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MERLIN Deep Radio Observations of Supernovae Remnants in M82.

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Abstract. An 8 day ($\sim$ 175 hours) deep integration at 5 GHz of the prototypical starburst galaxy M82 has provided the most sensitive (to date) high-resolution image of M82 with an angular resolution of 35mas and an rms noise level of 17 μJybeam^{-1}. These sub-arcsecond observations detected a number of radio supernovae remnants and have been used to produce detailed images revealing shell and partial shell structures. Additionally, use of an astrometrically aligned image from 36 hour observations in 1992 will enable an effective comparison of the supernova remnants at two epochs (seperated by 10 years). This will allow direct measurement of the expansion velocities of the individual remnants. We present an explanation of the methods to be used to measure the sizes of these supernova remnants and how these will be compared to give expansion velocity measurements.

Key words. Supernova remnants – galaxies: individual: M82 – galaxies: starburst – radio continuum: galaxies.

1. Introduction

M82 is a well known nearby starburst galaxy at a distance of $\sim$ 3.2 Mpc. MERLIN and VLA observations of the central 1kpc of M82 have revealed $\sim$ 30 compact sources, the majority of which are believed to be supernovae remnants (SNR) Unger et al. (1984); Kronberg et al. (1985); Kronberg & Sramek (1985); Muxlow et al. (1994). These SNR are typically less than 1000 years old and in the decade since their discovery have been imaged at high angular resolution with MERLIN. VLBI observations have also allowed study of the most compact (and inferred to be the youngest) sources at angular resolutions of a few mas (Pedlar et al. 1999; McDonald et al. 2001). Detailed expansion studies of the SNR in M82 have been limited by the poor signal-to-noise of earlier measurements. The 2002, $\sim$ 175 hour deep integration using MERLIN provides the first 5 GHz image with high signal-to-noise for the majority of the SNR. The 36 hour astrometrically aligned image observed in 1992 will enable a comparison between the two epochs of the resolved SNR, providing information on their evolution and specifically their expansion velocities. New optical-fibre wide-band links and more sensitive receiver systems are currently being developed for e-MERLIN. Future epochs will exploit the increased sensitivity of e-MERLIN allowing even more detailed stud-

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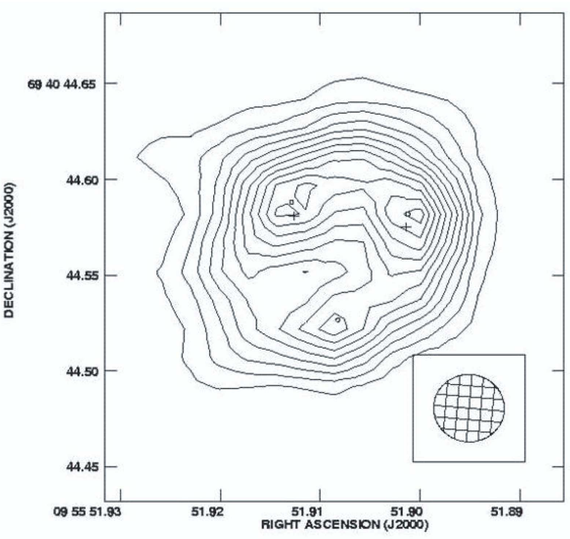

Fig. 1. Map of SNR 43.18+585 from the 2002 epoch convolved with a 35 mas beam, with contours at (1,2,3,...12) x 50 μJybeam^{-1}. Fitted positions for the 1992 epoch are shown as crosses (Muxlow et al. 2005).

ies of the expansion and evolution of these SNR.

2. MERLIN Observations

The 1992 observations were made on 2-3 July at 4.994GHz using the 6 elements of the MERLIN array and a total integration time of 36 hours (see Muxlow et al. (1994) for details). The 2002 MERLIN observations were taken over the period between 1 and 28th April and a total of 8 days observing ($\sim$ 175 hours on source). Both sets of observations were observed at the same frequency using the same flux (3C286) and phase calibrators (0955+697). The dataset from 2002 was processed using J2000 coordinates and an updated phase calibrator position. In order to astrometrically align these 1992 data, they were firstly precessed to J2000 coordinates and subsequent corrections were made to account for the error in the original assumed position of 0955+697. The peak of the most compact source in M82 (41.95+575) in the 1992 image was aligned under the peak as seen in the 2002 image. We are using different weighting schemes to optimise sensitivity and resolution.

