WITNESSING THE ASSEMBLY OF MASSIVE GALAXIES IN THE EARLY UNIVERSE

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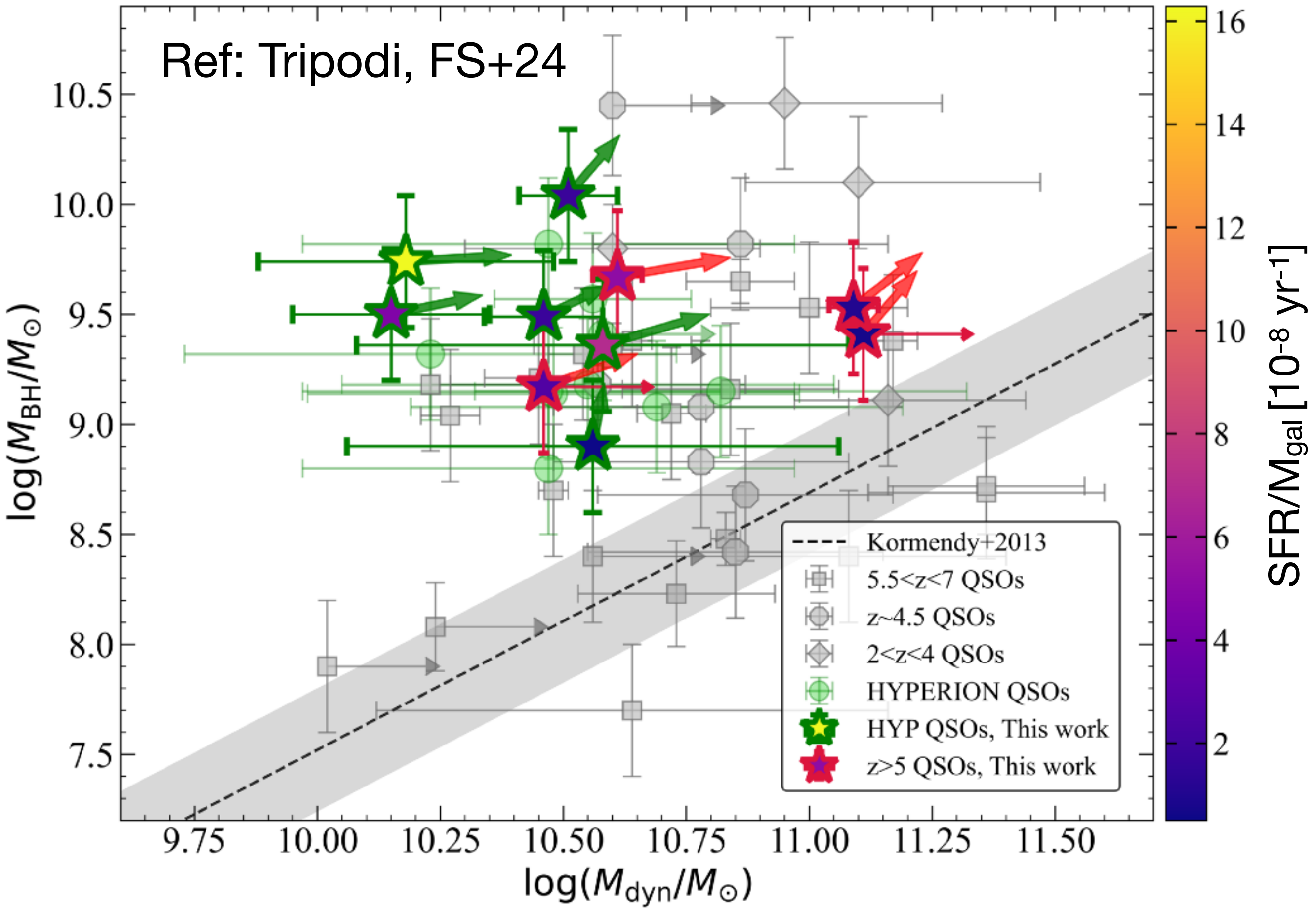
Fundings
- INAF Grant HSC Hyperion Science Collaboration (Zappacosta)
- INAF Grant ARCHIE ARchive Cosmic HI & ISM Evolution (Feruglio)

MASSIVE GALAXIES HOSTING QUASARS



See also: Volonteri+2012, Valiante+2017, Harikane+2023, Matthee+2023, Maiolino+2023

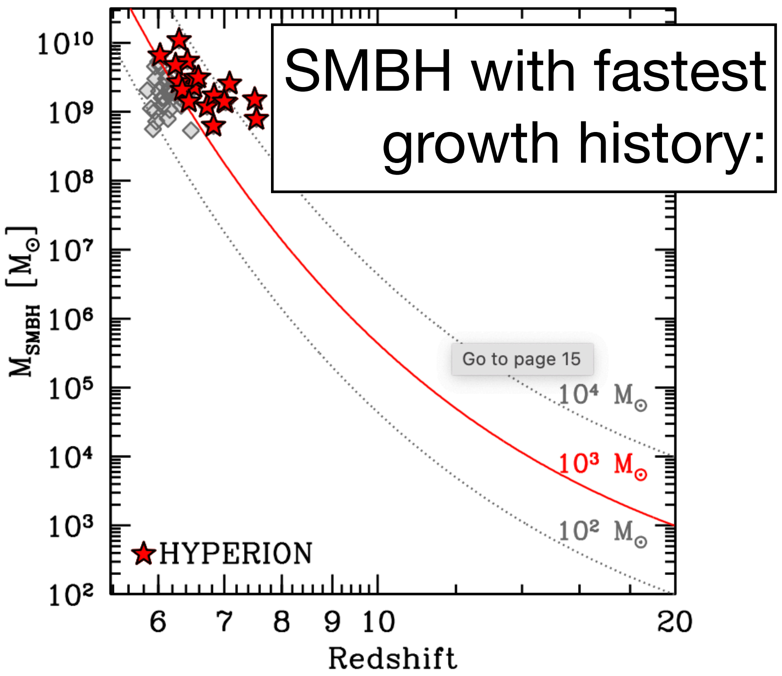
Open questions:

- ✳Are quasars (QSOs) and their host already co-evolving in the early Universe?
- ✳Which is the evolutionary path of high-z QSOs towards local (Kormendy+13) correlation?
- ✳How accurate are M_{BH} and M_{dyn} measurements (e.g., Lupi+24; Maiolino+24)?
- ✳Are luminous QSOs the progenitors of **massive and passive galaxies** at later epochs?

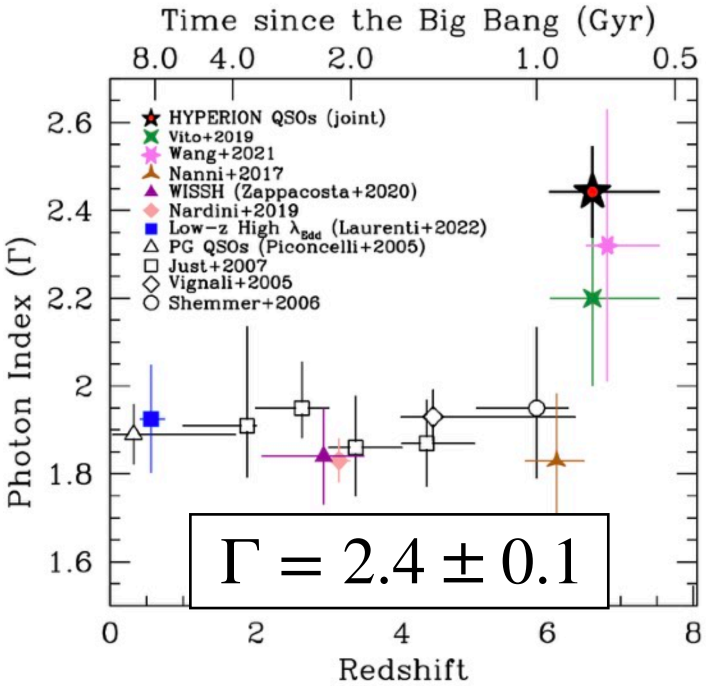
HYPERION QUASAR SURVEY

HYPerluminous quasar at the Epoch of ReionizatION

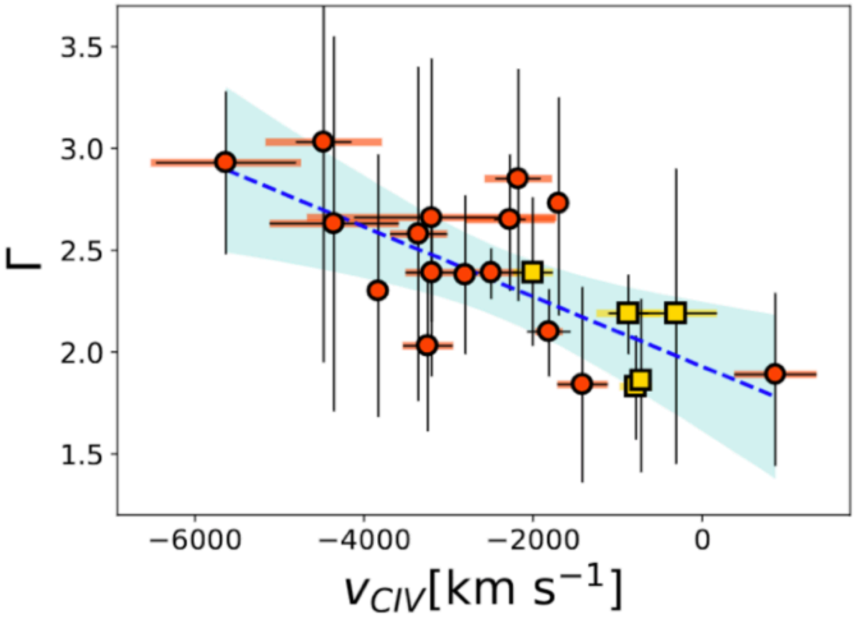
2 XMM-Newton Large Programs (PI:Zappacosta), 23 most massive SMBH at their epoch.



