The nature of the persistent radio source associated with FRB190520B

FTSky Wrokshop, ICTS

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What are FRBs?

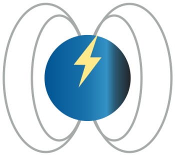
- The origin - an open question
- Are there different populations?

Repeaters | One off events?

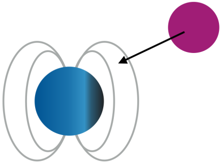
- Are there different progenitors?

e.g. : compact object mergers,

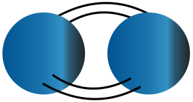
magnetars within a dense supernova



Magnetic field reconnection/ star quake



Interaction with asteroid/ axion nugget



Merger/Coalescence *

Model catalog : frbtheorycat.org. Images from Sriharsh Tendulkar's slides.

Unveiling FRB progenitors

Localisation

- Position of the burst source in the sky
- Aid in follow-up observations
- Use as probes of cosmology
- New instruments and commensal systems

EM follow-up observations

- Coupled with localisation $\rightarrow$ Insights into nature of progenitor
- Astrophysics of the environment and intervening medium
- Host studies
- Counterparts?
- Persistent emission?

Persistent Radio Sources

Persistent Radio Sources (PRSs)

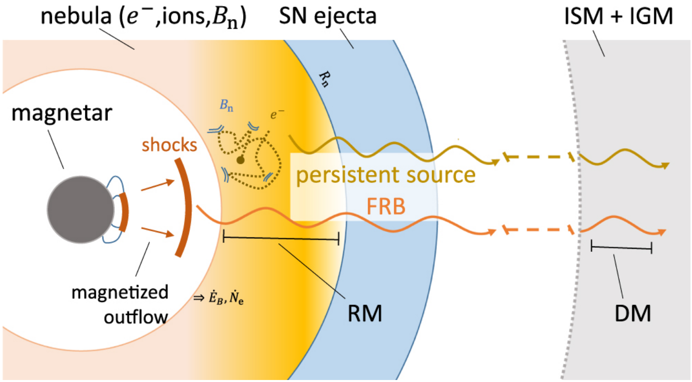
Table 2. Properties of Known FRB-PRS Systems.

Property	**FRB 20190417A**[a]	FRB 20121102A [b]	FRB 20190520B [c]	FRB 20201124A [d]	FRB 20240114A [e]
$DM_{host,rest}$ ($pc\,cm^{-3}$)	> 1212	$\lesssim 203$	137–707	150–220	142 ± 107
RM_{rest} ($rad\,m^{-2}$)	5,038–6,441	4.4×10^4–1.5×10^5	$[-3.6, +2.0] \times 10^4$	-661 ± 42	449 ± 13
z	0.128	0.193	0.241	0.098	0.130
L_ν ($erg\,s^{-1}\,Hz^{-1}$)	$\sim 8 \times 10^{28}$	$\sim 2 \times 10^{29}$	$\sim 3 \times 10^{29}$	$\sim 3 \times 10^{28}$	$\sim 2 \times 10^{28}$
ν of above	(1.5 GHz)	(1.4 GHz)	(1.7 GHz)	(1.6 GHz)	(5 GHz)
Spectral index, α	-1.20 ± 0.40	-0.15 ± 0.08	-0.41 ± 0.04	1.00 ± 0.43	-0.34 ± 0.21
Physical size (pc)	< 23	≤ 0.7	< 9	290–700	< 0.4
PRS-burst offset (pc)	< 26	< 40	< 80	< 188	~ 28
Host galaxy	Dwarf	Dwarf	Dwarf	Spiral	Dwarf

