ACTIVE GALAXIES IN A COMPLETE SAMPLE OF ISOLATED GALAXIES

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INTRODUCTION

Galaxy evolution depends strongly on the environment, in particular, galaxy-galaxy interaction can induce nuclear activity by removing angular momentum from the gas so feeding the central black hole. Hence a higher rate of nuclear activity is expected in interacting galaxies. Different studies of this topic lead to contradictory results. Some works conclude that galaxies hosting an active galactic nuclei (AGN) have a higher rate of companions than non active ones (Petrosian 1982, Dahari 1985, MacKenty 1989, MacKenty 1990, Rafanelli 1995). On the other hand other studies do not find this excess of interacting companion or find it only marginally (Bushouse 1986, Fuentes-Williams 1988, Laurikainen 1995). Most recent works find a different result depending on the type of Seyfert galaxy (Dultzin-Hacyan 1999, Krongold 2003).

To understand the role of the environment in evolution and galaxy properties like the interestelar medium (ISM), start formation and, in particular, nuclear activity we need a statistically significant sample of isolated galaxies. This sample is provided by the **AMIGA projet** (Analysis of the interstellar Medium of Isolated Galaxies; Verdes-Montenegro et al. 2005). The sample is based on the CIG catalog (Karachentseva 1973) and the data base includes blue luminosity, near-infrared luminosity, far-infrared (FIR) emission, atomic gas (HI) emission, radio continuum, and, for a red-shift limited subsample of 200 galaxies, CO and Ha emission.

One of our main goals is the study of the triggering of nuclear activity in non-interacting galaxies using different methods. We will focus on the well known radiocontinuum-FIR correlation in order to find radio-excess galaxies **(radio-excess selection)** which are candidates to host an active galactic nucleus (AGN). We also use the FIR color **(IRAS color selection)** to find obscured AGN candidates. We have looked for the existing information on nuclear activity in the Véron-Cetty catalogue and in the NASA Extragalactic Database (NED) **(literature data)**. Finally we have produce a **final catalogue** of AGN candidate galaxies which will provide a baseline for the study of the nuclear activity depending on the galaxy-galaxy interaction.

AMIGA PROJECT

The AMIGA (Analysis of the interstellar Medium of Isolated GAlaxies) sample (Verdes-Montenegro et al. 2005) has 1050 galaxies based on the Catalogue of Isolated Galaxies (Karachentseva 1973) with a refinement in the positions, morphologies, redshifts and isolation criteria. This is a multi-wavelength database to compare and discuss the properties of different phases of the ISM in a complete local sample of isolated galaxies.

The data is being released and periodically updated at **http://www.iaa.es/AMIGA.html**

Refinement:
- Positions (Leon & Verdes-Montenegro 2003).
- Morphologies (Sulentic et al. 2006 in press).
- Redshifts.- Redshift for 987 galaxies.
- Isolation criteria (Verley et al. 2006a in prep).

Multiwavelength:
- L_B (Verdes-Montenegro et al. 2005)
- Hα (Verley et al. 2006b in prep).
- FIR (Lisenfeld et al. 2006 in prep).
- HI (Espada et al. 2005; Espada et al. 2006 in prep).
- CO (in prep).
- Radiocontinuum (Leon et al. 2006 in prep).

Table 1. Galaxies with activity from the literature[1].

CIG	NED	V-C[2]
33	Sy? LINER	Sy?
45	HII	
55	LINER HII	
56	Sbrst	
57	Sy2	Sy2
...	...	...

[1] Available in electronic form at CDS and http://www.iaa.csic.es/AMIGA.html
[2] Sy = Seyfert; HII = Nuclear HII region; Sbrst= Starburst; SBNG = Small, Bright Nucleus Galaxy; NLAGN = Narrow Line Active Galaxies (a mixture of Seyfert 2's, LINERs, and starburst/AGN composites); DANS = Dwarf Amorphous Nuclei Starburst Galaxies

Table with the literature selected galaxies

LITERATURE DATA

We have done a cross-correlation of our sample with existing databases of active galaxies:

- The **NED** (NASA Extragalactic Database) database: Information on activity type (Seyfert, LINER, starburst, HII...). 76 galaxies found, 24 of them AGNs
- **Véron-Cetty** [Véron-Cetty y Véron 2003] Active galaxies catalogue. 11th edition. Information on Seyfert type. 27 galaxies found, 21 of them AGNs

THE DATA & THE SAMPLE

Far Infrared (FIR) is the thermal emission re-radiated by dust grains warmed up by radiation from young stars and the AGN. We have FIR data for 1030 galaxies of our sample, obtained from the IRAS satellite (Lisenfeld et al. 2006 in prep).

