AMIGA project

Analysis of the interstellar Medium of Isolated Galaxies

L. Verdes-Montenegro
Instituto de Astrofísica de Andalucía (IAA - CSIC)

International collaboration with > 30 researchers
from > 15 institutes
2PhDs finished, 3 more 2008, 1 by 2010
Either no real isolation definition:

FIELD galaxies (e.g. Kennicut & Kent ’83)
NORMAL galaxias (e.g. Boselli et al ’01)
Galaxies with no v-data not considered companions
(Kelm & Focardi ’04: isolated w.r.t. companions brighter than 15.5mag)

Or if well defined:

Monochromatic observations of large samples/
multiwavelength observations of small samples

10 – 100/200 members

(Huchra & Thuan ’77, Vettolani et al ’86, Márquez & Moles ’99, ’00,
Colbert et al ’01, Pisano et al ’02, Varela et al ’04)
GOALS

To **build** a catalogue of isolated galaxies:
- Well defined (isolation, completeness)
- Statistically significant
- With multiwavelength information (main focus ISM)

To **analyse** the catalogue:
- Multiwavelength characterization: ISM – SF – AGN
- Environmental level where interaction effects 1st detected
- Comparison with denser environments

To **make it public** for “self-service” use
THE SAMPLE

Amiga is a refinement of CIG: Catalogue of Isolated Galaxies (Karachentseva 1973)
Selected from CGCG (Zwicky) with mpg < 15.7 δ > -3

Strength:

- **Size**: 1050 galaxies
- **Isolation**: no similar sized galaxies (factor 4) within 40*R(companion) -> last interaction several Gyrs ago
- **Morphology**: permits discrimination based on types.
- **Depth**: large volume to allow sampling of the OLF.
- **Completeness**: 80-90% up to mZw(corr) = 15.0
PREVIOUS AND ON-GOING WORK

Revision of CIG:
- Positions
- Degree of isolation
- Optical characterization
- Morphological revision + OLF/types

Multiwavelength study:
- MIR and FIR properties using IRAS data ~ 1000 gal
- Radio-continuum emission
- Radio-FIR for radio-AGNs selection
- SDSS spectra for optical AGNs selection
- Hα + R (200 galaxies): study of bars ~ 50 gal
- Atomic gas: content and profiles ~ 1000 gal
PREVIOUS AND ON-GOING WORK

Exploitation: best candidates for a detailed study
- Tests of galaxy formation models with isolated galaxies
  Characterization of the neighborhood using SDSS/DR8
  Populations of globular clusters (GCs) with VLT & GTC
- Conditions for secular SF/AGN in isolated galaxies
  Physico-chemical conditions of the molecular gas
  SF in the outer parts of disks (XUV disks)
  SF in the inner parts of disks
  Origin of asymmetries in isolation
  • All details in AMIGA new Web Page
    VO interface with search utilities
PREVIOUS AND ON-GOING WORK

- Revised positions for CIG galaxies.

- The AMIGA project I. Optical characterization of the CIG catalog

- II. Morphological refinement. PhD on-going

- III. IRAS data and infrared diagnostics.
  Lisenfeld 2007 A&A 462,507-523

- IV. A catalogue of neighbours around isolated galaxies. PhD 2005
V. Quantification of the isolation. **PhD 2005**
Verley et al 2007 A&A 472, 121-130

VI. Radiocontinuum properties
Leon et al 2008, in press A&A

VII FIR and radio continuum study of nuclear activity. **PhD 2008**
Sabater et al 2008, in press A&A

- Star formation in isolated AMIGA galaxies: dynamical influence of bars **PhD 2005**
  Verley et al 2007 A&A 474, 43-53

- The large asymmetric HI envelope of the isolated galaxy NGC 864 (CIG 96) **PhD 2006**
  Espada, 2005 A&A, 442,455
REFINEMENT

- Positions revised for full CIG  (Leon & Verdes-M 2003)
- Redshifts/distances: Archival + bib:  989/1050 (+501)
- Optical  (Verdes-M et al 2005)
  - Completeness evaluation V/Vm test: ~ 90% to m = 15
  - OLF derivation: global + morphologies
    - E/S0s fainter than in field samples, low dens. env.
- Morphologies: large disagreements LEDA vs NED
  - Complete uniform revision (POSS II + SDSS + CCD)
  - Started PhD: A. Durbala (director: J. Sulentic)

