Astrophysical Phenomena Revealed by Space VLBI
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VSOP Imaging of the Unusual X-Ray Binary Star LSI+61°303

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Abstract

The HALCA spacecraft in combination with a large array of ground radio telescopes has been used to obtain multi-epoch images of a radio outburst of the radio emitting, X-ray binary star LSI+61°303. Preliminary results from two 6-hour segments separated by 28.6 hours are presented. The images reveal an apparently stationary pattern of symmetric emission extending about 2 mas on either side of a central source. The extended emission is reminiscent of the precessing radio jets seen in SS433. The central source is observed to expand at a rate of 0.2 mas/day. At the distance of LSI+61°303, this corresponds to $\sim$700 km s^{-1}.

1 Introduction

LSI+61°303 is one of the more unusual of known massive X-ray binary systems. It undergoes nonthermal radio outbursts every 26.5 days, that rise from quiescence to peak flux within 48 hours (Taylor & Gregory 1984). These are attributed to the eccentric orbit of a gravitationally collapsed object orbiting within the dense circumstellar envelope of a B0e star. In addition, the relative gamma-ray to X-ray luminosity of the system is far higher than in any other known X-ray binary system, indicating a fundamentally different energy production mechanism (Taylor et al. 1996).

Despite several ground-based VLBI observations of LSI+61°303, the properties of the radio emission region remain unclear. Observations near peak flux density a few days after onset of the outburst (Taylor et al. 1992, Massi et al. 1993) have shown a very compact source $\sim$1 mas in size, suggesting a low rate of expansion of a few hundred km s^{-1}. Observations at quiescence indicate a low level radio source with dimensions

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of $\sim$4 mas (Lestrade 1988; Taylor et al. 1992). In contrast, observations of a small flare following a major outburst indicate initial expansion velocities of order $\sim 0.06c$, with deceleration upon reaching dimensions of 2mas (Peracaula et al. 1998). A clear picture of the evolving radio emission, linking these diverse results, remains elusive.

A primary difficulty with ground-based VLBI studies is that the variability time scale of the emission is short compared to the time required to obtain sufficient visibility coverage with a typical ground array. Because of the high northern declination of the source ($+61^{\circ}$) joint VLBA/EVN observations provide reasonable 2-dimensional (u, v) coverage in a few hours, and the addition of rapidly changing baselines to the HALCA spacecraft allows us, for the first time, to obtain an unambiguous picture of the dynamical evolution of the outburst ejecta from LSI $+61^{\circ}303$ on sub-mas scales.

2 Observations and Analysis

LSI$+61^{\circ}303$ was observed at 5 GHz with HALCA and a ground array of 18 radio telescopes, including the Very Long Baseline Array, the European VLBI Network and the Very Large Array. The observations were carried out for 48 hours, beginning 00:59 U.T. on 16 September, 1999. The source is almost circumpolar at most observatories, allowing for continuous ground array coverage over the observing period.

The light curve of total flux density over the course of the observations is shown in Figure 1. At the beginning of the observations, the flux density decayed on a time scale of several hours, from a peak of about 190 mJy to 140 mJy. Thereafter the mean flux density remained stable for approximately a day with variations of approximately 10%.

Initial images have been constructed from two segments of data separated by 28.6 hours. These two data segments, shown by the solid horizontal bars in Figure 1), are referred to respectively as epoch 1 (09:50 U.T., September 16) and epoch 2 (14:10 U.T., September 17). The images are shown in Figure 2. For comparison the data have been restored with the same beam, equal to the uniform weight beam of epoch 1. Both images show a central resolved source and symmetric extensions toward the northeast and southwest, out to a radius of approximately 2 mas. The maximum extent appears similar in the two images. However, the central intense source has obviously grown in the northeast-southwest direction between the two epochs.

