The non-universality of the molecular gas depletion timescale in the local Universe

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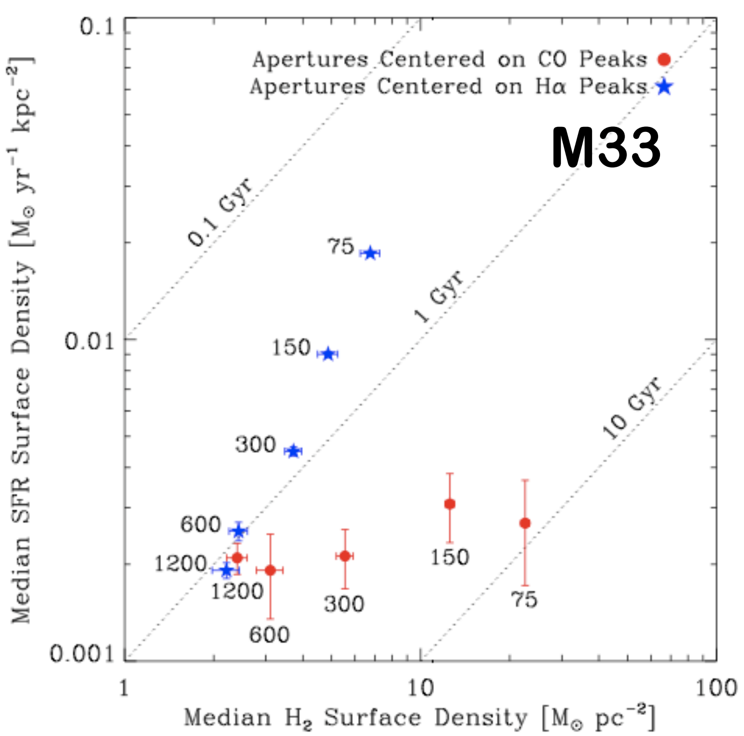
MPA/MPE

Galaxy Formation **- Durham, 18-22 July 2011**

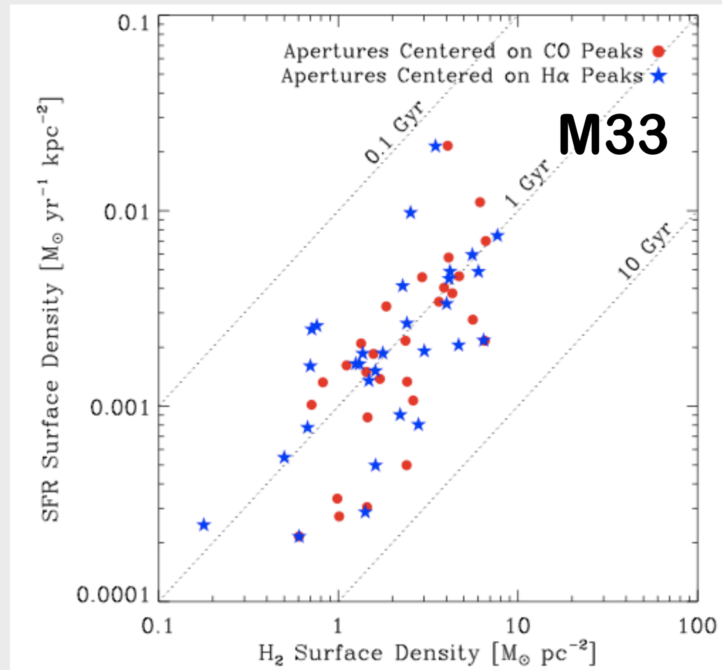
the star formation relation on various scales

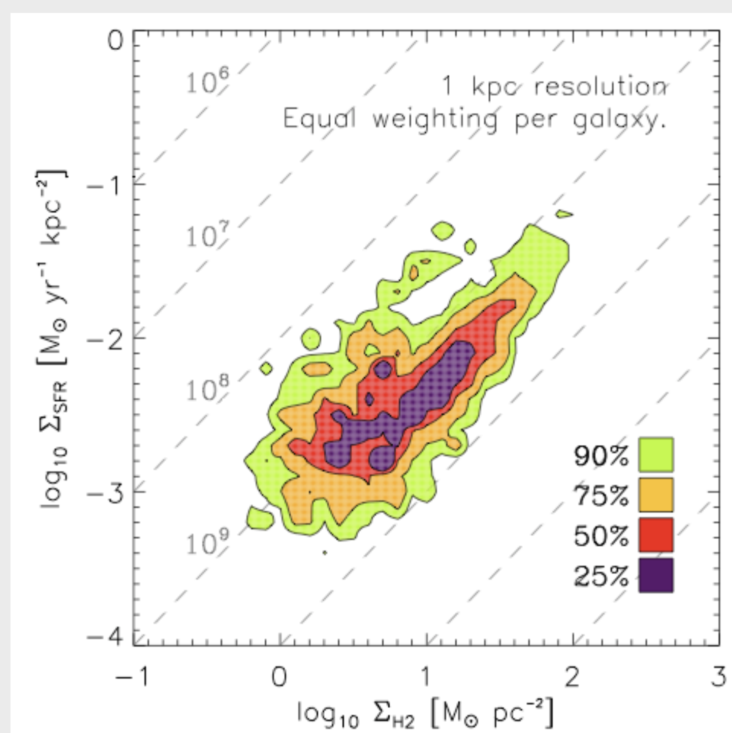
<500pc scales



Schruba et al. (2010)

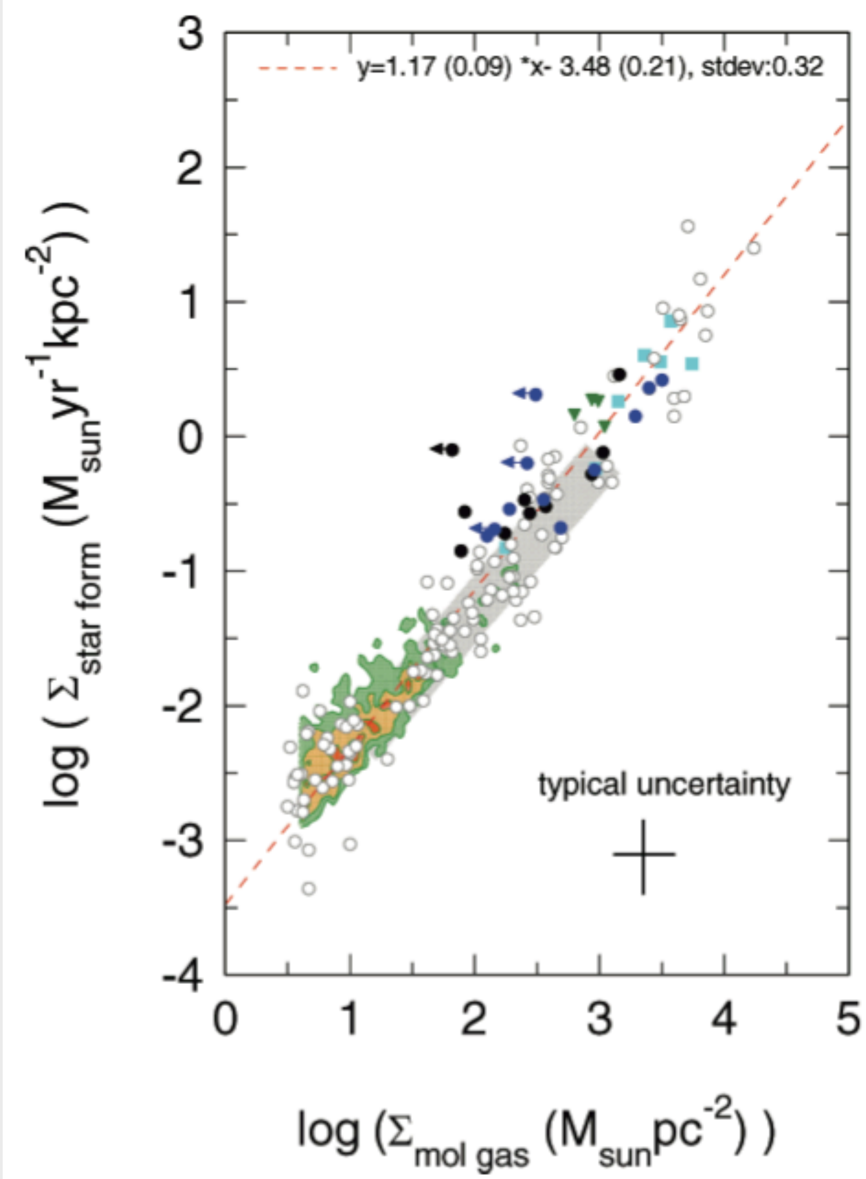
~kpc scales





Bigiel et al. (2011)

global scales



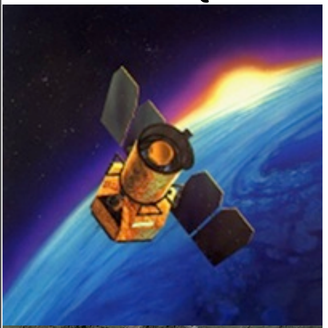
Genzel et al. (2010)

the “GALEX-Arecibo-SDSS Survey” (GASS)

Goal: Provide the first statistical sample of massive galaxies with homogeneously measured stellar and gas masses, to study their link with star formation and other global physical properties.

Project: 1000 galaxies with atomic gas measurements (Arecibo)
and 350 with molecular gas (550 hours at IRAM 30m).

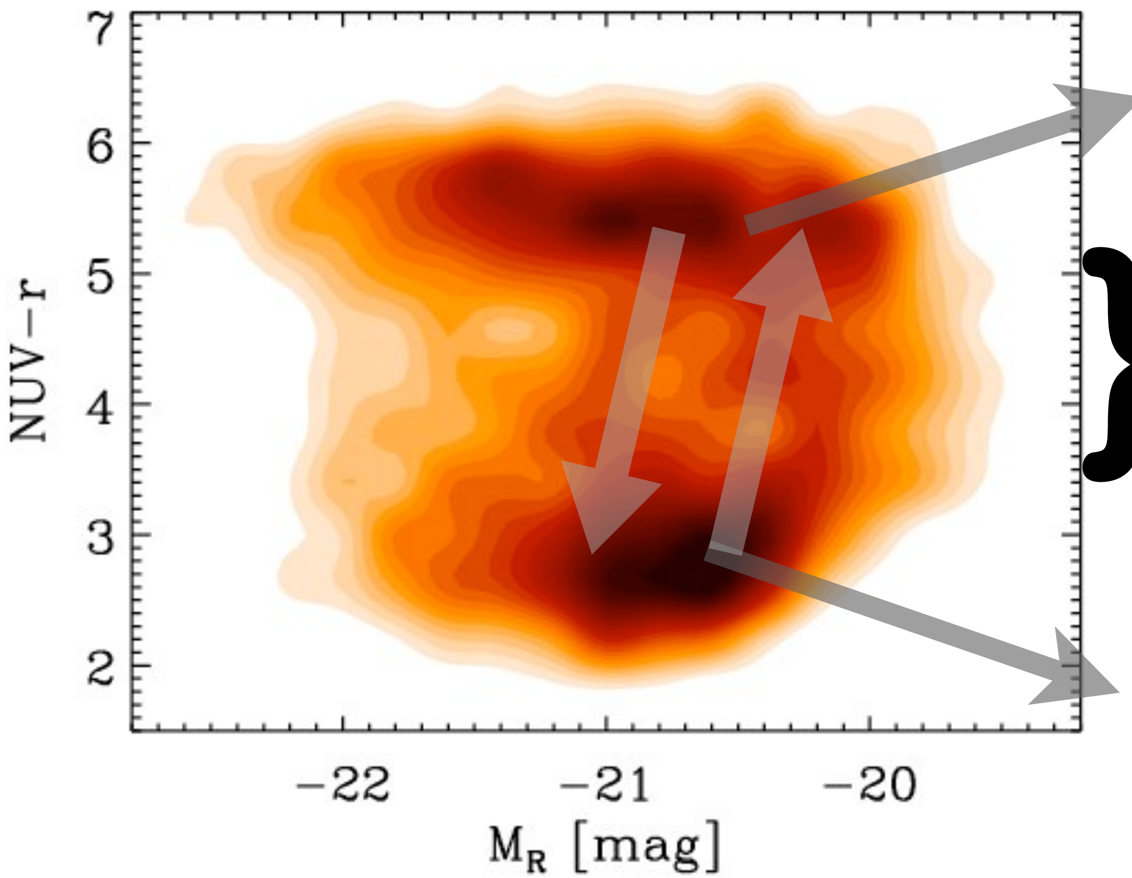
P.I.s: G. Kauffmann, D. Schiminovich, C. Kramer
(B. Catinella & A. Saintonge)




