High Precision Timing of Millisecond Pulsars at Nançay

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ABSTRACT

The Nançay radiotelescope in France is a large collecting area ($\sim$ 7000m2) with receivers between 1.1 and 3.5GHz. We are using this telescope to conduct high precision timing observations of millisecond pulsars. Started in 1988 with the 2 pulsars PSR B1937+21 and PSR B1821-24, the program was extended recently to more stable millisecond pulsars. Those millisecond pulsars were chosen with a measured Period derivative smaller than the Period derivative of one of the most stable pulsar, PSR B1855+09. A pulsar processor called NBPP (Navy Berkeley Pulsar Processor) was built during a collaboration between UC, Berkeley, NRL, Washington, DC and the Observatoire de Paris-Nançay. The NBPP is used to do very regular timing observations with the newly renovated receiving system.

INTRODUCTION

The Observatoire de Paris and the Station de Radioastronomie de Nançay started a program of regular millisecond pulsars timing observations in 1988. With its large collecting area (equivalent to a 100 meters dish) and its receivers optimized for 1.4GHz, this radiotelescope is ideally suited to observe and study millisecond pulsars. Indeed, this frequency is a good compromise between scintillation effects present at lower frequency and the fact that the pulsar signal is decreasing very rapidly with frequency. Furthermore, a major upgrade of the receiving system just completed with a full frequency coverage between 1.1 and 3.5GHz, a sensitivity improved by a factor 2.2 along with the capability to construct the Stokes parameters with the 50MHz bandwidth local autocorrelator.

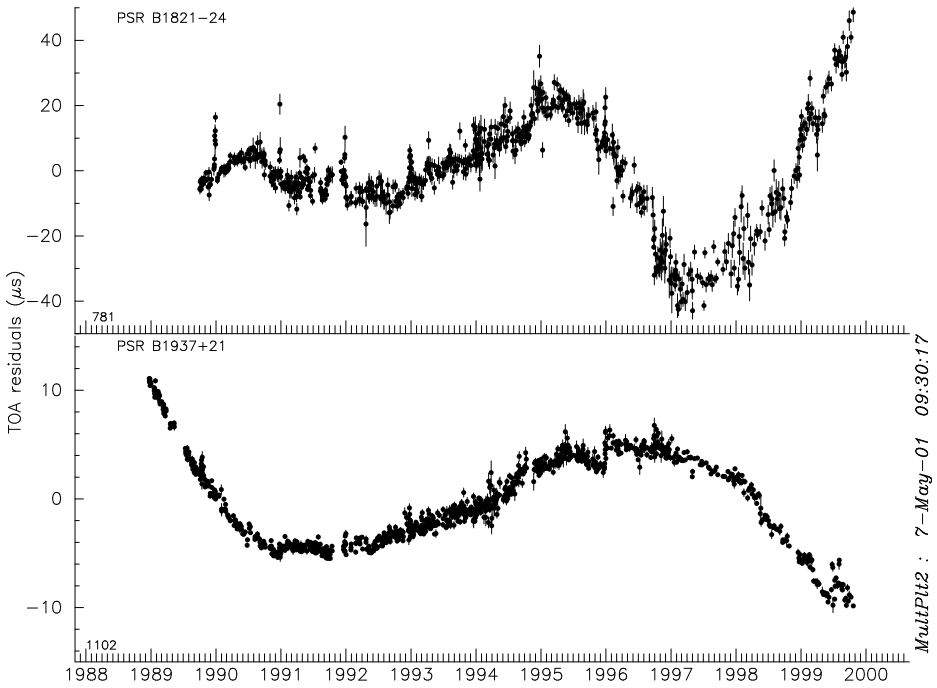

Figure 1: Residuals of Times Of Arrivals for the millisecond pulsar PSR B1937+21 (uncertainty $\sim 0.3\mu$s) and for the pulsar PSR B1821-24 (2μs) observed with the Nançay radiotelescope and the old system (now upgraded). Note that the PSR B1937+21 data span is almost 11 years with 1102 days of observations (every 3.6 days) and that exactly 219 420 141 212 rotations occured for this neutron star!

A DECADE OF OBSERVATION

The two pulsars PSR B1937+21 and PSR B1821-24 were the first ones to be observed with the swept-LO dedispersor designed and built in Nançay in 1986-88. Based at the beginning on a slaved VCO (Voltage Control Oscillator) driven by a parabolic saw-tooth signal, the system is now using a numerical oscillator (DDS Direct Digital Synthesizer). A GPS receiver is used as a permanent link between the Nançay clock (Rubidium) and the international UTC time scale. Fig.1 shows the Times Of Arrival (TOAs) residuals of those two pulsars obtained until the upgrade completed late 2000 - early 2001. The most important result to date from these dense series of observations is the detection of several Extreme Scattering Events in the directions of PSR B1937+21 and PSR B1821-24 ([1], [2] and [3]).

