Imaging ICRF3 sources at K band with the European VLBI Network

P. Charlot[1], M. E. Gomez[1,2], R. M. Campbell[3], M. Kettenis[3], A. Keimpema[3], A. Collioud[1]

[1] Laboratoire d'Astrophysique de Bordeaux, Université de Bordeaux, CNRS, Pessac, France,
[2] Faculty of Astronomical and Geophysical Sciences, University of La Plata, CONICET, La Plata, Argentina
[3] Joint Institute for VLBI ERIC, Dwingeloo, The Netherlands

Summary

We explore the capabilities of the European VLBI Network (EVN) to image radio reference frame sources at K band (22 GHz). The EVN includes long East-West and North-South baselines (from Europe to Asia and from Europe to South Africa) along with baselines of shorter and intermediate lengths within Europe, making it worthwhile to study its potential for snapshot imaging. To this end, we use a 22-telescope experiment carried out as part of the JUMPING JIVE project in October 2020 whose primary goal was to measure the geodetic positions of non-geodetic EVN antennas (i.e. antennas not equipped with the proper dual-frequency S/X (2.3/8.4 GHz) receivers traditionally used for geodesy). The network comprised 17 EVN telescopes along with four e-MERLIN out-telescopes (in the UK), and was augmented by the Hobart 26 m antenna (in Australia), who kindly agreed to join the experiment. Scheduling was accomplished by using sub-netting (ensuring a minimum of four stations per sub-net) to optimize the sky coverage at each telescope, as in standard geodesy experiments. A total of 80 sources belonging to the third realization of the International Celestial Reference Frame (ICRF3) were observed in the course of this experiment. Because the primary scope of the project was geodesy, all of these sources were chosen in the pool of ICRF3 defining sources. The resulting images may be used to further assess their compactness – and hence their astrometric suitability – at a frequency and a resolution higher than probed by the standard S/X observations that formed the basis for selecting those sources as ICRF3 defining sources

Introduction

The data analysed in this work were obtained as part of the JUMPING JIVE project, an EC funded project for the period 2016-2021, which was aimed to enhance the profile of the Joint Institute for VLBI ERIC. More specifically, the Work Package 6 "geodetic capabilities" was dedicated to implement and test a fully operational geodetic path at the EVN software correlator (SFXC) at JIVE and to measure the geodetic position of the non-geodetic EVN telescopes. For this objective, two experiments (EC065 and EC076) have been carried out using the EVN at K band in June 2018 and October 2020 (Gomez et al. 2020). Based on these data, positions at the cm level have been obtained for the EVN stations (Gomez et al. 2022, in preparation).

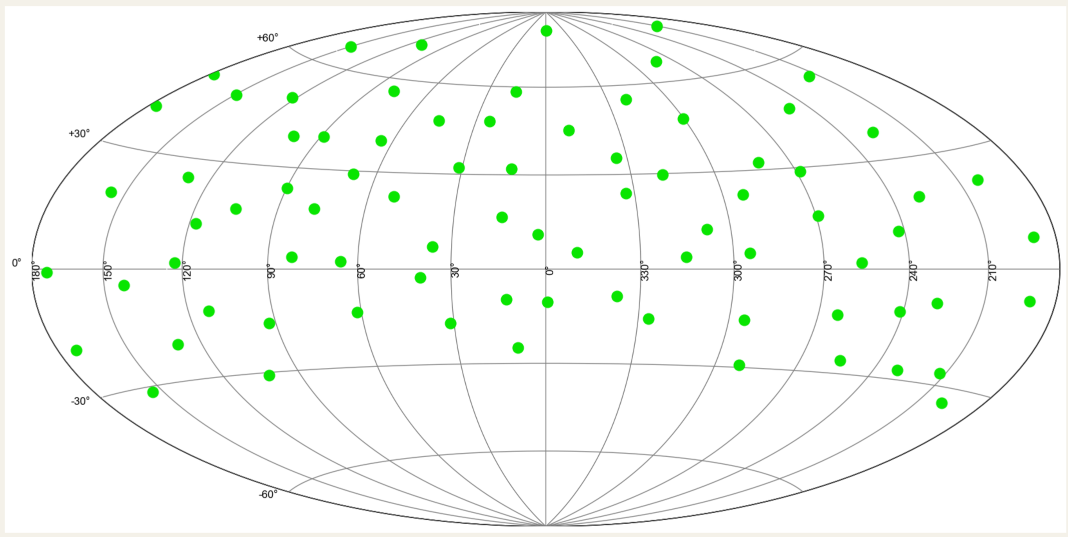
In this paper, we explore the use of the same data, more specifically those acquired during the second experiment (EC076), to image the sources observed in the course of the project. The two following sections describe the VLBI observing network, the source selection scheme and the scheduling strategy. Then, imaging results are described and a sample of the resulting images for 6 sources are shown. Comparisons with images obtained with the VLBA at K band and with images from an RDV (Research and Development with the VLBA) experiment at X band and at S band are provided to qualify the quality of the EVN images. Future prospects are drawn in the last section.

