

An unbiased sample of galaxies for the study of bar-nuclear activity

Luiz Albérico Da Silva Lima¹, Lucimara Martins², Paula R. T. Coelho³, & Dimitri Gadotti⁴

¹ Universidade Cruzeiro do Sul / Universidade Cidade de São Paulo e-mail: luiz_15_51@hotmail.com

² Universidade Cruzeiro do Sul / Universidade Cidade de São Paulo e-mail: lucimara.martins@cruzeirodosul.edu.br

³ Instituto de Astronomia, Geofísica e Ciências Atmosféricas- USP e-mail: pcoelho@usp.br

⁴ ESO - European Southern Observatory e-mail: dgadotti@eso.org

Abstract. The nuclear activity phenomenon is a result of the gas and star feeding of supermassive black holes (SMBHs) hosted in the central region of galaxies. In search of mechanisms that allow active galactic nuclei (AGNs) to be fed during their existence, the bars emerge as excellent candidates. We intend through measures of the properties of barred and unbarred galaxies obtained in the literature, to investigate the connexion of bars with nuclear activity. The initial data set is provided by Gadotti (2009) who made the decomposition of bar, bulge and disk for approximately 1 000 galaxies of Sloan Digital Sky Survey (SDSS) data release 2 and classified them as LINERs, Seyferts and normal. To get an unbiased sample for comparison, matching techniques were applied in the pre-treatment step by means of R `MatchIt` routine (Ho et al. 2007) that employs Rubin causal model, propensity score matching and nearest neighborhood algorithm. The `MatchIt` allows to extract a sub-sample of normal galaxies that have distributions very similar to the AGNs distributions on certain selected properties. In this work we will show how the routine was used to select an unbiased sample of galaxies with different activity classes, and how this will be used to study the relation bar-activity.

Resumo. O fenômeno de atividade nuclear é resultado da alimentação com gás e estrelas de buracos negros supermassivos hospedados na região central das galáxias. Na busca de mecanismos que permitam que os núcleos ativos de galáxia (AGNs) sejam alimentados durante sua existência, as barras surgem como candidatas. Pretendemos por meio de medidas de propriedades de galáxias barradas e não-barradas obtidas na literatura, investigar a conexão das barras com a atividade nuclear. Os dados iniciais são fornecidos por Gadotti (2009) que realizou a decomposição de barra, bojo e disco para aproximadamente 1 000 galáxias do data release 2 do Sloan Digital Sky Survey (SDSS) e as classificou como LINERs, Seyferts e normais. Para obter uma amostra livre de viés para a comparação, técnicas de *matching* foram aplicadas por meio da rotina `MatchIt` em R (Ho et al. 2007), que emprega o modelo causal de Rubin, *propensity score matching* e o algoritmo de *nearest neighborhood*. O `MatchIt` permite extrair uma subamostra de galáxias normais com distribuições muito semelhantes a das AGNs em certas propriedades selecionadas. Neste trabalho, mostraremos como a rotina foi utilizada para selecionar uma amostra livre de viés com diferentes classes de atividade, e como isto será usado para o estudo da relação barra-atividade.

Keywords. Methods: data analysis – Galaxies: active – Galaxies: nuclei

1. Introduction

The nuclear activity phenomenon is a result of the gas and star feeding of supermassive black holes (SMBHs) hosted in the central region of galaxies. Observational evidence accumulated over the last decades indicates that SMBHs exist in most galactic bulges.

In search of mechanisms that allow active galactic nuclei (AGNs) to be fed during their existence, the bars emerge as candidates. Barred galaxies are common (about 50% of the spirals).

We intend through measures of the properties of barred and unbarred galaxies obtained in the literature, to connect the existence or not of bars with nuclear activity. From the physical quantities available, like size, luminosity, mass of the bars, analysis will be done with assistance of statistical methods, in order to ensure absence of bias.

2. Methodology

We will use the sample from Gadotti (2009) that contains about 1 000 galaxies of Data Release 2 of Sloan Digital Sky Survey (SDSS). Gadotti decomposed these galaxies in bulge/bar/disc and measured their properties. The activity classification was made through the diagram BPT (Figure 1). In the group of AGNs are included the Seyferts and only LINERs with more intense [O III] lines to avoid the possible presence of objects with different ionization mechanism than an AGN.

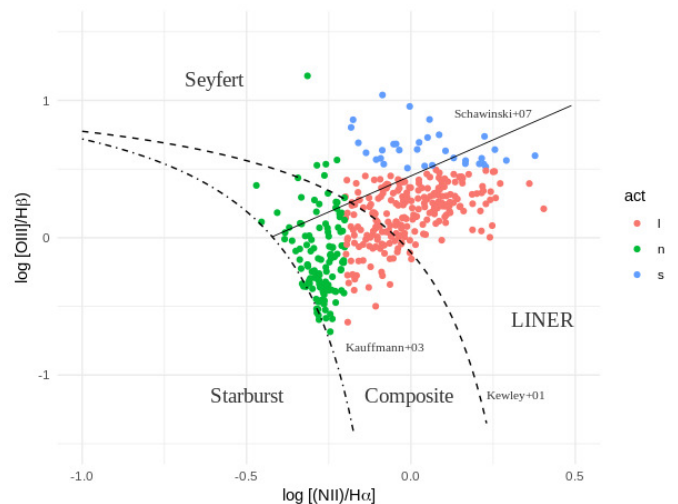


FIGURE 1. BPT diagram with objects from the sample provided by Gadotti (2009) classified as active. The different types of activity are identified with different colors.

