High-redshift quasars and the epoch of reionization

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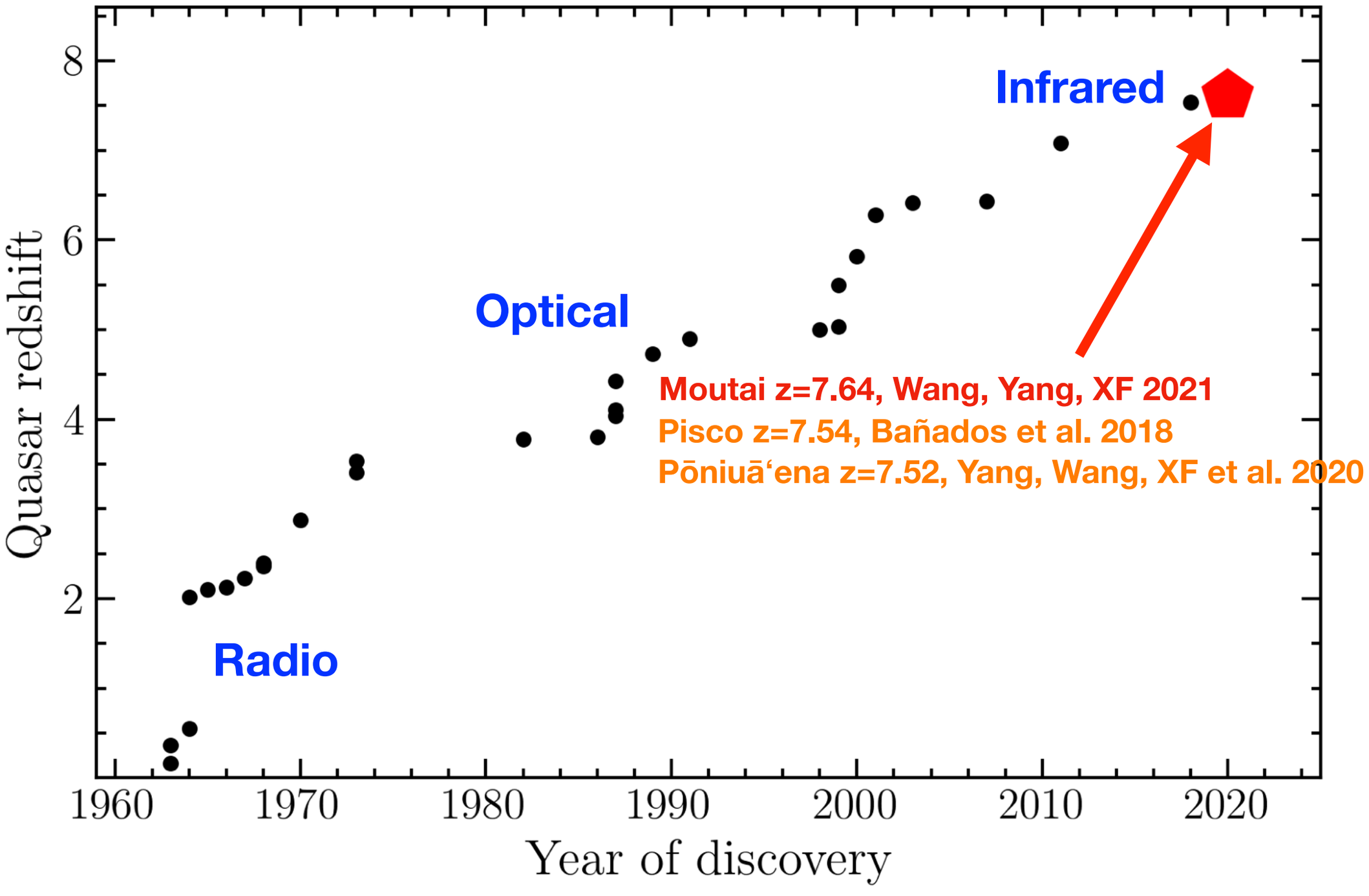
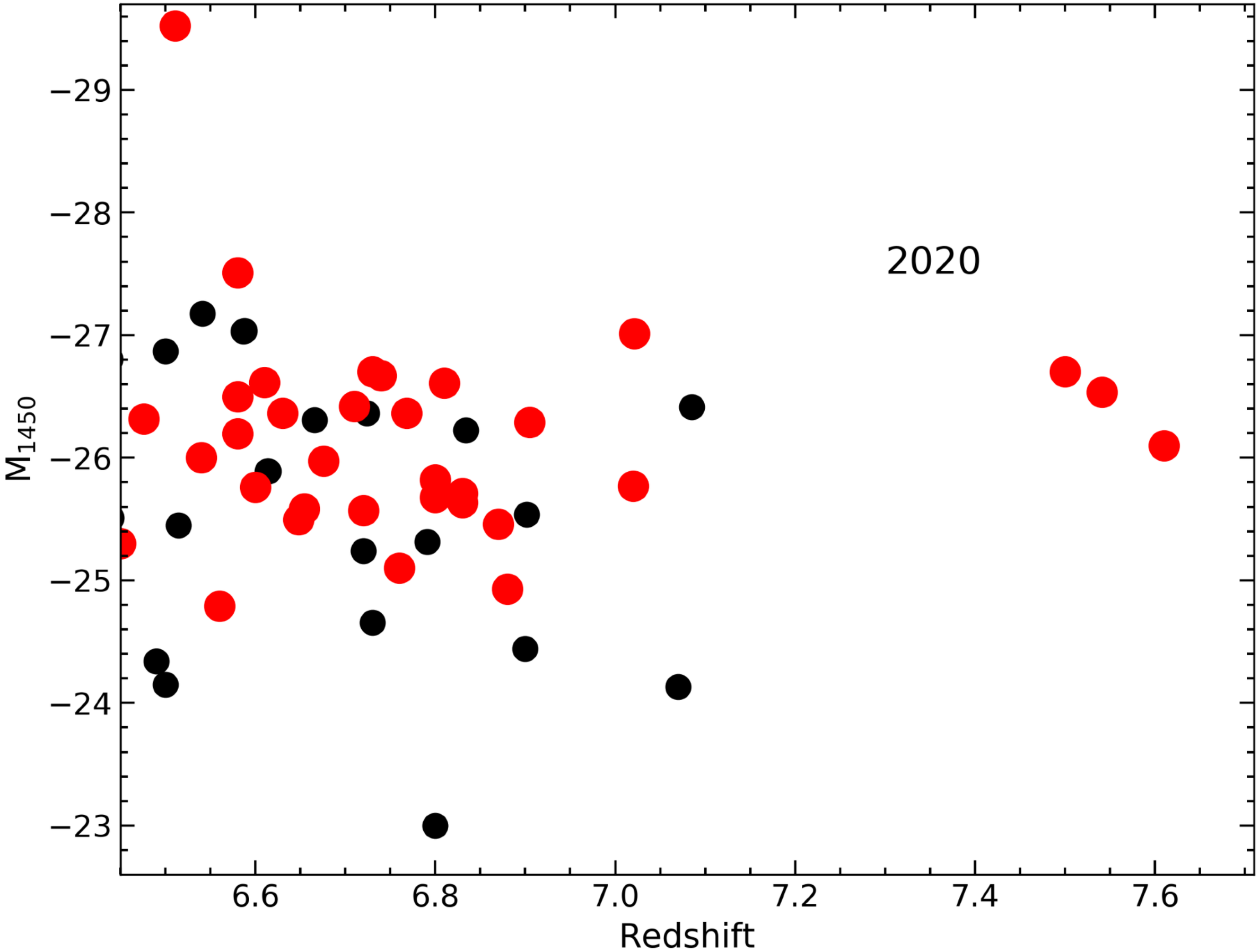
Probing early universe with high-redshift quasars

