AMIGA

Analysis of the Interstellar Medium of Isolated GAlaxies

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

The antennae
(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%.




12 -15 June - Galaxies in isolation - D. Espada

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.

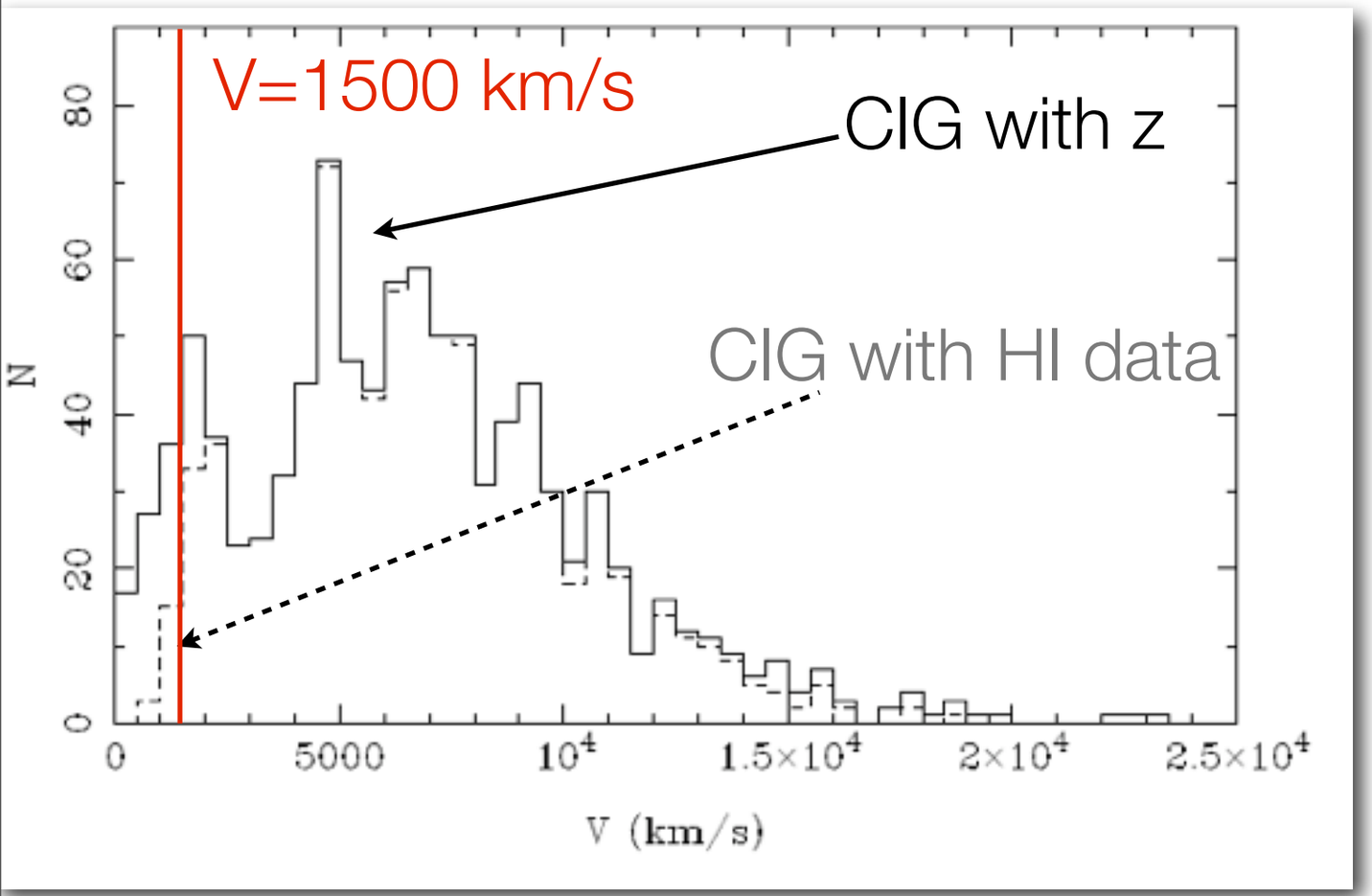
Derived HI parameters

- 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.

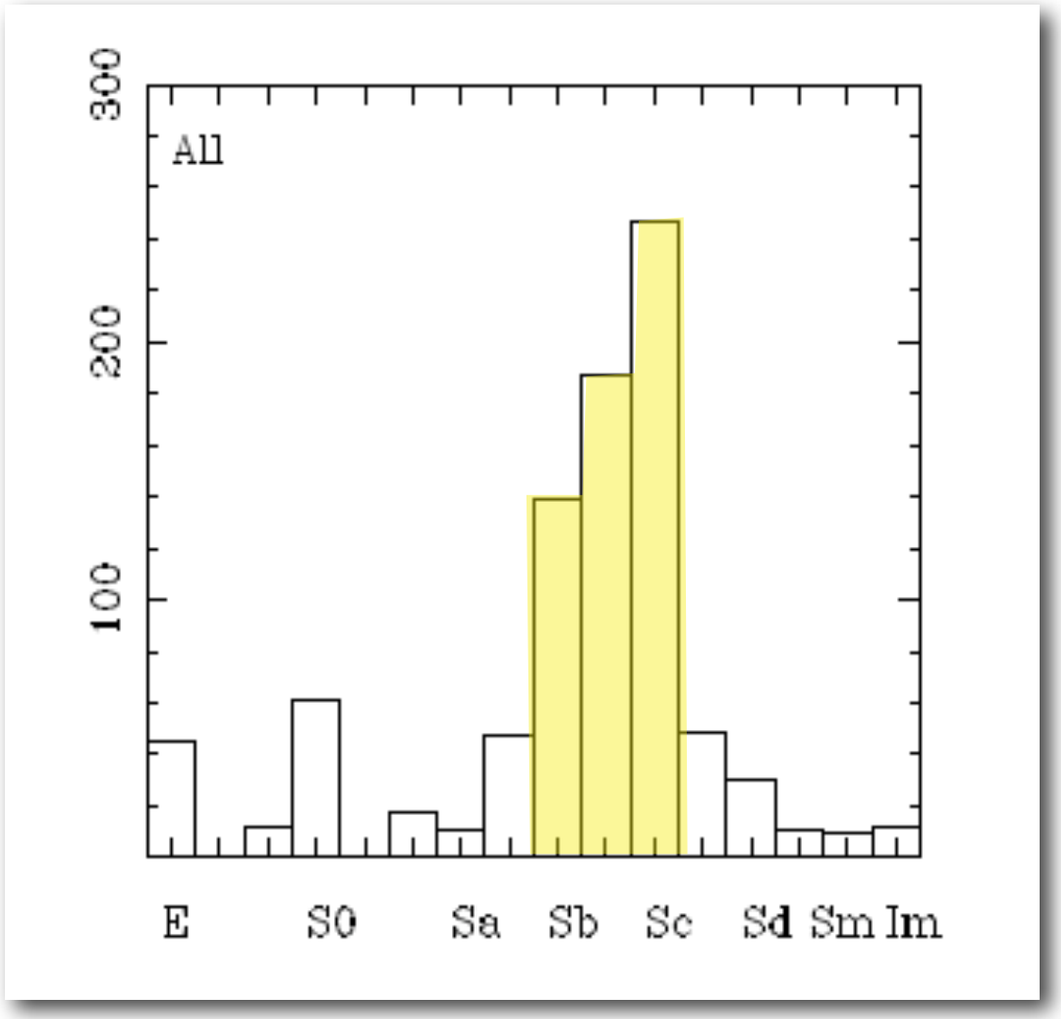
2. HI data for CIG galaxies

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

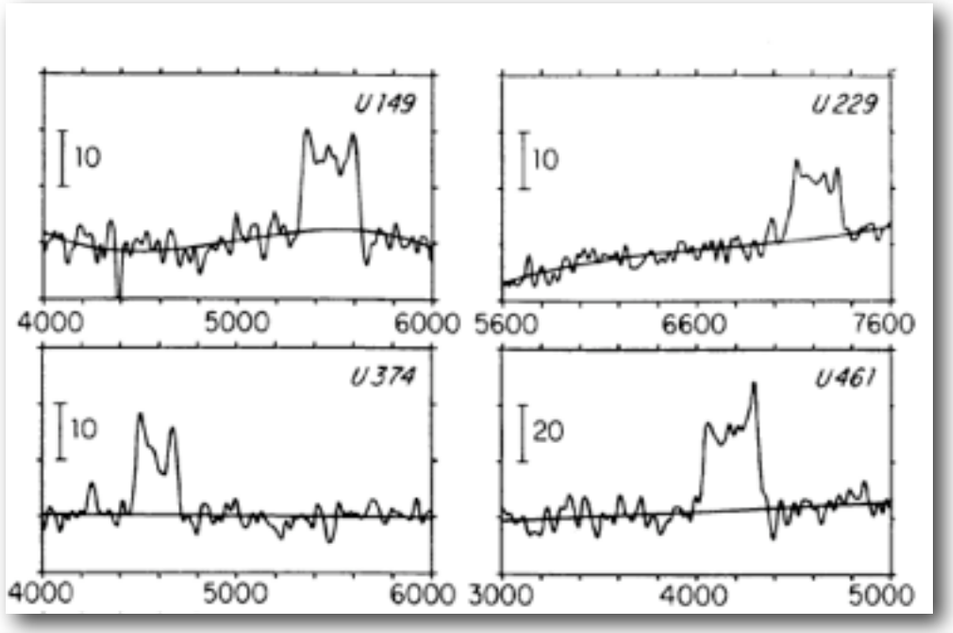


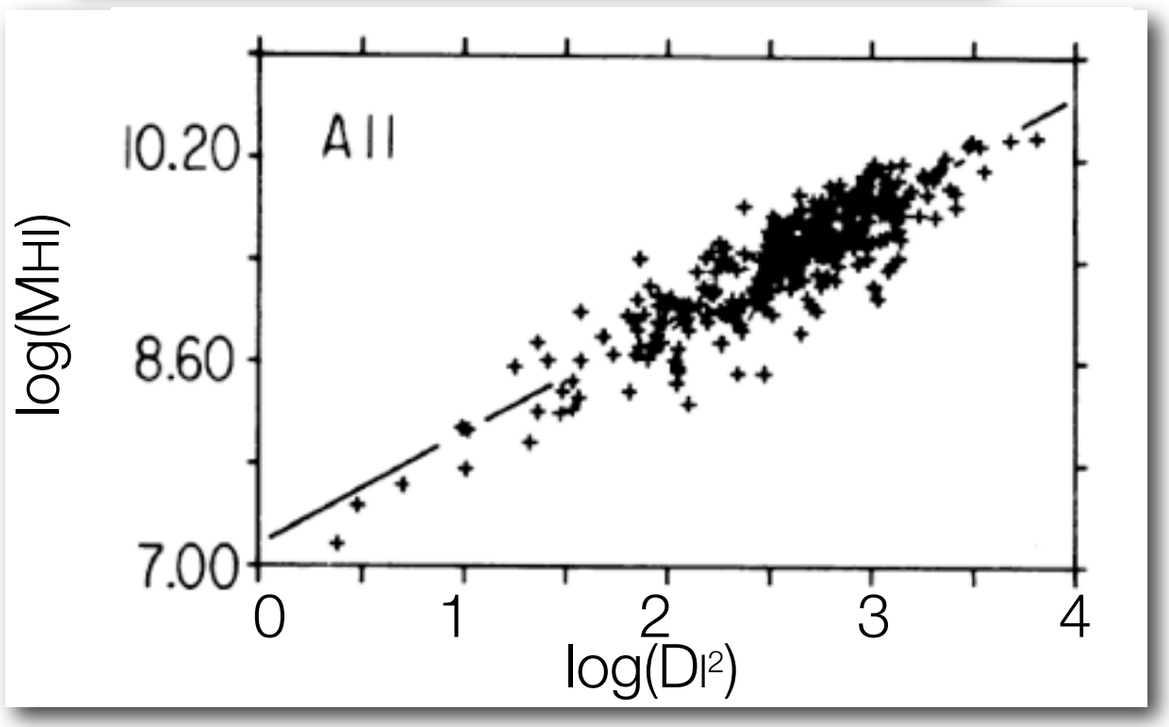
3. HI content

- Reference HI content normalcy: Haynes & Giovanelli (1984) (HG84).

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

- MHI as a function of optical properties (LB or linear size, and T)

