Fast Radio Bursts

Observational Status & Open Puzzles

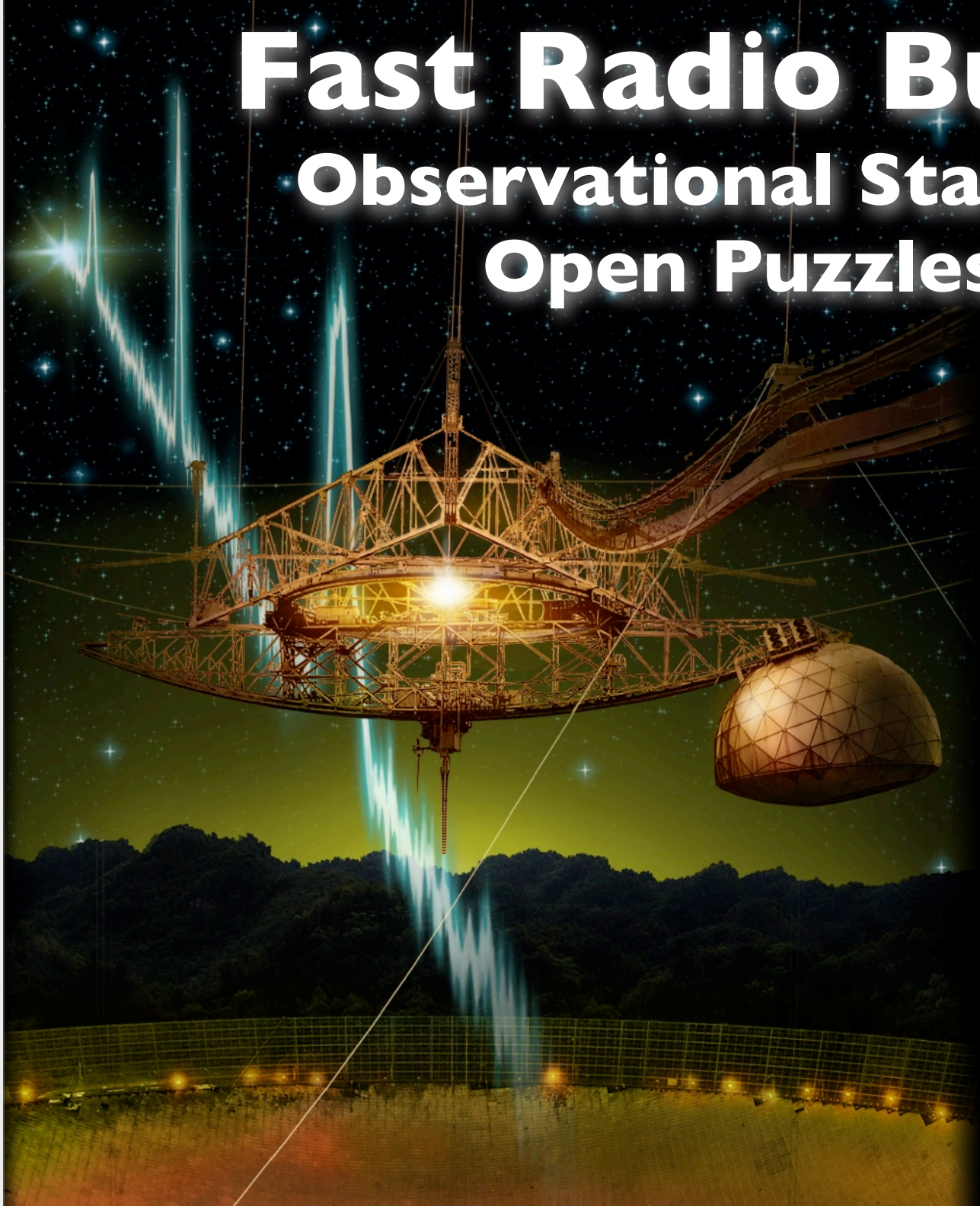
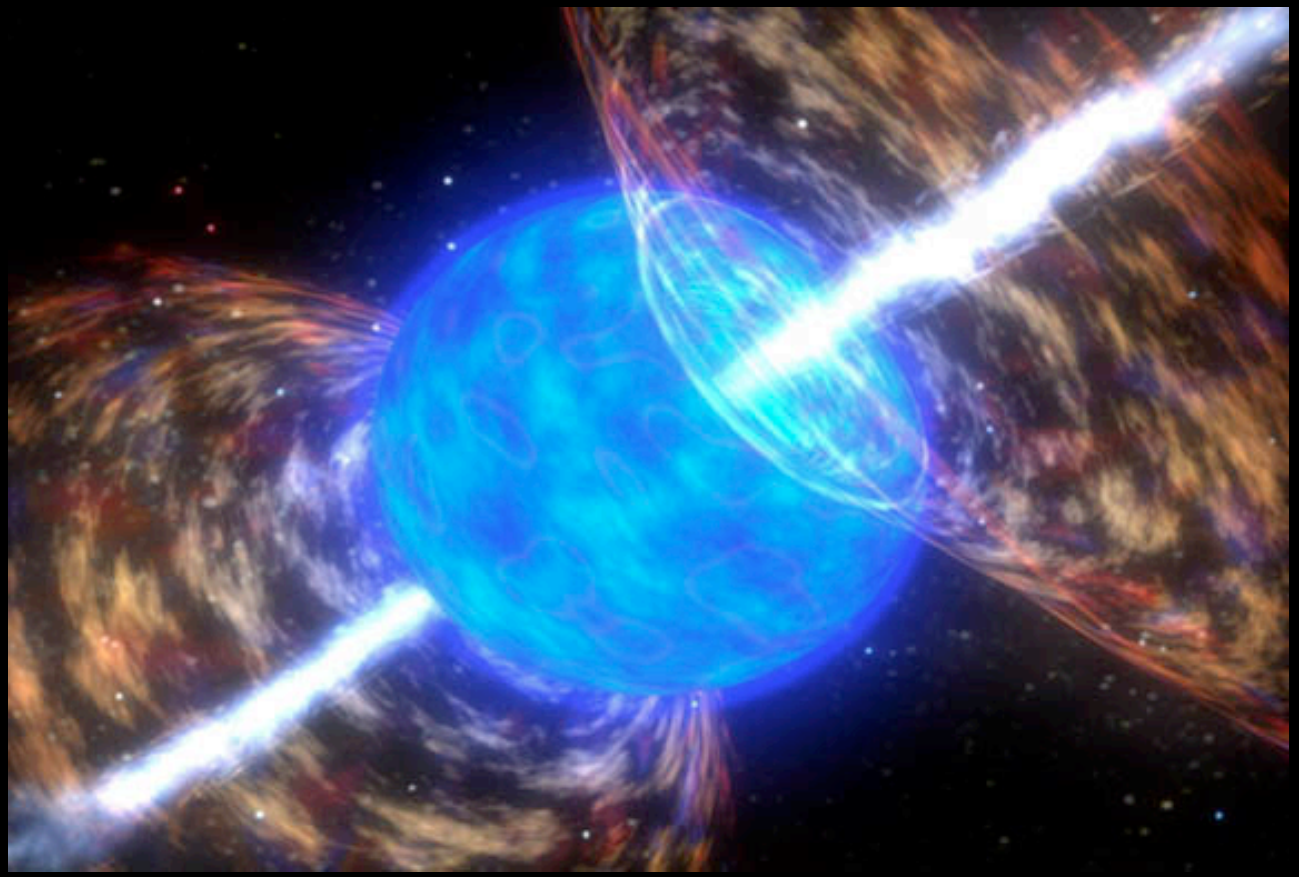


Image credit: Danielle Futselaar

Jason Hessels

University of Amsterdam
&
ASTRON
Netherlands Institute for Radio Astronomy

Gamma-ray Bursts

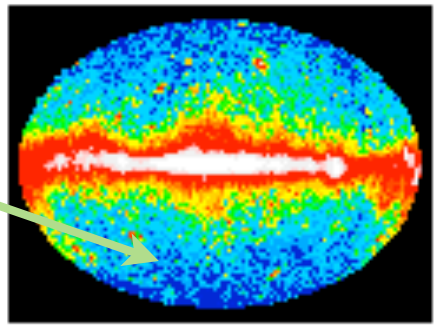


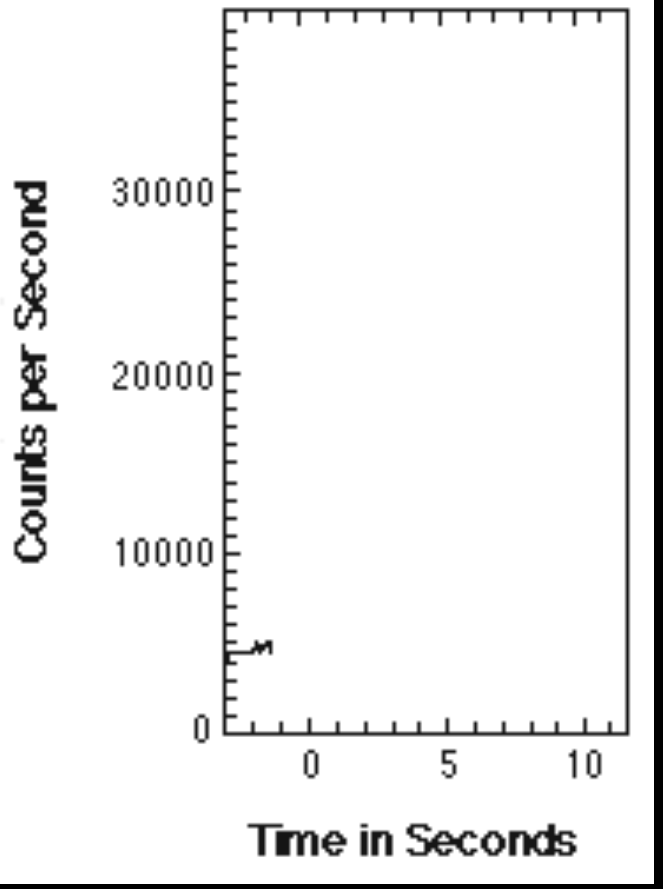
Are there also similar sirens of extreme (astro)physics to be found in the radio?

