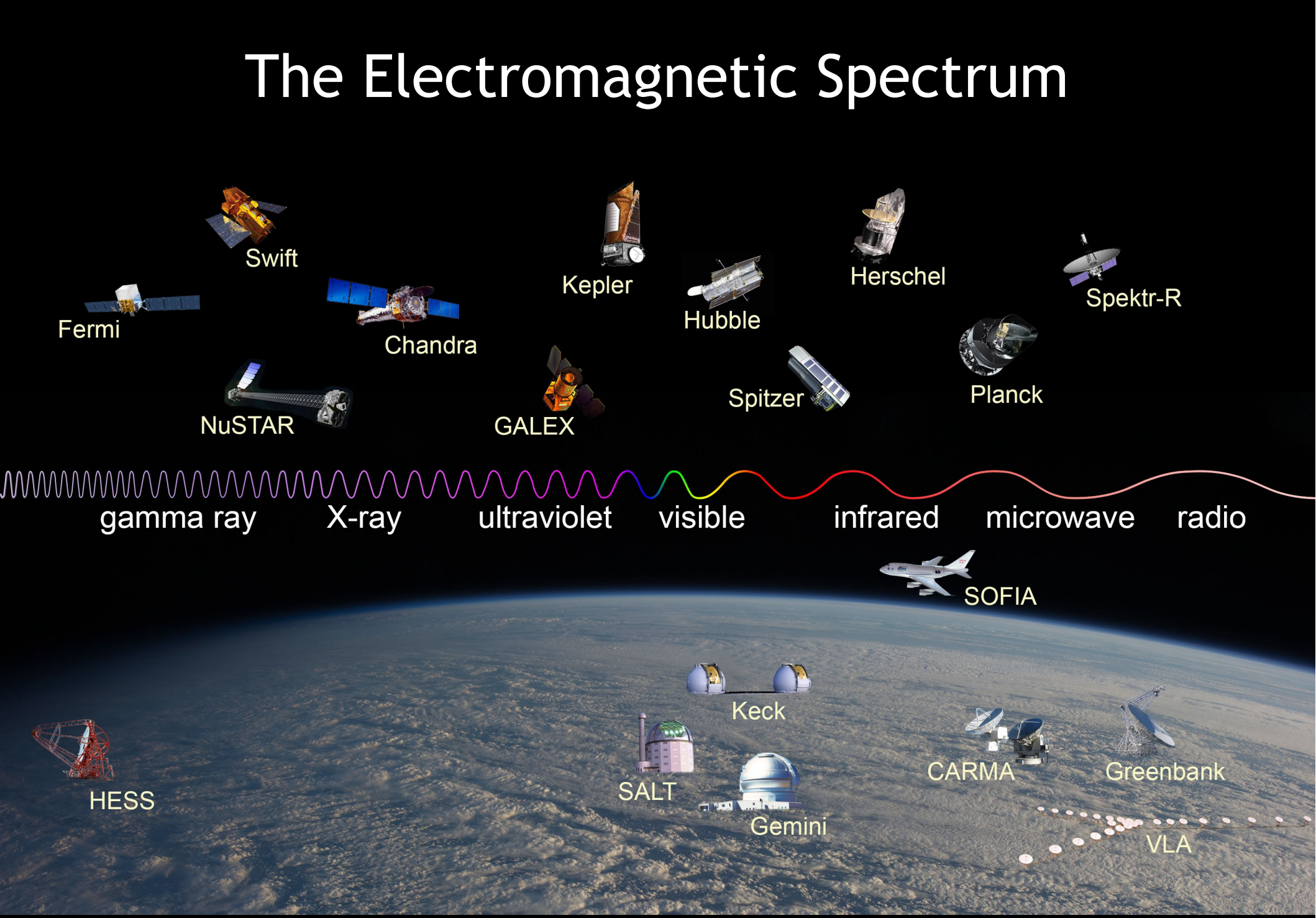
Fast Radio Bursts
Nature's Latest Cosmic Mystery

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

The Electromagnetic Spectrum



10 orders of magnitude change across the spectrum!

