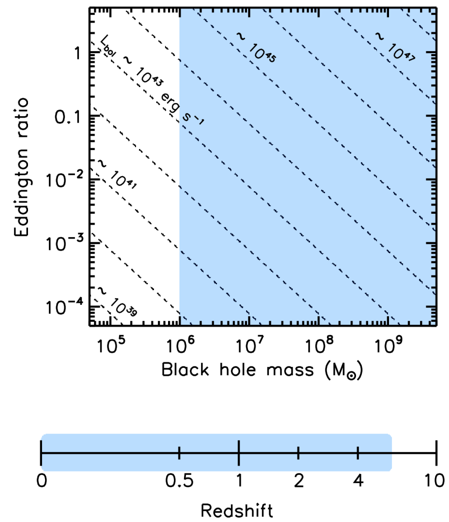
Astrophysical aspects of SMBH evolution in the LCDM Universe

Outline

- Evolution of SMBH parameters
- Modelling active galaxies
- Cosmic evolution of active galaxies
- Spatial distribution and clustering of active galaxies



Nikos Fanidakis

and C. S. Frenk, C. M. Baugh, C. Lacey, R. G. Bower, S. Cole, C. Done, R. Hickox

What Drives the Growth of Black Holes?, Durham, 26-29 July 2010

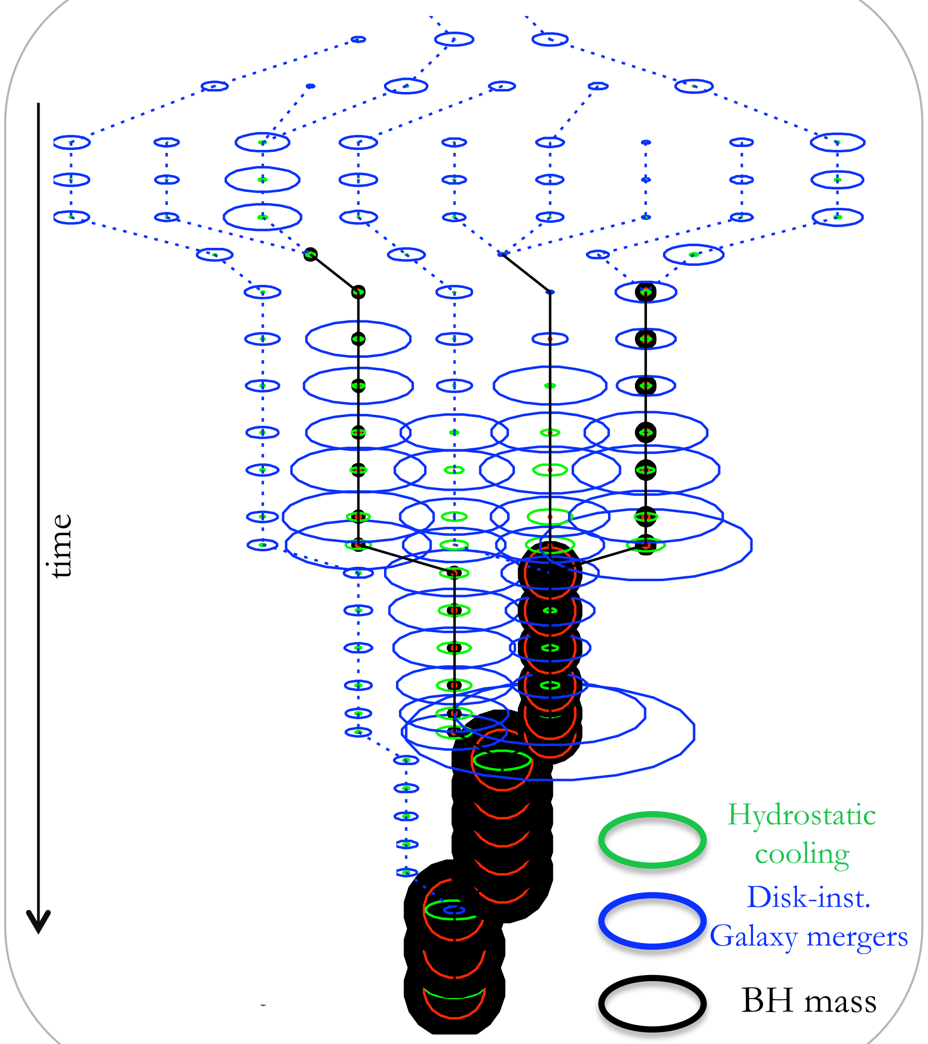
Durham University

MARIE CURIE ACTIONS

ICC Institute for Computational Cosmology

SMBH mass assembly in the Millennium

- SMBHs grow via gas accretion and BH-BH mergers.
- Accretion of gas (disk instabilities, galaxy mergers & quasi-hydrostatic cooling) is the main growth channel.
- At low redshifts, the BH mass is redistributed via binary mergers.



