

Milliarcsecond localizations as insights of the local environments and origins of Fast Radio Bursts

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on behalf of the PRECISE and AstroFlash projects



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Artwork credit: Danielle Futselaar



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astroflash-frb.github.io



What is a Fast Radio Burst (FRB)?

Fast Duration of $\sim 1 \mu\text{s}$ –10 ms

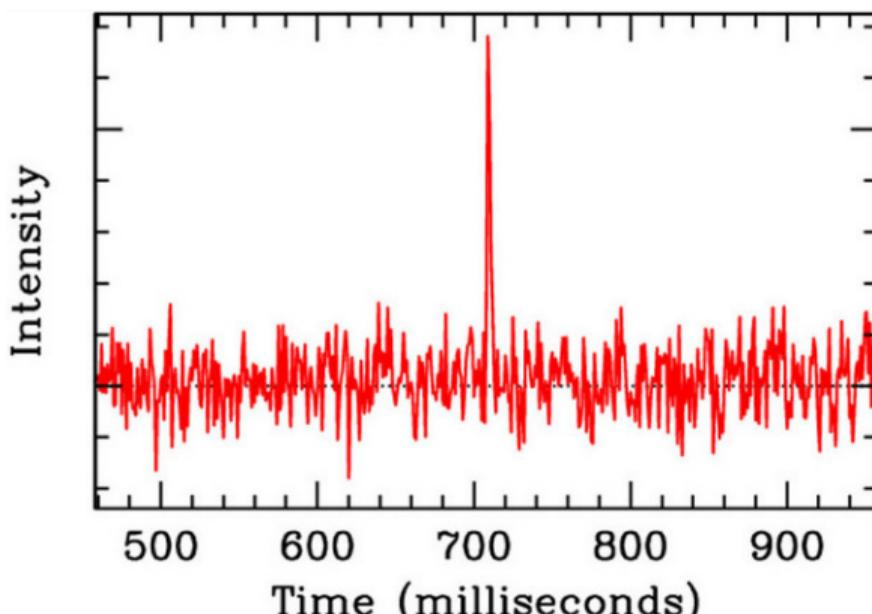
Radio Observed at 0.2–8 GHz

Burst Bright ~ 0.1 –100 Jy

Discovered by Lorimer et al. (2007)

Hundreds of them reported
(frbcat.org; Petroff et al. 2016)

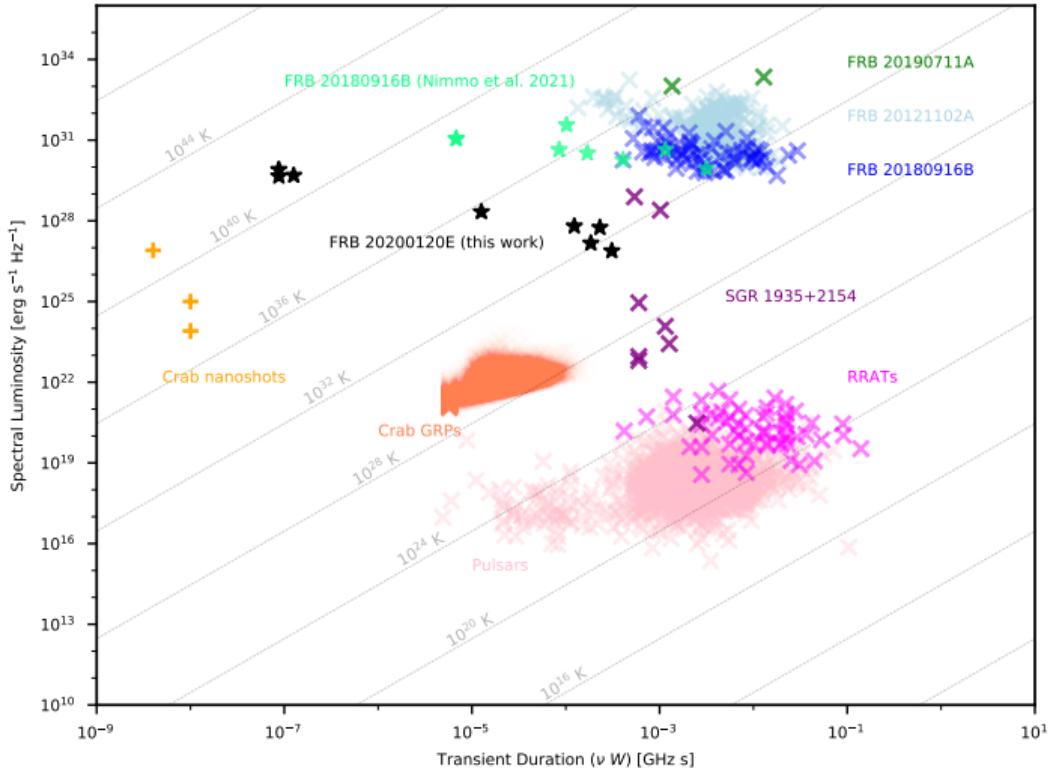
Origin: unknown



FRB 140514



The luminosity “problem”



(Nimmo et al. 2022, Nature Astronomy, 6, 393)



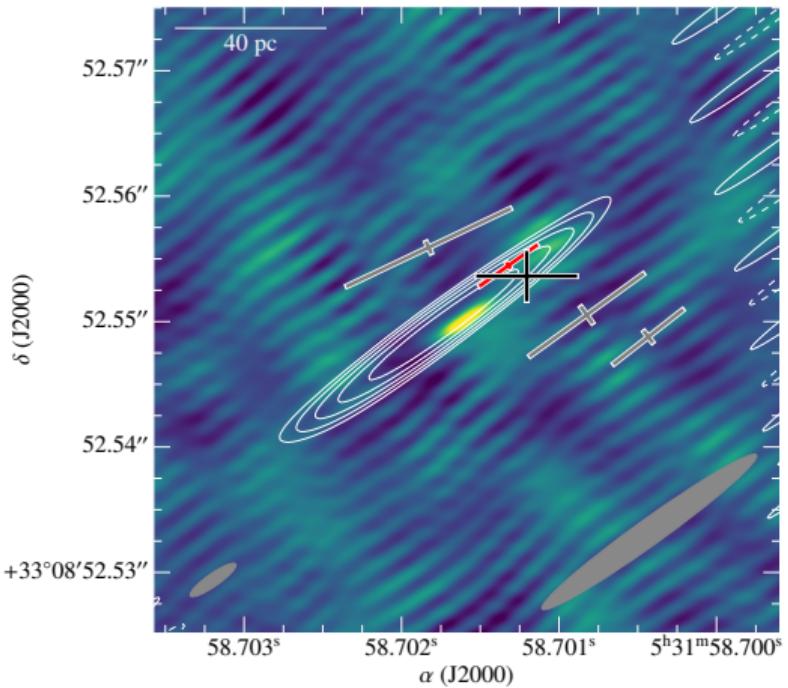
Why are FRBs important?