COLD GASS
CO Legacy Database for GASS
An IRAM Large Program
iram


GASS sample

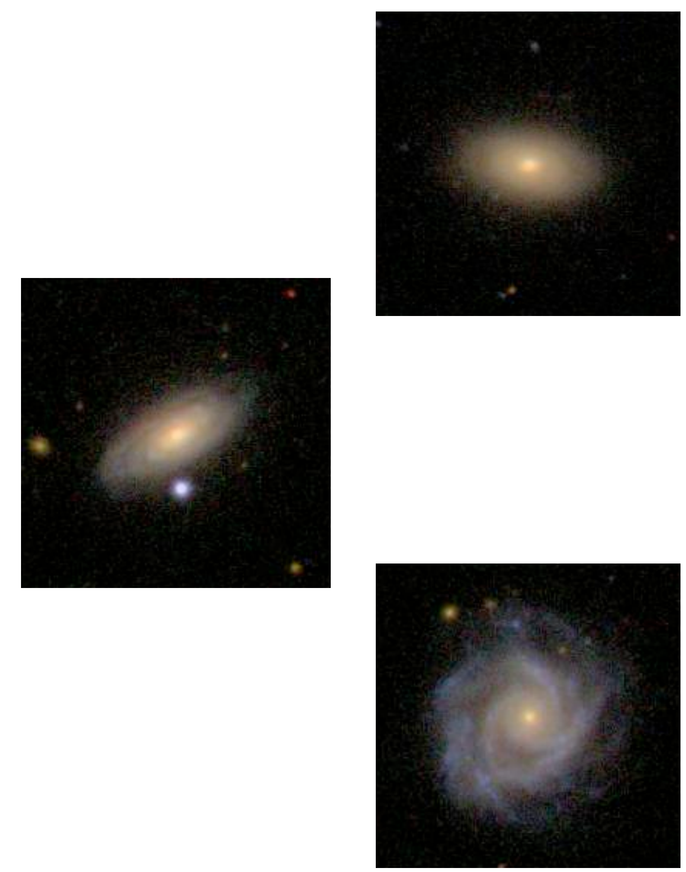
the sample is selected purely on mass ($M_* > 10^{10}$ $M_\odot$) and volume (100<D<200 Mpc)