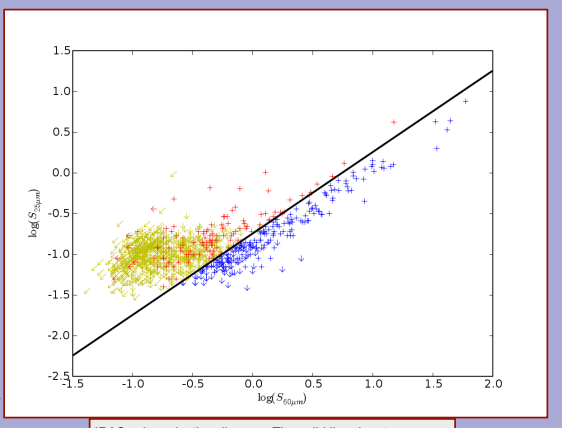
Radiocontinuum data come from three different sources: a) Westerbrock Northern Sky Survey (WENSS, 325 and 352 MHz), b) NRAO VLA Sky Survey (NVSS, 1.4 GHz) and Green Bank 6 (GB6, 4.85 GHz). Leon et al. 2006 in prep). We use NVSS data because it has the best detection rate and sensitivity and this survey contains all the galaxies belonging to our sample. The frequency of the observations is 1.4 Ghz.

Completeness of the sample: We have used a completeness test known as $\langle V/V_m \rangle$ as explained in (Verdes-Montenegro et al. 2005). We adopted m=15.0 as the cutoff magnitude necessary to have a reasonably complete sample. The complete subsample contains 736 galaxies.

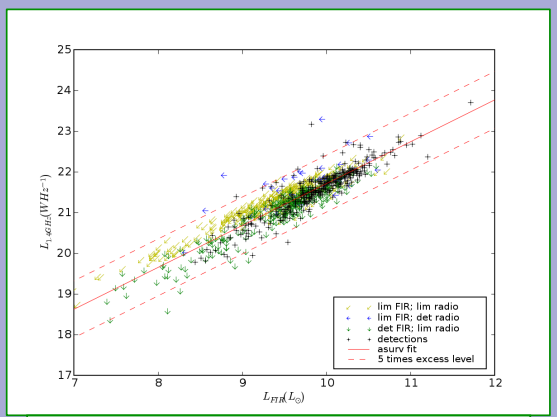
IRAS COLOR SELECTION

In the work of de Grijp et al. 1985 is shown a method to identify AGN candidates using FIR properties. Galaxies hosting an AGN have, in general, a flatter spectrum in FIR. This is due the hotter temperatures of the dust warmed by the central engine. The advantage of the method is that it can find obscured AGNs that can not be observed using other wavelengths or methods. The success rate of the method is about 70%. We select the galaxies with an spectral index between 25 μm and 60 μm of $\alpha_{25\,\mu m,60\,\mu m} > -1.958$.

We plot in the figure $\log(S_{25\mu m})$ versus $\log(S_{60\mu m})$. The spectral index of -1.958 is plotted as a black line. Galaxies above the line can be identified as AGN candidates. The crosses denotes detected data and the arrows are the upper limits. Finally we find 110 galaxies located above the line which are the AGN candidates of the total sample. There are **89 AGN candidates** for the complete sample. This is 12.3 % of the sample.



IRAS color selection diagram. The solid line denote an spectral index of -1.958. The red crosses and arrows are the galaxies selected as AGN candidates using this method.



Radio/FIR luminosity graph. We show the correlation as a solid line and the 5 times radio-excess and FIR-excess level as dashed lines. The galaxies above the upper dashed line are the radio-excess galaxies.

