THE OHIO STATE UNIVERSITY

Feasibility of detecting FRBs with ANITA

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Fast Radio Bursts

- Everything I know, I learned from Wikipedia…

Fast radio burst

From Wikipedia, the free encyclopedia

Not to be confused with Gamma-ray burst.

In radio astronomy, a **fast radio burst** (**FRB**) is a high-energy astrophysical phenomenon of unknown origin manifested as a transient radio pulse lasting only a few milliseconds. The first FRB was discovered by Duncan Lorimer and his student David Narkovic in 2007 when they were looking through archival pulsar survey data, and it is therefore commonly referred to as **Lorimer Burst**. Many FRBs have since been found, including a repeating FRB.[1] The origin of FRB is as yet unclear.

Fast Radio Bursts

Nomenclature [edit]

Fast radio bursts are named by the date the signal was recorded, as "FRB YYMMDD". The first fast radio burst to be described, the Lorimer Burst FRB 010724, was identified in 2007 in archived data recorded by the Parkes Observatory on 24 July 2001. Since then, most known FRBs have been found in previously recorded data. On 19 January 2015, astronomers at Australia's national science agency (CSIRO) reported that a fast radio burst had been observed for the first time live, by the Parkes Observatory.[2]

Fast Radio Bursts

Features [edit]

Fast radio bursts are bright, unresolved (pointsource-like), broadband (spanning a large range of radio frequencies), millisecond flashes found in parts of the sky outside the Milky Way. Unlike many radio sources the signal from a burst is detected in a short period of time with enough strength to stand out from the noise floor. The burst usually appears as a single spike of energy without any change in its strength over time. The bursts last for a period of several milliseconds (thousandths of a second). The bursts come from all over the sky, and are not concentrated on the plane of the Milky Way. Known FRB locations are biased by the parts of the sky that the observatories can image.

Summary of FRB Observations

- Wikipedia lists 23 detected bursts that occurred between 2001 to 2016
- One repeater: FRB 121102 (10 repeat bursts)
  - 2 on May 17th, 2015
  - 8 on June 2nd, 2015
- Didn't see any that occurred during an ANITA flight
- Typical fluences ~few Jy (recall 10^{-26} W/m^2/Hz)
  - Wikipedia list spans 0.3-120 Jy

Multiwavelength searches

- Swift high-energy (15-150 keV) counterpart of FRB131104
- Discovery of a transient gamma-ray counterpart to FRB 131104
  - https://arxiv.org/abs/1611.03139
  - Sub-threshold event (did not trigger the instrument)
  - Association is likely a coincidence
  - If the counterpart were real, it implies problems with the compactness of the source --- difficult for gamma-rays and radio to both escape a compact source (https://arxiv.org/abs/1611.03848)

Possibilities for FRB origin

- - Magnetar flares: https://arxiv.org/abs/0710.2006, https://arxiv.org/abs/1611.03848
- - Pulsars destroying asteroids: https://arxiv.org/abs/1603.08207
- - Weak stellar explosions: https://arxiv.org/abs/1703.06723
- - Extragalactic light sails: https://arxiv.org/abs/

Dispersion measure in astronomy

PULSAR DISPERSION MEASURE

In pulsar **astronomy** a handy quantity is the ***dispersion measure (DM)*** of a pulsar, which manifests itself observationally as a broadening of an otherwise sharp pulse when a pulsar is observed over a finite bandwidth. Technically the ***DM*** is the "integrated column **density** of free **electrons** between an observer and a pulsar". It is perhaps easier to think about dispersion measure representing the number of free electrons between us and the pulsar per unit **area**. So if we could construct a long tube of cross-sectional area 1 square cm and extending from us to the pulsar, the ***DM*** would be proportional to the number of free electrons inside this **volume**.

$$t_2 - t_1 = 4.15 \text{ ms } DM \left[\left(\nu_1 / \text{GHz} \right)^{-2} - \left(\nu_2 / \text{GHz} \right)^{-2} \right]$$

