HI Properties of Massive Galaxies

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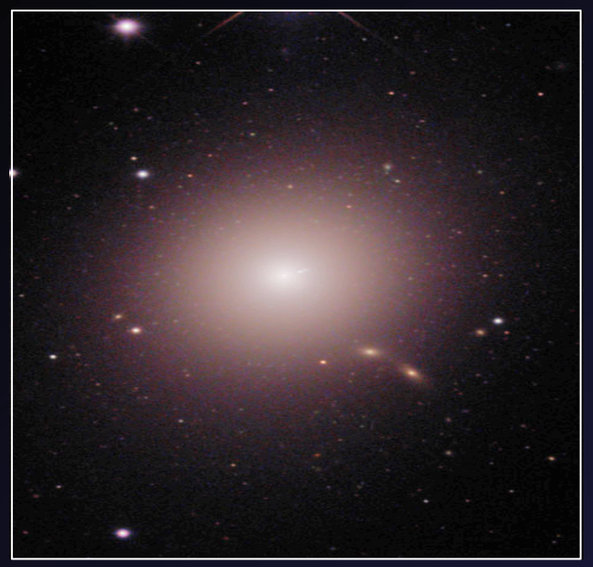
L. Cortese (ESO), A. Saintonge (MPE), R. Giovanelli, M. P. Haynes (Cornell),
T. Heckman, S. Moran (JHU) ...

TF35 Workshop, Green Bank, Apr 1 2012

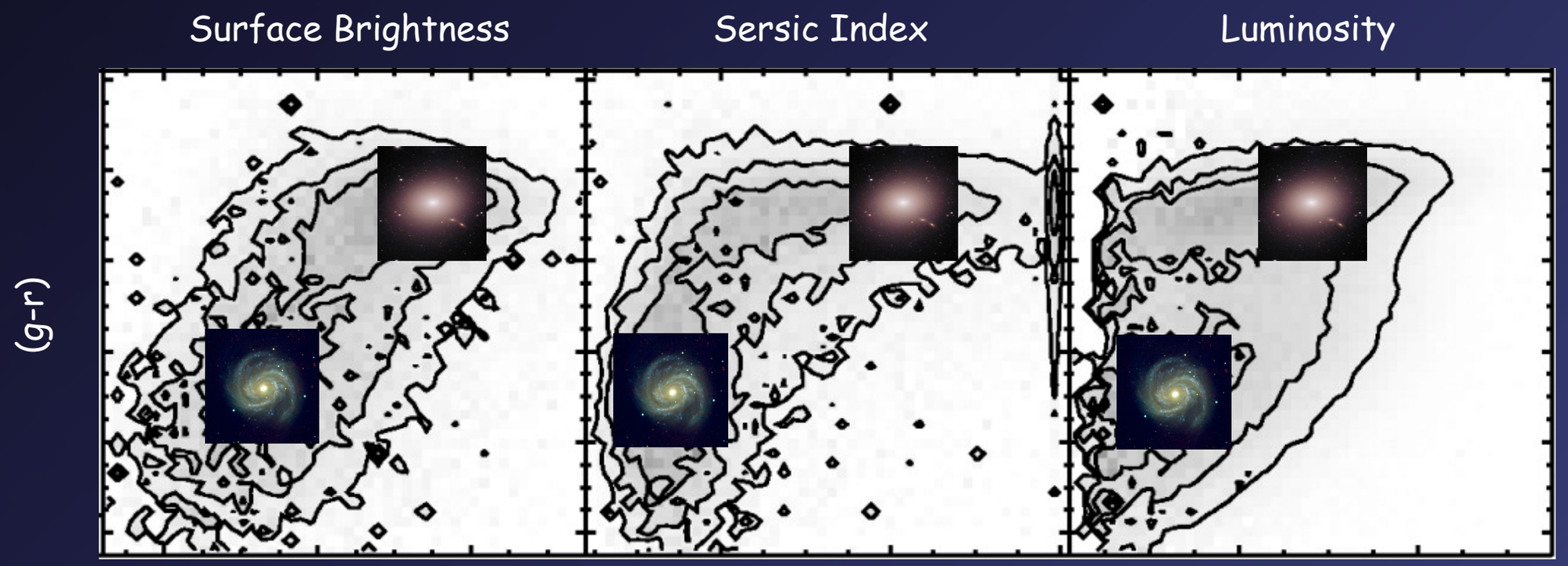
Galaxies: a Bimodal Population

Early-type galaxies



colors from red to blue
bulge-to-disk ratio decreases
star formation activity increases
stellar population age decreases

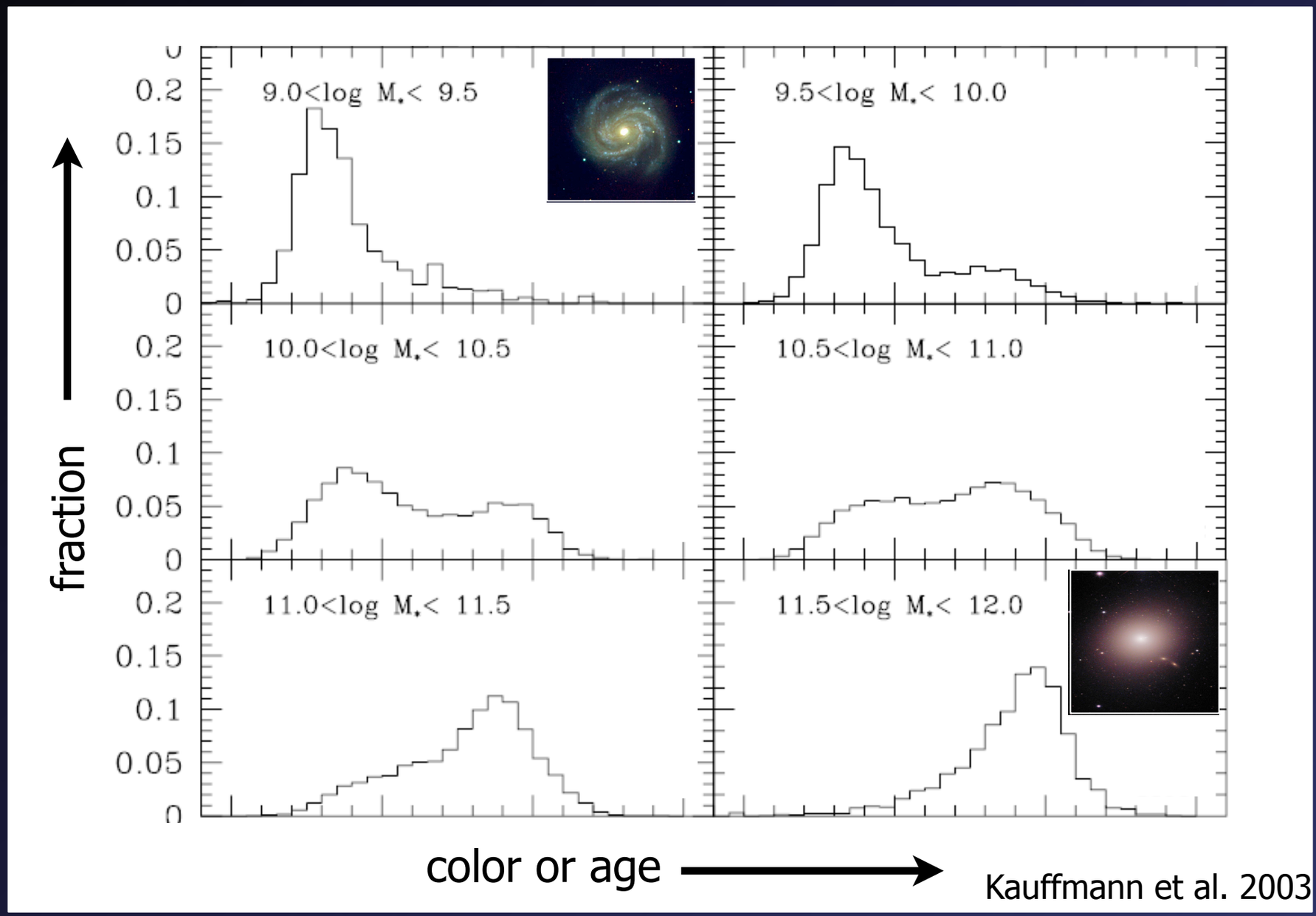
Late-type galaxies



Adapted from Blanton et al. 2005

Transition between blue and red sequence

blue, SF galaxies



Kauffmann et al. 2003

"red and dead" galaxies

- Transition mass at ~3 10^{10} $M_\odot$ (e.g. Strateva et al 01, Kauffmann et al 03, Baldry et al 04)
- Transition implies quenching of SF. The mechanism(s) involved must affect the HI gas
  → need to measure HI for large, representative sample of massive galaxies

GASS: The GALEX Arecibo SDSS Survey

P.I.: D. Schiminovich (Columbia)

- Targeted HI survey: ~**1000 galaxies** in SDSS+GALEX MIS+ALFALFA footprints, **selected only by redshift and stellar mass**:

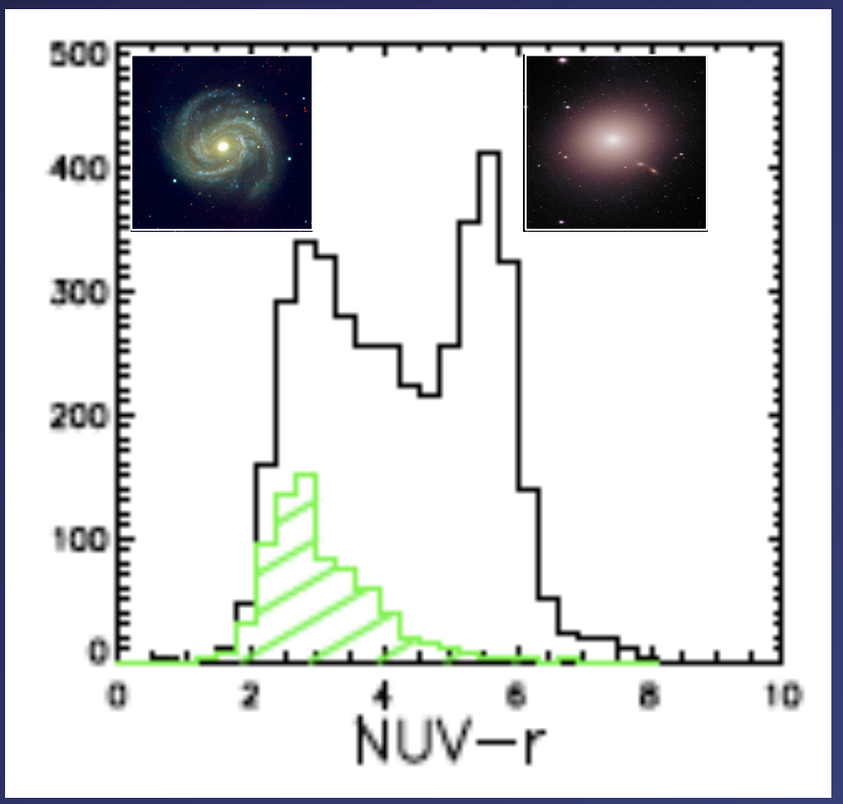
  $0.025 < z < 0.05$, $10 < \log M_\star/M_\odot < 11.5$

  Galaxies observed down to gas mass fraction limit of 1.5-5%

- First statistical sample of massive galaxies with homogeneously measured $M_\star$, SFR and gas properties

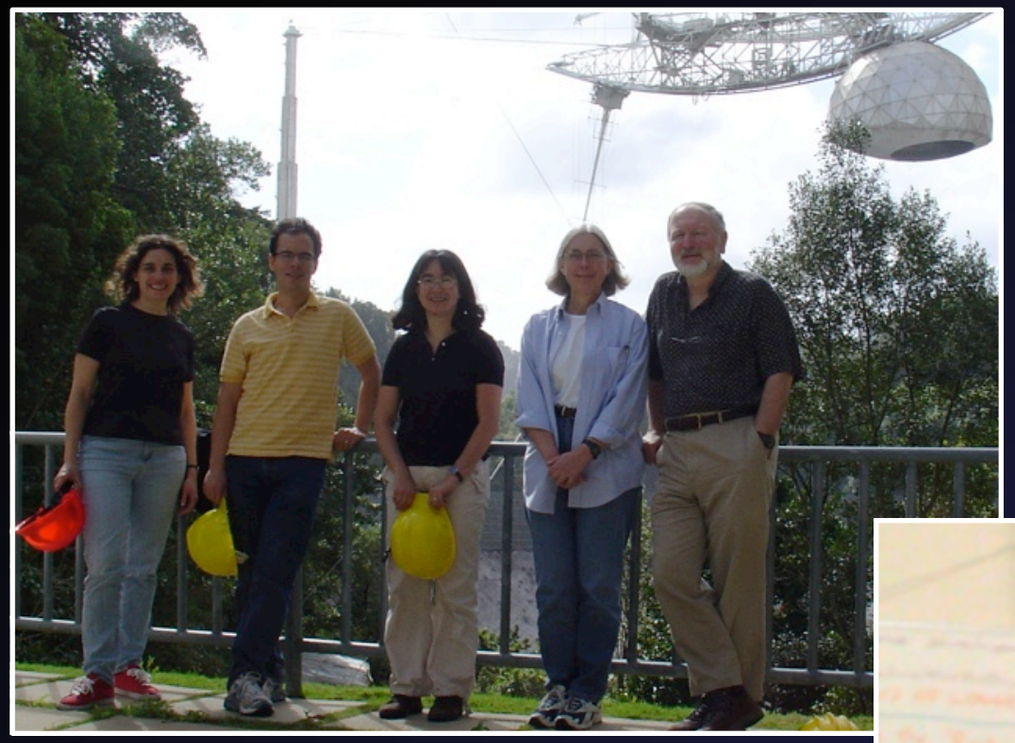
- Arecibo large program, started in March 2008.
  DR1: ~20% of survey (Catinella et al. 2010)
  DR2: ~50% of survey (Catinella et al., A&A subm)
  70% of survey completed

- ALFALFA detects ~20% (HI-richest objects)
  → NOT re-observed by GASS



Green: ALFALFA detections of GASS galaxies

GASS Team



BC, D. Schiminovich,
G. Kauffmann, M. Haynes,
R. Giovanelli

+ Jing Wang, Andrew Cooper
et al.

