Understanding the scatter in the HI-based star formation efficiency (SFE) in massive galaxies

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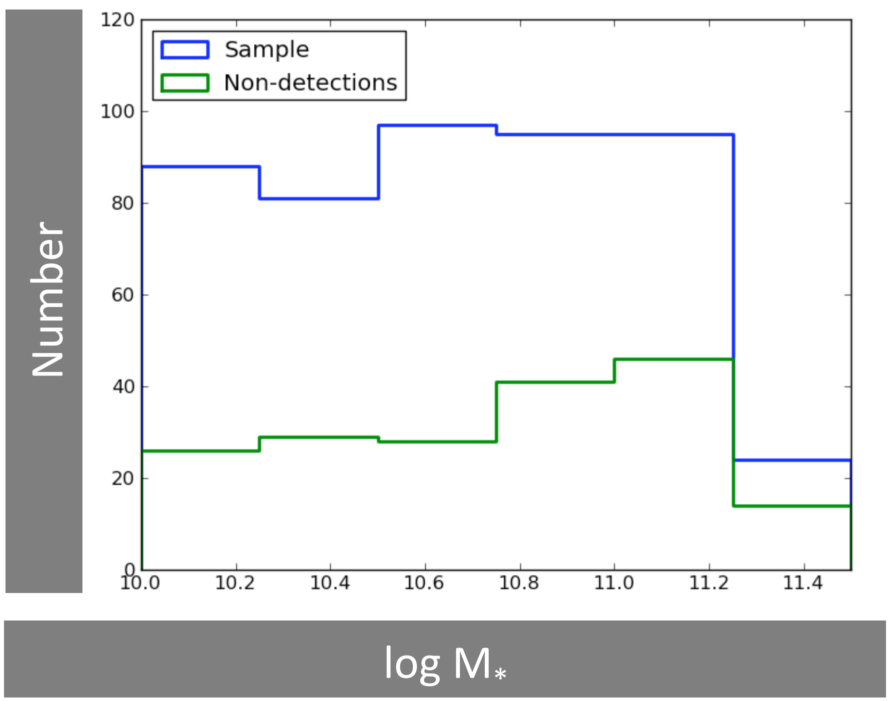
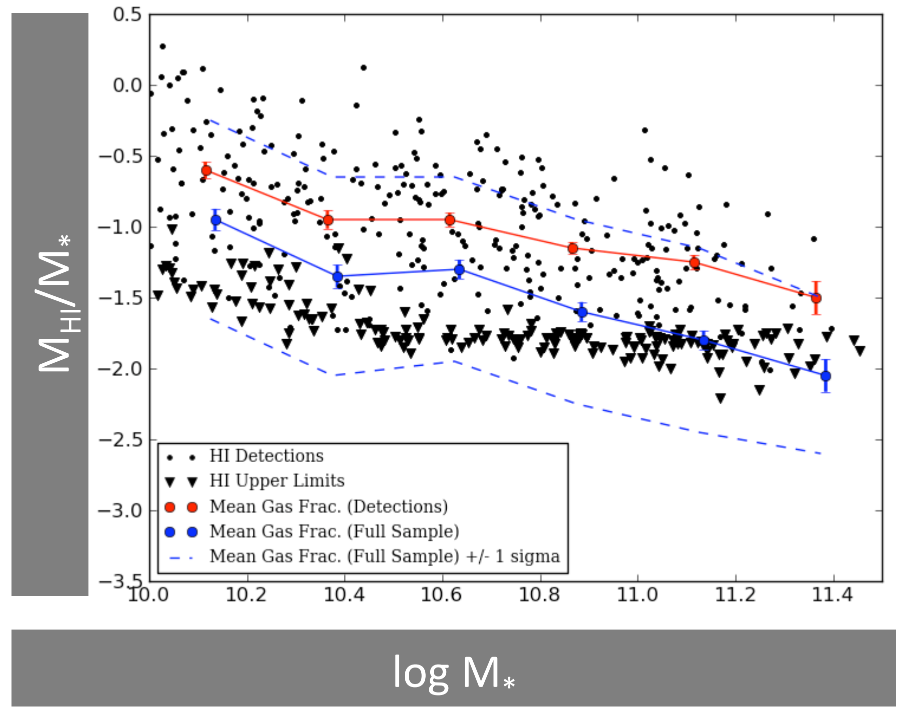
We are using galaxies observed in HI as part of the GASS survey (see Catinella et al. 2010) to investigate the scatter in the SFE described in Schiminovich et al. (2010). GASS is a targeted HI survey currently ongoing at Arecibo that will measure the HI content of 1000 massive (log M*/Msun > 10.0) galaxies in the local universe (z < 0.05). We are using Data Release 2, described in Catinella et al. 2011 (in prep.). DR2 includes 480 galaxies, of which 296 have HI detections. Upper limits are determined for the non-detections. *Below left:* stellar mass distribution of the sample. *Below right:* gas fraction for the sample. Mean gas fractions and scatter are calculated using a maximum likelihood analysis described in later slides.

