The first black holes and AGN

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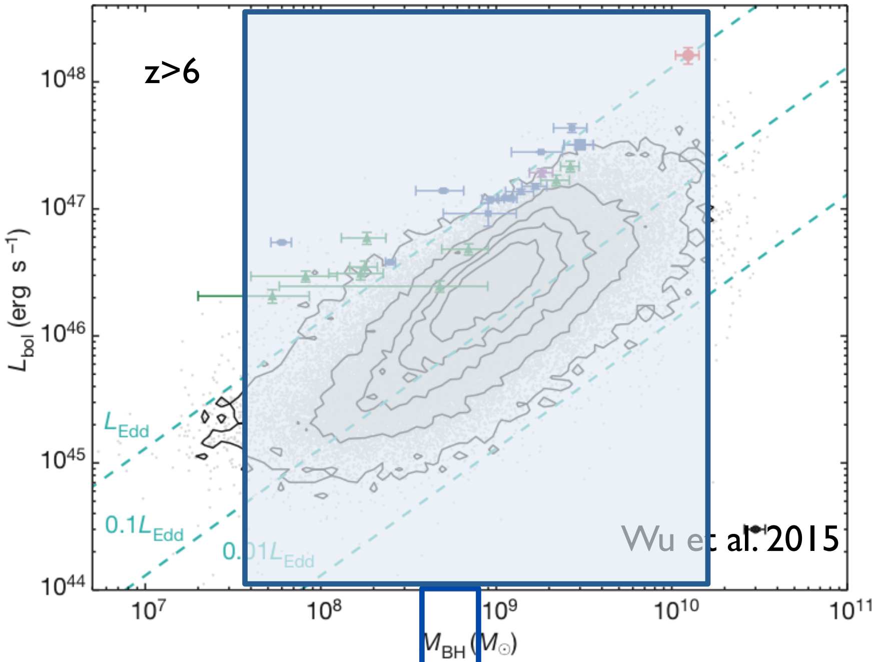
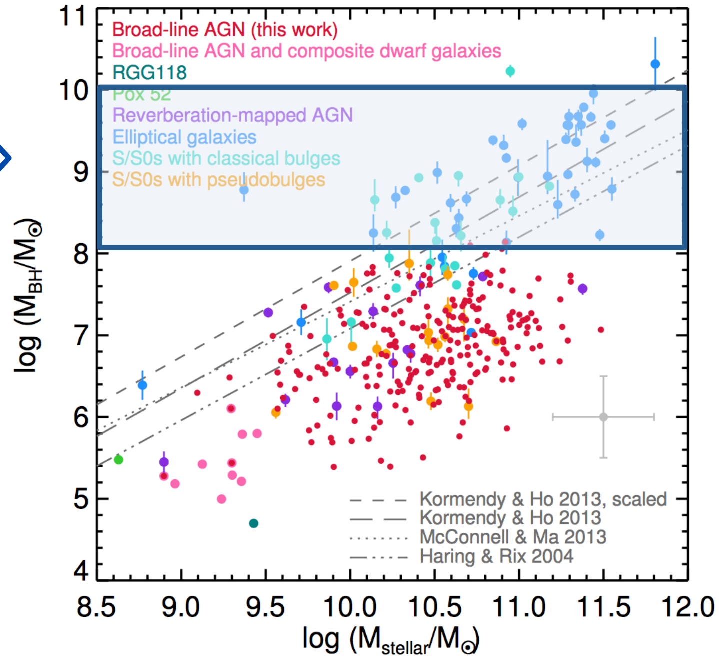
High-redshift quasars and local MBHs



As massive as the largest MBHs today, but when the Universe was ~ Gyr old



POX 52, NGC 4395: stellar mass 4×10^8 M_{sun}, M_{BH}~3×10^5 M_{sun}

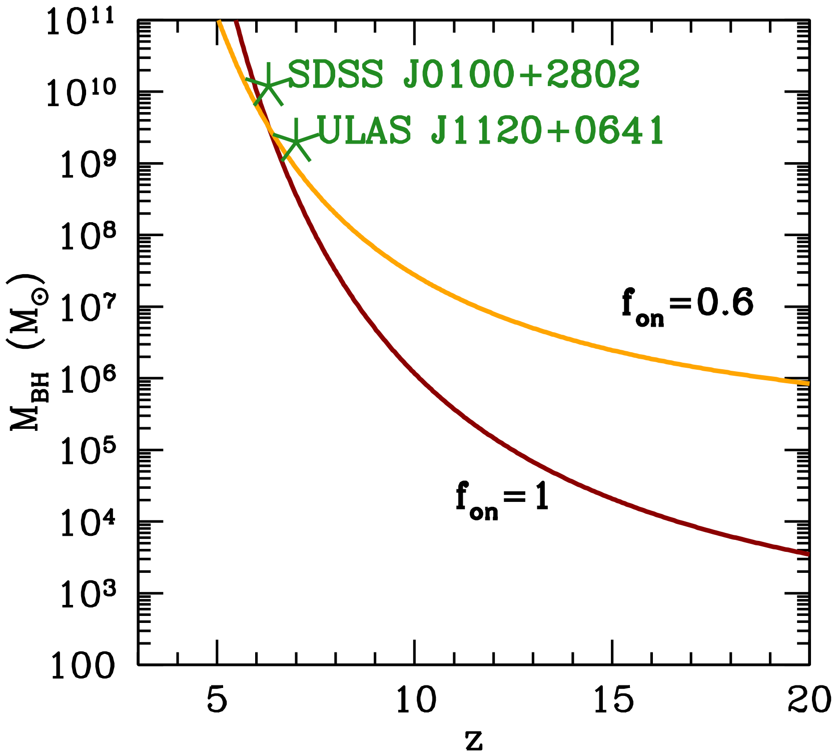
Galaxies without MBHs too

RGG18: M_{BH}~5×10^4 M_{sun}

High-redshift quasars

Very bright quasars in SDSS, CFHQ, UKIDDS with z>6 (Willott et al., 2003; Fan et al., 2006; Jiang et al., 2009)

Detection of a 2×10^9 M_{sun} BH at z=7 and a 10^{10} M_{sun} BH at z=6.3 (Mortlock et al., 2011, Wu et al. 2015)



<u>Requirement</u>:

- Need to grow at the Eddington limit for the whole time (M_0~300 M_{sun}) or 60% of the time (M_0~$10^5 M_{sun}$)

Eddington limit?

Gas infalls from the galaxy: how does the galaxy know that it has to feed the MBH *exactly* at the Eddington limit?

