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Optical spectroscopy of 3CR sample of radio sources at $z < 0.3$

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Abstract. We are carrying out a program of optical spectroscopy of the complete sub-sample of the 3CR catalog of radio sources at redshift $z < 0.3$. The sample consists of 113 3CR sources, comprising FR I, FR II radio galaxies and Quasars. Complete datasets in other bands are already or will be soon available for the whole sample but the optical spectra are sparse and inhomogeneous in quality. The observations are carried out at the 3.58m Telescopio Nazionale Galileo (TNG, La Palma). More than 100 sources have been already observed. We present here the preliminary results on the analysis of the high and low resolution spectra. We found that sources can be spectroscopically characterized as: High Excitation Galaxies (HEG), Low Excitation Galaxies (LEG) and "Relic" AGNs. This classification is supported by the optical - radio correlations in which objects spectroscopically different follow different correlations. We conclude that AGNs with the same radio power can be fueled with different accretion properties. "Relic" radio-galaxies are characterized by extreme low excitation spectra that we interpret as nuclei whose activity has recently turned-off. The full spectral catalog will be made available to the scientific community.

Key words. Galaxies: active – galaxies: elliptical and lenticular, cD – galaxies: nuclei – galaxies: jets

1. Introduction

Radio Loud AGNs represent about the 10 per cent of active galaxies, nevertheless they are among the most powerful objects in the Universe. Since they are powerful AGNs, they represent an important laboratory to study the formation and evolution of the nuclear activity.

Our aim is the investigation of their nuclear activity via optical and radio observations.

As emission lines presumably originate from gas photoionized by the radiation generated via the accretion process, their absolute luminosities and intensity ratios can provide information on the accretion itself and thus the physical conditions of the environment in which the jets are formed.

We focus on the homogeneous and vastly studied 3CR catalog of radio sources, being unbiased with respect to the nuclear/accretion properties.

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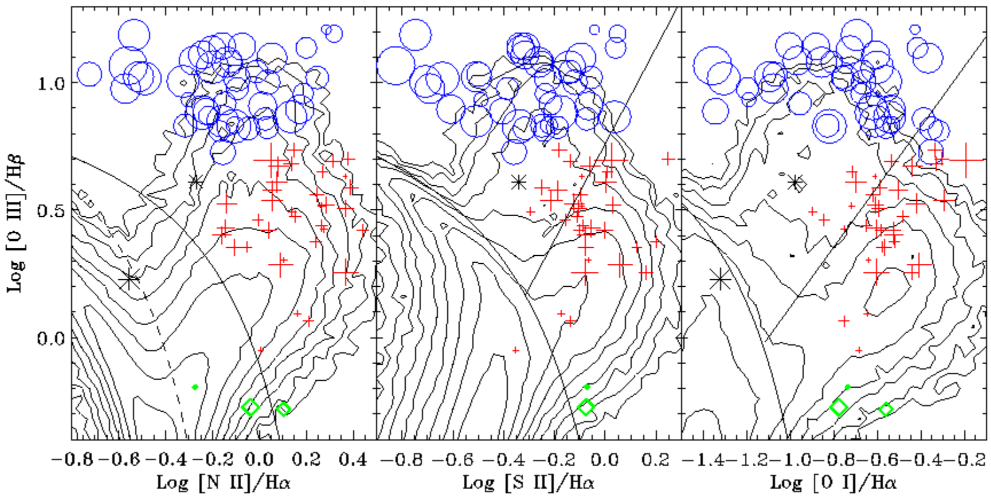

Fig. 1. The diagnostic diagrams are made of pair of emission lines ratios: the solid curve represents the separation between AGNs (above the line) and starburst galaxies (below the line). The contour lines indicate the distribution of the SDSS galaxies from Kewley et al. (2006). Blue circles are High Excitation Galaxies (HEG); red crosses are Low Excitation Galaxies (LEG); green diamonds are Relic AGNs; black asterisks are unclassified AGNs. The symbol size is proportional to the *L*([O III]) luminosity.

2. The sample and data analysis

We consider all sources belonging to the Third Cambridge Revised catalog (3CR) – namely all radio sources north of -05 degrees with flux density higher than 9 Jy at 178 MHz (Bennett 1962) – with redshift less than $z < 0.3$, resulting in a complete subsample of 113 objects.