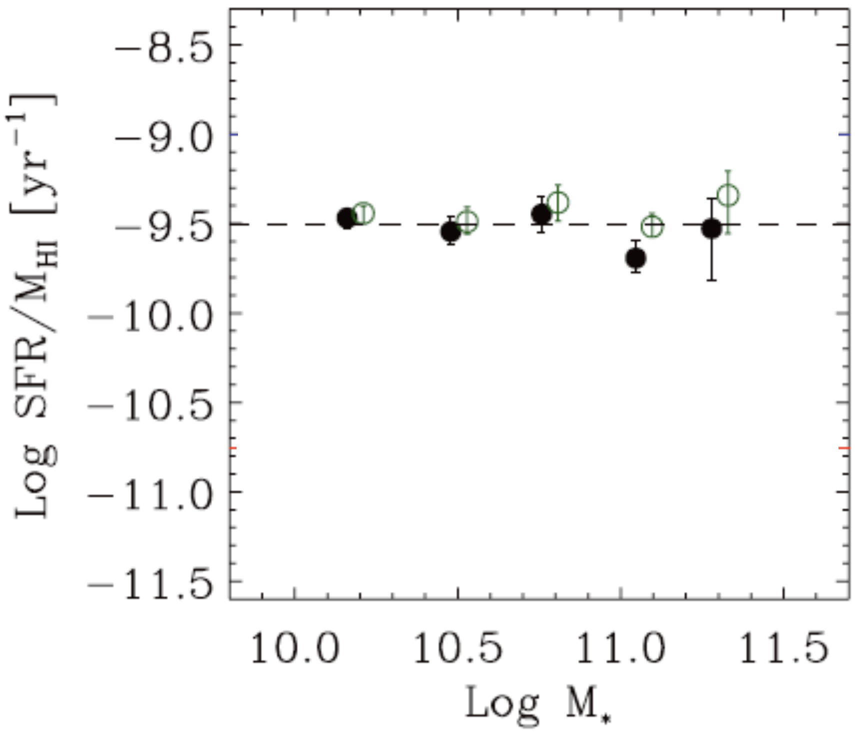




Background

Schiminovich et al. (2010) studied the HI-based star formation efficiency (SFE_{HI} = SFR/MHI) for GASS DR1. They found that the average SFE_{HI} for massive galaxies is constant (~$10^{-9.5}$ yr^{-1}; see figure at right) but varies widely among galaxies (see next slide).