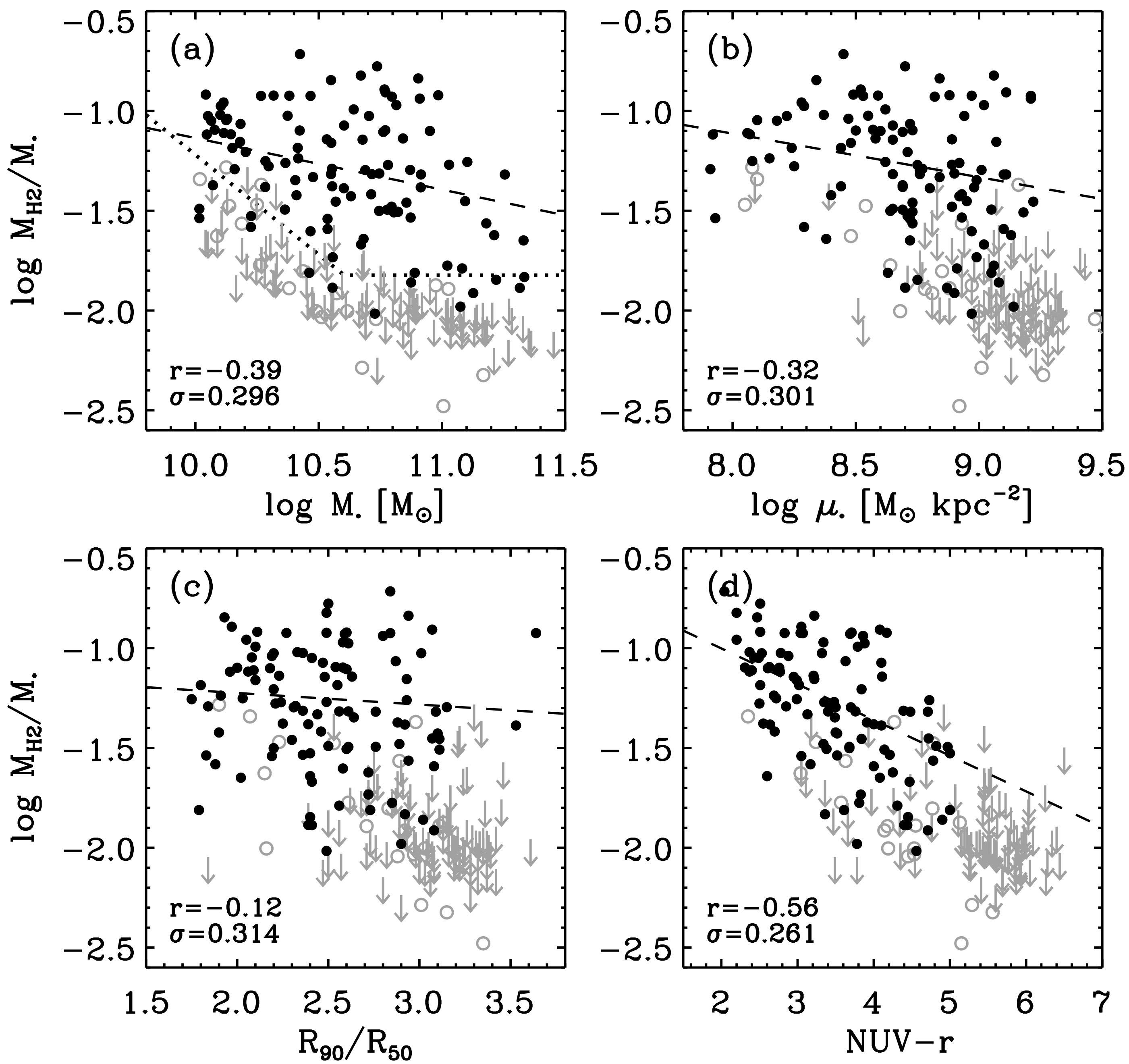
red sequence

transition

blue cloud

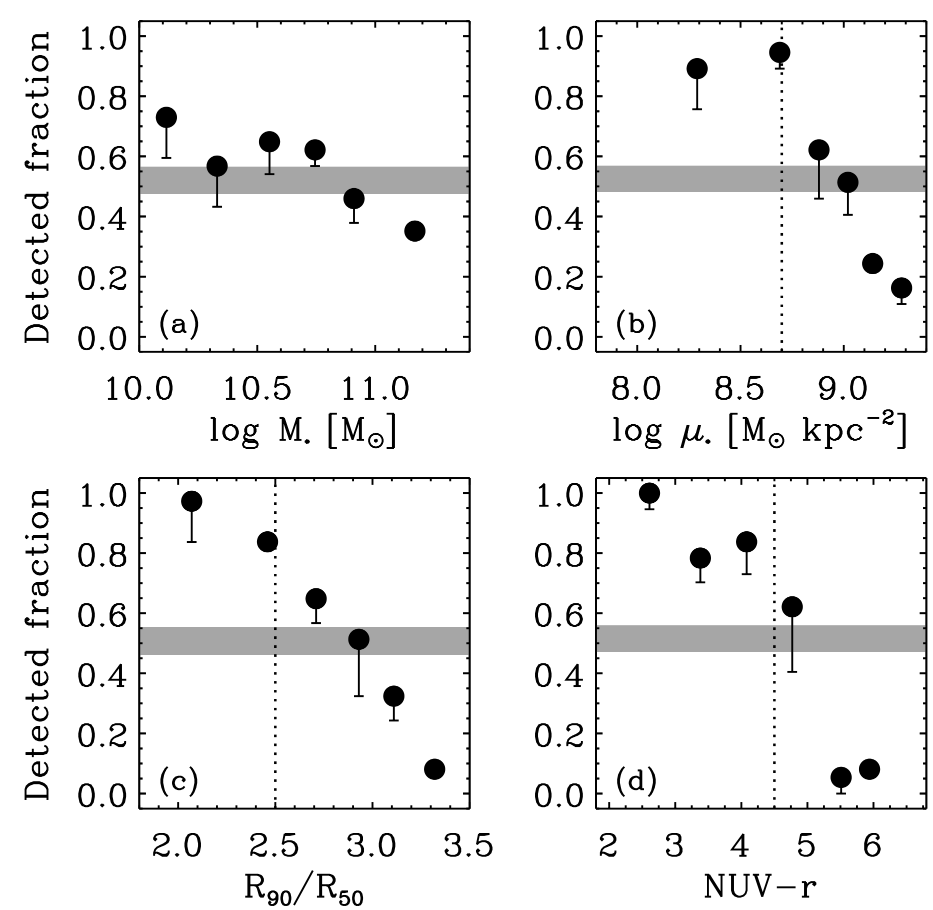


molecular gas and physical properties



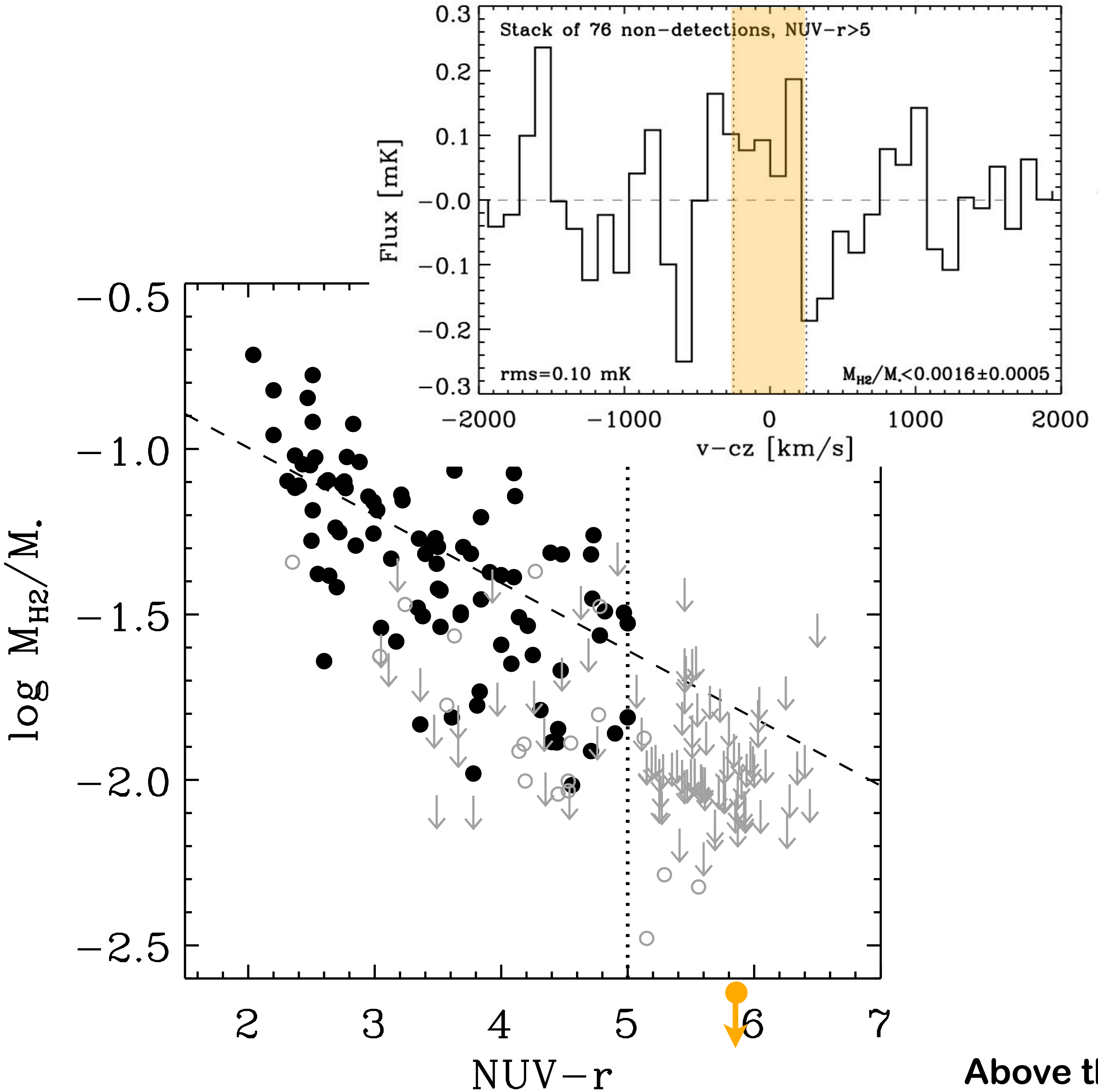
MH2/M* is on average 6%, with little dependence on stellar mass or concentration index. The ratio never exceeds 20% within our sample.

There are thresholds in mu*, C and NUV-r above which the molecular gas quickly stops being detectable at the MH2/M*~2% level.



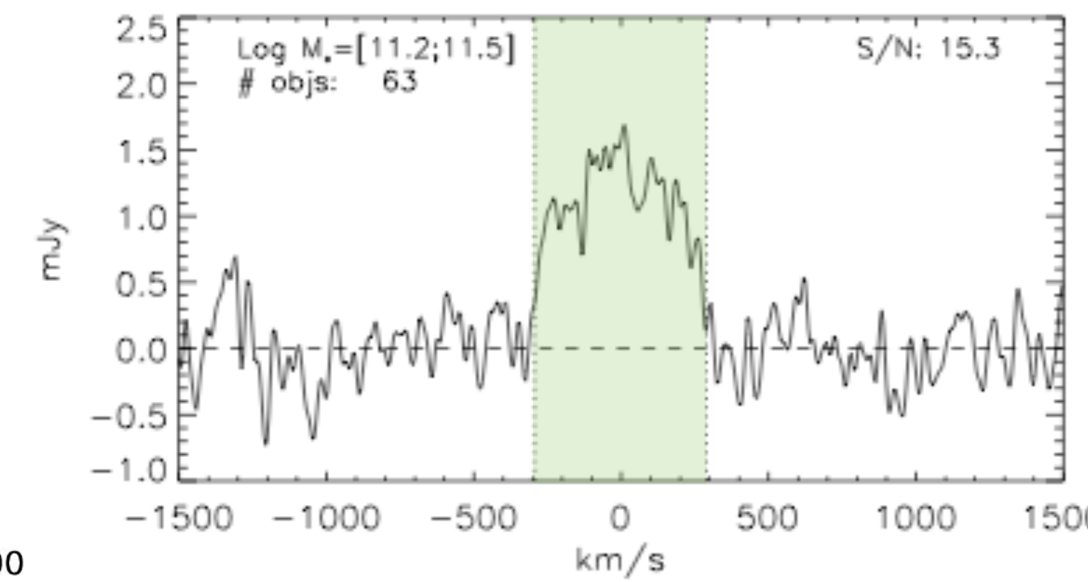
Saintonge et al. (2011a)

molecular gas in early-type galaxies

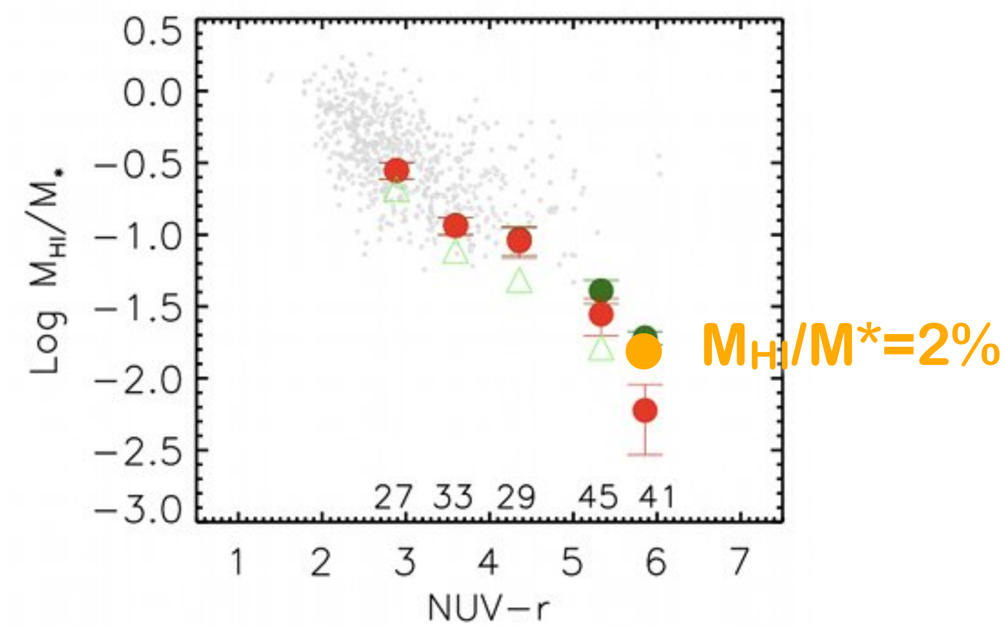


$M_{H2}/M^*<0.2\%$

Saintonge et al. (2011a)



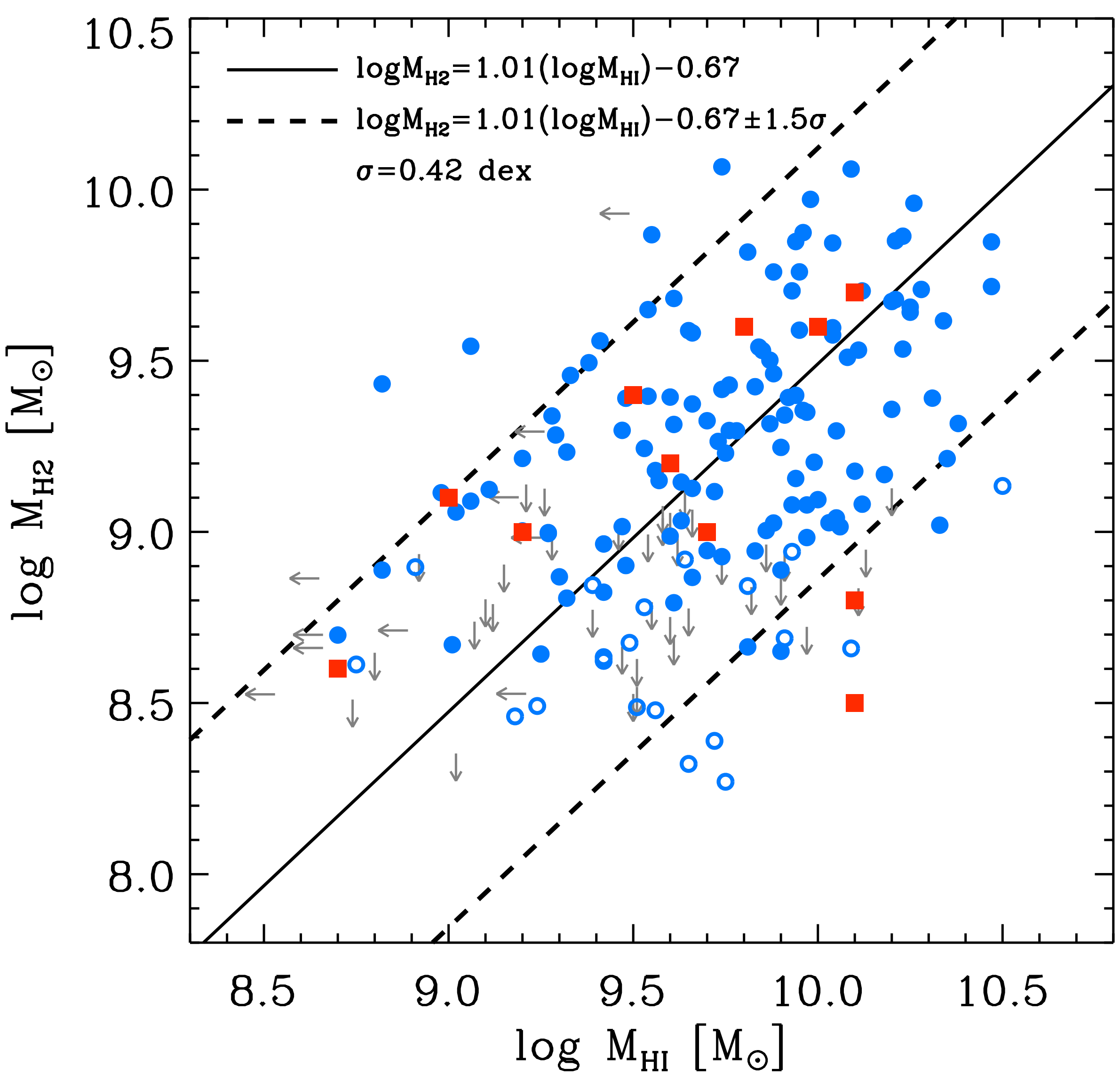
Fabello et al. (2010)



