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Slow solar wind in different phases of solar cycle as observed by Ulysses

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ABSTRACT

In this paper we have analysed slow solar wind observations from Ulysses' full orbit to study the slow solar wind during ascending phase, maximum phase and declining phases of solar cycle 22 and 23. The slow solar wind region occurred in equatorial region near the decline phase of solar cycle 22, polar region near the maximum phase of solar cycle 23 and ecliptic region near the decline phase of solar cycle 23. In polar region, Ulysses observed slow solar wind during solar maximum and this phase coincides with the polarity reversal phase. Active regions are occupied by mixed polarities. The presence of multiporarities plays a significant role for the slow solar wind formation. The multi polarities often form closed magnetic loops and they are found to spread over wide coronal surface, accompanying small coronal holes that forms ambient solar wind from the surface of Sun. With high concentrations of proton particle, the solar wind that emerges during the polarity reversal is found to have slow solar wind. The slow solar wind near solar maximum have been studied and found that the slowing down of solar wind is associated with solar active regions of multi poles. Moreover the magnetic loops existing among the Sun’s spots restrict the free flow of solar wind plasma.

Keywords : Heliosphere, Interplanenary Magnetic Field, Solar Wind, Slow Wind

I. INTRODUCTION

Charged particles (both electrons and positive ions) stream from the Sun known as the solar wind. Solar wind can be characterized in two main categories, the slow wind and the fast wind by this flow (Rosenbauer et al., 1977). The slow solar wind generally comes from lower solar latitudes in the minimum phase of the solar cycle. Minimum velocity of the slow solar wind (below 400 km/s) is the unexplained enigmatic properties. McComas et. al.,(1998) explained, the slow solar wind is associated with the streamers seen in coronagraph images, but its exact source is unclear. Number of studies had been done in regard with the Sun's plasma properties in its ecliptic region. But this study emphasis the Sun's plasma features in polar region especially in high latitude in slow solar wind.

Near solar minimum, when the Sun’s dipole field is dominant, the current sheet can be viewed as a plane tilted at the same angle as the dipole, embedded in the band of slow solar wind. This pattern of fast and slow solar wind is occassionately disturbed by transient flows associated with coronal mass ejections Pizzo (1991). At solar maximum, the large polar coronal holes disappear and are replaced by smaller, generally short lived coronal holes at all latitudes. All the three orbits of Ulysses observed fast and slow wind at all latitudes in the southern hemisphere (McComas et al, 2008). Throughout Ulysses’ first orbit, the solar wind displayed a remarkably simple bimodal structure with persistently fast, tenuous and uniform solar wind at high heliolatitudes and slower, more variable highly structured wind at low latitudes (McComas et al., 2000).

Many studies have shown that the distribution of low speed wind in solar activity minimum coincides with the equatorial streamers of higher density, the above mentioned feature is observed in the equatorial region when Ulysses journey in the ecliptic path towards Jupiter (McComas et al., 2000). The slow solar wind is related to closed solar magnetic lines and the heliospheric current sheet. Gibson (2001) explained that the coronal streamers emerge mainly from the regions of closed field structures, also the solar wind speed is found to be very nominal above the closed field structures. Lotova et al., (2002) observed that the slow wind streams dominate and the during years of maximum solar activity, closed or mixed magnetic structures.

By comparing the solar magnetic field, the evolution of slow speed solar wind and its origin have been investigated. Miyake et al.,(1988) compared the solar wind structure with interplanetary magnetic (IMF) polarity and found high speed streams usually has a single polarity. The solar wind flow pattern becomes more complex and variable, the magnetic field becomes multi polar towards maximum activity, and the solar wind source regions accordingly change in locations and spatial events.

II. 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. The parameters are scaled to 1AU and averaged over longitude. Slow solar wind is detected by the Ulysses from the beginning of 1991 to June 1992, April 1997 till the first part of August 2001, August 2002 to June 2003 and March 2004 to December 2005 data are taken for calculation that facilitates analysis.

The hourly averaged solar wind proton speed and the time period from 18 November 1990 till 30 June 2009 appear in figure 1 clearly shows the bimodal structure of the solar wind during the first orbit and the variable structure of solar wind in the second orbit. During the third orbit the return of bimodal structure of the solar wind is observed as the first orbit. From the Ulysses full orbit, data were being acquired when slow solar wind is detected nearly from the beginning of 1991 to June 1992, April 1997 till the first part of August 2001, August 2002 to June 2003 and March 2004 to December 2005.

