Pulsars and Transients with NenuFAR

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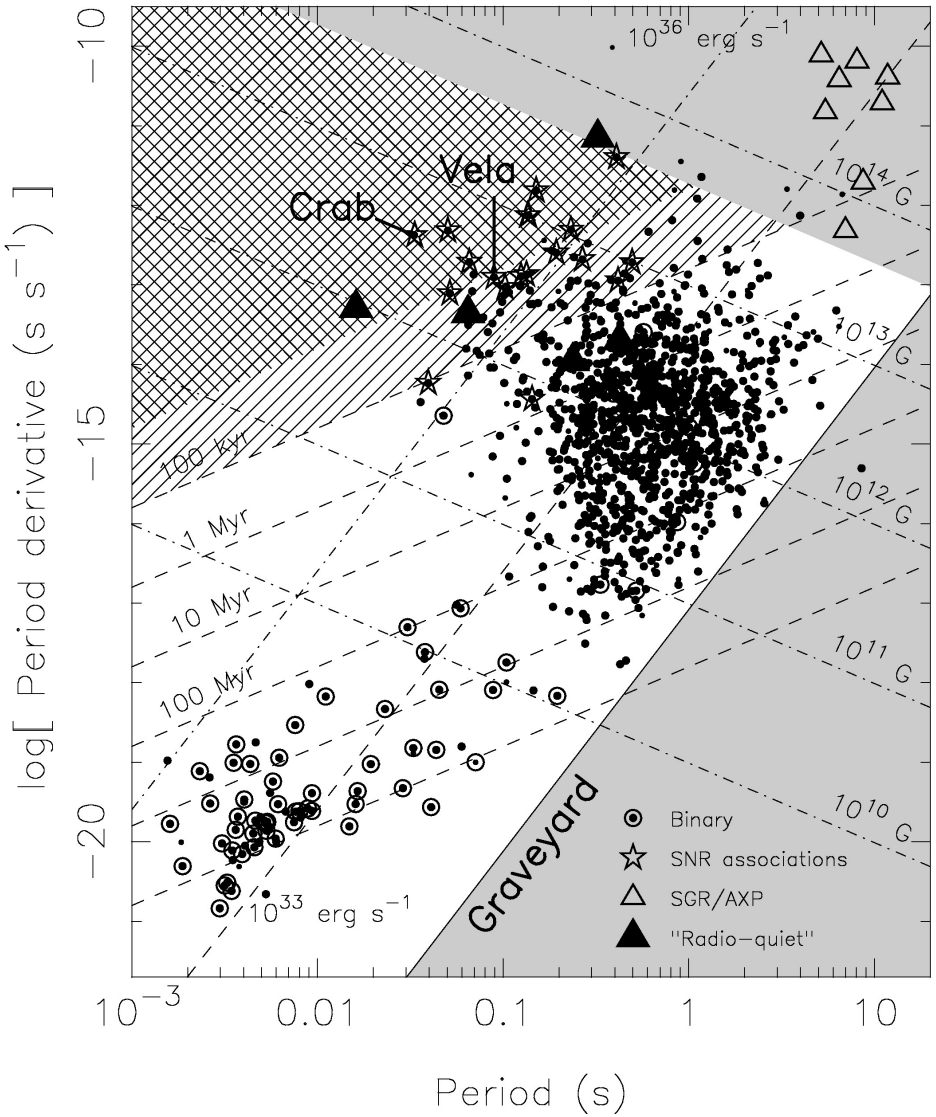
An outstanding stability for the fastest pulsars



