The Nançay pulsar instrumentation : The BON coherent dedispersor

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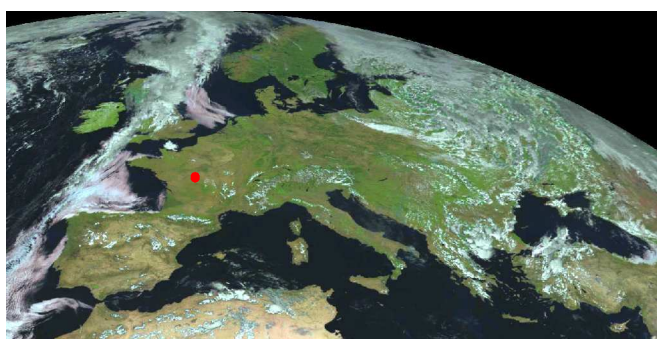
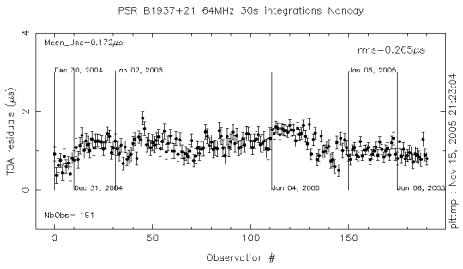
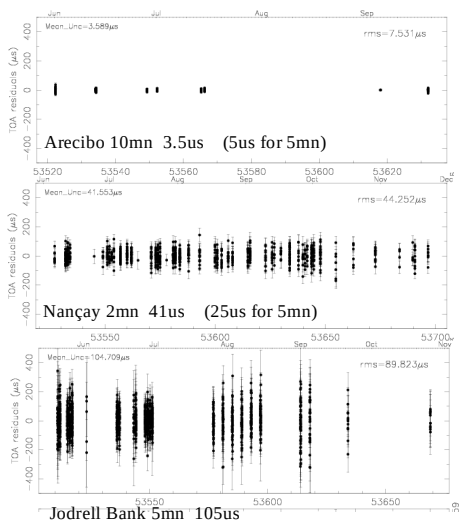
Abstract : We present here a summary of the Nançay pulsar instrumentation and the on going observational pulsar timing programs.
The Nançay coherent dedispersor is able to handle 128MHz of bandwidth. It is made of a spectrometer to digitize data voltages, plus four data servers to spread data out to a 70-node cluster of PCs (with Linux Operating System). Dedispersion is done by applying a special filter in the complex Fourier domain. This backend has been designed in close collaboration with UC Berkeley. It benefits from the many qualities of the large Nançay radiotelescope (NRT, equivalent to a 94 m circular dish), which receivers were upgraded in 2000. A factor of 2.2 sensitivity improvement was obtained at 1.4MHz, with an efficiency of 1.4K/Jy for a system temperature of 35K. A better frequency coverage was also achieved (from 1.1 to 3.5GHz).
The first two years of data acquisition demonstrates that the timing data quality is comparable with the Arecibo and Green Bank results. As an example, a Time Of Arrival (TOA) measurement accuracy better than 200ns (170-180ns) is obtained in only 30 seconds of integration on the millisecond pulsar PSR B1937+21. With this up to date instrumentation, we operate two main observational programs in pulsar timing with the Nançay antenna : 1) the radio follow-up of X- and gamma-ray pulsars for the building of a complete multi-wavelength sample and 2) the monitoring of both a millisecond pulsar timing array and a targeted list of binary or unstable pulsars for gravitational wave detection. Joining both list of targets, a total sample of 150 pulsars is then monitored regularly with a dense sampling in time.



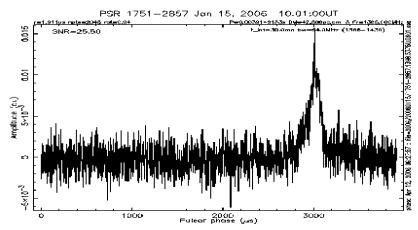


The TOA residuals for PSRB1937+21 are obtained with an accuracy of ~170 ns over only a 30s integration



Comparison of timing quality between Arecibo, Nançay and Jodrell Bank for the well known relativistic binary pulsar PSRJ1906+0746.

