Is FRB 150418 localized in WISE J0716−19? Clues from EVN observations

Benito Marcote

M. Giroletti, M. Garrett, Z. Paragi, J. Yang, K. Hada, C. C. Cheung

Joint Institute for VLBI ERIC (JIVE)

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EVN Symposium

Time-domain astronomy

There is a large number of sources that typically have only been studied with single dishes and not considered in VLBI (for obvious reasons):

- Pulsars
- Magnetars bursts
- Giant pulses (e.g. Crab)
- Rotating radio transients (RRATs)
- Fast Radio Bursts (FRBs)
- ...

All of them characterized by showing bright bursts lasting ms

Pulsar timing localization works really well with pulsars and observations along the years...but not for FRBs! (they do not repeat)

The EVN can help in the localization of FRBs and help to unveil their origin.

Fast Radio Bursts

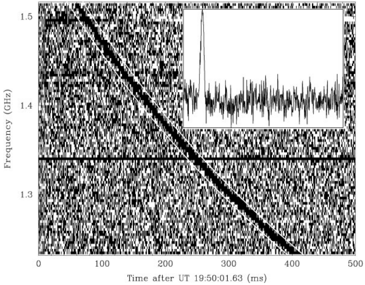
Transient sources exhibiting single short bright pulses: ∼Jy, ∼ms

Discovered by Lorimer et al. (2007)

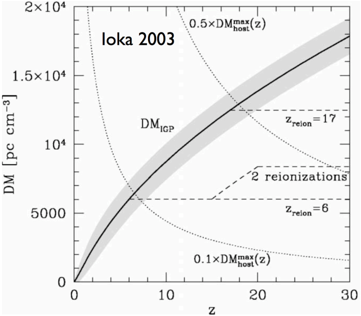
Not obvious associations

Origin? extremely young pulsars, magnetars? Galactic? Extragalactic?

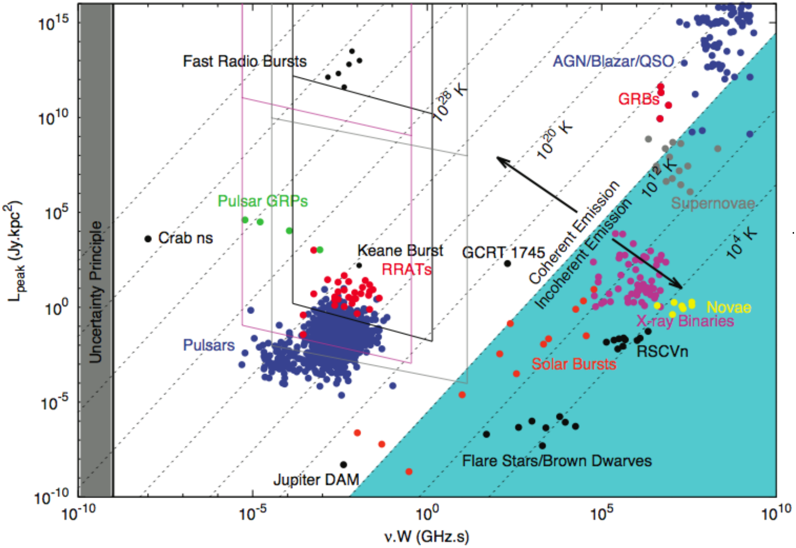
Large dispersion measure (DM) pointing to an extragalactic origin



Credit: Lorimer et al. (2007)



