
FRBs and Serendipity
Matthew Bailes
Swinburne University of Technology
ARC Laureate Fellow
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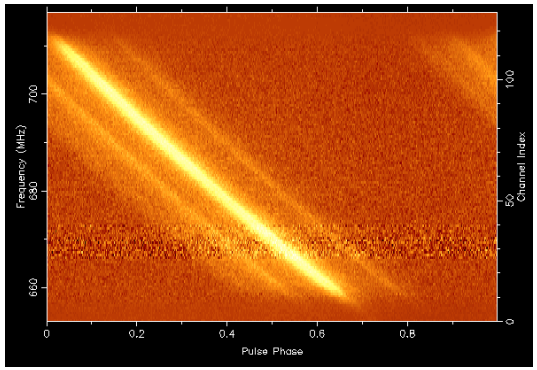
FRB Discovery

- 1967: Early Days (Hewish et al. 1968)
  - Chart recorders and repeated single pulses
- 1974: Filterbanks + Computers (Hulse & Taylor 1975)
  - FFT allowed large integration times, bandwidths
- 1982: MSPs (Backer et al. 1982)
  - Finer filters and more computers
- 2006: RRATs (McLaughlin et al. 2006)
  - Single pulsed “pulsars”



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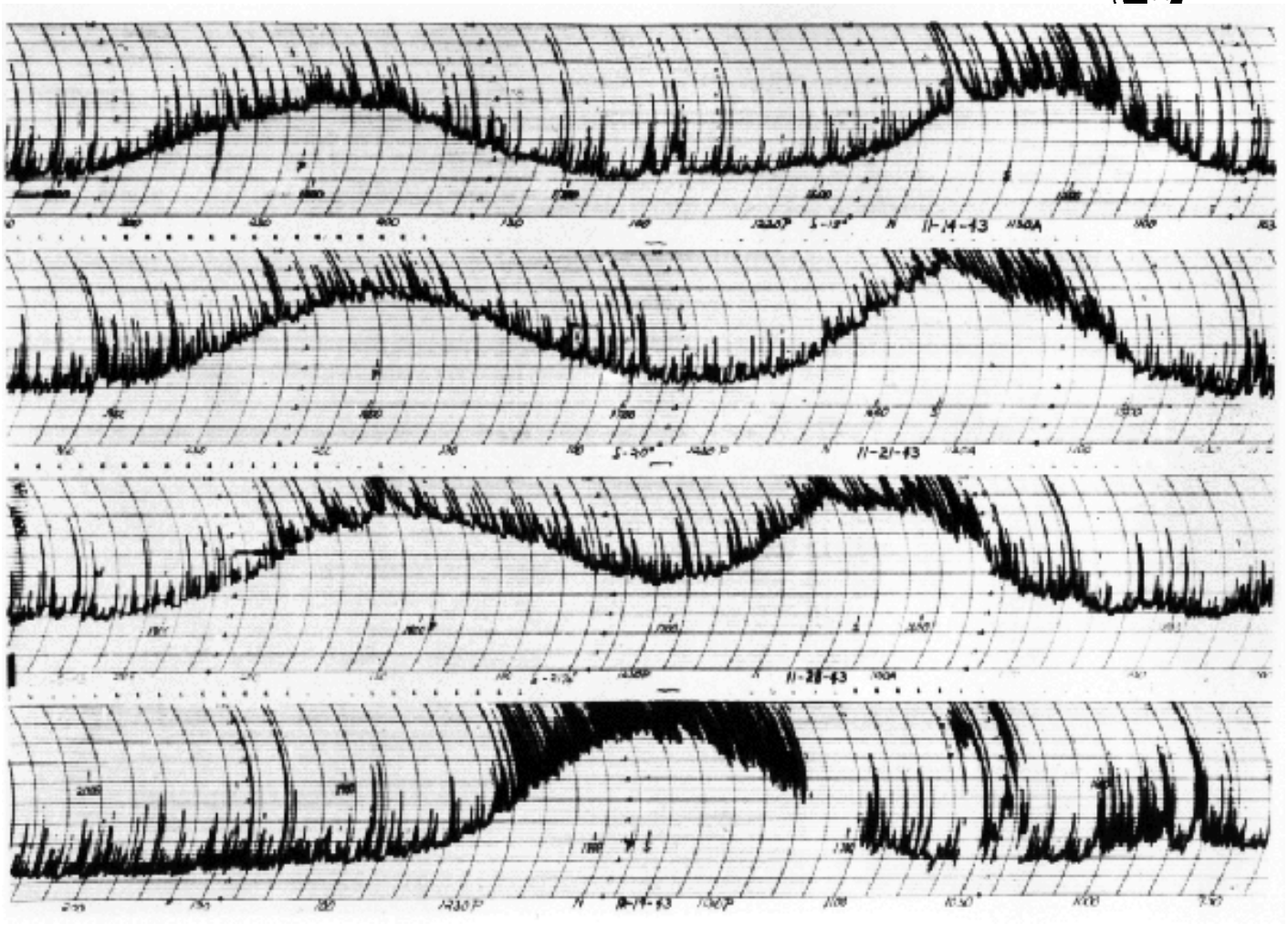
Grote Reber's Radio Data



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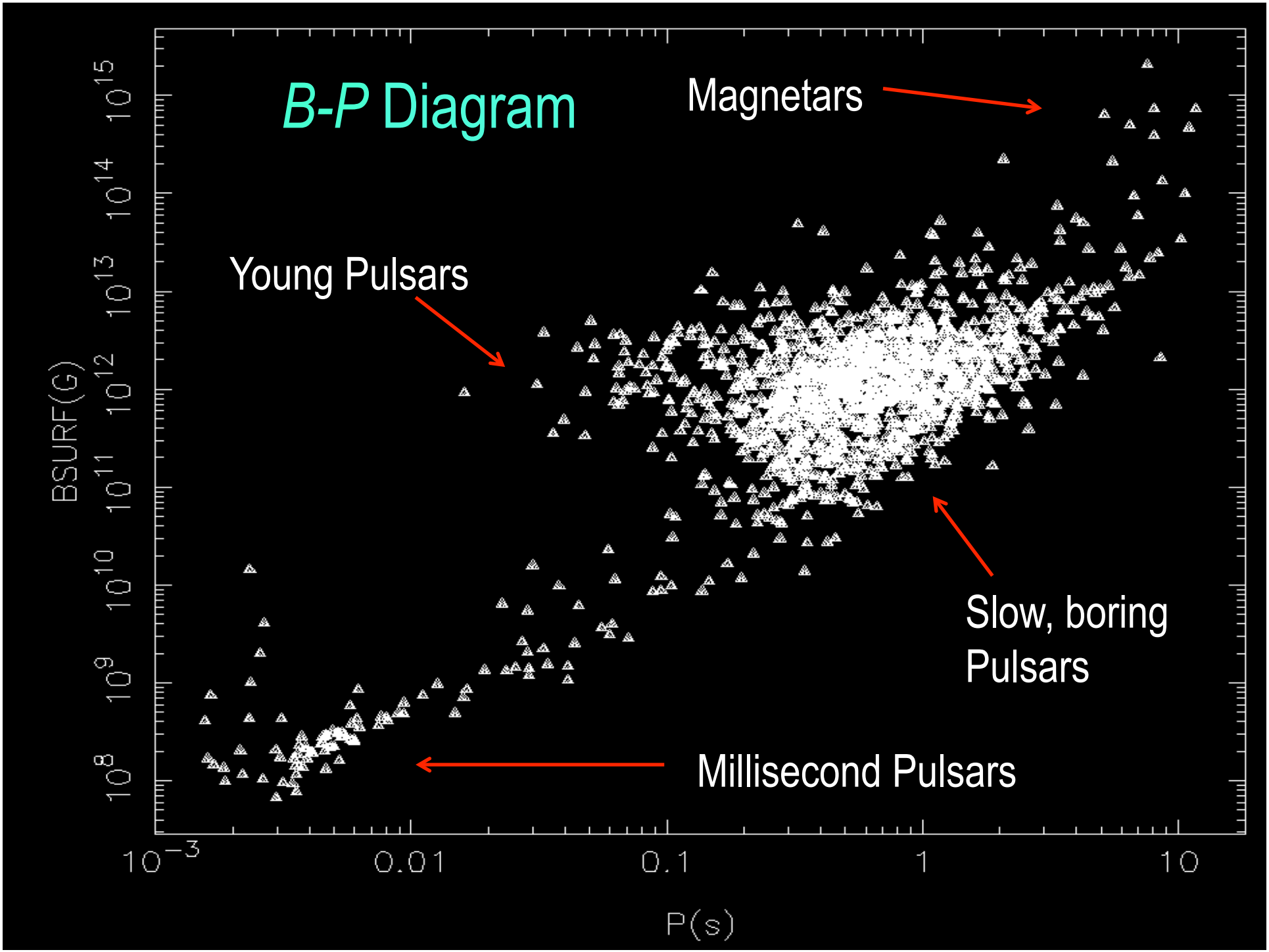
B-P Diagram
Magnetars
Young Pulsars
Slow, boring Pulsars
Millisecond Pulsars
BSURF(G)
P(s)
10^15
10^14
10^13
10^12
10^11
10^10
10^9
10^8
10^-3
0.01
0.1
1
10

Single Pulse Hunting – Nice (1999)

Radio Pulses along the Galactic Plane

David J. Nice

Joseph Henry Laboratories and Physics Department, Princeton University, Princeton, NJ 08544

Received 1998 September 8; accepted 1998 October 19

ABSTRACT

We have surveyed 68 deg^2 along the Galactic plane for single, dispersed radio pulses. Each of 3027 independent pointings was observed for 68 s using the Arecibo telescope at 430 MHz. Spectra were collected at intervals of 0.5 ms and examined for pulses with duration 0.5–8 ms. Such single-pulse analysis is the most sensitive method of detecting

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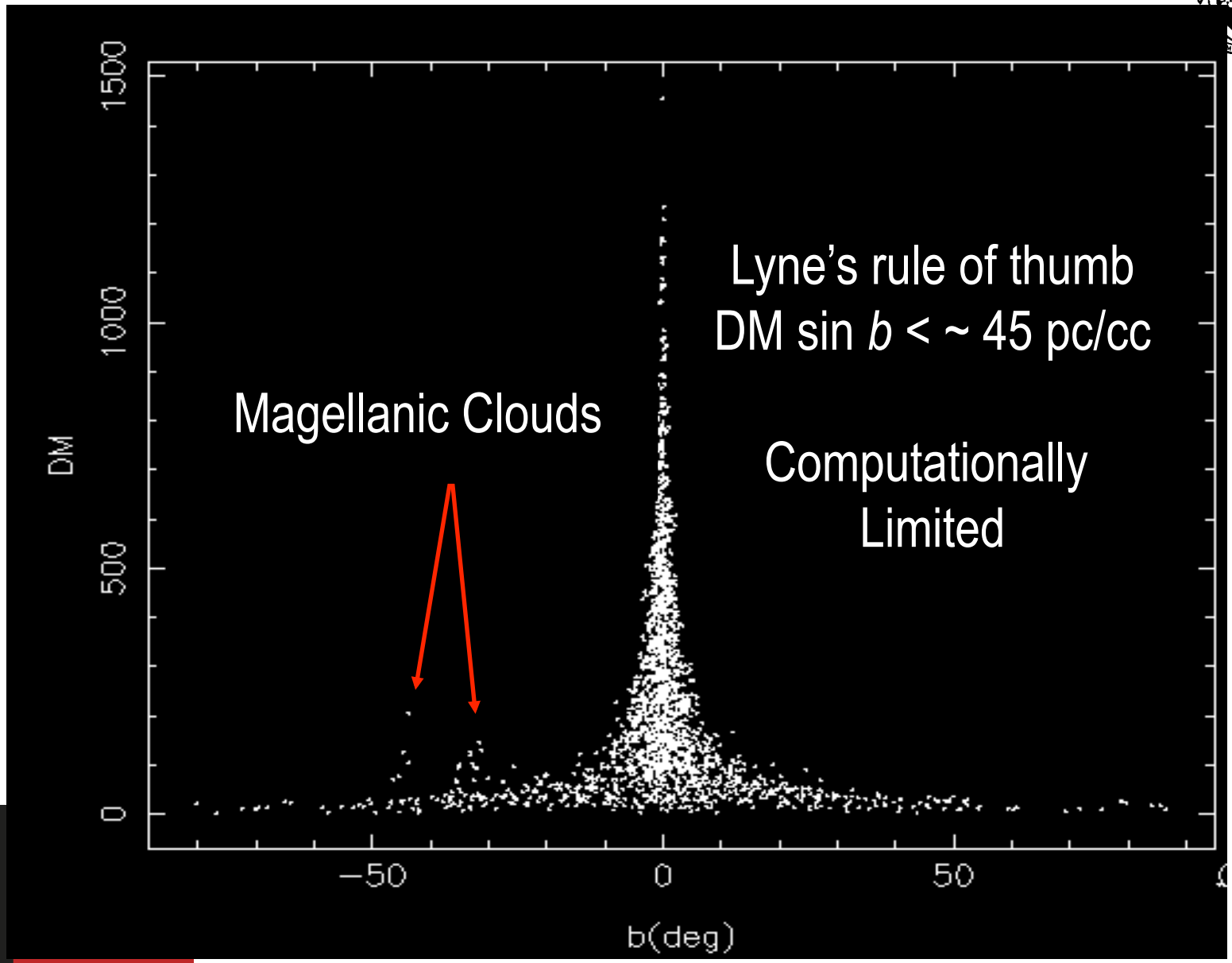
Pulsar Dispersion Measures



