Analysis of Solar Wind Proton Density on Ulysses in relationship with URAP Solar Radio Burst

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Abstract

Evolution (1990 – 2009) of solar wind proton density (n_p), temperature (T_p), speed (V_p), and magnetic field (B), has uncovered variances in long term with sun powered radio and plasma wave emanation, these amounts traversing an extensive territory scales demonstrative of turbulence. The idea of turbulence in the solar wind has been the subject of extraordinary research as it assumes few parts of plasma conduct as fundamental part of solar wind with increasing speed and warming of the expanded sun's corona. This examination is worried about the idea of thickness in the expanded solar corona and how it is been connected with the sunlight based radio burst. This stage contrast may add to the n_p-V_p exponent relationship with the solar cycle. Electromagnetic waves crossing the solar wind encounter dissemination because of turbulent density changes which prompts a wide assortment of practical problems like force glimmers, precise expanding, pulse spreading, and so forth. These perceptions give valuable imperatives on the amounts describing n_p turbulence. The normal solar wind n_p for the moderate wind is exceedingly connected with the sunspot number, however lags around 4 years by the pinnacle of the solar cycle.

Keywords: Radio burst, proton density, solar wind

Introduction

The solar wind rising up out of the sun's corona is observed to be inhomogeneous and creates convoluted three dimensional arrangement of the plasma heliosphere (Gosling & Pizzo., 1999). Outflowing surges of various rates and solar drifters present further confusions and advances the wind with tremendous changeability in its fundamental properties. In situ and in addition remote detecting perceptions of magnetic field, speed and density have uncovered fluctuations crossing an expansive scope of timescales (Sholly Kutty & Kurian., 2009). The pickup protons originated from local interstellar medium (LISM) neutral hydrogen (H) that floats into the heliosphere because of the movement of the Sun through the LISM (You et al., 2007). As it nearing the Sun, neutral H is ionized by two procedures, photo ionization and charge trade of solar wind protons. Upon ionization, these protons are quickly grabbed by the solar wind magnetic field. Because of the high relative speed of the approaching unbiased H as for the SW, the pickup procedure exchanges huge energy and momentum to the solar wind (Verma et al., 2014).

The protons of solar wind equalized by charge trade end up plainly energetic neutral atoms (ENAs) and are lost from the solar wind. (Devrie et al 2012) Jupiter's external magnetosphere is touchy to solar wind dynamic pressure changes. Be that as it may, the connection of Jupiter auroral emanations to sun based wind pressure is unpredictable (Riazantseva et al., 2002). Some hypothetical models foresee an anti connection between sun's wind pressure and fundamental auroral emanations, however a few perceptions have demonstrated that auroral and radio discharges are upgraded in the course of times of higher solar wind pressure are activated by interplanetary shocks (Jaime et al., 2002). All things considered there are numerous vulnerabilities concerning the landing of solar wind structures to Jupiter which make it hard to decide with certainty if discharges happen during compacted or tenuous solar wind regions (Hess et al., 2012). In association amongst moderate and quick solar wind happens when fast solar wind streams overwhelm moderate wind, making a corotating interaction region (CIR) of compacted warmed plasma at the main edge of the fast stream (Balveer et al., 2014). At low heliographic latitudes, such CIRs are ordinarily limited by forward and reverse waves on their driving and trailing edges separately that steepen into shocks everywhere at heliocentric distances. (Judith et al., 2015) Speeding up of protons up to 20 Mev energies happens at both of these shocks. Interplanetary shuttle close to Earth identify intermittent increments in the powers of energetic (<1Mev) protons during times of low solar activity (Lario et al., 2000).

The CME-driven shocks are probably going to be more grounded close to the Sun where the driving CMEs achieve their most extreme speed before decelerating because of the drag force applied by the surrounding medium. Shocks can likewise be straightforwardly recognized in situ in the solar wind based information as a broken bounce in n_p, T_p stream speed and B (Breech et al., 2009). There is a long standing level headed discussion over the launchers of the shock waves that deliver type II bursts. For the most part it is concurred that quick proliferating Coronal Mass Ejection (CMEs) can make spreading shock waves, either as bow shocks at the nose of the CME or as driven waves at the CME flanks. In the low corona there is also the likelihood that flares lighted impact waves proliferate outward and create type II bursts (Pohjolainen et al., 2013). The type II discharge comes about because of a shock travelling through the solar corona. The recurrence float permits an estimation of the shock speed if an electron density display is accepted for the corona (Barr et al., 2000). In the event that the type II reaches out to low frequencies underneath (10 MHz) it is thought to be a shock going before a CMEs, where as a low recurrence cut off over 20 MHz may infer a coronal shock delivered by a flare impact wave (Eamon et al., 2013 & Hamidi et al., 2014). Most type II emanation is not trailed by a solar particle event (SPE). Type II radio outflow happens at the nearby plasma recurrence and its harmonic so the recurrence of discharge is demonstrative of the heliocentric separation at which the radio emanation starts. From the common place density profiles in the corona, one can interpret that metric type II blasts are restricted to heliocentric separations ~ 2.5 R_s. Early space perceptions were gotten at frequencies underneath 2 MHz, which compare to radio blasts happening at heliocentric separations past ~ $10R_s$. The wavelength of type II burst starting in the heliocentric separation scope of 2 – 10 R_s is in the decametre – hectometric (DH) space (Gopalswamy et al., 2005).

