



*Detecting Fast Radio Bursts  
at the lowest frequencies and with the highest accuracy localizations*

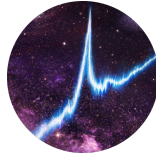
**Benito Marcote**  
Joint Institute for VLBI ERIC



**JIVE**  
Joint Institute for VLBI  
ERIC

## Introduction

- What is a Fast Radio Burst?
- Why do we care about FRBs?
- Localizing FRBs



## Challenges on FRB-VLBI localizations

- The only two mas localizations – with the EVN
- The uGMRT as a boost on EVN observations
- The uGMRT as simultaneous connected interferometer



## Summary and conclusions

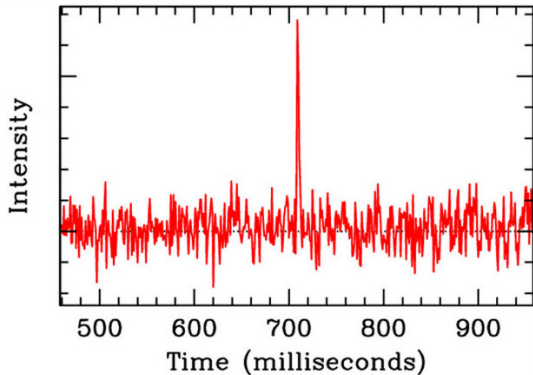
# Introduction

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# What is a Fast Radio Burst (FRB)?



- **Fast**  
Duration of  $\sim 10 \mu\text{s}$ –10 ms
- **Radio**  
Observed at 0.4–8 GHz
- **Burst**  
Bright  $\sim 0.1$ –100 Jy
- Discovered by [Lorimer et al. \(2007\)](#)
- Hundreds of them reported  
[\(Petroff et al. 2016\)](#)  
Dominated by CHIME/FRB detections



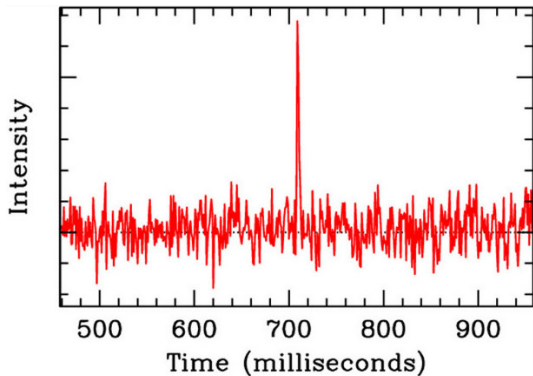
FRB 140514



# What is a Fast Radio Burst (FRB)?

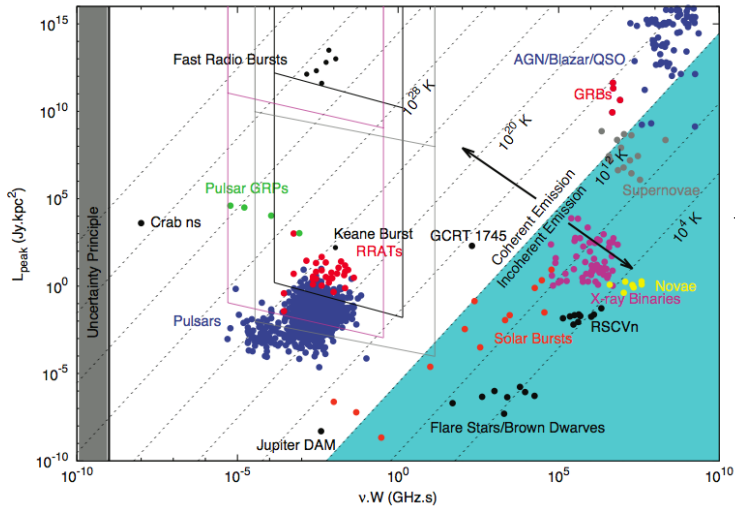


- Origin: unclear.
- Rates:  $\sim 10^{3-4} \text{ sky}^{-1} \text{ day}^{-1}$   
 $> 10^5 \text{ Gpc}^{-3} \text{ yr}^{-1}$
- Only a fraction show multiple bursts.
- Most of them poorly localized ( $\sim \text{arcmin}$ )  
No associated counterparts.
- Extragalactic: redshift  $\sim 0.1-3$ .
- One “Galactic FRB” (SGR J1935+2154).