The observations are carried on at the 3.58 m Galileo Telescope (TNG) in Canary islands. We use the DOLORES spectrograph with a slit of 2 arcseconds. For each target one low resolution spectrum (with the LR-B grism, 3000 - 8000 Å, resolution ∼20 Å) and two high resolution spectra (with the VHR-R grism, 6200 - 7800 Å, or the VHR-I, 7300 - 8900 Å, resolution ∼4 Å) were obtained. Exposure times range between 500 and 1000 sec depending on the redshift of the source. The IRAF software was used in order to subtract the bias, divide for the flat field, wavelength and flux calibrate the rough images. After correction for the Galaxy extinction, we considered two wavelengths ranges (of about 1000 Å) around Hα and Hβ and we subtracted the host galaxy stellar emission using the best fit single stellar model from the Bruzual & Charlot (2003) library. Finally the line intensities were obtained using the *specfit* package.

3. Results

3.1. Diagnostic diagrams

From the narrow emission line fluxes we can create the diagnostic diagrams (Fig. 1): these plots are composed by pairs of emission lines ratios which are sensitive to the ionizing radiation properties: the [O III]λ5007Å/Hβ is the most important estimator for the separation of galaxies into star-forming emission and AGN emission; the [N II]λ6583Å/Hα, [S II]$\lambda\lambda$6717,6731Å/Hα and [OI]λ6300Å/Hα are useful tools for distinguishing low from high excitation radiation.

In such diagrams it is possible to characterize the sources in at least 3 groups: High Excitation Galaxies (HEG), with typical [O III]λ5007Å/Hβ ratio >5; Low Excitation Galaxies (LEG), with [O III]λ5007Å/Hβ <5;

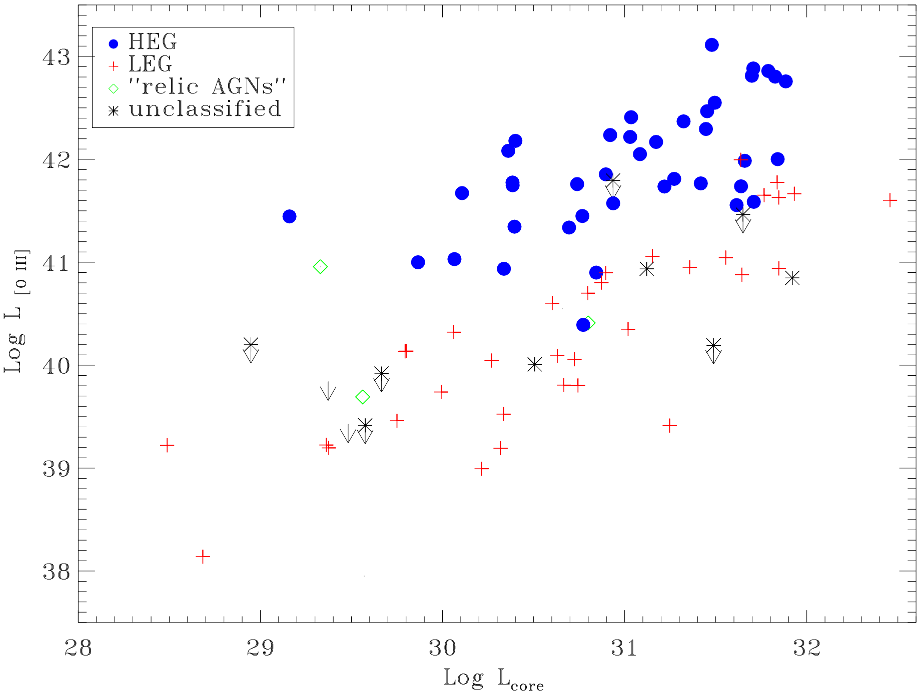

Fig. 2. [O III]λ5007Å emission line (erg/s) vs radio core power at 5 GHz (erg/s/Hz). Blue circles are High Excitation Galaxies (HEG); red crosses are Low Excitation Galaxies (LEG); green diamonds are "relic" AGNs; black asterisks are spectrally unclassified AGNs. Note the vertical offset between HEG and LEG.

and a handful of sources with very low [O III]λ5007Å/Hβ ratio (~0.5), which we tentatively identify with 'relic" AGNs, as explained below.

