Radio observations of super star clusters in dwarf starburst galaxies

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ABSTRACT
We present new radio continuum observations of two dwarf starburst galaxies, NGC 3125 and 5408, with observations at 4.80 GHz (6 cm) and 8.64 GHz (3 cm), taken with the Australia Telescope Compact Array (ATCA). Both galaxies show a complex radio morphology with several emission regions, mostly coincident with massive young star clusters. The radio spectral indices of these regions are negative (with $\alpha \sim -0.5$ to $-0.7$), indicating that the radio emission is dominated by synchrotron emission associated with supernova activity from the starburst. One emission region in NGC 5408 has a flatter index ($\alpha \sim -0.1$) indicative of optically thin free–free emission, which could indicate it is a younger cluster. Consequently, in these galaxies we do not see regions with the characteristic positive spectral index indicative of optically obscured star formation regions, as seen in other dwarf starbursts such as Hen 2–10.

Key words: galaxies: individual: NGC 3125 – galaxies: individual: NGC 5408 – galaxies: starburst – galaxies: star clusters – radio continuum: galaxies.

1 INTRODUCTION
Dwarf starburst galaxies are the more numerous and fainter counterparts of traditional starburst galaxies. Dwarf starbursts will have a particularly important role in the energizing and polluting of the intergalactic medium through galactic winds, as, because of their low escape velocities, even a moderate starburst event in a dwarf galaxy can result in the expulsion of a large fraction of the nuclear processed material in a superwind or outflow (Dekel & Silk 1986; Mac Low & Ferrara 1999; Strickland & Stevens 2000). Understanding the complexities of starburst processes in dwarf galaxies is therefore an important step in understanding the feedback processes between star formation and galactic evolution.

Radio continuum observations of starburst galaxies are particularly useful in studying the star formation processes, suffering little of the extinction that complicates matters in the optical and UV, which may appear to be more suitable wavebands for studying young massive star populations (see Hopkins et al. 2001, for a discussion of the merits of different wavelength regimes for finding star formation rates). Radio observations can also be used to study populations of supernovae remnants (SNRs) in starburst galaxies (e.g. Kronberg et al. 2000; Greve et al. 2002), and recent radio observations have revealed objects inferred to be optically obscured super star clusters (see below).

Earlier radio observations of dwarf starbursts, at low spatial resolution, have shown them to have a higher radio to optical luminosity ratio than normal spiral galaxies and spectral indices significantly flatter than a sample of spiral galaxies (Klein, Wielebinski & Thuan 1984). This was attributed to lower magnetic fields in the dwarf galaxies effectively suppressing non-thermal emission. However, more recent and higher resolution observations are showing a more complex and interesting picture. VLA observations of the dwarf starburst Henize 2-10 by Kobulnicky & Johnson (1999), (see also Kobulnicky & Johnson 2000) found several compact radio sources in the central regions. These sources have positive spectral indices (i.e. $\alpha > 0$, with the radio flux defined as $S_\nu \propto \nu^\alpha$), indicative of optically thick bremsstrahlung emission. These radio knots are believed to be unusually dense H II regions, with sizes of $\sim 3$–8 pc and densities $\sim 1500$–5000 cm$^{-3}$, associated with optically observed super star clusters.

Further, VLA observations of NGC 5253 (another dwarf starburst) showed unusually high levels of free–free emission, most of it from a single source (Turner, Ho & Beck 1998). Several regions with a positive spectral index were also detected, which were inferred to be young regions of star-forming activity. These authors also found regions of non-thermal emission, probably associated with SNRs. Further observations showed what was inferred to be a dense compact H II region, with a size of only 1–2 pc, but containing several thousand O-stars, and which was termed a ‘radio supernebula’ (Turner, Beck & Ho 2000).

Beck, Turner & Kovo (2000) have presented VLA observations of nine Wolf–Rayet galaxies (a particular class of starburst galaxies, containing very young and massive Wolf–Rayet stars, Conti 1991), including seven dwarf starbursts. In the majority of these galaxies the global spectral indices were much flatter than in spiral galaxies (the
only exception being NGC 3049 which is a large spiral galaxy as well as a Wolf–Rayet galaxy, which has a spectral index of $-0.7$. This flatter index indicates a higher fraction of free–free emission in these galaxies, and in fact many of the galaxies had regions with positive spectral index, indicative of self-absorbed free–free emission and hence very recent and compact star formation. These objects are probably related to the optical super star clusters (SSCs) observed with HST in many starbursts and galaxy mergers (see Whitmore 2002, for a review), but which are viewed at a younger age, and which are still enclosed within the parent cloud, obscuring them at optical wavelengths.