Barbara Catinella

Sean Moran

Arecibo control room

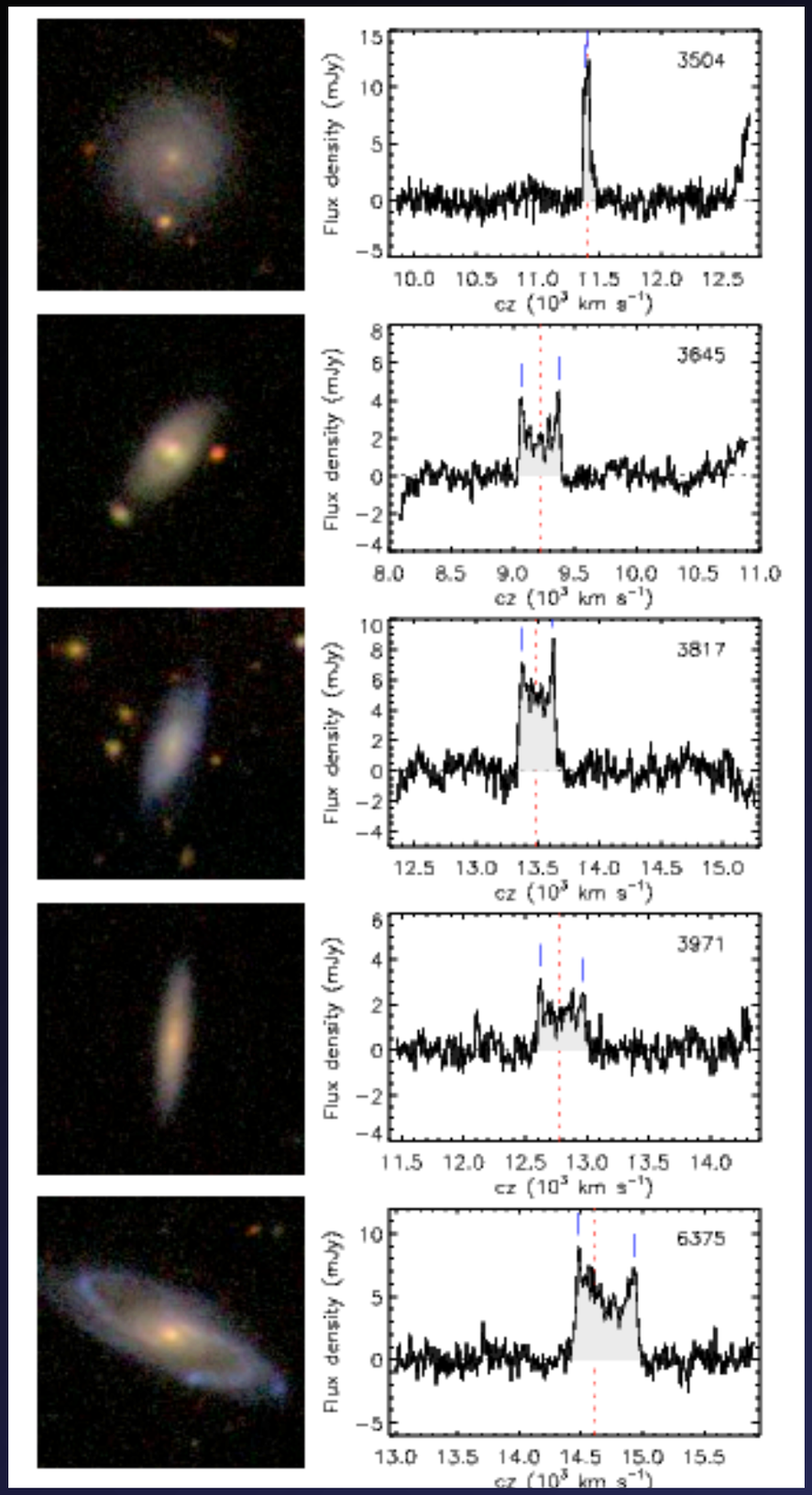
Silvia Fabello

Ronin Wu

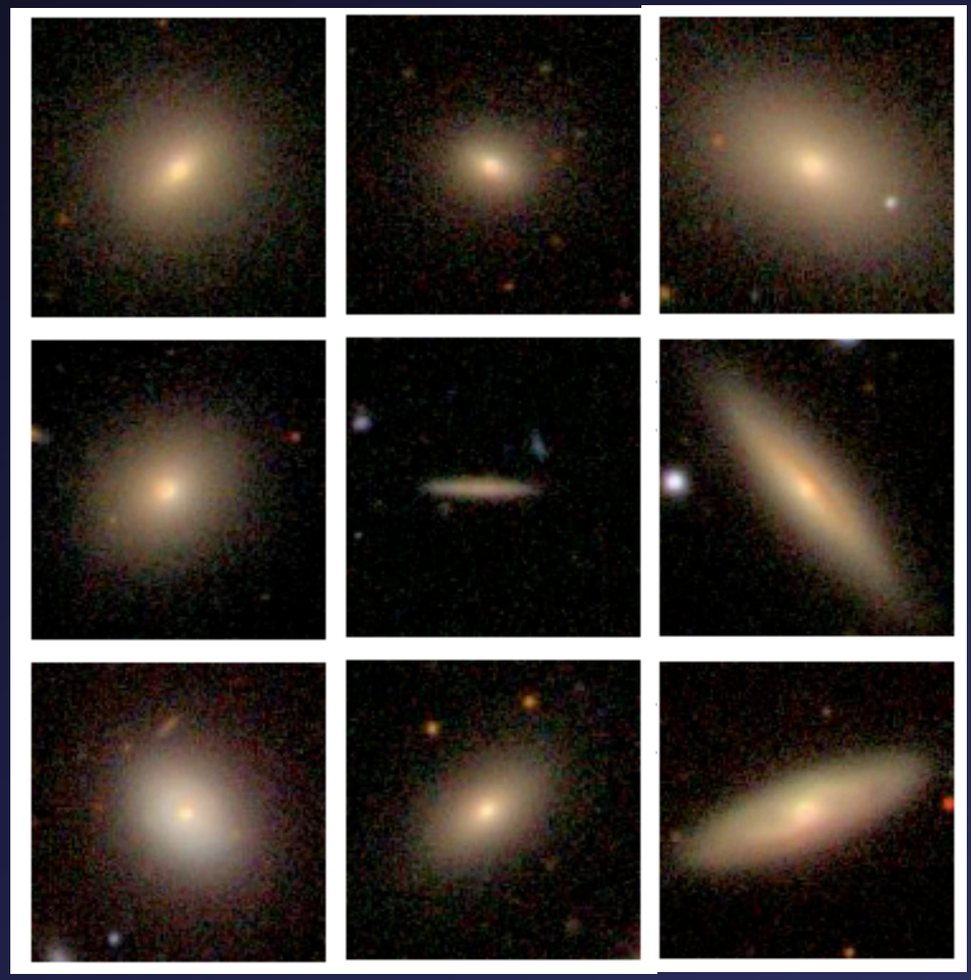
Jenna Lemonias

Cameron Hummels

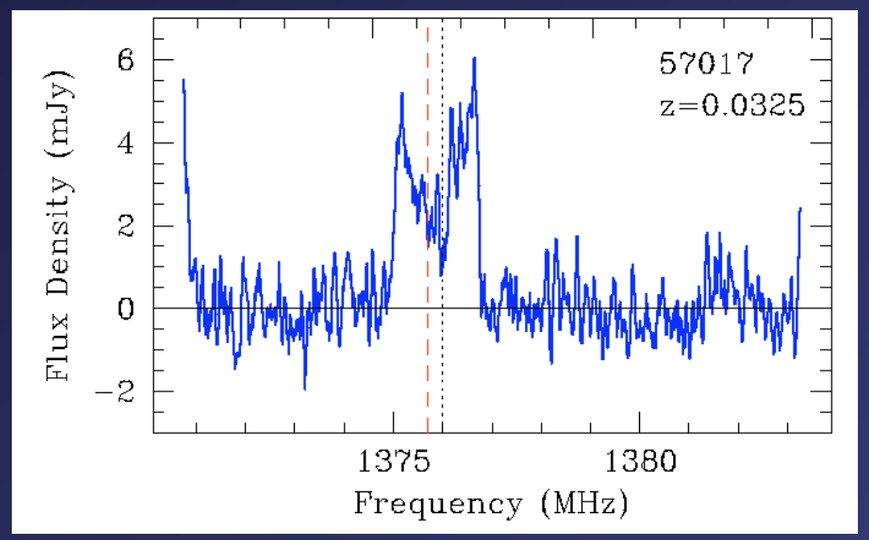
Detections



Non-detections



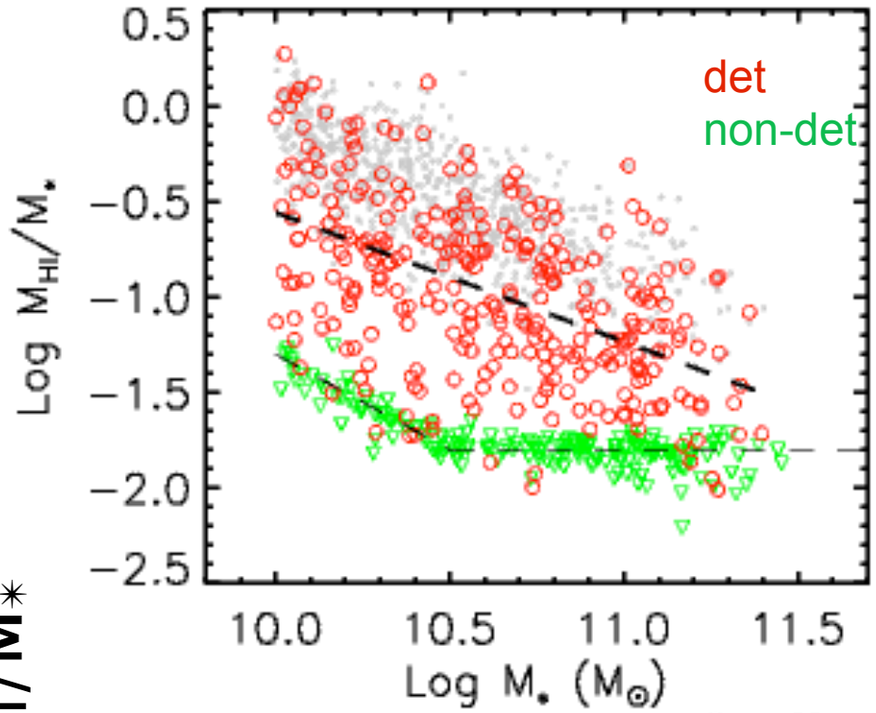
SDSS images: 1‘ (~30 kpc @ z=0.025)



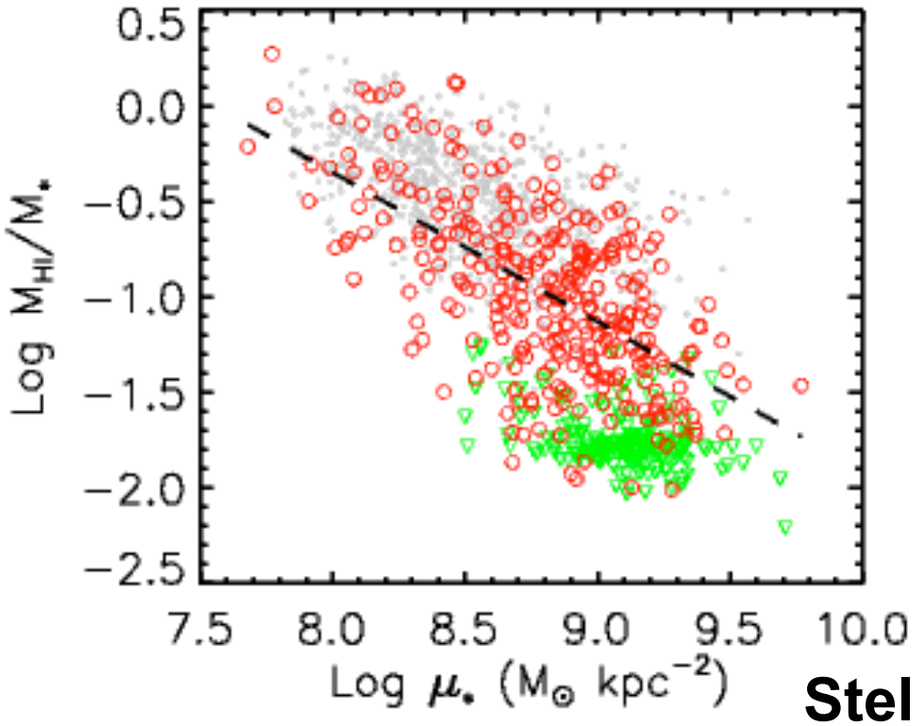
Single-dish HI profiles (beam ~4’): z, V_{rot}, HI flux

Gas Fraction Scaling Relations

DR2 gas fraction scaling relations



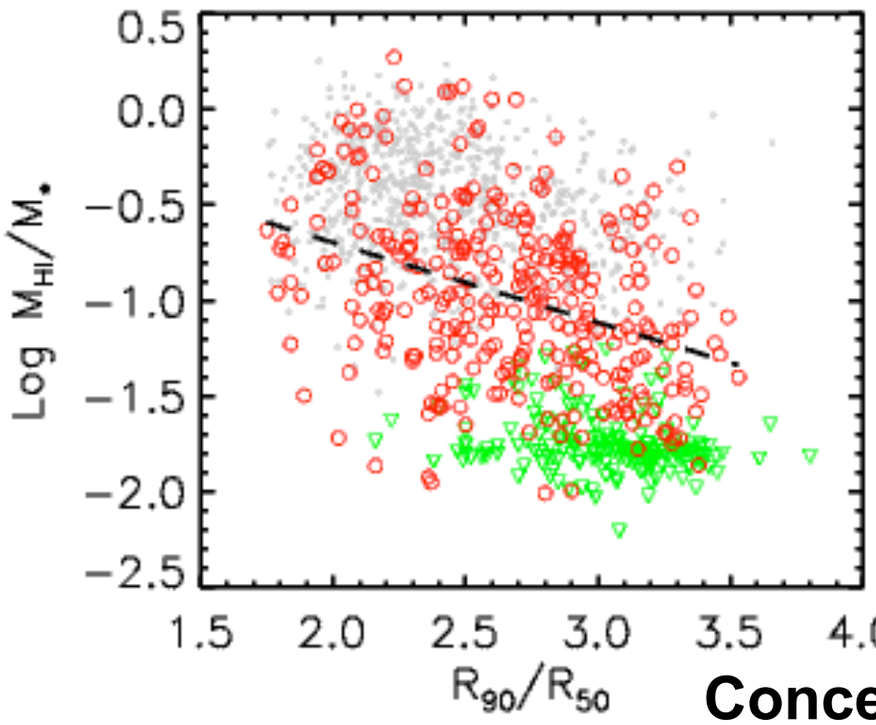
Stellar Mass



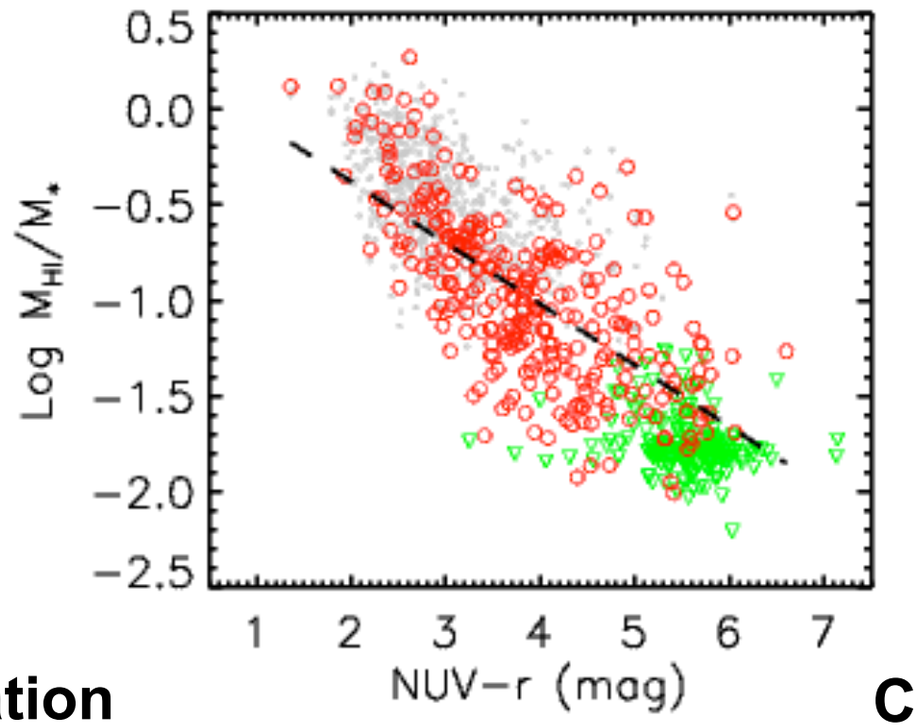
Stellar Mass Surface Density, $M_*/2\pi R_{50}^2$