To avoid bias, and analyze the effect of the bar in isolation, the matching process based on propensity score is adopted.

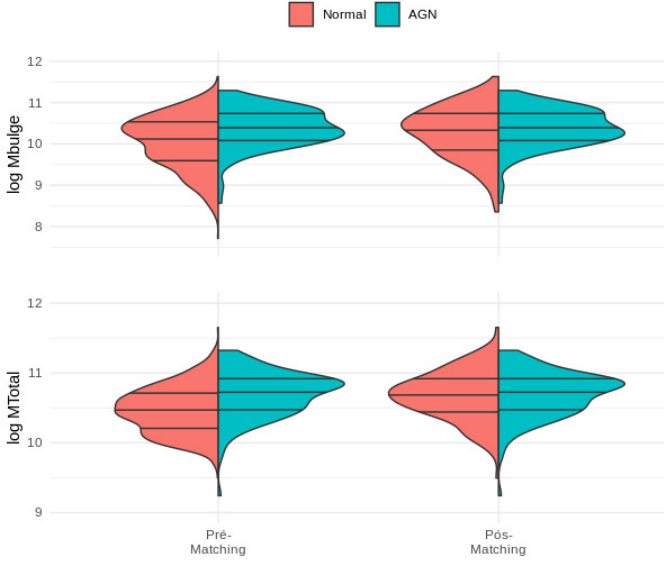


FIGURE 2. Pre and post-matching distributions for active and normal objects, similar to that found in de Souza, R. S. et al. (2006).

Propensity score of matching (PSM) is the probability that a unit be assigned to a given treatment given a set of covariates. It's defined as:

$$e(x) = P(z = 1 | x) \quad (1)$$

Matching is done through PSM, where the active and non-active group objects are paired based on the distance between the PSM of each object:

$$D_{ij} = |e_i - e_j| \quad (2)$$

3. Results and discussion

After the matching process the ideal result would be that $\tilde{p}(x|z = 1) = \tilde{p}(x|z = 0)$ where \tilde{p} represents the empirical distribution of cofactors. The closer to this result, the better the matching quality. The graphical diagnostics of the matching process are shown in Figure 2 and Figure 3. While the standardized difference in mean (SDM) is shown in Table 1.

Table 1. Normalized mean difference, before and after matching. The matching process obtained a great decrease of this parameter, indicating the effectiveness of the process. The table shows the cofactors that were randomized between the test and control groups, as well as the distance, defined as the difference between the propensity score of the pairs.

Randomized parameter	Pre-Matching (SDM)	Pos-Matching (SDM)
Distance	0.4590	0.0307
Mbulge	0.3697	-0.0662
Mtotal	0.5433	-0.0270

Following the criterion of more intense [O III] line LINERs and the matching process that randomized the bulge mass and total luminous mass distributions, a sample to study the activity-bar relationship with 132 active objects (Seyferts + LINERs) paired with classified as non-active objects is obtained.

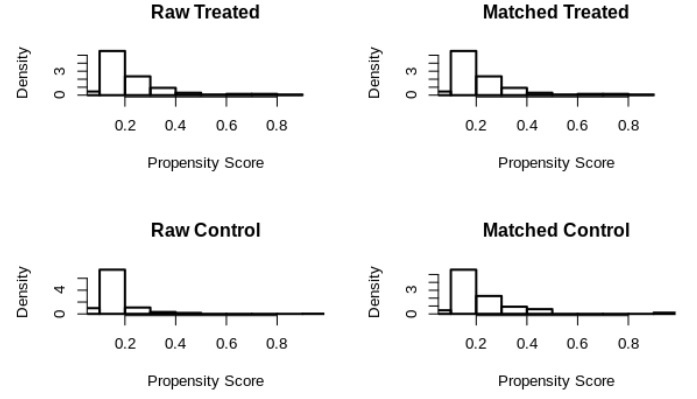


FIGURE 3. In the left figures are the plots before matching; on the right, after matching. In the ordinates are the control group quantiles while in the abscissa axis the test group distribution quantiles. The x and y axis scales are equal.

References

- Gadotti, D. A. 2009, MNRAS, 393, 1531.
 Ho, D. E. et al. 2007, PA, 2007, 15, 199.
 de Souza, R. S. et al. 2006, MNRAS, 461, 2115.
 Kauffmann, G. et al. 2003, MNRAS, 346, 1055.