Radio transients and neutron stars

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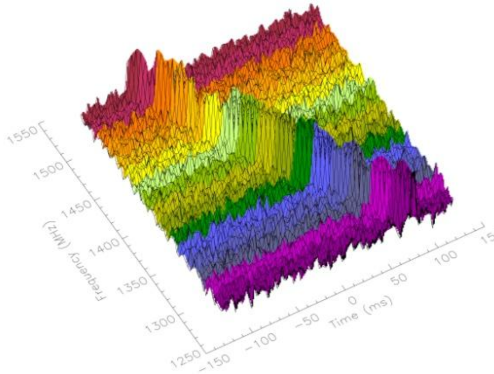
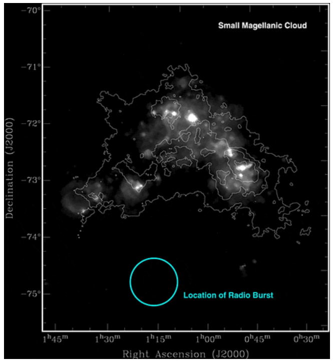
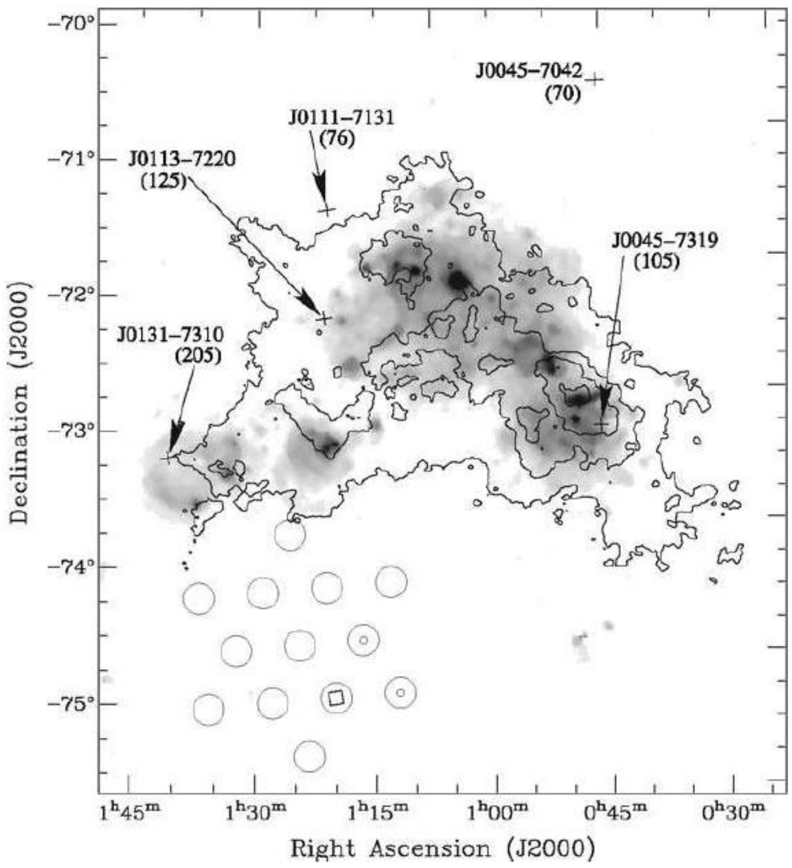


Fast Radio Bursts
(Lorimer+’ 07, Thornton+’ 13, Spitler+’14…)



