The Extreme Growth of SMBHs and Their Host Galaxies at $z \sim 5$

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With:

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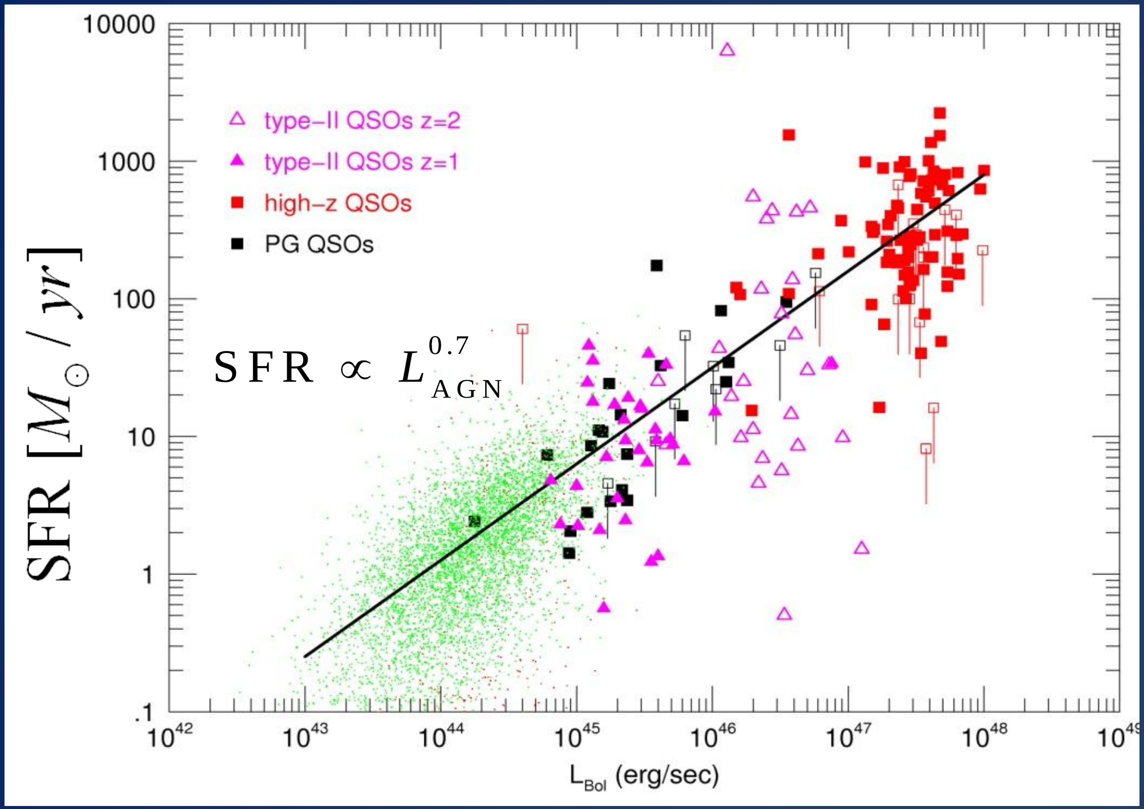
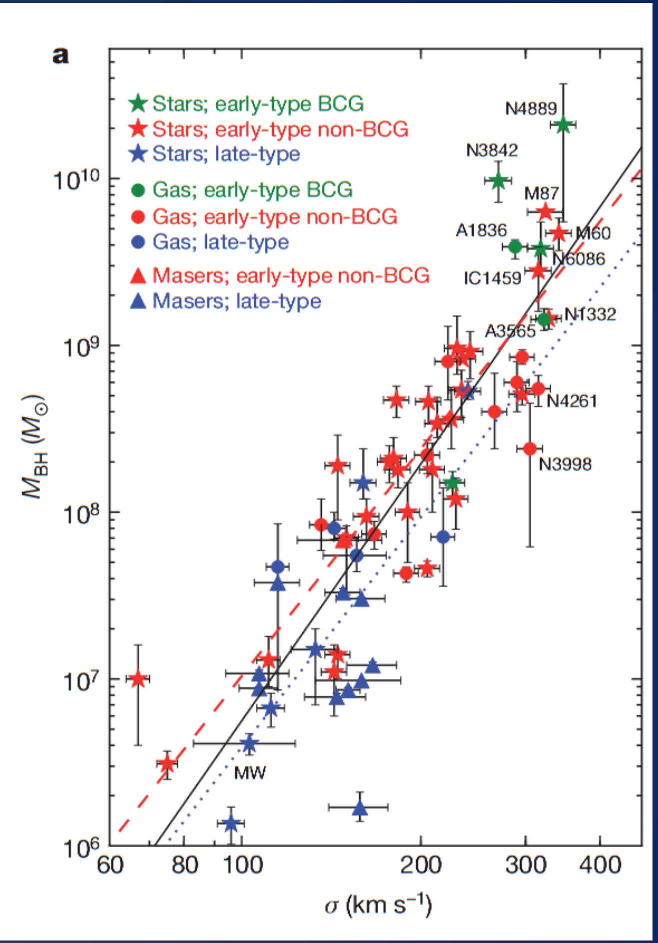
Massive Black Holes Conference, KITP, Aug. 5th 2013

A Merger-Driven Link Between AGNs and Hosts?



Lutz et al. (2008); Netzer (2009); Trakhtenbrot & Netzer (2010); Mainieri et al. (2011). Also Shao et al. (2010), Rosario et al. (2012)



McConnell et al. (2011)

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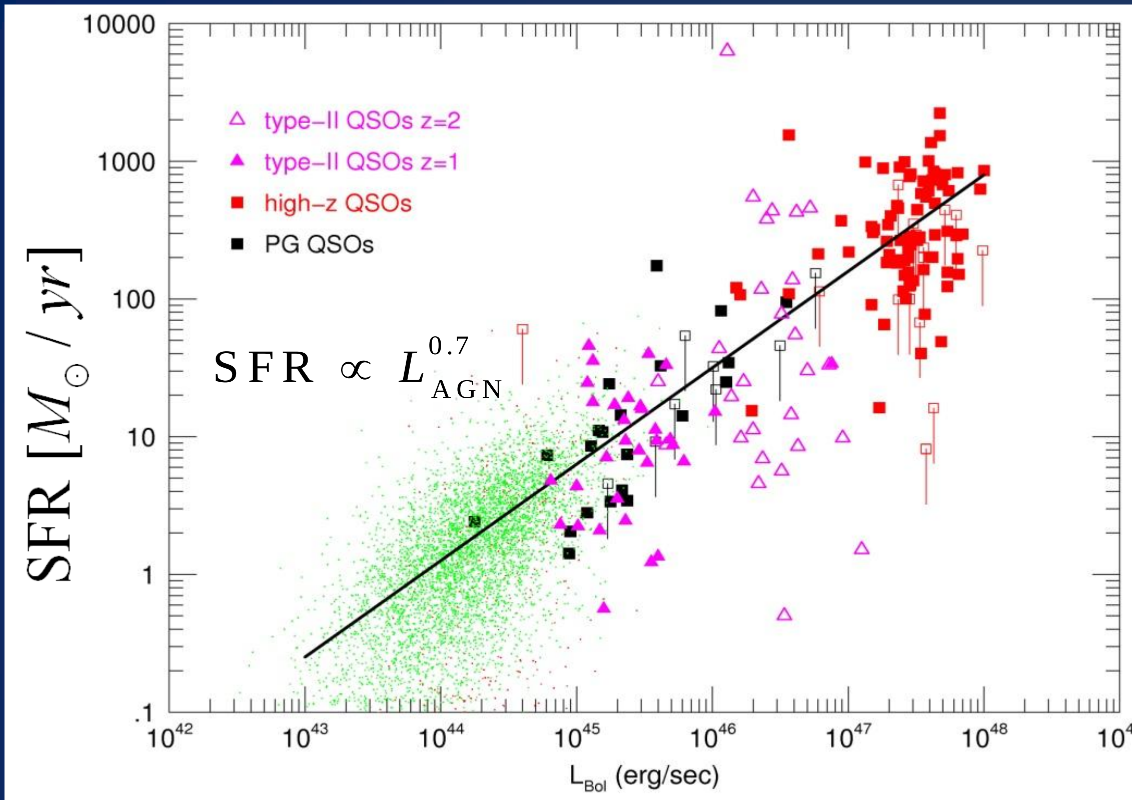