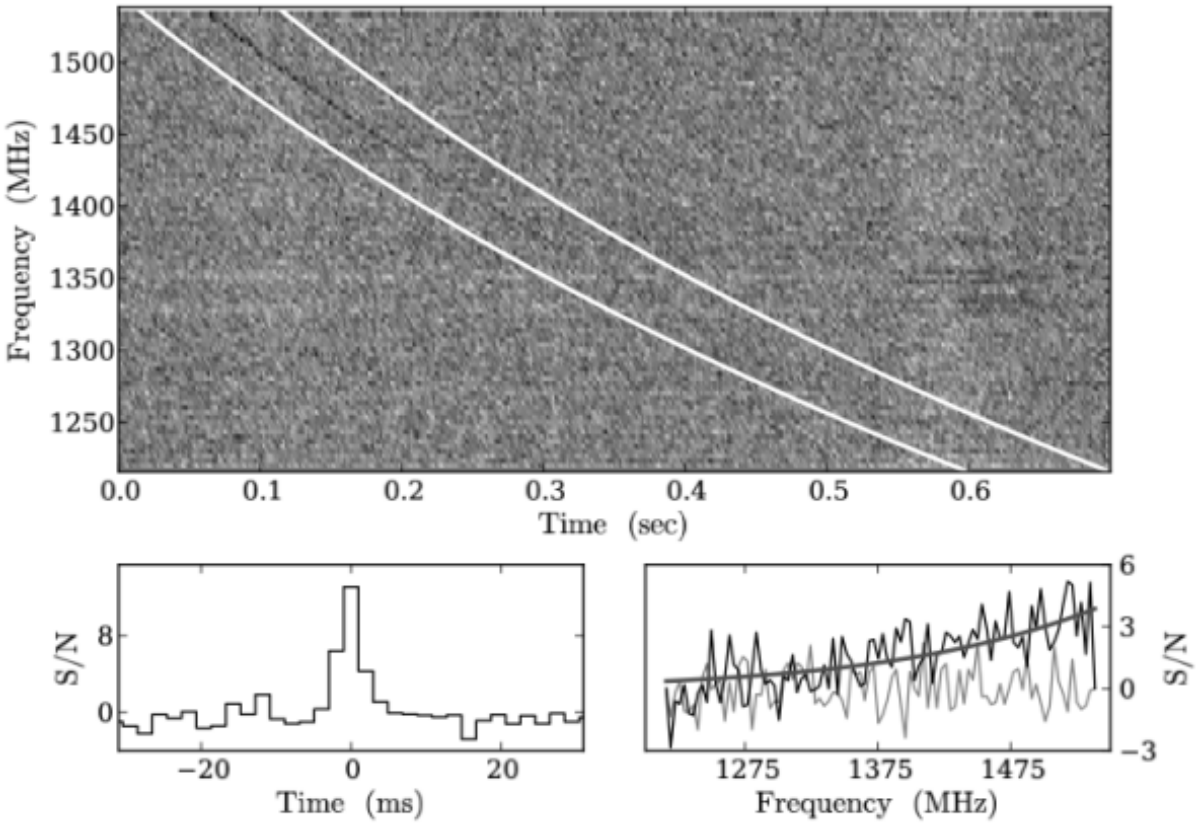
Dispersion measure for FRBs

Dispersion measures can be used in **conjunction** with a model of the **Galaxy**'s free electron density as a **distance** indicator. Dispersion measure is often quoted in the rather peculiar units of **pc** cm^{-3}. This makes it easy to determine the distance to a given pulsar. By knowing the mean electron density n_e in electrons cm^{-3}, the distance ***(D)*** to the pulsar can be computed from the dispersion measure ***DM***.

$$DM = n_e D$$

- DM of FRBs determined to be 100's of pc/cm^3
- Assuming come from extragalactic source
- Assuming not large amount of plasma around point of origin

