A GALAXY BASELINE: Multiwavelength Study of a Sample of the Most Isolated Galaxies in the Local Universe

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Abstract We introduce and describe main results of the AMIGA project. AMIGA involves a panchromatic characterization for many of the most isolated galaxies in the local Universe. Many of these galaxies have avoided major interaction events for all, or most, of their lives. Our studies show these galaxies to be the most IR/radio/optically ”quiet” sample that is known. AMIGA data is publicly released under a VO interface at http://amiga.iaa.es/ and are also accesible by standard VO tools, as e.g. TOPCAT.

1 Introduction

The AMIGA project (Analysis of the interstellar Medium in Isolated GAlaxies, http://www. iaa.csic.es/AMIGA.html; [31]) is focused on identifying a statistically-significant sample of the most isolated galaxies in the local Universe. A major goal is to quantify properties of the interstellar medium in these galaxies and the environmental relationship to star formation (SF) and nuclear activity. The AMIGA results fir naturally within the context of this conference representing the galaxy sample least masked by galaxy evolution. Like the San People of Namibia (the host country of this conference), AMIGA galaxies constitute the best footprints of the ancestors. But why is a sample of isolated galaxies needed? Observational evidence for the

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interaction-enhancement connection is difficult to establish quantitatively. The involved processes and their amplitudes are not well measured or understood: e.g. 1) pairs show a star formation excess but no HI deficit [37, 38], 2) Hickson Compact groups show morphology changes and HI depletion, but no excess SF, [33, 14, 3], 3) dependence of nuclear activity on environment is confused [7, 19, 25, 2] as well as 4) the enhacement of molecular gas in interacting samples [5, 26, 32, 22]. On the other hand most definitions of ”normal” or ”isolated” in the literature are ambiguous, e.g. field samples [17] might include any galaxy not belonging to a cluster, so galaxies in pairs, triplets and loose/compact groups would not necessarily be excluded. In other cases galaxies without velocity data are not considered companions [16]. When a well defined isolation criterion is used, the largest samples of isolated galaxies in the literature in most cases involve monochromatic observations of subsamples from the Catalog of Isolated Galaxies (CIG: [15] [31] and references therein). The CIG catalogue constitutes the starting point for the AMIGA project.

2 AMIGA sample description and revisions

We began with the CIG because of its numerous strengths: 1) Size: the sample is composed of n = 1050 galaxies, 2) Isolation: no similar sized galaxies (factor 4) lie within 20 times the diameter of the companion, likely containing many of the most isolated galaxies in the local Universe, 3) Morphological diversity, 4) Depth: the CIG samples a large enough volume of space to allow sampling the majority of the optical luminosity function, 5) Completeness: between 80 – 95% brighter than 15.0 mag. Complementarity also extends to existing multiwavelength data for the CIG (e.g. [1],[12], [37]). We are building upon those foundations by: refining the basic catalog, utilizing new multiwavelength databases and obtaining new radio and optical measures.

In previous works we revised all of the CIG positions [23] and compiled redshift/distances for more than 90% of the sample. We also performed an optical characterisation of the sample [31], but our two largest refinements involved uniform reevaluation of isolation degree and morphology.

2.1 Isolation revision

In [34] and [35] we processed large digitised POSS-I fields for 950 galaxies from the CIG and evaluated their degree of isolation down to $m_B \sim 17.5$ within a projected radius R$\geq$0.5 Mpc. Pairs that remained in Karachentseva’s revision were rejected while minor interactions were quantified, either calculating the local surface density or the external tidal force affecting each galaxy. Hence we defined various subsamples of galaxies according to their degree of isolation. The same parameters were calculated for samples of triplets, compact groups and clusters for comparison.

2.2 Morphology Refinement

We used the digitized POSS2 for a uniform revision of optical morphologies [28]. This allowed us to exploit the high resolution and dynamic range of the photographic emulsions used for that survey. About 20% of galaxies in the catalog (n = 193) were flagged for the presence of nearby companions or signs of distortion likely due to interaction, and this subsample is treated separately in our subsequent studies. The dominant (2/3) CIG subsample involves late-type Sb-Sc spirals while 14% of the sample is classified as early-type and distributed approximately equally between elliptical and lenticular galaxies. We have identified the most nurture free population of E's which appear to be less luminous even than those found in less restrictive field samples. These are perhaps the best candidate population of primordial, or at least minimally nurtured, early-type galaxies.

3 Detailed morphological study of selected subsamples

More recently [8] and [9] presented surface photometric and Fourier analysis of a representative 'prototypical' isolated sample of 100 Sb-c galaxies from the vetted CIG (M_i= -19 to -23) exploiting SDSS images. This structural analysis showed that most isolated galaxies in our sample: 1) likely host pseudobulges rather than classical bulges (bulge/total flux ratios were found to lie B/T$\leq$ 0.2 with Sersic indices generally $n_{BULGE} \leq 2.5$), and 2) host longer bars, are more symmetric, less concentrated and less clumpy than less isolated samples such as OSUBGS (Ohio State University Bright Galaxy Survey; [10]) or CSRG sample (Catalog of Southern Ringed Galaxies [6]) sample.