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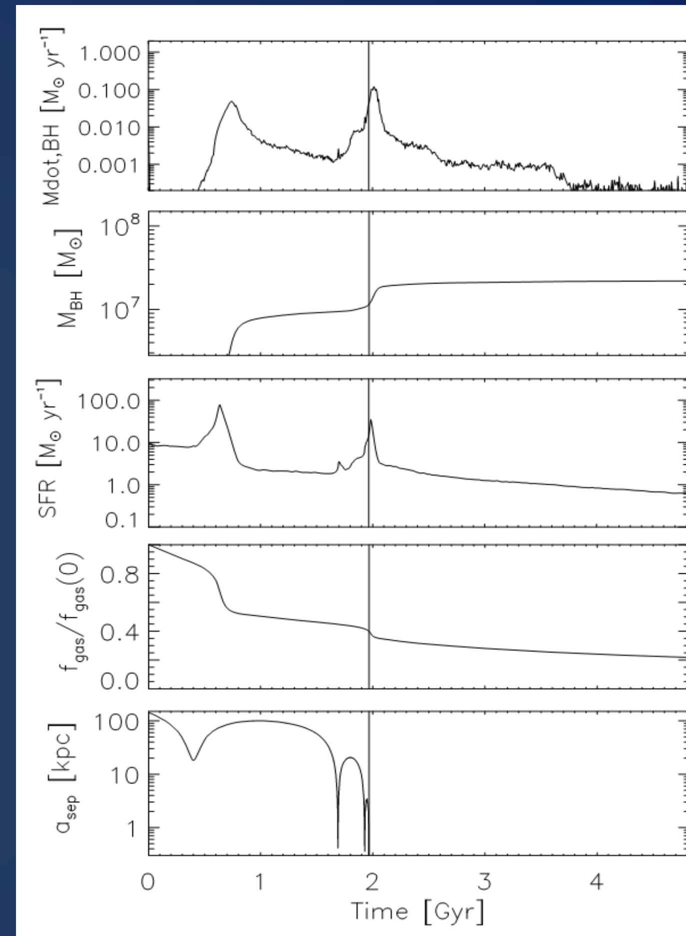
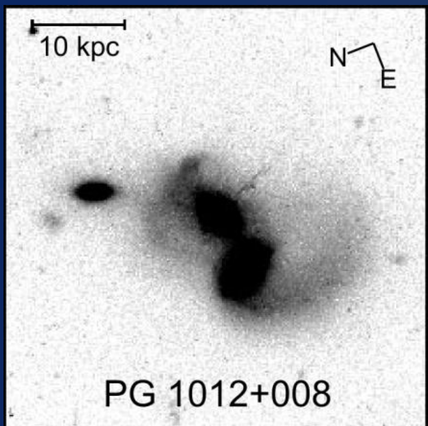


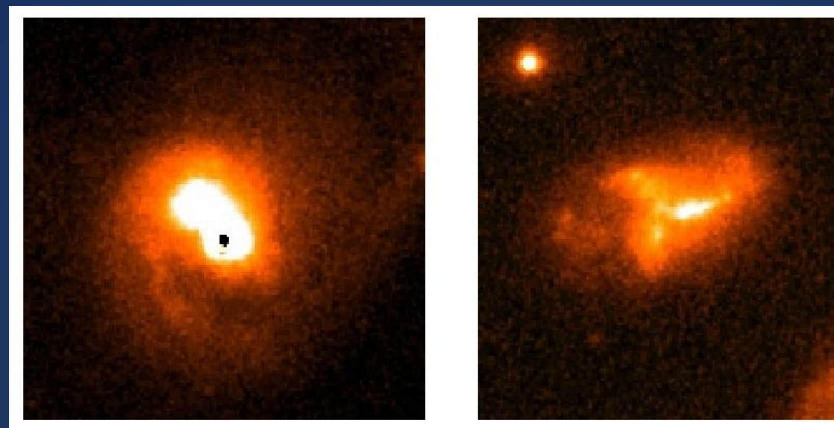
Blecha et al. (2011)

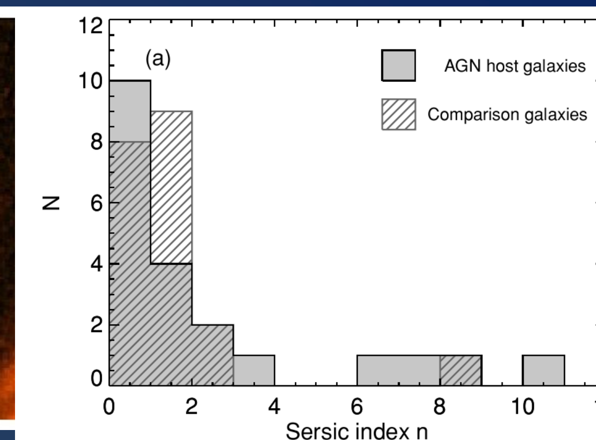
1. Rapid SMBH growth is accompanied by intense SF in the host
2. Only major mergers can lead to SFR >> 100 $M_\odot$/yr ?

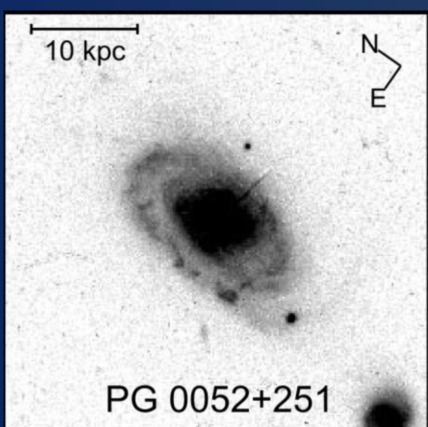
A Merger-Driven Link between AGNs and Hosts?

