A fast radio burst from a magnetar?



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What is an FRB?

FRB = Fast Radio Burst

Fast = Millisecond duration

Large dispersion measure (DM) \rightarrow Extragalactic (DM implied z ~ 0.1 - 3)

 \rightarrow Intrinsically bright (10³⁷ - 10⁴² erg)

Origin unknown!

630 published FRB sources24 with detected repetition

First CHIME/Catalog: 536 FRBs 1000s more to come in Catalog 2.







National Radio Astronomy

Yale 14117











CHIME/FRB is people.

1.00



Credit: Cherry Ng



Credit: Cherry Ng

Models for FRBs

Platts et al. 2018: "A Living Theory Catalog for Fast Radio Bursts" <u>https://frbtheorycat.org</u>

50+ theories



Magnetar giant flares, Giant pulses from pulsars Magnetized shocks in accreting binaries

Cataclysmic:



Collapse of compact object (e.g. supramassive NS -> BH; "blitzar")



Mergers: NS-NS, NS-BH, WD-WD, ...

So what's a magnetar?

A magnetar is a pulsar with a high magnetic field.

Magnetic field powers:

- High X-ray luminosity $(L_x > \dot{E})$
- Radiative activity in X/ɣ-ray:
 - Outbursts [weeks years]
 - Bursts [ms s]
 - Flares [s hrs]
- Rotational timing variations



Magnetars as FRBs

Magnetars have been a popular model for repeating FRBs:

- Short duration = compact object
- High magnetic is large reservoir for powering energetic bursts
- Many theories on how to generate FRBs from that reservoir.



FRB 20121102A: "The repeater"



HST Image (Bassa et al. 2017)



Lots of evidence for magnetar from first repeater :

- It repeats!
- Localized to star forming knot in a low-metallicity dwarf galaxy
 - Environment where young magnetars expected
- Co-located with bright radio point source
 - Central BH? Young SNR? Magnetar wind nebula?
- ~100% polarized with extreme Faraday rotation
 - Dense highly-magnetized environment.
 From central BH? Magnetar wind nebula?

z = 0.19

On April 28, 2020...

TITLE: GCN CIRCULAR NUMBER: 27665 SUBJECT: A Forest of Bursts from SGR 1935+2154 DATE: 20/04/28 14:28:46 GMT FROM: David Palmer at LANL <dmopalmer@gmail.com>

A Forest of Bursts from SGR 1935+2154

David M. Palmer (LANL) reports on behalf of the BAT Team:

At 18:26:20 of 2020-04-27 UT, the Swift Burst Alert Telescope (BAT) triggered and located a burst from the Soft Gamma Repeater SGR 1935+2154 (Trigger #968211) (GCN #27657; Barthelmy et al.). This burst, and many subsequent bursts described below, continuing to at least T+7 hours (the time of this writing) were also seen by Fermi/GBM (GCN #27659; Fletcher et al.)





On April 28, 2020...



Plot from CHIME/FRB internal viewer

Parameters	Values	
Event	82373240	
Beam	2067	
DM	332.57	
RA	315.1979928185	
Dec	25.1064648113	
Subbands	64	
Binning	1	
Time per sample (ms)	0.98304000000001	
L1 SNR	44.9272766113	
Intensity SNR	0	
Pulse Width	null	

20

15

10

5

Paul Scholz 11:28 AM

its a sidelobe and not that far off in dec from 21 deg



22° NOT TO SCALE, GALACTIC PLANE NOT

REPRESENTATIVE OF TIME OF DETECTION

Credit: Cherry Ng

Upon further investigation:

- Localization using model of beam response:
 - Position consistent with SGR 1935+2154
- DM = 332.8 pc/cc
 - Consistent with galactic origin and estimated distance to SGR 1935+2154

 \rightarrow It's a radio burst from SGR 1935+2154!



Scholz & CHIME/FRB Collaboration (2020), ATel 13681

Algonquin Radio Observatory





Wikipedia

CHIME/FRB Collaboration (2020)

STARE2 detection



Sacramento

OVRO

Francisco San Jose



[dB]

So how bright was it?

An order of magnitude or two less energetic than the faintest FRBs.

Not too far off, vastly narrows gap between Galactic magnetars and FRBs!

CHIME/FRB Collaboration (2020)



X-ray Burst

Detected by:

INTEGRAL (Mereghetti et al. 2020), Insight-HXMT (Li et al. 2021), Konus-Wind (Ridnaia et al. 2021), NICER (Younes et al. 2021), AGILE (Tavani et al. 2021)

X-ray burst counterpart to radio burst is:

- Not exceptional in detected flux
- An outlier spectrally, much harder spectrum than other X-ray bursts



NICER Younes et al. (2021)



not really...

So are FRBs magnetars?

Problems: Activity and Energetics

- FRB repetition rates up to ~10⁶ x higher than galactic magentars.
- FRBs energies up to ~10⁸ x higher than SGR 1935+2154 radio burst.

Large gaps to bridge!

Solution?

Young super-energetic magnetar?



Margalit et al. (2020)

So are FRBs magnetars?

Problem: Environment

Galactic magnetars are tightly clustered in galactic plane in spiral arms (Olausen & Kaspi 2014)

Because:

- Magnetars formed in core-collapse supernovae.
- Magnetars have short active lifetime so are found near their birth locations.



Olausen & Kaspi (2014)

European VLBI Network

PRECISE

Pinpointing Repeating CHIME Sources with EVN dishes

Jason Hessels Franz Kirsten Benito Marcote Kenzie Nimmo



Image credit: Danielle Futselaar, www.artsource.nl

FRB 20180916B (R3)

- FRB is 250 pc from star-forming region → 0.8 - 7 Myr to travel
- >> 0.01 Myr age for active magnetar

Magnetar doesn't quite fit



EVN localization: Marcote et al. (2020) **HST Imaging:** Tendulkar et al. (2020)



Bhardwaj et al. (2021)



- CHIME/FRB localization → Halo of M81 (Bhardwaj et al. 2021)
- PRECISE-EVN localization → M81 globular cluster (Kirsten et al., 2022)

Magnetar formed by accretion induced collapse or merger?

Not a magnetar?

FRB 20201124A



Keck ESI Image: Xu et al. (2021) arXiv:2111.11764

PRECISE-EVN Localization: Nimmo et al. (2021) arXiv:2111.01600



Location, Location, Location



FRB 20121102A

Environment supports CCSN magnetar origin.



Alternate magnetar formation channels? Non-magnetar origin?

Wouldn't it be nice if we just had VLBI localizations for all FRBs?

CHIME Outrigger Project





Photos credit: CHIME/FRB Collaboration, Jane Kaczmarek, Kevin Bandura, Jojo Boyle



Image Credit: Pranav Sanghavi

First VLBI-level localization of one-off FRB!



Cassanelli et al. (2022) submitted

Summary

- FRBs are still an interesting mystery!
- SGR 1935+2154 shows some FRBs are likely magnetars!
- But magnetars can't explain everything.
- CHIME/FRB and its outriggers will continue to untangle FRB origin.