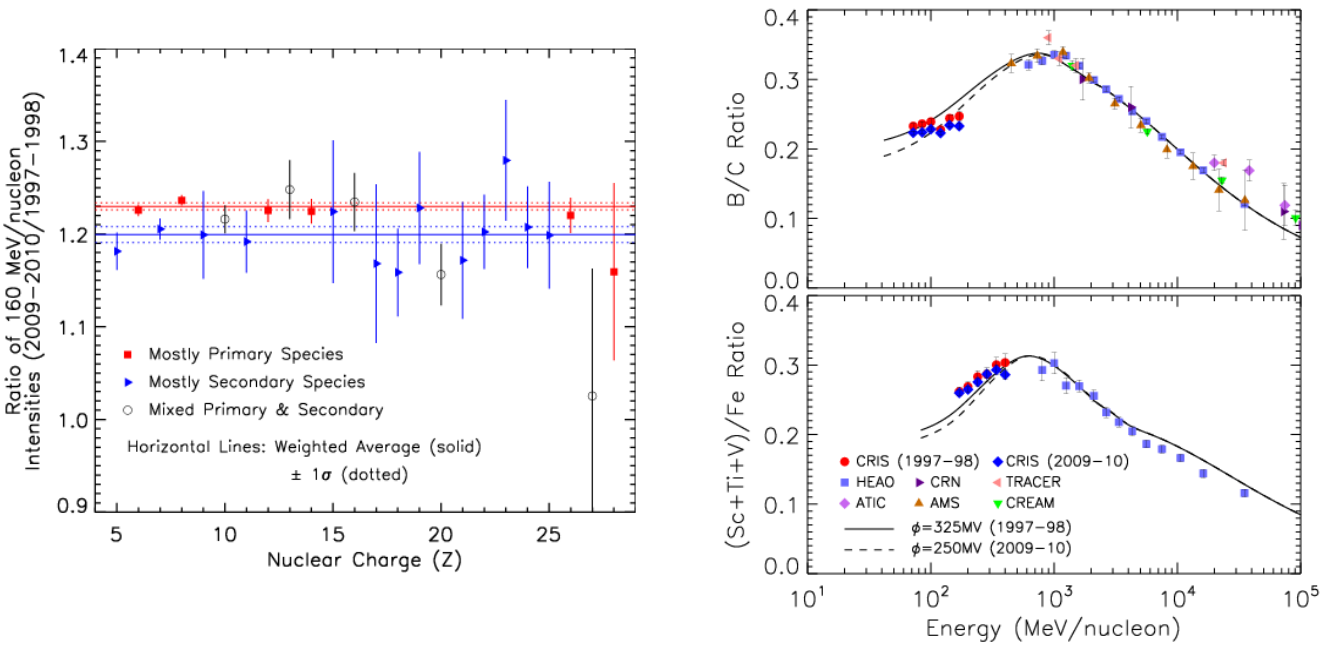
ACE News #160 – 6/12/13
Galactic Cosmic-Ray Composition During Solar Minimum Periods



FIGURES *Left: Ratio of the 2009-10 intensities relative to the 1997-98 intensities at 160 MeV/nucleon . Horizontal lines show the weighted averages of the ratios (with ± 1σ uncertainties) for the primary (red) and secondary (blue) species. Species that are a mix of primary and secondary nuclei (black) are excluded from the averages. Right: The secondary-to-primary ratios B/C (top panel) and (Sc+Ti+V)/Fe (bottom panel). CRIS data are given as red circles (1997-98) and blue diamonds (2009-10). Model results are also shown as solid (1997-98) and dashed lines (2009-10).*

As galactic cosmic rays (GCRs) diffuse into the heliosphere, their energy spectra are distorted by interactions with the magnetic field convected outward by the expanding solar wind. This process, called solar modulation, will cause GCRs with interstellar energies less than ~1 GeV/nucleon to lose a significant fraction of their energy due to adiabatic deceleration; these losses are smallest during the solar minimum periods of the ~11 year solar cycle. The most recent solar minimum period, which exhibited unusually low levels of solar modulation, featured record-setting GCR intensities in 2009-10 (see ACE News #122 and #134). Observations during this time are the closest we have come in the inner solar system to observing GCRs at interstellar medium (ISM) intensities.

The CRIS elemental composition and energy spectra for the 1997-98 and 2009-10 solar minimum periods are reported in Lave et al. (ApJ 770, 117, 2013). In the left figure we show the ratios of the 2009-10 intensities relative to the 1997-98 intensities at 160 MeV/nucleon. Species composed of mostly primary nuclei (those accelerated at the GCR source) are differentiated from those that are mostly secondary nuclei (those produced by fragmentation of the primary species in the ISM). Horizontal solid lines show the weighted averages of the ratios for the primary and secondary species (dotted lines: ± 1σ uncertainties on the averages). Three important conclusions may be seen here. First, for all species the 2009-10 intensities were higher than in 1997-98 by ~20%. Second, the composition of the primary species relative to one another is the same in both time periods. Third, secondary species do not show as large an intensity increase as the primary species.

The secondary-to-primary (S/P) ratios B/C and (Sc+Ti+V)/Fe, which are often used to test interstellar transport models, are shown in the figure on the right; this is an update of the results shown in ACE News #117. CRIS solar minimum observations from 1997-98 and 2009-10 are plotted at energies below ~400 MeV/nucleon, while data from other instruments are plotted at higher energies. Results from an interstellar transport model combined with a spherically symmetric solar modulation model are also shown. For a thorough description of the models, see Lave et al. (ApJ 770, 117, 2013).

At CRIS energies, we see that the S/P ratios are lower in 2009-10 than in 1997-98. This observation is consistent with the results in the left figure. Both figures show that in the more recent solar minimum, which had a lower level of solar modulation than in 1997-98, fewer secondary GCRs were observed relative to the primaries. With less solar modulation, the observed GCRs had lower interstellar energies than those seen in 1997-98. At CRIS energies, lower-energy particles traverse less material in the ISM, on average, which results in the production of fewer secondary species.

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