Time-domain sources



Credit: J. P. Macquart

Fast Radio Bursts

$\approx$20 FRBs have been discovered up to now

Event	Telescope	gl [deg]	gb [deg]	FWHM [deg]	DM [cm^{-3} pc]	S/N	W_{obs} [ms]	$S_{peak,obs}$ [Jy]	F_{obs} [Jy ms]	Ref
FRB010125	parkes	356.641	-20.020	0.25	790(3)	17	$9.40^{+0.20}_{-0.20}$	0.30	2.82	1
FRB010621	parkes	25.433	-4.003	0.25	745(10)		7.00	0.41	2.87	2
FRB010724	parkes	300.653	-41.805	0.25	375	23	5.00	$>30.00^{+10.00}_{-10.00}$	>150.00	3
FRB090625	parkes	226.443	-60.030	0.25	899.55(1)	30	$1.92^{+0.83}_{-0.77}$	$1.14^{+0.42}_{-0.21}$	$2.19^{+2.10}_{-1.12}$	4
FRB110220	parkes	50.828	-54.766	0.25	944.38(5)	49	$5.60^{+0.10}_{-0.10}$	$1.30^{+0.00}_{-0.00}$	$7.28^{+0.13}_{-0.13}$	5
FRB110523	GBT	56.119	-37.819	0.26	623.30(6)	42	$1.73^{+0.17}_{-0.17}$	0.60	1.04	6
FRB110626	parkes	355.861	-41.752	0.25	723.0(3)	11	1.40	0.40	0.56	5
FRB110703	parkes	80.997	-59.019	0.25	1103.6(7)	16	4.30	0.50	2.15	5
FRB120127	parkes	49.287	-66.203	0.25	553.3(3)	11	1.10	0.50	0.55	5
FRB121002	parkes	308.219	-26.264	0.25	1629.18(2)	16	$5.44^{+3.50}_{-1.20}$	$0.43^{+0.33}_{-0.06}$	$2.34^{+4.46}_{-0.77}$	4
FRB121102	arecibo	174.950	-0.225	0.05	557(2)	14	$3.00^{+0.50}_{-0.50}$	$0.40^{+0.40}_{-0.10}$	$1.20^{+1.60}_{-0.45}$	7
FRB130626	parkes	7.450	27.420	0.25	952.4(1)	21	$1.98^{+1.20}_{-0.44}$	$0.74^{+0.49}_{-0.11}$	$1.47^{+2.45}_{-0.50}$	4
FRB130628	parkes	225.955	30.655	0.25	469.88(1)	29	$0.64^{+0.13}_{-0.13}$	$1.91^{+0.29}_{-0.23}$	$1.22^{+0.47}_{-0.37}$	4
FRB130729	parkes	324.787	54.744	0.25	861(2)	14	$15.61^{+9.98}_{-6.27}$	$0.22^{+0.17}_{-0.05}$	$3.43^{+6.55}_{-1.81}$	4
FRB131104	parkes	260.549	-21.925	0.25	779(1)	30	2.08	1.12	2.33	8
FRB140514	parkes	50.841	-54.611	0.25	562.7(6)	16	$2.80^{+3.50}_{-0.70}$	$0.47^{+0.11}_{-0.08}$	$1.32^{+2.34}_{-0.50}$	9
FRB150418	parkes	232.665	-3.234	0.25	776.2(5)	39	$0.80^{+0.30}_{-0.30}$	$2.20^{+0.60}_{-0.30}$	$1.76^{+1.32}_{-0.81}$	10

Petroff et al. (2016)

Fast Radio Bursts

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Petroff et al. (2016)

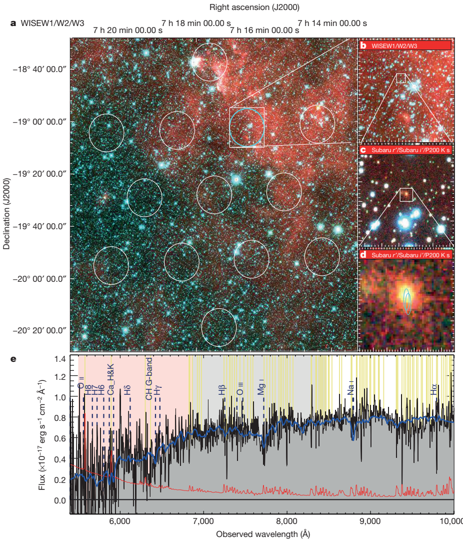
FRB 150418

The first announced association

Keane et al. (2016) reported the first localization of a FRB:
Detected by Parkes on 18/04/2015
Pulse width of 0.8 ± 0.3 ms
Linear polarization: $8.5 \pm 1.5\%$
Circular polarization $\sim$ zero.
DM= $776.25\ \mathrm{cm}^{-3}\ \mathrm{pc}$ ($\sim$4 times the expected Galactic contribution)

Follow-up with ATCA starting 2-hr later.
- Two variable compact sources detected.
One previously known source.
- A 6-d transient with $\alpha \sim -1.37$ consistent with an early-type galaxy.
The probability of having a spurious transient in the field: $< 0.1\%$

å The optical counterpart corresponds to a galaxy at $z \sim 0.5$: WISE J0716−1900



Credit: Keane et al. (2016)

FRB 150418

Publications after Keane et al. (2016)

6 publications in arXiv in less than 7 days (∼15 within 2 months).

Zhang (2016): Modeling of the afterglow constraining the isotropic energy of the explosion to be a few 10^{50} erg, comparable to that of a short duration GRB. Most plausible scenarios: mergers of BH-BH, NS-NS, or BH-NS (similar to GW 150914).

Williams & Berger (2016): WISE J0716−1900 exhibits a similar variability one year after the FRB in VLA data. The counterpart is better explained by a scintillating steady AGN. The chances of having a different transient source compatible with that distance is not negligible.

Vedanthan et al. (2016): ATCA and optical observations of WISE J0716−1900, finding a source consistent with an AGN.

Bassa et al. (2016): e-MERLIN, VLBA, ATCA, and optical observations. Persistent but variable compact radio source in the center of the optical galaxy: consistent with a weak radio AGN.

Marcote et al. (2016a,b);Giroletti et al. (2016): EVN. Keep listening!

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EVN observations

We conducted four e-EVN observations from March to June 2016 on WISE J0716−19 at 5.0 GHz.

