

# ***The Evolution of AGNs in EAGLE***

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EAGLE TEAM:


(Evolution and Assembly of Galaxies and their Environments

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The logo for the Virgo Consortium, featuring the word "VIRGO" in white capital letters on a black background with a bright yellow starburst effect.The logo for the Institute for Computational Cosmology (ICC), featuring the letters "ICC" in a bold, red, sans-serif font.

Institute for  
Computational Cosmology

# ***Outline***

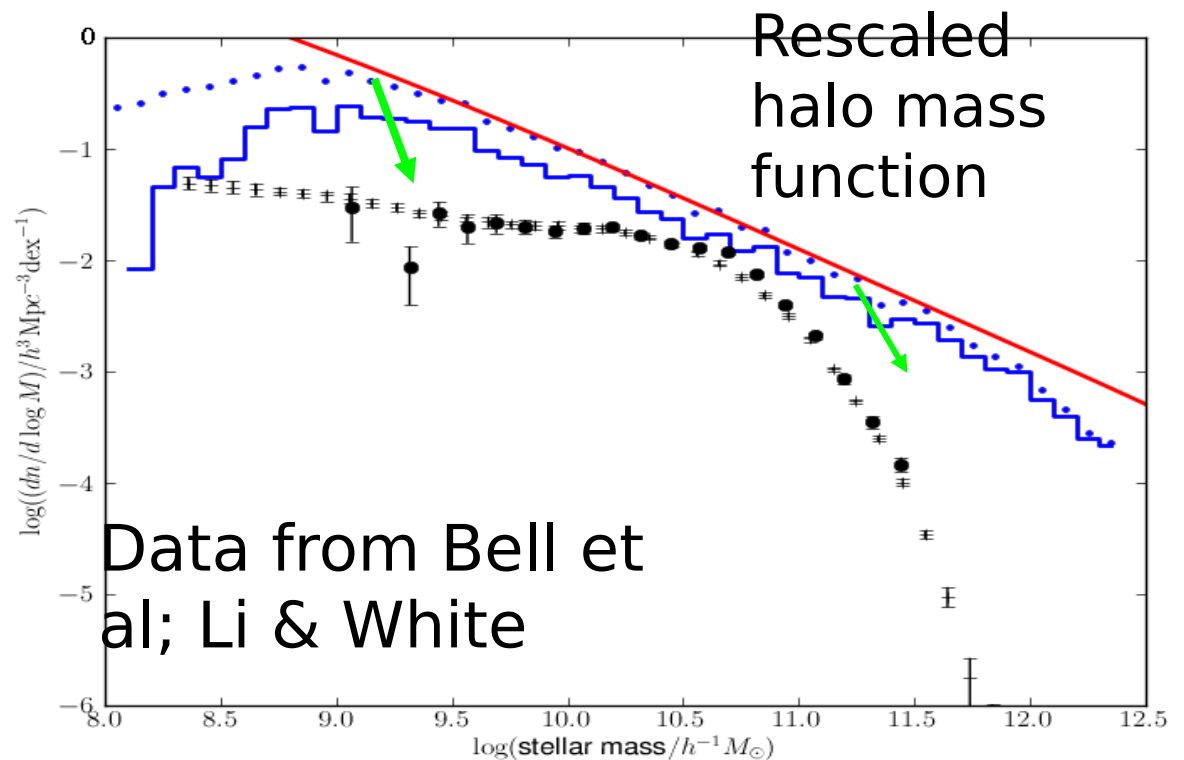
- Motivation
- The BH model in cosmological simulations
- AGN luminosity functions (preliminary results)
- Summary and Future work

# **Motivation:**

What is the the role of the BHs in the evolution of the galaxies?

# The shape of the galaxy mass function

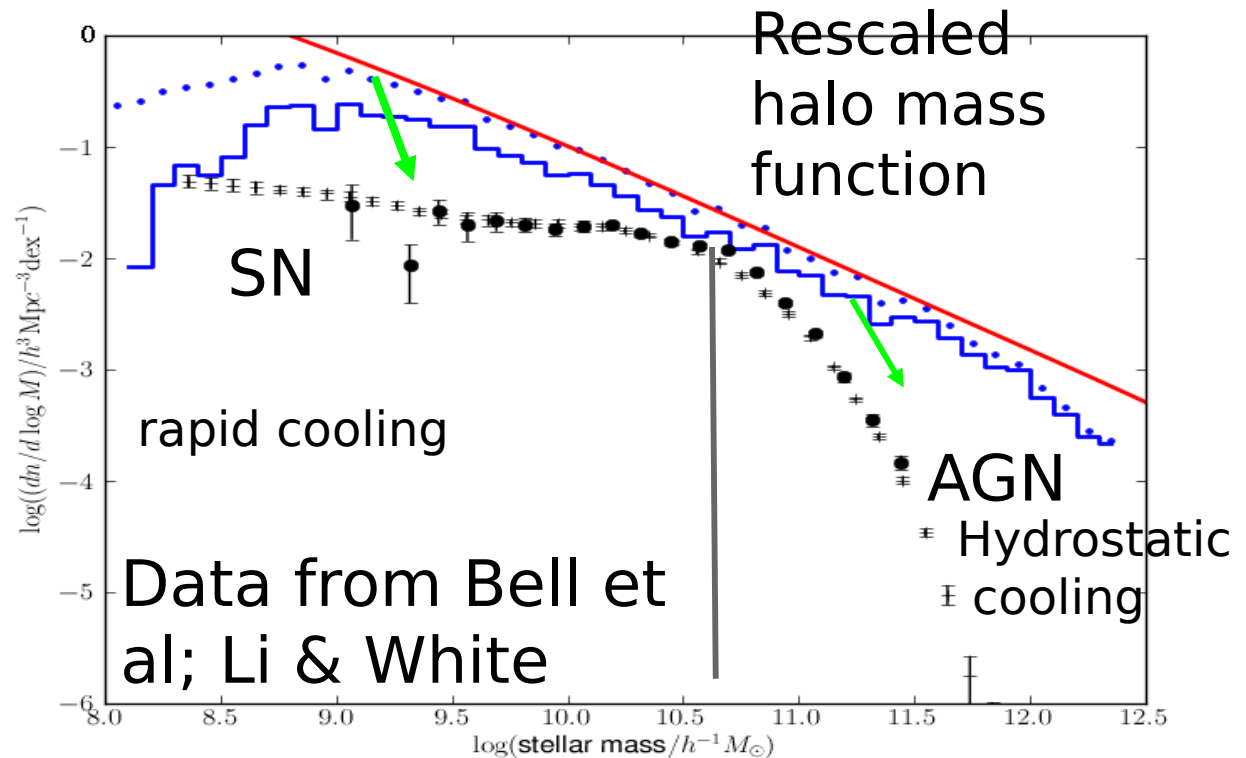
Discrepancy between halo mass function and stellar mass function



