

Cold gas in massive galaxies and across environments: challenges and prospects

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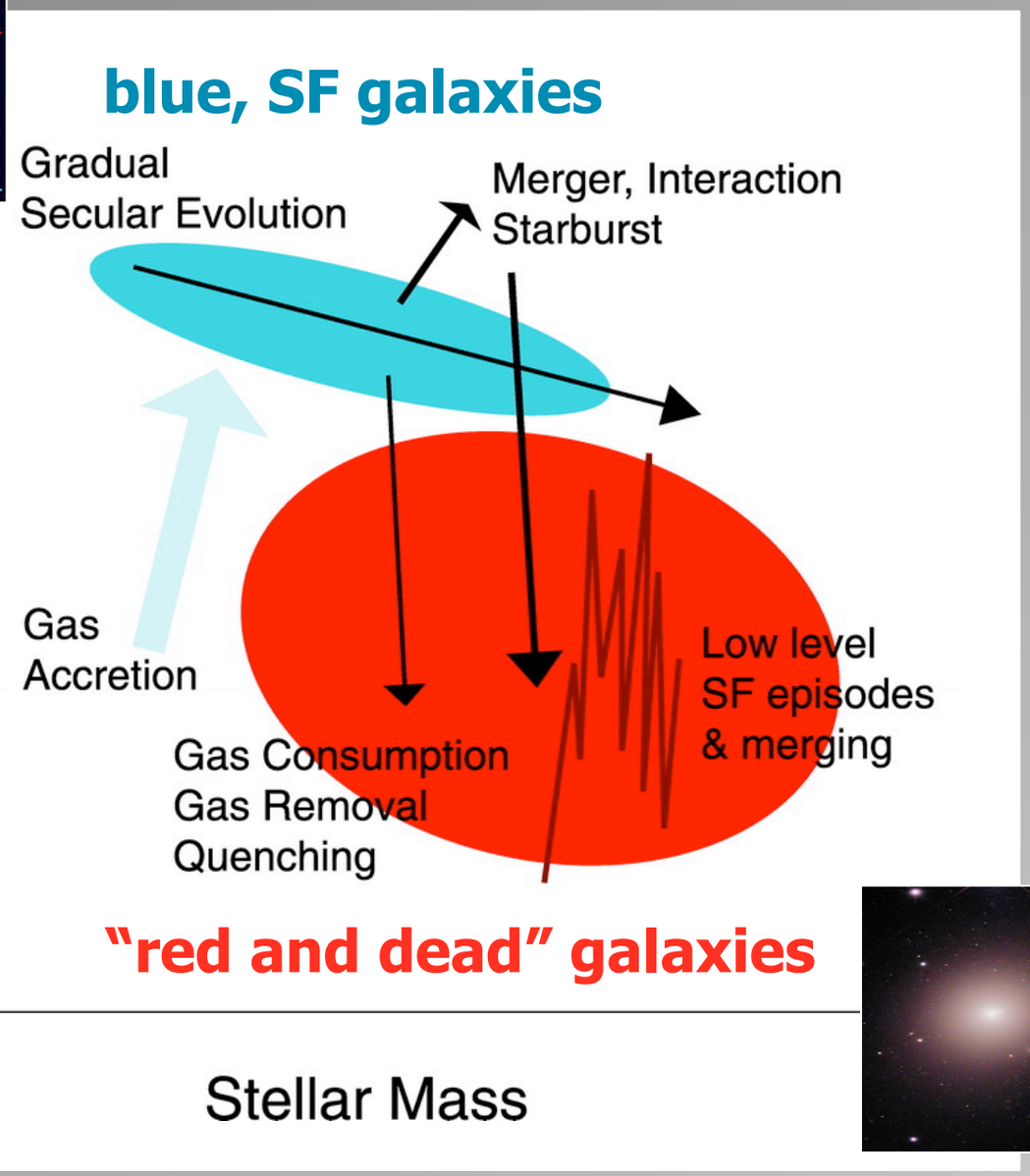
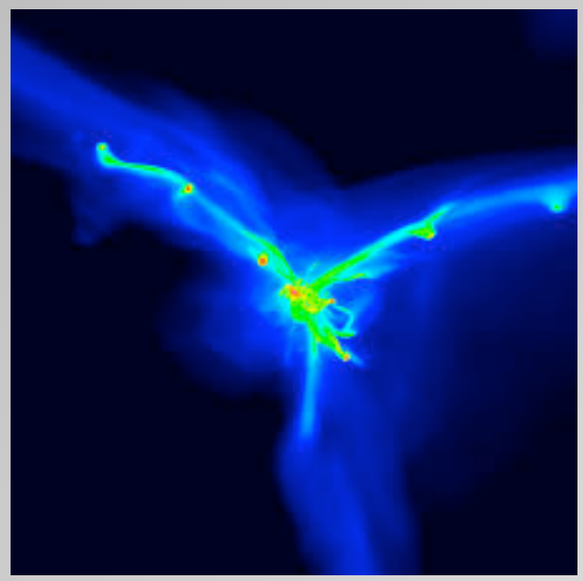
Galaxy “gastrophysics”





HI gas plays a key role in every step of galaxy evolution, but there is still a lot of work to do to understand how gas cycles in and out of galaxies

Two open questions for upcoming HI surveys

- How is the gas cycle of galaxies affected by the environment outside clusters?
- How does the gas content of galaxies depend on redshift?

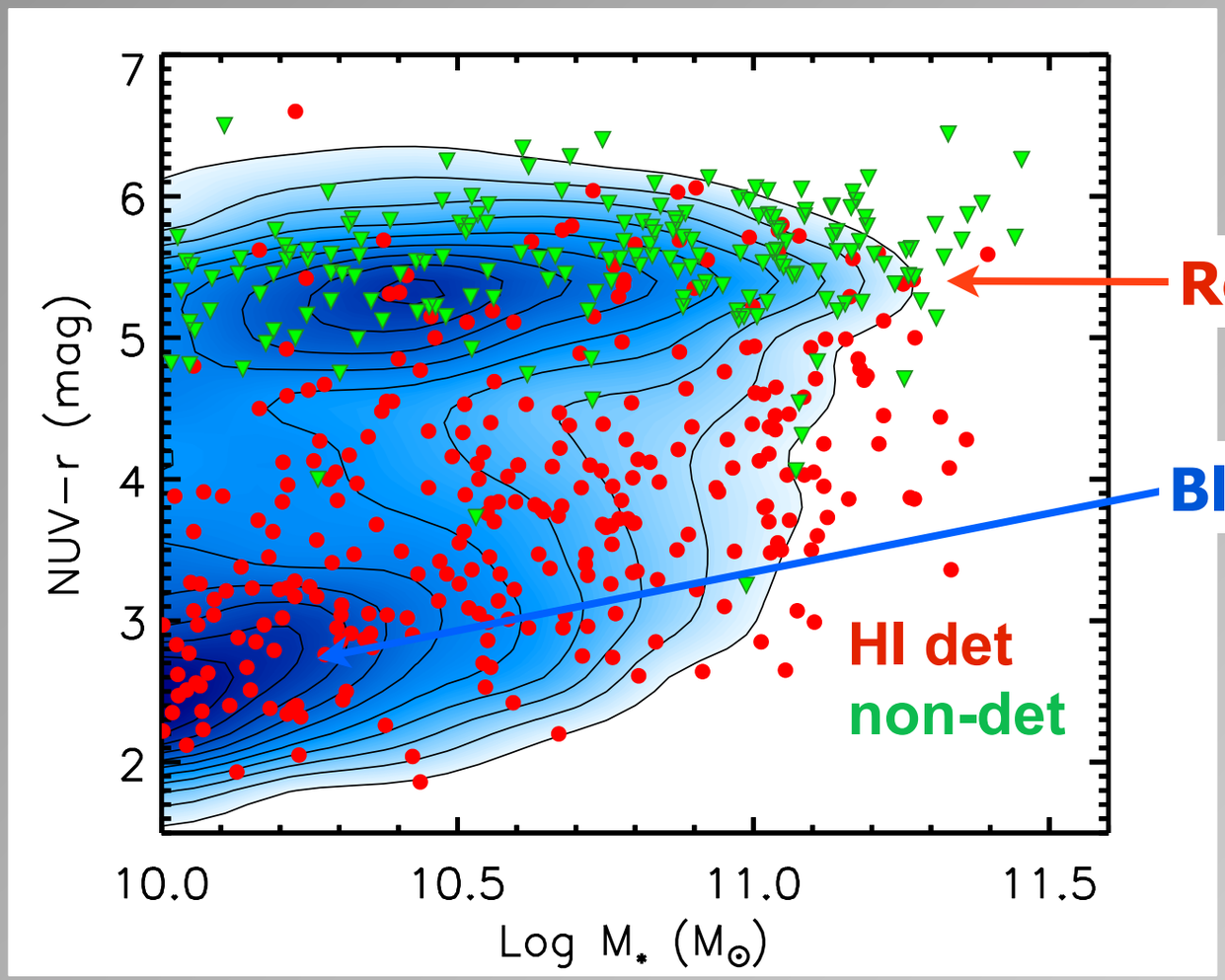
Scaling relations are powerful tools to address these questions

- Comparison of galaxy properties must be done **at fixed stellar mass**
- Need **large samples**, spanning range of environments and galaxy properties, and **probing the gas-poor regime**

GASS: The GALEX Arecibo SDSS Survey

Targeted HI survey: **~800 galaxies** with homogeneously measured $M_\star$, SFR and gas properties. Arecibo large program (2008-2012).