- Epoch of the first luminous quasars:
  - **can we reach z>10?**
- Growth of early supermassive black holes:
  - **massive BH seed needed?**
- Environment of early quasars:
  - **do they live in the most overdense environment and most massive galaxies?**
- History of reionization:
  - **when? sources? uniform or patchy?**

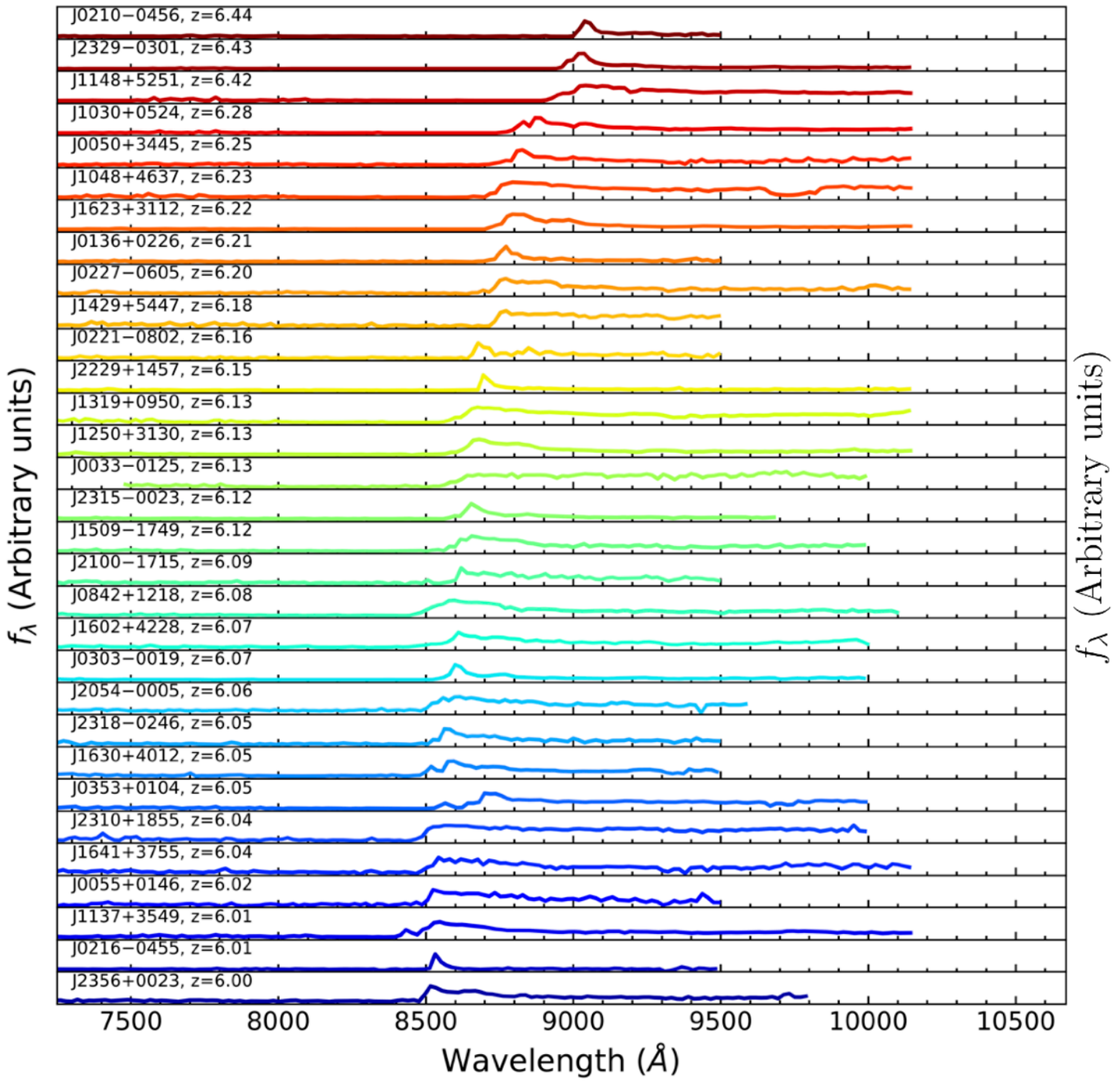
The Highest Redshift Frontier Now




