Research article Available online www.ijsrr.org ISSN: 2279–0543

International Journal of Scientific Research and Reviews

Ulysses Observation of Slow Solar Wind

Bidhu S S* and A Iren Sobia[1]

*Department of Physics, Nesamony Memorial Christian College, Marthandam, India.
Email : bidhuss@gmail.com
[1]Department of Physics, Muslim Arts College Thiruvithancode, India. Email : irensobia@gmail.com

ABSTRACT

Ulysses' in its full orbit around sun, spotted slow solar wind during ascending phase, maximum phase and declining phases of solar cycle 22 and 23. The spacecraft observed the slow solar wind in first orbit; during the decline phase of solar cycle 22, in second orbit; in polar region during the maximum phase of solar cycle 23 and in ecliptic region during the decline phase of solar cycle 23. When the polarity reversal takes place ie; during maximum phase of solar cycle 23, slow wind was found in polar region. The multiporarities have key-role for the formation of slow solar wind. The solar wind that emerges during the polarity reversal detected slow solar wind due to the high concentration of proton particle.

KEYWORDS: Solar wind, solar wind velocity, solar wind magnetic field

***Corresponding Author:**

Bidhu S.S

Department of Physics,

Nesamony Memorial Christian College,

Marthandam, India.

Email : bidhuss@gmail.com

INTRODUCTION

Charged particles (both electrons and positive ions) stream from the Sun known as the solar wind. Fast solar wind and slow solar wind are the two main categories this charged particles, solar wind (Rosenbauer et al., 1977). The slow solar wind generally comes from lower solar latitudes. Minimum velocity of the slow solar wind (~ 400 km/s) is the unexplained enigmatic properties. The more active regions on the Sun from the slow solar wind of the minimum type originates above. Mc Comas et. al.,(1998) explained, the slow solar wind is associated with the streamers seen in coronagraph images, but its exact source is unclear. The slow wind of the maximum type emerges from substantially larger areas distributed all over the Sun. 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.

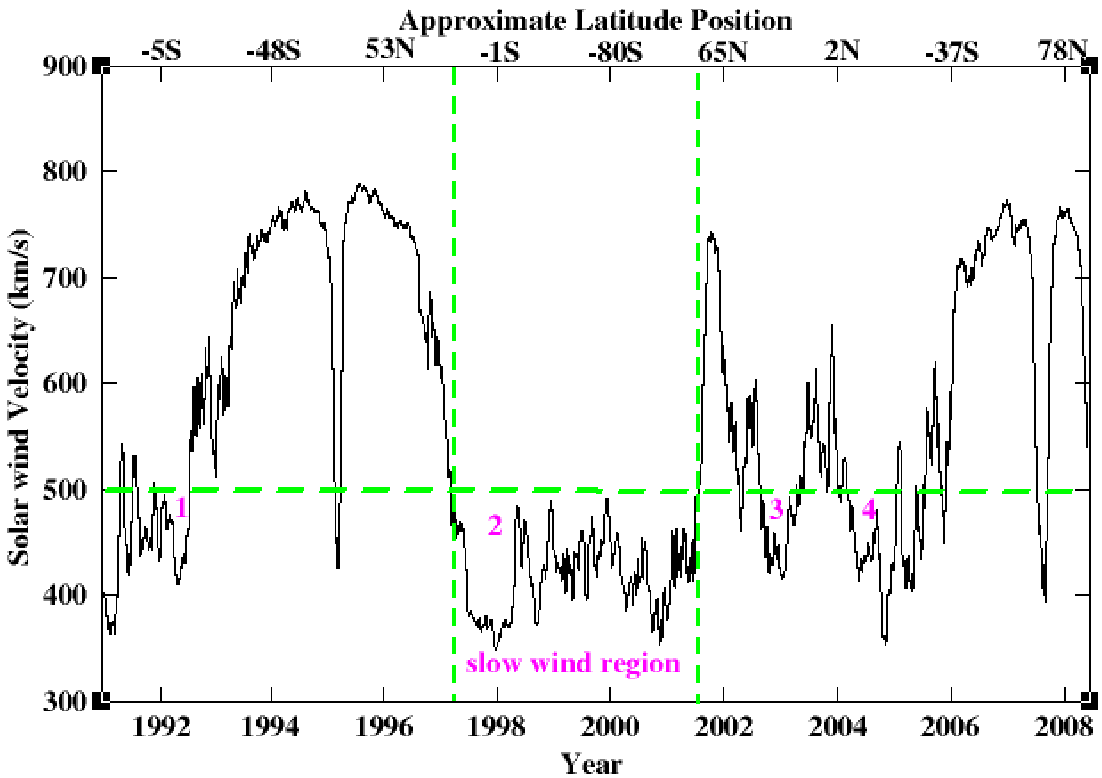
Many studies have shown that the distribution of low speed wind in solar activity minimum coincides with the equatorial streamers of higher density, the above mentioned feature is observed in the equatorial region when Ulysses journey in the ecliptic path towards Jupiter (Mc Comas et al., 2000). The 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. In this paper we discussed about the slow solar wind observed by Ulysses in its full orbit. During first and second orbit only Ulysses observed slow solar wind; in first orbit; during the decline phase of solar cycle 22, in second orbit; in polar region during the maximum phase of solar cycle 23 and in ecliptic region during the decline phase of solar cycle 23.

