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# SOLAR MAGNETIC FIELD OBSERVATIONS OVER ULYSSES' FAST LATITUDE SCAN

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**Abstract-This paper present the summary of the interplanetary magnetic field measurements obtained by the Ulysses magnetometer experiment during 1994 – 1995, 2000 – 2001 and 2007 – 2008, while the spacecraft made its fast transit from the southern (800 S) up to the northern polar regions (800 N) of the heliosphere, crossing the equatorial regions on the way. From the study carried out it is very well evident that during the first the first and the the third fast latitude scan between ~ 300 S and ~ 200 N proton density and interplanetary magnetic field is found increase. And at the same time temperature and solar wind velocity is found to be decrease between ~ 200 S and ~ 200 N. We also found that, both in the high and low latitude in the interplanetary magnetic field and proton density are found to be maximum in the second orbit, maximum solar activity. Another particular aspect found out is that in the first orbit and the third orbit, at the equatorial region solar wind velocity and proton temperature are less. But at the same time in the polar region it is very high.**
**Keywords : Heliosphere, Interplanenary magnetic field, Solar wind, Slow wind**

## INTRODUCTION

Ulysses has a significant characteristic feature of revolving around the Sun in latitudinal direction, whereas the other spacecraft remain in the same position and scan. Ulysses maintains a radial distance of 1AU, while it rotates from $80^0$ S to $80^0$ N. During its rotation in the first orbit, it falls in the 22nd solar cycle in minimum phase. In the second orbit, it occurs in the 23rd maximum phase. And during third orbit, it is found to be in the 23rd minimum phase. As a factor to be maintained, it is evident that during the solar rotation between $80^0$ S to $80^0$ N in clockwise direction, Ulysses travels too fast and fast latitude scan occurs maintaining 1AU radial distance.

The fast latitude scans are defined as the perihelion phases of the Ulysses orbit during which the spacecraft traverses heliographic latitudes between 80.2° S and 80.2° N, with a perihelion of 1.3 AU, in a little over 10.5 months. Trajectory information for the first fast scan, which took place between September 13 (day256) 1994 to July 31 (day 212) 1995, the second orbit between November 24 (day 329) 2000 and October 11 (day 284) 2001 and the third orbit between February 7 (day 38) 2007 to January 13 (day 13) 2008. Whereas the first in 1994 third in 2007 took place during a period approaching solar activity minimum, and the second fast latitude scan occurred close maximum in the 22nd and 23rd solar cycle.

The first out-of-ecliptic measurements of the magnetic field were made by Ulysses (Balogh et al., 2008). After Jupiter flyby in 1992 the probe attained a polar orbit around the Sun. The first orbit began in February 1992 at the middle of cycle 22. The spacecraft ascended in latitude approaching the sun’s South Pole during the rise in solar activity crossing the polar cap in the fall of 1994 during the descending phase of solar cycle 22. It then returned to low latitudes, crossed the solar equator and, in fall 1995, traversed the north polar cap. Ulysses observed a typical magnetic field sector structure at low latitudes, but in June 1993 the probe moved for the first time in to the unipolar region at 30◦ southern latitude (Smith et al., 1993). This disappearance of the sector structure was due to the increasing latitude of the probe and the decreasing heliospheric current sheet tilt due to declining solar activity. The probe completed the first pole-to-pole fast latitude scan in 1994 – 1995, measuring the magnetic field from −80.2◦ S to 80.2◦ N latitude in 322 days. Measurements during the first fast latitude scan showed that the radial component of the magnetic field is practically independent of latitude (Smith and Balogh, 1995). Ulysses confirmed the rather simple structure of the corona during solar minimum and showed that two kinds of wind dominate the heliosphere. A steady-state fast wind was continuously observed at high latitudes, coming from large polar coronal holes, whereas within 20°S and N a rather complex mixture of winds predominated in the solar equator (Phillips et al., 1995; McComas et al., 2000; Issautier et al., 1998; Neugebauer, 2001). Ulysses magnetic fields results from the southern polar regions have already been presented by Balogh et al. (1995) and a first analysis of the data from the fast crossing of the streamer belt regions has been carried out by Smith et al. (1995a).

The second orbit began in 1998 (aphelion) at the start of cycle 23. The spacecraft ascended in latitude approaching the sun’s South Pole during the rise in solar activity crossing the polar cap in the fall of 2000 during solar maximum. It then returned to low latitudes, crossed the solar equator and, in fall 2001, traversed the north polar cap. The observations cover the ascent to, and descent from, solar maximum so it is vital to reconcile the results with major changes occurring on the sun, the south polar cap, the magnetic polarity was inward indicating that the field had not yet reversed (Smith et al., 2001). Some solar physicists had claimed that the field had already reversed. However, Harvey and Recely (2002) have recently completed a study of polar coronal holes and polarity reversals including the recent solar maximum. They find

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that polar coronal holes disappear
many months (1.1 – 1.8 years) before the polar cap field reversal. In this instance, the south polar coronal hole disappeared in 2000.5 (consistent with disappearance of the fast wind) whereas the reversal of the south polar field (based on the disappearance and reappearance of polar crown filaments) occurred much later, between 2002.31 and 2002.46. Thus, the Ulysses and solar observations are, in fact, mutually consistent.