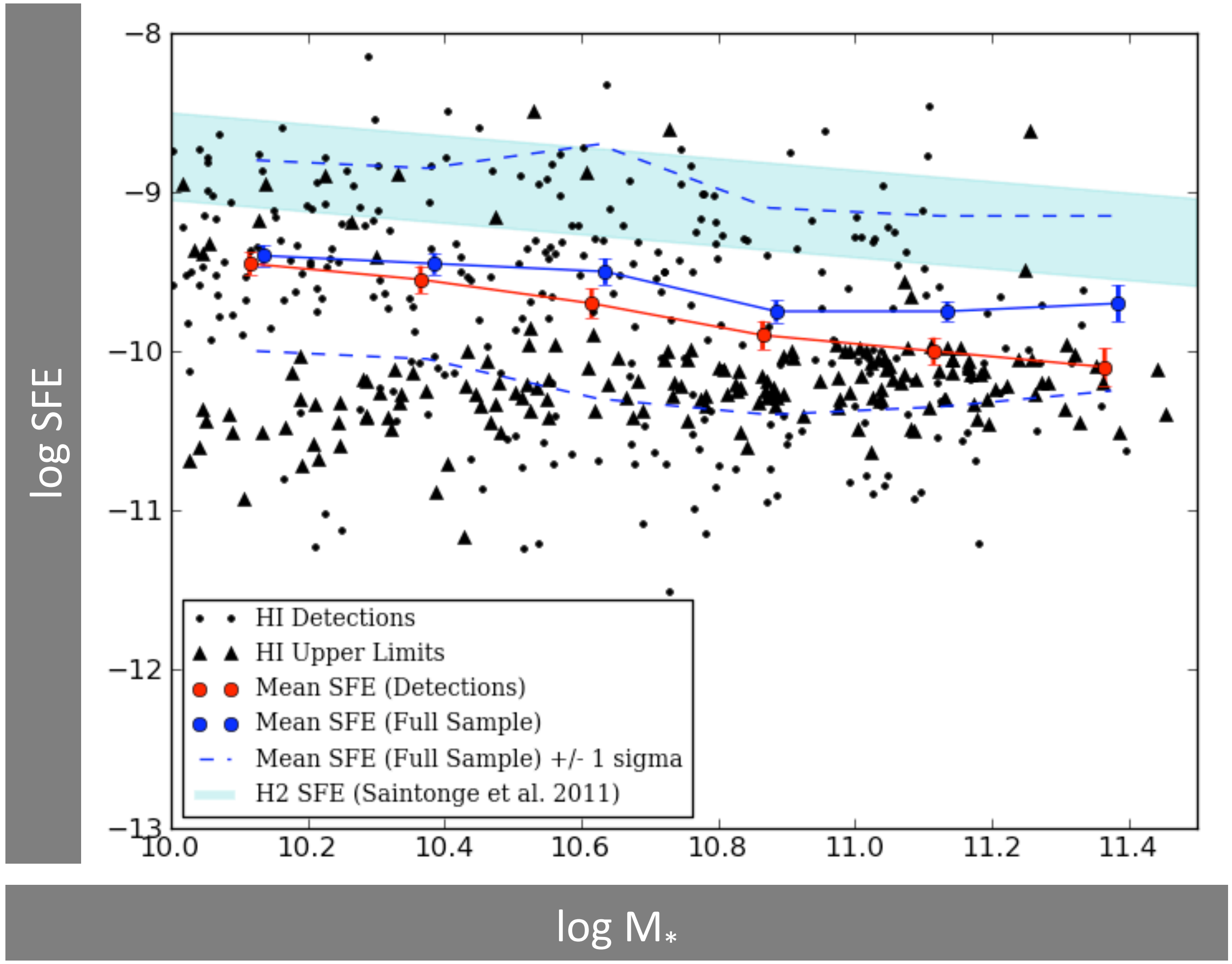
Measures of the star formation efficiency, and its scatter, have been studied for atomic and molecular gas and on local and global scales (e.g. Leroy et al. 2008, Bigiel et al. 2008, Bigiel et al. 2011). Saintonge et al. (2011) found that the global SFE_{H2} is dependent on stellar mass but has a smaller scatter than the HI-based SFE. Shi et al. (2011) found that including the stellar mass surface density as another parameter reduces the scatter in global and local SFEs.



Above: bin-averaged SFE_{HI} is constant with respect to M_* (Schiminovich et al. 2010).