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 VELOCITY -ULYSSES OBSERVATION

Figure 1: Solar wind velocity of Ulysses three orbits.



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. For this slow wind regions, the first slow wind region 1991 to June 1992 is in Ulysses' first orbit. The second and third slow wind regions, April 1997 till the first part of August 2001, August 2002 to June 2003 are in Ulysses' second orbit. The forth slow wind region, March 2004 to December 2005 is in Ulysses' third 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 equatorial and in the polar region.

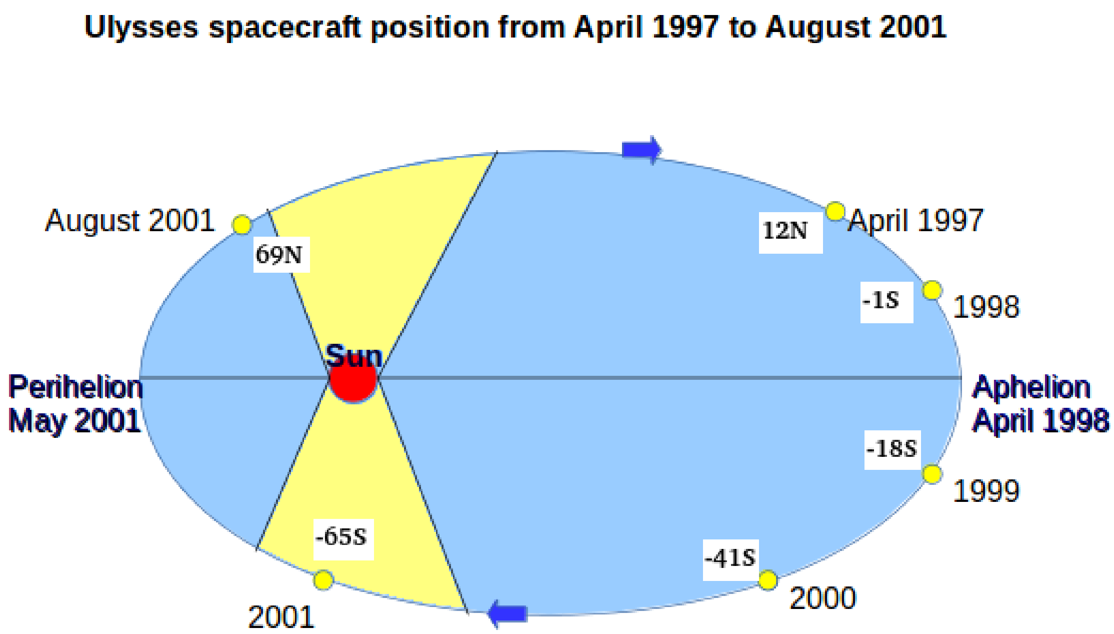


Figure 2: Ulysess position from April 1997 to August 2001

Figure: 2 shows the Ulysses position from April 1997 to August 2001. It is found that during the ascending phase of solar cycle 23, Ulysses' first and 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. This time periods, Ulysses in first and second orbits ie., in 13N to 0 in the northern hemisphere, 0 to 0 southern hemisphere and 0 to 69N northern orbit data are used to this study. Also the WIND spacecraft observations are used to study equatorial and low latitude solar wind during this simultaneous period. During December 1997 to May 2001 Ulysses covers southern hemisphere and during 2001 September December Ulysses covers northern polar hemisphere. Since WIND was in halo orbit at L_1 and Ulysses was at polar regions, the time changes with respect to both spacecrafts observations are slightly different of solar rotations. 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.