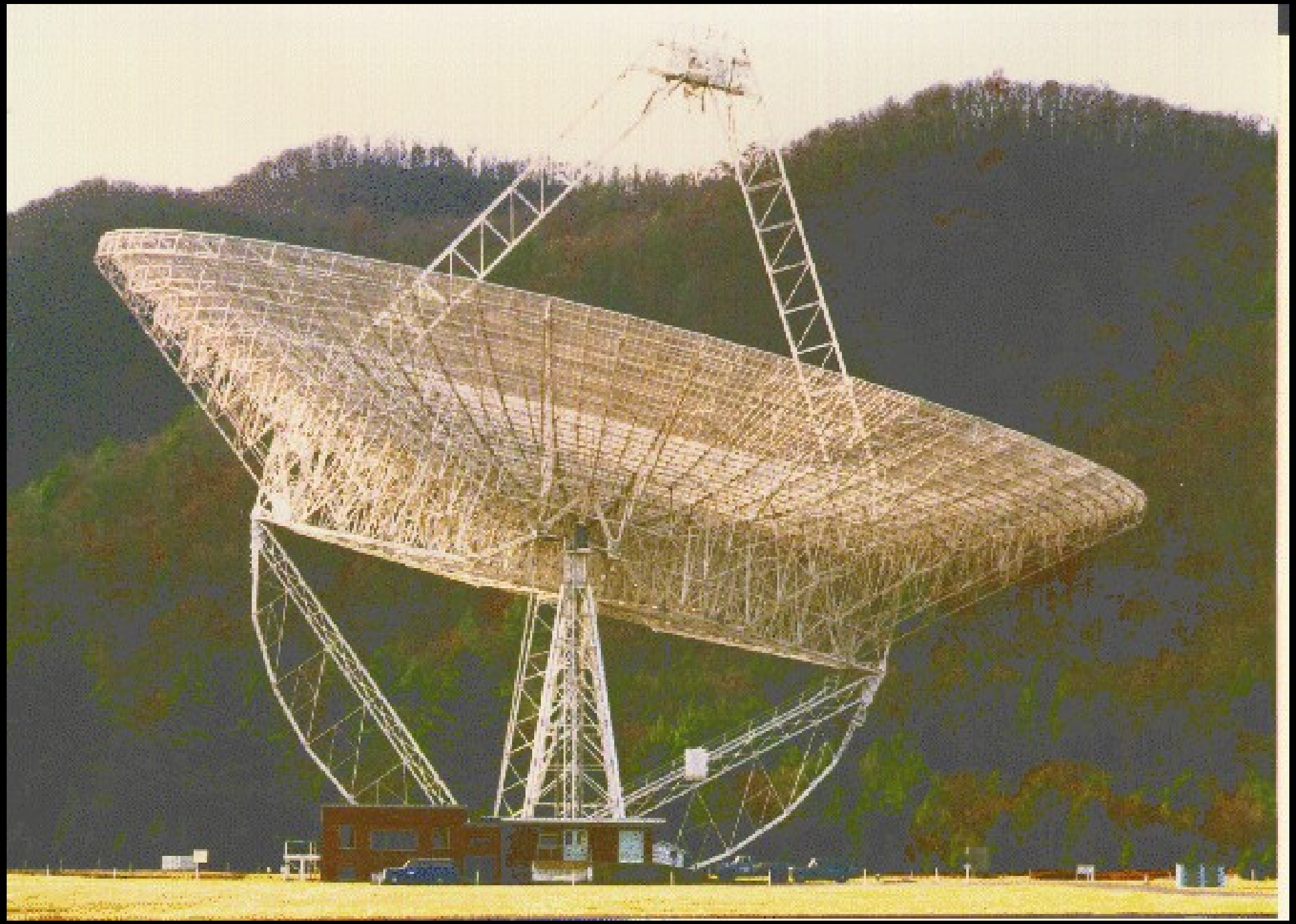
Credit: NASA

NATIONAL GEOGRAPHIC

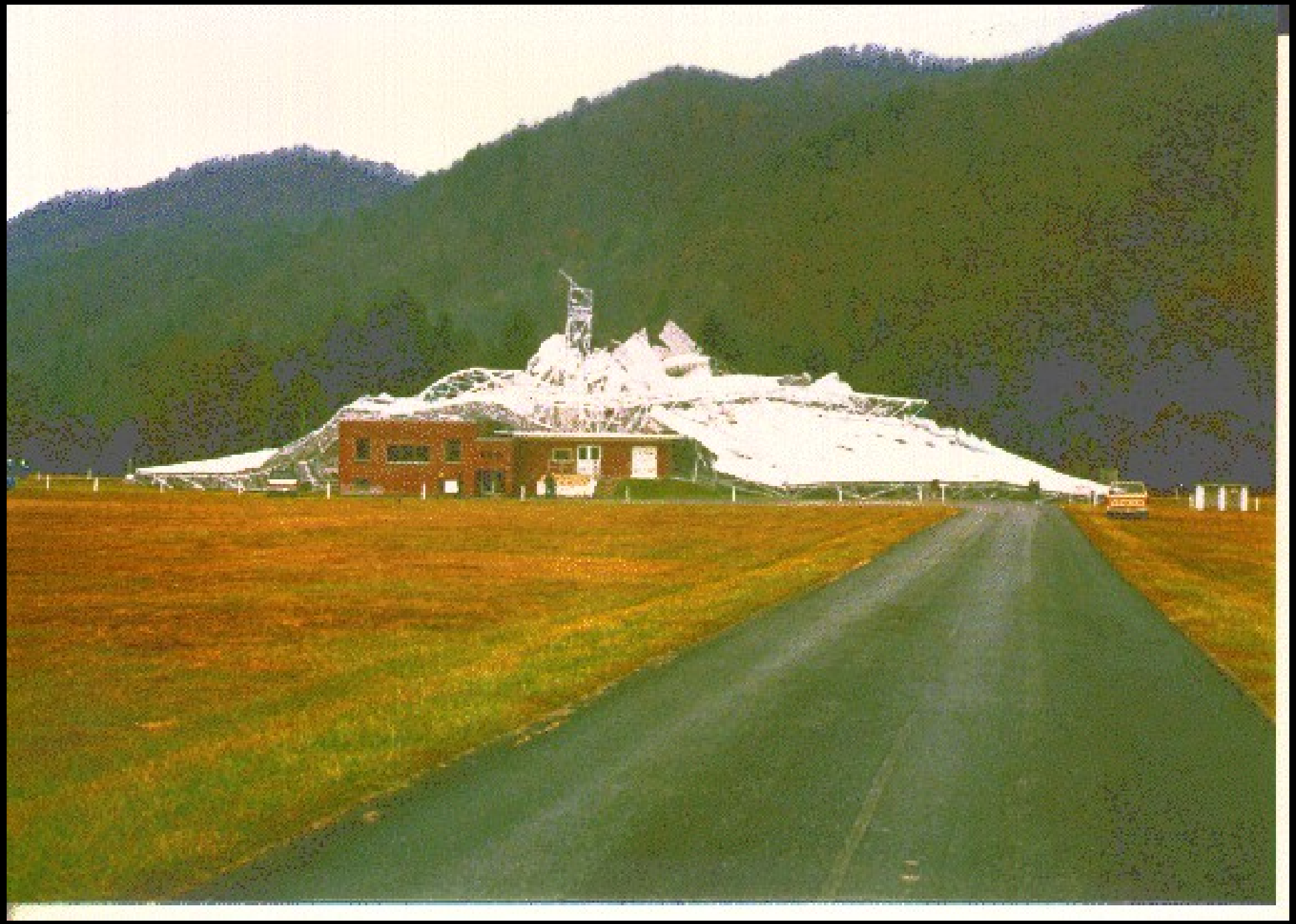
Photograph by Miloslav Druckmüller

MAGELLANIC CLOUDS. DECEMBER 2

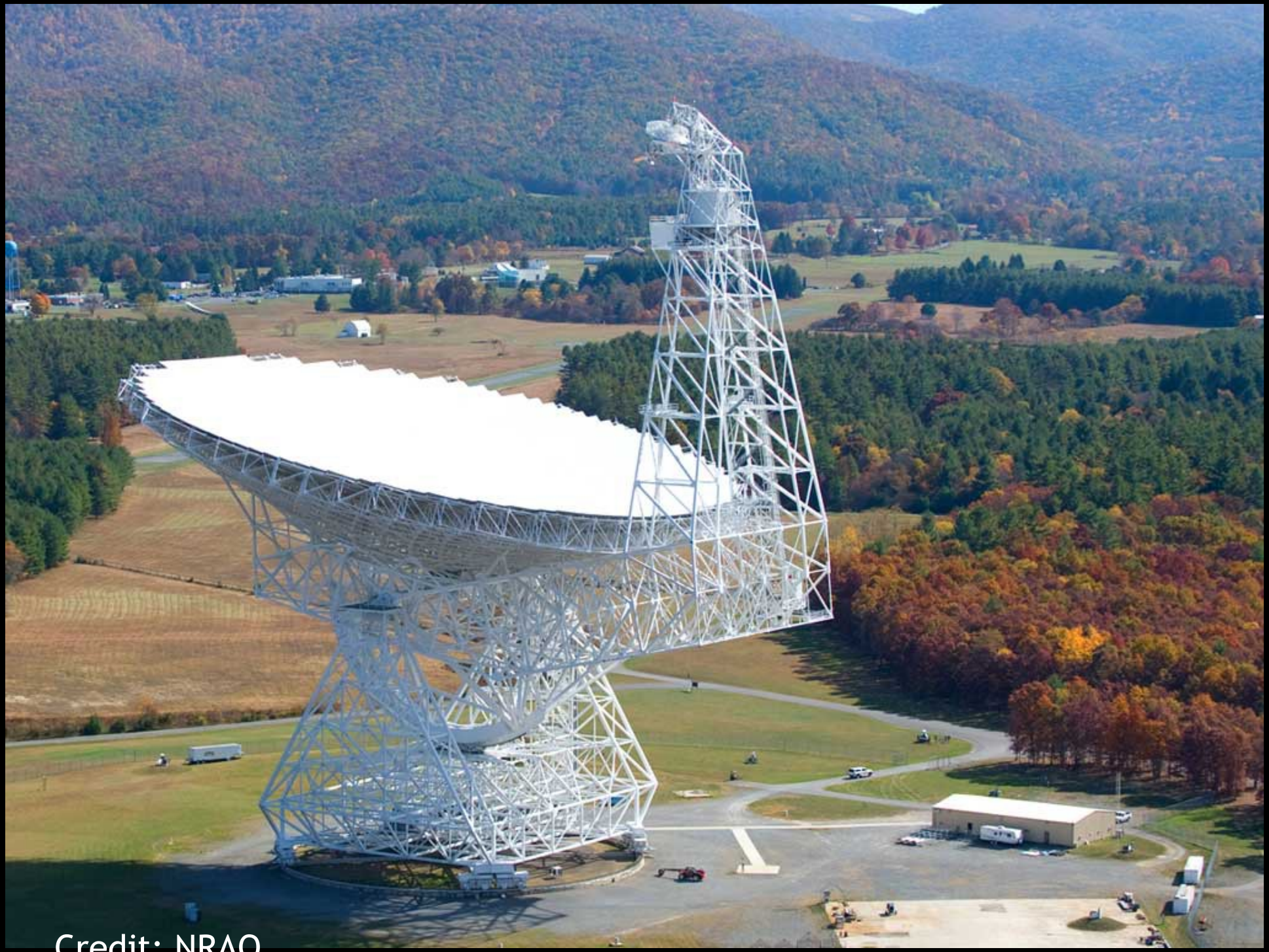

Credit: NRAO/AUI/NSF Audio:David Saroff (RIT)



November 15 1988 – Photo by Richard Porcas

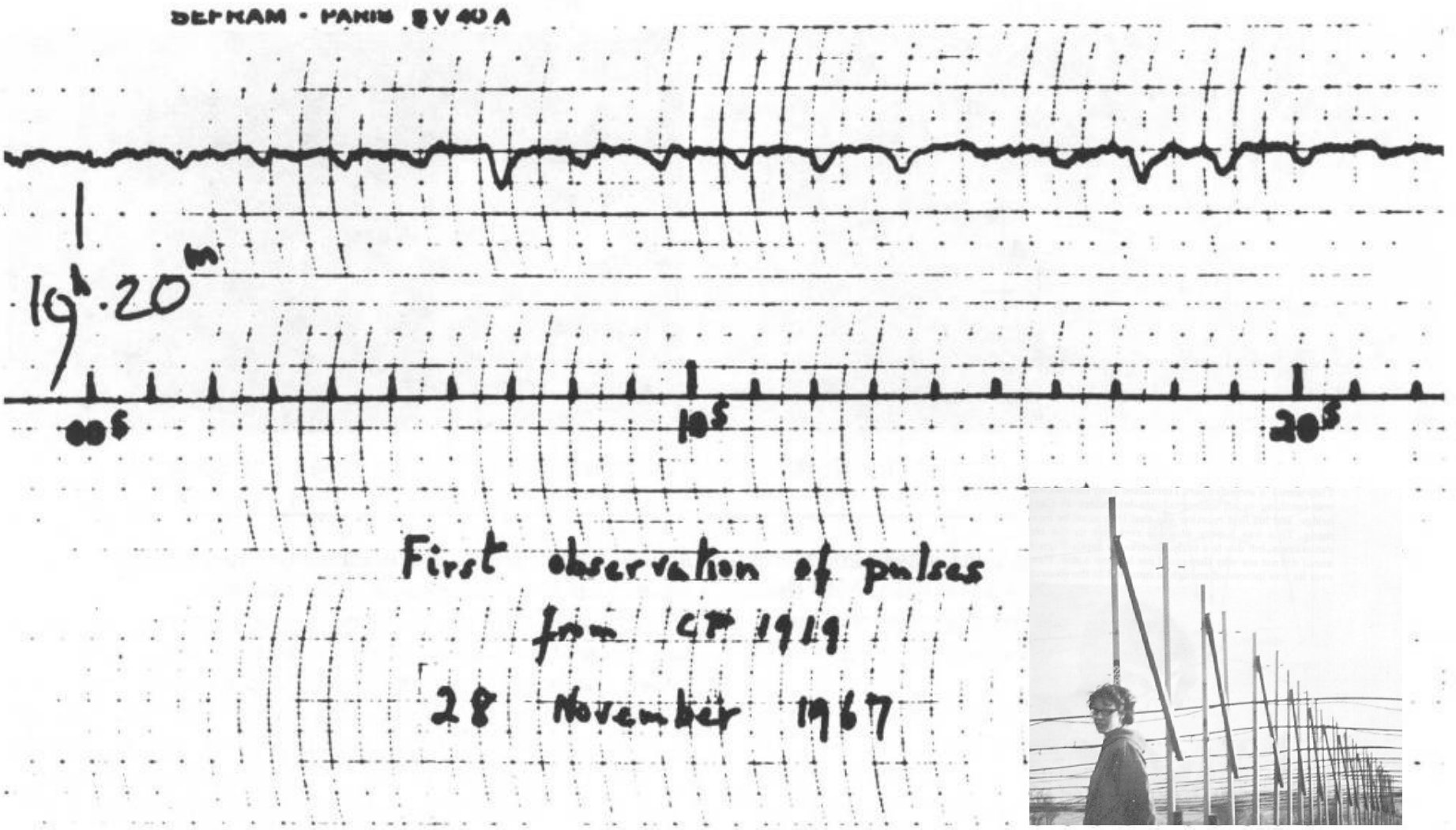


November 16 1988 – Photo by Richard Porcas



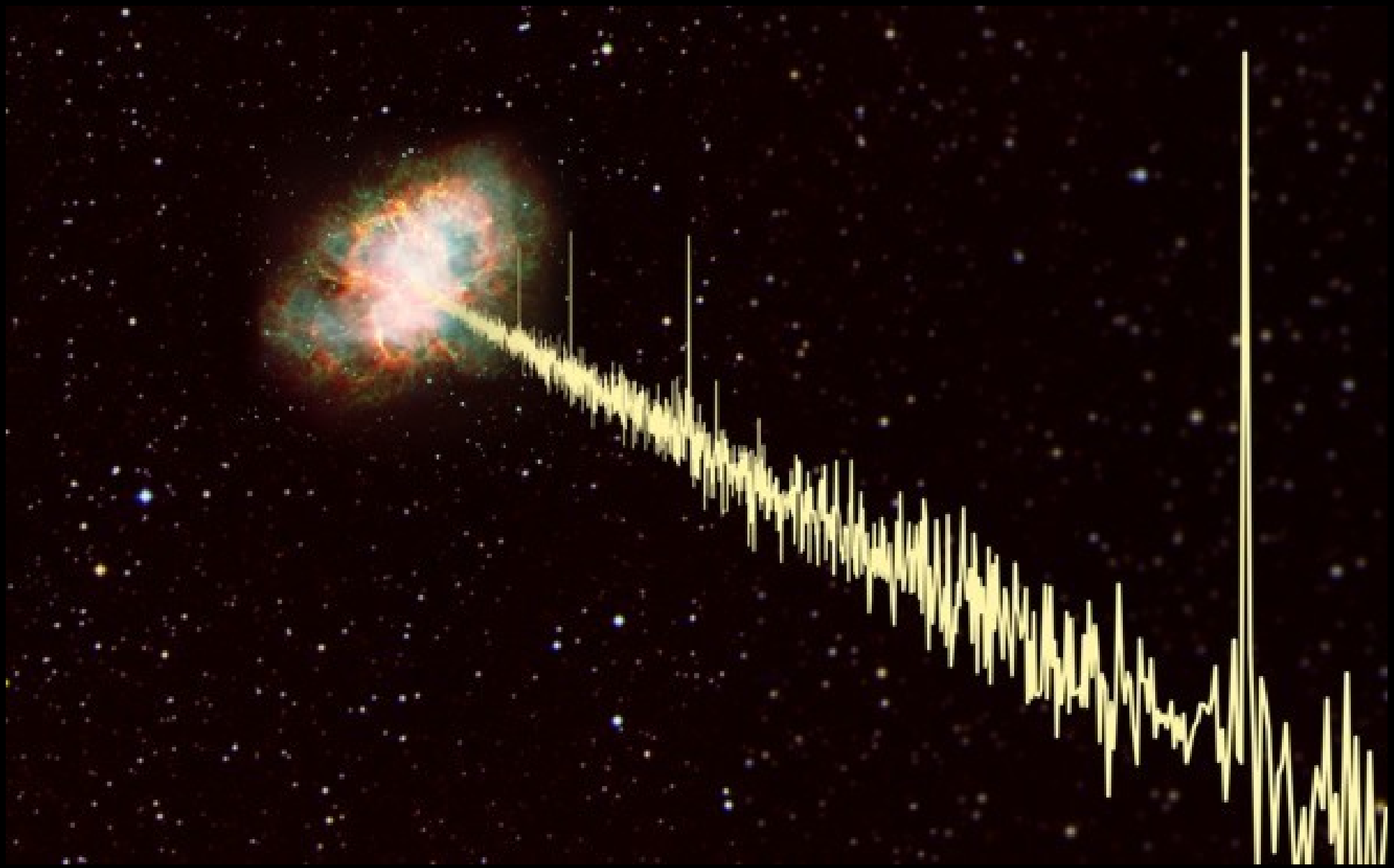
Credit: NRAO

In the beginning (1967) …
… there were PULSARS!



"I got it on a fast recording. As the chart flowed under the pen I could see that the signal was a series of pulses . . . 1⅓ seconds apart." (Deflections are down).

