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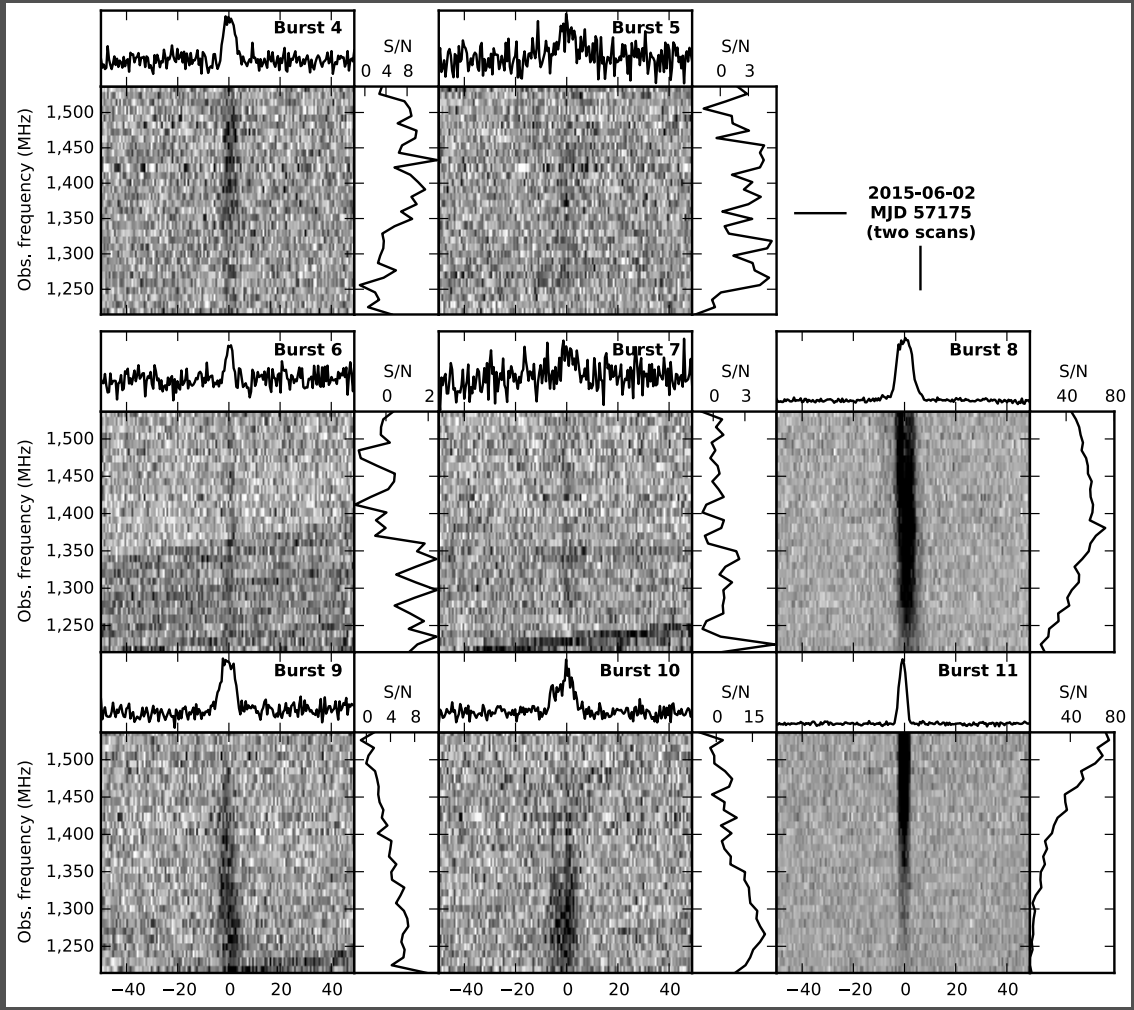
Localizing the Fast Radio Burst FRB 121102

FRB 121102: It repeats!

→ Rules out cataclysmic or explosive models, at least for this one source.

(Spitler et al. 2016)

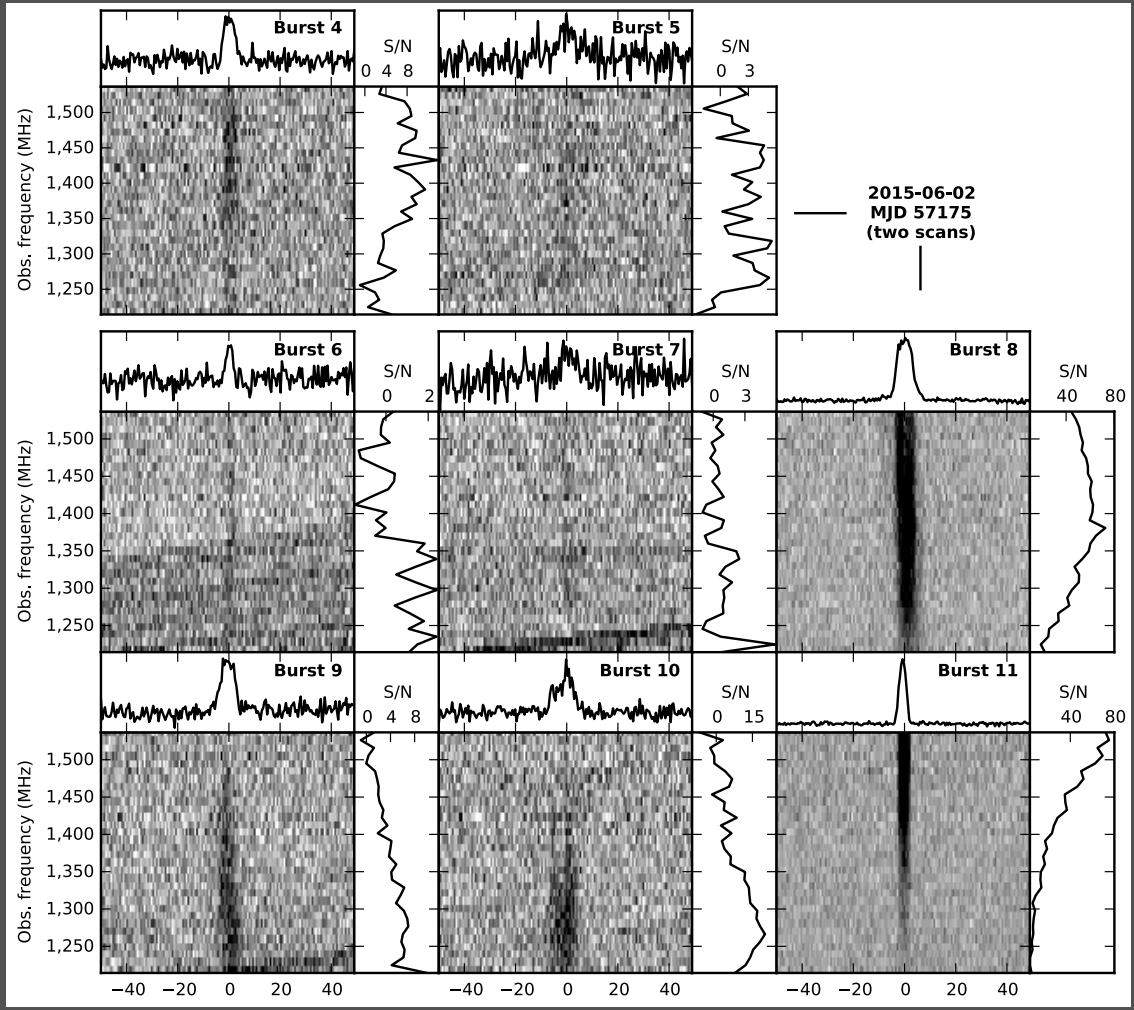


FRB 121102: It repeats!

