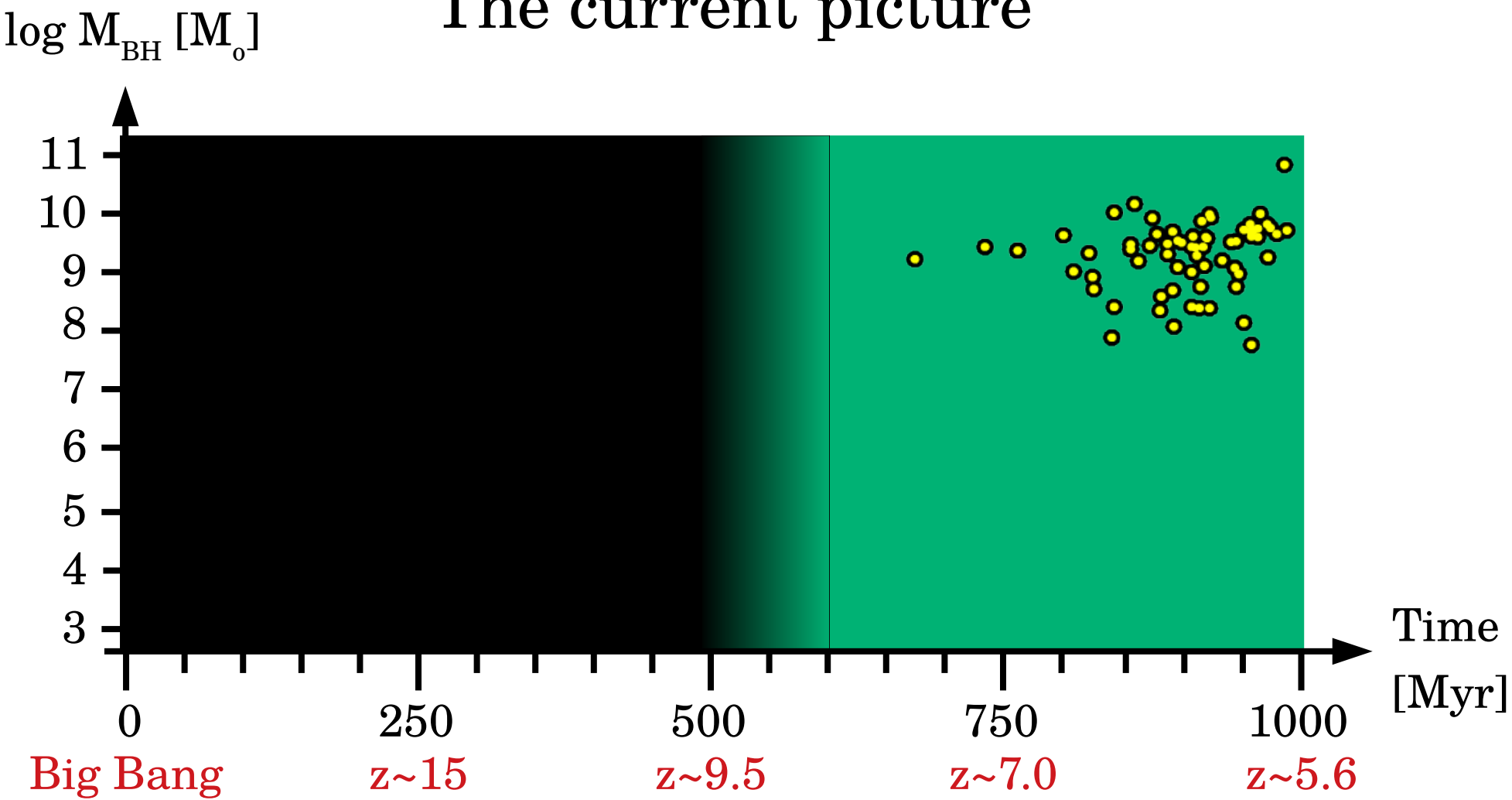
Roberto Decarli
INAF-OAS Bologna

The physics of the ISM in quasars at z>6

The current picture



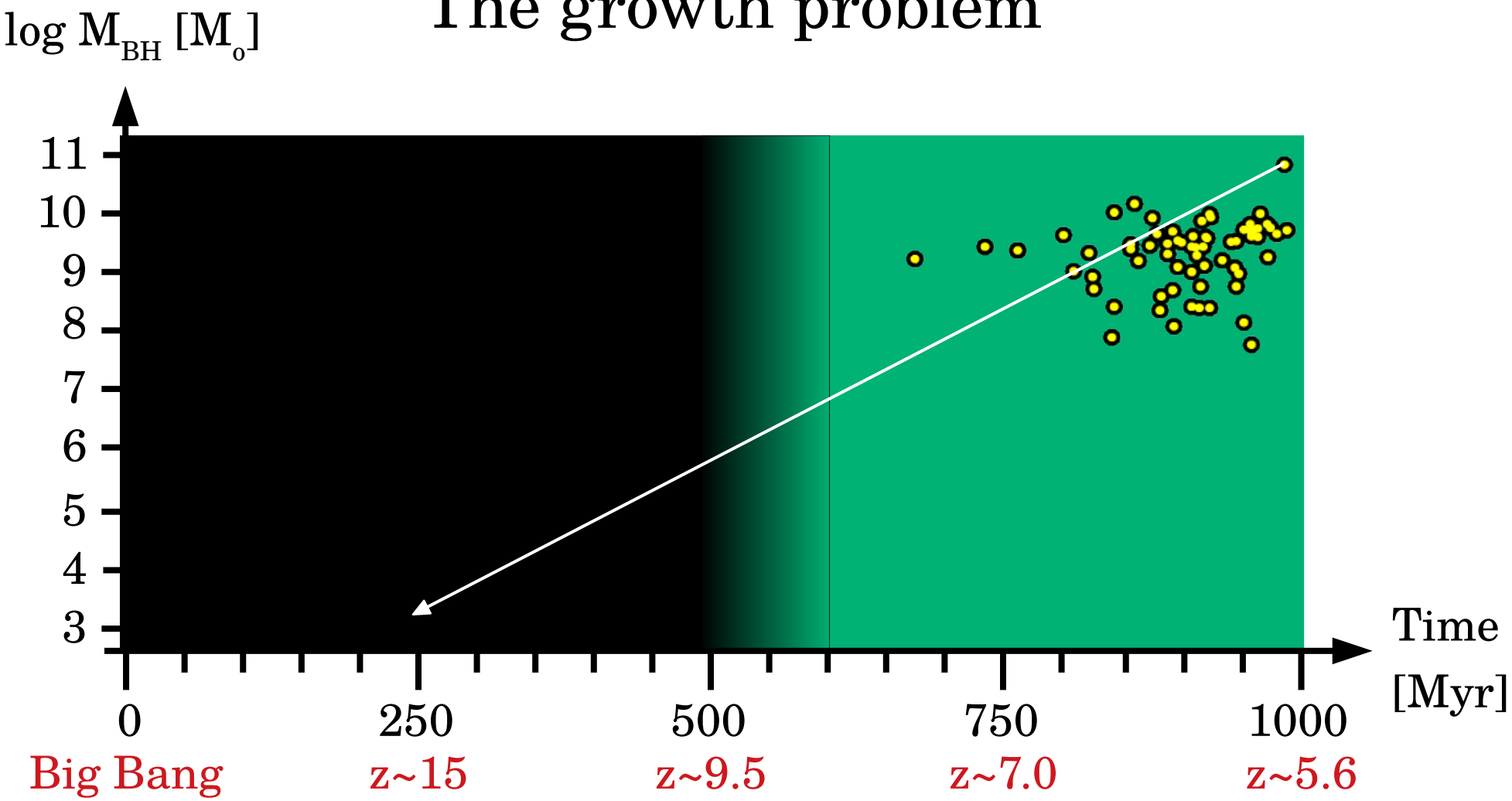
The growth problem

For Eddington-limited accretion,
e-folding = Salpeter time:

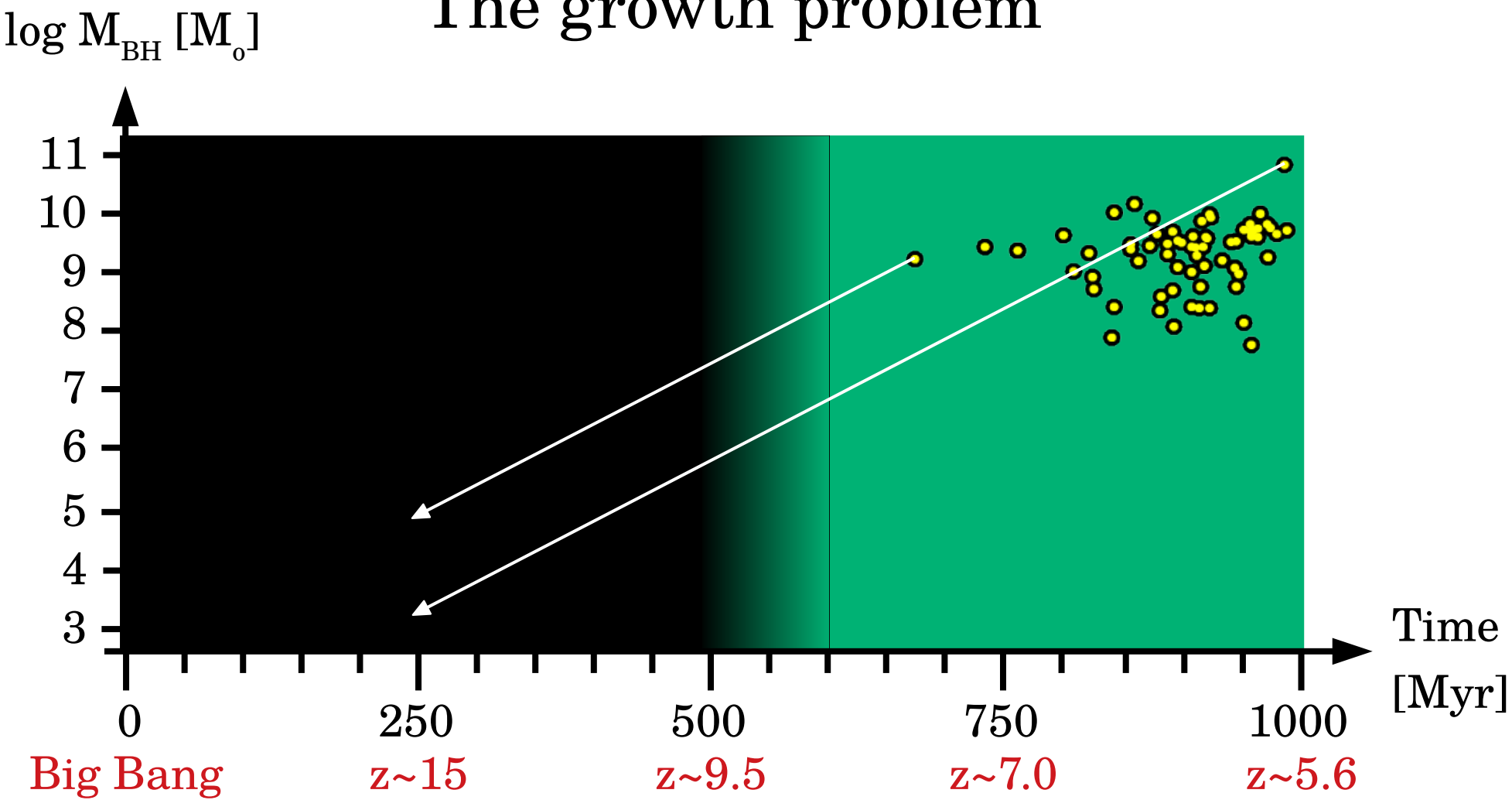
$$t_S = M/\dot{M} = 4.5 \times 10^7 \left(\frac{\epsilon}{0.1}\right) \left(\frac{L}{L_{\rm Edd}}\right)^{-1} \text{yr}$$

$$L_{\rm Edd} = \frac{4\pi G M m_{\rm p} c}{\sigma_{\rm T}} = 1.26 \times 10^{38} \left(\frac{M}{M_\odot}\right) \text{erg/s}$$