Gamma-ray Bursts

Typical FoV of a radio telescope is << 1 sq. deg.

~10 days/FRB





There is no sufficiently sensitive all-sky radio monitor, yet

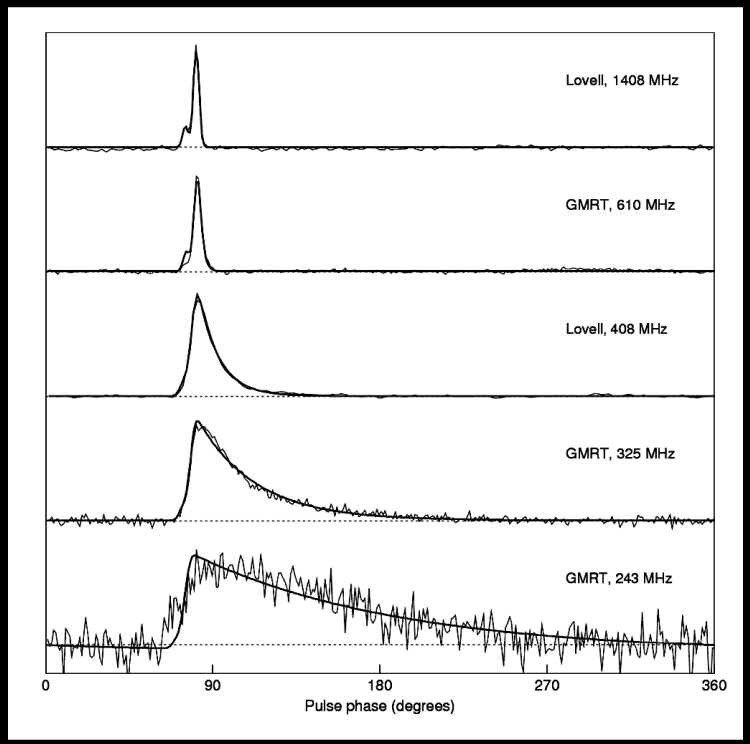
Propagation Effects

Observed signal →

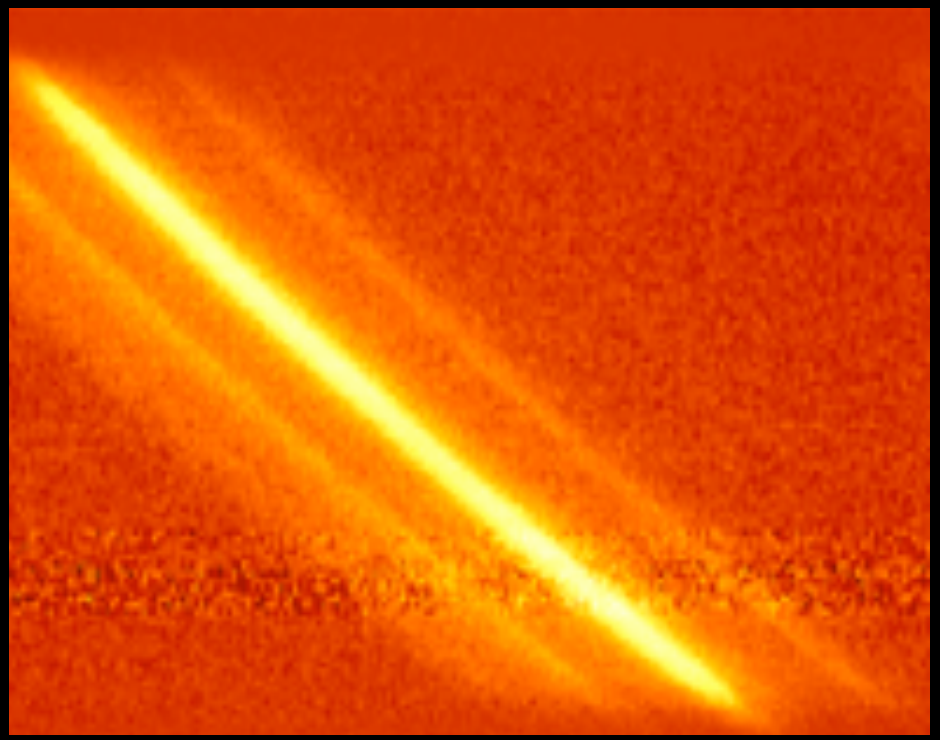
$$I(t) = g_r g_d S(t) * h_{\mathrm{DM}}(t) * h_d(t) * h_{\mathrm{Rx}}(t) + N(t)$$