Other examples of optically obscured SSCs seen at radio wavelengths are found in NGC 2146 (a spiral starburst galaxy), where a number of radio sources with positive spectral indices are seen, and that have been interpreted as being due to massive ultra-compact H II regions, indicative of extremely young star formation (Tarchi et al. 2000). Kobulnicky & Johnson (2001) and Johnson et al. (2001) summarise the status of radio observations of these young starburst regions, and coins the phrase ‘ultra-dense’ H II regions (or UDH II regions). It is worth noting that MERLIN observations of the nearby (2.2 Mpc) dwarf starburst NGC 1569 found no emission associated with the optically visible SSCs in this galaxy, but did find a number of radio supernovae or supernovae remnants (Greve et al. 2002).

In this paper we report on radio observations, taken with the Australia Telescope Compact Array (ATCA), of two dwarf starburst galaxies, NGC 3125 and 5408, which are also Wolf–Rayet galaxies. Because Wolf–Rayet galaxies contain very young massive stars and are thus sites of very recent star formation, they are the obvious place to look for optically obscured star clusters. Radio maps with good spatial resolutions are therefore very important in understanding the global properties of these objects.

The paper is organized as follows: in Section 2 the characteristics of the target galaxies are discussed, in Section 3 the radio observations and analysis are described and the results are discussed in Section 4. Parameters for NGC 3125 and 5408 are given in Table 1 and a summary of the ATCA radio observations of NGC 3125 and 5408 are given in Table 2.

## 2 The Target Galaxies

### 2.1 NGC 3125 (Tol 3, Tol 1004–296)

NGC 3125 is a dwarf starburst and has been classified as a Wolf–Rayet galaxy (Conti 1991). We assume a distance of 13.8 Mpc (Marlowe et al. 1995). In general terms NGC 3125 is a metal-poor, irregular amorphous dwarf galaxy, undergoing strong star formation activity. The stellar population seems to be the result of periodic bursts of strong star formation followed by periods of quiescence (Kunth, Maurogordato & Vigroux 1988). A spectral analysis by Vacca & Conti (1992) suggested that the emission line spectra required the presence of $\sim 500$ WN type Wolf–Rayet stars and $\sim 2500$ OB stars. Population synthesis by Raimann et al. (2000) suggests the presence of stars with ages ranging from 2–3 Myr up to $>500$ Myr. Their is no evidence of a recent merger for this galaxy.

Marlowe et al. (1995) and Marlowe, Meurer & Heckman (1999) observed NGC 3125 at optical wavelengths, as part of a study of several dwarf starbursts. Hα observations of NGC 3125 show bright emission from the central region, with a spatial extent of 25 arcsec ($\sim 1.7$ kpc) with three emission peaks in this region. In addition, filamentary Hα emission extending out to a radius of 40 arcsec was seen, as well as evidence of an outflow. NGC 3125 has also been observed with the Faint Object Camera on the pre-refurbishment HST, showing several SSCs in the central regions of the galaxy.

NGC 3125 has been observed with the Einstein and Rosat X-ray satellites (Stevens & Strickland 1999b). Although there is limited spectral information, on the basis of its likely X-ray properties (i.e. assuming that its X-ray spectrum is similar to that of other dwarf starbursts) it is the one of most X-ray over-luminous dwarf starbursts as compared to its $B$-band luminosity (Stevens & Strickland 1999a,b), with an X-ray luminosity of $L_X \sim 2 \times 10^{38}$ erg s$^{-1}$, in the 0.1–2.5 keV waveband.

### 2.2 NGC 5408

NGC 5408 is a starbursting dwarf irregular galaxy, and has three main nuclear $H$ II regions (Bohuski et al. 1972). Colour-wise, like NGC 3125, it is extremely blue, (indicative of very vigorous star formation). We assume a distance of 8 Mpc (Fabian & Ward 1993). Again, there is no indication of a recent merger that might have triggered the starburst.

NGC 5408 has been observed on several occasions at X-ray energies, and is very X-ray luminous for a dwarf galaxy (Fabian & Ward 1993; Stevens & Strickland 1999b). The X-ray morphology of NGC 5408, as seen by the ROSAT PSPC shows that the X-ray emission is broadly centred on the main nuclear $H$ II regions. The best-fit model for the X-ray spectra has $kT \sim 0.5$ keV with little local absorption. The X-ray luminosity (corrected for absorption) is $L_X \sim 3 \times 10^{39}$ erg s$^{-1}$ (0.1–2.5 keV).