- FRBs look like single pulses from pulsars but $\sim 10^{10}$ brighter.
- Possible emission from radio to gamma-rays?
- Trace properties of the intergalactic medium and Galactic Halos (Prochaska & Zheng 2019).
- 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 (Macquart et al. 2020), ...

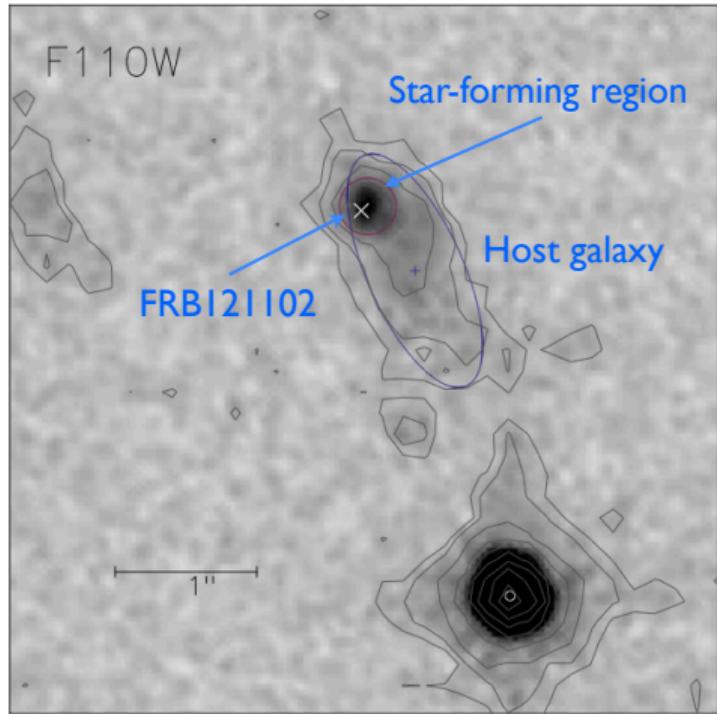
The Good

on precise localizations of FRBs

The First Precise Localization of a Fast Radio Burst: FRB 20121102A



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 Second Localized Repeating FRB: 20180916B



(CHIME/FRB et al. 2019, ApJL, 885, L24)

EVN: 4 bursts on 19 June 2019

localized to ~ 2 mas

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

At the edge of a star-forming region

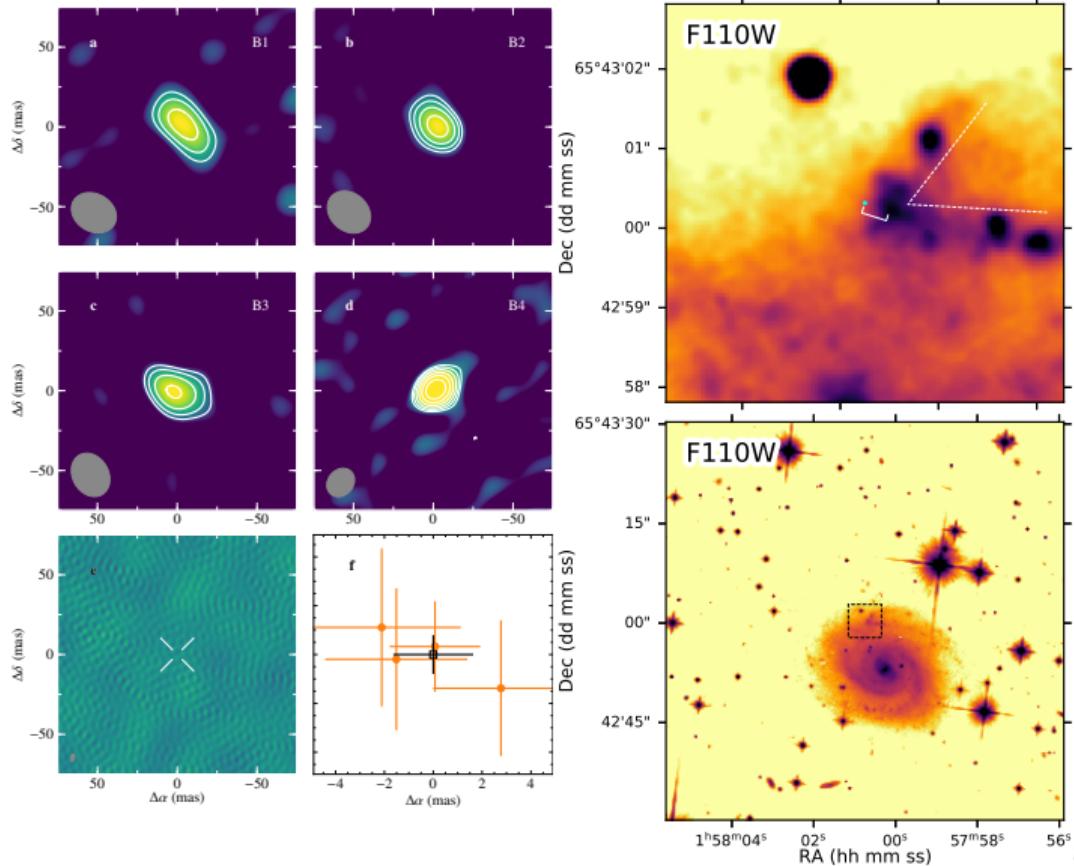
Tendulkar et al. (ApJL 2021, 908, L12)

