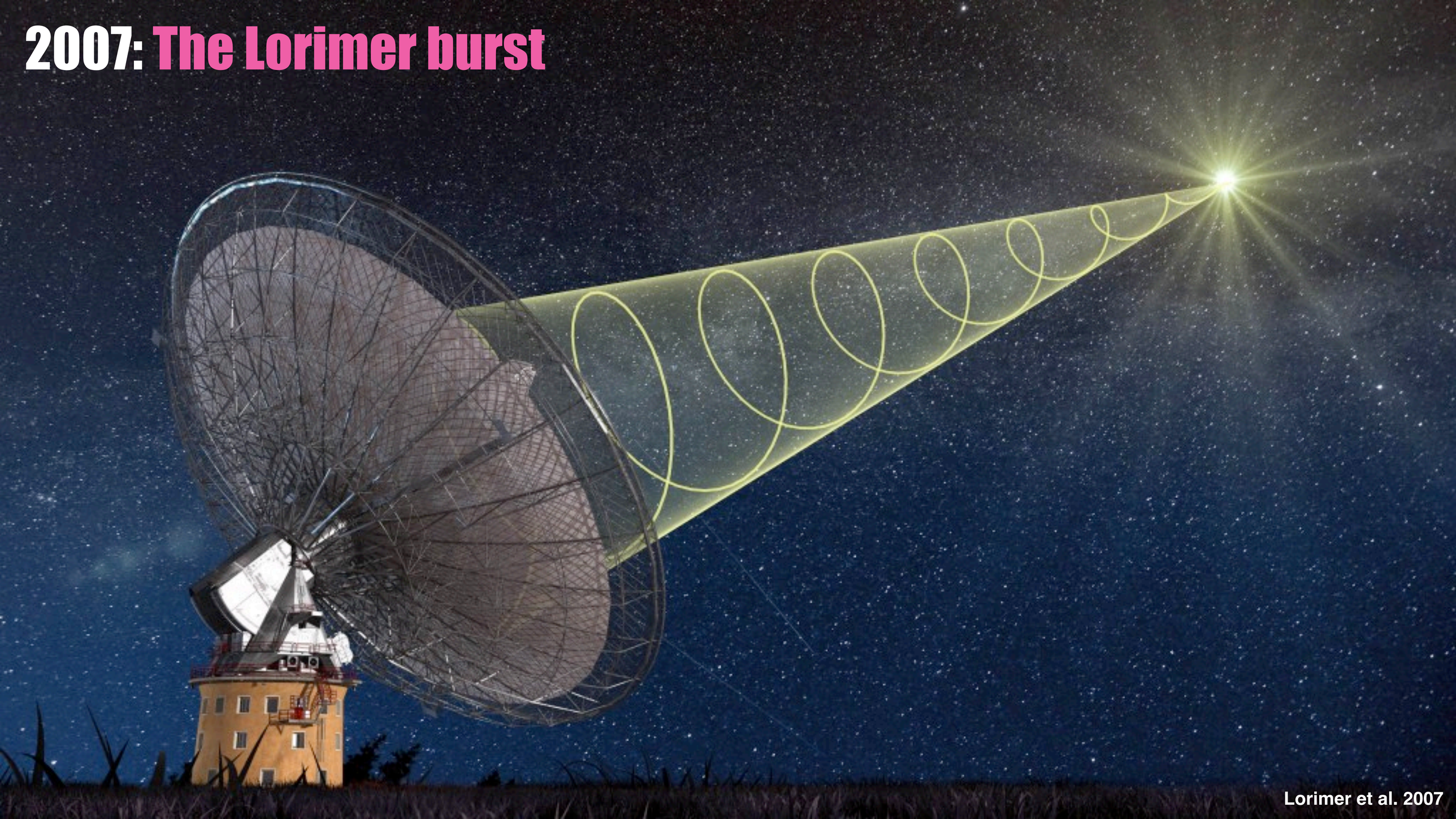
SEARCHING FOR FRB PERSISTENT RADIO SOURCE COUNTERPARTS IN DWARF GALAXIES USING LOFAR

DANY VOHL

IN COLLABORATION WITH
H. VEDANTHAM, J. HESSELS & C. BASSA

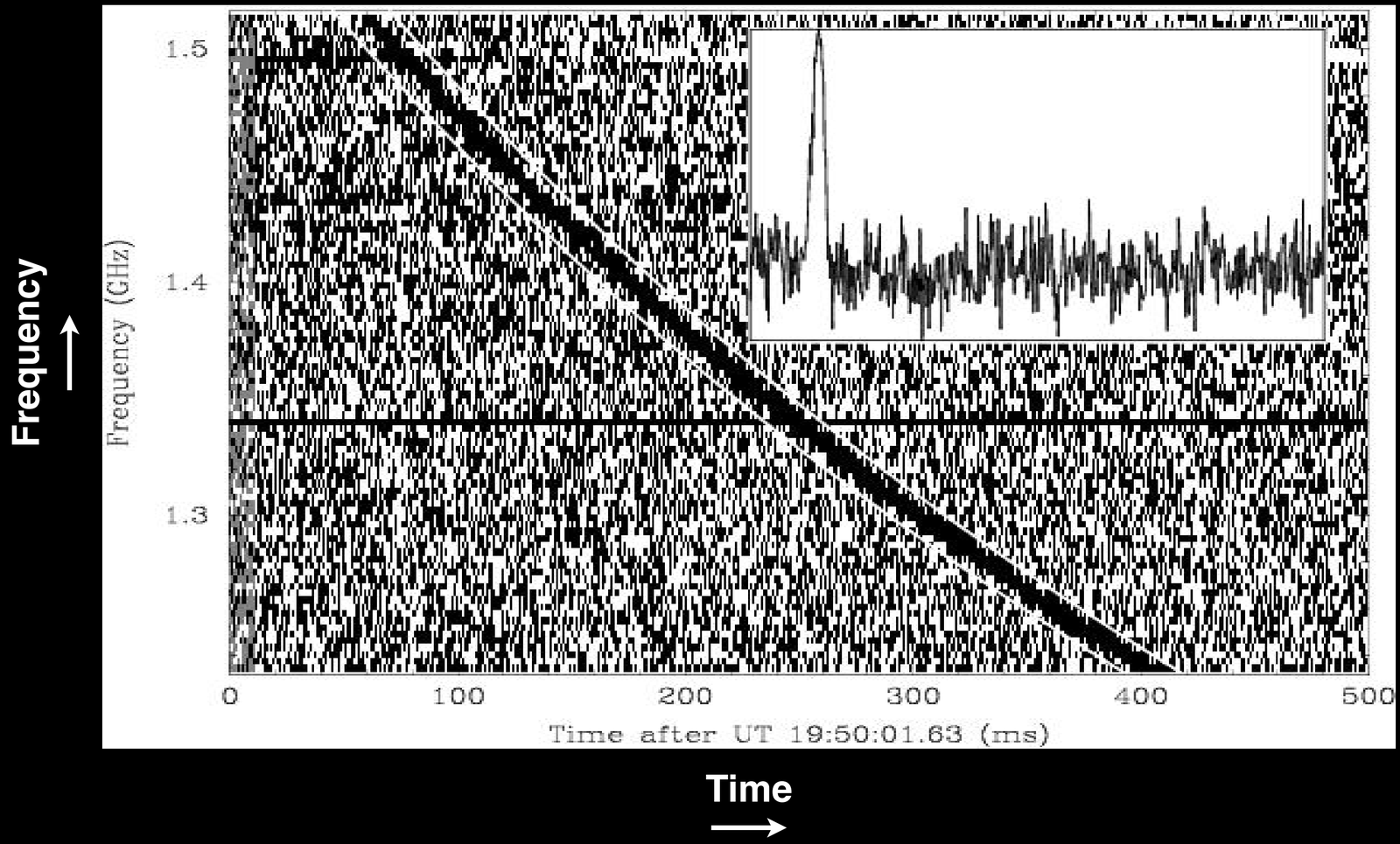
UNIVERSITY OF AMSTERDAM & ASTRON, THE NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY

