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Wide-field observations in the SDSS Stripe 82 with the European VLBI Network

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Abstract. We observed an area of sky located within the SDSS Stripe 82 field at 1.6 GHz with the European VLBI Network (EVN). There are fifteen mJy/sub-mJy radio sources within the primary beam of a typical 30-m class EVN radio telescope. Our aim was to obtain information on compact radio structures of all VLBI-detectable sources within this primary beam area. The source of particular interest is the recently identified radio quasar J222843.54+011032.2 (J2228+0110) at $z = 5.95$. The data correlation was performed at the EVN software correlator at JIVE (SFXC). Three targets (J2228+0110, J222851.45+011203.4, J222941.76+011428.5) were detected, all three with position offsets not exceeding the 3σ accuracy of the original low-resolution radio surveys. The detection rate of 20% is consistent with other wide-field VLBI experiments carried out recently (e.g. Middelberg *et al.* 2013). The project presented here demonstrates the ability of EVN in multiple-phase-centre experiments and paves the way for future large-scale EVN surveys of compact structures in extragalactic radio sources using the multiple-phase-centre VLBI technique.

Keywords. Wide-field VLBI, quasar, survey.

1. Introduction

Recently, Zeimann *et al.* (2011) identified a high-redshift radio quasar J2228+0110. The source is the second radio-selected $z > 5.7$ quasar and the fourth $z \sim 6$ quasar with flux density > 1 mJy at cm radio waves, that makes it a feasible target for VLBI to probe the physical properties at milli-arcsecond (mas) scales of the radio sources located in the early Universe. We observed a field centred midway between J2228+0110 and a strong in-beam phase calibrator J2229+0114 to investigate simultaneously the extremely high-redshift object and other fourteen neighbour mJy/sub-mJy radio sources resulted from the overlapping of the Stripe 82 VLA Survey (Hodge *et al.* 2011), the VLA FIRST Survey (White *et al.* 1997) and the NVSS (Condon *et al.* 1998), using the multiple-phase-centre mode (Deller *et al.* 2011; Morgan *et al.* 2011) of EVN in a combination with in-beam and nodding phase referencing.

Table 1. The physical parameters of the three detected sources

ID	Name	S_{VLBI} μJy	ϑ mas	θ_{min} mas	T_b 10^8 K	RA (J2000) HH:MM:SS	DEC (J2000) DD:MM:SS	P-Err mas
J2228+0110	J222843.54+011032.2	300 ±120	1.71 ±0.47	1.30	> 3.14	22:28:43.52679	01:10:31.9109	0.59
VLA-4	J222851.45+011203.4	340 ±190	-	1.30	> 0.89	22:28:51.44711	01:12:03.4259	0.60
FIRST-3	J222941.76+011428.5	1000 ±460	4.14 ±1.72	0.82	> 0.26	22:29:41.76034	01:14:27.4236	1.02

Col. 1−Col. 2: source ID used in the project and IAU source name (J2000); Col. 3: flux density recovered by VLBI; Col. 4: the size of the circular Gaussian model at FWHM; a point source model was used to fit the visibilities of VLA-4; Col. 5: minimum resolvable size of each source (Kovalev *et al.* 2005); Col. 6: brightness temperature; the T_b values of VLA-4 and FIRST-3 are estimated with $z = 0$ as spectroscopic redshifts are unavailable; the photometric redshift of VLA-4 is 0.74± 0.13 (SDSS DR9); no obvious optical counterpart of FIRST-3 is found in the SDSS Stripe 82 database. Col. 7−Col. 9: the astrometric position of the source derived by the phase-referencing techniques and the position error

2. Observations, results and discussion

The EVN EG057 experiment took place on 2011 Nov 1, with a total observing time of eight hours and a data rate of 1 Gbps per telescope. A ParselTongue script (Kettenis *et al.* 2006) was used to calibrate the sixteen sets of data simultaneously. A search for EVN detections was conducted in $4'' \times 4''$ areas around low-resolution positions of all targets. The ratios of peak brightness to noise (measured in dirty map with natural weighting) are 12.1, 7.7 and 8.3, for J2228+0110, VLA-4 and FIRST-3 respectively. All of them were observed with VLBI for the first time. The source J2228+0110 was undetected at the 3σ image noise level by WSRT observing simultaneously with EVN, which provides a flux-density upper limit of ∼0.58 mJy. The physical parameters measured by VLBI are listed in Table 1. The three targets appear to be compact, based on the VLBI flux densities obtained in our experiment and the values of VLA peak brightnesses which are 0.31 ±0.057, 0.37 ±0.064, 1.53 ±0.138 (mJy/beam) respectively. The result of the project allows us to conclude that the novel multiple-field-centre technique in combination with in-beam and nodding phase referencing offers an efficient tool for massive VLBI survey of extragalactic radio sources (e.g. Frey *et al.* 2008; Middelberg *et al.* 2013).

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