THE METALLICITY – GAS CONTENT CONNECTION

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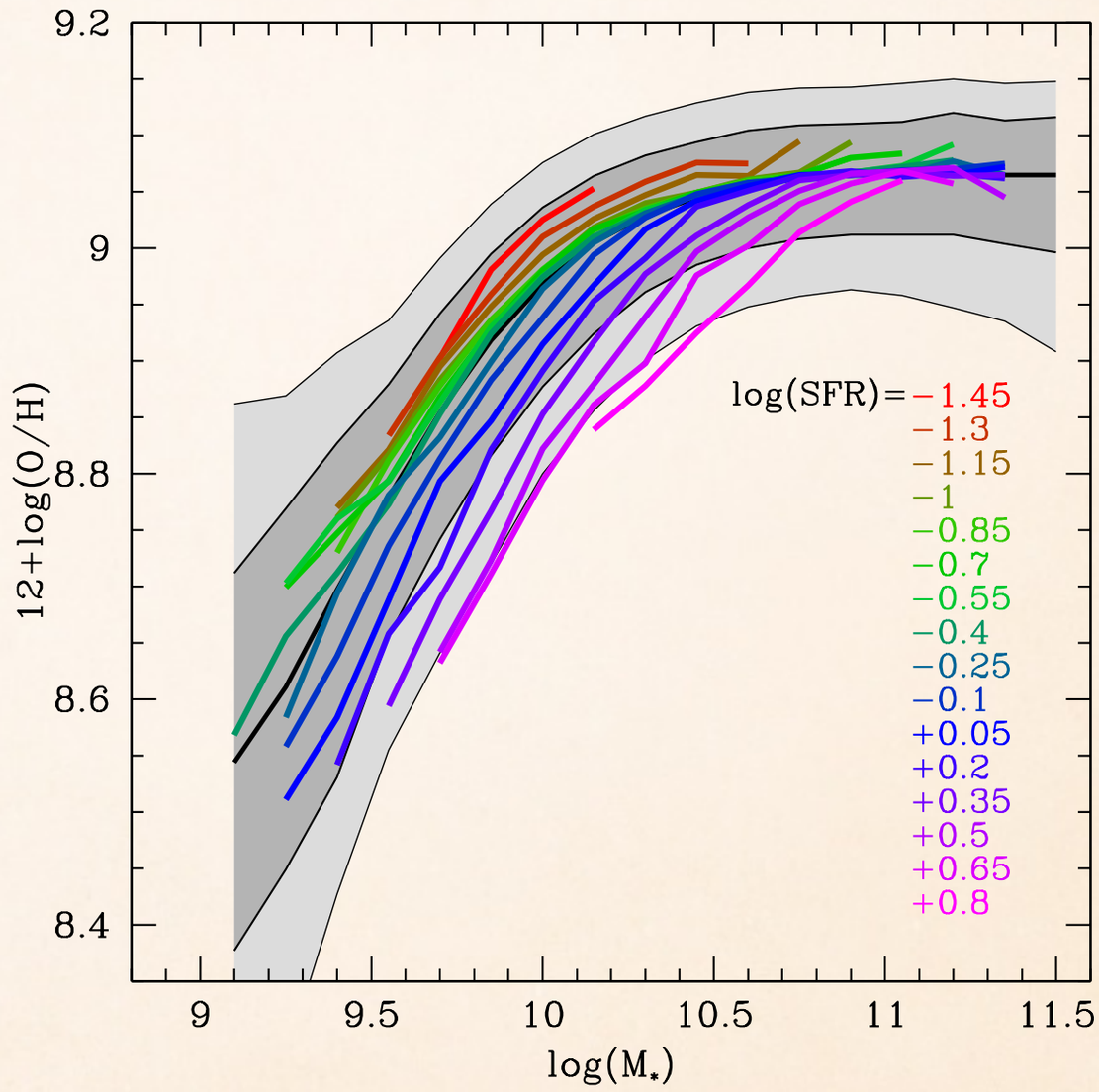
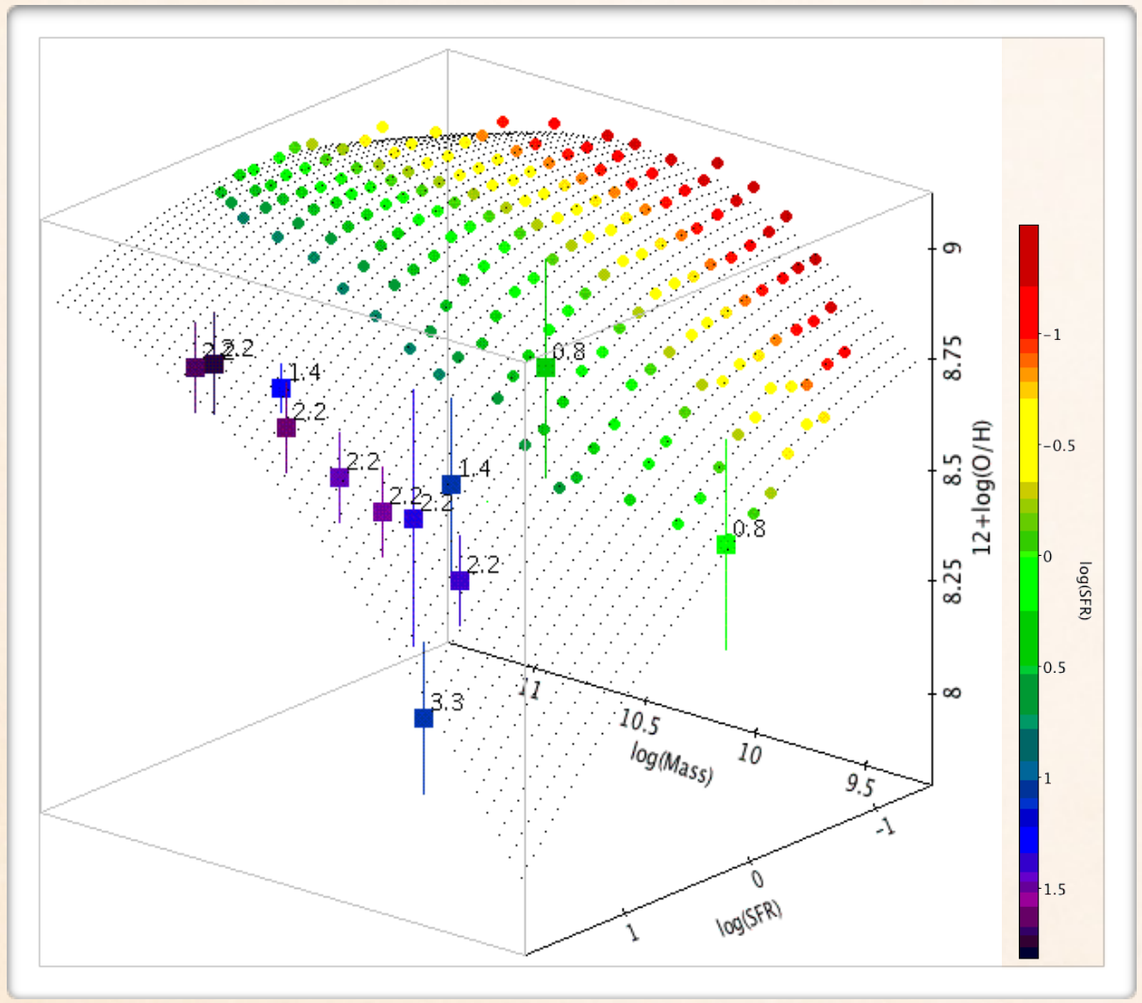
EXTENDING THE M*-Z RELATION

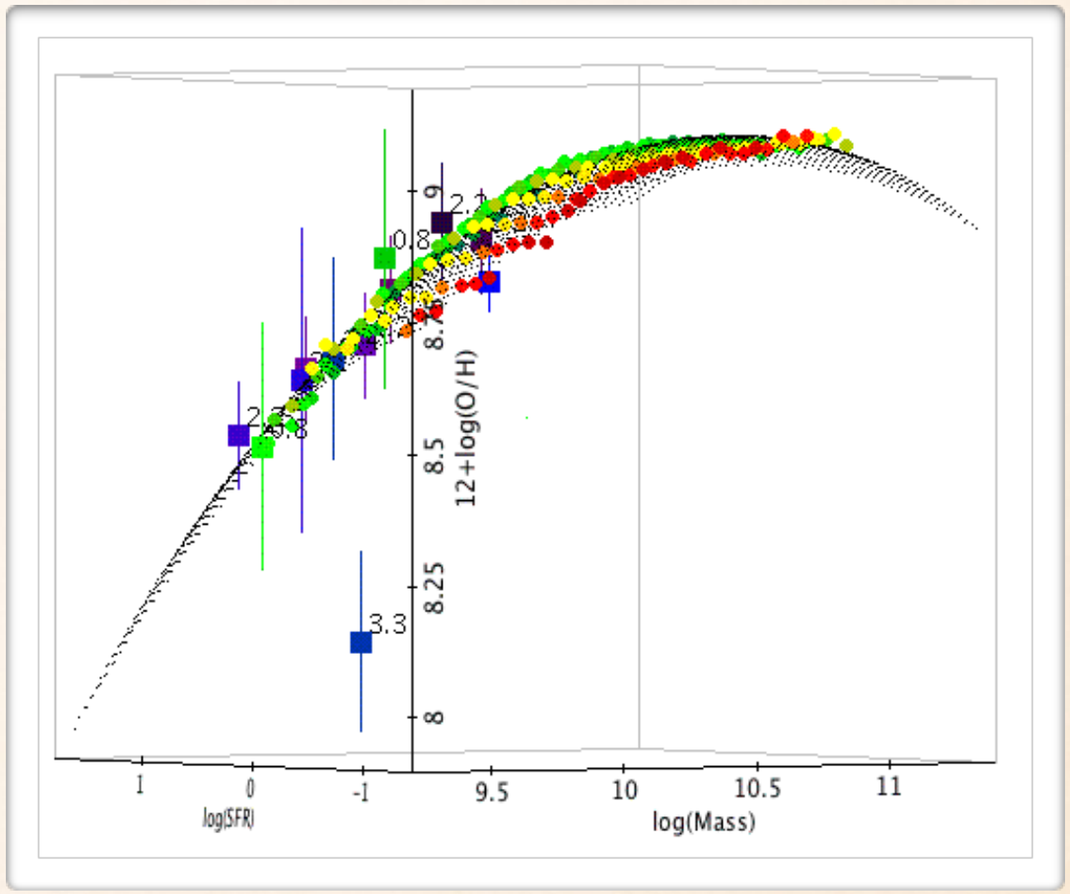
- Two papers in 2010: Mannucci et al. and Lara-Lopez et al.
- The scatter in the M-Z relation correlates with SFR



