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The Voyager Electron Telescope – A Status Report

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Abstract

The CRS instrument complement on Voyager 1 and 2 includes a small electron telescope covering the energy range from 6 – ~160 MeV. While recent observations out to 73 AU indicate the telescope response is dominated by background events produced by higher energy galactic cosmic ray ions, these data do provide upper limits on the electron intensity that are several orders of magnitude below the expected local interstellar levels. Since the background rate is expected to increase by less than a factor of ~3, the response of the electron telescope should be a sensitive indicator as the Voyagers approach the modulation boundary.

1 Introduction:

The galactic cosmic ray electron component should consist of directly accelerated primaries, of interstellar secondaries from the decay of charged pions, and at lower energies, knock-on electrons produced by the passage of higher energy cosmic rays through the interstellar medium. At energies below some 200 MeV these electrons are the source of the lower energy diffuse gamma and x-ray emissions from the galaxy and may play a major role in ionizing and heating the interstellar medium. Within the heliosphere they are strongly modulated, even at solar minimum. Between 1 and ~10AU at energies below some 40 MeV there is a large contribution from Jovian electrons. The Voyager missions to the outer heliosphere offer an ideal opportunity to directly observe this component and to study the modulation process at very low rigidities.

This paper gives an overview of the Voyager electron observations from 1985 to the present including solar electron events over the 1998-1999 period along with estimates of the upper limits of the spectral distribution at 70 AU and its comparison with recent estimates of the low energy interstellar electron spectra.

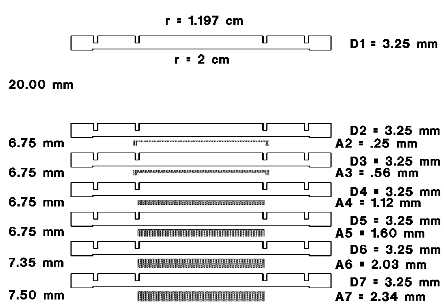

Figure 1a: ElectronTelescope Schematic

2 Observations:

The electron energy spectrometer (Stone et al., 1977) uses double-grooved solid state detectors that provide an active anti-coincidence shield around the telescope to reduce the background (Fig. 1a) and graduated tungsten inserts that define the energy response over a range that extends from 6 – ~160 MeV. Electrons and their energies are identified by a double dE/dx measurement in detectors D_1 and D_2 and by a simultaneous measurement of their range as determined by the penetration of detectors D_3 through D_7. The preflight accelerator calibration (Fig. 1b) is used to deconvolve the energy spectra from the measured range distributions.

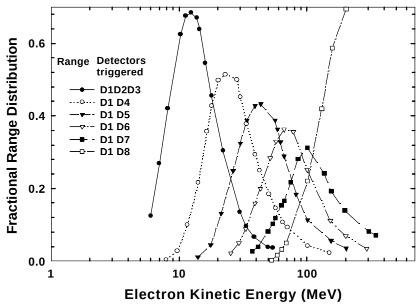

Figure 1b: Electron-calibration results for prototype Voyager Electron Telescope. The response curves shown represent the fractional distribution of mono-energetic electrons over the telescope ranges.

The time history (26 day averages) of 14-26 and 45-73 MeV electrons and 180-450 MeV/n He for V1 and V2 are shown in Figure 2 for the 1985.5-1999.3 time period. Over the 1987 solar minimum period the V-2 He intensity is appreciably greater than that of V-1 (33°N) which is at a greater heliocentric distance than V-2, but both are less than the P-10 He intensity at 43AU. This negative latitudinal gradient (McDonald et al., 1992, 1998; Webber and Lockwood, 1997) is consistent with the expected drift effects in this qA<0 epoch when ions move in along the heliospheric neutral current sheet and exit over the solar poles. The electrons should exhibit the opposite flow pattern with a positive latitudinal gradient. The fact that the electron time histories over this entire period closely follow that of He, and indeed exhibit a negative latitudinal gradient, provides the strongest evidence that the electron response is dominated by background produced by galactic cosmic ray protons with energies that are estimated to be greater than some 800 MeV. This lower limit on background protons is primarily constrained by the D_1,D_2 pulse height measurements. The significant difference between the V-2 and V-1 electron intensities at the time of the 1990 solar maximum is not understood. Unlike the cosmic ray ions, this difference leads to a negative radial gradient and possibly represents a longer-lived version of the solar interplanetary electron events discussed in the next paragraph. The energy spectra derived from the measured range distribution in late 1997 is shown in Fig. 4. These values should be regarded as upper limits on the electron intensity at 70AU over the

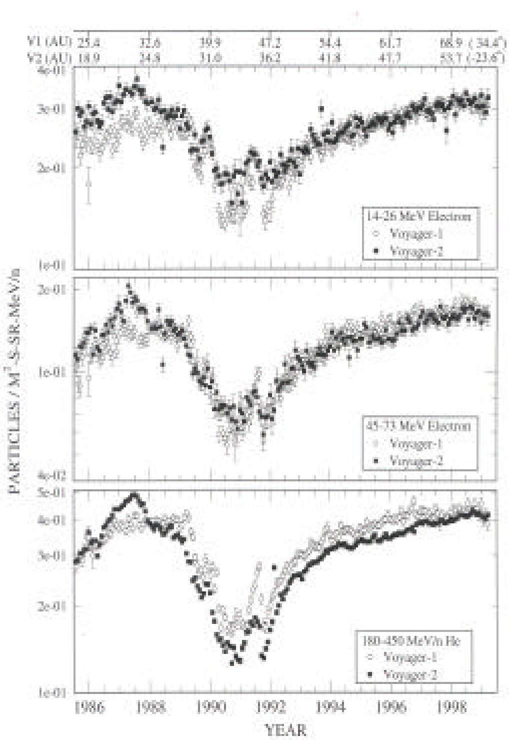

Figure 2: Time histories (26 day averages) of V-1 and V-2 electron telescopes corresponding to 14-26 and 43-73 MeV electrons. As discussed in the text these channels are still dominated by proton (>0.8GeV) produced background events. Also shown for comparison is the 180-450 MeV/n He intensity (26 day AVG) for the same time period.