The basic event of type III blasts right on time in the ascent of indiscreet sun oriented flares may demonstrate that open field lines are a fundamental piece of models for energy discharge by B in such flares. Sunlight based radio burst type III is a sun oriented burst and most prevailing with the sun oriented flare wonder was first presented by wild in 1963 in the recurrence run of 500 – 10 MHz (Hamish Andrew & Heather., 2014). There are three sub-types of III blasts start in the interplanetary (IP) medium which are i) Isolated type III erupts from vitality framework and little scale vitality discharges ii) Type III tempests. It is discovered that 60% of quick floats (sort III) sun powered radio blasts are synchronized in time with sun powered flares (Krupar et al., 2014). Type IV burst is a marker of the development of another dynamic area. It uncovers a wave - molecule and wave - wave communications in attractive traps in the sunlight based corona (Moncuquet et al., 2006). However the completely created type IV occasion is exceptionally unpredictable at meter wavelengths the sort IV burst is normally, however not perpetually, gone before by a sort II burst. There are two principle classifications of sun powered radio burst sort IV which is i) broadband radio pulsations (BBP) and ii) Zebra designs (ZP). The fine structures (FS) of sun powered type IV radio blasts are of key enthusiasm for flare plasma diagnostics in the low crown (Hamidi et al., 2014). At some stage the Ulysses rockets experience with Jupiter (nearest approach in February 1992), the radio and plasma waves instrument brought together radio and plasma wave (URAP) watched low recurrence (VLF < 20 KHz) emanations of Jovian beginning from separations of more than 2 AU (Karine et al., 1998). The watched VLF emanation is then an amalgamation of all the profoundly scattered low recurrence outflows created nearer to Jupiter including the Quasi – periodic (QP) blasts, the genuine continuum discharge and the low recurrence degree of different blasts like broadband kilometric radiation (Yuan Kuen et al., 1999). The watched 10 hour periodicity of the reradiated emanation just mirrors the 10 hour periodicity in these unique radio sources. (Kaiser et al., 2004)

Data Selection

The progress of the study is based on the two phases mainly the solar minimum and solar maximum of the solar cycle. The slow solar wind turbulence is usually thought to be fully developed, so that the radiation emitted from a distant ecliptic source is dominantly effected by the slow solar wind. It is well known that the properties of the solar wind depend on its flow speed. Therefore we only consider ecliptic sources so as to primarily study turbulence in the slow solar wind. Data from the joint ESA/NASA Ulysses mission show that the Sun has reduced its output of solar wind to the lowest levels since accurate readings are available. This current state of the Sun could reduce the natural shielding that envelops our solar system. To examine the evolution of the T_p-V_p and n_p-V_p relationships over time scales spanning multiple solar cycles, we primarily use the hourly data set available from the Ulysses solar wind plasma investigation (SWOOPS) instrument in the Ulysses spacecraft. The temperature and density measurements begin in 1965, to compensate for some differences in calibrations. The data were normalized by examining times when missions overlapped. The Unified Radio and Plasma Wave Experiment (URAP) is a set of instruments on the Ulysses spacecraft. It provides electric field measurements from "DC" to 1 MHz and magnetic field measurements from 0.22 to 450 Hz. These bandwidths permit the study of radio emissions from solar ejecta, interplanetary transients, and planetary magnetospheres and of in situ plasma waves associated with interplanetary shocks, coronal mass ejections, and other transients. The radio observations provide an important remote diagnostic of solar flares and shocks. The plasma wave observations are critical to the understanding of instabilities that exist throughout the interplanetary medium (IPM). Furthermore, analyses of the URAP data permit deriving fundamental characteristics of the solar wind, such as electron density and temperature which has been documented in (https://urap.gsfc.nasa.gov/)

Result and discussion

Spectral Evaluation of Solar Wind Parameters

The study focuses the unusual behaviour of solar wind with all the other parameters. Two specific events has been identified from the spectrum of solar wind parameters from Ulysses/SWOOPS in figure (1), which falls on the year 1995 and 2007 which comes under solar minimum. As per the statement the solar wind is a continuous outward stream of particles mostly protons and electrons from the Sun's hot corona. Energized by high temperatures in the corona, these particles leave the Sun at speeds ranging from 300 to 800 Km/s. So there should be rise in temperature for a solar wind to expand to maximum and vice versa. But in the year 1995 and 2007 there observed even with a rise in temperature there is a sudden fall in solar wind with the proximal temperature of corona.