(Mannucci+10)

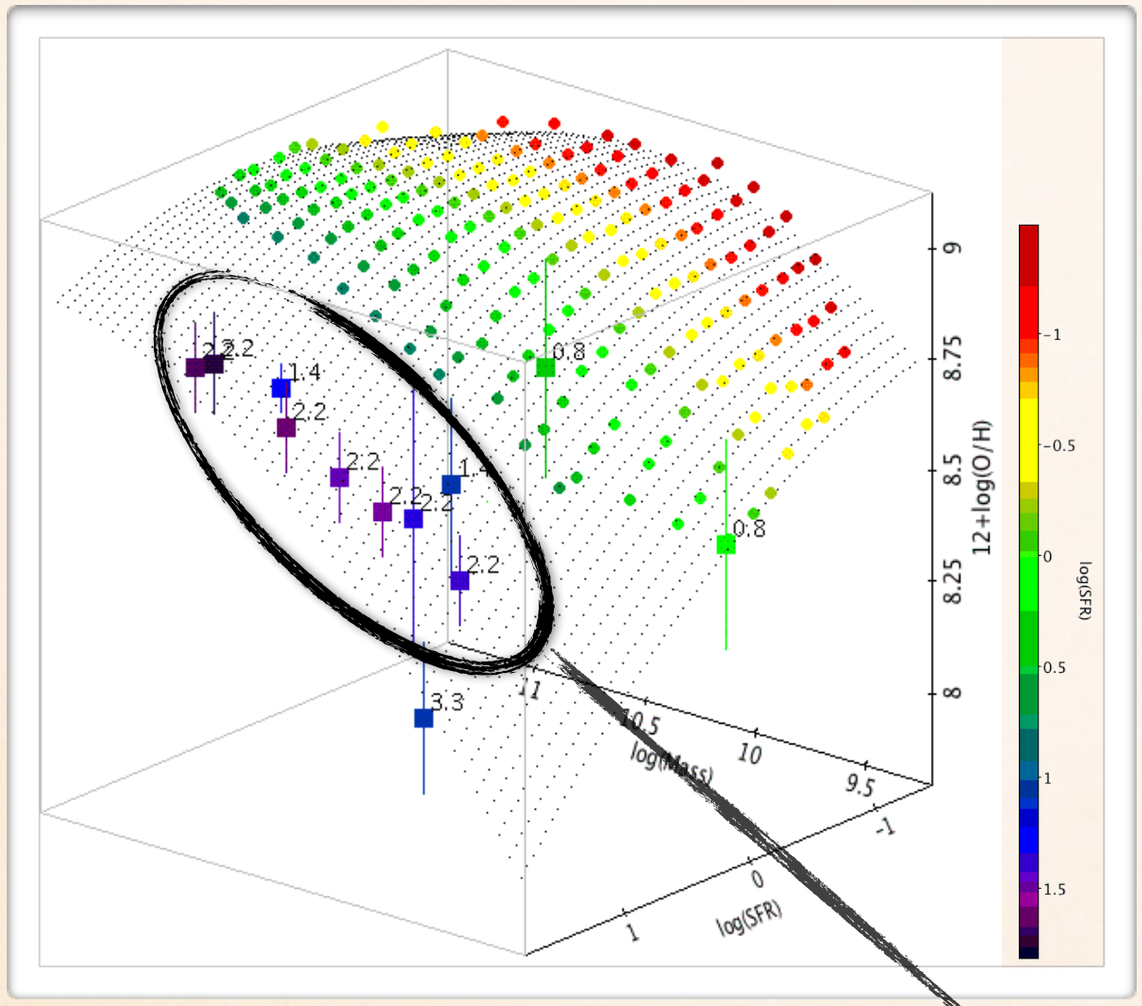
EXTENDING THE M*-Z RELATION

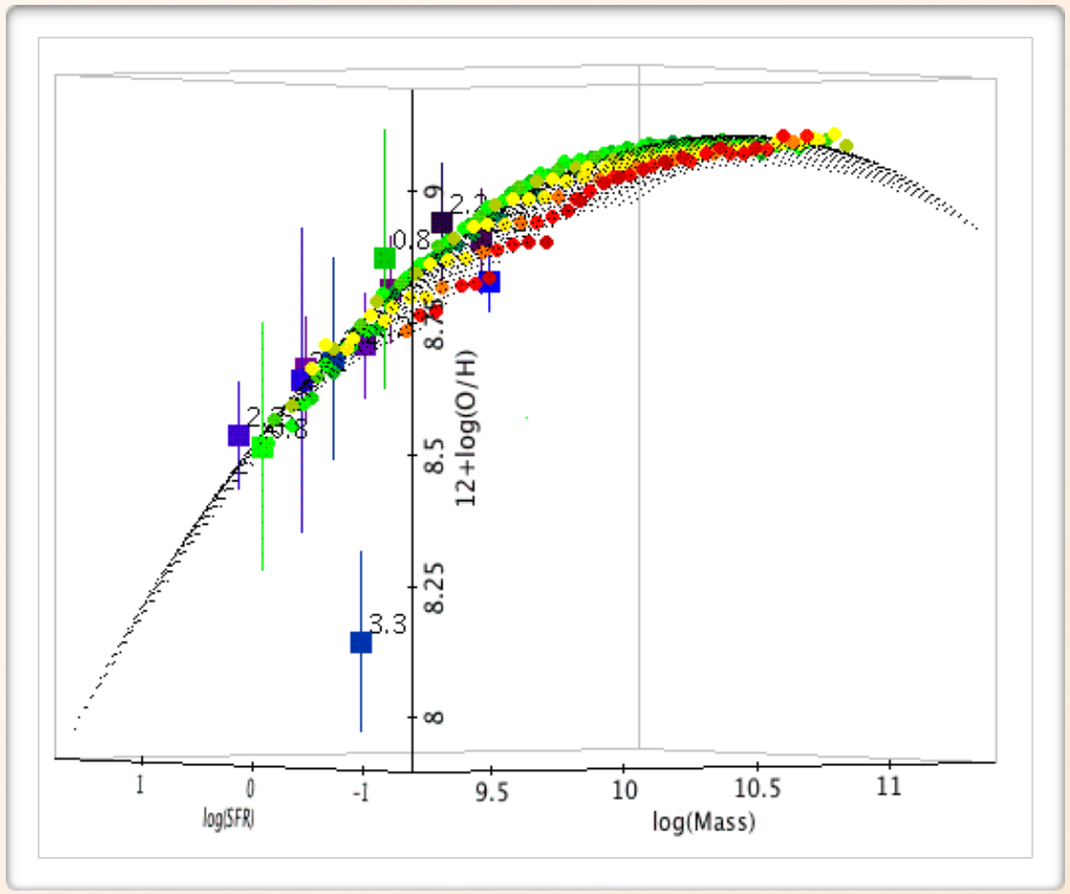




(Mannucci+10)

