AMIGA Project. Radio Continuum and Nuclear Activity in a Complete Sample of Isolated Galaxies.

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Abstract The aim of the AMIGA project (Analysis of the interstellar medium in isolated galaxies) is building a reference sample of isolated galaxies to study the role of the environment in galactic evolution. AMIGA began in 2003 and nowadays involves more than 30 participants from 15 international institutions. Radio continuum emission in isolated spiral galaxies is coming from disk-dominated emission in spiral galaxies, in contrast to the results found in high-density environments where nuclear activity is more frequent. The radio continuum power is lower on average in our sample than in interacting galaxies or galaxies without an environment selection criterion. This confirms the relevance of our sample as a baseline to study the effects of the environment. Finally, we have studied the nuclear activity in isolated galaxies. We used different selection methods of isolated galaxies with active nucleus: 1) the far infrared colours give us a fraction of 7 % to 20 % of AGN candidates and 2) the rate of radio excess galaxies in the correlation of far infrared with radio continuum is less than 1%, which is the lowest rate found comparing with samples in other environments. This confirms the role of the environment as fundamental in the triggering of the radio nuclear activity.

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1 The AMIGA project

In order to understand the role of the environment in the evolution and properties of galaxies like the interestelar medium (ISM), star formation and, in particular, nuclear activity we need a statistically significant sample of isolated galaxies. The AMIGA (Analysis of the interstellar Medium of Isolated GAlaxies)[1] sample [11] used as a starting sample the 1050 galaxies belonging to the Catalogue of Isolated Galaxies [3] with a refinement in the positions, morphologies, redshifts and isolation criteria. We built a multi-wavelength database in order to compare and discuss the properties of different phases of the ISM in a complete local sample of isolated galaxies. We used a completeness test known as $\langle V/Vm \rangle$ as explained in Verdes-Montenegro et al. (2005) obtaining a complete subsample which contains 719 galaxies. We have: 1) revised all of the CIG positions [4]; 2) optically characterised the sample [11]; 3) performed a revision of the morphologies [10]; 4) derived mid-infrared (MIR) and FIR basic properties [6]; 5) performed a careful reevaluation of the degree of isolation of the CIG [12, 13]; and 6) derived radio continuum properties [5]. 7) study of the radio continuum and far infrared nuclear activity [8].

We will present the results for the last two studies.

2 Radiocontinuum

The study of the radio properties of the AMIGA sample is intended to characterize the radio continuum emission for a sample less affected by the local environment to provide a control sample for galaxies in denser environment.

Radio continuum data at 325, 1420 and 4850 MHz were extracted from the WENSS, NVSS/FIRST and GB6 surveys, respectively. The source extractions have been obtained from reprocessing the data and new detections have been added to the cross-matched detections with the respective survey catalogs. We focus on the complete AMIGA subsample composed of 719 galaxies.

From the above four surveys a catalog of radio fluxes was obtained. Comparison between the NVSS and FIRST detections indicates that the radio continuum is coming from disk-dominated emission in spiral galaxies, in contrast to the results found in high-density environments where nuclear activity is more frequent (see Fig. 1). We also found the sample of isolated galaxies to have the lowest mean of radio continuum power comparing with a similar sample of galaxies but not selected with respect to its environment. The Schechter fit of the radio luminosity function indicates a major weight of the low-luminosity galaxies.

[1] http://www.iaa.es/AMIGA.html

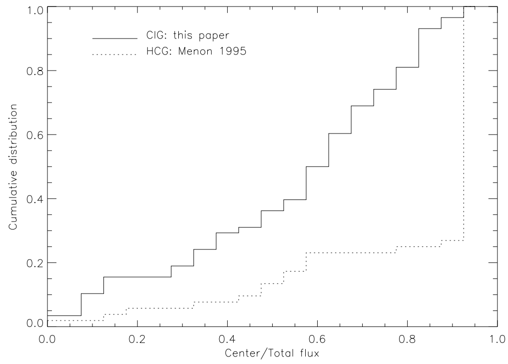

Fig. 1 Cumulative distribution of the FIRST/NVSS flux ratio for the AMIGA isolated galaxies (CIG; solid line) and the center/total flux ratio (dotted line) from Menon 1995 [7]. Source: S. Leon et al. 2008

3 Active Galactic Nuclei selection

We have made a catalogue of AGN candidates of isolated galaxies looking for data in the literature and using two selection methods: IRAS color and radiocontinuum-FIR correlation radio excess [8].

We have done a cross-correlation of our sample with: a) The NED (NASA Extragalactic Database) database: 77 galaxies found, 22 of them AGNs and b) Véron-Cetty & Véron (2006; [14]) active galaxies catalogue (12th edition): 25 galaxies found, 18 of them AGNs.

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 [1] and is broken if a strong radio emission exist from an radio-loud active nucleus. We use survival analysis methods [9] to compute the correlation, obtaining $\log L_{1.4GHz}(W\ Hz^{-1}) = [1.02 \pm 0.03] \log(L_{FIR}/L_{\odot}) + [11.4 \pm 0.3]$ (see Fig. 2). Radio-excess galaxies are the ones whose radio luminosity is larger than 5 times the value predicted by the radio-FIR correlation [15]. There are 6 radio-excess galaxies in the complete sample (n=710) which amount 0.8% of the sample. This is a very low rate.

In the work of de Grijp et al. [2] it 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 to 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 a spectral index betwen $25\mu m$ and $60\mu m$ of $\alpha_{25,60} > -1.958$ as shown in Figure 3. There are 58 AGN candidates for the complete subsample.