The observation in 1995 is more specifically leads to the examination which reveals a solar wind minimum even with a continuous outflow of temperature and proton density has observed with the reversal of magnetic field B. The solar wind also differs based on the origin of the Sun's surface, where exactly it comes from and how quickly that proton is been scattering. The solar wind is observed to exist in two fundamental states, termed the slow solar wind and the fast solar wind, though their differences extend well beyond their speeds. In near Earth space, the slow solar wind is observed to have a velocity of 300 – 500 Km/s, a temperature of $1.4 – 1.6x10^6$ K and a composition that is a close match to the corona. By contrast, the fast solar wind has a typical velocity of 750 Km/s, a temperature of $8x10^5$K and it nearly matches the composition of the Sun's photosphere.

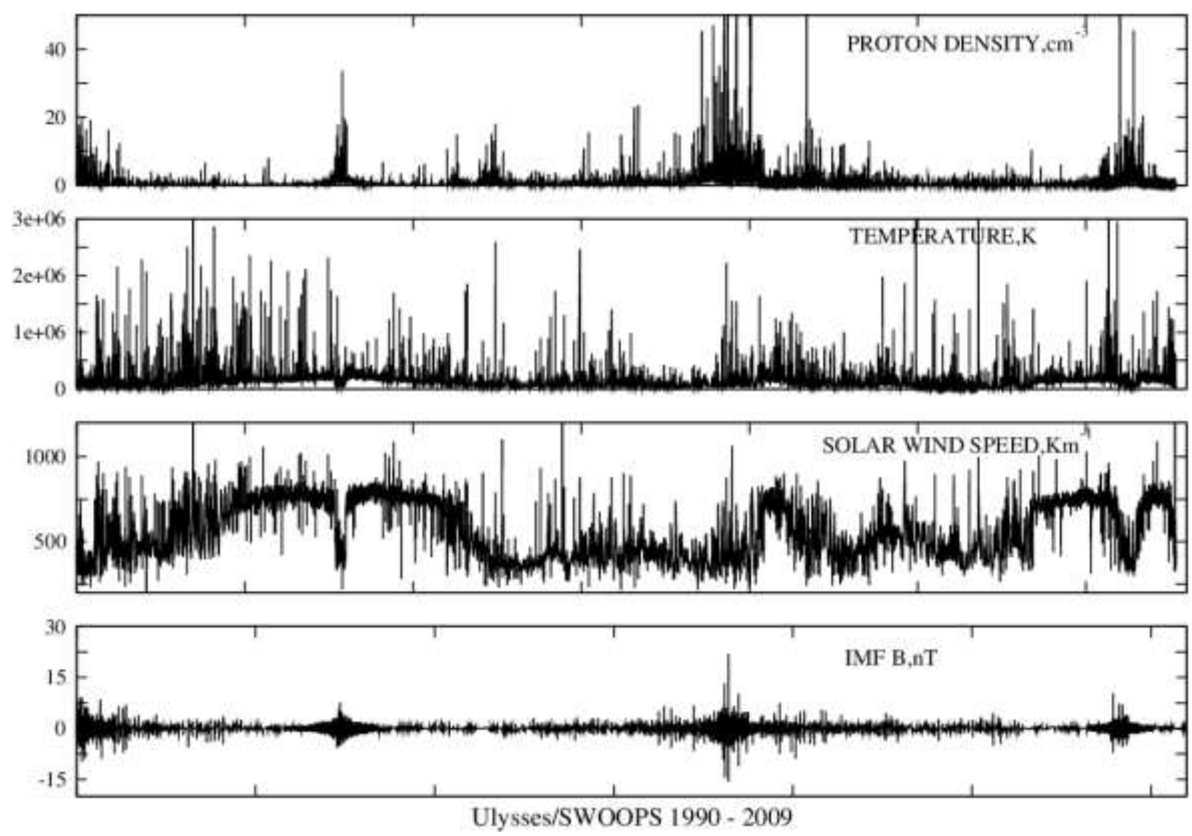

Fig.1: The spectrum of several solar wind parameters from a typical spacecraft Ulysses/SWOOPS is depicted for the years (1990-2009).