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The RRATs – Mc Laughlin et al. 2006

Name	RA (J2000) h m s	Dec (J2000) ° ′ ″	l °	b °	DM pc cm^{-3}	D kpc	w_{50} ms	S_{1400} mJy
J0848–43	08:48(1)	–43:16(7)	263.4	0.2	293(19)	5.5	30	100
J1317–5759	13:17:46.31(7)	–57:59:30.2(6)	306.4	4.7	145.4(3)	3.2	10	1100
J1443–60	14:43(1)	–60:32(7)	316.2	–0.6	369(8)	5.5	20	280
J1754–30	17:54(1)	–30:11(7)	359.9	–2.2	98(6)	2.2	16	160
J1819–1458	18:19:33.0(5)	–14:58:16(32)	16.0	0.1	196(3)	3.6	3	3600
J1826–14	18:26(1)	–14:27(7)	17.2	–1.0	159(1)	3.3	2	600
J1839–01	18:39(1)	–01:36(7)	30.1	2.0	307(10)	6.5	15	100
J1846–02	18:46(1)	–02:56(7)	29.7	–0.1	239(10)	5.2	16	250
J1848–12	18:48(1)	–12:47(7)	21.1	–5.0	88(2)	2.4	2	450
J1911+00	19:11(1)	+00:37(7)	35.7	–4.1	100(3)	3.3	5	250
J1913+1333	19:13:17.69(6)	+13:33:20.1(7)	47.5	1.4	175.8(3)	5.7	2	650

Fluence – 1-15 Jy-ms

Luminosity ~ 10-100 Jy kpc^2

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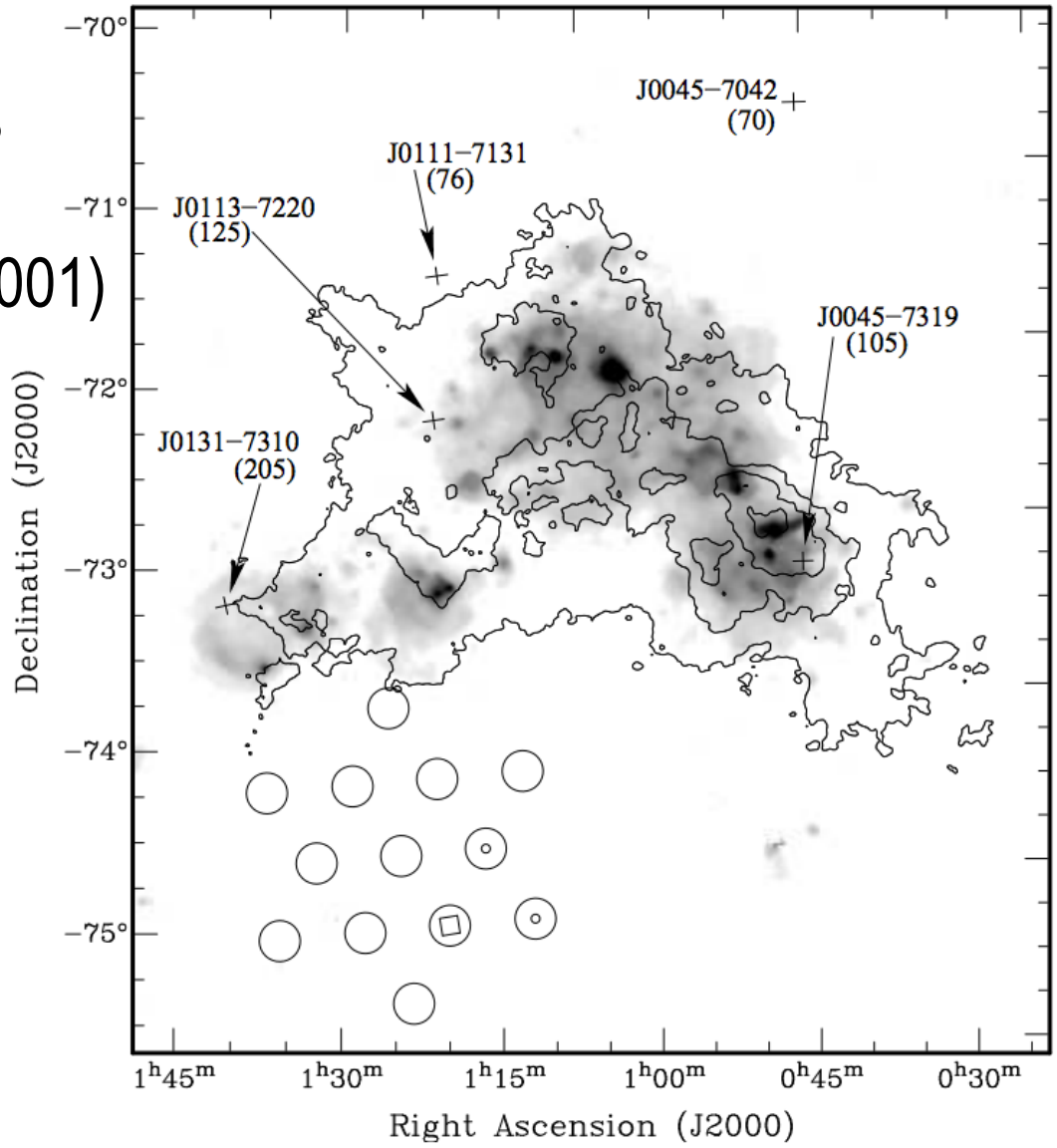
Lorimer Burst Discovery (2007)

Motivated by RRATs

Manchester et al. (2001) pulsar survey



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2007 Science paper

A bright millisecond radio burst of extragalactic origin

D. R. Lorimer,[1,2*] M. Bailes,[3] M. A. McLaughlin,[1,2]
D. J. Narkevic,[1] F. Crawford[4]

[1]Department of Physics, West Virginia University, P.O. Box 6315, WV 26506 USA

[2]National Radio Astronomy Observatory, P.O. Box 2, Green Bank, WV 24944

[3]Centre for Astrophysics and Supercomputing, Swinburne University of Technology,
P.O. Box 218, Hawthorn, Vic, 3122, Australia

[4]Department of Physics and Astronomy, Franklin and Marshall College, Lancaster, PA 17604 USA

*To whom correspondence should be addressed; E-mail: Duncan.Lorimer@mail.wvu.edu.

Accepted for publication in the journal Science

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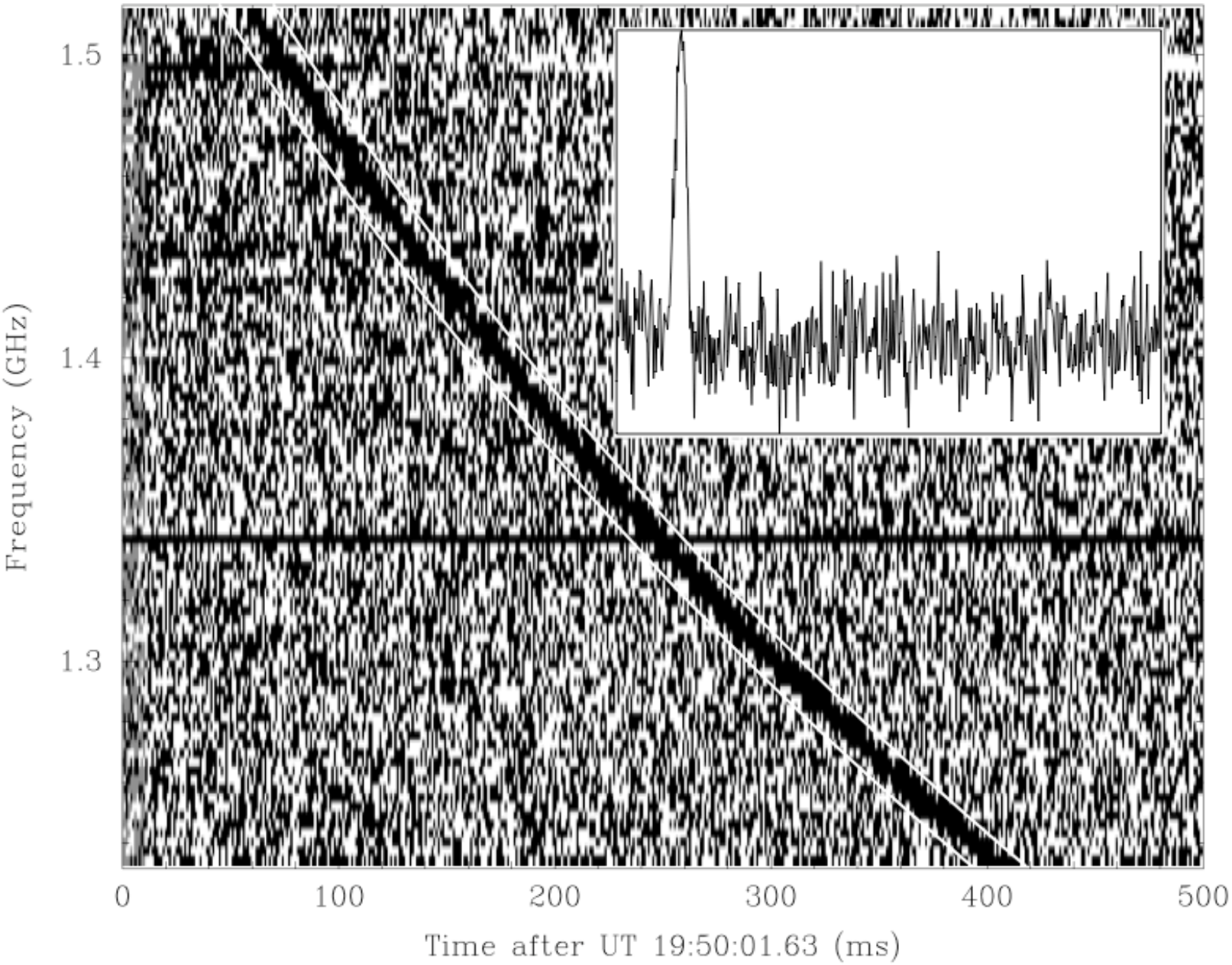
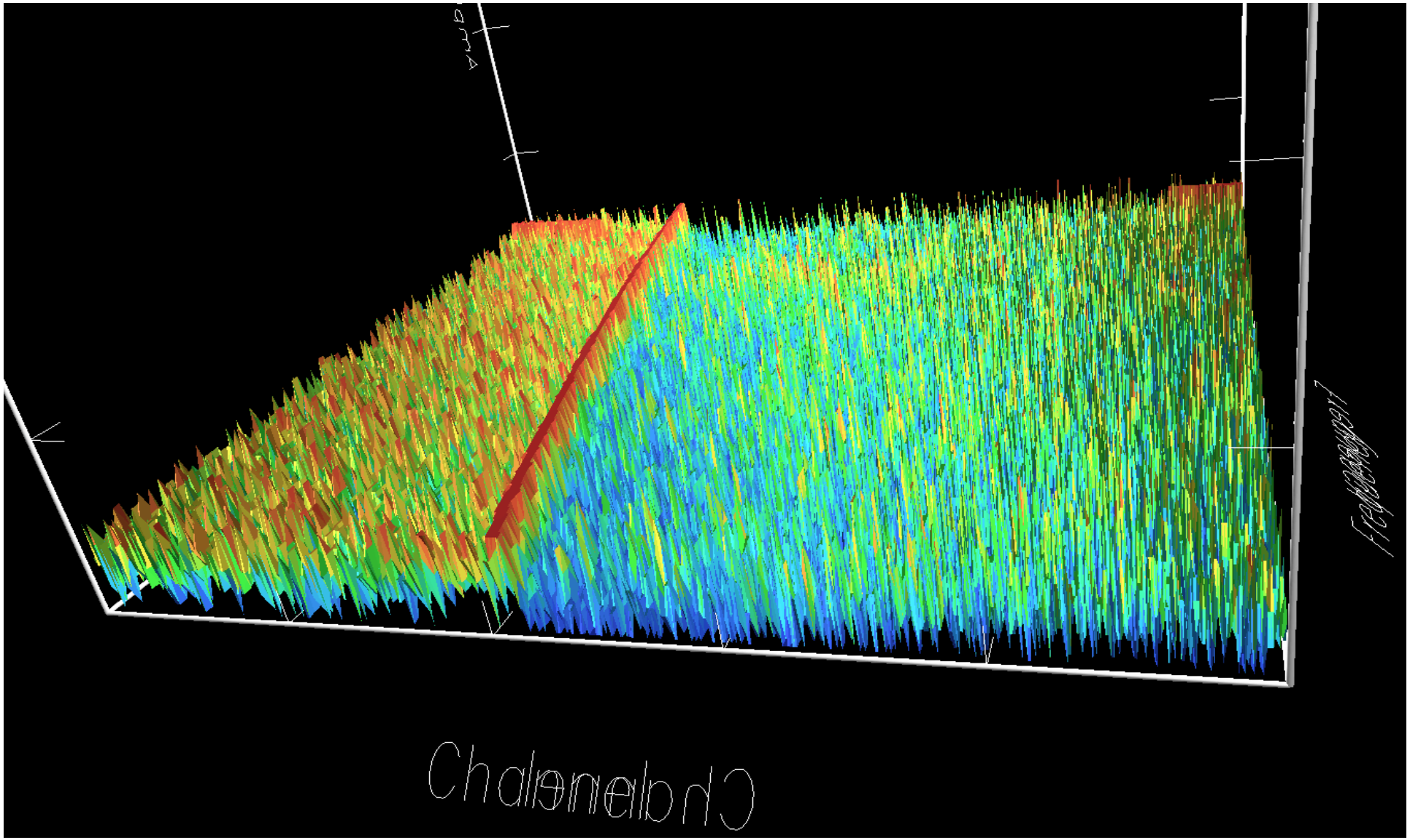
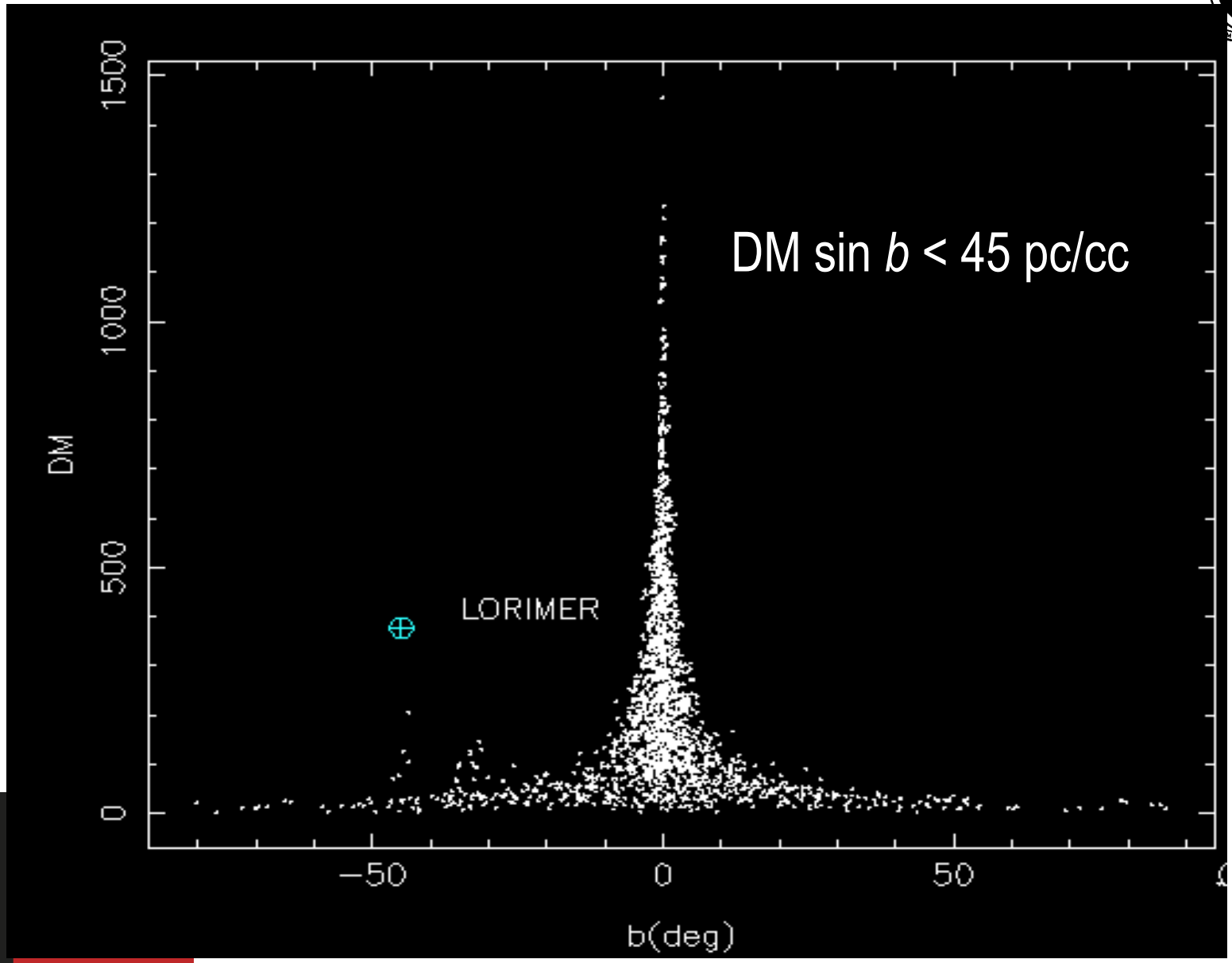
The LORIMER BURST (2001 data, published in Lorimer et al. 2007)



