Gas-phase environmental effects in the Spiderweb protocluster at z=2.16

Jose Manuel Perez-Martinez
(Tohoku Univ.)

Helmut Dannerbauer
(IAC)

Tadayuki Kodama
(Tohoku Univ.)

Yusei Koyama
(NAOJ-Subaru)

Subaru Users Meeting

January 11-13th, 2022

Contact: jm.perez@astr.tohoku.ac.jp

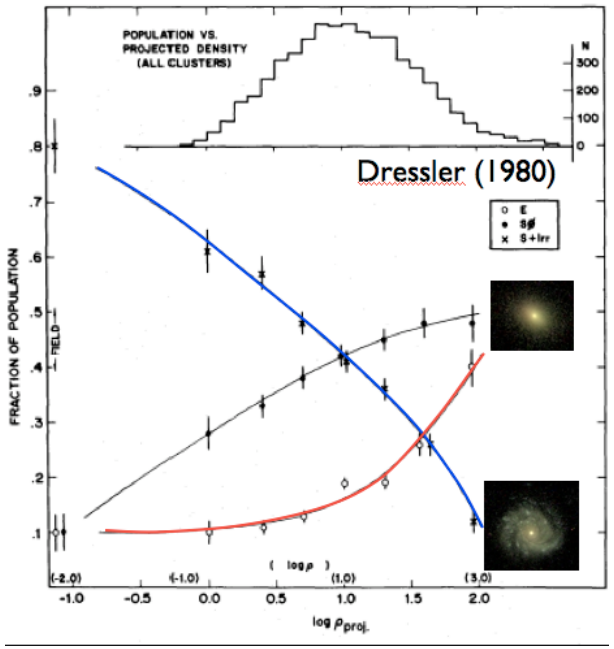
MAHALO
Subaru

Motivation

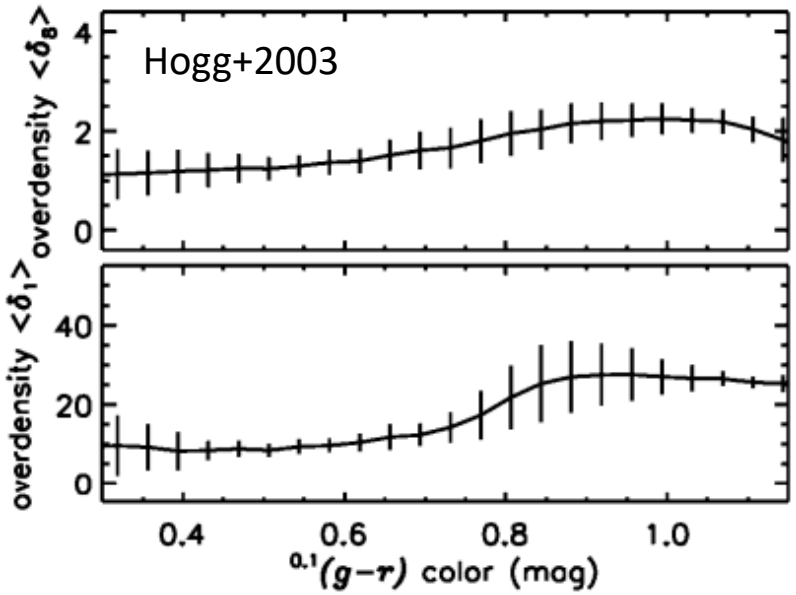
Mature Clusters:

Also metallicity enhancement: Maier+19a, Ciocan+20

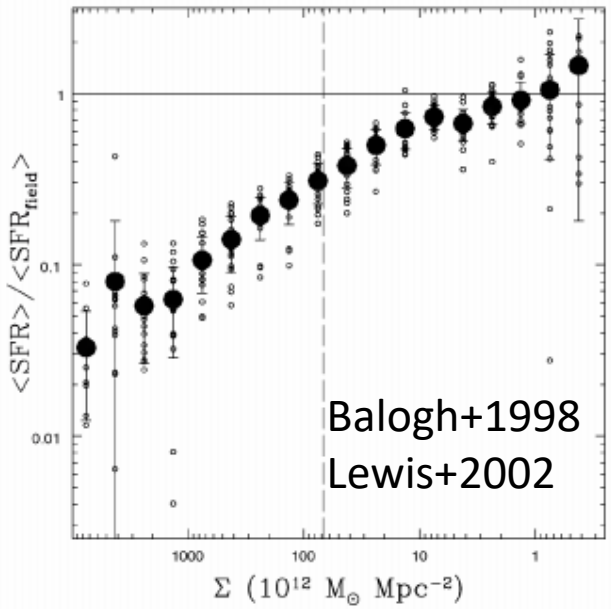
Morphology-density relation



Color-density relation



Star formation-density relation



Environmental Effects
(Mature clusters at z<1)

- Tidal interactions
- Mergers
- Strangulation
- Ram pressure stripping

However at z>2: (protoclusters)

- Increased merging activity
- Higher gas inflows and gas fractions
- Large-scale assembly (local vs global env.?)

