A Search for Radio Transients in the G-ALFA Continuum Transit Survey

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Abstract

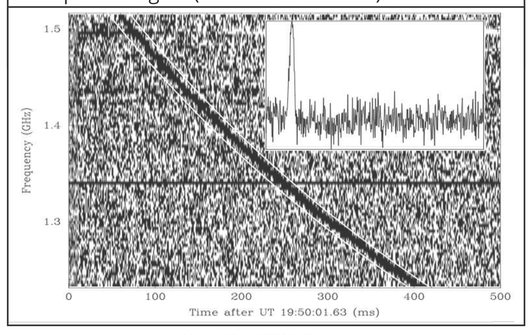
Transient events are signals that change over short time scales, such as pulsars, rotating radio transients (RRATs), and fast radio bursts (FRBs). Pulsars and RRATs are known to be rapidly rotating, highly magnetized neutron stars. However, there are many competing theories and models for the sources of FRBs. Through additional observations of the sky with high time resolution, it is possible to detect more of these extremely short lived events to help validate (or invalidate) some of these models. Using high time resolution data from the G-ALFA Continuum Transit Survey (GALFACTS) made at Arecibo, a standard dedispersion technique was applied to search for candidate radio signals at dispersion measures up to 1000 pc cm^{-3}. From the first 7% of GALFACTS data, 27 known pulsars have been detected by the search method, as well as 4 strong, previously unknown candidate objects. Three of these candidates have dispersion measures and periods consistent with their being pulsars, while the other one seen as just a single pulse and has a dispersion measure consistent with being either an FRB, an RRAT, or a long-period pulsar.

Background

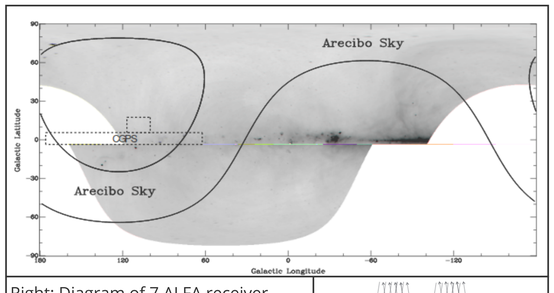
Radio Transients

- Pulsars
  - ► Rapidly rotating neutron stars
  - ► Very steady periods
  - ► Rotating Radio Transients (RRATs)
- Fast Radio Bursts (FRBs)
  - ► Extragalactic radio signals
  - ► 3 of 87 known to repeat, but not known to be periodic
  - ► Unknown source of bursts

First FRB detected, the 'Lorimer Burst'. Plot shows the dispersed signal as detected and the inset shows the dedispersed signal (Lorimer et al. 2007).

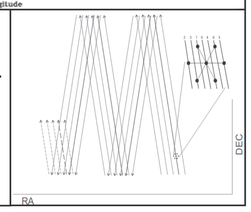


GALFACTS Data



Right: Diagram of 7 ALFA receiver beam tracks during nodding mapping procedure. From Taylor & Salter 2010.

Above: Range of Arecibo Sky transposed to Galactic coordinates. Figure from Taylor & Salter 2010.

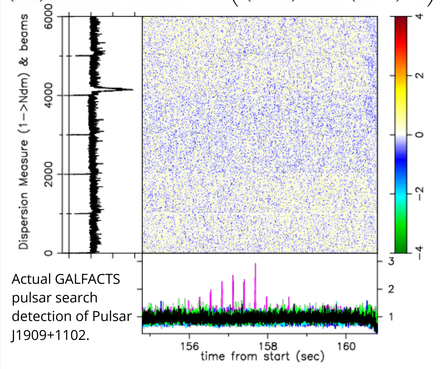


- Hexagonal 7 beam pattern scanned on meridian
- 300 MHz bandpass centered on 1375 MHz
  - ► 256 frequency channels
- 1 ms sample integration time
- All Arecibo sky
  - ► 4 blocks, each 6 hours wide in R.A.
  - ► 3 declination ranges
    - ⊳Northern: 19.8° < δ < 37.8°
    - ⊳Southern: -0.8° < δ < 16.8°
    - ⊳Zenith: 16.3° < δ < 20.3°
- Nodding scans at 1.53 °/min, with 51 s RA delay per day requiring 28 days for full coverage of a survey block.