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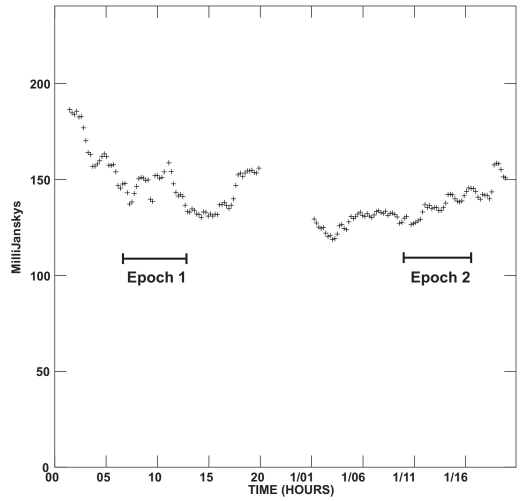

Figure 1: Radio light curve of LSI+61°303 during the VLBI observations obtained with the Very Large Array. The horizontal bars indicate the time ranges of the epoch 1 and 2 maps shown in Figure 2.

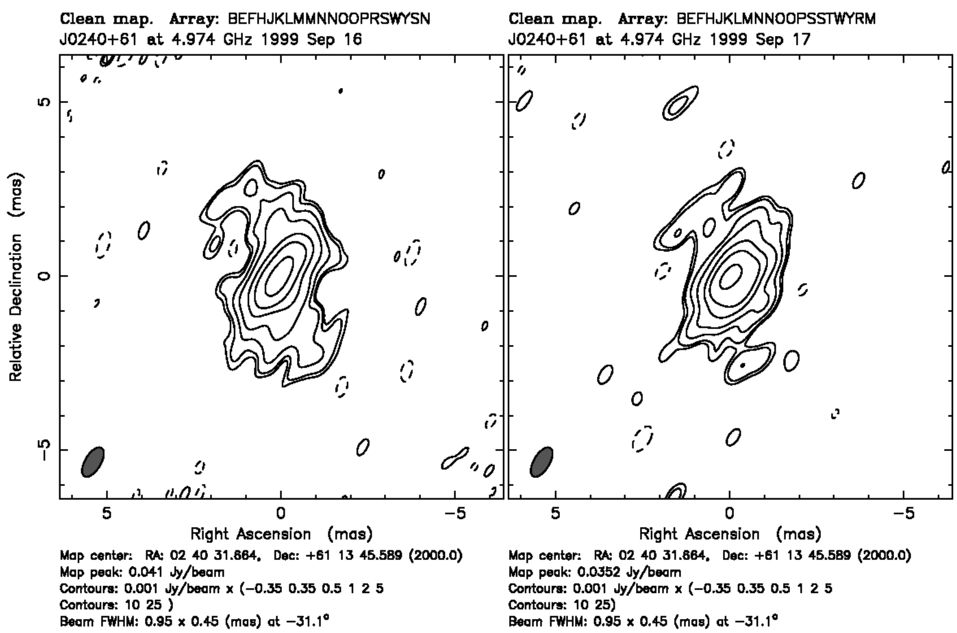

Figure 2: Two 5 GHz images of LSI+61°303 taken 28.6 hours apart. The epoch of each image is indicated in Figure 1. The map rms is ~ 0.1 mJy.

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The change in angular size of the central source allows, for the first time, a direct measure the expansion rate of the outburst ejecta of LSI+61°303. Table 1 lists the results of an elliptical Gaussian fit to the central source. The minor axis has expanded by 50% from 0.52 to 0.77 mas, corresponding a change of 0.5 AU at the 2.0 kpc distance of LSI+61°303 (Frail and Hjellming 1991). The inferred expansion velocity is 730 km s^{-1}, along a direction pointing toward the extended lobes.

Table 1: Elliptical Gaussian model fits to the central source.

	Flux Density (mJy)	Major Axis (mas)	Minor Axis (mas)	Position Angle (deg)
epoch 1	88	1.22	0.52	-36.7
epoch 2	89	1.06	0.77	-36.2

The overall size of the radio emission, about 4 mas, is similar to that derived by Lestrade (1988) at quiescence. The radio extensions may represent a) a quasi-steady state emission region that is continually replenished in energetic particles by the recurring outbursts, or b) a high velocity component of the outburst ejecta that rapidly expands to radii of 2 mas and then decelerates, as inferred by Peracaula et al. (1998).

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