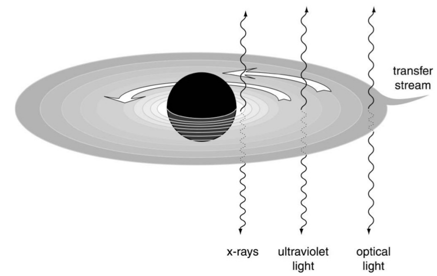
Black Holes Masses

1

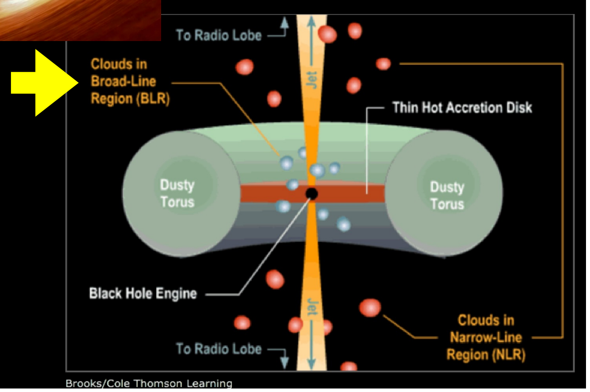
Energy Release From Central Engines

Some of it will emerge as a mix of ***thermal emission*** from various parts of the accretion disk; some emerges as a ***non-thermal synchrotron emission*** from particles accelerated by the magnetic fields embedded in the accretion disk or the BH itself



2

Unified Model for an actively accreting SMBH (Active Galactic Nucleus – AGN)



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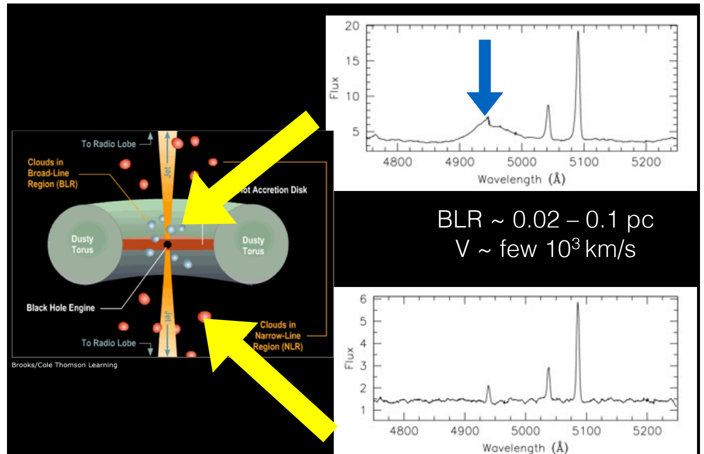

BLR ~ 0.02 – 0.1 pc
V ~ few 10^3 km/s

NLR 10 pc – 1 kpc
V ~ few x 100 km/s

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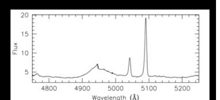
Then, assuming the gas clouds in the BLR are in virial equilibrium, the width of the emission line tells you the circular speed.

$$2K = -U \qquad V^2 = \frac{GM_{BH}}{fR} \qquad M_{BH} = fRV^2/G$$

Fudge factor for geometry of BLR $f = \sqrt{3/2}$

Radius of BLR (reverberation mapping for Local sources)

V from FWHM of emission lines (Hbeta, Mg II)



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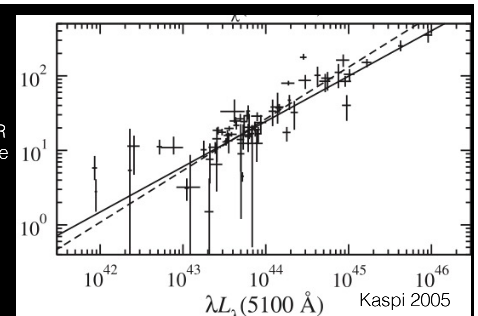
Correlation between BLR size, R, and luminosity of continuum

R_{BLR} α $L^{0.5}$



$$\log\left(\frac{M_{\rm BH,vir}}{M_\odot}\right) = a + b\log\left(\frac{L_{5100}}{10^{44}\,{\rm erg\,s^{-1}}}\right) + c\log\left(\frac{\rm FWHM}{\rm km\,s^{-1}}\right)$$

a =0.91, b = 0.5, c = 2

Vestergaard & Peterson 2006, Feng + 2014, Shen + 2015

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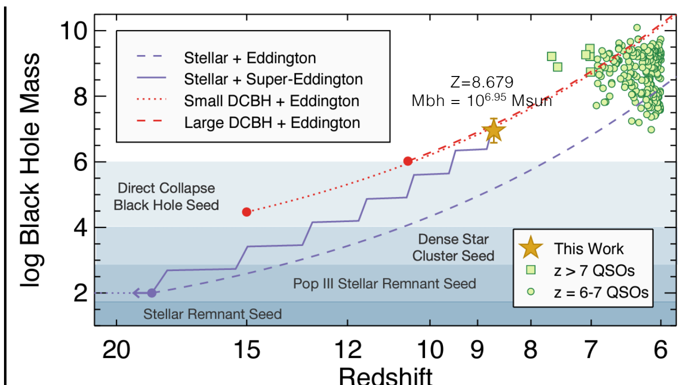

