Molecular gas in void galaxies (CO-CAVITY)

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The Calar Alto Void Integral-field Treasury surveY

(CAVITY)

project

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&

CAVITY team

(more than 40 researchers from 13 different institutions in 8 countries)

Introduction:

The majority of galaxies belong to groups and clusters tracing interconnected structures in a sponge-like fashion. This large-scale structure is characterised by clusters, filaments, walls, but also under-dense regions, called voids

The void regions and the galaxies within, represent an ideal place for the study of galaxy formation as they are largely unaffected by the complex physical processes that transform galaxies in high-density environments

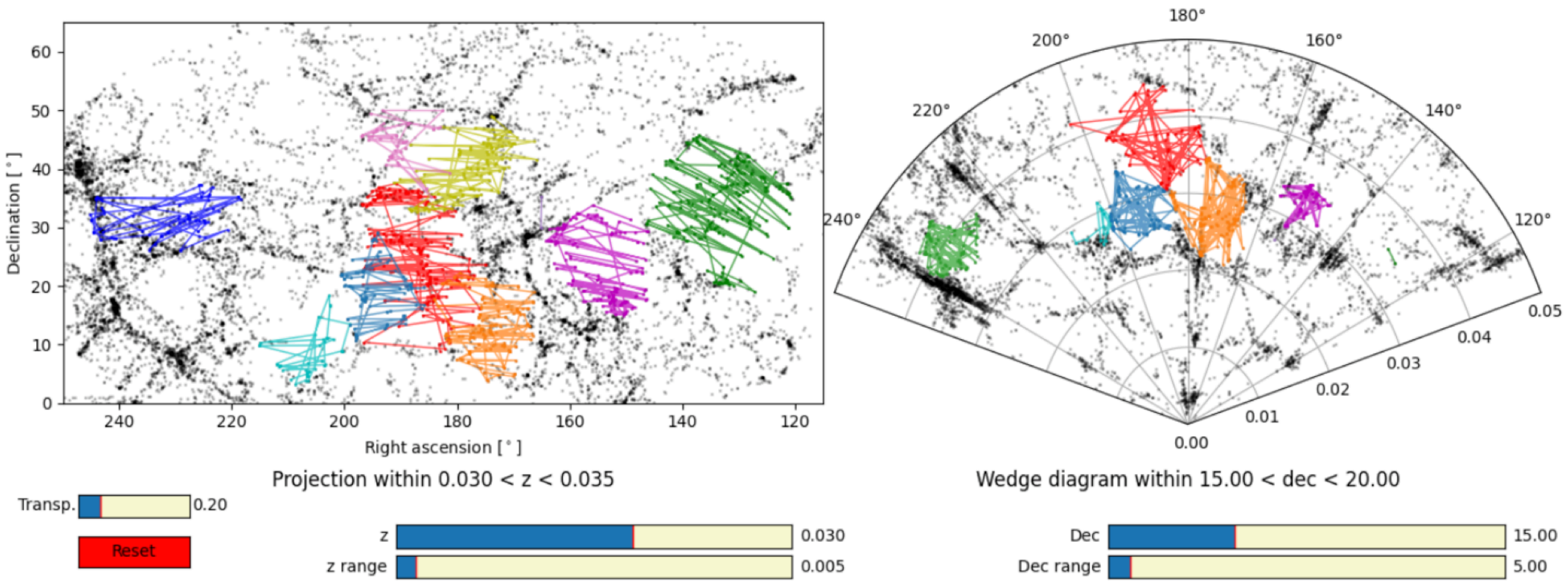
These void galaxies can shed light into galaxy formation and into the current challenges to the ΛCDM models

The main aims:

1. Determine how the environment has influenced the mass assembly (baryonic and dark) of void galaxies
2. Establish how galaxy formation and its properties are dependent on the larger-scale environment
3. Find the main driver of galaxy transformation

The CAVITY sample: ~ 300 galaxies distributed in 15 cosmic voids

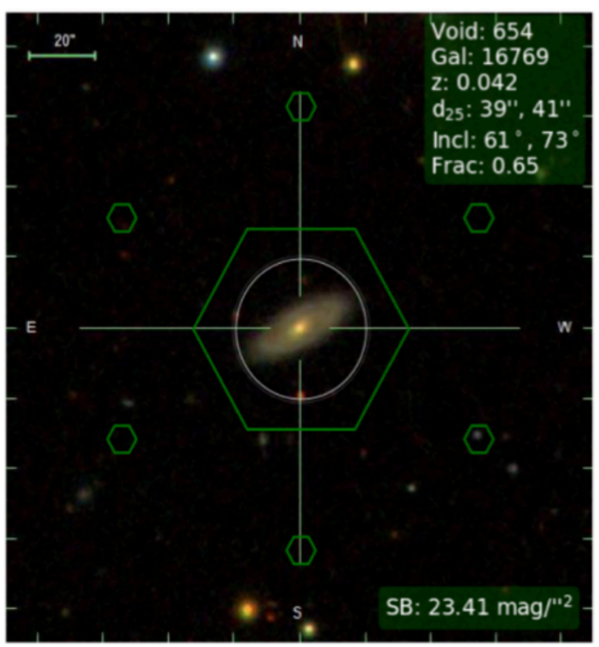
The sample has been specifically designed to sample galaxies within voids, probing voids of different sizes and dynamical stages, and also ensuring that the full 24th B-magnitude of the selected IFU-sample galaxies fits the field-of-view of the instrument to make sure that the analised properties can be rightfully compared