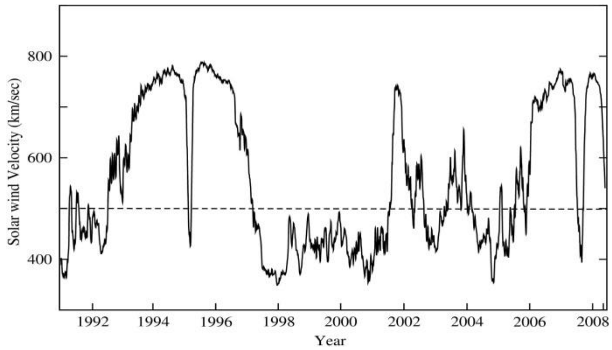

Figure 1: Solar wind velocity of Ulysses full orbits

III. LONGITUDINAL VARIATIONS OF SOLAR MAGNETIC FIELD AND SOLAR WIND PARAMETERS DURING SLOW SOLAR WIND

The solar wind basically flows with two distinct streams, high speed and low speed with different physical conditions. The coronal hole being an open field region and low density region is an established region of a high speed wind. The solar wind from the structured corona with heliospheric current sheet has been known for low speed streams. The low speed solar wind near interplanetary magnetic field polarity reversal has been observed by Gosling et al.,(1981). Many studies have shown that the distribution of low speed wind in solar activity minimum coincides with the equatorial streamers of higher density, the above mentioned feature is observed in the equatorial region when Ulysses journey in the ecliptic path towards Jupiter (McComas et al., 2000). The slow solar wind is related to closed solar magnetic lines and the heliospheric current sheet. The dipolar magnetic structure of the Sun during the minimum phase is associated with the closed magnetic field structure in the equatorial region. The coronal streamers emerge mainly from the regions of closed field structures and the solar wind speed is found to be very nominal above the closed field structures (Gibson, 2001). The evolution of slow speed solar wind and its origin have been investigated by comparing the solar magnetic field. In another study Kojima and Kakinuma (1987) have shown that the low speed wind distributes widely up to higher latitudes during solar activity maximum, Miyake et al., (1988) compared the solar wind structure with interplanetary magnetic (IMF) polarity and it was found that the high speed streams usually have a single polarity. The total IMF strength was also to fall less rapidly with distance in the slow wind than the fast, a result of the tighter Parker spiral structure in the low-speed wind. (Ebert et. al., 2009).

When the solar wind source regions accordingly change in locations and spatial events, the magnetic field becomes multi polar towards maximum activity and the solar wind flow pattern becomes more complex and variable. Woo and Habbal (2000) measurement confirmed that streamer stalks are the sources of slowest solar wind streams. During years of maximum solar activity, closed or mixed magnetic structures and slow wind streams dominate (Lotova et al., 2002).

Low average solar wind spreads to higher latitudes, reaching the poles at sunspot maximum, when the polar coronal holes have disappeared (Wang et al., 1990). The tangential component of the IMF was much stronger in the slow wind relative to the fast wind while the total IMF strength at 1 AU was enhanced as well. (Ebert et. al., 2009) and the radial component of the IMF are about the same in the slow and fast wind.

The simplest magnetic configuration of the Sun occurs during activity minimum. At this time the Sun's magnetic field can be approximated as a dipole whose axis is tilted slightly with respect to the axis of rotation. As the solar wind has a laminar flow when the solar magnetic field is in a simple dipole configuration with magnetic polarity it points inward in the south and outward in the north, it is also separated by neutral current sheet. The magnetic configuration of simple dipole is systematically destroyed and totally disorganized when the solar activity ascends from minimum to maximum phase, as a result mixed polarity other than dipole is thus evolved. A tremendous is exhibited in gaining control over the flow of solar wind, due to the influence of these more complicated fields. Ulysses in its second orbit observed unusually very slow solar wind as it was during the maximum phase starting from the ecliptic position to most of the entire southern hemisphere. The slow component of the solar wind is closely associated to the magnetic active regions on the Sun. So it is conjectured that the slow wind originates around the periphery of the active regions, where the magnetic field is relatively weak to open at some distance out from the Sun, as the bipolar magnetic fields of the active regions are too strong to be forced open by the coronal gas. Intertwined magnetic web is formed, by the complex magnetic fields formed by the sunspot restricting the free flow of the solar wind. When the sunspot starts slowly to switch over its polarity this period also coincides with the starting phase of the polarity reversal. Moreover the sunspot number shows an increasing trend and the orientation of the polarities which were found to be highly chaotic. In order to elucidate the nature of control by the complex field and the flow of slow solar wind, Ulysses SWOOPS solar wind data and the VHM magnetic field data have been utilized.