Gray: ALFALFA

Transition seen with μ_*, not M_*



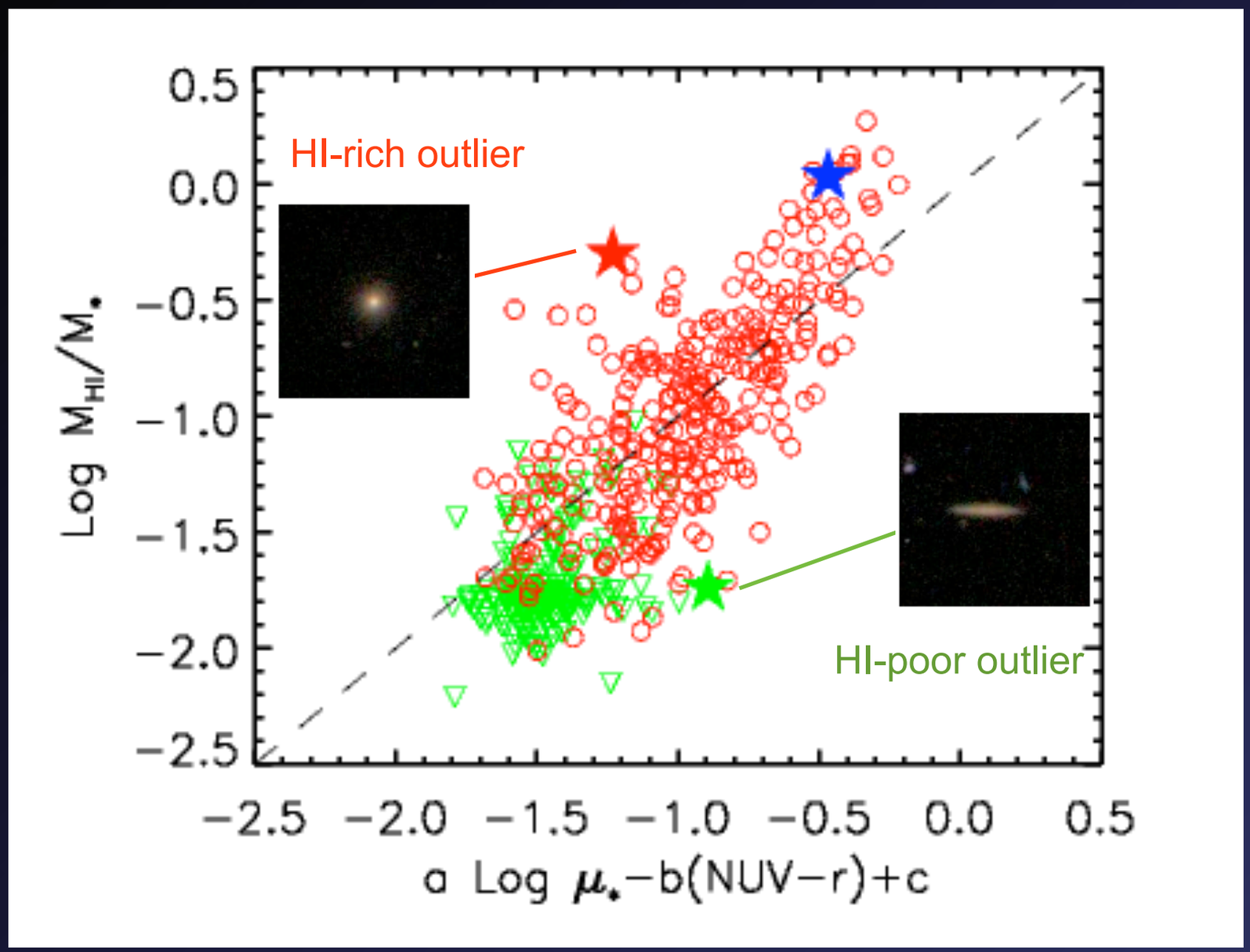
Concentration



Color

Catinella, Schiminovich, Kauffmann et al. 2010 & 2012 (A&A subm)

DR2 HI gas fraction plane

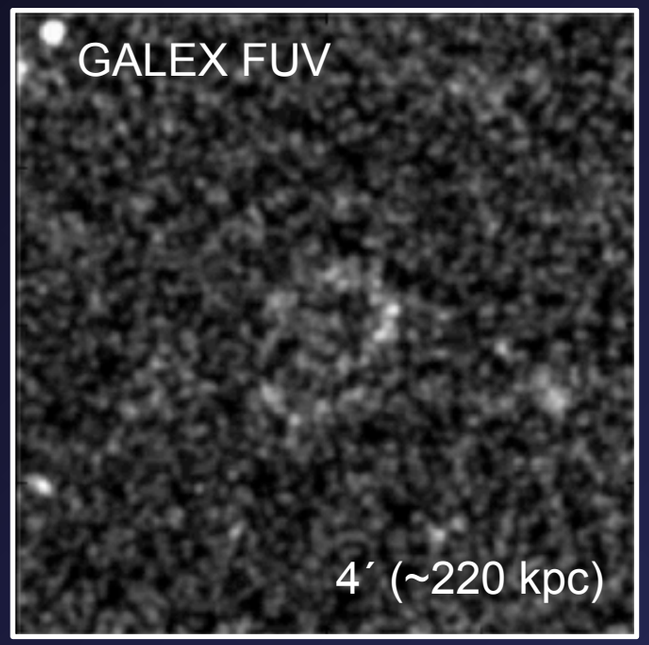


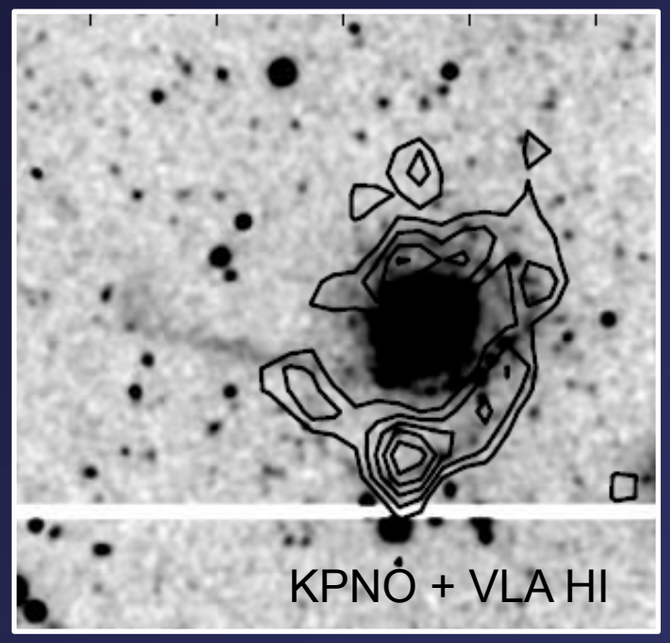
Transition galaxies: anomalous gas content given their optical/NUV colors and μ_*

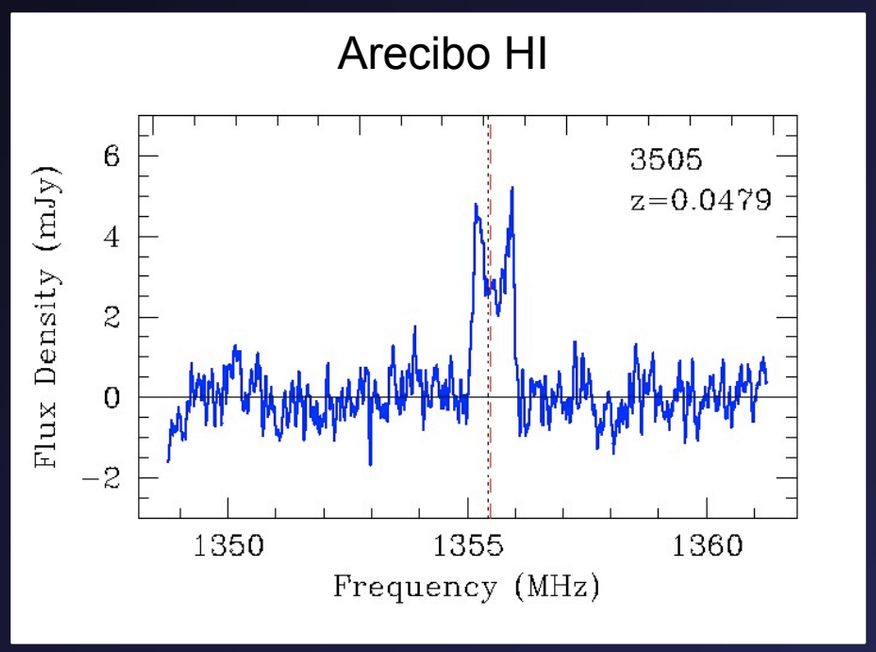
Catinella et al. 2010 & 2012 (A&A subm)

$$\Sigma_{\rm SFR} \propto \Sigma_{\rm gas}^{n} \quad \Rightarrow \quad {\rm SFR}/M_* \propto (M_{\rm gas}/M_*)^n \mu_*^{n-1}$$

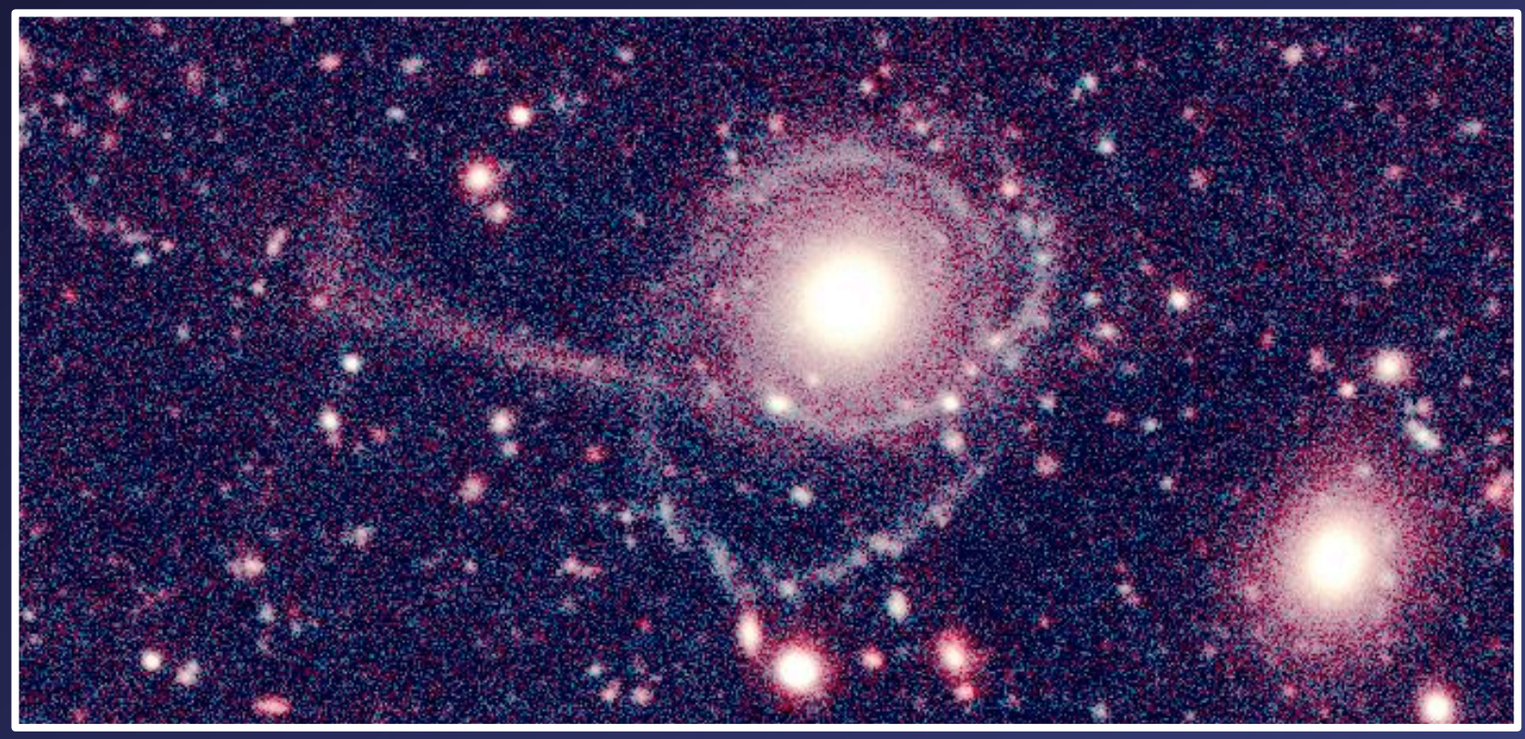
GASS 3505: a gas-rich, "red and dead" galaxy





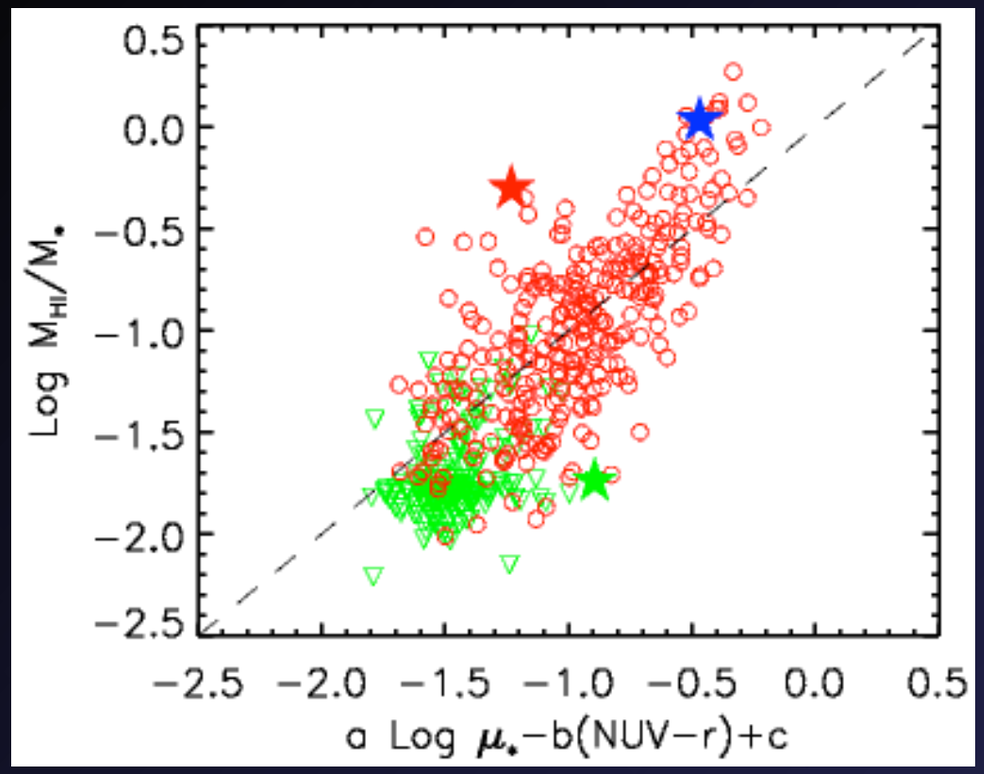


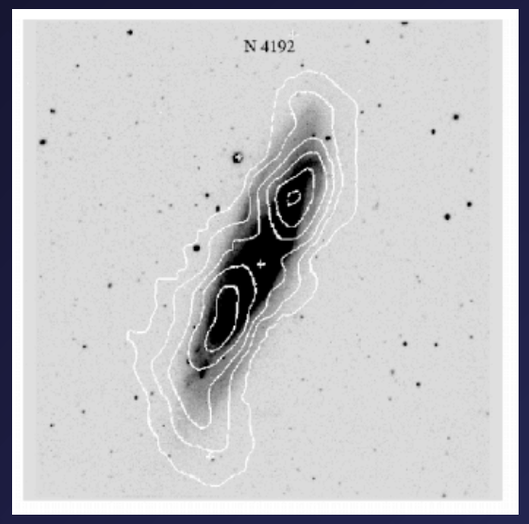
$\log M_{HI}/M_{\odot}=9.91$ $M_{HI}/M_{\star}=50\%$

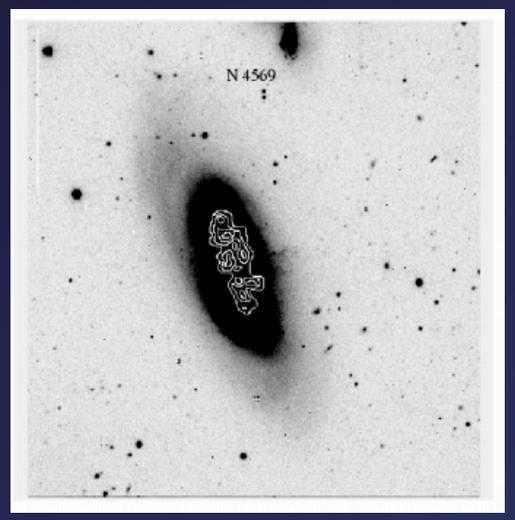


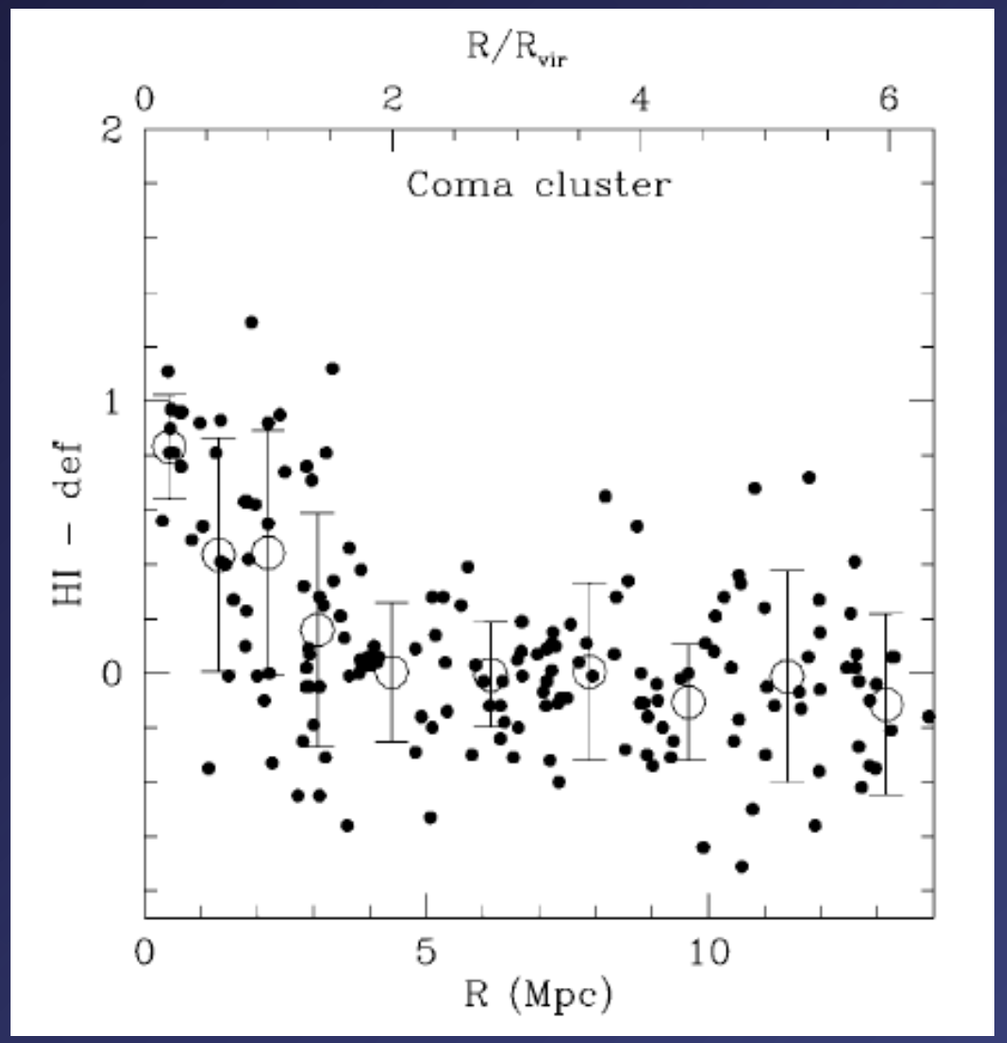
MMT g and r-band imaging (S. Moran)

Gas fraction plane and HI deficiency









HI deficiency (Haynes & Giovanelli 1984, Solanes et al. 1996...)

