Scaling Relations of Main Sequence and Green Valley Galaxies in ALMaQUEST

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on behalf of the ALMaQUEST team

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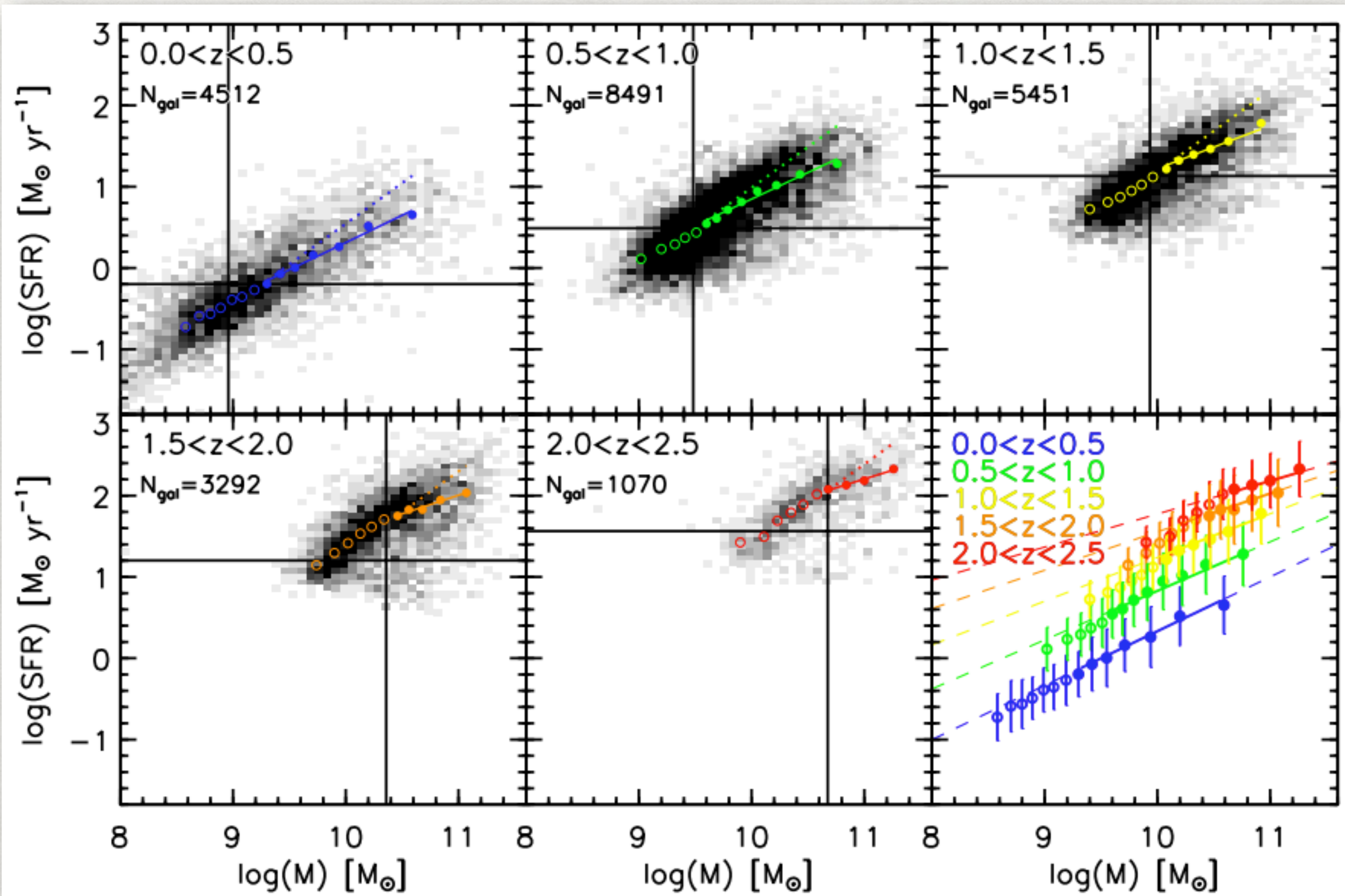
SDSS

Star-Forming Main Sequence

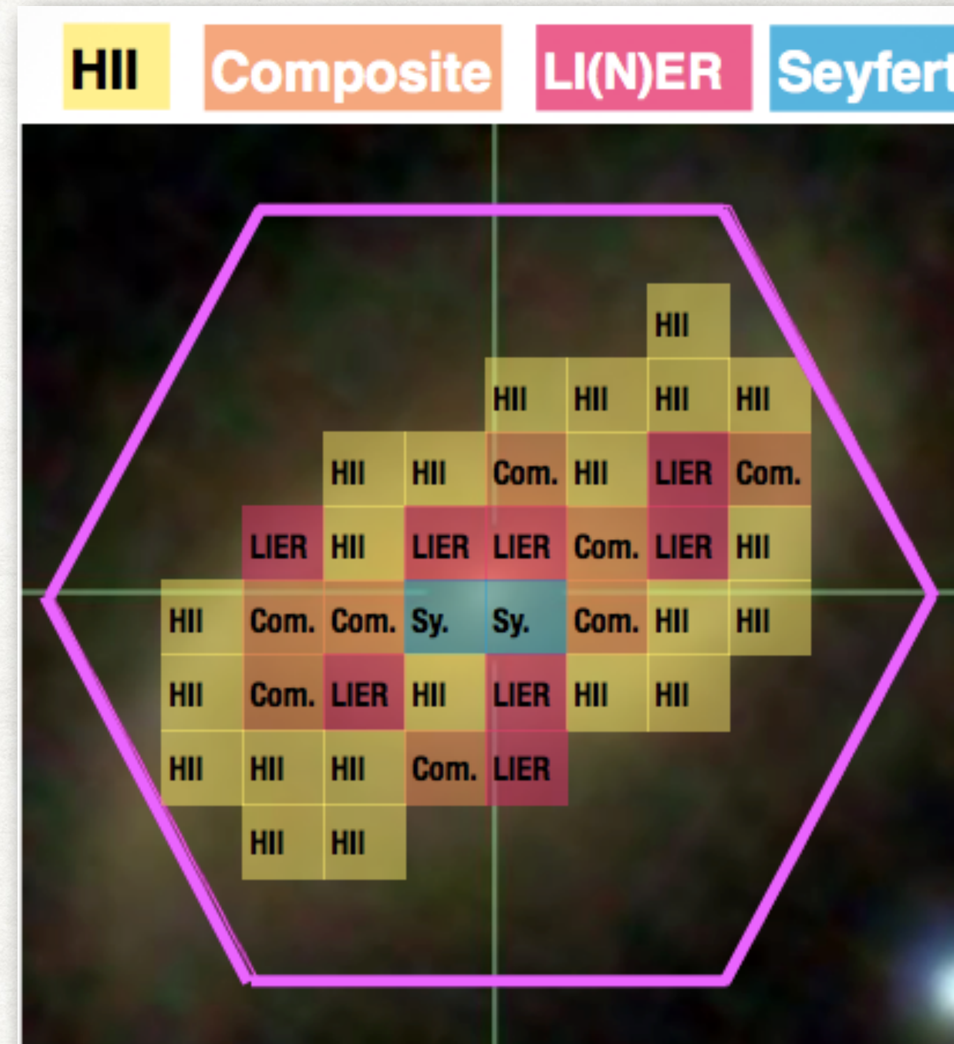
- A tight correlation between the total star formation rate and stellar mass for star-forming galaxies (e.g., Brinchmann+04; Noeske+07; Daddi+07; Elbaz+07; Whitaker +12)