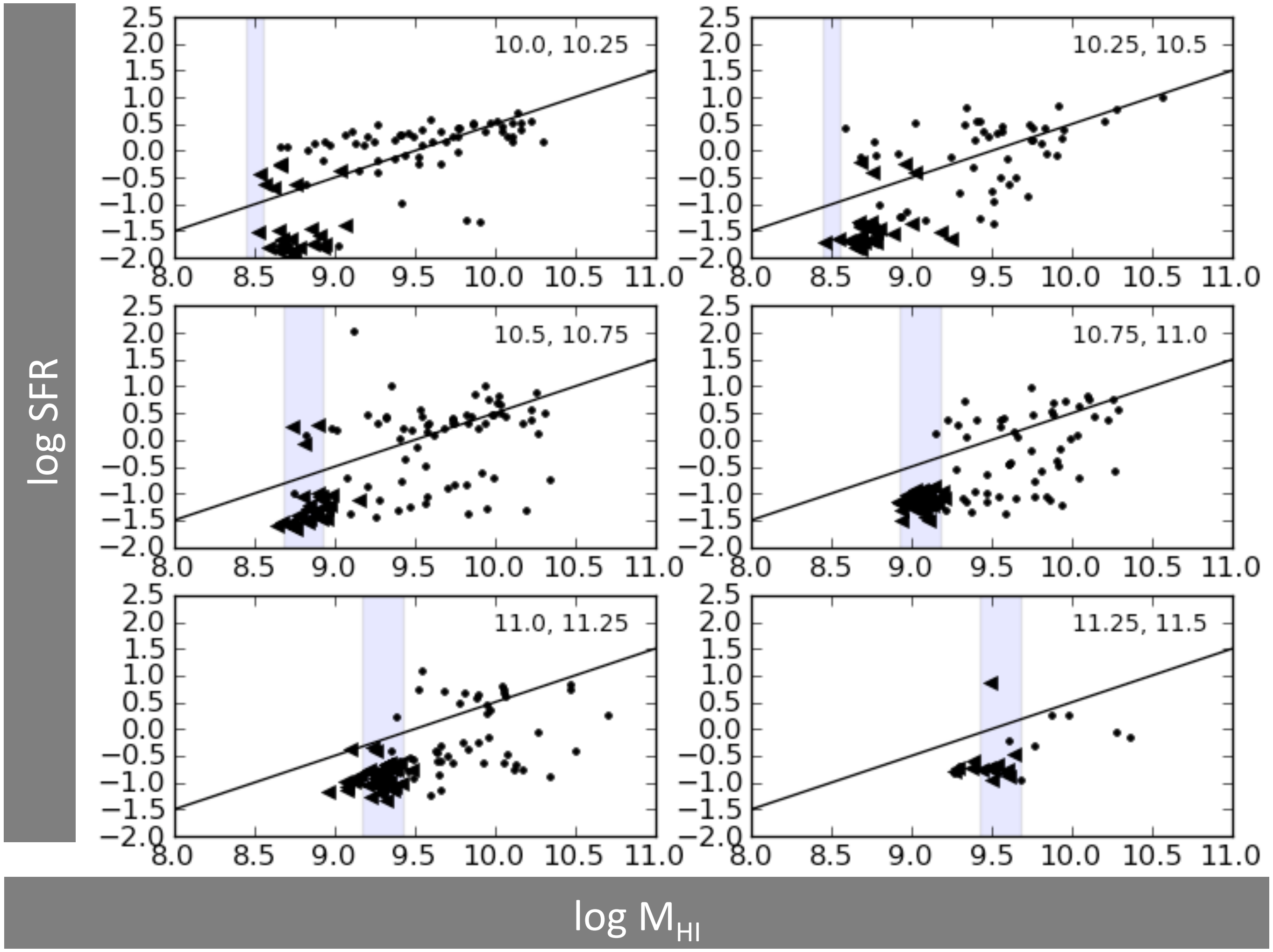
A wide range of SFEs points to a number of physical mechanisms that may affect the gas and SFR in a galaxy at a given time. We are analyzing the scatter in the SFE_{HI} in order to determine the processes (e.g. gas accretion, quenching of star formation) that drive the scatter in the SFE_{HI} at various stellar masses.