→ Rules out cataclysmic or explosive models, at least for this one source.

(Spitler et al. 2016)

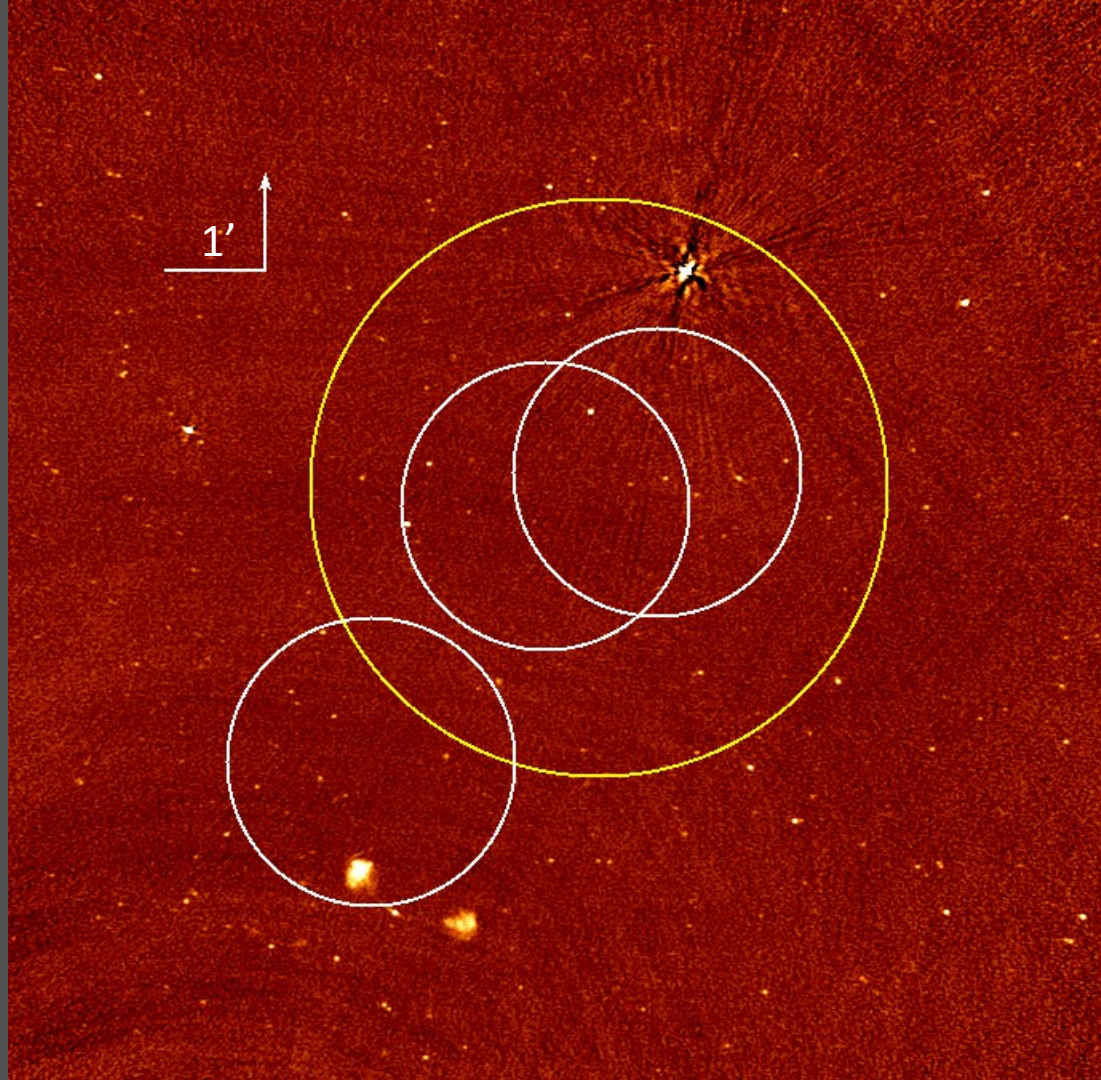
→ A better-than-random location to go fishing.



So where is it?

Arecibo detection beams cover dozens of sources in higher resolution VLA observations.

Original detection (Spitler et al. 2014) was apparently in a sidelobe.

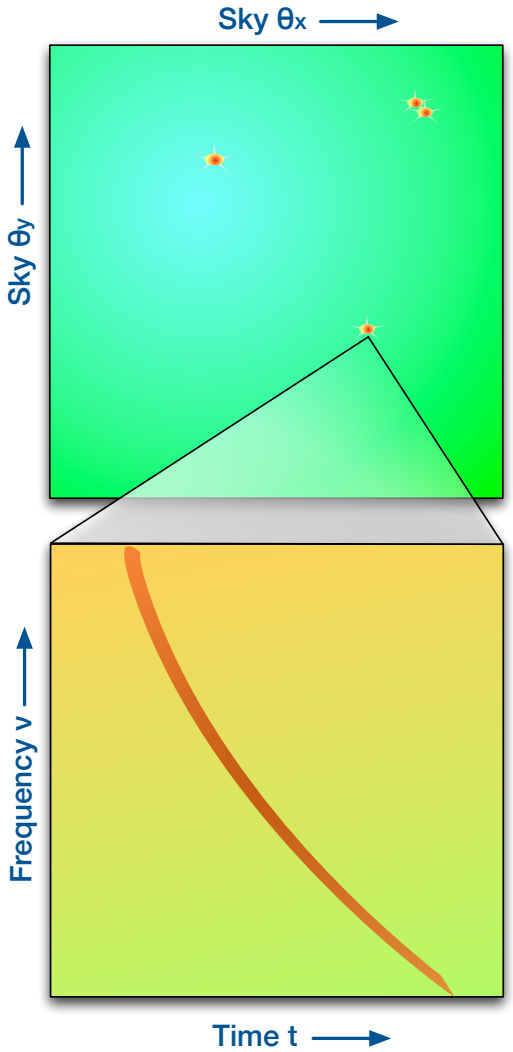


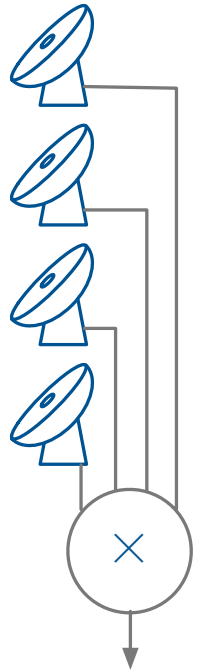
VLA localization

Fast sampled visibility data
(u, v, t, f).

→ 2.5 – 3.5 GHz.
→ 256 channels, 4 MHz each.
→ 5 ms visibility sampling.
→ 351 baselines.

= 1 TB/hr correlated data.
(Set by correlator throughput limit.)