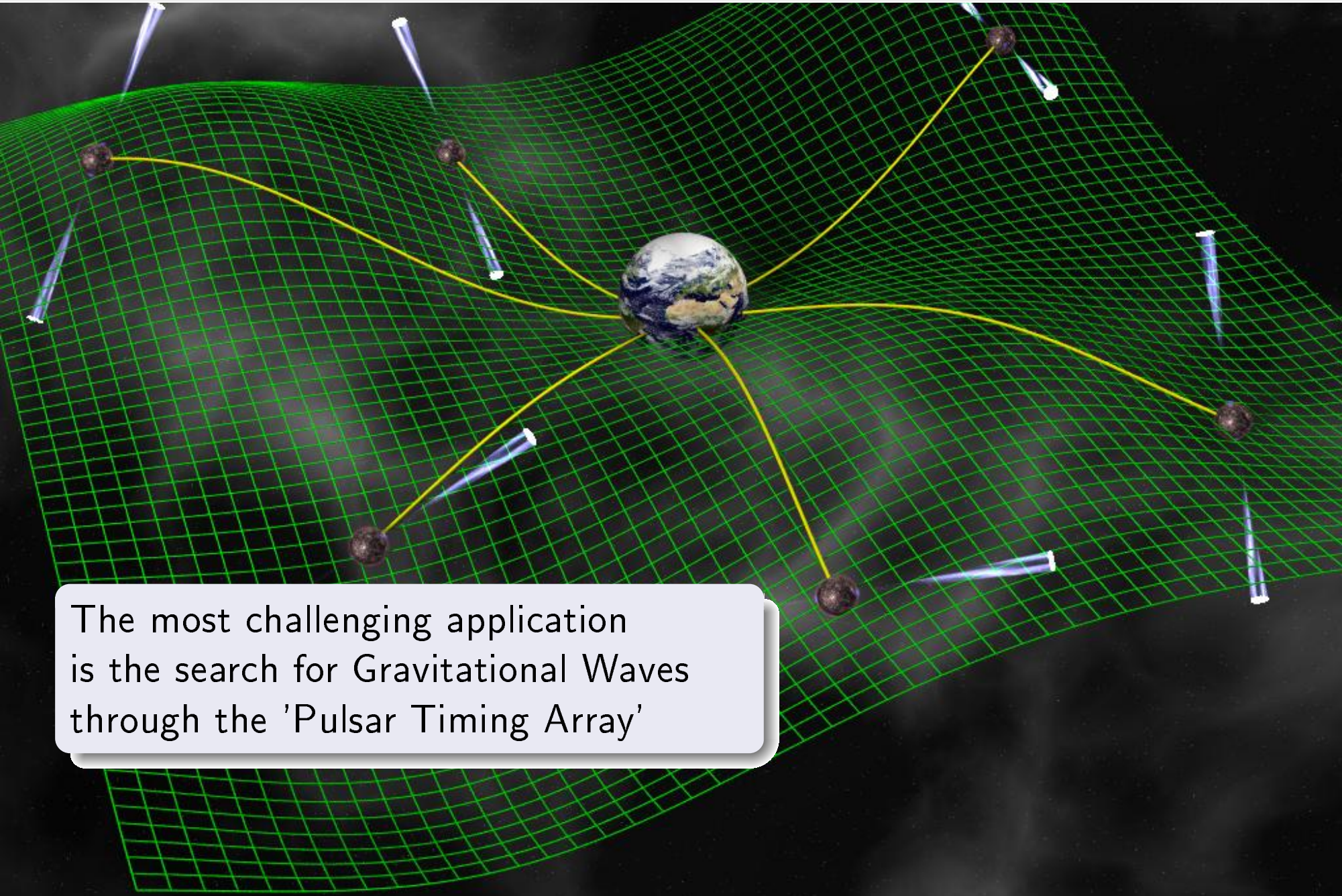
A first very short life...

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

... then eternity !

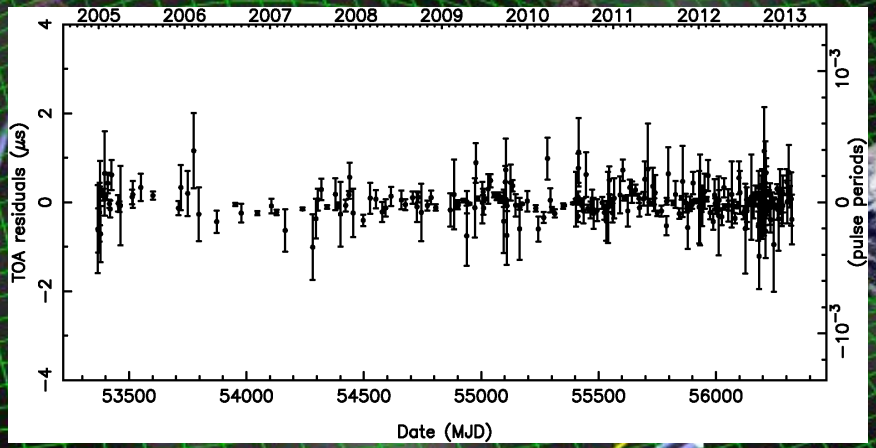
Those still present in a binary system
speed-up by angular momentum transfer,
and produce radio waves again,
those are
the recycled millisecond pulsars
with an extraordinary rotational stability !

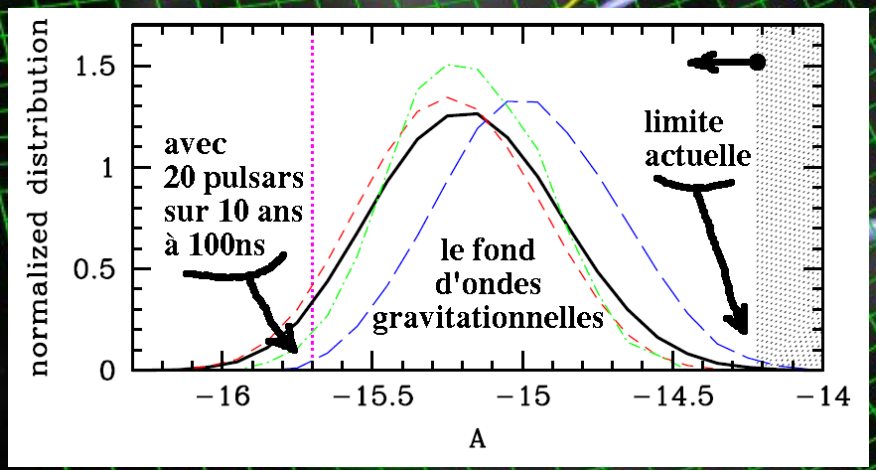
Alpar et al., Nature *300*, **728** (1982)