EXTENDING THE M*-Z RELATION

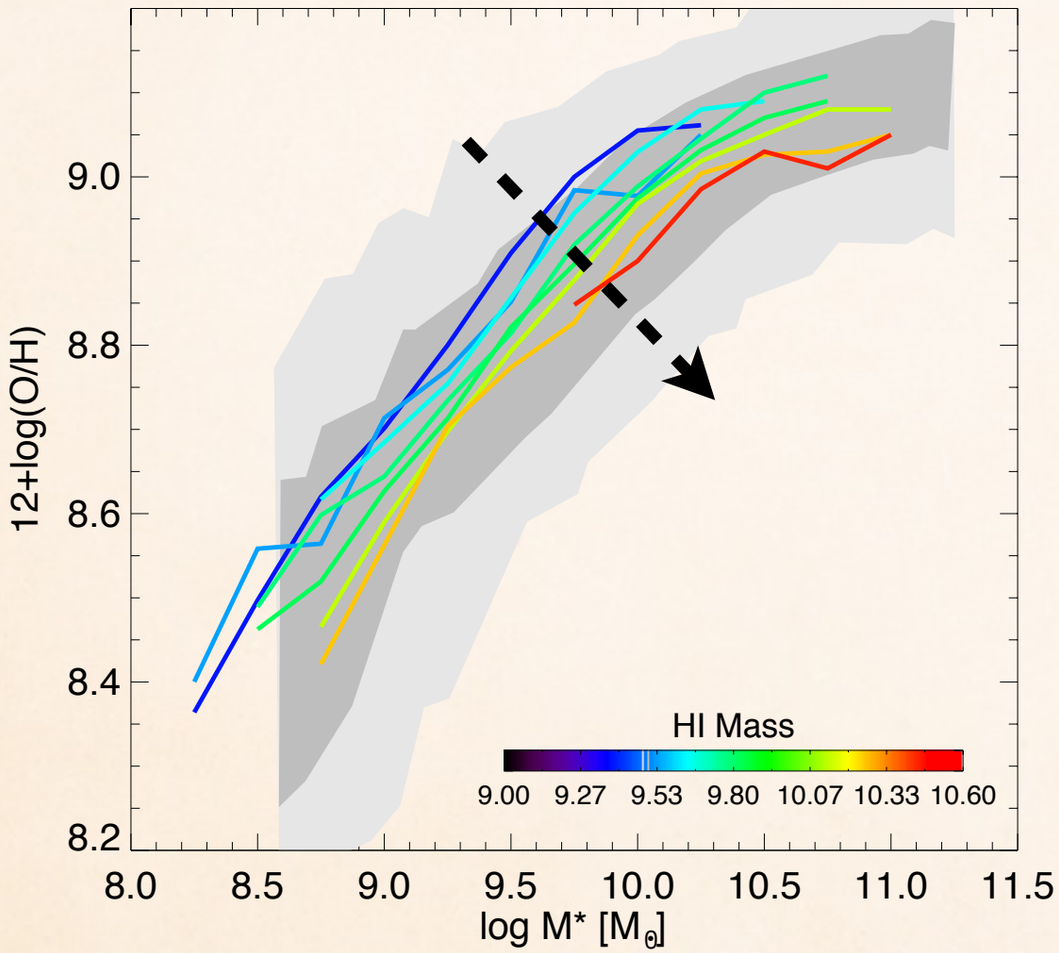


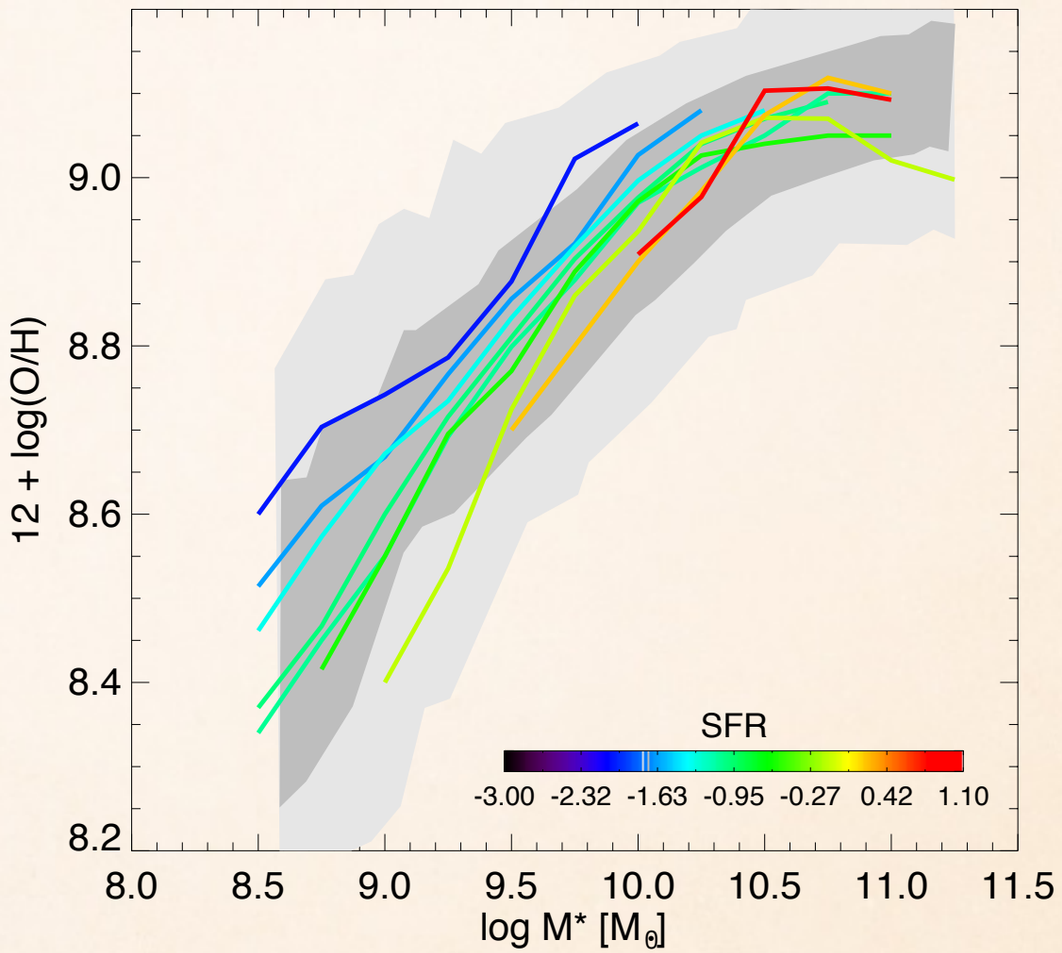


No evolution out to z ~ 2.5?

(Mannucci+10)

A HI FMR?



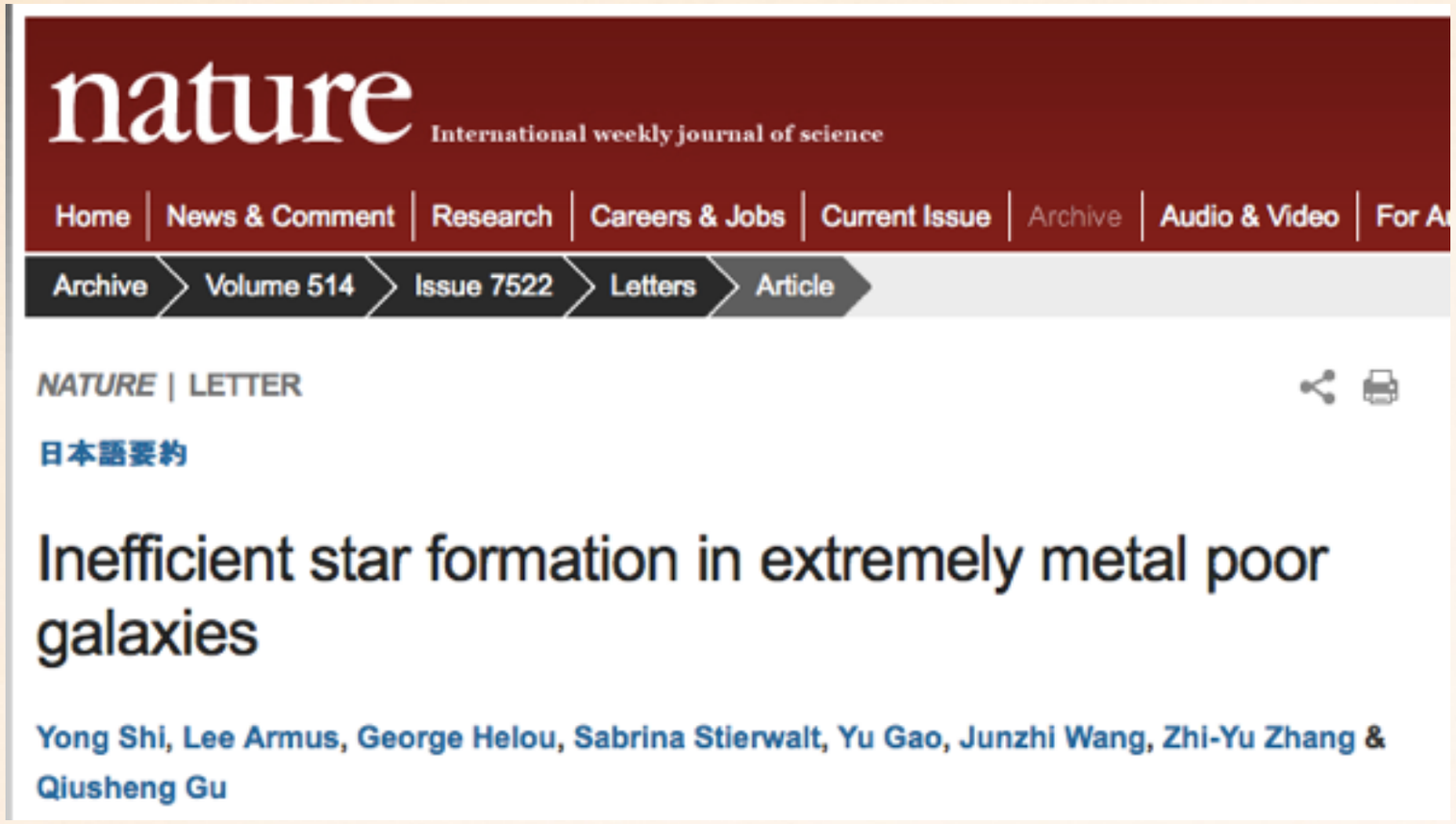


(Bothwell+13)

