Measuring the Mass and Accretion Rates of $z \approx 4.8$ Black Holes

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We present new measurements of M_{BH} and L/L_{Edd} in an optically selected, flux-limited sample of 44 type-I AGNs at $z \approx 4.8$. The data were obtained in a joint VLT-Gemini project, observing the MgII(λ2800Å) line in the H-band. The typical mass of these black holes is $\sim 10^9\ M_\odot$ and many accrete close to, or above the Eddington limit. The new results are compared with our own $z \sim 2.4$-3.3 samples and with the few reliable M_{BH} measurements at $z > 6$. We find that at $z \approx 4.8$, L/L_{Edd} is significantly *higher*, and that M_{BH} is *lower*, than at $z \sim 2.4$-3.3. We find no extremely massive ($M_{BH} \geq 10^{10}\ M_\odot$) objects at $z \approx 4.8$, although such SMBHs are clearly in place by $z \sim 3$. We suggest that at $z \approx 4.8$ the most massive BHs are observed in their first episode of fast growth. These sources reach their peak mass at $z \sim 2$-3, where they show a clear decline in growth rate.

A new sample of $z \approx 4.8$ Type-I AGNs with reliable M_{BH} & L/L_{Edd} measurements

- The most reliable M_{BH} (and thus L/L_{Edd}) estimators are based on the Hβ and MgII(λ2800Å) lines (Kaspi et al. 2005, McLure & Dunlop 2004). The CIV(λ1549Å)-based method is known to be unreliable (Baskin & Laor 2005; Netzer et al. 2007; Shen et al. 2008).
- This means that above $z \sim 2$, reliable estimates of M_{BH} & L/L_{Edd} can only be obtained for small samples, through NIR spectroscopy.
- A flux-limited sample of $z \approx 4.8$ SDSS AGNs was chosen to observe the MgII line in the H-band. The observations were split between the **Gemini-North/NIRI and VLT/SINFONI** instruments.
  - Unlike $z > 6$ samples, this sample is large and flux limited.
  - It holds a large fraction of all the $z \sim 4.8$, type-I SDSS AGNs.
  - The sample spans the luminosity range $46.6 \leq \log(L_{bol} / [erg/sec]) \leq 47.7$

Results from the $z \approx 4.8$ sample

- Accretion rates range $\mathbf{0.2 \leq L/L_{Edd} \leq 3.9}$. More than 30% of sources accrete close to, or above the Eddington limit and ~60% above L/L_{Edd}=0.5. This implies short e-folding times of only $\sim$20-220 Myr.
- BH masses range $8.4 \leq \log(M_{BH}/M_\odot) \leq 9.7$. The median value is $\mathbf{\log(M_{BH}/M_\odot)=9}$.
- About 65% of the $z \approx 4.8$ SMBHs had enough time to grow to their observed M_{BH} given their observed L/L_{Edd}.

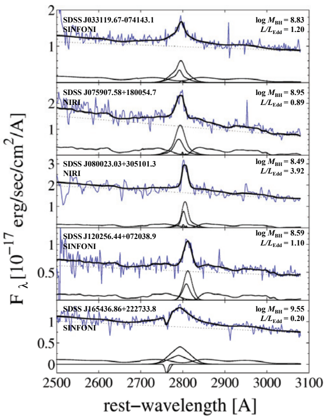


Fig. 1: sample spectra of $z \approx 4.8$ AGNs observed with VLT/SINFONI and Gemini-N/NIRI. All spectra were fitted with continuum, Fe II/III and MgII(λ2800Å) components. We used the McLure & Dunlop (2004) M_{BH} estimator and newly-calibrated bolometric corrections