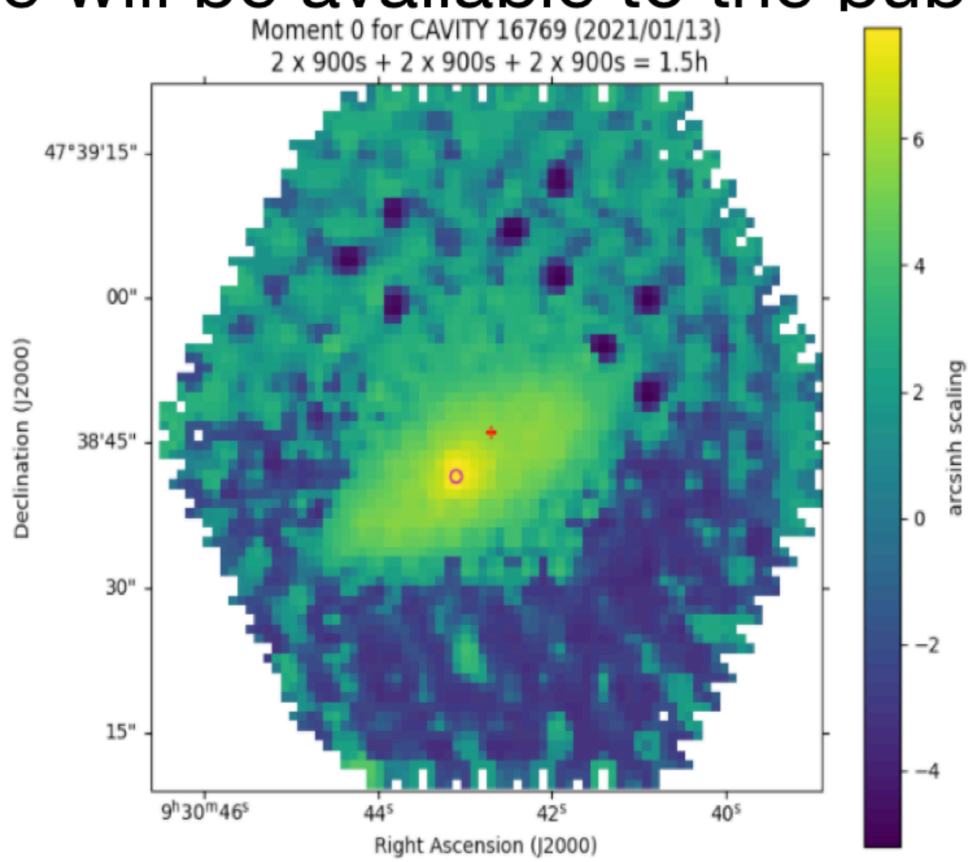


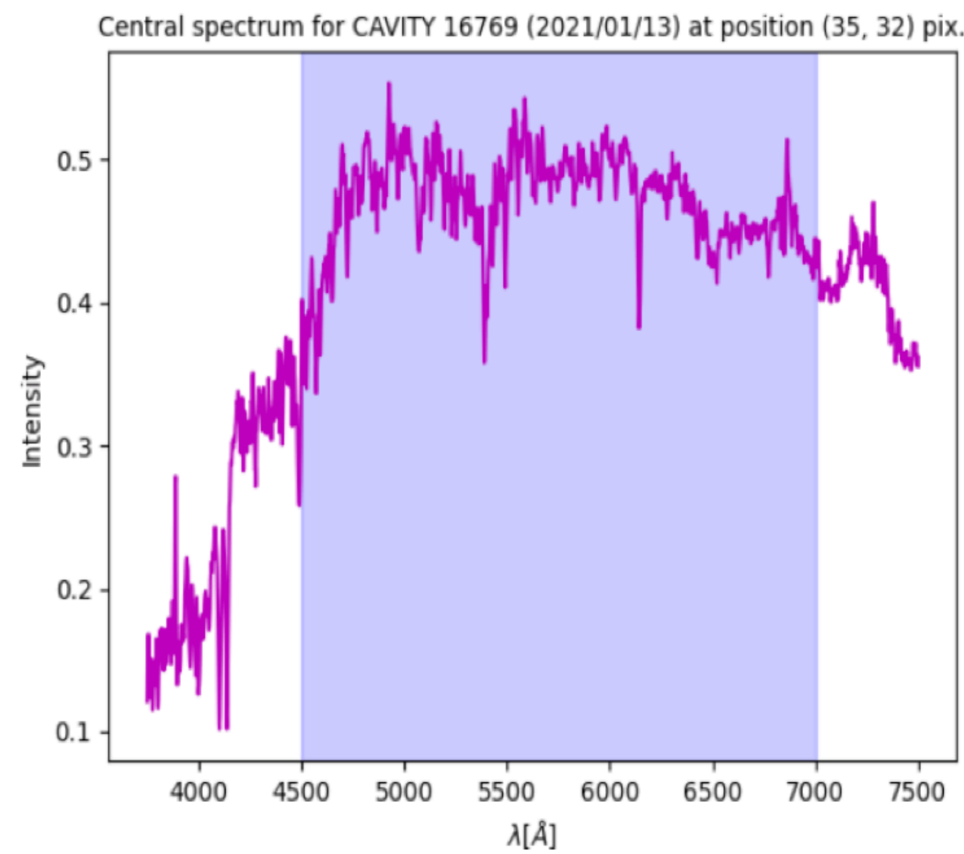
CAVITY observations officially started on January 2021, and are performed with the Postdam Multi Aperture Spectrograph (PMAS, Roth et al. 2005) in the PPaK mode (Verheijen et al. 2004) at the 3.5 m telescope Calar Alto Observatory (CAHA)

The science fiber are comprised in an hexagonal configuration covering a field-of-view of 74” × 64”

The first data-release will be available to the public in 2023







For more info:
https://cavity.caha.es/

CO-CAVITY:

Study of the cold molecular gas through radio-mm observations

MH_2 mass content

SFE

Gas fraction

Time depletion

I_{co} (1-0) / I_{co} (2-1)

Observations & Data reduction & Quality Control:

Observations:

- 30 mts IRAM (EMIR - FTS)
- December 2021 to February 2023
- Wobbler switching
- 30min to 4hrs

Data reduction:

- Discard poor scans
- Modify central frequency ($V_c = 0$)
- Correct platforming effects
- Adjust and subtract a linear baseline
- Sum and smooth (V_{res} ~20 km/sec)

Quality Control:

- Detection
- Flat baseline
- Velocity window
- Comparison between the CO(1-0) and CO(2-1) emission

Results summary:

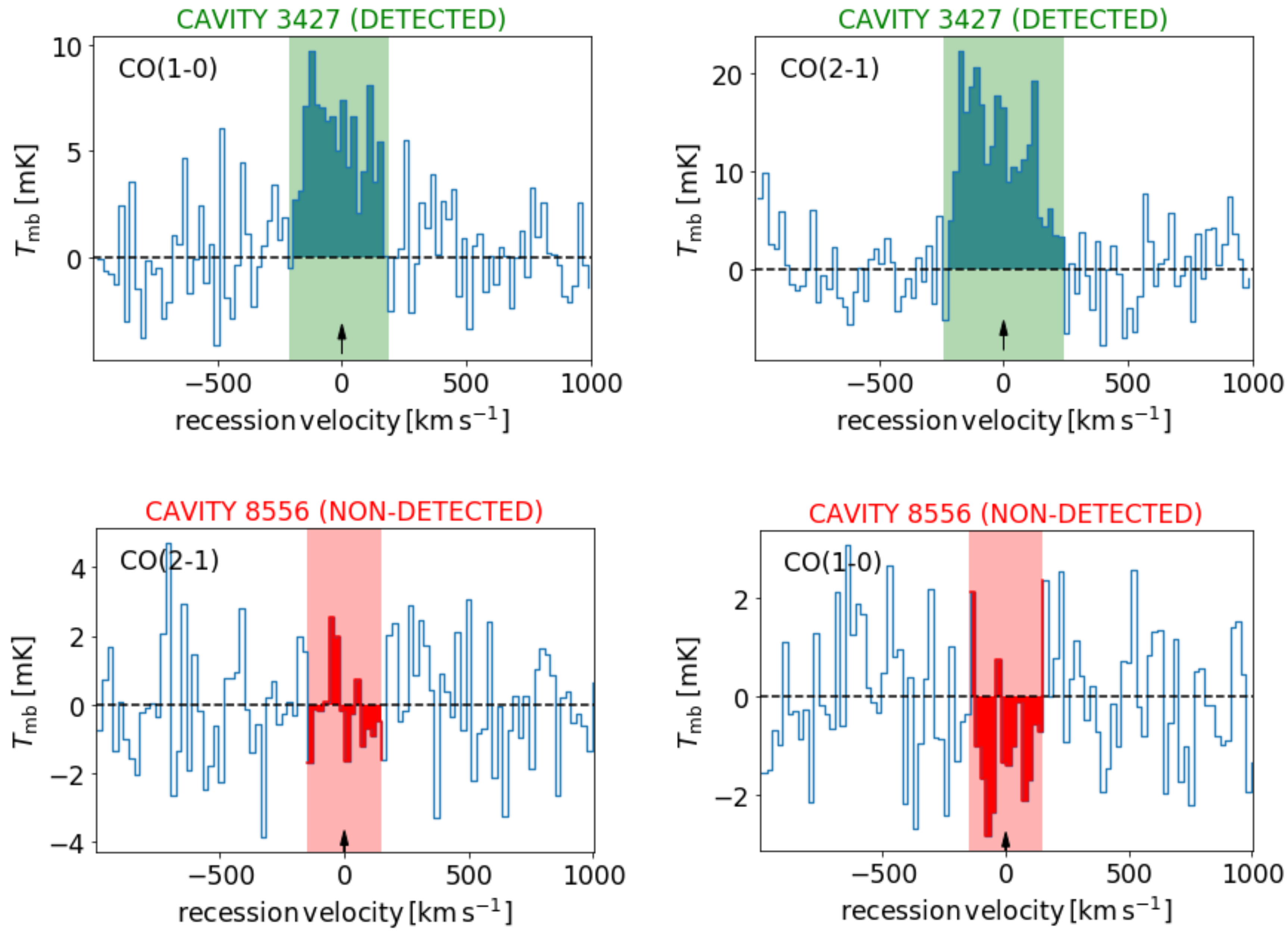
106 objects

CO (1-0)

detections (S/N > 5): 64
tentative (3 > S/N < 5):9
non-detected (S/N < 3): 33

CO (2-1)

detections (S/N > 5): 63
tentative (3 > S/N < 5): 9
non-detected (S/N < 3): 35



7 galaxies undetected in CO(1-0), but detected in CO(2-1)

16769, 26668, 37605, 39573, 40774, 51442 and 65887

Control Sample:

xCOLD GASS: The xGASS (Catinella et al. 2018, the extended GALEX Arecibo SDSS Survey) is a HI survey of 1179 galaxies. xCOLD GASS (Saintonge et al. 2017) is an IRAM 30 m telescope H_2 legacy survey of 532 galaxies.

Galaxies inhabiting voids and clusters (Pan et al. 2012 & Tempel 2017) and AGN's were removed

Additional Sample:

VGS: Pilot project of 20 galaxies observed with the 30 Mts (Domínguez-Gómez et al 2022). The HI data taken from Westerbork Synthesis Radio Telescope (presented in Kreckel et al. 2012).

Additional data:

HI:

ALFALFA Survey (36 detection and 20 upper limits)

Metallicity:

Calculated by Duarte-Puertas using O3N2 calibrator.