The bursts appear in a ~ 4 -d window
with a period of 16.35 ± 0.15 days

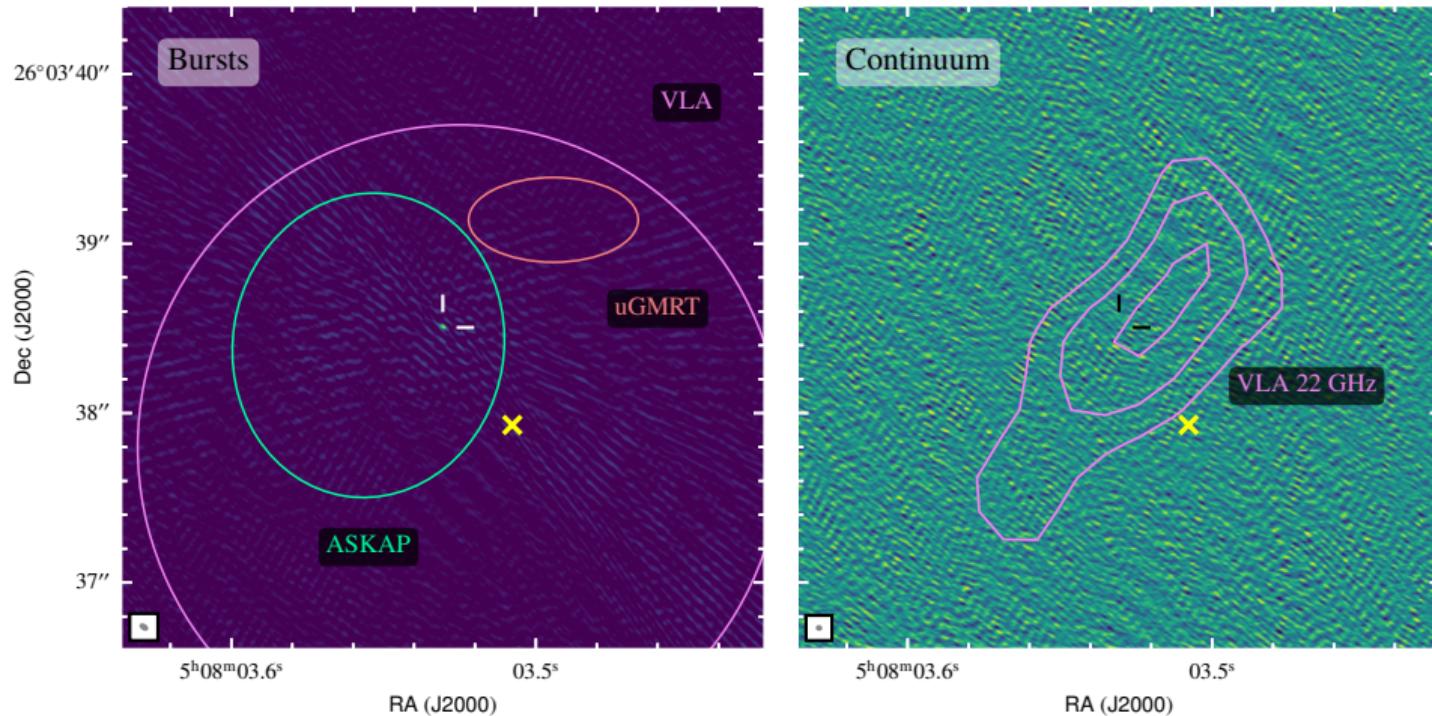
(CHIME/FRB et al. 2020, Nature, 582, 351)

Shortest components of $3\text{--}4 \mu\text{s}$

Nimmo et al. (2021, Nat Astr, 5, 594)

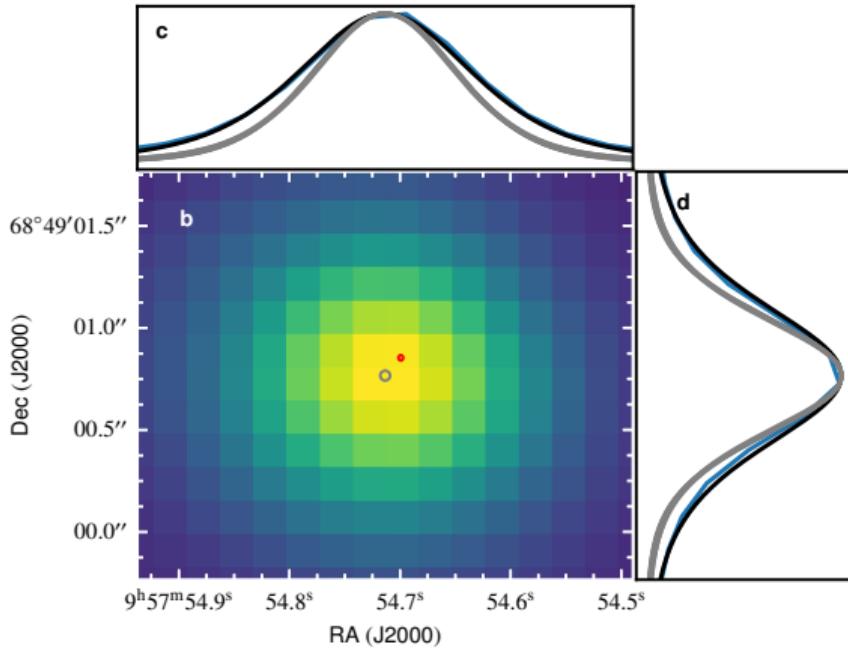
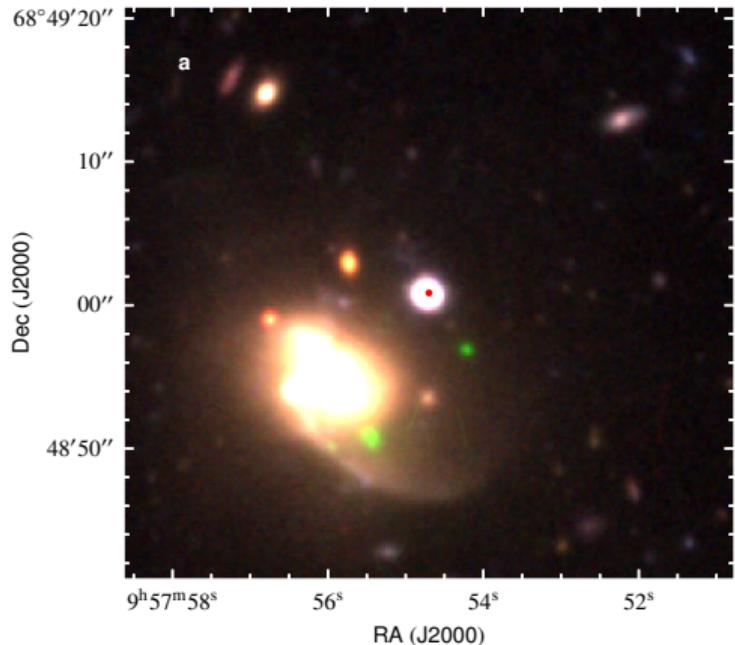


FRB 20201124A



13 + 5 bursts in two observations (Marcote et al. 2021, ATel #14603; Nimmo et al. 2022, ApJL, 927, L3)

FRB 20200120E — M81



(Kirsten, Marcote et al. 2022, Nature, 602, 585)

(Nimmo et al. 2022, Nature Astronomy, 6, 393)

The Bad

on precise localizations of FRBs

10^{-7}

$\gtrsim 2\,500$ hours observed...
... $\lesssim 1$ second of FRB signals!



