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The inteplanetary magnetic field associated to the propagation of solar relativistic particles

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The origin and the propagation of high energetic solar particles (450 MeV- few GeV) in the interplanetary medium remains a complex topic. These relativistic solar particles, detected at the Earth by neutron monitors (called Ground level enhancement, GLE), have been previously accelerated close to the Sun. In order to be detected at the Earth, these relativistic particles have to travel along an interplanetary magnetic field (IMF) connecting the acceleration site and the Earth.

Generally, the nominal Parker spiral (SP), is considered for ensuring the magnetic connection to the Earth. However, in most of GLEs the IMF is highly disturbed, and the active regions (ARs) associated to the GLEs are not always located close to the footprint of the nominal Parker spiral. If the AR is not connected to the Earth by the nominal Parker spiral, which is the IMF connecting the acceleration site and the Earth during the GLEs?

A possible explanation of relativistic particles propagation under these circumstances are transient magnetic structures, travelling in the IMF as Interplanetary coronal mass ejections (ICMEs).
In order to check this interpretation, we studied in detail the magnetic connection for 10 GLEs of the last solar cycle.

Using the magnetic field and the plasma parameter measurements (ACE/MAG and ACE/SWEPAM), we find that relativistic particles associated to ARs located close to the footprint of the nominal Parker spiral tend to propagate along this nominal Parker spiral (2 clear cases) or in a solar wind disturbed by a previous magnetic perturbation (3 cases). Instead, the GLEs associated to ARs which is clearly not-well connected tend to propagate in an interplanetary coronal mass ejection or in the back of a previous ICME. More specifically on the 3 not-well connected cases, two propagate in the back of an ICME and one of them propagates in the ICME.

Depending in which IMF particles propagate, the path length can display significant differences. Using the velocity dispersion method applied to energetic protons measured by SoHO/ERNE and the relativistic particles measured by the neutron monitor network, we determined the path length travelled by particles. These lengths are consistent with the IMF determined previously. Thus, when particles travel, e.g. in an ICME, the length approaches 2 AU, whereas the length associated to particles propagating along the nominal Parker spiral is of the order of 1-1.2 AU.

This consistency in the results leads us know the interplanetary medium in which these relativistic particles propagate for these 10 GLEs, which can be relevant if we want to study deeply each event.