3.2. Optical - radio comparison

In order to assess any relation between the radio/jet properties and the nuclear ones, the lines luminosities – in particular the [O III]λ5007Å – have been compared with the radio core emission at 5 GHz $L_{\rm core}$.

As shown in Fig. 2, while for a fixed $L_{\rm core}$ HEG (blue circles) and LEG (red crosses) are separated by about a factor of $\sim$ 30 in L([O III]), this does not appear to be connected with radio power. Trends of correlations between line and radio luminosities appear for both populations, but there is no transition from LEG to HEG with increasing radio emission.

This suggests that HEG and LEG might be associated to different accretion mechanisms producing the same AGN manifestation in terms of radio emission and jet properties.

The same behaviour appear to be present in the relation between [O III]λ5007Å and extended radio emission at 178 MHz, as reported in Fig. 3. Again two separate correlations can be distinguished: HEG (blue circles) and LEG (red crosses) differ by about a factor of $\sim$ 10 in L([O III]) over the entire radio power range.

3.3. A new spectroscopic class associated to relic AGNs?

Interestingly, the (few) sources spectroscopic defined above as "relic" galaxies reveal to have

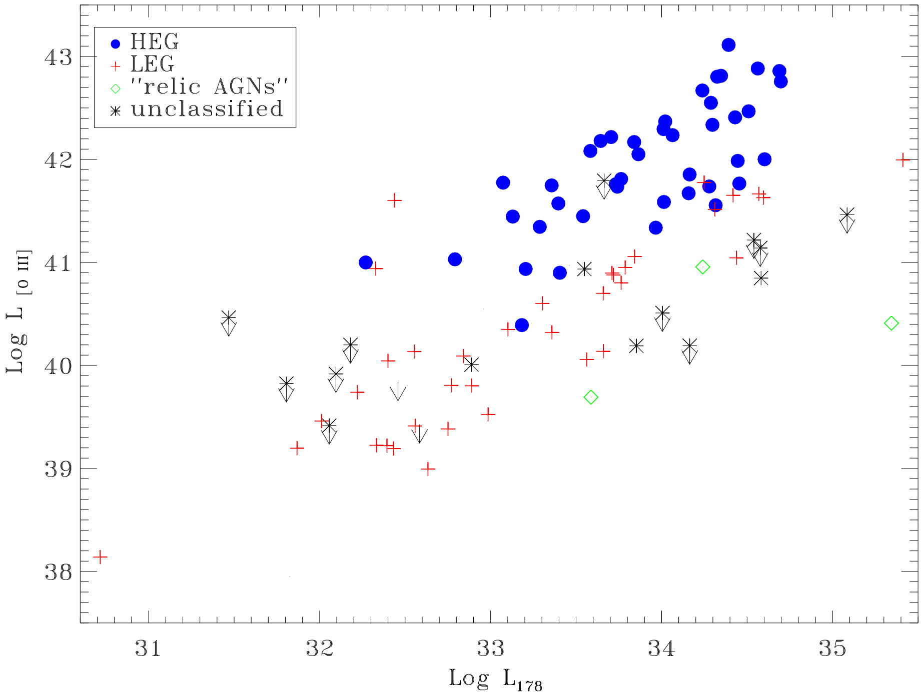

Fig. 3. [O III]λ5007Å emission line (erg/s) versus extended power at 178 MHz (erg/s/Hz). Blue circles are High Excitation Galaxies (HEG); red crosses are Low Excitation Galaxies (LEG); green diamonds are Relic AGNs; black asterisks are spectrally unclassified AGNs. Note the relatively low [O III] fluxes of the "relic" RG.

among the lowest levels of L([O III]) emission. They are thus characterized by small [O III]λ5007Å/Hβ ratio (Fig. 1), weak [O III]λ5007Å luminosity and small ratio of core vs extended radio emission (see Figs. 2 and 3).

From these findings our best hypothesis for these sources is that they are galaxies in which the nuclear activity has "recently" turned off: this could explain their weak/absent radio core but still the presence of the extended radio emission which would react to changes of central activity on much longer timescales. The weak line emission and extreme line ratios can just reflect the response of the Narrow Line Region gas – on < kpc scales – to a vanishing photoionizing nuclear radiation on an intermediate timescale between core and large scale radio emission. The actual number density of such "relic" sources would provide a crucial piece of information on the duty-cycle of activity of the engine and in turn on the coevolution and relationship between the host galaxy and the active nucleus.

References

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