Searching for Fast Radio Bursts from radio wavelengths to very high-energy gamma-rays

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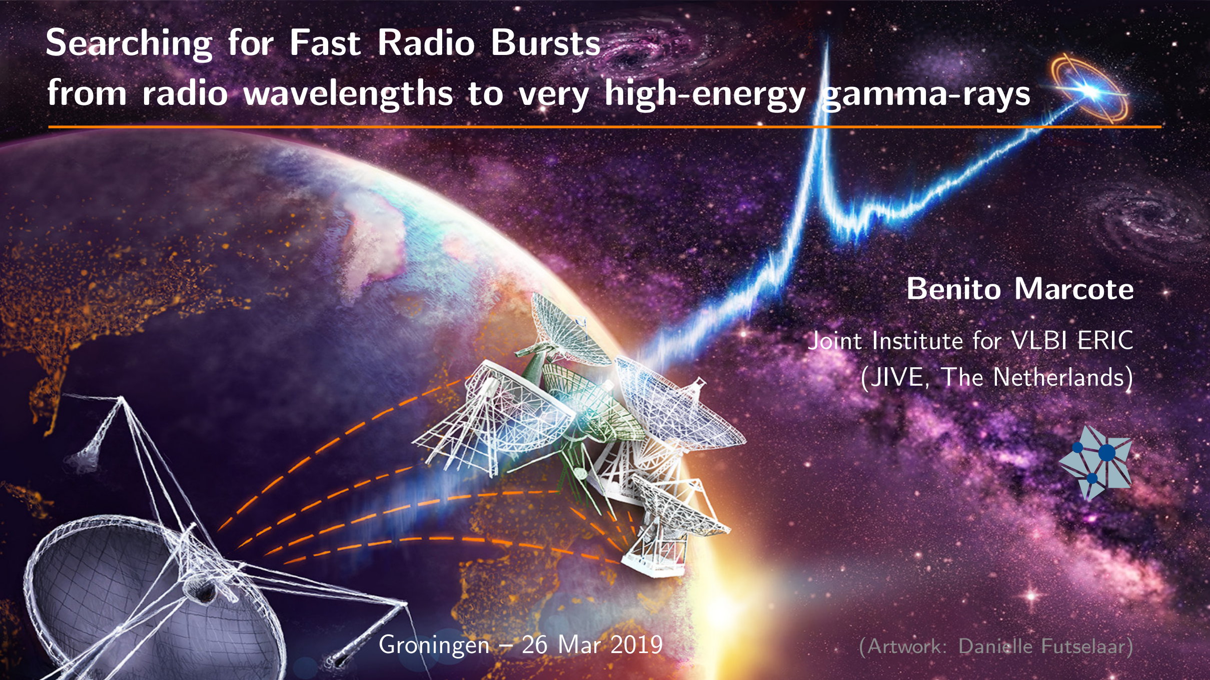
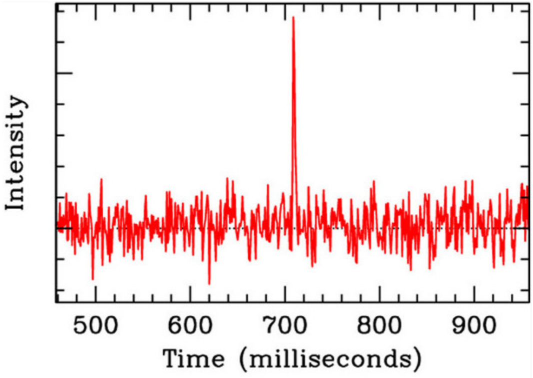


(Artwork: Danielle Futselaar)

Fast Radio Bursts (FRBs)

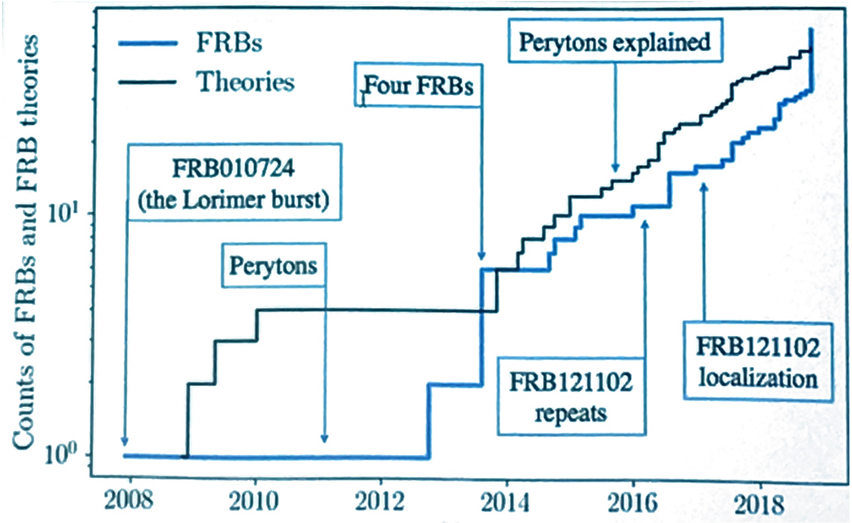
- **Fast and strong radio flashes**
- Duration of a few milliseconds
- Discovered by Lorimer et al. (2007)
  Many FRBs known to date
- Only a few show multiple bursts
- Rate: $\sim 10^{3–4}$ sky^{-1} day^{-1}
- Origin: unknown



FRB 140514

Do FRBs exhibit multi-wavelength/messenger emission?

