THE SIDEREAL SEMI-DIURNAL VARIATION OBSERVED AT HIGH ZENITH ANGLES AT MAWSON, 1968-1984, AND THE POLARITY OF THE SOLAR MAIN FIELD.

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ABSTRACT.

High zenith-angle North/South telescopes viewing equatorially and at mid-latitudes through 40 MWE of atmosphere have been operating at Mawson since early 1968. It is evident that a sidereal semi-diurnal component of galactic origin has been observed, over and above a possible spurious component proposed by Nagashima, arising from a bi-directional component of the solar anisotropy. Although a very pronounced reduction in the semi-diurnal galactic response followed the reversal of polarity of the solar main field during 1969-1971, so far the observations indicate that there has been no recurrence of a larger galactic response following the reversal of polarity around 1981. The possible role of the latitudional extent λ_o of the wavy neutral sheet is discussed.

Introduction.

There is now considerable evidence for the existance of a sidereal semi-diurnal variation of galactic origin at the low end of the high energy spectrum, from detecting systems whose median rigidities of primary response, Pm, to the omnidirectional intensity range from $\sim 10^{14}$v down to $\sim 10^{11}$v (Jacklyn, 1970; Gombosi et al., 1975; Sakakibara et al., 1976, 1979, 1984; Bergeson, 1979). From the underground vertical detectors at Hobart (Pm $\approx 10^{11}$v), for instance, the long-term average amplitude, 1958-1963, has the reported value of 0.0084 $\pm$0.0014%, far in excess of the estimated spurious amplitude of 0.0036 $\pm$0.0002% that is due to seasonal modulation of the solar semi-diurnal variation (Nagashima et al., 1984).

What is at issue in this paper is the role of the alternating +ve and -ve polarity states of the solar main field in affecting observations of the sidereal semi-diurnal component through associated changes in the heliomagnetic modulating regime. The extensive calculations of Nagashima et al. (1982) have shown that heliomagnetic modulation may differ considerable between the two polarity states. There are indications from his work that in the +ve polarity state (field directed away from the sun in the northern space of the heliosphere) a semi-diurnal galactic response may be relatively suppressed at the field-sensitive rigidities. It has seemed that this might explain why it was that relatively large variations characteristic of a bi-directional sidereal anisotropy were observed with detectors of the shallow-depth type, underground and at the surface, between 1958 and 1969, when the polarity state was -ve, whereas they were very much smaller in the following years of +ve polarity (Jacklyn and Duldig, 1983). More than that, in the earlier years the second harmonic observed with detectors viewing equatorially was significantly larger than that observed at mid-latitudes (Jacklyn, 1970). This suggests that helio-magnetic modulation at that time may not have seriously affected the characteristic latitude dependence of the second harmonic.

Observations now available from successive -ve, +ve and -ve polarity states are discussed here. They concern mainly the results from high zenith-angle telescopes that have been operating at Mawson since 1968.

Observations.

Equatorial and mid-latitude observations have been obtained from Geiger counter telescopes, one group located underground at Hobart (43°S) and the other at the surface at high zenith-angles at Mawson (67°S). All inclined telescopes were aligned in the geographic meridian plane. The mean absorber depth at Hobart was approximately 50 MWE. At Mawson the absorber depth of 40 MWE was entirely atmospheric. Telescope characteristics and the data periods used in the present comparison are listed in Table 1. Further details have been published elsewhere (Jacklyn, 1970; Jacklyn and Vrana, 1969).

TABLE 1.

Telescope Characteristics.

Period	Place	Site	Geometric aperture zenith	Geometric aperture azimuth	Inc.	Asympt.* Lat.	Count rate (10^3/hr)
1958-65	Hobart	UG	126°	126°	Vert.	-39°	70
1961-62	Hobart	UG	90°	90°	30°N	-20°	17
1968-69	Mawson	Surface	20°	126°	76°N	10°	6
			20°	126°	76°S	-42°	6
1974-84	Mawson	Surface	20°	126°	76°N	-6°	40
			20°	126°	76°S	-47°	40

*Mean asymptotic latitude of viewing at median rigidity Pm.

The size of the surface telescope system at Mawson was increased from one to three crossed telescopes between 1969 and 1974 and the geometry modified to improve the counting rate and to allow the North asymtotic cone to straddle the equator more effectively. In the result there was an insignificant improvement in the coupling cinstants of response to a second harmonic. That is, the response characteristics that are of relevance here were unchanged.

In Figure 1, the results of observations of the sidereal second harmonic are shown in relation to the succession of polarity states of the heliosphere that occurred between 1958 and 1984, as shown at the foot of the Figure. Consider first the period, 1958-1968, of -ve polarity. Although the counting rate of the single high zenith-angle telescope at Mawson was very low, there was remarkable similarity between the equatorial and mid-latitude vectors at Mawson (amplitudes 0.051 ±0.015% and 0.016 ±0.015%. during 1968-69 and the more significant vectors (amplitude 0.024 ±0.010% and 0.006 ±0.002%) observed at Hobart during 1958-63. At both places the equatorial amplitudes in particular were each greatly in excess of that of the spurious component of solar origin (0.005 ±0.0008% at Hobart and 0.005 ±0.002% at Mawson).