Studies of the radio power and FIR emission of galaxies have been performed mostly for two kinds of samples: those referred to as field galaxies in the literature where usually no environmental selection criterion was applied, and cluster samples (see table 1). The comparison shows that the AMIGA sample has the lowest ratio of radio-excess galaxies, both globally and separated into early and late types.

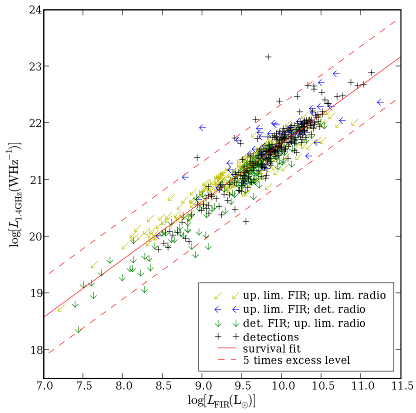

Fig. 2 Radio versus FIR luminosity for the complete subsample ($n = 710$). We show the correlation as a solid line and the 5 times radio-excess and FIR-excess levels as dashed lines. The galaxies above the upper-dashed line are the radio-excess galaxies. Source: J. Sabater et al. 2008

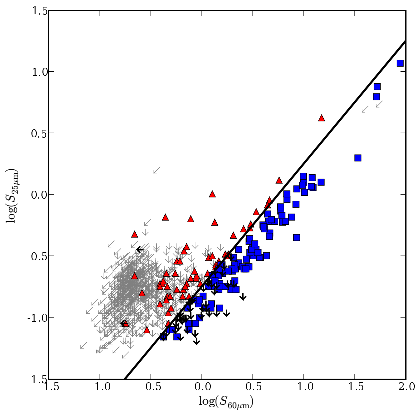

Fig. 3 Plot of $\log S_{25\mu m}$ versus $\log S_{60\mu m}$ for the total sample ($n = 1030$). The solid line corresponds to $S_{25\mu m}/S_{60\mu m} = 0.18$. Galaxies classified as AGN-candidates lie above this line and are plotted as triangles and black left-arrows. Galaxies classified as non AGN-candidates are below the line, plotted with squares and black down-arrows. The remaining galaxies can not be classified due to upper limit in the fluxes (grey arrows). Source: J. Sabater et al. 2008

4 Conclusions

- Our sample is mostly radio quiet, with most galaxies (98.6%) having radio powers lower than 10^{23} W Hz^{-1}, consistent with the high ratio of late-type galaxies in our sample.
- Radio continuum is coming from disk-dominated emission in spiral galaxies, in contrast to the results found in high-density environments where nuclear activity is more frequent.

Table 1 Rate of radio-excess galaxies in the literature.

		Rate of Radio-excess galaxies[1]								
		Total			E-S0a			Sa-Irr		
Sample	Environment	N[2]	F5[3]	F3[3]	N[2]	F5[3]	F3[3]	N[2]	F5[3]	F3[3]
AMIGA[4]	Isolated	397	0.8	4.0	21	4.7	19.1	376	0.5	2.1
Condon 1991	-	122	32.0	33.6	11	90.9	90.9	71	9.9	12.7
Yun 2001	-	1809	1.3	-	-	-	-	-	-	-
Corbett 2002	-	82	2.4	4.9	-	-	-	-	-	-
Condon 2002	-	1897	8.2	10.8	287	42.2	51.6	1498	2.1	3.4
Drake 2003	-	178	55.1	60.7	-	-	-	-	-	-
Omar 2005	Eridanus group	72	2.8	2.8	20	5.0	5.0	46	2.2	2.2
Niklas 1995	Virgo cluster	37	-	16.2	2	-	0.0	35	-	17.1
Andersen 1995	Cluster & group (poor)	23	8.7	21.7	-	-	-	-	-	-
	Cluster & group (rich)	20	15.0	25.0	-	-	-	-	-	-
Miller 2001	Clusters $0 < r < 1$ Mpc	120	28.3	37.5	54	46.3	53.7	53	3.8	17.0
	Clusters $1 < r < 2$ Mpc	96	21.9	29.2	23	60.9	73.9	50	6.0	10.0
	Clusters $2 < r < 3$ Mpc	94	6.4	12.8	19	26.3	31.6	47	0.0	4.3
Reddy 2004	X-ray clusters	114	13.2	19.3	33	30.3	45.5	81	6.2	8.6
	X-ray clusters core	33	24.2	39.4	15	40.0	66.7	18	11.1	16.7
	X-ray clusters ring	81	8.6	11.1	18	22.2	27.8	63	4.8	6.3

[1] The percentages are computed over the number of galaxies for each morphological subsample.
[2] Number of galaxies in the total samples or the morphological subsamples.
[3] F3: factor 3 radio excess; F5: factor 5 radio excess. Figures given in percentages.
[4] All percentages for the fraction of radio-excess galaxies are upper limits as explained in Sect. 2.

- We have selected radio-excess candidate galaxies above the radio-FIR correlation for our complete subsample, and revised the results using FIRST data to exclude back/foreground sources. We find less than 0.8% radio-excess galaxies with an excess of a factor 5 and less than 4.0% for a lower excess of a factor 3.
- Using the IRAS flux ratio $S_{25\mu\mathrm{m}}/S_{60\mu\mathrm{m}}$ to select AGN candidates we find a frequency of AGN candidates of $< 28\%$ with a lower limit of $< 7\%$.
- From NED and the Véron-Cetty catalogues, we found $n = 29$ AGN candidates (including LINERs and NLAGN).
- The final catalogue contains a total of 89 AGN candidates. This catalogue is available in electronic form at the CDS[2] and at the AMIGA web page[3].

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[2] ftp://cdsarc.u-strasbg.fr/
[3] http://www.iaa.csic.es/AMIGA.html

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