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EVN OBSERVATIONS: UNVEILING THE HEART OF LIRGS AND ULIRGS

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RESUMEN

Con la alta sensibilidad y resolución que brindan instrumentos como el “European Very Long Baseline Interferometry Network” (EVN), es posible estudiar las regiones nucleares y circunnucleares de galaxias luminosas ($L_{\rm FIR} > 10^{11}\ L_\odot$) y ultraluminosas ($L_{\rm FIR} > 10^{12}\ L_\odot$) en el infrarrojo (LIRGs y ULIRGs, respectivamente), en las que las altas tasas de formación estelar (SFR) garantizan la aparición de radio supernovas (RSNe) brillantes. En este trabajo presentamos algunos resultados recientes de nuestra campaña de observaciones con el EVN hacia el sistema de galaxias en interacción Arp 299, y hacia una de las ULIRGs más lejanas y luminosas del Universo local, IRAS 23365+3604.

ABSTRACT

With the very high sensitivity and resolution provided by instruments such as the European Very Long Baseline Interferometry Network (EVN), it is possible to study the nuclear and circumnuclear regions in Luminous ($L_{\rm FIR} > 10^{11}\ L_\odot$) and Ultraluminous ($L_{\rm FIR} > 10^{12}\ L_\odot$) Infrared Galaxies, where the high Star Formation Rates (SFR) guarantee the occurrence of bright Radio Supernovae (RSNe). In this work we present some recent results from our EVN campaign of observations towards the interacting system Arp 299, and one of the brightest and farthest ULIRGs in the local Universe, IRAS 23365+3604.

Key Words: galaxies: individual (IRAS 23365+3604, Arp 299) — galaxies: starburst — supernovae: general

1. INTRODUCTION

Luminous Infrared Galaxies with $L_{\rm FIR} > 10^{11}\ L_\odot$ (named LIRGs) and $L_{\rm FIR} > 10^{12}\ L_\odot$ (named ULIRGs) are very interesting objects thought to represent an important stage in the formation of Quasars (QSO) and powerful radio galaxies (Sanders & Mirabel 1996). Most of them seem to be the products of Galaxy-Galaxy interactions, mergers or bar instabilities, i.e., when no recent merger activity is found (see e.g., the contribution on isolated LIRGs from Fuentes-Carrera et al. 2011). Low redshift LIRGs are rare, but at $z \sim 1$ (Le Floc'h et al. 2005) are found to dominate the IR background, as well as the SFR density. The same is true for ULIRGs, but at $z \sim 2$ (Caputi et al. 2007).

(U)LIRGs exhibit two main facets. These galaxies radiate most of their energy in the FIR (40–500 μm) and display quasar-like luminosities. Nevertheless, (U)LIRGs also have FIR, mm, and radio characteristics which resemble those of star-forming galaxies (see e.g., Soifer et al. 1987; Sanders & Mirabel 1996). Very important questions arise: What is powering these galaxies? What mechanism is responsible for the heating of the large reservoirs of gas and dust contained in the inner kpc region of these systems? Is it an Active Galactic Nucleus (AGN) and/or a starburst (SB)? To answer these questions we have to observe deep in the “hearts” of these galaxies.

The knowledge retrieved from other studies is our point of departure. For example, Condon (1992) has shown that the RSN rate is proportional to the SFR, and these two scale with $L_{\rm FIR}$. According to this relation, we have that high SFR ensures high Core Collapse SN (CCSN) rates, which for (U)LIRGs, turns out to be at least one or two orders of magnitude larger than in normal galaxies such as the Milky Way.

CCSN counts will help to constrain the IMF of massive stars and give estimates of the SFR in a given galaxy. We should use instruments which provide high-angular resolution and sensitivity in order to detect CCSNe which are embedded in very dusty environments and thus subject to high extinction. The technique called Very Long Baseline Interferometry (VLBI) fulfils our requirements. In particular, we have used the European VLBI Network (EVN).

