In a Galaxy far far away…
The mystery of Fast Radio Bursts

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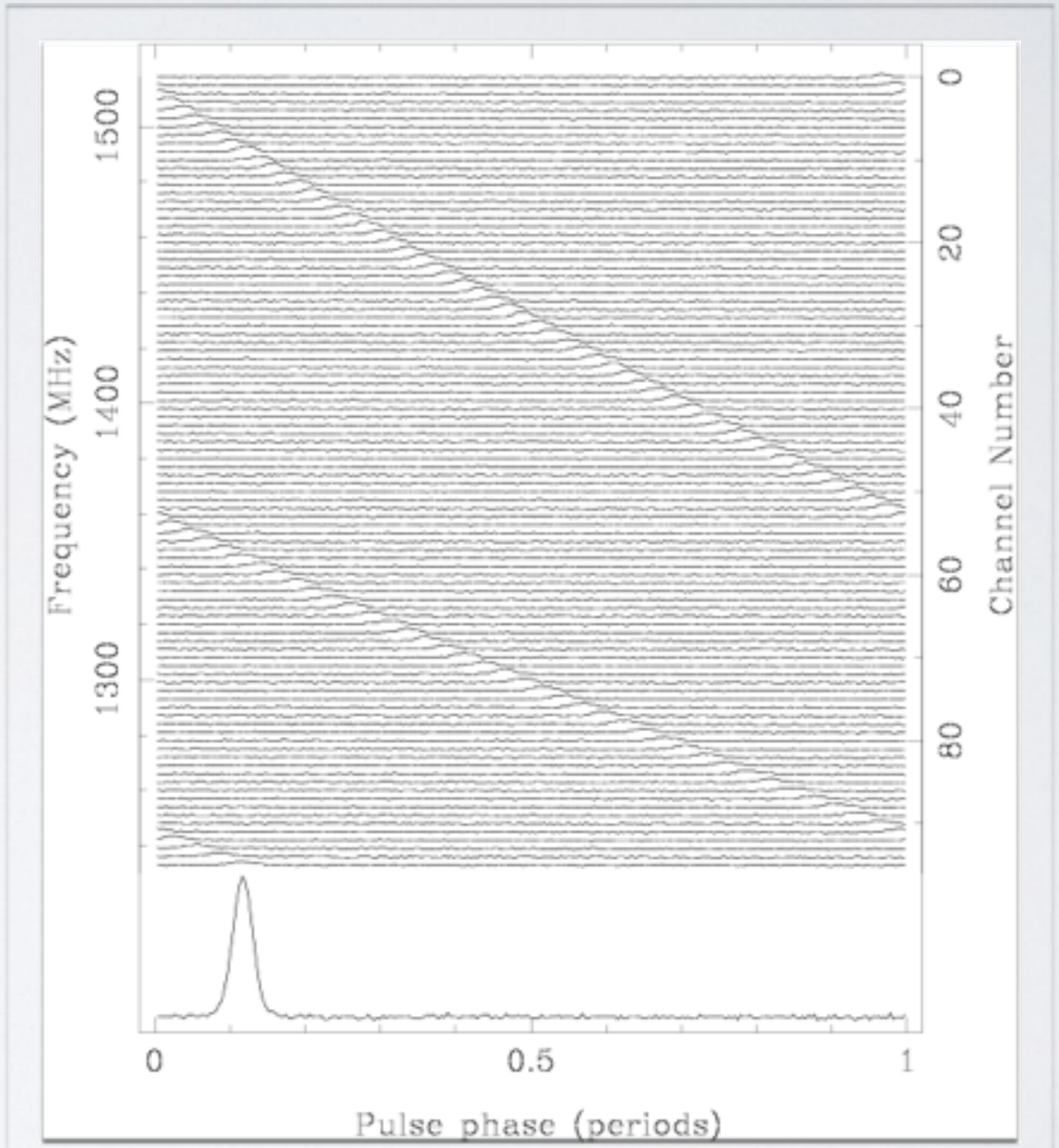
Dispersion of a radio signal

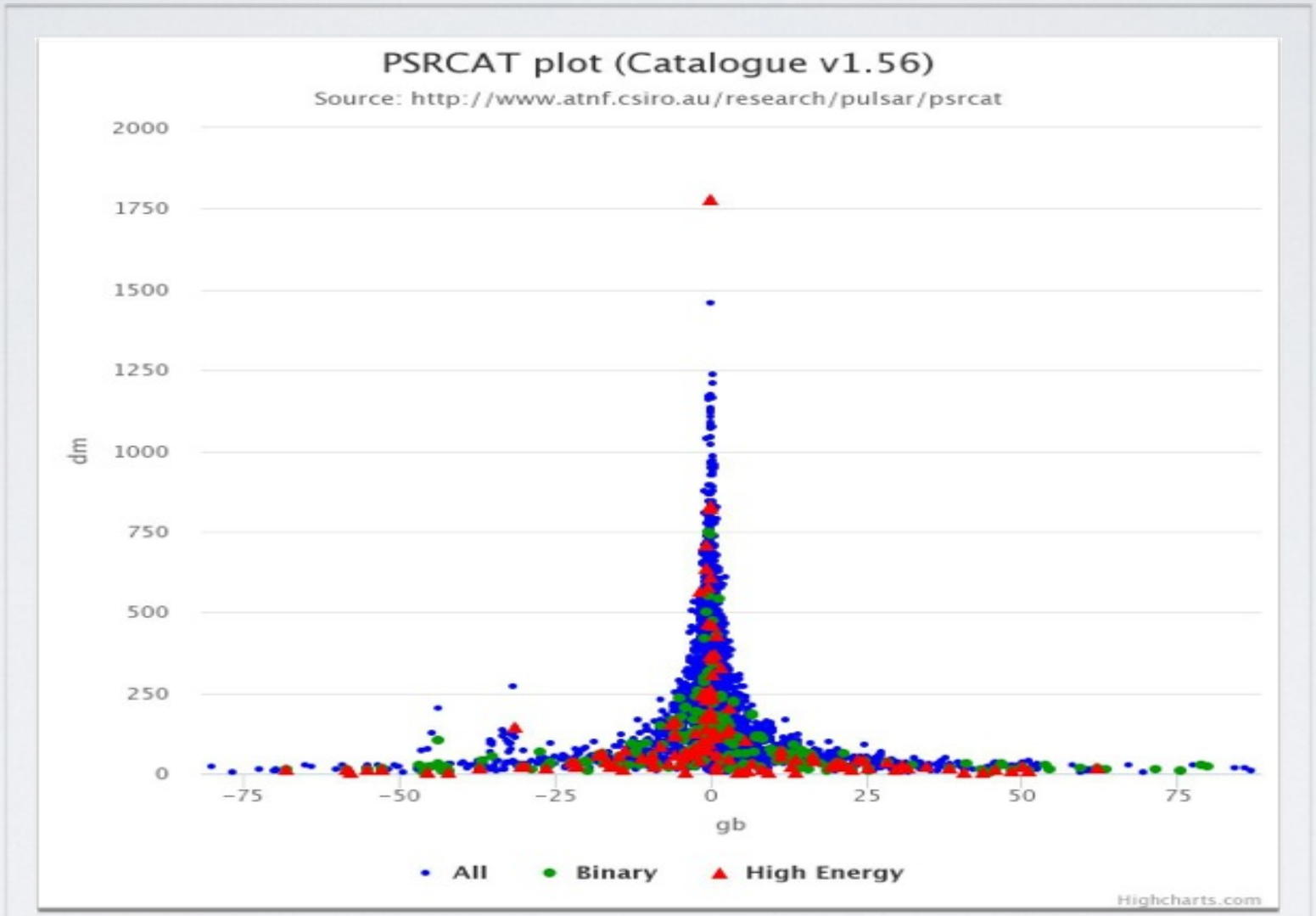
Travelling through an ionised medium, radio waves arrive earlier at higher frequencies.

$$dt = 4.15 \left(\frac{1}{\nu_1^2} - \frac{1}{\nu_2^2} \right) DM \quad \text{ms},$$

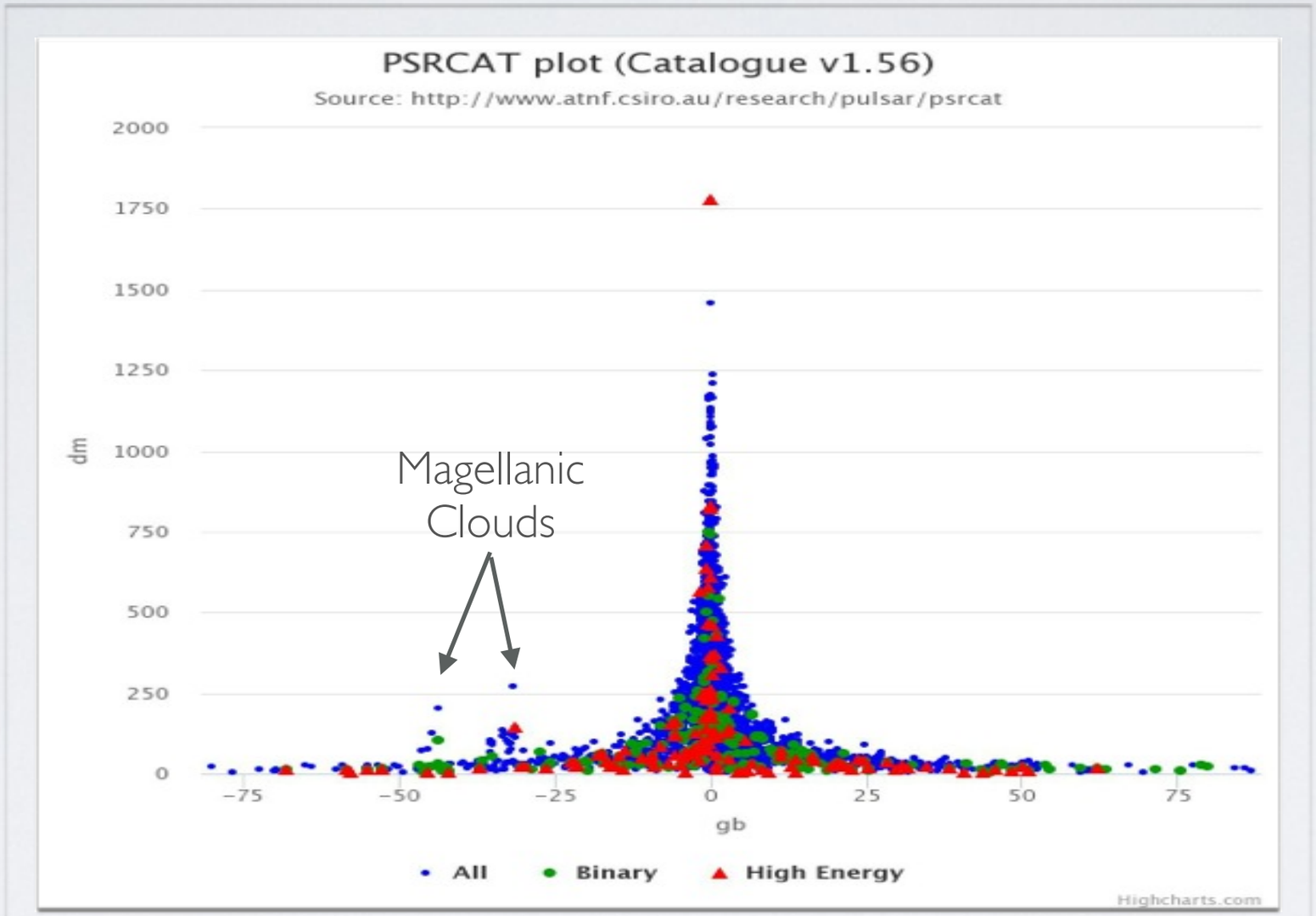
$$DM = \int_0^d n_e \, ds$$



PULSARS' DM


PSRCAT plot (Catalogue v1.56)
Source: http://www.atnf.csiro.au/research/pulsar/psrcat
2000
1750
1500
1250
1000
750
500
250
0
dm
−75
−50
−25
0
25
50
75
gb
All
Binary
High Energy
Highcharts.com

PULSARS' DM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25
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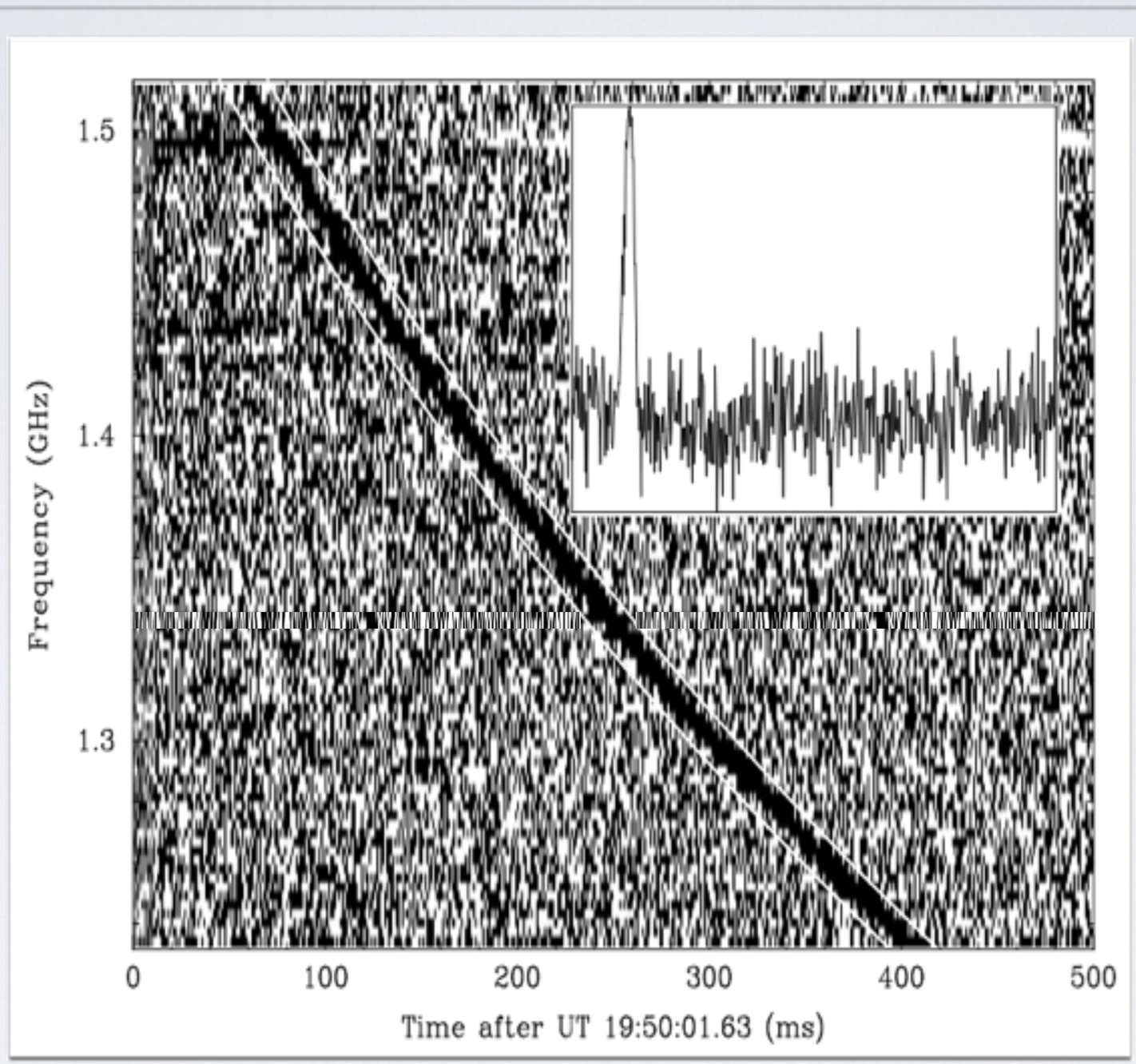
Highcharts.com

2007: The Lorimer Burst



Lorimer et al 2007

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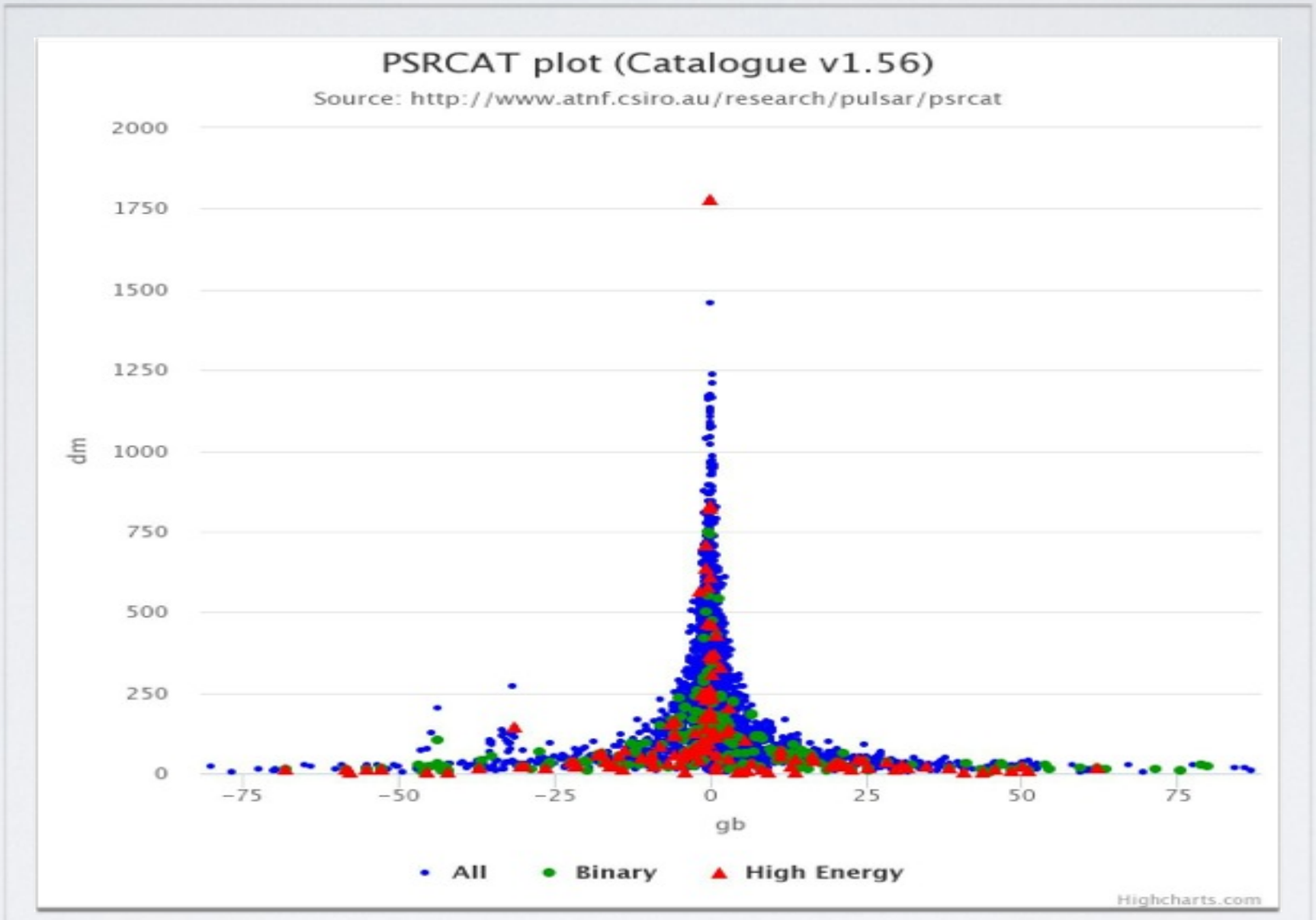