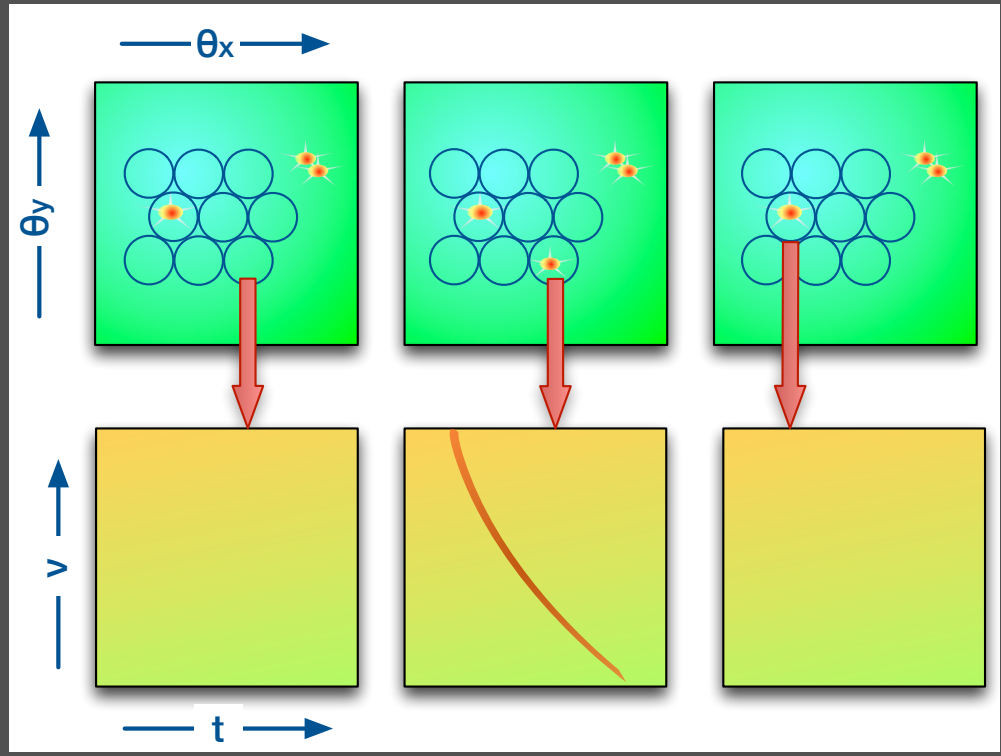
$V_{ij}(\nu, \Delta\nu, t, \Delta t)$

VLA localization

Fast sampled visibility data (u, v, t, f).

Beam-formed Search:

- Tile region with phased-up beams.
- Search for pulse in time domain (t, DM).

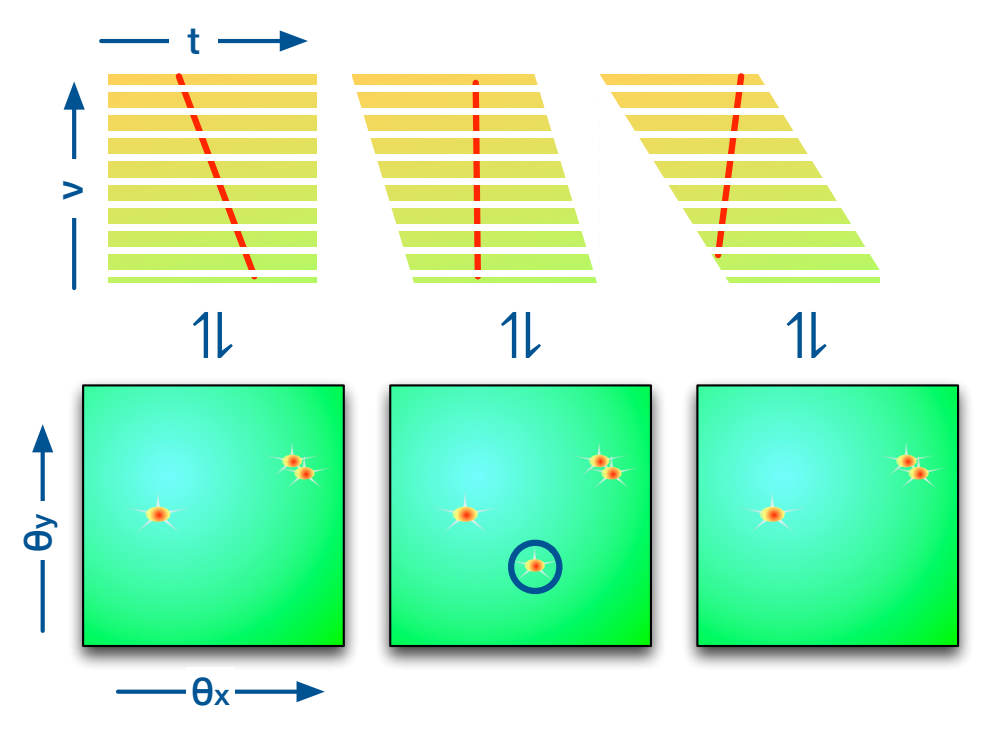


VLA localization

Fast sampled visibility data (u, v, t, f).

Millisecond Imaging:

- De-disperse visibilities, make images for each sample time.
- Search for transient source in image domain.



VLA localization

Fast sampled visibility data (u, v, t, f) for ~83 hours of observing.

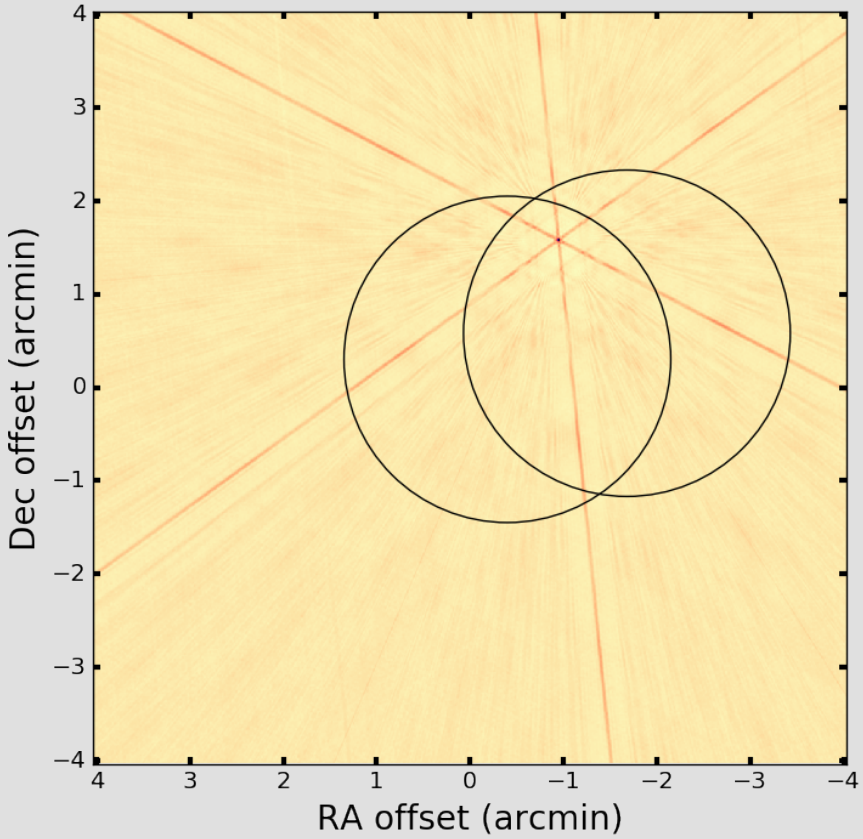
Millisecond Imaging:

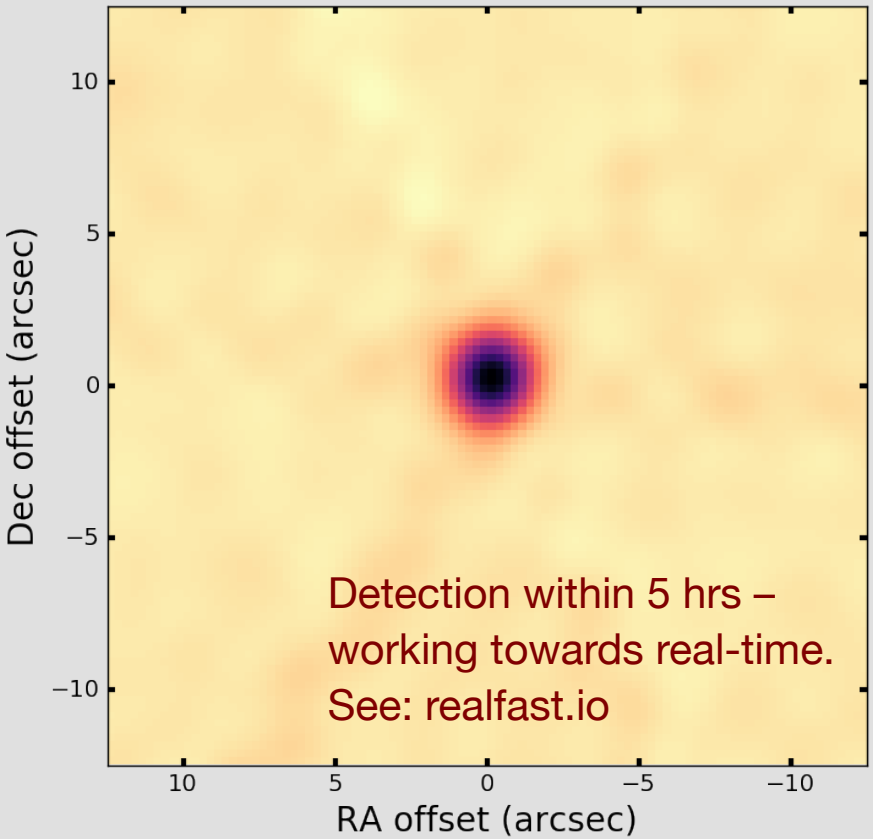
- De-disperse visibilities, make images for each sample time.
- Search for transient source in image domain.

Beam-formed Single-pulse Search:

- Tile region with phased up beams.
- Search for pulse in time domain (t, DM).

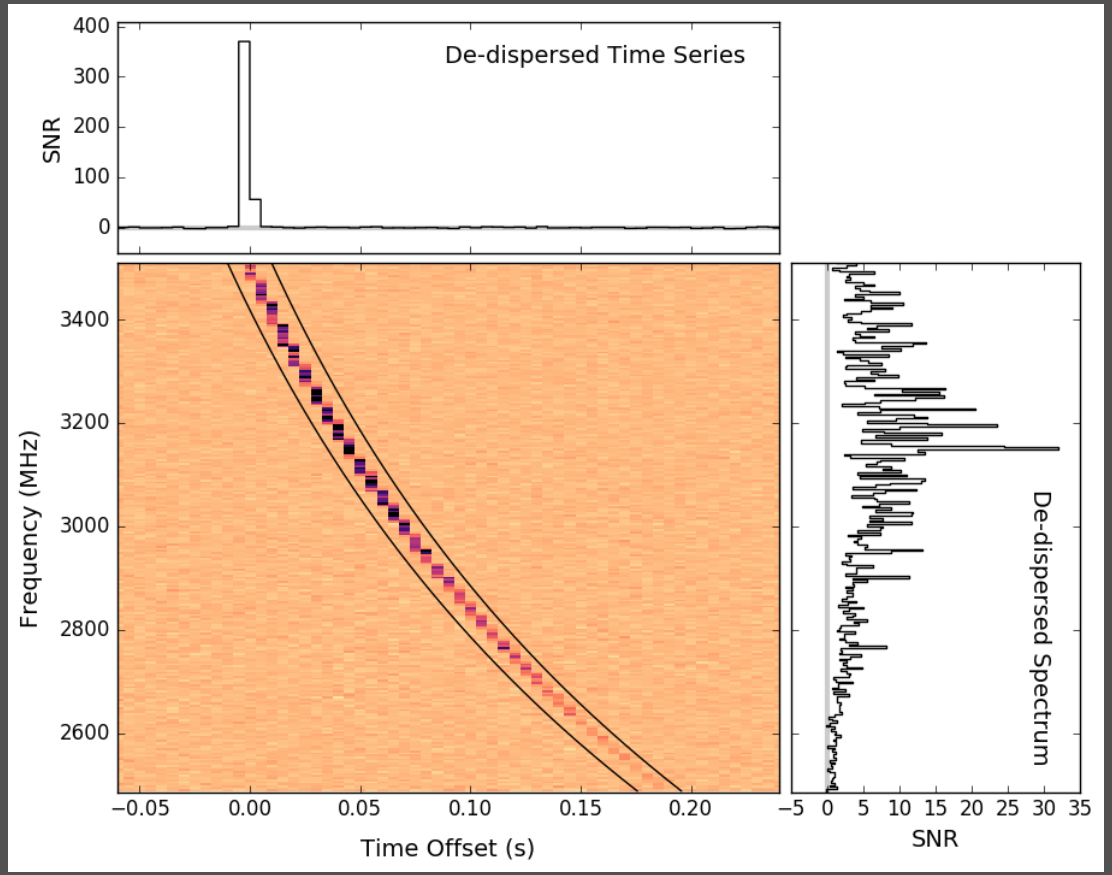
VLA localization: success!





Detection within 5 hrs – working towards real-time. See: realfast.io

VLA beam-forming: pulse sweep



Pulse S/N ratio peaks at the image peak pixel.

