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MULTIPOLE STRUCTURE OF THE HELIOMAGNETIC FIELD AND NORTHSOUTH ASYMMETRY IN THE HELIOSPHERIC CURRENT SHEET

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Abstract

North South asymmetry in the heliospheric current sheet (HCS) defined as the difference in the maximum heliolatitudinal extension of the HCS in the northern and southern heliospheres, can be classified into two different types In the first type of asymmetric HCS, the transition heliographic latitude θ_T where the dominant polarity of the IMF observed during a solar rotation reverses sign, lies in the same heliohemisphere where the HCS has maximum heliolatitudinal extension, while in the second type of asymmetric HCS the opposite is true Fourier spectra of the inferred HCS using white light corona observations during few solar rotations suggest different solar origins for the two types of asymmetric HCS structures In the first type of HCS the dc component of the fourier spectra is prominent and the origin of the corresponding solar magnetic system is possibly shifted from the centre of the Sun, while for the second case the dc component is not so prominent and the asymmetry arises mainly due to the presence of various magnetic multipoles in the heliomagnetic field

1 Introduction

Interplanetary magnetic field (IMF) sector structure discovered first by Wilcox and Ness (1965) is now described in terms of a warped heliospheric current sheet (HCS) separating heliohemispheres of opposite magnetic polarity The structure and evolution of the HCS have been studied by many authors (Newkirk and Fisk, 1985, Hoeksema et al , 1982 1983, Hoeksema, 1984, Korzhov 1983 Akasofu and Fry, 1986) The heliospheric current sheet is often found to be placed asymmetric about the heliographic equator (Korzhov, 1983 Tritakis, 1984a 1984b) Oshervoich et al (1984 1985) explained the observed north-south asymmetry in the solar coronal structure during sunspot minimum as due to the presence of a magnetic quadrupole in the heliomagnetic field It is now known that the role of the higher order solar magnetic multipoles cannot be neglected when interpreting the structure of the HCS during a solar cycle (Hoeksema, 1984 Saito and Swinson, 1986) It has been shown that the presence of higher order solar magnetic multipoles in the Sun in addition to the solar magnetic dipole can introduce north-south asymmetry in the HCS (Girish and Nayar 1986 1988)

In this work we have analysed the HCS structure inferred from white light corona observations (Korzhov 1982) and evaluated the Fourier components for few solar rotations The results show two types of north-south asymmetry in the HCS In the first type a prominent dc component is present in the Fourier spectra of the HCS possibly due to a shift in the origin of the solar magnetic system from the centre of the Sun For this type of HCS the transition heliolatitude θ_Γ (where the dominant polarity of the interplanetary magnetic field (IMF) observed during a solar rotation period reverses sign) lies in the same heliohemisphere where the HCS has maximum heliolatitudinal extension In the second type of HCS, dc component is weak compared to the amplitude of the other harmonics present in the Fourier spectra resulting in a asymmetric HCS for which θ_Γ will lie in a heliohemisphere opposite to the one where the HCS has maximum heliolatitudinal extension

2 Different Systems of Asymmetry in the Current Sheet

Inferred HCS position near 2 R_o in heliocentric coordinates for several carrington rotations between 1580-1672 from white light corona observations (Korshov, 1982) is fourier analyzed in the form

$$\theta = a_o + \sum_{n=1}^{N/2} a_n \cos n\Phi + \sum_{n=1}^{N/2} b_n \sin n\Phi \qquad (1)$$

where Φ is the heliographic longitude and θ , the heliographic latitude of the HCS a_n b_n are the fourier coefficients determined from a set of N data points (θ_i Φ_i) during a solar rotation period Typical Fourier spectra of the HCS geometry shows significant amplitudes upto 5th or 6th harmonic Generally higher harmonics dies of exponentially in amplitude The first harmonic in the HCS is interpreted as due to a solar magnetic dipole and the second third and other higher harmonics are similarly due to the magnetic quadrupole actupole etc present in the heliomagnetic field (Saito and Swinson 1986, Hoeksema 1984) We define the asymmetry factor Δ as the difference in the maximum heliographic latitudinal extension of the HCS in the northern and southern heliospheres Let us also define a parameter (concerning the IMF effects due to an HCS) the transition latitude θ_Γ as the heliographic latitude at which the dominant polarity of the IMF observed during a solar rotation period just reverses sign (Rosenberg and Coleman, 1969 Girish and Nayar 1988) The plane given by θ_Γ = constant separates regions of dominant IMF of opposite magnetic polarities in the heliosphere For a sinusoidal and symmetric HCS this plane is simply the solar equatorial plane The position of θ_Γ in the heliosphere depends on the geometry of the HCS We can identify from the inferred HCS data that there exist different types of asymmetric HCS structures with different values of θ_Γ and Δ We discuss here only on two major 'systems of asymmetry' in the HCS which has different solar regions and IMF sector structure effects

Table 1

Amplitudes of the first ten harmonics present in the inferred HCS data

Carrington rotation number	1	2	3	4	5	6	7	8	9	10
1662	12 08	10 25	5 91	0 63	1 83	0 33	1 43	0 76	0 8	0 55
1670	42 89	10 59	1 92	2 37	2 05	1 80	2 47	0 88	0 99	1 21
1581	15 09	12 21	7 27	5 74	3 24	1 78	0 92	1 48	1 24	0 73
1671	46 45	18 85	5 69	5 61	3 15	1 73	1 89	1 81	1 18	0 85