Whitaker+12

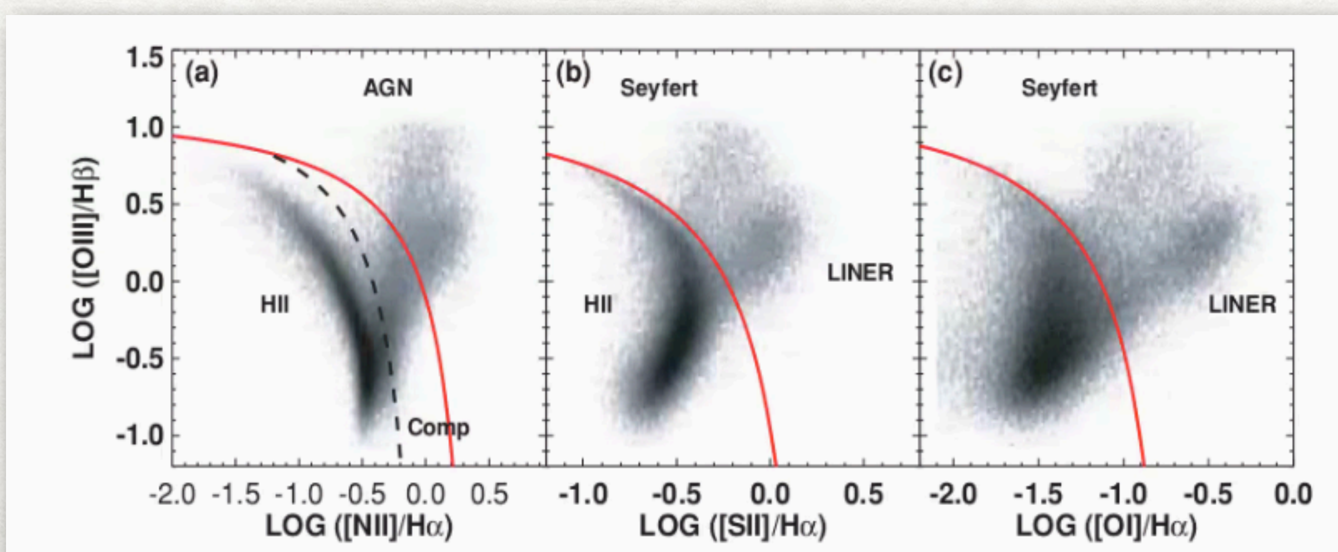
$$M_* = \int SFR\, dt$$

From Global to Resolved Properties
— "resolved main sequence" on kpc scales



credit: H.-A Pan

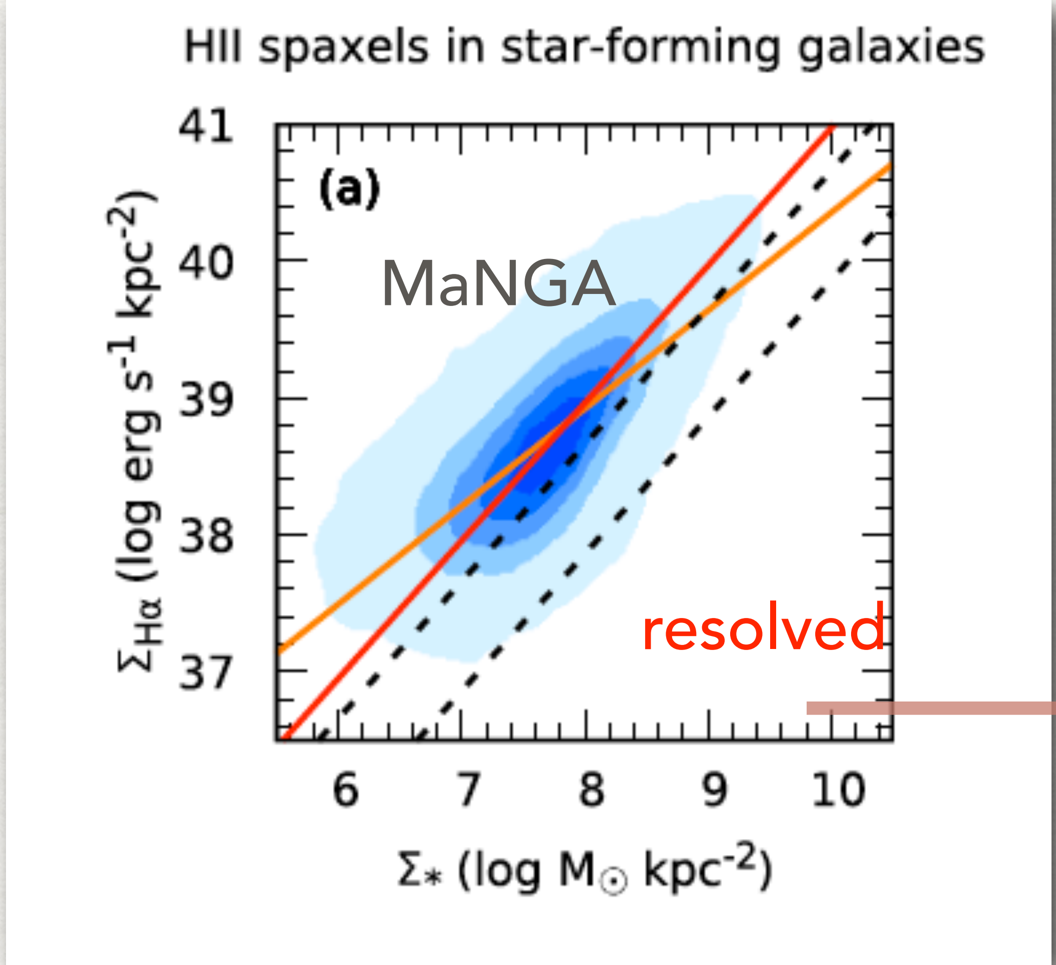
BPT Diagram

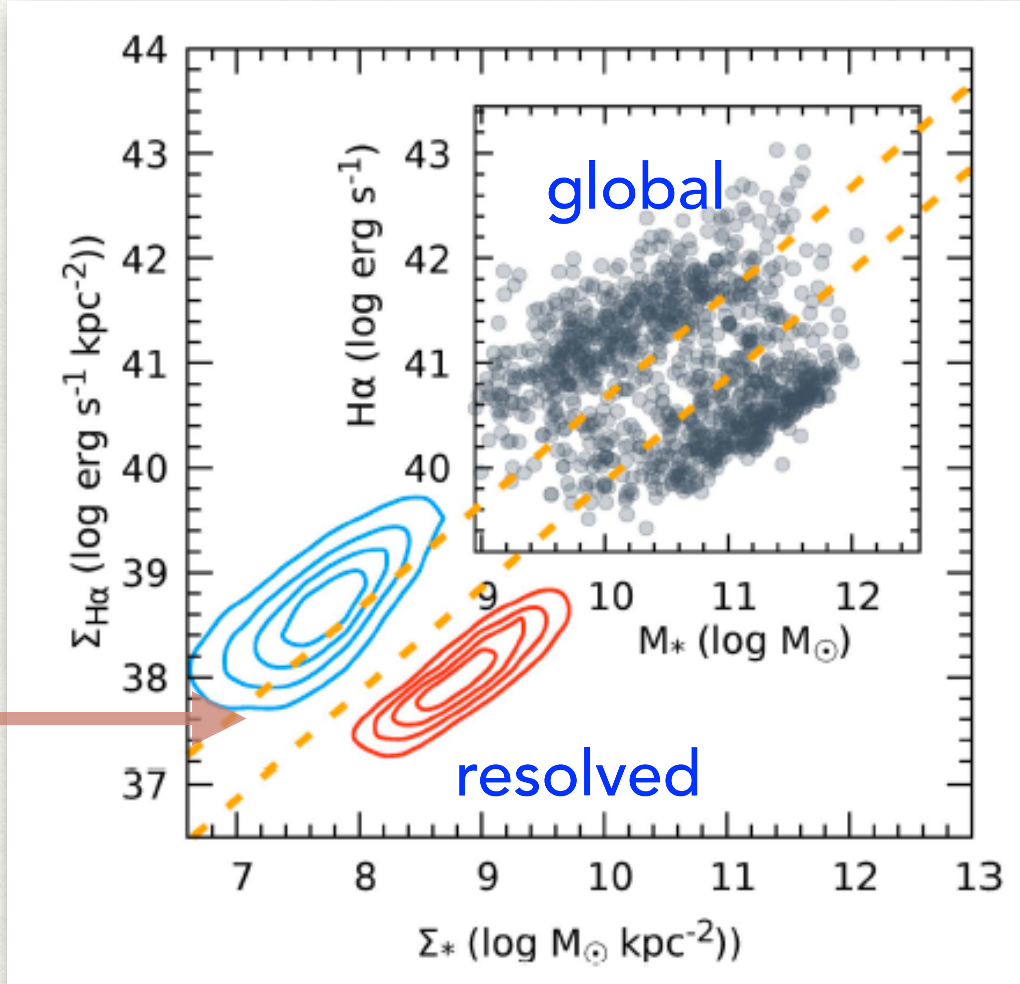


From Global to Resolved Properties

— "resolved star-forming main sequence" (rSFMS) on kpc scales

Hsieh, Lin+2017

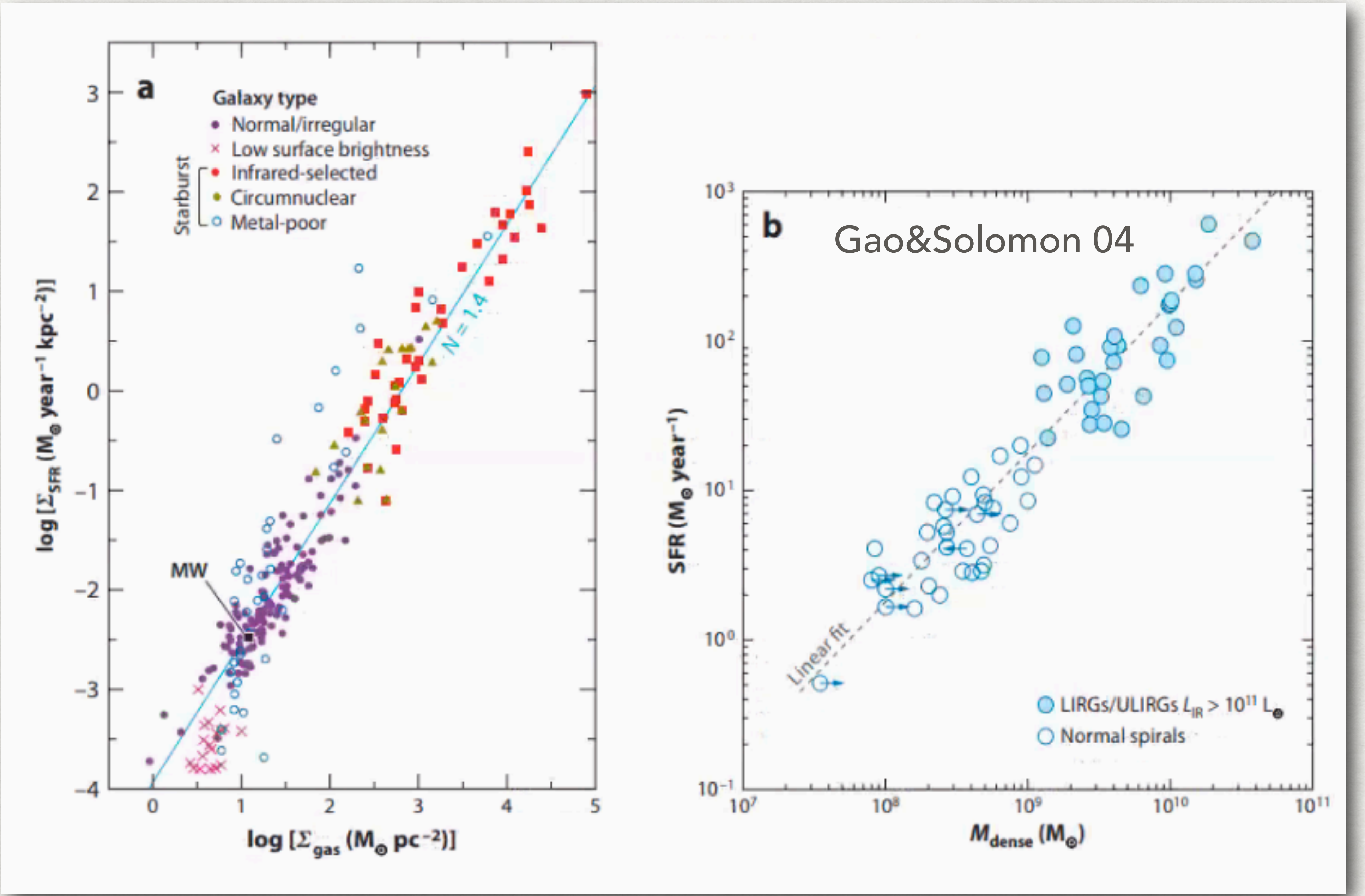




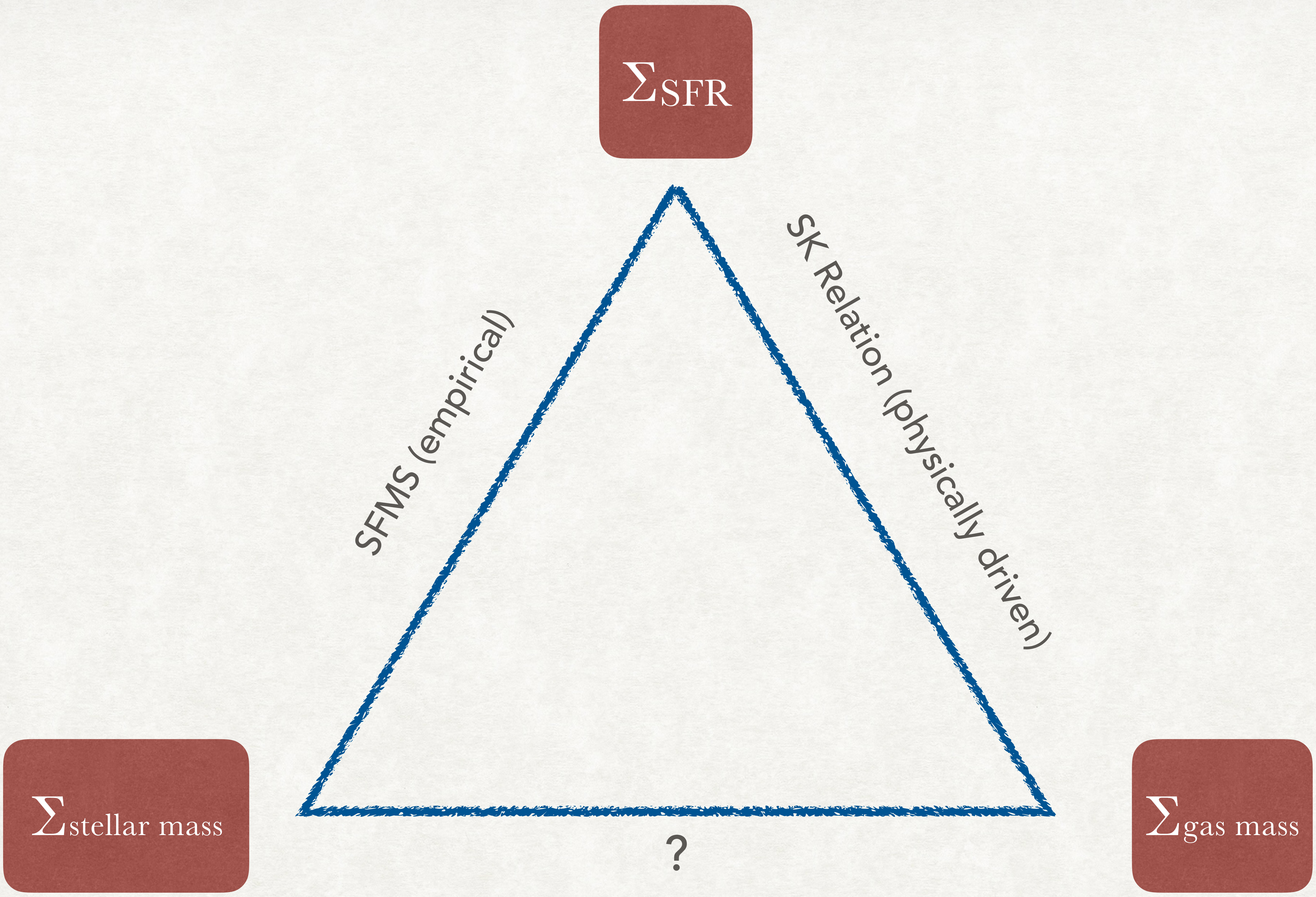
(Also see Cano-Diaz+16; Abdurrouf & Akiyama 17; Ellison+18; Pan+18; Medling+18; Cano-Diaz+19)

Schmidt-Kennicutt (SK) Relation