JWST CEERS

Green & Ho 2005
Larson 2023

$$M_{\rm BH} = 2.4\times10^6\left(\frac{L_{\rm H\beta}}{10^{42}\ {\rm erg\ s^{-1}}}\right)^{0.59}\left(\frac{\rm FWHM_{H\beta}}{10^3\ {\rm km\ s^{-1}}}\right)^2 M_\odot. \qquad (5)$$

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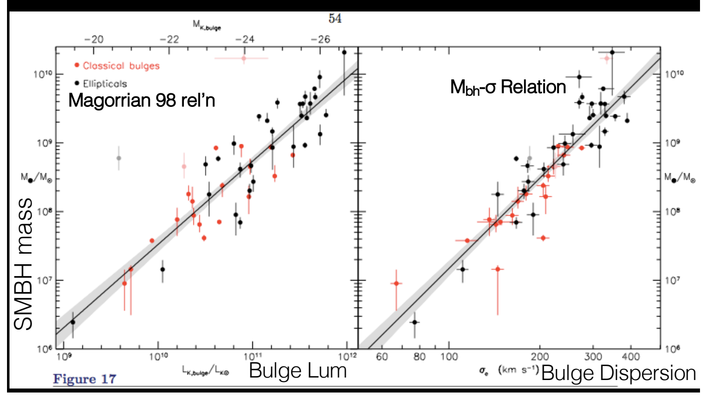
Kormendy & Ho 2013 Equations 6 and 7

Magorrian Relation

$$\frac{M_\bullet}{10^9\ M_\odot} = \left(0.542^{+0.069}_{-0.061}\right)\left(\frac{L_{K,\rm bulge}}{10^{11}\ L_{K\odot}}\right)^{1.21\pm0.09}$$

M_{bh}-σ Relation

$$\frac{M_\bullet}{10^9\ M_\odot} = \left(0.309^{+0.037}_{-0.033}\right)\left(\frac{\sigma}{200\ {\rm km\ s^{-1}}}\right)^{4.38\pm0.29}$$



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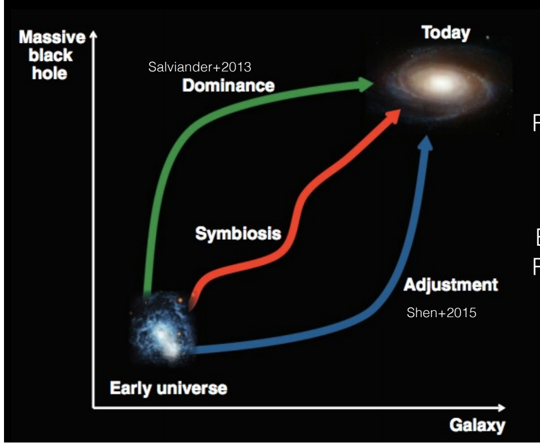
M-sigma / Magorrian relations indicate that the growth of SMBHs and their galaxy hosts are related



Halo Regulated?

And/Or

Black Hole Regulated?

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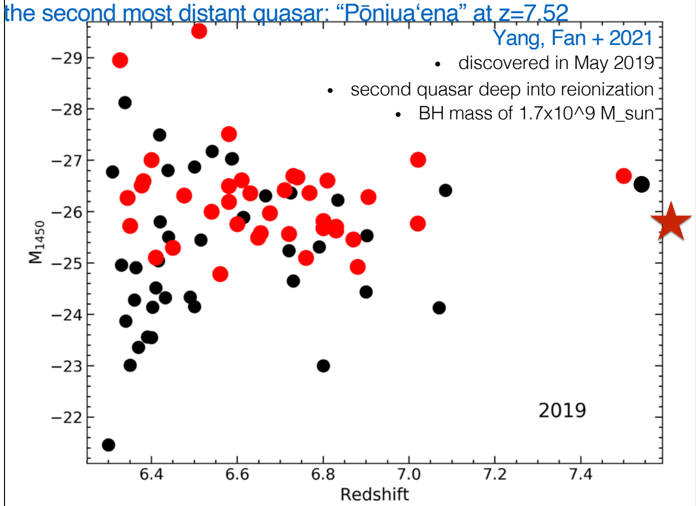
the second most distant quasar: "Pōniua'ena" at z=7.52



