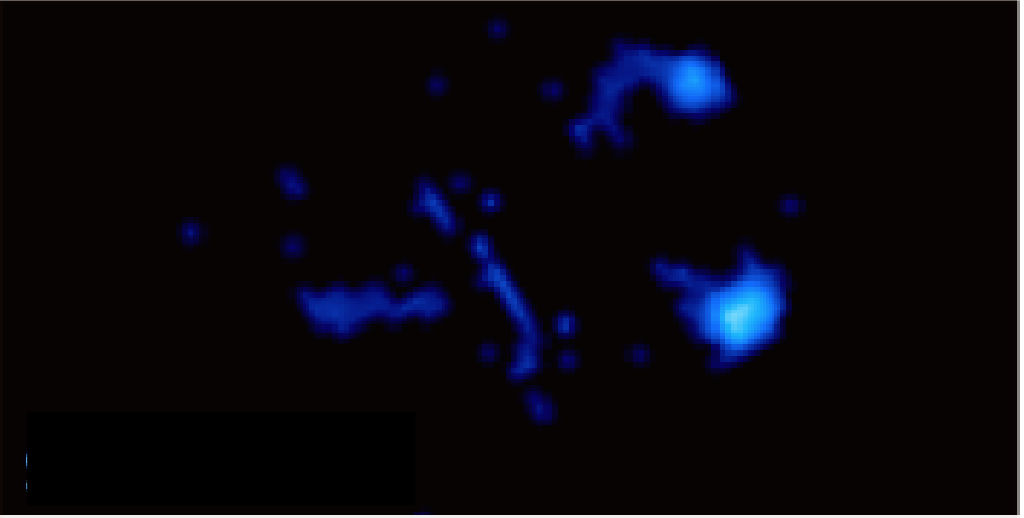
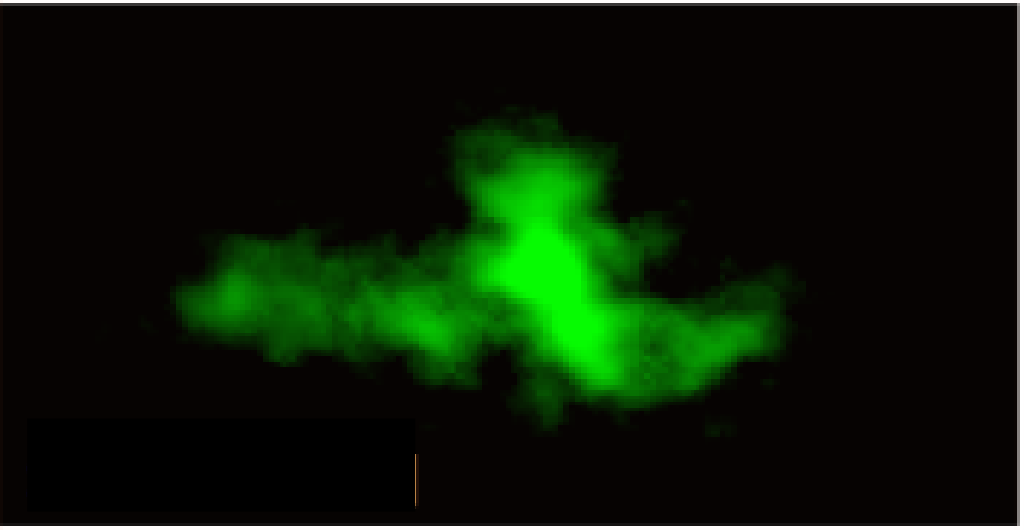
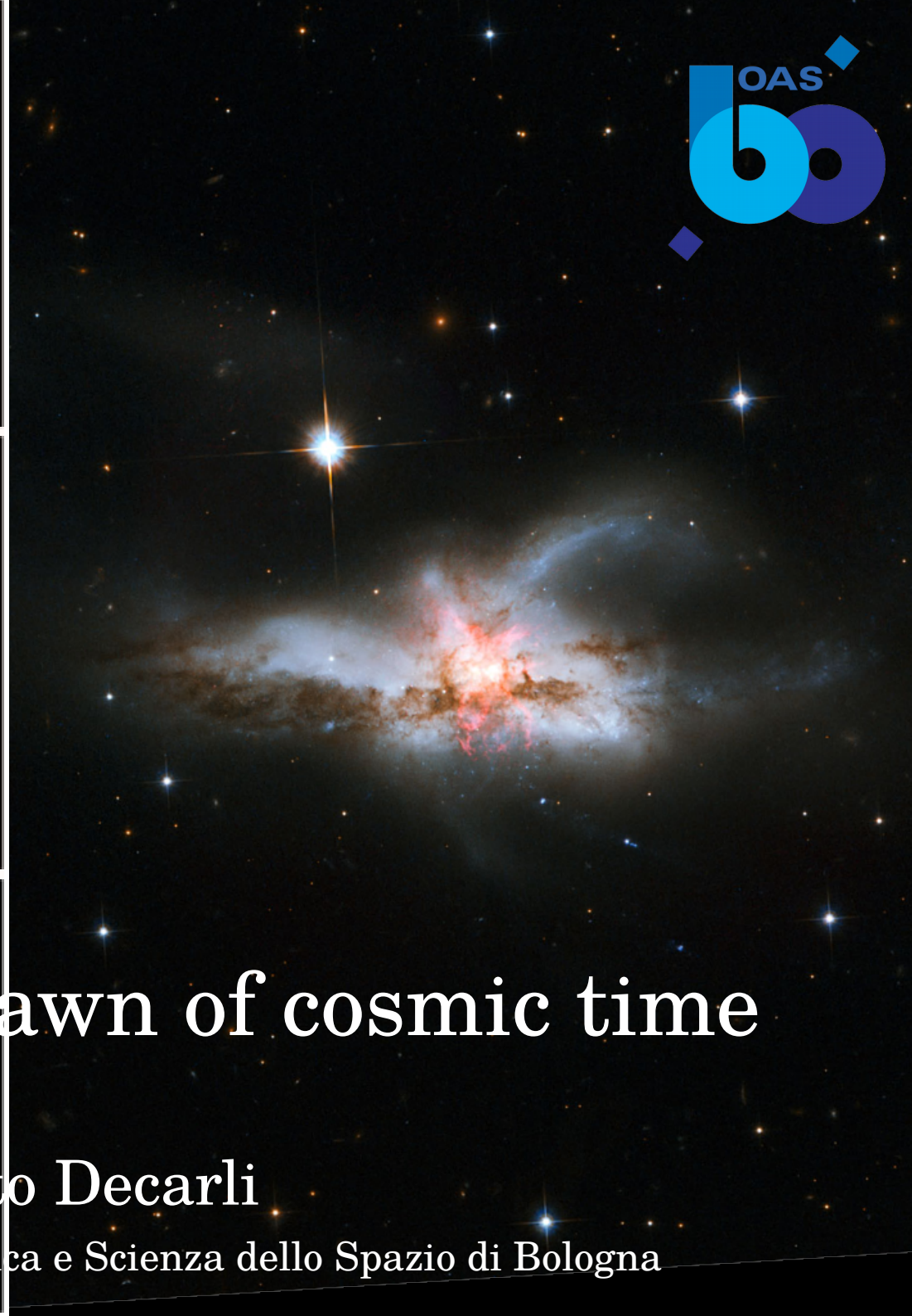


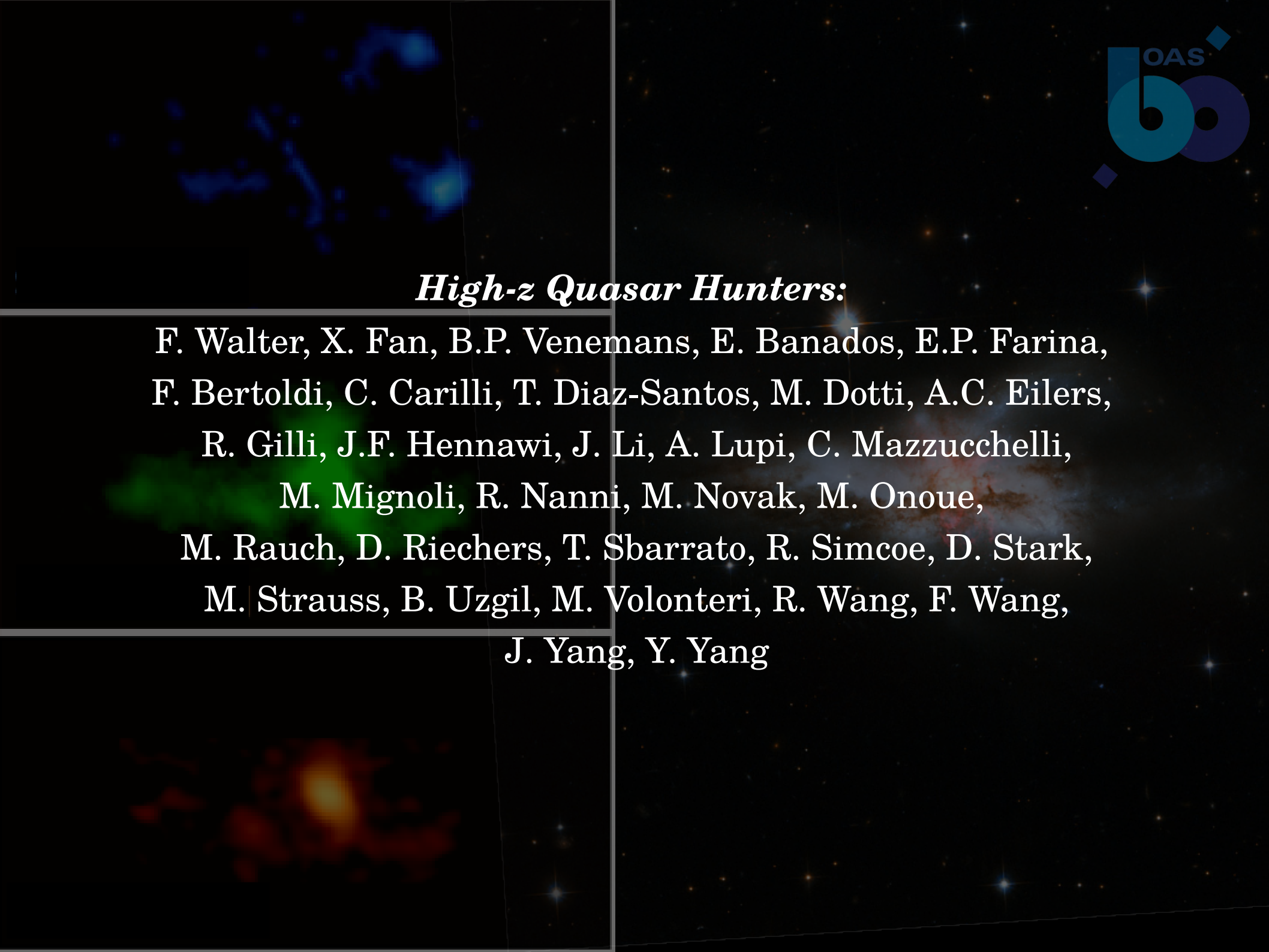




Quasars at the dawn of cosmic time

Roberto Decarli

INAF – Osservatorio di Astrofisica e Scienza dello Spazio di Bologna



High-z Quasar Hunters:

F. Walter, X. Fan, B.P. Venemans, E. Banados, E.P. Farina,
F. Bertoldi, C. Carilli, T. Diaz-Santos, M. Dotti, A.C. Eilers,
R. Gilli, J.F. Hennawi, J. Li, A. Lupi, C. Mazzucchelli,
M. Mignoli, R. Nanni, M. Novak, M. Onoue,
M. Rauch, D. Riechers, T. Sbarrato, R. Simcoe, D. Stark,
M. Strauss, B. Uzgil, M. Volonteri, R. Wang, F. Wang,
J. Yang, Y. Yang

Quasars at z>6: Why should we care?

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z=6 → age of the universe: <1 Gyr

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Not much time to …

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put black holes together

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form metals and dust

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Not much time to …

- put black holes together
- put galaxies together
- form metals and dust
- form structures

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Not much time to …

- put black holes together
- put galaxies together
- form metals and dust
- form structures
- ionize the Universe

Quasars at z>6: Why should we care?

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Not much time

Extremely luminous and star-forming

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ideal signposts for structures

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ideal background sources for abs studies

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Extremely luminous and star-forming

ideal signposts for structures

ideal background sources for abs studies

conditions absent in the local universe

Quasars at z>6: Why should we care?

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A few observational benefits

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z~5 is almost as difficult… but “less exciting”

Quasars at z>6: Why should we care?

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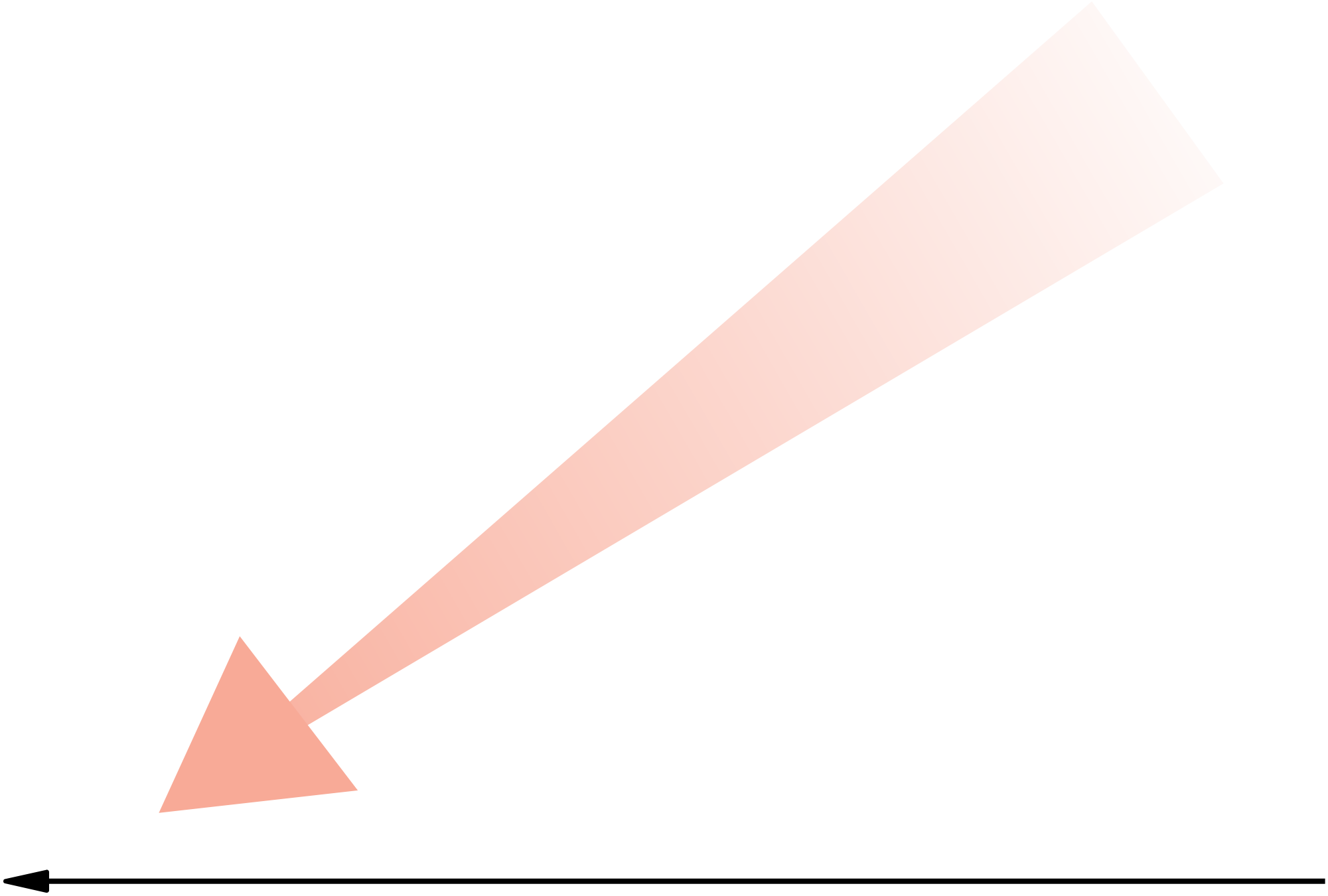
Extremely luminous and star-forming

A few observational benefits

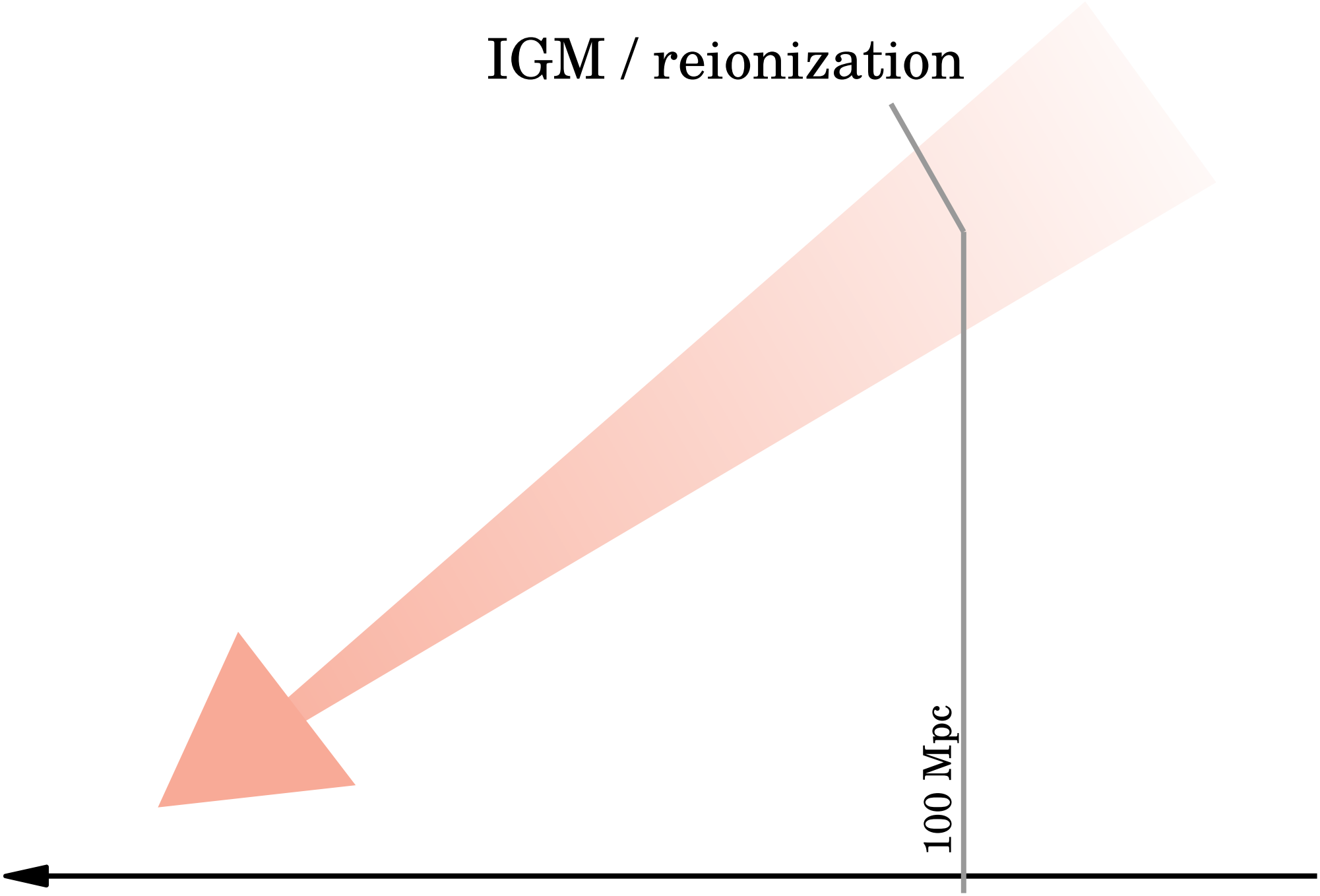
z~5 is almost as difficult… but "less exciting"

FIR x (1+z) = mm (sky transparency)

Quasars at z>6



Quasars at z>6



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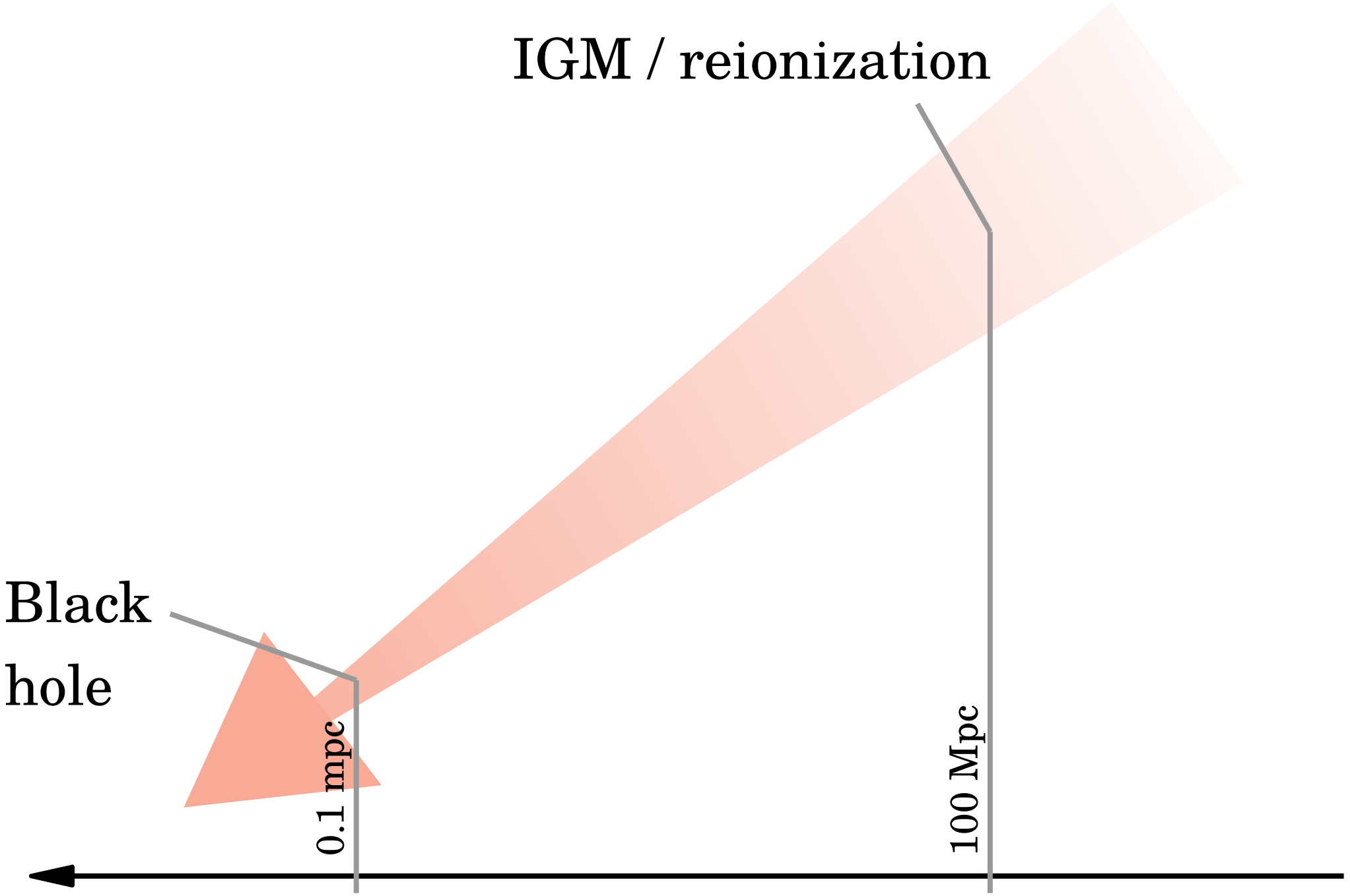
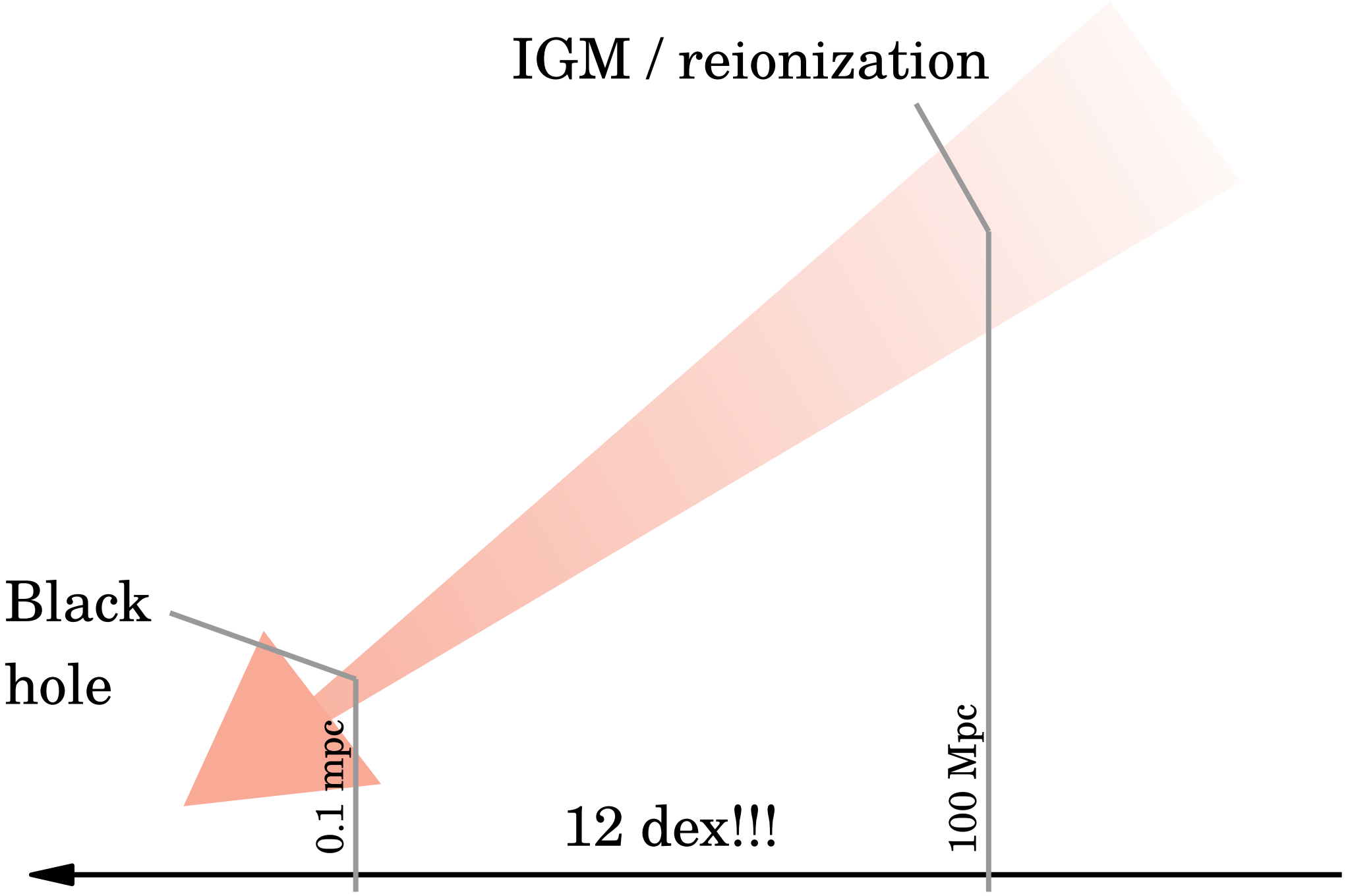
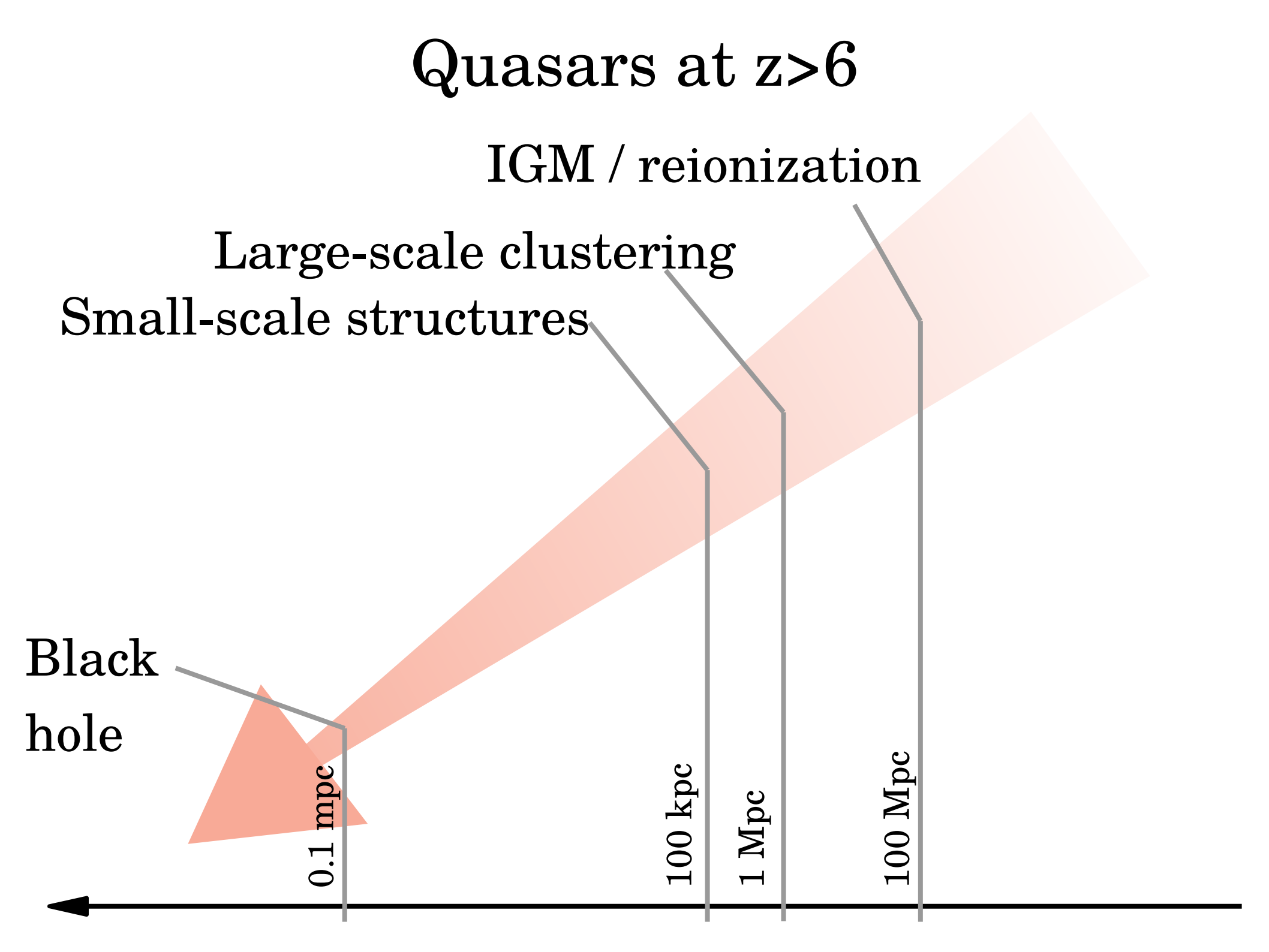
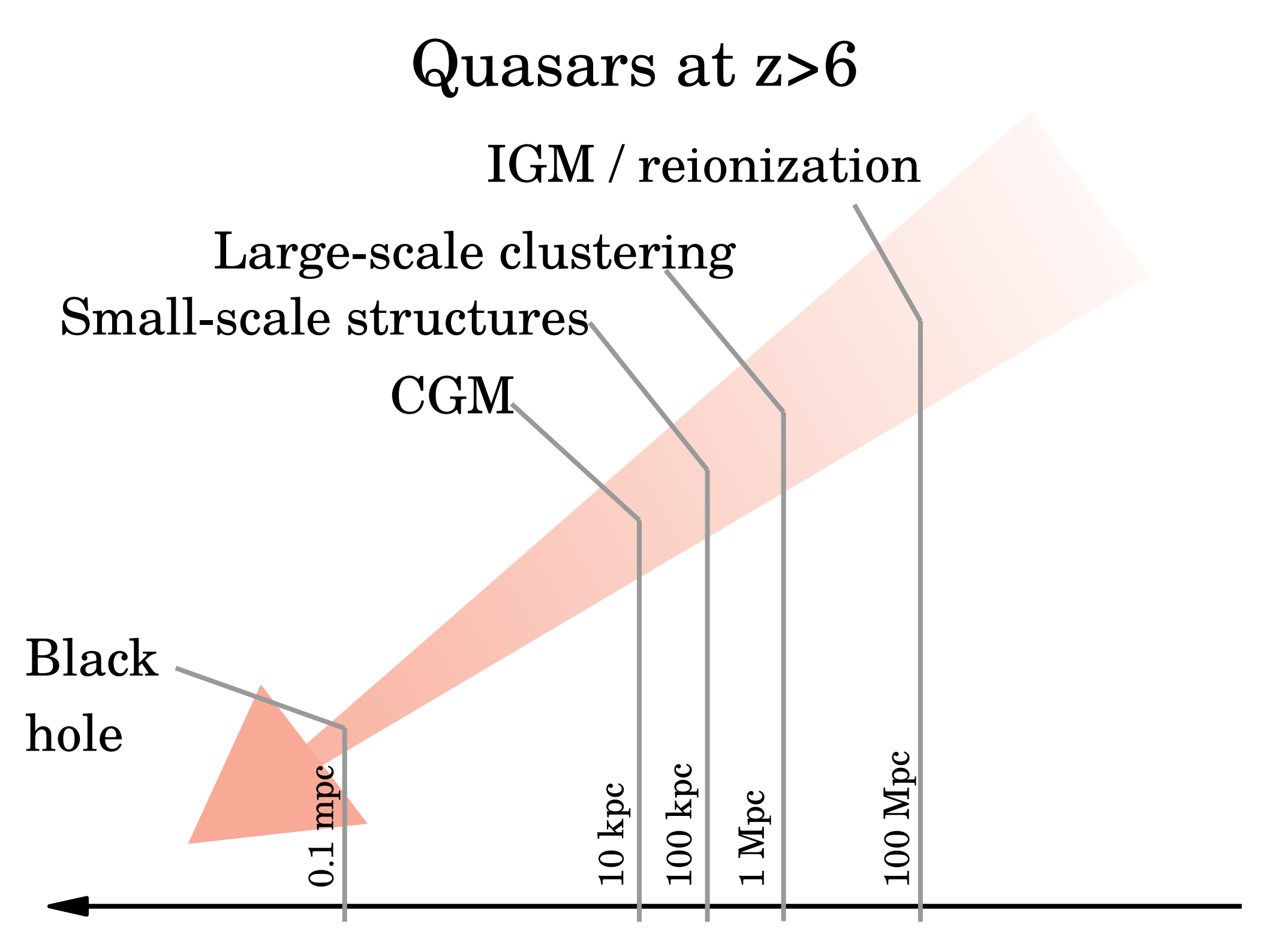


