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# INDUCED ACTIVITY IN MIXED-MORPHOLOGY GALAXY PAIRS[1]

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RESUMEN

Presentamos los resultados de un estudio espectroscópico de los núcleos de una muestra de 97 espirales en pares aislados de galaxias con morfología mixta (E+S). Nuestros resultados principales son: (1) Encontramos actividad nuclear no térmica (NAG) en 40% de las espirales en estos pares. (2) Tan solo una de las 39 galaxias activas detectadas muestra actividad de tipo 1. (3) Los NAGs tienden a tener compañeras más cercanas que las galaxias con formación estelar. Estos resultados contradicen las expectativas de un Modelo Unificado simple para Seyferts, donde los efectos de obscurecimiento y orientación son los únicos relevantes. En cambio, apoyan claramente un modelo evolutivo en el cual las interacciones inducen la actividad nuclear.

ABSTRACT

Results from a spectroscopic study of the nuclear emission of a sample of 97 spirals in isolated galaxy pairs with mixed morphology (E+S) are presented and discussed. The Main results of this study are: (1) AGN activity is found in 40% of the spiral galaxies in these pairs, (2) Only one out of the 39 AGN found shows type 1 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.

*Key Words:* galaxies: active — galaxies: interactions



## 1. INTRODUCTION

An outstanding issue in understanding the Active Galactic Nuclei (AGN) phenomenon is the role that cicumgalactic environment actually plays on triggering the central engine. In an attempt to elucidate this question, several efforts in the past decade have focused on studying the environment of AGN, from a few kiloparsecs around the galactic nucleus to some hundreds of kiloparsecs around the host galaxy. Being the closest non-thermal dominated active nuclei, most of the investigations have dealt with samples of Seyfert galaxies. LINERs are also commonly observed, however, the nature of their dominating emission mechanism is not yet well established (Krongold et al. 2003; González-Martín et al. 2006).

It has been suggested that Seyfert 2 galaxies are found in interaction as frequently as starburst galaxies (Krongold et al. 2002), while Seyfert 1 galaxies are found less frequently in interaction, comparably as often as non-active galaxies (Dultzin-Hacyan et al. 1999; Krongold et al. 2001). The most recent studies confirm these findings with physical companions verified with radial velocities measurements of the neighboring galaxies (Koulouridis et al. 2006a,b).

While previous studies compare the environment of well defined samples of active versus non-active galaxies, the present work adopts a complementary approach by studying the incidence of nuclear activity in a well defined sample of interacting galaxies. In particular, we focus on the sample of isolated galaxy pairs with mixed (E+S) morphology studied by Hernández-Toledo et al. (1999, 2001), drawn from the Catalog of Isolated Pairs in the Northern Hemisphere (KPG; Karachentsev 1972). Being relatively simple systems where a gas-rich galaxy interacts with a gas-poor companion, these pairs are a unique laboratory to study the effect of tidal forces in triggering nuclear activity, potentially with a cleaner interpretation of the origin and evolution of the gaseous component.

This contribution summarizes the results of nuclear spectroscopic measurements for a sample of 97 spirals in isolated galaxy pairs with mixed morphology from the *Catalog of Isolated Pairs* (CPG; Karachentsev 1972). Sample properties and additional details can be found in Hernández-Toledo et al. (1999, 2001), and González et al. (2008, hereafter G08).

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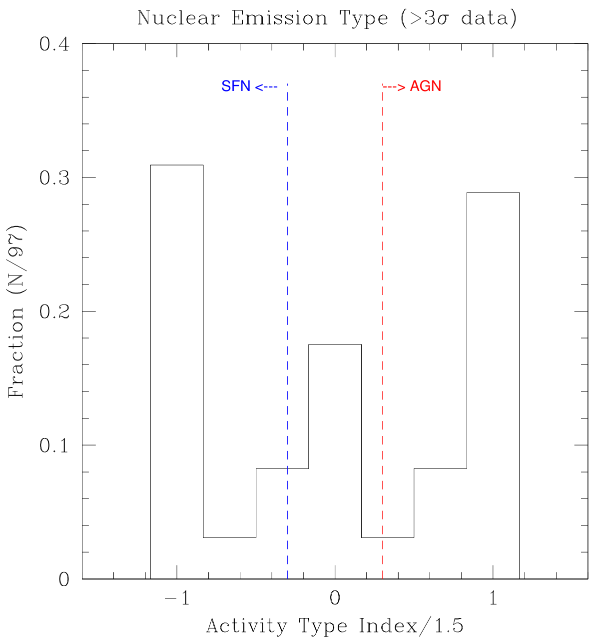


Fig. 1. Distribution of Activity Type Index (ATI) for 97 spirals in (E+S) galaxy pairs. Galaxies with ATI $>0.45$ are clear-cut AGN, while spirals with ATI $<-0.45$ have a Star-Forming Nucleus (SFN).

