THE JOVIAN ELECTRON SPECTRUM: 1978-1984*

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ABSTRACT. Observations of Jovian electrons through six consecutive 13-month Jovian synodic periods from 1978 to 1984 have been made by the University of Chicago electron spectrometer onboard the ISEE-3 (ICE) spacecraft. The Jovian electron spectrum was determined from 5 to 30 MeV and was found to have a shape which is not a power law in kinetic energy, but cuts off at approximately 20 MeV. The average shape of the spectrum over each of the six intervals of best magnetic connection remains the same for all intervals within uncertainties.

1. INTRODUCTION. Observation of interplanetary electrons of Jovian origin at 1 AU provides a unique opportunity to study the propagation of charged particles in the inner heliosphere. Jupiter is a point source of particles imbedded in the solar cavity which sweeps through a range of magnetic connection to the earth with a well defined period. Previous investigators of Jovian electrons at 1 AU during the period of solar minimum (1,2) successfully applied a convection-diffusion model of propagation, determined the value of the "cross-field" diffusion coefficient, and demonstrated the modulation properties of corotating interaction regions. The study presented in this paper goes beyond the previous work into the time of solar maximum with observations by the University of Chicago spectrometer onboard the ISEE-3 spacecraft.

2. METHOD. A detailed description of the University of Chicago electron spectrometer onboard ISEE-3 is given in reference (3). The observations from ISEE-3 are unique in two aspects: the large change in the level of solar activity during the active life of the spacecraft and the absence of magnetospheric effects as the spacecraft was positioned at the inner Lagragian point during most of the flight. Also, the instrument was very stable over the six years of observations. The single factor restricting continuous coverage of Jovian electrons is contamination by solar flare electrons. Elimination of solar flare contamination periods is handled by monitoring the spectral index of electrons observed on IMP-8 at lower energy (1-3 MeV). A better solar flare monitor is being developed using data from the Max-Planck-Institute ULEWAT instrument on ISEE-3 which is also free from magnetospheric effects.

The question of instrument stability in time is critical for solar modulation studies. The solid state detectors and plastic anticoincidence detectors show stability at the 3% level in all calibration and consistency checks over the duration of the flight. The ethylene gas Cerenkov detector used for proton rejection has a small gas leak, and loses approximately 1 atm of pressure per year from an initial pressure

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of 18 atm. The change in Cerenkov threshold is continually measured by a change in the pulse height distribution of the Cerenkov signal. The CsI calorimeter also exhibits a drift due to gain changes in the photomultiplier tube for which a correction is made using pulse height analysis of the signal from minimum ionizing protons.

Excellent background rejection is obtained with the requirement of a Cerenkov signal coincident with a stopping particle. The modulation of the flux of Jovian electrons at 1 AU due to changes in the degree of magnetic connection of the spacecraft to Jupiter can be used to further improve background rejection of particles which are not electrons, as well as electrons which are not Jovian in origin. The 10 MeV energy bin was chosen to monitor the Jovian modulation because it is the bin with the highest background rejection efficiency and because solar flares only rarely emit electrons at 10 MeV. A regression of daily rates of each energy bin relative to the 10 MeV bin determines the spectral shape of the Jovian component.

3. RESULTS. An example of a Jovian electron energy spectrum determined by the regression technique during the first epoch of best connection (Oct. 27, 1978 to Feb. 24, 1979) is shown in Figure 1. The spectrum is normalized by the average flux in the 10 MeV bin with the assumption that the flux in that bin is totally free of background. One characteristic of the Jovian electron spectral shape of particular interest is the roll off at energies above 20 MeV. The existence of a high energy limit to the Jovian interplanetary emission was first suggested in (4) and has implications for the acceleration of Jovian electrons, as will be discussed in a separate paper.