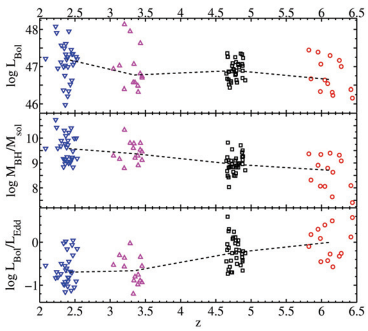
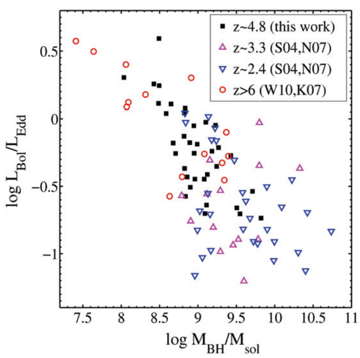


Fig. 2 (top) and 3 (bottom): comparison of the main properties of the $z \approx 4.8$ sample to those of other samples at $z \approx 2.4$, $z \approx 3.3$ and $z > 6$. The dashed lines in Fig. 2 connect median values.



Comparison with other $z > 2$ samples

The various diagrams shown here compare the distributions of M_{BH} & L/L_{Edd} for 4 different samples: (1) The new $z \approx 4.8$ sample (2+3) The $z \approx 2.4$ and the $z \approx 3.3$ samples of Shemmer et al. (2004; **S04**) and Netzer et al (2007; **N07**), and (4) a combined sample of $z > 6$ measurements from Kurk et al. (2007; **K07**) and Willott et al. (2010; **W10**).

This comparison shows that:

1. The new $z \approx 4.8$ sample has a significantly **higher L/L_{Edd} than at $z \sim 2.4$-3.3**, (by $\sim$0.45 dex.) and a **lower M_{BH}**.
2. The fraction of $z \approx 4.8$ sources which had time to grow at their observed accretion rates is higher than the fraction observed at lower redshifts.
3. The short e-folding times, lower M_{BH} and higher L/L_{Edd} all suggest that the $z \approx 4.8$ SMBHs could be the **parent population** of the most massive BHs observed at $z \approx 2.4$ and $z \approx 3.3$.

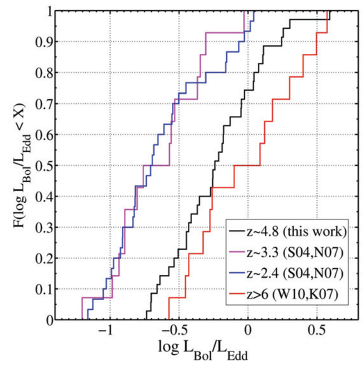
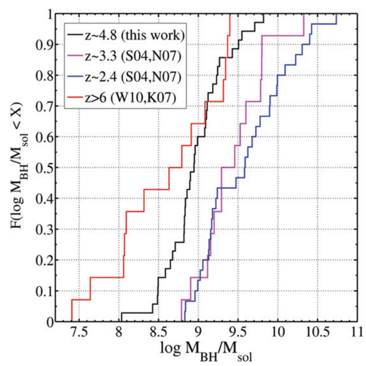


Fig. 4 and 5: cumulative distributions of L/L_{Edd} (top) and M_{BH} (bottom) for the $z \approx 4.8$ sample and other samples at $z \approx 2.4$, $z \approx 3.3$ and $z > 6$. Note the increase in M_{BH} and decrease in L/L_{Edd} with cosmic time.



Conclusions:

Our new observations show that SMBHs experience an epoch of fast growth at $z \approx 4.8$ which eventually produces the most massive BHs observed at $z \sim 2$-3. At $z \sim 2.4$-3.3, the BH growth slows down, and both M_{BH} & L/L_{Edd} show little or no evolution.

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References: Baskin & Laor (2005), MNRAS, 356, 1029 ● Kaspi et al. (2005), ApJ 629, 61 ● Kurk et al. (2007) , ApJ 669, 32 [**K07**] ● McLure & Dunlop (2004), MNRAS 352, 1390 ● Netzer et al. (2007), ApJ 1256, 671 [**N07**] ● Shemmer et al. (2004), ApJ 614, 547 [**S04**]● Shen et al. (2008), ApJ 680, 169 ● Willott et al. (2010), ApJ 134, 2435 [**W10**]