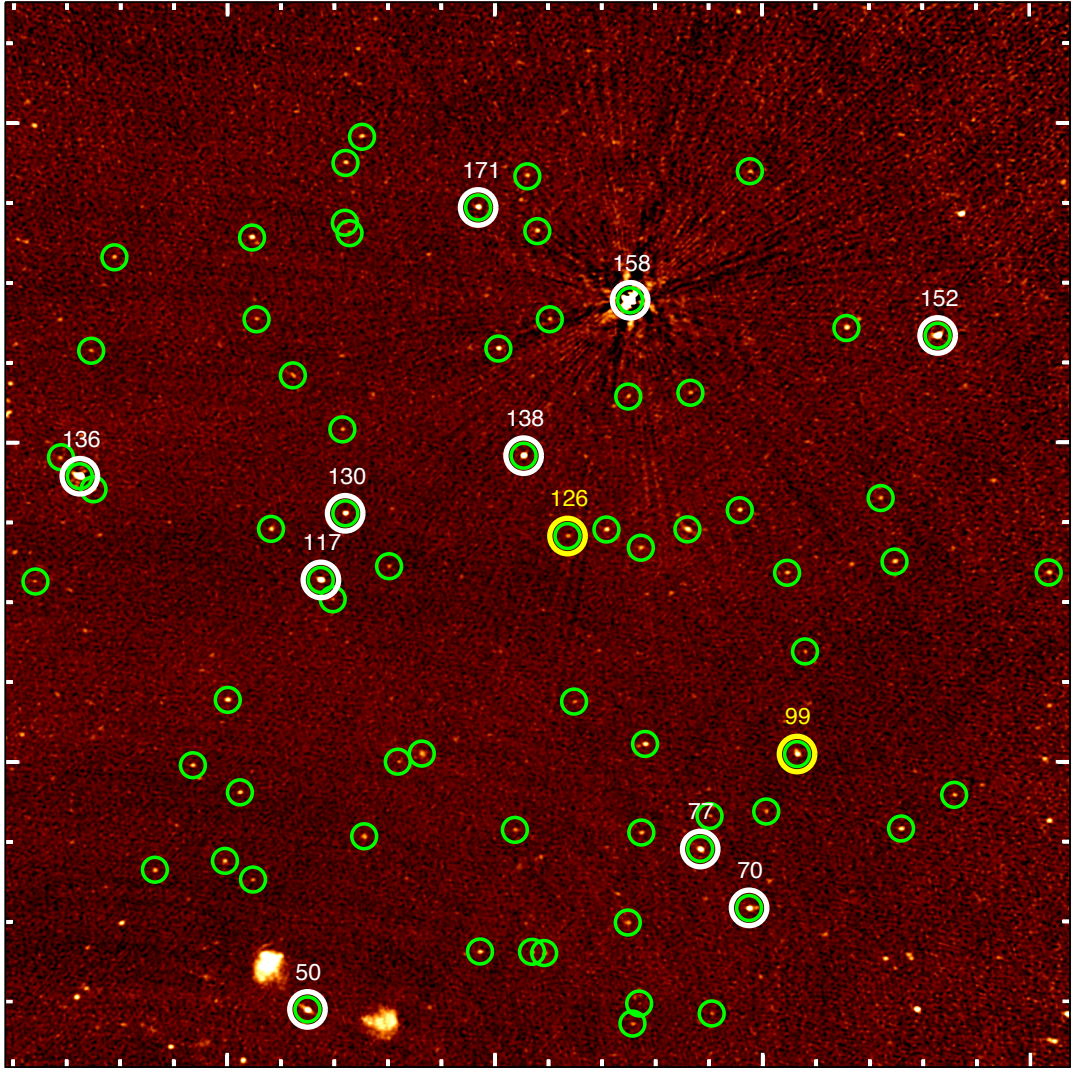
Lines indicate ν^{-2} sweep.

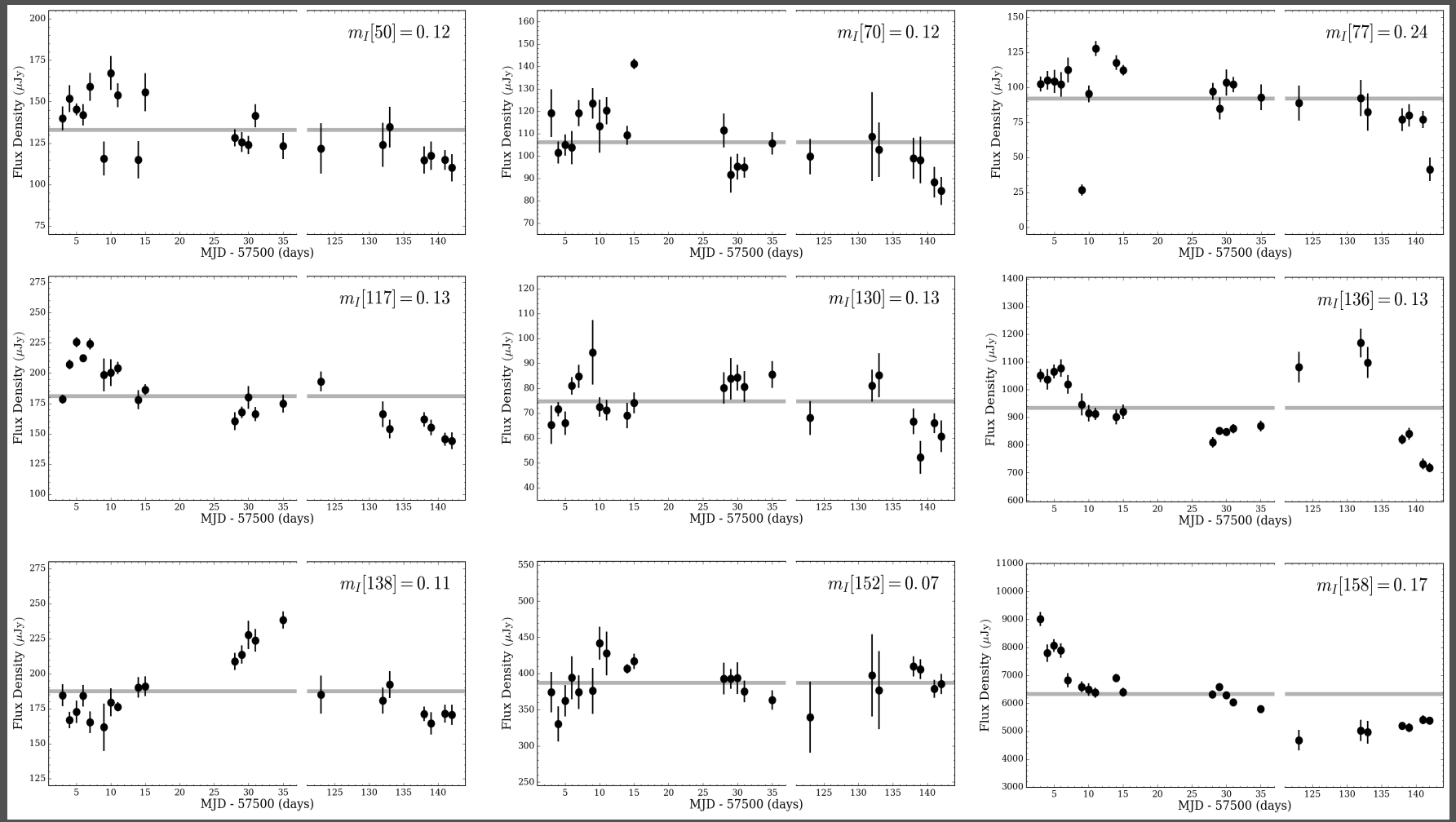
Work by graduate student Robert Wharton.

Field Variability

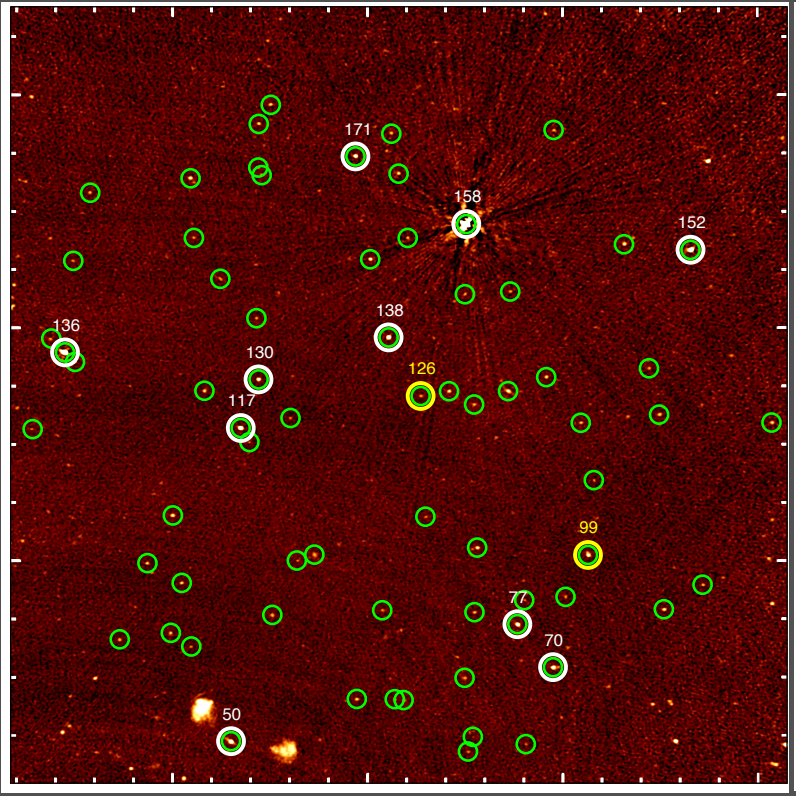
- 69 sources detected in ~most epochs.
- Variability is common.

