THE HEAVY IONS IN SPACE EXPERIMENT

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ABSTRACT

The Heavy Ions in Space (HIIS) experiment was developed at Naval Research Laboratory and is currently in orbit onboard NASA's Long Duration Exposure Facility (LDEF). HIIS will record relativistic cosmic ray nuclei heavier than magnesium and stopping nuclei down to helium. The experiment uses plastic track detectors that have a charge resolution of 0.15 charge units at krypton (Z=36) and 0.10 charge units, or better, for nuclei lighter than cobalt (Z=27). HIIS has a collecting power of 2 square meter steradians and it has already collected more than a year's data.

1. Introduction. The Long Duration Exposure Facility (LDEF), a shuttle-launched free-flying satellite, was placed in a 28.4 degree inclination orbit at 476km on April 7, 1984. The LDEF spacecraft is a cylindrical structure, 14 feet in diameter and 30 feet long. The HIIS experiment is contained in two trays on the space-facing end of the spacecraft. LDEF will be retrieved on a later shuttle mission and returned to earth.

2. Scientific Objectives. The specific scientific objectives of this experiment are: (1) To measure the elemental composition of galactic cosmic rays. Particular emphasis will be placed on measuring individual elemental abundances for the elements zinc (Z=30) through zirconium (Z=40). These measurements will make it possible to compare the even and odd elements which have quite different nucleosynthetic origins (Cameron, 1982). (2) To measure the fluence, composition, energy spectra and arrival directions of low energy heavy ions that stop in the detector. Such ions could not have reached the LDEF orbit from outside the magnetosphere if they were fully ionized. The data collected on these ions will be examined in order to determine their origin.

3. Description of the Apparatus. The flight apparatus is shown in figure 1. Each tray contains four modules, each containing two detector stacks, a main stack and a top stack. The main stacks are sealed in a container that is filled with an atmosphere of dry breathing air. The lid of the module is an aluminum honeycomb structure with a thickness of 0.4 g/sqcm. The main stacks are 9.5 cm thick. In seven of the eight modules, the top stack is above the lid of the module, protected only by the thermal blanket. In the eighth module, this stack has been located

inside the sealed container under a specially designed lid consisting of 125 micrometer kapton film, aluminized on both sides.

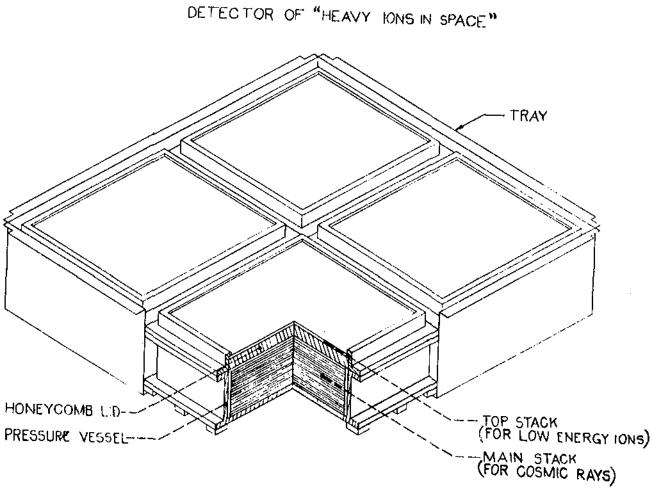

Figure 1: An LDEF tray containing four HIIS modules.

These track detector stacks will be used to measure the charge and the arrival direction of the ions that were recorded during the mission. In the case of stopping ions, the range will also be measured, and this will be used to estimate the energy of these ions.

4. Charge Resolution. The charge resolution of American Acrylics CR-39, used in HIIS, has been measured, with a 1.47 GeV/amu krypton beam at the BEVALAC. Figure 2 shows the results of the exposure. The resolution, 0.14 charge units at krypton, is adequate to resolve bromine from a much larger peak at krypton. Even a single rubidium ion, resulting from charge exchange, can be identified alongside the krypton peak. The resolution improves for lighter nuclei. We obtain 0.1 charge units resolution at iron. Similar results have been obtained for Pershore CR-39. To estimate the resolution of these detectors in a cosmic ray experiment, however, other effects must be considered.

