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Environment, interactions, and their effect on a sample of 300000 galaxies

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Abstract

The origin and evolution of galaxies is closely related to that of the central supermassive black holes (SMBH) that many of them harbour. Interactions between galaxies can trigger their central SMBHs and this nuclear activity could be the origin of the star formation quenching observed in massive galaxies located in dense environments. Hence, these feedback phenomena could play a fundamental role in galactic evolution. However, the relationship between environment and nuclear activity is not completely clear and contradictory results are found in the literature. We present a study based on a sample of ∼300000 Sloan Digital Sky Survey (SDSS) galaxies. Three environmental parameters (tidal forces, local density and cluster richness) were defined and computed for these galaxies. Nuclear activity was also classified based on optical and radio data. The discrimination between galaxy environment and one-on-one interactions and the consideration of different types of accretion (high-excitation and low-excitation) allow us to reconcile the apparently contradictory results found in the literature.

1 Introduction

The effect of the large-scale environment and galaxy interactions on the triggering of an active galactic nuclei (AGN) has previously been studied by many authors, but contradictory results have been found (e.g. [5] and references therein). Part of the confusion may involve the different definitions of "interaction" used in the previous studies. The different types of AGN considered may also affect the results obtained. Two main feeding mechanisms can be found in AGN: a) "standard" high-excitation radiatively-efficient mode, and b) low-excitation radiatively-inefficient mode (see [1] and references therein). Radiatively-efficient

AGN include luminous radio AGN and the optical or X-ray AGN while radiatively-inefficient ones are observed as low-luminosity radio AGN.

We aim to study the effect of the environment and interactions on radio and optically selected AGN. In [7] and [8], the prevalence of radio and optical AGN in isolated galaxies (AMIGA sample of isolated galaxies, [11]) was studied. The prevalence of optical AGN was indistiguishable from that of galaxies in a sample of compact groups [6] at a fixed stellar mass and morphology. A low fraction of radio AGN was found (0% to 0.8%), significantly lower than that of samples in denser environments. For the study outlined here, we took a different approach. Instead of considering samples of galaxies in well-defined environments, a set of environmental parameters was quantified for a large sample of galaxies.

2 Summary

The sample was based on the seventh data release (DR7) of the Sloan Digital Sky Survey (SDSS) and is composed of galaxies from the main spectroscopic sample with a redshift between 0.03 and 0.1 (final sample: 267977 galaxies). Our aim was to check the dependence of the different nuclear activity types on the environment and interaction. Hence, optically and radio selected nuclear activity types were considered. Data based on optical spectra were drawn from the Max Plank Institute for Astrophysics and Johns Hopkins University (MPA-JHU) added value spectroscopic catalogue. Information about total stellar mass and classification of the optical nuclear activity can be found in this catalogue. [1] present the radio nuclear activity classification for these galaxies. Thresholds in [O III] and radio luminosities were applied in the AGN classification to avoid the possible incompleteness bias. Reliable estimations of the cluster richness using a friends of friends algorithm (as explained in the next paragraph) could only be obtained for galaxies with $M_r - 5\log(h) = -20$. These galaxies constitute the *reduced sample*, which was used when the cluster richness parameter was needed for the analysis.

We chose three different parameters to trace different aspects of the environment and the interaction level. We defined a local density and a tidal forces estimator and obtained an estimation of group richness from the literature. The local density estimator traces the density of companions around the target galaxy and is defined by the distance to the 10th nearest neighbour (e.g. [3]). The tidal estimator traces the relative tidal forces exerted by companions with respect to the internal binding forces of the target galaxy [12]. The last parameter is an estimation of the number of galaxies in the cluster or group to which our target galaxy belongs, obtained from [10].

We performed a Principal Component Analysis (PCA) to break them down into the independent physical processes by removing the possible correlations between parameters. The component PCA1 follow the direction of the increase of the density (and the cluster richness) and also the tidal forces. PCA2 seems to trace one-on-one interactions. PCA3r is practically not affected by the tidal force and is driven by the difference between the density and the cluster richness. The environmental parameters and the PCA components are shown in Fig. 1.

