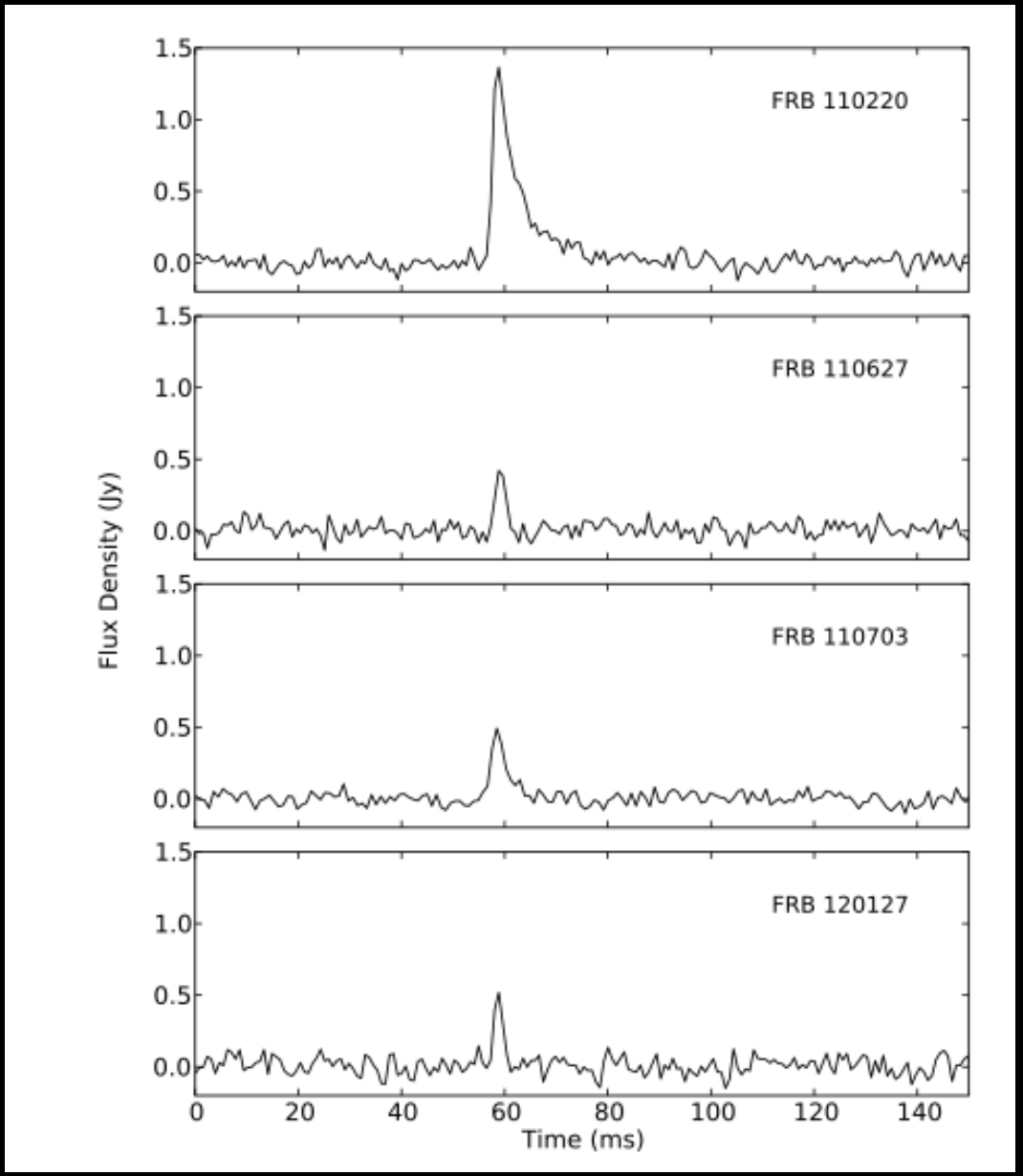
The discovery of Fast Radio Bursts (FRBs)

Duncan Lorimer, Dept. of Physics and Astronomy, West Virginia University

FRB lowdown

- 8 published so far
- Flux > 0.5 Jy @ 1.4 GHz
- Pulse widths > few ms
- Highly dispersed
- Weakly scattered
- Apparently singular
- Few arcmin localization
- No counterparts so far
- Infer ~10,000/day/sky

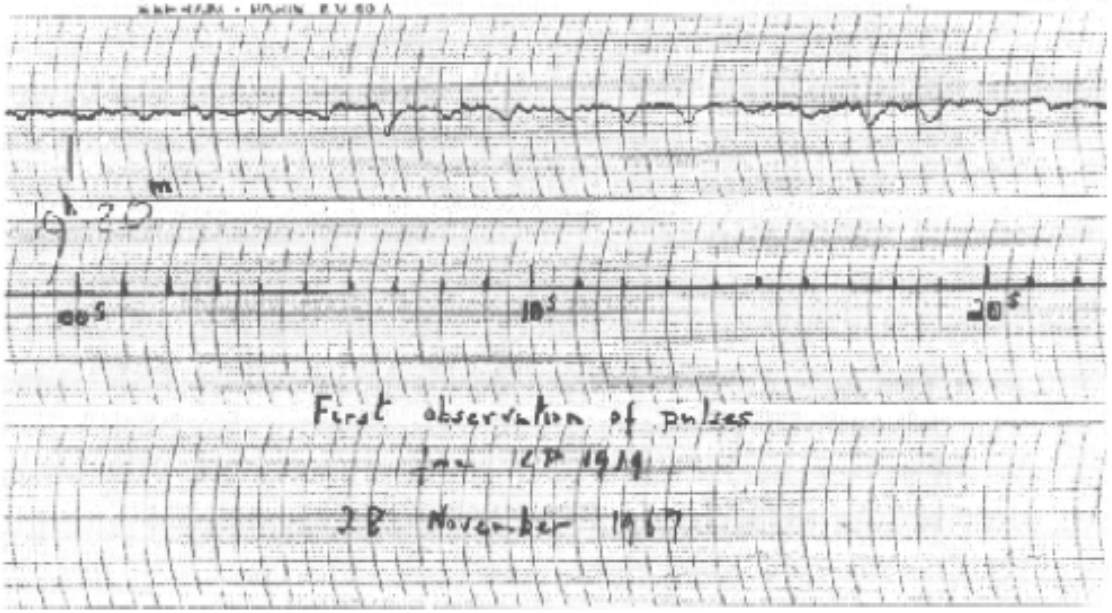


From Thornton et al. (2013)

NATIONAL GEOGRAPHIC

Photograph by Miloslav Druckmüller

MAGELLANIC CLOUDS. DECEMBER 201



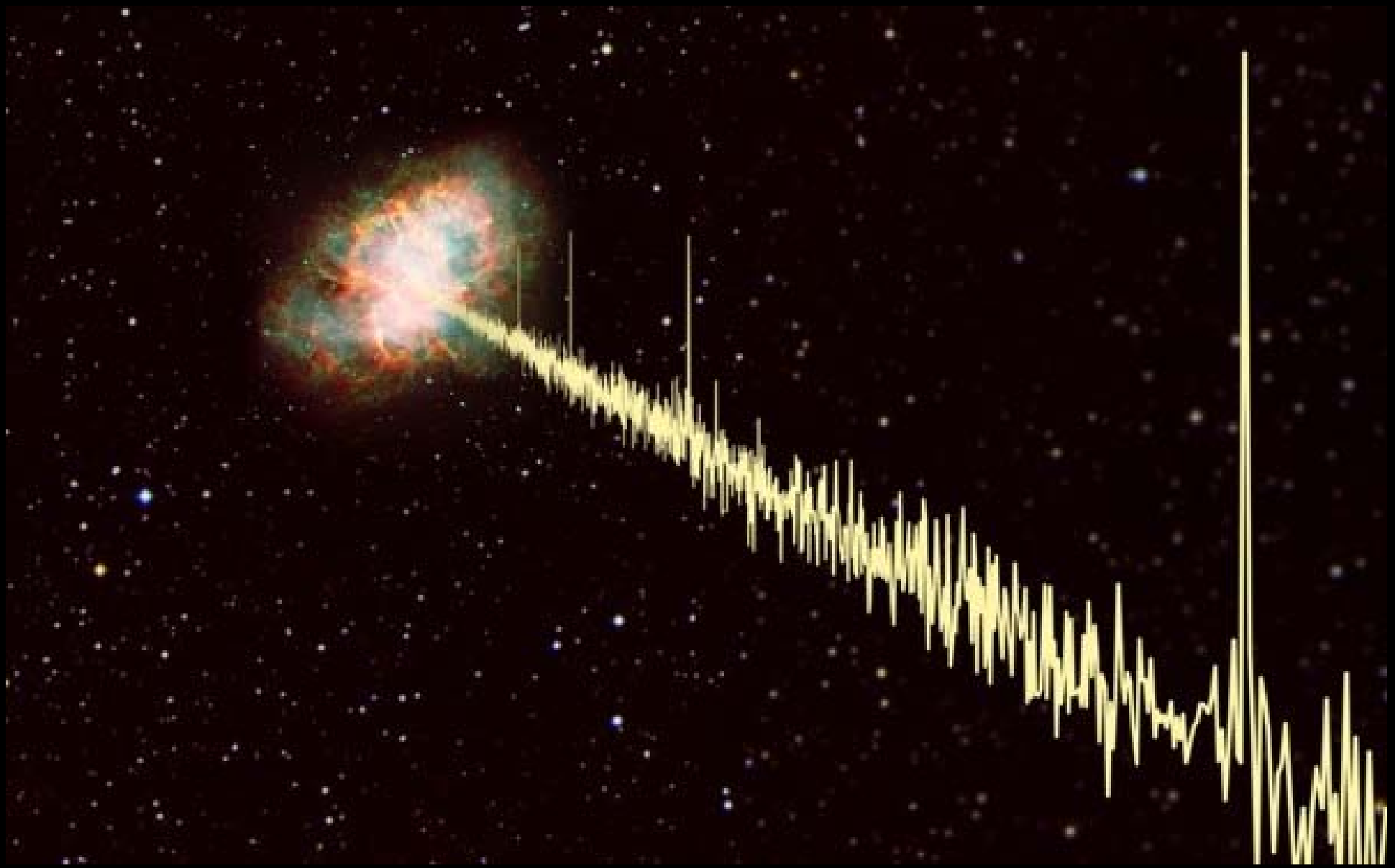
Observation of a Rapidly Pulsating Radio Source

by

A. HEWISH
S. J. BELL
J. D. H. PILKINGTON
P. F. SCOTT
R. A. COLLINS

Mullard Radio Astronomy Observatory,
Cavendish Laboratory,
University of Cambridge

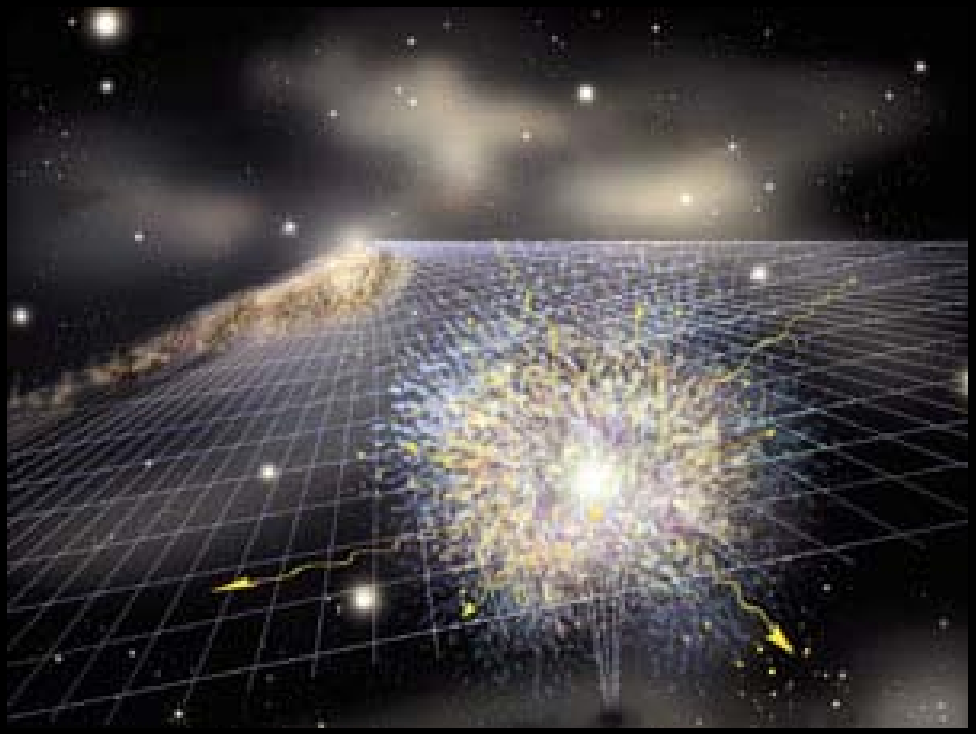
Unusual signals from pulsating radio sources have been recorded at the Mullard Radio Astronomy Observatory. The radiation seems to come from local objects within the galaxy, and may be associated with oscillations of white dwarf or neutron stars.