HIdef = Log <M(HI, D_{opt},Type)> - Log $M(HI)_{obs}$

HIdef = 1 $\Rightarrow$ $M(HI)_{obs}$= 0.1 x $M(HI)_{expected}$

Boselli & Gavazzi (2006)

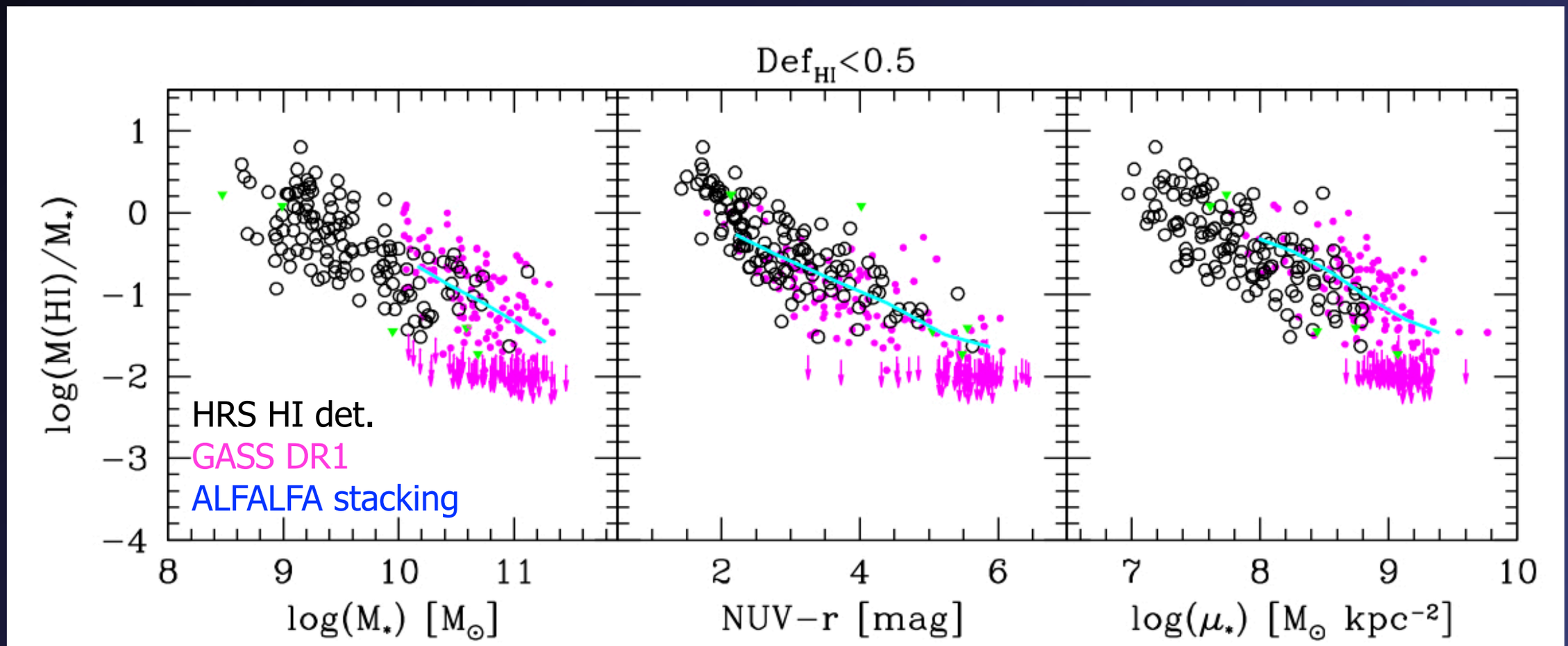
HRS HI scaling relations

Herschel Reference Survey (Boselli et al 2010)

322 galaxies (62 E/SO, 260 Sp./Irr)

Volume/Stellar Mass limited - From isolated to cluster galaxies

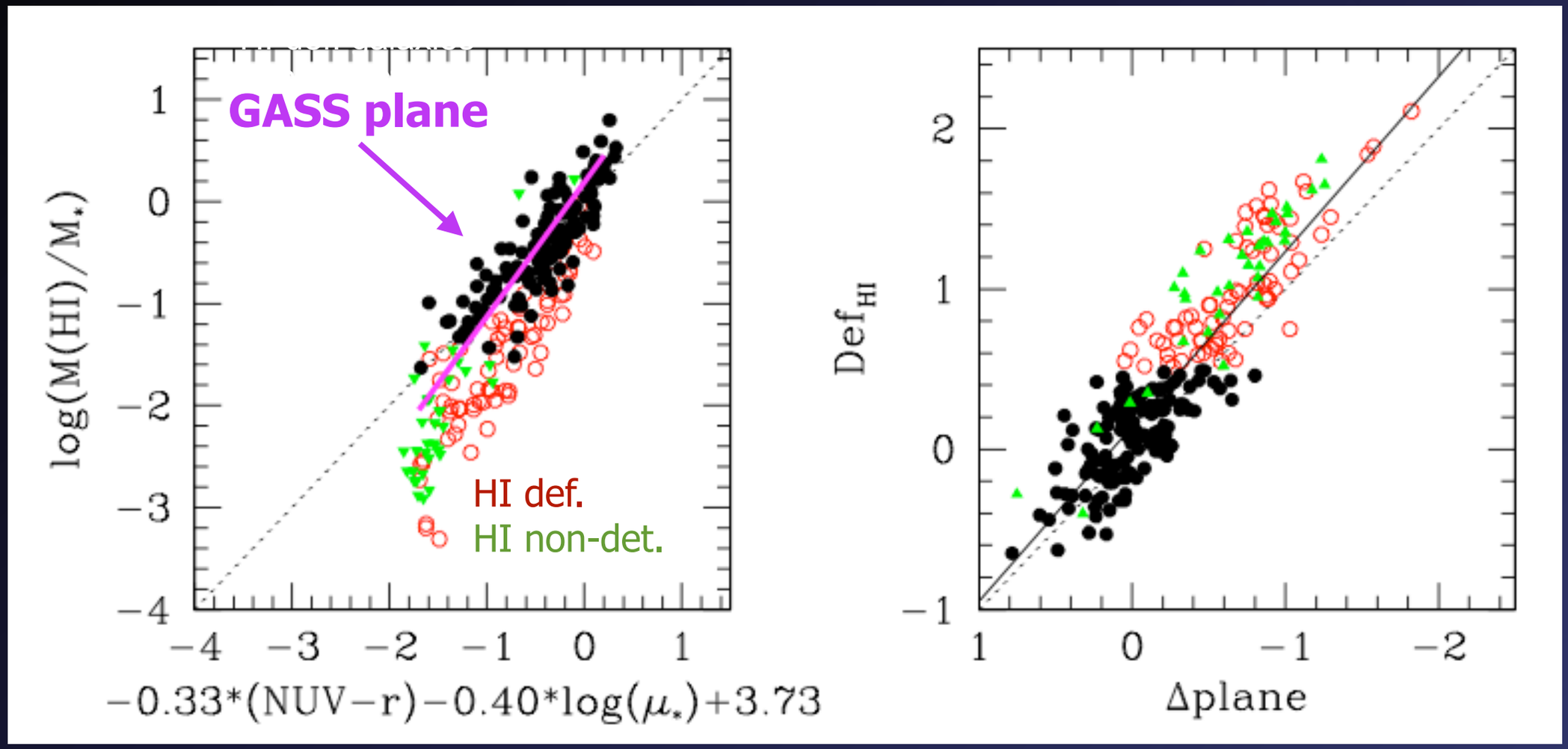
Nicely extend GASS scaling relations to lower $M_\star$ and $\mu_\star$



Cortese, Catinella et al. 2011

HI gas fraction plane and HI deficiency

HRS plane for HI-normal galaxies



Cortese, Catinella et al. 2011

Strong correlation between HI deficiency and distance from the gas fraction plane → the two approaches are consistent

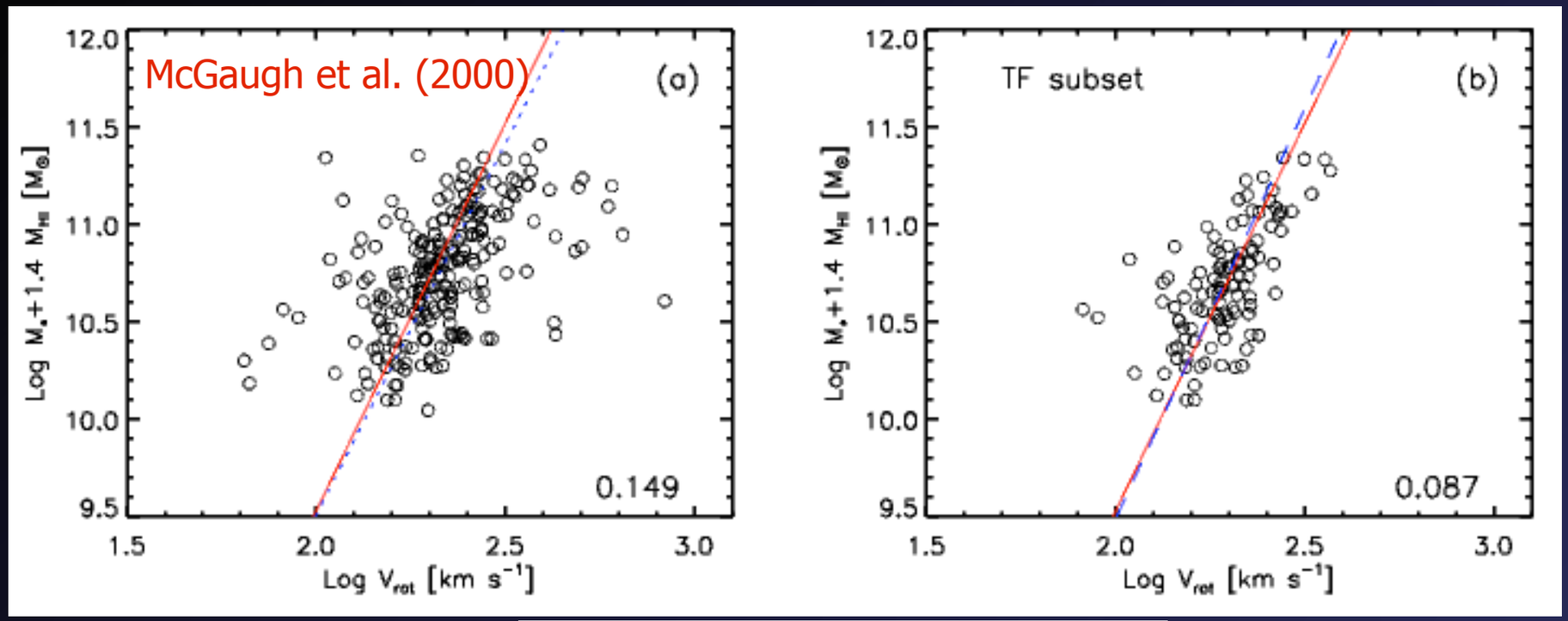
Dynamical scaling relations

Tully-Fisher (1977) relation:
- luminosity vs. rotational velocity
- inclined spirals

Faber-Jackson (1976) relation:
- luminosity vs. stellar velocity dispersion
- elliptical galaxies

* distance indicators
* constrain galaxy formation and evolution models & simulations

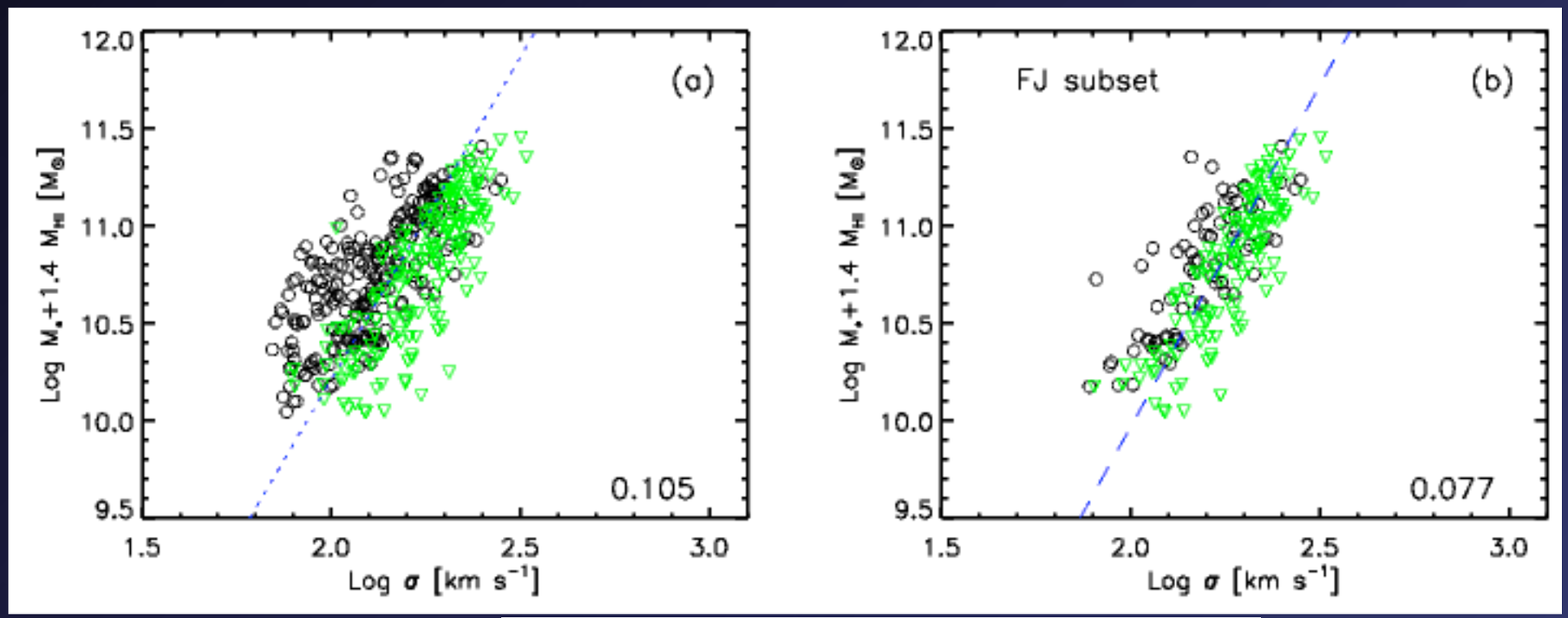
Baryonic Tully-Fisher and Faber-Jackson relations