Assembly tree from Malbon et al. 2007

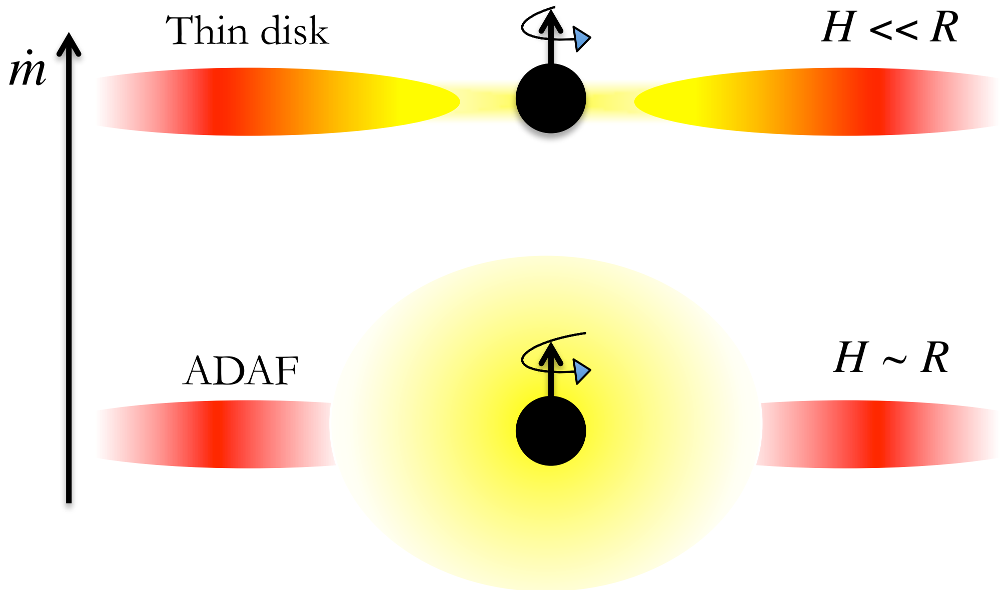
Modelling active nuclei

Disk geometry depends on the accretion rate!

The jet power is proportional to the square of BH spin:

$$L_{jet} \propto (H/R)^2 B_\phi^2 M_{BH} \dot{m} a^2$$

Blandford & Znajek 1977



$\dot{m} = \dot{M}/\dot{M}_{Edd} > 0.01 \rightarrow$ Thin disk

Disk $\rightarrow L_{bol,TD} = \varepsilon M_{BH} \dot{m}\ c^2$

Jet $\rightarrow L_{jet,TD} = 7.9 \times 10^{35}\ M_{BH}^{1.1} \dot{m}^{1.2} a^2$

$\dot{m} = \dot{M}/\dot{M}_{Edd} < 0.01 \rightarrow$ Thick disk

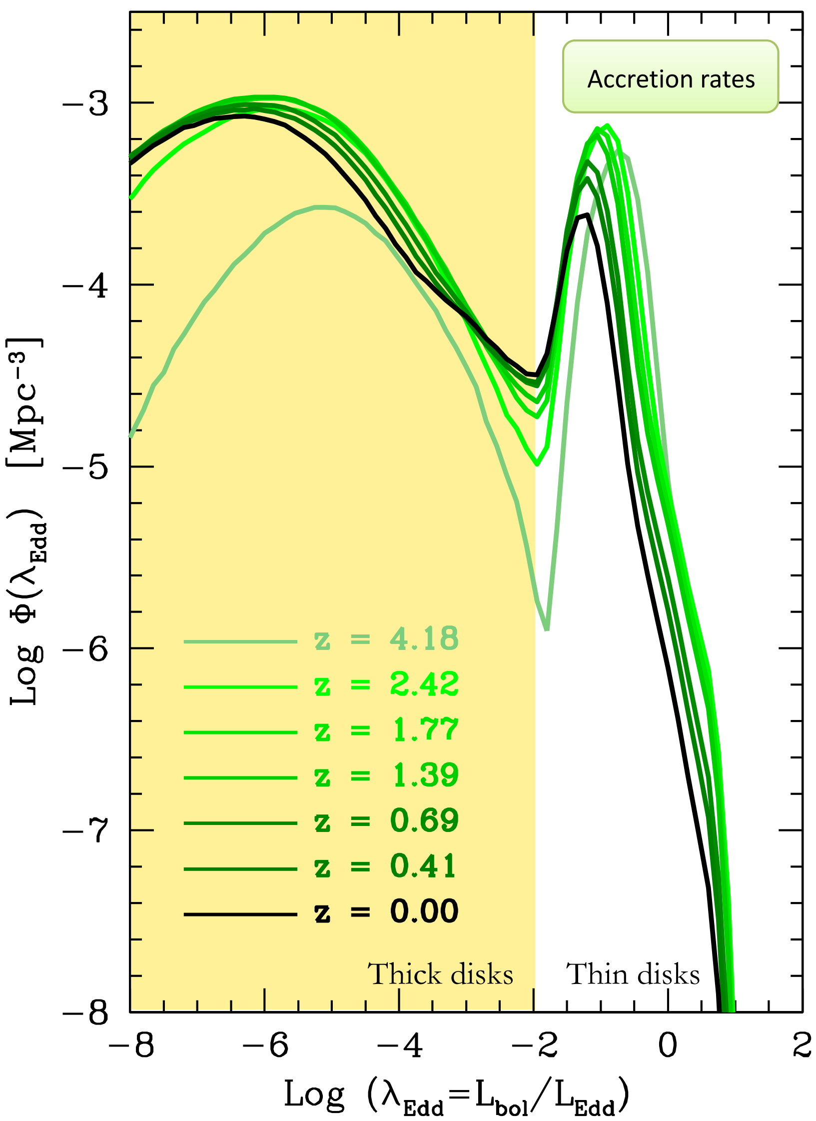
Disk $\rightarrow L_{bol,ADAF} \propto M_{BH} \dot{m}^2$