2007: The Lorimer burst



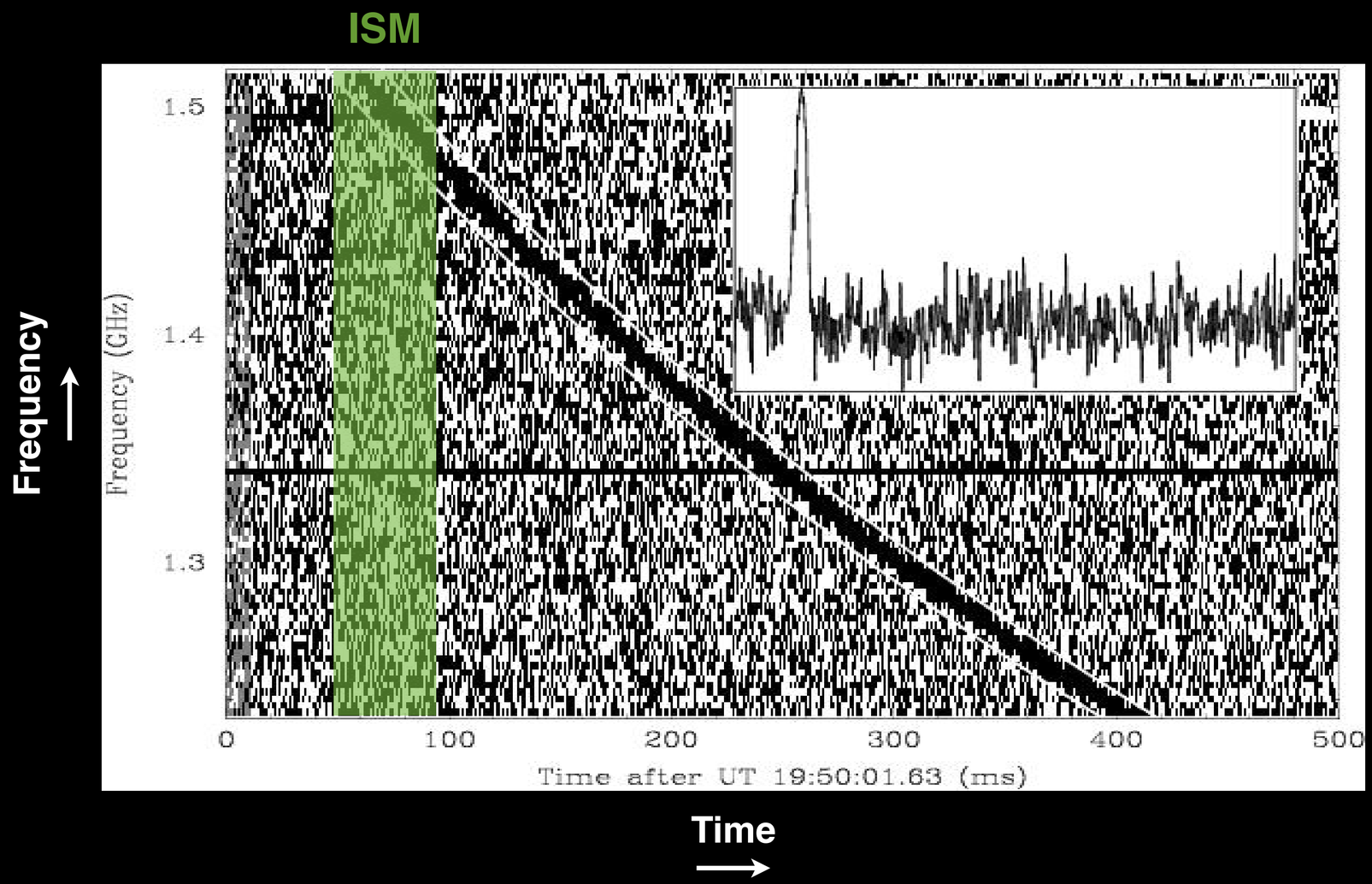
Lorimer et al. 2007

2007: The Lorimer burst



Lorimer et al. 2007

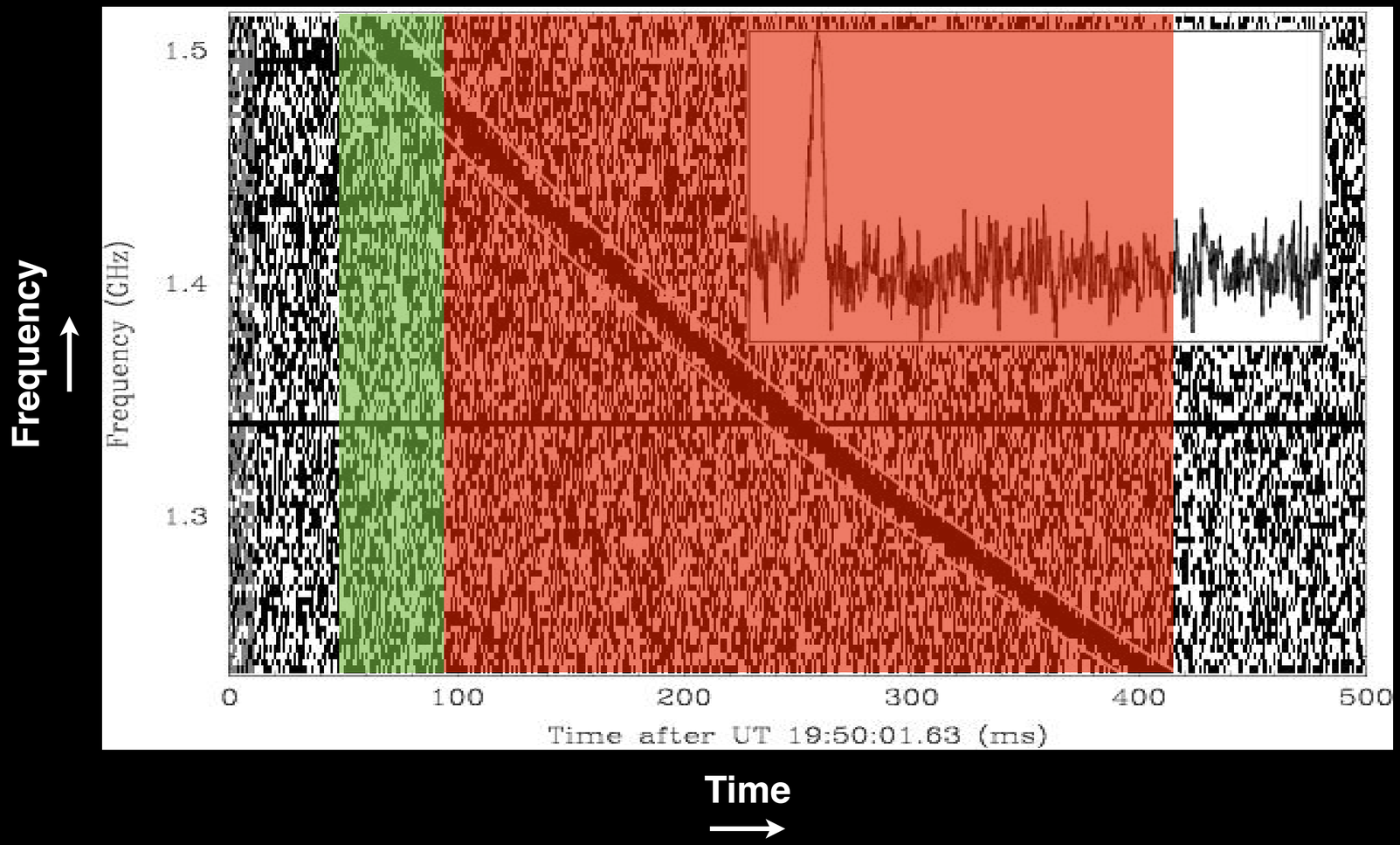
2007: The Lorimer burst



Lorimer et al. 2007

2007: The Lorimer burst

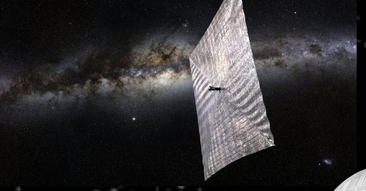
ISM IGM (intergalactic medium) + Host?



Lorimer et al. 2007

Some shocking facts

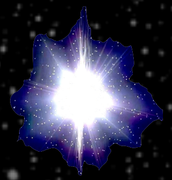
- Last 100 times shorter than the blink of an eye.
- Created long-long ago in galaxies far-far away.
- Same energy as the Sun emits in one day.



Light Sails

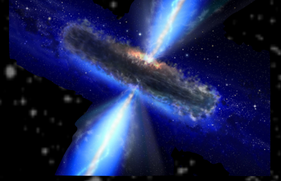
Death Stars

Merging Black Holes



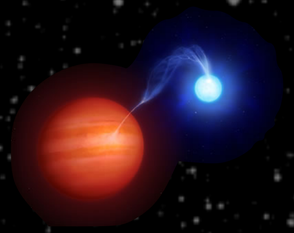
Supernovae

Magnetars

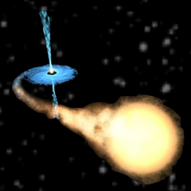


Accreting Massive Black Hole

The Unknown

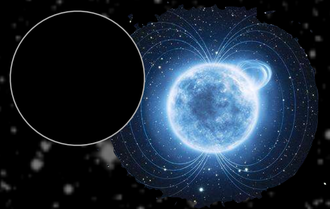


Interacting Binary



Microquasar

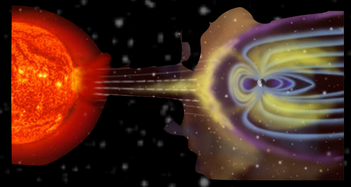
Evaporating Black Holes



Black Hole Battery

Super-giant Pulses

extra-Galactic

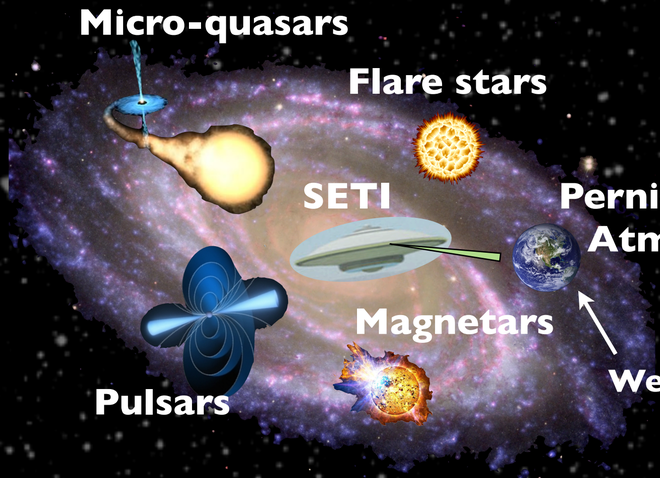


Cosmic Comb

Gamma-ray Bursts

The Gruffalo

Galactic



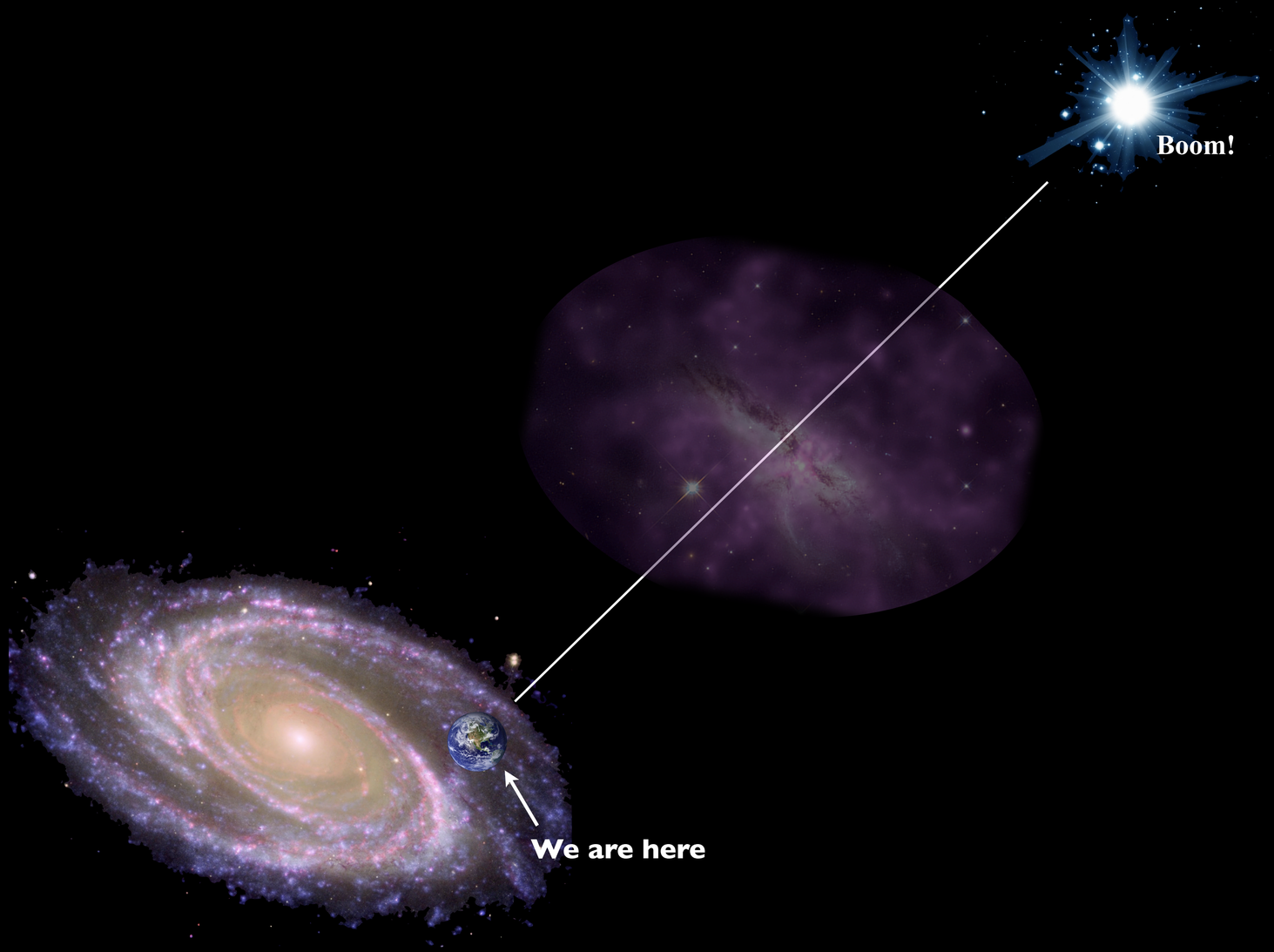
According to the *arXiv*, there are >100 types of FRBs

"Blitzars"