Note in particular the high sampling rate obtained at Nançay



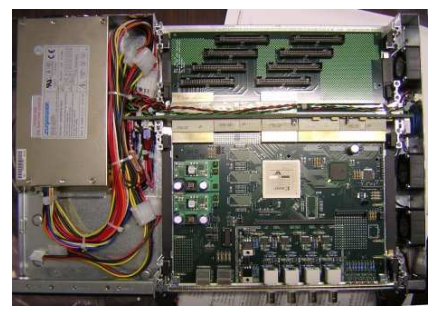
Daily profile of the very faint pulsar PSRJ1751-2857 (60 micro-Jansky) obtained in 30 mn of integration

The SERENDIP5 spectrometer of the digital dedispersor

Developed by the Space Sciences Laboratory (University of California, Berkeley) and used for pulsar purpose at Nançay, Arecibo and Green Bank

Consists of two boards:
- an industrial board 'Motorola CPV5350 CPU' (embedded Linux)
- a Xilink Virtex-II FPGA board (XC2V4000)

INPUT :	OUTPUT :
2 complex polarizations	32 x 4MHz
(4 signals, 128MHz, 8 bits)	4 Gbs data stream



The PC cluster

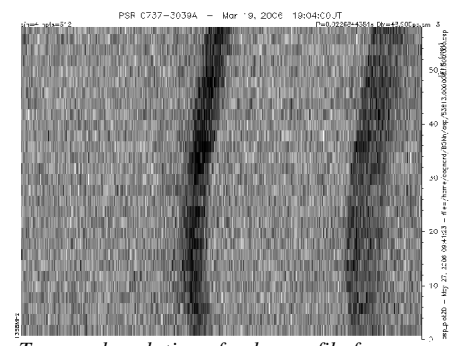
1 master bi-Athlon 1.2GHz, 2Go of RAM
70 nodes bi-Athlon 1.2GHz, 1 Go of RAM, 10Go of storage
Gigabit network (bandwidth 32GBs) + switch Cisco 6009
operating system : Linux, kernel 2.4.2

The BON pulsar archive : http://klun.obs-nancay.fr/

The BON pulsar archive contains close to five thousands daily pulse profile (30mn-1hour integration over frequency channels and sub-integrations) and multiple time-phase-frequency plots of 30sec-2mn sub-integrations.
Two kinds of request are available: either by object name (e.g. PSR 0950+08, PSR 1821-24, PSR 1937+21) or using an SQL sentence (e.g. : "mjd>53550 and snr>30")
The result of the request is a single line or a table with the following parameters or flags:

* object name and pointer towards a GIF image of the daily profile (Objname) or a 2D plot showing sub-integrations/frequency-channels
* gregorian date of the observation
* modified julian date of the observation (mjd)
* center frequency in MHz (midfreq)
* bandwidth in MHz (BandWidth)
* Signal to noise ratio (Snr)

Three target lists are available, corresponding to the three main observational programs at Nançay (see below)



Temporal evolution of pulse profile for PSRJ0737-3039A shown as a series of 2 mn sub-integrations