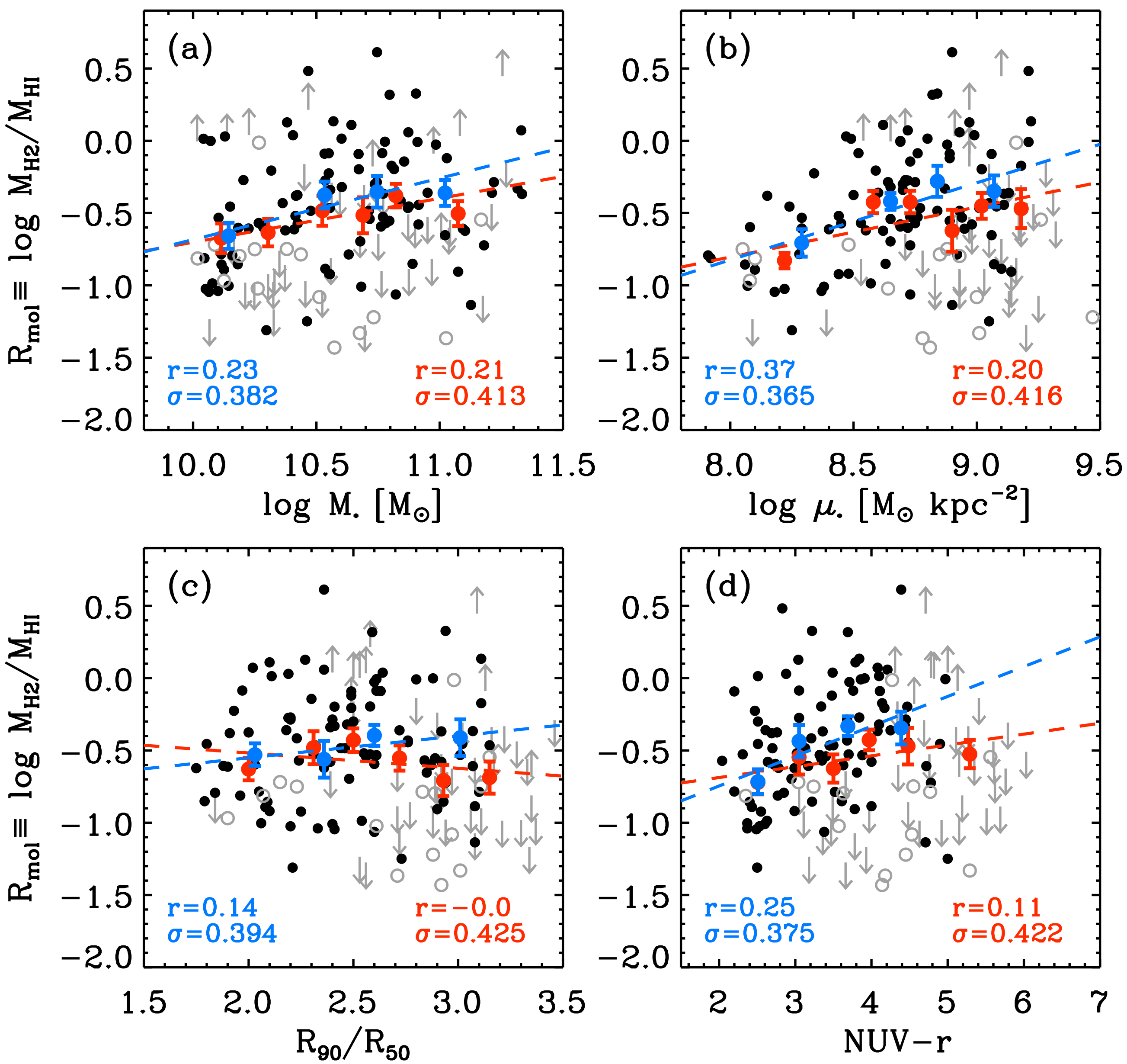
Catinella et al. (2010)

Above these thresholds (here NUV-r is shown), any significant cold gas found is in the atomic phase, not in the molecular phase. This conclusion is reinforced by the stacking of the CO non-detections.

the balance of atomic and molecular gas



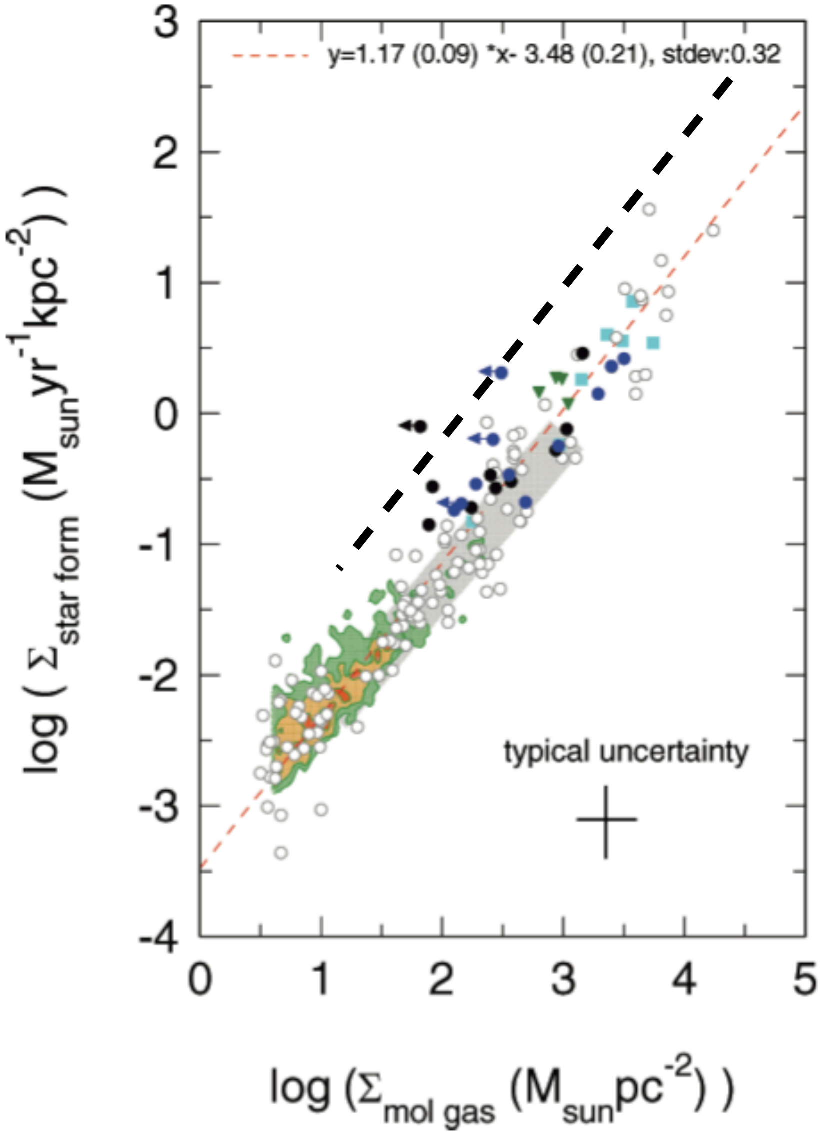
Saintonge et al. (2011a)



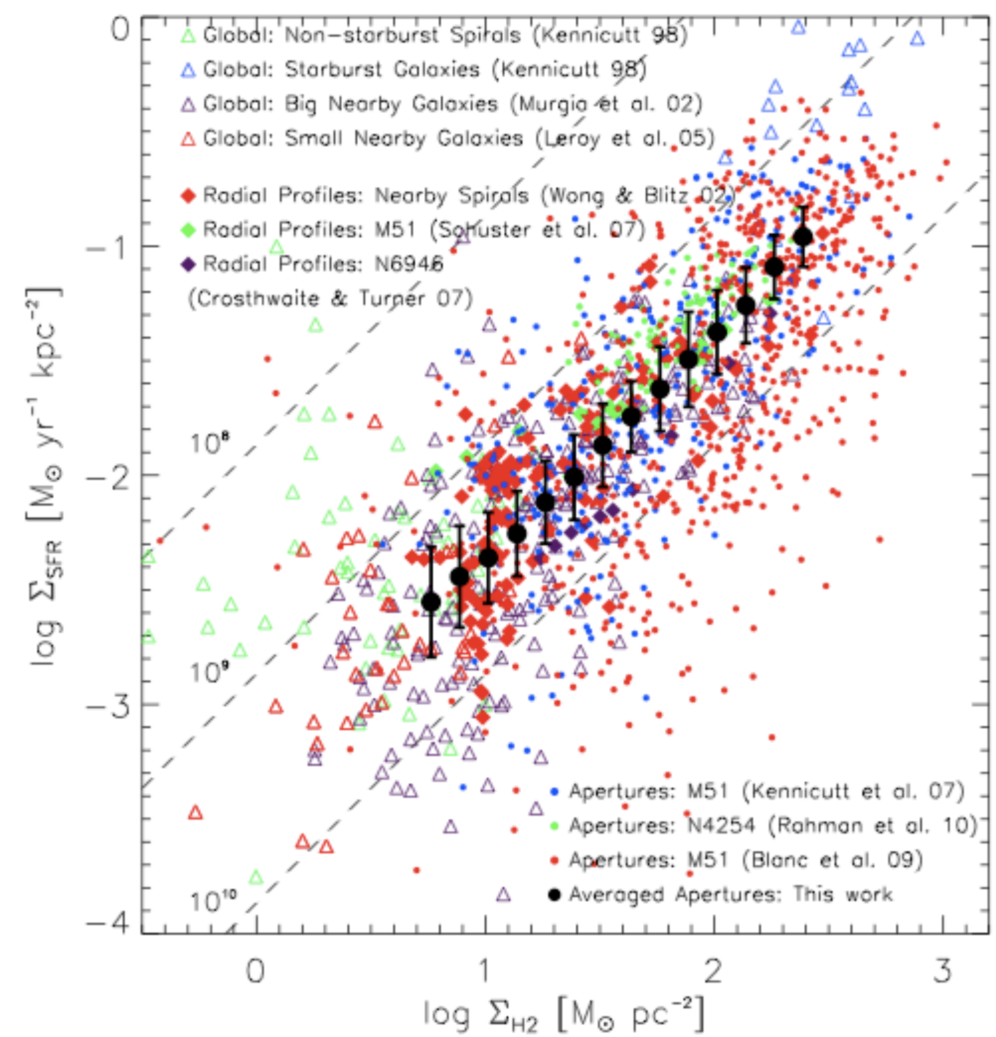
On average, $M_{H2}=0.3M_{HI}$ but huge galaxy-galaxy variations that do not correlate much with global physical parameters.

the balance between gas and star formation

Genzel et al. (2010)



Bigiel et al. (2011)



$$t_{dep}(H_2) = M_{H2}/SFR$$

↓

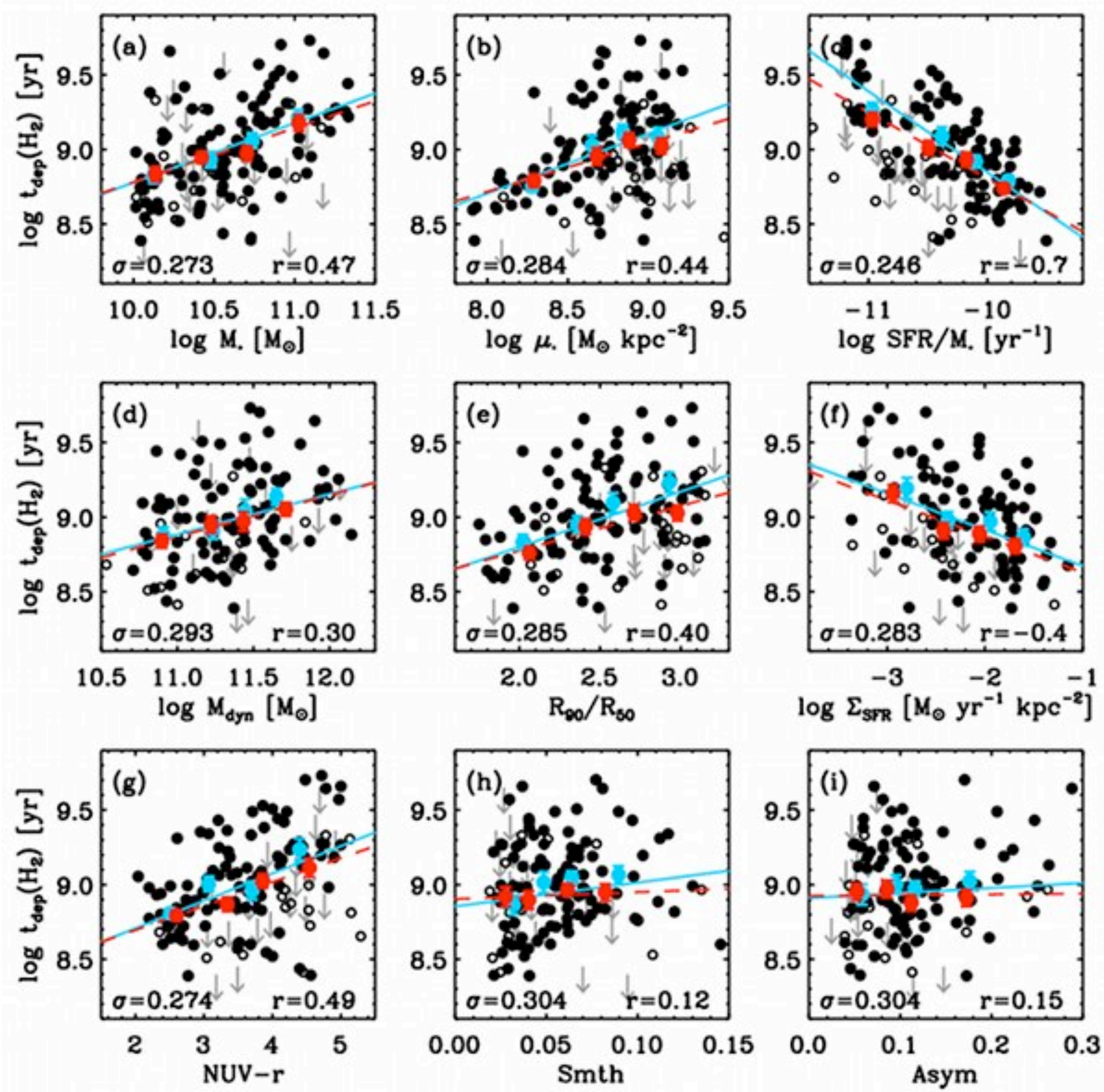
period of time over which star formation can be sustained at the current rate, assuming the system is closed