Figure: Hessels

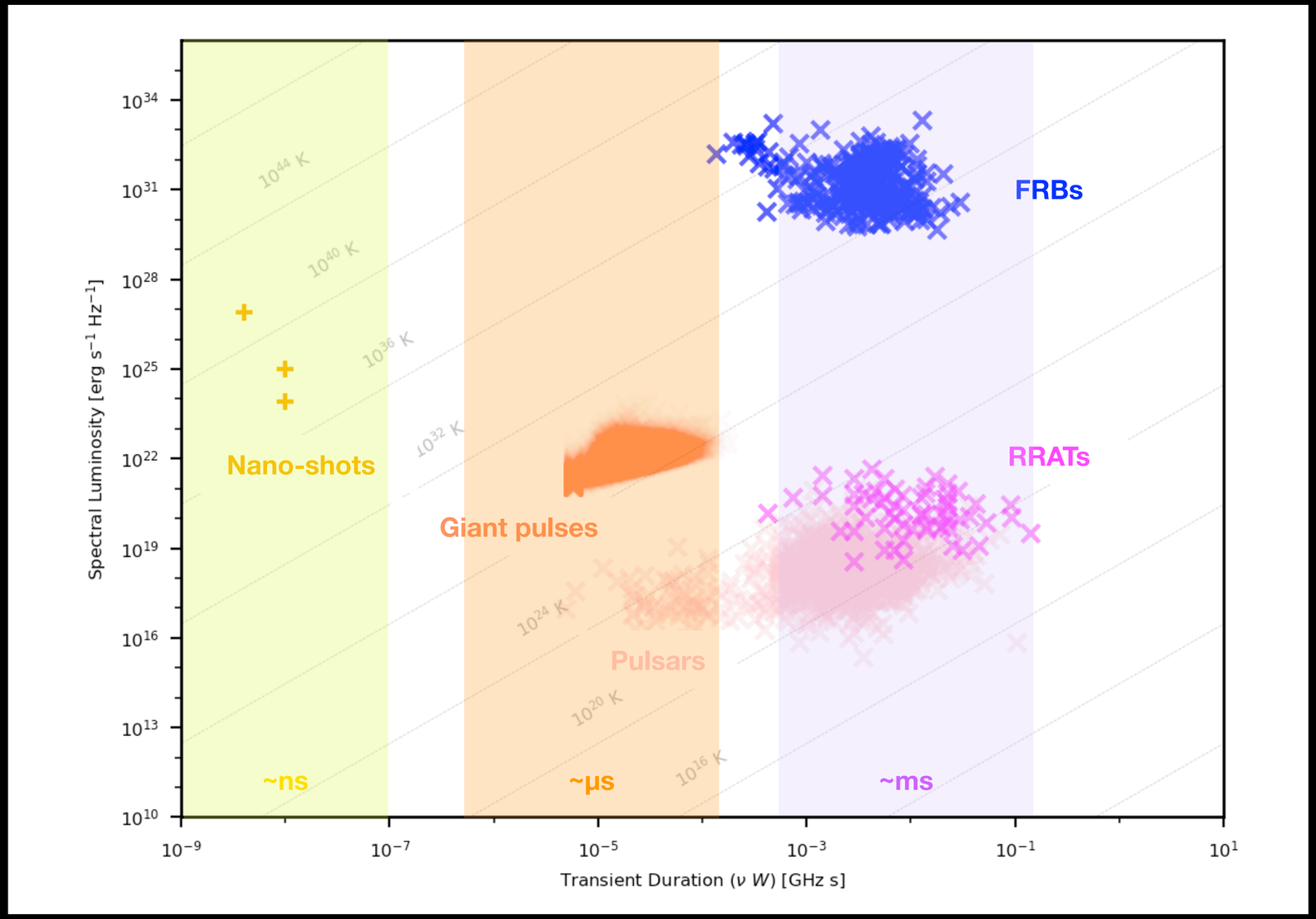
frbtheorycat.org; Platts et al. 2018

What good are they to anybody anyway?



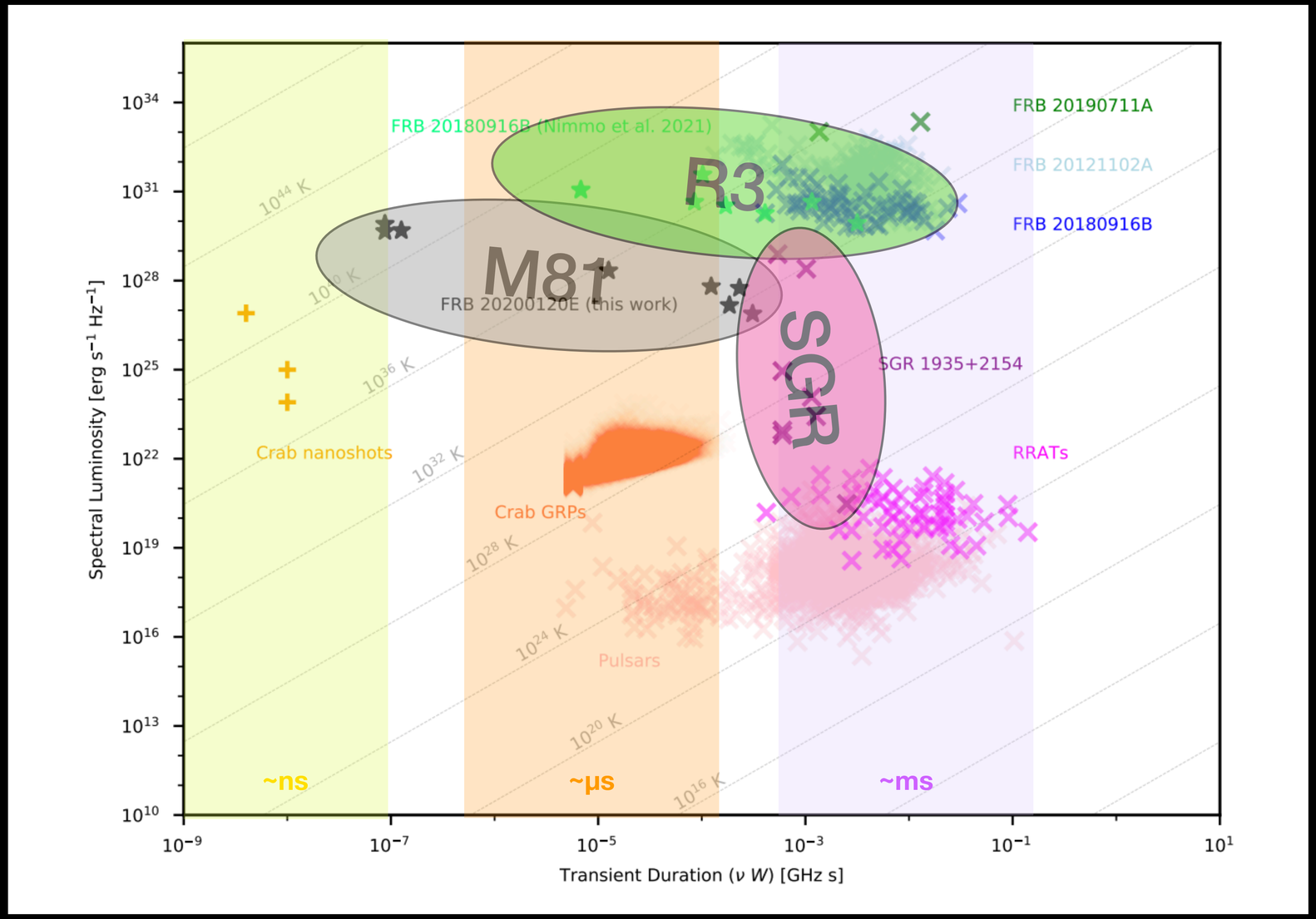
- Sites of extreme energy density. Important probes of extreme (astro)physics.
- New type of astrophysical object?
- Probes of intervening material.

Filling in the transient phase space



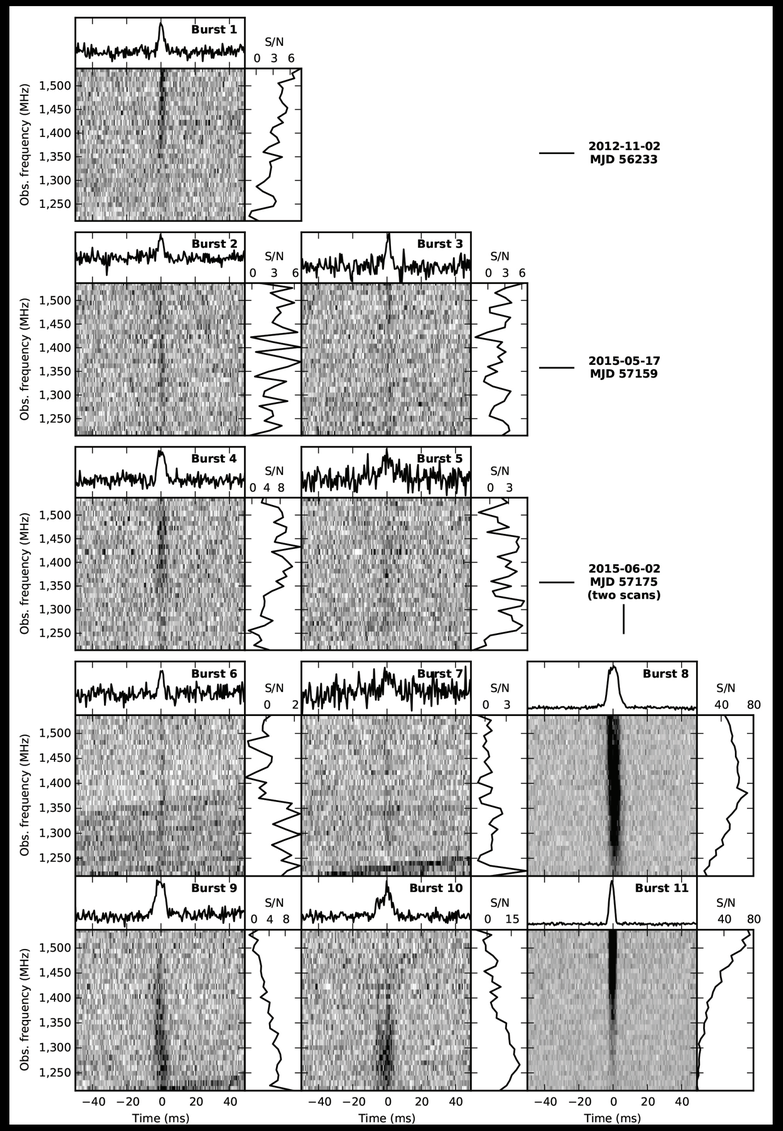
Nimmo

Filling in the transient phase space



Nimmo

FRB 121102 repeats!

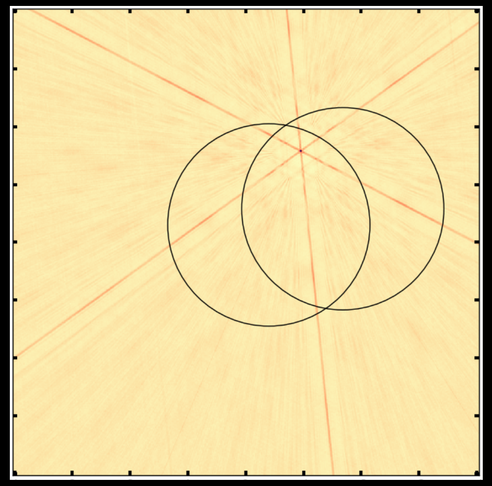


Spitler, Scholz, JH et al. 2016
Scholz, Spitler, JH et al. 2016

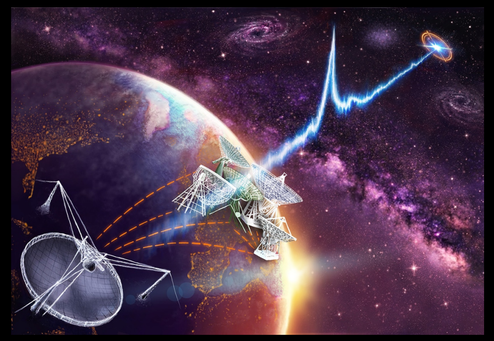
Image credit: Daniëlle Futselaar

FRB 121102 localised!

