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FEEDBACK BETWEEN HOST GALAXY AND NUCLEAR ACTIVITY

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RESUMEN

Uno de los problemas fundamentales en el estudio de la actividad nuclear en galaxias (AGN) es comprender cuáles son los mecanismos para el encendido de la emisión no térmica en sus núcleos. Hay que dilucidar tanto el origen del gas que es acretado hacia el agujero negro, como los mecanismos físicos para que se produzca la necesaria pérdida de momento angular y el gas caiga hacia el centro. Dicho de otro modo, el objetivo es entender bajo qué condiciones se enciende la actividad AGN. Aún quedan muchos aspectos al respecto que son objeto de debate. En esta contribución se discuten en concreto el papel que juega la interacción gravitacional y la relevancia del tipo morfológico de la galaxia anfitriona así como del entorno, para entender si la actividad AGN está más relacionada con los efectos de interacción, o si por el contrario es debida a procesos de evolución secular en la galaxia albergadora.

ABSTRACT

One of the main issues concerning Nuclear Activity in galaxies (AGN) is to understand the triggering mechanisms for the onset of non-thermal emission in their nuclei. Both the origin of the gas accreted onto the black hole and the physical mechanisms for the loss of angular momentum required for this funnelling to be effective, have to be elucidated. In other words, the goal is to understand the necesary conditions to switch on the AGN activity. But many aspects of the investigation are still a matter of debate. Among them, the role played by gravitational interactions and the relevance of the host galaxy need to be clarified. In this contribution, the different relationships between AGN activity, the morphological type of the host galaxy and the environment are discussed, in order to understand whether the AGN activity is more related to interacting effects or otherwise can be due to the secular evolution in the hosting galaxies.

Key Words: galaxies: active — galaxies: interactions — galaxies: structure

1. INTRODUCTION: NATURE OR NURTURE?

Already in the 80's the possible relationship of AGN activity with the host galaxy has been raised (Heckman 1980). It seems to be related to the shape of the gravitational potential: earlier galaxies, with larger contributions from elliptical-like components, host AGN activity more frequently. The properties of galaxies have long been known to depend on the environment in which they are located, with ellipticals mostly residing in rich clusters, and spirals mainly found in their outskirts (i.e. Dressler 1980; Balogh et al. 1998). Therefore, special care is needed when trying to disentangle internal from external drivers. The use of control samples matching both in morphology and environmental status will be crucial at this respect.

Galaxies properties can change with time both by secular processes and by the effects of interactions with neighbours or with the surroundings. Secular evolution has been suggested as a possible mechanism to make galaxies evolve from later to earlier types; this could be the case specially within the group of spiral galaxies. The response of the disk to an initial small external perturbation would produce gravitational instabilities in the disk giving rise to the formation of a bar wit the subsequent transfer of material to the center; eventually, the bar itself will be destroyed due to the huge accumulation of gas. Strong gravitational interaction can produce similar effects, but at more violent levels and, depending on the relative masses of the systems involved, giving rise to the formation of elliptical galaxies (Mihos et al. 1992; Barnes & Hernquist 1996).

AGN activity has to be sustained by some processes fuelling the nucleus. Angular momentum loose have to operate in order to make the material to be funnelled to the center. The large scale processes driving material to the central regions have been explored as eventually related to those required much closer to the nuclear black hole. In this contribution, we analyse how AGN are related to nature, i.e, the properties of the galaxy hosting an AGN, and how

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AGN relate to nurture, i.e, with externally triggered modifications. All in all, we will keep in mind that the power of the AGN is another parameter to consider, as clearly illustrates the case of the strongest AGN (quasars) corresponding to the most massive galaxies or the strongest interactions.

2. THE ROLE OF THE LOCAL/LARGE SCALE ENVIRONMENT

The studies of local (few kiloparsecs) and large (some hundred megaparsecs) environments of AGN have pointed to differing results concerning whether they are similar to those of inactive galaxies. Virani et al. (2000), Schmitt et al. (2001), Schmitt (2001), among others, have concluded that no difference is found. Other investigations suggest that the number of companions is higher for Seyfert galaxies than for non-Seyferts (Dahari 1985a,b), with clear differences between Seyfert 1 and Seyfert 2 (Dultzin-Hacyan et al. 1999; Krongold et al. 2001, 2003; Koulouridis et al. 2006a,b) and even depending on the power of the AGN (Hao et al. 2005a,b). The main limitations of these studies relate to the sample selection, completeness and matching procedure for control galaxies. The wavelength used for selecting the AGN samples could also play a role, as optically selected AGN could be biased against obscured objects.

