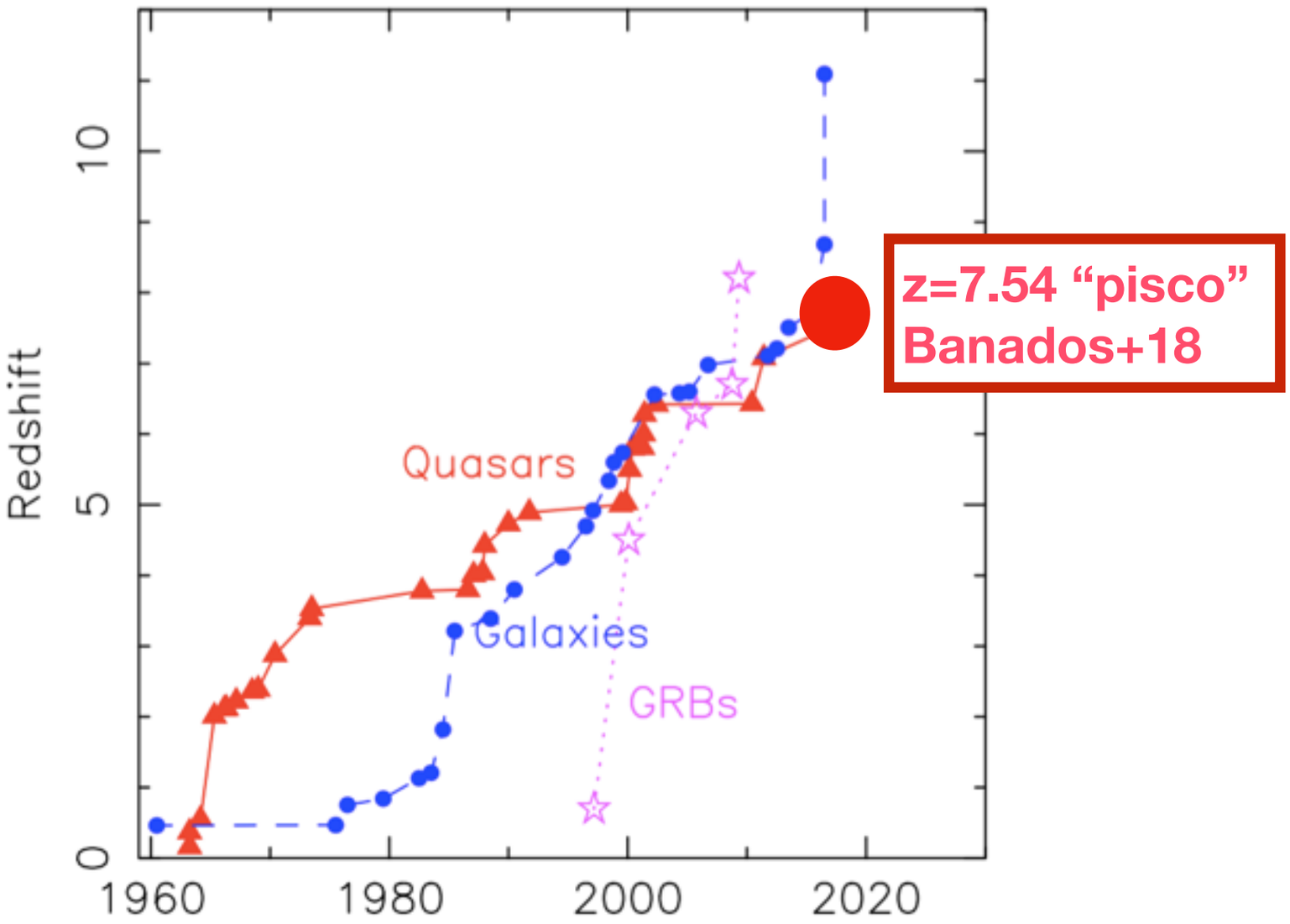
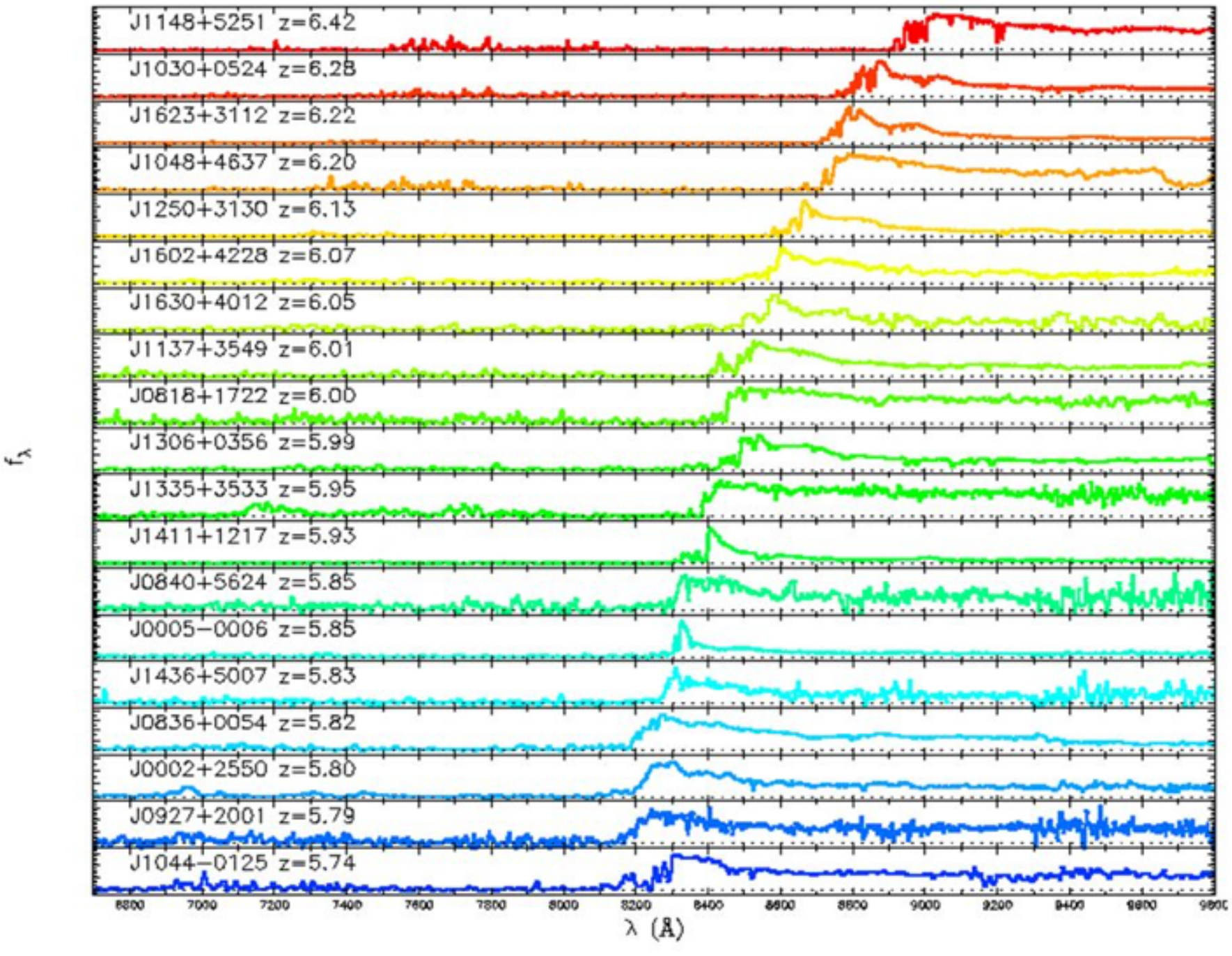
The Most Distant Quasars

Xiaohui Fan (Arizona)