Old 1-bit Hardware
RFI algorithm Zapped the Lorimer Burst!



Pulsar Dispersion Measures



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Doubts:

- Distance of ~300 Mpc?
- Brightness ridiculously large (10^{10} x brighter than RRATs)
- It didn't repeat (!!!)
- No-one else could find one.
  - ATA Fly's eye survey, Westerbork, old and new Parkes surveys – all nothing
- Where were all the fainter ones???

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Quoting Lorimer et al. (2007)

"Perhaps the most intriguing feature of this burst is its 30-Jy strength. While this has allowed us to make a convincing case for its extraterrestrial nature, the fact that it is over 100 times our detection threshold makes its uniqueness puzzling.

Often, astronomical sources have a flux distribution that would naturally lead to many burst detections of lower significance; such events are not observed in our data."

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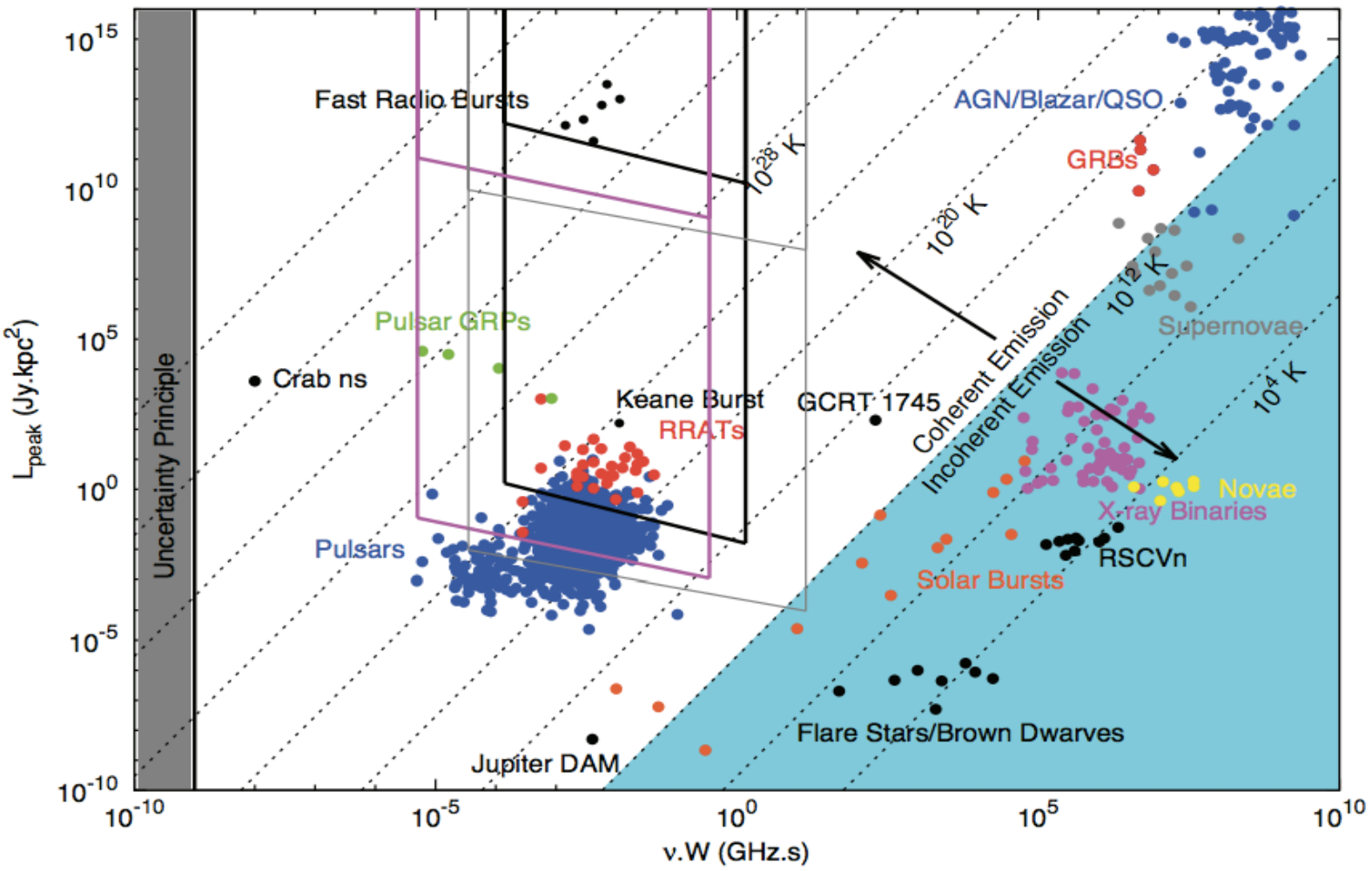
And 10 orders of magnitude brighter??



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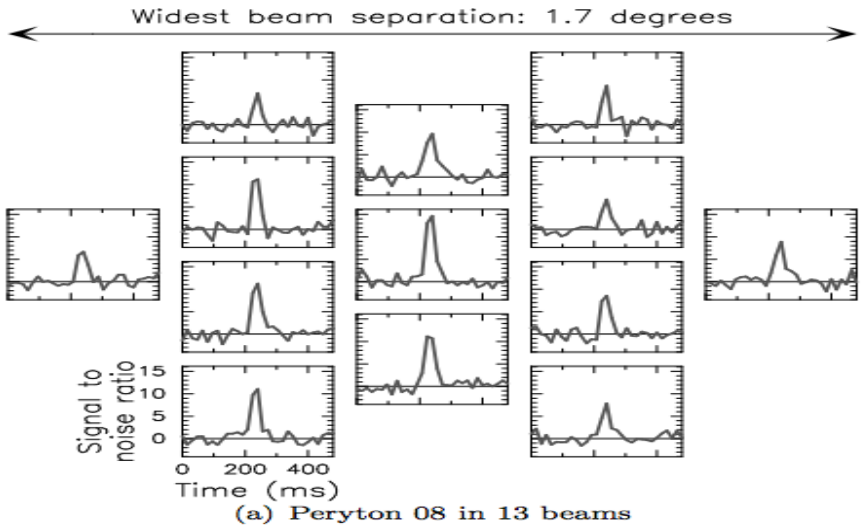
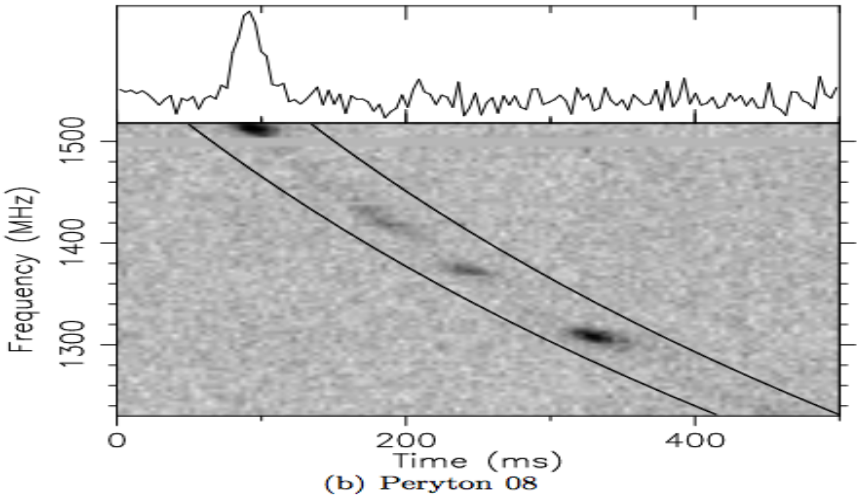
The "Perytons": FRB-like events, DM~375??