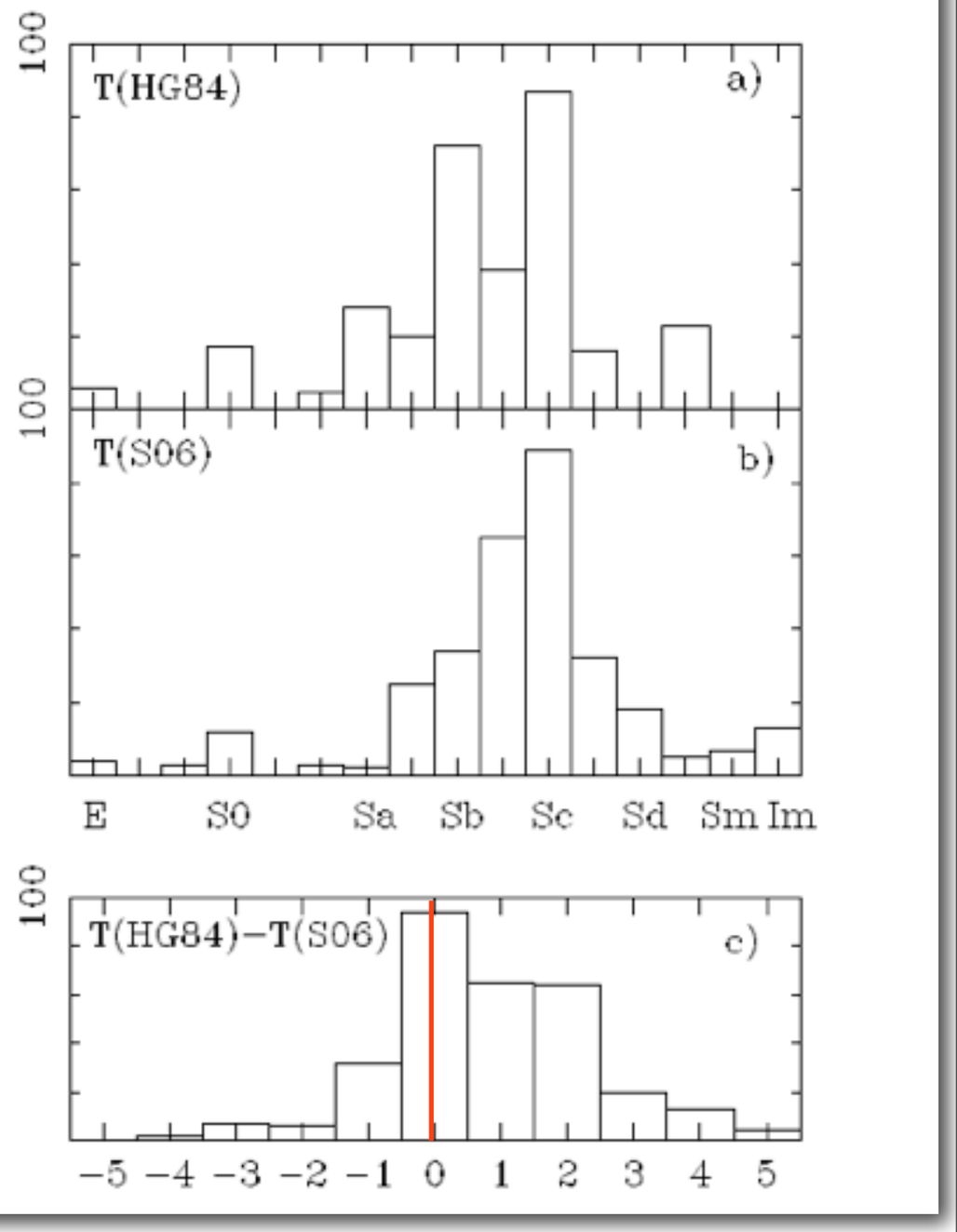




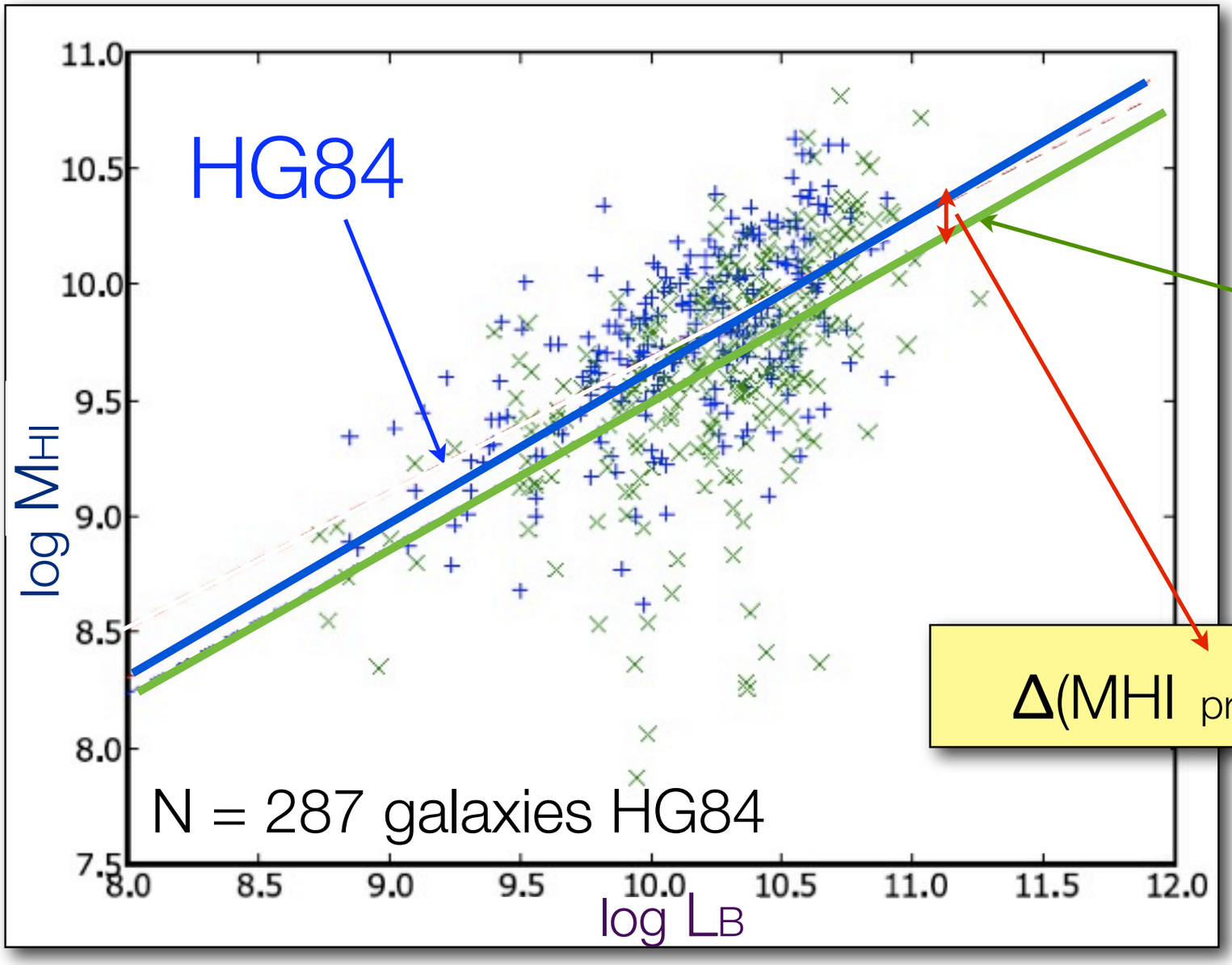
3.1. HI data, HG84 vs AMIGA

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

Type	N_{AMIGA}	N_{HG84}
E, E/S0, S0, S0/a	140	14
Sa, Sab	59	37
Sb	149	71
Sbc	192	38
Sc	250	80
Scd, Sd	80	38
Sdm,Sm ,Im,Pec	40	9
All	910	287

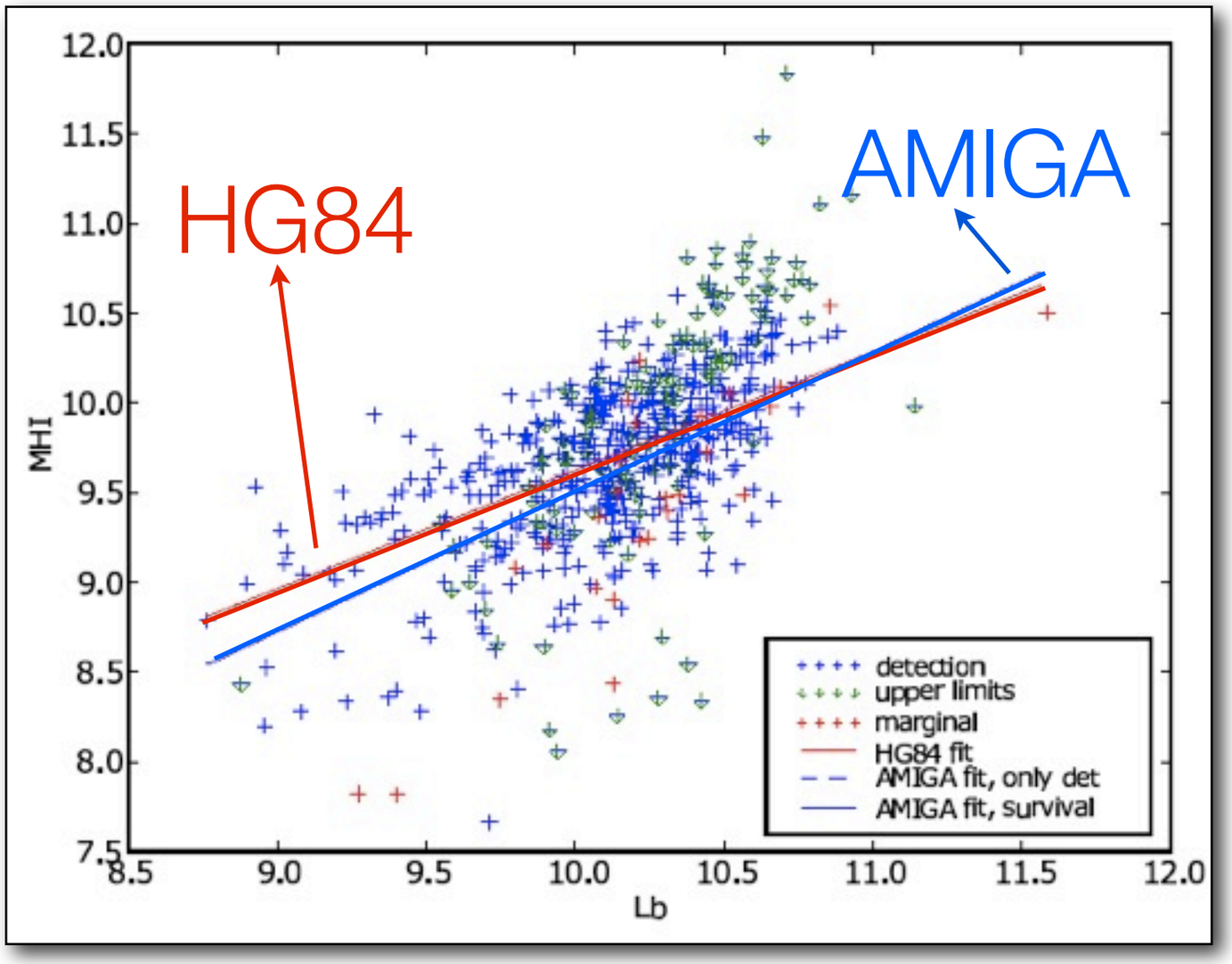


3.2. Comparing two samples: MHI vs LB



Artificial offset due to different correction systems for MHI and LB!

3.3. MHI vs LB: 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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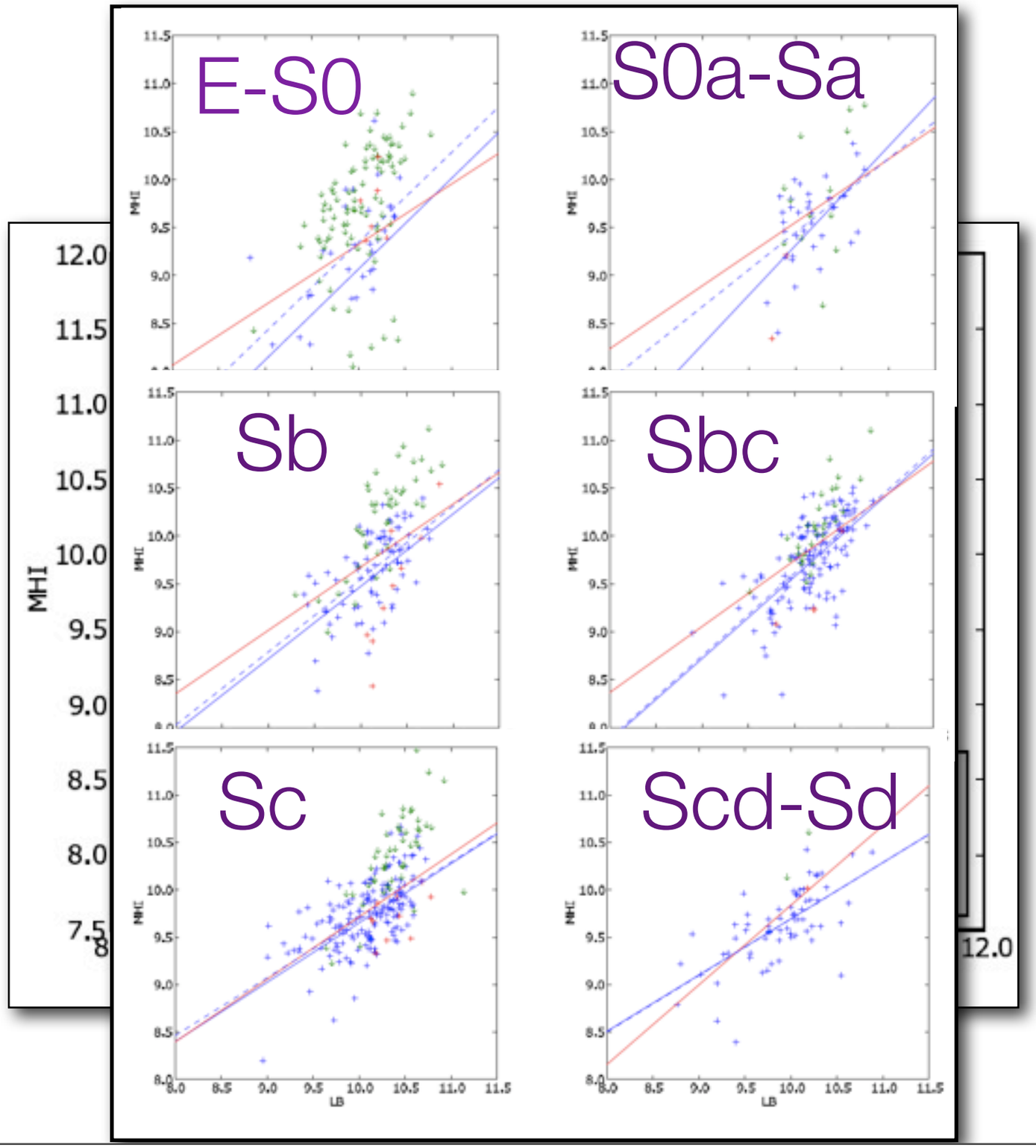