-A tight relation between star formation rate and gas (surface density)



Kennicutt & Evans 12

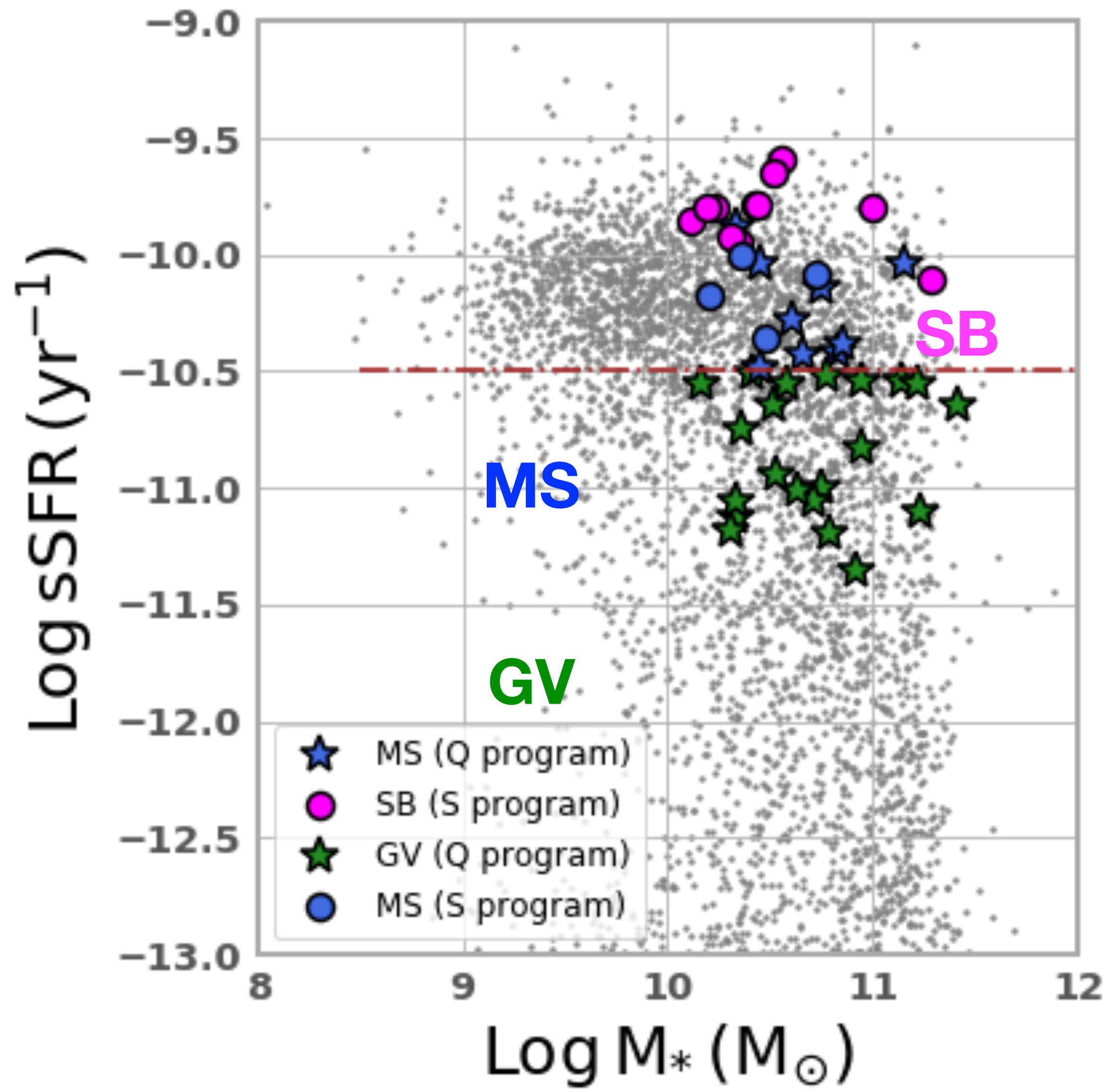

ΣSFR
SFMS (empirical)
SK Relation (physically driven)
Σstellar mass
?
Σgas mass

ALMaQUEST :

ALMA-MaNGA QUEnching and STar formation

(PIs: L. Lin & S. Ellison)

- ALMA CO(1-0) followups for 46 MaNGA selected sample
- z ~ 0.03; $10<\log(M_*/M_\odot)<11.5$
- ALMA Resolution:
    - ~2.5″ (spatial)
    - 11 km/s (spectral)
- Target classes:
    - 14 Main-sequence galaxies
    - 20 Green valley galaxies
    - 12 Central starburst galaxies