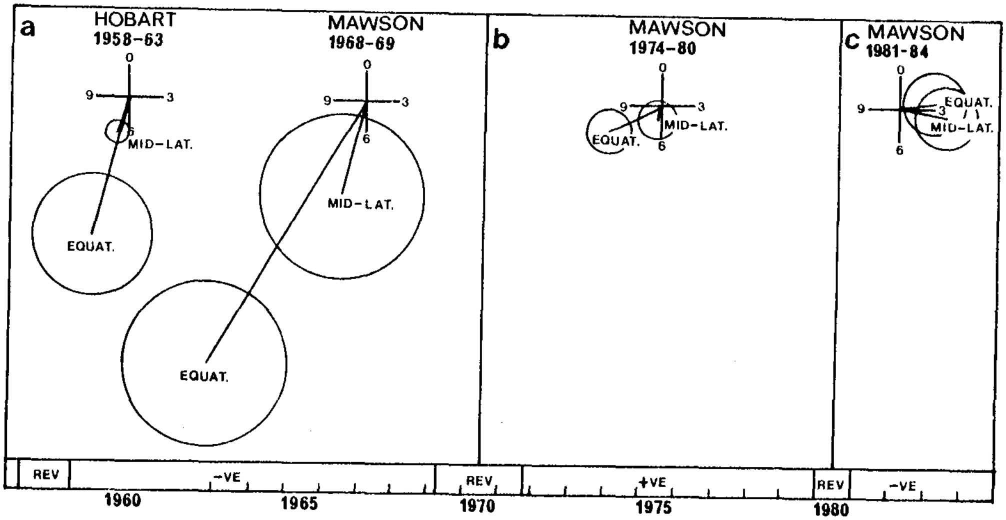

Fig. 1. Sidereal semi-diurnal vectors observed with the telescope systems at effective depths of 40-50 MWE.

(a) within the period of -ve polarity, 1958-1970, from Hobart underground vertical (mid-latitude), Hobart underground 30°N (equatorial), Mawson surface 76°S (mid-latitude) and Mawson surface 76°N (equatorial).

(b) within the period of +ve polarity, 1971-1980, from Mawson surface 76°S and 76°N.

(c) within the period of -ve polarity, 1981-1984, from Mawson surface 76°S and 76°N.

The SD circles are derived from observed fluctuations in the data.

Observations with a seven-fold increase in counting rate of the high zenith-angle equipment commenced at Mawson in 1973, after the helio-magnetic field polarity had reversed. Averaged over the following years of +ve polarity, 1974-1980, the sidereal second harmonics in the north and south directions were very small (Fig. 1b). However, the equatorial amplitude (0.010 ±0.004%) was significant and almost twice the amplitude of the estimated spurious component (0.005 ±0.0004%). The result tended to support the evidence for a latitude dependence of amplitude found in the earlier period of -ve polarity.

The most recent results, 1981-1984, relate to the present conditions of -ve polarity. There are no indications (Fig. 1c) of a return to the large equatorial amplitudes that seemed to be characteristic of the earlier period of -ve polarity. In fact, the average amplitudes to date are not greater than the estimated spurious effect.

Discussion.

Further evidence for the reality of a bi-directional galactic response at shallow depths during 1958-1970 was presented at the previous Conference from observations of the characteristic diurnal counterpart of the second harmonic (Jacklyn and Duldig, 1983). It was suggested there that suppression of response might have occurred in the epoch of +ve polarity that followed. This was apparent not only because of the reduction of the Mawson equatorial semi-diurnal amplitude, but because there was no associated reduction of the solar semi-diurnal amplitude, thus indicating that there had been suppression not of the spurious but of a genuine galactic response.

It seems now that suppression of semi-diurnal response has continued into the present epoch of -ve polarity, at least up to the end of 1984. The possibility is in accord with the evidence given by Bercovitch that the magnitude of change in sidereal diurnal response of the Ottawa Horizontal Muon Array that was predicted to follow the latest reversal of polarity did not occur (Bercovitch, 1984). That this might have been due to increased scattering in the -ve polarity state was discounted. However, he has pointed out, on the basis of the heliomagnetic model of Nagashima et al. (1982), that if the latitudinal amplitude λ_o of the wavy neutral sheet was sufficiently large in both polarity states the expected change in the diurnal response should be small. Thus, as Nagashima et al. (1984) have noted, characteristic differences between the two polarity states tend to become lost as λ_o increases.

It seems, then, that λ_o might be the critical factor. Perhaps it was a smaller latitudinal extent of the waviness of the neutral sheet during 1958-1969 that resulted in the larger galactic semi-diurnal response evidenced during that period of -ve polarity.

Conclusion.

Although there is persistant evidence in the long term for a semi-diurnal variation of galactic origin at the shallow depths of observation, it now appears that there are groups of years when the response is suppressed and that they are not necessarily associated with a particular polarity state of the heliosphere. When large amplitudes were observed, during 1958-1969, notably in the equatorial direction, the polarity was -ve, but some other factor or factors must have favoured the increased response. It is suggested that a possible factor might have been a relatively small amplitude λ_o of the neutral sheet.

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