# The shape of the galaxy mass function

Feedback from SN + AGN to match up stellar mass function

Bower et al.  
2006;  
Croton et al.  
2006



# Tools: Cosmologic Simulations

## EAGLE

State-of-art, high resolution simulation follows evolution of a 100Mpc region. Advanced subgrid physics included (Michelle Furlong's talk)

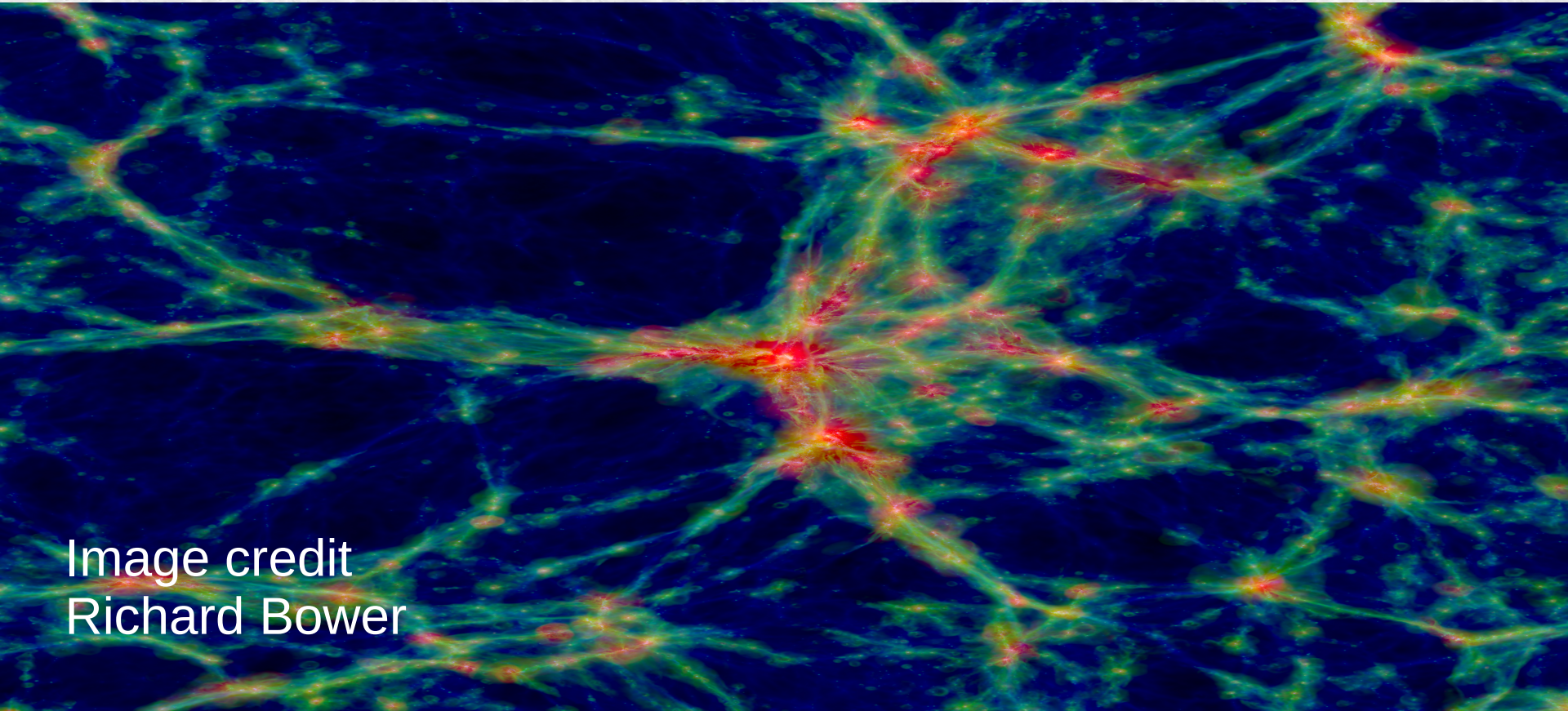


Image credit  
Richard Bower

# **The BH accretion model**

in Cosmological simulations

*Arxiv:1312.0598*

# The BH physics in cosmological simulations

## OWLS:

Booth &  
Schaye  
2009

Springel et  
al 2005

## BH seeds ( $10^5 M_{\text{sun}}$ )

are injected into well resolved halos  
( in our simulations  $\sim 1e10 M_{\text{sun}}$ ).