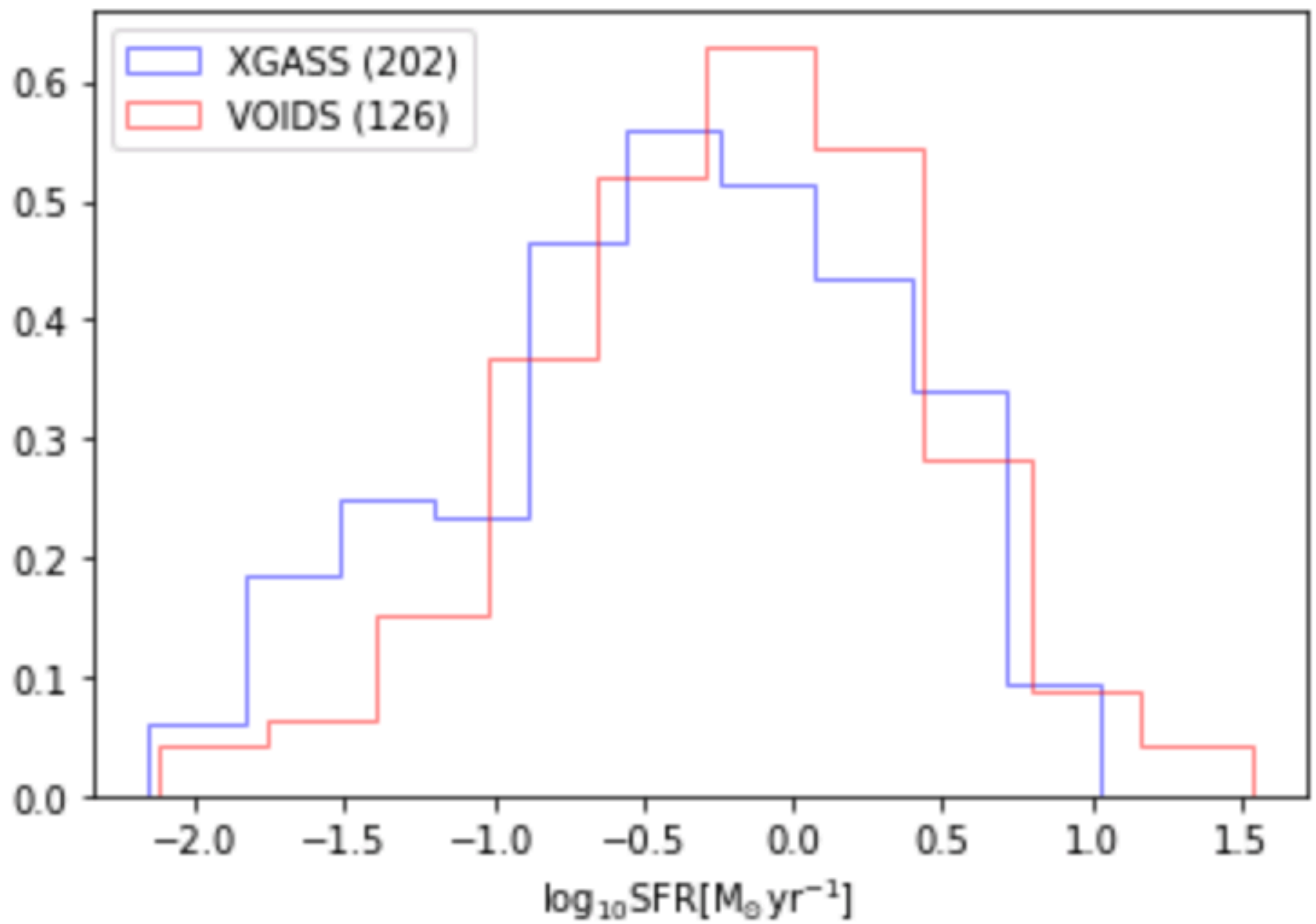
SFR:

Calculated by Duarte-Puertas ($\mathrm{H}\alpha$ refined model in Duarte Puertas et al. 2017)

M_*:

MPA-JHU catalogue (https://wwwmpa.mpa-garching.mpg.de/SDSS/DR7/)

SFR's



XGASS (202)
VOIDS (126)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
$\log_{10}\mathrm{SFR}[M_\odot\,yr^{-1}]$

Distance to the main sequence

- Janowiecki+2020

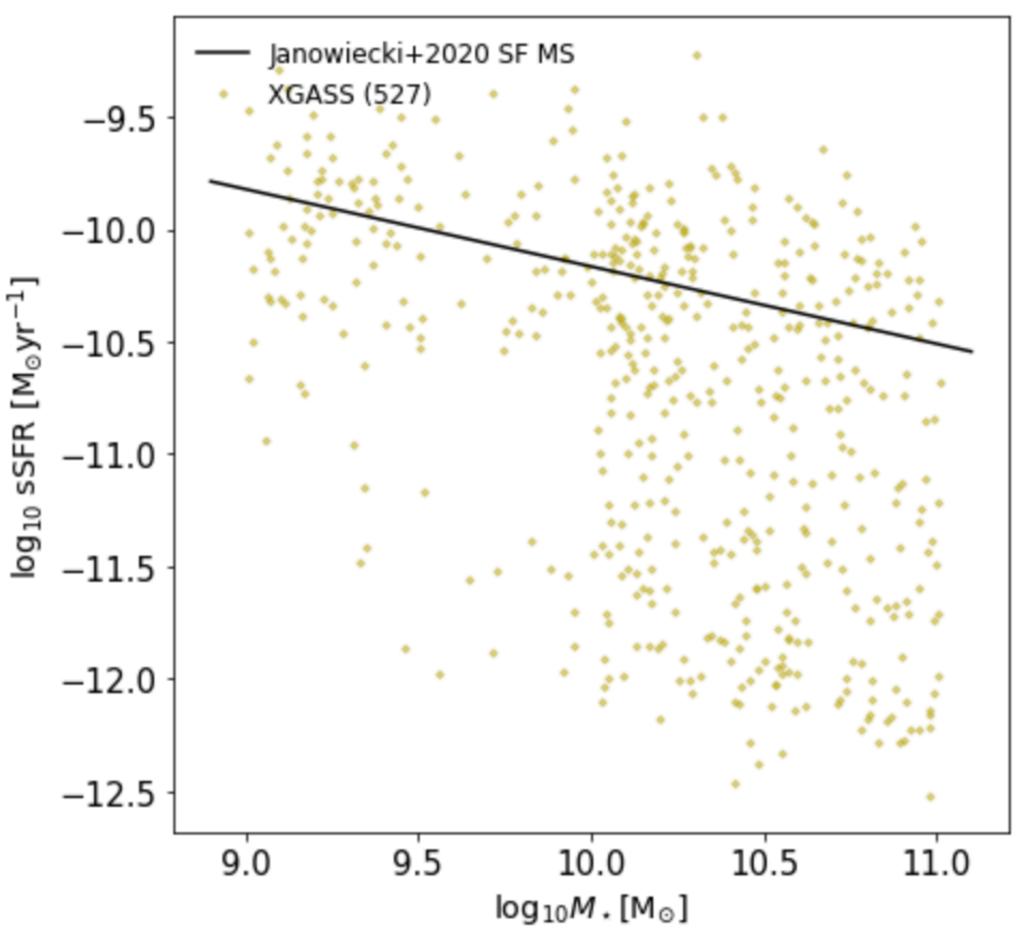
$$\Delta SFMS = log\frac{SFR}{M_{star}}[yrs^{-1}] - log\frac{SFR_{MS}}{M_{star}}[yrs^{-1}]$$

