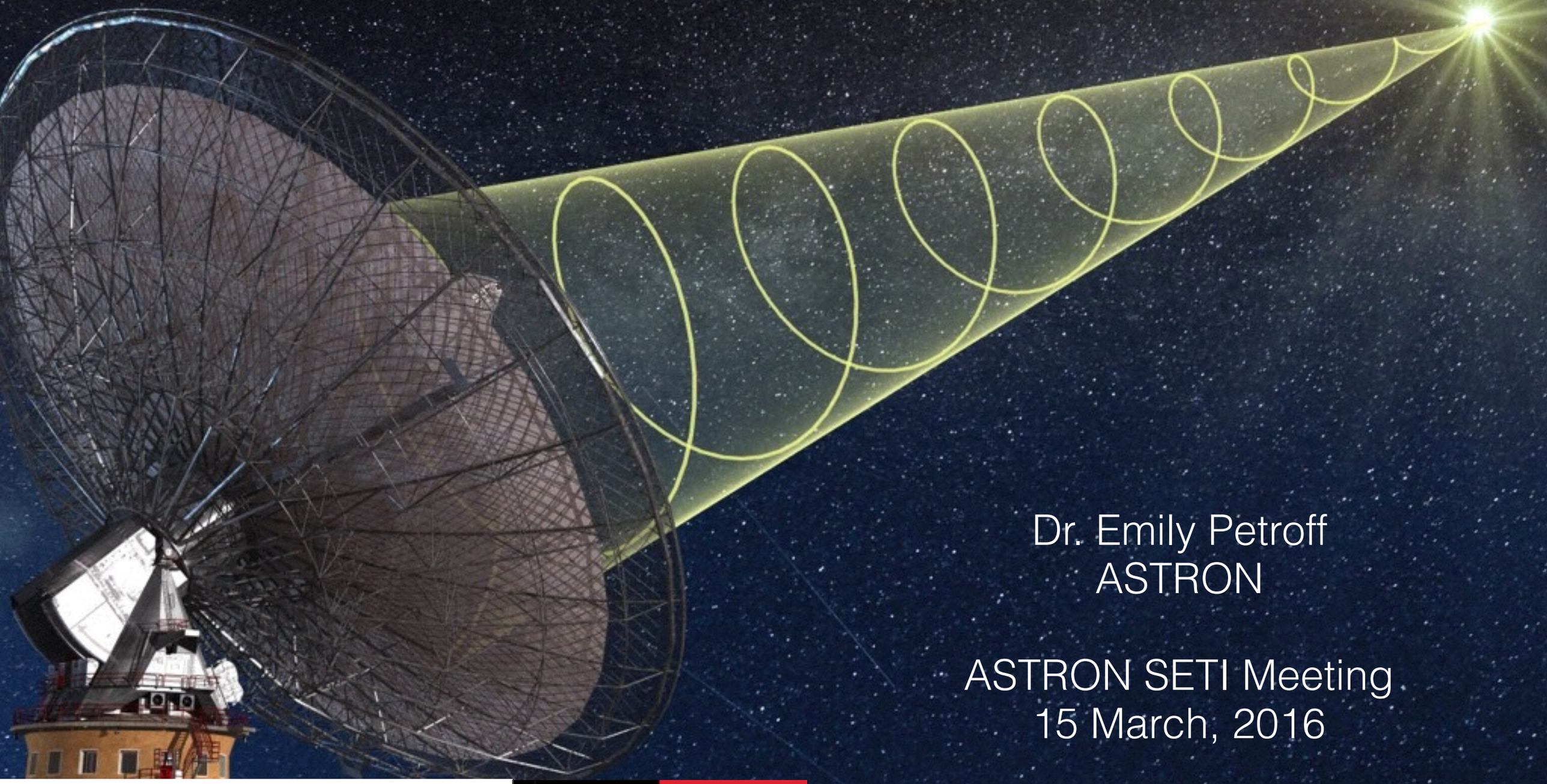
SETI and Fast Radio Bursts



Dr. Emily Petroff
ASTRON

ASTRON SETI Meeting
15 March, 2016

ASTRON
Netherlands Institute for Radio Astronomy

SWINBURNE UNIVERSITY OF TECHNOLOGY

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General Outline

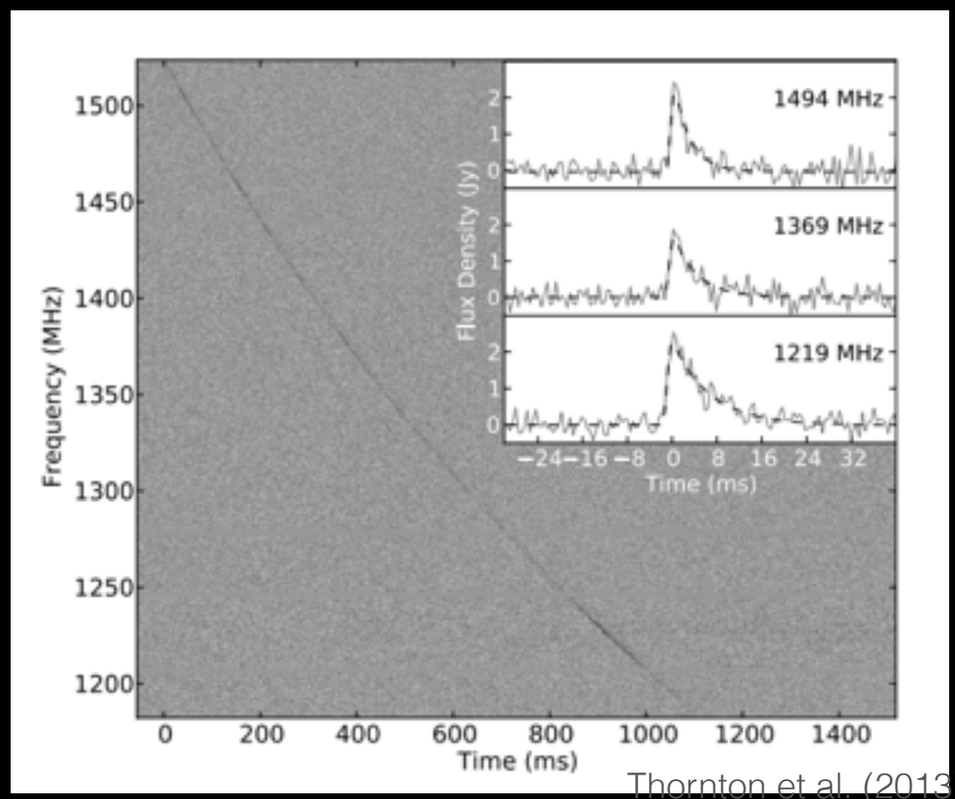
- Introduction to fast radio bursts
    - What we know and what we don’t know
- Next steps in FRB science
- How we search for FRBs in radio data
    - Challenges and opportunities
- Application to SETI science
    - Breakthrough listen

Fast radio bursts (FRBs)

what we know

- Bright, short radio pulses
- High dispersion measure (DM)

$$DM = \int_0^d n_e \, ds$$



Thornton et al. (2013)

- DM(FRB) ~ 10x DM(MW)
- Extreme environments; lots of material along the line of sight
- One seen to repeat! One seen to have fading afterglow!

Fast radio bursts (FRBs)

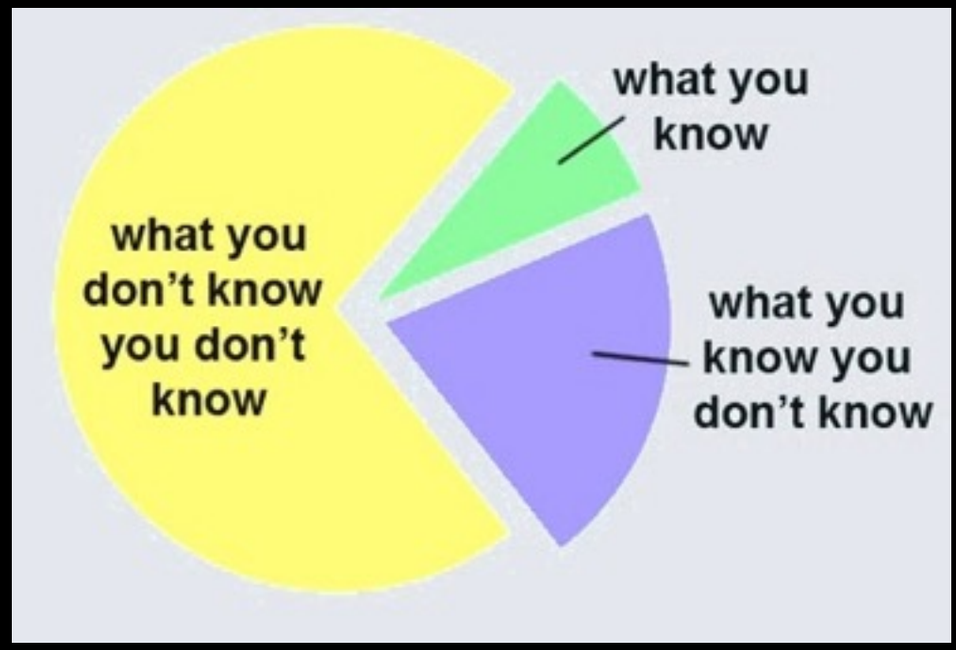
what we think we know

- Excess DM comes from IGM
- Sources at cosmological distance ~ 1 - 5 Gpc
- Compact object progenitors
  - magnetar flares, binar mergers, young pulsars, neutron star collapse
- Rate ~ 5,000 sky^{-1} day^{-1}

Fast radio bursts (FRBs)

what we don't know
(but we're probably close to figuring out)

- Origins
- Visible at other wavelengths?
- Two (or more) sub-populations?
  - one repeating one cataclysmic?
- Polarisation - measure magnetic fields?
- Cosmology with FRBs?