Moroianu et. al. 2025, arXiv:2509.05174 and refs. therein

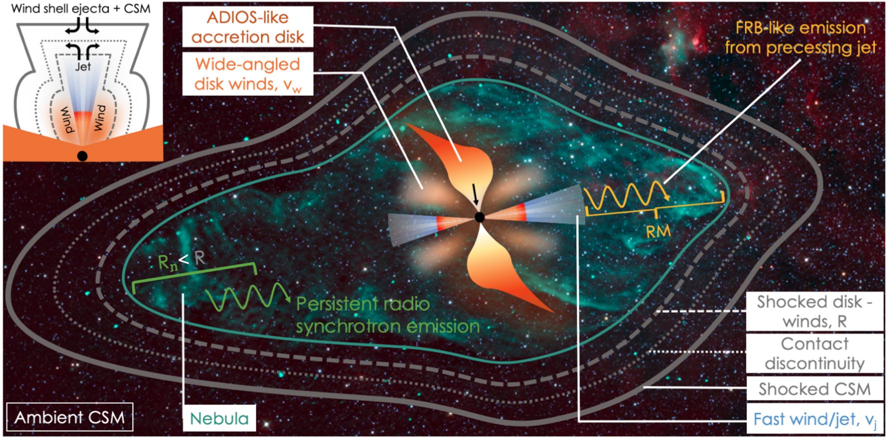
Possible Models*

Magnetar Wind Nebula Model



Murase et. al. 2016, Margalit and Metzger 2018

Hypernebula Model



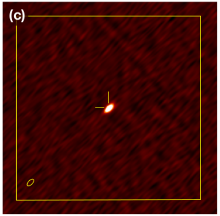
Sridhar and Metzger 2022

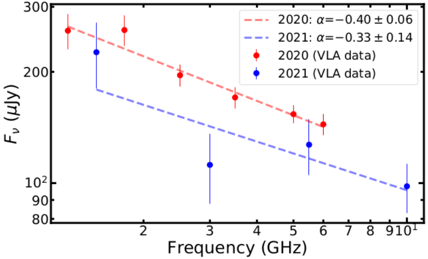
Persistent radio source associated with FRB190520B

Persistent radio source associated with FRB190520B

Small sample of sources with persistent radio emission

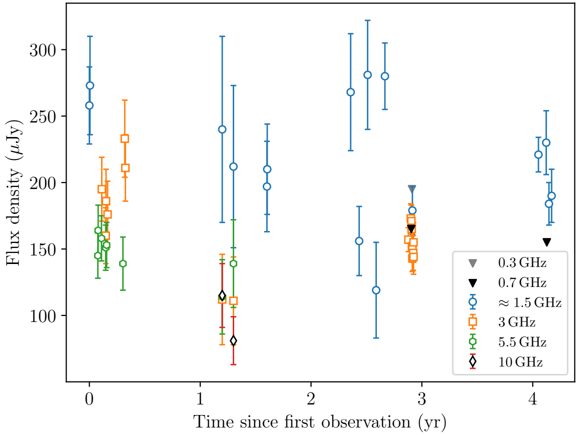
- FAST discovery and localisation to dwarf high star forming host galaxy (Niu et al. 2022)
- Associated compact PRS
- PRS spectrum resembles that of FRB121102
- Lack of low frequency observations
- Compiled long term data from uGMRT and VLA - study temporal and spectral evolution





Figures from: Niu et. al. 2022 and Zhang et al. 2023, Bhandari et. al. 2023

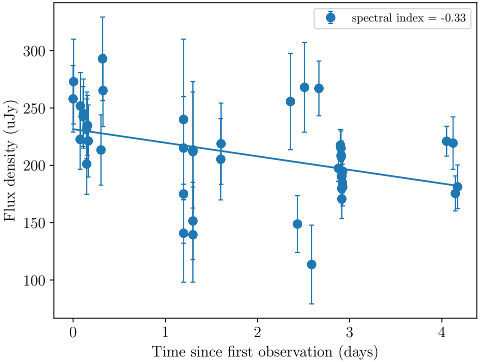
Varying flux density of PRS190520 over time



Balasubramanian et. al. 2025 under review in ApJ

Slow decay over time

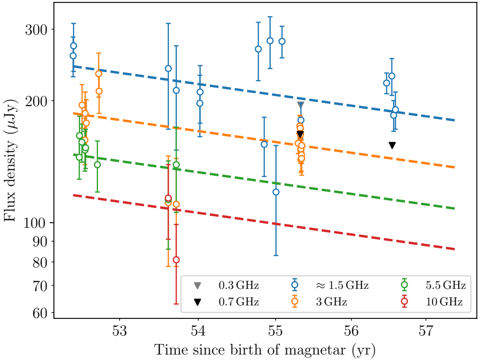
Scaled all data to 1.5 GHz assuming a spectral index of -0.33