Emitted signal

Scattering

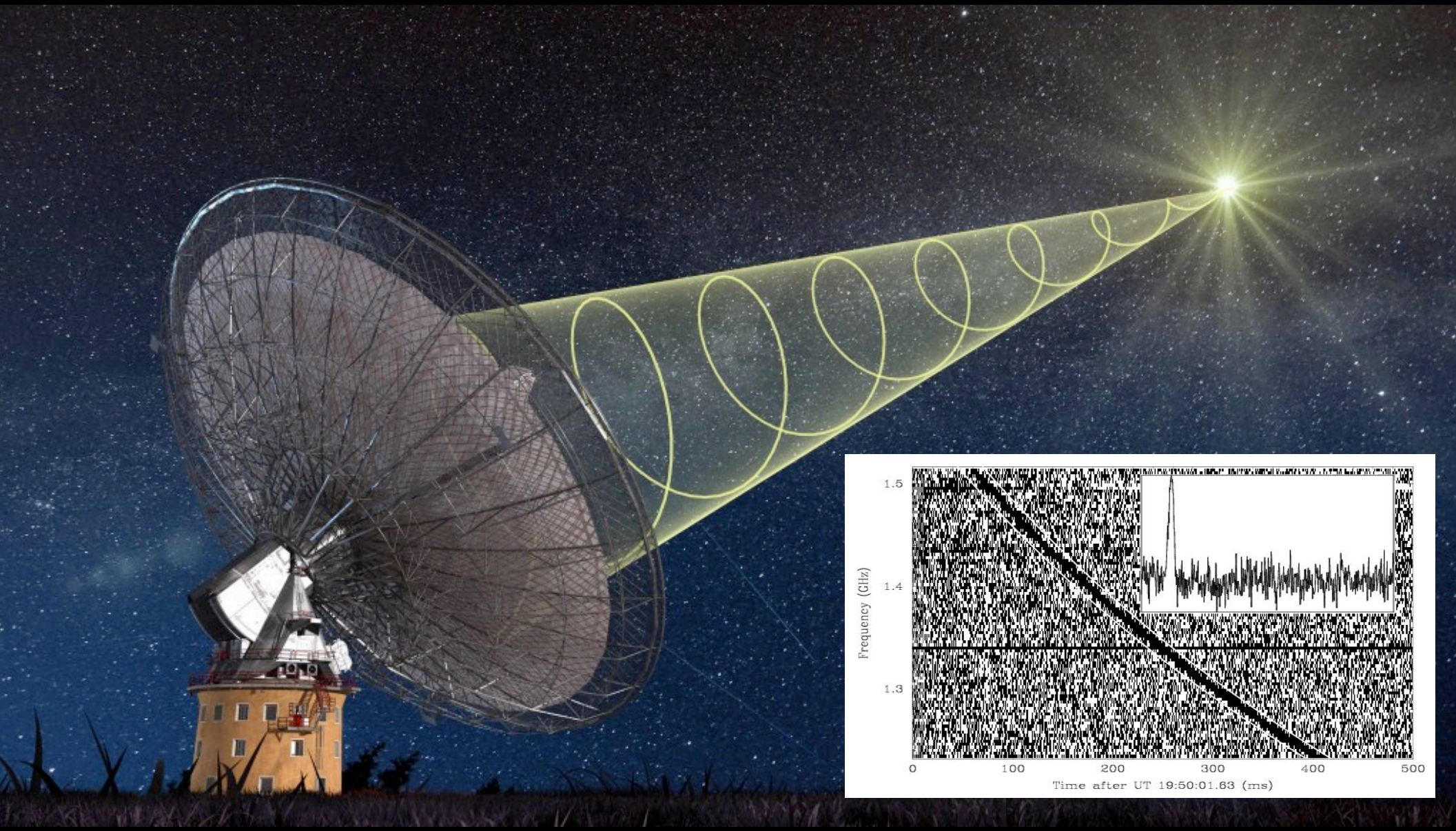


Dispersion



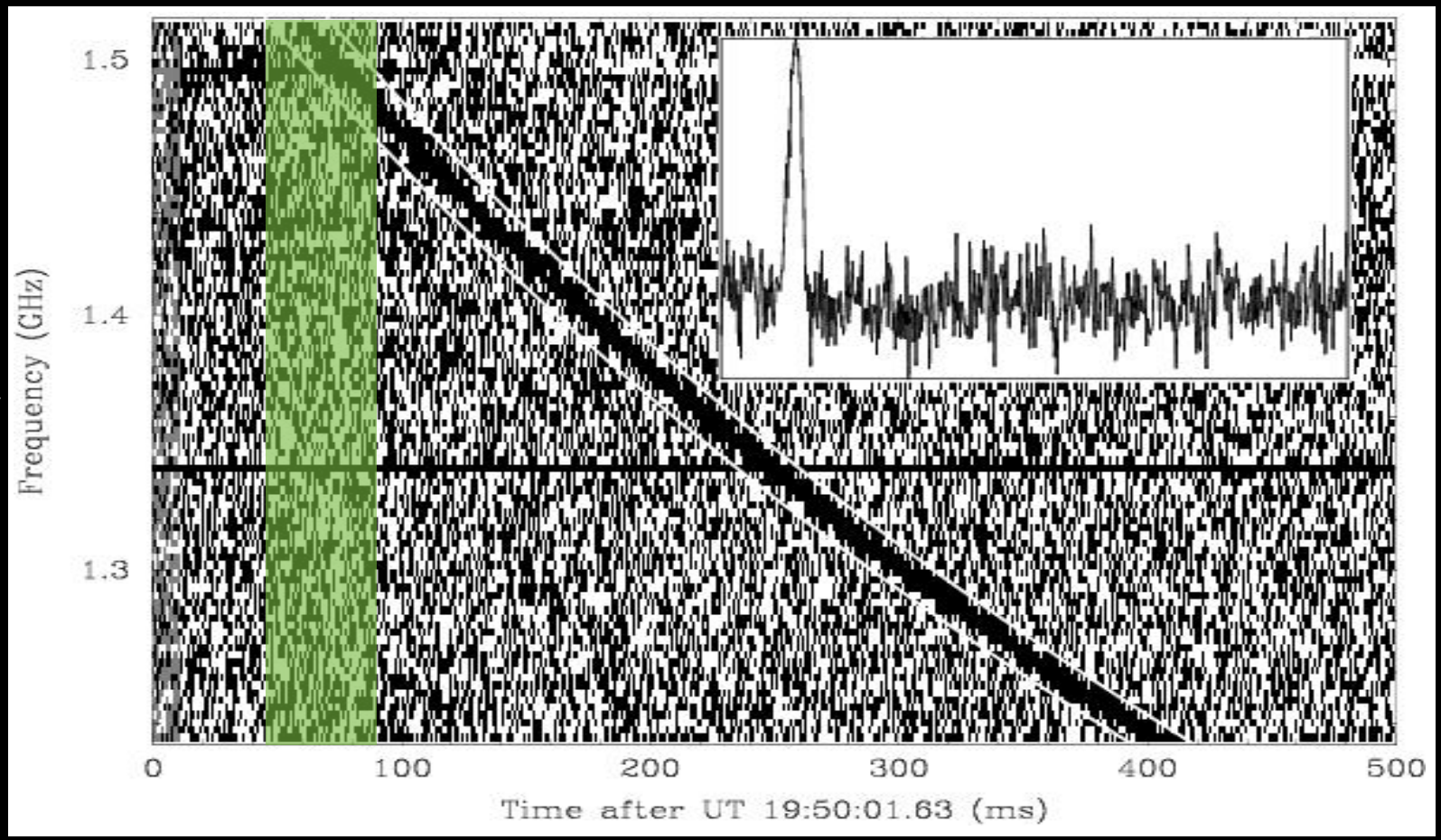
A hindrance but also a help

2007: The Lorimer Burst



Lorimer et al. 2007

2007: The Lorimer Burst

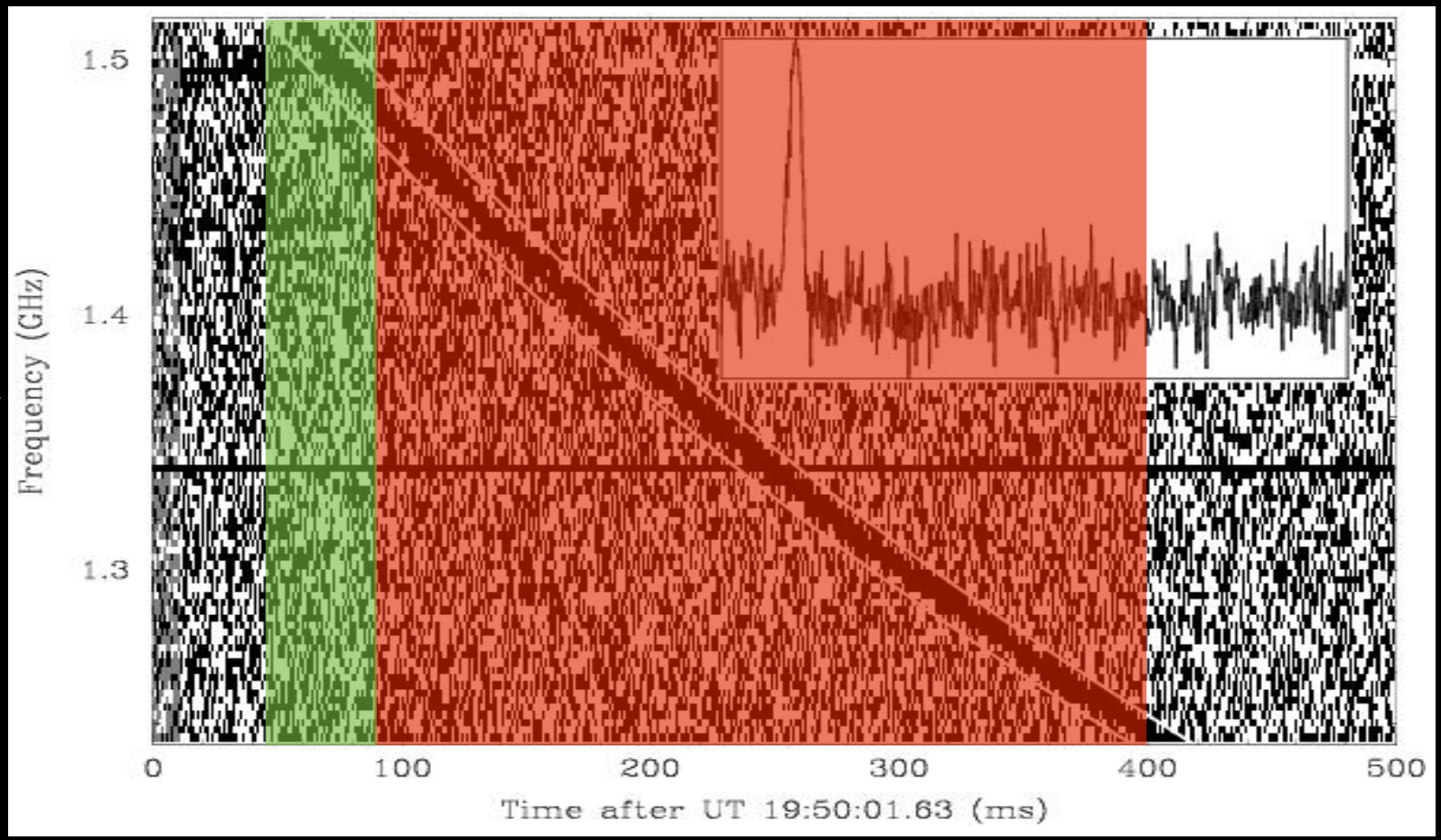


Must be hundreds if not thousands of these /sky/day

Lorimer et al. 2007

2007: The Lorimer Burst

ISM IGM + Host?