3. Evolution

The shell structures and partial shell structures observed in the deep 2002 images enable the sizes of the SNR to be measured. Comparison of the observed sizes between the 1992 and 2002 epochs allows calculation of the expansion velocities of the SNR. By comparing the 1992 and 2002 MERLIN observations, the most compact source (41.95+575), appears to have an expansion velocity of 2800±300 km/s (Muxlow et al. 2005). This is in good agreement with the results of the global VLBI observations (2500±550 km/s) which have been used to study the most compact SNR in M82 (McDonald et al. 2001).

Positional fits of the peaks of emission for SNR 43.18+585 (see Fig 1), coupled with integrated annular profiles have shown the peaks to move outward by 7.05±0.15 mas between the 1992 and 2002 epochs, imply an expansion velocity of 10,500±750 km/s (Muxlow et al. 2005). The sizes and expansion velocities will be systematically measured for as many of the SNR as possible that appear in these two epochs of data. This will be done using a variety of methods which will differ slightly as a consequence of the structure of the individual remnants. One dimensional cuts across the SNR and the subsequent measurement of the distance between the two peaks of emission is one method of measuring the sizes of the more compact, shell structured remnants. This method can also be used to measure the major and minor axes of the less uniform or partial shell structured remnants and coupled with integrated annular profiles to estimate a mean size. Gaussian fitting of the peaks (or knots) of radio emission will also be used to estimate the size of the SNR, along with the above methods. For the more compact and circular remnants a subtraction will also be performed between the two images which will be used to estimate a size. Comparison of the positions as observed in both the 1992 and 2002 epochs will then be used to determine the expansion velocities. Some preliminary results for the most compact sources present in M82 were published in Muxlow et al. (2005).

The detailed images of M82 will allow measurements of the sizes of the majority of the resolved SNR. This will enable us to revise the 5 GHz flux vs. diameter plot (see Fig 2), increasing the accuracy as well as the number of points. This will further our understanding of this relation with the eventual goal of being able to determine whether there is a size cut-off as a consequence of behaviour intrinsic to the SNR.

4. Conclusions

MERLIN 2002 deep integration observations of M82 have been used to make detailed images of supernovae remnants. These images will be used to measure the sizes of the SNR using a variety of methods. Use of the 1992 observations will enable a calculation of expansion velocities by a comparison of measured sizes for the majority of the resolved SNR.This will be used to revise the 5GHz flux vs. diameter plot. Observations of the SNR at future epochs using e-MERLIN will provide a detailed long-term study of the expansion and evolution of the SNR, with the deep 2002 MERLIN observations acting as the first epoch.

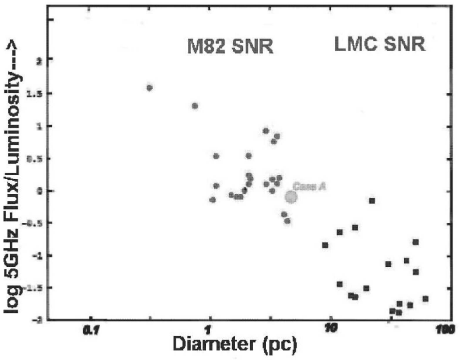

Fig. 2. Plot of the 5 GHz flux density against diamater for the M82 and LMC remnants (Muxlow et al. 1994).

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References

Kronberg, P., Bierman, P., & Schwab, F., 1985, ApJ, 291, 693

Kronberg, P., & Sramek, R., 1985, Science, 277, 28

McDonald, A., Muxlow, T., Pedlar, A., Garret, M., Wills, K., Garrington, S., Diamond, P., & Wilkinson, P., 2001 MNRAS 322, 100.

Muxlow, T., Pedlar, A., Wilkinson ,P., Axon, D., Sanders, E., & de Bruyn, A. 1994, MNRAS, 266, 455

Muxlow, T., Pedlar, A.,Riley, J., McDonald, A., Beswick, R. & Wills, K., 2005 Marcaide, J., Weiler, K., eds, Proc. IAU Colloquim 192. Springer Proceedings in Physics, Pg 227.

Pedlar, A., Muxlow, T., Garret, M.A., Diamond, P., Wills, K., Wilkinson ,P., & Alef, W. 1994, MNRAS, 266, 455

Unger, S., Pedlar, A., Axon, D., Wilkinson, P., & Appleton, P., 1984, MNRAS, 211, 783