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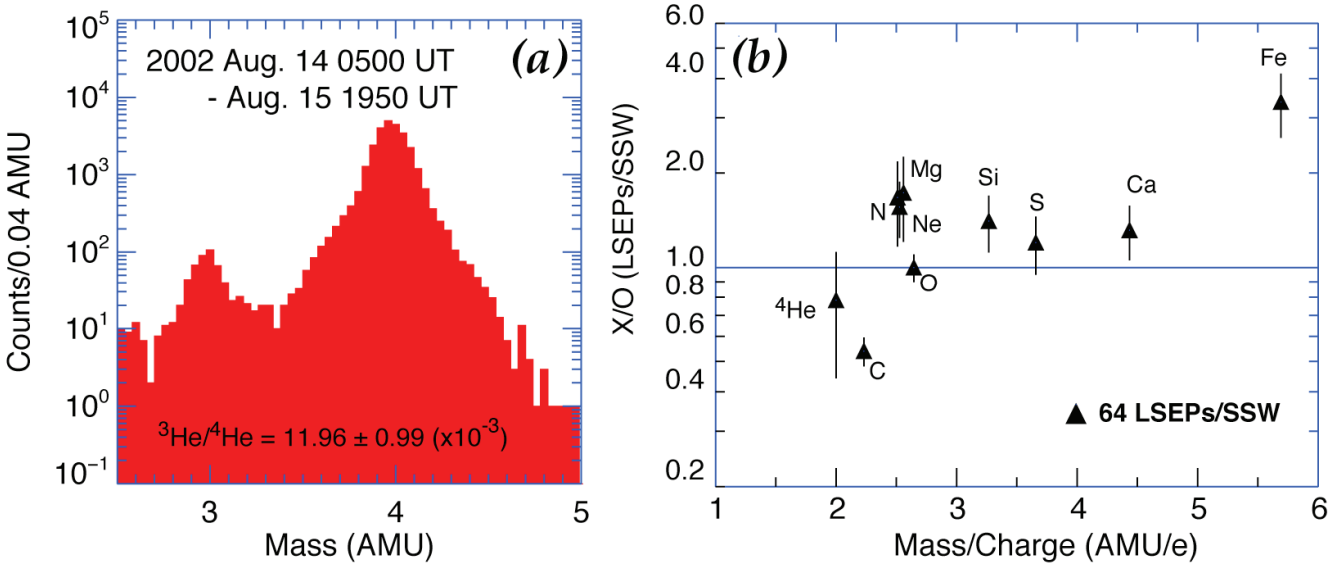
Elemental Abundances of Low-energy Heavy Ions in Large Solar Energetic Particle Events of Cycle 23

Up until the mid-1990's, energetic ions in large solar energetic particle (LSEP) events were believed to occur when shock waves driven by fast coronal mass ejections or CMEs accelerated coronal or solar wind material near the Sun and in interplanetary space. Since shocks typically energize particles via a first-order Fermi or diffusive process, the accelerated ion population was expected to exhibit systematic differences when compared with the source material. In this scenario the LSEP events should be essentially devoid of 3He ions that are extremely rare in the solar wind (relative abundance $<10^{-4}$); simultaneously, the heavy ion elemental abundances should be systematically depleted according to the ion's mass-per-charge (M/Q) ratio when compared with the solar wind values since shocks are less efficient at accelerating higher M/Q ions.

In order to assess the merits of this paradigm, and determine representative average values of the low energy SEP abundances, we surveyed the elemental composition of 0.1–2. MeV/nucleon He–Fe nuclei during 64 LSEP events of cycle 23 using the ACE / ULEIS instrument during the period November 1997 – January 2005.



Our results show that the composition of the energetic ion population is quite unlike either the presumed coronal or solar wind seed reservoirs with 46% of the events having 3He/4He ratios enhanced between factors of ~4–150 over the corresponding solar wind value (e.g., see panel a). In addition, we find that the average LSEP abundances are not organized in any simple manner with respect to physical quantities such as the ion's M/Q ratio when compared to the slow solar wind values (see panel b). These observed differences are unlikely to be solely due to fractionation introduced by shock acceleration or transport mechanisms. Instead our results are consistent with other ACE surveys at higher energies, and confirm that the seed population for LSEP events originates primarily from the solar wind suprathermal tail that contains important contributions from a variety of sources. These sources include suprathermal flare material enriched in 3He and the heavy ions such as Ne–Fe, leading to the large enhancements of these ions seen in our average abundances.

For further details see, Desai et al. Astrophysical Journal, Vol. 649, 470–489, 2006.

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