Detection of Fast Radio Bursts with the NRT

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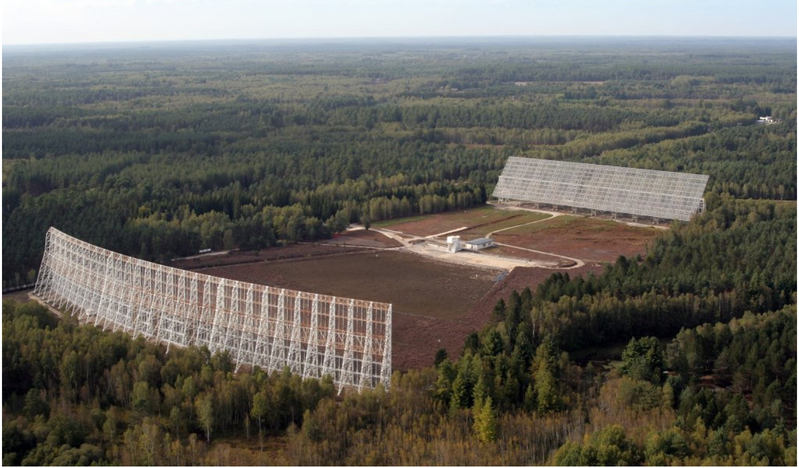


The Nançay Radio Telescope (NRT)

Kraus meridian design (monitoring not survey), ∼ a 94m dish, tracking ∼ 1hr/day
2 receivers (1.1-1.8 and 1.6-3.5GHz)

Detection of rapidly time varying sources (transients)

1. dispersion in the ISM can be a problem...

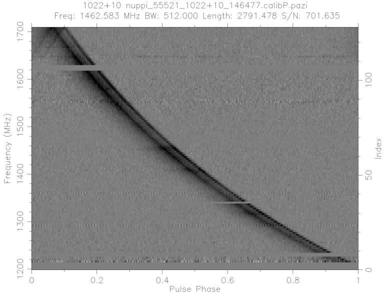
the Interstellar Medium (ISM) is **a cold and ionized plasma**

at a given frequency, the wave is delayed w.r.t. 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
integrated electronic content along the line of sight

$$DM = \int n_e dl$$

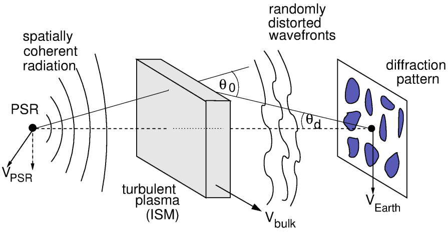


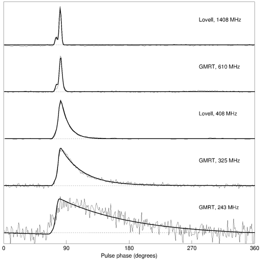
a dispersed (folded) pulse from pulsar J1012+5304 pulse over 1.2→1.7 GHz P=5.25ms DM=9.0233 pc.cm^{-3}

an **homogeneously ionized** ISM would be **nice,**
we known how to de-disperse,
but...

Detection of rapidly time varying sources (transients)

2. scattering by the ISM is even worse...



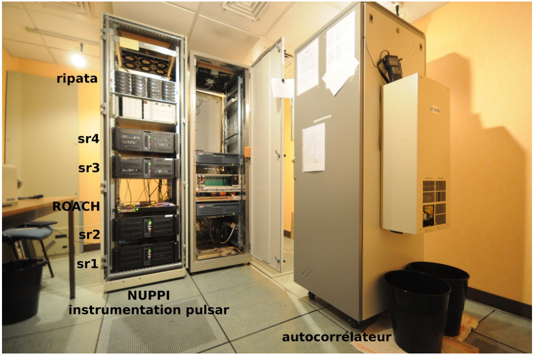


While the ionised ISM produces the total dispersive delay,
turbulent inhomogeneities generate multi-propagation and so
intensity scintillation (in time and frequency) and **temporal broadening**

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

No real medicine !