The third orbit began in June 2004 at the middle of cycle 23. The spacecraft ascended in latitude approaching the sun's South Pole during the rise in solar activity crossing the polar cap in the fall of 2007 during the descending phase of solar cycle 23. It then returned to low latitudes, crossed the solar equator and, in fall 2008at the solar minimum of solar cycle 23, traversed the north polar cap.

During the Fast Latitude Scan, the slow wind and two magnetic sectors were present to 70°N, when the Ulysses travelled northward rightly in November 2000 to October 2001. At higher latitudes, fast wind was observed, at first intermittently during two solar rotations and then continuously in the polar cap. The magnetic polarity in the fast wind had reversed and was now inward in the north. According to Harvey and Recely (2002), the reversal occurred between 2001.19 and 2001.34. The north polar coronal hole, which had disappeared earlier, re-formed prior to 2001.4. In order to cover the Polar Cap a large mid-latitude coronal hole spread northward. The solar observations are again consistent with what Ulysses found.

Here, Ulysses data are used to deduce the behaviour of the dipolar component of the solar magnetic field around solar maximum, showing the reversal to be largely consistent with a simple rotation of the dipole field component. The observations also show that the magnetic dipole field during this period was rotating at a slower rate than the Carrington reference frame. Although plasma observations during the solar maximum fast latitude scan revealed a highly-complex mixture of flows (McComas et al., 2002), magnetic field observations during the same period showed a surprisingly simple picture, similar to that expected for a simple dipole field with axes close to the solar equator (Jones and Balogh, 2003). We restrict the results presented here to the data returned from the latter part of the first orbit to the end of 2002.

In contrast, during the rising phase of solar activity 22 to the 2001 maximum, Ulysses showed a dramatically different corona, and a complex solar wind structure with different regimes, slow and intermediate wind from streamers, flow interactions, in addition to sporadic fast flows from small coronal holes at all heliolatitudes (Luhmann et al., 2002; McComas et al., 2003; Smith et al., 2003; Issautier et al., 2004). During the 2001 maximum, a long interval of fast wind coming from a polar coronal hole was however observed at high northern latitudes above 72°N (McComas et al., 2002). During that period, among other parameters, the proton density and proton temperature and solar wind velocity were found to changes depending up on the polarity reversal. Near the minimum of cycle 23 when the solar magnetic dipole reversed with respect to the previous minimum, Ulysses undertook a third pole- to-pole fast transit Since February 2007 (Smith et al., 2003) to January 2008.

## DATA ANALYSIS

The joint NASA/ESA Ulysses mission has provided the first direct, in situ measurement of high latitude, slow as well as dense solar wind in the interplanetary medium. Ulysses orbits three times around the Sun, which covers the declining phase of solar cycle 22 and ascending and declining phase of solar cycle 23. Spatial structure of solar wind in respect with the solar phase is provided by the observations from the two full orbits. The data from Solar Wind Observations over the Poles of the Sun (SWOOPS) (Bame et al., 1992) and Vector Helium Magnetometer (VHM) (Balogh et al., 1992) Ulysses experiments are utilized for carrying out this work. The solar magnetic parameters and solar wind plasma parameters are used for the analysis.

## MAGNETIC FIELD OBSERVATION OF THE FAST LATITUDE SCANS PERIODS

An overview of the Ulysses magnetic field observations obtained as Ulysses travelled northwards from $80^0$S to $80^0$ N is shown by Figure 1. The top panel shows the magnetic field of the Ulysses' first polar orbit, the middle and bottom panel shows the solar magnetic field of the Ulysses' second and third polar orbit respectively with respect to the heliographic latitude. During the minimum phase of the Sun, the Sun's global magnetic dipole field structure dominates. The equatorial corona is tied to the Sun leaving the other regions magnetically open, this is evident in which is kept by dipole structure.

The toroidal fields (sunspots) spread over the mid latitude and equatorial regions on the surface of Sun, in addition to the global dipole field during the maximum phase. This makes the Sun a multipolar one and breaks its temporal and spatial homogeneity. During solar minimum, the Ulysses' measurement of interplanetary magnetic field is consistent to our expectation. Equatorial regions push more flux in to the interplanetary medium than the high latitudinal regions.

The magnetic field in the polar coronal hole regions shows minimum strength. It also show fluctuations and structures which are likely due to the presence of large amplitude Alfven waves, which are commonly observed at high heliolatitudes (Smith et al., 1995a). The inclination of the heliospheric current sheet is closely correlated with sunspot number and varies from low to high inclination between solar minimum and solar maximum. This relation can be easily explained in terms of the behaviour of the solar dipole, which is nearly aligned with the solar rotation axis near solar minimum. Heliospheric current sheet is stable during minimum sunspot phase and lie nearly flat. The Ulysses recorded full flow of solar wind from the fully developed coronal hole of maximum magnetic strength. The south polar field is found to be much stronger than it is in the north polar field. This imbalance of north and south results in differences in high latitude interplanetary magnetic field strength and solar wind velocity. The differences between the distribution of solar wind and interplanetary magnetic field between two poles may give some idea about the solar wind acceleration process due to polar magnetic structure (Hoeksema, 1995). The very existence of different solar wind stream types implies that the different acceleration processes are influenced by the parameters of magnetic field in the source region. Over the 11 years of solar cycle, the coronal magnetic field structure drastically evolves with the solar cycle and hence the coronal magnetic acceleration. During maximum solar activity, closed or mixed magnetic structures and slow wind dominate. In the epoch of minimum activity, the magnetic structures are mostly of an open type and generate fast solar wind streams (Lotova et al., 2002).