The recent dramatic increase in the number of AGN (from several hundreds to several thousands) has resulted in the possibility of approaching this study with statistical significance. The main result with the first data release by Miller et al. (2003) is that of a constant fraction of AGN with projected galaxy density. In contrast, for higher densities the fraction of passive galaxies is enhanced and that for star forming galaxies decreases.

Kauffman et al. (2003) found that type 2 AGN are almost exclusively massive galaxies, with the AGN fraction strongly declining for $M* < 10^{10} M_{\odot}$. They have similar sizes and stellar masses than normal early-types but show slightly different stellar ages than the parent general population. They also found that high power AGN (those with log (L[OIII]) > 7.0) show somewhat younger stellar populations. Kauffmann et al. (2004) obtain a larger fraction of high power AGN in lower density environments, whereas at a fixed AGN power, the hosts are similar for any density.

Sorrentino et al. (2006) conclude that Sy1 and Sy2 galaxies have similar large scale environments with a higher percentage of Sy2 appearing in close pairs. They suggest that some of the conflicting previous results could be a consequence of not taking into account the necessity to distinguish between close and large scale environments when studying the eventual effects of the gravitational interactions as related to AGN activity.

3. AGN AND BARS

Previous to studies of huge samples in the last few years, the connection between the presence of AGN activity and the morphology of the host galaxy had been stressed from earlier studies (Heckman 1980). AGN hosts are more frequently found in early types, with a peak of the morphology distribution in Sb spirals (Heckman 1980; Márquez & Moles 1994; Moles, Márquez, & Pérez 1995; Ho et al. 1997; Knapen et al. 2000; Maia et al. 2003; Wake et al. 2004; Kauffman et al. 2004). Already in these works the need of explaining the internal mechanisms to be related to the onset of nuclear activity in galaxies was one of their first aims, and the presence of an asymmetric component of the gravitational potential was invoked as a main driver. Whereas in the case of interacting galaxies the departure from the symmetry is immediately provided by the tidal forces, isolated galaxies deserve closer inspection, since the asymmetry should come from the host itself. But in spirals the presence of such internal asymmetric component is very frequent. At least two thirds of spiral galaxies are barred (Mc Leod & Rieke 1995; Mulchaey et al 1997; Eskridge et al. 2000; Grosbol et al. 2004).

The importance of the presence of a bar in a spiral galaxy has been established already in the pioneering numerical simulations of barred galaxies (Hohl 1971; Sellwood 1981). A bar is described as a component that ridigly rotates over a differentially rotating disk, what gives rise to different resonances usually associated to ring features. Bars are easily formed in minor mergers (Hernquist & Mihos 1995; Barnes & Hernquist 1996), and some of their effects on the host galaxy are to dynamically heat the disk and to produce net inflows to the central regions. Such inflows directly explain the observed flatness in metallicity gradient in barred galaxies. The infalling processes also relate to the various star forming features observed in barred galaxies, since they are expected to be different for old/young and strong/faint bars. The final stages of the infalling process, those of material accumulated onto the central region and bar destruction, have been explored, by means of numerical simulations: starting from a late type spiral that respond to a small perturbation of the disk, a bar is generated, which provokes the transport of some disk material to the center; this enhances the bulge component and destroys the bar itself, so that the galaxy finally ends up as an earlier unbarred galaxy.