Recovering The Pulse

Dispersion: Ionized media introduce a frequency-dependent lag to the time of arrival for electromagnetic waves, quantified by the "Dispersion Measure" (DM).

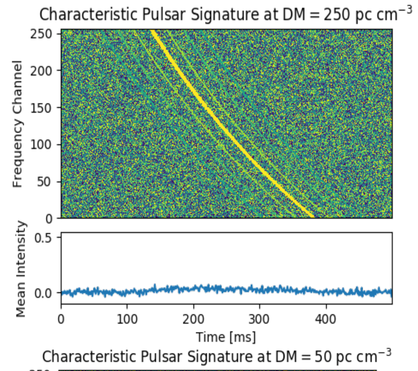
$$\left(\frac{\Delta t}{\text{ms}}\right) = 4.15 \times 10^6 \times DM \times \left(\left(\frac{f}{\text{MHz}}\right)^{-2} - \left(\frac{f_{ref}}{\text{MHz}}\right)^{-2}\right)$$



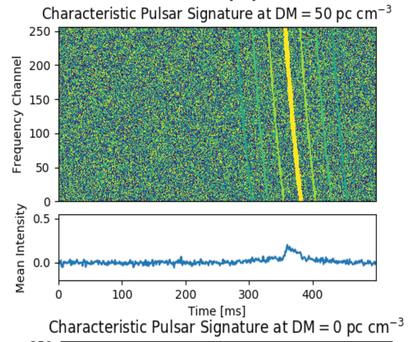
Actual GALFACTS pulsar search detection of Pulsar J1909+1102.

Plots below show the simulated data for 256 frequency channels between 1225 MHz and 1525 MHz at three DM values. Each DM value is a single row of the above plot.

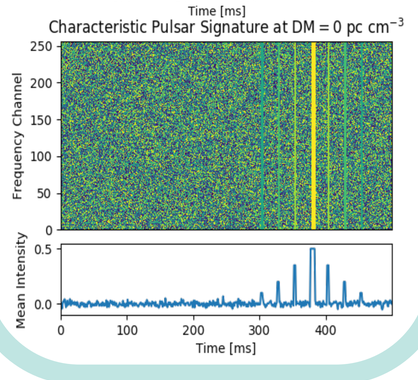
Characteristic Pulsar Signature at DM = 250 pc cm^{-3}