Observing network

The observing network used to acquire the data involved in this work includes all EVN radio telescopes that have the capability to observe at K band, namely 17 telescopes in Europe, Asia and South Africa. The network was further augmented with the four e-MERLIN out-stations in the UK and the 26 m antenna located in Hobart (Australia), in all forming a large network of 22 stations. The e-MERLIN stations provides short baselines which helps with the recovery of extended structure, while the Hobart telescope helps with the North-South resolution of the network.

Source selection and scheduling

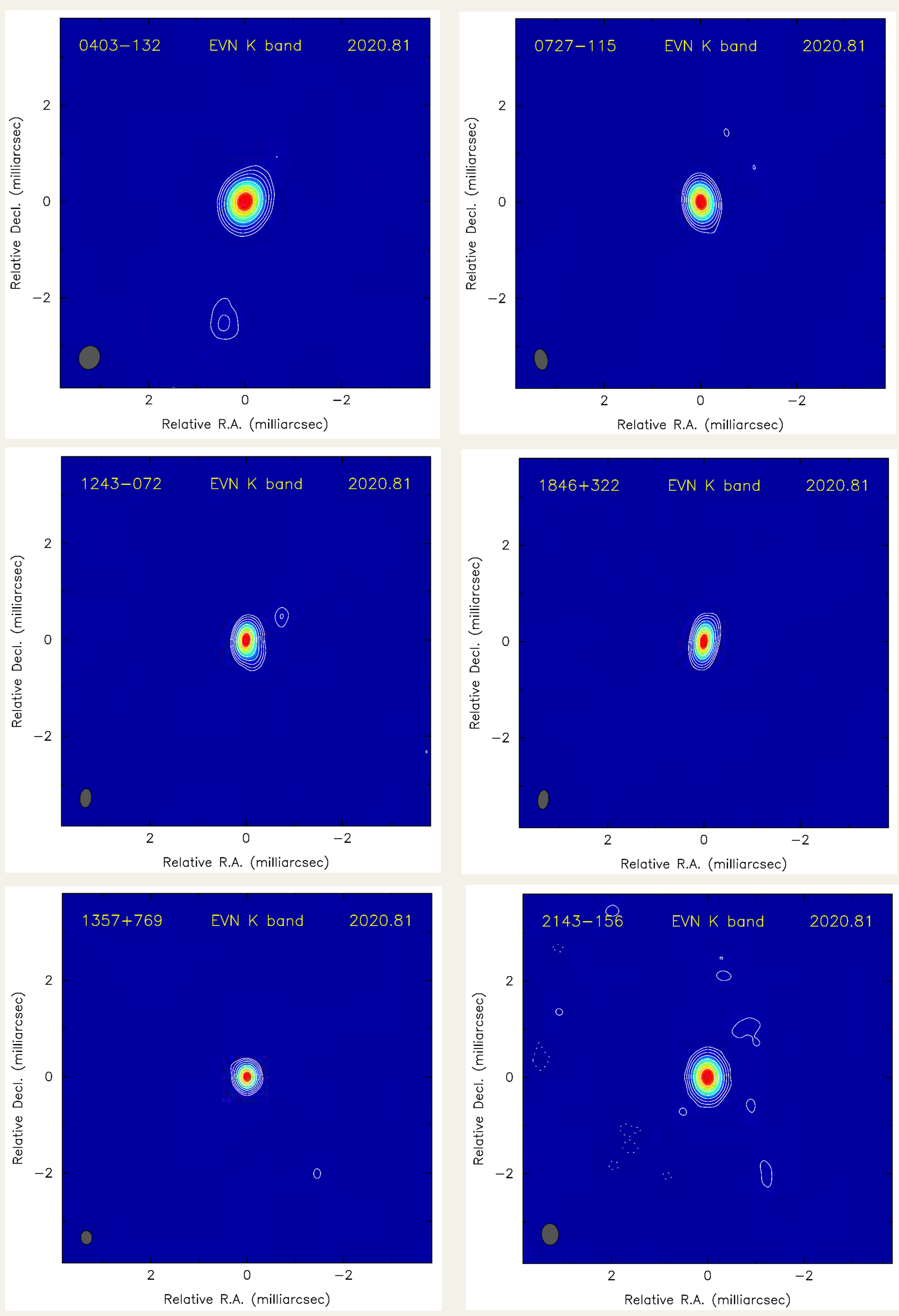
A total of 80 sources belonging to the third realization of the International Celestial Reference Frame (Charlot et al. 2020) were observed during the experiment. Because the primary scope of the project was determine the geodetic positions of the EVN telescopes, all sources were chosen among the pool of ICRF3 defining sources. This selection should limit potential source structure effects since the defining sources are deemed to be compact. We arranged for these 80 sources to be well spread in right ascension and declination, as reflected by the sky distribution plotted in the figure below. No sources below -30° declination were selected because the network would be reduced to the single baseline from Hartebeesthoek to Hobart in this case, which would make imaging then impossible.