Quasars at z>6




Quasars at z>6
IGM / reionization
Large-scale clustering
Small-scale structures
Black hole
0.1 mpc
100 kpc
1 Mpc
100 Mpc


Quasars at z>6
IGM / reionization
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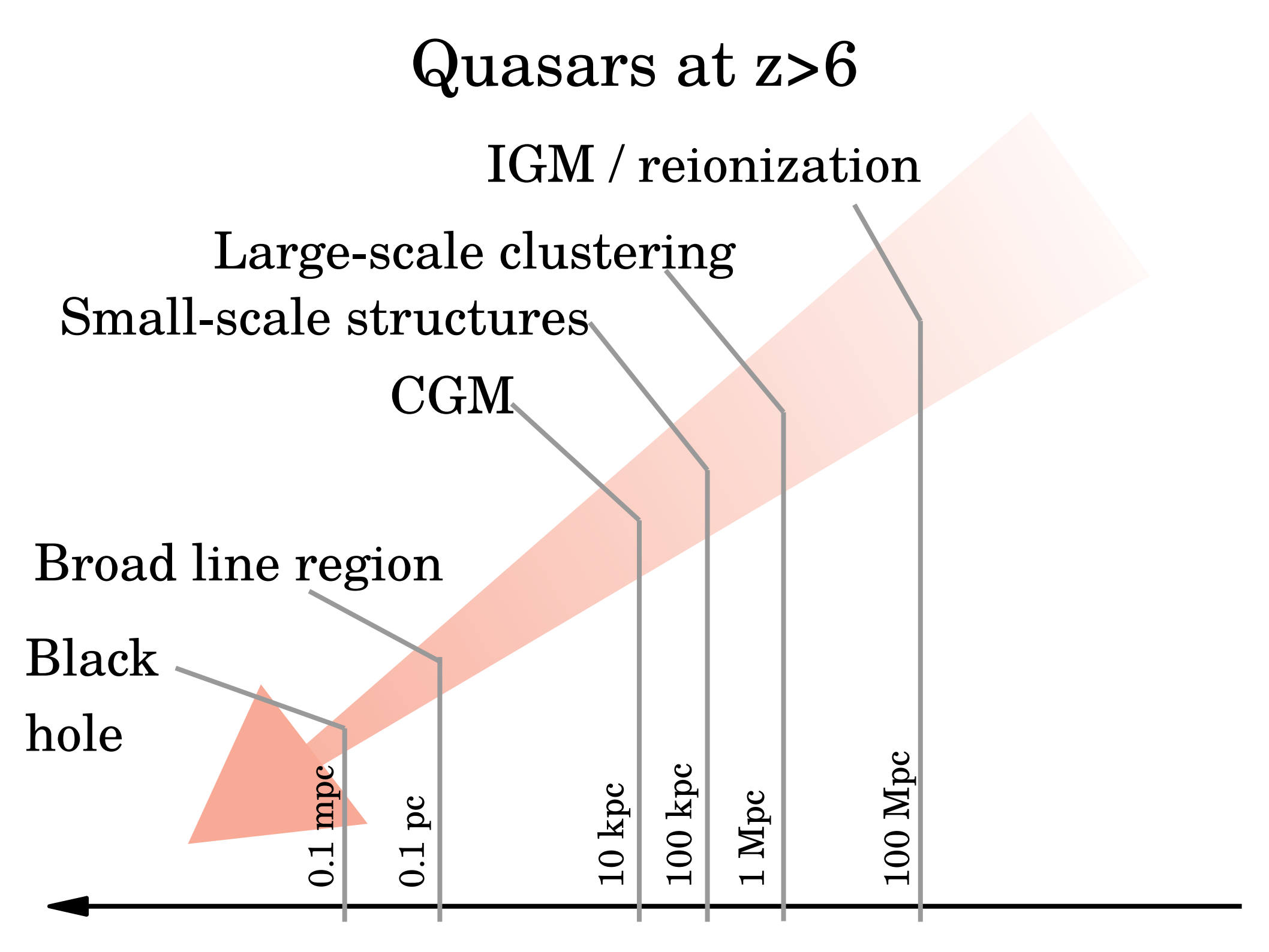
Quasars at z>6
IGM / reionization
Large-scale clustering
Small-scale structures
CGM
Broad line region
Black hole
0.1 mpc
0.1 pc
10 kpc
100 kpc
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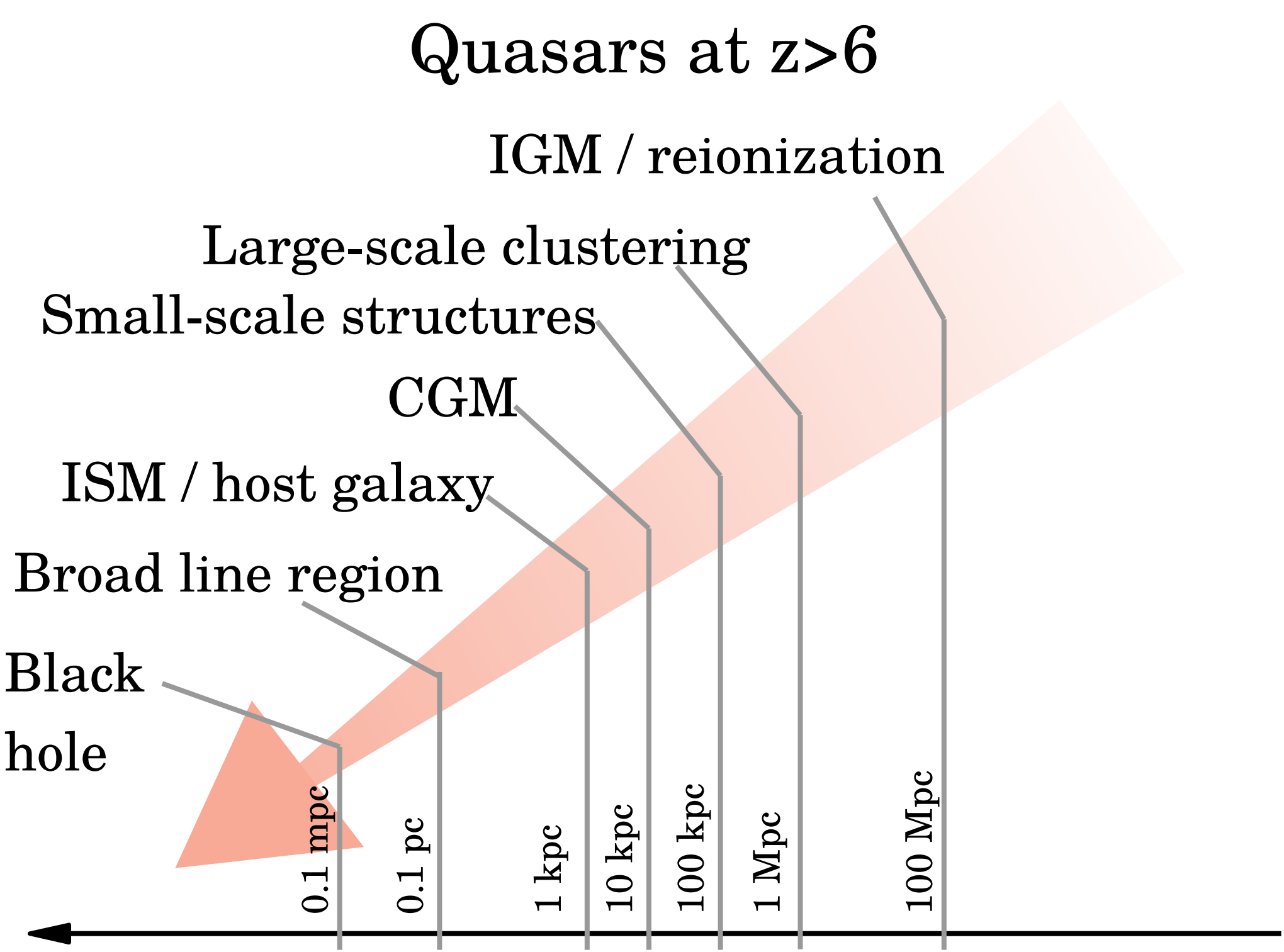
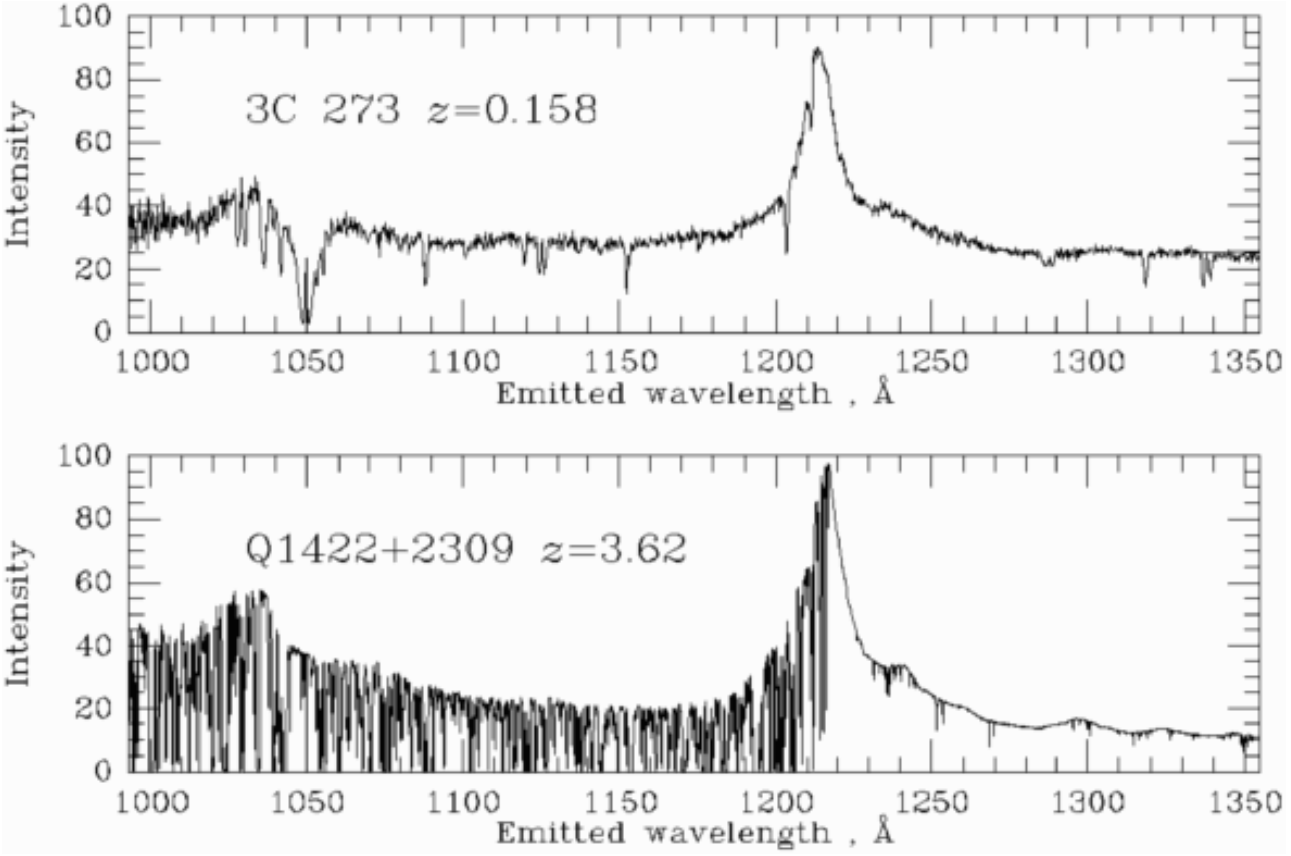
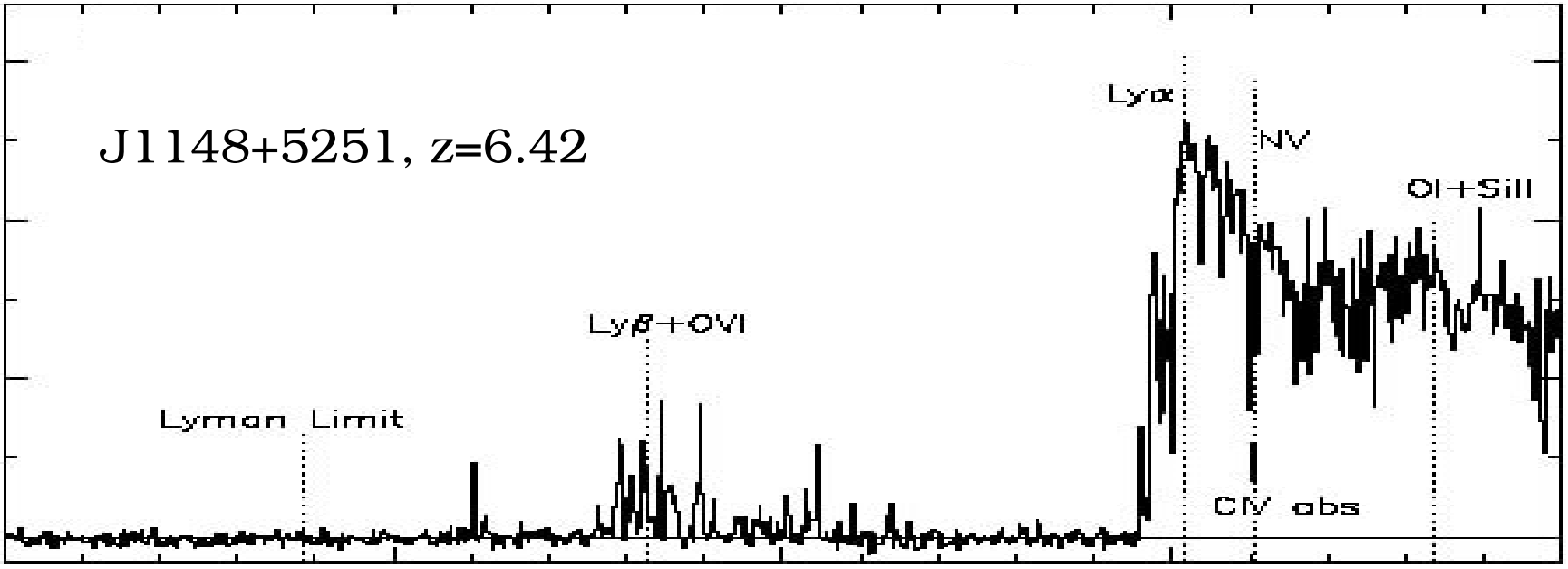

Quasars at z>6
IGM / reionization
Large-scale clustering
Small-scale structures
CGM
ISM / host galaxy
Broad line region
Black hole
0.1 mpc
0.1 pc
1 kpc
10 kpc
100 kpc
1 Mpc
100 Mpc

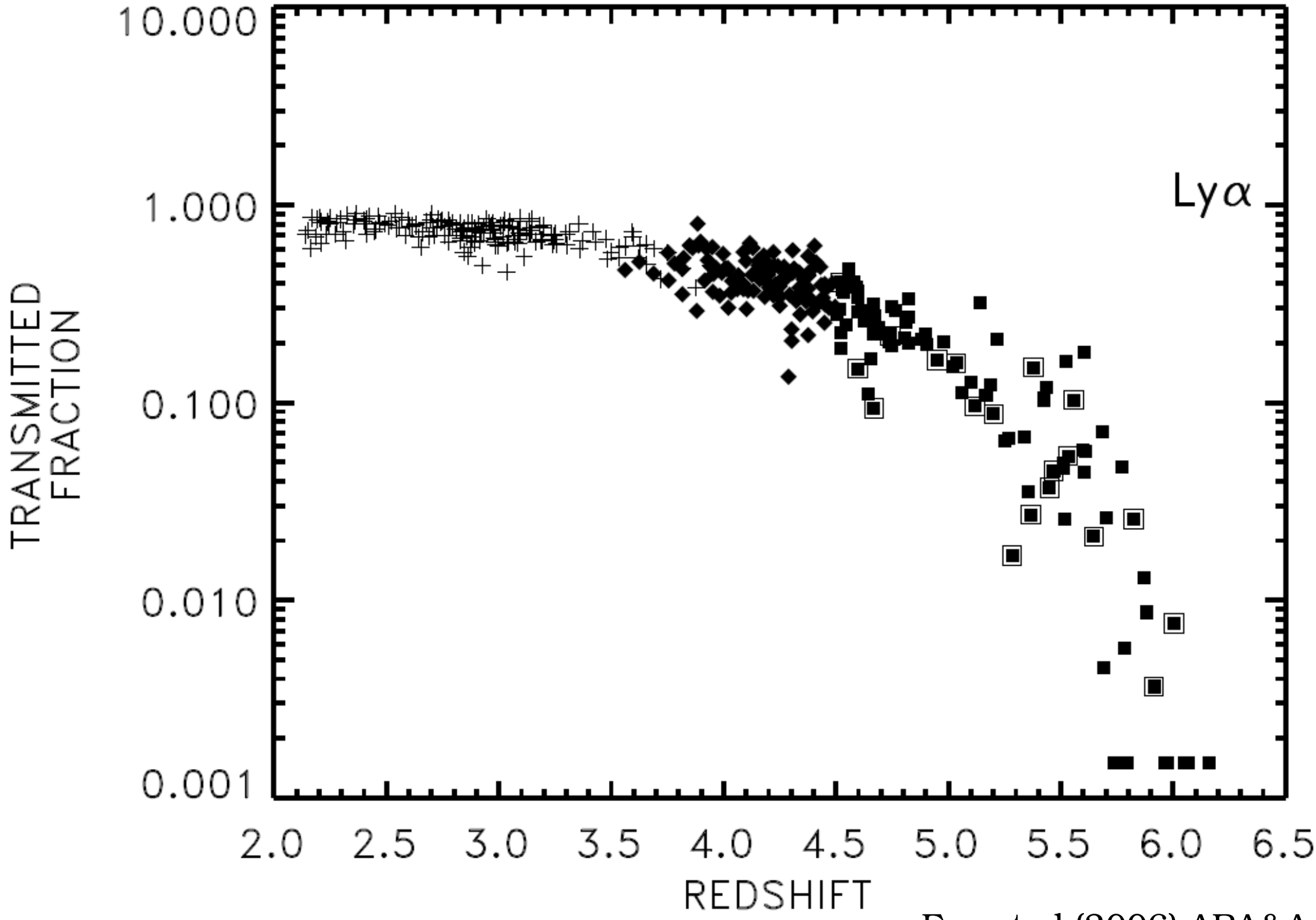
GP absorption

→ unique colors

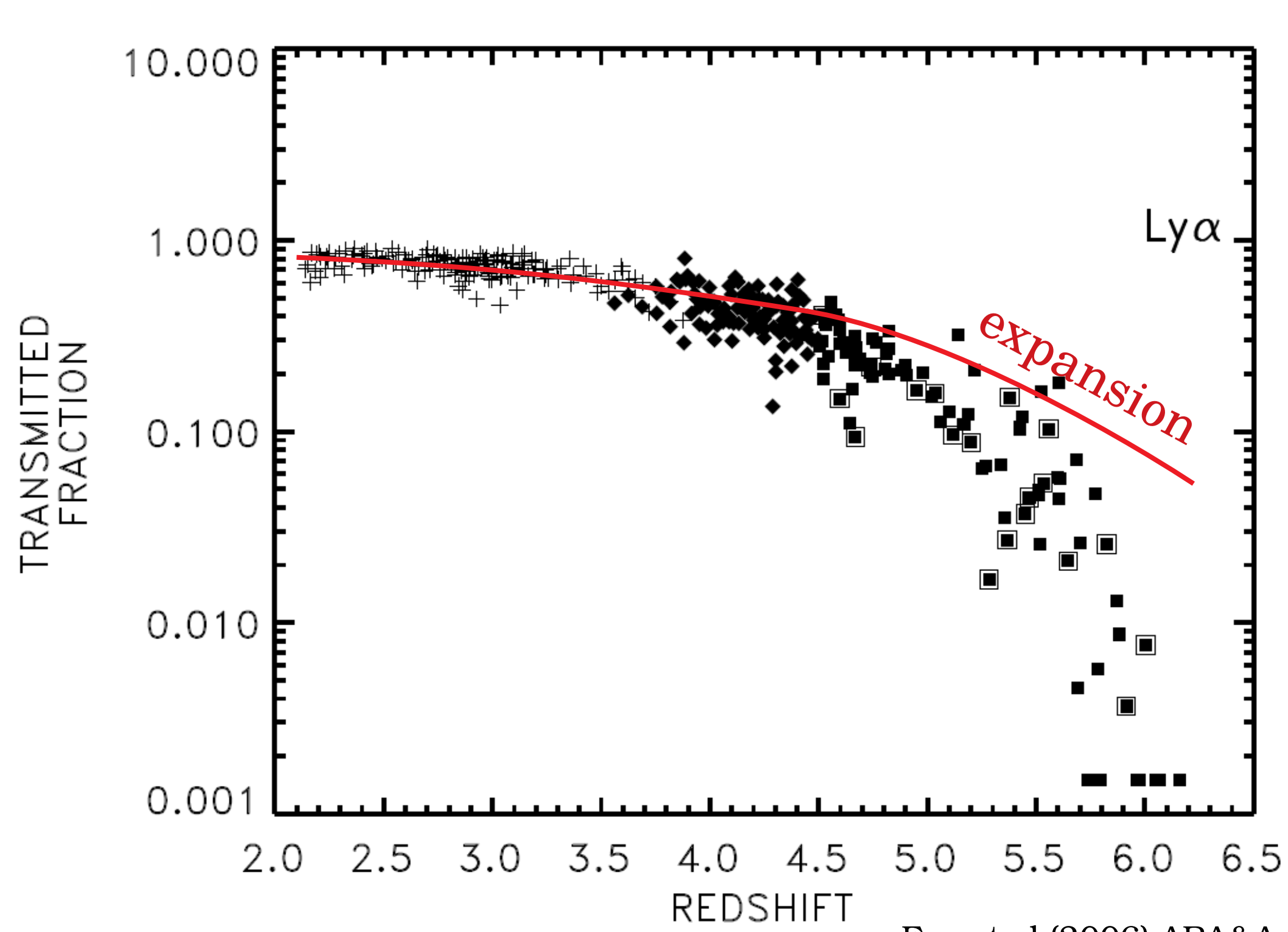


Redshift





Fan et al (2006) ARA&A



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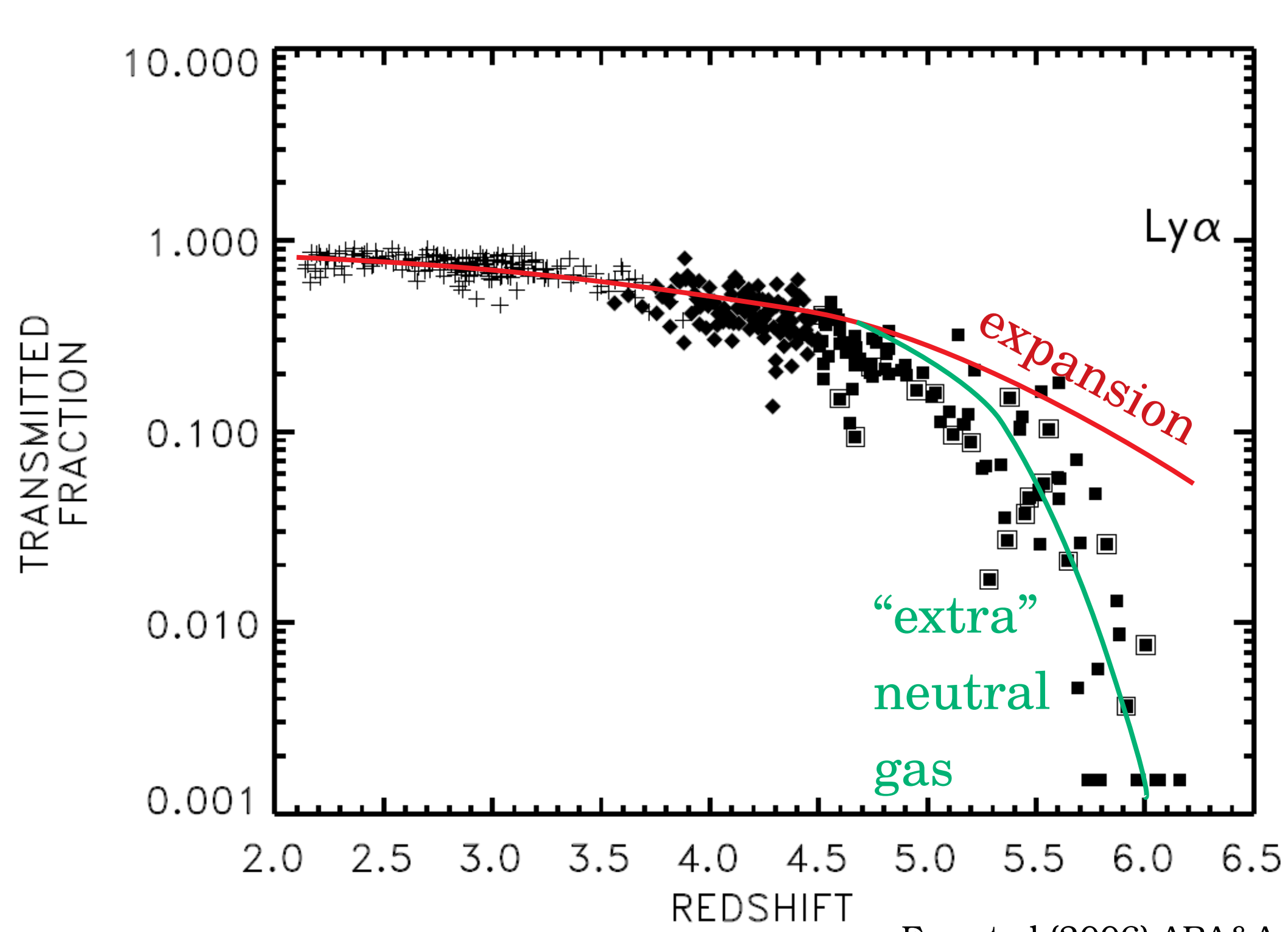
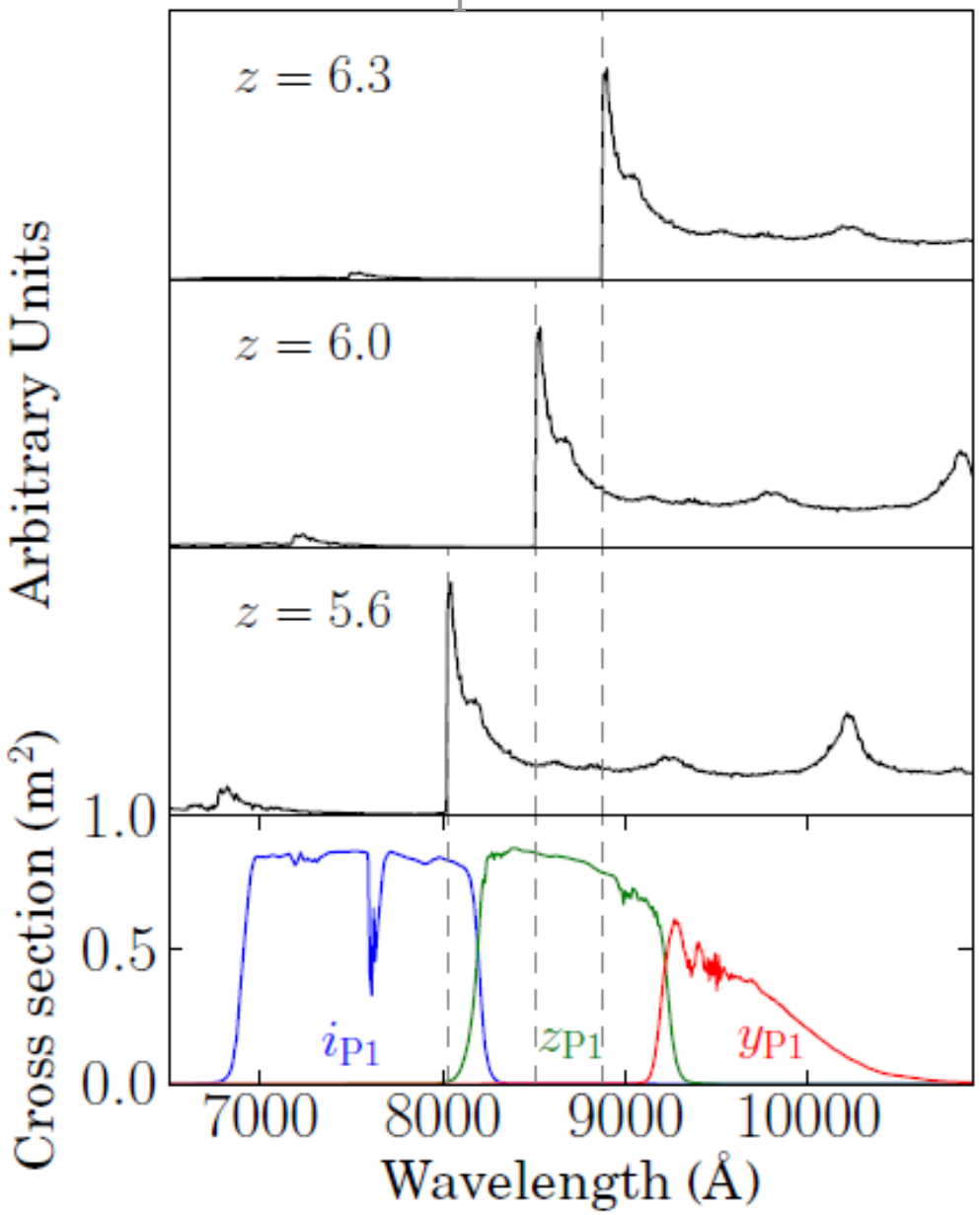