NGC 5408 has also been observed at higher spatial resolution with the ROSAT HRI (Fourniol, Pakull & Motch 1996), showing that the X-ray emission is dominated by a single point-like source, which is not obviously co-located with any of the SSCs in NGC 5408. The origin of the X-ray emission is rather unclear, possibly a single X-ray luminous SN, thermal emission associated with H II regions, an ultraluminous X-ray binary or even a background quasar.

## 3 The Radio Continuum Observations

NGC 3125 and 5408 were observed with the Australia Telescope Compact Array (ATCA), at Narrabri, New South Wales, Australia. The observations were performed on 2000 March 25 and March 31, with the array in the 6 km (6D) configuration. The observations were performed simultaneously at 4.80 GHz (6 cm) and 8.64 GHz (3 cm). Observations of the target galaxy and a phase calibrator were alternated through the 12 h observing run, giving a total of about 10 h spent on source. The secondary flux calibrators used in these observations were 1016–311 for NGC 3125 and 1349–439 for NGC 5408, along with the standard ATCA primary calibrator, 1934–638. The flux densities for the various calibrators were as follows; for the primary calibrator 1934–638, 2.842 Jy (6.46 GHz) and 5.829 Jy (4.80 GHz). For the secondary calibrator the flux densities were; for 1016–311, 0.592 Jy (8.64 GHz) and 0.583 Jy (4.80 GHz), for 1349–439, 0.394 Jy (8.64 GHz) and 0.452 Jy (4.80 GHz).
During the first run looking at NGC 3125 on 2000 March 25 problems with one of the antennas was encountered, restricting the \((u, v)\) coverage somewhat and some further scans on NGC 3125 were performed during the second run, which concentrated on NGC 5408. In addition, some further scans were made of NGC 3125, using the 6 km (6C) array, during a subsequent run (2000 October 25).

The ATCA data were processed using the MIRIAD package (Sault, Teuben & Wright 1995). The data were calibrated and cleaned using standard techniques, with the inversion done using uniform weighting. To estimate the spectral indices of the emission regions we have convolved the higher resolution (8.64 GHz) map to match that of the lower resolution (4.8 GHz) image. Flux errors were estimated as in Venturi et al. (2001), and errors on the spectral index were estimated using standard propagation of error expressions.

### 4 RESULTS AND DISCUSSION

#### 4.1 NGC 3125

The radio images of NGC 3125 at 4.80 GHz and 8.64 GHz are shown in Fig. 1. The beam sizes for these observations are 6.06 \(\times\) 2.66 arcsec\(^2\) at 4.80 GHz and 3.34 \(\times\) 1.50 arcsec\(^2\) at 8.64 GHz. For the 8.64 GHz observations the beam-size corresponds to a size of 250 \(\times\) 100 pc at the assumed distance of 13.8 Mpc. Note, that because of the antenna failure the spatial resolution of the NGC 3125 observations are lower than those presented for NGC 5408.

The observed radio morphology shown in Fig. 1 consists of two main emission regions or knots, which we designate NGC 3125:A and 3125:B. Taking the position from the 8.64 GHz data as the most reliable, the sources are located at (RA, Dec.) = 10\(^h\)06\(^m\)33\(^s\), −29\(^\circ\)56′06\(\prime\).6 (source A) and 10\(^h\)06\(^m\)33.99\(\prime\), −29\(^\circ\)56′12.25\(\prime\). (Source B), and are separated by \(\sim 8\) arcsec.

Using the MIRIAD IMFIT package we have measured the flux for these two sources using a Gaussian fit for each, and the results are shown in Table 3. The fitting suggests that the sources are at most only marginally larger than the beam size. The derived flux densities at 4.80 GHz for the two sources are 5.9 mJy (NGC 3125:A) and 4.3 mJy (NGC 3125:B), and the spectral indices are \(\alpha = -0.5\), for NGC 3125:A and \(\alpha = -0.6\) for NGC 3125:B.