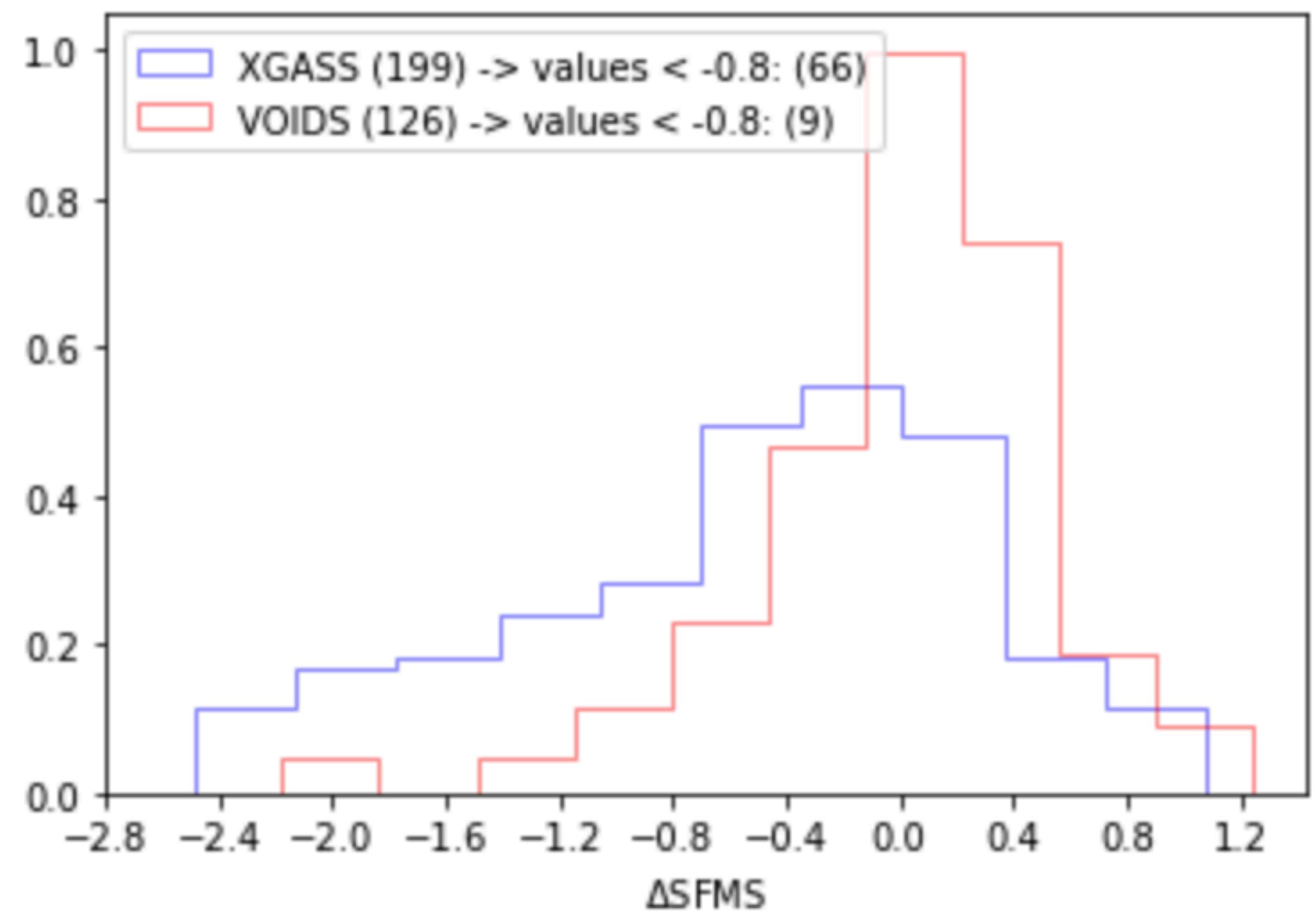
SF main sequence (Janowiecki+2020)

$$log\frac{SFR_{MS}}{M_{star}}\ (yr^{-1}) = m_{SFMS}\ (log\frac{M_{star}}{M_{\odot}} - 9) + b_{SFMS}$$

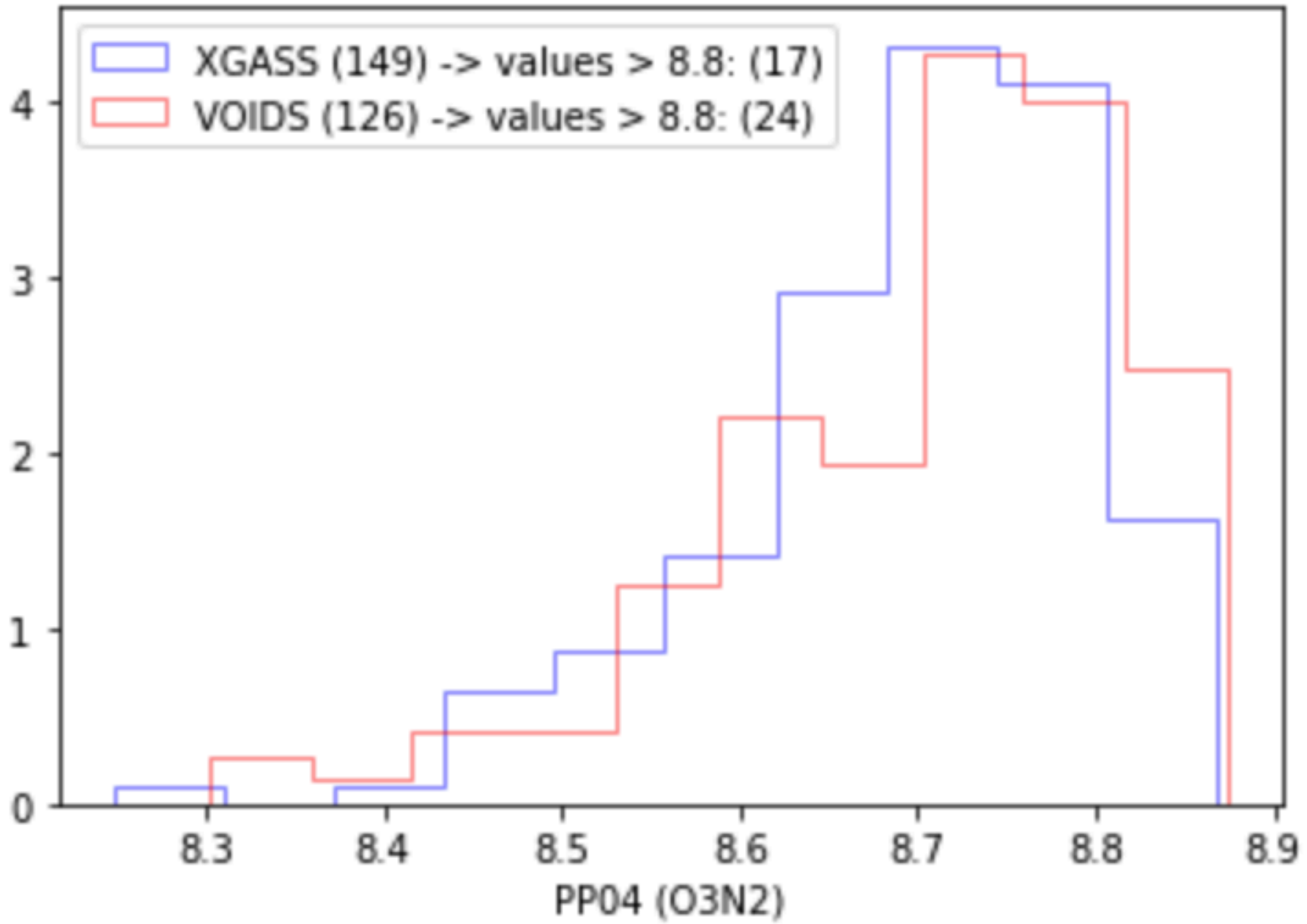
$$m_{SFMS} = -0.344 \pm 0.101$$

$$b_{SFMS} = -9.822 \pm 0.057$$





Metallicities



Preliminary analysis: Alpha_co factor

Alpha CO factor (Accurso+2017)

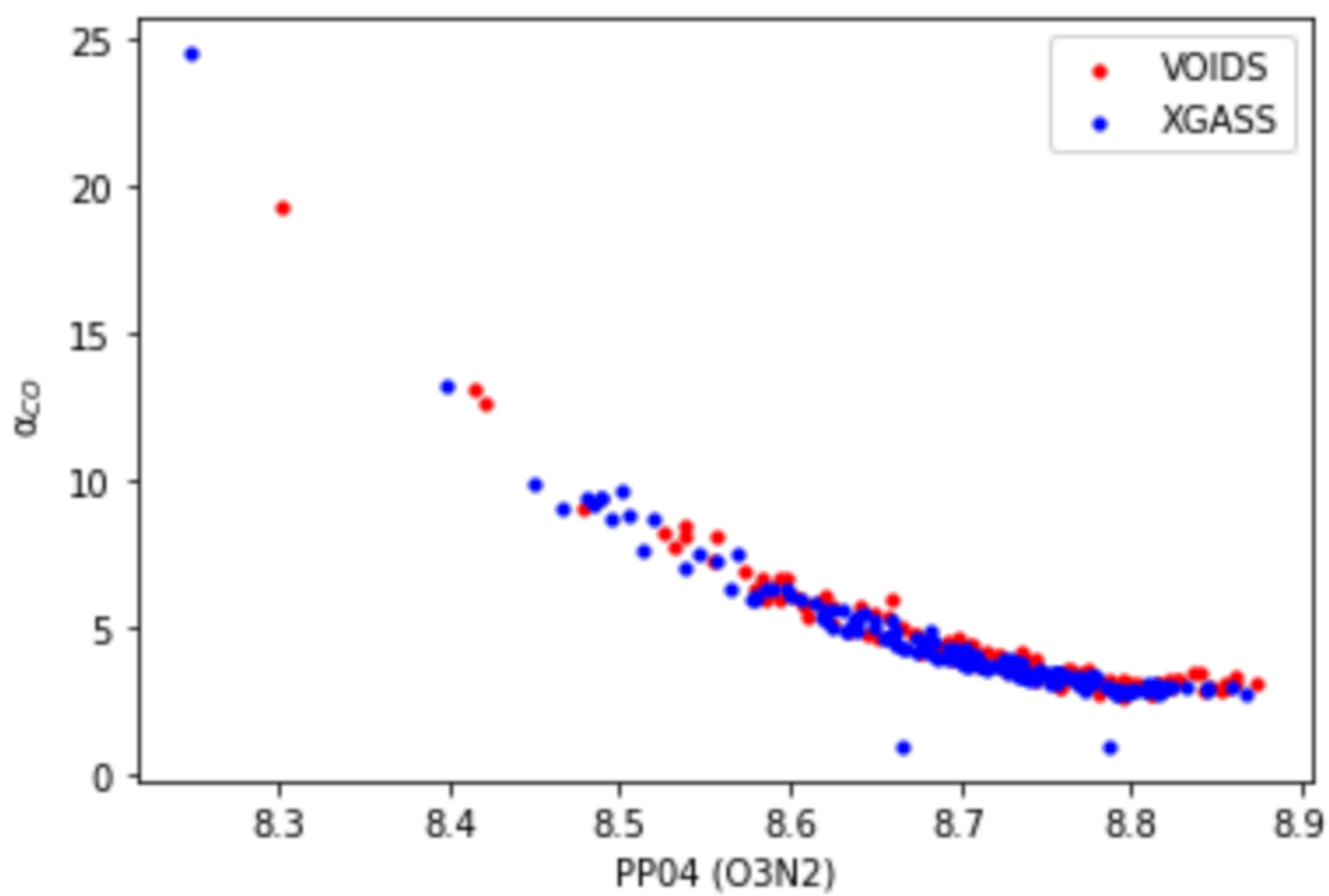
$$\log \alpha_{CO}\ (\pm 0.165 dex) = 14.752 - 1.623[12 + \log(O/H)] + 0.062 \log \Delta(MS) \quad (eq.\ 25)$$