Our target: PKS1138 at z=2.16

~100 $H\alpha$ narrow-band detections using Subaru/MOIRCs

<u>Extensively studied</u> in the past:

a) Pentericci+98, Miley+06, Emonts+16 & +18 → Spiderweb

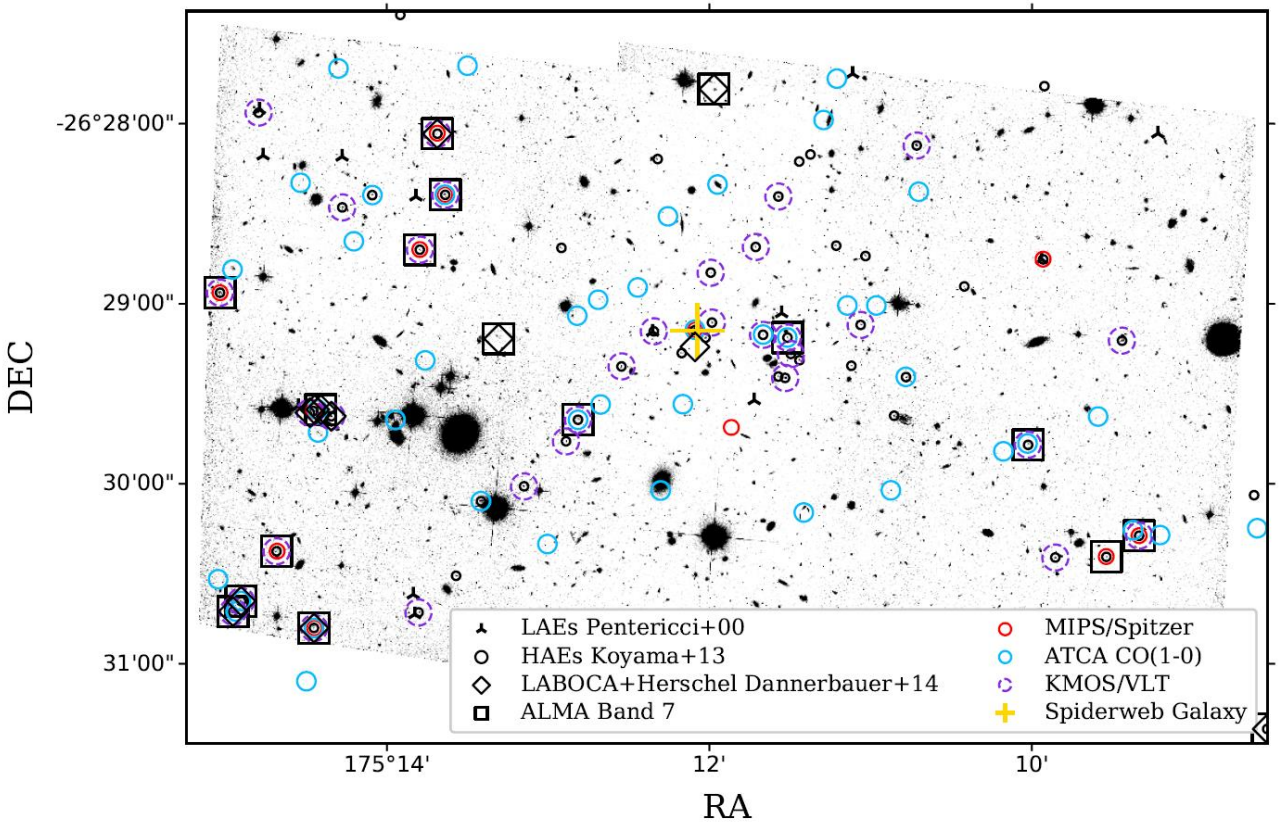
b) Kurk+00, Pentericci+00 → LAEs

c) Kurk+04a, Kodama+07, Tanaka+13 → Red sequence

d) Dannerbauer+14, Dannerbauer+17 → Dusty Starburst

e) Koyama+13, Shimakawa+15 & +18, **This Work!** → HAEs

f) Jin+21 → CO(1-0) Luminosity function **(NEXT TALK!)**



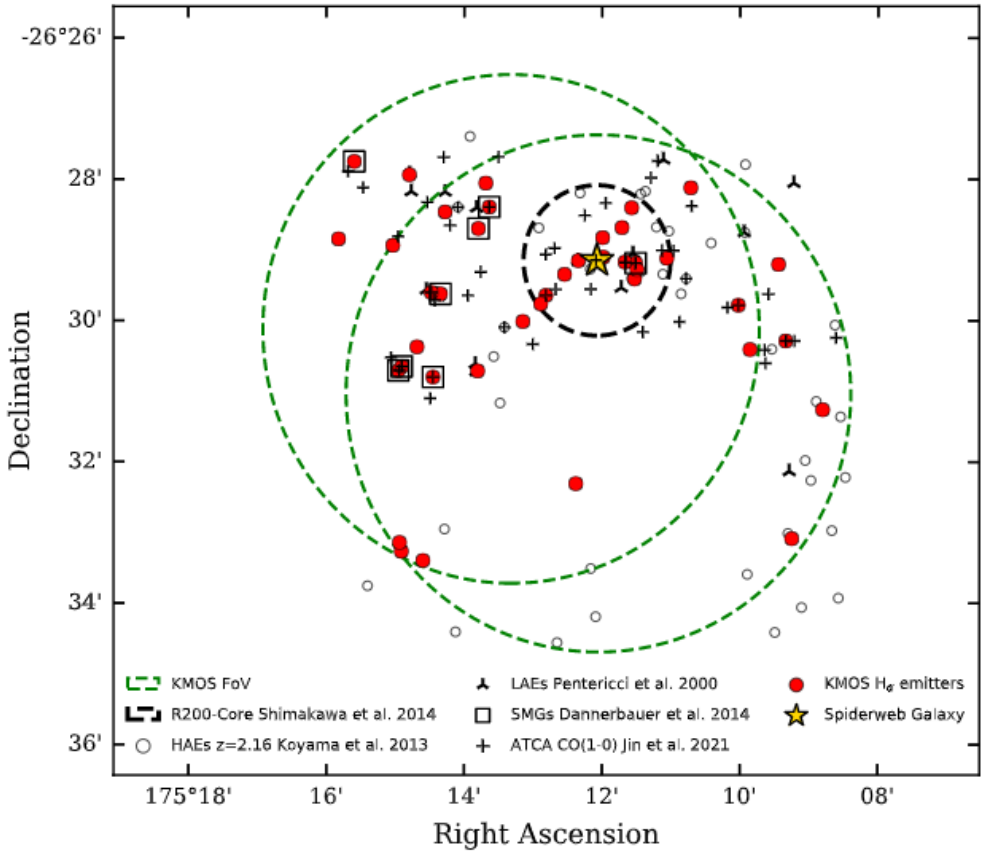
Protocluster showing several infalling filaments and M_{200} above $10^{14} M_{\odot}$ → One of the most massive (assembling) structures at this redshift.

