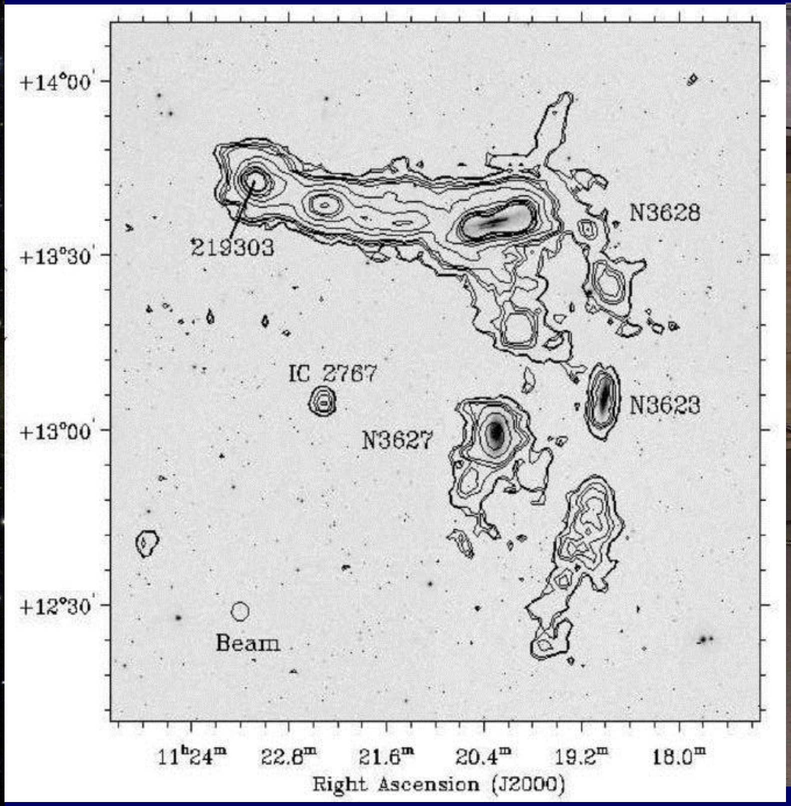
Evidence of Environmental Effects in Star-Forming Galaxies

Martha Haynes

Cornell University



Disclaimer:

In a 35 min talk, I have to be selective in how much detail/what works I reference.

Apologies if I do not mention you and/or your favorite work.

Anyway, there are going to be lots of great talks in this subject coming up!

Environmental effects in SF galaxies

Basic picture: Star formation declines if the galaxy density reaches some threshold value.

How, when, where and why do galaxies stop accreting cool gas?

- Once they stop accreting gas, how is star formation impacted?

How, when, where and why do galaxies lose their cool gas?

- Once the gas is lost, how is star formation impacted?

This talk: A review of the evidence of environmental effects in star-forming galaxies in groups/clusters

Including a bit of history

Environmental effects in SF galaxies

Basic picture: Star formation declines if the galaxy density reaches some threshold value.

How, when, where and why do galaxies stop accreting cool gas?

- Once they stop accreting gas, how is star formation impacted?

How, when, where and why do galaxies lose their cool gas?

- Once the gas is lost, how is star formation impacted?

This talk: A review of the evidence of environmental effects in star-forming galaxies in groups/clusters

Including a bit of history

Environmental effects in SF galaxies

Basic picture: Star formation declines if the galaxy density reaches some threshold value.

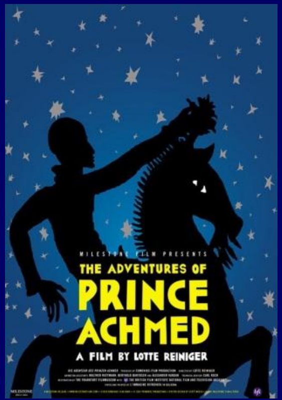
How, when, where and why do galaxies stop accreting cool gas?

- Once they stop accreting gas, how is star formation impacted?

How, when, where and why do galaxies lose their cool gas?

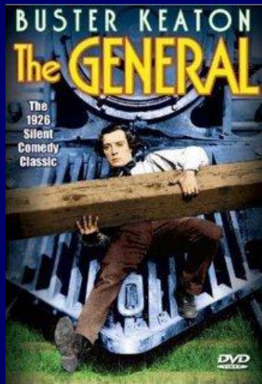
- Once the gas is lost, how is star formation impacted?

This talk: A review of the evidence of environmental effects in star-forming galaxies in groups/clusters



Including a bit of history

1926: Hubble 's morphogical classification scheme
Contributions from the Mount Wilson Observatory / Carnegie Institution of Washington, vol. 324, pp.1-49

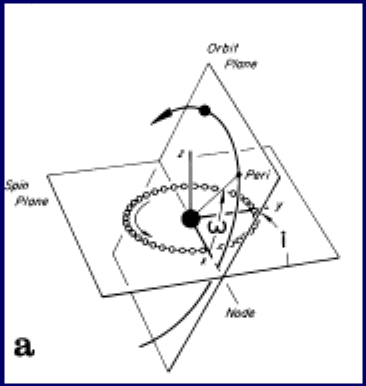


Drivers of environmental evolution

Gravitational:

- Galaxy-galaxy: slow encounters, mergers – tidal structures

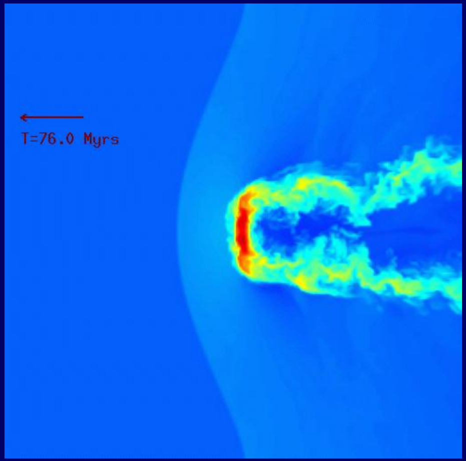
  Toomre & Toomre 1972, ApJ 178, 623



Gas dynamics :

- Ram pressure stripping

  Gunn & Gott 1972, ApJ 176, 1



Starvation: no reservoir to fuel SF

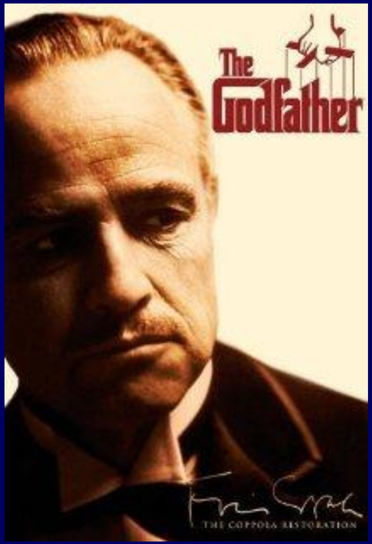
Larson, Tinsley & Caldwell 1980, ApJ 237, 692

Drivers of environmental evolution

Gravitational:

- Galaxy-galaxy: slow encounters, mergers – tidal structures

  Toomre & Toomre 1972, ApJ 178, 623



1972

Gas dynamics :

- Ram pressure stripping

  Gunn & Gott 1972, ApJ 176, 1

1980

Starvation: no reservoir to fuel SF

Larson, Tinsley & Caldwell 1980, ApJ 237, 692

Drivers of environmental evolution

Gravitational:

- Galaxy-galaxy: slow encounters, mergers – tidal structures
  Toomre & Toomre 1972, ApJ 178, 623
- Galaxy-cluster field: flyby interactions
  Miller 1986 A&A 167, 41
- Galaxy-multiple galaxies: harassment
  Moore, Lake & Katz, 1988, ApJ 495, 139

Gas & stars

Gas dynamics :

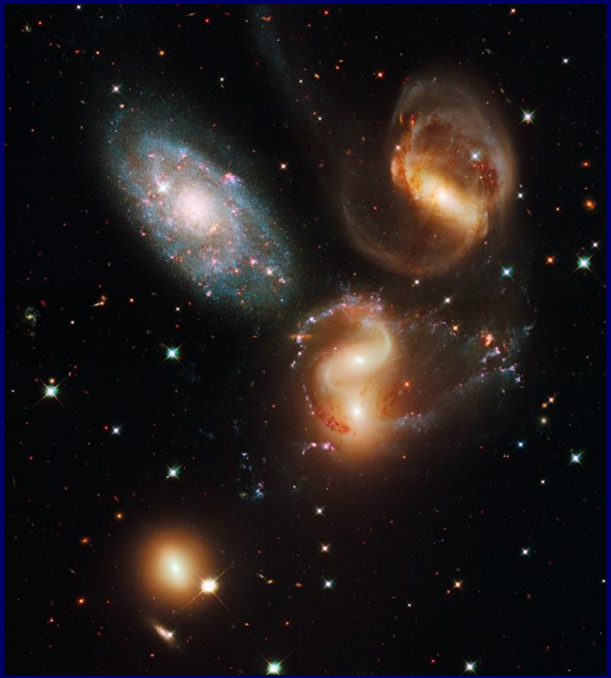
- Ram pressure stripping
  Gunn & Gott 1972, ApJ 176, 1
- Turbulent viscous stripping
  Nulsen 1982, MNRAS 198, 1007
- Thermal conduction
  Cowie & Songaila 1977, Nature 266, 501

Gas only

Starvation: no reservoir to fuel SF
Larson, Tinsley & Caldwell 1980, ApJ 237, 692

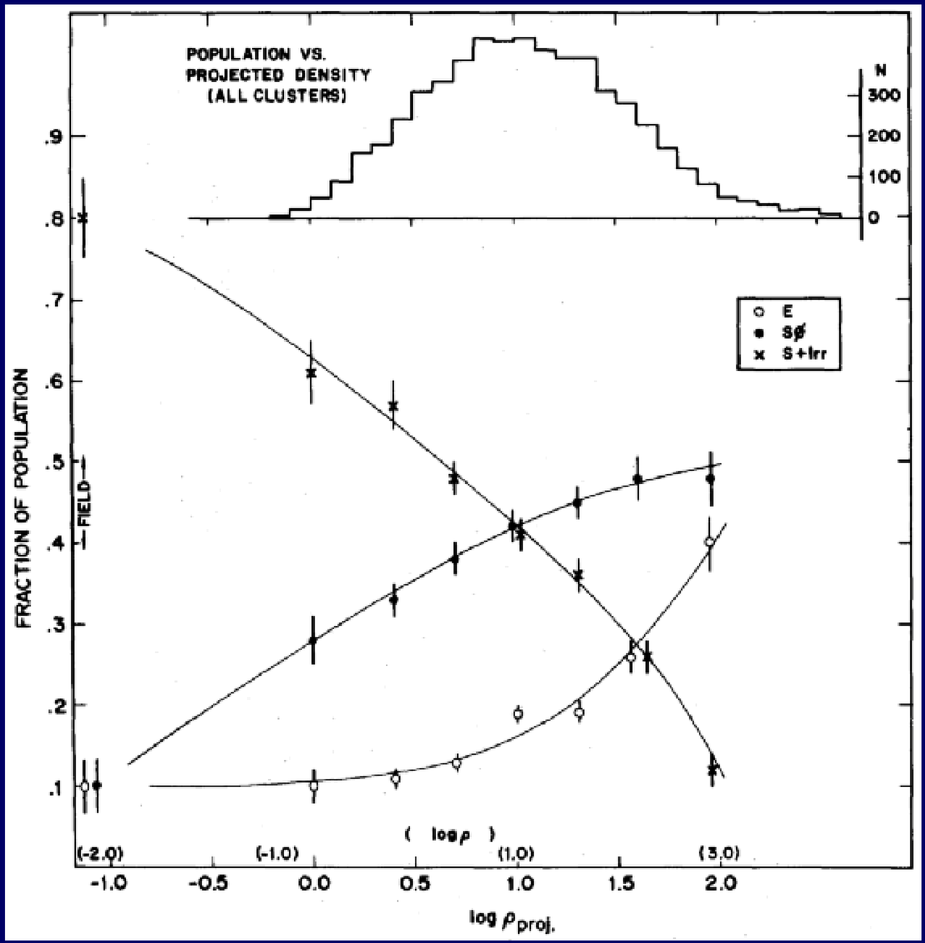
Evidence of environmental effects:

- Morphological segregation
- Morphological disturbance
- HI deficiency
- HI/Ha distributions



Evidence of environmental effects:

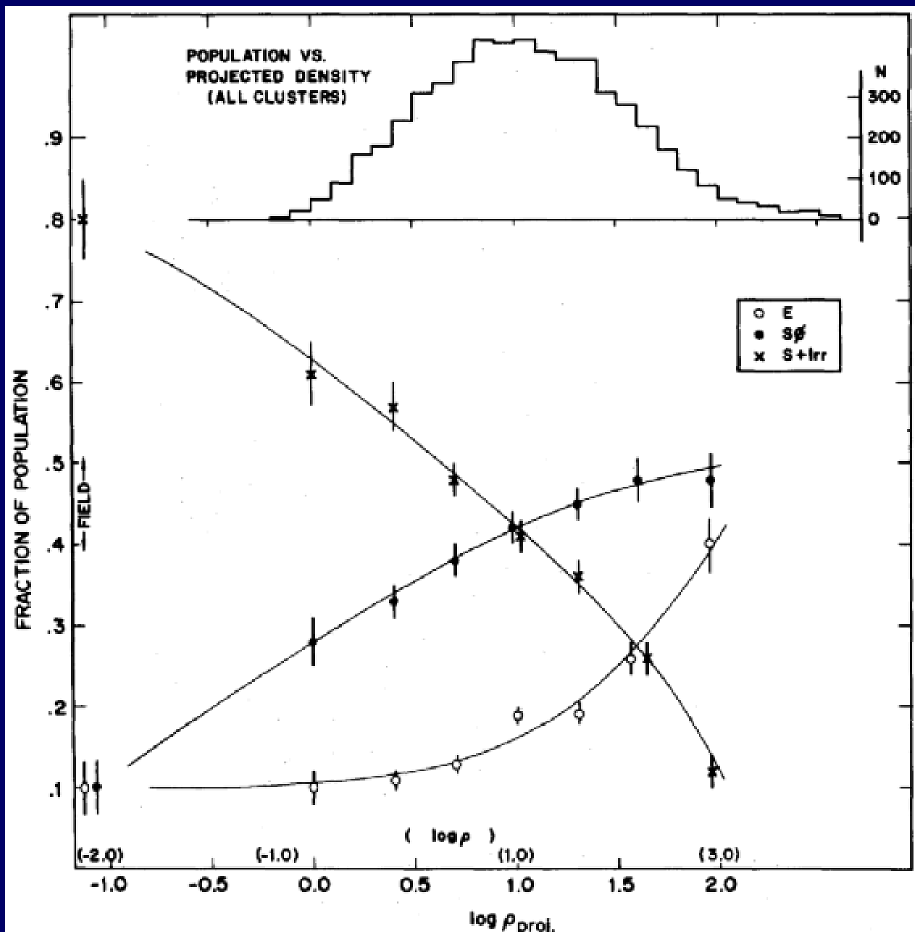
- Morphological segregation



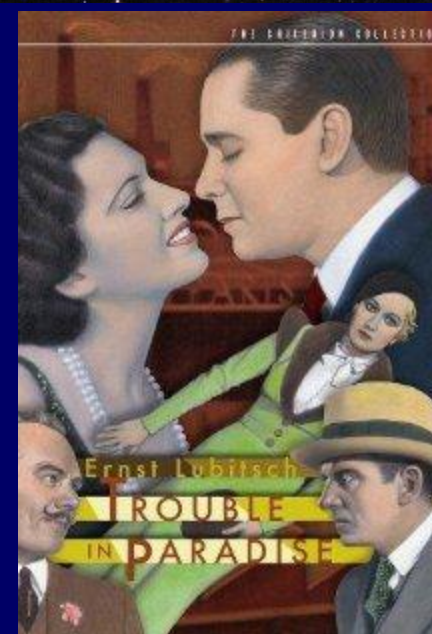
Dressler 1980

Evidence of environmental effects:

- Morphological segregation



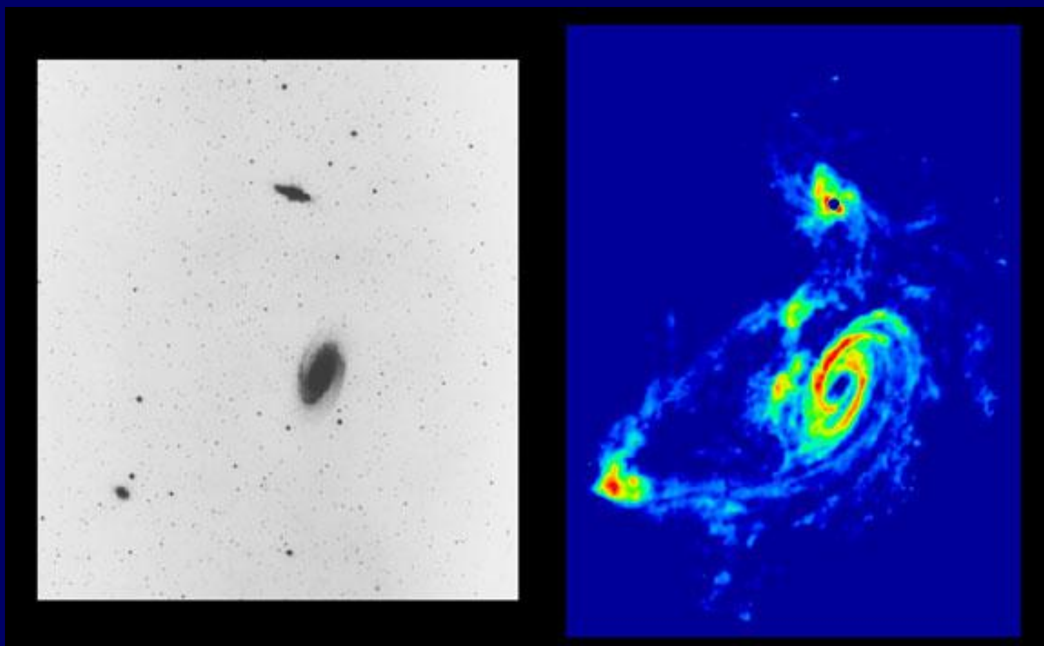
Dressler 1980



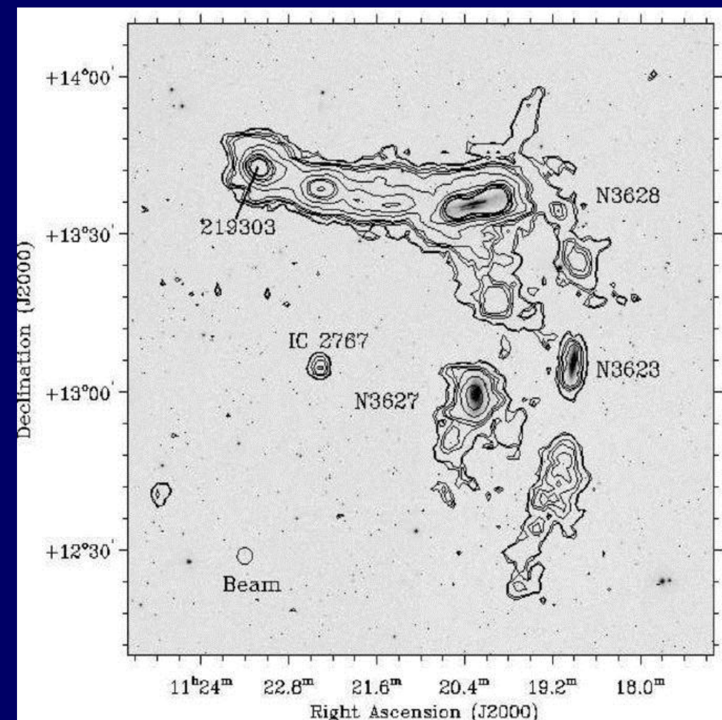
1932

Evidence of environmental effects:

- Morphological disturbance => clear evidence
  - As a kinematic tracer, HI is very useful!



