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High-resolution radio observations of nuclear and circumnuclear starbursts in Luminous Infrared Galaxies

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High-resolution radio observations of nearby starburst galaxies have shown that the distribution of their radio emission consists of a compact ($\leq$ 150 pc), high surface brightness ($T_b \geq 10^3$ K) central radio source immersed in a low surface brightness circumnuclear halo. This radio structure is similar to that detected in bright Seyferts galaxies like NGC 7469 or Mrk 331, which display clear circumnuclear rings. While the compact, centrally located radio emission in these starbursts might be generated by a point-like source (AGN), or by the combined effect of multiple radio supernovae and supernova remnants (e.g., the evolved nuclear starburst in Arp 220), it seems well established that the circumnuclear regions of those objects host an ongoing burst of star-formation (e.g., NGC 7469; [3], [1]). Therefore, high-resolution radio observations of Luminous Infra-Red Galaxies (LIRGs) in our local universe are a powerful tool to probe the dominant dust heating mechanism in their nuclear and circumnuclear regions.

In this contribution, we show results obtained from VLA-A, MERLIN, and EVN (VLBI) radio observations of the galaxies NGC 7469 ($D \approx 70$ Mpc) and IRAS 18293-3413 ($D \approx 79$ Mpc), where two extremely bright radio supernovae have been found. High-resolution studies of these and other LIRGs would allow us to determine the core-collapse supernova rate in th them, as well as their star-formation rate.

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1. Introduction

Galaxies at the highest infrared luminosities ($L_{\rm IR}[8-1000\ \mu m] \geq 10^{12} L_{\odot}$), known as Ultra-Luminous Infrared Galaxies (ULIRGs), appear to be advanced merger systems and may represent an important stage in the formation of quasi-stellar objects. The bulk of the energy radiated by ULIRGs is infrared emission from warm dust grains heated by a central power source. The critical question concerning these galaxies is whether the dust in the central regions ($r \lesssim 1$ kpc) is heated by a starburst or an active galactic nucleus (AGN), or a combination of both. Mid-infrared spectroscopic studies of ULIRGs suggest that the vast majority of these galaxies are powered predominantly by recently formed massive stars, with a significant heating from the AGN only in the most luminous objects [7]. These authors also found that at least half of ULIRGs are probably powered by both an AGN and a starburst in a circumnuclear disk or ring. These circumnuclear regions are located at radii $r \simeq$700 pc from the nucleus of the galaxy, and also contain large quantities of dust.

High-sensitivity, high-resolution radio observations can prove to be extremely important in studying both the nuclear and circumnuclear regions of ULIRGs, as radio emission is not affected by dust extinction, and the use of VLBI techniques allows for parsec, or even sub-parsec resolution. Indeed, [3] have discovered a bright radio supernova (SN 2000ft) in the circumnuclear starburst region of the Highly Luminous IR Galaxy NGC 7469, and the most spectacular evidence of a compact starburst in a ULIRG is the discovery of a population of bright radio supernovae and supernova remnants in the nuclear regions of Arp 220 [6] and Mrk 273 [2], using VLBI observations.

2. VLA, MERLIN, and VLBI observations of (circum)nuclear starbursts

In Figure 1, we show a few examples where high-resolution radio observations have been extremely useful in unveiling dust-enshrouded supernovae in circumnuclear starbursts, as SN 2000ft in NGC 7469 (panel a; see also [3] and [1]), or SN 2004ip in IRAS 18293-3413 (panel c and [5]). SN 2000ft was first discovered at radio wavelengths [3], and therefore its case nicely shows that high-resolution radio observations of (circumn)nuclear starbursts are crucial to unveil supernovae in dust-enshrouded environments. Further, the monitoring of SN 2000ft showed that it is likely a type IIn event [1], like e.g., SN 1986J in NGC 891 [4], i.e., and behaves in much the way standard radio supernovae evolve. We also show in panel (b) 18 cm high angular resolution radio observations of the innermost $\sim$ 200pc of the nuclear region of NGC 7469 (panel b) imaged with MERLIN (top) and the EVN (bottom). The EVN image shows a number of compact regions, whose exact nature is still under discussion, and will be presented elsewhere.

It is foreseeable that the advent of the SKA will permit to carry out such studies for a large sample of LIRGs in the local universe. This should allow us to settle the question of the dominant heating mechanism in LIRGs and ULIRGs in the local universe. In addition, the enormous sensitivity of the array would allow to fill in the existing gap between the young supernova phase and its late, supernova remnant phase, by permitting to image historical supernovae that cannot be currently imaged due to limiting sensitivity of the existing VLBI arrays.

