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The Circumnuclear Starburst and the Nuclear Region of the LIRG NGC 7469

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The Luminous Infrared Galaxy NGC 7469 consists at radio wavelengths of a bright unresolved core and an extended emission region, associated with the circumnuclear starburst. Within the circumnuclear star-forming ring (diameter of around 1 kpc), we have found evidence of a type IIn radio supernova: SN 2000ft. SN 2000ft is still powered by the interaction with the Circumstellar Medium (CSM). Within the nuclear region ($\leq$ 50 pc), we find evidence for a low-luminosity AGN probably coexisting with recent bursts of star-formation.

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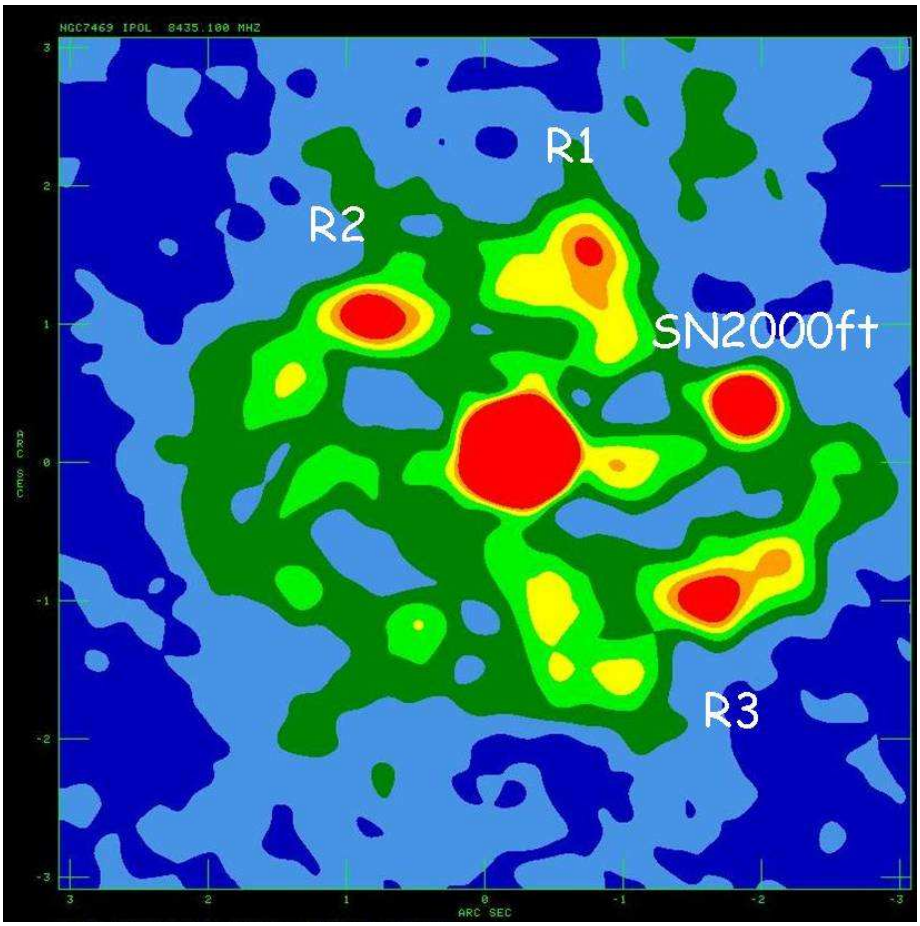

Figure 1: 8.4 GHz VLA Image of NGC 7469 with a resolution of 300 milliarcsec. Both the circumnuclear starburst, with three star-forming regions (R1, R2 and R3) and the Radio Supernova SN 2000ft within it, and the nuclear region are detected.

1. The LIRG NGC 7469

NGC 7469 is a well known barred spiral galaxy located at a distance of 70 Mpc (for an H_0= 70 km s^{-1} Mpc^{-1}) containing a luminous Seyfert 1 nucleus surrounded by a dusty starburst of about 1 kpc in size [3]. There is evidence for a 10^7 $M_\odot$ central black hole coming from reverberation mapping [9]. NGC 7469 is also a very luminous infrared galaxy with $\log(L_{FIR}/L_\odot) = 11.7$ where 2/3 of the luminosity is emitted by the starburst. Davies et al. (2004) [4] report the existence of a nuclear starburts with a size of 50 pc.