Characteristic Chirp



Discovery plots of the Fast Radio Burst FRB 121102 made with the Arecibo telescope. The top panel shows the dispersion measure profile; the bottom left shows that strong signal lasting only a few milliseconds; and the bottom right panel shows the pulse versus non-pulse. (Credit: Spitler et al. 2014)

The Karl G. Jansky Very Large Array

Emily/Flickr

Mysterious radio bursts originate outside the Milky Way

By Govert Schilling | Jan. 4, 2017 , 1:00 PM

Fortunately, one discovered in 2012 with the 305-meter radio telescope in Arecibo, Puerto Rico, turned out to repeat at irregular intervals. Known as FRB 121102, its location on the sky has now been monitored for many tens of hours by the National Radio Astronomy Observatory's Karl G. Jansky Very Large Array (VLA) in Socorro, New Mexico (an array of 27 radio dishes), and the European VLBI Network (EVN)—a continent-wide collaboration of radio telescopes.

Between 23 August and 18 September 2016, the VLA detected nine bursts. Those observations, published today in *Nature*, reveal that the location of the bursts coincides with **a faint, remote galaxy** that also hosts a faint, persistent source of radio waves. Four additional bursts from the same source were found on 20 September 2016 by the EVN, which, along with data from the Arecibo dish, helped provide **an even more precise localization** within the galaxy, according to a paper published today in *Astrophysical Journal Letters*.

Using the optical 8.1-meter Gemini North telescope on Mauna Kea in Hawaii, astronomers then managed to determine the galaxy's distance: **more than 3 billion light-years**, as reported in a second paper in the same issue of *Astrophysical Journal Letters*. "Surprisingly, the host galaxy [of FRB 121102] is a puny, star-forming dwarf system," says ASTRON's Cees Bassa, who led the optical observations together with Shriharsh Tendulkar of McGill University in Montreal, Canada. Because dwarf galaxies contain so few stars, this suggests that whatever is responsible for FRB 121102 has a better chance of forming in tiny galaxies than large, spiral ones.

Could ANITA see a cosmic FRB?

- Repeater FRB is 0.4 Jy=4×10^{-25} W/m^2/Hz at 1.4 GHz
- No naively, taking flat spectral index, we'd see:
  - 4×10^{-25} W/m^2/Hz (1m^2) (1000 Hz)= 4×10^{-22} W
  - $P=V^2/R \rightarrow \sqrt{(4 \times 10^{-22}\ W * 50\ \Omega)} = 1.4 \times 10^{-10}$ V.
  - Nope!
- How steep would the spectral index have to be before voltage gets to ~10's x10^{-6} in our band
  - Peter has answers

ANITA's unique role, Part I: Low frequencies

- Most FRB observations are reported at frequencies above our band (≳ 1 GHz)
-

ANITA's unique role, Part II: Wide field of view

- Compare to CHIME

ANITA's unique role, Part III: Nice view of galaxy?

Fancy this…

- Imagine there is a galactic population at low frequencies and they are more common than the cosmic ones at high frequencies

Search for galactic FRBs?

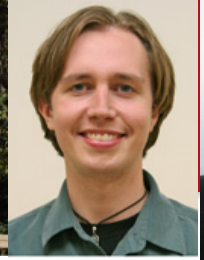
- Tighter chirp due to little or dispersion after leaving source

Buffers

- 120 ns between events in a 4-deep event buffer
- Once 4-deep buffer is filled, 1.5 ms*4 to readout