Super-Eddington *accretion* does not imply highly super-Eddington *luminosity*

Trapping of radiation: photons are advected inward with the gas, rather than diffuse out

Luminosity highly suppressed $L \cancel{\propto} \dot{M}$ $L \propto \ln(\dot{M})$

Only short periods needed to ease constraints (e.g. MV & Rees 2005; MV, Silk & Dubus 2015; Pacucci, MV et al. 2015a,b; Lupi et al. 2016)

High-redshift AGN

No detection in X-ray stacking of LBGs at z>6:
$L_X<10^{42}$ erg/s (Willott 2011; Fiore et al. 2012; Cowie et al. 2012; Treister et al. 2013)

Searches for point sources in deep X-ray fields has also led to inconclusive/conflicting results (Giallongo et al. 2015; Weigel et al. 2015; Cappelluti et al. 2015)

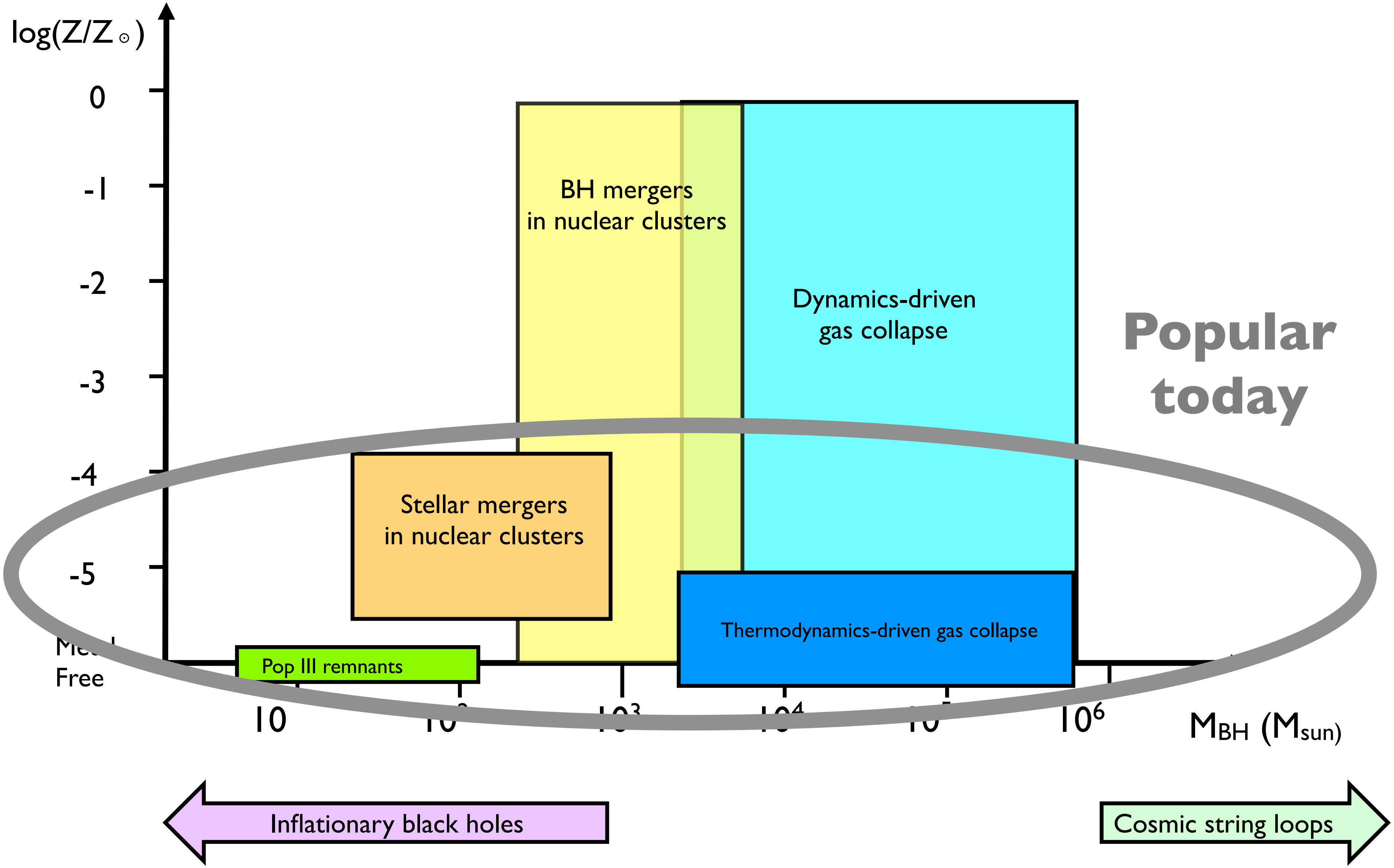
High-redshift MBHs

The billion solar masses MBHs powering the observed $z>6$ quasars are the tip of the iceberg

Very biased, dense halos

What do we expect for *normal* MBHs in *normal* galaxies?

How do MBHs form?



A physical approach to seed cosmological simulations with MBHs

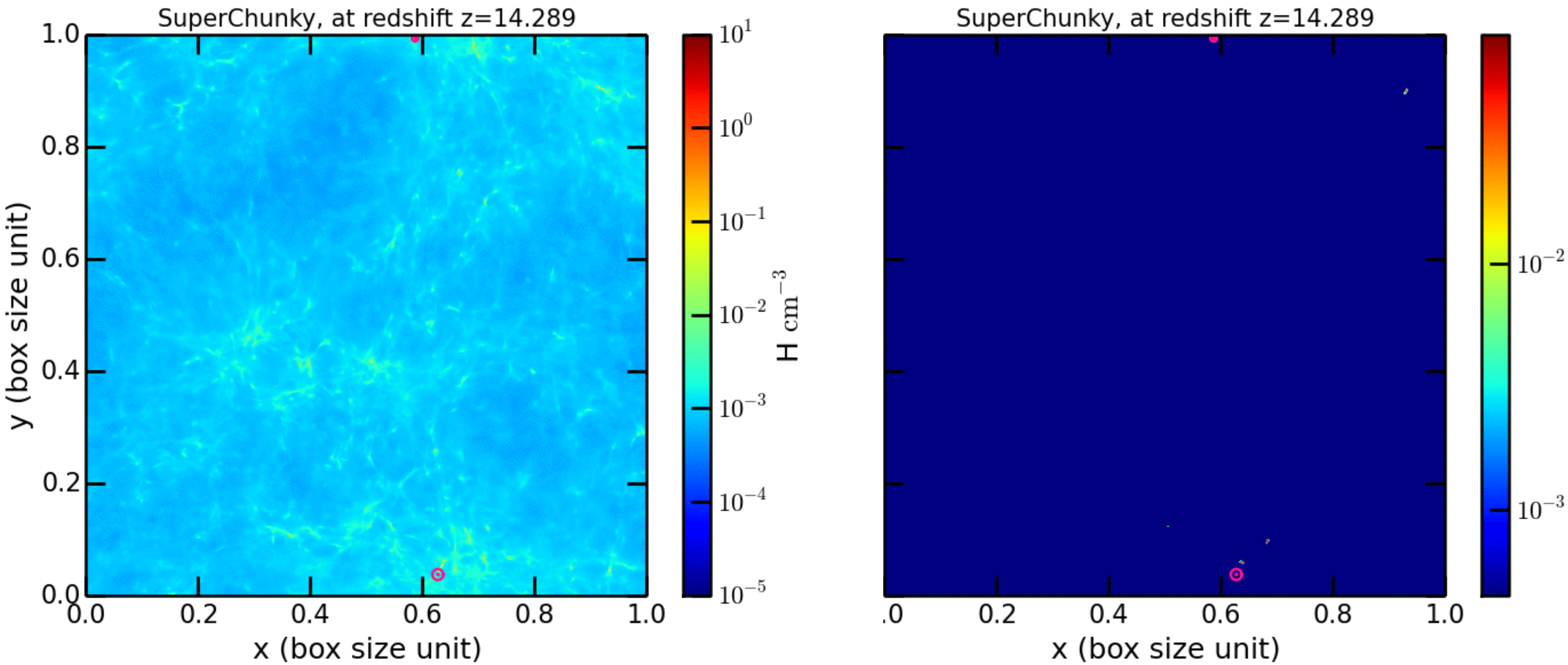
Ramses: Grid-based hydro solver with mesh refinement (Teyssier 2002)