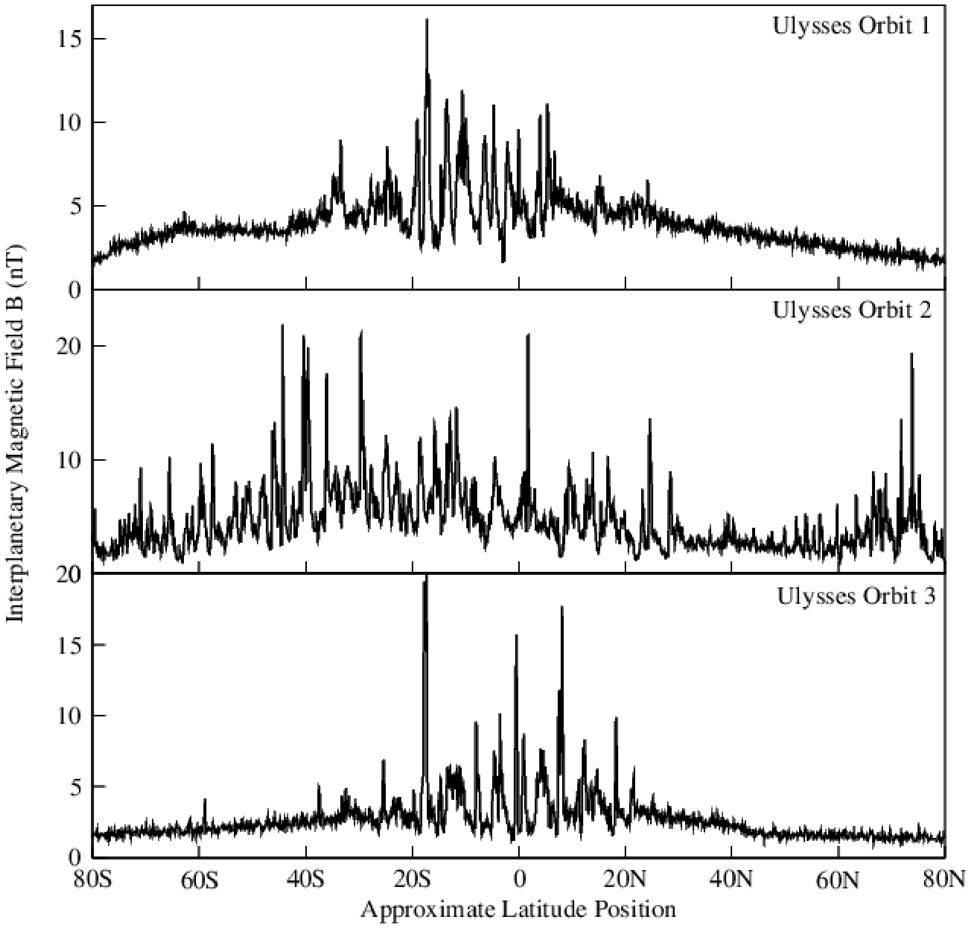


*Figure 1: Interplanetary magnetic field of Ulysses three orbits*

It is found that in the first orbit and the third orbit, at the equatorial region interplanetary magnetic field is high. And at the same in the polar region it very less. It's just because the strength of the coronal hole in the polar region is maximum. Between ~ $30^0$S and ~ $20^0$ N, the interplanetary magnetic field is found to be at the maximum both in the first and third orbits. It is also found that, both in the equatorial and polar regions the interpolator magnetic fields are found to be maximum in the second orbit.

Near the solar maximum, the polar fields are weak and in the process of reversing, while the fields in the active regions which determine the resultant equatorial dipole are numerous and strong (Smith, 2001). Near heliospheric current sheet during minimum phase, Ulysses observed low latitude streamers. The streamers show its presence in higher latitudes, as the Sun gains magnetic multipoles in the maximum phase. The high speed solar wind from coronal holes over-expands to cover much larger solid angle at several solar radii than the coronal holes cover in the lower corona. This super radial expansion is driven by the higher pressure in coronal holes and acts to equalize the magnetic pressure, as demonstrated by (Smith and Balogh., 1995). Also the expansion may be due to the variation of magnetic field at the source surface to lower corona or photosphere is maximum at higher latitude (Horsbury and Balogh, 2001). The dipole tilt maximum occurs in the descending phase of the solar cycle and Ulysses measured the tilt that is, the opposite polarities in the beginning of the first rotation.

During the maximum phase, Ulysses spacecraft encountered a highly unusual magnetic field structure in high solar latitudes. In its second orbit, Ulysses observed highly variable and almost equal solar magnetic field B in all heliolatitudes. Slow and intermediate solar wind and coronal transients and their mutual interactions (similar to those customarily found at low latitudes) were present from the equator to the south polar cap. At the solar minimum, the magnetic polarity was not found unidirectional. As overall activity is increased, the fast wind disappeared and the slow interactive wind gradually filled in all latitudes. The overall reduction in solar wind speed is because of the magnetic field configuration during the maximum phase. The heliospheric current sheet became increasingly warped, highly structured and steeply inclined with the advancing of solar activity. As the solar maximum is approached, the magnetic field evolved into a complex multi polar field with many active regions. The solar cycle induced reorganization of the solar magnetic poles may be the main cause of the overall decrease in solar wind speed (King, 1976). The latitudinal gradients of B are steeper in solar minimum and more or less flat around solar maximum. Ulysses found that the interplanetary magnetic field is stronger at equator than at poles during solar minimum and the field is evenly distributed over the entire surface during maximum. The overall global heliospheric magnetic field B hardly shows any noticeable variation during the magnetic reversal phase.