It has been found that plastic track detectors change their response to ionizing particles with temperature at the time the particles are registered (Thompson et al. (1983)). The registration temperature effect has been investigated (Adams et al., 1984) for relativistic iron nuclei and stopping helium ions in CR-39 track detectors. These ions are more lightly ionizing than those used in the earlier work. Adams et al. found a smaller effect that had a temperature dependence opposite in sign to that observed by Thompson et al. This suggests that the registration temperature effect may not exist for ions that are somewhat more ionizing. Recently, we have measured the registration temperature effect for relativistic krypton ions. We find a very small effect of the same sign as reported earlier for relativistic iron. Our measurements show a reduction in the track-to-bulk etch rate ratio of 0.07 percent per degree centigrade between 0 and -78 degrees centigrade for CR-39.

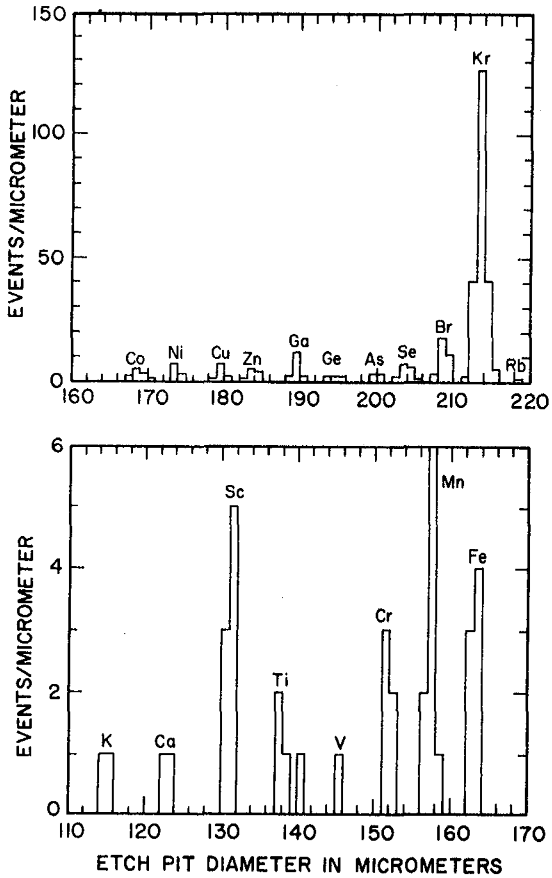

Figure 2: The distribution of average etch pit diameters for tracks from a relativistic krypton beam fragmented in a tank of water. The beam was normally incident on the detector stack. The tracks were measured in five sheets of American Acrylics CR-39 that had been etched at 70 degrees centigrade for 84 hours in 6.25N NaOH plus 0.04 percent Benax. Because of nuclear fragmentation in the detector sheets, and occasional overlapping tracks, all ten etch pits could not be measured on some tracks. Events were included in this plot if three or more etch pits had been measured on the track.

If we take this result as typical for relativistic nuclei from zinc to zirconium, the full range of temperature variation expected for the HIIS main detector stacks would only spread the individual charge peaks by +/- 0.14 charge units. The registration temperature effect is, therefore, expected to have a minor effect on the charge resolution in this part of the periodic table. A separate investigation for stopping ions from helium to silicon shows that individual charges can be resolved in this region as well.

5. Capabilities of the Experiment. The HIIS experiment has been recording ion tracks for more than a year. It should already have recorded 12,000 tracks due to cosmic rays from copper(Z=29) to zirconium. This is more than four times larger than the sample reported for the HEAO-C experiment (Binns et al., 1983). In addition to the lighter nuclei, some 49 tracks should have been recorded by cosmic rays heavier than tungsten.

The two square meter steradian collecting power of the HIIS experiment is much larger than that of the electronic charged particle telescopes which have been used to study stopping ions. HIIS will detect stopping oxygen nuclei from 8 to 300 MeV/amu. For stopping iron, the energy range is 15 to 800 MeV/amu.

The exposure obtained, to date, on LDEF would make possible the detection of particle fluxes as low as $1.5X10^{-8}$ particles/meter sq.ster.sec. If the anomalous component ions are not fully ionized (Fisk et al., 1984), they should be found stopping in the HIIS detectors (O'Dell et al, 1977). Other sources of stopping heavy ions may be the inner radiation belt, or cosmic ray splash albedo. Chan and Price (1975) and Biswas et al. (1977) report observing stopping ions outside SKYLAB which were thought to be trapped radiation. The HIIS experiment has already accumulated more than 300 times the exposure of the SKYLAB experiment, so it may be possible to extend these earlier measurements. Humble et al. (1979) have considered the contribution from splash albedo and estimate that this effect is small, but Blanford et al. (1972) report detecting stopping heavy ions in balloon flights over Texas that they attribute to re-entrant splash albedo. This source may also contribute to the observed flux of stopping ions in the HIIS experiment.

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7. References

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