Virginia Tech
Invent the Future

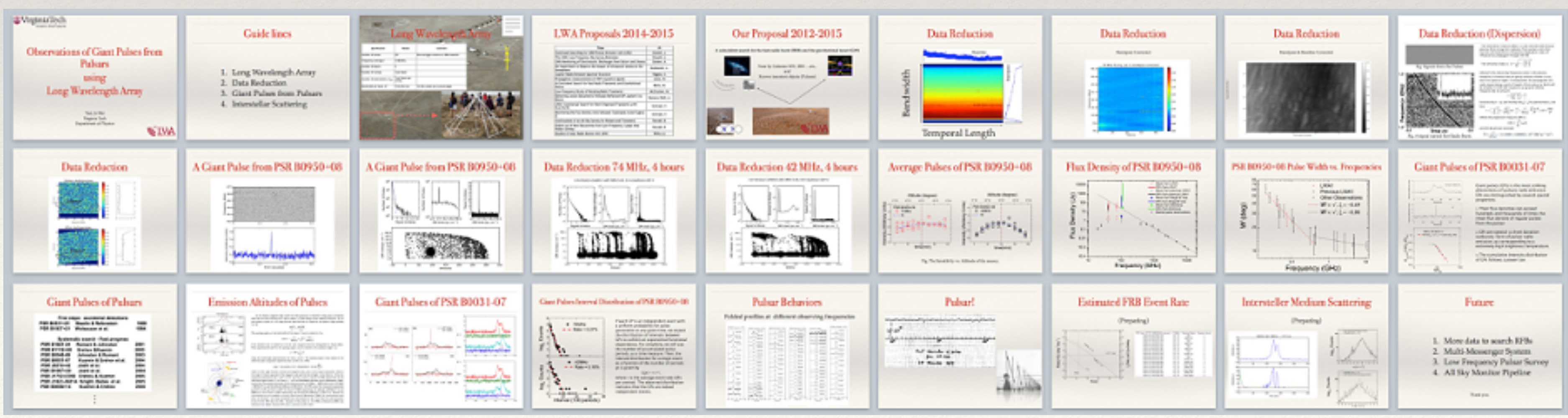
Observations of Giant Pulses from Pulsars using LWA1

Tsai, Jr-Wei
Virginia Tech
Department of Physics

LWA
Long Wavelength Array

Guide Lines

1. Proposal
2. Data Reduction
3. Searching of Radio Transients
4. Giant Pulses from Pulsars



Our LWA Proposal 2012-2016

A coincident search for the fast radio burst (FRB) and the gravitational wave (GW)

Strategies

1. Beamed-Radio Joint Survey
2. GW Triggered Observation
3. All-Sky Joint Survey

"Multi-Messenger Astronomy of Gravitational-Wave Sources with Flexible Wide-Area Radio Transient Surveys"

—APJ, Oct. 2015

On Going

nature International weekly journal of science

Home | News & Comment | Research | Careers & Jobs | Current Issue | Archive | Audio & Video

News & Comment > Column > Muse > 2015 > November > Article

NATURE | COLUMN: MUSE

Alexa Keefe

Has giant LIGO experiment seen gravitational waves?

An improbable rumour has started that the observatory has already made a discovery — but even if true, the signal could be a drill.

