Observations radio de pulsars binaires relativistes à Nançay

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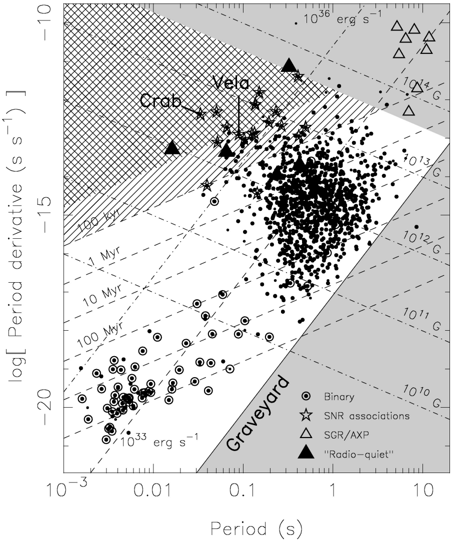
Nançay Radio Telescope

An outstanding stability for fast recycled pulsars



A first very short life...

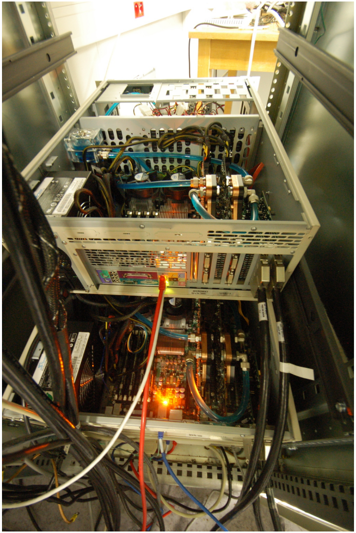
After a birth at ∼30ms,
the pulsar is rapidly slowing down
and stops emission after
few millions years.

... then eternity !

Those still present in a binary system
speed-up by angular momentum transfer,
and produce radio waves again,
those are
the recycled millisecond pulsars
with an outstanding rotational stability !

Alpar et al., Nature *300*, **728** (1982)

GPUs based coherent dedispersion at Nançay



Removing the dispersive effect

The ionised ISM produce dispersion
best measures need coherent dedispersion
where dispersion removed before detection

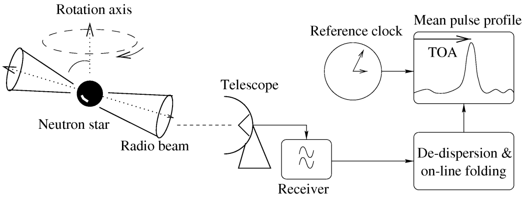
Diversion of GPUs

Using high performance graphical card (GPU),
water-cooled to increase their lifetime,
4 PCs with 8 GTX280 can easily
dedisperse bw 512MHz
(16Gb/s) in real time

An ultimate precision

Timing uncertainty can be
as good as 20ns for a few pulsars.

Pulsar Timing



Measuring a time of arrival

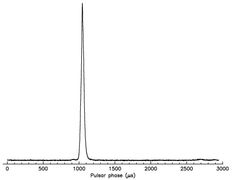
a large radiotelescope
a good clock,
and a special **instrumentation**
to remove the ISM dispersion

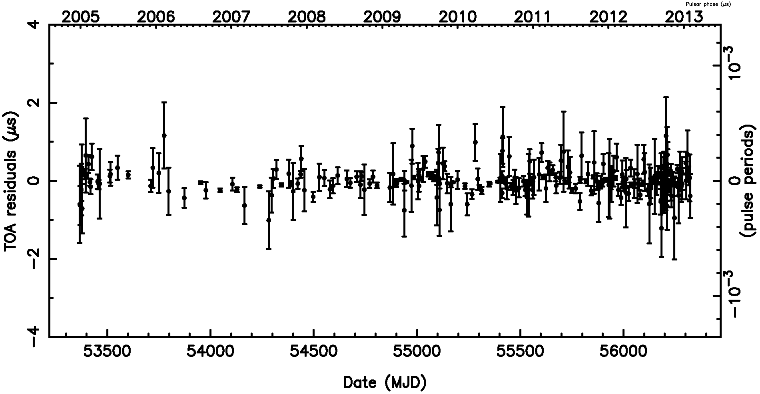
Analysis of a collection of measured times of arrival (ToAs)

→ Having a set of parameters (period, position, etc...),
→ computing 'calculated times of arrival',
→ fitting the parameters by minimization of the differences (called residuals)
between 'measured ToAs' and 'calculated ToAs'
→ looking at the residuals to find unmodeled effects...

