTEM OSCILLATIONS ABOUT THE GALACTIC PLANE ON THE COSMOGENIC NUCLIDE PRODUCTION IN METEORITES

V.Vanzani $^{1,2}$, S.Sartori $^{1,2}$, C.Tuniz $^{3,4}$, B.M.Stievano $^{2}$, F.Marzari $^{1}$

$^1$ Dipartimento di Fisica, Università, Padova; $^2$ I.N.F.N., Laboratori Nazionali di Legnaro (Padova); $^3$ Dipartimento di Fisica, Università, Trieste; $^4$ I.N.F.N., Sezione di Trieste.

It has been suggested that the Solar System periodic oscillation about the galactic plane can modulate the flux of the galactic cosmic rays (GCR) entering in the inner parts of the Solar System (ISS) [1,2]. As the Sun approaches the galactic plane, GCR flux in the ISS should increase because of the reduction of the heliosphere by the interstellar medium characterized in the galactic disc by denser clouds of gas tightly coupled to stronger galactic magnetic fields [1,3]. In addition, the confinement of lower-energy cosmic rays to low galactolatitudes by magnetic fields should enhance the increase of GCR flux due to the heliosphere reduction [2].

To describe the modulating effect on the cosmogenic nuclide production, arising from the harmonic oscillation of the Sun about the galactic plane, we make the simple model assumption for the production rate $P(t) = P_0 + P_1 \sin(\beta - \alpha t)$, where $P_0$ is the constant term (assumed to be dominant according to current views), $\alpha = 2\pi T^{-1}$, with $T$ the half-period of oscillation of the Sun in its galactovertical motion. Note that the Sun crosses the midplane twice in each period, so that the harmonic-component period of the production rate is half the period of the Sun oscillation [Fig. 1]. According to [4], we take $\alpha = 0.2 \text{ Ma}^{-1}$, which corresponds to $T = 31.4 \text{ Ma}$, as in the periodic occurrence of terrestrial mass extinctions, and assume that the last passage of the Sun through the galactic plane occurred in the past 3 Ma. We tentatively put $\beta = 2$ (the phase at the present): this choice is consistent with the data on $^{10}$Be concentrations in the deep-sea sediment core RC 12-65 [5].

In Figs. 2 $+4$ we compare, for the pair $^{26}$Al $-$ $^{53}$Mn, the lattice of curves obtained in the constant production model (dashed lines) with the lattice obtained in the oscillating production model, introduced here (solid lines). Each activity is normalized to its maximum value (its limit for $t = 0$ and $T \rightarrow \infty$): $P_{0\lambda} + P_{1\lambda} \lambda (\alpha^2 + \lambda^2)^{-1}(\lambda \sin \beta + \alpha \cos \beta)$, which can be regarded as the definition of the saturation value in this context. We take $P_{0\lambda} = 0.3 P_{0\alpha}$ for both the radionuclides. The Figs. 2, 3 and 4 contain also the $^{26}$Al and $^{53}$Mn data for selected non-Antarctic, Yamato and Allan Hills meteorites taken from [8], [10] and [11] respectively (in this preliminary work their errors, typically $\sim 10 \%$, are not plotted). The saturation activities were taken from [10].

On the whole the two lattices have approximately the same form, but they differ in the details: the two models give exposure ages which can differ up to a maximum of some Ma. Unfortunately the actual uncertainties on the data do not allow to appreciate such differences. Further work is needed in handling experimental data for different meteorites: corrections due to differences in chemical composition and shielding geometry; estimate of
possible multistage exposure effects. To properly determine the exposure and terrestrial ages several cosmogenic radioisotopes have to be analysed in a large number of meteorites. Accelerator Mass Spectrometry (AMS) allows fast measurements of long-lived cosmogenic isotopes (LLCI) on sub-gram samples of extraterrestrial materials and, therefore, is suitable for this kind of routine analysis. An AMS system based on the 16 MV Tandem of the Laboratori Nazionali di Legnaro is being developed to detect LCCI in natural samples. Present sensitivity allows measurements of $^{10}$Be and $^{36}$Cl in meteorites. Improvements of the system are in progress to detect heavier nuclides like $^{41}$Ca, $^{53}$Mn and $^{129}$I.


Figure captions: Fig.1: Periodic oscillation of the cosmogenic production rate (solid line) arising from the harmonic oscillation of the Solar System about the galactic plane (symbol-made line, to take into account that last passage occurred in the last 3 Ma; the crossing-points are sketched). Arbitrary units in the ordinates, time in Ma in the abscissa. Figs 2–4: Exposure age–terrestrial age plot in the constant production model (dashed lattice) and in the oscillating production model (solid lattice). Data and age estimates for non–Antarctic (Fig. 2), Yamato (Fig.3), and Allan Hills (Fig.4) meteorites.