# Anomalous cosmic ray studies using the geomagnetic field

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Citation: AIP Conference Proceedings **382**, 621 (1996); doi: 10.1063/1.51515
View online: http://dx.doi.org/10.1063/1.51515
View Table of Contents: http://scitation.aip.org/content/aip/proceeding/aipcp/382?ver=pdfcov
Published by the AIP Publishing

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**Abstract.** We use instrumentation on SAMPEX and the Earth's field as a magnetic filter, to obtain a "pure" sample of anomalous cosmic rays. The energy spectrum of anomalous oxygen is found to extend to ~100 MeV/nuc, which has implications for models of the acceleration of these nuclei.

Anomalous cosmic rays (ACRs) originate from interstellar neutral particles ionized by solar UV or charge exchange with the solar wind and then accelerated to ~5 to 50 MeV/nuc, presumably at the solar wind termination shock. According to this model, ACRs should be singly-ionized, and Klecker et al. [1995] find that at ~10 MeV/nuc <10% of ACRs have charge Q≥2. ACRs therefore have much greater magnetic rigidity than galactic cosmic rays (GCRs) or solar energetic particles with the same energy/nuc, and they can be observed to lower latitude. Using the Earth's field as a magnetic rigidity filter, we have obtained a "pure" sample of ACRs and measured their composition and energy spectra.

The observations were made with the MAST instrument on SAMPEX from 6 July 1992 to 7 January 1995. At mid-latitudes ($\Lambda \approx 40°$ to $60°$), fully-stripped GCRs are not allowed but singly-charged ACRs have access because of their greater magnetic rigidity. Figure 1 compares ACR energy spectra from the mid-latitude region with interplanetary spectra from $\Lambda>65°$. Note that the spectra of ACR N and Ne extend to >50 MeV/nuc, while ACR oxygen extends to ~100 MeV/nuc. This implies that the ACR accelerator must be capable of accelerating particles to at least ~1.6 GeV, considerably beyond the ~240 MeV "maximum" energy estimated by Jokipii [1990] for acceleration at the termination shock. However, the observed spectrum does steepen at ~15 MeV/nuc (Figure 1), consistent with Jokipii's estimate.

The acceleration of singly-charged ACRs to >1 GeV must occur in less time than the lifetime against electron stripping at ~100 AU, estimated by Jokipii [1992] to be ~5 years for 10 MeV/nuc ACRs. Jokipii also estimates that diffusive shock acceleration to 10 MeV/nuc at ~100 AU takes a minimum of 0.5 years for a perpendicular shock, the presumed termination shock geometry. Acceleration times for 100 MeV/nuc ACRs would be ~10 times longer (Jokipii 1992), and the integrated probability of stripping one or more electrons would be considerably greater than at lower energy because of the much greater pathlength traversed. This suggests that higher energy ACRs may not all be singly-charged, and that charge state measurements of higher energy ACRs may provide insight into the acceleration times of ACRs in the outer heliosphere.

For further results of this study, see Mewaldt et al. (1995).

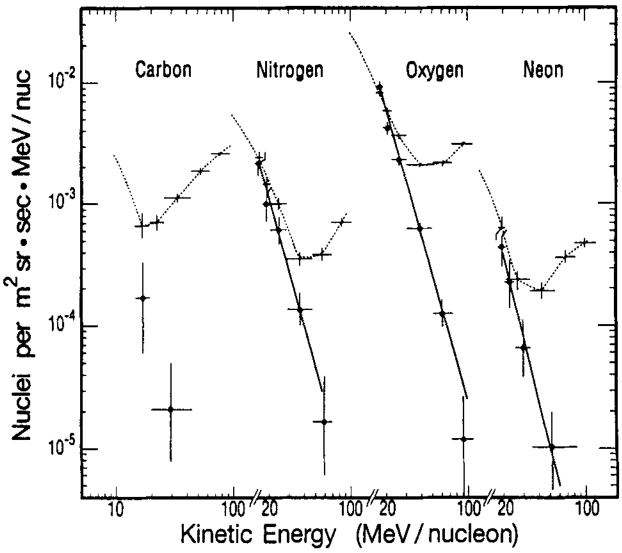


**Figure 1.** Energy spectra of ACRs measured at mid-latitudes are compared to interplanetary spectra from $\Lambda>65°$ (dashed). Solid lines show least-square power-law fits with spectral indices for N, O, and Ne of -3.6±0.4, 3.2±0.2, and -4.2±0.9 respectively.

**Acknowledgments.** Supported by NASA under NAS5-30704 & NAGW-1919.

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