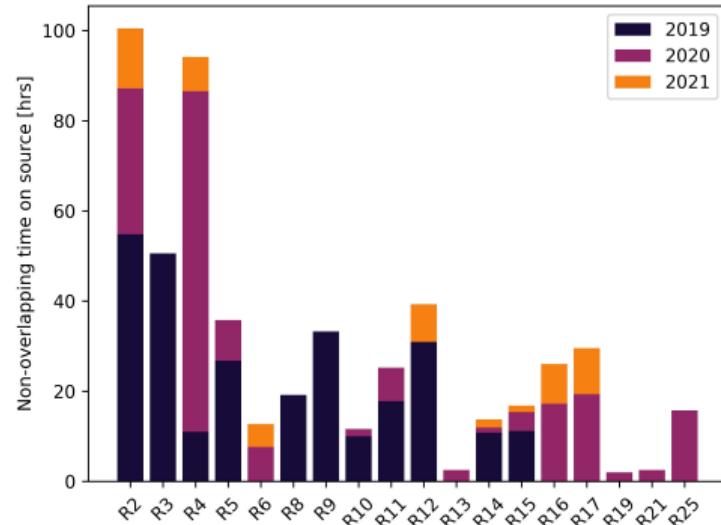
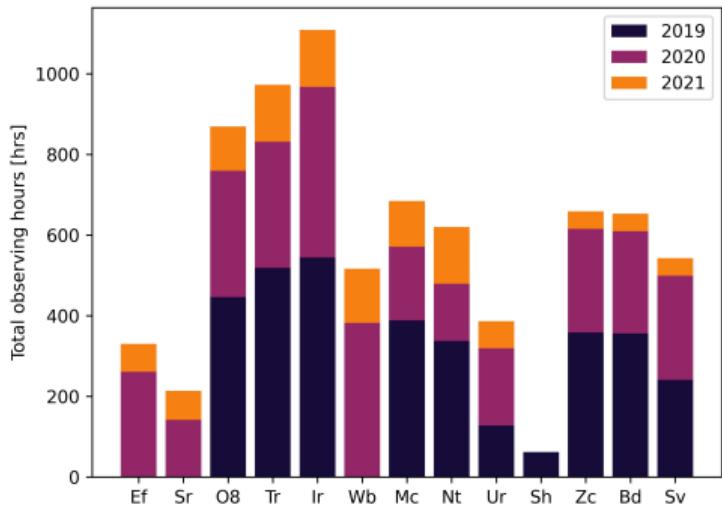
JIVE

Joint Institute for VLBI
ERIC



EUROPEAN
VLBI
NETWORK

Pinpointing Repeating Chlme Sources with EVN dishes (PRECISE)



Director's approval: Onsala, Torun , KVAZARs, Shanghai, Westerbork, Urumqi

Dedicated proposals: Irbene, Medicina, Noto, Effelsberg, Sardinia

Effelsberg: five hours per week (dual recording: DBBC and pulsar backend)

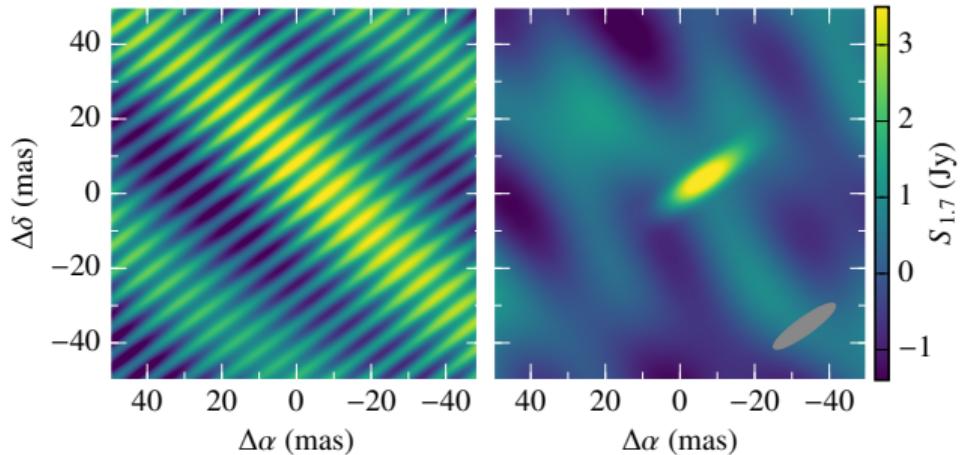
Sardinia: six hours per week (helped to implement and commission dual recording)

In case of bursts: **correlation at JIVE** via an EVN (correlator-only) proposal.

The Ugly

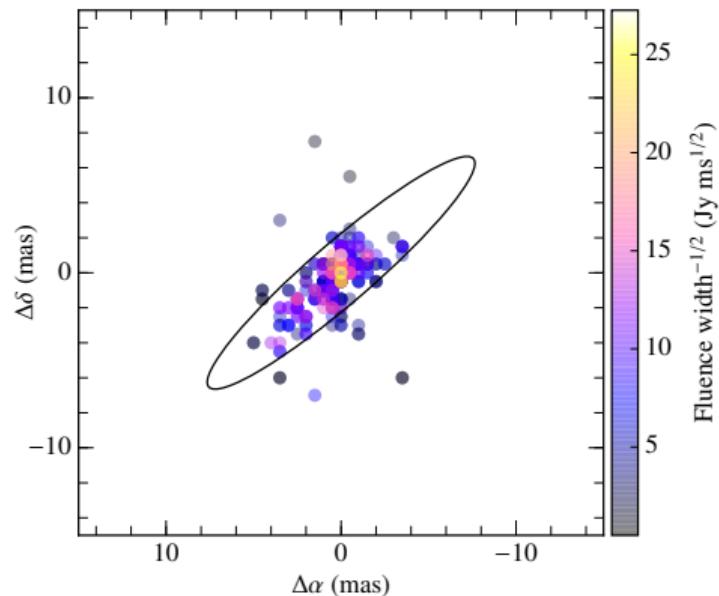
on precise localizations of FRBs

Astrometry from millisecond-duration bursts: FRB 121102



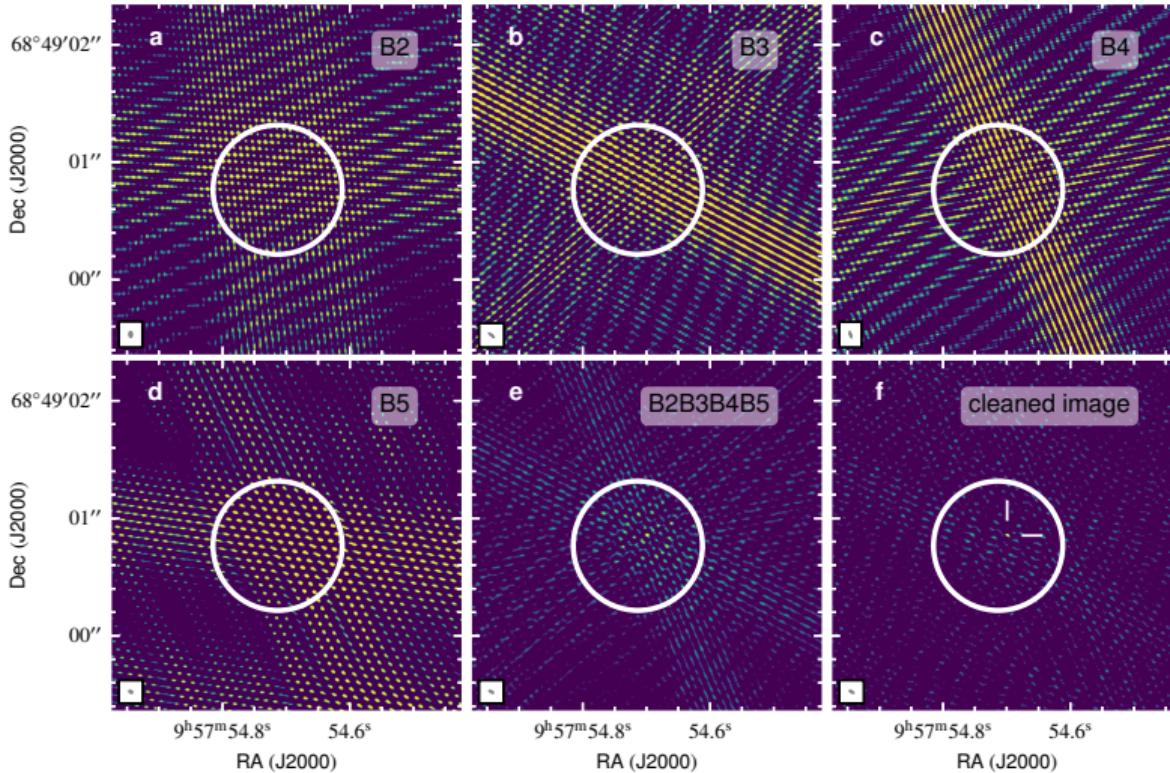
Dirty and clean image from FRB 20121102A.

