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Activity induced by gravitational interaction in galaxy pairs

Mixed (E+S) morphology pairs

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Abstract. A systematic study of the nuclear emission of a sample of 97 spirals in isolated galaxy pairs with mixed morphology (E+S) shows that: 1) AGN activity is found in 40% of the spiral galaxies in these pairs, 2) Only one out of the 39 AGN found has type 1 (Broad line Component) activity, and 3) AGN tend to have closer companions than star forming galaxies. These results are at odds with a simple Unified Model for Seyferts, where only obscuration/orientation effects are of relevance, and neatly support an evolutionary scenario where interactions trigger nuclear activity, and obscuration/orientation effects may be complementary in a certain evolutionary phase.

Key words. Nuclear Activity - Galaxy Interactions

1. Introduction

One of the outstanding problems in the understanding of Active Galactic Nuclei (AGN) phenomenon is the role of the circumgalactic environment in the triggering of the central engine. In an attempt to elucidate this question, in the past 10 years several efforts have focused in the study of the environment of AGNs, from a few kiloparsecs around the galactic nucleus to some hundreds of kiloparsecs around the host galaxy. Most of the investigations have dealt with samples of Seyfert galaxies, because these are the closest clearly non-thermal dominated active nuclei. LINERs are easy to observe, however, the nature of the dominating emission mechanism is not well established yet (Krongold et al 2003; González-Martín et al. 2006).

It has been suggested that Seyfert 2 galaxies are in interaction with the same frequency than star-forming galaxies (Krongold et al. 2002), while Seyfert 1 galaxies are in interaction less frequently, comparably as often as non-active galaxies (Dultzin-Hacyan et al. 1999, Krongold et al. 2001). The most recent studies confirm these findings considering physical companions, i. e. not only from companions selected from statistical considerations but from actual measurements of radial veloc-

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ities for the neighboring galaxies (Koulouridis et al., 2006a 2006b).

In all the above analyses the environment of well defined samples of active vs. non-active galaxies were compared. In the present paper we adopt a complementary approach. We study the incidence of nuclear activity in a well defined sample of interacting galaxies. We focus on the sample of isolated mixed-morphology galaxy pairs studied by Hernández-Toledo et al. (1999, 2001), obtained from the Catalog of Isolated Pairs in the Northern Hemisphere (KPG; Karachentsev 1972).

These pairs are a unique laboratory to study the effect of tidal forces in triggering nuclear activity because they are relatively simple systems where a gas rich galaxy interacts with a gas poor one. In such systems a clean interpretation of the origin and evolution of the gaseous component is possible.

In this paper we present high resolution, long-slit, spectroscopy for the spiral component of 97 mixed morphology pairs from the *Catalog of Isolated Pairs* (CPG; Karachentsev 1972). For details on the properties of the mixed pair sample see Hernández-Toledo et al. (1999, 2001), and Gonzalez et al. (2008, hereafter G08).

2. Observations and data reduction

The spectroscopic observations were carried out at the Observatorio Astronomico Nacional [1] in San Pedro Mártir, Baja California, Mexico. The spectra covered the wavelength interval λ5700-7750Å at a 4.6Å resolution. The data reduction was carried out using XVISTA [2] data reduction package using standard procedures. Details about the observations and data reduction procedures can be found in G08.

[1] The Observatorio Astronómico Nacional is operated by the Instituto de Astronomía of the Universidad Nacional Autónoma de México at Sierra de San Pedro Mártir, Baja California, México.

[2] XVISTA is distributed by Jon Holtzman at Nuevo México State University: http://astro.nmsu.edu/ holtz/vista

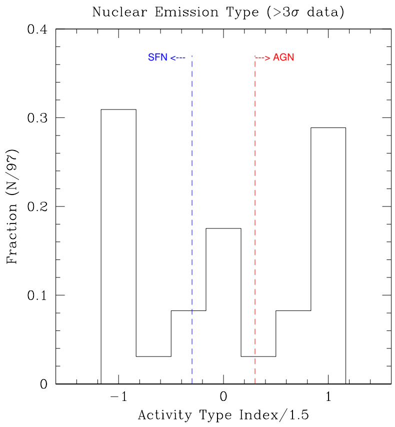

Fig. 1.