**RADIAL COMPONENT OF THE MAGNETIC FIELD**

The magnetic field observations obtained as Ulysses travelled northwards from $80^0$S to $80^0$ N is shown in Figure 2. The top panel shows the magnetic field of the Ulysses' first polar orbit, the middle and bottom panel shows the solar magnetic field of the Ulysses' second and third polar orbit respectively with respect to the heliographic latitude. The radial component of the heliospheric magnetic field, normalized by 1AU. The measurements from Ulysses are from many different latitudes. However, it has been shown from Ulysses that the latitude variations in the heliospheric radial magnetic field are weak, as is to be expected (Smith and Balogh, 1995; Balogh and Smith, 2001). The radial component of the heliospheric magnetic field is thus a measure of the average value of the component of the solar magnetic field that opens into the heliosphere, the so-called open magnetic flux of the Sun. Note that the normalized radial component varies over the solar cycle, increasing near solar maximum, and it attains its minimum value in solar minimum. Note also that the minimum value of the normalized radial component is lower in the cycle 23 solar minimum than it was in the previous solar minimum.

When Ulysses travelled northwards from $80^0$S to $80^0$N, overview of the magnetic field observations are obtained. Defining the magnetic field direction in the RTN coordinate system, simultaneously figure 2 shows the radial magnetic field magnitude, during the magnetic field observation. The RTN coordinate system is defined by an R axis pointing radially ant sunward, such that the RT plane is inclined to the equator at an angle equal to the heliographic latitude of the spacecraft, with T in the direction of solar rotation and N perpendicular to the RT plane, positive northwards. Smith & Balogh (1995) have carried out such an analysis using the Ulysses data from the first slow latitude scan southwards to $80^0$S. Investigation on the solar magnetic field in the Ulysses' fast latitude scan period is the aim of this chapter. The radial component of the magnetic field, measured by Ulysses but referenced to 1 AU, as a function of heliolatitude. The first and third panel of figure 2, represents the first and third fast latitude scan period of Ulysses. The equtorial region of this two orbits are in between $20^0$ S to $20^0$ N, and the magnetic field of radial component was found to have nearly a constant magnetitude. In first and third orbits, the magnetc field was change the sign between south and north region in the equtorial region.

But the second fast latitude scan period, the polarity reversal took place. The change in sign between the southern and northern regions is simply due to crossing of the heliospheric current sheet into the opposite polarity region. In the maximum phase, the polar coronal holes disappeared much before the polar cap field. The south polar coronal hole disappeared in the middle of the year 2000, whereas the reversal took place in the beginning of 2003 (between February and April) (Smith and Marsden, 2003). Though the interchange of polarities between south and north poles during maximum has been detected many times since 1960, Ulysses magnetic field data gives a clearer picture of the nature of reversal of polarity.