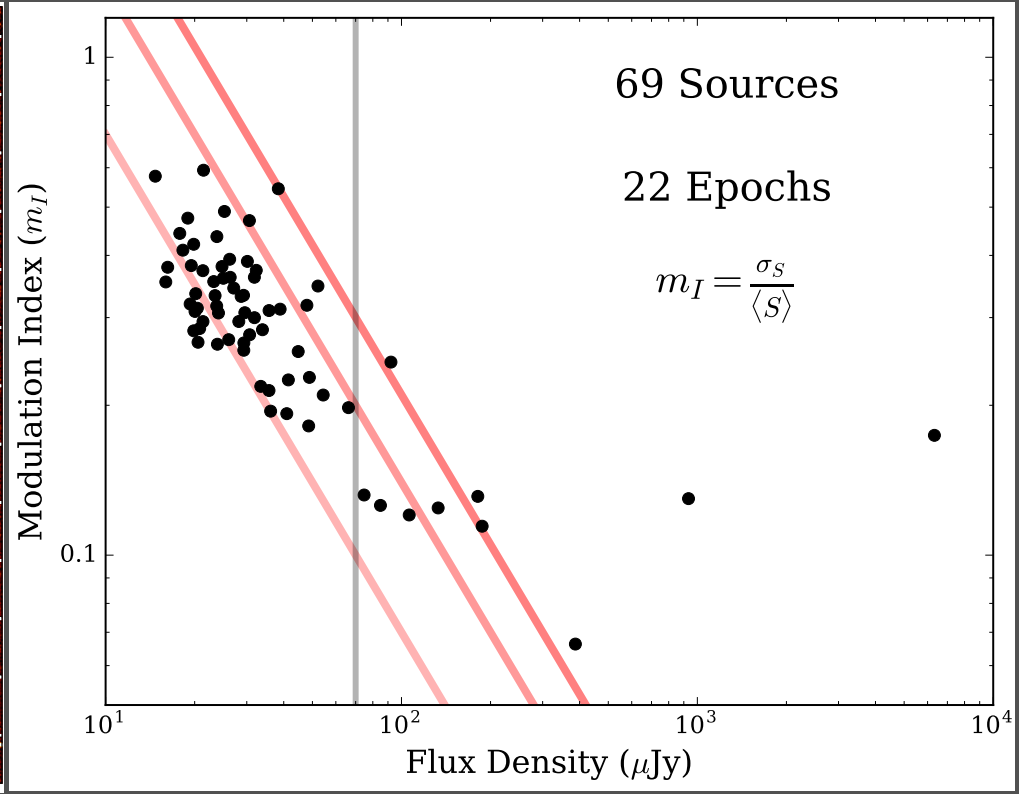
$$m_I = \sigma_S / \langle S \rangle$$



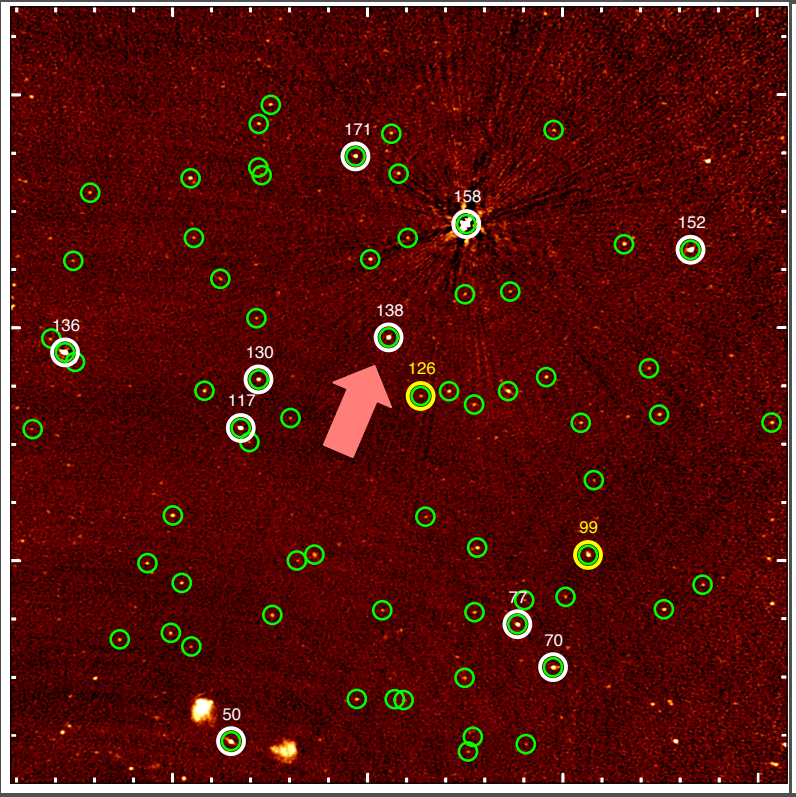

$m_I[50] = 0.12$
$m_I[70] = 0.12$
$m_I[77] = 0.24$
$m_I[117] = 0.13$
$m_I[130] = 0.13$
$m_I[136] = 0.13$
$m_I[138] = 0.11$
$m_I[152] = 0.07$
$m_I[158] = 0.17$
Flux Density (μJy)
MJD - 57500 (days)

