The EPACT Experiment for the WIND Spacecraft

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Abstract

This paper describes the Energetic Particle: Acceleration, Composition and Transport (EPACT) experiment for the WIND spacecraft which is to be launched in late 1992.

1. Introduction. The EPACT experiment is designed to study the acceleration, composition and transport of a wide variety of energetic particle populations, including particles from solar flares, particles accelerated in interplanetary shocks, the anomalous component, and the galactic cosmic rays. It is intended to be a major step forward over the instruments which we flew previously on ISEE-3. WIND will be moving between the earth and the sunward Lagrangian point, L1, for its first year and a half in space and then will be injected into a halo orbit around L1. WIND will therefore be in an ideal location for observing interplanetary particles essentially continuously. An on-board tape recorder will also make it possible to have continuous data coverage, potentially for more than five years.

2. Experiment Goals. Observations of particle populations to date have frequently been limited by detection sensitivity. For example, He^3-rich events were once thought to be rare. By using very thin detectors (15 microns) in order to lower the threshold energies and take advantage of the steep energy spectra, we were able on ISEE-3 to substantially increase our sensitivity and hence establish that He^3-rich events occur near earth on average every three weeks. These events are also closely correlated with Type III radio bursts, but there are many Type III bursts for which we observe no He^3. With greater sensitivity, then, we might observe that He^3-rich events are even more common. In addition, with greater sensitivity we could observe the abundances of heavy elements in many more of these events. As another example, efforts have been made to establish that the anomalous component is singly charged by using the earth's magnetic field as a magnetic spectrometer. These efforts have been seriously hampered by the fact that no contemporary measurements of the anomalous component immediately outside the earth's magnetosphere have been available: the anomalous component fell below the threshold of detectability as a result of solar modulation. One of the goals of the EPACT instrument therefore is to greatly increase our sensitivity for observing low energy particles. This will make it possible to observe the elemental composition in individual impulsive flare events and interplanetary shock events and, potentially, to make the first observations of ultra-heavy nuclei in solar flares.

A second goal is to measure the isotopic composition of energetic particles in solar flares, in the anomalous component, and in the galactic cosmic rays. The cause of the enhancement of He^3 in He^3-rich events by factors of more than 2000 relative to He^4 is still a mystery. Observations of the isotopes of other elements might be able to provide clues to this process. The anomalous component is evidently a sample of the local interstellar medium, so its isotopic composition is also of interest. The isotopic abundances of the galactic cosmic rays have begun to be measured, and it

appears that there are significant differences relative to the solar system which can provide clues to the origin and acceleration of the galactic cosmic rays.

Finally, we are interested in the propagation of energetic particles, both within the solar system and from cosmic sources. Transport processes will be studied in conjunction with other spacecraft such as Ulysses, the Pioneers and the Voyagers, in addition to using observations of local anisotropies.

3. Description of EPACT. The EPACT experiment must make observations over an extremely broad range of elements, energies, and intensities. As a result, EPACT consists of multiple telescopes, which also provides a level of protection against single-point failures. Solid-state detectors are used throughout for reliability and long-term gain stability. The individual telescopes include 3 Low Energy Matrix Telescopes (LEMT), two Alpha-Proton-Electron Telescopes (APE-A and APE-B), an Isotope Telescope (IT), and a Supra Thermal Energetic Particle Telescope (STEP). All but STEP use the dE/dx by E method of particle identification. STEP, a late addition to EPACT, measures time-of-flight and energy, from which particle mass can also be obtained. STEP was originally built for the U.S. Solar Polar spacecraft. Salient characteristics of these telescopes are presented in Table 1, while their charge and energy ranges are illustrated in Figure 1 (the Isotope Telescope is not included in Figure 1, but its range largely coincides with that illustrated for the two APE detectors taken together, not including the hashed area in the figure which corresponds to penetrating particles).