FRB 140514

# The luminosity “problem”

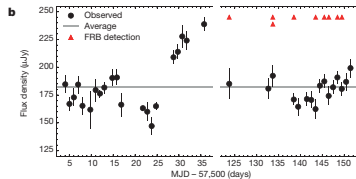
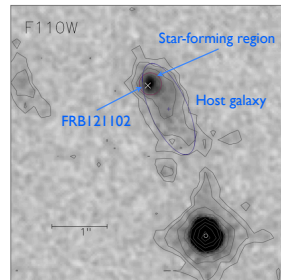
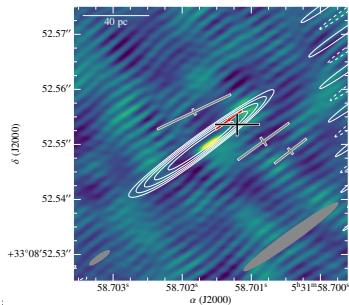
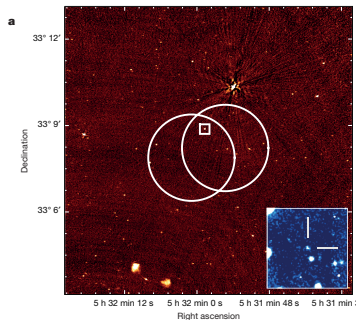


Pietka et al. (2015)



- FRBs look like single pulses from pulsars but  $\sim 10^{10}$  more luminous.
- Possible emission from radio to gamma-rays?
- Trace properties of the intergalactic medium (IGM).
- Can probe the reionization history of H and He in the Universe.
- Constraints on fundamental physics (equivalence principle, photon mass,...).
- Constrain the baryon content of the Universe, ...

# The first known repeater: FRB 121102



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

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

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

Chatterjee et al. (2017, Nature, 541, 58)



Study of the persistent emission.

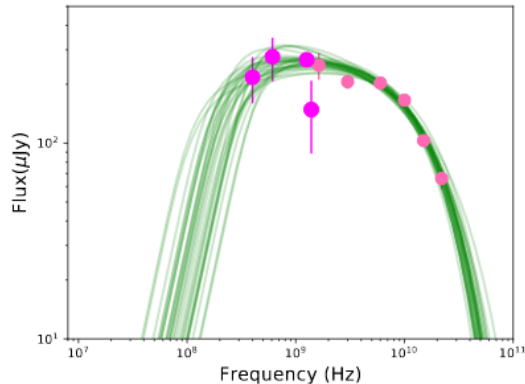
VLA spectra from 1–20 GHz.

uGMRT to recover the low-frequency part.

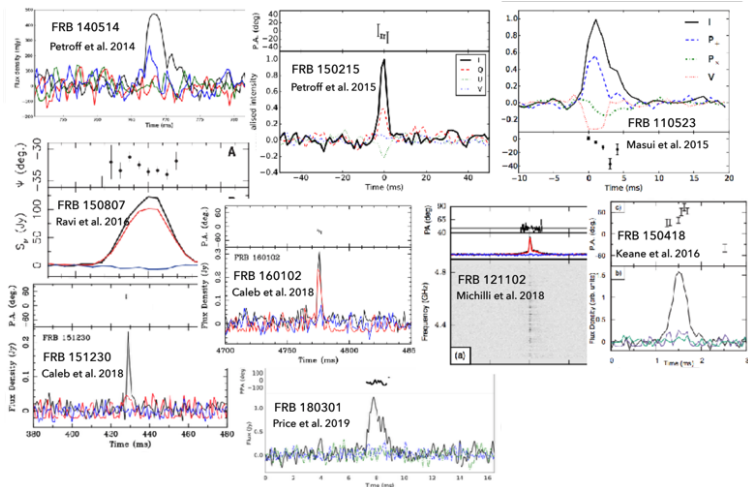
Providing constraints on  $B$ ,  $t_{\text{age}}$ ,  $\nu$ .

Resmi, Vink & Ishwara-Chandra (2020)

On-going GMRT-LOFAR studies.