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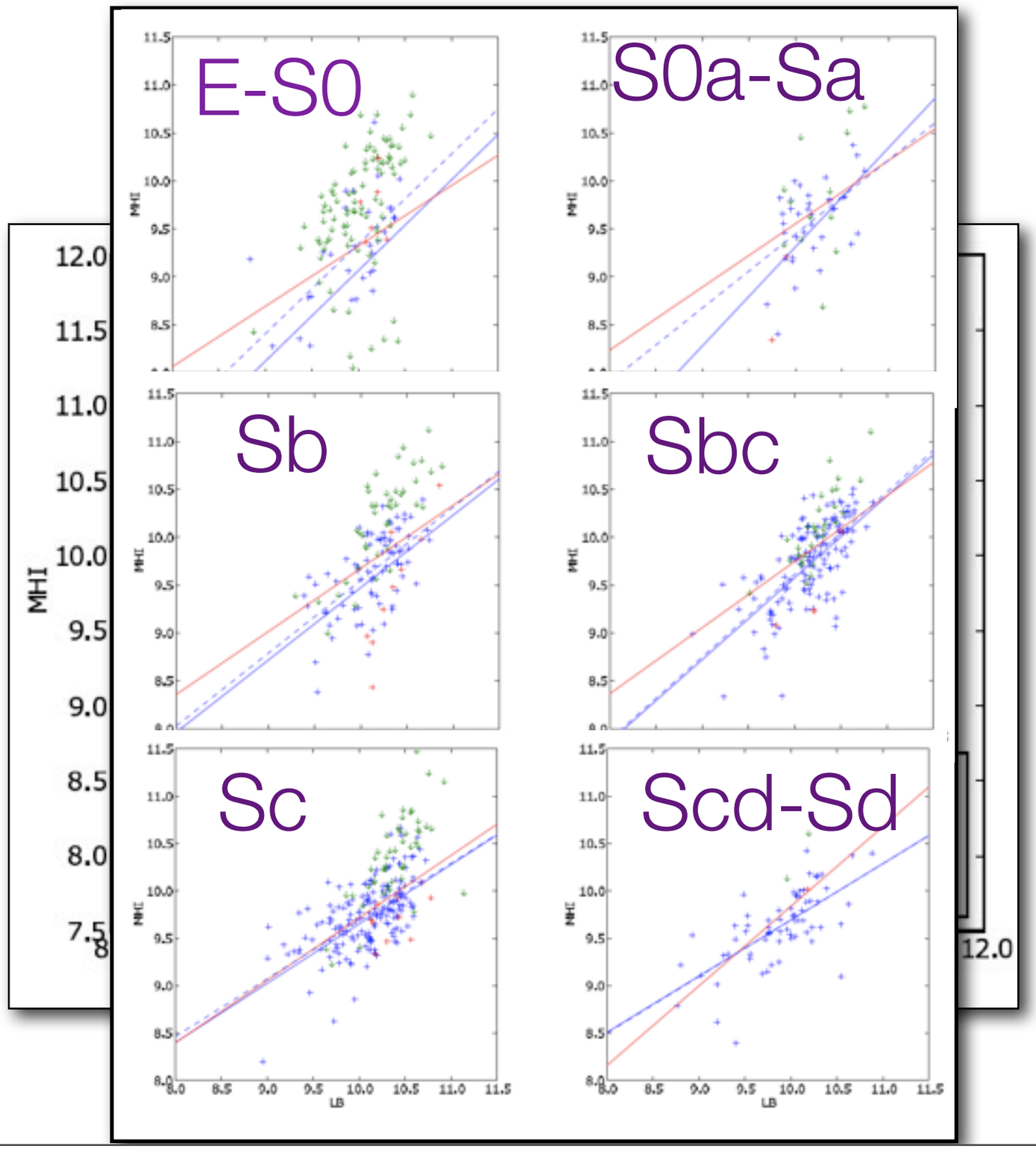

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-Differences with HG84

T < Sbc (in especial E-S0) and T > Scd - Sd.

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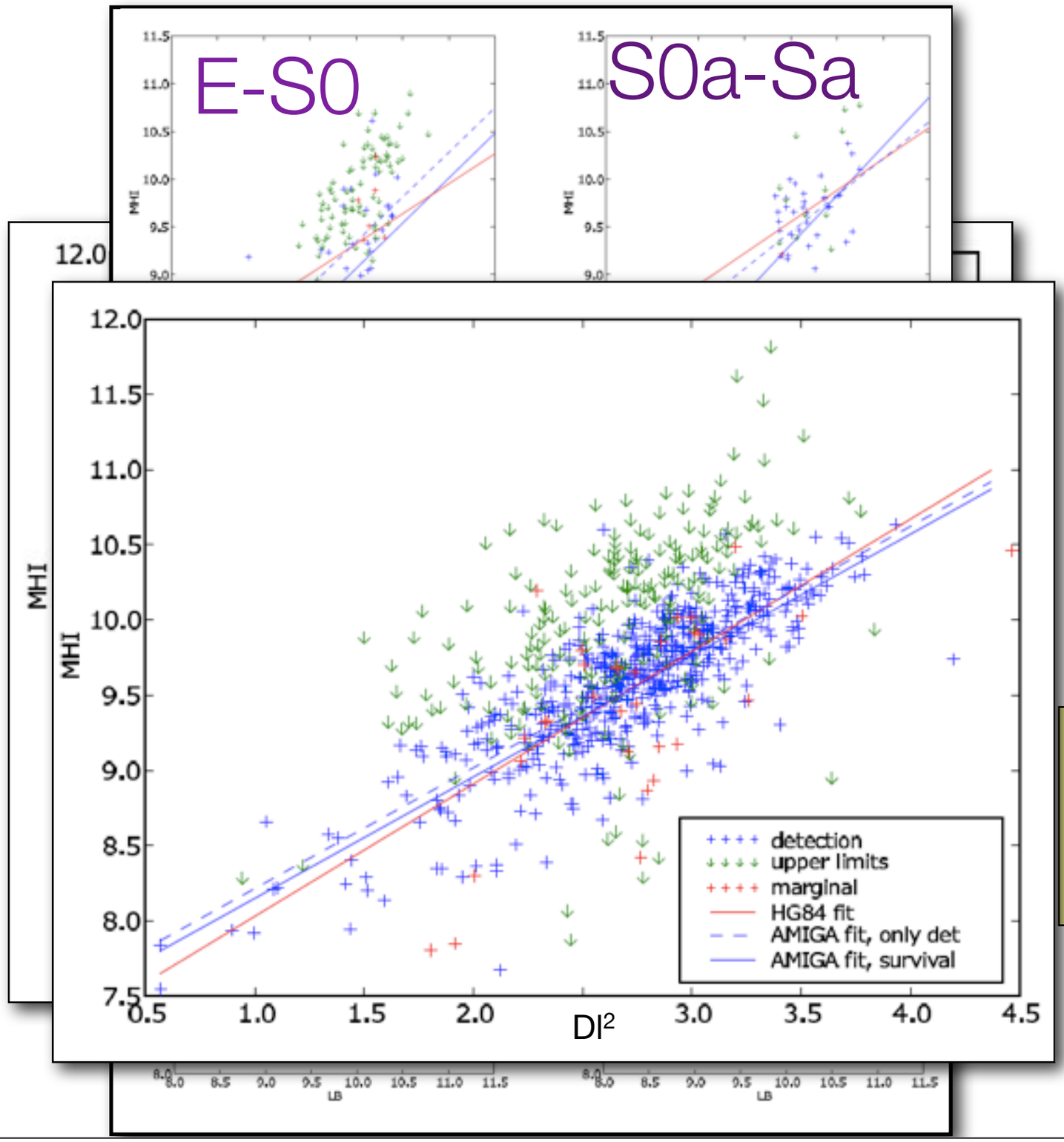

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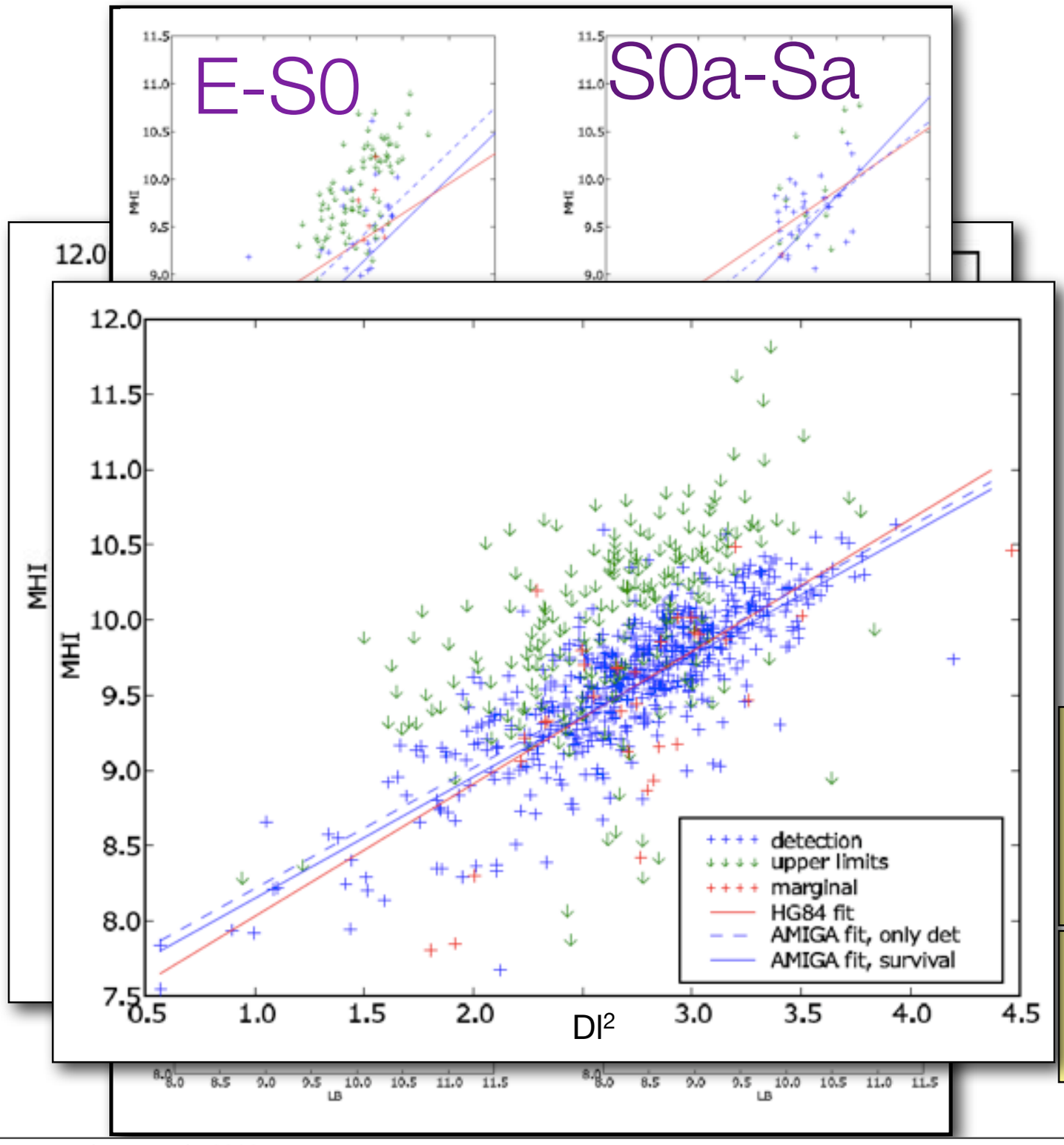

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-Differences with HG84
T < Sbc (in especial E-S0) and T > Scd - Sd.

-MHI - LB have lower dispersion than MHI - D_I^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)

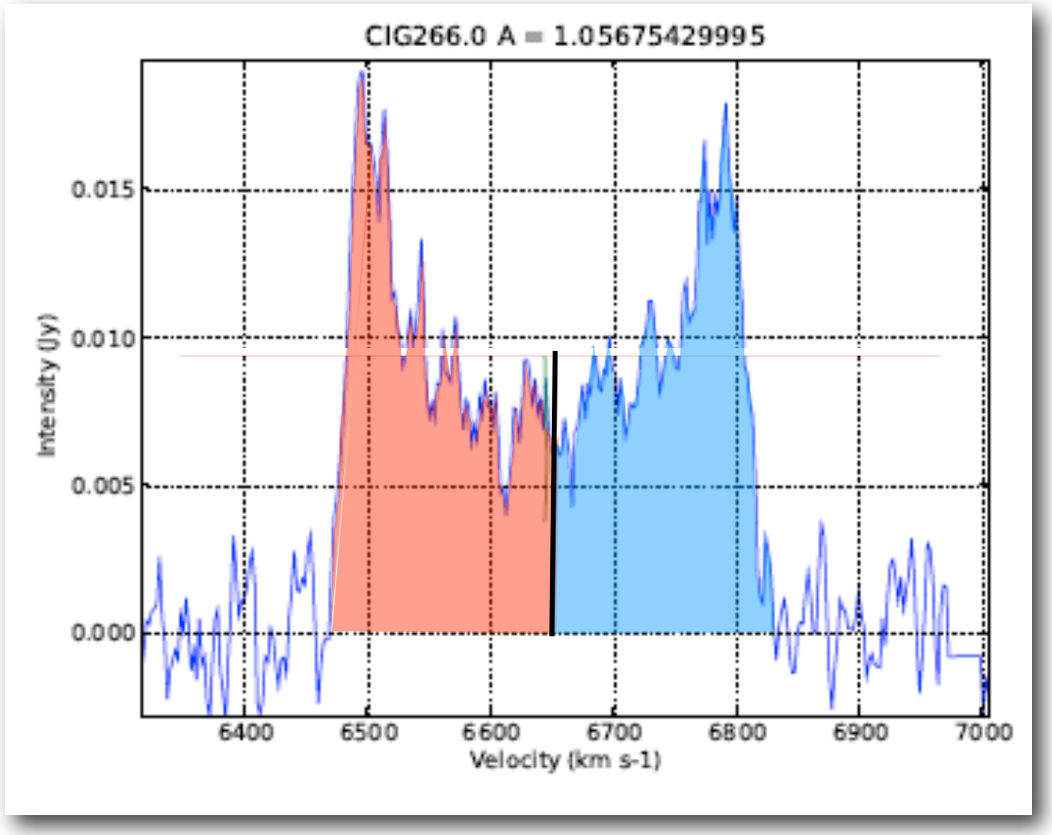
-Sustained long-lived lopsidedness due to non-circular motions (e.g. Baldwin et al. 1980)

-Cosmological gas accretion (e.g. Bournaud et al. 2005)

-Halo - disk misalignment (e.g. Noordermeer et al. 2001)

- ...

