Ionic Charge States in Impulsive SEP Events

New measurements of the mean ionic charge (Q_m) of Fe in impulsive solar energetic particle (SEP) events with our experiments onboard SOHO and ACE show a systematic increase of Q_m with energy between ~0.01 and 0.6 MeV/nuc. This increase demonstrates that in these events stripping during acceleration in a dense plasma in the low corona is important and provides an upper limit of ~2 R_s for the altitude of the acceleration region.

Solar energetic particle events are thought to have two basic classes, usually referred to as "impulsive" and "gradual". Gradual events are related to CMEs (Coronal Mass Ejections) and interplanetary shocks, whereas impulsive events are related to flares. Our first direct charge state measurements for SEPs with ISEE-3 about 20 years ago showed that one of the characteristic differences between these 2 types of events are the ionic charge states of heavy ions. Whereas in gradual events the mean ionic charge of elements in the range O – Fe is mostly compatible with solar wind charge states, the heavy ion charge states in impulsive events at ~0.5-1.0 MeV/nuc had been found to be significantly larger (e.g. Q_m~20 for Fe, Klecker et al., 1984).

Gradual Events

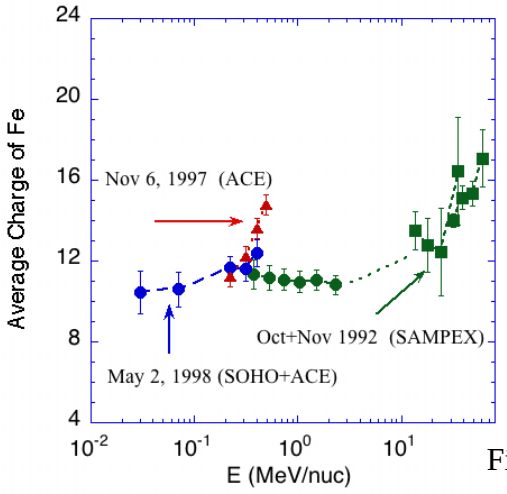

Fig. 1

Impulsive Events

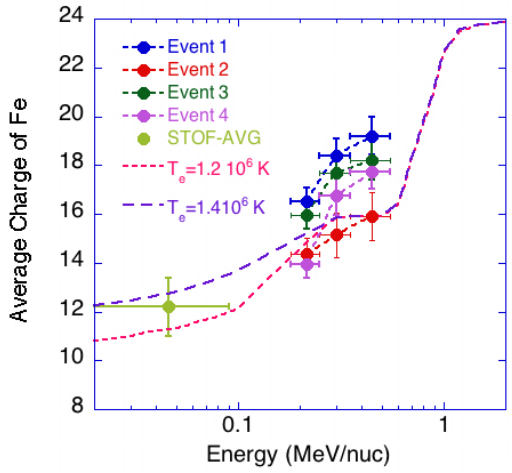

Fig. 2

Combining measurements of the experiments STOF onboard SOHO and SEPICA onboard ACE we are now able to extend the energy range to ~0.01 – 0.6 MeV/nuc. Fig. 1 and Fig. 2 show the mean ionic charge of Fe for typical gradual and impulsive events, respectively. Whereas the gradual events exhibit a large variability of the mean ionic charge of Fe from Q_m (E) ~ const to increases by several charge states in the energy range 0.1 - 40 Mev/nuc, the impulsive events consistently show a large increase (ΔQ ~4-8) with energy at E < 1 MeV/nuc (Möbius et al., 2003), combined with low charge states of Q_m~ 11-13 at E < 0.1 MeV/nuc (Klecker et al., 2004). The substantial increase at energies of ~ 0.1 - 0.6 MeV/nuc is consistent with the prediction of models that combine acceleration in a high-density plasma environment with stripping during the acceleration (e.g. Kocharov et al., 2000). The relatively low charge states at low energies, compatible with T_e ~1.5 10^6K, show that high ionic charge states in impulsive events are not caused by high temperatures, as previously thought, but by stripping in a dense environment in the low solar corona at R < 2 R_s.

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Möbius, E., Y. Cao, M.A. Popecki, et al., 28th ICRC, 6, 3273, 2003

B. Klecker, in collaboration with E. Möbius, M.A. Popecki