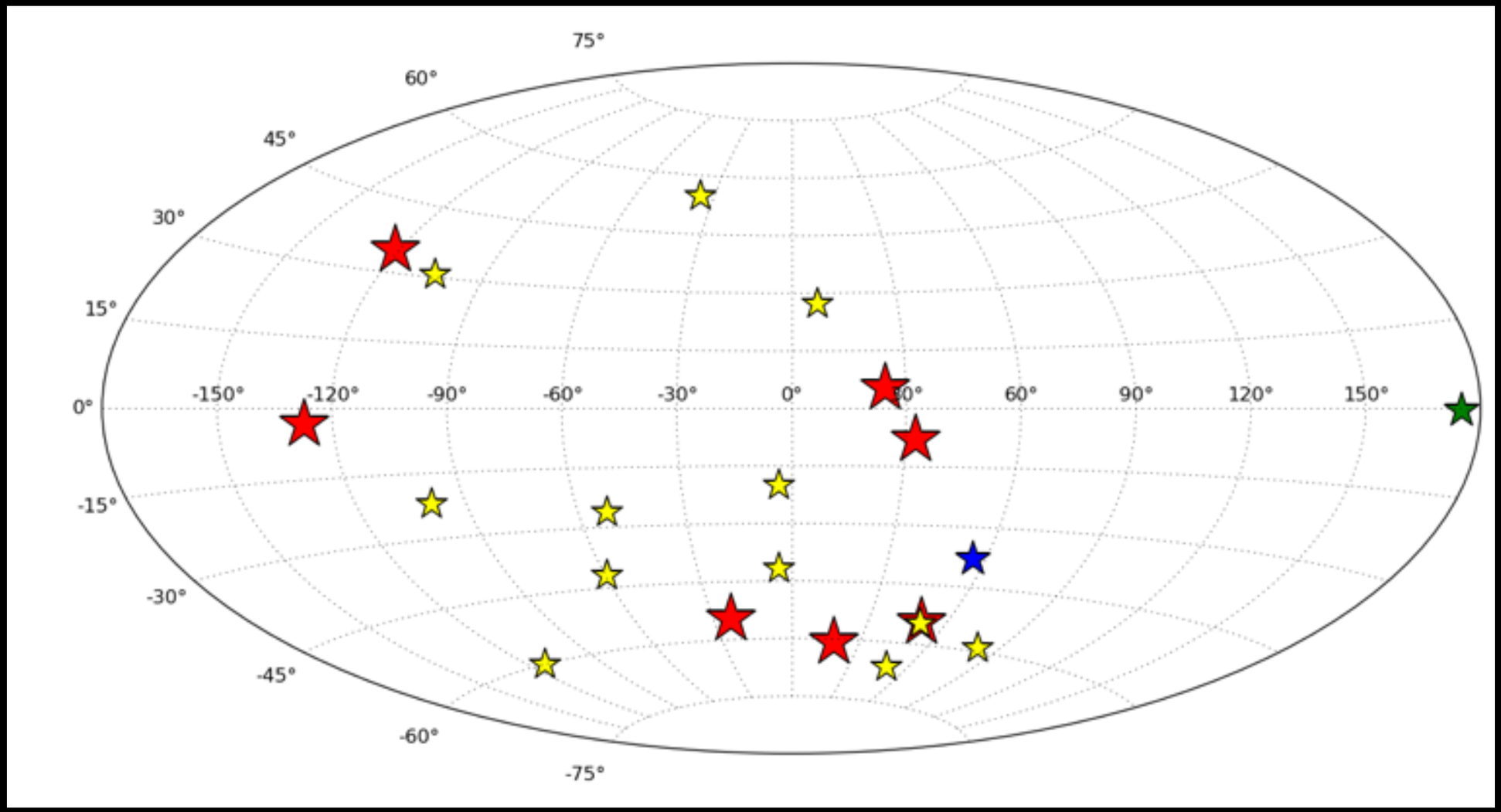
FRBs up until now

- First discoveries years later in archival data

Name	Event date	Discovery date	Lag
FRB 010125 Burke-Spolaor/Bannister	2001	2014	13 years
FRB 010724 Lorimer	2001	2007	6 years
FRB 110220 Thornton	2011	2013	2 years
FRB 140514 Petroff	14 May, 2014 17:14:11 UT	14 May, 2014 17:14:30 UT	20 seconds

FRBs up until now

- Real-time discovery is now possible
- 22 known FRB sources to-date
- Found at 3 telescopes



FRBs up until now

- All published bursts compiled in the fast radio burst catalogue (FRBCAT)

Swinburne Pulsar Group

> Swinburne Pulsar Group > FRBCAT

FRB Catalgoue

This catalogue contains up to date information for the published population of Fast Radio Bursts (FRBs). This site is maintained by the FRBcat team and is updated as new sources are published or refined numbers become available. Information for each burst is divided into two categories: intrinsic properties measured using the available data, and derived parameters produced using a model. The intrinsic parameters should be taken as lower limits, as the position within the telescope beam is uncertain. Models used in this analysis are the NE2001 Galactic electron distribution (Cordes & Lazio, 2002), and the Cosmology Calculator (Wright, 2006).

You may use the data presented in this catalogue for publications; however, we ask that you cite the paper, when available (Petroff et al., in prep.) and provide the url (http://www.astronomy.swin.edu.au/pulsar/frbcat/).

Catalogue Version 1.0

Event	Telescope	gl [deg]	gb [deg]	FWHM [deg]	DM [cm^{-3} pc]	S/N	W_{obs} [ms]	$S_{peak,obs}$ [Jy]	F_{obs} [Jy ms]	Ref
FRB010125	parkes	356.641	-20.020	0.25	790(3)	17	$9.40^{+0.20}_{-0.20}$	0.30	2.82	1
FRB010621	parkes	25.433	-4.003	0.25	745(10)		7.00	0.41	2.87	2
FRB010724	parkes	300.653	-41.805	0.25	375	23	5.00	$>30.00^{+10.00}_{-10.00}$	>150.00	3
FRB090625	parkes	226.443	-60.030	0.25	899.55(1)	30	$1.92^{+0.83}_{-0.77}$	$1.14^{+0.42}_{-0.21}$	$2.19^{+2.10}_{-1.12}$	4
FRB110220	parkes	50.828	-54.766	0.25	944.38(5)	49	$5.60^{+0.10}_{-0.10}$	$1.30^{+0.00}_{-0.00}$	$7.28^{+0.13}_{-0.13}$	5
FRB110523	GBT	56.119	-37.819	0.26	623.30(6)	42	$1.73^{+0.17}_{-0.17}$	0.60	1.04	6
FRB110626	parkes	355.861	-41.752	0.25	723.0(3)	11	1.40	0.40	0.56	5
FRB110703	parkes	80.997	-59.019	0.25	1103.6(7)	16	4.30	0.50	2.15	5
FRB120127	parkes	49.287	-66.203	0.25	553.3(3)	11	1.10	0.50	0.55	5

http://www.astronomy.swin.edu.au/pulsar/frbcat/

An exciting year for FRBs

- January 2016 - Masui et al.
    - A fast radio burst with the GBT. Evidence for dense material around the progenitor.
- February 2016 - Keane et al.
    - A fading radio afterglow associated with an FRB. First measurement of a redshift.
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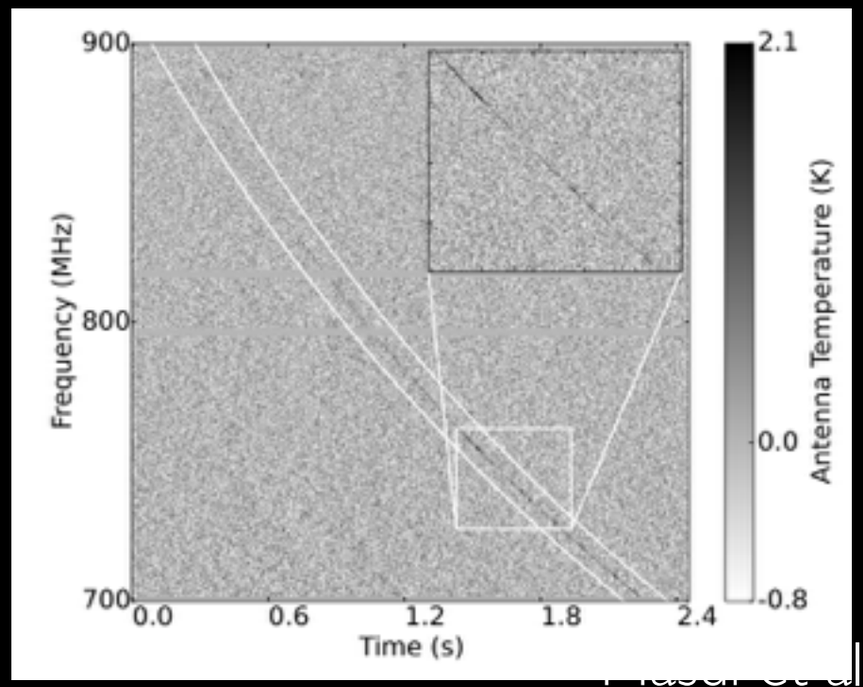