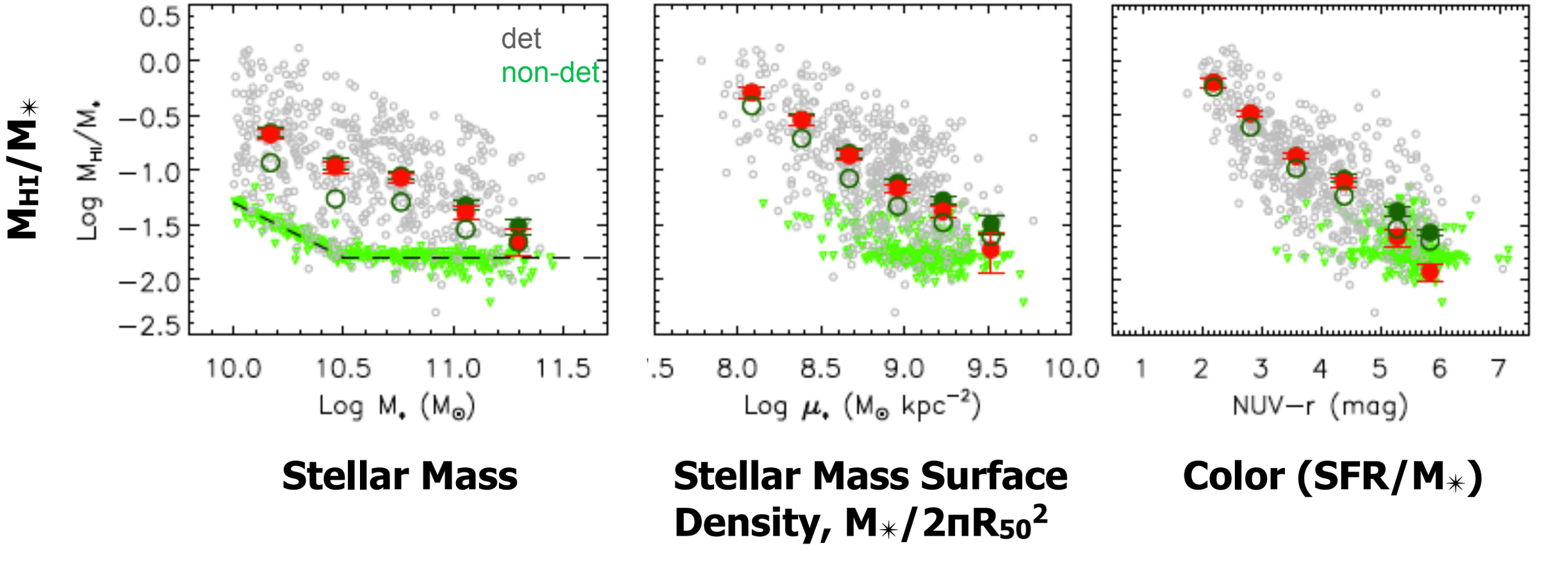
- **Volume-limited: 0.025< z <0.05**
- **Stellar mass selected**: **10< log $M_\star/M_\odot$ <11.5**
- **Gas fraction limited: $M_{HI}/M_\star$ > 1.5%**



Final data release (DR3; Catinella et al. 2013) available at:

www.mpa-garching.mpg.de/GASS/

Gas content vs structural / SF properties of galaxies



Stellar Mass

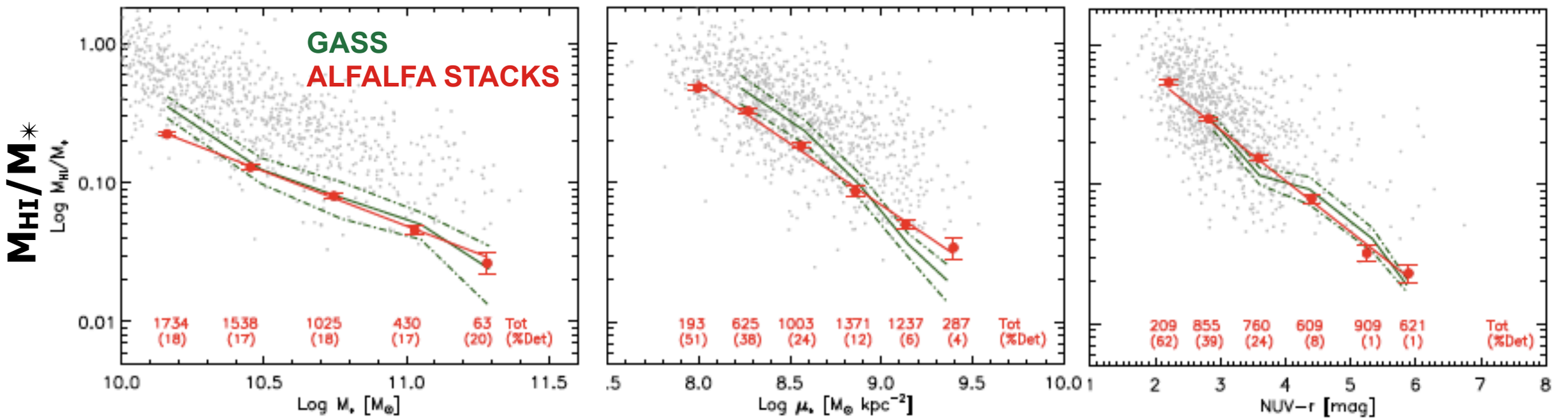
Stellar Mass Surface Density, $M_*/2\pi R_{50}^2$

Color (SFR/M_*)

