MERLIN observations of GRS 1915+105:
a progress report

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Abstract
We present a progress report on MERLIN radio imaging of a radio outburst from GRS 1915+105. The major
ejection occurred at the end of a $\sim 20$ day ‘plateau’ state, characterised by low/hard X-ray fluxes and a relatively
strong flat-spectrum radio component. Apparent superluminal motions have been mapped with unprecedented
resolution, and imply higher velocities in the jet than previously derived.

1. Introduction and Observations
We have observed the superluminal X-ray transient (Mirabel & Rodriguez 1994, hereafter MR94) with
the MERLIN array in 1997 October – November following a major radio outburst.
The MERLIN observations were made with an angular resolution of 40 mas, five times better than
previous VLA mapping, at a frequency of 5 GHz, on ten occasions over a period of 12 days. The radio flux
from GRS 1915+105 was also simultaneously monitored at 2 & 8 GHz with the Green Bank Interferometer
(GBI) and at 15 GHz with the Ryle Telescope (RT). Over the same period the system was monitored in
soft X-rays with the Rossi XTE satellite.

2. X-ray and radio state
Prior to our MERLIN observations GRS 1915+105 had clearly been in an unusual state in both X-rays
and radio, summarised in Fig. 1. Approximately 25 days prior to our first epoch of mapping, the source
had undergone a significant radio flare, and then entered a ‘plateau’ state. This state is characterised
by relatively bright and stable radio emission with a flat / inverted spectrum, and low but persistent
X-ray emission with a hard spectrum. Previous monitoring reported at 15 GHz with the RT in Pooley &
Fender (1997) and at lower frequencies in Bandyopadhyay et al. (1998) confirm the association between
the plateau state and relatively bright radio, and perhaps infrared, emission.

3. Superluminal ejections
As indicated in Fig. 1, a sequence of ten MERLIN high-resolution radio maps were made of GRS
1915+105. The first four of these are presented in Fig. 2, revealing the clear expansion of the source on
Fig. 1. Radio (GBI) and X-ray (XTE) monitoring around the time of the MERLIN observations of GRS 1915+105. Around MJD 50725 a significant radio flare signals the beginning of the plateau state, characterised by relatively bright and stable flat-spectrum radio emission and steady, hard-spectrum emission in X-rays. The flare at the end of the plateau period triggered our MERLIN observations, indicated by diamonds on the top panel. Images from the first four epochs of MERLIN observations are presented in Fig. 2.
Fig. 2. Radio maps of GRS 1915+105 from the first four epochs of our MERLIN observations. The observing frequency is 5 GHz (6 cm) and the angular resolution 40 mas. In the first two epochs the core and receding component are blended together; by the third epoch core and approaching (SE) and receding (NW) components are clearly resolved. The proper motions are significantly higher than those reported in MR94 (see text). The unit contour level for each epoch is indicated on the right side of the figure, and the maps have been rotated clockwise by ∼145 degrees for clarity.
daily timescales. The jet sidedness is consistent with that reported in MR94, and we are able to track
the proper motions of three approaching and one receding components over the entire set of images. The
position angle of the ejections, approximately 145 degrees, is also very similar to that reported in MR94.
All ejections are consistent with ballistic motions to better than 10%, and we find best-fits to the
proper motions of:

$$\mu_{\text{app}} = 23.6 \pm 0.5$$

and

$$\mu_{\text{rec}} = 10.0 \pm 0.5$$

mas. d\(^{-1}\), significantly greater than those reported in MR94. All fits are good, with \(\chi^2_{\text{red}} \leq 1\). The
proper motion of 17.6 ± 0.4 mas. d\(^{-1}\) reported by MR94 for the approaching component can be ruled
out for this ejection; fixing the proper motion to this value does not give an acceptable fit to the data.

Initial analysis of the proper motions, under the standard assumption of an intrinsically symmetric
ejection, suggests that we are measuring significantly greater velocities (by \(\geq 10\%\)) than MR94, at a
similar angle to the line of sight (most likely in the range 60 – 70 degrees).

Again assuming a symmetric ejection, we can use the proper motions to place limits on the distance to
GRS 1915+105. At the most extreme, given the measurement uncertainties, the distance must be \(\leq 13.6\)
kpc. A more likely upper limit is \(\leq 11.2\) kpc, i.e. significantly closer (although within their estimated
errors) than the best estimate of 12.5 kpc used by MR94.

4. Conclusions
We have presented preliminary results from a major set of MERLIN observations of GRS 1915+105
simultaneous with multiwavelength radio and X-ray monitoring. While the nature of the plateau state
itself remains unclear, it is now certain that the radio flaring associated with the end of the state is
associated with relativistic ejections.

These ejections, in particular the approaching component, have significantly higher proper motions
than those recorded by MR94, most simply interpreted as higher intrinsic velocities at a similar angle
to the line of sight. We also find that GRS 1915+105 is likely to be significantly closer than the best
estimate of 12.5 kpc of MR94.

More details of the observations, including spatially resolved linear polarisation maps, and their inter-
pretation, will be found in a paper to be submitted to MNRAS.

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