Description of Proton Density Deceleration in contrast to URAP:

The solar wind proton density spectrum consists of large scales, which could also referred as outer scales where the injection of energy takes place and results the establishment of the flow in nonlinear pattern. The slow solar wind is twice as dense as variable in nature as the fast solar wind. We have compared the significant event with the solar radio burst occurs on the particular day. Figure (2) shows the comparison of the plotted Ulysses solar wind proton density with the Ulysses radio astronomy data (URAP) on March 22, 1995. It is visibly clear that a sharp peak occurs both on the SWOOPS data and URAP data between 16:00 UT to 20:00 UT, which energizes the results of rise in proton density to drive in the same way and it remains low rest of the day. The angular solar wind distribution of ions is rather difficult and quite dissimilar pattern of waves, which is parallel and perpendicular to the direction of magnetic field. Occasionally there occurs an elliptical outline with their magnetic field along the greatest dimensions. We have compared the significant event with the solar radio burst occurs on the particular day. Figure (3) manifests the comparison of the plotted Ulysses solar wind parameter with the Ulysses radio astronomy data (URAP) on September 3, 2007. It is clear that no evidence of sharp peak occurs both on the SWOOPS data and URAP data between 00:00 UT to 24:00 UT, which leads to the results of no rise in the proton density in the same way the radio burst mechanism and it remains low throughout the day.

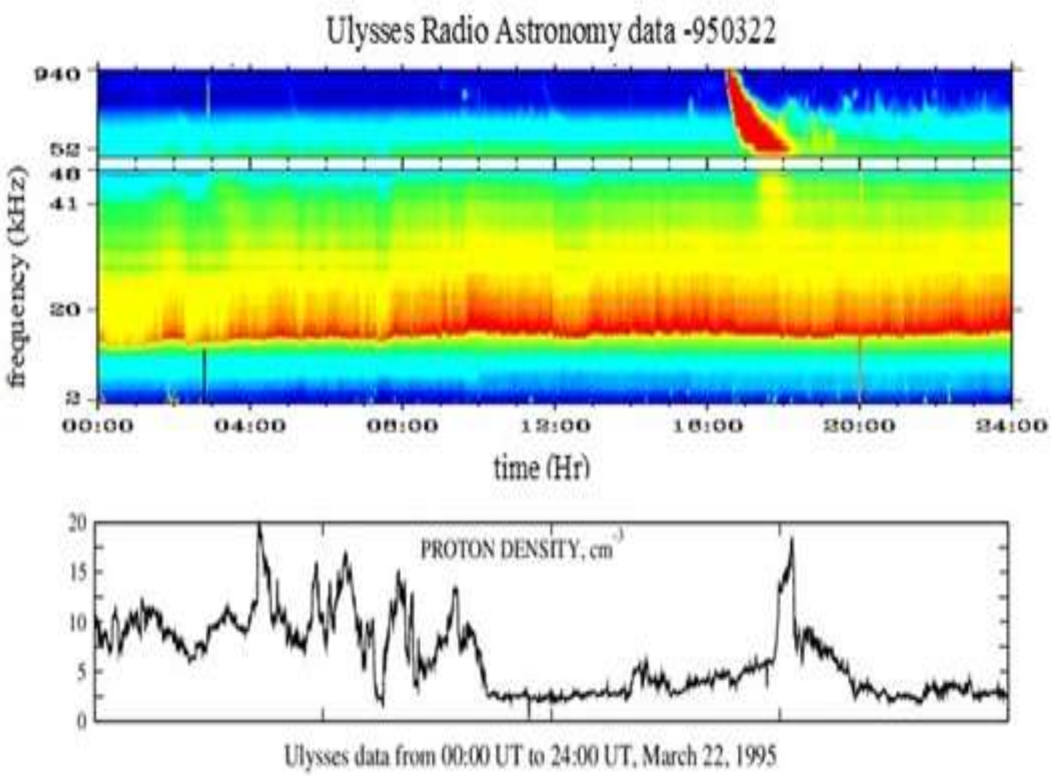

Fig. 2: Solar radio outburst from daily URAP Radio Astronomy Receiver (RAR) has given a dynamic spectra (top panel) detected by Ulysses is correlated with the solar wind proton density profile for a impulsive burst on March 22, 1995