100 Sb-Sc, 1500 < v < 10000 km/s m_B<15 i < 70°
FT and CAS parameters of SDSS-i images  PhD 2008
Karachentseva (1986): visual examination of plates

Our revision:

- POSS-I & II, R >=0.5 Mpc, m_B<17.5
- Reduced with AIMTOOL/LMORPHO (Odewahn ’95, ’96)
- Star/galaxy separation
- Catalog of all potential companions: 54,000 positions, magnitudes, areas, v when available
  (30% with v from 12 catalogues)
- Checked Karachentseva’s criterium:
  Neighbours statistically a background population
  Factor 4 size = Δv 20000 km/s: very restrictive
REFINEMENT: Isolation

- Quantification: CIG, 41 triplets, 34 groups, 15 clusters:
  - Local number density $\eta_K$
  - Tidal force estimation $Q$
- Higher parameters
  - Failing Karachentseva’s
  - Flagged as optically distorted
    Sulentic et al. (2006)
- Final revised catalogue, $n = 791$
  - $Q \geq -2$ (1% binding forces)
  - $\eta_K > 2.4$
- Next step: analysis of SDSS DR6

Search by these parameters enabled in our VO interface

(Verley PhD; Verley et al 2007ab)
MULTIα STUDY: FIR emission

- Existing samples are biased toward bright FIR
- 4 IRAS bands coadded for 1030/1050 CIG (vs previous 524)

- Strong LFIR-LB correlation, baseline for interacting samples
- \( \log(L_{\text{FIR}}) : \text{only 2\% >10.5 } L_{\text{sol}}. \)
- Comparison with 2445 galaxies of CfA sample:
  \[ \langle \log(L_{\text{FIR}})_{\text{CfA}} \rangle = \langle \log(L_{\text{FIR}})_{\text{AMIGA}} \rangle + 0.26 \]

FIR emission is a variable enhanced by interaction

AMIGA: **lowest possible mean value**, nurture-free zero point

(Lisenfeld et al 2007)
Comparison NVSS vs FIRST @21cm, Radio/LB (R)
- disk-dominated SF vs nuclear for high-dens. Env.
- less than 3% of the sample with R > 100 (AGN) (Leon et al 2008, in press)

Radio-FIR correlation to select radio-excess galaxies
< 0.4% of radio-excess galaxies
All types increase with environment density
Higher in early types for all environments

Environment and not only density-morphology relation
Isolated E/S0 show a particularly low level of radio-activity

Next step: analysis of SDSS spectra of 300 CIG
MULTIA STUDY: Globular clusters

- Study of GCs population in isolated galaxies
  - LF beyond turn-over, shape, different pops, dynamics
- Pre-imaging BVR 18 CIGs @WHT, INT, 2.2m&3.5m@CAHA, NOT
- 6 hours @VLT with FORS2

- GCs in Leo I: std DM & rotation
  (Bergond et al 2006, A&A 448, 155)
- Study of ICGCs in Fornax: infalling
- BH detection in GC in Virgo
  (Bergond et al 2007, in press in A&A)

PNe with 3D-NTT?
MULTI A STUDY: Globular clusters

- $v < 2000$ km/s 4'x4' ~30 kpc radius
- Abs. Mag 5007A -4.5
- [OIII] 4959 & 5007
- Comparison PNe (Pop I) with GCs (Pop II)
MULTIα STUDY: Molecular & Ionized gas

- Complete reference sample for $M(H_2)$ and $H\alpha$, $f(LB, \emptyset, t)$
  - CO single dish for 205 galaxies $1500 < v < 5000$ km/s
    * IRAM 30m, FCRAO, Nobeyama 470h
  - $H\alpha+r$ images for 205 galaxies $1500 < v < 5000$ km/s
    * 120 nights 1.5m@OSN, 2.2m@CAHA, 1.5m@CAHA, 1.0@JKT, 1.5@SPM

- $H\alpha$ luminosity function: SF as a function of the environment
- HII regions size and L distribution
- SF in the inner parts of galaxies