The ultra-stable pulsar PSR J1909-3744 at Nançay

For the pulsar J1909-3744
(P=2.95ms, DM=10.39pc.cm^{-3}, P_b=1.53d)
the ToAs residuals
are characterized by an rms ~90ns





Two main pulsar programs at Nançay

Multi-wavelength observations ~1000hr/yr

Title : **Multi-wavelength study of pulsars from radio to TeV photons : a joint long term program with FERMI**

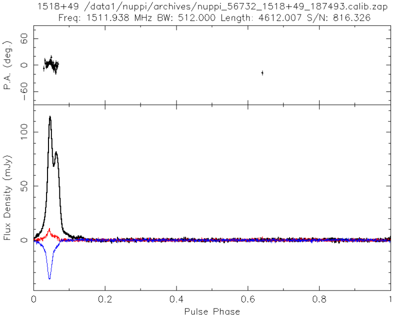
Ephemeris for ~120 pulsars are continuously produced
to search for high energy pulsations and constrain emission processes

The Pulsar Timing Array (PTA) ~2000hr/yr

Title : **Timing of an array of millisecond pulsars (MSPs) and detection of multi-wavelength gravitational waves**

Around 30 highly stables millisecond precisely timed once a week
to search for the signature of gravitational waves (GW) background
High precision ToAs from relativistic binaries also used to conduct Tests of Gravitation

PSR J1518+4904, a low mass Neutron Star



PSR J1518+4904

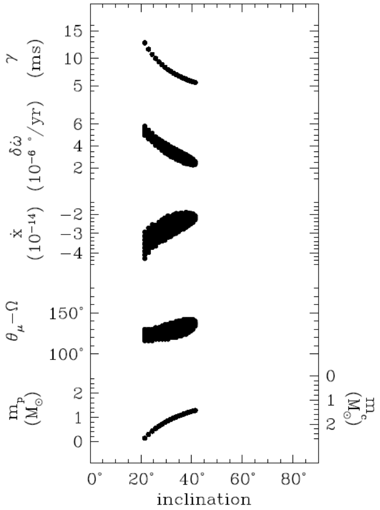
$P = 40.93$ms
$DM = 11.6114$ pc.cm^{-3}
$P_b = 8.634$ days
a.sini = 20.04 lt-s, e = 0.2494

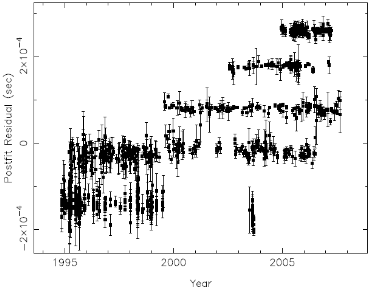
Data

a combination of ToAs coming from 4 european and from Green Bank (US) radio telescopes

	Effelsberg[b]	Jodrell Bank	Nançay[b]	Westerbork	Green Bank[b]	All combined
Number of TOAs	71	292	145	126	382	1016
Time span (MJD)	52 481–54 166	49 797–53 925	53 307–54 200	51 389–54 337	49 670–52 895	49 670–54 337
Rms individual data set[a] (μs)	3.3	10.7	3.3	5.2	8.2	6.0
Observed Frequencies (MHz)	1400	400, 600, 1400	1400	840, 1380, 2300	350, 370, 575, 800	

PSR J1518+4904, a low mass Neutron Star



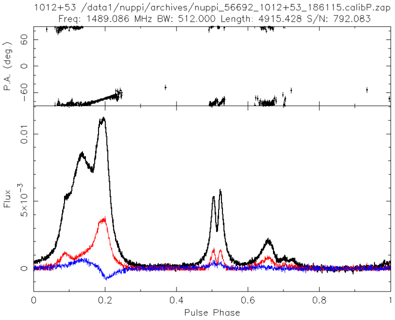


- a better periastron advance $\dot{\omega}$
- a significant proper motion μ

$\rightarrow$ a low mass pulsar $m_p < 1.17\ M_\odot$

Janssen et al., A&A 490, 753 (2008)

PSR J1012+5307, indep. limits on $\dot{G}$ and dipole radiation



PSR J1012+5307

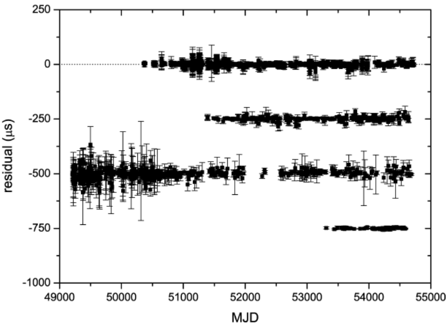
P $= 5.25$ms
DM $= 9.0231$ pc.cm^{-3}
$P_b = 0.60467$ days
a.sini $= 0.582$ lt-s, e $= 1.2 \times 10^{-6}$