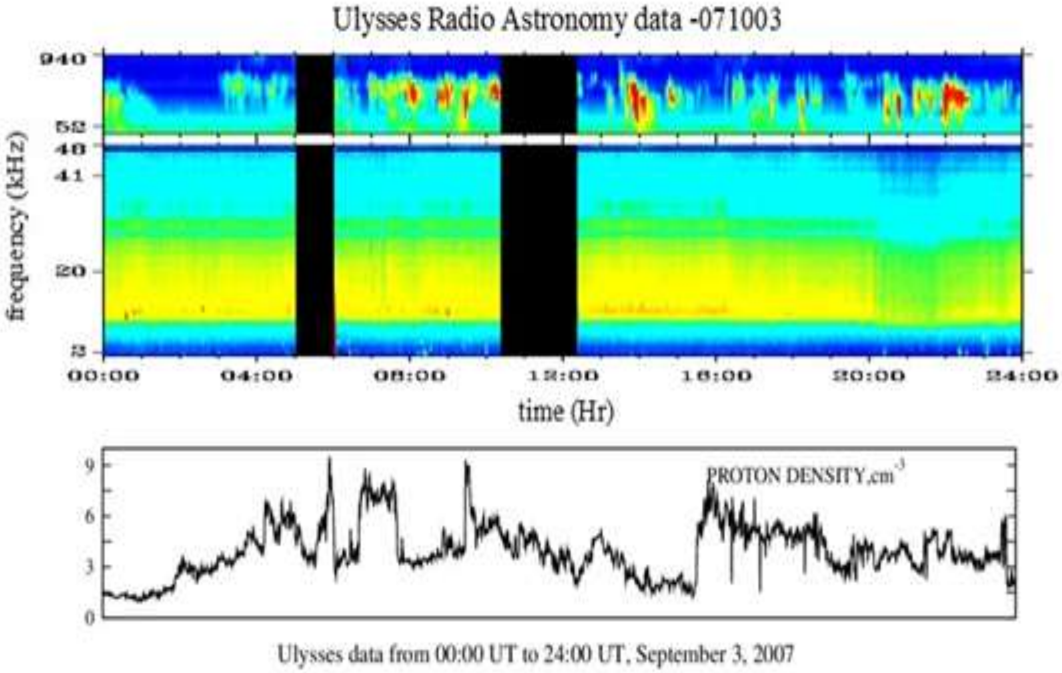

Fig.3: Solar radio outburst from daily URAP Radio Astronomy Receiver (RAR) has given a dynamic spectra (top panel) detected by Ulysses is correlated with the solar wind proton density profile for a impulsive burst on September 3, 2007

Interpretation of the Solar Wind Instabilities with Radio Burst:

As the solar wind pattern expands it limits the temperature of ion in solar wind which is parallel and perpendicular to the interaction of particle wave. The denser slow solar wind has a longer time of transit which is not collisionless entirely. The electric potential could have an effect on the observed distributions of the solar wind. The fast solar wind has isotropic temperatures which is comparatively more than in the slow solar wind.