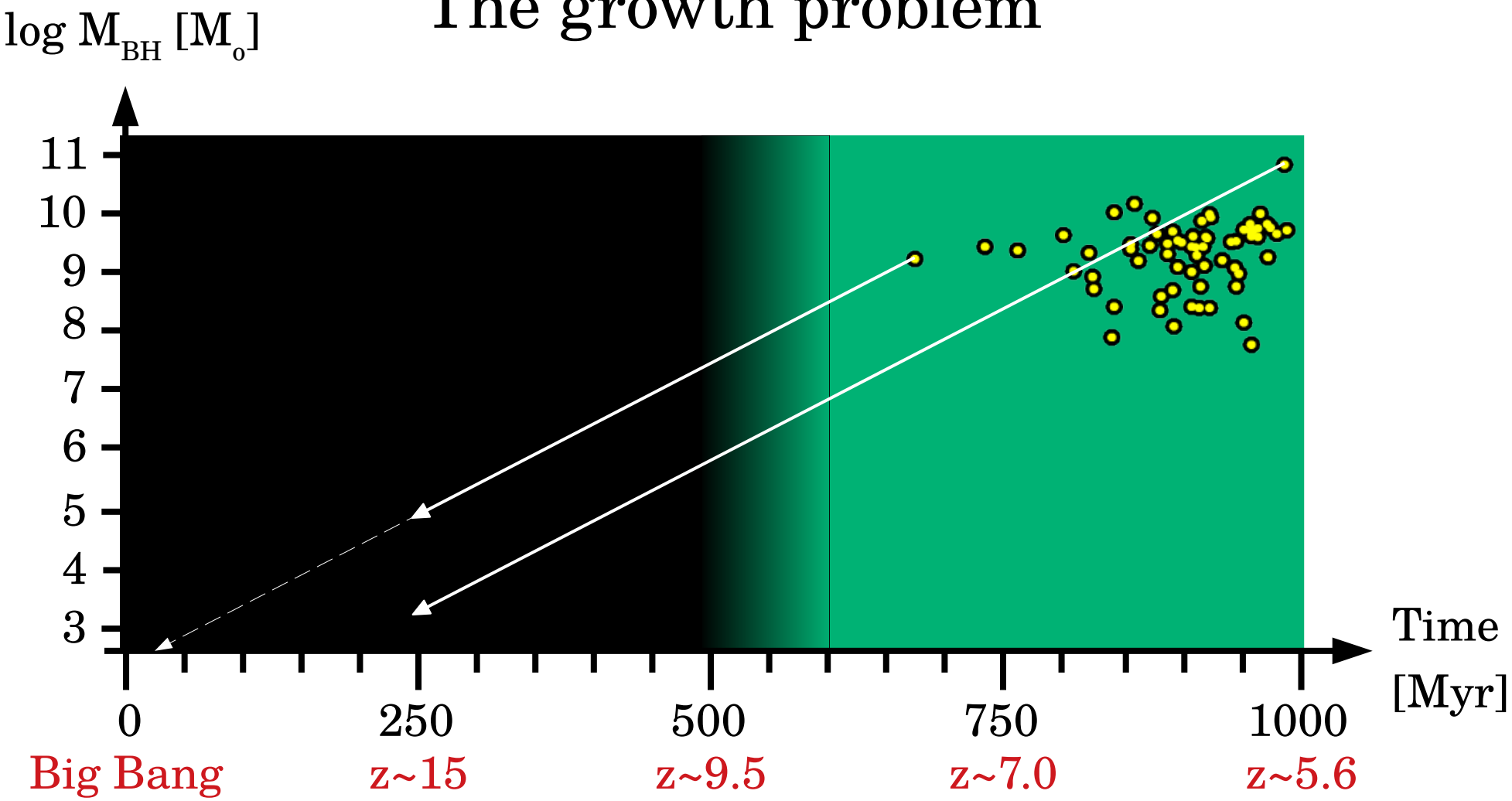
The growth problem



The growth problem



The growth problem

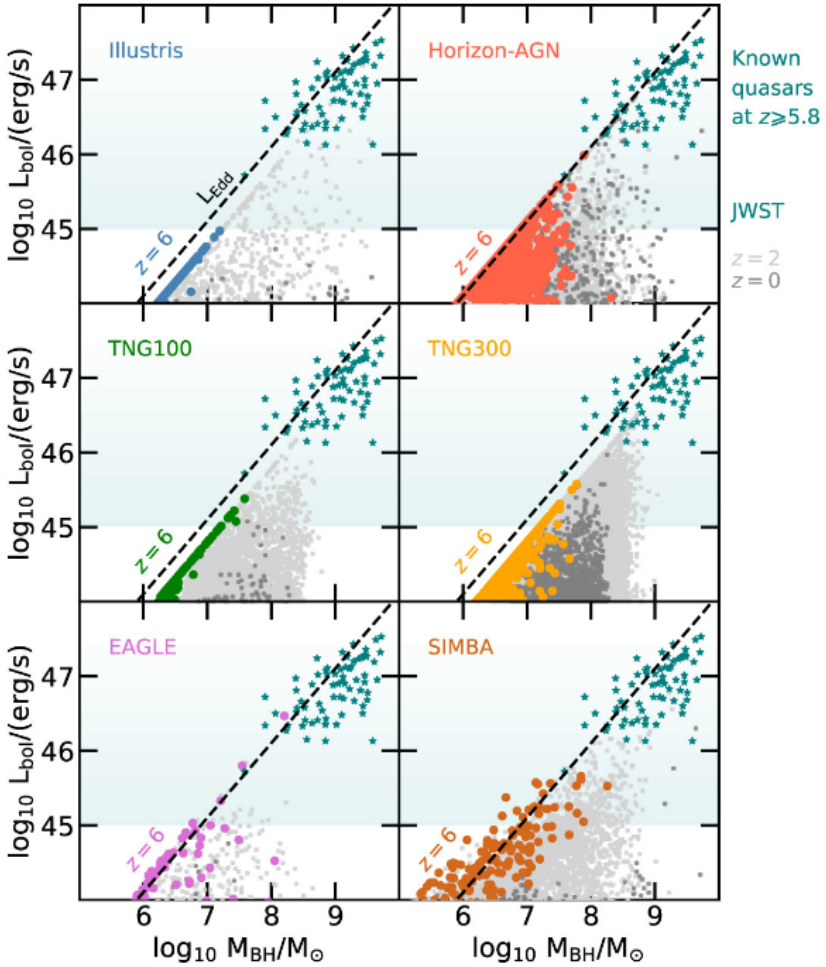


How do quasars and their host galaxies form?

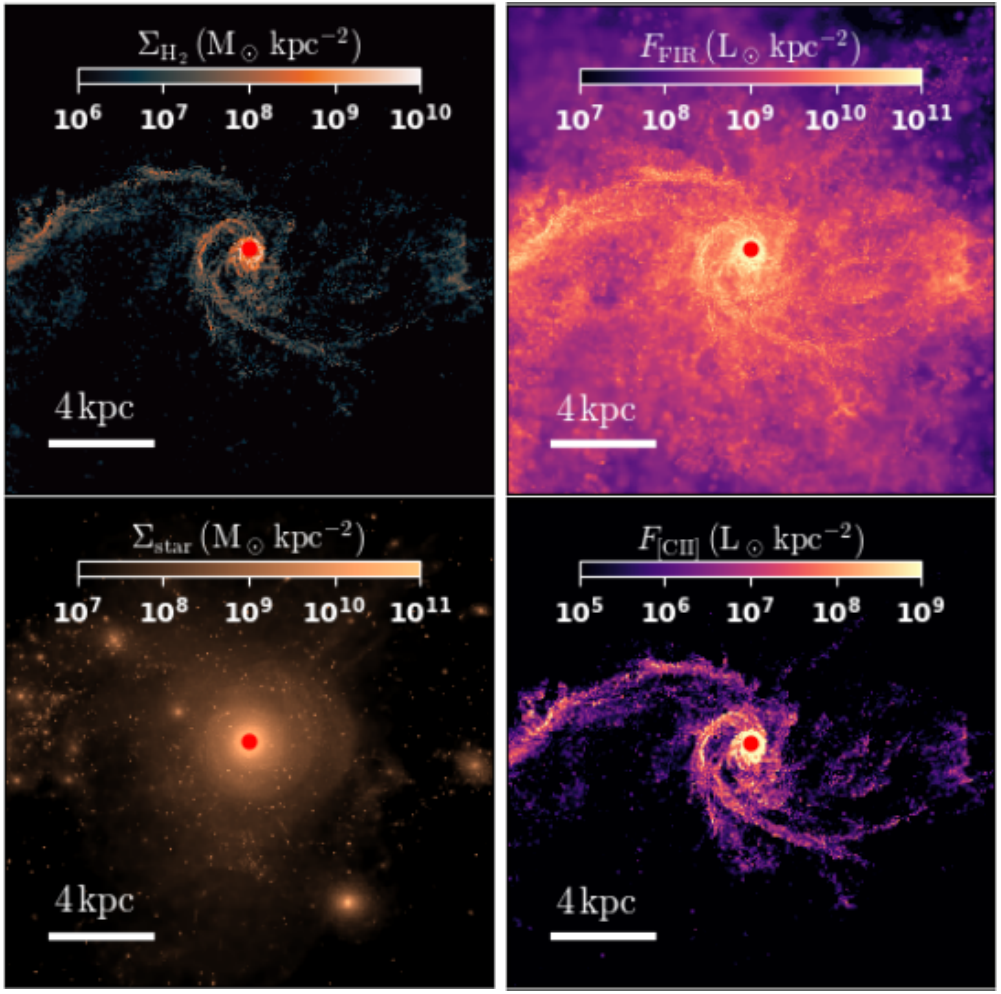
Numerical predictions limited by:

- volume
- prescriptions on BH seeds
- prescriptions on BH feeding
- prescriptions on feedback

Habouzit et al. (2022)



How do quasars and their host galaxies form?



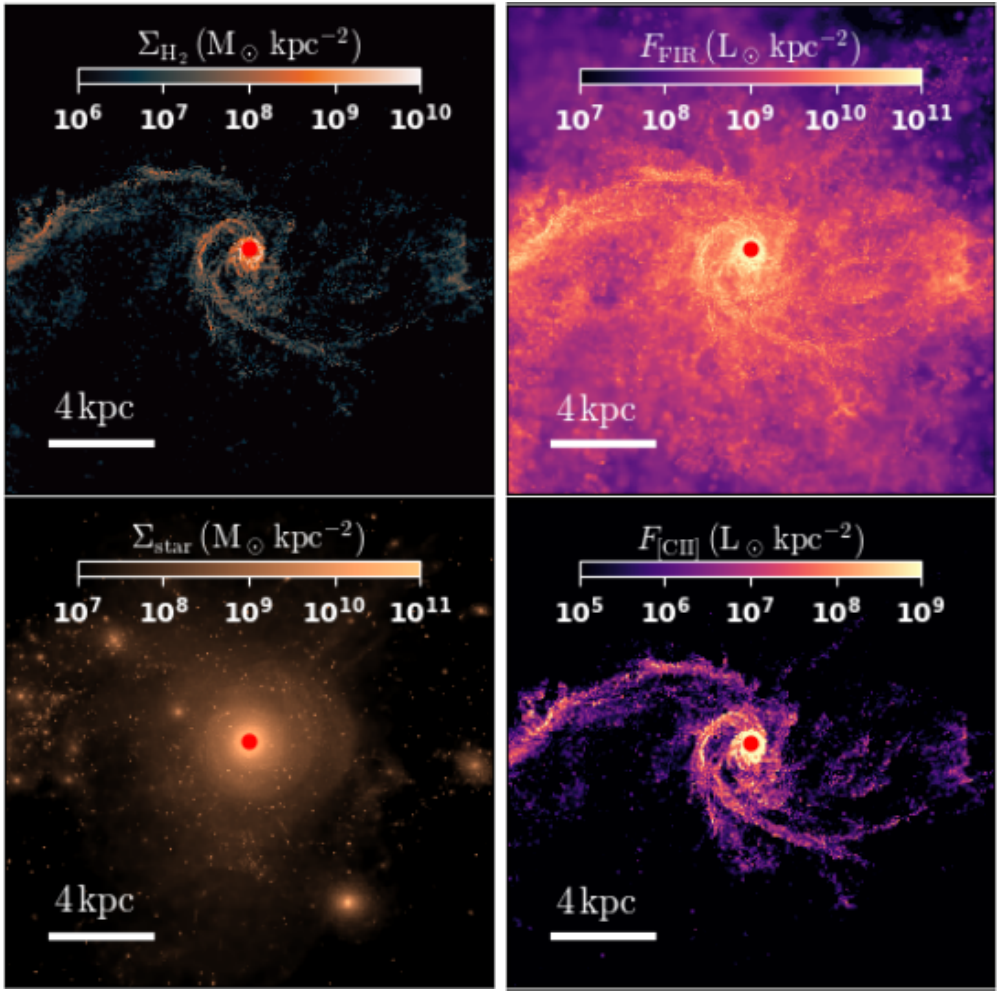
z=7 quasar host galaxy

Zoomed-in sims predict:

- morphology
- size
- ISM conditions (n, T, U, …)
- abundances
- CGM
- environment

Lupi et al. (2021)

How do quasars and their host galaxies form?



z=7 quasar host galaxy

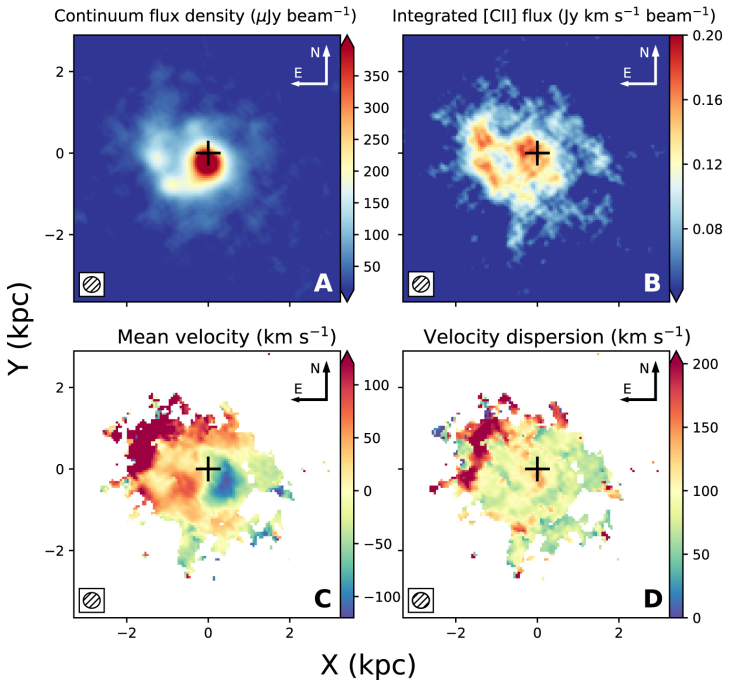
Zoomed-in sims predict:

- morphology
- size
- ISM conditions (n, T, U, …)
- abundances
- CGM
- environment

→ Observable quantities!