The most challenging application
is the search for Gravitational Waves
through the 'Pulsar Timing Array'

Gravitational Wave search





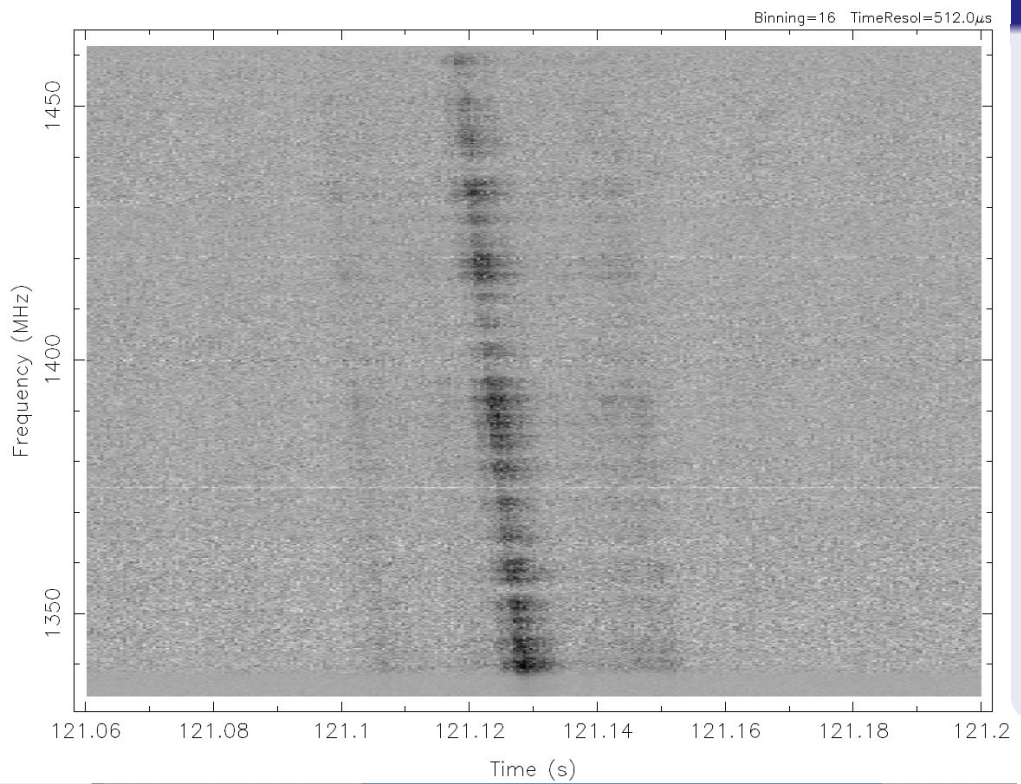
Times of Arrival (ToAs) can be as precise as ∼100ns (i.e. J1909-3744 at Nançay)
The current best limits are close to theoretical expectations

(Sesana, MNRAS 2013)

We need excellent ToAs as clean as possible, despite numerous ISM effects

The effects of the interstellar medium

-1- dispersion



A dispersed pulse from pulsar B0329+54 with DM= 26.8pc.cm^{-3} (140ms, 128MHz)

a cold and ionised plasma

In radio observations, we got a delay with respect to infinite frequency

$$t = \int_0^d \frac{dl}{v_g} - \frac{d}{c} \equiv k \frac{DM}{f^2}$$

with $k = \frac{e^2}{2\pi m_e c}$

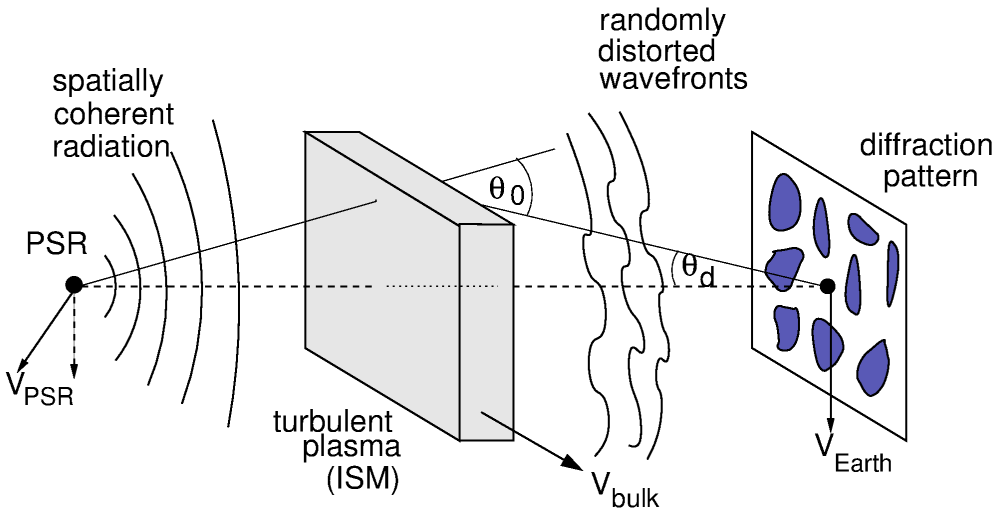
and DM the 'Dispersion Measure' or integrated electronic content along the line of sight