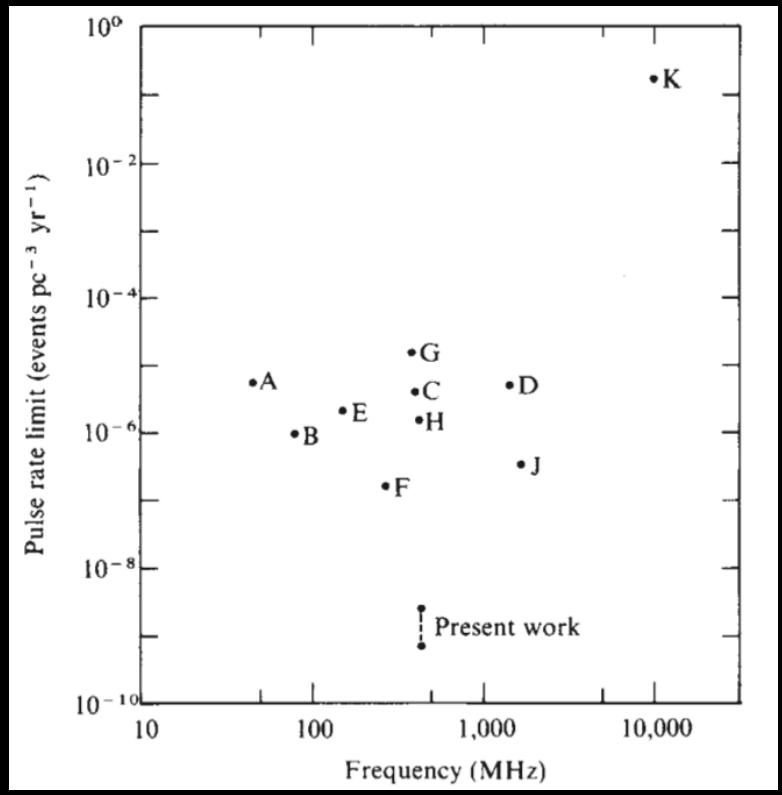
Credit: Joeri van Leeuwen

Nature Vol. 277 11 January 1979

A sensitive search for radio pulses from primordial black holes and distant supernovae



Credit: Aurore Simonet



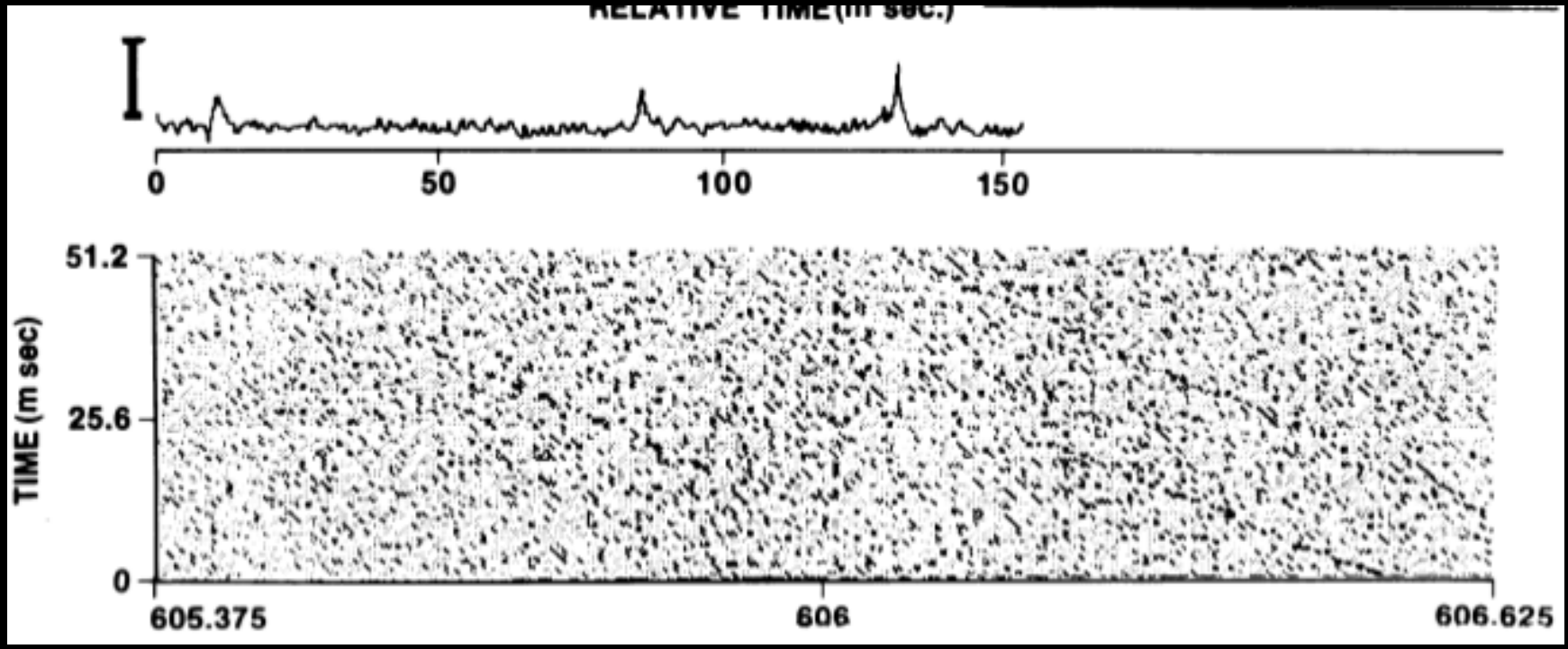
Phinney & Taylor (1979)

DISCOVERY OF MILLISECOND RADIO BURSTS FROM M87

I. R. Linscott and J. W. Erkes[1]
Dudley Observatory, Schenectady, New York
Received 1979 August 10; accepted 1979 December 19

ABSTRACT

Highly dispersed radio pulses have been detected from M87 at radio frequencies of 430, 606, and 1420 MHz. The pulse sweep rates scale with the third power of the observing frequency as expected from the cold plasma law. The sweep rates correspond to dispersion measures in the range 1–5 × 10^3 parsec cm^{-3}. The pulses frequently appear grouped together separated within the group by approximately 50 ms. Peak power levels of 100 Jy and temporal widths of a few ms for individual pulses are found, and the group repetition rate is of the order of 1 s^{-1}.



NO RADIO PULSES FROM M87

J. H. TAYLOR AND P. R. BACKUS
Department of Physics and Astronomy, University of Massachusetts, Amherst
AND
M. DAMASHEK
National Radio Astronomy Observatory, Green Bank, West Virginia
Received 1980 September 22; accepted 1980 November 26

ABSTRACT

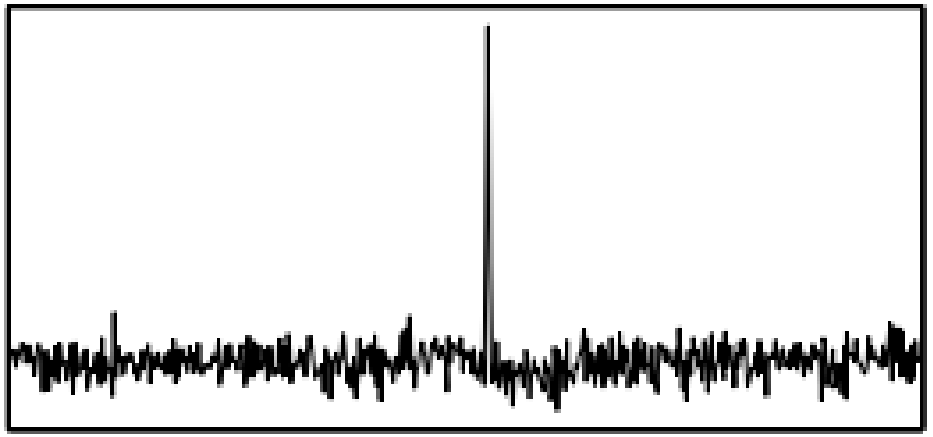
We have searched, without success, for dispersed radiofrequency pulses from the giant elliptical galaxy M87. Our sensitivity was comparable to that of Linscott and Erkes, who claim to have detected such pulses, and our effective observing time was much longer than theirs. We conclude that either the source of emission is highly variable and was inactive during our observations, or the pulses do not exist.

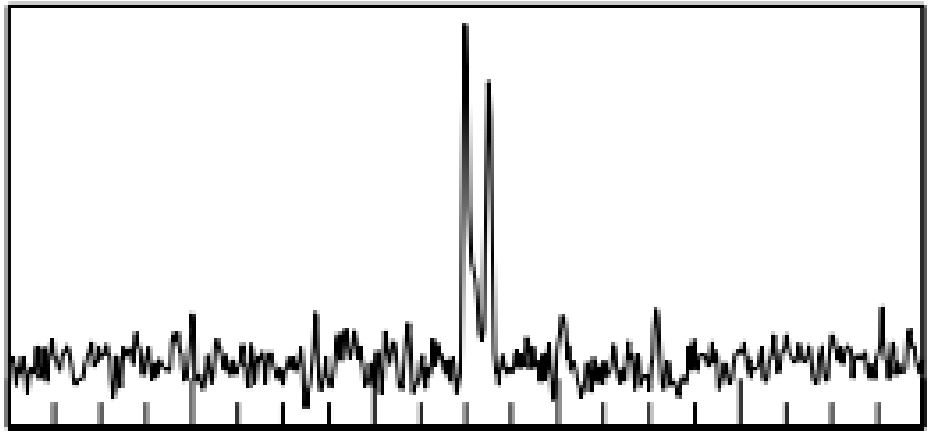
RADIO PULSES ALONG THE GALACTIC PLANE

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 highly scattered or highly dispersed signals from pulsars with large pulse-to-pulse intensity variations. A total of 36 individual pulses from five previously known pulsars were detected, along with a single pulse not associated with a previously known source. Follow-up observations discovered a pulsar, PSR J1918+08, from which the pulse originated. This pulsar has a period of 2.130 s and a dispersion measure of 30 pc cm^{-3}, and it has been seen to emit single pulses with strength up to 8 times the average.



