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Prospects of Pulsar Timing at High Frequencies Including Polarization Measurements

Abstract

We have been exploring the possibility of high frequency pulsar timing with the Effelsberg radio telescope. We describe briefly the instrumentation for such a project and discuss its advantages in comparison to low frequency timing. Successful observations of some millisecond pulsars at 4.85 GHz as well as the results from an ongoing timing experiment at 1.4 GHz give further confidence in the proposed scheme.

I Introduction

Pulsar timing has long been used to determine crucial parameters such as pulsar position and proper motion and, in the case of binary systems, orbital elements and relativistic parameters. It obviously requires high precision in the determination of the times-of-arrival (TOAs) of pulses. In most cases the TOA measurements are limited by effects intrinsic to the pulsar known as timing noise (e.g., Arzoumanian et al. 1994), or extrinsic effects caused by the interstellar medium (ISM). In order to be able to make full use of the information provided by timing, perturbations introduced by the ISM onto the TOAs must be removed. Since these time perturbations are frequency dependent, becoming less severe at high radio frequencies, we have been exploring the possibility of timing observations at frequencies higher than 1.4 GHz. The *Effelsberg Pulsar Observing System* (EPOS) has been continuously improved, enabling us to make regular high precision timing (e.g., Wolszczan, these proceedings; Doroshenko et al. 1997) and polarization observations (Xilouris et al. 1998) of millisecond pulsars since April 1994.

II Observations

Our observations have been made at the 100-m radiotelescope of the MPIfR near Effelsberg, using a highly sensitive 1.4/1.7 GHz HEMT-receiver ($T_{\rm sys} \approx 25$ K). During all regular timing sessions we have obtained full polarization information by an adding polarimeter preceding a 4-channel 60 $\times$ 667 kHz post-detection hardware dedisperser called *PSE* (Von Hoensbroech & Xilouris 1997). The data were sampled with a maximum resolution of 0.2 μs. Sub-integrations of 15-sec duration were time stamped with signals provided by the station H-maser, itself synchronized to UTC via GPS. Recently, we have installed aside the PSE a clone of the *Coherent Dispersion Removal Processor* constructed by the Berkeley pulsar group. This wide bandwidth system called *Effelsberg-Berkeley-Pulsar-Processor* will allow high frequency work, obtaining also full polarization information (for details see Backer et al. 1997).

III High frequency observations

Kaspi et al. (1994) and Backer (these proceedings) have nicely demonstrated the impact of observed DM variations on the obtained timing residuals. We propose to make regular timing observations at frequencies higher than 1.4 GHz to minimize the disturbing effects of the ISM. Observations by Kijak et al. (1997) show that a number of the strongest millisecond pulsars are detectable at 4.85 GHz. Observing time and signal-to-noise ratio can, however, be optimized at an intermediate frequency like 2.7 GHz at which the impact of DM variation would be effectively reduced by a factor of almost four compared to 1.4 GHz. We have made first observations with a new, high sensitivity HEMT receiver centered at 2.7 GHz ($T_{\rm sys} \approx 25$ K, $G = 1.5$ K/Jy), which have shown that large portions of this band are unusable due to radio interference. However, observations at 2.7 GHz revealed that free bands are existing at the lower edges of the used bandwidth, so that tuning of the receiver is currently investigated.

IV Polarization measurements

Obtaining full polarization information during timing observations as done with EPOS, provides a unique chance to extract additional information about the observed source in particular for binary systems (Damour & Taylor 1992). Polarization data can, for instance, be used to derive the relative orientation of spin and magnetic axis, allowing a study of the spin-orbital coupling in binary systems. Simultaneous measurements of pulsar structure parameters deriving the emission beam geometry (e.g., Kramer et al. 1998) can be used to separate relativistic effects incorporated into observed values of classical parameters. For an excellent review the interested reader is referred to Damour & Taylor (1992). For the purpose of precise timing it is important to emphasize the significance of correct gain calibration and guaranteed gain stability for the observing session. The general high degree of millisecond pulsar polarization, in particular the circular component, can impose spurious TOA variations if the gains between the two polarizations are not properly balanced. The polarimetric properties of our instrumental set-up have been extensively explored by Von Hoensbroech & Xilouris (1997). Here, the emphasis was to minimize the instrumental polarization and to guarantee proper gain calibration. Regular checking of the polarization characteristics of the instrumental set-up can be done by tracking well known slow rotating pulsars guaranteeing the polarization purity of the signals. Additionally, frequent observations of unpolarized continuum sources enable a reliable gain calibration, which in turn is checked by injecting noise diode signals of known strength in the signal path after each pulsar scan.

V Conclusions

The possibility of regular timing observations at high frequencies have been explored using the Effelsberg radio telescope. Regular timing observations at a frequency as high as 2.7 GHz, could provide information capable of eliminating the "interstellar weather" effects on pulsar timing (see the contribution by D. C. Backer). Although further investigation is required as to find the exact frequency range that will be free of interference, the sensitivity of the Effelsberg receivers and the time stability of the pulsar data taking system have proven so far that such an enterprise is feasible. In turn, it can be used to investigate the properties of the ISM. As has been shown by Xilouris et al. (1998), one of the striking features in millisecond pulsar profiles is their weak evolution with frequency, e.g., between 430 MHz and 1400 MHz. Observations at 4.85 GHz (Kijak et al. 1997) show that major profile changes are not expected any further. This would allow a straightforward interpretation of profile features at a wide frequency range. Our current results suggest that extremely valuable information can be obtained by tracing also the polarization characteristics of the received emission at high frequencies. Since millisecond pulsars appear to be much weaker sources and significantly depolarized at 4.85 GHz, we conclude that a frequency of 2.7 GHz looks indeed as a very good compromise as a future standard timing frequency.

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