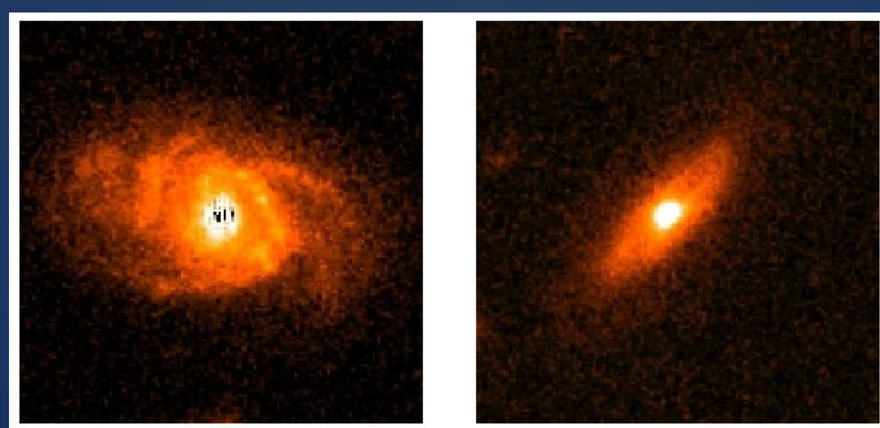
$z \sim 0$ | $z \sim 1$ | $z \sim 2$

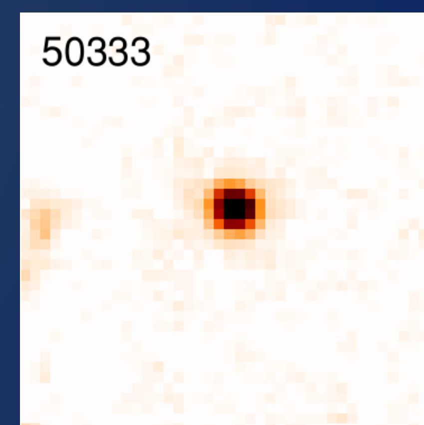










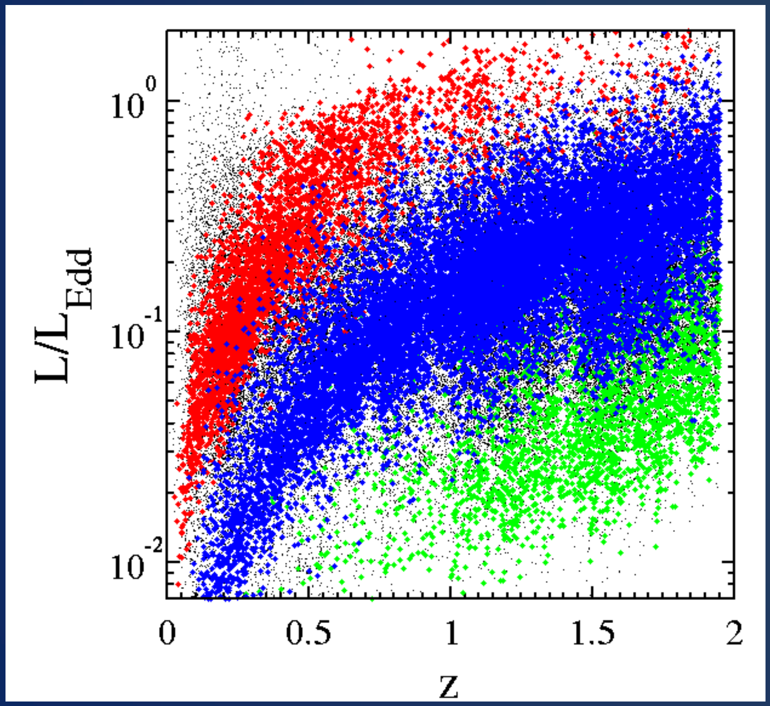


Bahcall et al. (1997) | Cisternas et al. (2011) | Schawinski et al. (2011)

➔ we should focus on faster-growing and/or higher-z systems

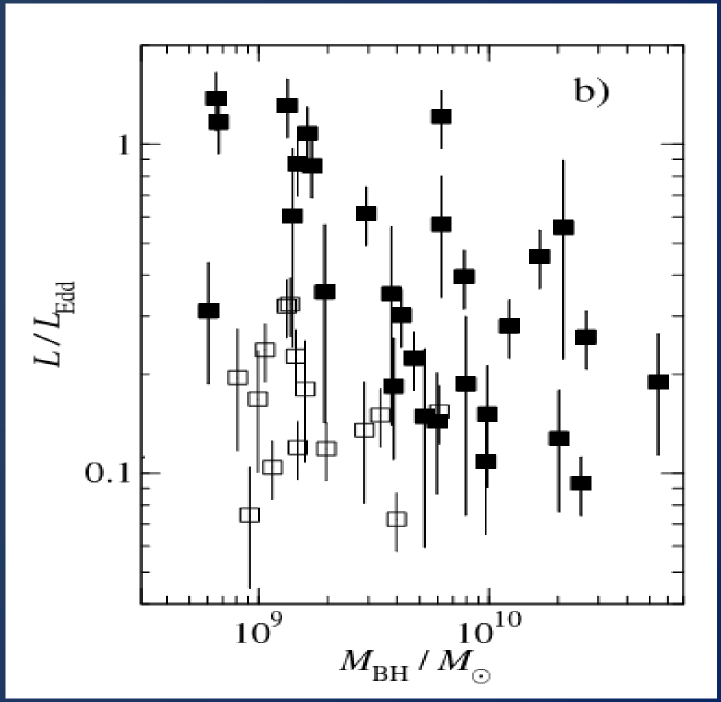
The build-up of the most massive BHs

1. A local relic population of extremely massive SMBHs ($M_{\rm BH} \sim 10^{10}\, M_{\odot}$)
2. At $z < 2$ most SMBHs in luminous QSOs did not have enough time to grow, given the observed accretion rates
3. SMBHs with $M_{\rm BH} \sim 10^{10}\, M_{\odot}$ and sub-$L_{\rm Edd}$ are already in place at $z \sim 2$-3.5



$M_{\rm BH} = 4\times10^{7}$ 4×10^{8} 1.5×10^{9}

Trakhtenbrot & Netzer (2012)



$z \sim 2.5$-3.5

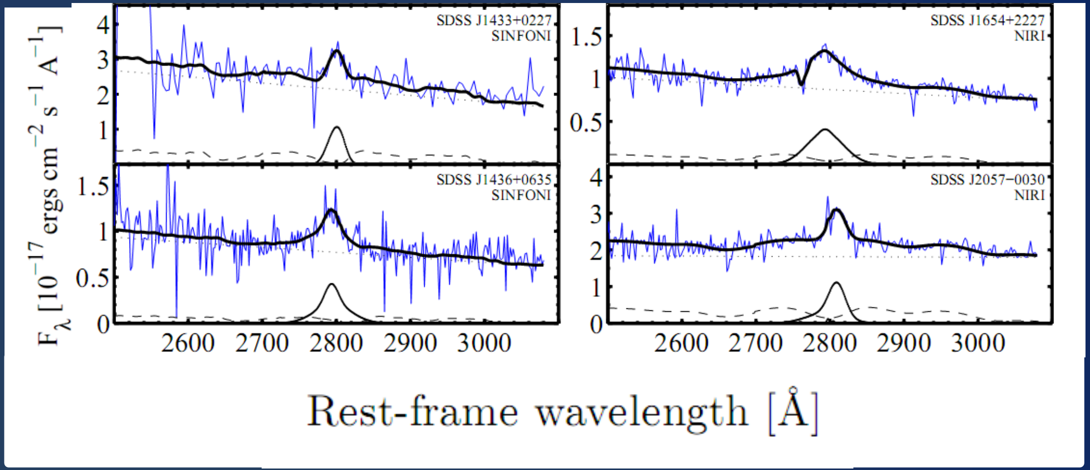
Shemmer et al. (2004) ; Netzer et al. (2007);
also: Marziani et al. (2009); Dietrich et al. (2009)

The Unique SDSS Sample at $z \sim 4.8$

40 QSOs at $z = 4.65 – 4.95$

- Redshift chosen to allow measurement of MgII(λ2800Å)
- Selected from SDSS/DR7, and further flux limited.
- Follows the flux distribution of all z~4.8 SDSS QSOs
  ~1/4 of all similar SDSS QSOs
- *H*-band spectroscopy with VLT/SINFONI and Gemini-N/NIRI
  ~2.5-3 hours per source

Trakhtenbrot et al. 2011 (ApJ 730, 7)



$$M_{BH} = 3.2 \times 10^6 \left(\frac{L_{3000}}{10^{44}\ \mathrm{erg\ s^{-1}}} \right)^{0.62} \left(\frac{\mathrm{FWHM(MgII)}}{1000\ \mathrm{km/s}} \right)^2 M_\odot$$

McLure & Dunlop (2004)

Distributions of M_{BH} and L/L_{Edd} at $z \sim 4.8$

- Black hole masses:

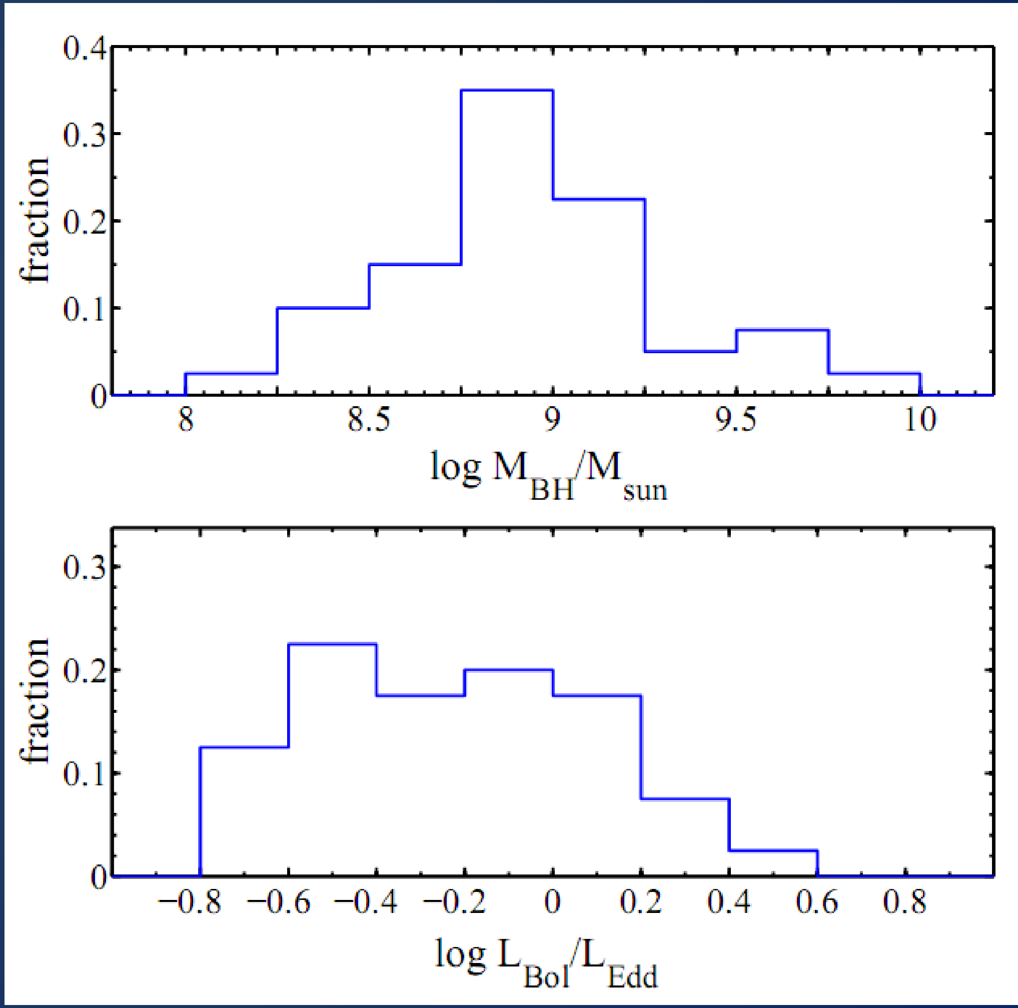
$$10^8 \leq M_{BH} \leq 6.6 \times 10^9 \, M_\odot$$

$$\langle M_{BH} \rangle \simeq 8.4 \times 10^8 \, M_\odot$$

- Accretion rates:

$$0.2 \leq L / L_{Edd} \leq 3.9$$

$$\langle L / L_{Edd} \rangle \simeq 0.6$$



Growth from Seed BHs

- Assuming constant L/L_{Edd} and $\eta = 0.1$ ➔ exponential growth

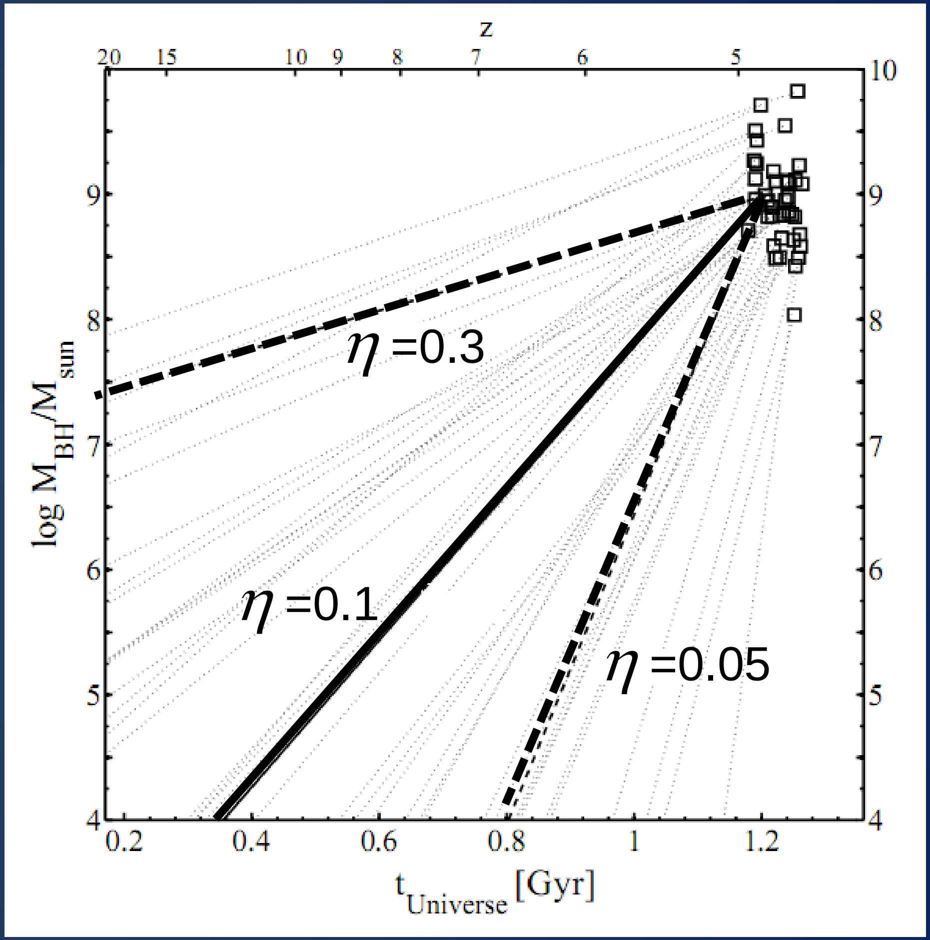
➔ ~40% may have grown from stellar remnants