PhD Simon Verley (Advised by F. Combes, LVM)
SF in the inner parts of galaxies

- Frequency and origin of bars: 45 largest and low i galaxies
  - 42% - E: strong central peak, no Hα in bar but at the end

CIG 1001 = NGC 7428
SF in the inner parts of galaxies

- Frequency and origin of bars: 45 largest and low $i$ galaxies
  - 20% - F: smoother morphology, no central emission in H$\alpha$

CIG 808 = UGC 10862
SF in the inner parts of galaxies

- Frequency and origin of bars: 45 largest and low $i$ galaxies
  - 18% - $G$: H$\alpha$ emission in the bar

CIG 754 = UGC 10490
SF in the inner parts of galaxies

42/20/18% - E/F/G

Interpreted as secular evolution: constraints on phases lifetime
Numerical simulations constraints SF law: likely = Schmidt law

To be tested by:

- Numerical sim. of gas flow in barred potential (+SF)
- Comparison with Hα and molecular gas velocity field
- Find best model, pattern speed and bar strength
- Gravity torques and gas in/outflow

(Verley et al 2007c)
MULTIA STUDY: Atomic gas

Reference for \( M(\text{HI}) = f(LB, \varnothing, t) \) (previous: HG84, \( n = 324 \))

- Single dish: for 910 CIG
  - > 100 papers + own data (Arecibo, GBT, 100m, Nancay)
- Improved quantity & quality

Origin of ISM in E/S0s

- 27% isolated E/S0 detected in HI
- \( M_B \) not compatible with fossil group
- HI with double horned profiles:
  - disks from accretion event or low L spiral mergers

(Espada 2006, PhD)
MULTIA STUDY: Atomic gas

- Origin of asymmetries in isolated galaxies:

  Surprising result: really isolated?

- Asymmetry calculated, and cleaned:
  - 21% of asymmetric profiles

- Discarded:
  - Small companions in the beam

(Espada 2006, PhD)
Origin of asymmetries in isolated galaxies

- VLA mapping of 12 isolated/asymmetric
  - Asymmetries in the velocity field
  - Few HI companions (mass limit $5 \times 10^6 M_{\text{sol}}$)
  - Upper limit to cloud accretion
  - No tidal tails

- Detailed study of extreme case CIG 96

(Espada et al 2005)
CIG 96 = NGC 864

3D-NTT@Meudon Apr08

AMIGA
ANALYSIS OF THE HI DATA. HI profile asymmetries

HI MAPS of IG, OWN OBSERVATIONS: CIG0096

HI distribution and velocity field, VLA, 24'

Optical, DSS2, 6'

Analysis of the Interstellar Medium of Isolated Galaxies

3D-NTT@Meudon Apr08
Origin of asymmetries in isolated galaxies

- External perturbation favoured:
  Accretion of small companion outside of the optical but within the HI at a radial velocity lower than the maximum

- Major axis:
  break in velocity in outer parts, faster than Keplerian
Origin of asymmetries in isolated galaxies

- New higher resolution VLA C+D data:
  - signs of central perturbation (counter-rotation?) along minor axis, but hole in atomic gas

NEED FOR HIGH-RES OPTICAL DATA TO LOOK FOR SIGNS OF ACCRETION
Building a reference of isolated galaxies for the study of ionized gas (physics+kinematics+DM) in environmental studies (100 AMIGAs observable from NTT 1500-5000 km/s) + search for gas rich satellites with wide field FP mode

Detailed study of specific problems:
- constrain the origin of asymmetries in isolated galaxies, combined with numerical simulations
- understand the different morphologies/SF of bars
- PNe to trace DM?
AMIGA & 3D-NTT

Field of view:
- Individual galaxies: 1-4 arcmin size
- Search for satellites: larger available field

Spectral resolution:
- Kinematics: high-res
- Satellites: lower res, wide bandwidth

Angular resolution: highest for inner parts

A proposal for Large International Program at ING submitted in February (PI. J. Beckman) for ~100 AMIGAs

Collaboration with Kapteyn and Obs. Paris on GIPSY-VO
Colloquium in Granada  12-15th May 2009

“GALAXIES IN ISOLATION: EXPLORING NATURE VERSUS NURTURE”

Instituto de Astrofísica de Andalucía

More in http://amiga.iaa.es:8080/CIG09/