The prescription should only be applied to galaxies with 7.9 < [12 + log (O/H)] < 8.8 and -0.8 < $\log \Delta$ MS < 1.3

For values [12 + log (O/H)] > 8.8 set [12 + log (O/H)] = 8.8

For values -0.8 < $\log \Delta$(MS) set $\log \Delta$(MS) = -0.8

$$[12 + \log(O/H)] = 8.73 - 0.32 \times O3N2$$



Preliminary analysis: Molecular gas mass

Calculate MH2

- From Solomon et al., 1997

$$L'_{CO}[K\ km\ sec^{-1}] = 3.25 \times 10^7 S_{CO} \Delta V \nu^{-2} D_L^2 (1+z)^{-3}$$

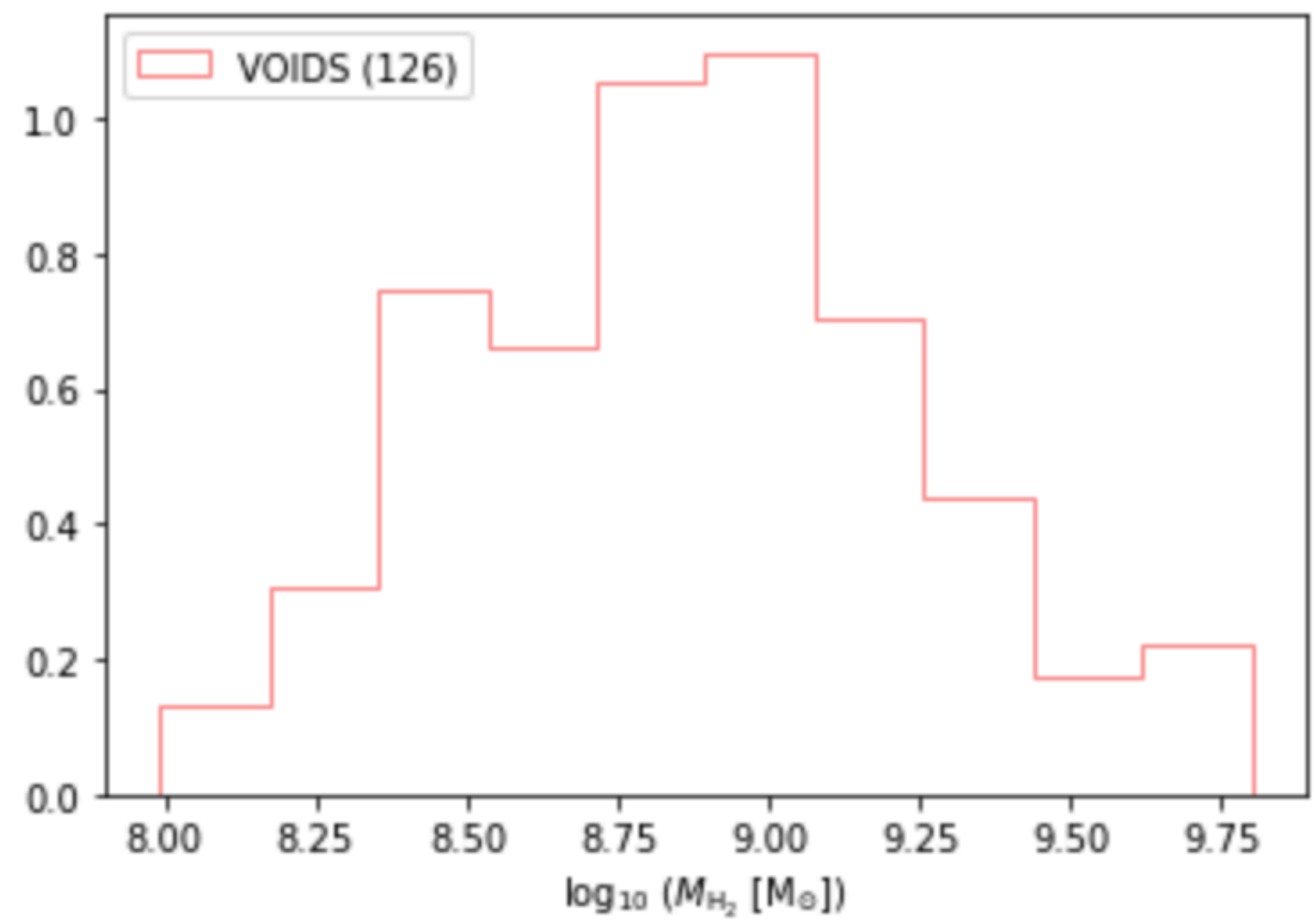
$$S_{CO}\Delta V[Jy\ km\ sec^{-1}] = K_{i-s} \times I_{CO}[K\ km\ sec^{-1}]$$