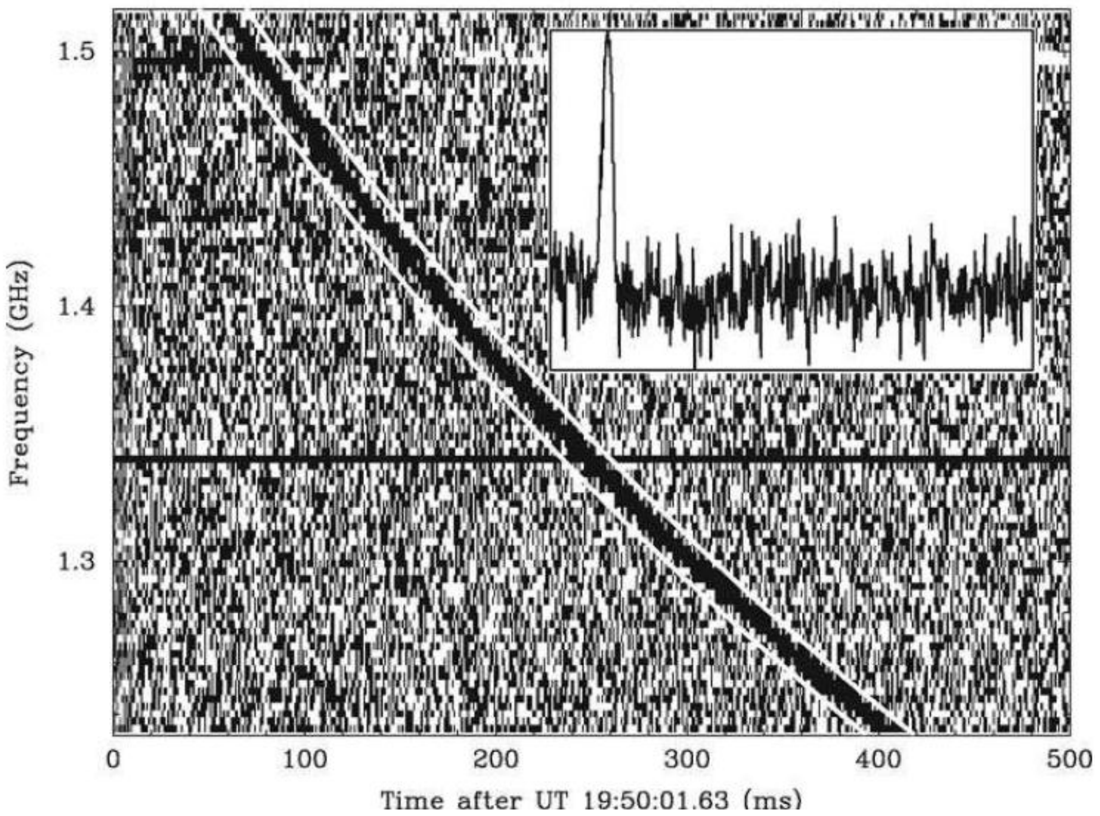
Millisecond extragalactic radio burst



Discovered by Lorimer et al. [Science 318, 777 (2007)]
1.4 GHz, Parkes

~30-40 Jy, < 5 msec
3 degrees from SMC

Millisecond extragalactic radio burst

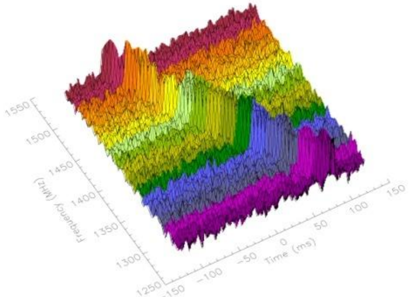


[Science 318, 777 (2007)]

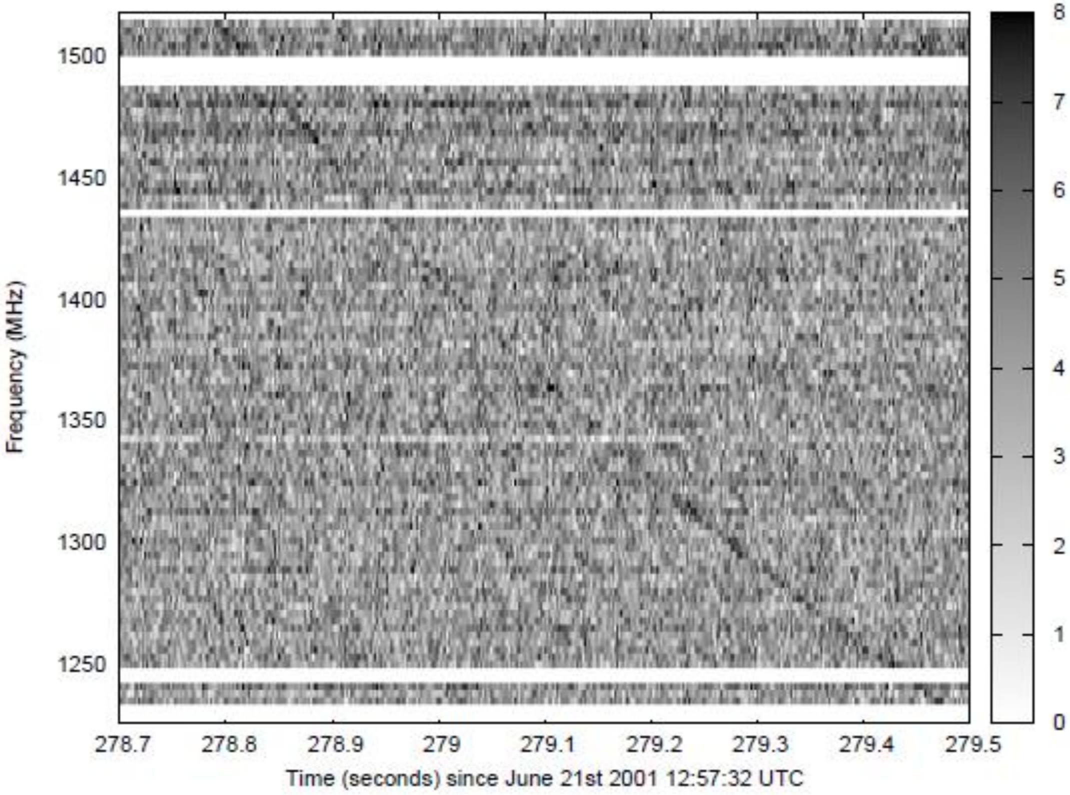
Large DM 375 cm^{-3} pc
Extragalactic
Distance ~< 1 Gpc
(>600 Mpc from optical limits on the host galaxy)

Rate ~ 90/day/Gpc^3

This rate is much lower than the SN rate, but much larger that the rate of GRBs.



A second example?