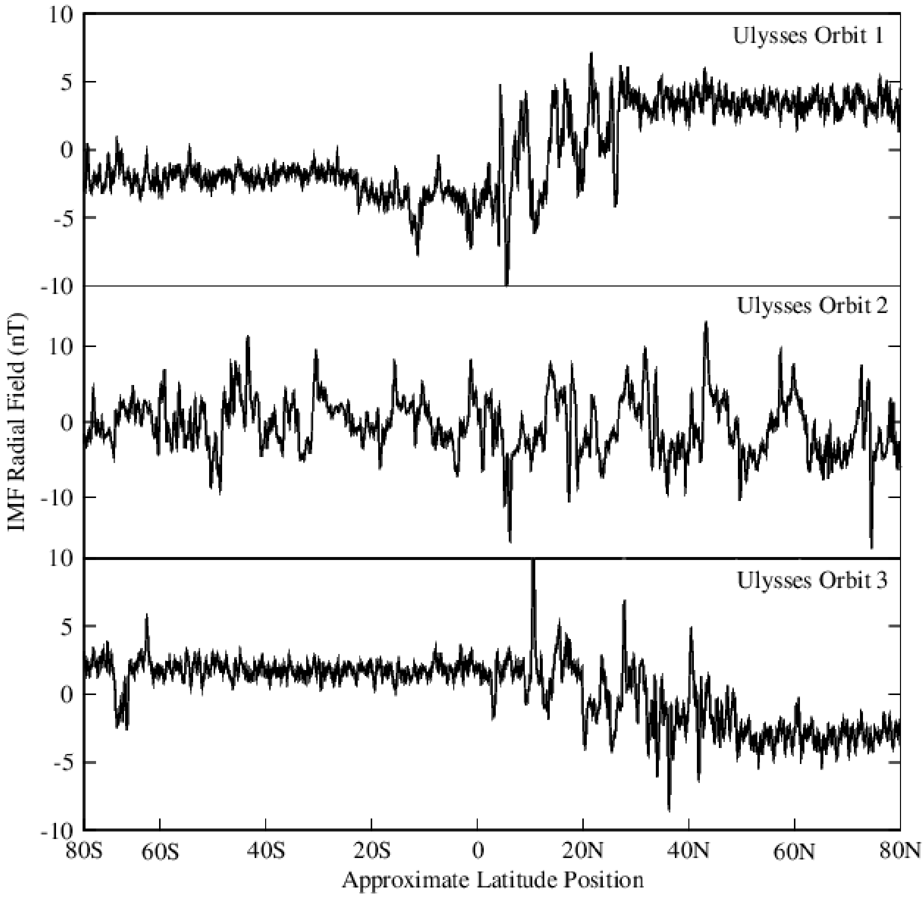


*Figure 2: The IMF radial field of Ulysses full orbits*

In solar maximum, Ulysses witnessed changed south pole from the north pole. Now the solar mean polar field strengths is combined with a bias of the south polarity flux for both the poles. This is exclusively due to the larger area occupied by the south polarity. The Sun behaved like a monopole and this effect is carried to the interplanetary magnetic field. The radial solar magnetic field showed the reversal of polarity in a more complicated manner. In the maximum phase, the magnetic asymmetry in terms of polarity has been started with the appearance of predominant South polarity. The variations are very difficult to explain if we consider the global solar field more of a dipole in nature during the reversal phase. Moreover, variations cannot be deep rooted but the variable field must be confined to layers close to the Sun.

**SOLAR WIND SPEED AT THE TIME OF FAST LATITUDE SCANS**

An overview of the solar wind velocity of Ulysses observations obtained as Ulysses travelled northwards from $80^0$S to $80^0$ N is shown by Figure 3. The top panel shows the solar wind velocity of the Ulysses' first polar orbit, the middle and bottom panel shows the solar wind velocity of the Ulysses' second and third polar orbit respectively with respect to the heliographic latitude. From these observations it is found that in the first orbit and the third orbit, at the equatorial region solar wind velocity is less. And at the same in the polar region it very high. Between ~ $20^0$S and ~ $20^0$ N, the solar wind velocity is found to be at the maximum both in the first and third orbits. The solar wind speed was high poleward of ~ $20^0$ latitude in both hemispheres (Balogh, 2002). Its also found that, both in the equatorial and polar regions the solar wind velocity is found to be maximum in the second orbit. The fast streams, prevailing at higher latitudes during minimum, disappear almost entirely during solar maximum, and the wind becomes slow and highly structured in space and variable in time. The solar wind is very slow and passive in the southern hemisphere, but for few sharp peaks in the ecliptic region. Unlike in the southern hemisphere, the solar wind is very erratic in the northern hemisphere and the solar wind speed is substantially enhanced. The Ulysses observed a polar coronal hole with smaller area compared to that observed during the minimum phase. This maximum phase is coincided with the solar polarity reversal. Well before the reversal phase, the solar wind is found to be comparatively slower and smoother. A limited number of coronal transients are observed during the first polar orbit of Ulysses. Since the occurrence rate of solar transients follows the solar activity cycle, Ulysses observed more solar transients during the maximum than the solar minimum. The enhanced solar transients during maximum phase are the main reason for erratic variations of solar wind speed. Ulysses observations show that slow and mixed solar wind extends to higher latitudes at solar maximum.

A large part of the heliosphere is dominated by solar wind emerging from polar coronal holes, during the solar minimum.

Also, transient coronal holes still significantly contribute to the maximum solar wind. However, the average solar wind speed is typically lower. This slow speed is clearly the property of the transient coronal holes not a signature of stream-stream interaction in the heliosphere (Zurbuchen and Fisk, 2002). The white light measurement near corona provide the most compelling evidence for radial expansion of the solar wind taking place close to the source region before evolution (Woo and Habbal , 2000).