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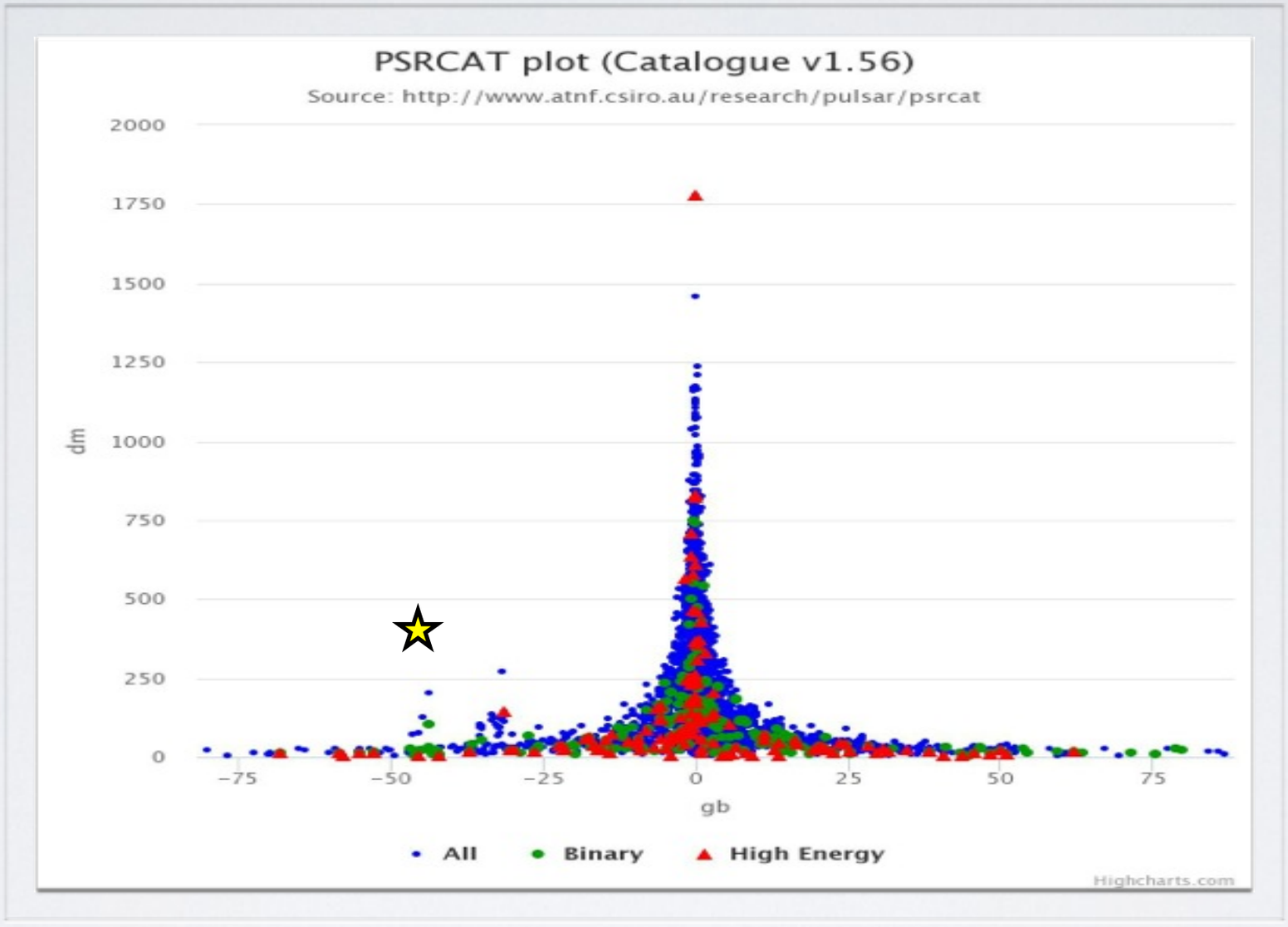

First case of detection of an extragalactic dispersed radio burst

2013: The discovery of a Population of Fast Radio 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]
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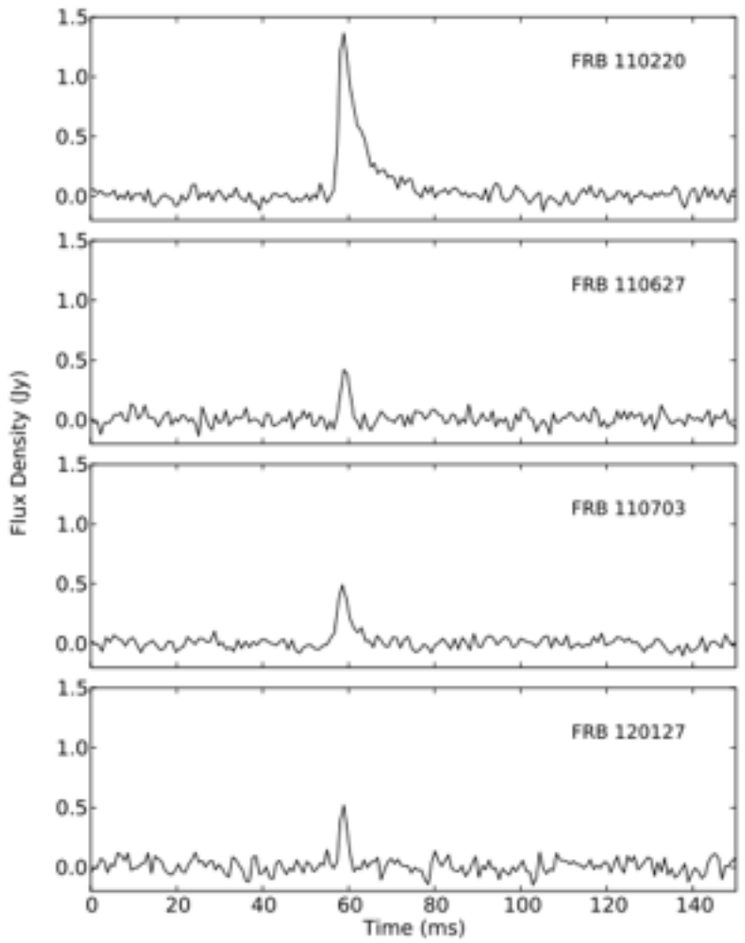
A. Possenti,[7] W. van Straten[3,4]

Published in *Science*, Vol. 340, Issue 6141 (5th July 2013)



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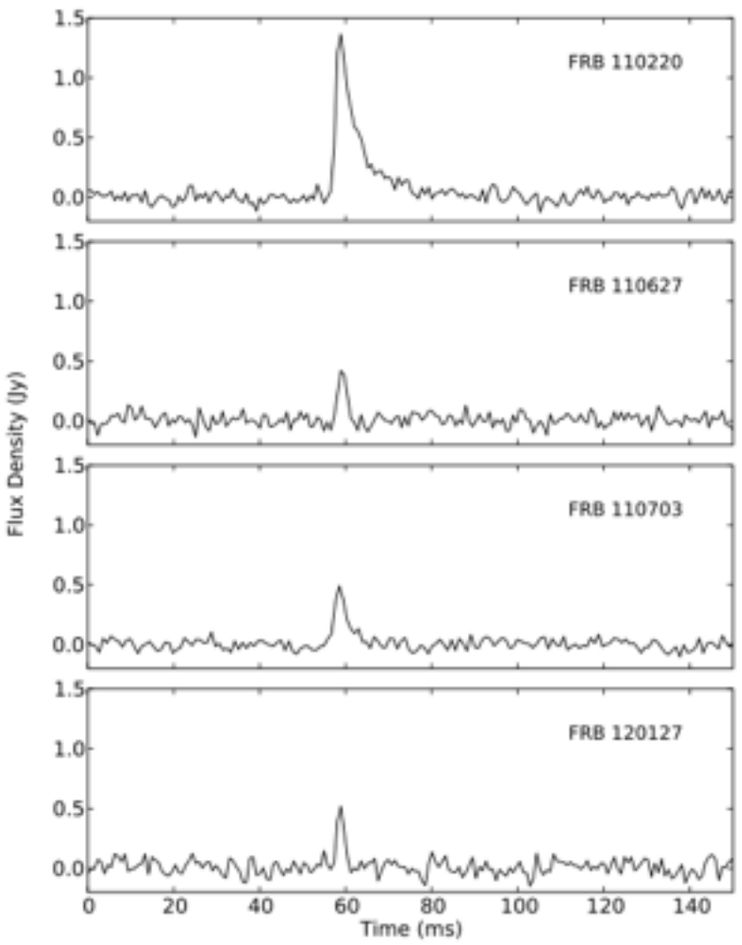
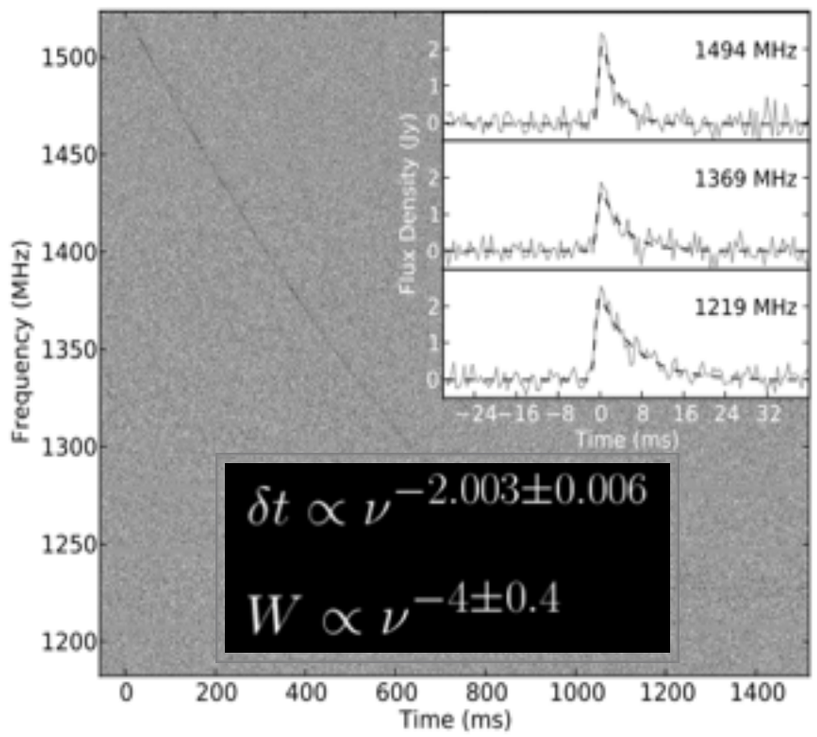
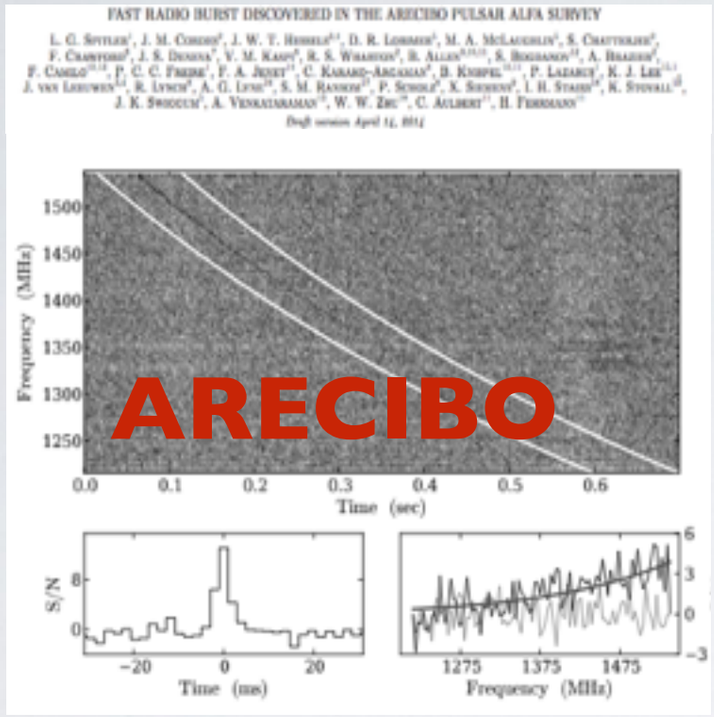
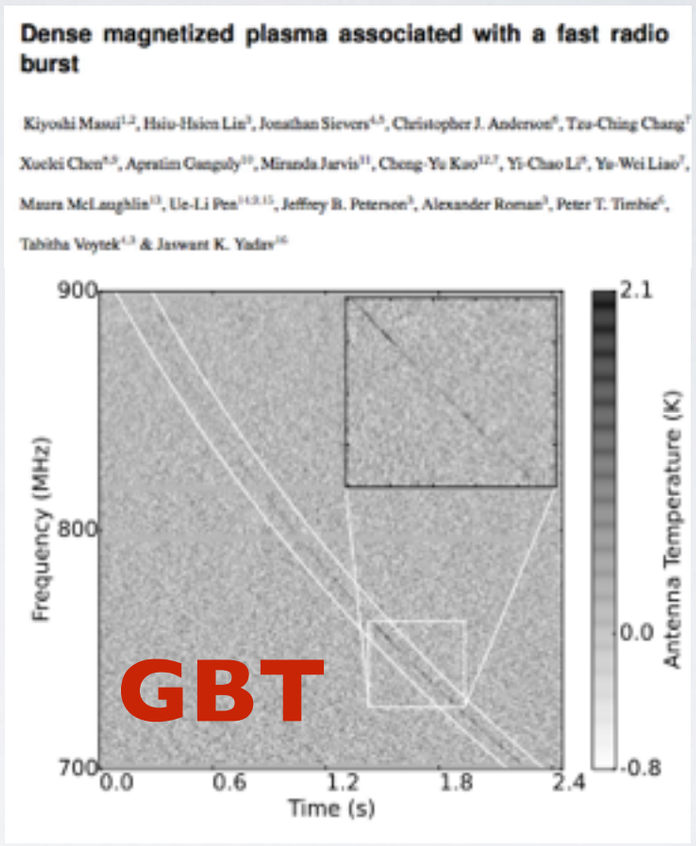


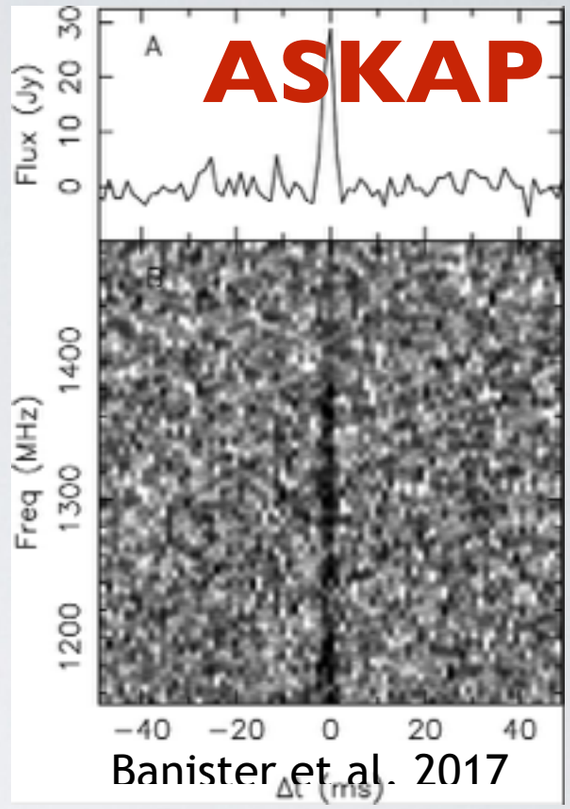


Clear signature of a signal undergoing scattering in FRB110220

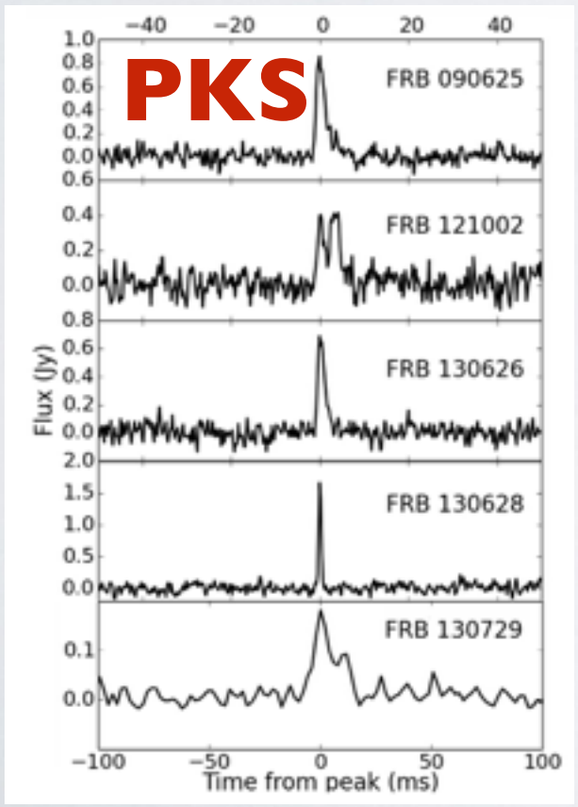
More FRBs from more telescopes!