4.1 HI asymmetry parameter ($A_{flux\ ratio}$)



$$A_{l/h} = \frac{A_l}{A_h} = \frac{\int_{V_l}^{V_m} S_v dv}{\int_{V_m}^{V_h} S_v dv}$$

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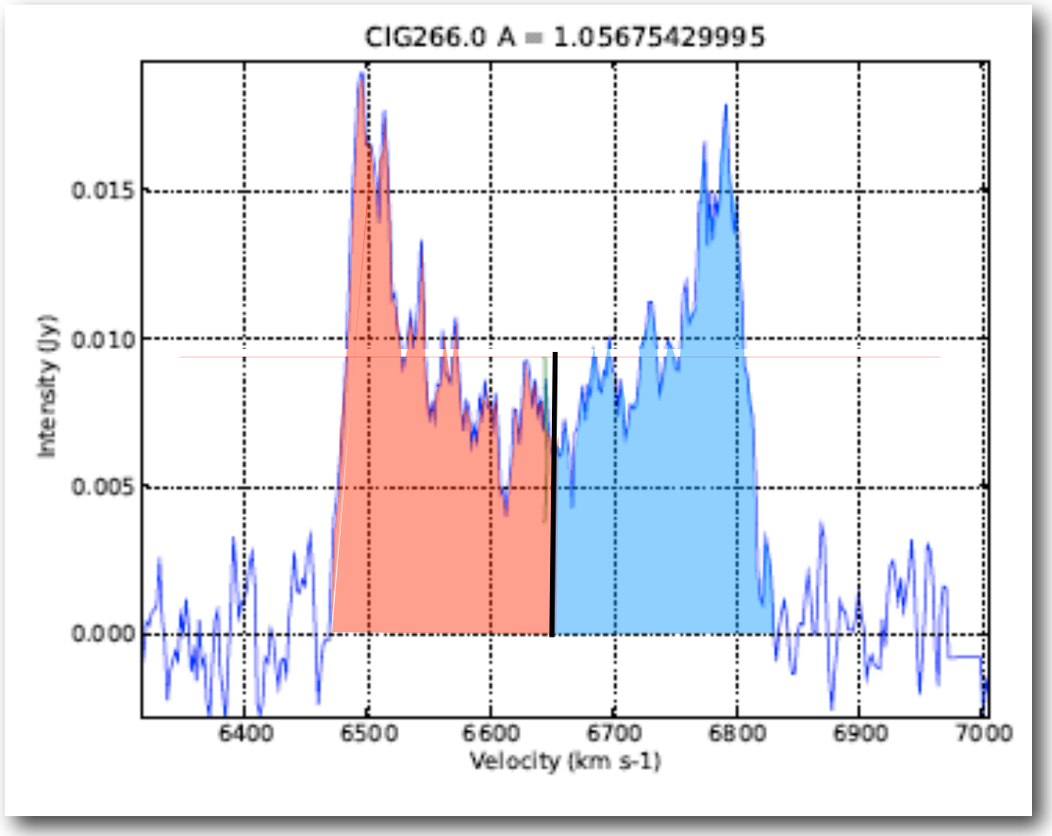

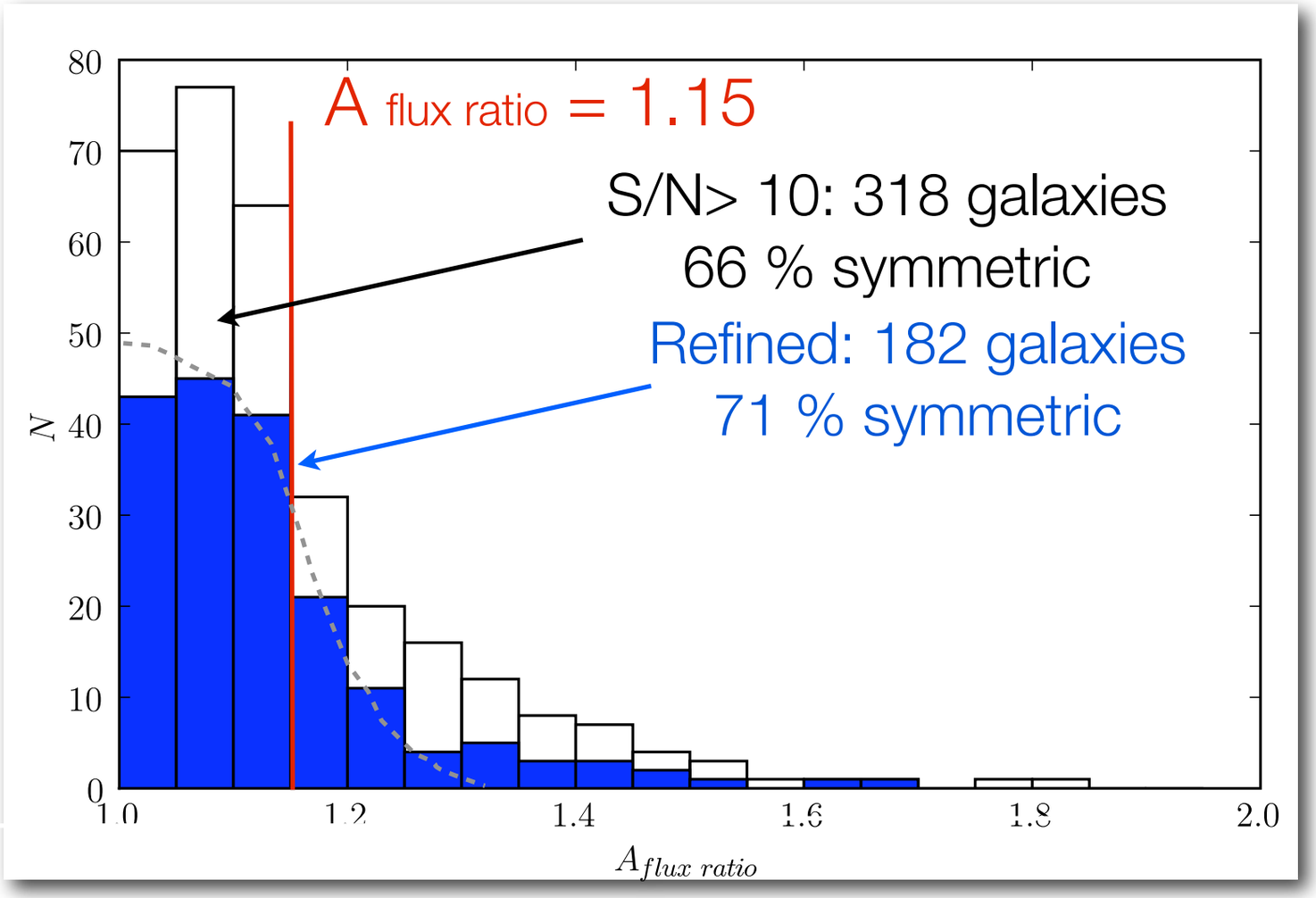

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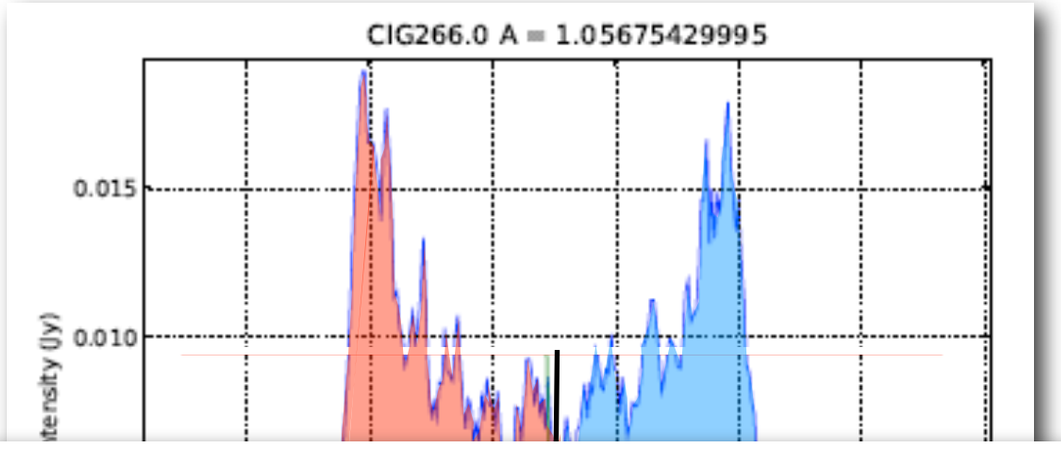
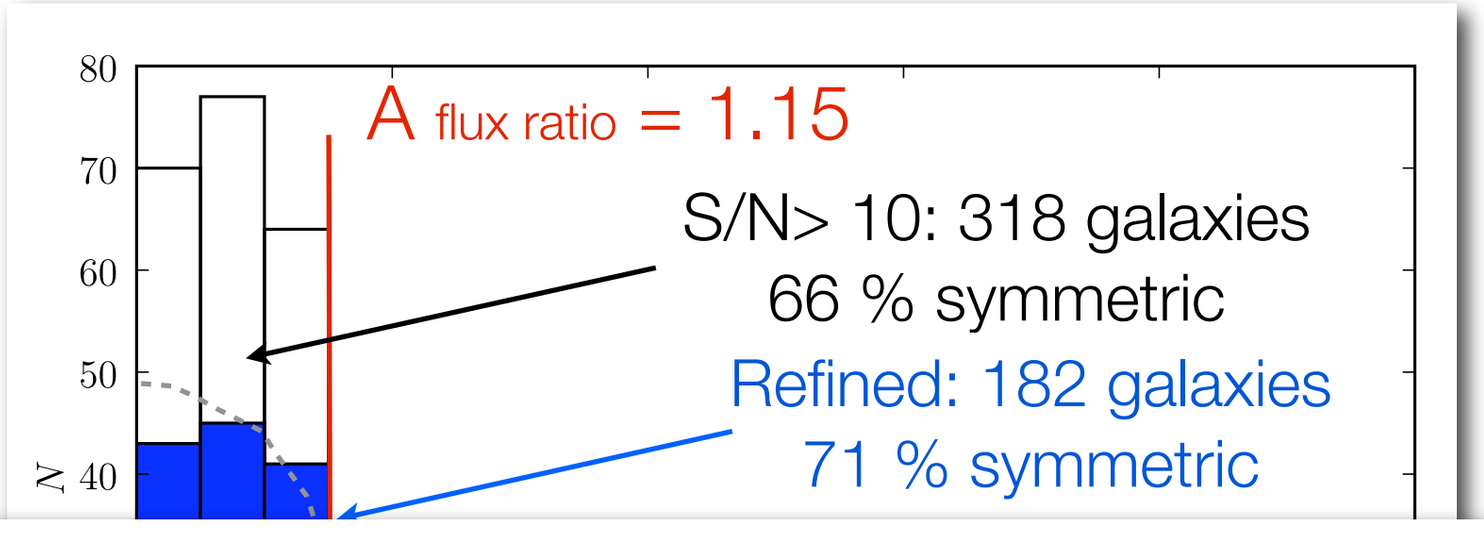
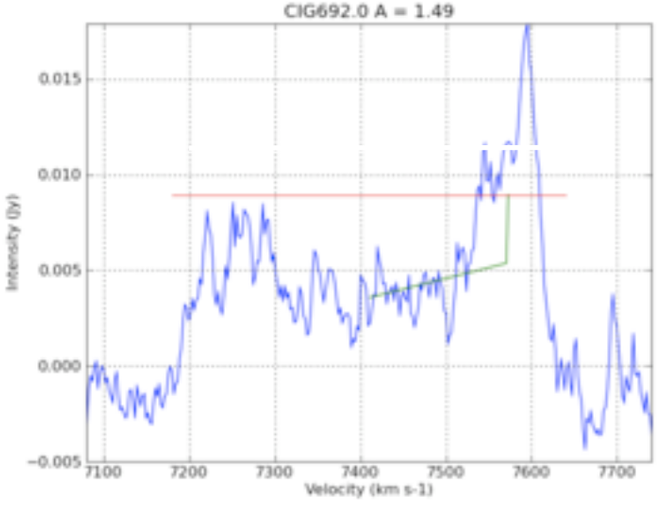