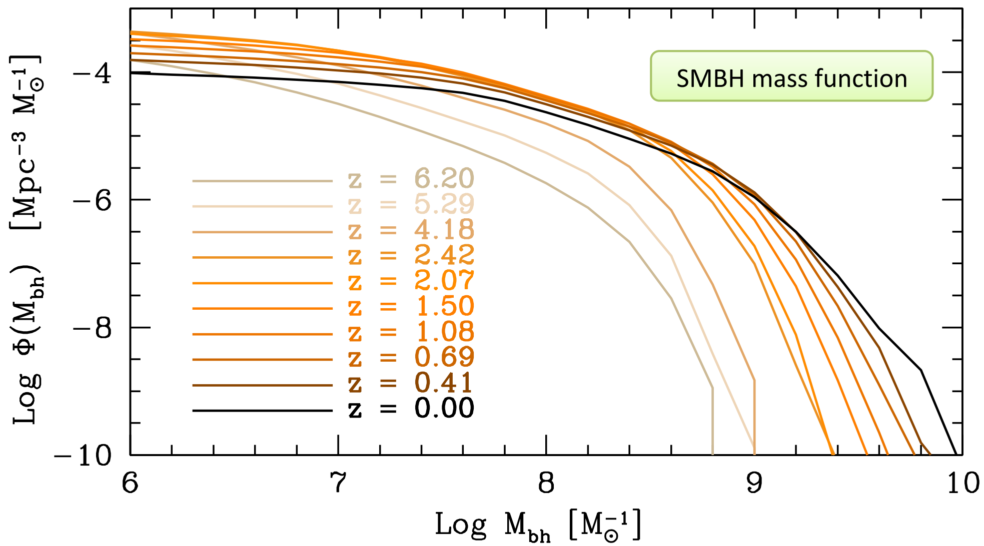
Jet $\rightarrow L_{jet,ADAF} = 2 \times 10^{38}\ M_{BH} \dot{m} a^2$

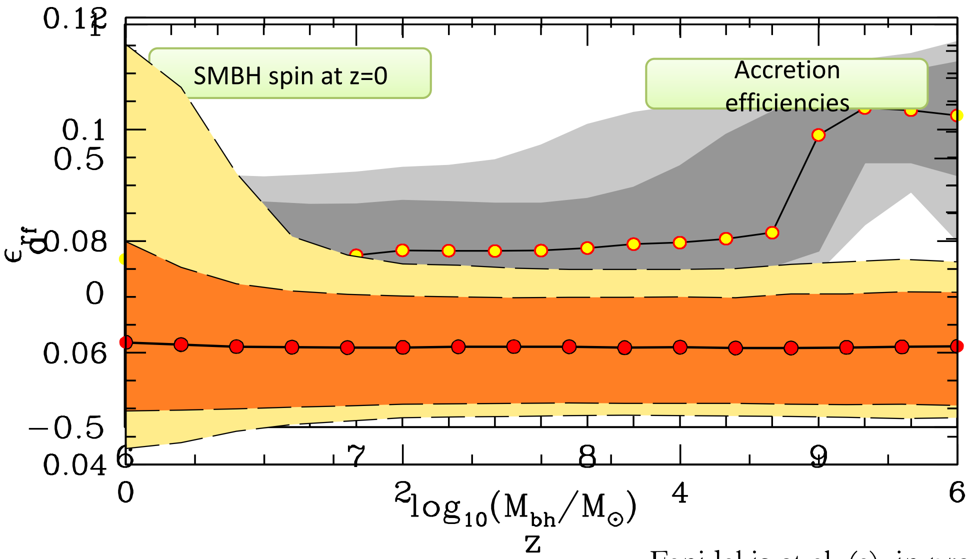
L_{bol} is limited to $L_{bol} = L_{edd}(1 + \ln \dot{m})$ for super-Eddington flows

Fanidakis et al. (2010)