Ref: Zappacosta+23 A&A



Steep X-ray spectrum may be signature of disk-wind interaction that makes corona colder.



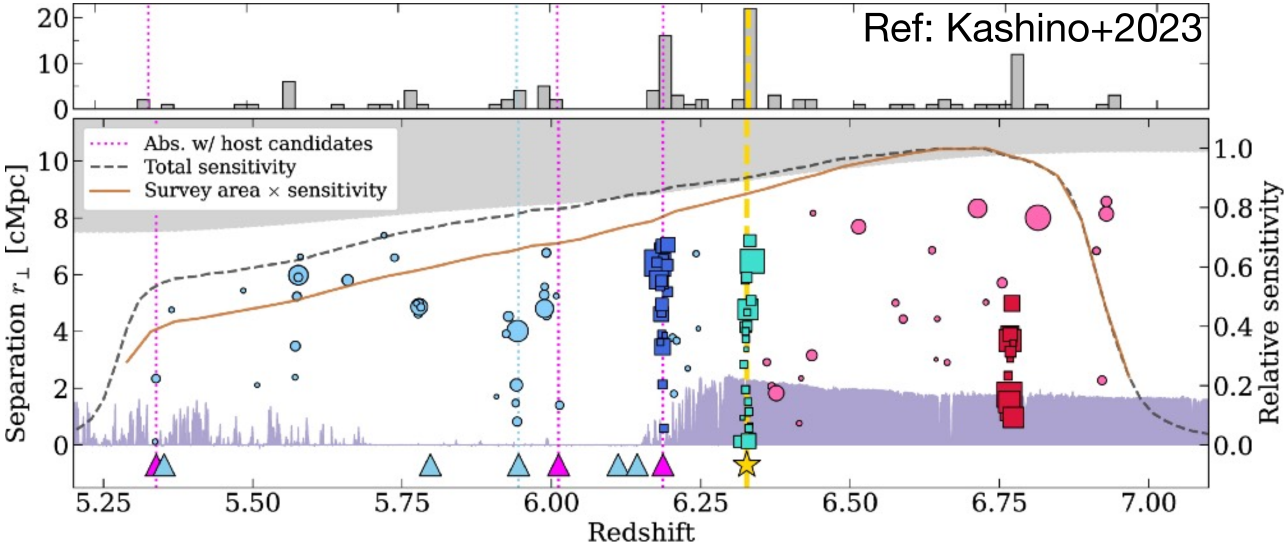
X-ray steepness correlates with C IV line shift

Ref: Tortosa, FS+24

ENVIRONMENT & MERGERS

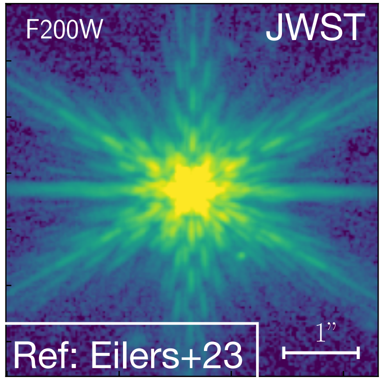
JWST EIGER obs. of QSO SDSSJ0100+2802:

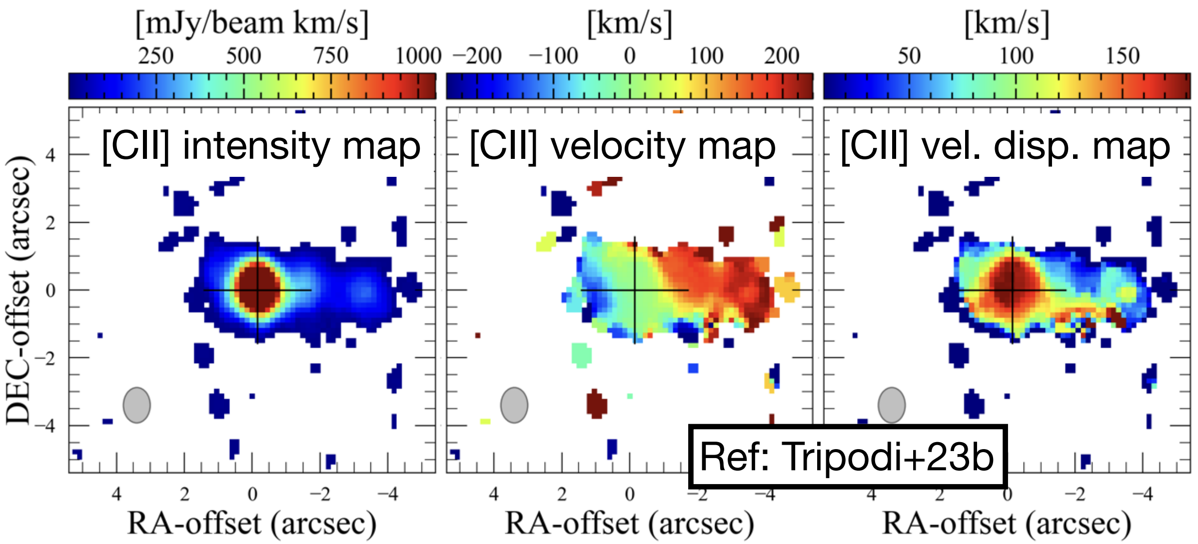
- Tens of [OIII] emitters detected at ~QSO redshift.
- **The largest galaxy overdensity** known at this redshift.



ALMA [CII] obs. of SDSS J0100+2802:

- Dust-obscured merging companion undetected in JWST/NIRCAM.





SUB-MM VIEW OF FIRST QUASARS

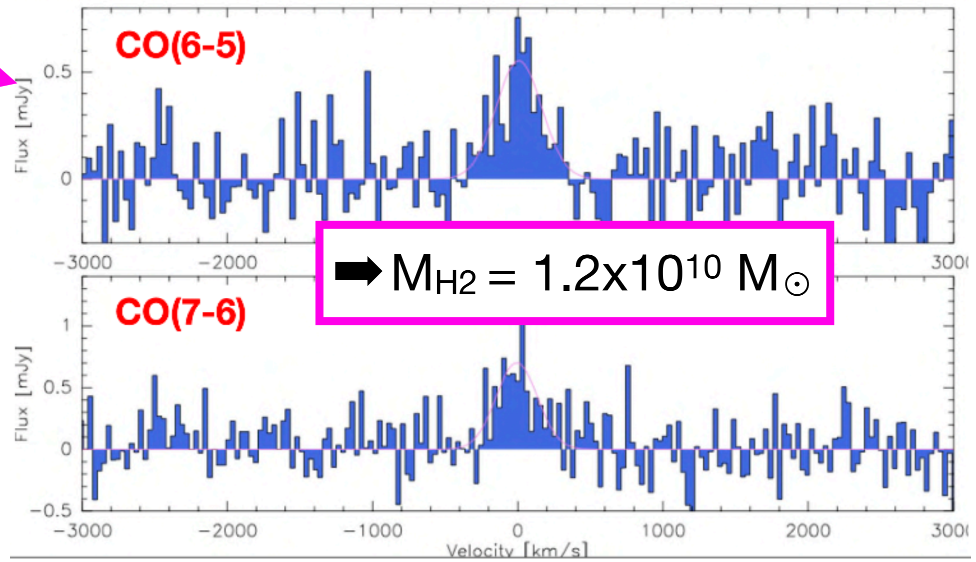
THE SAMPLE (Fan+23)

QSO	z	CO
J031343.84–180636.40	7.6423	UL (Salvestrini+)
J134208.11+092838.61	7.54	UL (Novak+19)
J100758.27+211529.21	7.5149	Det (Feruglio+23)
J112001.48+064124.30	7.0848	Cont.UL
J124353.93+010038.50	7.0749	UL (Salvestrini+)
J003836.10–152723.60	7.034	UL (Salvestrini+)
J235646.33+001747.30	7.01	Cont.UL (Salvestrini+)
J025216.64–050331.80	7.0006	UL (Salvestrini+)

We complete the survey of z>7 QSOs targeting CO lines with NOEMA (S23CX; PI: Feruglio).

In the end:

- **1 CO detection.**
- **5 upper limits.**
- 2 non detections.