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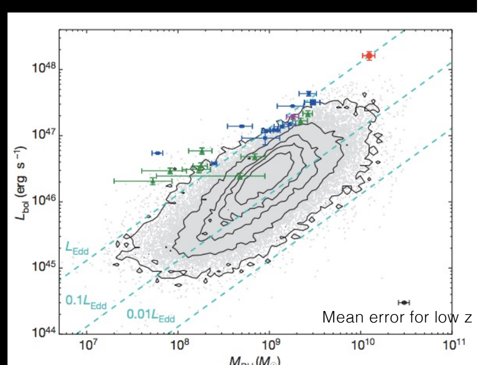
Most massive SMBH at z ~ 6.3

M_{bh} = (1.24 +/- 0.19) x 10^{10} M☉ Wu + 2015

Isn't super high z, but *much more massive* than other high z SMBHs.

Most massive SMBH we know of at any redshift is ~ 7e10 Msun



Dominance?

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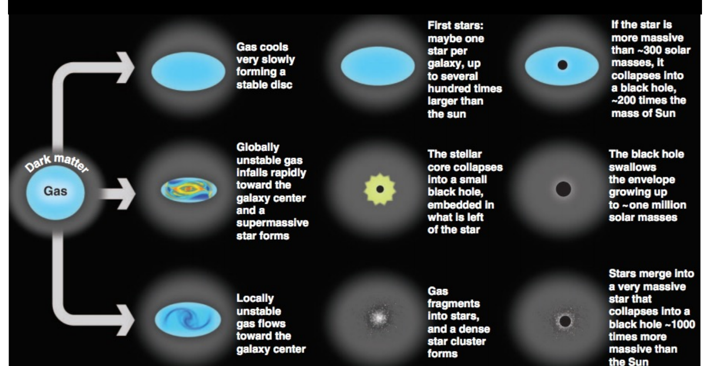
Origin of SMBH Seeds



Volonteri+2012

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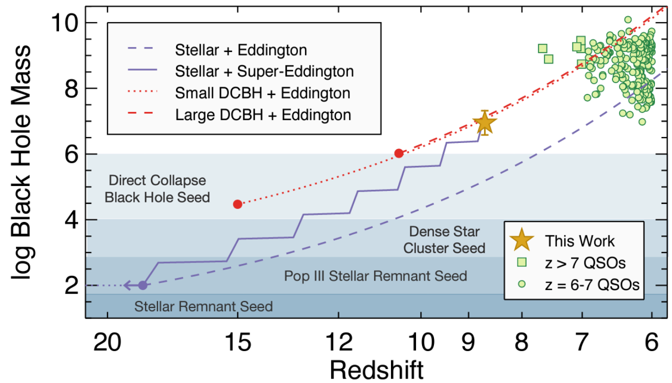
JWST!!!!!



Larson 2023

DCBH = Direct Collapse Black

Yang+2021 ApJ 923

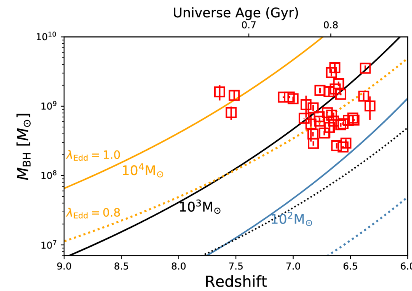


Figure 8. BH mass measurements (red open squares) obtained from our quasar sample compared with the BH growth tracks with different seed BH masses. The three solid curves represent the BH growth tracks with seed BH masses of $10^2\ M_\odot$ (blue), $10^3\ M_\odot$ (black), and $10^4\ M_\odot$ (orange), assuming Eddington accretion since $z = 30$. The three dotted lines are the BH growth tracks with constant Eddington ratio $\lambda_{Edd} = 0.8$, which is the peak of the Eddington ratio distribution from our sample. All these tracks are based on the assumption of a radiative efficiency of 0.1. With Eddington accretion, most of the quasars in our sample require massive seed BHs with masses $\gtrsim 10^3\ M_\odot$ at $z = 30$, and the three $z = 7.5$ quasars require $\gtrsim 10^4\ M_\odot$ seed BHs. A later starting time for BH growth, lower accretion rate, or higher radiative efficiency will result in a requirement of even more massive seed BHs. With $\lambda_{Edd} = 0.8$, most of the quasars will need $\gtrsim 10^4\ M_\odot$ BH seeds at $z = 30$.

Blackhole seeds more massive than 1,000M$\odot$ are necessary to grow the observed most massive high z supermassive black holes

$$\eta \dot{M} c^2 = L_{edd}$$