But still the question was whether there was a clearcut relation between the presence of a bar and the AGN activity. Whereas a consensus has not been reached at this respect (see Knapen et al. 2000; Laine et al. 2002; Laurikainen et al. 2004), most works conclude that there is not an excess of bars among Seyfert galaxies (Moles, Márquez, & Pérez 1995; Mc Leod & Rieke 1995; Ho et al. 1997; Mulchaey & Regan 1997). Since bars evolve with time, some complications are expected in such a simple expectation, what could be related to the result by Hunt & Malkan (1999) of a higher percentage of outer rings in Seyfert 1 galaxies. The main concerns of all these works are related to the sample numbers, the sample selection procedures, and the way the control samples are defined. But in addition to all these eventual biases, the mechanism that is expected to drive the feeding material to the nuclear source has to operate down to the scales close enough to the nucleus. Large scale bars seem to be limited to produce such transport only till the region of the innermost resonance, at scales of about 1 kpc, where the material is trapped and no more inflow occurs. Several mechanisms have been proposed that could help in getting rid of the angular momentum at this point and drive the material closer to the center (Maciejewski et al. 2001; Jogee 2004). One of the first mechanism to be the required second step was that of nuclear bars, nested with respect to the large scale, primary bar (Norman & Silk 1983; Shlosman et al. 1989; Wozniak et al. 1995; Friedli et al. 1996; Jungwiert et al. 1997; Pfenniger 2001). Nevertheless, the results provided by the observations agree that no more nuclear bars are found in Seyfert galaxies (Regan & Mulchaey 1999; Márquez et al. 1999, 2000). But on the contrary there seems to exist an excess of nuclear spirals (Martini & Pogge 1999; Martini et al. 2001; Shlosman & Heller 2002) or nuclear disks (Pogge & Martini 2002) that can be stellar and decoupled from the main galactic disk (Emsellem et al. 2001). Only when the presence of elongations is considered instead of that of a well defined bar, a slight excess (at 2σ level) is found: central region of galaxies hosting HII, Syfert 2, Seyfert 1 and LINER nuclei are progressively less asymmetric (Hunt & Malkan 2004) a result that is interpreted in terms of an evolutionary scenario. Such evolutionary scheme seems to agree with that based on the results of the stellar population synthesis, which appear to be older when going from HII to Seyfert 2 to LINERs (Boisson et al. 2000, 2002, 2004; Frémaux et al. 2006).

3.1. *Isolated galaxies and the DEGAS proyect*

Coming back to the possibility of interactions providing the required asymmetry of the gravitational potential, and in an attempt to clarify the role played by the internal structure of the host galaxies, we started a project devoted to the characterization of ISOLATED Seyfert galaxies and its comparison with a matched control sample of ISOLATED spirals. The project DEGAS (Dynamics and nuclear Engine of Galaxies of Spiral type) was aimed at constructing a sample of nearby Seyfert galaxies from the Véron-Cetty & Véron (1993) catalogue, with intermediate inclinations, with no reported belonging to any group or pair, with no companion at a projected distance of 600 kpc and with redshift difference smaller than 500 km s^{-1}, and with no projected companion in the DSS plates. The control sample was selected from the RC3 catalogue, imposing the same conditions for the absence of companions, and matching in redshift distribution, inclination and morphological type (including the percentage of barred galaxies). The final samples amounted to 18 and 15 Seyfert and control galaxies, respectively.

The main results from the analysis of their NIR J and Ks images were that Seyfert and non-Seyfert hosts shared similar bulges and disk properties (sizes, luminosities and surface brightnesses), but primary bars were also equivalent in both samples; secondary bars were found both in Seyferts (9 out of 12) and control (6 out of 10) galaxies. To characterize the gas kinematics, we obtained long slit spectroscopy along several position angles; the redulting kinematical properties of Seyfert and control galaxies appeared to be indistinguishable from those of early spiral types: same rotation curve shape, same position in the Tully-Fisher diagram, same disk metallicities, same kind of kinematical peculiarities in the central regions (Márquez et al. 2002, 2004).

For deeper investigating how matter gets down into the nuclear region, a subsample was selected to study their morphological properties and the stellar and gaseous kinematics. We characterize the main properties of the host by using optical and/or NIR images from HST. The stellar kinematics was characterized with additional long slit spectroscopy along several position angles in the region of CaT, for obtaining stellar rotation curves and velocity dispersions and a stellar population tracer through the equivalent with of the CaT absorption lines, EW(CaT). Such study allowed us to detect the presence of a stellar velocity dispersion drop in the central 1–3 arcseconds in 5 galaxies, spatially coinciding with an increase in EW(CaT), that could hint the presence of young stars (red supergiants). Nine other galaxies in our sample had previously found to show such a drop. The analysis of the HST imaging of the total 14 galaxies resulted in most of them hosting such a nuclear disk-like structure, spatially coinciding with the region where the velocity dispersion drop and the peak in EW(CaT) occur (Márquez et al. 2003). This result was interpreted in terms of the models by Wozniak et al. (2003), that predict the formation of velocity dispersion drops once the gas coming from the outer, cooler disk, is driven to the center by the large-scale bar effects, giving rise to a decoupled nuclear disk. The gas velocity dispersion is hence smaller, so is that of the stars formed from it. Wozniak & Champavert (2006) have recently updated the results from this modelling, and provided time scales for the whole process (less than 500 Myr for the formation of the drop, and lifetime dependent on the availability of fuel).