BH mass, accretion rates and efficiencies

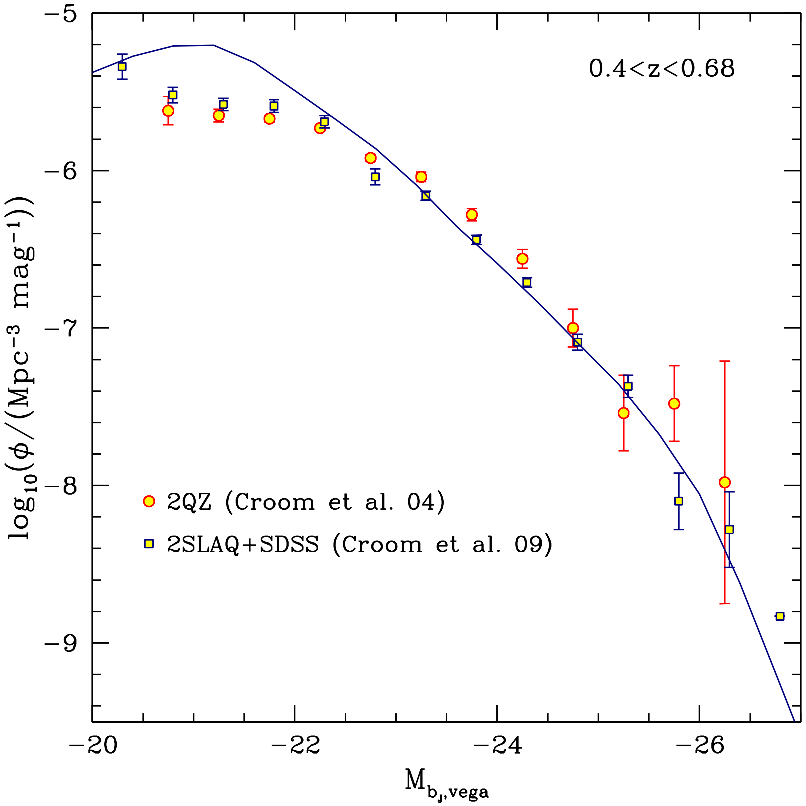




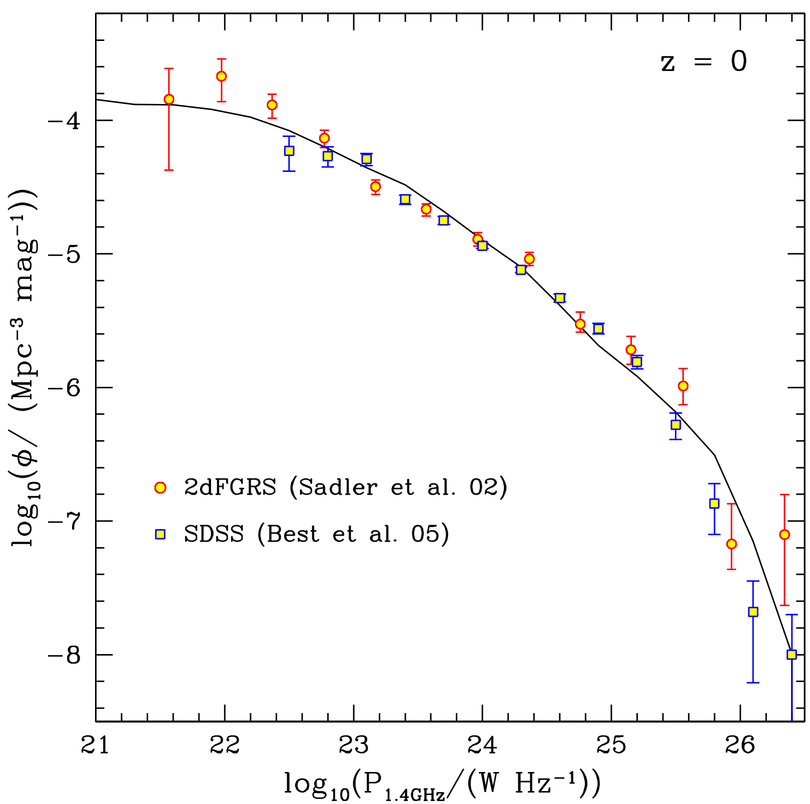


Fanidakis et al. (a), in prep.