Fraser et al. 2016

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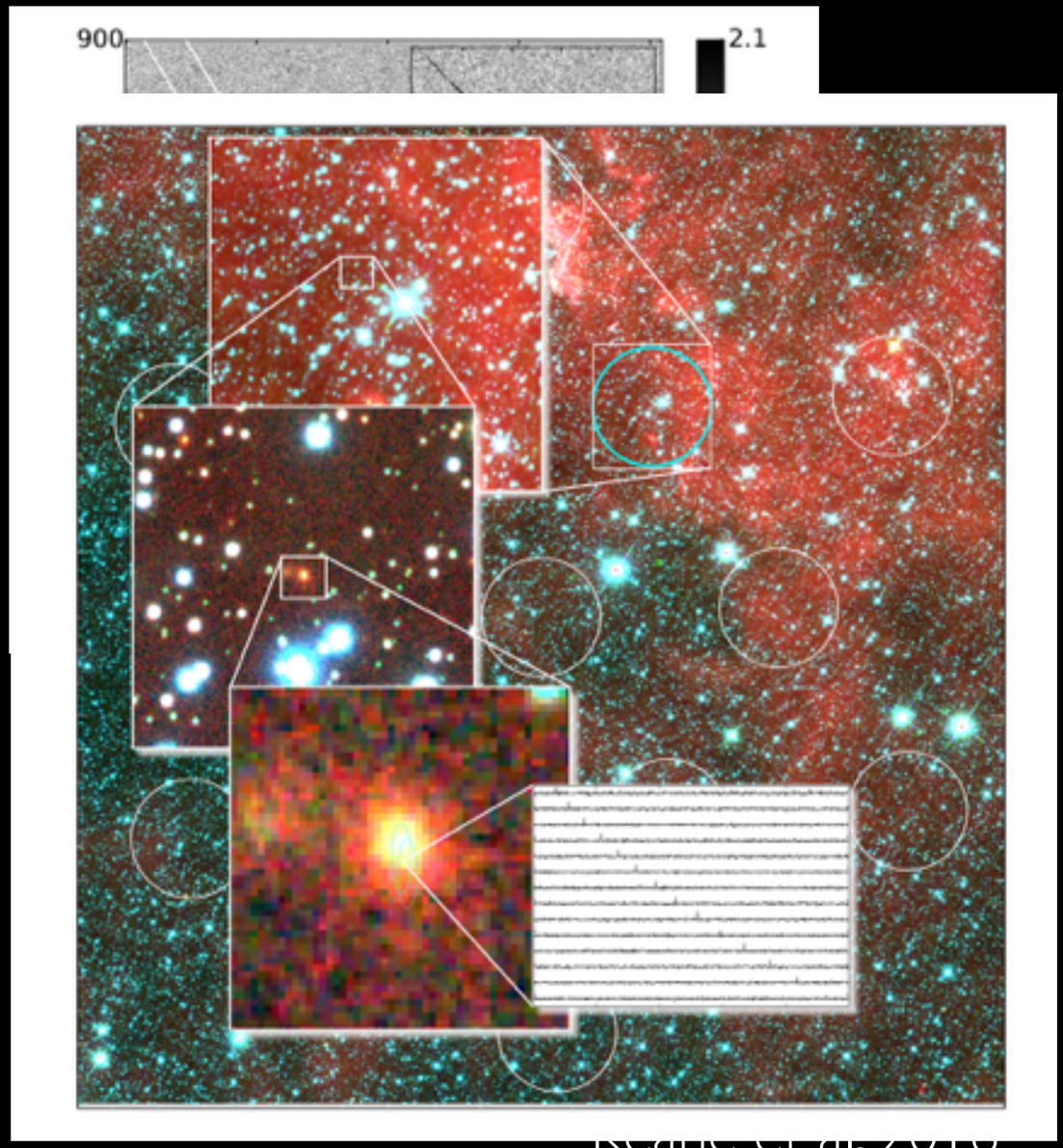

Keane et al. 2016

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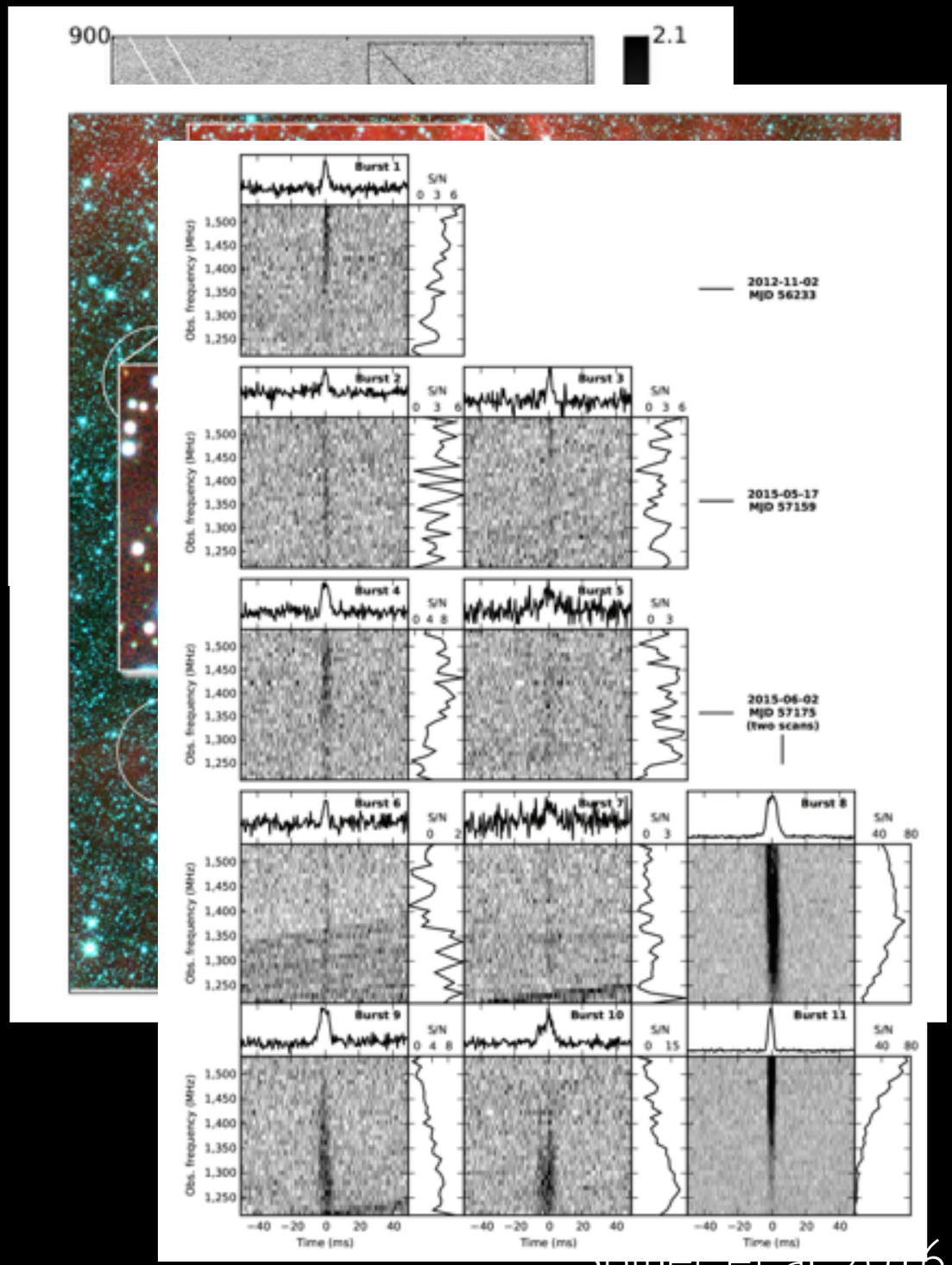

Spitler et al. 2016

An exciting year for FRBs

- Keane et al. - radio afterglow
    - 6 day fading radio source aligned with elliptical galaxy at z = 0.492
    - DM of FRB and redshift of galaxy line up well
    - preferred progenitor model: colliding neutron stars?

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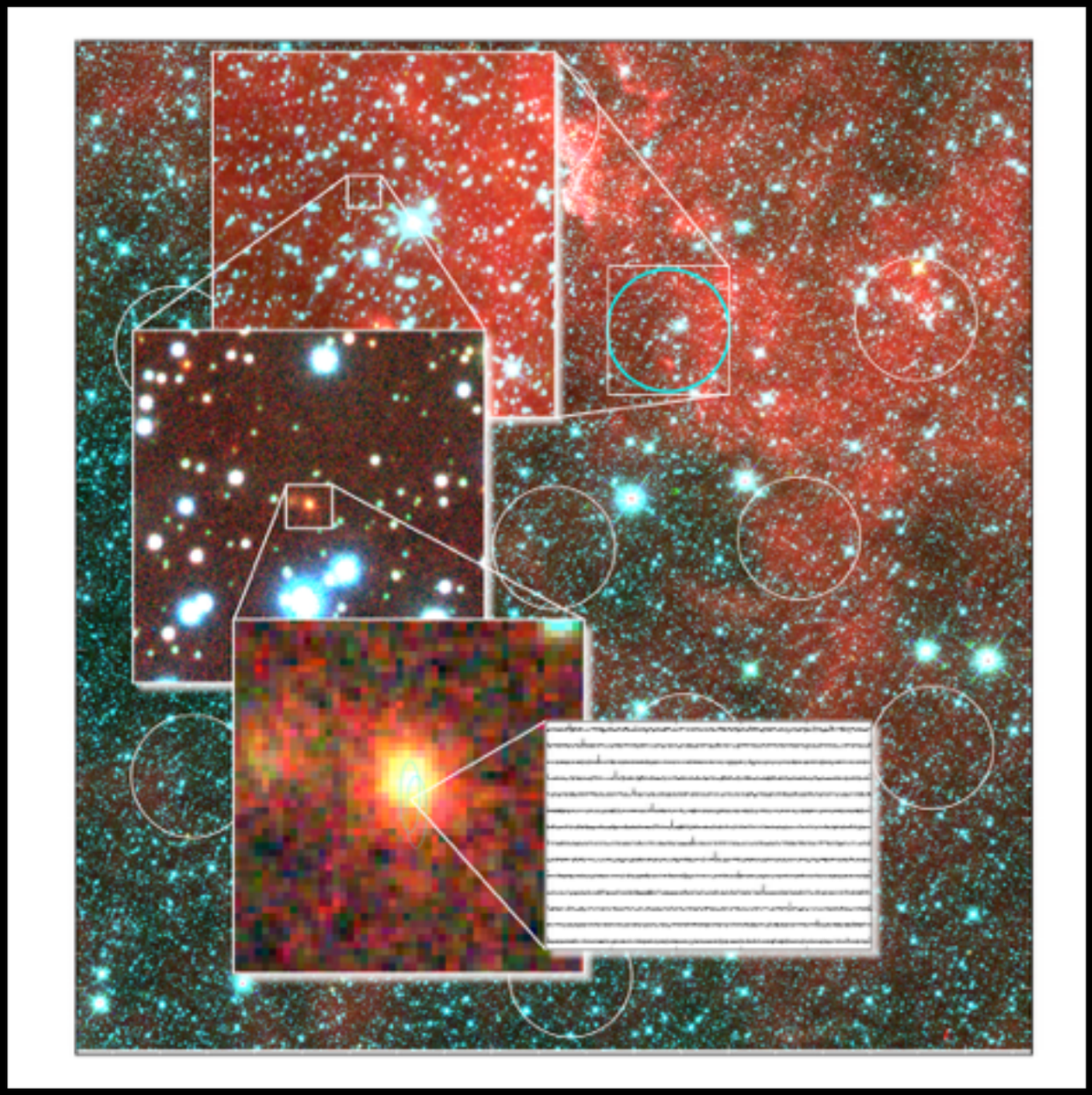