LEMT- One of the three identical LEMT's is illustrated in Figure 2. It consists of 16 thin (18 micron) front detectors arrayed on a dome to minimize pathlength variations, a residual E detector and an anti-coincidence detector. The multiple front detectors provide immunity from micrometeorites and a coarse measure of position. The residual E detector is segmented into 5 strips on each side which divide the detector into 25 logical segments for coarse position resolution. As the spacecraft spins, the entire sky is covered by the telescopes. The LEMT's have a collection power 100 times greater than their predecessors on ISEE-3. Since the telemetry allocation has increased by only a factor of 4, extensive onboard data processing is a necessity. Each event is characterized by a

Table 1: EPACT TELESCOPES

	LEMT	APE-A	APE-B	IT	STEP
Charge Range	1 90	-1 - +26	-1 - +26	2-26	2-26
Energy Range					
Electrons (MeV)	--	0.2-2	1-10	--	--
Helium (MeV/n)	1 1-11	4.3-25	19-500	3.4-85	<0.1-10
Iron (MeV/n)	1.7-43	14-100	73-300	10-360	<0.1-1
Geometry Factor (cm2-sr)	3 x 17	1.2	1.6	8	2 x 0.4
Isotope Resolution	He3 He4	He3/He4	He3/He4	ΔM=0.3 at Fe	He3/He4

pulse height from a front detector, and a pulse height and a position from the residual E detector. The two pulse heights are each converted to one of 64 logarithmically spaced channels using table look-up; a slight correction is made to the front detector pulse height which takes into account the inclined particle path and the thickness of the particular front detector. The resulting pulse heights are then used to enter a 64x64 entry identification table which yields the software address where the event is to be counted. About 200 different particle type/energy bins will be accumulated in this manner. The particle identification algorithm takes about 70 microseconds.

APE-A/B- The Alpha-Proton-Electron telescopes (not illustrated) are solid-state detector telescopes of fairly conventional design. The APE-B telescope utilizes curved front detectors to minimize pathlength variations. The on-board processing algorithm is similar to that of the Isotope Telescope except that the particle incident angle is not measured. The purpose of the APE telescopes is to reduce the dynamic range requirements on the Isotope Telescope. They also provide redundancy for the measurement of heavy elements.

IT- The Isotope Telescope is illustrated in Figure 3. The front two detectors are two-dimensional position-sensitive detectors which have 85 strips on each side at a half mm pitch. They are interconnected by 50 micron wide resistive strips which are part of the metallization pattern which forms the primary strips. This approach greatly reduces the number of connections which would have to be made to the detector surface if the resistors were external to the detector. In addition, 5 preamplifiers are connected at regular intervals to each side of each detector to reduce the charge collection time and cross-talk between the two sides. These position sensitive detectors are new in concept and need to undergo accelerator tests to prove their capability.

An on-board processing algorithm evaluates the quantity

$$z' = \left(\frac{k}{\Delta x_0 2^{\gamma-1}}\right)^{\frac{1}{\gamma+1}} \left(\cos\theta\left(E^{\gamma} - E'^{\gamma}\right)\right)^{\frac{1}{\gamma+1}}$$

as a measure of a particle's mass, where E is the incident energy, E' is the residual energy, θ is the incident angle and k, γ are parameters of a power law fit to the range-energy curves. An initial version of this algorithm takes approximately 1 msec for each particle.

STEP- STEP is illustrated in Figure 4. It uses large-area microchannel plates and shaped potentials to collect electrons from a thin foil at the front and from the total energy detector at the rear to form start and stop signals, respectively, for measuring the incident particle velocity. The velocity combined with the total energy measurement allows the particle mass to be determined. The lower end of the STEP energy range may be lower than that depicted in Figure 1 depending upon the foil thickness which is finally chosen.