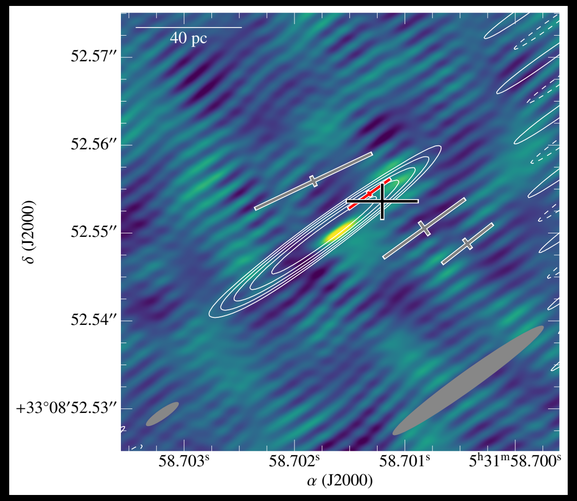
VLA



Chatterjee et al. (2017)

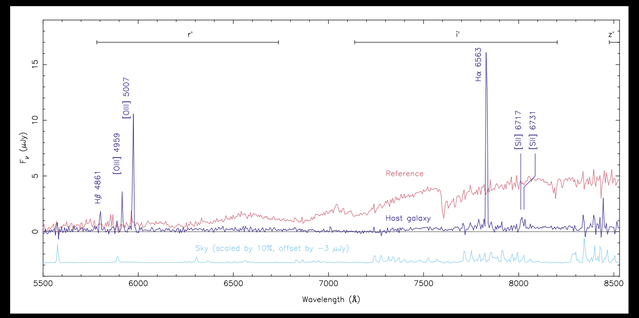


EVN



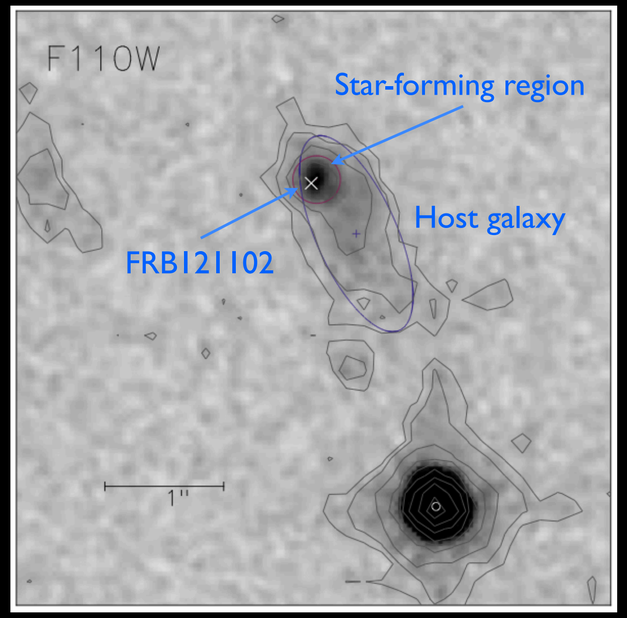
Marcote, Paragi, JH et al. (2017)

Gemini



Tendulkar et al. (2017)

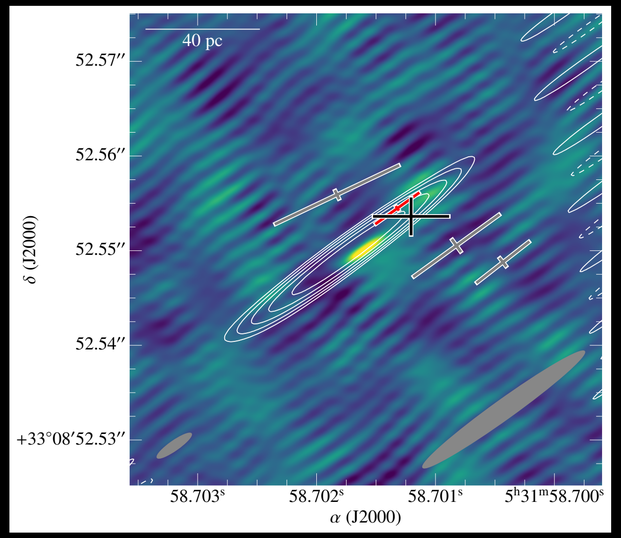
HST



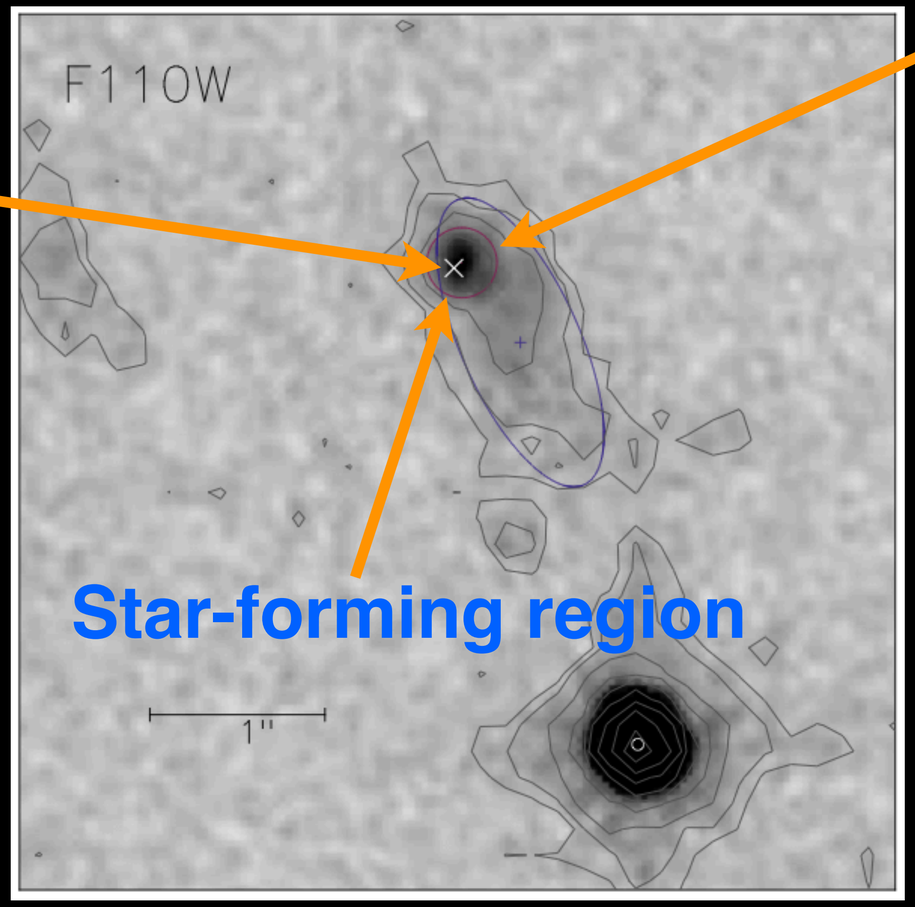
Bassa et al. (2017)

FRB 121102
host & local environment

Marcote, Paragi, JH et al. 2017

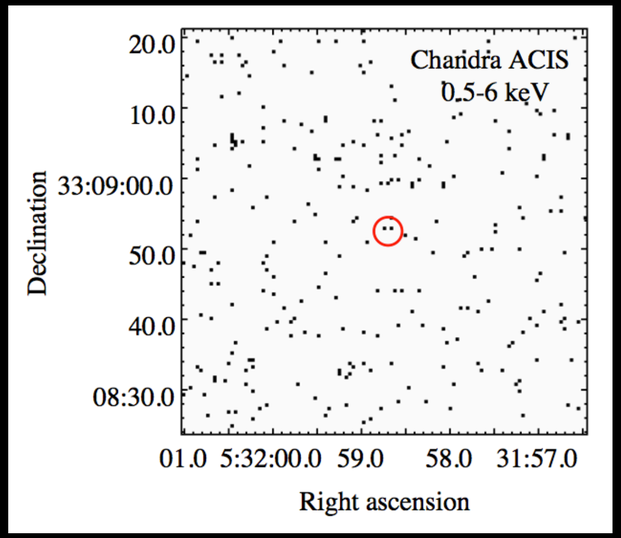


Compact radio source



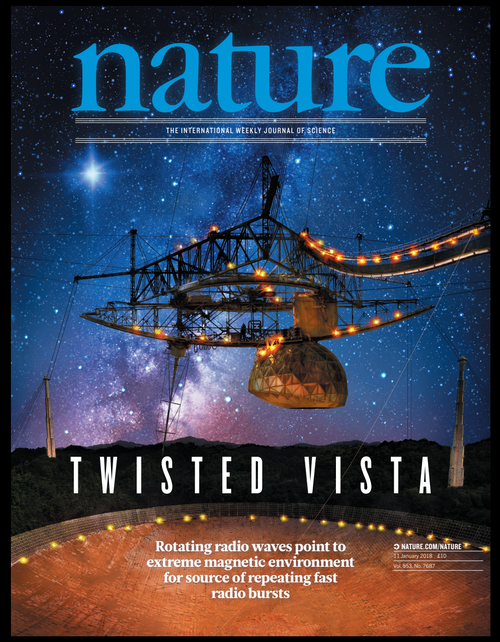
Bassa et al. 2017

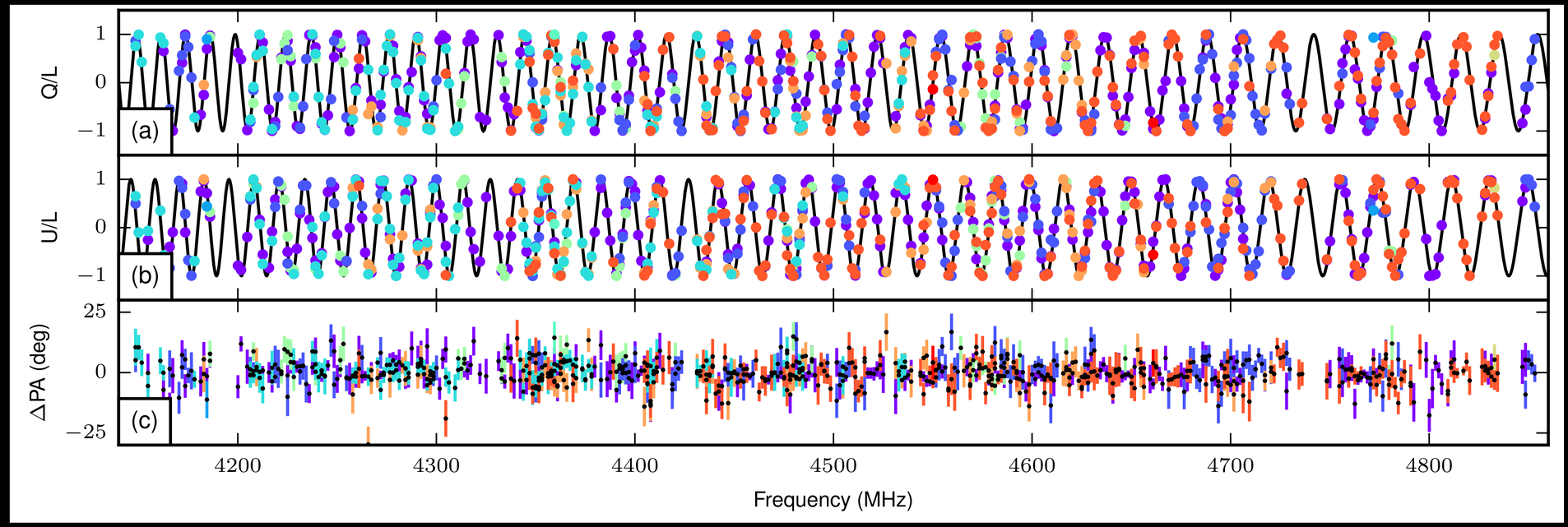
Scholz, Bogdanov, JH et al. 2017



No X-rays or gamma-rays

FRB 121102 is in an extreme magneto-ionic environment





Michilli, Seymour, JH et al. 2018

In a dense nebula?
Near an accreting massive black hole?!

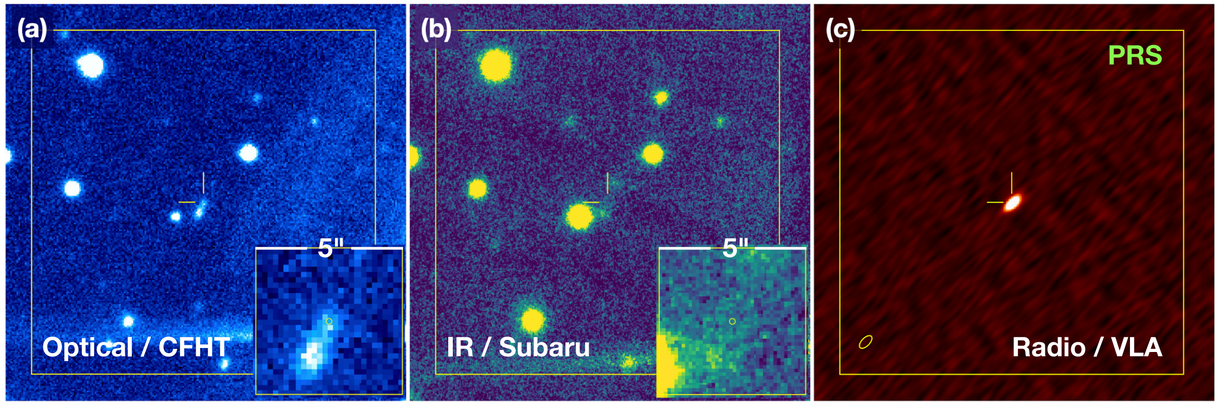
Our EU-TSP:
Can we find more FRB sites by identifying persistent radio sources in dwarf galaxies?