Created for  
simulations  
at low  
resolution  
 $\sim 10^8$

## Growth BH

**BH mergers** and **Gas accretion** usually  
modelled as **Bondi accretion limited by Eddington**  $M_{\text{sun}}/\text{particle}$

## Thermal AGN feedback

Stochastic approach, energy fraction stored until

$$E_{\text{BH}} > E_{\text{thres}}$$

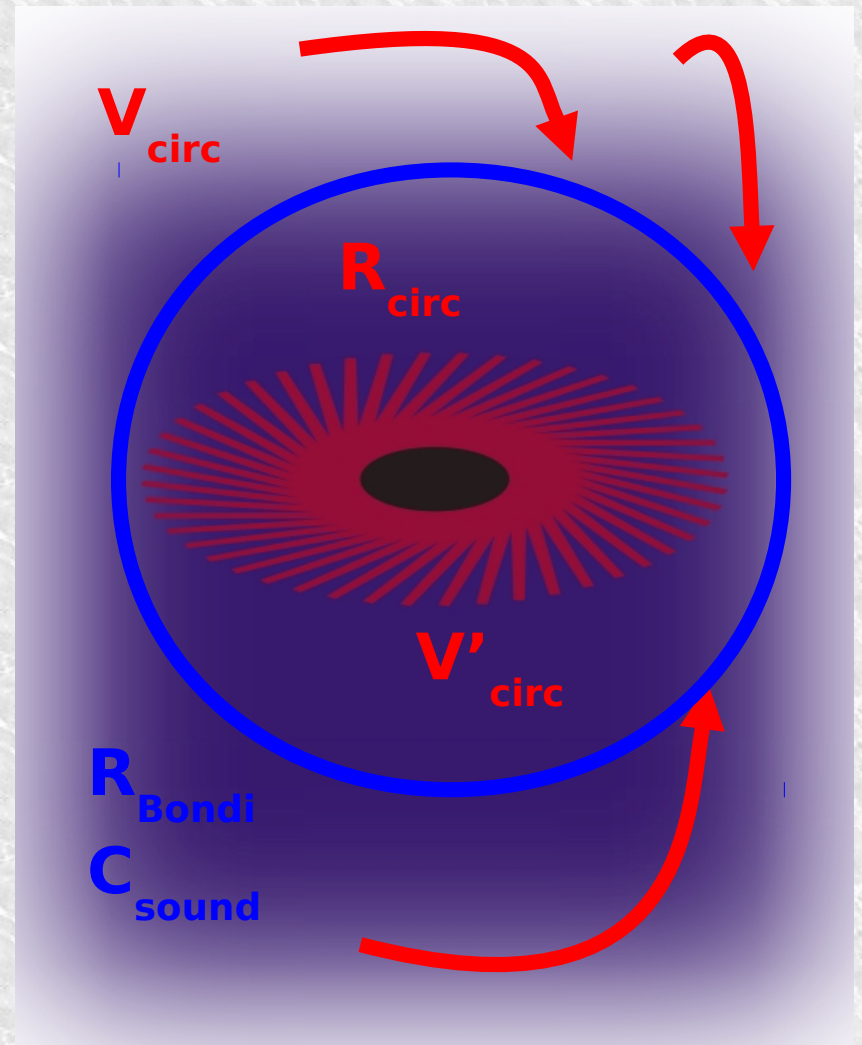
( enough to heat 1 neighbour by  $10^8$  K)



