Abstract

The extended narrow-line region (ENLR) is a puzzling structure of highly ionized gas which is observed in several nearby active galactic nuclei (AGN). It is usually characterized by a conical or bi-conical shape, it is also called ionization cone, and even though the spectral properties are similar to those of the narrow-line region (NLR), it can be extended up to 20-30 kpc. It is often aligned with the radio emission of the host galaxy and the complex kinematics observed in some objects suggests an interaction of the ENLR with the radio jets of the host. The aim of this work is to measure the physical properties of the NLR/ENLR gas as a function of velocity in two nearby galaxies with detected radio emission, IC 5063 and NGC 7212, by using high resolution spectra ($R \sim 8000$). The high resolution allows to highlight peculiar features of the line profiles like multiple peaks and asymmetries and, dividing the lines in velocity bins, it is possible to measure the properties of the gas as a function of velocity. To this aim, we also compared the observed spectra with photo-ionization and shocks models obtained with the code SUMA. This in turn will allow to study the interaction between the gas and the radio jets of the galaxies.

The Sample

IC 5063: lenticular galaxy classified as Seyfert 2 ($z=0.011$), with ENLR (Fig. 1). It is very radio loud (2 order of magnitude larger than typical Seyfert 2 galaxies [7]) and it is one of the most studied AGN. Fast outflows ($v \sim 600 \text{ km s}^{-1}$) are observed in all different kinds of gas [8].

NGC 7212: spiral galaxy in a triple system of interacting galaxies, classified as Seyfert 2 with ENLR ($z=0.026$, Fig. 2). The gas has peculiar properties in the interacting region [5]. There are signs of radial motion of the gas.

Observations and Data Reduction

The targets were observed with the MagE spectrograph of the Magellan telescope. The data are echellelette spectra which cover a wavelength range from 3000 to 10000 Å, with a resolution $R \sim 8000$. We extracted 1D spectra for several regions of each galaxy using, as reference, the $H\alpha$ profile along the slit (Fig. 3). We later subtracted the stellar continuum with STARLIGHT ([2], [3], [6], Fig. 5: spectrum without stellar continuum) and we deblended the most important blended emission lines (Fig. 4).

Data Analysis

We compared the profile of several emission lines in each region (Fig. 6). After that we analyzed the spectra improving the method described by [9]. We divided the strongest lines ([O II]3726, 3729, Hβ, [O III]4959, 5007, [O I]6300, Hα, [N II]6584, [S II]6717, 6731) in small velocity bins ($v \sim 100 \text{ km s}^{-1}$) and we measured each flux. We finally produced several diagnostic diagrams (BPT, [1], Fig. 7) and we measured several other quantities to investigate the properties of the gas (Fig. 8).

Then, we tried to reproduce the observed flux in each bin with the code SUMA [4], to study the influence of shocks in the ionization of the gas and to recover some information (such as metallicity) which is not possible to recover from the analysis of the emission lines.

Conclusions

The analysis of the line profiles revealed that the NLR kinematics is very complex. Lines emitted by ions with different ionization potential can have different profiles. Some of the features of the line profiles can be explained by fast outflows of gas which were previously observed in both galaxies [5], [8]. The main ionization mechanism is photo-ionization by the AGN but several regions show signs of ionization by shocks. This is also confirmed by SUMA simulations. Both shocks and outflows could be effects of the interaction of the radio jets of the galaxies with the gas of the NLR (Fig. 9), but further investigation is needed to shed lights on this mechanism.

More details on this work will be available in: Congiu et al., 2017, MNRAS, submitted

Bibliography: [1] Baldwin et al., 1981, PASP, 93, 5; [2] Cid Fernandes et al., 2005, MNRAS, 358, 363; [3] Cid Fernandes et al., 2007, MNRAS, 375, L16; [4] Contini et al., 2012, A&A, 545, 72; [5] Cracco et al., 2011, MNRAS, 418, 2630; [6] Mateus et al., 2006, MNRAS, 370, 721; [7] Morganti et al. 1998, ApJ, 115, 915; [8] Morganti et al., 2007, A&A, 476, 735; [9] Ozaki S., 2009, PASJ, 61, 259; [10] Tadhunter et al., 2001, MNRAS, 327, 227.