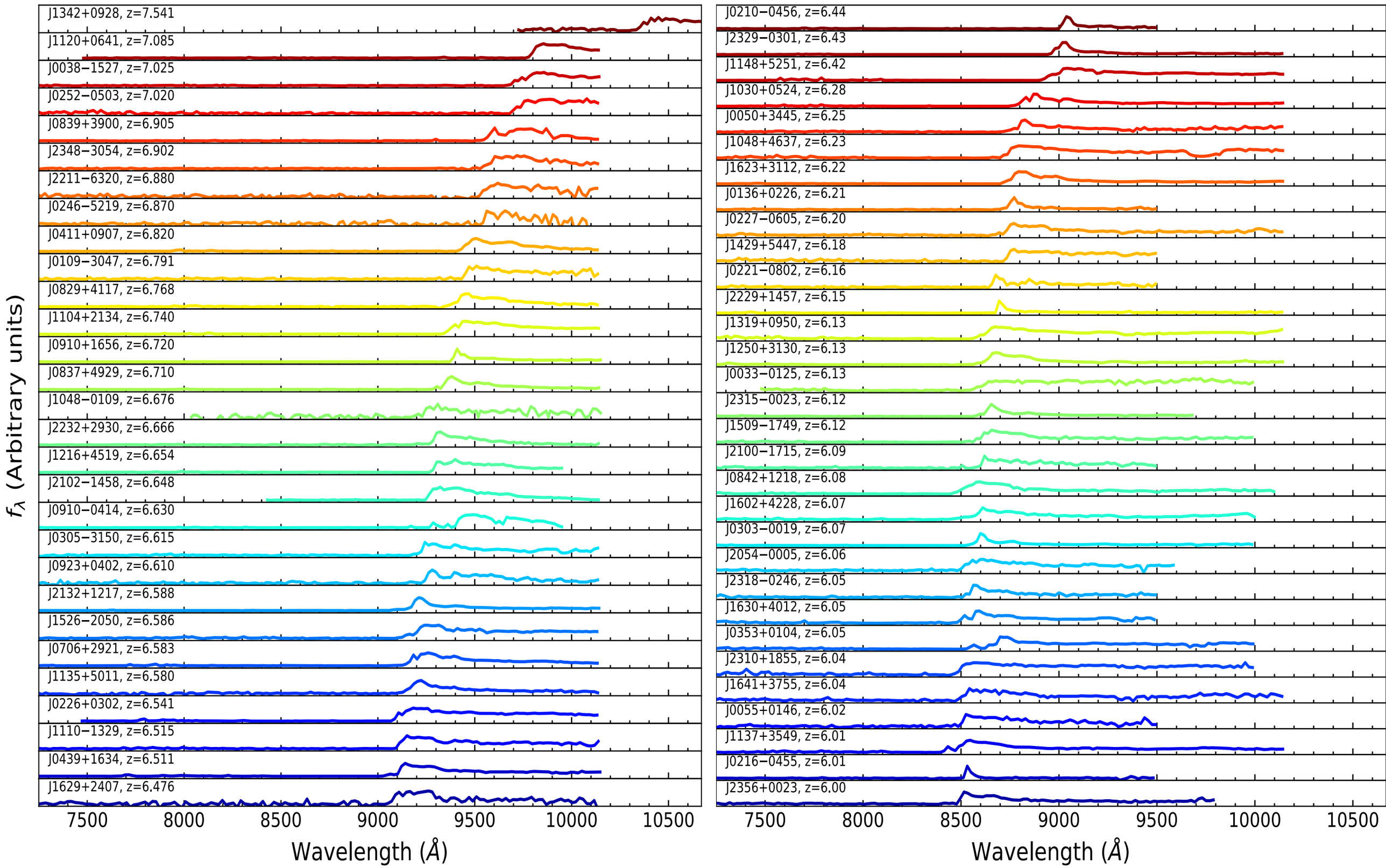
The highest redshift frontier now



z~6 quasars: 2006



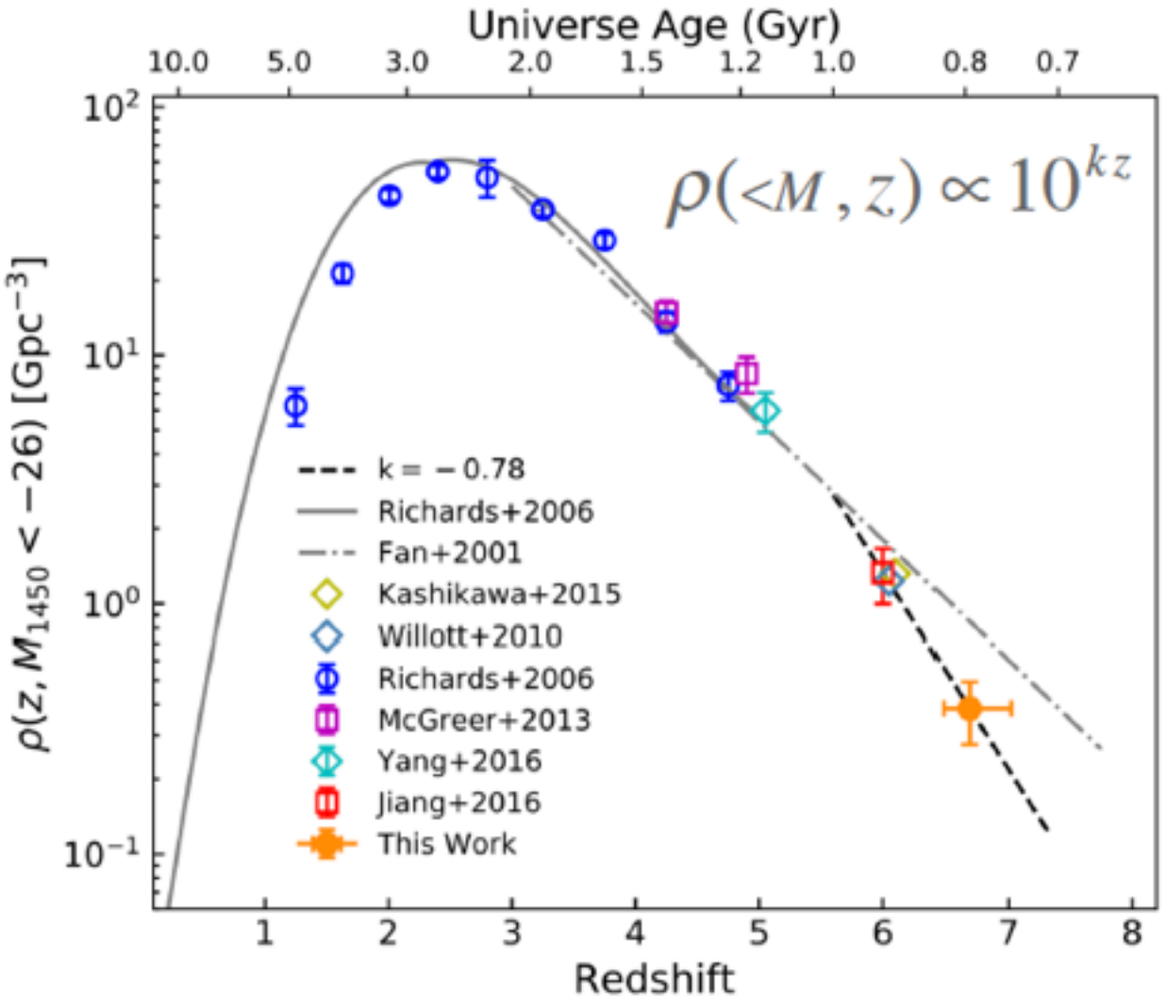
Now… a few more reionization-era quasars



