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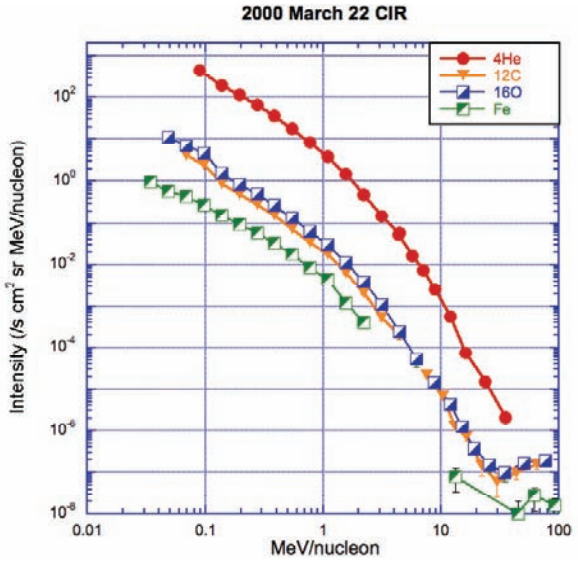
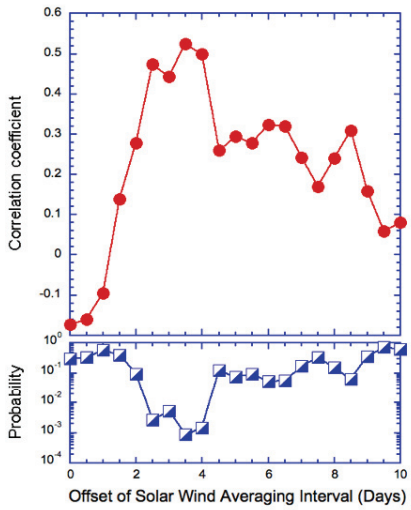
Abundances and Energy Spectra of CIR Heavy Ions During Solar Cycle 23

Corotating Interaction Regions (CIRs) arise when fast solar wind streams overtake slower solar wind in the inner heliosphere (<few AU). The interaction between the two streams leads to enhanced levels of turbulence and the eventual formation of shocks which propagate away from the stream interface in both outward (forward) and inward (reverse) directions. Energetic particles are often observed from CIRs, which occur throughout the solar activity cycle but are most prominent during the declining phase. We used ULEIS and SIS to survey 41 CIRs during 1997-2007 obtaining spectra up to a few MeV/nucleon in all cases, and up to >20 MeV/nucleon in the most intense events.



Typical CIR spectra showing hard slope at low energies, steepening above 1 MeV/n. The spectral forms are very similar, so that ratios are constant within a factor of ~2 over an energy range where intensities change by a factor of 10^8. Flattening at high energies is due to galactic cosmic rays.



Correlation coefficient between Fe/O ratio in CIR energetic particles vs. solar wind Fe/O sampled from 0 to 10 days prior to the CIR passage. The correlation is low for simultaneous comparison, however, if the CIR Fe/O is compared to the solar wind Fe/O 2-4 days preceding the CIR, the correlation is strong.

Below ~1 MeV/nucleon the spectra are power laws in kinetic energy/nucleon with average spectral index 2.51 ± 0.10, rolling over above ~1 MeV/nucleon to power law spectra with average index 4.47 ± 0.17 (see left figure). The spectral shapes for different species are similar, leading to relative abundances that are constant over our energy range even though the intensities cover up to 8 orders of magnitude. Except for an overabundance of ^{4}He and Ne, the abundances are quite close to the abundance of the fast solar wind. We have found ^{3}He/^{4}He ratios to be enhanced over solar wind values in ~40% of the CIRs. The Fe/O ratio in individual CIRs is observed to vary over a factor of ~10, and is strongly correlated with the solar wind Fe/O ratio measured 2-4 days preceding each CIR (see right figure). Taken together with previous studies showing the presence of pick-up He^+ in CIRs, the observational data provides evidence that CIR energetic particles are accelerated out of a suprathermal ion pool that includes heated solar wind ions, remnant suprathermals from impulsive solar energetic particle events, and pick-up ions.

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