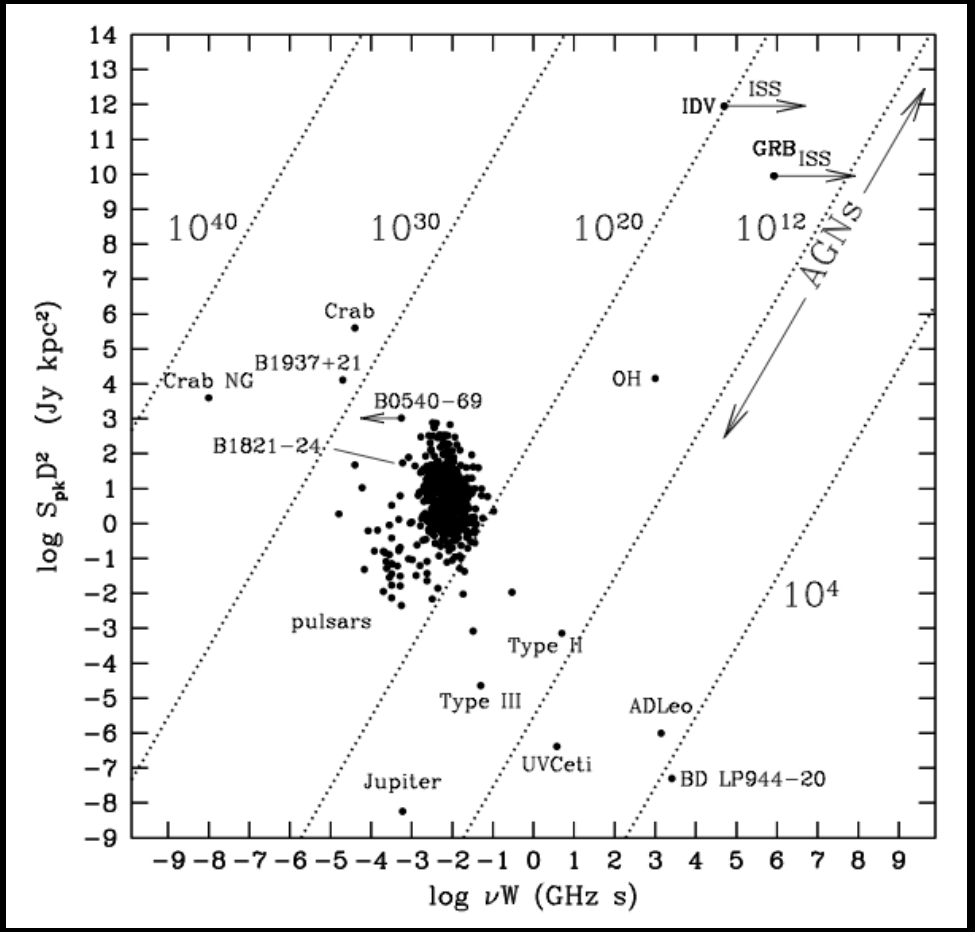


SEARCHES FOR FAST RADIO TRANSIENTS

J. M. CORDES[1] AND M. A. MCLAUGHLIN[2]

Received 2003 April 21; accepted 2003 July 2

"...the next few decades will undoubtedly bring about a greater understanding of radio-bursting objects, including Crab-like pulsars in other galaxies, counterparts to high-energy bursting sources, and other classes of objects that are yet to be discovered."



Transient radio bursts from rotating neutron stars

M. A. McLaughlin[1], A. G. Lyne[1], D. R. Lorimer[1], M. Kramer[1], A. J. Faulkner[1], R. N. Manchester[2], J. M. Cordes[3], F. Camilo[4], A. Possenti[5], I. H. Stairs[6], G. Hobbs[2], N. D'Amico[5,7], M. Burgay[5] & J. T. O'Brien[1]

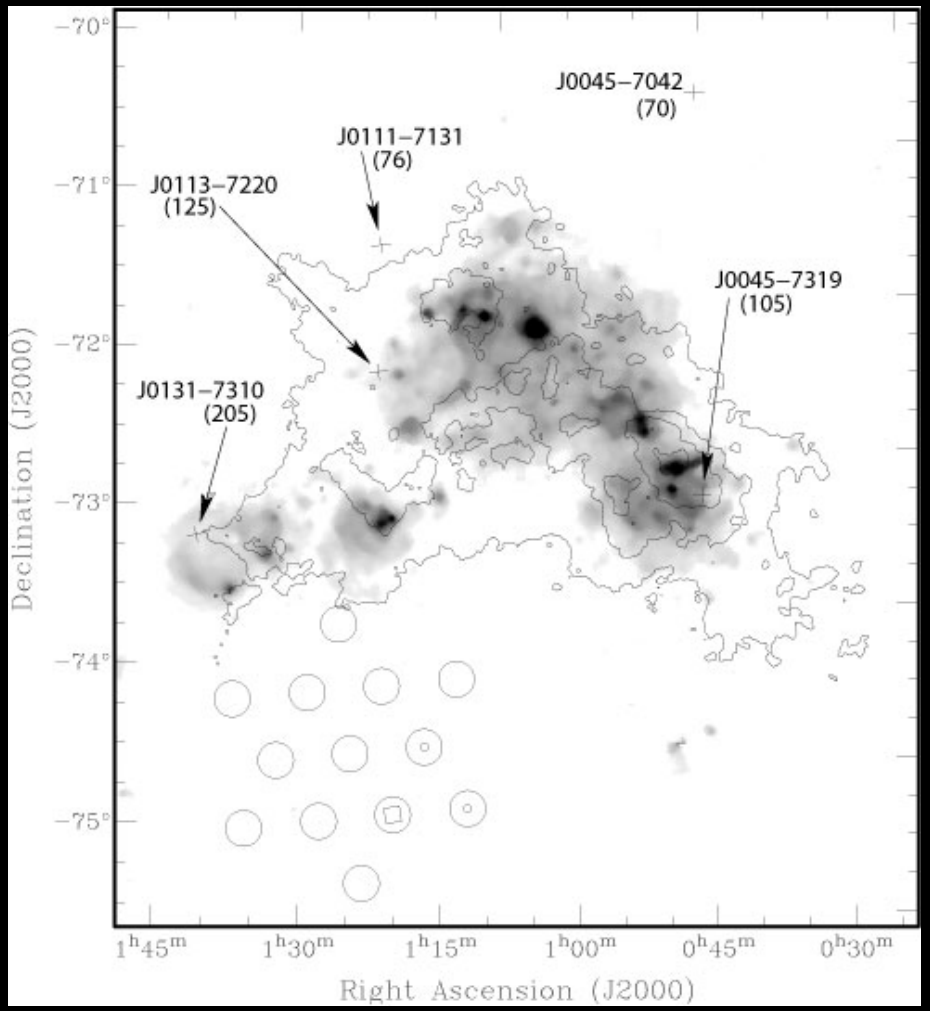
Rotating Radio Transients (RRATs)

DISCOVERY OF 14 RADIO PULSARS IN A SURVEY OF THE MAGELLANIC CLOUDS

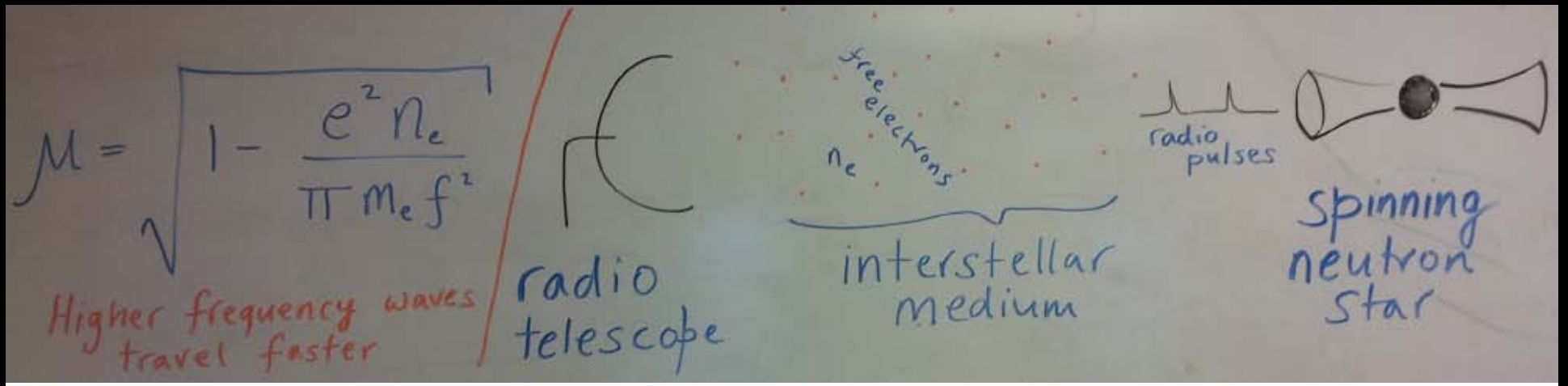
R. N. MANCHESTER,[1] G. FAN,[2,3] A. G. LYNE,[4] V. M. KASPI,[3] AND F. CRAWFORD[5]

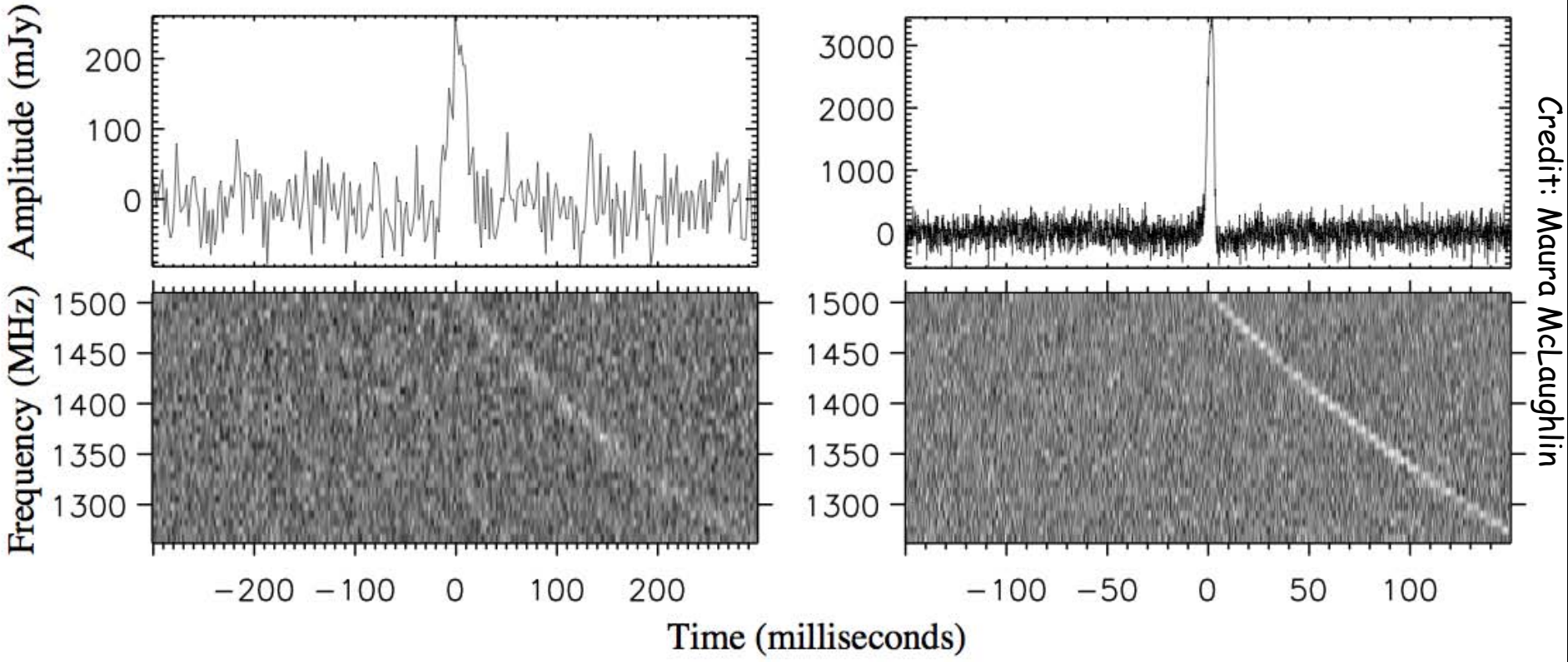
Received 2006 February 23; accepted 2006 April 19