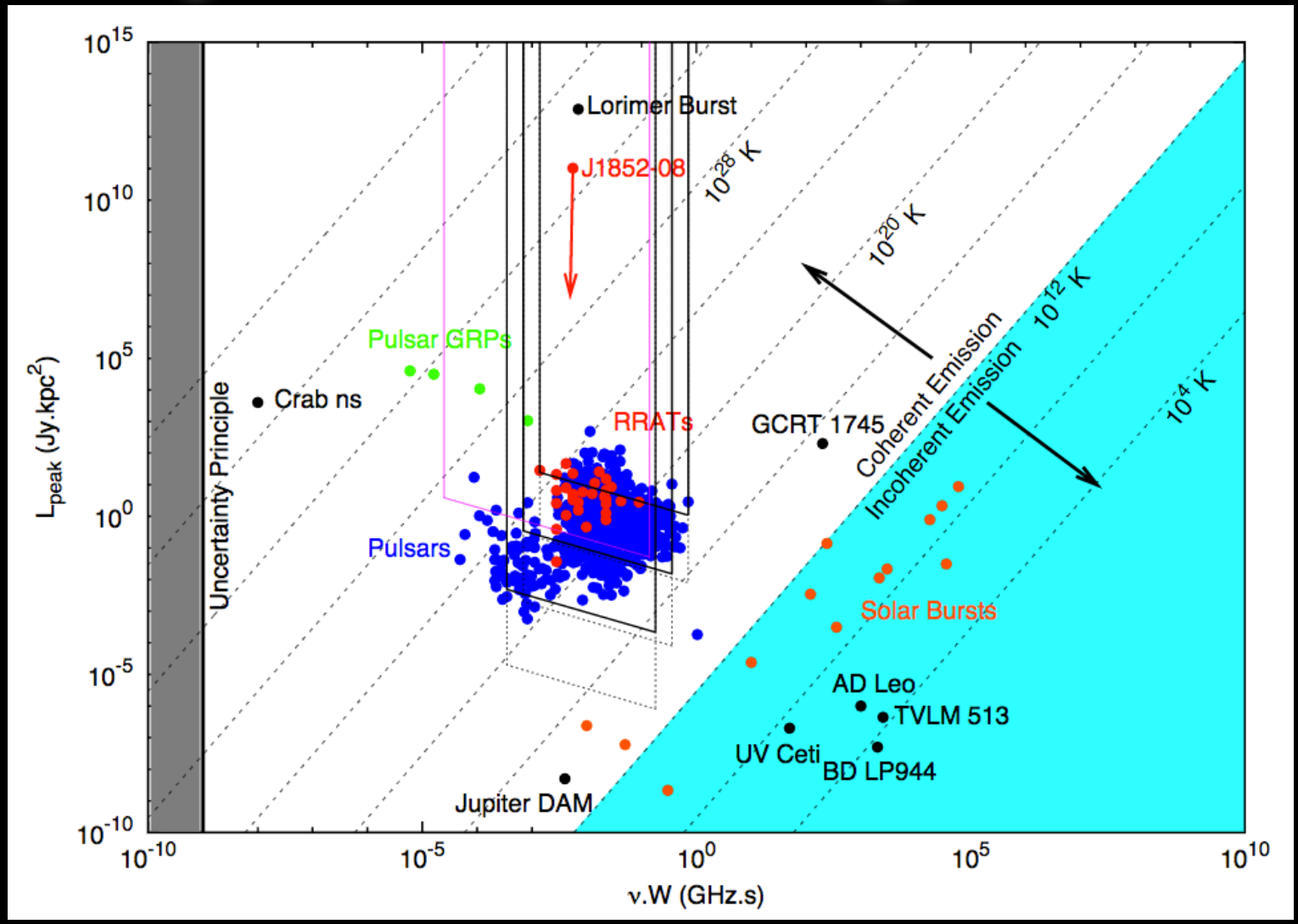
Frequency

Time

Delay too large to come from just the galaxy

Lorimer et al. 2007

Charting a new area of parameter space



Keane et al. 2012

See also Cordes et al. 2004

Ye Olde FRB History

A few interesting FRB-like papers, in retrospect

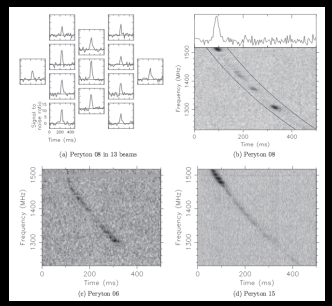
< 2007

Time passes and no more bursts...

Perytons

(the Parkes microwave)

Burke-Spolaor et al. (2011)

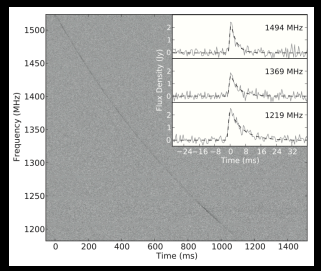


2011

The Thornton Bursts

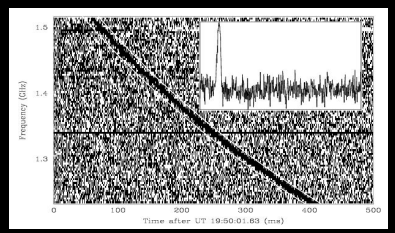
(a population of FRBs)

Thornton et al. (2013)



2013

2007

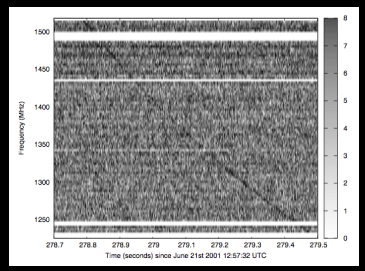


The Lorimer Burst

(the first FRB)

Lorimer et al. (2007)

2011



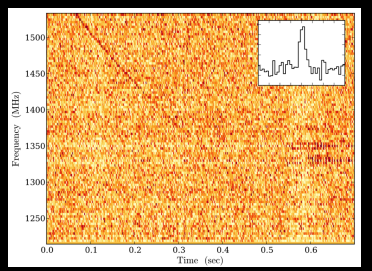
The Keane Burst

(an FRB or RRAT?)

Keane et al. (2011)

Keane et al. (2012)

2014



The Spitler Burst

(first non-Parkes FRB)

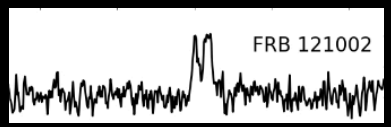
Spitler et al. (2014)

Ye Olde FRB History

2015

First multi-peak bursts

Champion et al. (2016)

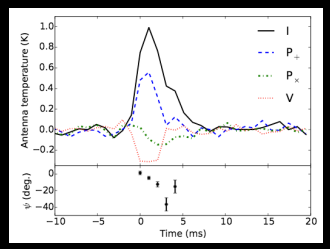


2015

The Masui Burst

(first with an RM)

Masui et al. (2015)

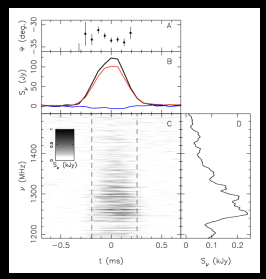


2016

Another super-bright FRB

(Lorimer-like)

Ravi, Shannon et al. (2016)



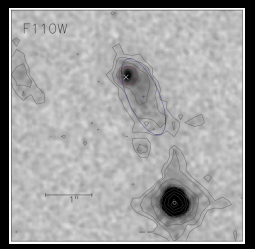
2017

FRB121102 host identified

(in a star-forming dwarf)

Tendulkar et al. (2017)

Bassa et al. (2017)

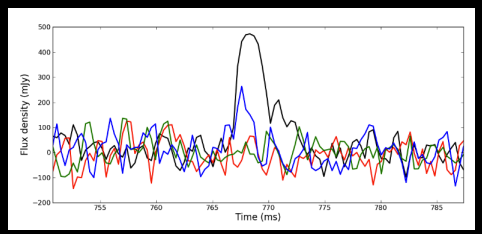


< 2018

Next repeater?

Next loc. & host?

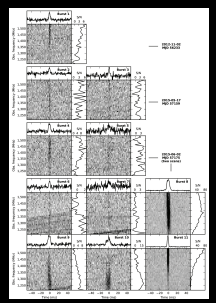
2015



First real-time burst & polarization

Petroff et al. (2015)

2016



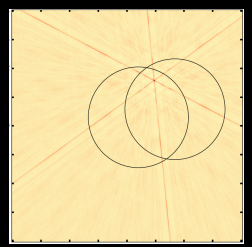
FRB121102: The Repeater

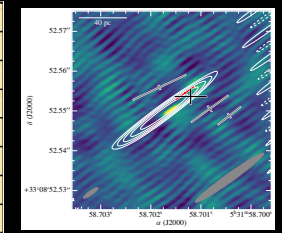
(still the only known)

Spitler et al. (2016)

Scholz et al. (2016)

2017





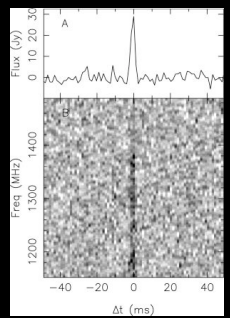
FRB121102 localized

(to milliarcseconds)

Chatterjee et al. (2017)

Marcote et al. (2017)

2017



UTMOST & ASKAP FRBs

(population deluge soon?)

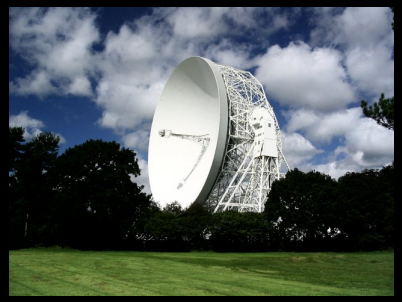
Caleb et al. (2017)

Bannister et al. (2017)

FRB Discovery Scoreboard

Arecibo (1.4 GHz): 1

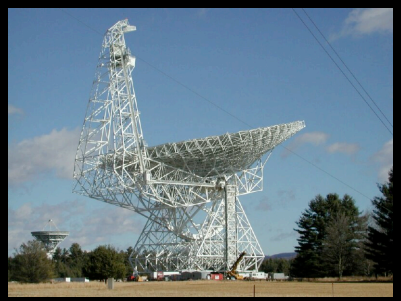
Arecibo (0.3 GHz): 0



Lovell (1.4 GHz): 0

ASKAP (1.4 GHz): 3?