Lin et al. 2020, submitted

http://arc.phys.uvic.ca/~almaquest/

Hα intensity

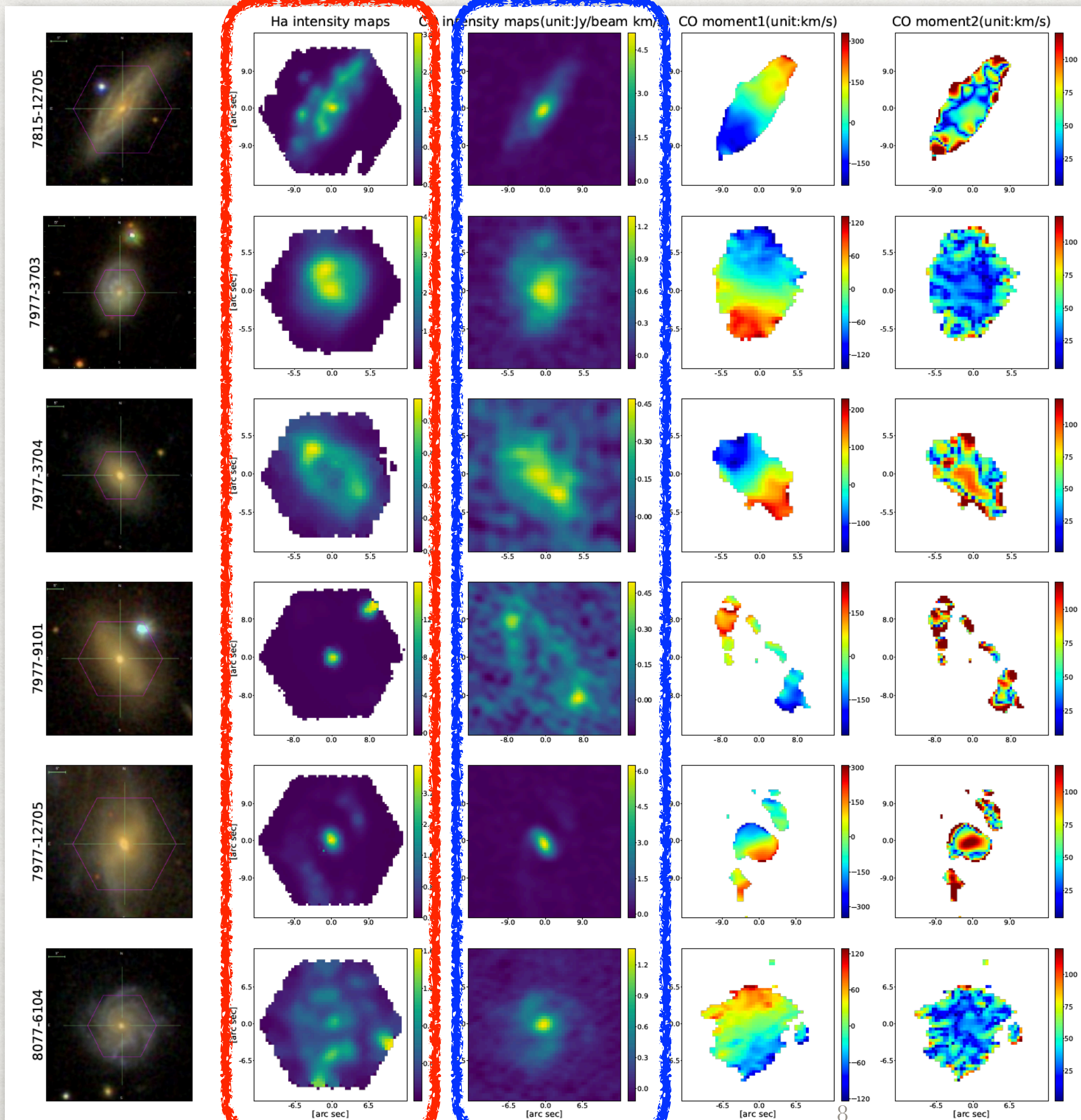
CO intensity

CO velocity

CO velocity dispersion

ALMaQUEST

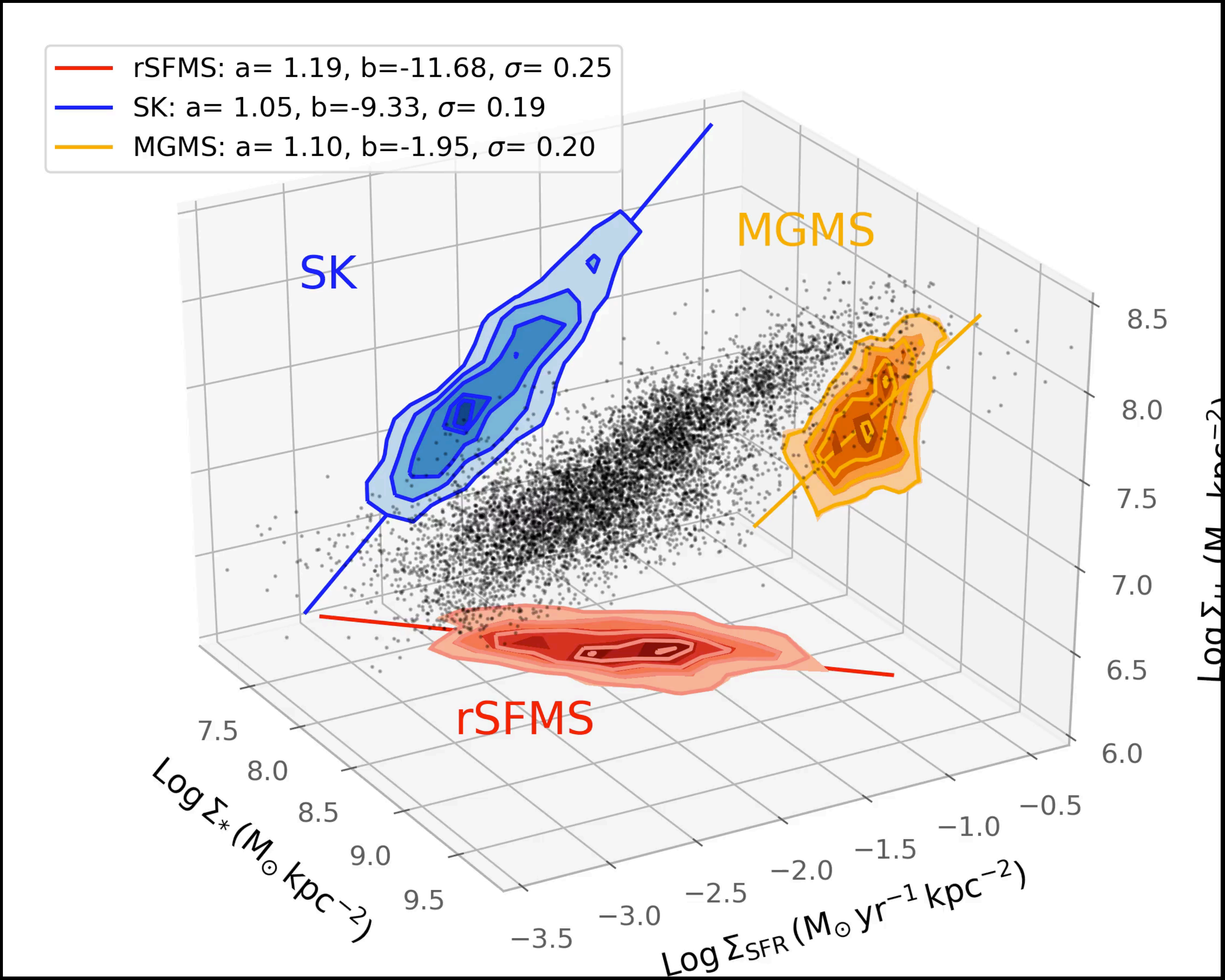
(Lin+2020, submitted)



A diversity in the contrast between Ha and CO emissions

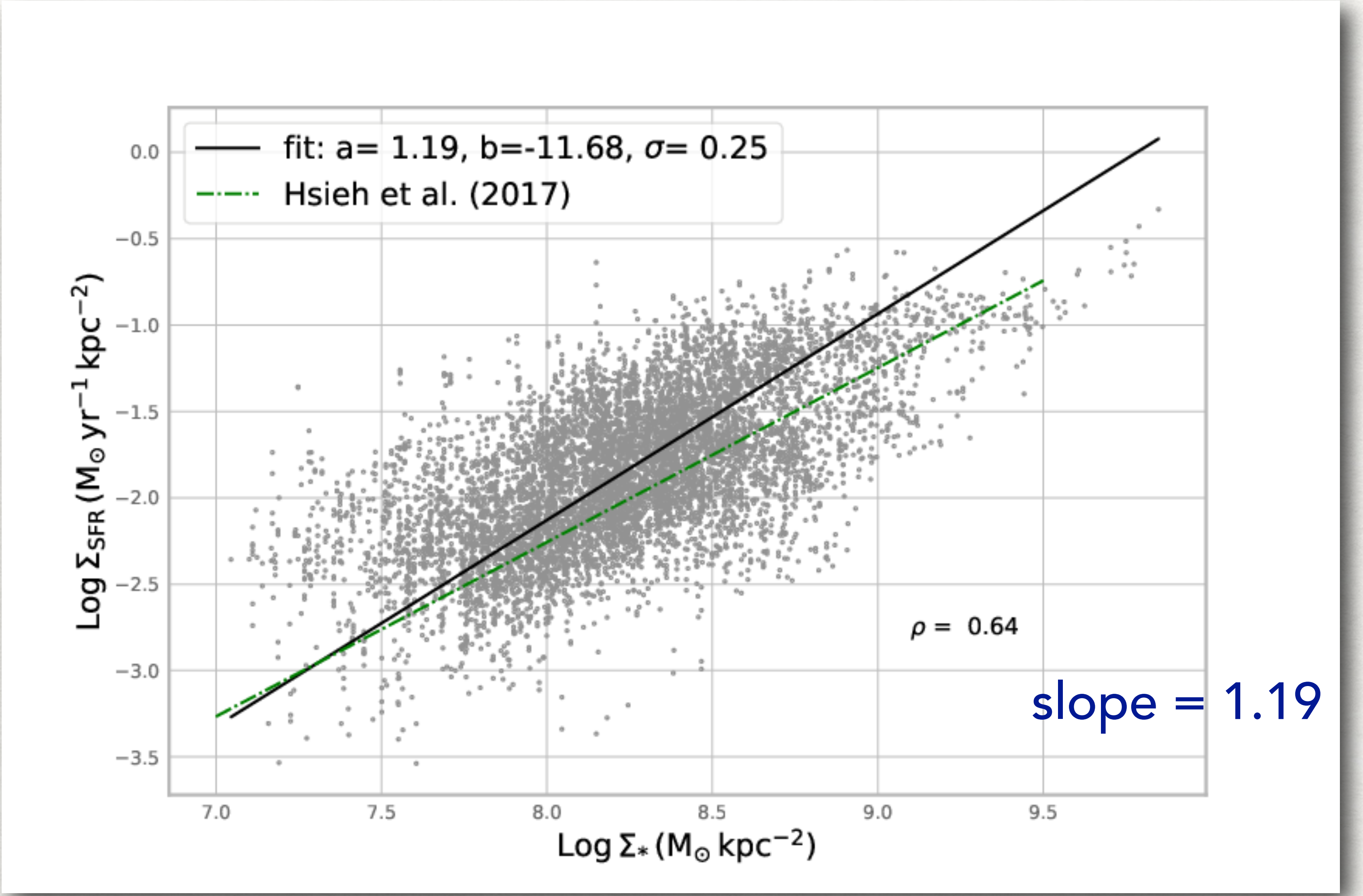
- Star-formation efficiency: $SFE = SFR/M_*$

- Gas fraction: $f_{H2} = M_{H2}/M_*$



rSFMS: a= 1.19, b=-11.68, σ= 0.25
SK: a= 1.05, b=-9.33, σ= 0.19
MGMS: a= 1.10, b=-1.95, σ= 0.20
SK
MGMS
rSFMS
8.5
8.0
7.5
7.0
6.5
6.0
7.5
8.0
8.5
9.0
9.5
Log Σ* (M⊙ kpc−2)
−3.5
−3.0
−2.5
−2.0
−1.5
−1.0
−0.5
Log ΣSFR (M⊙ yr−1 kpc−2)