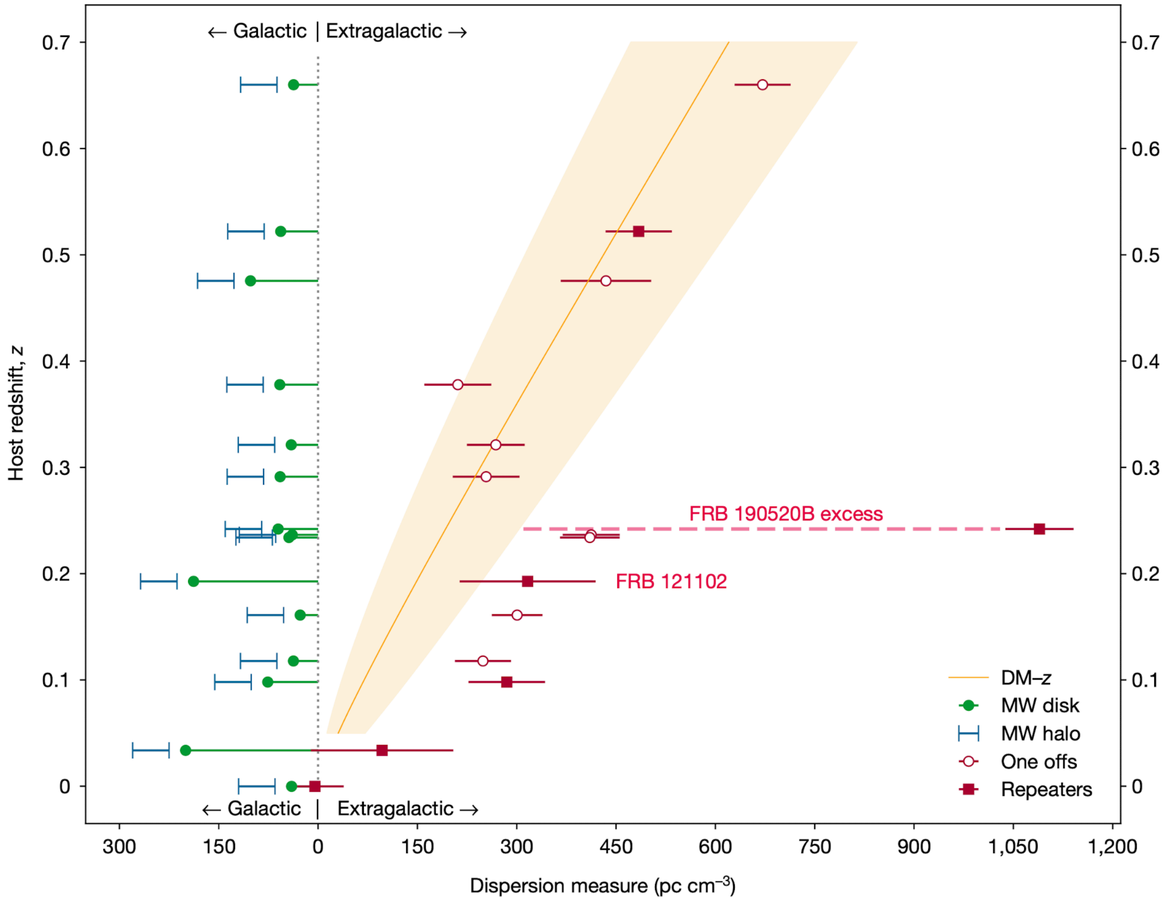
FRB 20190520B (PRS2)

Only the 2nd known repeating FRB co-located to PRS

- Detected with the FAST telescope (Niu *et al.* 2022)

- Star forming dwarf host galaxy
- Large DM_{Host} contribution
- High repetition rate





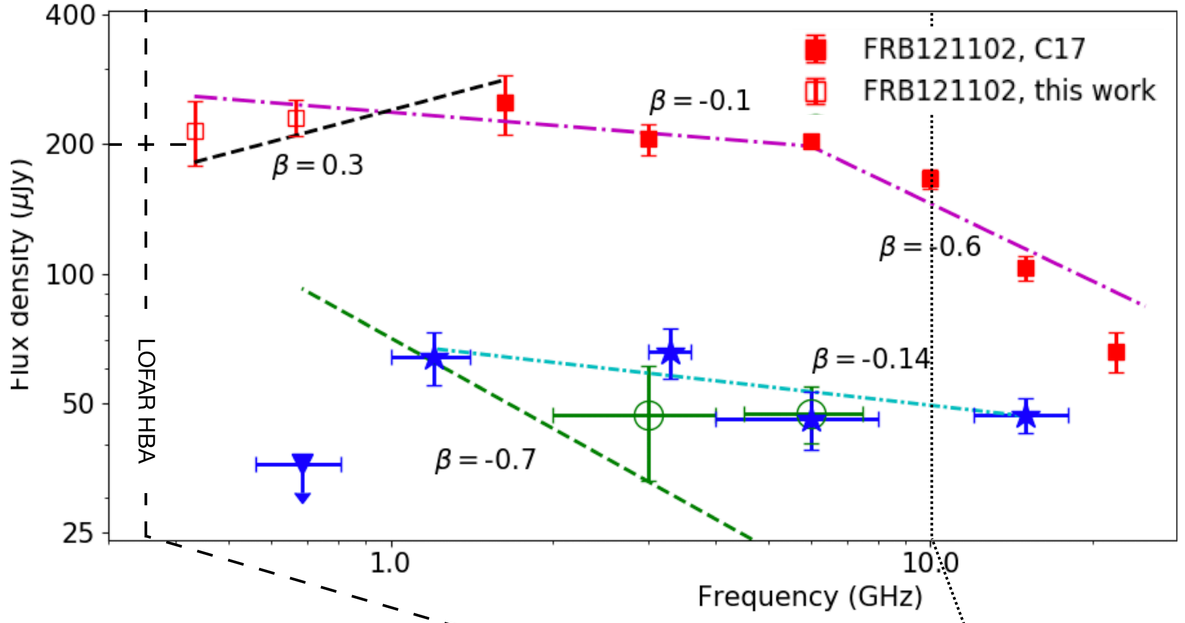
Law *et al. 2022:*

“Given that FRBs occur with a high volumetric rate (comparable to that of core-collapse supernovae; Luo et al. 2018; Perley et al. 2020) and that PRS are luminous,
it may be that PRS constitute a significant new class of extragalactic radio source.”

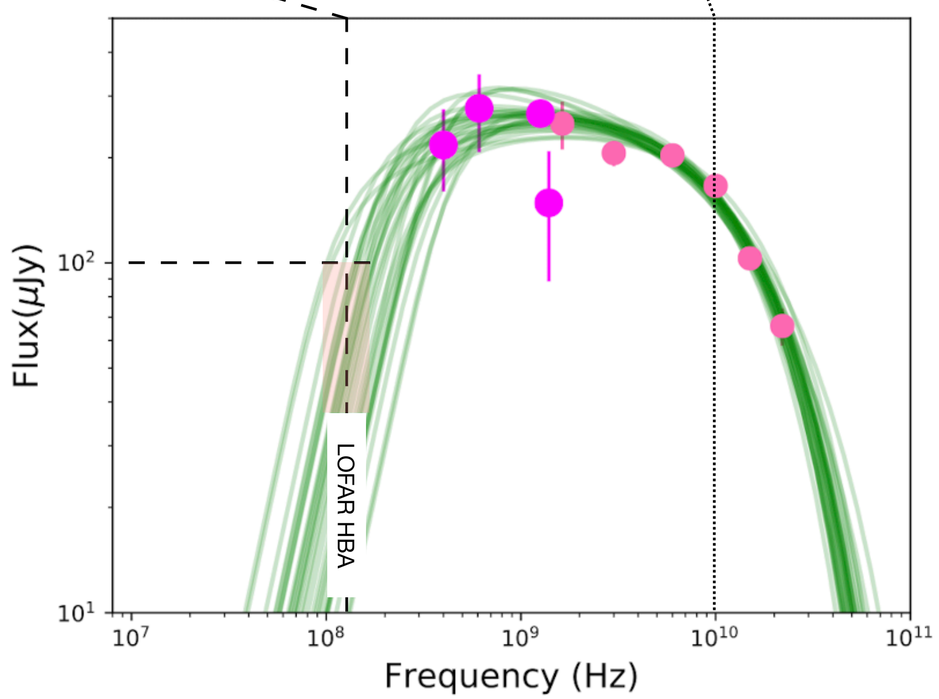
“[In] the local universe, **PRS potentially amount to as much 1% and 7%** of the **radio-luminous AGN** and **star-forming galaxy populations**, respectively.”

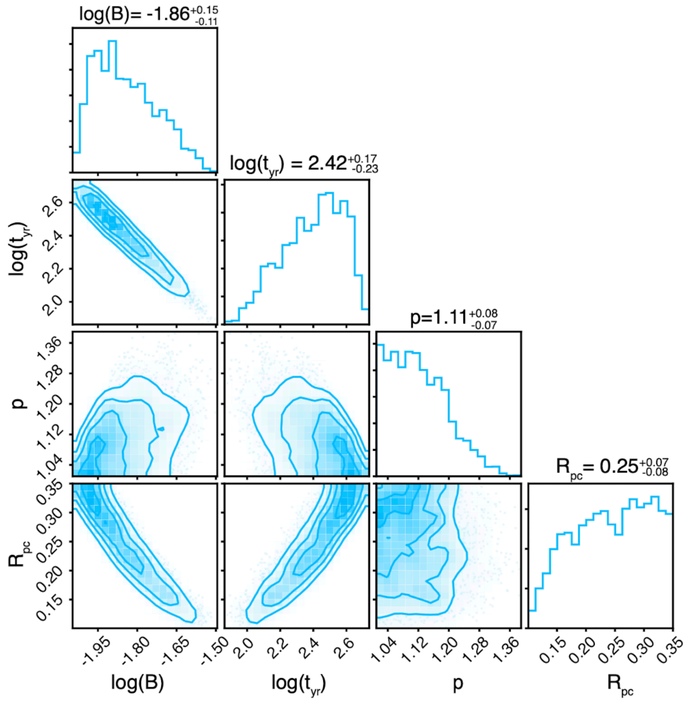
To improve our understanding of PRSs, it is imperative to increase the known sample size

PRS121102 spectrum



Mondal+22



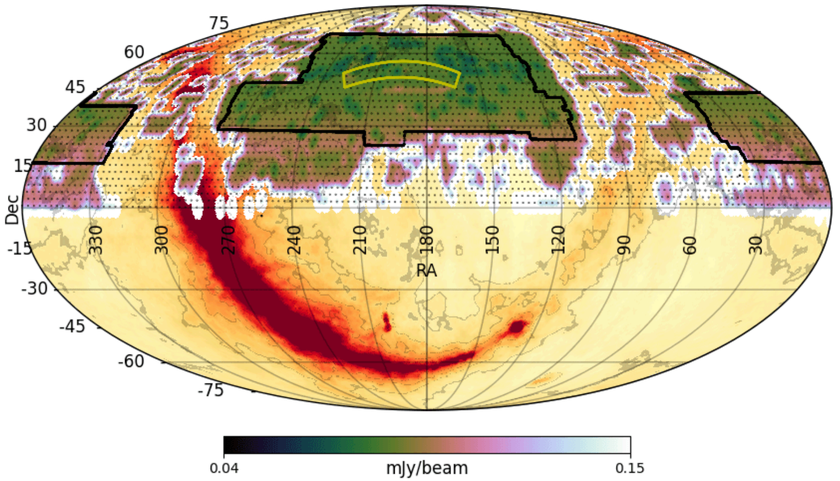


Resmi+22

Search for PRS signature

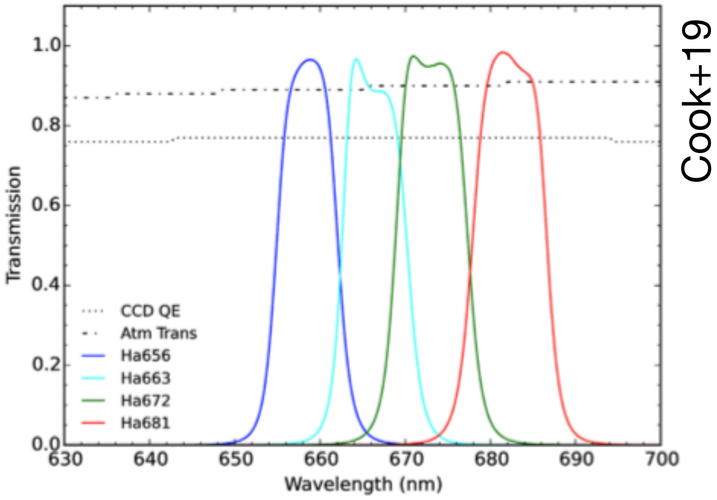
Targeted search for compact radio sources coincident with dwarf galaxies