>500 at z>5; ~150 at z>6; >=6 at z>7

closing in to the era of first quasars

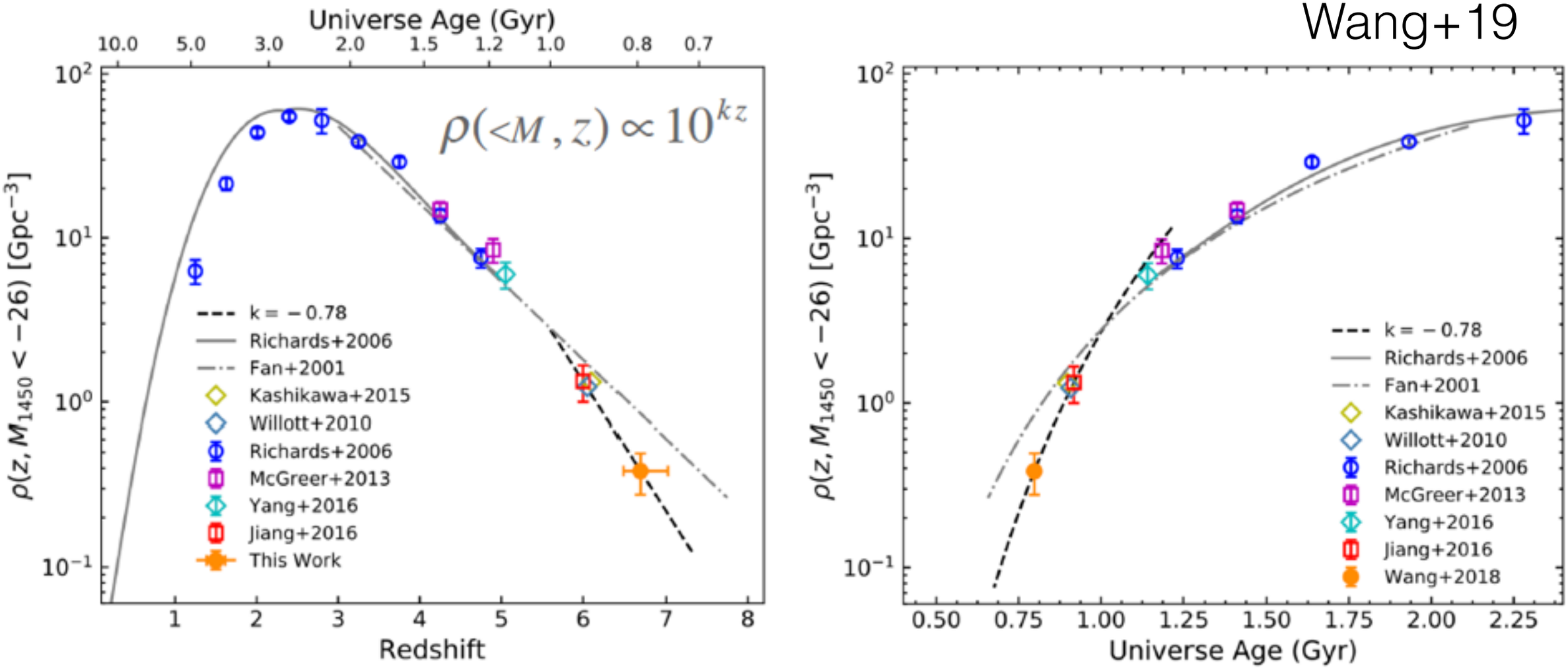
Wang+19



- **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**

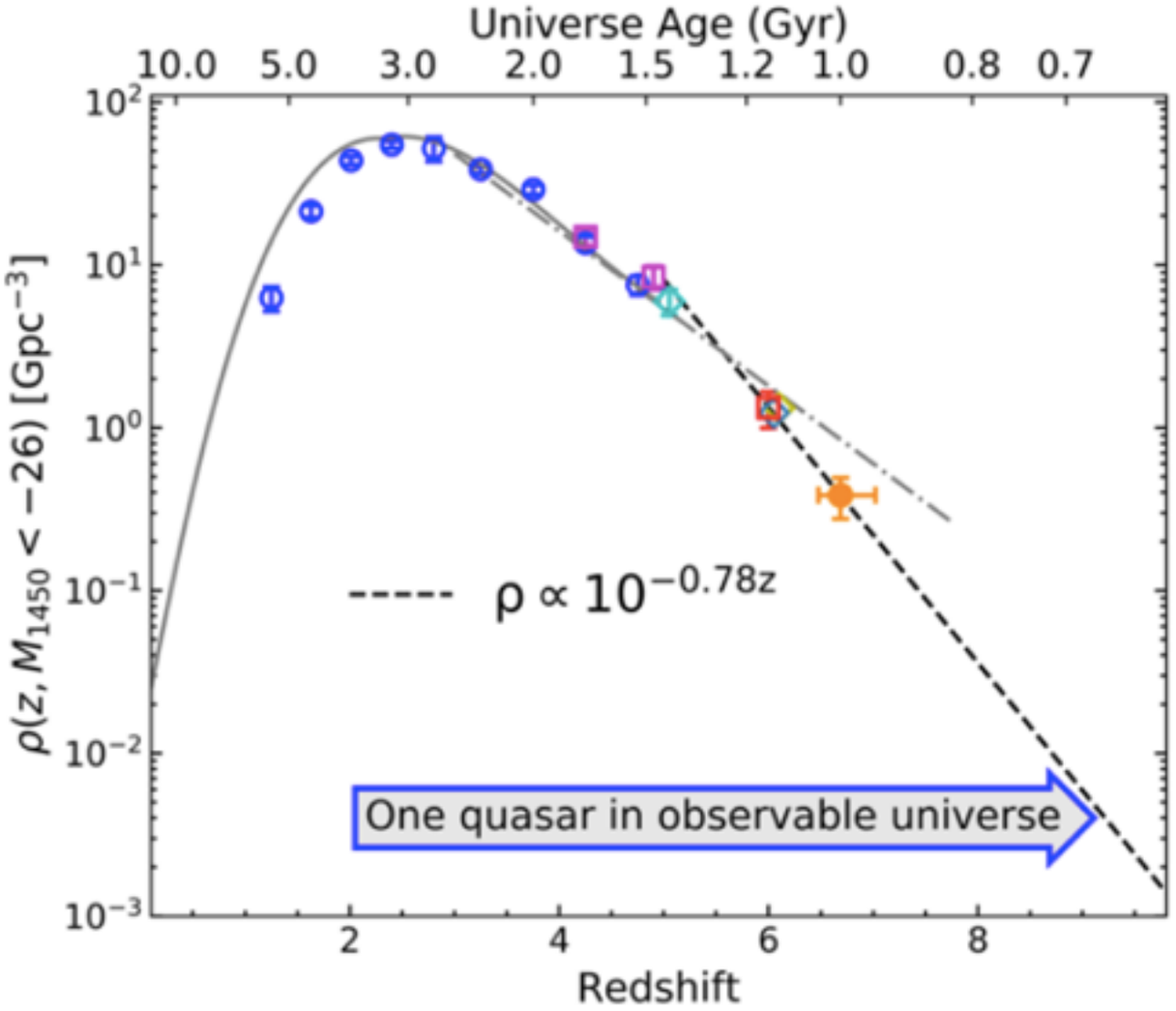
closing in to the era of first quasars

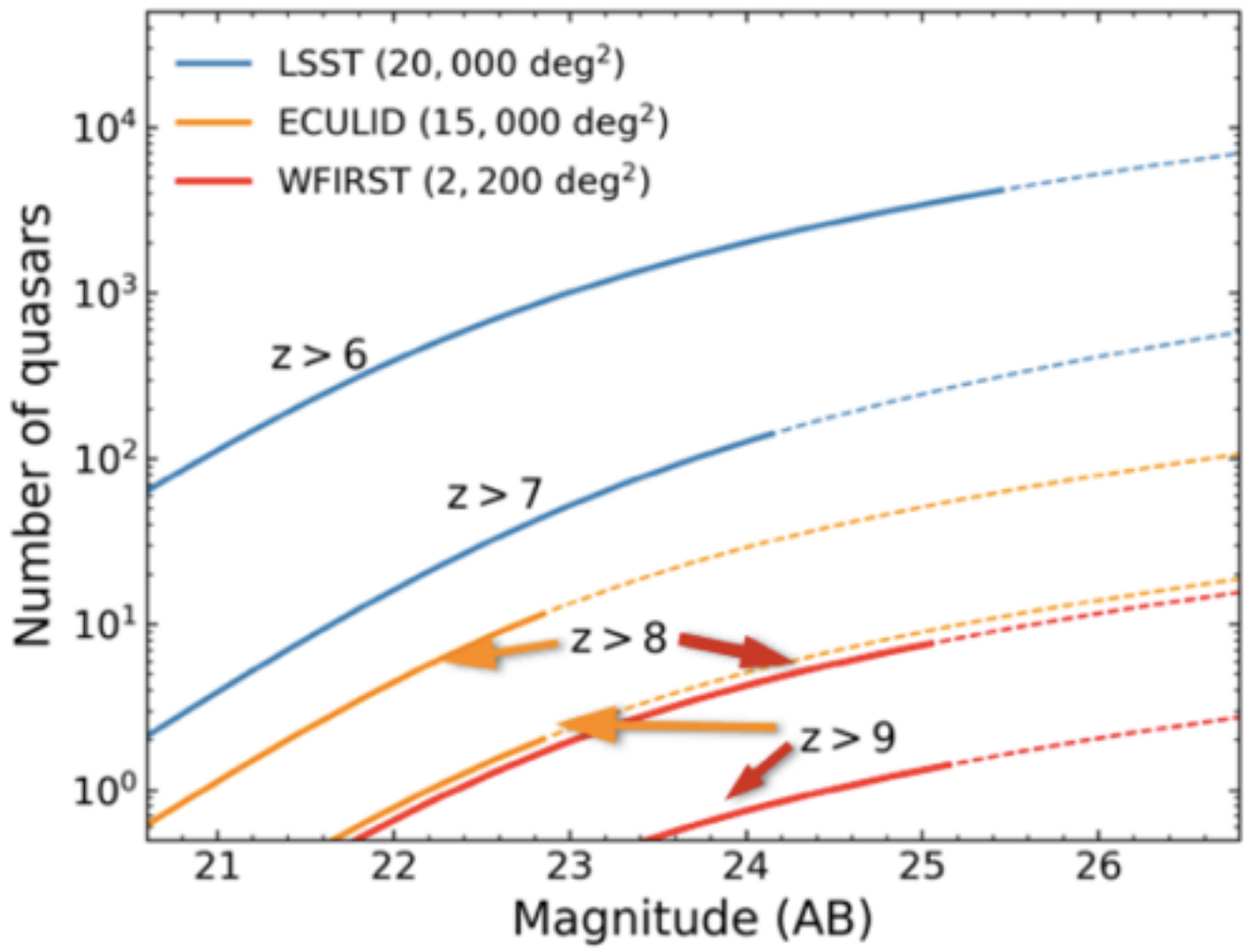
Wang+19



- **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**

