# Development of a digital receiver for the detection and processing of Fast Radio Burst with the Dr. Carlos Varsavsky radio telescope

**S. B. Araujo Furlan [1,2], G. E. Romero [1,3], G. Gancio [1]**

*[1] Instituto Argentino de Radioastronomía - CONICET, [2] Facultad de Matemática, Astronomía, Física y Computación – UNC, [3] Facultad de Ciencias Astronómicas y Geofísicas - UNLP*

Thanks to the new generation of digital receivers available at the IAR, developed by the CASPER collaboration (Collaboration for Astronomy Signal Processing and Electronics Research), it is possible to elaborate and implement new techniques for digital signal processing, increasing the observational capabilities and flexibility of the radio telescopes of the IAR.

The present work describes a proposal for the creation of a new high-bandwidth receiver, based on the ROACH (Reconfigurable Open Architecture Computing Hardware) board for the detection and study of the radio transients known as Fast Radio Bursts (FRB). These are extremely rapid (~1ms) flares that occur at cm-wavelengths of unknown origin. FRBs can be identified because they shift in frequency due to the refractive effects of the interstellar medium. Here we describe the hardware that will be used, the software tool-flow already provided by CASPER, as well as the tools developed for the acquisition and processing of the signals.

***Contact:*** *saraujo@iar.unlp.edu.ar*

# FRB 101

Fast Radio Burst (FRB) are millisecond-duration emission pulses. They are similar in some aspects to pulses from radio pulsars (PSR), but their fluxes densities are about ten billion times larger than PSR's, and their spectra are radically different from, those shown by most known radio sources [1]. Like pulsars, the emission from FRB involves coherent radiation [1,2,3,4,5,6]. The first one was discovered on 2007 [2], and since then dozens have been discovered (FRBs' catalog: frbcat.org [7]), and some were observed to repeat [8,9,10]. The nature of FRBs and their source is still a mystery, with their dispersion measurement and sky distribution implying an extragalactic origin [1,11]. Recently an FRB was associated with a local magnetar (SGR 1935+2154) [12,13,14].

The ultra fast variation and randomness of the emission makes them **difficult to be detected**.

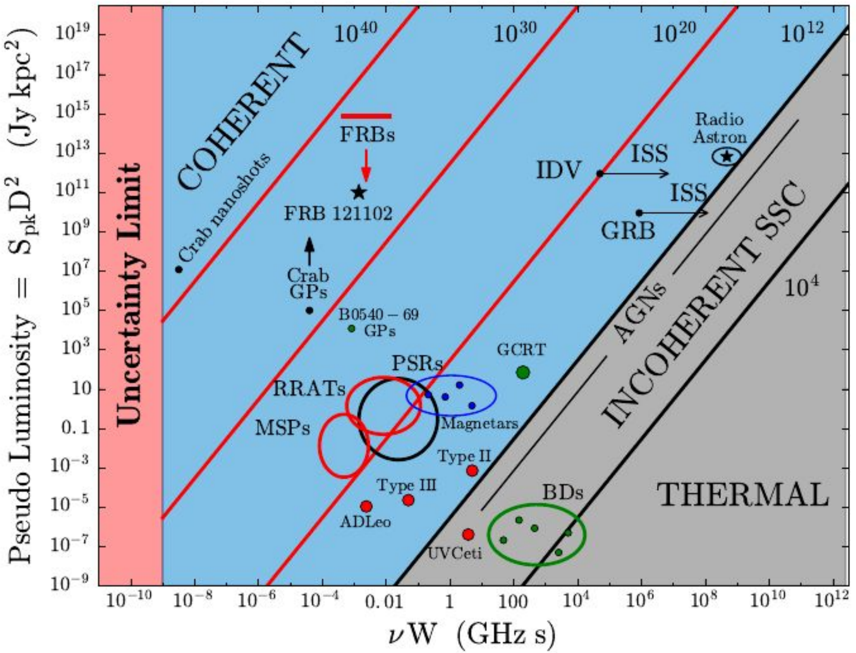
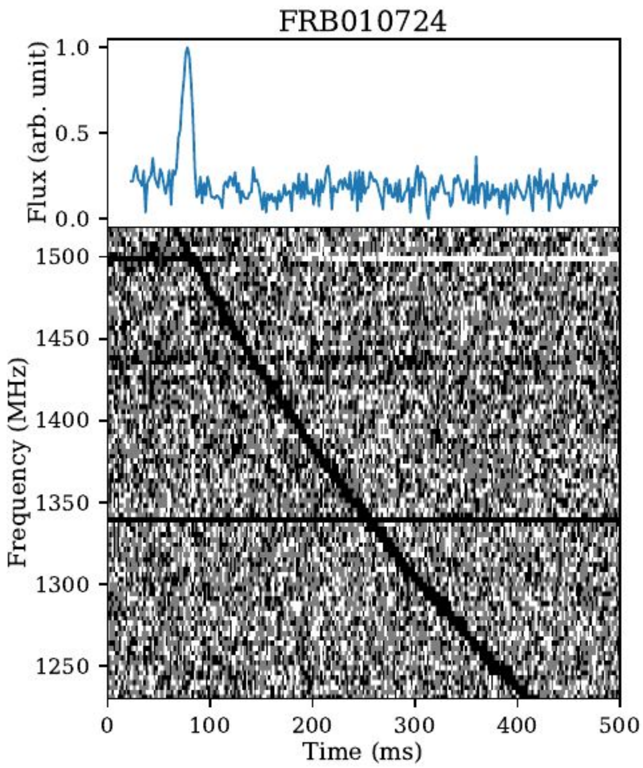