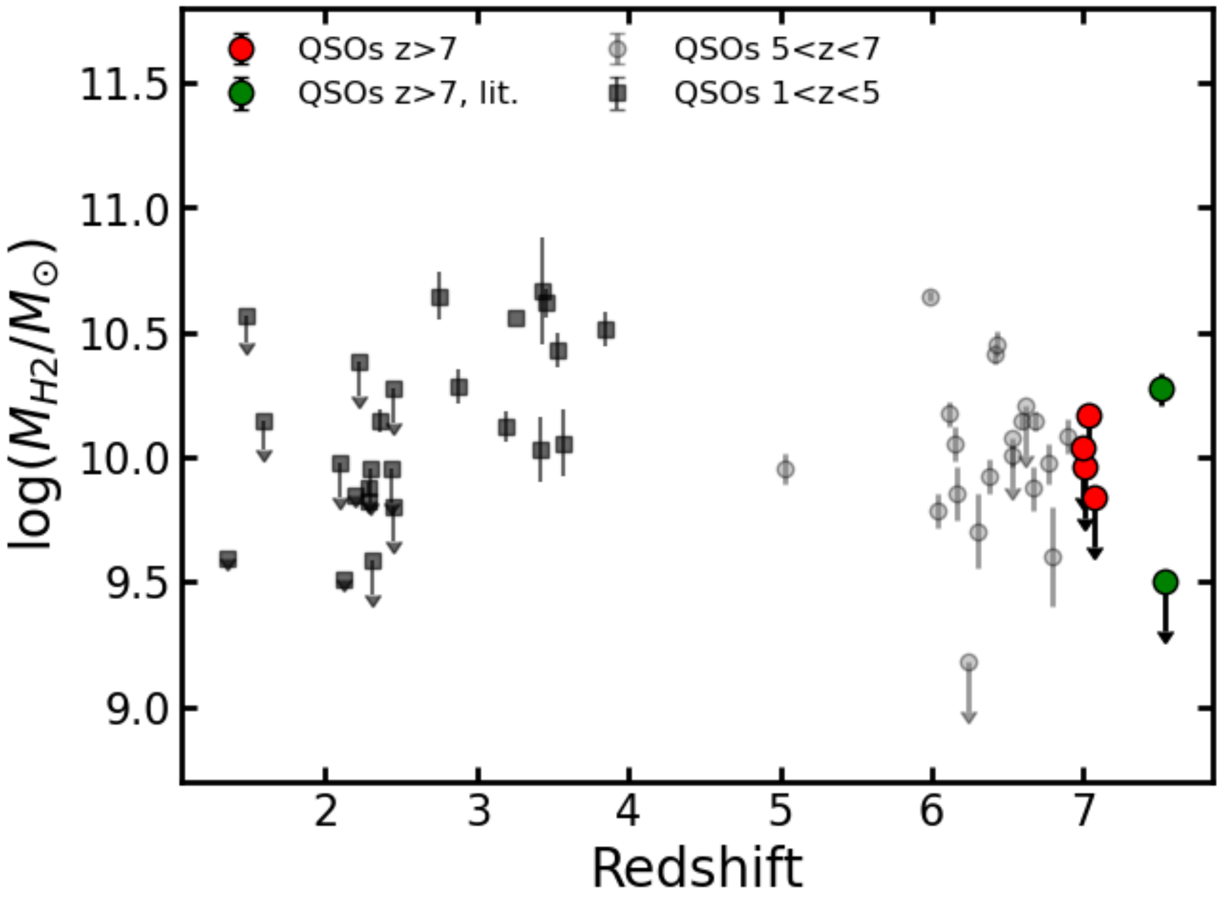
Ref: Feruglio+23 ApJL

MOLECULAR GAS CONTENT IN THE FIRST QUASARS

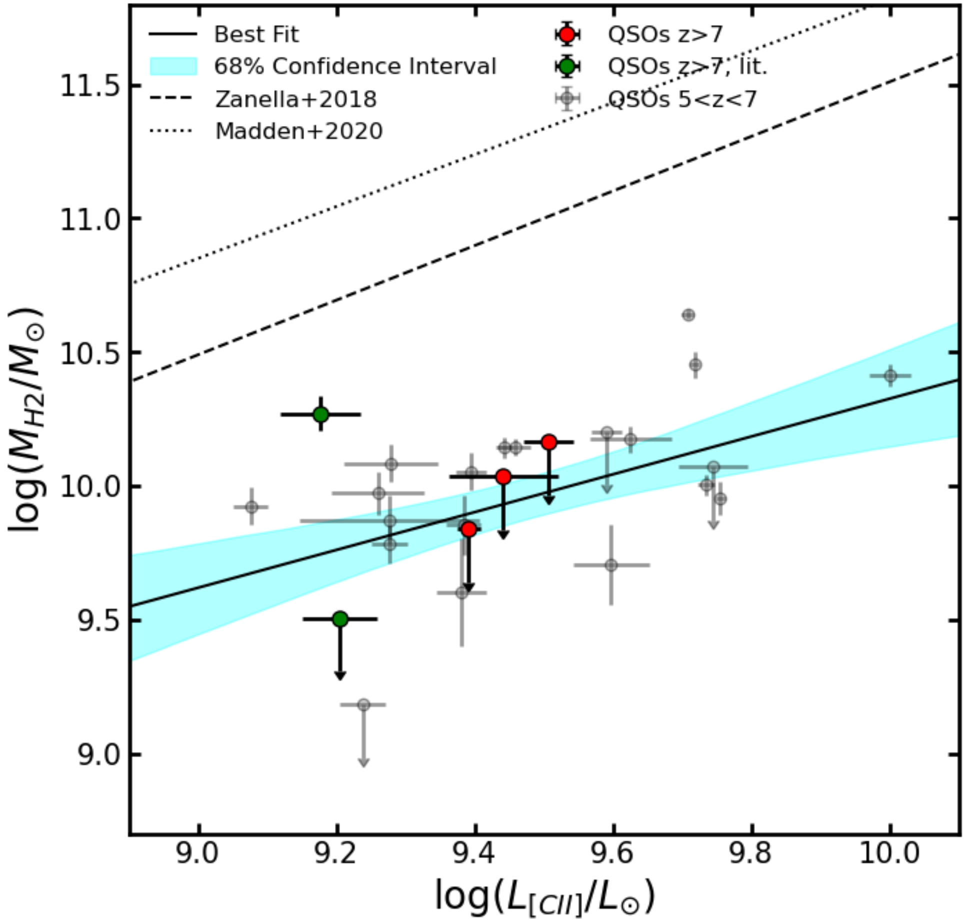
$$\log(M_{H2}) = \alpha_{CO} \times \log(L'_{CO(1-0)})$$

- No evidence for significant evolution of the molecular gas content in the first billion years.

- Ref:
  - 1<z<5 QSOs from Bischetti+21, Bertola+24; Salvestrini+in prep.;
  - 5<z<7 QSOs from Venemans+17, Decarli+22, Kaasinen+24, Tripodi+24b;



DOES [CII] LUMINOSITY TRACE M_{H2}?



- [CII]158μm traces different phases of the ISM (e.g., Casavecchia+24).
- M_{H2}-$L_{[CII]}$ calibrations are mostly based on lower-z SFGs or local dwarfs (Zanella+18; Madden+20).
- Ref:
  - 5<z<7 QSOs from Venemans+17, Decarli+22, Kaasinen+24, Tripodi+24b.