MWA (0.2 GHz): 0



GBT (0.8 GHz): 1

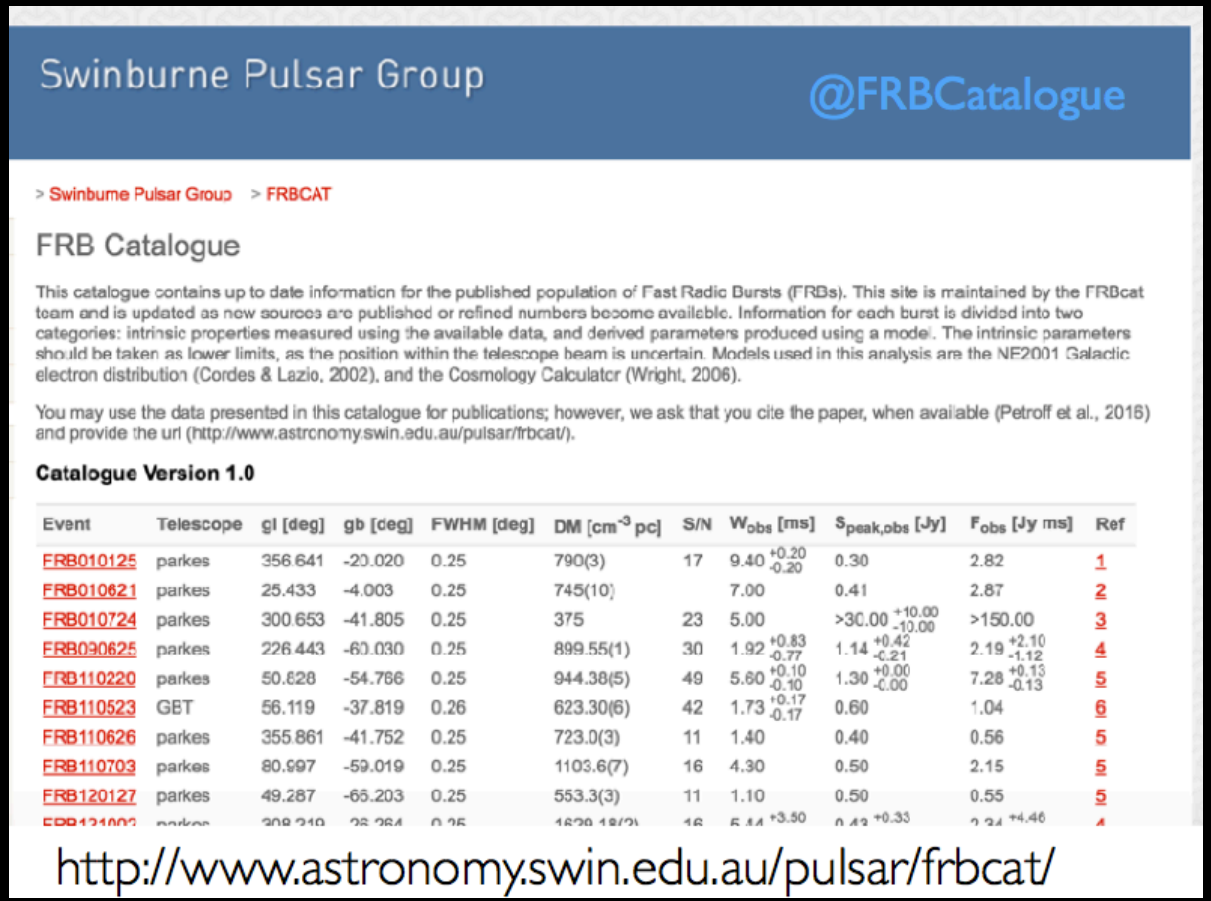
GBT (0.3 GHz): 0

Parkes (1.4 GHz): 21?

LOFAR (0.1 GHz): 0

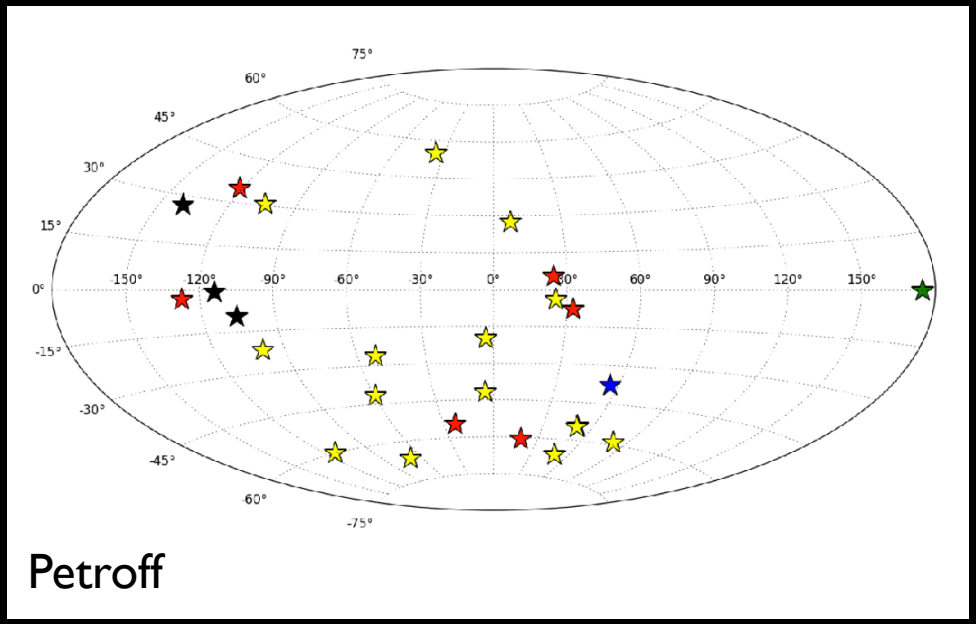
UTMOST (0.8 GHz): 3

FRBCAT



Petroff et al. (2016)

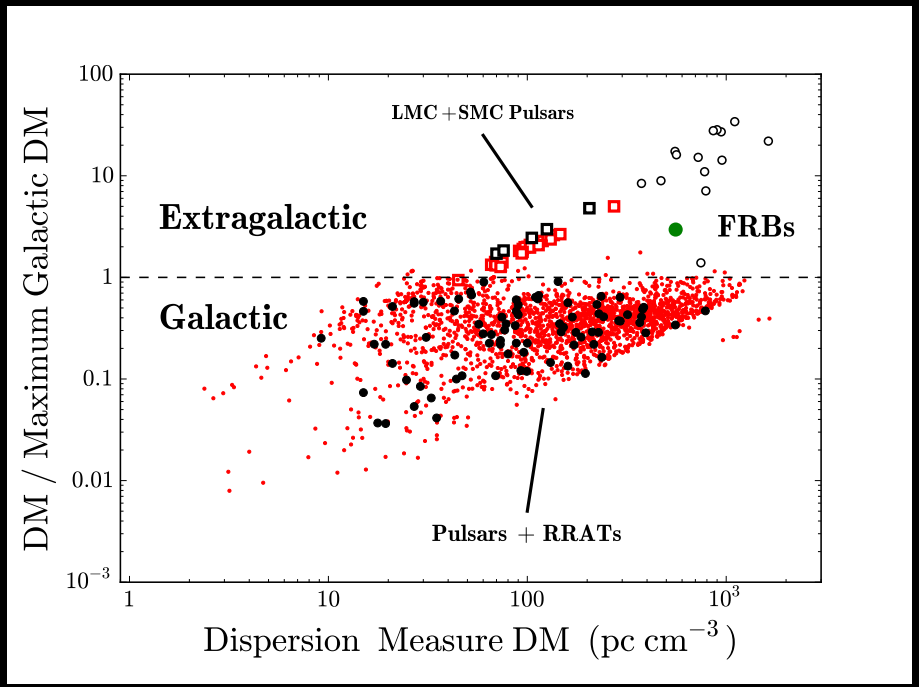
FRB Population



Petroff

Parkes published GBT Arecibo

Parkes unpublished UTMOST

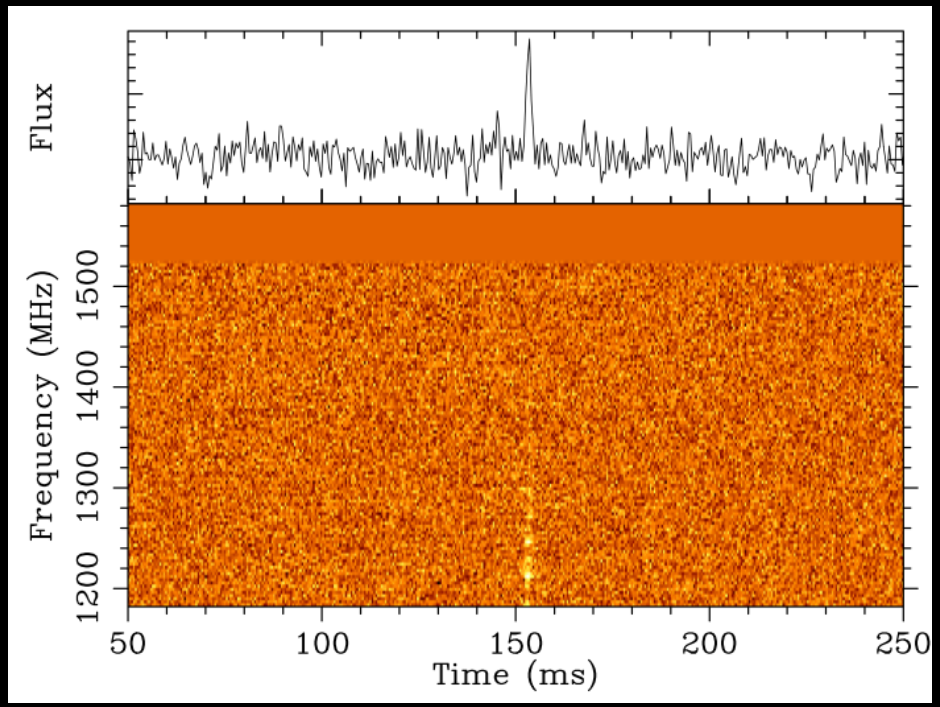


Cordes

- ~29 known FRBs
- ~7 unpublished (or published on FB)
- Event rate is
  >1000s /day/sky
- That's how small the field-of-view of a typical radio telescope is!

