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QUIETTIME ELECTRON INCREASES

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The IMP spacecraft have been monitoring the behavior of cosmic rays in the interplanetary medium almost continuously since the earth 1960's. In particular, the behavior of 0.5- to 1.9-pJ (3- to 12-MeV) interplanetary electrons has been studied. I would like to tell you today about a new cosmic ray phenomenon that has been detected in the behavior of these electrons, and about a possible explanation for this phenomenon, which, if correct, gives us some real clues about interplanetary conditions far beyond the orbit or Earth.

In Figure 1, I have plotted the daily averages of the 0.5- to 1.9-pJ (3- to 12-MeV) electron intensity that was observed from the IMP's by McDonald, Cline, and Simnett (Ref. 1). These data cover the period 1965 through 1968. The abrupt increases in the intensity, which are marked by the dark boxes, are solar flares. The brackets mark the new phenomena that I would like to tell you about. These are known as quiettime electron increases.

There is present throughout this period a relatively steady background flux of galactic electrons. Quiettime increases give every impression of being simply localized increases in this background flux. We suspect this because quiettime increases occur in anticoincidence with increases in the flux of low-energy solar protons. We can be sure of the galactic origin for the electrons in quiettime increases by examining their spectra. Quiettime increases and the galactic background both have the same spectral index of about -2. Quiettime increases occur when there is an enhanced influx of galactic electrons into the inner solar system.

Now clearly, quiettime increases must occur when conditions that normally exclude a large fraction of the 0.5- to 1.9-pJ (3- to 12-MeV) galactic electrons from the inner solar system are altered, permitting more electrons to enter. This exclusion is due presumably to magnetic irregularities that are carried outward with the solar wind. There is no evidence, however, either from gradient measurements or from diffusion coefficients that can be inferred from solar flare time profiles that 0.5- to 1.9-pJ electrons experience much scattering in the inner solar system. In the case of the electrons, the region where the scattering occurs, the modulating region, must lie far beyond the orbit of Earth.

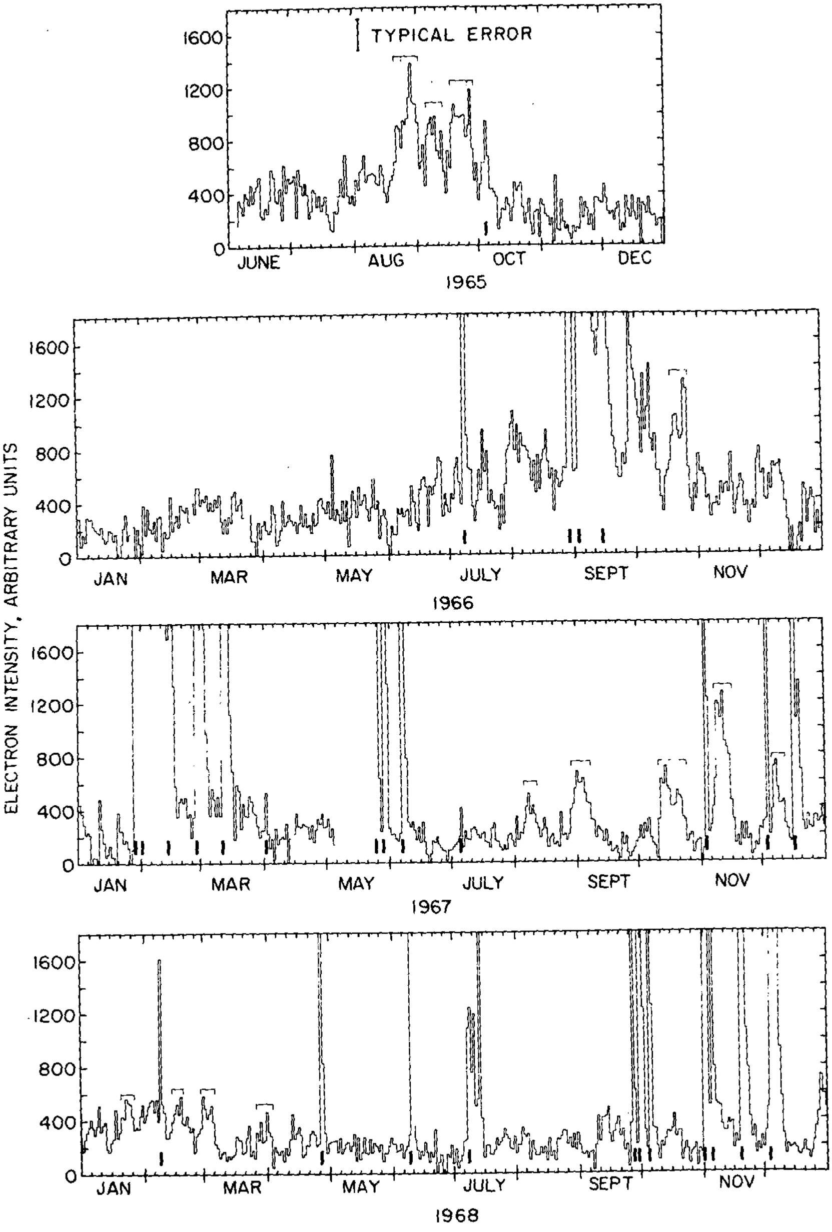

Figure 1–Daily averages of the 0.5- to 1.9-pJ (3- to 12-MeV) electron intensity as obtained from IMP data.