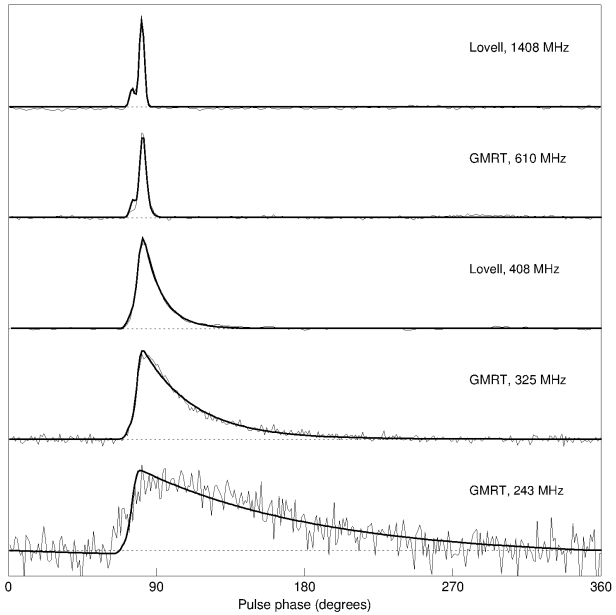
$$DM = \int n_e dl$$

an homogeneous ionized ISM would be nice, but...

The effects of the interstellar medium

-2- multi-propagation





While the ionised ISM produces the total dispersive delay,
turbulent inhomogeneities generate multi-propagation and so
intensity scintillation (in time and frequency) and temporal broadening

Narayan, Phil.Trans.Royal Soc. of London A 341, 151 (1992)

NenuFAR will be a low frequency SENSITIVE instrument

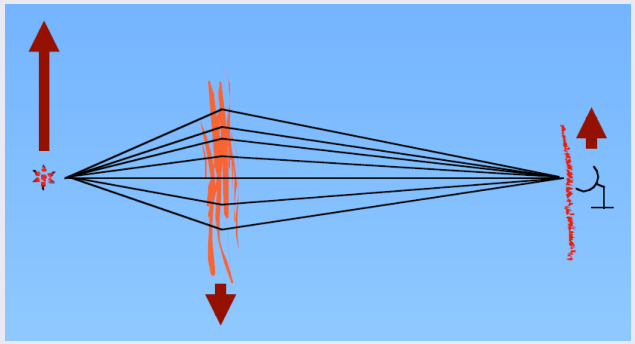
Let's try to use it to observe pulsars to probe the ISM !