Credit: ATNF

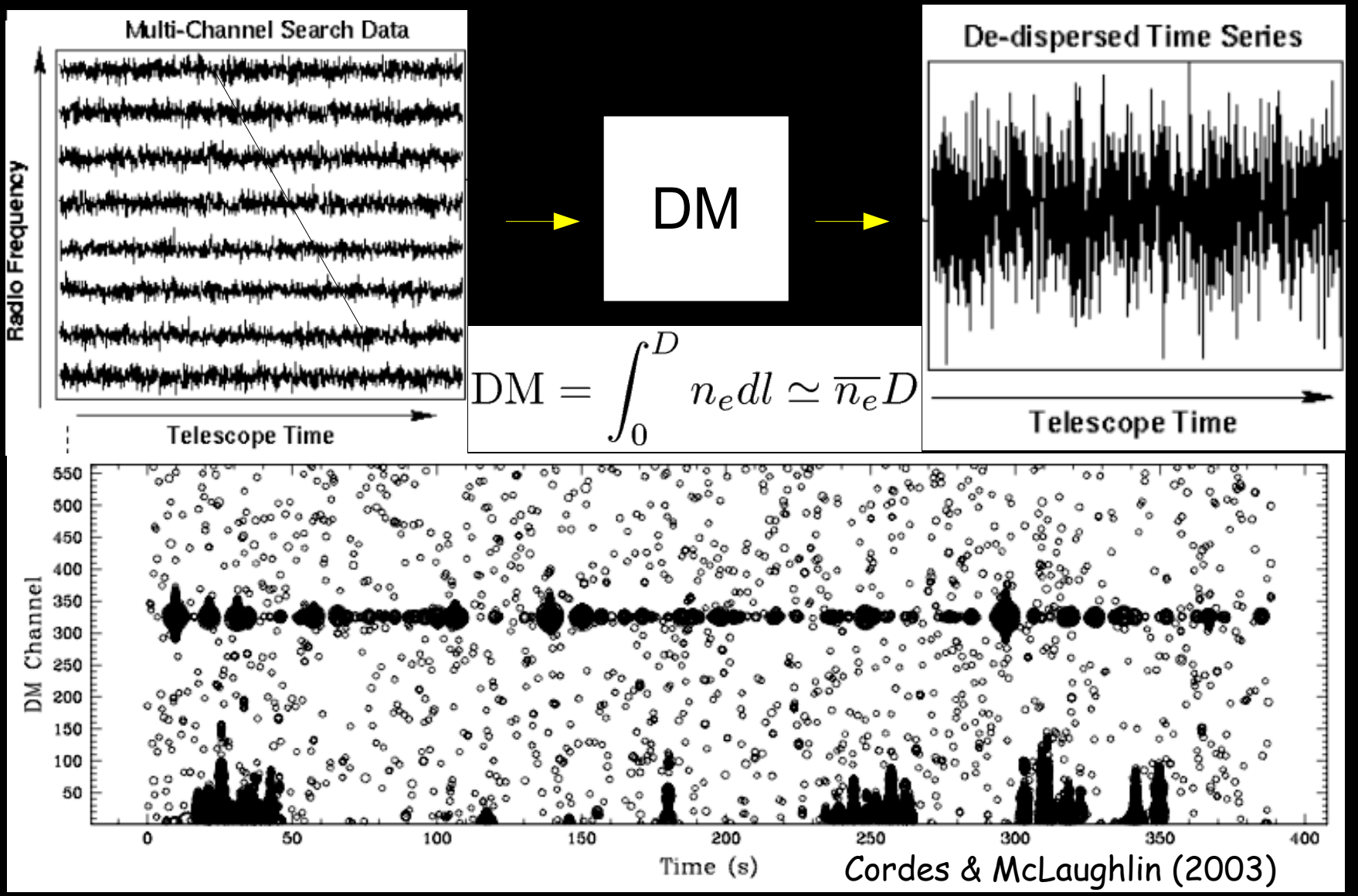


Credit: Froney Crawford

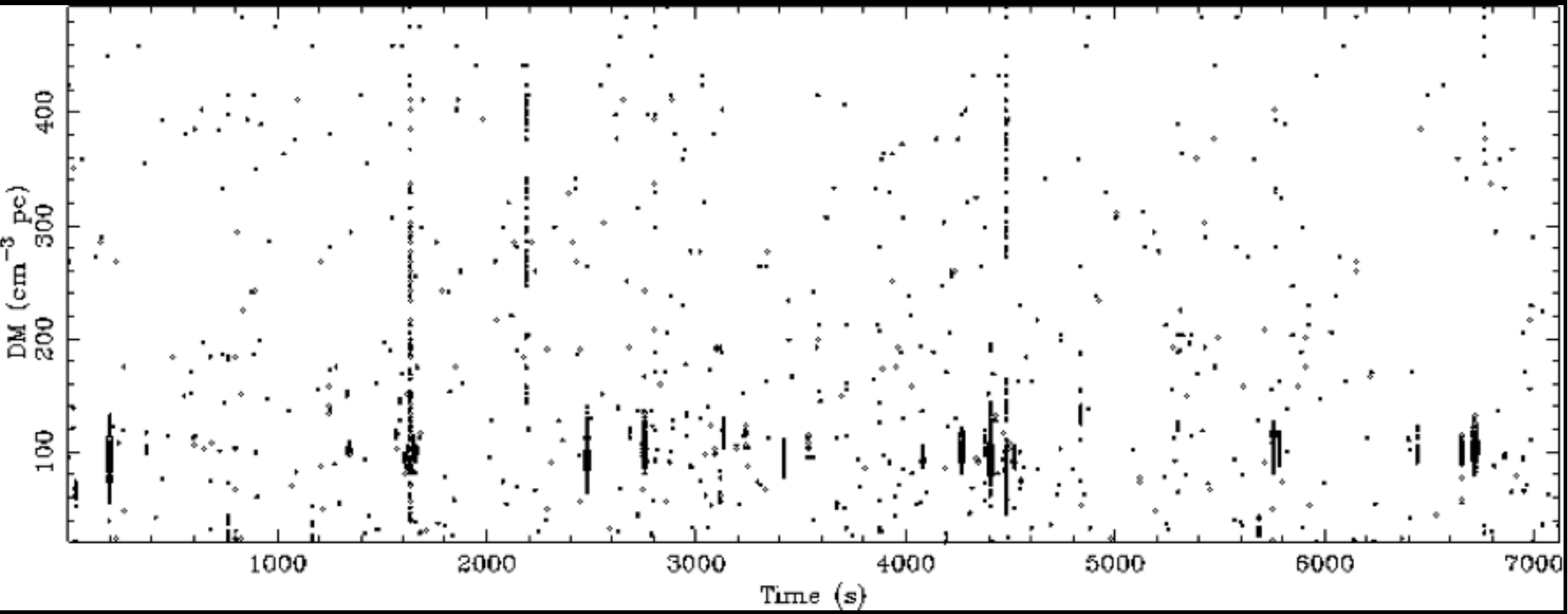

$\mu = \sqrt{1 - \frac{e^2 n_e}{\pi m_e f^2}}$
Higher frequency waves travel faster
radio telescope
free electrons
n_e
interstellar medium
radio pulses
spinning neutron star


Amplitude (mJy)
200
100
0
3000
2000
1000
0
Frequency (MHz)
1500
1450
1400
1350
1300
−200 −100 0 100 200
−100 −50 0 50 100
Time (milliseconds)
Credit: Maura McLaughlin

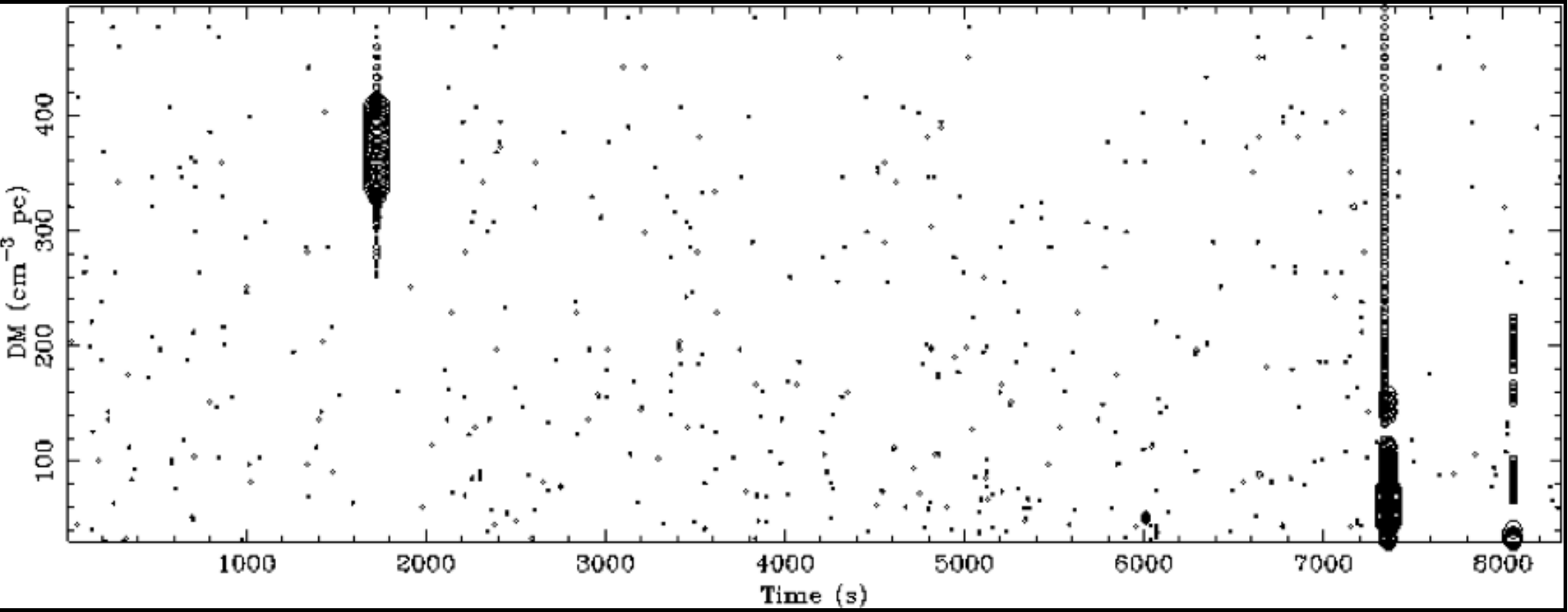
Single-pulse search pipeline

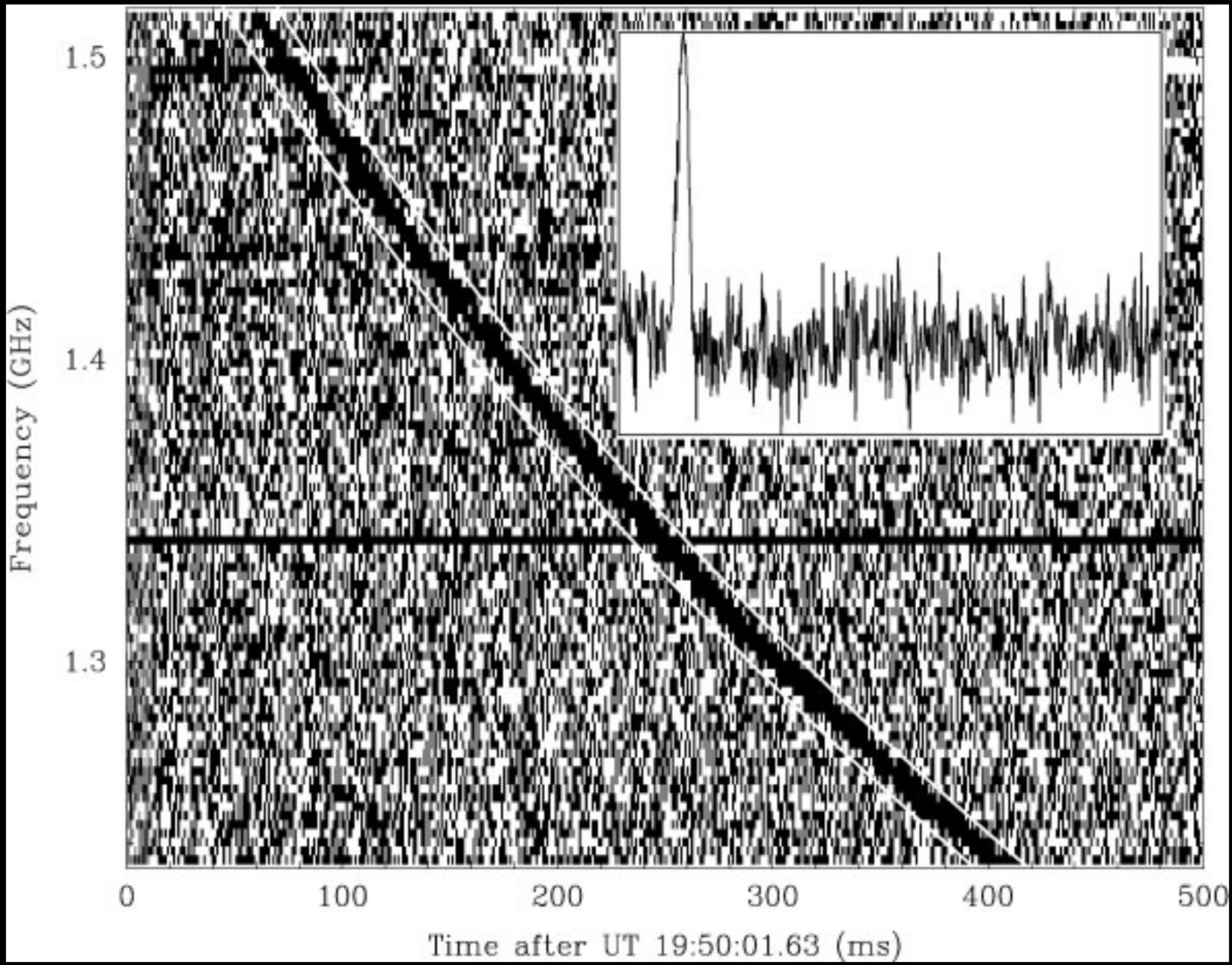


Example diagnostic plot



An unexpected signal!