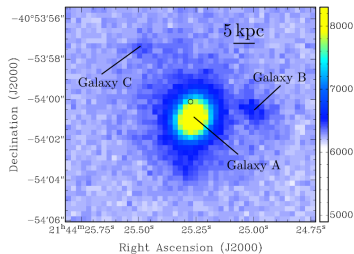
# FRB polarization profiles



Credit: M. Caleb

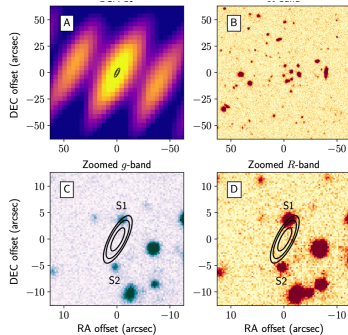


## Localizations of (apparently) non-repeating Fast Radio Bursts to arcsecond level (ASKAP, DSA)



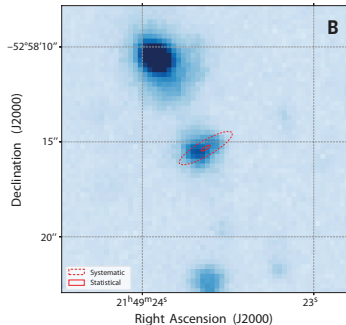
Lenticular galaxy at  $z \sim 0.3$

Bannister et al. (2019)



Elliptical galaxy at  $z \sim 0.66$

Ravi et al. (2019)

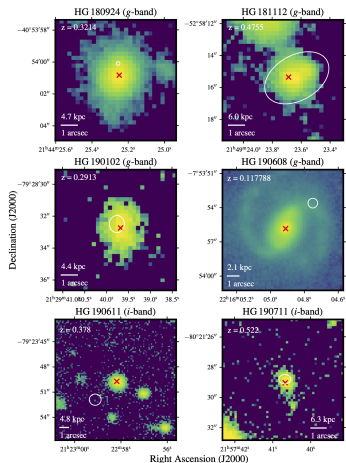


Star-forming galaxy at  $z \sim 0.5$

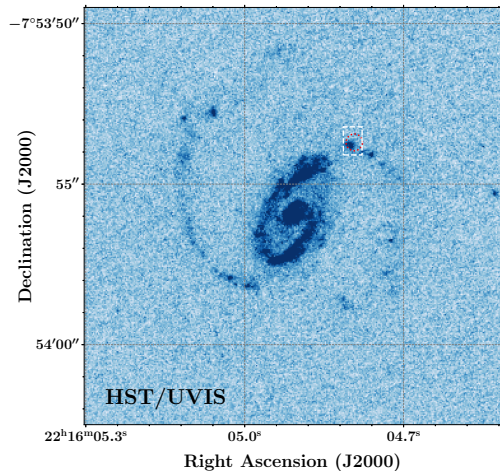
Prochaska et al. (2019)



## Localizations of (apparently) non-repeating Fast Radio Bursts to arcsecond level by ASKAP



Macquart et al. (2020)



Chittidi et al. (2020)



# The precise localization of a second repeating FRB



EVN observations of CHIME repeaters since 2018  
(PIs: Marcote, Nimmo, Kirsten)

Success on FRB 180916.J0158+65:

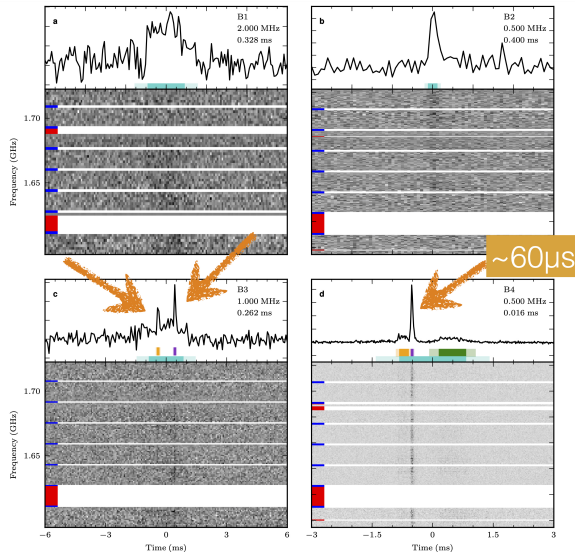
- The most active FRB from CHIME data
- Potentially the closest one (low DM)