SOLAR MAGNETIC FIELD DURING SLOW SOLAR 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.

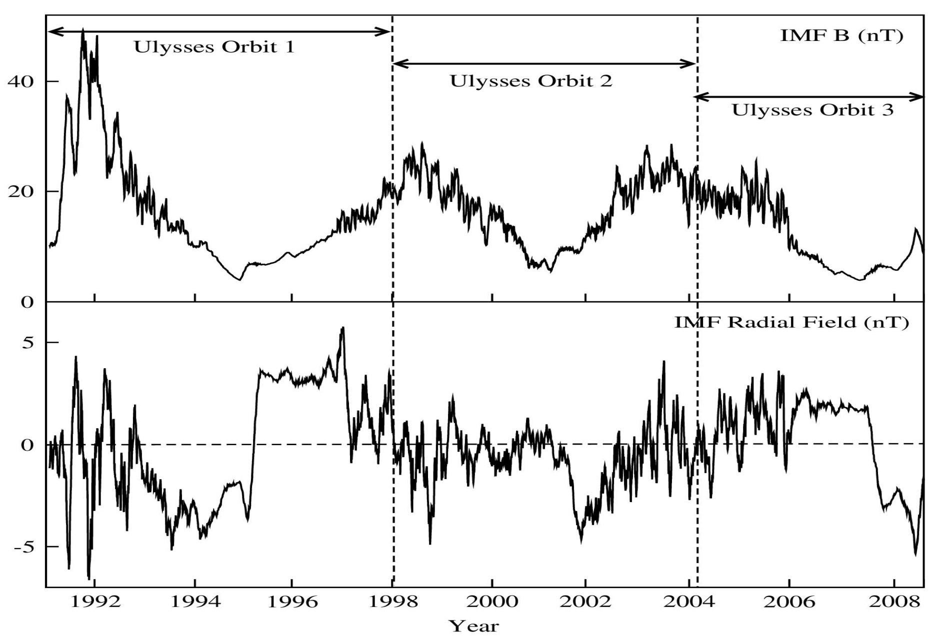


Figure 3: Global magnetic field and IMF radial field

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 happen 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.

The figure 3 shows the global magnetic field and interplanetary magnetic field of radial component. The first panel of figure 3 shows the global magnetic field, recorded by the Ulysses magnetometer which shows variations alike the radial IMF variations. 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. 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.

The second panel of figure 3 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. 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 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.,1994). According to Harvey, the reversal occurred between the period 19th day of 2001 and 34th day of 2001 (Harvey and Recely, 2002).

SUMMARY AND CONCLUSION

The study of the long term variations in the proton parameters of the solar wind at different phases were different; Sun at different phases reorganize the global magnetic field through dynamo action. Form this study, we investigated the variations of slow solar wind velocity and magnetic field of slow solar wind. During the period; June 1991 to June 1992, Ulysses observed multi-polarity regions. Ulysses observed slow solar wind in both in the equatorial and in high latitudes of solar surface. Slow wind were found during descending phase of 22 solar cycle and maximum and descending phase of 23 solar cycle irrespective of latitude. During minimum phase, the solar wind speed is tends to become low as slow solar wind in solar equator than at the high latitude. Ulysses detected Slow solar wind regions are detected at four different occasion of solar cycle 22 and 23. The differences found in the third and the fourth slow solar wind regions are closely observed and included.

