Mem. S.A.It. Vol. 76, 586

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Is 41.95+575 in M82 actually an SNR?

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Abstract.
The radio supernovae and supernova remnants (SNR) in the nearby starburst galaxy M82 have been the subject of intense study by a number of research groups for many years. Recent high-resolution radio imaging with MERLIN and VLBI resolve all the ∼30 SNR found within the central kiloparsec of M82 indicating that they are less than ∼2000 years old. Global VLBI studies of one of these objects, 41.95+575, show an unusual double-lobed structure with a modest expansion speed of ∼1800 km/s and an age of around 100 years. The flux density of 41.95+575 has been decreasing at 8.8%/year since monitoring began in the 1960s, inferring that at outburst the flux density would have been around 100 Jy! In addition, MERLIN 408 MHz imaging shows that 41.95+575 sits at the centre of a compact HII region with a radius of ∼100 light years. We explore the possibility that 41.95+575 is not a conventional SNR, but the decaying product of a violent GRB event in M82 which occurred around 100 years ago.

Key words. galaxies: GRB – galaxies: starburst – galaxies: ISM – supernova remnants: invidual:41.95+575

1. Introduction

By far the most extensive studies of extragalactic supernova remnants (SNR) have been carried out in the prototypical starburst galaxy M82. Following the detection of several compact radio sources in the central kiloparsec of M82 (Kronberg & Wilkinson 1975), MERLIN and VLA observations identified a population of ∼50 objects (Unger et al. 1984), (Kronberg et al. 1985). Subsequent spectral analysis (McDonald et al. 2002) shows that around 30 of these are most probably SNR with the remainder being compact HII regions. Deep MERLIN imaging at 5 GHz (Muxlow et al. 1994, Muxlow et al. 2005) has shown that the SNR are extended with typical sizes of a few parsecs and with shell or partial-shell radio structures and expansion velocities, where measured, of up to around 10,000 km/sec..

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2. The Unusual Object 41.95+575

41.95+575 is the brightest and most compact source in M82 (See Figure 1). First detected in 1965 (Bash 1968) it has been the target for VLBI studies since the mid-1970s. Early radio images showed its appearance to be elongated and unlike that of other more typical shell-like SNR. More recent high-resolution global VLBI imaging (McDonald et al. 2001)

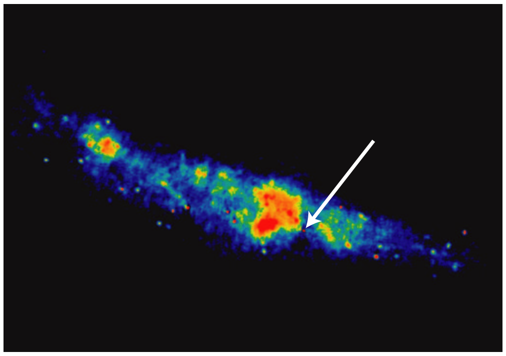

Fig. 1. A combined MERLIN+VLA 5 GHz image of M82 with 41.95+575 indicated by the arrow.Angular resolution 75mas.

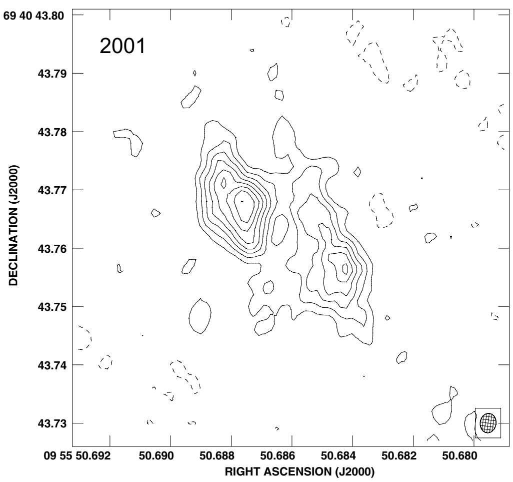

Fig. 2. A global VLBI 5 GHz image of 41.95+575, epoch February 2001. Angular resolution 3mas.

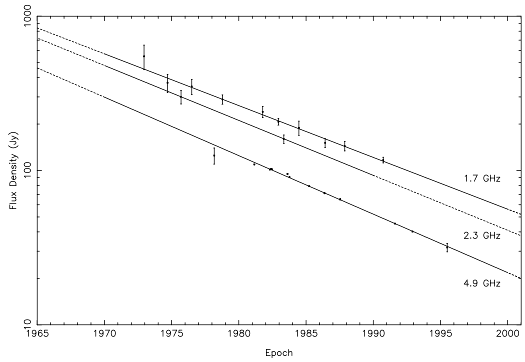

Fig. 3. The flux density of 41.95+575 over the last 30 years.