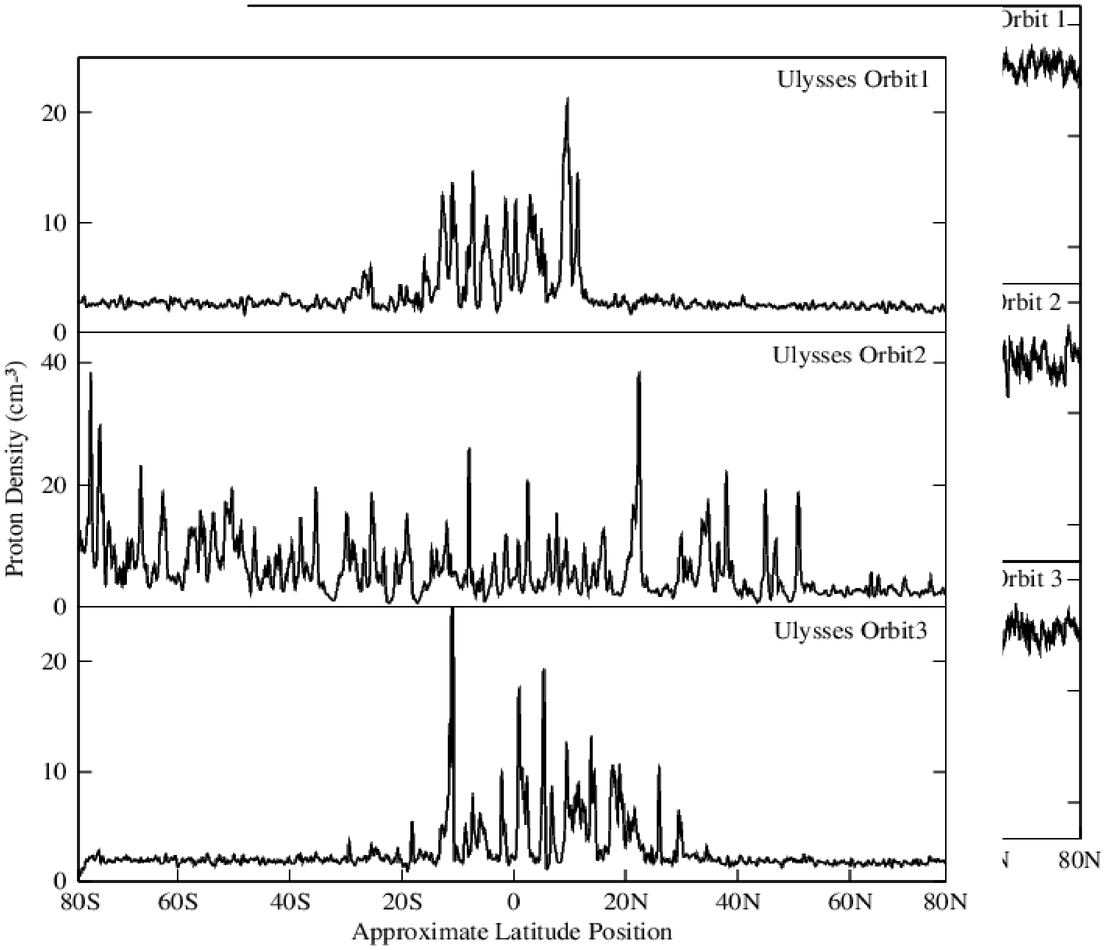


*Figure 3: Solar wind velocity at the time of fast latitude scans*

In contrast, as Ulysses ascends to mid-latitudes in its second orbit, it observed highly irregular solar wind with much less periodic corotating interaction region CIRs (McComas and Gosling, 2000). This is due to the increased solar activity and related development of coronal complexity throughout the epoch. The Ulysses recorded coronal complexity in terms of high latitude random occurrence of streamers and substantial increase in CME driven disturbances. The CME's disturb the smooth flow of solar wind temporally and spatially.

**SOLAR WIND PROTON DENSITY AT THE TIME OF FAST LATITUDE SCANS**

Figure 4 shows the proton density of Ulysses observations obtained as Ulysses travelled northwards from $80^0$S to $80^0$ N. The top panel shows the proton density of the Ulysses' first polar orbit, the middle and bottom panel shows the proton density of the Ulysses' second and third polar orbit respectively with respect to the heliographic latitude. The proton number observed by Ulysses has been maximum in the equatorial regions, where the solar wind streams velocity is extremely very low (figure 4). The proton emission is in fact independent of any latitudinal structure (Bruno et al., 1986). In general, it is found that the regions close to the current sheet bring out more particle

*Figure 4: Solar wind proton density at the time of fast latitude scans*

flux (protons and helium) than regions of higher latitudes. This behaviour is common to both the phases of the solar cycle. The minimum density of solar wind particle near ecliptic plane is observed during magnetic field polarity reversal in the polar region (Kovalenko, 1988). In its second rotation around the Sun, Ulysses observed nearly equal distribution protons in all heliolatitudes, which directly attributes to the activity of the Sun. Maximum solar activity, coupled with magnetic polarity reversal phenomenon, makes the solar surface a complicated magnetic network. The sparse structure with maximum values arise because of the fast scan where few values are averaged in a particular latitude whereas on the opposite side dense structure with minimum values are observed due to averaging more valves in a particular latitudes. The slow scan in the ecliptic region detects many transients. Proton emission showed uniform variation in the entire southern hemisphere. This was the period when the toroidal field dominates over the poloidal field. Also, it is interesting to note that the toroidal field and the radial field are found to be moving in parallel to each other.

From this observations it is found that in the first orbit and the third orbit, at the equatorial region proton density is high. And at the same in the polar region it very less. Between ~ $30^0$S and ~ $20^0$ N, the proton density is found to be at the maximum both in the first and third orbits. Its also found that, both in the equatorial and polar regions the proton density is found to be maximum in the second orbit. In principle, this slow variation of proton particles could be associated with the suppression of solar plasma outflow, because of an increase in the number and size of magnetic field loops in the solar corona during the pre-reversal phase of solar maximum activity. This magnetic coupling may preserve more protons in the outer corona, to show a marginal increase in the proton number. The emission of particles was highly varying, when the solar surface exhibited a complicated magnetic field configuration.

**SOLAR WIND TEMPERATURE AT THE TIME OF FAST LATITUDE SCANS**

Figure 5 shows the proton temperature of Ulysses observations obtained as Ulysses travelled northwards from $80^0$S to $80^0$ N. The top panel shows the proton temperature of the Ulysses' first polar orbit, the middle and bottom panel shows the proton temperature of the Ulysses' second and third polar orbit respectively with respect to the heliographic latitude. From this observation it is found that in the first orbit and the third orbit, at the equatorial region proton temperature is less. And at the same in the polar region it very high. Between ~ $20^0$S and ~ $20^0$ N, the proton temperature is found to be at the maximum both in the first and third orbits. The average solar wind temperature varies in accordance with the phase of the solar cycle. It is lower near solar maximum and higher near solar minimum. Ulysses' first orbit coincided with minimum phase and the solar wind temperature has been found maximum above the polar coronal regions, where the solar wind speed is maximum. The solar cycle variation of temperature in the outer heliosphere is much smaller than that observed at 1 AU. The latitudinal dependence of the proton temperature decreases towards the current sheet Bruno et al. (1986).