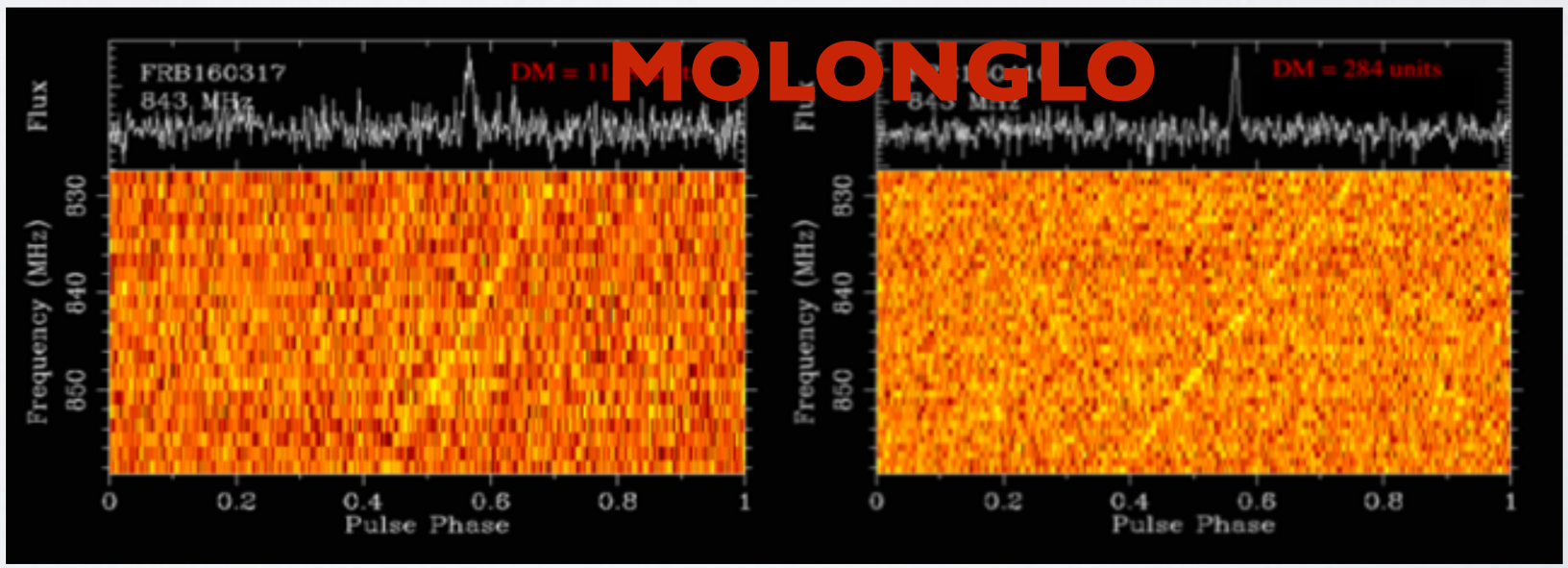




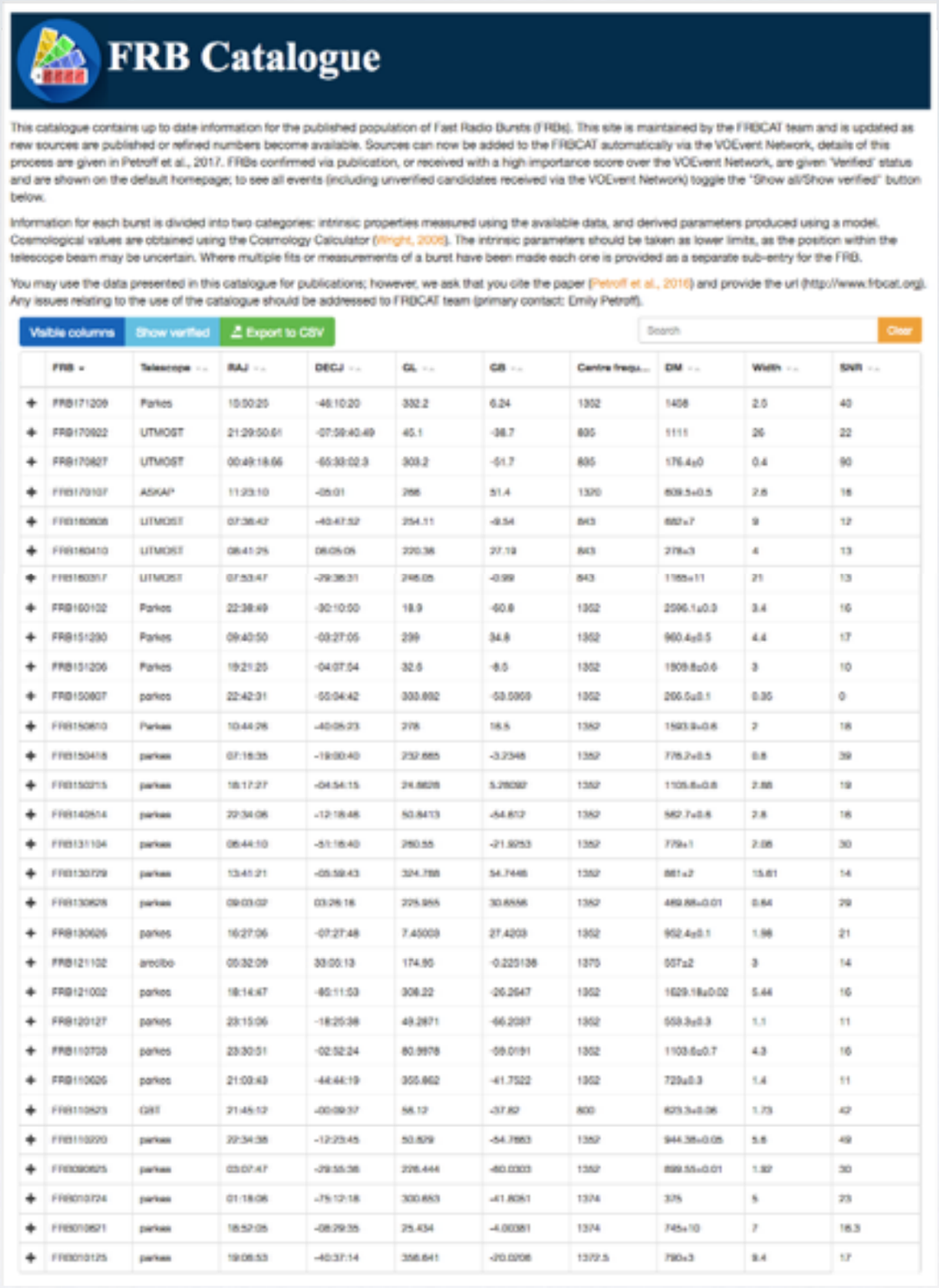


Banister et al. 2017





THE OFFICIAL CATALOGUE OF PUBLISHED FRBS



FRB Catalogue

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. Sources can now be added to the FRBCAT automatically via the VOEvent Network, details of this process are given in Petroff et al., 2017. FRBs confirmed via publication, or received with a high importance score over the VOEvent Network, are given 'Verified' status and are shown on the default homepage; to see all events (including unverified candidates received via the VOEvent Network) toggle the "Show all/Show verified" button below.

Information for each burst is divided into two categories: intrinsic properties measured using the available data, and derived parameters produced using a model. Cosmological values are obtained using the Cosmology Calculator (Wright, 2006). The intrinsic parameters should be taken as lower limits, as the position within the telescope beam may be uncertain. Where multiple fits or measurements of a burst have been made each one is provided as a separate sub-entry for the FRB.

You may use the data presented in this catalogue for publications; however, we ask that you cite the paper (Petroff et al., 2016) and provide the url (http://www.frbcat.org). Any issues relating to the use of the catalogue should be addressed to FRBCAT team (primary contact: Emily Petroff).

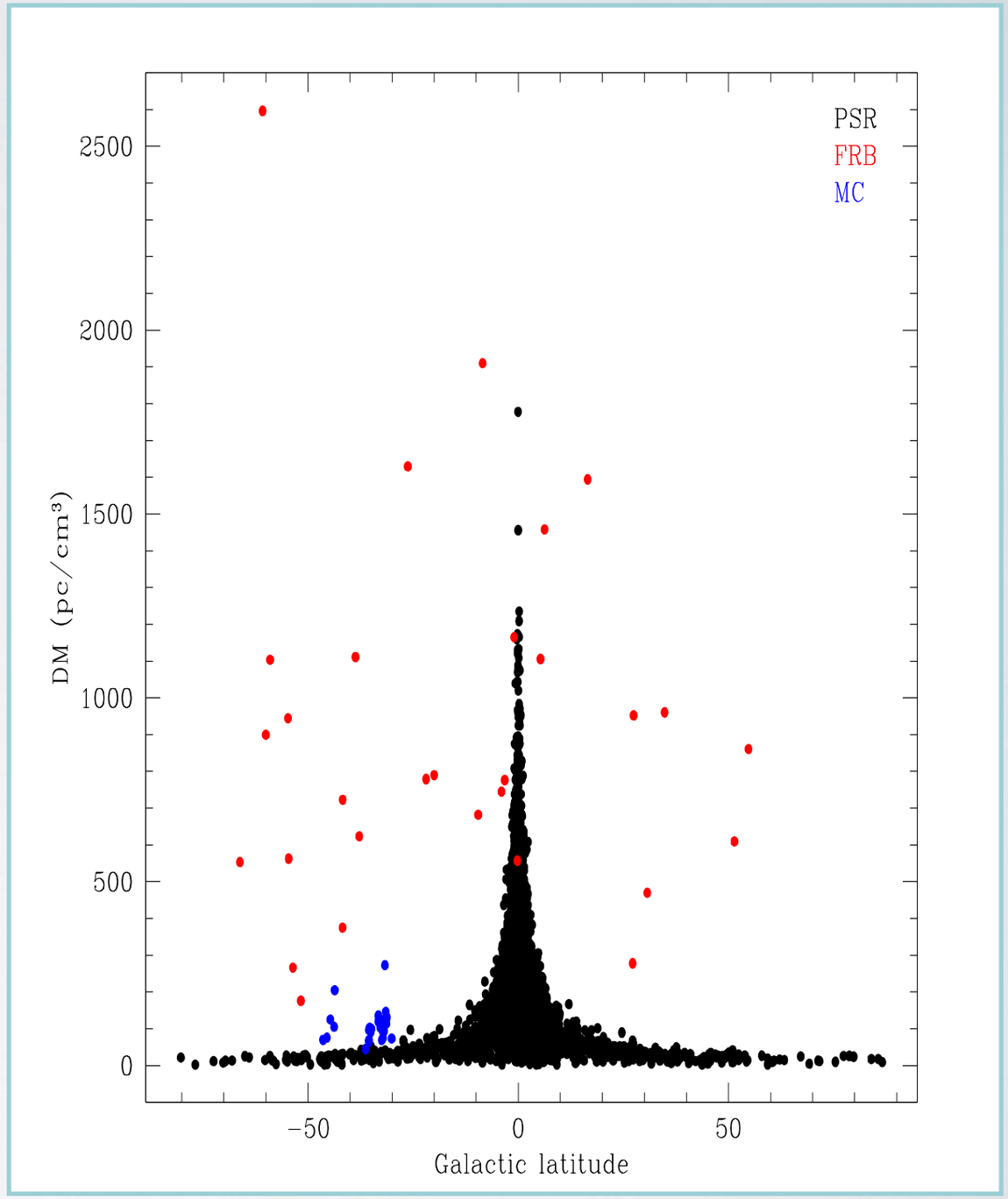
Visible columns | Show verified | Export to CSV | Search | Clear

	FRB	Telescope	RAJ	DECJ	GL	GB	Centre frequ...	DM	Width	SNR
+	FRB171209	Parkes	10:00:20	-46:10:20	332.2	6.24	1352	1458	2.0	40
+	FRB170922	UTMOST	21:29:50.61	-07:59:40.49	45.1	-38.7	835	1111	26	22
+	FRB170827	UTMOST	00:49:18.66	-65:33:02.3	303.2	-51.7	835	176.4±0	0.4	90
+	FRB170107	ASKAP	11:23:10	-05:01	266	51.4	1320	609.5±0.5	2.6	16
+	FRB160808	UTMOST	07:38:42	-40:47:52	254.11	-9.54	843	682±7	9	12
+	FRB160410	UTMOST	08:41:25	06:05:05	220.38	27.19	843	278±3	4	13
+	FRB160317	UTMOST	07:53:47	-29:36:31	246.05	-0.99	843	1165±11	21	13
+	FRB160102	Parkes	22:38:49	-90:10:50	18.9	-60.8	1352	2596.1±0.3	3.4	16
+	FRB151230	Parkes	09:40:50	-03:27:05	239	34.8	1352	960.4±0.5	4.4	17
+	FRB151206	Parkes	19:21:20	-04:07:04	32.6	-8.0	1352	1909.8±0.6	3	10
+	FRB150807	parkes	22:42:31	-55:04:42	330.892	-53.5909	1352	266.5±0.1	0.35	0
+	FRB150610	Parkes	10:44:26	-40:05:23	278	16.5	1352	1593.9±0.6	2	16
+	FRB150418	parkes	07:18:35	-19:00:40	232.665	-3.2348	1352	776.2±0.5	0.8	39
+	FRB150215	parkes	18:17:27	-04:54:15	24.8828	5.28397	1352	1105.6±0.8	2.88	19
+	FRB140514	parkes	22:34:06	-12:18:48	50.8413	-54.672	1352	562.7±0.6	2.8	16
+	FRB131104	parkes	06:44:10	-51:16:40	260.55	-21.9253	1352	779±1	2.08	30
+	FRB130729	parkes	13:41:21	-05:59:43	324.788	54.7446	1352	861±2	15.61	14
+	FRB130626	parkes	09:03:02	03:26:16	225.955	30.6556	1352	469.88±0.01	0.64	29
+	FRB130626	parkes	16:27:06	-07:27:48	7.45009	27.4203	1352	952.4±0.1	1.98	21
+	FRB121102	arecibo	05:32:09	33:00:13	174.95	-0.225136	1370	557±2	3	14
+	FRB121002	parkes	18:14:47	-60:11:53	308.22	-26.2647	1352	1629.18±0.02	5.44	16
+	FRB120127	parkes	23:15:06	-18:25:38	49.2871	-66.2087	1352	553.3±0.3	1.1	11
+	FRB110718	parkes	23:30:51	-02:52:24	80.9978	-59.0191	1352	1103.6±0.7	4.3	16
+	FRB110626	parkes	21:00:43	-44:44:19	350.862	-41.7522	1352	723±0.3	1.4	11
+	FRB110523	GBT	21:45:12	-00:09:37	56.12	-37.82	800	623.3±0.06	1.73	42
+	FRB110220	parkes	22:34:38	-12:23:45	50.829	-54.7883	1352	944.38±0.05	5.6	49
+	FRB090625	parkes	03:07:47	-29:55:38	226.444	-60.0303	1352	899.55±0.01	1.92	30
+	FRB010724	parkes	01:18:06	-75:12:18	300.653	-41.8061	1374	375	5	23
+	FRB010621	parkes	16:52:05	-08:29:35	25.434	-4.00381	1374	745±10	7	16.3
+	FRB010125	parkes	19:08:53	-40:37:14	356.641	-20.0208	1372.5	790±3	9.4	17

frbcat.org

OBSERVATIONAL FEATURES

- Burst of ≈ millisecond duration
- Dispersion measure DM > few × DM_{MW} (the expected Milky-Way contribution)
- Dispersion delay consistent with ν^{-2} (e,g. $\nu^{-2.003\pm0.006}$, $\nu^{-2.000\pm0.006}$, $\nu^{-1.998\pm0.003}$)
- When measurable, scattering time compatible with Kolmogorov (e.g $\nu^{-4.8\pm0.4}$, $\nu^{-4.0\pm0.4}$, $\nu^{-3.6\pm1.4}$)
- Peak Flux density at 1.4 GHz ≈ 0.1-10 Jansky
- Fluence at 1.4 GHz ≈ 0.1-10 Jansky * ms



[Thornton et al 2013, Spitler et al 2014, Masui et al 2015, Keane et al 2016, Champion et al 2016, FRB catalogue]

Distance from the Dispersion Delay

If the frequency dependent arrival time of the FRBs is due to dispersion in a cold plasma, it is possible to use the observed DM to constrain the distance of the source.

Building up on pioneering works of [Ioka 2003] and [Inoue 2004], one can write the relation between DM, the Luminosity Distance DL , the redshift z, the matter density parameter in the universe Ω_m, the mean number density n_0 of nucleons at z=0 and fe ≈ 0.88 at low redshift

[Zheng et al. 2014]

$$\mathrm{DM} \cong n_0 f_e D_L \left[1 + 0.932z + (0.16\Omega_m - 0.078)z^2\right]^{-0.5}$$

which has an accuracy $\lesssim$0.5% for $0 < z < 3$ with $0.25 < \Omega_m < 0.35$

Derived Features

Given the observed parameters

Assuming that the extra-DM is mainly due to the Inter Galactic Medium, one can derive the following additional parameters:

- Red-shift $0.2 < z < 2.0$ (IGM from [Ioka 2003;Inoue 2004])
- Co-moving distance $1 < D\ (Gpc) < 3$
- Isotropic emitted energy $10^{38} < Eiso\ (erg) < 10^{40}$
- Brightness temperature $10^{33} < T\ (K) < 10^{36}$
- Event Rate $10^{3;4}$ per sky per day ($10^{-2;-3}$ per galaxy per year)

So, what are FRBs?

- Bursts from corona of very nearby flare stars [Loeb et al. 2013]
- Asteroid/Planet/WD magnetosphere interaction with the wind from a orbited pulsar/NS [Mottez & Zarka 2014]
- Core Collapse SuperNovae, [Thornton et al 2013]
- Binary WD merger to highly magnetic rapidly spinning WD [Kashiyama et al 2013]
- Binary Neutron Star merger; short hard GRBs [Keane et al. 2012, Totani et al 2013, Zhang et al 2014]
- Evaporating primordial BH [Keane et al 2012]
- BH to WH quantum transition [Haggard & Rovelli 2014]
- Collisions btw axion stars and neutron stars [Iwazaki 2014]
- Explosive decay of axion miniclusters [Tkachev 2014]
- Superconducting cosmic string (SCS) loops [Cai et al. 2012] oscillating in cosmic magnetic fields [Yu et al 2014]
- Blitzar: Collapse to BH of a supramassive NS [Falcke & Rezzolla 2014] from an original scenario of [Vietri & Stella 2000]
- Magnetar giant flares [Popov & Postnov 2010, Thornton et al 2013]
- Hyper Pulses from extra-galactic NSs [Cordes & Wasserman 2016]
- Pulsar magnetorsphere “combed” by plasma stream (AGN, SN, GRB,…) [Egorov & Postnov 2009; Zhang 2017]

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If cosmological, with a series of independent z determinations (from the identification of the source at other wavelengths), one could

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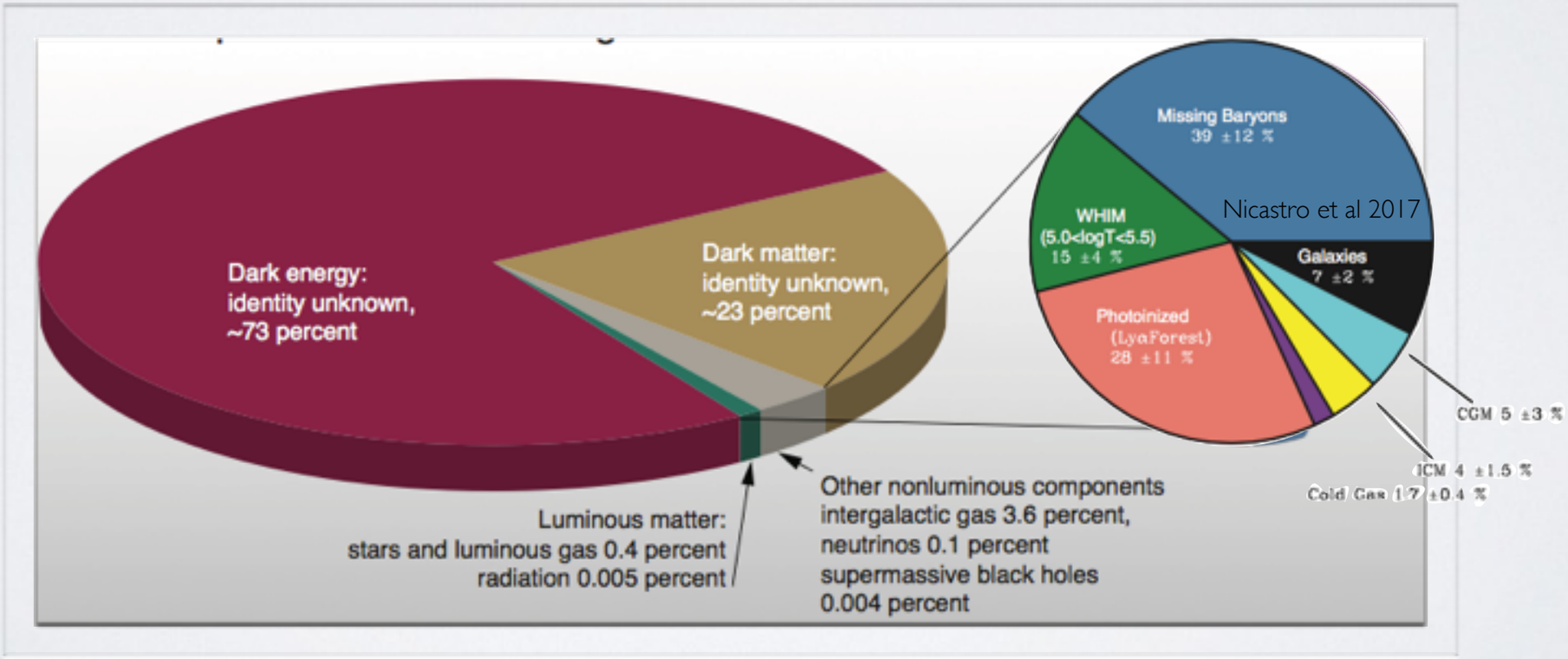
- measure the missing baryonic matter in the Universe [MacQuinn 2014]]



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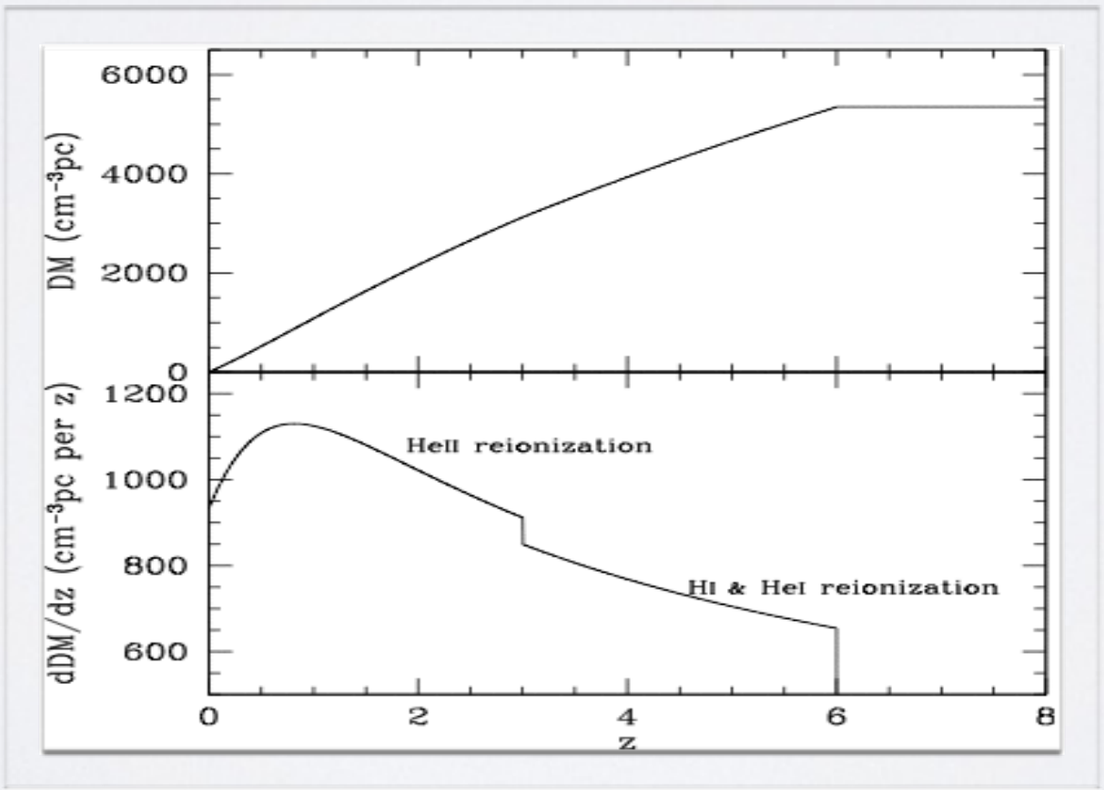

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- constrain the EoS of the "dark energy" [Gao et al 2014; Zhou et al 2014]
- put constraints to fundamental quantities and laws [Wei et al 2015]
- put limits to the existence of floating MACHO-like objects in the IGM via gravitational lensing [Zheng et al. 2014]
- 3D clustering of the electrons in the Universe, with > 10000 FRBs, even without redshift [Masui & Sigurdson 2015]
- put limits to the fraction of "dark matter" in MACHO of $>20M_\odot$ via counting the number of echoes due to gravitational lensing [Munoz et al 2016]

How to track an FRB to its galaxy far far away?