Strongly asymmetric

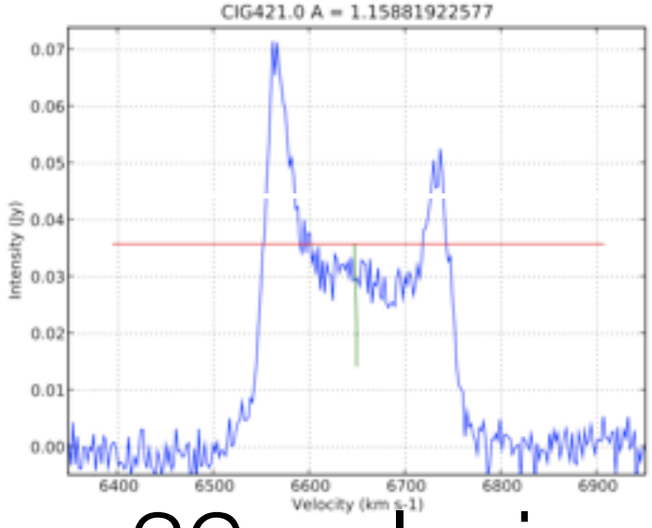
$A_{flux\ ratio} > 1.3$



14 galaxies

Slightly asymmetric

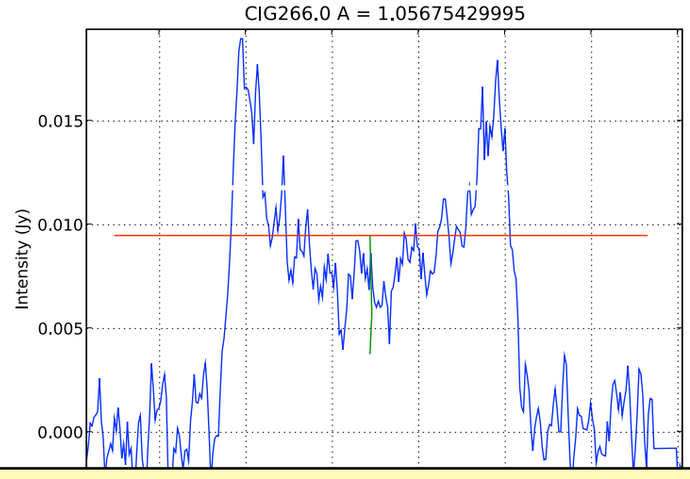
$1.15 < A < 1.3$



39 galaxies

Symmetric

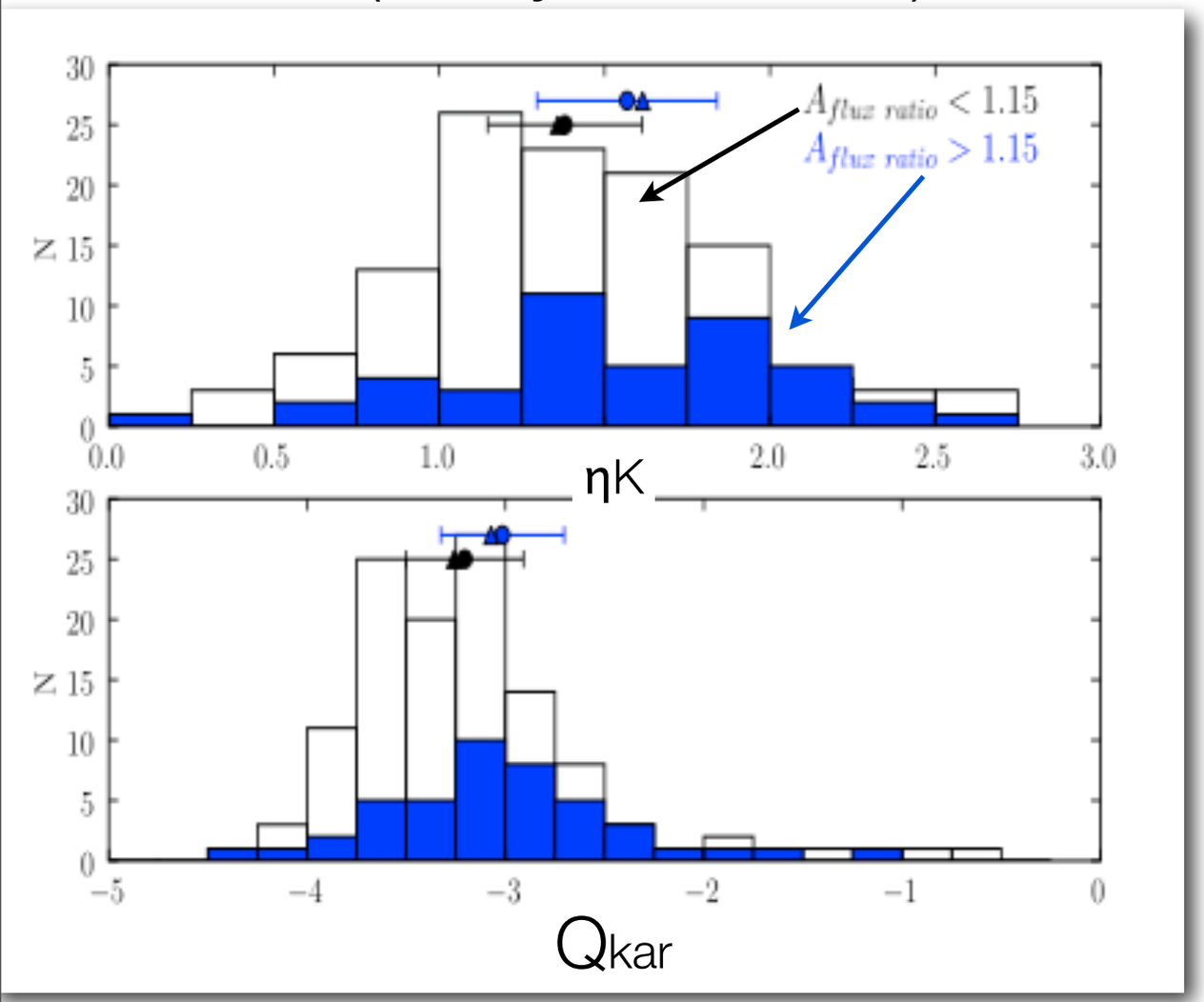
$A < 1.15$



129 galaxies (71%)

4.2 HI asymmetry parameter and environment

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



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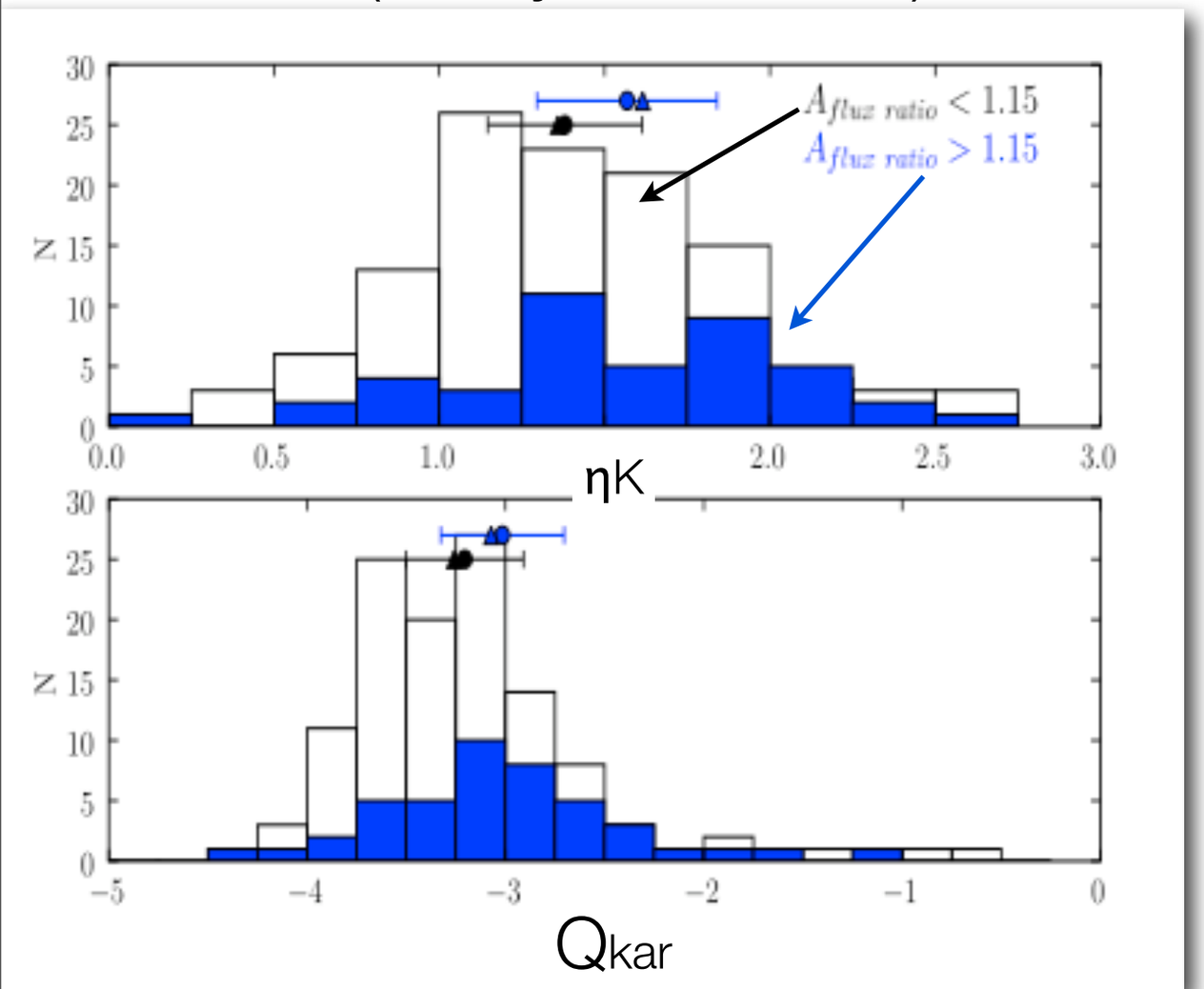
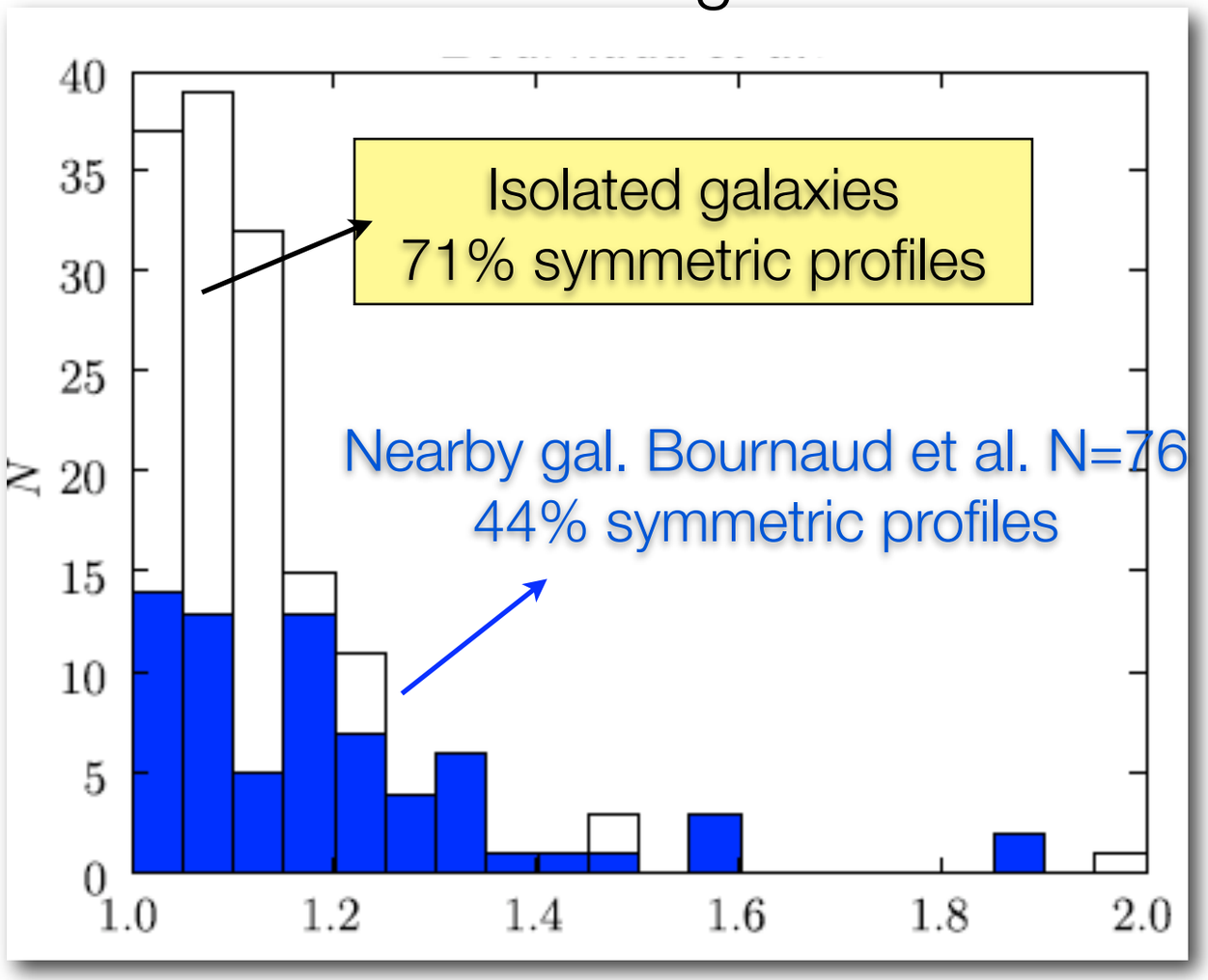


b) Other samples of galaxies maybe interacting



5. HI Atlas of isolated galaxies

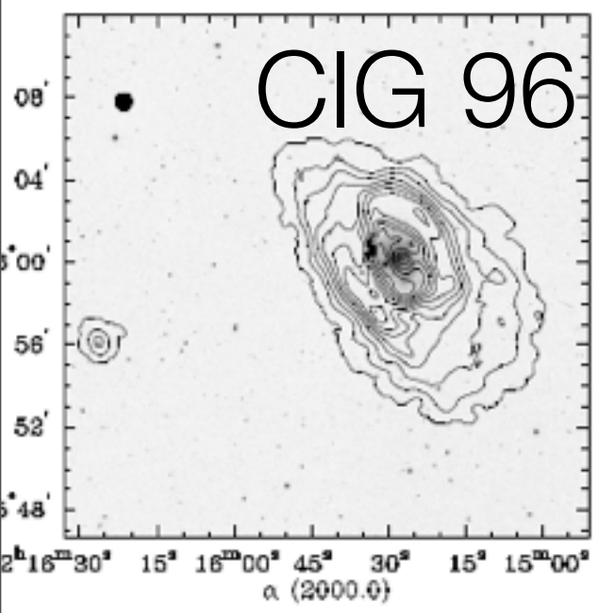
We know the lopsidedness rate in isolated galaxies, but what is its origin? VLA observations are needed:

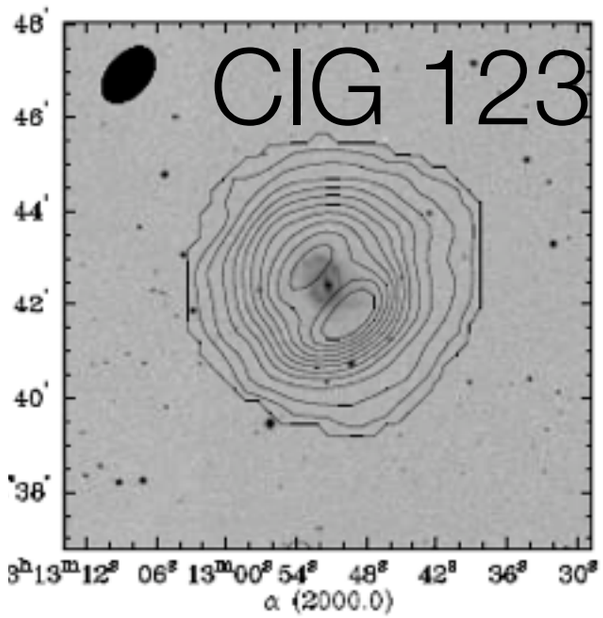
- Asymmetry in the HI profiles is produced by confusion with HI-rich companions,
- Presence of tidal extended structures which may imply interaction with another galaxy,
- Asymmetry in the HI distribution or velocity field?.