- Cooling/Star formation (Rasera & Teyssier 2006)
- Supernova feedback (Dubois & Teyssier 2008, Teyssier et al. 2013, Dubois et al. 2015)
- BH accretion + AGN feedback (Dubois et al. 2012)

MBH seeds (sink particles) formed in:

- overdense bound collapsing regions
- metal-poor ($Z<10^{-3.5}\,Z_{sun}$)
- initial mass of BH:
  - one by one
  - based on stellar IMF + stellar mergers

Habouzit, MV, Dubois 2016



Density map
BHs form only in high gas-density regions

Metallicity map
BHs form in low-metallicity regions

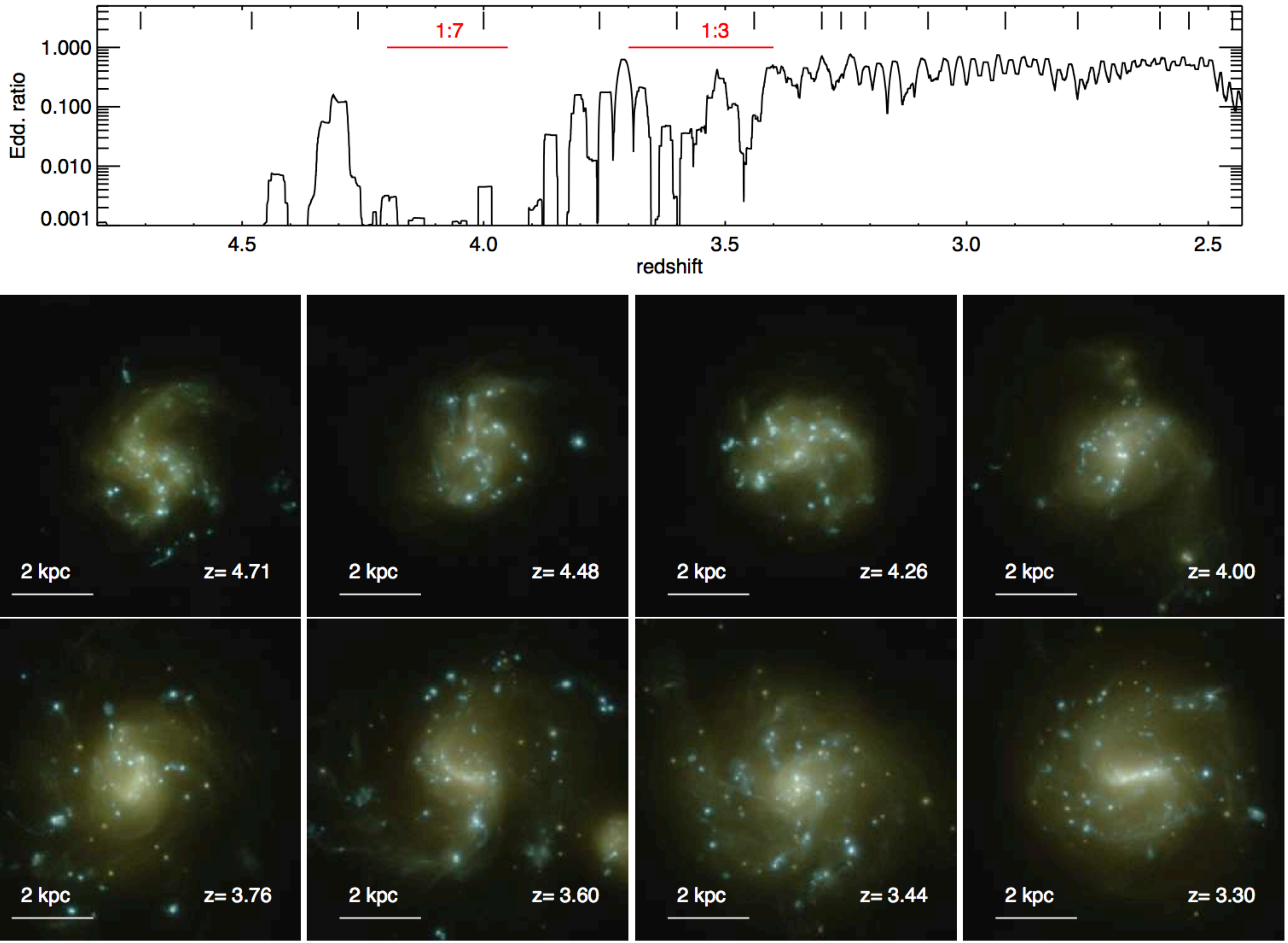
(10 Mpc)^3 cosmo hydro simulation:
Spatial resolution 80 pc
DM resolution 2 10^6 M_{sun}

Habouzit, MV, Dubois 2016

How do galaxies feed *normal* MBHs?