2020
−29
−28
−27
−26
−25
−24
−23
M_{1450}
6.6
6.8
7.0
7.2
7.4
7.6
Redshift

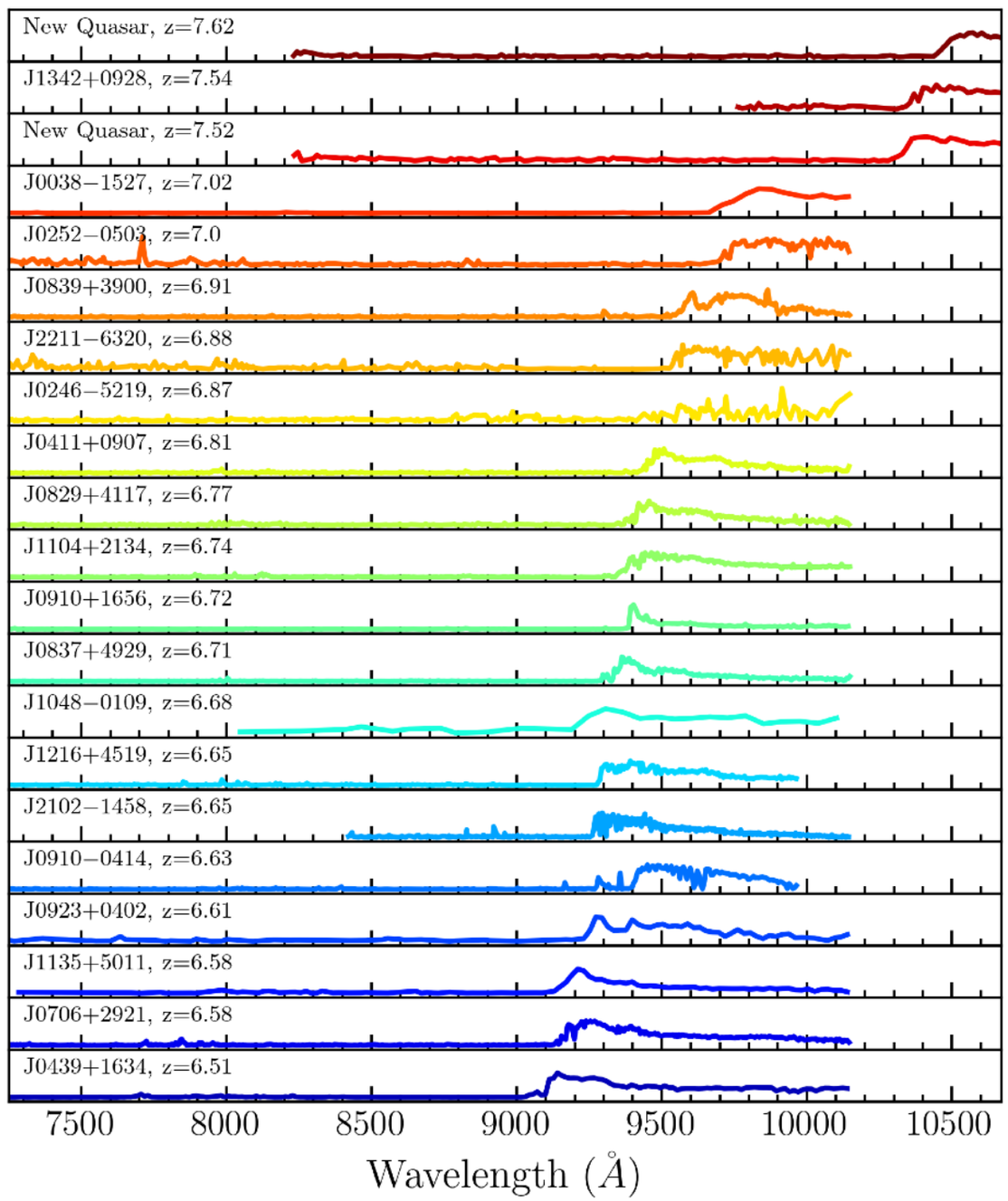
Deep into the Reionization Epoch

Quasars at the End of Reionization



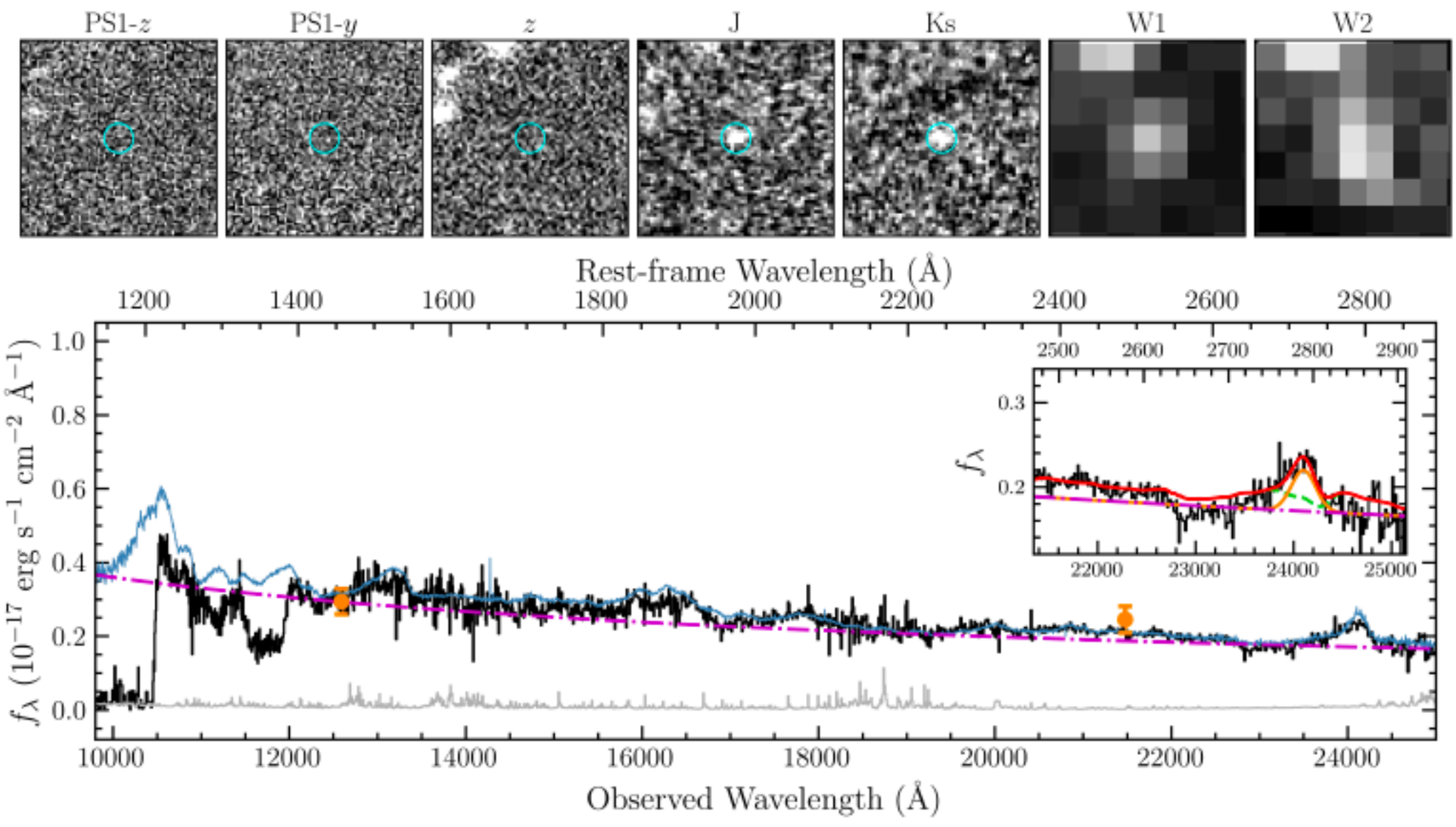
From 2000 to 2010

Reionization-Era Quasars



From 2011 to Now

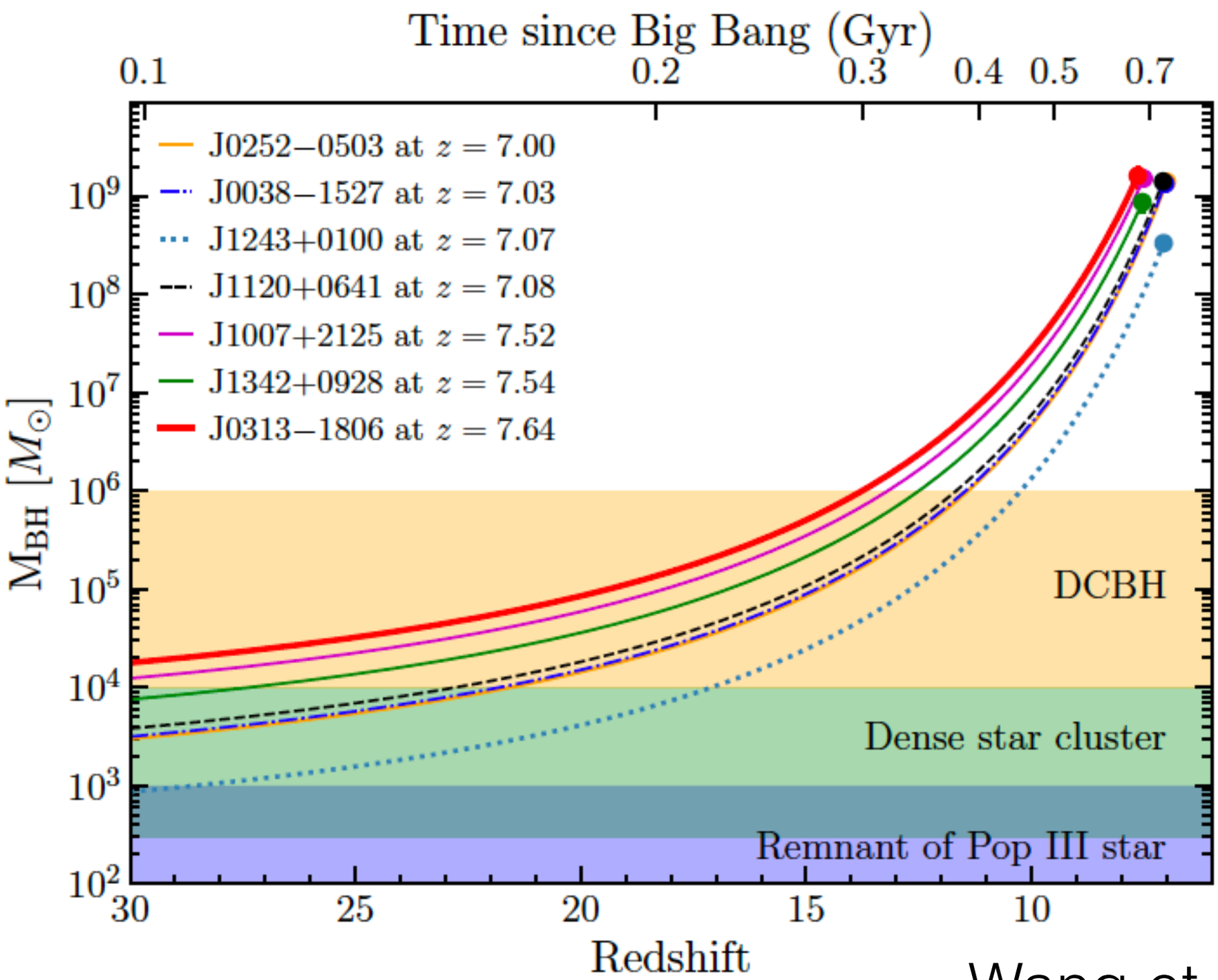
New Redshift Record Holder: J0313-1806 at z=7.64