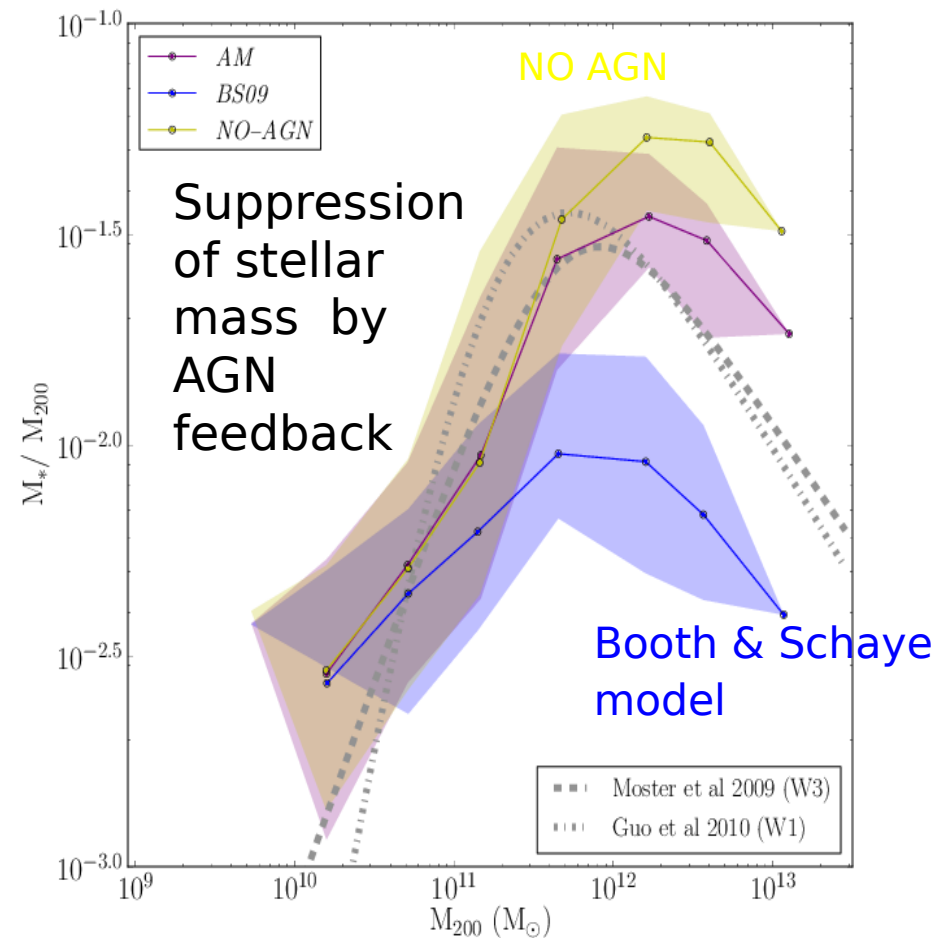
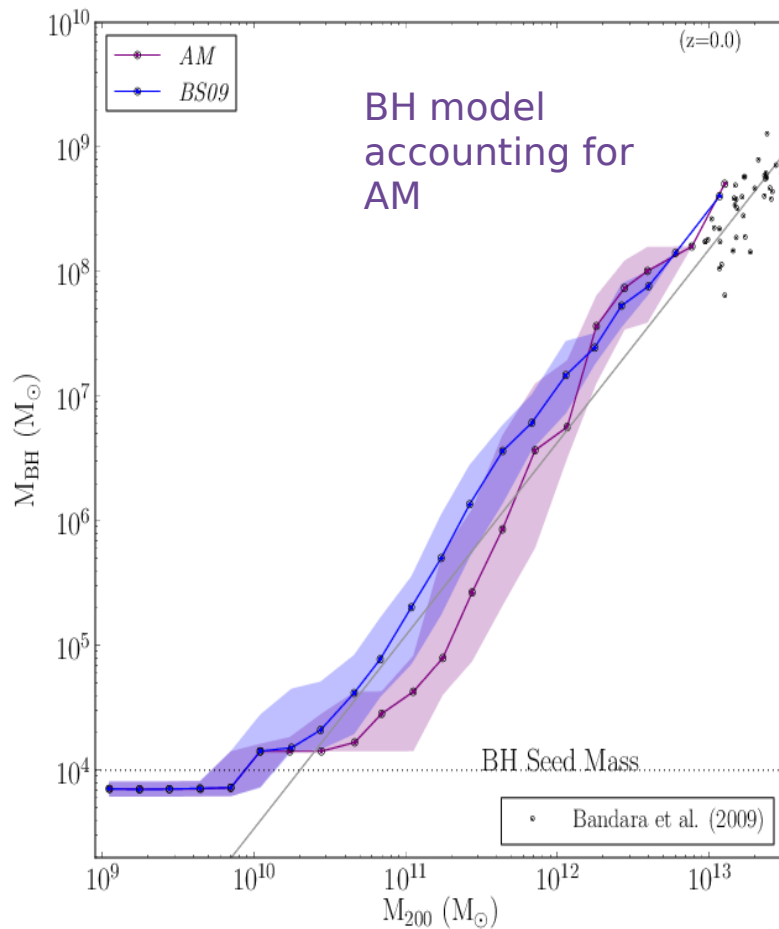
# Accounting for AM

**Observationally motivated:** Gas in disk galaxies, merging galaxies and luminous starburst seem to reside in rotationally supported discs (Downes & Solomon 1998)

Suppression of BH accretion rates depends on  $V_{\text{circ}}$  and  $C_{\text{sound}}$