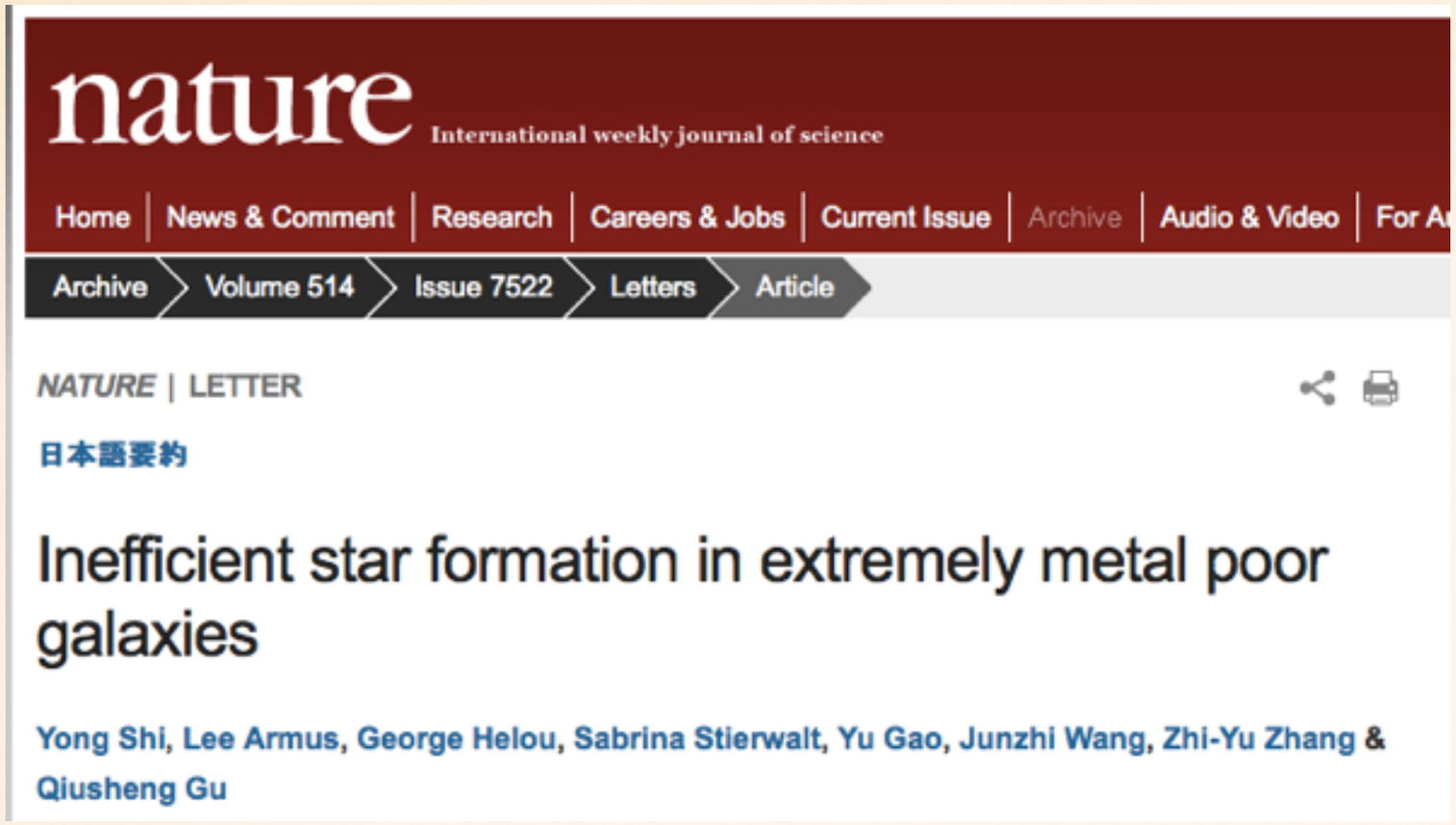
MOLECULAR GAS...

- H_2 is more correlated with star formation, and expected based on SFR-FMR

- BUT, statistically more challenging...



Shi et al. (2015)
Low SFE at low metallicity



Shi et al. (2015)
Low SFE at low metallicity

Dib et al. (2011)
Low SFE at HIGH metallicity

THE APEX LOW REDSHIFT LEGACY SURVEY FOR MOLECULAR GAS

ALLSMOG

THE APEX LOW REDSHIFT LEGACY SURVEY FOR MOLECULAR GAS

ALLSMOG

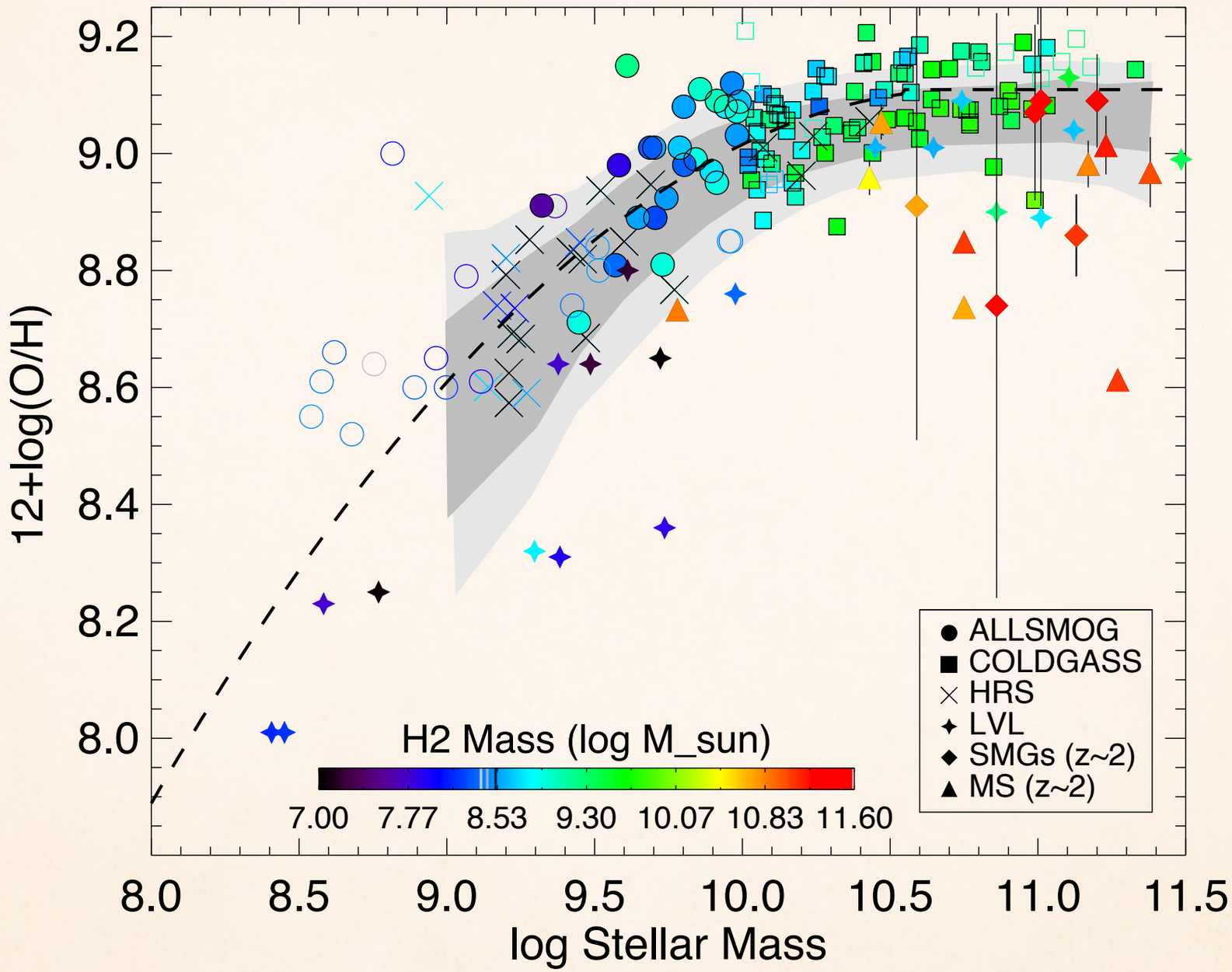
- Selected from SDSS, requiring a well-defined metallicity
- All spectra publicly available at www.mrao.cam.ac.uk/ALLSMOG
- Bothwell et al. (2014)