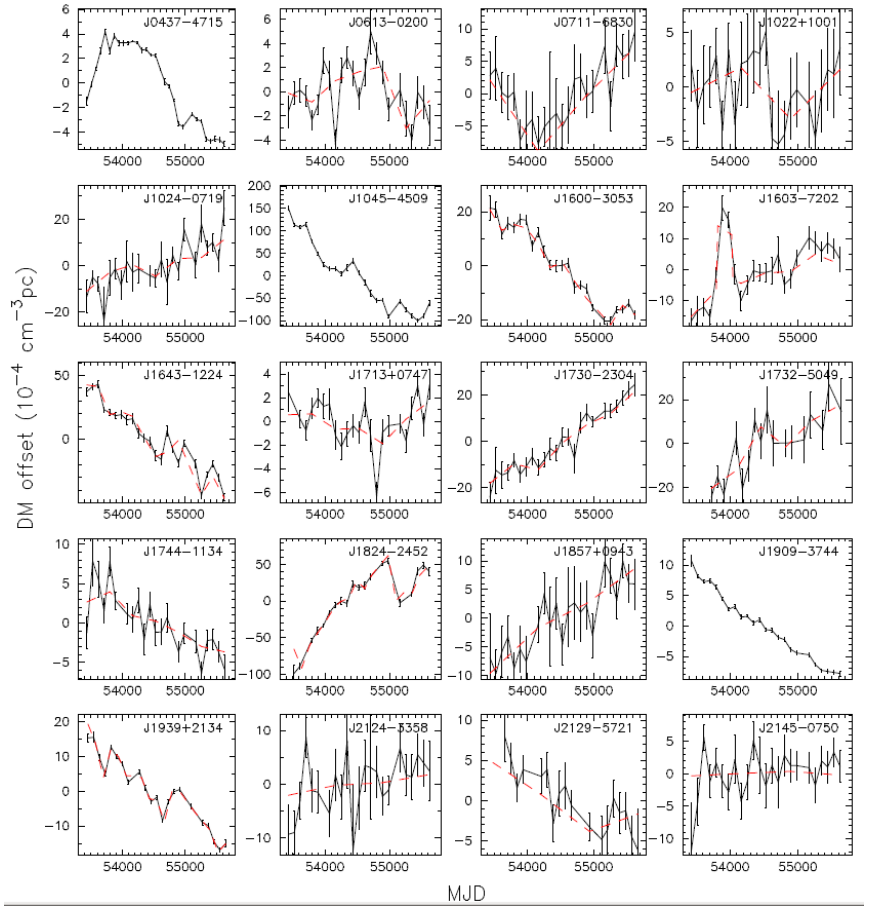
Dispersion Measure variations

a ionized turbulent medium

inhomogeneous ionized ISM produces **DM variations**,
usually easy to measure
using different spaced frequencies
for radio observations

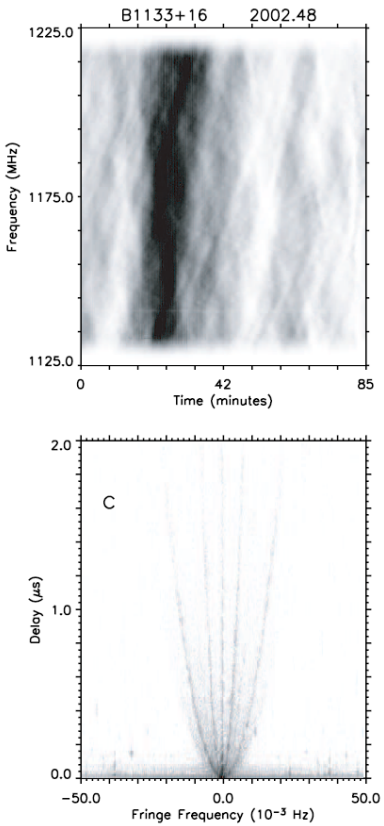
while scattering
produces **multi-propagation**
and a cigar shape probed volume
which is highly dependent
on the radio frequency
→ **difficult to measure**
reliable DM variations

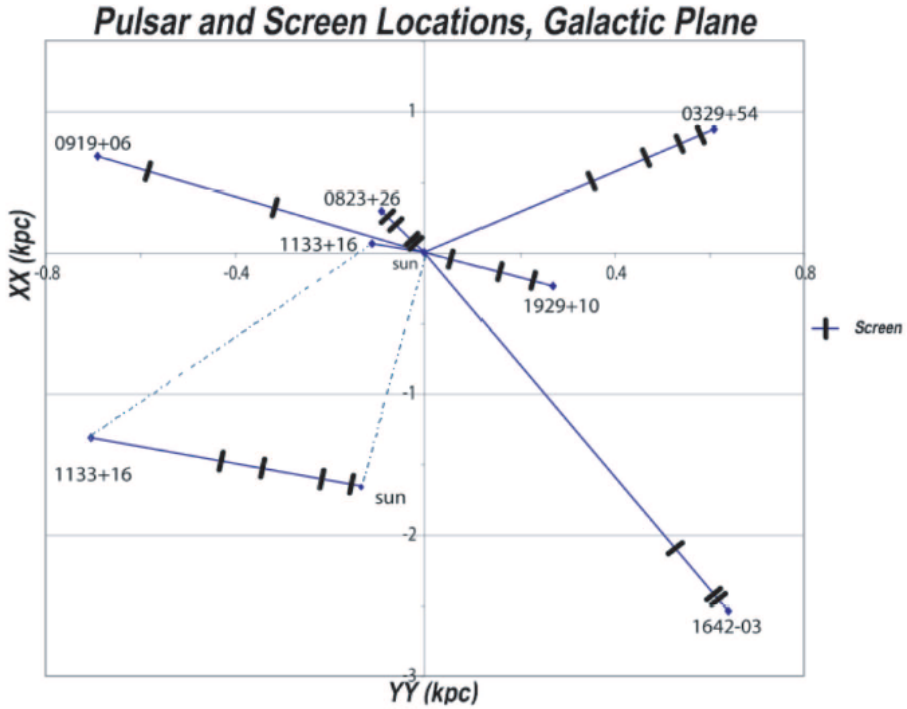




measured Dispersion Measure variations
Keith et al., MNRAS 429, 2161 (2013)