We can compare the positions of these radio sources with the optical star clusters in NGC 3125. As noted by Marlowe et al. (1995) there are three peaks in the H\(\alpha\) surface brightness within the central 1.7 kpc corresponding to star clusters. We can obtain more accurate positions of these star clusters using archival HST Faint Object Camera, and if we designate these clusters NGC 3125:SC1–3, the locations of the optical SSCs are (RA, Dec. J2000):

| NGC 3125 | NGC 5408 |
|----------|----------|
| Date | 2000 March 25 | 2000 March 31 | 2000 October 25 | 2000 March 31 |
| Configuration | 6D | 6D | 6C | 6D |
| RA (J2000) | 10h06m33s | 14h03m19s | 14h03m19s | 14h03m19s |
| Dec. (J2000) | −29′56′03′′ | −29′56′03′′ | −29′56′03′′ | −41′23′18′ |
| Frequencies | \(4.80\) GHz, \(8.64\) GHz | \(4.80\) GHz, \(8.64\) GHz | \(4.80\) GHz, \(8.64\) GHz | \(4.80\) GHz, \(8.64\) GHz |
| Total bandwidth | 128 MHz | 128 MHz | 128 MHz | 128 MHz |
| Beam size | 3.34 \(\times\) 1.50 arcsec\(^2\) \((8.64\) GHz\) | 1.60 \(\times\) 0.97 arcsec\(^2\) \((8.64\) GHz\) | 6.06 \(\times\) 2.66 arcsec\(^2\) \((4.80\) GHz\) | 2.90 \(\times\) 1.76 arcsec\(^2\) \((4.80\) GHz\) |
| Flux calibrator | 1934 | 1934 | 1934 | 1934 |
| Phase calibrator | 1016–311 | 1349–439 | 1349–439 | 1349–439 |

Note. "The same for all observations.

#### 4.2 NGC 5408

The radio continuum images of NGC 5408 at 4.80 GHz and 8.64 GHz are shown in Fig. 2. The beam size for these observations are 2.90 \(\times\) 1.76 arcsec\(^2\) at 4.80 GHz and 1.60 \(\times\) 0.97 arcsec\(^2\) at 8.64 GHz. It is clear that NGC 5408 has a somewhat more complex radio morphology than NGC 3125, with four discrete sources, which we shall designate NGC 5408:A–D, in order of increasing RA. All four sources are apparent in the 4.80 GHz image, with NGC 5408:C showing up as an extension to the brightest source (NGC 5408:B). NGC 5408:C is more apparent in the higher resolution 8.64 GHz image, while NGC 5408:D is only clearly seen in the 4.80 GHz map.

Again, using the MIRIAD IMFIT package we have measured the flux densities of these sources, and these and the spectral indices for the four discrete sources and these are listed in Table 3. With the exception of source A, all of the spectral indices are strongly negative. For source A the index is much flatter.

We can compare the positions of the radio sources with those of optical star clusters. Archival HST WFPC2 data reveals several compact regions of star formation within NGC 5408, with positions (RA, Dec. J2000):

| NGC 5408 | SSC1 | SS2 | SSC3 |
|----------|------|-----|------|
| NGC 5408 | 14\(^h\)03\(^m\)18\(\prime\).4, −29′56′12′.8 | 14\(^h\)03\(^m\)18\(\prime\).4, −29′56′12′.8 |
| NGC 5408 | 14\(^h\)03\(^m\)18\(\prime\).4, −29′56′12′.8 |
| NGC 5408 | 14\(^h\)03\(^m\)18\(\prime\).4, −29′56′12′.8 |
| NGC 5408 | 14\(^h\)03\(^m\)18\(\prime\).4, −29′56′12′.8 |

The regions SSC1 and SSC2 may be composed of more than one star cluster. The radio source A is associated with SSC1 and radio source NGC 3125:B is associated with either or possibly both SSC2 and SSC3 (these two objects being separated by only 0.2 arcsec). It is worth noting that in the FOC image other fainter star clusters are visible in NGC 3125.
emission. At cm wavelengths most H II regions are optically thin, resulting in a synchrotron spectrum. In all H II regions the radio spectrum does turnover at low frequencies (for instance, for Orion this occurs at $\lambda \sim 1$ m).

(i) Supernovae and supernova remnants: cosmic rays accelerated by supernovae and supernova remnants, which then interact with the interstellar magnetic field to emit synchrotron emission. The typical spectral index of this synchrotron emission will be $\alpha \sim -0.7$. In starburst and normal galaxies this component will tend to be distributed throughout the disc. However, in NGC 3125 and 5408 we are dealing with dense stellar clusters, which could contain many SN remnants in a small volume, giving rise to a compact region of synchrotron emission.