At the extremes

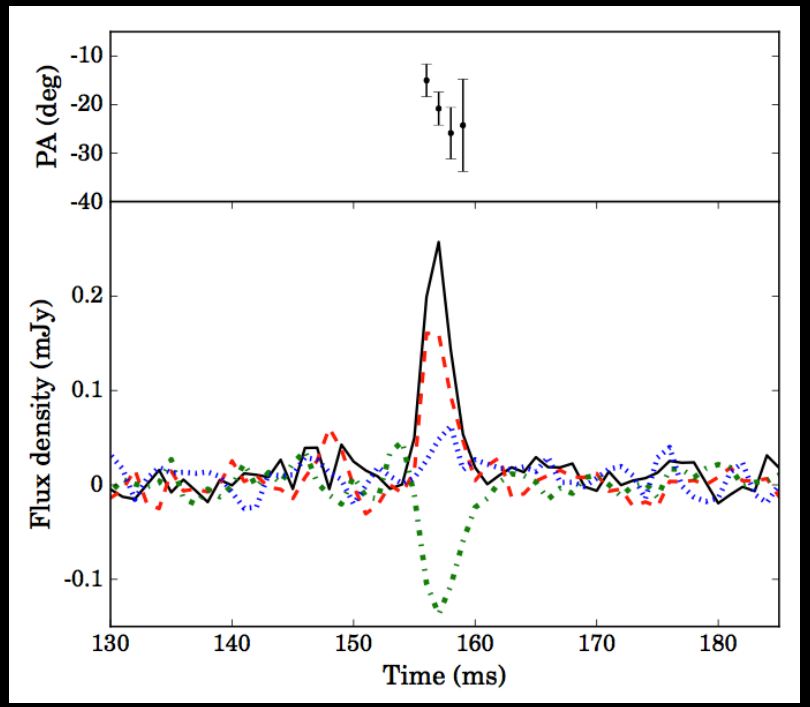
FRB110214



Petroff

- DM = 170pc/cc
- z < 0.05
- Detected in outskirts of the receiver beams

FRB160102



Caleb

- DM = 2600pc/cc
- z < 2.1
- RM = -220rad/m2
- 1.1ms, unscattered

FRB observables

- Dispersion measure
- Dispersion index
- Scattering measure: LOS inhomogeneity
- Scattering index
- Polarization: local magnetic field
- Rotation measure: B-field in local environment
- Spectrum
- Scintillation
- Pulse width
- Pulse fluence (and luminosity if redshift is known)
- Pulse morphology
- Non-dispersive pulse drifts in time-frequency
- Periodicity or lack thereof
- Host galaxy and position therein as well as redshift
- Sky and redshift distributions
- Constraints on prompt optical, X-ray & gamma-ray emission
- Constraints on optical, X-ray & gamma-ray afterglow


Merging Black Holes
Supernovae
Magnetars
Evaporating Black Holes
Super-giant Pulses
?
extra-Galactic
The Unknown
Gamma-ray Bursts
So what are they?
Micro-quasars
Flare stars
Galactic
SETI
Pernicious RFI
Atmospheric effects
"Blitzars"
Magnetars
We are here
Pulsars

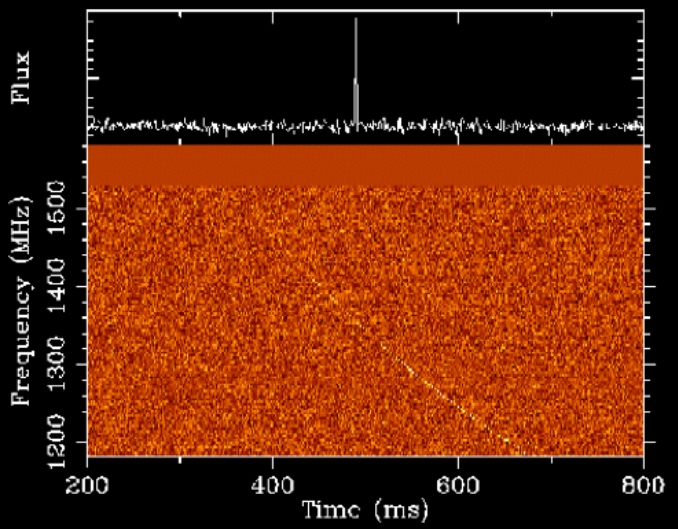
Observed FRB properties

Gruffalo model

Hessels et al. (*Nature*, submitted)

Observed FRB properties

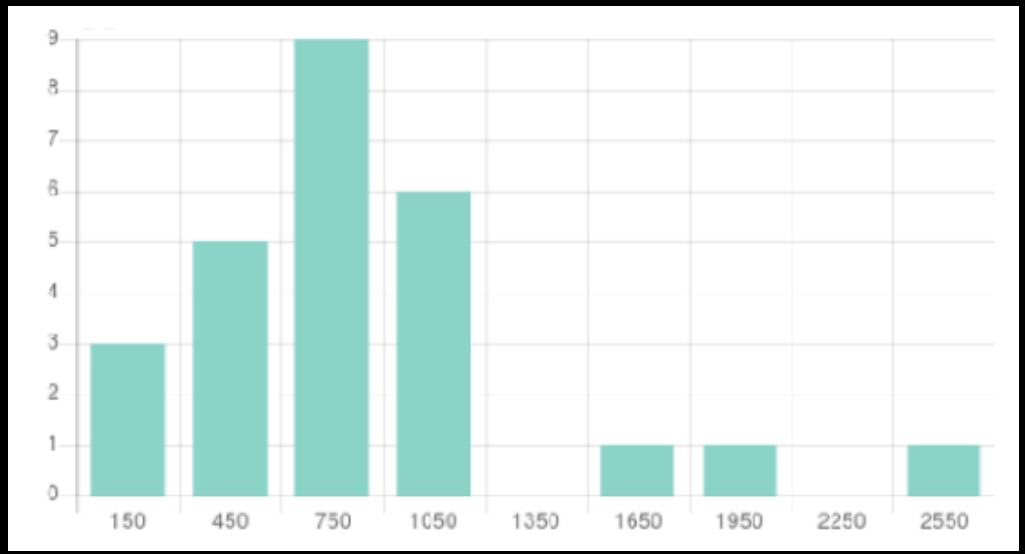
Pulse widths:
0.3 - ~10ms (and longer?)
Some scattered; some not
Are some intrinsically
delta functions?



Ravi, Shannon et al. (2016)

DMs: most between
500-1000pc/cc

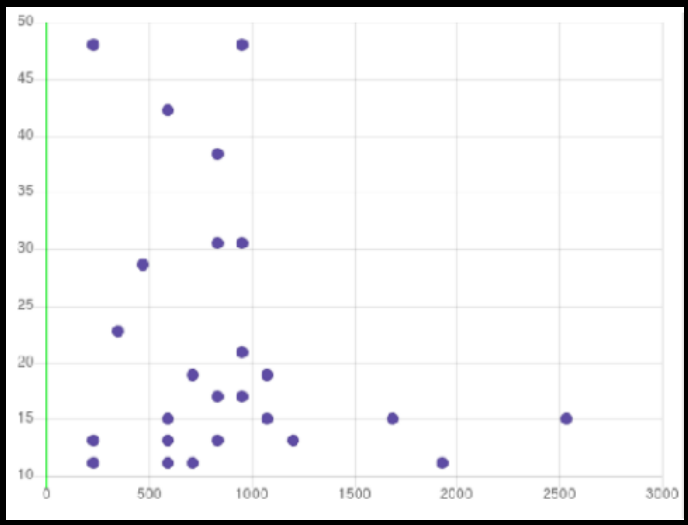
DM-Redshift: 0.05 < z < 2.1
(assuming all from IGM)



Petroff DM (pc/cc)

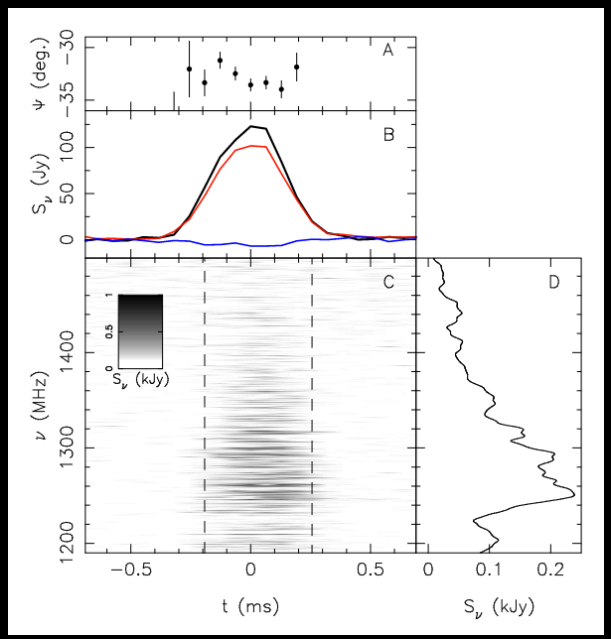
Observed FRB properties

Brightness: not strongly correlated with distance; not standard candles (beamed!).
Some hint that the lower-DM ones might be closer.



