First Results from the Advanced Composition Explorer (ACE)

NASA's Advanced Composition Explorer (ACE) was launched August 25, 1997 carrying six high-resolution spectrometers that measure the elemental, isotopic, and ionic charge state composition of nuclei from H to Ni ($1 \leq Z \leq 28$) from solar wind energies (~ 1 keV/nucleon) to galactic cosmic ray energies (~ 500 MeV/nucleon). Data from these instruments are being used to measure and compare the elemental and isotopic composition of the solar corona, the nearby interstellar medium, and the Galaxy, and to study particle acceleration processes in a variety of environments. ACE also carries three instruments that provide the heliospheric context for these composition observations by monitoring the state of the interplanetary medium. These three instruments (along with a fourth) also provide NOAA with continuous real-time solar-wind data from ACE's orbit about the inner Lagrangian point (L1). Table 1 summarizes characteristics of the ACE instruments.

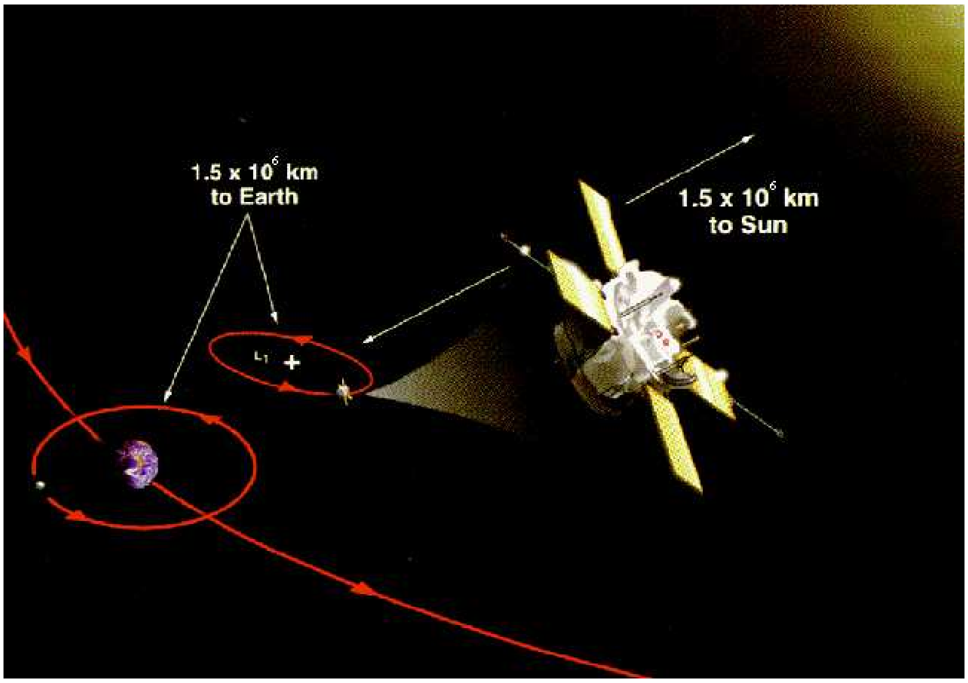

Figure 1: ACE at L1, between the Earth and the Sun.

New results from ACE were reported on May 26 during a special session of the Spring AGU Meeting in Boston. Highlights included new measurements of coronal mass ejections (CMEs) made with the SWICS, SWIMS, SWEPAM, and MAG sensors. In particular, the CMEs observed on Feb. 4-5, 1998 and May 2-4, 1998 were found to have very unusual composition. During the May event the observed ionic charge states of Fe ranged from never-before-seen (to our knowledge) Fe^{3+}, indicating very cold plasma with an electron temperature of $\sim 10^5$ K, to periods dominated by Fe^{16+}, indicating very hot plasma with several$\times 10^6$ K. Figure 2 shows measurements of the ionic charge state composition of Fe during two separate hours separated by less than a day; note the second period when very hot and very cold plasma co-exist. These data provide valuable information about

Table 1: ACE Instrumentation

Sensor	Full name	Measured Species	Measured Quantities	Typical Energy (MeV/nuc)	Technique
CRIS	Cosmic Ray Isotope Spectrometer	$2 \leq Z \leq 30$	Z, M, E	$\approx$ 200	dE/dx - E
SIS	Solar Isotope Spectrometer	$2 \leq Z \leq 30$	Z, M, E	$\approx$ 20	dE/dx - E
ULEIS	Ultra Low Energy Isotope Spectrometer	$2 \leq Z \leq 28$	M, E	$\approx$ 1	TOF - E
SEPICA	Solar Energetic Particle Ionic Charge Analyzer	$2 \leq Z \leq 28$	Q, Z, E	$\approx$ 1	E/Q dE/dx - E
EPAM	Electron, Proton & Alpha monitor	H, He, e^-	Z, M, E	$\approx$ 0.3	dE/dx - E
SWIMS	Solar Wind Ion Mass Spectrometer	$2 \leq Z \leq 30$	M, E/Q	$\approx$ 0.001	E/Q TOF - E
SWICS	Solar Wind Ion Composition Spectrometer	$2 \leq Z \leq 30$	Z, E	$\approx$ 0.001	E/Q TOF - E
SWEPAM	Solar Wind Electron, Proton & Alpha Monitor	H, He, e^-	E/Q dist.	$\approx$ 0.001	E/Q
MAG	Magnetometer	B	B_x,B_y,B_z		Triaxial fluxgate