Three EVN observations during 2019 at 1.7 GHz

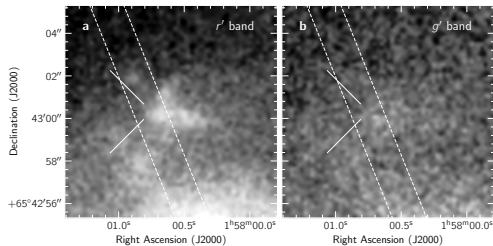
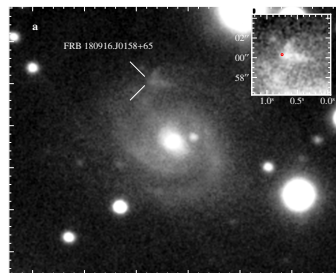
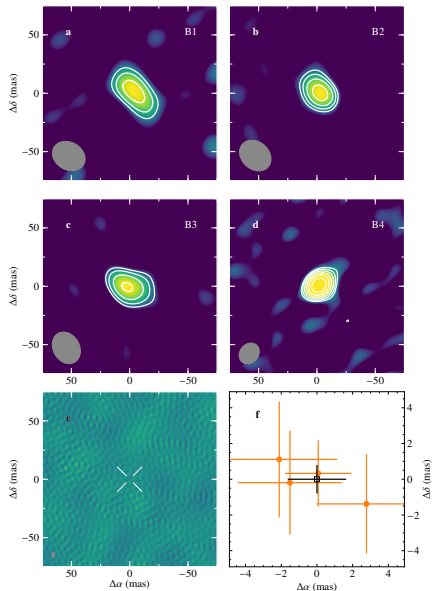
Eight telescopes + Effelsberg parallel recording

Four bursts detected on 19 June 2019

Marcote et al. (2020, Nature, 577, 190)



# The precise localization of a second repeating FRB: 180916





15 bursts detected with the uGMRT

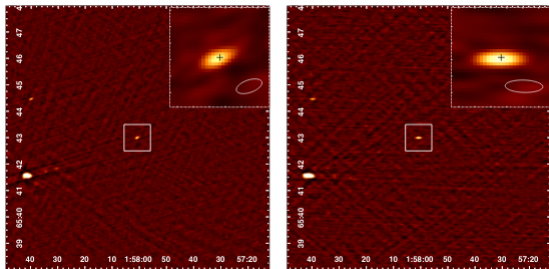
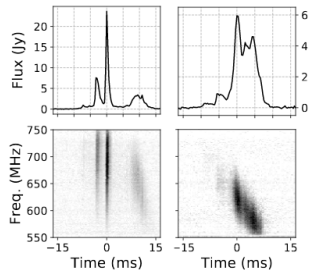
550–750 MHz

Three 2-h observations  
(detecting 0, 12, and 3 bursts)

All beamforming detections

Two of them also visible in image plane

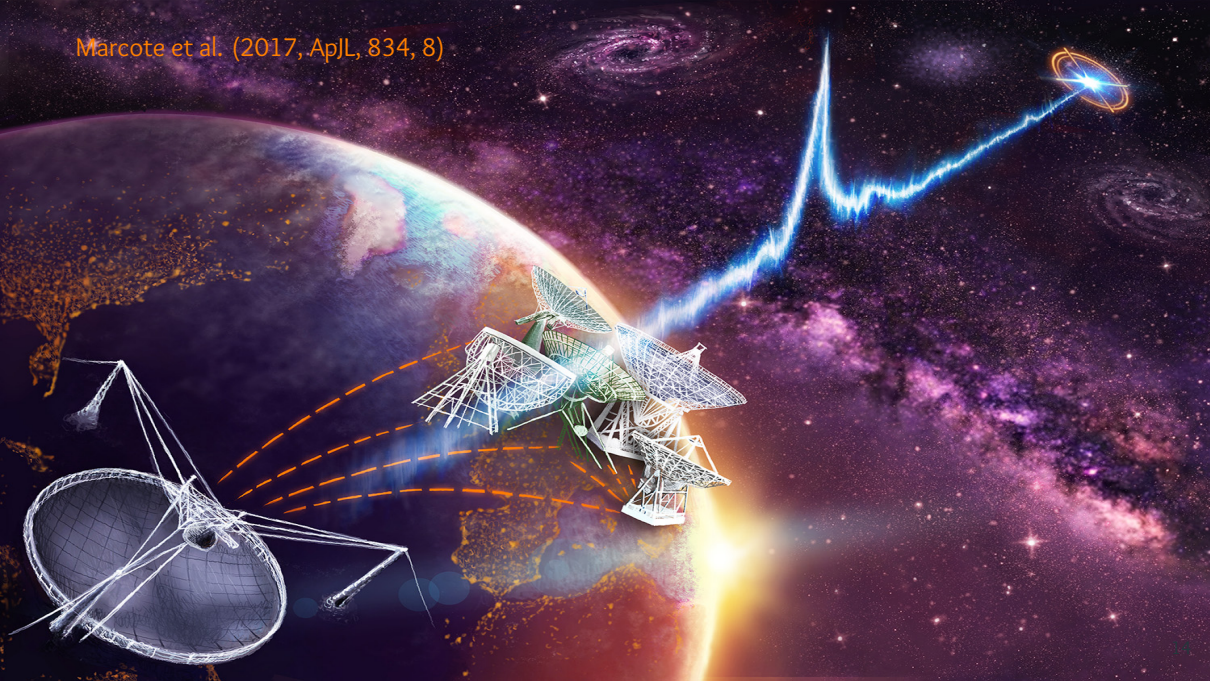
Marthi et al. (2020)