1.5
1.4
1.3
Frequency (GHz)
0
100
200
300
400
500
Time after UT 19:50:01.63 (ms)

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]

Pulsar surveys offer a rare opportunity to monitor the radio sky for impulsive burst-like events with millisecond durations. We analyzed archival survey data and found a 30-jansky dispersed burst, less than 5 milliseconds in duration, located 3° from the Small Magellanic Cloud. The burst properties argue against a physical association with our Galaxy or the Small Magellanic Cloud. Current models for the free electron content in the universe imply that the burst is less than 1 gigaparsec distant. No further bursts were seen in 90 hours of additional observations, which implies that it was a singular event such as a supernova or coalescence of relativistic objects. Hundreds of similar events could occur every day and, if detected, could serve as cosmological probes.

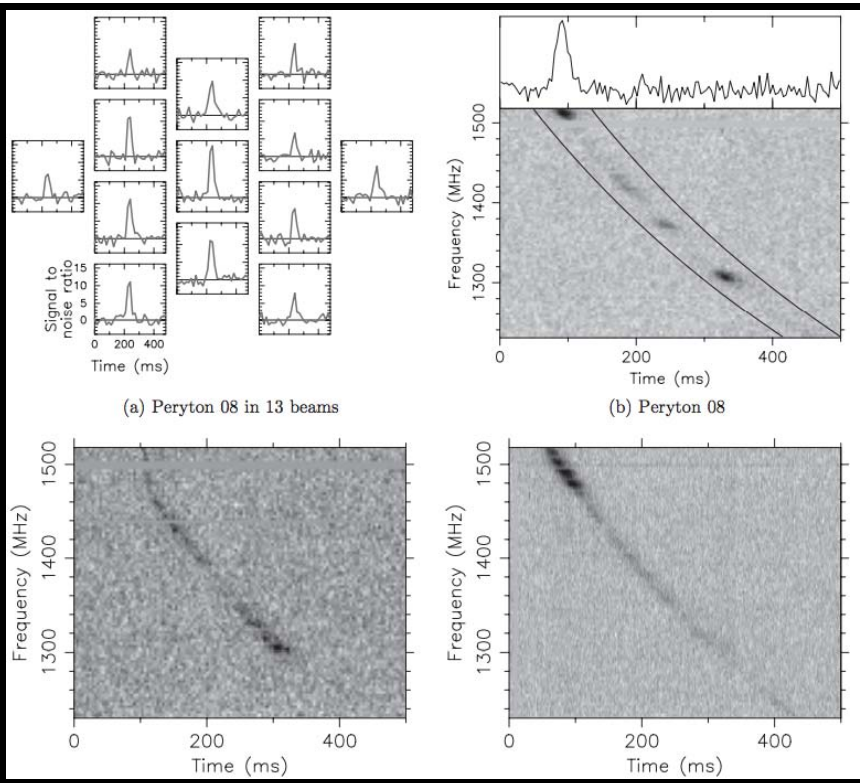
Questions:

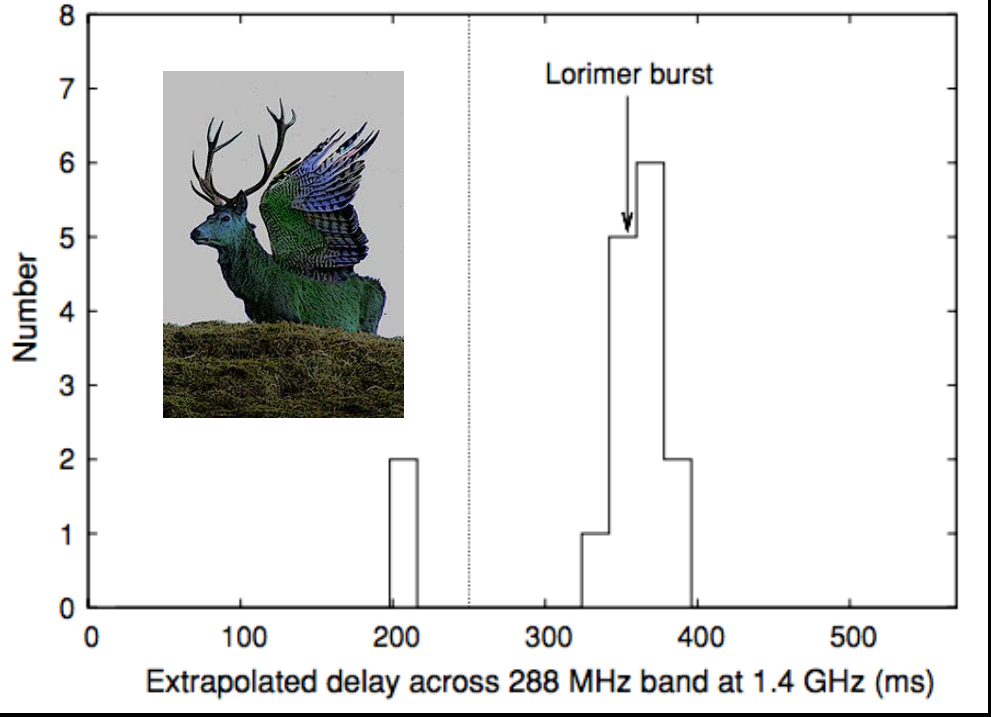
* Why so bright?
* Why no weaker events?
* Detectable in other surveys?

THE ASTROPHYSICAL JOURNAL, 727:18 (5pp), 2011 January 20 doi:10.1088/0004-637X/727/1/18

RADIO BURSTS WITH EXTRAGALACTIC SPECTRAL CHARACTERISTICS SHOW TERRESTRIAL ORIGINS

S. BURKE-SPOLAOR[1,5], MATTHEW BAILES[1], RONALD EKERS[2], JEAN-PIERRE MACQUART[3], AND FRONEFIELD CRAWFORD III[4]
[1] Centre for Astrophysics and Supercomputing, Swinburne University of Technology, Mail H39, P.O. Box 218, Hawthorn VIC 3122, Australia; sburke@astro.swin.edu.au
[2] CSIRO Australia Telescope National Facility, P.O. Box 76, Epping NSW 1710, Australia
[3] ICRAR/Curtin Institute of Radio Astronomy, GPO Box U1987, Perth WA 6845, Australia
[4] Department of Physics and Astronomy, Franklin and Marshall College, Lancaster, PA 17604, USA
Received 2010 July 19; accepted 2010 October 29; published 2010 December 28





Even my own wife begins to doubt…

A search for dispersed radio bursts in archival Parkes Multibeam Pulsar Survey data

Manjari Bagchi,* Angela Cortes Nieves and Maura McLaughlin†
Department of Physics, White Hall, West Virginia University, Morgantown, WV 26506, USA

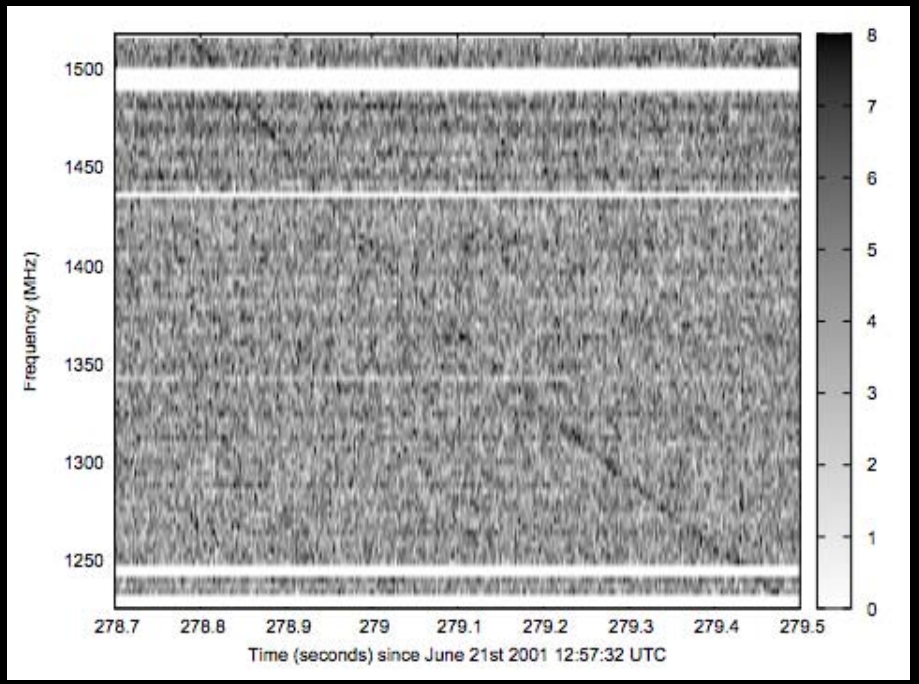
"Moreover, the lack of highly dispersed celestial signals is [sic] the evidence that the Lorimer burst is unlikely to belong to a cosmological source population."

…but then, in 2012, along came this

On the origin of a highly-dispersed coherent radio burst

E.F. Keane[1], B.W. Stappers[2], M. Kramer[1,2] & A.G. Lyne[2]
[1] *Max Planck Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany.*
[2] *University of Manchester, Jodrell Bank Centre for Astrophysics, School of Physics & Astronomy, Manchester M13 9PL, UK.*

"The burst is also consistent with the radio signal theorised from an annihilating mini black hole."