(ii) H II regions: hot electrons in H II regions generate free–free emission. At cm wavelengths most H II regions are optically thin, resulting in a flat spectrum ($\alpha = -0.1$). However, some compact H II regions are seen to be optically thick, giving rise to a rising spectrum at cm wavelengths (NGC 5253 – Turner, Ho & Beck 1998; Hen 2–10 – Kobulnicky & Johnson 1999; NGC 2146 – Tarchi et al. 2000; M82 – McDonald et al. 2002. In these cases, which are probably associated with very young super star clusters, the gas densities are sufficient to cause a turn-over in the emission at low frequencies. In all H II regions the radio spectrum does turn over at some sufficiently low frequency (for instance, for Orion this occurs at $\lambda = 1$ m).

(iii) The radio emission from ultra-luminous infrared galaxies is optically thick to free–free absorption, so that the typical synchrotron spectrum of these galaxies is flattened at low frequencies (Condon et al. 1991).

The combined result of these effects in Seyfert and starburst galaxies is to produce a typical radio spectral index of $\alpha \sim -0.7$ (from the extended synchrotron emission) with a flattening at low frequencies in some starburst sources because of free–free absorption.

For NGC 3125 and 5408, the morphology and spectral indices of the radio knots imply that the observed emission is primarily associated with Type II supernova activity which is associated with star formation activity within the star clusters. The exception is
NGC 5408:A, which has a flatter index indicative of optically thin free–free emission. The obvious interpretation is that in this source, which is associated with an SSC, the emission is dominated by the H II region, and that the cluster is perhaps younger than the others in NGC 5408 and supernova activity has not yet begun to dominate the radio emission.

The next step is to see if we can develop a coherent picture of the star-forming behaviour of these galaxies. It is worth noting that in these galaxies the optical light may be dominated (or have a substantial contribution) from the star clusters, but it is likely that the stellar content these clusters only comprise a few percent of the total stellar mass in the galaxies. However, these clusters may provide a substantial fraction of the ongoing star formation in the galaxy.

We can estimate the expected supernova rate in the radio emitting regions. Assuming that the 4.80 GHz flux is non-thermal emission, then the implied SN rate in the various radio emitting regions can be estimated from (Condon & Yin 1990):

\[ L_{\text{6cm}}(\text{WHz}^{-1}) = 1.3 \times 10^{23} \left( \frac{\nu}{1\text{GHz}} \right)^{0.8} v_{\text{SN}} \text{yr}^{-1} \]  

For NGC 3125 this corresponds to SN rate of \( v_{\text{SN}} = 4 \times 10^{-3} \text{ yr}^{-1} \) for NGC 3125:A and \( v_{\text{SN}} = 3 \times 10^{-3} \text{ yr}^{-1} \) for NGC 3125:B. The corresponding SN rates for the NGC 5408 regions are in the range \( v_{\text{SN}} = (1-5) \times 10^{-4} \text{ yr}^{-1} \).

Similarly, we can estimate the star formation rates from both far-infrared (FIR) observations and these radio observations. The FIR rates will apply to the whole galaxy while the radio ones will apply to the observed emission regions (see Hopkins et al. 2001, for a comparison of the various methods for estimating star formation rates in galaxies)

The FIR luminosities of \( L_{\text{FIR}} = 4.0 \times 10^{42} \text{ erg s}^{-1} \) (NGC 3125) and \( L_{\text{FIR}} = 7.4 \times 10^{41} \text{ erg s}^{-1} \) (NGC 5408). From Kennicutt (1998) we can estimate the total star formation rate (SFR) in each galaxy from the following relationship:

\[ \text{SFR(}M_\odot \text{yr}^{-1}) = 4.5 \times 10^{-44} L_{\text{FIR}}(\text{erg s}^{-1}) \]  

where the mass range for the star formation rate is assumed to be \( 0.1-100 \ M_\odot \) and \( L_{\text{FIR}} \) is the far-infrared luminosity. This means that the estimated total SFR in the two galaxies are 0.18 \( M_\odot \) \text{ yr}^{-1} (NGC 3125) and 0.033 \( M_\odot \) \text{ yr}^{-1} (NGC 5408). Note, that assuming a Salpeter IMF, the star formation rate of high mass, that is stars with \( M_i > 10 \ M_\odot \), will be about 10 per cent of this value.