$$M_{H2}\ [M_\odot] = f_{ap}\ \alpha_{CO}\ L'_{CO}$$

$$\alpha_{CO}\ \ variable\ \ according\ \ the\ \ metallicity$$

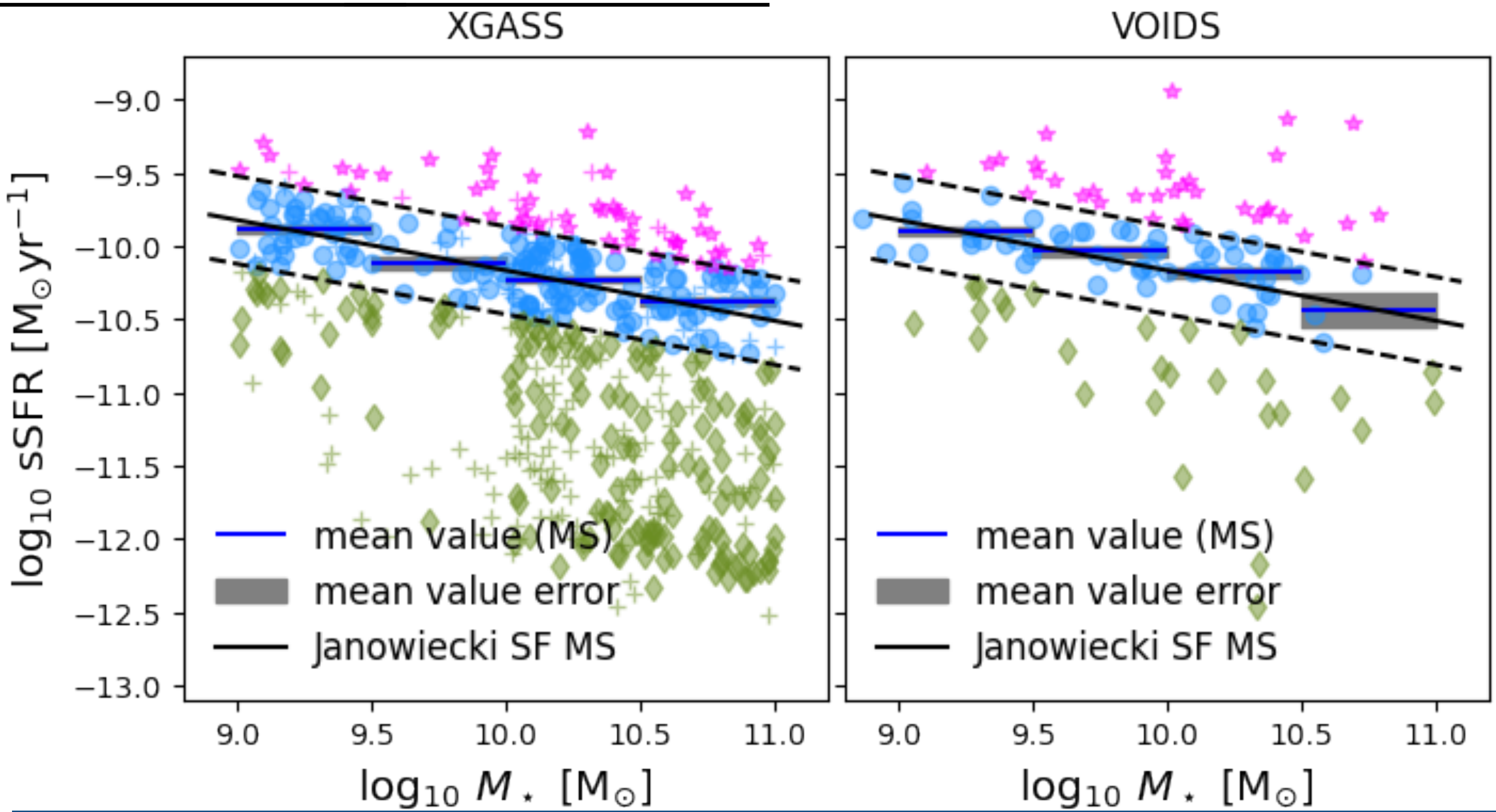
- For non-detections:

$$I_{CO} < 3 \times rms\ [Jy] \times \sqrt{\delta_v * \Delta_V}$$



Preliminary analysis: sSFR

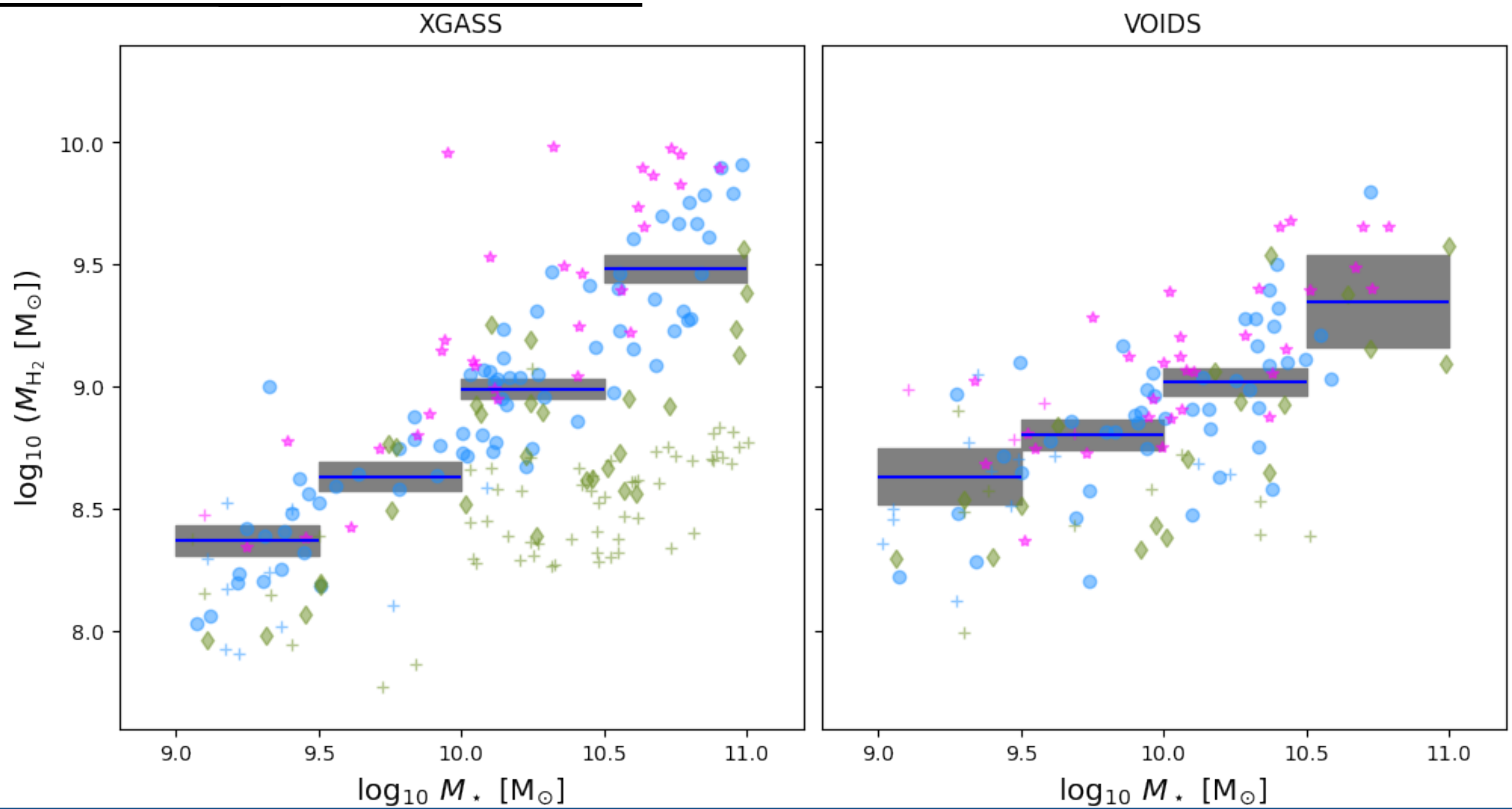
$$sSFR = \frac{SFR}{Mstar}\ [yrs^{-1}]$$



Pink —> above the MS
Blue —> in the MS
Green —> below the MS

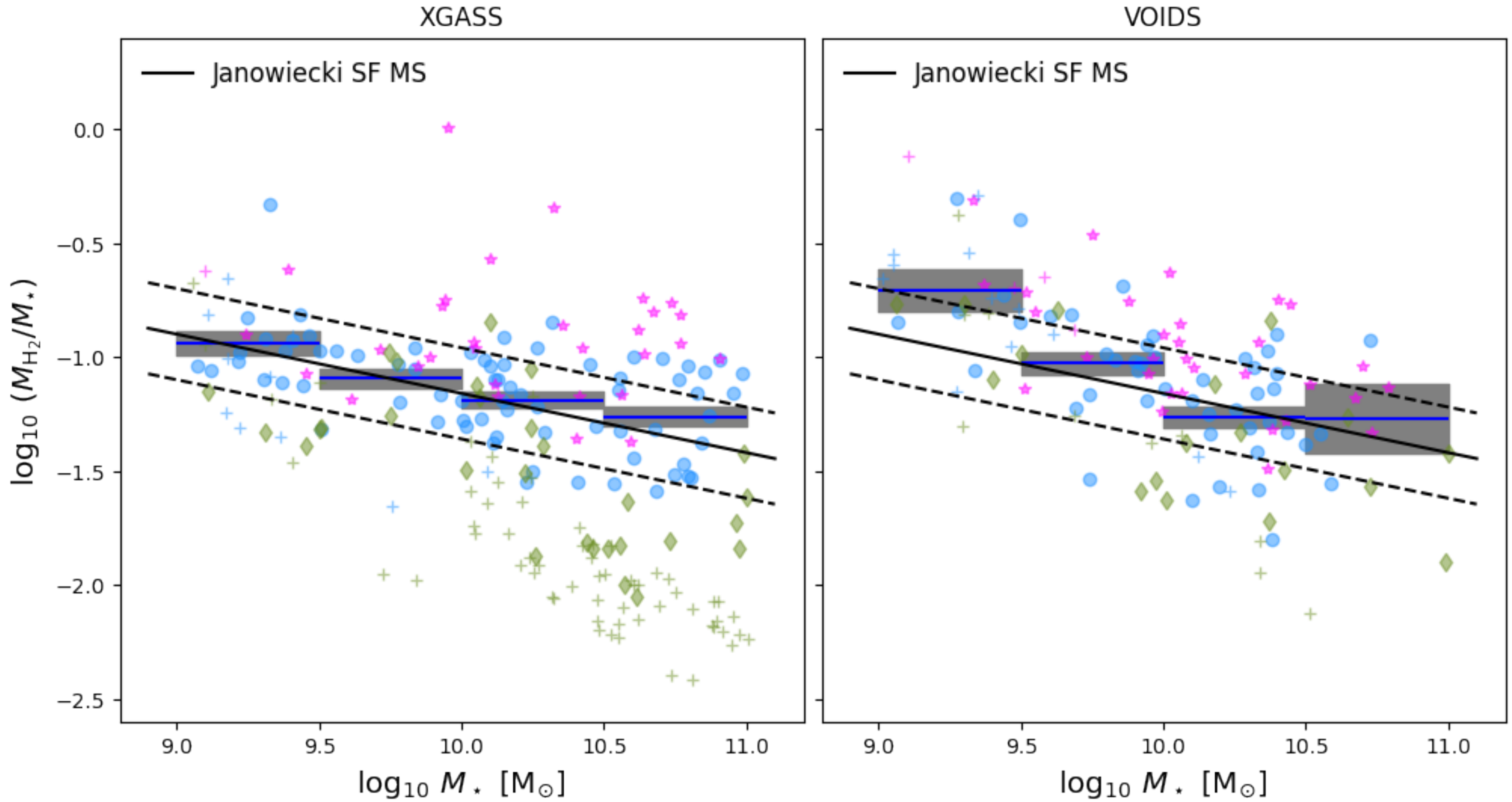
Log M*				
Sample	9.0 - 9.5 M*	9.5 - 10.0 M*	10.0 - 10.5 M*	10.5 - 11.0 M*
XGASS log (sSFR)	-9.887 +/- 0.025 (43/8)	-10.120 +/- 0.042 (21/5)	-10.229 +/- 0.023 (81/24)	-10.376 +/- 0.028 (49/13)
VOIDS log (sSFR)	-9.899 +/- 0.036 (16/0)	-10.036 +/- 0.032 (16/0)	-10.183 +/- 0.033 (24/0)	-10.437 +/- 0.113 (13/0)