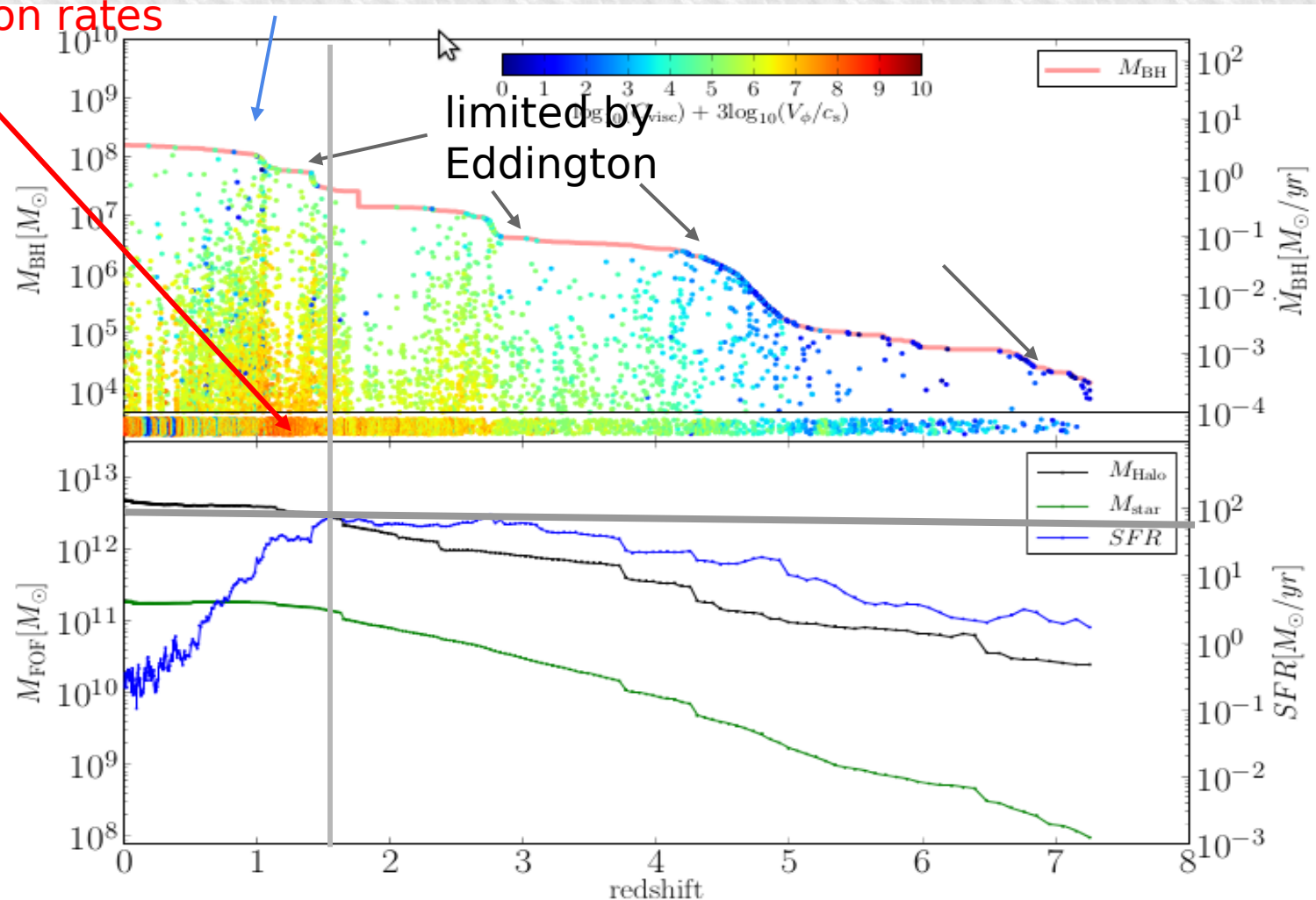
# Effects of the AM model on galaxies



# Evolution of the BHs in the AM model

large suppression in accretion rates

relative small suppression



# Evolution of the BHs in the AM model



Movie credit: Richard Bower

# **The Evolution of AGNs**

IN THE VIRTUAL UNIVERSE OF EAGLE