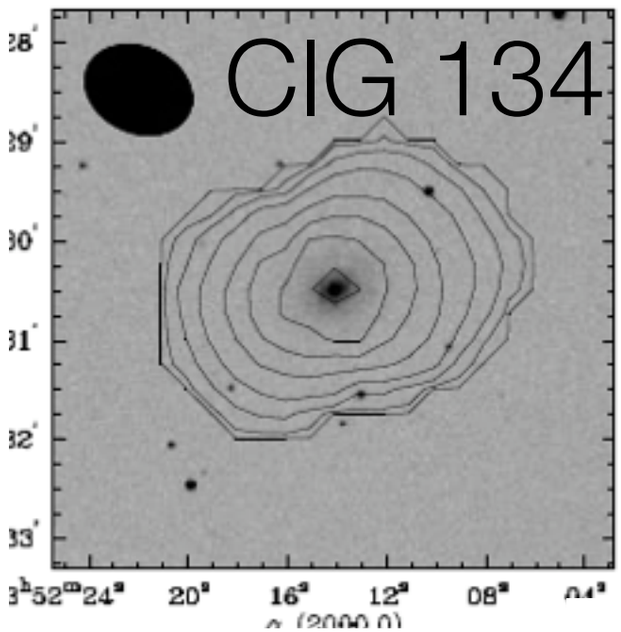
-VLA subsample: 8 asymmetric and 4 symmetric HI profiles

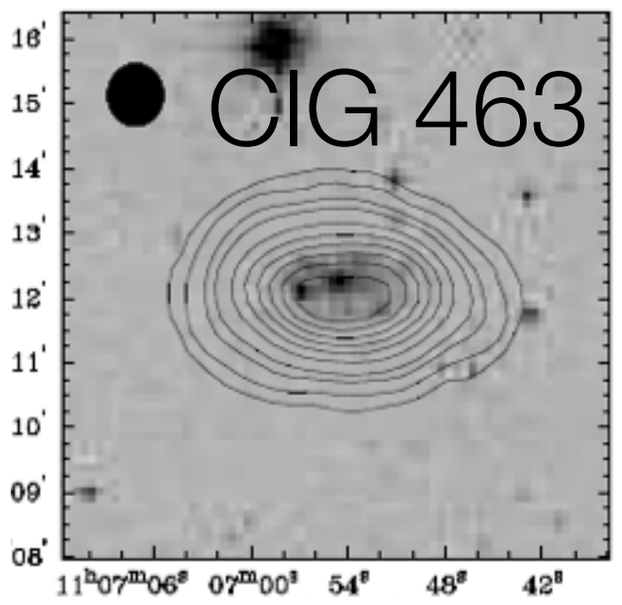
Espada et al. 2005 A&A 442 455 (CIG 96)
Espada PhD 2006

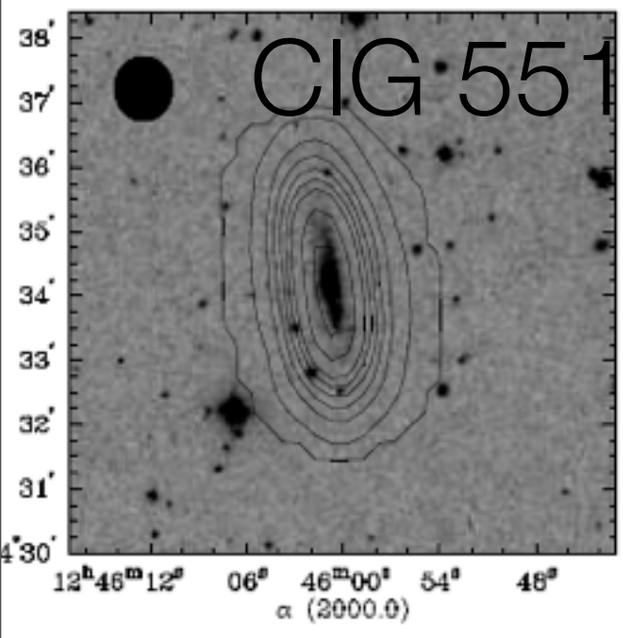
5. HI Atlas of isolated galaxies

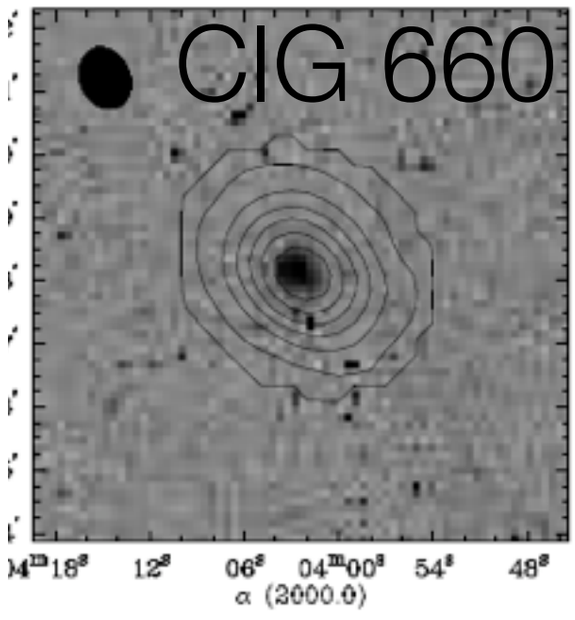


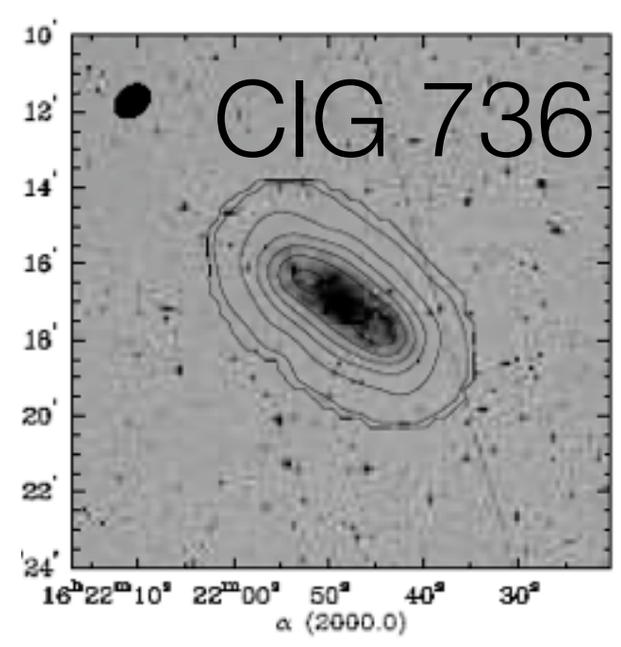


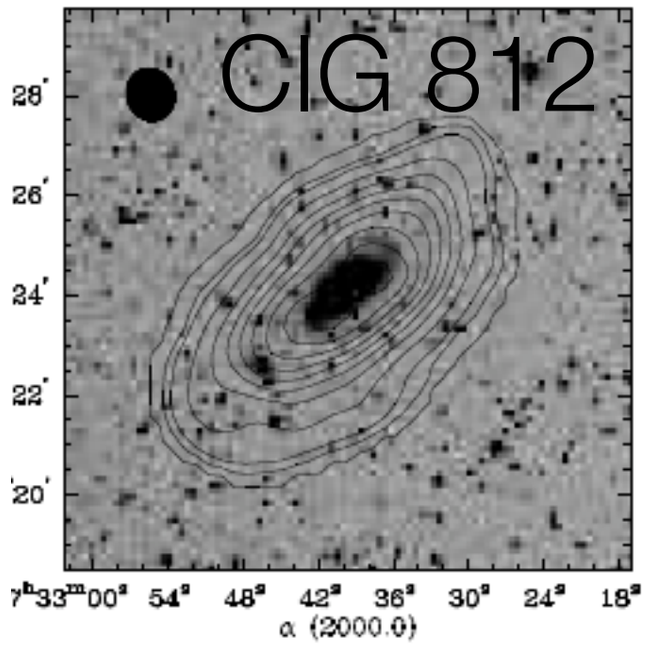






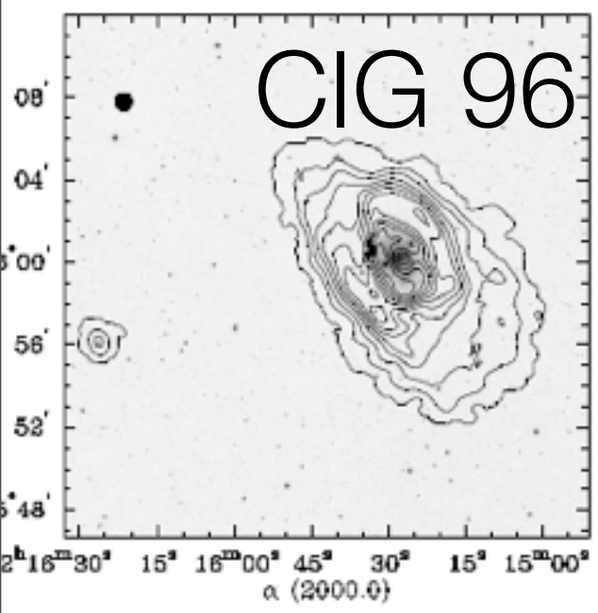


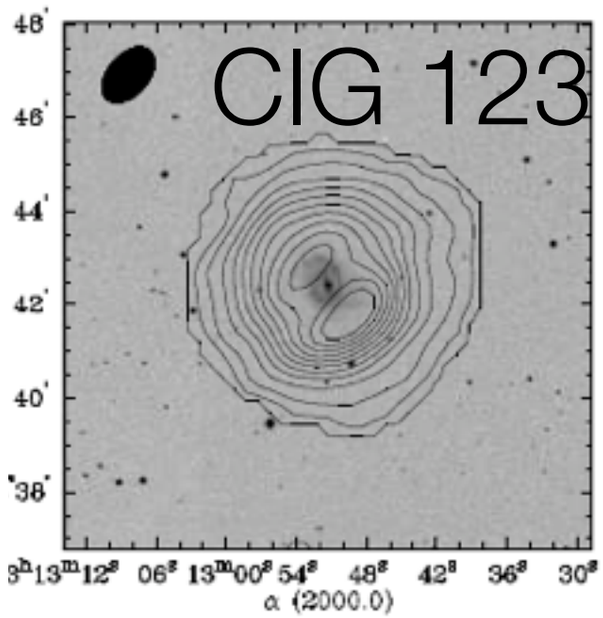


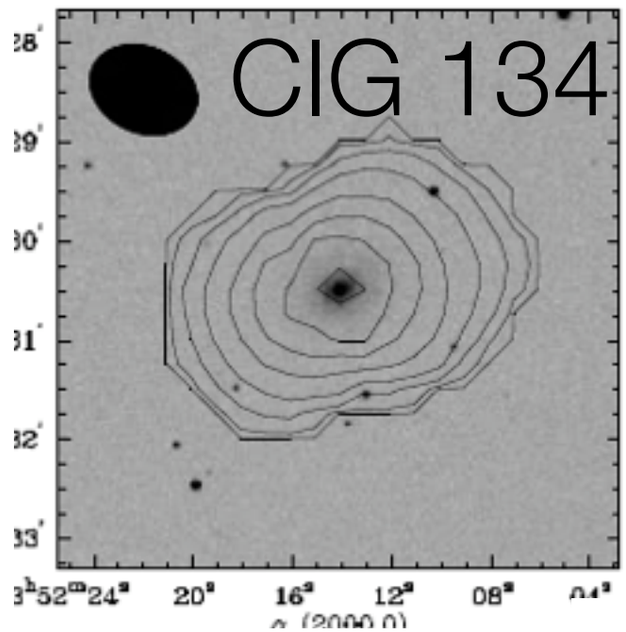


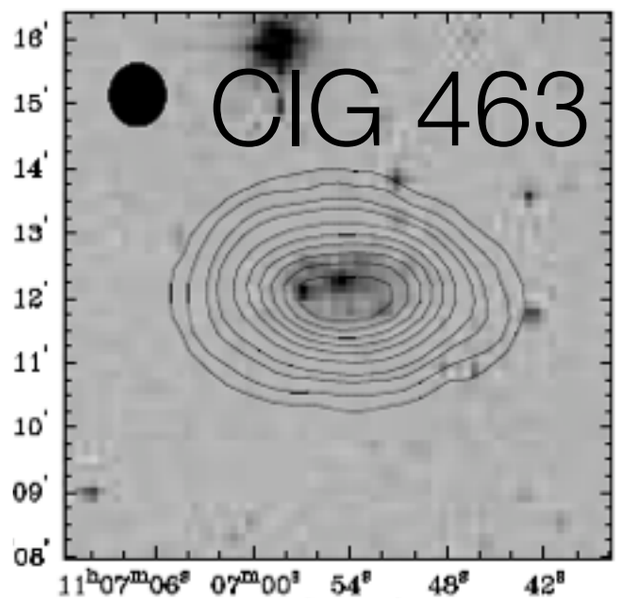
Espada et al. 2005 A&A 442 455 (CIG 96)
Espada PhD 2006