Fan et al (2006) ARA&A

Adapted from Bañados+2016



From broad-band i, z, y, NIR photometry

→ quasar candidates

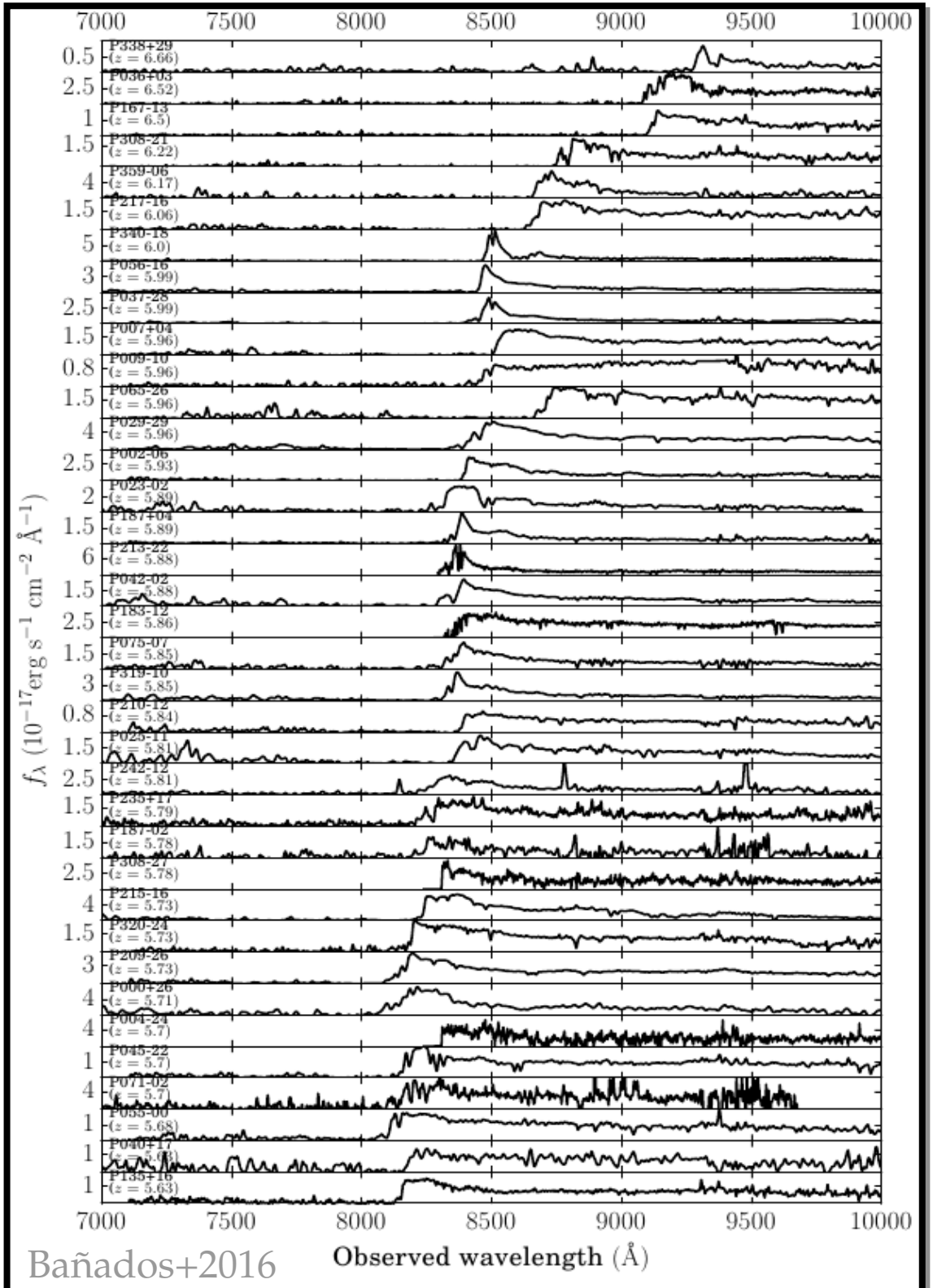
Discovery of

~320 quasars at z>5.5

~180 at z>6.0

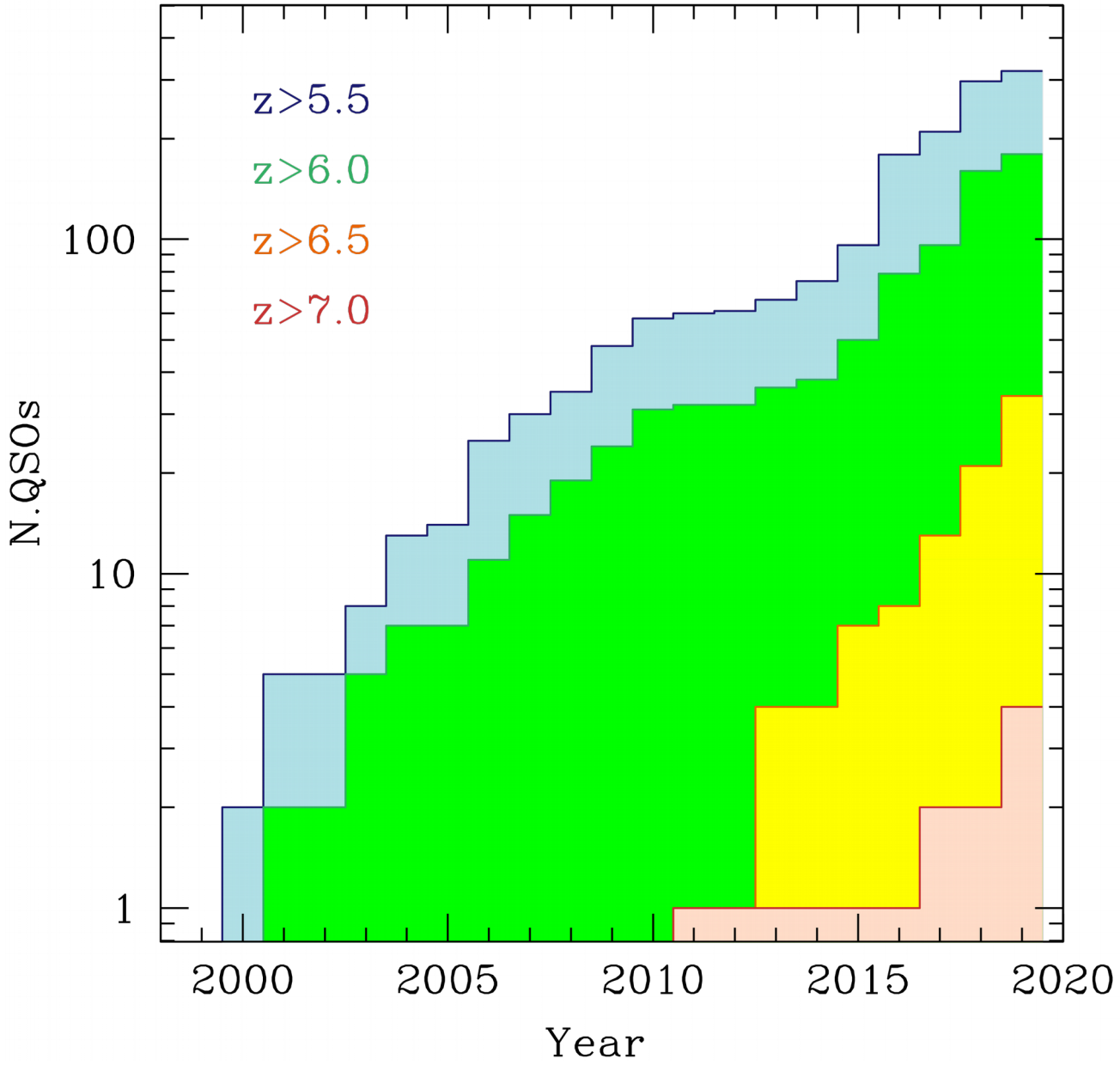
22(+6) at z>6.5

2(+2) at z>7.0



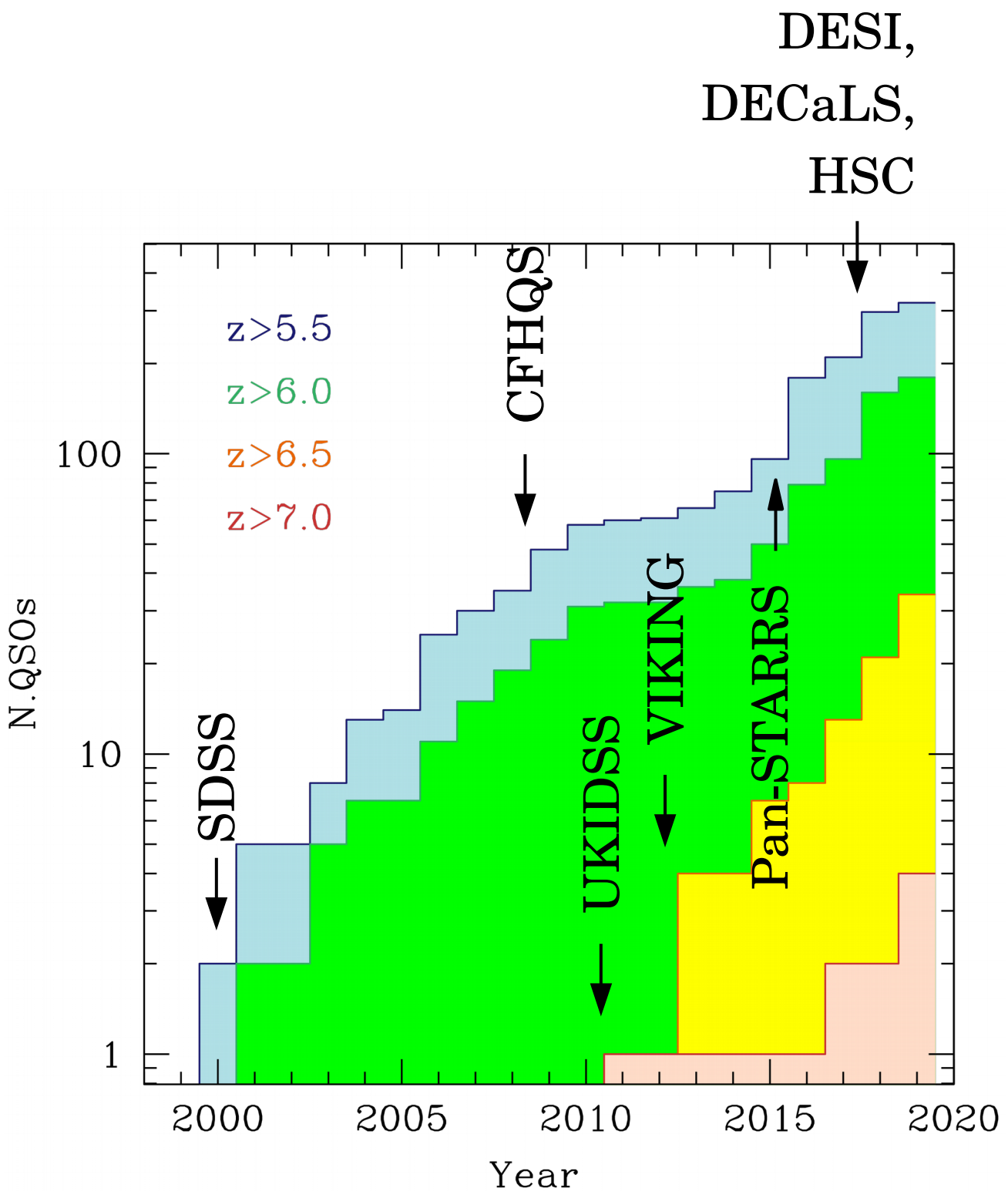
Bañados+2016

The time is now!



The time is now!

Wide area (>1000 deg^2) opt/NIR surveys are in full swing



Reply | Reply All | Forward | Archive | Junk | Delete | More

From Eduardo Banados

Subject **pisco sour quasar**

10/03/2017 11:21

To Fabian Walter <walter@mpia.de>, Venemans Bram <venemans@mpia-hd.mpg.de>, Me <decarli@mpia.de>, Chiara Maz: **4 more**

Dear all,

We are concluding the last night at Magellan. We observed more than 100 objects and we are happy to tell you that we have a winner! See attached the 'pisco sour' z>7.2 quasar.

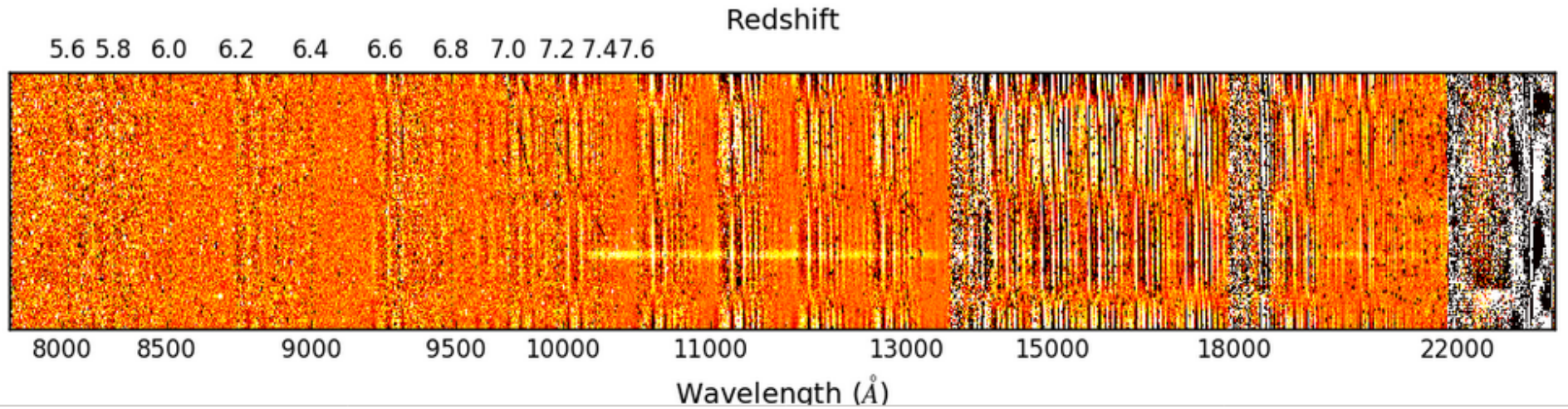
This quasar came from my selection and I'd kindly ask you to keep it quiet for now and not to share the good news outside this group.
Let's think what we can do with it and what proposals to write over the weekend and perhaps we skype next week to discuss how to proceed.

Now is pisco sour time.

Cheers,

Eduardo & Dan

piscosour_quasar.png



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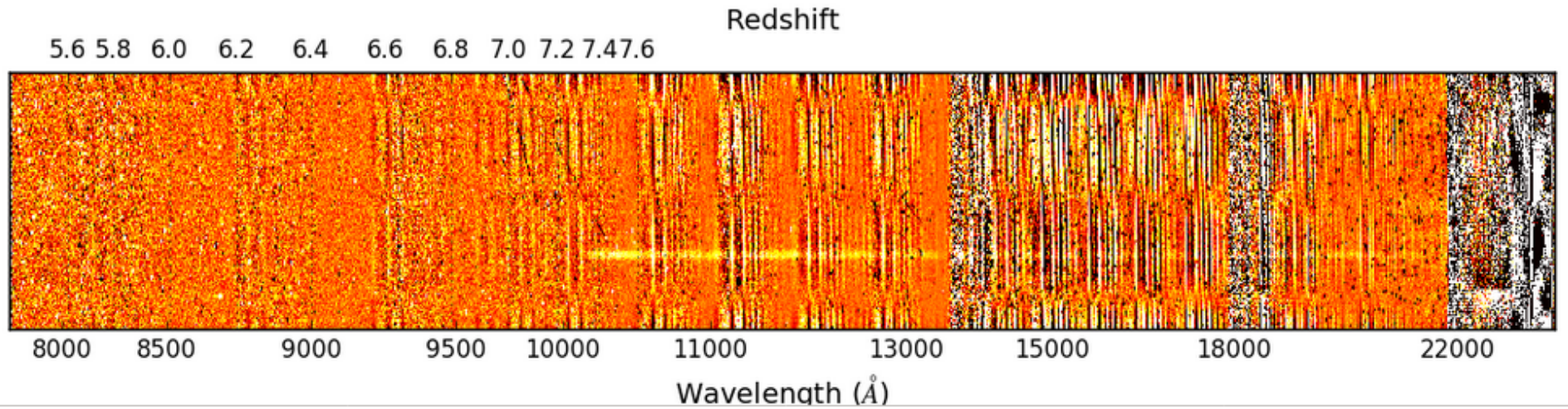

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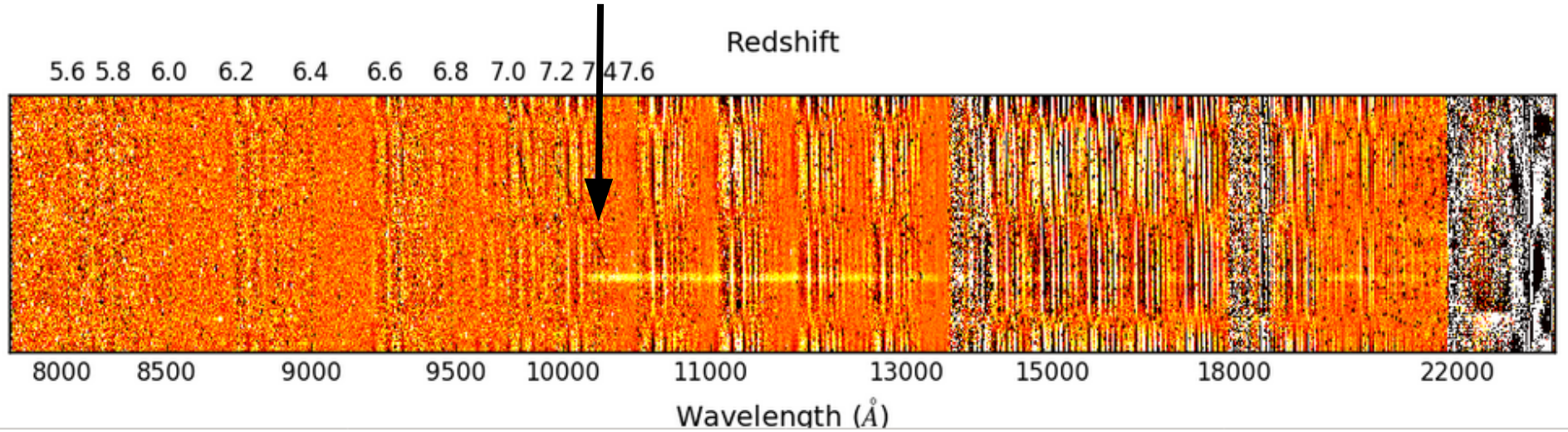

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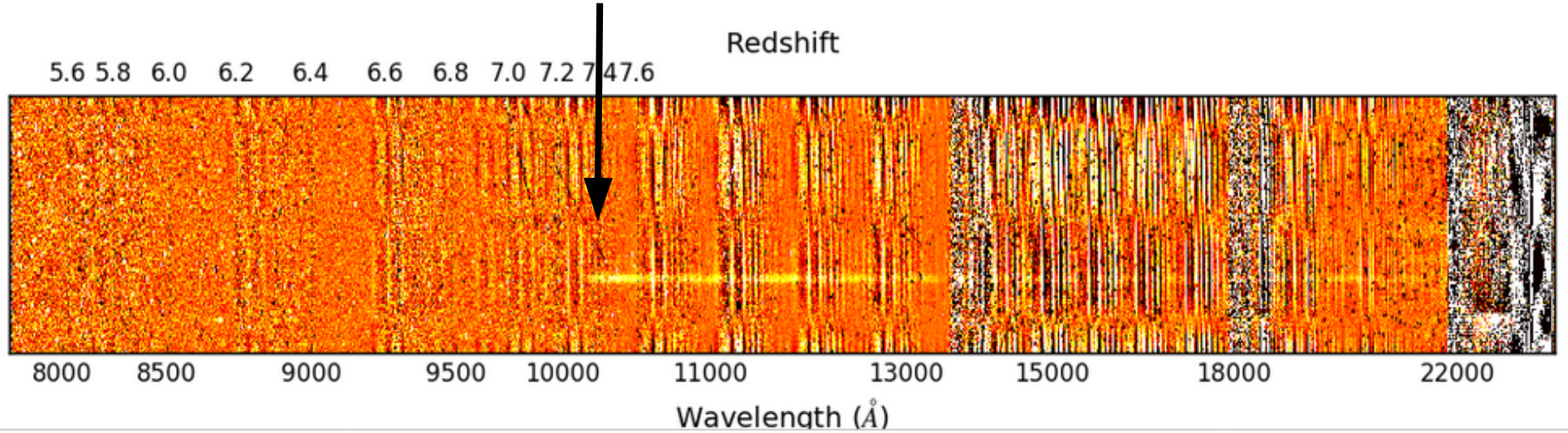
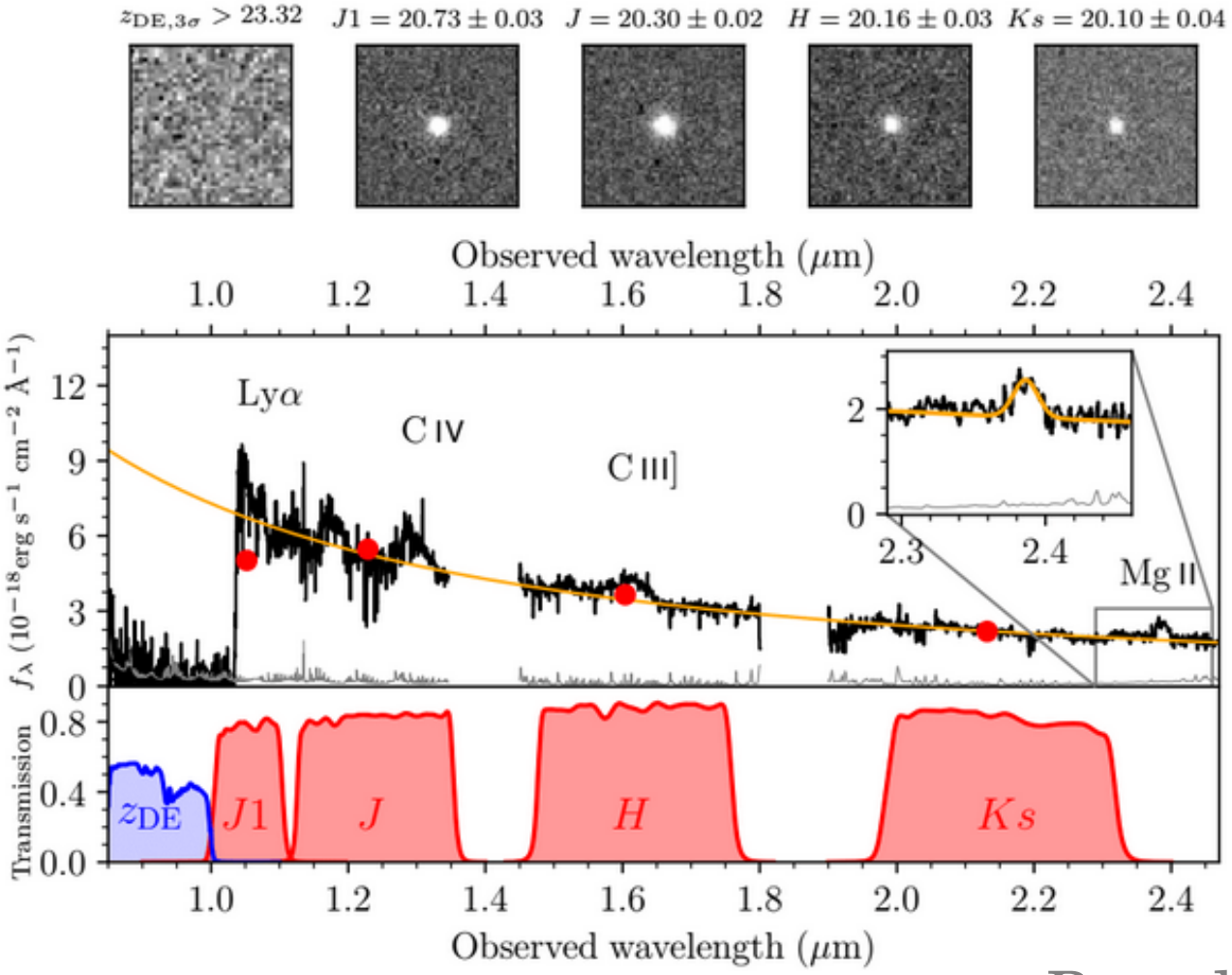


The most distant quasar

“Pisco” @ z=7.54



Banados et al. (2018)

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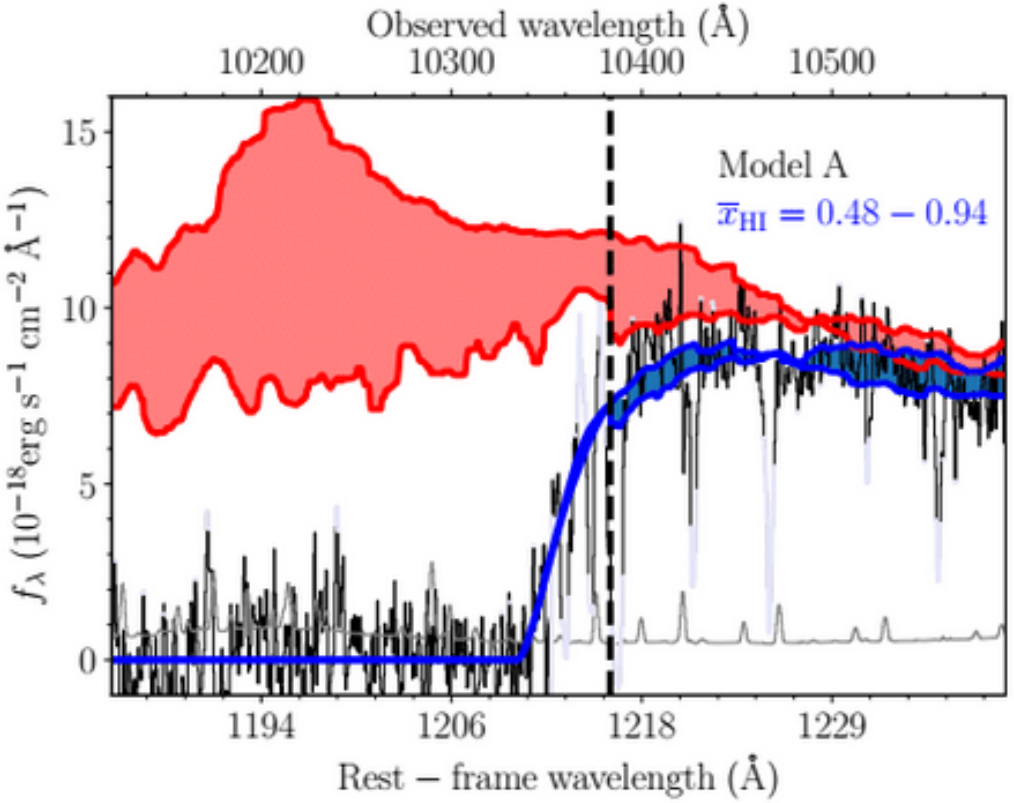