The form of the energy spectrum of Jovian electrons determined by the regression technique is found to be the same for each epoch of best connection. Therefore, within statistical errors, the average spectral shape of the Jovian quiet-time increases is constant over the period of observation covering six Jovian seasons. Further, the correlation of the daily rates of each energy bin with the reference 10 MeV bin is better fit by a linear regression than by any higher order polynomial during any one epoch of best connection, implying that the spectral shape is constant over a time scale as short as one day. The chi-square goodness of fit parameter degrades with the separation in mean energy of a bin from the reference 10 MeV bin. Because of limited statistics, the interpretation of this uniform scatter about the regression fit line as fluctuations of the spectral shape about an average shape cannot be quantified. Specifically, 10 hour variations in

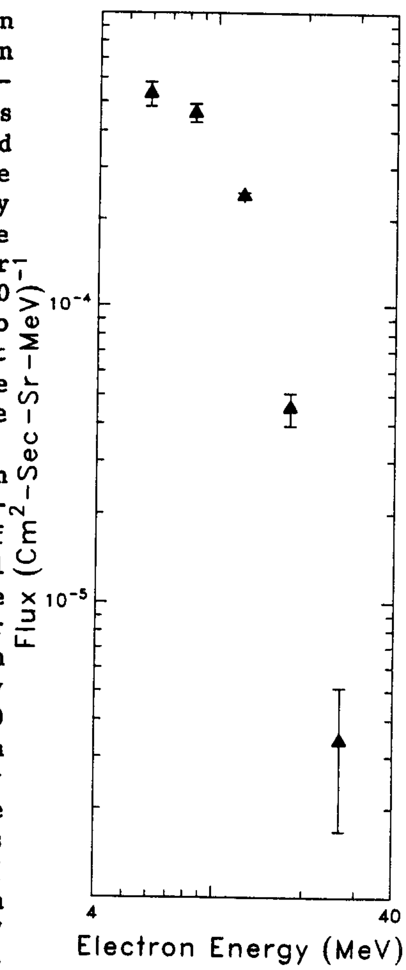

Fig. 1: Jovian electron spectrum determined by regression fit technique during Dec. 1978 epoch.

the spectral shape were searched for using several techniques and none were found.

4. DISCUSSION. The spectral shape of Jovian electrons below 10 MeV presented in this paper is flatter than the kinetic energy power law index of 1.5 reported in (5). However, the spectral index reported at lower energies (.2-1 MeV) of -1.3 or less (6) coupled with the observed roll off above 20 MeV demonstrates that a power law spectrum is a poor approximation in this energy regime. Relying on the background rejection efficiency of the instrument, an average spectrum over the same time interval can be generated which includes the electron component not modulated by the change in the magnetic connection of the spacecraft to Jupiter (and therefore excluded from the spectrum obtained by the regression technique) (Figure 2). This spectrum more closely matches that of Eraker and Simpson (5) and, in comparison with the spectrum obtained by the regression technique, suggests the existence of a significant non-Jovian component at lower energies which would probably be of solar origin. A low energy solar electron component could also explain the degradation of the goodness of fit parameter at these energies.

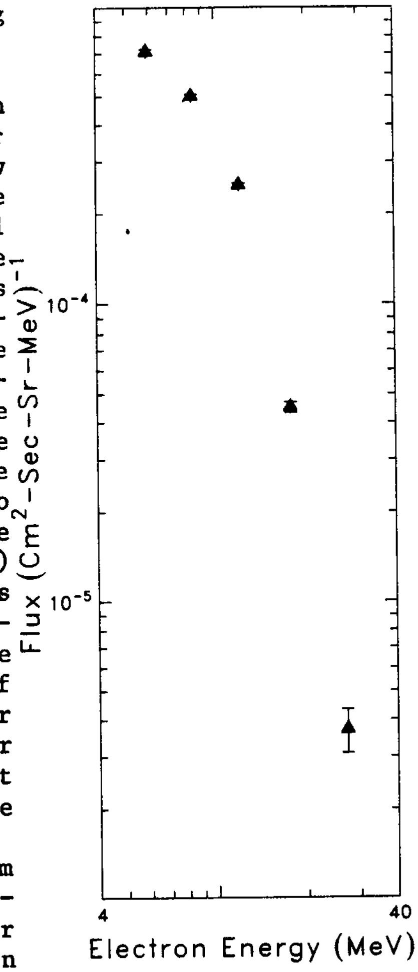

Fig. 2: Spectrum of all electrons during December 1978 epoch.

The constancy of the spectral shape from epoch to epoch during the onset of solar maximum activity demonstrates the lack of solar cycle modulation of the Jovian electron spectrum. This lack of solar modulation is consistent with the conclusions from the radial gradient measurements of cosmic rays (7) that during solar maximum activity 99% of modulation occurs at a solar distance >31 AU. The difference in solar modulation of galactic particles and the relatively local Jovian particles is very clearly seen in the intensity-time plots in Figure 3. While galactic relativistic protons of significantly higher rigidity undergo an obvious solar cycle intensity variation, the Jovian electrons continue with the same 13-month cycles fit by the same convection-diffusion model envelope as observed during solar minimum activity. The only solar cycle effect in the Jovian electrons noted to date is a more impulsive rise and fall of individual increases.