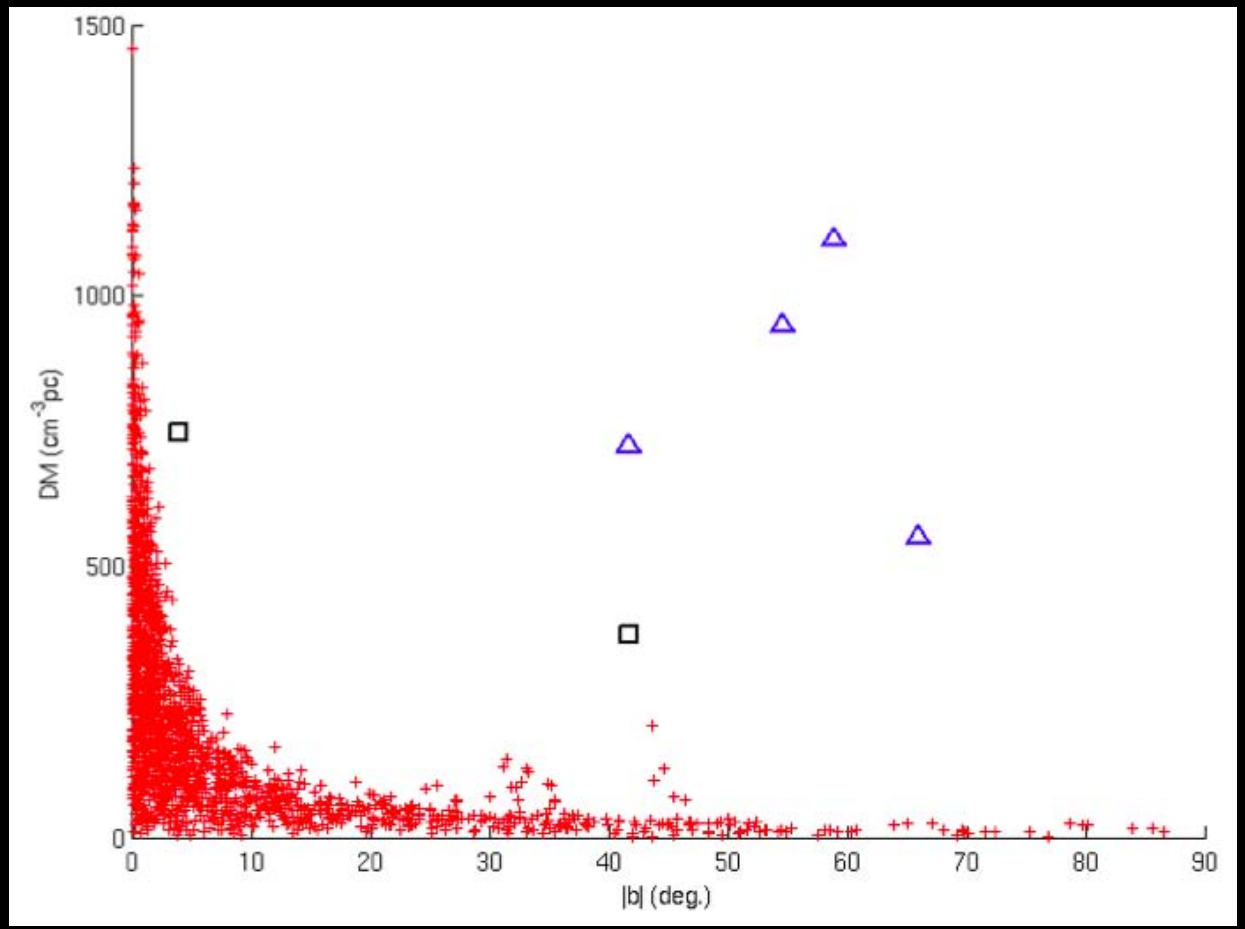


Credit: Keane et al. 2011/2012

DM = 746 pc/cc
W=8 ms

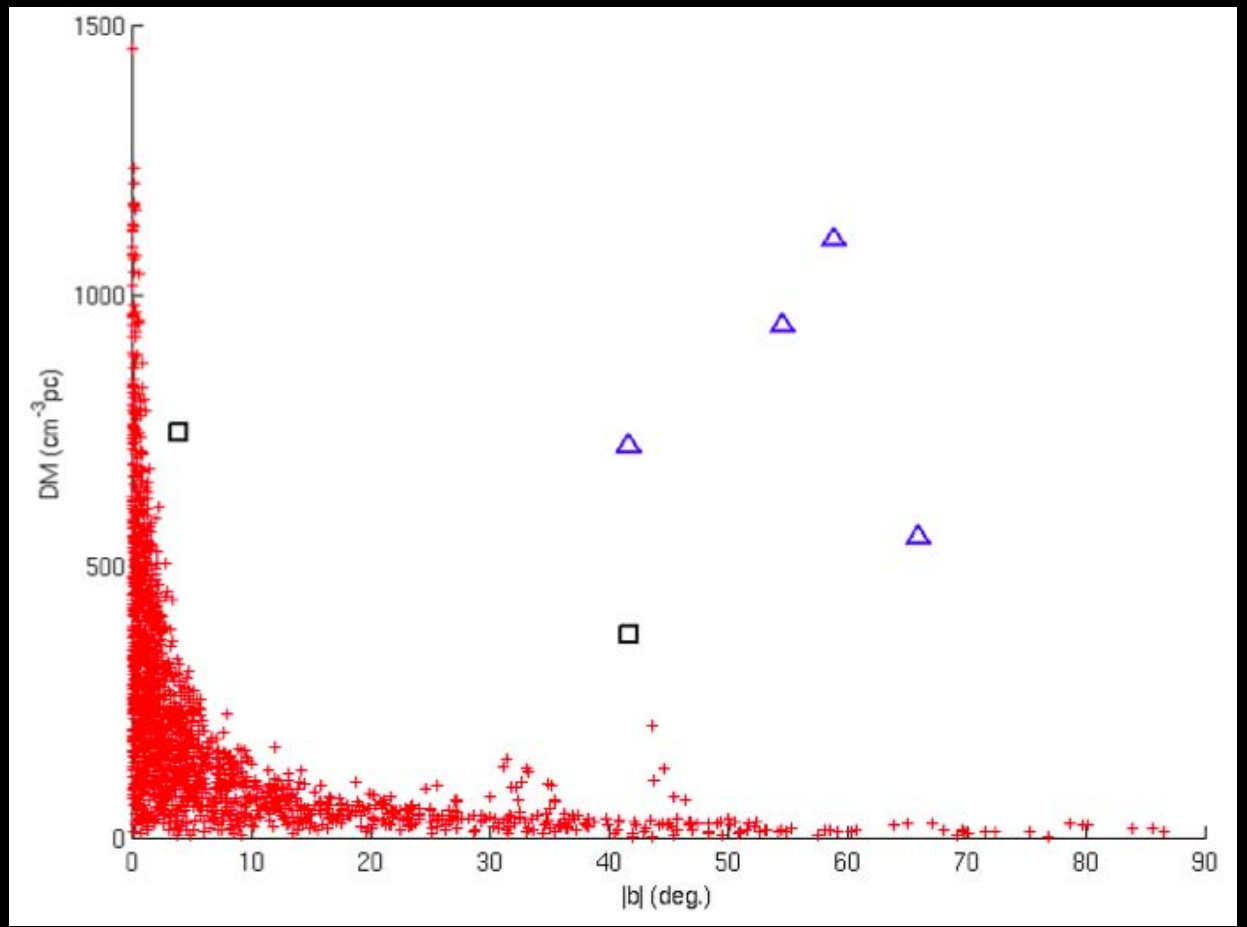
A Population of Fast Radio Bursts at Cosmological Distances

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. J. Champion,[9] P. Coster,[2,3] N. D'Amico,[10,7] 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]



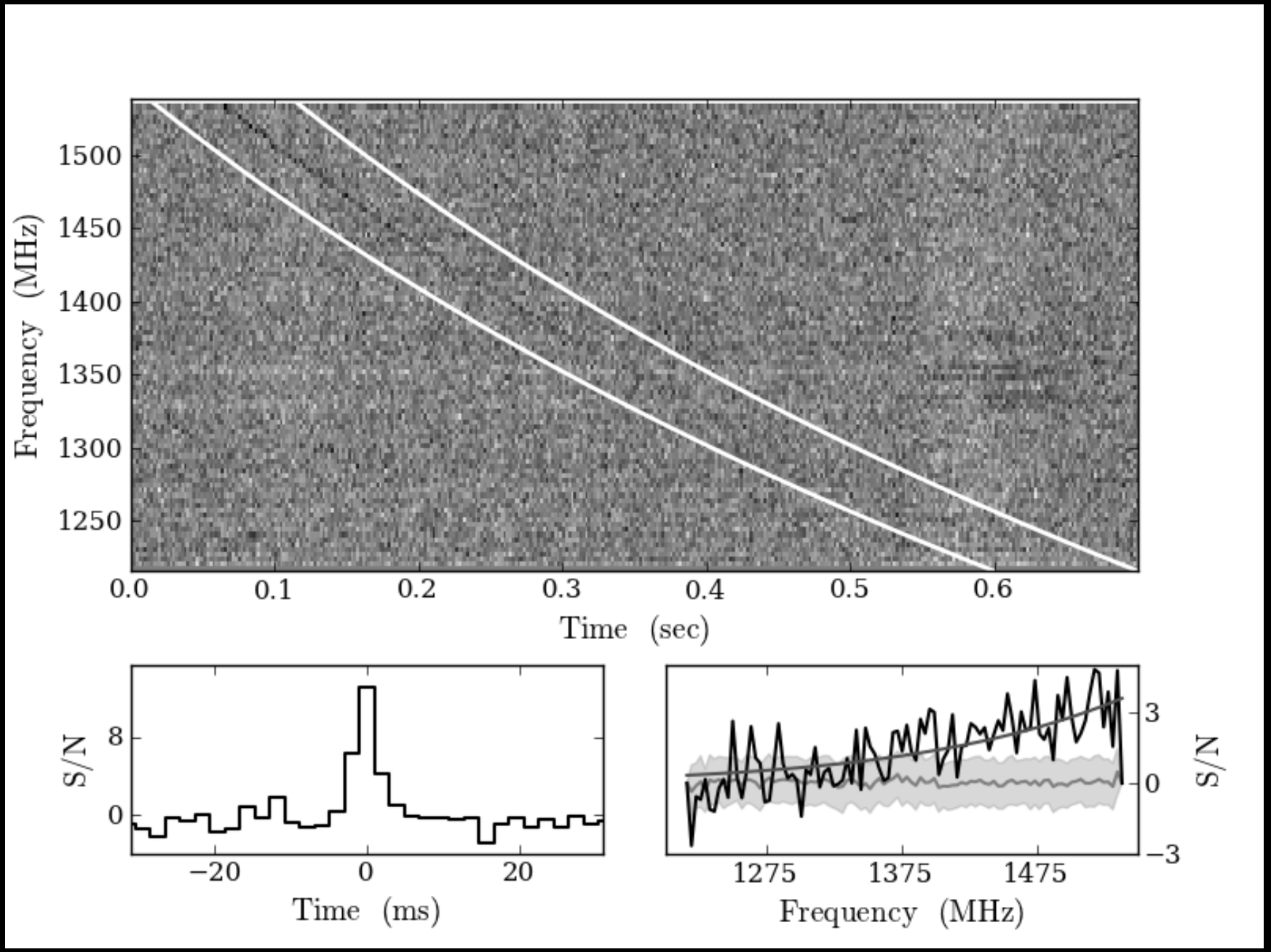
A Population of Fast Radio Bursts at Cosmological Distances

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. J. Champion,[9] P. Coster,[2,3] N. D'Amico,[10,7] 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]