Astrometry limited by signal-to-noise ratio



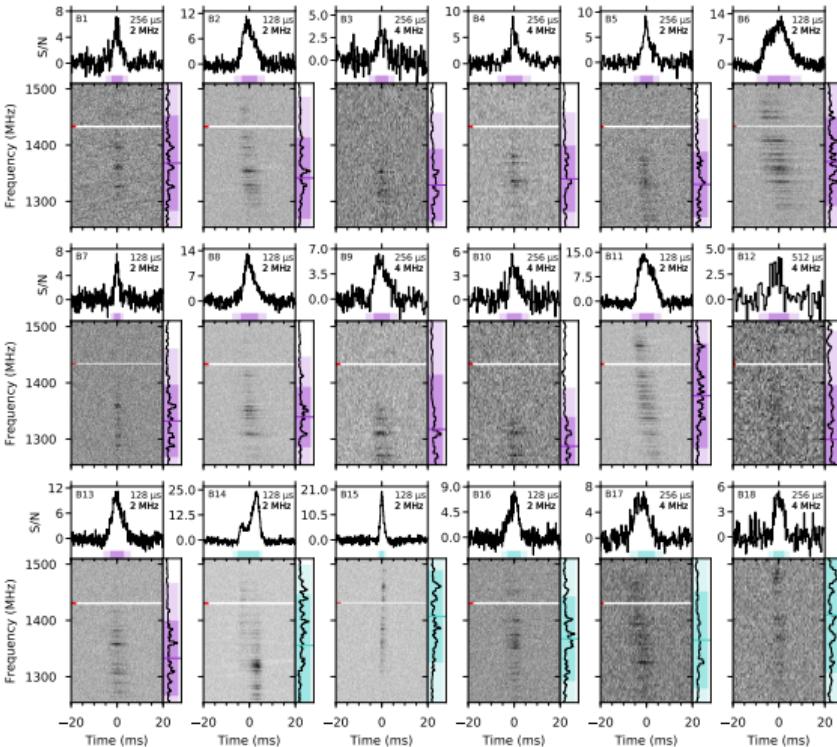
Positions derived from 406 pulses from the pulsar B0525+21

Astrometry from millisecond-duration bursts: FRB 20200120E

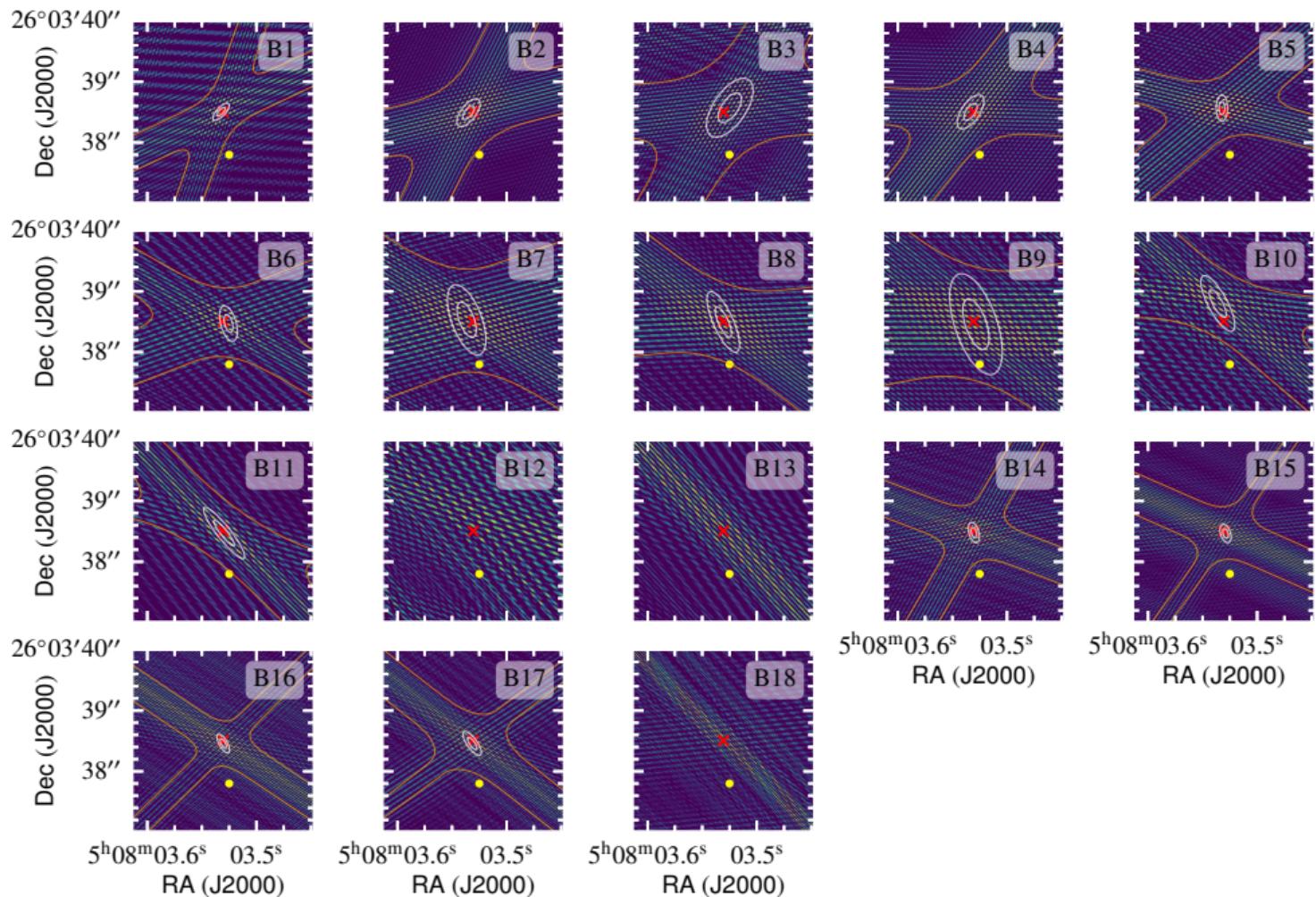


(Kirsten, Marcote et al. 2022, Nature, 602, 585)