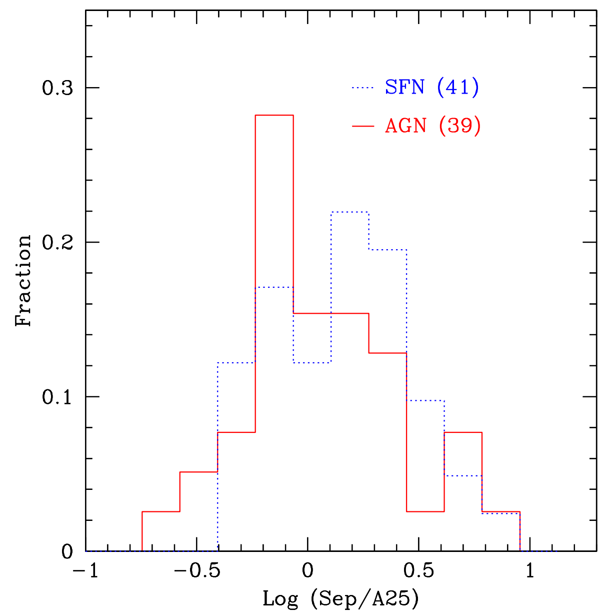


Fig. 2. Distribution of pair separation (in units of the 25th mag arcsec$^{-2}$ isophote diameter) for both AGN (solid line) and Star-Forming Nuclei (dotted line).

## 2. OBSERVATIONS AND DATA REDUCTION

The spectroscopic observations were carried out with the 2.1 m Telescope of the Observatorio Astronómico Nacional[5] in San Pedro Mártir, Baja California, Mexico. The long-slit spectra cover the wavelength interval $\lambda$5700–7750 Å with a 4.6 Å resolution. Data reduction was carried out using the XVISTA[6] package following standard procedures. For the present study, the central 3 arcsec spectrum of each galaxy was extracted after removing rotation (see G08 for details).

## 3. ACTIVITY DIAGNOSTIC CRITERIA

Given the limited wavelength range covered, we lack the [O III]/H$\beta$ ratio to be able to distinguish between Seyferts and LINERs and in this work are simply lumped as AGN. At the moment, we also do not separate Starburst from normal star-forming galaxies and considered both as non-active cases, hereafter referred to as "Star-Forming Nuclei" (SFN).

To quantitatively classify the spiral galaxies in our sample into AGN and SFN we defined an "Activity Type Index" (ATI) based on all three [SII]/H$\alpha$, [NII]/H$\alpha$, and [OI]/H$\alpha$ line ratios measurements and errors, combined with their thresholds from the literature (see G08 for full details).

## 4. RESULTS

Figure 1 presents the distribution of the Activity Type Index (ATI) for the 97 nuclei of spirals in isolated (E+S) pairs. Objects with ATI above 0.45 can be considered clear-cut AGN, while ATI $<-0.45$ nuclei are bona fide SFN. Intermediate ATI values may include composite AGN+Starburst, pure Starburst or faint AGN. The figure clearly shows that 40% of the spirals in these pairs show AGN activity. This AGN fraction is clearly higher than found in non-interacting field galaxies, usually estimated to be about 10%.

Measuring accurate line-widths we also separate type 1 from type 2 AGN in our sample. An outstanding result is that only a single one, out of the 39 detected AGN, shows the presence of a significant broad H$\alpha$ component (Type 1).

Finally, the AGN activity excess found in the present sample can be directly connected to interaction effects. Figure 2 shows the pair-separation distributions of the AGN and SFN subsamples. Spirals in (E+S) isolated pairs that harbor an AGN are typically closer to their elliptical companion.

[5]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.

[6]XVISTA is distributed by Jon Holtzman at Nuevo Mexico State University (`http://astro.nmsu.edu/~holtz/vista`).

## 5. DISCUSSION

The most striking result in our analysis is that only a single one, out of the 39 clear-cut AGN in our sample, is of type 1. Even though the present analysis does not separate LINERs from Seyferts, this result is very much at odds with the simplest formulation of the Unified Model of Seyferts (UM). A 2.6% frequency of type 1 activity is too low to be explained with an obscuration/orientation effect alone. Ho et al. (1997) found that $\sim 20\%$ of their nearby low-luminosity AGN sample (of both LINERs and Seyferts) present broad lines, while the expectation of the UM is $\sim 60\%$ for type 1 Seyferts. Furthermore, our sample of spirals in isolated (E+S) pairs also show a clear connection between interaction and nuclear activity, essentially of type 2. All these facts may naturally follow from the evolutionary scenario developed by Krongold et al. (2002, 2003).

In this scenario, besides the potential obscuring/inclination effects present at any of the evolutionary phases, the onset of both nuclear activity and enhanced nuclear star formation is a consequence of the infall of large amounts of gas towards the nucleus, induced by strong tidal forces during the interaction with a nearby companion of similar mass, and follow four distinct phases:

(a) In the early stages of the interaction, a strong Starburst dominates the emission during a first phase of the evolution.

(b) As more material falls into the innermost regions, the onset of non-thermal activity begins. At first, not only the non-thermal power is low but also the nuclear region (including any broad line clouds present) is fully obscured, and only a type 2 AGN could be observed at this second phase. During this stage, there is a high probability for the detection of the nearby companion.

(c) As even more material keeps falling, the accretion rate gradually increases, and only a partial obscuration is expected as the spherical distribution of dust flattens out to form a torus, such that both broad and narrow line AGN can be observed during this third phase.

(d) In the final stages, most of the dust is either destroyed or swept away by both the winds of massive stars and the AGN itself, and a naked type 1 AGN neatly emerges at the fourth and final phase of this evolutionary scenario. After a timescale of $\sim 10^9$ yr the evidence of possible past interactions can be erased, either through the completion of a merging event or through the dissolution of an unbounded interacting pair. In order to explain why type 2 AGN are often found in interacting systems while type 1 AGN are rarely found with companions, the evolution towards the final fourth phase should take about this long.

At least qualitatively, the described evolutionary scenario naturally accounts for the main statistical properties of the nuclear emission found in previous studies and the results from the present sample of spirals in isolated (E+S) galaxy pairs, implying that interactions play a key role in the triggering and evolution of nuclear activity.

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