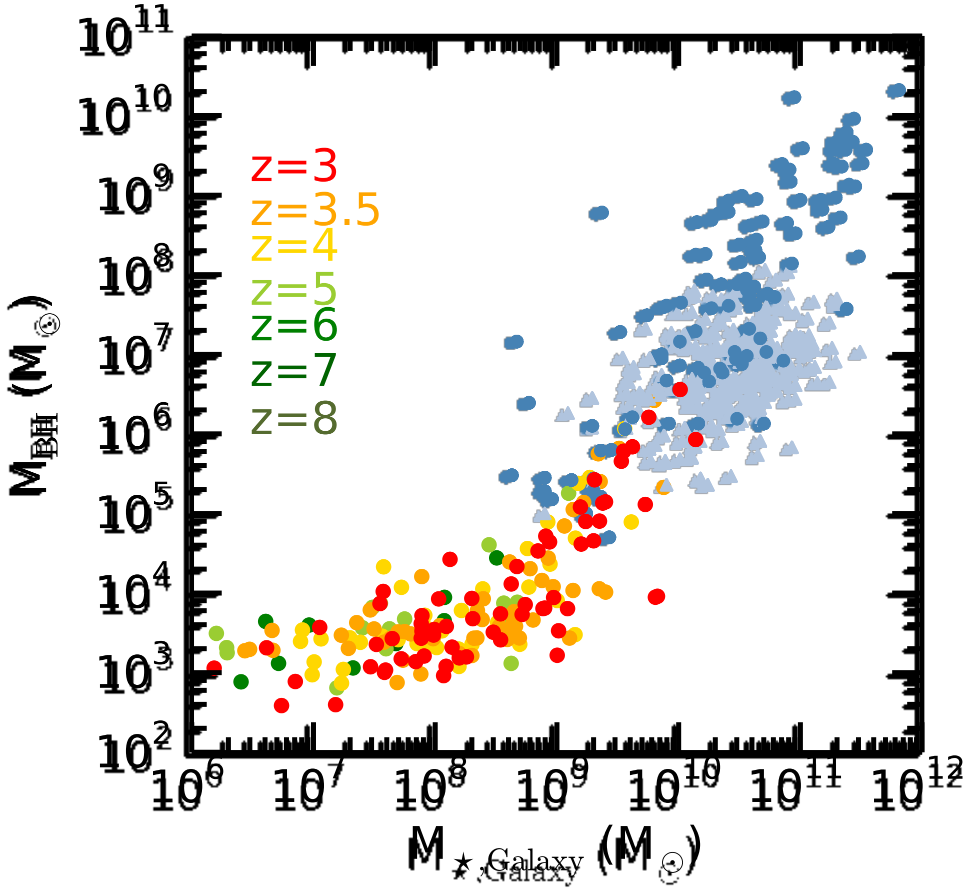
Low-mass BHs in low-mass galaxies: fragile environment

Interplay between SN feedback and MBH accretion: SN feedback is sufficient to energize the gas and suppress accretion (Dubois+14)



SETH, Ramses Cosmological Zoom, ~5pc resolution, Dubois, MV+14

How do galaxies feed *normal* MBHs?

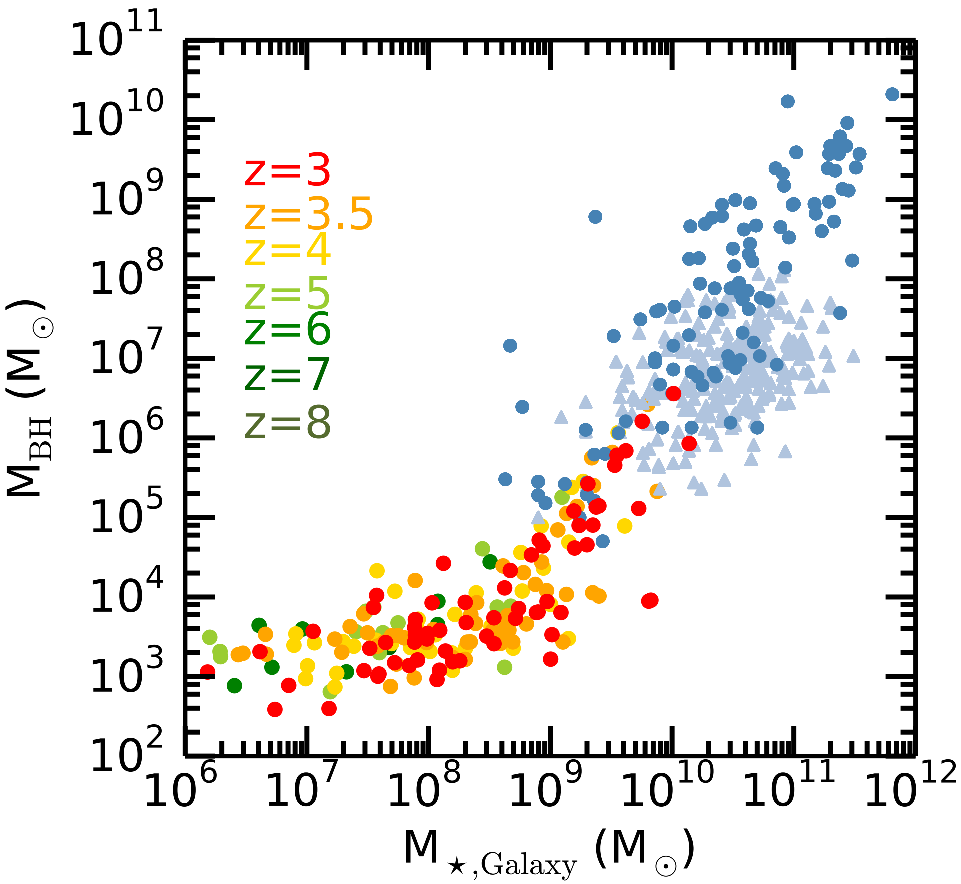


z=0 **BHs** and **AGN**
(Reines & Volonteri 2015)