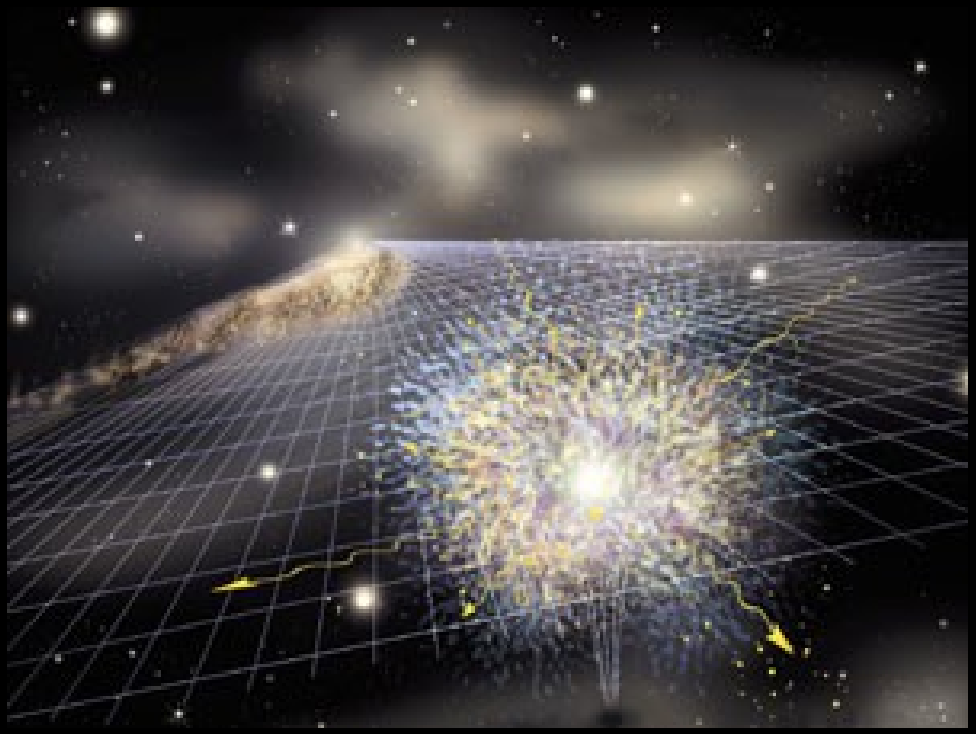
Credit: Joeri van Leeuwen



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

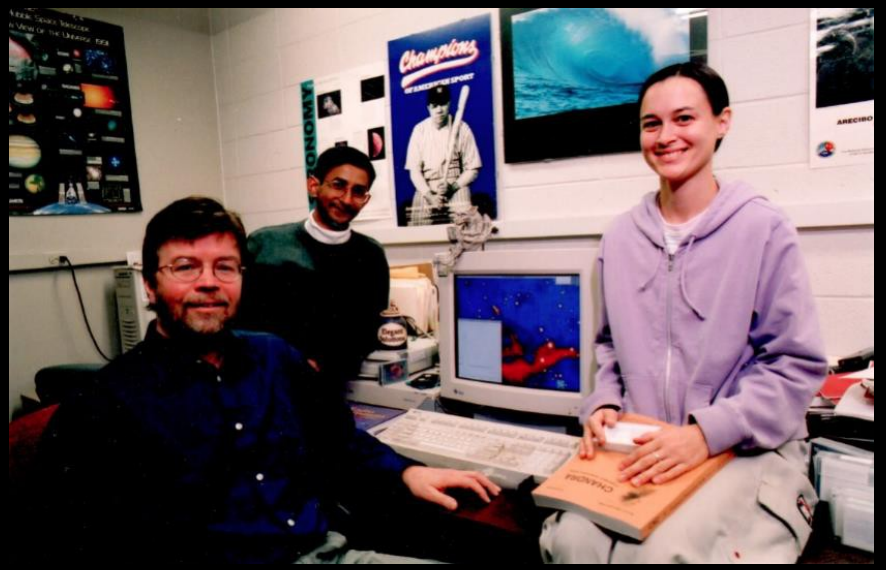
Credit: NAIC

SEARCHES FOR FAST RADIO TRANSIENTS

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

Received 2003 April 21; accepted 2003 July 2

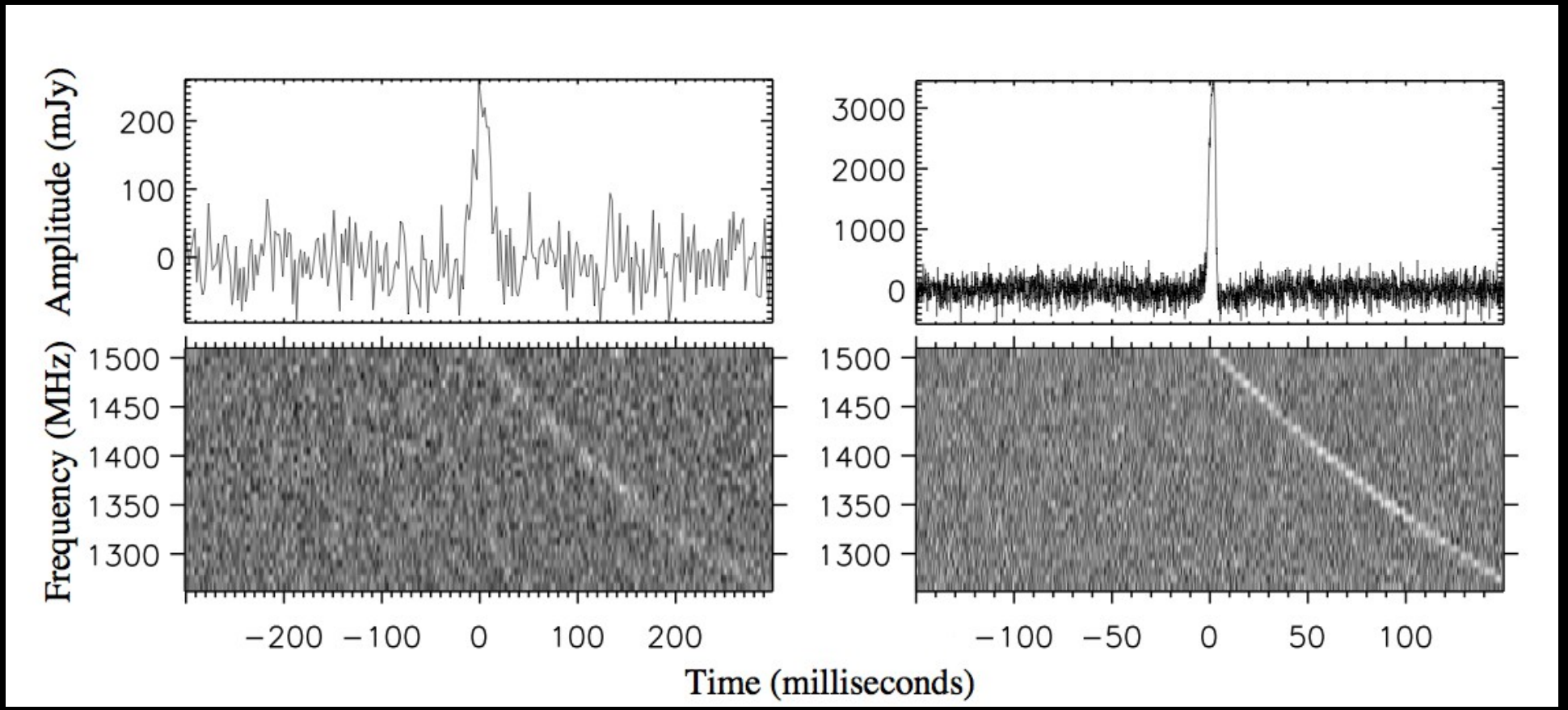
"...the next few decades will undoubtedly bring about a greater understanding of radio-bursting objects, including Crab-like pulsars in other galaxies, counterparts to high-energy bursting sources, and other classes of objects that are yet to be discovered."



Rotating Radio Transients (RRATs; 2004)

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]



Credit: Swinburne Astronomy Productions and CAASTRO

The delay of the pulse is characterized by a single quantity known as the “dispersion measure” (DM)

Larger DM ▫ Larger distance

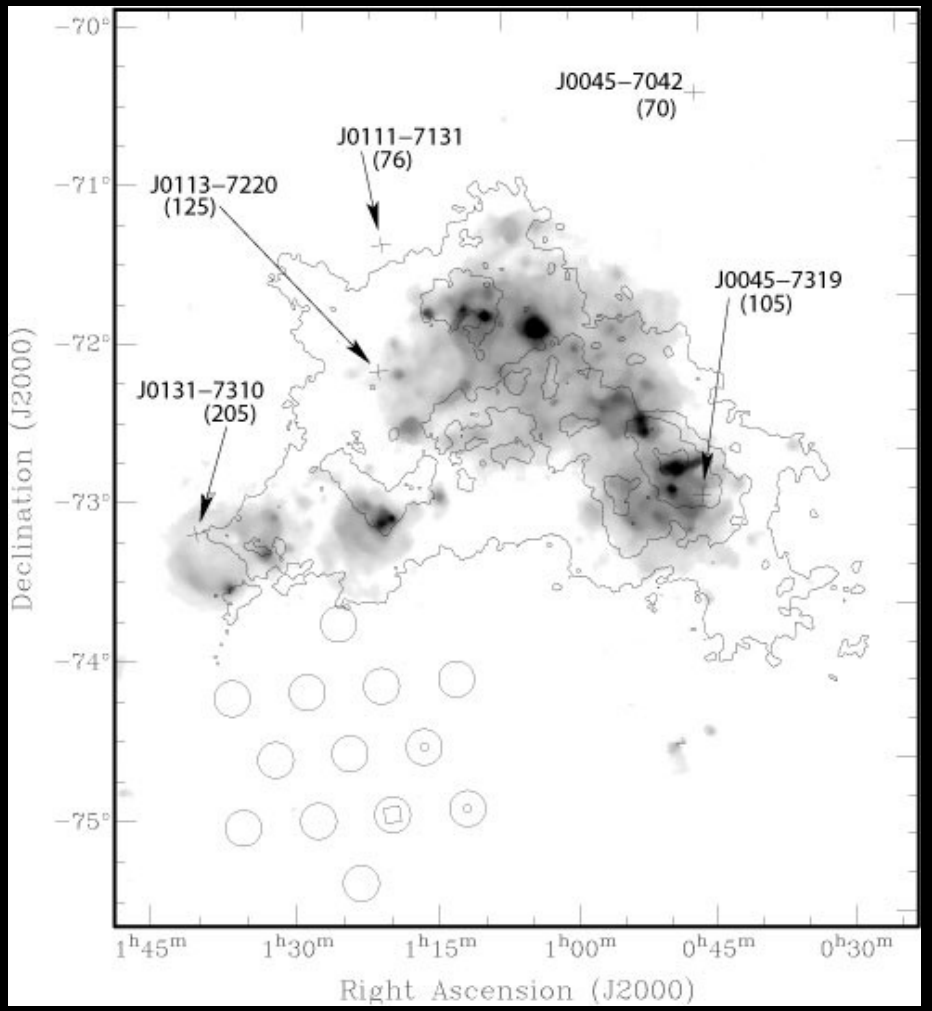
In the Milky Way, roughly...

DM = 1 ▫ 100 light years

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

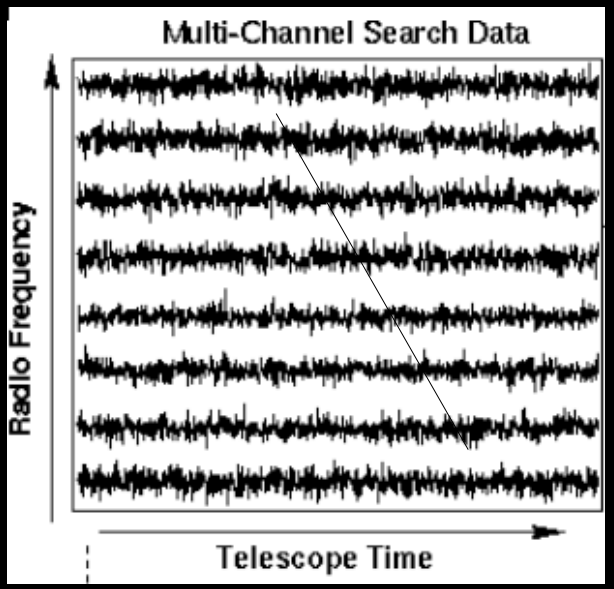
R. N. MANCHESTER,[1] G. FAN,[2,3] A. G. LYNE,[4] V. M. KASPI,[3] AND F. CRAWFORD[5]