- **Radio reference catalog**:
  - LoTSS 2nd data release (Shimwell *et al. 2022)*
    - > **4 million radio sources**
    - Central frequency: 144 MHz
    - ~5500 deg^2 covered
    - **0".2 astrometric accuracy** (comparable to optical surveys)
    - Point source completeness to 90% at 0.8 mJy/beam



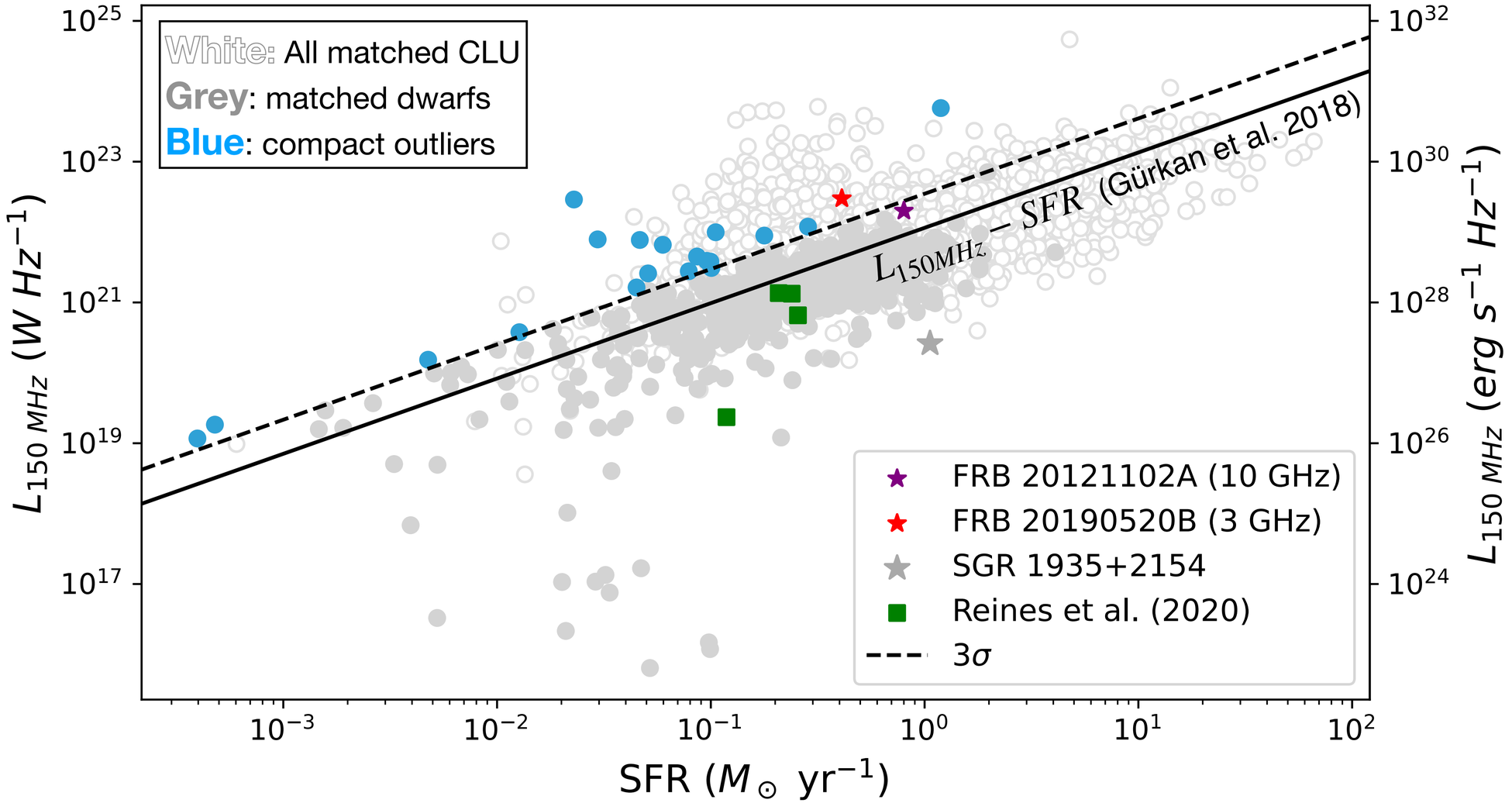
Shimwell+22

- **Optical target catalog**:
  - Census of the local Universe (Cook *et al.* 2019)
    - **270 000 sources** over **3π of the sky**
    - Observed in four H-alpha bands
      - Corresponding to -0.0026 < *z* < 0.0471
    - **Provides various physical properties**: e.g.
      - **Mstar** (from WISE1), **SFR** (GALEX FUV flux)
        - Spans dwarf galaxies to larger spirals



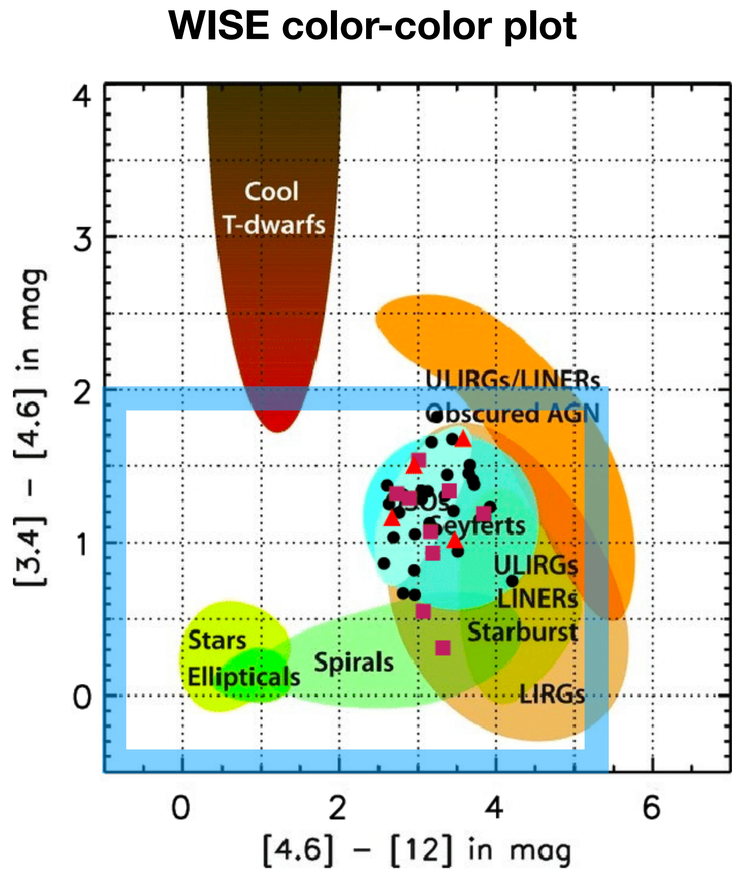
Cook+19

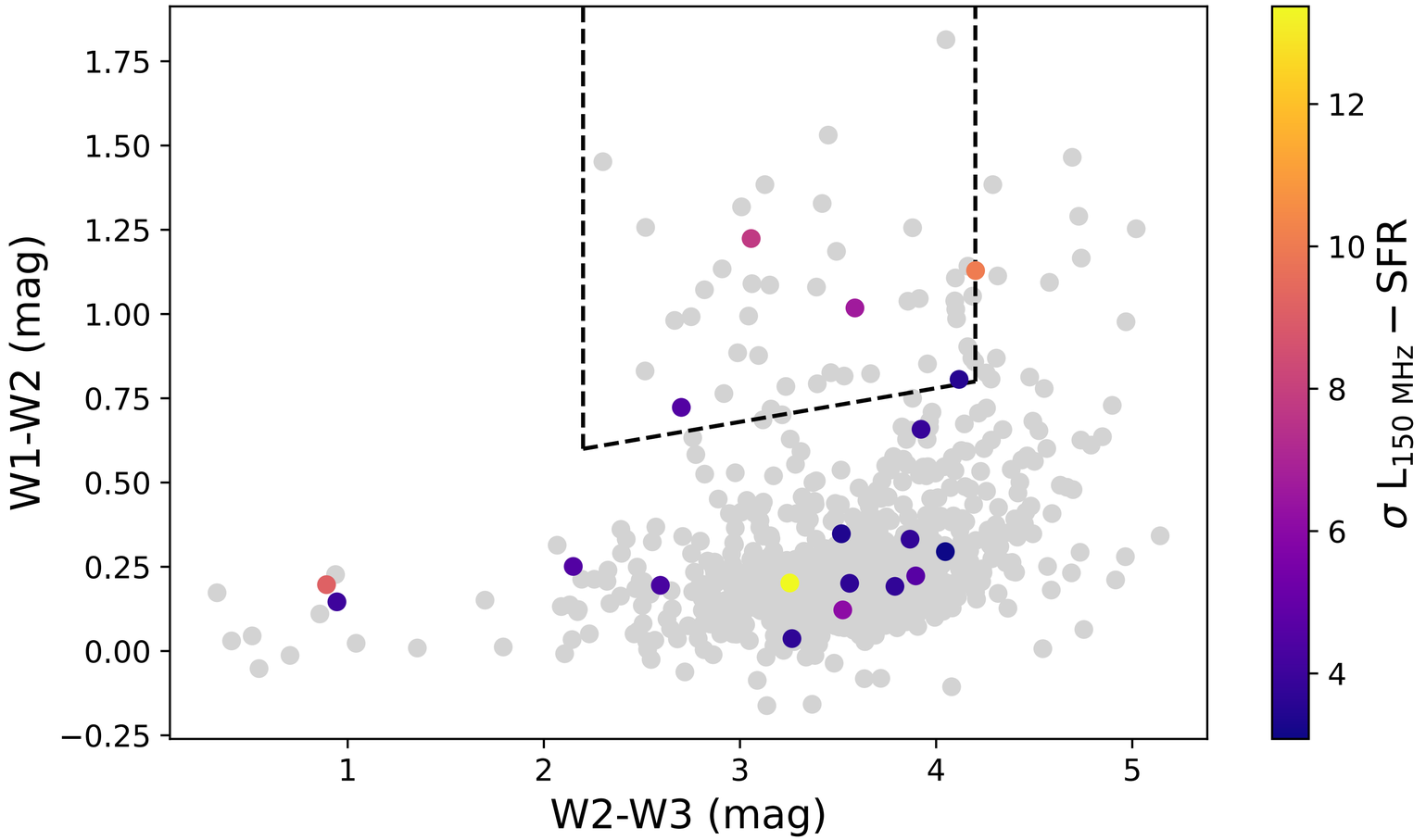
Over-luminous compact sources



(Vohl et al., in prep.)