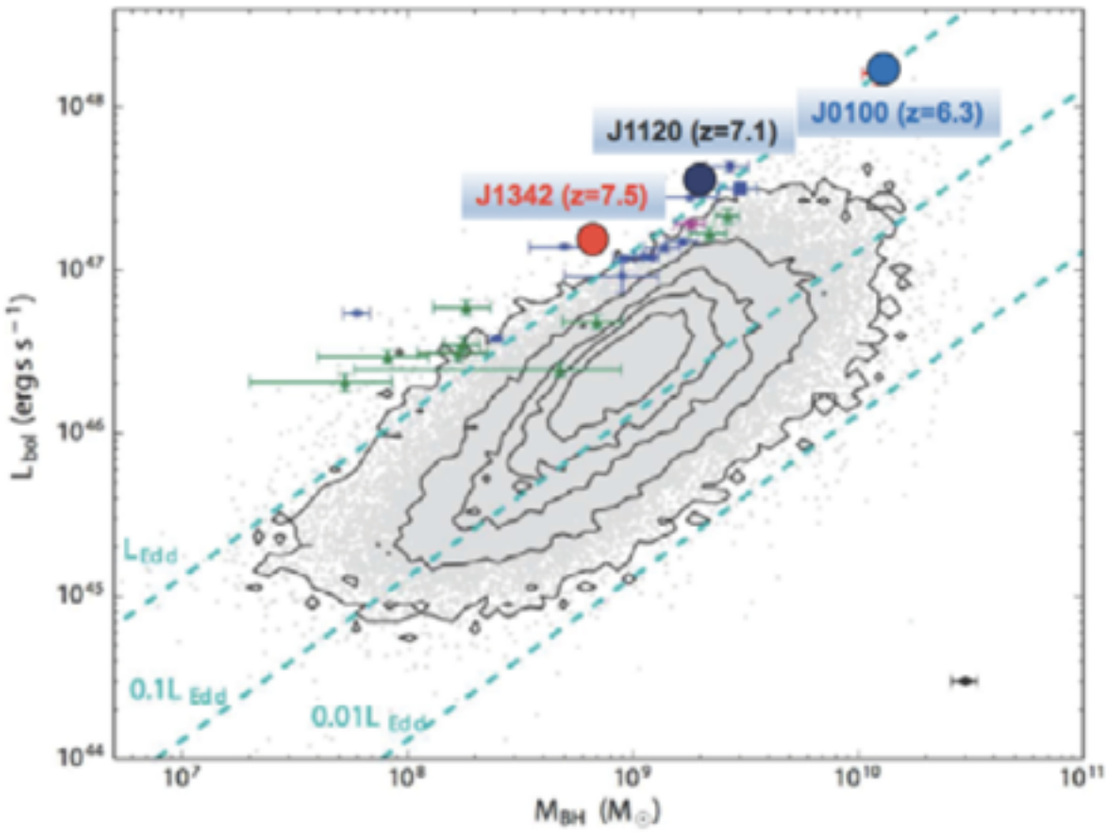
the first quasars

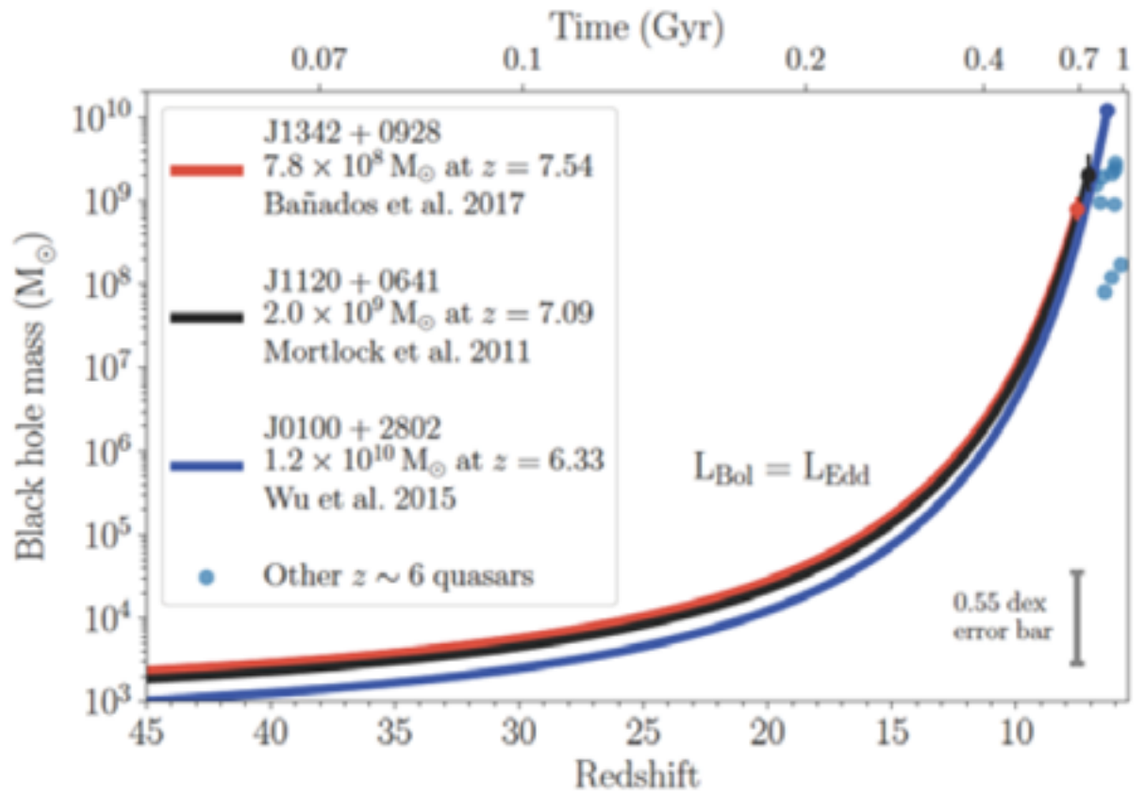




- **only ~1 quasar with billion M_sun BH (M<-26) at z>9 in the observable universe -> the first quasars**
- **find them? Euclid + LSST**
- **identify them? need spectroscopic identification of faint (AB~23-25) in IR -> JWST? ELTs?**