most previous studies find the molecular gas depletion time to be constant at ~1-2 Gyr for normal star-forming galaxies, both at low and high redshifts.

molecular gas depletion time variations

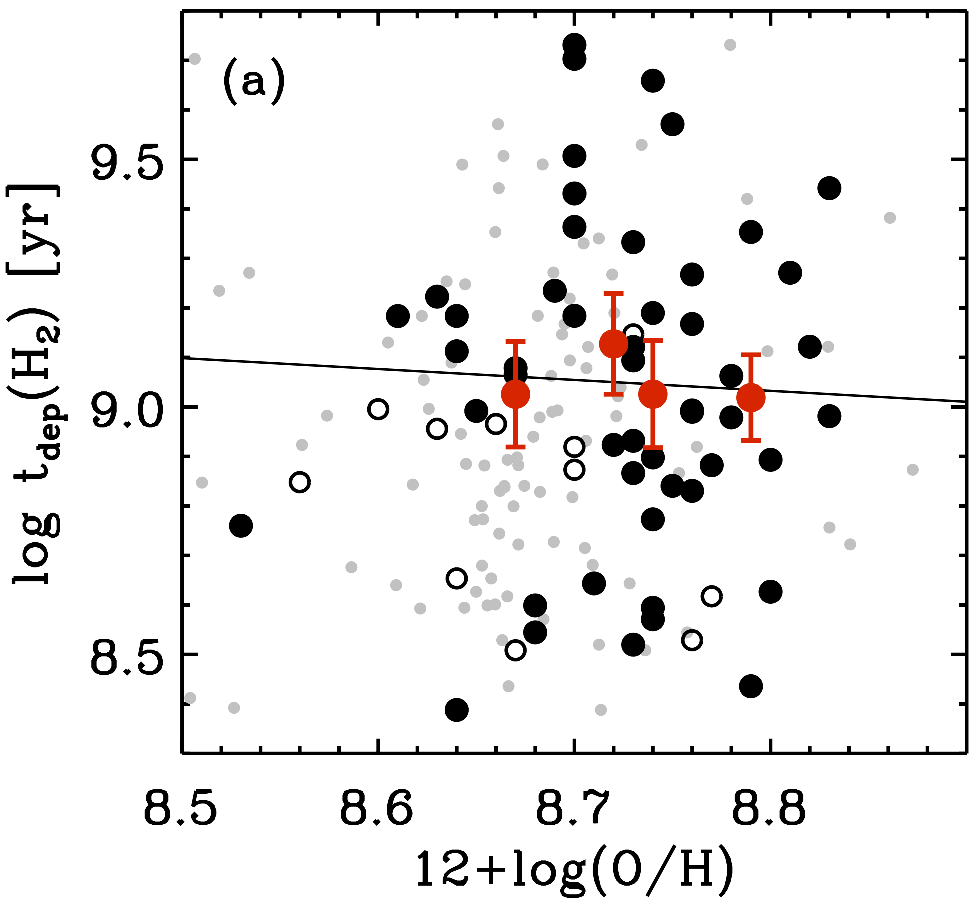
Within the COLD GASS sample, the molecular gas depletion time is found to vary with a large number of global parameters. The strongest dependencies are with quantities relating to star formation.

COLD GASS can find these trends, which were not seen in previous samples, because of the broader parameter spacesit covers (e.g. in mu* and SSFR), being a complete mass-limited sample.

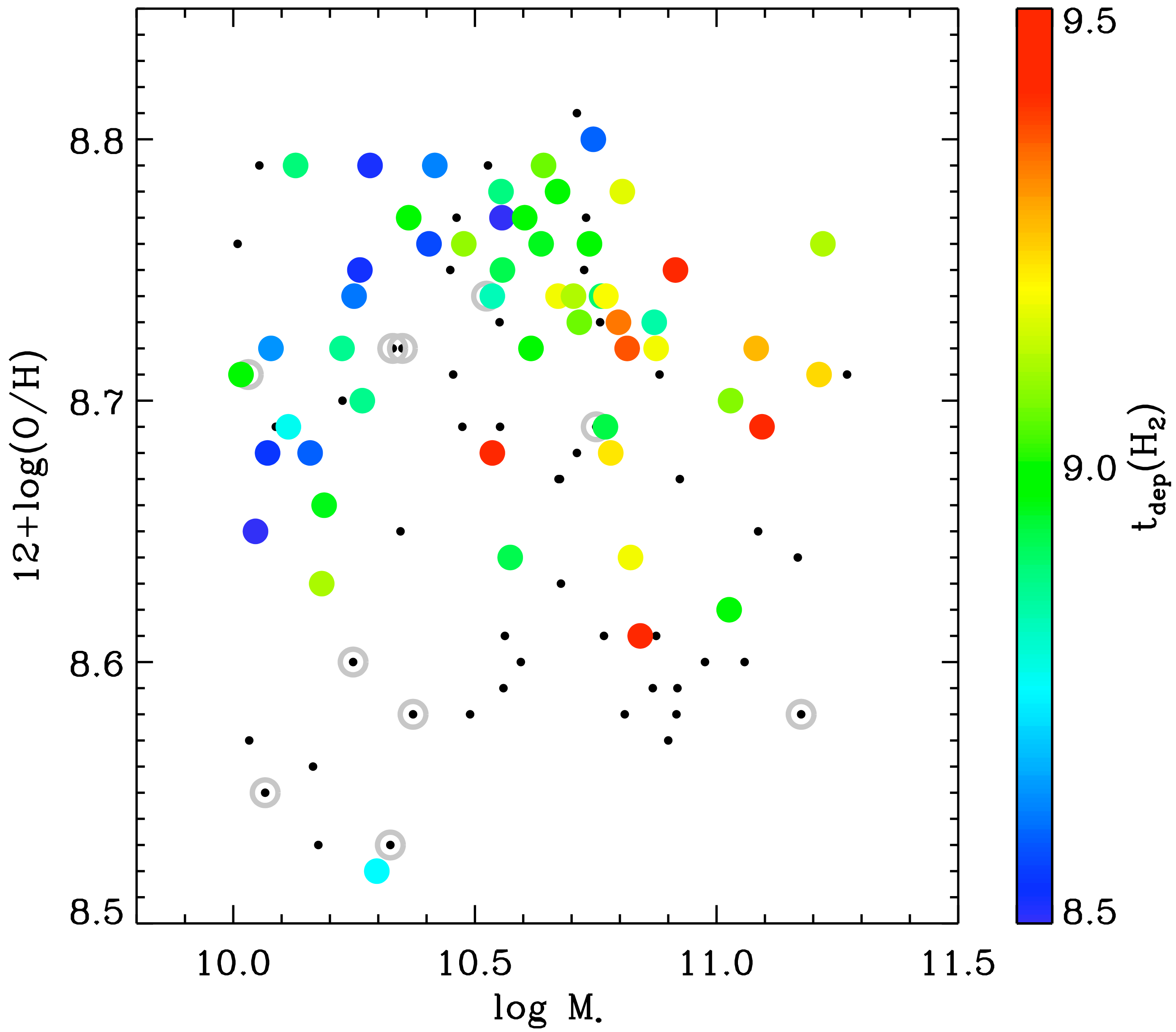


Saintonge et al. (2011b)

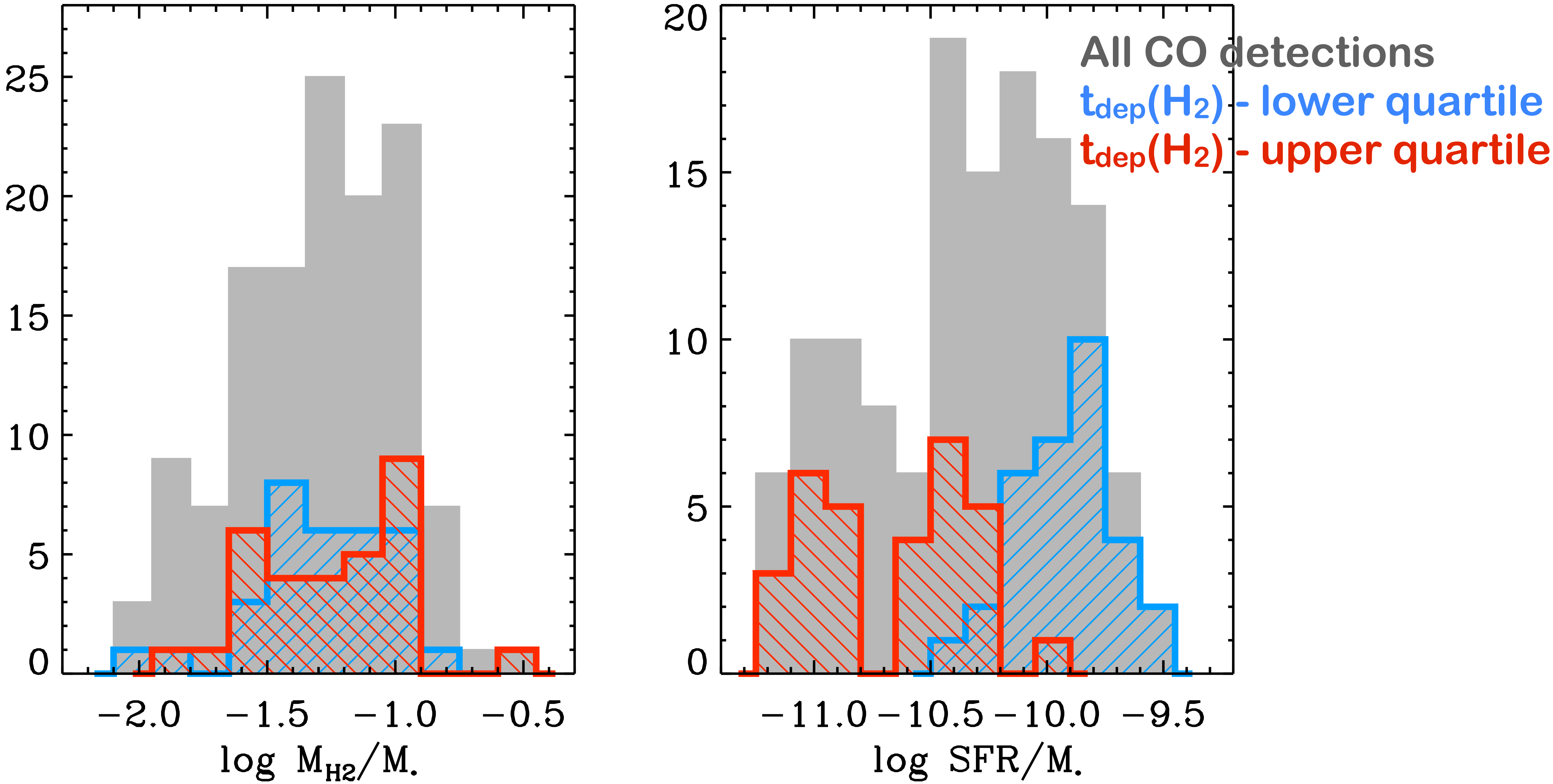
a metallicity effect on X_{CO}?