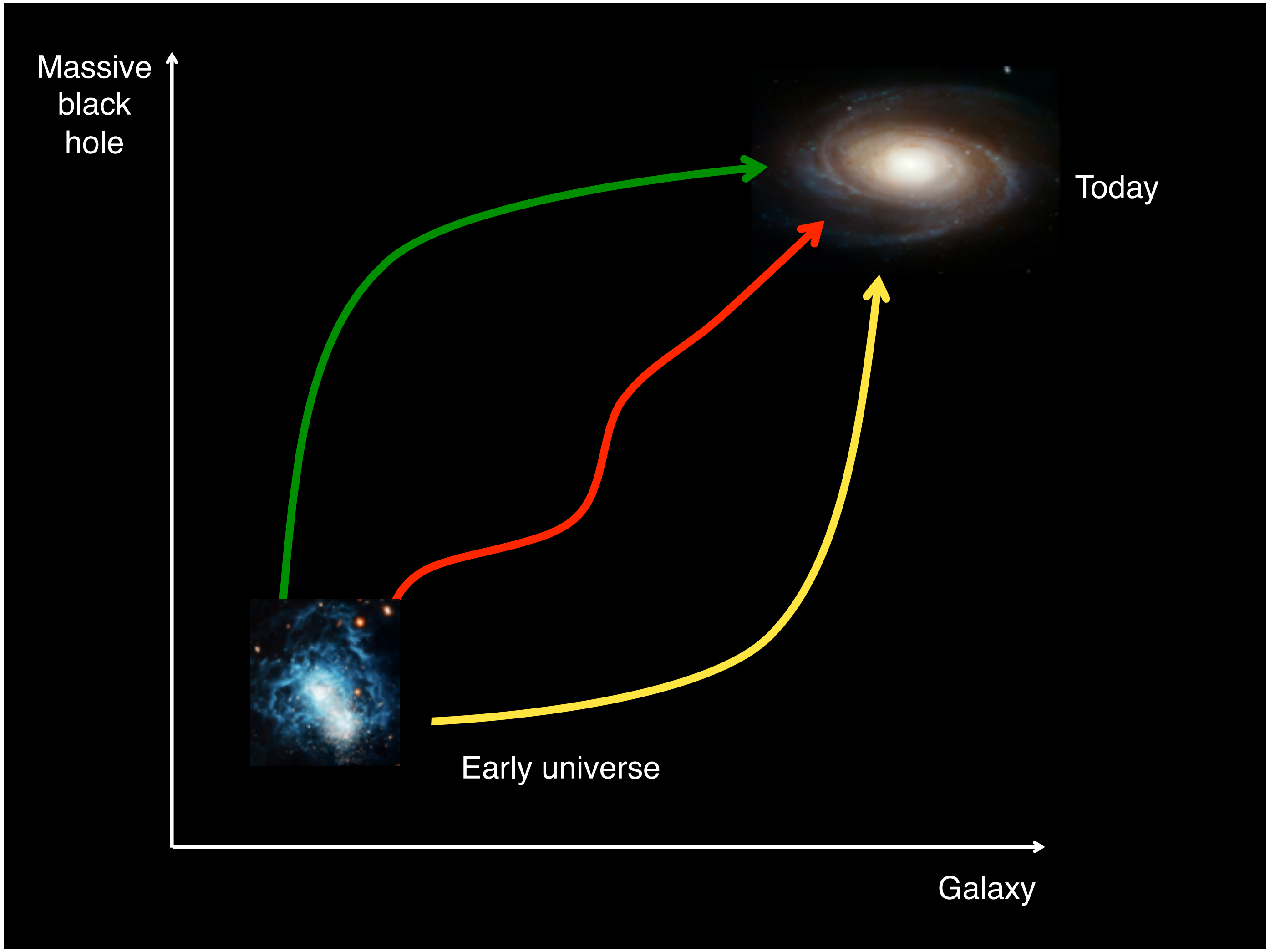
10 Mpc
cosmological volume,
~80pc resolution

Habouzit, MV, Dubois 2016

How do galaxies feed *normal* MBHs?

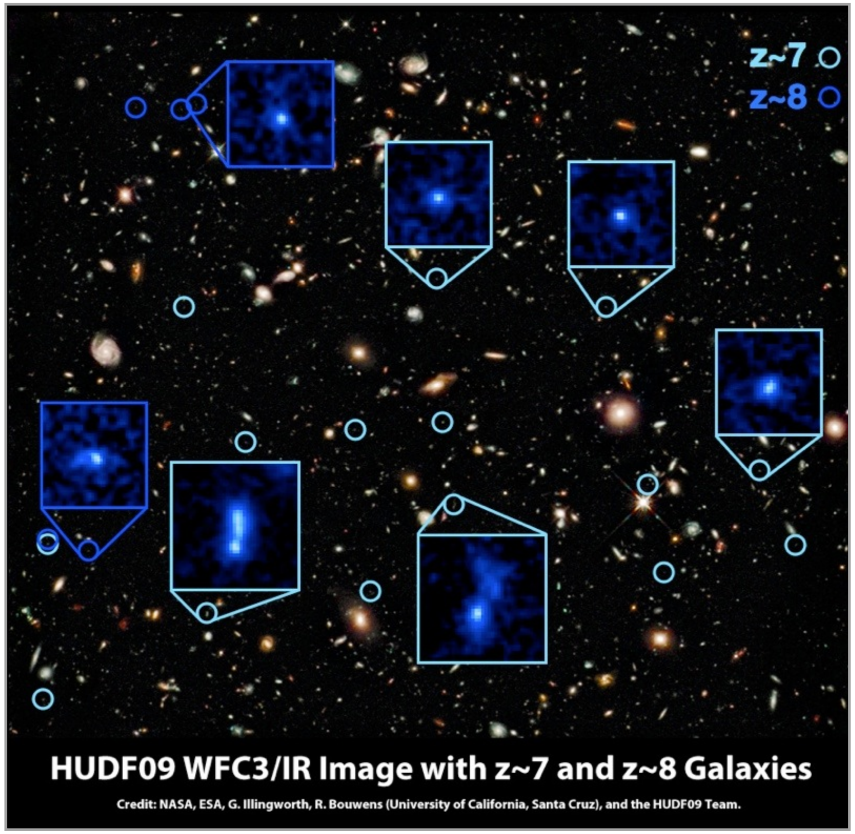


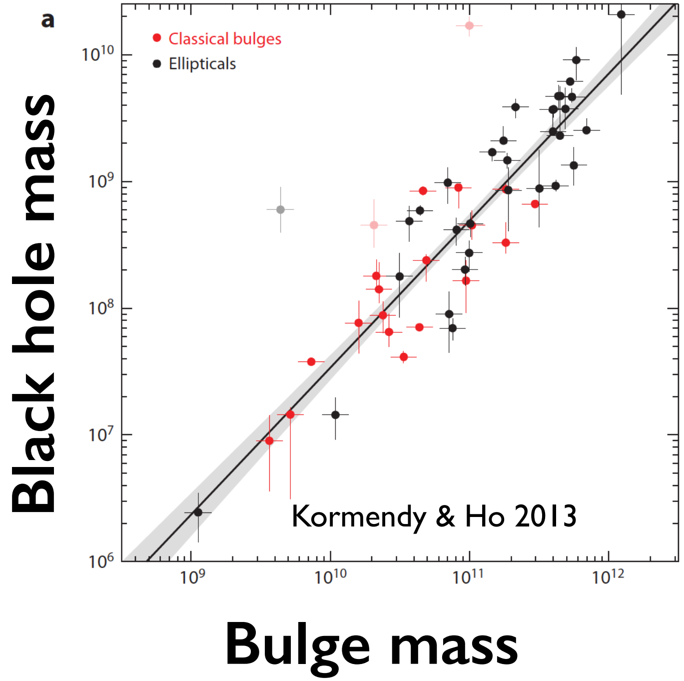
Growing black holes in growing galaxies



Searches for AGN in galaxies with stellar masses ~10^9 M_{sun} at z > 6 have found very few, if any, black holes