# Motivation: EAGLE

Main goal : Reproduce the stellar mass function at  $z=0$

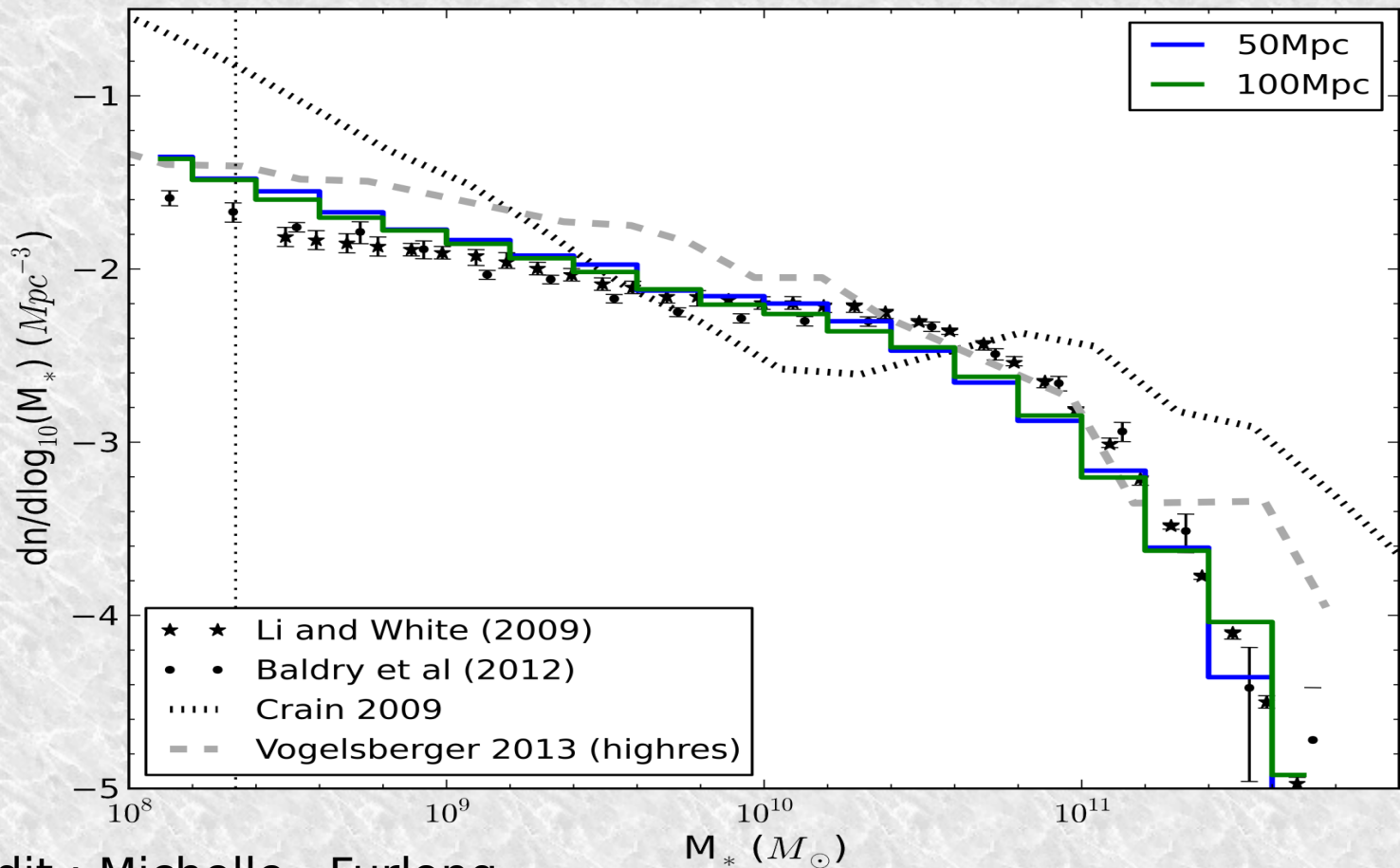
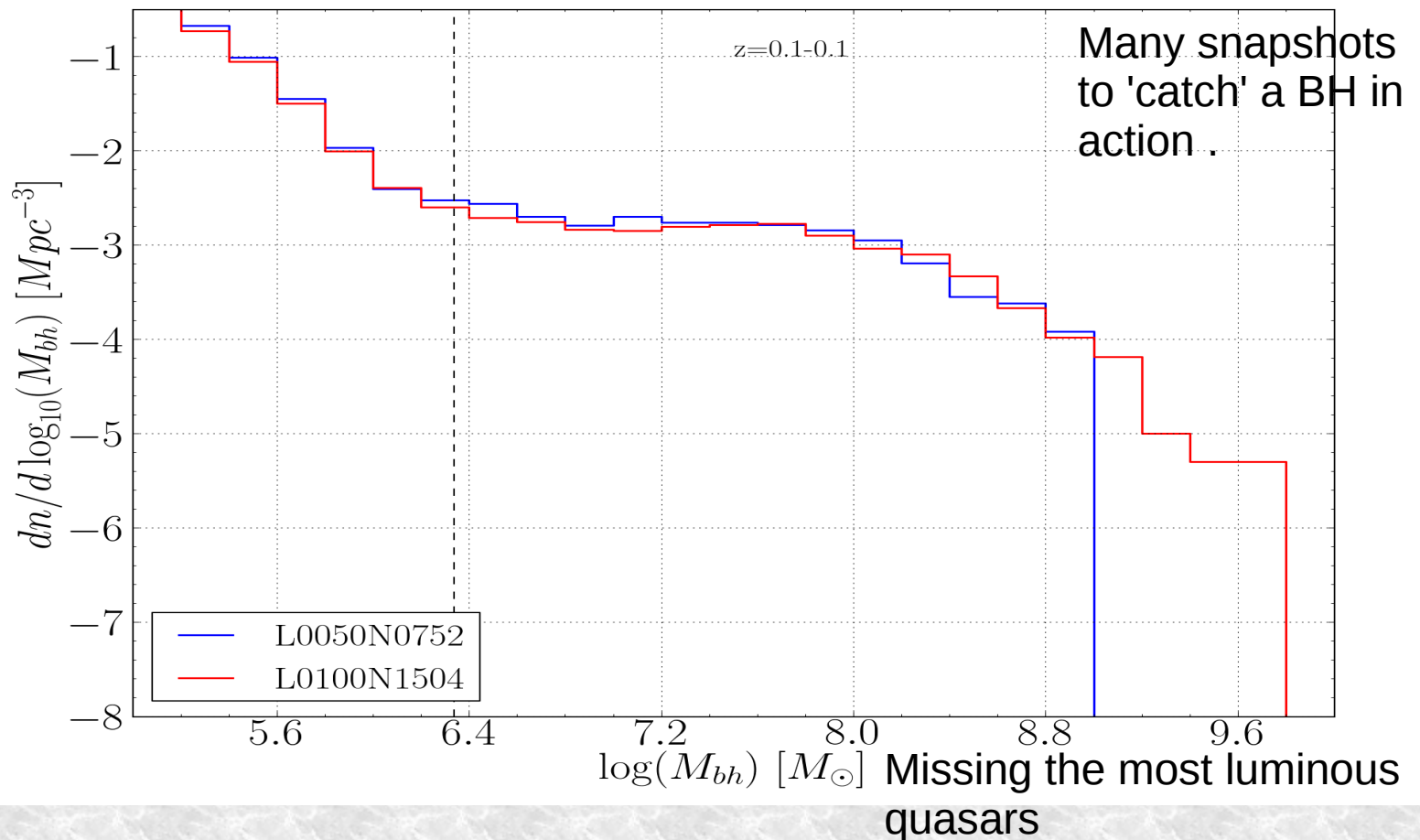


Image Credit : Michelle Furlong

# Advantages of EAGLE

Understand the connection between the evolution of black holes and evolution of galaxies.

