Pulsars and Bubble Dynamics

Ramen Kumar Parui

Aero Communication Station (ACS), Imphal Airport, P.O.-Tulihal, Imphal-795140, India

Abstract. Based on recent observation of the dominance of the flare generated solar wind streams over the co-rotating streams and a significant lowering in the cosmic ray intensity in the abnormal year of the solar activity period, I have predicted the occurrence of discernible changes in magnetic field strength and the thickness of the shell of the local bubble during high sunspots years of the solar cycle period. In order to observe the variation, both in the magnetic field strength and in the thickness of the compressed shell, a proposal of continuous monitor of these two parameters through the observation of Faraday Rotation Measure has been proposed with an emphasize to the observations in the period of next abnormal year of the solar cycle in near future.

1 Introduction

Radio observations of the interstellar medium (ISM) indicate a hierarchy of structures in the composition of the ISM masses from about $1\,M_\odot$ to $10^6\,M_\odot$ and with sizes from 10^{-4} to 100 pc. Dense shells around massive stars are formed when surrounding interstellar medium is swept up by the fast stellar winds of massive stars. Shells formed around single massive stars are called "bubbles" and the typical sizes of bubbles are $5 - 40$ pc. Recently Burrows and Guo (1996) identified some absorption features associated with the shell of the Local Bubble created by the fast stellar winds. Earlier, Vallee (1993) showed that the shell near the Sun is a magnetic shell and played an important role for enhancing the Faraday Rotation Measure of the more distant compact objects. Based on these above I have applied snowplow theory on the Local Bubble of the Sun in order to understand the stellar bubble dynamics. The snowplow theory of bubble formation indicates that the magnetic field strength in the shell has a link with the compressed shell thickness (Δr) by the relation (Vallee, 1993):

$$\mathbf{B}_{\text{shell}} = \mathbf{B}_{\text{outside}} \left[1 - \left(1 - \frac{\Delta r}{r_{\text{out}}}\right)^3\right]^{-k} \tag{1}$$

where B_{outside} = magnetic field strength outside the shell in the general stellar medium, $\Delta r = r_{\text{out}} - r_{\text{in}}$, r_{in} and r_{out} being the inner and outer radii for this shell. $k = 1$ represents the matter in a shocked medium. Again Faraday Rotation (θ) is interrelated with the strength of the magnetic field B of the ISM through the relation:

$$\theta = \frac{C_V\, d}{\mu_0 \mu_r} B \tag{2}$$

where C_V = Verdet's constant, d = the length of the way through the magnetic field B, μ_r = relative permeability of the medium.

According to Weaver et al. (1977) the fast stellar winds are adiabatically shocked to $10^6 - 10^7$ K due to pressure in a homogeneous medium of ISM (Chu and Mac Low, 1996). These shocked stellar winds act like a piston which drives the expansion of the outer shell of swept-up ISM. This means that stellar winds play a critical role in the formation of thickness of the compressed shell. As the temperature rises up to $10^6 - 10^7$ K within the ISM due to the heating of the stellar winds, this may cause a variation in C_V and μ_r. Typically, the variations in C_V and μ_r in $10^5 - 10^6$ K are very small (Jackson, 1985, Cox and Snowden, 1986), we can neglect it.

A recent investigation (Pandeya et al, 1997) on high speed solar wind indicates its two varieties namely, co-rotating streams and flares generated streams depending upon its source of origin. This flare generated streams are short-lasting but its dominance has a significant contribution in lowering the solar wind speed on short-term basis during long-term solar cycle period. In this paper, I have presented the possible effect on the shell thickness and its magnetic field strength due to this low solar wind speed and its possible measure through Faraday Rotation Measure.

2 Recent Result on Solar Wind Streams

High speed solar winds are distinguished into two categories depending upon their locations (Mavromichalaki, 1988) namely:

- the co-rotating or coronal hole associated streams (CS) emitted by coronal holes. This is long-lasting high speed solar wind streams whose apparent tends to recur at intervals of ~ 27 days;
- the flare generated streams (FGS) associated with strong active regions emitting solar flares. These are short lasting in character.