A flexible instrumentation : NUPPI



Nançay Ultimate Pulsar Processor

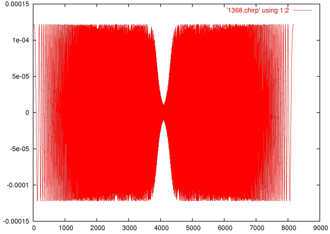
4 nodes / 8 GPUs to process a 512MHz band in real-time (16Gb/s)
- coherent dedispersion mode over 128x4MHz (FFT - filter - FFT^{-1})
  $\hookrightarrow$ folded for pulsars $\hookrightarrow$ **non-folded, binned, for known repeating FRBs**
- survey mode 1024x0.5MHz / 64μs, total intensity, 4bits
- wave forms dump mode (over 128MHz bw)

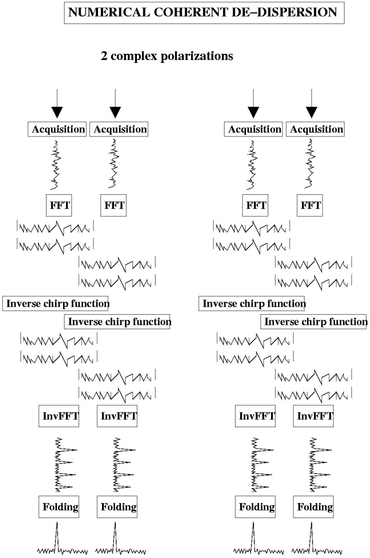
Coherent dedispersion

ISM dispersion acts as a phase filter only.
On the **recorded voltages** induced by the incoming electromagnetic radiation, the 'digital' coherent dedispersion applies an inverse transfer function in the complex Fourier domain :

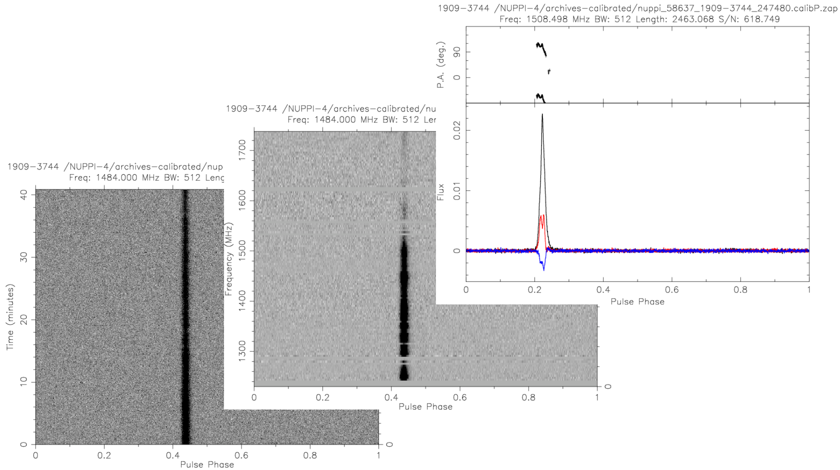
FFT + inverse filter + FFT^{-1}
(with overlap management)

For large bandwidth and **real-time** processing instrumentations, we need a **huge computing power !**





A typical pulsar observation

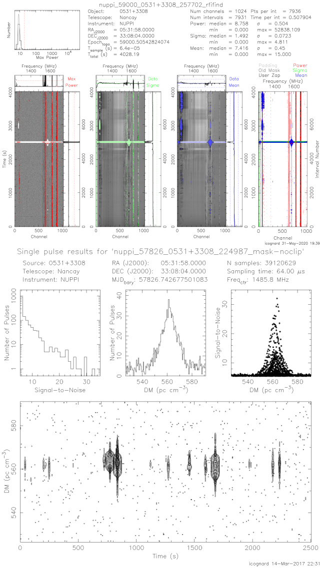


The highly stable millisecond pulsar J1909-3744
observed in folded coherent dedispersion mode