3. Activity diagnostic criteria

Since we lack the O III/H_β ratio (due to the wavelength coverage) we are unable to distinguish between Seyferts and LINERs. Thus, we labeled both as AGN. On the other hand, we are also unable to distinguish between Starburst and normal star-forming galaxies. Therefore this group is considered as non-active and is hereafter referred to as "normal galaxies"

To classify the spiral galaxies into AGN and normal galaxies we have defined an "Activity Type Index" (hereafter ATI) based on a combination of the diagnostic line ratios found in the literature (see G08 for details). The ATI takes into account a linear combination of the SII/H_α, NII/H_α, and OI/H_α. Each of these line ratios is weighted by its S/N. If the significance of a given line ratio is less than 3σ the weight was set to zero. Otherwise, the weight was calculated using the square of the S/N. See G08 for full details.

In Figure 1 the distribution of the ATI for the 97 nuclei is presented. Objects with ATI below -0.3 were considered "normal galaxies". Objects with ATI above 0.3 were considered clear cut AGNs. In the range between these thresholds, it is not possible to separate among pure AGN, composite AGN+Starburst or pure Starburst systems. Therefore objects in

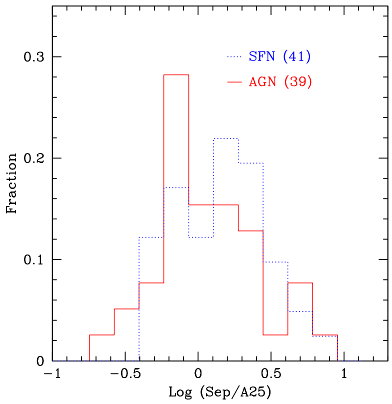

Fig. 2.

this range are referred to as "unclassified systems".

4. Results

Figure 1 shows that 40% of the spirals in mixed pairs show AGN activity. This percentage is clearly higher than than the the one found in field (non-interacting) galaxies, which is usually estimated around 10%.

We further check the fraction of type 1 vs. type 2 AGN in our sample. An outstanding result is that only 1 out of the 39 objects classified as AGN in our analysis shows the presence of a broad Hα component, and thus is a Type 1 object.

Finally, we examined the relation between the ATI and the separation of the galaxies in the pairs (normalized by the spiral galaxy diameter measured down to the 25th isophote). The result is shown in Fig. 2. We can see a clear cut difference between the distribution of the separations between "normal" galaxies (SFN stands for galaxies with Star Forming Nuclei), and galaxies with active nuclei (AGN). The difference is in the sense that the Spiral galaxies that harbor an active nucleus tend to be closer to their elliptical neighbor. (a KS test gives a 99% confidence level) .

5. Discussion

The most striking result in our analysis is that only 1 out of the 39 AGN can be classified as type 1. Even if in the present analysis we cannot separate LINERs from Seyferts, this result is very much at odds with the expectation of the so-called Unified Model (UM). A frequency of 2.6% for the presence of type 1 activity is too low to be explained with an obscurationorientation effect alone. Ho et al. (1997) found that ∼20% of their sample of nearby low-luminosity AGN (including LINERs and Seyferts) observed with HST presented broad lines (the expectation of the UM is that ∼60% of Seyferts should be type 1).

Our results also show a clear connection between interaction and nuclear activity, in particular of type 2 activity. This fact follows naturally from the evolutionary model developed by Krongold et al. (2002, 2003). In this model, the onset of both nuclear activity and enhanced nuclear star formation is due to the tidal forces that induce the infall of large amounts of gas into the nucleus. These tidal effects are produced by an interaction with a nearby (similar mass) companion.

In the first stages of the interaction, a Starburst should dominate the emission. As more material falls into the innermost regions, the onset of non-thermal activity begins. At this stage, the non-thermal power is low, and there is full obscuration of the nuclear region (including the broad line clouds), therefore only a type 2 AGN is observed. During this stage, the model predicts a high probability for the detection of a nearby companion. As even more material falls, the accretion rate is increased, and partial obscuration is expected (as the initial spherical distribution of obscuring dust should flatten to form a torus), so both types of AGN can be observed. In the final stage, the dust is sweeped away by both the winds of massive evolved stars and the AGN itself. In this stage a naked type 1 AGN neatly emerges. A timescale of 10^9 yr is required to erase all evidence of possible past interactions (either through the completion of a merging event between two galaxies of similar mass, or through the dissolution of an unbounded interacting companion). This naturally explains why type 2 AGN are often found in interacting systems, while type 1 AGN are rarely found with companions. We notice that this evolutionary scenario does not exclude the effect of a possible obscuring/inclination combined effect, such as the one postulated in the UM. Our scenario includes the UM, but only at a given evolutionary stage. The above evolutionary scenario explains in a straight forward way the results found in this work for the spiral component of the mixed morphology pairs. This implies that interactions play a key role in triggering nuclear activity.

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