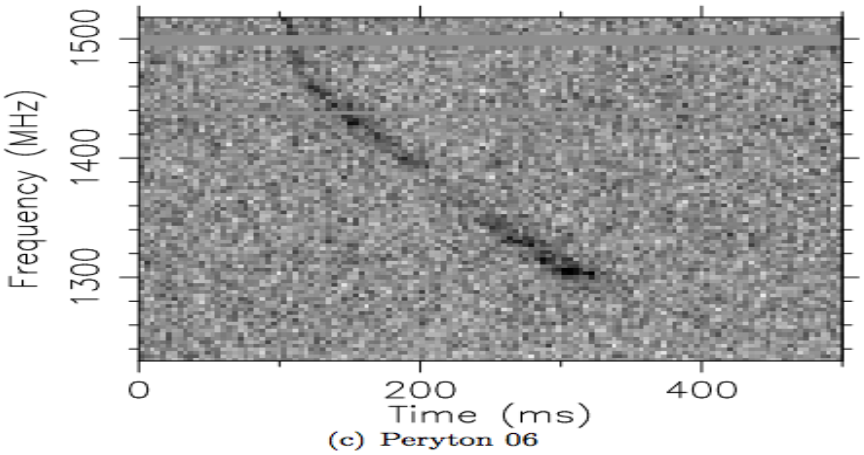
Burke-Spolaor et al. (2011)



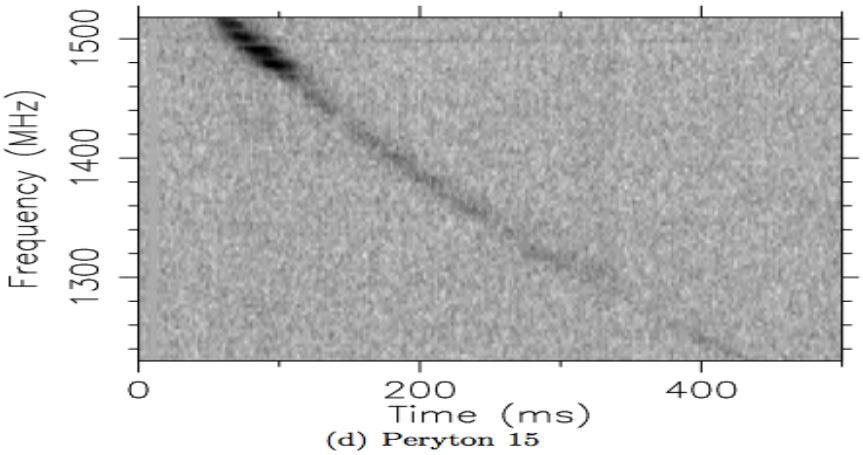
(a) Peryton 08 in 13 beams



(b) Peryton 08



(c) Peryton 06



(d) Peryton 15

The “Keane” Burst (2012)

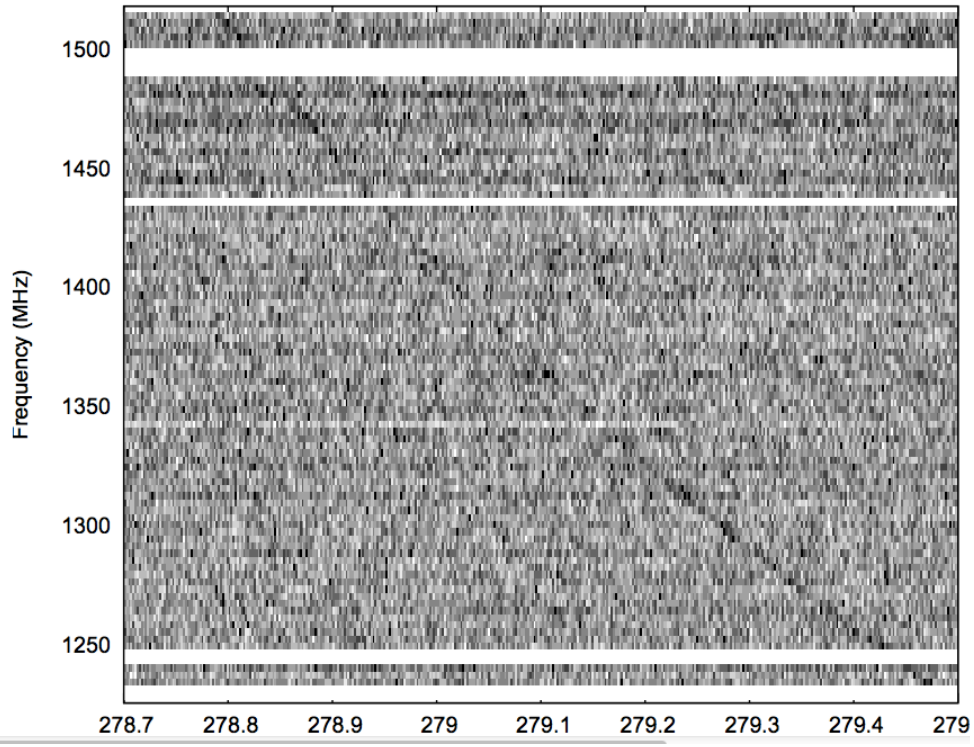
- An FRB “in the plane” DM=746 pc/cc.
  - ☐Possibly galactic event?
  - ☐Bannister & Madsen(2014) argued against an extra-galactic event.
  - ☐Not much scattering?

On the origin of a highly dispersed coherent radio burst

E. F. Keane,[1★] B. W. Stappers,[2] M. Kramer[1,2] and A. G. Lyne[2]

[1]*Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany*
[2]*School of Physics & Astronomy, Jodrell Bank Centre for Astrophysics, University of Manchester, Manchester M13 9PL*

Accepted 2012 June 14. Received 2012 June 13; in original form 2012 April 10



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HTRU Surveys

- HITRUN Surveys (Keith et al. 2010)
- Employed iBOB boards with FPGAs
- 1024 x 0.4 MHz channels (340 MHz usable)
- 8x frequency resolution, 2-4x time resolution, 2-bit data
- Aim was to slice through dispersion
  - Find MSPs
  - Higher DM pulsars
  - Relativistic binaries
  - Lorimer bursts

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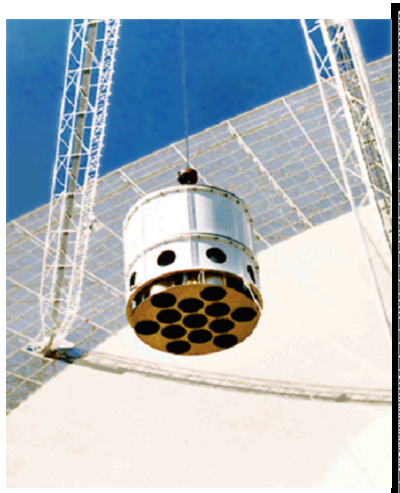

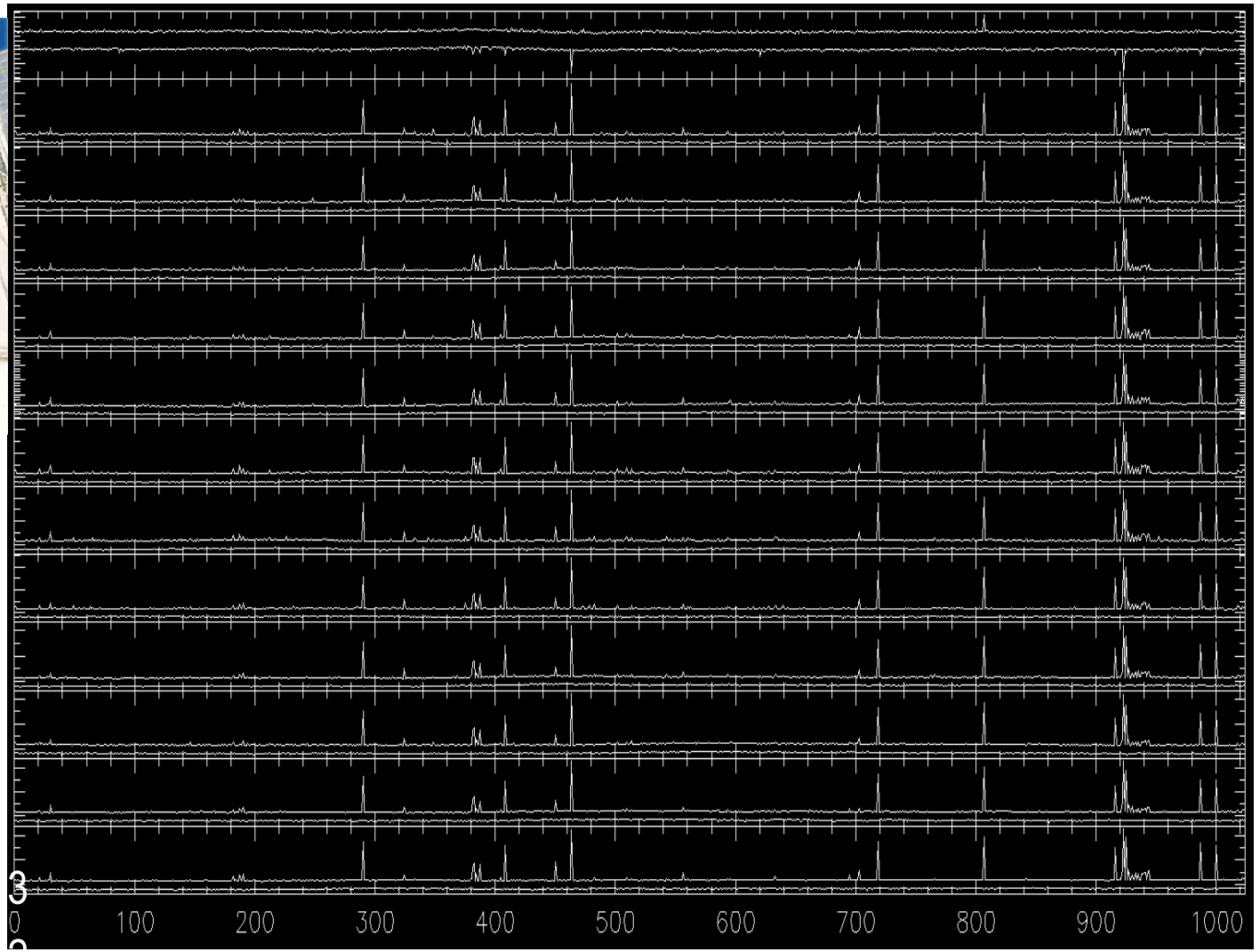

Local Interference is ridiculously correlated between beams

Kocz developed eigenvector common RFI removal algorithms

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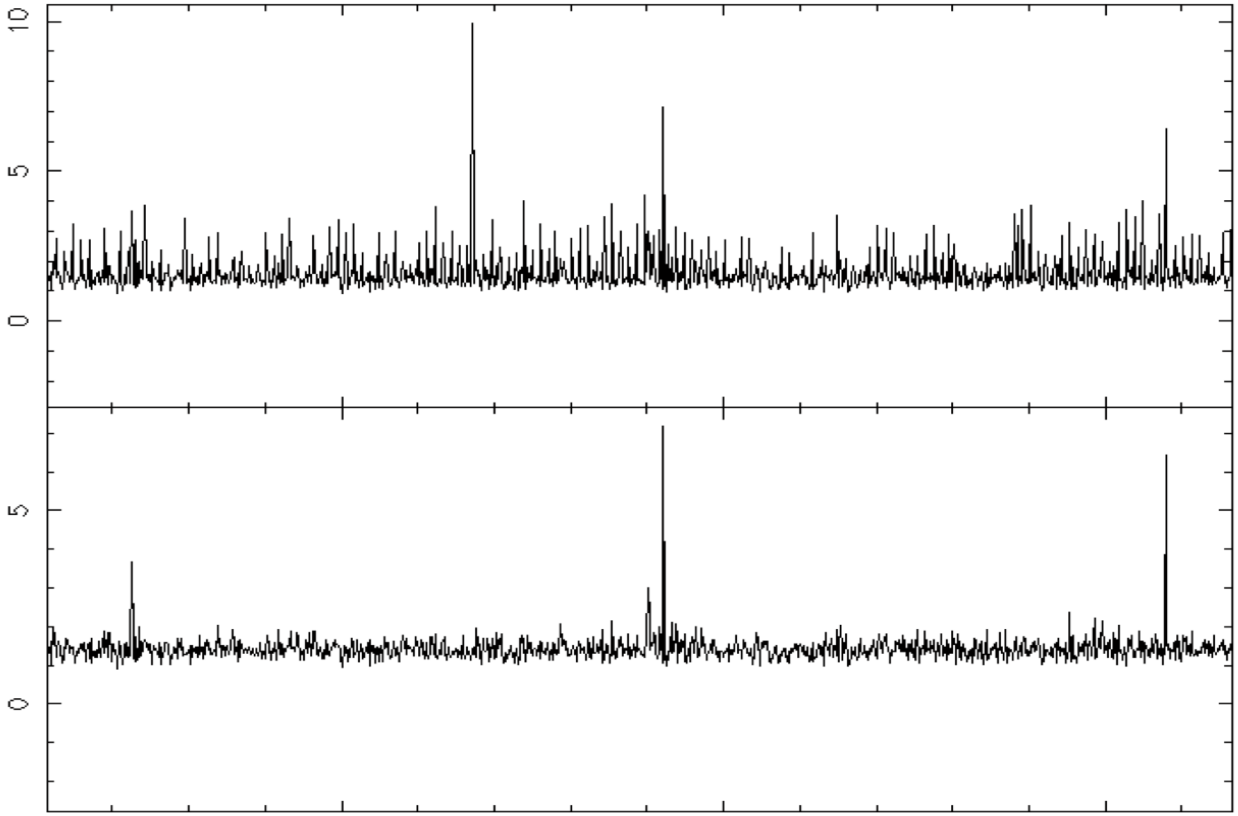
Use common RFI to remove it