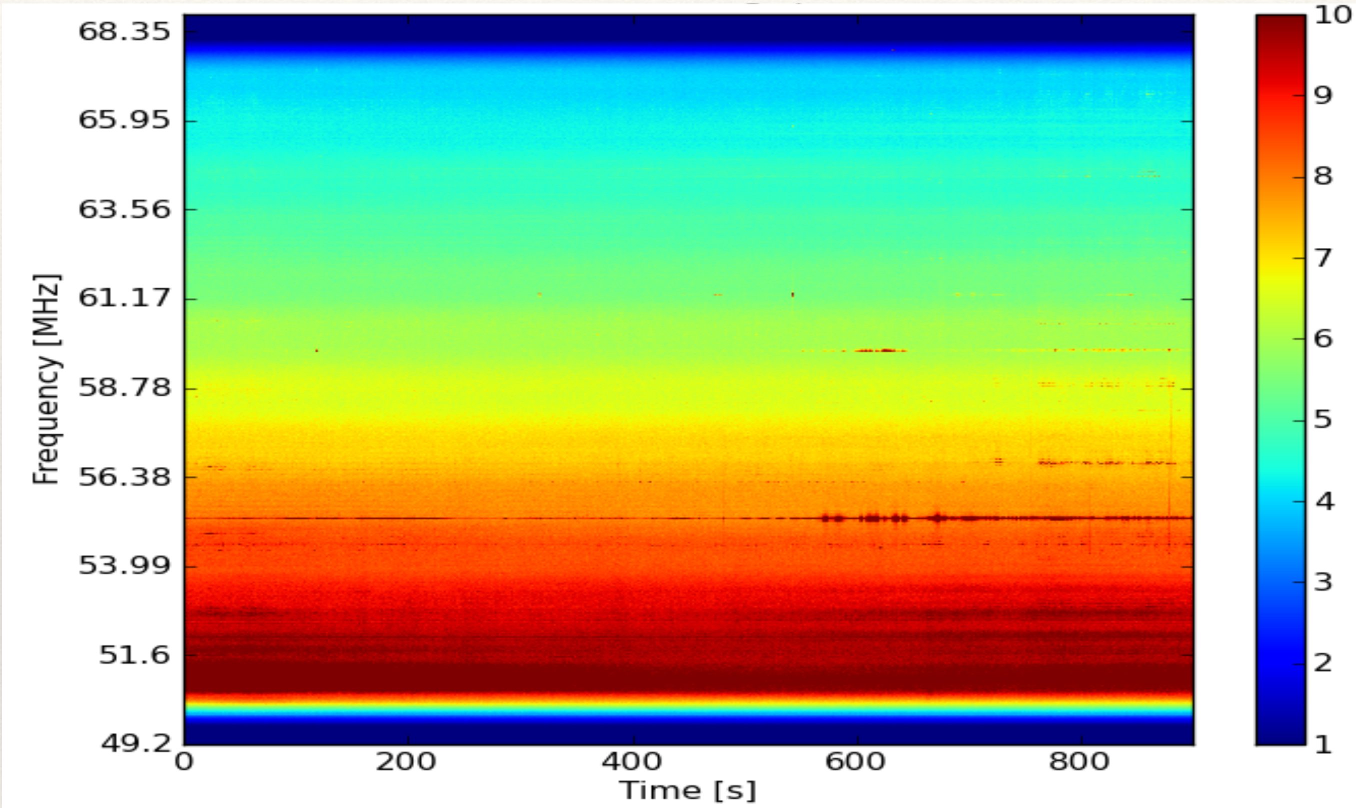
Davide Castelvecchi

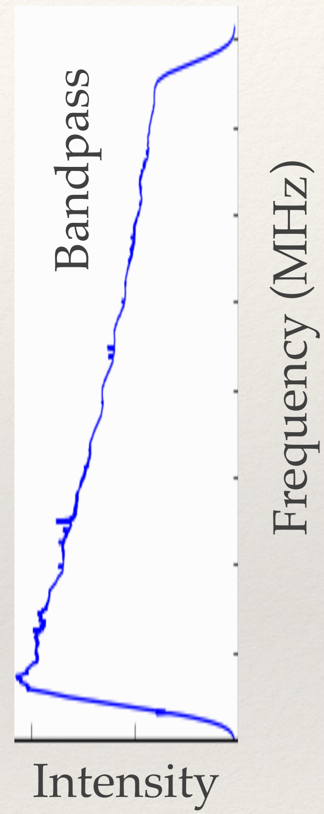
30 September 2015

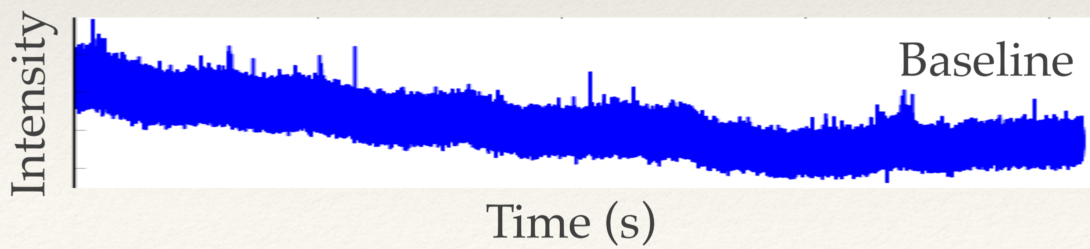
Rights & Permissions

On 25 September, a sensational rumour appeared on Twitter: Lawrence Krauss, a cosmologist, reported hearing that the world's largest gravitational-wave observatory had seen a signal, barely a week after its official re-opening.