RADIO-EXCESS SELECTION

Radiocontinuum-Far Infrared correlation

One of the tightest correlations in astrophysics is the one between the FIR and the radiocontinuum emission. This correlation is produced by the stellar formation (Condon 1991). This correlation is broken if a strong radio emission exist from an radio-loud active nucleus.

We use survival analysis methods to compute the correlation. The Schmitt method (Schmitt 1985) allow us to use the information carried by the upper limits.

$\log[L_{1.4\ GHz}(W\ Hz^{-1})] = \mathbf{[1.03\pm0.03]}\ \log[L_{FIR}/L_{\odot}] + \mathbf{[11.4\pm0.3]}$

$\log[L_{1.4\ GHz}(W\ Hz^{-1})] = \mathbf{[0.96\pm0.04]}\ \log[L_{60\mu m}/L_{\odot}] + \mathbf{[12.5\pm0.4]}$

In both cases the slope is close to 1 within the error. This confirms the linearity of the radio-FIR correlation for our sample.

Radio-excess galaxies are the ones whose radio luminosity is larger than 5 times the value predicted by the radio-FIR correlation (Yun et al. 2001).

There are 8 radio-excess galaxies in the complete sample (n=726) which amount 1.1% of the sample. This is a very low rate.

Q parameter

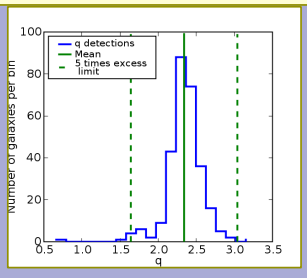
The q-parameter (Helou 1985) is a good estimator of the deviation from the radio-FIR correlation. It has been found to be independent of the starburst strength (Lisenfeld et al. 1996) and distance (Yun et al. 2001). It is defined as:

$$q \equiv \log\left(\frac{FIR}{3.75\cdot10^{12}Wm^{-2}}\right) - \log\left(\frac{S_{1.4GHz}}{Wm^{-2}Hz^{-1}}\right)$$

$$FIR = 1.26\cdot10^{-14}\left(2.58S_{60\mu m} + S_{100\mu m}\right)Wm^{-2}$$

We have computed the q parameter with the galaxies detected either in FIR and in radiocontinuum (n = 288). In the figure is shown a histogram of the q parameter. The **mean value is 2.34** with a sigma of 0.24. Radio-excess galaxies are located in the left tail of the histogram with lower q values. There are 4 over 288 which are 1.4% of the galaxies studied. This result is consistent with the study of the luminosities using upper limits.

q parameter histogram. The mean is shown with a solid line and the 5 times excess as dashed lines. Radio-excess galaxies are located in the left tail of the histogram with lower q values.



FINAL CATALOGUE AND CONCLUSIONS

In this work we have produced a catalogue of AGN candidates for the CIG sample. Therefore we can study nuclear activity in a complete low density well defined sample of isolated galaxies. This catalogue will be the baseline for forthcoming studies about nuclear activity-environment relation.

The **final catalogue** is composed by the active galaxies found in the NED and the Véron-Cetty catalogue (n=26), the radio-excess galaxies selected using the FIR-radiocontinuum correlation (n=10) and the AGN candidates selected using the IRAS color criteria (n=110) . The catalogue will be available in the AMIGA project web page.

The activity rate derived from the radio-FIR correlation is very low (1.1%) in comparison with denser environments. This shows us how **environment is fundamental for the nuclear activity**.

http://www.iaa.es/AMIGA.html

ONGOING AND FUTURE WORK

- Ongoing paper with the results (Sabater et al. 2006 in prep).
- Determination of the presence of a compact nucleus in radio-excess galaxies: VLA (observation & archive) and FIRST catalogue.
- Verification of activity using:
  - Interaction tracers (isolation parameter, HI asymmetries, etc.).
  - Galactic properties (morphology, presence of a bar, etc.).
- Study of the physics of AGN - Interstellar medium interaction (observing CO(1-0), CO(2-1), HCN, SiO).
- Relationship between activity and near infrared properties.