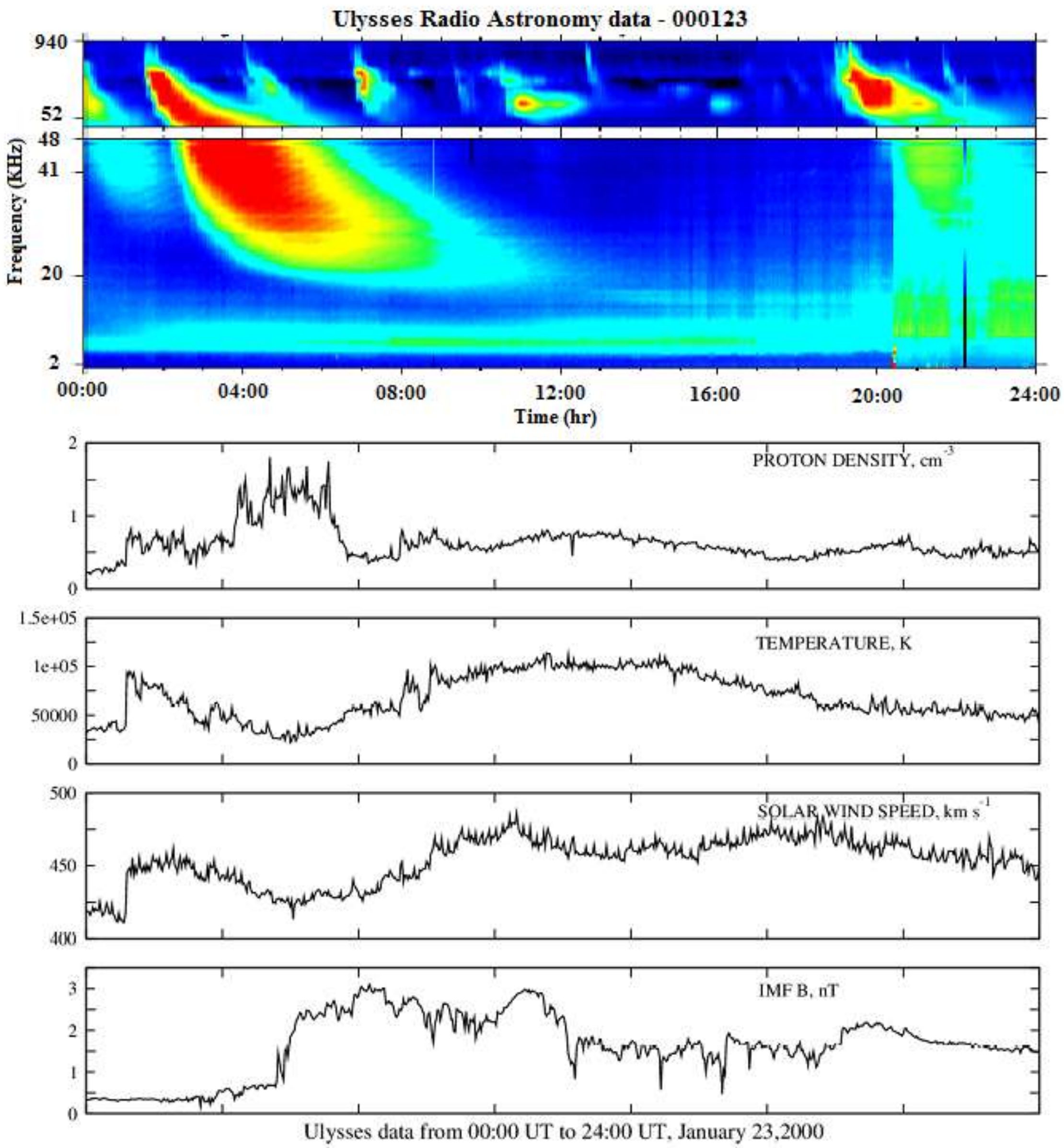

Fig.4: Frequency-time spectrogram of Solar radio outburst from daily URAP Radio Astronomy Receiver(RAR) has given a dynamic spectra(top panel) detected by Ulysses is correlated with the solar wind parameters profile for a impulsive burst on January 23,2000.

Figure (4) shows a different panel of solar wind parameters with a highly variable velocity of solar wind. It can be as slow 420 kms^{-1} as and faster than 490 kms^{-1}, but classically lies about 400 kms^{-1}. It is much more variable than the proton density, ranging from about 0.5 cm^{-3} to 1.9 cm^{-3}. Thus the energetic pressure changes blows adjacent to the magnetosphere that are principally controlled by the

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fluctuation of proton density. It is apparently clear that a sharp peak occurs both on the SWOOPS data and URAP data between 02:00 UT to 06:00 UT, which energizes the results of rise in proton density to drive in the same way and it remains low rest of the day. But shocking there is a drop in temperature scale and solar wind vice versa.