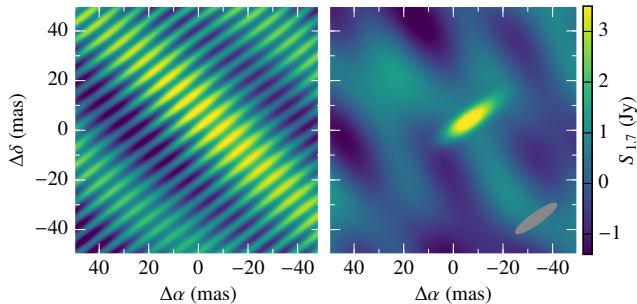


## Challenges on FRB-VLBI localizations

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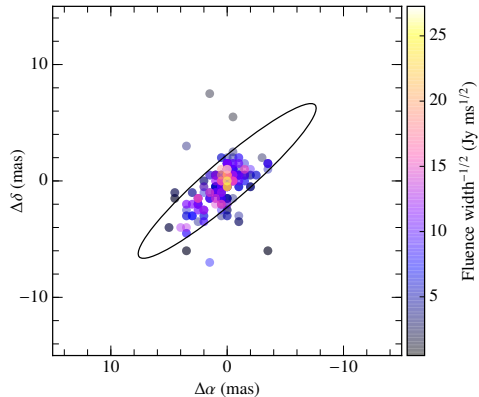
Marcote et al. (2017, ApJL, 834, 8)





Dirty and clean image from FRB 121102.

Astrometry limited by signal-to-noise ratio



Positions derived from 406 pulses from the pulsar B0525+21

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



## *(phasing-up uGMRT)*

- Strongest dish in the array.
- Sensitive baselines with the Eastmost dishes.
- Connecting the longest baselines of the EVN.
- Sensitive burst searches.

## *(interferometric uGMRT data)*

- A connected interferometer within the network.
- Absolute flux density scale.
- Simultaneous arcsec/mas scales.





- **Fast Radio Bursts** are a remarkable new type of astrophysical objects of unknown nature.
- Important implications in fundamental physics and cosmology.
- But only a handful of them have been precisely localized to date.
- Sensitivity is critical to detect & pinpoint them (EVN, FAST examples).
- Plus, the low frequencies are leading now the studies of these sources.
- uGMRT together with the EVN would boost these science case.
- But same applies to a large number of (weak) transients (like high-energy binaries!).



A night sky filled with stars and a bright purple beam of light. Several radio telescope dishes are visible in the foreground, some pointing towards the beam. The beam starts from a bright purple star in the upper left and curves downwards and to the right. The text "Thank you!" is written in a white, serif font in the upper right quadrant.

*Thank you!*

# The Dispersion Measure



Light is dispersed by the material in the medium.