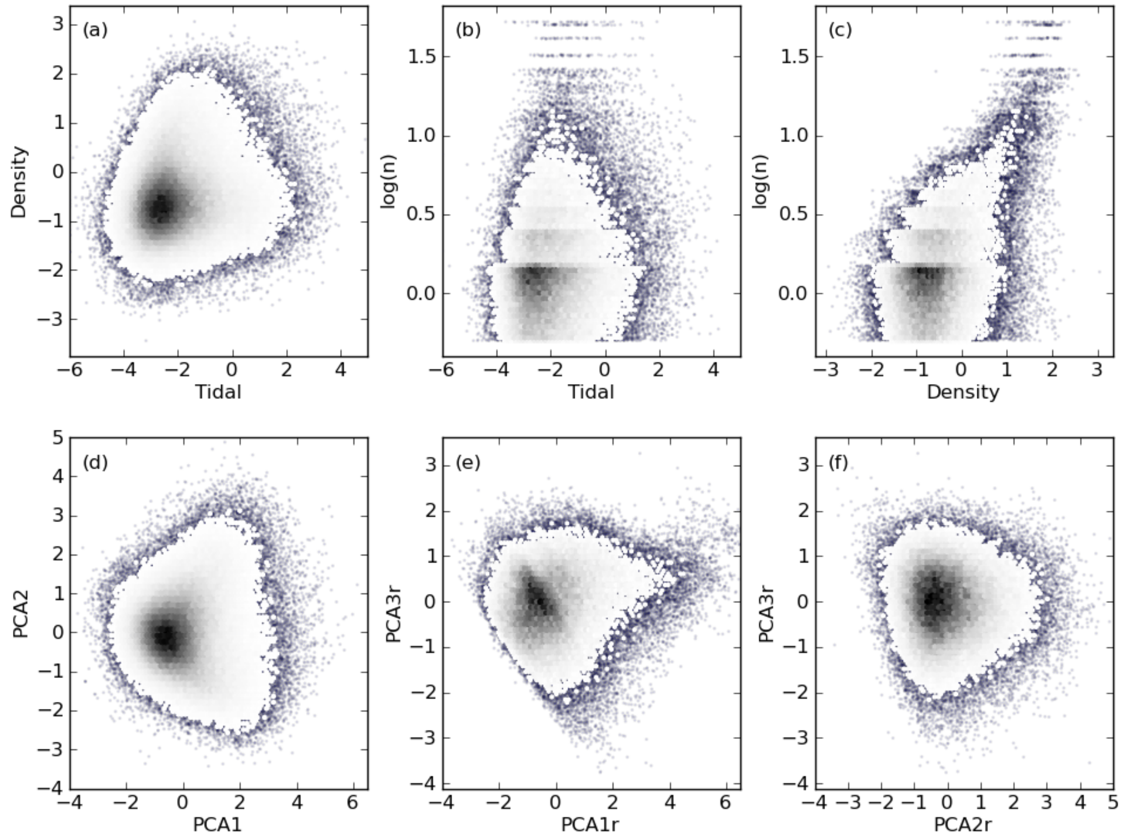

Figure 1: Environmental parameters. Panels (a) and (d) show the distribution for the whole sample and the rest of the panels for the reduced sample. The reduced sample is composed by the galaxies with $M_r - 5\log(h) = -20$ (the galaxies with a reliable cluster richness paramenter available). A suffix is appended to PCA components that refer to the reduced sample. The values for the target galaxies are shown as a grey-scale density cloud and dots for the outliers. A random offset (ranging from -0.5 to 0.5) was introduced in the cluster richness parameter (n) to allow a proper visualisation of the plots.