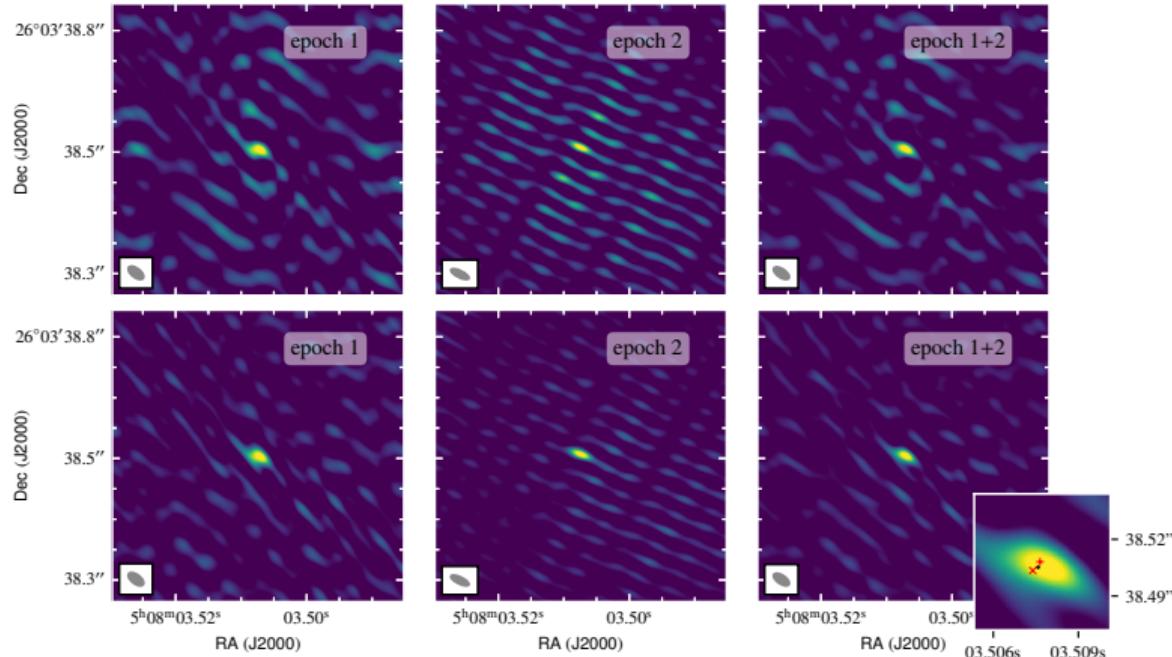
Astrometry from millisecond-duration bursts: FRB 20201124A



Nimmo et al. (2022, ApJL, 927, L3)

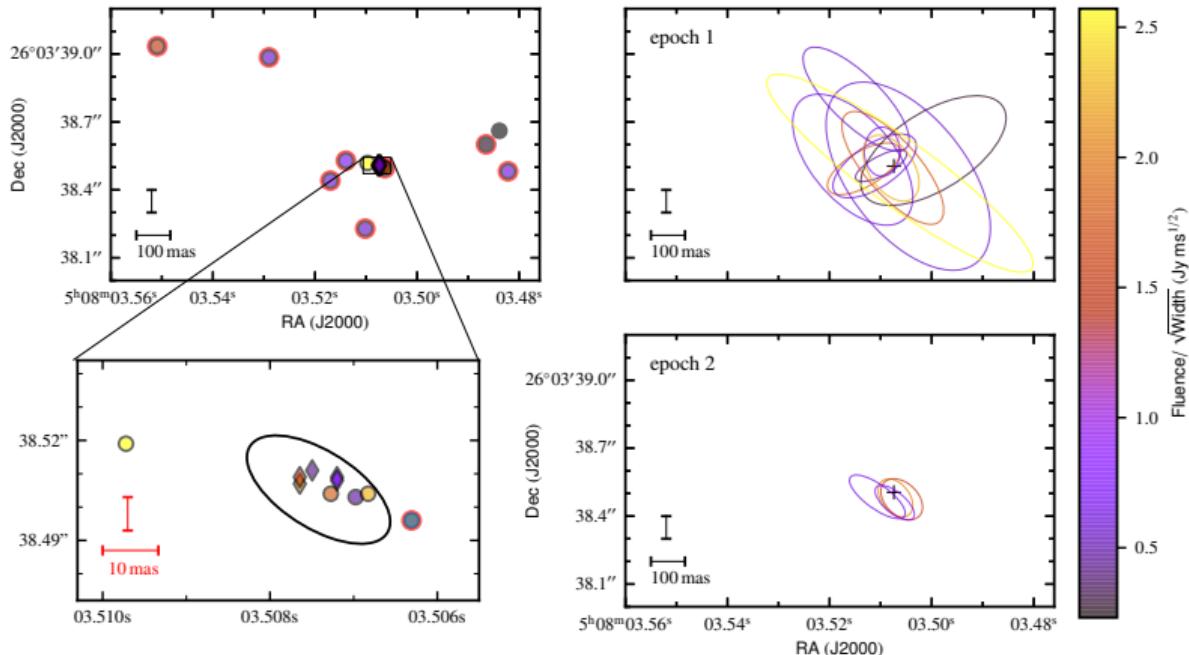


Astrometry from millisecond-duration bursts: FRB 20201124A



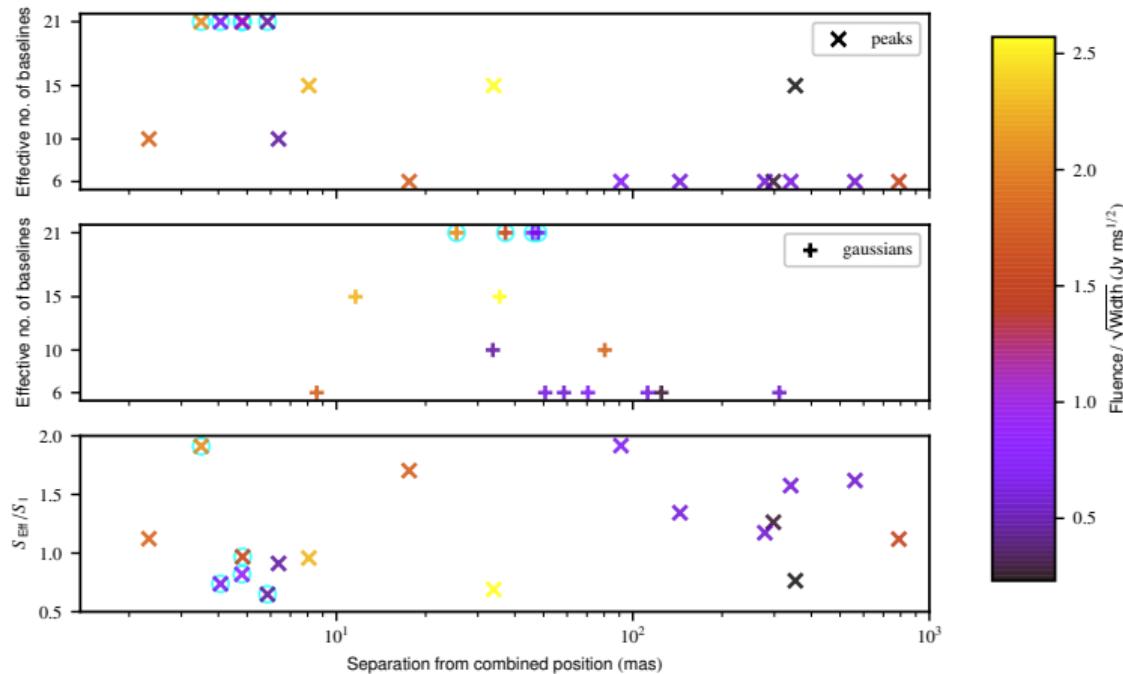
Nimmo et al. (2022, ApJL, 927, L3)

