Nuclear Activity in Galaxies Across Cosmic Time
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Detailed characterisation of LINERs and retired galaxies in the local universe

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Abstract. We present a detailed characterisation of physical properties of low-ionization nuclear emission-line regions (LINERs) and retired galaxies (RGs) in the local universe for redshift range $0 < z < 0.4$ and two subranges $z < 0.1$ and $0.1 < z < 0.4$. Furthermore, we test the effectiveness of WHAN diagnostic diagram in separating the two populations. We used photometric data, public spectroscopic data and morphological classification from SDSS-DR8, MPA-JHU SDSS-DR8 catalogue and Galaxy Zoo survey, respectively. We studied the distribution of LINERs, RGs and AGN-LINERs in relation to luminosity, stellar mass, star formation rate (SFR), colour, and their location on the SFR-stellar mass and colour-stellar mass diagrams. We then studied the morphologies of both populations. Results have shown that for higher redshift range, AGN-LINERs have higher apparent g magnitude, SFRs and dominate on/above the main sequence (MS) of star formation compared to RGs. However, both populations have similar stellar mass and luminosity distributions at all redshift ranges hence suggesting a significant difference in terms of star formation of RGs and AGN-LINERs with redshift. However, larger and more complete samples of LINERs are needed from the future surveys (e.g., LSST) and missions (e.g., JWST) to study in more details the properties of RGs and AGN-LINERs and find alternative methods of separating the two populations, since using simply WHAN diagram from our study we do not find it to be effective for separating the two populations.

Keywords. LINERs; retired galaxies; WHAN diagnostic method.

1. Introduction

Low-ionization nuclear emission-line regions (LINERs) dominate two third of all active galactic nuclei (AGN) and about one third of all galaxies in the local universe (Kewley *et al.* 2006). LINERs represent the most numerous local AGN population and could be the link between normal and active galaxies as suggested by their low luminosities (Márquez *et al.* 2017). Studying physical properties of LINERs helps to understand the standard model of AGN, AGN triggering mechanisms, and the role of AGN in galaxy formation and evolution. Optical classifications using BPT diagrams fail to separate LINERs and retired galaxies (RGs) since they include RGs that cover most of the region assigned as LINERs (Stasińska *et al.* 2008). Using WHAN diagnostic diagram, (Cid Fernandes *et al.* 2011) classified galaxies into SF, strong AGN, weak AGN, RGs, and passive galaxies.

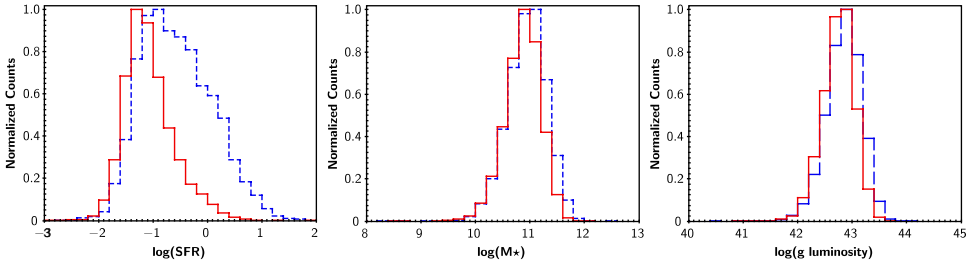

Figure 1. Distribution of SFR (*left*), stellar mass (*middle*), and g band luminosity (*right*), of RG (red solid lines) and AGN-LINER (dashed blue lines) galaxies.

However, their study did not deal with detailed characterisation of AGN-LINERs and RGs. Therefore, it is important to test the WHAN effectiveness in separating the two populations. LINERs have not been studied much at higher redshifts, and only few studies are known (Tommasin *et al.* 2012; Pović *et al.* 2016). Our study characterises in detail AGN-LINERs and RGs in the nearby universe by testing different properties, including morphology, and by testing the effectiveness of WHAN diagram in two redshift subranges.

2. Data

Photometric data were taken from SDSS-DR8†, public spectroscopic data from the MPA-JHU SDSS-DR8 catalogue (Brinchmann *et al.* 2004), while morphological classification was taken from Galaxy Zoo survey containing 667, 944 galaxies (Lintott *et al.* 2008).

3. Sample selection

A total of 17, 036 LINERs were separated from star forming, composite and Seyfert 2 galaxies using BPT diagrams based on [OIII]/Hβ, [NII]/Hα, [SII]/Hα, and [OI]/Hα line ratios (Kewley *et al.* 2006). We separated LINERs into 64% RGs and 36% AGN-LINERs using conditions EW(H$_\alpha$) ≤ 3 Å and EW(H$_\alpha$) > 3 Å, respectively (Cid Fernandes *et al.* 2011). We cross-matched 17, 036 LINERs with the Galaxy Zoo survey and obtained 16, 032 LINERs where 44.7% were elliptical and spiral galaxies and 55.3% unclassified galaxies. We analysed the location of both RGs and AGN-LINERs at different redshifts in relation to the main-sequence (MS) of star formation (SF) by considering the results from Elbaz *et al.* (2007). We plotted rest-frame $u - r$ colour versus stellar mass diagram values based on Schawinski *et al.* (2014).

4. Analysis and results

We have found that for low redshift subrange, RGs are slightly brighter in g band than AGN-LINERs. AGN-LINERs have higher SFRs especially at higher redshift subrange compared to RGs (see Fig. 1 left plot) and hence dominate on/above the MS and in the blue cloud. Generally, RGs and AGN-LINERs have similar stellar masses and luminosities and hence difficult to separate them in terms of these properties as can be seen in (Fig. 1 middle plot) and (Fig. 1 right plot), respectively. Majority of all morphological types are early-types dominating below the MS and in the red sequence and green valley, while few sources especially AGN-LINERs suggest the presence of late-types.

† http://www.sdss3.org/dr10/spectro/galaxy_mpajhu.php

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5. Conclusions

The connection between RGs and LINERs has been one of the long standing problems in astrophysics for understanding better the entire picture of galaxy formation and evolution. Our results could be important in understanding better RGs and AGN-LINERs based on physical properties and morphological classifications. Results also suggest finding an alternative method in separating the two populations.

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