Scatter in the SFE_{HI} vs. M_* Relation



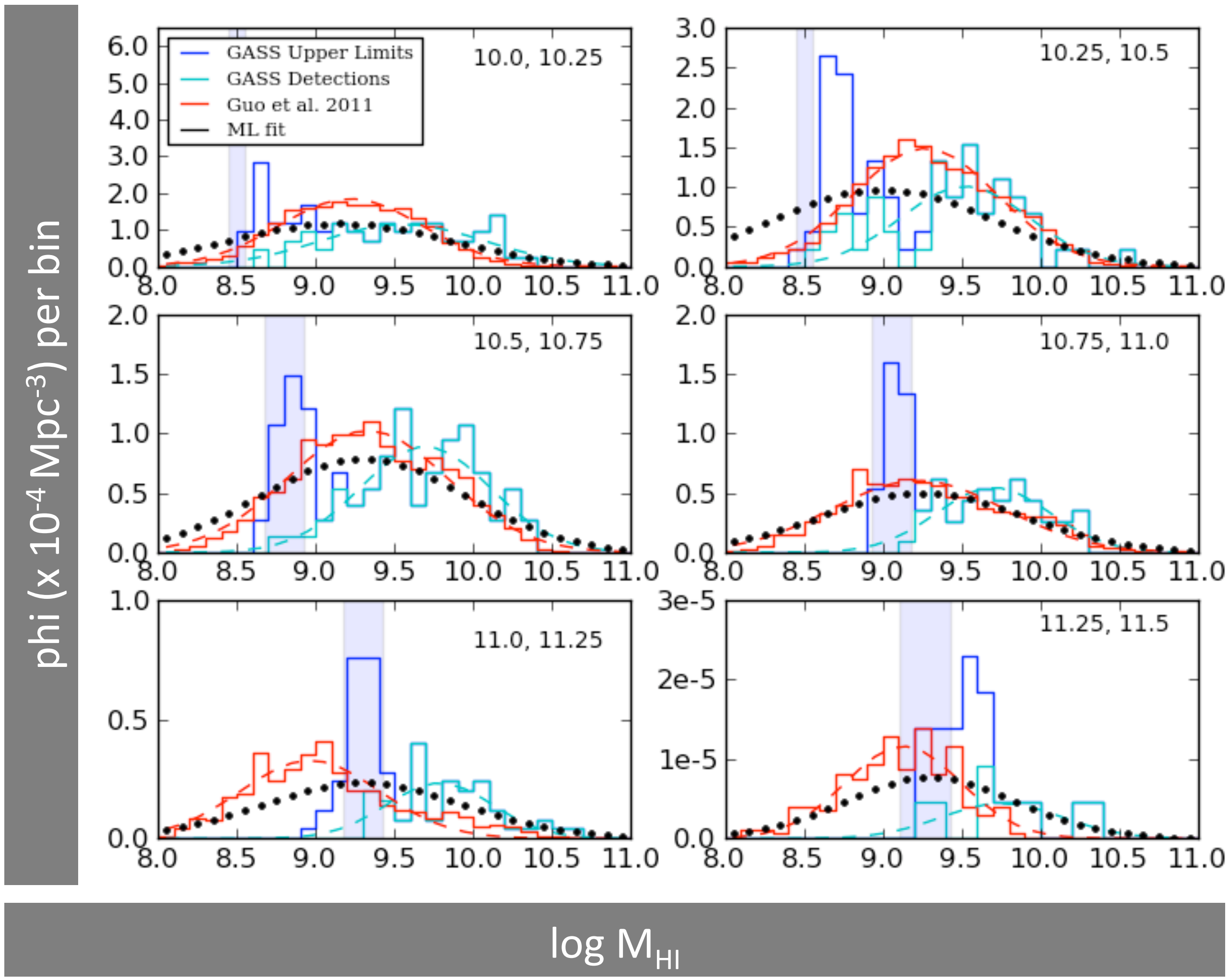
We show log SFE_{HI} vs. log M_* for the sample. This plot emphasizes the scatter in the SFE at all stellar masses. HI detections are shown as black dots and HI upper limits are shown as black triangles. We determine the bin-averaged SFEs in two ways using a maximum likelihood fit to a simple log-normal distribution: we include only detections (red circles) and HI non-detections as well (blue circles). Offsets in the abscissa are for illustrative purposes only. Blue dashed lines enclose ± 1σ of the SFE for HI detections and non-detections. Note that the scatter in the H_2-based SFE (cyan region) is much smaller than that for SFE_{HI}.

The SFR-M_{HI} Plane



We show GASS detections (dots) and upper limits (triangles) in the SFR-M_{HI} plane in log M_* bins (indicated in the upper right corners). The GASS detection limit is indicated by the vertical bar. A constant $SFE_{HI} = 10^{-9.5}$ yr^{-1} is shown by the solid line. Note that there is a weak correlation between SFR and M_{HI} at low M_* but the correlation falls apart at higher M_*. The lack of a correlation is further evidence of the degree of scatter in the star formation efficiency.