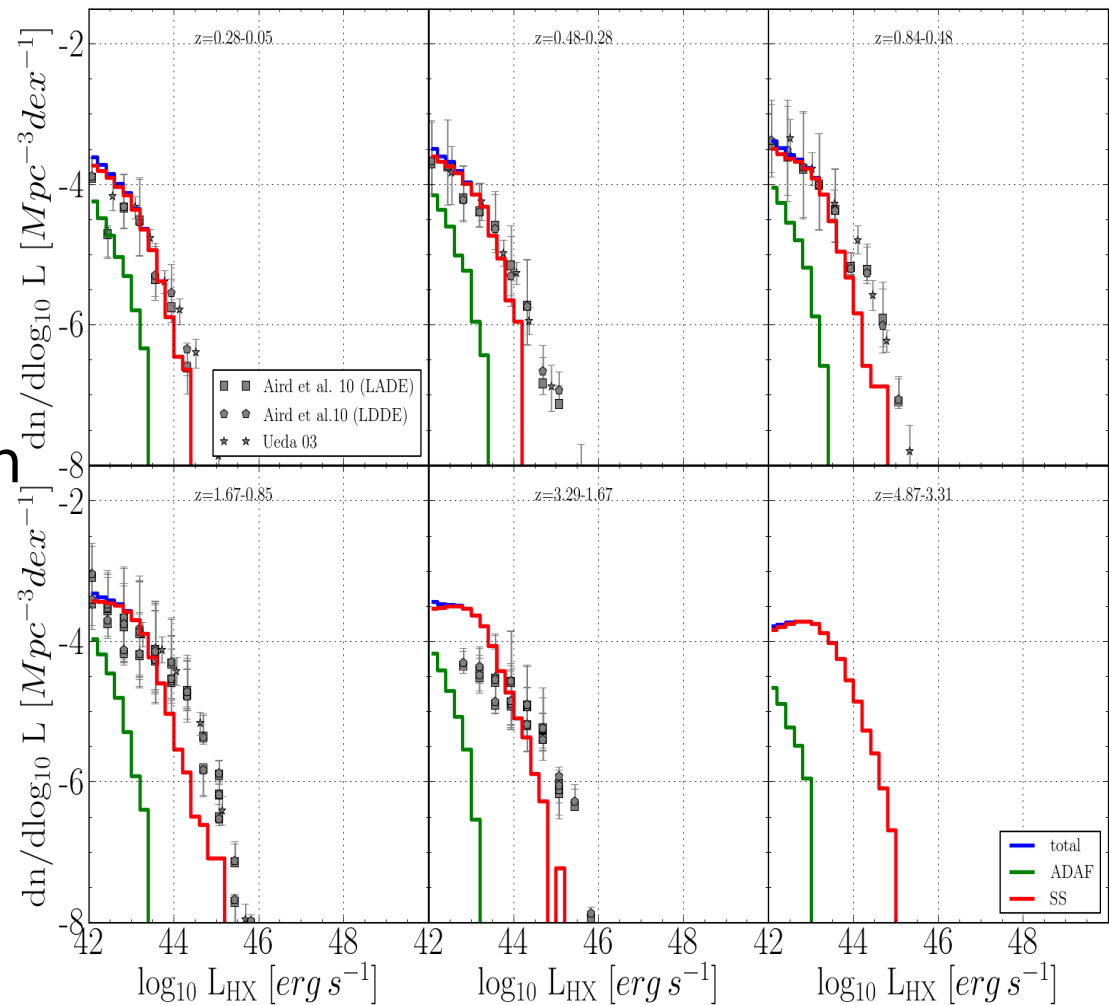


# Hard X ray AGN luminosity simulation

Ad hoc for relatively low luminous AGNs

Bolometric corrections derived by Marconi et al 2004.