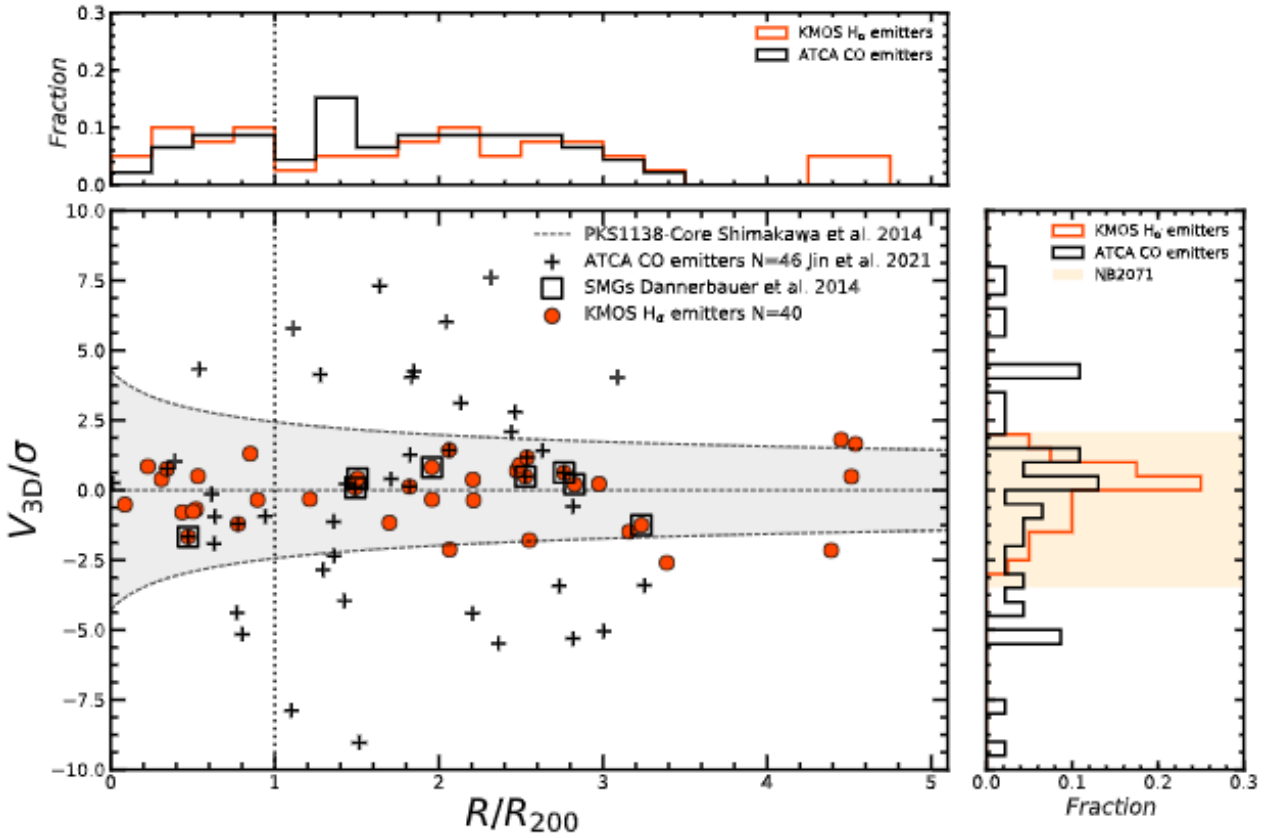
KMOS Spectroscopic follow-up

- Two KMOS pointings in K-band (3h) aiming to obtain Hα and [NII] at z=2.16 **to study SFR, 12+log(O/H), and gas fraction (VLA/ATCA).**