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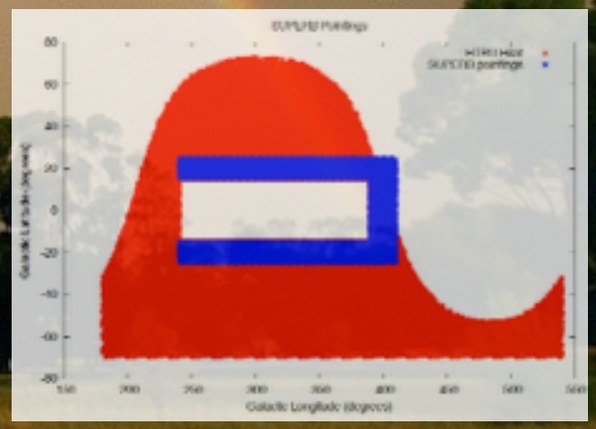
SUPERB: FRBs IN REAL TIME!

SUrvey for Pulsars and Extragalactic Radio Bursts

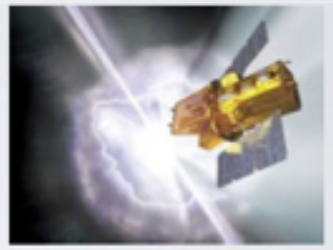
20cm, 13-beams receiver
-120 < l < 30; 15 < |b| < 25
30 < l < 50; |b| < 25

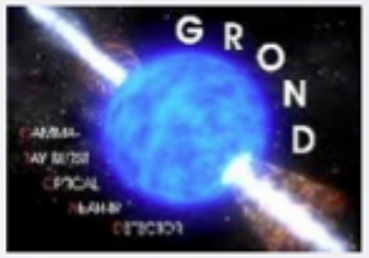
SUPERBx ongoing
|b| > 25º



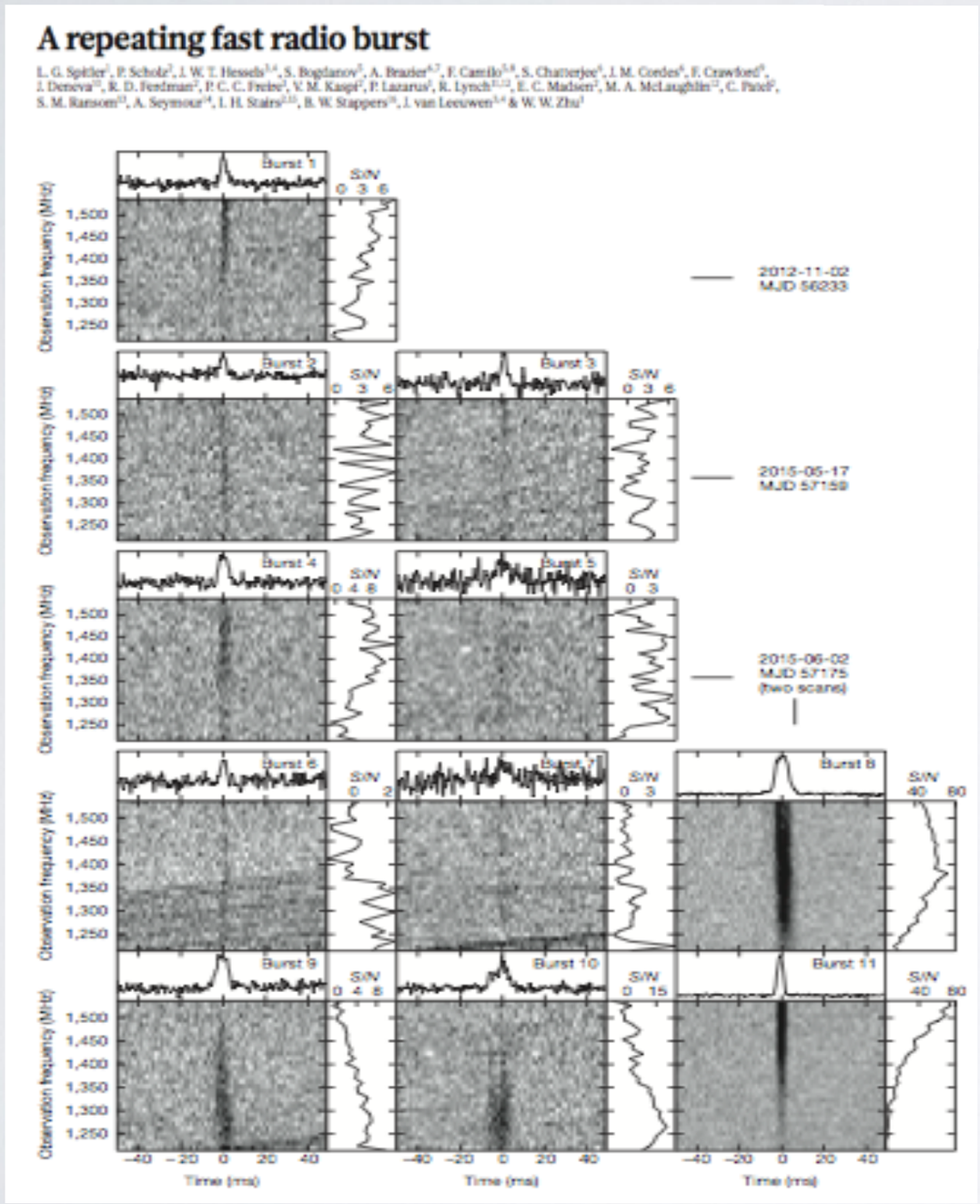
The FRB search is done in RAM “live” thus leading to real time discoveries

SUPERB FOLLOW-UP





FRB121102: THE REPEATER!



Follow-up pointings with Arecibo (1.4 GHz) and Green Bank (2.0 GHz) telescope toward the position of FRB121102 [Spitler et al. 2014]

seen to repeat!
[Spitler et al. 2016]

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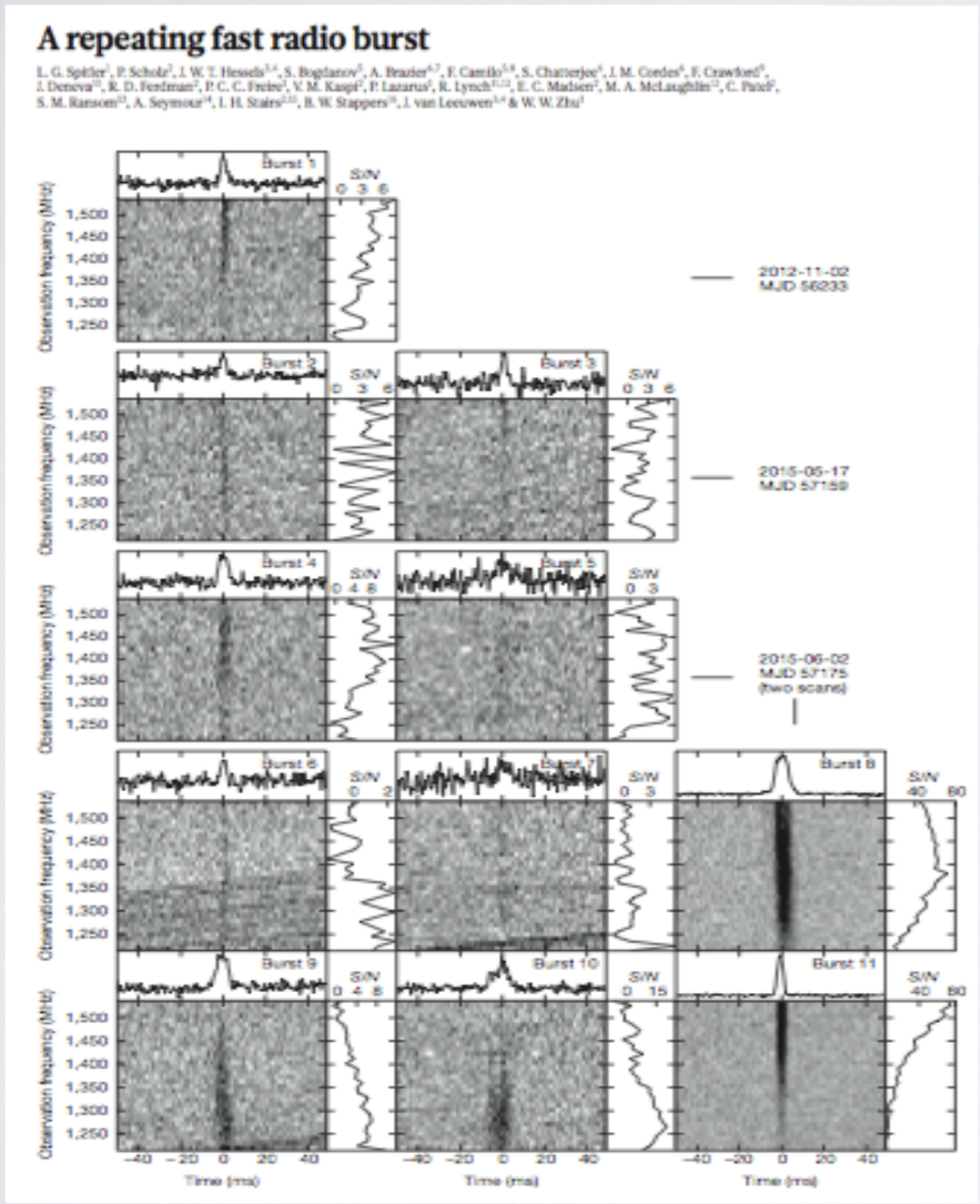

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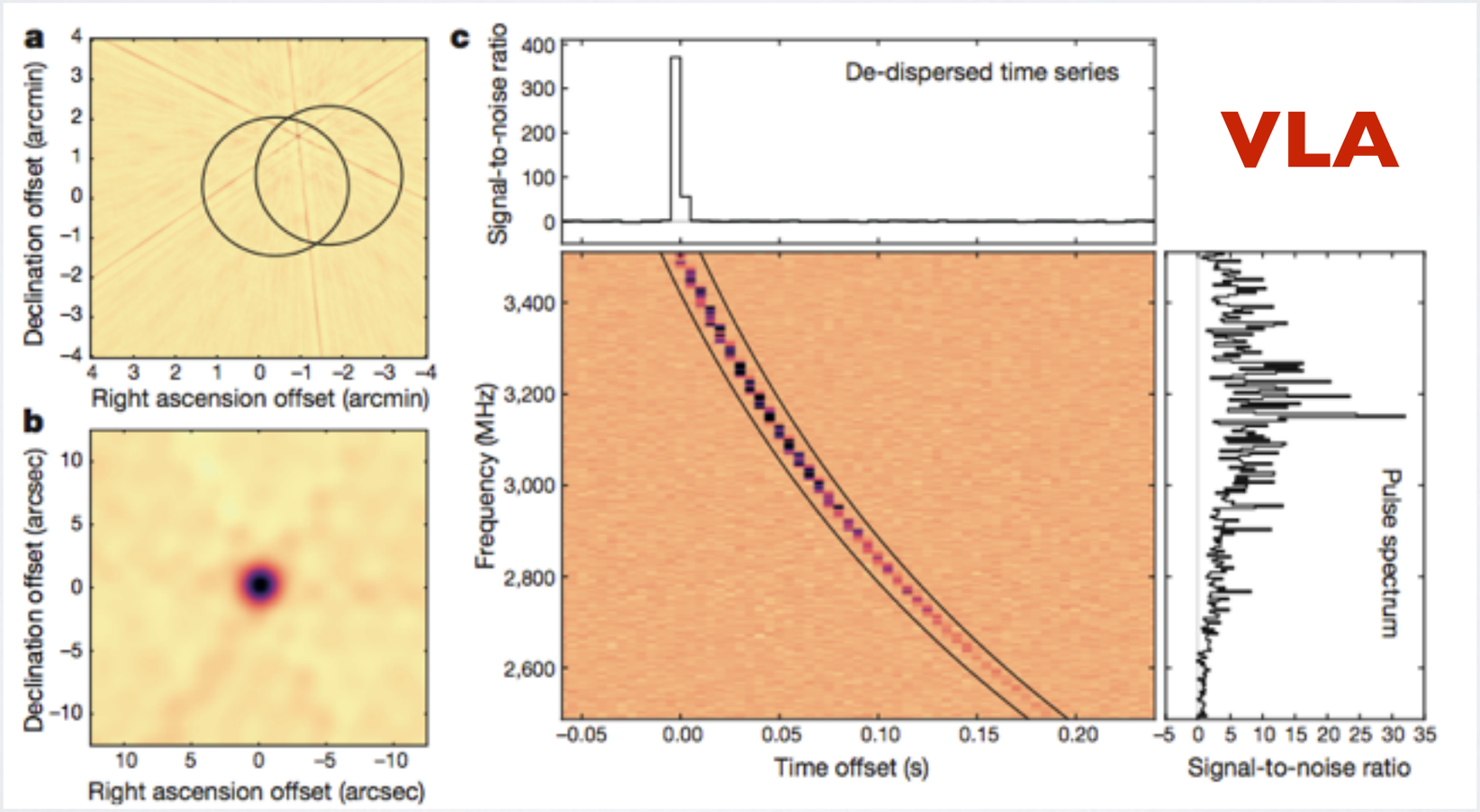
THE REPEATING FRB121102 - LOCALISATION

LETTER

doi:10.1038/nature20797

A direct localization of a fast radio burst and its host

S. Chatterjee[1], C. J. Law[2], R. S. Wharton[1], S. Burke-Spolaor[3,4,5], J. W. T. Hessels[6,7], G. C. Bower[8], J. M. Cordes[1], S. P. Tendulkar[9], C. G. Bassa[6], P. Demorest[3], B. J. Butler[3], A. Seymour[10], P. Scholz[11], M. W. Abruzzo[12], S. Bogdanov[13], V. M. Kaspi[9], A. Keimpema[14], T. J. W. Lazio[15], B. Marcote[14], M. A. McLaughlin[4,5], Z. Paragi[14], S. M. Ransom[16], M. Rupen[11], L. G. Spitler[17] & H. J. van Langevelde[14,18]



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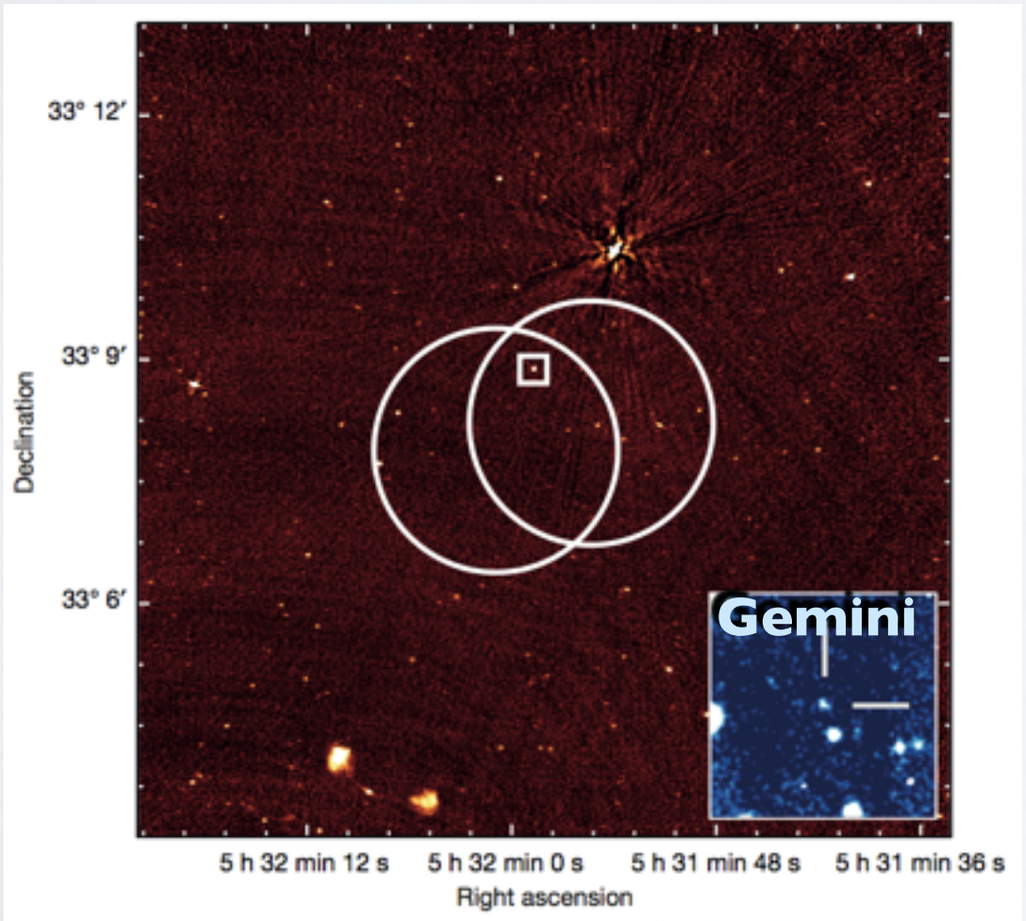
doi:10.1038/nature20797

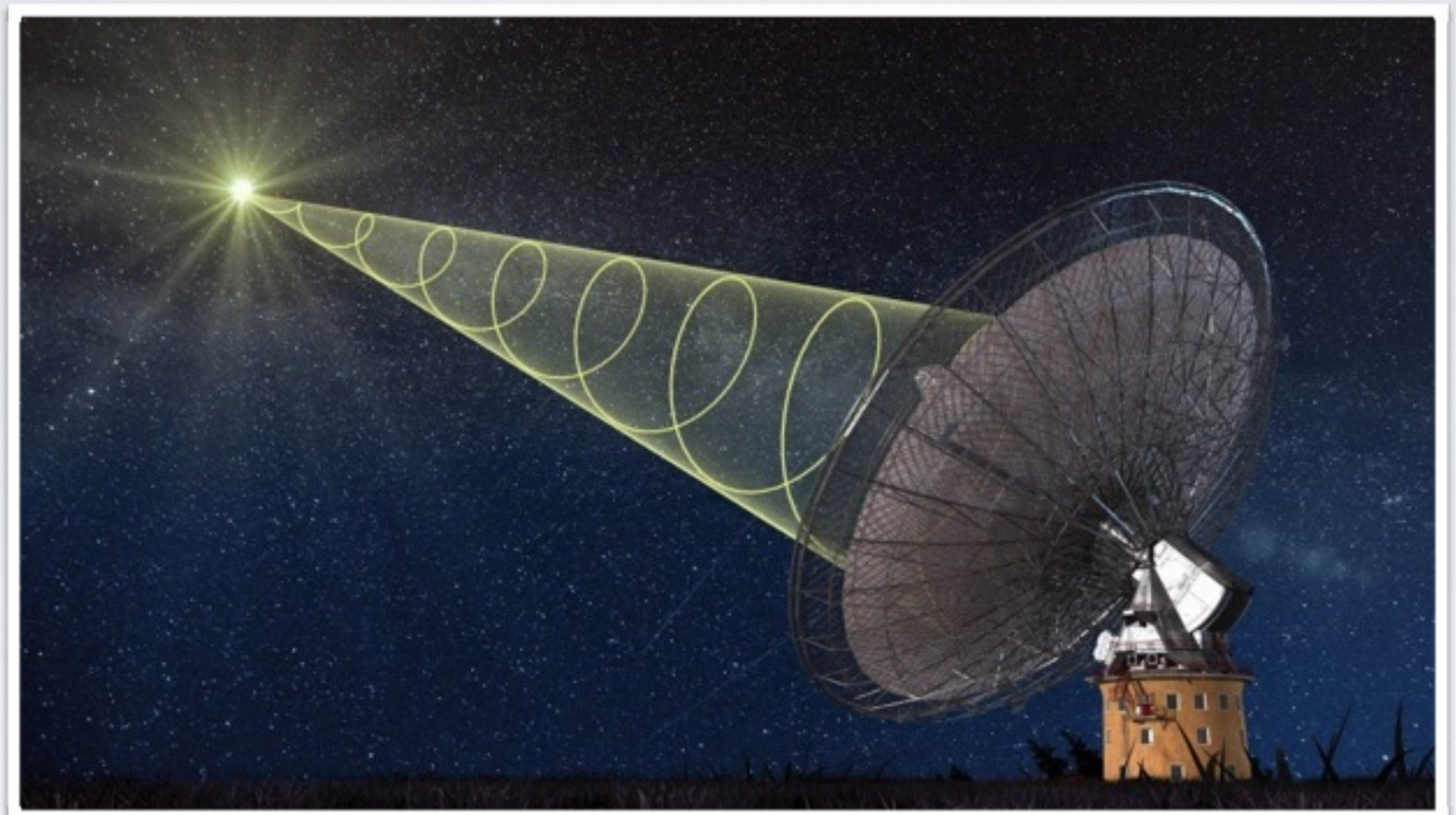
A direct localization of a fast radio burst and its host

S. Chatterjee[1], C. J. Law[2], R. S. Wharton[1], S. Burke-Spolaor[3,4,5], J. W. T. Hessels[6,7], G. C. Bower[8], J. M. Cordes[1], S. P. Tendulkar[9], C. G. Bassa[6], P. Demorest[3], B. J. Butler[3], A. Seymour[10], P. Scholz[11], M. W. Abruzzo[12], S. Bogdanov[13], V. M. Kaspi[9], A. Keimpema[14], T. J. W. Lazio[15], B. Marcote[14], M. A. McLaughlin[4,5], Z. Paragi[14], S. M. Ransom[16], M. Rupen[11], L. G. Spitler[17] & H. J. van Langevelde[14,18]



dwarf starburst galaxy
at z ~0.2

So, what are FRBs?