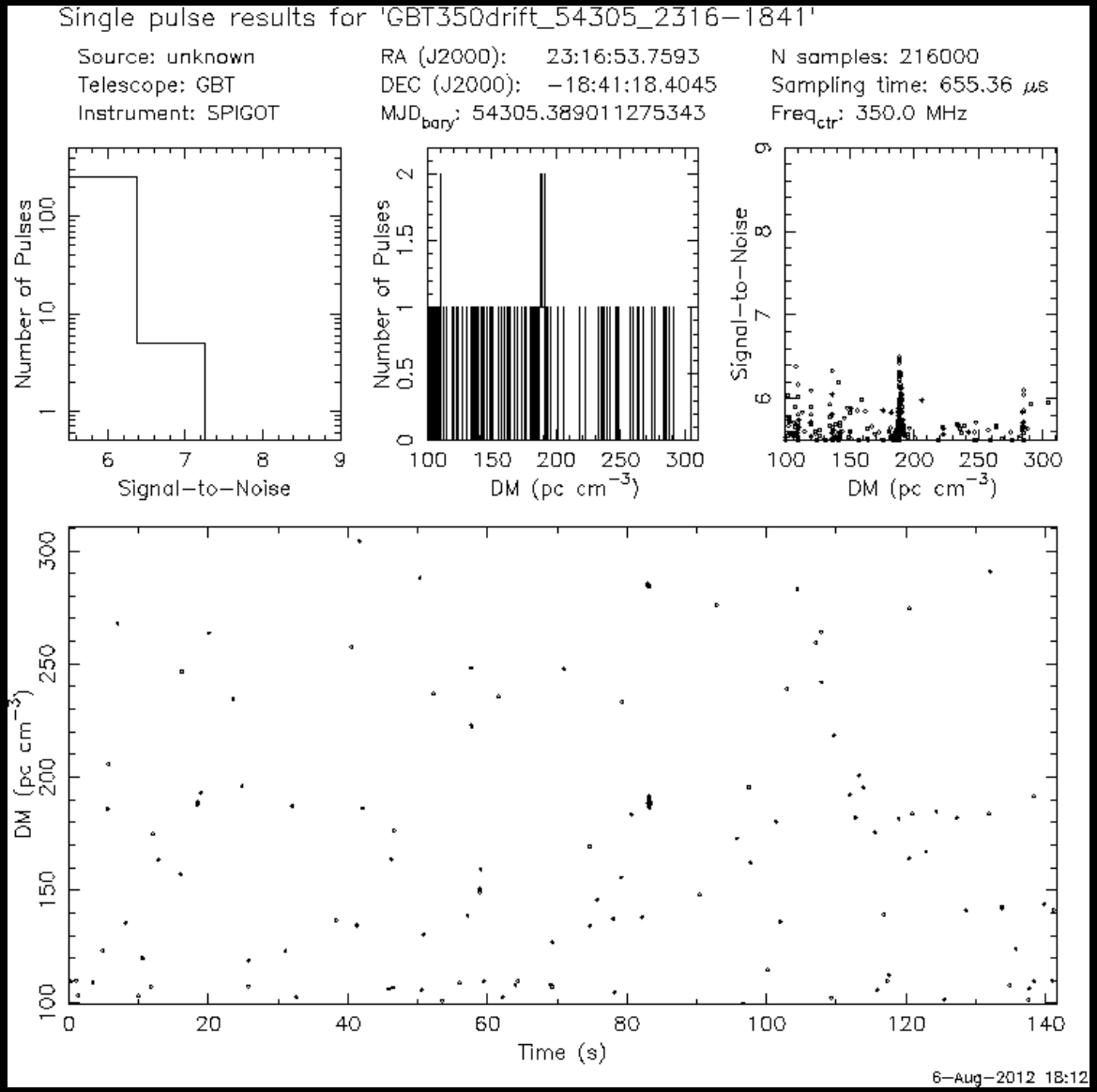
- Lorimer bursts?
- Sparkers?
- FARTS?
- FRBs

An FRB at Arecibo



Credit: Spitler et al. (2014)

Faint events are harder to see

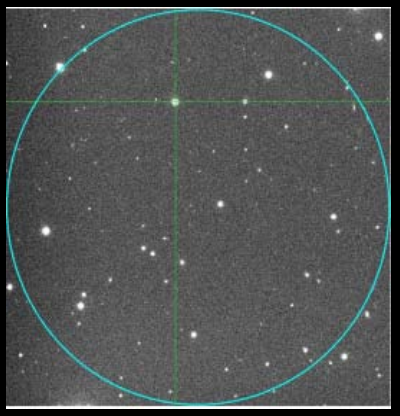


Credit: Scott Ransom

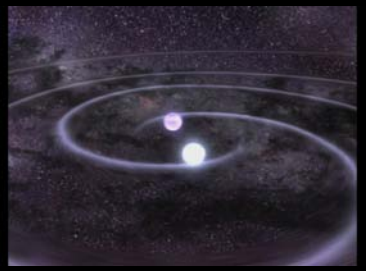
What could they be?

- Local
  - Atmospheric Peryton idea
    (Kulkarni et al. 2014)

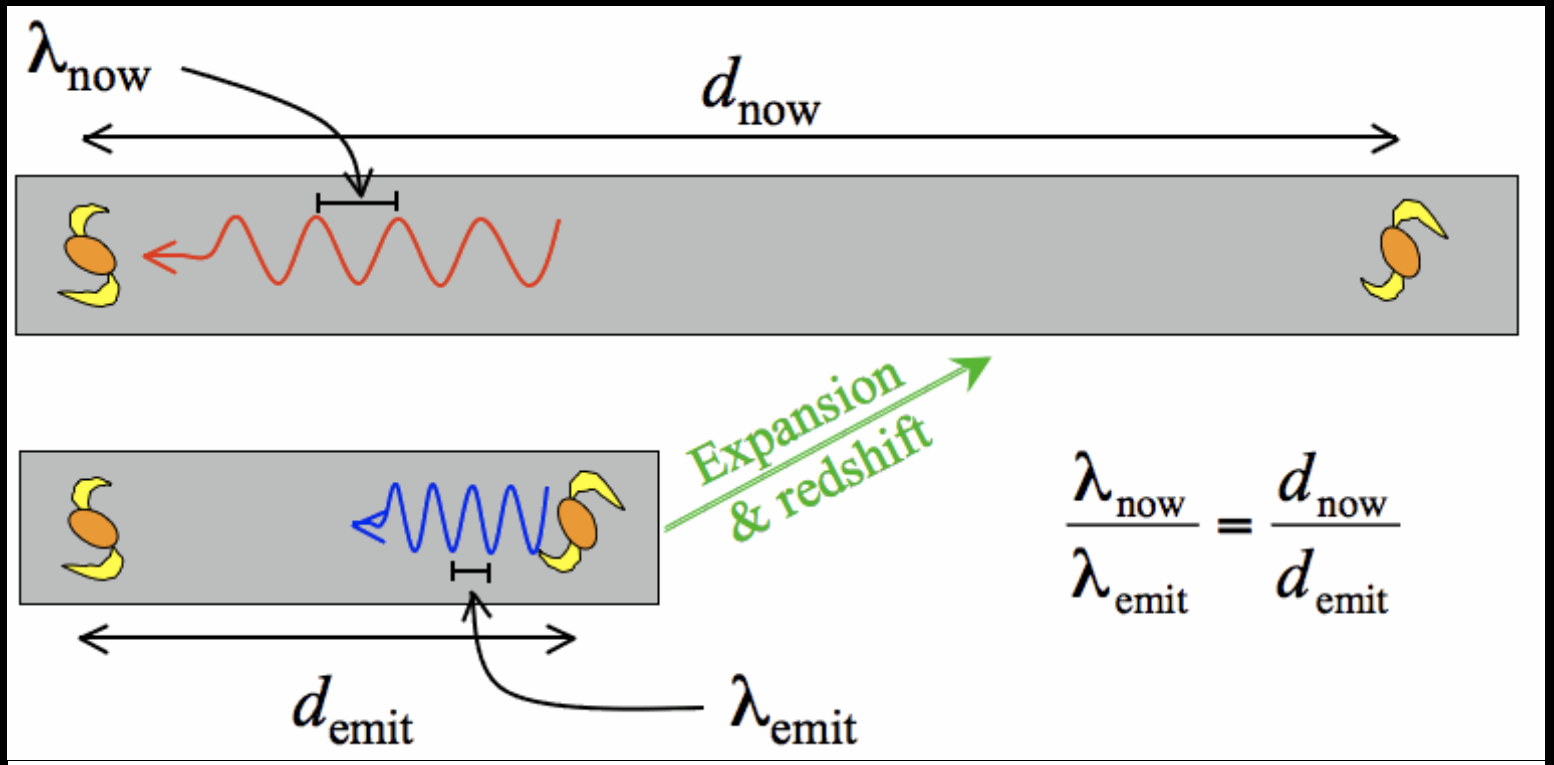
- Extra-terrestrial
  - Alien signals
    (Luan & Goldreich 2014)
- Galactic
  - Flare stars
    (Loeb et al. 2014)



- Extragalactic
  - Favored cosmic catastrophe
    (Cobbly et al. 2014)



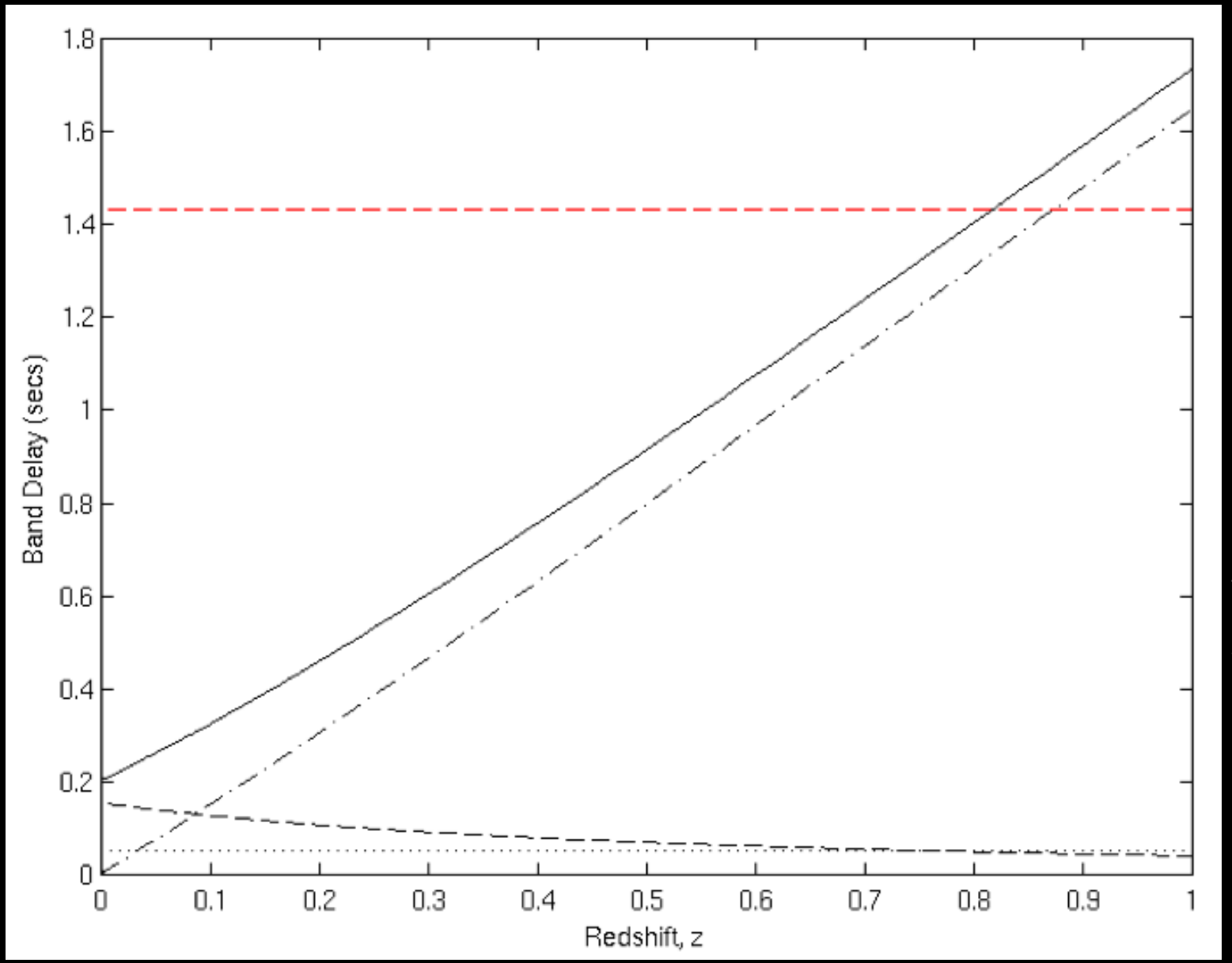
Cosmological redshift



$$z = \frac{\lambda_{obs} - \lambda_{emit}}{\lambda_{emit}} \rightarrow (1+z) = \lambda_{obs}/\lambda_{emit}$$