Looking up

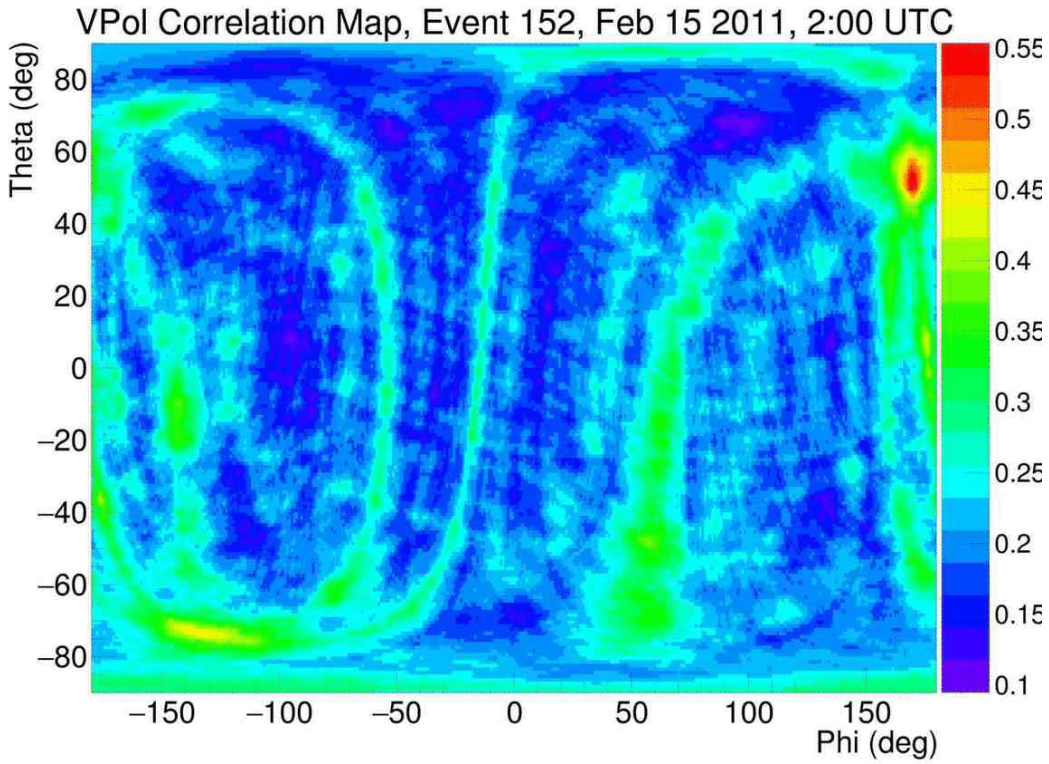
- Just do neutrino search, look up?
- Look for buffer filling up, look for characteristic spectrogram?
- Understanding the sky better is good for understanding neutrino background because stuff reflects off the ice

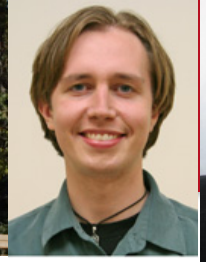

Serendipity: Solar flare Feb 15th, 2011

Eugene Hong
Carl Pfendner
Brian Clark

- ARA Testbed: We found 300 events pointing nicely at the Sun - thousands with cuts loosened
- Nicely reconstruct to the Sun