GASS DR2, N=480
(~300 detections)

BARYONIC MASS

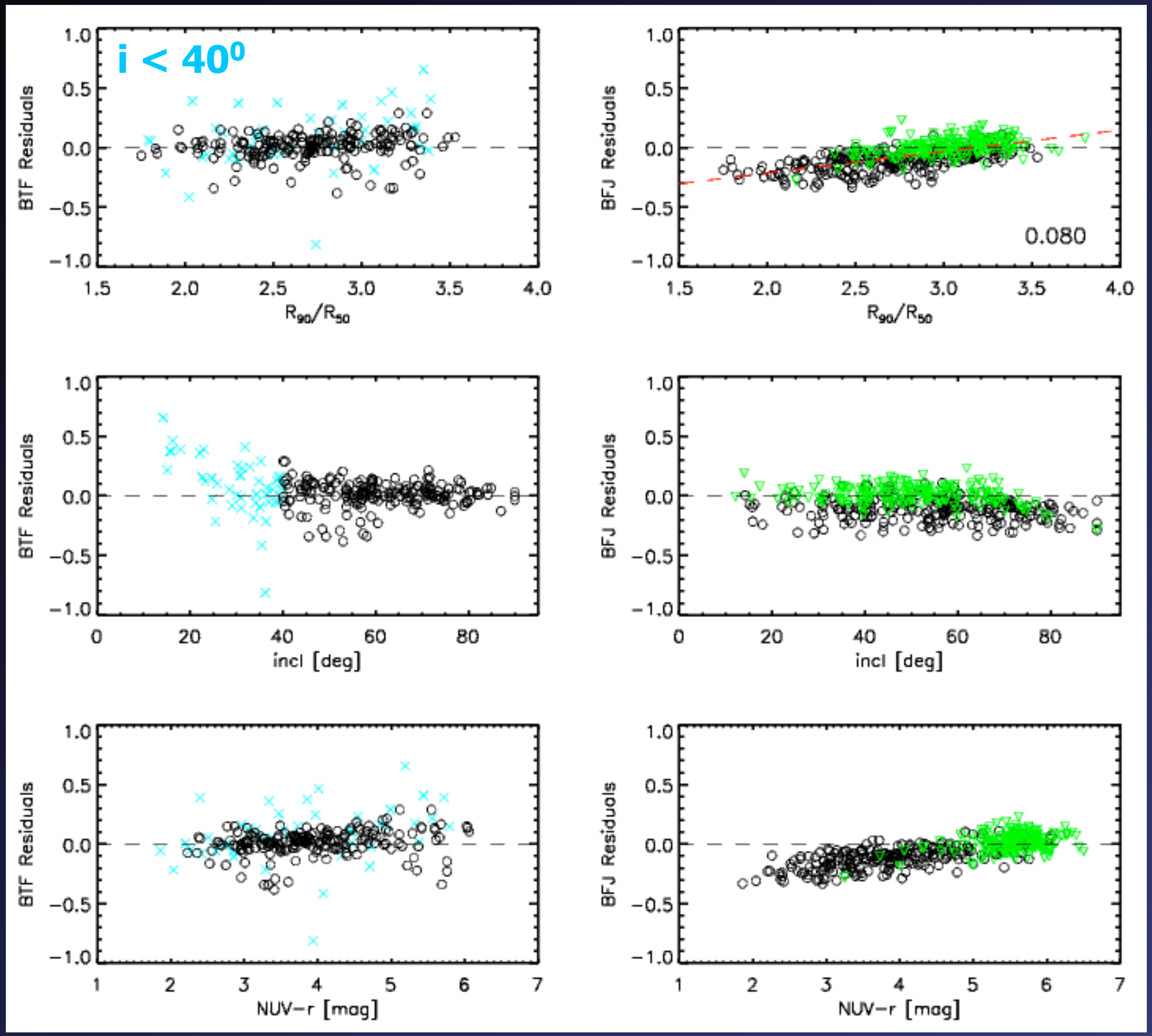
HI ROTATIONAL VELOCITY



STELLAR VELOCITY DISPERSION

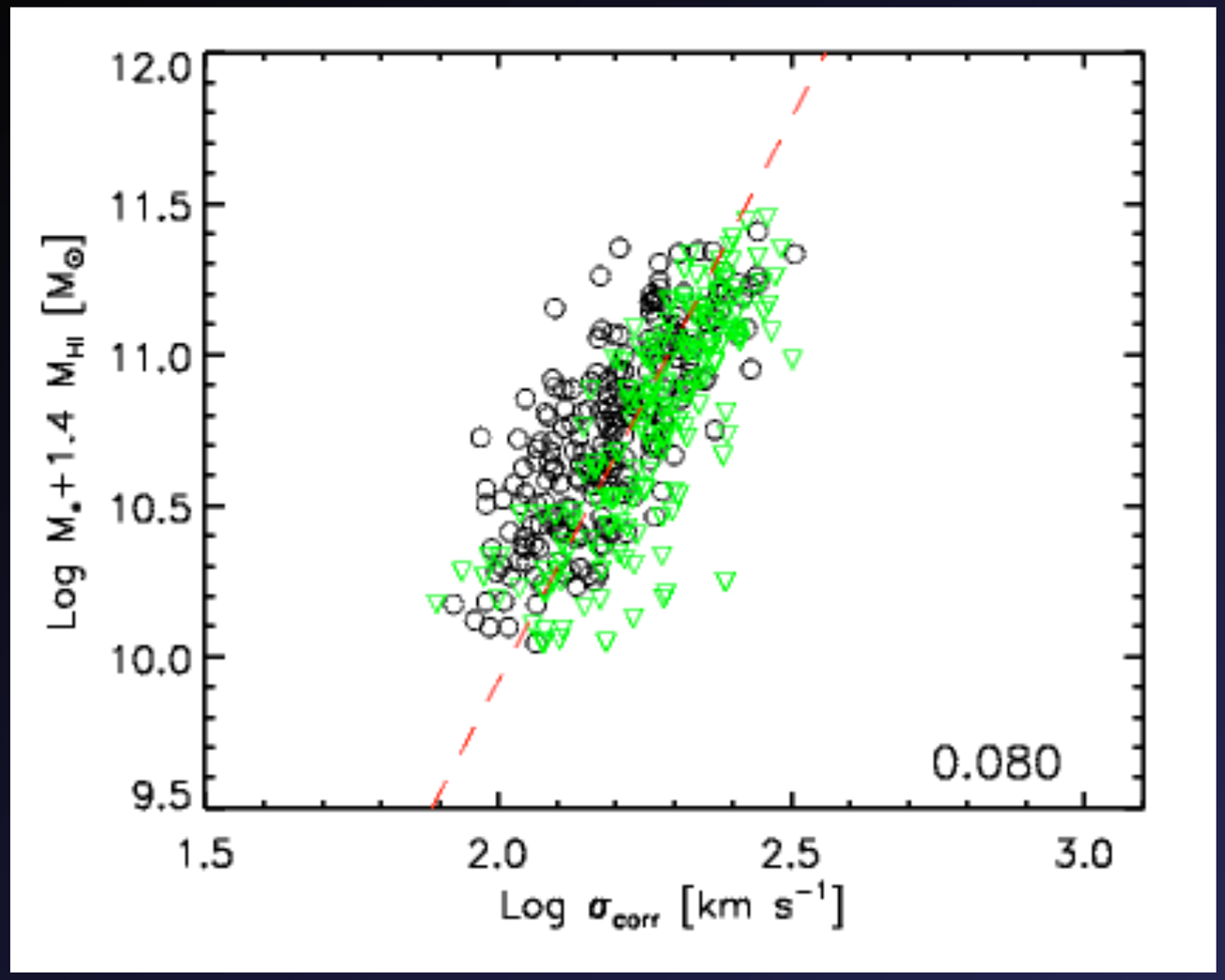
Catinella, Kauffmann et al. 2012

Baryonic TF and FJ Residuals



Baryonic FJ corrected for dependency on R_{90}/R_{50}

BARYONIC MASS



CORRECTED STELLAR VELOCITY DISPERSION

Catinella, Kauffmann et al. 2012

No sample pruning!

No morphological selection, no inclination cuts

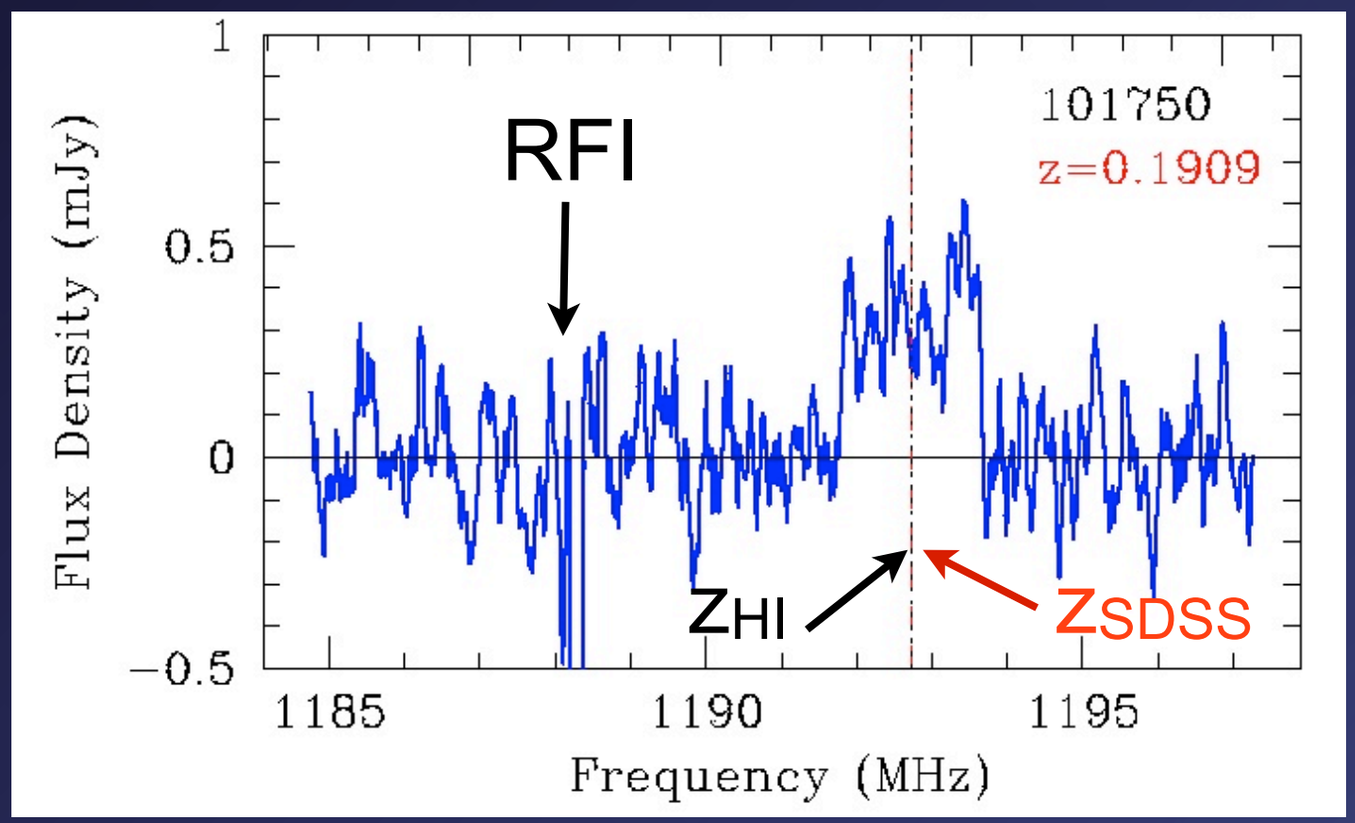
- applicable to large samples
- less affected by systematics than TF, FJ -- interesting for evolution of scaling relations
- comparison with models

GASS Scaling Relations: Reference for Higher-z Studies

Comparison with HI observations of SDSS-selected galaxies at z~0.2

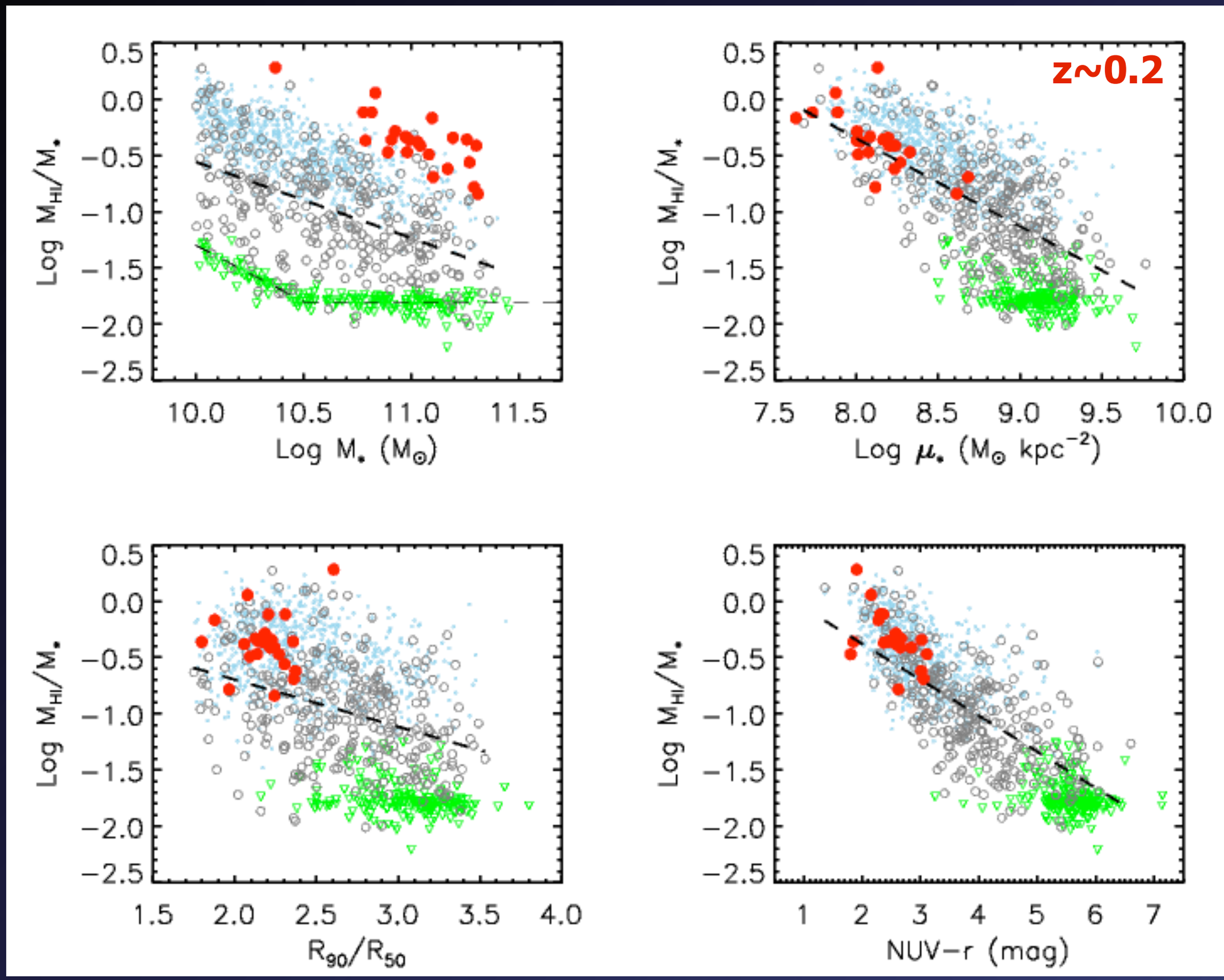
- Observations completed in 2011
- 53 galaxies targeted, 0.16 < z < 0.26
- 29 detections, ~10 marginal
- HI mass $2 - 8 \times 10^{10}\ M_{\odot}$
- on-source integration time of 1-5 hrs per object