I. Resolved Star-Forming Main Sequence (rSFMS)

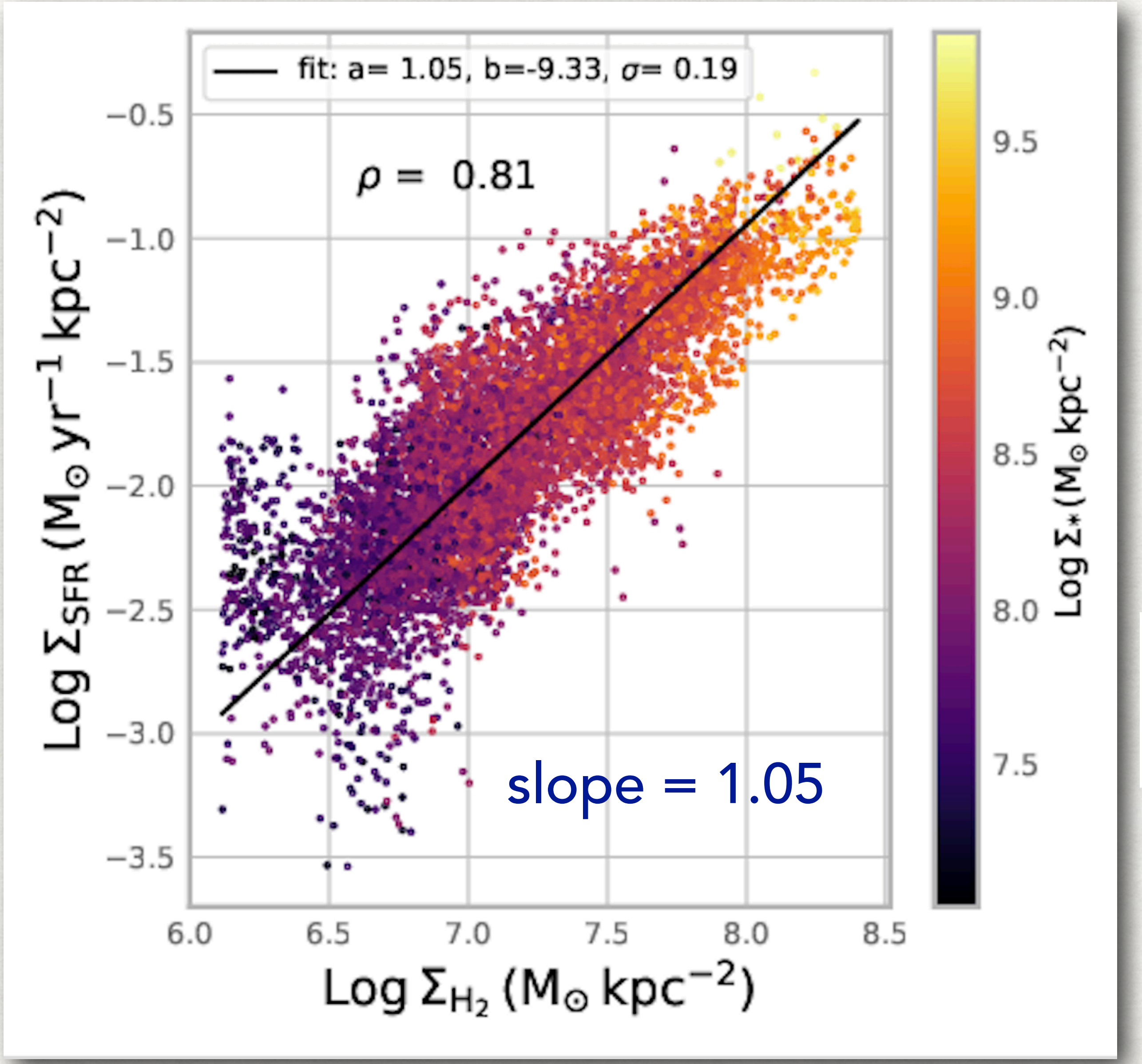


slope = 1.19

Lin+19b
Ellison+, submitted

- The best fit using the HII spaxel of 14 MS galaxies is in good agreement with the full MaNGA SF sample.

II. Schmidt-Kennicutt (SK) Relation

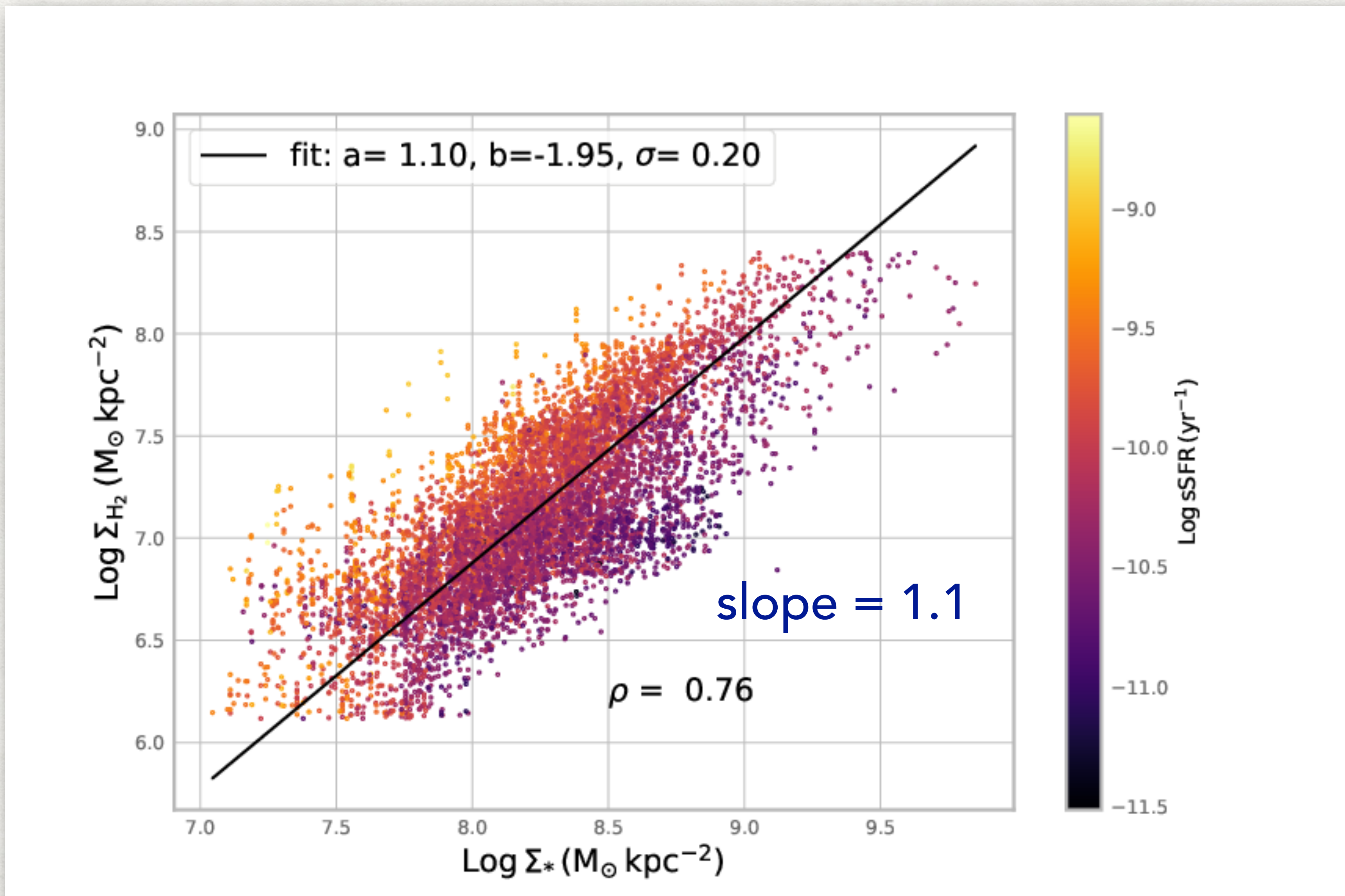


Lin+19b
Ellison+, submitted

- A linear slope is found in the resolved SK relation

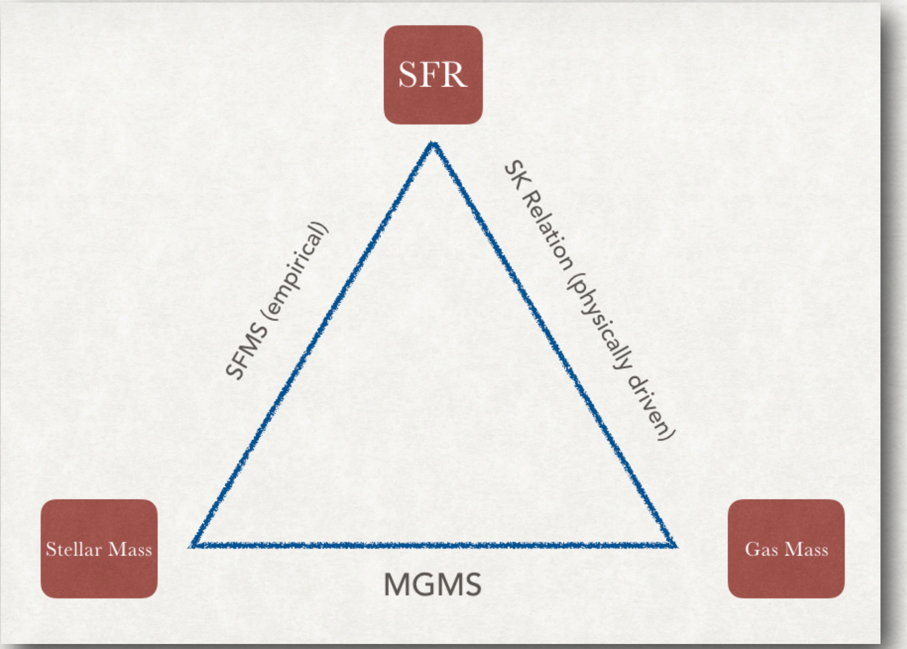
III. Molecular Gas Main Sequence (MGMS)

Lin+19b; Ellison+, submitted
(also see Wong+13)



- The surface density of the molecular gas mass traces the stellar mass surface density with slope ~ 1.

Which One is More Fundamental?



$$\Sigma_{SFR} \propto \Sigma_{H_2}{}^{a} \qquad \text{(SK)}$$

$$\Sigma_{H_2} \propto \Sigma_*{}^{b} \qquad \text{(MGMS)}$$

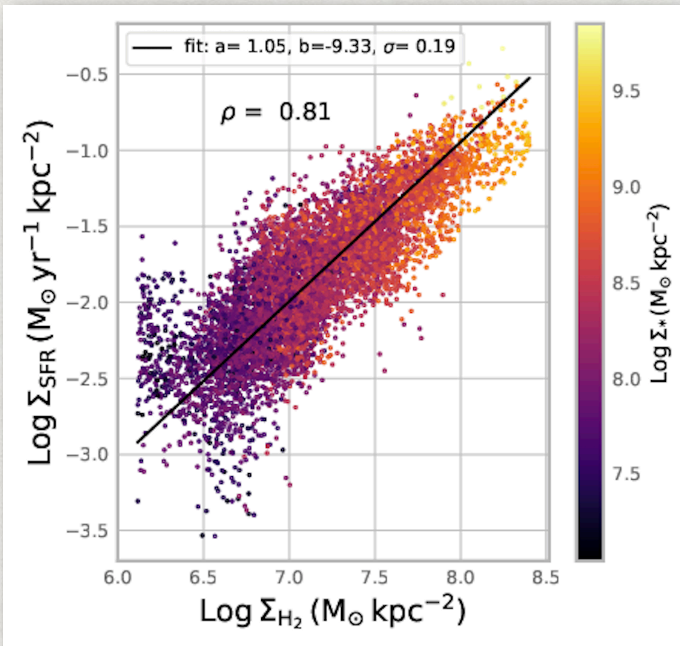
$$\Sigma_{SFR} \propto \Sigma_*{}^{a*b} = \Sigma_*{}^{c} \qquad \text{(rSFMS)}$$

a = 1.05, b = 1.1 => c = 1.16

c (measured) = 1.19

- Scatter: rSFMS > MGMS > SK
- Pearson's correlation:

  rSFMS < MGMS < SK

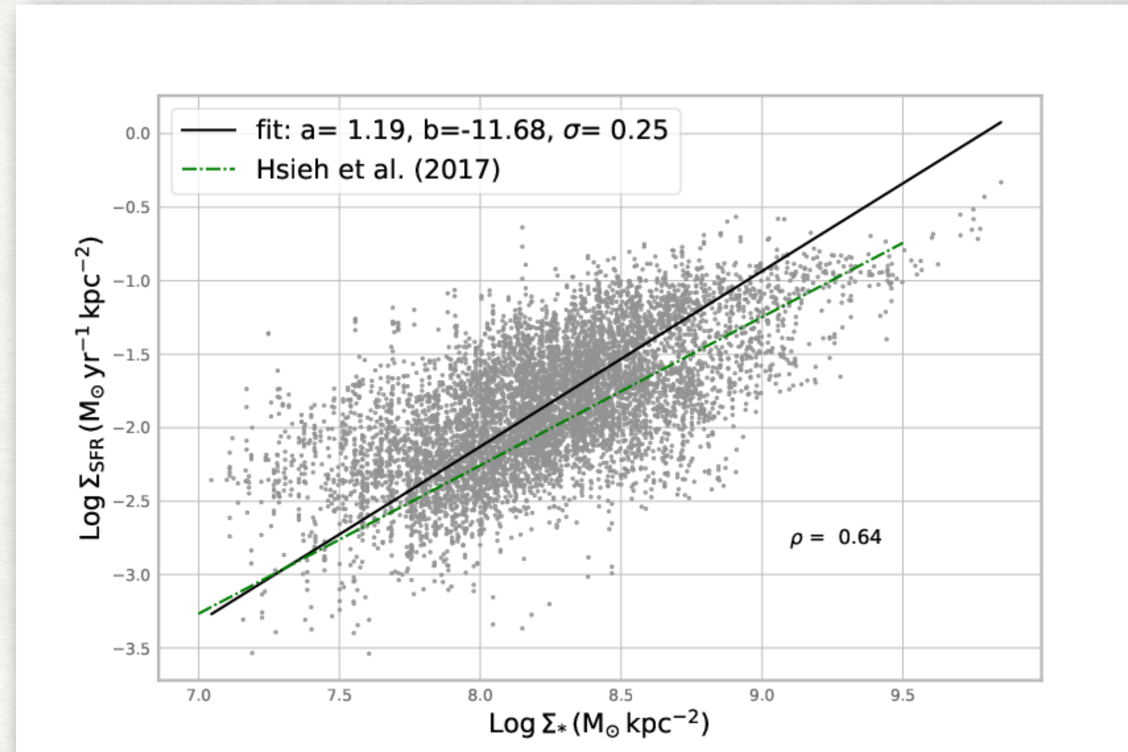


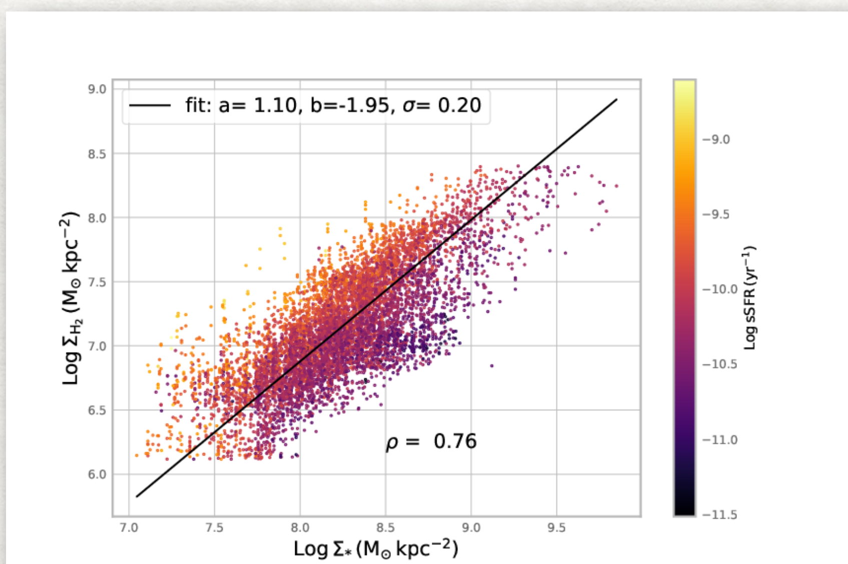
SK relation

+

=

rSFMS





MGMS

- For star-forming spaxels of main-sequence galaxies, rSFMS is a natural consequence of the combination of SK and MGMS.

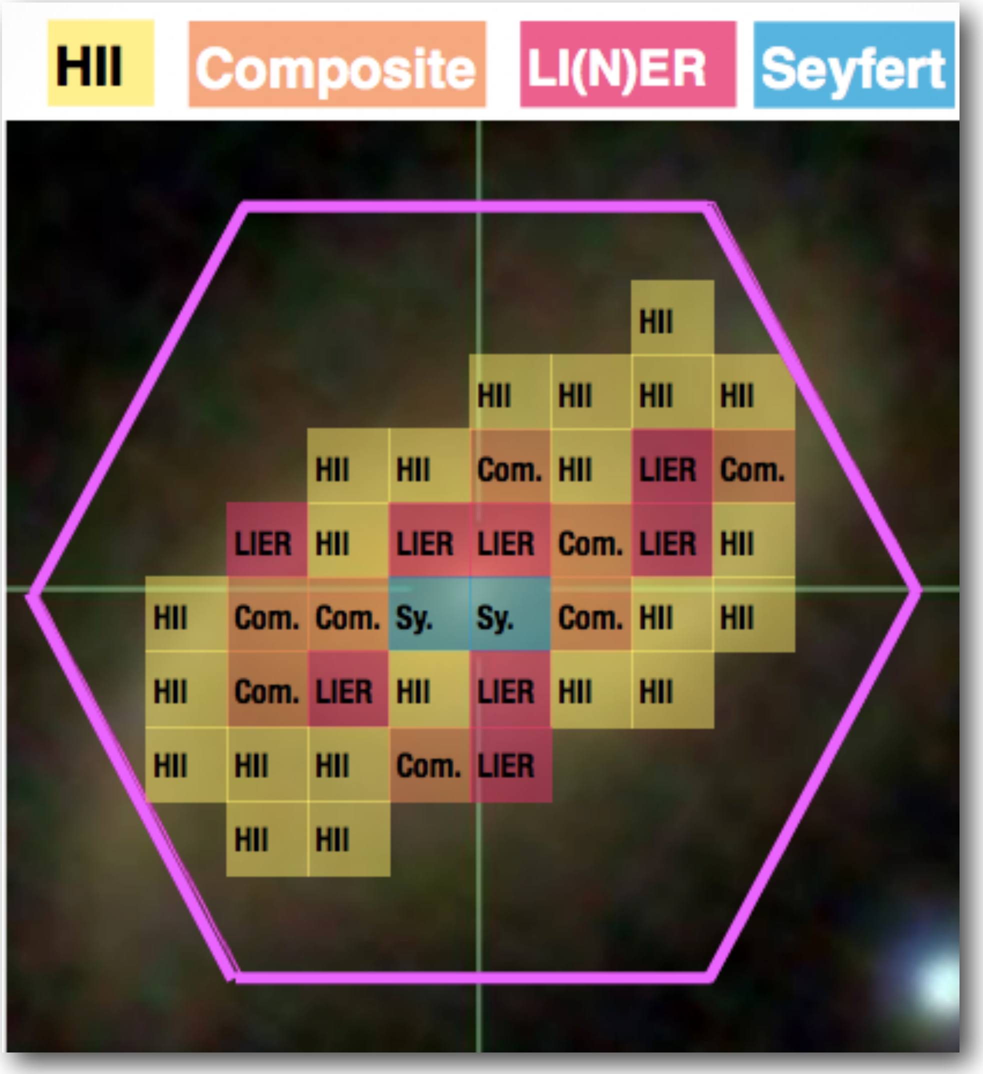
What about GV galaxies?

GV contains non-negligible fraction of non-SF spaxels
=> need to consider those regions, too

- Galaxy type: MS vs. GV
- Spaxel type: SF vs. retired

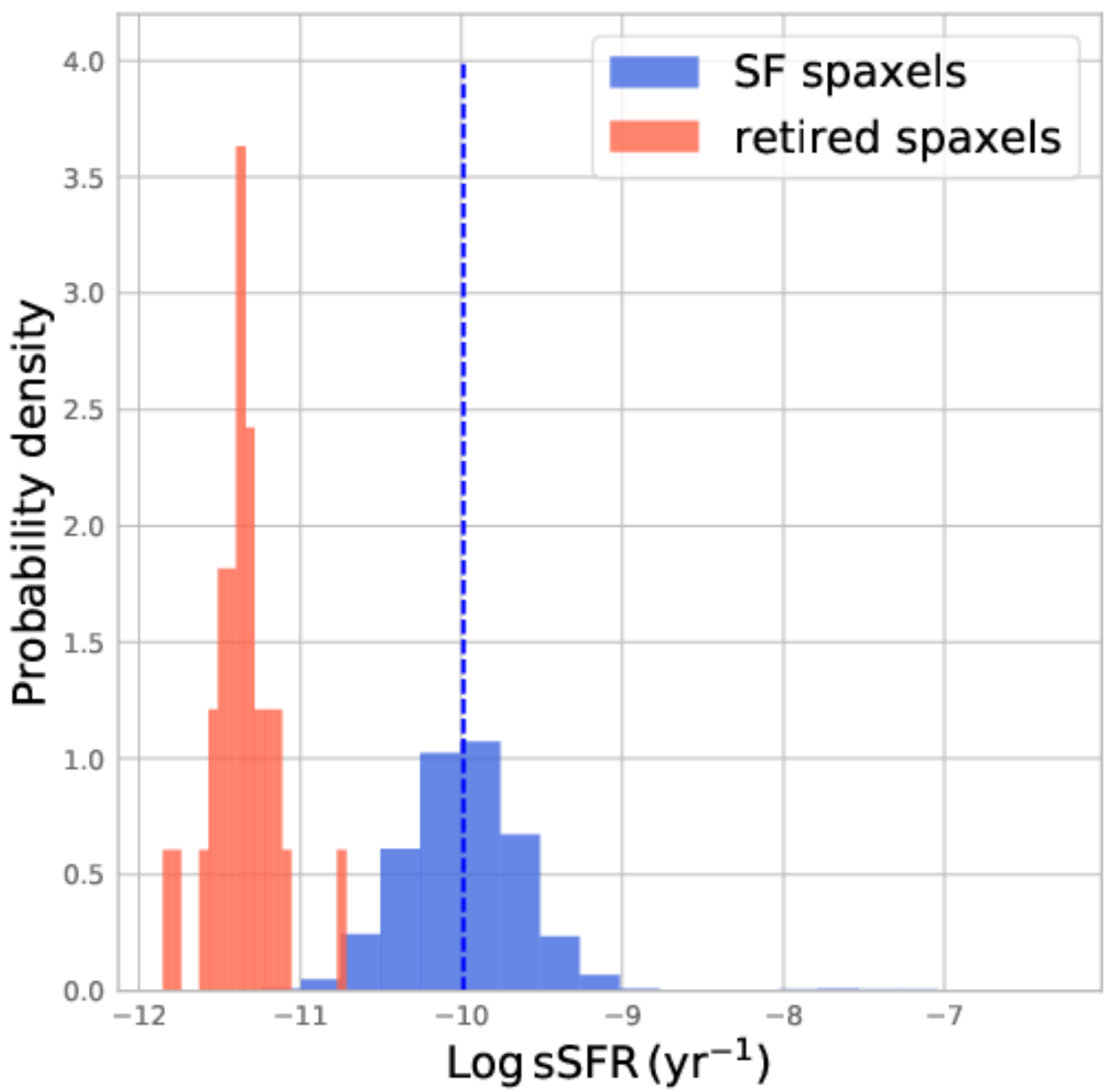
Retired spaxels:

BPT-classified LINERs & EW(Ha) < 3A

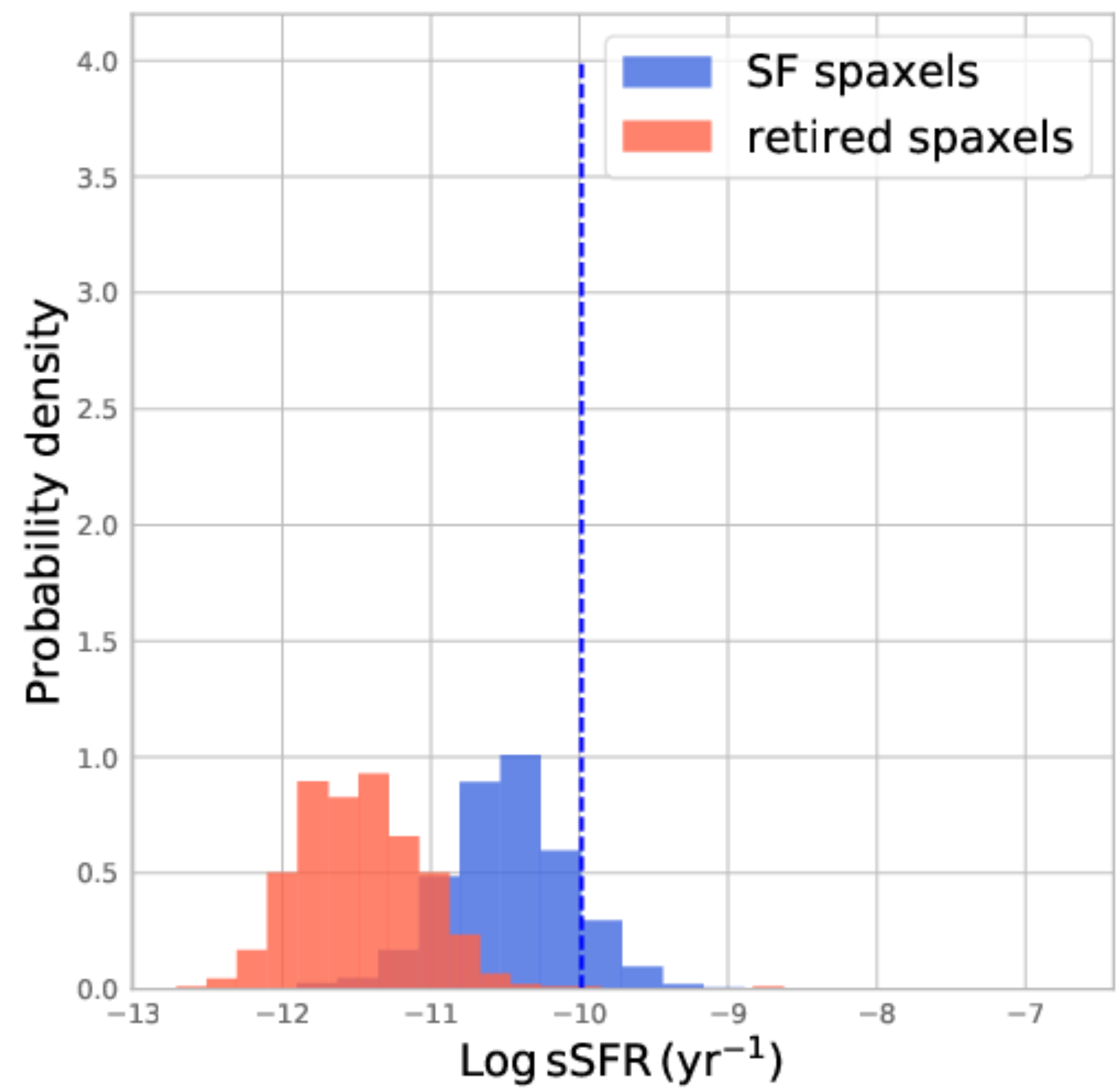


sSFR

MS galaxies



GV galaxies



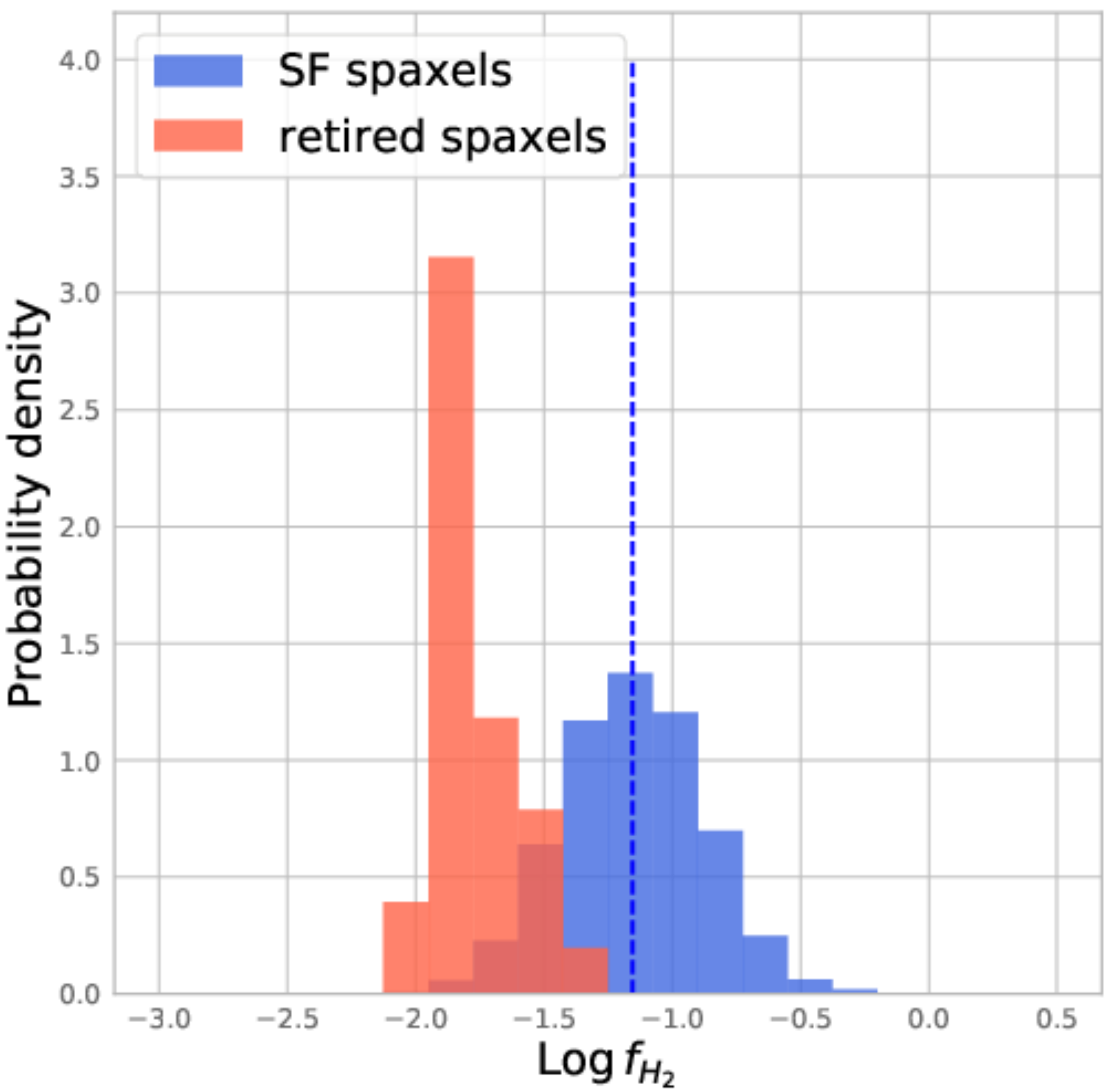
By definition, GV has lower sSFR.