Possible origins of FRBs



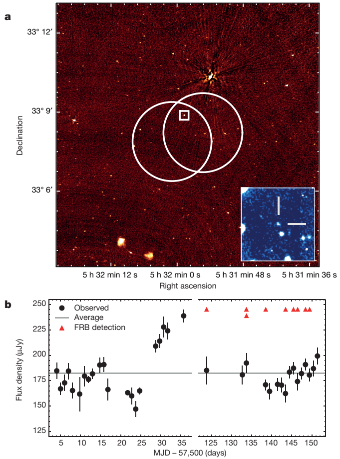
Credit: V. Ravi


Merging Black Holes
Supernovae
Magnetars
Evaporating Black Holes
Super-giant Pulses
The Unknown
extra-Galactic
Implied rate of 1000s per day, per sky... but what are they?
Gamma-ray Bursts
Micro-quasars
Flare stars
Galactic
SETI
Pernicious RFI
Atmospheric effects
"Blitzars"
Magnetars
We are here
Pulsars
Credit: Jason Hessels

The first repeater FRB 121102

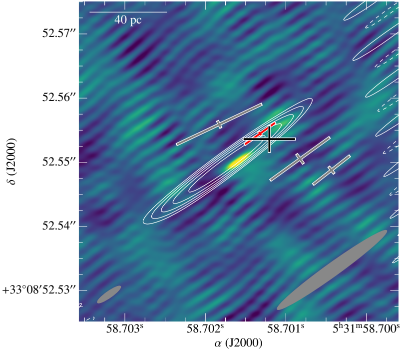
- The first repeater:
  Spitler et al. (2014, 2016), Scholz et al. (2016)
- $L_{\text{bursts}} \sim 10^{42}$ erg s^{-1}
- Low-metallicity star-forming dwarf galaxy
- $z = 0.193, \quad L_{\text{d}} = 972$ Mpc
- Persistent and compact radio source < 0.7 pc
- $L_{\text{persistent}} = 3 \times 10^{38}$ erg s^{-1}
- Variability ($\sim 10\%$) uncorrelated with bursts

The first repeater FRB 121102

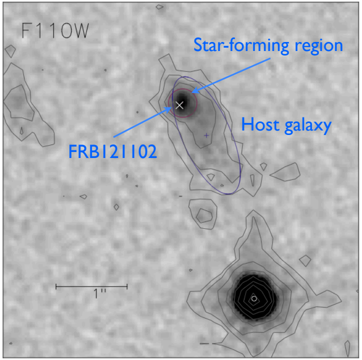


Chatterjee et al.

(2017, Nature, 541, 58)



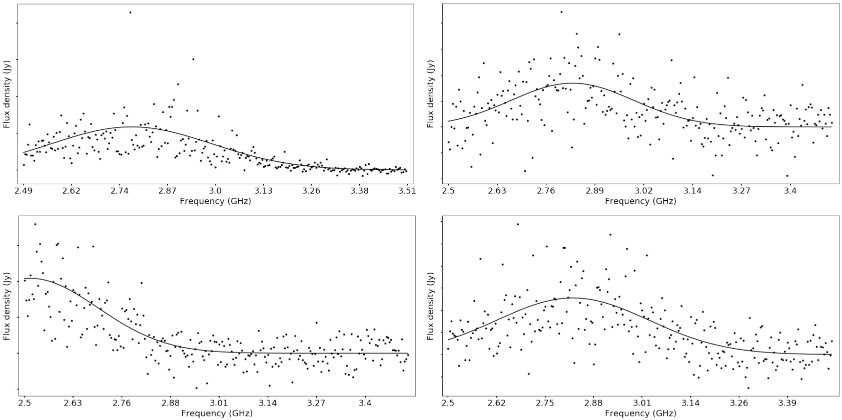
Marcote et al. (2017, ApJL, 834, 8)



Tendulkar et al. (2017, ApJL, 834, 7)

Bassa et al. (2017, ApJL, 843, 8)

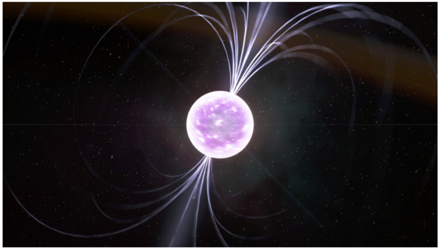
The first repeater FRB 121102



Bursts seem to be localized in frequency, with typical widths of hundreds of MHz.