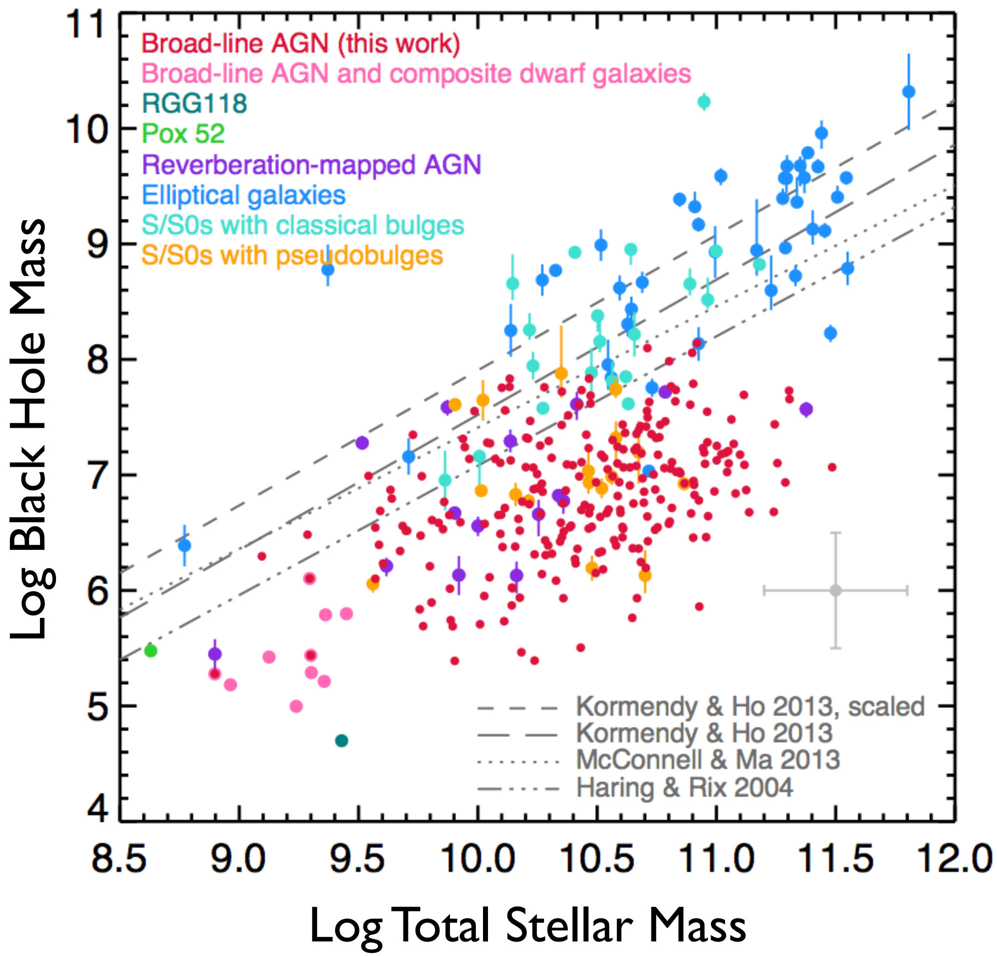
(Willott 2011; Fiore et al. 2012; Cowie et al. 2012; Treister 2013; Giallongo et al. 2015; Weigel et al. 2015; Cappelluti et al. 2016)





Expect M_{BH} ~10^6 M_{sun}

M_{BH} vs galaxy at high redshift



BH mass

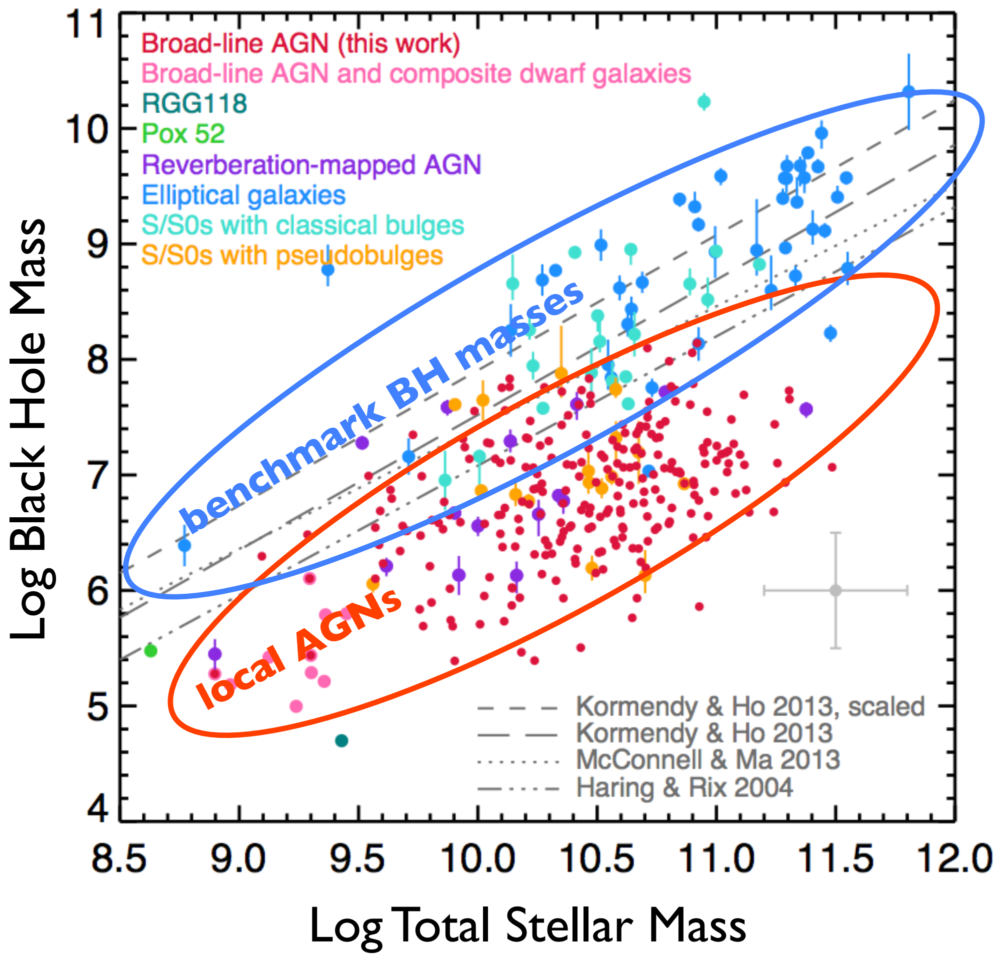
vs.

total galaxy stellar mass

(341 nearby galaxies)