Polarization: sometimes none, sometimes circular, sometimes linear

Rot. Measure: 2 FRBs with high RMs; 2 consistent with the expected Milky Way contribution



Ravi, Shannon et al. (2016)

Observed FRB properties

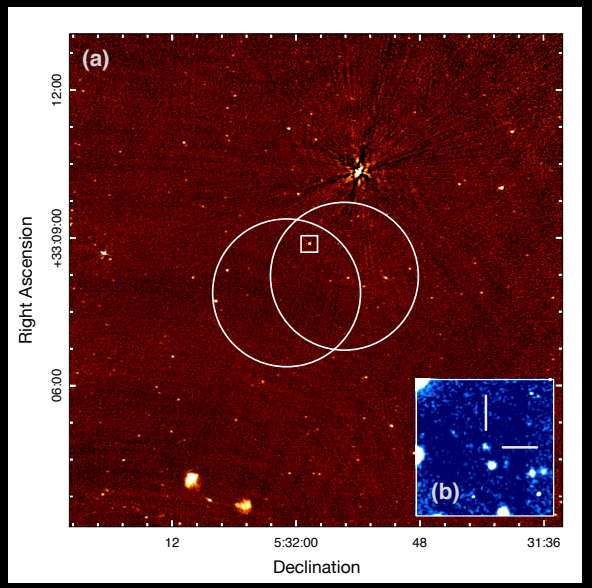
FRB121102 is a gold mine

Multi-wavelength persistent counterparts: radio (compact!) & optical (star formation!); no X-ray or gamma-ray

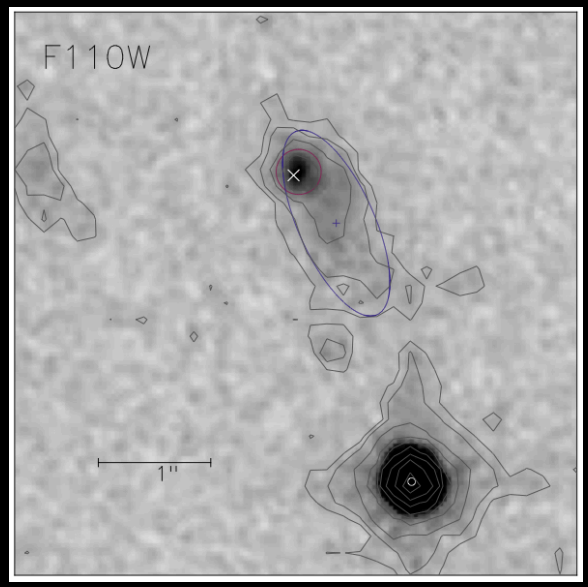
Multi-wavelength prompt emission: none.

Periodicity: none detected yet

Host: dwarf

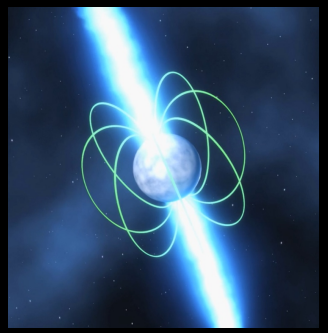


Chatterjee et al. (2017)



Bassa, Tendulkar et al. (2017)

How many classes of FRBs?



Pulsar on steroids

Repeaters

(Spitler et al. 2016)

vs.

Cataclysm

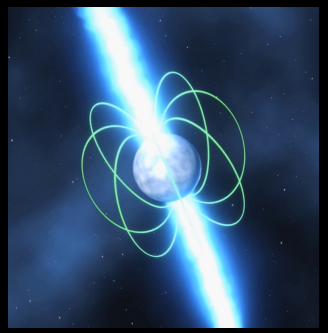
(Apparent?) non-repeaters

(Petroff et al. 2015)

FRB131104: 170hrs
FRB140514/110220: >50hrs

Diff widths and spectra?
Lensing?
Arecibo sensitivity matters?

How many classes of FRBs?



Pulsar on steroids

Repeaters

(Spitler et al. 2016)

vs.

Cataclysm

(Apparent?) non-repeaters

(Petroff et al. 2015)

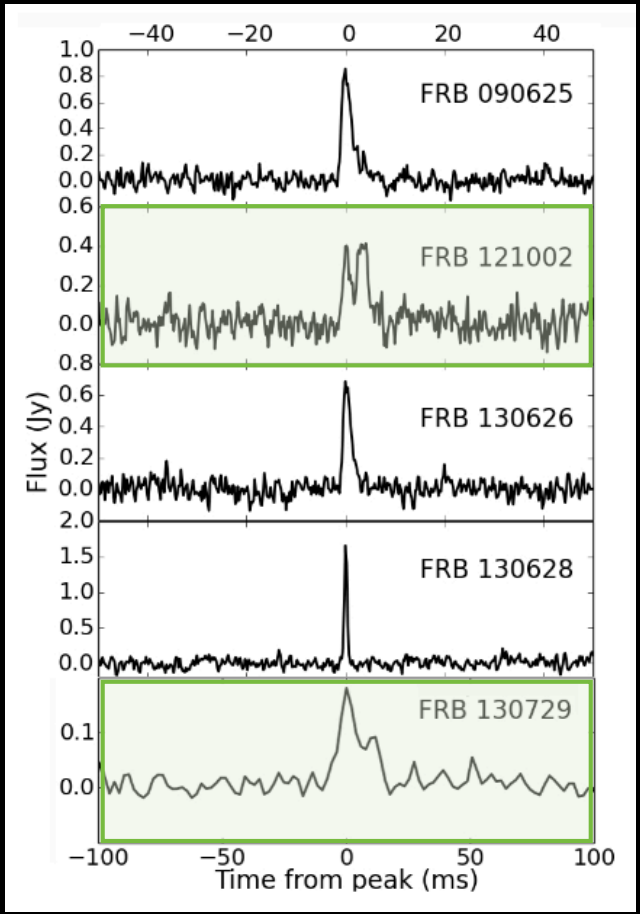
FRB131104: 170hrs

FRB140514/110220: >50hrs

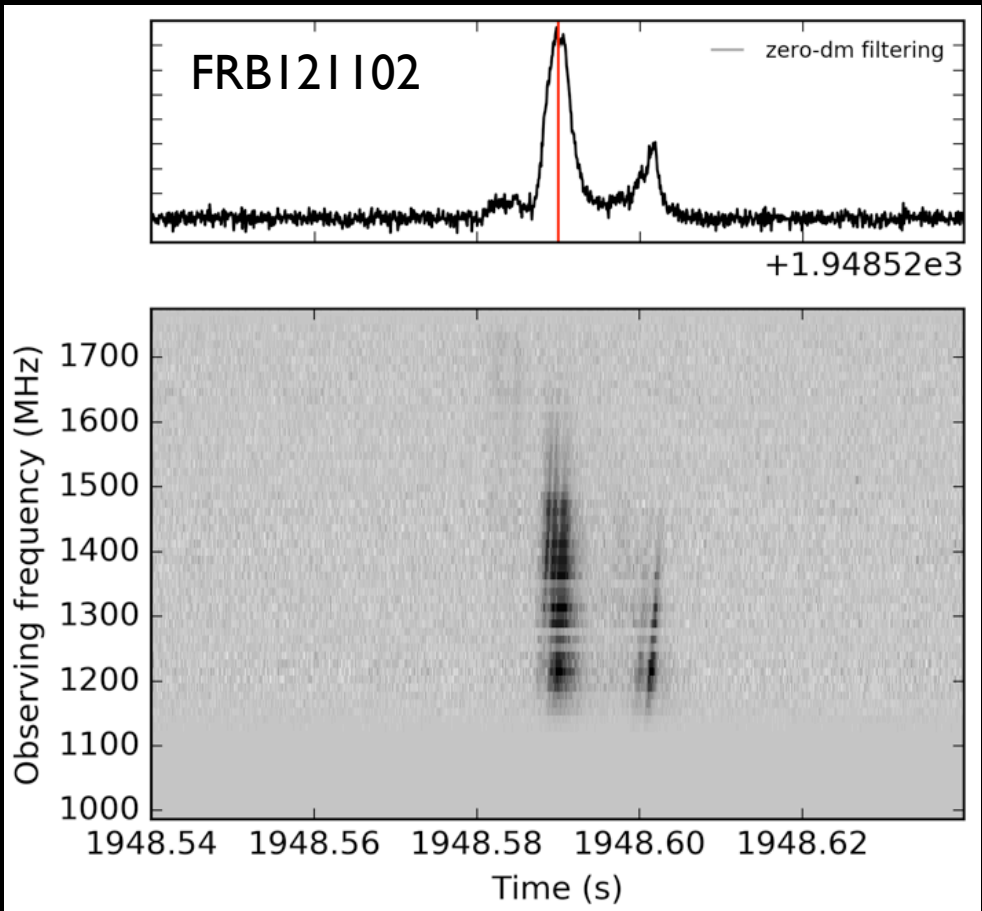
NB: according to the *arXiv*, there are >40 types of FRBs

