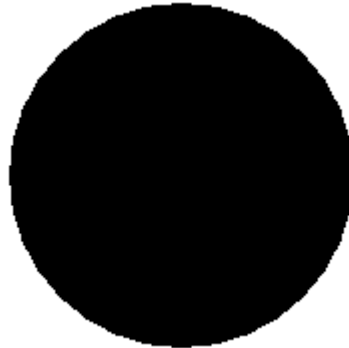


Supermassive black holes: formation and evolution



Céline Hadziioannou, 3 march 2005

Supermassive Black Holes (SMBH) appear to be present in most local galaxies.

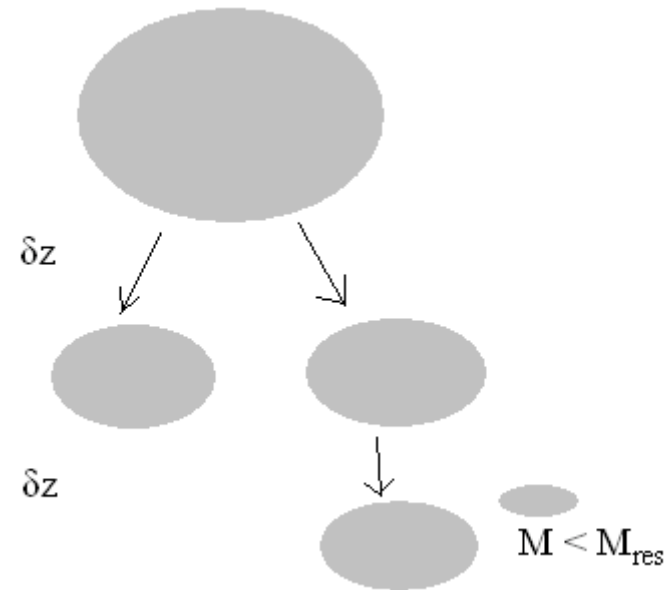
- How did they get there?
- How do they evolve?
- What makes them grow?
- What happened at $z \sim 2$?

How did they get there?

Volonteri, Haardt, Madau 2003 (VHM):

Construct binary merger tree.

First: model a halo
(using EPS formalism)

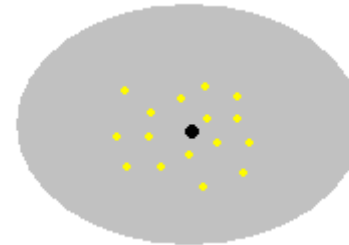


How did they get there?

Next:

Introduce a BH seed, using VMS $\sim 150 M_{\text{sun}}$.