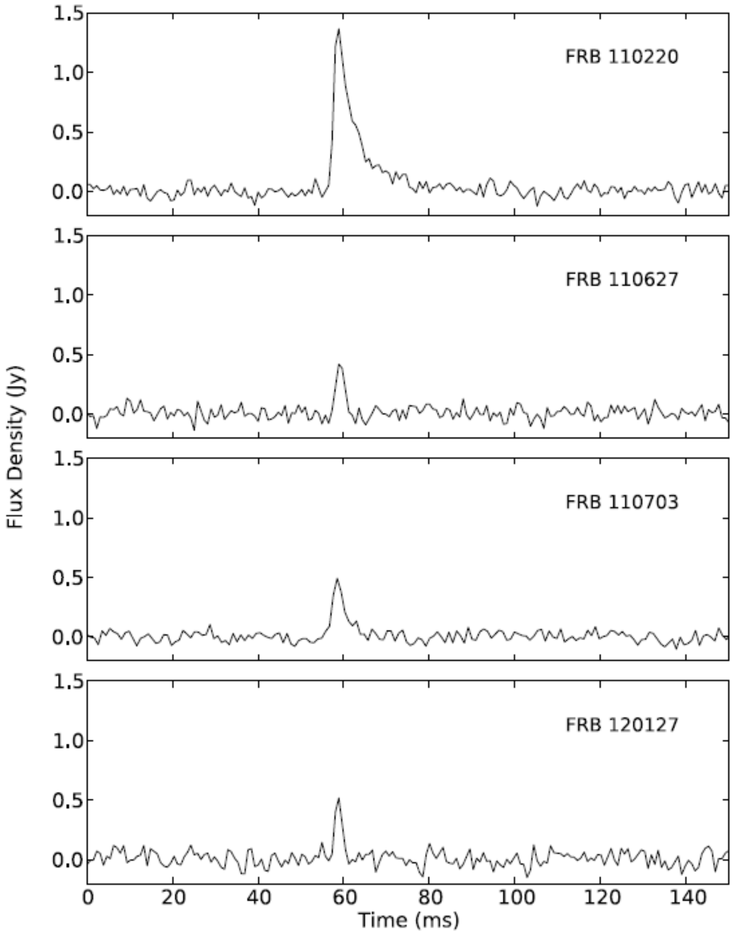
7.8 msec
0.4 Jy

Nearly in the Galactic plane

Keane et al. 1206.4135

New FRBs

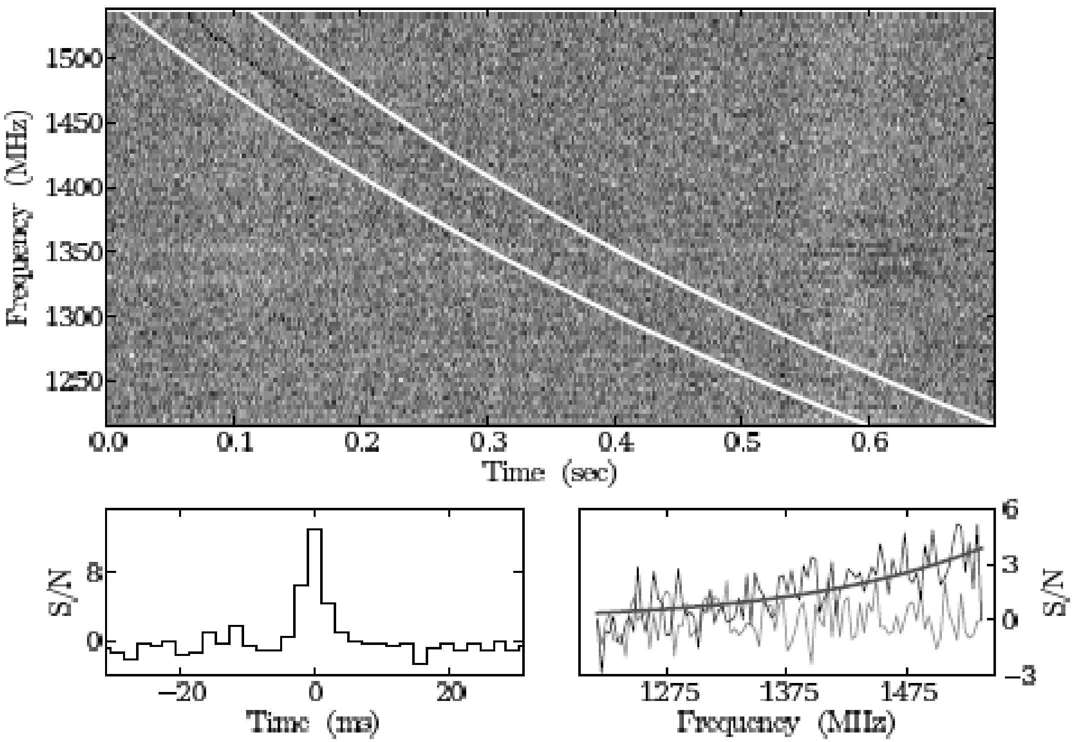
Four new bursts discovered (Parkes).
Now it is clear that we deal with a class of events.
Origin – unknown



Flux ~ 1 Jy, Fluence ~ (0.6-8) Jy ms
E_{radio}~10^{38}-10^{40} erg
DM~550-1100, z~0.5-1, d~1.7-3.2 Gpc
|b|>41^o
Rate ~$10^{4+/-0.5}$ d^{-1} sky^{-1} up to ~3 Gpc
(~100-1000 per cubic Gpc per day)