➔ Another ~20% may have grown from seeds with

$$10^3 < M_{seed} < 10^5 M_\odot$$

- When assuming $\eta = 0.05$, all sources satisfy $M_{seed} \leq 10^6 M_\odot$

➔ low/moderate spins are required to match seed models



Overall Evolution of M_{BH}

NIR ←→ optical

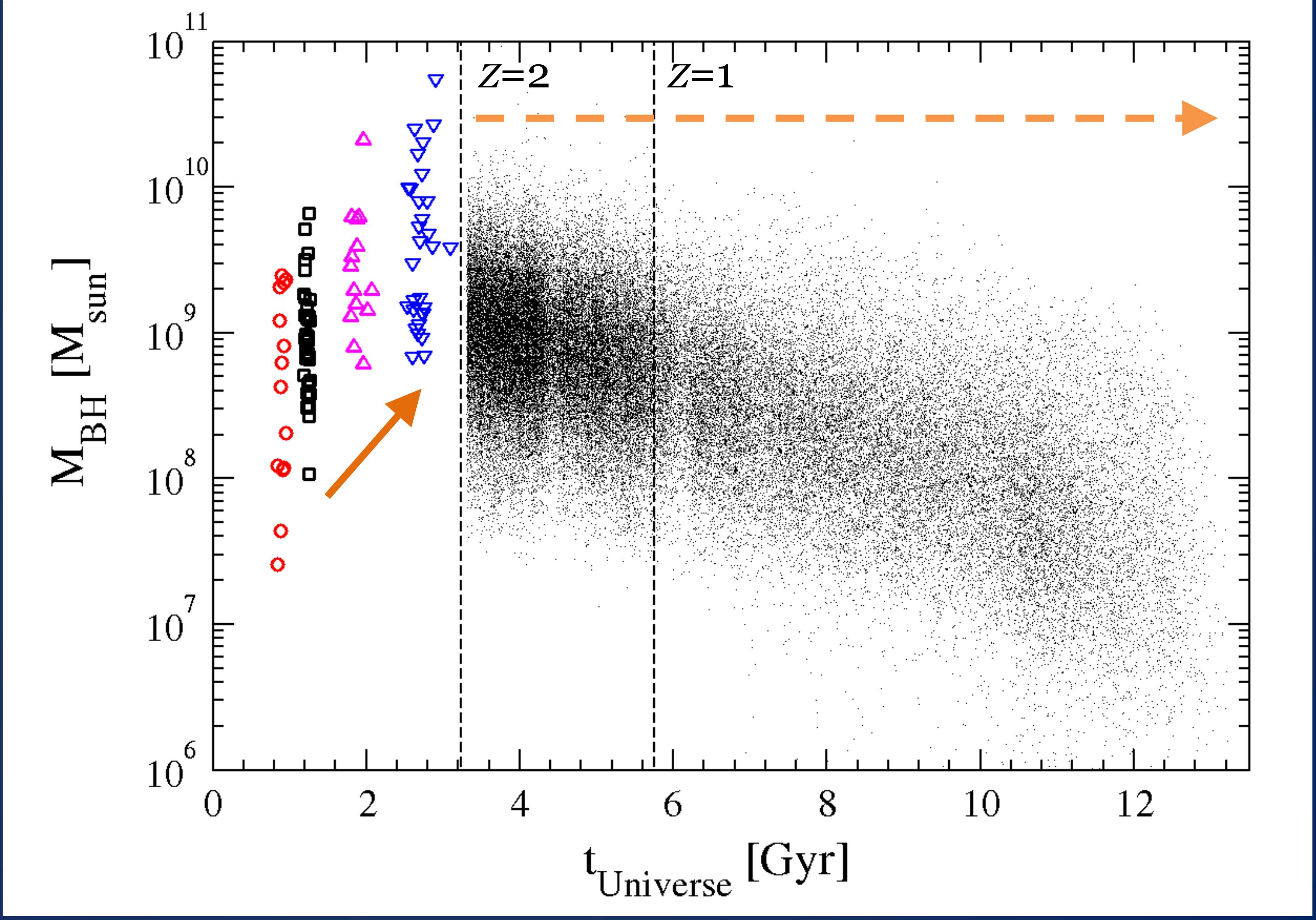
z~6.2
Willott+10, Kurk+07

z~4.8
Trakhtenbrot+2011

z~3.3
Netzer+07,Shemmer+04

z~2.4
[Netzer+07,Shemmer+04]

z<2
SDSS; Netzer & Trakhtenbrot (2007) Trakhtenbrot & Netzer (2012)

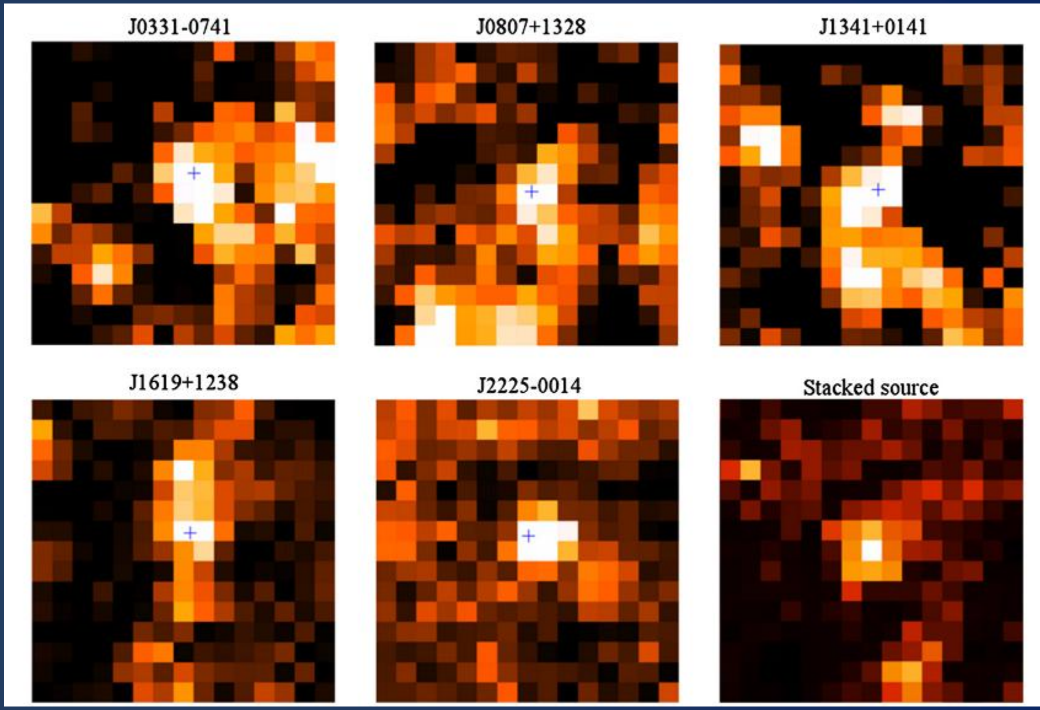


see also B. Kelly's talk…

Herschel Observations

- *Herschel*/SPIRE imaging at 250, 350 & 500 μm → rest-frame ~40-85 μm cold dust heated by SF
- PSF~18” → ~64 kpc/pix … … but Spitzer imaging helps to identify interlopers
- Extended sample of 44 sources Analysis of first 25 targets presented in Mor et al. (2012)

Netzer et al. 2013 (arXiv:1308.0012)



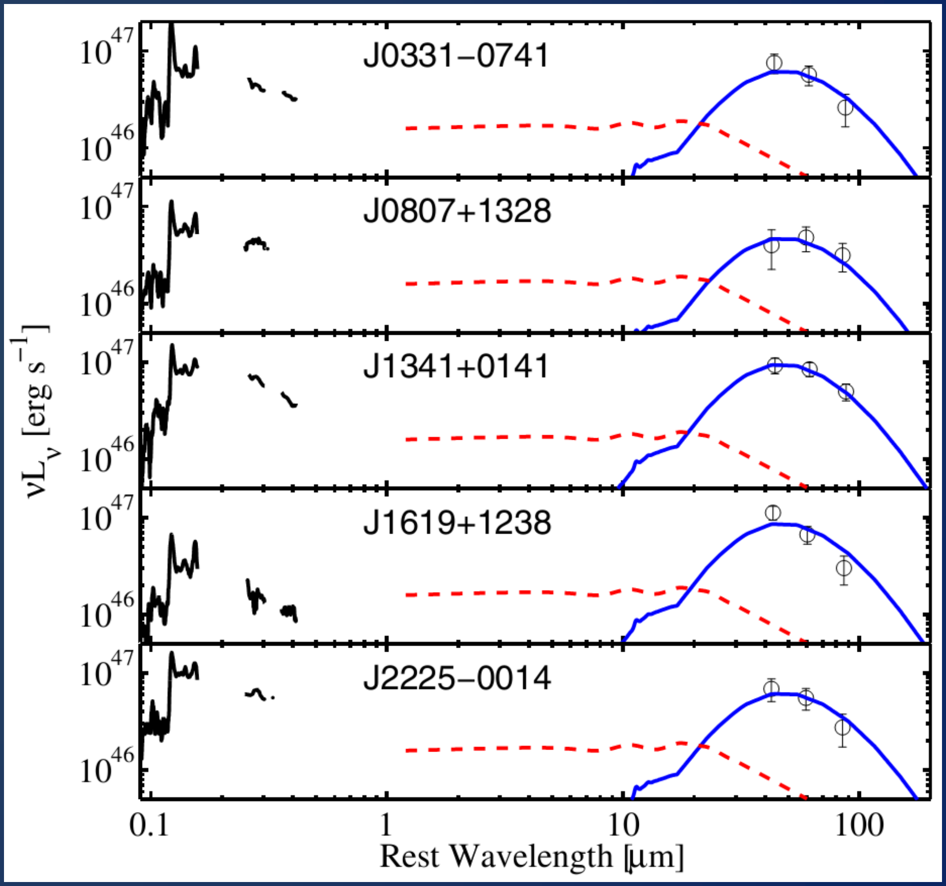
- 10 detected at >3σ in at least 2 bands
  $f_{350} \sim (23\text{-}45) \pm 7$ mJy , confusion limited
- Significant detection in stack of “non-detections”