Scintillation arcs

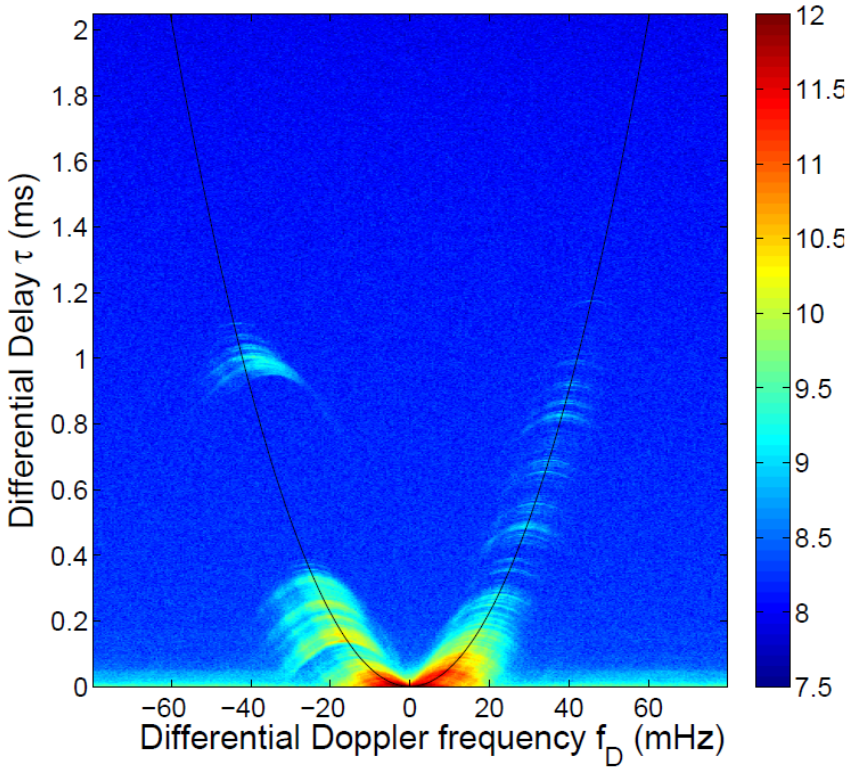




a dynamic spectra with both high time and frequency resolutions and high SNR
the computation of the secondary spectra (2D FFT of dymanic spectra)
$\rightarrow$ detection of 'scintillation arcs', each corresponding to a given screen
where interferences occurs between the central point and points along the motion axis

Stinebring, Chin.J.Astron.Astrophys. 6, 204 (2006)

Inverted arclets

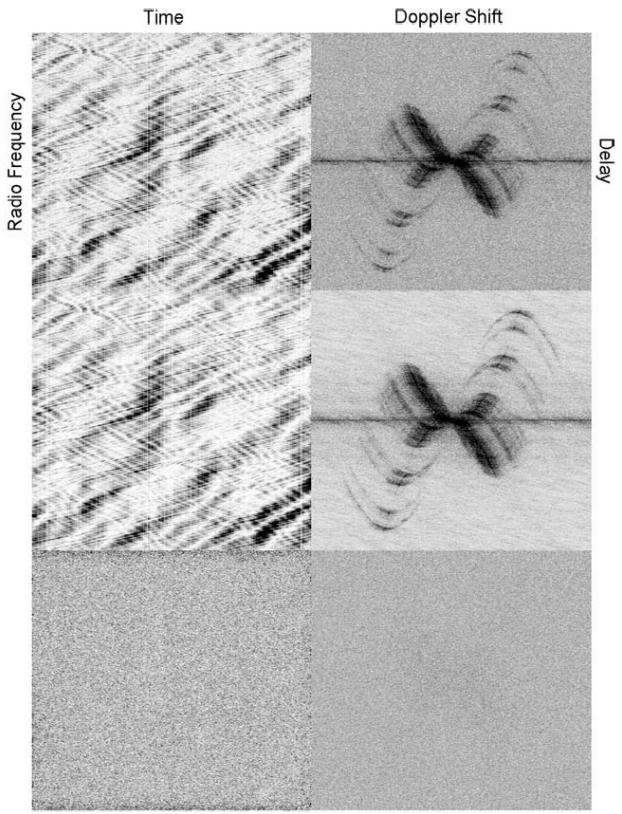


Pulsar B0834+06
at 314.5MHz (bw 8MHz)
Arecibo

Interference between a bright spot in the periphery of the image and the rest of the image produces inverted parabolae or arclets

Brisken et al., ApJ 708, 232 (2010)

