A GALAXY BASELINE: Multiwavelength sample of the most isolated galaxies in the local Universe

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Instituto de Astrofísica de Andalucía - CSIC (Granada, SPAIN)

NGC 7217 (CIG 947), WHT

Analysis of the interstellar Medium of Isolated GAlaxies

THE AMIG@S

Starts in 2003 @IAA (PI: L. Verdes-M)

Staff

Jack Sulentic (IAA)

Ute Lisenfeld (Univ. Granada)

Postdocs

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Simon Verley (Univ. Granada)

Gilles Bergond (CAHA)

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PhDs:

Vicent Martínez (IAA)

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Software development (radio-VO, archives, tools for 3D data):

Pique Ruiz del Mazo (IAA)

Víctor Espigares (IAA)

Since 2006 Coordin

+ Internatior

ESO (Chile), Obs. M

UMASS, Mc Donald

Analysis of the interstellar Medium

Unblemished beauty. Isolated galaxies like NGC 7217 may have evolved undisturbed for billions of years.

GRANADA, SPAIN—Laden with 400 billion stars, countless planets, and vast clouds of gas, our Milky Way galaxy pinwheels through the void. Its spiral arms stretch 50,000 light-years and revolve once every 220 million years, as we plunge at 400,000 kilometers per hour toward the neighboring

"If there really are significant numbers of isolated galaxies, and if we can collect large enough samples of them, then they're certain to provide some sort of fundamental insight into galaxy evolution," says Jack Sulentic, an astronomer here at the Institute for Astrophysics of Andalusia (IAA). Astronomers

in Ukraine, working with her husband, Igor Karachentsev of the Special Astrophysical Observatory in Nizhnij Arkhyz, Russia. "We divided our work," she says. "Igor worked with the pairs, and I work on the isolated galaxies."

Karachentseva analyzed photos taken in the 1950s with a 1.2-meter telescope in the famed Palomar Observatory Sky Survey. She declared a galaxy isolated if no neighboring galaxy lay closer than 20 times the neighbor's radius or was more than four times as big in diameter as the galaxy in question. Those rules selected galaxies that had not suffered an interaction in roughly 3 billion years. The Karachentseva catalog of 1051 galaxies is "still the best game in town," say Sulentic, who works on the Analysis of the Interstellar Medium of Isolated Galaxies (AMIGA) project at IAA.

Now, however, astronomers are trawling the enormous data sets produced in the past decade in ever-bigger sky surveys. In optical wavelengths, the Six-Degree Field Galaxy Redshift Survey has used a 1.2-meter telescope on Siding Spring Mountain, Australia, to pinpoint a total of 125,071 galaxies; the Two-Degree Field Galaxy Redshift Survey has used a neighboring 4-meter telescope to spot 221,414 more;

ESO (Chile), Obs. Marseille, Obs. Paris, CfA, ASIAA-Taiwan, MPIfA (Bonn), UMASS, Mc Donald Obs., Arcetri, UNAM, IAC, Kapteyn Institute, ATNF

WHY ISOLATED GALAXIES?

Why am I interested?

- AMIGA closest sample to unmasked galaxy evolution

- Best footprints of ancestors

WHY ISOLATED GALAXIES?

Direct interaction-enhancement connection difficult to establish

Amplitude and processes not well quantified/understood

- Pairs: SF excess but no HI deficit

(Xu & Sulentic ´91, Zasov & Sulentic ´94)

- HCGs: Morphology changes and HI depletion, not excess SF

(e.g. VM et al ´01, Iglesias-Páramo & Vílchez ´99, Bitzakis et al ’10)

- AGN Activity Frequency

(e.g De Robertis et al ´98, Krongold et al ´03, Miller et al ‘03, Best et al ‘05)

- Is H_2 increased by interactions? Contradictory results

(Braine & Combes 1993, Perea et al 1997, Verdes-M et al 1998, Leon et al 1998)

DO WE NEED A NEW SAMPLE?

- Ambigous definition of “isolated” and “normal”

  FIELD galaxies (e.g. Kennicut & Kent ´83)

  “NORMAL” galaxies (e.g. Boselli et al ´01)

  Galaxies without 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, Smith et al ‘07)

GOALS

- To **build** a catalogue of isolated galaxies:
  - Well defined (isolation, completeness)
  - Statistically significant
  - With multiwavelength information (main focus ISM)
  - Continuous vetting
- To **analyze** the catalogue:
  - Multiwavelength characterization: ISM – SF – AGN
  - Comparison with denser environments

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http://amiga.iaa.es

AMIGA DATABASE searchable via ISM)

VO TOOLS like TOPCAT

or using

AMIGA-WEB VO INTERFACE

- To **make it public** for "self-service" use

METHOD: Starting sample, continuous vetting

Amiga is a refinement of CIG:

Catalogue of Isolated Galaxies (Karachensetva 1973)

Selected from CGCG (Zwicky) with mpg < 15.7 $\delta > -3$

- **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 10.000 -15.000 km/s

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Catalog

Selected from

ø = 25 kpc

V = 150 km s−1

d(neighb) = d(CIG)

3 x 10^9 years to travel D = 20*d*

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REVISIONS, OPTICAL CHARACT.

- Positions revised for full CIG (Leon & Verdes-M '03, A&A 411, 391)
- Redshifts/distances (Verdes-M et al '05, A&A, 436,443)
- Optical completeness evaluation, V/Vm test:

80-95% level up to m = 15 (before < 80%)

Comparison with different samples and environments

E/S0s fainter than in field samples, reflecting CIG lower density environment. Most nurture free population of Es

- Morphologies: complete revision:

Uniform reclassification using digitized POSS II

Cross-check SDSS (~ 200 galaxies) & 47 nights Obs. SN:

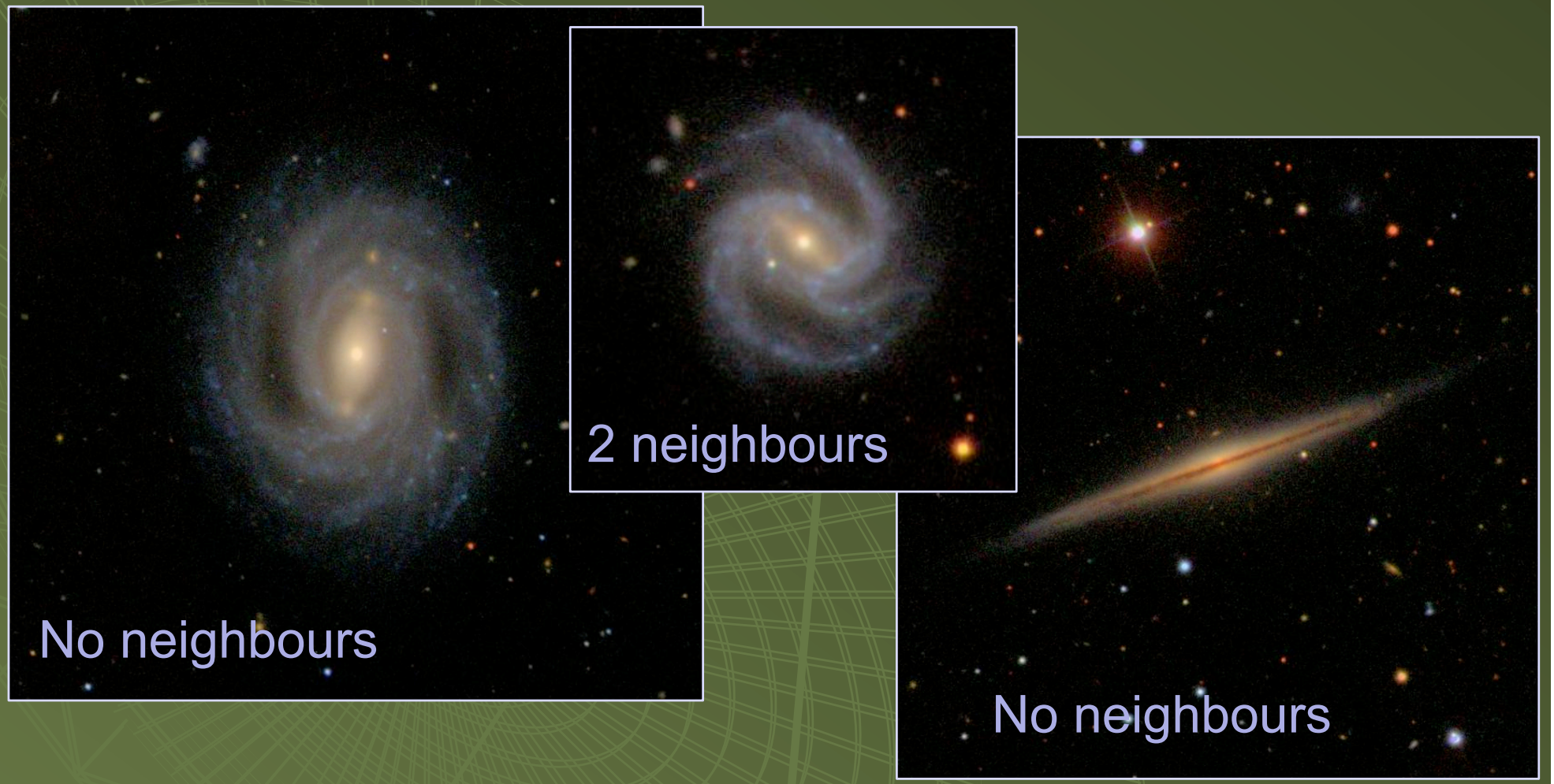
ΔT = 1-2

(Sulentic et al 2006, A&A 449,937)

REVISIONS

(Sulentic et al 2006, A&A 449,937)

CIG/AMIGA is dominated by spirals, 63% Sb-Sc



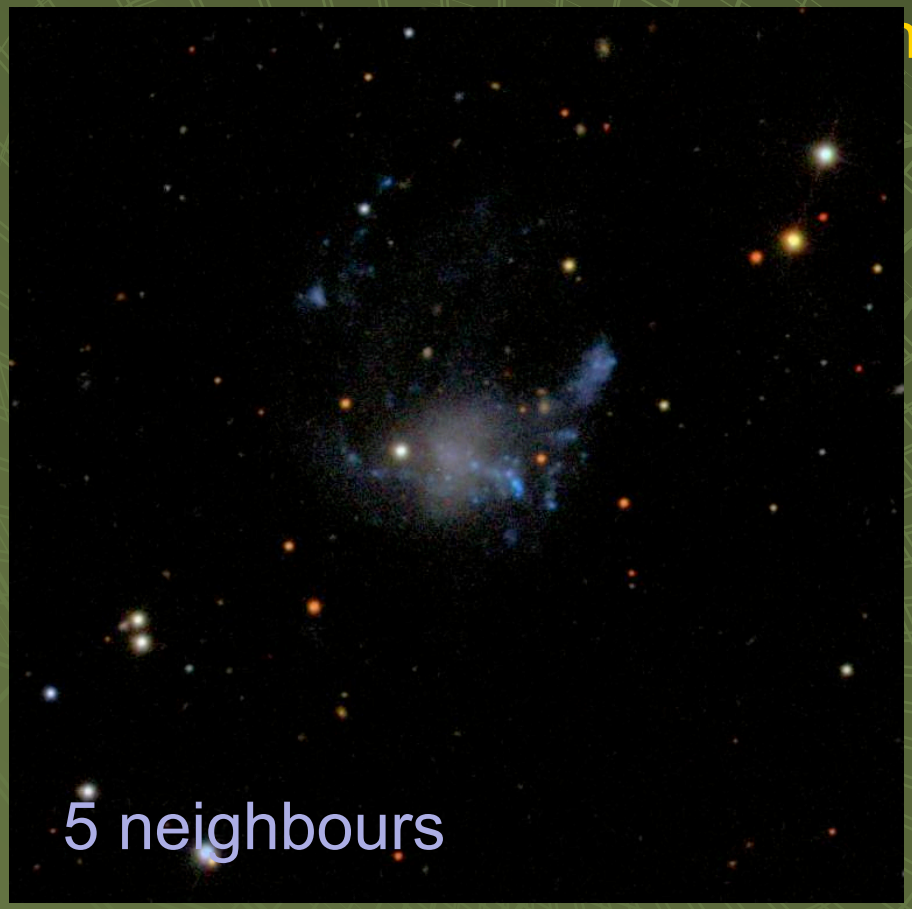
SDSS + CCD for 85% of AMIGA

Increase of late types fraction

(Sulentic et al in prep).

REVISIONS

- Distorted objects flagged
- Candidates to minor interactions



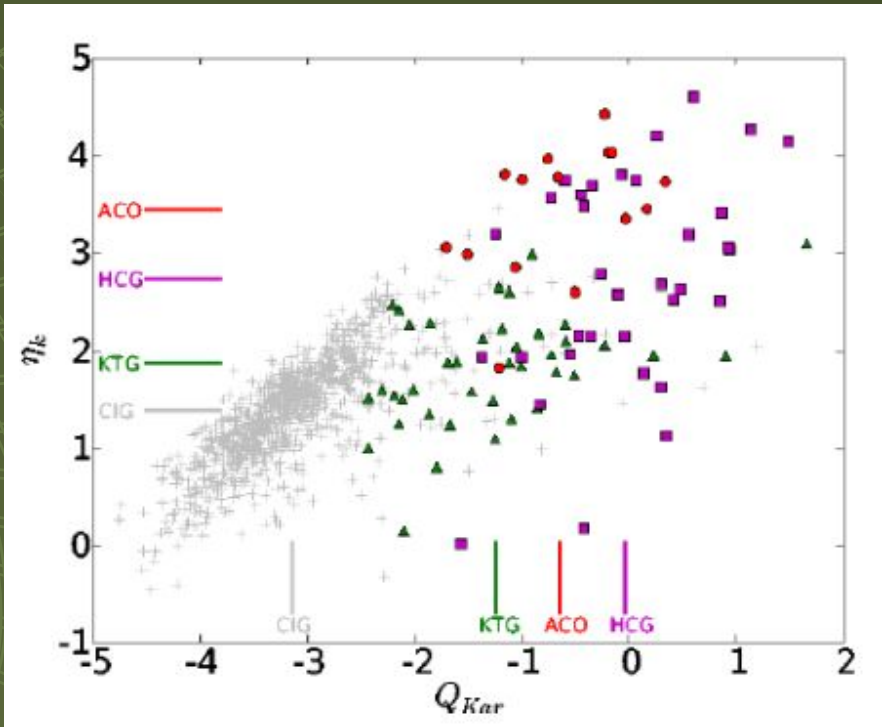
Isolation

(Verley PhD;
Verley et al 2007ab, A&A)