E = energy, M = Mass, Z = nuclear charge, Q = Ionic charge, B = magnetic field

the CME during the period between the time of solar observations with imaging instruments on SOHO, and in situ plasma observations at 1 AU, i.e., electron and proton distributions measured by SWEPAM.

A suite of new instruments on ACE (as well as instruments on other spacecraft such as SAMPEX and Wind) recorded the first large solar particle events of the new solar cycle, including the Fe-rich events of 11/4/97 and 11/6/97. Figure 3 shows time-intensity plots of oxygen from two ACE instruments for the Nov. 6, 1997 event that extend over three decades in energy/nucleon.

The Nov. 6 event was of particular interest for several reasons: (1) It had a very hard energy spectrum (power-law index of approximately -2 at high energies) and was also detected by ground-level neutron monitors. (2) It provided unambiguous evidence for large mass fractionation effects (neutron-rich isotopes such as ^{22}Ne, ^{26}Mg, and ^{44}Ca were found by the SIS instrument to be over-abundant by factors of $\sim$ 2 or more). (3) The observed solar-particle charge states of several heavy elements, including Si and Fe, were found to increase with increasing energy/nucleon by both the SEPICA instrument and by SAMPEX. Figure 4 also indicates that the charge state composition of oxygen varied with time during this event. (4) The event was also observed by Ulysses at $\sim$ 5 AU, permitting an excellent opportunity to study the radial evolution of a large solar particle event with

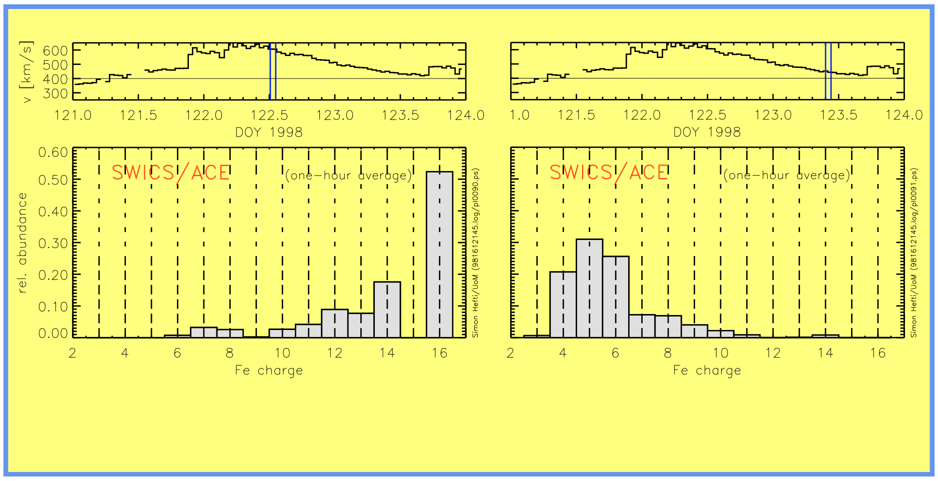

Figure 2: The ionic charge-state composition of Fe observed by SWICS/ACE during a CME in early May, 1998. Shown are 1-hour averages from two time periods; a movie that can be viewed at http://www.srl.caltech.edu/ACE/ACENews16.html shows the entire time history of this event.

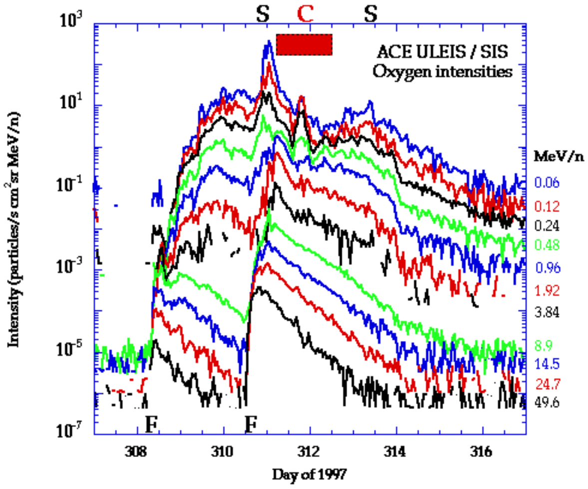

Figure 3: The intensity of oxygen nuclei from $\sim$ 0.06 to $\sim$ 50 MeV/nuc observed by the ULEIS and SIS instruments on ACE during the large SEP events of early November, 1997.

instruments such as EPAM/ACE and EPAM/Ulysses.