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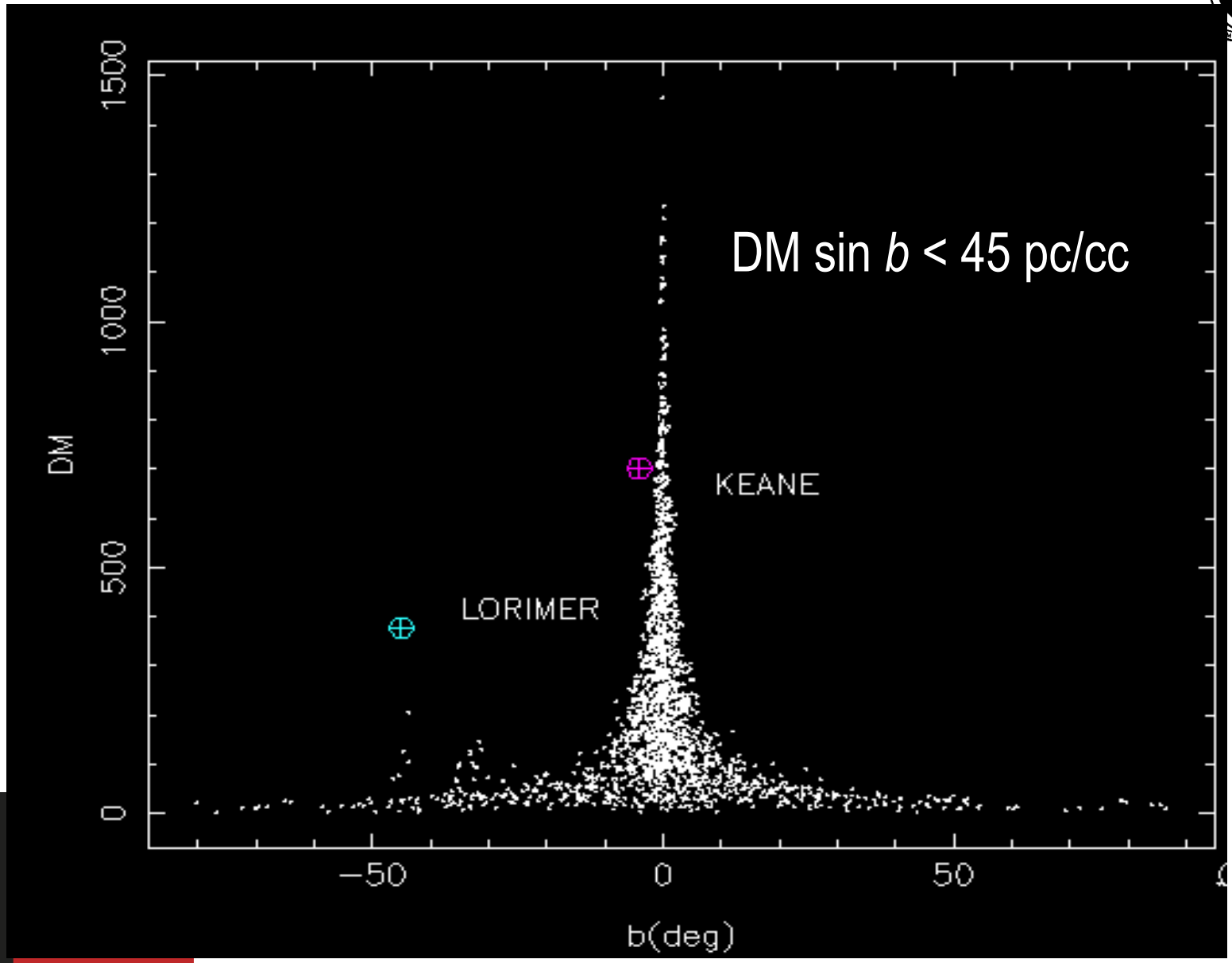
Pulsar Dispersion Measures



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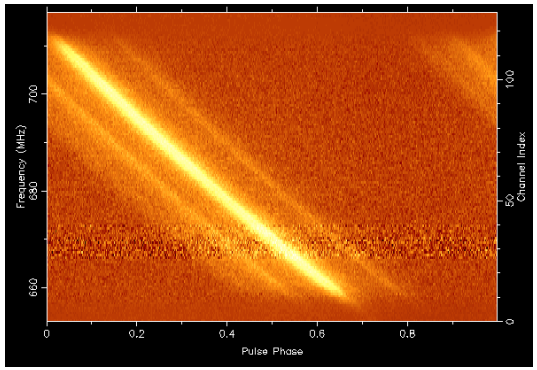
Dispersion Smearing with the Andrew Lyne 3 MHz Filterbanks

$$t = 8.3us \frac{B}{MHz} \frac{DM}{pc/cc} \left(\frac{nu}{GHz} \right)^{-3}$$



- For DM = 375, smear was 3.7 milliseconds
- For DM = 1000, smear was 10 milliseconds
- For DM = 2500, smear was 25 milliseconds

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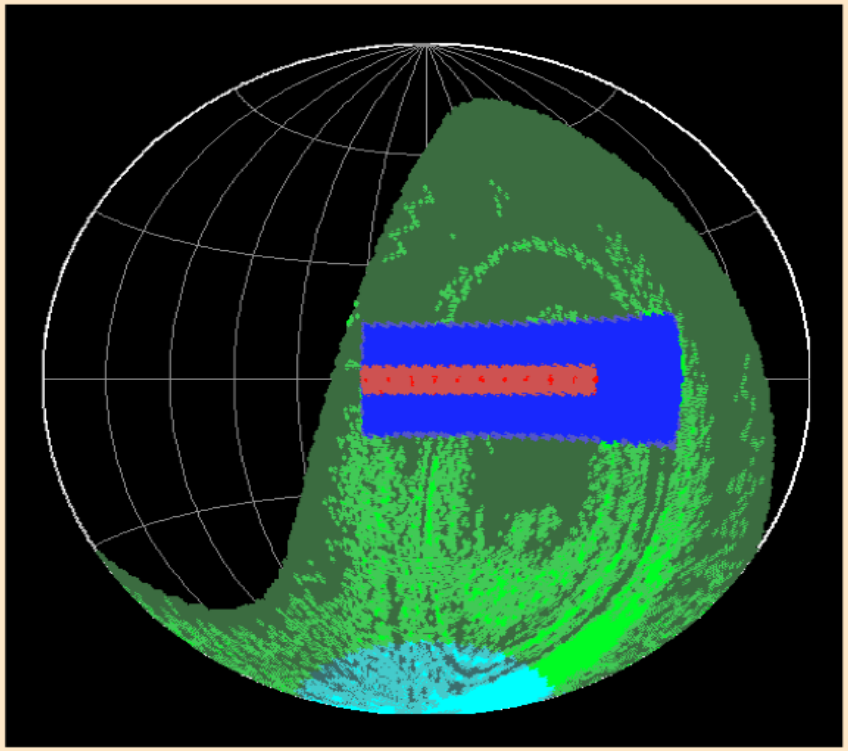
HITRUN Regions



Galactic plane:
70 min/pointing
-80° < gl < 30°
|gb| < 3.5°
1240 pointings
11% observed

Intermediate latitudes:
512 s/pointing
-120° < gl < 30°
|gb| < 15°
6690 pointings
100% observed
99% (56%) processed

All-sky:
256 s/pointing
the remaining southern sky

36450 pointings
18% observed
10% processed

Success! Thornton et al. (2013) bursts

A Population of Fast Radio Bursts at Cosmological Distances

D. Thornton,[1,2]* B. Stappers,[1] M. Bailes,[3,4] B. Barsdell,[3,4] S. Bates,[5] N. D. R. Bhat,[3,4,6] M. Burgay,[7] S. Burke-Spolaor,[8] D. Champion,[9] P. Coster,[2,3] N. D'Amico,[7,10] A. Jameson,[3,4] S. Johnston,[2] M. Keith,[2] M. Kramer,[9,1] L. Levin,[5] S. Milia,[7] C. Ng,[9] A. Possenti,[7] W. van Straten[3,4]

Searches for transient astrophysical sources often reveal unexpected classes of objects that are useful physical laboratories. In a recent survey for pulsars and fast transients, we have uncovered four millisecond-duration radio transients all more than 40° from the Galactic plane. The bursts' properties indicate that they are of celestial rather than terrestrial origin. Host galaxy and intergalactic medium models suggest that they have cosmological redshifts of 0.5 to 1 and distances of up to 3 gigaparsecs. No temporally coincident e- or gamma-ray signature was identified in association with the bursts. Characterization of the source population and identification of host galaxies offers an opportunity to determine the baryonic content of the universe.

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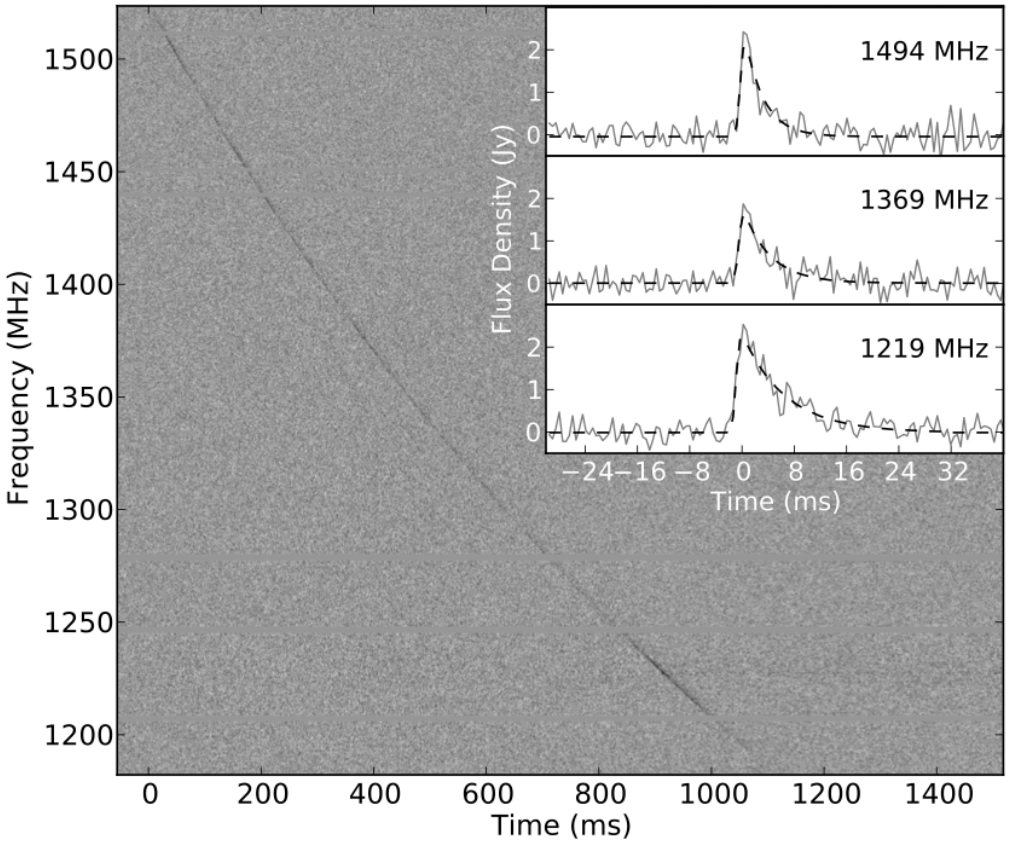
FRB 110220 – the first HTRU FRB

- DM = 944 cm^{-3} pc; W = 5.6 ms
- Evidence of scatter broadening
- But 49 sigma!!!



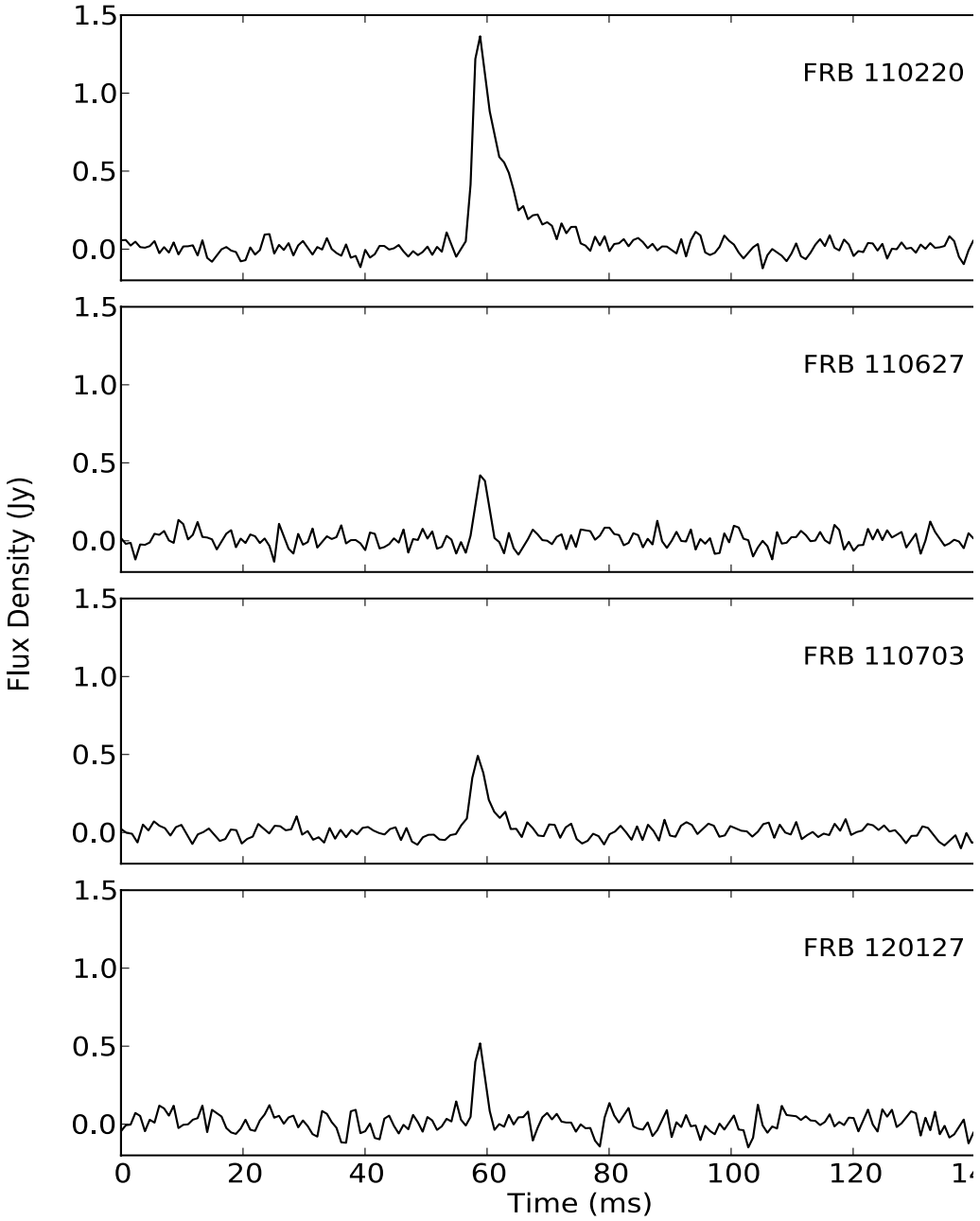
- Bright enough to fit the pulse shape as a fn. of frequency to find dispersion & scattering indices

$$\delta t \propto \nu^{-2.003 \pm 0.006}$$

$$W \propto \nu^{-4 \pm 0.4}$$

Thornton FRBs

- Required hires filterbanks
- Most would have been smeared out in old filterbanks
- A new phase space was being explored
- ”Four-minute mile”