Thornton et al. 1307.1628

FRB 121102



Spilter et al. 2014

FRB011025

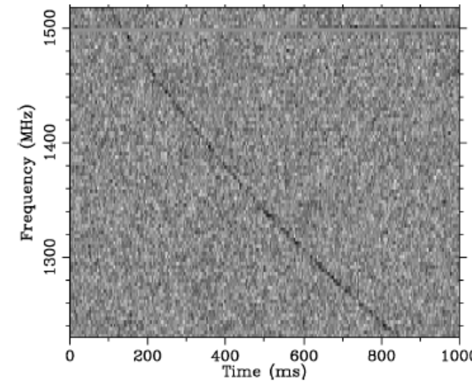
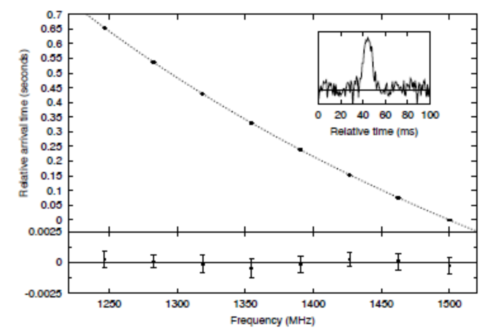
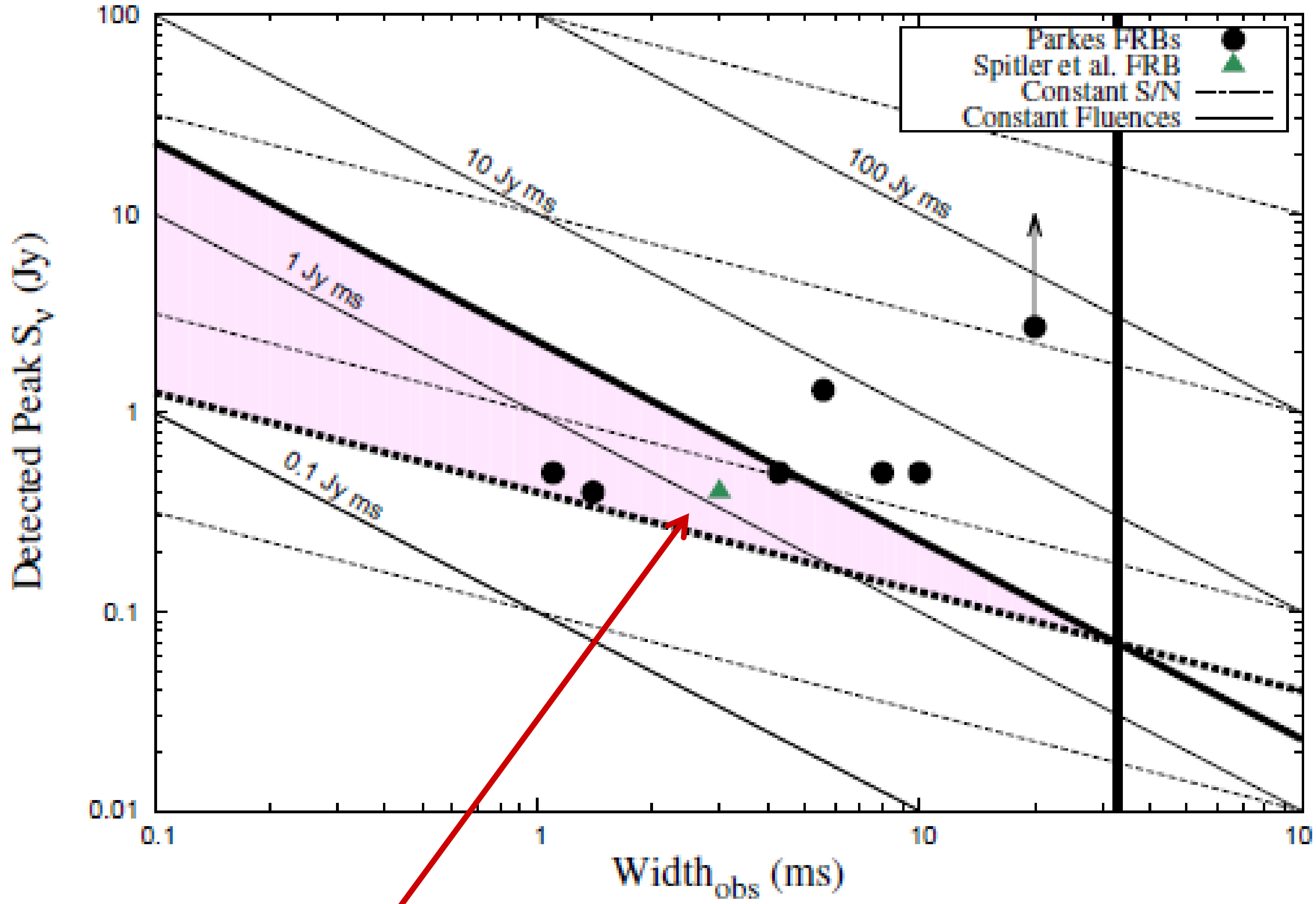


Figure 1. The spectrogram of FRB 011025, with arbitrary power scale plotted in reverse greyscale. One frequency channel containing known narrow-band interference ($f \sim 1500$ MHz) was removed.