growth timescale of the earliest supermassive black holes

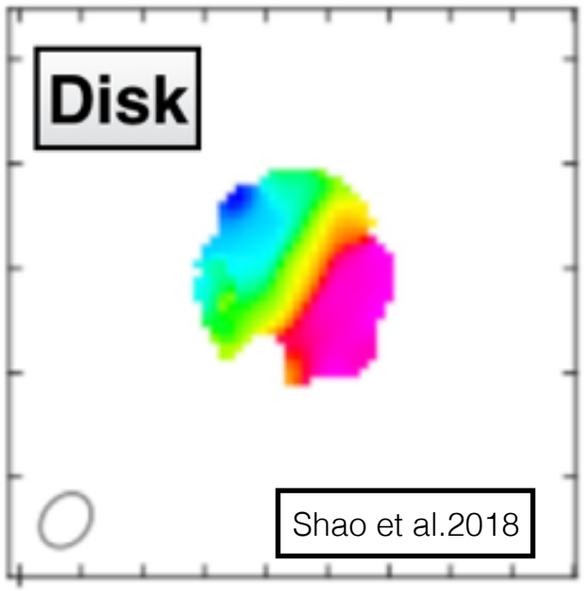


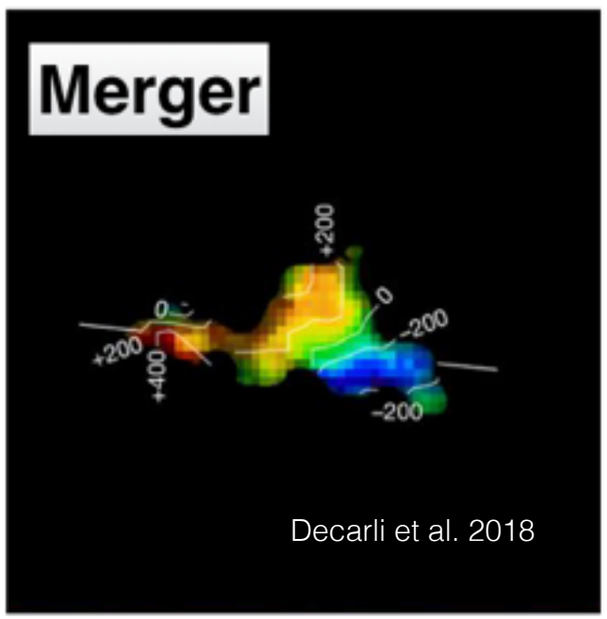


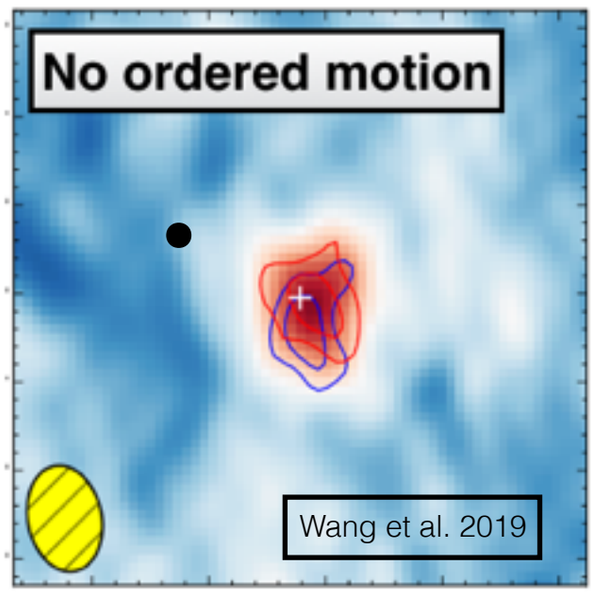
Banados+18

- Eddington timescale ~40 Myr
- at z>7: the age of the universe is less than 20 e-folding time
- requires initial seed of $>10^3 M_{sun}$ even with non-stop Eddington accretion

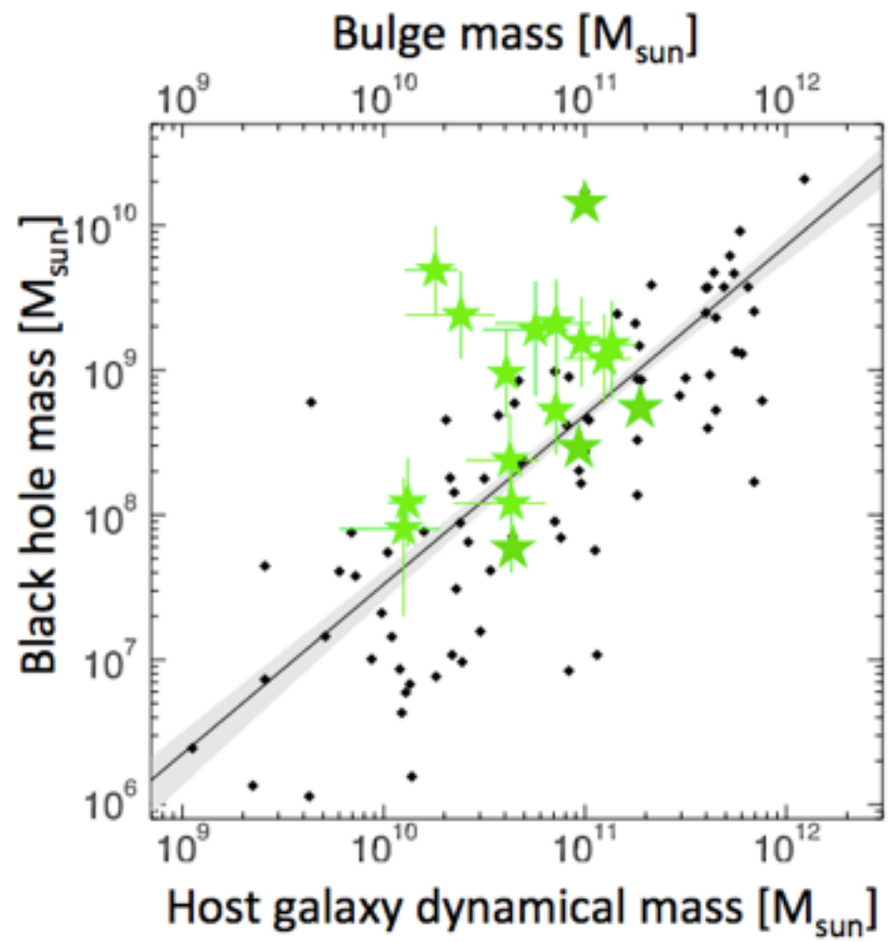
Co-evolution of BHs and galaxies? Or not?







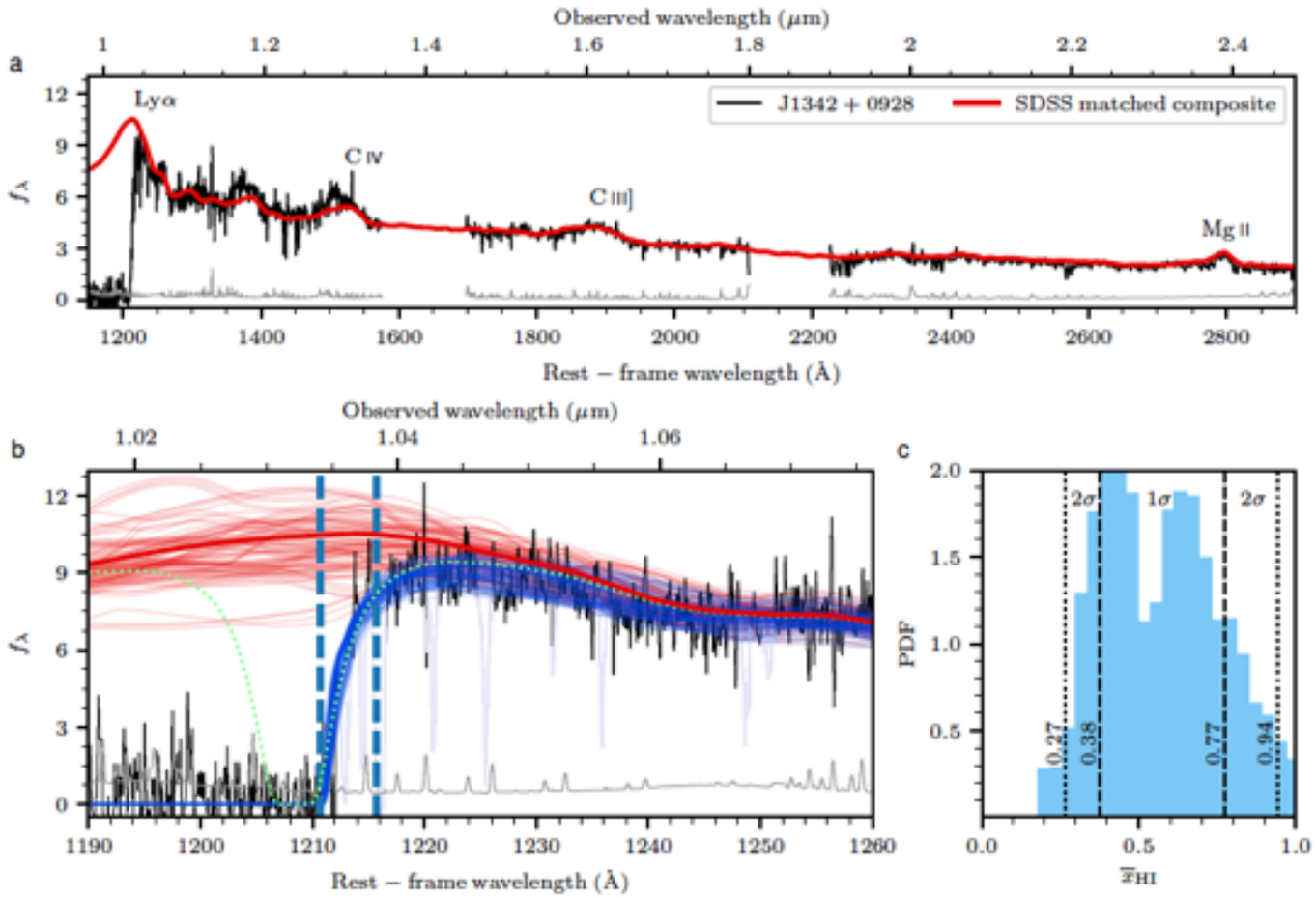
- Kinematics from ALMA/[CII] with sub-kpc spatial resolution
- **Diversity in host galaxy properties**
- SFR ~100 - few x1000 M_sun/yr -> sites of massive galaxy assembly
- But with modest dynamical mass:
  - **on average ~order of mag below local M-sigma relation**
- **No strong correlation between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