Interstellar holography

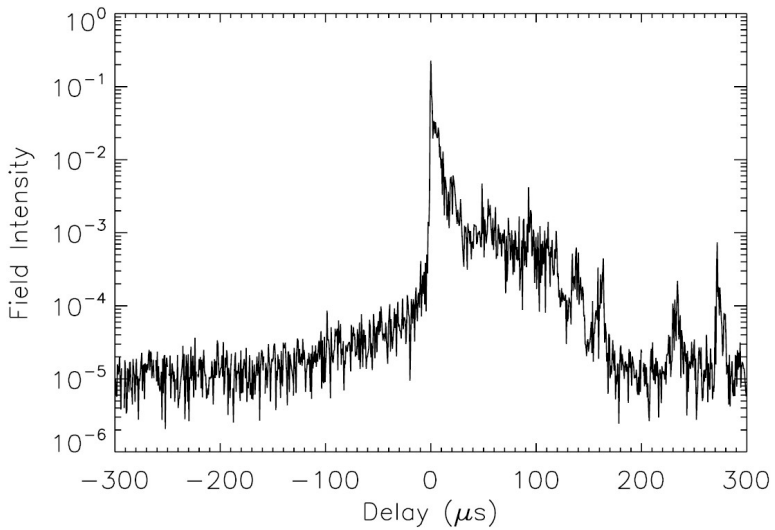


PSR B0834+06, Arecibo, 321MHz
Dynamical and secondary spectra :
data, model and residuals

Impulse response

a high SNR dynamic spectra,
the calcul of the 'secondary spectrum',
and the adjustment of thousands of coefficients describing the electric field
provide the impulse response of the medium

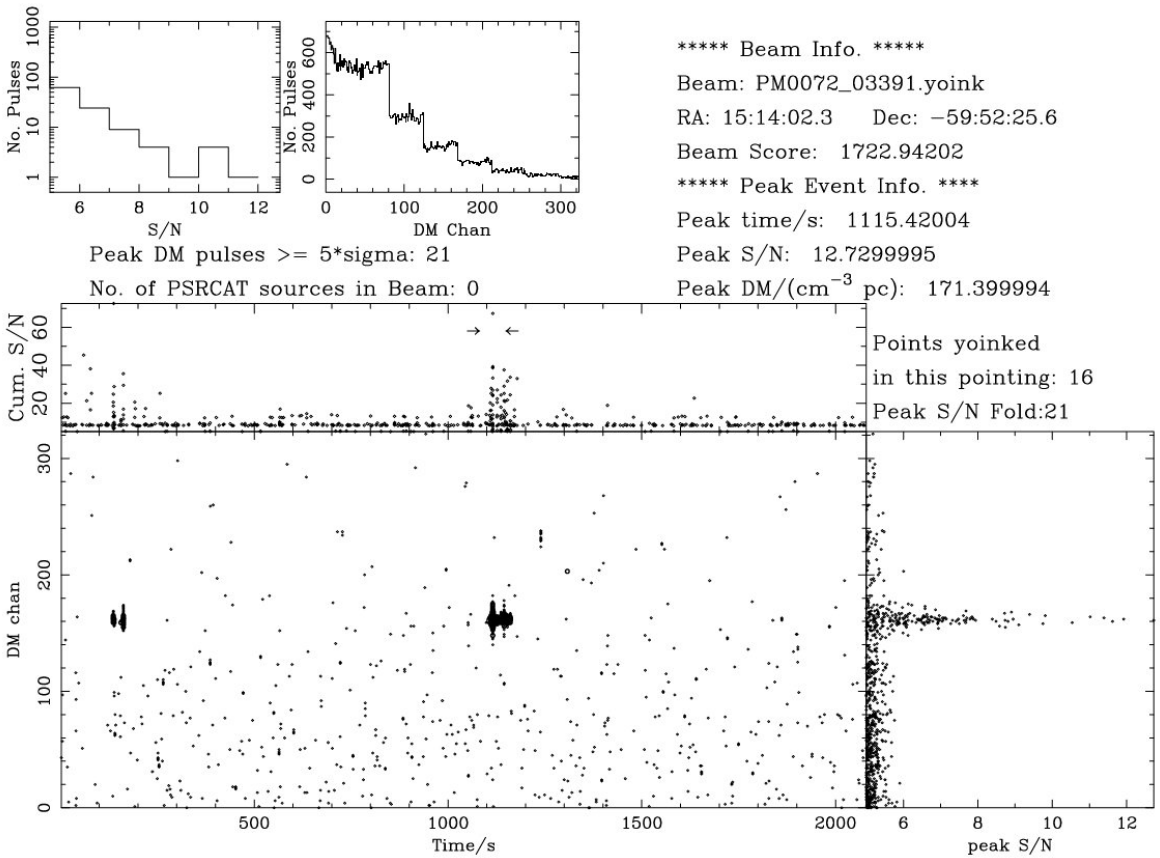
Here, multi-propagation delays up to 100 μs are observed
and the pulse has a mean delay $\sim$15μs...
Walker et al., MNRAS 388, 1214 (2008)



NenuFAR will be a very large instantaneous field of view instrument

Let's try to find transient sources ! !