Low redshift Universe



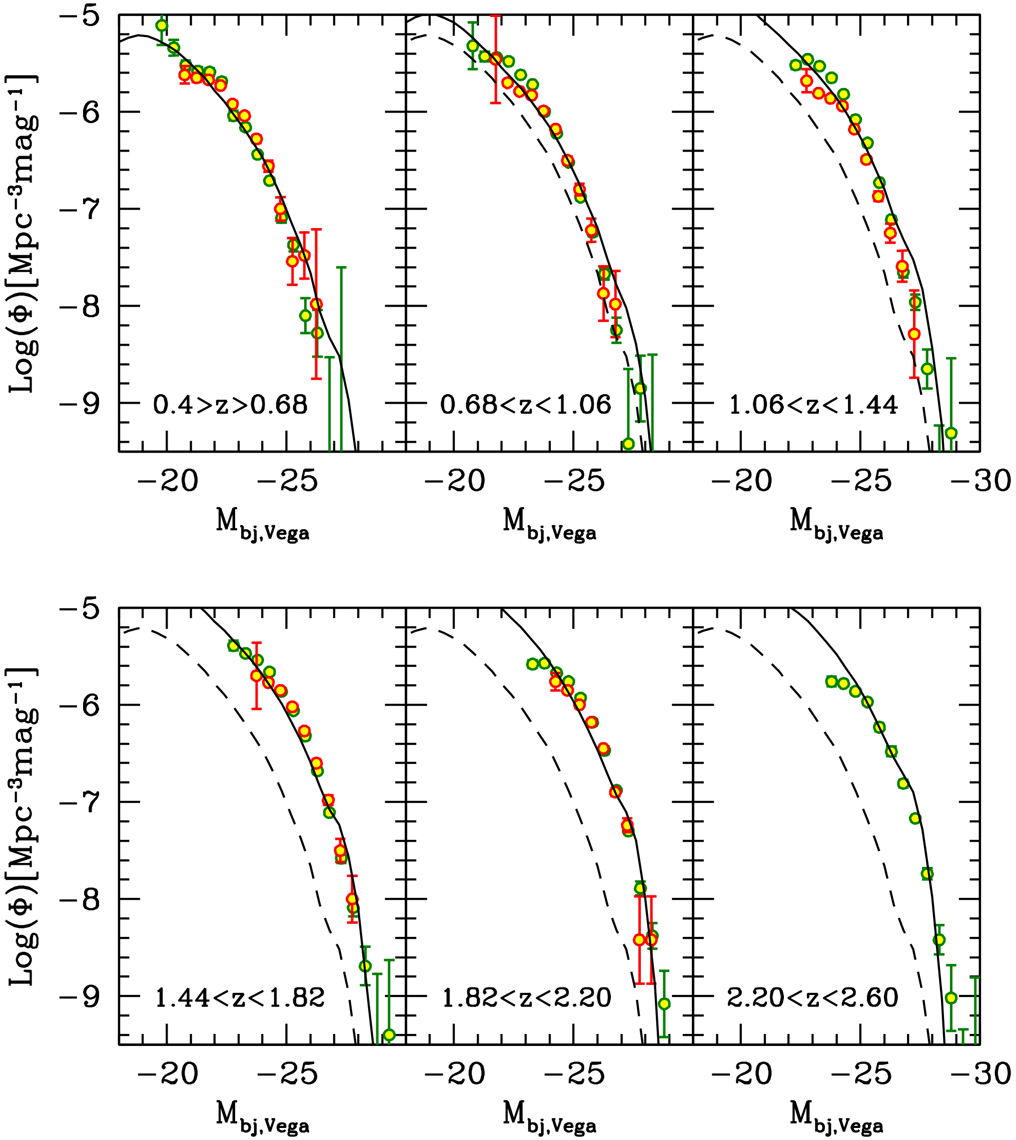
Optical luminosity function



Radio luminosity function

Fanidakis et al. (2010)

Cosmic evolution of quasars: b_j-band LFs



The quasar LF evolves strongly with redshift.

↓

Gas accretion was considerably more significant at high redshifts.

2QZ (Croom et al. 2006)

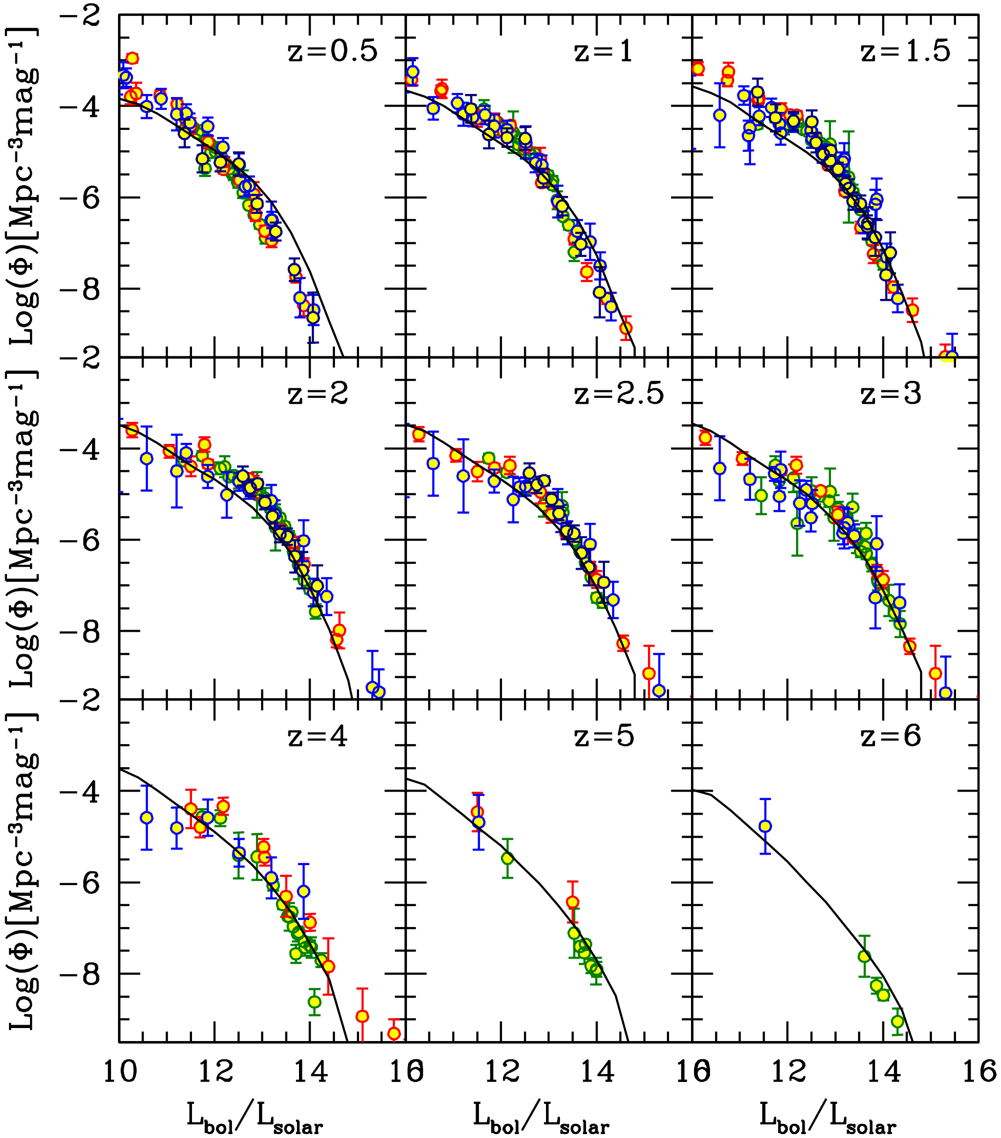
2SLAQ+SDSS (Croom et al. 2009)

Model fit

Model fit at 0.4>z>0.68

Fanidakis et al. (a), in prep.

Cosmic evolution of quasars: L_{bol} LFs



The model provides a good fit to the observations up to z=6.