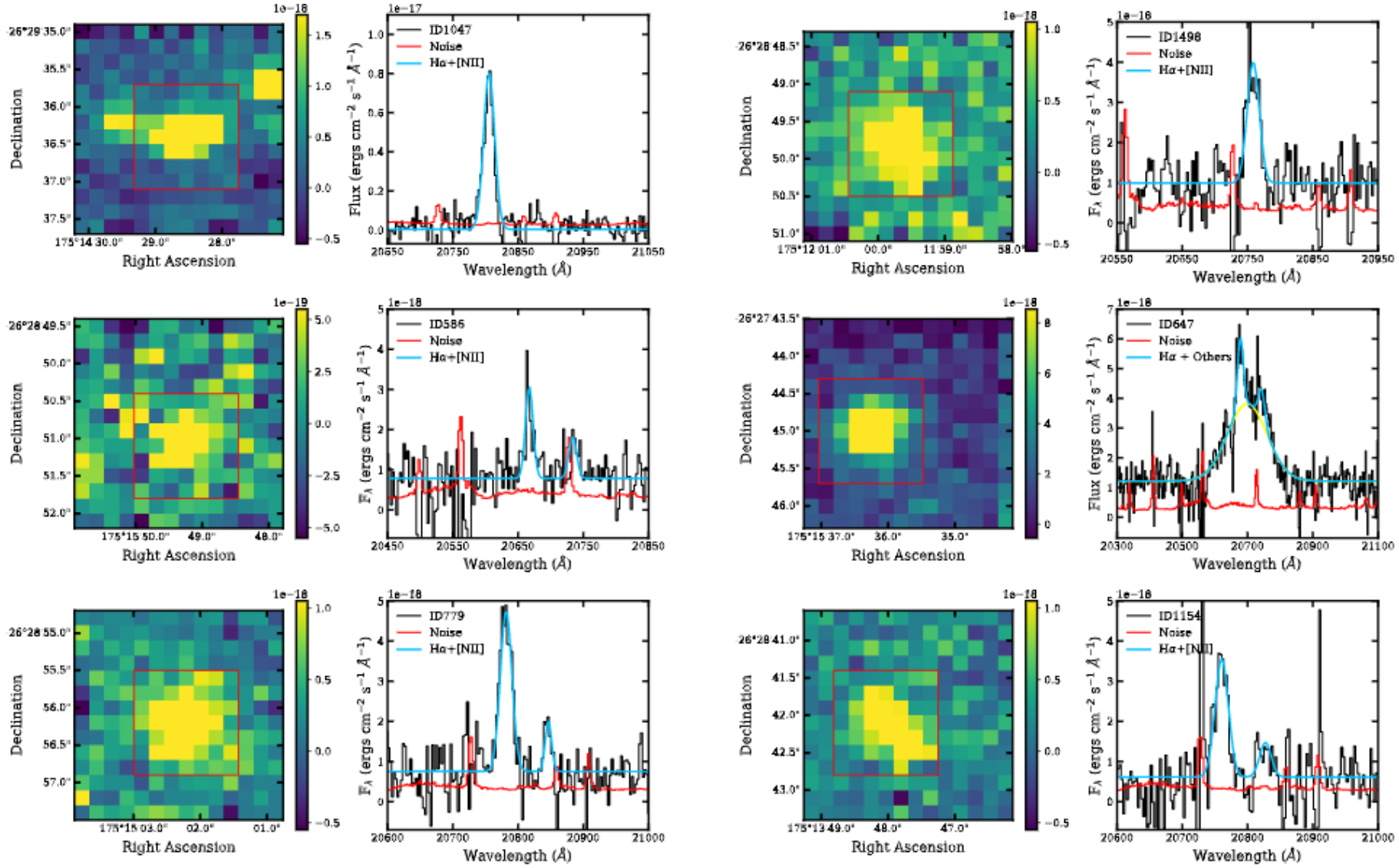
A) **42 objects** from previous data (BB/NB photometry, Koyama+13) covering different density regimes.

B) **39 Hα spec-confirmed members**, 2 objects with no emission, 1 background galaxy at z=3.16