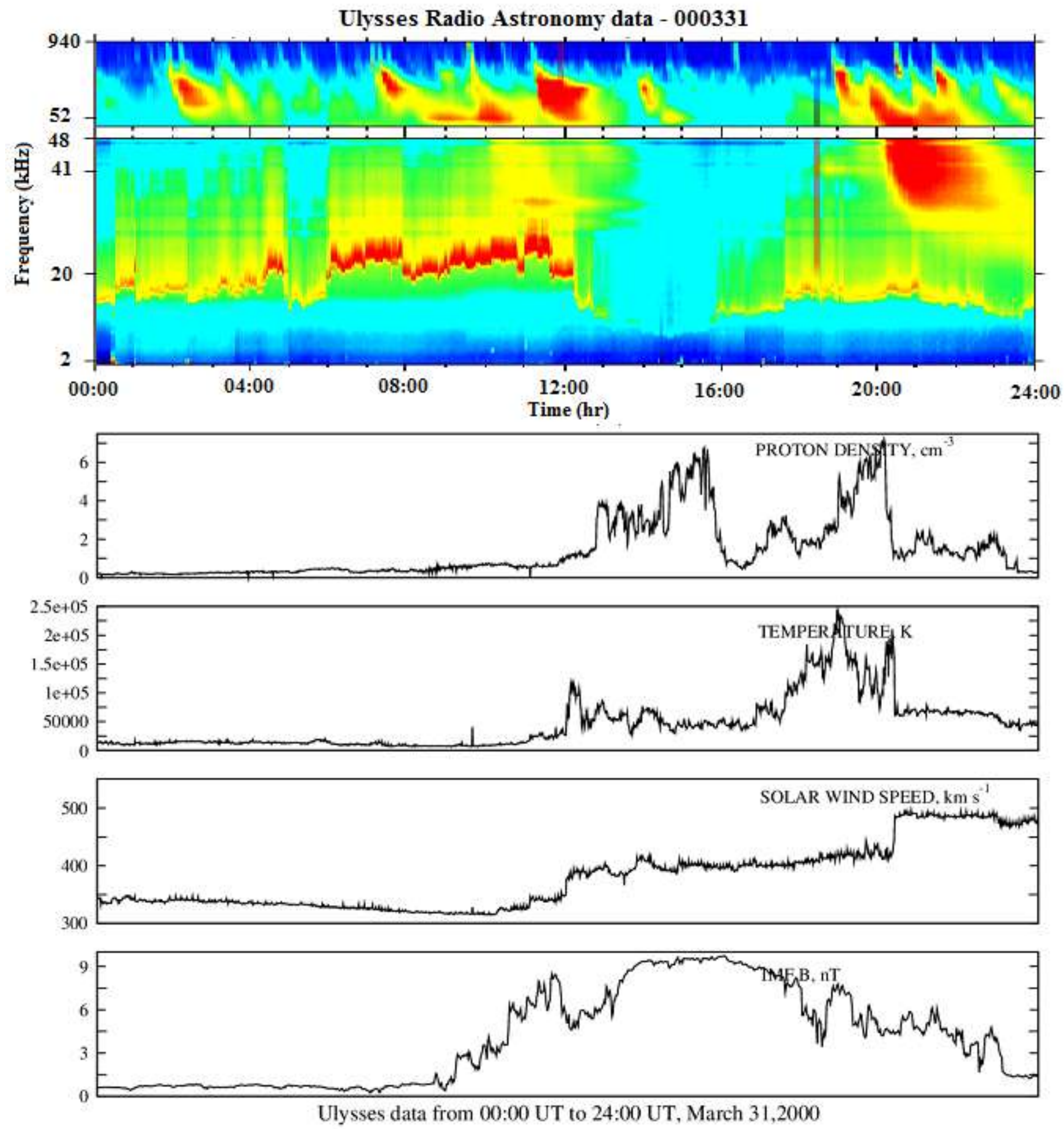

Fig.5: Frequency-time spectrogram of Solar radio outburst from daily URAP Radio Astronomy Receiver(RAR) has given a dynamic spectra(top panel) detected by Ulysses is correlated with the solar wind parameters profile for a impulsive burst on March 31,2000.

Figure (5) is again a solar event in solar activity maximum which shows a different panel of solar wind parameters with a highly variable velocity of solar wind. Here the proton density variation is quiet unpredictable, ranging from about 0 cm^{-3} to 6.6 cm^{-3}. The formation of active radio burst makes all the solar wind parameters to elevate little except the magnetic field of the solar wind which drops. It is apparently clear that a sharp peak occurs both on the SWOOPS data and URAP data between 20:00 UT to 24:00 UT, which energizes the results of rise in proton density to drive in the same way the temperature and the solar wind velocity and it remains low rest of the day.

Conclusions

The detailed analysis of solar wind parameters reveals the significant results when correlated with the solar radio and plasma wave ejection.

1. The variation of T_p-V_p greatly resembles the same effect throughout the years (1990-2009), except the precise events E_1 and E_2 in wind speed
2. The relationships between n_p and V_p particularly shows a distinct phases n_p depend mostly on the IMF,B
3. Using the great statistics and accuracy of measurements of the proton density n_p and temperature T_p with the radio burst, has driven micro stabilities in the solar wind , which shows a intense peak even in the solar minimum(1995)
4. At the plasma frequency f > 940 KHz depending on solar wind conditions the frequency band exhibits a unusual drift for more than two solar cycles from 1990 - 2009 .
5. The magnetic field goes on maximum when the solar wind decreases, which ensures that the solar wind greatly affects the magnetic field of the corona. So that, if the velocity of solar wind reaches 800km/s. The T_p and n_p over the holes of corona are low and the magnetic field is fragile, so the field lines are released to space.

At present times, the solar wind speed is the easiest parameter to predict based on solar observations and prior solar wind observations. Changes in the n_p with solar cycle has become wider the slow solar wind abundance ratio improvement that occurs at solar maximum; therefore, the slow wind density probably has intense solar cycle dependence than the helium abundance. The fast solar wind n_p also has some solar cycle dependence in phase with the cycle. The shorter and less intense radiation with the cosmic ray count rates are almost predated by weaker events with a decrease in the counting rate. Therefore those weaker events which are interrelated to weaker shocks cause the emission of weaker radio burst in outer heliosphere. Conversely, the slow wind proton density depends on the solar cycle which is out of phase by approximately 4 years. Consequently, significant comprehensible interaction between the V_p and both the n_p and T_p enables further empirical forecasting and yields great associations, which the physical models may reproduce. Changes in the n_p on the magnitude of the solar cycle will generate consequent changes in the environment of Earth space and taken as a whole scope of the heliosphere. Therefore, the solar wind differences between density and speed (n_p - V_p) is often considered to be moderately constant on the time scales of solar rotation, the sharpness in the n_p-V_p depends greatly on the slow solar wind of the entire solar cycle.