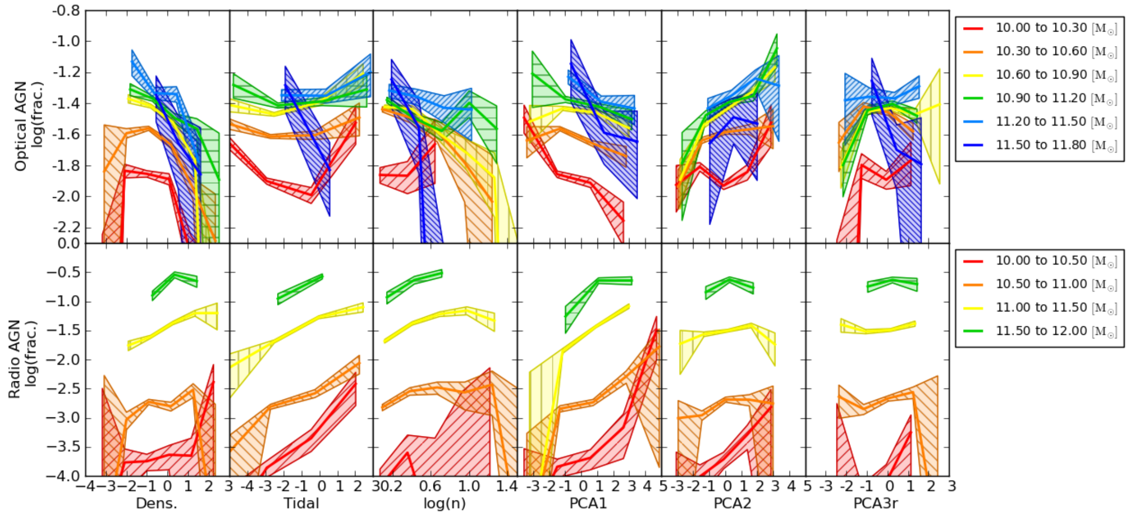

Figure 2: Fraction of optical or radio AGN galaxies, segregated in mass slices, with respect to the different environmental parameters. The bins with less than 20 galaxies (large error bars) were removed from the plots. Filled regions mark the $\pm 1\sigma$ error zone.

The strong dependence of the prevalence of AGN with the mass of the host galaxy in the case of optical [4] and radio [2] AGN has to be considered. Hence, we divided the sample in bins with masses for optical AGN that are shown in Fig. 2. The monotonic increase of the fraction of active galaxies with respect to the mass of the host is clearly visible. This increase is steeper for radio AGN than for optical AGN. To discard the effect of the mass on the fraction of AGN, we performed an stratified study of the ratio of AGN with respect to each environmental parameter. The trends found for each AGN type with respect to the environmental and PCA parameters are shown in Fig. 3.

Of the parameters studied, mass is confirmed to be the main driving factor for the triggering of an AGN, especially for radio AGN [2, 4] as shown in Fig. 2. However, local density and interactions also play a significant role on the prevalence of nuclear activity. The relations obtained show the clearly different and even opposite tendencies depending on the environmental or PCA parameter used. We found a decrease of optical nuclear activity, including star forming nuclei (SFN), towards denser environments. On the other hand, an increase of the prevalence of radio nuclear activity is found towards higher densities. There is also an increase of the prevalence of SFN, optical and radio AGN with one-on-one interactions. It is clear that interactions and environmental density are complementary factors that must be taken into account to get a complete view of the external phenomena that affects the triggering of an AGN. The trends found can be explained if the different parameters trace different physical processes that affect the triggering of nuclear activity.

The results outlined here will be presented in detail in a forthcoming paper recently submitted to MNRAS [9].