Also reported at the Boston AGU meeting were new measurements of the isotope ratios ^{18}O/^{16}O and ^{22}Ne/^{20}Ne in anomalous cosmic rays (ACRs), which represent a sample of the local interstellar medium that gets accelerated to energies > 10 MeV/nucleon at the solar wind termination shock. Figure 5 illustrates the first reported energy spectra for the rare isotopes ^{18}O and ^{22}Ne in ACRs. While additional analysis is required to compare the observed abundances of these isotopes in ACRs with those in the solar system, it is clear that the ^{22}Ne/^{20}Ne ratio in ACRs is much less than in galactic cosmic rays (where ^{22}Ne/^{20}Ne $\simeq 0.4$ after fragmentation corrections), substantiating SAMPEX and Voyager determinations that galactic cosmic rays are not simply an accelerated sample of the local

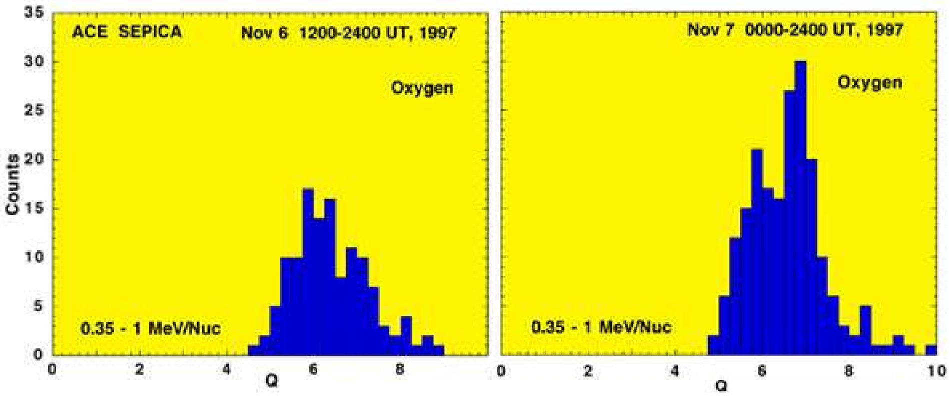

Figure 4: Variation in the ionic charge state composition of oxygen observed by SEPICA/ACE during the Nov. 6, 1997 solar particle event. A rough estimate yields a temperature of $\sim 2 \times 10^6$ for the first period and $\sim 2.3 \times 10^6$ K for the second.

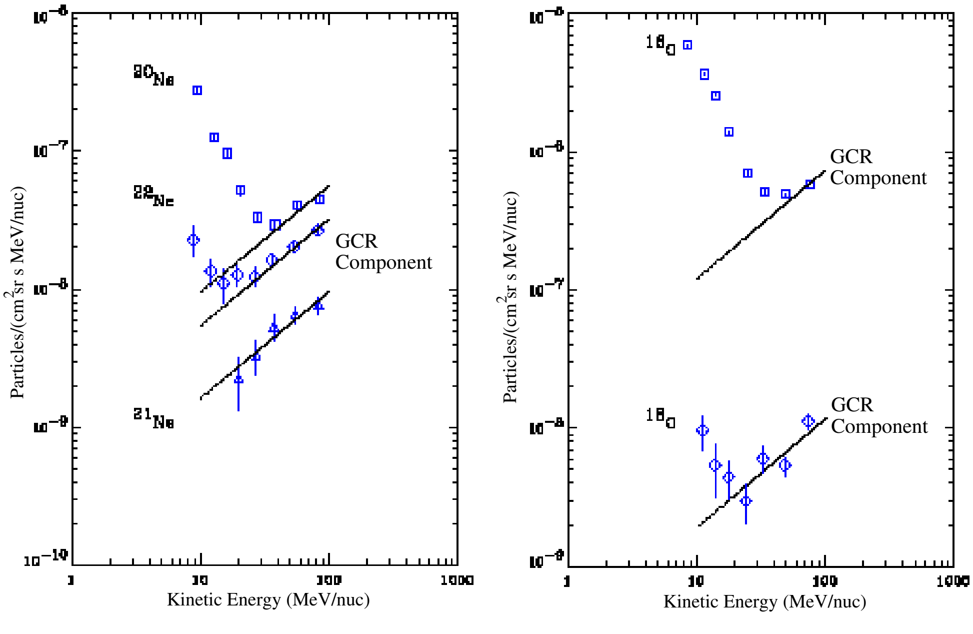

Figure 5: Quiet-time energy spectra of O and Ne isotopes observed by SIS/ACE showing anomalous cosmic ray enhancements in the rare isotopes ^{18}O and ^{22}Ne.

interstellar medium.