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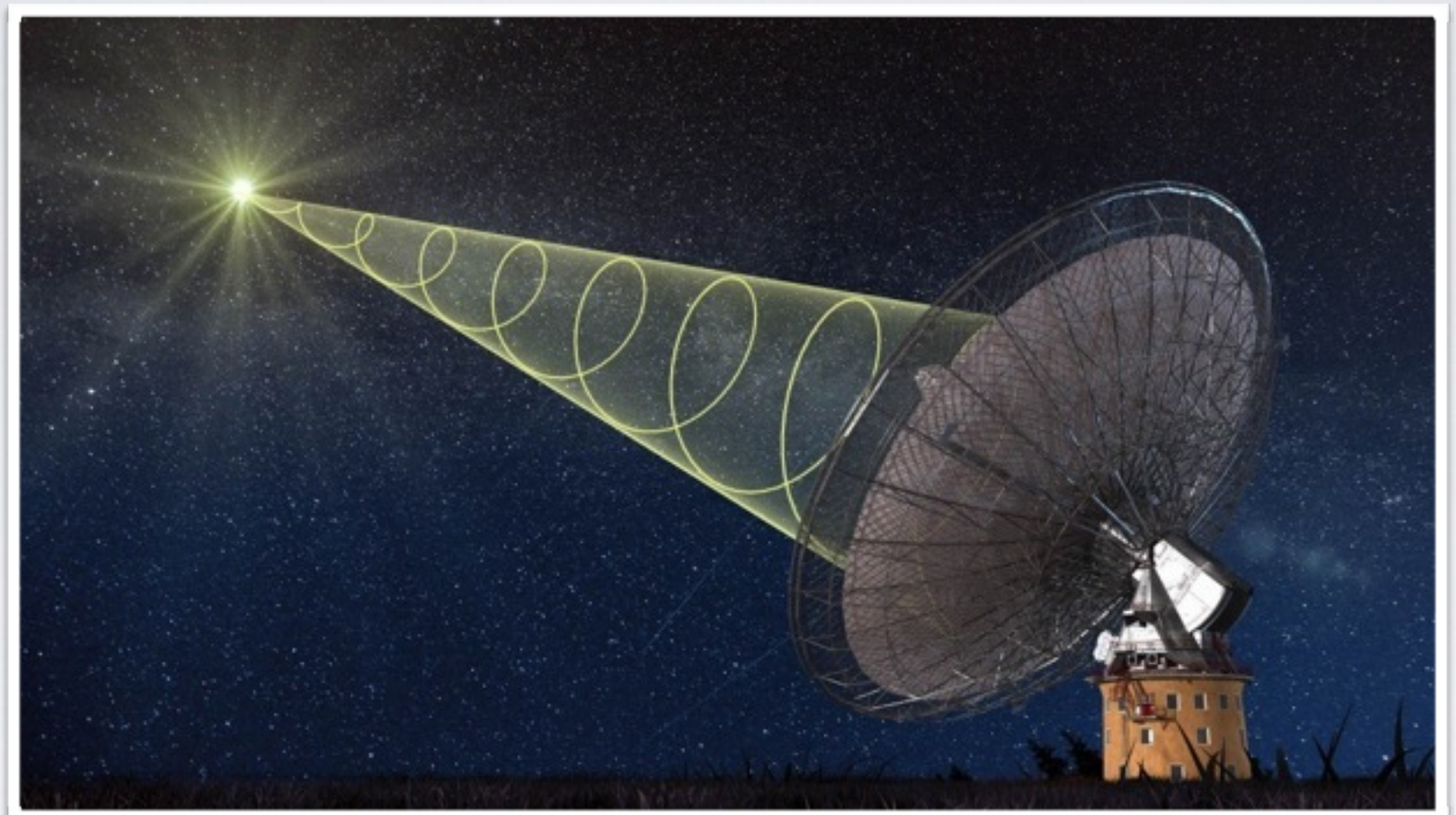
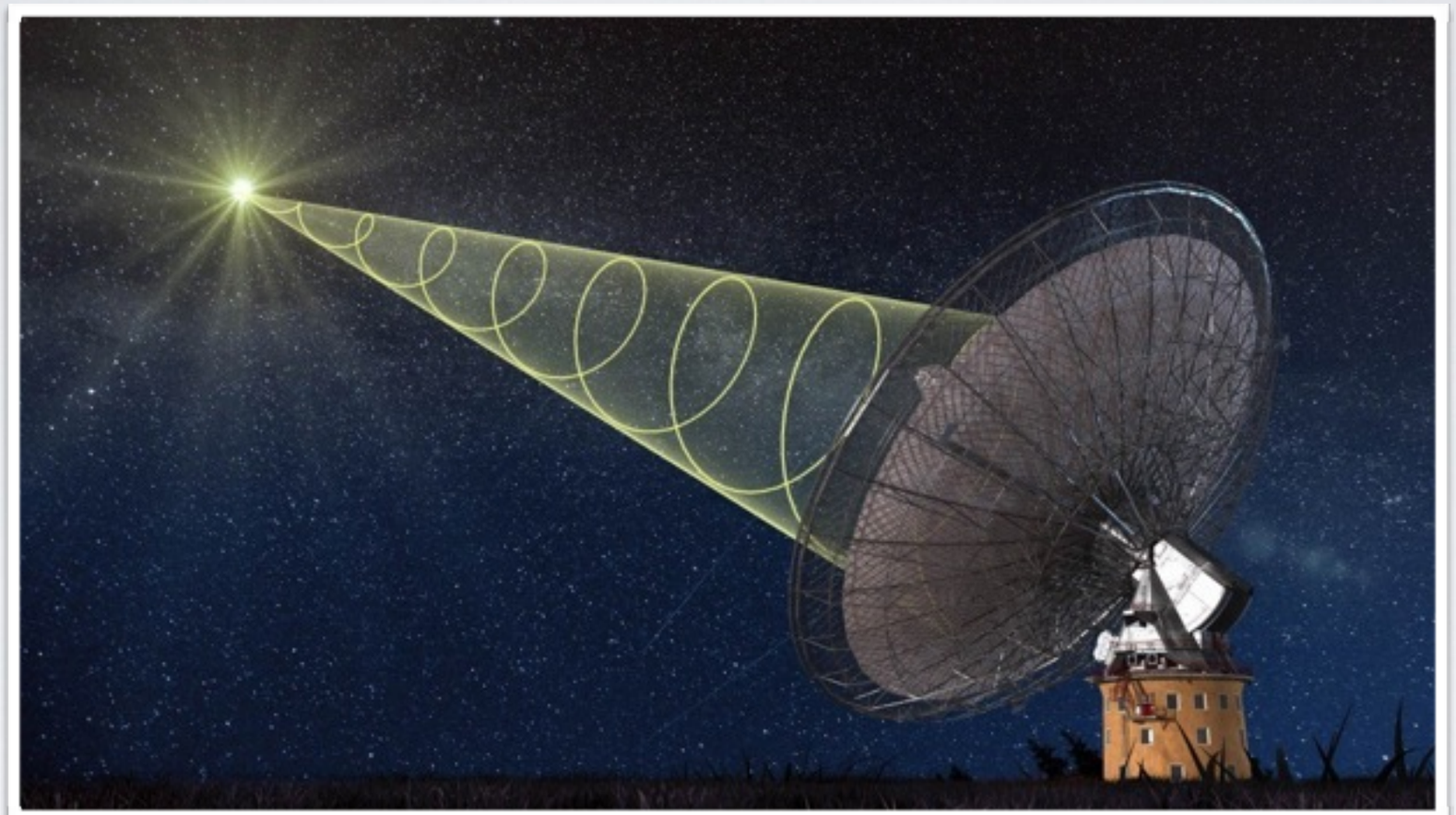


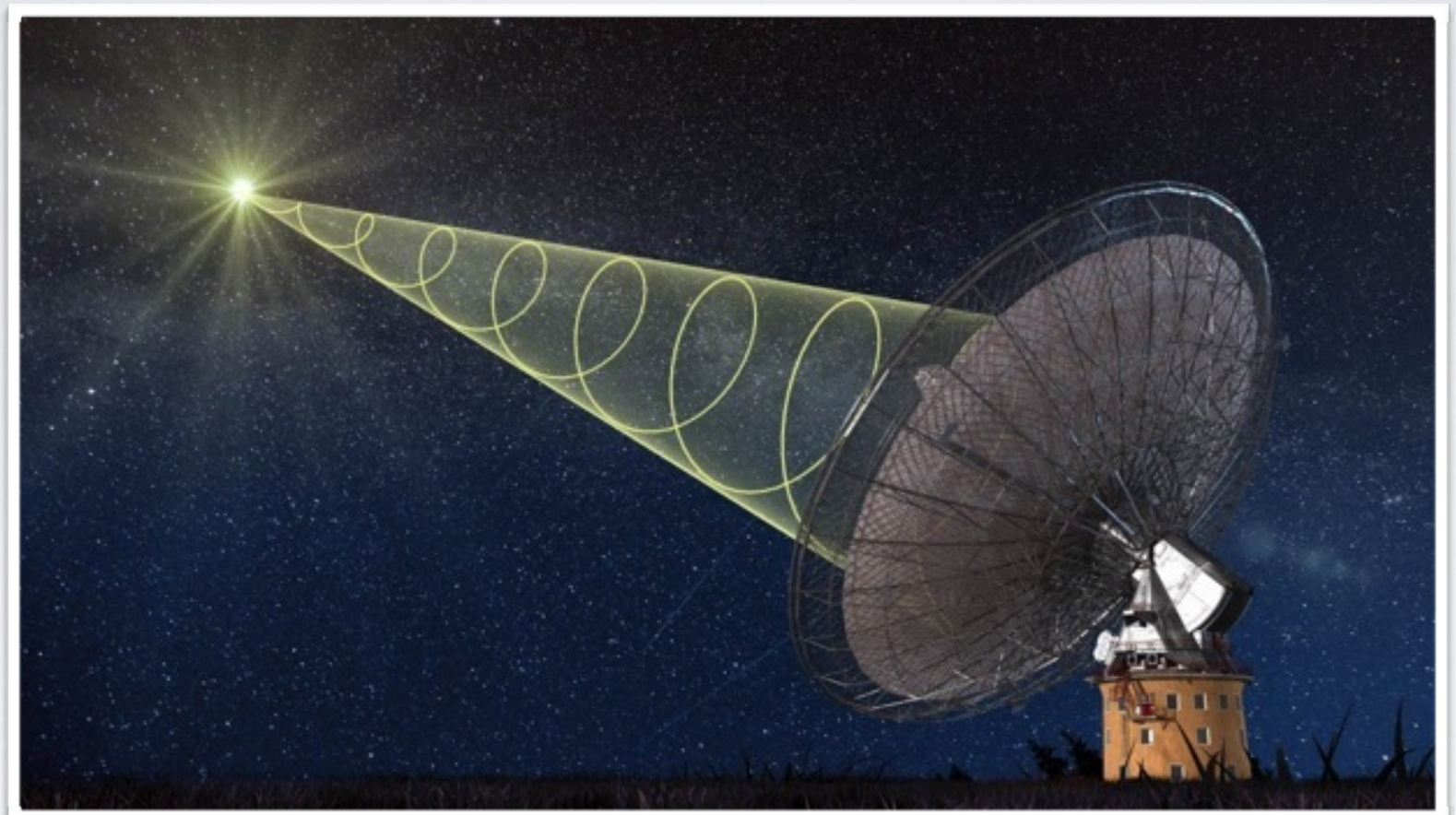
Extragalactic!

So, what are FRBs?



Extragalactic!
One repeats: no catastrophic origin.

So, what are FRBs?



Extragalactic!
One repeats: no catastrophic origin.
More than one family?

Need more FRBs and more localisations.

New instrumentation for FRBs

CHIME

HIRAX

PAF - Apertif

MeerKAT, ASKAP, SKA

HERA

UTMOST 2-D

Realfast @VLA

New instrumentation for FRBs

CHIME

HIRAX

Large FoV + localisation
FRBs daily!

MeerKAT, ASKAP, SKA

HERA

PAF - Apertif

UTMOST 2-D

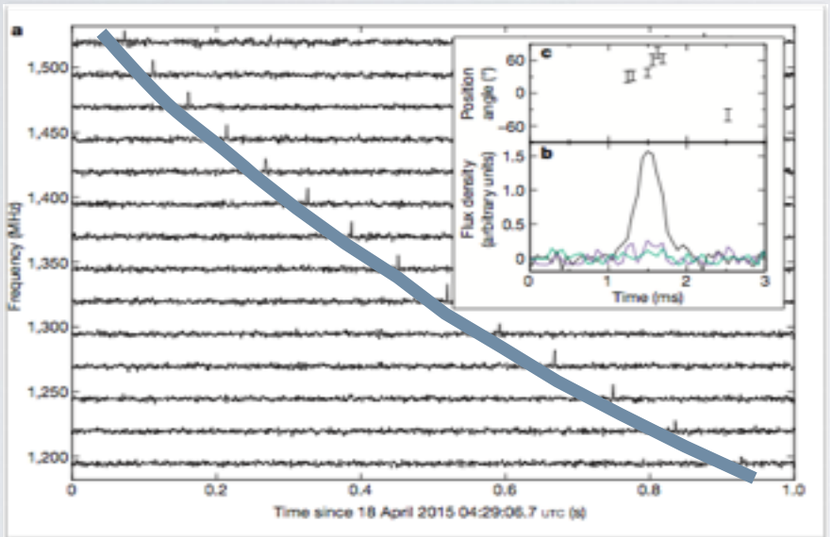
Realfast @VLA

... STAY TUNED ...

THANKS !

NOTABLE FOLLOW-UPS: FRB150418

DM 776 pc/cm^3



[Keane et al. 2016, Nature]

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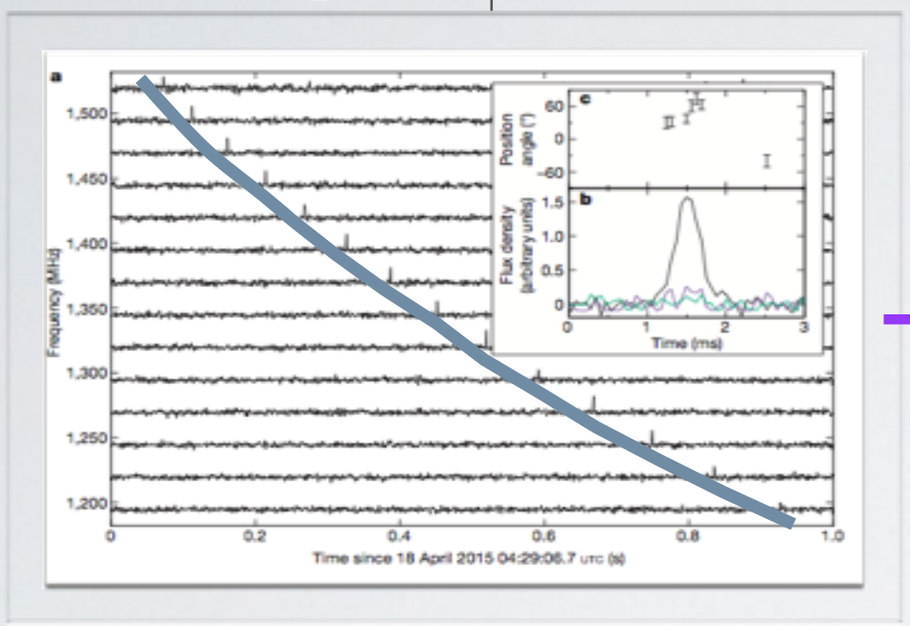
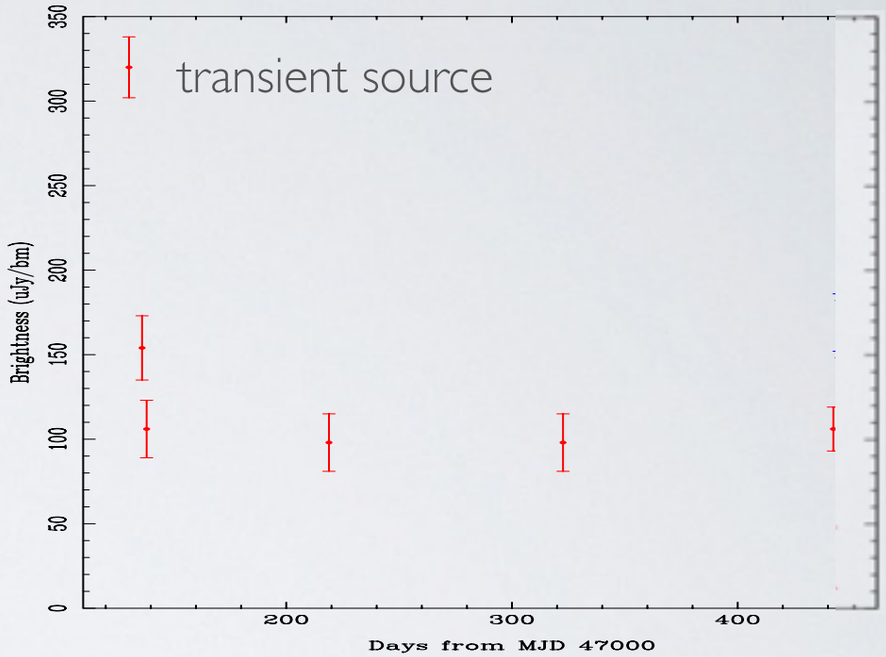