The solar wind source regions accordingly change in locations and spatial events and the solar wind flow pattern becomes more complex and variable (Marsch, 2006). Woo and Habbal, (2000) made measurement of structures around equatorial region which ultimately restricts the free flow solar wind in the interplanetary region. This could be the reason for the slow solar wind flow in the equatorial region. The slow wind extends far beyond the equatorial region to higher latitude during the solar maximum. And the very slow winds during solar maximum are associated with solar active regions. The activity is distributed more or less uniformly over longitude and polarities in sunspot maximum and is found to be mixed. These closely mixed polarities limit the area of open flux and reduce the solar wind flow (Miyake et al., 1988). The existence of multi-poles in the southern hemisphere is observed by Ulysses in its second rotation, even in high latitudes.

Solar wind disappearance event that occurred on 11 May 1999 has been observed by many observers and its related to a large scale solar phenomena like periodic solar polar field reversal and discussed the possibilities of shutting down of solar wind for more than one day (Usmanov et al., 2000). Moreover the radial magnetic field components of global solar field and the normal field aligned to strengthen the magnetic structure in that region. As an extremely slow phenomenon, the polarity reversal mechanism takes place in the solar interior, rightly at the bottom of the convective zone. The polarity reversal at the poles happens nearly one year after the sunspot maximum. The time interval between the two polar reversals is called the dipole cycle. The nature of solar global field reversal is exhibited, during the solar cycle due to the variation of magnetic field components. The field reversal is found to be a slowly varying phenomenon as the radial field shows the overall field directed towards the spacecraft. The magnetic loops in the photosphere are tied to the surface since the polarity reversal phase keeps them so. The equatorial region is occupied by the sunspots of multi polarities during the solar minimum and as a result magnetic loop like structure is formed around the equatorial region. Towards the end a reduced flow of solar wind in that region is noted.

A.Solar magnetic field

The figure 2 shows the global magnetic field, recorded by the Ulysses magnetometer which shows variations alike the radial IMF variations of Ulysses full orbits. An increase in the magnetic field intensity in the polar regions was not seen, as expected. Instead, Ulysses found an increase in intensity of the magnetic field in the equatorial region than near the poles. But for a small increase in intensity of magnetic field during maximum, the overall intensity of the magnetic field is found to be nearly the same for both the phases of the Sun.

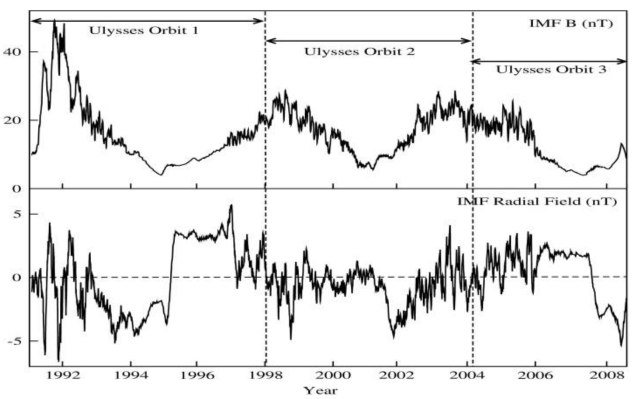

Figure 2. Shows the global magnetic field and IMF radial field for Ulysses full orbits

The overall field is minimum around the poles and maximum around the mid-latitudes which dominate during the maximum phase. The global solar field shows smooth peak during minimum phase and humped peak during maximum. According to Howard and La Bonte (1981), the absolute value of the magnetic flux, peaks strongly at active region latitudes and is very small by comparison in polar regions at all phases in the solar cycle. While the fields in the active regions which determine the resultant equatorial dipole are numerous and strong (Smith, 2001) near the solar maximum the polar fields are weak during the process of reversing. Ulysses observed low latitude streamers near heliospheric current sheet during minimum phase. 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). Ulysses spacecraft encountered a highly unusual magnetic field structure in high solar latitudes during the maximum phase. In its second orbit, Ulysses observed highly variable and almost equal solar magnetic field B in all heliolatitudes. The field is evenly distributed over the entire surface during maximum and during solar minimum, Ulysses found that the interplanetary magnetic field is stronger at equator than at poles. The overall global heliospheric magnetic field B hardly shows any noticeable variation during the magnetic reversal phase.