Astrometry from millisecond-duration bursts: FRB 20201124A



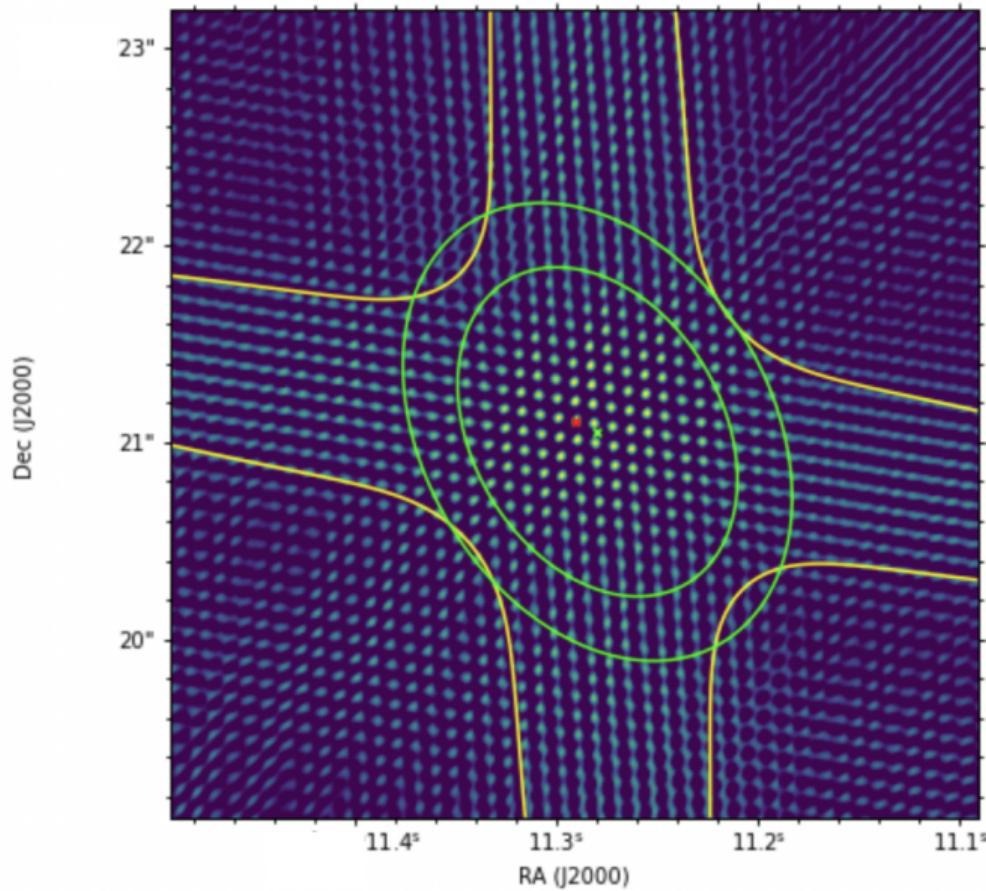
Nimmo et al. (2022, ApJL, 927, L3)

Astrometry from millisecond-duration bursts: FRB 20201124A



Nimmo et al. (2022, ApJL, 927, L3)

Under the oven...



Summary and conclusions



- **Fast Radio Bursts** are a remarkable new type of astrophysical objects of unknown nature
- Hundreds of them have been discovered in the last years
But only tens of them (handful of repeaters) have been precisely localized to date
- Every localization is still opening new questions (!)
- We can do ***milliarcsecond*** astrometry of ***millisecond*** bursts with the EVN!
And ***hundreds of milliarcsecond*** localizations with limited number of EVN antennas!

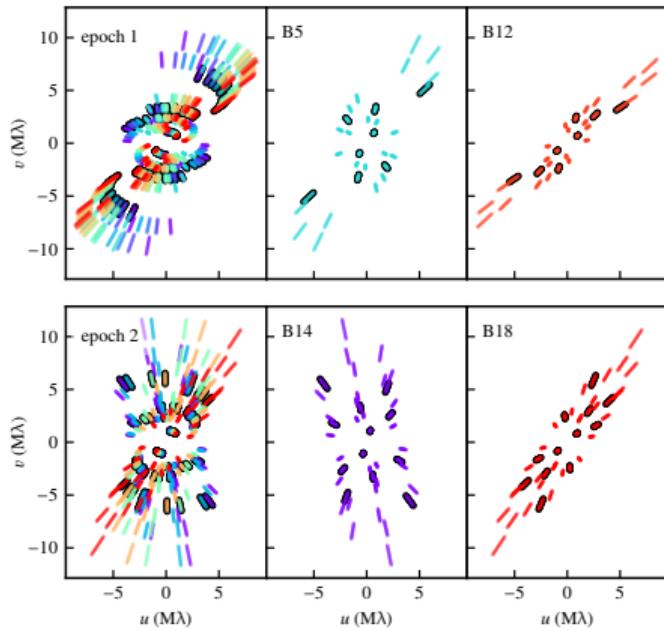


Thank you!