- Karachentseva (1986): visual examination of plates
- Our revision: POSS-I & II, R >=0.5 Mpc, m_B<17.5
  - Catalog of all potential companions: 54.000
- Quantification: CIG, 41 triplets, 34 groups, 15 clusters :
  - Local number density η_K
  - Tidal force estimation Q

Final revised catalogue, n = 791

- Q >-2 (1% binding forces)
- η_K > 2.4



On-going SDSS study

Detailed morphologies

100 Sb-Sc, 1500 < v < 10000 km/s m_B<15 *i* < 70º

Fourier decomposition and CAS parameters of SDSS-I

Most isolated galaxies

in our sample:

- host pseudobulges rather than classical bulges
- host longer bars
- are more symmetric
- less concentrated and
- less clumpy

than less isolated samples

(Durbala et al '08, MNRAS 390, '09 MNRAS 397)

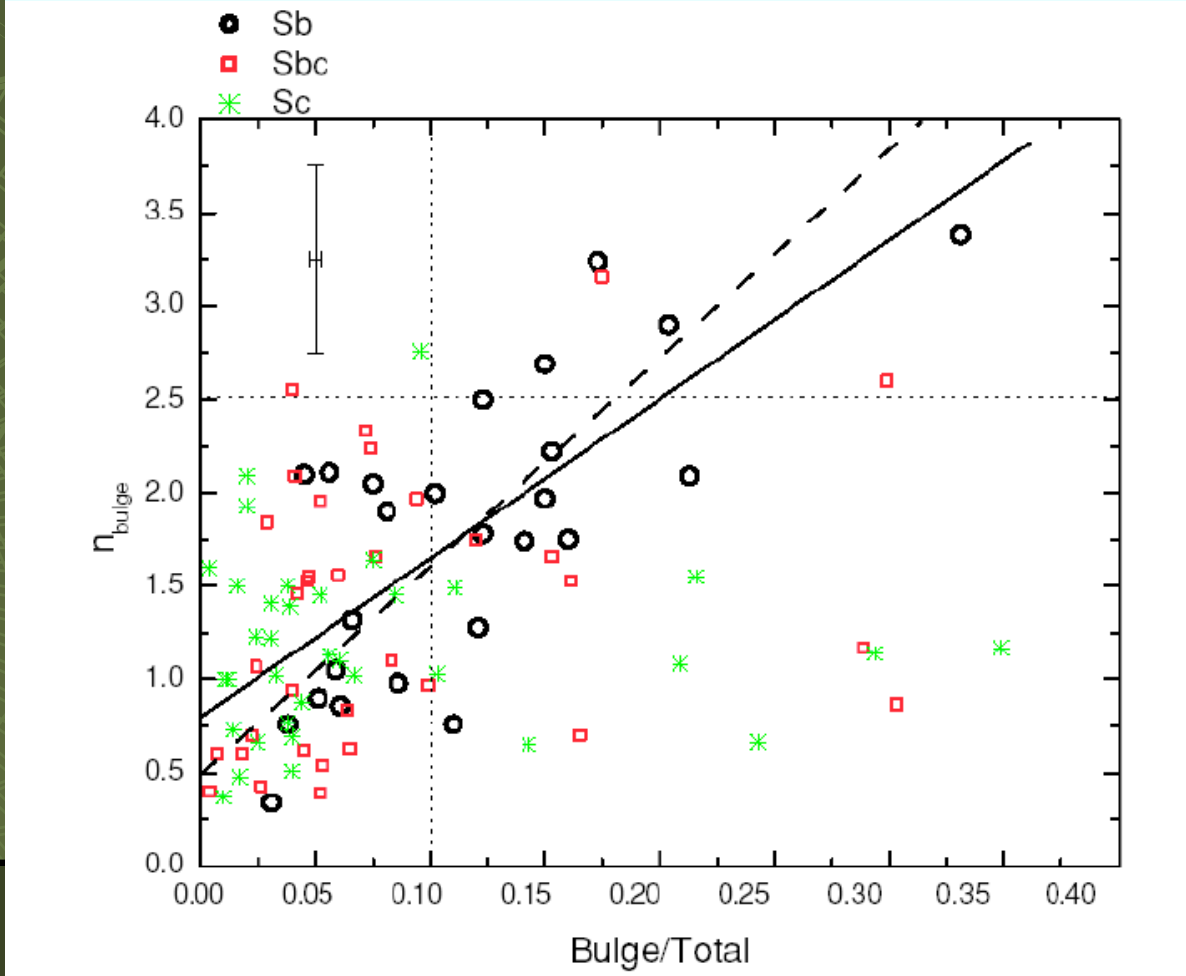


Figure 4. Bulge Sérsic index versus bulge/total luminosity ratio. A linear

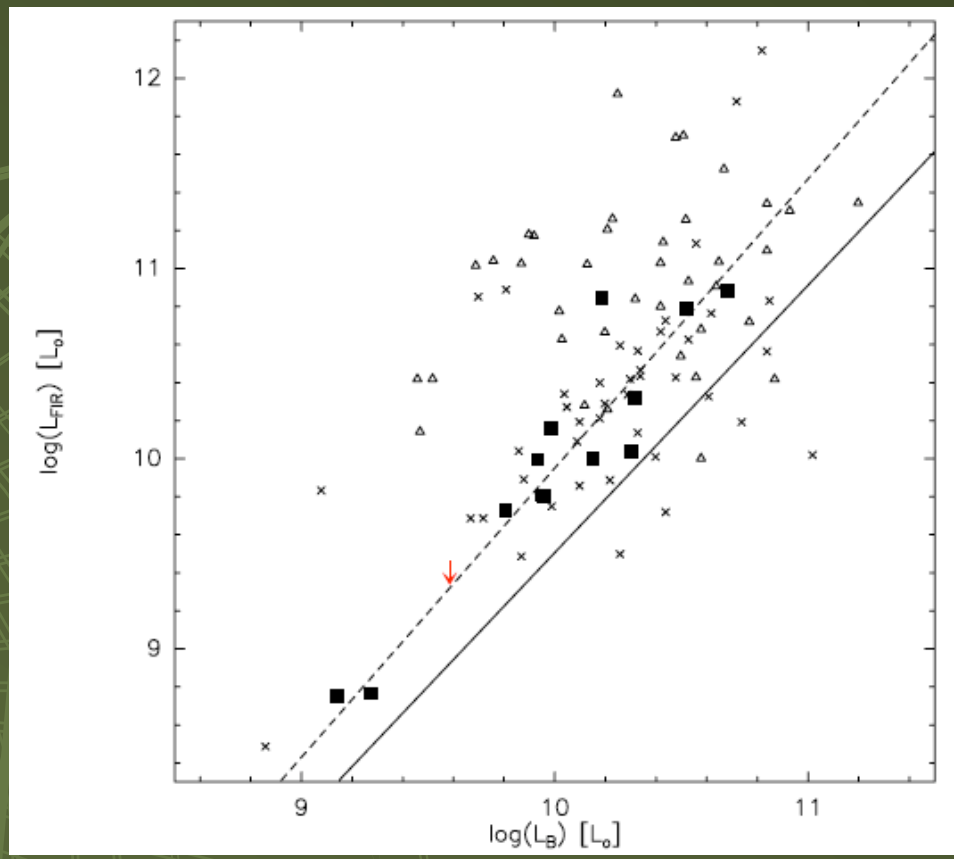
FIR, Radio, Nuclear activity

Analysis of complete sample + ASURV

4 IRAS bands coadded for 1030 CIG: snr x 3-5

- Strong LFIR-LB correlation, baseline for interacting samples
- $\log(L_{FIR})$: only 2% >10.5 L_{sol}
- Comparison with 2445 galaxies of CfA sample:

$\langle \log(LFIR)_{CfA} \rangle = \langle \log(LFIR)_{AMIGA} \rangle + 0.26$



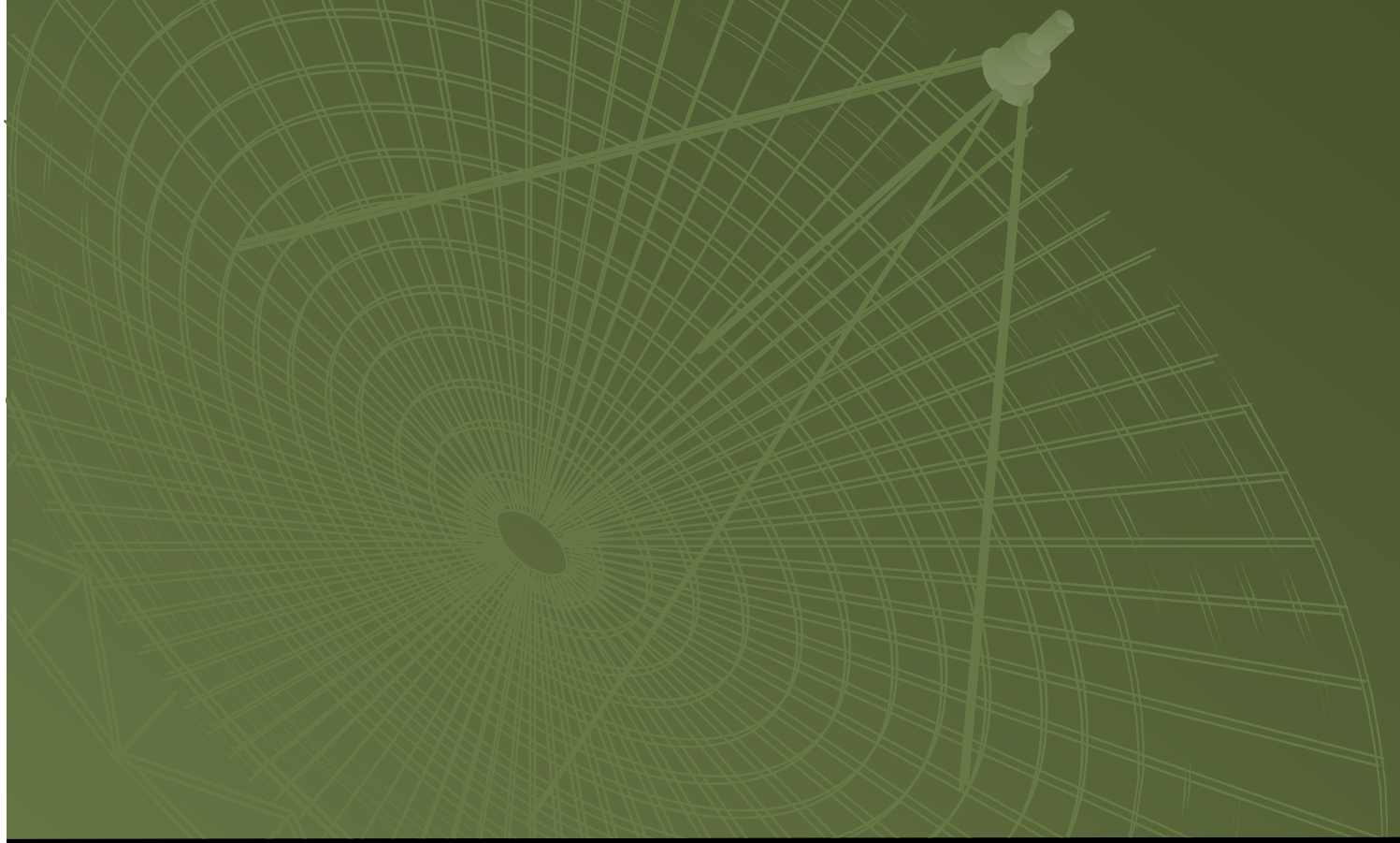
FIR emission is a variable enhanced by interaction

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

FIR, Radio, Nuclear activity

- Comparison NVSS vs FIRST: (Leon et al 2008, A&A 485, 475)
  - disk-dominated emission in spirals (vs nuclear in high dens)

Very low level of radiocont, dominated by mild disk SF



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- Radio-FIR correlation to select radio-excess galaxies
  - 0.0% of radio-excess galaxies (after FIRST rejection)
  - Increase with environment density for all types
  - Higher in early types for all environments

Environment plays crucial direct role in triggering radio nuclear activity and not only via density-morphology relation

