Is FRB 150418 Localized in WISE J0716−19? Clues from EVN Observations

© B. Marcote[1], M. Giroletti[2], M. A. Garrett[3], Z. Paragi[1], J. Yang[4], K. Hada[5], T. W. B. Muxlow[6], C. C. Cheung[7]

[1] Joint Institute for VLBI ERIC, The Netherlands
[2] INAF Istituto di Radioastronomia, Italy
[3] Netherlands Institute for Radio Astronomy (ASTRON), The Netherlands
[4] Department of Earth and Space Sciences, Chalmers University of Techn., Onsala Space Observatory, Sweden
[5] Mizusawa VLBI Observatory, National Astronomical Observatory of Japan, Japan
[6] Jodrell Bank Centre for Astrophysics/e-MERLIN, University of Manchester, UK
[7] Space Science Division, Naval Research Laboratory, USA

FRB 150418 is the first fast radio bursts claimed to be localized. Keane et al. (2016) reported its association with a radio transient source hosted by an elliptical galaxy, WISE J0716−1900, located at a distance of $z = 0.492 \pm 0.008$. However, this association has been questioned with recent VLA observations, which would support that the transient source is actually an active galactic nucleus (AGN) and thus unlinked with the origin of FRB 150418. Here we present the observations conducted with the European VLBI Network (EVN) at 5.0 GHz at four different epochs, together with three simultaneous e-MERLIN observations, to clarify the origin of the transient source located in WISE J0716−1900. We report a compact radio source on milliarcsecond scales with a persistent flux density of 115 ± 9 $\mu\mathrm{Jy\,beam}^{-1}$, which implies a luminosity of $(1.13 \pm 0.15) \times 10^{23}$ W Hz^{-1} given the distance of the galaxy. Additionally, the compactness of the source allows us to estimate a brightness temperature of $T_{\rm b} \geq 10^{8.5}$ K. These results are consistent with a scintillating low-luminosity AGN located in the center of WISE J$0716 - 1900$.

Keywords: galaxies: active, VLBI.

1 Introduction

Fast Radio Bursts (FRBs) are transient sources characterized by exhibiting a strong single short pulse (with a duration of milliseconds or submilliseconds). Since the first discovery in 2007 [1], tens of these events have been observed up to now [2]. However, the origin of FRBs remains unknown, mainly due to the poor localization, which does not allow us to identify their potential counterparts. Both Galactic and extragalactic origins have been proposed. The observed pulses resemble the pulsar ones, and thus preferring a Galactic origin. However, the large dispersion measure (DM) observed in the pulses indicates an extragalactic origin. Many scenarios have been proposed up to now to explain the FRBs, most of them based on cataclysmic events. However, the identification of the first repeating FRB [3] indicates that there could be, at least, two different scenarios. Recently, the first precise localization of a FRB has been reported [4]. FRB 150418 was discovered by the Parkes Telescope on 2015 April 18, exhibiting a DM of $776.25\ \mathrm{cm}^{-3}\ \mathrm{pc}$. A follow-up with the Australia Telescope Compact Array (ATCA) started 2-hr after the FRB discovery leaded to the detection of a radio transient source located in an elliptical galaxy at $z = 0.492 \pm 0.008$, WISE J0716−1900. This radio transient source has been reported to be the putative afterglow produced by the FRB.

This association would confirm the extragalactic origin of the FRBs. However, these results have been widely discussed during the last months. Recent results [5, 6] obtained by the Karl G. Jansky Very Large Array (VLA) one year after the FRB 150418 discovery show that the radio transient source hosted by WISE J0716− 1900 is consistent with an active galactic nucleus (AGN), and inconsistent with an afterglow.

Here we summarize the results obtained with the European VLBI Network (EVN) and e-MERLIN of WISE J0716−1900. These results try to clarify the reported association with FRB 150418 and if the radio transient source can be explained by an AGN. Preliminary results were published in two Astronomer's Telegram [7, 8] and the full results can be found in [9]. In Sect. 2 we describe the conducted observations and the data reduction. Sect. 3 shows the obtained results from these observations, and in Sect. 4 we discuss these results and present the conclusions of this work.