1 arcmin
~ 200 kpc @ z=0.2



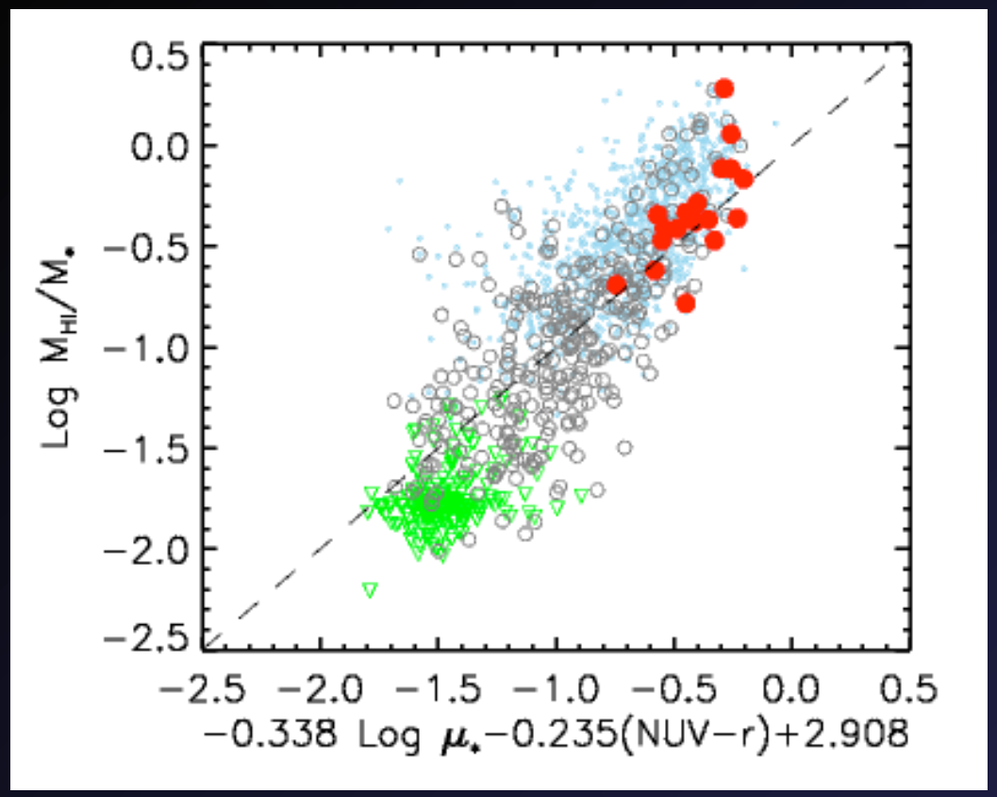
Catinella, Haynes, Giovanelli et al. 2008, ApJL

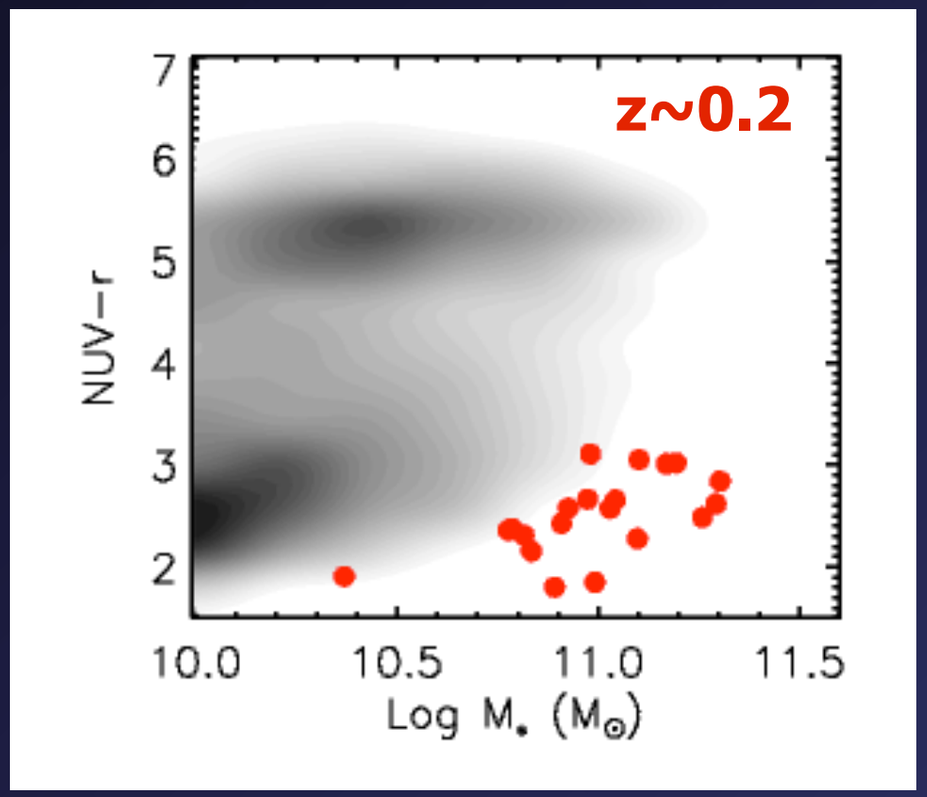
Comparison with GASS DR2 scaling relations

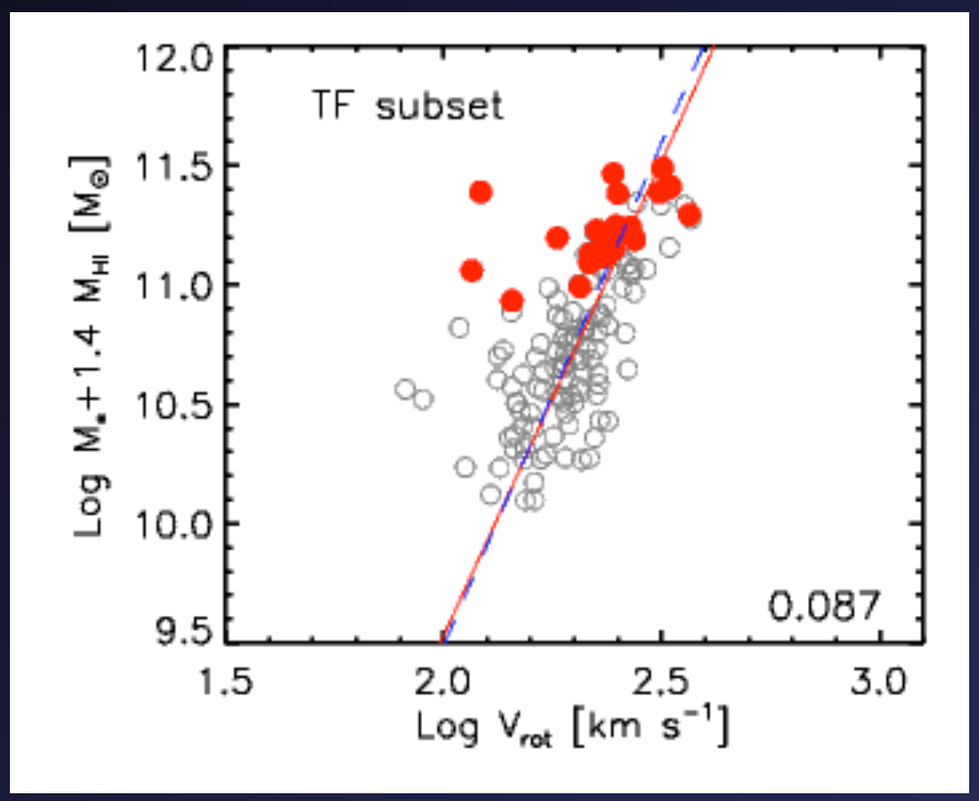


Catinella et al. (in prep.)

Comparison with GASS gas fraction plane and BTFR



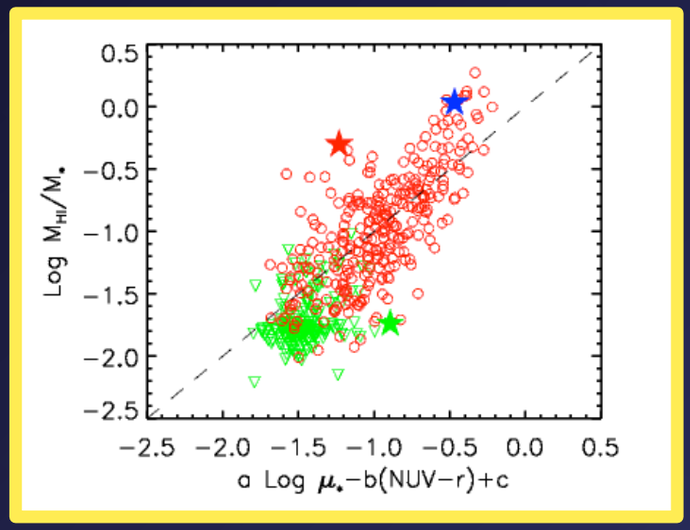




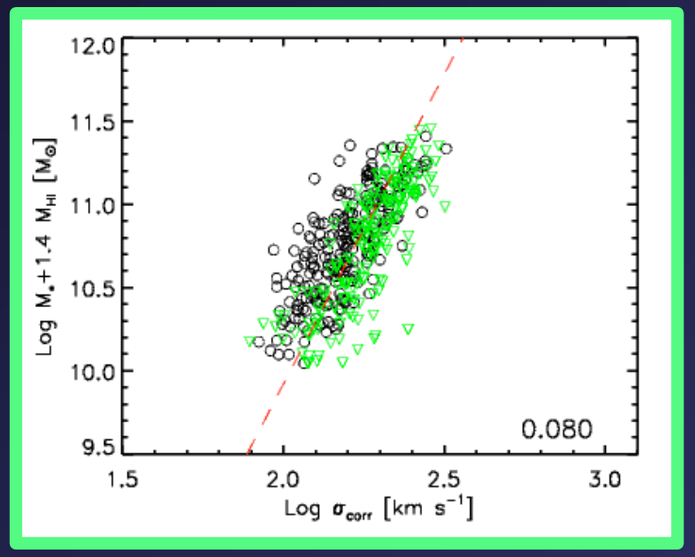
- rare galaxies (regardless of HI content)
- include the most HI-rich galaxies known
- highest-z HI detections
- “normal” SF properties for their HI content
- prototype of galaxies that will be detected in large numbers by SKA and its pathfinders

SUMMARY

- GASS is the first study to specifically target a sample that is homogeneously selected by stellar mass (10< log $M_\star/M_\odot$ <11.5).

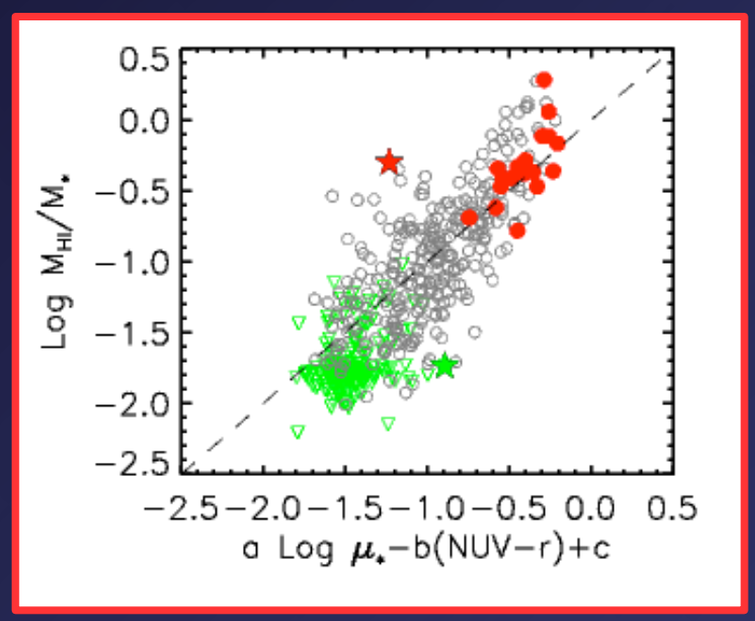


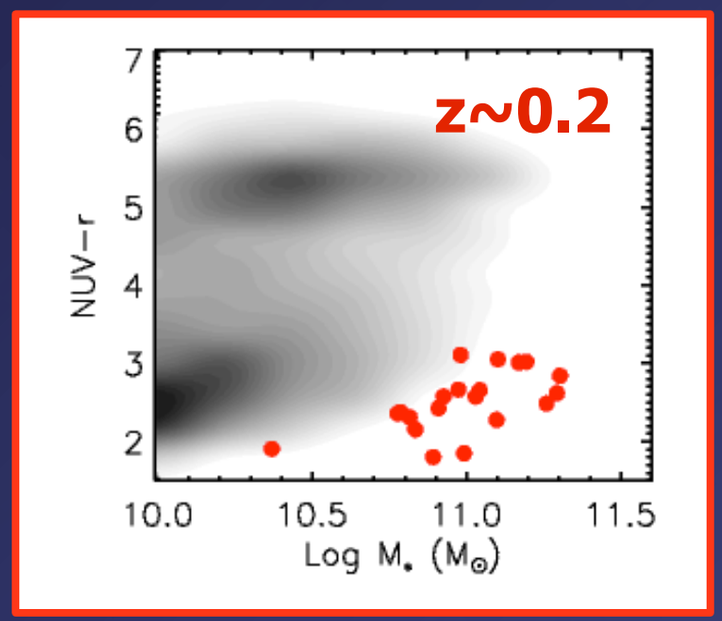
- HI gas fraction scaling relations



- Dynamical scaling relations

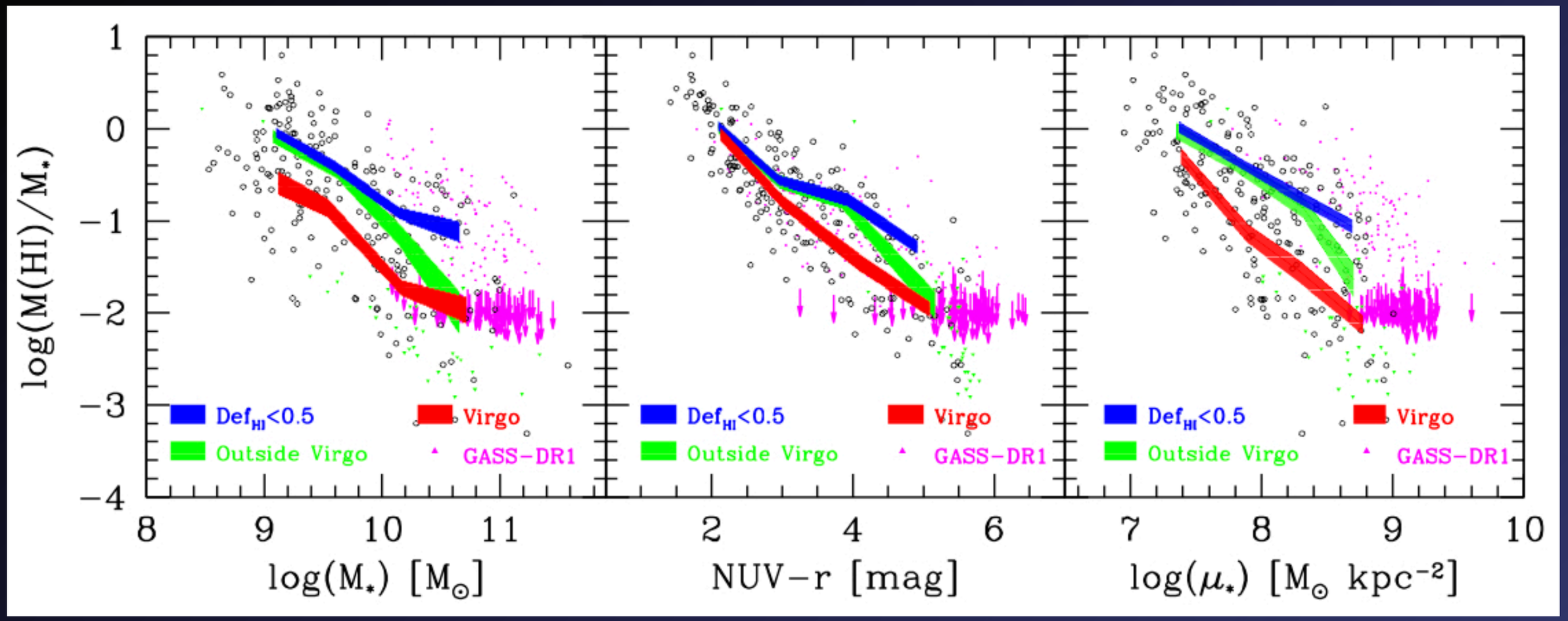
- Arecibo observations of z~0.2 galaxies