sSFR of GV is lower than that of MS for both SF or retired spaxels

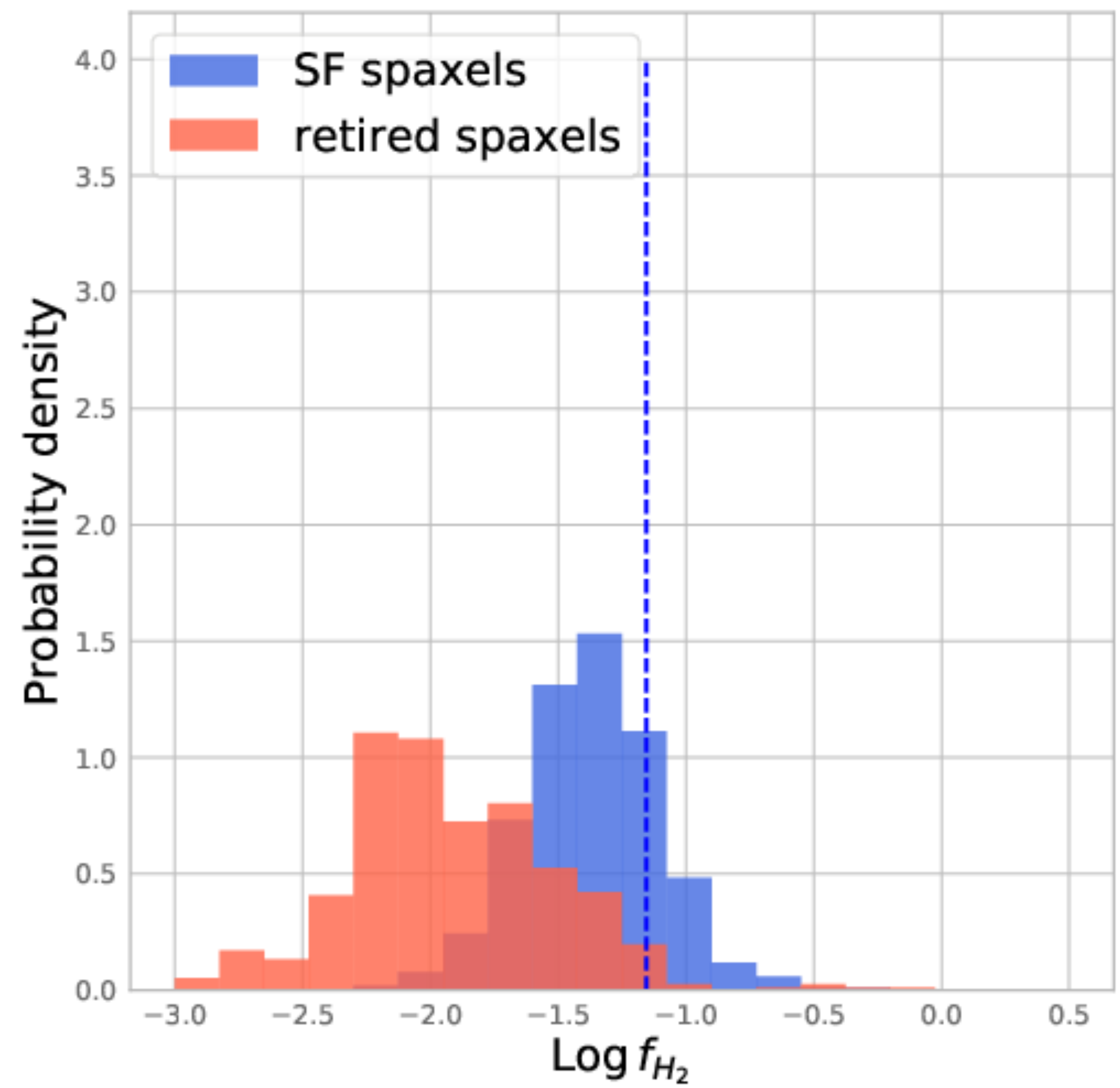
Lin+, in prep.

f_{H2}

MS galaxies



GV galaxies

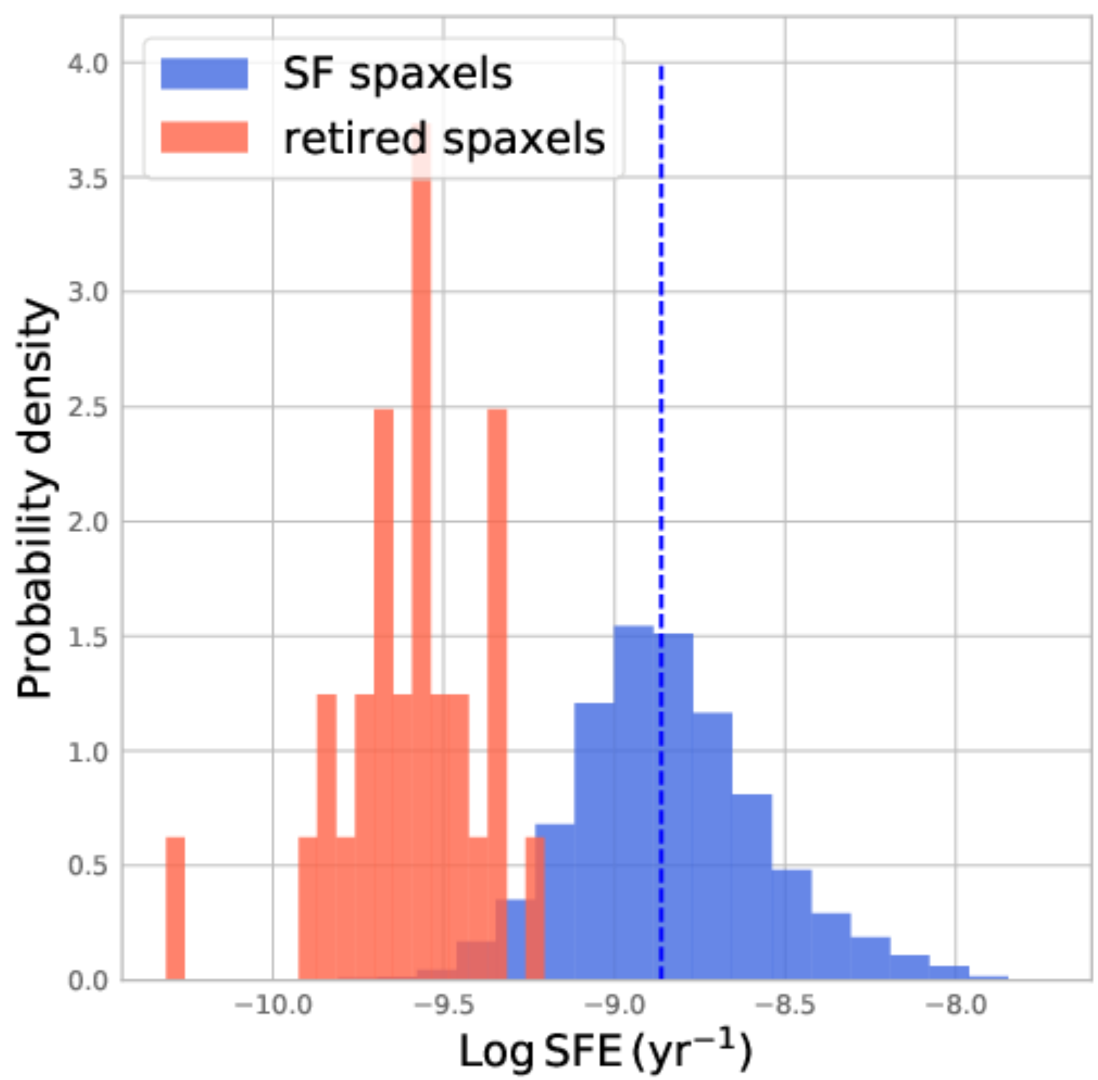


f_{H2} of GV is lower in both SF and retired spaxels than that of MS

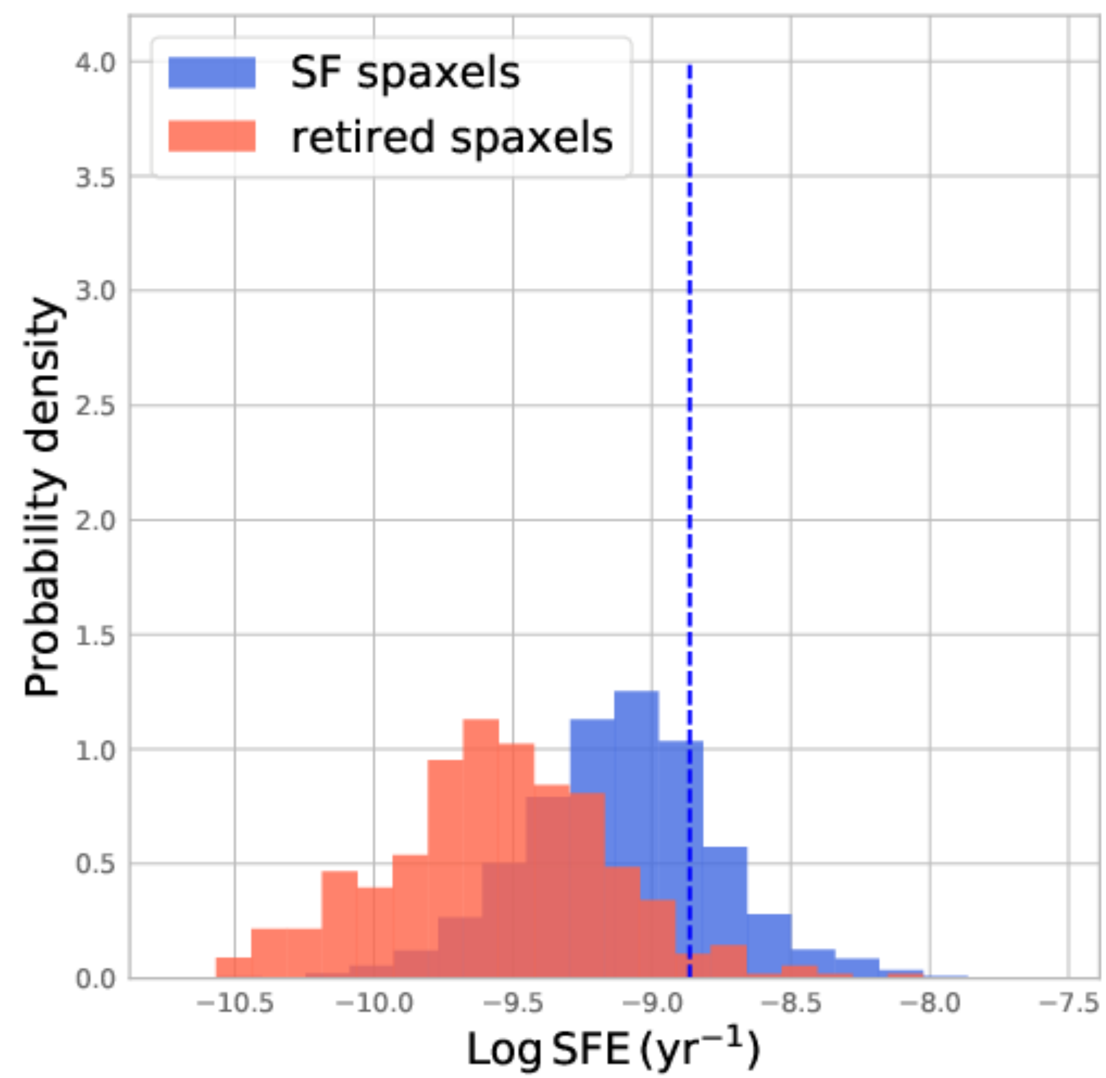
Lin+, in prep.

SFE

MS galaxies



GV galaxies



SFE of GV is lower in both SF and retired spaxels than that of MS

Lin+, in prep.

SUMMARY

- ALMaQUEST (Lin et al. 2020, submitted).
    - ALMaQUEST provides dataset to simultaneously study the relationships between SFE, M_*, and M_{gas} at kpc scales for starburst, main sequence, and green valley galaxies.
- Scaling relations of MS galaxies (Lin et al. 2019)
    - At kpc scales, the surface densities of SFR, M_*, and M_{gas} are tightly correlated with each other. In addition to the known rSFMS and SK relations, there also exists a 3rd relation: molecular gas main sequence (MGMS).
    - rSFMS is a natural consequence of the combination of SK and MGMS.
- Scaling relations of GV and retired regions (Lin et al. in prep.):
    - GV galaxies not only have lower sSFR (by definition), but also lower gas fraction (f_{H2}) and star formation efficiency (SFE), in either star-forming or retired spaxels.

See Sara's talk this afternoon (scatters in the scaling relations)