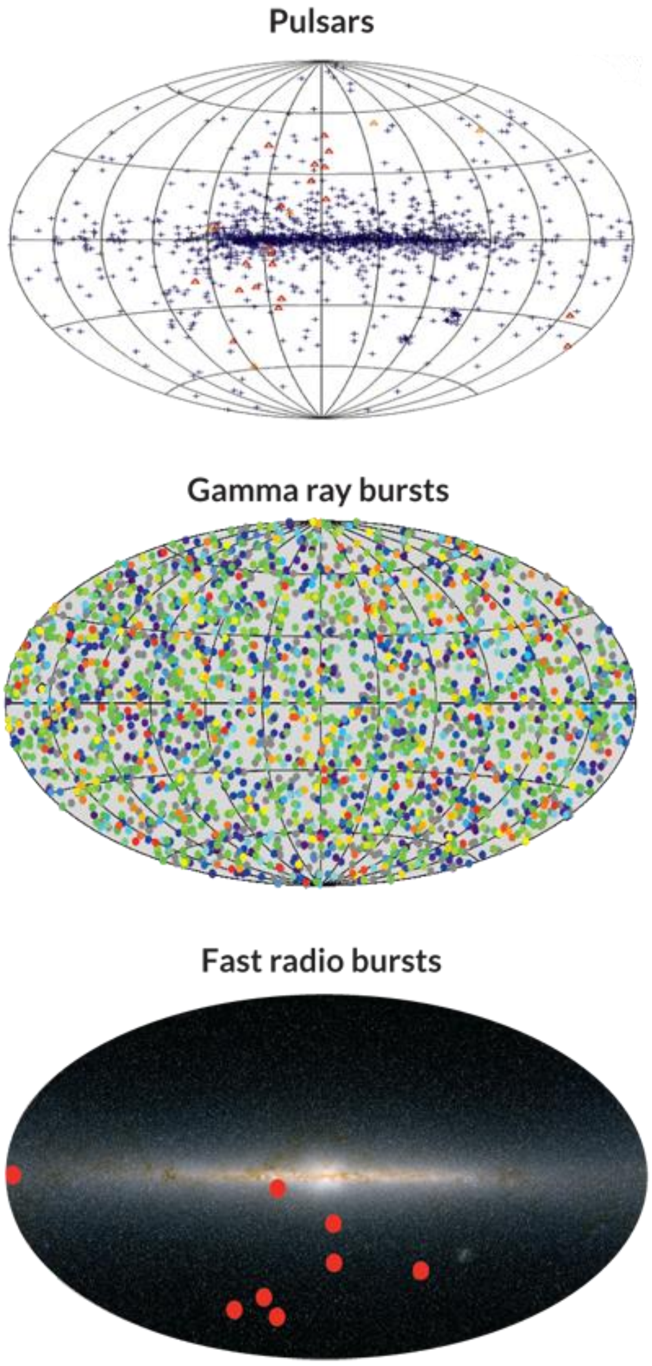


Burke-Spolaor, Bannister 1407.0400



Arecibo burst (FRB121102)
Spitler+'14

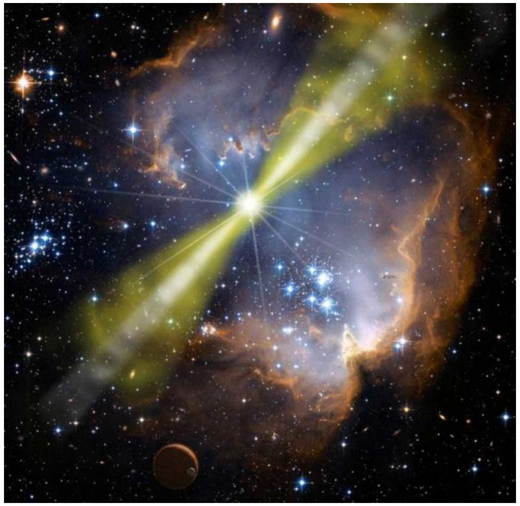
Keane 1409.6125



Sky distribution

Credits: Green Bank Telescope, West Virginia Univ; G. Fishman *et al*/BATSE, CGRO, NASA.; J. Carpenter, T.H. Jarrett/2MASS, R. Hurt, C. Crockett

Like an old puzzle ....



GRBs: 1967 – end of 90s

FRBs: 2007 - ....?

