FIRST ESTIMATES OF CORONAL ELECTRON DENSITY FROM ACCURATE TRACKING OF CHANGES IN PULSAR DISPERSION MEASURE

***Divya Oberoi*[1], *Amrit l. Ahuja*[2], *Yashwant Gupta*[3]**

[1] MIT Haystack Observatory, Westford, MA 01886, USA (doberoi@haystack.mit.edu)

[2] Tata Research Development and Design Center -Tata Consultancy Services, Pune, Maharashtra, India

[3] National Center for Radio Astrophysics, Tata Institute for Fundamental Research, Pune, Maharashtra, India

A novel technique for estimating pulsar dispersion measures with uncertainties as low as 10^{-4} pc cm^{-3}, without requiring absolute timing information, has recently been developed at GMRT. This technique, tailored for simultaneous multi-frequency GMRT observations, makes it feasible to detect solar coronal electron density changes by tracking changes in observed DM of a pulsar as it passes close to the Sun. This provides an attractive alternative to the current options of spacecraft occultaions and pulsar timing studies. Initial results from GMRT observations of a carefully selected pulsar at epochs spanning three weeks are presented.

1 Extended Abstract

Accurate measurements of coronal electron density in the region close to the Sun are essential inputs to theoretical studies of the solar wind. To date, the only means available for direct measurements of coronal electron densities have been either using occultaions of spacecraft (for instance Helios - Bird, 1982; Ulysses - Bird et al., 1996) or pulsar timing studies, requiring μs level absolute timing accuracies. The latter rely on observing pulsars as they pass close to the Sun and measuring the residual dispersion delay in pulse arrival times relative to established pulse time-of-arrival models, which are then used to determine the coronal electron density (e.g. Counselman III and Rankin, 1972; Phillips and Wolszczan, 1991; Cognard et al., 1996). The passage of pulsar signal through the coronal plasma also leads to a corresponding increase in the dispersion measure (DM). The expected enhancement in DM lies in the range $\sim 10^{-2} pc\ cm^{-3}$ to $\sim 10^{-4} pc\ cm^{-3}$ at distances of $1°$–$10°$ from the Sun. While the timing observations can provide error bars of order μs, corresponding to $\sim 5 \times 10^{-4} pc\ cm^{-3}$, sufficient to detect heliospheric plasma, the uncertainty in DM measurements is usually considerably larger, $\geq 10^{-2} pc\ cm^{-3}$ (Ord et al., 2007). A novel technique for estimation of pulsar DM with measurement uncertainties as small as $10^{-4} pc\ cm^{-3}$, that does not require absolute timing information has recently been developed and demonstrated using GMRT data (Ahuja et al., 2005, 2007). This technique uses simultaneous multi-frequency observations and exploits some unique GMRT hardware design features to estimate dispersion delay. Simultaneous observing at 235, 327 and 610 MHz provides the long lever arm along the frequency axis which leads to a corresponding reduction in the the error in DM estimation.

The most important sources of uncertainty in estimating the absolute values of DM using multi-frequency measurements are 1) the S/N achieved, 2) the stability of the profiles at each epoch, and 3) the changes in the pulsar profile across the frequency range of observation, especially for pulsars with complex profiles. By observing for sufficiently long durations the first two concerns can be adequately addressed, leaving the evolution in the pulsar profile as the dominant source of uncertainty. Estimating coronal electron column density requires measurement of relative changes in DM. These relative measurements can reasonably be expected to be free from systematic biases due to evolution of the pulsar profile with frequency and the complexity of the profile. Simulations to obtain quantitative estimates of the accuracy of relative DM measurements for the case of a simple profile (B1642-03) and for a complex profile (B1133+16) confirmed that while the absolute value of DM estimated by this technique worsened as the pulsar profile grew more complex, the fidelity with which relative changes in the DM could be determined remained largely unaffected. These simulations also indicate that relative DM changes as small as 1 part in 10,000 can be reliably measured using this technique with observations having S/N of a few hundred.

Observations of pulsar B2045-15 were carried out in January-February 2006 over a three week period at 11 epochs as it passed close to the Sun, and pulsar B1642-03 was observed as a control pulsar. Current analysis indicates that the 1 σ error bar on DM estimates achieved are $\sim 1 \times 10^{-4} pc\ cm^{-3}$ far away from the Sun, which increase to $\sim 3 \times 10^{-3} pc\ cm^{-3}$ close to the Sun. Preliminary results from the analysis of these data will be presented.

2 References

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