Mann Kendall test for monotonic trends $\implies$ decreasing trend

Balasubramanian et. al. 2025 under review in ApJ

Constraint on age of magnetar

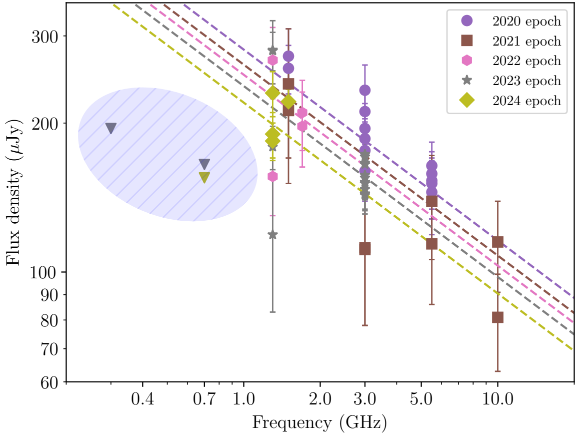


Contraint on magnetar wind nebula $t_{\text{age}} \approx 52$ years

Hypernebula model does not predict a decay at these timescales*

Balasubramanian et. al. 2025 under review in ApJ, * Sridhar et. al. 2022

Break in the spectrum below 1 GHz

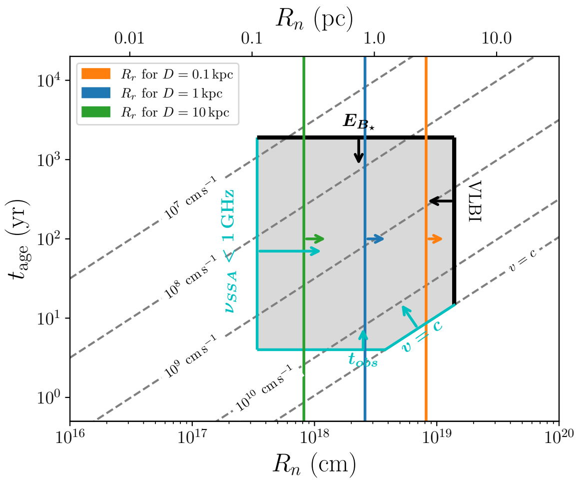


Break in spectrum below 1 GHz

Balasubramanian et. al. 2025 under review in ApJ

Scintillation? – Constraints on size

Conservative lower limit on size of PRS



Bhandari et. al. 2023, Balasubramanian et. al. 2025 under review in ApJ

Summary

- Progenitor of FRBs – an open question
- Need better localisation and follow-up observations
- Small fraction of sources associated with persistent radio source
  - great candidates to understand FRB origins
- PRS associated with FRB190520B
  - slow decay of flux density with time
  - constraint on age of magnetar if powered by a MWN
  - spectral break at frequencies < 1 GHz
  - observed variability due to scintillation?


Thank You!
Any Questions?

Backup-1 : MWN model that was fit

Energy injection from the magnetar

$$\dot{E} = (\alpha - 1)\frac{E_{B_\star}}{t_0}\left(\frac{t}{t_0}\right)^{-\alpha} \quad \text{for} \ \ \mathrm{t} \geqslant \mathrm{t}_0, \quad \text{ff} > 1 \tag{1}$$

Flux density decay

$$F(\nu, t) = A\,\nu^{-\left(\frac{\alpha-1}{2}\right)}\left(\frac{t_{\rm obs} + t_{\rm age}}{t_{\rm age}}\right)^{-\left(\frac{\alpha^2+7\alpha-2}{4}\right)}, \tag{2}$$

Margalit and Metzger 2018 ApJL 868 L4

Backup-2 : Scintillation calculations

$\theta_F = \sqrt{c/2\pi\nu D}$ $\quad \xi = (\nu_0/\nu)^{17/10}$ $\quad \nu_0 = 12.53\,\mathrm{GHz}$ (NE2001) $\quad d_{\mathrm{lum}} = 1218\,\mathrm{Mpc}$

if $D = 1\,\mathrm{kpc}$

Expected modulation $$m_{\mathrm{exp}} = \xi^{-1/3} = \left(\frac{\nu}{\nu_0}\right)^{17/30} = 0.29 \tag{3}$$

Angular size of screen $$\theta_r = \theta_F \xi = 276.6\,\mathrm{mas} \tag{4}$$

Physical size of screen $$R_r = \theta_r d_{\mathrm{lum}}/2 = 5.0 \times 10^{18}\,\mathrm{cm} = 1.6\,\mathrm{pc} \tag{5}$$

Refractive scintillation timescale $$t_r = 2\left(\frac{\nu_0}{\nu}\right)^{11/5} = 10.2\,\mathrm{days} \tag{6}$$

Observed modulation $$m_{\mathrm{obs}} = \frac{1}{\overline{F_i}}\sqrt{\frac{N}{N-1}\left(\overline{F_i^2} - \overline{F_i}^2\right)} \tag{7}$$

Scintillation calculation contd.

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Dataset	t_r (days)	m_exp	m_obs	Characteristic sizes and time scales									modified t_r (days)	New nu_0 (GHz)
				Screen distnance = 0.1 kpc			Screen distance = 1 kpc			Screen distance = 10 kpc				
				theta_F (uas)	theta_r (pc)	theta_s (pc)	theta_F (uas)	theta_r (pc)	theta_s (pc)	theta_F (uas)	theta_r (pc)	theta_s (pc)		
Data as it is	10.20	0.29	0.23	21.44	5.30	6.48	6.78	1.68	2.05	2.14	0.53	0.65	12.80	18.93
Removing best fit line			0.22			6.80			2.15			0.68	13.43	20.92