COSMIC RAY INTENSITY AND THE TILT OF THE NEUTRAL SHEET

T. Saito[1] and D. B. Swinson[2]

[1] Onagawa Magnetic Observatory and Geophysical Institute, Tohoku University, Sendai 980, JAPAN

[2] Department of Physics and Astronomy, The University of New Mexico, 800 Yale N.E., Albuquerque, NM 87131

ABSTRACT

Recent publications have related long-term variations in cosmic ray intensity at the earth with long term variations in the tilt of the neutral sheet in the inner heliosphere. In this paper we compare the tilt of the neutral sheet from 1971 to 1974 with the cosmic ray intensity at earth, recorded by the Mt. Washington neutron monitor. The remarkable large decreases in cosmic ray intensity which occurred in 1973 and 1974 correlate well with excursions in the tilt of the neutral sheet which occurred earlier during these same two years.

INTRODUCTION: Recently Hoeksema et al. [1982, 1983] have determined the structure of the heliospheric current sheet, computed on a source surface at 2.35 solar radii, using solar magnetograph data from the Stanford Solar Observatory. They note that the extent in latitude of the neutral sheet slowly increased from ~15° near sunspot minimum in 1976, to ~50° by 1978, and extending nearly to the poles by solar maximum. Similar behavior has been noted earlier by Saito [1975, 1984]; in Figure 1 examples of the neutral sheet configuration near solar minimum (1954) and close to solar maximum (1968-69) are shown. The sheet is obtained by drawing the Parker spirals from the interplanetary neutral line on the solar source surface (the central sphere), where the source surface sphere with real radius of 2.6 solar radii is exaggerated in the figure to a radius of 30 solar radii for clarity. The outer sphere, which has a radius of one astronomical unit, shows the neutral sheet configuration near the earth.

The neutral sheet, as displayed in Figure 1, will of course extend well beyond the earth, presumably to the limits of the heliosphere, and will therefore influence the trajectories of incoming galactic cosmic rays which will eventually be detected at the earth. It would seem probable that a greater inclination of the current sheet (from its position at solar minimum), with its accompanying enhanced warping, would present a potentially longer path for galactic cosmic rays between the heliopause and the earth, and would lead to a reduction in cosmic ray intensity at the earth. Kota and Jokipii [1983] have calculated particle trajectories in a 3-dimensional IMF, incorporating a wavy neutral sheet,

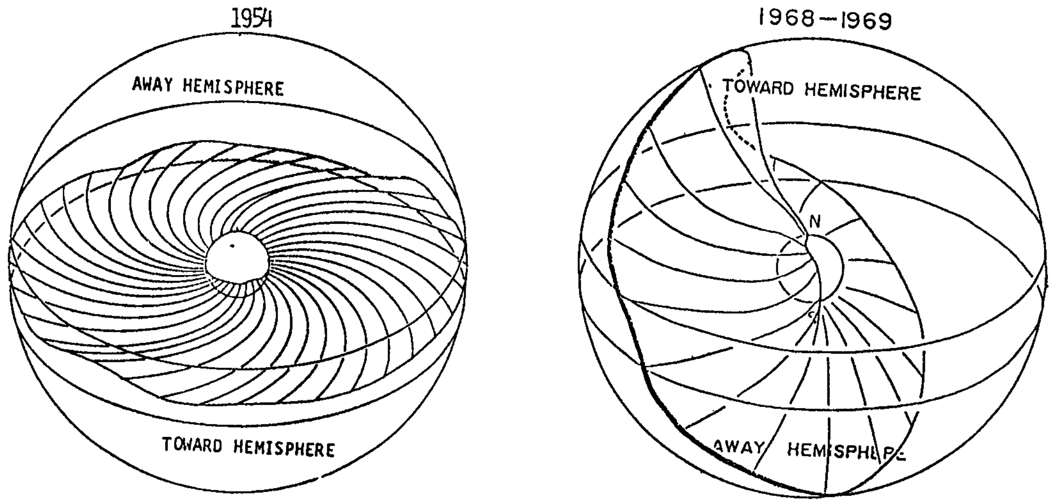

FIG. 1. Neutral sheet configuration between the sun and the earth near solar minimum (1954) aand near solar maximum (1968-69).

for both polarities of the sun's polar magnetic field. They find that, when the field is away from the sun in the sun's northern hemisphere (qA+), cosmic rays enter the heliosphere preferentially by way of the poles, while for the opposite magnetic configuration (qA-) cosmic rays enter preferentially via the neutral sheet. By incorporating a tilt angle for the neutral sheet that is small near solar minimum and larger at solar maximum, they are able to account for the variation in cosmic ray intensity at the earth during the two solar cycles from 1958 to 1980.

Smith and Thomas [1985] have used the data of Hoeksema et al. [1982, 1983] to determine the inclination of the neutral sheet from 1976 to 1982, and they have compared the inclination with cosmic ray intensity at earth measured by the Deep River neutron monitor, and with cosmic ray intensity measurements in space made by Pioneer 10 as it proceeded from 10 to 30 AU. They note, as was predicted by Kota and Jokipii [1983], that the sensitivity of the cosmic ray intensity to changes in the tilt of the neutral sheet was significantly different before and after the reversal of the heliospheric magnetic field. They observed a good correlation between increasing tilt angle and decreasing cosmic ray intensity, with the sensitivity being enhanced when the field was inward in the northern solar hemisphere (qA-).