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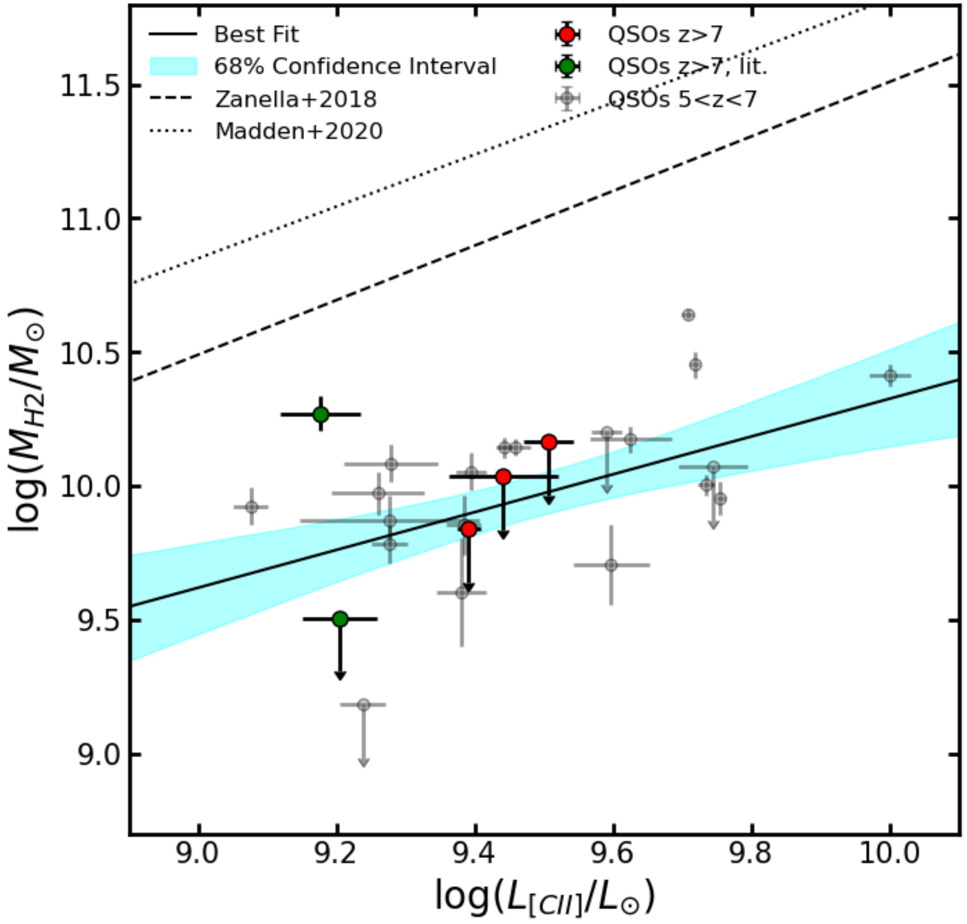
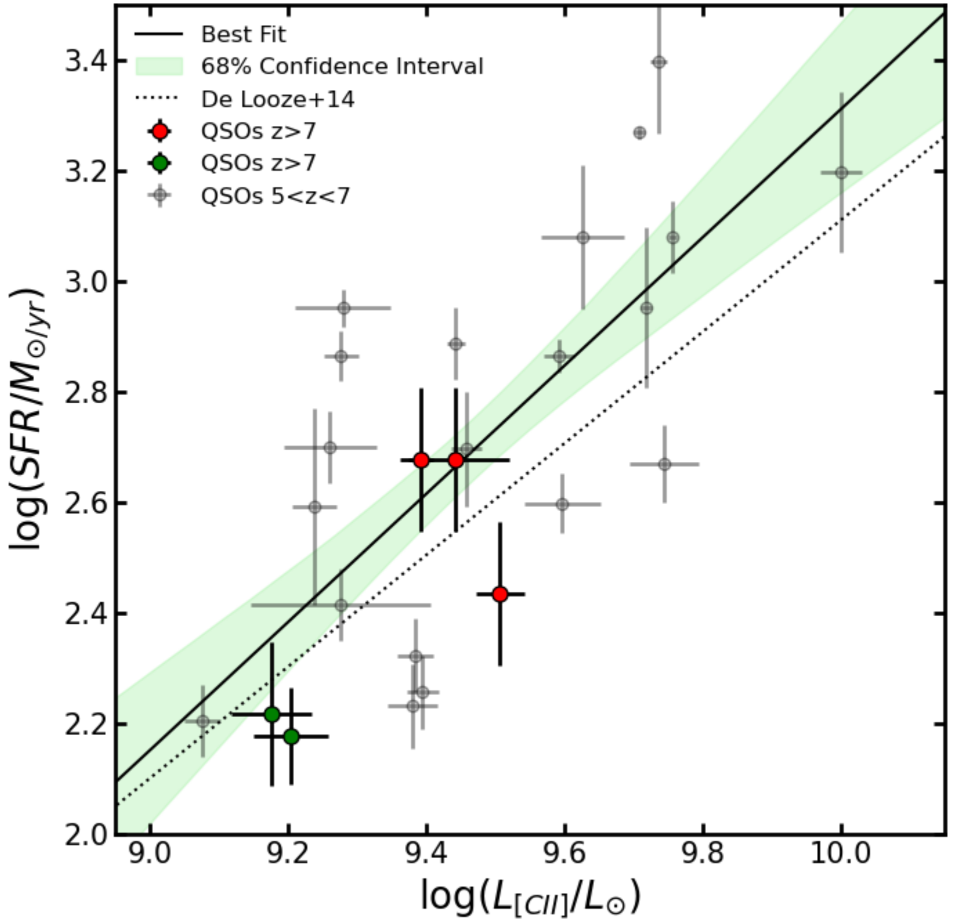
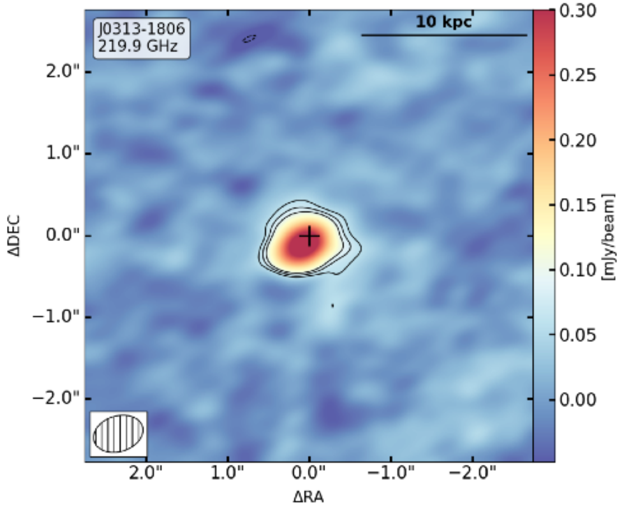


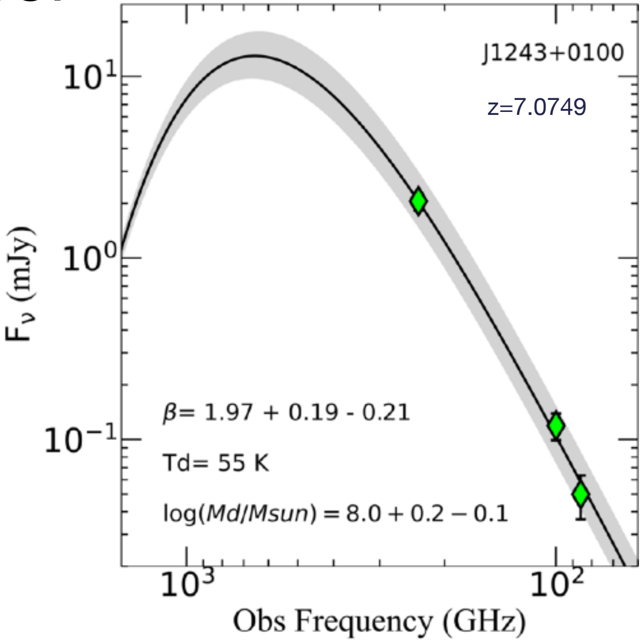


$$\log(M_{H2}/M_{\odot}) = (0.75 \pm 0.31)\log(L_{[CII]}) + (2.87 \pm 0.07)$$

CONTINUUM EMISSION: DUST PROPERTIES AND SFR

- We modelled the far-IR SED emission with a modified black body with the ***Eos-DustFit*** (Tripodi, FS+24).
- We assume
  - T_{dust} ~55 K (Tripodi, FS+24).
  - SFR ∝ L_{FIR}, but ~50% of L_{FIR} due to dust heated by the QSO.





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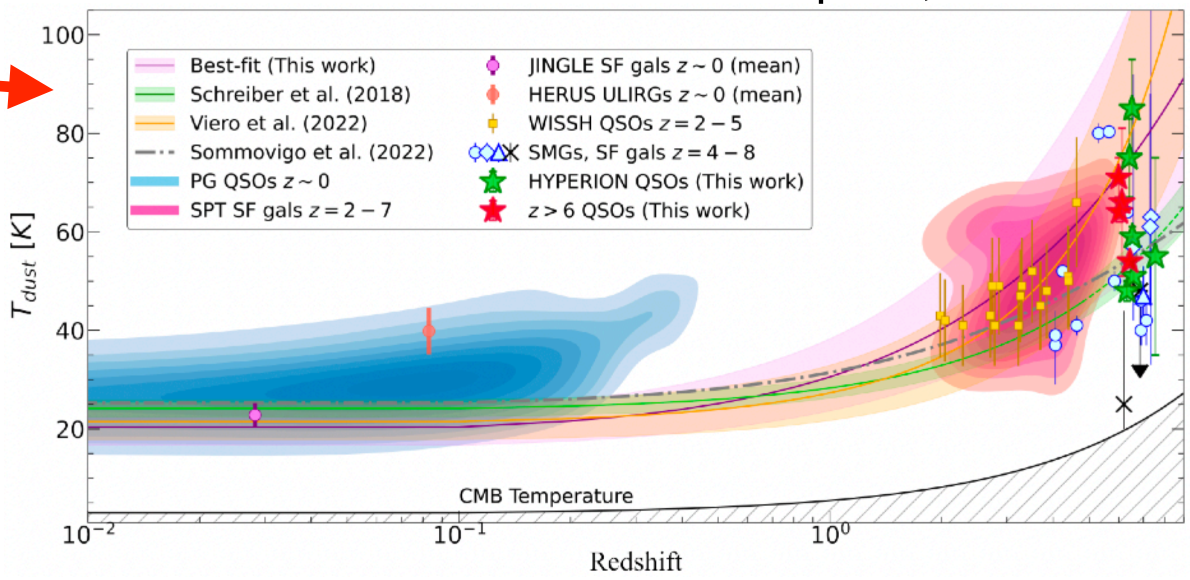
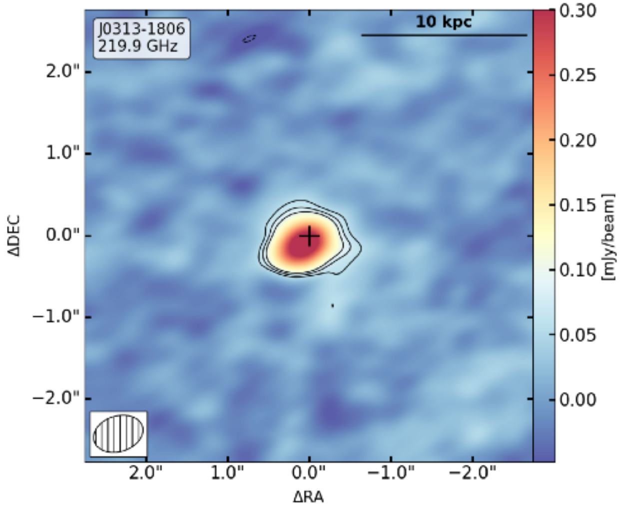
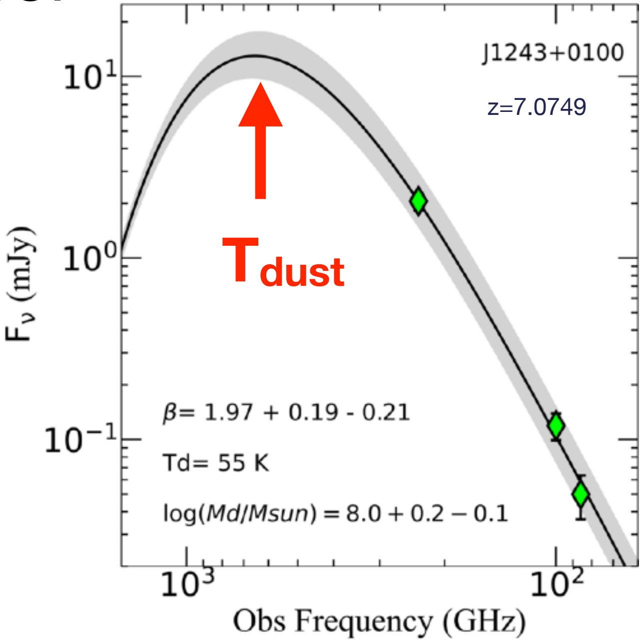
Tripodi, FS+24