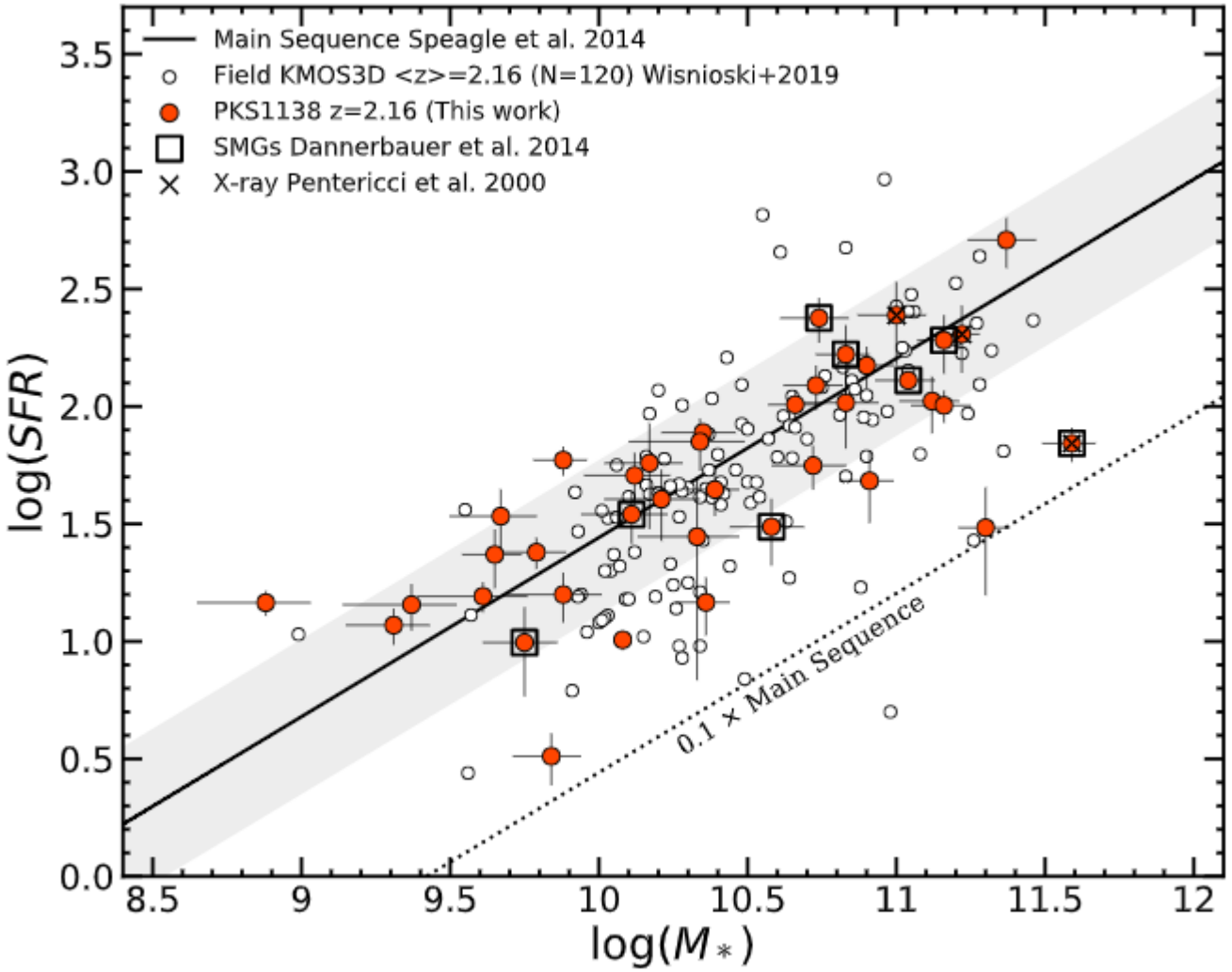




Some Examples



The Main Sequence of Star Formation



→ Kennicutt+98 SFR(Hα) calibration modified for Chabrier IMF and dust extinction correction following Wisnioski+19 (Av & Av_extra)

Most objects lie around the "main-sequence" (Speagle+14) and KMOS3D coeval field galaxies (Wisnioski+19).

A few galaxies may be in the process of quenching.

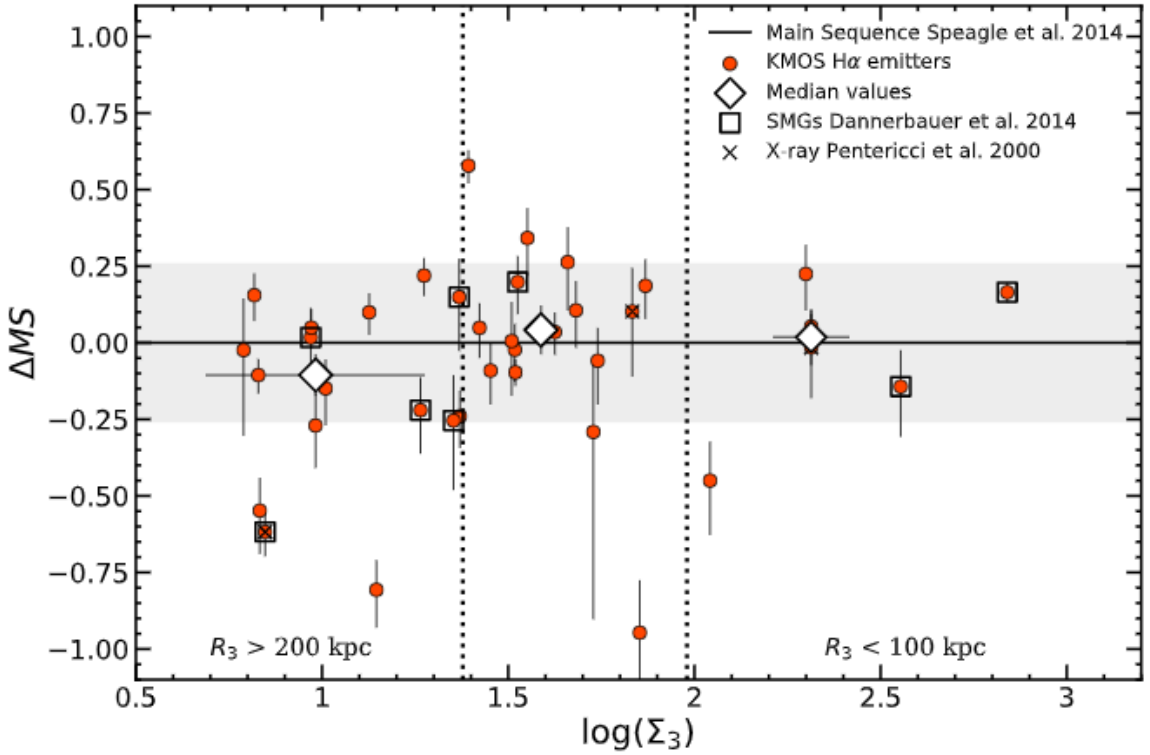
Next step: <u>Local vs Global environment analysis</u>