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We can actually get a measure of the location of this modulating region by considering the sequence of events that might lead to a quiettime increase. The mean field direction in a modulating region far beyond Earth will be essentially azimuthal about the Sun, so particles will pass through this region principally by diffusing perpendicular to the field. Perpendicular diffusion, in turn, is caused principally by field-line random walk; that is, the amount of random walking that individual field lines do about the mean field direction. In the solar system, field-line random walk is caused mainly by photospheric turbulence, the base of the field lines moves randomly with the photospheric turbulence, and then the random walk is executed as the solar wind drags out the field.

We have, then, the following sequence of events leading to a quiettime increase. A group of field lines executes a larger-than-average random walk in the photosphere. The solar wind drags out these field lines past the orbit of Earth to a modulating region lying further out. When they reach this modulating region, more 0.5- to 1.9-pJ (3- to 12-MeV) electrons diffuse through the region and propagate back into the inner solar system, and we have a quiettime increase at Earth. Clearly the delay time between when the field lines with their large random walks pass Earth and when the quiettime increase occurs is a measure of how long the solar wind takes to get to this modulating region, a measure of how far the modulating region is away.

One useful indicator of the random walk is the amplitude of the diurnal anisotropy, as is measured by neutron monitors. Low-amplitude anisotropies occur in coincidence with large random walk. We looked back, then, before each of the quiettime increases to see whether they were preceded by periods of low-amplitude anisotropy. We found that at five solar rotations before each of the well-defined quiettime increases there was a period of low anisotropy, signifying a period of large random walk.

An example of this is shown in Figure 2. This is an enlargement of the electron data shown in the previous figure for a period in February and March of 1968. The brackets mark two quiettime increases. The shading in this diagram denotes interplanetary sector structure, white for sectors that are directed mainly away from the Sun, gray for those directed mainly toward the Sun. The amplitude of the diurnal anisotropy five solar rotations before these events is plotted at the top, in percent. The average anisotropy for the whole year surrounding this period was 0.4 percent. We consider as small any amplitude less than 0.3 percent; that is, below the dashed line. As you can see, if you trace back along the field lines to where these quiettime increases occur, you find that each of these

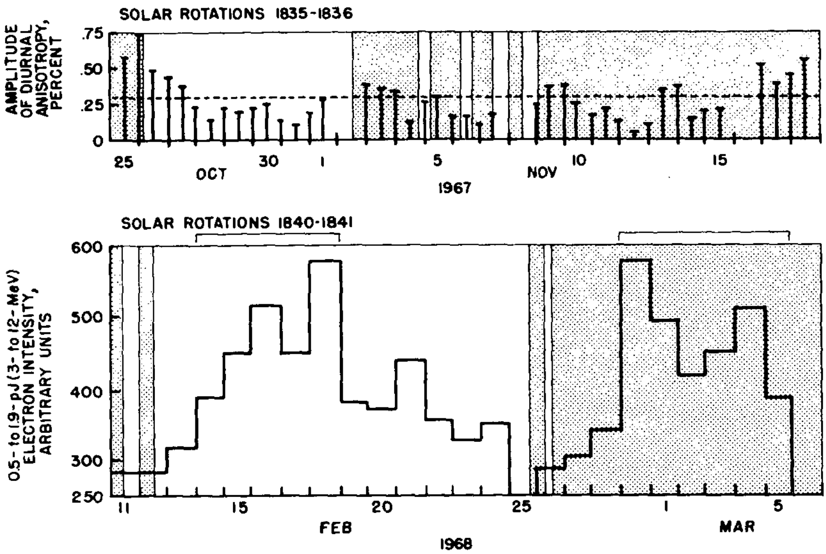

Figure 2–An enlargement of the electron data illustrating how the quiettime increases are preceded by periods of low-amplitude anisotropy.

quiettime increases was preceded five rotations earlier by an extended period of low-amplitude diurnal anisotropy, a period of large random walk.

The solar wind travels roughly 6 AU per solar rotation and in five rotations would carry field lines with their large random walk to a distance of 30 AU. Thus, the delay of five solar rotations between when the random-walking field lines pass Earth and when the quiettime increase occurs, indicates that the modulating region for electrons lies approximately 30 AU from the Sun.

Observations of quiettime increases allow us to make a prediction about interplanetary conditions far beyond Earth. We predict the existence of another modulating region for cosmic rays, 30 AU from the Sun.

REFERENCE

1. McDonald, F. B.; Cline, T. L.; and Simnett, G. M.: The Multifarious Temporal Variations of Low Energy Relativistic Cosmic Ray Electrons. NASA TMX 658-11, Jan. 1972.