References

[1] Balveer.S.Rathore., Dinesh .C.Gupta and Parashar.K.K., International Journal of Geosciences, 2014, 5,1602-1608.

[2] Barr.R., Llanwyn Jones.D and Rodger.C.J., Journal of Atmospheric and Solar Terrestrial Physics, 2000 , 62,1689-1718.

[3] Breech.B., Matthaeus.W.H., Cranmer.S.R., Kasper.J.C and Oughton.S., Journal of Geophysical Research, 2009,vol 114, A09103.

[4] Devrie.S.Intriligator., Thomas Detman., George gloecker., Christine Gloeckler., Murray Dryer.,Weisun., James Intriligator and Charles Deehr., Journal of Geophysical Research, 2012, vol 117, A06104.

[5] Eamon.O.Gorman., Graham.M.Harper., Alexander Brown., Stephen Drake and Anita.M.S.Richards., The Astronomical Journal, 2013, 146:98.

[6] Gopalswamy.N., Aguilar Rodriguez.E., Yashiro.S., Nunes.S., Kaiser.M.L and Howard.R.A., Journal of Geophysical Research, 2005, vol 110, A12S07.

[7] Gosling.J.T and Pizzo.V.J., Space Science Reviews ,1999,89:21-52.

[8] Hamidi.Z.S., Fatin Nabila Mokthtar., Shariff.N.N.M., Marhana omar Ali., Nurulhazwani Husien., Sabri.S.N.U., Zainol.N.H., and Monstein.C., World Scientific News 2016,34, 121-134.

[9] Hamidi.Z.S., Ibrahim.M.B., Shariff.N.N.M and Monstein.C., International letters of chemistry , physics and astronomy, 2014, vol 19(2), 160-170.

[10] Hamish Andrew Sinclair Reid and Heather Ratcliffe., Research in Astronomy and Astrophysics, 2014, vol 14, 773-804.

[11] Hess.S.L.G., Echer.E and Zarka.P., Planetary and Space Science, 2012, vol 70, 114-125.

[12] Jaime.A.Araneda, Adolfo.F.Vinas and Hernan.F.Astudillo., Journal of Geophysical Research, 2002,vol 107, No A121453.

[13] Judith de Patoul., Claire Foullon and Pete Riley., The Astrophysical Journal, 2015, 814: 68.

[14] Karine Issautier., Nicole Meyer-Vernet., Michel Moncuquet and Sang Hoang., Journal of Geophysical Research, 1998, vol 103, 1969-1979.

[15] Kaiser.M.L., Farvell.W.M., Kurth.W.S., Hospodarsky.G.B and Gurnett .D.A., Journal of Geophysical research, 2004, Vol 109, A09S08.

[16] Krupar.V., Maksimovic.M., Santolik.O., Kontar.E.P., Cecconi.B., Hoang.S., Kruparova.O.,Soucek.J., Reid.H., Zaslavsky.A., Solar Physics,2014 .

[17] Lario.D., Marsden.R.G., Sanderson.T.R., Maksimovic.M., Sanahuja.B., Balogh.A., Forsyth.R.J., Lin.R.P and Gosling.J.T., Journal of Geophysical Research, 2000, Vol 105, 18235 – 18250.

[18] Moncuquet.M., Matsumoto.H., Bougeret.J.L., Blomberg.L.G., Issautier.K., Kasaba.Y., Kojima.H., Maksimovic.M., Meyer-Vermet.N., Zarka.P., Advance in space Research,2006.

[19] Pohjolainen.S., Allawi.H., Valtonen.E ., Astronomy and Astrophysics, 2013, 558, A7.

[20] Riazantseva.M.O., Dalin.P.A., Dmitriev.A.V., Yu.V.Orlov., Paularena.K.I., Richardson.J.D and Zastenker.G.N., Journal of Atmosphere and Solar Terrestrial Physics, 2002,Vol 64,657-660.

[21] Shollykutty John and Kurian.P.J., Research in Astronomy and Astrophysics, 2009, Vol 9,485-493.

[22] Verma.P.L., Puspraj Singh and Preetam Singh., Journal of Physics: Conference series 2014, 511, 012060.

[23] You.X.P., Hobbs.G.B., Coles.W.A., Manchester.R.N and Han J.L., The Astrophysical Journal 2007,671: 907-911.

[24] Yuan-Kuen Ko., George Gloeckler., Christina.M.S.Cohen and Antoinette.B.Galvin., Journal of Geophysical Research, 1999,Vol 104, 17005 – 17019.