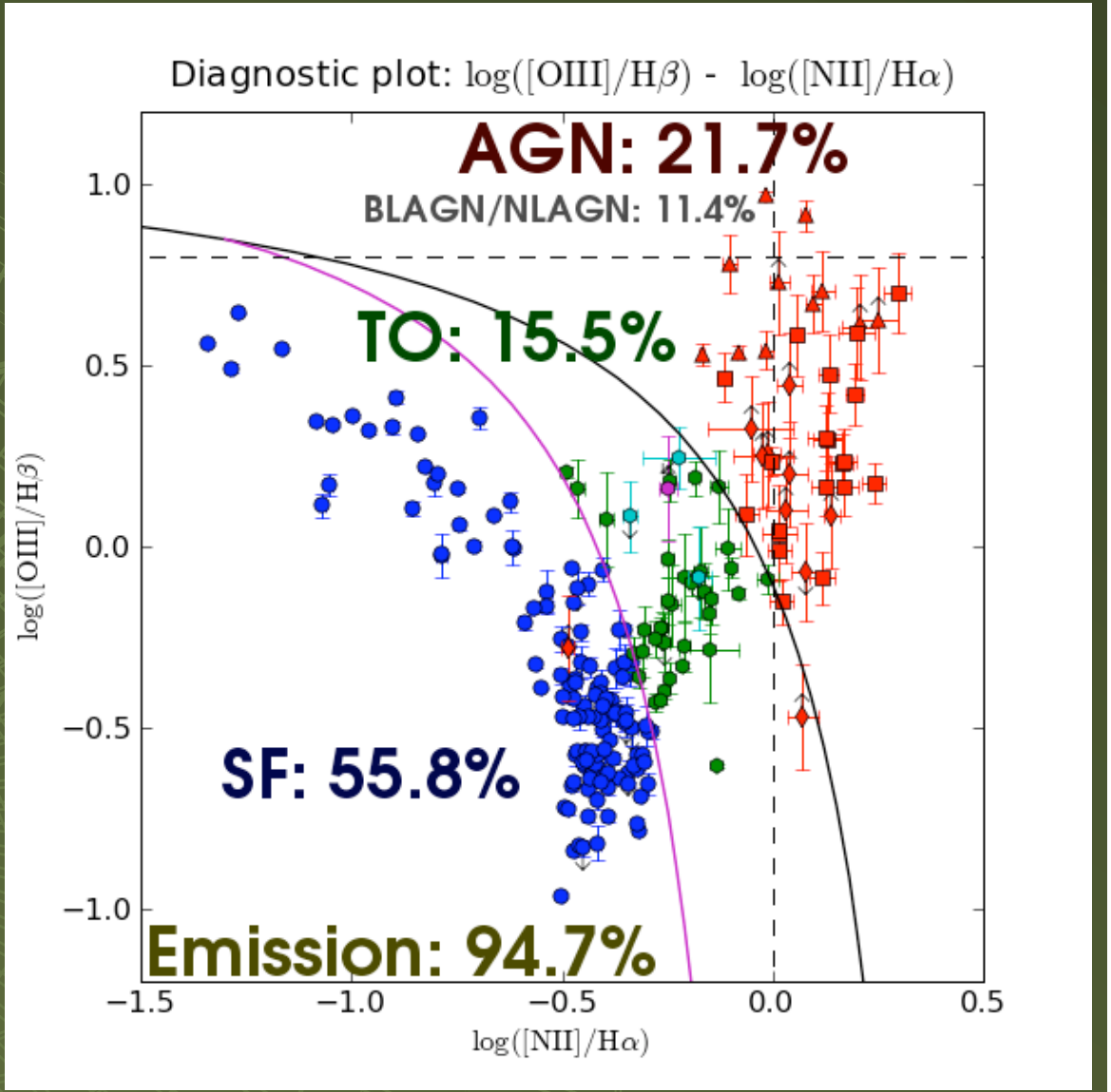
Isolated E/S0 show a particularly low level of radio-activity

(Sabater 2009, PhD; Sabater et al 2008, A&A 486, 73)

Nuclear activity (work in progress)

- SDSS-DR6
  350 AMIGAs
- Subtraction of stellar population using starlight. Fit of lines.
- BPT diagnostic diagram
- Work in progress

(Sabater PhD 2009,
Sabater et al 2010ab in prep)



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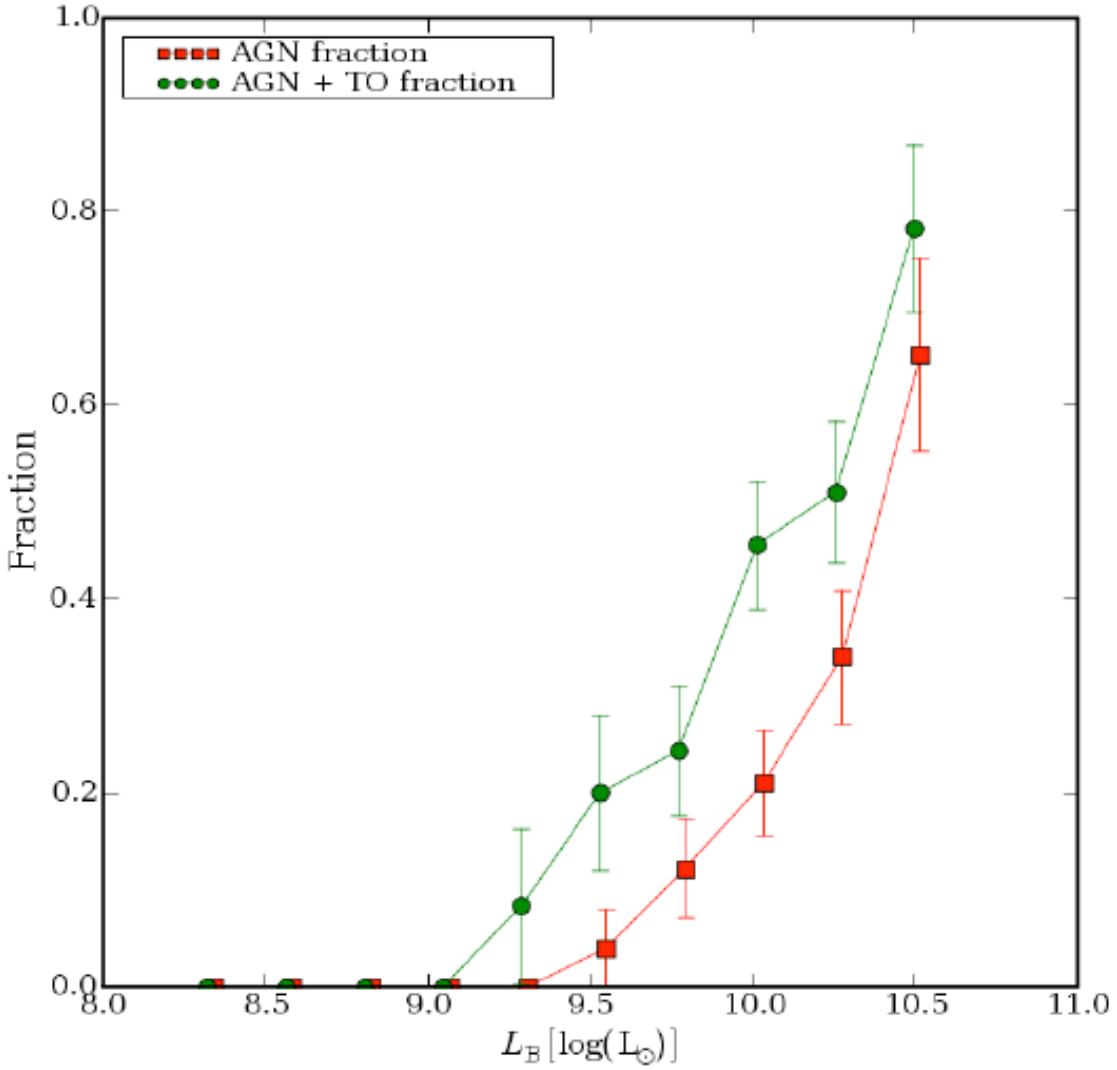