Preliminary analysis: MH_2-M_*



	Log M_*			
Sample	9.0 - 9.5 M_*	9.5 - 10.0 M_*	10.0 - 10.5 M_*	10.5 - 11.0 M_*
XGASS log (MH_2)	8.371 +/- 0.064 (22/8)	8.633 +/- 0.057 (11/1)	8.991 +/- 0.041 (27/1)	9.483 +/- 0.056 (22/0)
VOIDS log (MH_2)	8.633 +/- 0.115 (16/9)	8.804 +/- 0.060 (16/1)	9.019 +/- 0.056 (24/2)	9.349 +/- 0.189 (3/0)

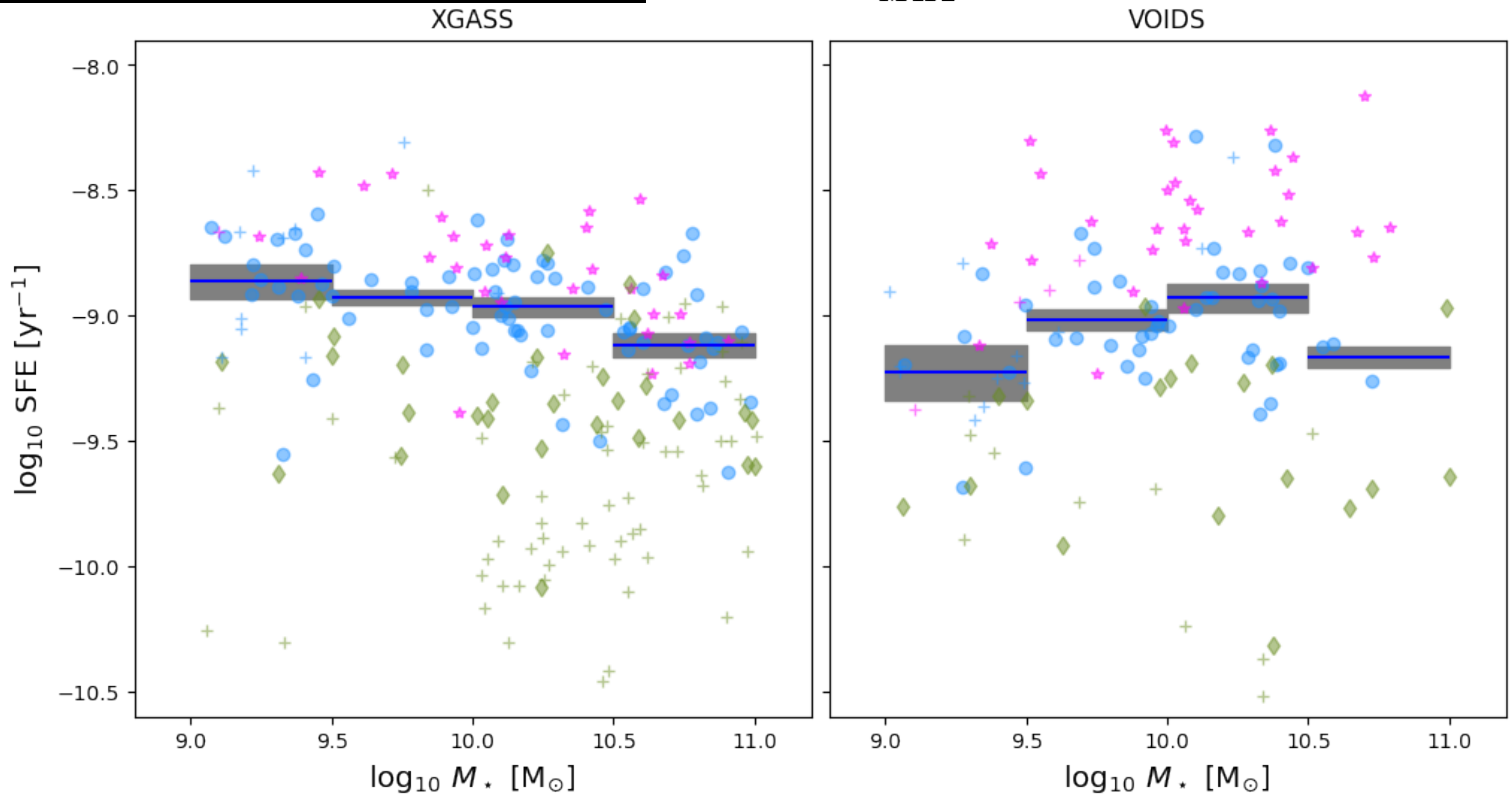
Preliminary analysis: $M_{H_2}/M_* - M_*$



Log M*				
Sample	9.0 - 9.5 M*	9.5 - 10.0 M*	10.0 - 10.5 M*	10.5 - 11.0 M*
XGASS log (M_{H_2}/M_*)	−0.938 +/− 0.052 (22/8)	−1.095 +/− 0.041 (11/1)	−1.190 +/− 0.036 (27/1)	−1.261 +/− 0.043 (22/0)
VOIDS log (M_{H_2}/M_*)	−0.710 +/− 0.094 (16/9)	−1.027 +/− 0.050 (16/1)	−1.265 +/− 0.048 (24/2)	−1.272 +/− 0.151 (3/0)