Lupi et al. (2021)

Imaging dust and gas at 100s pc resolution

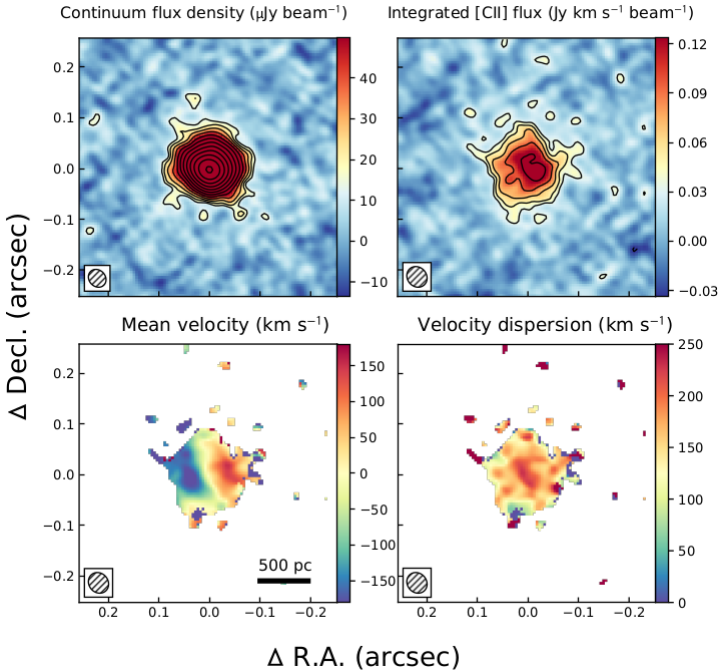


J0305-3150 (z=6.6)

Resolution:

76 mas ~ 400 pc

Venemans et al. (2019)

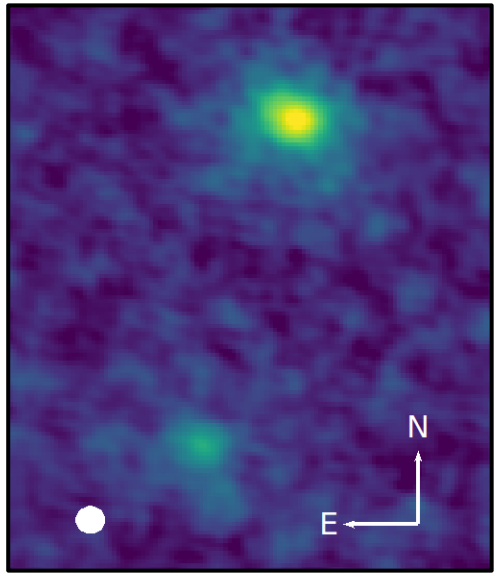


J2348-3054 (z=6.9)

Resolution:

36 mas ~ 200 pc

Walter et al. (2022)



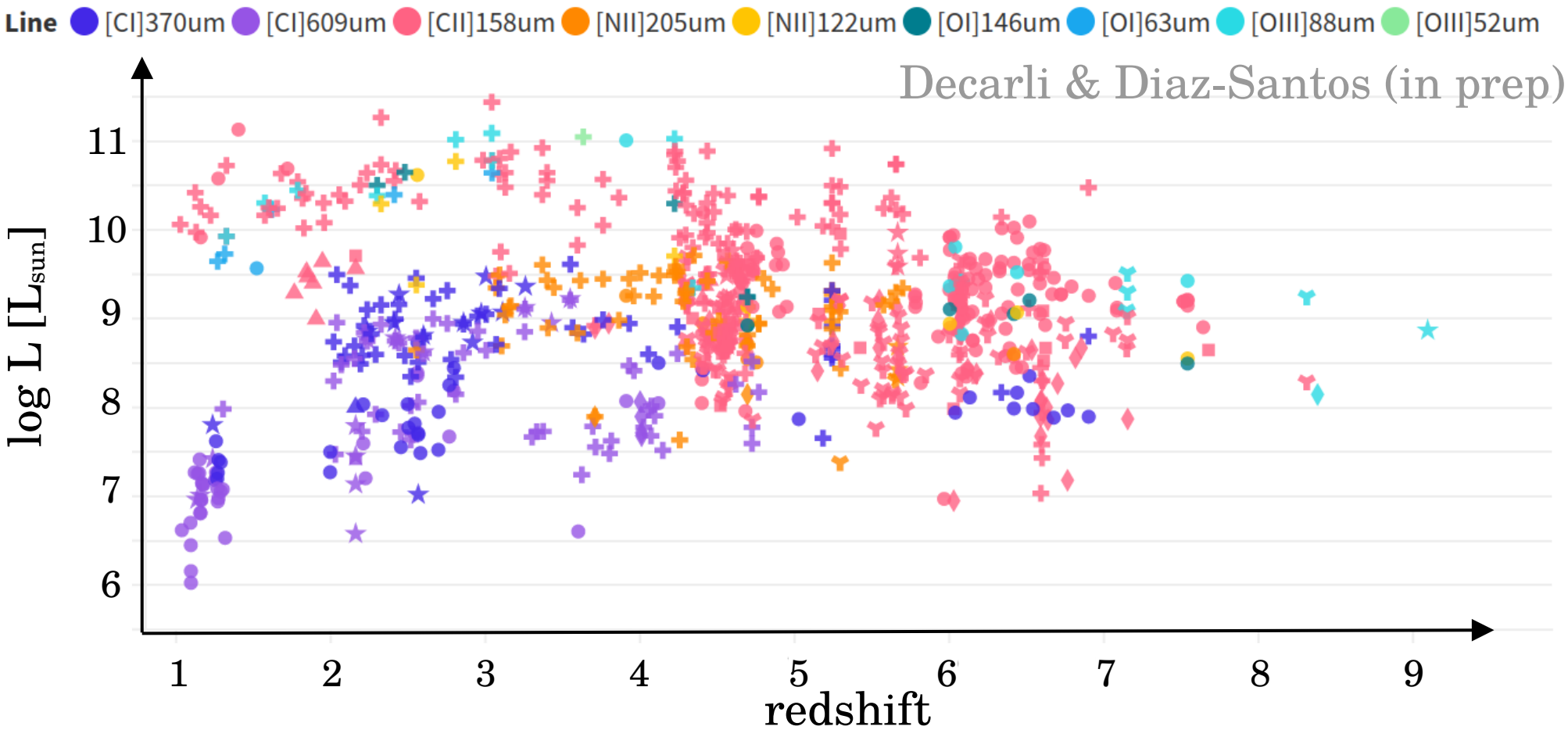
PJ231-20 (z=6.6)

Resolution:

86 mas ~ 470 pc

Decarli et al. (in prep)