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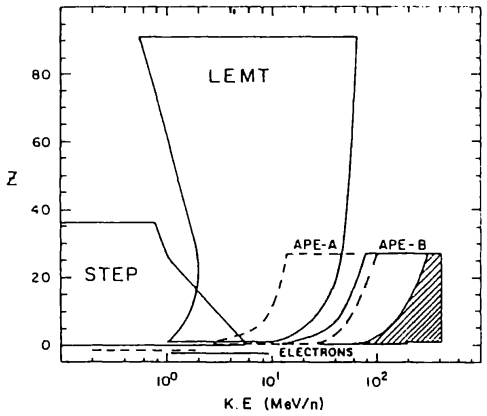

Figure 1- EPACT charge and energy ranges.

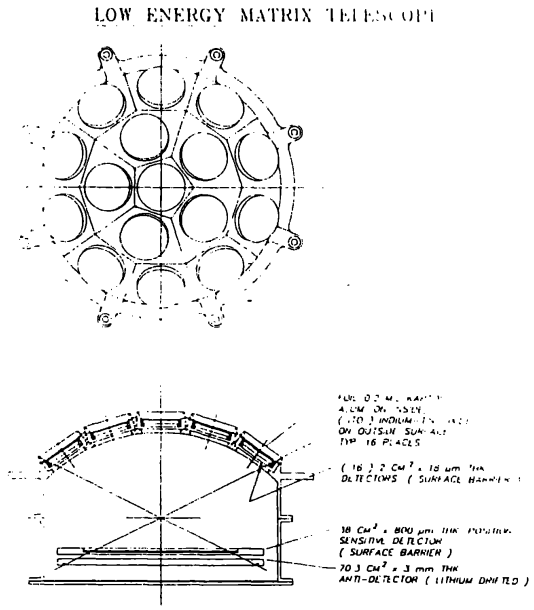

Figure 2- One of 3 Low Energy Matrix Telescopes.

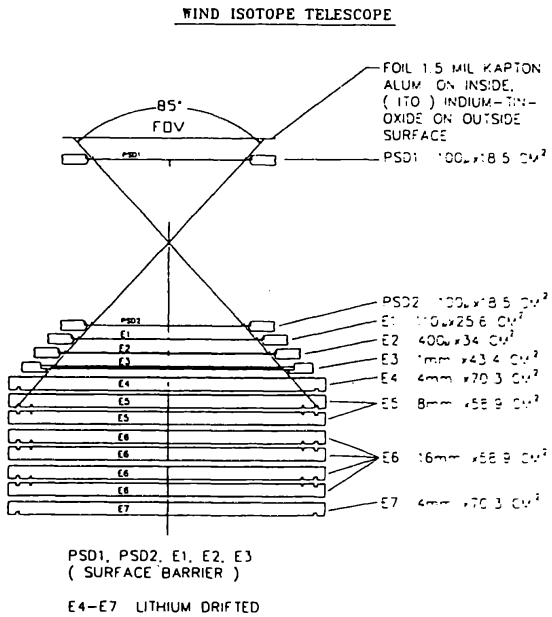

Figure 3- The Isotope Telescope.

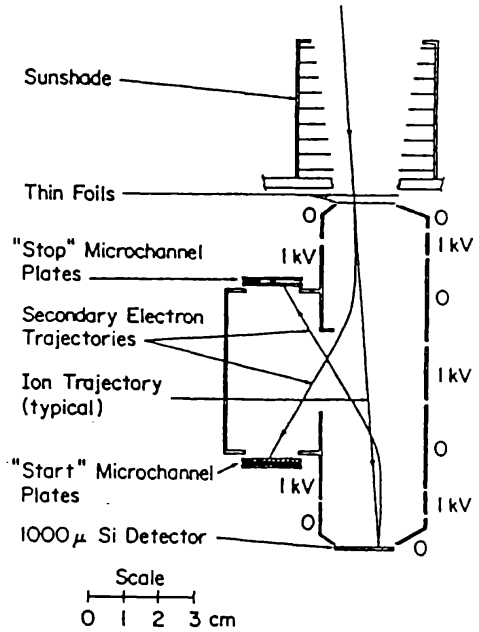

Figure 4- STEP.