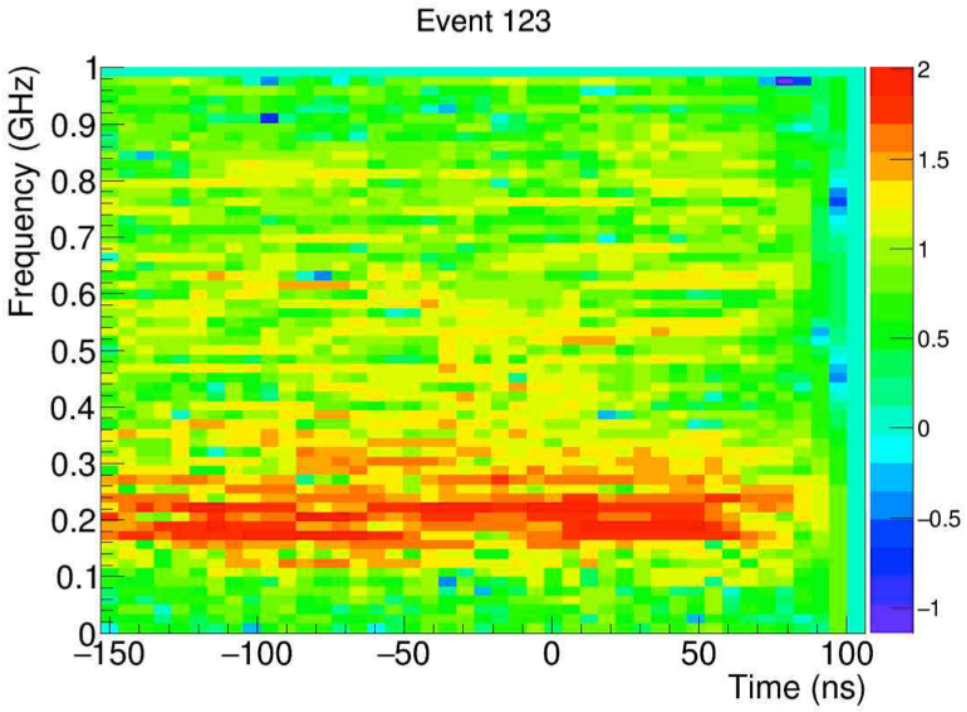
- Not impulsive
- Not CW
- Not thermal
- Paper in the works

