The Most Distant Quasars

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The highest redshift frontier now



z~6 quasars: 2006



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Now... a few more reionization-era quasars

	Wavelength (Å)				Wavelength (Å)						
	7500 8000	8500 9000 9500	10000	10500	7500	8000	8500	9000	9500	10000	10500
	J1629+2407, z=6.476				J2356+0023, z=	6.00				<u> </u>	
	J0439+1634, z=6.511		·····		J0216-0455, z=	6.01			<u> </u>	· · · ·	<u> </u>
	J1110-1329, z=6.515				J1137+3549, z=	6.01					<u> </u>
	J0226+0302, z=6.541				J0055+0146, z=	6.02					
	J1135+5011, z=6.580				J1641+3755, z=	6.04			<u> </u>		
	J0706+2921, z=6.583				J2310+1855, z=	6.04			<u> </u>		
	J1526–2050, z=6.586				J0353+0104, z=	6.05					
	J2132+1217, z=6.588				J1630+4012, z=	6.05			<u> </u>		
	J0923+0402, z=6.610				J2318-0246, z=	6.05					
	J0305-3150, z=6.615				J2054-0005, z=	6.06					
ť	J0910-0414, z=6.630				10303-0019.7=	6.07				· · · · ·	
3	J2102–1458, z=6.648				JU042+1218, Z=	6.07				· · · · ·	
Art	J1216+4519, z=6.654				JZIUU-1/15, Z=	6.09		· · · · · · · · · · · · · · · · · · ·	····		
oit	J2232+2930, z=6.666				J1509–1749, z=	6.12	~		~~~~		
rai	J1048–0109, z=6.676		~~~~~		J2315-0023, z=	6.12					
Σ	J0837+4929, z=6.710				J0033-0125, z=	6.13			~~~~~~		
ЧN	J0910+1656, z=6.720				J1250+3130, z=	6.13			<u> </u>	· · · · ·	
nits	J1104+2134, z=6.740				J1319+0950, z=	6.13					<u> </u>
()	J0829+4117, z=6.768				J2229+1457, z=	6.15		· · · · ·	<u></u>		
	J0109-3047, z=6.791				J0221-0802, z=	6.16					
	J0411+0907, z=6.820				J1429+5447, z=	6.18			<u> </u>		
	J0246-5219, z=6.870	N	~~~~~~		J0227-0605, z=	6.20		<u> </u>	<u> </u>		
	J2211-6320, z=6.880				10136+0226 7=	6.21				<u> </u>	
	J2348-3054, z=6.902				J1048+4037, Z=	6.23			<u> </u>	· · · · ·	
	J0839+3900, z=6.905				J0050+3445, z=	6.25					
	J0252-0503, z=7.020				J1030+0524, z=	6.28				· · · · ·	
	J0038–1527, z=7.025			<u> </u>	J1148+5251, z=	6.42				· · · · ·	
	J1120+0641, z=7.085	· · · · · · · · · · · · · · · · · · ·			J2329-0301, z=	6.43				· · · · ·	
	J1342+0928, z=7.541				J0210-0456, z=	6.44		~			

>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

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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



- 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





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

"pisco" z=7.54



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

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?







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: "Poniua'ena" at z~7.5

- 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??

Yang+ in prep



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?