2 Observations and data reduction

We observed WISE J0716−1900 at four different epochs spanning 2016 March 16 to June 2 with the EVN at 5.0 GHz. Nine stations participated in these observations: Effelsberg, Hartebeesthoek, Jodrell Bank (Mark2), Medicina, Noto, Onsala, Torun, Yebes, and Westerbork single telescope. The data were acquired in real time using the e-EVN setup, and correlated using the SFXC software correlator at JIVE. In both facilities we phase-referenced the target source to J0718−1813 in a cycle of 2.5 min on the target and 1.5 min on the calibrator, which is 0.9° offset. Each observation span 5.5 hr, with around 2.4 hr on the target source. e-MERLIN observed simultaneously during the three last epochs at the same frequency and with the same observational approach.

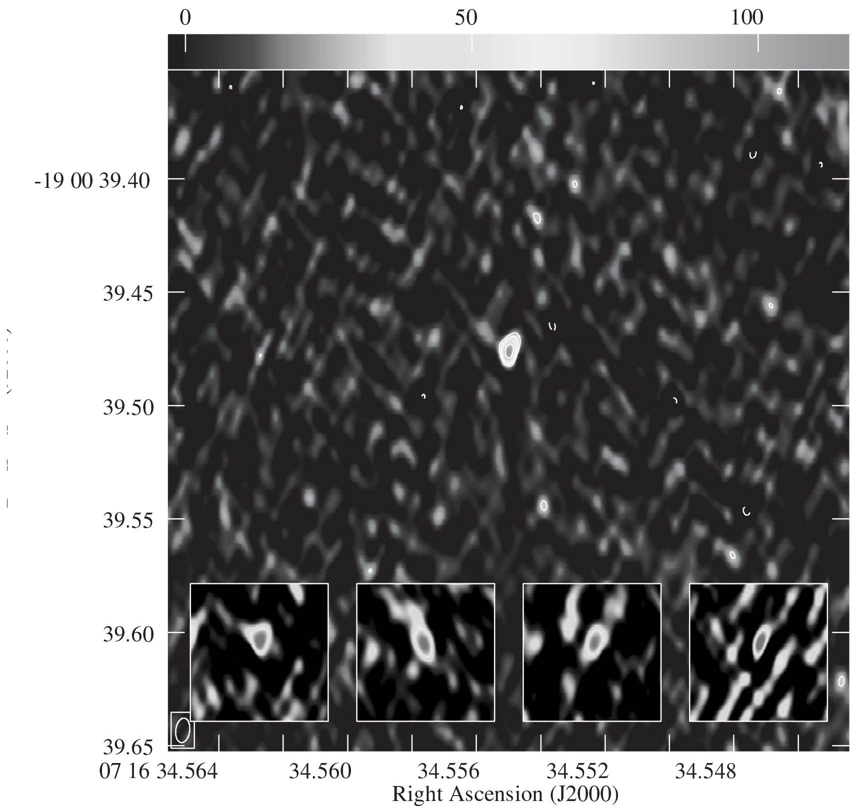

Fig. 1. EVN images of WISE J0716−1900 at 5 GHz. The main panel shows the averaged image obtained combining all EVN data. The contours start at ±3 times the rms noise of $8.9\ \mu\mathrm{Jy\ beam}^{-1}$. The synthesized beam ($10.9 \times 6.1\ \mathrm{mas}^2$, $\mathrm{PA} = -7°$) is shown in the bottom left corner. The bottom panels show the obtained images in the individual four epochs. The color scale indicates the surface brightness between -3 and $115\ \mu\mathrm{Jy\ beam}^{-1}$

The data reduction was performed following standard VLBI procedures within AIPS*. The calibrator was imaged and self-calibrated using the Caltech Difmap package. We applied these corrections to the target source, which was finally imaged.

3 Results

The EVN and e-MERLIN data show a compact and persistent radio source located at $\alpha(\mathrm{J2000}) = 07^{\mathrm{h}}16^{\mathrm{m}}34.55496(7)^{\mathrm{s}}$, $\delta(\mathrm{J2000}) = -19°00'39.4754(8)''$ (see Fig. 1). The four epochs are consistent with an average flux density of

*The Astronomical Image Processing System, AIPS, is a software package produced and maintained by the National Radio Astronomy Observatory (NRAO).