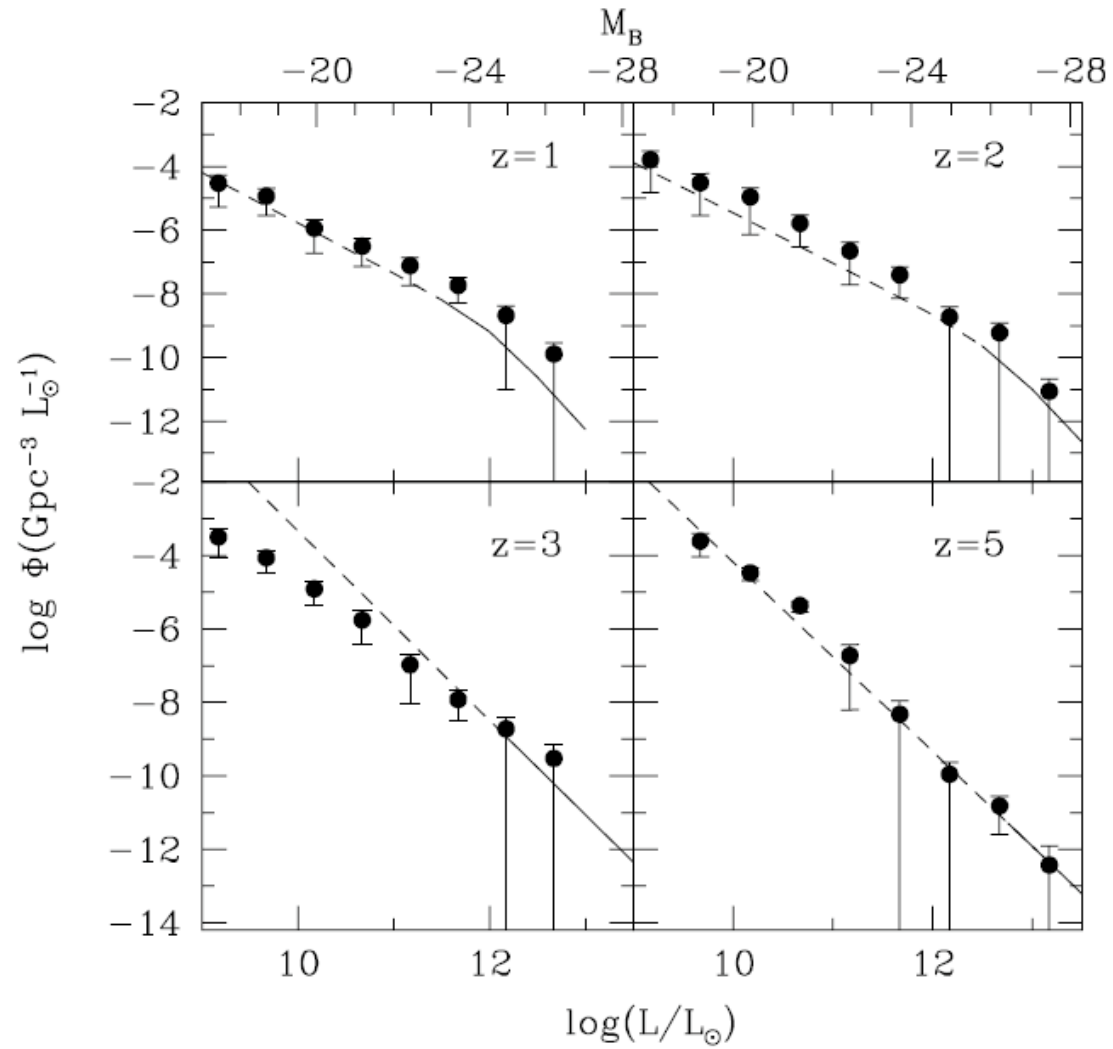
- mergers (major & minor)
- accretion on BH
- binary BH systems



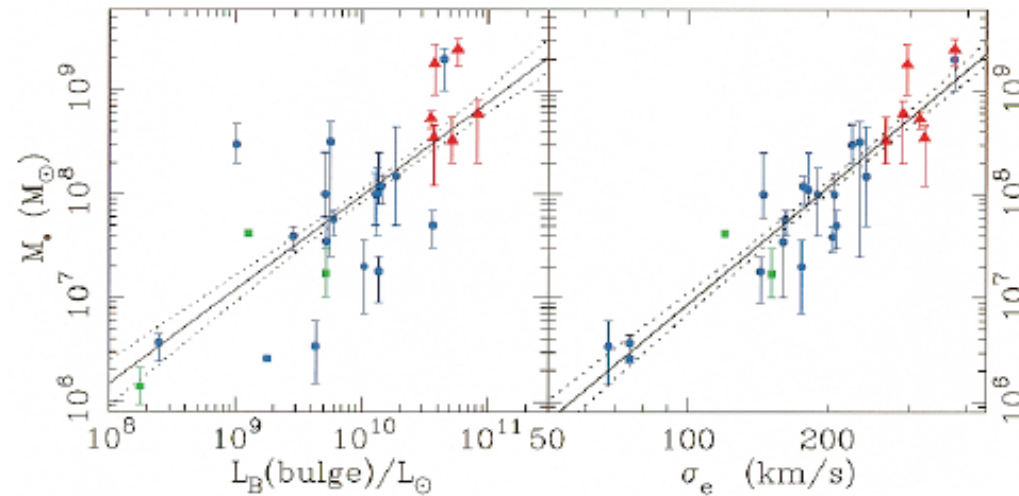
Binary BH systems

- Reduce separation by expelling stars
- Gravitational waves
- Triple interactions -> wandering BHs

