LATITUDINAL VARIATION OF SOLAR WIND VELOCITY

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Abstract. Single station solar wind velocity measurements using the Ooty Radio Telescope (ORT) in India (operating at 327 MHz) are reported for the period August 1992 to August 1993. Interplanetary scintillation (IPS) observations on a large number of compact radio sources covering a latitudinal range of $\pm 80^{\circ}$ were used to derive solar wind velocities using the method of fitting a power law model to the observed IPS spectra. The data shows a velocity versus heliographic latitude pattern which is similar to that reported by Rickett and Coles (1991) for the 1981-1982 period. However, the average of the measured equatorial velocities are higher, being about 470 km s^{-1} compared to their value of 400 km s^{-1}. The distribution of electron density variations (ΔN_e) between $50R_{\odot}$ and $90R_{\odot}$ was also determined and it was found that ΔN_e was about 30% less at the poles as compared to the equator.

1. Introduction

Interplanetary scintillation (IPS) observations of compact extragalactic radio sources have been used extensively for investigations on several properties of the solar wind plasma. Multi station IPS observations for determining the velocity of the solar wind have been described by Rickett & Coles (1991) and references therein. These three station IPS studies show that the annual average velocity of solar wind increases markedly with heliospheric latitude (both in the northern and southern hemispheres), during times of low and declining solar activity. Although these observations were made on 20 to 50 radio sources only, they were distributed widely in space. Hence, velocities of solar wind originating from a large range in heliographic latitude (γ) could be determined ($-60^{\circ} \leq \gamma \leq 60^{\circ}$). This is in contrast to *in situ* spacecraft measurements which are restricted mostly to the ecliptic plane. The notable exception will be the measurements by the spacecraft Ulysses during its solar polar passage in 1994-95.

Manoharan & Ananthakrishnan (1990) used model fitting techniques to estimate successfully the solar wind velocity from a single radio telescope on a routine basis. This was applied to IPS observations of a large number of sources using the Ooty Radio Telescope (ORT) during the period August

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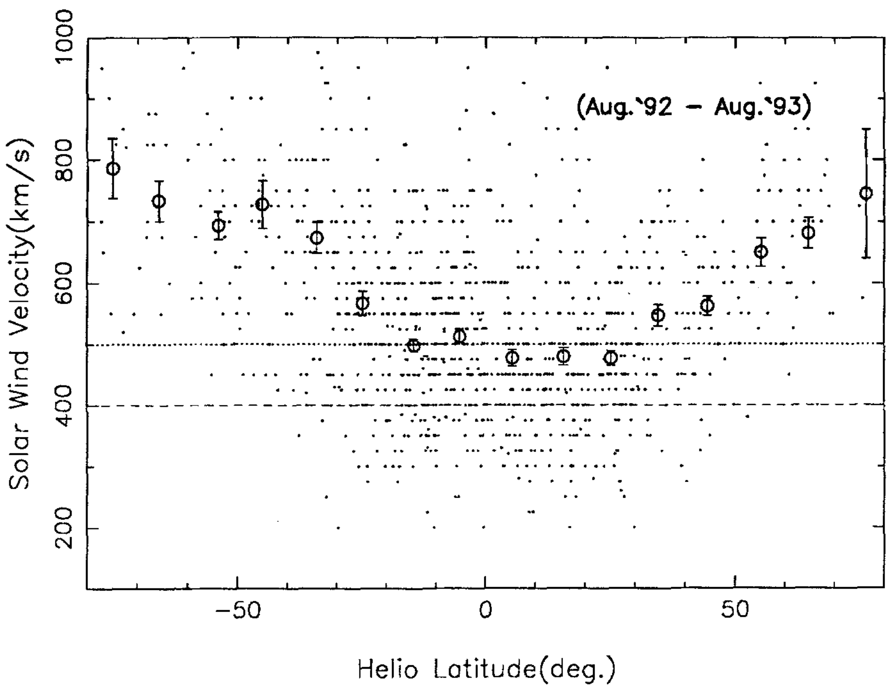

Fig. 1. Scatter plot of the single station solar wind velocities as a function of heliographic latitude. Each velocity was determined using spectra with signal to noise ratio greater than 20 db and sources in with $15^o \leq \epsilon \leq 50^o$.

1992 to August 1993 (Balasubramanian *et.al.*, 1993). About 1000 strongly scintillating sources were observed, at three different solar elongations (ϵ) between 10^o and 50^o. The heliographic latitudes of these sources were in the range $\pm 80^o$. In this paper we present the results obtained from the above data on variation of solar wind velocities with heliographic latitude. Also described are the latitudinal distribution of electron density variations in the solar wind.