Data Reduction

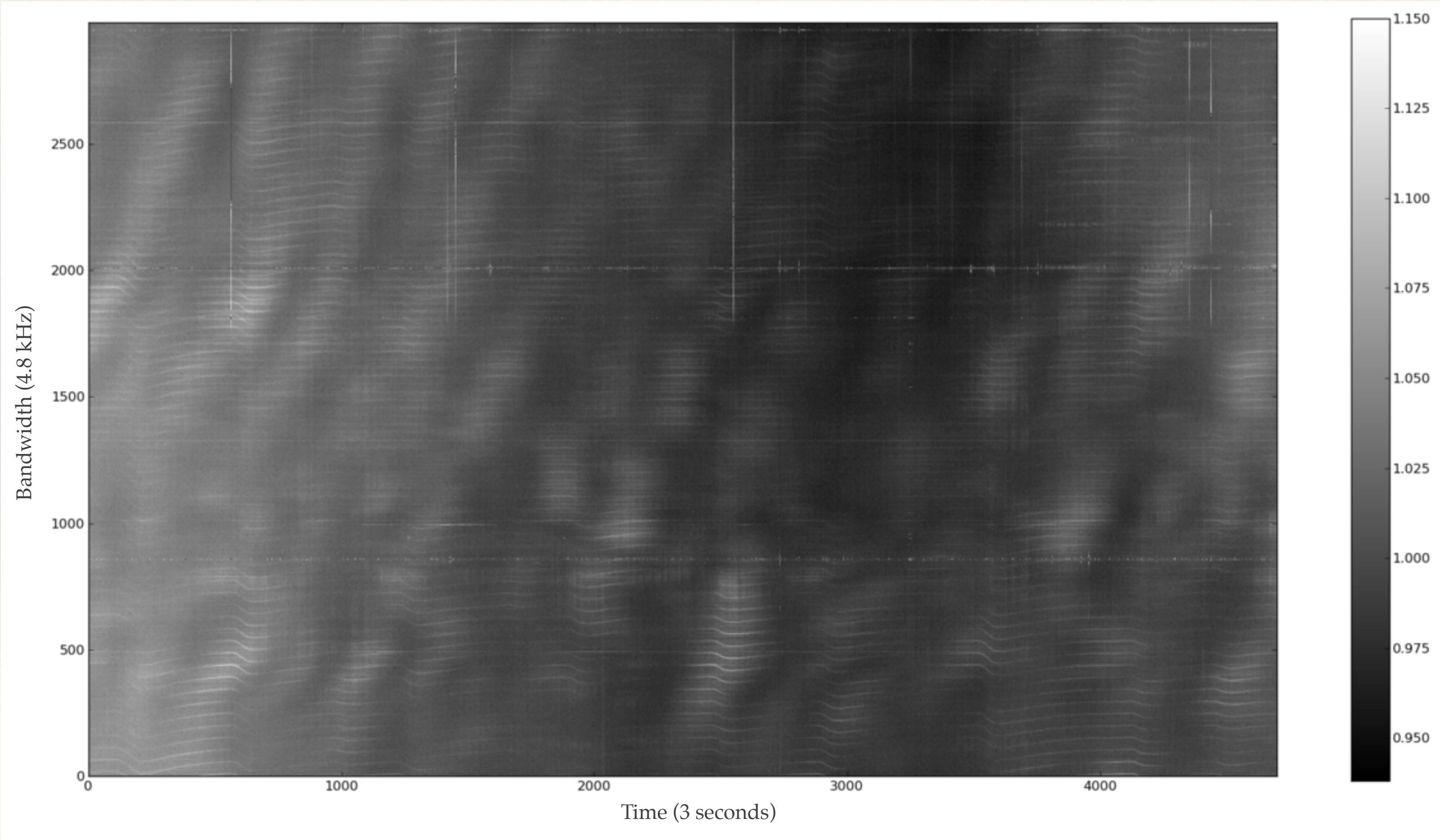






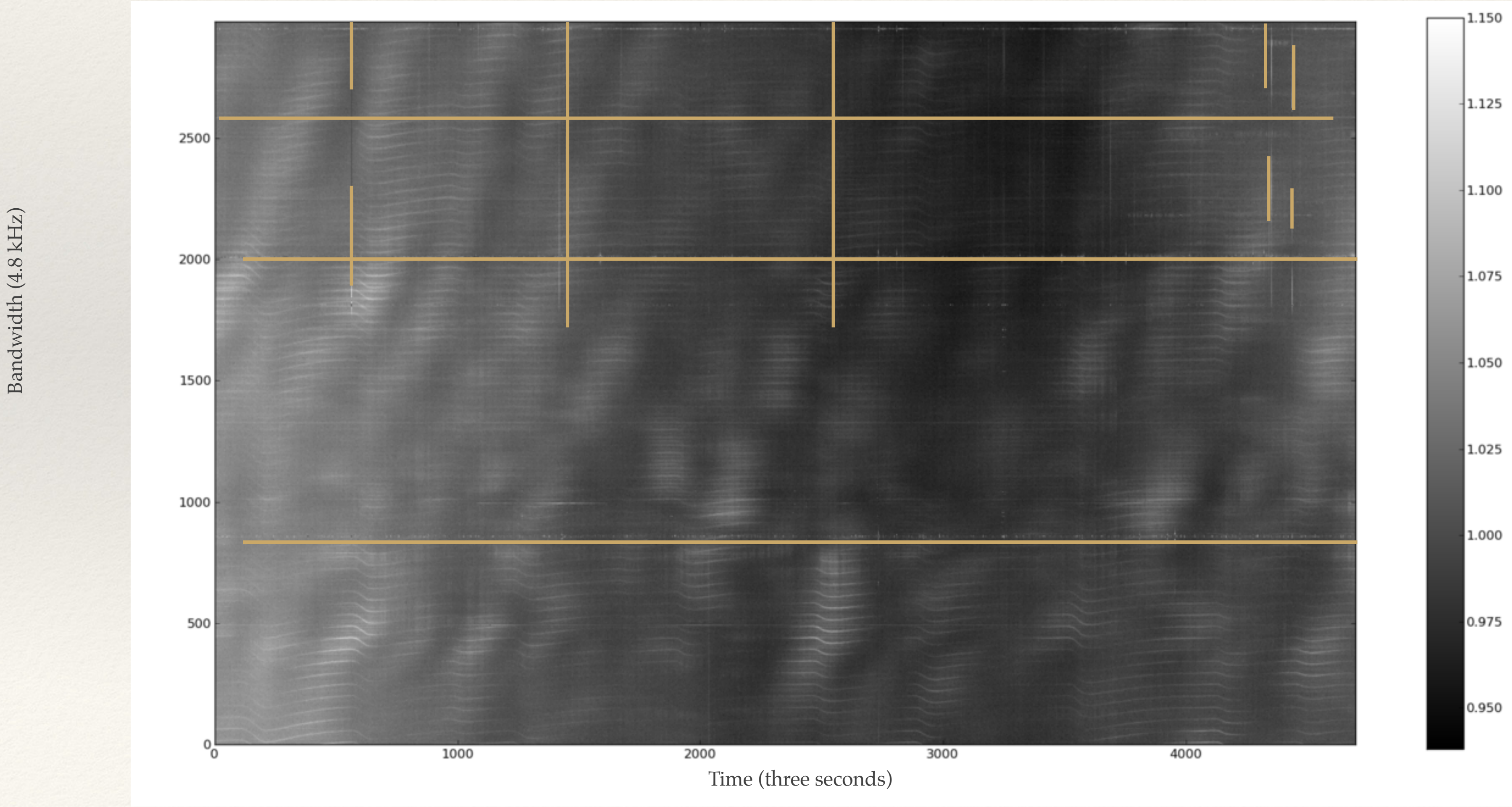
Data Reduction

Bandpass & Baseline Corrected

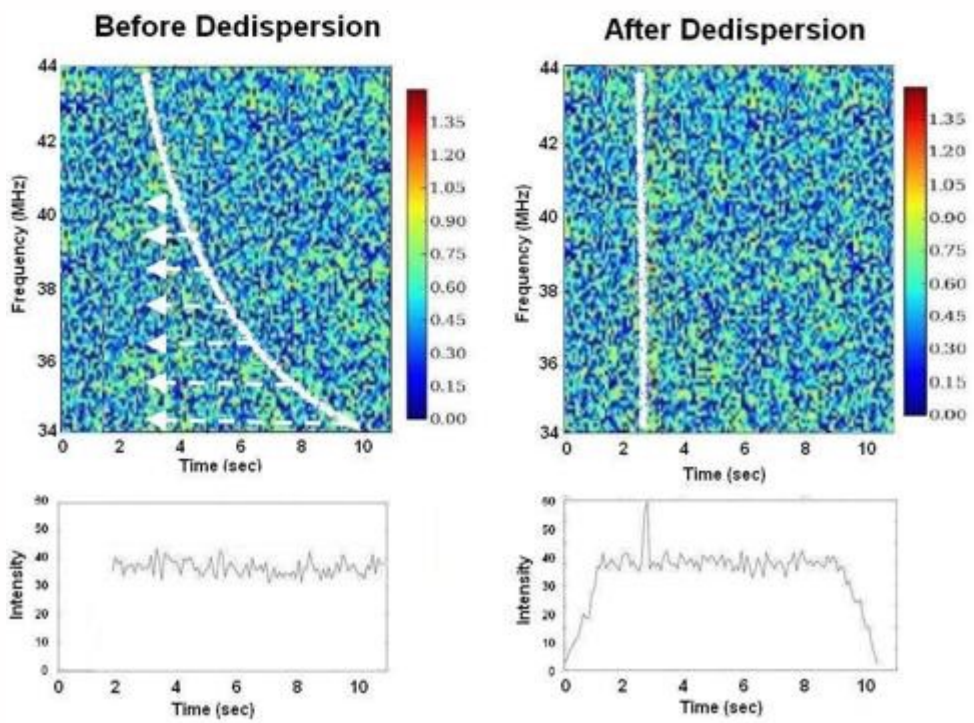


Data Reduction

Bandpass & Baseline Corrected + Radio Frequency Interference Removal



Data Reduction



The interstellar medium (ISM) is a cold, ionized and tenuous plasma. Electromagnetic radiation from pulsars and other sources will experience a frequency-dependent index of refraction as propagate through the ISM.

Then refractive index $\mu = \sqrt{1 - \left(\frac{f_p}{f}\right)^2}$

where f is the observing frequency and f_p is the plasma frequency assuming homogeneity. It follows that the group velocity of wave is less than the speed of light **c**.