Using PRESTO https://github.com/scottransom/presto

NRT survey mode files : total intensity, 4 bits

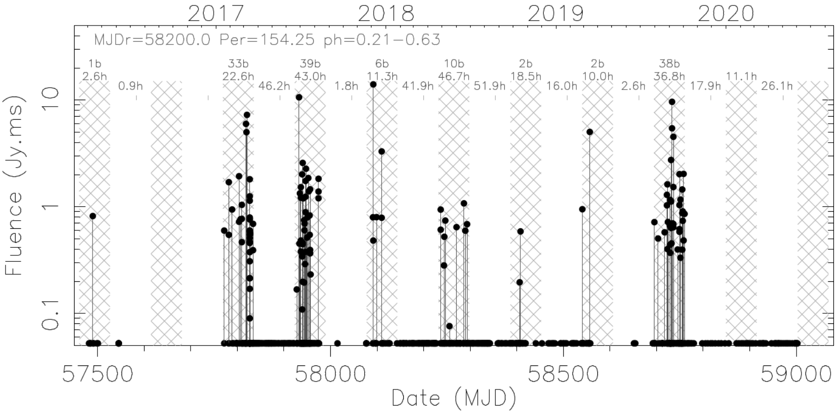
- **rfifind** to flag freq-time regions as RFIs
- **prepsubband** used to dedisperse
  for 1 or several DMs and integrate
- **single_pulse_search.py** to search
  for bursts (many boxcar widths)



A serie of 17 bursts
from FRB121102
over 42mins
on March 14, 2017

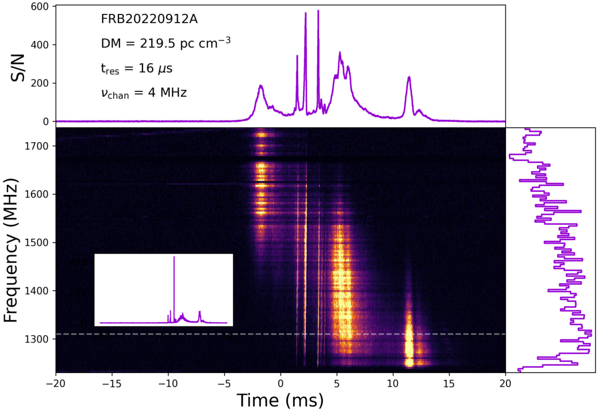
Using PRESTO https://github.com/scottransom/presto

Many bursts on FRB121102 and a ∼160 days activity 'period'



The ECLAT program...

A key-program monitoring a dozen of repeating FRBs with the NRT
Hewitt, Hessels, Cognard et al (obs= Nançay , analysis= Amsterdam)
codedi, non-folded files : 4 stokes, 32bits float



The ECLAT program...

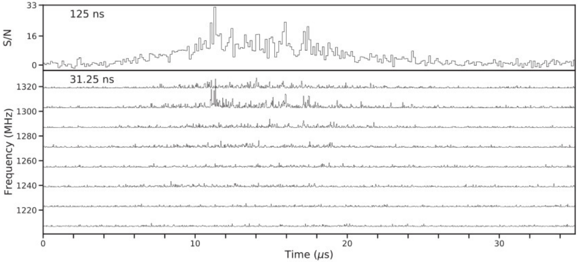


Figure 5. The top panel shows the brightest microshot in burst B2 at 125 ns time resolution. In the bottom panel, the time profile for each of the eight subbands is shown at a time resolution of 31.25 ns, which is the best possible time resolution we can obtain with the Westerbork data. The majority of the emission is concentrated towards the top of the Westerbork observing band.

raw data recorded at Westerbork (16MHz bw → 31.25ns resolution)