The local LIRG NGC 5135: AGN and SN activity traced by NIR IFU spectroscopy

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Abstract. By observing the local luminous infrared galaxy NGC 5135 with the near-IR IFU spectrograph SINFONI (ESO VLT), we report a ∼ 600 pc (in projection) AGN outflow traced by [SiVI] λ1.96 μm emission. This is the largest outflow traced by a coronal line ever reported. Its large spatial scale suggests that shocks, in addition to AGN continuum emission, are needed to locally produce [SiVI] emission. We also show, for the first time, clear kinematical evidence of the AGN-outflow vs. ISM interaction through variations in the 2D velocity fields of different gas phases. Such local perturbations in the kinematics clearly match the outflow structure.

We use the [FeII] λ1.64 μm emission, a supernovae tracer, to estimate the supernovae rate in different star-forming knots (∼ 250 pc across) within the central 2.3 kpc of NGC 5135. The estimated supernovae rates go from 0.02 − 0.08 yr$^{-1}$ being in excellent agreement with predictions from 6 cm radio emission in the same areas.

1. Introduction

Since their discovery (Kleinmann & Low 1970; Rieke & Low 1972), the importance of low-redshift (z) Luminous (10$^{11}$L$_{\odot}$ ≤ L$_{IR}$ ≤ 10$^{12}$L$_{\odot}$, LIRG) and Ultraluminous (L$_{IR}$ ≥ 10$^{12}$L$_{\odot}$, ULIRG) Infrared Galaxies has been widely recognized. While LIRGs appear to be mostly spirals (Arribas et al. 2004; Alonso-Herrero et al. 2006), ULIRGs are strongly interacting systems and mergers (e.g. Bushouse et al. 2002) evolving into intermediate-mass ellipticals (e.g. Genzel et al. 2001). Local (U)LIRGs have been proposed as possible counterparts of the submillimeter population observed at higher z (Blain et al. 2002, for a review). Also, cosmological surveys with Spitzer have shown that the majority of infrared (IR) selected galaxies at z < 1 are in the LIRG class, while LIRGs and ULIRGs make a significant contribution to the IR galaxy population and to the star formation at 1 < z < 2 and z ≥ 2, respectively (e.g. Pérez-González et al. 2005; Caputi et al. 2007).

Detailed investigations of the physical properties, stellar populations, AGN-starburst connection and gas flows on these complex systems can only be obtained through integral field spectroscopy (IFS). Initial studies of small samples of (U)LIRGs based on 4-meter class telescope optical IFS have already been obtained (e.g. Colina et al. 2005;
Monreal-Ibero et al. 2006; Alonso-Herrero et al. 2009). To extend these studies to larger samples, and also to the near-IR, we have started a survey of low-\(z\) (U)LIRGs using state-of-the-art IFS like VLT/VIMOS (optical: Arribas et al. 2008; Rodríguez-Zaurín et al. 2010) and VLT/SINFONI (near-IR: Bedregal et al. 2009, 2011). This survey will allow us to characterize the kpc-scale ionization and kinematics of a representative sample of low-\(z\) (U)LIRGs covering a wide luminosity range, several morphologies from spirals to interacting and advanced mergers, as well as different classes of activity. This will also form a local reference for future IFS studies of high-\(z\) IR galaxies with instruments such as the Near-IR Spectrograph (NIRSpec) and Mid-IR Instrument (MIRI) on board of the James Webb Space Telescope (Gardner et al. 2006).

As part of our survey, we present some of our first results with SINFONI showing the power of near-IR IFS by studying the local LIRG NGC 5135. This is an SBab galaxy at \(z = 0.01396\) (from NED\(^{1}\), at \(\approx 58.7\) Mpc assuming \(H_0 = 70\) km s\(^{-1}\) Mpc\(^{-1}\)) which belongs to a group of seven galaxies (Kollatschny & Fricke 1989). Its dual nature as a starburst hosting an AGN and its almost face-on sky orientation make NGC 5135 an ideal prototype-object for detailed studies of these hybrid systems. In this proceeding, we focus on the AGN and SN activity of this galaxy, stressing their interaction with the local interstellar medium (ISM).

2. AGN-outflow and its interaction with the local ISM

The ionization potential required to produce the [SiVI]\(\lambda 1.96\)\(\mu\)m line (167 eV) is usually associated to Seyfert activity where the gas is excited just outside the broad line regions of AGNs (e.g. Rodríguez-Ardila et al. 2006).