To fill-up the gap: SUPERB project

- Parkes (detection) + Molonglo (follow-up)
- PI: Keane, Bailes

Hypotheses

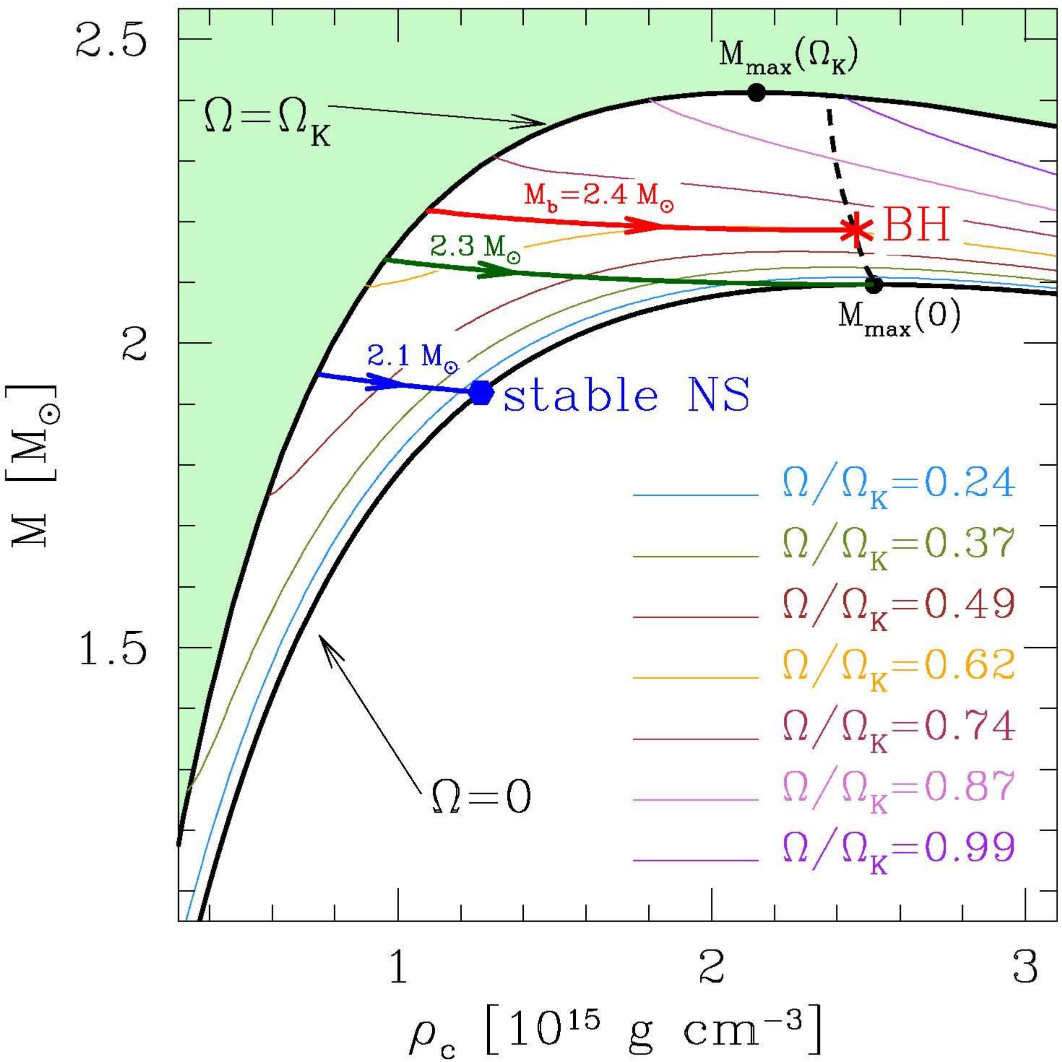
- Supramassive NSs (Falcke & Rezzolla, Zhang)
- WD+WD (Kashiyama +'13)
- Flaring stars (Loeb +'14)
- GRBs (Zhang'14)
- NS+NS merger (Totani' 13, Lipunov, Pruzhinskaya '14, this
- Magnetar giant flares (Popov, PK'07, Lyubarsky'14)
- Primordial BHs (Keane et al.)
- Superconducting cosmic strings (Yu+'14)
- Terrestrial origin(Kulkarni+'14)
- ……

In all models it is expected that emission is coherent (Katz 2013).

Brightness temperature is very high: >~10^{34} K.

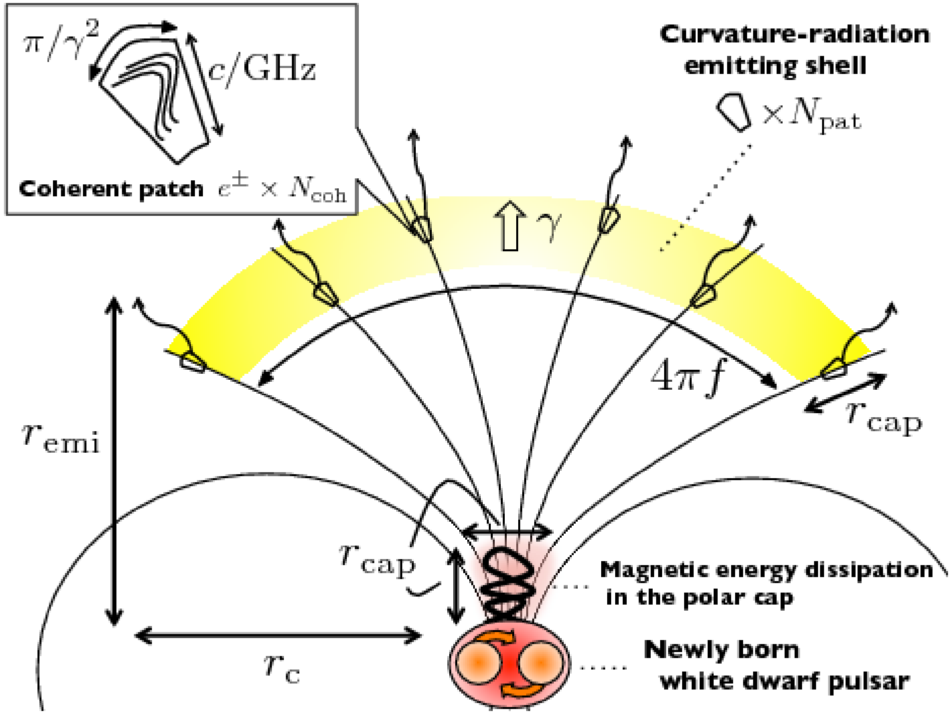
Relativistic motion can help to avoid induced Compton and Raman scattering of intense short radio pulse propagating in realistic astrophysical environments (Lyubarsky'08)