BH Mass: 1.6x10^9 M_sun

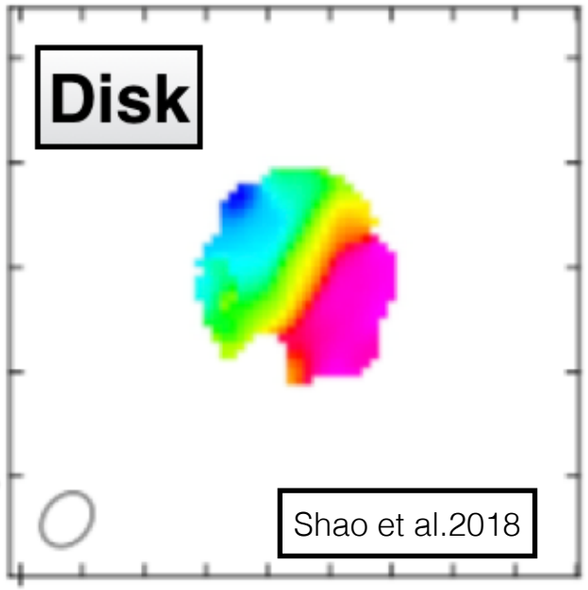
Wang et al. 2021

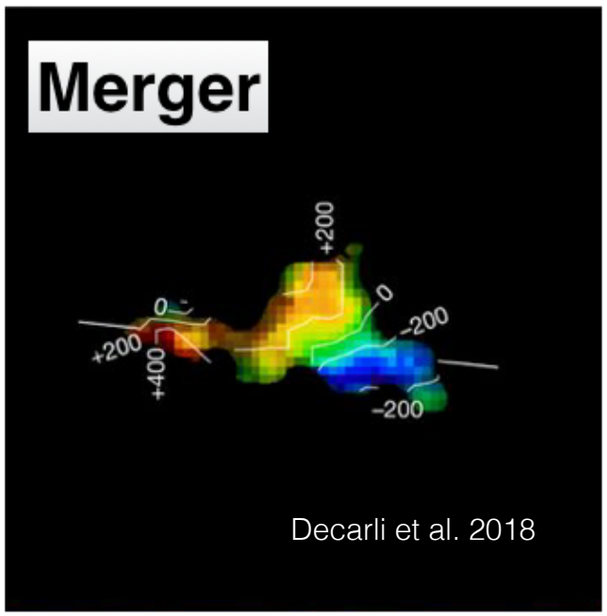
Constraints on BH seeds

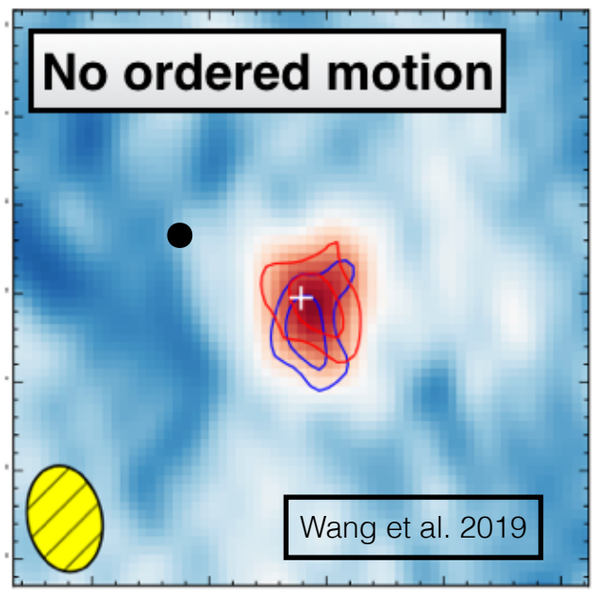


Wang et al. 2021

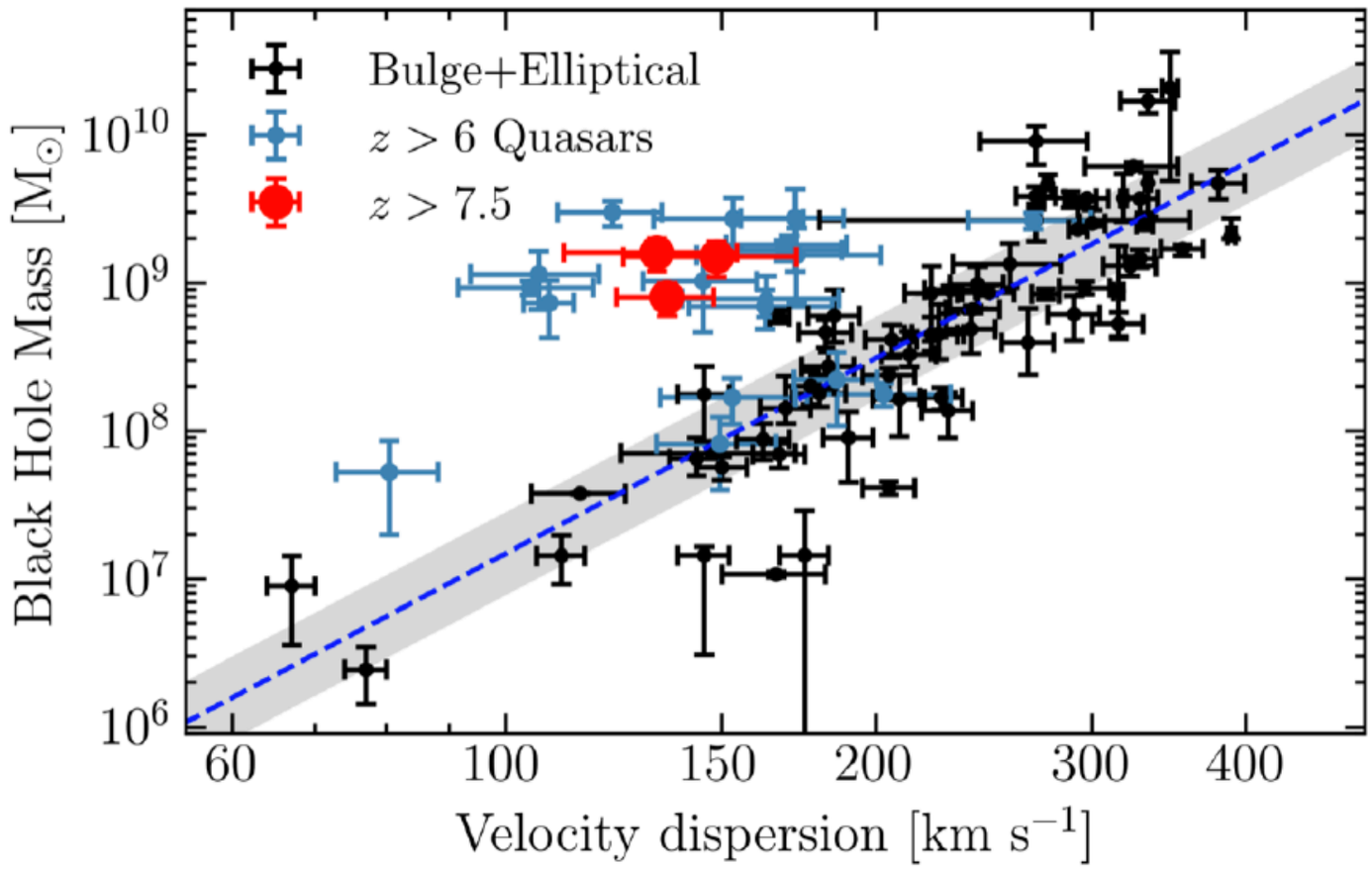
Co-evolution of BHs and galaxies? Or not?