Reines & MV 2015

M_{BH} vs galaxy at high redshift



$M_{BH} \sim 10^{-3}\ M_{gal}$

$M_{BH} \sim 10^{-4}\ M_{gal}$

Reines & MV 2015

M_{BH} vs galaxy at high redshift

stellar mass ~10^9 M_{sun}

M_{BH} ~10^{-3} M_{gal}

M_{BH} ~10^6 M_{sun}

M_{BH} ~10^{-4} M_{gal}

M_{BH} ~10^5 M_{sun}

AGN expected to be less luminous

Expect 0-3 AGN with L_X >10^{42} erg/s in the 4Ms CDFS

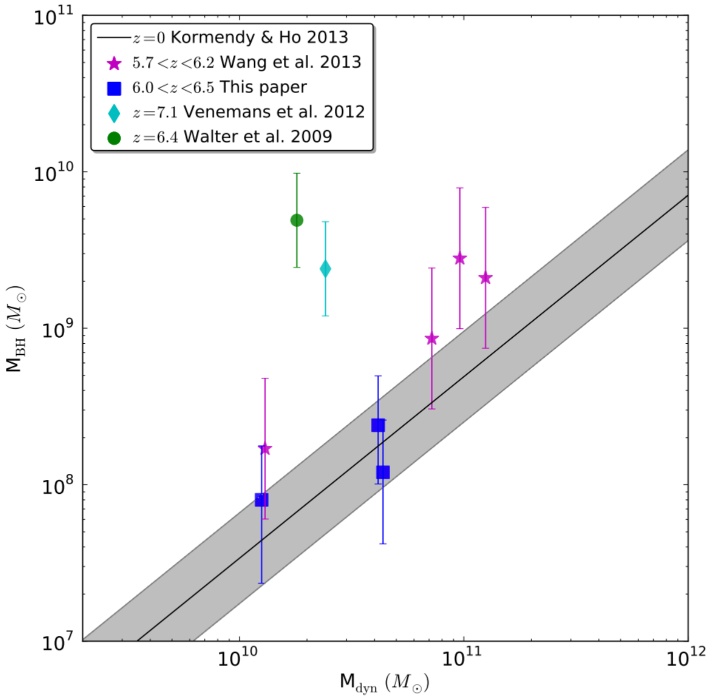
Consistent with current limits/candidates

MV & Reines 2016

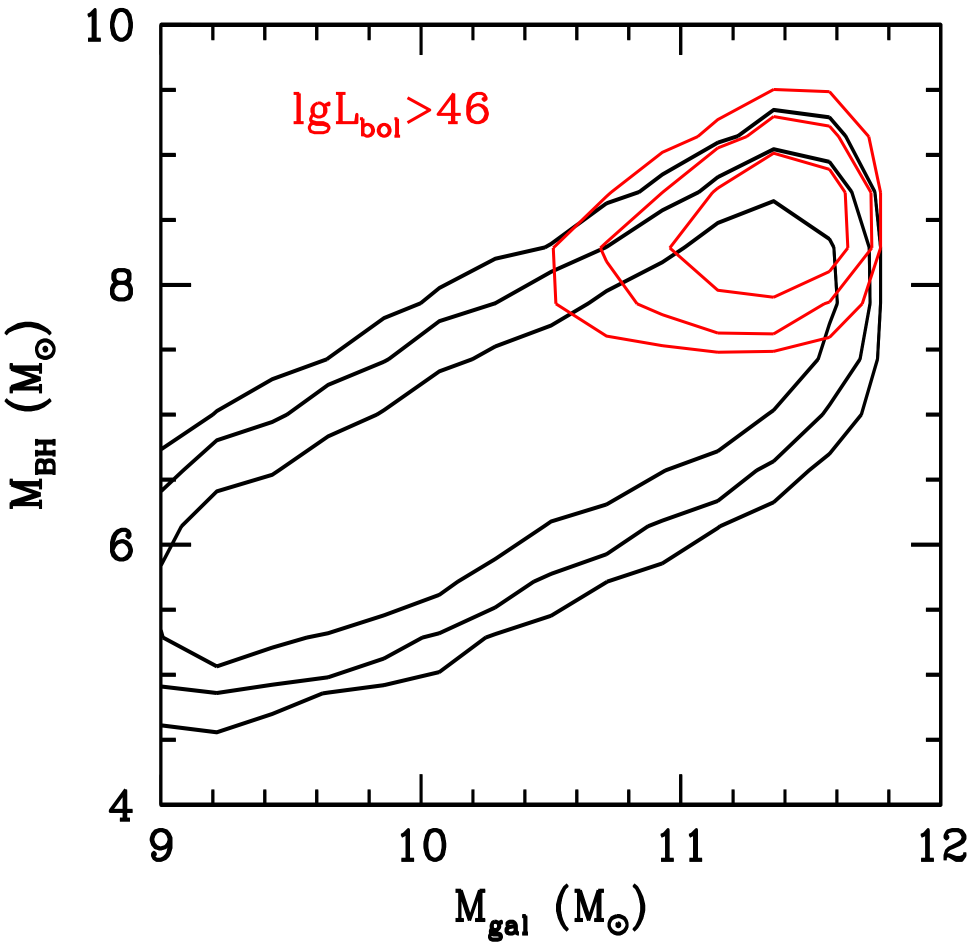
High-redshift MBHs

Current limits/candidates high-z AGN compatible with a population of MBHs similar to low-z counterpart in galaxies of similar mass

How about the high-z quasars?