Sample contamination (1)





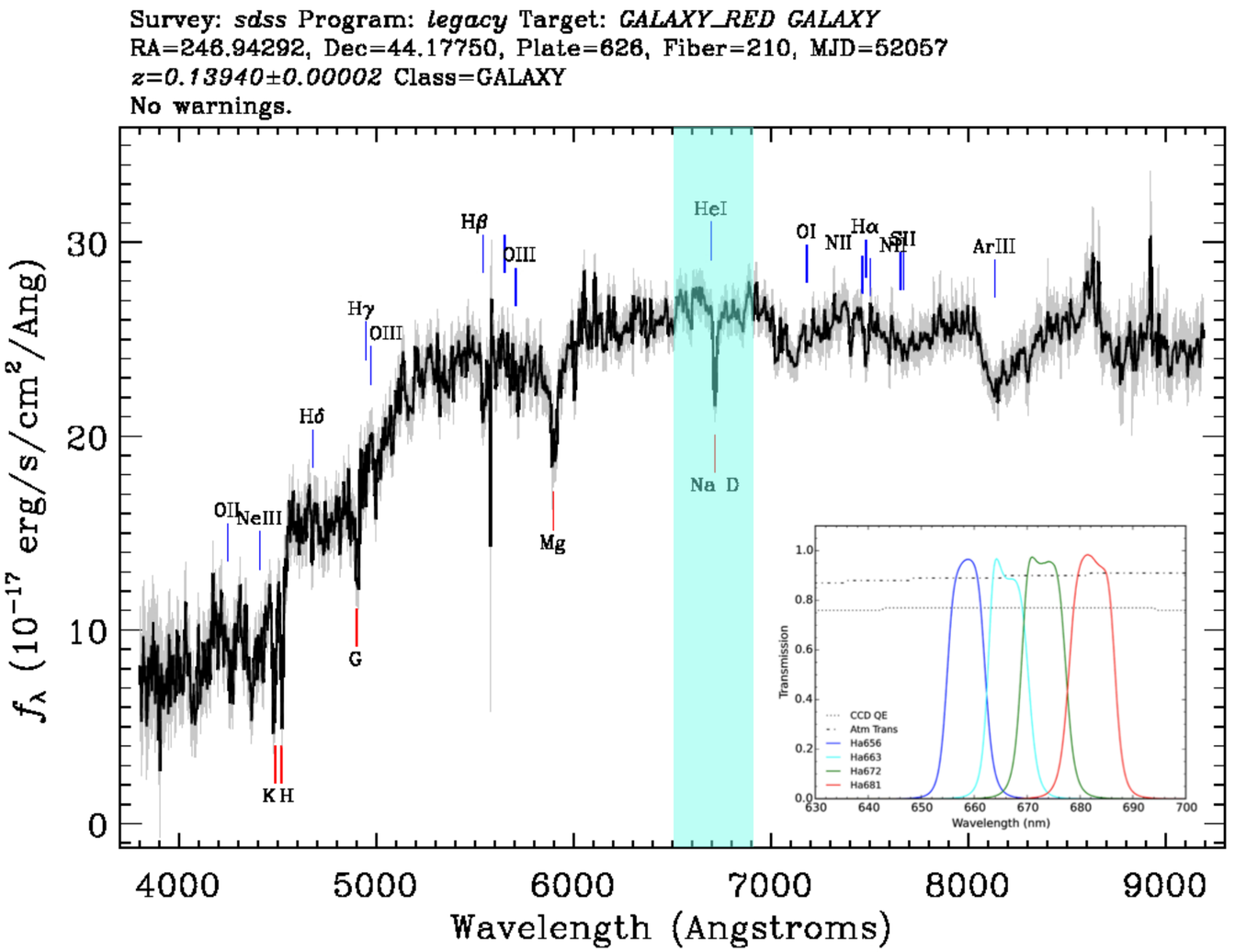
LaMassa et al. ApJ. (2017)

(Vohl et al., in prep.)

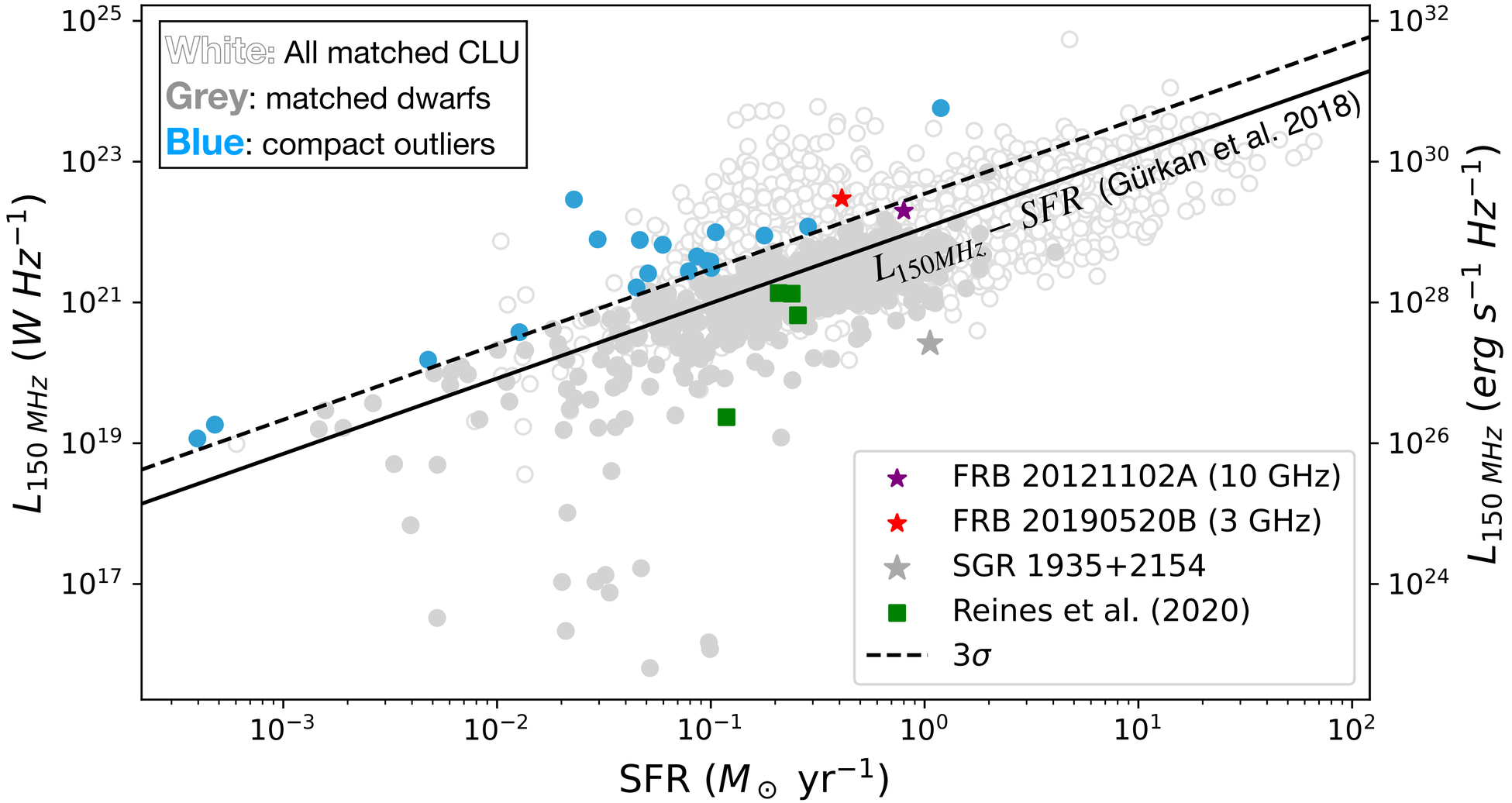
Sample contamination (2)

Incorrect redshift assignation in CLU

- **Emission line redshifted to $H\alpha$ filter**
- E.g. here
  - Redshift (CLU): 0.0204
  - Redshift (SDSS): 0.13940