As we can see in the Fig. 1 flux map, the [SiVI] line traces the galaxy nucleus and it also presents a weaker “plume” to the North-East (NE). This particular region, in terms of projected spatial scales, is the largest reported in literature for a coronal line (\(\approx 600\) pc in this case) being \(\sim 4\times\) larger than previous reports on different Seyfert

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\(^{1}\)http://nedwww.ipac.caltech.edu/
Figure 2. Stellar and gas velocity fields with [SiVI] emission contours overplotted. Clearly the [SiVI] outflow (NE) matches with blueshifted regions in all gas phases.

galaxy samples (e.g. [Prieto et al. 2005; Rodríguez-Ardila et al. 2006]). This finding, together with evidence for a similar (weaker) structure to the South-West (SW), suggest that we have detected, for the first time, the presence of ionizing cones in NGC 5135. According to [Rodríguez-Ardila et al. 2006], the morphology of [SiVI] and other coronal gas is preferably aligned with the direction of the traditional lower-ionization cones (i.e. traced by [OIII]) seen in Seyfert galaxies.

Now we compare the information from [SiVI] with the kinematics of the other galaxy components to disentangle the real influence of the AGN on its neighborhood. A key observation comes from Fig. 2. We plot the velocity fields of CO, Brγ, H2, HeI and [FeII] while overplotting the flux contours of [SiVI] emission. In most of the panels we clearly see how the AGN NE outflow coincides with gas blueshifted regions in the North half of our field-of-view (FoV).

As we see, the stellar and many of the gas velocity (V) fields roughly coincide in the sense of being redshifted to the North and blueshifted to the South of our FoV. Differences, however, appear between stellar and gas components in the redshifted (North) region, where gas phases present a “double lobe” structure in V, totally absent in the stars. The spatial coincidence of the [SiVI] ‘plume’ structure with this area suggests an interaction between the AGN-outflow and the surrounding gas, blueshifting their V fields along the projected cone.
3. [FeII] as a Supernovae tracer

For many years different authors have suggested that the [FeII]-emission from galaxies traces the fast shocks produced by supernovae (SN) remnants and so, their SN activity (e.g. Colina 1993; Alonso-Herrero et al. 2003; Labrie & Pritchet 2006).

Different authors have derived empirical and theoretical relations we can use to estimate the SN rate directly from the [FeII] emission (Calzetti 1997; Alonso-Herrero et al. 2003) and from 6 cm radio data (Huang et al. 1994; Perez-Olea & Colina 1995; Neff et al. 2004). We select five regions (labeled from B-F in Fig. 3) corresponding to Brγ and [FeII] peaks (starforming regions) using circular apertures of 0.91′′ (≈ 260 pc in diameter).

In Table 1 we present the SN rates derived from [FeII] and 6 cm radio data (Ulvestad & Wilson 1989) for regions B-F.

Table 1 clearly shows the excellent agreement between [FeII] and radio SN rate predictions for these ∼ 250 pc-scale regions. This agreement is totally independent of the correlation or model used to estimate the SN rate. These results provide additional support to previous findings in normal starburst galaxies like M82 and NGC 253 where similar SN rates are predicted from [FeII] and 6 cm radio emission. As a comparison,
The predictions in this table are one order of magnitude lower than those of the brightest radio region in Arp 299 (0.5-1.0 yr$^{-1}$, Neff et al. 2004), a bright IR luminous galaxy.

4. Conclusions

Our main conclusions are

- We report a ∼600 pc (in projection) AGN outflow traced by [SiVI] emission. This is the largest outflow traced by a coronal line ever reported. This structure is at least 4× larger than any previous detection in active galaxies. Pointing in opposite direction, a fainter counter-[SiVI]-cone has been also detected.

- Using 2D kinematics, we have found clear evidence of AGN-outflow versus ISM interaction. The different gas phases show perturbed velocity fields along the AGN outflow structure.

- The SN rates derived from the [FeII] emission are in excellent agreement with 6 cm radio emission predictions, reinforcing the use of [FeII] as a SN activity tracer. Typical rates between 0.02-0.08 yr$^{-1}$ were found for individual ∼250 pc regions.

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