B. Solar wind velocity

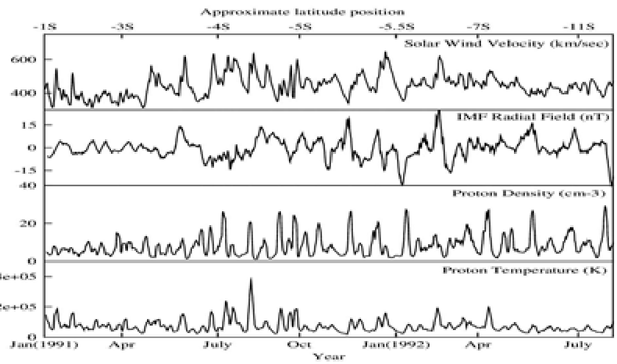

Figure 3a: Shows slow solar wind, Ulysses is in its first orbit, during descending phase of solar cycle 22

Figure 3a shows the slow solar wind for Ulysses first orbit. From the beginning of 1991 to June 1992, the spacecraft is found to travel in the ecliptic region. Figure 3b, Shows the slow solar wind for Ulysses second orbit in the ascending phase. It is found that during the ascending phase of solar cycle 23, Ulysses'

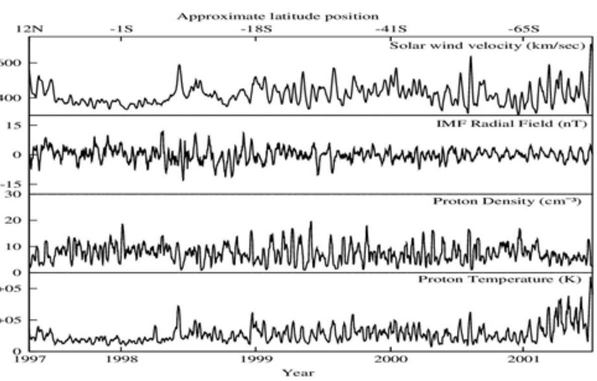

Figure 3 b: Shows the ascending and the maximum phase of the solar cycle 23, Ulysses in its second orbit at April 1997 to August 2001.

second orbit on the Southern hemisphere, covers ecliptic region from April 1997 to September 2000, January 2001 to August 2001 and polar region from September 2000 to January 2001. Figure 3c, Shows the slow solar wind for Ulysses second orbit in the descending

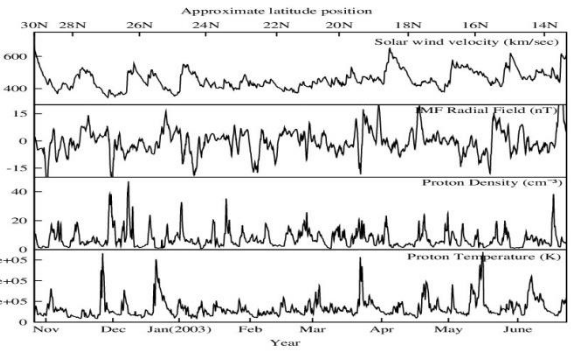

Figure 3 c: Shows the descending phase of the solar cycle 23, Ulysses in its second orbit at August 2002 to June 2003.

phase. The descending phase of solar cycle23 is from August 2002 to June 2003 covering ecliptic region when Ulysses was in its second orbit. Figure 3d shows the slow solar wind for Ulysses third orbit in the descending phase. When Ulysses was in its third orbit, it undergoes descending phase in the 23rd cycle from March 2004 to December 2005 covering ecliptic region.