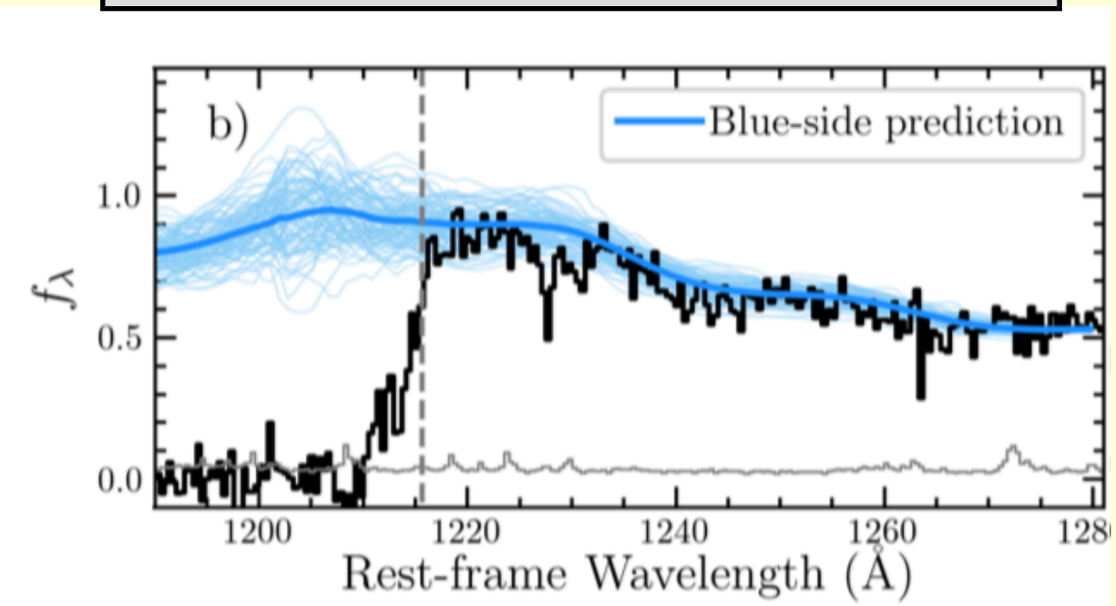
- Kinematics from ALMA/[CII] with sub-kpc spatial resolution
- **Diversity in host galaxy properties**
- SFR ~100 - few x1000 M_sun/yr -> sites of massive galaxy assembly
- But with modest dynamical mass:
  - **on average ~order of mag below local M-sigma relation**
- **No strong correlation between BH and SFR/mass of hosts**



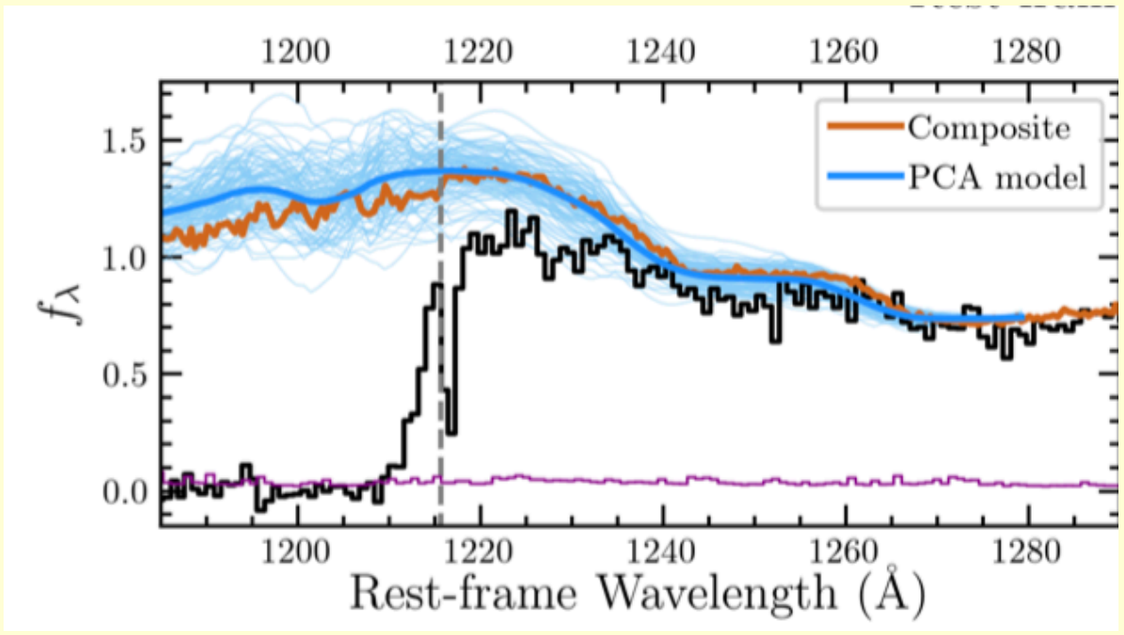
Wang+21

Patchy Reionization?