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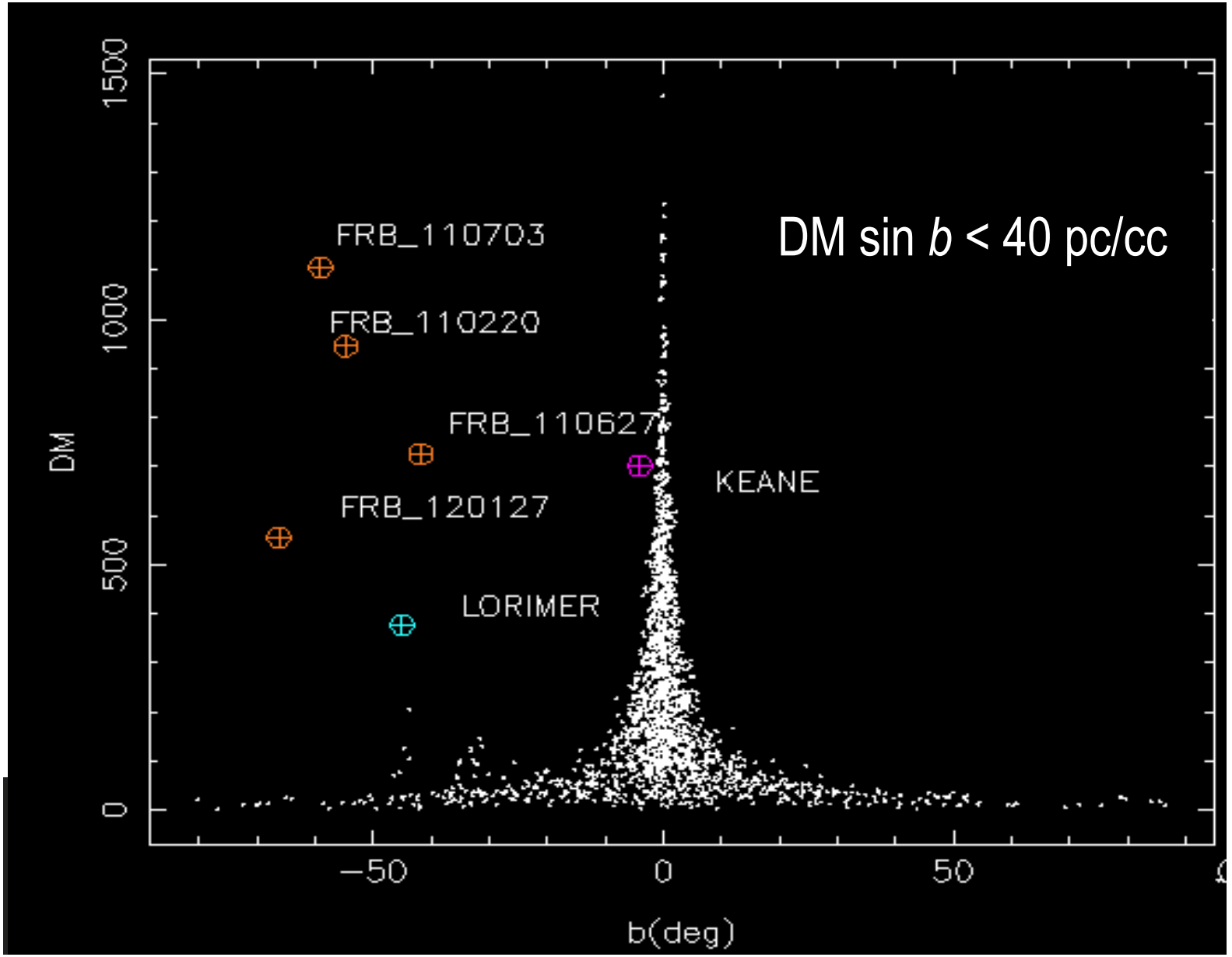
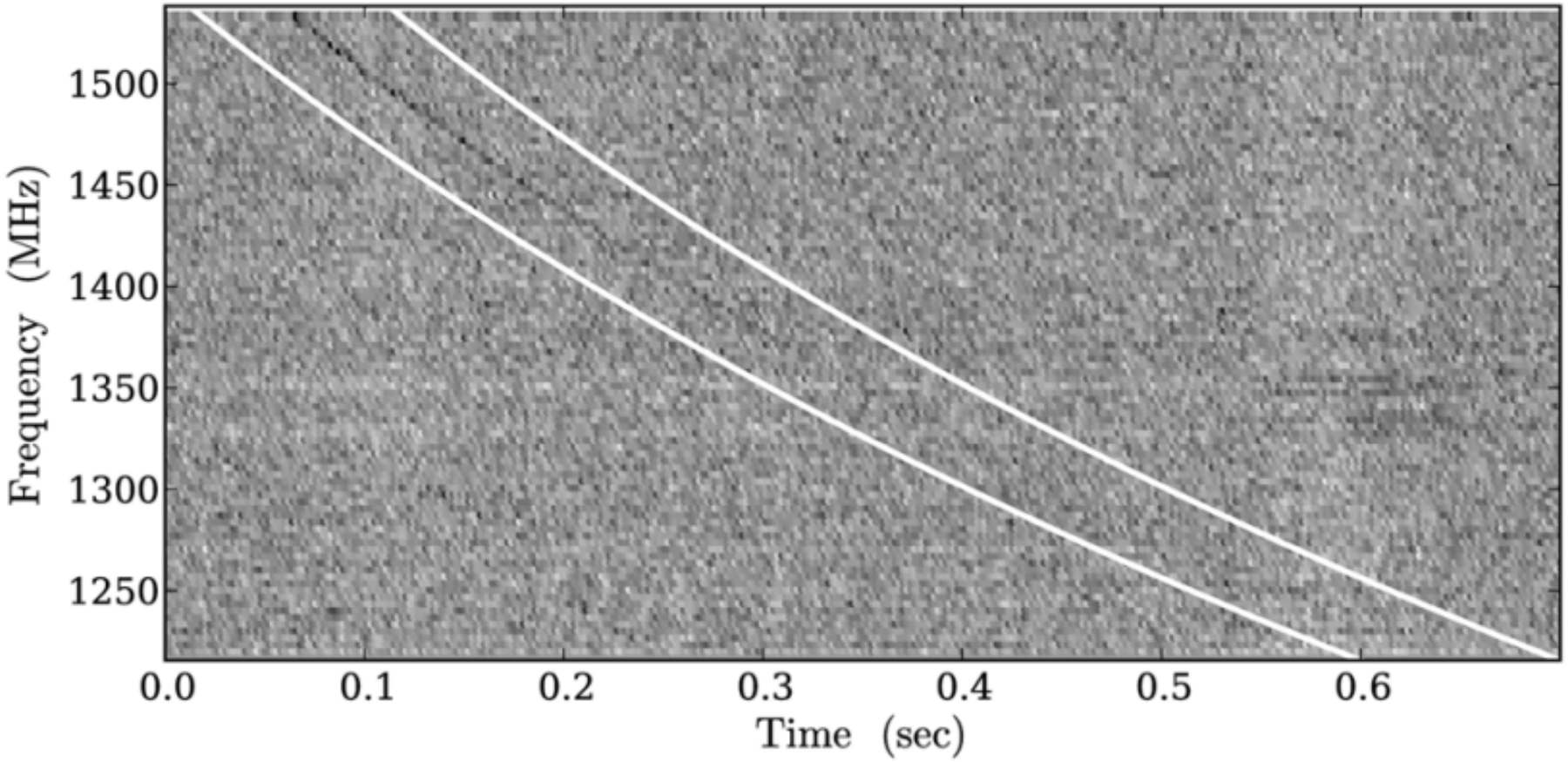
Pulsar Dispersion Measures vs FRB DMs

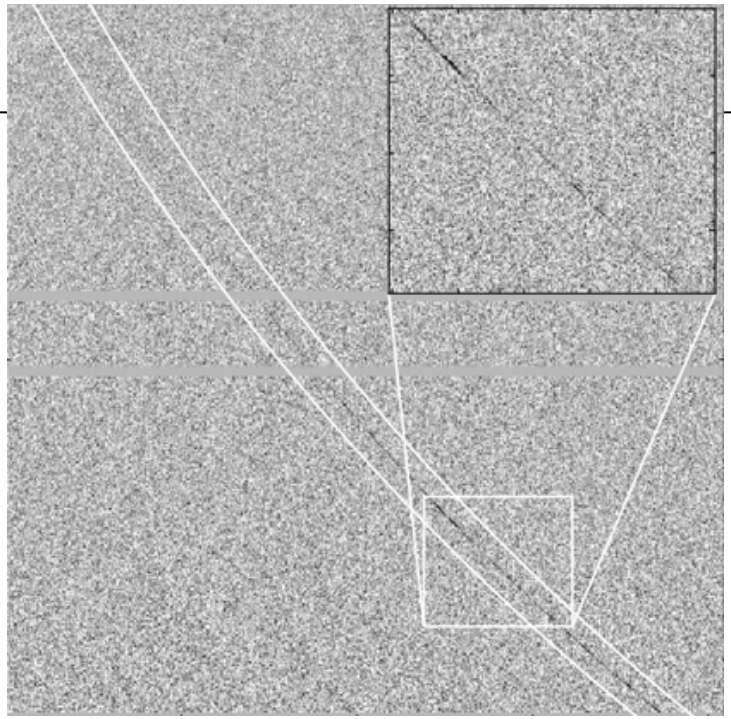


The Arecibo Burst! (Spitler et al. 2014)

- FRB 121102
  - DM=557 pc/cc
    - (BTW 557 ~ 1.5 * 375), b~0.0, l~180



A GBT Burst!



- FRB 110523 DM=623 (Masui et al. 2015)
  - 42 sigma! Large Rotation Measure? Scattering, RM “perfect”
- FRBs exist at 800 MHz! But are FRBs “relatively local”?

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Kulkarni et al. (2014)'s abstract

First, the detection of a single FRB by an interferometer with a kilometer (or longer) baseline will prove that FRBs are of extraterrestrial origin.

Second, we urge astronomers to pursue observations and understanding of Perytons since they form (at least) a formidable foreground for the FRBs.

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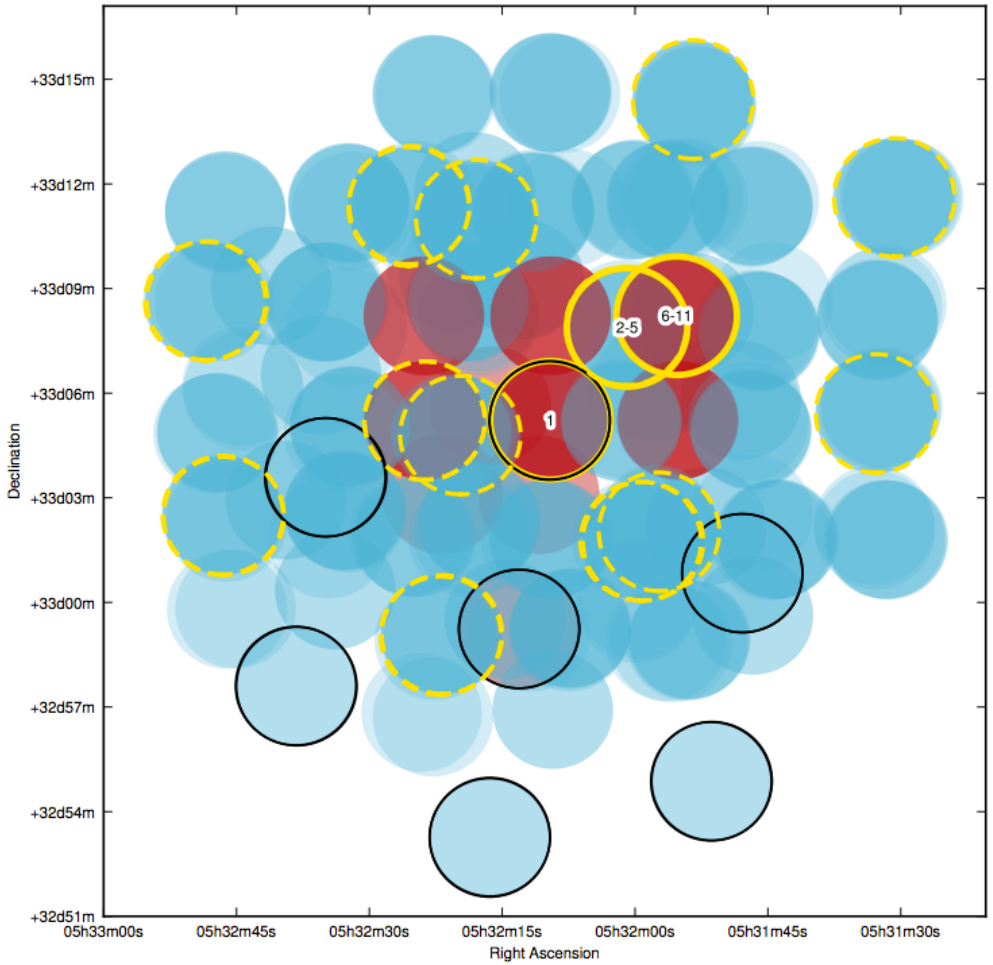
The Repeating Fast Radio Burst aka “The repeater” (Spitler et al. 2016)

- The Arecibo FRB repeats!



