The starburst-AGN disconnection

R. Cid Fernandes$^{1,2}$, M. Schlickmann$^1$, G. Stasińska$^2$, N. Vale Asari$^{1,2}$, J. M. Gomes$^{1,3}$, W. Schoennell$^1$, A. Mateus$^4$, L. Sodré Jr.$^4$
(the SEAGal collaboration)

$^1$Departamento de Física, CFM, UFSC, Florianópolis, SC, Brazil
$^2$LUTH, Observatoire de Paris, CNRS, Université Paris Diderot, Meudon, France
$^3$GEPI, Observatoire de Paris, CNRS, Université Paris Diderot, Meudon, France
$^4$Instituto de Astronomia, Geofísica e Ciências Atmosféricas, USP, SP, Brazil

Abstract. Optical studies of starbursts, AGN and their connections usually leave out galaxies whose emission lines are too weak to warrant reliable measurement and classification. Yet, weak line galaxies abound, and deserve a closer look. We show that these galaxies are either massive, metal rich star-forming systems, or, more often, LINERs. From our detailed stellar population analysis, we find that these LINERs have stopped forming stars long ago. Moreover, their ionizing radiation field is amazingly consistent with that expected from their old stellar populations alone. The black-hole in the centers of these massive, early-type galaxies is not active enough to overwhelm stellar ionization, and thus, despite their looks, they should not be called AGN.

1. Introduction

The connection between star-formation (SF) and AGN has been the subject of much work over the past two decades, and this conference shows that there is still plenty to be done. There is now solid evidence that these two phenomena coexist and scale with each other in at least part of the AGN population. As an example, Fig. 1 shows the correlation between specific SF rate and black-hole accretion rate for galaxies classified as type 2 AGN in the SDSS. The current SF rate is computed from our spectral synthesis analysis with starlight (Cid Fernandes et al. 2005), whereas, following current ideas (Heckman et al. 2004), $L_{[OIII]}/σ^2$ is used as a proxy for $\dot{M}/M_\bullet$. The strong correlation between these completely independent tracers of SF and AGN activity is indicative of a connection, even though a comprehensive and physically sound framework in which this and other global relations can be understood is still lacking.

This contribution presents an unconventional perspective on SF-AGN connections. In fact, we talk more about disconnections! Looking at plots like Fig. 1, one may wonder who is missing? Who are the AGN sitting in galaxies which no longer form stars? At an even more basic level, how many galaxies are not plotted there because we do not have enough data to classify them as AGN?

We start drawing attention to the fact that optical studies of starbursts and AGN normally set aside a huge population of objects with weak emission lines, inducing potentially dangerous biases. We then set out to place this “forgotten” population in the context of current spectroscopic categories. We show that the
Figure 1. (a) Relation between the STARLIGHT-derived specific SFR and a proxy for the “specific black-hole accretion rate” for ∼ 10000 type 2 AGN in the SDSS-DR5. All objects lie above the Kewley et al. (2001) maximal-starburst line in the BPT diagram. Lines mark the 5, 50 and 95 percentiles. (b) SFR versus [OIII] luminosity (an indicator of accretion rate). Unlike in panel a, the correlation here is partly induced by distance-dependence.

majority of these sources look like low-luminosity AGN (a.k.a. LINERs), but can instead be understood in terms of the retired galaxy model described by Stasińska et al. (2008) and Vale Asari elsewhere in this volume.

2. The “forgotten” population of weak line galaxies in the SDSS

In an era where surveys flourish, and this very volume is a testimony of this trend, galaxies are often tagged as “starburst” or “active” on the basis of relatively little data. Even worse, in many cases the data is not enough to warrant a convincing classification, and such objects are usually set aside.