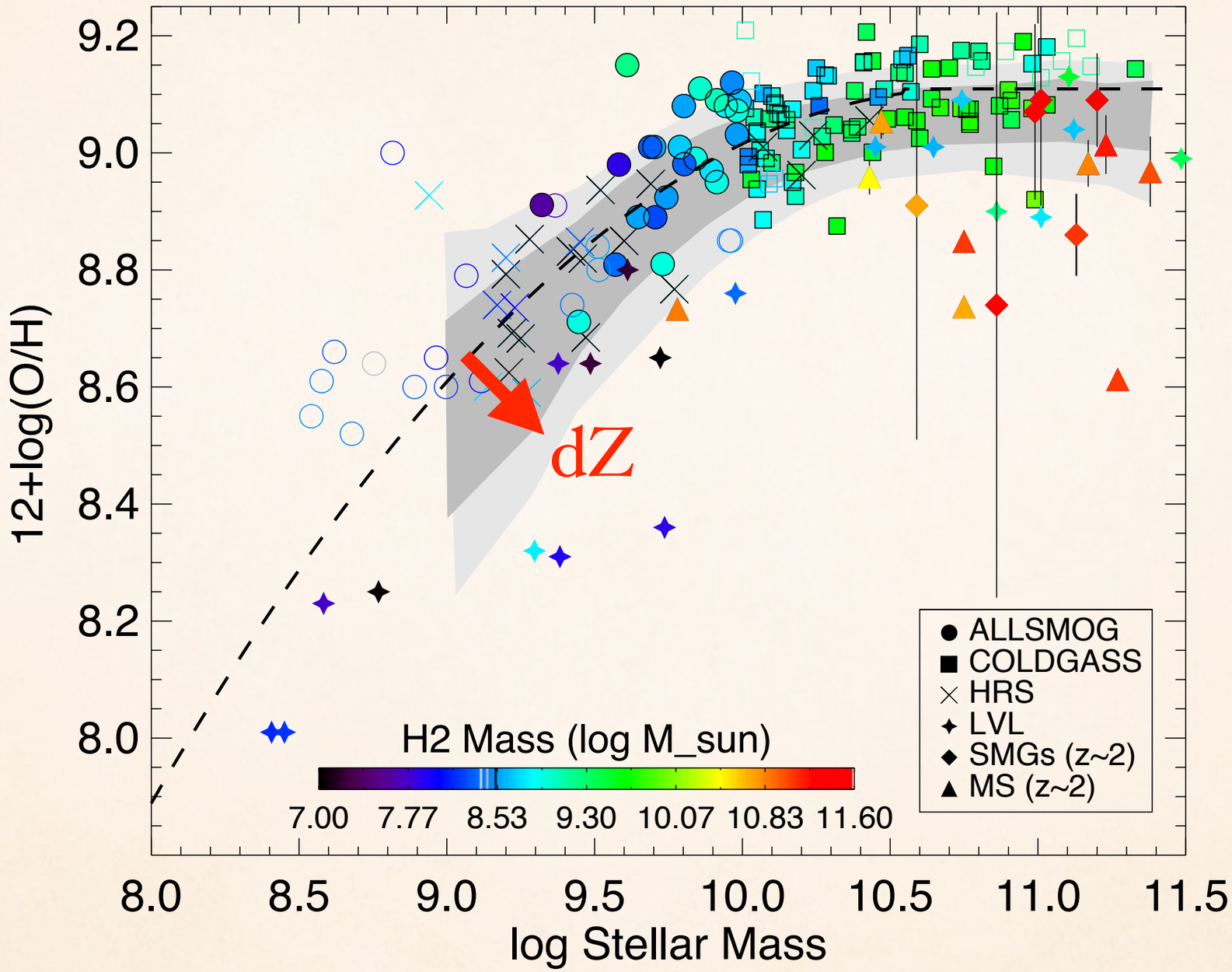
H2 AND METALLICITY

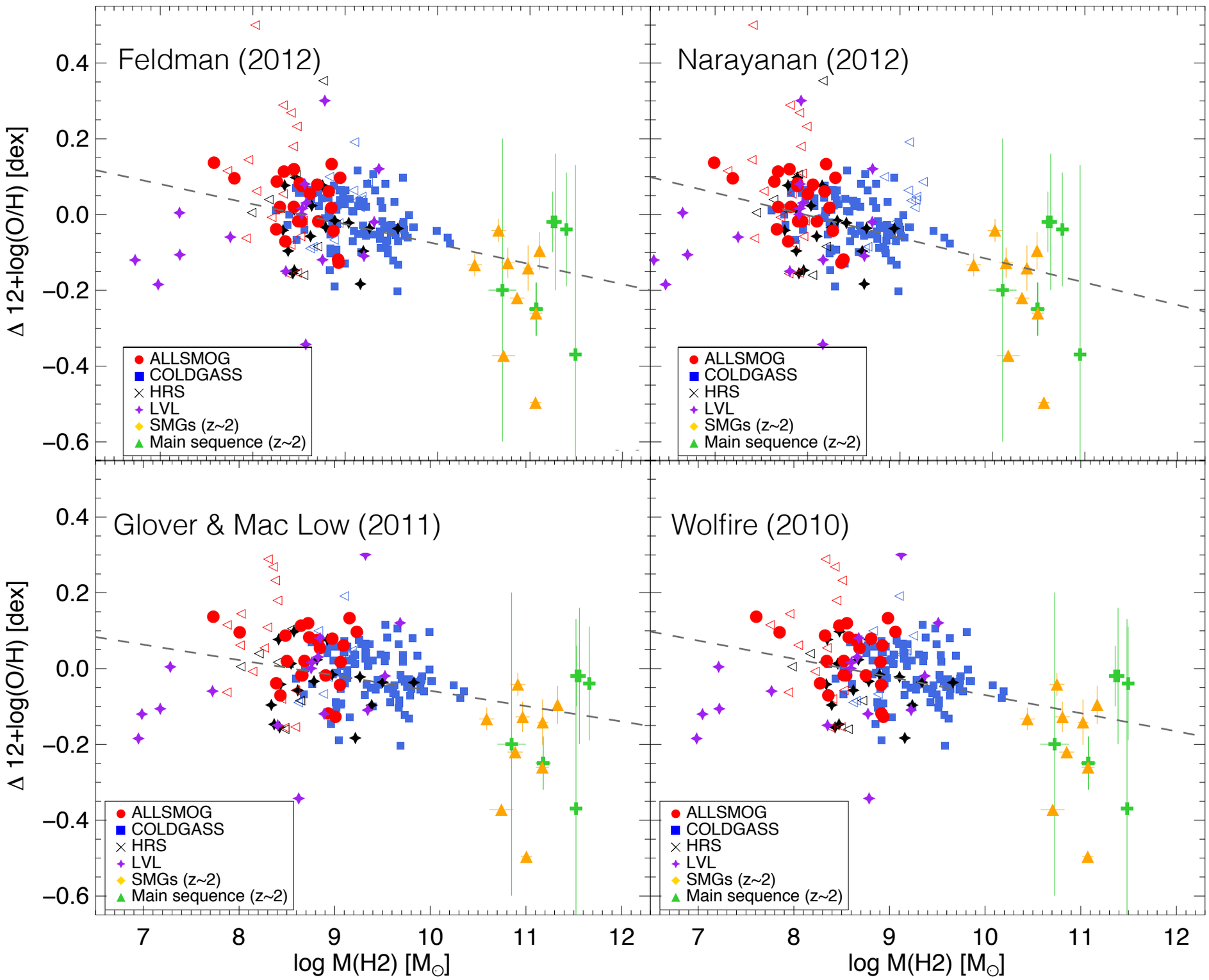
- ALLSMOG
- COLD GASS
- HRS
- LVL
- BzK
- SMGs

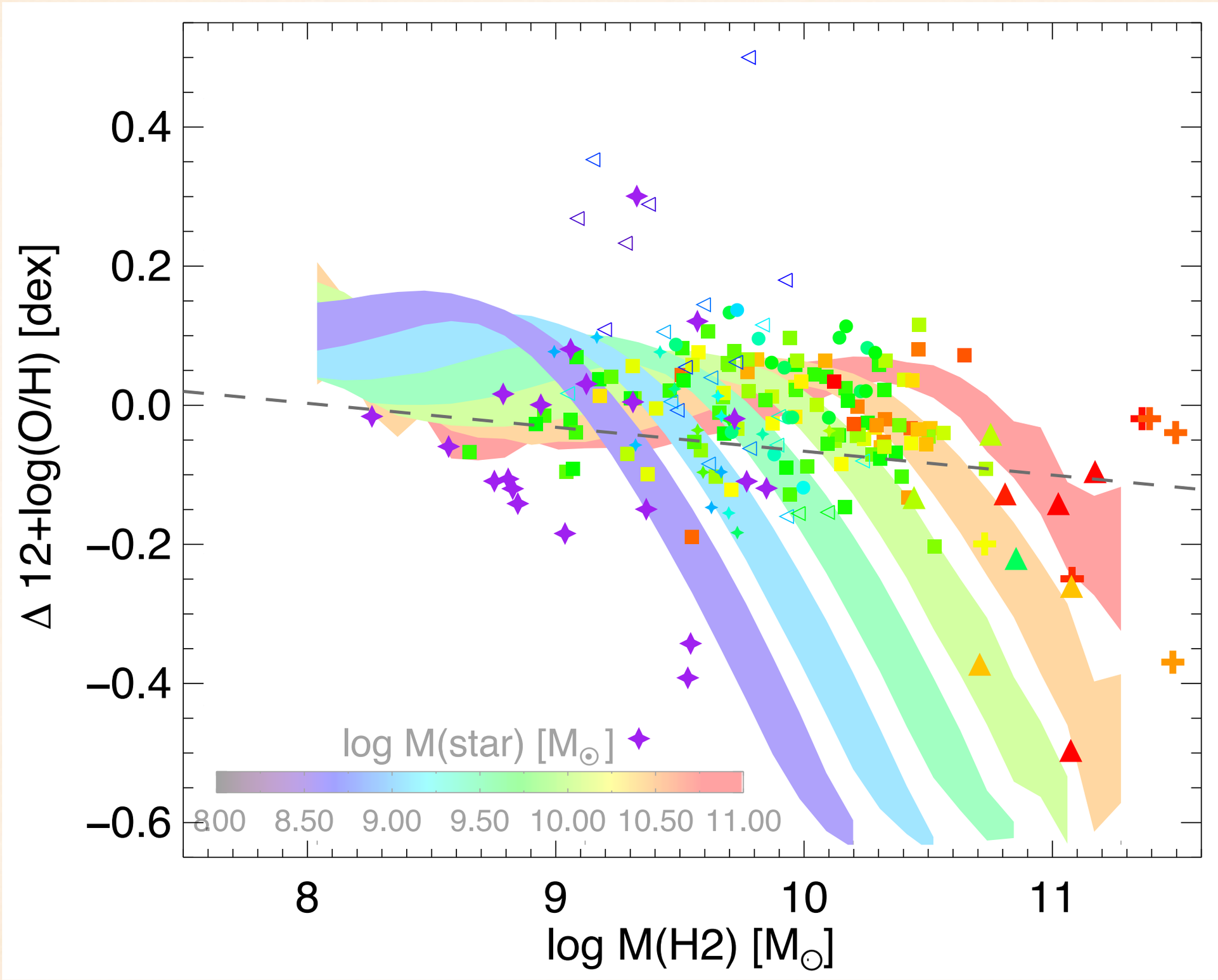
H2 AND METALLICITY

- ALLSMOG 42
- COLD GASS 115
- HRS 24
- LVL 22
- BzK 9
- SMGs 9


9.2
9.0
8.8
8.6
8.4
8.2
8.0
12+log(O/H)
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
log Stellar Mass
H2 Mass (log M_sun)
7.00
7.77
8.53
9.30
10.07
10.83
11.60
ALLSMOG
COLDGASS
HRS
LVL
SMGs (z~2)
MS (z~2)