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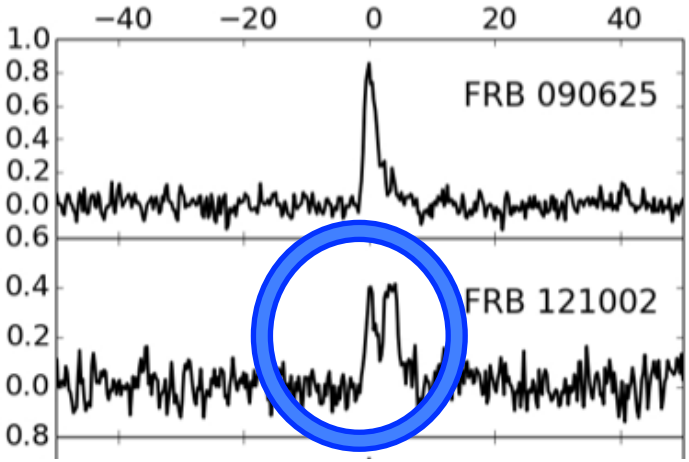
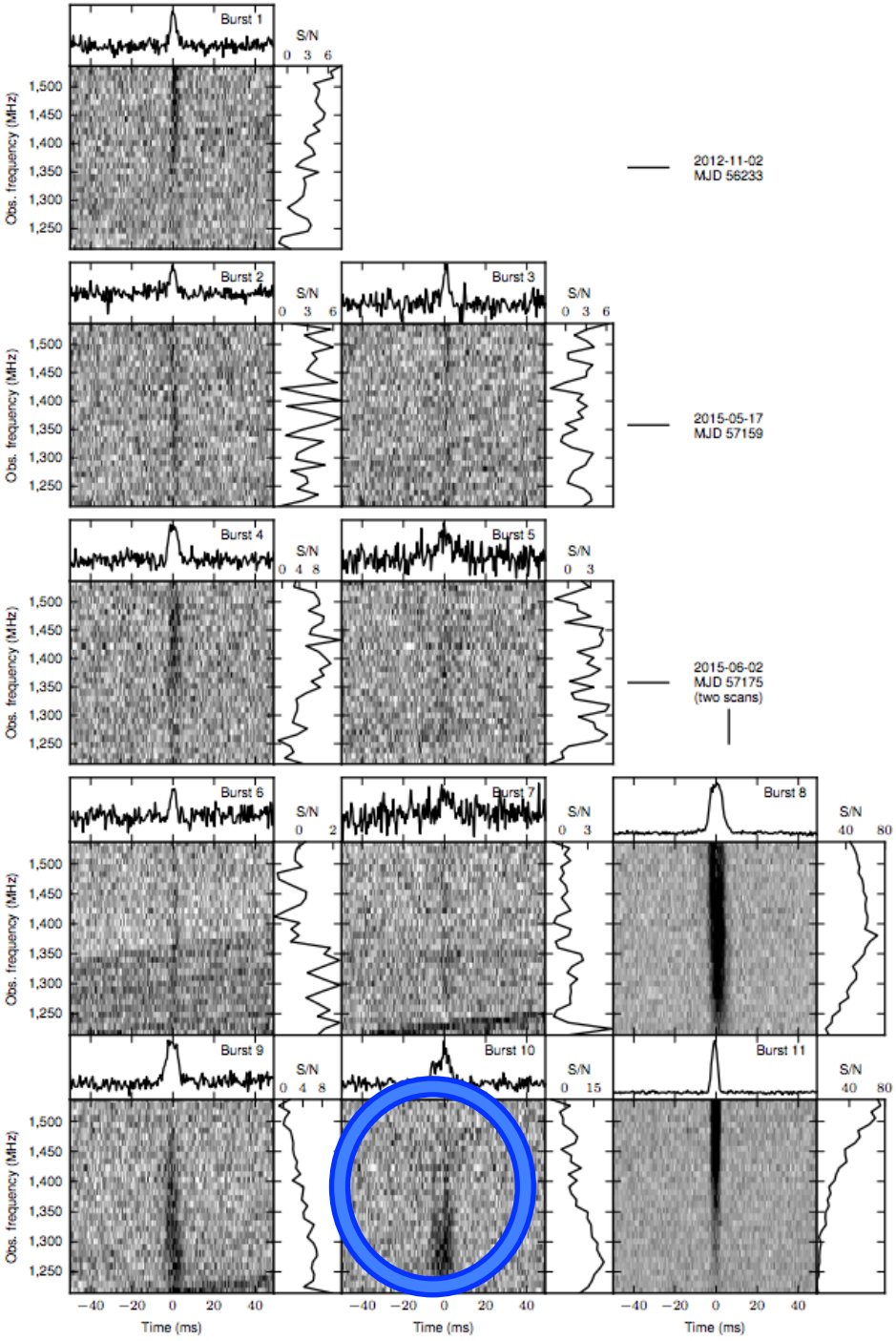
The repeating Fast Radio Burst (Spitler et al. 2016)

- The Arecibo FRB repeats!!!
- Almost certainly a neutron star – magnetar?
  - ☐ Distance?
  - ☐ Energy?
  - ☐ Scintillation?
- Two classes?





DM search space

- Lorimer et al. DM = 375
- Burke-Spolaor & Bailes searched Edwards et al. and Jacoby et al. surveys
  - Max DM was 600! (missed DM > 600 FRB)
- Real-time FRB Heimdall pipeline (Jameson/Barsdell)
  - Uses GPUs
  - DM searched up to 1500 pc/cc
  - Moved to 2000 pc/cc – soon found DM=1912 pc/cc!
  - Moved to 3000 pc/cc – soon found DM=2600 pc/cc!

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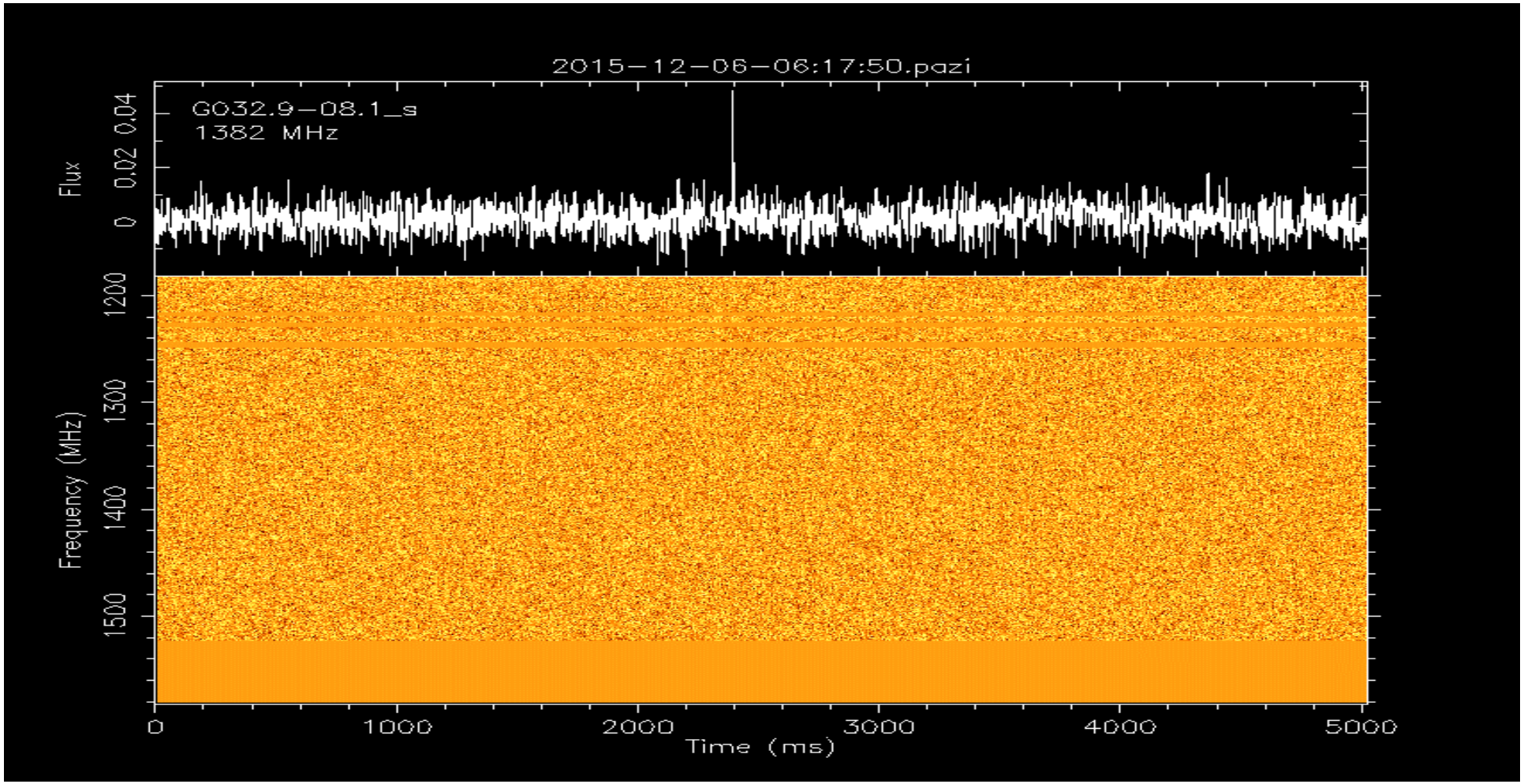
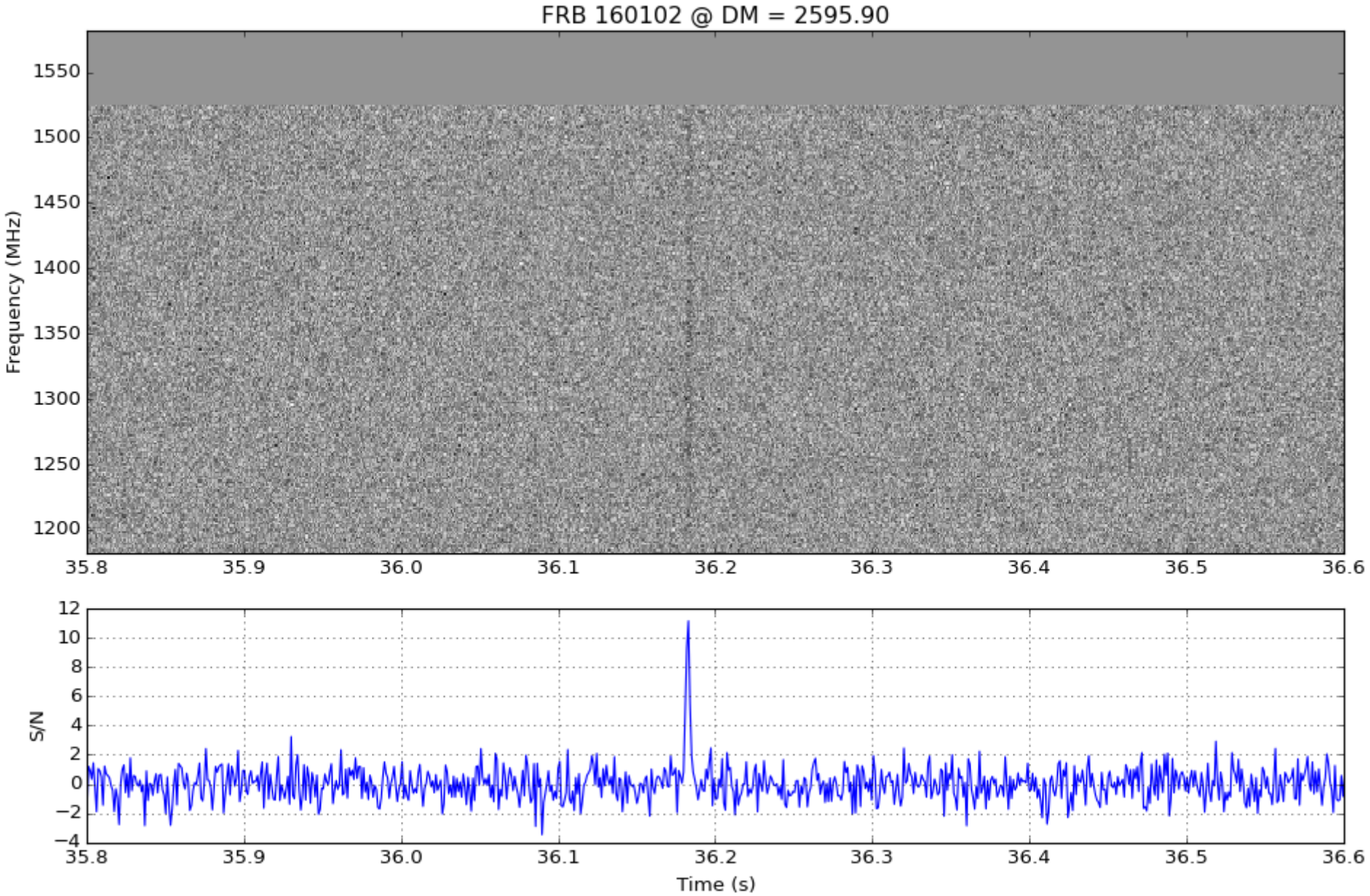
SUPERB Latest Developments (1)

- FRB 151206
  - DM = 1912 pc/cc!