Results VHM: B-band Luminosity function of quasars



The $m_{BH} - \sigma_c$ relation: a sidestep to Gebhardt et al. 2000

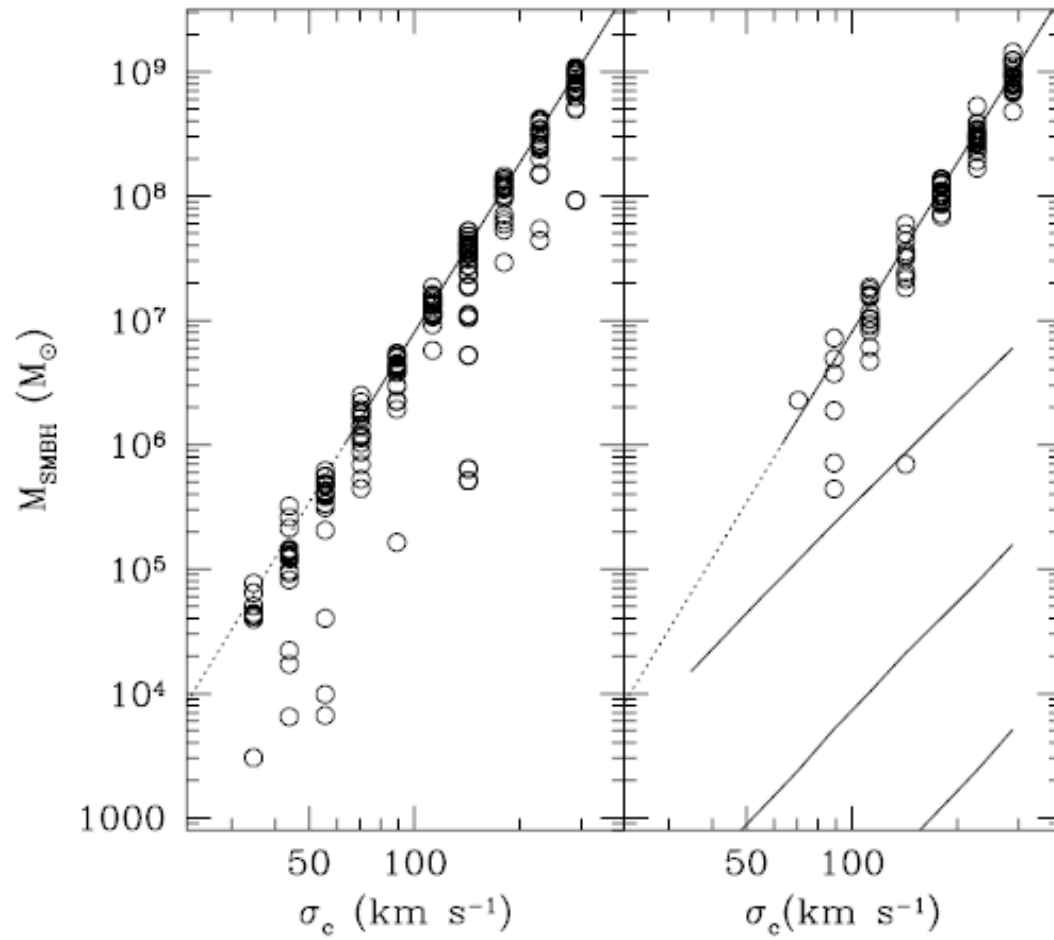


$$M_{bh} = 1.2 \times 10^8 M_{\odot} \left(\frac{\sigma_e}{200 \text{ km s}^{-1}} \right)^{3.75}$$

Wyithe & Loeb
2003:

$$\frac{M_{bh}}{M_{bulge}} = 0.001 \left(\frac{F_{SN}}{0.5} \right) \left(\frac{F_q}{0.07} \right)^{-1} \left[\frac{\xi(z)}{\xi(2)} \right]^{1/2} \left(\frac{1+z}{3} \right)^{3/2}$$

Back to VHM:

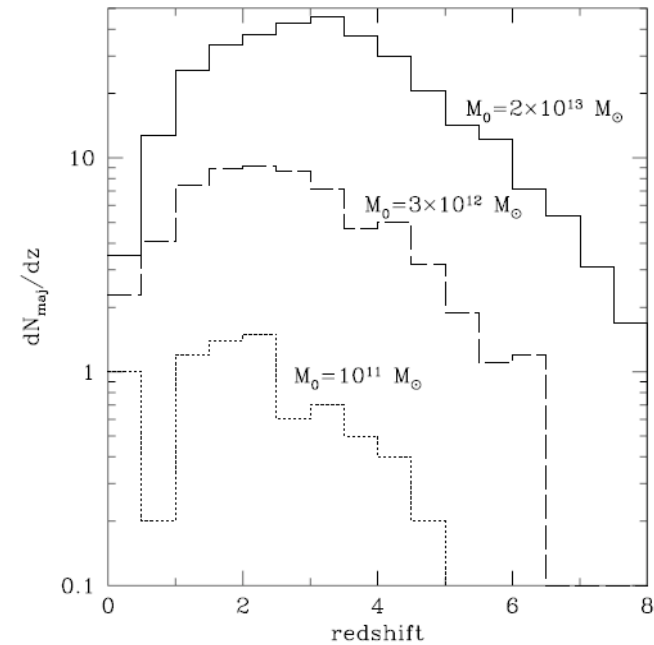


What happened at $z \sim 2$?

Kaufmann & Haehnelt 2000 (KH)

Peak in quasar activity at $z \sim 2$, why?

KH focus on the lower redshifts, for 2 different cosmologies: CDM and Λ CDM



Assumptions:

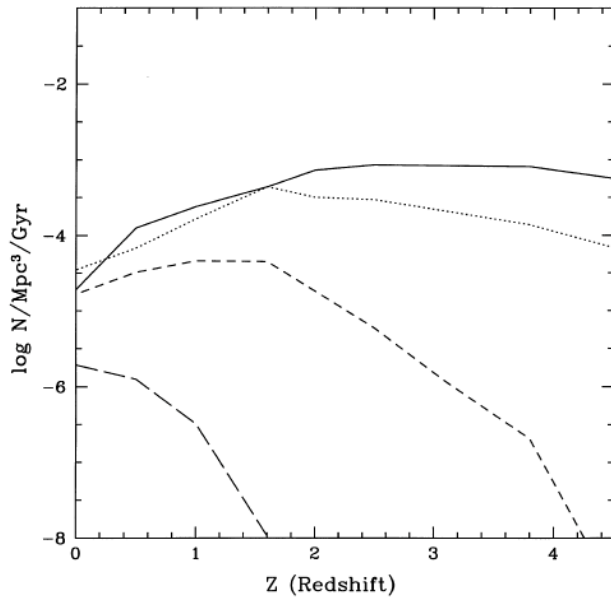
- BH form and grow mainly during major mergers
- BH coalesce at once after merger, and accrete gas
- Gas consumption rate efficiency scales with z
- Cooling & star formation:

$$\dot{M}_* = \alpha M_{\text{cold}} / t_{\text{dyn}}$$

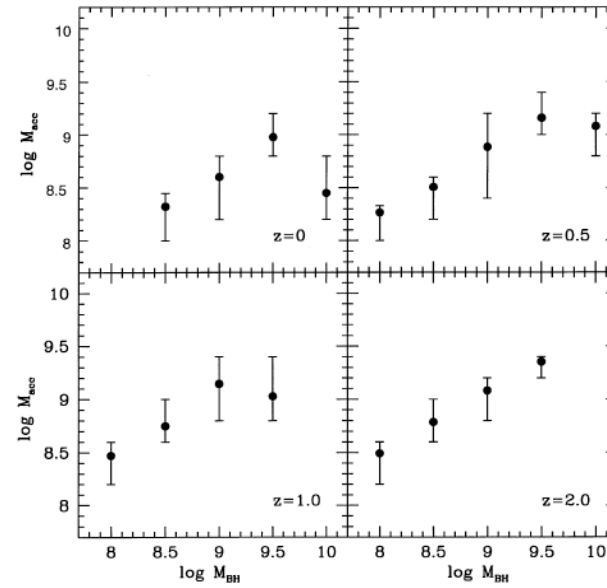
$$\alpha = cst \quad \text{or:}$$

$$\alpha(z) = \alpha(0)(1+z)^{-\gamma} \quad \text{with} \quad \gamma = 1-2$$

Results KH:

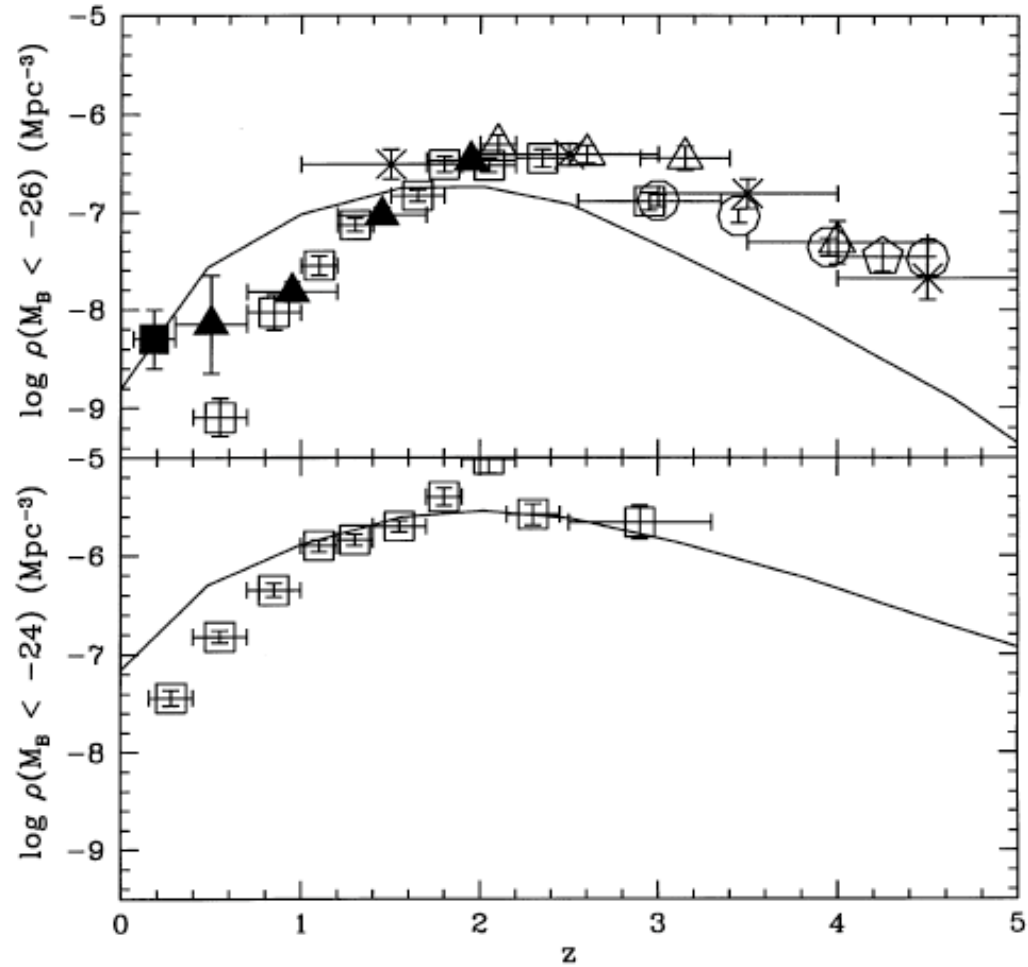


Number of major mergers per Gyr per Mpc^3



Avg. mass accreted by BHs

Results KH in Λ CDM:



Evolution of space density of quasars

What happened at $z \sim 2$?

- Decrease in merging rates
- Decrease in gas available for fuel
- Assumption: BHs accrete mass more slowly at later times

Conclusions:

How did they get there?

How do they evolve?

What makes them grow?

What happened at $z \sim 2$?