Publ. Astron. Obs. Belgrade No. 96 (2017), 281 - 286 *Contributed Paper*

STAR FORMATION IN THE MOST LUMINOUS LINERs

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Abstract. Estimates of the star formation rates (SFRs) in local LINERs, based on different methods, can differ by large factors. This may be attributed to the confusion between active galactic nuclei (AGN) and star formation contribution from the host galaxy. We propose to obtain high spatial resolution, long slit spectra for a sample of local type-I and type-II LINERs at $0.04 < z < 0.11$. They will allow to distinguish between the AGN and starburst emission and to estimate the specific SFR (sSFR) by using the D_n4000 method. These observations will be used together with infra-red data (1) to determine the location of luminous local LINERs in the SFR vs. stellar mass diagram, (2) to compare them with local high ionisation AGN, and (3) to estimate the reliability of sSFR estimators based on UV, optical and IR indicators.

1. INTRODUCTION

Low Ionization Nuclear Emission line Regions (LINERs) are galaxies whose optical spectra are dominated by emission lines from low ionization species (e.g., [OI], [NII], [SII]). In the local universe they usually reside in early-type galaxies, and are the most common among galaxies hosting Active Galactic Nuclei (AGNs), with numbers that exceed those of high ionization AGNs (type-I and type-II Seyfert galaxies and quasars) by a factor of 10 or more (Heckman 1980). They are classified by their position in the BPT diagram (Kauffmann et al. 2003; Kewley et al. 2006) based on narrow emission line ratios, e.g. [OIII]/Hβ, [NII]/Hα and [OI]/Hα. Line ratios similar to those of LINERs are also observed in other sources such as evolved stars (e.g. Cid Fernandes et al. 2010) and regions of shock excited gas (e.g. Dopita et al. 1997). Thus additional diagnostics are required to distinguish such objects from AGN-type LINERs (the LINERs in the present work are excited by a central AGN; e.g. Ferland and Netzer 1983). They are distinguished from high ionization AGNs in two major ways: the level of ionization of their lines is much lower and the normalized accretion rate onto the central black hole is 1 - 5 orders of magnitude smaller. Like other AGNs, they can be divided into type-I (broad Balmer emission lines) and type-II (only narrow emission lines) LINERs.

The best studied very nearby LINERs (e.g. Ho 1997; Ho 2008) are found in the nuclei of galaxies with little or no evidence for active star formation (SF). In recently published paper by Tommasin et al. (2012), using Herschel/PACS observations the authors showed that the far infrared (FIR) luminosities of 35 out of 97 high luminosity LINERs at $z \sim 0.3$ are on average by 2 orders of magnitude higher than the FIR luminosities of nearby LINERs. Even assuming that all the observed Hα fluxes were due to SF (a wrong assumption since a non-negligible contribution is expected from the AGN excitation) it is still not possible to recover the SF rate (SFR) indicated by the FIR observations. Several possibilities could explain the obtained result: first, that smaller nuclear regions were analysed in local LINERs in comparison with the $z \sim 0.3$ sample and therefore the measured fluxes are contaminated from non-nuclear star-forming regions. Second, there might be a selection effect in FIR, since only 35 out of 97 sources were analysed. Third, it could be that still an insufficient population was studied systematically with sensitive FIR instruments in the local universe. Forth, it could be due to the real evolution in the AGN and SF properties from $z \sim 0$ to $z \sim 0.3$ LINERs. A combination of the previous possibilities may be also at work.

We suspect that active SF in LINER host galaxies has escaped the attention of most earlier studies that focused on the innermost part of nearby galaxies. The way to test this idea, understand the LINER phenomenon in relation to SF galaxies, and verify the evolution observed in Tommasin et al. (2012) is to conduct a detailed, ground based spectroscopy of luminous local ($z < 0.1$) LINERs and to use different methods to measure their SFR.

We suggest a systematic study of a flux limited sample of the most luminous (in terms of AGN luminosity) local LINERs, selecting a luminosity range that correspond to that of Tommasin et al. (2012) sample. We propose to obtain long slit spectra for a selected sample, which allows to distinguish between the AGN and starburst emission and to estimate the specific SFR using different methods.