The scheduling of the experiment was accomplished using NASA's SKED software. While the sky coverage above each telescope was optimized in the usual way to permit the estimation of tropospheric parameters for geodesy, we also arranged for the observations to be reasonably well spread over all sources and forced each scan to include a minimum of four telescopes. Overall, the number of scans per source was in the range of 2 to 10, with a mean value of 5.6, while the number of observations ranged from 30 to 546, with a mean value of 257. Due to the large network, one-third of the scans had more than 10 stations and 10% had 16-18 stations, which is very favourable for imaging.

Imaging results

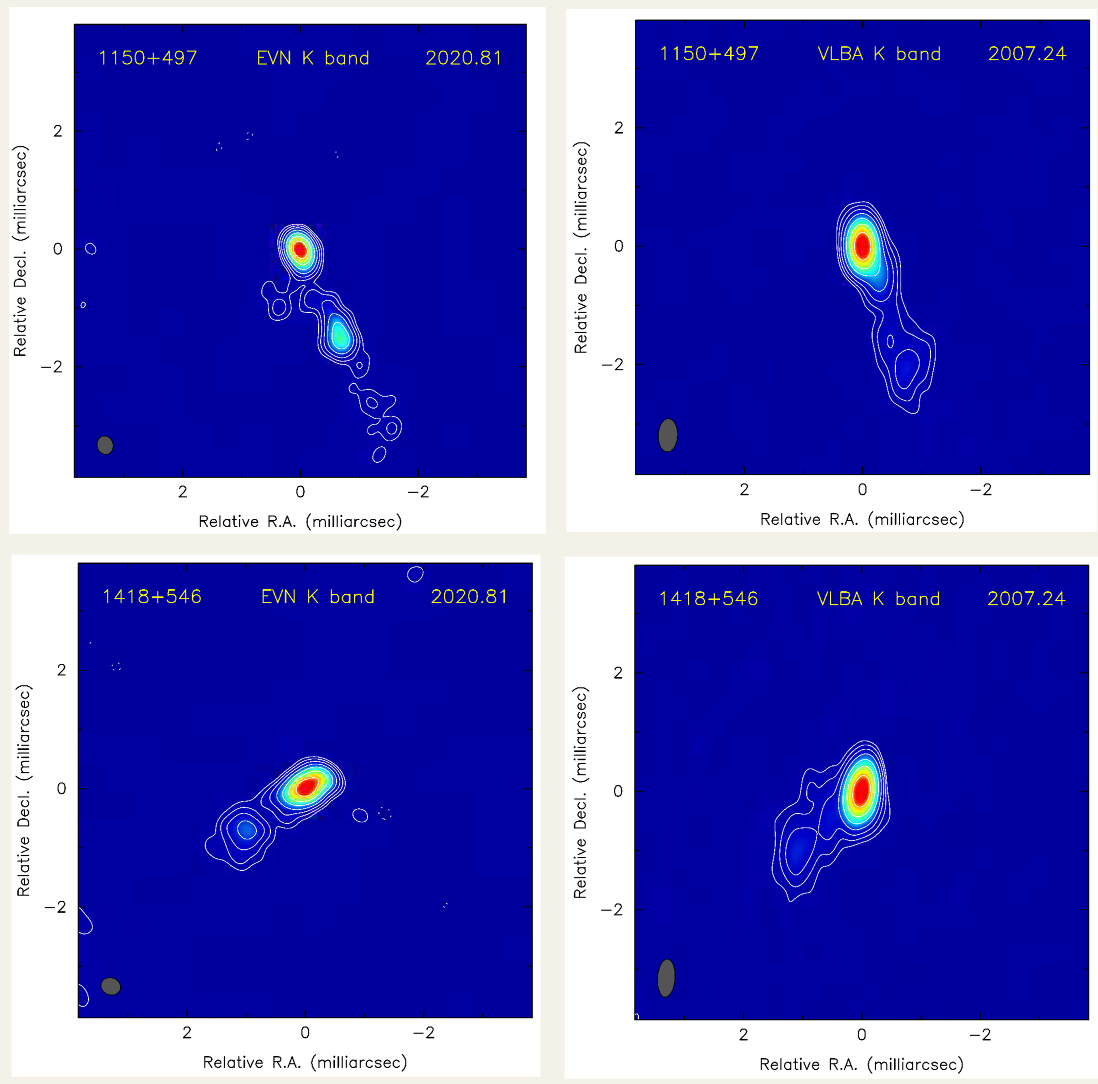
The imaging was conducted using an automatic script based on the EVN pipelined data with no recalibration and no sophisticated editing of the data. Despite this brutal approach, the vast majority of the 80 sources have been imaged, proving the potential of the EVN for such work. A sample of the images produced is shown in the figures below. Apart from a few exceptions (see next section), the sources are found to be mostly very compact at the EVN resolution (0.2 mas), confirming that they qualify well as defining sources for the celestial frame. The dynamical range of the images is generally at the 1% level or better.