Received 2006 February 23; accepted 2006 April 19

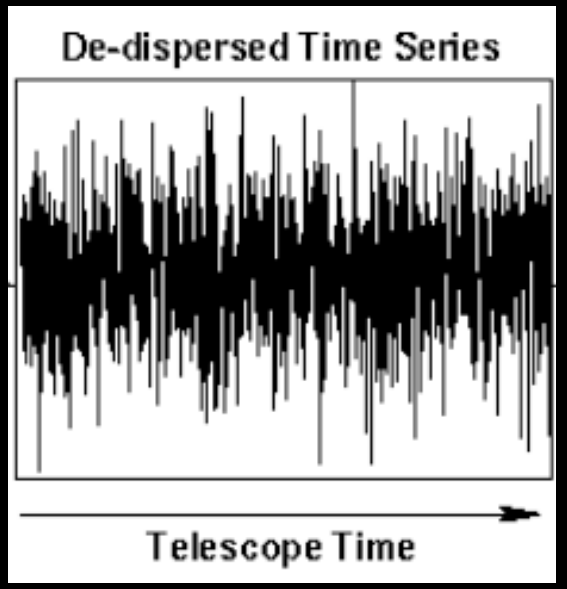


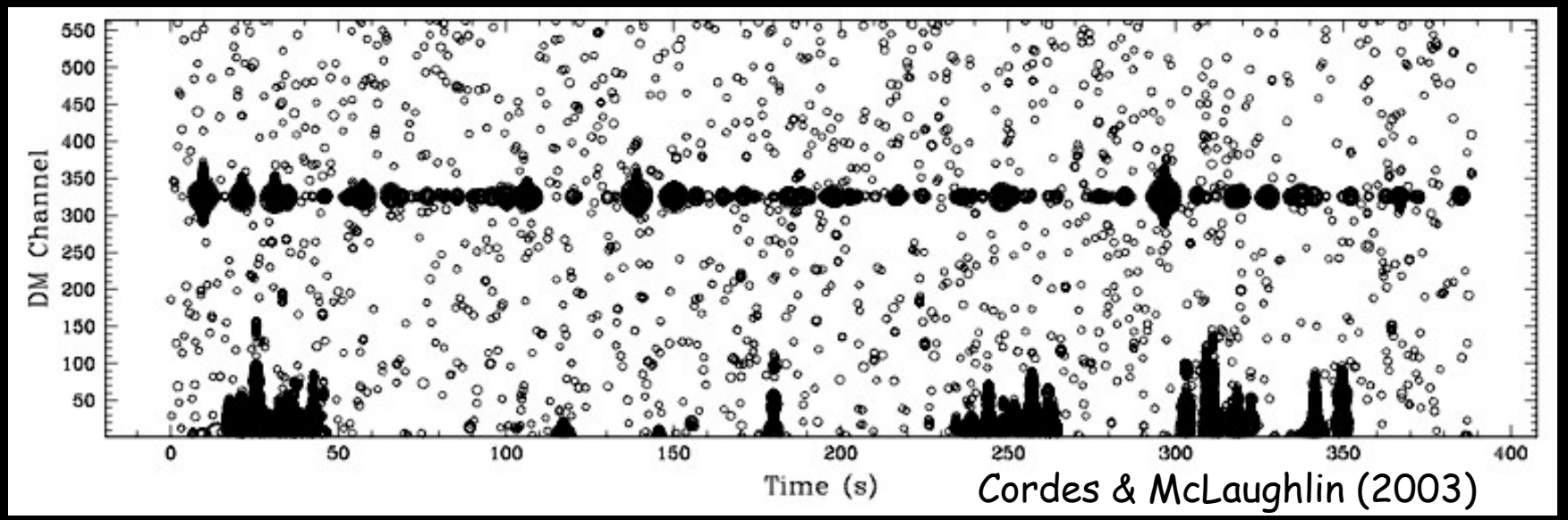
Credit: Froney Crawford

Single-pulse search pipeline



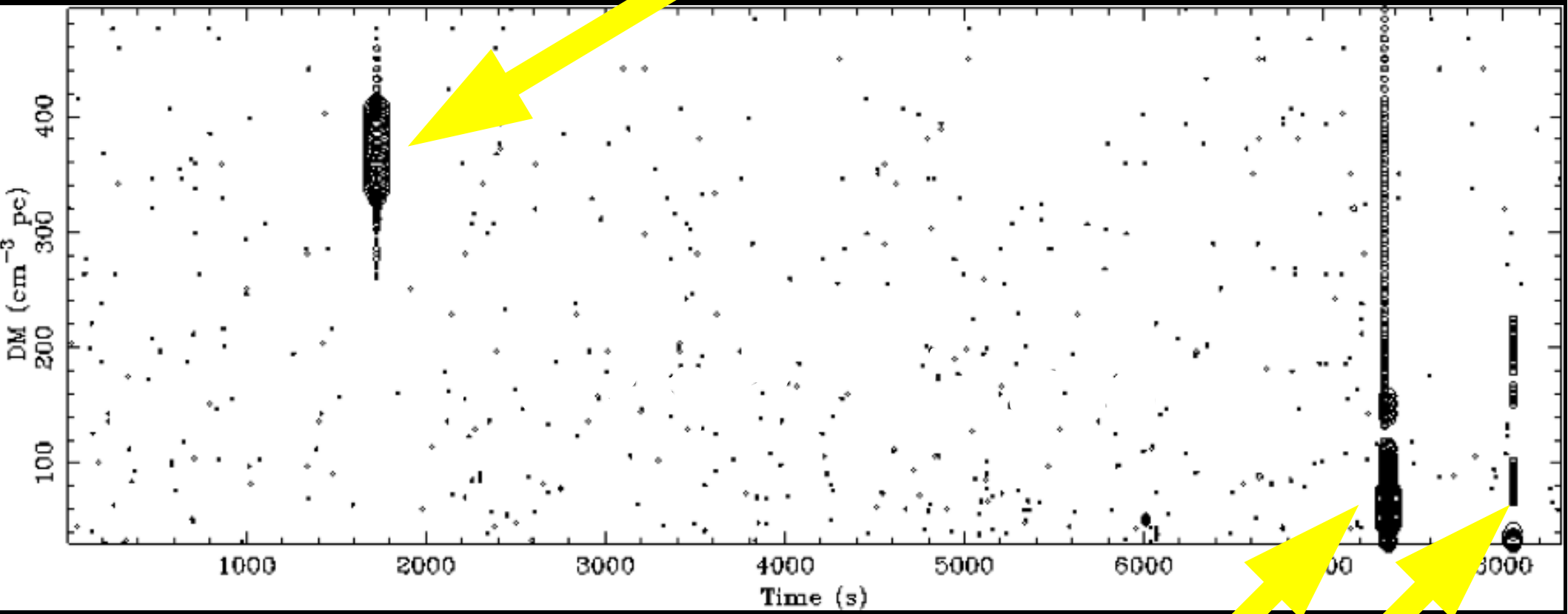
DM





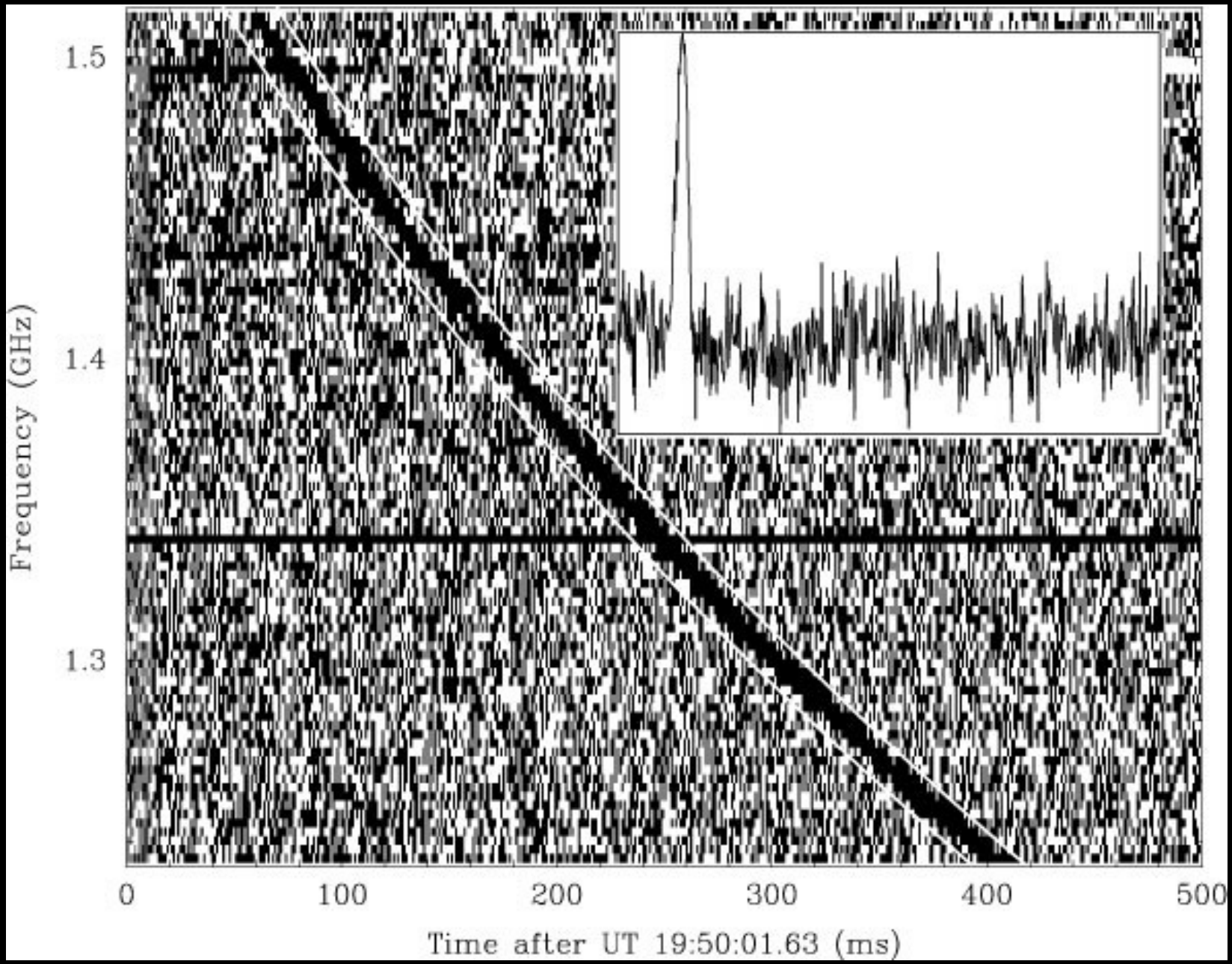
Cordes & McLaughlin (2003)

An unexpected signal!



Interference

The “Lorimer” burst...

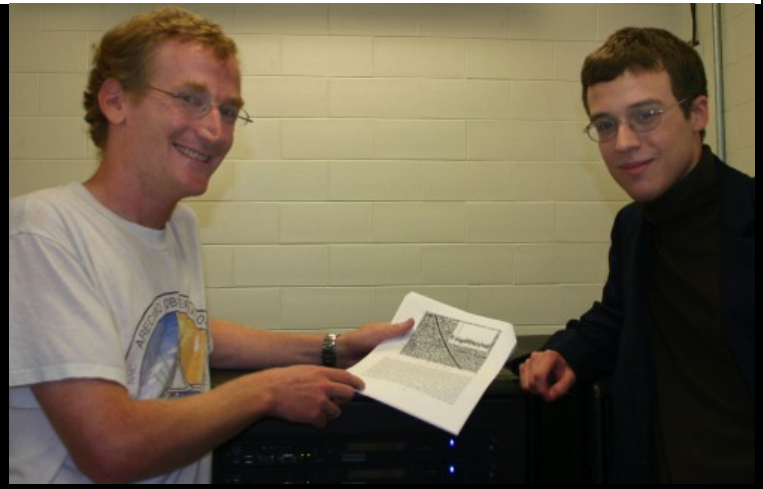


A Bright Millisecond Radio Burst of Extragalactic Origin

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.

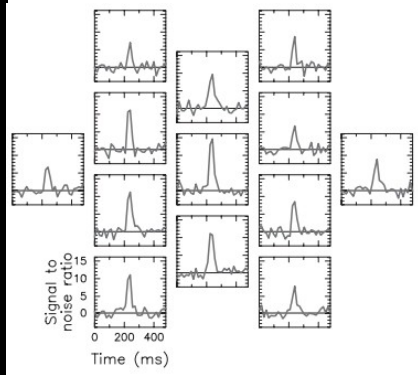
- Why so bright?
- Where are fainter ones?
- What is rate on sky?
- Detectable in other surveys?