In the case of the SDSS, one has to make do with optical spectra, classifying galaxies on the basis of their location in diagnostic diagrams such as the classical [OIII]/Hβ × [NII]/Hα BPT diagram. The SDSS is an exquisite data set, but an awful lot of its galaxies do not have enough $S/N$ in their emission lines to allow a reliable classification. To illustrate the size of this problem, we select galaxies where both Hα and [NII]λ6584 are detected with $S/N > 3$. Of this population of emission line galaxies, about 1/5 do not have [OIII]λ5007 and/or Hβ detected with the same level of confidence, such that a rigorous BPT classification is not possible. This may not seem so much, but it so happens that this fraction increases to over 1/2 counting only objects where log [NII]/Hα > −0.2, a criterion which completely excludes pure SF systems. These objects thus pertain to the “AGN-wing” in the BPT diagram, but are they LINERs, Seyferts, or SF+AGN composite systems? Clearly, one would like to have a better idea of what these galaxies are, as neglecting such a numerous population may introduce severe biases, with potentially hazardous consequences.

An unorthodox but statistically valid way to investigate the nature of these weak line galaxies (WLGs) is to plot them in the BPT diagram irrespective of the $S/N$ of their emission lines. This is done is Fig. 2 where the grey points
Figure 2. BPT diagram for galaxies with $S/N > 3$ in at least H$\alpha$ and [NII]. Grey dots correspond to objects with $S/N > 3$ in all BPT lines. Blue, green and red dots and contours correspond to WLGs of different types. Dotted curves mark the SF/AGN borderlines of (from left to right) Stasińska et al. (2006), Kauffmann et al. (2003) and Kewley et al. (2001), while the diagonal line is the Seyfert/LINER borderline derived by Schlickmann (2008) by means of optimal separation techniques applied to the (more complex and “expensive”) Kewley et al. (2006) classification scheme.

correspond to galaxies with $S/N > 3$ in H$\beta$, [OIII], H$\alpha$ and [NII]. Contours are used to indicate the location of WLGs, split in those with: (i) $S/N > 3$ in H$\beta$ but not in [OIII], (ii) $S/N > 3$ in [OIII] but not in H$\beta$, and (iii) those where neither H$\beta$ nor [OIII] has $S/N > 3$. Galaxies with weak [OIII] but strong H$\beta$ are located at the bottom of the SF wing, where metal rich SF systems are expected to be, intruding a little bit into the AGN wing. These are the most massive and metal rich SF galaxies. WLGs of type (ii) and (iii), however, are some other sort of thing. They are well within the AGN wing, heavily skewed towards its low excitation, LINER-like branch. The diagonal line in Fig. 2 maps the Seyfert/LINER separation of Kewley et al. (2006), which requires [OI] and [SII] lines, to the BPT plane. In her MSc thesis, Marielli Schlickmann proposes alternative methods to rescue WLGs from the classification limbo. Her more robust results confirm the overall picture sketched above in Fig. 2. Discounting weak-[OIII] sources, most WLGs look like LINERs.

LINERs are thus much more common than one would think selecting only galaxies with decent $S/N$ in all BPT lines. But what are LINERs? Despite early warnings that they constitute a mixed bag (Heckman 1987), “LINER” and “low luminosity AGN” are basically synonyms in the current literature. Sure enough, many nearby, well studied LINERs are truly Active Galactic Nuclei, in the sense that they have accreting nuclear black-holes. LINERs in the SDSS, including the weak-line ones described above, are all massive and early-typish, and thus should also harbor super-massive black-holes. But are these black-holes truly active? In other words, are they responsible for the emission lines we see?
3. The starburst-AGN disconnection: LINERs as retired galaxies

Further insight can be gained by inspecting the star-formation history (SFH) of galaxies across the BPT diagram. We have done this several times before, but now we include WLGs. Fig. 3a shows the specific SF rate as a function of lookback time for galaxies with $S/N > 3$ in all four BPT lines. The balance of current to past SF shifts gradually from the top of the SF wing to its bottom, and there are also differences along the AGN wing, both vertically and horizontally, with Seyferts having significantly more recent SF than LINERs. Fig. 3b shows the SFHs of WLGs, again using the dangerous but statistically valid trick of computing [OIII]/H$\beta$ using data where at least one of these lines has very low $S/N$. Galaxies with weak [OIII] but “strong” ($S/N > 3$) H$\beta$ all show significant ongoing SF, confirming that they are indeed SF systems. Those with weak H$\beta$ but strong [OIII], however, have essentially no SF in the past $\sim 10^8$ yr. Their SFHs are similar to those of LINERs in Fig. 3a, but with even less SF in the recent past. Star-birth, therefore, cannot be responsible for any significant part of the ionizing radiation field in LINERs. But what about “star-retirement”?