An exciting year for FRBs

- Spitler et al. - repeating burst
    - periods of high activity where several repeat pulses are found
    - large variations in spectral index even within a single observation
    - preferred progenitor: young Crab-like neutron star in another galaxy

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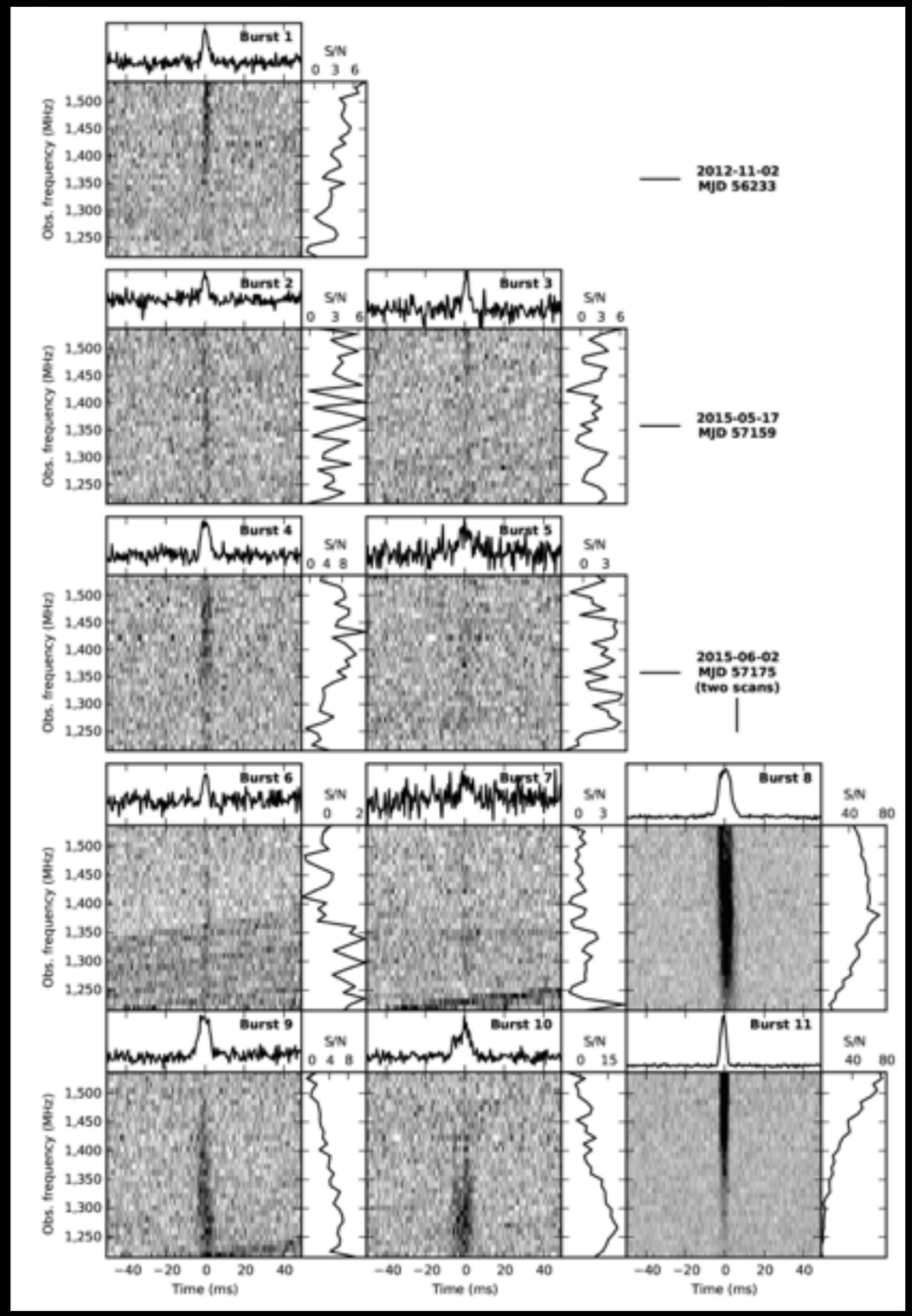


Next steps

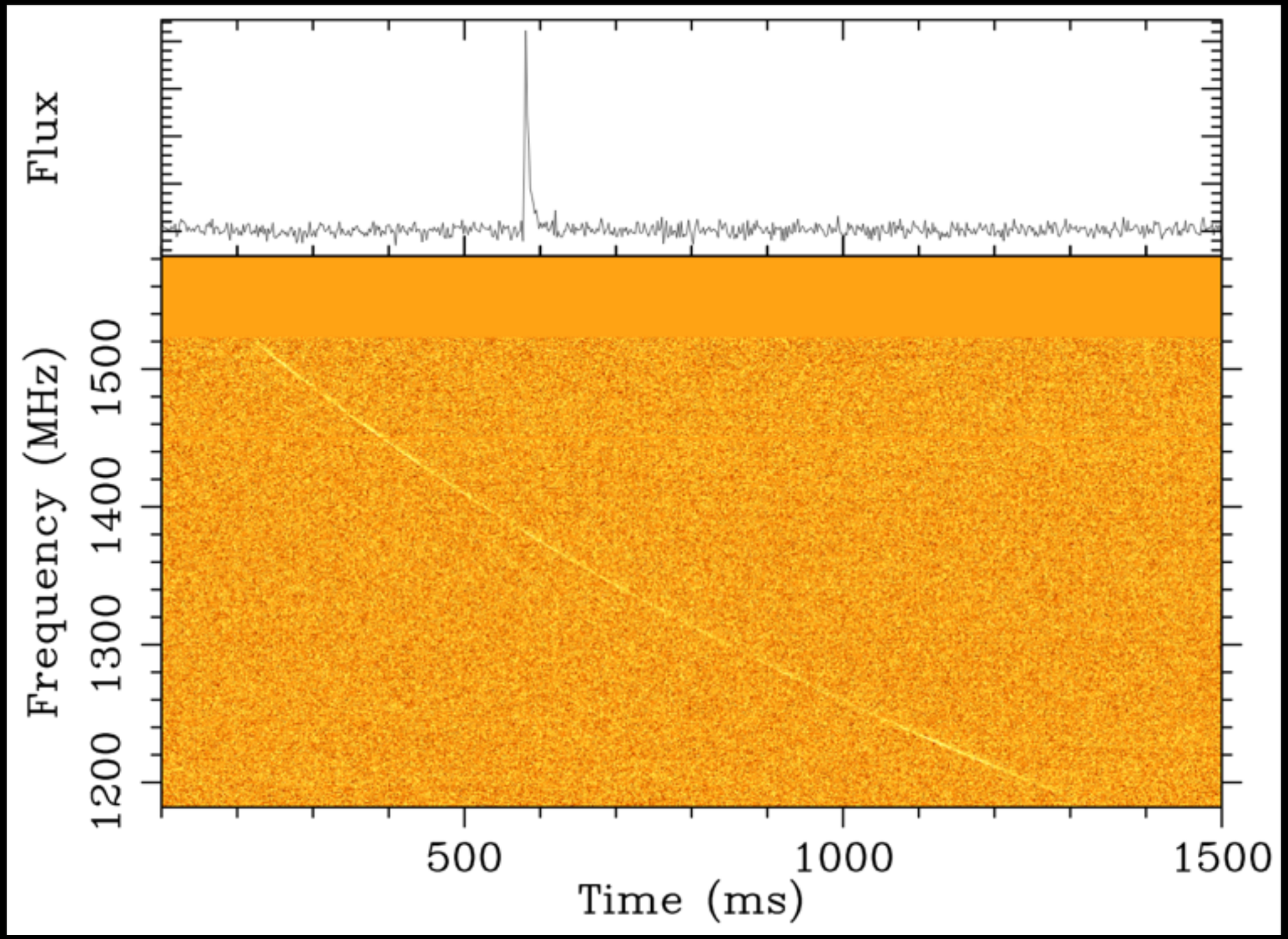
Next steps

Find more FRBs!