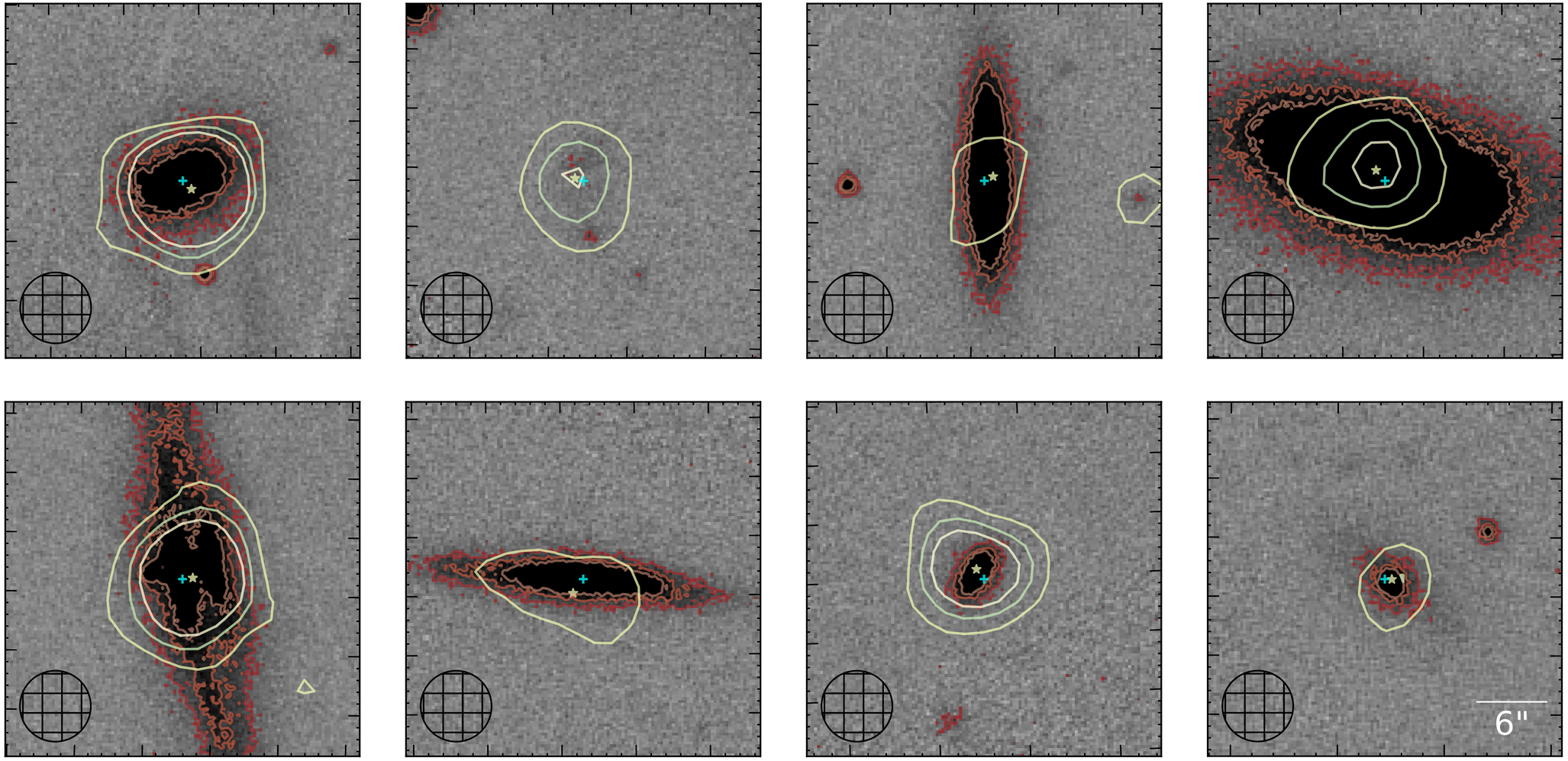


Over-luminous compact sources



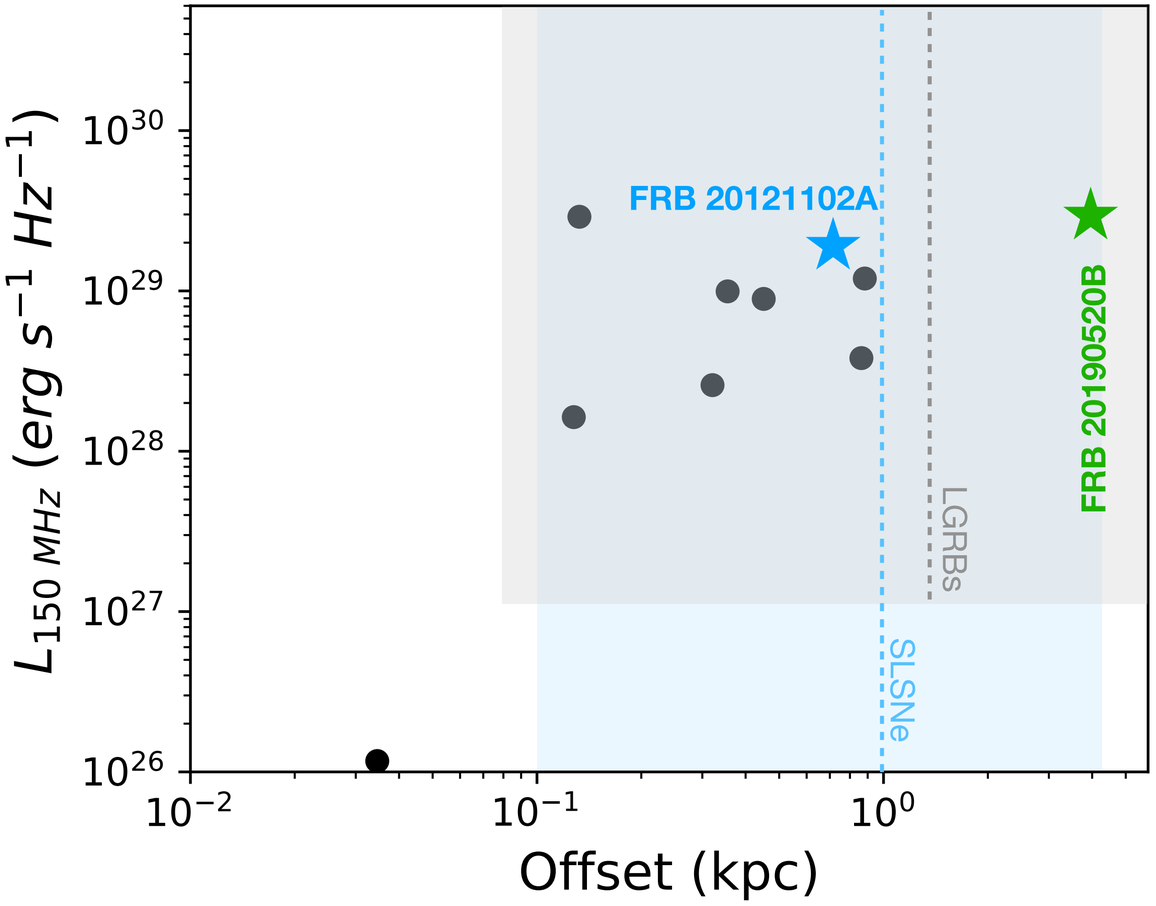
(Vohl et al., in prep.)

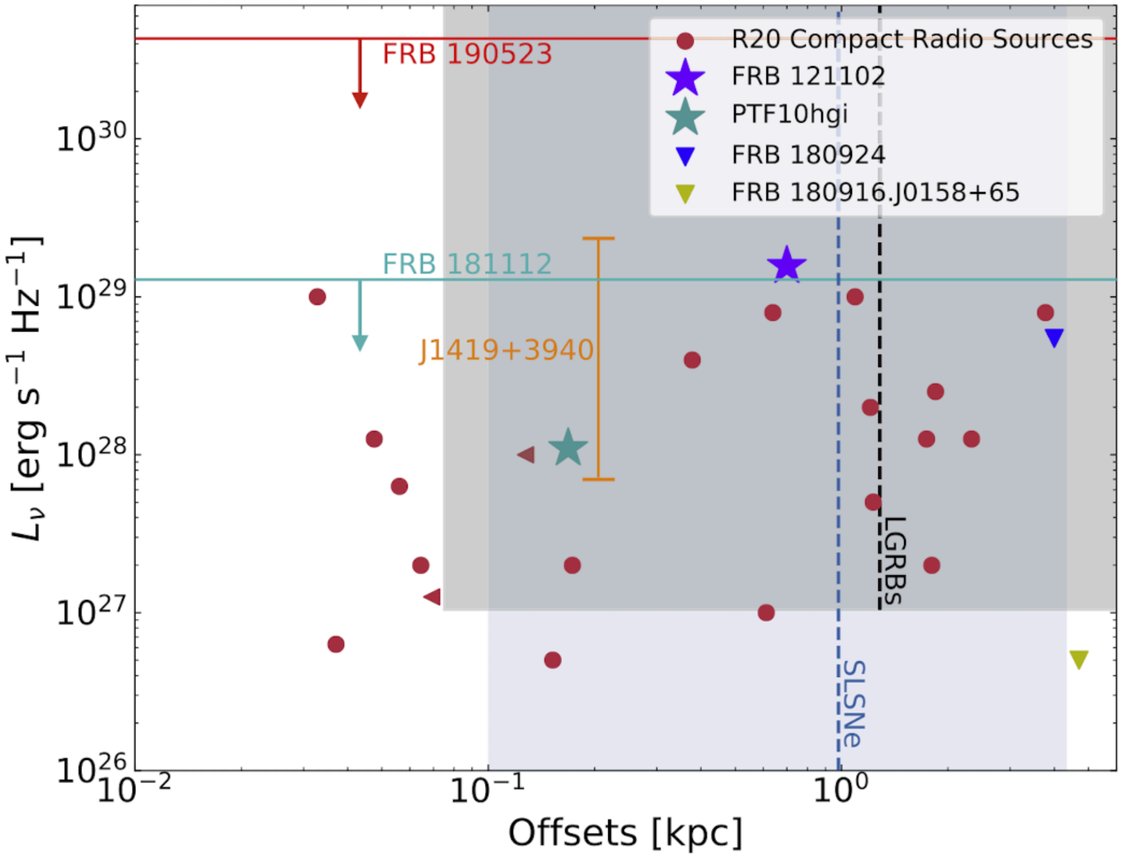
Candidates



(Vohl et al., in prep.)

Separation from nucleus





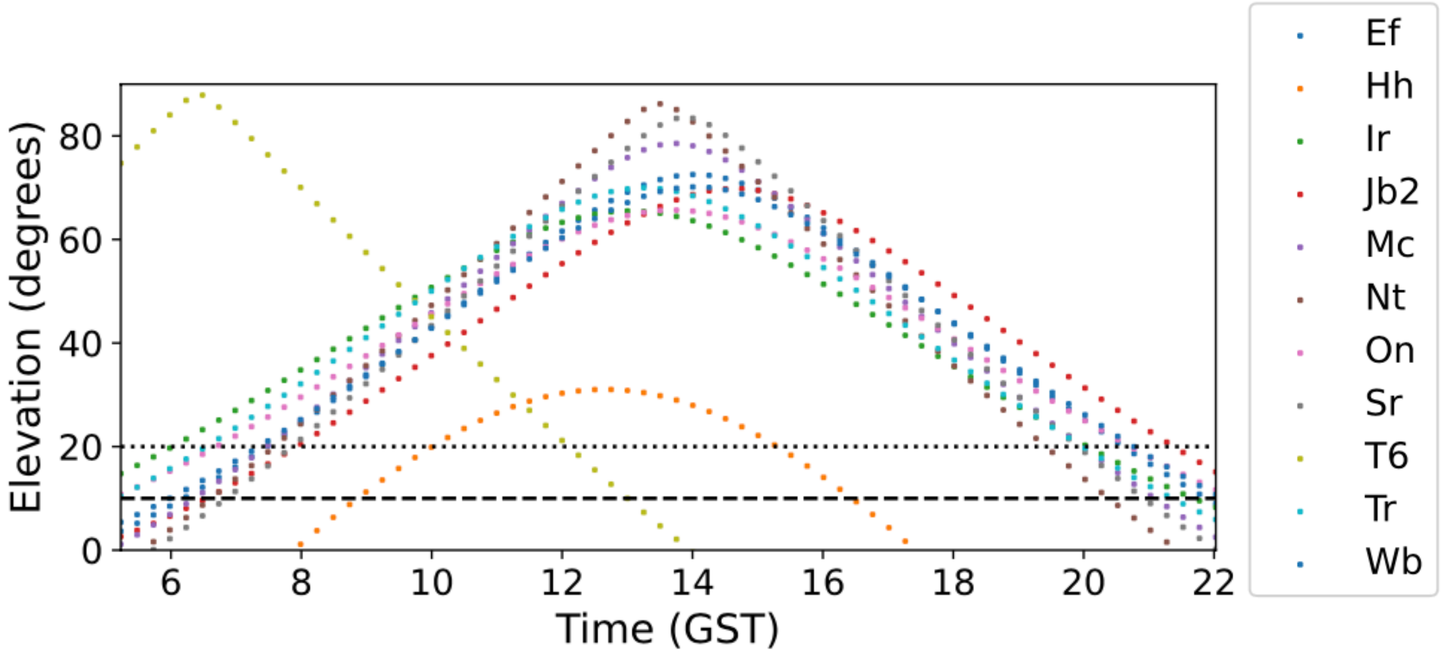
Eftekhari *et al.* 2020

Preliminary

Shaded regions from
Lunnan et al. 2015; Blanchard et al. 2016

Planned VLBI follow-up

- A critical step to establish candidates as potential FRB hosts
  - Conclusively determine the compactness of these sources
- Proposed time for VLBI follow-up observations with EVN at 18 cm



Extreme Universe

ESCAPE AND EOSC FUTURE SCIENCE PROJECTS

Virtual Research Environment (VRE)
Data Lake & Rucio
Virtual Observatory (VO)
Zenodo

Compact objects

The discovery of fast radio bursts (FRBs) is one of the most intriguing radio astronomical discove
times. FRBs are radio spikes of millisecond duration originating from cosmological distances. Th
FRBs remains elusive, but their short duration implies a compact origin.

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Reproducibility

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matchmak...	5 minutes ago

matchmaker.ipynb

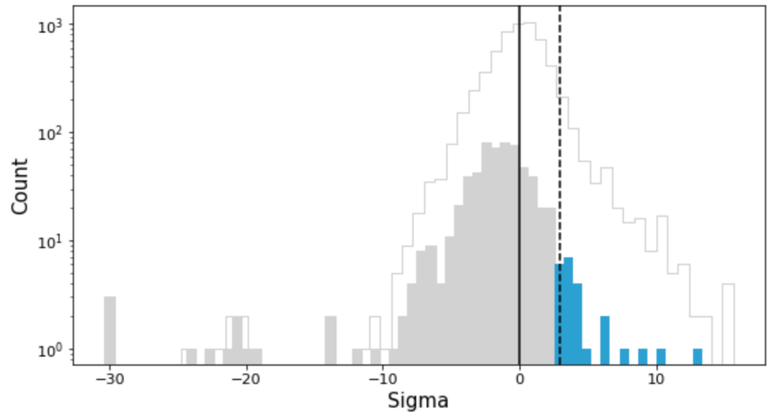
Code

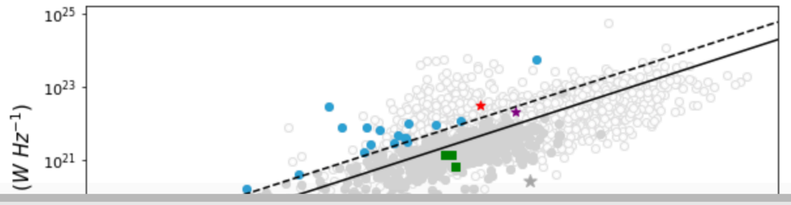
Ready Python 3

```
)
ax.plot(
    [box[2][0], box[1][0]], [box[2][1], maxed],
    linestyle='--',
    color='black'
)
if maxed != 1.7:
    ax.set_ylim(ylim)
ax.set_xlabel('W2-W3 (mag)')
ax.set_ylabel('W1-W2 (mag)')



plt.tight_layout()
plt.savefig(f"{check_folder_exists_or_create('images')}/selection_{state_prefix}.pdf", dpi=250)
```





EOSC Future

Simple 1 0 Python 3 | Idle Mode: Command Ln 1, Col 1 matchmaker.ipynb

Summary

- PRS counterparts to FRB may be a new class of extragalactic radio sources
- Established 8+ PRS candidates from LoTSS
- Planned EVN observations to establish their compactness
- Follow-up search for FRBs at these locations
- Should let us tell more about Law *et al. 2021* proposition

d.vohl@uva.nl