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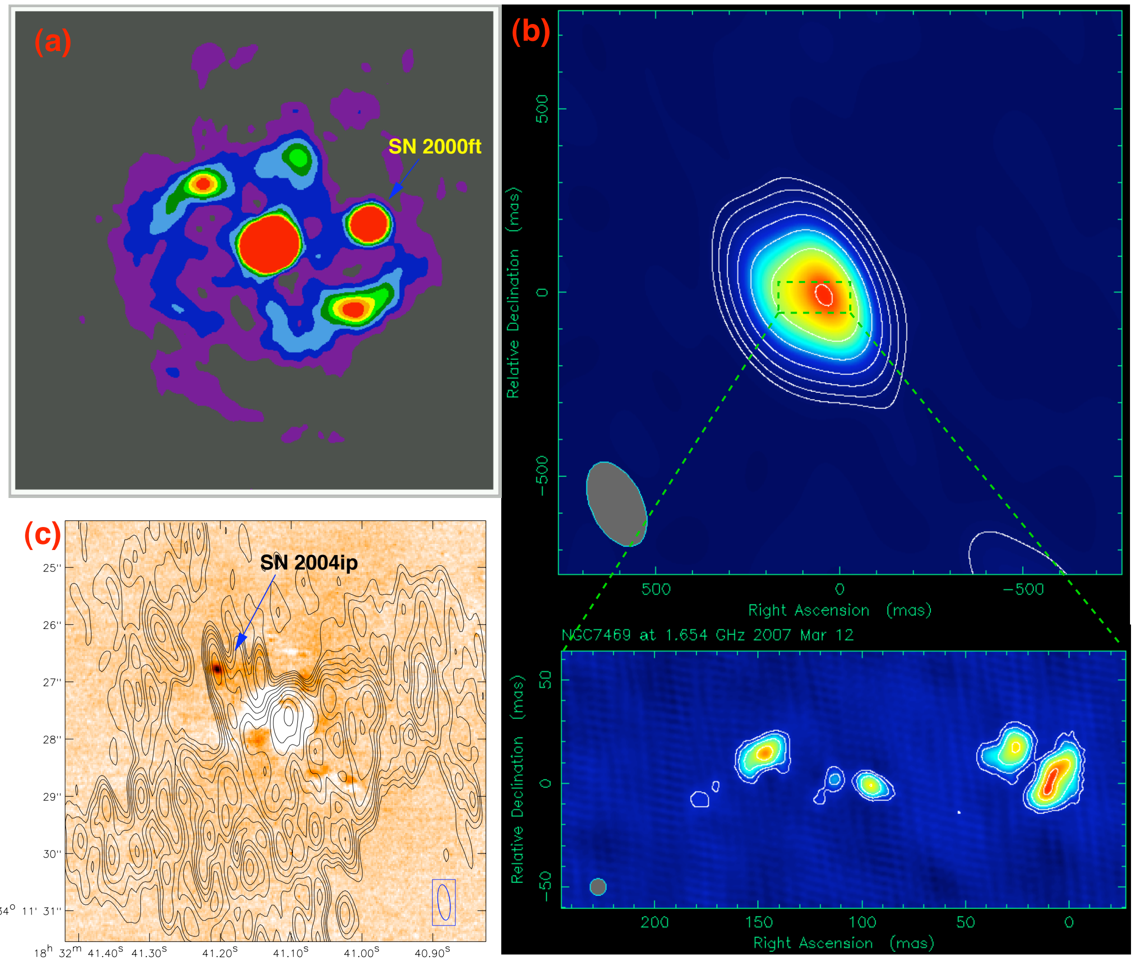

Figure 1: Panel (a): 8.4 GHz VLA discovery image of the radio supernova SN 2000ft in the galaxy NGC 7469 [3]; panel (b): 1.7 GHz simultaneous, MERLIN (top) and EVN (bottom) images of the nucleus of galaxy NGC 7469; note that the EVN image clearly discerns the substructure tha is not resolved by MERLIN (Alberdi et al. in preparation); panel (c): 8.4 GHz VLA image of SN 2004ip, whose detection at radio wavelengths three years after its explosion confirmed it core-collapse nature [5].

References

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