9 participating stations: Effelsberg, Jodrell Bank, Westerbork, Medicina, Noto, Onsala, Torun, Yebes, and Hartebeesthoek.

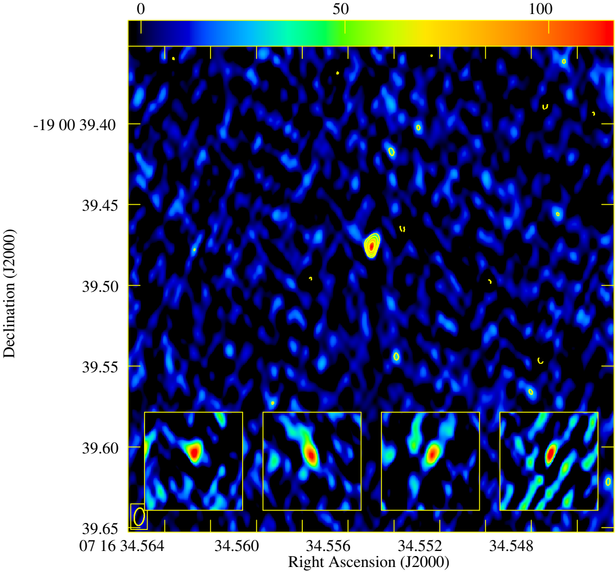
We also conducted simultaneous e-MERLIN observations at three epochs.

Epoch		EVN data				e-MERLIN data				
Date in 2016	MJD	HPBW (mas × mas, °)	I_{peak} (μJy beam^{-1})	I_{noise} (μJy beam^{-1})	$S_{5.0,JMFIT}$ (μJy)	HPBW (mas × mas, °)	I_{peak} (μJy beam^{-1})	I_{noise} (μJy beam^{-1})	$S_{5.0,JMFIT}$ (μJy)	$\Delta S_{5.0}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
March 16	57463.8	10.1 × 6.2, 3.9	123	18	125 ± 22	…	…	…	…	
May 10	57518.6	9.7 × 6.1, 8.7	113	14	137 ± 20	261 × 25, 12	169	55	176 ± 58	40 ± 60
May 31	57539.6	10.9 × 6.1, −7.5	107	16	117 ± 20	231 × 27, 11	145	48	158 ± 51	40 ± 55
June 2	57541.6	9.3 × 5.3, 1.3	133	20	125 ± 32	212 × 28, 10	254	52	272 ± 59	145 ± 70

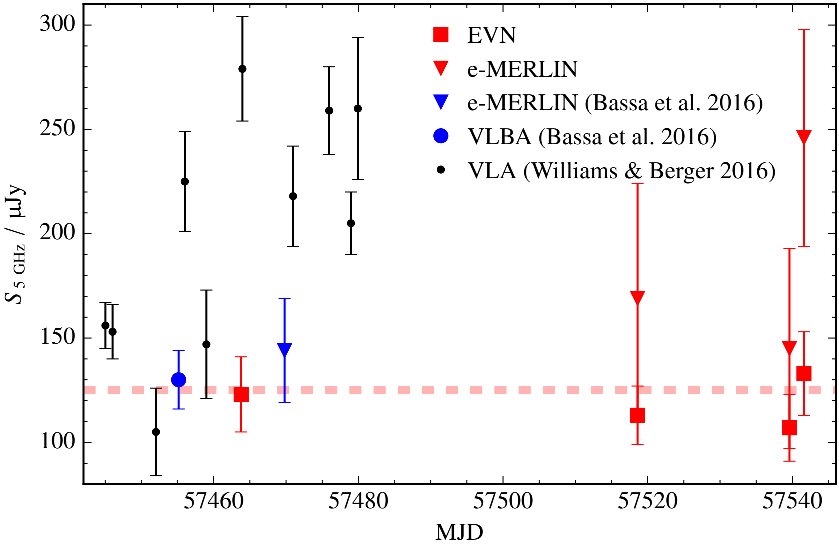
EVN observations

Peak brightness
(μJy beam^{-1}):

$$I_{\rm Mar16} = 123 \pm 18$$
$$I_{\rm May10} = 113 \pm 14$$
$$I_{\rm May31} = 107 \pm 16$$
$$I_{\rm Jun2} = 133 \pm 20$$
$$I_{\rm sum} = 115 \pm 9$$



EVN observations



Discussion and conclusions

- The VLBI observations show a compact $\sim$130-μJy source persistent on day-to-month timescales.
- Bolometric radio luminosity of 5.6×10^{39} erg s^{-1}.
- Brightness temperature of $\gtrsim 10^{8.5}$ K.
- But the VLA data indicate variability! on hour timescales?
- Missing VLA flux? no more compact sources in the field.
- The compact source seems to be compatible with a scintillating low-luminosity AGN.
- Origin of FRB 150418?

Giroletti et al. (2016) available at A&A tomorrow!