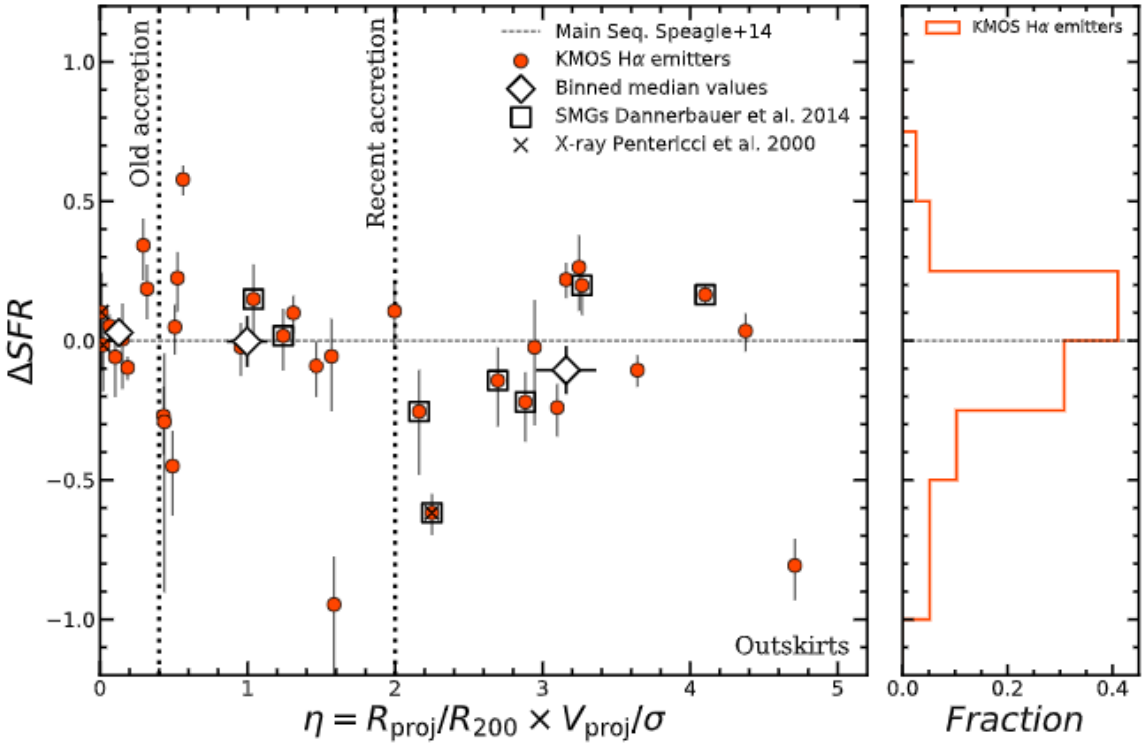
$$\Sigma_{\mathrm{Nth}} = N/\pi r_{\mathrm{Nth}}^2$$ (Local projection)

$$\eta = R_{\mathrm{proj}}/R_{200} \times V_{\mathrm{proj}}/\sigma$$

(Caustics of phase-space, Noble+13)

SFR and Local vs Global Environment

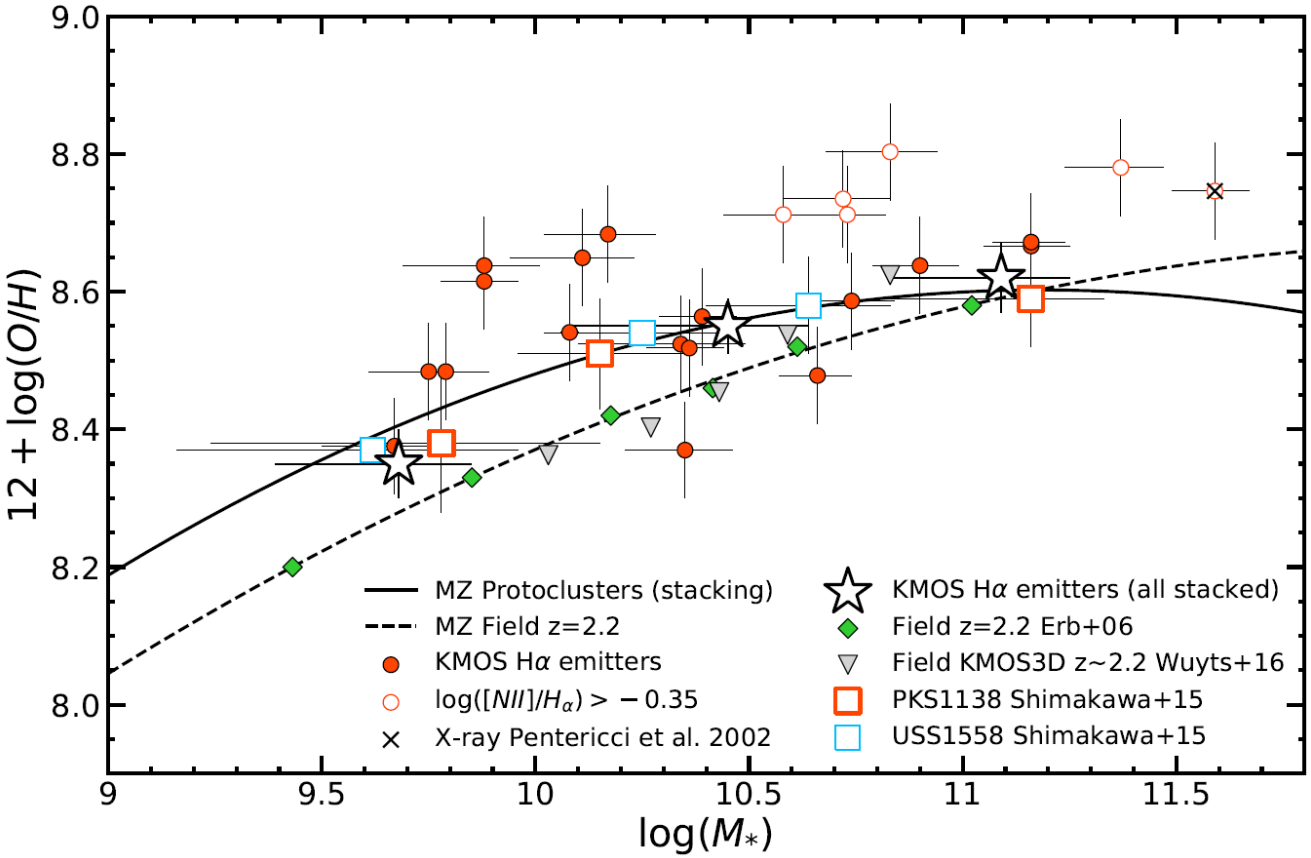




Significant scatter in the SFR-M_* with respect to local and global environment.
Results compatible with the field Main Sequence → <u>No significant Env. dependence.</u>

Mass-Metallicity relation

- Clear [NII] detections mostly probe the high metallicity end → Stacking of “non-detections” is required.