Model fit

emission lines

IR

hard x-rays

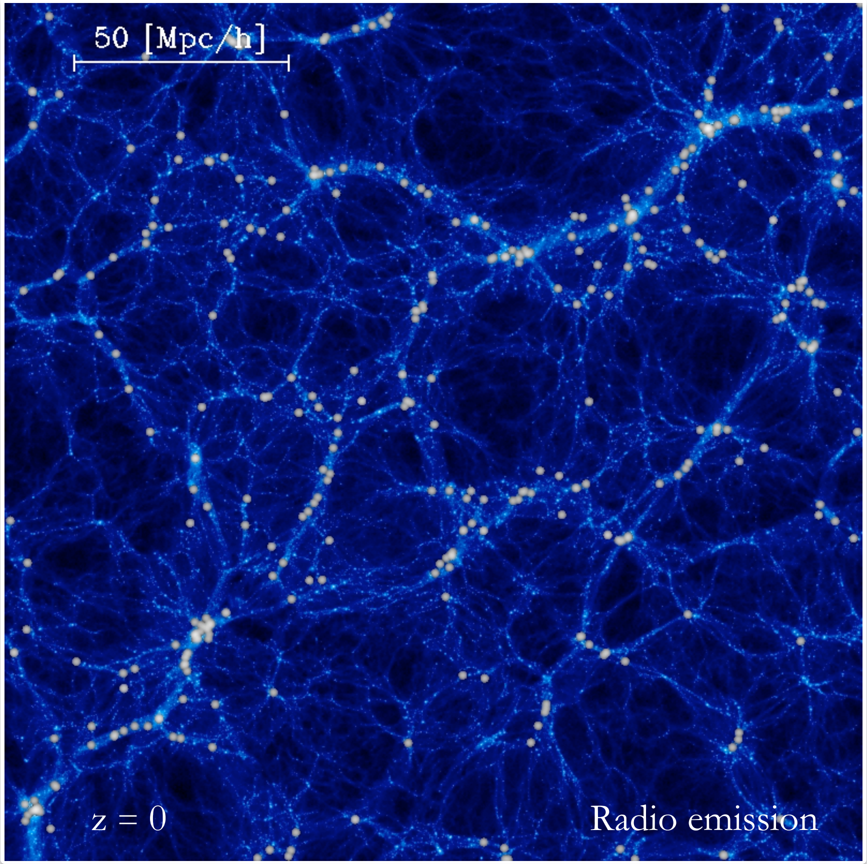
soft x-rays

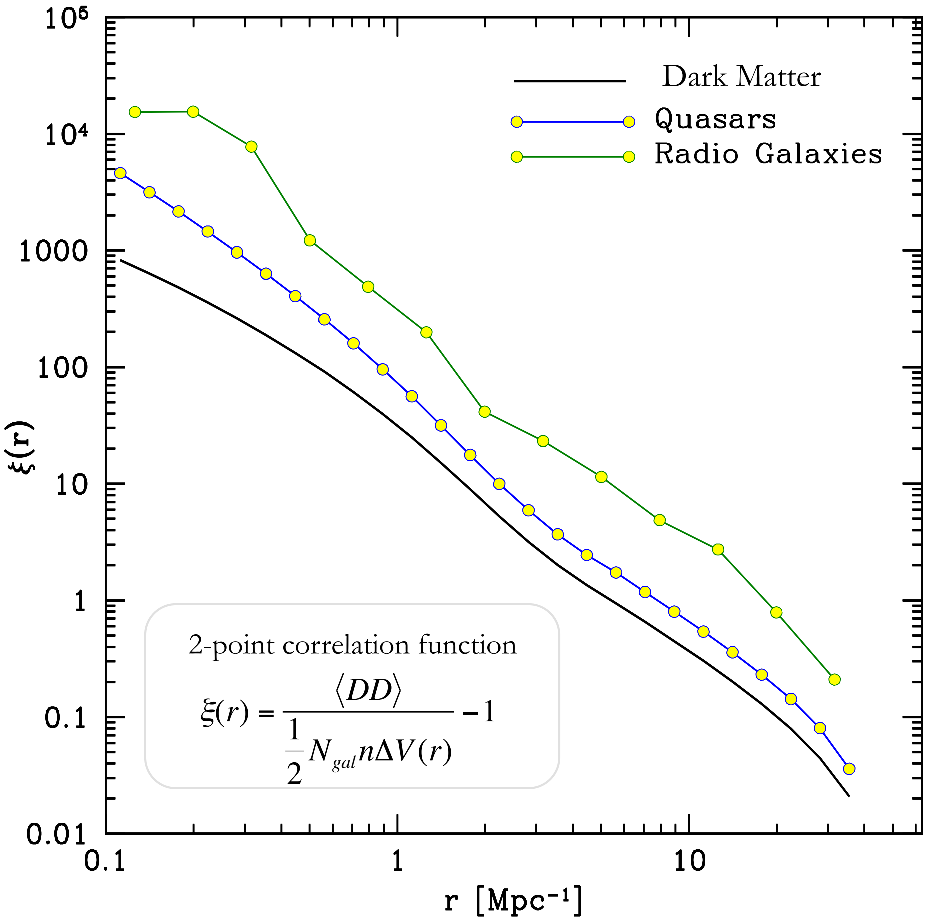
optical

Hopkins et al. (2007)

Fanidakis et al. (a), in prep.