Characteristic Pulsar Signature at DM = 50 pc cm^{-3}

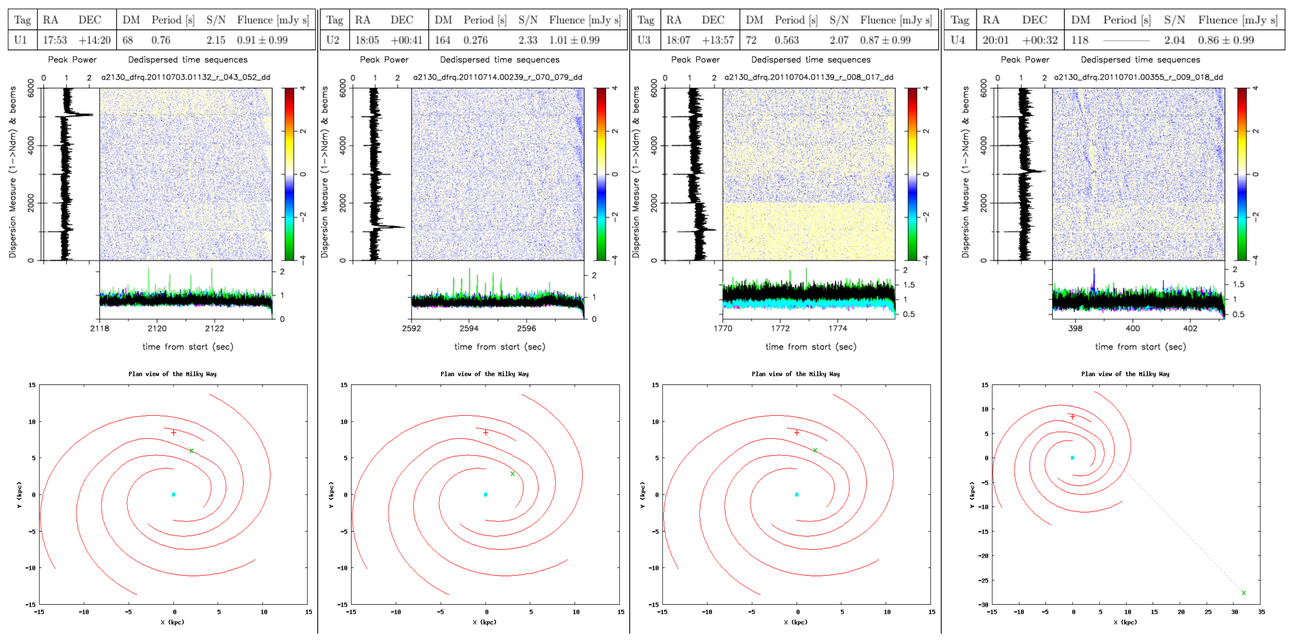


Characteristic Pulsar Signature at DM = 0 pc cm^{-3}

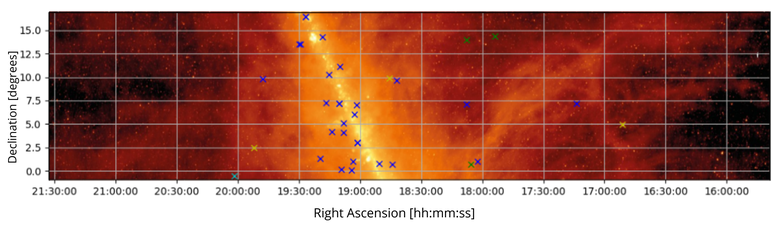


GALFACTS Transient Search Results

- Total of 34 significant signals
  - ► 27 objects matched with entries in Pulsar catalogs
  - ► 3 of these PSRs were detected on up & down scans
  - ► 4 unlisted in major Pulsar, RRAT, or FRB catalogs
- A number of lower significance, but tantalizing, high DM single pulses that will be further examined as potential FRBs/RRATs/long-period pulsars.



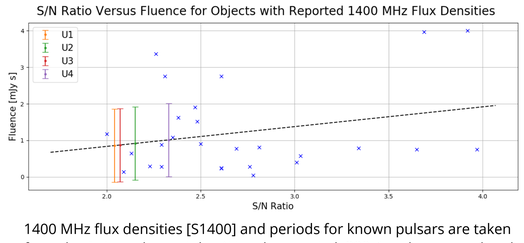
Distance estimates and Milky Way plots obtained via a Galactic free electron density model and tool provided by the Pulsar Search Collaboratory (http://pulsarsearchcollaboratory.com/tools/) (Rosen et al. 2010).



All detected search transients and a few calibration continuum radio sources mapped on a Stokes-I image of the GALFACTS S3. The GALFACTS image was provided by Prof. A. R. Taylor (priv. comm.).

Blue **X**'s mark detected but-known Pulsars, yellow **X**'s mark calibration sources, green **X**'s mark unknown repeating sources, with a cyan **X** marking an unknown single pulse source.

S/N Ratio Versus Fluence for Objects with Reported 1400 MHz Flux Densities



1400 MHz flux densities [S1400] and periods for known pulsars are taken from the ATNF pulsar catalog (Manchester et al. 2005) and compared to the measured signal to noise ratio. A linear fit is used to obtain fluence estimates of unknown objects for future observations.

Moving Forward

1) Follow-up observations of unknown sources

2) Continue processing GALFACTS data

3) Expand DM range from 1000 to 3000+ pc cm^{-3}

4) Improve analysis methods and search pipeline

5) Obtain more accurate measurements

GBT Image from https://i2.wp.com/greenbankobservatory.org/wp-content/uploads/2016/06/DSC_0209.jpg

References and Acknowledgements

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