Studies on solar wind streams as well as cosmic ray transient variations are normally based on the fact that coronal hole associated streams are dominated during low solar activity period while dominance of flare generated streams during high solar activity period. In a recent study of solar activity during the period 1979 to 1990 (which covers the descending and ascending phases of solar activity cycle 22) Pandeya et al. (1997) found that solar wind velocity is one of the main responsible factors which produces changes in cosmic ray intensity and the flare generated streams, through sudden storm commencements in a short-term period, produce a significant lowering in solar wind speed, i.e. during high solar activity years, particularly in the abnormal year (i.e. 1989) of solar cycle 22 the flare generated high speed solar wind streams (FGS) were found larger than the co-rotating streams (CS).

3 Effects on Shell Thickness and Possible Detection

The dominance of flare generated streams over the co-rotating streams during the period of high solar activity may produce a change in shell thickness Δr as well as in the magnetic field strength of the shell. The main reason is that enhancements in the magnetic field of the inter-planetary medium are generally observed during the high solar activity period. As we know, magnetic fields can effectively confine bubbles, an enhanced magnetic field definitely produces a change in shell configuration i.e. in shell thickness of local bubble. As the duration between the occurrence of the Flare Generated Streams and its dominance over the co-rotating streams is ~days, these magnetic effects can be observed as an enhanced Faraday Rotation Measure of distant compact objects seen through the shell of the local bubble near the Sun.

Typical value of the change in Faraday Rotation is $\Delta\theta \approx 10^{-20}$ arcmin for a newly expanding shell of the bubble; and $\Delta\theta \approx 10^{-14}$ arcmin when the shell has expanded to sizes ~ parsecs with $C_V \approx 10^{-26}$ arcmin /Gauss/cm for the interstellar medium.

If the measurements will be done in the radio frequency band $\approx 10^8$ Hz then the above values could be increased by a factor $\approx 10^{14}$ which is still too less. Although it is an undetectable range at present but we have a hope that it can be possible with more advanced techniques of measurement in the near future.

As the change due to the enhanced magnetic field will be prominent particularly in the abnormal year, we therefore have to wait for the next abnormal year. In order to get an exact picture of the variation in shell thickness and its magnetic field strength, continuous observations throughout the solar activity cycle are very much essential, because only continuous observations can help us to correlate the effects of high speed solar wind variation on the bubble which ultimately offers the exact picture of bubble dynamics.

Acknowledgements. The author is grateful to Rodrigo Supper (MPE Garching) for his valuable comments and suggestions for improvement of this paper.

References

Burrows D.N., Guo Z., 1996, in "Proc. of the International Conference on *Röntgenstrahlung from the Universe* in Würzburg", eds. H.U. Zimmermann, J.E. Trümper & H. Yorke, MPE Report 263, p.221

Chu Y.-H., Mac Low M.-M., 1996, in "Proc. of the International Conference on *Röntgenstrahlung from the Universe* in Würzburg", eds. H.U. Zimmermann, J.E. Trümper & H. Yorke, MPE Report 263, p.241

Cox D.P., Snowden S.L., 1986, Adv. Space Res. 6 (2), 97

Jackson J.D., 1985, Classical Electrodynamics, Wiley Eastern, New Delhi, p.189

Mavromichalaki H., Vassilaki V., Marmatsouri E., 1988, Solar Phys. 115, 345

Pandeya A., Shrivastave P.K., Sabbah I., El-Borie M.A., 1997, Indian J. Phys. 71B, 455
Vallee J.P., 1993, ApJ 419, 670
Weaver R., McCray R., Castor J., Shapiro P., Moore R., 1977, ApJ 218, 377
Zirker J.D., 1977, Rev. Geophys. Space Phys. 15, 257