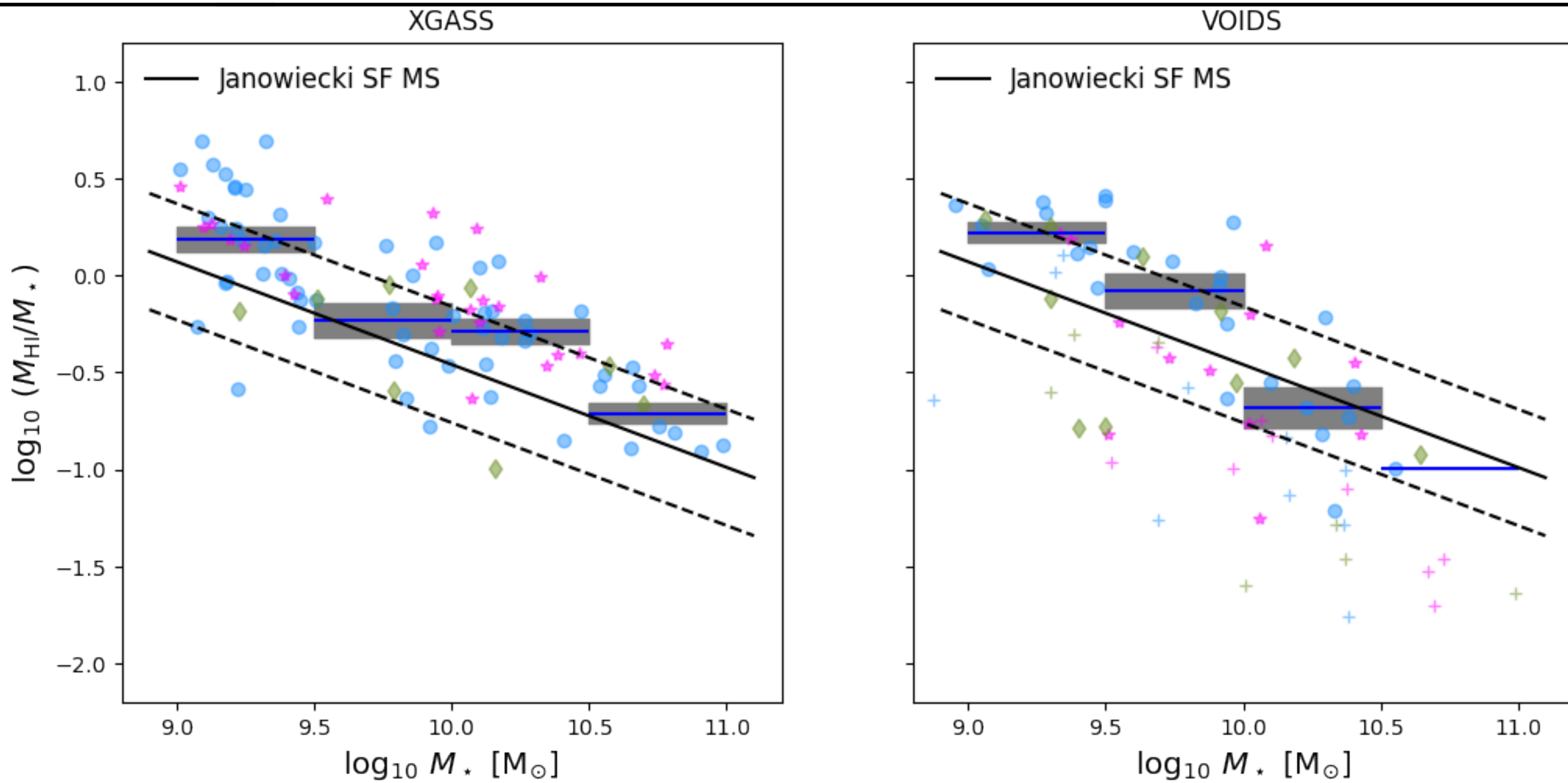
Preliminary analysis: SFE

$$SFE = \frac{SFR}{MH2}\ [yrs^{-1}]$$



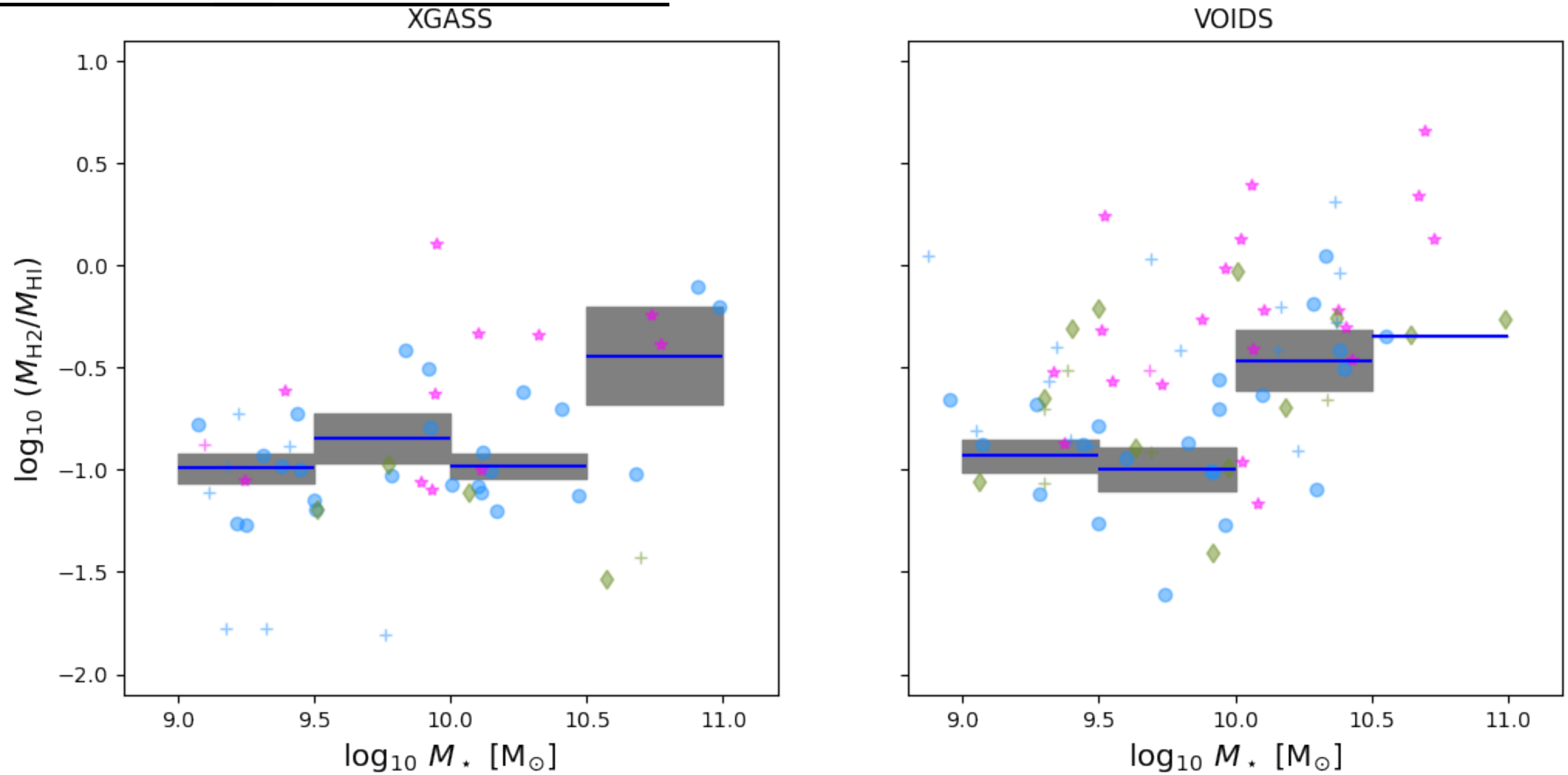
Log M*				
Sample	9.0 - 9.5 M*	9.5 - 10.0 M*	10.0 - 10.5 M*	10.5 - 11.0 M*
XGASS log (SFE)	-8.863 +/- 0.067 (22/8)	-8.927 +/- 0.030 (11/1)	-8.964 +/- 0.039 (27/1)	-9.116 +/- 0.047 (22/0)
VOIDS log (SFE)	-9.226 +/- 0.110 (16/9)	-9.014 +/- 0.041 (16/1)	-8.929 +/- 0.057 (24/2)	-9.165 +/- 0.039 (3/0)

Preliminary analysis: **MHI/M* - M*** **Only ALFALFA detections (cut in rms and redshift)**



	Log M*			
Sample	9.0 - 9.5 M*	9.5 - 10.0 M*	10.0 - 10.5 M*	10.5 - 11.0 M*
XGASS log (MHI/M*)	0.185 +/- 0.064 (25/0)	-0.234 +/- 0.088 (12/0)	**-0.288 +/- 0.061** (14/0)	-0.711 +/- 0.055 (9/0)
VOIDS log (MHI/M*)	0.221 +/- 0.054 (11/2)	-0.077 +/- 0.091 (10/2)	**-0.684 +/- 0.106** (12/5)	-0.994 +/- 0.000 (1/0)

Preliminary analysis: MH_2/MHI



Log M*				
Sample	9.0 - 9.5 M*	9.5 - 10.0 M*	10.0 - 10.5 M*	10.5 - 11.0 M*
XGASS log (MH_2/M_*)	-0.992 +/- 0.074 (13/6)	-0.846 +/- 0.124 (7/1)	-0.981 +/- 0.063 (9/0)	-0.441 +/- 0.237 (3/0)
VOIDS log (MH_2/M_*)	-0.932 +/- 0.080 (11/5)	-0.997 +/- 0.108 (10/2)	-0.464 +/- 0.147 (12/6)	-0.345 +/- 0.000 (1/0)

Conclusions:

- We have observed 106 galaxies in voids belonging to the CAVITY sample with the IRAM 30m telescope
- We have calculated the MH_2 gas content ($\log MH_2 \sim 8.0 - 9.8\ M_{sun}$)
- We have analyzed main properties such as sSFR, SFE, gas fraction (MH_2/M_*), and MHI
- The properties analysed seem very similar in void and control (wall, filament) galaxies.

THANKS!