Herschel Observations → SFRs

- FIR SED fitted by a grid of templates (Chary & Elbaz 2001)
  each template defines L_{FIR}
  (no free parameters)
- MIR ("torus") emission negligible

→ 10 detections (~23%)
all with $L_{FIR} > 10^{13}\, L_{\odot}$
SFR ~ 1300-4200 $M_{\odot}$/yr

→ Stacked "source" (~77%)
SFR ~ 450 $M_{\odot}$/yr



assuming a Chabrier IMF;
a Salpeter IMF would increase SFRs by ~1.6x

Extreme SFRs for fast-growing SMBHs

Two sub-groups:

Herschel-detected and non-detected

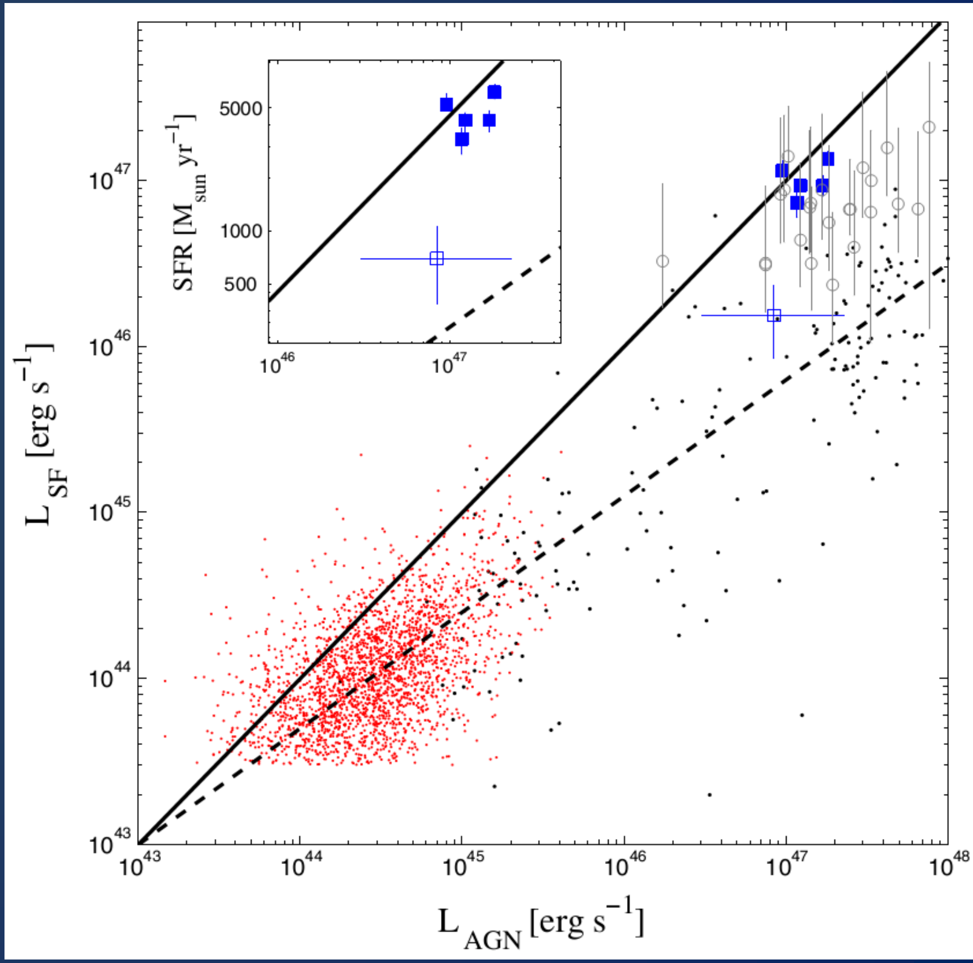
- SFR is higher (a factor of >5)
- $M_{\rm BH}$ is higher (a factor of ~3)

- mergers vs. "secular"?
- feedback within ~100 Myr?
- location of groups w.r.t the "main SF sequence"?
- SF-AGN duty cycle?

The SMBHs can reach ~10^{10} $M_\odot$ within ~100 Myr

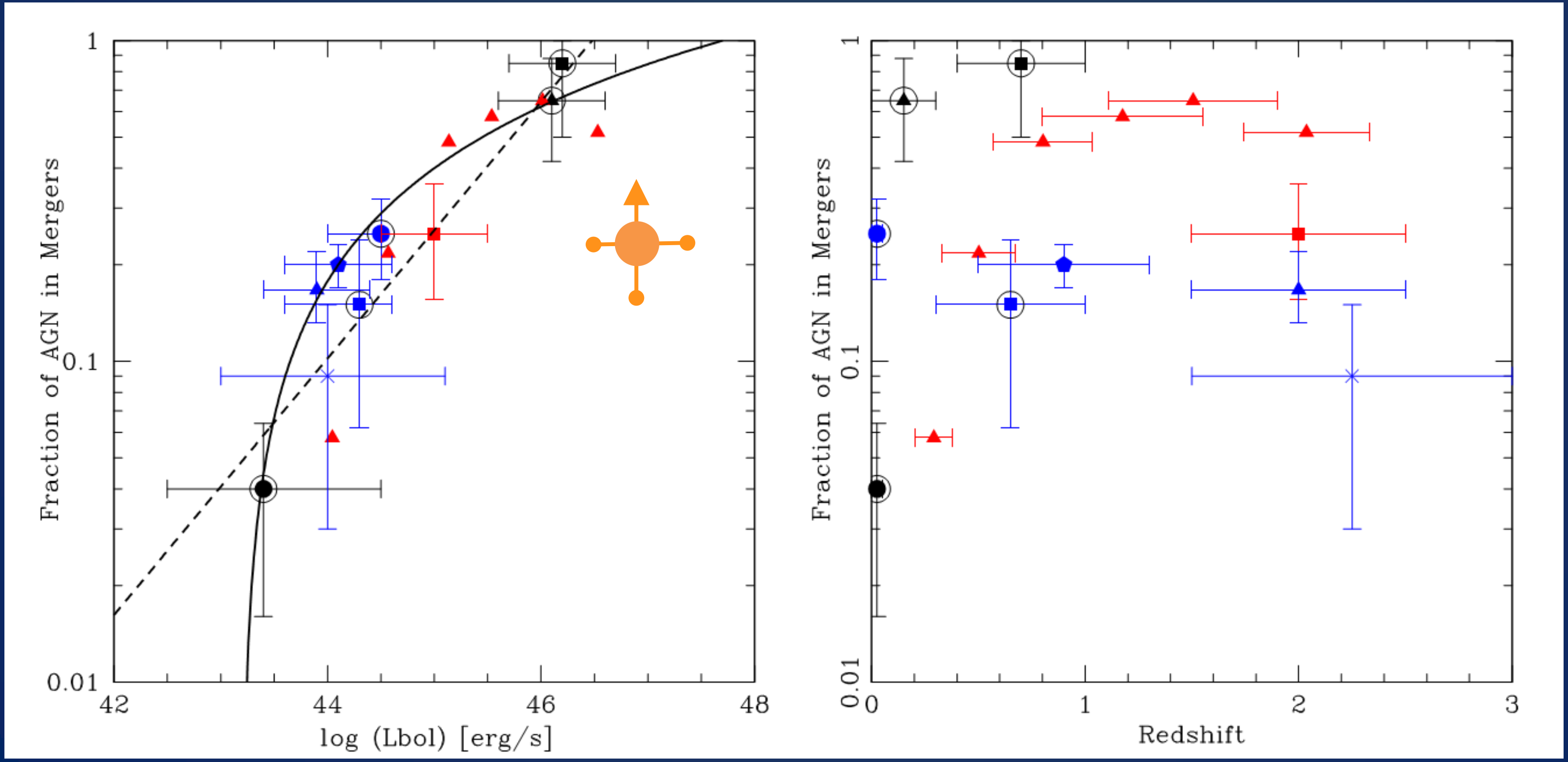
→ different locations on relic $M_{\rm BH}-M_*$ or $M_{\rm BH}-\sigma_*$ relations?

large scatter at the high-$M_{\rm BH}$ end?