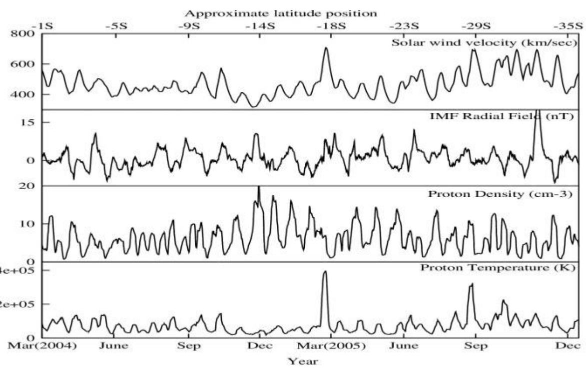

Figure 3 d : Shows the descending phase of the solar cycle 23, Ulysses in its third orbit at March 2004 to December 2005.

During the maximum phase of solar activity the first panel of following four figures shows the flow of solar wind measured by Ulysses. The solar wind speed maximum is observed at the poles during the solar minimum and as a result in the southern hemisphere, the solar wind gradient in the high latitude is found to be 10 km s−1. Solar cycle variations dominate both the phases of the solar cycle at higher heliolatitudes. During the course of the solar activity cycle, significant changes are undergone by the solar wind.The slow solar wind was cooler and denser than the fast wind (Ebert et. al., 2009). During the minimum phase, the solar wind possesses a uniform laminar fast flow and moderate erratic wind during the maximum phase. The solar wind features are more pronounced in the inner heliosphere than in the outer heliosphere in general. During the maximum phase, the Ulysses first orbit around the Sun coincides with the minimum phase of the solar cycle and the second orbit. The slow wind region detected during the period April 1997 to August 2001 is the one that last lasted for a longer period. And it is the only one region which is found both in the equtorial and in the polar region.

The above figures show the flow of solar wind measured by Ulysses during the maximum phase of solar activity. 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. For few sharp peaks in the ecliptic region, the solar wind is very slow and passive in the southern hemisphere.

Unlike in the southern hemisphere, the solar wind is very erratic in the Northern hemisphere and the solar wind speed is substantially enhanced. Ulysses observes a polar coronal hole with smaller area is compared to that observed during the minimum phase. This maximum phase is coincided with the solar polarity reversal. The solar wind is found to be comparatively slower and smoother before the reversal phase. During the first polar orbit of Ulysses, limited number of coronal transients is observed. Ulysses observed more solar transients during the maximum than the solar minimum due to the occurence rate of solar transients which follows the solar acitivity cycle. The main reason for erratic variations of solar wind speed is the enhanced solar transients during maximum phase. Slow and mixed solar wind extends to higher latitudes at solar maximum is shown by Ulysses' observations.

The slow wind during solar maximum which is extended far beyond the equatorial region to higher latitude and the very slow winds during solar maximum are associated with solar active regions. In sunspot maximum the activity is distributed more or less uniformly over longitude and polarities are found to be mixed. These closely mixed polarities limit the area of open flux and reduce the solar wind flow (Miyake et al., 1988) Ulysses in its second rotation observed the existence of multi-poles in the southern hemisphere, even in high latitudes. The decrease in solar wind speed near solar maximum have been studied in detail and figure 2 clearly, shows that the slowing down of solar wind is associated with solar active regions of multi-poles. The figure points out that the magnetic field with multi polarity regions with equal strength in polarity (positive - negative) highly restricts the flow of solar wind. Unlike the fast speed stream which emanates from the open field regions of coronal holes, the origin of low speed wind flow has not been thoroughly explained, (Janardhan et al., 2006). Normally the low speed flow is confined to low latitude regions. Ulysses observation is the first to detect low speed wind both in the low and high latitudes. Wang et al., (1990) observed low speed solar wind emerging from the tops of closed loops in helmet streamers situated near active regions. The second panel of the above four figures shows the variation of solar wind parameters with respect to radial magnetic field is displayed. The dipole structure keeps the equatorial corona tied to the Sun leaving the other regions magnetically open. In addition to the global dipole field, the toroidal fields (sunspots) spread over the mid latitude and equatorial regions of the surface of Sun, this occurs during the maximum phase. This makes the Sun a multipolar one and breaks its temporal and spatial homogeneity. The Ulysses's measurement of IMF during solar minimum is consistent to our expectation. Than the high latitudinal regions, equatorial regions push more flux in to the interplanetary medium