M_{HI} Distributions vs. M_*

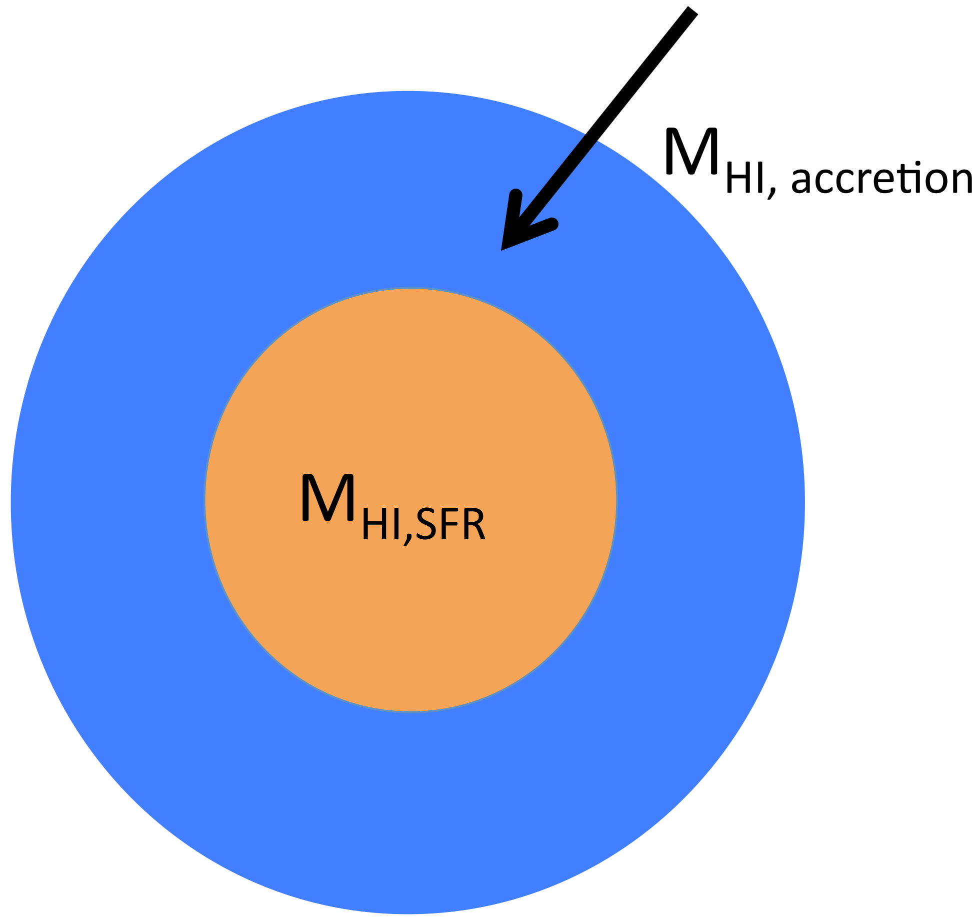


We determine the M_{HI} distribution in M_* bins as a first step in measuring the gas content of our sample. The GASS detection limit is indicated by the vertical bar. GASS galaxies and galaxies in Guo et al. (2011) simulations exhibit distributions that are approximately log-normal. We have chosen to fit a simple Gaussian (cyan, red dashed lines) to the GASS detections and Guo simulation and we applied a maximum likelihood analysis to determine a Gaussian that incorporates the GASS upper limits (black dashed lines). We note that it is likely that the true distributions are more complicated than a simple log-normal. The data and the model match fairly well, but the Guo simulation appears less gas-rich, especially at high stellar masses.

SFE_{HI} Model

$\Delta\ M_{accretion}$ → $\Delta\ M_{HI,\ reservoir}$ → $\Delta\ M_{HI,\ SFR}$ = $\Delta\ M_{H2,\ SFR}$