High sensitivity X-band VLA observations show NGC 7469 to consist of a bright unresolved core and an extended emission region, associated with the circumnuclear starburst, showing a two-arm spiral-like morphology [1] (see Fig. 1). The radio core, with an average flux density of $\simeq$12 mJy, contributes about 60% of the integrated emission at 8.4 GHz. We initiated an 8.4 GHz VLA monitoring program of NGC 7469. Our observations allowed us [3] to detect a strong, compact radio supernova –SN 2000ft– in its circumnuclear starburst, at a distance of 1.65 arcsec (600 pc)

from the galaxy core at a Position Angle (PA) of 282°, in a low surface brightness region both in the ultraviolet and mid-infrared [5]. Alberdi et al. (2006) and Pérez-Torres et al. (2009) [1, 6] have shown that, although SN 2000ft is exploding in a very dense, dusty, magnetized and radiation dominated environment compared to the local interstellar medium of spirals, its evolution during the first six years after its detection shows the typical characteristics of a luminous type II supernovae and is still powered by the interaction of the ejecta with the CircumStellar Medium (CSM).

1.1 The Circumnuclear Starburst

Apart from SN 2000ft, there is no evidence for any other radio supernova more luminous than about $L_{peak} \sim 6 \times 10^{26}$ erg s^{-1} Hz^{-1}, suggesting that no other type IIn supernovae has exploded since the year 2000 in the nuclear starburst of NGC 7469[6]. Díaz-Santos et al. (2007) [5] reported the existence of two different stellar populations within the circumnuclear starburst: an intermediate age population (14-35 Myr) traced by the UV-optical-NIR continuum, and a young (5-6 Myr) highly obscured population traced by the MIR-radio continuum. This supports an scenario where many instantaneous bursts occur in the circumnuclear starburst of NGC 7469 with a spread in ages.

2. The Nuclear Region of NGC 7469

Our EVN+MERLIN map obtained at 1.6 GHz from observations performed in March 2007 (see Fig. 2), with an angular resolution of 30 mas, shows a structure consisting of an elongated core-jet structure within the galaxy nucleus, while the diffuse emission from the circumnuclear starburst is completely resolved out. The nuclear region has an integrated flux density of 26.3 mJy within an angular region of ∼150 mas (∼ 50 pc; at the distance of NGC 7469, 1 mas = 0.32 pc), with the core (probably, the westernmost component) having a flux density of 10.42 mJy.

In order to clarify the nature of the (sub-)parsec scale structure of the nuclear region of NGC 7469, in March 2007 we performed EVN observations at 6cm and 18cm (see Fig. 3). The images show that the NGC 7469 nucleus consists of at least four/five compact sources located along an east-west line, with no evidence for diffuse emission or a jet-like structure connecting the compact sources. Even combining the MERLIN with the EVN array, which provide intermediate angular resolution and is sensitive to more extended structures, we don't find background emission abridging the emission coming from the different components.

We have labelled the individual sources as A, B, C and D, from west to east. Some of the components (B and C) are unresolved, while the others have evidences for substructure (for example, the westernmost source A [2]). All the components have a typical size of ≤ 2 pc, with typical luminosities $\leq 5 \times 10^{27}$ erg/s/Hz.

2.1 The nature of the components

It is still unclear whether these components trace i) an AGN core-jet structure, ii) compact starforming regions where individual or clumps of radio supernovae are exploding (e.g. Arp 220 [8]) or iii) both, as we have recently found for Arp 299 [7]:

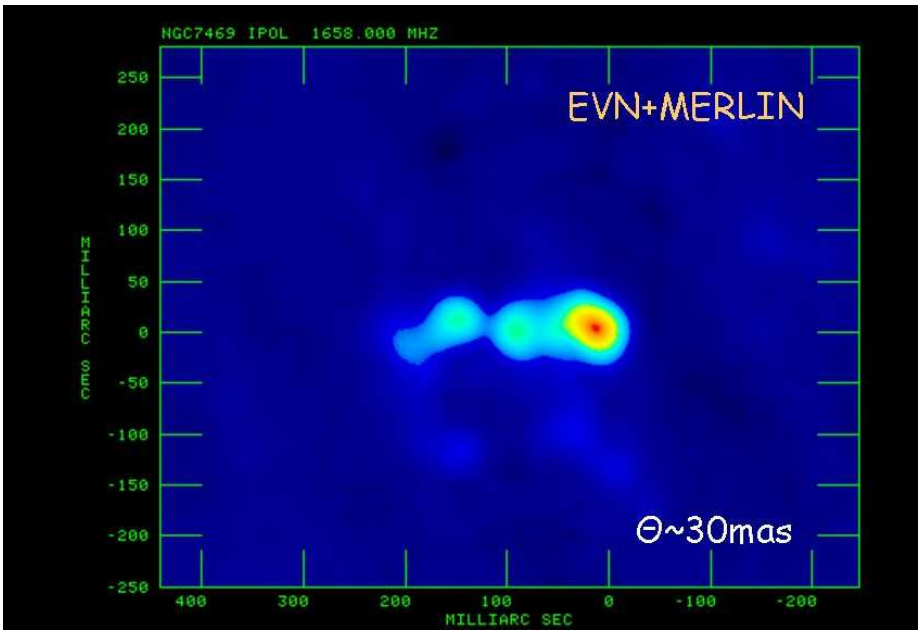

Figure 2: EVN+MERLIN Image of NGC 7469 at 18cm taken on March 2007, with an angular resolution of 30 mas [2].

- On one hand, there are strong arguments in favour of the presence of an AGN: i) the pc-scale structure shows a well defined west-east orientation, consistent with the MERLIN images; ii) the westernmost component (A) presents a kind of jet-like structure, with some indications of spectral index stratification as suggested by the shift in the maximum of the source at 18cm with respect to the 6cm image; iii) the basic VLBI structure is similar between different epochs, although there are indications of structural and flux density variability with time. In fact, comparing EVN observations at 6cm performed on 16 June 2006, 2 March 2007 and 21 March 2010 [2], we have found flux density and structural changes in component A, as well as flux density variability in B; iv) NGC 7469 is a Seyfert 1 galaxy, with evidence for a 10^7 solar masses black hole coming from reverberation mapping; v) additionally, the supernova rate for NGC 7469 is a factor of 5 lower than for Arp 220 (based on their infrared luminosities) and one would expect radio supernovae to be found in the starburst ring more than in the Seyfert 1 nucleus, which should be coincident with compact AGN emission.

- On the other hand, a spectral index map based on our quasi-simultaneous 6cm/18cm EVN images from Fig. 3 show that none of the components has a flat/inverted spectrum (all the nuclear components show steep spectra, with values between -1 and -0.3, with the western-most component having the less steep spectral index), which could be interpreted in terms of young starforming regions (where core-collapse supernova are currently exploding), and elder regions, formed by chains of supernova remnants. We also note that all the VLBI sources are within an area of 50 pc, which is also the size of the nuclear starburst reported by Davies et al. (2004) [4].