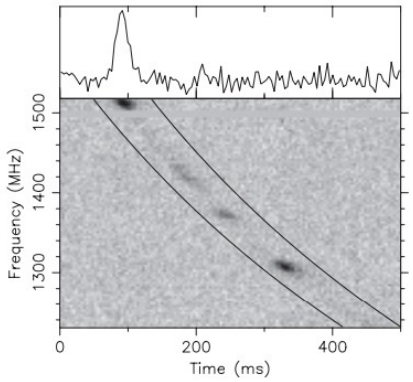
The Astrophysical Journal, 727:18 (5pp), 2011 January 20 doi:10.1088/0004-637X/727/1/18

RADIO BURSTS WITH EXTRAGALACTIC SPECTRAL CHARACTERISTICS SHOW TERRESTRIAL ORIGINS

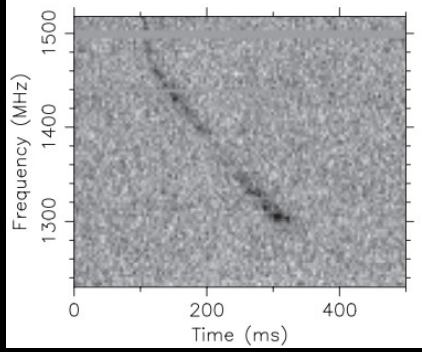
S. Burke-Spolaor[1,5], Matthew Bailes[1], Ronald Ekers[2], Jean-Pierre Macquart[3], and Fronefield Crawford III[4]
[1] Centre for Astrophysics and Supercomputing, Swinburne University of Technology, Mail H39, P.O. Box 218, Hawthorn VIC 3122, Australia; sburke@astro.swin.edu.au
[2] CSIRO Australia Telescope 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

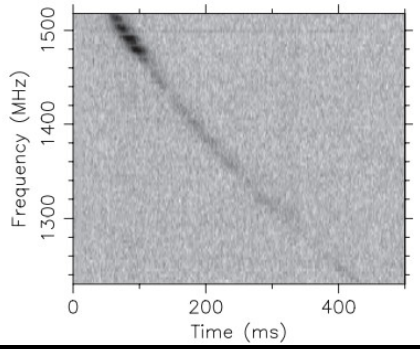


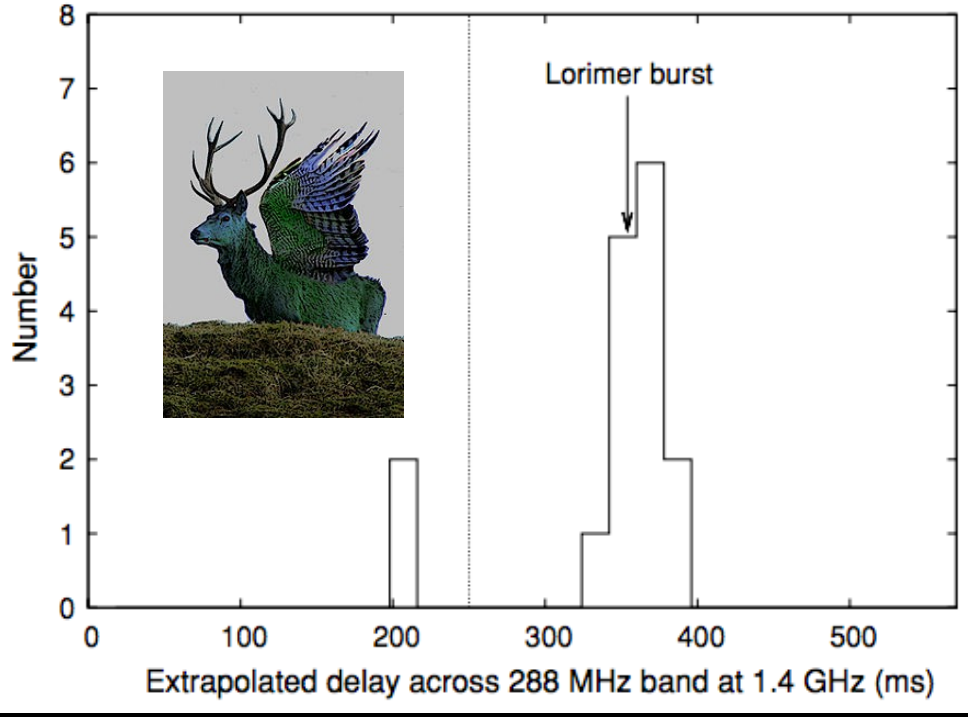
(a) Peryton 08 in 13 beams



(b) Peryton 08







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

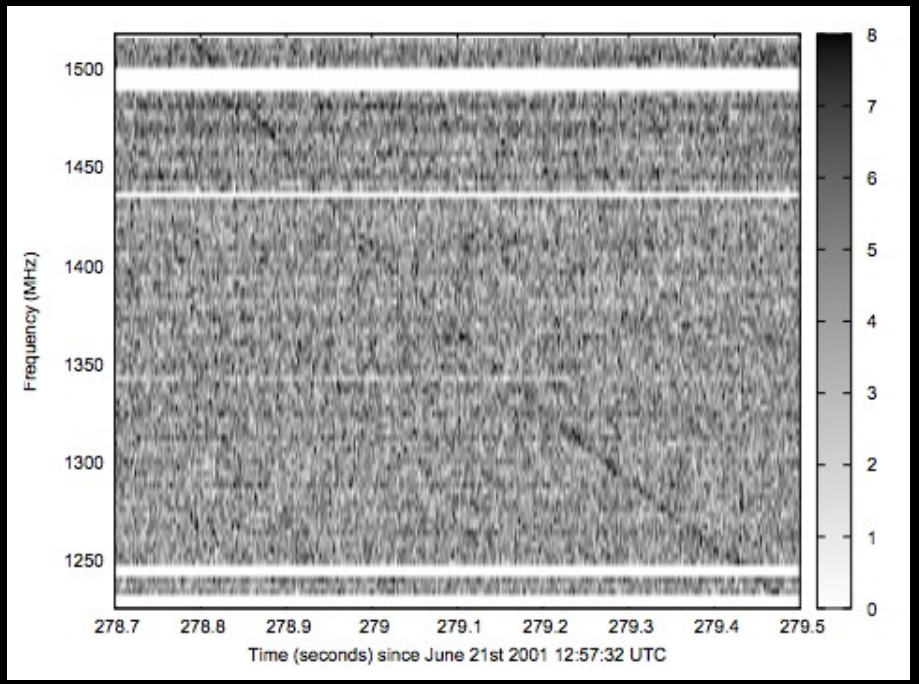
"Moreover, the lack of highly dispersed celestial signals is evidence that the Lorimer burst is unlikely to belong to a cosmological source population."

…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."



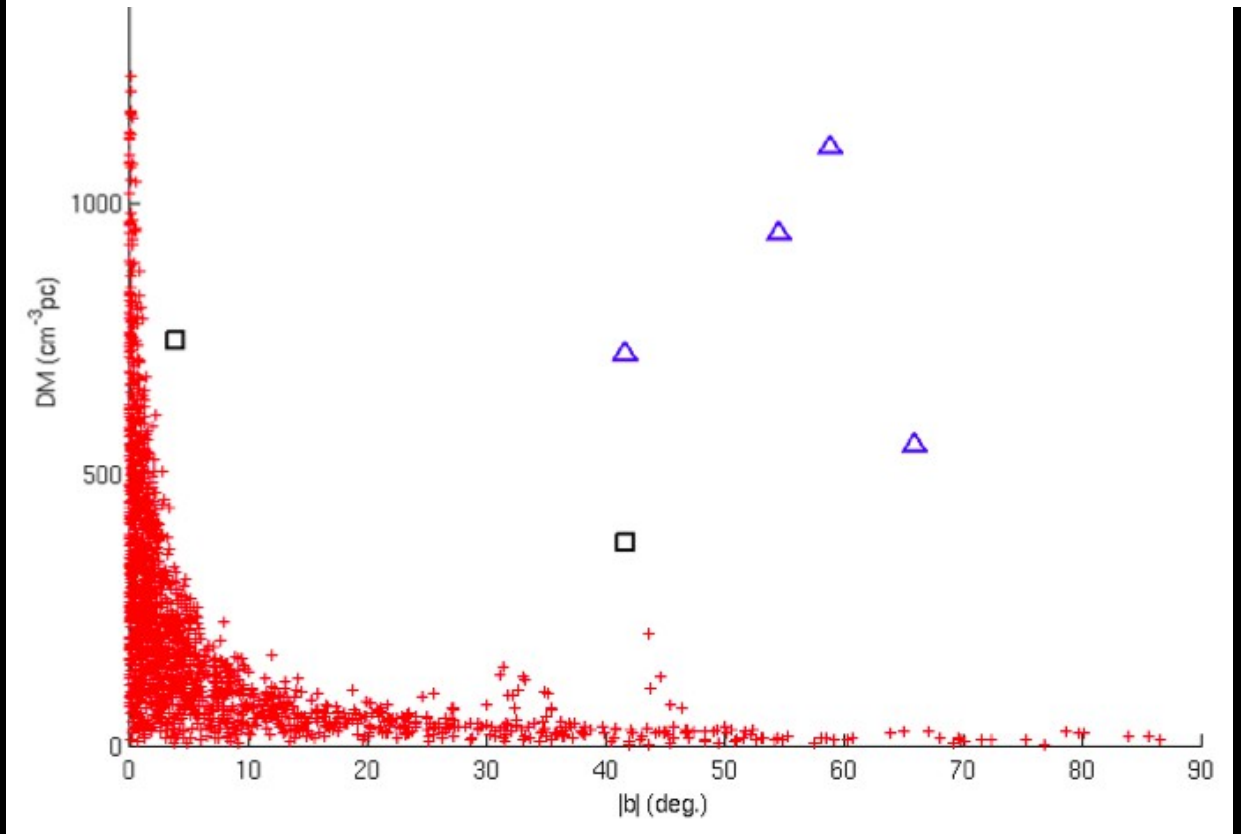
Credit: Keane et al. 2011/2012

DM = 746 pc/cc
W=8 ms

… more good news followed in 2013

A Population of <insert name here> at Cosmological Distances

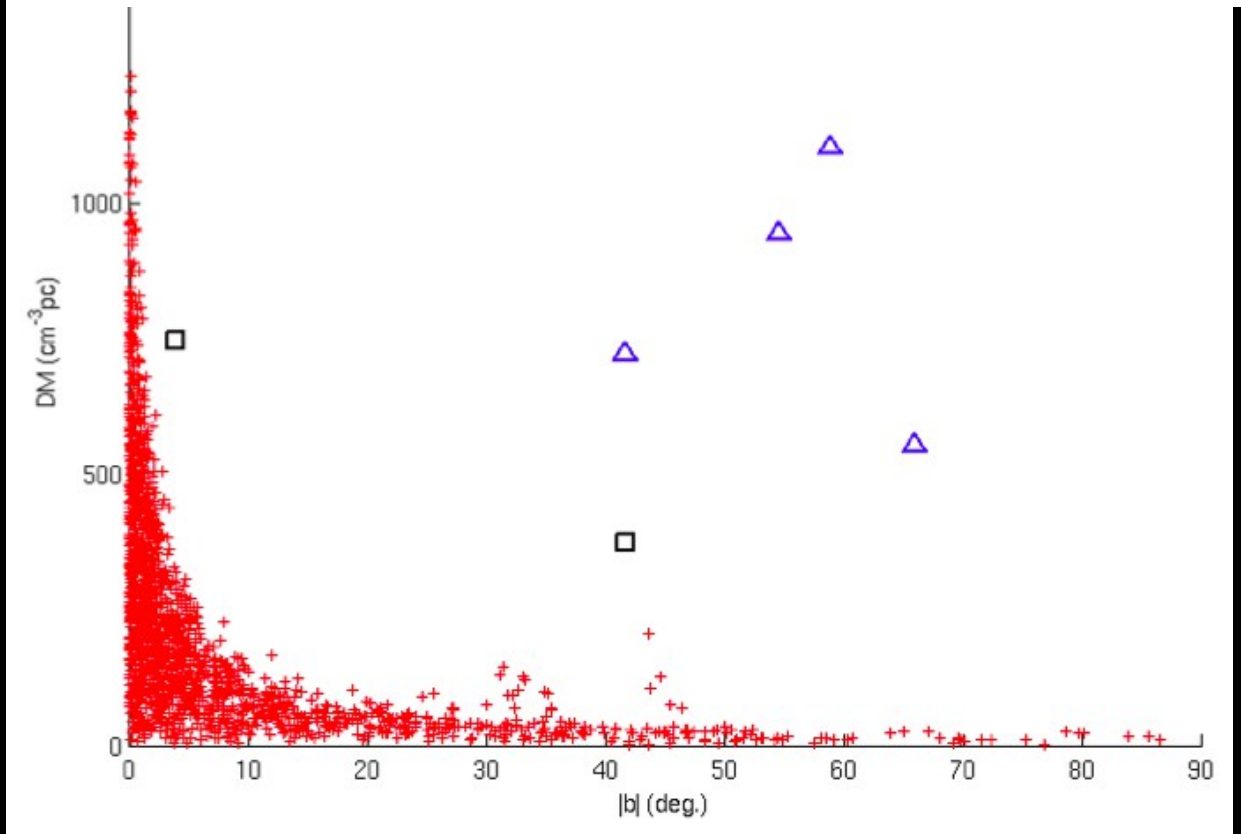
D. Thornton,[1,2*] B. Stappers,[1] M. Bailes,[3,4] B. Barsdell,[3,4] S. Bates,[5] N. D. R. Bhat,[3,4,6] M. Burgay,[7] S. Burke-Spolaor,[8] D. J. Champion,[9] P. Coster,[2,3] N. D'Amico,[10,7] A. Jameson,[3,4] S. Johnston,[2] M. Keith,[2] M. Kramer,[9,1] L. Levin,[5] S. Milia,[7] C. Ng,[9] A. Possenti,[7]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