**Fig. 1:**Time-luminosity phase space for radio transients showing the product of peak flux Spk in Jy and the square of the distance D in kpc vs the product of frequency in GHz and pulse width W in s. The diagonals lines represent lines of constant brightness temperature. PSR denote pulsars, GP giant pulsar, MSP millisecond pulsars, RRAT rotating radio transients, GRB gamma ray burst, IDV intra-day variable, ISS interstellar scintillation and GCRT Galactic center transient source. [1]

# How do we detect them?




FRBs are found using data that is very similar to the one used in pulsar surveys, high time resolution spectra (~ 100 μs) with ~ 1000 frequency channels across a total bandwidth of MHz. They are observed at low frequencies, most were discovered predominantly at ~1.5 GHz, but there has been a large number of recent discoveries in the 0.4 – 0.8 GHz band. [1]

They are distinguished because of the **shift in frequency on a scale of ms** that the pulses suffer, which is due to propagation effects of the ISM in the signal.

The technical challenge here is having a telescope that has the right bandwidth to be able to observe the shift, this translates to having a digital receiver with large bandwidth, and few observatories have that capacity nowadays. The observational challenge also includes the randomness of the pulses, because of this, the detection of the events need large observation campaigns in order to detect a FRB.

**Fig. 2:** FRB 010724, the first-reported fast radio burst. The lower panel shows the shift of the burst across the time-frequency plane. The upper panel shows the total pulse intensity after removing the best-fit quadratic dispersion sweep and frequency-averaging across the band. [2]

# Our project

## Objectives

- ➔ Development of a digital receiver of new generation implemented on the Dr. Carlos Varsavsky radio telescope
- ➔ Use and adapt the existing software for FRB identification to implement in observations with the new receiver.
- ➔ Carry out an observation campaign monitoring known magnetars, searching for FRB originating in them.

## The New Receiver

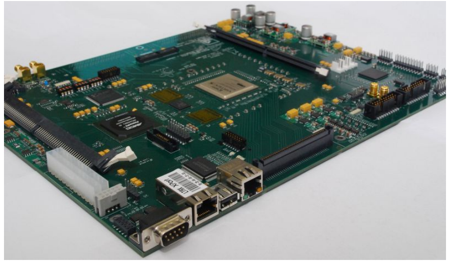


**Fig. 3:** ROACH v1.00

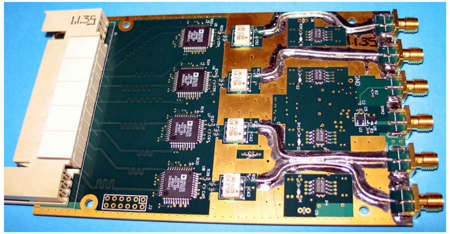


**Fig. 3:** ADC4x250-8

Is based on a FPGA processing board developed by the CASPER collaboration (*Collaboration for Astronomy Signal Processing and Electronics Research*), specifically the **ROACH** (*Reconfigurable Open Architecture Computing Hardware*).
It has a Virtex5 FPGA which is the centerpiece of the board, and a Power PC that runs Linux in order to configure the FPGA. The output is on four CX4 connectors that provide a total of 40 Gbits/sec bandwidth.

In order to provide the signal to the board, a ADC is used, **ADC4x250-8**. Of the 4 IN ports, we will use 2 for both polarizations of the antenna. <u>The ADC will dictate the frequency and the bandwidth</u>.

# The New Receiver

The central frequency of the Dr. Carlos Varsavsky radio telescope is 1420 MHz, and has a down-conversion to an IF of 150 MHz.

⇩

The ADC has a maximum bandwidth of 150 MHz, we will use a **bandwidth of 100 MHz**, so the **frequency range observed** is going to be from **1370 – 1470 MHz**, or in terms of IF 100 – 200 MHz.

⇩

The FPGA will be configured to take high speed spectrums during the observation, in order to have the right frequency-time space.

## CASPER toolflow

The current CASPER toolflow was designed to enable users to quickly and effectively turn high-level digital signal processor (DSP) designs into FPGA bitcode. In order to do so, the user specifies a DSP using Simulink, a MATLAB graphical programming tool. To/from DSP pipelines are specified using CASPER's *xps_library* Simulink blocks. DSP functionality is specified using CASPER's *casper_library*. Then with Xilinx's ISE14.7 the project is generated and can be compile into the FPGA, and delivers to the user *.fpg* file. To configure the FPGA a python library is needed, *casperfpga*, this allows us to interact and program the FPGA board in a very simple way. Finally the design for the DSP has been program to the FPGA and we can access the data that it generates with this library. [15]

# Current Status

★ Now we are in the process of carrying out tests with the ROACH board with the Dr. Carlos Varsavsky radio telescope.

★ Also we are making a first observation campaign with the current receptor. The aim of this campaign is to make a preliminary study of the sources and the process for the data analysis. The magnetars chosen for this were J1550-5418 and J1622-4950. Later on, when the campaign with the ROACH itself is carried out, we expect a better S/N in comparison.

★ In parallel, we are also studying the current FRB's detection software.

# Future work

Carry out the final tests of the new receptor so this can be stablished to the Dr. Carlos Varsavsky radio telescope.

Adapt the current software for FRB's detection to our specification

Make the observation campaign of the south magnetars with the aim of finding FRB within the data of the magnetars radiation.

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