2 hr interferometry



[Keane et al. 2016, Nature]

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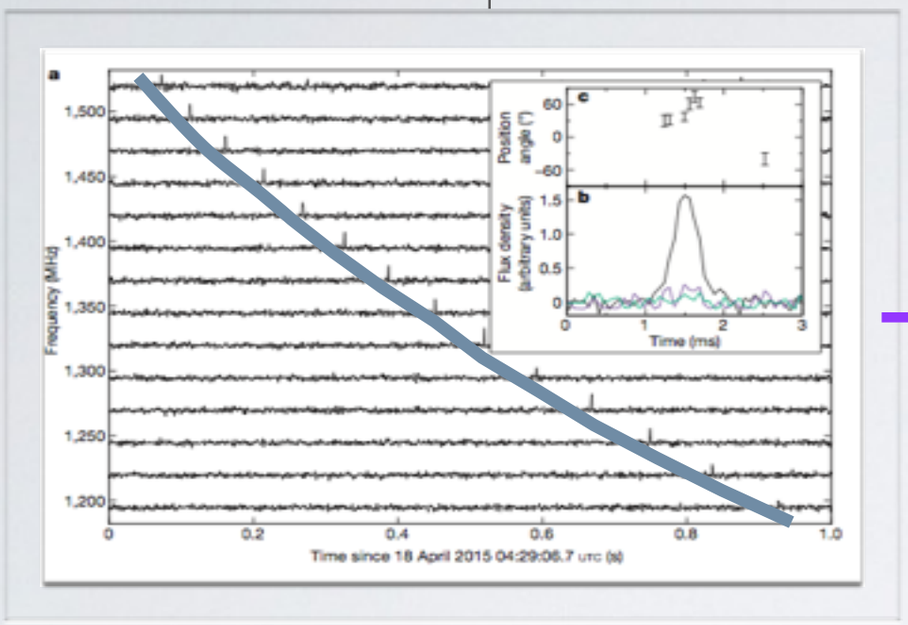

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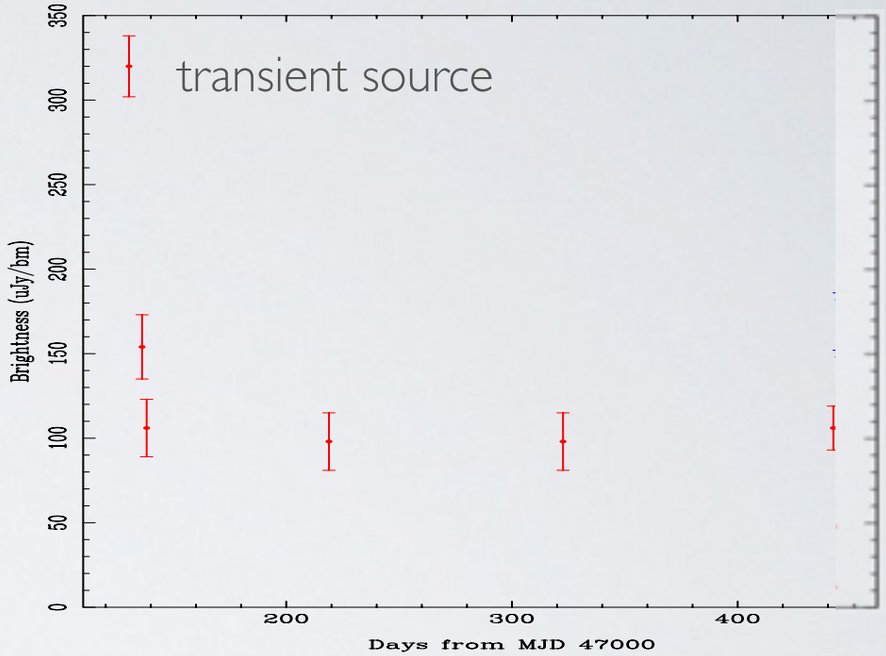

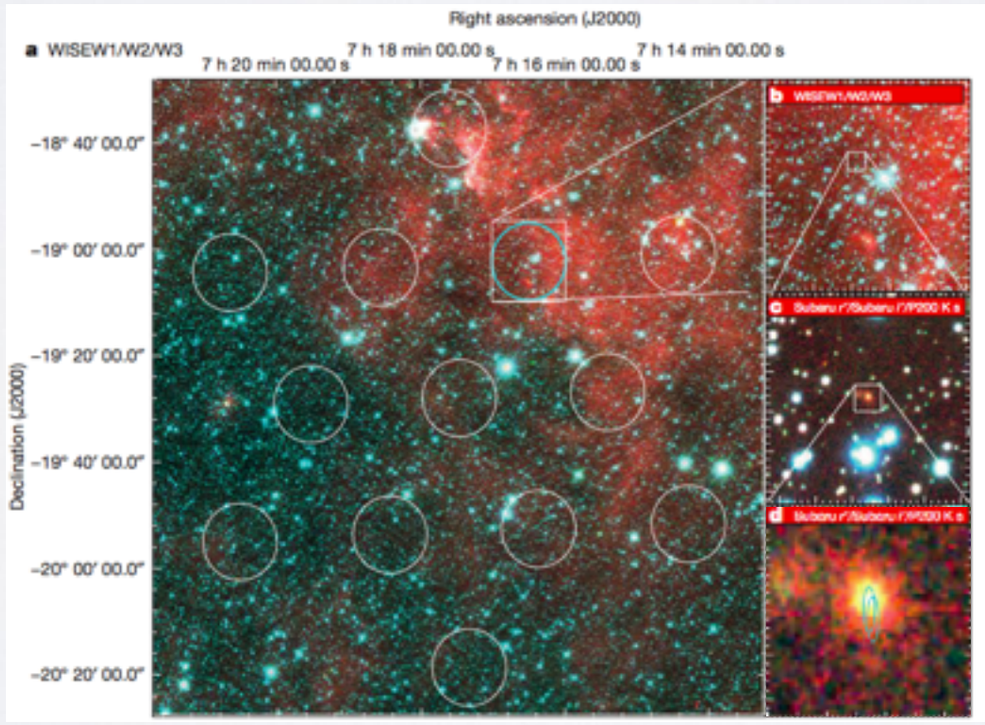

[Keane et al. 2016, Nature]

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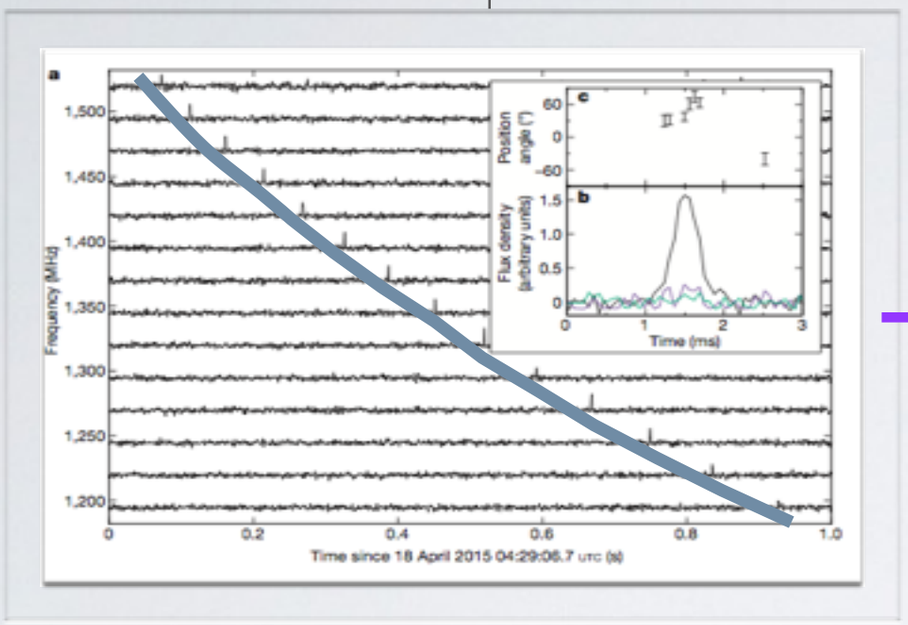

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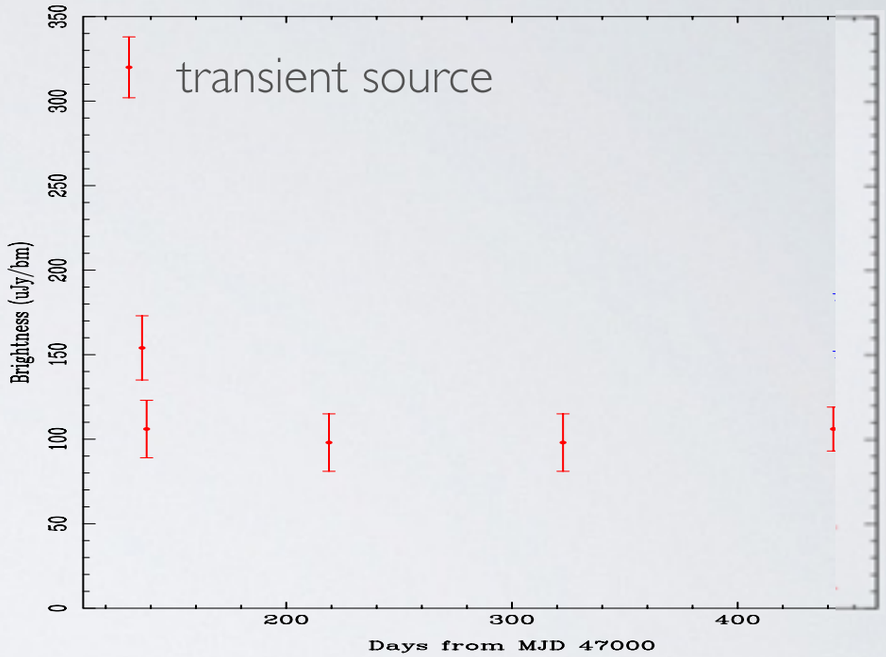

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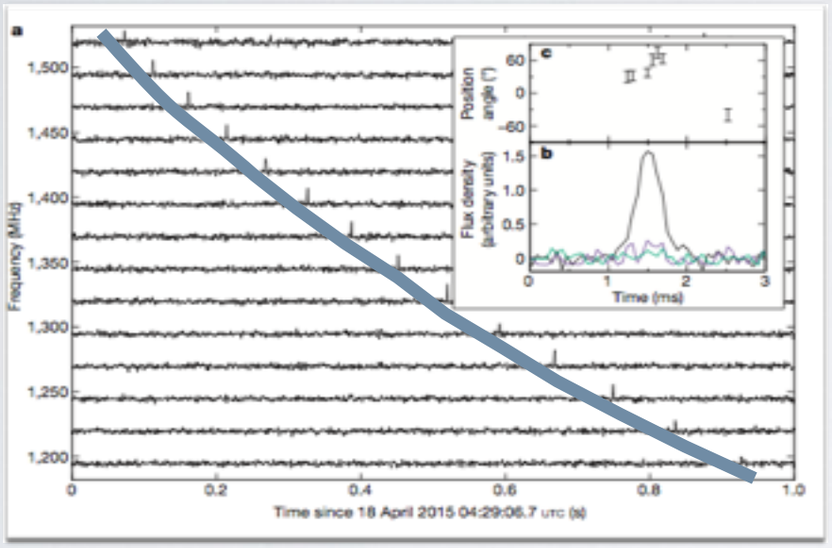

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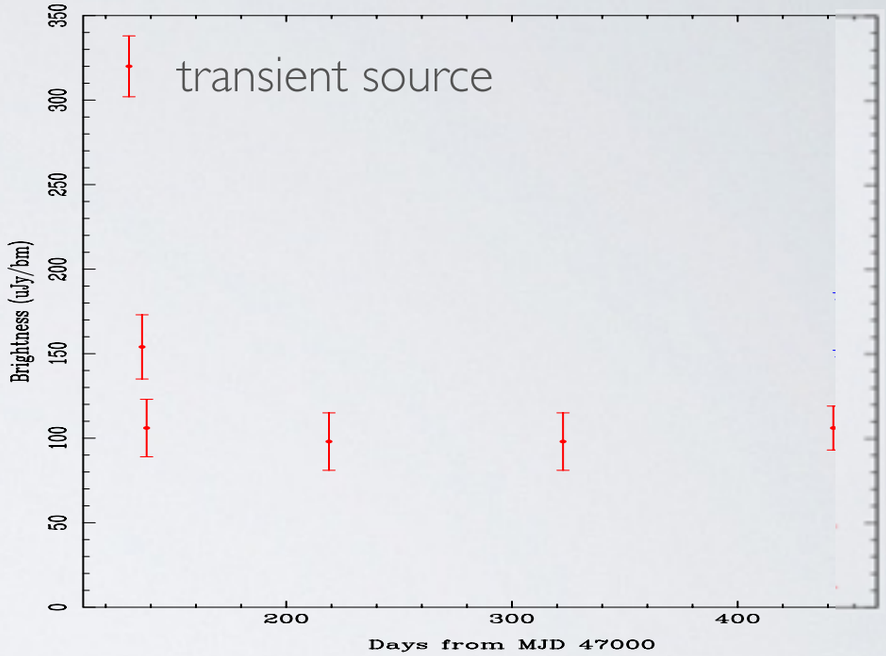

From z and DM_{IGM}, for each given set of cosmological parameters H_0 , Ω_m and Ω_Λ, plus the fraction of ionised atoms f_e , one can get the baryon density along the line of sight Ω_{IGM}

$$DM_{IGM} = \frac{3cH_0\Omega_{IGM}}{8\pi G m_p} \int_0^z \frac{(1+z')f_e(z')dz'}{[(1+z')^3\Omega_m + \Omega_\Lambda]^{0.5}}$$

[Keane et al. 2016, Nature]

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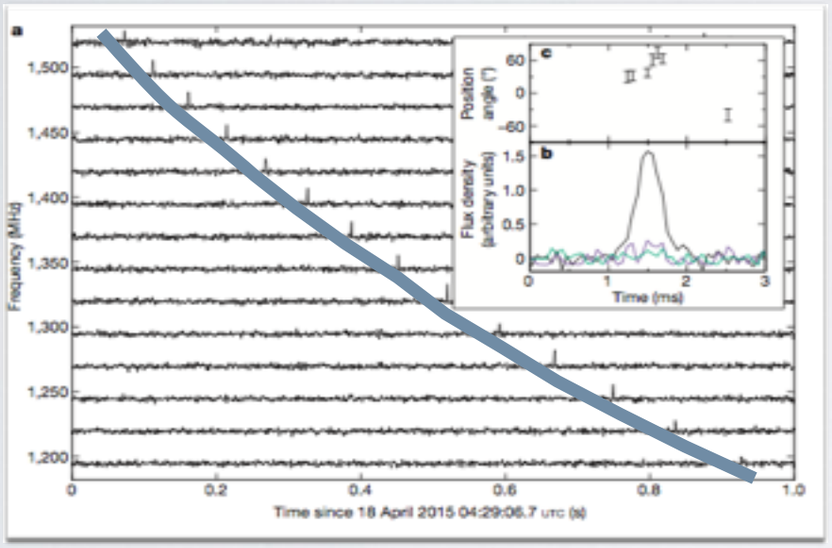
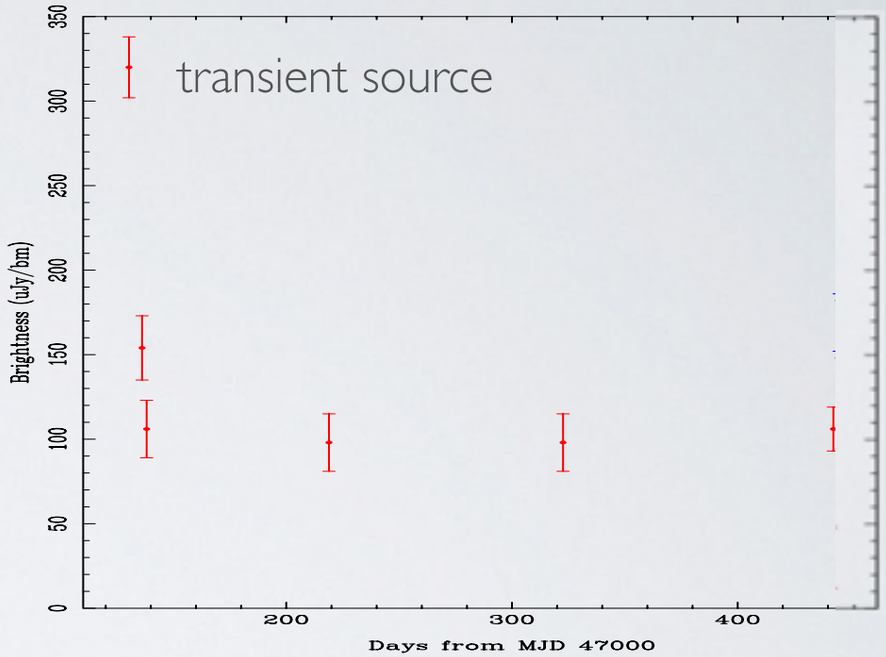


2 hr interferometry



From z and DM_{IGM}, for each given set of cosmological parameters H_0 , Ω_m and Ω_Λ, plus the fraction of ionised atoms f_e , one can get the baryon density along the line of sight Ω_{IGM}

$$DM_{IGM} = \frac{3cH_0\Omega_{IGM}}{8\pi G m_p} \int_0^z \frac{(1+z')f_e(z')dz'}{[(1+z')^3\Omega_m + \Omega_\Lambda]^{0.5}}$$

$\Omega_{IGM} = 4.9\ \% \pm 1.3\ \%$

[Keane et al. 2016, Nature]

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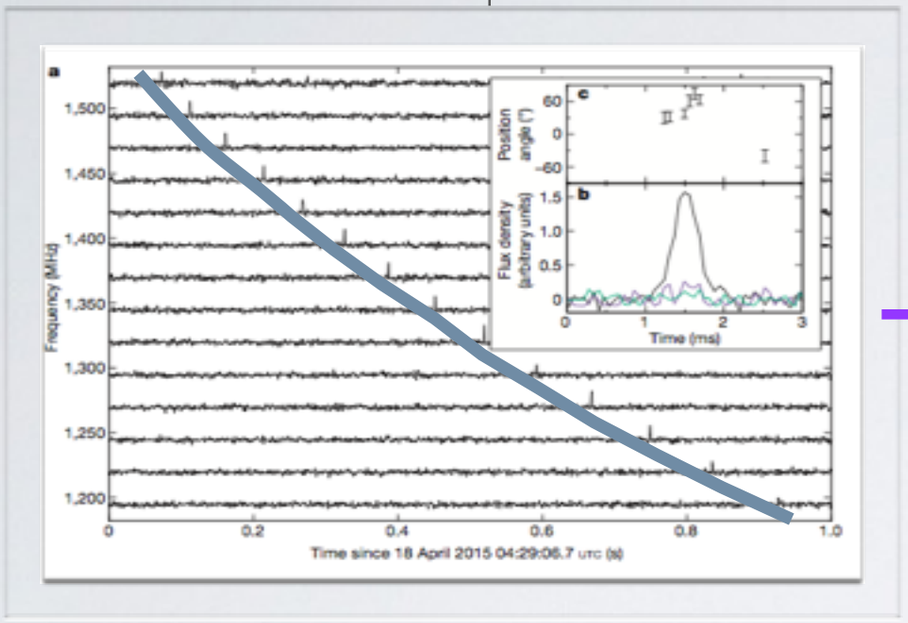
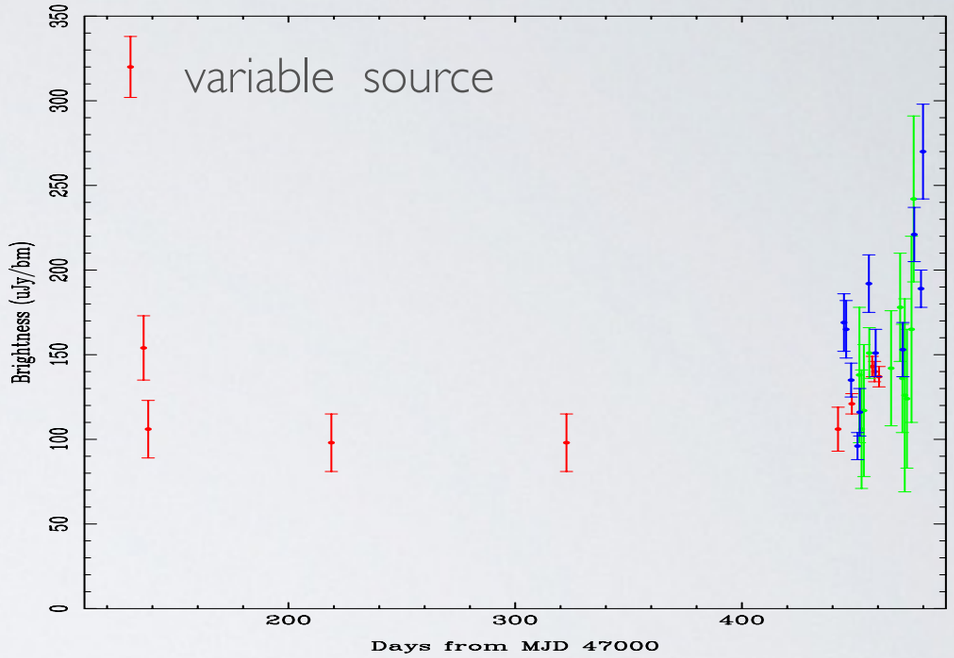