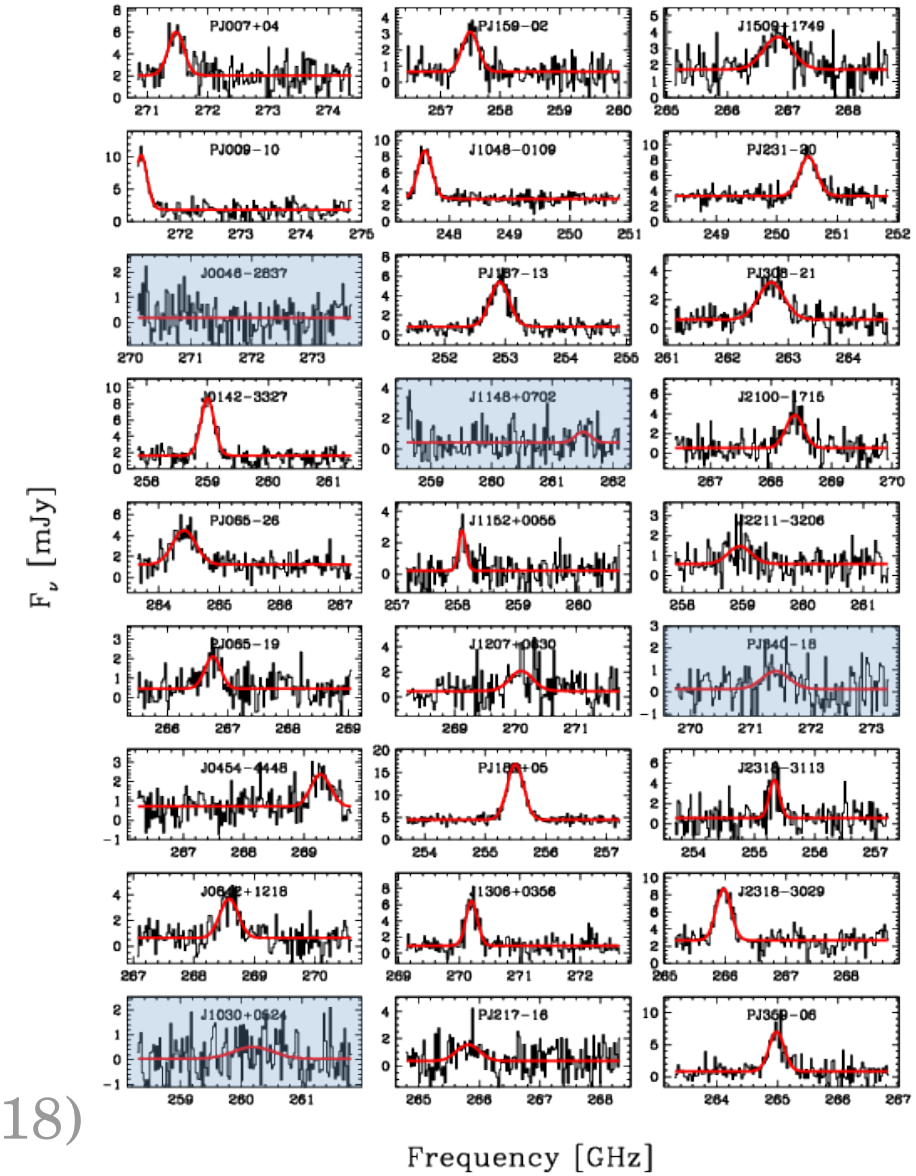
Multi-λ campaigns



A systematic survey of gas and dust in z>6 quasars

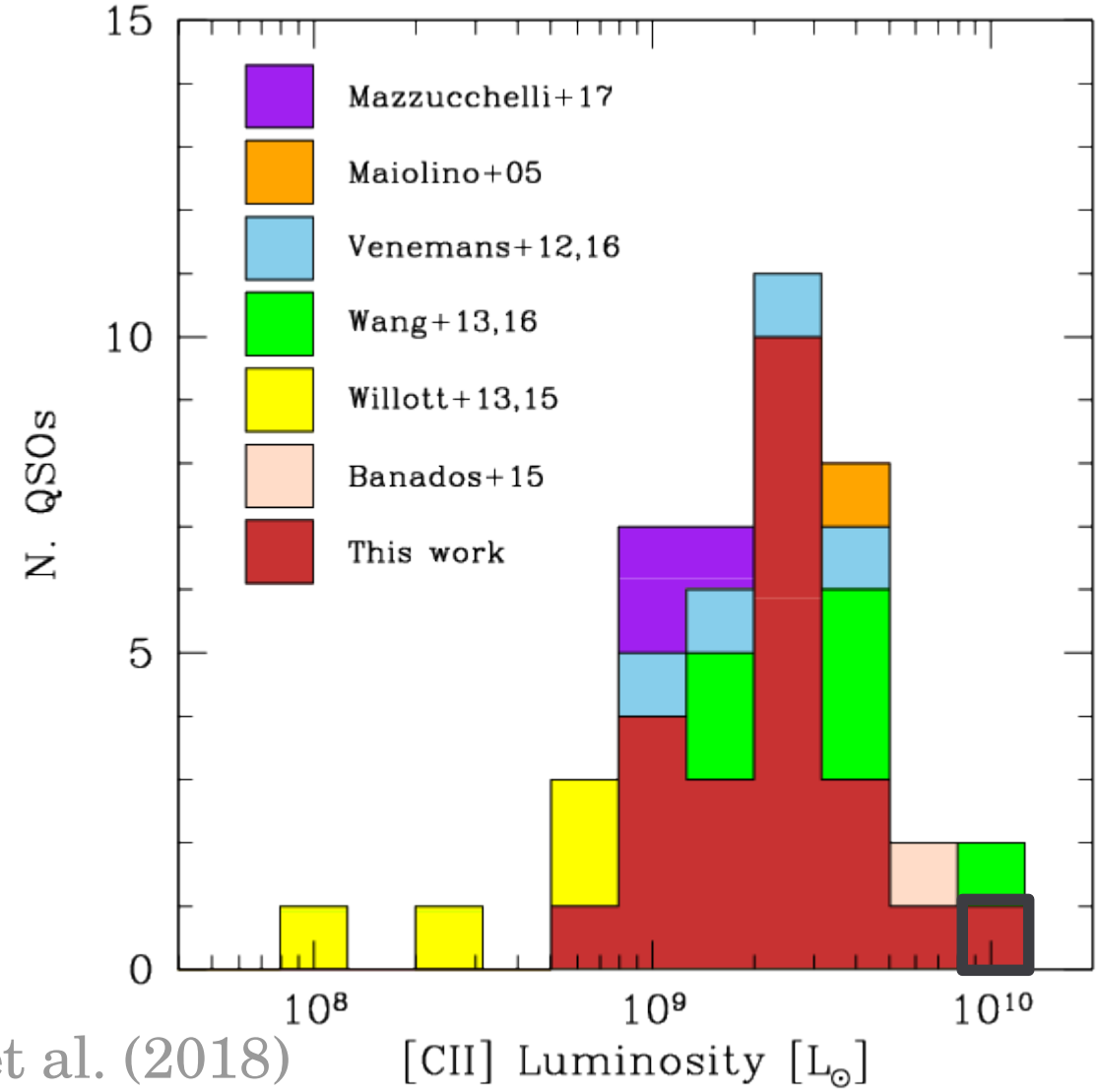
27 observed,
23 detected (85%)

10 min on source!



Decarli et al. (2018)

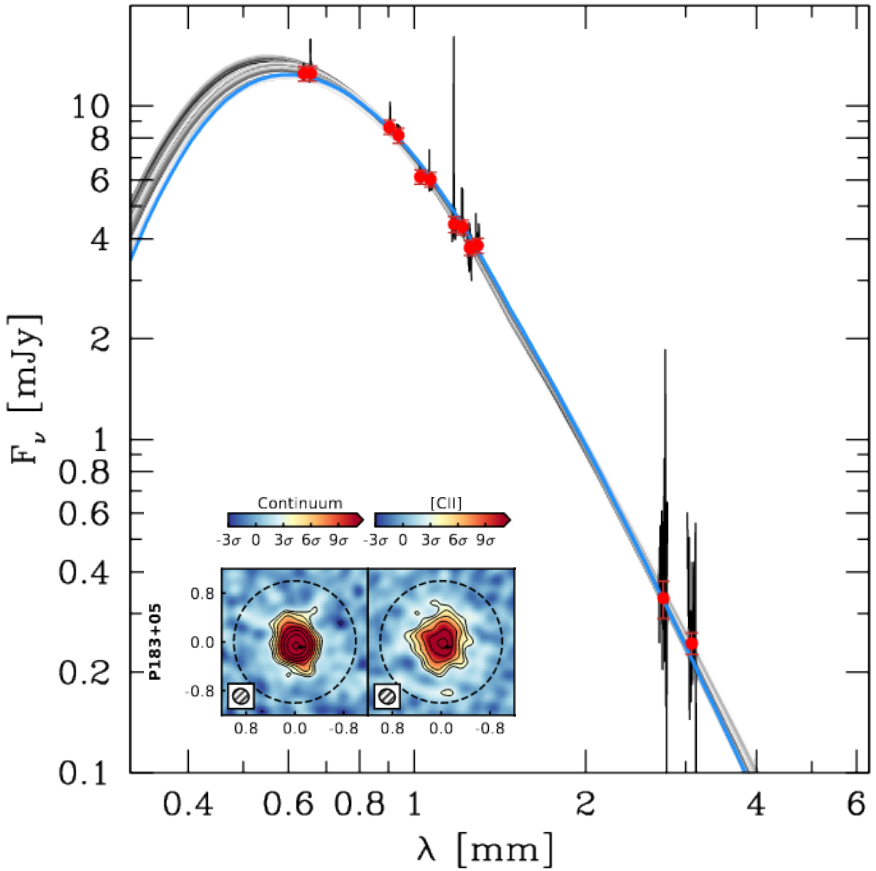
The luminous QSO PJ183+05 @ z=6.44



Decarli et al. (2018)

Multi-λ campaign: Dust continuum

Decarli et al. (2023)



Multi-λ campaign: Dust continuum

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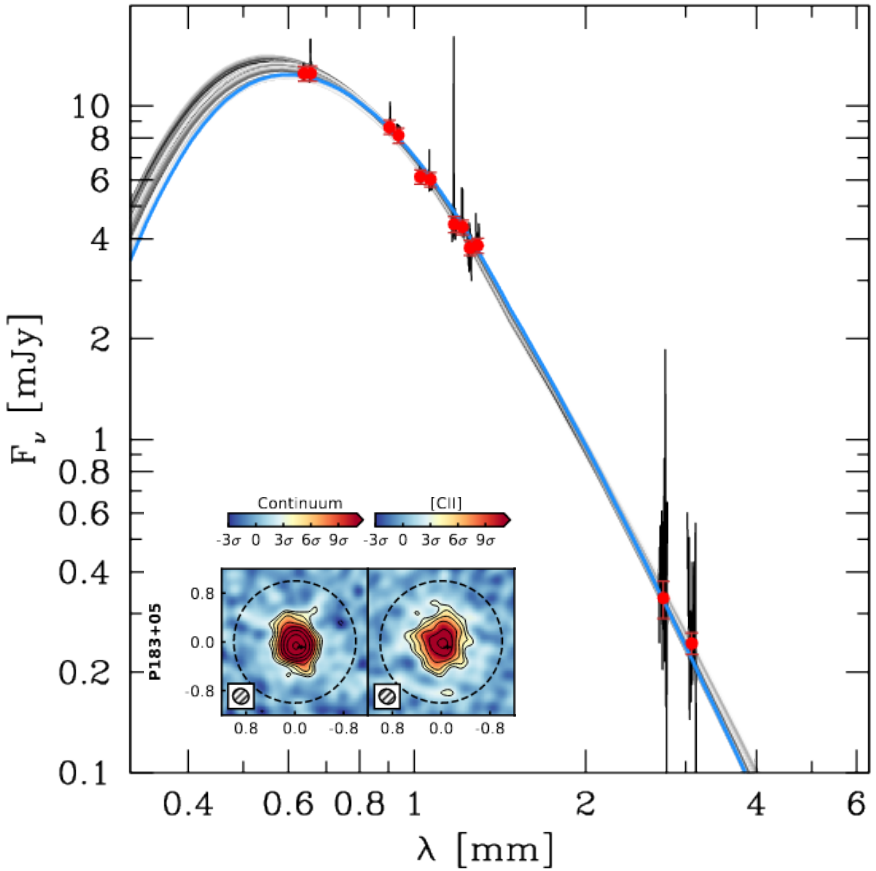

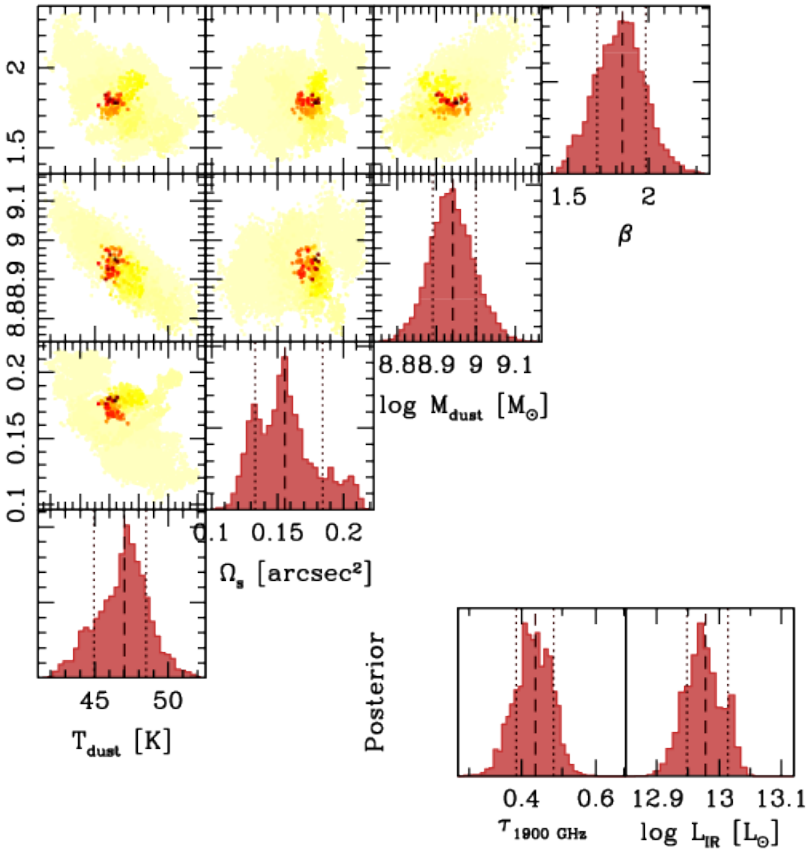

Multi-λ campaign: Dust continuum

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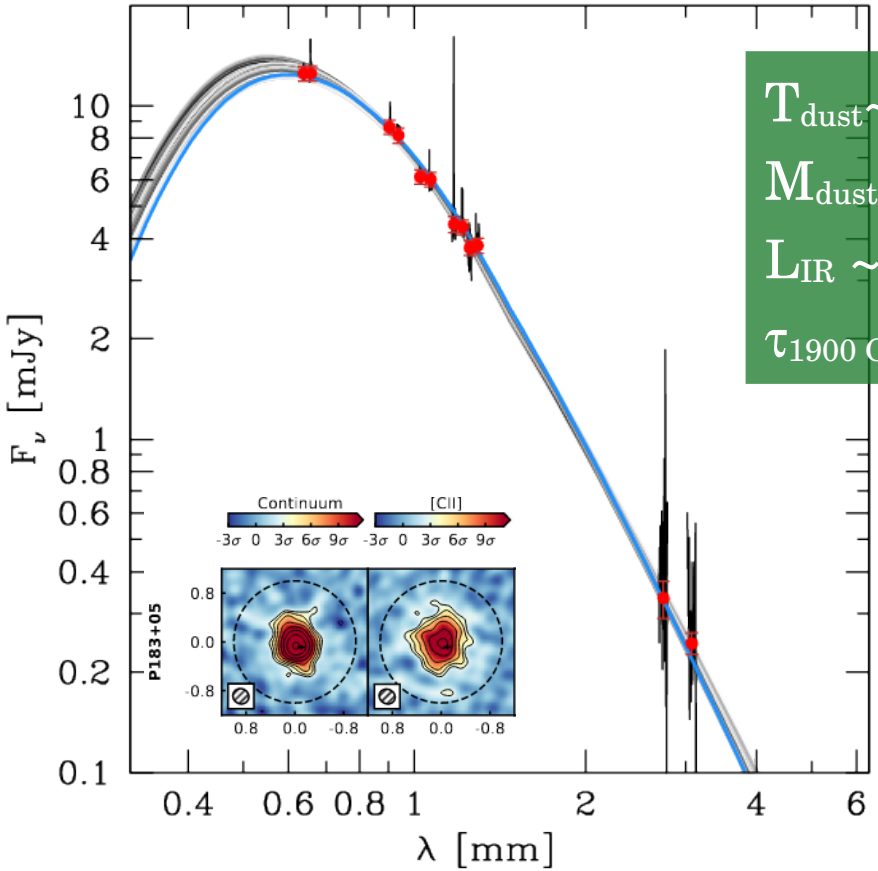
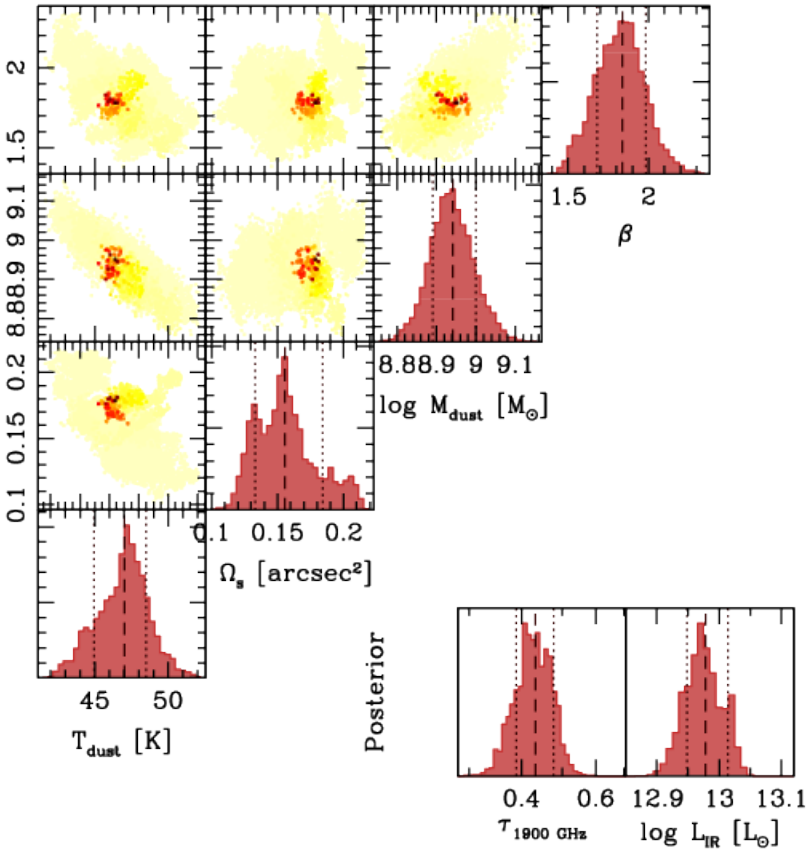