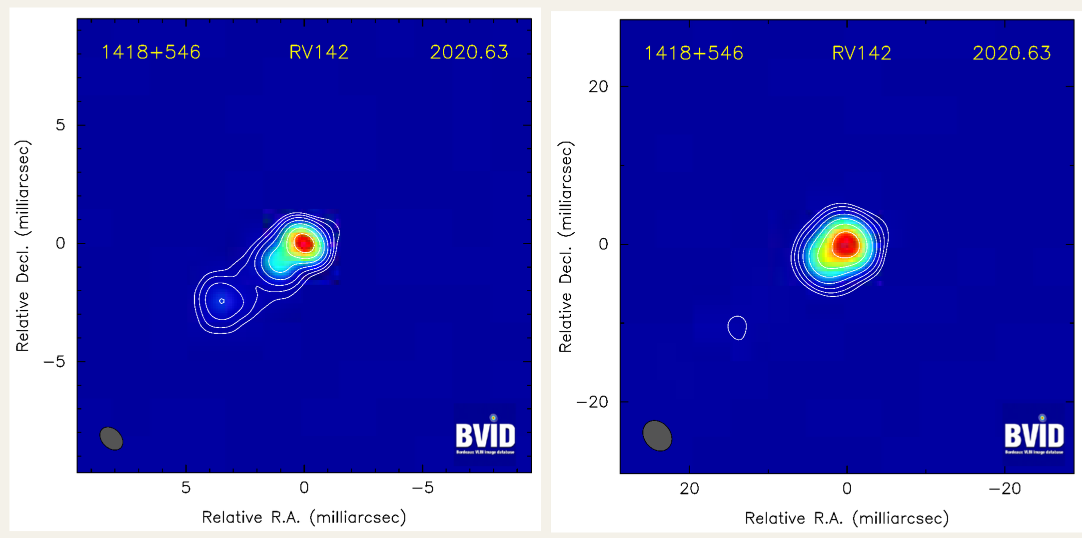
Note: contour levels are drawn at +/- 1, 2, 4, 8, 16, 32 and 64% of the peak brightness.

Comparing with other VLBI images

The following figures compare our EVN images of two sources that are not point-like (1150+497 and 1418+546) with previously published VLBA images of the same two sources, also at K band (Charlot et al. 2010). Though not at the same epoch, the EVN and VLBA images (left and right panels, respectively) compare well, indicating similar jet-like structure for the two sources. The comparison also shows that the EVN provides somewhat higher resolution, which should help to probe source structure even closer to the core, for the benefit of the celestial reference frame.



The figures below show images of the source 1418+546 at X and S bands for an epoch close to that the EVN data. These images were produced from the RDV (Research and Development with the VLBA) session 142 carried out in August 2020 and available from the BVID (Bordeaux VLBI Image Database). Comparison with the K band EVN image shows consistent structure at the three frequency bands, confirming the quality of the derived EVN images.



Future prospects

Our immediate objective is to refine the calibration and data editing and from there to finalize the imaging. These high-resolution K band images will be useful to assess the continued suitability of the ICRF3 defining sources, e.g. through the estimation of their compactness and structure index. Having demonstrating the potential of the EVN for this work, we also plan to engage further observations, focusing at first on the rest of the ICRF3 defining sources.

References

Charlot, P., Boboltz, D. A., Fey, A. L., Fomalont, E. B., Geldzahler, B., et al., 2010, AJ, 139, 1713-1770

Charlot, P., Jacobs, C. S., Gordon, D., Lambert, S., de Witt, A., et al., 2020, A&A, 644, A159

Gomez, M. E., Charlot, P., Campbell, R. M., Kettenis, M., Keimpema, A., 2020, Proceedings Journées 2019, Ed. C. Bizouard, Obs. Paris, p. 181.

Acknowledgements

We are indebted to the Hobart team at the University of Tasmania for agreeing to participate in this experiment, which helped to strengthen the North-South geometry of the network. The European VLBI Network is a joint facility of independent European, African, Asian, and North American radio astronomy institutes. Scientific results from data presented in this poster are derived from the EVN project code EC076. This research received funding from the European Union's Horizon 2020 Research and Innovation Programme, under grant agreement No. 730884. We are also grateful RadioNet for its support.