☺ Thanks! ☺

HI scaling relations and environment

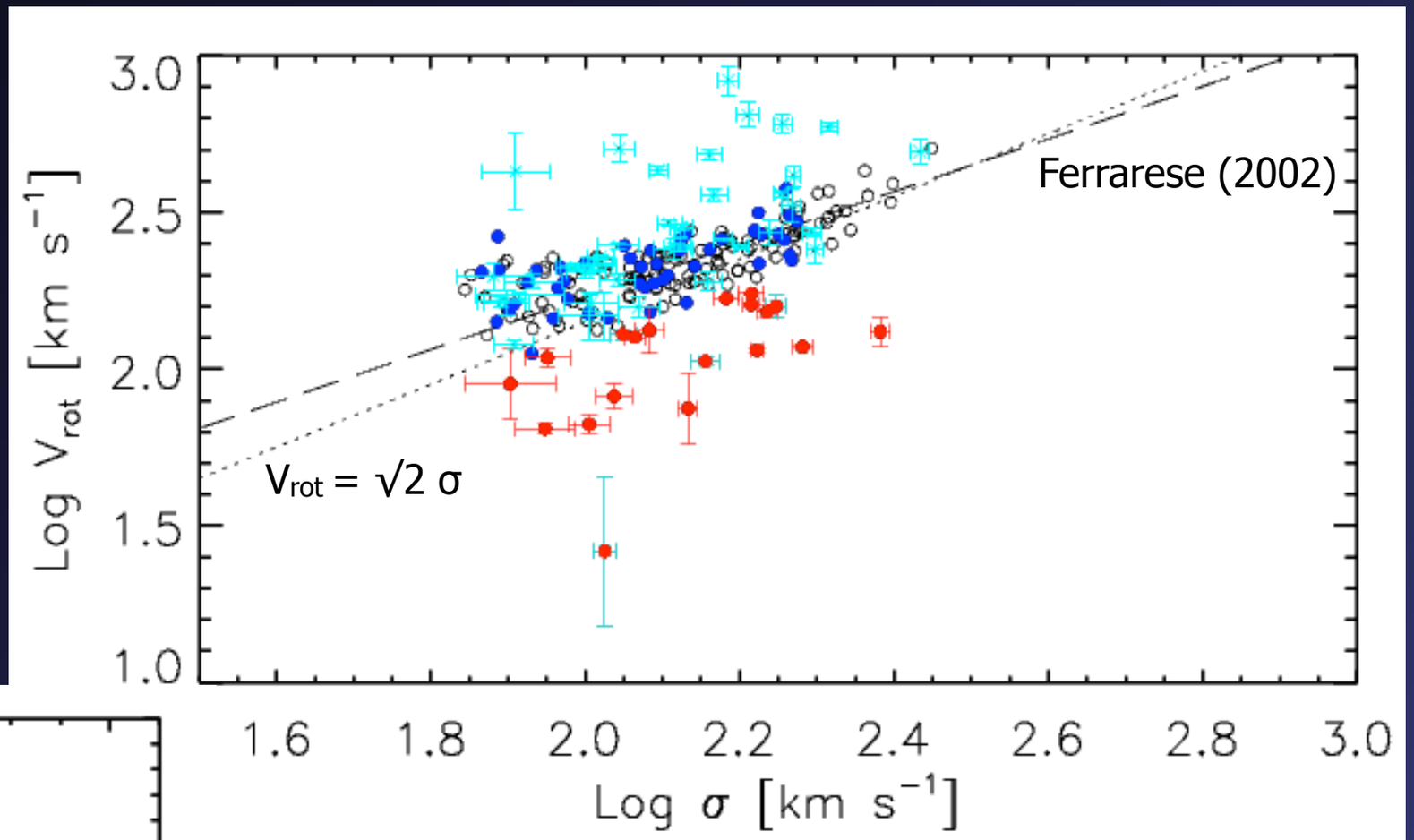


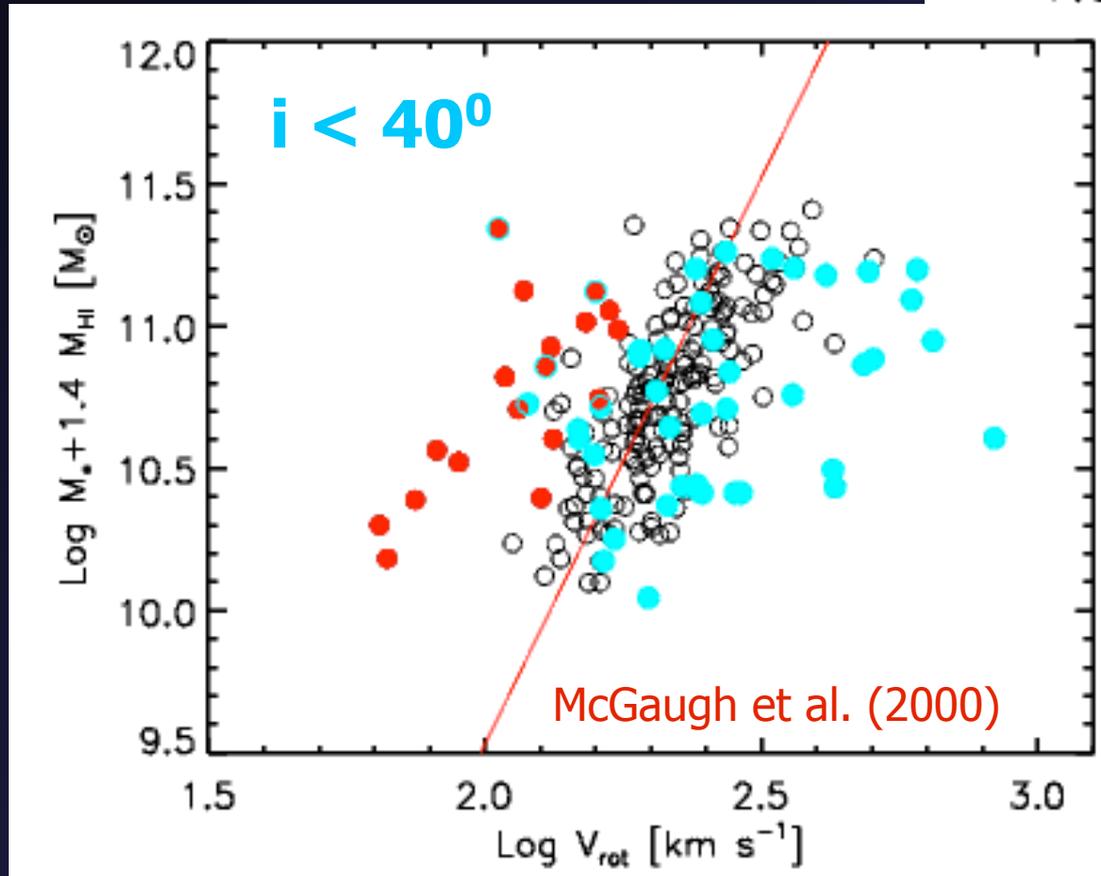
Cortese, BC et al. 2011

HRS: strong difference between field and cluster galaxies

GASS+ALFALFA stacking will sample the intermediate to isolated density regime

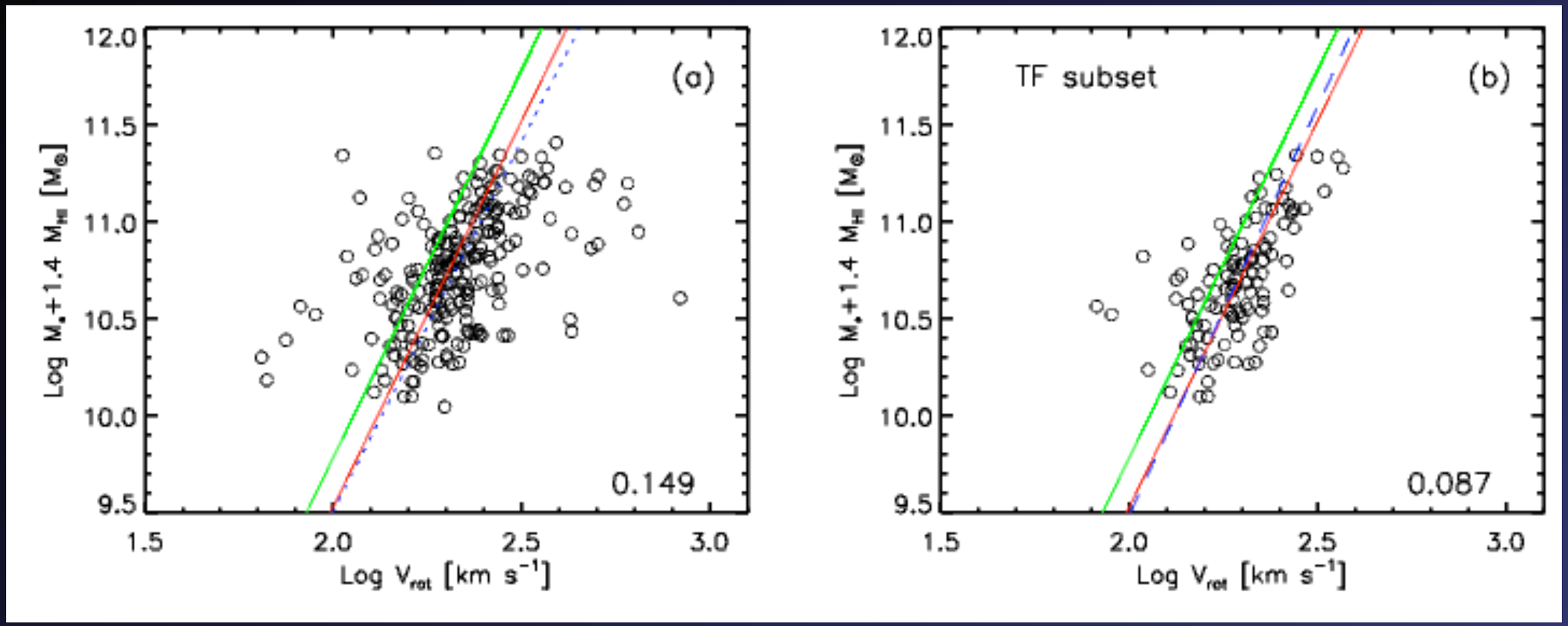
Baryonic TF outliers and V_{rot}/σ





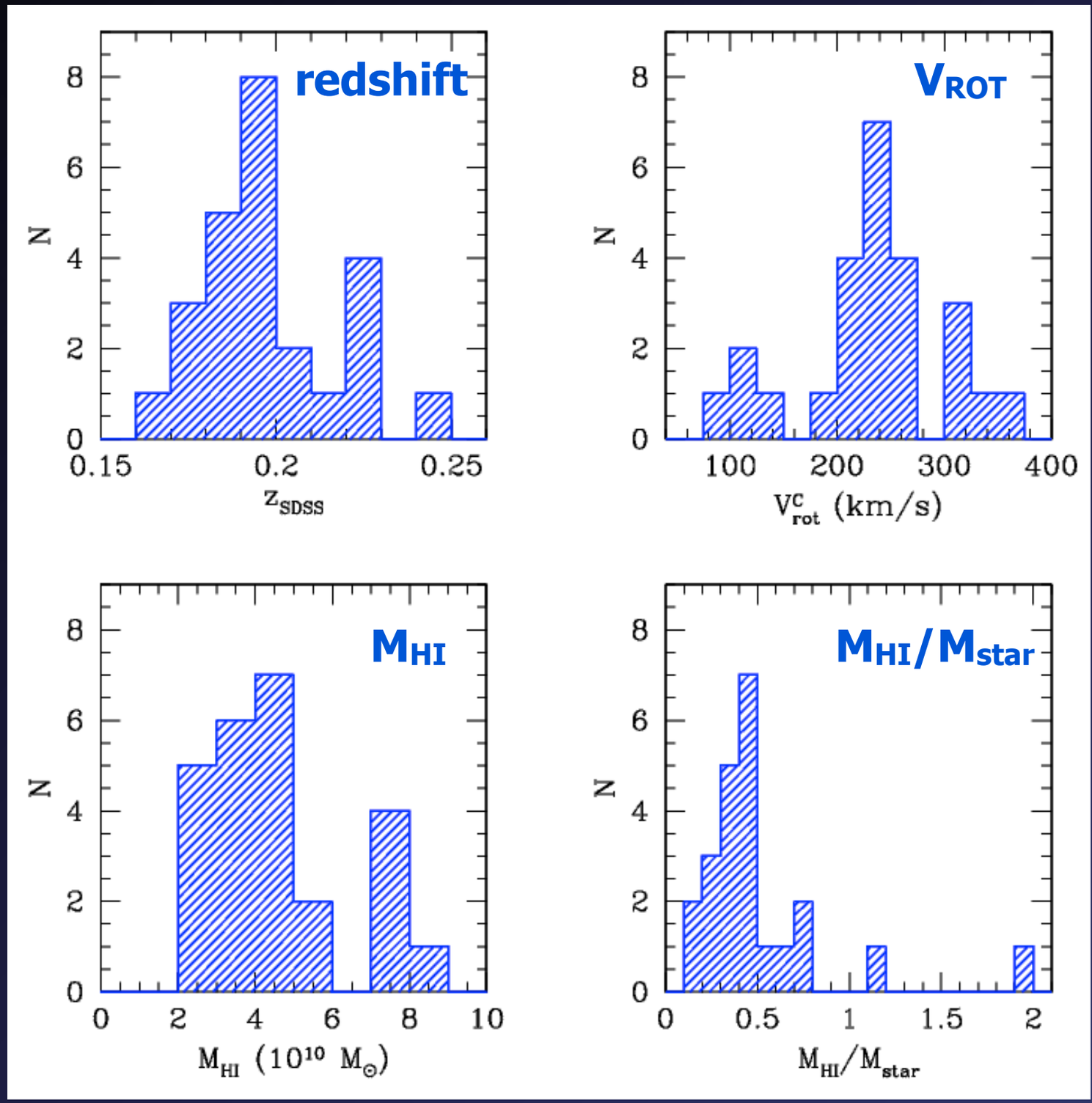
Red outliers: include galaxies with disturbed morphology, low S/N or disturbed HI profiles, wrong inclination...

Baryonic TF and MOND



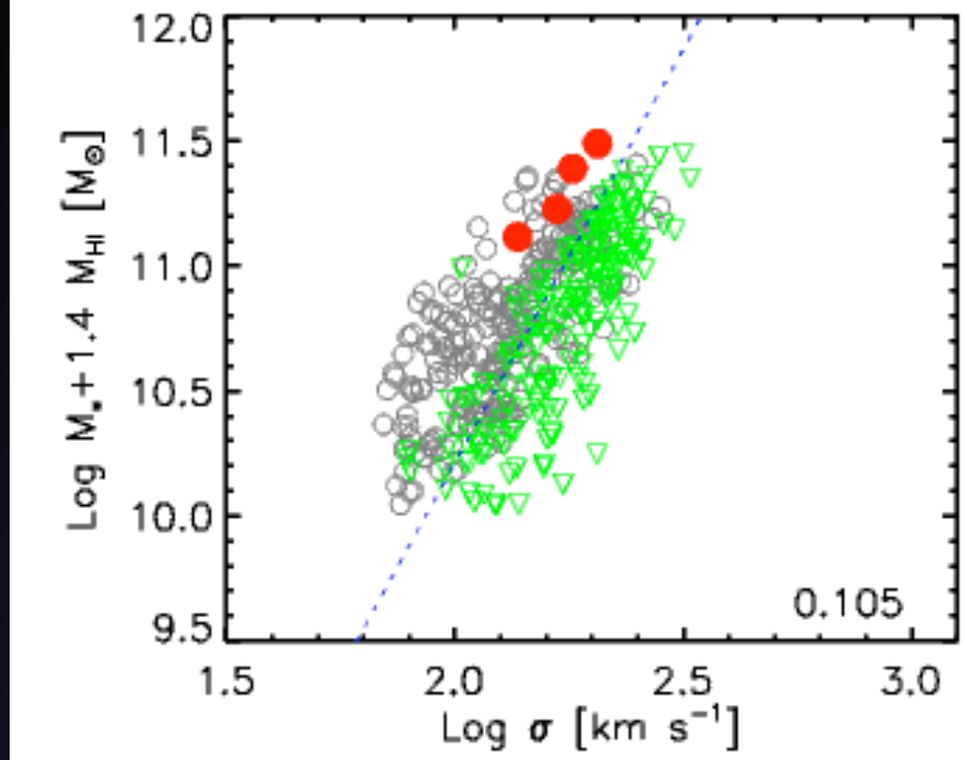
MOND prediction: $G\, M_{bar}\, a_0 = V_{rot}^4$