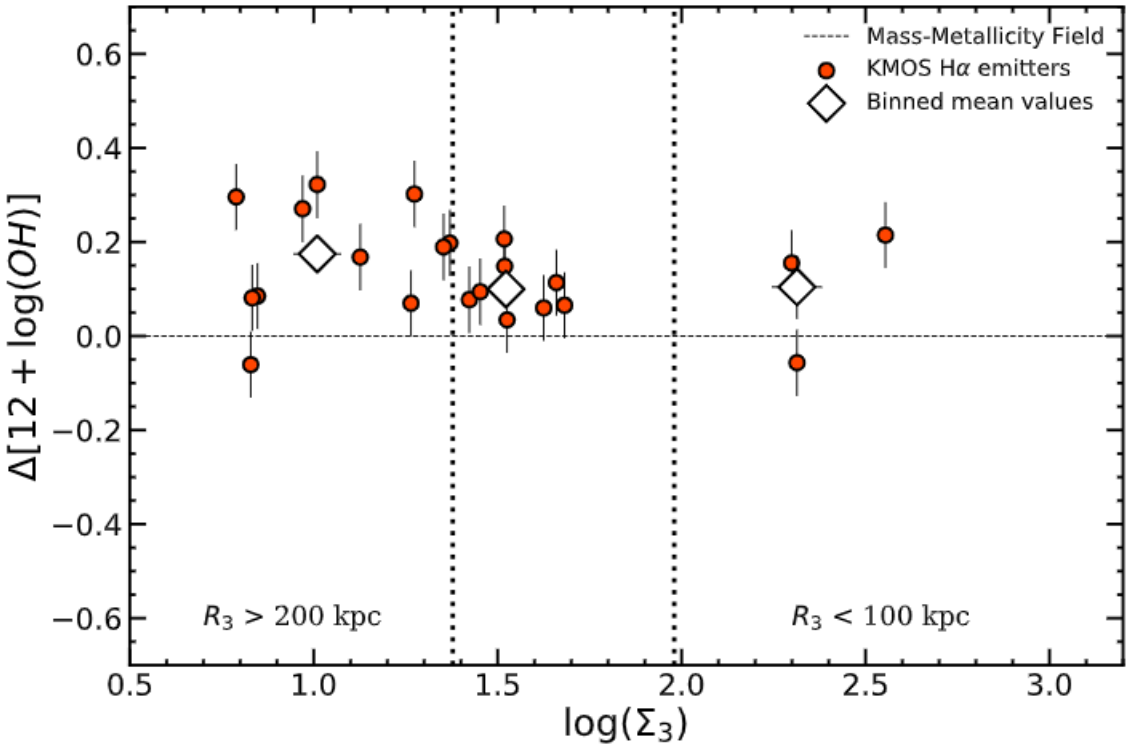


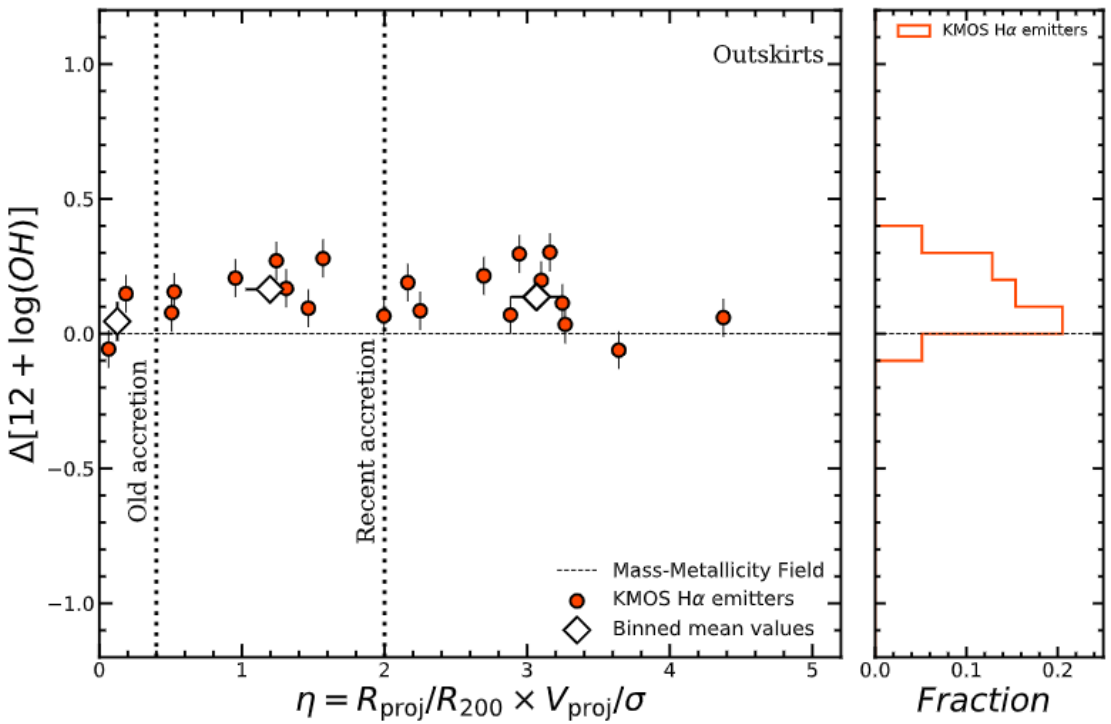
Metallicity enhancement (0.1-0.2 dex) for some galaxies in PKS1138 with respect to the field.