Consequently, the propagation of a radio signal along a path of length d from the source to the observer will be delayed in time with respect to a signal of infinite frequency by an amount

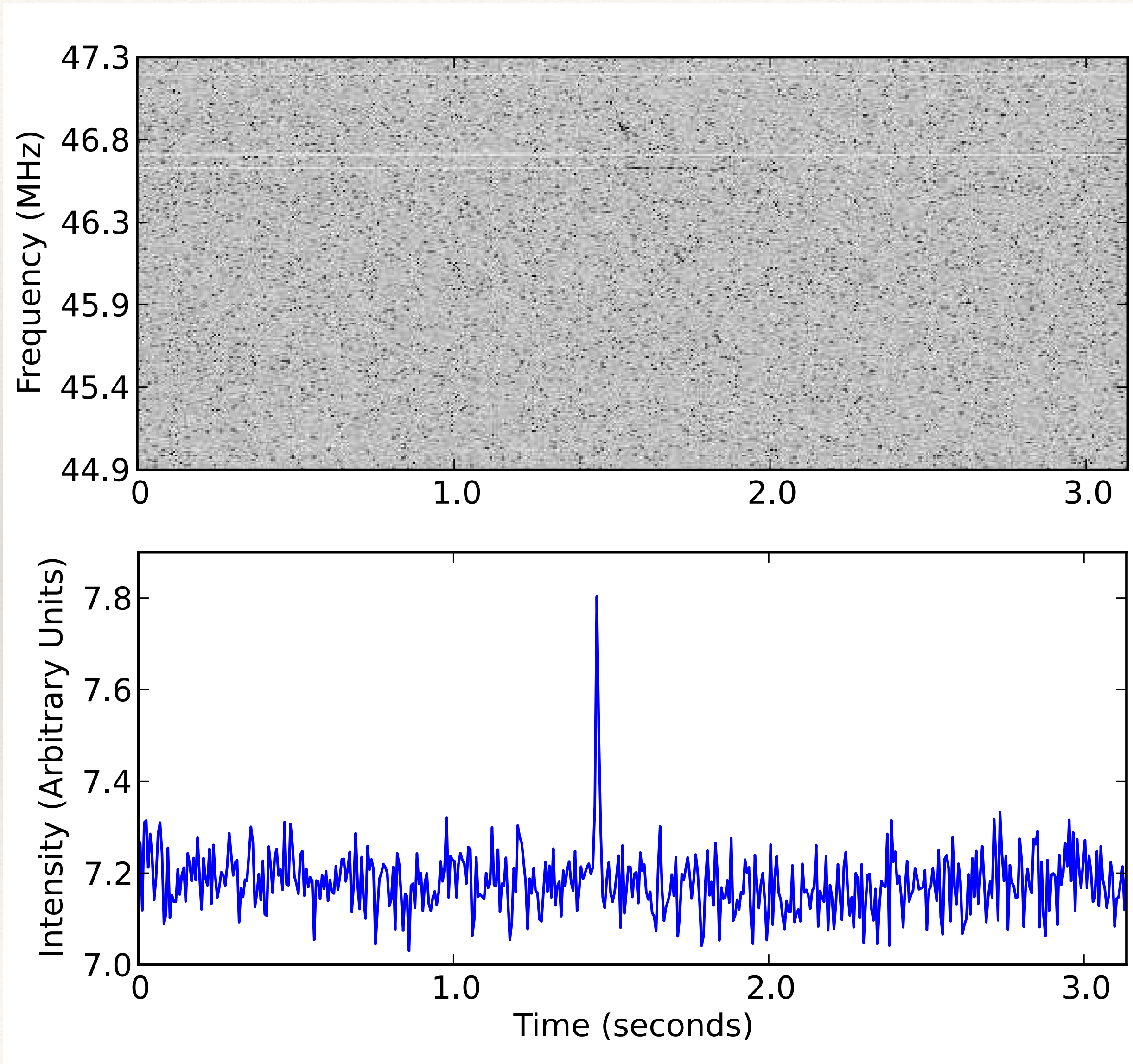
$$t = \left(\int_0^d \frac{dl}{v_g}\right) - \frac{d}{c}.$$

Substituting the group velocity v_g with **c**μ, and noting that $f_p \ll f$ to approximate μ, we find the time delay Δt as

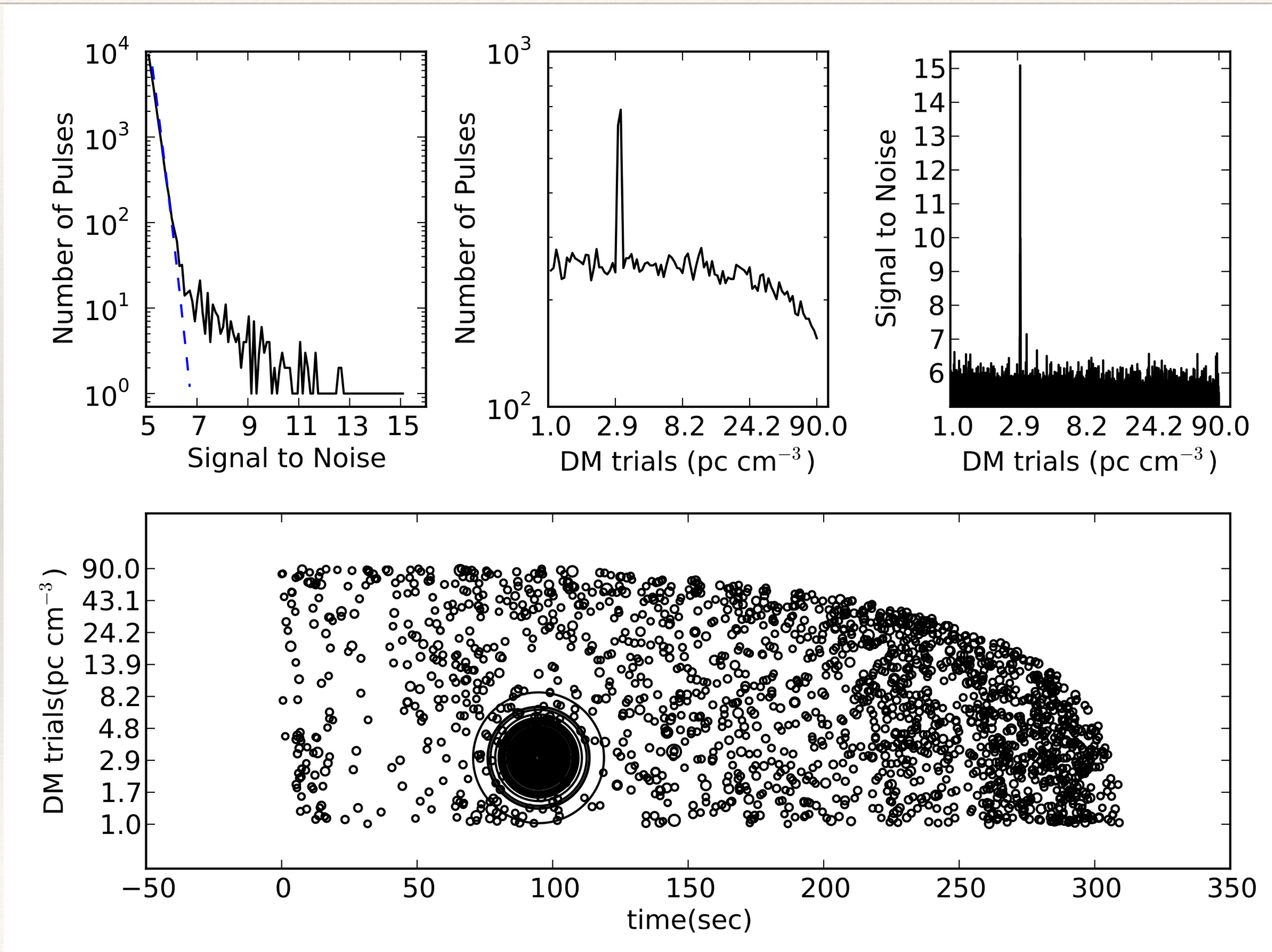
$$\Delta t \approx 2.6\text{s} \times DM_{\text{pc cm}^{-3}} \times (\nu / 40\text{MHz})^{-2},$$

where the DM is the dispersion measure – the electron number density integrated within the distant from source to observer.