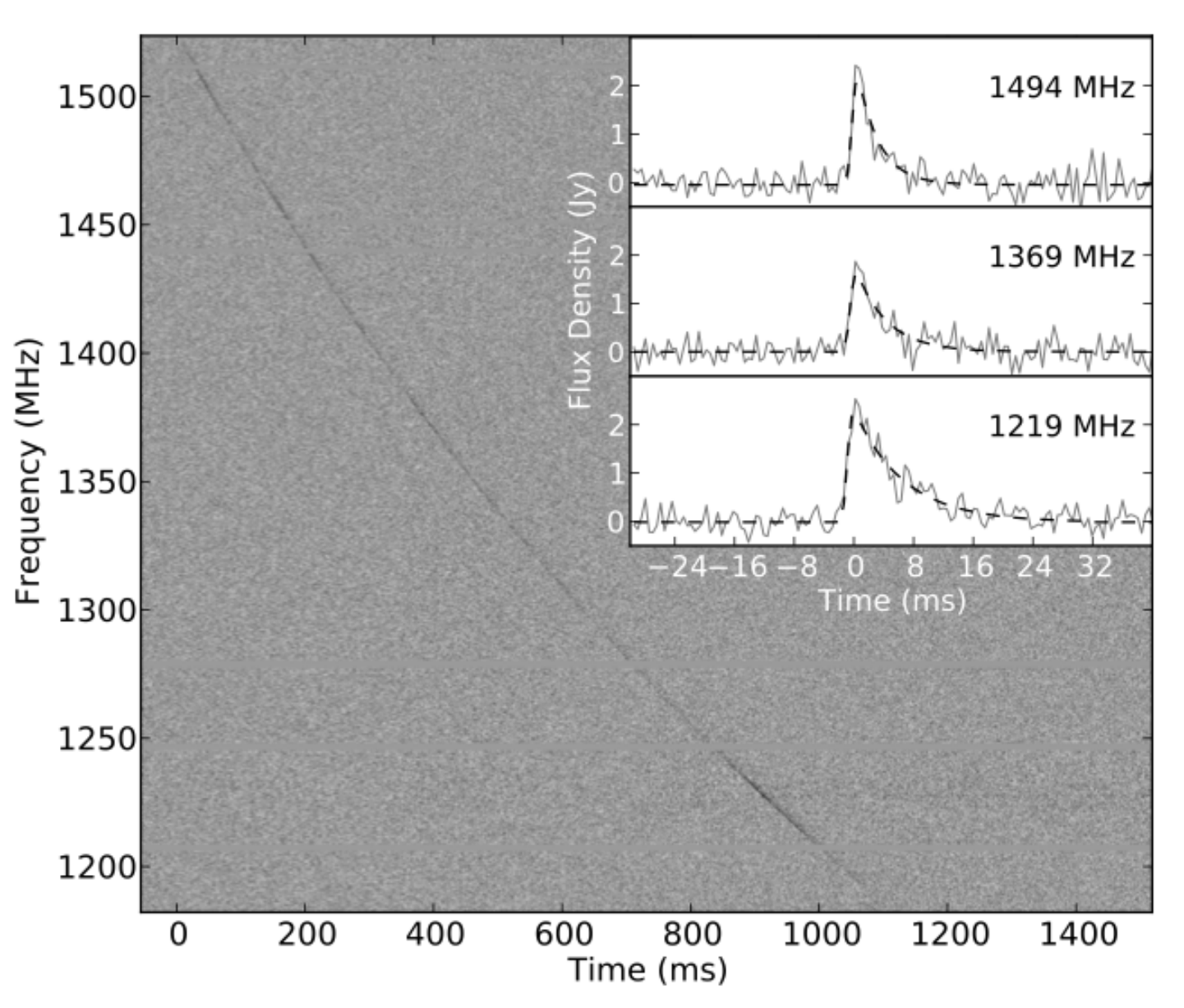
Credit: Whittle "Extragalactic Astronomy" (UVA)

DM delay in FRB 110220



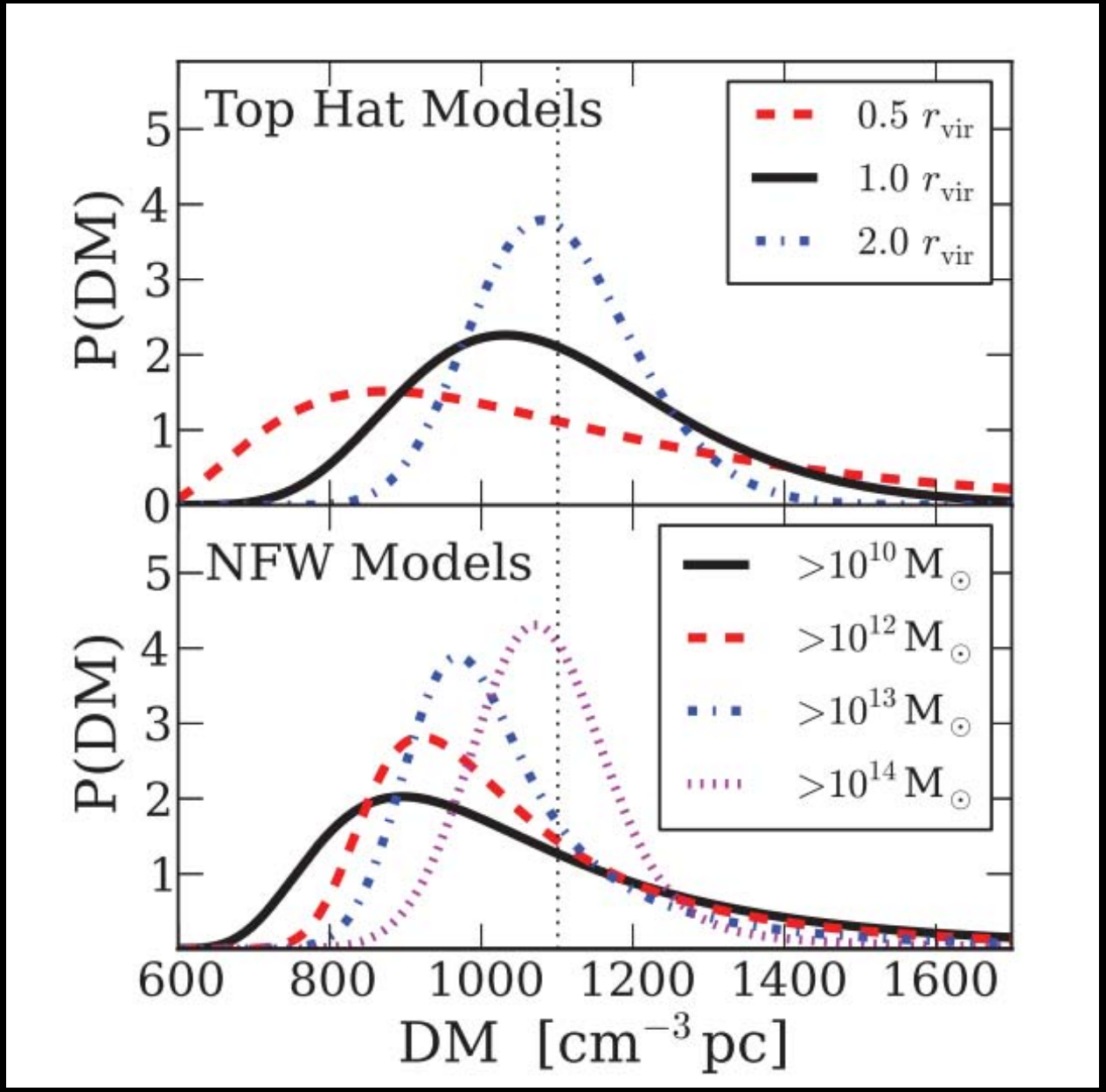
Credit: Thornton et al. (2013)

Scattering in FRB 110220



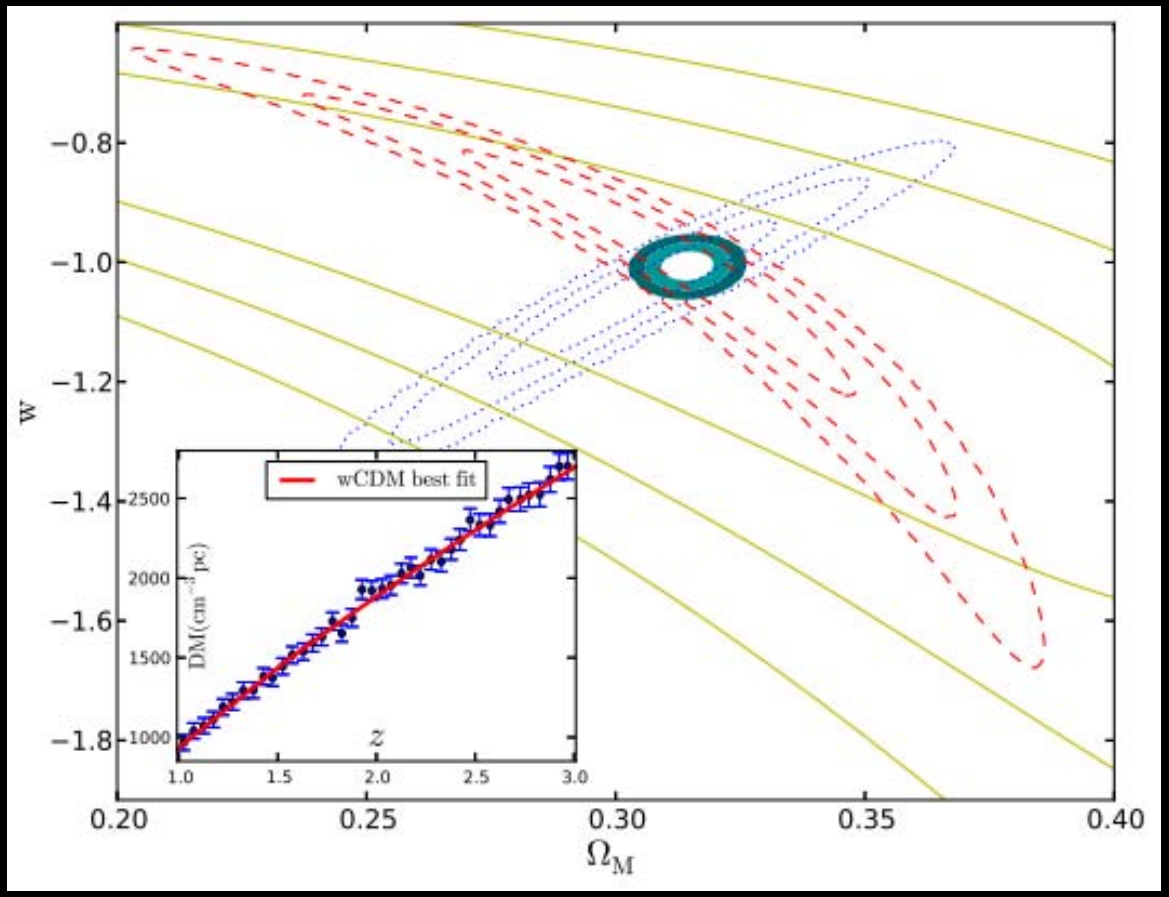
Credit: Thornton et al. 2013

Probing the missing baryons



Credit: McQuinn (2014)

FRBs as cosmic rulers



Credit: Zhou et al (2014)

$$\langle \mathrm{DM_{IGM}} \rangle(z) = \Omega_\mathrm{b} \frac{3H_0 c}{8\pi G m_\mathrm{p}} \int_0^z \frac{(1+z') f_\mathrm{IGM} \left(\frac{3}{4} X_\mathrm{e,H}(z') + \frac{1}{8} X_\mathrm{e,He}(z')\right)}{\{\Omega_\mathrm{M}(1+z')^3 + \Omega_\mathrm{DE}(1+z')^{3[1+w(z')]}\}^{1/2}} dz'$$

What are people doing

- Searching archival data
- Follow-up on existing bursts
- Realtime detectors on large/small dishes
- Staring at the sky with interferometers

(My) bold predictions

- 2015: counterparts found
- 2020: 100s FRBs found
- 2025: 1000s of FRBs known
- 2030: FRBs essential cosmological tools