Trincheri & di Serego Alighieri (1991) and later Binette et al. (1994) proposed that post-AGB stars and white dwarfs could be responsible for the gas ionization in elliptical galaxies. Stasińska et al. (2008) revisited this idea, and, with the aid of the stellar populations derived by STARLIGHT, produced self-consistent models which show that indeed many LINERs can be explained in this way. In that paper we required good $S/N$ in all BPT lines to ensure reliable data and classification. With this standard quality control, and using Bruzual & Charlot (1993) models, $\sim 1/4$ of SDSS LINERs are compatible with being retired galaxies whose gas is ionized by old stars. Fig. 4 shows that this fraction increases a lot including WLGs. The x-axis in these histograms is the ratio of the observed H$\alpha$ luminosity to that expected from post-AGB and white dwarfs alone. Only galaxies above the Kauffmann SF/AGN line are included in this
The starburst-AGN disconnection: LINERs as retired galaxies

Figure 4. Ratio between the observed Hα luminosity and that predicted counting only ionization by post-AGB stars for a sample of over 10^5 non-SF galaxies. Grey lines are for strong line sources (S/N > 3 in all BPT lines). Red and green lines are WLGs (as in Fig. 2). Panel (a) includes all galaxies, while in (b) only those without significant recent SF are plotted.

exercise. The plot shows that most WLGs are consistent with the retired galaxy model to within a factor of 3. Most strong line galaxies, on the other hand, require far more ionizing photons than old stars can provide. This bona-fide AGN population shrinks dramatically in number when filtering out galaxies where over 5% of the light comes from populations younger than 10^8 yr (Fig. 4b), where the “starburst-AGN connection” is in full swing. The bimodality in Fig. 4 is much less pronounced among systems dominated by old stellar populations.

To summarize, many (actually: most, if WLGs are not ignored) LINER-looking systems in the SDSS are consistent with being retired galaxies, whose ionizing photons are produced by ageing stars. This is not to say that they do not contain a massive black hole, but until the black hole is proven to be active by means of independent data, they should not be included in any census of actively accreting black-holes.

References
Binette, L., Magris, C. G., Stasińska, G., & Bruzual, A. G. 1994, A&A, 292, 13
Bruzual, G., & Charlot, S. 2003, MNRAS, 344, 1000
Cid Fernandes, R., Mateus, A., Sodré, L., Stasińska, G., & Gomes, J. M. 2005, MNRAS, 358, 363
Heckman, T. M. 1987, Observational Evidence of Activity in Galaxies, 121, 421
Kauffmann, G., et al. 2003, MNRAS, 341, 33
Kewley, L. J., Dopita, M. A., Sutherland, R. S., Heisler, C. A., & Trevena, J. 2001, ApJ, 556, 121
Kewley, L. J., Groves, B., Kauffmann, G., & Heckman, T. 2006, MNRAS, 372, 961
Trinchieri, G., & di Serego Alighieri, S. 1991, AJ, 101, 1647
Schlickmann, M. (2008), Msc thesis, UFSC. (www.starlight.ufsc.br)
Stasińska, G., Cid Fernandes, R., Mateus, A., Sodré, L., & Asari, N. V. 2006, MNRAS, 371, 972
Stasińska, G., Asari, N. V., Cid Fernandes, R., Gomes, J. M., Schlickmann, M., Mateus, A., Schoenell, W., & Sodré, L., Jr. 2008, MNRAS, 391, L29