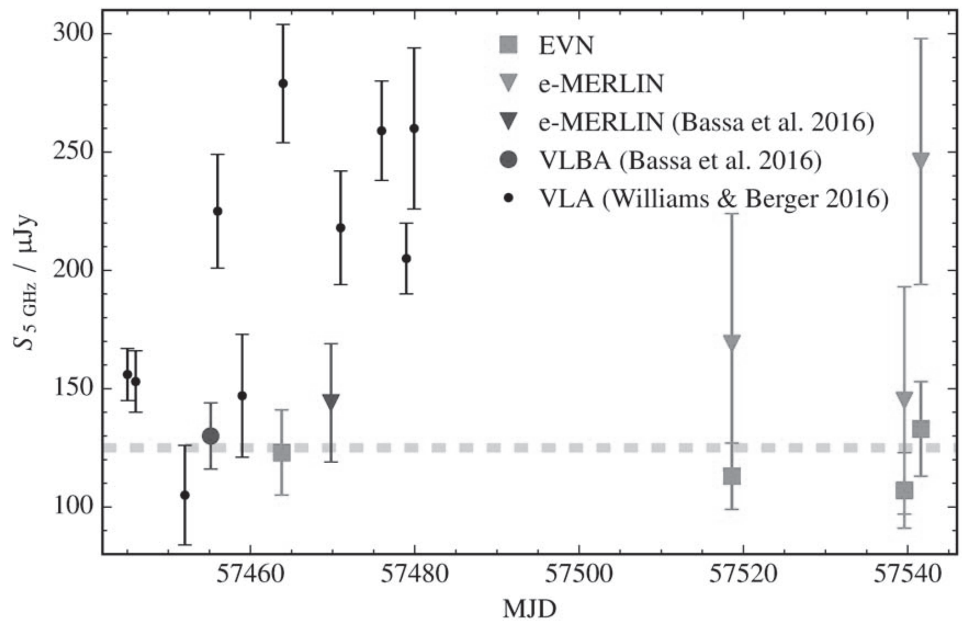

Fig. 2. Light-curve of WISE J0716−1900. The EVN data presented here are shown by the black squares. The simultaneous e-MERLIN observations are represented by the black triangles. We also show contemporaneous e-MERLIN and VLBA data [10] represented by open triangles and circles, respectively. Contemporaneous VLA data [6] are also shown by small black circles. The average flux density obtained by all the VLBI data is represented by the horizontal dashed line

115 ± 9 μ beam^{-1} (Fig. 2). The e-MERLIN data provide less accurate flux density measurements due to calibration issues and a smaller number of stations, which produced a poorer uv-coverage.

4 Discussion and conclusions

The data presented here show a compact radio source with a consistent flux density along the four epochs. Additionally, the measured flux densities are consistent with the ones obtained in other VLBI observations [10]. Given the luminosity distance of WISE J0716−1900 ($d_{\rm L} = 2.81$ Gpc), this flux density implies a monochromatic luminosity of $(1.13 \pm 0.15) \times 10^{23}$ W Hz^{-1}. Additionally, the compactness of the source allows us to estimate a brightness temperature of $T_{\rm b} \geq 10^{8.5}$ K.

The fact that all the VLBI observations show a consistent flux density contrasts with the VLA measurements [6], which show a significant variability. We note that the VLBI results average data for several hours, whereas the VLA is sensitive to much shorter timescales. In this sense, WISE J0716−1900 could exhibit variability on $\sim$minute to hour timescales which would be smeared out on longer timescales.

These results can be easily explained by a scintillating low-luminosity AGN in the nucleus of WISE J0716−1900. In this case, any relationship with FRB 150418 could be completely spurious.

References

1. *Lorimer D. R., Bailes M., McLaughlin M. A., Narkevic D. J., & Crawford F.* — 2007, Science. — 318. — 777.
2. *Petroff E., Barr E. D., Jameson A., et al.* — 2016. — Publ. Astron. Soc. Australia. — 33. — e045.
3. *Spitler L. G., Scholz P., Hessels J. W. T., et al.* — 2016. — Nature. — 531. — 202.
4. *Keane E. F., Johnston S., Bhandari S., et al.* — 2016. — Nature. — 530. — 453.
5. *Williams P. K. G., Berger E.* — 2016. — The Astronomer's Telegram. — 8946.
6. *Williams P. K. G., Berger E.* — 2016. — ApJL. — 821. — L22.
7. *Marcote B., Giroletti M., Garrett M., et al.* — 2016. — The Astronomer's Telegram. — 8865.
8. *Marcote B., Giroletti M., Garrett M., et al.* — 2016. — The Astronomer's Telegram. — 8959.
9. *Giroletti M., Marcote B., Garrett M. A., et al.* — 2016. — A&A. — 593. — L16.
10. *Bassa C. G., Beswick R., Tingay S. J., et al.* — 2016. — MNRAS. — 463. — L36.