Latest Developments (3)



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Australian National University

THE UNIVERSITY OF SYDNEY

CSIRO

Manisha Caleb
On behalf of UTMOST collaboration

The UTMOST: A hybrid digital signal processor for the Molonglo Observatory Synthesis Telescope.

Matthew Bailes[1], Andrew Jameson[1], Chris Flynn[1], Timothy Bateman[2,5], Ewan D. Barr[1], Shivani Bhandari[1], Manisha Caleb[3], Duncan Campbell-Wilson[5], Anne J. Green[5], Richard Hunstead[5], Fabian Jankowski[1], Evan Keane[4], Vikram Ravi[1,6], Vivek Venkatraman Krishnan[1]

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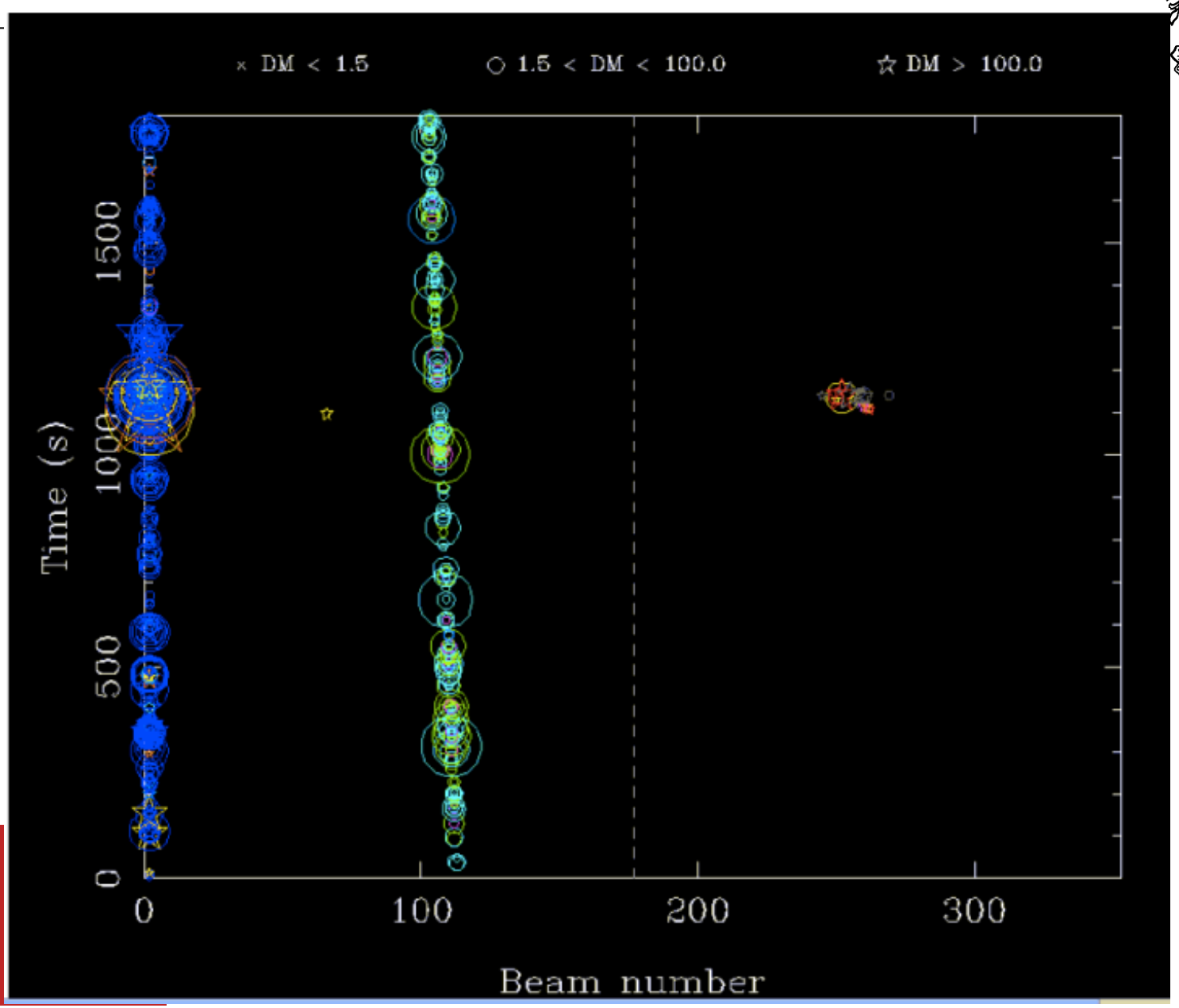
Miscellaneous Radio Astronomy

A Search for Transient Events at 843 MHz

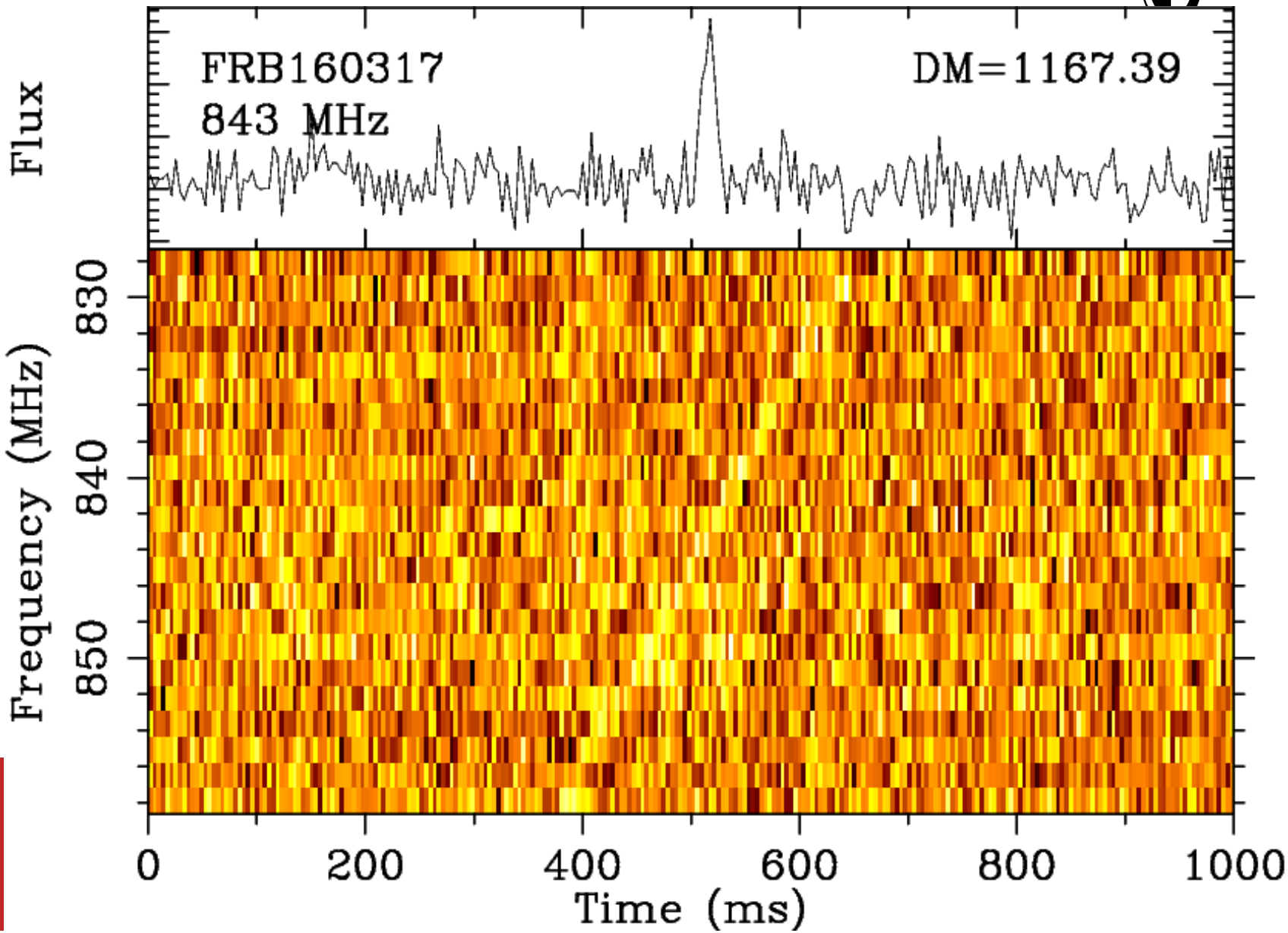
S. W. Amy, M. I. Large, *School of Physics, University of Sydney*
A. E. Vaughan, *School of Mathematics, Physics, Computing and Electronics, Macquarie University*

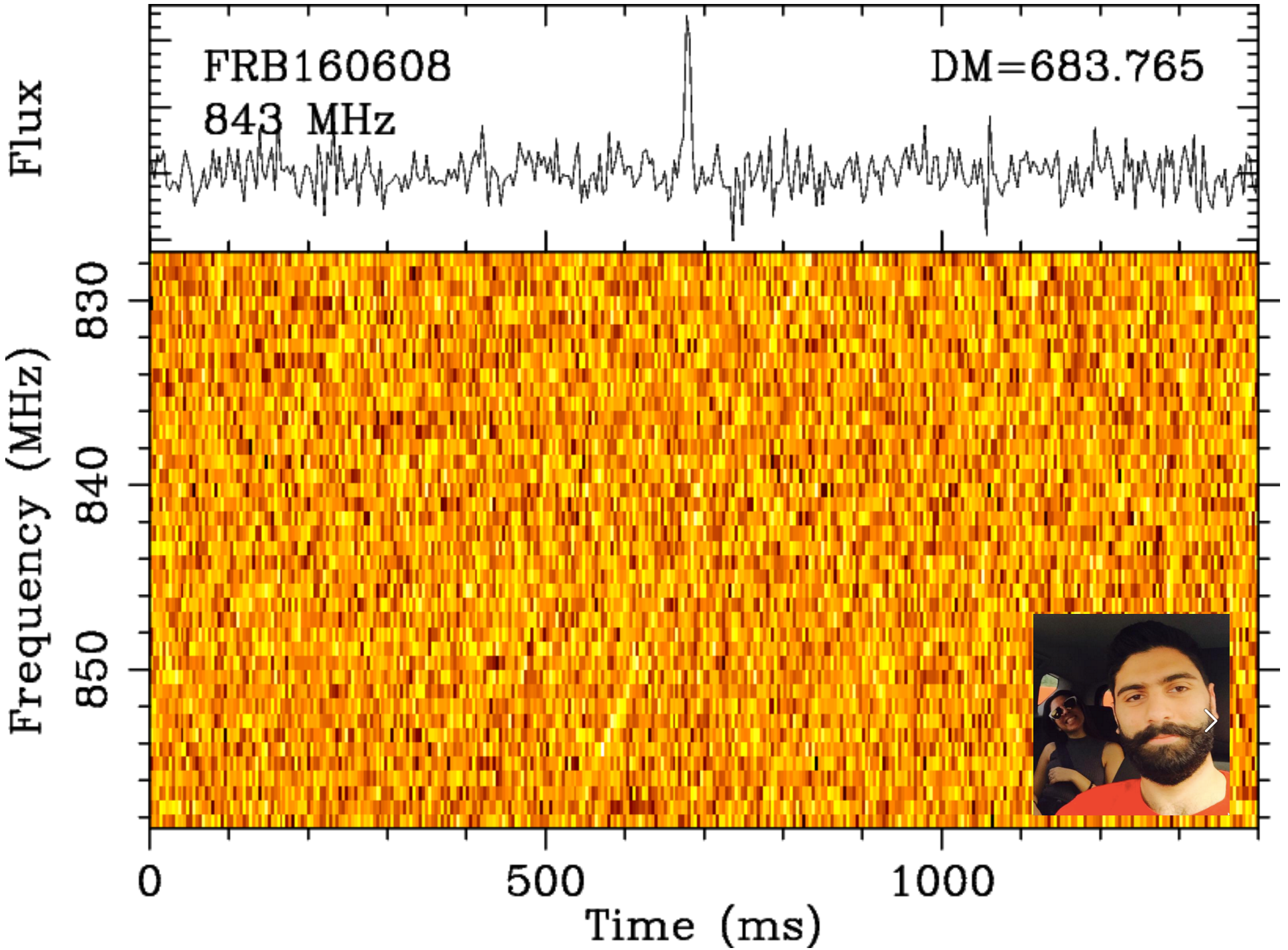
Abstract: The Molonglo Observatory Synthesis Telescope is equipped with a transient event monitoring system which operates during normal synthesis observations. The device is

Pulsar detections



Molonglo FRBs!!!




FRB160608
843 MHz
DM=683.765
Flux
Frequency (MHz)
830
840
850
0
500
1000
Time (ms)

FRB Discovery

- Required pulsars to be discovered first
  - Without PSRs, instrumentation incapable of detection
- Data volume so large requires “clever algorithms” to handle it
  - RFI rejection deleted Lorimer burst, PSR J0437-4715
  - DM sin b < 45
  - Often blinds us to new discovery space
- PKS MB receiver pivotal in FRB discovery
- A proposal to search for FRBs would be rejected by any sane time assignment committee
  - “Theoretically impossible”

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