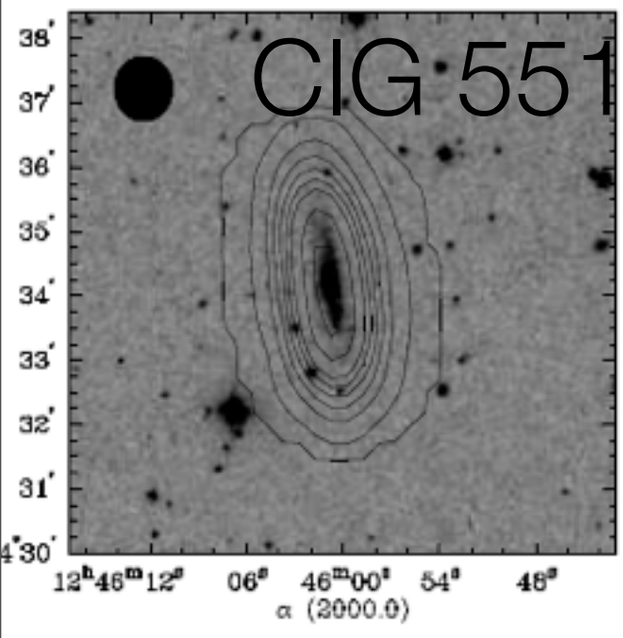
5. HI Atlas of isolated galaxies

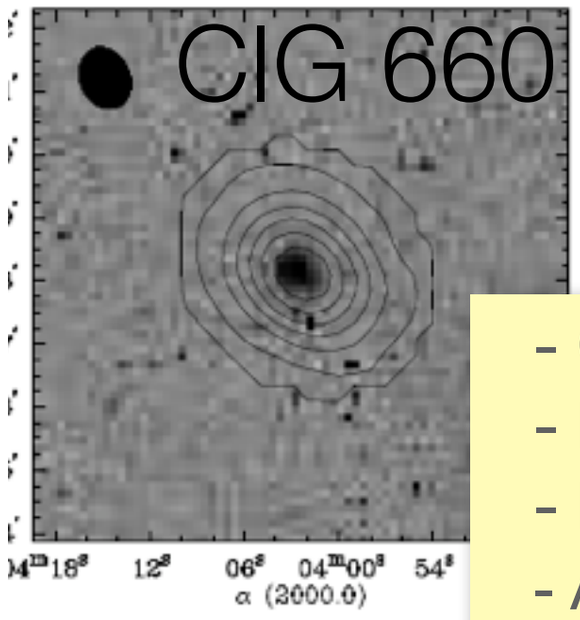


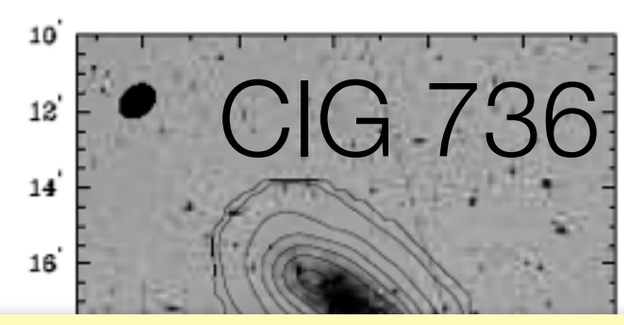


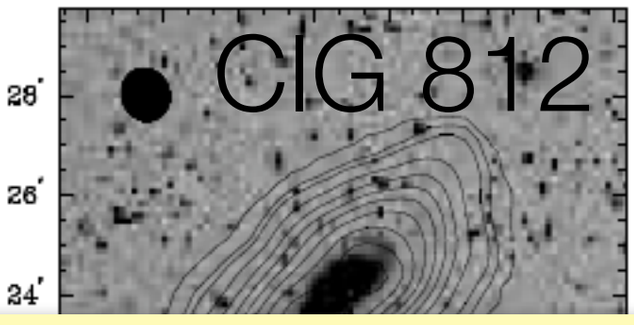










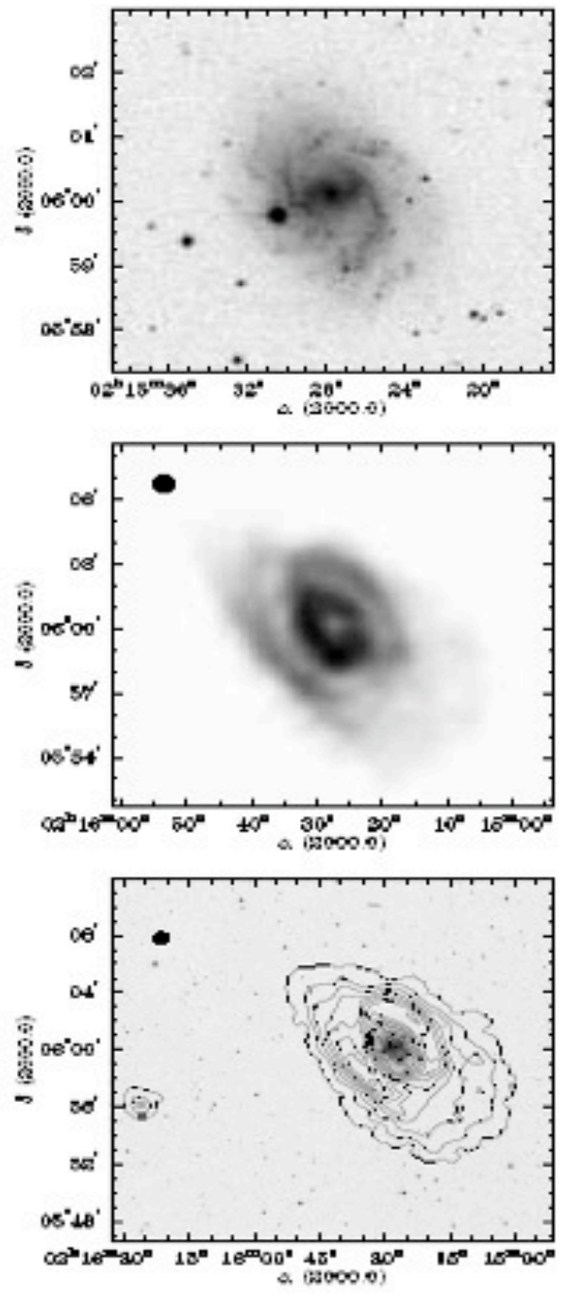


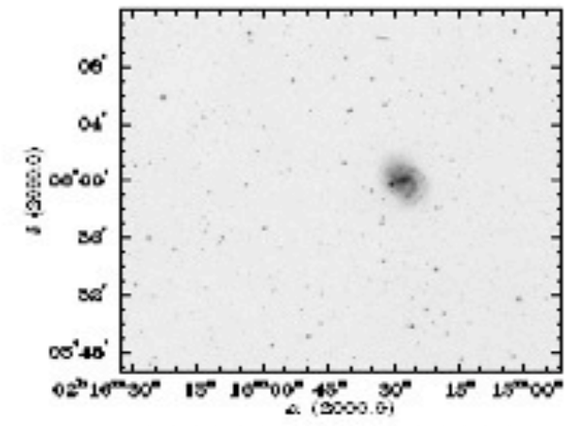
- Connection optical and HI asymmetries?
- No HI-rich companions
- No tidal tails
- Asymmetry mostly in velocity field

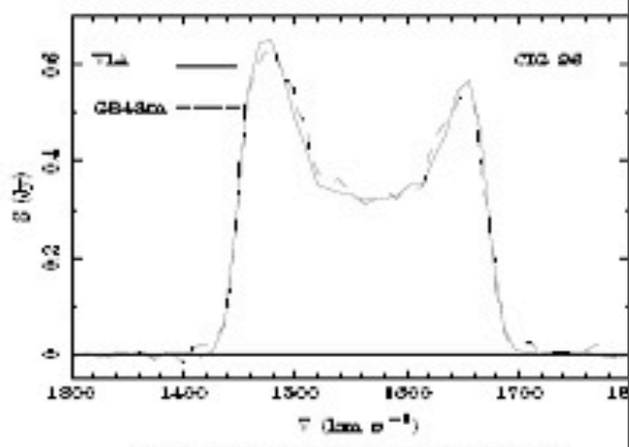
Espada et al. 2005 A&A 442 455 (CIG 96)
Espada PhD 2006

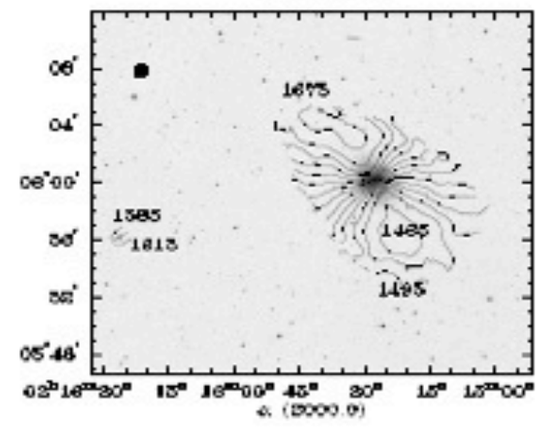
5. HI Atlas of isolated galaxies

Source: CIG 96		
Morphology		SBc
α(2000)	(hh:mm:ss)	02:15:27.6
δ(2000)	(dd:mm:ss)	06:00:09.0
Optical field sizes	($' \times '$)	5.6 × 5.6, 25.4 × 25.4
Observing time	(hours)	4
Central velocity	(km s^{-1})	1572
Spatial resolution	($''$)	15
Number of channels		64
Velocity resolution	(km s^{-1})	10.4
Beam size	($\alpha \times \delta$, $'' \times ''$)	49.8 × 46.0
Conv. beam size	($\alpha \times \delta$, $''$)	70.4 × 65.3
PA (N to E)	($^\circ$)	-6
HI data parameters		
Channel maps		
Field size, channels	($'$)	17.0 × 17.0, 22 - 46
Velocities	(km s^{-1})	1436.7 - 1686.6
rms noise channel	(mJy/beam)	0.66
Contours	(mJy/beam)	3, 10, 21, 42, 56, 70, 84, 98, 112
Global HI profile		VLA — GB43m (HG98)
HI flux	(Jy km s^{-1})	103 — 102.8
Heliocentric velocity	(km s^{-1})	1557 — 1562
HI profile width 20%	(km s^{-1})	238 — 239
M_{HI}	(10^9 $M_\odot$)	7.24 — 7.53
HI maps		
Field size	($' \times '$)	5.6 × 5.6
HI map contours	(mJy/beam km s^{-1})	1, 100, 250, 750, 1000, 1250, 1500, 1750, 2000, 2250, 2500
	(10^{20} cm^{-2})	0.1, 6, 15, 45, 60, 75, 90, 105, 120, 135, 150
Velocity contours	(v_{max} - v_{min}, δv) (km s^{-1})	1465 - 1675, 15
Comments		
Companion α=02:16:26.90,	δ=05:56:24.0, v=1605	(1572-1655), $M_{HI} \simeq 10^8$ $M_\odot$









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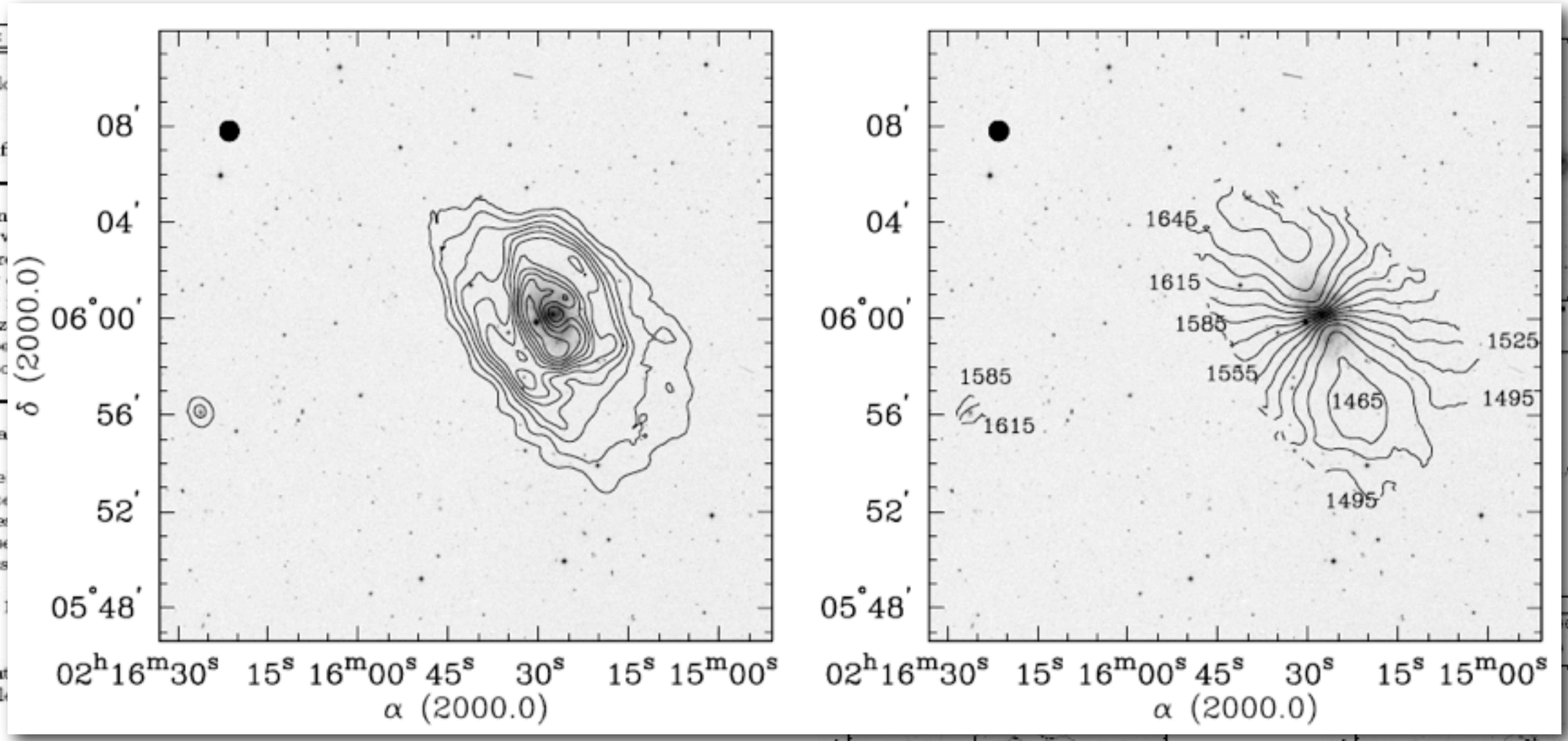
5. HI Atlas of isolated galaxies



Source:		
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Contours		
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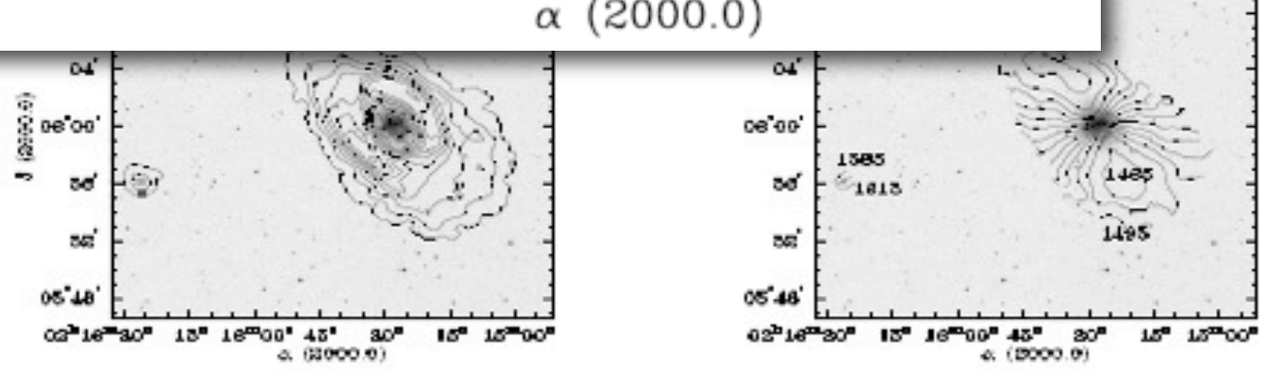
HI maps		
Field size	(′ × ′)	5.6 × 5.6
HI map contours	(mJy/beam km s^{-1})	1, 100, 250, 750, 1000, 1250, 1500, 1750, 2000, 2250, 2500
	(10^{20} cm^{-2})	0.1, 6, 15, 45, 60, 75, 90, 105, 120, 135, 150
Velocity contours	(v_{max} - v_{min}, δv) (km s^{-1})	1465 - 1675, 15
Comments		
Companion α=02:16:26.90,	δ=05:56:24.0, v=1605	(1572-1655), $M_{HI} \simeq 10^9$ $M_\odot$



