Setting the normalcy level of HI properties in isolated galaxies

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1. Introduction: Atomic gas (HI)

- HI is one of the components of the ISM most sensitive to environmental effects:
  - Tidal interactions (e.g. Beale & Davies 1969)
  - Ram pressure by hot gas in the ICM (e.g., Vollmer et al. 2001)
  - Other mechanisms: gas accretion, dark matter, etc.

- HI ↔ Molecular Clouds ↔ Star Formation

(Hibbard et al. 2001)
1. Introduction: Goals HI studies

- To characterize the HI properties of a large and well defined sample of isolated galaxies:

  1) **HI content.**
  (Enlarge and revise studies using \(N = 324\) CIG galaxies in Haynes & Giovanelli 1984)

  2) **Rate and origin of HI asymmetries.**
  (Most of previous studies do not use a strict isolation criterion)

- Compare with other components of ISM, and other galaxies in denser environments.

  (Espada PhD, 2006)
2. HI data for CIG galaxies

**Literature**

- **Literature:** (N = 431 gal.) RC3, Hyperleda and Huchtmeier & Richter (1989). Compilation of HI data from 50 papers.
- **Ongoing surveys:** AGC (Arecibo, N = 273), KLUN/KLUN+ (Nançay, 42) and HIPASS (Parkes, 120).

**Observations**

- **Arecibo:** N = 34, 70% detection rate
- **Effelsberg:** 186, 67%
- **GBT:** 51, 94%
- **Nançay:** 217, 30%
2. HI data for CIG galaxies

Procedure for the reduction

- **Selection**: comparison between different observations for the same galaxy (extent/beam).
- **Homogenization** of the HI data, different origin of the observations.
- **Data reduction**: baseline substraction, interference elimination, smoothing, etc.

Derived HI parameters

- **HI parameters**: integrated flux density, widths at 25, 30 and 50%, velocity and asymmetry coefficients.
- **Consistency** between different reduction packages (IDL, TOOLBOX, ANALYZ-GALPAC).
- **Correction** to the width and integrated density flux.
2. HI data for CIG galaxies

HI data for **837 galaxies** (610 detected, 38 tentatively detected)

- **Velocities**: as CIG refined sample, from 1500 to 15000 km/s
- **Morphologies**: mostly Sb-Sc, improve statistics on E-S0 and Sd-Im
3. HI content


• $N = 324$ CIG galaxies (287 detected, Arecibo telescope)

• MHI as a function of optical properties (LB or linear size, and T)
3.1. HI data, HG84 vs AMIGA

- Selection and homogenization
- **Number**: factor 2 and 3 more galaxies detected and observed, respectively
- **Morphology revision** (Sulentic et al. 2006)

<table>
<thead>
<tr>
<th>Type</th>
<th>( N_{AMIGA} )</th>
<th>( N_{HG84} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>E, E/S0, S0, S0/a</td>
<td>140</td>
<td>14</td>
</tr>
<tr>
<td>Sa, Sab</td>
<td>59</td>
<td>37</td>
</tr>
<tr>
<td>Sb</td>
<td>149</td>
<td>71</td>
</tr>
<tr>
<td>Sbc</td>
<td>192</td>
<td>38</td>
</tr>
<tr>
<td>Sc</td>
<td>250</td>
<td>80</td>
</tr>
<tr>
<td>Scd, Sd</td>
<td>80</td>
<td>38</td>
</tr>
<tr>
<td>Sdm,Sm, Im, Pec</td>
<td>40</td>
<td>9</td>
</tr>
<tr>
<td>All</td>
<td>910</td>
<td>287</td>
</tr>
</tbody>
</table>
3.2. Comparing two samples: $M_{\text{HI}}$ vs $L_{\text{B}}$

Artificial offset due to different correction systems for $M_{\text{HI}}$ and $L_{\text{B}}$!

$N = 287$ galaxies HG84

$\Delta(M_{\text{HI}} \text{ predicted}) = 0.1$

AMIGA (Verdes-Montenegro et al. 2005 + Espada 2006)
3.3. $M_{HI}$ vs $L_B$: complete sample and morphology

- Complete sample (Verdes-Montenegro et al. 2005), $N = 662$.
- Upper limits (noticeable effect in E-S0)
- Morphology (Sulentic et al. 2006)
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  $T < Sbc$ (in especial E-S0) and $T > Scd - Sd$. 
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- Differences with HG84
  $T < S_{bc}$ (in especial E-S0) and $T > S_{cd} - S_d$.

- $M_{HI} - L_B$ have lower dispersion than $M_{HI} - D_l^2$
4. HI asymmetries

- High percentage rate >50%! of lopsided HI profiles in “field/isolated” galaxies (e.g. Richter & Sancisi 1994, Haynes et al. 1998).

- Artificial origin:
  - Pointing offsets
  - Gas-rich companions in the beam.