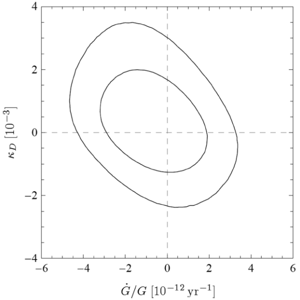
Data

a combination of ToAs coming from 4 european radio telescopes

Properties	Effelsberg	Jodrell Bank	Westerbork	Nançay
Number of TOAs	1972	600	234	86
Time span (MJD)	50371–54717	49221–54688	51389–54638	53309–54587
rms of individual set(μs)	2.7	8.6	2.9	1.9
Observed frequencies (MHz)	860, 1400, 2700	410, 606, 1400	330, 370, 840, 1380	1400

PSR J1012+5307, indep. limits on $\dot{G}$ and dipole radiation





a weak but independent limit on tha variation of G and dipole radiation parameter κ_D
Lazaridis et al., MNRAS 400, 805 (2009)

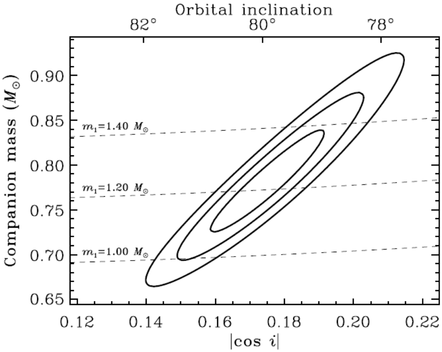
PSR J1802-2124

PSR J1802-2124

$P = 12.6$ms, $DM = 149.6$ pc.cm^{-3}
$P_b = 0.69$ d
a.sini $= 3.71$ lt-s, $e = 2.5\times10^{-6}$

Data

Combination of ToAs
coming Parkes, Green Bank and Nançay



the Shapiro delay provides $m_p = 1.24 \pm 0.11$ $M_\odot$
Ferdman et al., ApJ 711, 764 (2010)

PSR J1614-2230

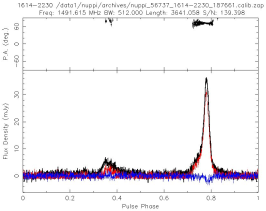
$P = 3.15\text{ms}$, $DM = 34.48\text{pc.cm}^{-3}$
$P_b = 8.68\text{d}$, $m_p = 1.97 \pm 0.04\ M_\odot$

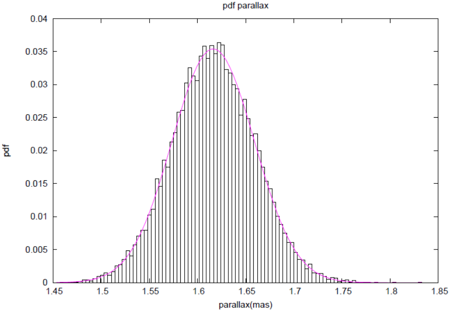
Green Bank + Nançay data

Combining Green Bank (rare and precise) with Nançay (numerous and less precise) provides the first 'good' estimate of the distance $\sim 620 \pm 40$ pc

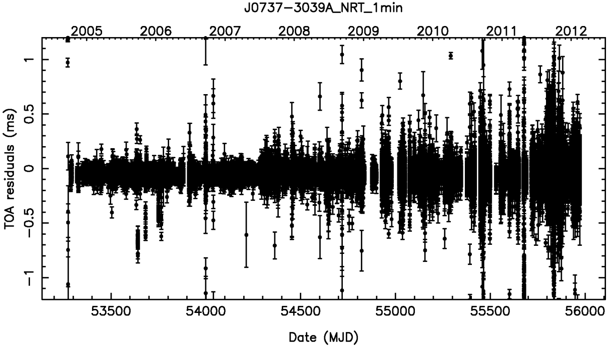
MCMC estimation (A.Lassus, PhD 2013)