Law et al. (2017, ApJ, 850, 76L)

Possible origins of FRB 121102



- Pulsar/magnetar powering up a young superluminous supernovae?
  (e.g. Margalit et al. 2018, Metzger & Margalit et al. 2019)

- Young pulsar/magnetar interacting with a massive black hole?
  (e.g. Pen & Connor 2015, Cordes & Wasserman 2016, Zhang 2018)

Different scenarios. . . different expectations

- **In a magnetar scenario**. . .
  Quasi-simultaneous X-ray to MeV gamma-ray bursts
  X-ray/radio $\sim 10^4$ (Lyutikov 2002)
  $\sim 10^{42\text{–}43}$ erg s^{-1} above 1–10 keV for 0.1–1 s
  $\sim 10^{45\text{–}46}$ erg s^{-1} above MeV–GeV for 0.1–10 ms (Metzger et al. 2019)
- **Ultrarelativistic outflows interacting with the nebula**. . .
  TeV flashes, TeV/radio $\sim 10^{5\text{–}6}$ (Lyubarsky 2014, Murase et al. 2016)
- **Synchrotron maser emission. . .**
  TeV bursts "could" happen if external shock strong enough (Lyubarsky 2014)
- ***B* reconnections near the magnetar surface. . .**
  Bursts up to optical wavelengths: independent ones, lower rate (Kumar et al. 2017)
- **Coherent curvature emission. . .**
  Only radio bursts (Ghisellini & Locatelli 2017)

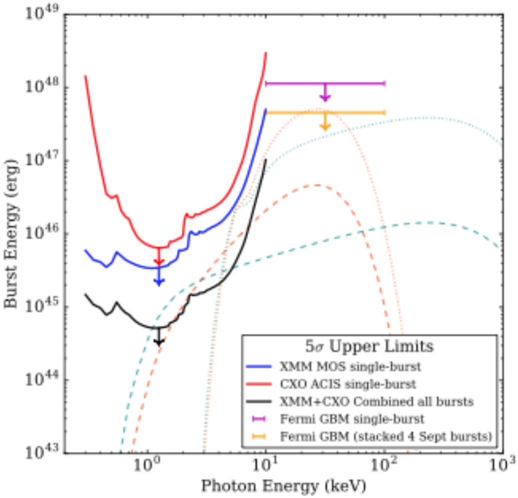
Searches at other wavelengths

- **Radio & optical observations**

  $\lesssim 3.2$–20 mJy (10–0.1 ms)
  Radio-to-optical slope $\lesssim -0.32$
  (giant Crab pulses: ~ -0.2)
  (MAGIC Collaboration et al. 2018)

- **Radio & X-ray observations**

  Simultaneous: $\lesssim 4 \times 10^{45}$ erg
  At any time: $\lesssim 6 \times 10^{46}$ erg
  (Radio-to-X ratio $< 10^{-6}$–10^{-8})
  (Scholz et al. 2017)



Scholz et al. (2017)

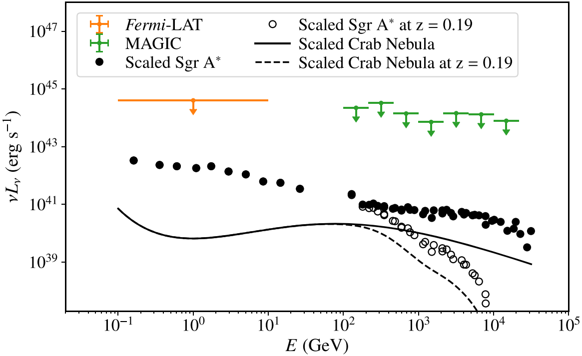
Simultaneous radio, optical and TeV observations

Bursts at other wavelengths:

- $L_{>0.1\ \mathrm{TeV}} \lesssim 3 - 14 \times 10^{49}$ erg s^{-1}
- Imply a released energy $E_B \lesssim 10^{48}$ erg
- Hyper-flares from magnetars:
  $E_B \sim 10^{46}$ erg
- $\sim$ 500 bursts required, or CTA!

Persistent counterpart:

$F_{1\text{–}0.1\ \mathrm{TeV}} \lesssim 0.5\text{–}20 \times 10^{44}$ erg s^{-1}



(MAGIC Coll. et al. 2018, MNRAS, 481, 2479)

Conclusions

- Large number of FRBs discovered nowadays.
- FRB 121102 is still the only deeply studied FRB.
- All burst emission has been observe at 0.4–6 GHz
- Searches from infrared to gamma-ray observatories are required.
- Constraining models: giant Crab pulses-like? Magnetar?
- Lack of sensitivity at X-ray and gamma-rays: nearby FRBs, or CTA.

Thank you!