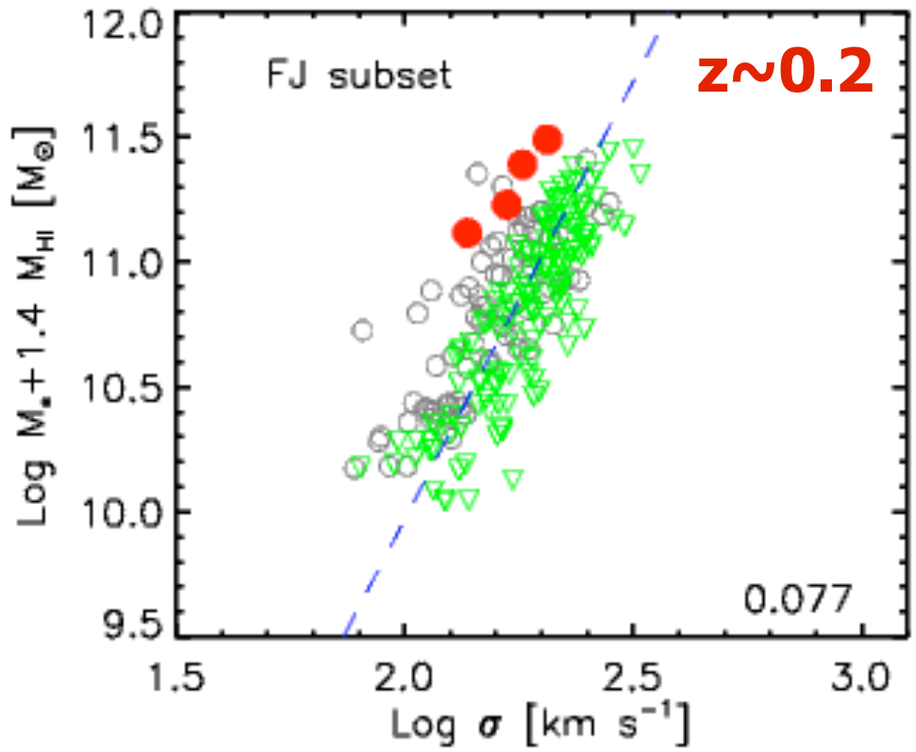
Properties of z~0.2 Arecibo detections

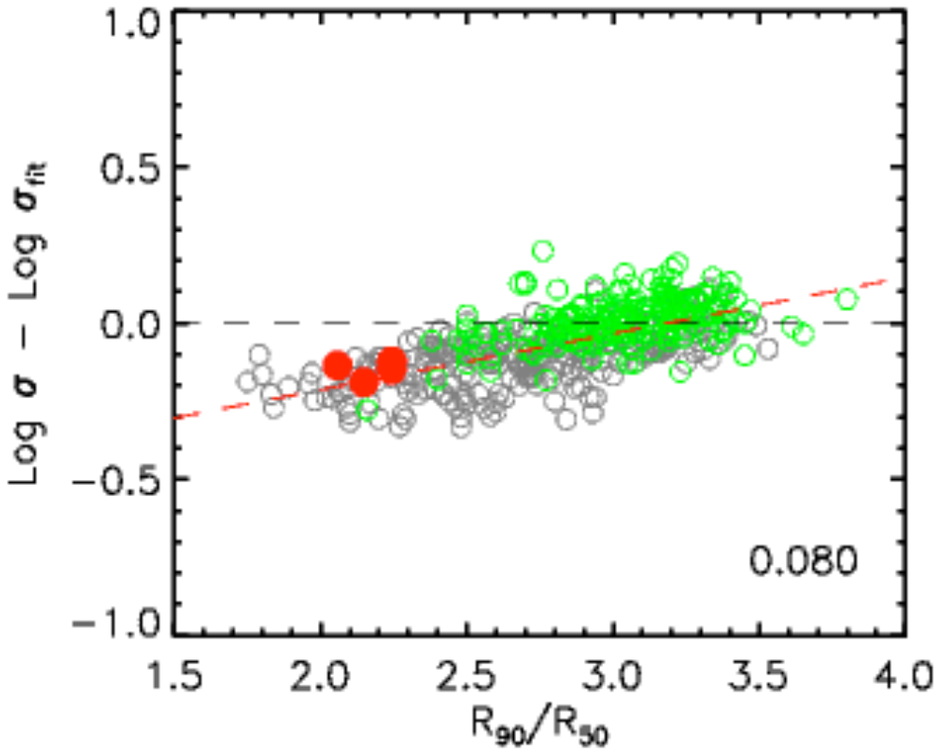


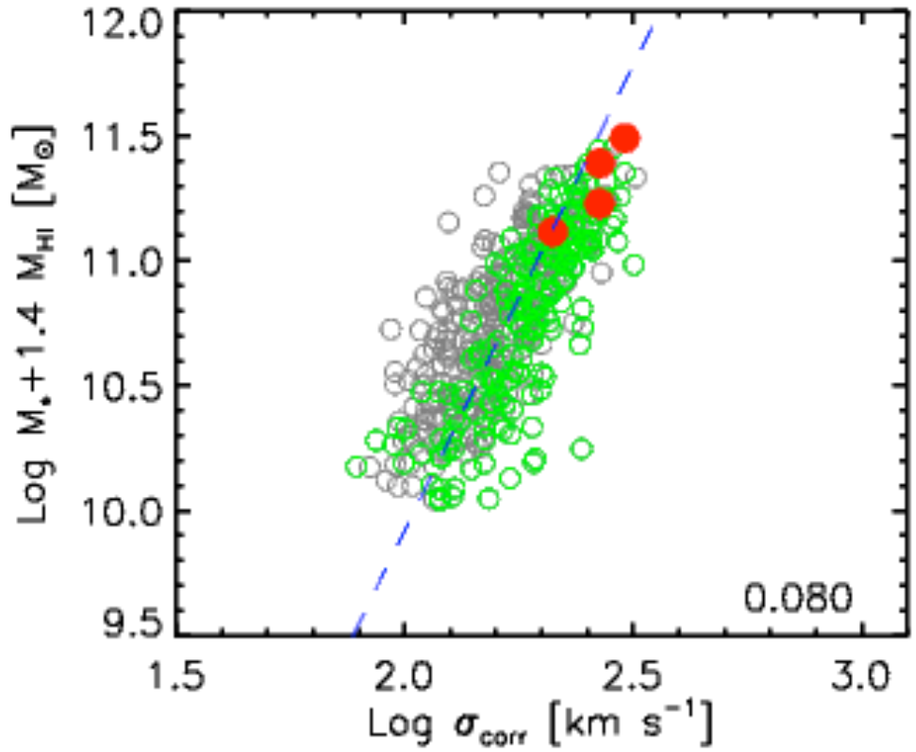
Among the most HI massive galaxies known

Comparison with GASS DR2 baryonic FJR

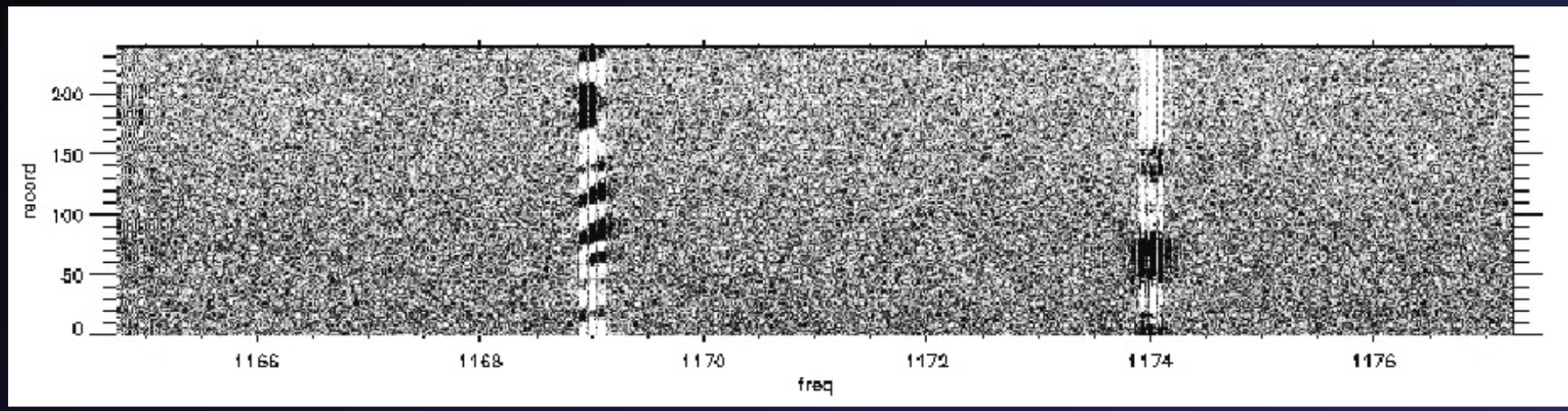


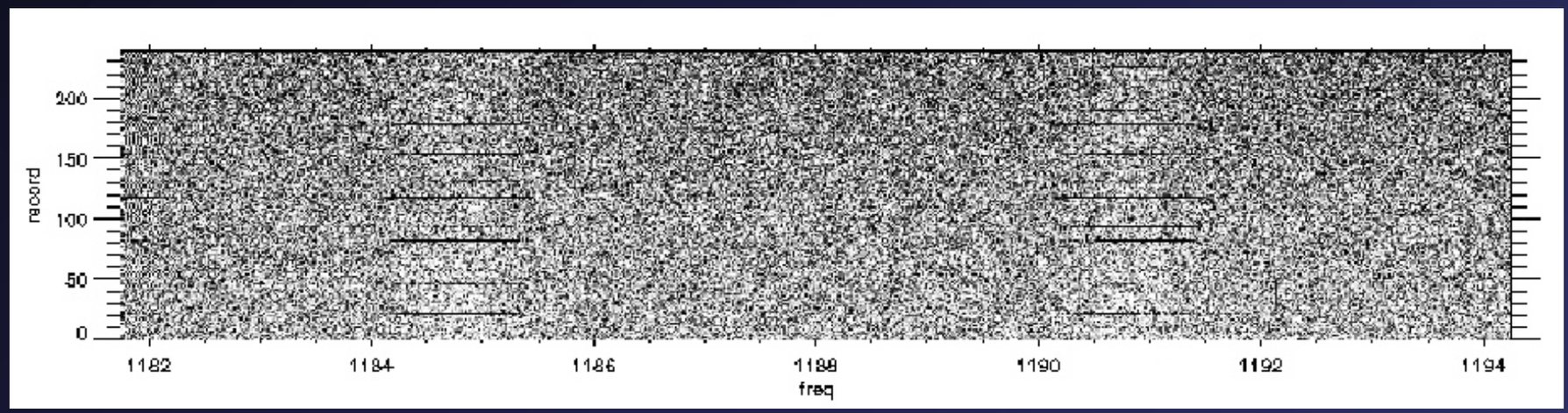


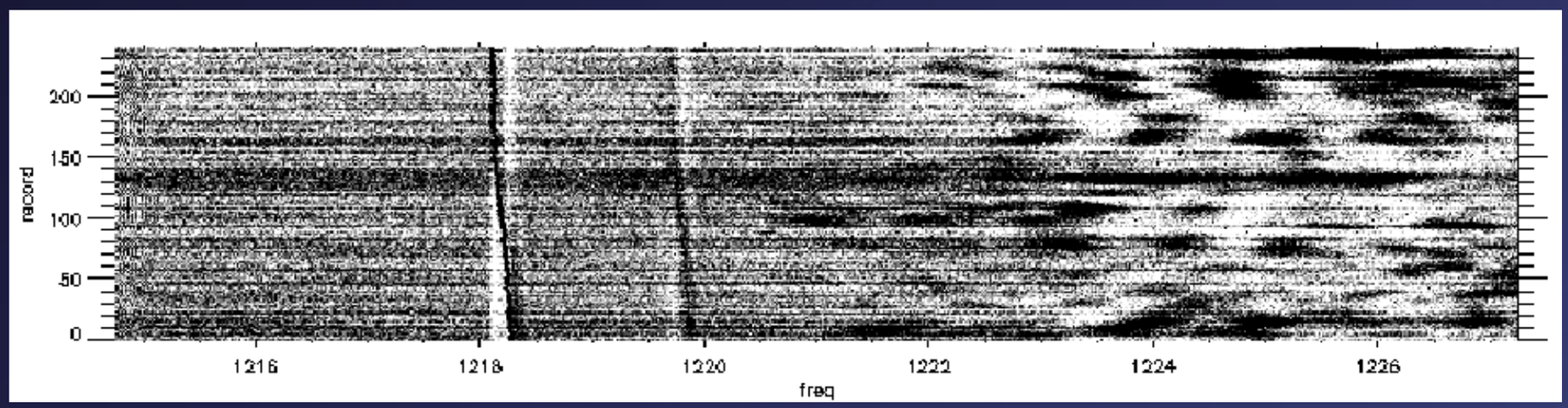




Radio Frequency Interference (RFI)





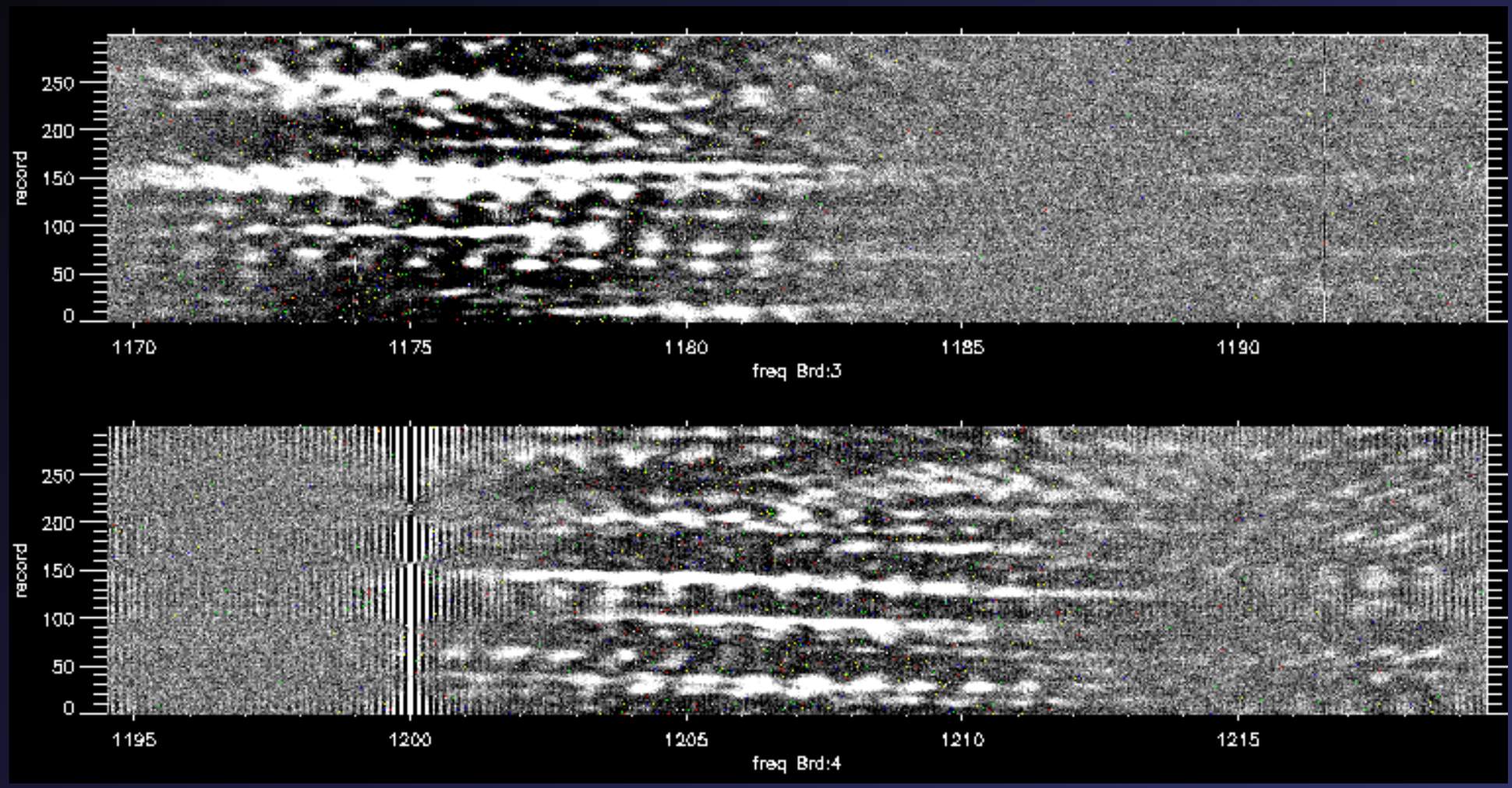


Time →

Frequency →

Satellite RFI

Time →



Frequency →