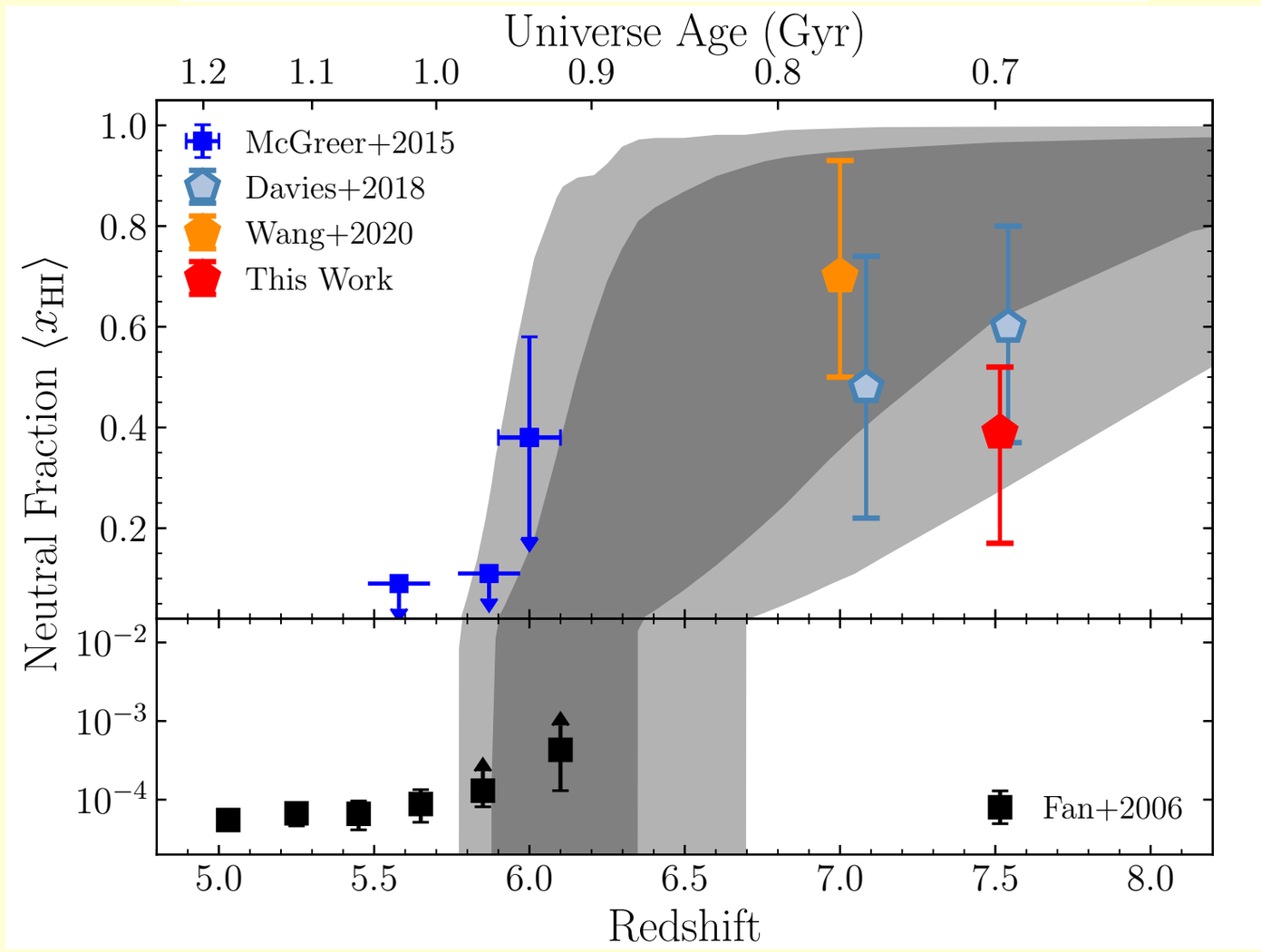
z=7.5: weak Ly a damping wing



z=7.0: strong Ly a damping wing



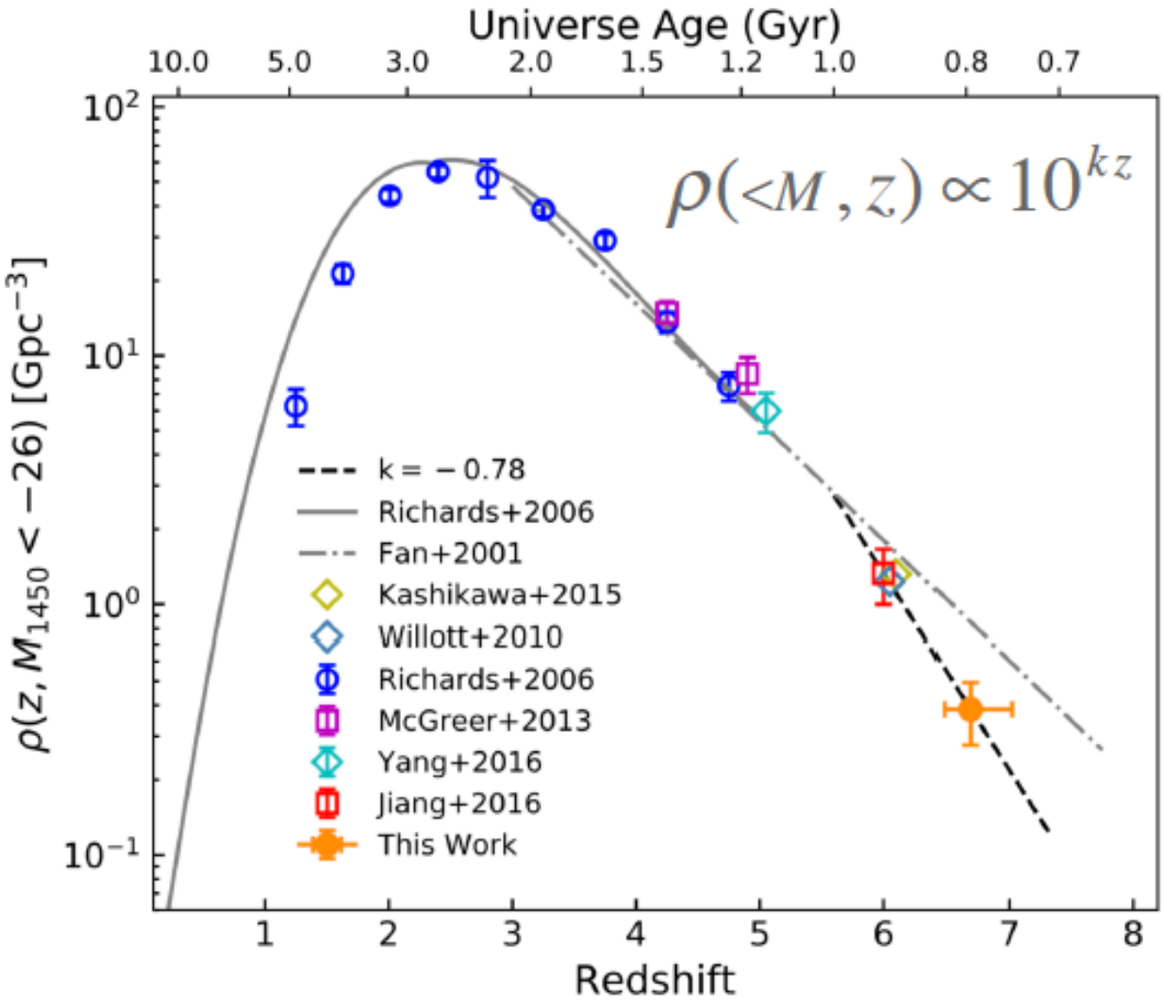
Evolution of neutral fraction

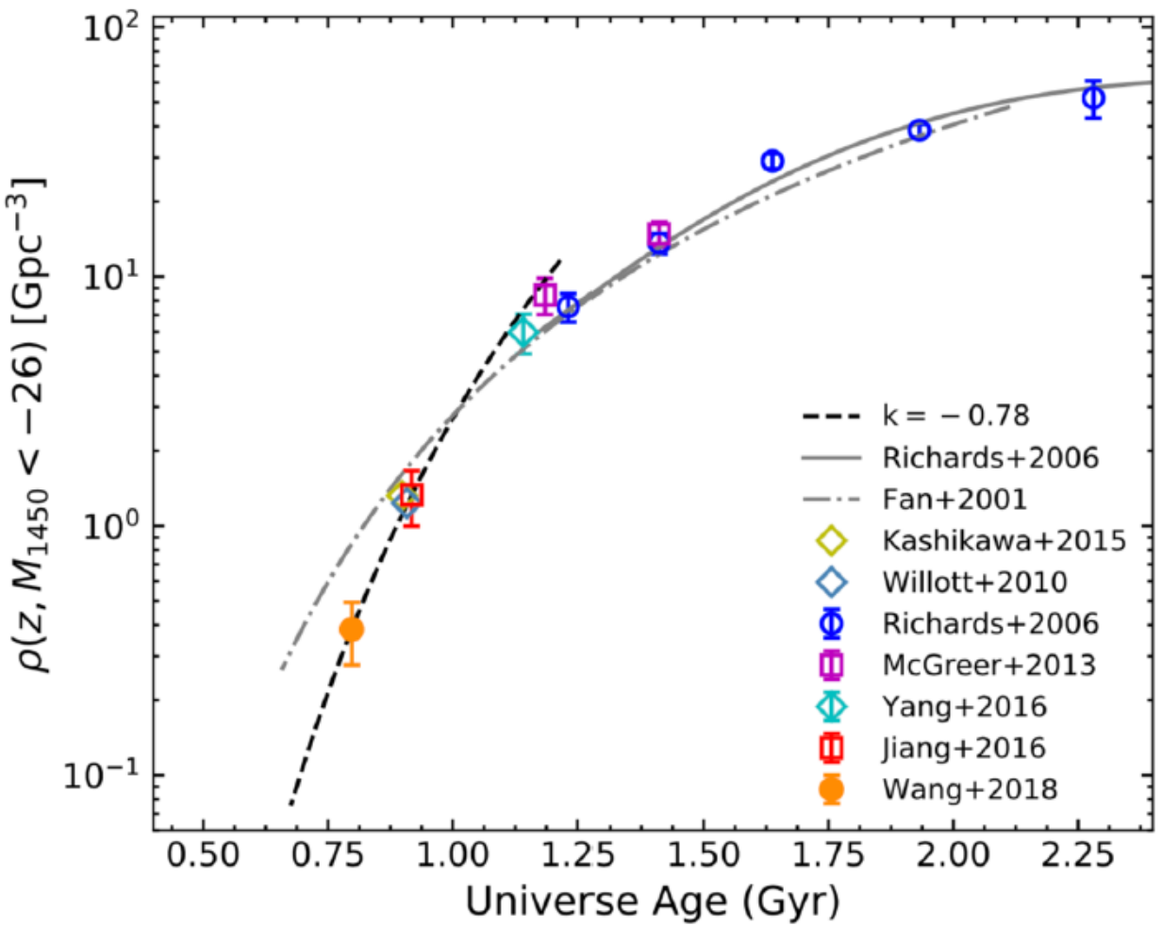


Wang+20, Yang+20

closing in to the era of the first quasars

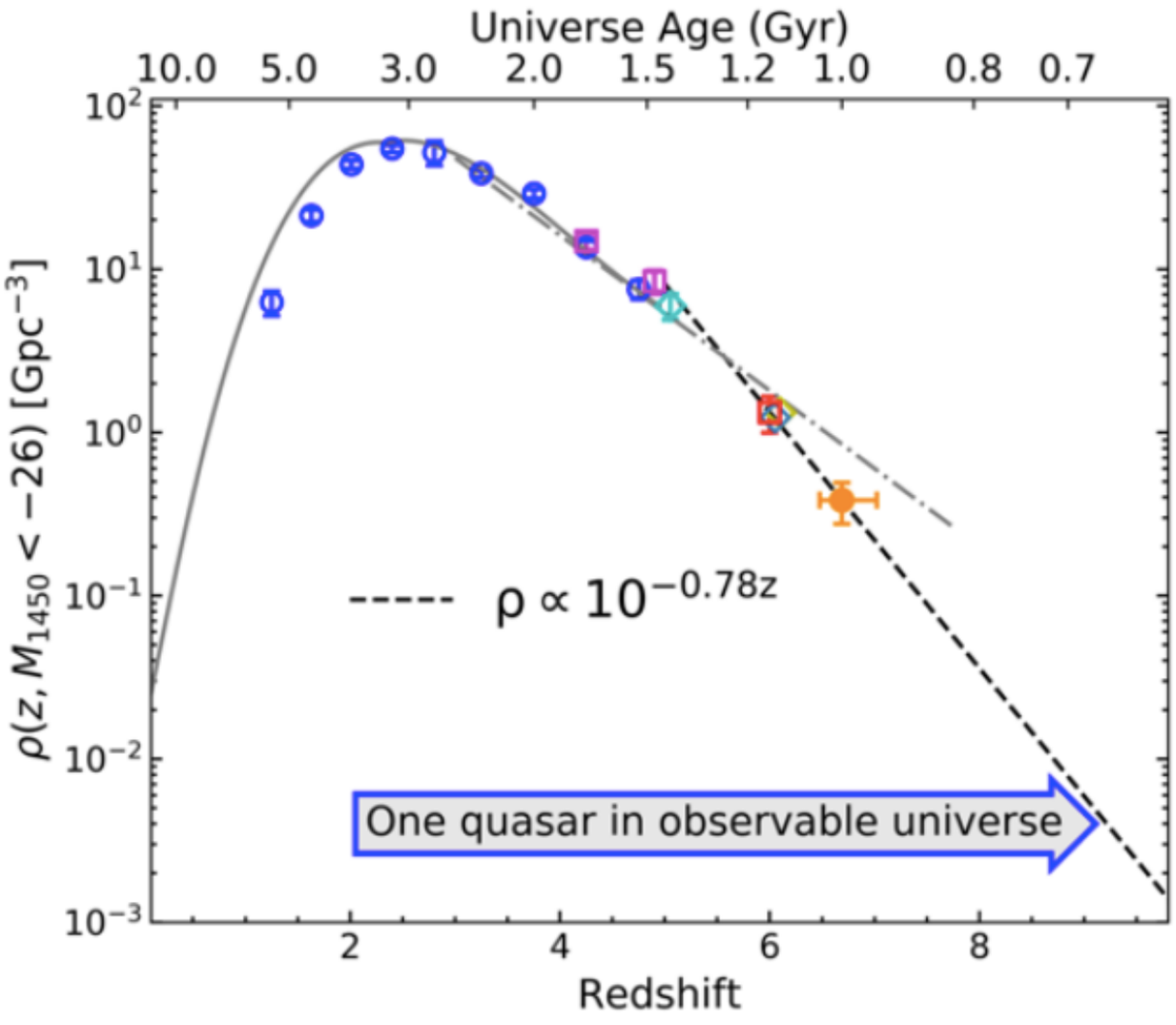
Wang+19

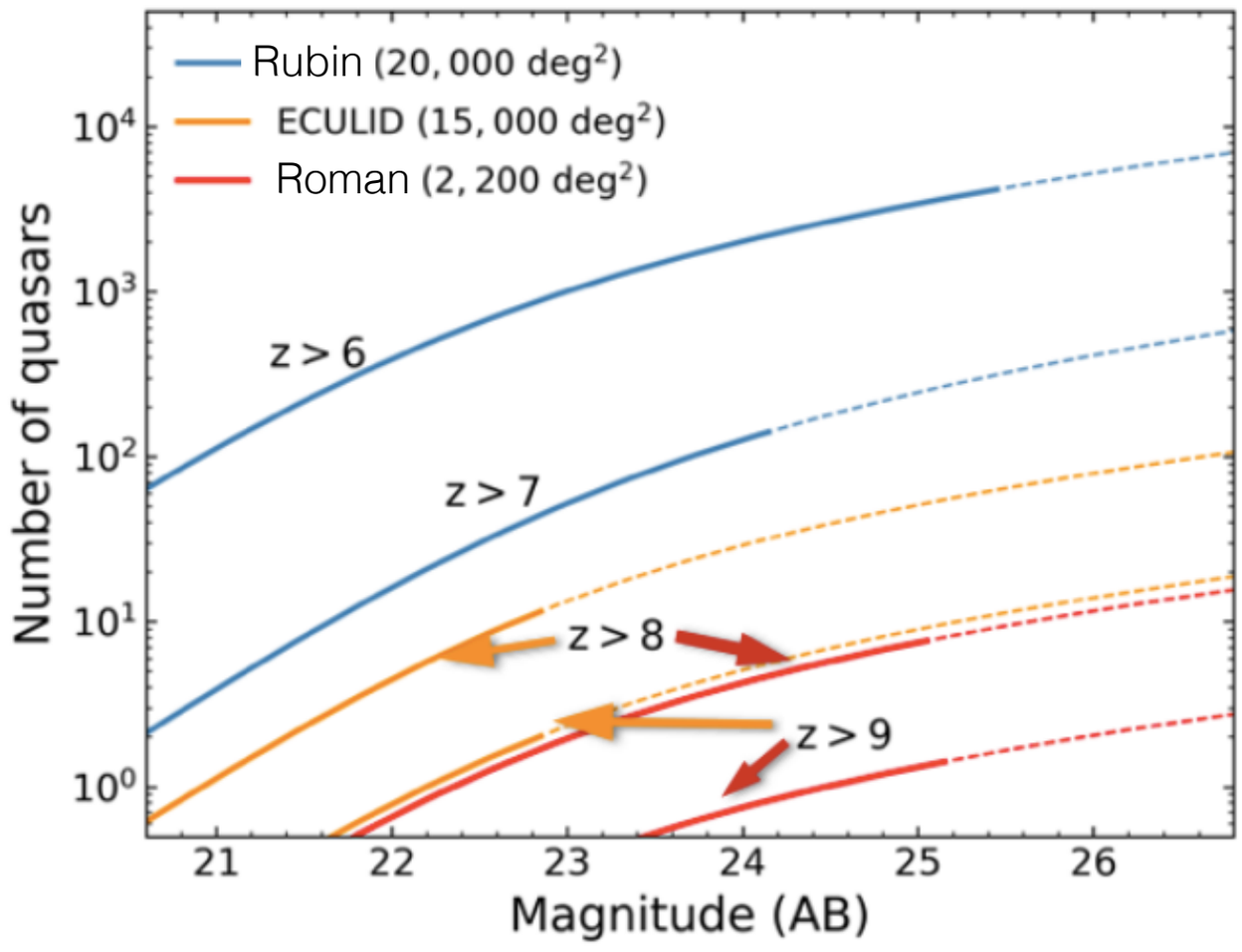




- **first determination of quasar luminosity function at z~7**
- quasar density evolution accelerated at z>6
- e-folding time for quasar density growth: 80 Myr (delta z = 0.6)
- comparable to Eddington timescale (45 Myr)
- **quasar population growth is accretion-limited**