… more good news followed in 2013

A Population of Lorimer bursts at Cosmological Distances

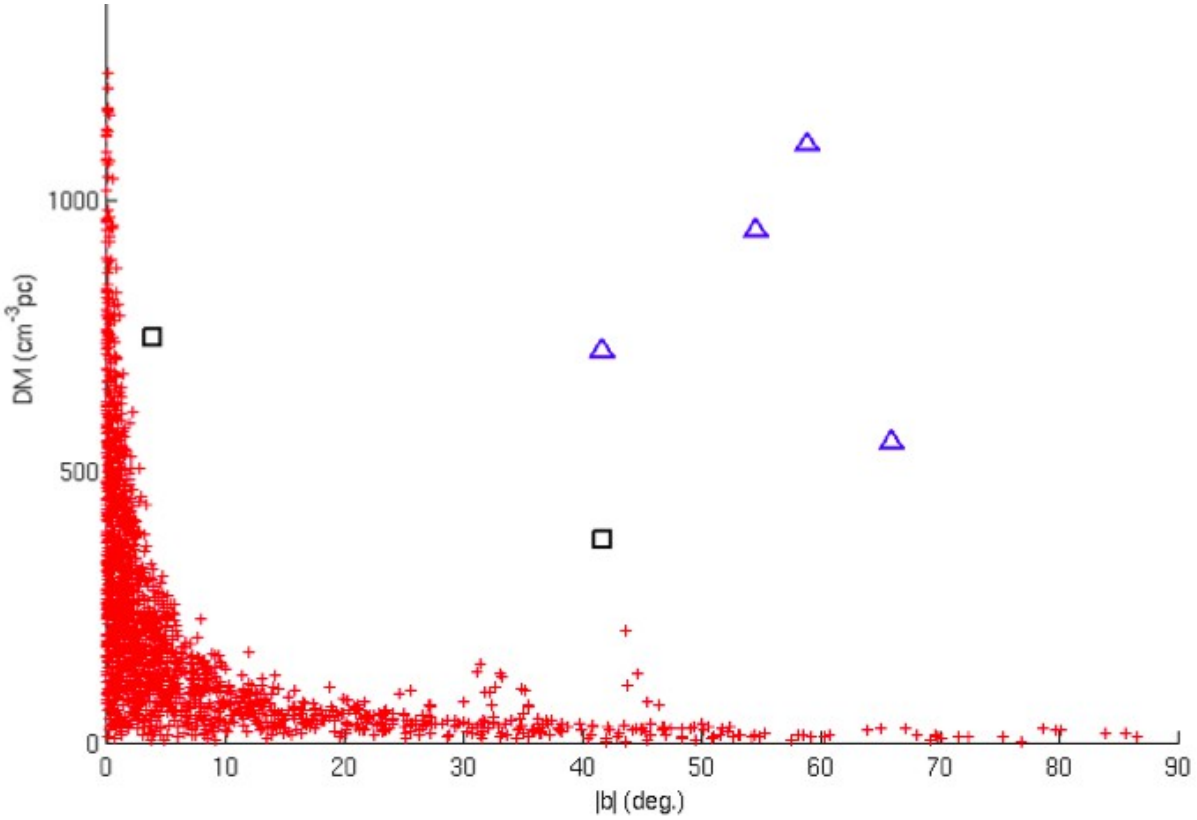
D. Thornton,[1,2*] B. Stappers,[1] M. Bailes,[3,4] B. Barsdell,[3,4] S. Bates,[5] N. D. R. Bhat,[3,4,6] M. Burgay,[7] S. Burke-Spolaor,[8] D. J. Champion,[9] P. Coster,[2,3] N. D'Amico,[10,7] A. Jameson,[3,4] S. Johnston,[2] M. Keith,[2] M. Kramer,[9,1] L. Levin,[5] S. Milia,[7] C. Ng,[9] A. Possenti,[7]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



… more good news followed in 2013

A Population of Sparkers at Cosmological Distances

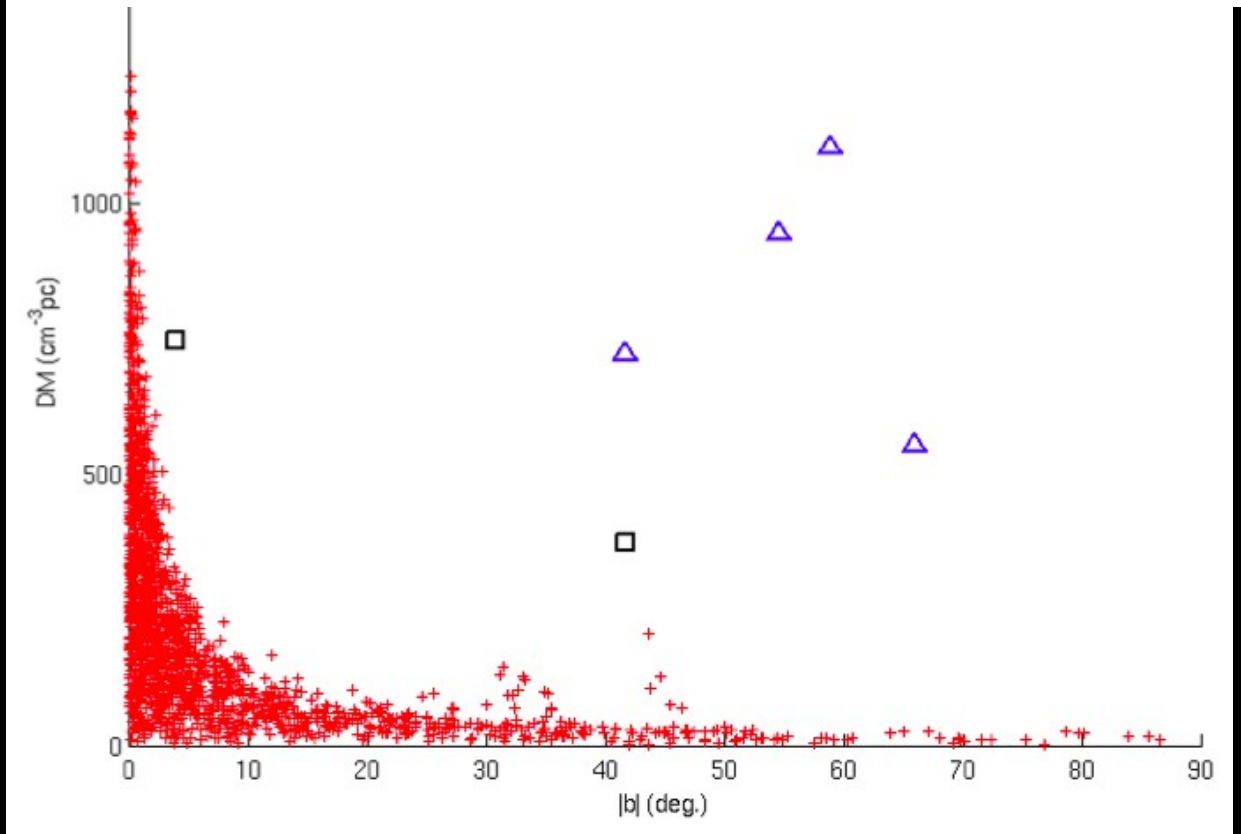
D. Thornton,[1,2*] B. Stappers,[1] M. Bailes,[3,4] B. Barsdell,[3,4] S. Bates,[5] N. D. R. Bhat,[3,4,6] M. Burgay,[7] S. Burke-Spolaor,[8] D. J. Champion,[9] P. Coster,[2,3] N. D'Amico,[10,7] A. Jameson,[3,4] S. Johnston,[2] M. Keith,[2] M. Kramer,[9,1] L. Levin,[5] S. Milia,[7] C. Ng,[9] A. Possenti,[7]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



… more good news followed in 2013

A Population of Fast Radio Transients 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]

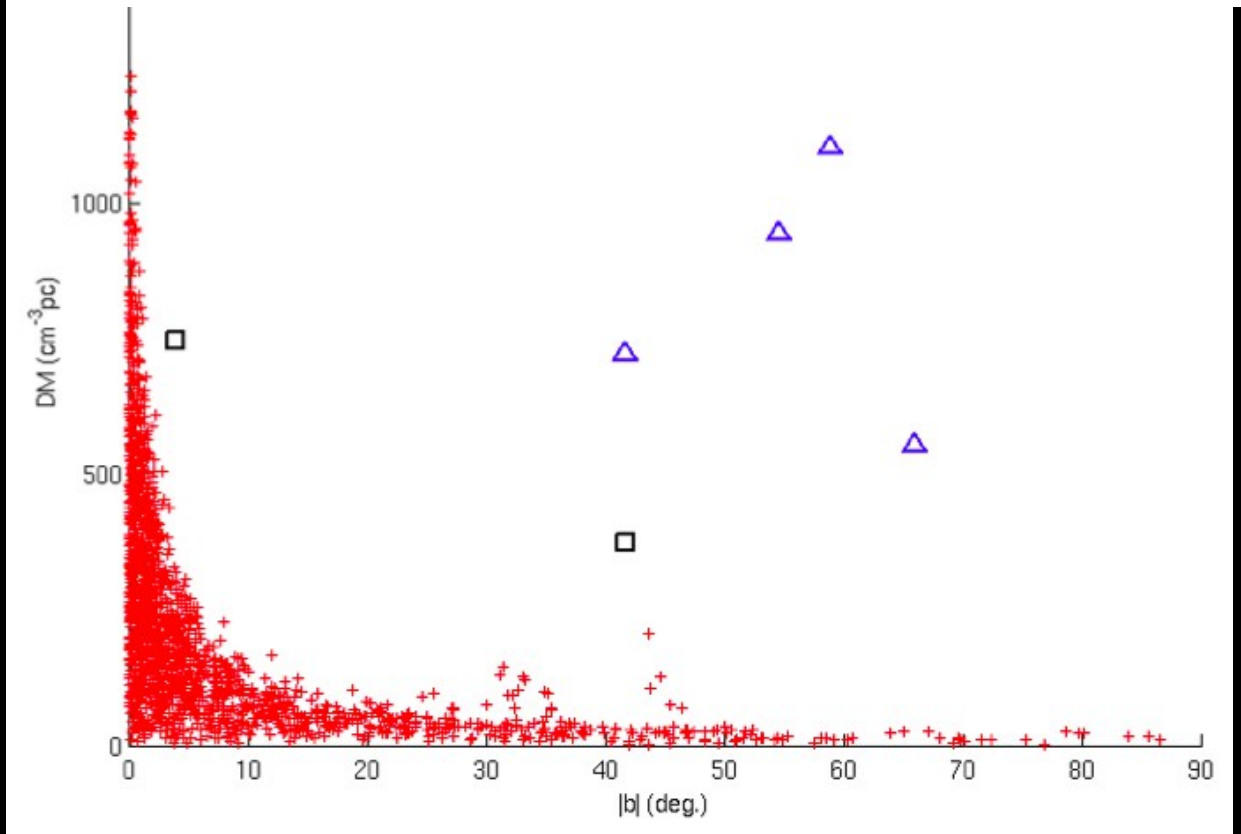


FARTs?