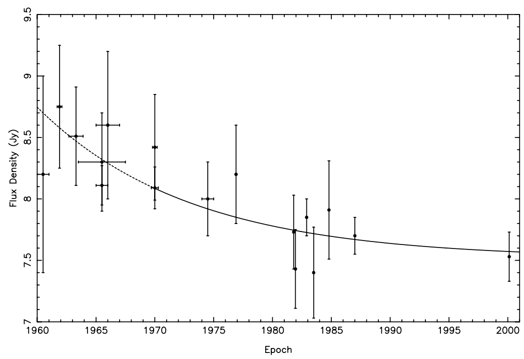

Fig. 4. The total 1.4 GHz flux density of M82, showing the clear contribution of 41.95+575 during the 1960s and 1970s.

(Muxlow et al. 2001) (Riley et al. 2005) have confirmed its unusual double-lobed structure, comprising of two separated components with connecting emission, see Figure 2.

Analysis of the positions of the two main peaks in the VLBI images shows that their separation is increasing at a rate of 0.24mas/yr (equivalent to an expansion velocity of ~1800 km/s at a distance of 3.2 Mpc). Since the measured separation was found to be 22.4mas in 2001, assuming a constant rate of expansion yields an upper limit to the age of the object at around 100 years.

Figure 3 shows that 41.95+575 has decreased in flux density at ~8.8% per year since monitoring of this individual object began in the early 1970s. This is again an unusual characteristic since no evidence of any significant variability has been found in any of the other SNR in the central nuclear kiloparsec region of M82. Tracing this variability to even earlier epochs is somewhat problematical since observations from such dates often contain larger measurement errors. However it is clear that in the 1960s, 41.95+575 was making a significant contribution to the total flux density of M82 (Figure 4).

Detailed monitoring has shown that the measured rate of fading of 41.95+575 at radio wavelengths has remained constant for more than 30 years. We have argued that this source may have an age of around 100 years.

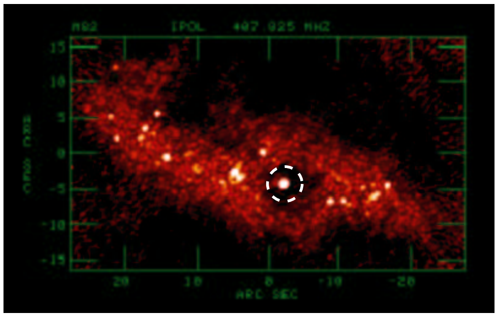

Fig. 5. The 408 MHz MERLIN image of M82 showing significant free-free absorption and a large HII region surrounding 41.95+575 with a radius of ∼100 light years (marked).

Extrapolating the fading rate back to zero age indicates that at birth 41.95+575 would have been a remarkably bright radio source with a flux density of ∼170 Jy at 1.4 GHz.

Low frequency, sub-arcsecond resolution radio imaging with MERLIN at 408 MHz has shown that much of the extended radio emission in the central nuclear region of M82 exhibits significant free-free absorption (Wills et al. 1997). In addition, 41.95+575 shows another notable feature in this low frequency image. It is found to lie at the centre of a large HII region of diameter ∼4.5 arcsecond, which translates to a radius of approximately 100 light years, see Figure 5.

3. Radio supernova remnant or GRB afterglow?

It appears that 41.95+575 is the product of an unusually powerful event. The implied peak 5 GHz radio luminosity at birth of 2×10^{30} erg/s/Hz is two orders of magnitude greater than the brightest Type IIn radio supernovae SN1986j and SN1988z, ∼30 times that of the Type 1b/c SN1998bw, associated with GRB980425, but approaches that of the typical radio after-glows of long-duration gamma-ray bursts (e.g. 10^{31} erg/s/Hz for the well-studied GRB030329, (Berger et al. 2003)). In addition, GRBs are expected to produce long-lived photo-ionised bubbles in the surrounding ISM with radii ∼100 pc for total burst energies $\sim 10^{52}$ erg (Perna et al. 2000). If 41.95+575 was associated with a GRB which occurred in M82 100 years ago then we would expect it to sit within an HII region which could be no larger than the one seen in Fig.5. Furthermore, light curves of GRBs strongly suggest that ejection is in the form of oppositely-directed jets which would provide a natural explanation for the highly unusual bipolar morphology seen in the VLBI images.

Further work is in progress on the intriguing suggestion that 41.95+575 is the evolving radio afterglow of a 100 year old GRB event.

Acknowledgements. MERLIN is run by the University of Manchester as a National Facility on behalf of PPARC. The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities.

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