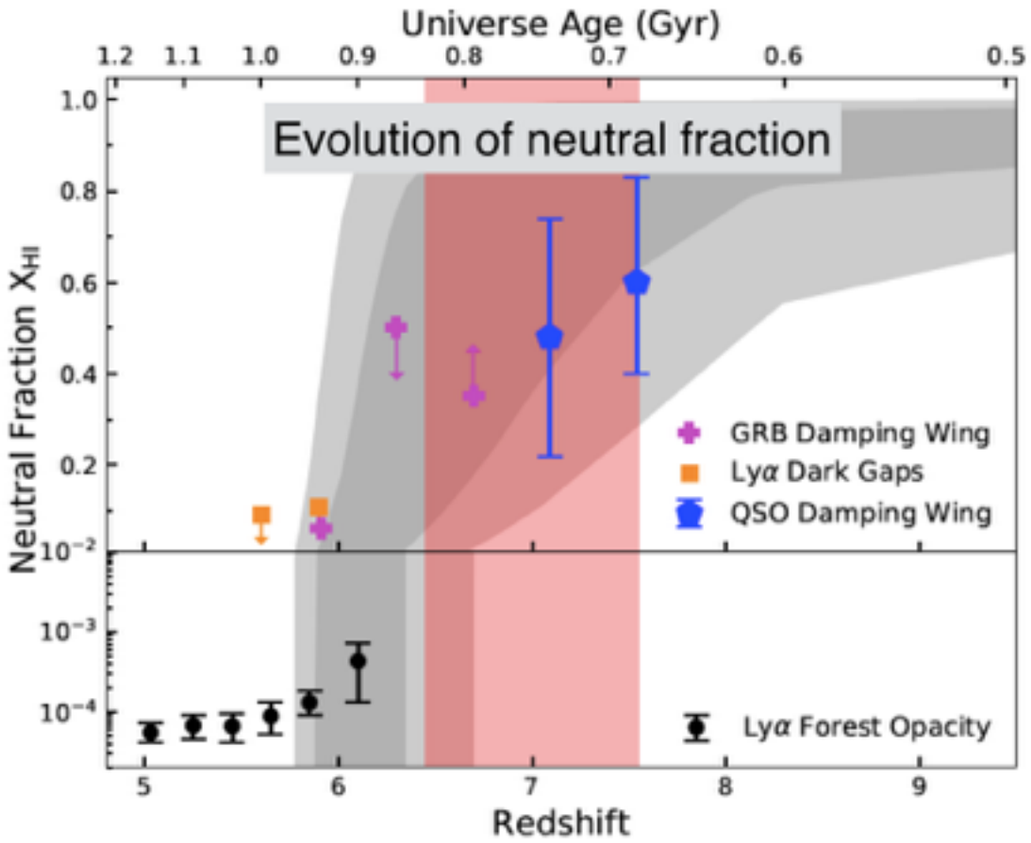
Decarli+18

Probing Reionization History of the Most Distant Quasars: Gunn-Peterson Damping Wing in z>7 quasars

“pisco” z=7.54



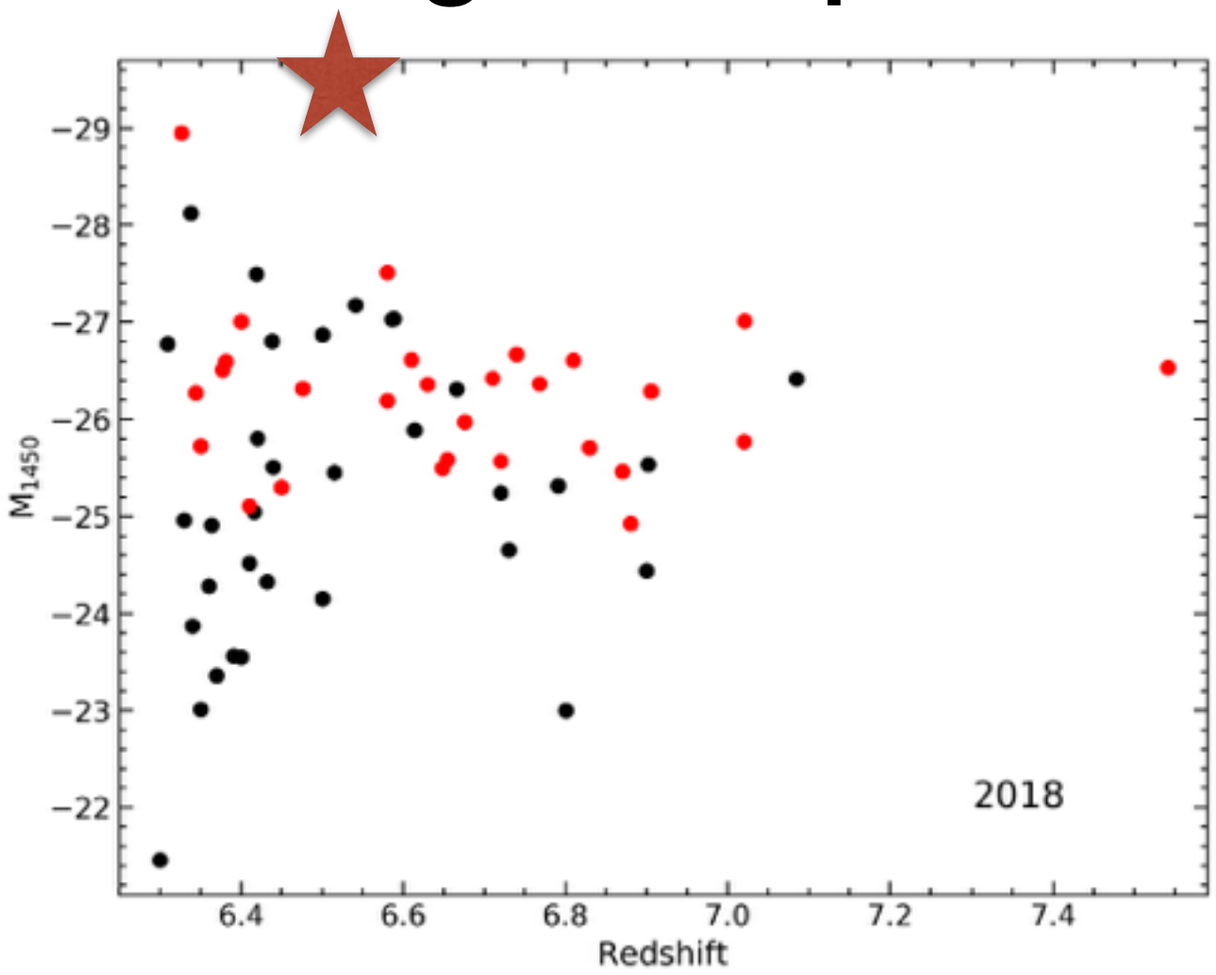
$$\bar{x}_{\rm HI} = 0.55^{+0.22}_{-0.17}$$

