IC 883 and PGC 043234: the Stories of Steady and Intermittent Accretion Onto a SMBH

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It is well established that the merger among gas-rich galaxies can trigger both starbursts and the onset of an active galactic nucleus (AGN). We present results on EVN observations toward the AGN hosts IC 883 and PGC 043234, both mergers although at different stages in their evolution. IC 883 is an advanced merger in which the star formation dominates the global energetics of the system. However, our observations show that the nuclear region is dominated by an AGN that has a core-jet morphology. The core has a very inverted spectrum and a low frequency turnover at 4.4 GHz, indicating this is a young source ($\sim 3 \times 10^3$ yr). PGC 043234 is a post-starburst galaxy which seems to be the remnant of a merger and has a negligible star formation. This system recently hosted the tidal disruption event (TDE) ASASSN-14li. Our EVN observations have allowed us to resolve the system into two components 2pc apart. The components resemble a core-jet/outflow system, whose secondary component can be related directly to ASASSN-14li, if its motion is superluminal, or to a past AGN flare or TDE if its motion is subluminal. The exciting possibility exists that both components are instead a binary BH system. Can IC 883-like systems become PGC 043234-like systems? Multi-wavelength unbiased surveys are needed to directly test this connection, and in particular, we note that VLBI observations can help shedding light into the AGN activity in the different evolutionary stages.

Keywords: VLBI, Transients, galaxy nuclei, active galaxies.

1 Introduction

The interaction of gas rich galaxies via mergers or close encounters can give rise to sudden, violent star formation (SF), often accompanied by the presence of an active galactic nucleus (AGN; see e. g., Di Matteo et al. 2007). The merger gives

rise to a system whose energy is mostly emitted in the IR with a luminosity above $10^{11}\,L_{\odot}$ (Kilerci Eser, Goto, Doi 2014). It has been found that these systems start being dominated by star formation and at later stages, by an AGN, as shown by optical diagnostic diagrams which take into account infrared luminosity and the merger stage (Yuan et al. 2010). This trend is also supported by the studies of Wild et al. (2009), who found that the gas exhaustion and the feedback from SNe will contribute to the star formation decay, allowing thereafter a more efficient accretion onto the black hole (BH). It is worth noting, however, that the AGN can be triggered early on in the merger, although it will appear as highly obscured and will often go unnoticed, especially in the optical (Satyapal et al. 2014).

What happens when the star-formation ceases or it is low enough that can be considered as negligible? Such systems, called post-starburst galaxies, have been observed and there is evidence pointing to gas-rich galaxy mergers as their progenitors (Yang et al. 2004). These systems are quiescent and can be characterised by a strong Balmer line absorption and low [O II] emission. They are thought to be the link between galaxy mergers with very active star formation (SF) and early-type galaxies.

The study of the nuclear regions in dusty mergers can greatly benefit from the use of radio observations. The radio offers an extinction-free view of dusty objects, as well as a very high-angular resolution, thanks to the use of very long baseline interferometry (VLBI).

2 The parsec-scale jet in IC 883

In Romero-Cañizales et al. (2012) we found an AGN candidate source. It dominates the radio emission at both circumnuclear and nuclear scales. Nevertheless, the energetics in this luminous infrared galaxy is dominated by the active star formation at basically all wavelengths.

With the aim of characterising the AGN candidate, we performed three yearly epochs of EVN observations from 2012 to 2014 at three different frequencies (1.6, 4.9 and 8.4 GHz). At the highest frequency, and thus at the highest angular resolution, we detect the core plus an extended structure in 2012. This structure seems to increase in size in 2013 and finally in 2014 the secondary source is clearly disentangled from the core as a separate component, only 0.6 pc away from the core. We interpret this as a newly ejected component. Using a previous epoch at the same frequency, we find evidence for the recurrence of the jet activity in IC 883 (see Fig. 1).

The spectral energy distribution for the core is characterised by an inverted spectrum ($\alpha \sim 2.5$, $S \propto \nu^{\alpha}$) between 1.6 and 4.9 GHz, and a low frequency turnover at ~ 4.4 GHz. We can then infer a young AGN age, as well as other properties which make it similar to the so-called Gigahertz-peaked spectrum sources. All the details as well as a full analysis of the X-ray emission will soon be published in Romero-Cañizales et al. (2017).

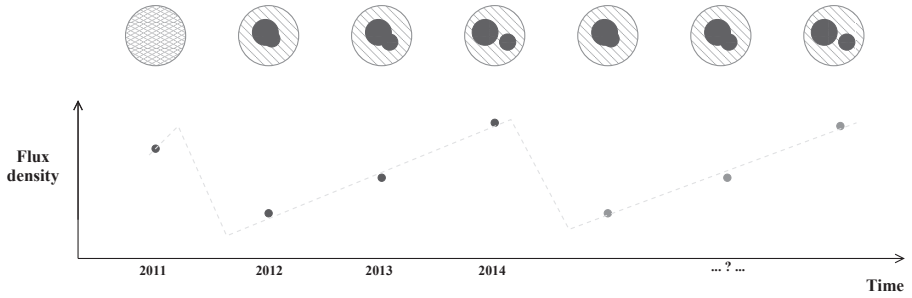

Fig. 1. Toy-model of the recurrent jet activity in IC 883 as inferred from EVN observations at 8.4 GHz. In 2011 with the VLBA, we detect a single component at the position of the core with a FWHM$\sim 2.4 \times 1.2$ mas (Romero-Cañizales et al. 2012). The three following epochs were observed with the EVN at an improved FWHM of $\sim 1 \times 0.6$ mas. A secondary component seems to have been ejected from the core as depicted in the top of the figure and which are an actual representation of what is obtained in the contour maps. An extrapolation of the flux density variability (red dots) would indicate that this activity is recurrent