The molecular gas depletion time does not appear to depend on metallicity *within our mass range*. In the mass-metallicity plane, it is clear that variations in tdep happen along the mass axis, and not the Z axis.

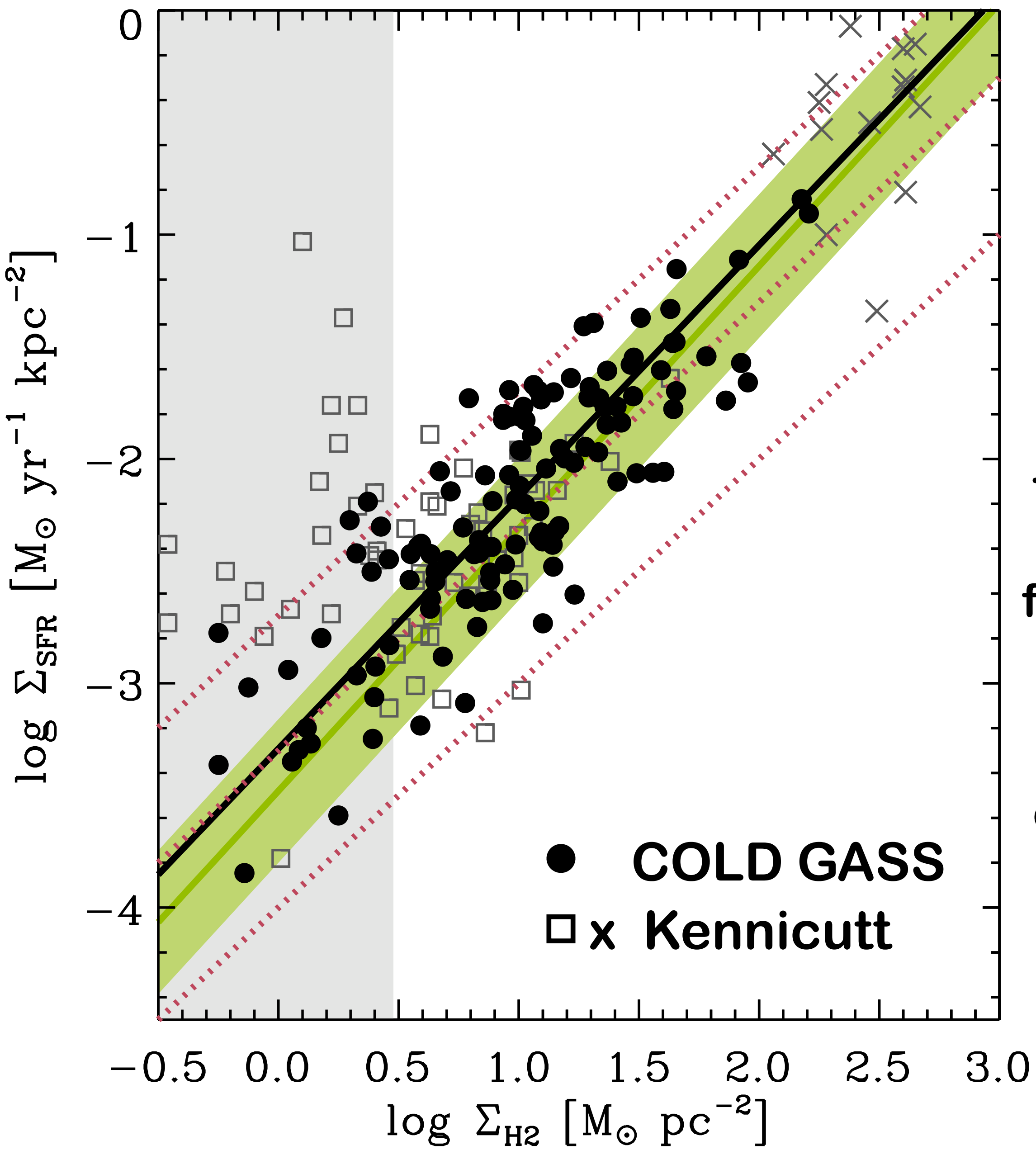


a metallicity effect on X_{CO}?



No evidence for metallicity effects on X_{CO}
(within our sample of massive galaxies!)

the global star formation law

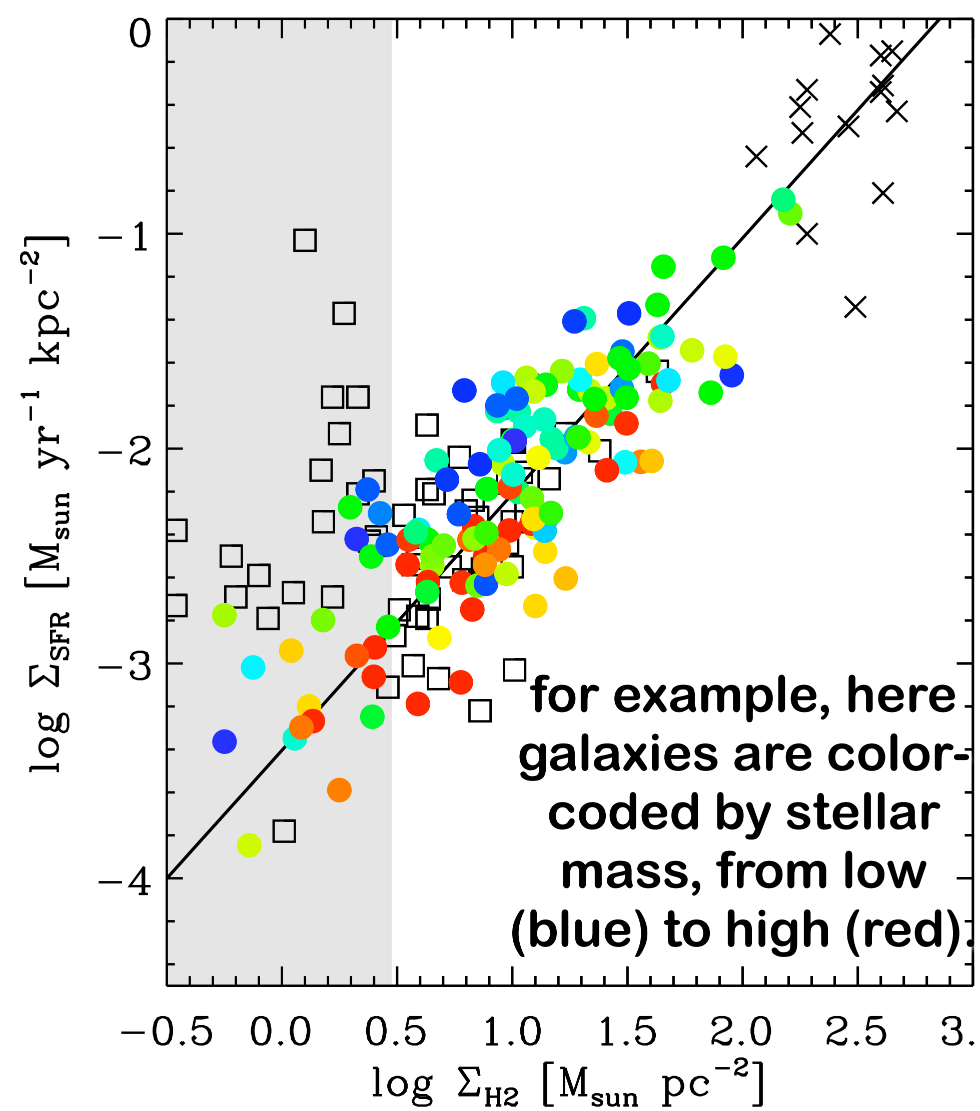


Genzel et al. (2010):
y=1.17x-3.48
standard deviation: 0.32

COLD GASS:
y=1.20x-3.42,
standard deviation: 0.32

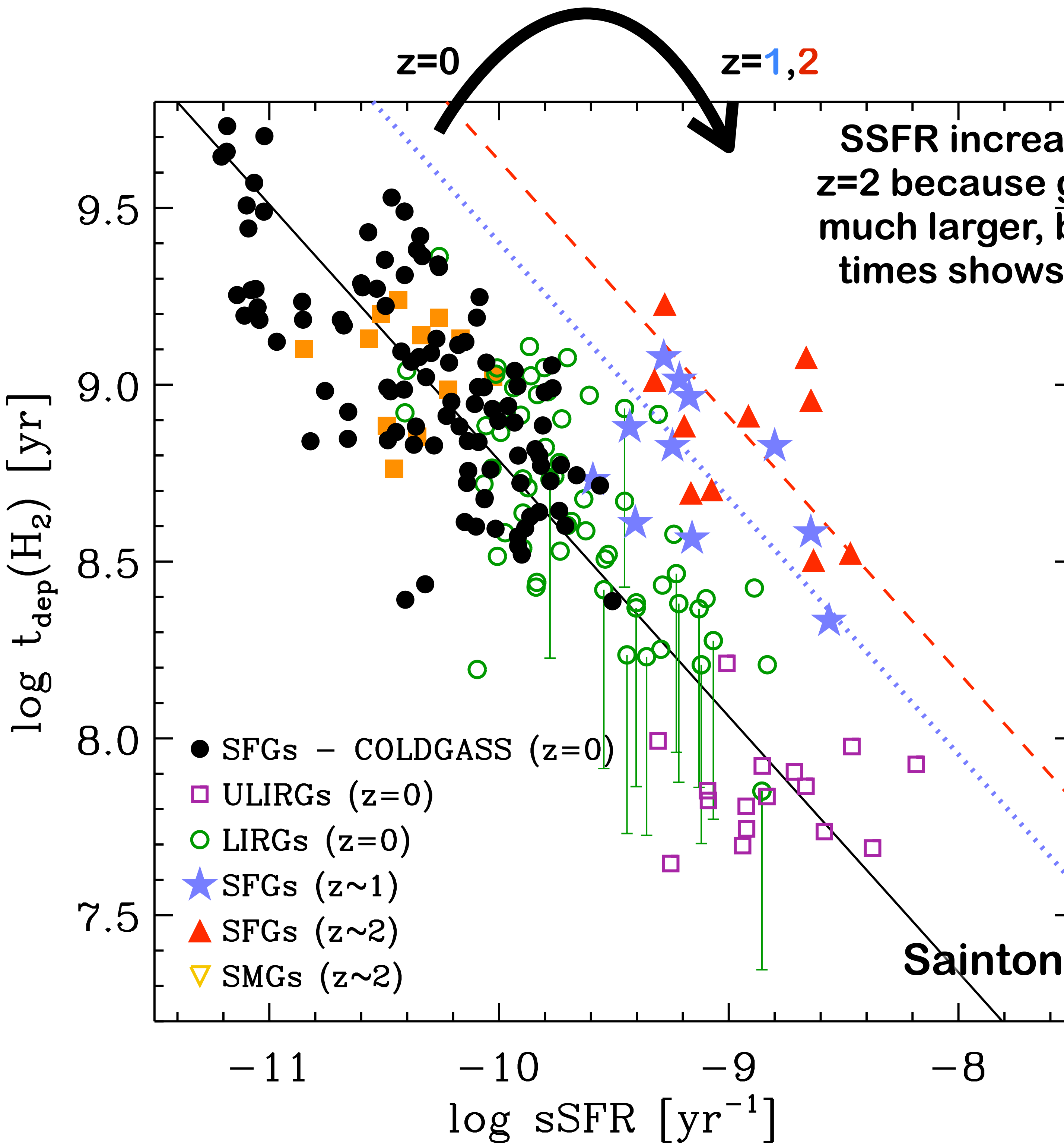
The scatter and slope of the KS relation found previously using various compilations of galaxies is reproduced by the complete COLDGASS sample.