T_{dust}~47 K

M_{dust} ~ 10^9 M_o

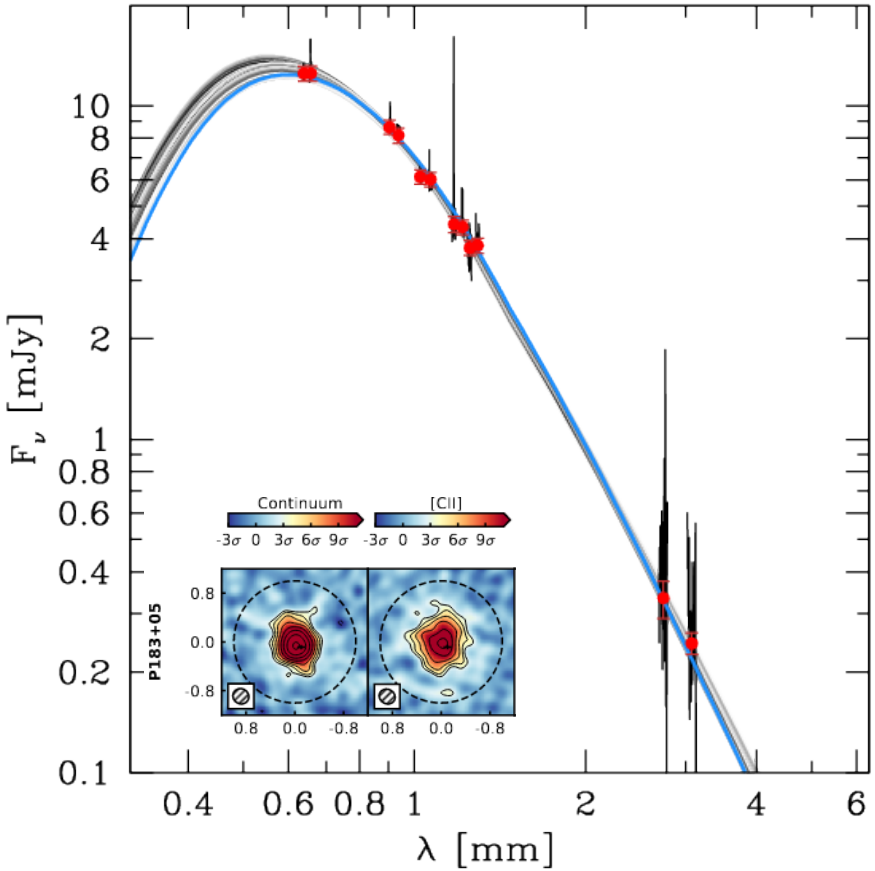
L_{IR} ~ 10^{13} L_o

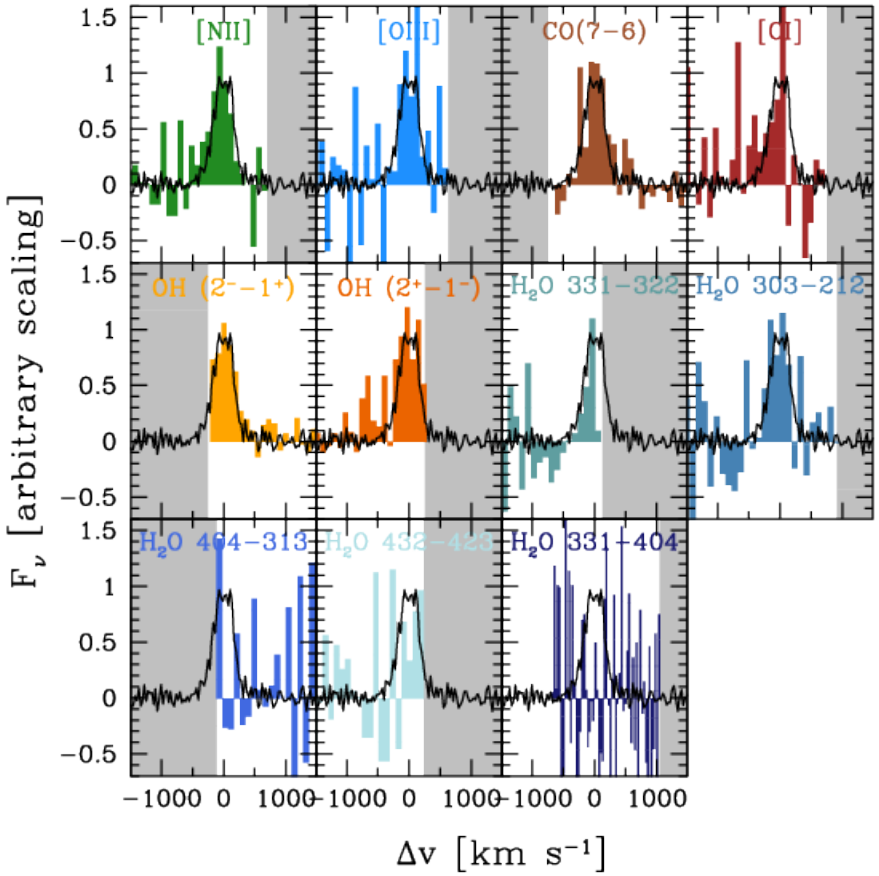
$\tau_{1900\ GHz}$~0.4



Multi-λ campaign: Lines

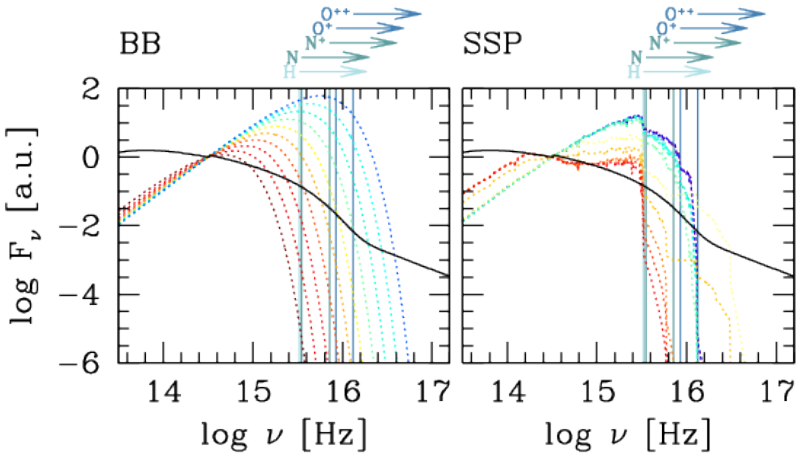
Decarli et al. (2023)





Emission line predictions

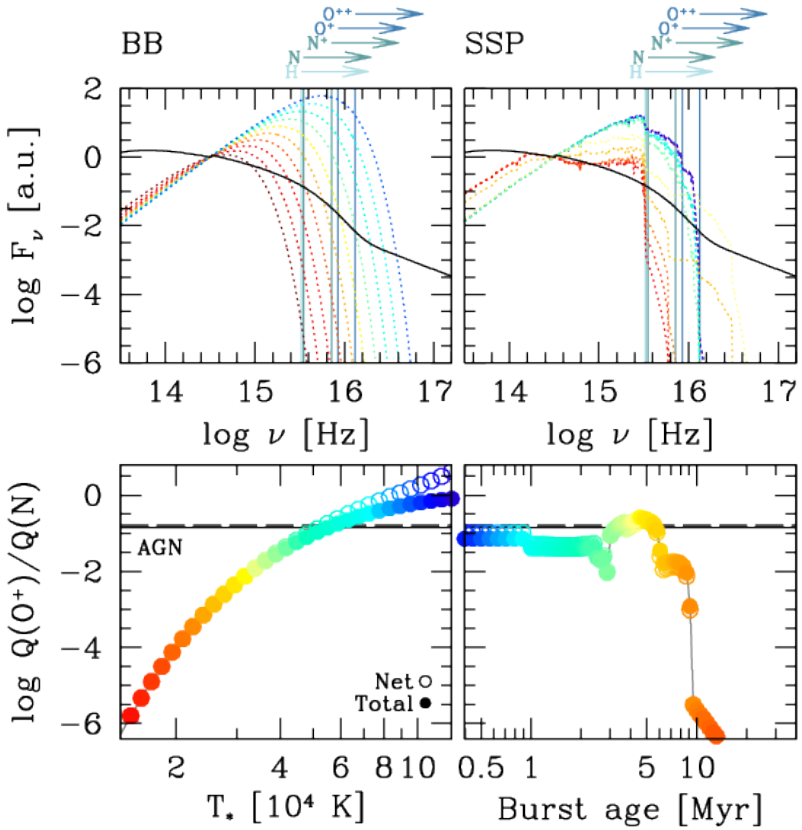
Radiation field templates



Decarli et al. (2023)

Emission line predictions

Radiation field templates



Decarli et al. (2023)