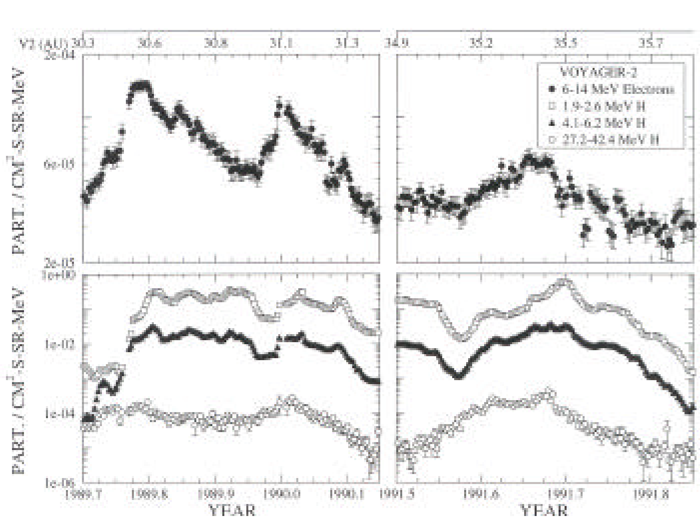

Figure 3: Time histories of solar/interplanetary proton and electron increases associated with GMIRs near the solar maximum period of cycle 22. The second panel (1991.5-1991.8) was associated with the March/June periods of intense solar activity. This electron event was barely detectable at V-1, at some 11 AU greater heliocentric distance, suggesting a strong negative radial gradient for this component.

solar minimum period of cycle 22.

The episodes of strong solar activity over the last half of 1989 and in June 1991 produced well-defined, delayed, electron increases in the outer heliopshere at V-2 (Fig. 3). These electron events are closely related to the enhanced fluxes of low energy protons associated (Fig. 3) with the global merged interactions regions produced by the coalescence of multiple coronal mass ejections. It is believed, but not established, that these electrons are a small remnant of the original solar electron component whose energies have been partially maintained through their interactions with the interplanetary shocks associated with the GMIR, and whose intensities are decreasing rapidly with increasing heliocentric distance.

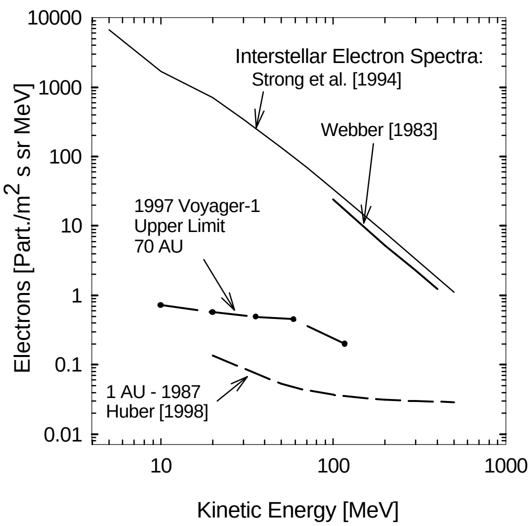

Figure 4: Comparison of the upper limit to the V-1 electron intensity at 70 AU derived from the measured range distribution in 1997. Also shown are the interstellar electron spectra of Webber et al. (1983) and Strong et al. (1994) and the 1987 quiet time measurements of Huber 1998 at 1 AU.

3 Discussion

Webber et al. (1980), using new data on the low-frequency galactic non-thermal radio emission and Strong et al. (1994) using the diffusive galactic continuum gamma ray emission from the Comptel experiment on the Compton Gamma Ray Observatory over an energy range of 0.75-30 MeV have obtained new estimates of the interstellar electron spectra from 70-1200 MeV and 1-1000 MeV respectively (Fig. 4). The agreement between these 2 very different approaches is quite good.

These new estimates of the local interstellar electron spectra are more than 1150 times larger than the upper limit to the Voyager electron intensity at 20 MeV, and 130 times larger at 100 MeV at a heliocentric distance of 70 AU (Fig. 4).

These differences are significantly larger than the expected increase in background (less than a factor of 3) when Voyager reaches the intensity of galactic cosmic ray protons expected in local interstellar space (Webber et al. 1987). The response of the electron telescope as it moves into the regions of the outer heliosphere accessible to 6 – 160 MeV electrons should be a very sensitive indicator of Voyager's approach to the modulation boundary. The electron intensities are monitored on a monthly basis (~ every .3AU).

Also shown in Fig. 4 are the 1AU compilations of ISEE-3/ICE and balloon measurements by Huber 1998 over the 1987 solar minimum period. A comparison with the 70AU upper limits suggest that the electron radial gradients over the 20-100 MeV energy range are small between 1 and 70AU and there must be a strong increase in the gradients between 70AU and the modulation boundary. It would not be surprising if most of the modulation of this component occurs in the region of the heliosheath.

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