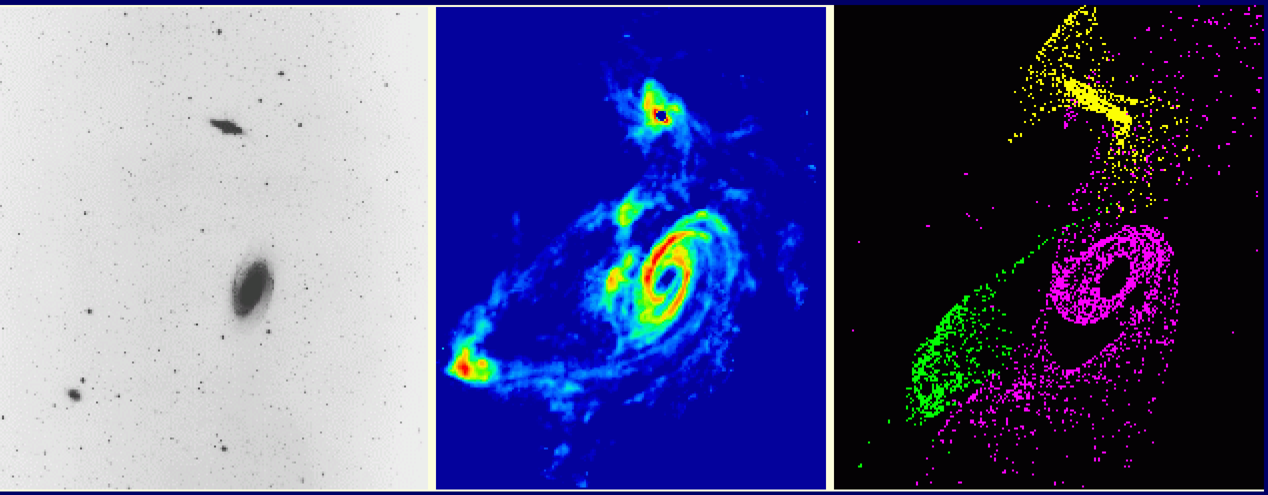
M81/M82/NGC3077
http://messier.seds.org/more/m081gr.html



Leo Triplet
Stierwalt+ 2009
AJ 138, 338

Evidence of environmental effects:

- Morphological disturbance => clear evidence
  - As a kinematic tracer, HI is very useful!

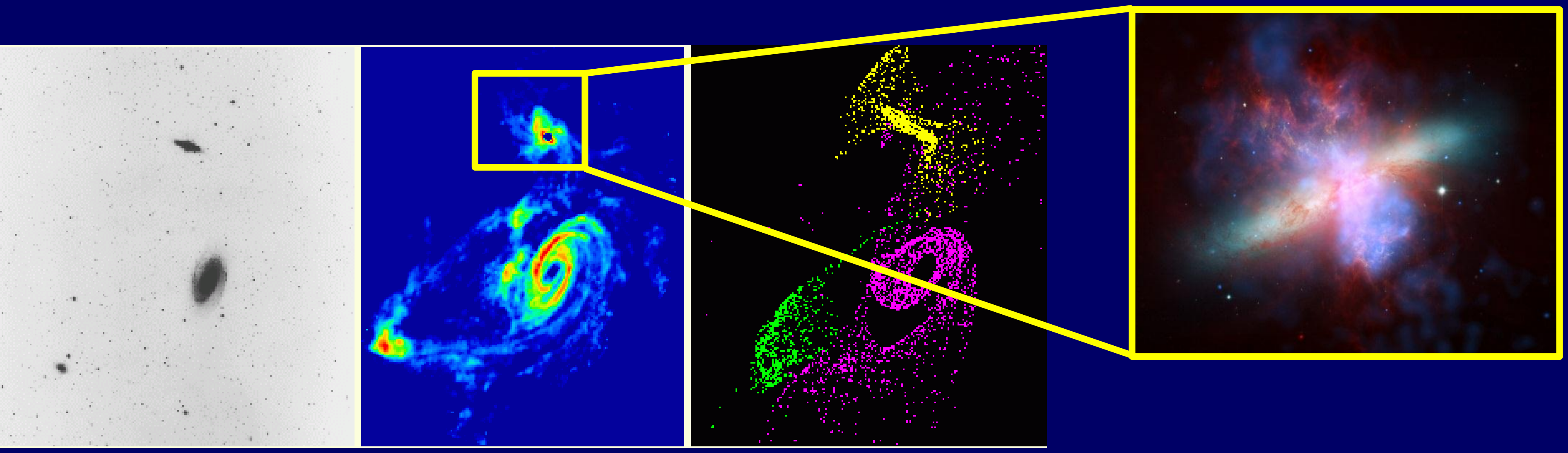


Gross features in HI can be reproduced by slow encounter of the 3 galaxies.

M81/M82/NGC3077
Movie by Min Yun
http://www.astro.umass.edu/~myun/m81hi.html

Evidence of environmental effects:

- Morphological disturbance => clear evidence
  - As a kinematic tracer, HI is very useful!

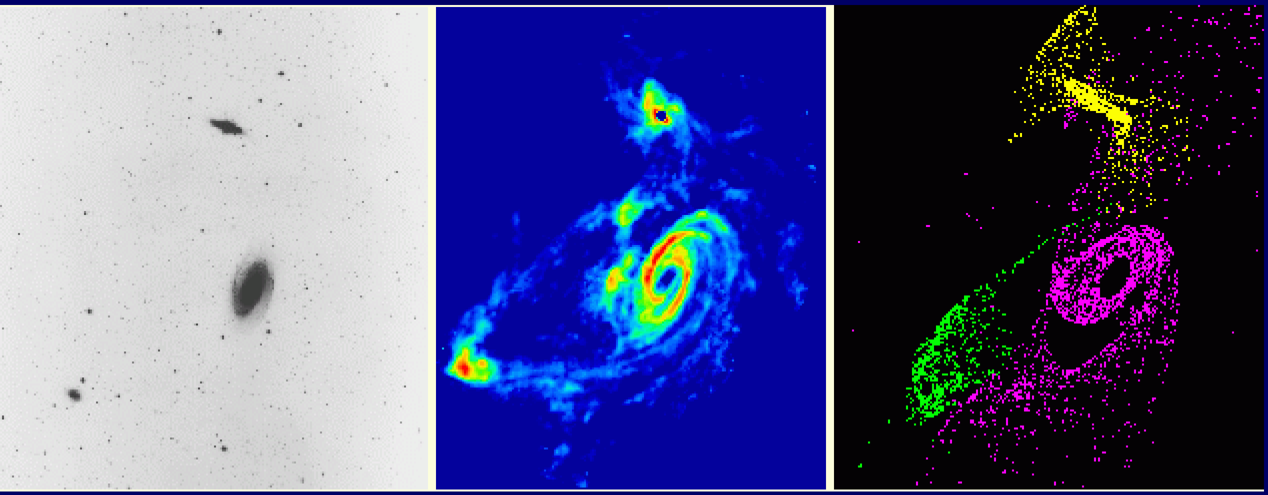


Starburst triggered in M82

M81/M82/NGC3077
Movie by Min Yun
http://www.astro.umass.edu/~myun/m81hi.html

Evidence of environmental effects:

- Morphological disturbance => clear evidence
  - As a kinematic tracer, HI is very useful!



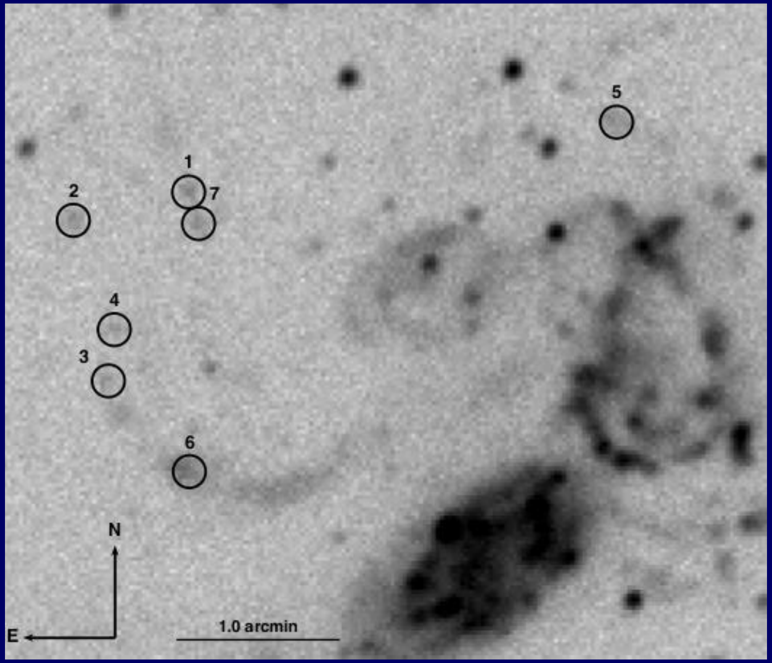
1934

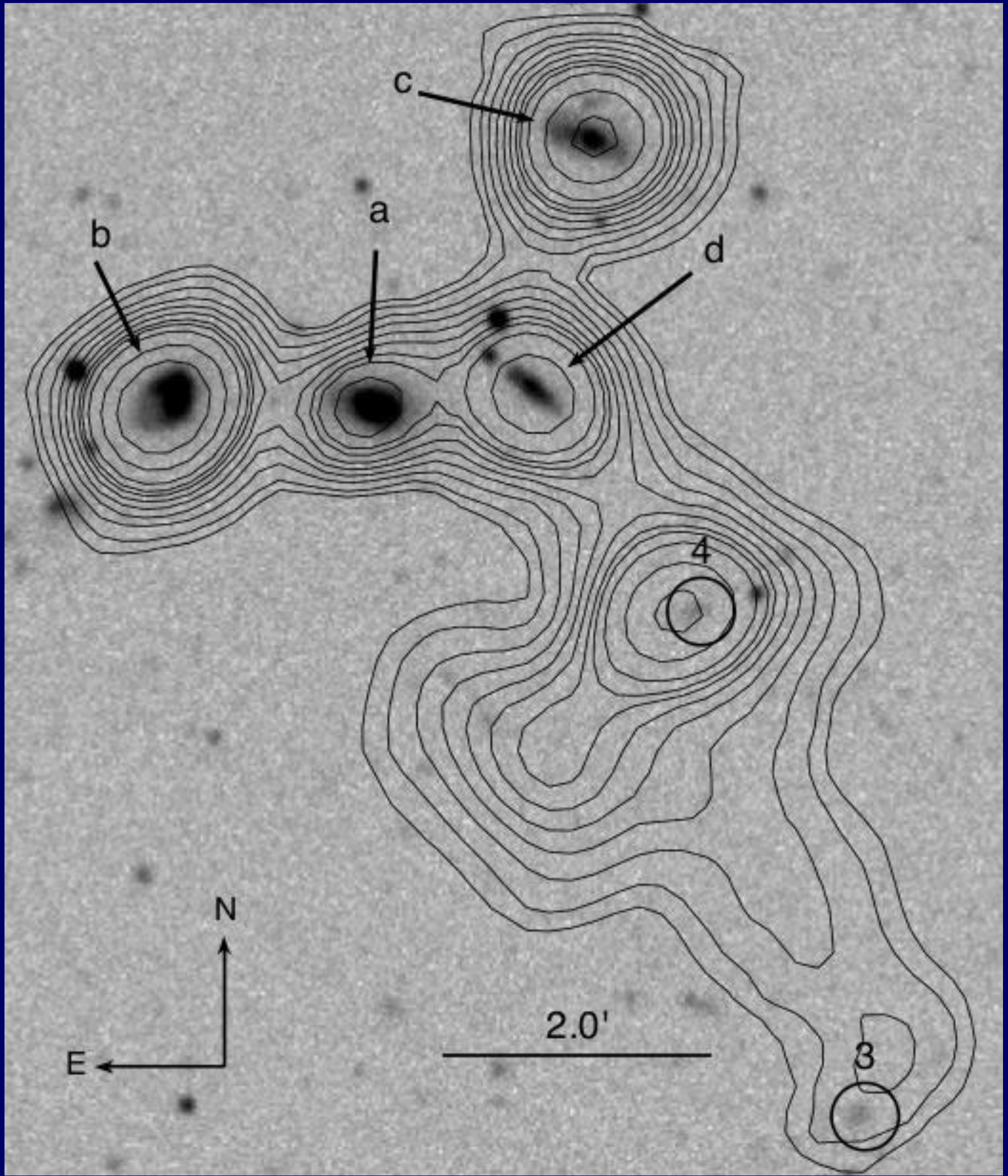
M81/M82/NGC3077
Movie by Min Yun
http://www.astro.umass.edu/~myun/m81hi.html

TDG formation in Compact Groups

De Mello+ 2012 astro-ph/1206.0318

- Gemini spectra of 14 objects found in tails of HCGs
  - Metallicities close to solar
  - Very young ages (< 100 Myr)



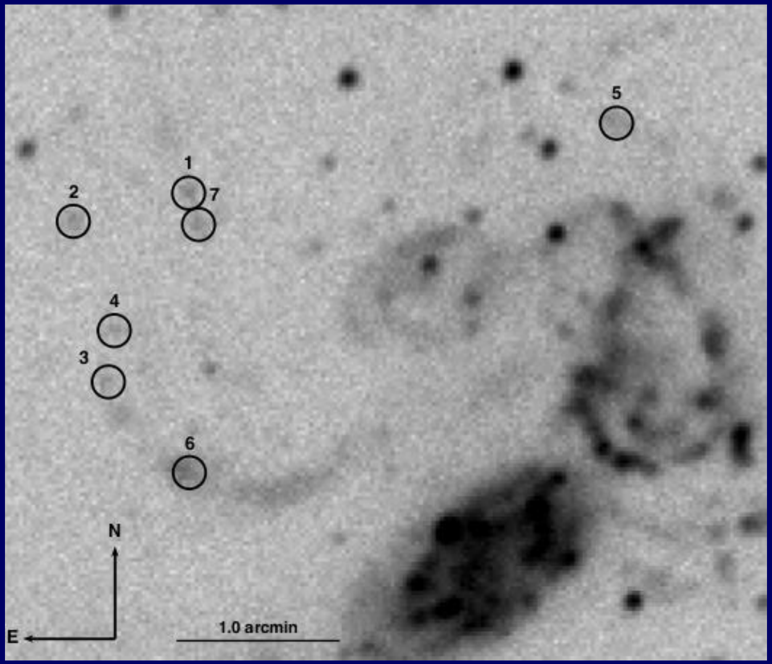


Several talks/posters at this conference !

TDG formation in Compact Groups

De Mello+ 2012 astro-ph/1206.0318

- Gemini spectra of 14 objects found in tails of HCGs
  - Metallicities close to solar
  - Very young ages (< 100 Myr)



Several talks/posters at this conference !

1954

Evidence of environmental effects:

- HI deficiency
  - Virgo cluster
    - Davies and Lewis 1973, MNRAS 165, 231
    - Chamaraux, Balkowski & Gerard 1980, A&A 83, 38

    Early works noted differences between Virgo and field spirals and residual dependence of M_{HI}/L on luminosity

Comparative HI content relative to "isolated" galaxies

- Use linear diameter and include morphological type dependence
- Define deficiency as difference between the difference, on a logarithmic scale, between the observed HI mass and that expected for a "normal" galaxy of similar linear size and optical morphology.

$$\langle DEF \rangle = \langle \log M_{HI}(D_{lin},T) \rangle - \log M_{HI,obs}$$

Haynes & Giovanelli 1984, AJ 89, 758

Quantifying HI Content

Haynes & Giovanelli 1984 AJ 89, 758

Standard of HI normalcy established for sample of 324 isolated galaxies drawn from the Catalog of Isolated Galaxies (Karachentseva 1973, Soobshch. Spets. Astrofiz. Obs., Vyp. 8, 72

Scaling relation for disks
HI mass <=> linear diameter

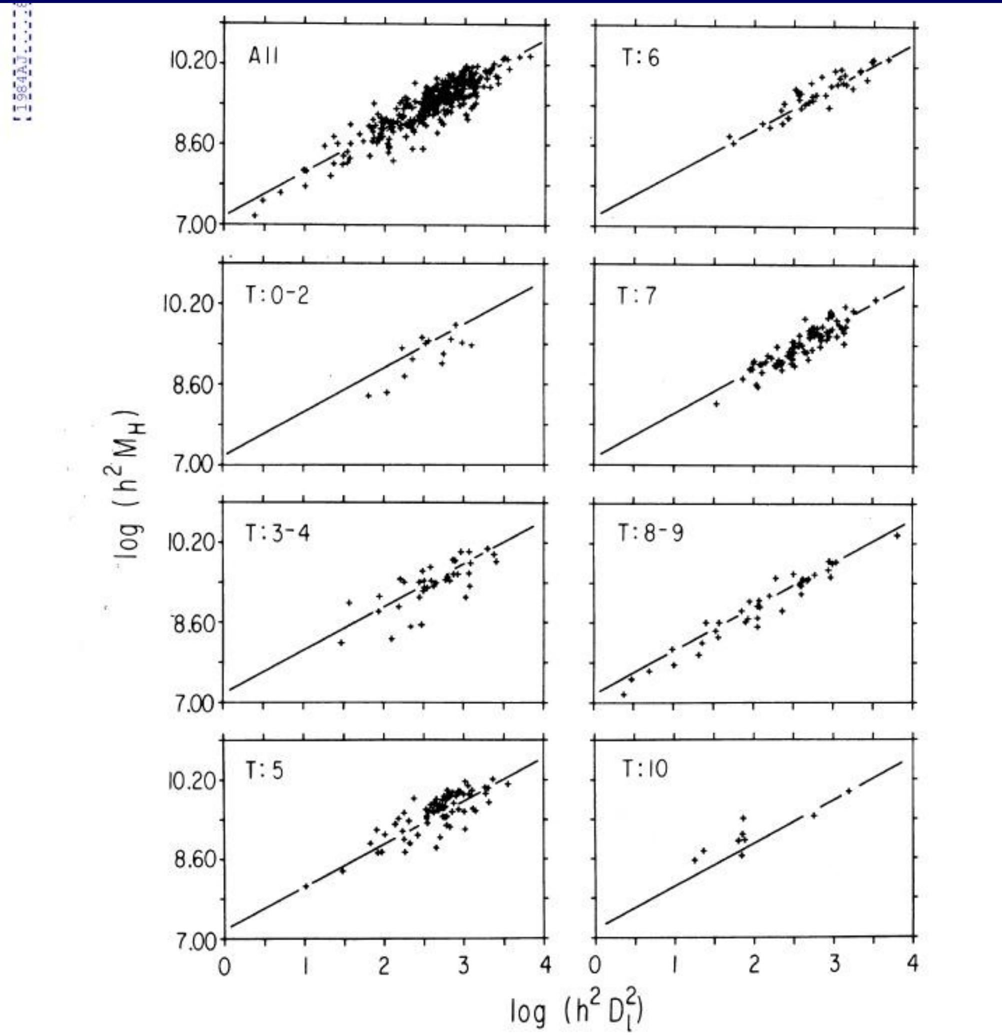
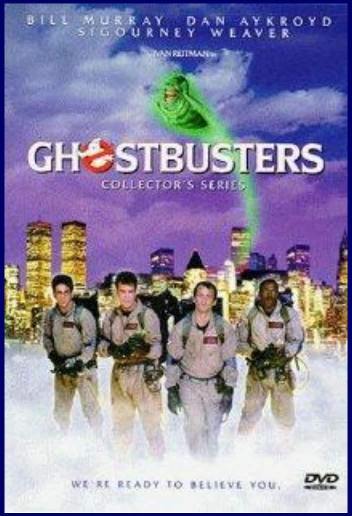


FIG. 7. Relationships between the scaled H I mass h^2M_H and the squared linear optical diameter hD_l for different morphological groups. Solid lines indicate the single regression line, fit to the set of all detected galaxies (upper left panel), whose coefficients are given in Table V.