Emission line predictions

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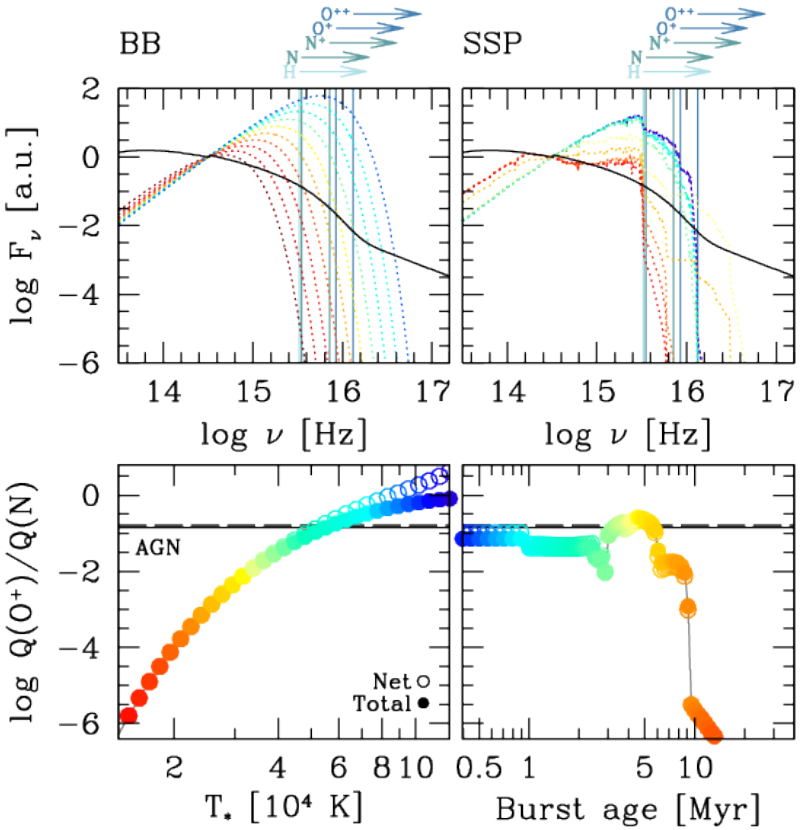
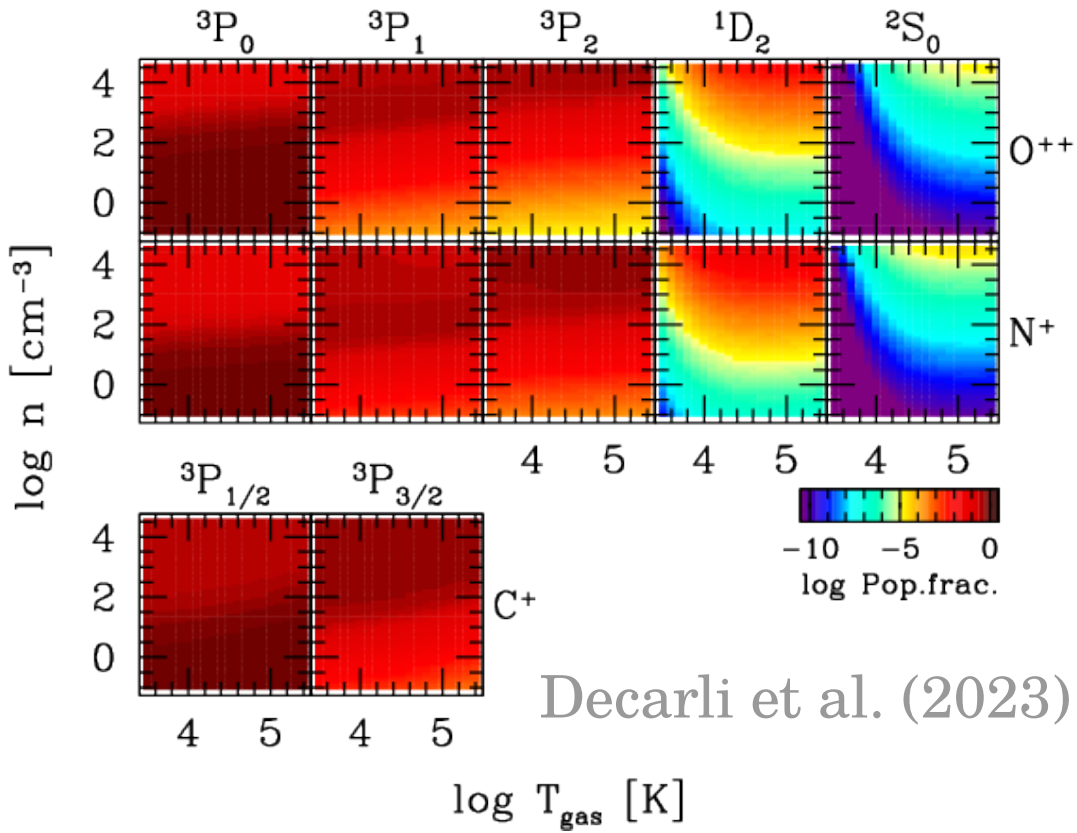
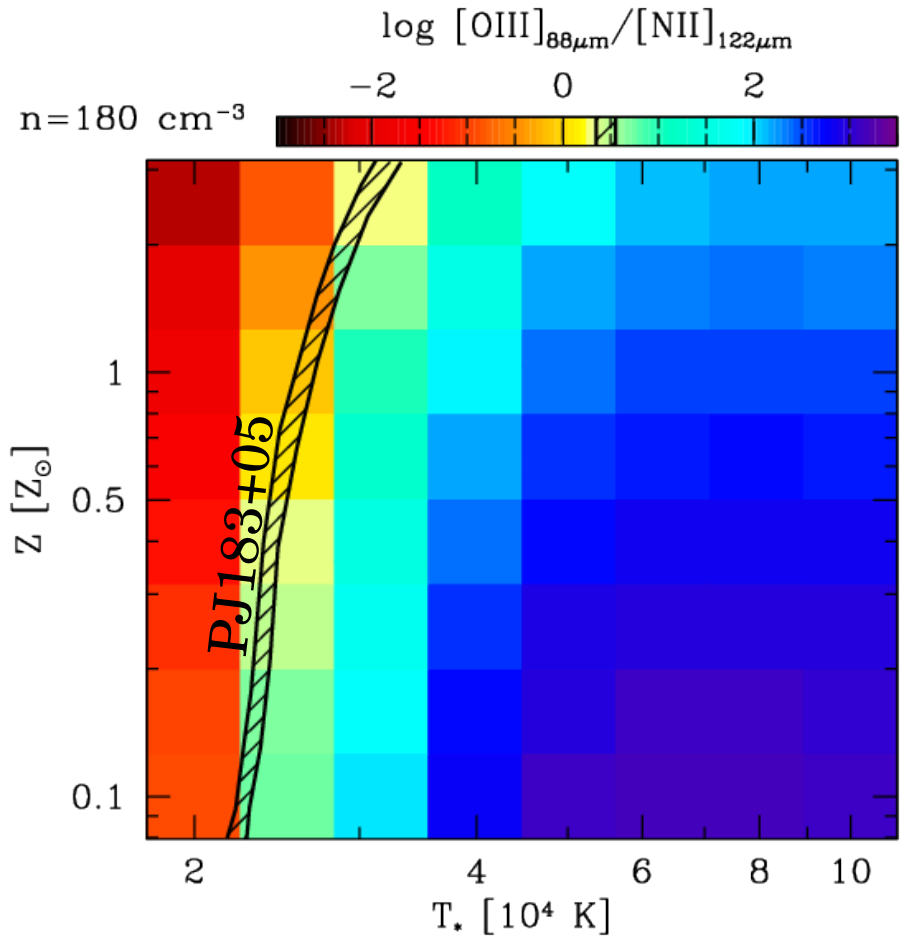


Energy level population

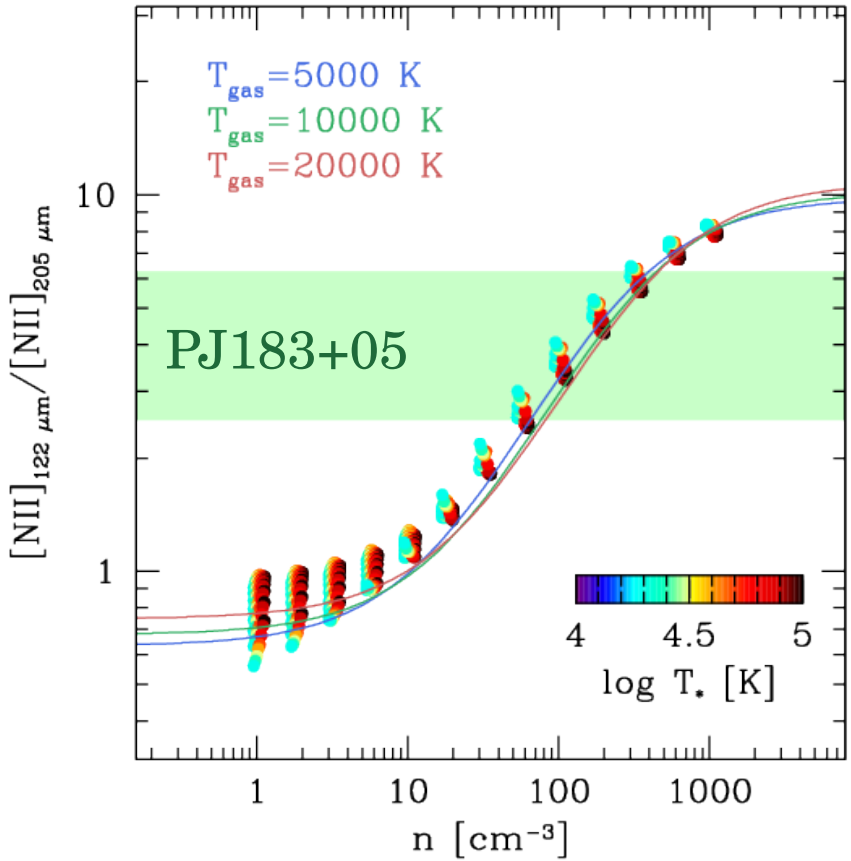


Decarli et al. (2023)

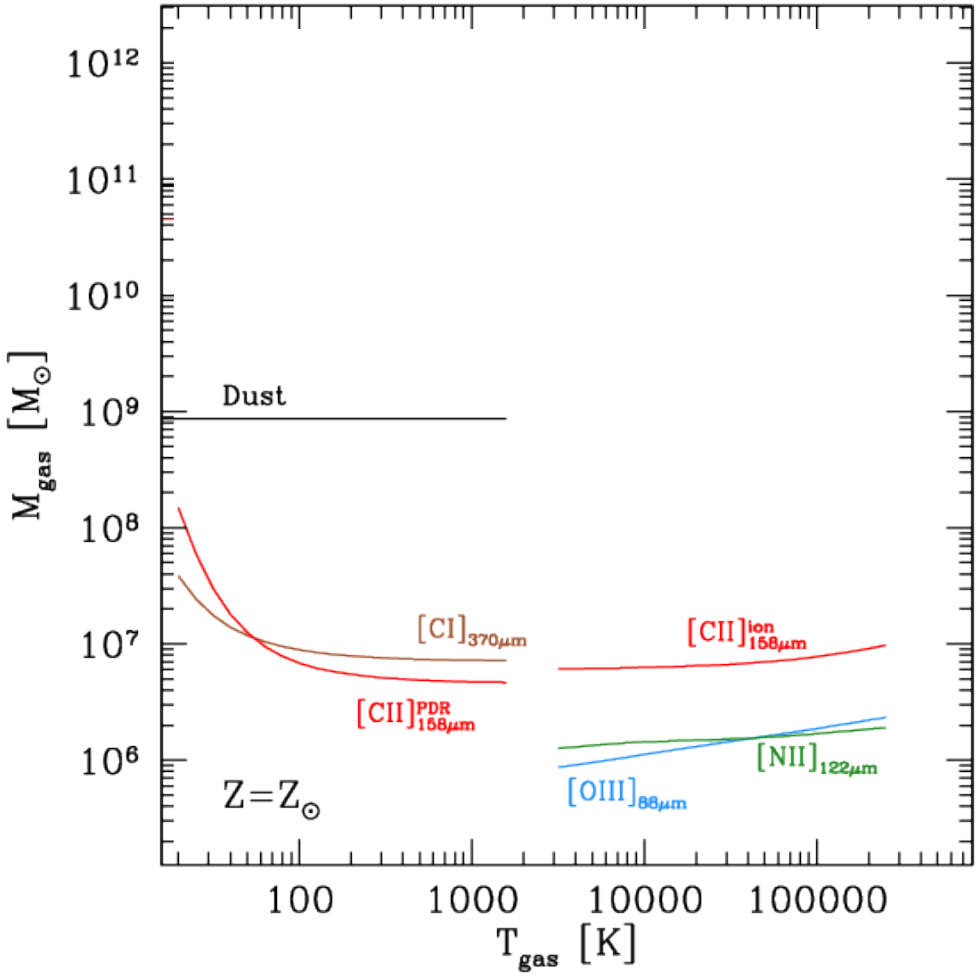
Data vs Radiative Transfer models



Decarli et al. (2023)



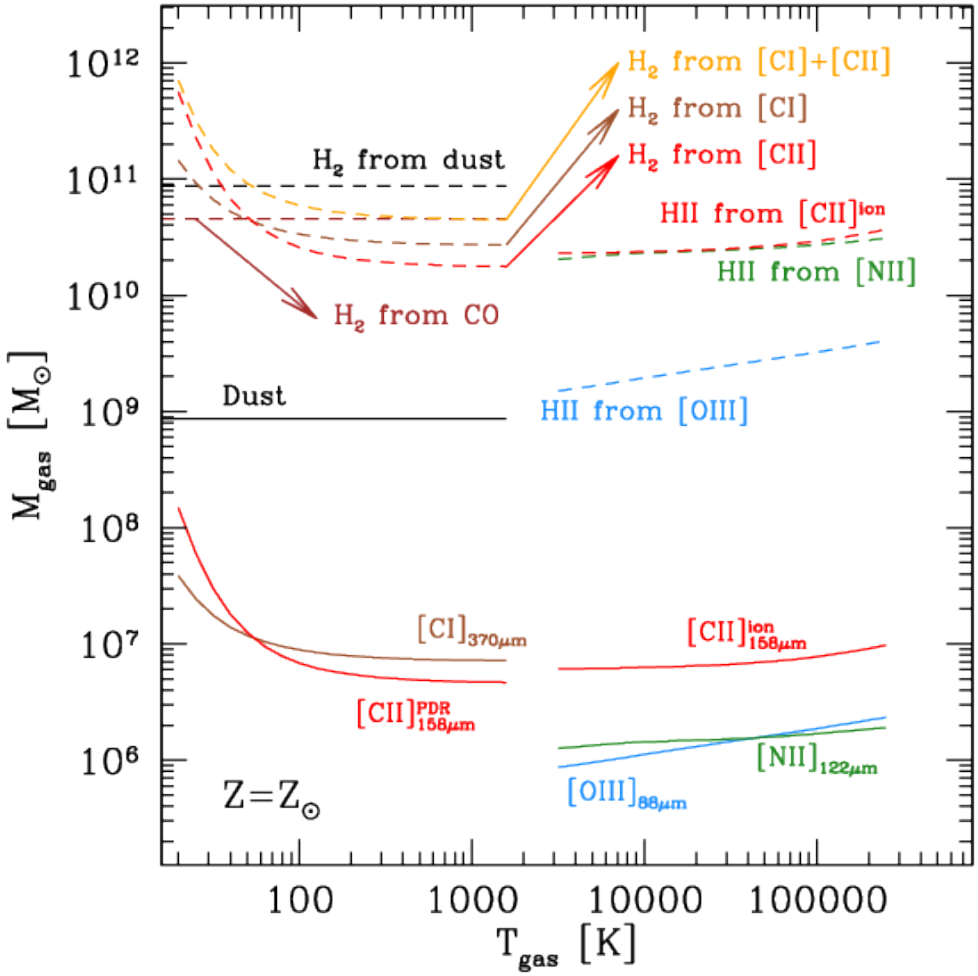
Mass budget



PJ183+05 @ z=6.4386

Decarli et al. (2023)