RRATs : sporadically pulsing pulsars (McLaughlin et al., 2006)



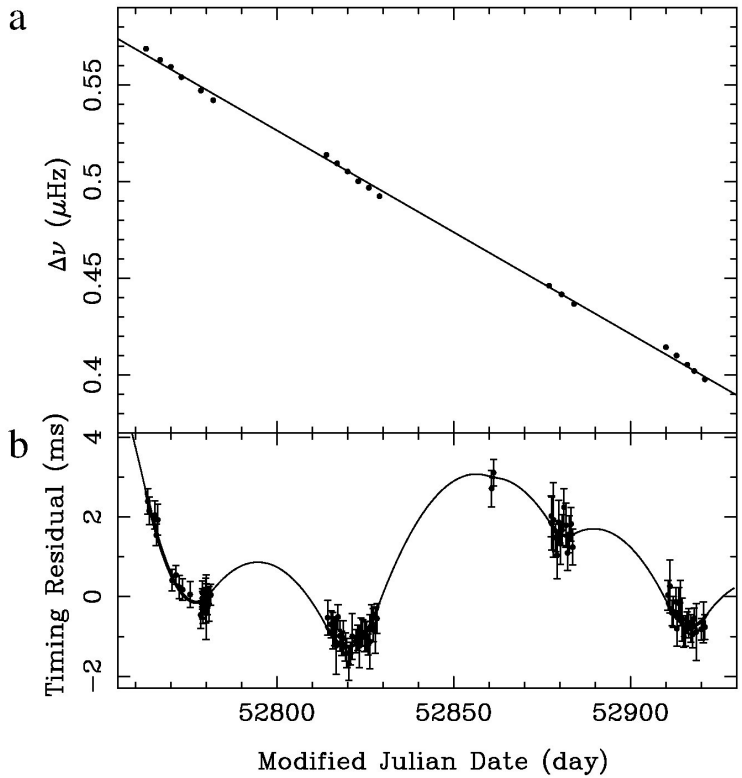
RRATs are probably just extreme nulling pulsars...
just ON a few % of the time and OFF for the rest
they are really **interesting as a population** to check that
there isn't any birth rate problem

Intermittent pulsars

An intermittent pulsar is successively ON and OFF with timescales of weeks-months and braking changing by ∼50%

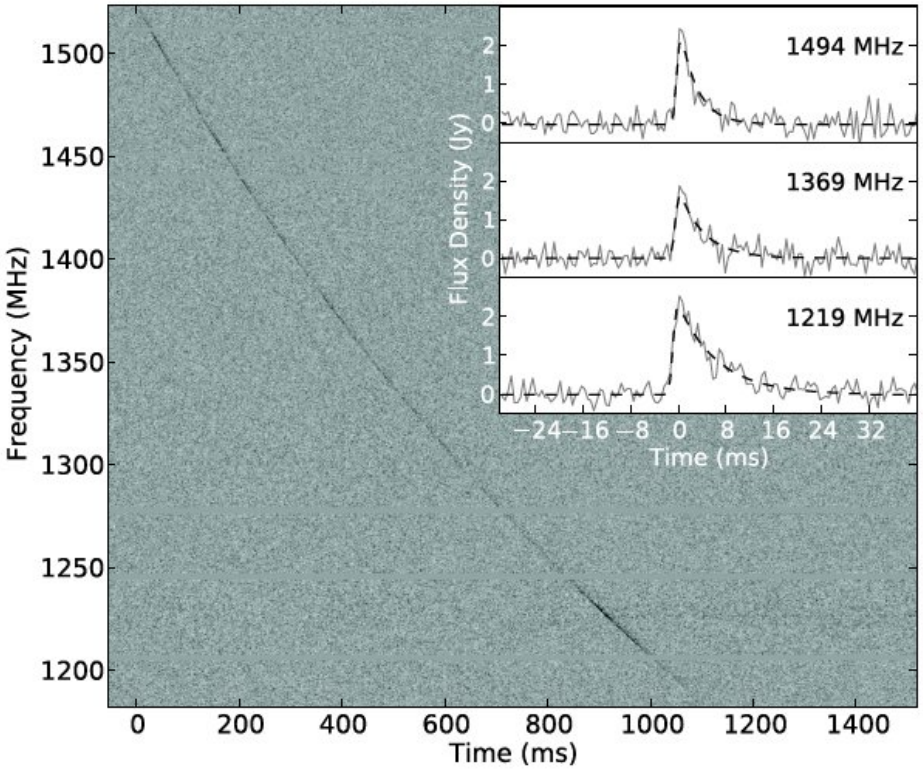
Easier to find with a telescope having a large field of view

Interesting to probe the **magnetic engine** of the radio emission



Evolution of the rotational frequency for pulsar B1931+24
Kramer et al., Science 312, 549 (2006)

Lorimer bursts or FRB (Fast Radio Bursts)



FRB 110220 z∼0.8 ?

(Thornton et al., Science 1307, 1628, 2013)

very high DM dispersed events (DM $\sim$ 500-1000 pc.cm^{-3})
$\rightarrow$ probably of extra-galactic origin (still unknown)

but very rare electrons at mid-point minimizes the scattering
and make possible low frequency detections Lorimer et al., MNRAS 436, L5 (2013)

NenuFAR, an 'FRB factory' ? ... Beware ! Possible confusion with GRBs afterglow.