Catinella et al. 2010, 2012b & 2013

HI mass fraction most tightly correlated with μ_* and NUV-r

Scaling relations from ALFALFA stacking

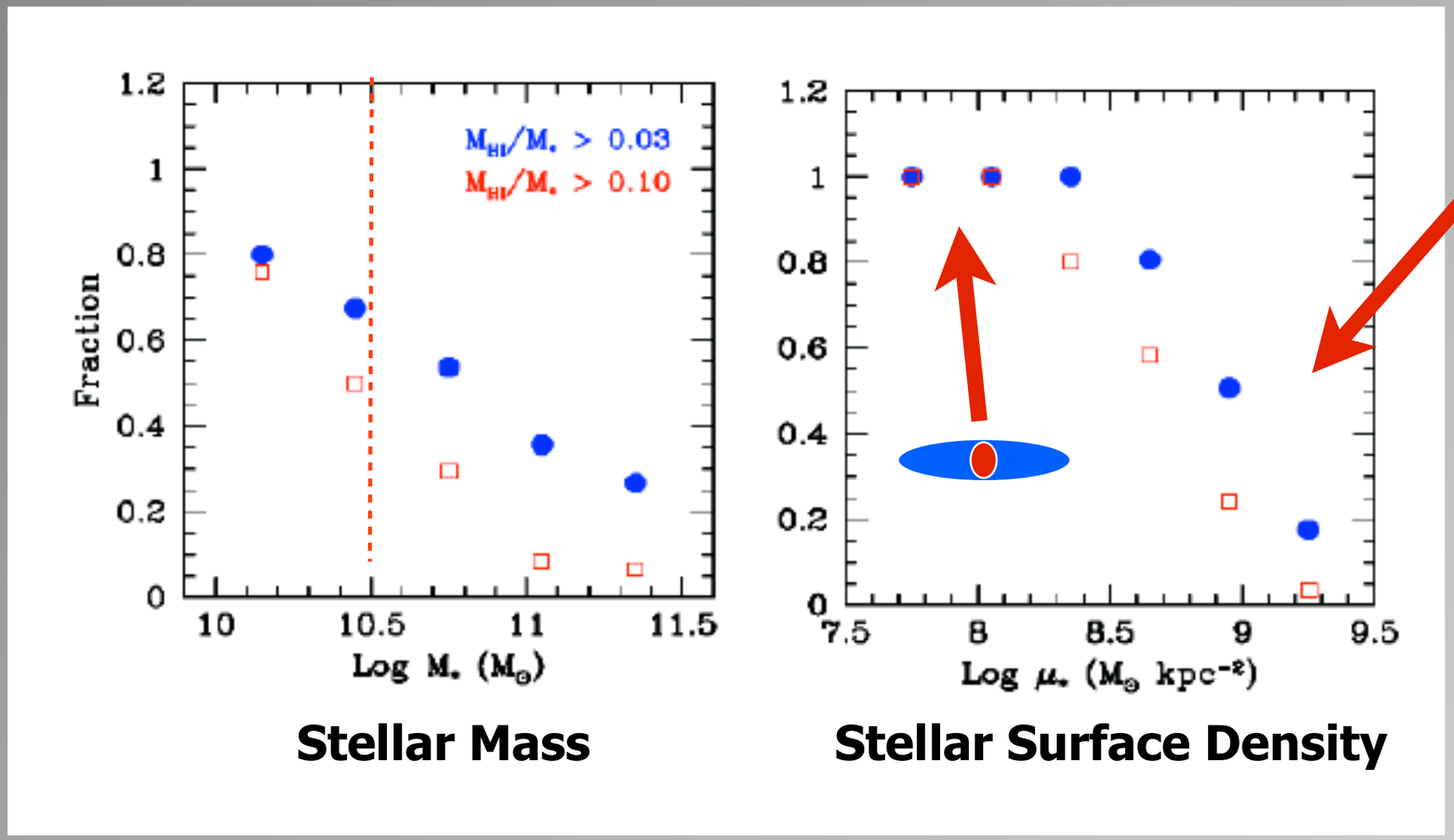


Stellar Mass **Stellar Surface Density** **NUV-r**

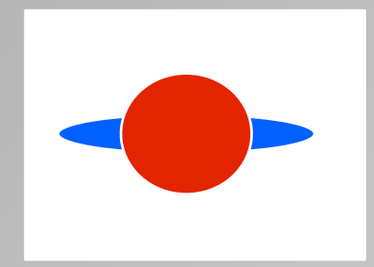
Fabello, Catinella et al. 2011

- HI stacking: powerful technique for upcoming SKA precursor surveys
- Complementary to (not a substitute for) individual detections

Galaxy structure and gas content



Stellar Mass **Stellar Surface Density**



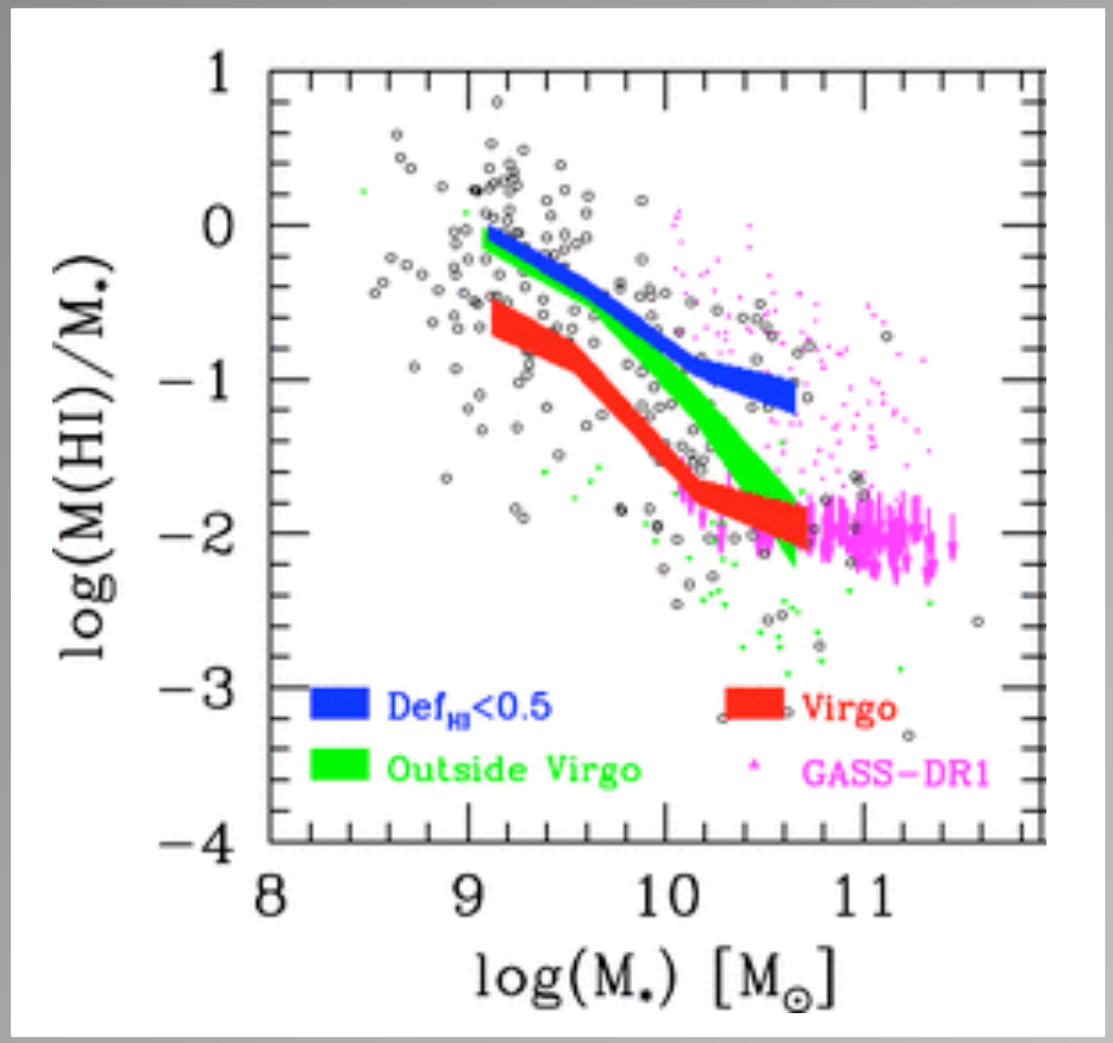
Not reproduced by models (Kauffmann et al. 2012)

Catinella et al. 2010

Transition seen in μ_*, not in M_*

Scaling relations and environment

Powerful tools to study effects of environment on galaxy evolution



Cortese, Catinella et al. (2011)

Herschel Reference Survey
(Boselli et al 2010): 322 galaxies
(62 E/SO, 260 Sp./Irr)

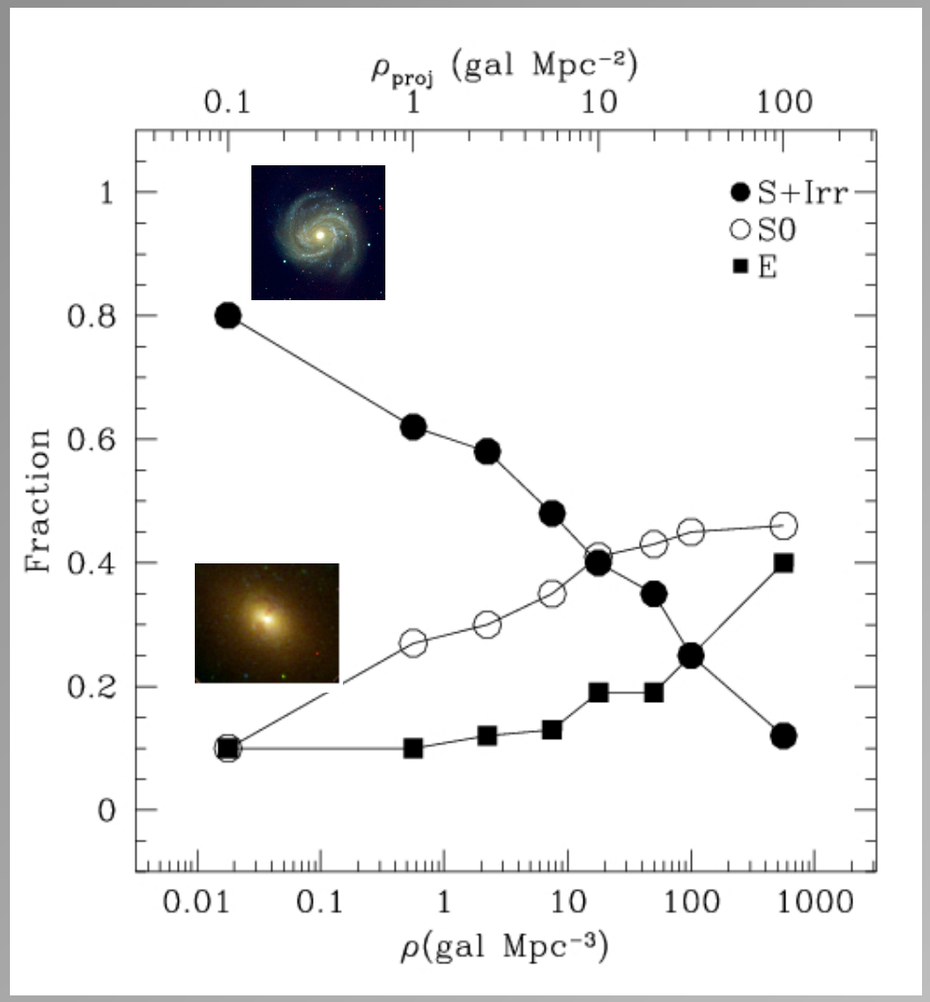
Volume/Stellar Mass limited - from isolated to cluster galaxies

Clusters are rare! Only 10% of local galaxies reside in clusters. What about HI content of galaxies in groups?