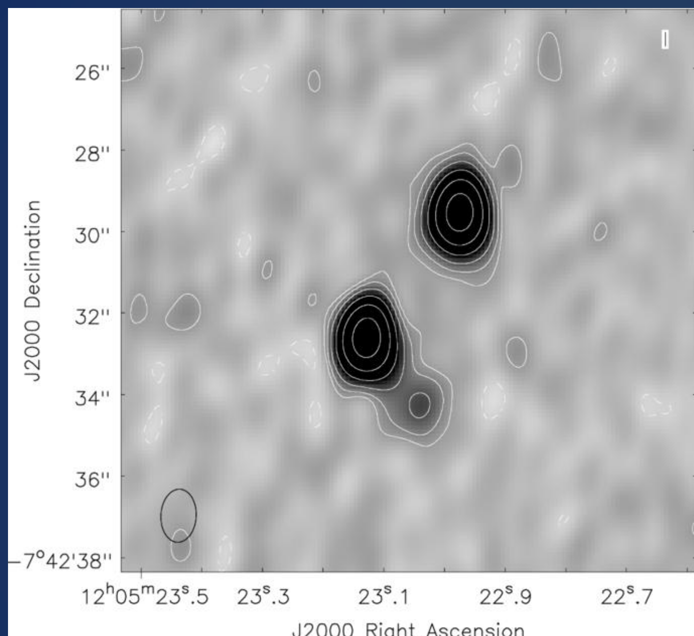
Merger Rate in AGN Hosts

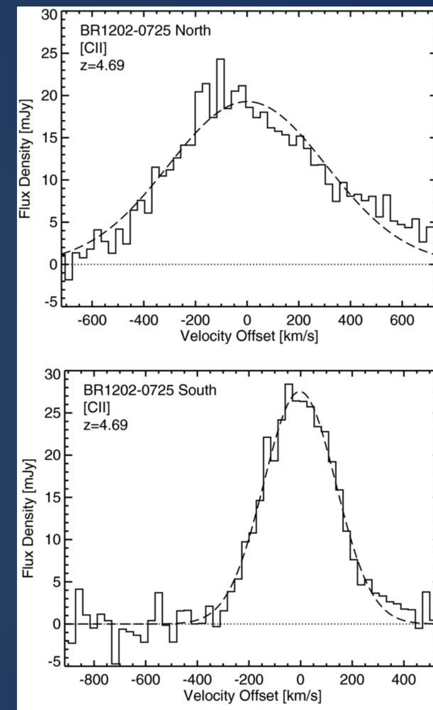
- Treister et al. (2012) compiled merger rate estimates:
  "Major Galaxy Mergers Only Trigger the Most Luminous AGNs"
- **IF** only the Herschel detections are mergers, our data suggests a major merger fraction of $23^{+10}_{-7}\ \%$



Detecting Mergers with ALMA

BR 1202-0725 - a luminous QSO at $z=4.7$





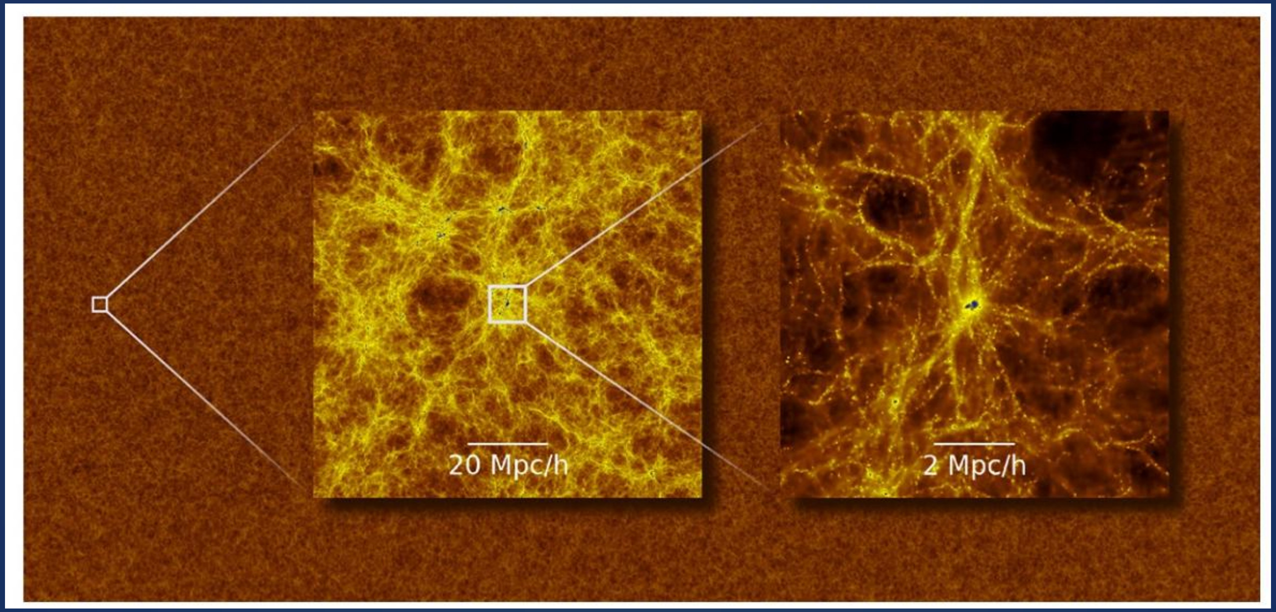
Wagg et al. (2012) – 25 minutes on-source with ALMA (SV)

→ Dynamical masses and ISM physics of hosts!

Similar work on z~6 QSO hosts by R. Wang et al.

Cosmic Environments with LBGs (?)

- First SMBHs grew in very massive, rare DM halos (Sijacki et al. 09, DeGraf et al. 2012, Di-Matteo el al. 2012)
- Densest regions in the high-z Universe (local BCGs?)