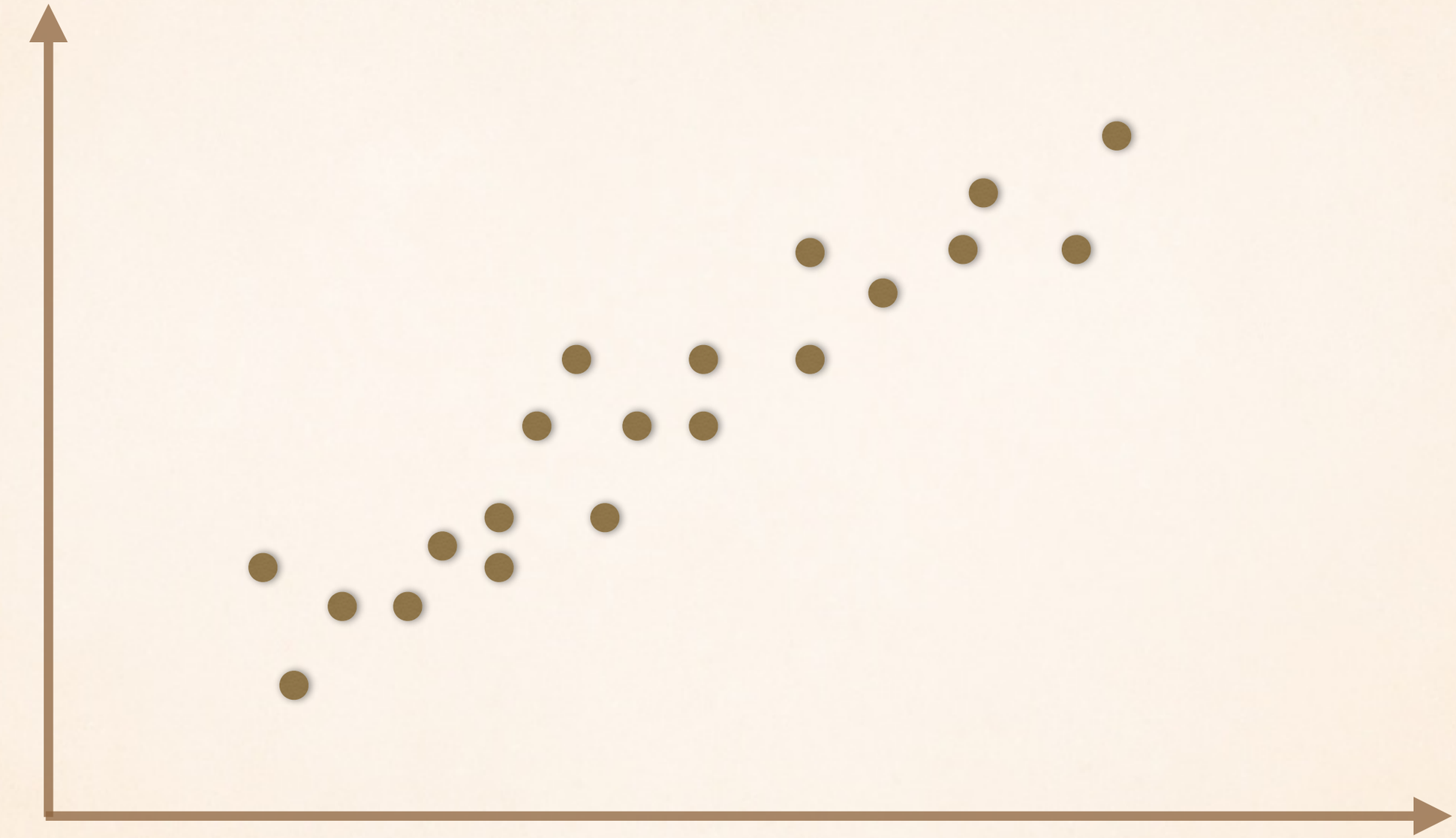

9.2
9.0
8.8
8.6
8.4
8.2
8.0
12+log(O/H)
dZ
H2 Mass (log M_sun)
7.00 7.77 8.53 9.30 10.07 10.83 11.60
ALLSMOG
COLDGASS
HRS
LVL
SMGs (z~2)
MS (z~2)
8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5
log Stellar Mass

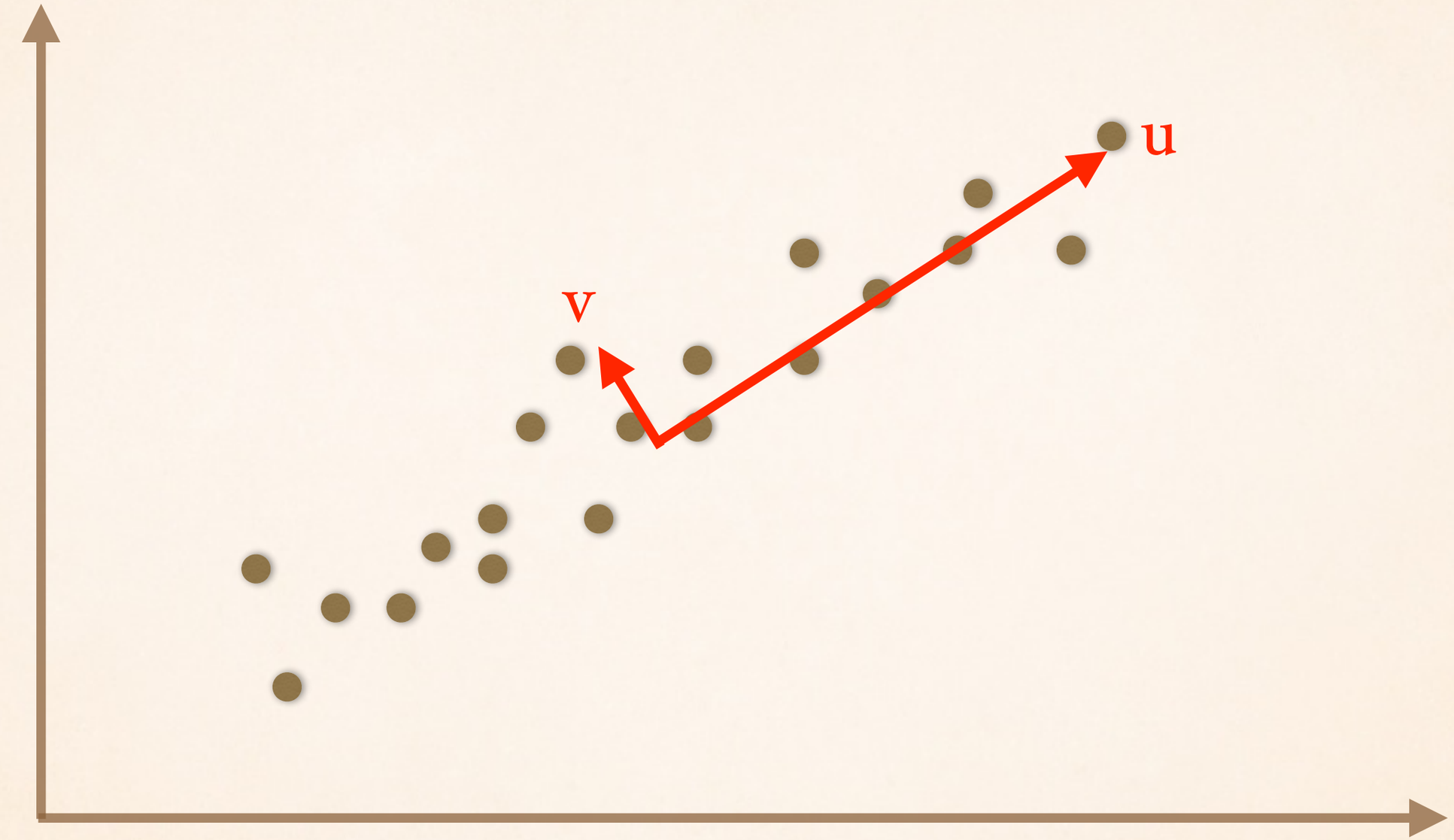

Feldman (2012)
Narayanan (2012)
Glover & Mac Low (2011)
Wolfire (2010)
ALLSMOG
COLDGASS
HRS
LVL
SMGs (z~2)
Main sequence (z~2)
Δ 12+log(O/H) [dex]
log M(H2) [M⊙]
0.4
0.2
0.0
−0.2
−0.4
−0.6
7
8
9
10
11
12


0.4
0.2
0.0
−0.2
−0.4
−0.6
Δ 12+log(O/H) [dex]
log M(star) [M⊙]
8.00
8.50
9.00
9.50
10.00
10.50
11.00
8
9
10
11
log M(H2) [M⊙]