C. Interplanetary magnetic field of radial component

The second panel of figure 2 shows the polarity change of interplanetary magnetic field of radial component. During minimum phase, near the equatorial plane due to the presence of sunspots, the polarity fluctuations are always confined to ecliptic region. Most of the solar surface is occupied by regions of magnetic multi poles except for the narrow polar region, during maximum phase. Over the solar corona and into the interplanetary medium the dominant solar global dipolar magnetic structure extends its control. The solar magnetic field changes greatly during the solar cycle, as does the coronal and the interplanetary magnetic field. Around the solar minimum Sun retains its simple dipole field and the entangled dipole field mixed with multipolar field around the solar maximum. One of the most striking features of the solar activity cycle is the reversal of the solar polar magnetic field. During the two activity phases of the Sun, an excellent map of changing magnetic field configuration is provided by the journey of the Ulysses spacecraft over the high latitudes in the northern and southern hemispheres of the Sun is found. The global dipole field change is provided during the Ulysses' journey over the high northern latitude, when the solar activity was around the maximum phase. Observations during the solar minimum showed a clear and strong, negative and positive polarity respectively in the southern and northern hemisphere. Ulysses observed negative polarity in the southern hemisphere and once again it recorded negative polarity in the northern hemisphere, during the solar maximum phase. 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 the northern hemisphere, Ulysses observed the polarity change in the peak of solar maximum activity.

The characteristics of the polar reversal play a significant role, in determining the coronal field and the interplanetary magnetic field. During the reversal, usually just after the solar maximum, the solar minimum configuration of the dipole component disappears and the heliospheric current sheet moves to higher latitudes (Hoeksema, 1991). The dipole tilt, the rotation of the Sun, and the acceleration of the solar wind cause hills and valleys in the HCS which spirals outward like the ballerina skirt. Between solar minimum to solar maximuml, the inclination of heliospheric current sheet is closely correlated with the sunspot number and varies from low to high inclination. The solar magnetic dipole, which is nearly aligned with the solar rotation axis near minimum, is almost equatorial at the maximum (Smith, 2001). According to Balogh et al. (1999) the propagation of waves during the polarity inversion shows that these are caused by large scale folds in the magnetic field, rather than by opposite polarity magnetic flux originating near the Sun. Jones et al., (2003) found that the process of polarity reversal took over a period of several months, also they expect the dipole tilt occurred in a sudden manner. The source surface models described by Sanderson et al., show that the dipole term can dominate even at maximum solar activity (Sanderson et al.,1994b). According to Harvey, the reversal occurred between the period 19th day of 2001 and 34th day of 2001 (Harvey and Recely, 2002).

D. Solar Wind Density

The third panel of above figures shows proton particle variations, which shows variations alike the radial IMF variations. The proton number observed by Ulysses is maximum in the equatorial regions, where the solar wind streams velocity is extremely very low. In general, proton density is greater for slower solar wind. The magnetic sector boundary crossings are identified as regions of increased number of protons (Steinberg and Lazarus, 1996). The proton number observed by Ulysses is maximum in the equatorial regions, where the solar wind streams' velocity is extremely very low. 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 flux (protons and helium) than regions of higher latitudes. For both the phases of the solar cycle this behaviour is common. Near ecliptic plane, the minimum density of solar wind particle is observed during the magnetic field polarity reversal in the polar region (Kovalenko, 1988).

Regading proton density, the region covering the period from March 2004 to December 2005, ranges till 20 cm-3. In the other region the covers during the period from August 2002 to June 2003, proton density peaks of the proton density fiund ranges above $20cm^{-3}$ in abundance. All the parameters found in the decending phase of the 22nd solar cycle and the decending phase of the 23^{rd} solar cycle (which begins 1991 and ends in June 1992) and found to be the same (which begins in March 2004 and gets ended in December 2005).

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. 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. During the pre-reversal phase of solar maximum activity because of an increase in the number and size of magnetic field loops in the solar corona slow variation of proton particles could be associated with the suppression of solar plasma outflow according to this principle. This magnetic coupling may preserve more protons in the outer corona, to show a marginal increase in the proton number. When the solar surface exhibits a complicated magnetic field configuration, the emission of particles highly varies.

E. Solar Wind Temperature

The second slow solar wind region is found in the ascending phase of the 23rd solar cycle and also it is in the maximum phase. Both the third and fourth slow sloar wind regions occur during the descending phase of the 23^{rd} cycle. The differences found in the third and the fourth slow solar wind regions are closely observed and included. It is significant that during the descending phase of the 23rd solar cycle, the temperature is maintained upto 1.5×10^{5} K. The region corered during August 2002- 2003, temperature is not maintained within a particular reading, there are continuous peaks and downs to be down. In short, there is no constant temperature that prevails during the descending phase of the 23rd cycle, which in the third slow solar wind region.