Quantifying HI Content

Haynes & Giovanelli 1984 AJ 89, 758

1984



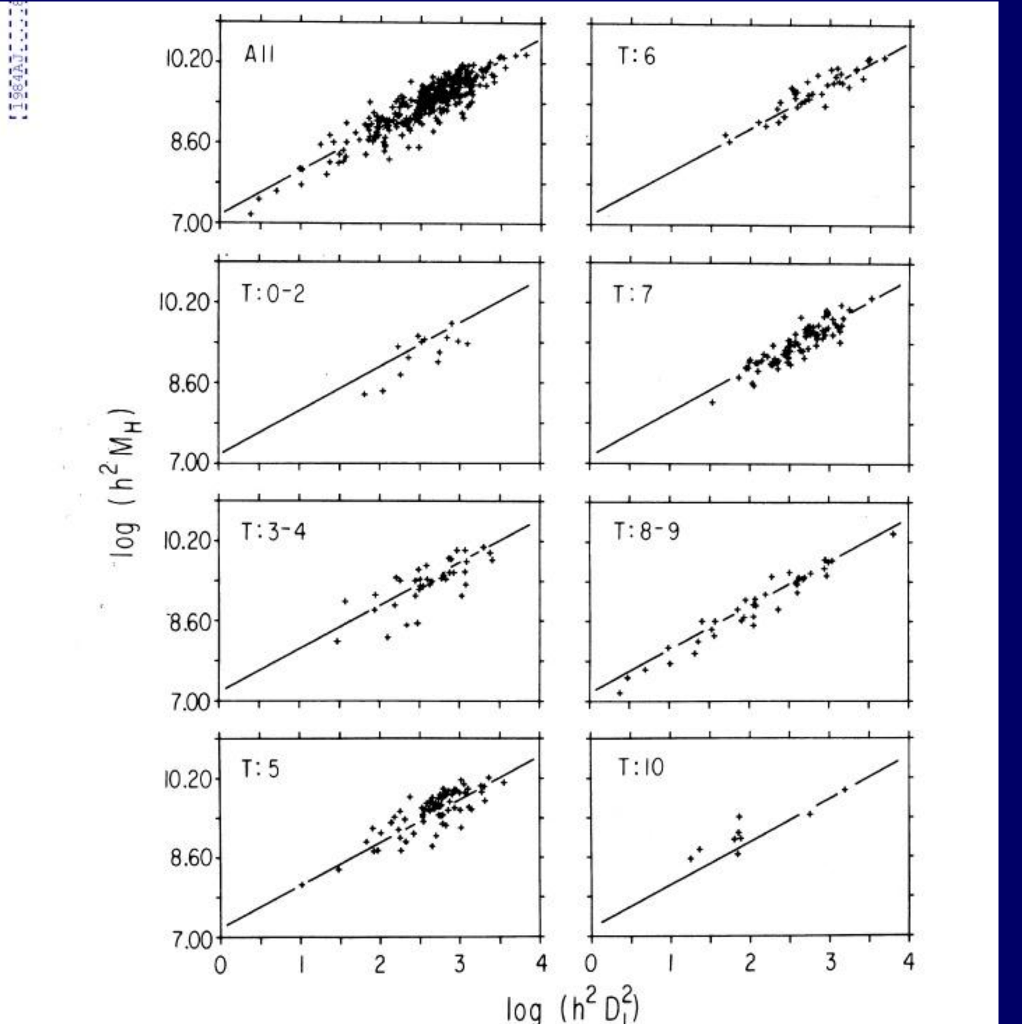


FIG. 7. Relationships between the scaled H I mass $h^2 M_H$ and the squared linear optical diameter hD_l for different morphological groups. Solid lines indicate the single regression line, fit to the set of all detected galaxies (upper left panel), whose coefficients are given in Table V.

Quantifying HI Content

Haynes & Giovanelli 1984 AJ 89, 758

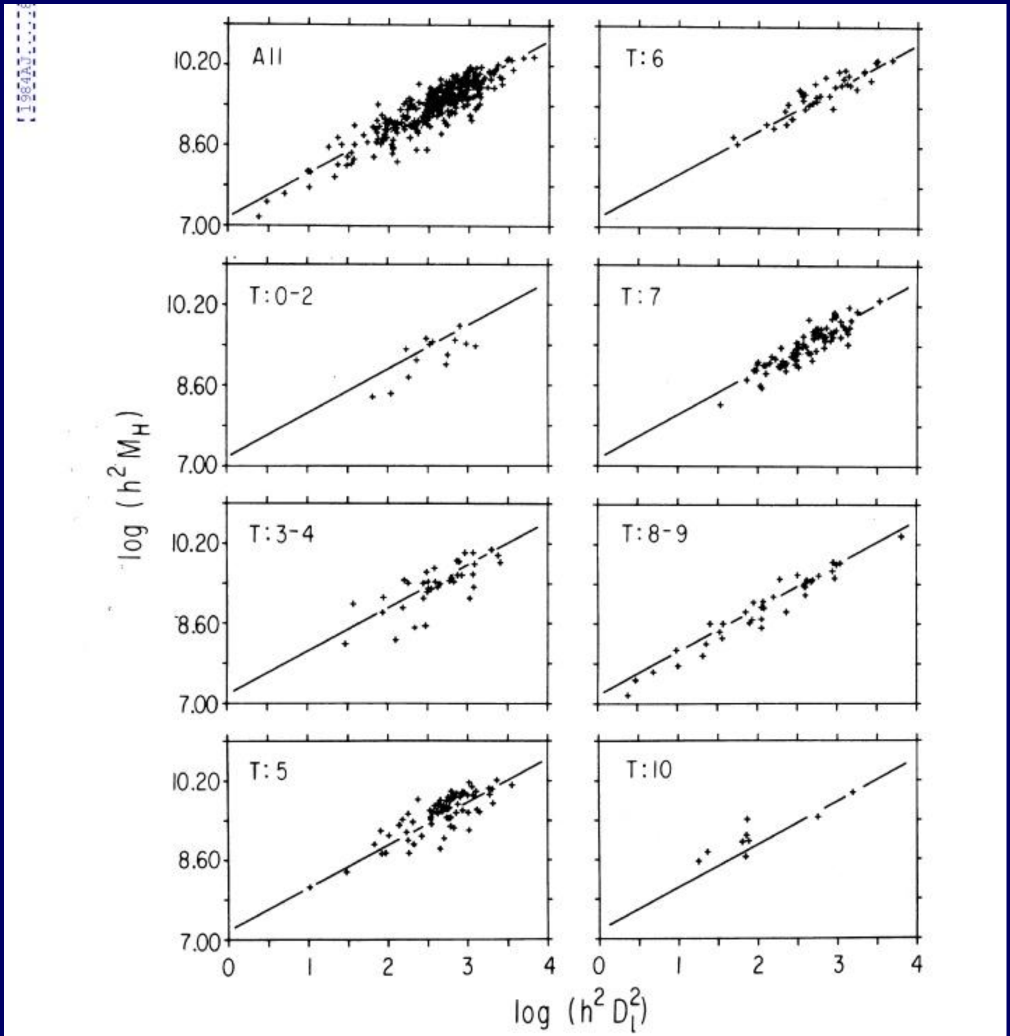


FIG. 7. Relationships between the scaled H I mass $h^2 M_H$ and the squared linear optical diameter hD_l for different morphological groups. Solid lines indicate the single regression line, fit to the set of all detected galaxies (upper left panel), whose coefficients are given in Table V.

Quantifying HI Content

Toribio+ 2011 ApJ 732, 93

- Based on ALFALFA survey and SDSS
- Principal component analysis with all available parameters

THE ASTROPHYSICAL JOURNAL, 732:93 (12pp), 2011 May 10 TORIBIO ET AL.

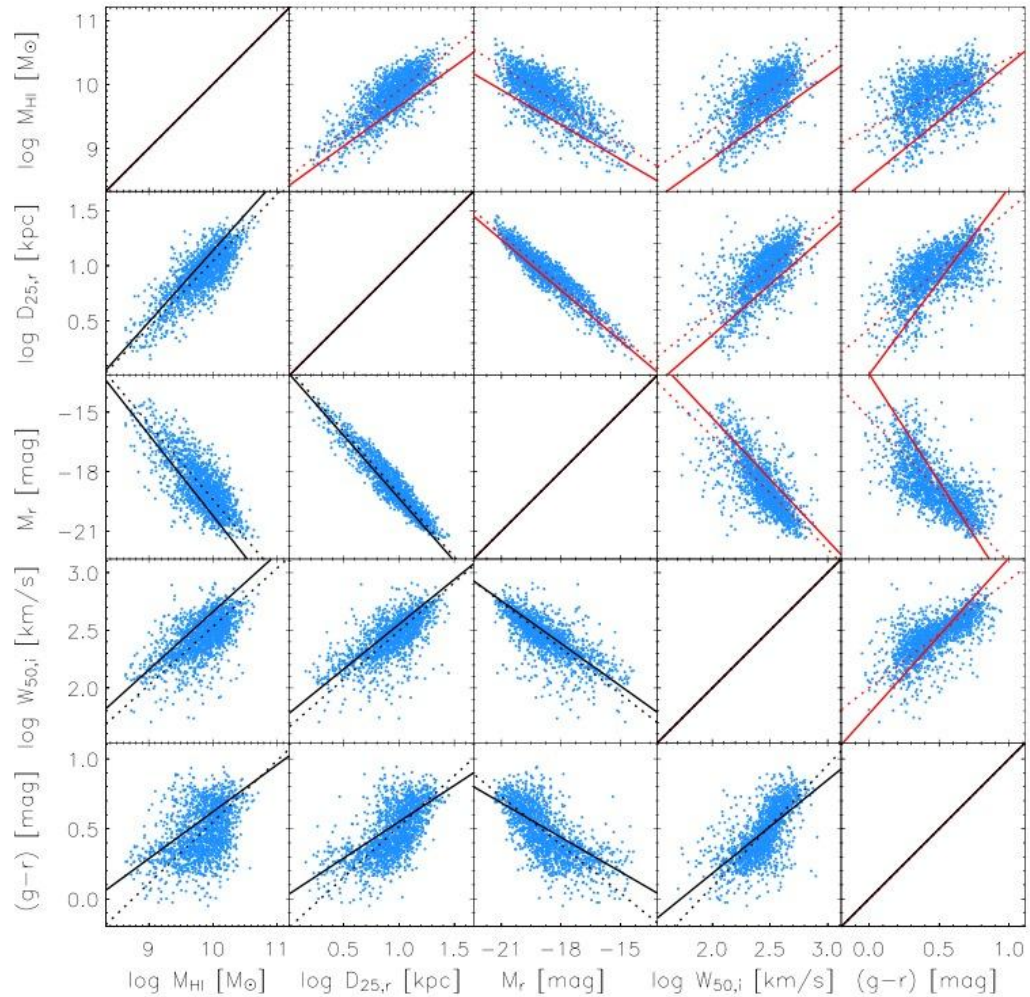


Figure 2. Empirical relations for pairs of properties from LDE-HQ data. $1/V'_{max}$-weighted (solid) and unweighted (dotted) direct regression fits to the joint distributions are shown in red color above the diagonal of the plot, whereas orthogonal fits are shown below it. All correlations are corrected for attenuation (Equation (3)).

Effect of environment on HI scaling relations

Cortese+ 2011, MNRAS 415, 1797
Stay tuned for Luca's talk!

HI deficiency expressed as offset from the "HI gas-fraction plane"

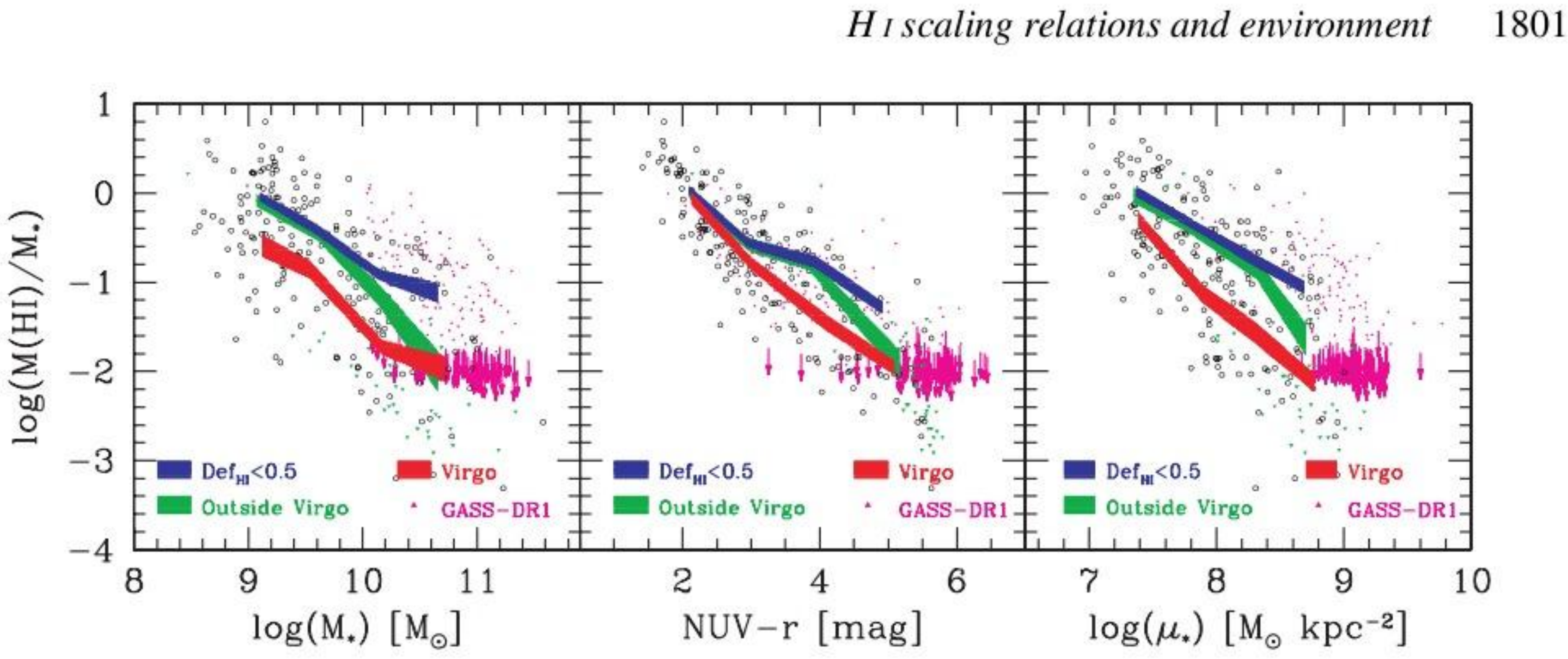


Figure 3. The average H I mass fraction [i.e. ⟨log ($M(HI)/M_*$)⟩] scaling relations for different samples. H I-normal galaxies and systems belonging to or outside Virgo are indicated by blue, red and green lines, respectively. For comparison, GASS DR1 is shown in magenta.