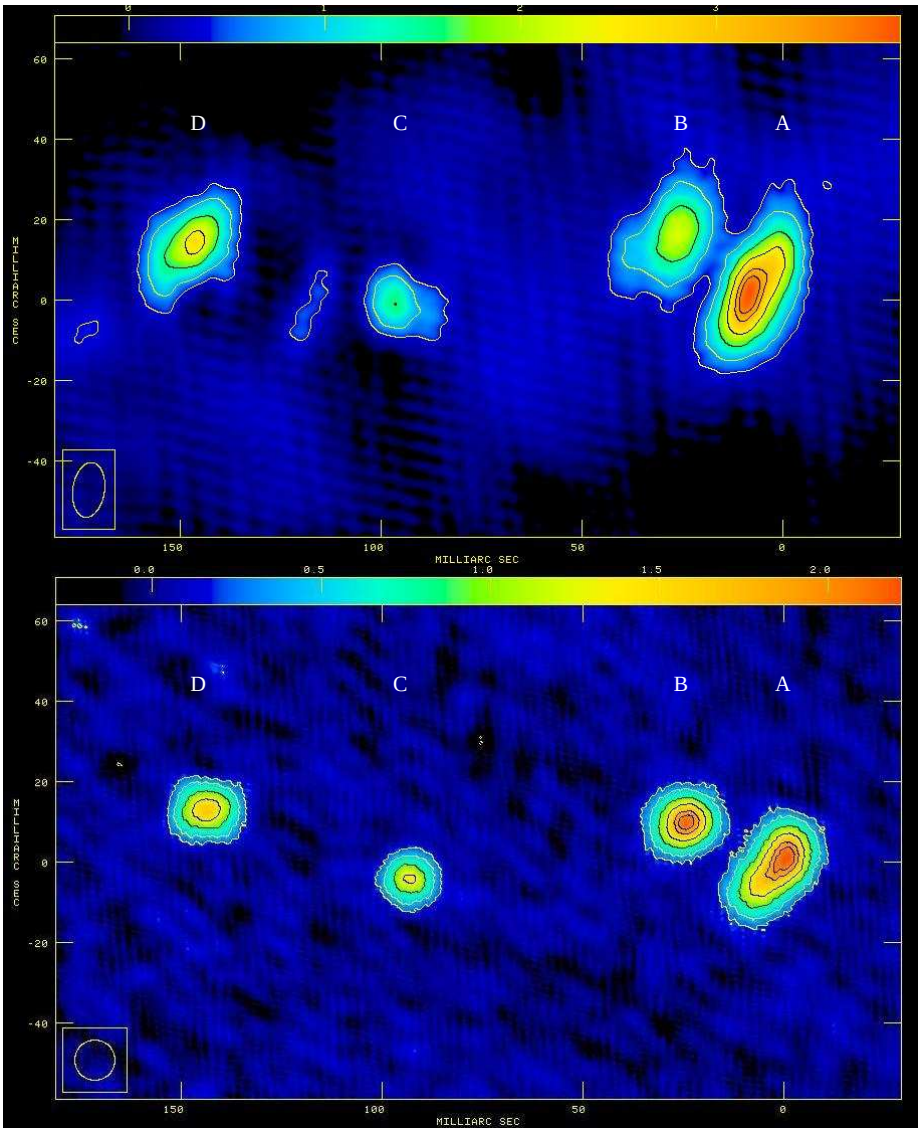

Figure 3: EVN Images of NGC 7469 at 18cm and 6cm taken on March 2007, with an angular resolution of 10 and 6 mas, respectively [2].

We could interpret the nature of the different radio components: the morphology, spectral index, variability and radio luminosity (3×10^{38} erg s^{-1}) of component A are consistent with that of a low-luminosity AGN (LLAGN), although in the optical and infrared the AGN looks rather luminous; component B is rather compact and presents both flux density and spectral index variability with time; component C is very compact ($\theta \leq 3$mas; $T_B > 5 \times 10^6$K), quite steady in flux, with a steep spectral index ($\alpha_C \sim 0.5$), consistent with a long-lasting radio supernova candidate; component D has a compact source within a extended flux region, with a spectral index of $\sim$-1. Components B and C could be associated with standing shocks from the LLAGN jet or with long-lasting radio supernovae or supernova remnants related to the nuclear starburst. The coexistence of a LLAGN and bursts of star formation was already reported in the case of Arp 299A by Pérez-

Torres et al. (2010) [7].

Recent results from MIDI/VLTI have shown that the compact structure of NGC 7469 is resolved with a fringe spacing of 25 mas, which provides a limit for the size of the dust distribution of the order of 10 pc [10], consistent with the size of the A-B complex. It also favours the interpretation of component A as the putative AGN candidate.

3. Conclusions

We have found evidences for a low-luminosity AGN in the nuclear region of NGC 7469, probably coexisting with recent bursts of star formation within an area of 50 pc. Moreover, we should note that in the case of Arp 299A a young radio supernova exploded at a mere distance of two parsecs from the putative AGN [7]. These results are of relevance for theoretical accreting models in the nuclear regions of LLAGN.

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