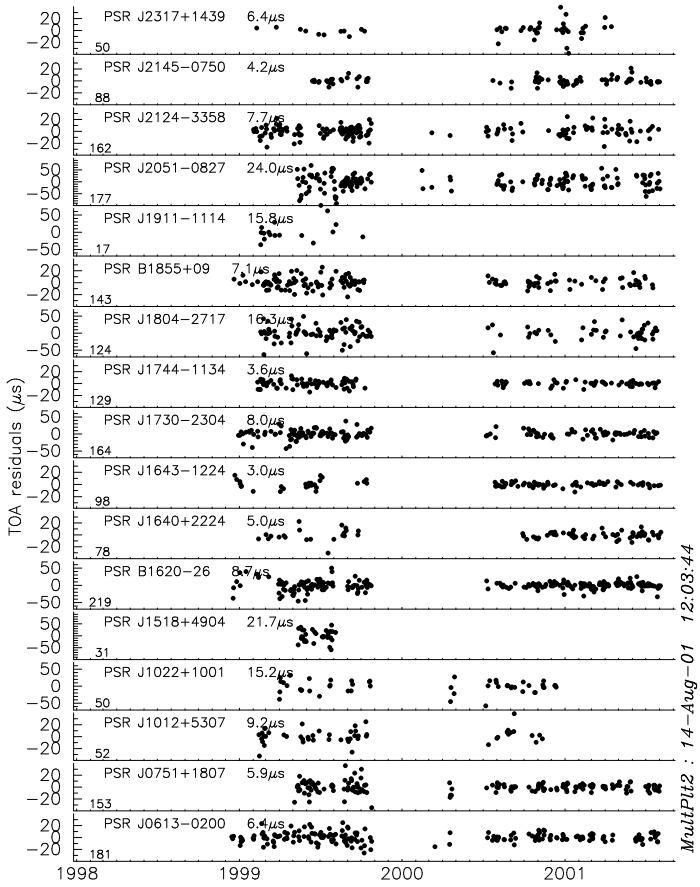

Figure 2: Residuals of Times Of Arrivals for the millisecond pulsars observed at Nançay with the newly upgraded radiotelescope and the NBPP.

AN ARRAY OF PULSARS

A larger number of millisecond pulsars is now regularly timed in Nançay with the NBPP (Navy Berkeley Pulsar Processor). This instrumentation [4] was brought and used in Nançay to acquire pulsar search data. The NBPP is now used to time around twenty millisecond pulsars using its real-time folding capability. We have selected $\sim$ 20 millisecond pulsars with period time derivatives smaller than $\dot{P}$ of the most rotationally-stable pulsar B1855+09 (i.e. $\leq 2 \times 10^{-20} s/s$).

Fig.2 shows the TOAs residuals for some of the millisecond pulsars observed. Timing precision is below 10μs for 2/3 of the pulsars shown. Those precise measurements will even be better in the near future with the improvement due to the upgrade of the telescope. For example, Fig.3 shows the TOAs residuals for the pulsar PSR J0613-0200 with data taken before

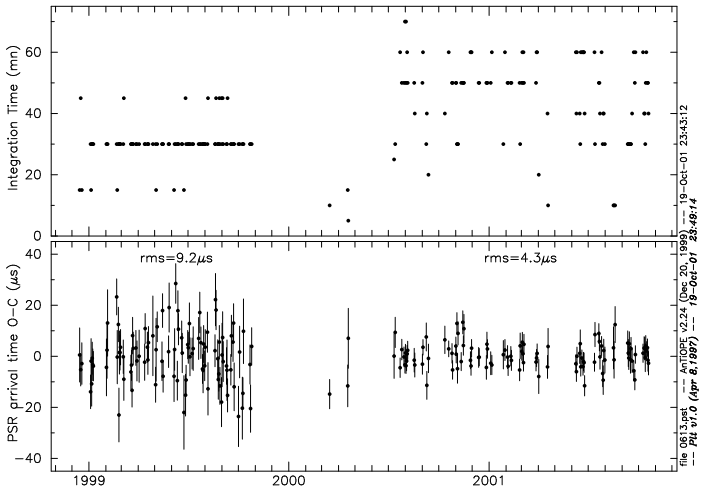

Figure 3: Residuals of TOAs for the millisecond pulsar PSR J0613-0200 observed at Nançay with the NBPP, before and after the upgrad of the radiotelescope. An obvious improvement is visible (which is not related to the fact that the completion of the upgrade gives us back the full length of the track and the possibility to do longer observations.

and after the upgrade. A factor $\sim$2 is seen is the rms of those "white" residuals indicating that the uncertainty is much better with the newly renovated telescope.

CONCLUSION

With a newly renovated receiving system and a pulsar instrumentation continuously improved (see communication 1869 in the present Conference), the Nançay radiotelescope will be able to acquire an other decade of high precision timing measurements on even more millisecond pulsars than the previous decade.

REFERENCES

[1] Cognard, 1993, *Nature*, **366**, 320

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[3] Lestrade, Rickett & Cognard 1998, *A&A*, **334**, 1068

[4] Foster et al., in ASP Conf. Ser. Vol 105, Pulsars : Problems and Progress (San Francisco: ASP), 25