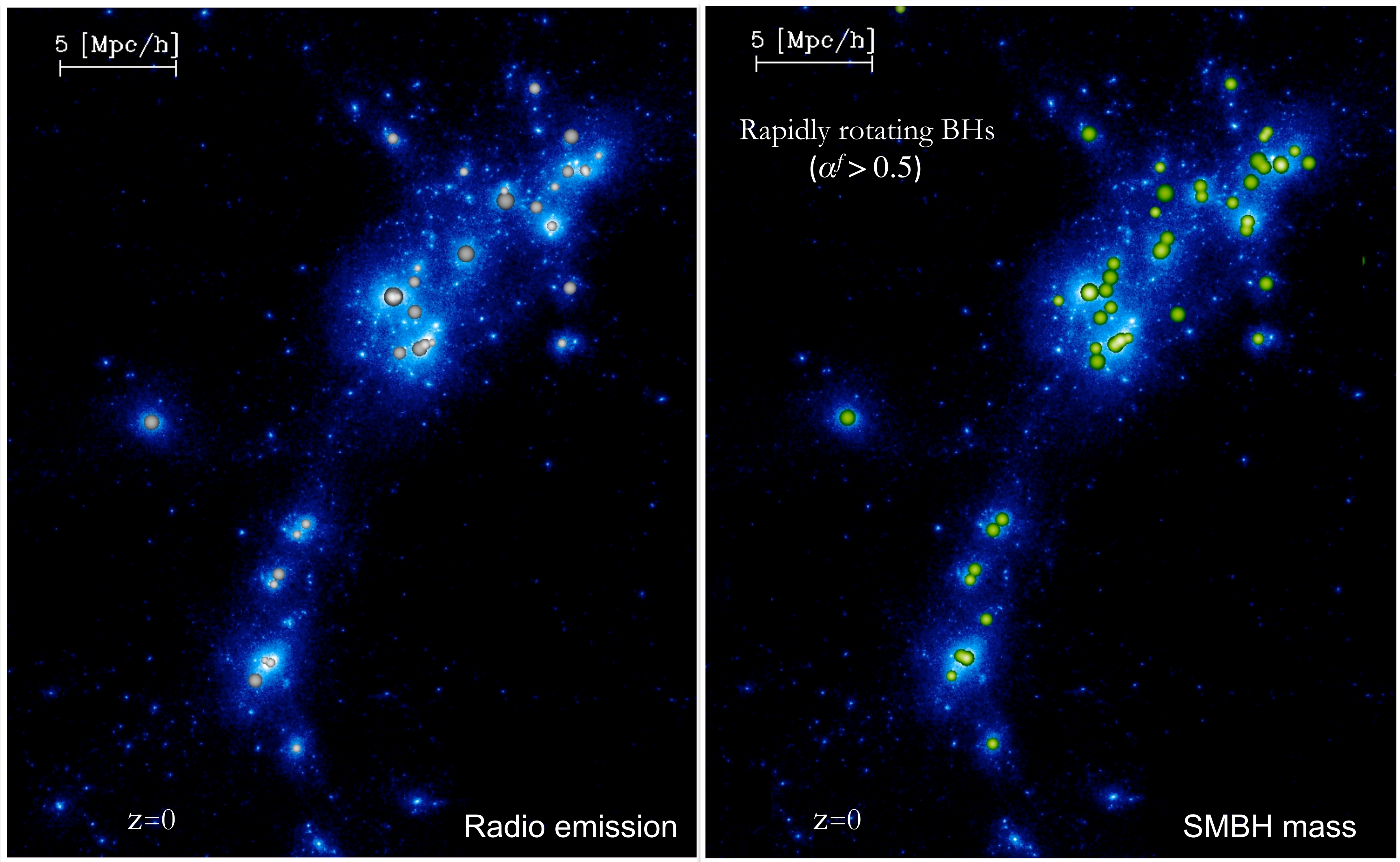
Spatial distribution and clustering of AGN





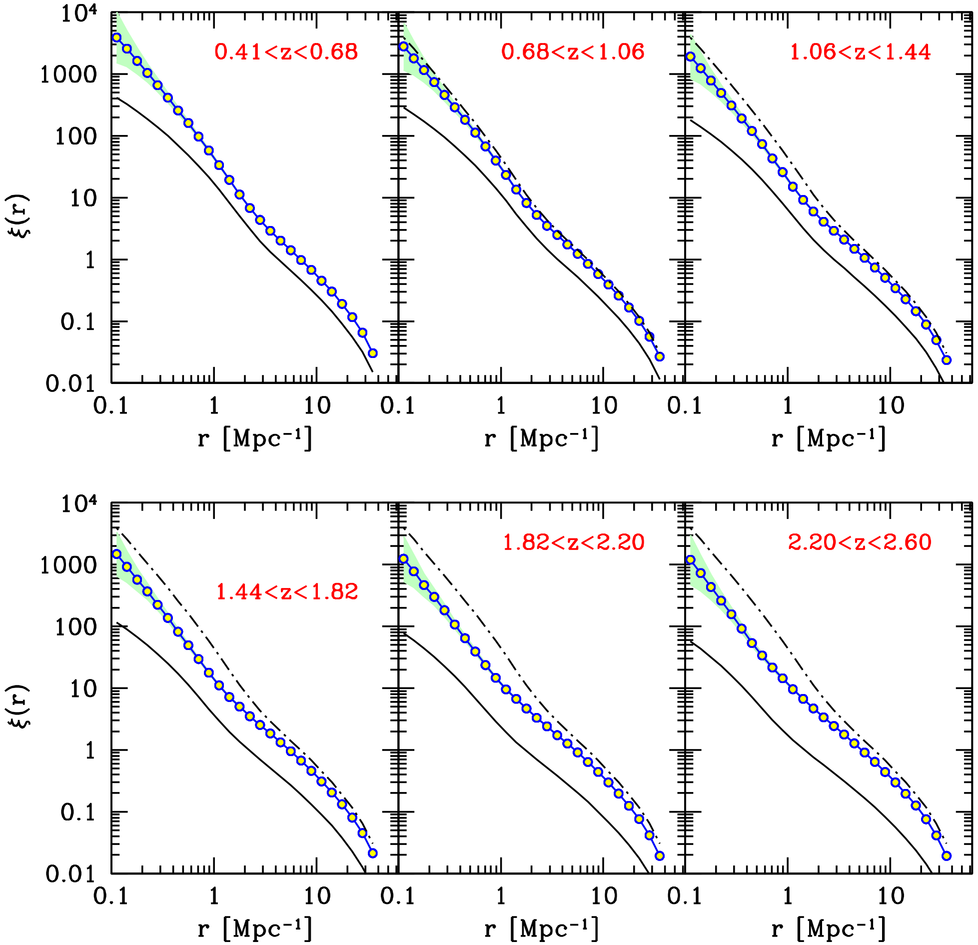
Fanidakis et al. (b), in prep.