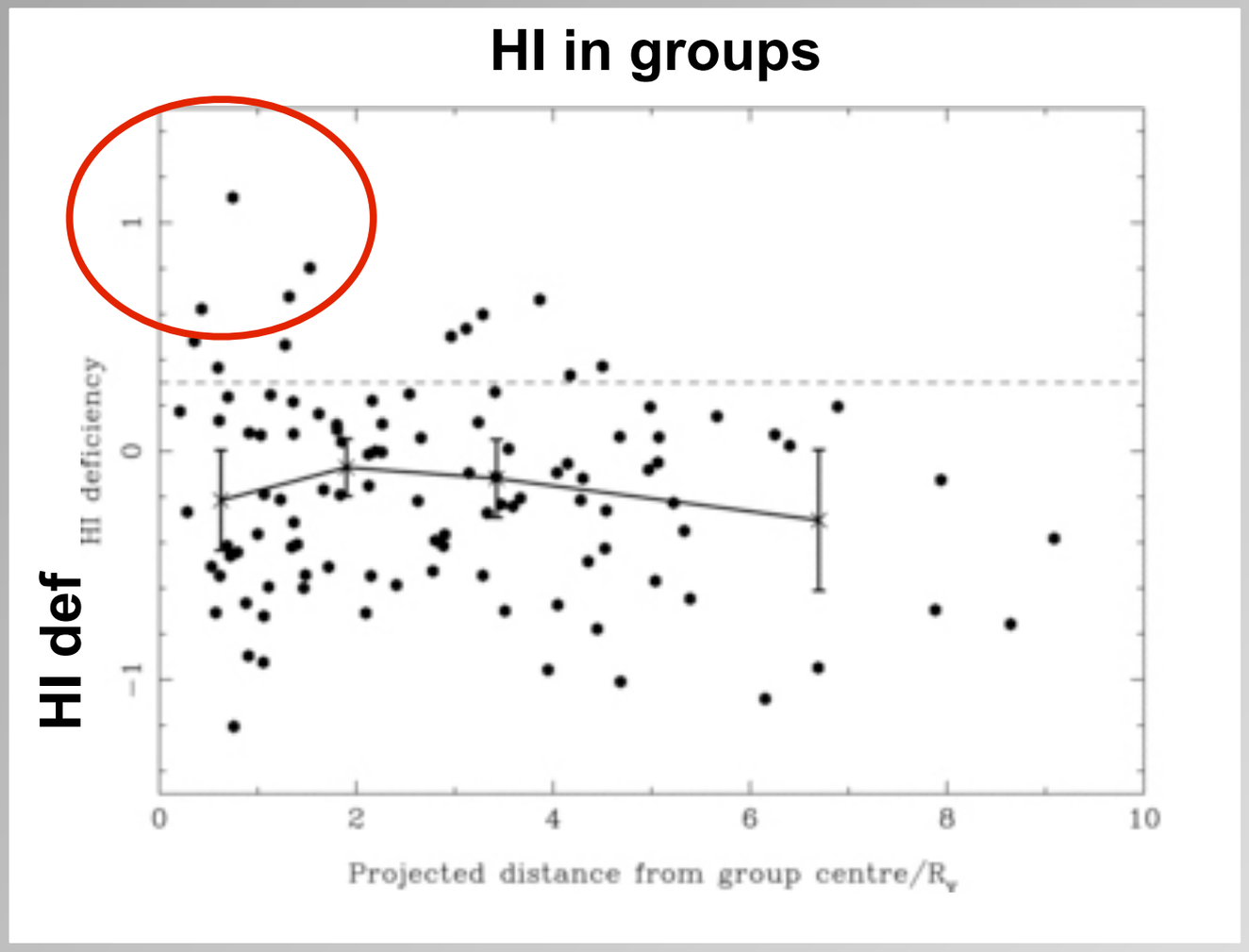
HI content determined primarily by stellar mass, environment is secondary.
Environmental comparisons must be done **at fixed stellar mass**.

Group environment: does it matter?

Optical studies show that environment acts well before reaching the dense cluster environment (Dressler 1980, Lewis et al 02, Gomez et al 03...)



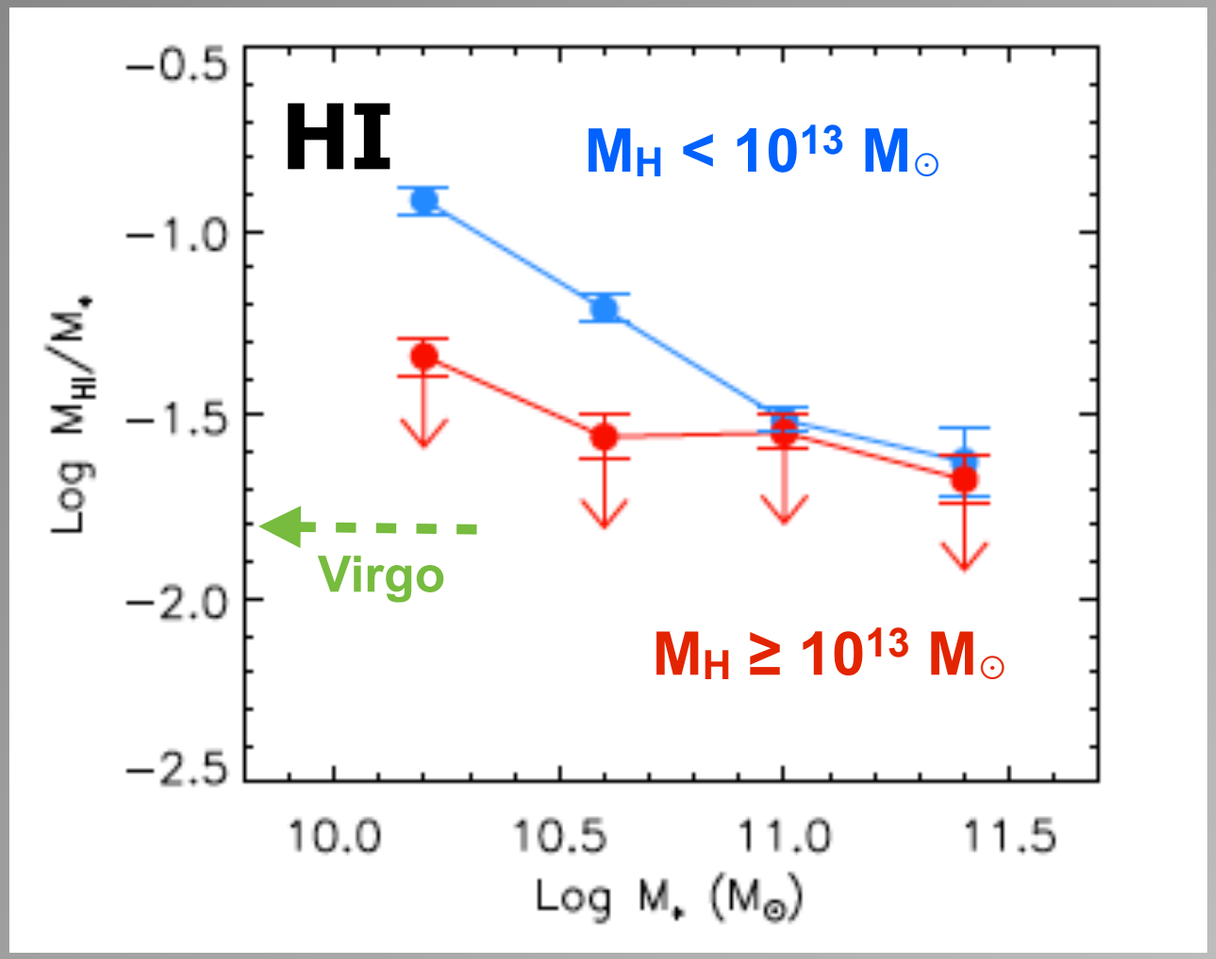
Adapted from Dressler (1980)