We obtained Hα and Gunn r photometric data for more than 200 spiral galaxies from AMIGA. in order to separate the effects of local environment from internal dynamical processes. The 45 largest and least inclined galaxies were selected for morphological study including the modes of spiral structure as well as bar strength. We also estimated the torques between gas and the bulk of the optical matter using Fourier analysis [36]. We concluded that isolated galaxies do not appear to be preferentially barred or unbarred. Comparison of the Hα distributions with the results of numerical simulations helped to set constraints on the SF law, which is likely to differ from a genuine Schmidt law. The frequently observed phenomenon of star formation avoiding the bar, in spite of large gas density there, suggests that it is probable that the relative velocity of the gas in the bar also needs to be taken into account.

4 FIR emission, radiocontinuum emission and nuclear activity

We studied IR emission properties of the AMIGA sample [21] since MIR/FIR emission are regarded as sensitive interaction diagnostics. The 4 IRAS bands were coadded for 1030 CIG galaxies increasing the archival signal-to-noise ratio by a factor 3-5. The complete sample was used for characterization of the LFIR-LB correlation as a reference for evaluating IR properties of interacting samples. Galaxies suspected interacting in [28] were excluded. Only 2% of the galaxies showed log(LFIR) $>$ 10.5 Lsol. Comparison with 2445 galaxies from the magnitude limited CfA sample, selected without environmental discrimination, showed a significantly higher mean log(LFIR), $<$log(LFIR)CfA$>$ = $<$log(LFIR)AMIGA$>$ + 0.26, whereas the mean log(LB) was the same as the AMIGA sample. The galaxies flagged as interacting lie above this correlation showing a systematic enhancement in LFIR.

Radio continuum data at 325, 1420, and 4850 MHz were extracted from the WENSS, NVSS/FIRST, and GB6 surveys [20]. Comparison between NVSS and FIRST results indicate that radiocontinuum emission in AMIGA spirals is disk-dominated and likely driven by low to moderate star formation. In contrast compact groups members show an excess of nuclear radio emission. Furthermore, the derived radio luminosities for detections reveal a very radio-quiet sample, with most detections showing radio/optical luminosity ratios R=1-10.

We also considered the radio - FIR correlation for our sample in order to study nuclear activity in non-interacting galaxies ([27]. We searched for radio-excess galaxies which are candidate AGNs and FIR colours to find obscured AGN candidates. There are no radio-excess galaxies in our sample above a factor 5 of radio excess, which is the lowest rate found in comparison with other samples in denser environments. We conclude that the environment plays a crucial and direct role in triggering radio nuclear activity and not only via the morphology-density or the density-luminosity relations. We also used SDSS nuclear spectra for AMIGA galaxies to search for spectroscopic signatures of AGN and to study the properties of the underlying stellar populations. We produced a final catalogue of AGN-candidate galaxies indicating 22% as an upper limit for the AGN fraction. We are currently studying this rate for samples with higher environmental densities in the bibliography, with a special care to perform the analysis in exactly the same way, in order to avoid biased results.

5 Atomic gas

We also explored properties of the cold gas in AMIGA galaxies using HI data for $\sim$ 800 galaxies which is about three times more than the classical study by [18]. We presented the preliminary results in [11]. We have also quantified the degree of asymmetry of the HI single dish profiles, and revised the results from the bibliography suggesting that more than half of the galaxies present a perturbed HI independently of the environment ([29],[13],[24],[30],[4]). Our study shows that AMIGA

exhibits the lowest HI asymmetry level in the local Universe. We found that field samples present an excess of $\sim$ 20% more asymmetric HI profiles than those in CIG. Still a small percentage of galaxies in our sample present large asymmetries. We have started a follow-up of isolated and asymmetric systems using high resolution VLA and GMRT maps give insight into the origin of such asymmetries.

6 Concluding remarks

We suggest that the size of AMIGA sample and the strength of the isolation criterion make it the optimal statistical reference sample for studying the low density tail of the two-point correlation function and/or morphology-density relation. The AMIGA vetted CIG is the largest compilation of the most isolated galaxies in the local Universe. Other samples in the bibliography appear to contain more luminous early-types and spirals with large bulges than found in the CIG. The fact that we find differences with other samples at optical, FIR, radiocontinuum, and HI wavelengths argues that these galaxies have spent most of their lives in relative isolation. The low luminosity early-type fraction and the large fraction of small bulge spirals cannot have experienced major nurture events (i.e. mergers) in their lives. This is the closest we are likely to come to identifying a population of galaxies whose properties are dominated by nature rather than nurture.

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