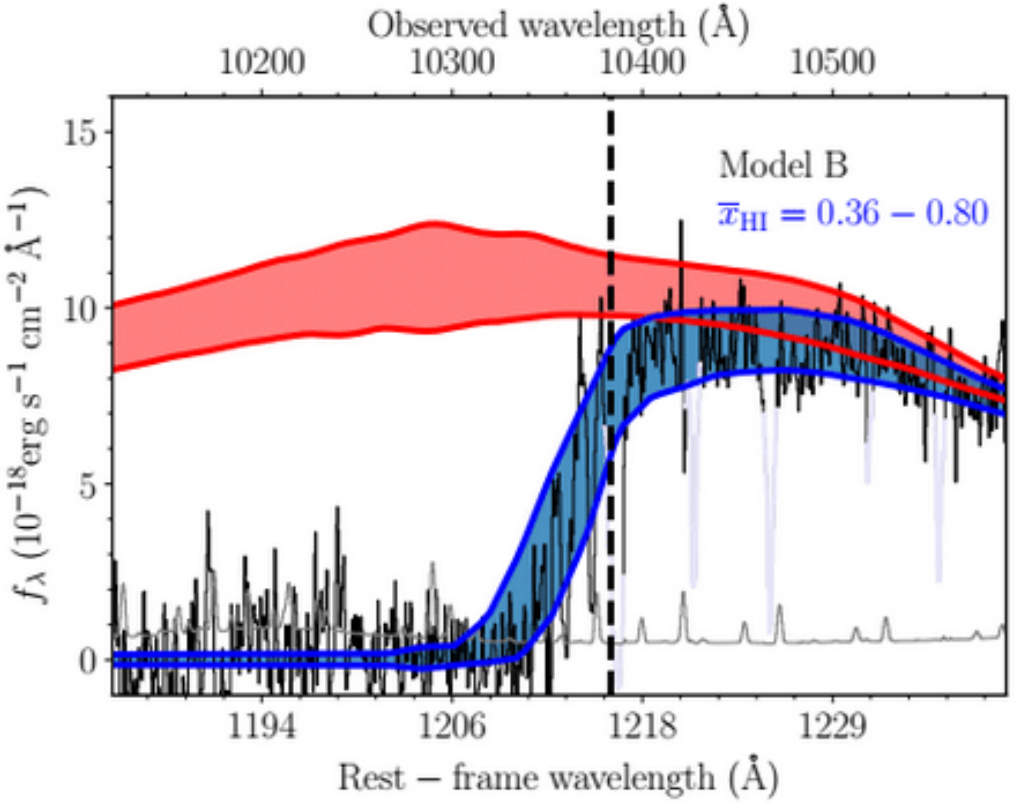

Banados et al. (2018)

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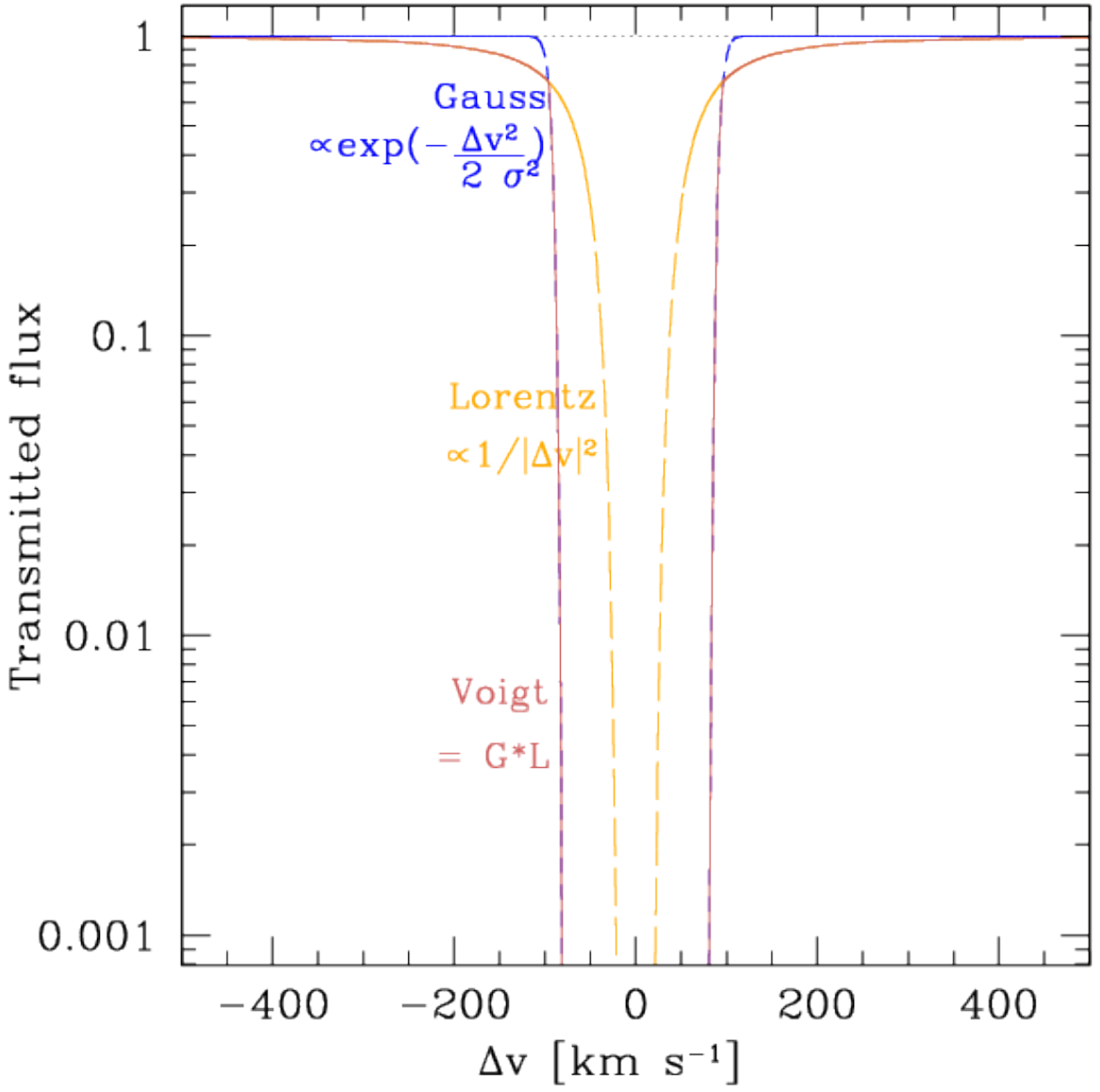

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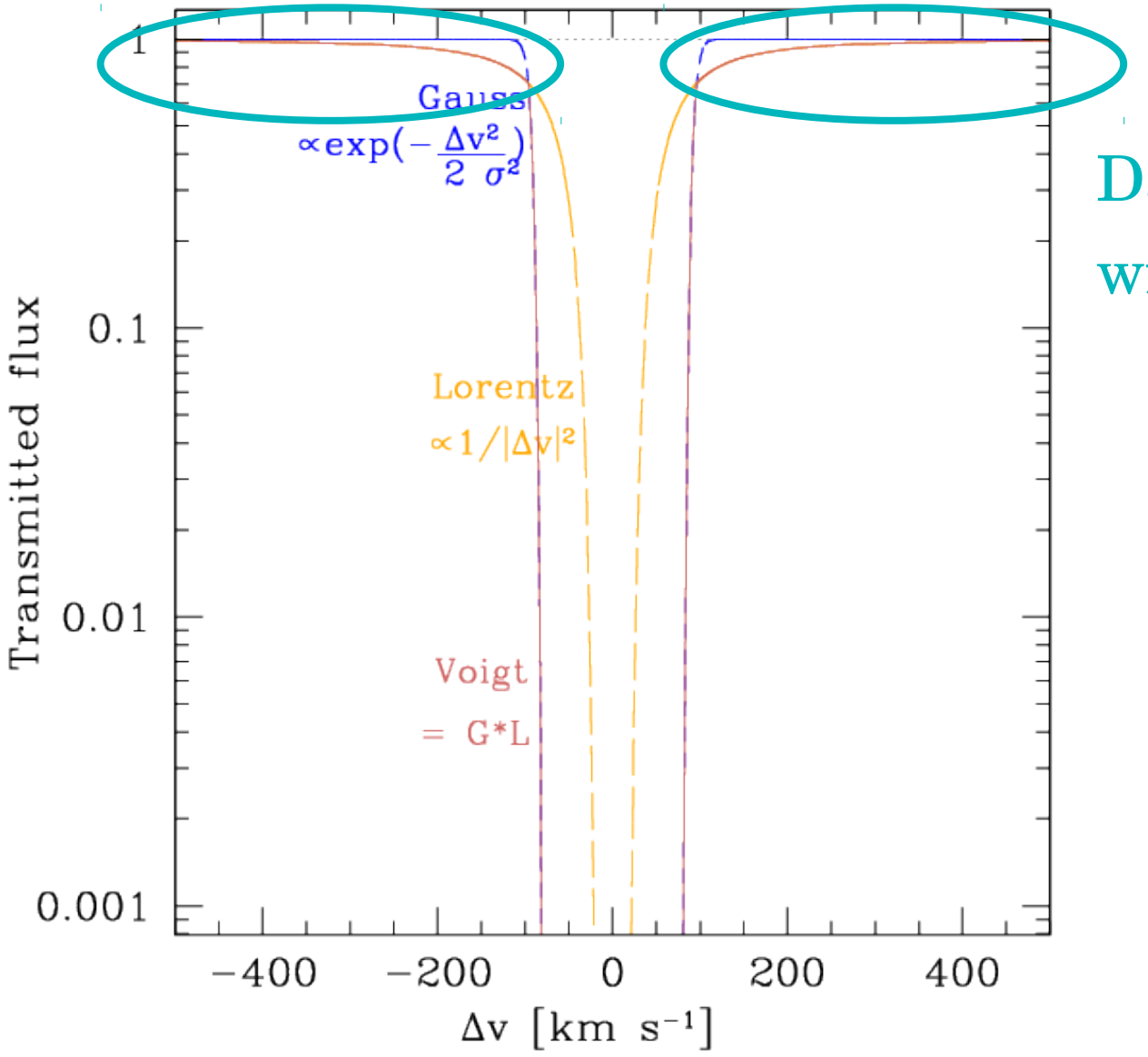
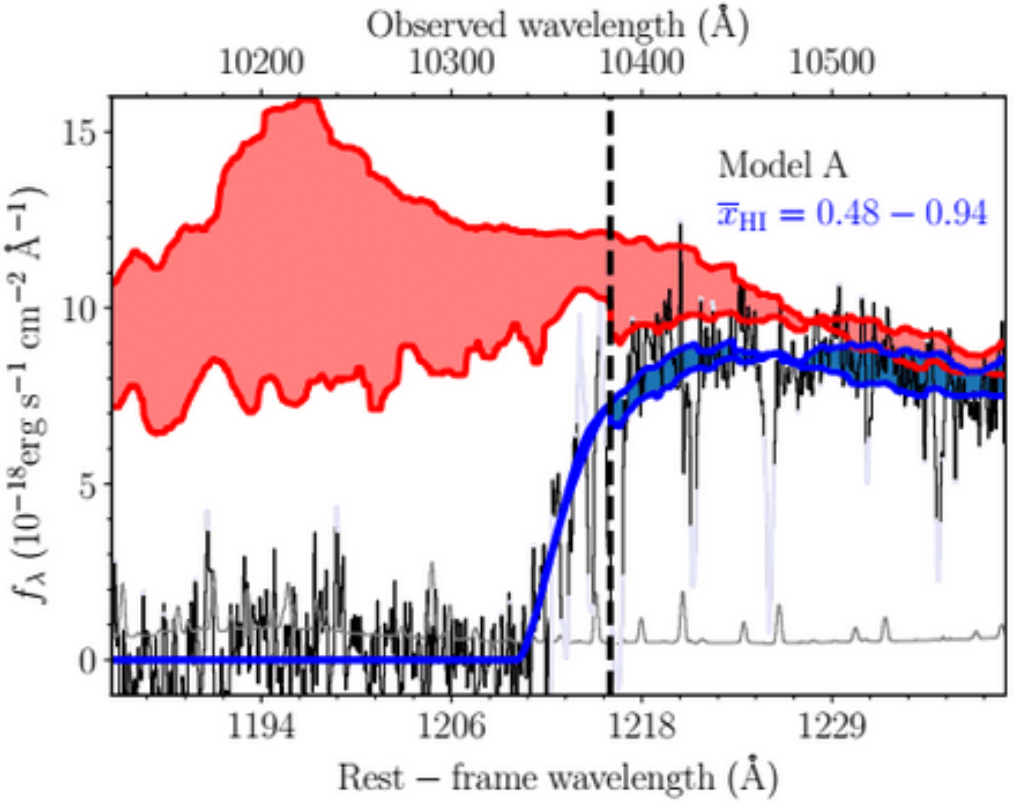
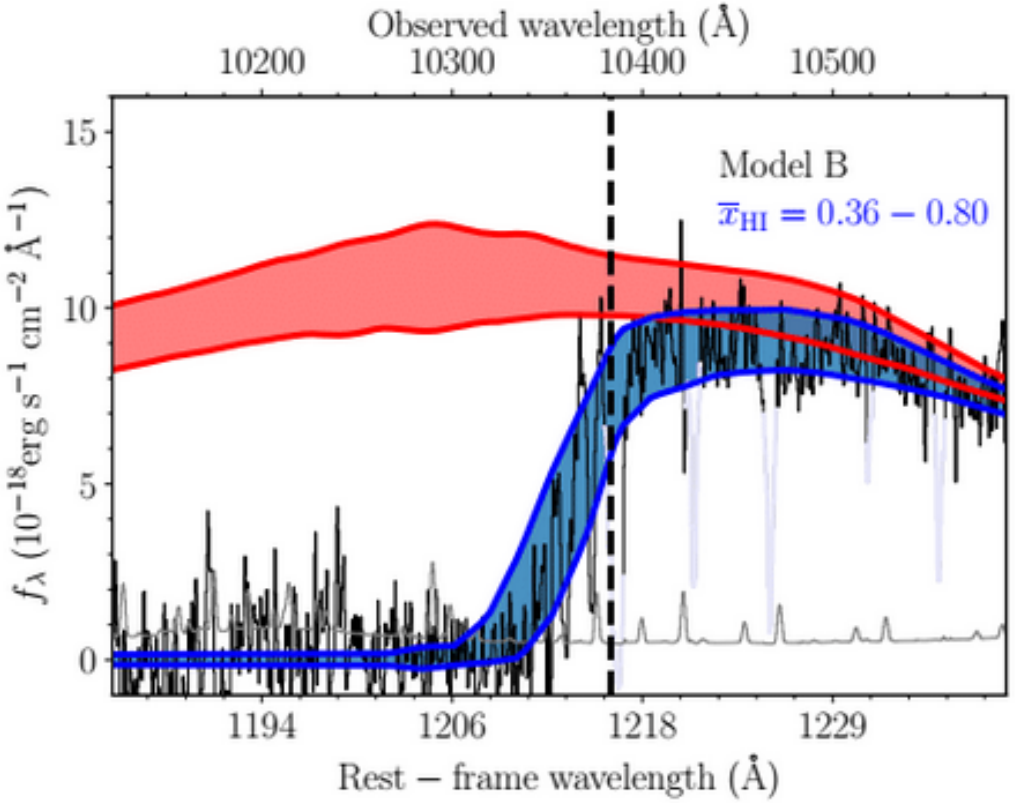


Damping wings

The most distant quasar

“Pisco” @ z=7.54





Banados et al. (2018)

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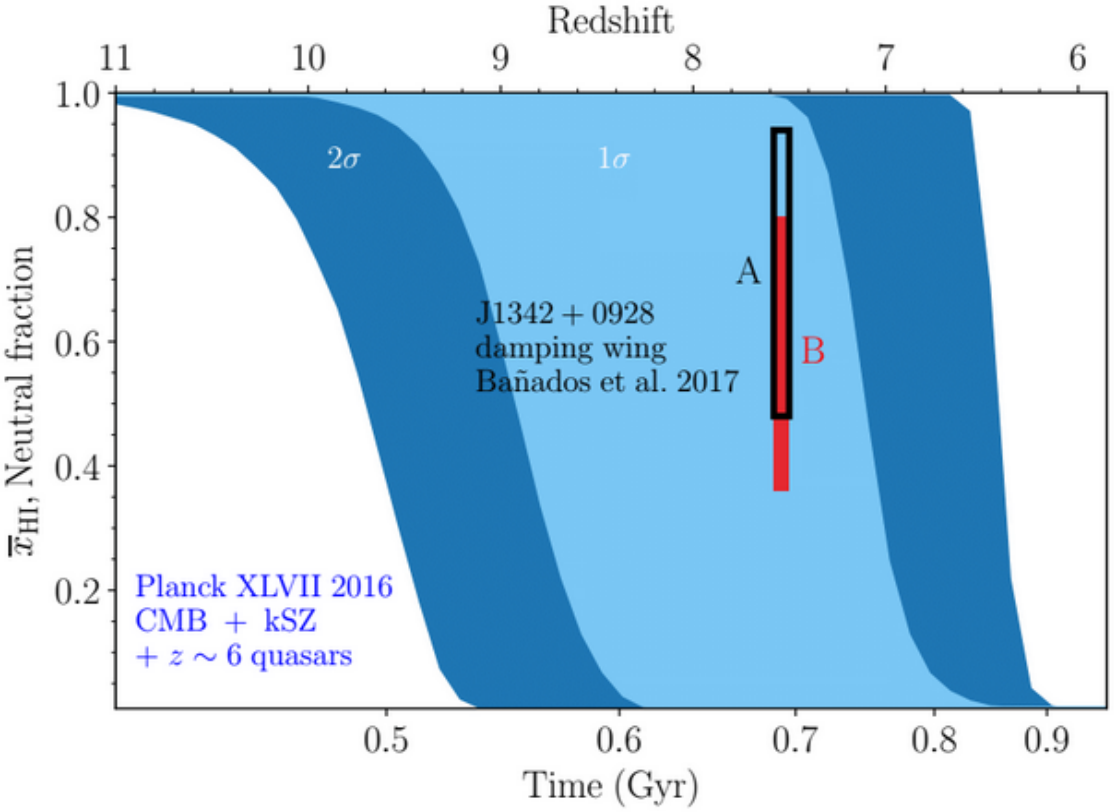
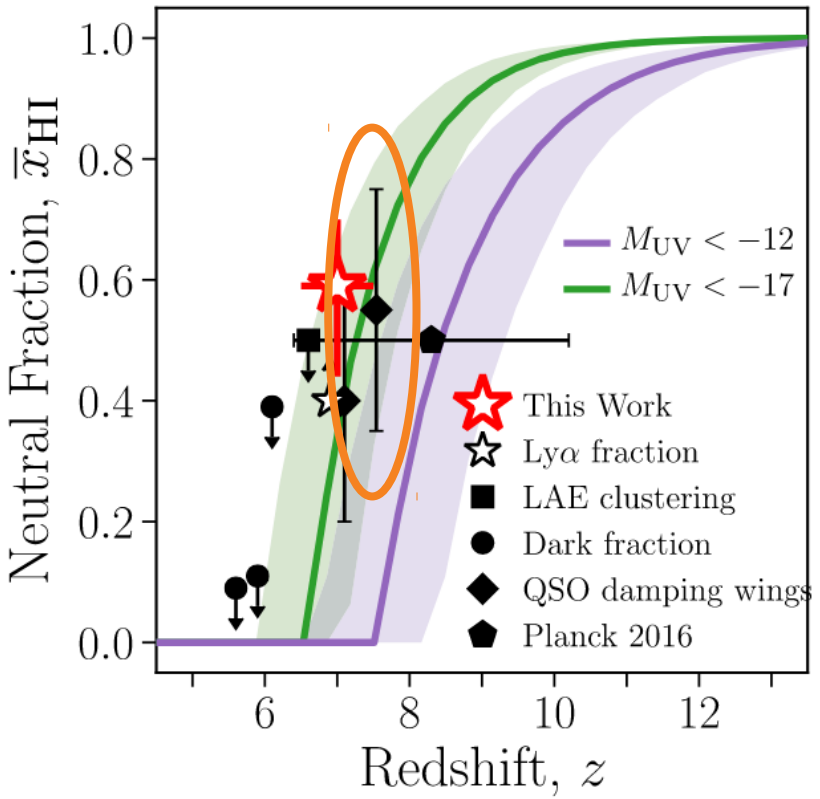
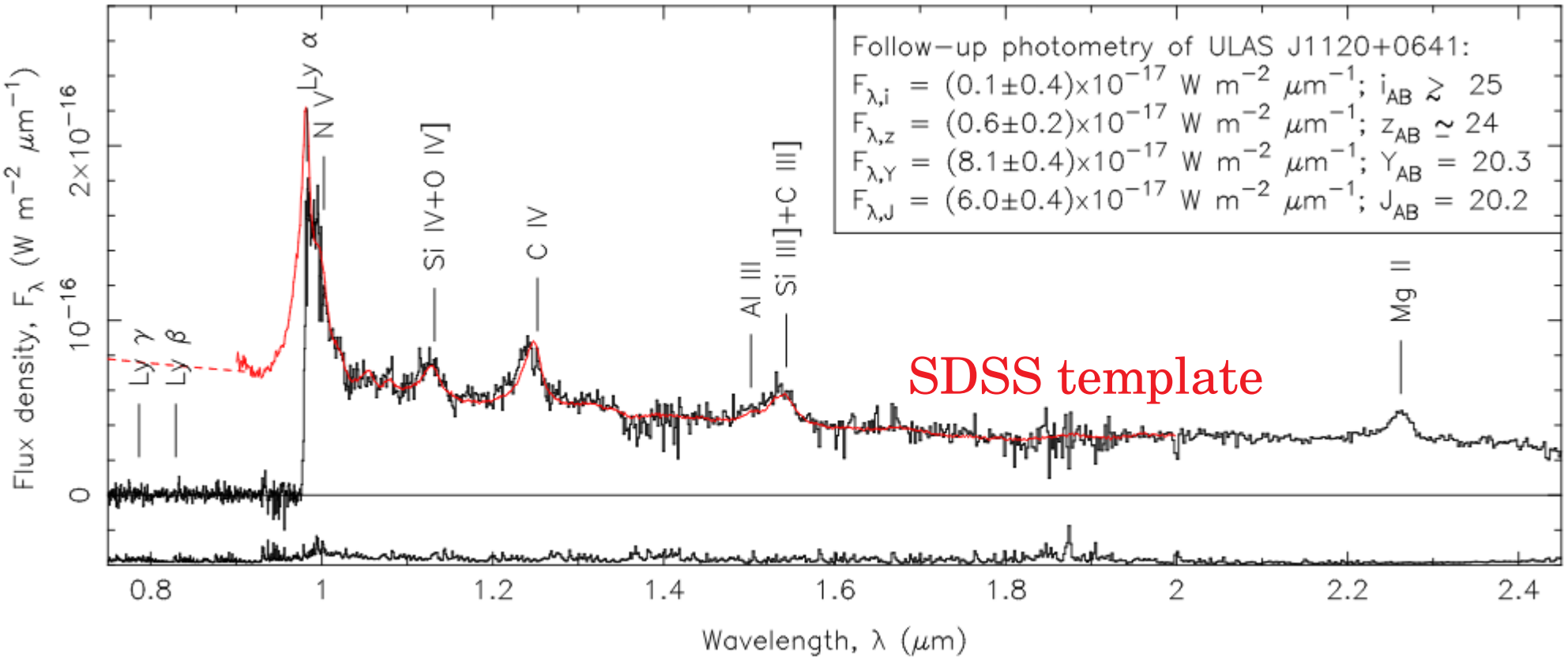




Banados et al. (2018)

Mason et al. (2018)

Evolution is in the details

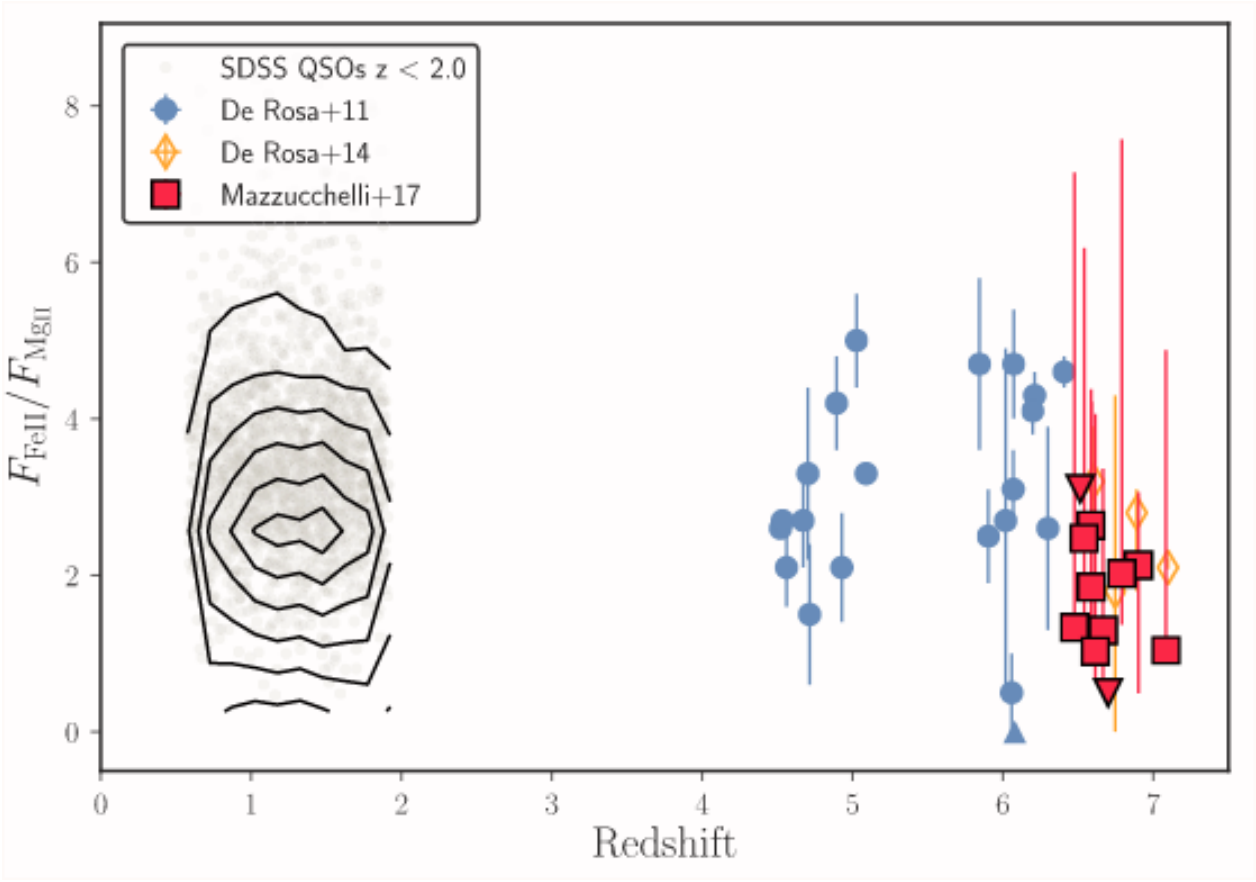


Mortlock et al. (2011)

Evolution is in the details

FeII/MgII:
tentative proxy for abundance of α-elements

No clear evolution between z~7 and z~1

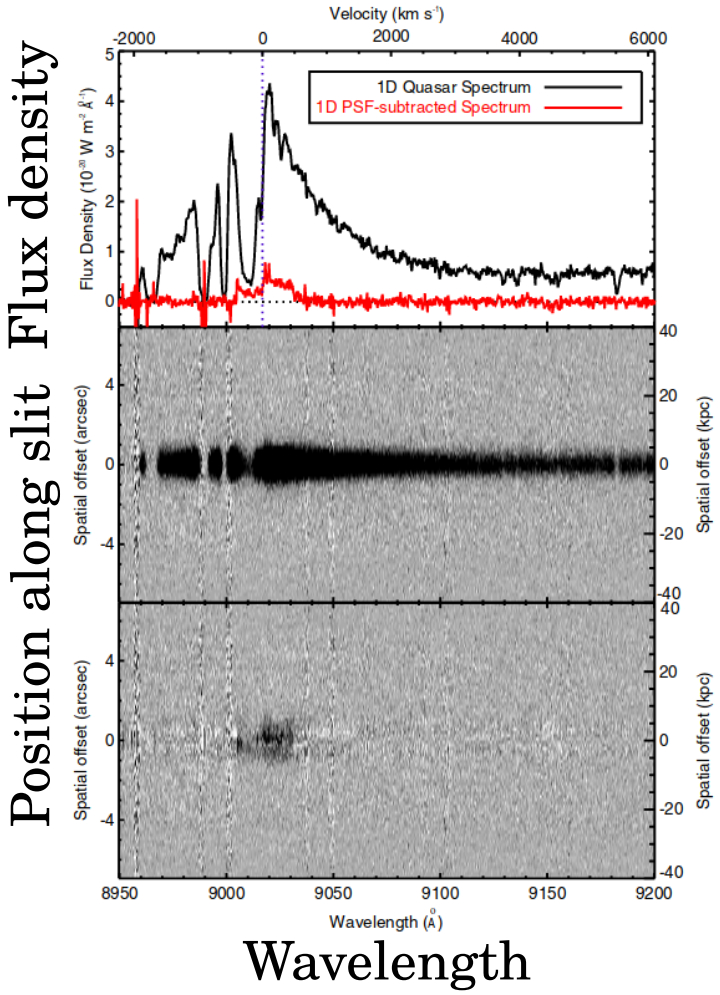


Redshift

Mazzucchelli et al. (2017)

Light on the CGM at z~6.6

Extended Lyα?