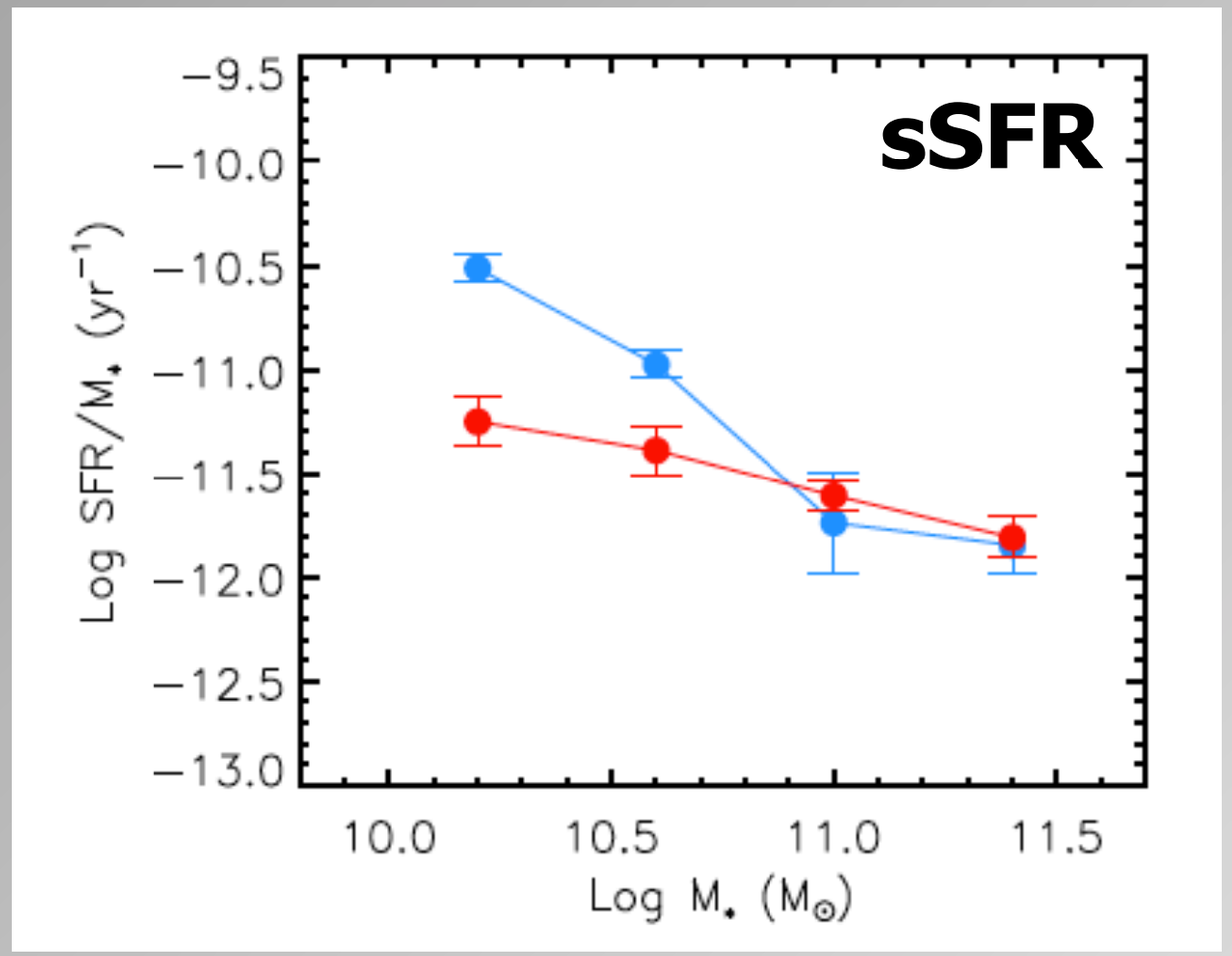


Kilborn et al. (2009)

At which density does the environment start affecting galaxy evolution?

HI content (and SF) suppressed in groups





Catinella, Schiminovich, Cortese et al. 2013

First statistical evidence for suppression of HI gas *at fixed stellar mass* in groups with halo mass $M_H \geq 10^{13}\ M_\odot$

- Extend to lower stellar mass and larger samples.
- Need to probe gas-poor regime and variety of environments. Stacking science.

Pushing to higher redshift: a glimpse into SKA science

Detection of 21 cm emission at z > 0.1 is DIFFICULT

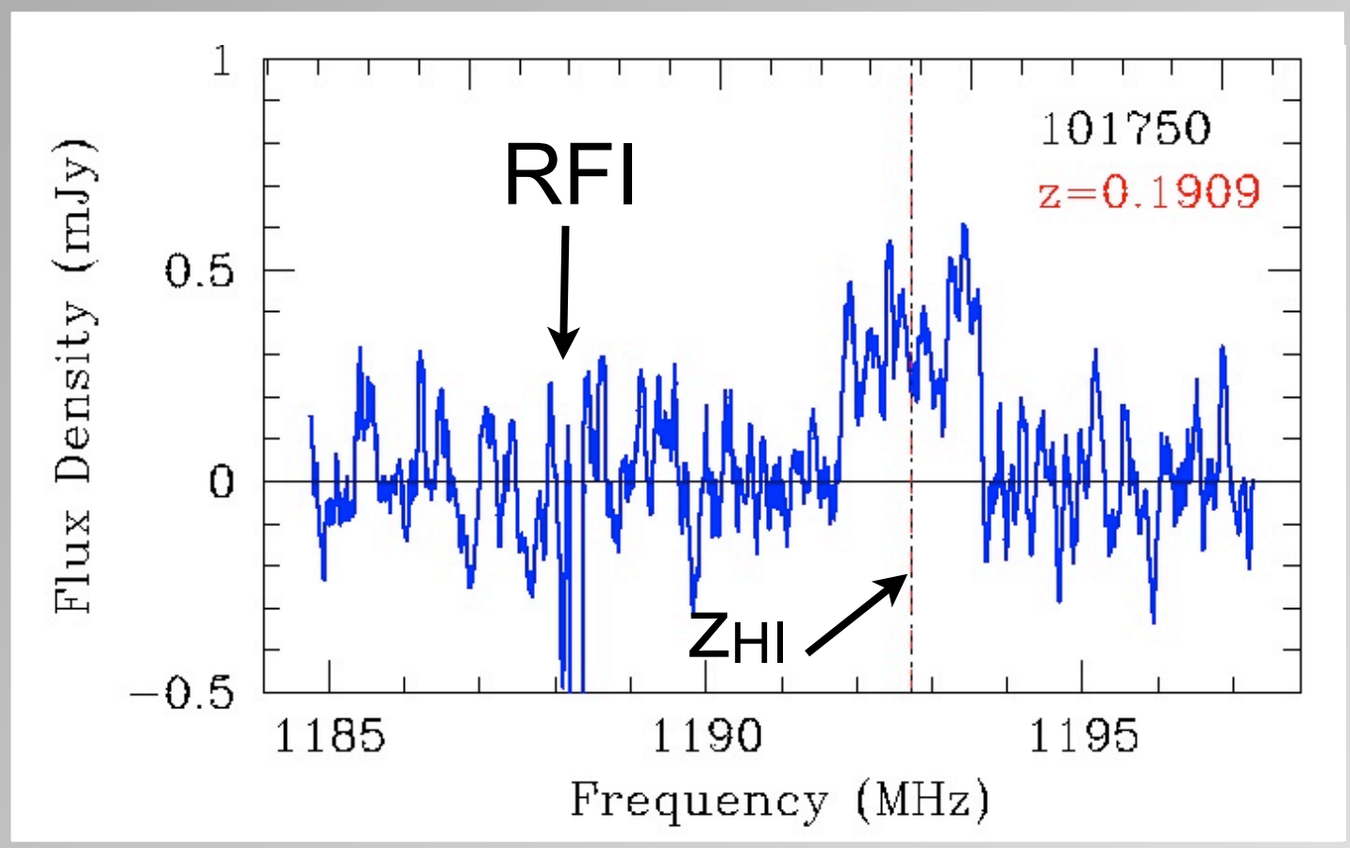
- weak signals → very long integration times
- radio frequency interference (RFI)