3 ASASSN-14li and its host

PGC 043234 is a post-starburst galaxy which in 2014 had an extraordinary flare in the optical. The flare was associated to a tidal disruption event (TDE) and named ASASSN-14li, as it was discovered by the All-Sky Automated Survey for Supernova (ASAS-SN; Shappee et al. 2014). VLT-MUSE observations of PGC 043234 revealed this galaxy resulted from a merger, and shows emission consistent with a pre-existing AGN (Prieto et al. 2016).

A plethora of observations at different wavelengths toward ASASSN-14li along with models can be found in the literature. In the radio, the emission at arcsec-resolution has been interpreted as originating from a non- or mildly-relativistic ejecta or the unbound tidal debris from the TDE (Alexander et al. 2016, van Velzen et al. 2016, Krolik et al. 2016). Alexander et al. 2016 and van Velzen et al. 2016 also find evidence for radio emission from a pre-TDE AGN which must be subject of large radiative losses.

We performed observations with the EVN and detected two components (see Fig. 2): the brightest one, probably related with the pre-TDE AGN, and the second one, probably related to the ejecta (Romero-Cañizales et al. 2016). If such ejecta is related to ASASSN-14li, then it must have moved at high relativistic speeds. Another possibility is that the emission corresponding to the TDE is still within the region of the brightest component and the other component simply corresponds to a past TDE or AGN flare, and moves at subluminal speeds. A third possibility comes from the expectation of having a binary BH in a post-starburst galaxy that has resulted from a merger event in the past. These possibilities will be tested in the future with our upcoming EVN observations.

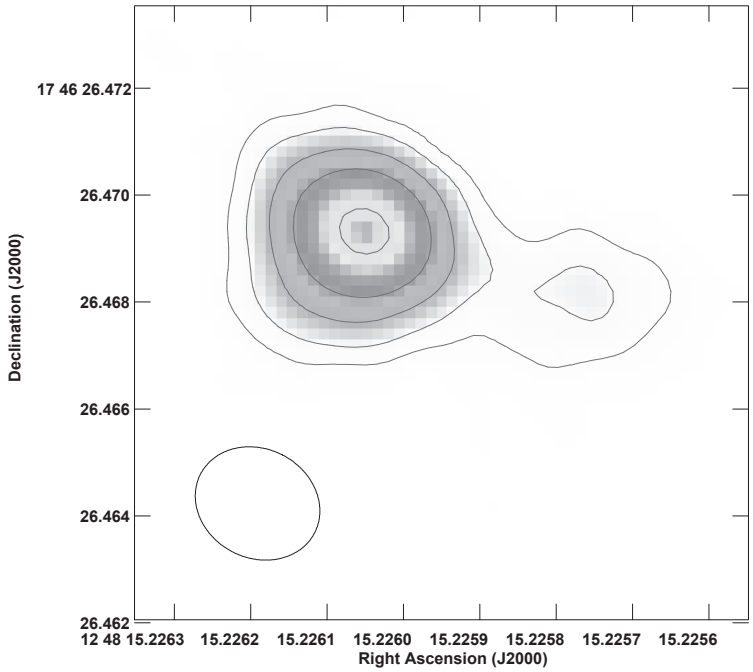

Fig. 2. EVN Contour map of PGC 043234 nuclear region at 5 GHz (from Romero-Cañizales et al. 2016). Levels are at 13.6μJy/beam $\times$(−3, 3, 5, 9, 15, 27)

4 Summary

We have presented recent results from two different galaxies observed with the EVN. In the first case we have discovered a parsec-scale radio jet from a young AGN hosted by a luminous infrared galaxy at ~ 100 Mpc. The star-formation currently dominates the energy output in the system and very likely, the AGN is in its way to become more powerful and dominate over the star formation activity later on (Romero-Cañizales et al. 2017). In the second case, we found evidence of jet/outflow activity in an old AGN hosted by a post-starburst galaxy at ~ 90 Mpc (Romero-Cañizales et al. 2016). Presumably the gas supply is not able to sustain neither the star formation nor the accretion onto the BH anymore. However, the accretion onto the BH was activated by the tidal disruption of a star wandering in the sphere of influence of the BH. We note that only VLBI studies allow such discoveries, given the distance to the galaxies and the size of the regions involved (of only a few parsecs), where the jet/outflow activity is taking place.

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