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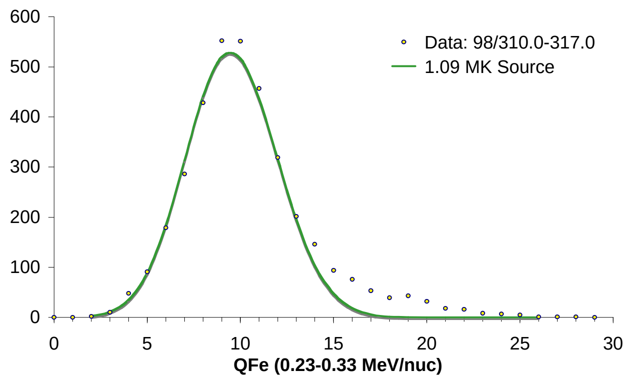
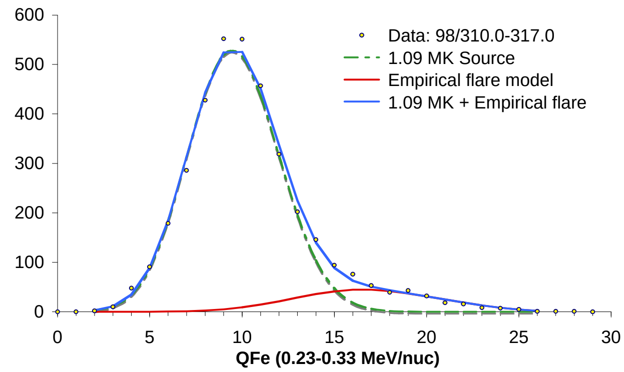
Ionic Charge State Distributions as a Diagnostic of Diverse SEP Sources





Fe charge state distribution at 0.23-0.33 MeV/nuc for the November 6-12, 1998 SEP period as obtained with ACE SEPICA is shown in comparison with a single-temperature equilibrium source on the left and in combination with a model of flare-associated charge states on the right.

Solar energetic particle events (SEP) have often been classified as either gradual or impulsive, referring to particle acceleration by shock or flare-related processes. The extent to which these two may operate concurrently is still a subject of debate. Ionic charge state observations can provide insight into the locations where SEPs are produced and their source distributions established. Going beyond mean charge states, detailed charge state distributions may serve as diagnostic indicators of the original source populations that are accelerated. The Fe charge state distribution from a period that featured a halo CME on November 5 and a series of C and M class flares at western longitudes on the Sun (between W18 and W81) is shown above. The distribution peaks near Q = 10 and features a tail toward higher charge states.

The actual source distribution may be inferred through forward modeling, in which an input distribution is convolved with the instrument response function. Using this technique, the observed distribution was compared to various input models to test whether more than one source of SEPs was present. On the left, a pure equilibrium distribution at a coronal temperature of 1.09 MK (Bryans et al., ApJ Supplement, 167:343–356, 2006) that could have been accelerated by an interplanetary shock is compared to the observations. The model has a peak at $Q \approx 10$, but no tail, clearly not sufficient to explain the observations. The remaining tail could arise from a flare-associated source. Therefore, an empirical flare model was compiled by combining charge-state distributions observed in six flare-associated events at 0.23-0.33 MeV/nuc. This model makes no attempt to quantify the effects on the charge state distribution of either stripping during acceleration (ACE News 80 and 107) or of exposure to a high-temperature environment. The empirical flare model was added to the equilibrium model in the right figure. Apparently, both components are required to explain the observed distribution. The good agreement suggests that the SEPs in the November 6-12, 1998 period may have partly come from shock acceleration in the high corona or interplanetary medium, where stripping effects are relatively weak, and partly from a flare-associated source.

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