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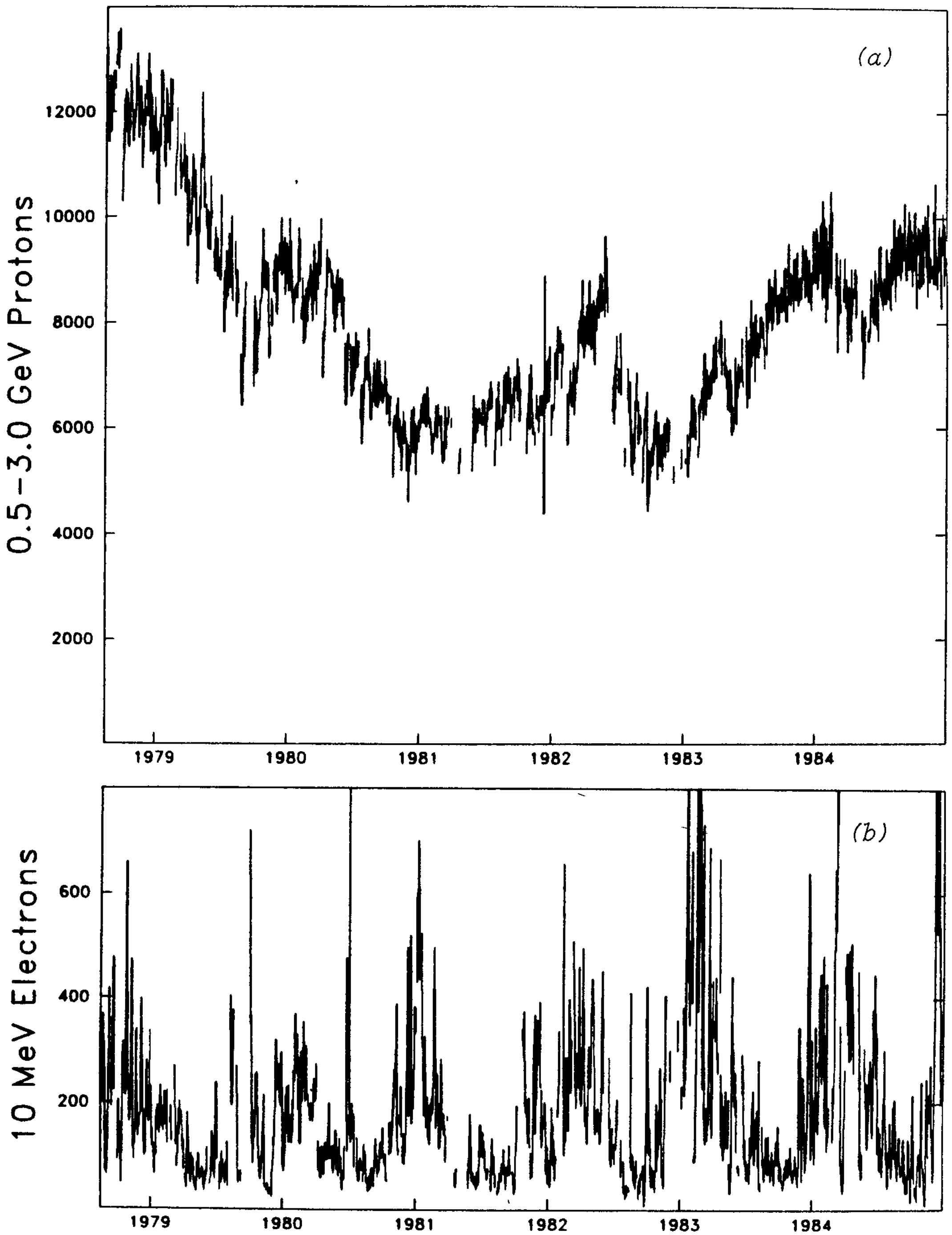

Fig. 3: Daily rates of protons (a) and electrons (b) observed by ISEE-3. No flare subtraction has been made in these plots.