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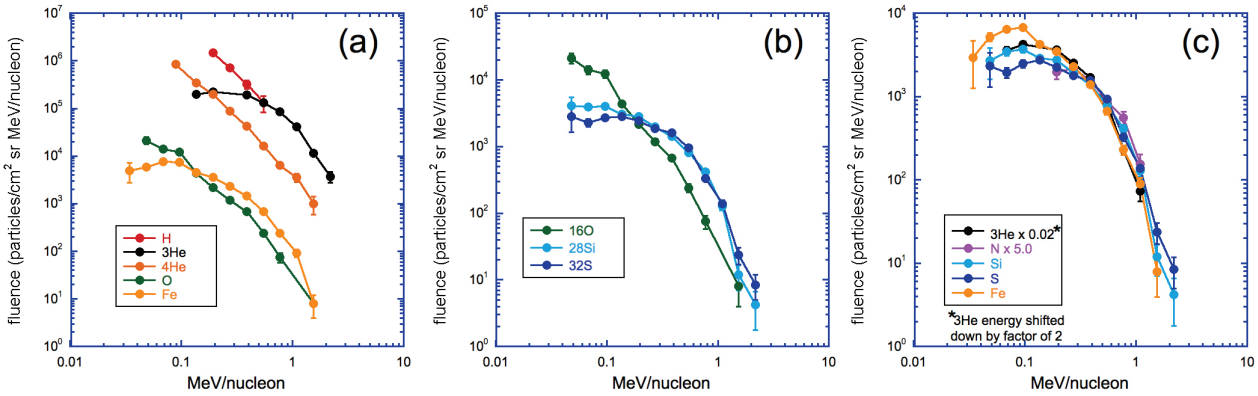
Evidence for a Common Acceleration Mechanism for ^{3}He and Heavy-ion Enrichments in Impulsive SEP events



Differential fluences for the May 16, 2014 event: (a) H, ^{3}He, ^{4}He, O, and Fe, (b) O (repeated) Si, and S, and (c) comparison of heavy-ion and ^{3}He spectra where ^{3}He has been shifted downward in energy by a factor of 2.

^{3}He-rich solar energetic particle (SEP) events are of special interest in particle acceleration studies since their enormous enrichments of ^{3}He (up to factor of >10,000) suggest the presence of physical mechanisms different from those in large, shock-associated SEP events. The large ^{3}He enrichments are also associated with more modest (factor ~10) but very clear enrichments of heavy ions up to Fe that increase monotonically with mass. However, since the degree of enrichment of ^{3}He and of Fe were found to be uncorrelated, it appeared that this association was not due to the accelerating mechanism itself, but rather was a separate effect. The first observations of ^{3}He and Fe spectra to lower energies on ACE revealed a new property, namely that the ^{3}He and Fe spectra were often curved (see panel a), but this was observed only in some events. Others had power-law spectra suggesting more typical acceleration processes such as a shock.

An exception from the monotonic enrichment enhancements in heavy ions was found in a few small events (ACE NEWS #62) where the elements Si and S were enhanced more than Fe. We surveyed the entire ACE mission for additional such events and found 16, with one extraordinary case on May 16, 2014 where the spectra extended to higher energies than the others. The solar source for this event is typical of other ^{3}He rich events with type III emission, impulsive electrons, etc. (Nitta et al. ApJ, 806, 235, 2015) with a possible exception being cooler material located near the site of the event. Panel (b) shows the O, Si, and S spectra from this event, where the O spectrum is crossed by both Si and S, leading to very large Si/O and S/O ratios in the range ~0.5-1 MeV/nucleon. Such spectral crossings have never before been reported. Panel (c) shows that the heavy ion spectra for N, Si, S and Fe are all very similar above ~100 keV/nucleon, and have the same shape as ^{3}He if the ^{3}He energy is scaled by a factor of 2.

The similarity of the ^{3}He and heavy ion spectra in this event suggests that a single acceleration mechanism may be responsible for all the spectra. The crossing of heavy-ion spectra results in highly energy dependent abundance ratios: for example from panel (b) it is clear that Si and S are highly enriched at the highest energies, but at lower energies the ratios are more nearly normal for SEPs. Thus, only a small fraction of the heavy ions are enriched, and indeed, the effect may be better understood as being due to the highest energy/nucleon achieved for particular ions. For example, if the S spectrum is shifted down by a factor of 3.8, it produces a S/O ratio typical of impulsive SEP events; for Si the corresponding factor is 2.2. Thus the observed enrichments in these events may be due to the maximum energies of the ions and not an enhancement at all energies. For additional details and references see Mason et al. (ApJ, 823, 138, 2016; doi: 10.3847/0004-637X/823/2/138).

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