In this paper we examine the correlation between the inclination of the neutral sheet between 1971 and 1974 and the cosmic ray intensity at the earth as measured by the Mt. Washington neutron monitor during that period.

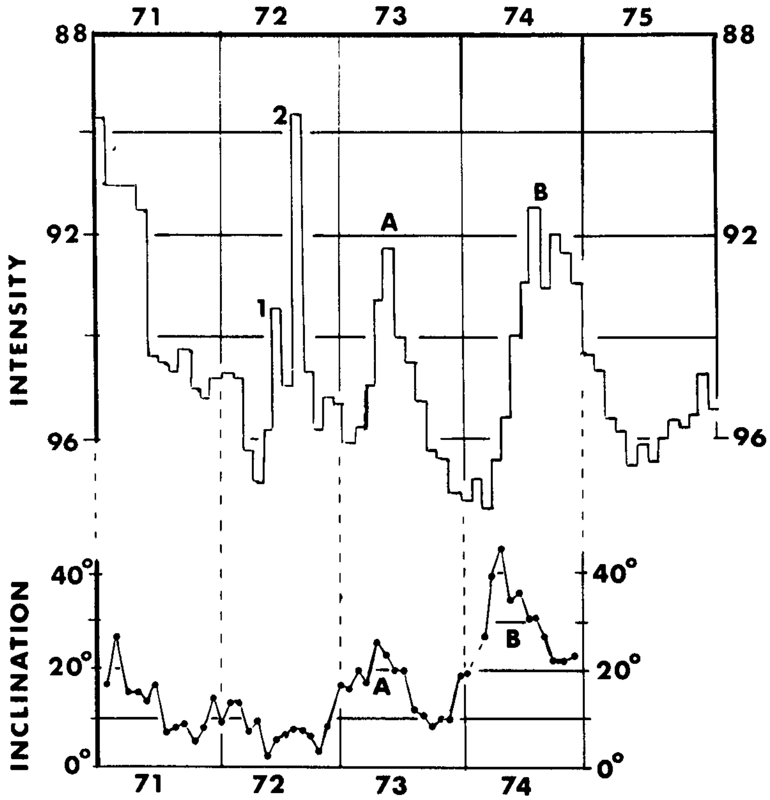

FIG. 2. (Top) Mt. Washington Neutron Monitor monthly average counting rate for 1971-1975, with intensity scale inverted, and (bottom) the average inclination of the neutral sheet for each solar rotation for 1971-1974.

<u>DATA</u>: K-Corona data have been used to determine the configuration of the heliomagnetospheric neutral sheet, and the inclination has been obtained for every Carrington rotation from 1971 to 1974. The basic data are the synoptic charts of K-corona intensity from 1971 to 1974. The latitude of the neutral line $\Lambda_o(\Phi)$ for a certain longitude Φ is obtained as $\Lambda_o(\Phi) = 1/2 \{\Lambda_N(\Phi) + \Lambda_S(\Phi)\}$, where Λ_N and Λ_S indicate the latitudes of the northern and southern borders of the bright K-coronal belt at longitude Φ. We define the tilt of the neutral sheet as the angle between the plane fitted to the various values of $\Lambda_o(\Phi)$, for one rotation, and the heliographic equator. The average inclination angles for each rotation are displayed at the bottom of Figure 2. At the top of the Figure the monthly average Mt. Washington neutron monitor counting rate is displayed [Lockwood and Webber, 1984], with the scale inverted i.e., intensity increases in the downward direction. The rate is normalized to 100 = 2506. In addition to the general correlation between the cosmic ray intensity and the inclination angle over the entire period, we note two very marked decreases in cosmic ray intensity in 1972; these are labeled 1 and 2 in Figure 2.

These decreases are due to events on the sun, and are not related to any changes in the neutral sheet. The most marked of these decrases (#2) occurred in August 1972 and was so energetic that it was observed even by underground muon telescopes at Embudo and Socorro (with threshold regidities 19 GV and 45 GV), as well as by neutron monitors [Swinson, 1973].

The other two notable cosmic ray intensity decreases occurred in 1973 and 1974 and they have not thus far been accounted for. They are labeled A and B in Figure 2. These two large intensity decreases were preceded by two large excursions in the inclination of the neutral sheet, also labeled A and B in Figure 2. In light of this, as well as the previous observations, it seems reasonable to ascribe the intensity decreases to the excursions in the inclination of the neutral sheet. The delay between the maximum inclination of the neutral sheet and the subsequent minimum in cosmic ray intensity can be accounted for by noting that the inclinations noted in Figure 2 are observed at the solar source surface, and this pattern has to be carried out to the outer heliosphere at the solar wind speed before incoming galactic cosmic rays realize its full effect.

These correlations between cosmic ray intensity and the inclination of the neutral sheet provide further support for the gradient drift model of cosmic ray modulation.

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