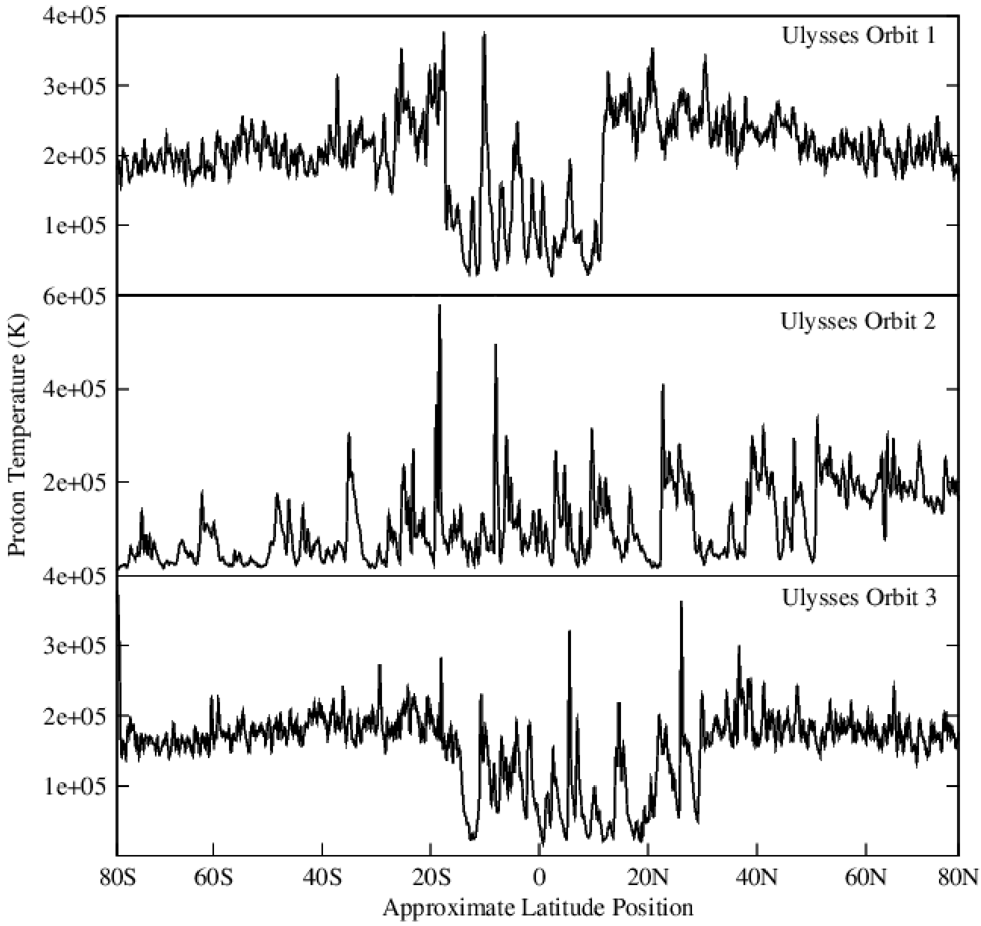


*Figure 3.5 : Solar wind temperature at the time of fast latitude scans*

The most important result obtained in this work is the presence of strong latitudinal gradient in solar wind temperature. The gradient is an extended phenomenon and does not appear to be associated with a particular phase of the solar cycle (Gazis et al., 1994). The latitude gradient remains almost unchanged over the course of solar maximum phase as observed by Ulysses in its second orbit around the Sun. The average solar wind temperature appeared to wary with solar cycle. It is lower near solar maximum and higher near solar minimum. This is not surprising, since similar behaviour has previously been observed in 1 AU, but the solar cycle variation of temperature in the outer heliosphere is much smaller than that observed near 1 AU. The most striking behaviour of our observation is the strong latitudinal variation in solar wind temperature. During this minimum phase, this gradient is an extended phenomenon and appears to be associated with a particular phase of solar cycle. Also the latitudinal gradient of solar wind temperature in the outer heliosphere is associated with some large scale gradient in the solar wind source region and not on the solar magnetic latitude. The solar wind temperature appears to arise from some hidden physical process other than thermal phenomenon.

**POLARITY REVERSAL DURING FAST LATITUDE SCANS**

The dominant solar global dipolar magnetic structure extends its control over to the solar corona and into the interplanetary medium. During the solar cycle, the solar magnetic field changes greatly as does the coronal and the interplanetary magnetic field. Simple dipole field around the solar minimum and the entangled dipole field mixed with multipolar field around the solar maximum is retained by the Sun. One of the most striking features of the solar activity cycle is the reversal of the solar polar magnetic field. During two activity phases of the Sun, the journey of the Ulysses spacecraft over the high latitudes in the northern and southern hemispheres of the Sun provides an excellent opportunity to map the changing magnetic field configuration. When the solar activity was around the maximum phase, Ulysses journey over the high northern latitude provided a good opportunity to observe the global dipole field change. During the solar minimum, observations made showed a clear and strong negative and positive polarity respectively in the southern and northern hemisphere. Ulysses observed negative polarity in the southern hemisphere during the solar maximum phase, and once again it recorded negative polarity in the northern hemisphere. This change is attributed to the phenomenon of polarity reversal. During the epoch of maximum solar activity, the polarity reversal takes place which lies in the middle period of the solar cycle. While moving quickly from the southern hemisphere to northern hemisphere, Ulysses observed the polarity change in the peak of solar maximum activity.