2 hr interferometry

Johnston et al. 2017



[Keane et al. 2016, Nature]

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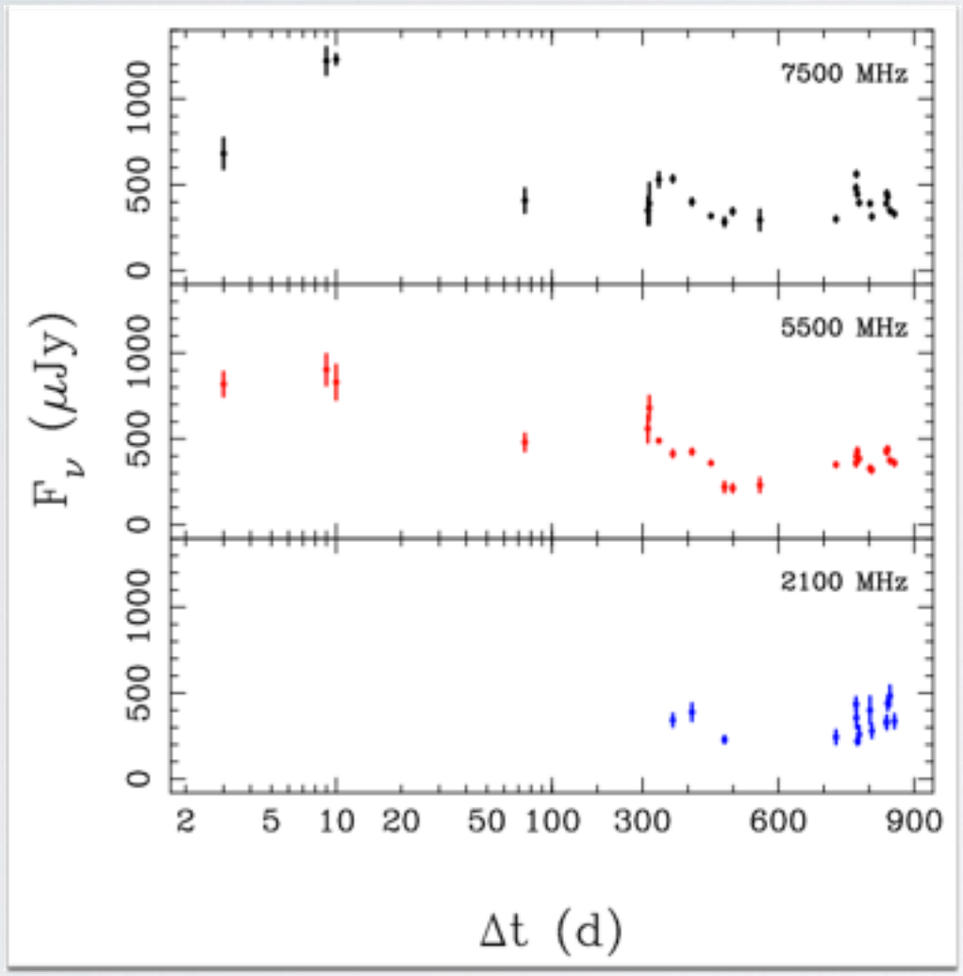
NOTABLE FOLLOW-UPS: FRB 131104

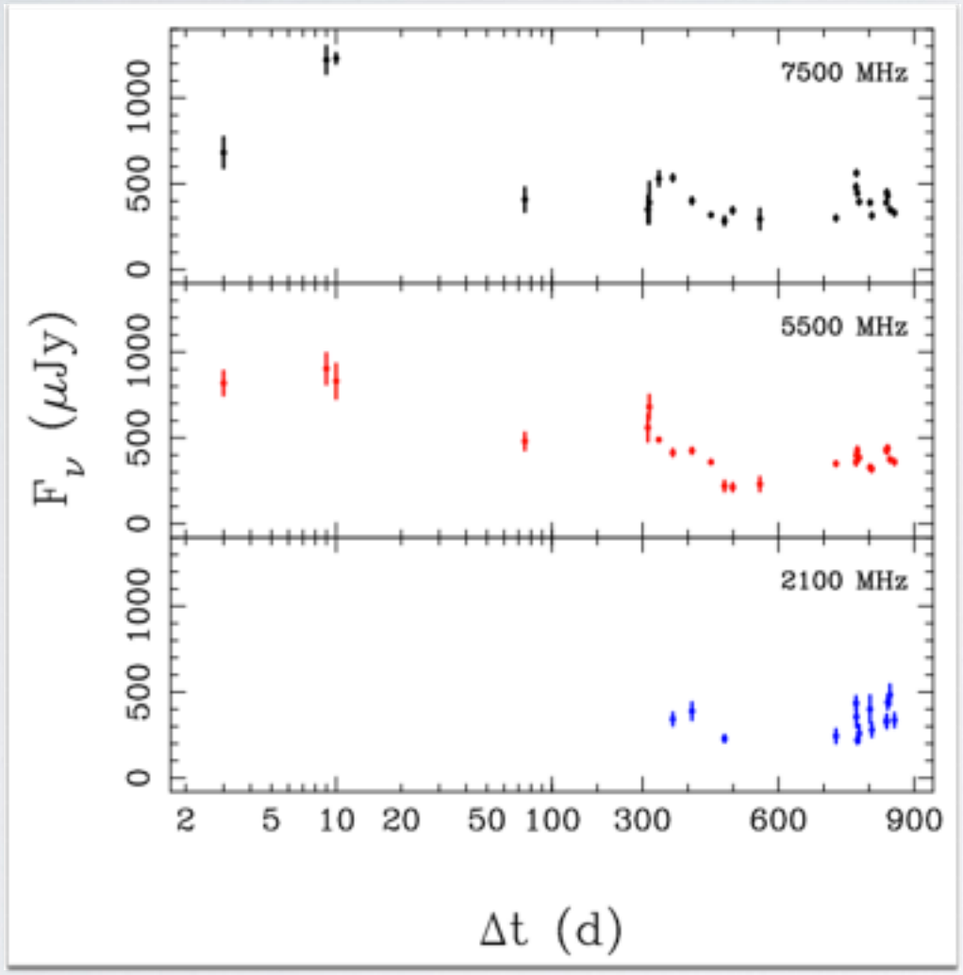
Triggered ATCA



Shannon & Ravi 2016

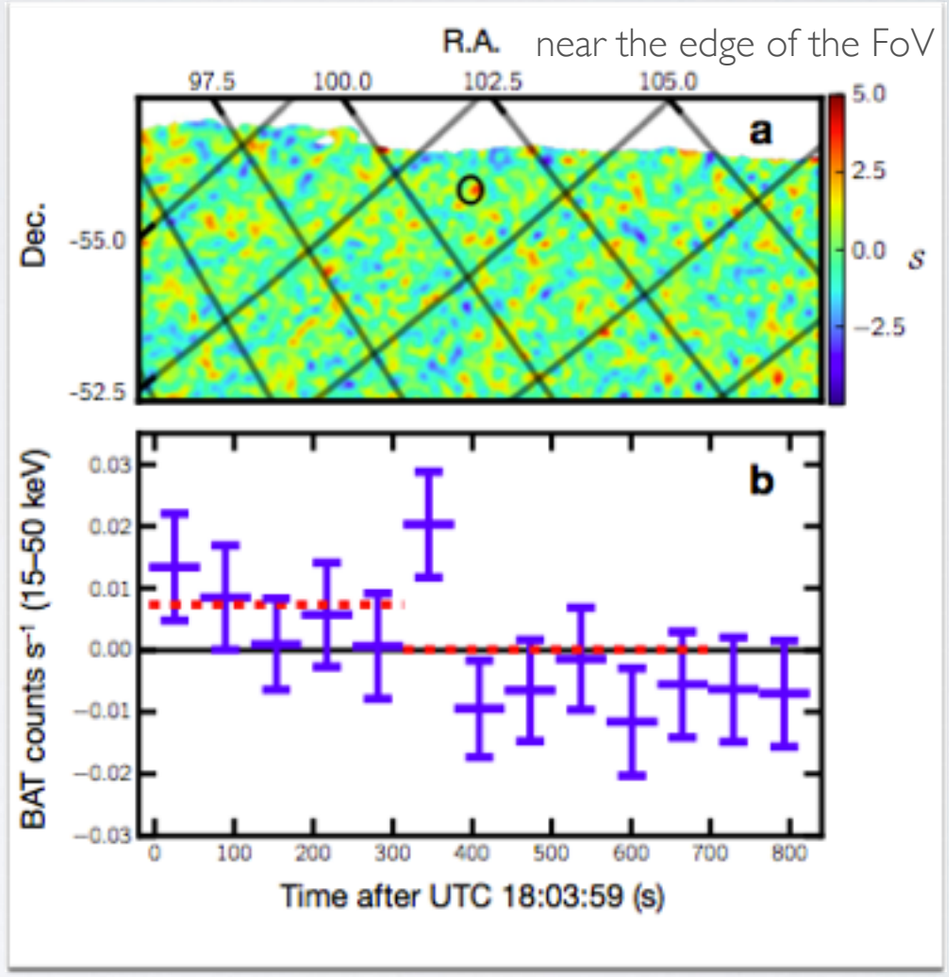
Notable Follow-ups: FRB 131104

Triggered ATCA



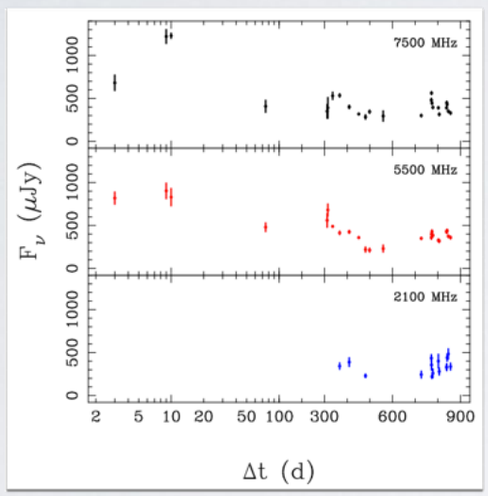
Shannon & Ravi 2016

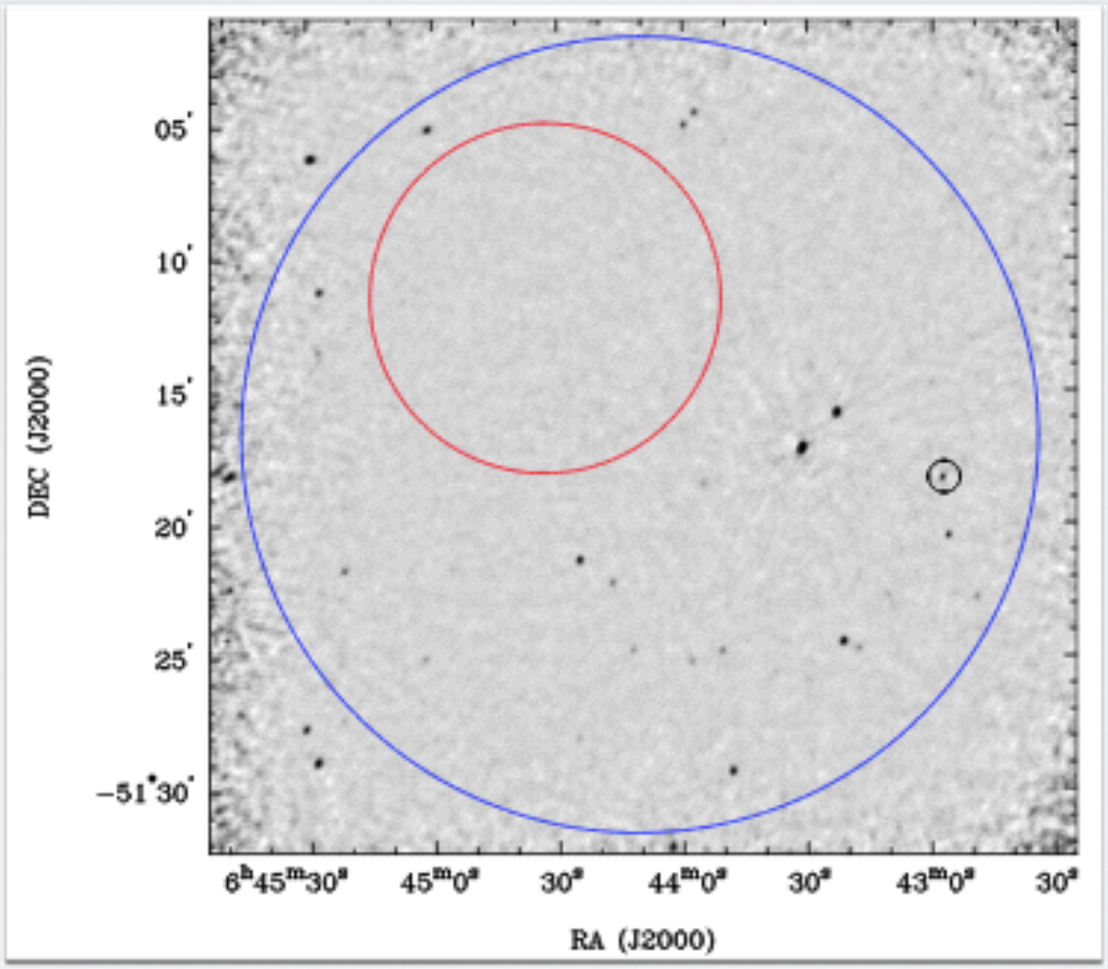
Untriggered Swift BAT

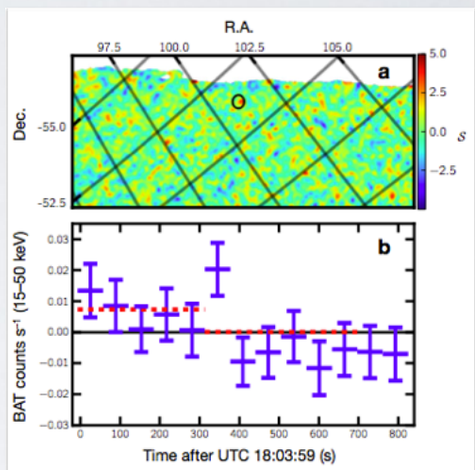


De Launay et al. 2016

Notable Follow-ups: FRB 131104





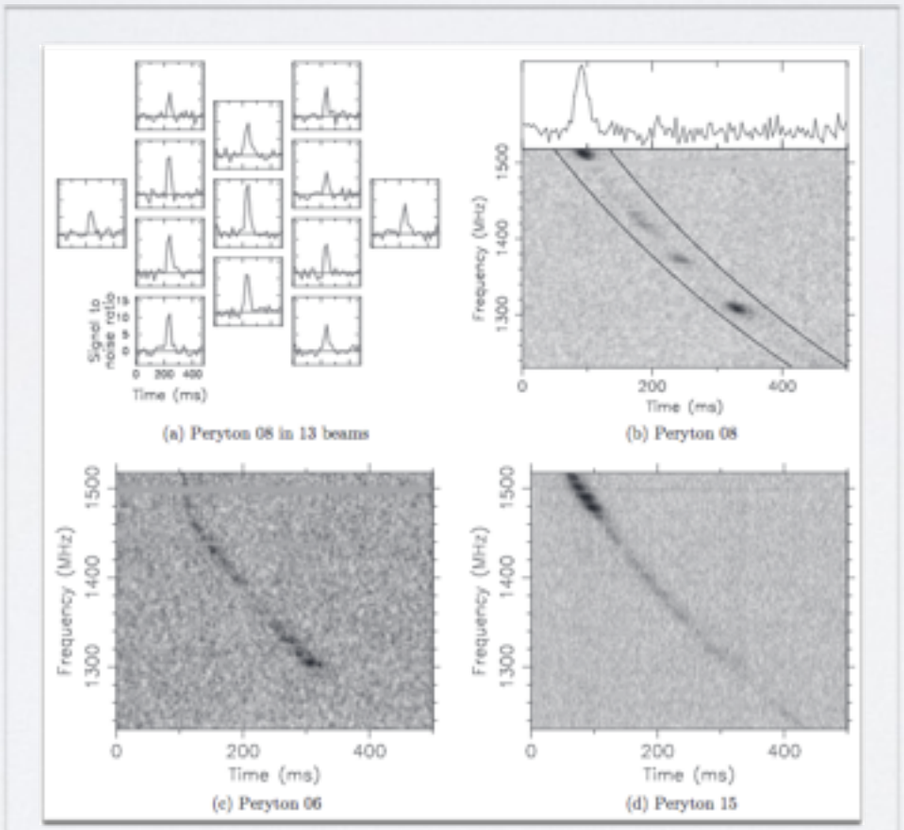


Shannon & Ravi 2016

2011: PERYTONS SET BACK THE FIELD

Abstract:

frequency sweep with a shape and magnitude resembling the Lorimer Burst. These new events were detected in a sidelobe of the Parkes Telescope and are of clearly terrestrial origin, with properties unlike any known sources of terrestrial broadband radio emission. The new detections cast doubt on the extragalactic interpretation of the original burst, and call for further



Burke-Spolaor et al. 2011. ApJ.