Mass budget



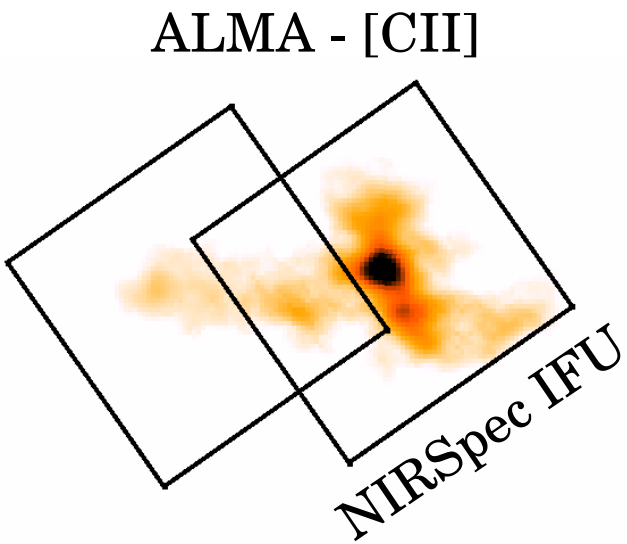
Multi-phase mass budget

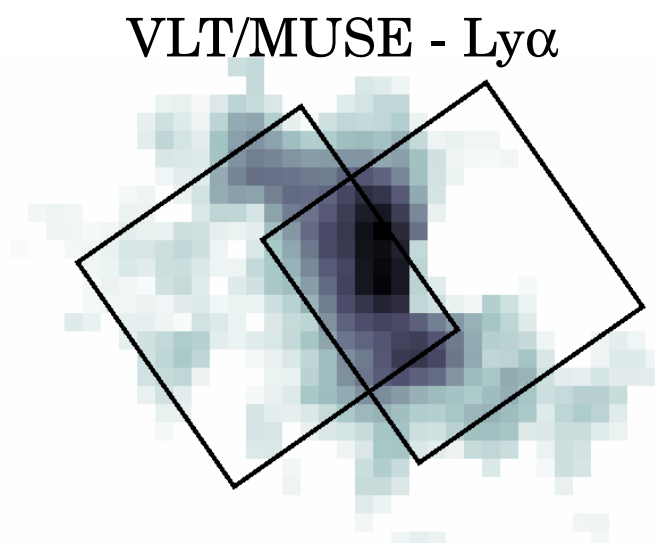
PJ183+05 @ z=6.4386

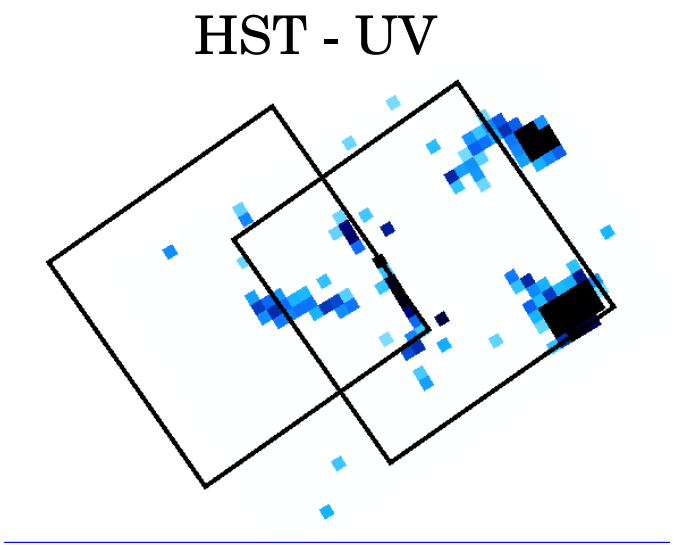
Decarli et al. (2023)

A quasar-satellite merger at z=6.2

(JWST cycle 1)



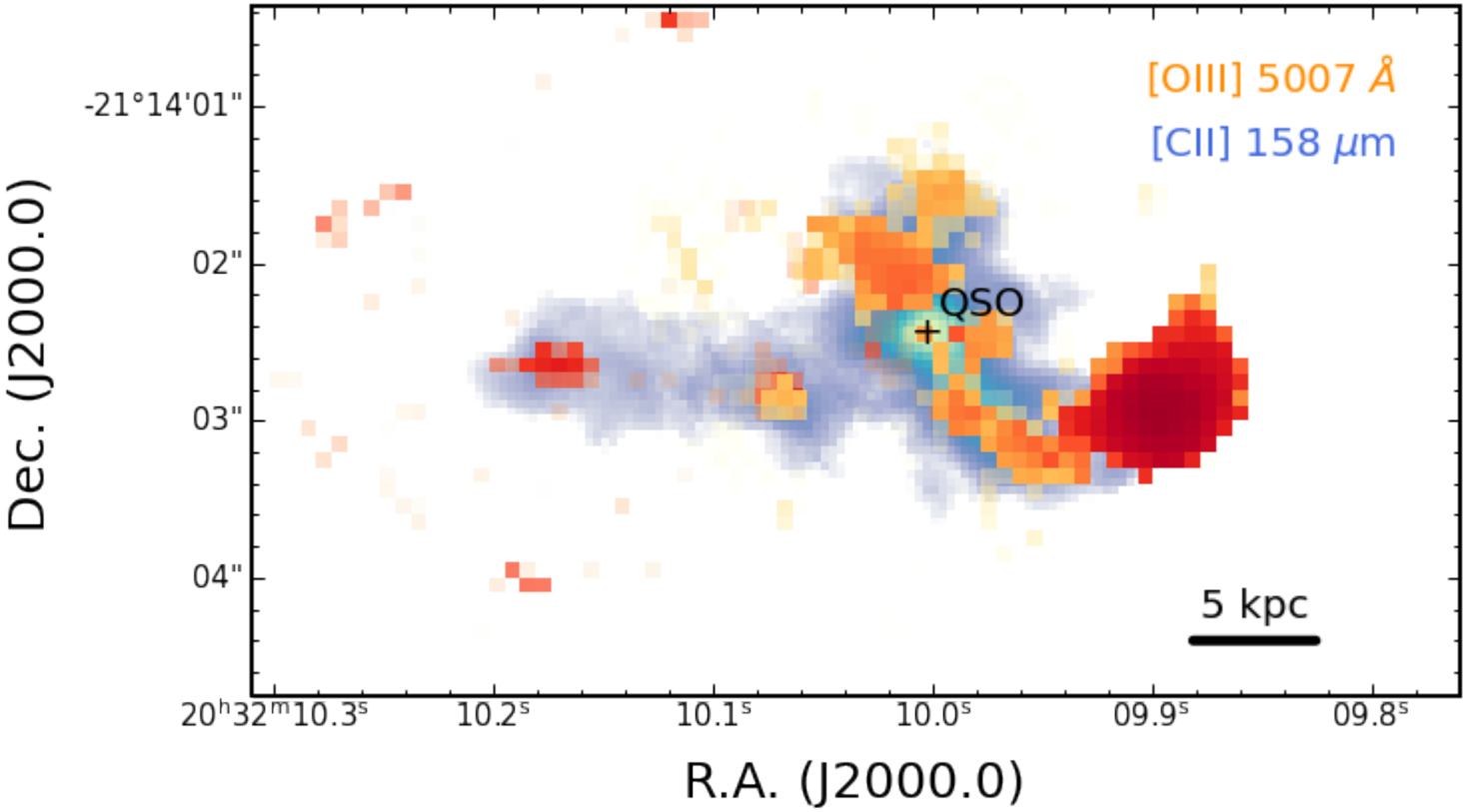




Decarli et al. (2019),
Farina et al. (2019)

A quasar-satellite merger at z=6.2

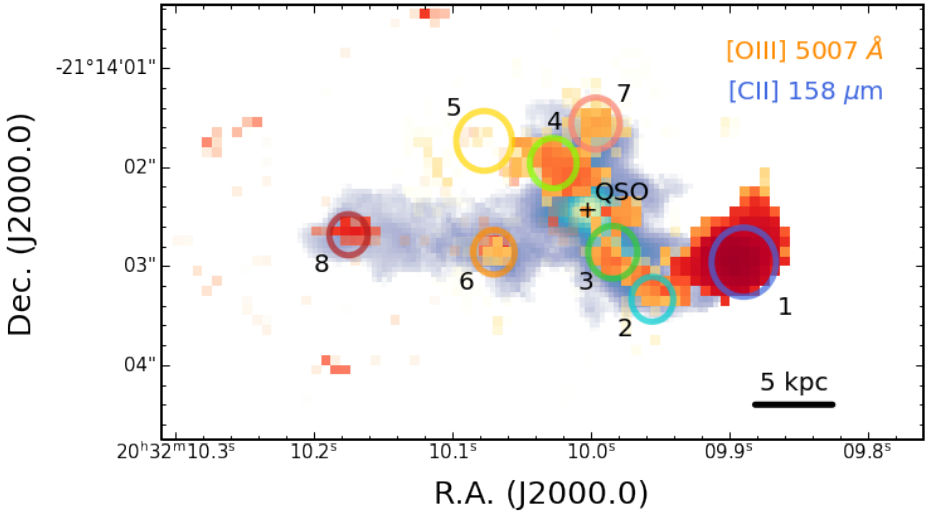
(JWST cycle 1)

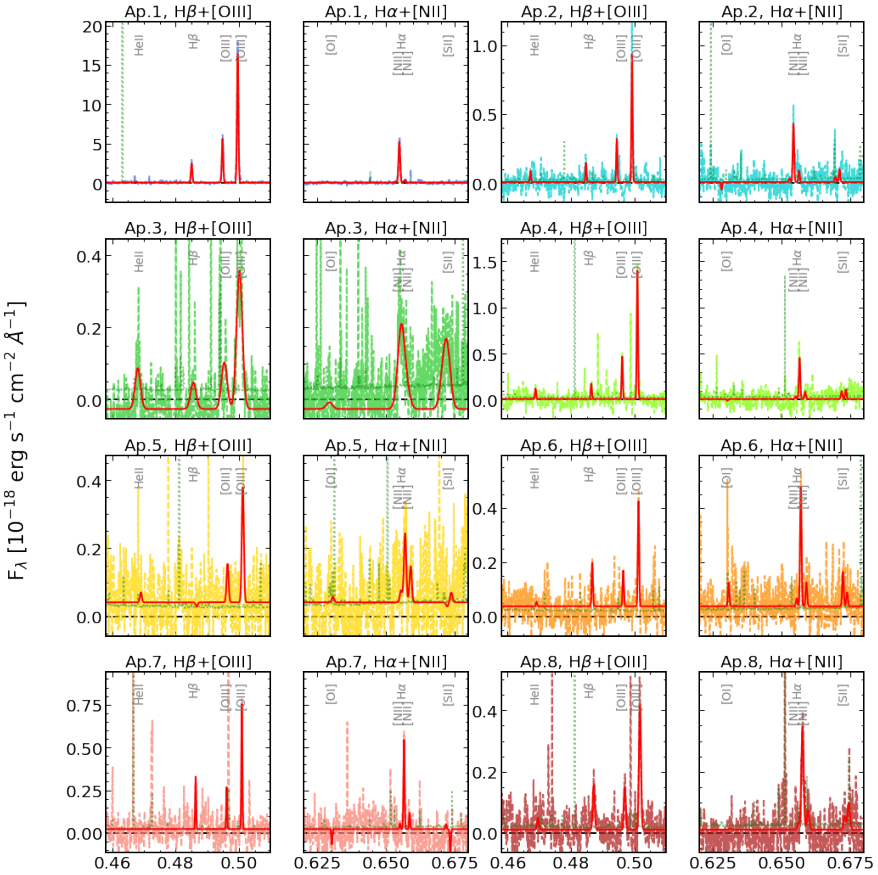


Decarli et al. (in prep)