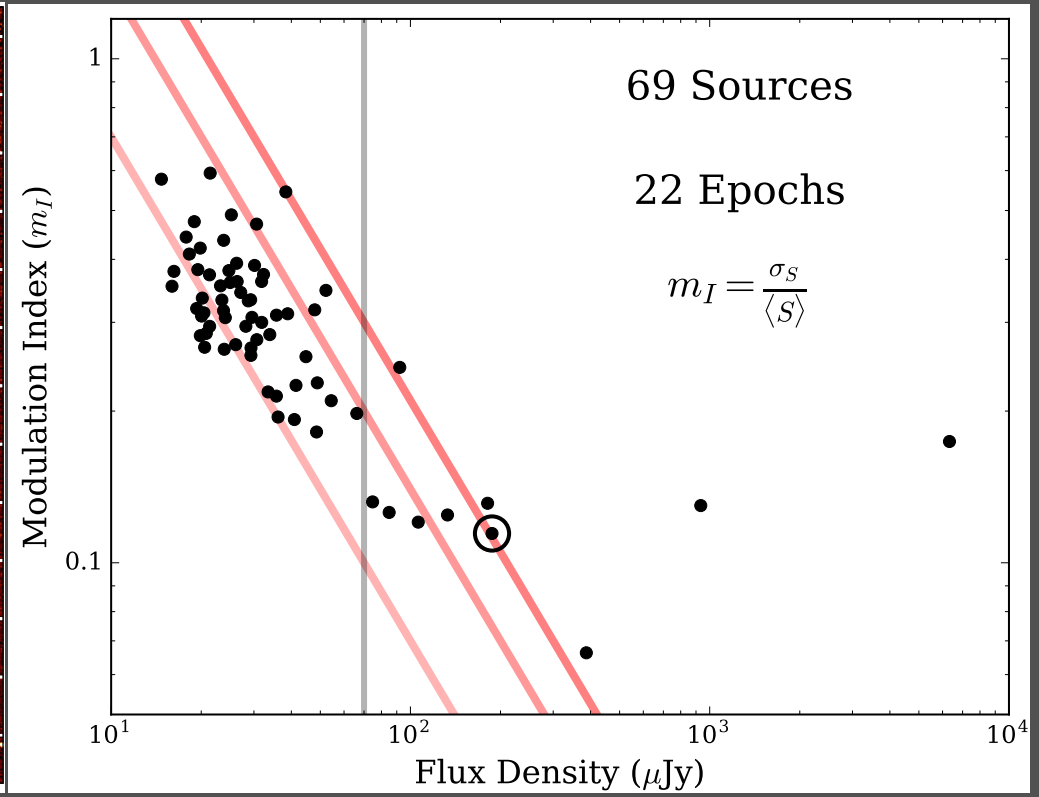
Field Variability





Field Variability

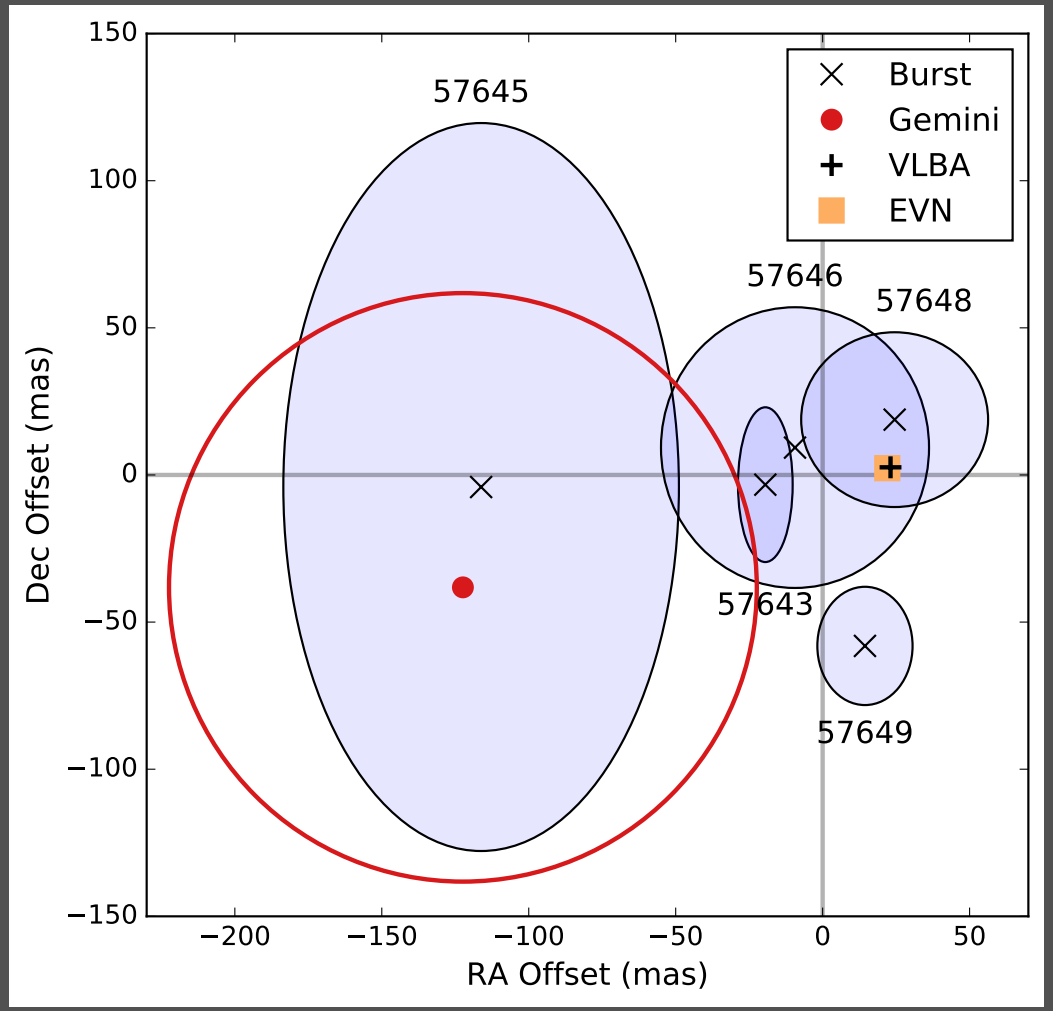


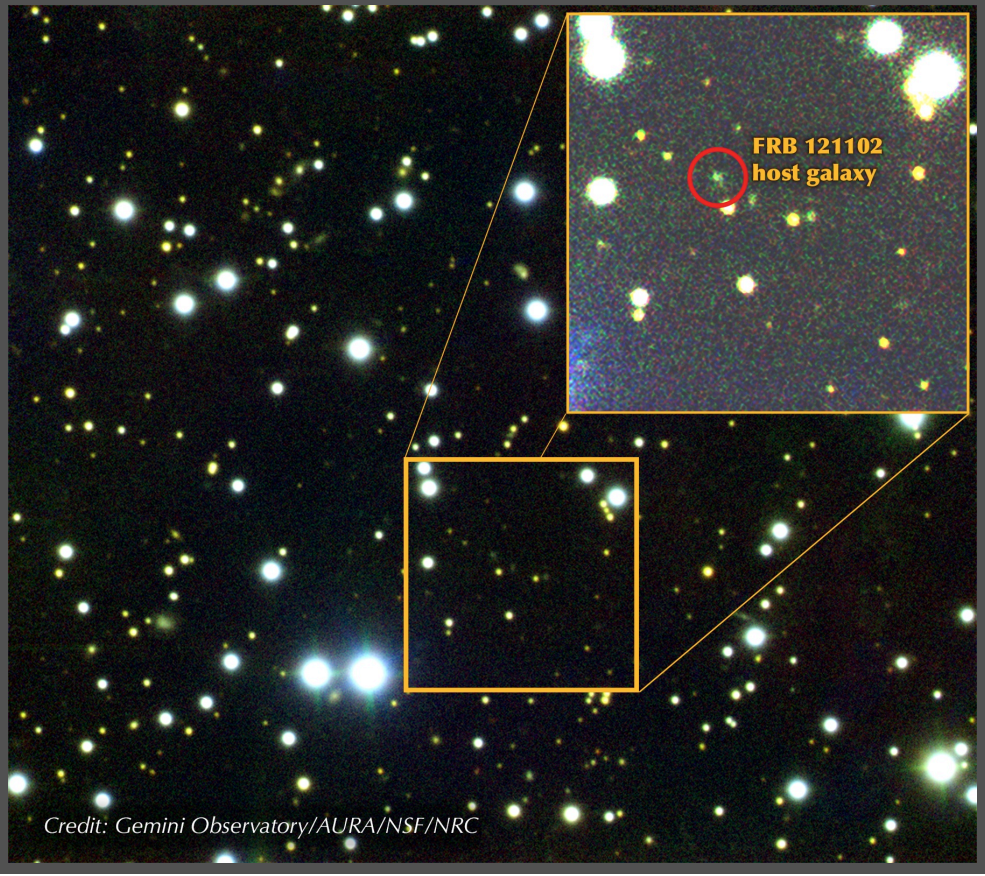


→ Host counterpart: variability may be necessary, but not sufficient.