In fact, almost NOTHING is known about the HI content of galaxies above z=0.1

Arecibo observations of SDSS-selected galaxies at z>0.16

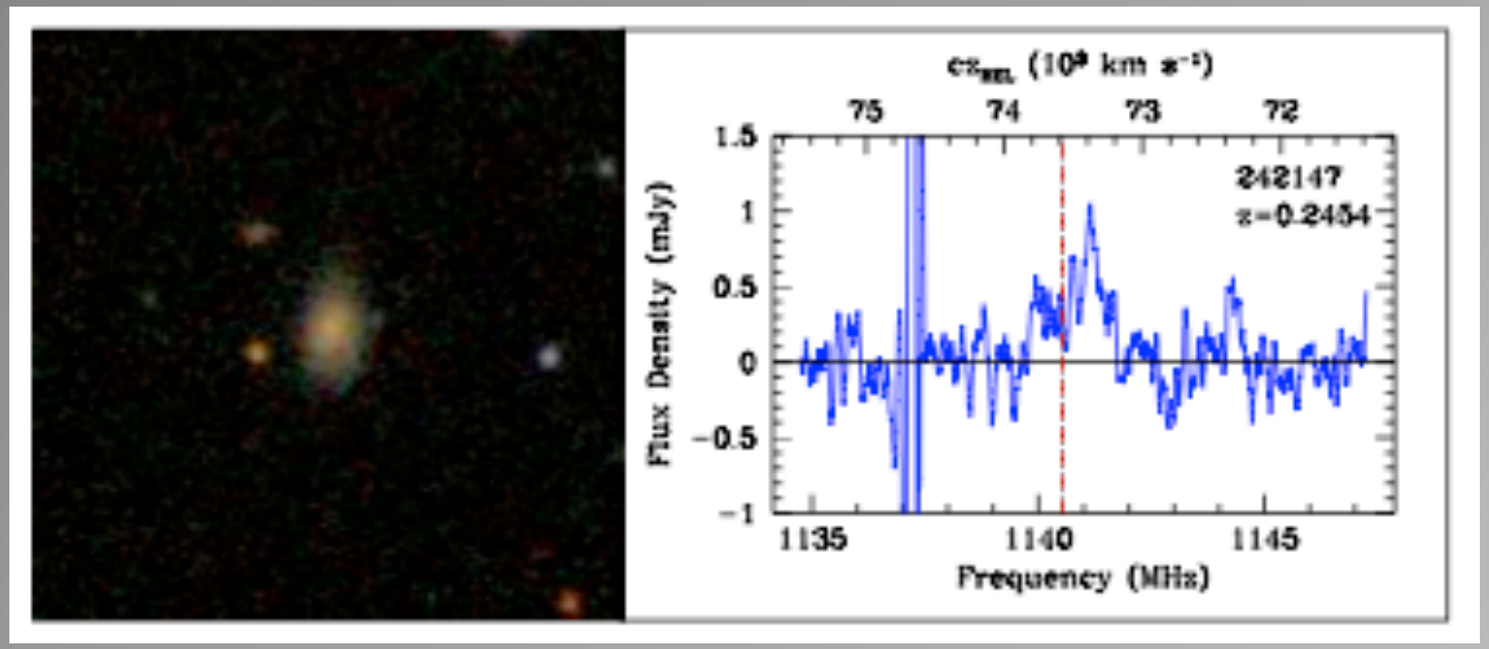
- Galaxies selected from SDSS according to z, presence of Hα line emission, inclination, disk morphology, and relative isolation
- observations completed in 2011
- 53 galaxies targeted, 0.16 < z < 0.26
- **on-source integration time of 1-5 hr per object; ~400 hr telescope time**

1 arcmin
~ 200 kpc @ z=0.2



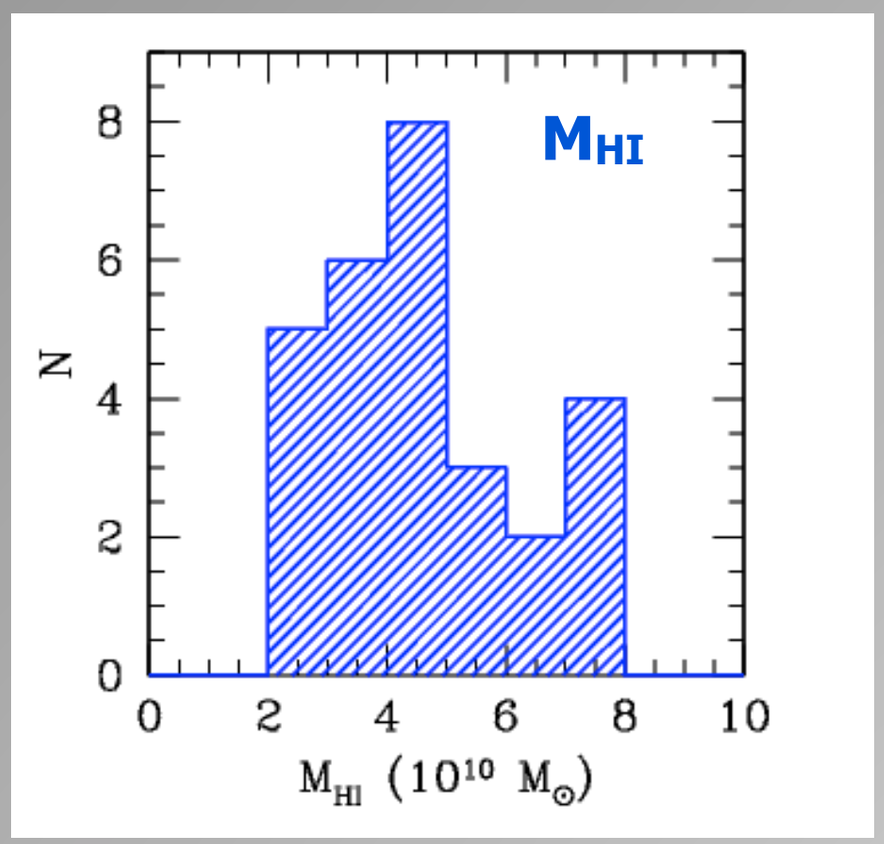
Catinella et al. 2008, ApJL

The very HI-rich Universe



Catinella et al. 2008, ApJL

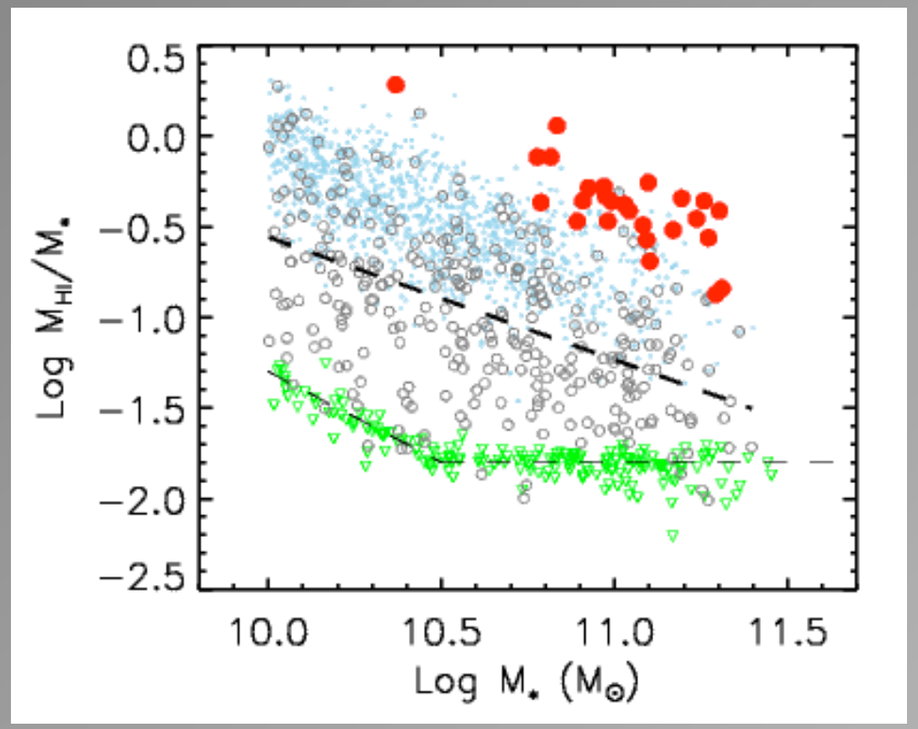
Highest z detection of HI emission from a galaxy to date (z=0.25)