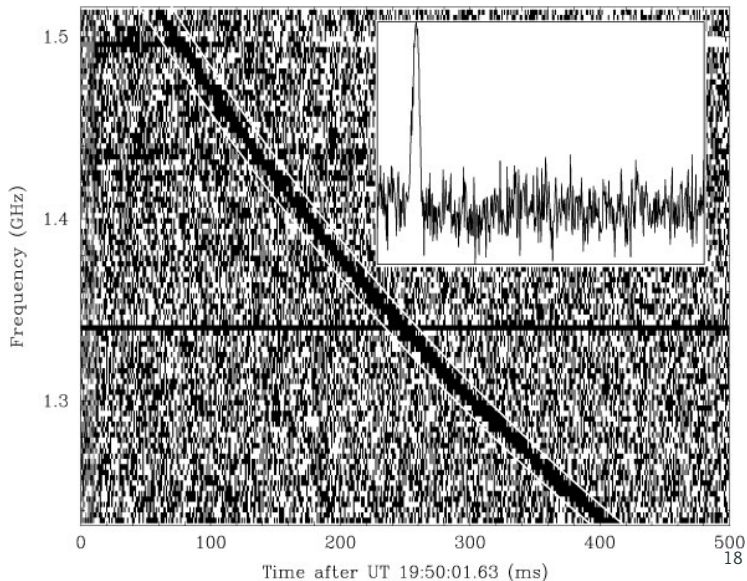
Dispersion Measure:

$$DM = \int n_e dl \propto \nu^{-2}$$

All FRBs show unexpected large DMs.

Much larger than the contribution of our Galaxy

Estimated  $z \sim 0.16-3$



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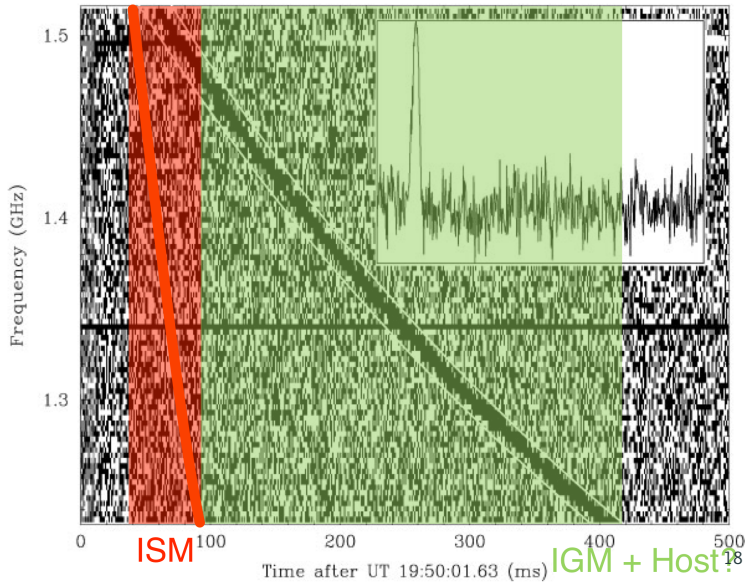
Dispersion Measure:

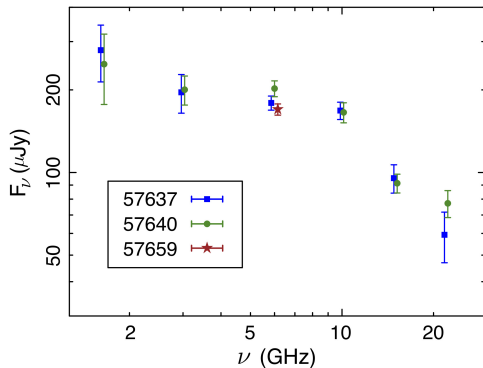
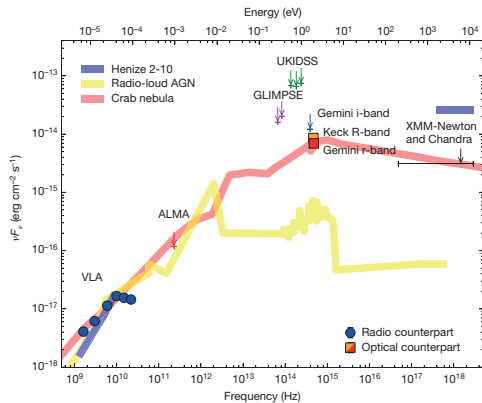
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SED and radio spectrum of FRB 121102

(Chatterjee et al. 2017, Nature, 541, 58)