Blitzar model (Falcke & Rezzola, Zhang)



- **Test: association with GRBs**
- **Rapid radio follow-up is required**

WD+WD (Kashiyama+13)



- **Test: association with type Ia supernovae**

Kulkarni et al. analysis

This authors discuss all proposed explanations for FRBs starting with *perytons* – local events. Still, they can be an option. It is necessary to have more observations, in particular to have simultaneus observations of flares by (at least two) different telescopes.

The Galactic origin is absolutely ruled out (see also Tuntsov'14, Katz'14).

Extragalactic origin seems to be more natural.

After careful analysis of different possibilities, the authors favour the model related to giant flares of magnetars.

We have situation similar to that with GRBs in 70s-90s!

1402.4766

Volumetric Rates of Selected Cosmic Explosions

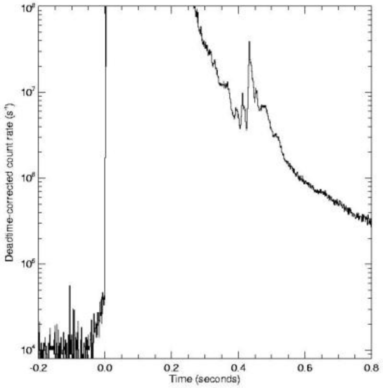
Class	Type	Φ $\mathrm{Gpc^{-3}\,yr^{-1}}$	Ref
LSB (low)	BC	100–1800	[1,2]
LSB (high)	Obs	1	[1]
	BC	100–550	[1]
SHB	Obs	> 10	[3a]
	BC	500-2000	[3b]
In-spiral	Th	3×10^3	[4]
SGR	Obs	$< 2.5 \times 10^4$	[5]
Type Ia	Obs	10^5	[6]
Core Collapse	Obs	2×10^5	[7]
FRB	Obs	$\approx 2 \times 10^4$	[8,9]

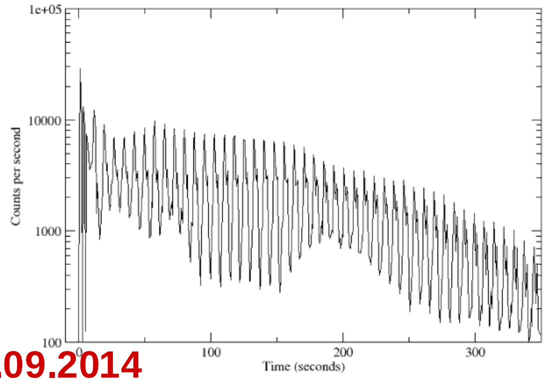
Kulkarni + ‘14

Hyperflare from an extragalactic magnetar

The rate about 100 per day per cubic Gpc is about
the expected rate of extragalactic hyperflares of magnetars.

<u>Raising time</u>
The raising part of the burst 27 Dec 2004 was about 5 msec. This is about what was observed for the mERB.
<u>No GRB was detected at the time of mERB</u>
This is natural as a hyperflare is undetectable from ~600Mpc.
<u>Host galaxy</u>
SGRs are expected to be related to starformation sites.
➔ the host galaxy can be a dusty starforming galaxy





Popov, Postnov <u>arXiv:0710.2006</u>

"Hyperflares of SGRs as an engine for millisecond extragalactic radio bursts "

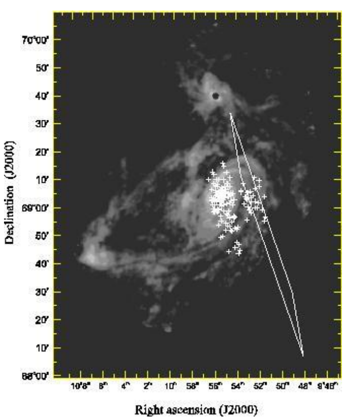
- Dedispersed width of two FRB (110220 and 011025) is consistent with being due to scattering (Katz'14) ➔ plasma parameters suggest dense hot environment (ionized starburst or a protogalaxy)
- Consistent with magnetar hypothesis

Rate of hyperflares

* The rate of hyperflares per galaxy R~1/1000 yrs (Popov, Stern ‘06)
* Lazzati+’05: R <1/130 yrs (upper limit)
This results are based on no detection of SGR bursts by BATSE towards local galaxies and Virgo cluster.