2. SAMPLE SELECTION

We used the Sloan Digital Sky Survey (SDSS) Data Release 7 (DR7) data, and applied classical diagnostic diagrams (Kewley et al. 2006) to select LINERs. To measure the AGN luminosity, we used the method (Netzer 2009) based on Hβ and [OIII] lines. Finally, we selected 47 luminous LINERs, with AGN luminosities $10^{44.2} < L(AGN) < 10^{45.2}$. We divided the sample into two groups using their Galex observations. 25 objects in the first group show FUV and NUV flux distributions that are consistent with the Galex Point Source Function (PSF), i.e. with a nuclear UV point source and are likely to be type-I LINERs. We refer to them as nuclear LINERs. The remaining sources show UV images that are consistent with uniform stellar emission across the host and are thus likely to be type-II LINERs. We refer to them as extended LINERs.

3. SAMPLE PROPERTIES

Using the SDSS spectroscopic data we estimated the continuum AB magnitude at $6500\AA$, whose distribution can be seen in Fig. 1 (top left). We divided the sample into a so-called bright sample ($m_{6500}(AB) < 17.2$), and faint sample ($m_{6500}(AB) > 17.2$).

The redshift distribution of the selected sample is shown in Fig. 1 (top right). As can be seen, the selected LINERs occupy the range $0.04 < z < 0.11$, with the mean values of 0.09, 0.084, and 0.094 for the total, bright, and faint samples, respectively.