the first quasars

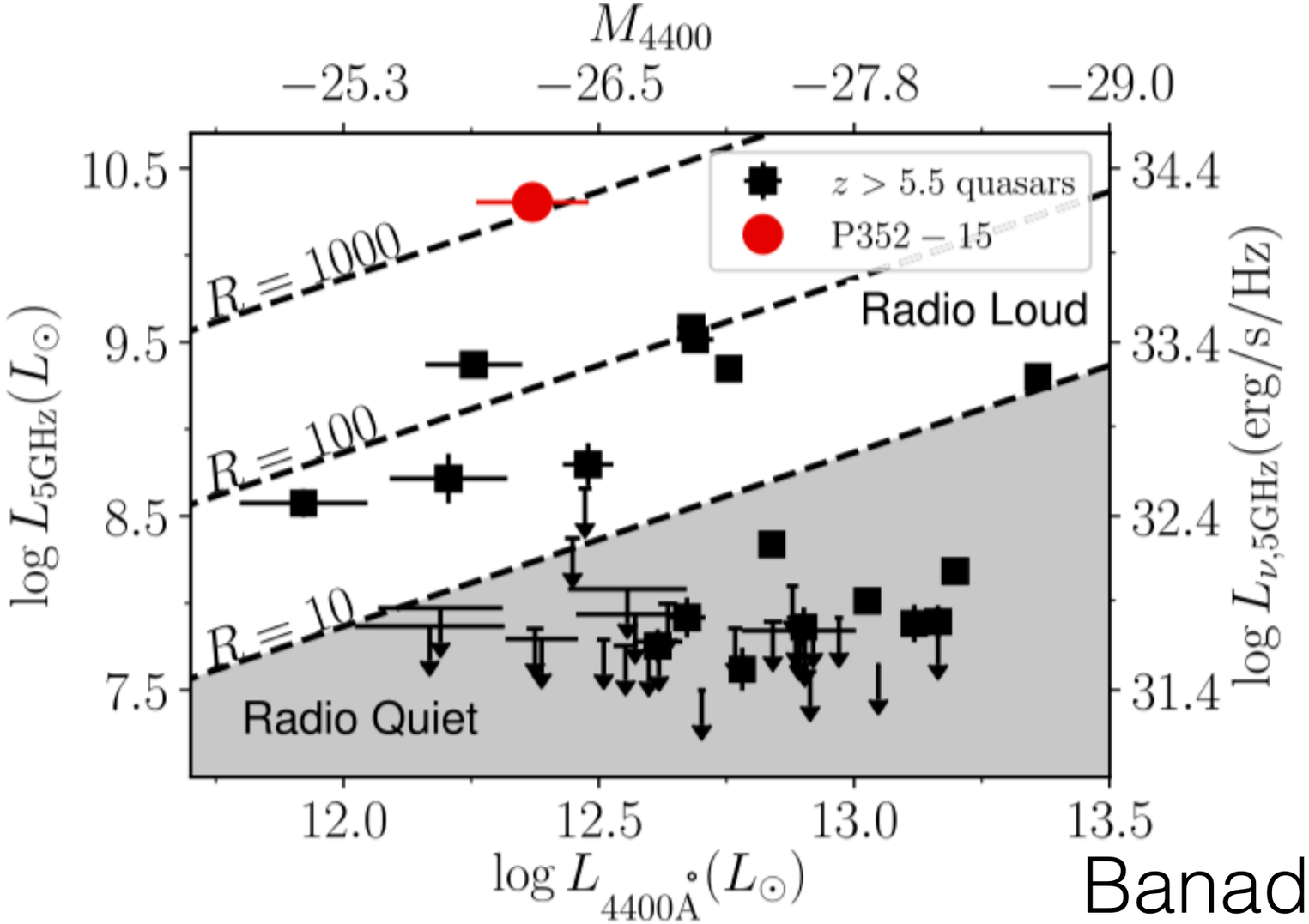




- **only ~1 quasar with billion M_sun BH (M<-26) at z>9 in the observable universe -> the first quasars**
- **find them? Euclid/Roman + Rubin/LSST**
- **identify them? need spectroscopic identification of faint (AB~23-25) in IR -> JWST? ELTs?**

the first radio-loud quasars

- radio-loud fraction <=10% at z>6; no strong evolution in flux-limited sample
- radio-loud quasars at z>6: 21cm forest to probe reionization
- ngVLA + deep-IR wide-field survey for discovery and followup



Banados+18

Summary

- Combination of deep optical, near-IR and mid-IR photometric selection allows the first systemic surveys of luminous quasars at z>=7, with recent record-breaking discoveries of z>7.5 quasars

- Detection of Gunn-Peterson damping wings suggests a high IGM neutral fraction at z>7, and a rapid reionization at z=6-8 and considerable scatter

- Ten billion solar mass black holes at the end of reionization: direct collapse of large mass seed black holes in early universe

- The most distant quasars live in diverse galactic environment

- rapid decline in quasar density at z>6: first luminous quasar in the observable universe at z~9

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