But thanks to the size and homogeneity of the sample, we are starting to see some structure in the scatter about the relation.



linking the various galaxy populations

at z=0, the depletion time decreases from the value of 1Gyr found in normal star-forming galaxies to the value of <100Myr found in major mergers (ULIRGs). The population of local LIRGs appears to extend the trend between these two extrmes.

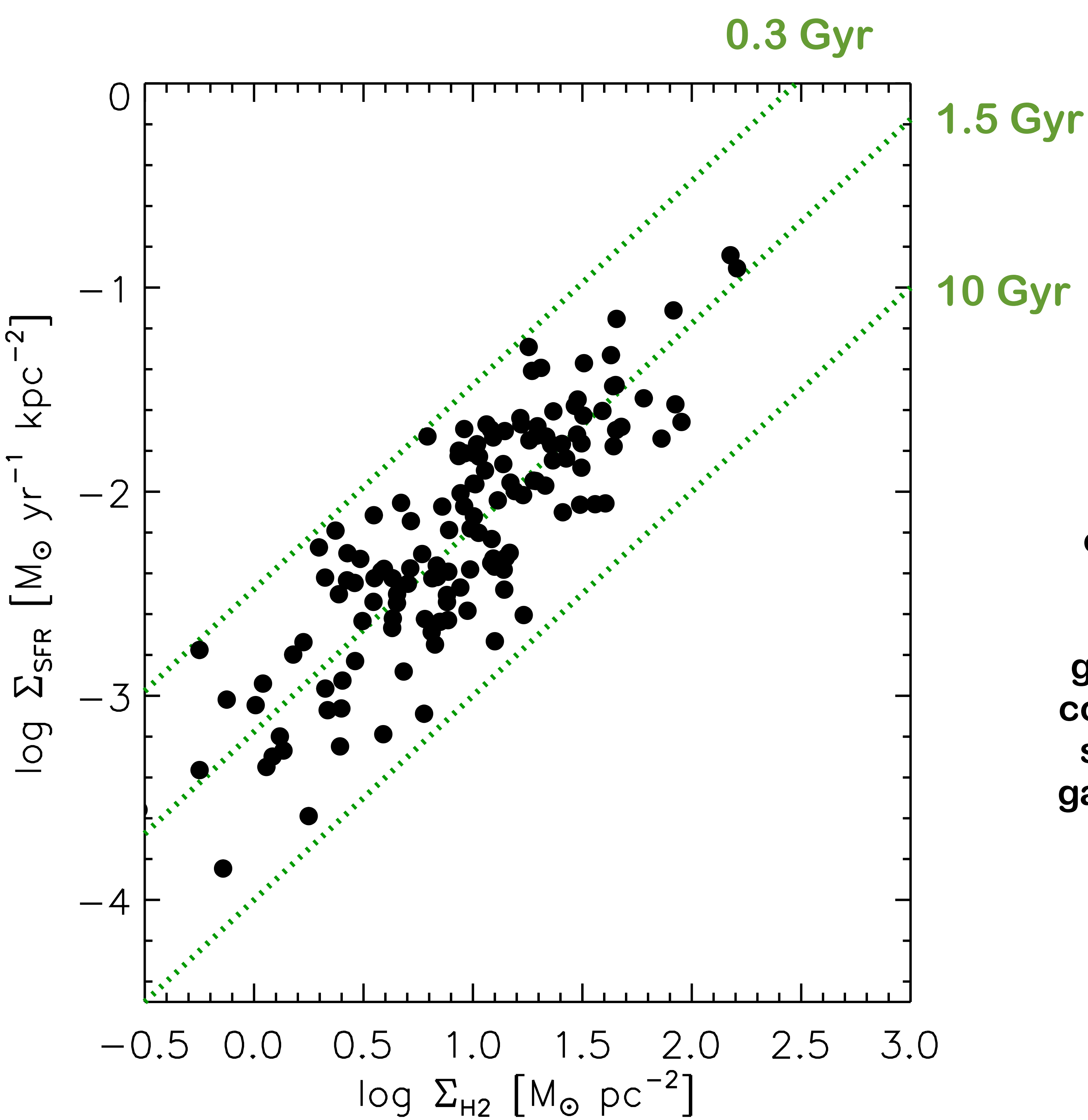


SSFR increases from z=0 to z=2 because gas fractions are much larger, but the depletion times shows little evolution.

Saintonge et al. (2011b)

data from: Leroy et al. (2009), Howell et al. (2010), da Cunha et al. (2010), Genzel et al. (2010), Hainline et al. (2010), Saintonge et al. (2011b)

explaining the depletion time variations

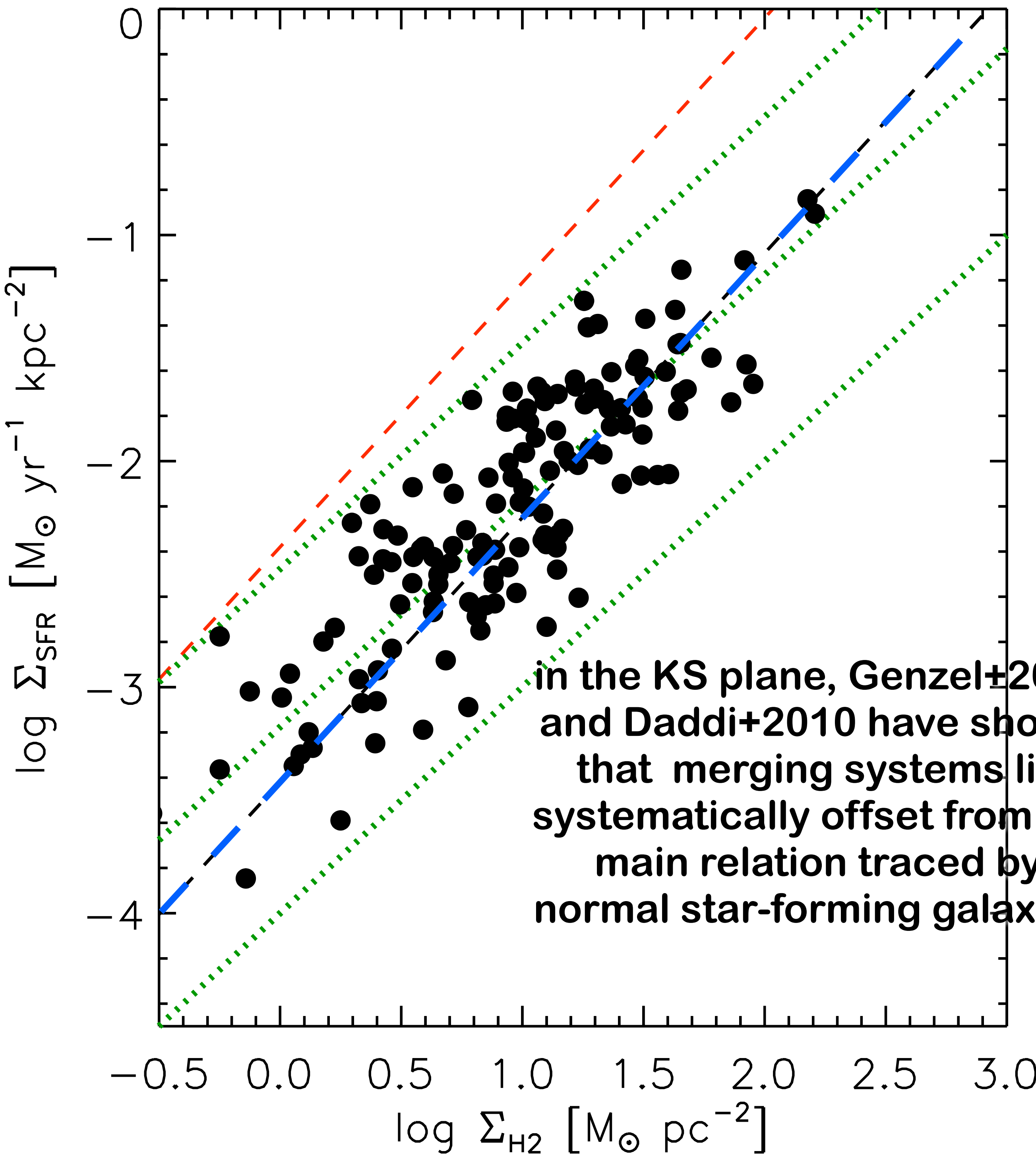


on average, the molecular gas depletion time is ~1.5 Gyr, but large galaxy-to-galaxy variations within our complete and representative sample of M*>10^10 Msun galaxies, with values ranging from 300 Myr to ~10 Gyr.