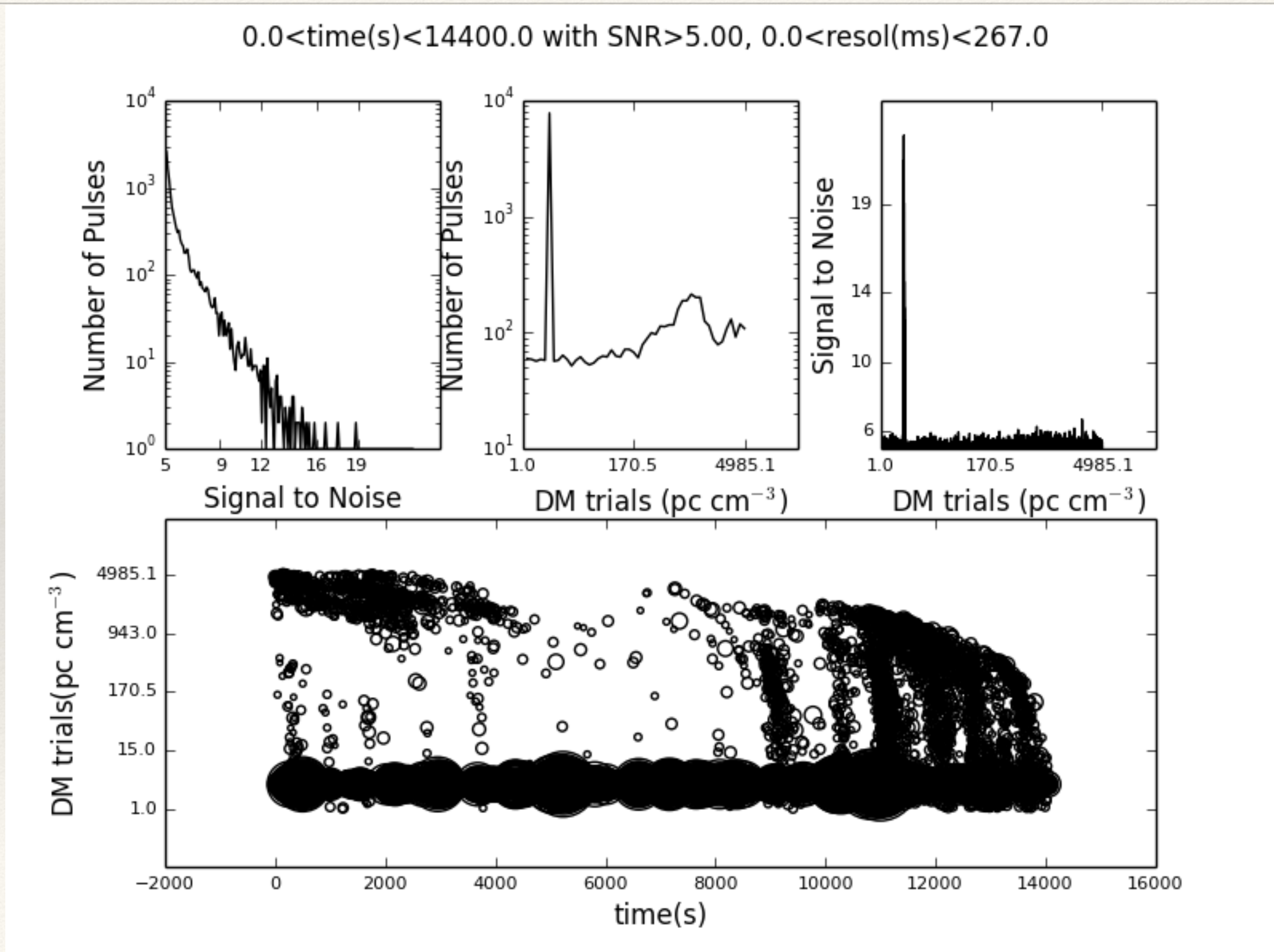
A Giant Pulse of PSR B0950+08



A Giant Pulse from PSR B0950+08



Data Reduction 42 MHz, 4 hours

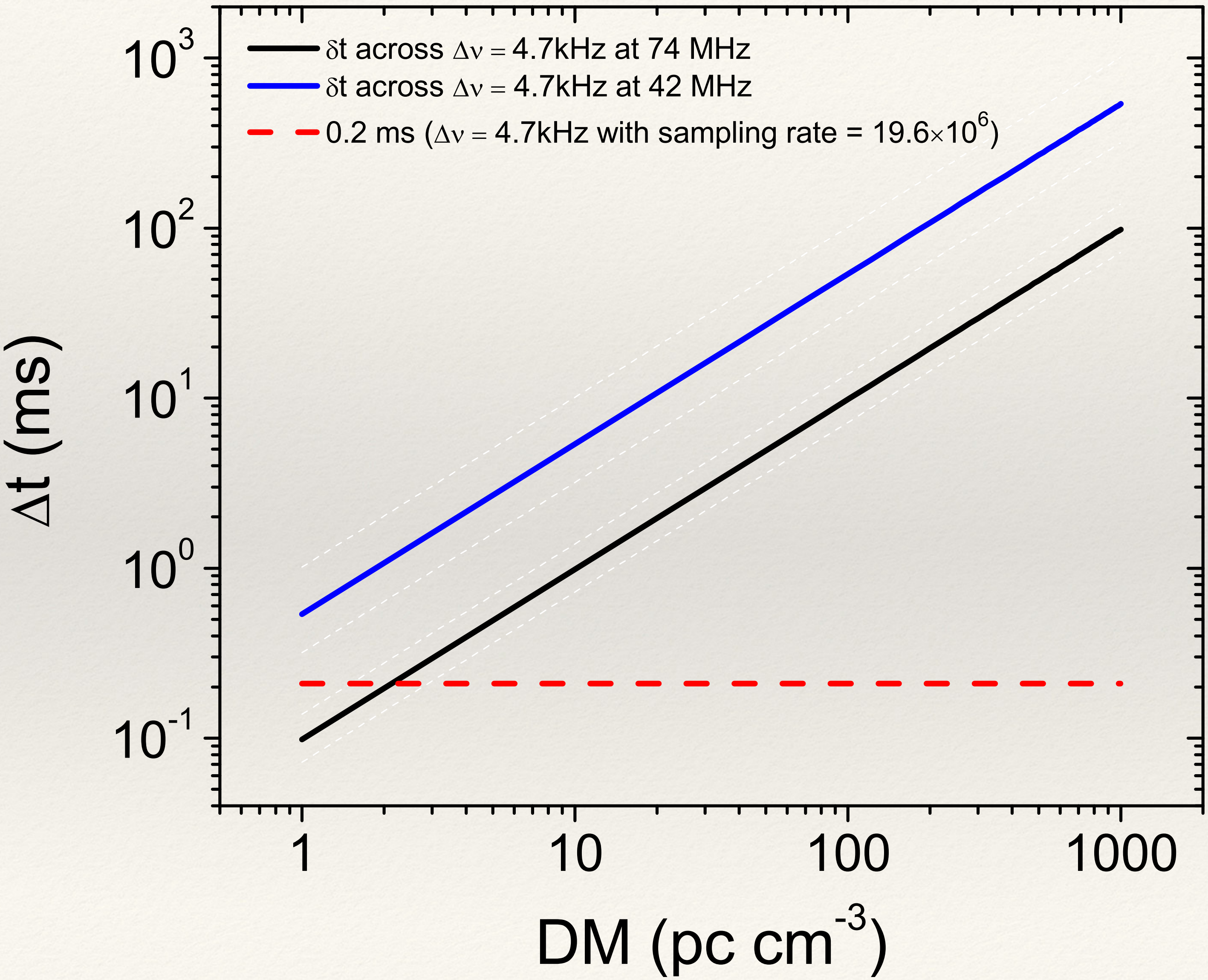


The Upper Limit of the FRB Event Rate

UTC time (YYYY/MM/DD/hr:min:sec)	f (MHz)	Tracking Object	Duration (hour)
2013 07 26 09:37:08.182	38 , 74	M31	4
2013 07 26 09:37:08.183	38 , 74	B0031-07	4
2013 07 27 09:33:12.273	38 , 74	M31	4
2013 07 27 09:33:12.274	38 , 74	B0031-07	4
2013 07 28 09:29:16.364	38 , 74	M31	4
2013 07 28 09:29:16.365	38 , 74	B0031-07	4
2013 09 21 03:48:12.273	45 , 74	M31	4
2013 09 21 03:48:12.273	45 , 74	B1937+21	4
2013 09 22 03:44:16.364	45 , 74	M31	4
2013 09 22 03:44:16.364	45 , 74	B1937+21	4
2014 01 25 06:45:00.000	42 , 74	B0950+08	4
2014 01 25 06:45:00.000	42 , 74	Ursa Major	4
2014 01 26 06:41:04.091	42 , 74	B0950+08	4
2014 01 26 06:41:04.091	42 , 74	Ursa Major	4
2014 01 27 06:37:08.182	42 , 74	B0950+08	4
2014 01 27 06:37:08.182	42 , 74	Ursa Major	4