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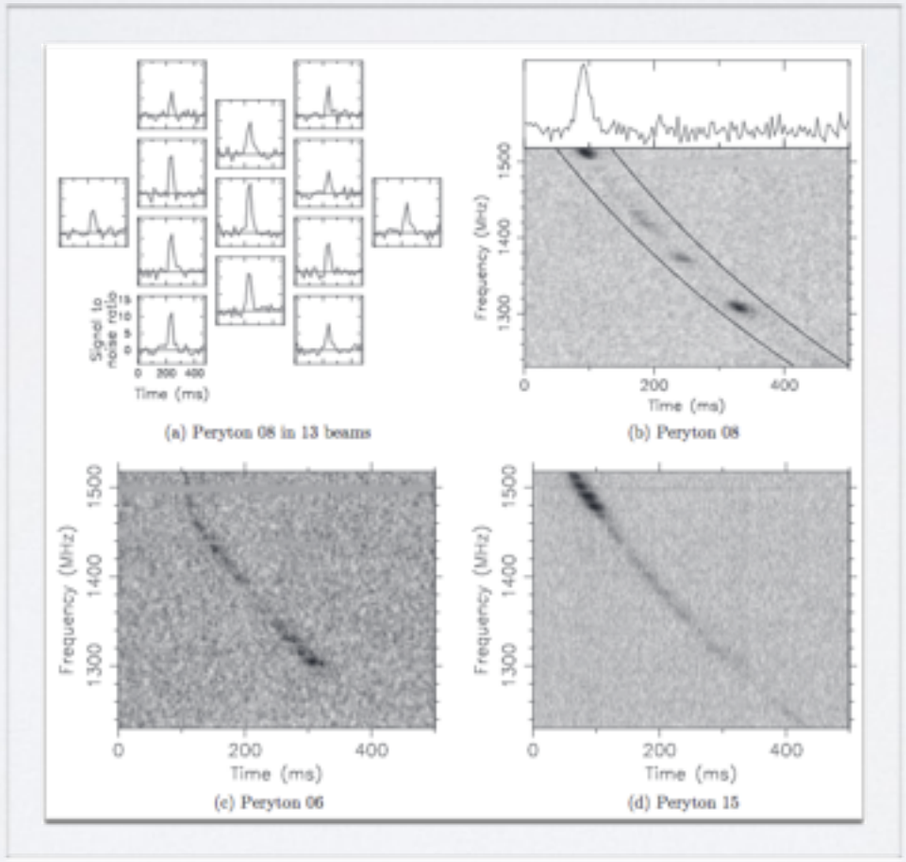

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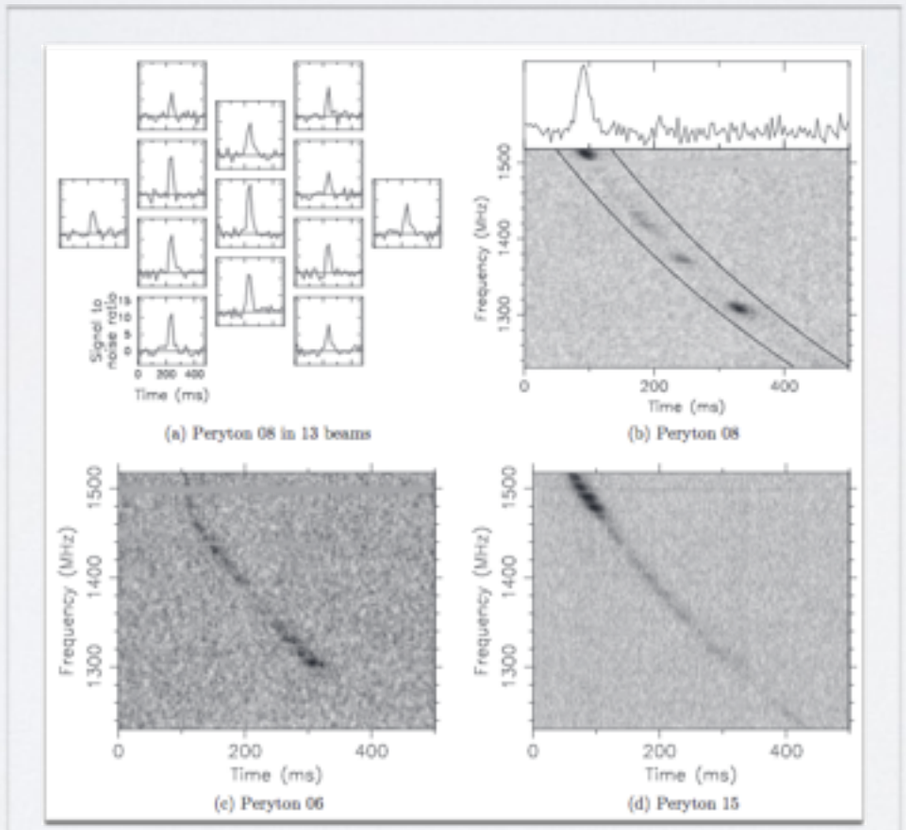

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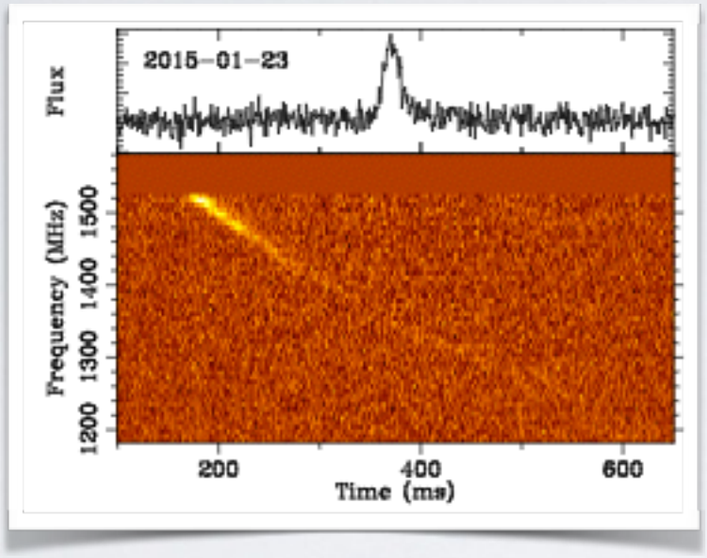
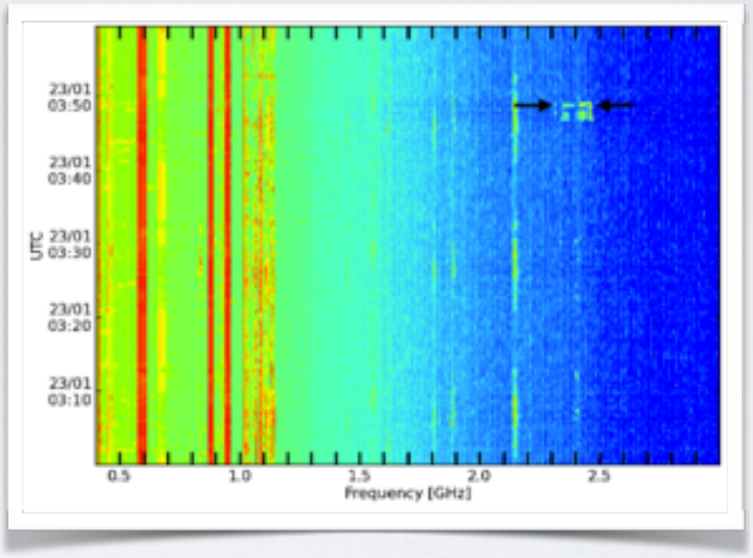
2015: PERYTONS' MYSTERY SOLVED!





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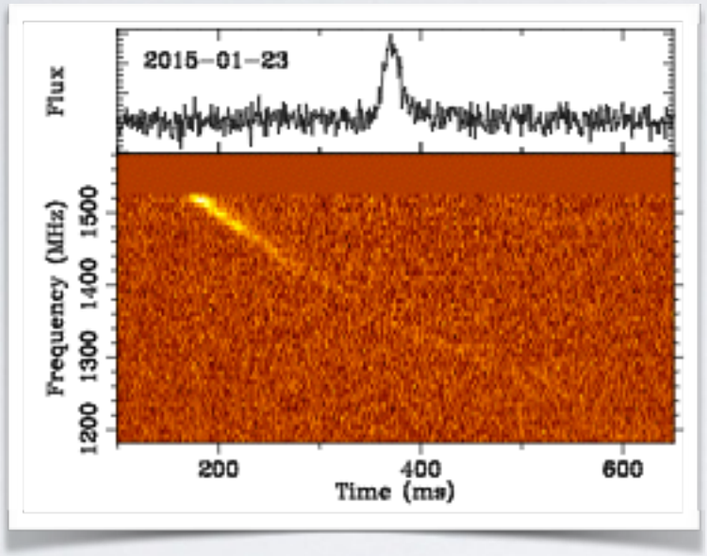
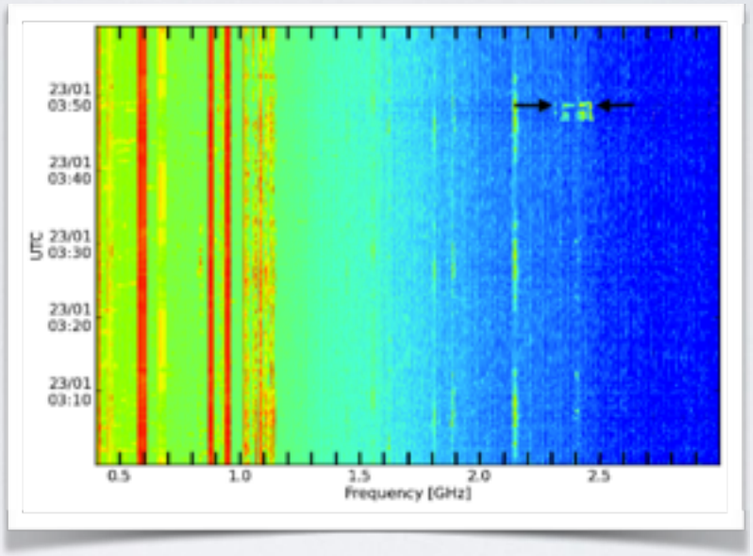
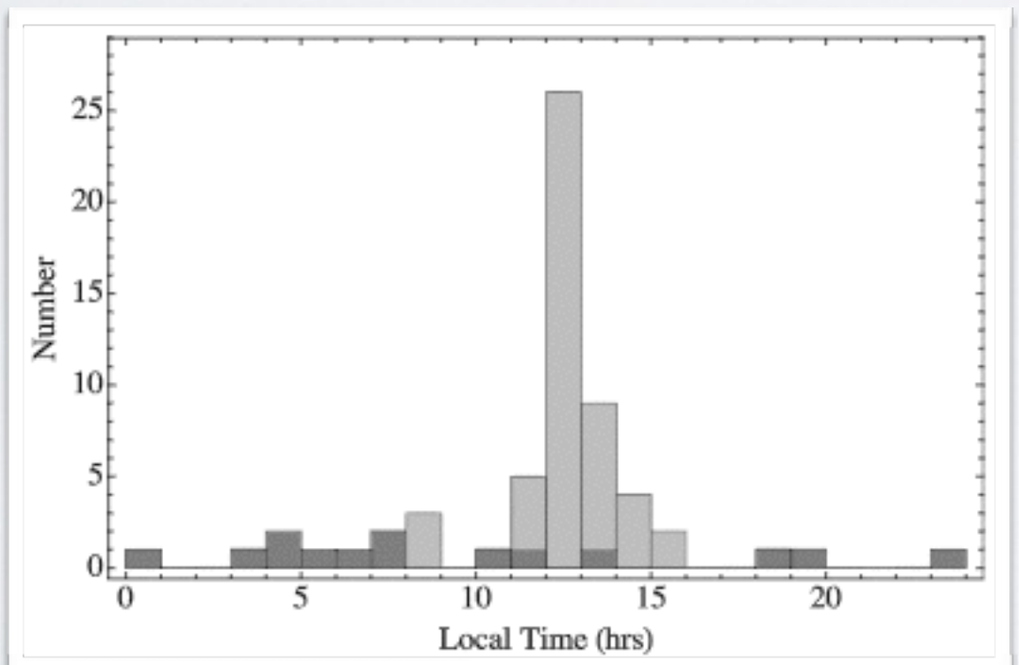




Petrof et al. 2015 (MNRAS)



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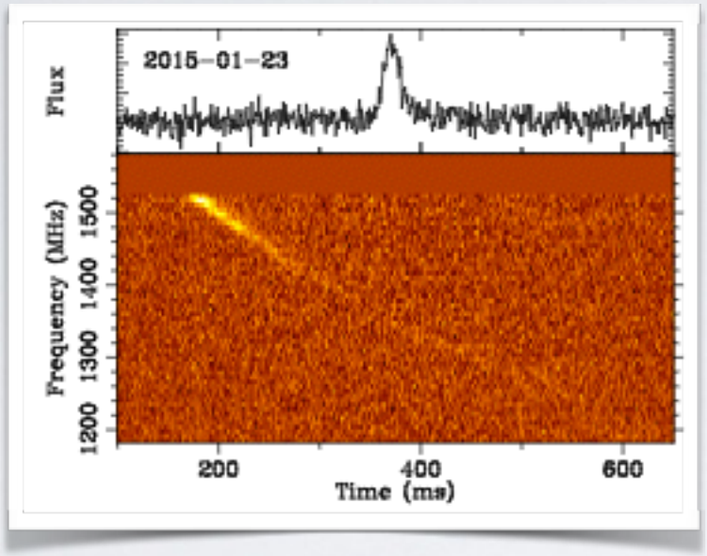

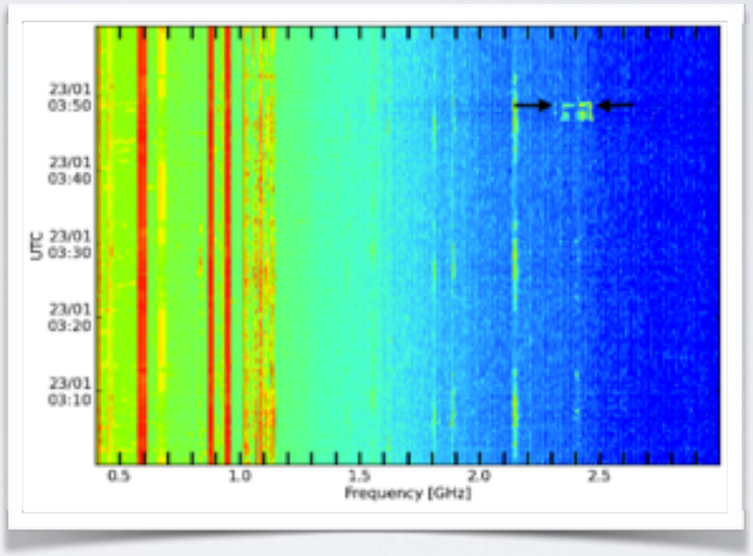

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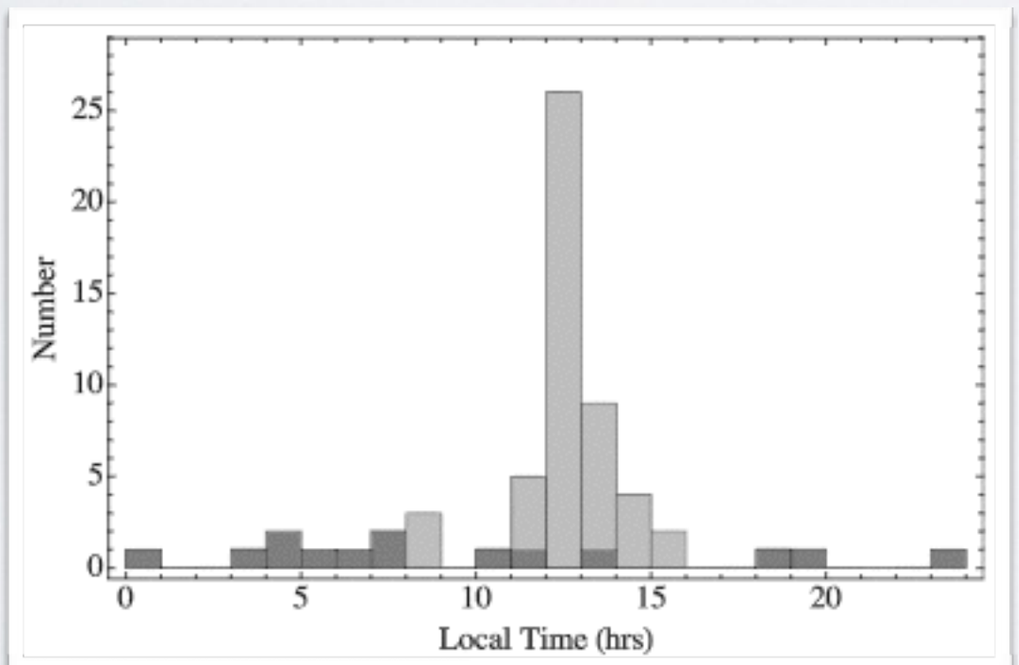
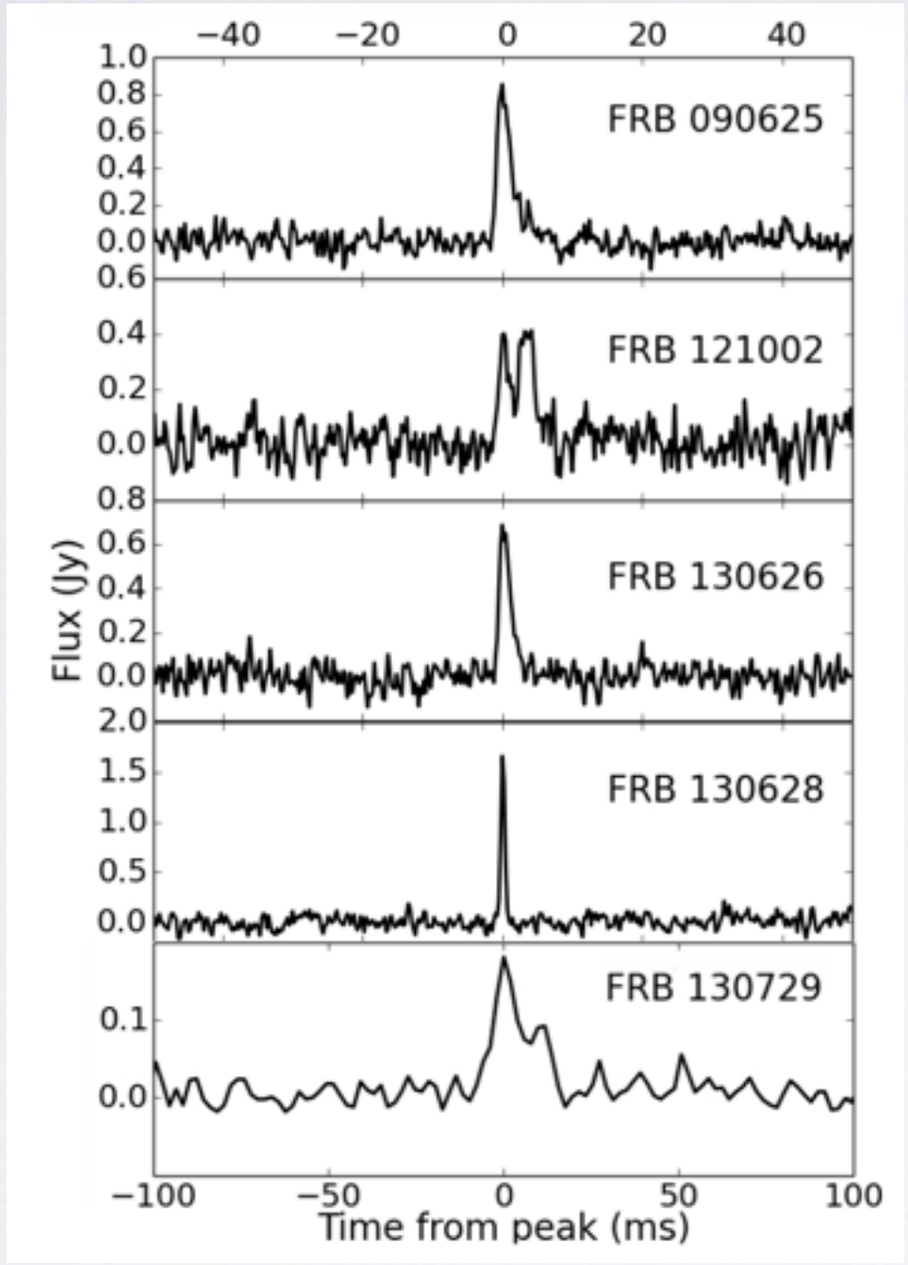
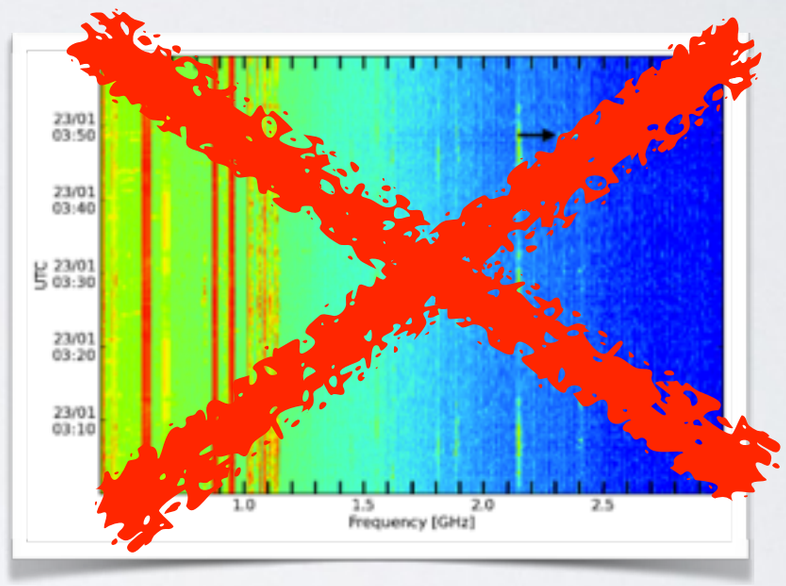


2016: More FRBs from Parkes





Champion et al. 2016. MNRAS.