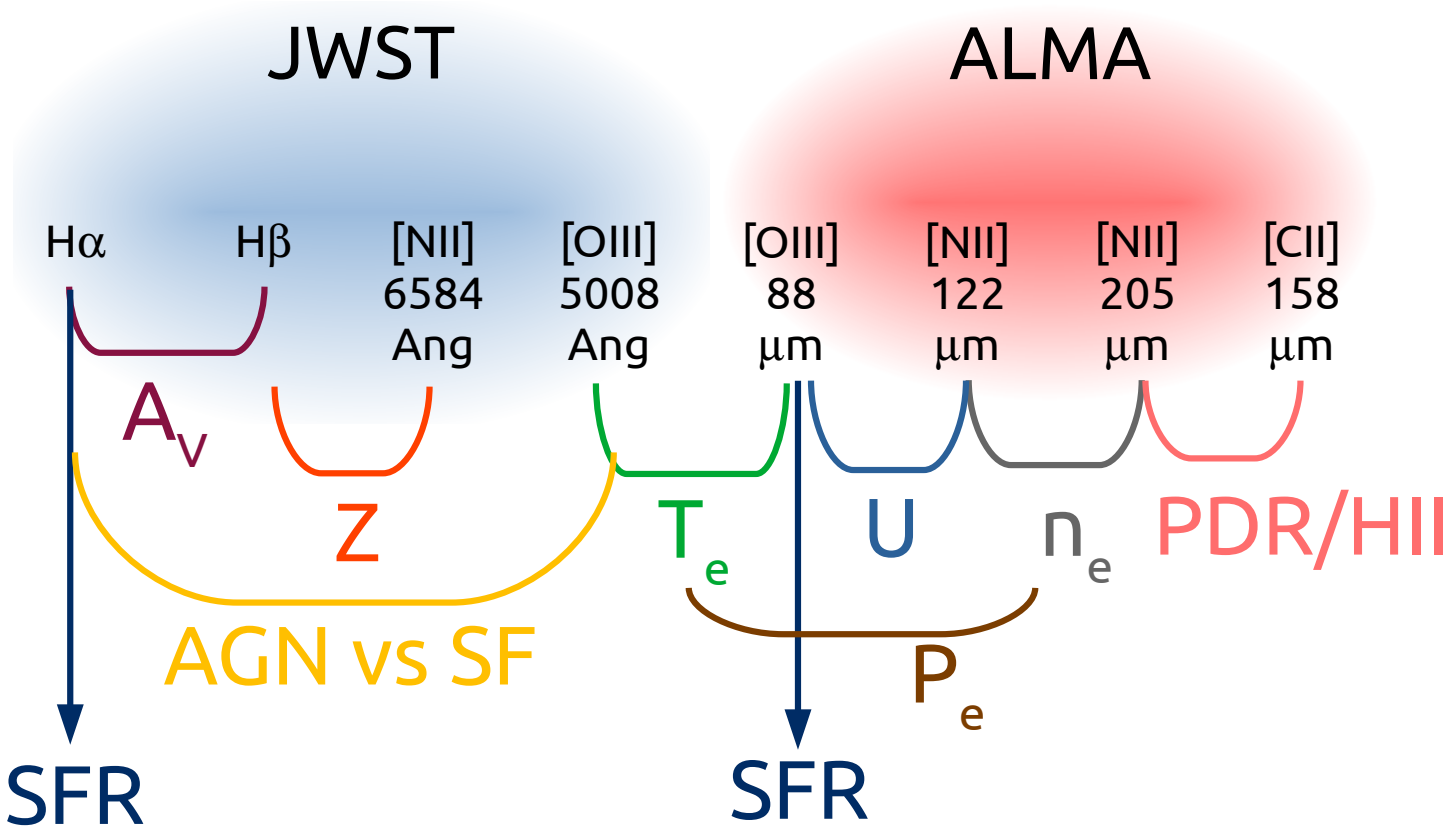
A quasar-satellite merger at z=6.2

(JWST cycle 1)





Decarli et al. (in prep)



A_V = Dust extinction

Z = metallicity

AGN vs SFR = dominant source of photoionization

T_e = electron temperature

U = ionization parameter

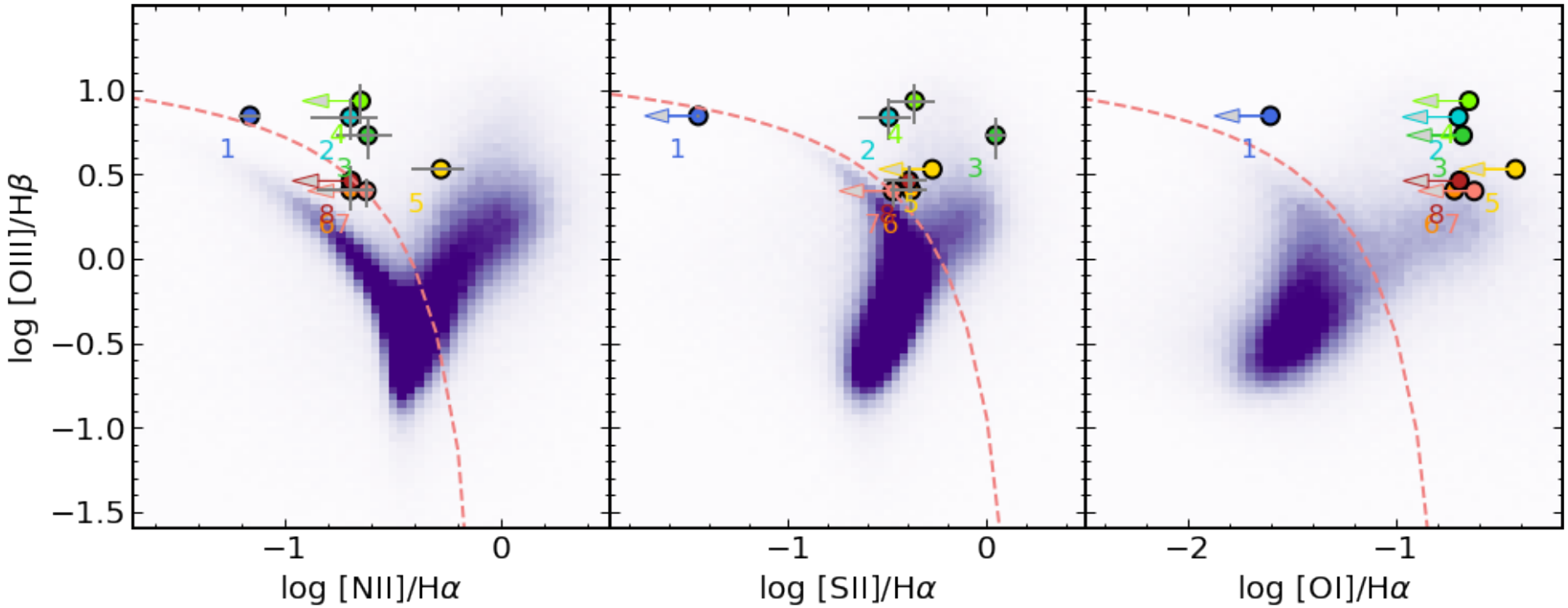
n_e = electron density

P_e = electron pressure

PDR/HII = fraction of [CII] arising from PDRs vs HII regions

A quasar-satellite merger at z=6.2

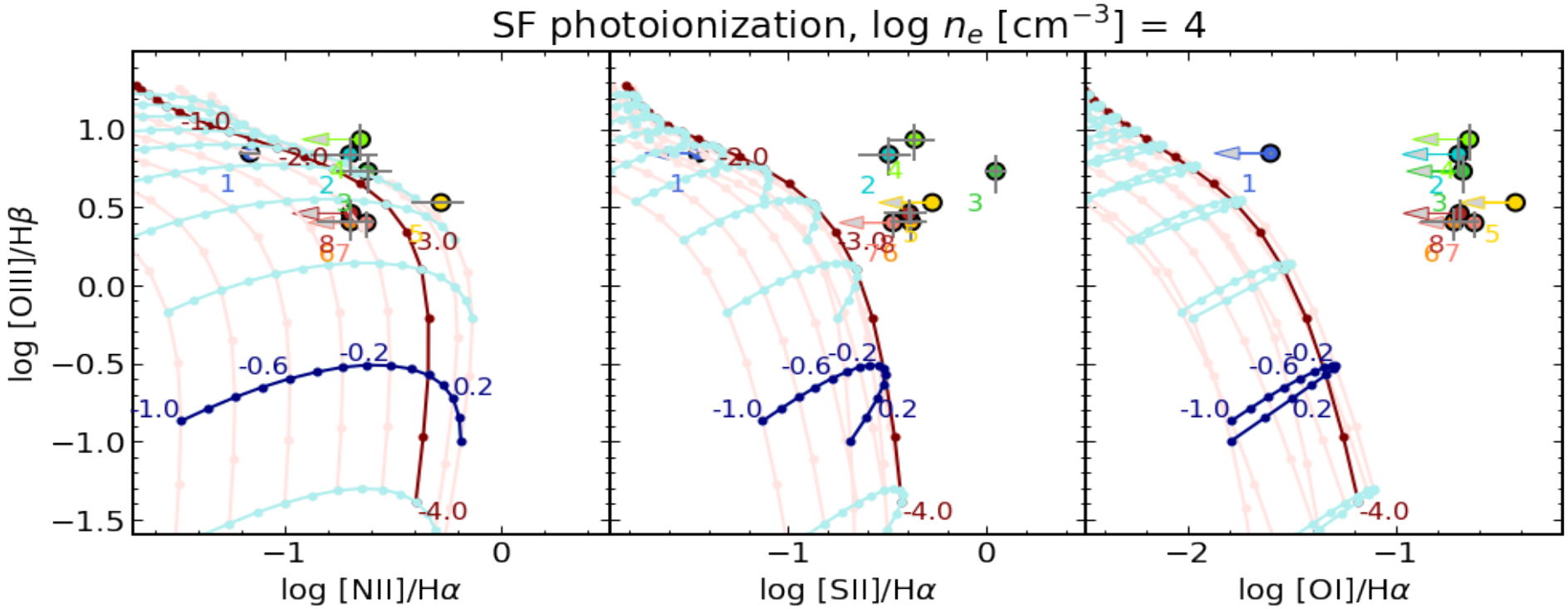
(JWST cycle 1)



Decarli et al. (in prep)

A quasar-satellite merger at z=6.2

(JWST cycle 1)



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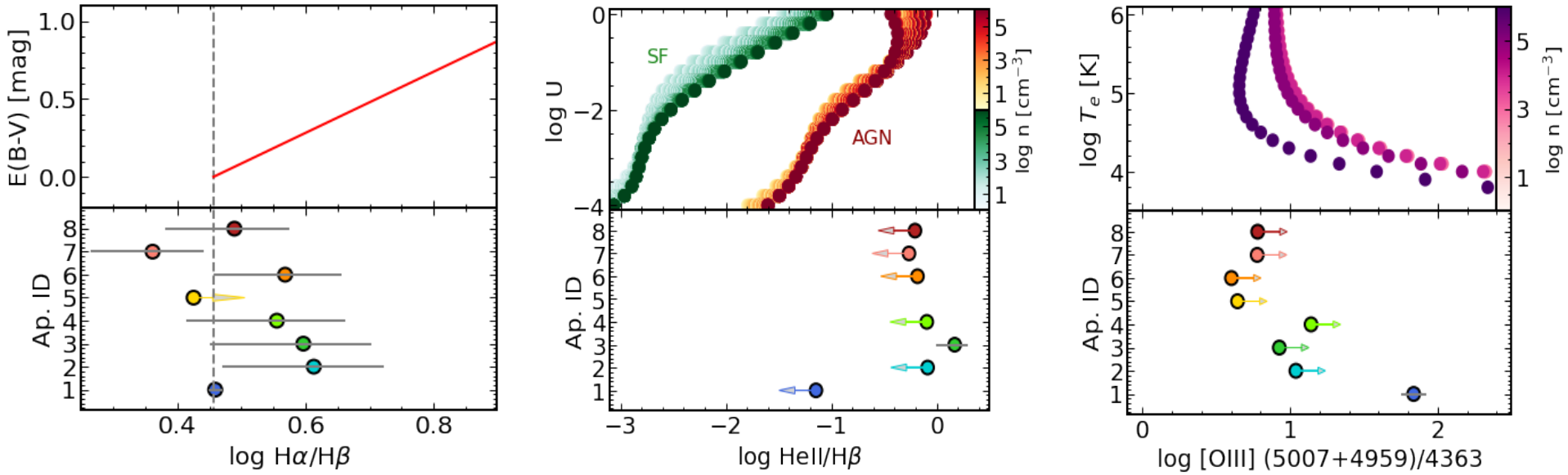
A quasar-satellite merger at z=6.2

(JWST cycle 1)



Decarli et al. (in prep)