See also: Faisst+17; Schreiber+18; Sommovigo+20; Viero+22, Witstok+22.

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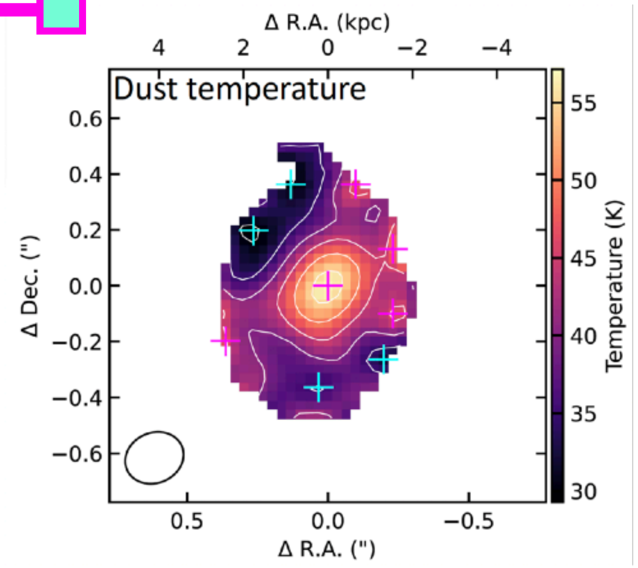
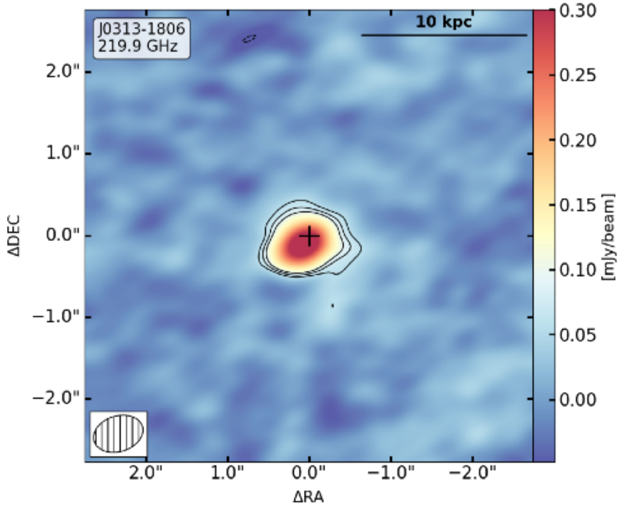
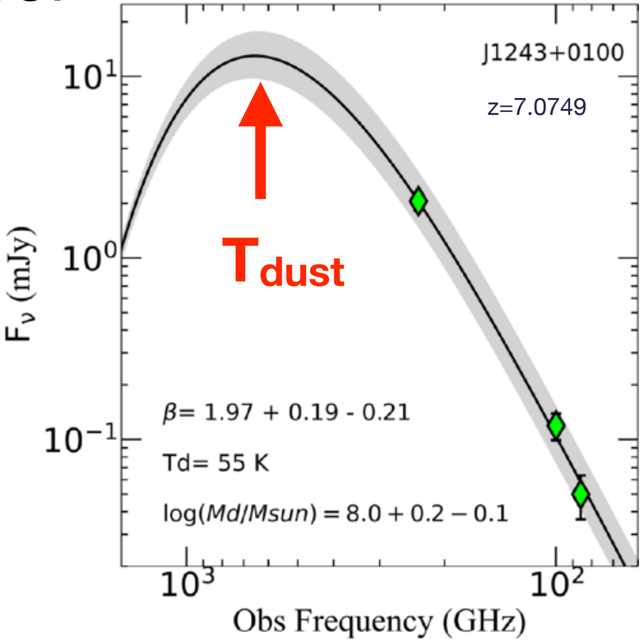
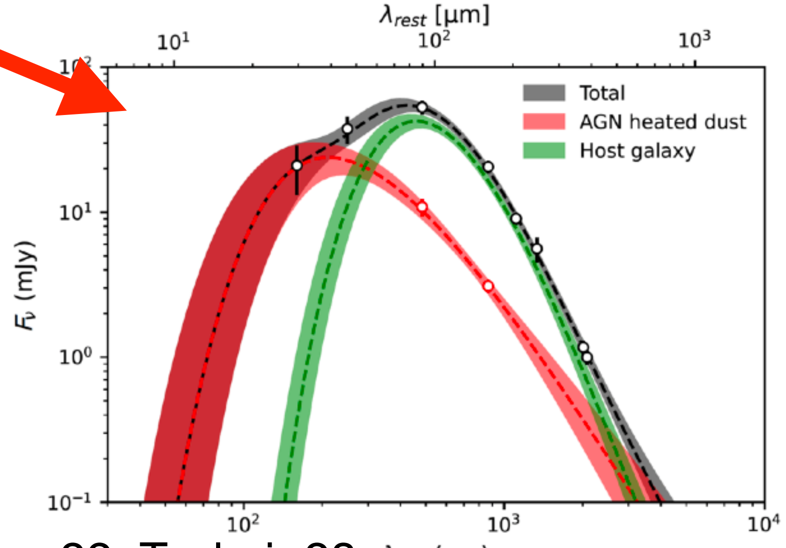






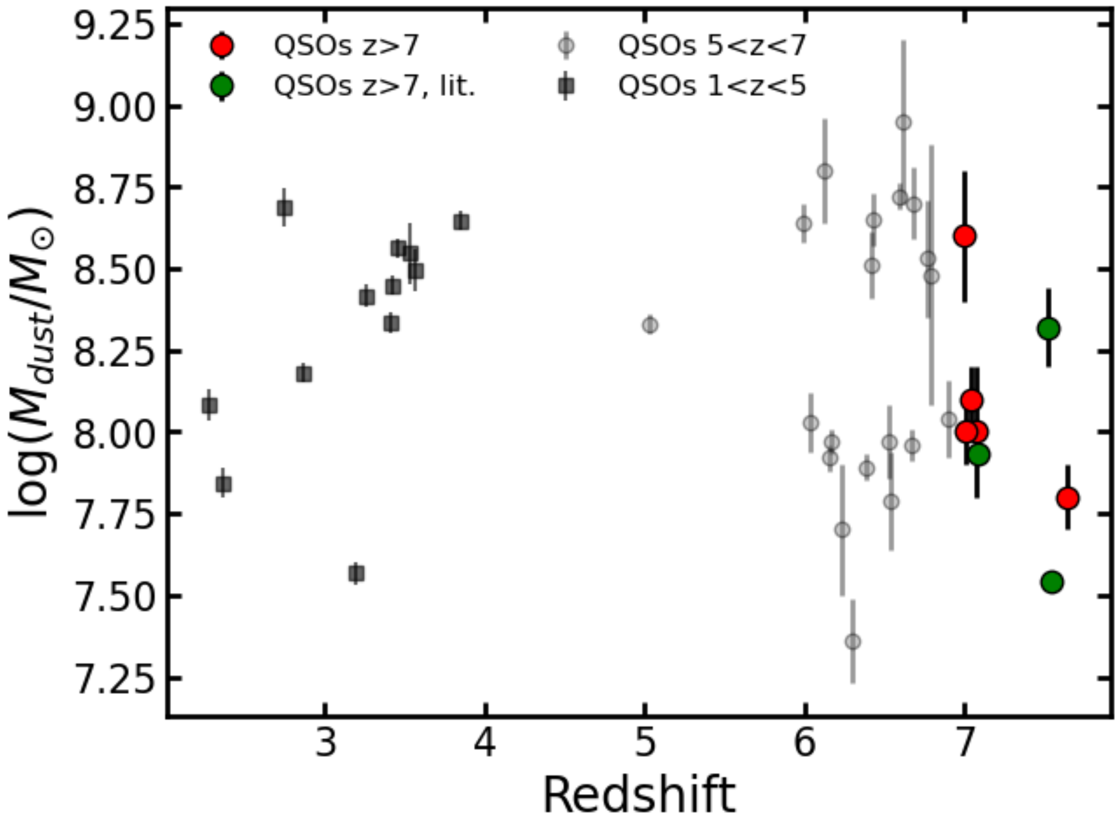


See Walter+22; Tsukui+23.