The proton temperature in the slow wind falls less sharply with distance than in the fast wind (Ebert et. al., 2009) and also explained this is likely due to compressional heating from shocks formed at the leading edge of SIRs in the highly variable slow solar wind.

The fourth panel of above four figures shows that, at the equatorial regions, the solar wind temperature has been in minimum value, where the wind speed is minimum. The solar cycle variation of temperature in the outer heliosphere is much smaller than that observed at 1 AU. The average solar wind temperature varies in accordance with the phase of the solar cycle. Solar wind temperature is lower near solar maximum and higher near solar minimum. Ulysses' first orbit coincided when the minimum phase and the solar wind temperature were found to be maximum above the polar coronal regions, where the solar wind speed is maximum. Figure 2 shows that, at the equatorial regions, the solar wind temperature remains in minimum value, where the wind speed is minimum. 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). The presence of strong latitudinal gradient in solar wind temperature is the most important result obtained in this work. 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). As observed by Ulysses in its second orbit around the Sun, the latitude gradient remains almost unchanged over the course of solar maximum phase. The average solar wind temperature appeared to vary with solar cycle. It is lower near solar maximum and higher near solar minimum. Since similar behavior is previously observed in 1 AU and it is also found that the solar cycle variation of temperature in the outer heliosphere is much smaller than that observed near 1 AU, proving to be not a matter of surprise. The strong latitudinal variation in solar wind temperature is the most striking behavior of our observation. This gradient is an extended phenomenon and appears to be associated with a particular phase of solar cycle, that's in the minimum phase. 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.

In the Southern hemisphere, the solar wind temperature with respect to latitude is exhibited. It is found that in the Northern hemisphere variations are much more and in general, temperature varies linearly. 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 vary with solar cycle but, it is lower near the solar maximum and higher near the solar minimum. So the graph is studied from top to bottom in the following order, solar wind velocity, radial interplanetany magnetic field, proton density and proton temperature.

IV. RESULTS AND DISSCUSION

Sun at different phases reconstructs the global magnetic field through dynamo action which is suggested by the study of the long term variations in the proton parameters of the solar wind at different phases. Multipolarity regions are observed in the first period that is between June 1991 to June 1992. During the solar minimum period, the particle flux density is very low with high speed polar coronal streams and it is comparatively high in the equatorial solar wind streams. Both in the equatorial as well as in high latitudes the solar wind speed is very slow. The slow solar wind is detected during the maximum phase that could be due to the polarity reversal phase. The Negative polarity is observed both in the northern and southern hemisphere during the solar maximum phase. The slow speed solar wind near solar maximum have been studied and found that the slowing down of solar wind is associated with solar active regions of multipoles during polarity reversal phase (Iren et al.,2015),

During minimum phase, the solar wind speed is an average considerably faster at high latitudes than at the solar equator. Slow solar wind regions are detected at four instances. First slow solar wond is found in the decending phase of the 22nd solar cycle. The second slow solar wind region is found in the ascending phase of the 23rd solar cycle and also it is in the maximum phase. Both the third and fourth slow sloar wind regions occur during the descending phase of the 23rd cycle. The differences found in the third and the fourth slow solar wind regions are closely observed and included. It is significant that during the decending phase of the 23rd solar cycle, the temperature is maintained upto 1.5×10^5 K. The region corered during during August 2002-2003, temperature is not maintained within a particular reading, there are continuous peaks and downs to be down. In short, there is no constant temperature that prevails during the desending phase of the 23rd cycle, which in the third slow solar wind region.

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V. CONCLUSION

During the maximum phase the overall field is minimum around poles and maximum around the mid-latitudes. Smooth peak during minimum phase and humped peak during maximum is detected in the global solar field, while the sunspot field dominates. Due to the reformation of wide coronal holes in the maximum phase the slow wind dominates in the beginning of Ulysses second orbit at solar maximum. Multipoles are found in abundance in the slow wind region, April 1997 to July 2001 as observed in the graph. The solar particle flux is found to be larger in the slow wind regions in the solar maximum.

VI. ACKNOWLEDGEMENTS

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