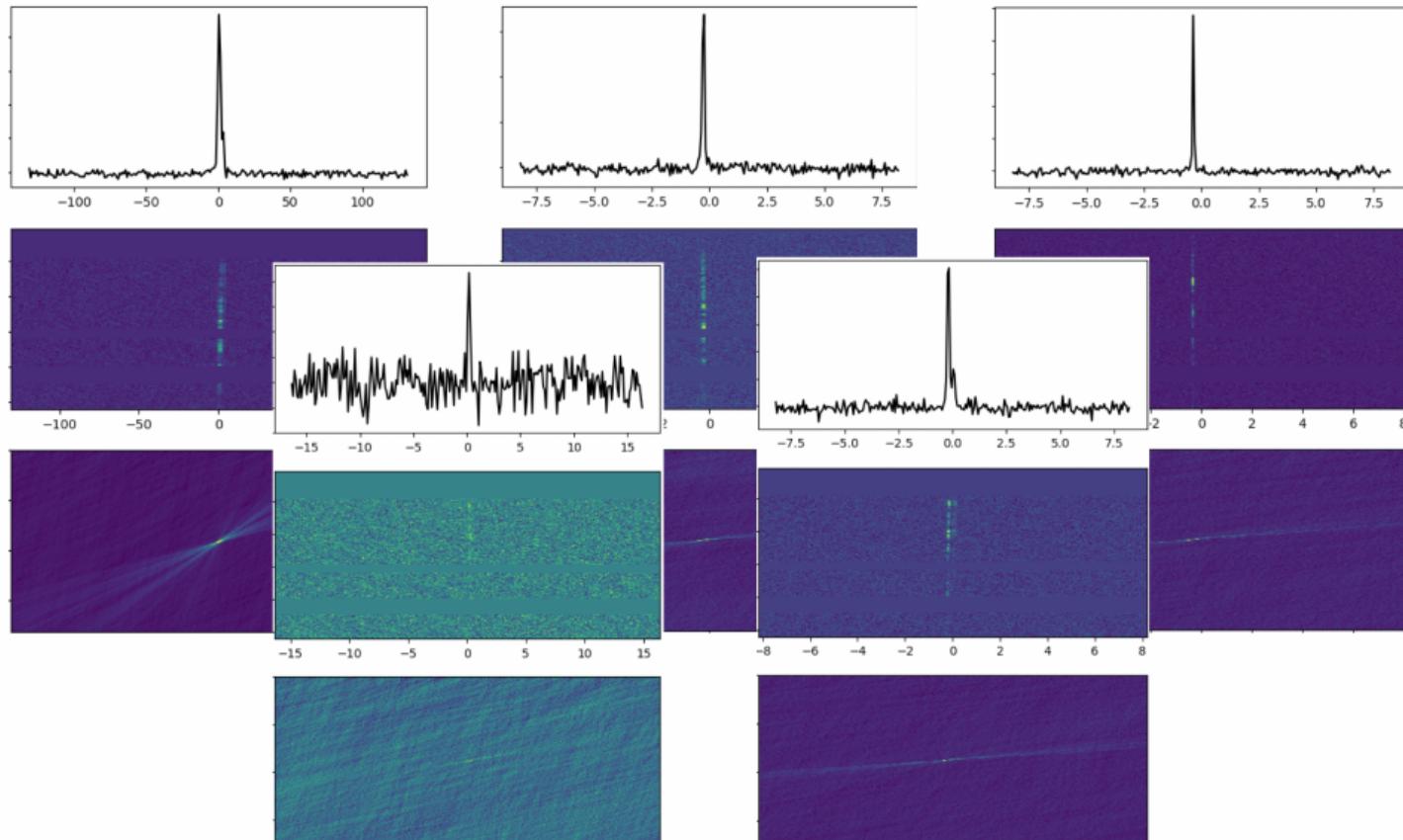
marcote@jive.eu

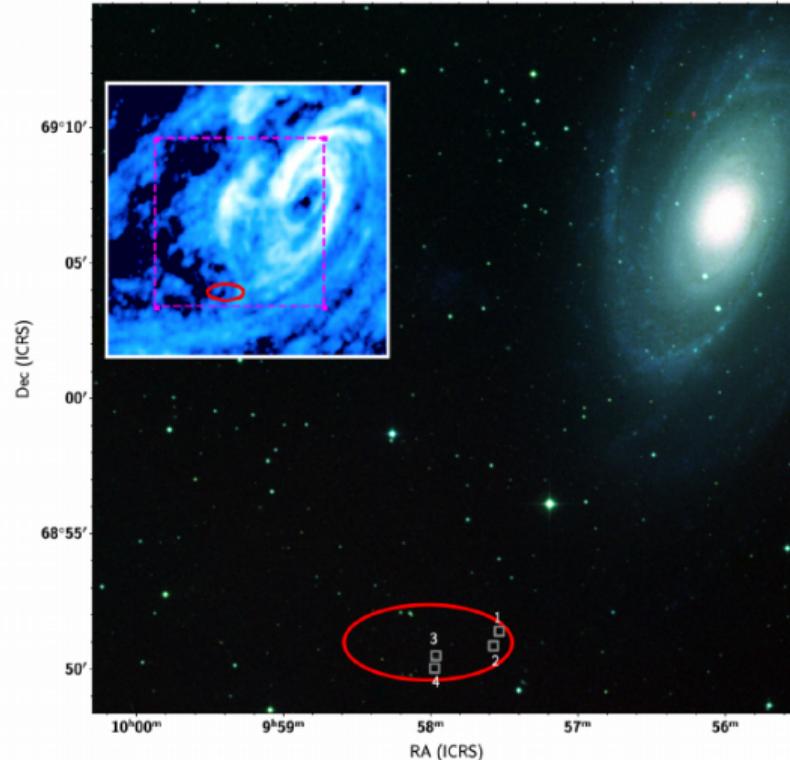
astroflash-frb.github.io

Astrometry from millisecond-duration bursts



Pinpointing Repeating CHIME Sources with EVN dishes (PRECISE)





(1) M81 HII region, (2) X-ray source, (3) M81 globular cluster, (4) radio source

The Second Localized Repeating FRB: 20180916B

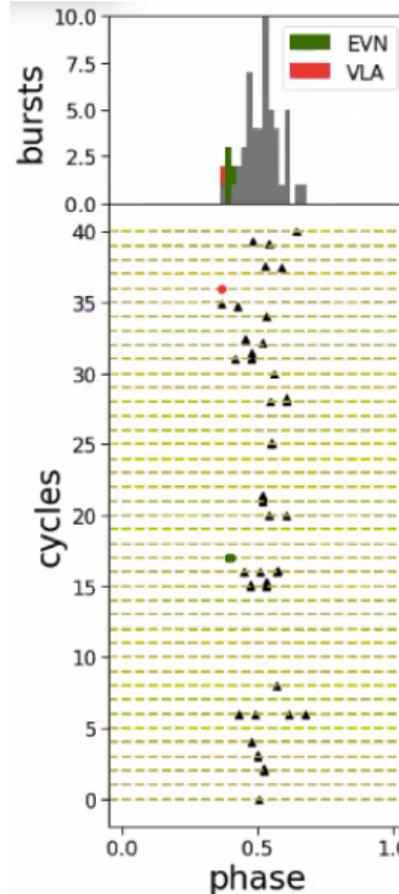


After that a periodic pattern was discovered in FRB 20180916B:

Binary system? Precession? Spin?

Note the similar evidences in FRB 20121102A, with a periodicity of ~ 150 days

(Rajwade et al. 2020)



The Second Localized Repeating FRB: 20180916B



EVN baseband data

Highly linearly polarized ($\gtrsim 80\%$)
No circularly polarized ($\lesssim 15\%$)

Constant polarization Position Angle
but with a few deg. variations

Magnetospheric origin?

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