The spacecraft’s first and third fast latitude scan, during which Ulysses travelled from high southern to high northern latitudes in less than 11 months, took place near a minimum in the solar cycle. Then the spacecraft repeated the second fast latitude scan near solar maximum, solar magnetic polarity reversal took place. The open magnetic field lines originating in the regions of opposite magnetic polarity are separated by the heliospheric current sheet, which is explained by Smith et. al., (2001). As the dipole begins to reverse orientation, near the solar maximum, the heliospheric current sheet is expected to extend over an ever-increasing heliolatitude range.

An initial overview of the HMF polarity at Ulysses around solar maximum was presented by Jones and Balogh (2002). There are obvious differences in the polarity distribution between this mission phase and solar minimum fast latitude scan. Although the polarity distribution was probably evolving rapidly during this period, the fast pace of Ulysses’ motion around its second perihelion provided the closest we can currently attain to a global “snapshot” of the HMF polarities during this key phase in the solar activity cycle. Both polarities continued to be detected at the spacecraft, in approximately equal proportions with each solar rotation, until northern mid-heliolatitudes were reached, during the entire period. The last clear HCS crossing was seen at Ulysses, at a heliolatitude of ∼67◦ N, around near the middle of 2001. After the exception of brief reversals within transient structures, from that time onwards, the northern (inward) polarity was the only one detected. As the new northern polarity was clearly dominant at this time, this constrains the time of polarity reversal at the source surface to earlier than near the middle of 2001.

Solar wind parameters during this period show a complex mixture of fast and intermediate speed flows, probably resulting from interactions between slow streams and faster flows from coronal holes and the interplanetary counterparts of coronal mass ejecta (McComas et al., 2002). When extrapolating single-point sampling of HMF polarity to a global view care should always be taken. The magnetic polarity distribution is, however, simple enough, with a two-sector structure seen in the $80^0$ S to $60^0$ N heliolatitude range, to be fairly confident that the sector structure seen was a result of the solar magnetic dipole being tipped such that its axis was near orthogonal to the Sun’s rotation axis.

In determining the coronal field and the interplanetary magnetic field, the characteristics of the polar reversal plays a significant role. Usually just after the solar maximum, the solar minimum configuration of the dipole component disappears during the reversal and the heliospheric current sheet moves to the higher latitudes (Hoeksema, 1991). When the solar magnetic field is a simple dipole configuration with magnetic polarity points inward in the south, the solar wind has a laminar flow and outward in the north, it is separated by neutral current sheet. The magnetic configuration of simple dipole is systematically destroyed, when the solar activity ascends from minimum to maximum phase and it is totally disorganized and has mixed polarity other than dipole (eg quadrupole) has evolved. During polarity reversal, solar wind alone is detected. Since at solar minimum, there is hike in temperature, coronal holes are found. Proton density is very less. Proton temperature and the proton density are inversely proportional to each other. When proton temperature is found to increase ultimately proton density decreases.

**SUMMARY AND CONCLUSION**

From this above observations it is found that in the first orbit and the third orbit, at the equatorial region the interplanetary magnetic field and proton density are high. And at the same in the polar region it very less. Between ~ $30^0$S and ~ $20^0$ N, the interplanetary magnetic field and proton density are found to be at the maximum both in the first and third orbits. Its also found that, both in the equatorial and polar regions the interplanetary magnetic field and proton density are found to be maximum in the second orbit. Also it is found that in the first orbit and the third orbit, at the equatorial region solar wind velocity and proton temperature are less. And at the same in the polar region it is very high. Between ~ $20^0$S and ~ $20^0$ N, the solar wind velocity and proton temperature is found to be at the maximum both in the first and third orbits.

Solar wind velocity and temperature are higher at high latitudes, while the density is lower, especially around the coronal holes. The fast streams, prevailing at higher latitudes during minimum, disappear almost entirely during solar maximum, and the wind becomes slow and highly structured in space and variable in time. Ulysses observations show that slow and mixed solar wind extends to higher latitudes at solar maximum. The solar wind at low latitudes tends to be structured into alternating streams of high and low speed flows that rotate with the Sun. Ulysses observed highly variable and almost equal IMF in all heliolatitudes during its second orbit. The average solar wind temperature is lower near solar maximum and higher near solar minimum. The most striking result of the observations is that the strong latitudinal gradient in solar wind temperature and the latitudinal gradient remains almost unchanged over the course of solar maximum.

The data presented here represents first direct measurements of the solar polar magnetic fields at solar maximum. From this observation as expected, the polarity distribution was much more complex than that near solar minimum. The polarity distribution detected by Ulysses indicates that the magnetic reversal in the solar wind source surface occurred between November 2000 and August 2001, and is likely to have been early within that time range. Ulysses observed negative polarity in the southern hemisphere and once again it recorded negative polarity in the northern hemisphere while moving quickly from the southern hemisphere to northern hemisphere during the solar maximum phase. The Sun behaved like a monopole and this effect is carried in to the interplanetary magnetic field. This change is attributed to the phenomenon of polarity reversal. While the sunspot field dominates during the maximum phase, the overall field is minimum around poles and maximum around the mid-latitudes. Due to the reformation of wide coronal holes in the maximum phase, at solar maximum the slow wind dominates in the beginning of Ulysses second orbit.

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