Consider the inferred HCS on carrington rotation 1662 (Fig 1) Amplitudes of the first ten harmonics using (1) during this period are given in Table 1 One finds that the average heliographic latitude of the current sheet or the dc component 'a_o in (1) is prominent and comparable with other harmonics present in the fourier spectra The θ_Γ calculated using the geometry of the HCS is -12 3 The asymmetry factor $\Delta \sim -31$ implying a southward depressed current sheet Now consider the inferred HCS on carrington rotation 1670 Amplitudes of various harmonics present in the HCS are given in Table 1 Here also 'a_o' is prominent as in the previous example but of opposite sign Here $\Delta \sim 34°$ implying a northward depressed current sheet and θ_Γ is evaluated as +7

In the above two examples we find that a_o and θ_Γ are in the same heliohemisphere where the HCS has more heliolatitudinal extension We can call this kind of asymmetry in HCS as Type I

Now let us examine the HCS structure in Carrington rotation 1581 (Fig 2) We find here $\theta_\Gamma = 9$ 6 , but $\Delta \sim = -19°$, resulting in a southward depressed current sheet Another HCS under consideration is the northward depressed one ($\Delta \sim 20°$) during solar rotation no 1671 Here $\theta_\Gamma = -22$ 4

In the last two examples of HCS we find that θ_Γ lies in a heliohemisphere opposite to the one where HCS has more heliolatitudinal extension We call this kind of asymmetry in current sheet as Type II Here the dc component is not so prominent in comparison with the amplitudes of various harmonics present in the Fourier spectra given in Table 1 during both solar rotations under consideration

3 Discussion

In this work we have examined two different systems of asymmetry

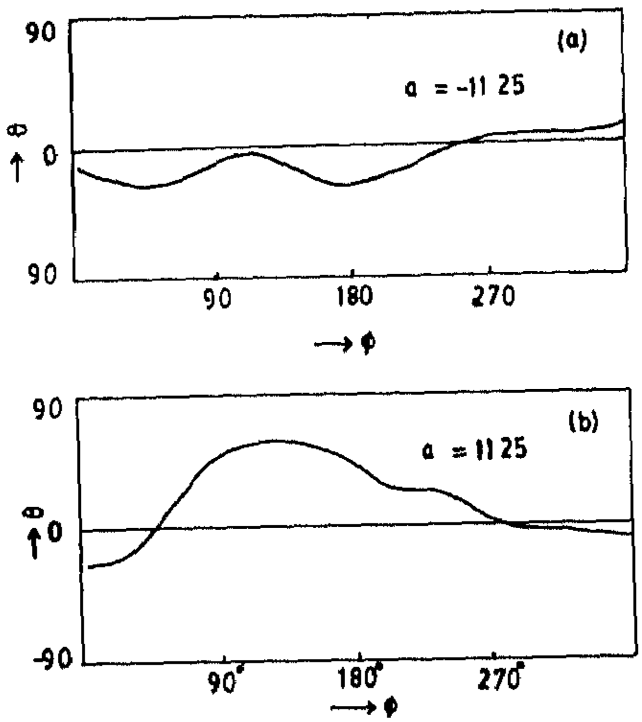

Fig 1 Inferred heliospheric current sheet for Carrington (a) 1662 and (b) 1670

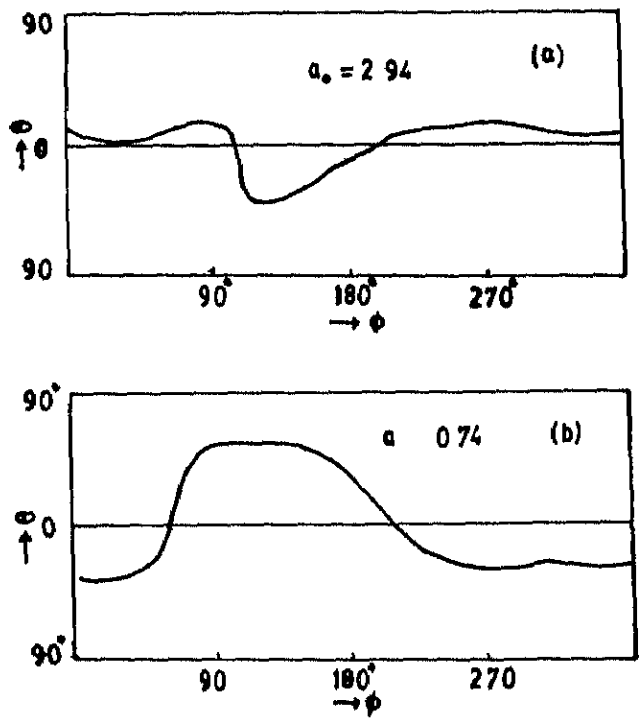

Fig 2 Inferred heliospheric current sheet for the carrington rotations (a) 1581 and (b) 1671

in the inferred HCS data Different types of asymmetry can be shown due to the relative magnitudes of various harmonics in (1) and the value of 'a_o' contributing to the geometry of the HCS The presence of latitudinal offset component' with respect to heliographic equator in Type I HCS implies that the solar magnetic field is more ordered in a system where the origin is shifted from the centre of the Sun to a point northward or southward of solar equator The monopole component in the spherical harmonic analysis of inferred coronal magnetic field data is found to be nonzero in most of the solar rotations in solar cycle 21 (Hoeksema 1984) This is similar to the 'eccentric dipole description of the geomagnetic field It is found that the frequency of Type II asymmetry is more compared to that of Type I from the available data over two solar cycles Both types of asymmetry originates in a heliomagnetic field where higher order magnetic multipoles are present But in the case of Type II the average heliographic latitude of the HCS 'a_o' is small and the various harmonics in (1) contributes mainly to the asymmetry in it Thus we have found two types of north-south asymmetry in the heliospheric current sheet with different solar origins and possibly different IMF sector structure effects

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