Willott et al. (2011)

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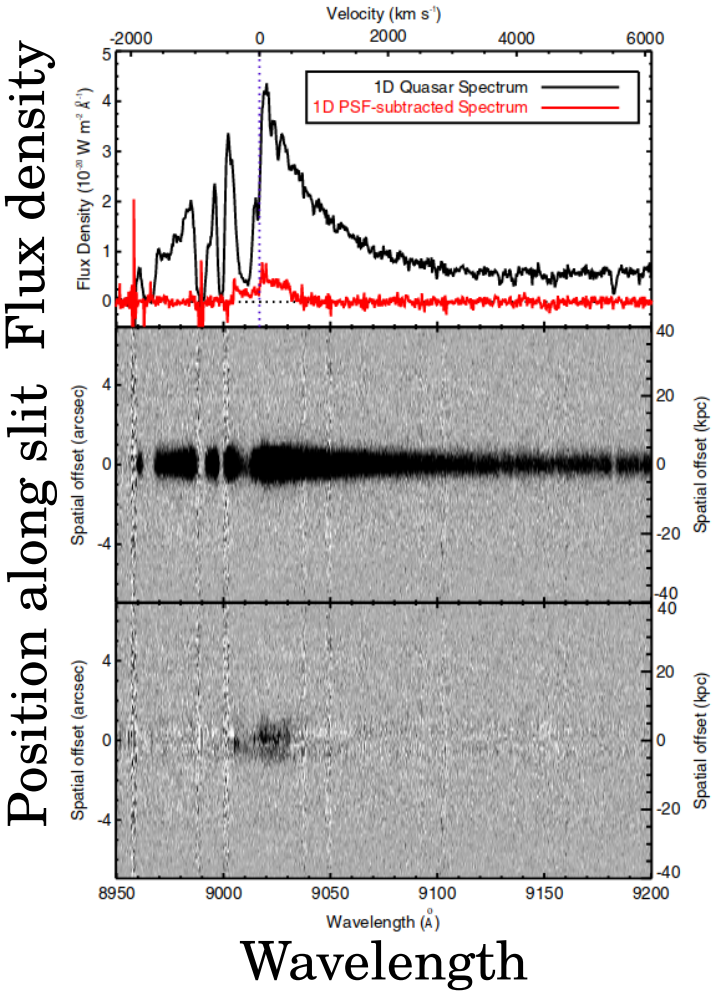
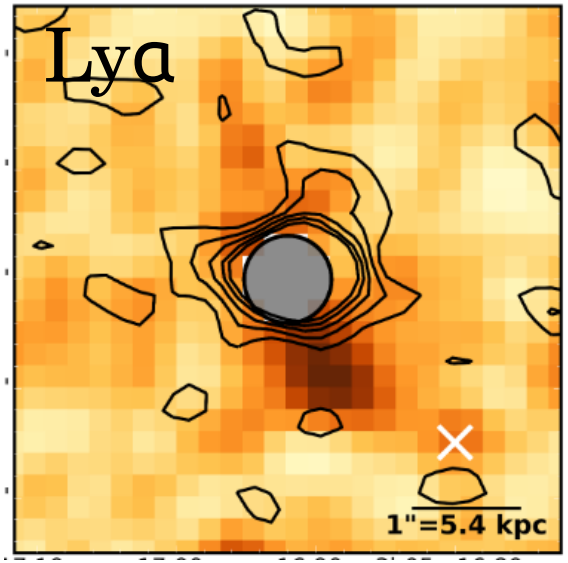


First map (MUSE)



Willott et al. (2011)

Farina et al. (2017)

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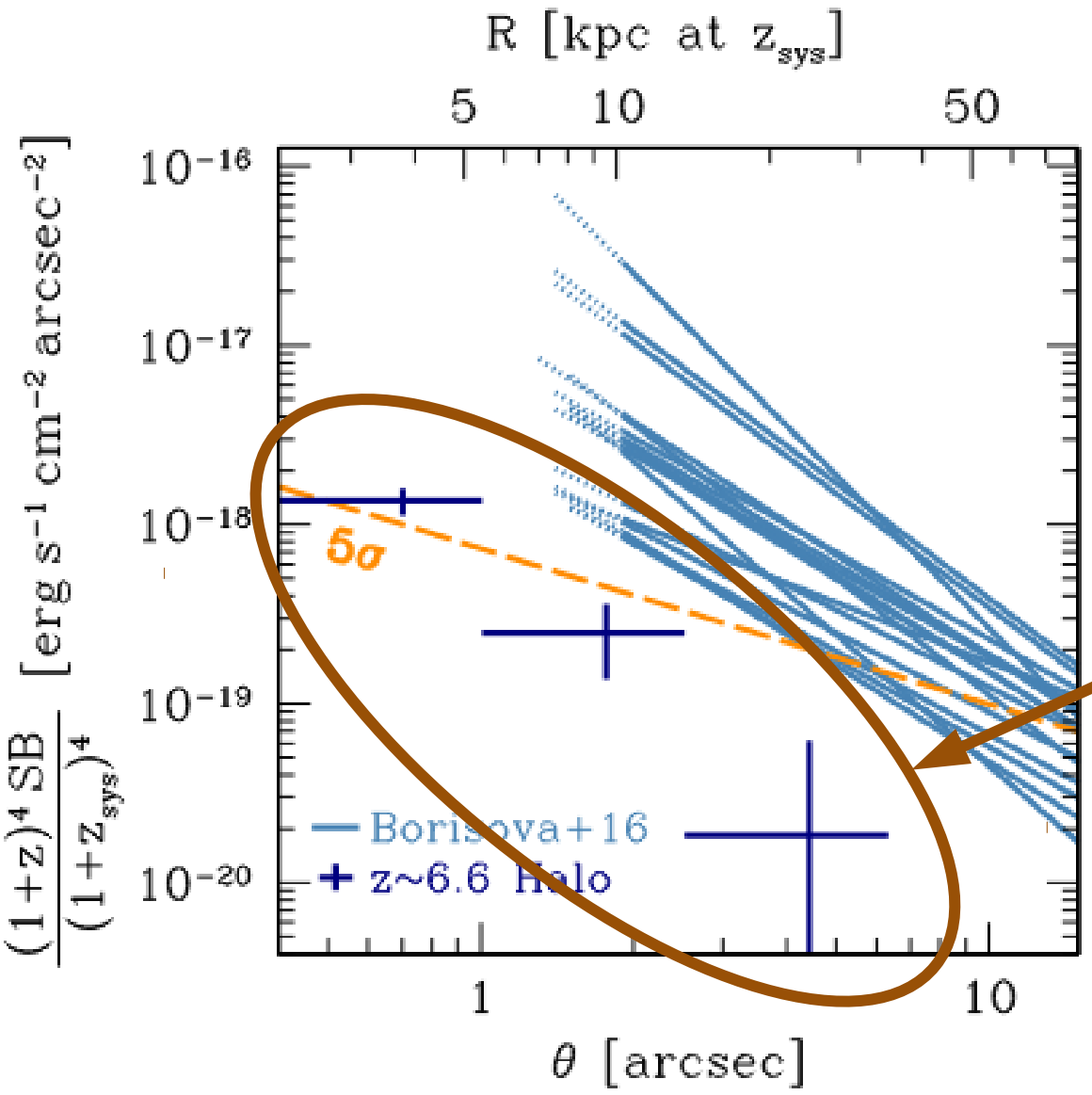
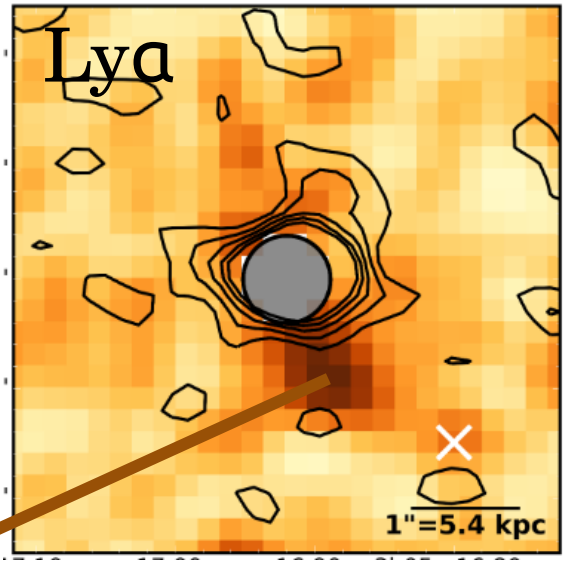
First map (MUSE)



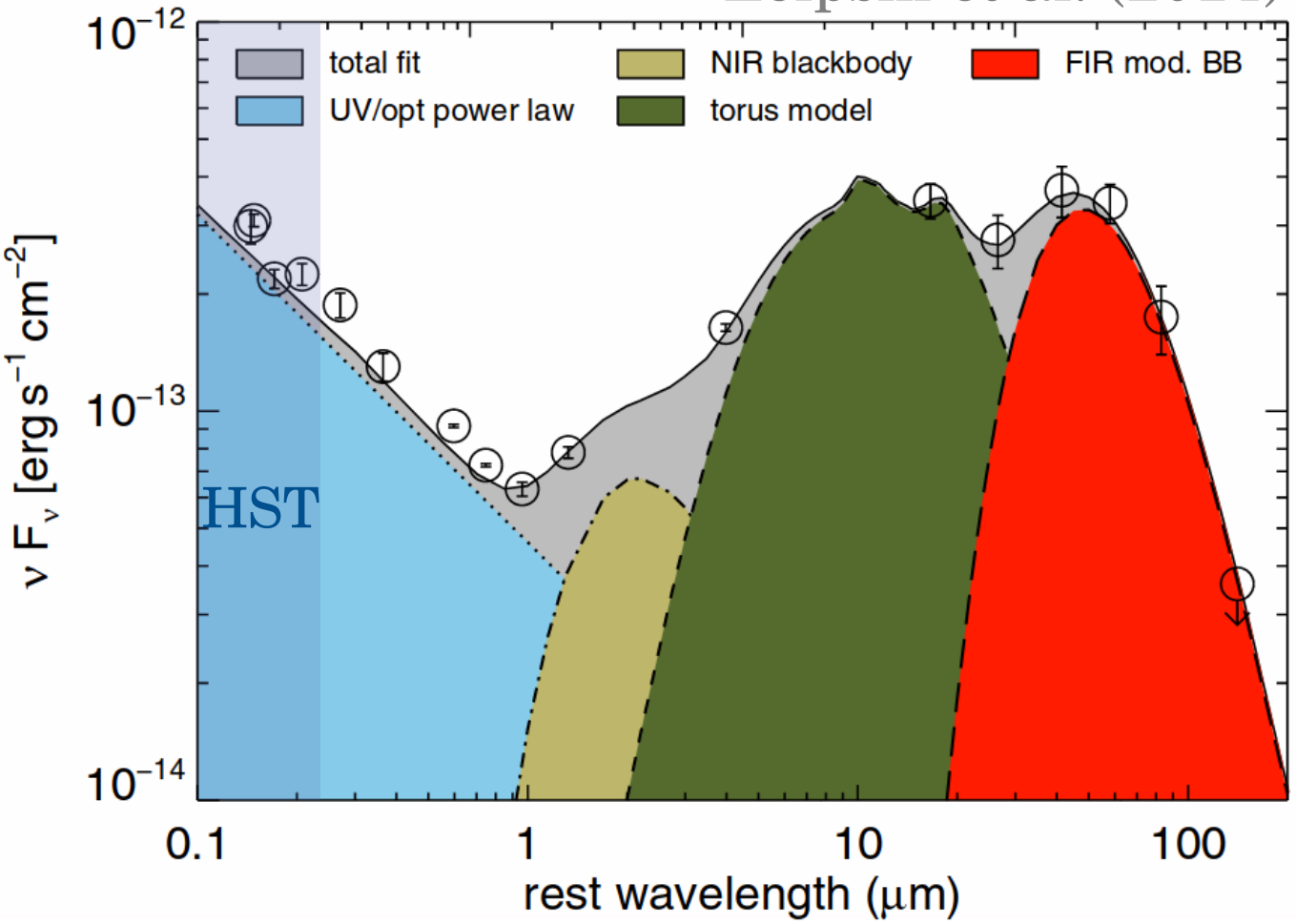


Farina et al. (2017)

What about their host galaxies?

Starlight is outshone by the quasar

Leipski et al. (2014)



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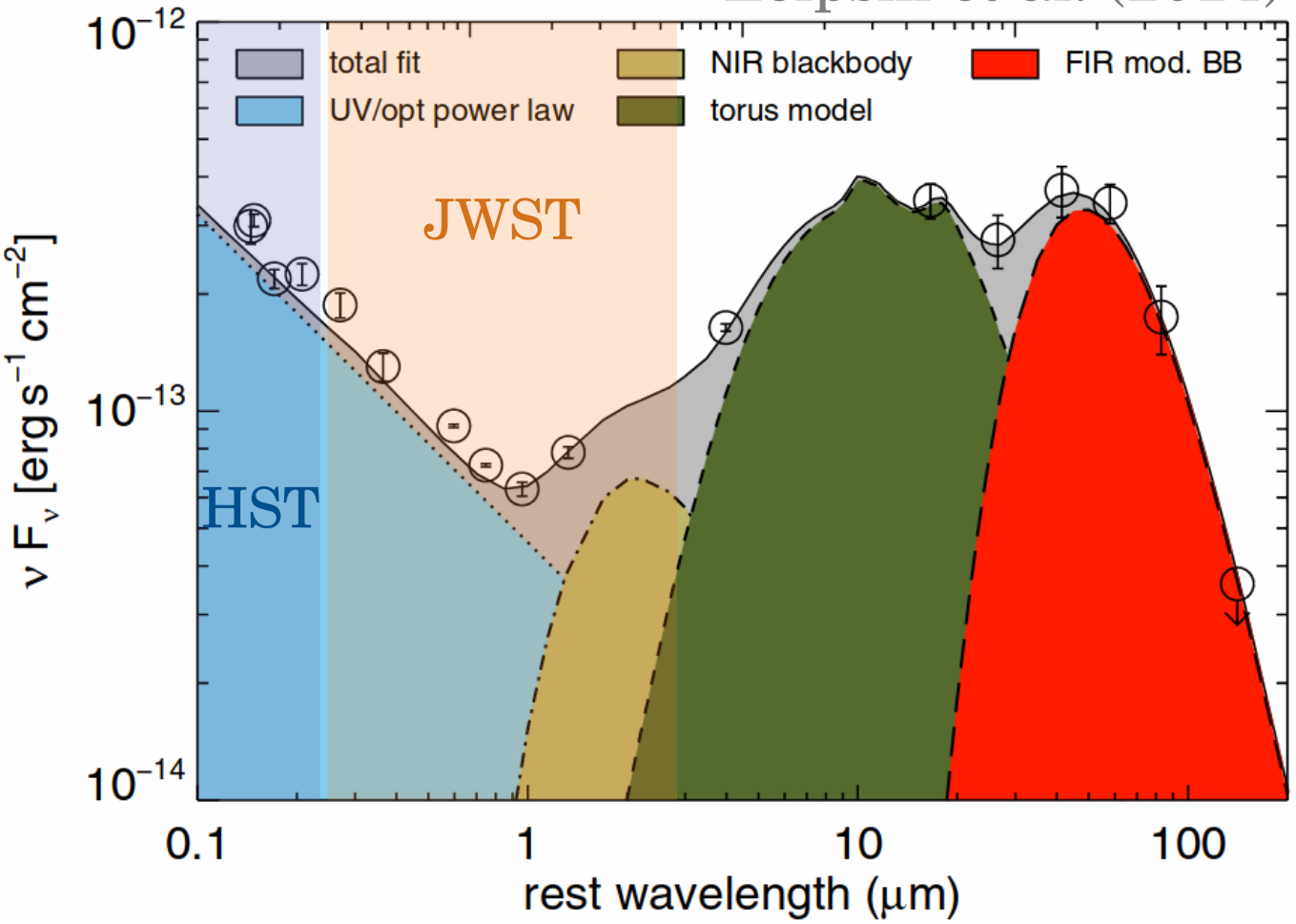
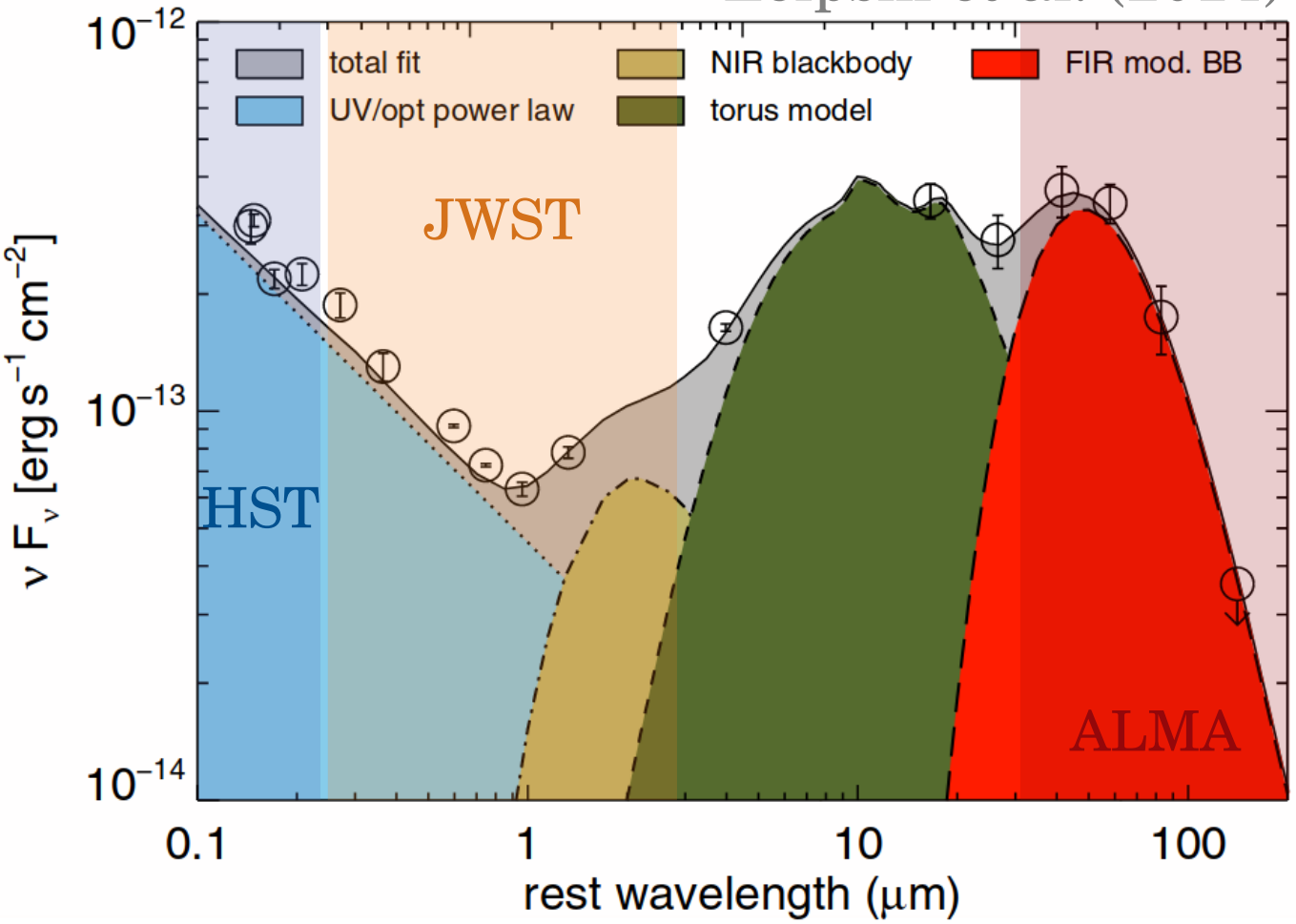


Starlight is outshone by the quasar

Need JWST

What about their host galaxies?

Leipski et al. (2014)



Starlight is outshone by the quasar

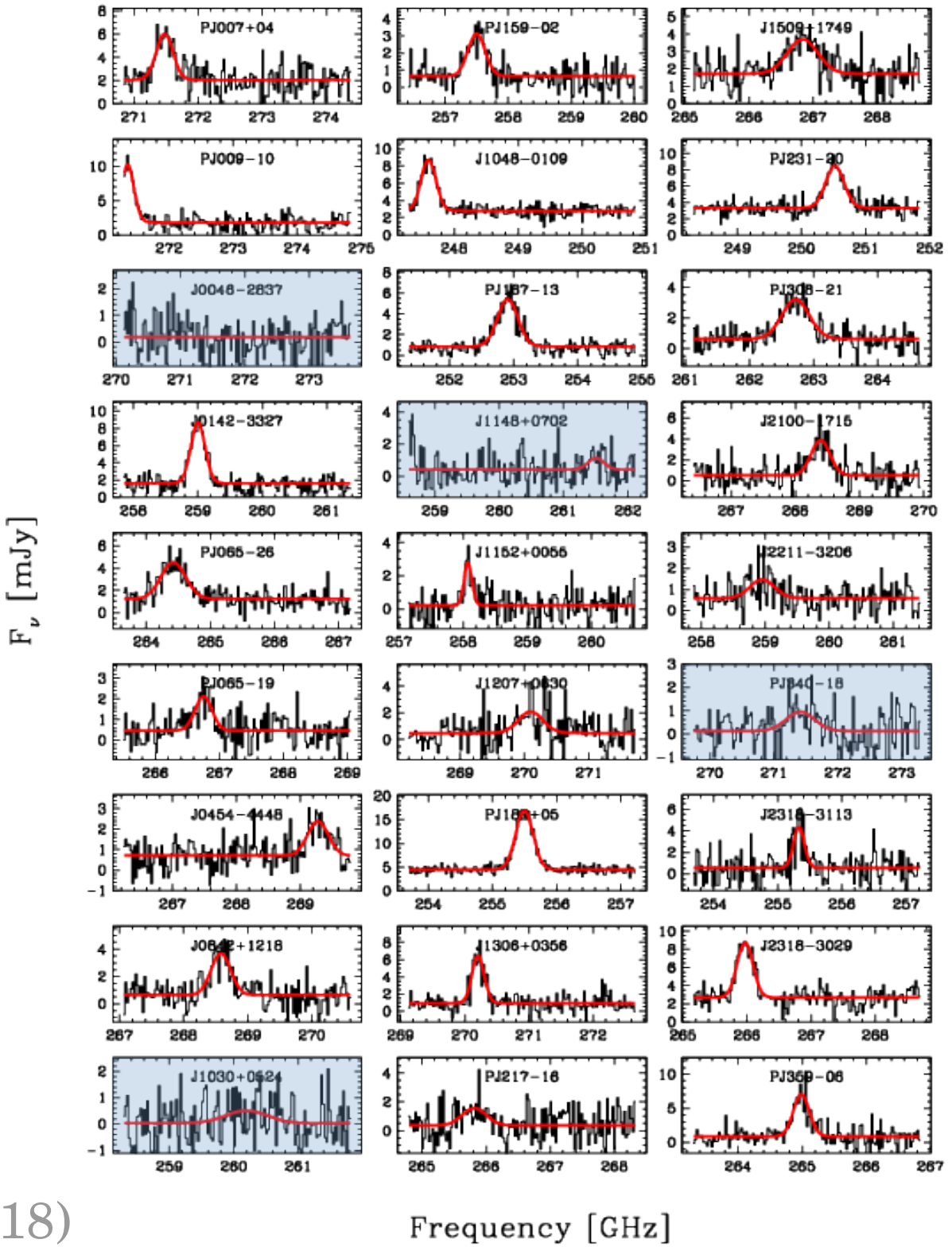
Need JWST

Dust & gas FIR emission is accessible!

ALMA survey of
gas and dust
in z>6 quasars

35 proposed,
27 observed,
23 detected (85%)

10 min on source!

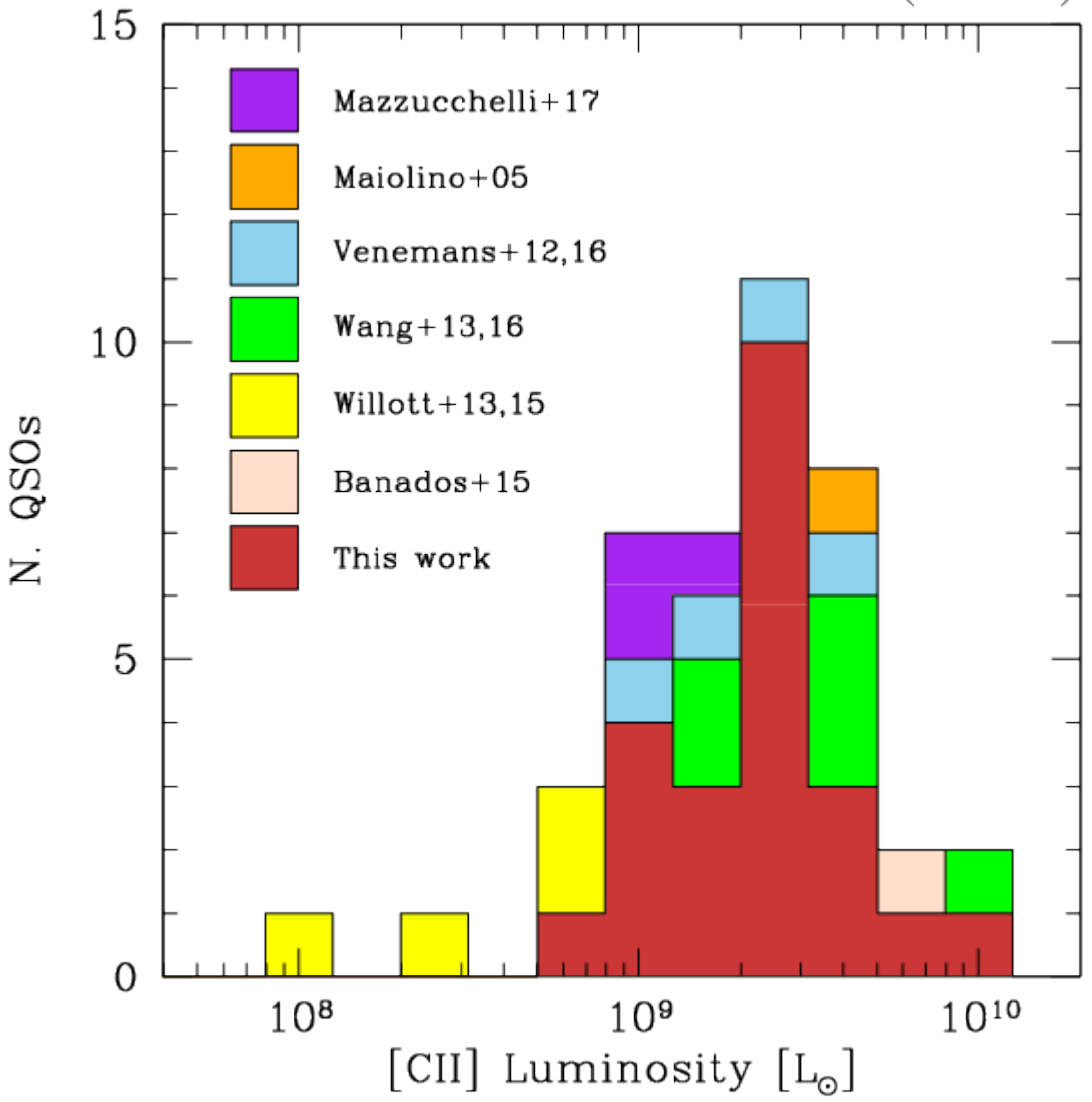


Decarli et al. (2018)

A systematic survey of z>6 quasars

5x bigger sample than previous studies

Decarli et al. (2018)

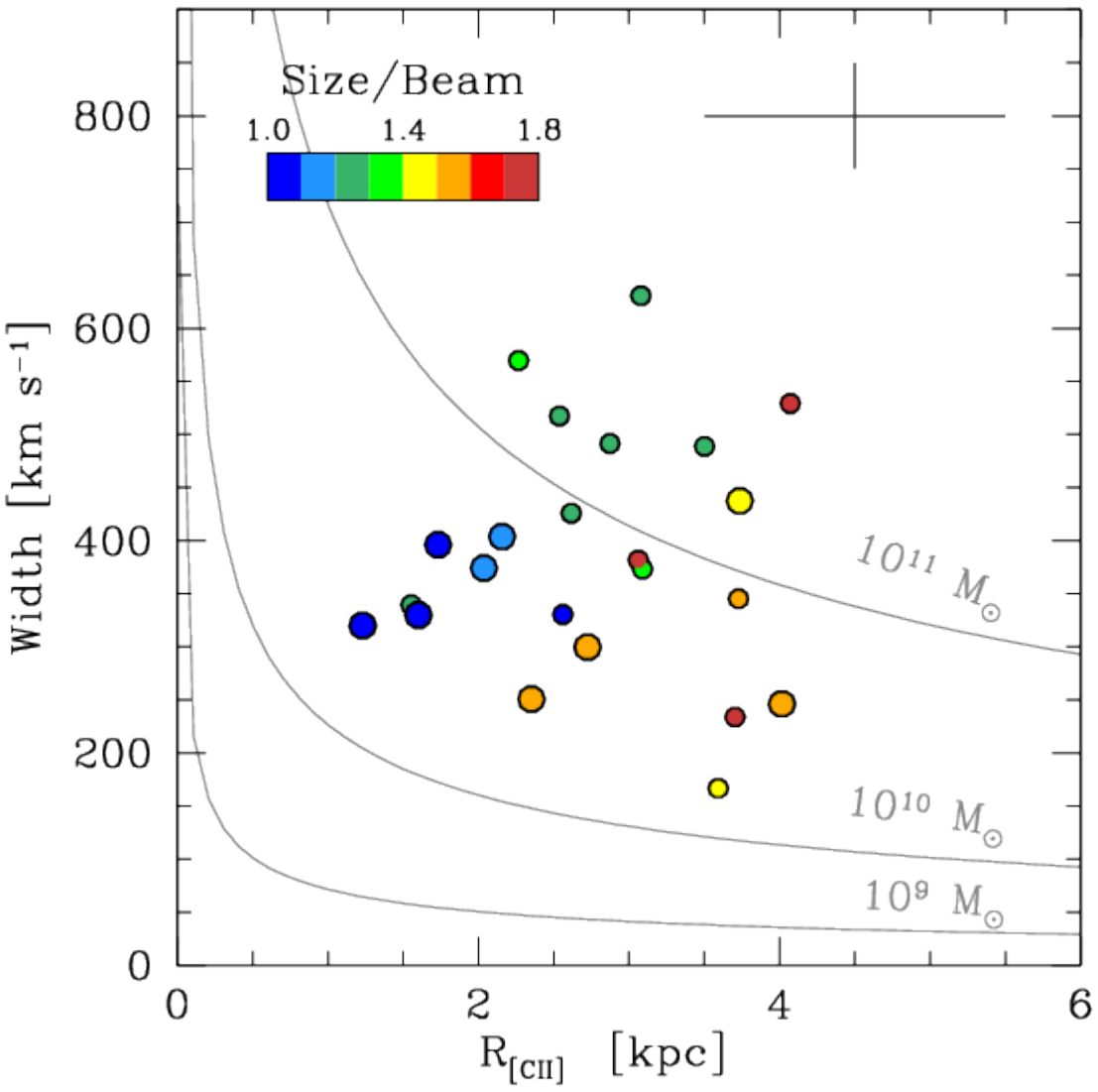


A systematic survey of z>6 quasars

Rough M_{dyn} estimates:

~$2x10^{10} – 3x10^{11}$ M_o

Decarli et al. (2018)



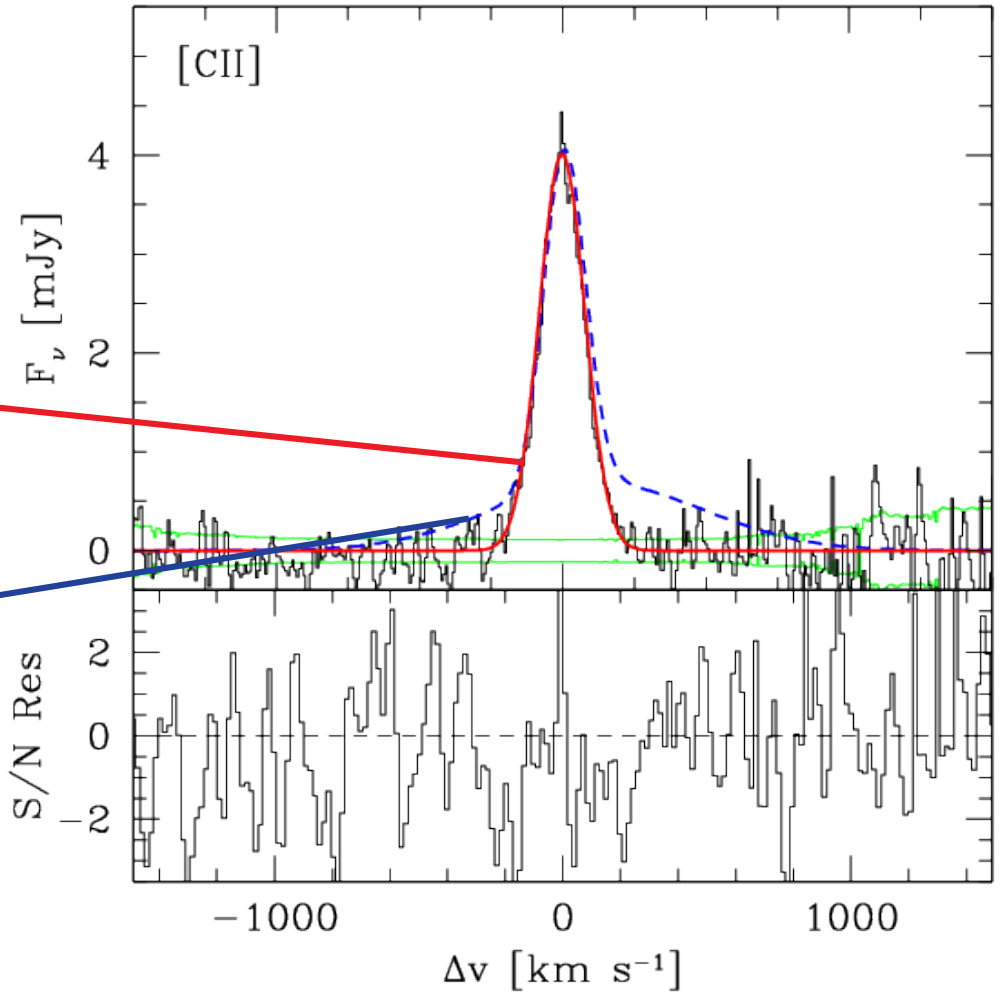
A systematic survey of z>6 quasars

No broad ("outflow"-like) wings from [CII] stacks!

Our sample

J1148+5251 (Cicone et al. 2015)

Decarli et al. (2018)

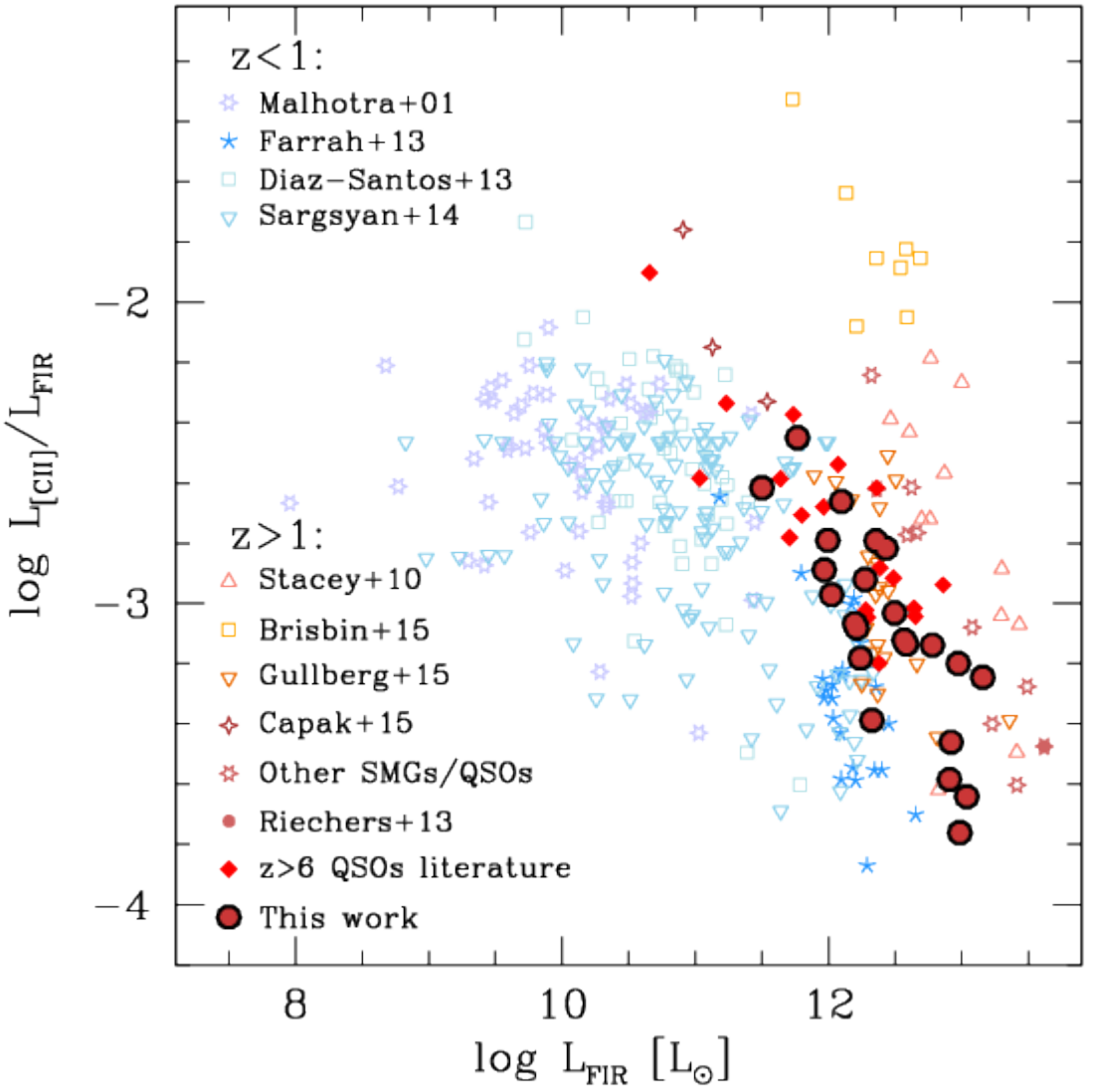


A systematic survey of z>6 quasars

[CII] = gas cooling

FIR = star formation

Decarli et al. (2018)



A systematic survey of z>6 quasars

[CII] = gas cooling

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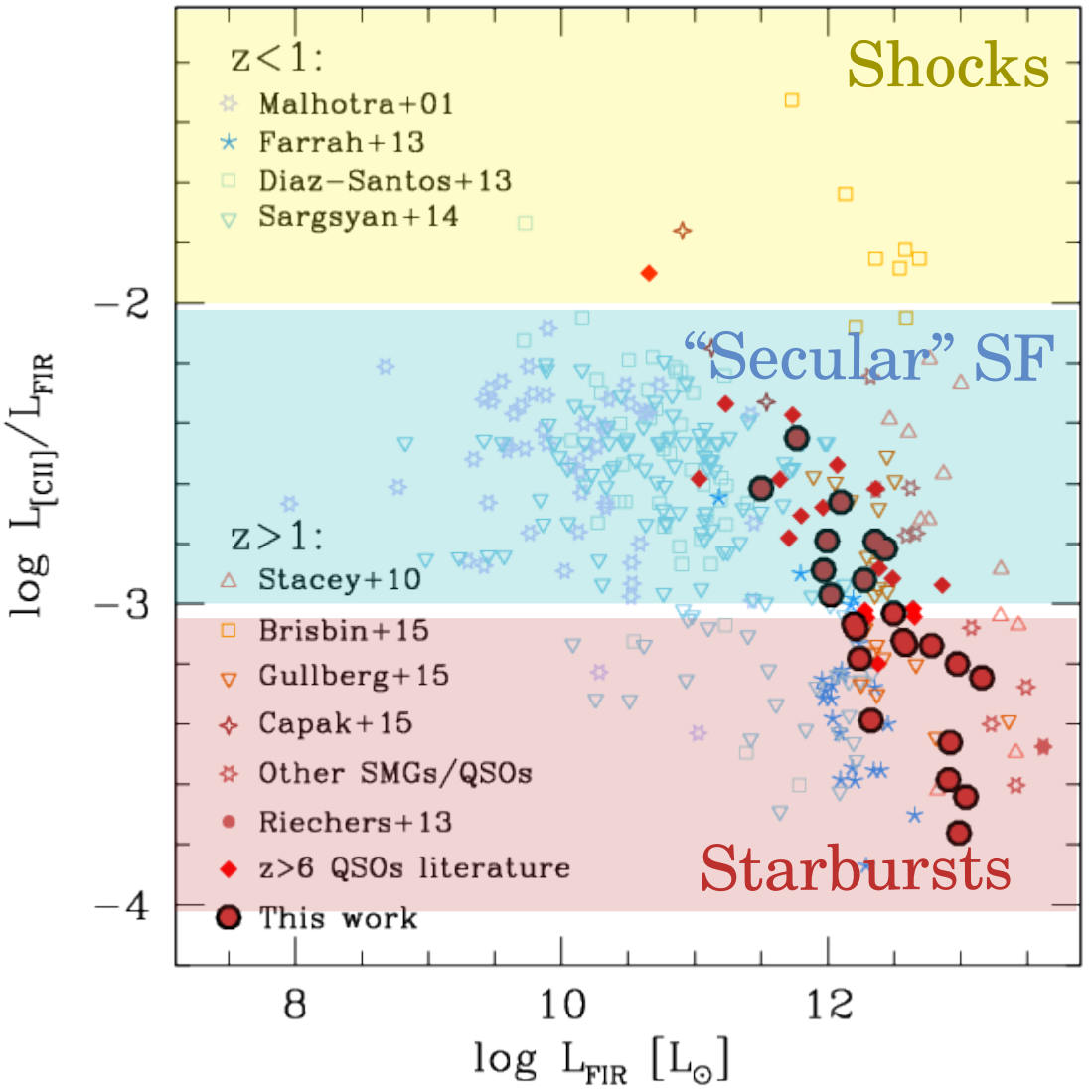
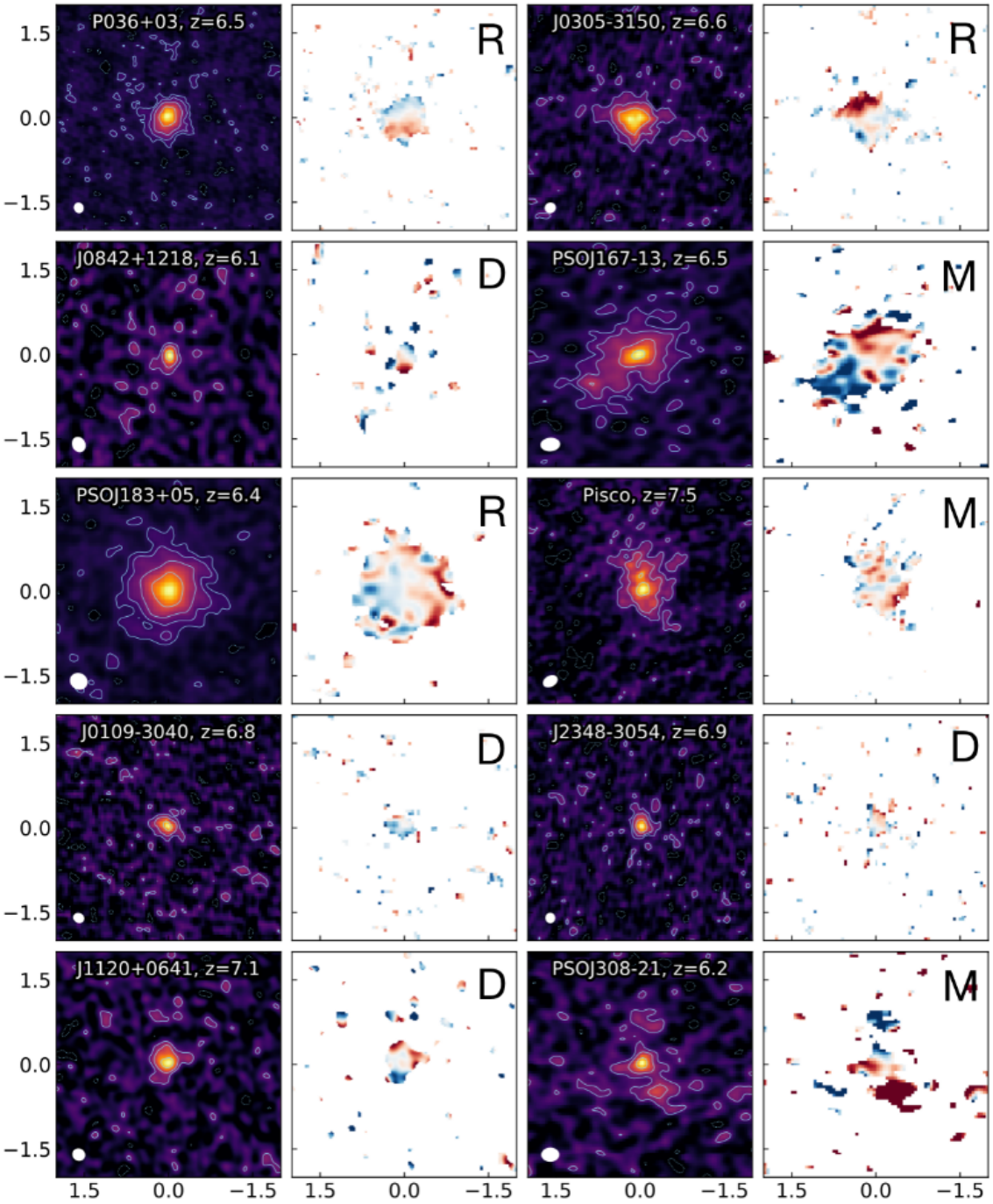
Decarli et al. (2018)



A systematic survey of z>6 quasars

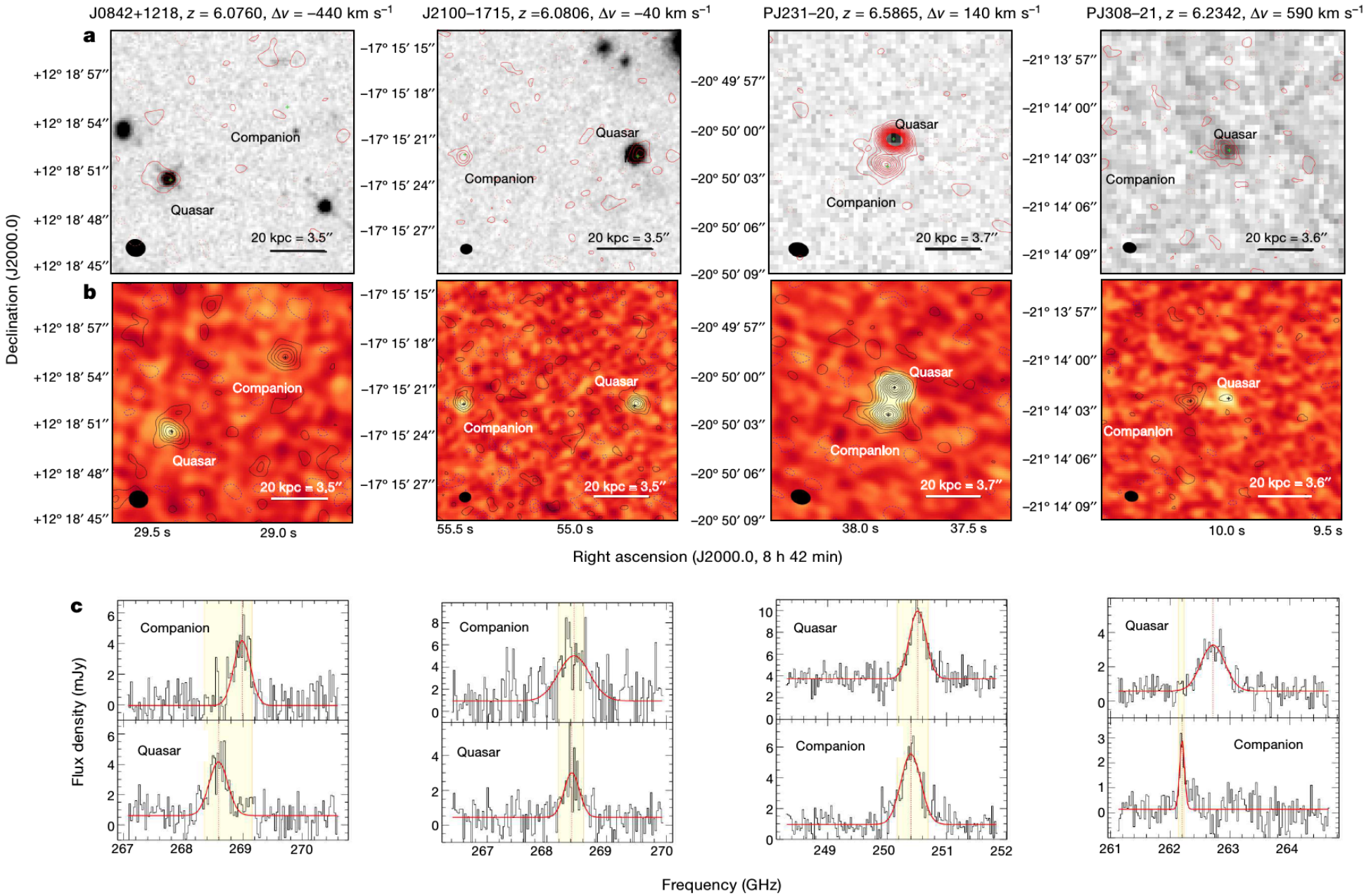
High-res follow-up
(0.2” ~ 1 kpc):