important for high energy efficiency



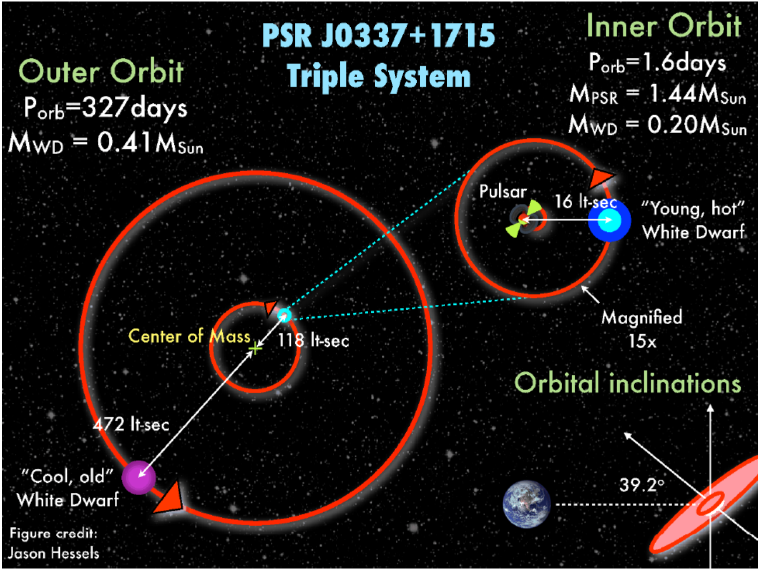


PSR J0737-3039A, the double pulsar

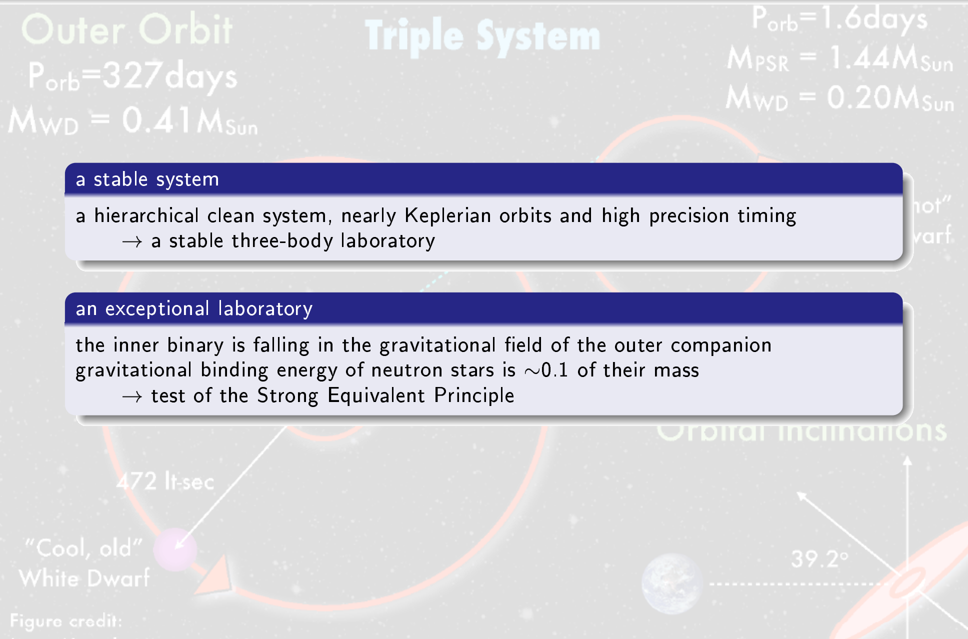


Work still in progress...
Data reduction nearly finished $\rightarrow \sim$ 60000 1min ToAs !
paper in preparation with Michael Kramer, MPIfR Bonn

Triple system J0337+1715



Triple system J0337+1715 : test of SEP

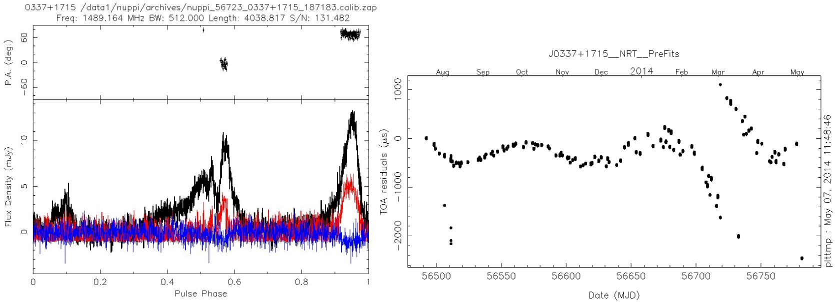


a stable system

a hierarchical clean system, nearly Keplerian orbits and high precision timing
→ a stable three-body laboratory

an exceptional laboratory

the inner binary is falling in the gravitational field of the outer companion
gravitational binding energy of neutron stars is ∼0.1 of their mass
→ test of the Strong Equivalent Principle



Nançay observations

Started end of July 2013
- with a high cadence (1 every ~2.5days), already ~4000 ToAs
- characterized by a mean uncertainty is ~2μs over 2 minutes integrated profiles

M2 student starting to work on it
collaboration with A.Archibald (ASTRON) for SEP test

Conclusion

Present

- a new 512MHz bw pulsar instrumentation (2011)
- a limit on the super-massive black holes binary system GWB
- a successful collaboration with FERMI (tons of new detections : radio, high energy)
- also : magnetar very close the Galactic Center (magnetic field estimation)
- J1518+4904, J1012+5307 and J1802-2124 results

Future

- upgrade of the pulsar instrumentation (512MHz→1.5-2GHz)
- better limit of the GWB (within the collaborations EPTA, IPTA)
- double pulsar J0737-3039A tests
- test of SEP with triple system J0337+1715

  + new test/results coming from new exciting pulsars to be discovered