Using the results of Condon (1992, see also Haarsma et al. 2000) we can estimate the star formation rates in the radio regions from these radio observations. The implied total star formation rate in the two regions in NGC 3125 is 0.3 \( M_\odot \) \text{ yr}^{-1} and in NGC 5408 the figure is 0.09 \( M_\odot \) \text{ yr}^{-1}, somewhat higher than the FIR values.

As an aside, we can compare the estimated SN rates with the theoretical expectations from Leitherer & Heckman (1995). For an ongoing starburst with a star formation rate of 1 \( M_\odot \) \text{ yr}^{-1}, a Salpeter IMF and solar abundance, the expected supernova rate is \( t_{\text{SN}} \sim 0.02 \text{yr}^{-1} \). For the SFR rates estimated above, this corresponds to supernova rates of \( v_{\text{SN}} = 3.6 \times 10^{-3} \text{ yr}^{-1} \) for NGC 3125 and 6.6 \( \times 10^{-4} \text{ yr}^{-1} \) for NGC 5408. Comparing these values to the estimated SN rates above, there is reasonable agreement between the integrated SN rates in the various radio emitting regions and these expectations.

As discussed earlier, both galaxies are also X-ray luminous. There are several potential mechanisms for generating the X-rays: an AGN, X-ray binaries, SNRs and emission from superbubbles. There is no evidence for an AGN, and while individual supernovae or SNRs can be very radio and X-ray luminous (Van Dyk et al. 1993; Fabian & Terlevich 1996; Immler & Lewin 2002), their duration as high-luminosity objects is short-lived. Consequently, high-mass X-ray binaries, associated with the active star formation in these galaxies, are likely to provide much of the observed X-ray emission.

Extrapolating from the star formation rate in our own Galaxy (~0.1–0.2 \( M_\odot \) \text{ yr}^{-1}) we can estimate the number of luminous X-ray binaries in each system. The Galaxy has an estimated population of luminous high-mass X-ray binaries (HMXBs) of \(~27 \pm 19\) (Dalton & Sarazin 1995). Based on this, these two dwarf starbursts should have a high-mass X-ray binary population of \( 20 \pm 10 \) for NGC 3125.
and $5 \pm 2$ for NGC 5408. Note that this refers only to the most luminous HMXBs, namely those with $L_X \geq 10^{37}$ erg s$^{-1}$.

The observed X-ray luminosities of these galaxies are $L_X = 2 \times 10^{39}$ erg s$^{-1}$ (NGC 3125) and $3 \times 10^{40}$ erg s$^{-1}$ (NGC 5408), meaning that NGC 5408 is substantially more X-ray luminous than NGC 3125, although having a smaller star formation rate. The X-ray emission from NGC 3125 could be dominated by X-ray binaries, however, this is unlikely to be the case for NGC 5408 and we may need an additional very X-ray luminous source, such as the objects seen by the Chandra satellite in other star-forming galaxies (for instance Kaaret et al. 2001) believed to be intermediate mass black-holes.

Consequently, from these observations, we can conclude that the radio emission in NGC 3125 and 5408 is predominantly non-thermal in nature and is most likely dominated by processes associated with Type II SNRs which are associated with recent starburst activity in the massive stellar clusters. Only one source in NGC 5408 has a flatter spectral index indicative of optically thin free–free emission. It will remain to be seen if the cluster associated with this radio source is younger than the other clusters in this galaxy. In the case of NGC 3125 we have a coherent picture, whereby the expected star formation rate, supernovae rate and massive X-ray binaries populations can give rise to the observed properties, while in the case of NGC 5408 although the FIR and radio luminosities are broadly consistent the galaxy is substantially X-ray overluminous. This galaxy may well be the home of a single super-luminous system such as has been seen in several other galaxies.

One problem with the simple analysis presented here is that it has mostly assumed a constant star formation rate. In many of these stellar clusters there may be a coeval population of stars and in this situation the SN rate can be very time variable. A more detailed optical analysis is needed for these galaxies, to investigate the masses/ages of the star clusters. However, these new observations are throwing some more light on the radio evolution of massive star clusters in dwarf starbursts.

In conclusion, we have presented new radio observations of two dwarf starburst galaxies, NGC 3125 and 5408. Several discrete regions of radio emission are seen in these galaxies, most of them associated with massive young star clusters. The radio spectral indices indicate the emission is dominated by synchrotron emission associated with supernova activity, though in one case a flatter spectrum is observed, possibly indicative of a younger cluster.

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