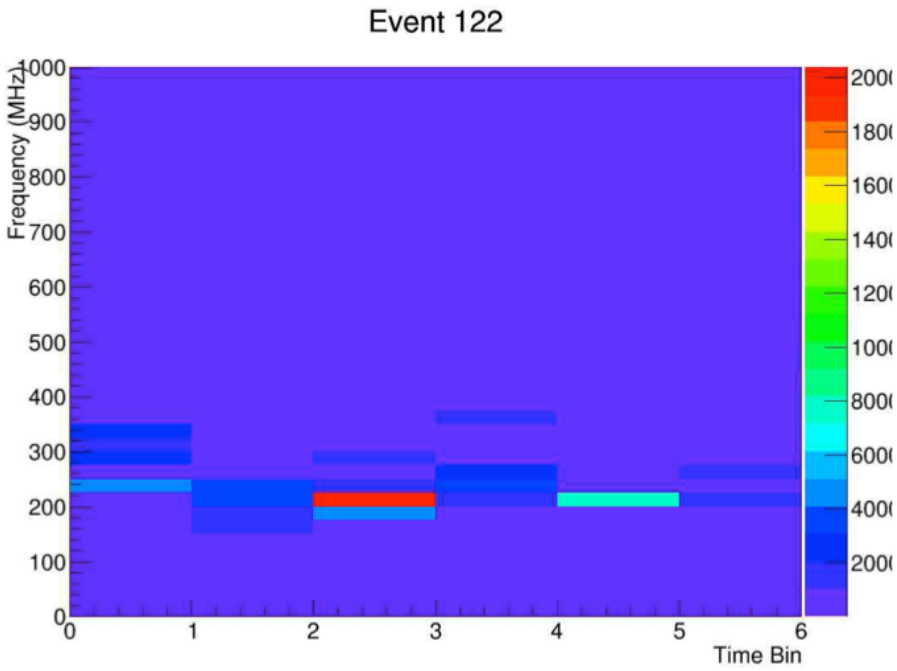




Spectrograms

- Within an event

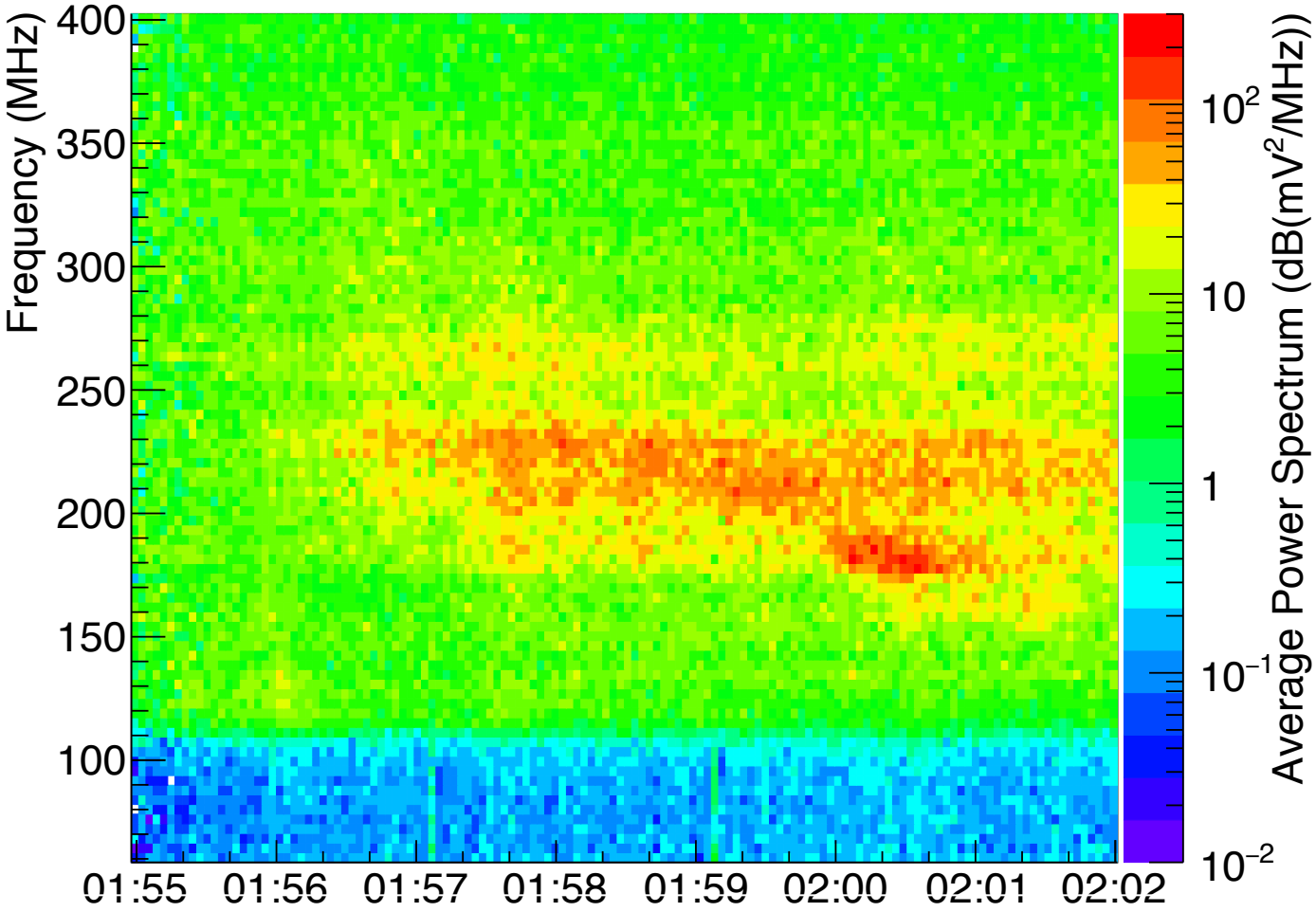
Eugene Hong
Carl Pfendner
Brian Clark





Spectrograms

- Paste together events



Plan

- How it fits with neutrino program
- If we don't find low frequency FRBs,
  - limit on magnetar population in galaxy? determines how many neutron stars with very high B field are formed-> stellar evolution -> why are we here
  - Tell you something about physical conditions at FRB production site
- If you do see low frequency FRBs you can put bounds on compactness of source, on its chances as a CR/nu emitter

Plan

- Take ANITA-II cuts and look up?
- ANITA-I?

Mauricio

- Can he work with us on an FRB search and look at data
- Worked with us on ARA GRB search
- Also excited to help with Oindree's GRB search
- Understands data privacy, etc.