After stacking our whole sample we find **agreement with Shimakawa+15** (MOIRCs stacking).

Significant amount of galaxies with $\log([NII]/H\alpha) \geq -0.3$ → **Possible enhancement of AGN fraction**.

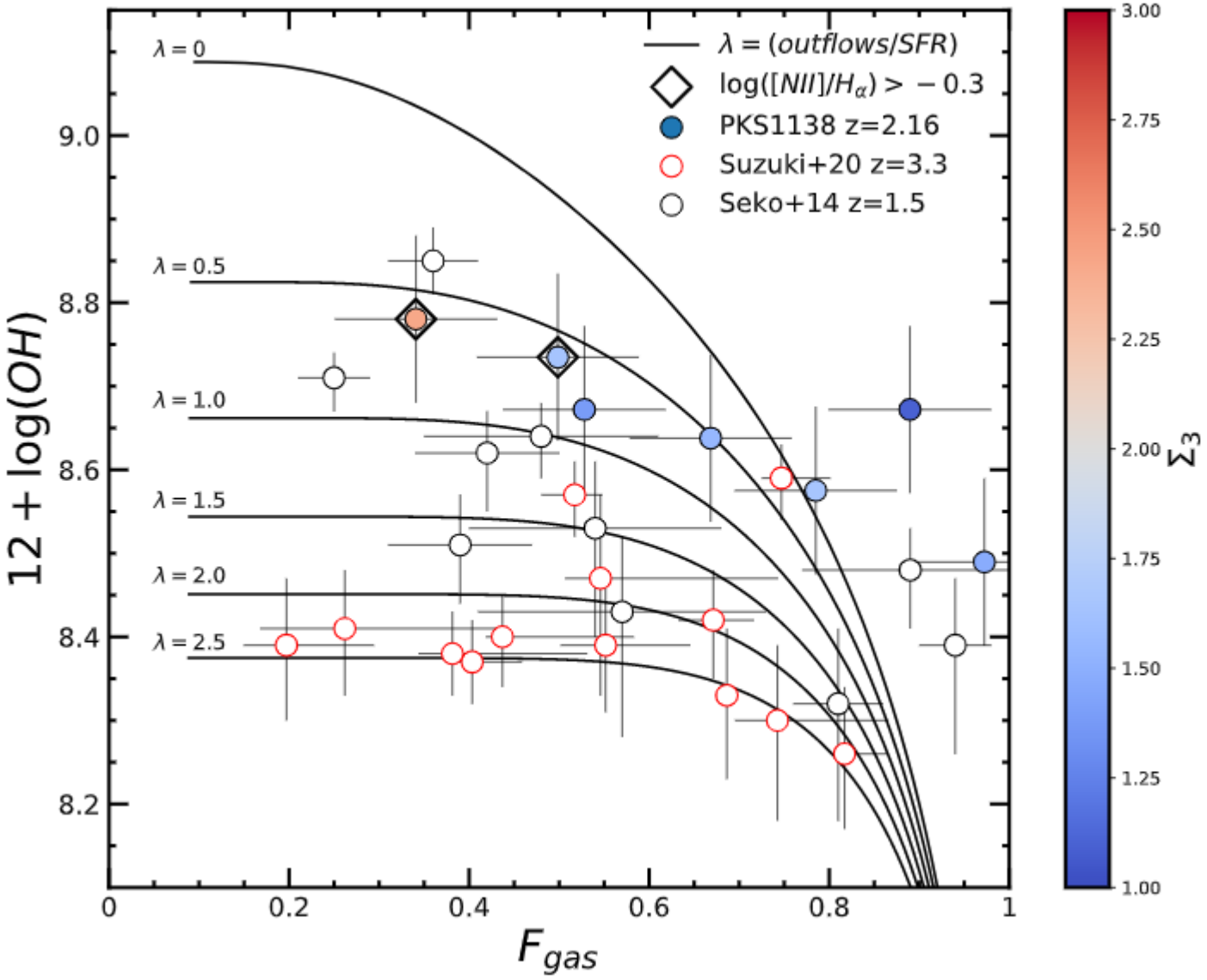
Metallicities and Local vs Global Environment





Local and global environmental indicators show **enhacement (0.1-0.2 dex) in different density regimes.**

Gas metallicity – Gas fraction relation



Molecular gas information CO(1-0) available from VLA/ATCA → See Jin et al. 2021

→ **Metallicity dependant CO luminosity conversion** of Tacconi+2018.

→ All these galaxies have **SFR compatible with the Main Sequence. However,** they seem to be **metal-enriched** for their gas fraction.

→ Protocluster environment may help to **confine galaxies (cutting inflows and suppresing outflows),** forcing galaxies to recycle their gas and enriching their ISM.

→ AGN contribution remains nuclear and requires further study.

Summary

1) Spectroscopic confirmation of 39 Hα emitters within the PKS1138 protocluster at z=2.16.

2) We measured SFR using the Hα emission line and found **mean SFR values compaible with the field MS** (Speagle+14) using local and global environmental indicators. **First signs of quenching in a few galaxies.**

3) We measured **Hα+[NII] metallicities** (Pettini+04) to study the mass-metallicity relation.

→ Our stacked results suggest a **metallicity enhancement for galaxies residing in protoclusters** with respect to the field (Erb+06, Wisnioski+19) at similar redshift. Agreement with Shimakawa+18.

→ **No clear correlation with environmental indicators.** The enrichment affects objects across the whole structure.

→ Significant fraction of galaxies with large $[NII]/H\alpha$ ratios. **Possible AGN fraction enhancement.**

4) Smaller mass loading factors for protocluster galaxies in contrast to the field → Hints early environmental confinement.