2. OUR PROJECTS

In this section we show some recent results from our EVN observations toward two sources we have been monitoring. We want to remind the reader at this point, the importance of performing observa-

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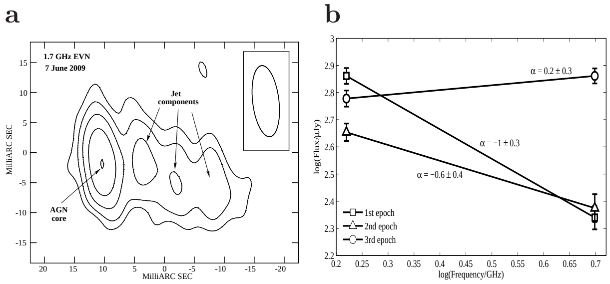

Fig. 1. (a) EVN image at 1.7 GHz of the innermost nuclear region of IC 694, evidencing the core-jet morphology typical of AGNs. (b) Spectral index evolution of the nuclear zone in IRAS 23365+3604 through three epochs of EVN observations.

tions covering different frequencies and times, since we can then retrieve precious information about the nature of the sources.

2.1. *Arp 299*

Arp 299 is the merger at a distance of 45 Mpc of two galaxies: IC 694 and NGC 3690. About half of the system's total $L_{\rm FIR}$ is concentrated in IC 694, as well as ≈70% of the total 5 GHz radio emission (see e.g., Neff et al. 2004). Hence, IC 694 is an excellent target to probe its CCSN rate and SFR. In fact, high-angular resolution observations of IC 694 have shown that this core contains a wealth of compact components within its innermost nuclear region (Neff et al. 2004; Ulvestad 2009; Pérez-Torres et al. 2009). To characterise the compact components found in 5 GHz EVN images from 2008, Pérez-Torres et al. have been monitoring IC 694 and discovered a dusty-buried Low Luminosity AGN (LLAGN) among the 26 non-thermal sources of the nuclear region (Pérez-Torres et al. 2010). The discovery of the coexistence of a strong SB and a LLAGN (see Figure 1a) is a stunning result. But more important is the fact that in this case, the heating mechanism is vastly provided by a powerful SB.

2.2. *IRAS 23365+3604*

IRAS 23365+3604 is an advanced merger at a distance of 252 Mpc. This is one of the most brightest and farthest ULIRGs in the local Universe. A CCSN rate of ≈5 SN/year is inferred from its high luminosity. We have performed multi-epoch, -frequency EVN observations toward this system. A nuclear SB of size ≈200 pc is revealed in our images. With the current resolution we cannot resolve out the extended emission and detect compact sources (such as SNe). However, analysing the flux density variation of the nuclear region, it is possible to infer the variation in flux of sources therein and/or appearance of new sources (SN) which would be seen first at higher frequencies and later at lower frequencies (Weiler et al. 2002), see Figure 1b where we show the evolution of the spectral index from the nuclear region. For further details, we refer the reader to Romero-Cañizales et al., in preparation.

3. DISCUSSION

We have shown some of our results obtained with the EVN. This is an excellent tool which has aided the discovery of the long-sought AGN in IC 694 and to obtain very deep and high-angular resolution radio images of one of the most distant ULIRGs in the local Universe. In the two examples we show, we see how important is to have high-angular resolution: at the distance of Arp 299 it is possible to resolve out the extended emission, whereas the same is not possible in IRAS 23365+3604, which is almost six times farther away. Still, a similar scenario is expected in the heart of this object.

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REFERENCES

Caputi, K. I., et al. 2007, ApJ, 660, 97
Condon, J. J. 1992, ARA&A, 30, 575
Fuentes-Carrera, I., et al. 2011, RevMexAA (SC), 40, 119
Le Floc'h, E., et al. 2005, ApJ, 632, 169
Neff, S. G., Ulvestad, J. S., & Teng, S. H. 2004, ApJ, 611, 186
Pérez-Torres, M. A., Alberdi, A., Romero-Cañizales, C., & Bondi, M. 2010, A&A, 519, L5
Pérez-Torres, M. A., Romero-Cañizales, C., Alberdi, A., & Polatidis, A. 2009, A&A, 507, L17
Sanders, D. B., & Mirabel, I. F. 1996, ARA&A, 34, 749
Soifer, B. T., Neugebauer, G., & Houck, J. R. 1987, ARA&A, 25, 187
Ulvestad, J. S. 2009, AJ, 138, 1529
Weiler, K. W., Panagia, N., Montes, M. J., & Sramek, R. A. 2002, ARA&A, 40, 387