- Physical origin:
  - Distant tidal encounters (e.g. Beale & Davies 1969, Kornreich et al. 2002)
  - Major or minor mergers (e.g. Walker et al. 1996)
  - Sustained long-lived lopsidedness due to non-circular motions (e.g. Baldwin et al. 1980)
  - Cosmological gas accretion (e.g. Bournaud et al. 2005)
  - Halo - disk misalignment (e.g. Noordermeer et al. 2001)
  - ...
4.1 HI asymmetry parameter ($A_{\text{flux ratio}}$)

\[
A_{l/h} = \frac{A_l}{A_h} = \frac{\int_{V_m} S_v dv}{\int_{V_h} S_v dv}
\]
4.1 HI asymmetry parameter ($A_{\text{flux ratio}}$)

$$A_{l/h} = \frac{A_l}{A_h} = \frac{\int_{v_m}^{v_l} S_v dv}{\int_{v_l}^{v_h} S_v dv} \frac{v_l}{v_h}$$

$A_{\text{flux ratio}} = 1.15$

S/N > 10: 318 galaxies
66% symmetric
Refined: 182 galaxies
71% symmetric
4.1 HI asymmetry parameter ($A_{\text{flux ratio}}$)

- Strongly asymmetric: $A_{\text{flux ratio}} > 1.3$
  - 14 galaxies

- Slightly asymmetric: $1.15 < A < 1.3$
  - 39 galaxies

- Symmetric: $A < 1.15$
  - 129 galaxies (71%)

S/N > 10: 318 galaxies
66% symmetric
Refined: 182 galaxies
71% symmetric
4.2 HI asymmetry parameter and environment

a) CIG Isolation parameters
   (Verley et al. 2007)
4.2 HI asymmetry parameter and environment

a) CIG Isolation parameters (Verley et al. 2007)

b) Other samples of galaxies maybe interacting

- Isolated galaxies: 71% symmetric profiles
- Nearby gal. Bournaud et al. N=76: 44% symmetric profiles
5. HI Atlas of isolated galaxies

We know the lopsidedness rate in isolated galaxies, but what is its origin? VLA observations are needed:

- Asymmetry in the HI profiles is produced by confusion with HI-rich companions,
- Presence of tidal extended structures which may imply interaction with another galaxy,
- Asymmetry in the HI distribution or velocity field?

-VLA subsample: 8 asymmetric and 4 symmetric HI profiles

Espada et al. 2005 A&A 442 455  (CIG 96)
Espada PhD 2006
5. HI Atlas of isolated galaxies

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- Connection optical and HI asymmetries?
- No HI-rich companions
- No tidal tails
- Asymmetry mostly in velocity field

Espada et al. 2005 A&A 442 455  (CIG 96)
Espada PhD 2006
5. HI Atlas of isolated galaxies

**Source: CIG 96**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morphology</td>
<td>SBc</td>
</tr>
<tr>
<td>α(2000)</td>
<td>02:15:27.6</td>
</tr>
<tr>
<td>δ(2000)</td>
<td>06:00:09.0</td>
</tr>
<tr>
<td>Optical field sizes</td>
<td>(5.6 × 5.6, 25.4 × 25.4)</td>
</tr>
<tr>
<td>Observing time</td>
<td>4 hours</td>
</tr>
<tr>
<td>Central velocity</td>
<td>1572 km s⁻¹</td>
</tr>
<tr>
<td>Spatial resolution</td>
<td>15 arcsec</td>
</tr>
<tr>
<td>Number of channels</td>
<td>64</td>
</tr>
<tr>
<td>Velocity resolution</td>
<td>10.4 km s⁻¹</td>
</tr>
<tr>
<td>Beam size</td>
<td>(49.8 × 46.0)</td>
</tr>
<tr>
<td>Conv. beam size</td>
<td>(70.4 × 65.3)</td>
</tr>
<tr>
<td>PA (N to E)</td>
<td>-6</td>
</tr>
</tbody>
</table>

**HI data parameters**

- Channel maps
- Field size, channels: (')
- Velocities: 1436.7 - 1686.6 km s⁻¹
- rms noise channel: 0.66 mJy/beam
- Contours: 3, 10, 21, 42, 56, 70, 84, 98, 112 mJy/beam
- Global HI profile: VLA — GB43m (HG98)
- HI flux: 103 — 102.8 Jy km s⁻¹
- Heliocentric velocity: 1557 — 1562 km s⁻¹
- HI profile width 20%: 238 — 239 km s⁻¹
- M_HI: 7.24 — 7.53 (10⁶ M☉)

**HI maps**

- Field size: (5.6 × 5.6)
- HI map contours: 1, 100, 250, 750, 1000, 1250, 1500, 1750, 2000, 2250, 2500 km s⁻¹
- (10¹⁹ cm⁻²)
- 0.1, 6, 15, 45, 60, 75, 90, 105, 120, 135, 150
- Velocity contours: 1465 - 1675 km s⁻¹

**Comments**

- Companion α=02:16:26.90, δ=05:56:24.0, v=1605 (1572-1655), M_HI>10⁸ M☉

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Summary

1) **AMIGA**: Largest compilation of HI data for isolated galaxies (CIG), as part of multi-wavelength information.

2) **HI content**. Refined HG84 (selection, number, completeness, morphology) to predict HI content in denser environments. Use the same correction system for different samples!

3) **Asymmetries**. Tidal interactions play an important role on HI lopsidedness.
   - 71% symmetric ($A_{\text{flux ratio}} < 1.15$) in CIG. ↑ 25% more than in other field galaxy samples.
   - 29% asymmetric: one horn higher than the other. No HI-rich companions nor tidal tails. Minor mergers? gas accretion limit $5 \times 10^6$ Msun.