Evidence of environmental effects:

- Virgo: an ideal, nearby laboratory for detailed study of the mechanisms which cause the HI deficiency

Davies and Lewis 1973, MNRAS 165, 231
Chamaraux, Balkowski & Gerard 1980, A&A 83, 38

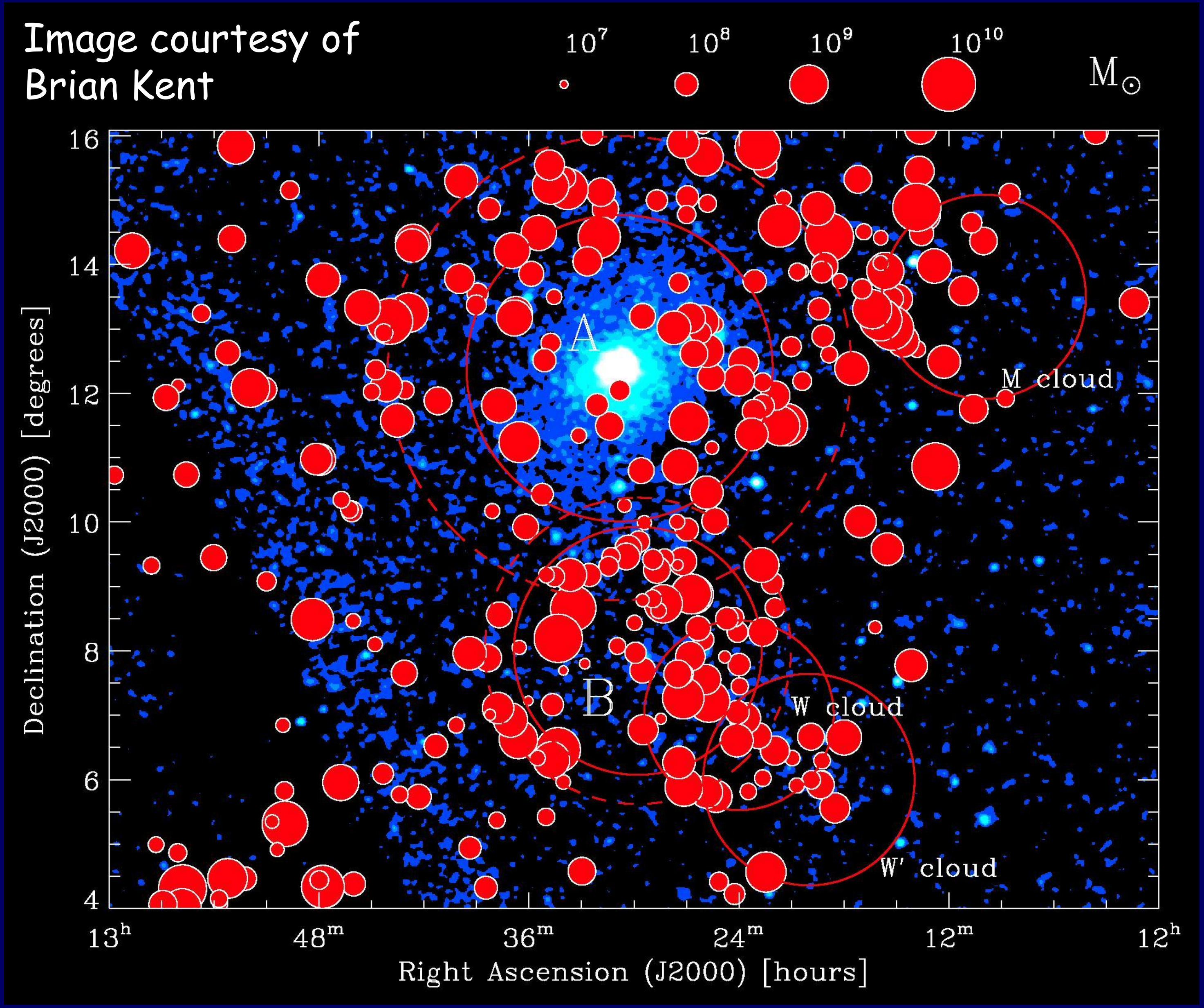
Evidence of environmental effects:

- Virgo: an ideal, nearby laboratory for detailed study of the mechanisms which cause the HI deficiency

Davies and Lewis 1973, MNRAS 165, 231
Chamaraux, Balkowski & Gerard 1980, A&A 83, 38

1973

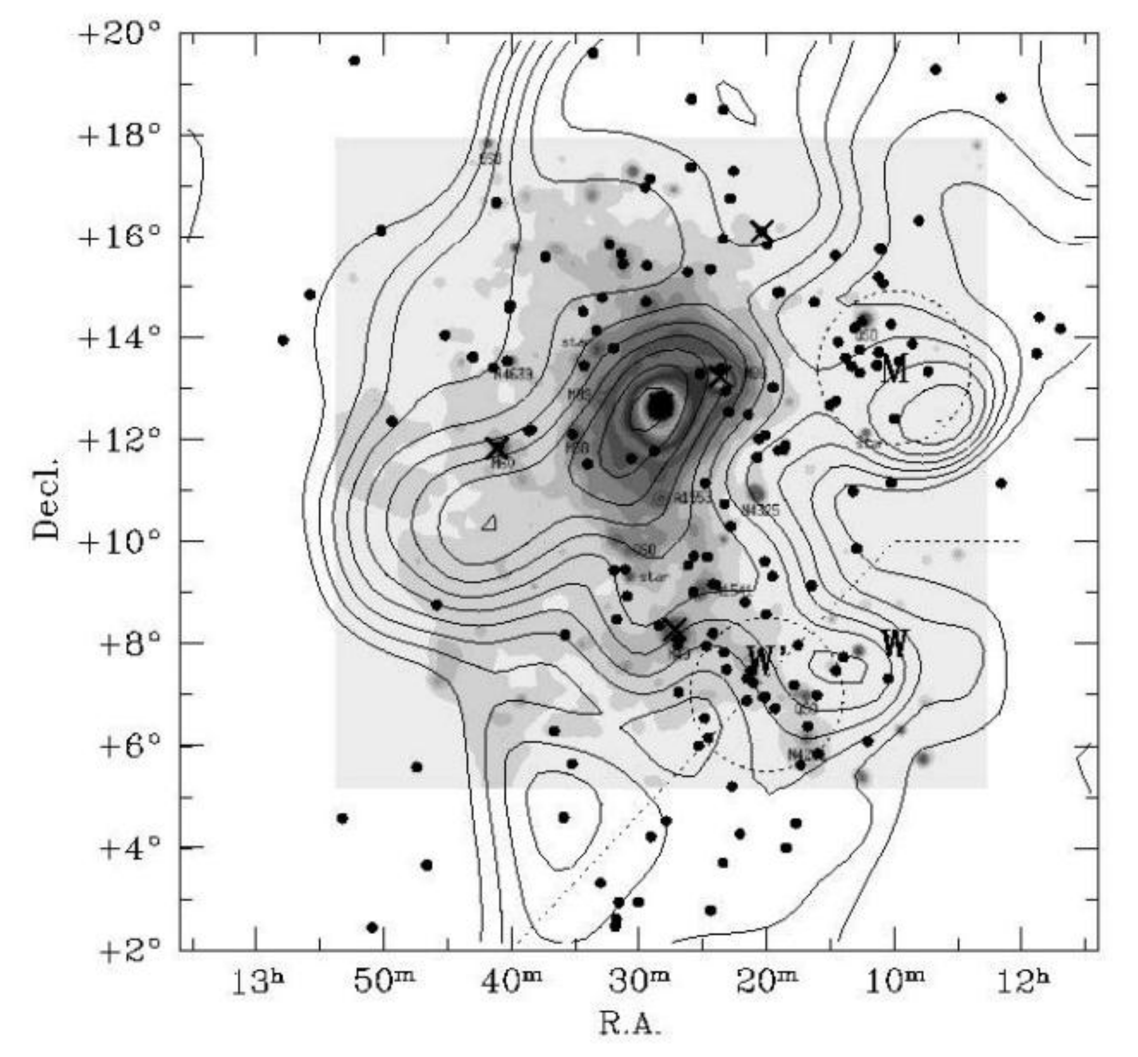
ALFALFA: A wide angle view of Virgo



HI Deficiency in Virgo

Solanes+ 2002
AJ 124, 2440

- 161 spiral galaxies
- Use TF relation to estimate cluster structure



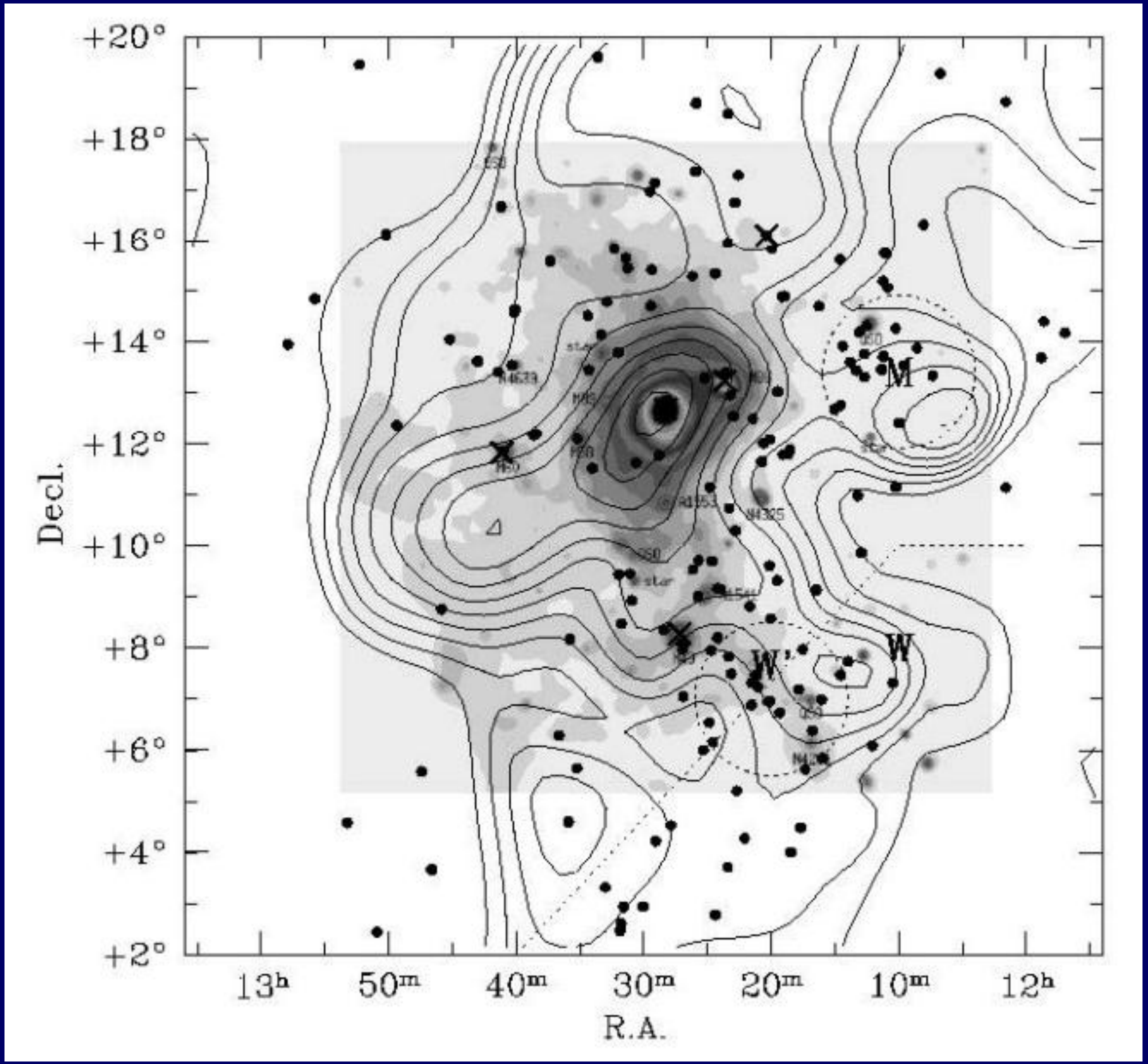
Grayscale: ROSAT
Contours: HI Def

HI Deficiency in Virgo

Solanes+ 2002
AJ 124, 2440

- 161 spiral galaxies
- Use TF relation to estimate cluster structure

2002



Grayscale: ROSAT
Contours: HI Def

HI debris in Virgo found by ALFALFA

Haynes, Giovanelli & Kent, 2007, ApJ 665, L19
Koopmann+ 2008, ApJ 682, L85
Kent+ 2007, ApJ 665, L15
Kent+ 2009, ApJ 691, 1595
Kent, 2010, ApJ 725, 2333

HI debris traced over ~250 kpc

- High speed encounters?

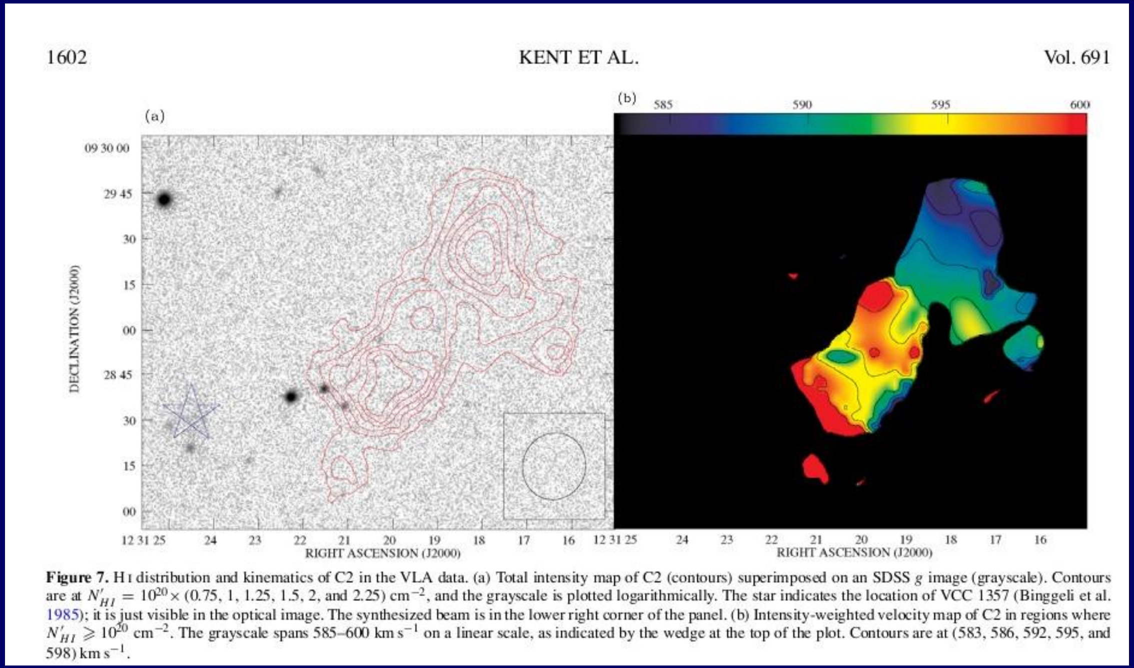
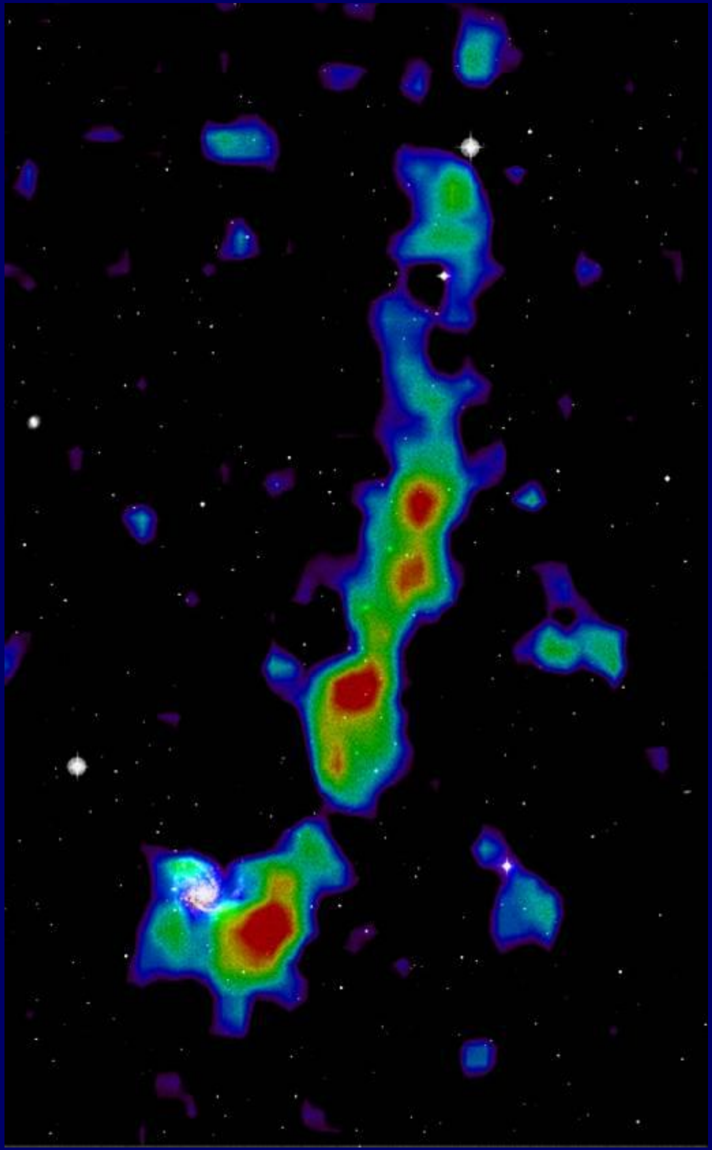

1602 KENT ET AL. Vol. 691

Figure 7. H I distribution and kinematics of C2 in the VLA data. (a) Total intensity map of C2 (contours) superimposed on an SDSS g image (grayscale). Contours are at $N'_{HI} = 10^{20} \times (0.75, 1, 1.25, 1.5, 2, \text{and } 2.25)\ \text{cm}^{-2}$, and the grayscale is plotted logarithmically. The star indicates the location of VCC 1357 (Binggeli et al. 1985); it is just visible in the optical image. The synthesized beam is in the lower right corner of the panel. (b) Intensity-weighted velocity map of C2 in regions where $N'_{HI} \geqslant 10^{20}\ \text{cm}^{-2}$. The grayscale spans 585–600 km s^{-1} on a linear scale, as indicated by the wedge at the top of the plot. Contours are at (583, 586, 592, 595, and 598) km s^{-1}.



VCC/M49

Arrigoni Battaia+ 2012 astro-ph/1205.3095

- Sancisi+ (1987) found HI cloud displaced from VCC1249 towards M49
- McNamara+ (1994) showed trail of debris offset from HI gas
- GUViCS, NGVS and new Ha imaging
- Both ram-pressure stipping and tidal interaction with M49

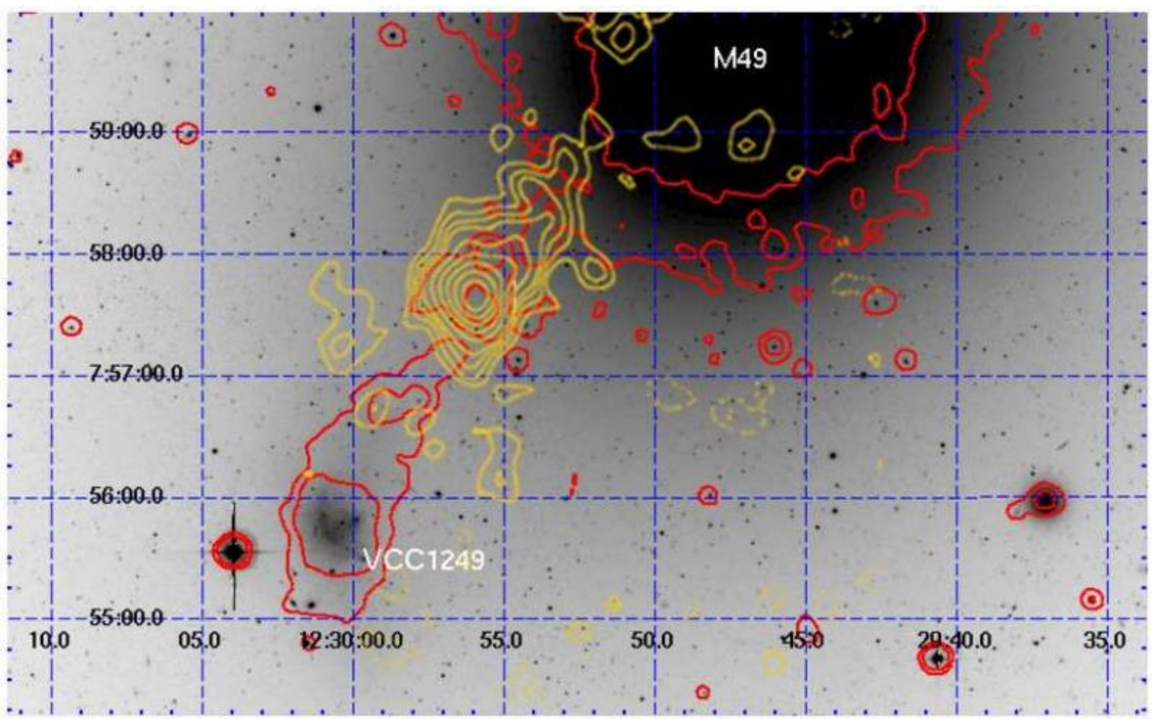


Fig. 6. NGVS g image of VCC1249 (bottom-left) and of M49 (top-center) on which the NUV contours (red) and the HI contours taken from McNamara et al. (1994) (yellow) are superposed (the coordinates are precessed from B1950 originally used, to J2000). Note that the peak of the HI cloud nearly coincides with the peak of the NUV emission at the position of the region C2 (LR1 in Lee et al. 2000).