DEGENERACY

- Previous work (HI, SFR) had sample sizes of >1000s
- With large samples, you can control for degeneracy
- With smaller samples (~200), it's more difficult
- Use Principle Component Analysis




u
v

$$PC_1 = 0.578(M^*) - 0.807(MH_2) + 0.118(Z)$$
$$PC_2 = -0.759(M^*) - 0.585(MH_2) - 0.284(Z)$$
$$PC_3 = 0.299(M^*) - 0.075(MH_2) - 0.951(Z)$$

$$PC1 = 0.578(M^*) - 0.807(MH_2) + 0.118(Z) \quad 80\%$$
$$PC2 = -0.759(M^*) - 0.585(MH_2) - 0.284(Z)$$
$$PC3 = 0.299(M^*) - 0.075(MH_2) - 0.951(Z)$$

$$PC1 = 0.578(M^*) - 0.807(MH_2) + 0.118(Z)$$ 80%
$$PC2 = -0.759(M^*) - 0.585(MH_2) - 0.284(Z)$$ } 98%
$$PC3 = 0.299(M^*) - 0.075(MH_2) - 0.951(Z)$$

$$PC1 = 0.578(M^*) - 0.807(MH_2) + 0.118(Z) \quad 80\%$$
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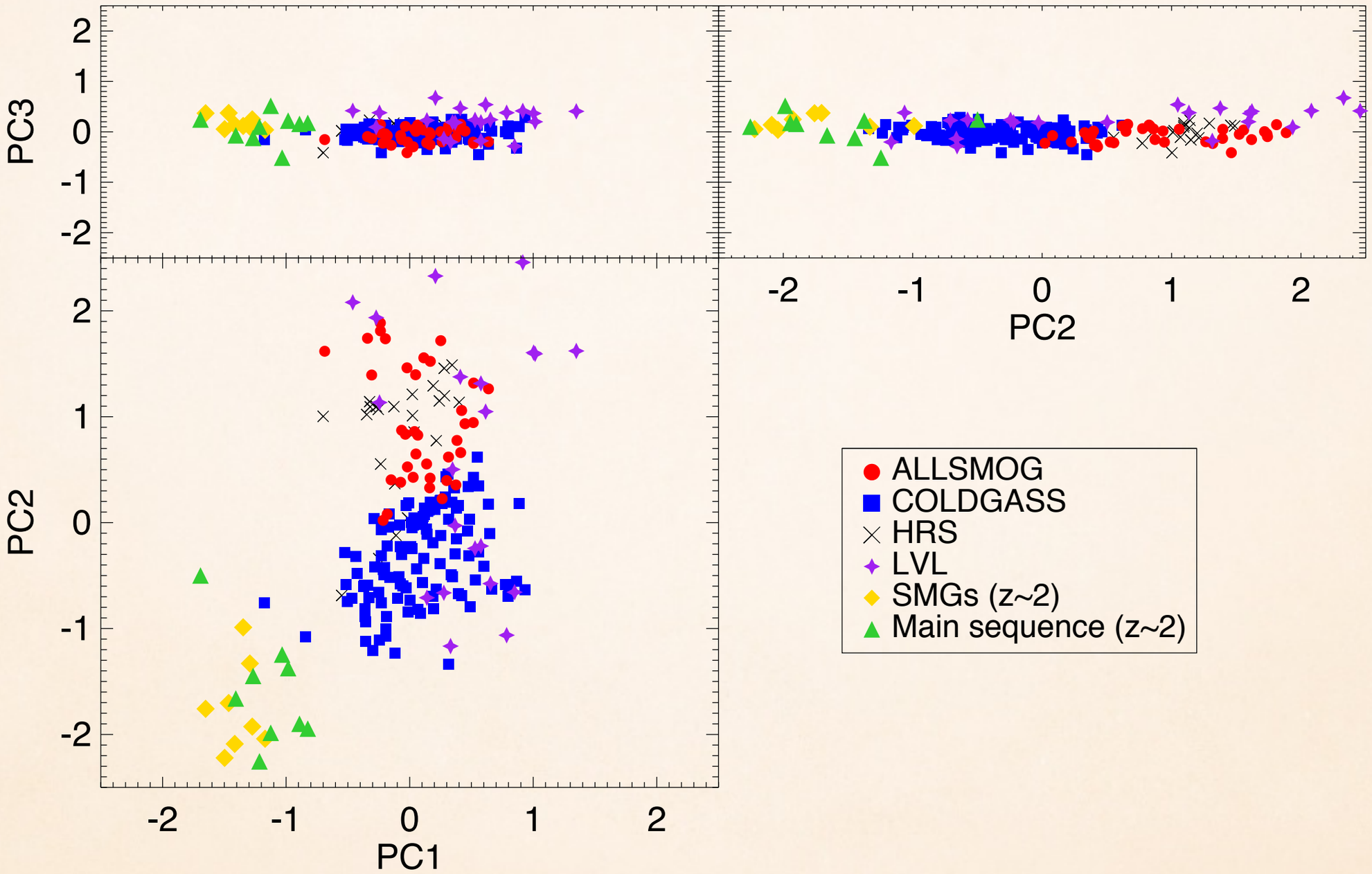
$$PC3 = 0.299(M^*) - 0.075(MH_2) - 0.951(Z)$$



$$PC3 = 0.299(M^*) - 0.075(MH2) - 0.951(Z)$$

$$= 0 \text{ (to within 2\%)}$$

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$$0.299(M^*) - 0.075(MH2) - 0.951(Z) = 0$$

$$PC_3 = 0.299(M^*) - 0.075(MH_2) - 0.951(Z)$$

$$= 0 \text{ (to within 2\%)}$$

$$0.299(M^*) - 0.075(MH_2) - 0.951(Z) = 0$$

$$12+\log(O/H) = 0.31\ (\log M^*) - 0.08\ (\log MH_2) + 6.53$$

$$PC3 = 0.299(M^*) - 0.075(MH2) - 0.951(Z)$$

$$= 0 \text{ (to within 2\%)}$$

$$0.299(M^*) - 0.075(MH2) - 0.951(Z) = 0$$

$$12+\log(O/H) = 0.31\ (\log M^*) - 0.08\ (\log MH2) + 6.53$$

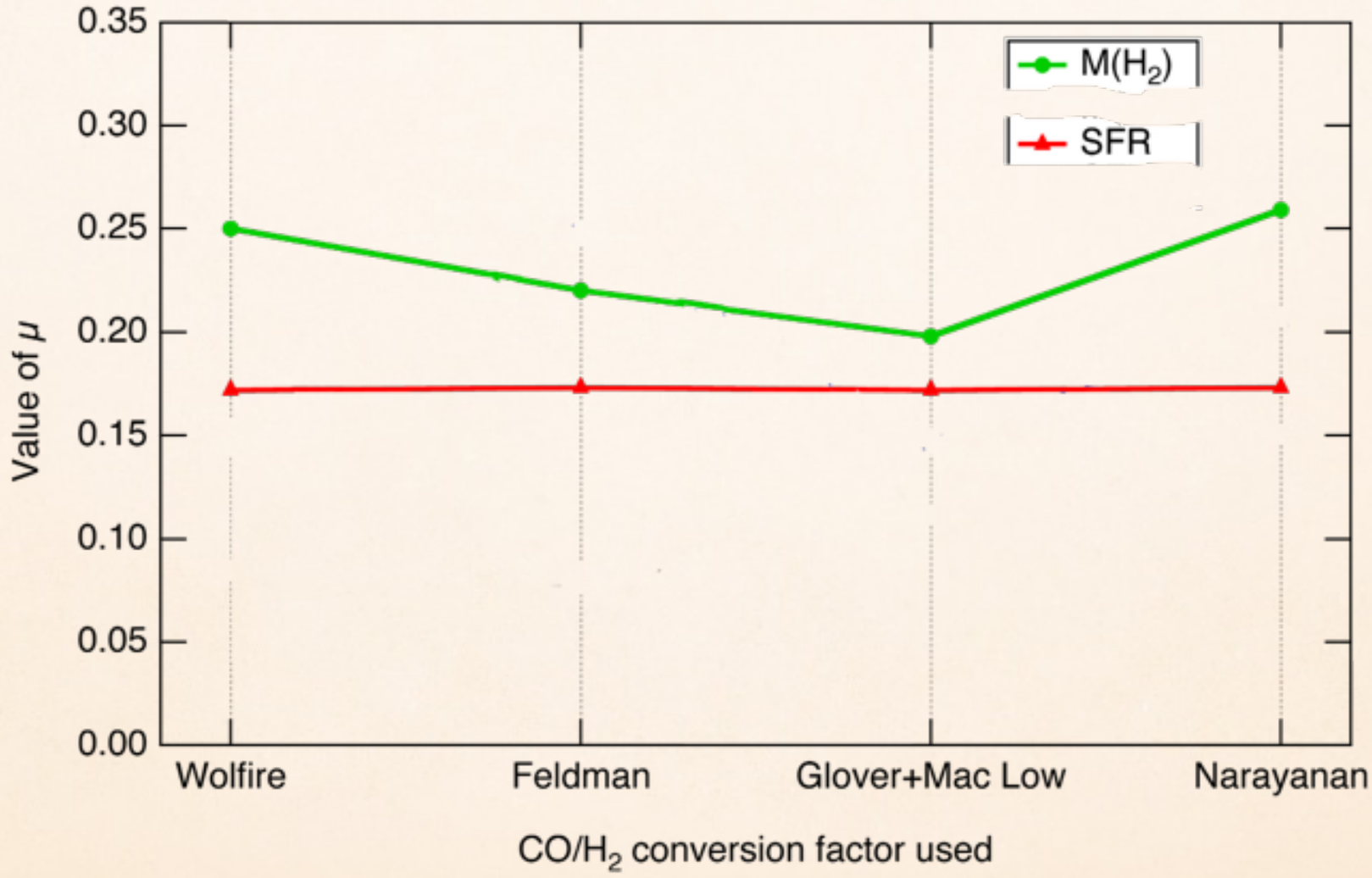
- Metallicity PRIMARILY determined by stellar mass
- Secondary dependence on H2 content, effect is ~1/4 as strong