Radio counterpart

- Persistent, variable, 180 μJy radio counterpart.
- Separation <15 mas (<40 pc at 1 Gpc).

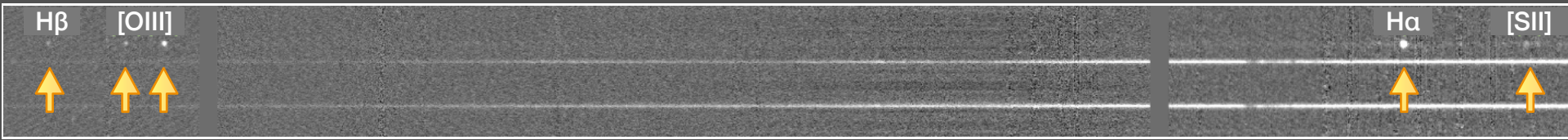




Optical counterpart

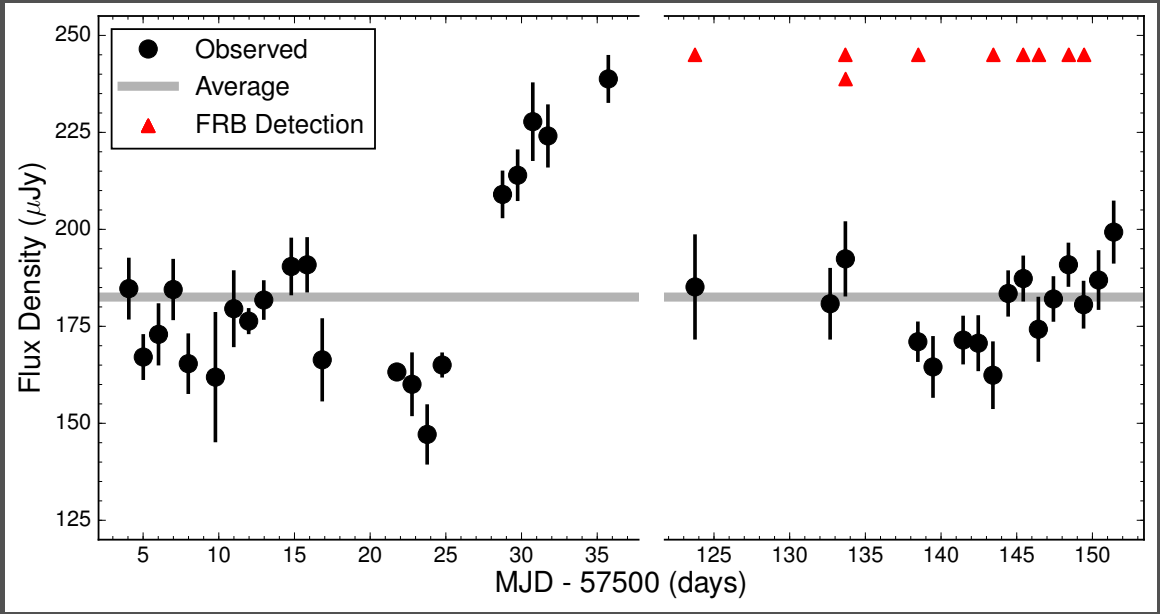
Deep imaging with Gemini:
25th magnitude counterpart.

→ Dwarf galaxy.
→ Emission dominated by spectral lines.
→ z = 0.193;
host is ~1 Gpc away.



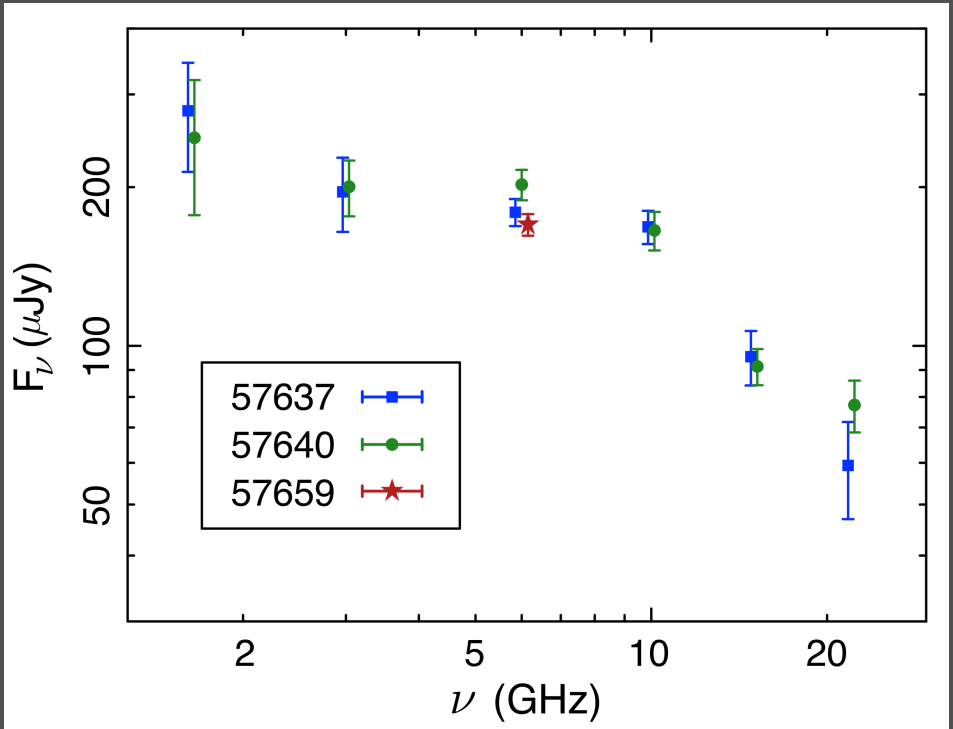
What is the persistent radio source?

- Bursts appear to be sporadic, not a constant rate.



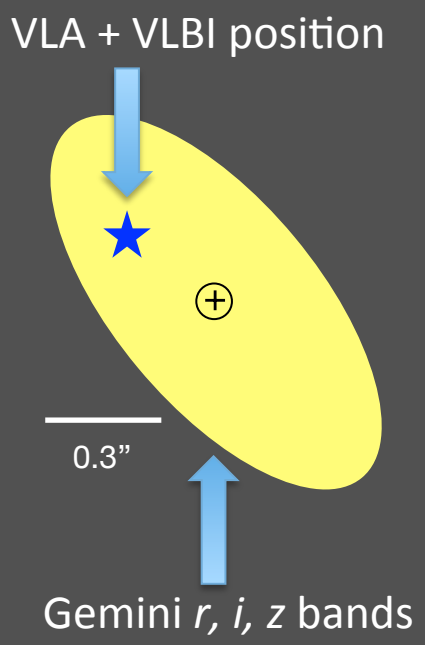
What is the persistent radio source?

- Bursts appear to be sporadic, not a constant rate.
- Spectrum is non-thermal, but not a simple power law.



What is the persistent radio source?

- Bursts appear to be sporadic, not a constant rate.
- Spectrum is non-thermal, but not a simple power law.
- Appears displaced from host galaxy center of light.
- Inconsistent with AGN.



Summary

→ Localized FRB 121102, to ~15 milliarcsec precision.

→ Persistent, variable radio counterpart.

→ Host is a dwarf galaxy at z~0.193.

Not yet addressed:

→ Mechanism of the bursts. Magnetar models? AGN models?

→ How typical is FRB 121102?
Do all FRBs repeat? Or are there multiple classes of FRBs?