2. Analysis and Results

2.1. Latitudinal Variation of Observed Velocities

The velocities derived from the spectral fitting method were first sorted to remove spectra derived from observations at solar elongation $\epsilon < 15^o$. This was done so as to remove the effects of strong scattering, which could extend a few degrees beyond $\epsilon = 12^o$ during disturbed conditions, and cause one to overestimate velocities. Next, the spectra are sorted to remove those having signal to noise ratio (S/N) $<$ 20 db. The velocities, determined from spectra with S/N greater than 20 db and $\epsilon \geq 15^o$ are plotted in figure 1, as a function

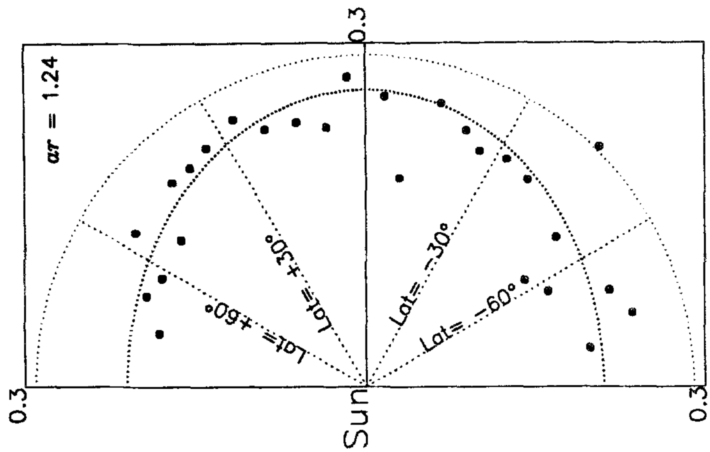

Fig. 2. Polar plot of scintillation index as a function of helio latitudes for sources in the distance range $50R_{\odot}$ to $92R_{\odot}$. The radial dotted lines are drawn at intervals of 30^o in helio latitude and the finely dotted semi-circle is a reference circle. The dotted semi-ellipse is a best fit ellipse to the data and has an axial ratio of 1.24.

of heliographic latitude, for each observation. The individual velocity measurements are shown by small dots, while the large open circles represent the mean velocities in each 10^o bin of latitude. The error bars are $\pm 1\ \sigma$ and are weighted by the number of points in each bin. The individual very low or very high values for velocities could have larger errors in the model fitting. Only the average trend is considered here. It can be seen that the velocities begin to increase beyond $\sim 10^o$ on either side of the equator, from ~ 450 km s^{-1} to reach a value of ~ 800 km s^{-1}. The average equatorial velocity V_o and the gradient of velocity increase can be determined (Manoharan, 1991) by using the simple empirical relation $V = V_o(1+\eta \sin^2\gamma)$ where, γ is the heliographic latitude and η is called the activity factor and varies with solar cycle. The straight line fit gives $V_o = 469$ km s^{-1}. The factor η is equal to 0.68 and the velocity gradient over 90^o of latitude is 3.6 km s^{-1} deg^{-1}. These values are in agreement with the determinations of annual averages for the same parameters for the declining period of the previous cycle; however, the average equatorial velocity V_o seems greater than that reported by Rickett and Coles (1991) by ~ 70 km s^{-1}.

2.2. Latitudinal Variation of Electron Density Fluctuations

In the weak scattering region m is directly proportional to the rms electron density fluctuations (ΔN_e) and is a function of elongation (ϵ), angular source size (θ) and heliographic latitude (γ). This fact can be used to study the variations in ΔN_e with latitude, by comparing measurements of m at the same ϵ for sources of the same angular size. From the spectral fitting method (Manoharan & Ananthakrishnan, 1990) source sizes can also be reliably determined for spectra having S/N in excess of 20 db. For this purpose we selected all sources with 100 mas $\leq \theta \leq$ 150 mas (1 mas = 1 milli arcsecond) observed in the range $13^o \leq \epsilon \leq 25^o$, corresponding to distances of 50 to 92 solar radii from the sun. The results are presented in figure 2 which is a polar plot of scintillation index m vs γ with the sun at the origin. As all observations were made east of the sun, we have an one-sided plot. Each of the plotted points, shown by filled circles, represents the average value of m over a 6^o bin of γ. It is clear from figure 2 that the ΔN_e distribution deviates from spherical symmetry as one approaches the poles. The axial ratio of the best fit ellipse was found to be 1.24, while the reduction in ΔN_e at the poles was about 19% which implies reduction in the electron density towards the poles.

3. Discussion and Conclusion

A recent study (Manoharan, 1993) used the turn over distances (which occurs at $\sim 40 R_\odot$) of compact scintillating sources at 327 MHz and examined the variation of ΔN_e as a function of γ. It was shown that the ΔN_e distribution changed from being spherically symmetric at solar maximum to a distribution that was flattened towards the polar regions at solar minimum with a reduction of ΔN_e in the poles by a factor of $\sim$2.5. Our observations show a much smaller departure from spherical symmetry in the ΔN_e distribution which is to be expected in the early part of the declining phase of the current solar cycle. The velocity gradient, too, compares well with the previous measurements (Rickett & Coles, 1991). The observed ΔN_e distribution and the velocity gradient suggests that the polar coronal hole regions have begun to expand equatorward. It will be very interesting to compare these results with those from the Ulysses satellite.

4. Acknowledgements

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