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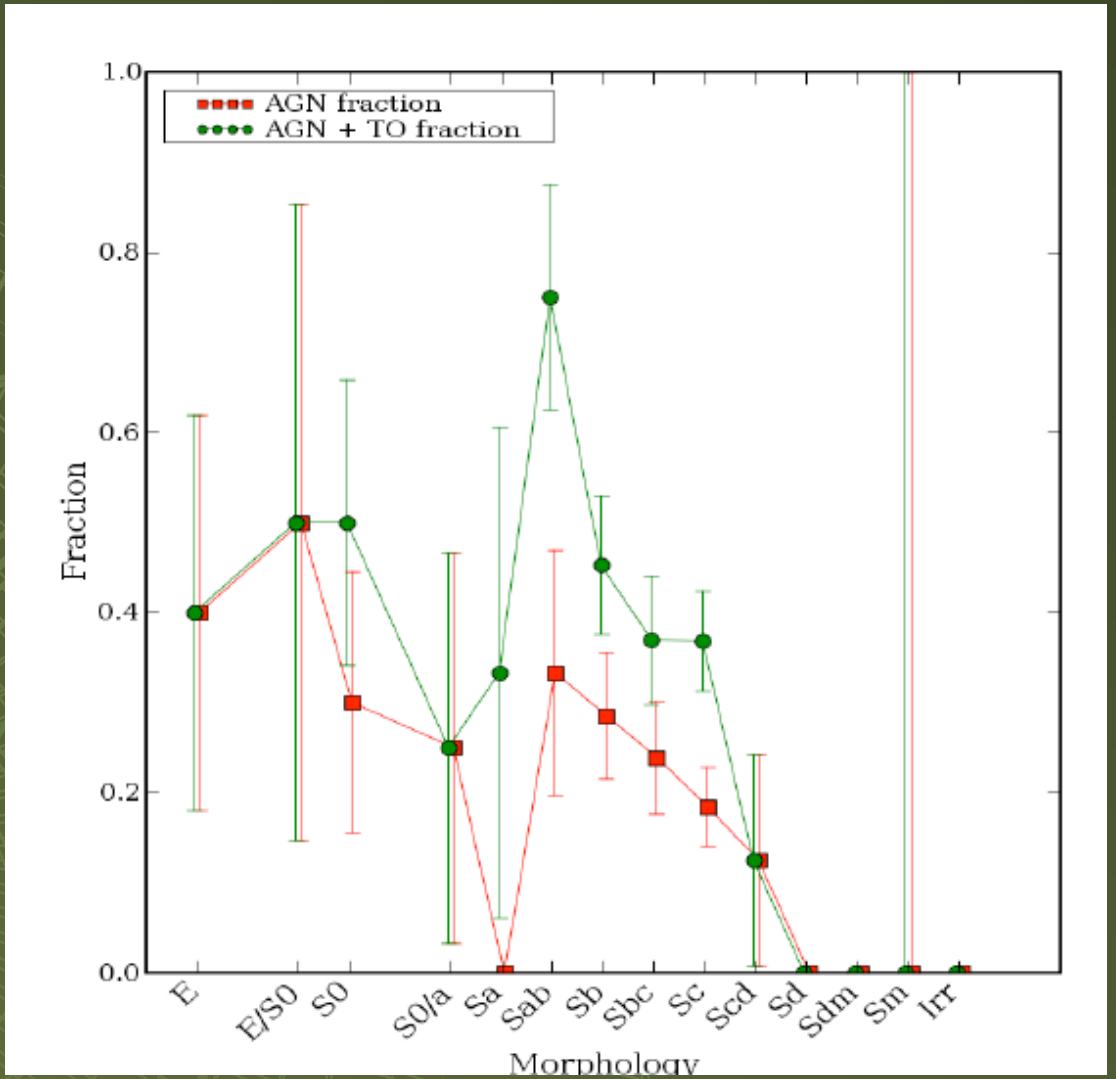
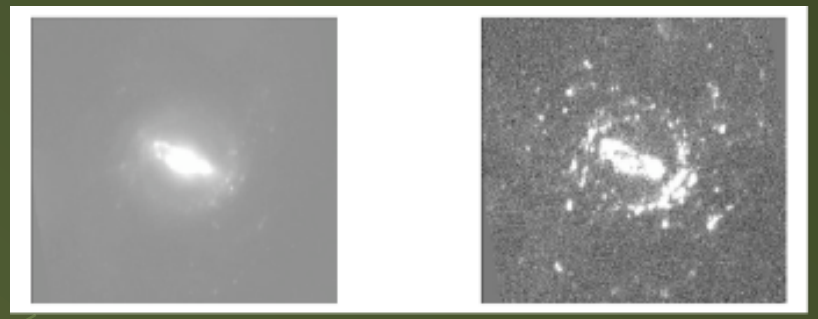


(Sabater PhD 2009, Sabater et al 2010ab in prep)

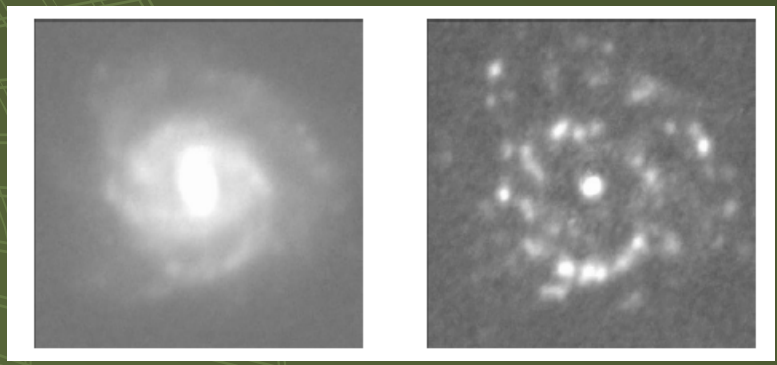
Star formation Hα (HαLF in progress)

Hα+r 205 galaxies 1500 < v < 5000 km/s (120 nights@1-2m tel)

Frequency & origin of bars: 45 largest and low *i* galaxies



- 60% barred
  - 18% Hα emission in the bar
  - 42% strong central peak, no Hα in bar but at the end
  - 20% smoother morphology, no central emission in Hα



- Interpreted as secular evolution: time constraints
- Numerical simulations: constrains SF law, differs from Schmidt

(Verley et al 2007, A&A 474, 43)