REFERENCES

1. Balogh. A, Beek.T. J, Forsyth. R.J, Hedgecock.P. C, Marquedant.R.J, Smith.E. J, Southwood. D.J, Tsurutani. B. T. The Magnetic Field Investigation on then *Ulysses* Mission: Instrumentation and Preliminary Scientific Results. Astronomy and Astrophysics Supplement Series; 1992;221-236,

2. Balogh, A., R. J. Forsyth., E. A. Luck., and T. S. Horbury. Hemispheric magnetic field polarity inversions at high latitudes, Geophysical Research Letters; 1996;26:631-634.
3. Bame. S.J, Mc Comas. D.J, Barrowclough. B.L, Phillips. J.L, Sofaly. K.J, Chavez. J.C, Goldstein. B.E, Sakurai. R.K. The Ulysses Solar Wind Plasma Experiment Astronomy and Astrophysics Supplementary Series; 1992;92:237-265.
4. Gibson, G. Global solar wind structure from solar minimum to solar maximum., Space Science Reviews; 2001;97:69-79.
5. Harvey, K., and F. Recely. Polar coronal holes cycles 22 and 23, Solar Physics; 2002; 211, 31-52.
6. Hoeksema, J. T. Large scale solar and heliopheric magnetic fields, Advanced Space Research; 1911;11(1):15-(1)24.
7. Horbury, T. S., and A. Balogh, Evolution of magnetic field fluctuations in high speed solar wind streams: Ulysses and helios observations., Journal of Geophysical Research; 2001; 106(15):929-15,940.
8. Howard, R., and B. J. La Bonte. The Sun is observed to be torsional oscillator with a period of 11 years. The Astrophysical Journal 1981; 239: L33.
9. Jones, G. H., A. Balogh, and E. Simth. Solar magnetic field reversal as seen at ulysses, Geophysical Research Letters; 2003; 30: ULY2,1-4.
10. Lotova, N. A., V. N. Obridko, K. V. Vladdimirsk, M. K. Bird, and P. Janardhan. Flow
11. sources and formation laws of solar wind streams, Solar Physics 2002; 205: 149-163.
12. Marsch, E. Coronal origins of the solar wind-sources of steady streams and transients flows caused by solar magnetic eruptions, ILWS WORKSHOP 2006, GOA, FEBRUARY 19-20; 2006.
13. McComas, D. J., S. J. Bame, S. J. Barker, W. C. Feldman, J. L. Phillips, P. Riley, and J. W. Griffee, Solar wind electron proton alpha monitor (SWEPAM) for the Advanced Composition Explorer, Space Science Reviews; 1998; 86:563.
14. McComas, D. J., B. L. Barraclough., H. O. Funsten., and J. T. Gosling. Solar wind observations over ulysses first full polar orbit, Geophysical Research Letters: Space Physics; 2000;105(A5):10,419–10,433.
15. Miyake, W., K. Kobayashi., K. I. Oyama., T. Mukai., T. Abe., T. Terasama., K. Yumoto., T. Saito., K. Hirao., A. J. Lazarus., and A. D. Johnstone. Multispacecraft observations of heliospheric structure of the solar wind speed, Planetary Space Science; 1998;12: 1329-1342.
16. Rosenbauer, H., Schwenn, R., Marsch, E., Meyer, B., Miggenrieder, H., Montgomery, M.D.,

17. Muehlhaeuser, K.H., Pilipp, W., Voges, W., Zink, S.M. A survey on initial results of the HELIOS plasma experiment. Journal of Geophysics Zeitschrift Geophysik,; 1997;42:561–580.
18. Sanderson, T. R., R. G. Marden, and K. P. W. Ulysses high latitude observations of ions acclerated by co-rotating interaction regions., Geophysical Research Letters; 1994;21:1113-1116.
19. Smith, E. J. The heliospheric current sheet, Journal of Geophysical Research: Space Physics; 2001;106(15):819-15,831.
20. Usmanov, A., M.L.Goldstein, and W.M.Farrell. A view of inner heliosphere during may 10-11 1999 low density anomaly., Geophysical Research Letters; 2000;27:3765-3768.
21. Wang, Y. M., N. R. S. Jr., and A. G. Nash. Latitudinal distribution of solar wind speed from magnetic observations of the sun, Nature 1990:347:439-444.
22. Woo, R., and S. R. Habbal. Connecting the sun and the solar wind: Source regions of the fast wind observed in interplanetary space, Journal of Geophysical Research: Space Physics 2000; 105(12):667-12,674.