Variety in size,
morphology,
and dynamics

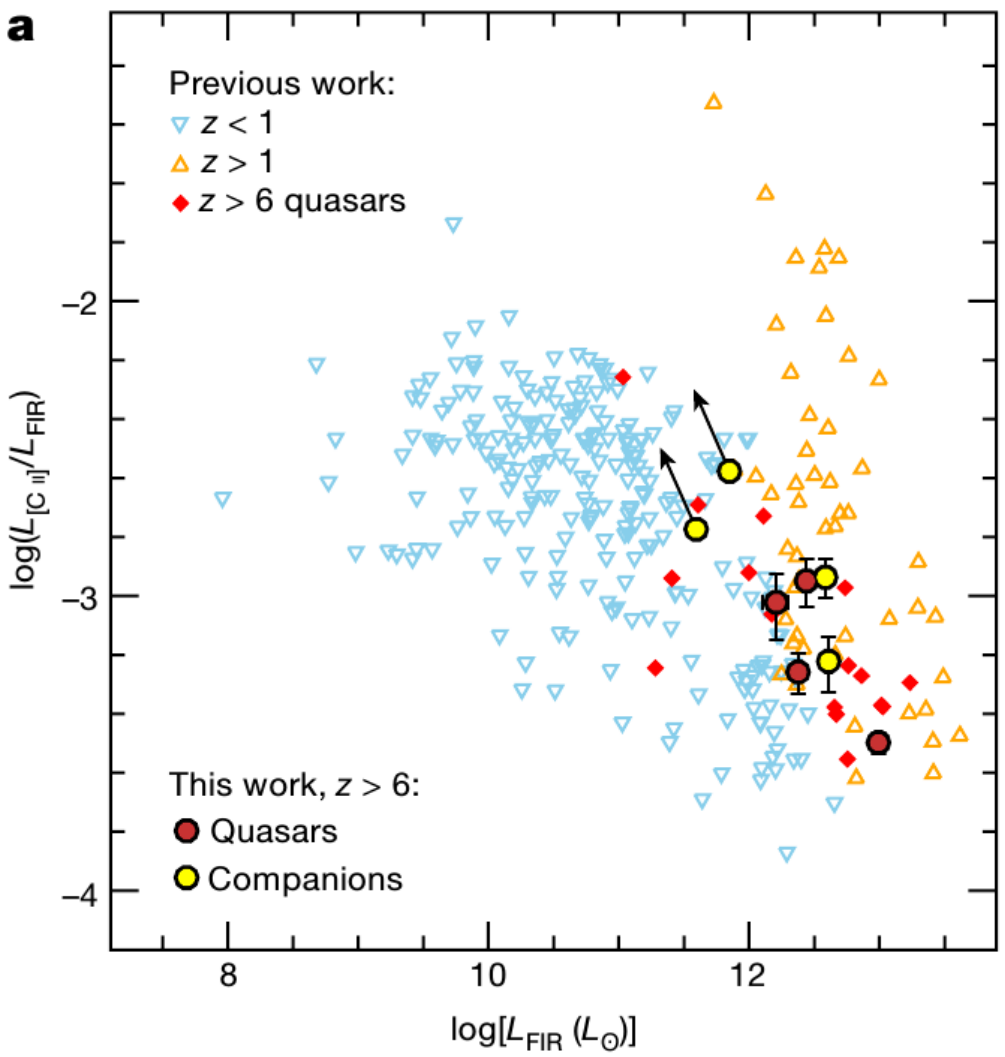


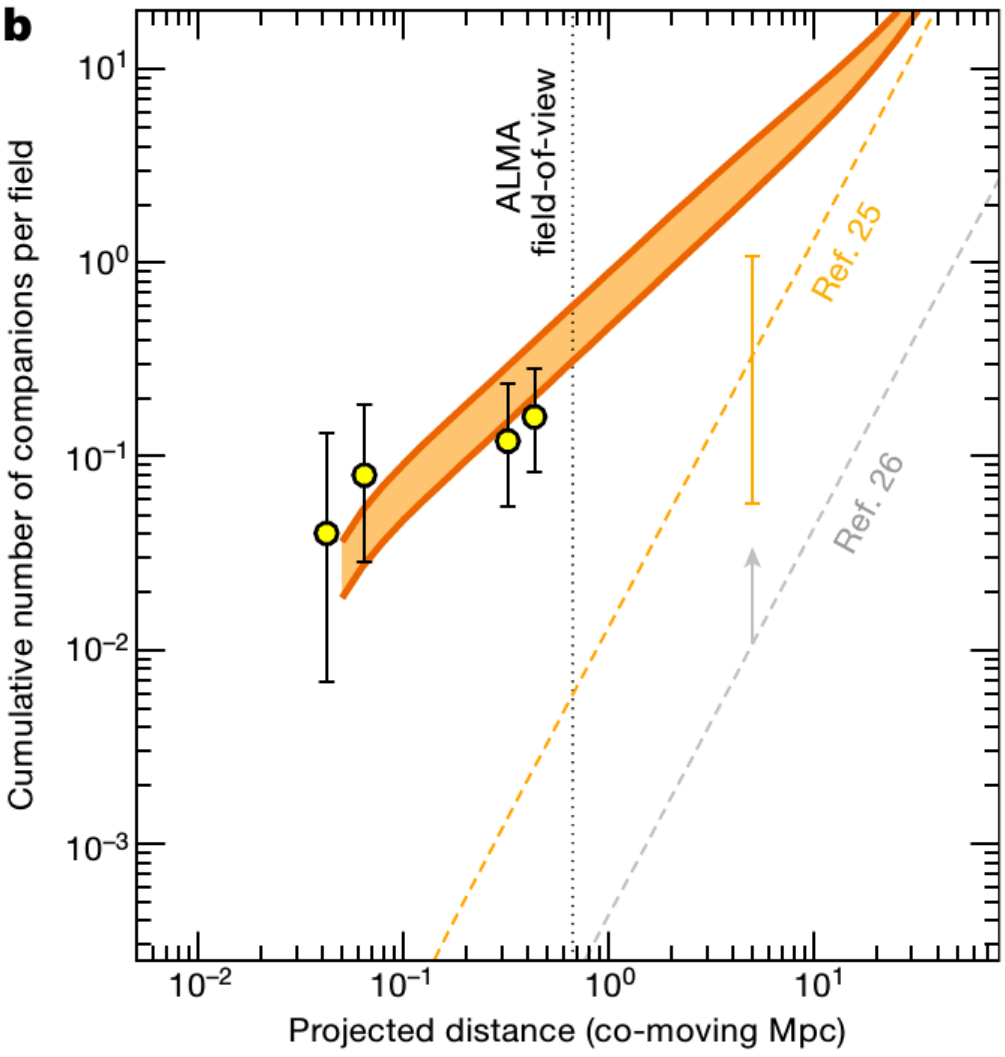
Companions of quasars at z>6

Decarli et al. (2017) Nature



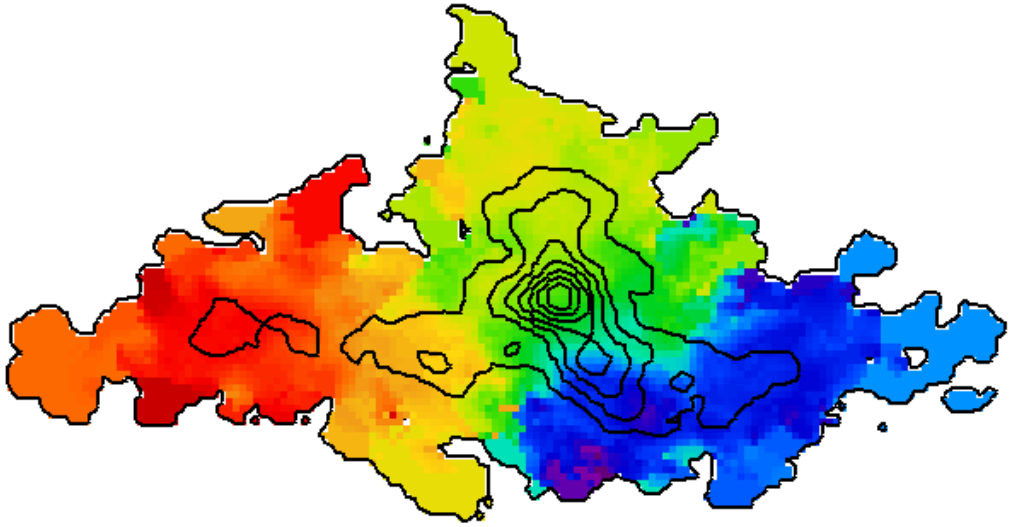
Companions of quasars at z>6

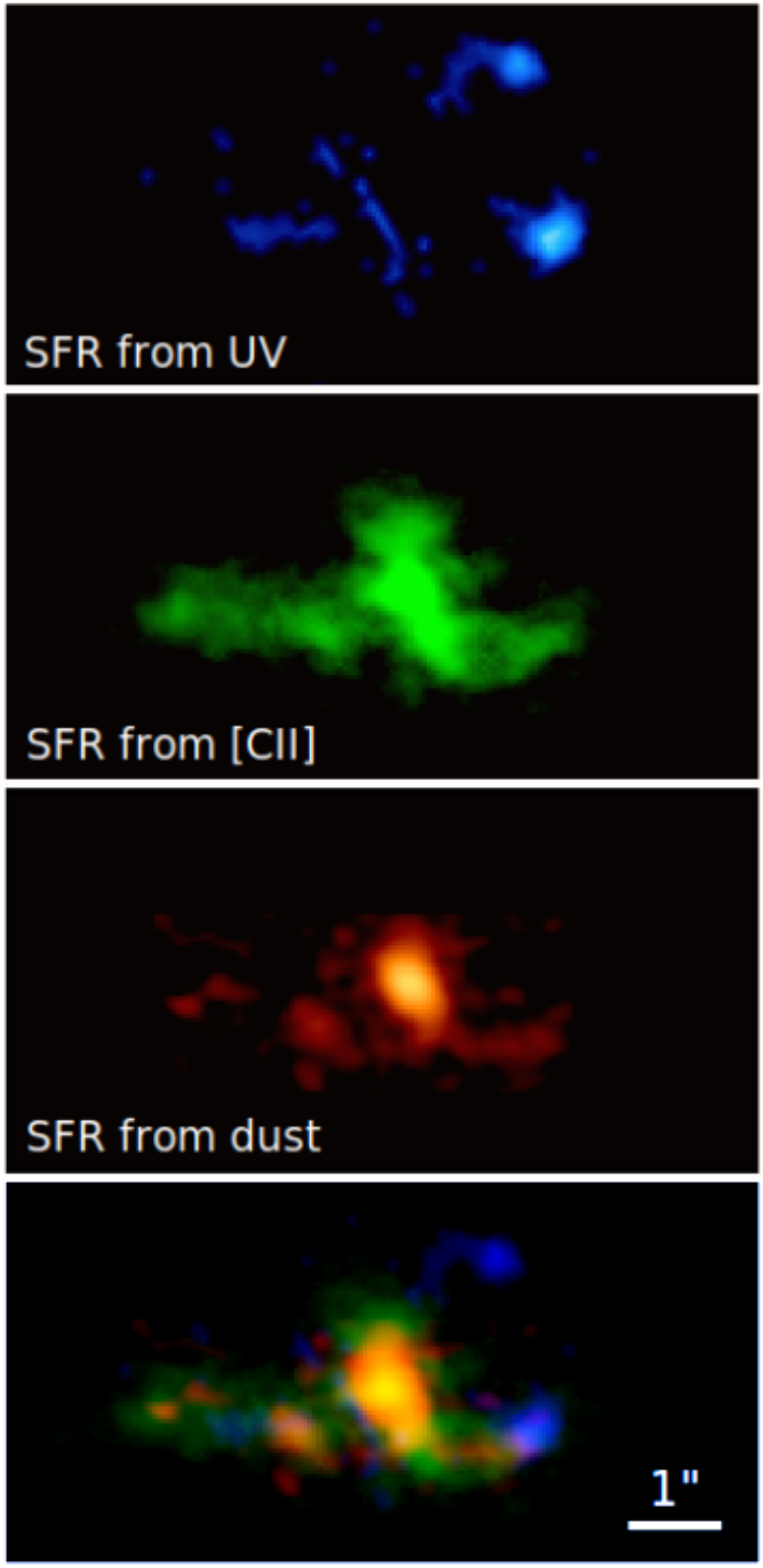




Decarli et al. (2017) Nature

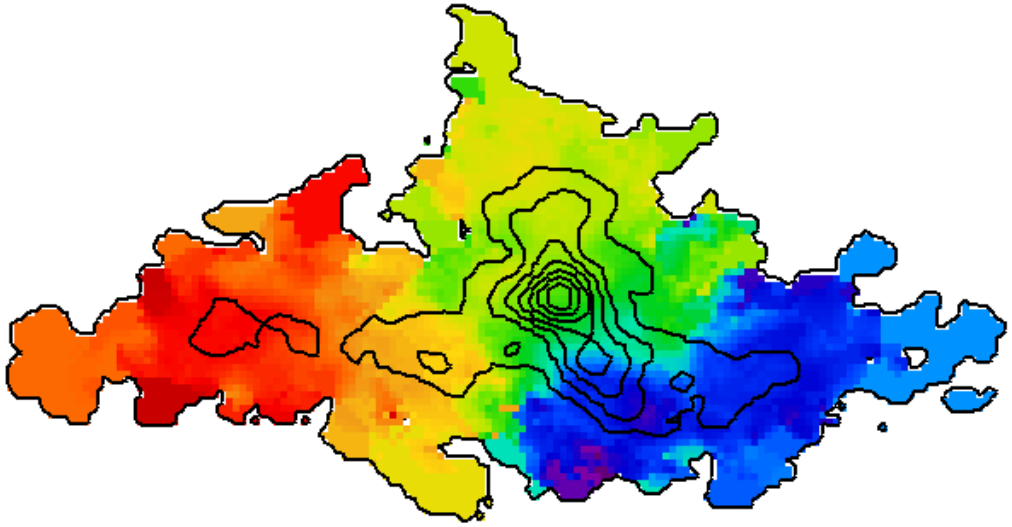
Image of a merger at z=6.234

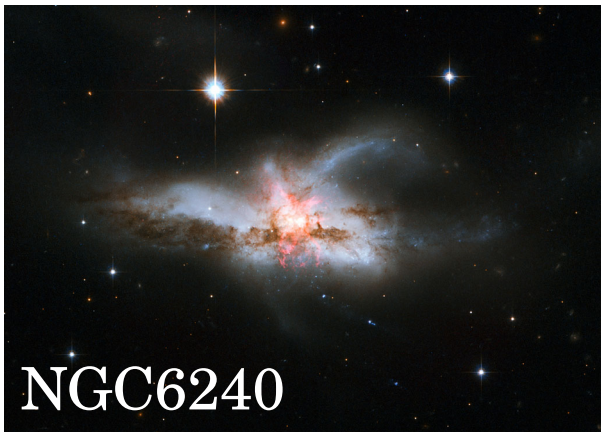


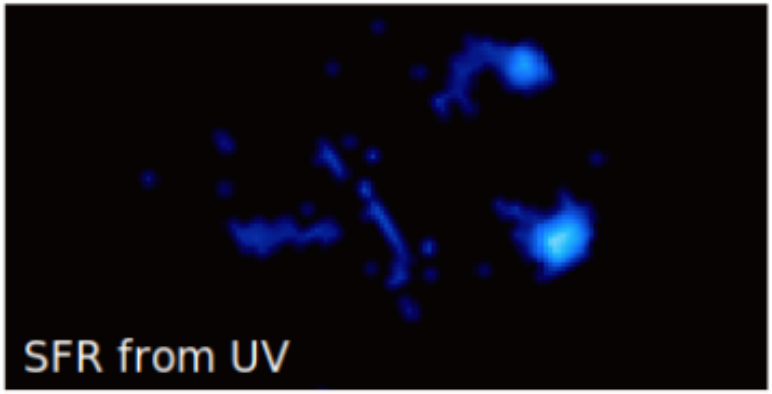


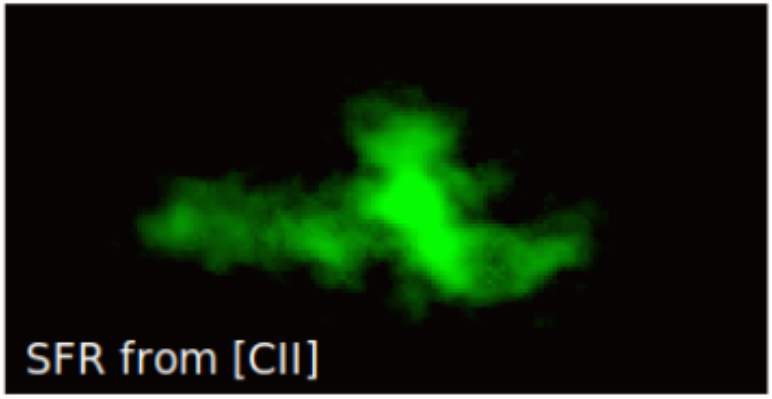
Decarli et al. (in prep)

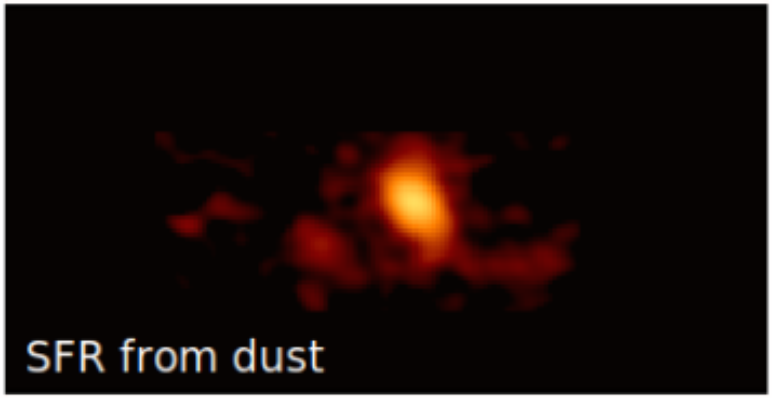
Image of a merger at z=6.234

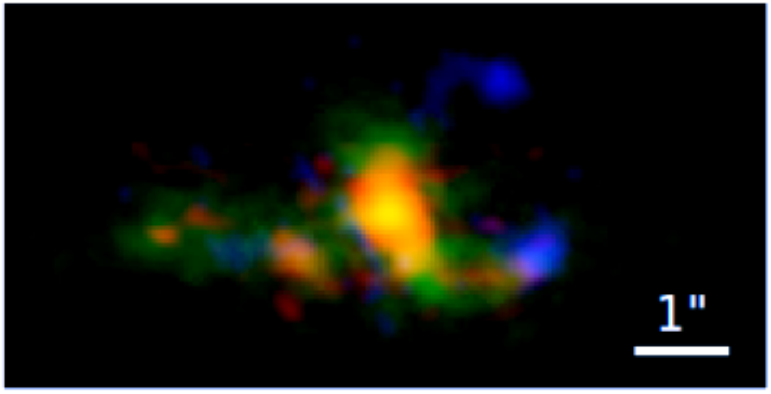








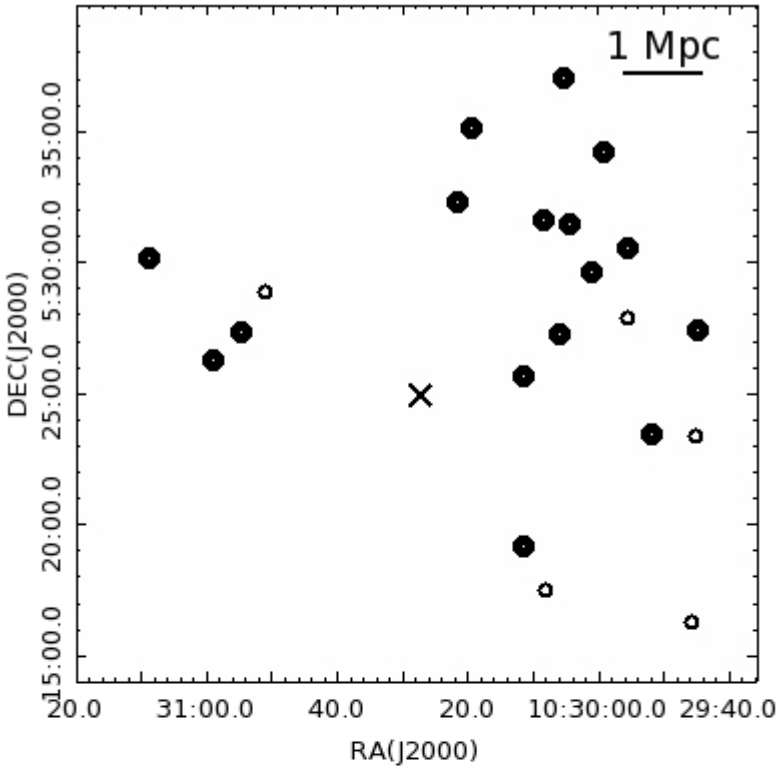


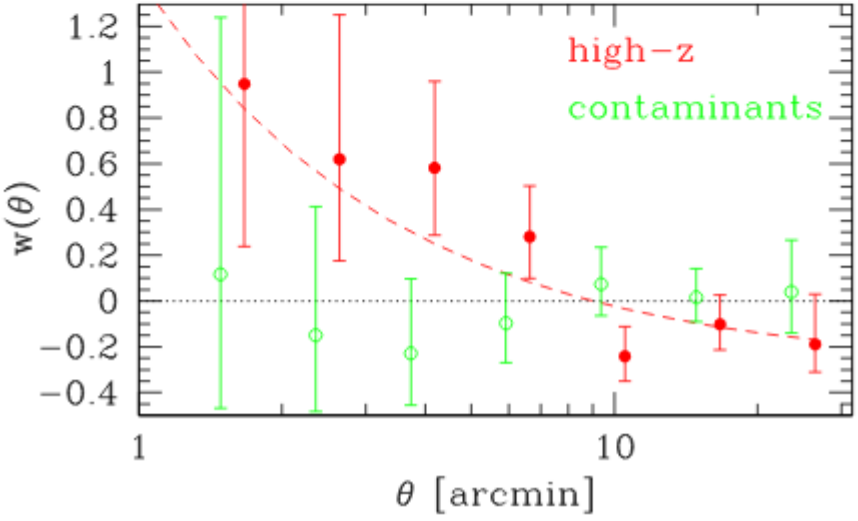


Decarli et al. (in prep)

Large-scale environment

Companion galaxies
selected via dropout techniques
+ follow-up campaigns

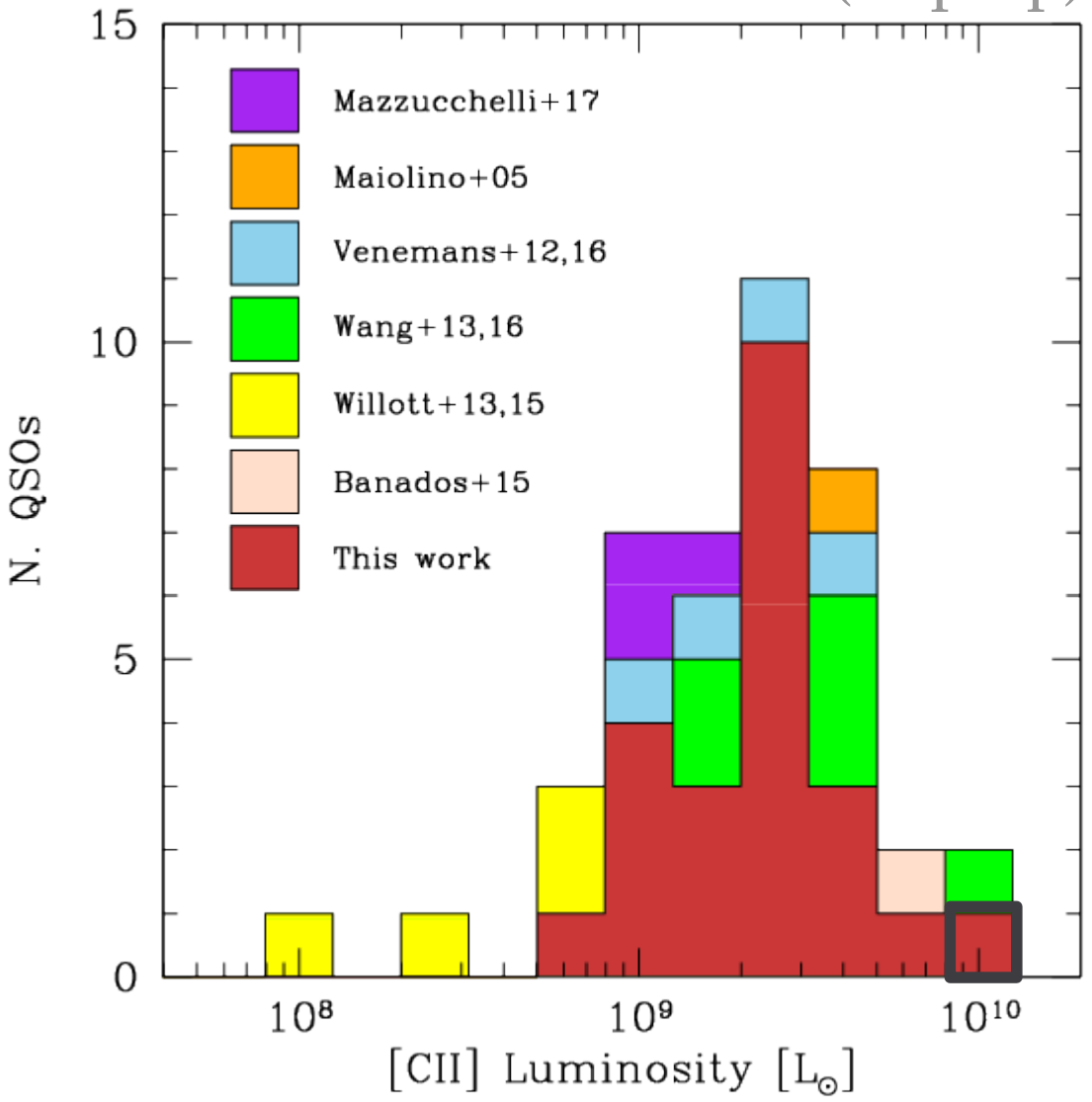




Balmaverde et al. (2017)

The ISM in the first massive galaxies

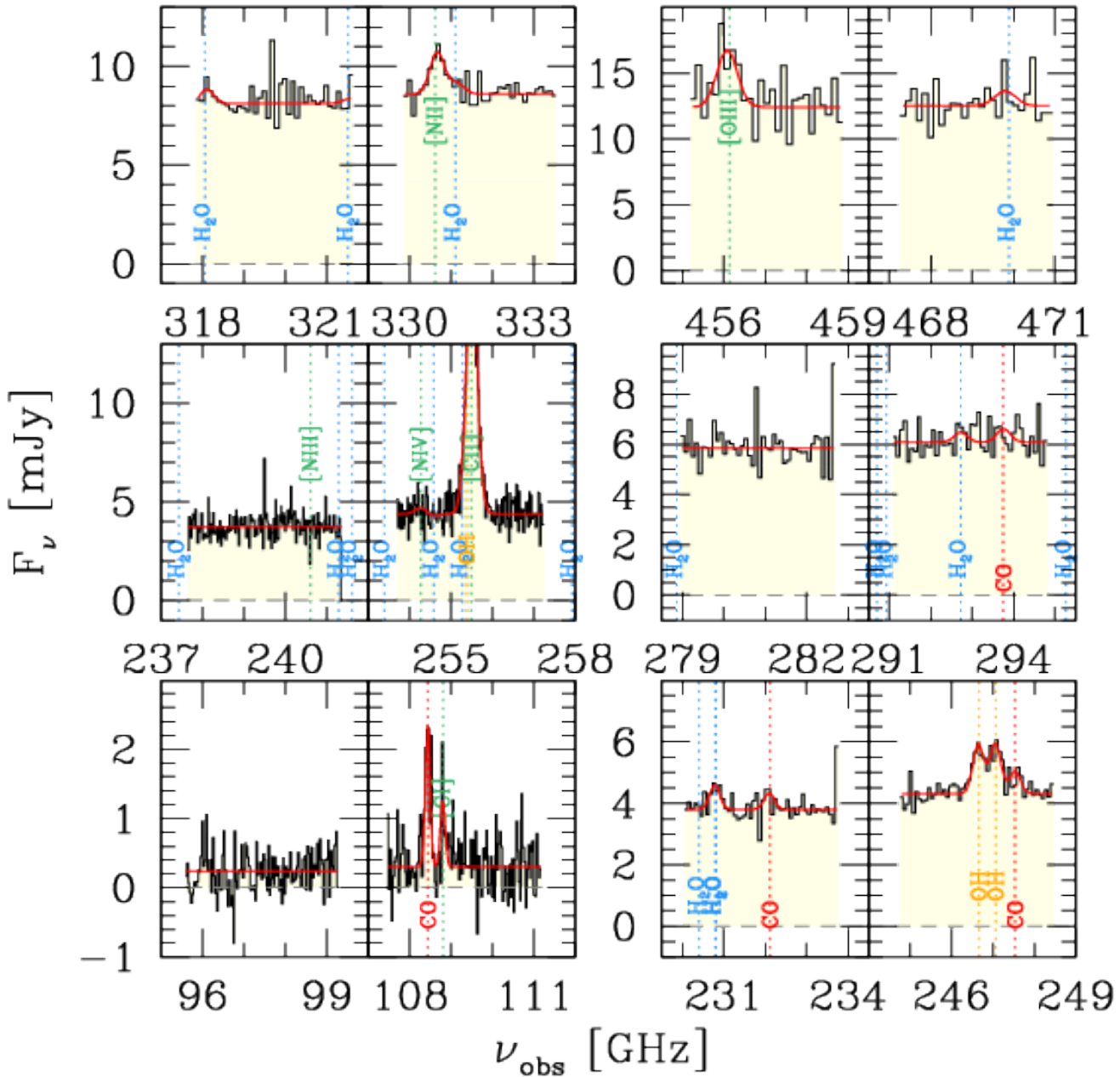
Decarli et al. (in prep)



Our pick:

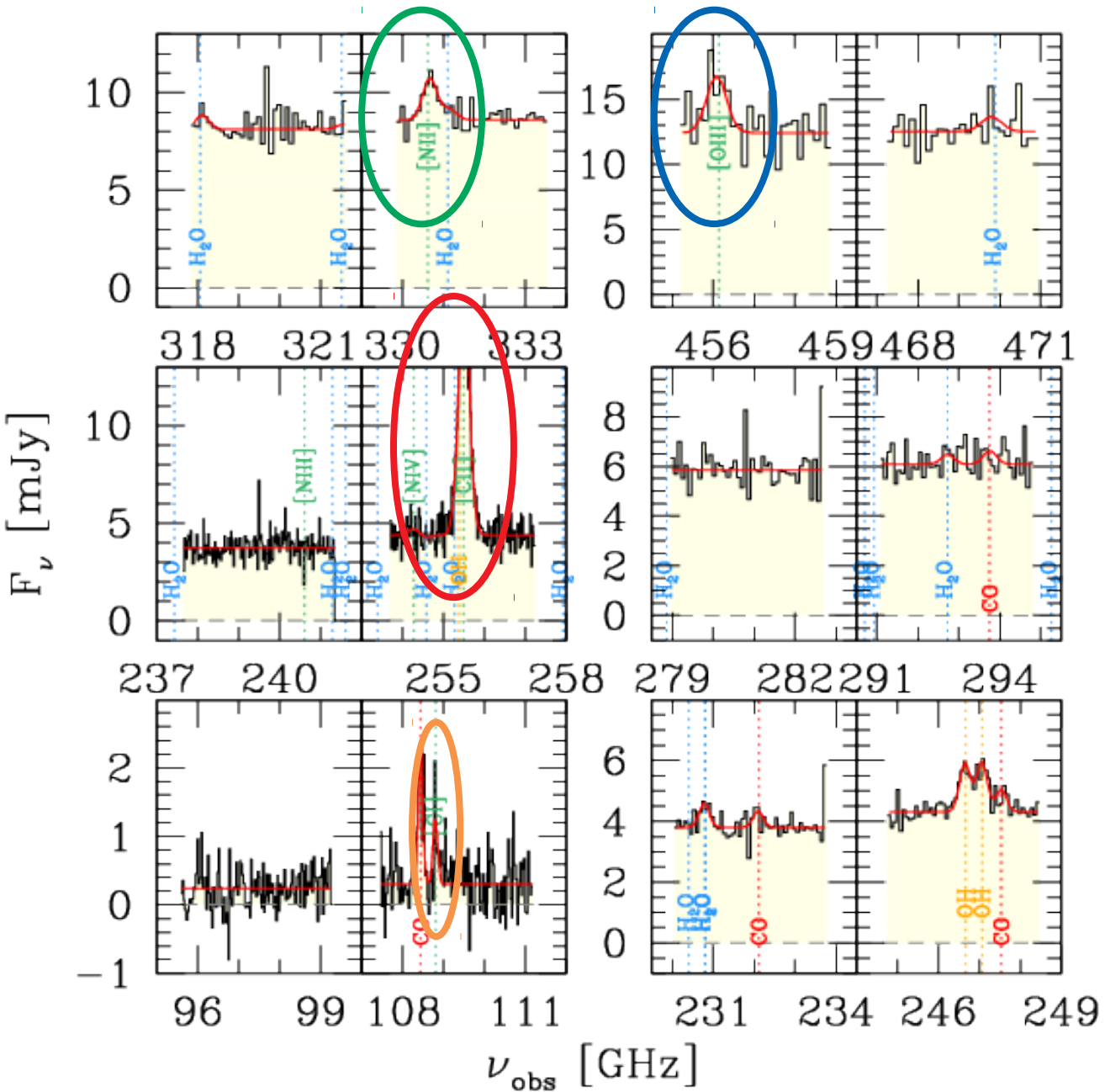
PJ183+05, z=6.43

ISM in quasar hosts at z>6



18 lines in
6 frequency
settings

ISM in quasar hosts at z>6



FSLs:

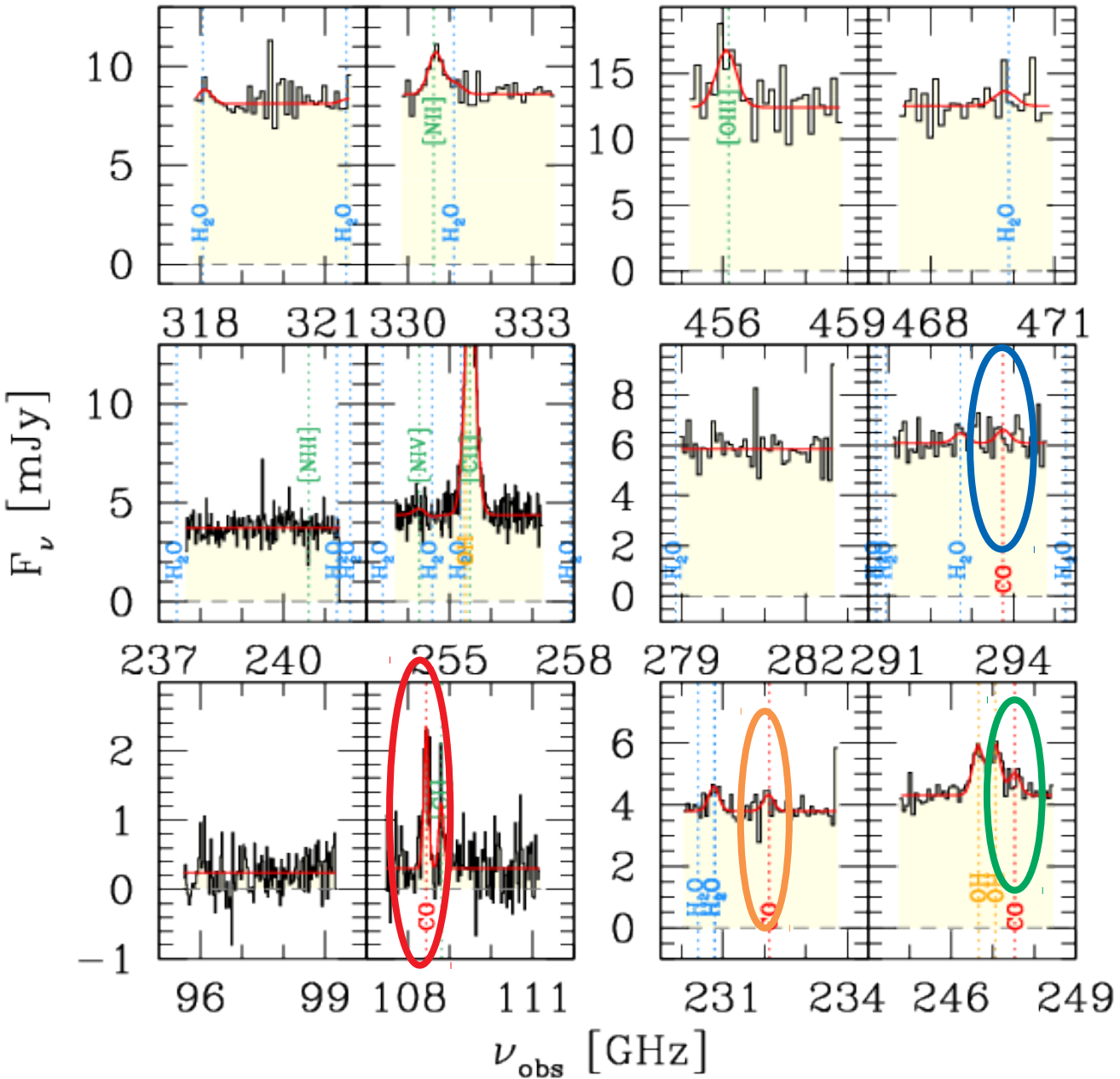
[OIII] 88um,

[NII] 122 um,

[CII] 158um,

[CI] 370um

ISM in quasar hosts at z>6



CO:

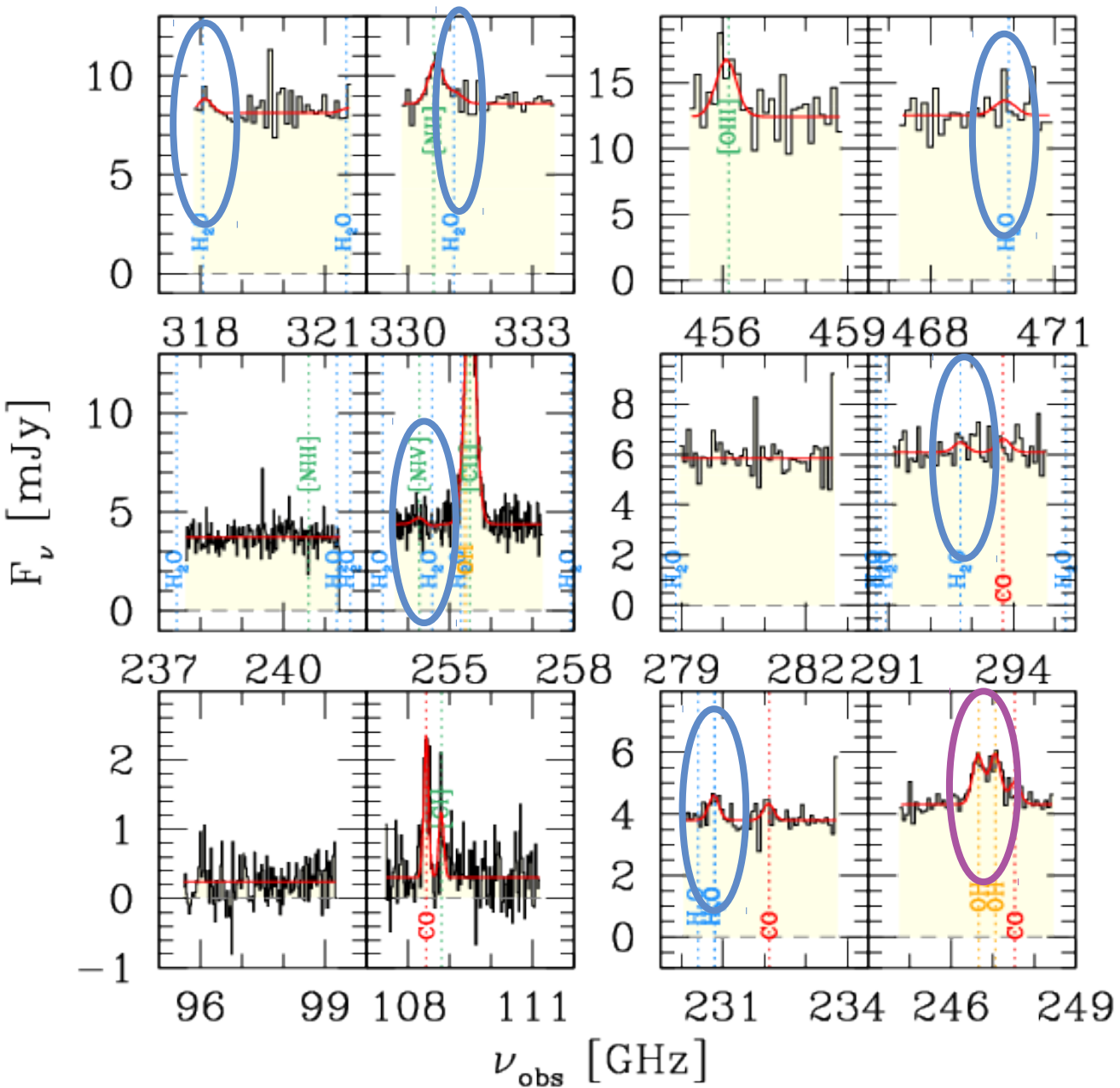
CO(7-6),

CO(15-14),

CO(16-15),

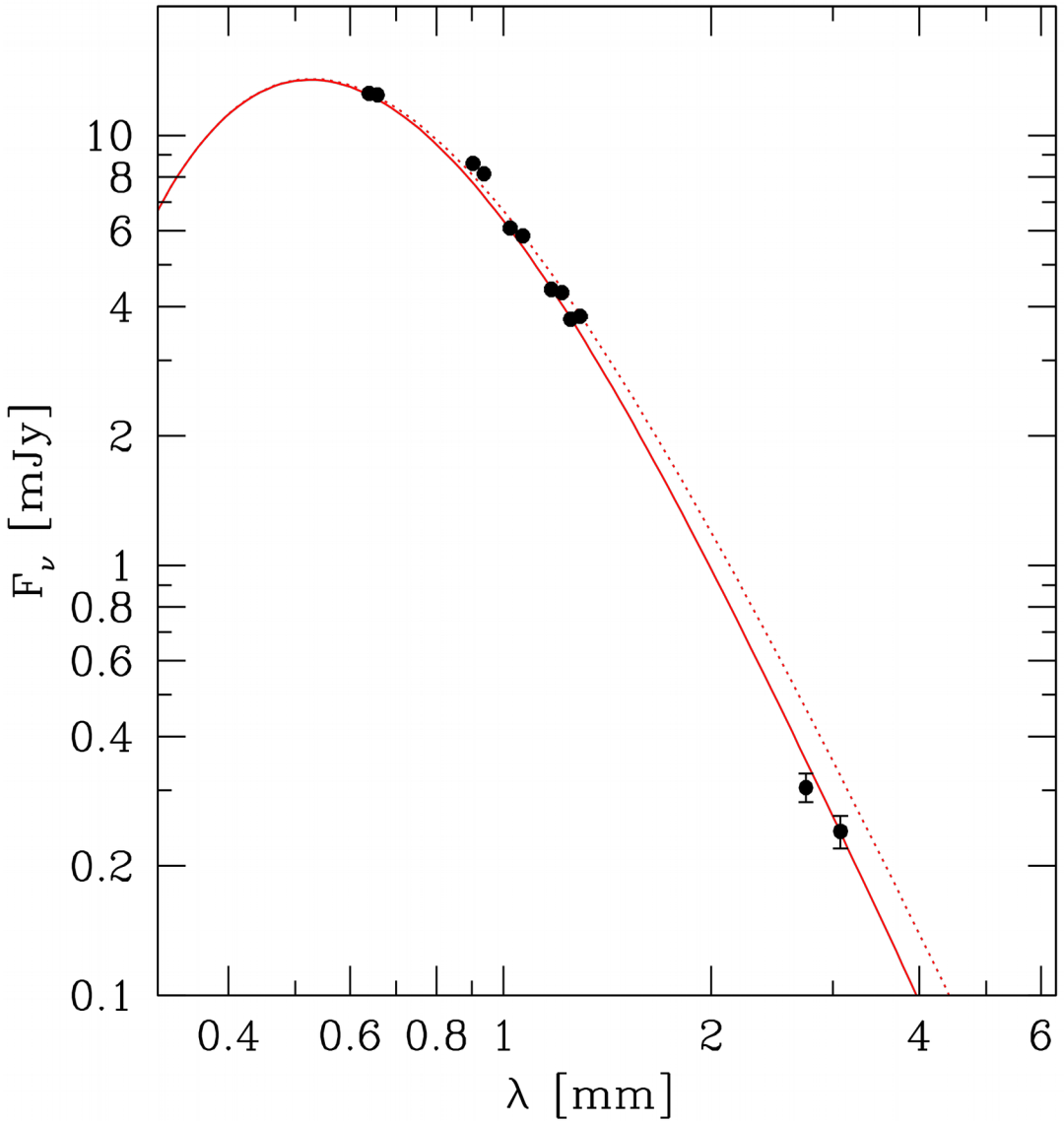
CO(19-18)

ISM in quasar hosts at z>6



Multiple H_2O lines, OH

ISM in quasar hosts at z>6



Dust

T_{dust}=45 K

M_{dust}=7e8 M_o

Insight on ISM properties at z~6.5

From CO: two phases

Bulk:

M_{H2} > 2e10 M_{sun}

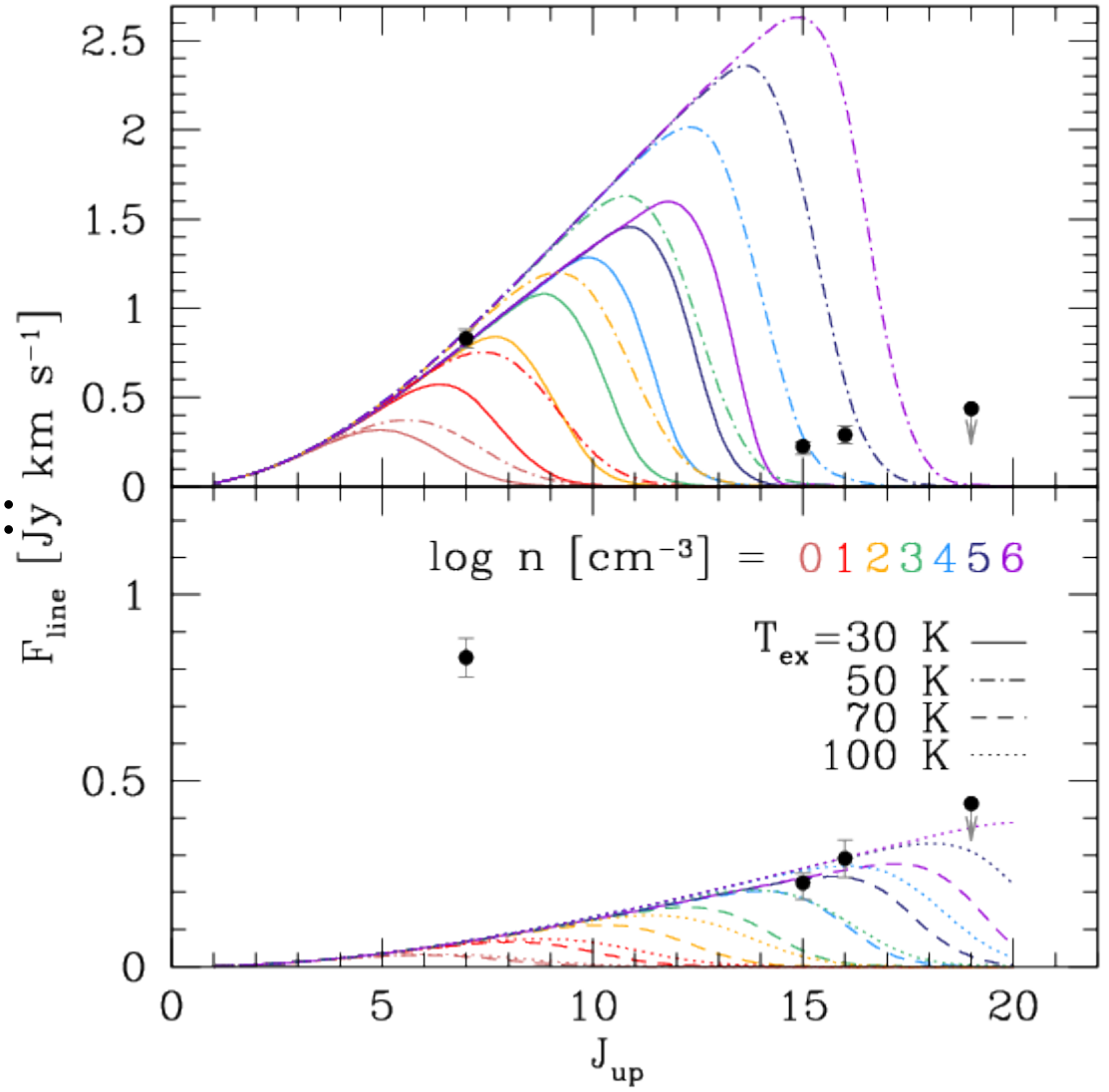
n_{H2}~200,000 cm^{-3}

High-excitation component:

M_{H2} ~1.5e9 M_{sun}

n>100,000 cm^{-3}

T_{ex}>50 K



[work in progress]

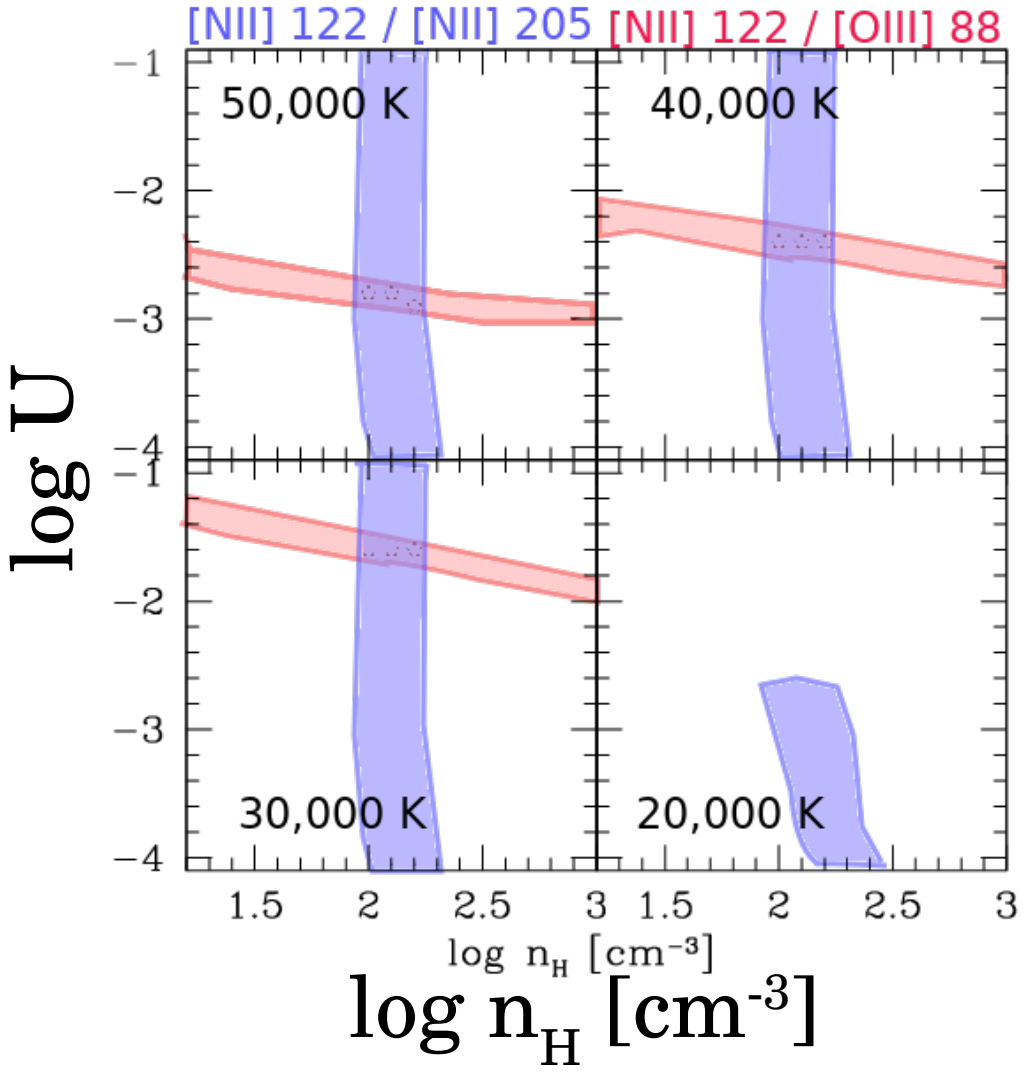
Insight on ISM properties at z~6.5

From [NII] 122/205:

n_{HII}=100-200 cm^{-3}

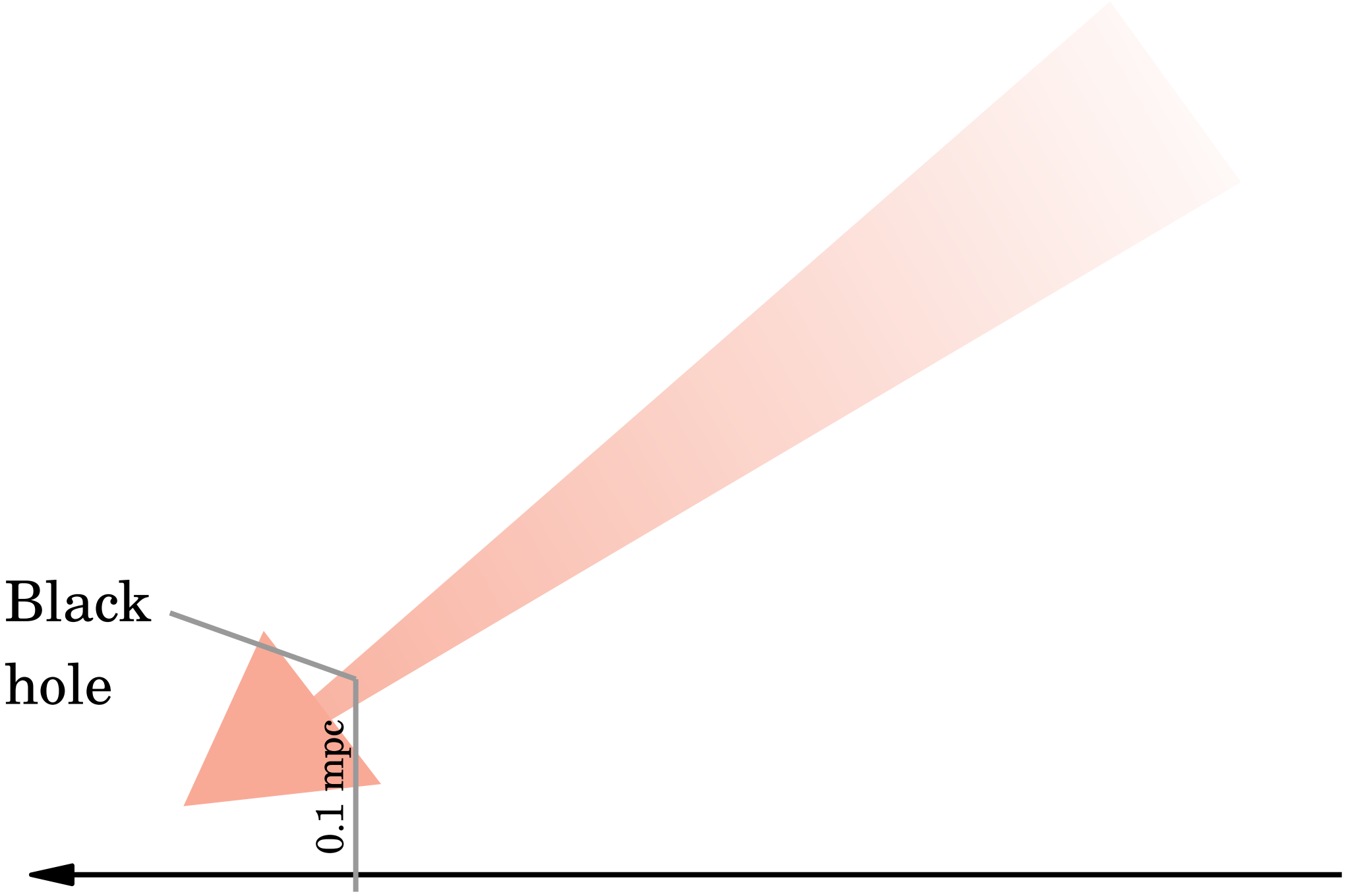
From [OIII]/[NII]:

hard ionization field

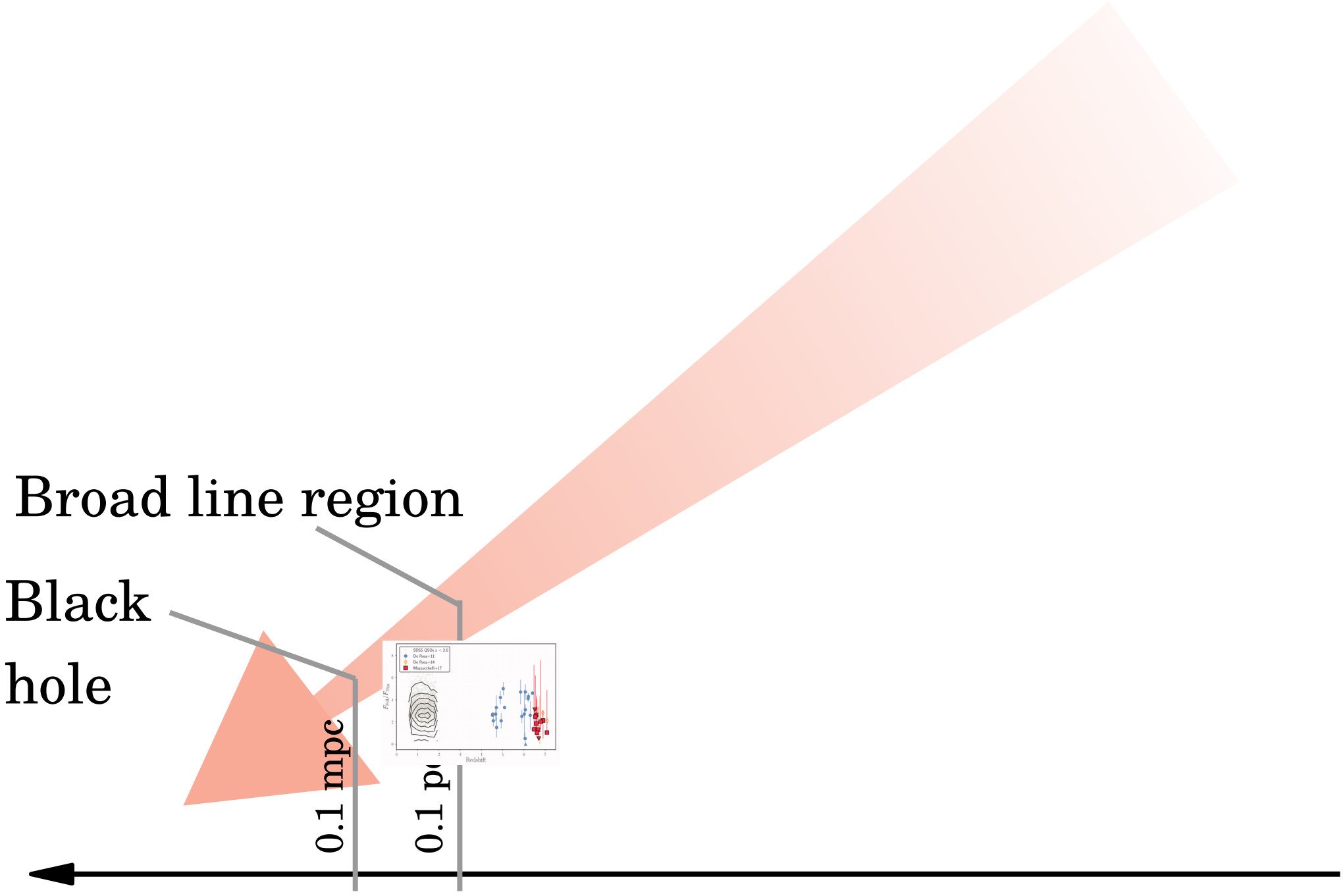


[work in progress]

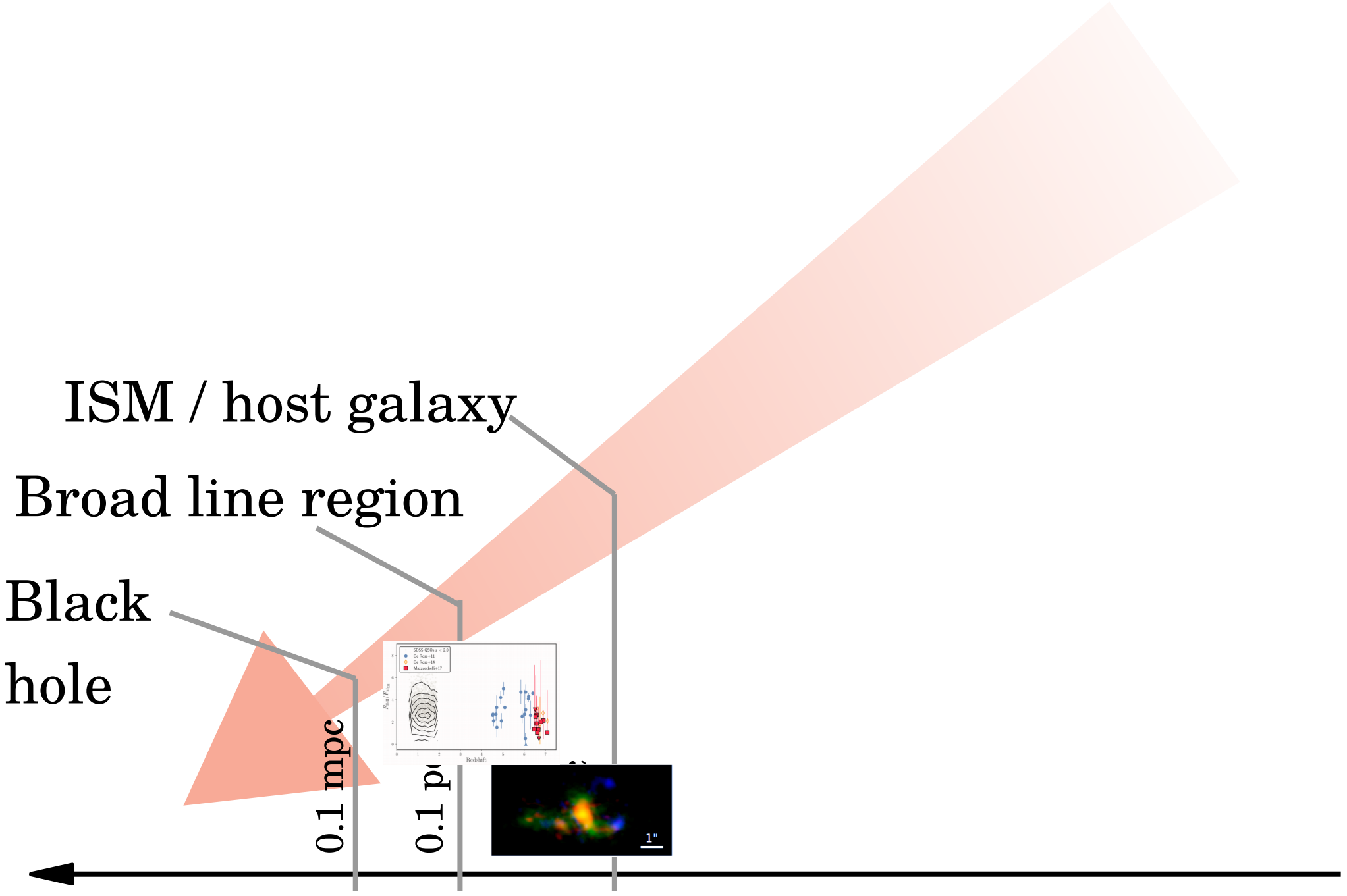
Conclusions



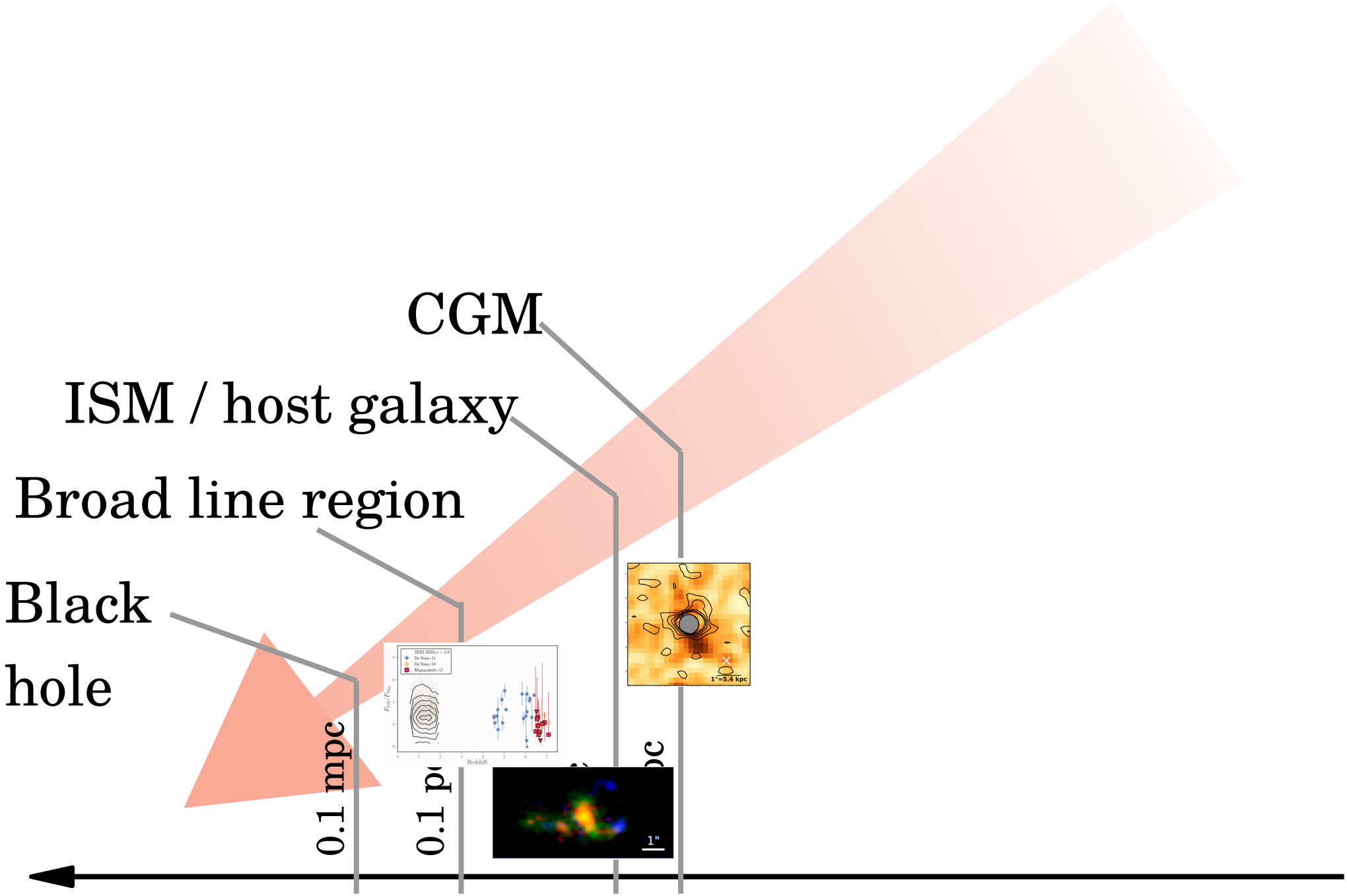
Conclusions



Conclusions



Conclusions



Conclusions

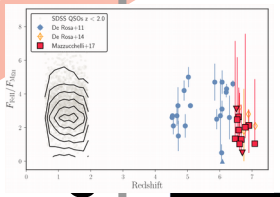
Small-scale structures

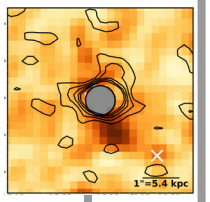
CGM

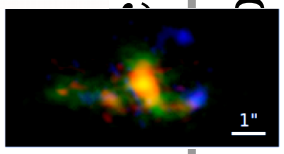
ISM / host galaxy

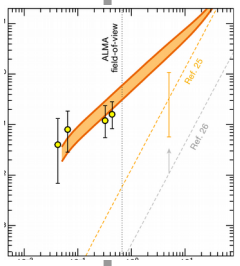
Broad line region

Black hole









0.1 mpc

0.1 p

pc

Conclusions

Large-scale clustering

Small-scale structures

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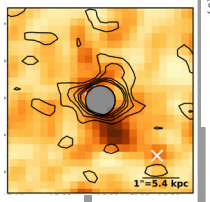
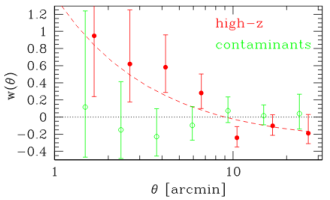
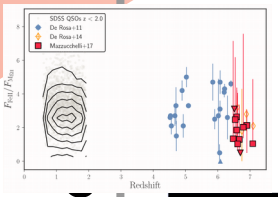
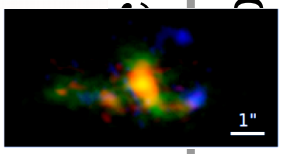
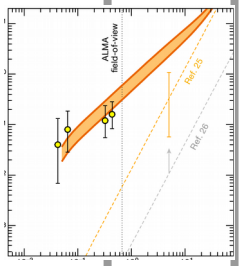
Black hole











0.1 mpc

0.1 p

pc

Conclusions

IGM / reionization

Large-scale clustering

Small-scale structures

CGM

ISM / host galaxy

Broad line region

Black hole