Double-peaked bursts

At least some of the Parkes bursts are similar in this regard



Champion et al. (2016)

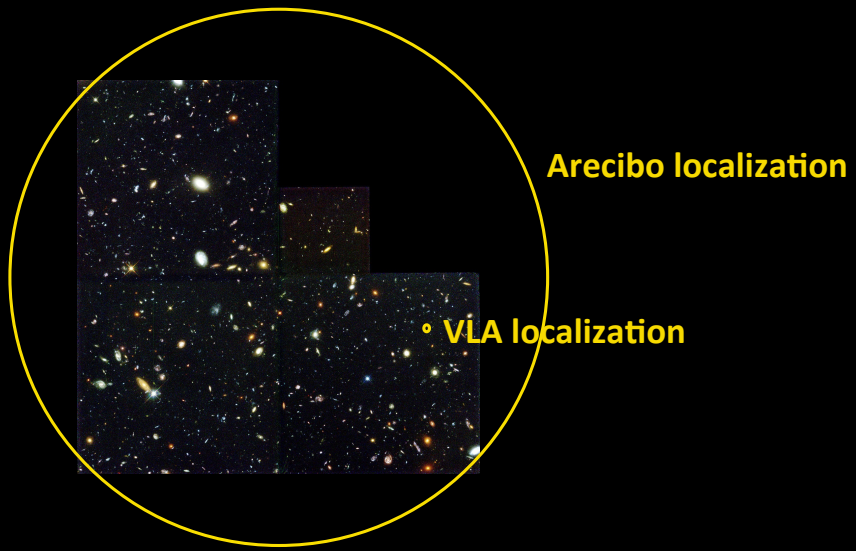


Michilli & Gourdji

What are the host galaxies?

- Will all FRBs be hosted in low-metallicity, dwarf galaxies?

- Requires: more sub-arcsecond localizations and redshifts.

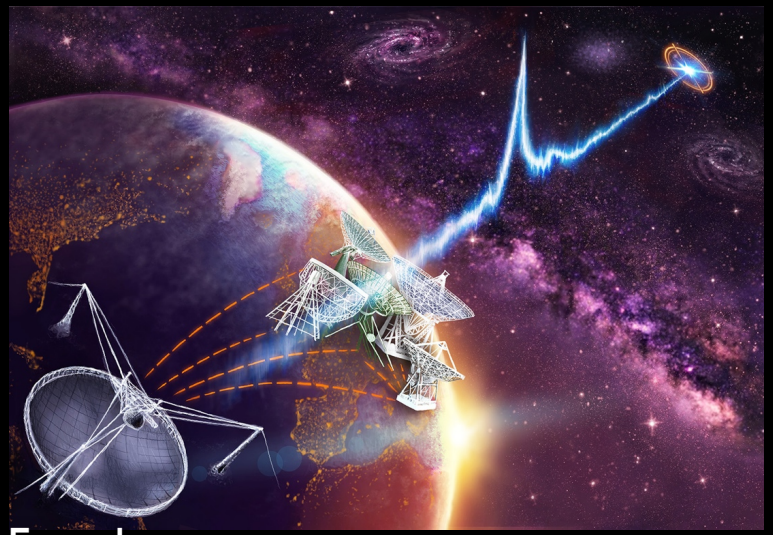


Futselaar

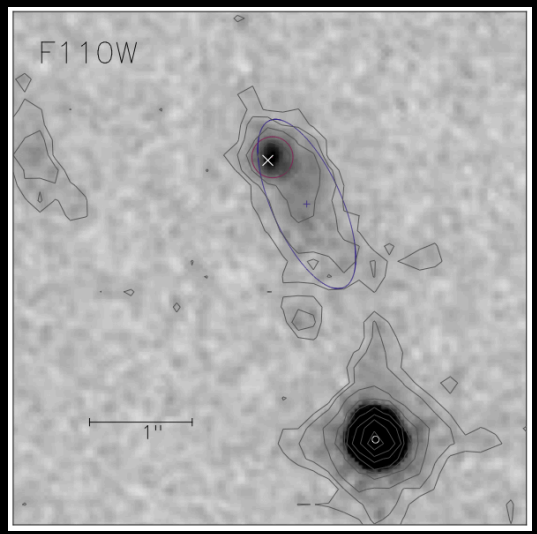
What are the host environments?

- Will all FRBs be hosted in starforming regions with compact radio counterparts?

- Requires: more milli-arcsecond radio localizations and sub-arcsecond optical observations. Also more RMs!



Futselaar

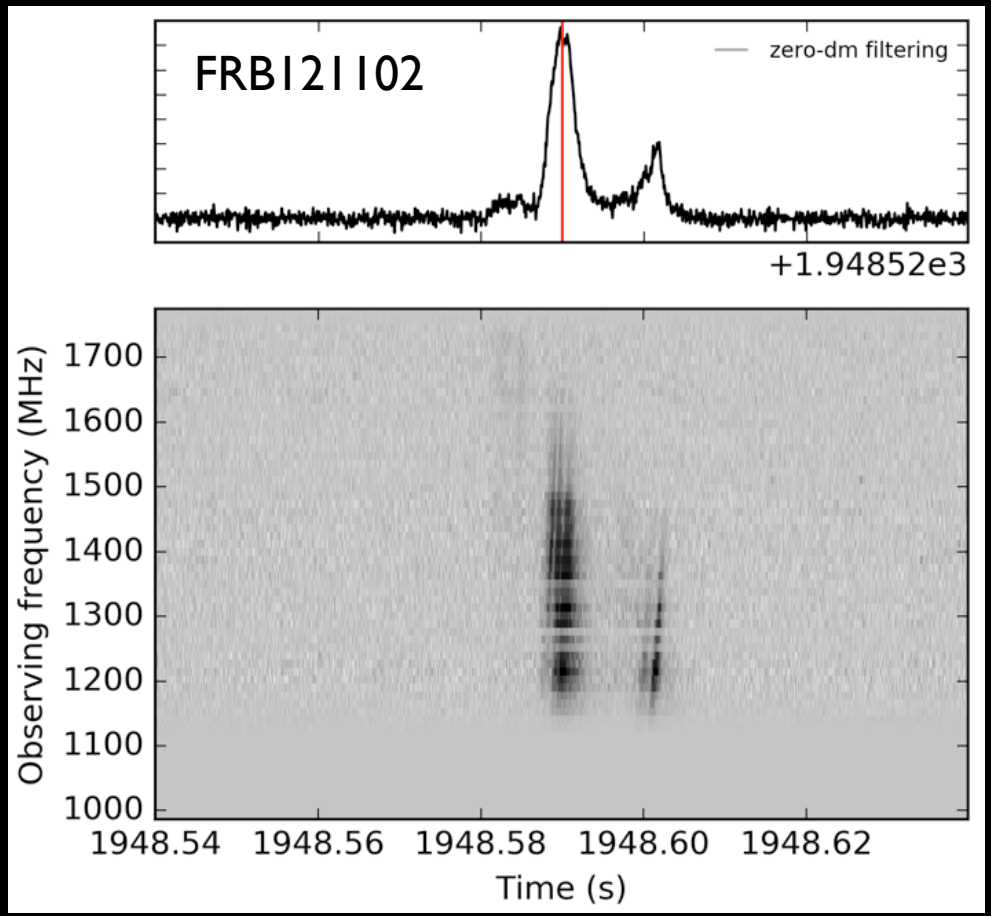


Bassa, Tendulkar et al. (2017)

What is the emission mechanism?

- Obviously coherent, but is the source rotational, magnetic, gravitational (accretion?)

- Requires: coherent dedispersion with full Stokes parameters. Wide-band observations. Base-band data. Very clever theorists.

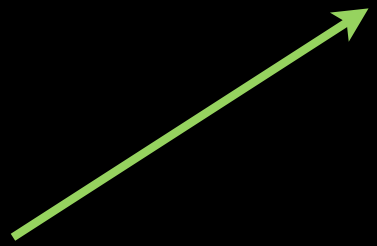


Michilli & Gourdji

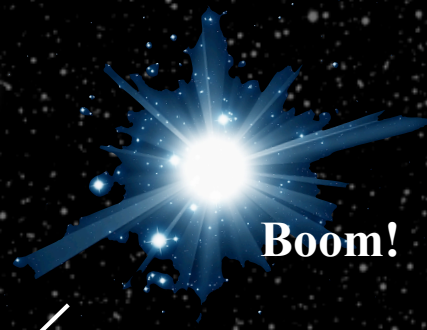
What is the emission mechanism?

We've spent 50 years puzzling over how pulsars work, so it's great to see so many brilliant theorists ready for 50 years of FRB puzzles.

- Requires: coherent dedispersion with full Stokes parameters. Wide-band observations. Base-band data. Very clever theorists.



What Good are They to Anybody Anyway?



- Sites of extreme energy density. Important probes of extreme (astro)physics?

- New type of astrophysical object?

- Probes of intervening material.

Working and Upcoming FRB Factories

- Strike various balances between localization precision, yield, observing frequency and sensitivity
- More localizations before end of 2017?
- Double population in next year?

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