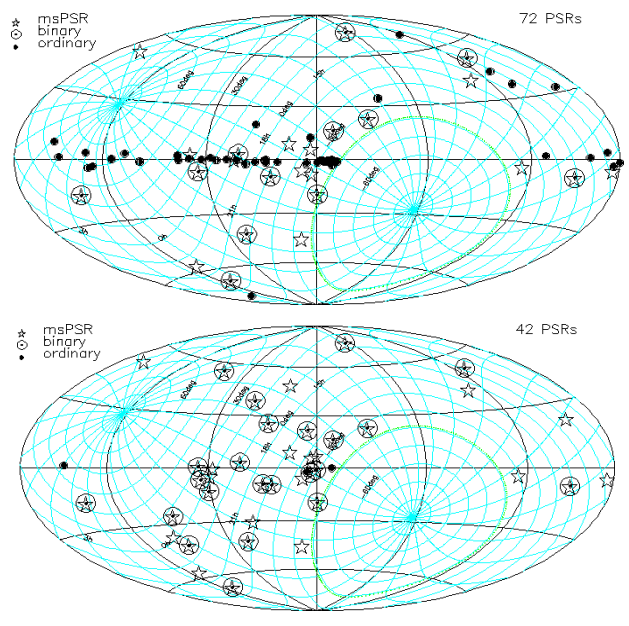
Scientific programs

The 16th and 17th January 2006, a national workshop on pulsar astronomy gathered in Paris some 40 researchers from various fields, such as gravitational waves, high energy astrophysics and compact objects, the study of the Galactic halo, or the definition of reference frames (see http://lpce.cnrs-orleans.fr/~pulsar/). As a result of this meeting, a wide consortium was created to support radio observations of pulsar with the Nançay antenna and two large programs were clearly identified as a priority for the French community: 1) the radio follow-up of X- and gamma-ray pulsars (from XMM-Newton, HESS, INTEGRAL and GLAST) for the building of a complete multi-wavelength sample and 2) the monitoring of both a millisecond pulsar timing array and a targeted list of binary or unstable pulsars for gravitational wave detection. To these main programs, we added a long term timing of Globular Cluster millisecond pulsars to the aim of a kinematical study of the Galactic Halo.

The high energy program consists in the radio follow-up of X- and gamma-ray pulsars for the building of a complete multi-wavelength sample. The goal of this project is double : 1) provide strong constraints on the physics and emission mechanisms of pulsars , 2) guarantee the success of pulsar harvest at high energy by providing good and contemporaneous ephemeredes for folding the few gamma and X-ray photons . As an example, one foresees that GLAST could detect over a hundred gamma ray pulsars, as compared to the fewer than 10 presently known. We then proposed a pilot program to prepare long-term timing for GLAST. It consists in the monitoring of about 140 pulsars with a sampling in time depending on the stability properties of each object. This program officially started in July 2006 and it should continue all during the 5 to 10 years of the GLAST mission.

The building of long series of TOA of many pulsars distributed on the celestial sphere for studying the **gravitational wave background** is certainly one of the most exciting quest. To this purpose, we are monitoring a set of 42 among the most stable pulsars in order to build the required timing network. These high quality data should help to test the existing theories of Gravitation at various scales and frequencies. New pulsar instrumentations (like BON) already provide the necessary accuracy for studies complementary to those made with the first generation of gravitational telescopes : VIRGO, LIGO and LISA. A timing array of very stable pulsars should allow the detection of low frequency (nHz) primordial waves or other stochastic astrophysical background. Pulsars located in binary systems allow us to investigate Gravitation in strong field, while young and unstable pulsars will be used, in collaboration with VIRGO/LIGO, to detect gravitational waves emitted when the neutron stars oscillates.

The absolute space motion and orbits of Globular Clusters (GC) are keys for investigating the Galactic potential and dynamical mass, i.e. the quantity and the distribution of dark matter. While only a dozen of GCs possess a proper motion optical measurement with respect to an extragalactic frame, pulsar timing offers the opportunity to greatly enlarge the sample. At the present day, there are three GCs with a proper motion known from pulsar measurement (NGC6626, NGC6121 and NGC104), but the number of known millisecond pulsars host by GCs has grown dramatically in the last couple of years and 19 of such clusters can now be targeted by Nançay antenna. A four years timing program should be able to provide the full astrometrical information needed.



Aitof projection of the high energy sample (top) and pulsar timing array (bottom) currently being monitored at Nançay. Symbols denote the class of pulsar : millisecond (msPSR), binary and ordinary.