Next steps

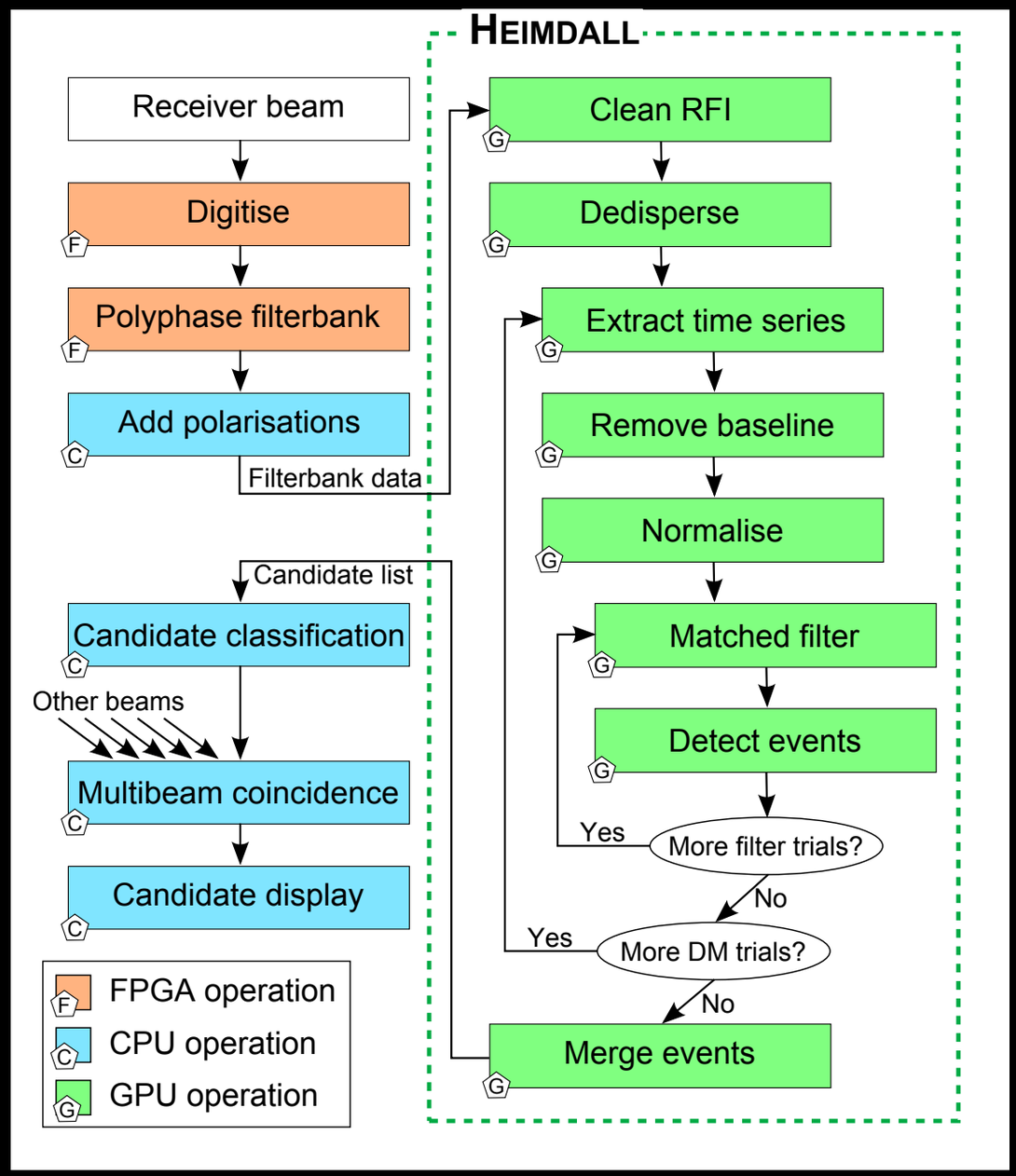
- Search for FRBs with more telescopes
    - New initiatives at VLA, GBT, Arecibo, eMERLIN, CHIME, UTMOST, MWA, LOFAR
    - Apertif upgrade to WSRT
    - ALERT project at ASTRON to search for FRBs in real-time over a huge FoV
- Continuing searches with Parkes

How we search for FRBs



How we search for FRBs

- Want fast search code
  - run time < data time
- Heimdall
  - GPU-based
  - Uses gulps of data
  - 16 s gulp -> 10 s
- Cuts made after candidates merged from all beams



Barsdell PhD Thesis

Challenges and Opportunities

- Challenges
    - Radio frequency interference poses a real threat
    - Search can lag behind real-time in high RFI environment
        - Need to search a lot of data to find one
- Opportunities
    - We want to run this search code on HUGE volumes of time-binned data
    - Projects with similar data interests are highly compatible

Application to SETI science

- FRBs (so far) detected at ~1 GHz; observe around 1.4 GHz line
- Survey large areas of sky
- Record data at high time resolution
- Require large fractional bandwidth
- Could repeatedly survey same areas (search for repetition)

Breakthrough listen

- At Parkes:
    - 25% of 5 years = 465 days of integration time
    - Implies around 40 FRBs will occur in the beams (may be less due to apparent lower numbers of bursts at low latitudes)
    - System enables commensal observing with FRB search hardware

Breakthrough possibilities

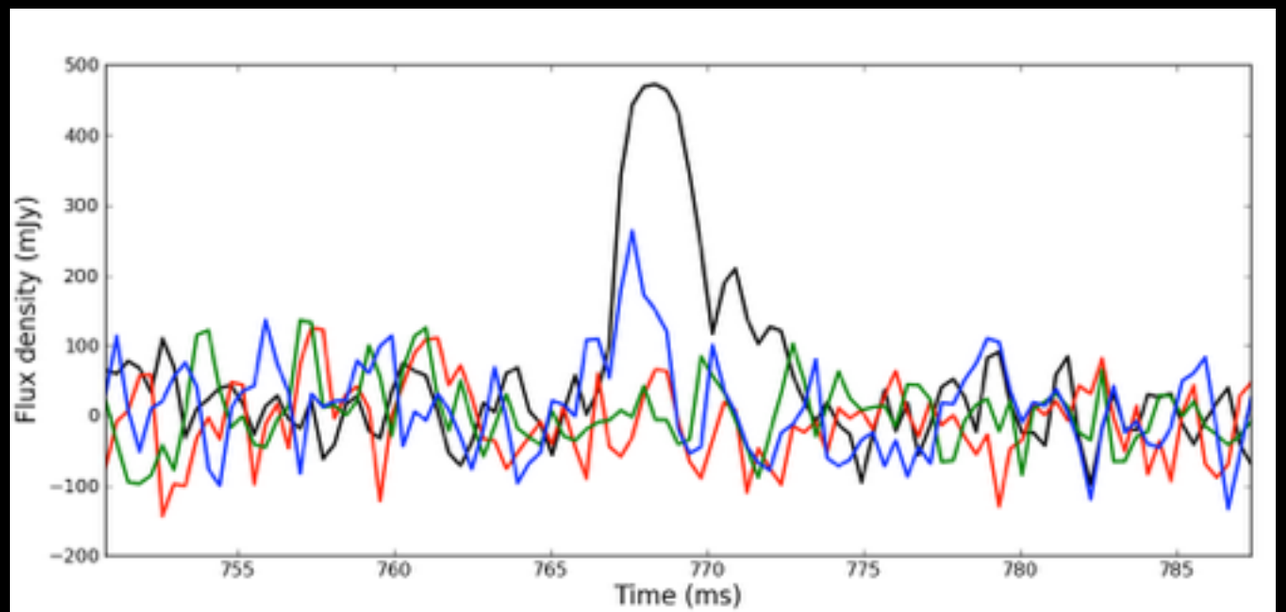
- Real-time RFI rejection (higher rates? 2x sensitivity?)
- Hyperfine channels (another rate increase?)
- Finer DM steps
- Full Stokes parameters all the time (save polarization)
- Machine learning?
- Keep voltages for:
    - post facto coherent dedispersion - intrinsic widths
    - VLBI?
    - positional determination?

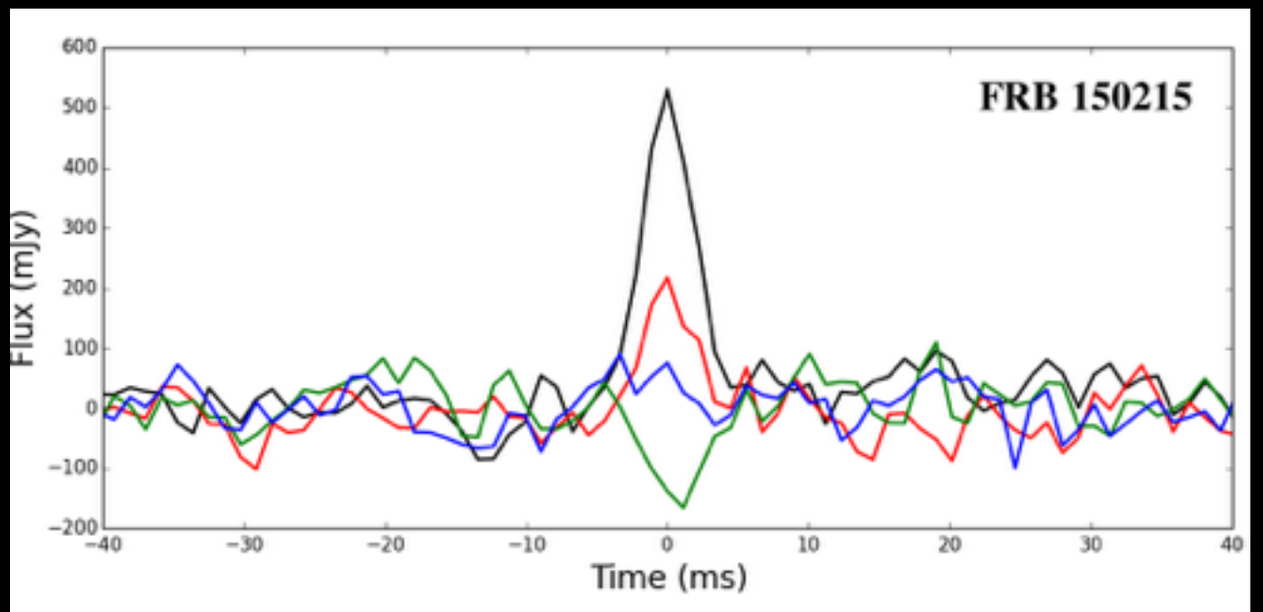
SETI searches and FRBs

- We want very similar data type/quality
- Work together to further both goals
- Lots of interesting discoveries to be made in both fields
- FRB searches as ‘secondary science’ to SETI
- Looking forward to working with the SETI community!

Thank You!