2015 04 27 02:15:00.000	42 , 74	B1112+50	4
2015 04 27 01:00:00.000	42 , 74	M81	4
2015 04 28 02:11:00.000	42 , 74	B1112+50	4
2015 04 28 00:56:00.000	42 , 74	M81	4
2015 04 29 02:07:00.000	42 , 74	B1112+50	4
2015 04 29 00:52:00.000	42 , 74	M81	4
2015 04 30 02:03:00.000	42 , 74	B1112+50	4
2015 04 30 00:48:00.000	42 , 74	M81	4

Assuming a typical zenith angle of 30°, this gives a FWHM of 5.7° at 38MHz, which corresponds to an area of ~26 deg^2 for each beam. In addition to synthesized beams, we have no FRB detection with S/N threshold > 7 from 96 hours of beam tracking observation from LWA1, with dispersion measure trials from 1 to 5000 pc cm^{-3}. Our observation gave a upper FRB event rate < 4.0×10^2 day^{-1} sky^{-1}, or 4.1×10^{-4} hr^{-1} deg^{-2} at 38 MHz.

The Temporal Smearing Across a Channel



Know Pulsars with Giant Pulses

First steps - accidental detections

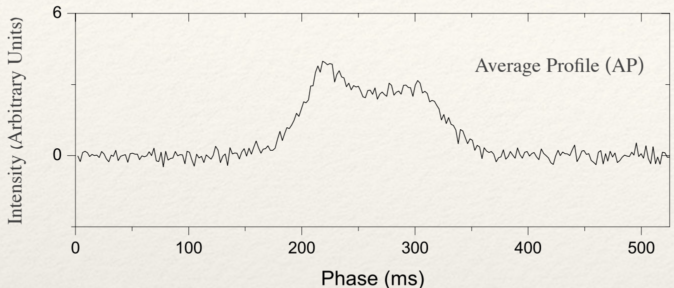
PSR B0531+21	Staelin & Refenstein	1968
PSR B1937+21	Wolszczan et al.	1984