Finally, the CRIS instrument on ACE is providing new measurements of the isotopic composition of galactic cosmic rays with unprecedented statistical accuracy. New measurements of Fe, Ni, and Co isotopes in galactic cosmic rays are being used to measure the abundances of rare isotopes such as ^{57}Co and ^{59}Ni which can decay only by electron capture, which permits them to be used as clocks to measure the time that elapsed from nucleosynthesis to cosmic ray acceleration (at which time the nuclei will rapidly become stripped and can no longer decay). The measured abundances of ^{59}Ni

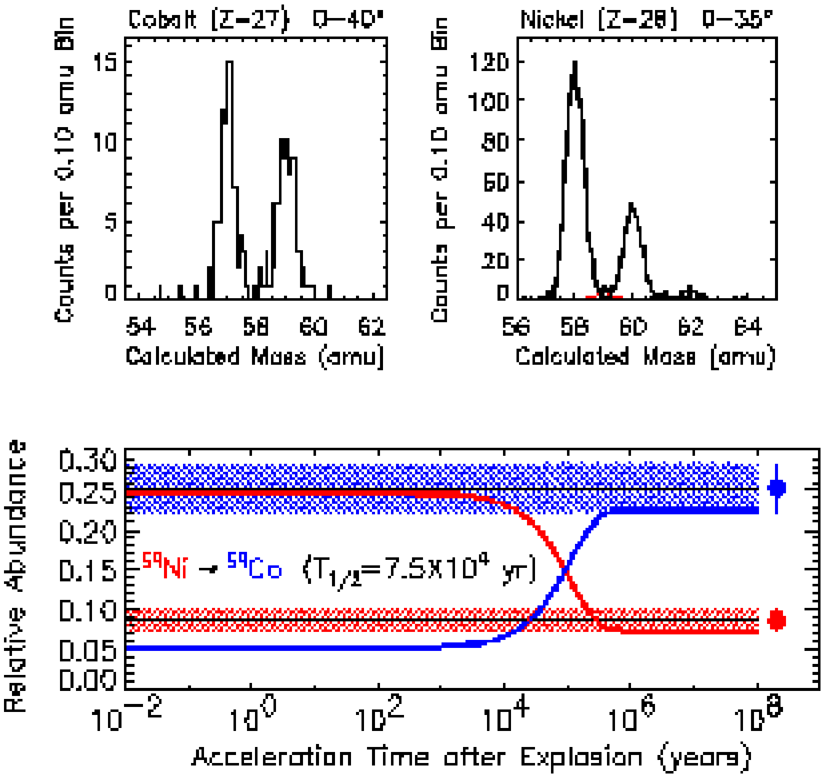

Figure 6: The top two panels show mass histograms of cobalt and nickel isotopes observed by CRIS. Note the low abundance of ^{59}Ni. The curves show calculations of how the abundances of ^{59}Ni and ^{59}Co are expected to depend on the elapsed time between the supernova explosion and cosmic ray acceleration. The hatched bands show ranges of ^{59}Ni and ^{59}Co that are consistent with the data, indicating a time delay of $> 10^5$ years.

and ^{59}Co (see Figure 6) indicate a long time-delay (at least 10^5 years) between the nucleosynthesis and acceleration of cosmic ray nuclei.

At the present time all nine instruments are performing as designed with one exception - SEPICA has suffered a failure in the isobutane system for one of its three, independent electrostatic charge state analyzers. Although this "fan" had higher resolution than the other two, the resolution and collecting power of the remaining two fans far exceeds that of any previous charge state analyzers in this energy range, and this failure will not prevent SEPICA from achieving its objectives. Data from ACE are down-linked to the Deep Space Network three hours a day. To date more than 99.9% of the recorded data have been recovered.

A forthcoming issue of Space Science Reviews will feature a series of articles that describe the ACE instruments, spacecraft, mission, the ACE Science Center, and the Real Time Solar Wind system, as well as review articles that address the scientific objectives of ACE. New results from ACE are posted periodically on the "ACE News" web site at

http://www.srl.caltech.edu/ACE/ACENews_curr.html.

For example, a recent ACE News Item displays a movie of ionic charge-state measurements from the May CME event described above. To receive notice of new postings of ACE News send e-mail to mewaldt@srl.caltech.edu with the subject ”ACE News E-mail List”. Real-time solar-wind data from ACE are available within 5 minutes of receipt at

http://sec.noaa.gov/ace/ACErtsw_home.html.

More complete listings of interplanetary ”Browse Parameters” from ACE, including solar wind, magnetic field, and charged particle data, are available within a week of receipt. See the ACE home page

http://www.srl.caltech.edu/ACE/index.html

for this and other ACE links.

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