… more good news followed in 2013

A Population of Fast Radio Bursts at Cosmological Distances

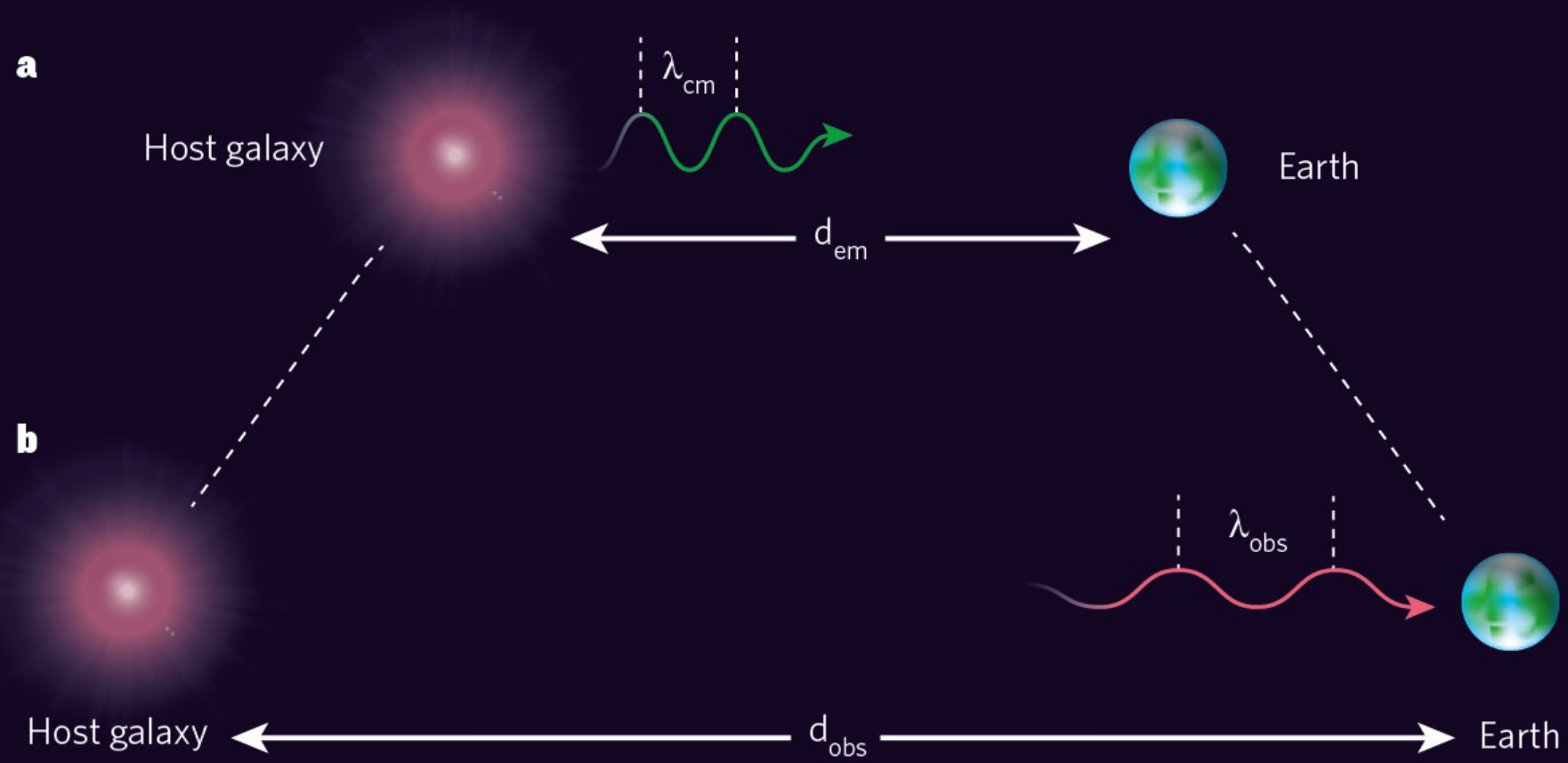
D. Thornton,[1,2*] B. Stappers,[1] M. Bailes,[3,4] B. Barsdell,[3,4] S. Bates,[5] N. D. R. Bhat,[3,4,6] M. Burgay,[7] S. Burke-Spolaor,[8] D. J. Champion,[9] P. Coster,[2,3] N. D'Amico,[10,7] A. Jameson,[3,4] S. Johnston,[2] M. Keith,[2] M. Kramer,[9,1] L. Levin,[5] S. Milia,[7] C. Ng,[9] A. Possenti,[7]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



FRBs

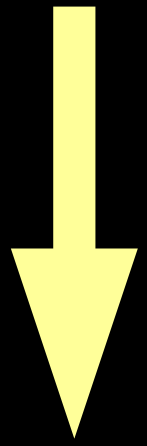
YYMMDD

Cosmological redshift



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

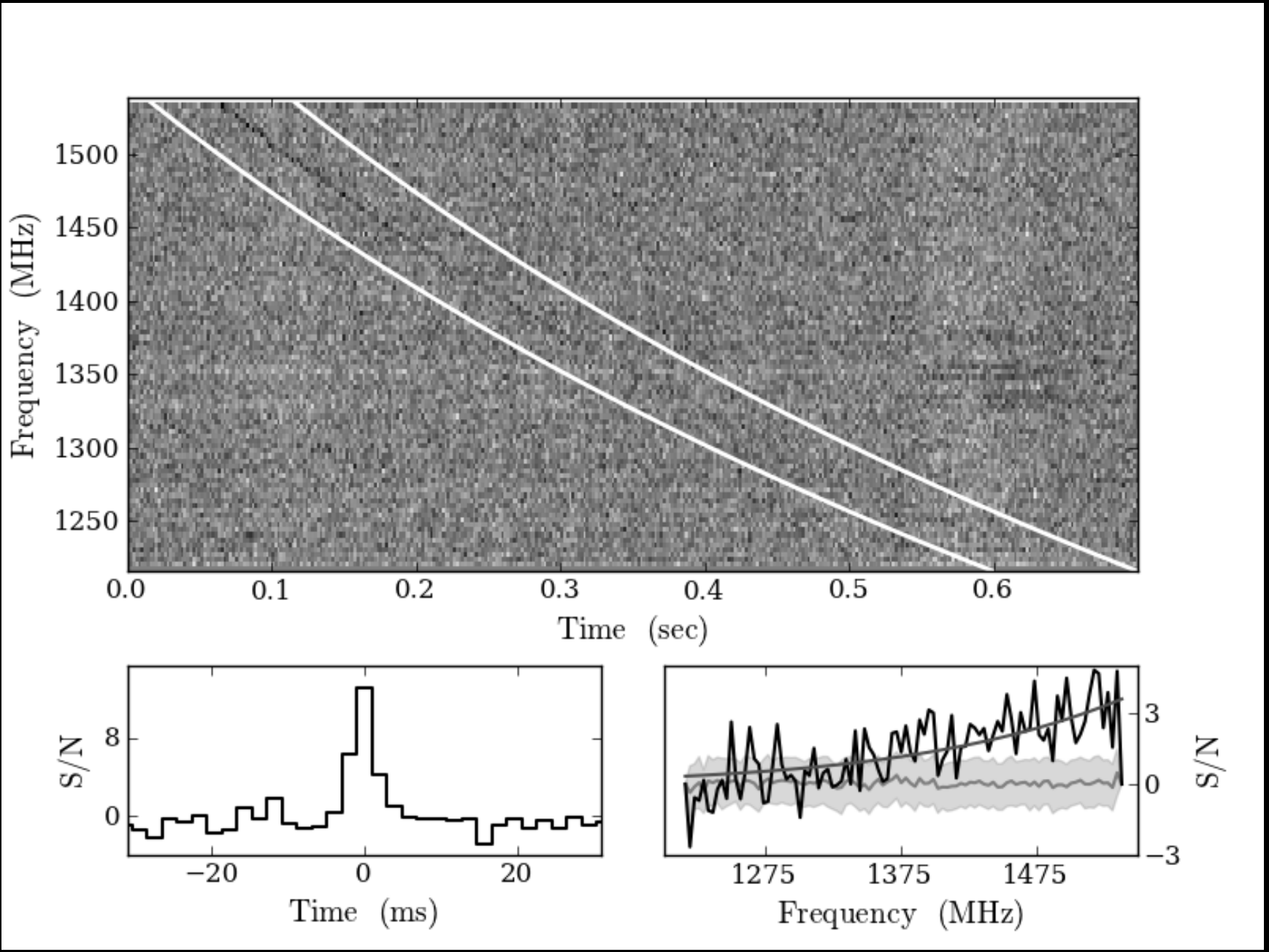
DM ~ 1000 z



Distance
and energy
estimates

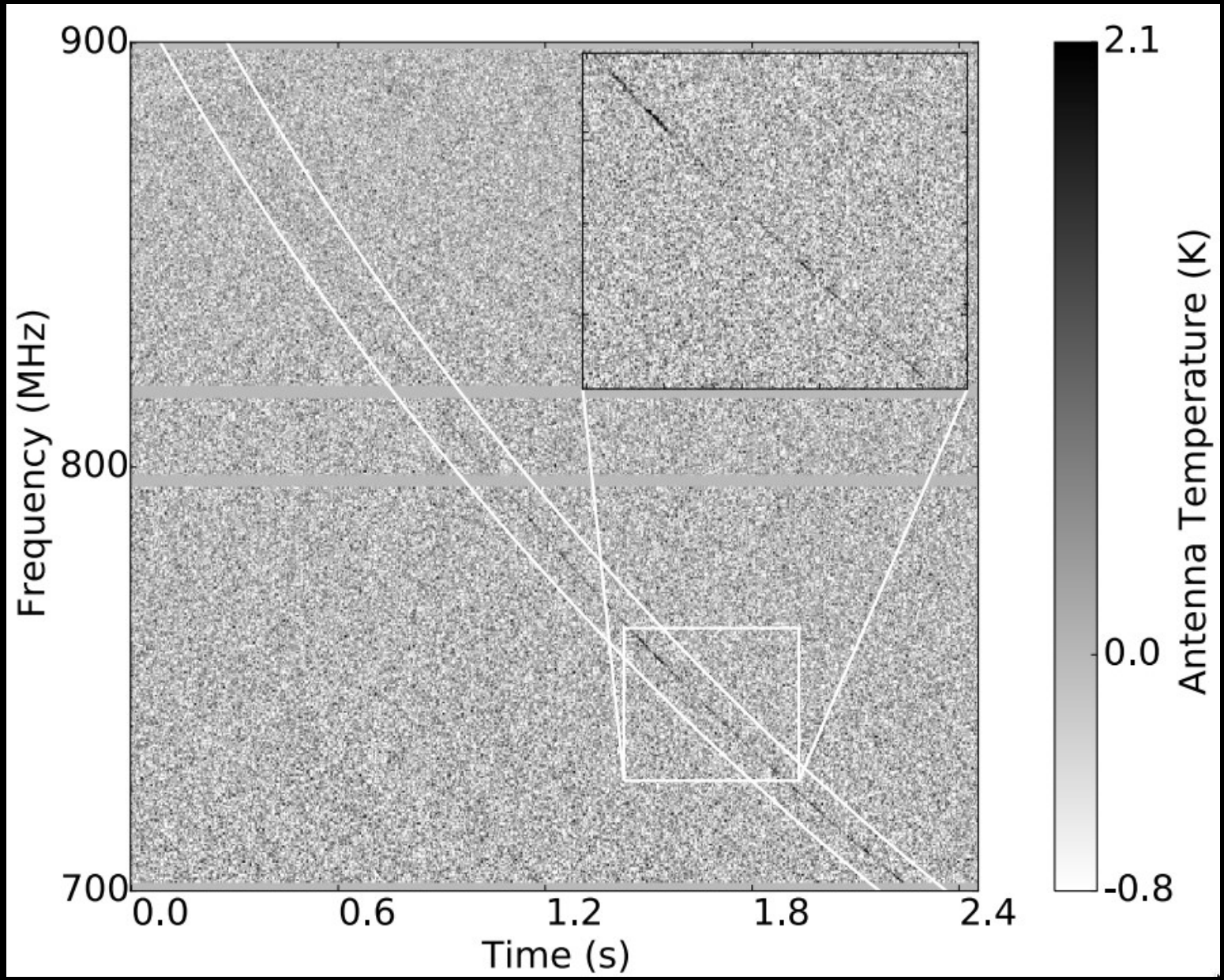
DM = 500 ▫ z=0.5 ▫ 5 billion years
For a typical FRB ▫ 1 month of Sun

2014: FRB 121102 at Arecibo



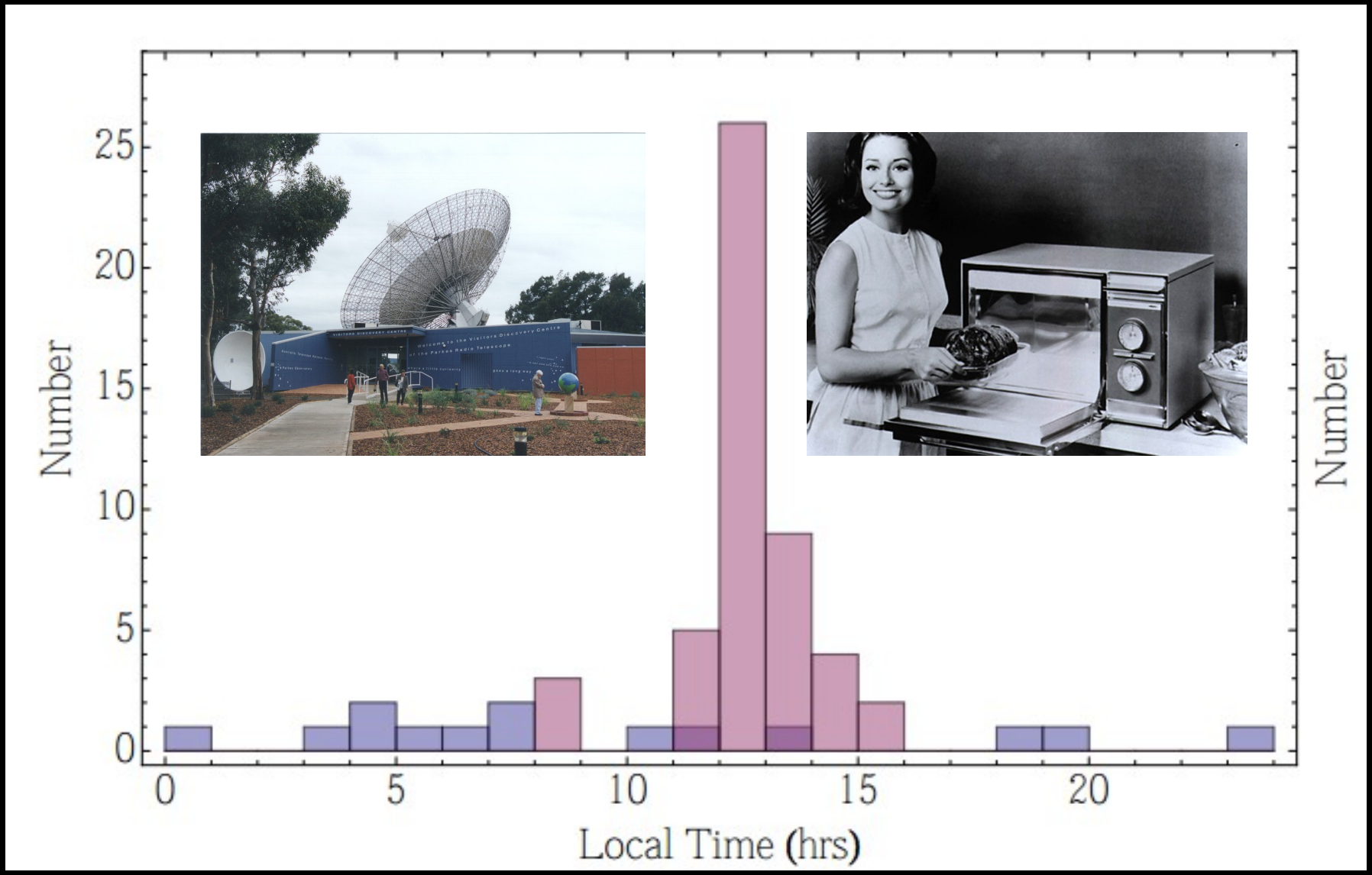
Credit: Spitler et al. (2014)

2015: FRB 110523 at GBT



Credit: Masui et al. (2015)

2015: Peryton mystery solved...