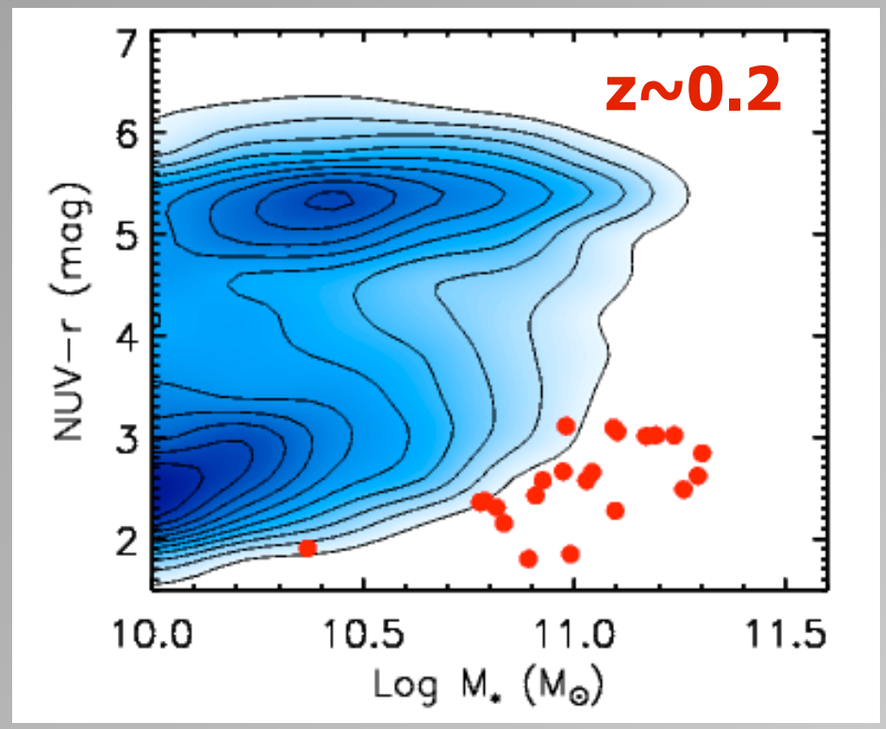


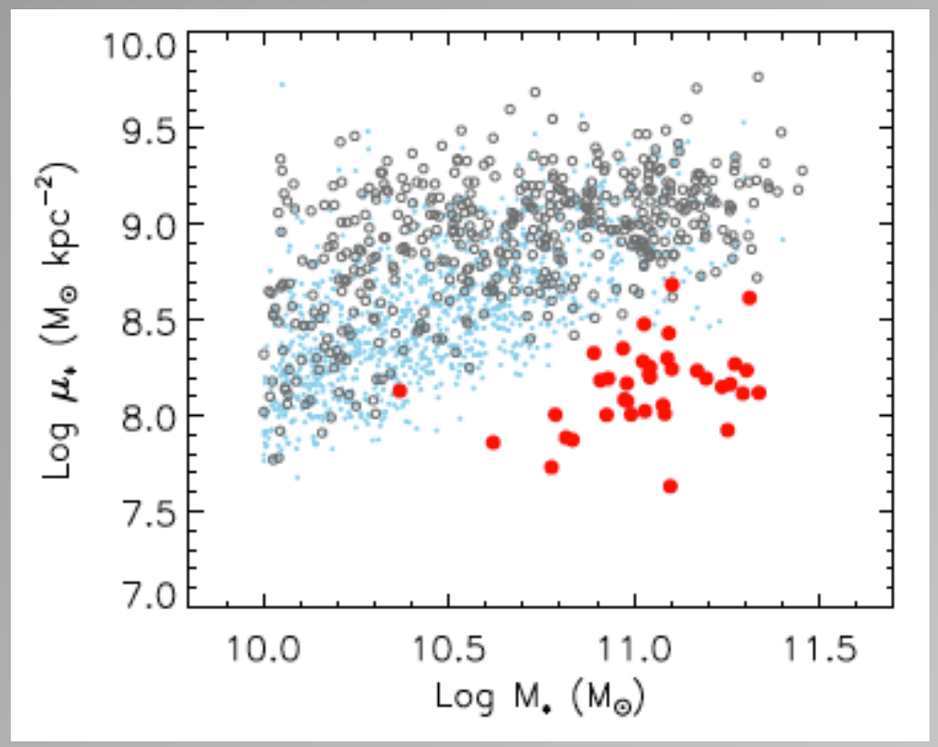
Among the most HI massive galaxies known

- 29 detections + ~10 marginal
- $0.16 < z < 0.26$
- HI mass $2 - 8 \times 10^{10}\ M_\odot$
- Stellar mass $> 10^{10}\ M_\odot$
- NUV-r < 3.5 mag (blue sequence)
- SFR = ~5-30 $M_\odot$/yr

What can we say about this population?





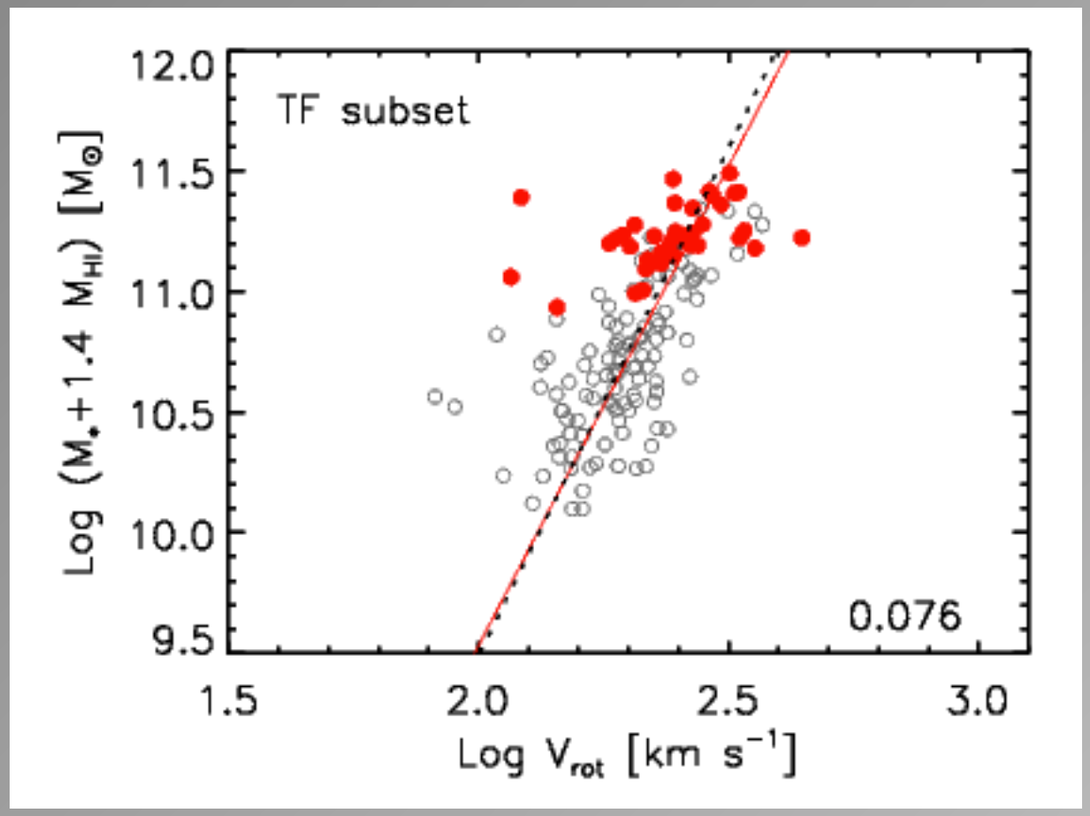


✦ unusually HI-rich and blue galaxies, rare at z=0 → by selection!

✦ low stellar mass surface densities typical of disks

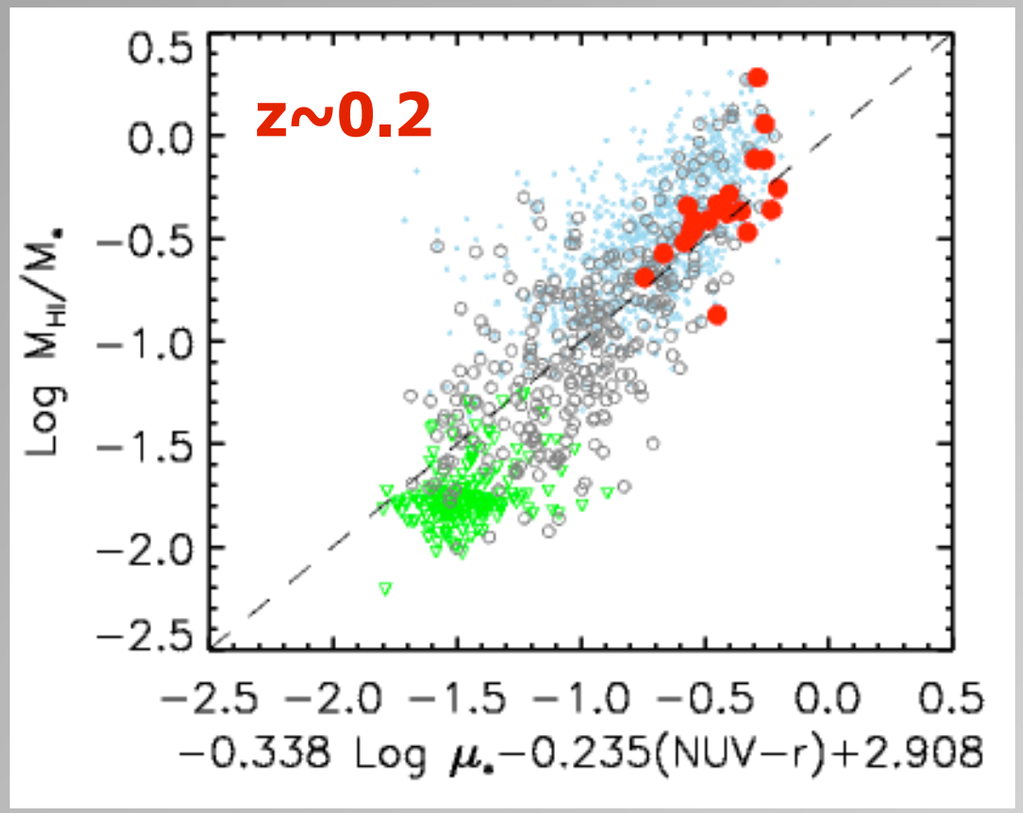
Catinella & Cortese (in prep.)