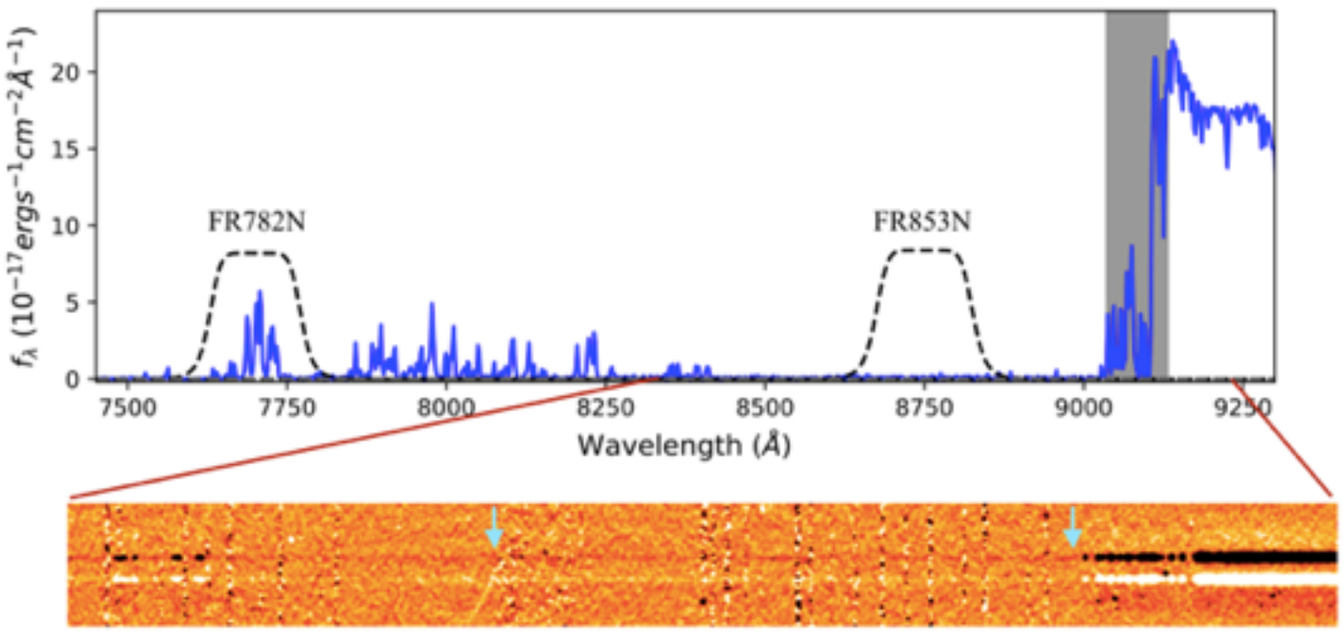


Banados+18

Two recent discoveries

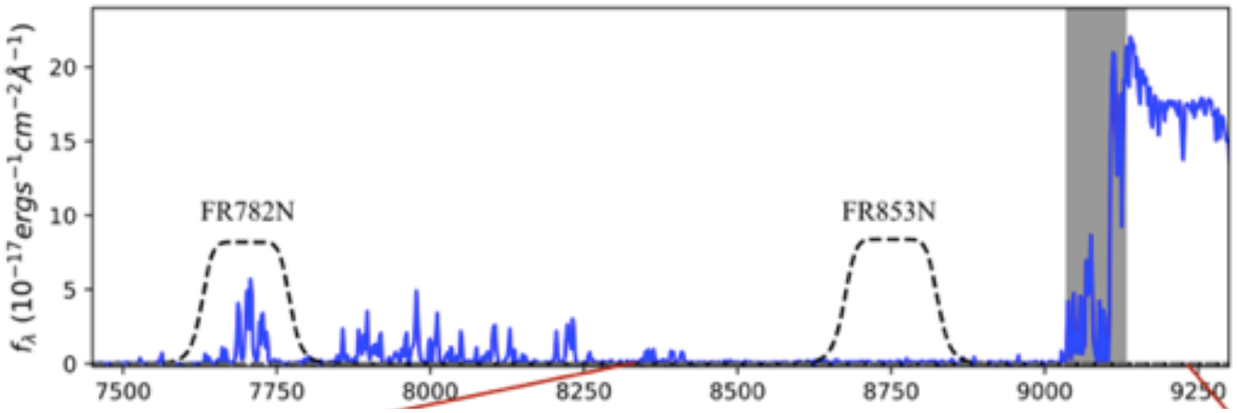
the brightest quasar in the early universe





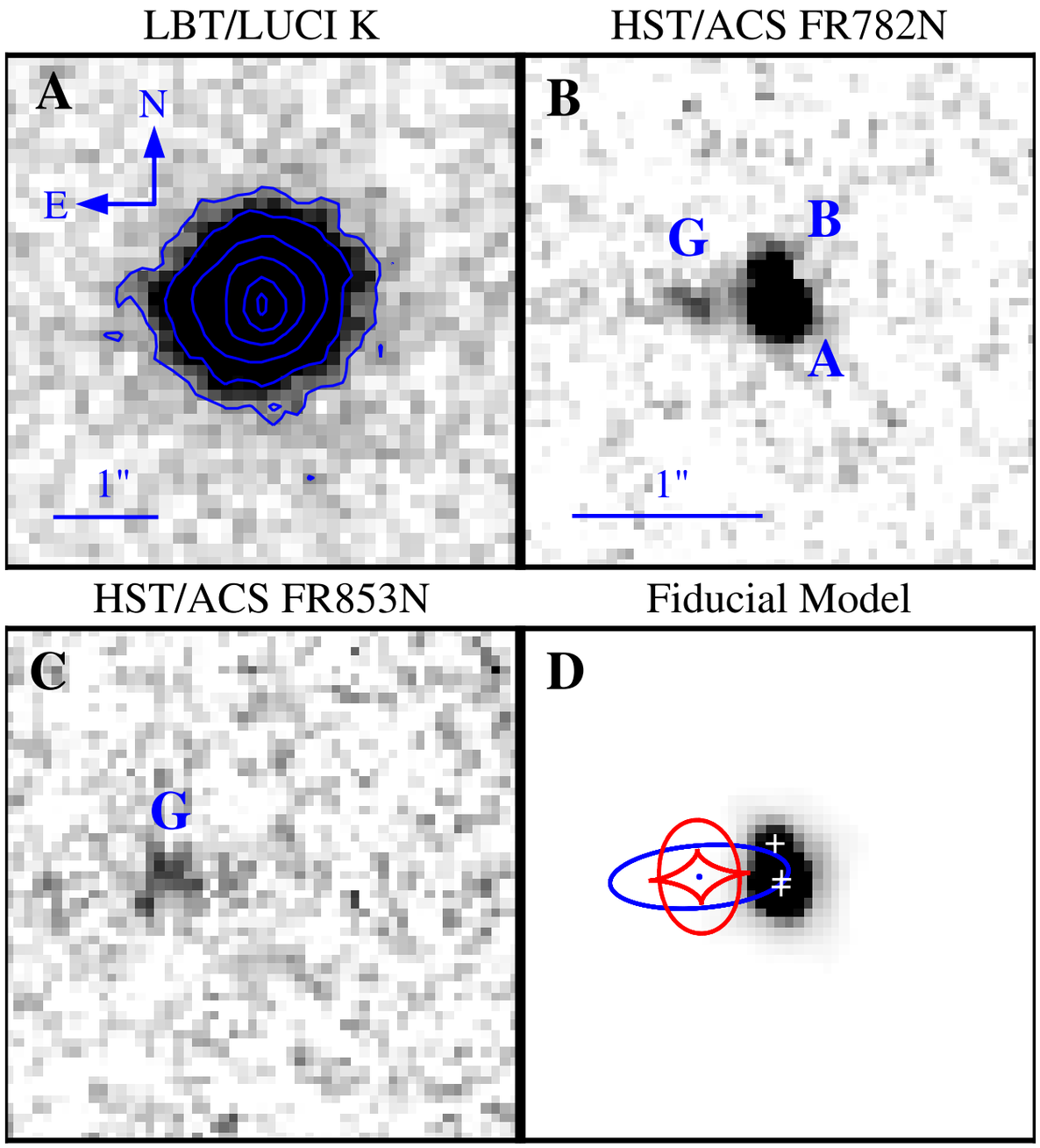
- **J0439+1634 (z=6.51): M~-30; K~15 (strong detection in 2MASS)**
- how could it be this bright???
- faint trace of light in quasar absorption trough -> lensing galaxy?