NGC 4694/VCC 2062: a tidal dwarf

Duc+ 2007, A&A 475, 187

VCC 2062:

- Strong CO
- High O/H
- Low M_{dyn}

=> Tidal dwarf

P.-A. Duc et al.: An old TDG in the Virgo cluster 189

Fig. 1. VLA map of the HI gas distribution (in blue) around NGC 4694 (*to the left*) and VCC 2062 (*to the right*) superimposed on a true colour (*BVR*) optical image of the system. The GALEX-FUV emission, tracing regions of recent star formation, is overlaid in red. The field of view is $9' \times 6'$. North is up and East to the left.

HI deficiency => truncated disks

Giovanelli & Haynes 1983, AJ 88, 881
Warmels & vanWoerden 1984 ASSL 111, 251

The HI disks in highly deficient Virgo spirals are smaller than the disks in normal spirals outside Virgo.

- Suggestive of ram pressure stripping

HI deficiency => truncated disks

Giovanelli & Haynes 1983, AJ 88, 881
Warmels & vanWoerden 1984 ASSL 111, 251

The HI disks in highly deficient Virgo spirals are smaller than the disks in normal spirals outside Virgo.

- Suggestive of ram pressure stripping

The advent of HI synthesis mapping

- Sensitivity limited: the HI deficient galaxies are hard to detect!
- Resolution still limited (spatial and spectral)
- Limited bandwidth (only part of the full cluster velocity range)

HI deficiency => truncated disks

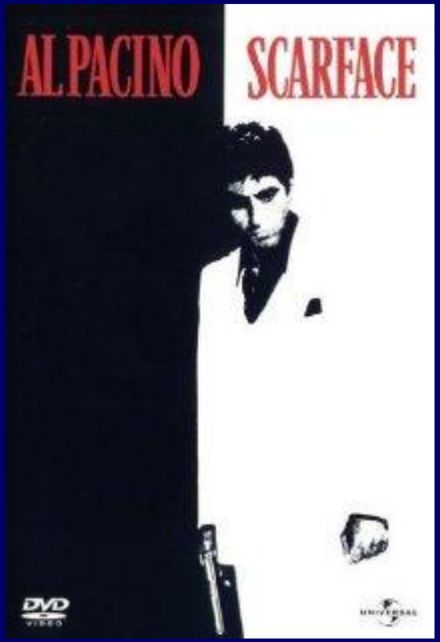
Giovanelli & Haynes 1983, AJ 88, 881
Warmels & vanWoerden 1984 ASSL 111, 251

The HI disks in highly deficient Virgo spirals are smaller than the disks in normal spirals outside Virgo.

- Suggestive of ram pressure stripping

The advent of HI synthesis mapping

- Sensitivity limited: the HI deficient galaxies are hard to detect!
- Resolution still limited (spatial and spectral)
- Limited bandwidth (only part of the full cluster velocity range)



1983

HI deficiency => truncated disks

Giovanelli & Haynes 1983, AJ 88, 881
Warmels & vanWoerden 1984 ASSL 111, 251
Cayatte+ 1990, AJ 100, 604

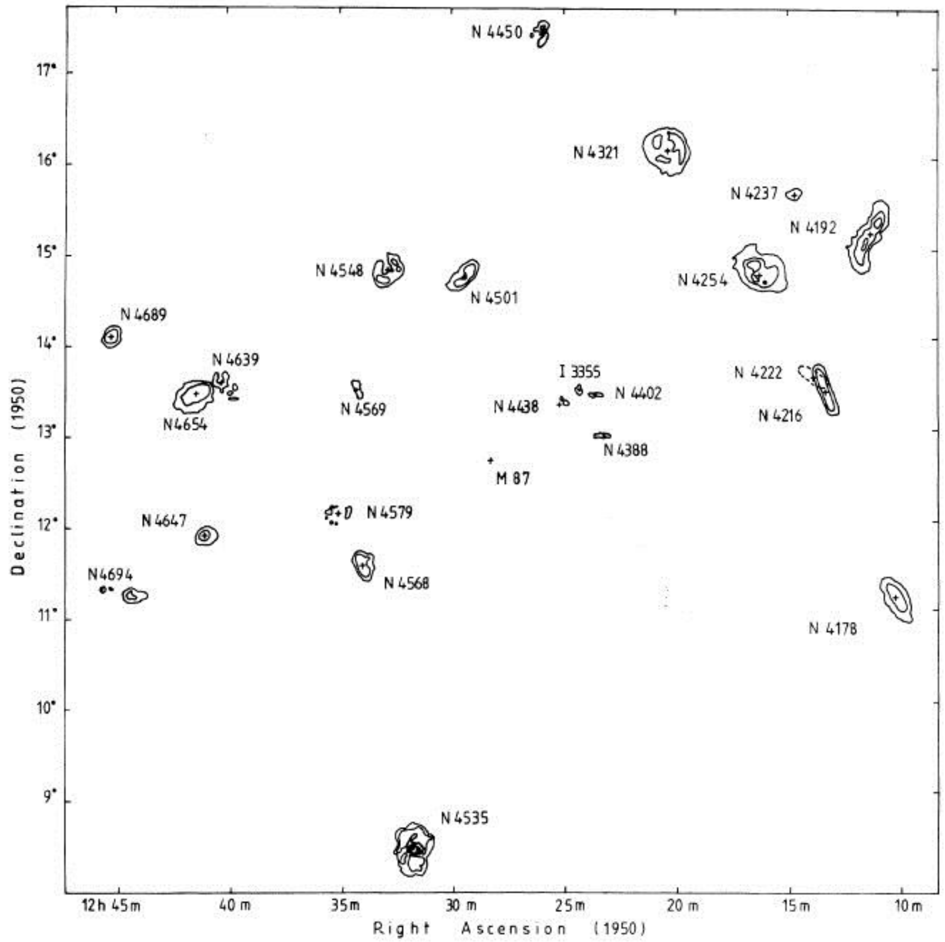
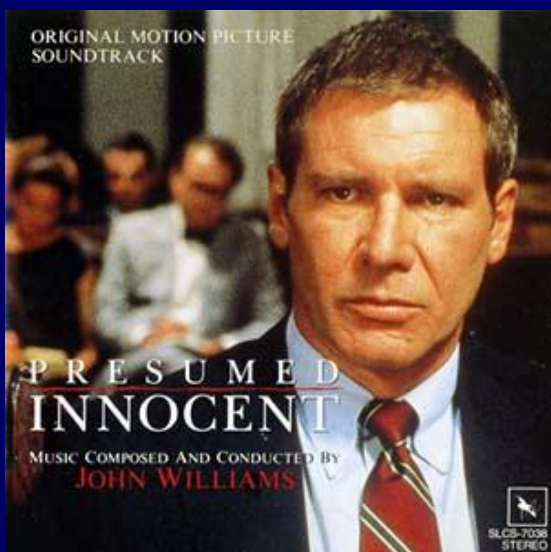


FIG. 23. Integrated neutral hydrogen maps of the brightest spirals in the Virgo Cluster center. Each map has been drawn at the galaxy position indicated by a cross and magnified by a factor of 5 compared with the scale in right ascension and declination. The first contour in each map corresponds approximately to a column density of 10^{20} atoms cm^{-2} (even if it is not the case in the maps published in Figs. 1–22 especially for NGC 4388, 4450, 4569, 4694).

HI deficiency => truncated disks

Giovanelli & Haynes 1983, AJ 88, 881
Warmels & vanWoerden 1984 ASSL 111, 251
Cayatte+ 1990, AJ 100, 604



1990

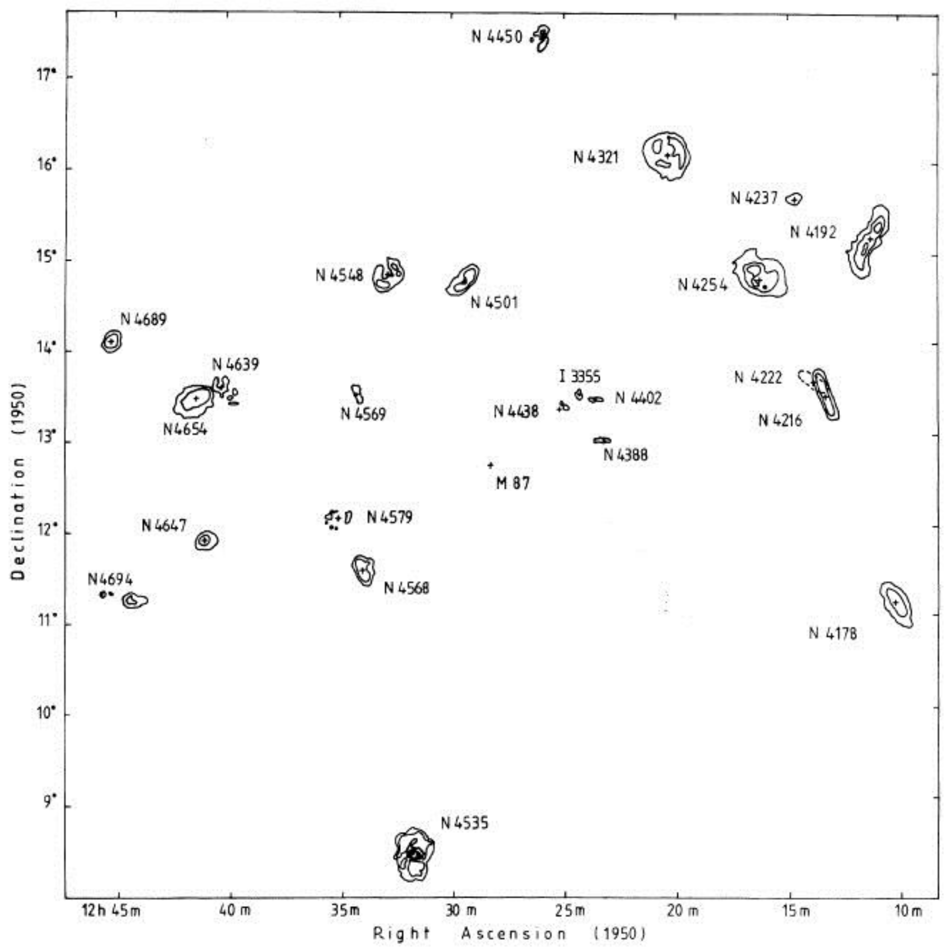


FIG. 23. Integrated neutral hydrogen maps of the brightest spirals in the Virgo Cluster center. Each map has been drawn at the galaxy position indicated by a cross and magnified by a factor of 5 compared with the scale in right ascension and declination. The first contour in each map corresponds approximately to a column density of 10^{20} atoms cm^{-2} (even if it is not the case in the maps published in Figs. 1–22 especially for NGC 4388, 4450, 4569, 4694).

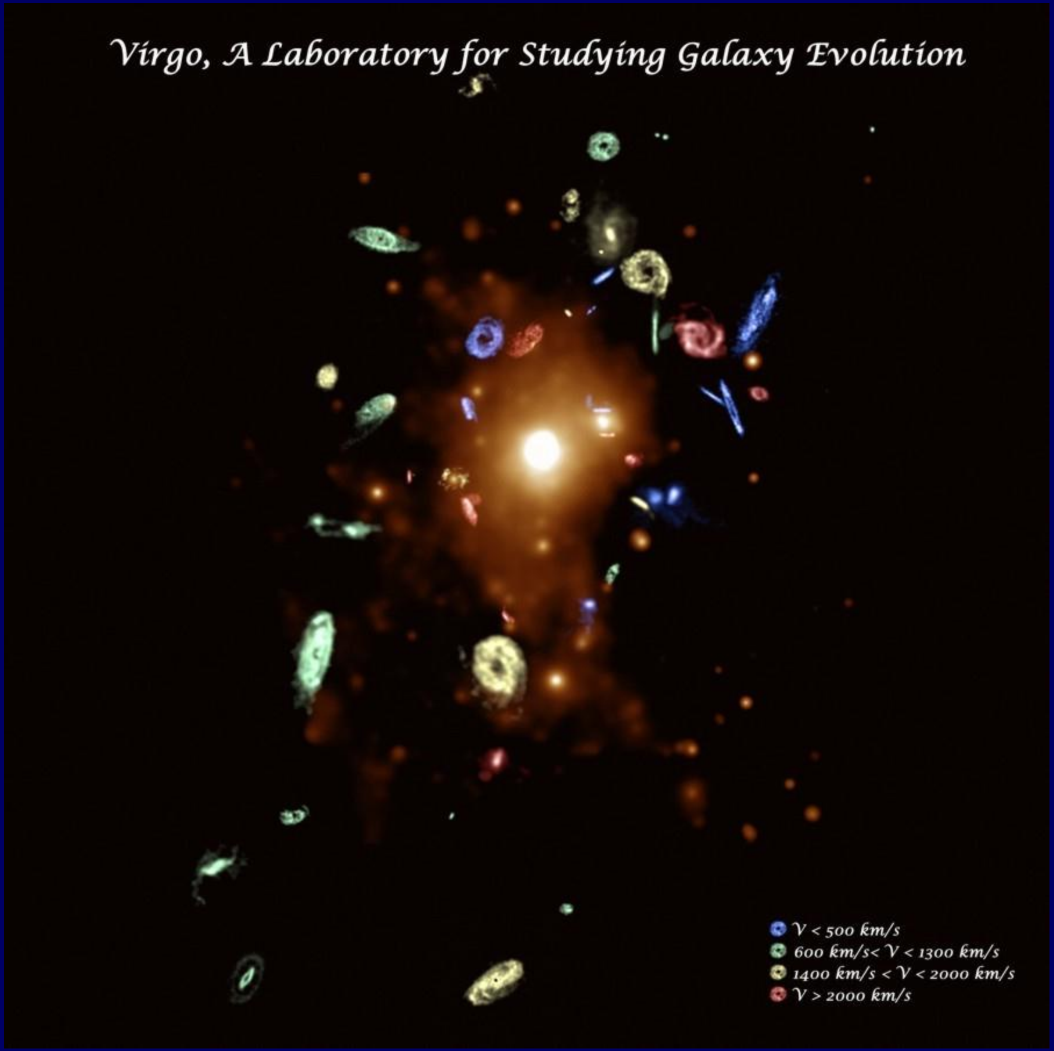
VIVA: VLA Virgo HI survey

Chung+ 2009, AJ 138, 1741

HI deficient galaxies in center

HI deficient galaxies=>
truncated HI disks

Tails point away from M87



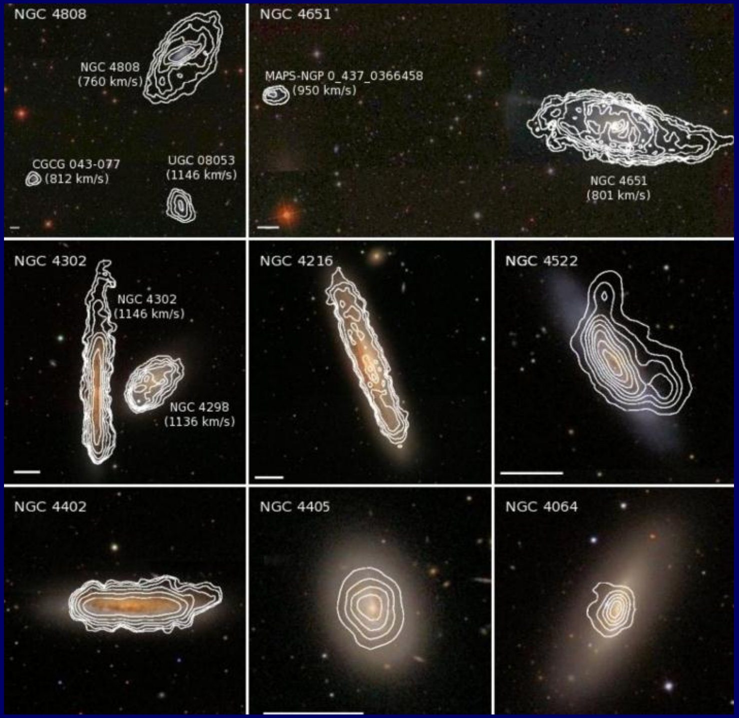
VIVA: VLA Virgo HI survey

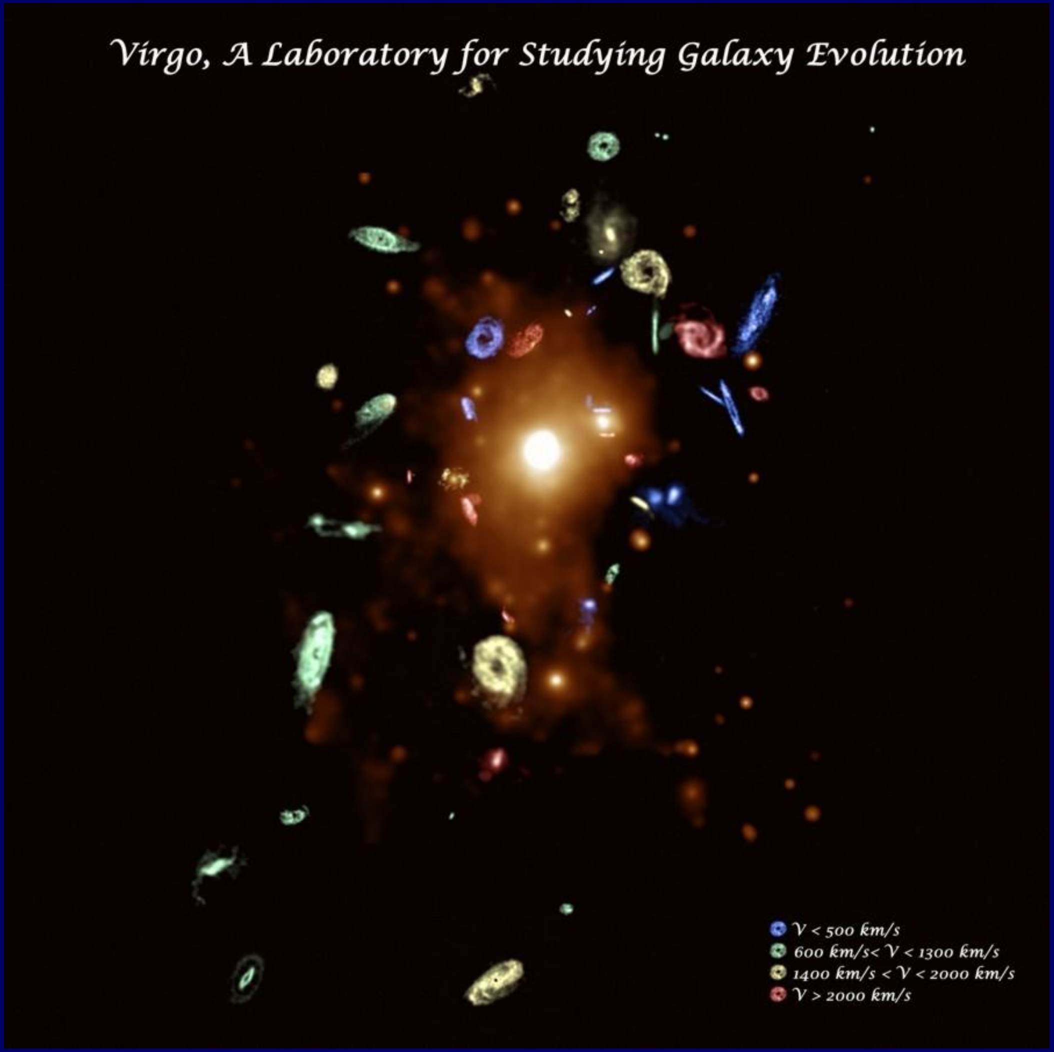
Chung+ 2009, AJ 138, 1741

HI deficient galaxies in center

HI deficient galaxies=>
truncated HI disks

Tails point away from M87





Truncated Hα disks

Koopmann & Kenney 1998, ApJ 497, L75
Koopmann & Kenney 2004, ApJ 613, 866

Virgo galaxies have reduced SFR compared to the field

- SF disks are truncated relative to field spirals
- Strong correlation between HI deficiency & normalized Hα flux