A unique sample of rare, very HI-rich galaxies



Baryonic Mass

Log Vrot



MHI/M*

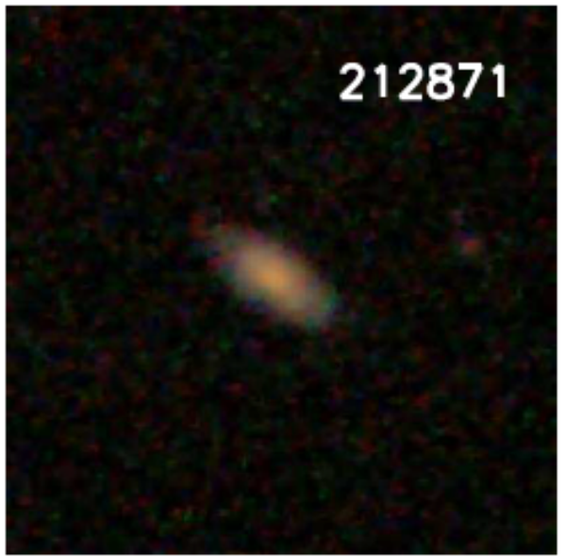
predicted M_{HI}/M_*

- ✦ HI masses are as expected from their stellar surface densities and NUV-r colors
- ✦ probe HI-star formation connection in unusually HI-rich regime
- ✦ these are the galaxies that SKA and its pathfinders will detect at higher z

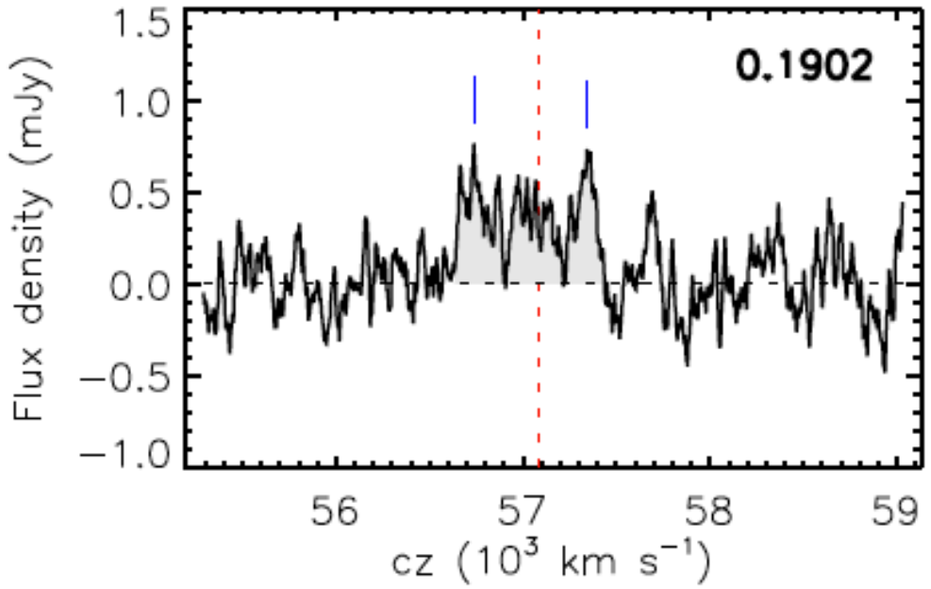
Catinella & Cortese (in prep.)

Atomic and molecular gas

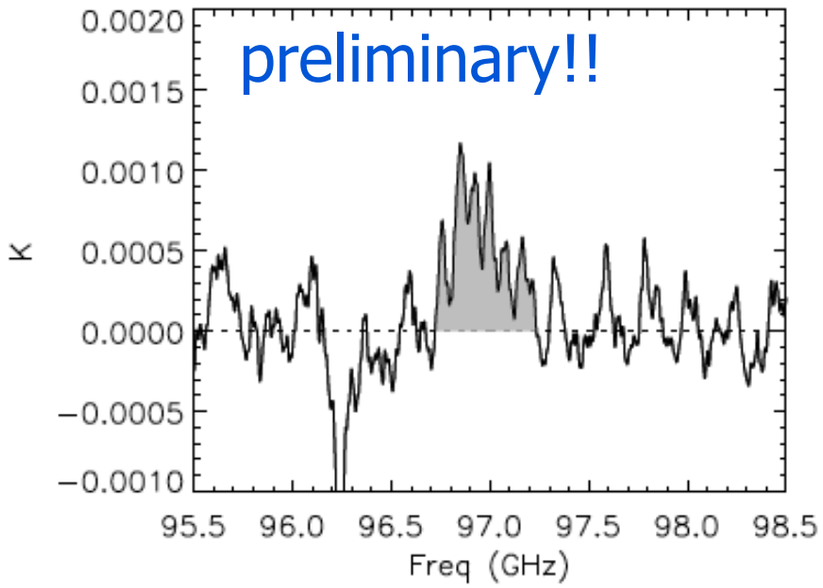
SDSS



Arecibo HI



IRAM CO(1-0)



Catinella & Cortese (in prep.)

Log Stellar mass = 11.27 $M_\odot$

Log HI mass = 10.7 $M_\odot$

Log H_2 mass ~ 10.2 $M_\odot$

SFR ~25 $M_\odot$/yr

ALMA and SKA precursor telescopes will study this population in detail in the next few years!!

Do all these galaxies host exceptionally large molecular gas reservoirs as well?

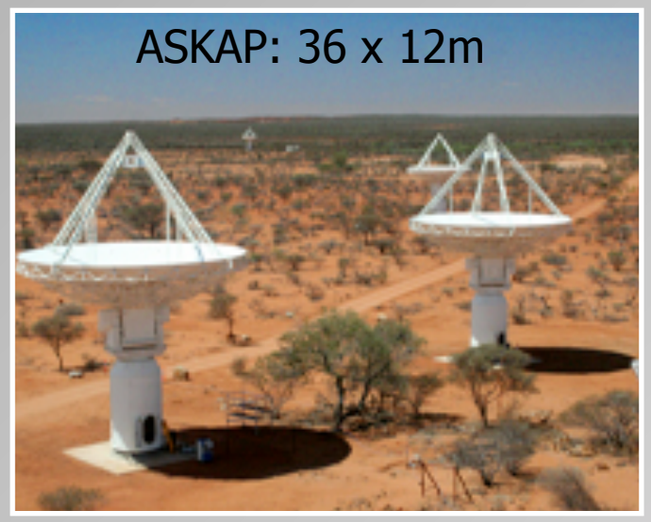
Outlook

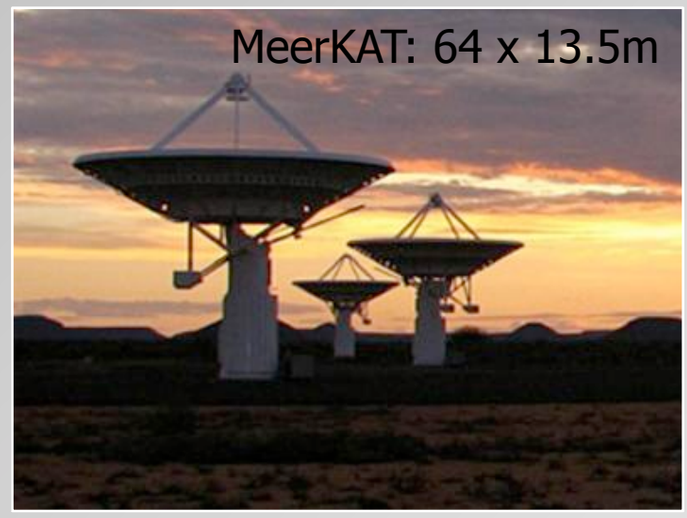
Effect of environment on gas: statistical studies

- Compare properties at fixed stellar mass, need to reach gas-poor regime
- Large-area, shallow surveys (e.g. WALLABY/WNSHS, ALFALFA) with stacking
- Deep surveys targeting range of environments also with detections

HI properties beyond z~0.1

- Deep surveys on small fields (e.g. DINGO, LADUMA)
- Glimpse of science to come from deep Arecibo observations





The Role of Hydrogen in the Evolution of Galaxies

September 15-19 2014, Kuching, Malaysia (Borneo)

http://astronomy.swin.edu.au/research/conferences/gas2014