Black Holes from Stars to Galaxies – Across the Range of Masses
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First e-VLBI observations of GRS 1915+105

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Abstract. We present results from the first successful open call e-VLBI science run, observing the X-ray binary GRS 1915+105. e-VLBI science allows the rapid production of VLBI radio maps, within hours of an observation rather than weeks. A total of 6 telescopes observing at 5 GHz across the European VLBI Network (EVN) were correlated in real time at the Joint Institute for VLBI in Europe (JIVE). Throughout this, GRS 1915+105 was observed for a total of 5.5 hours, producing 2.8 GB of visibilities of correlated data. The peak brightness was 10.2 mJy per beam, with a total integrated radio flux of 11.1 mJy.

The use of the Internet for VLBI data transfer offers a number of advantages over conventional recorded VLBI, including improved reliability due to real time operation and the possibility of a rapid response to new and transient phenomena. Decisions on follow-up observations can be made immediately after the observation rather than delayed by potentially weeks due to problems in shipment of tapes/discs to the correlator. One aim of the project was also to develop a strategy for rapid response (ToO) e-VLBI observations for when this technique is more mature.

In this e-VLBI experiment, the data were transferred from the telescope to the correlator using Mark 5A disk-based VLBI data systems. These units have been fitted with 1 Gbps Network Interface Cards which allow the units to transfer the telescope data to the correlator over the Internet and private optical networks at rates exceeding 100 Mbps. Production Internet connections for institutions within each participating country are provided and controlled by the local and national network providers. Most of the telescopes connect to the national networks, and then are connected to the GÉANT 2 network allowing pan-European multi-gigabit connectivity.

On 2006 April 20–21 the e-EVN observed GRS 1915+105 at 4.994 GHz using phase-referencing for a total time of 5.5 hours. Each station sustained a transfer rate of 128 Mbps across the e-VLBI network. The radio image of GRS 1915+105 on 2006 April 20 – 21 is shown in Fig. 1 (left) using a *uv* weighting robustness parameter of 0. The source had a position of R.A. $19^{\rm h}\ 15^{\rm m}\,(11.548 \pm 0.001)^{\rm s}$ and Dec. $10^\circ\ 56^{'}\,(44.71 \pm 0.01)^{''}$ (J2000). The detected source has a major and minor axis of 9.8×6.9 mas, observed with a beam size of 9.6×6.5 mas, respectively. This was de-convolved with the beam which revealed an extended component of 2.7×1.2 mas at a position angle of $140\ (\pm 2)^\circ$. This is similar

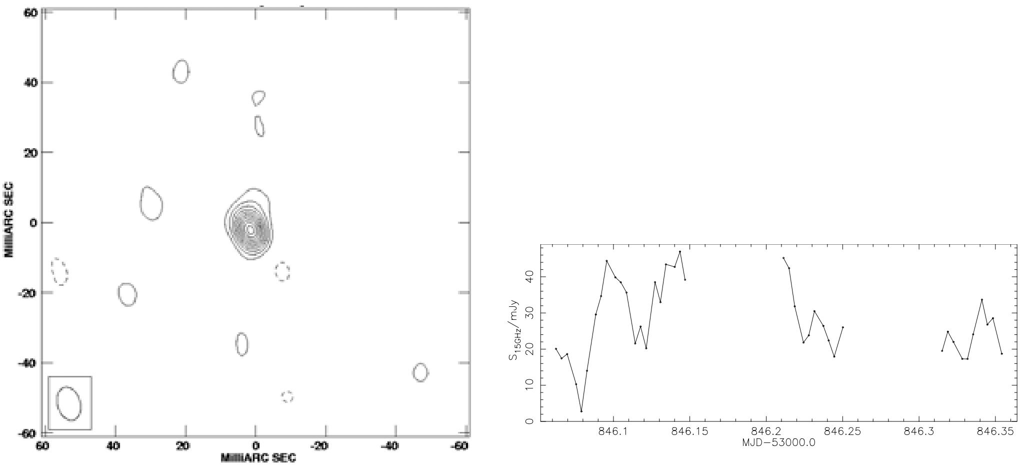

Figure 1. Left: e-EVN map of GRS 1915+105 at 5 GHz using 6 telescopes on 21 April 2006. Contour levels are (-1, 1, 2, 4, 6, 8, 10) times 1 mJy per beam, with an rms of 0.3 mJy. Right: Ryle Radio Telescope 15 GHz flux monitoring of GRS 1915+105, observed at 2006 April 21 01:27–08:32 UT.

to the P.A. of the large scale jets previously observed (Fender *et al.* 1999). The total integrated radio flux density was 11.1 ($\pm$0.6) mJy.

Fig. 1 (right) shows the Ryle Radio Telescope data on 2006 April 21 between 01:27–08:32 UT. A flare of 40 mJy was detected, which quickly decayed to $\sim$ 20 mJy within 4.5 hours. Assuming equipartition and the flare expands isotropically the minimum energy in the magnetic field for a distance of 11 kpc (Fender *et al.* 1999) is 2×10^{41} ergs. Using the de-convolved size from the image rather than assuming spherical expansion, we find a minimum energy of 1×10^{40} ergs, a lower value due to the source being collimated. This is unlike the major flares studied by the VLA and MERLIN (Mirabel & Rodriguez 1994) where the decay is over several days and the ejecta can be followed for up to 2 months after the flare. The behaviour of the strong flare is consistent with the shock-in-jet model (Miller-Jones *et al.* 2005); however the short flares seem to show the characteristic of an expanding source without continuous ejection of relativistic electrons.

The use of e-VLBI enabled us to obtain images within approximately a day of the VLBI run, rather than the many weeks needed for conventional recording based observations. This work clearly shows the ability of the e-EVN to produce high resolution radio maps in real time, hence eliminating the need of tape / disc recording. In the future, e-VLBI transmission rates will keep increasing with network development, yielding higher sensitivities and longer baselines will be achieved with the addition of more telescopes to the network.

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