DUST MASSES IN THE FIRST QUASARS

Copious amount of dust at z>7:

$$M_{dust} \sim 0.2 - 1 \times 10^8 M_{\odot}$$



- **Dust aggregation within ISM** is highly efficient at z>7, exceeding dust destruction rates in massive systems (Popping+17).
- No evidence for an evolution of dust masses with redshift.

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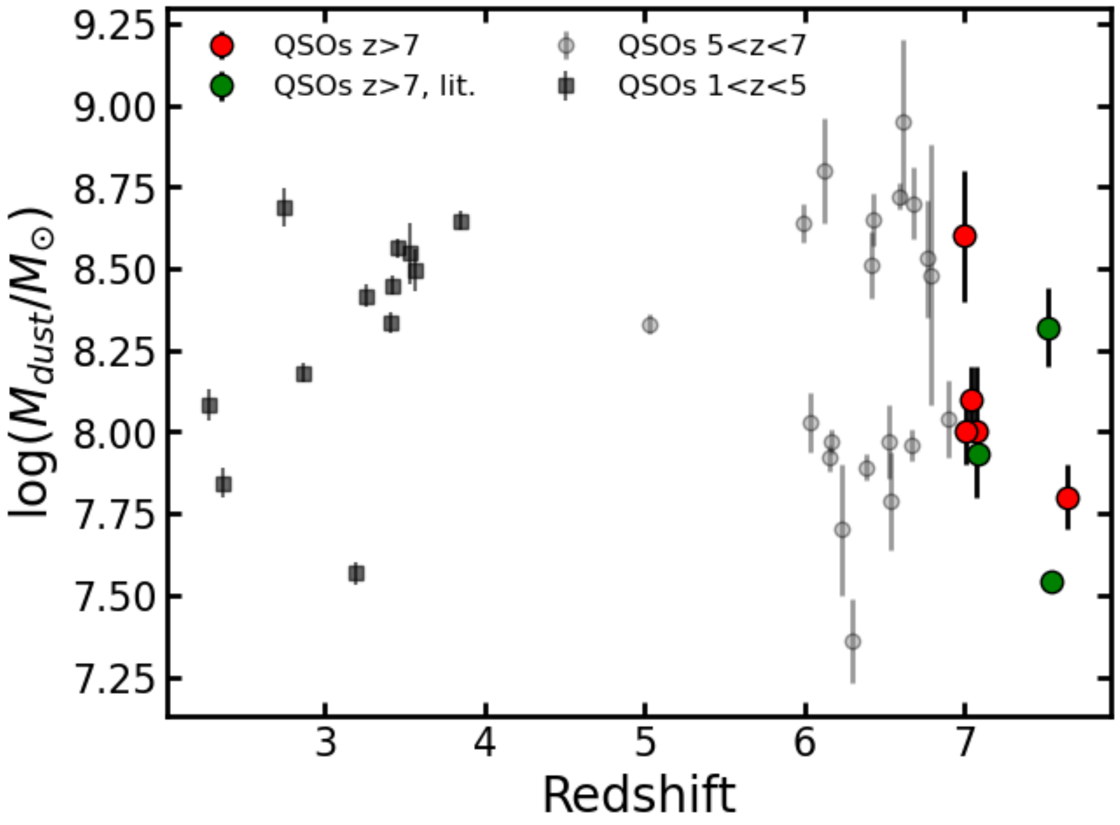
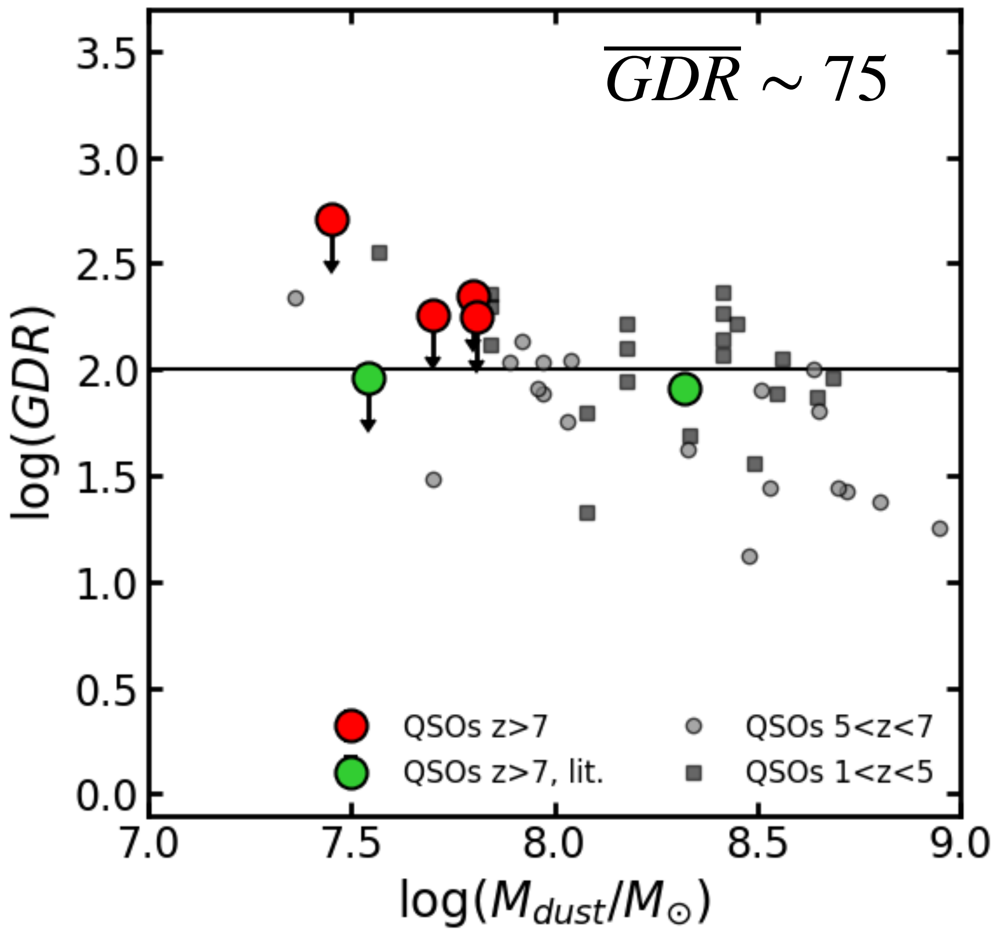
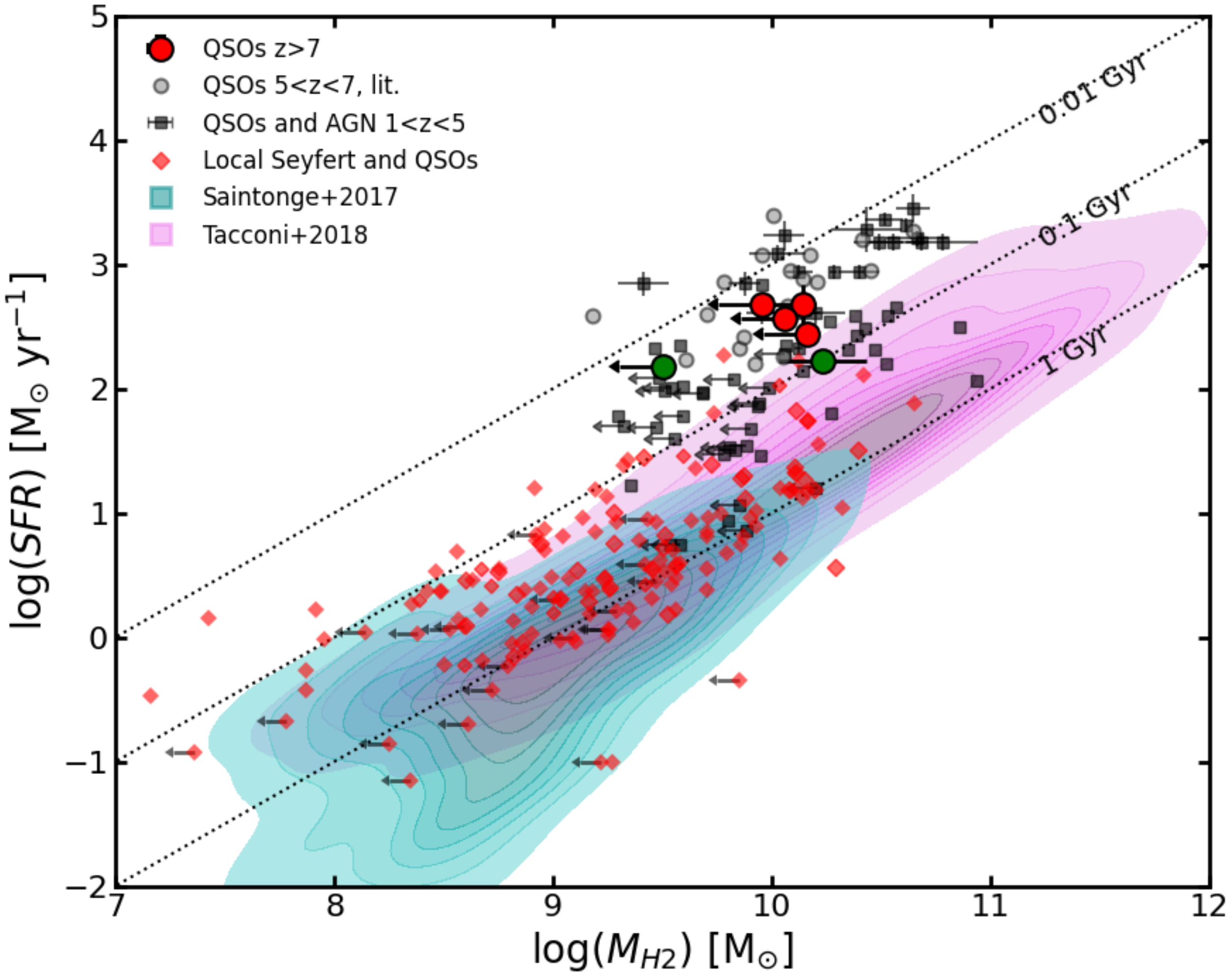


Gas-to-dust ratios $GDR = M_{H2}/M_{dust}$



HOST-GALAXY BUILD UP AT Z>7



Ref: Salvestrini, in prep.