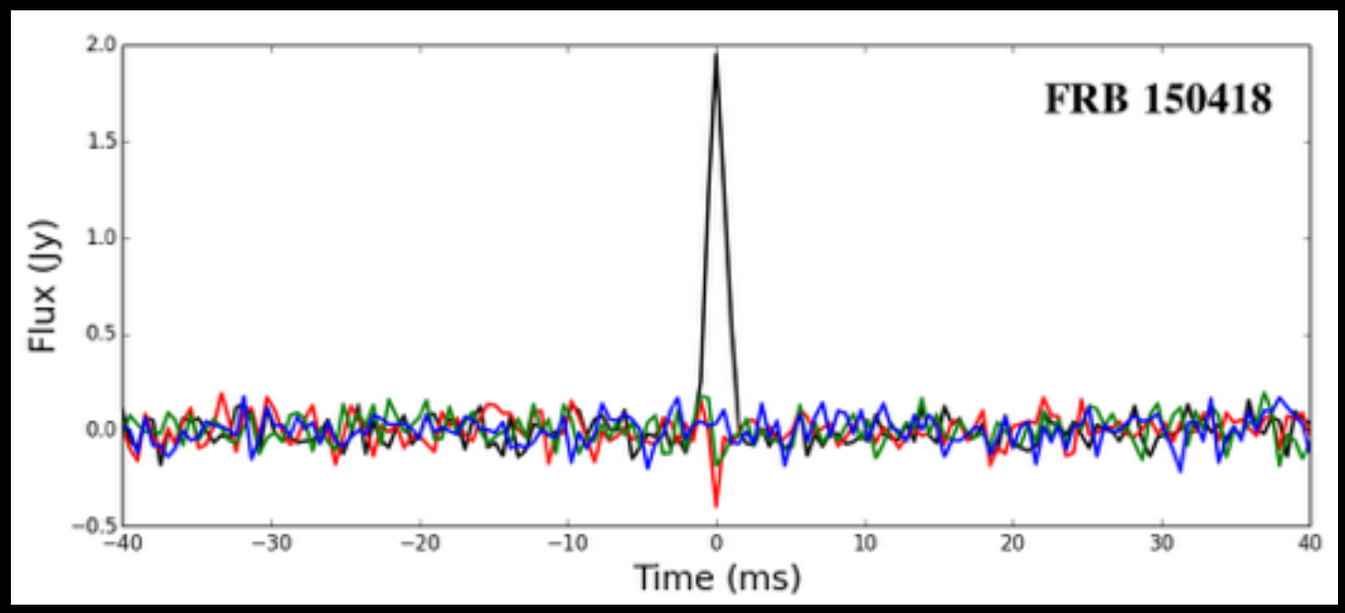
Real-time detections





FRB polarization measurements

Petroff et al. (2015a)



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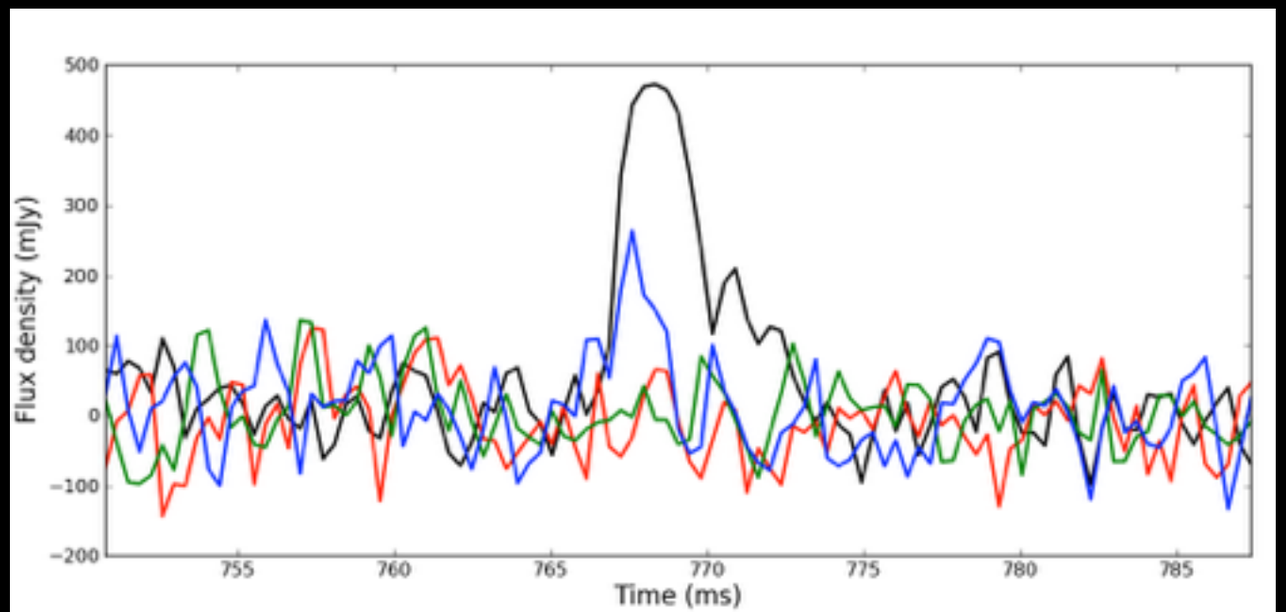

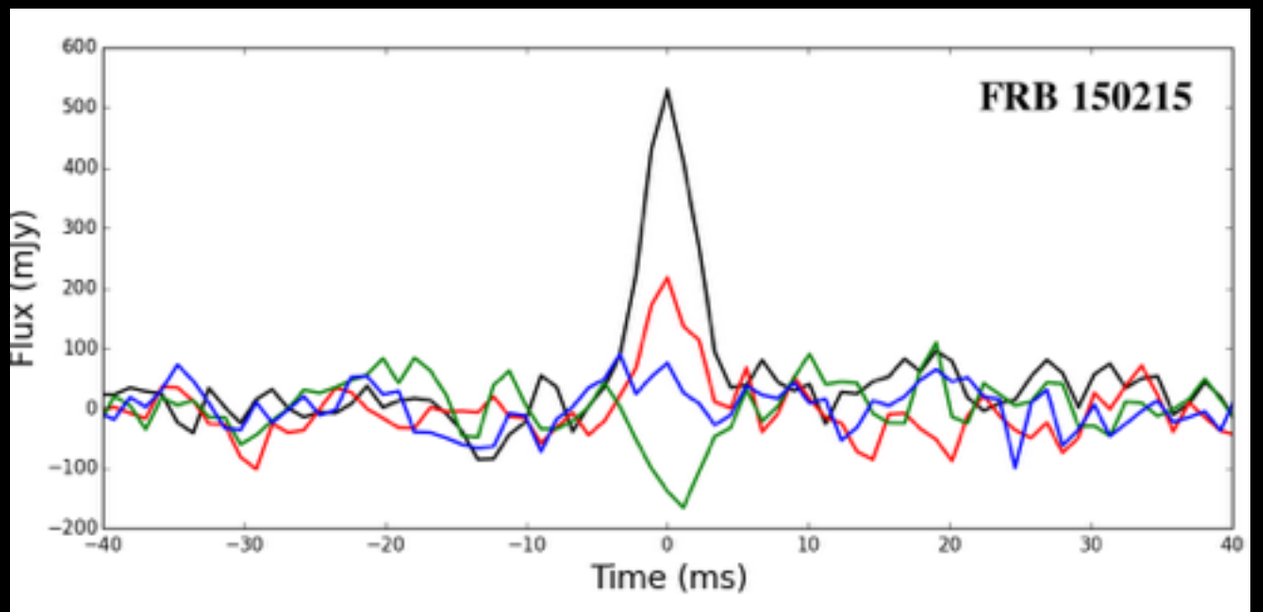

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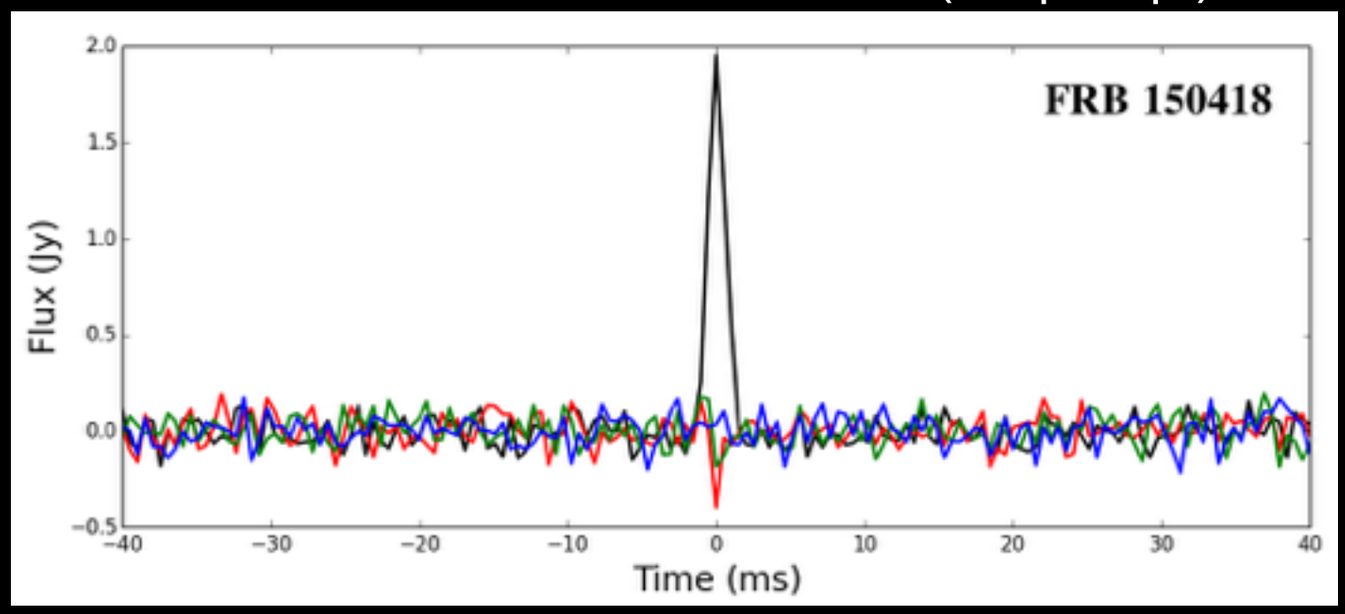