4. A GENERAL PICTURE FOR LOW-LUMINOSITY AGN

A relatively recent consensus has been achieved on the presence of a black hole (BH) in the center of any massive galaxy (Magorrian et al. 1998; Ferrarese & Merrit 2000; McLure & Dunlop 2002), irrespective of whether it hosts an AGN or not. In addition, the properties of such BHs seem to be shared by both active and non active galaxies. Both types show the same relationship between the mass of the BH and the mass of the large scale spheroid hosting it (McLure & Dunlop 2004). From the preceding discussion the properties of the host galaxies seem to be equivalent, both morphology and kinematics, at least at scales of the order of the disk, bulge and/or bar components. The differences, if any, have hence to occur at scales much closer to the center, not still resolved by present day observations of the analysed samples. If even at much smaller scales no differences are found, an alternative explanation would be that the AGN activity can be switched on and off. This may be the case explored by the numerical simulations by Bournaud & Combes (2002), that reproduce the evolution of galaxies, moving along and across the Hubble diagram, with any galaxy being able to become barred, or active, or both, and spend some time as an early type or late type.

Nevertheless, a number of complications appear when trying to analyse in depth the different mechanisms related to the fuelling of low-luminosity AGN. Martini (2004) proposed four reasons to explain why surveys have been unsuccessful up to now in resolving this question: (a) the current classifications for fuelling mechanisms are too broad, and additional refining is required, in particular for describing bars, since strong or faint bars are expected to produce different effects, (b) there are correlations between the fuelling mechanism and the fuelling rate, that are easier to identify for higher accretion rates (related to mergers), but deserves much closer inspection of the central parsec region at the lowest accretion rates (where other processes like dynamical friction on molecular clouds, stellar disruptions, many forms of turbulence, mass loss, etc, have an increasing relative importance), (c) multiple fuelling mechanisms may be operating, as it is the case for bars and interactions (but even when only isolated galaxies are considered, as it was the case for the DEGAS project, the results are not conclusive), (d) the two main time scales operating are the AGN lifetime and the fuelling time, so the time dependence is important and has to be taken into account. The analysis therefore requires a broader description of the physical situation of the central regions, and the dynamical information is crucial at this respect.

The approach of the NUGA (Nuclei of Galaxies) consist on a very detailed analysis of the dynamical properties of a sample of nearby active galaxies using, in addition to the morphology, the 2D kinematics of the molecular gas with high spatial resolution. García-Burillo et al. (2005) present such analysis for a small sample of galaxies, which allows them to derive an scenario for self-regulated activity in low-luminosity AGN. An initial asymmetry in the disk would produce the formation of a bar, therefore a nuclear ring, where the infall of gas produced by the bar would accumulate it. When massive enough, this circumnuclear ring would produce auto-destructive effects, weakening the bar, and allowing the viscosity in the ring to be responsible for additional inflow. The process finally ends in an again axisymmetric configuration.

5. FUTURE PROSPECTS

Both the detailed study of nearby galaxies and the statistical approach of massive surveys will be complementary in the study of the relationship between the structure of the galaxy, the environment and the power of the AGN it hosts. On one hand, detailed, high resolution studies of individual galaxies, with the requirement of providing dynamical clues of the different phases are still needed. For nearby galaxies, projects like NUGA are expected to produce fruitful results in the near future. High resolution imaging of a large number of distant galaxies has recently started to allow the exploration of how frequent single or even double bars are at z=0.1

(see Lisker et al. 2006, within the GOODS survey), what opens the possibility of studying evolutionary effects. On the other hand, precious informations remain to be extracted from existing massive surveys like SDSS, in terms of a much more detailed characterization of the morphological types, but also on the presence and strengths of bars (see Ball et al. 2004, 2006 and EFIGI project, Baillard et al. 2006) and the characterization of the interaction state for AGN hosts and for comparable control samples. Finally, focused numerical simulations with all the required ingredients, as those provided by Wozniak et al. for reproducing velocity dispersion drops, both for small (host) to large (environment) scales will help to understand the physical processes that give rise to the presence and onset of AGN activity in galaxies.

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