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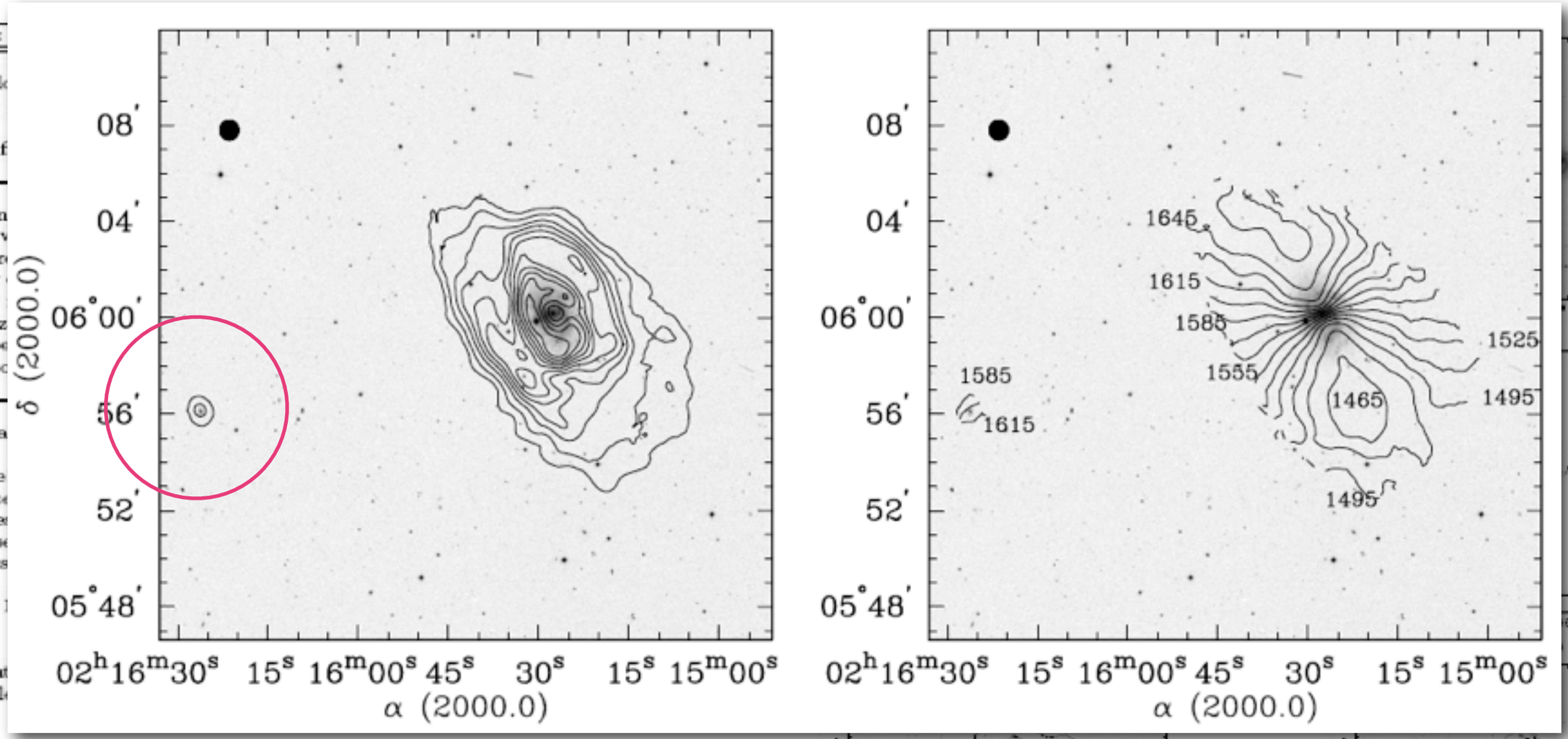

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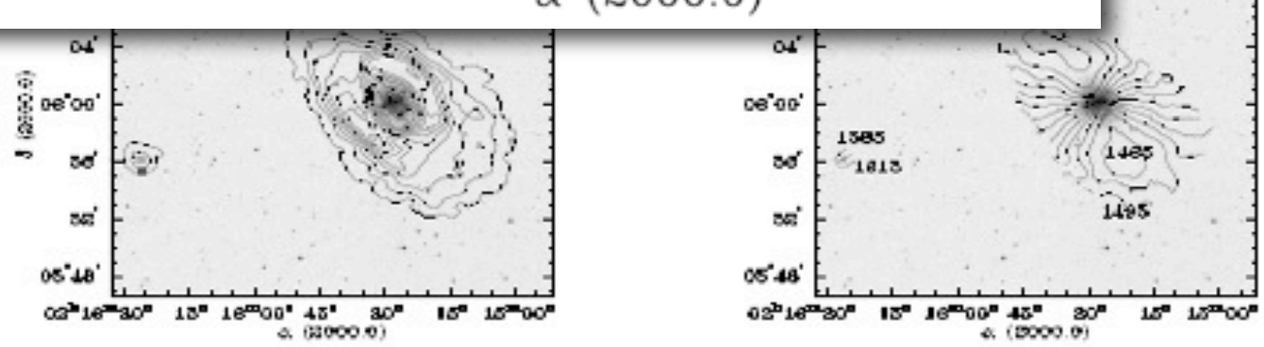

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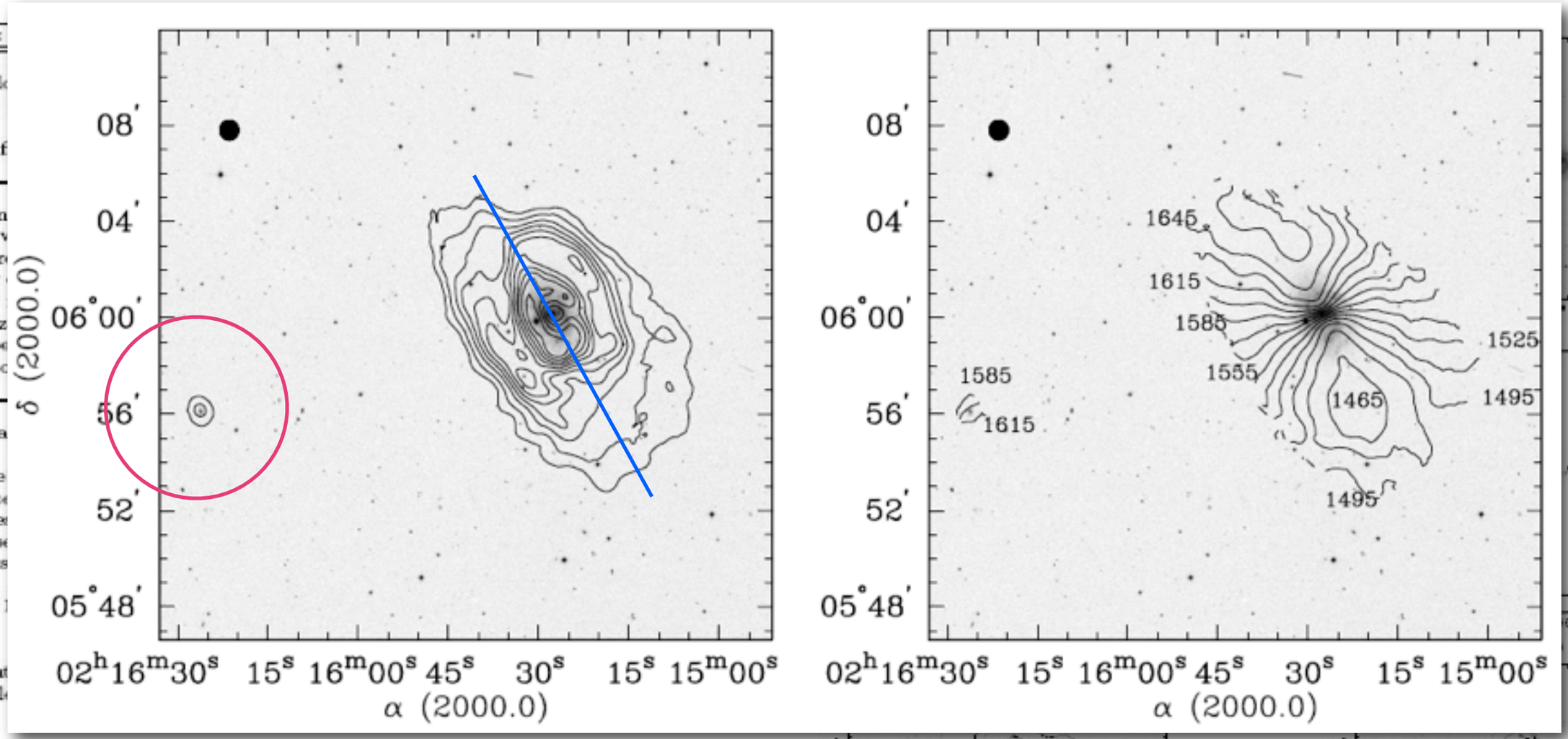

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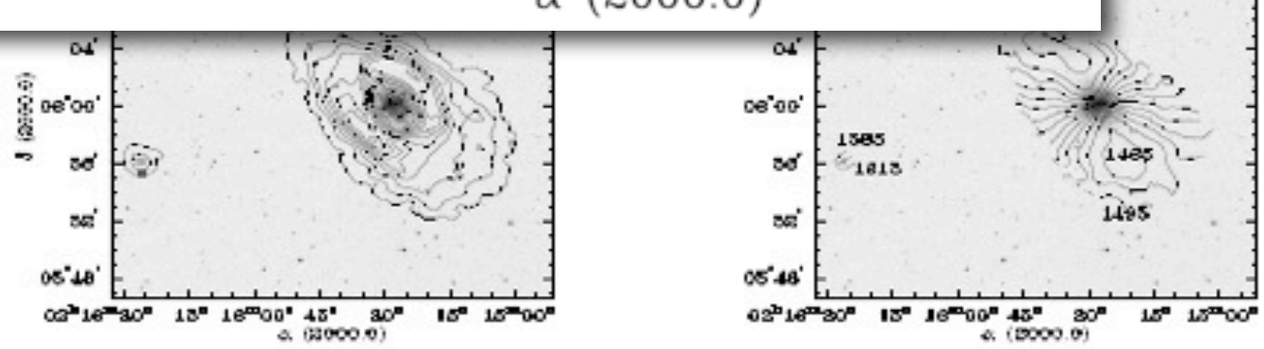

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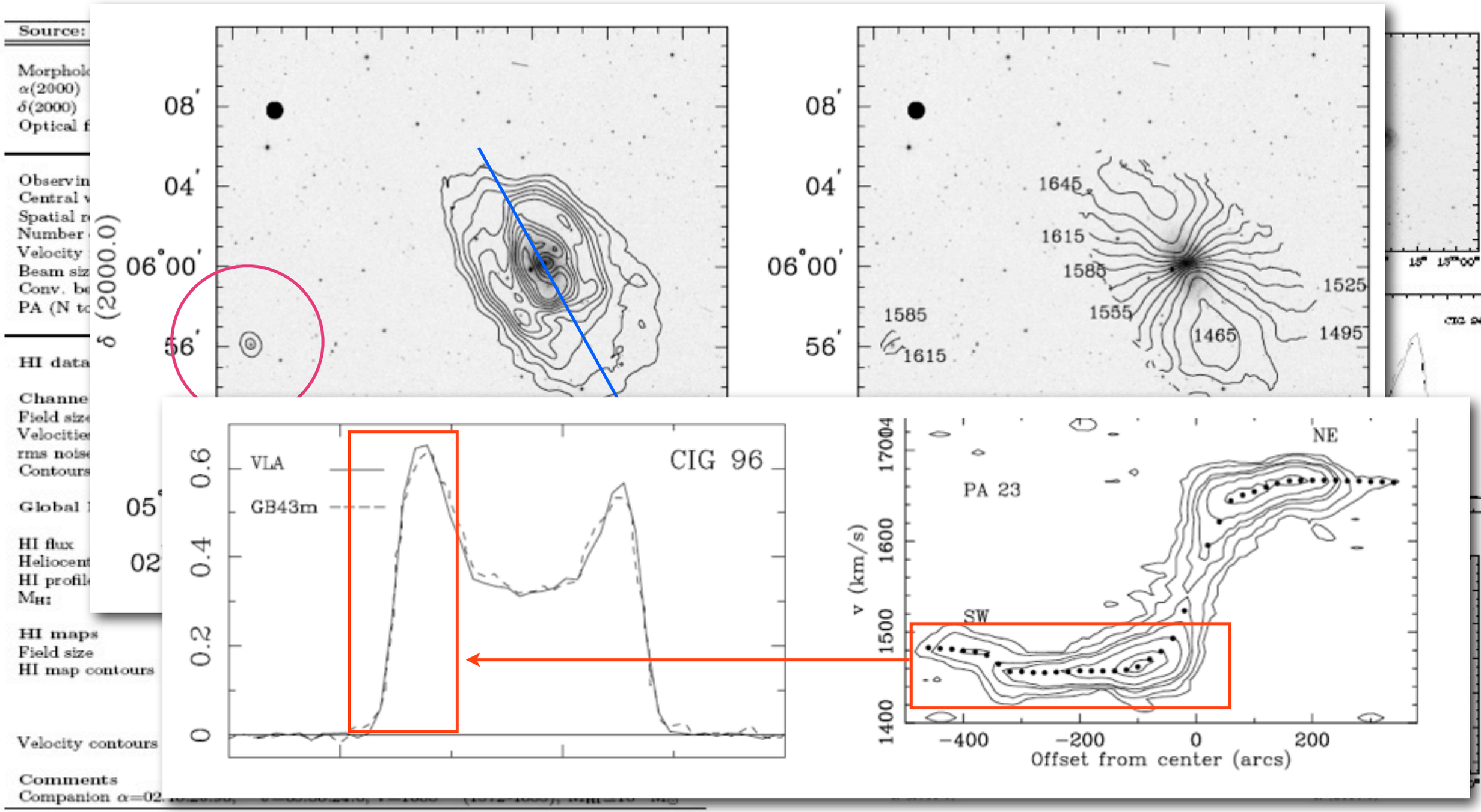

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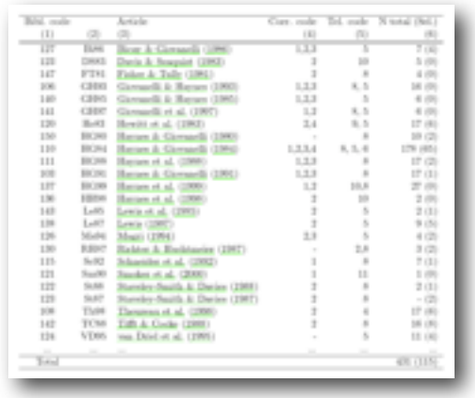
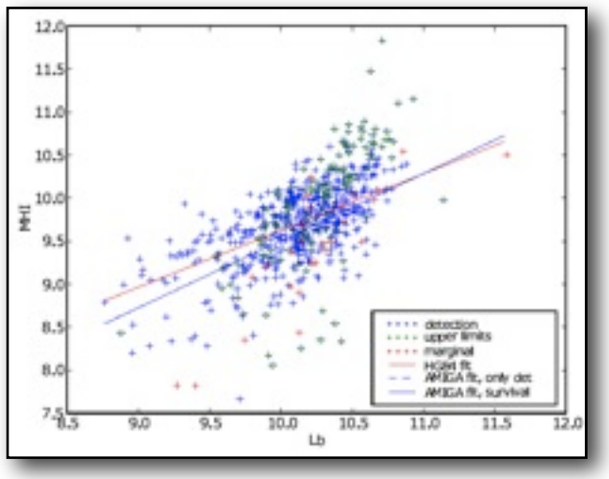
Summary

AMIGA — Analysis of the Interstellar Medium of Isolated GAlaxies

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 ($A_{flux\ ratio}<1.15$) 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 x 10^6 Msun.