A strongly lensed quasar at the epoch of reionization



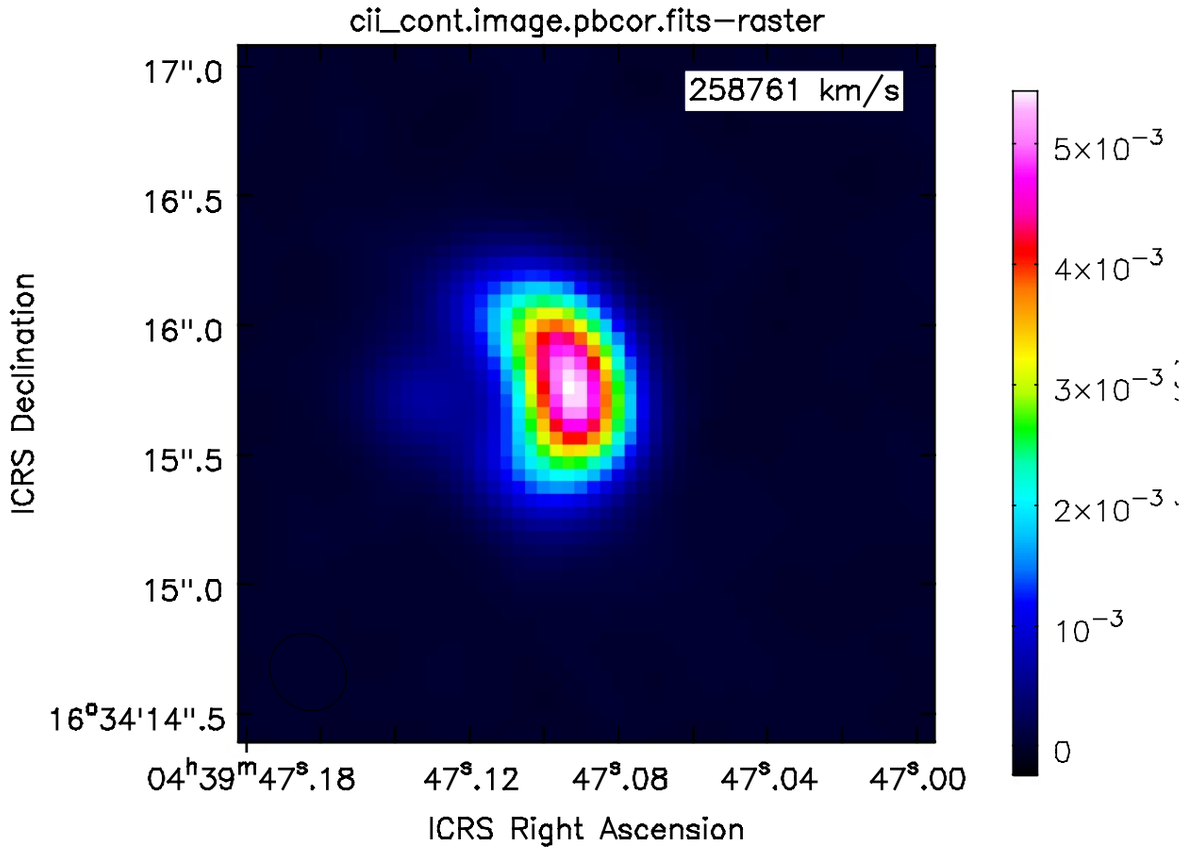
- image size: 0.2” -> among the most compact lens ever known
- **three image lens model with total magnification of ~50**
- faint lensing galaxy at z~0.7 (photo-z)
- first lensed quasar at reionization epoch
  - previous record at z=4.8
  - no known lensed quasar among >500 quasars at z>5
  - prediction: 5-20% due to magnification bias
  - selection effect?

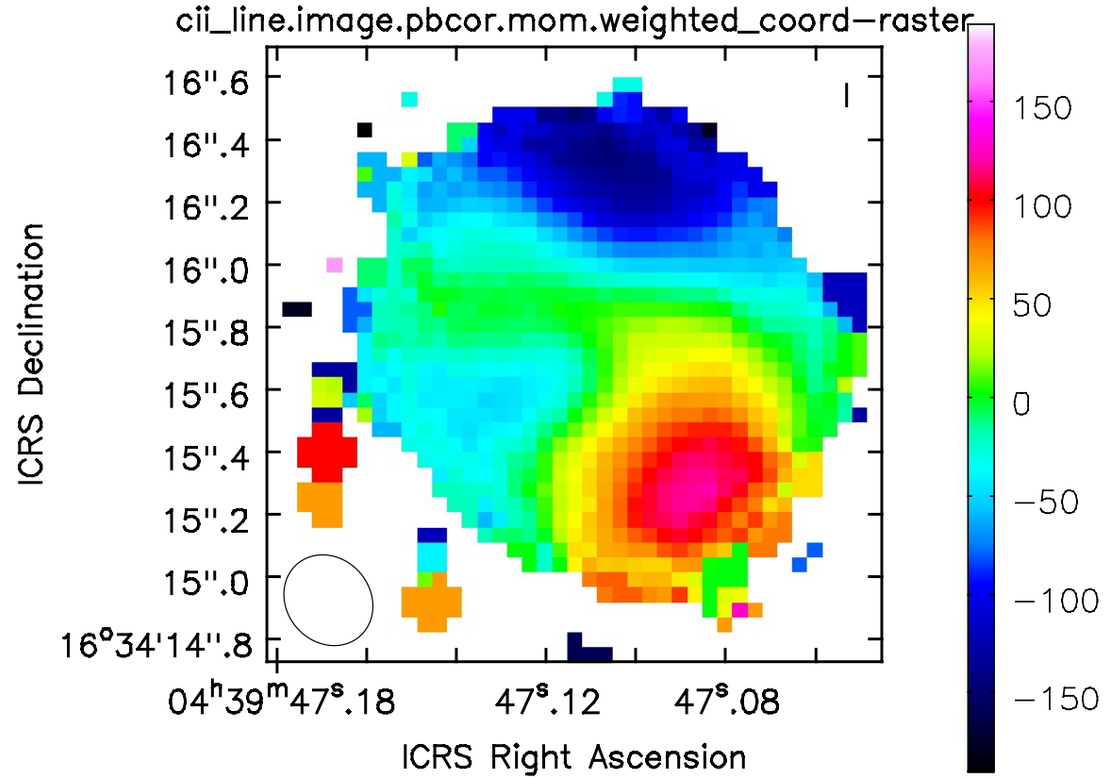
a missing population of lensed high-z quasars!



XF+19

ALMA [CII] imaging of the most distant lensed quasar at z=6.5: resolving the BH sphere of influence at cosmic dawn





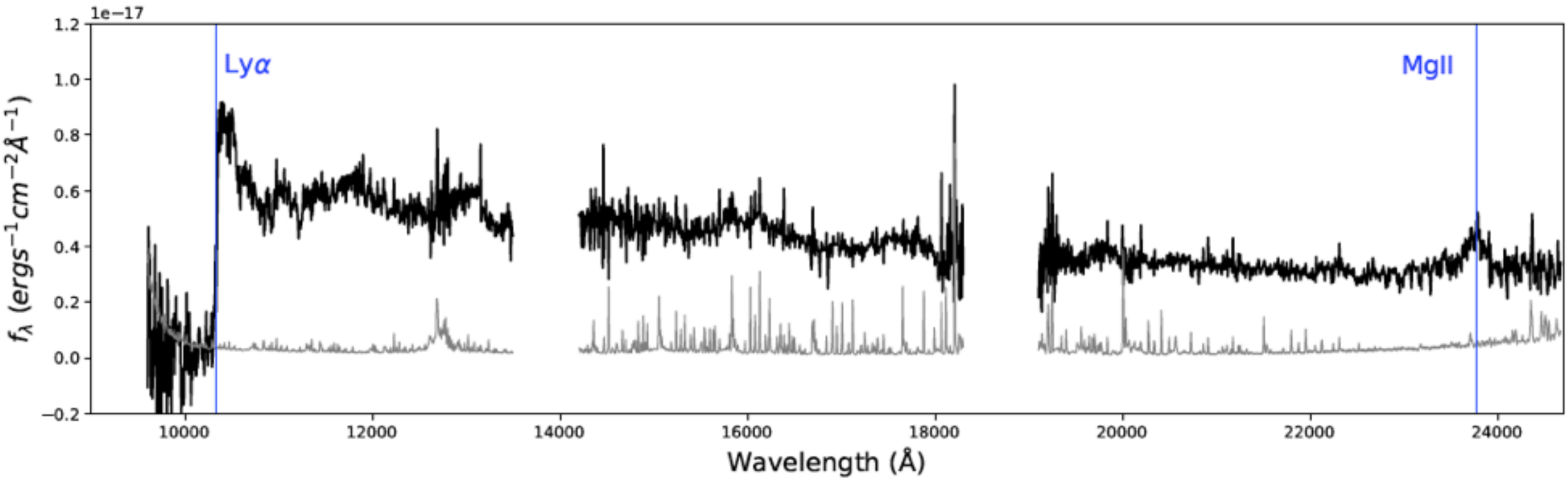
- **brightest far-infrared source at high-redshift - multiple line detections in FIR and submm (Yang+19)**
- **combination of high intrinsic luminosity and high magnification: zoom in to the BH environment**
- in January: 0.25” resolution
- now: 0.05” resolution -> resolve the BH sphere of influence (< 50pc after magnification)

stay tuned..

A record-tying(?) quasar: “Pōniua‘ena” at z~7.5

Yang+ in prep

- second quasar deep into reionization
- slightly brighter than “Pisco” (z=7.54)
- BH mass of 1.7x10^9 M_sun
- **lack of strong damping wing? highly ionized IGM? patchy reionization??**



Hawaiian name: Pōniua‘ena

unseen spinning source of creation, surrounded with brilliance

Summary

- Luminous quasars discovered up to z~7.5
  - accelerated evolution at z>6
  - **planned wide-field surveys will identify the first luminous quasars at z~9-10 in the next 5-10 years**
- A missing population of lensed quasars at high-z
  - **possibility of zooming in to the BH sphere of influence**
- Quasars as probe of reionization
  - suggesting a significantly neutral IGM at z~7.5
  - **maybe with large lines of sight variations?**