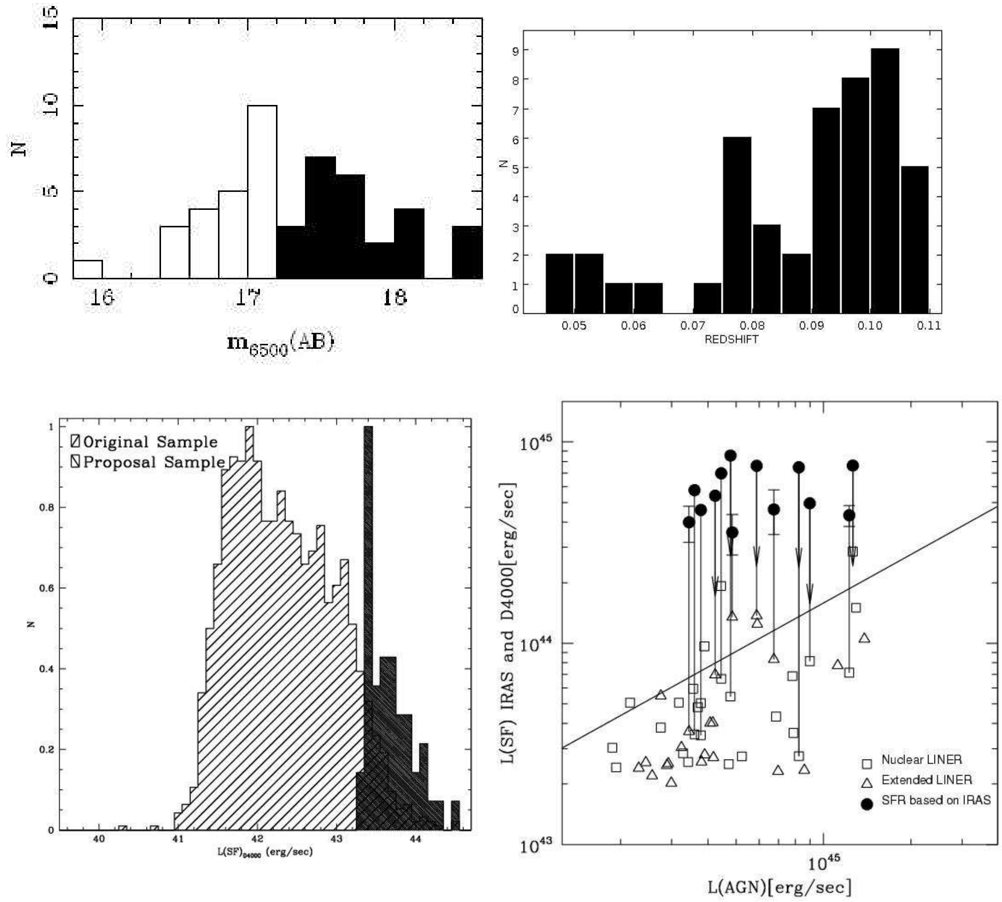

Figure 1: *Top left:* Distribution of m_{6500}(AB) magnitudes of the selected sample (faint LINERs in black). *Top right:* Redshift distribution of the selected sample. *Bottom left:* SF luminosity of the selected sample (in black) and all LINERs at $z < 0.11$. *Bottom right:* Relation between SF and AGN luminosities of selected sample, comparing the estimations provided by IR data (filled symbols) and those from D_n4000 (open symbols).

We used the D_n4000 method (Brinchmann et al. 2004) to estimate the SFRs which, combined with the SDSS-based estimates of the stellar mass, M_*, can be used to derive SFRs. The SF luminosities estimated in this way are shown in Fig. 1 (bottom left), where they are compared with all LINERs with $z < 0.11$. The selected sample is on the high D_n4000 of the histogram with a mean SFR(D_n4000) of about $\sim 1\,M_\odot\,yr^{-1}$.

13 of the sources have 60 μm and 100 μm IRAS detections that, when transformed to SFR, provide SFR by an order of magnitude larger than the D_n4000 estimates, as shown in Fig. 1 (bottom right). Eleven more sources have WISE-based 22 μm measurements and those, when assumed to be entirely due to SF, give SFRs that are much smaller and more consistent (but still higher) than the D_n4000 estimates. Thus,

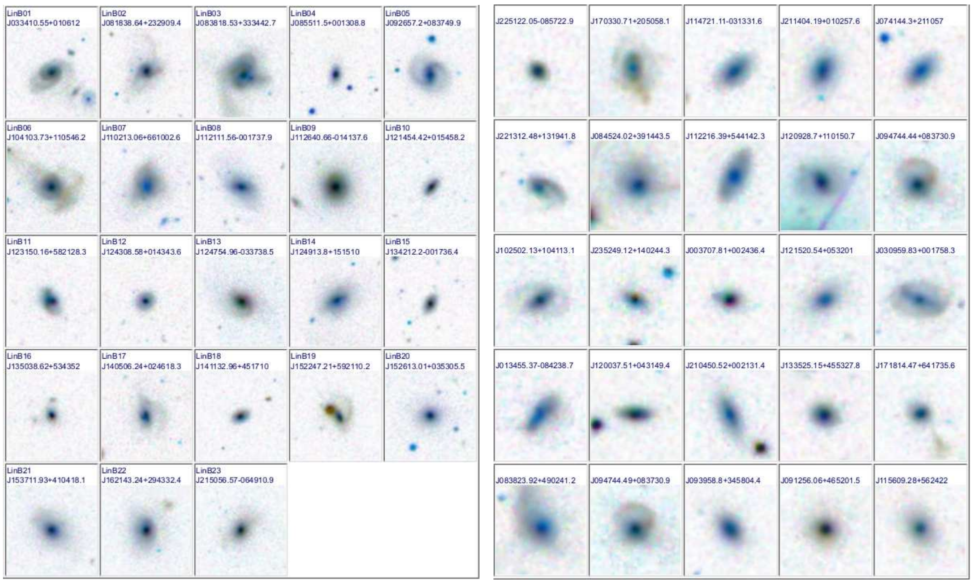

Figure 2: SDSS colour images of selected bright *(left)* and faint *(right)* sample.

we have three very different SFR estimates based on three different methods and an additional confusion due to the AGN. We suppose that most of the confusion is due to the use of the integrated line intensity from the central 3 arcsec of the galaxy in SDSS mixing up AGN and SF contributions. Spatially resolved spectroscopy is required to test this hypothesis.

We checked visually the morphologies of the selected sample (see Fig. 2), finding both early- and late-type galaxies, as well as signatures of interactions in a number of cases.

4. DATA

We obtained ∼1" long-slit spectroscopic data with the CAHA/TWIN spectrograph, and for 10 bright sources, with the NOT/ALFOSC spectrograph. Standard reduction procedures were used. We also were awarded with priority 2 Herschel time (PI. Netzer) whose data will supply accurate SFR estimates for about 13% of the sources. IRAS and WISE IR data are also available for the galaxies in our sample.

