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Tracking pulsar dispersion measures using the GMRT

Amrit Lal Ahuja[1] , Yashwant Gupta[2], Ajit K Kembhavi[1], Vasant Kulkarni[2]
[1] *IUCAA, Post Bag 4, Ganeshkhind, Pune 411007, India*
[2] *NCRA, Post Bag 3, Ganeshkhind, Pune 411007, India*

Abstract. We present preliminary results from an ongoing program of accurate pulsar dispersion measure (DM) measurements using the GMRT. From simultaneous dual frequency observations, we are able to determine DMs to accuracies of 1 part in 10^4 and better. For 4 of the 12 pulsars studied, we find our mean DM value to be significantly different from the expected value. For most of the pulsars, we detect significant variations of the DM on time scales of weeks to months.

1. Observations and techniques

Accurate measurements of pulsar DMs can detect small variations of DM with time, which provide an important tool to probe the structure of the ionized ISM. The capability of simultaneous dual frequency pulsar observations makes the GMRT an ideal instrument for such studies. In our observations, carried out typically once a fortnight for a target of 12 pulsars, the delay between the pulse profiles at the two observing frequency bands (usually 243 & 325 MHz or 243 & 610 MHz) is entirely due to dispersion; hence, accurate measurement of this delay can yield precise estimates for the DM.

To maximise the precision of the DM estimate, the total time delay is computed as the sum of an integer sample delay (including multiple pulsar period delays) and a fractional sample delay. The latter is estimated by fitting a linear slope to the phase of the cross-spectrum of the average profiles at the two frequencies, after correcting for the integer sample shift. The error on the estimate is determined by the noise in the phase, which depends on the signal to noise ratio of the two profiles. Resulting DM accuracies are 1 part in 10^4 or better, for most of our observations.

The effect of systematics such as changes in pulse shapes at the two frequencies is minimised in our experiment by using fairly nearby frequencies (<= one octave apart) and concentrating on pulsars with simple, single-component-dominated profiles.

2. Preliminary results

From the time series of DM for each pulsar (see figure 1 for an example), we compute the mean and the rms uncertainty. For the following pulsars, the mean value of the DM agrees, within 2-sigma error limits (which range from 3.4×10^{-3} to 1.1×10^{-1} over all pulsars), with the catalog value : PSRs B0329+54 (delta DM = 0.0073), B0834+06 (0.0034), B0950+08 (-0.0010), B1133+16 (-0.016), B1919+21 (0.012), B1929+10 (-0.0030), B2045-16 (-0.008) & B2217+47 (0.0024). However, it is significantly different for PSRs B0818-13 ($-0.067; -15\sigma$), B0823+26 (-0.022; -9σ), B1642-03 ($0.070; 30\sigma$) & B2016+28 ($-0.022; -5\sigma$) The first three of these have single component profiles and problems with choice of fiducial point are unlikely to be the cause. These discrepancies are being investigated in detail.

Further, we are able to detect significant temporal variations of DM for many of the pulsars. These range from quasi-sinusoidal variations with periods of several months (PSR B1642-03) to long-term linear trends (PSR B2217+47); though most other pulsars show random fluctuations on time scales of the order of weeks to months. The rms of the fluctuations (obtained from the rms of the time series, after correction for the effect of estimation noise) ranges from about 1.2×10^{-3} to 7.1×10^{-3} for most pulsars, with two pulsars (B1133+16 & B2045-16) showing significantly higher values at 1.3×10^{-2} & 5.2×10^{-2}, respectively.

The observed variations are unlikely to be due to the plasma in the solar system, as the expected amplitude and time range of these are much smaller than what we see. A small fraction of the DM variations could be due to refractive scintillation effects – we estimate a 40 microsec time delay as the typical upper limit due to differential, geometric delays between the observing frequencies. The remaining fluctuations are likely to be due to actual changes in the total integrated column density of electrons due to the large scale electron density fluctuations in the ISM. For B1642-03, the results are almost certainly influenced by the presence of a known HII region along the line of sight. Further studies, to be done on our final, 2 year data base, will address these issues in detail.

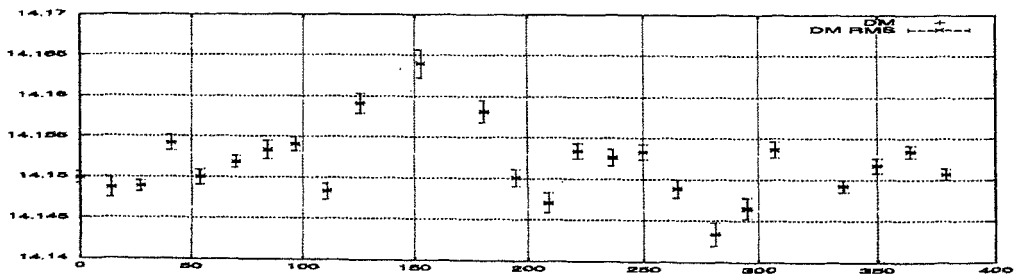

Figure 1. Variation of DM for PSR B2016+28 over the time interval 08 Jan 2001 to 22 Jan 2002, as a function of day number. The catalog value for the DM is 14.176 pc/cc.