- z>7 QSOs show low depletion time: $t_{dep} = M_{H2}/SFR \lesssim 0.1 Gyr$

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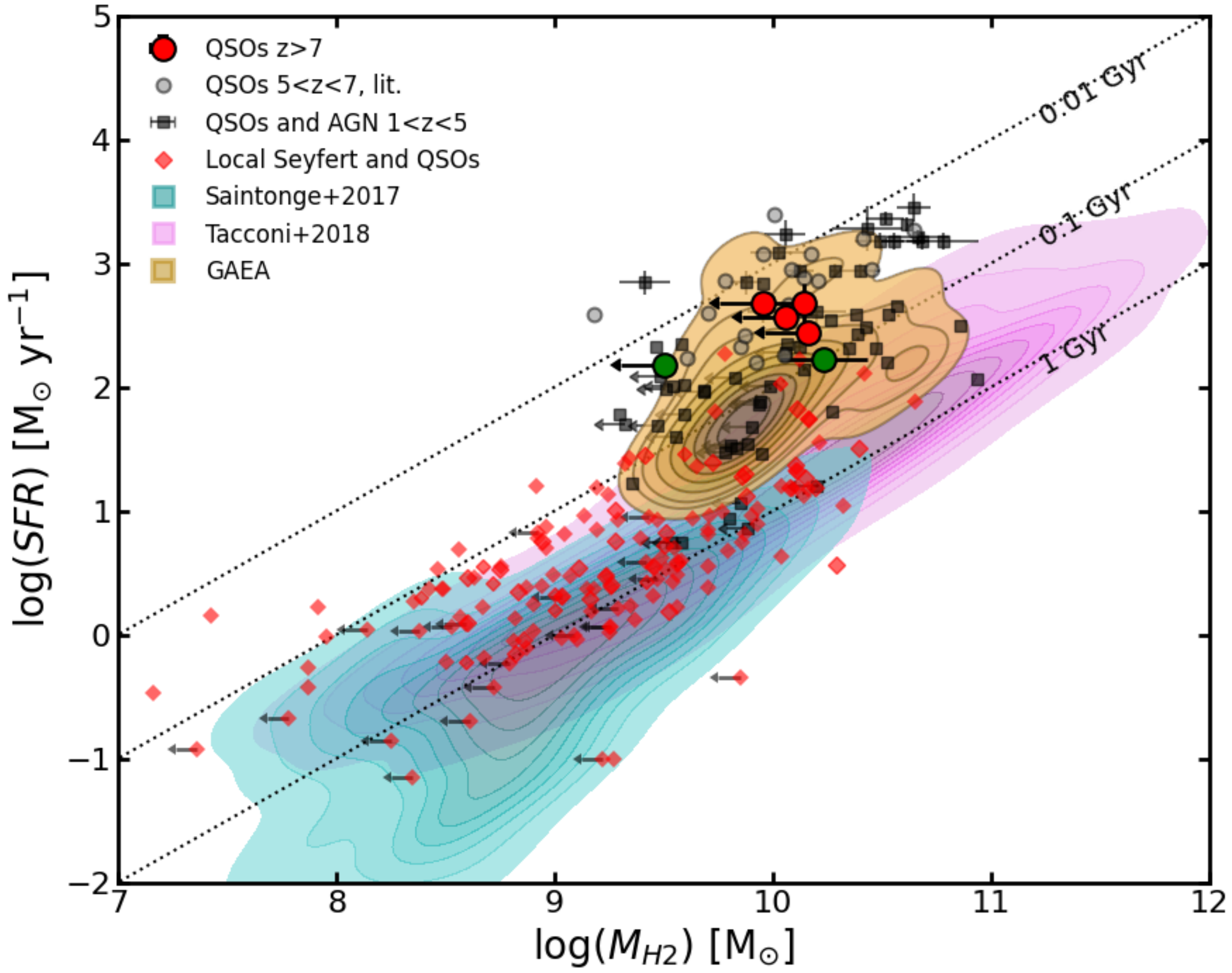

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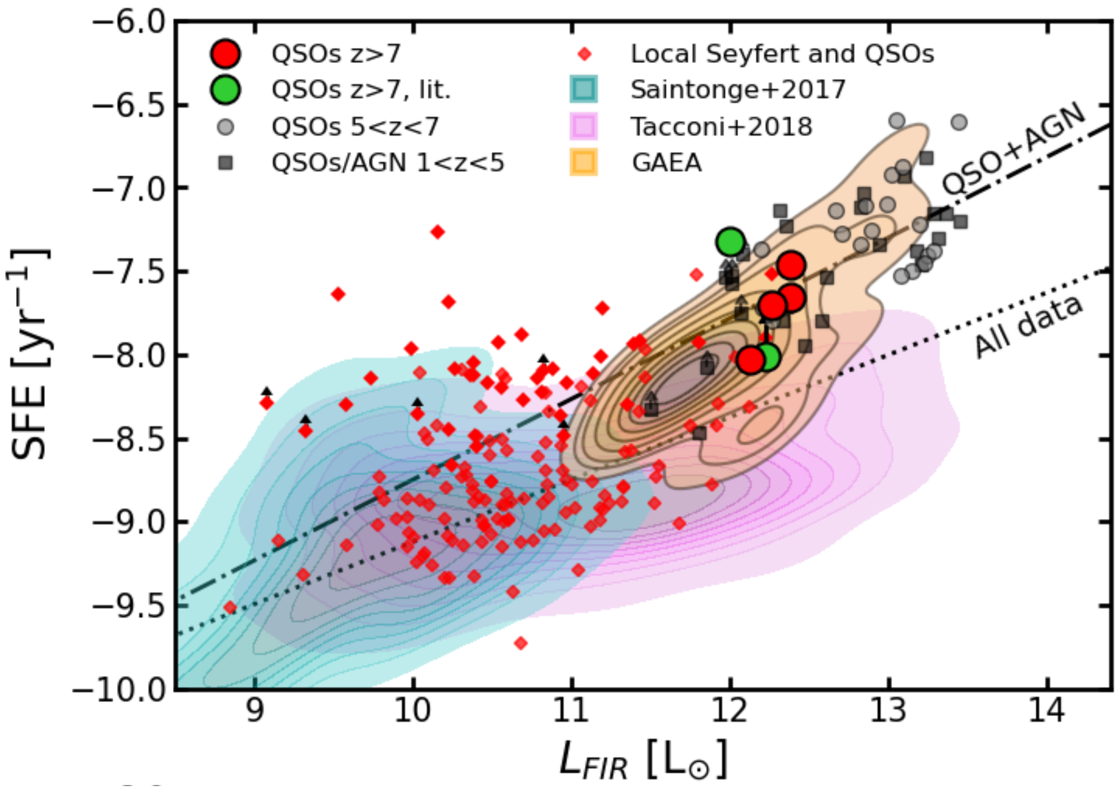
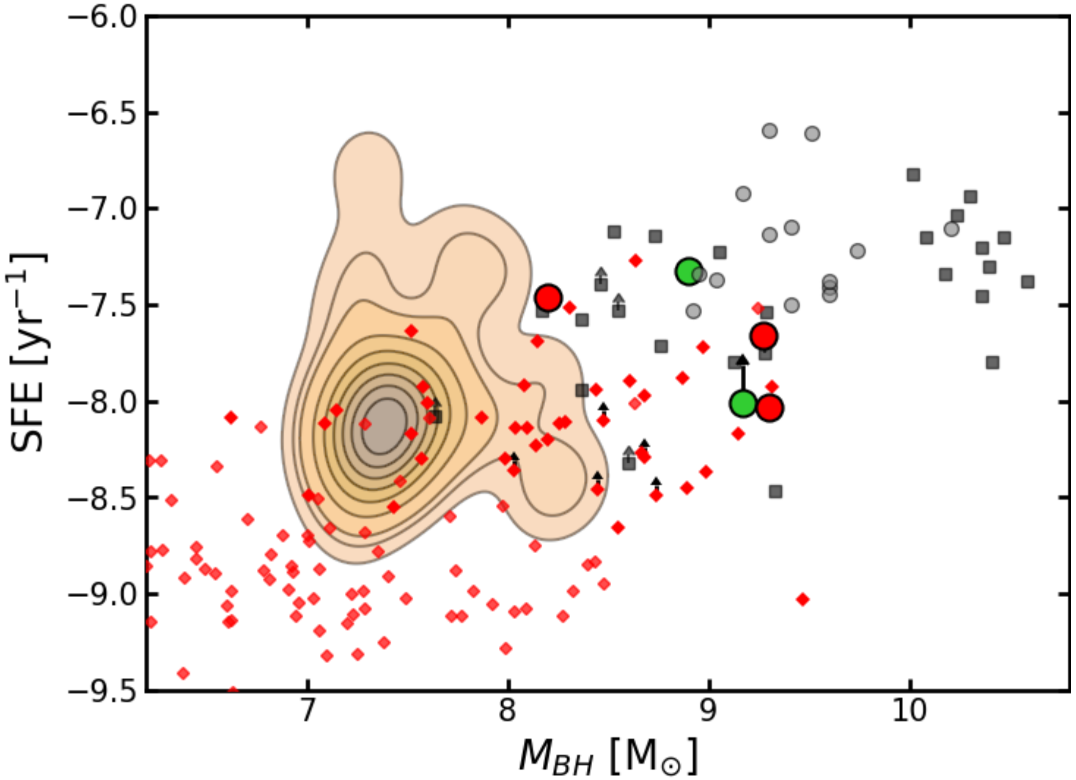
- z>7 QSOs show low depletion time: $t_{dep} = M_{H2}/SFR \lesssim 0.1Gyr$
- We also compare with the results from the **GAEA** semi analytical model (SAM; De Lucia+17, 24, Fontanot+20).
- QSOs from **GAEA** SAM have an extremely efficient feedback.