Figure 3 shows an example of spectra obtained with the NOT/ALFOSC spectrograph for a sample of six bright LINERs (black solid lines). As a sanity check, we compared our spectra and [OIII]5007 flux measurements with that from SDSS, finding a good correlation.

5. WORK IN PROGRESS

The observations obtained within this project will help to separate between AGN and starburst emissions, and will be used: (1) to see what are the IR and SF properties of the most luminous local LINERs, (2) to test the possible evolution in the AGN and

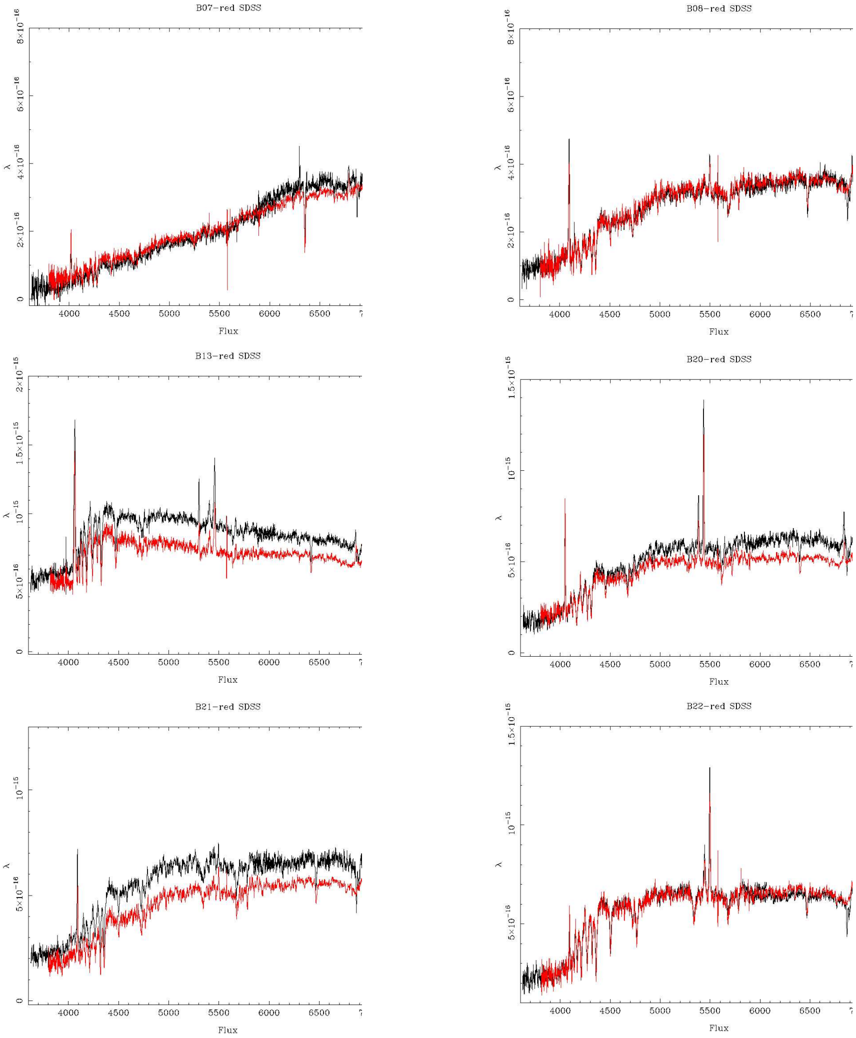

Figure 3: Example of $\sim$3" NOT spectra (in black), and their corresponding 3" SDSS spectra (in red).

SF properties, (3) to compare the selected sample with local high ionisation AGN, (4) to estimate the reliability of sSFR estimators based on UV, optical and IR indicators, and (5) to test if there are FIR differences between UV nuclear and extended LINERs.

Acknowledgments

MP acknowledge financial support from JAE-Doc program of the Spanish National Research Council (CSIC), co-funded by the European Social Fund. This research was supported by the Junta de Andalucía through project TIC114, and the Spanish Ministry of Economy and Competitiveness (MINECO) through projects AYA2010-15169 and AYA2013-42227-P.

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