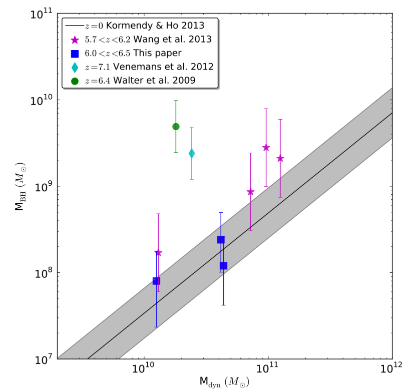


M_{BH} vs galaxy at high redshift



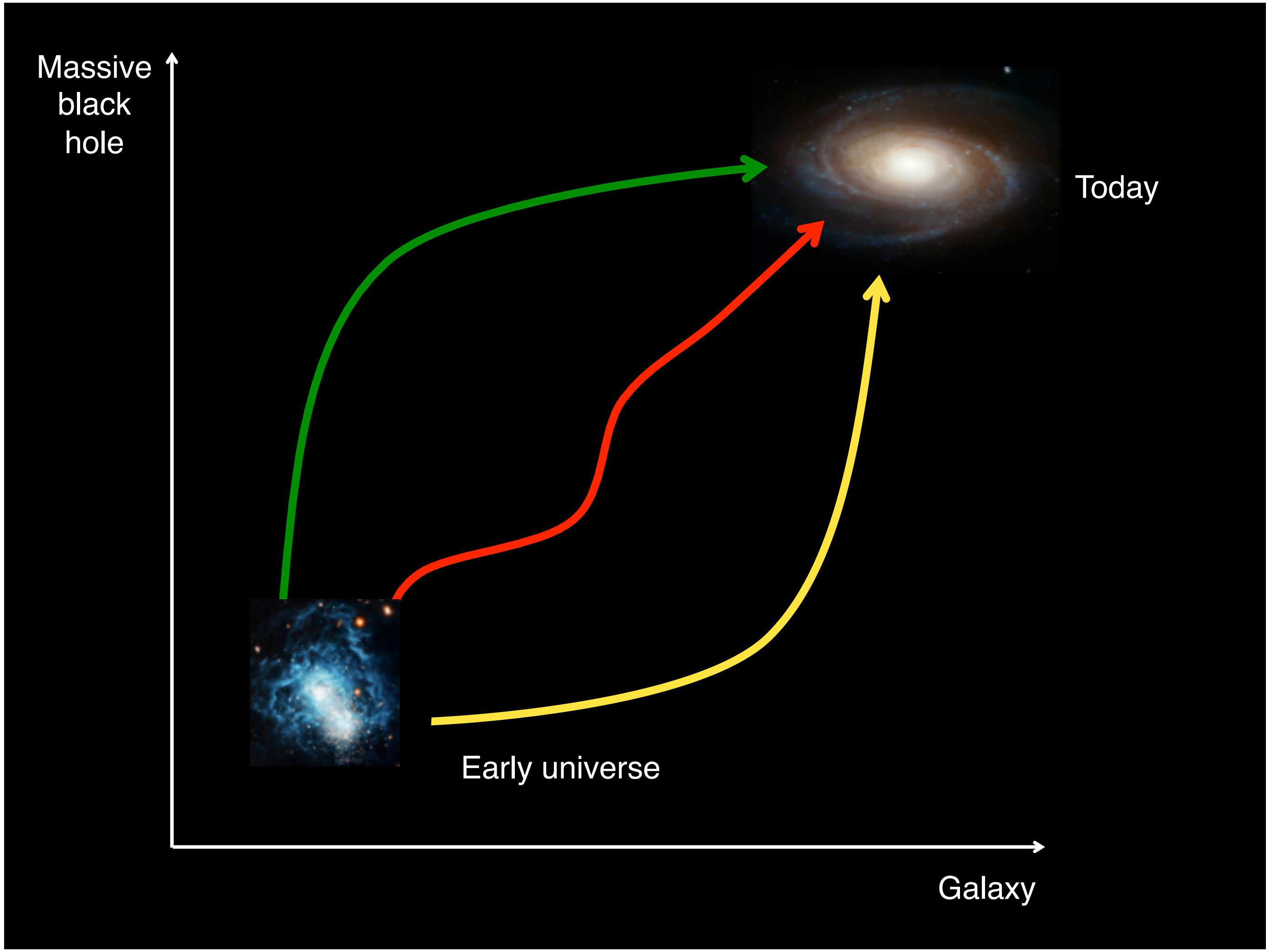
Current large-shallow surveys select only the most luminous quasars, $L_{bol} > 10^{46}$ erg/s

$\Rightarrow$ the most massive holes at a given stellar mass



Lauer et al. 2007; MV & Stark 2011; MV & Reines 2016

Growing black holes in growing galaxies



Growing black holes in growing galaxies: contribution to reionization

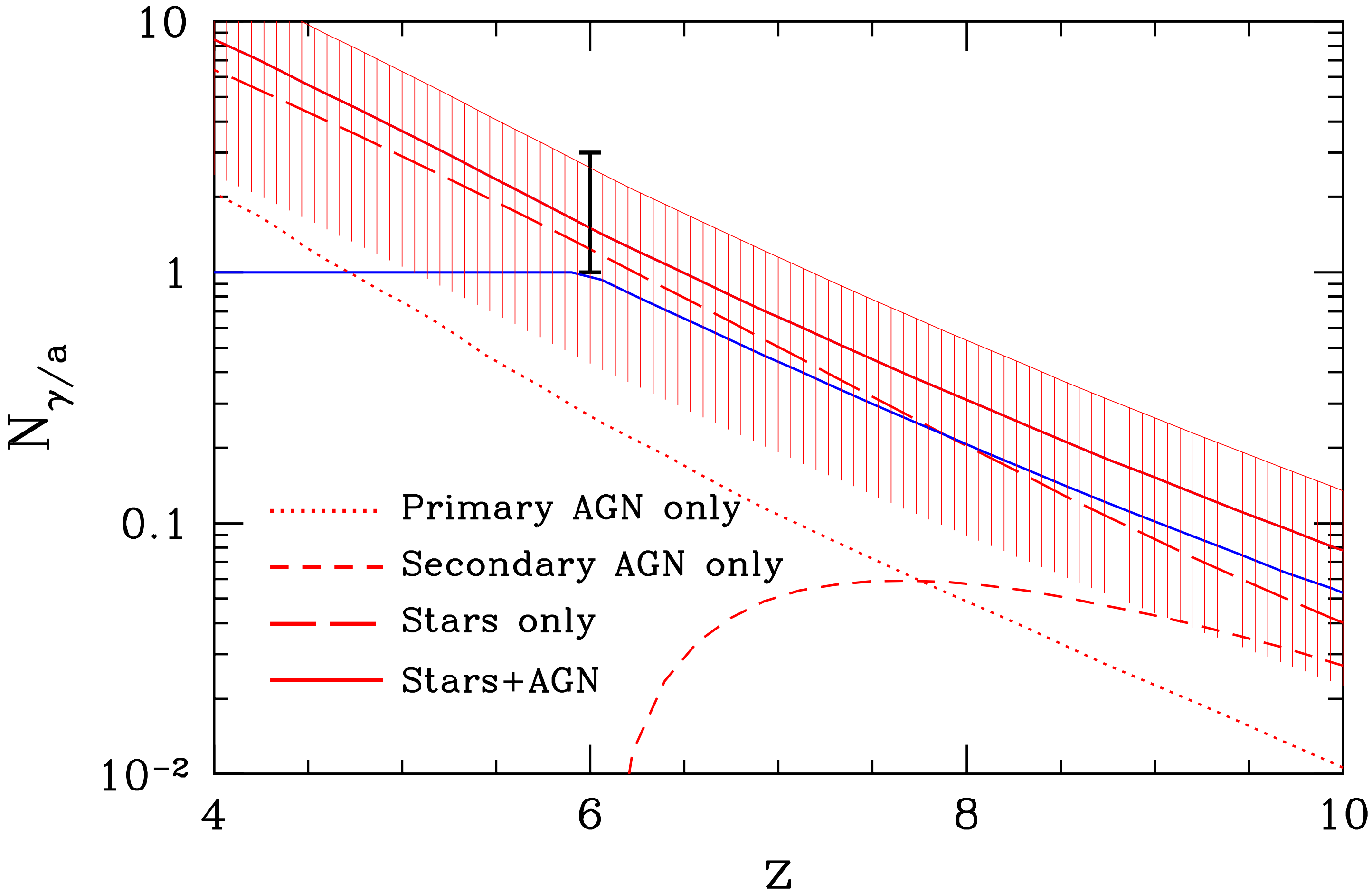
Galaxies form stars and emit ionizing photons

MBHs accrete and emit ionizing photons

Relative Role of Stars and Quasars in Cosmic Reionization

MBHs predicted to contribute 20-50% of ionizing photons (MV & Gnedin 2009)

Growing black holes in growing galaxies: contribution to reionization



MV & Gnedin 2009

High-redshift MBHs

“Ab-normal” MBHs in “normal” galaxies are those that grow fast and can be detected as luminous quasars

“Normal” MBHs in “normal” galaxies may grow slowly

Current limits/candidates high-z AGN compatible with a population of MBHs similar to low-z counterpart in galaxies of similar mass

Relative role of stars and MBHs in cosmic reionization