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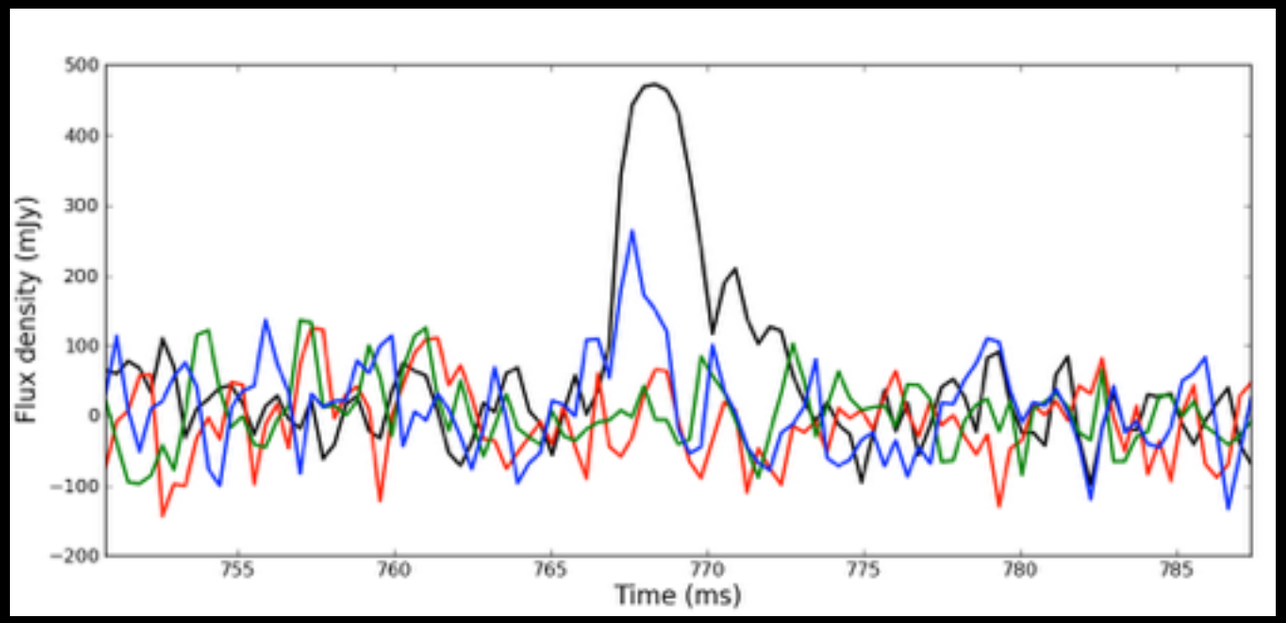

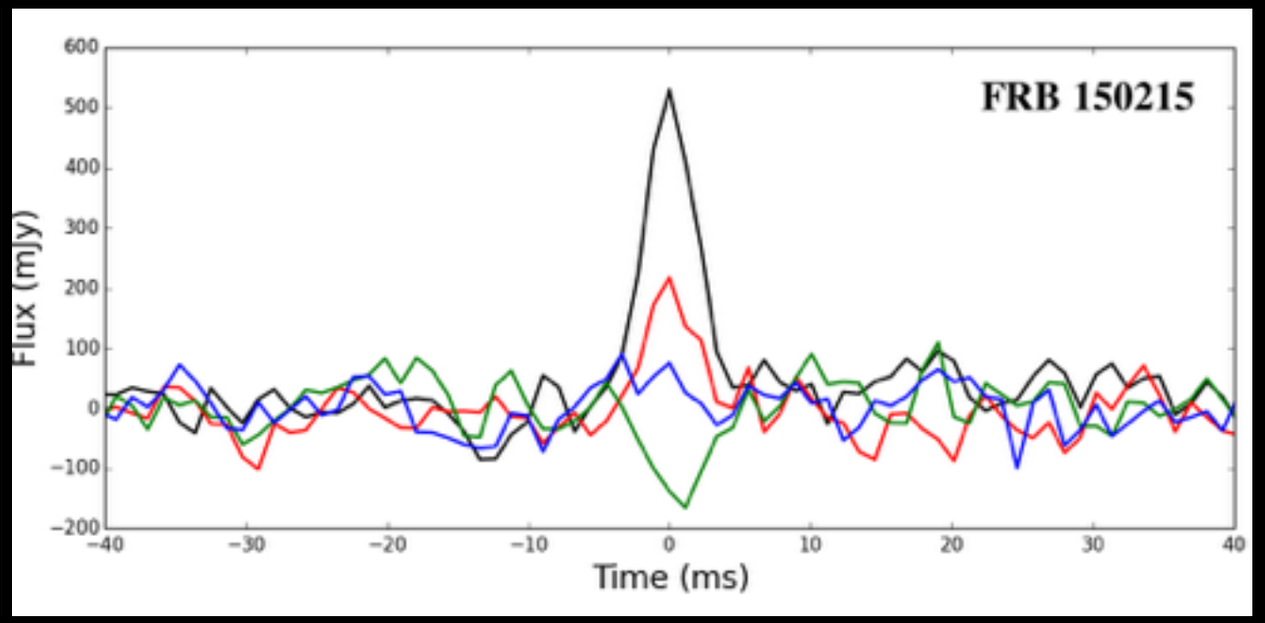

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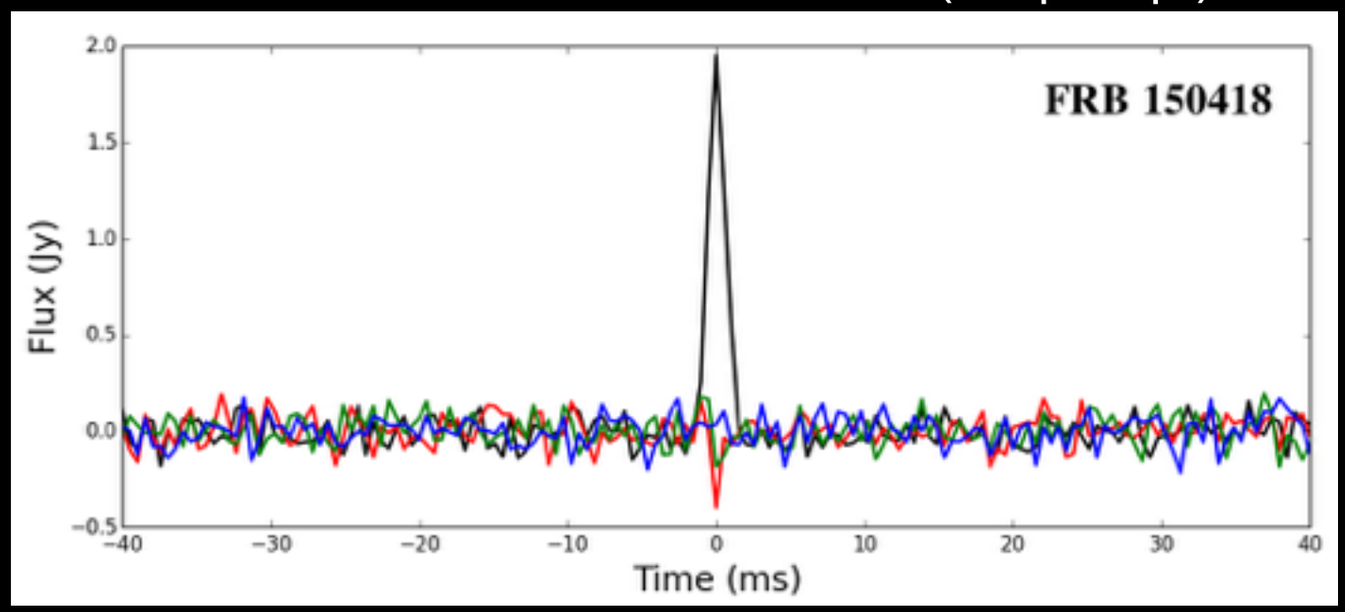
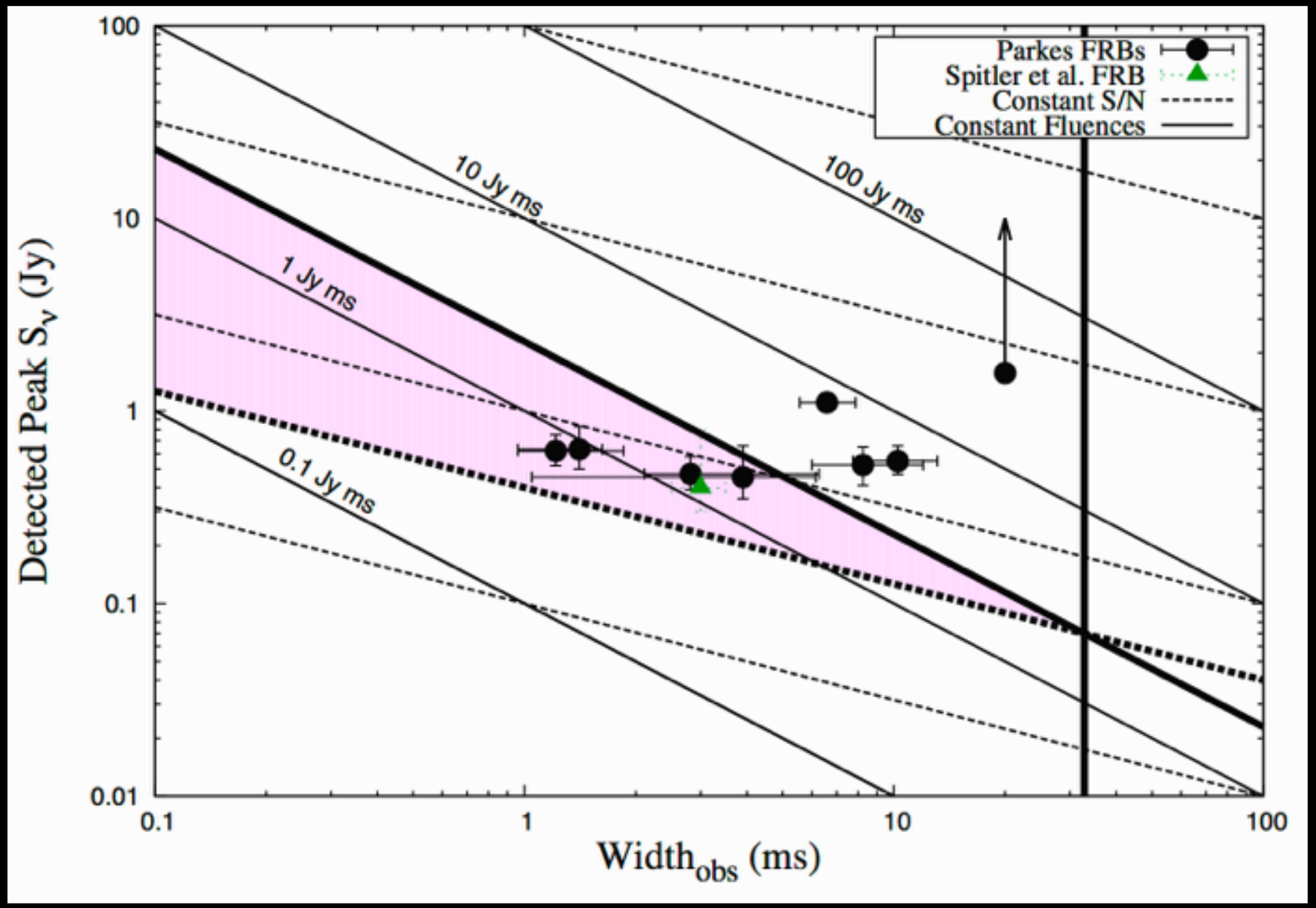
21±7% CP
~40% LP
<10% LP or CP