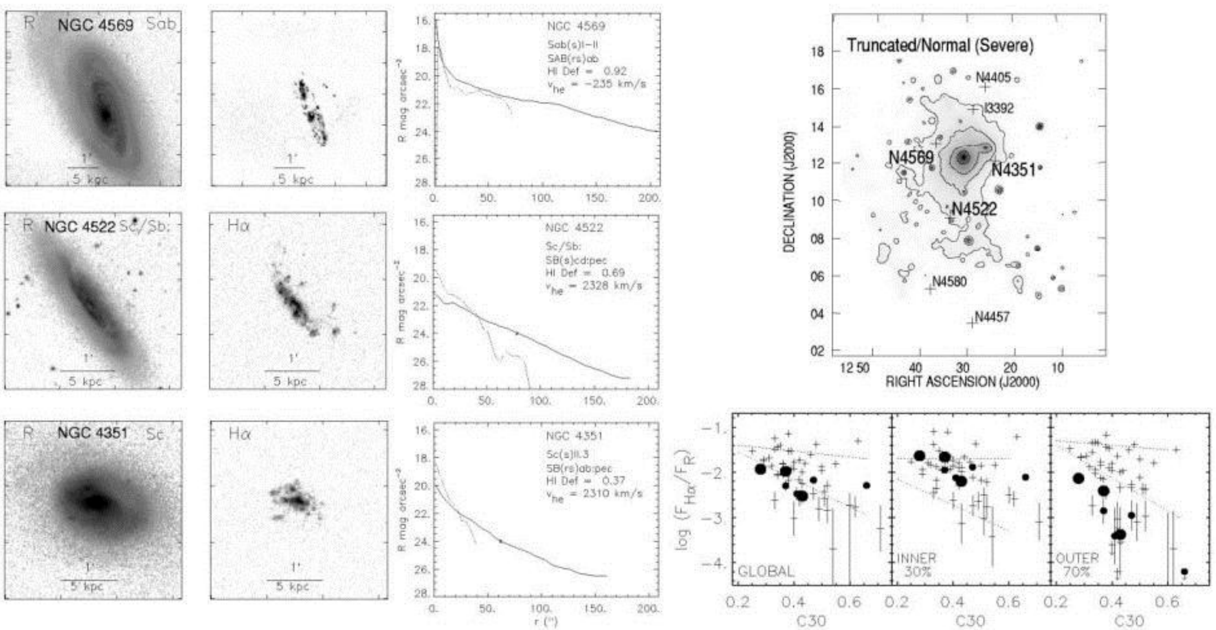


FIG. 6.—Three Virgo Cluster galaxies with star-forming disks truncated within $0.4r_{24}$, normal-enhanced inner star formation rates, peculiar Hα distributions, and possibly extraplanar emission. NGC 4569 has a ring of star formation at about $0.3r_{24}$ and a detached arm of H II regions, which may be extraplanar (Hensler et al. 2003). NGC 4522 appears to be interacting with the ICM, on the basis of the extraplanar H II regions and disturbed H I and radio continuum (Kenney & Koopmann 1999; Kenney et al. 2004). The Hα emission in NGC 4351 is offset from the apparent center in R. See Fig. 4 for details on the plots.

Virgo Herschel Reference Sample: Disks

Cortese+ 2010 A&A 518, L49

- Herschel-SPIRE shows truncated dust disks in HI-deficient spirals

Stay tuned for Luca's talk!

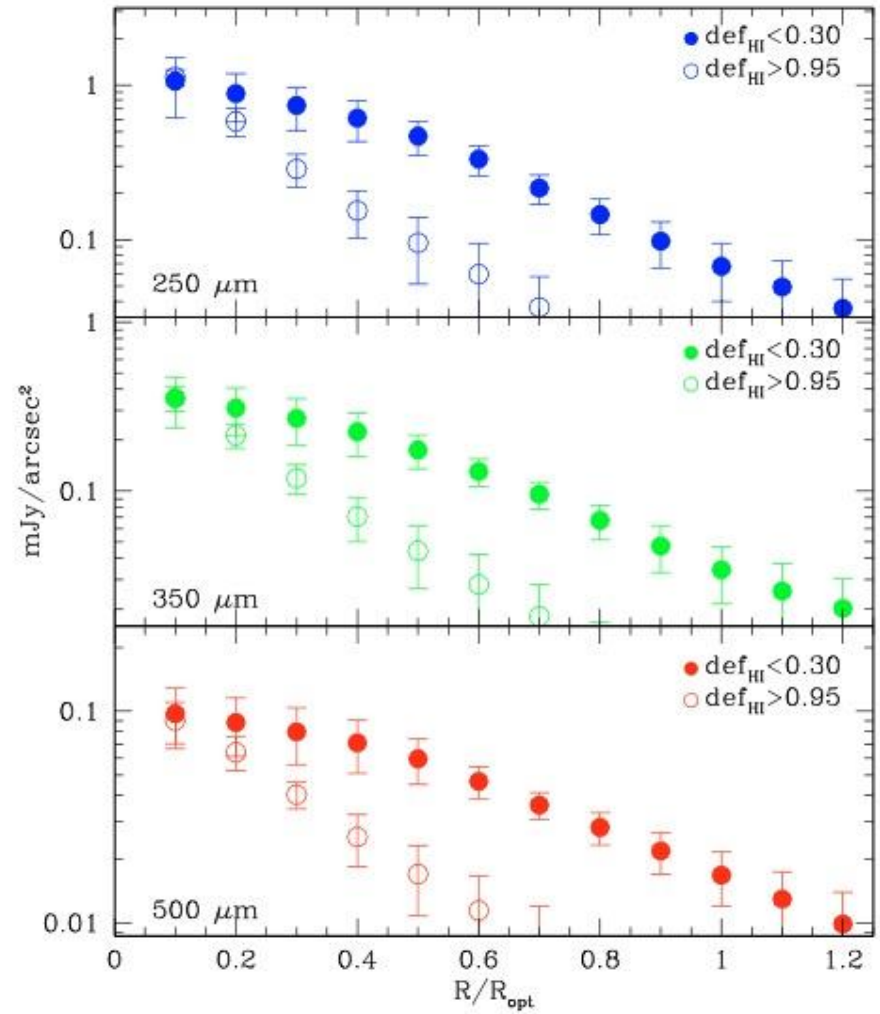


Fig. 4. Average submm surface-brightness profiles in bins of normalized radius for normal and highly HI-deficient galaxies.

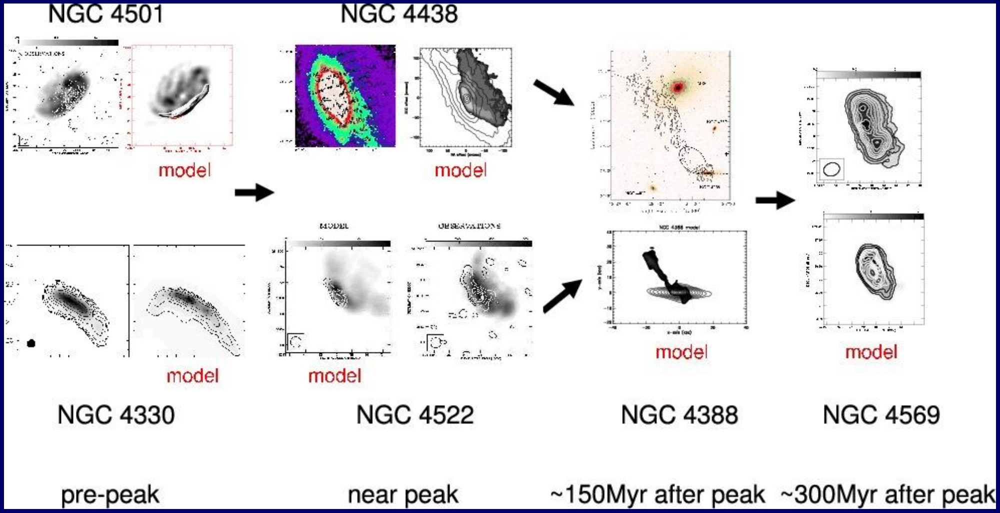
SFE in 12 Virgo spirals

Vollmer+ 2012 A&A 453, A33

- Detailed comparison of Virgo spirals with field sample
- VIVA-HI + CO + GALEX + Spitzer
- Inside truncation radius, HI +CO distributions "normal"
- SFE wrt molecular gas appears normal; wrt total gas is high, because μ_* is also high.
- Ram pressure stripped extraplanar gas shows depressed SFE wrt total gas => gas density decreases, SF drops

  …. But not always! (NGC 4569)

More on this from several of the authors!



Vollmer 2009 A&A 502, 427

SFE in 12 Virgo spirals

Vollmer+ 2012 A&A 453, A33

- Detailed comparison of Virgo spirals with field sample
- VIVA-HI + CO + GALEX + Spitzer
- Inside truncation radius, HI +CO distributions "normal"
- SFE wrt molecular gas appears normal; wrt total gas is high, because μ_* is also high.
- Ram pressure stripped extraplanar gas shows depressed SFE wrt total gas => gas density decreases, SF drops

  .... But not always! (NGC 4569)

More on this from several of the authors!

1939

Studies of other clusters:

- HI deficiency
  - Giovanelli & Haynes 1985, ApJ 292, 404   9 clusters

- Clear "pattern" of HI deficiency
- Some evidence that L_X more important than galaxy density

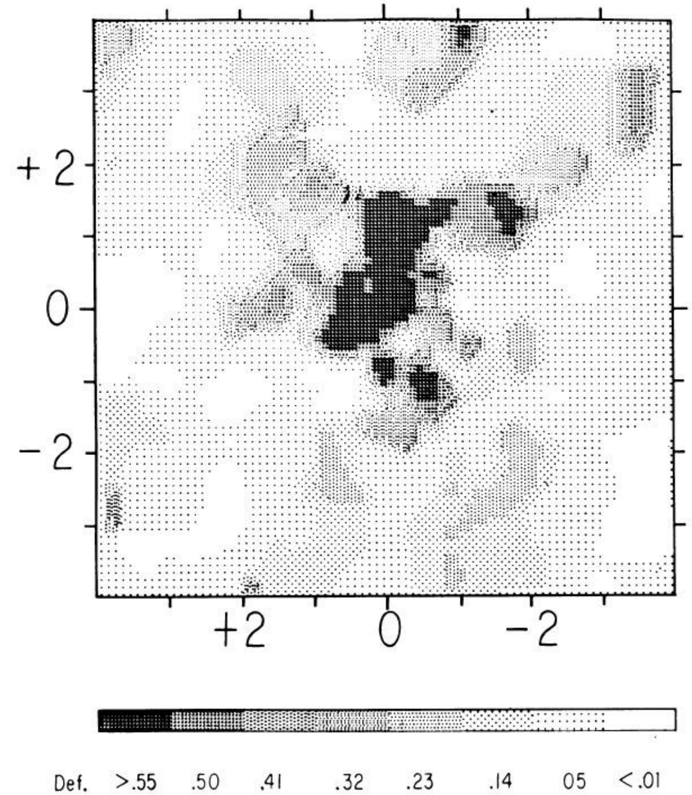


FIG. 8.—Shade plot illustrating the radial gradient in the H I content of galaxies in the composite cluster. The shade intensity is proportional to a mean value of deficiency, computed for each cell as the distance-weighted average of the *Def* values of the four galaxies nearest the cell center.

Global HI deficiency in nearby clusters:

- HI deficiency
  - Giovanelli & Haynes 1985, ApJ 292, 404 9 clusters

1985

420 GIOVANELLI AND HAYNES Vol. 292

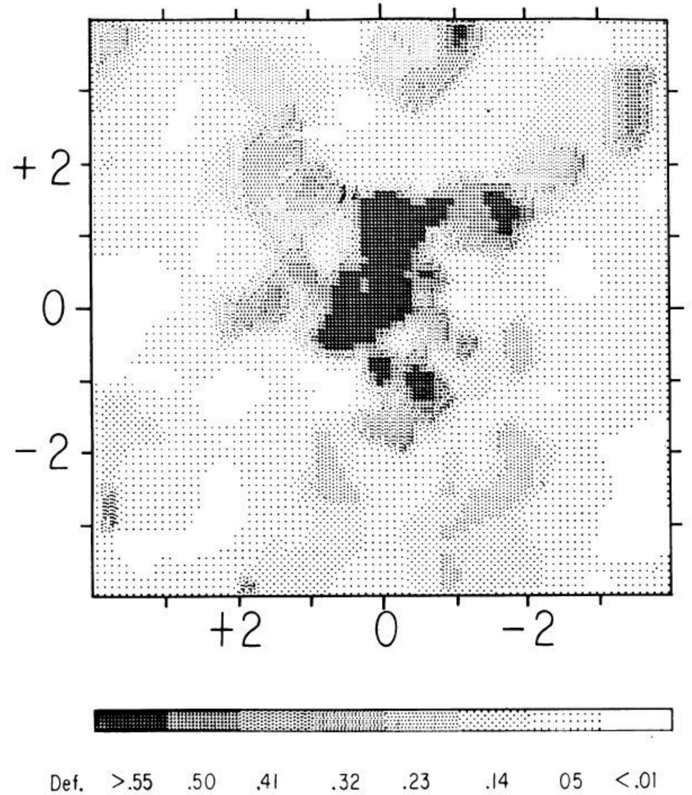


FIG. 8.—Shade plot illustrating the radial gradient in the H I content of galaxies in the composite cluster. The shade intensity is proportional to a mean value of deficiency, computed for each cell as the distance-weighted average of the *Def* values of the four galaxies nearest the cell center.

Global HI deficiency in nearby clusters:

- HI deficiency
  - Giovanelli & Haynes 1985, ApJ 292, 404   9 clusters

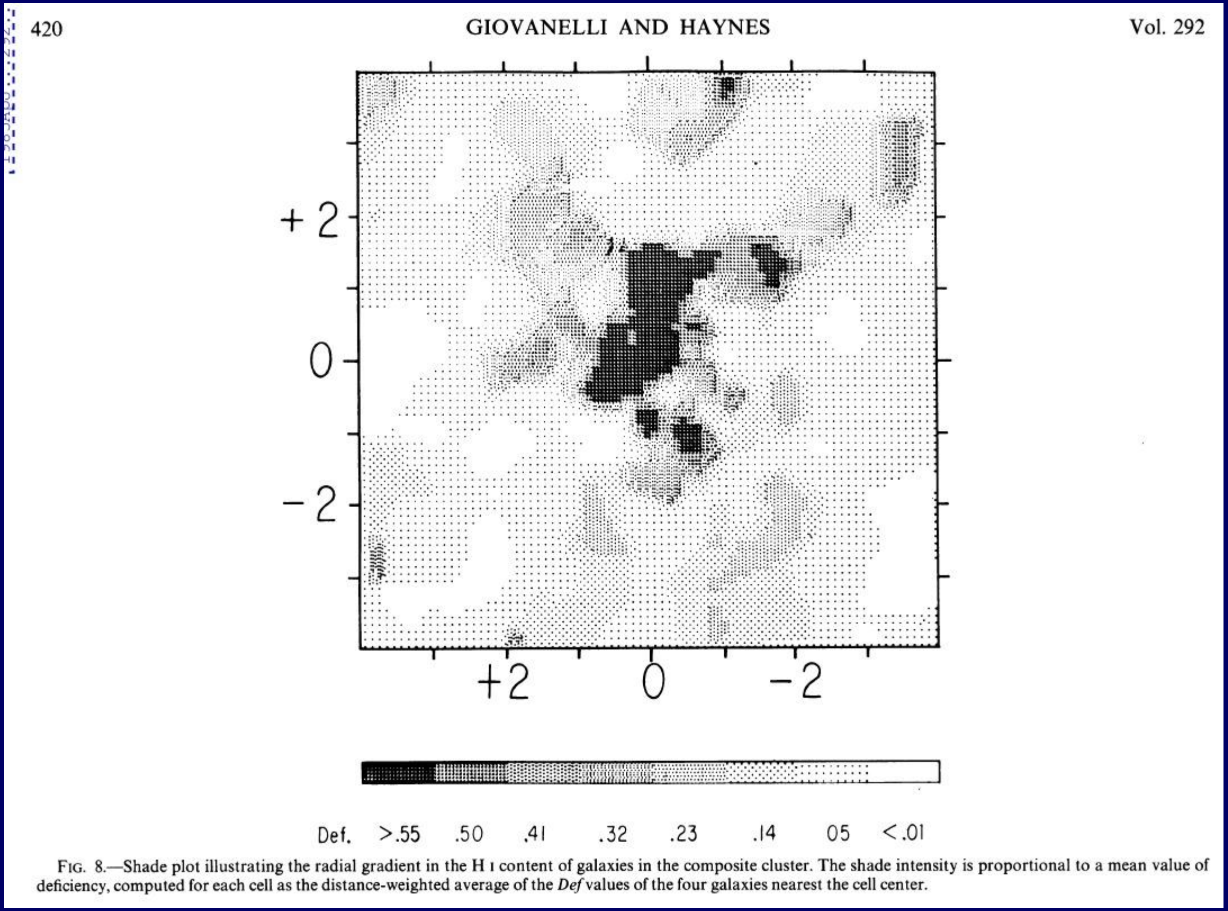

420   GIOVANELLI AND HAYNES   Vol. 292

FIG. 8.—Shade plot illustrating the radial gradient in the H I content of galaxies in the composite cluster. The shade intensity is proportional to a mean value of deficiency, computed for each cell as the distance-weighted average of the *Def* values of the four galaxies nearest the cell center.