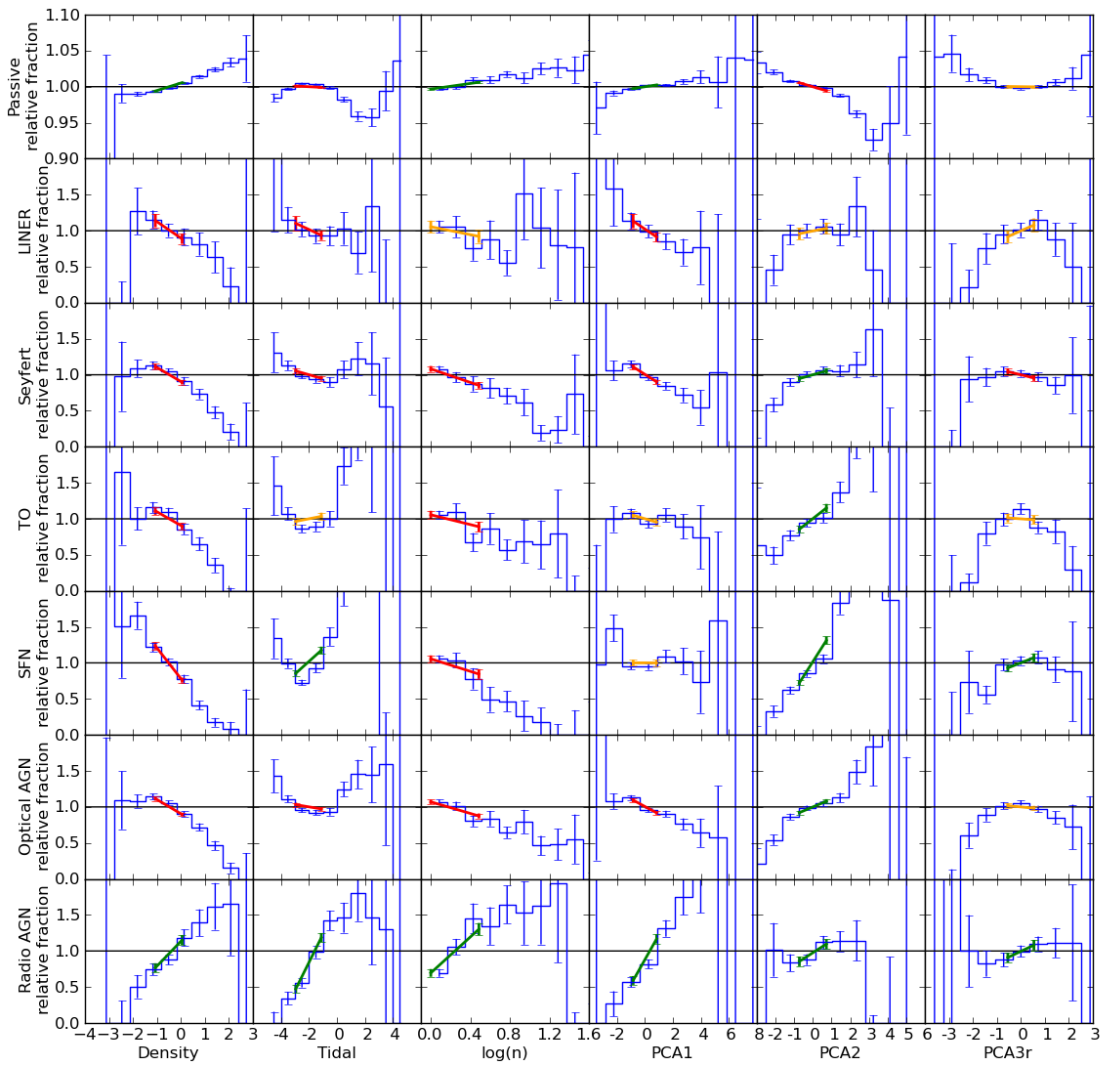

Figure 3: Relative fraction of galaxies of one type, corrected by the effect of mass, with respect to the different environmental parameters (f). The blue thin solid lines mark the detailed trend of f with respect to each environmental parameter. The thick solid lines defined by two points show the coarse general trend of f. The colour of the thick colour line indicates whether a flat trend is compatible within the error (orange) or not (increase – green; decrease – red).

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