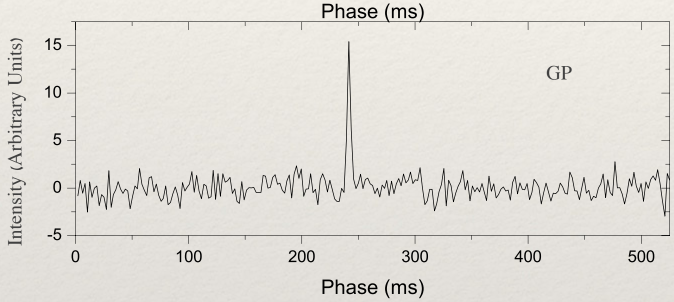
Systematic search - Fast progress

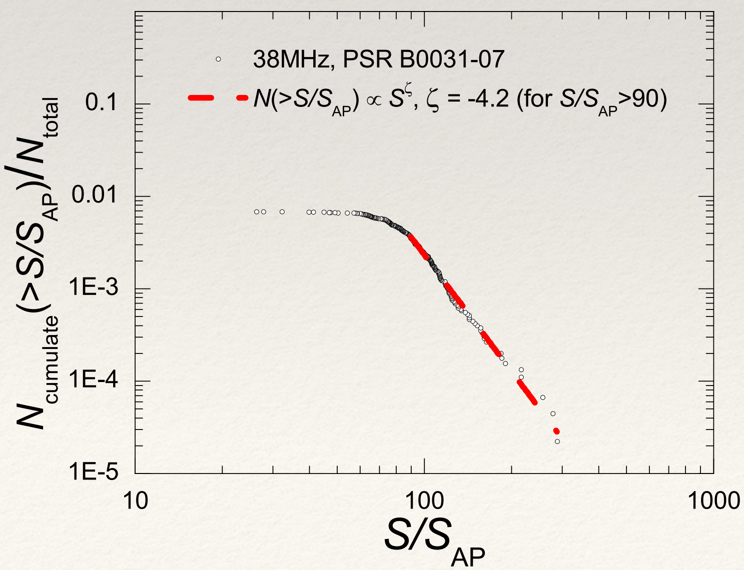
PSR B1821-24	Romani & Johnston	2001
PSR B1112+50	Ershov &Kuzmin	2003
PSR B0540-69	Johnston & Romani	2003
PSR B0031-07	Kuzmin & Ershov et al.	2004
PSR J0218+42	Joshi et al.	2004
PSR B1957+20	Joshi et al.	2004
PSR J1752+2359	Ershov & Kuzmin	2005
PSR J1823-3021A	Knight, Bailes et al.	2005
PSR B0656+14	Kuzmin & Ershov	2006

⋮

Giant Pulses of Pulsars







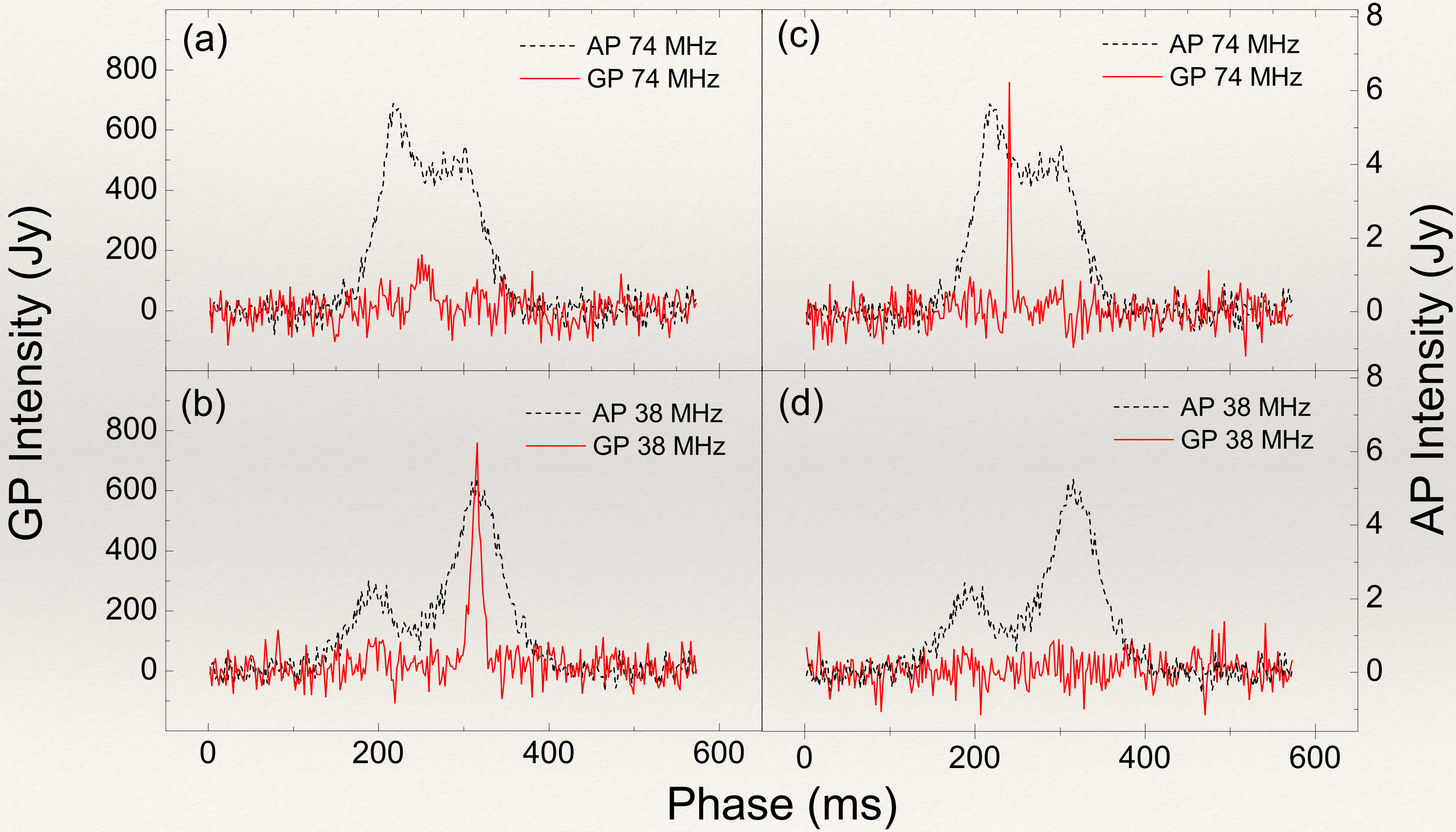
Giant pulses (GPs) is the most striking phenomena of pulsars radio emission. GPs are distinguished by several special properties:

1. Their flux densities can exceed thousands of times the mean flux density of regular pulses from the pulsar.

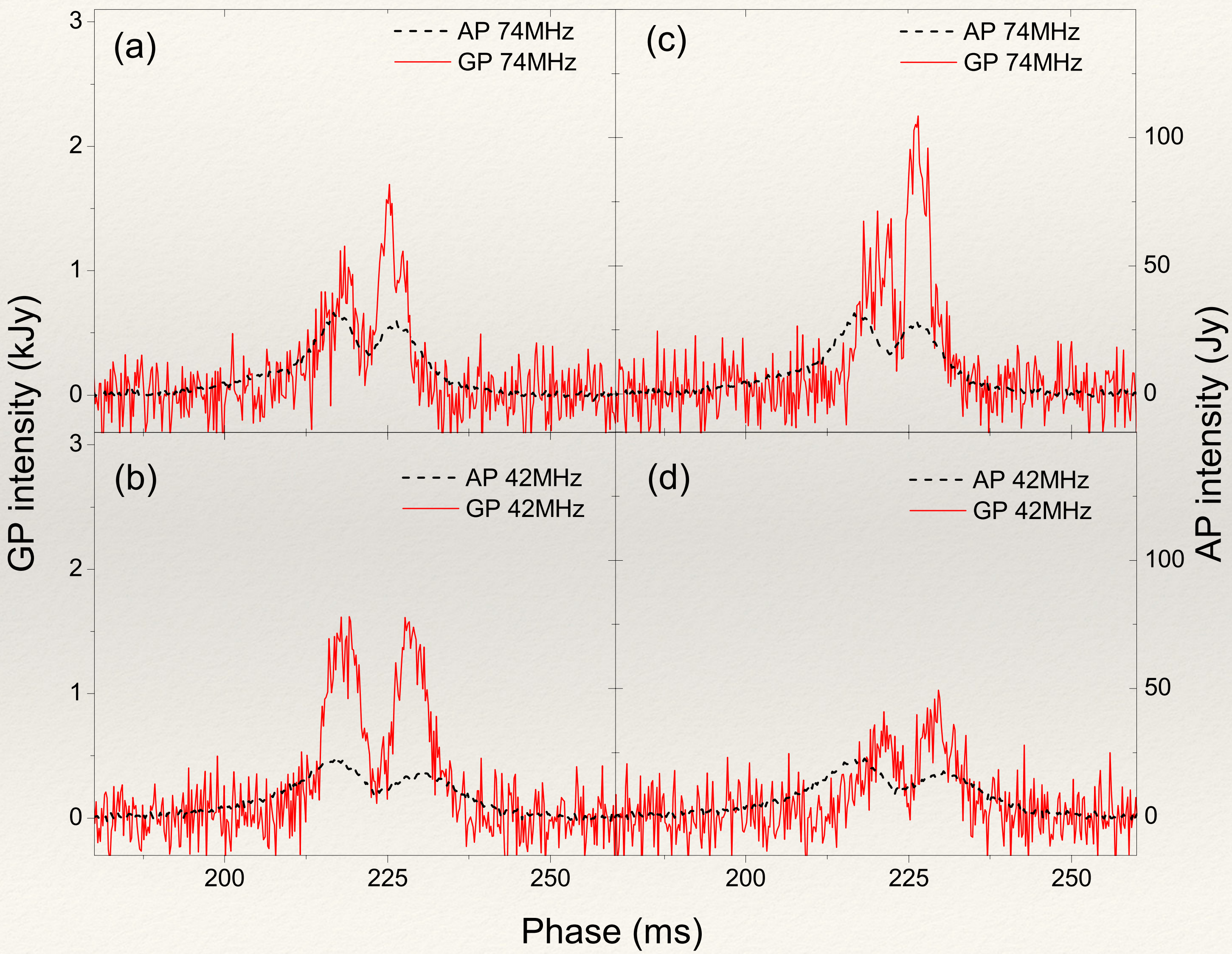
2. GPs are special short duration outbursts of pulsar radio emission, as corresponding to an extremely high brightness temperature.

3. The cumulative intensity distribution of GPs follows a power-law.

Giant Pulses of PSR B0031-07

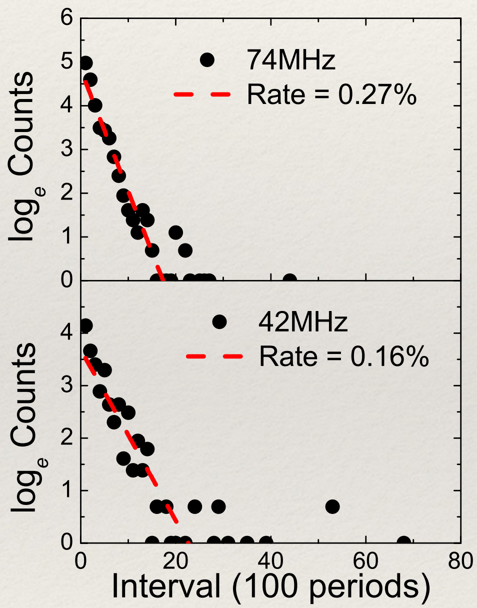


Giant Pulses of PSR B0950+08

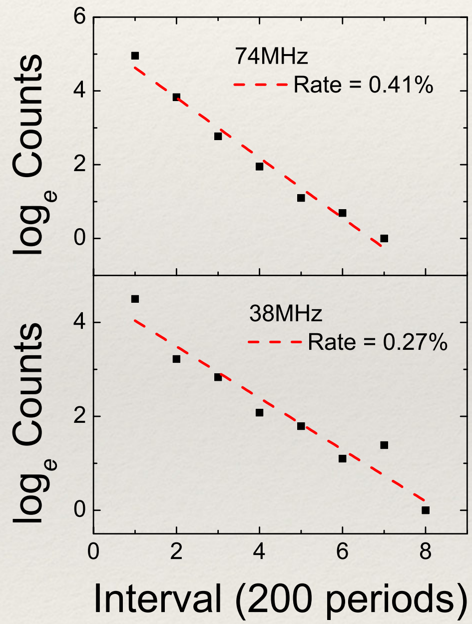


Randomness of Giant Pulses

PSR B0950+08



PSR B0031-07



If each GP is an independent event with a uniform probability for pulse generation at any given time, we expect the distribution of intervals between GPs to exhibit an exponential functional dependence. For simplicity, we will use the number of accumulated pulse periods, as a time measure. Then, the interval distribution for a single event as a function of the number of periods (p) is given by

$$I_1(p) = r\, e^{-r\,p},$$

where r is the average event rate (GPs per period). The observed distribution indicates that the GPs are indeed independent events.

Summary

1. We had zero events with SNR > 7σ at dispersion measure trials from 1 to 5000 pc cm^{-3}, covering 96 hours of observation with a mean FOV < 5.7° (Ellingson et al. 2013b) using LWA1; which gives an upper FRB(S>166Jy) rate of 4.1×10^{-4} hr^{-1} deg^{-2} or 16 day^{-1} sky^{-1}.
2. We measure the intensity and pulse width of average pulses from PSR B0950+08 and PSR B0031-07; those results are comparable with other observations with similar observing frequencies.
3. We observed giant pulses from PSR B0950+08 and PSR B0031-07, and confirmed that giant pulses are independent events for pulse generation at given times for both pulsars.
4. The giant pulses show a narrow band behavior, and the phase time shifts within the range of average pulse's profile.

"Simultaneous Observations of Giant Pulses from Pulsar PSR B0031-07 at 38 MHz and 74 MHz"
submitted, September, 2015

"Simultaneous Observations of Giant Pulses from Pulsar PSR B0950+08 at 42 MHz and 74 MHz"
submitted, August, 2015

"Observations of Giant Pulses from Pulsar B0950+08 using LWA1"
Astronomical Journal, January 19th, 2015

Future

1. More data to search for FRBs
2. Multi-Messenger System
3. Low Frequency Pulsar Survey
4. All Sky Monitor Pipeline

Thank you.