Evidence of environmental effects:

Solanes+ 2001, ApJ 548, 97

1900 spirals in 18 nearby clusters

Look at global trends with L_X, T_X, σ, richness, spiral fraction

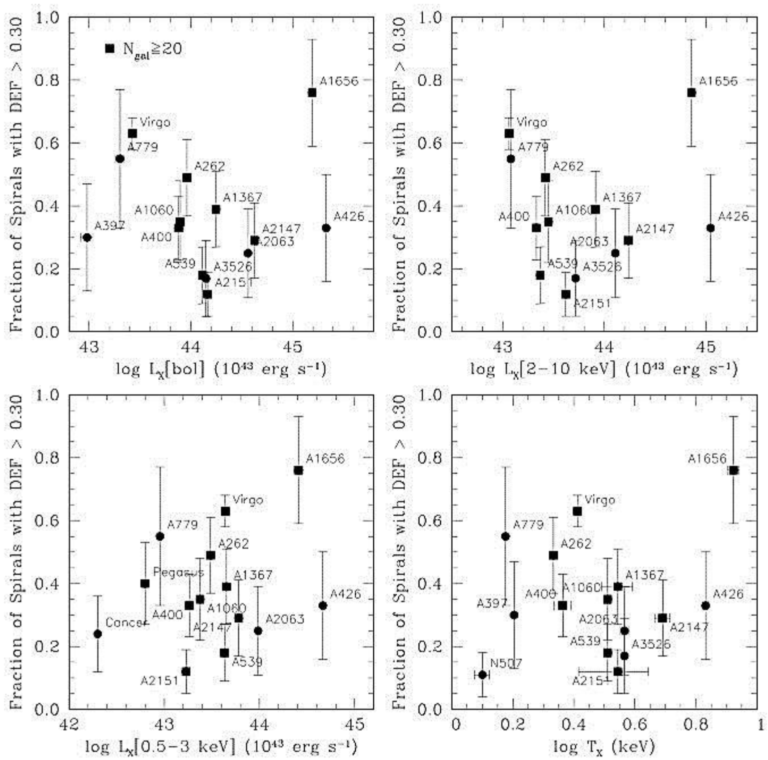


FIG. 6.—From left to right and top to bottom, spiral fraction within $1R_A$ with a deficiency parameter DEF larger than 0.30 vs. cluster bolometric, 2–10 keV, and 0.5–3.0 keV X-ray luminosities, and cluster X-ray temperature. Squares identify clusters with a minimum of 20 objects in the central region. Vertical error bars correspond to 1 σ Poisson confidence intervals except for the temperature where the quoted uncertainties are 90% for the *ASCA* observations and 68% for the *Einstein* estimates (see Table 2).

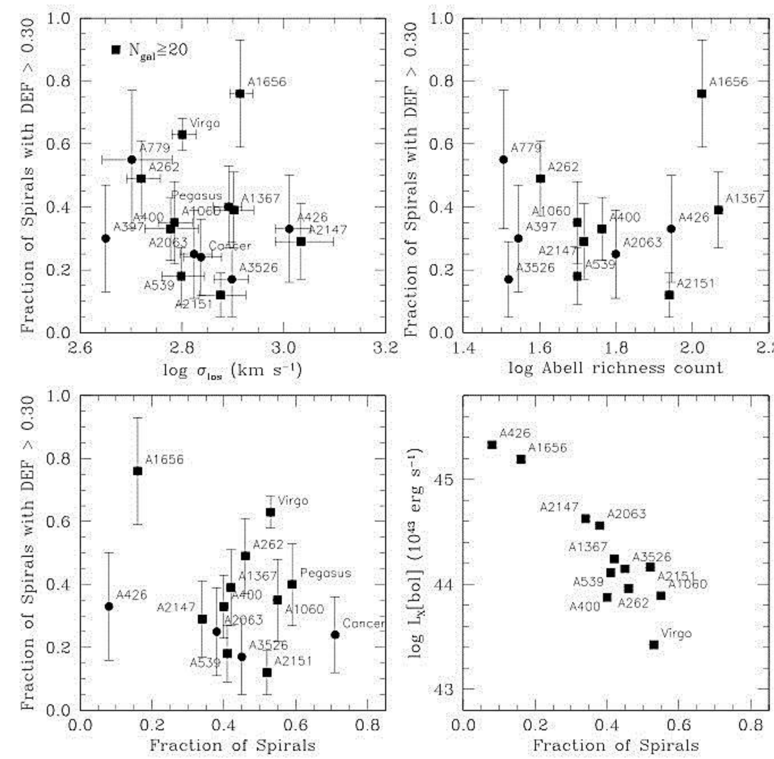


FIG. 7.—From left to right and top to bottom, spiral fraction within $1R_A$ with a deficiency parameter DEF larger than 0.30 vs. cluster velocity dispersion, Abell richness count, and total fraction of spirals. The bottom right-hand panel shows the bolometric X-ray luminosity plotted against the total fraction of spirals. Vertical error bars correspond to 1 σ confidence intervals. In the bottom right-hand panel the size of the symbols is larger than the error bars.

Evidence of environmental effects:

Solanes+ 2001, ApJ 548, 97

1900 spirals in 18 nearby clusters

- 2/3 of clusters show significant HI deficiency
- Early-type spirals and dwarfs appear more HI deficient
- HI deficiency traced to 2 R_A
    - Degree of deficiency increases towards center

- Evidence that gas-poor spirals in HI deficient clusters more in orbits more radial than those of the galaxies with healthy gas contents

Evidence of environmental effects:

Solanes+ 2001, ApJ 548, 97

1900 spirals in 18 nearby clusters

- 2/3 of clusters show significant HI deficiency
- Early-type spirals and dwarfs appear more HI deficient
- HI deficiency traced to 2 R_A
  - Degree of deficiency increases towards center

- Evidence that gas-poor spirals in HI deficient clusters more in orbits more radial than those of the galaxies with healthy gas contents

2001

Coma = Abell 1656

High richness, high L_X, low spiral fraction, => strong HI deficiency

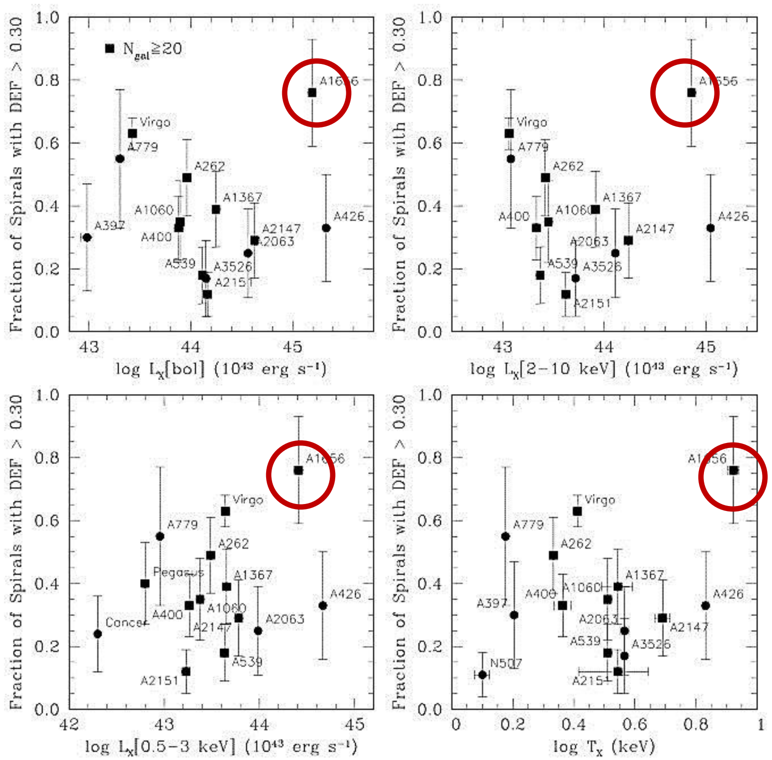


FIG. 6.—From left to right and top to bottom, spiral fraction within $1R_A$ with a deficiency parameter DEF larger than 0.30 vs. cluster bolometric, 2–10 keV, and 0.5–3.0 keV X-ray luminosities, and cluster X-ray temperature. Squares identify clusters with a minimum of 20 objects in the central region. Vertical error bars correspond to 1 σ Poisson confidence intervals except for the temperature where the quoted uncertainties are 90% for the *ASCA* observations and 68% for the *Einstein* estimates (see Table 2).

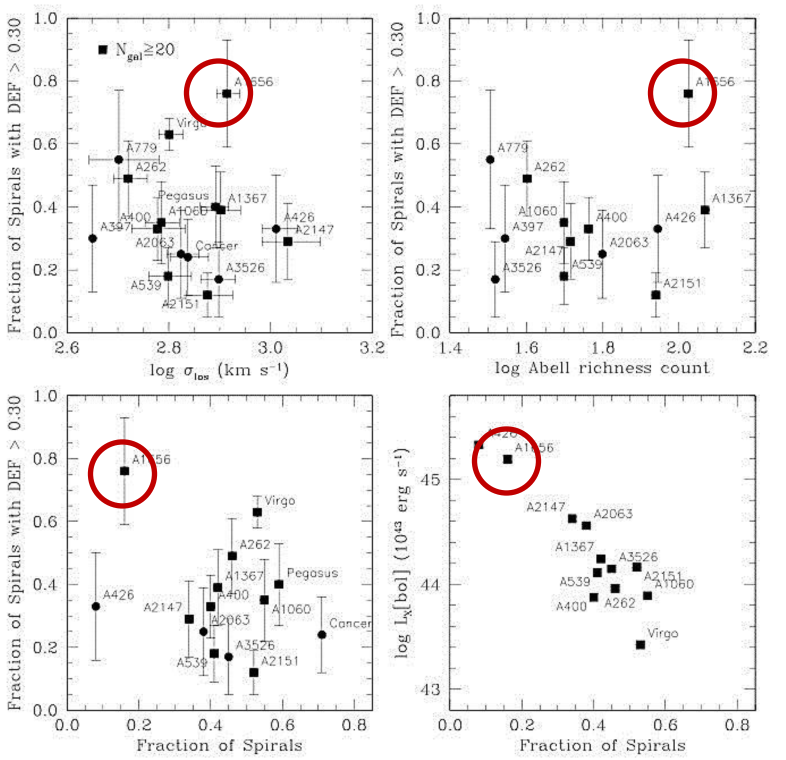


FIG. 7.—From left to right and top to bottom, spiral fraction within $1R_A$ with a deficiency parameter DEF larger than 0.30 vs. cluster velocity dispersion, Abell richness count, and total fraction of spirals. The bottom right-hand panel shows the bolometric X-ray luminosity plotted against the total fraction of spirals. Vertical error bars correspond to 1 σ confidence intervals. In the bottom right-hand panel the size of the symbols is larger than the error bars.

Abell 1367

Intemediate richness, L_X, moderate spiral fraction

No. 1, 2001 H I CONTENT OF SPIRALS. II. 105

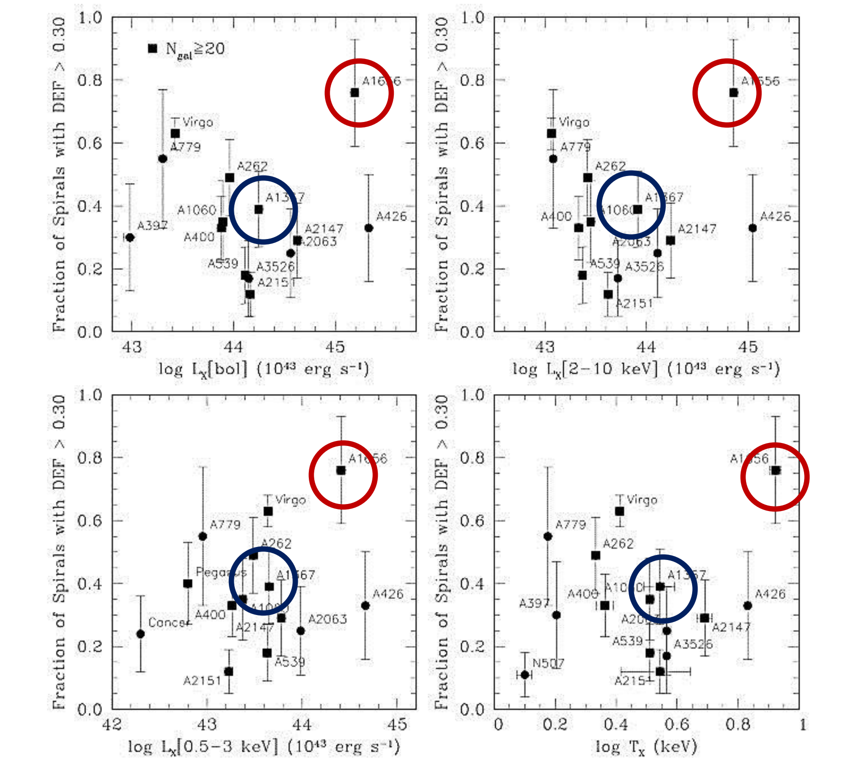


FIG. 6.—From left to right and top to bottom, spiral fraction within $1R_A$ with a deficiency parameter DEF larger than 0.30 vs. cluster bolometric, 2–10 keV, and 0.5–3.0 keV X-ray luminosities, and cluster X-ray temperature. Squares identify clusters with a minimum of 20 objects in the central region. Vertical error bars correspond to 1 σ Poisson confidence intervals except for the temperature where the quoted uncertainties are 90% for the *ASCA* observations and 68% for the *Einstein* estimates (see Table 2).

106 SOLANES ET AL. Vol. 548

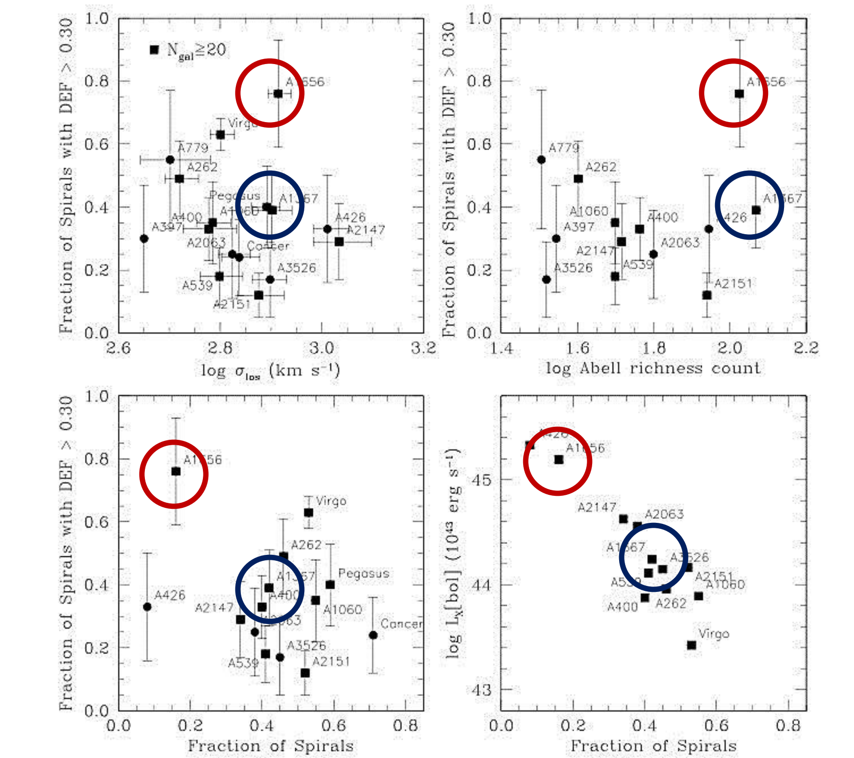


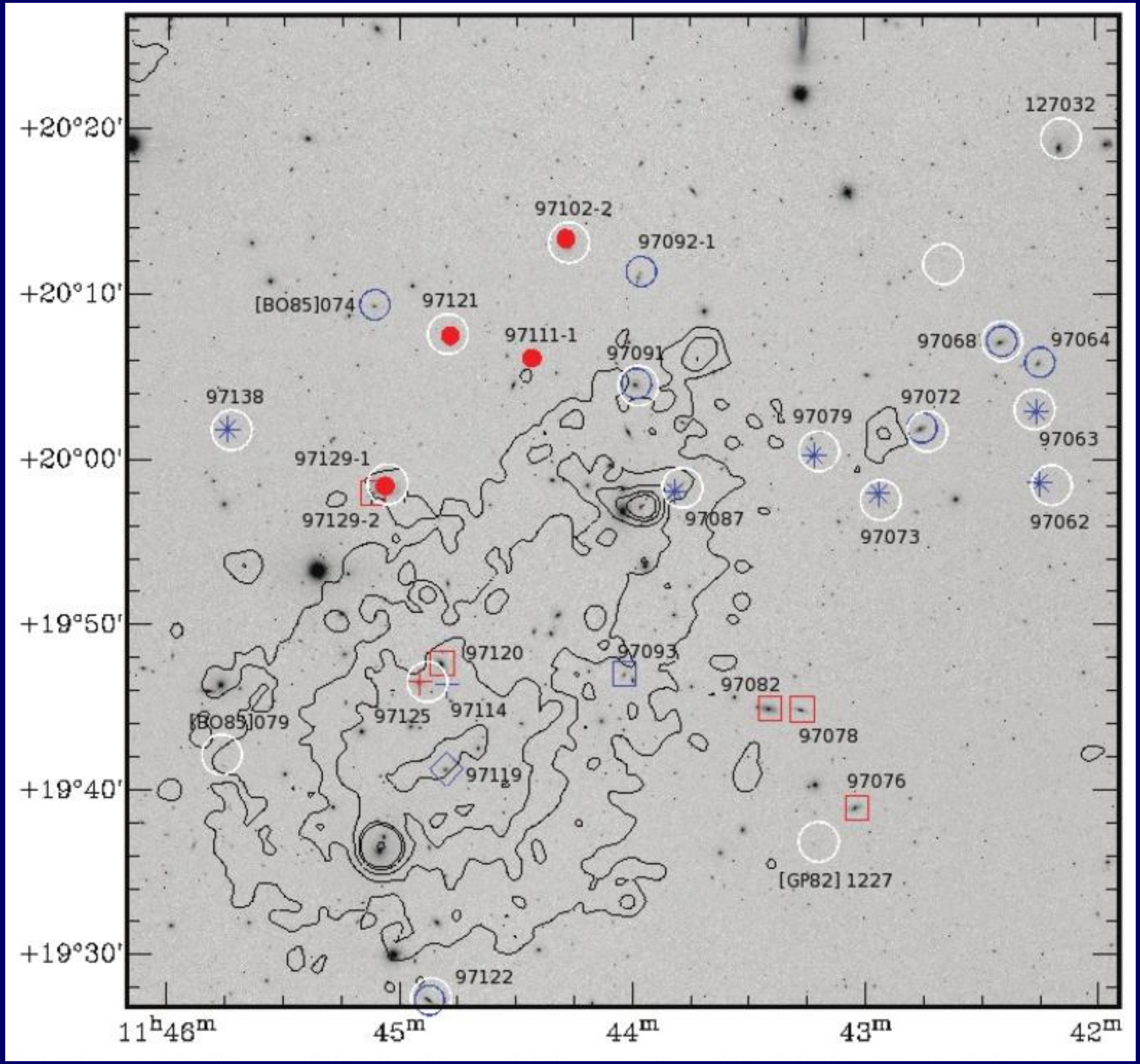
FIG. 7.—From left to right and top to bottom, spiral fraction within $1R_A$ with a deficiency parameter DEF larger than 0.30 vs. cluster velocity dispersion, Abell richness count, and total fraction of spirals. The bottom right-hand panel shows the bolometric X-ray luminosity plotted against the total fraction of spirals. Vertical error bars correspond to 1 σ confidence intervals. In the bottom right-hand panel the size of the symbols is larger than the error bars.