BigBlack simulation: (0.75 Gpc)^3 , only 8 comparable z~5 QSOs

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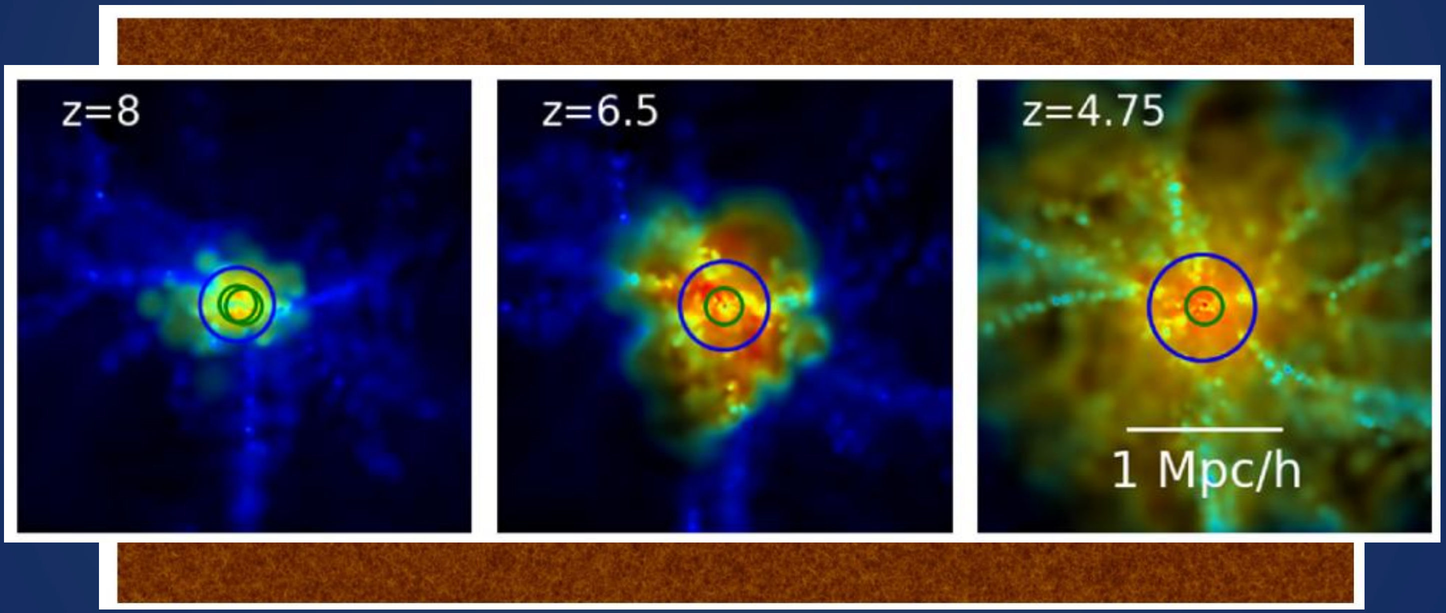

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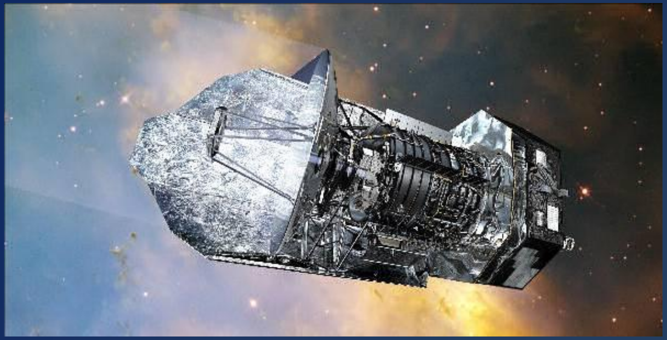
Test these ideas, by looking for over-densities of z~4.8 LBGs (“V-dropouts”) around the z~4.8 QSOs

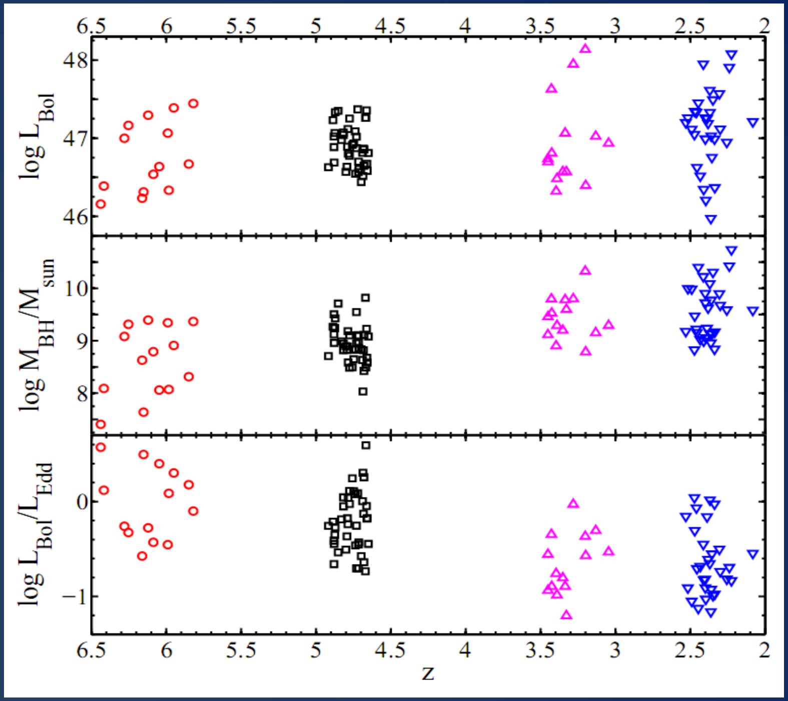
Summary

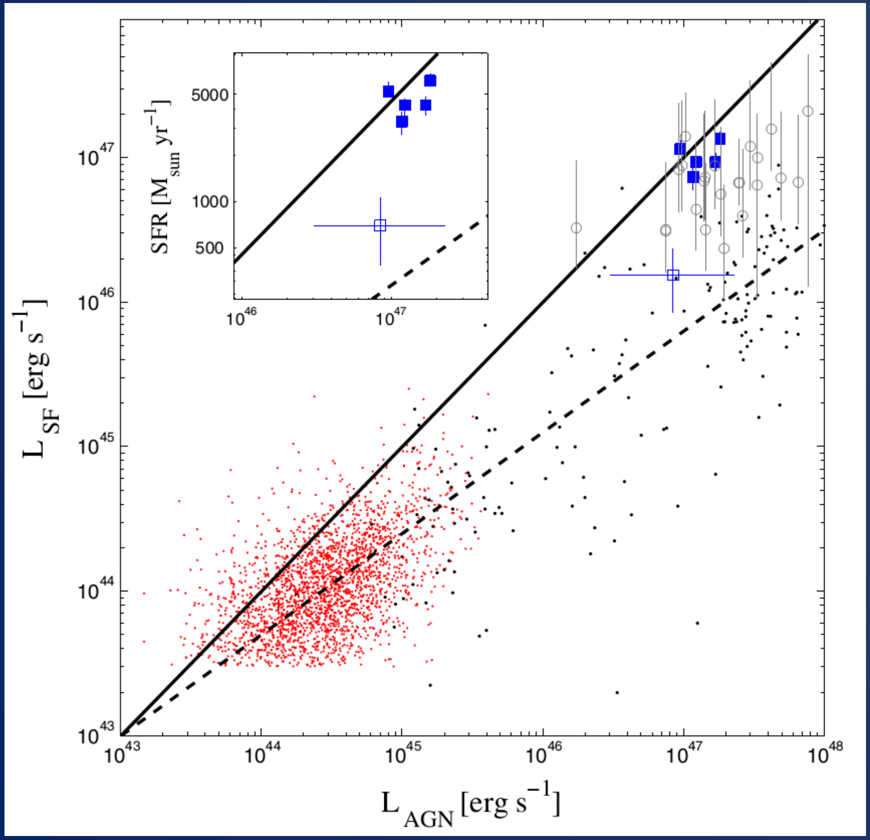
1. A large and flux-limited sample at z~4.8 with reliable $M_{\rm BH}$ and $L/L_{\rm Edd}$ estimates [Trakhtenbrot et al. 2011]
2. Masses are lower, and accretion rates are higher, than lower-z samples ➔ epoch of fast growth of the most massive BHs
3. Herschel revealed SMG/merger-like SFRs in ~1/4 of sources and a significant signal in stacking analysis of the remaining ~3/4 (main-sequence-like?) [Netzer et al. 2013]

- Future ALMA observations can provide morphology, dynamical masses and conditions in the ISM
- Future wide-field, deep imaging can probe cosmic environments

~25% of z~5 QSO hosts have SMG/merger-like SFRs







Thank you!