$$12+\log(O/H) = 0.31\ (\log M^*) - 0.08\ (\log MH_2) + 6.53$$

$$12+\log(O/H) = 0.29\ (\log M^*) - 0.04\ (\log SFR) + 6.14$$

$$12+\log(O/H) = 0.31\ (\log M^*) - 0.08\ (\log MH2) + 6.53$$

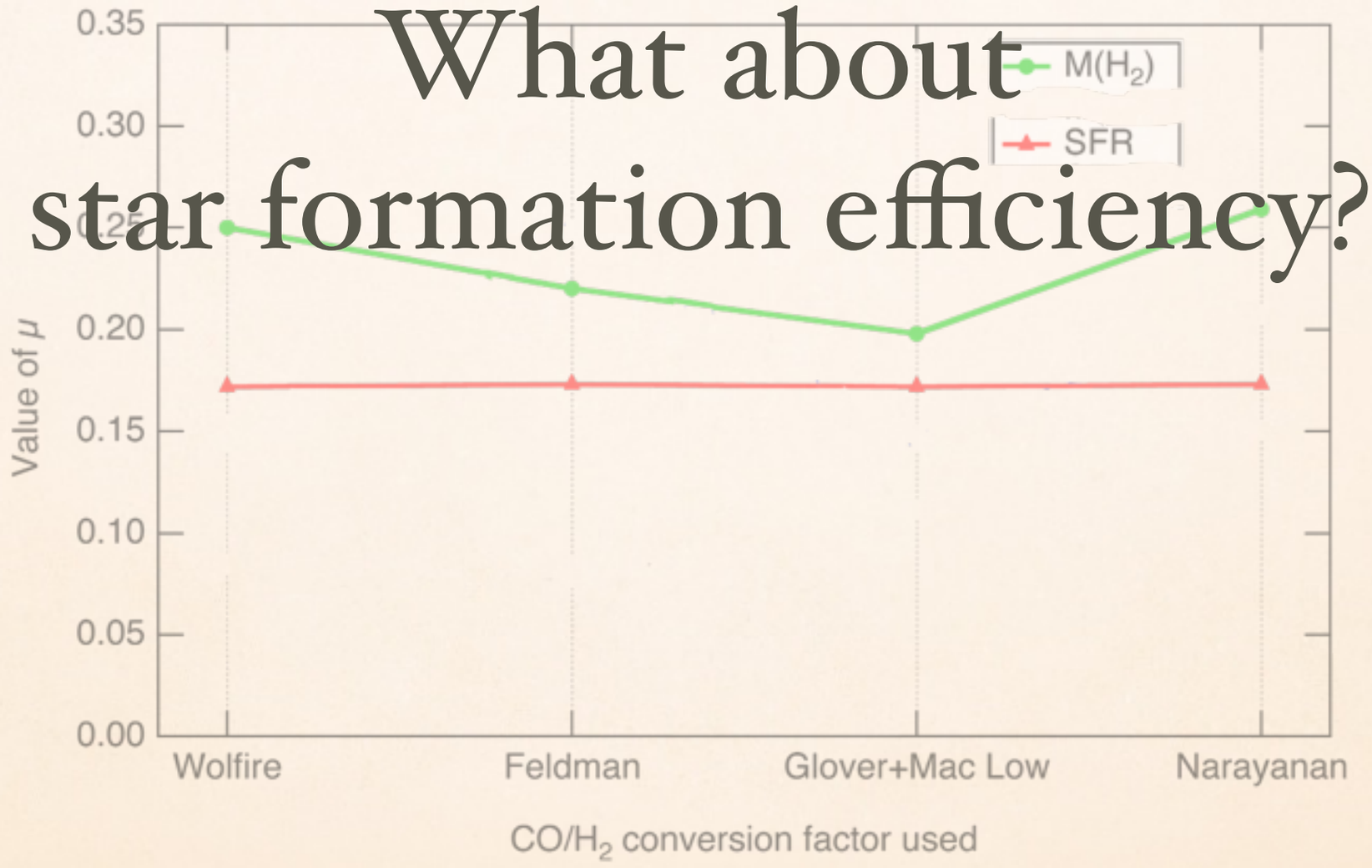
$$12+\log(O/H) = 0.29\ (\log M^*) - 0.04\ (\log SFR) + 6.14$$



$$12+\log(O/H) = 0.31\ (\log M^*) - 0.08\ (\log MH2) + 6.53$$

$$12+\log(O/H) = 0.29\ (\log M^*) - 0.04\ (\log SFR) + 6.14$$

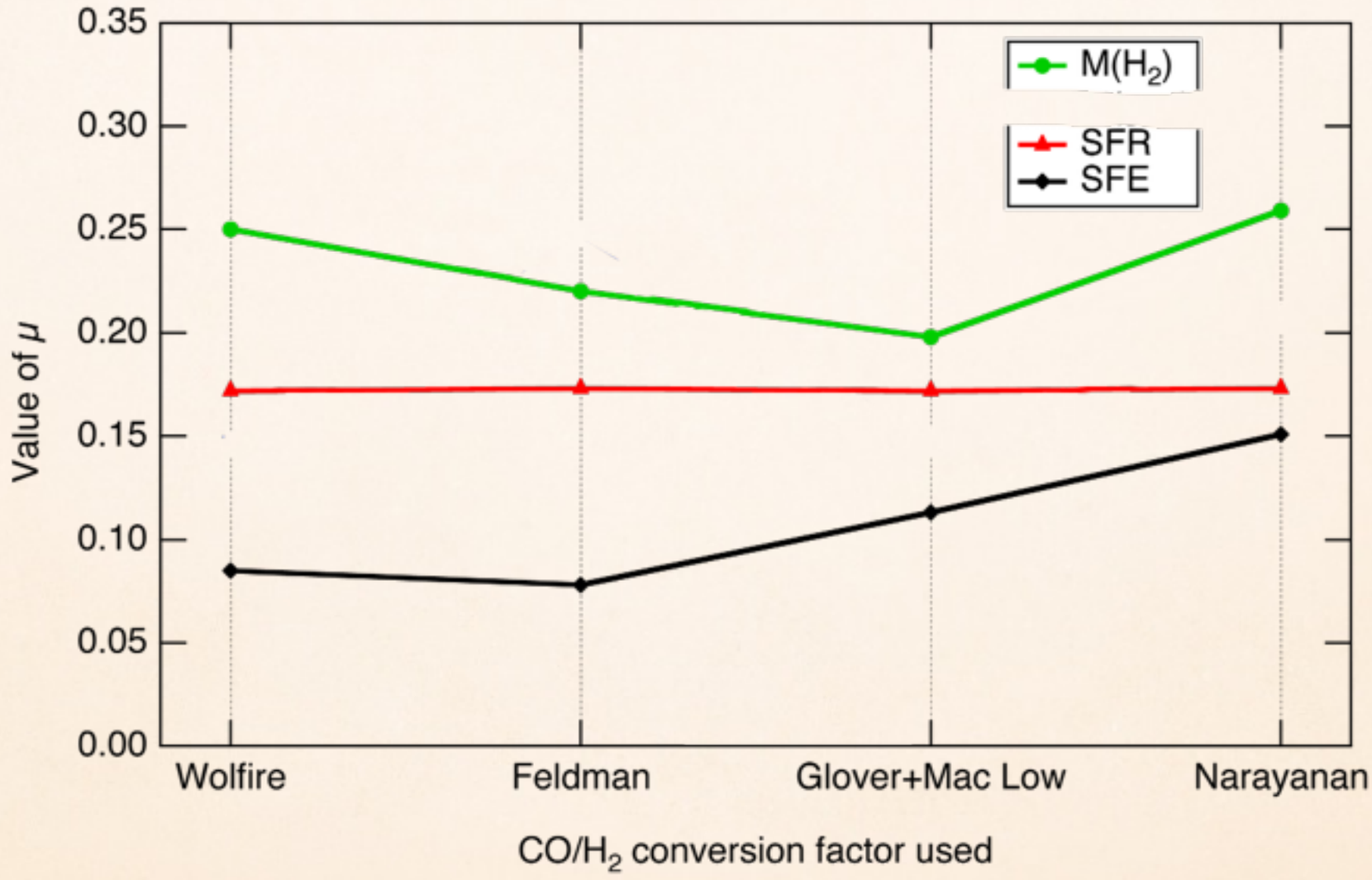
What about star formation efficiency?



$$12+\log(O/H) = 0.31\ (\log M^*) - 0.08\ (\log MH_2) + 6.53$$

$$12+\log(O/H) = 0.29\ (\log M^*) - 0.04\ (\log SFR) + 6.14$$

$$12+\log(O/H) = 0.25\ (\log M^*) - 0.007\ (\log SFE) + 6.45$$



CONCLUSIONS

- There is a H2 `Fundamental Metallicity Relation'
- Molecular gas is likely the strongest secondary correlation in the mass-metallicity relation
- There is little connection between star formation efficiency and metallicity