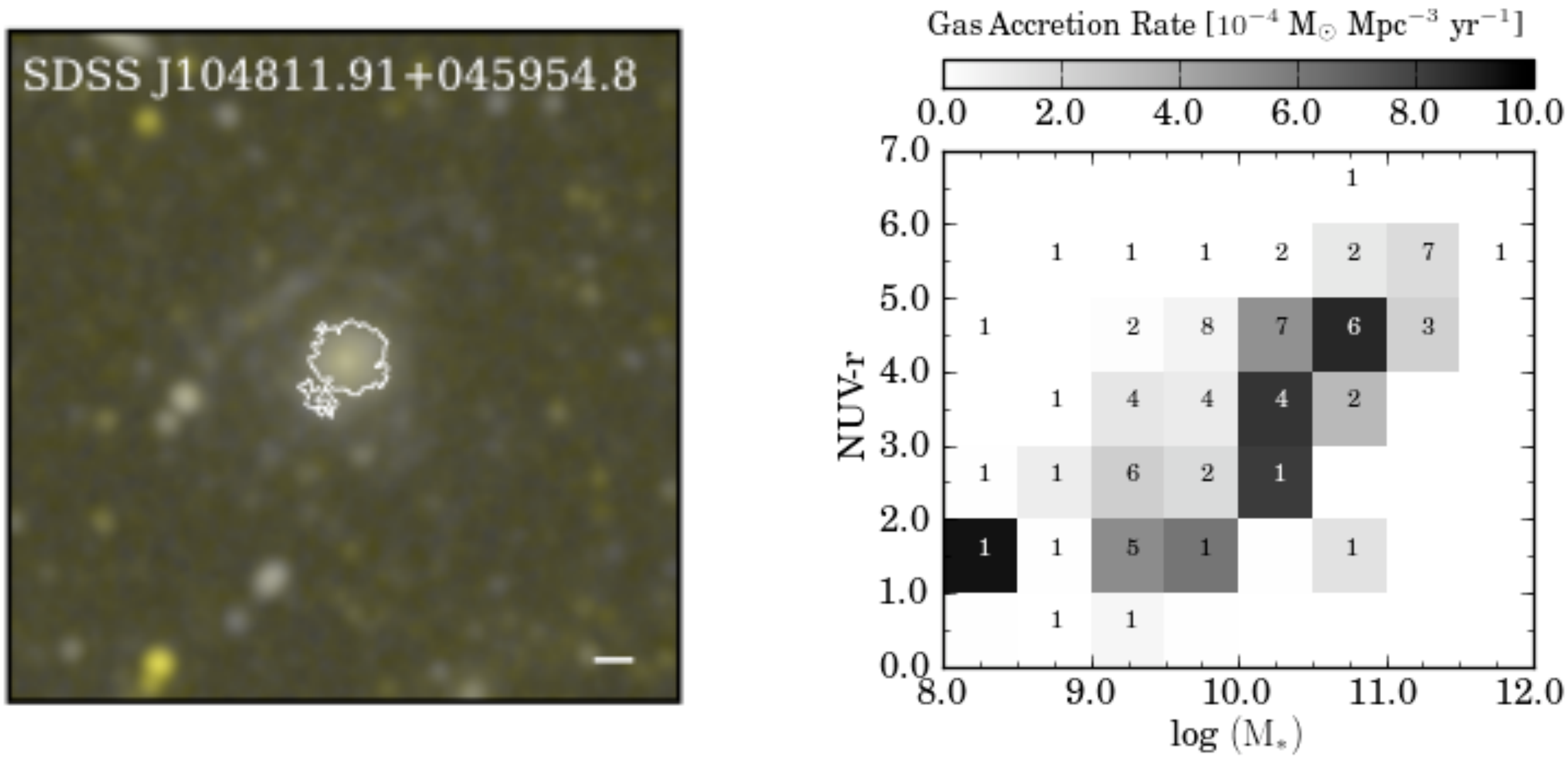
One possible SFE_{HI} model divides the total measured M_{HI} into two components: *HI in the inner disk* involved in star formation and *HI in the outer disk* that has been recently accreted. This will allow us to model the flow of gas from the time it accretes onto a galaxy and forms an HI reservoir to when it finally condenses to form stars.



Treating the HI as two distinct but related components will provide insight into the role that HI reservoirs may play in the scatter in the SFE. The outer parts of galaxies have been shown to harbor vast HI reservoirs and low levels of star formation, which together produce low efficiencies that may drive the scatter in the global SFE (Lemonias et al. 2011, Bigiel et al. 2011, Wyder et al. 2009).

XUV-disks

Extended-UV disks (XUV-disks) are galaxies with low levels of star formation in their outer parts. Recent work has shown that a sizeable fraction of local galaxies may exhibit XUV-disks and that XUV-disks may have large gaseous reservoirs that sustain the outer star formation (Thilker et al. 2007, Lemonias et al. 2011). The low efficiencies in the outer extents of XUV-disk galaxies may contribute to the scatter in the SFE_{HI}.



Left: Example of an XUV-disk. *Right:* We estimate the rate of gas accretion onto XUV-disk galaxies in the color-stellar mass plane. This estimate relies on the assumption that the XUV-disk traces the extent of the HI reservoir and the HI surface density is consistent with those previously measured for XUV-disks. See Lemonias et al. (2011).

Summary and Future Work

This work is being done to understand the physical processes that contribute to the scatter in the global star formation efficiency of massive galaxies. The scatter appears to be sensitive to the HI content of a galaxy.

- We quantify the scatter in the HI-based SFE for massive galaxies observed by GASS.
- We have determined distribution functions for the measured HI in GASS galaxies and compared them to distributions derived from simulations.
- We will derive a SFE model to determine the effect that an HI reservoir, and the low levels of star formation that it sustains, has on the global SFE.

References

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