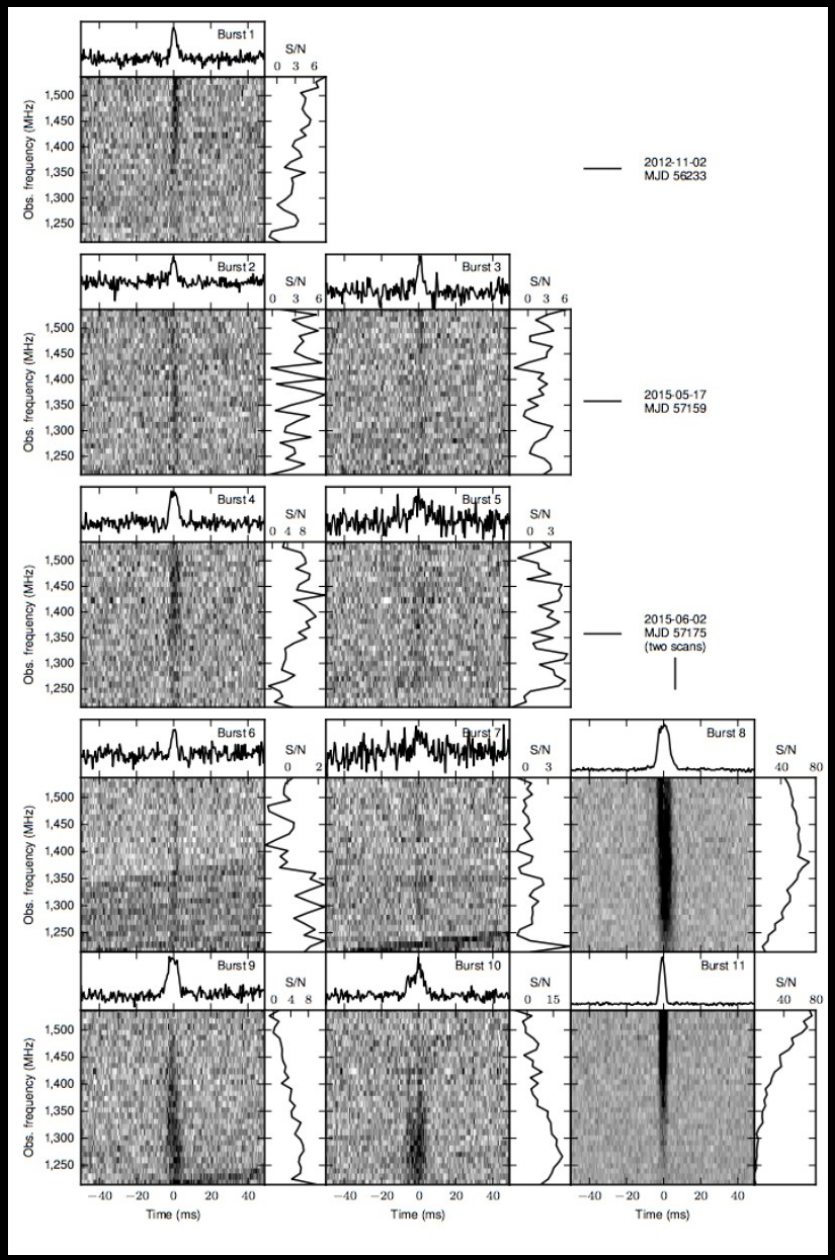


Credit: Petroff et al. (2015)

More theories than bursts!

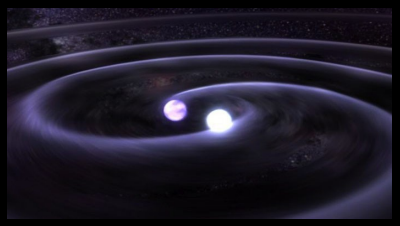
- Colliding compact objects (e.g. NS-NS)
- Supernovae
- Collapsing NS ▫ BH (blitzar)
- Black hole absorbing NSs
- Giant pulses from pulsars/magnetars
- Neutron star – asteroid belt interaction
- More exotic (strange) star interactions
- Galactic Flare Stars
- Cosmic strings
- White holes
- Extra-terrestrial signals

2016: FRB 121102 repeats!

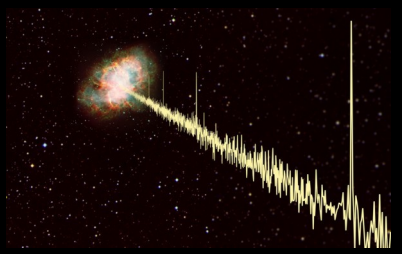


Credit: Spitler et al. and Scholz et al. (2016)

- No!



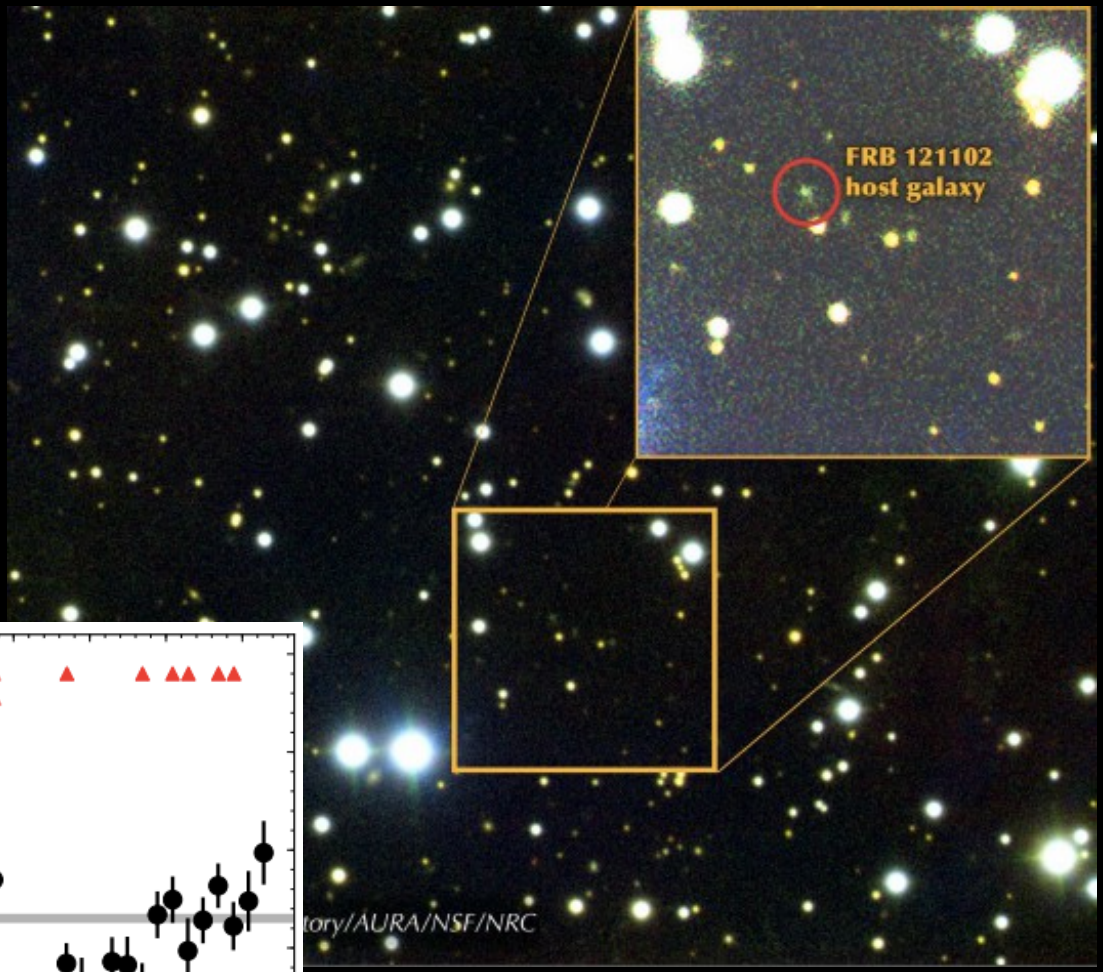
- No!

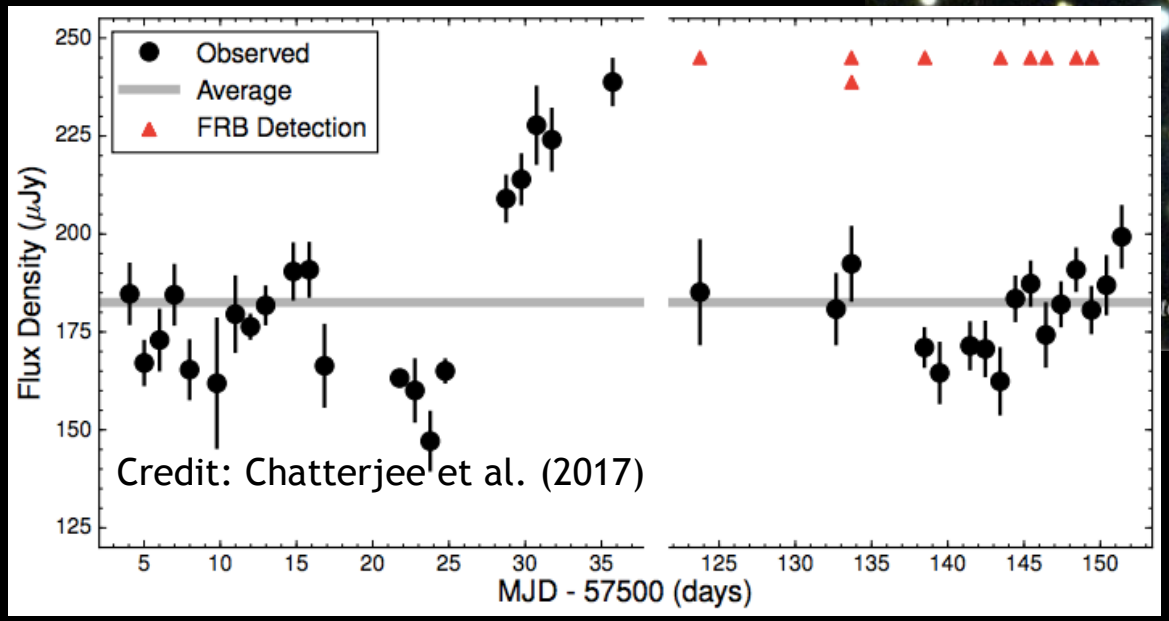


- Maybe?

… or maybe something else?

2017: FRB 121102 localized!





z = 0.19
(2.3 billion yr)

Open questions

- What is the source of FRB 121102?
  - Are the radio sources related?
  - Magnetar/AGN interaction?
- Is FRB 121102 representative?
  - Do all FRBs repeat?
  - Are there multiple classes?
- What are best strategies going forward?
  - Positional localization crucial
  - Large area coverage also needed

(My) bold predictions

- 2020: 100s FRBs found
  - A new telescope in Canada (CHIME)
- 2025: 1000s of FRBs known
  - Other facilities worldwide
- 2030: FRBs essential cosmological tools?
  - Hotly debated this week!

Thanks for supporting this work!