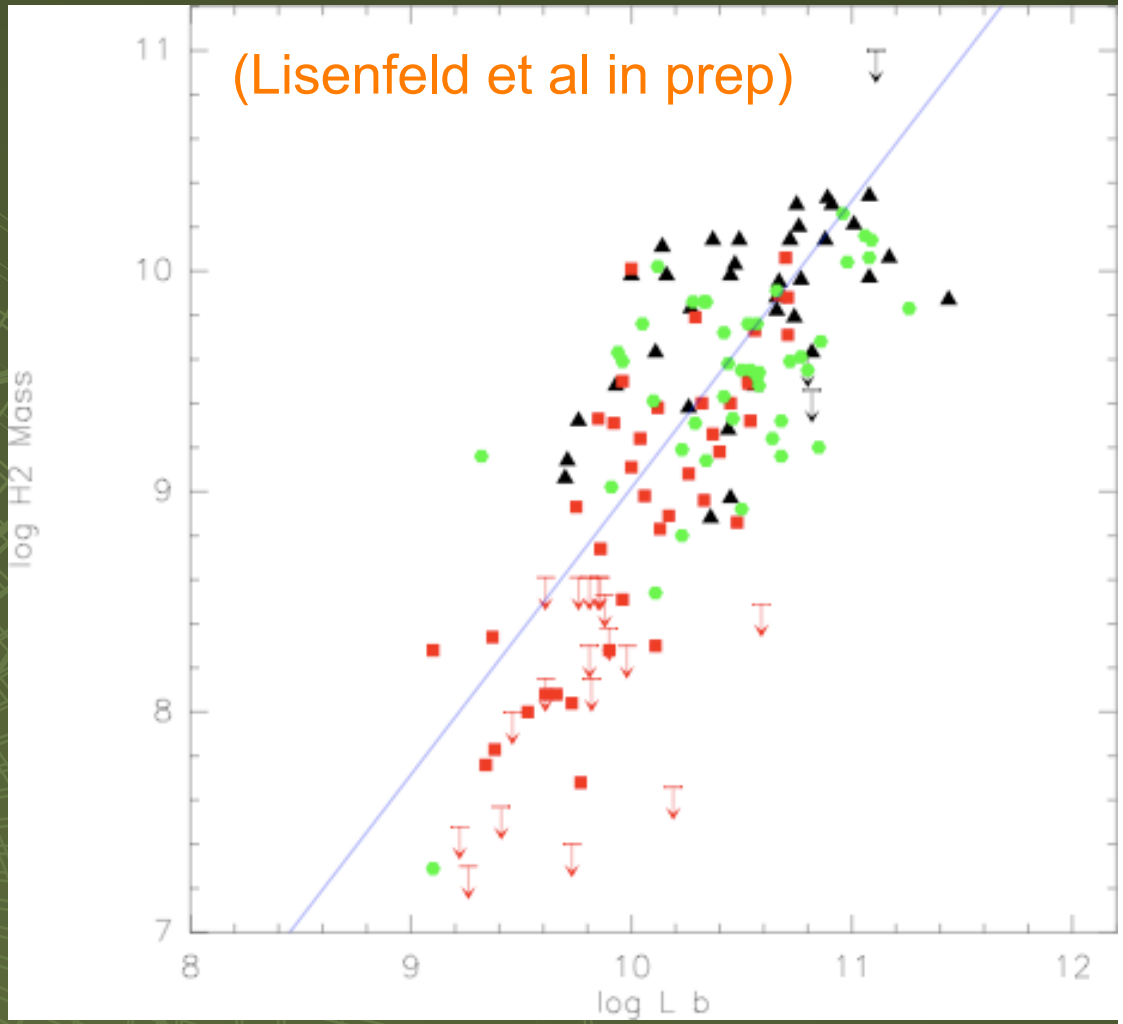
Molecular gas content $M(H_2) = f(LB, Ø, t)$

CO single dish 205 AMIGAs

1500 < v < 5000 km/s

Major axis maps for ~ 20

IRAM 30M, FCRAO, Nobeyama 470h



No enhancement in

- Weakly interacting pairs

(Solomon & Sage 1988)

- Strongly interacting pairs

(Sanders et al 1991)

- Virgo galaxies

(K&Y 88, Bosselli et al 1995)

Hickson Compact Groups on-going 83gal@20HCGs (PhD V. Martínez)

Atomic gas

M(HI) = f(LB, Ø, t)

- Reference for M(HI) = f(LB, Ø, t) (previous: HG84, n = 324)
  - Single dish: for 910 CIG
    - ➢ 100 papers + own data (Arecibo, GBT, 100m, Nancay)
- 27% isolated E/S0 detected in HI
- Asymmetries: 50-75% in previous works, isolated/dense envs

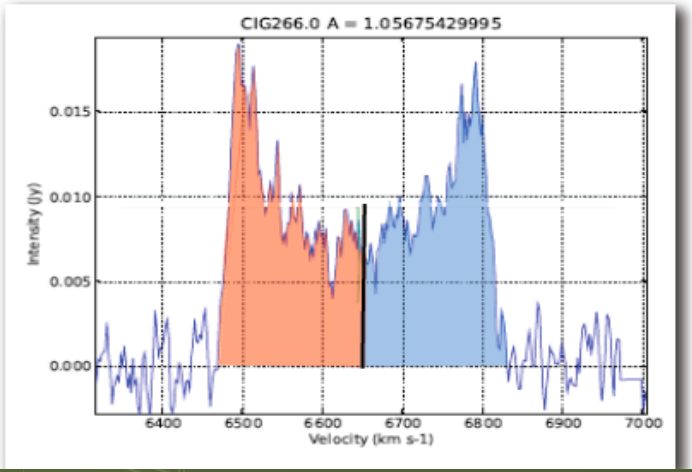
(n=104, Haynes et al 1998; n=30, Matthews et al 1998)

(Swaters et al 2002, Richter & Sancisi 1994), Sulentic & Arp 1983, n = 76, Bourneaud et al'05)

Surprising result: really isolated?

Cleaned from pointing errors or beam attenuation:

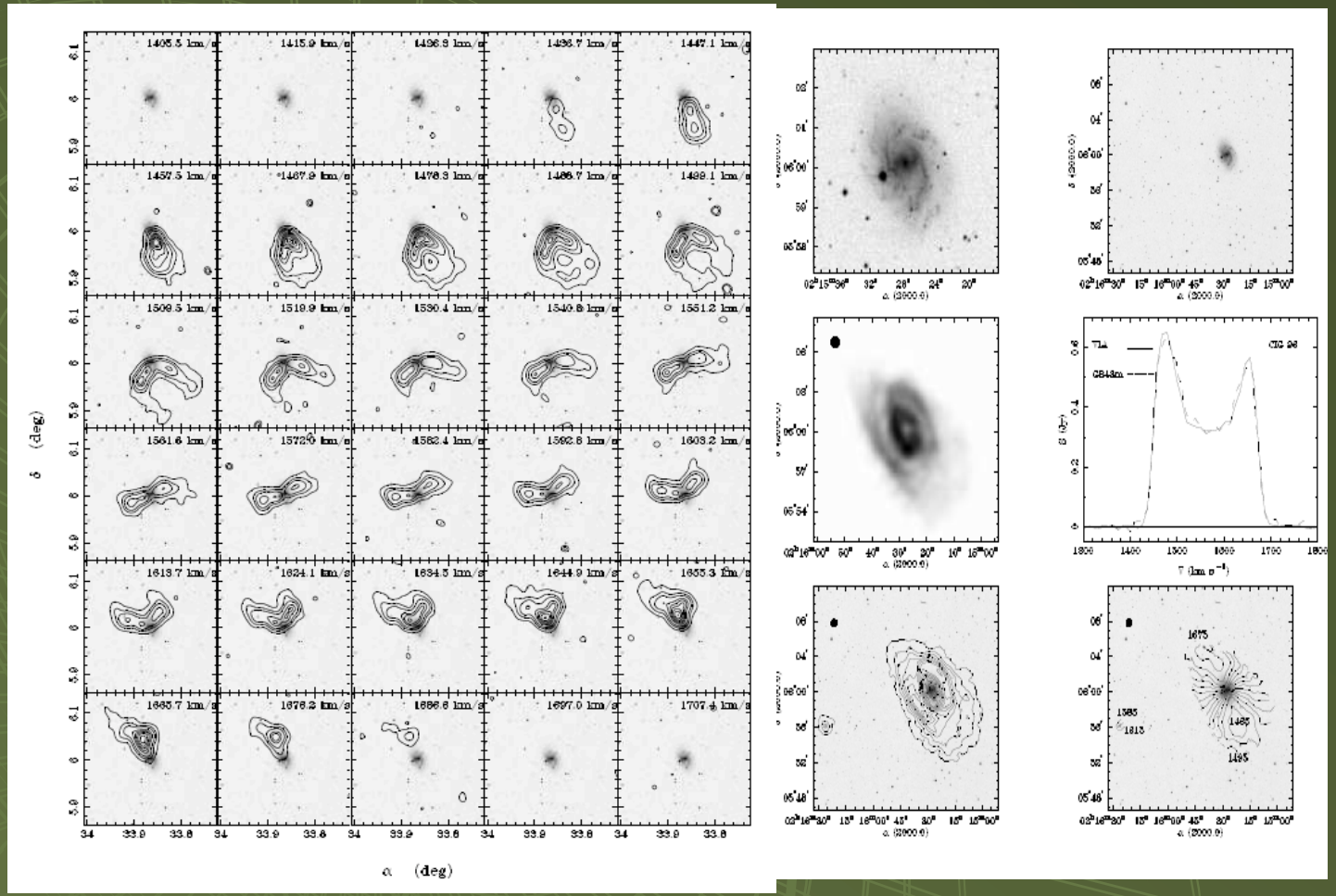
21% of asymmetric profiles



(Espada et al. In prep)

Origin of asymmetries in isolated galaxies

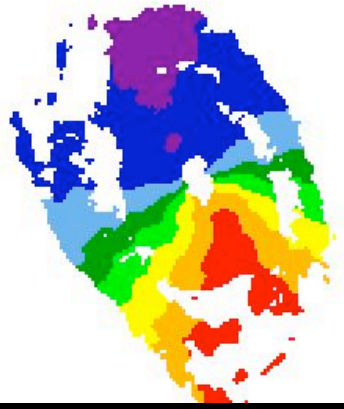
- VLA+GMRT mapping of 15 isolated/asymmetric

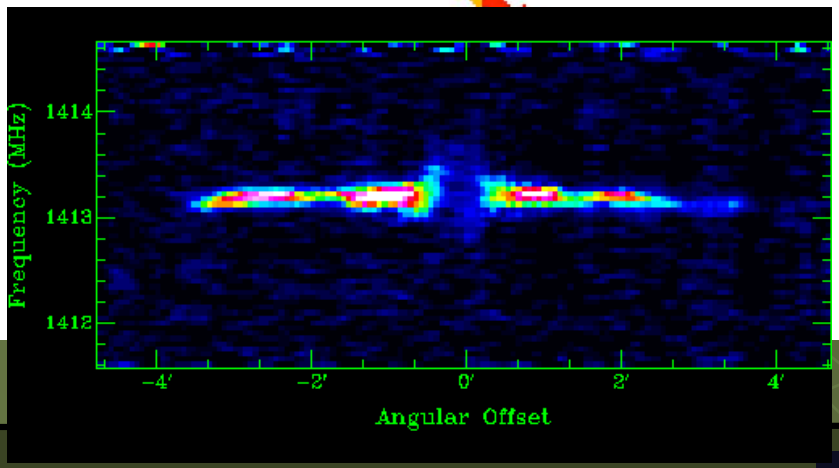


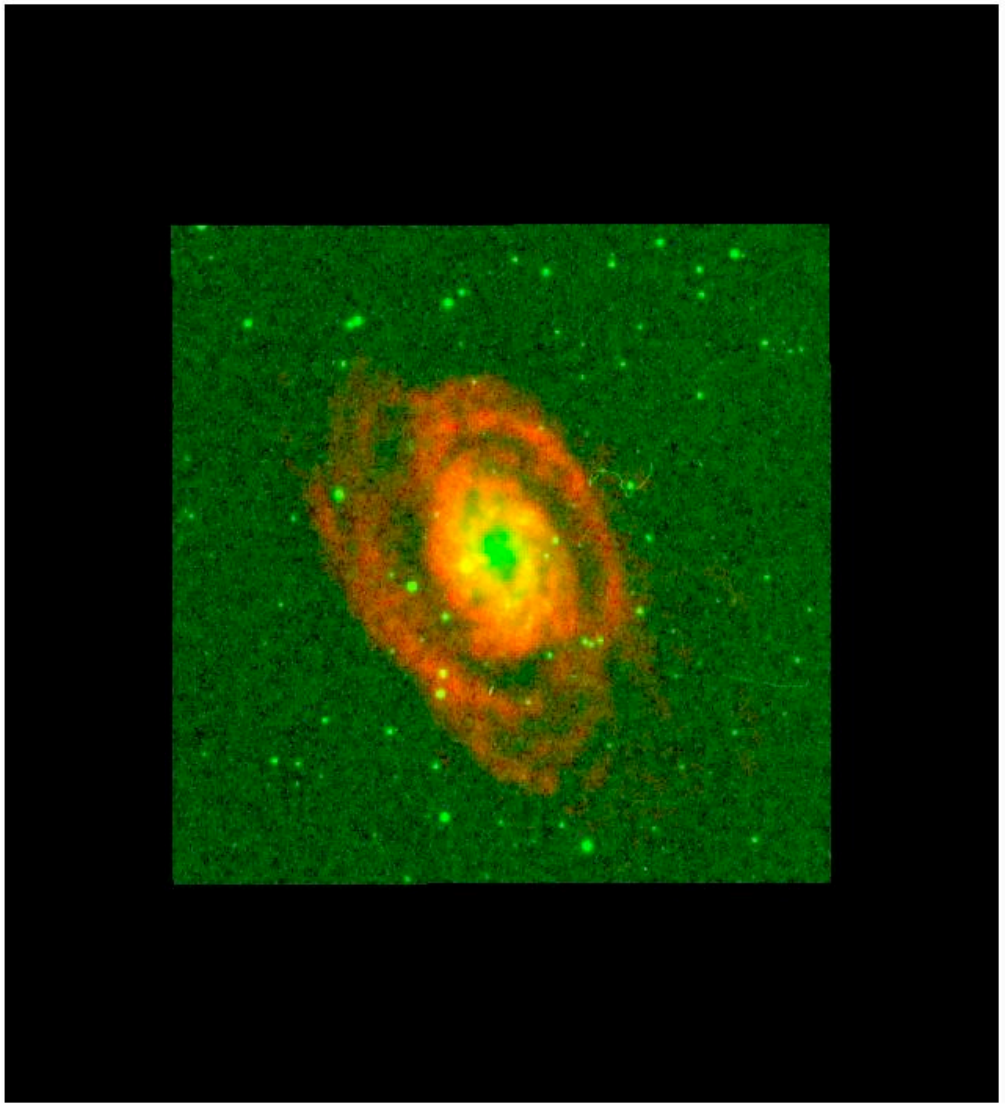
(CIG 96: Espada et al 2005, A&A 442, 455)

Origin of asymmetries in isolated galaxies

New VLA C+D data







CONCLUSIONS

- Sb-Sc dominant population
- LOWEST VALUES relative to any other samples of:
  - LB of both late and early types
  - Sersic index of late types (pseudobulges)
  - Optical asymmetry, clumpiness, concentration
  - LFIR
  - Radiocontinuum (disk dominated)
  - Nuclear activity
  - HI Asymmetry