** 5-50 times lower than the galactic rate of SN.

➔ **the rate of hyperflares is expected to be ~20-200 per year per cubic Gpc, in good correspondence with FRB rate.**



Candidate bursts in local galaxies:
M81 group of galaxies: M81 itself, M82, M83
(Frederiks+’05)

More candidates
(Mazets+, Frederiks +, Golenetskii +, Ofek +, Crider ....),
including one in the direction of M31.

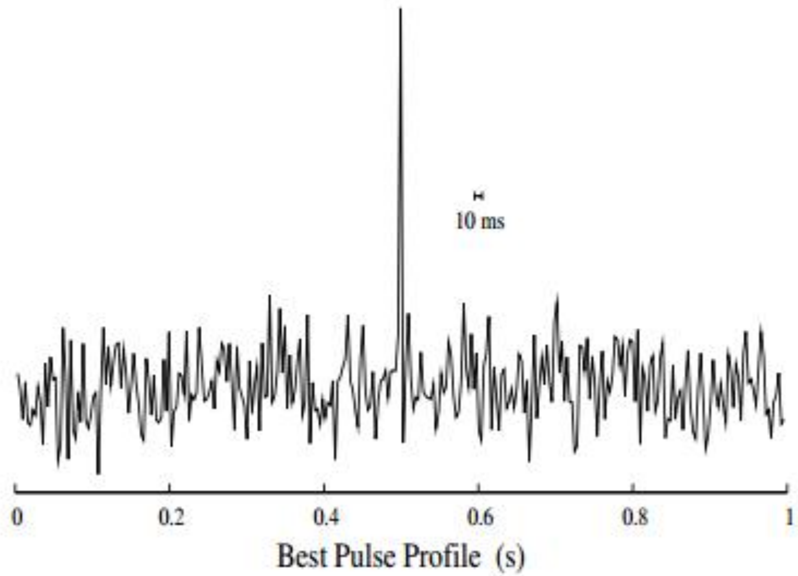
Radio bursts from M31

Rubio-Herrera +'13 reported radio bursts from M31

~1-4 Jy, millisecond duration.

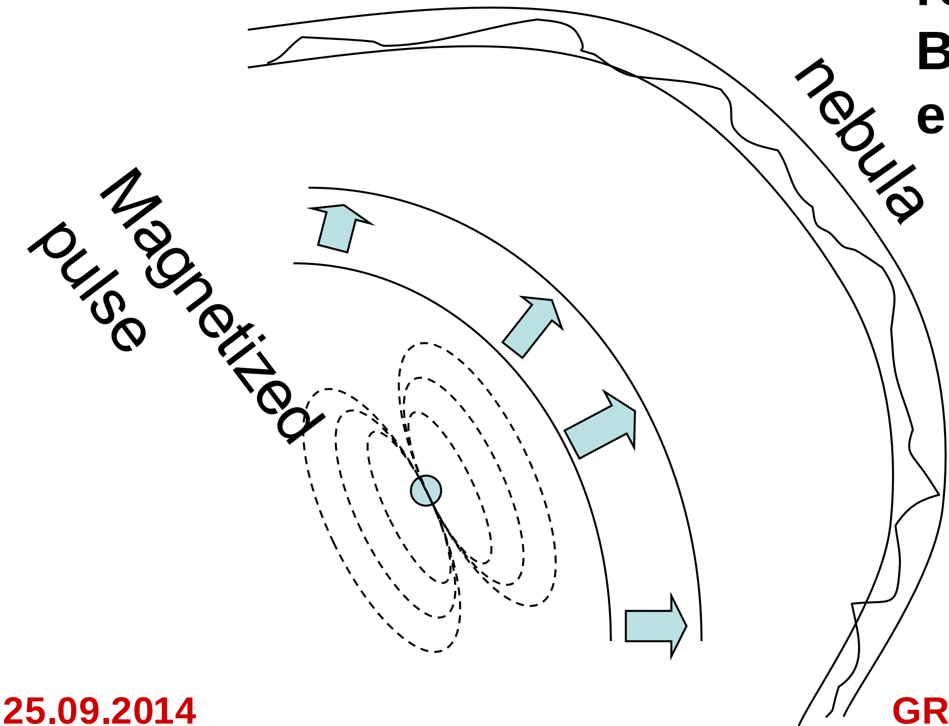
In one case, probably, repetitions.
Compatible with magnetar activity in M31

It is necessary to assume that one of magnetars in M31 was in active phase during observations. If so, the rate of bursts can be much different in future observations.



Physical model
(Y.Lyubarsky '14)

synchrotron maser emission from relativistic, magnetized shocks



Two shock waves (forward and reverse are formed after the magnetized pulse reaches the magnetar nebula.
Both shock waves can result in maser emission.

1401.6674

- Magnetosphere restructuring → magnetar giant flare → electromagnetic pulse
- Interaction with PWN (Gogus's talk)→ wind termination shock (relativistic, forward and reverse)
- Maser synchrotron GHz emission from FS ~ 10^{46} ergs (Langdon+'88, Hoshino+'92,Gallant+'92)
- TeV synchrotron emission from FS ~ 10^{48} ergs in 0.1 ms This prediction can be used to test the model.

Conclusions

- Fast Radio Bursts – a new growing class of transient phenomena
- large DM, high brightness temperature → non-thermal emission
- Origin unknown, but likely extragalactic
- Of extragalactic models, flares from magnetars are consistent with statistical properties and can be explained by a physical model