HOST-GALAXY BUILD UP AT Z>7

Star formation efficiency ($SFE = SFR/M_{H2}$) **increases with redshift**, but beware selection effects!



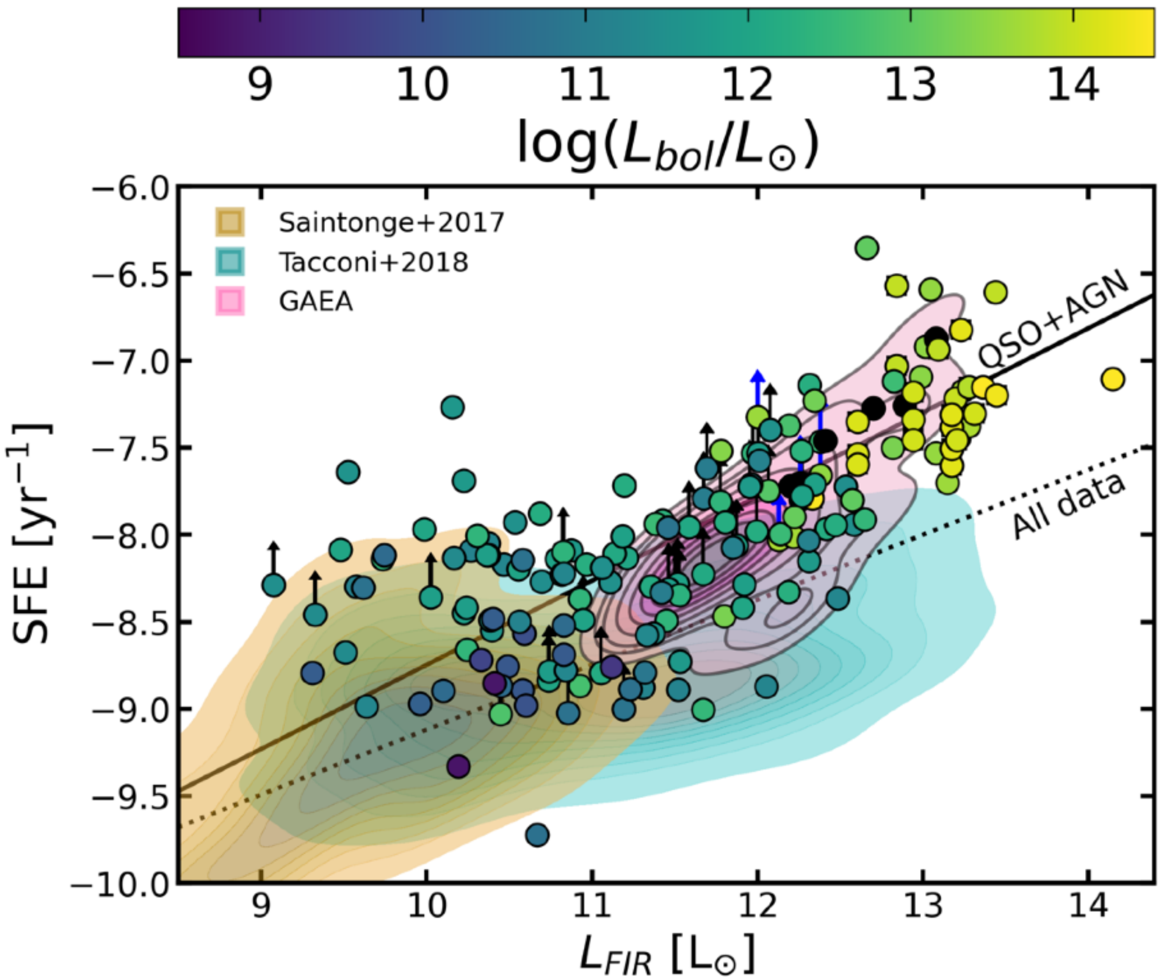


Ref: Salvestrini, in prep.

HOST-GALAXY BUILD UP AT Z>7

Irrespective of redshift, **SFE increases with L_{bol}**: 1) QSO triggers SF in the host.

2) Starburst phase favours QSO.



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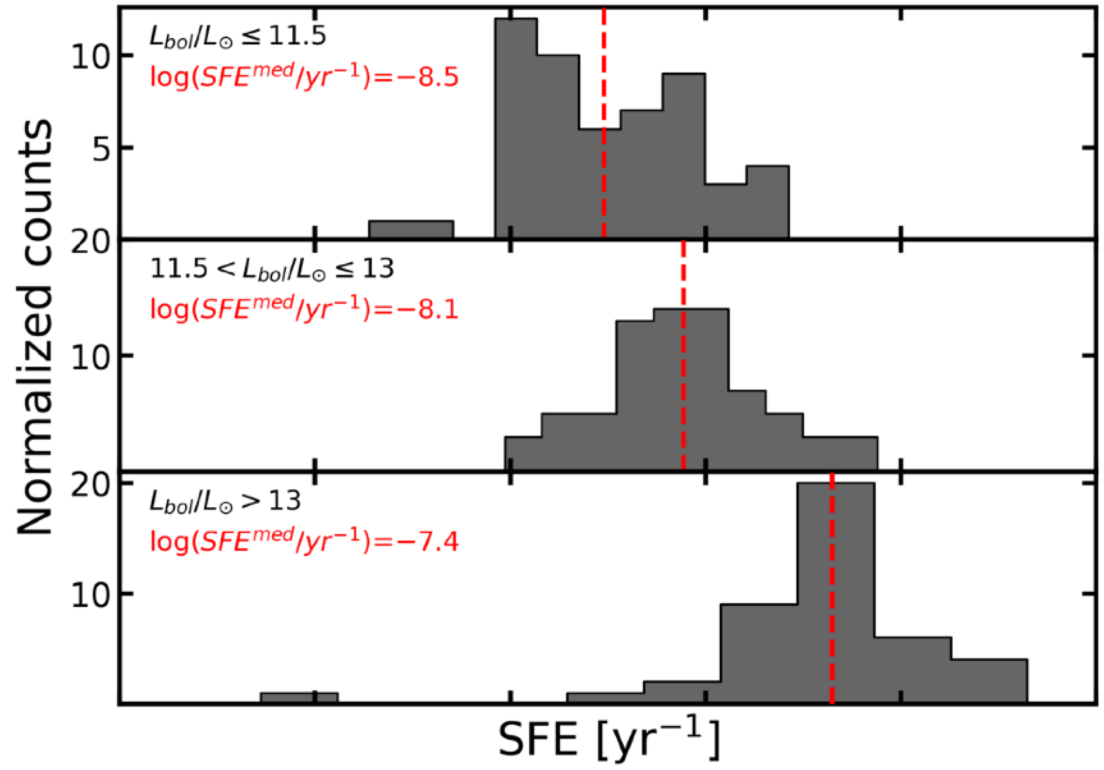

CONCLUSIONS

Conclusions

- ALMA is crucial to investigate the host galaxy's ISM in high-z QSOs, but a larger statistics is needed, also including the population of high-z AGN discovered by JWST.
- Among eight QSOs known at z>7, only one has a significant CO detection (Feruglio+23).
- Bright QSOs (L_{bol}>$10^{46.5}$ erg/s) show **no evidence for evolution of dust masses and gas-to-dust ratio with redshift.**
- GAEA SAM predicts a rapid quench, followed by minor AGN burst at later epochs: high-z QSOs are the progenitor of massive passive galaxies?
- **SFE correlates with L_{bol}**, this suggests that the physical processes that favour the starburst phase in the host galaxy enhance the accretion onto the SMBH, igniting the QSO phase.

The results will be submitted soon (Salvestrini+): stay tuned!