Consider quasars when BHs are accreting  $> 1\%$  of Eddington

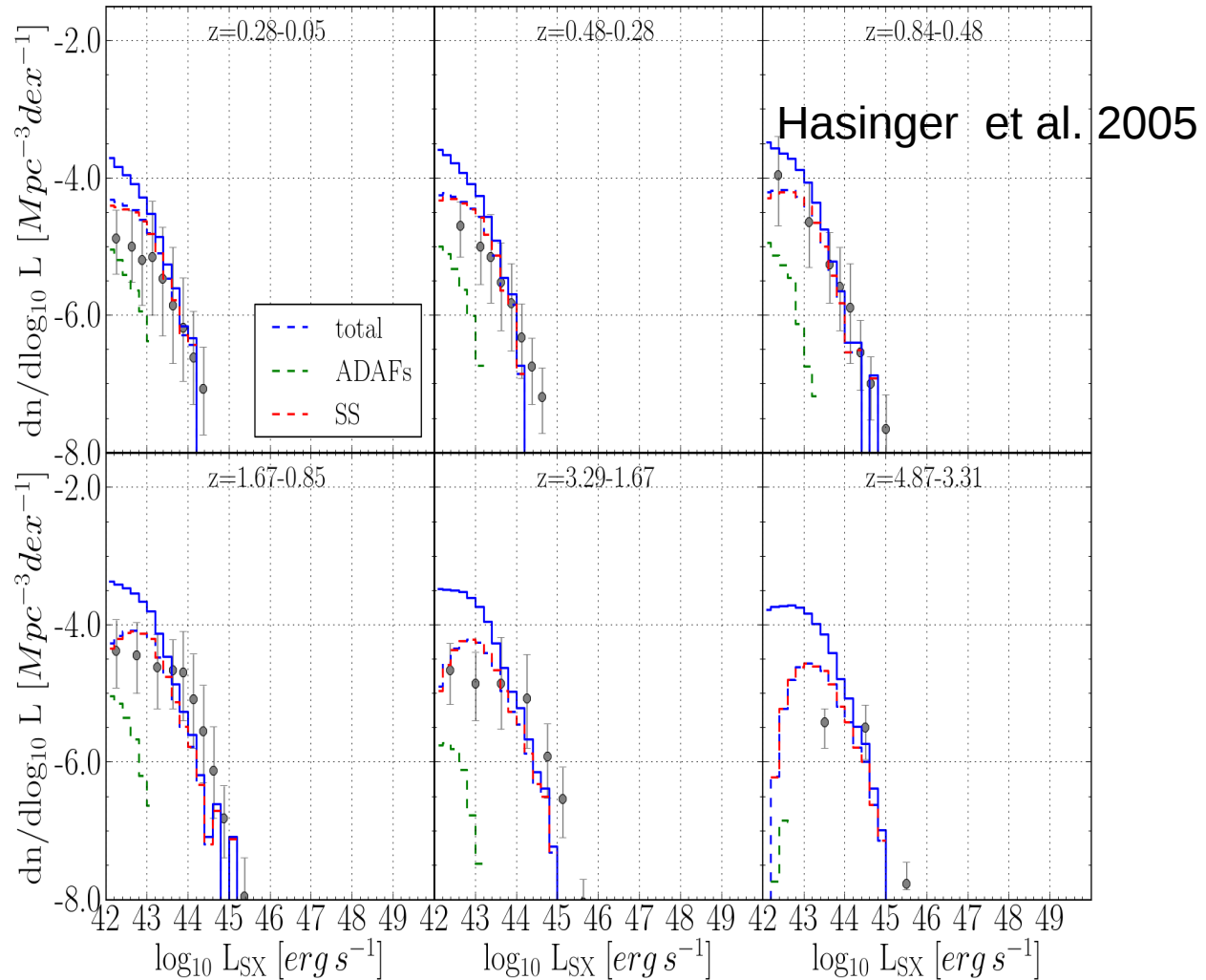




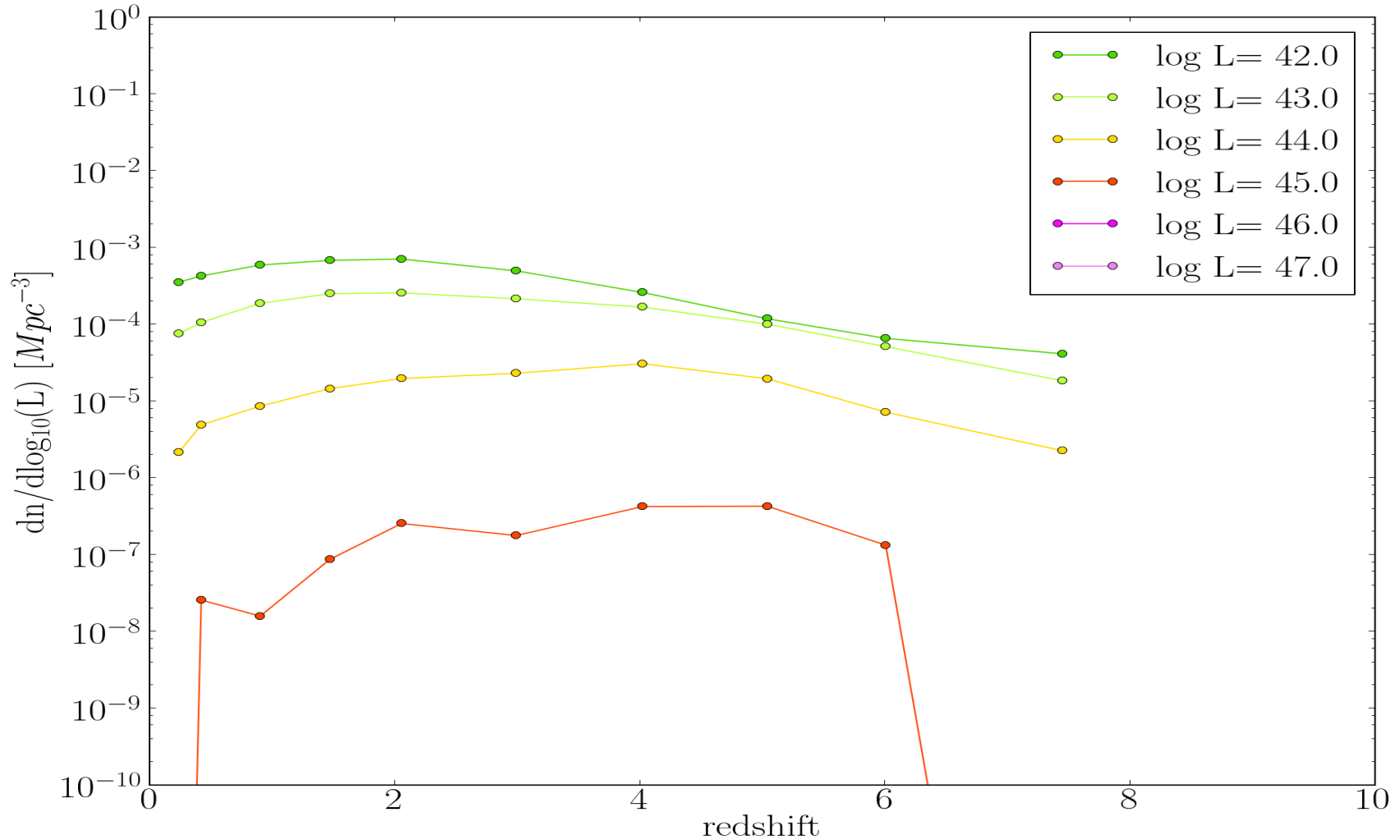
# Soft X-ray Luminosity function

Fraction of obscured AGNs calculated from an empirical law (Hasinger et al 2008).

Depends on luminosity and weakly on redshift



# Total number of densities of quasars



# Summary and future work

- EAGLE Universe supports that AGN feedback produces the break in the galaxy mass function.
- A new model of BH accretion accounting for angular momentum reproduces the stellar mass function.
- Angular momentum (regulates the frequency of outburst).
- EAGLE designed to reproduce the SMF at  $z=0$ , perfect laboratory to study the connection between BHs and Galaxies.
- AGN luminosities in Hard X and Soft X rays in good agreement with observations
- *Work in progress*: Bolometric AGN luminosity, Soltan argument and comparison with SFRs.