Petroff et al. (in prep)



The FRB rate?

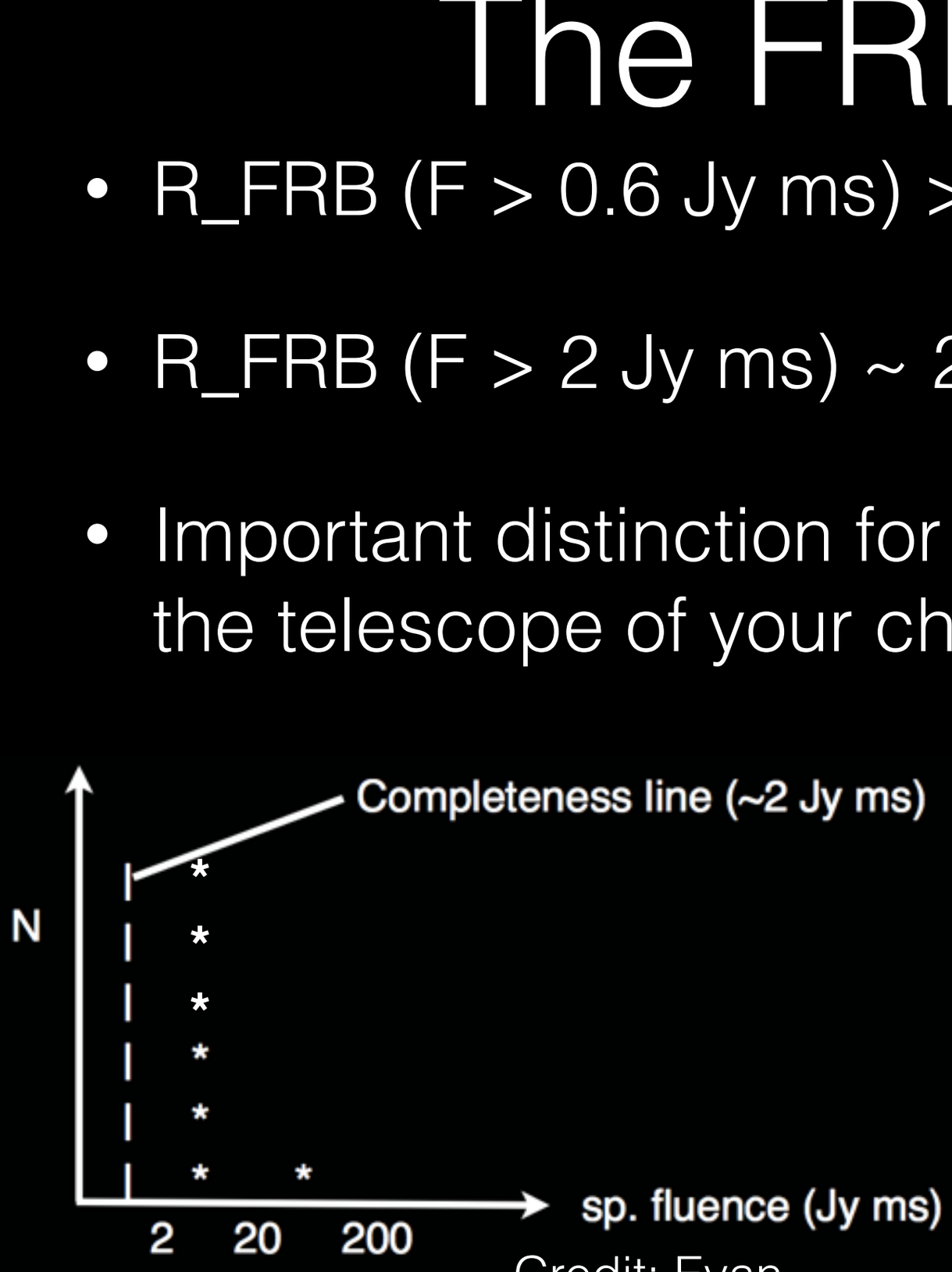
- Fluence completeness



Keane & Petroff (2015)

The FRB rate?

- R_FRB (F > 0.6 Jy ms) > 5.7 x 10^3 sky^{-1} day^{-1}
- R_FRB (F > 2 Jy ms) ~ 2500 sky^{-1} day^{-1}
- Important distinction for converting the rate to the telescope of your choice



Credit: Evan

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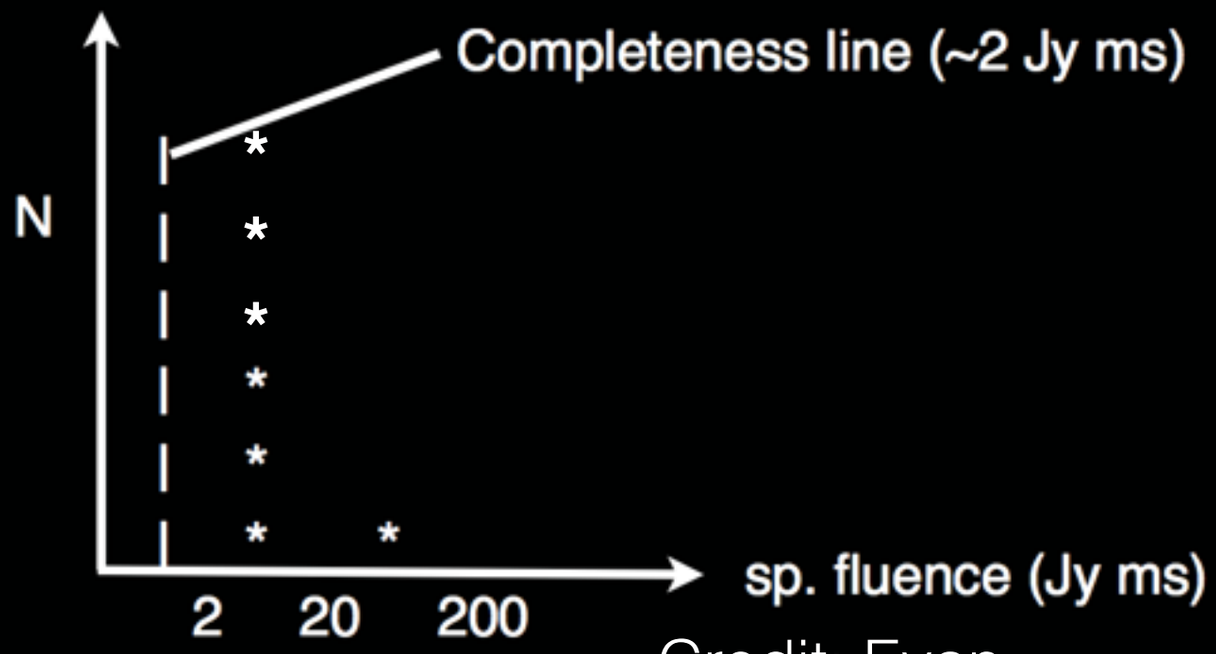

Credit: Evan

Galactic latitude $\lvert b\rvert$ (deg)	$R_{\rm FRB}$ ($\mathcal{F} > 0.6$ Jy ms)	$R_{\rm FRB}$ ($\mathcal{F} > 2$ Jy ms)
$0 - 19.5$	$> 1.3^{+2.9}_{-1.1} \times 10^3$	$0.69^{+2.5}_{-0.6} \times 10^3$
$19.5 - 42$	$> 6.0^{+7.7}_{-3.9} \times 10^3$	$1.5^{+5.6}_{-1.4} \times 10^3$
$42 - 90$	$> 8.2^{+7.2}_{-4.4} \times 10^3$	$4.7^{+6.1}_{-3.1} \times 10^3$