explaining the depletion time variations

merging galaxies

normal starforming galaxies

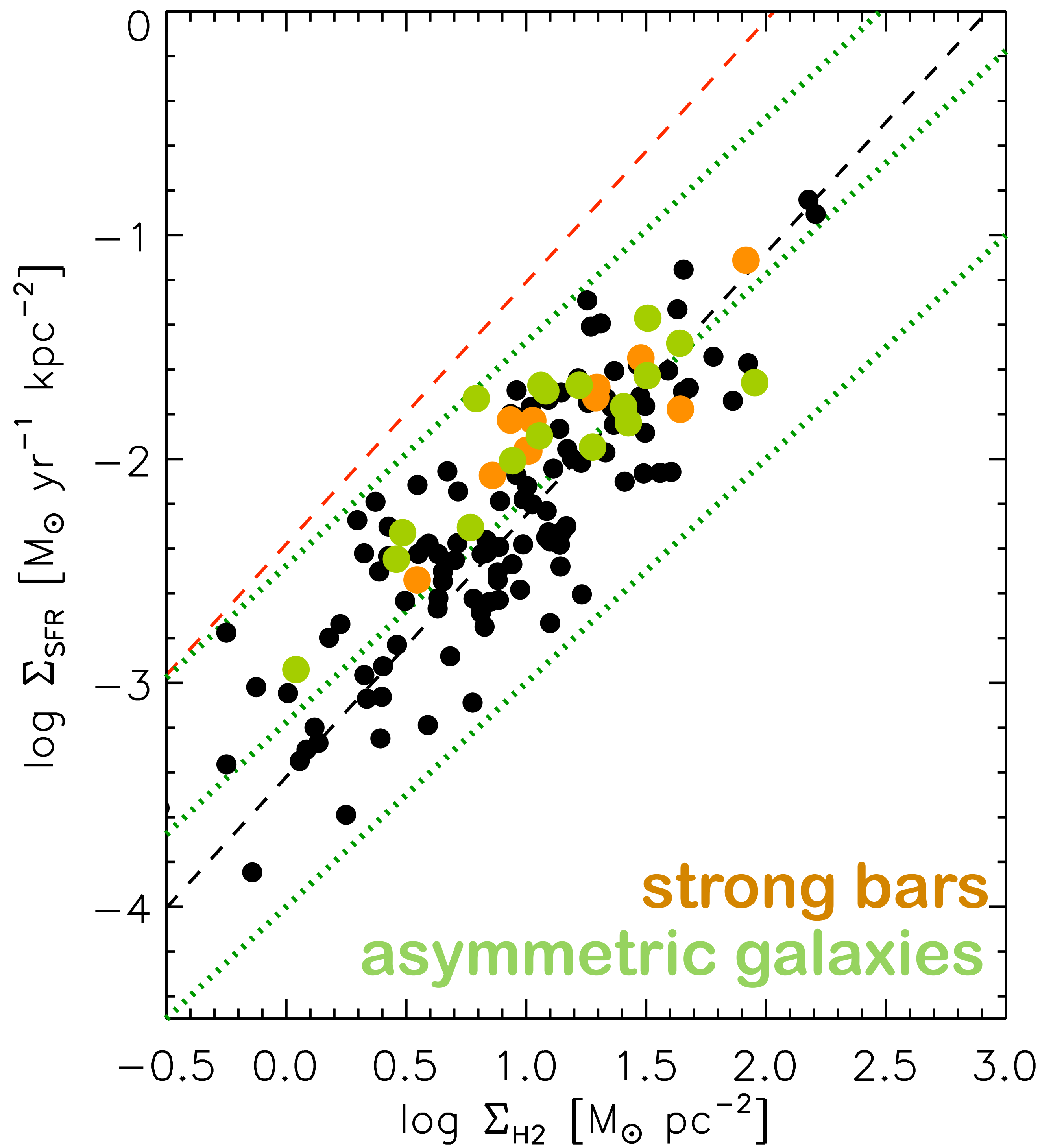


in the KS plane, Genzel+2010 and Daddi+2010 have shown that merging systems lie systematically offset from the main relation traced by normal star-forming galaxies.

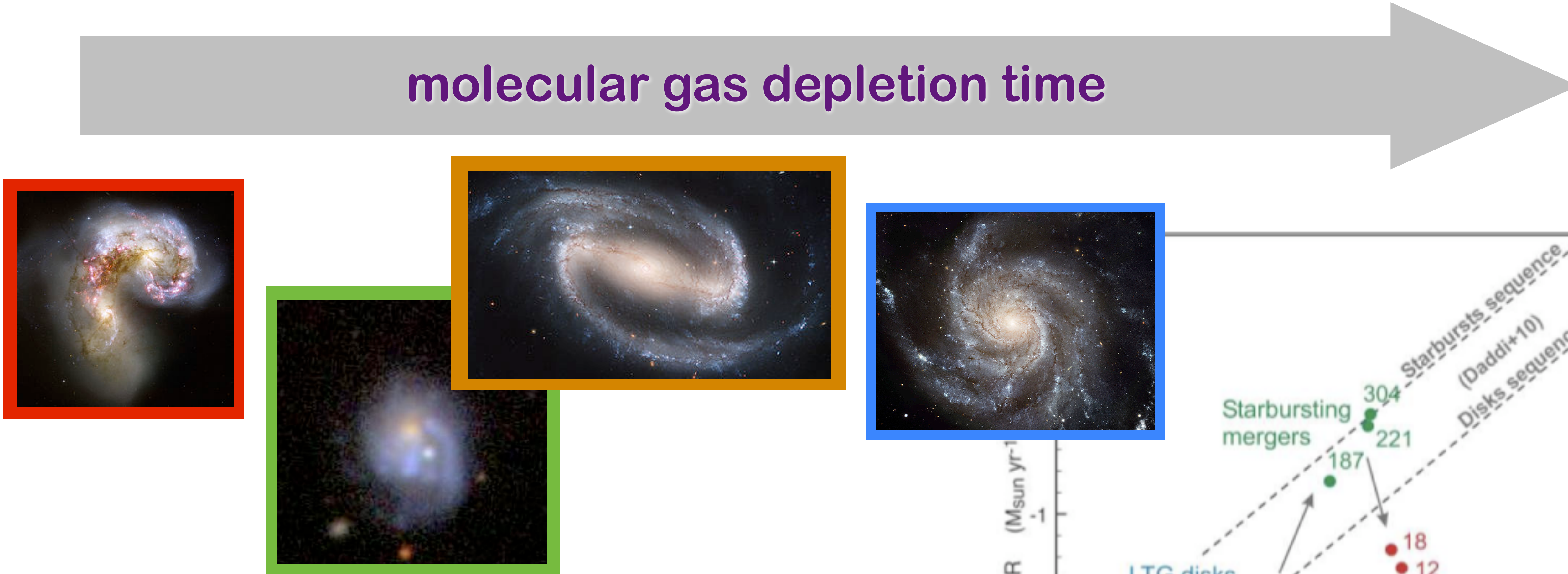
explaining the depletion time variations

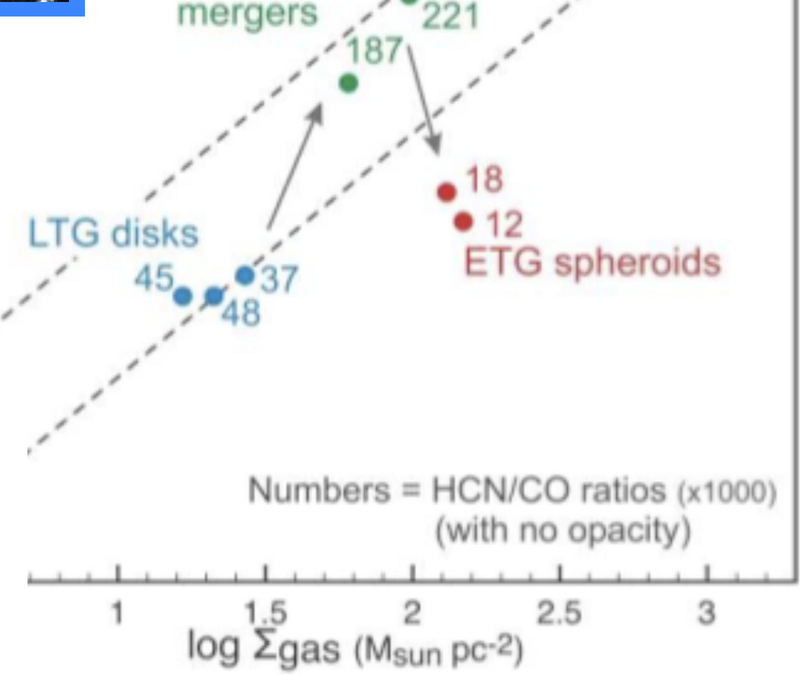
can we explain the scatter within the normal population along these same lines? Since the galaxies with the strongest dynamical disturbances (major mergers) lie the farthest off the main KS relation, what about the galaxies with more minor disturbances?

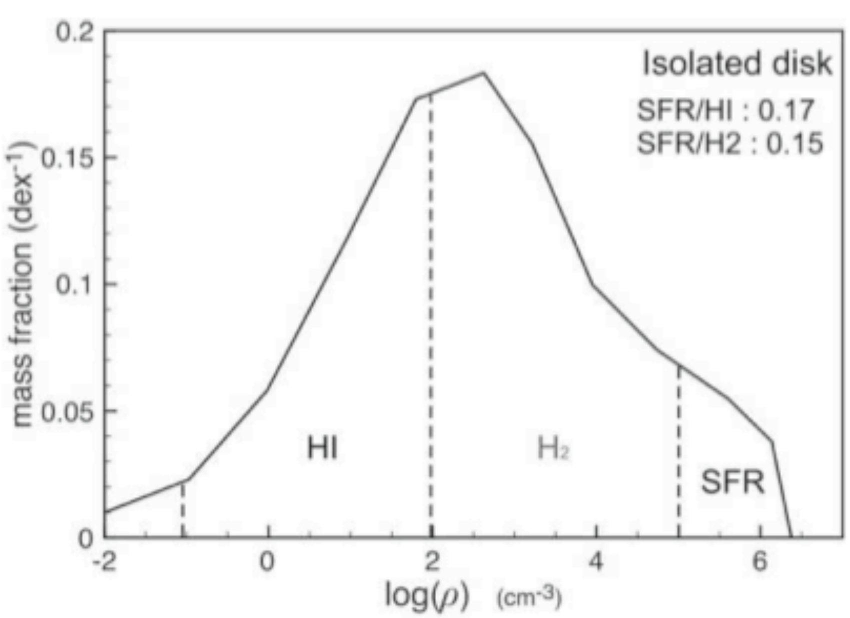
indication in the COLD GASS sample that the galaxies with strong bars and marked lopsidedness then to lie on the short depletion time side of the relation, toward the branch traced by the major mergers.

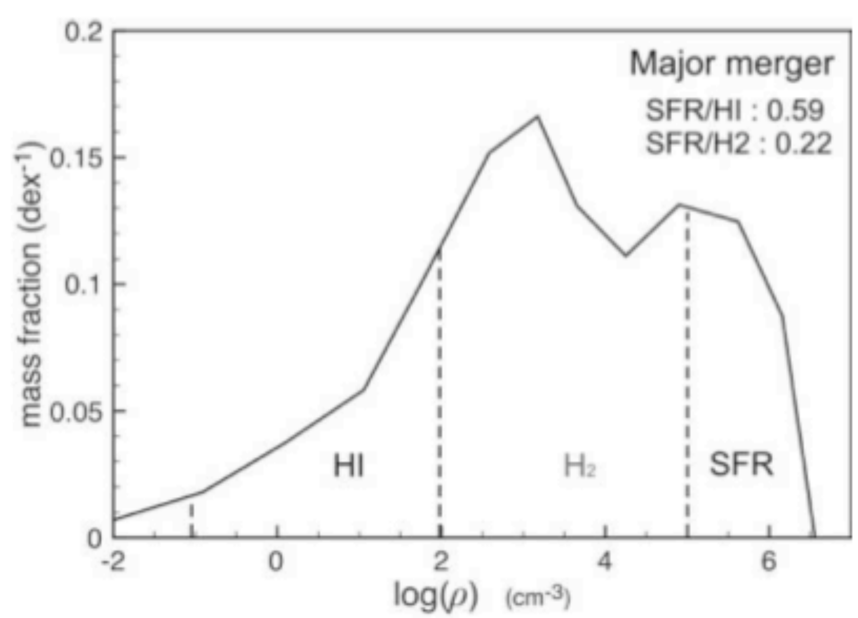


explaining the depletion time variations









Bournaud (2011)

also Martig et al. (2009), Crocker et al. (2011)

summary

- COLD GASS offers a complete view of the balance between HI, H_2 and stars in massive galaxies
- There are sharp thresholds in galaxy properties, above which any cold gas is found in the atomic phase.
- The molecular depletion timescale is not universal: varies from ~500Myr to 3Gyr in the mass range of 10^{10} to $10^{11.5}$ M_{sun}.
- The t_{dep}-sSFR relation extends smoothly from the normal COLD GASS galaxies to nearby LIRGs and ULIRGs
- Normal galaxies at z=1,2 are displaced from this plane, having longer depletion times at fixes sSFR, owing to their large gas fractions.
- At z=0, t_{dep} variations among star forming disks can be explained in part by a range of dynamical processes.