HI in A1367

Scott+ 2010
MNRAS 403, 1175

- Global trend of increasing <Def> toward center not seen
- Many spirals have moderate <Def> and blue colors; HI intensity max displaced from OC
- Combination of ram pressure and gravity

- A1367 more complex than Coma or Virgo



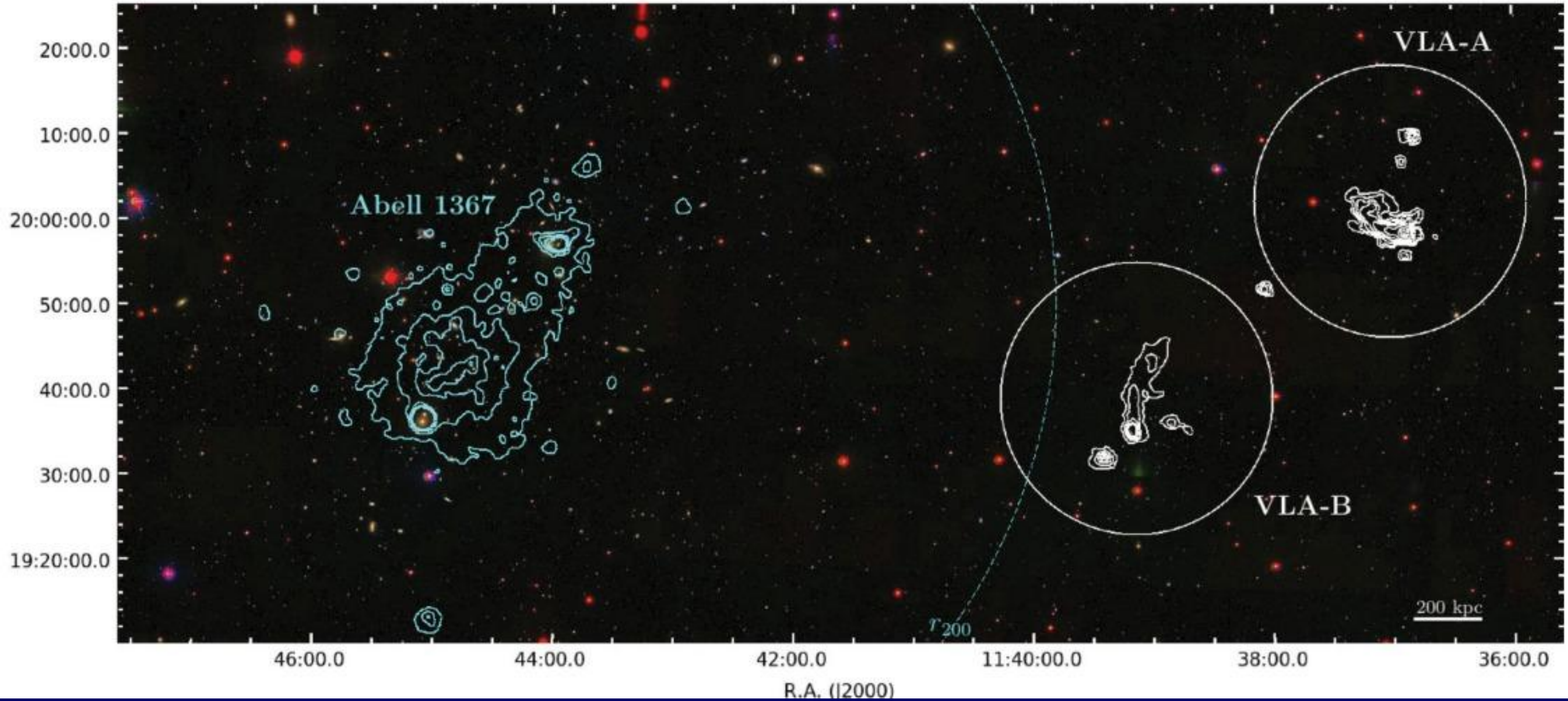
HI in A1367

Tails extending over ~200 kpc

- One: low-velocity tidal interaction
- But the other uncertain: high speed encounter?

Scott+ 2012 MNRAS 419, L19

Two long H I tails in Abell 1367 L21

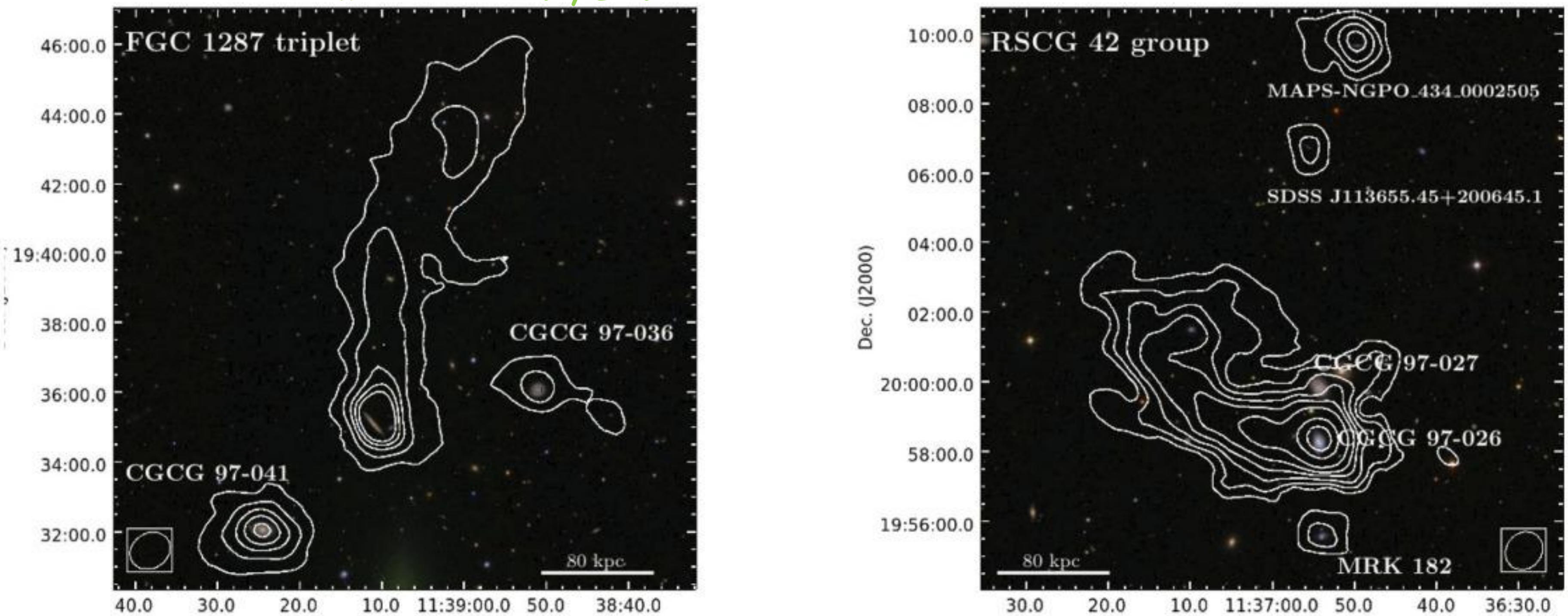


HI in A1367

Tails extending over ~200 kpc

- One: low-velocity tidal interaction
- But the other uncertain: high speed encounter?

Scott+ 2012 MNRAS 419, L19



A2151: Hercules

- Rich cluster
- Low L_X, T_X
- Spiral-rich (52%)
- Marginal HI deficiency fraction (0.12 vs 0.76 for Coma, 0.63 for Virgo)

- Still assembling???

Dickey 1997 AJ 113, 1939
Blind VLA survey: tough!

Star formation in Hercules: A2151

Cedres+ 2009 AJ 138, 873

- 11 pointings covering 0.15 sq deg
  => ~ 7% of total area
- Ha emitting galaxies avoid main X-ray peak, but are found in regions of high galaxy density

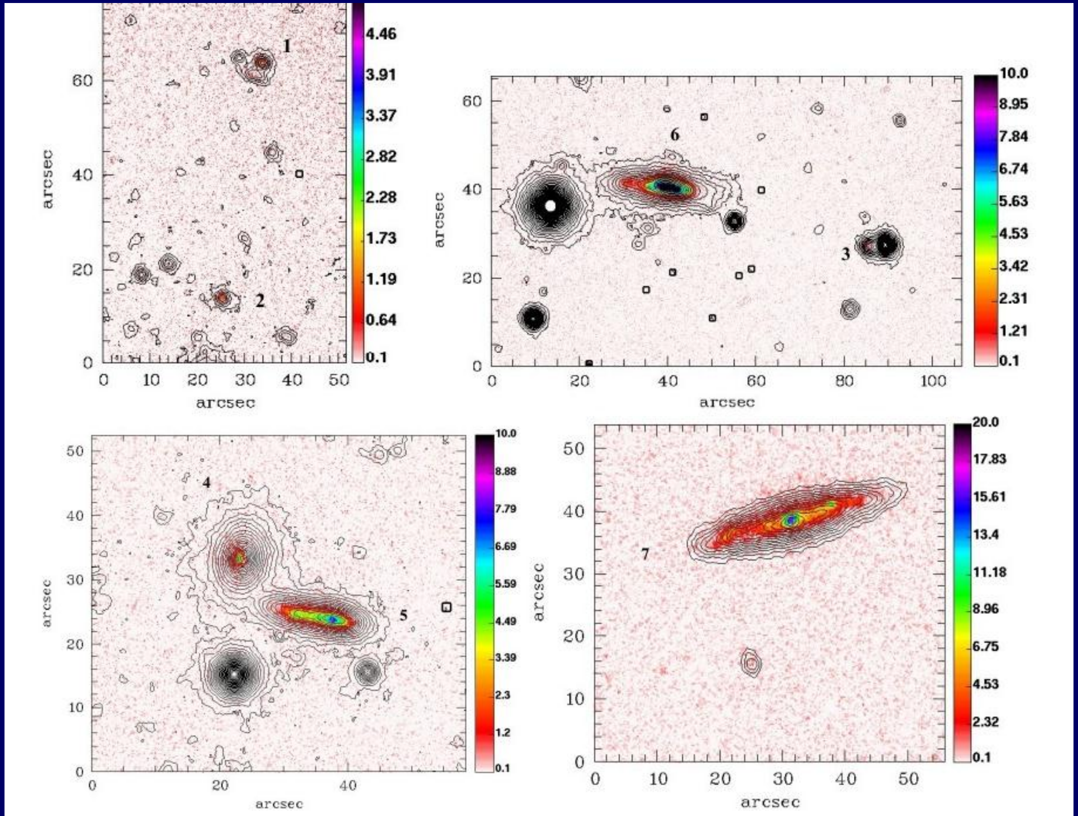


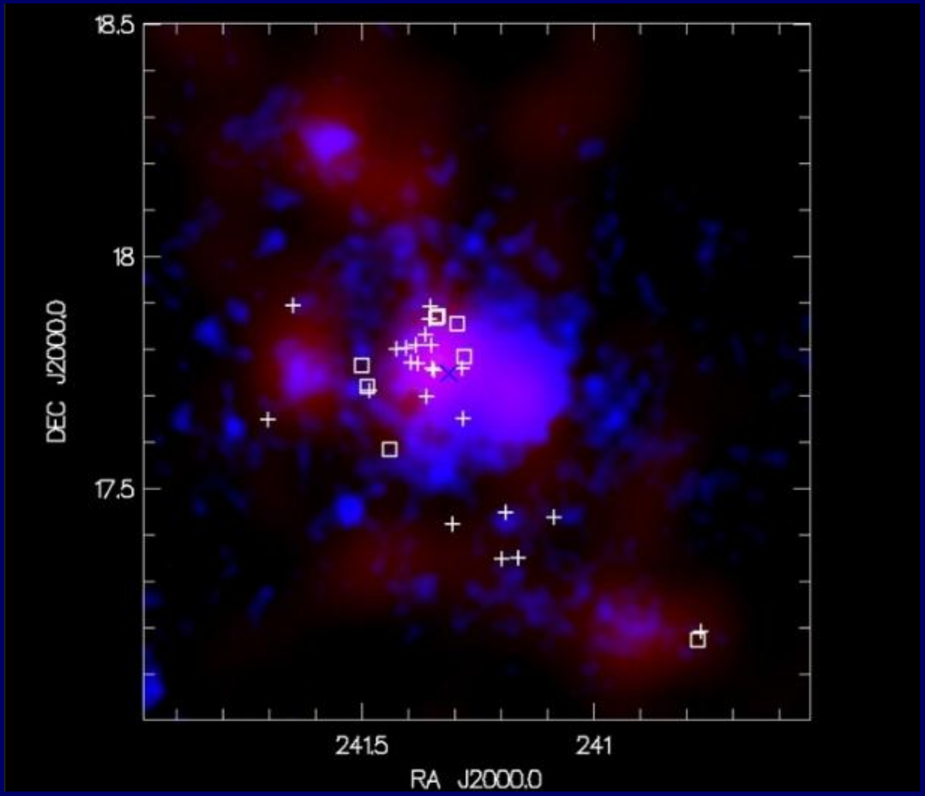
Figure 5. Hα frames of the A2151 emitting galaxies with the r contours overimposed. The Hα surface brightness is indicated by the color scale to the right of each image in 10^{-16} erg cm^{-2} s^{-1} $arcsec^{-2}$. The superposed contours are in AB magnitudes $arcsec^{-2}$. The lowest contour is at 24 mag $arcsec^{-2}$ and the increment is 0.2 mag $arcsec^{-2}$. North is at the top; east is at the left.

Star formation in Hercules: A2151

Petropoulou+ 2011, ApJ 734, 32

Spatially resolved spectroscopy of 27 SF galaxies selected from the Ha survey => three categories

1. Chemically evolved spirals with truncated ionized disks and nearly flat oxygen gradients => ram pressure stripping
2. Chemically evolved dw/Irr populating highest density regions, possible products of tidal interactions
3. Lower metallicity dwarfs => "newcomers"



Red: galaxy density; blue: ROSAT

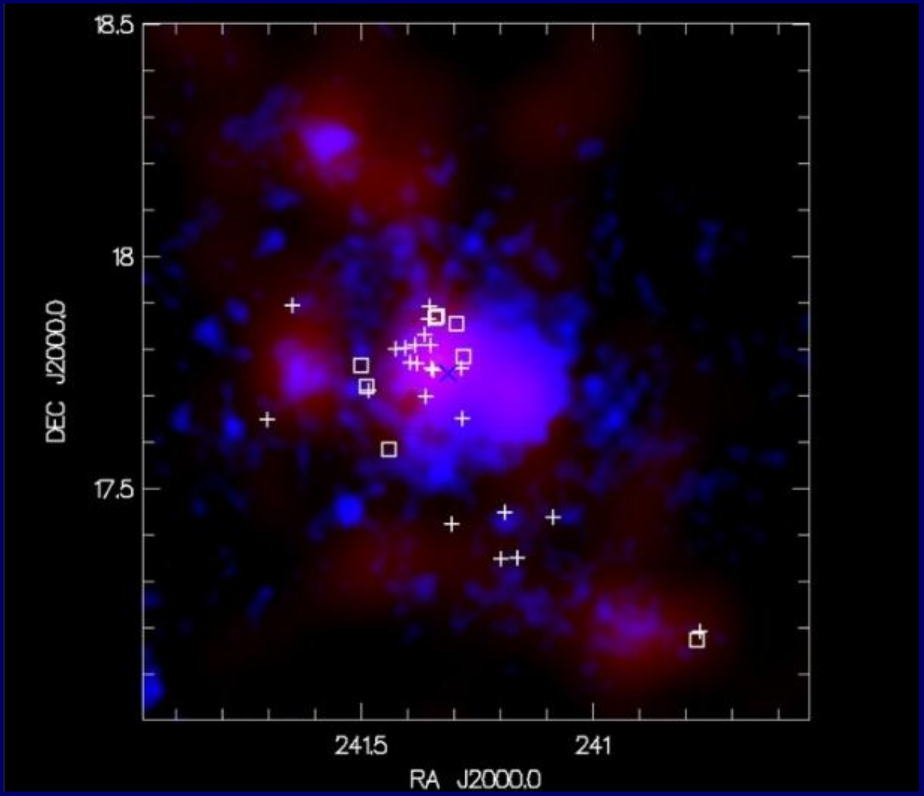
Star formation in Hercules: A2151

Petropoulou+ 2011, ApJ 734, 32

Spatially resolved spectroscopy of 27 SF galaxies selected from the Hα survey => three categories

1. Chemically evolved spirals with truncated ionized disks and nearly flat oxygen gradients => ram pressure stripping
2. Chemically evolved dw/Irr populating highest density regions, possible products of tidal interactions
3. Lower metallicity dwarfs => "newcomers"

1946



Red: galaxy density; blue: ROSAT

What I hope to learn:

- Where (in terms of local density, M_{halo}) do environmental effects become important?
- How can we determine the relative impacts of ram pressure stripping versus gravitational stripping (of any sort)?
- How does stripping fit into the picture of dynamical evolution of a cluster/group/filament (e.g., orbits, on-going infall…)?
- How does this translate into what we (can) observe at higher z?

What I hope to learn:

- Where (in terms of local density, M_{halo}) do environmental effects become important?
- How can we determine the relative impacts of ram pressure stripping versus gravitational stripping (of any sort)?
- How does stripping fit into the picture of dynamical evolution of a cluster/group/filament (e.g., orbits, on-going infall…)?
- How does this translate into what we (can) observe at higher z?

- I still don't really understand the interplay between HI, H_2 (as traced by CO) and SF.
- Probably multiple processes at play