The location of rapidly rotating SMBHs



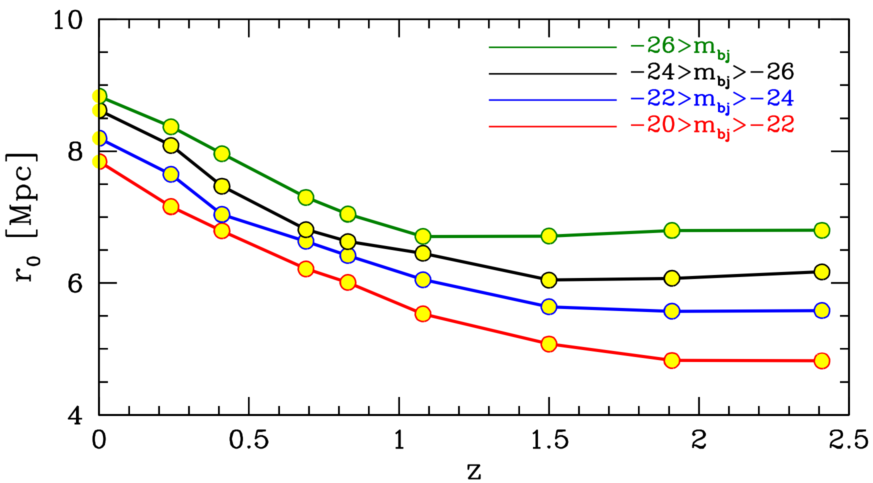
Fanidakis et al. (b), in prep.

Quasar clustering



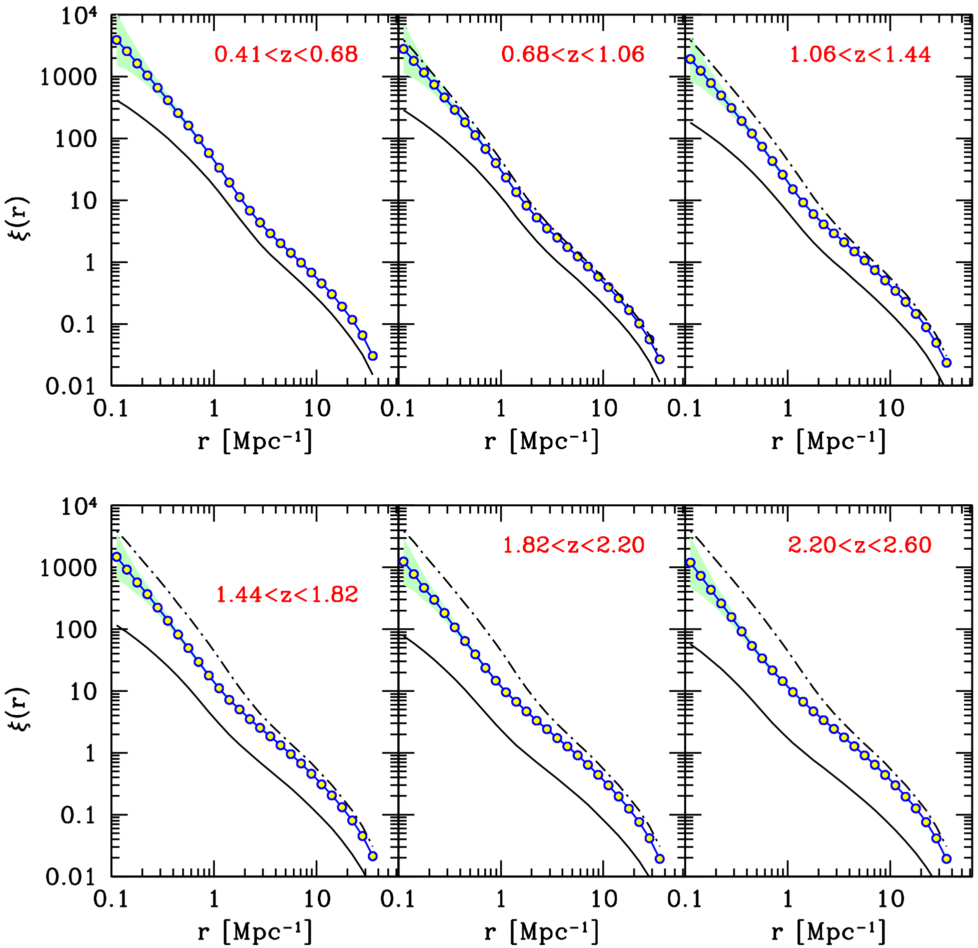
Correlation length, r_0

$$\xi(r) = \left(\frac{r}{r_0}\right)^{\gamma}$$



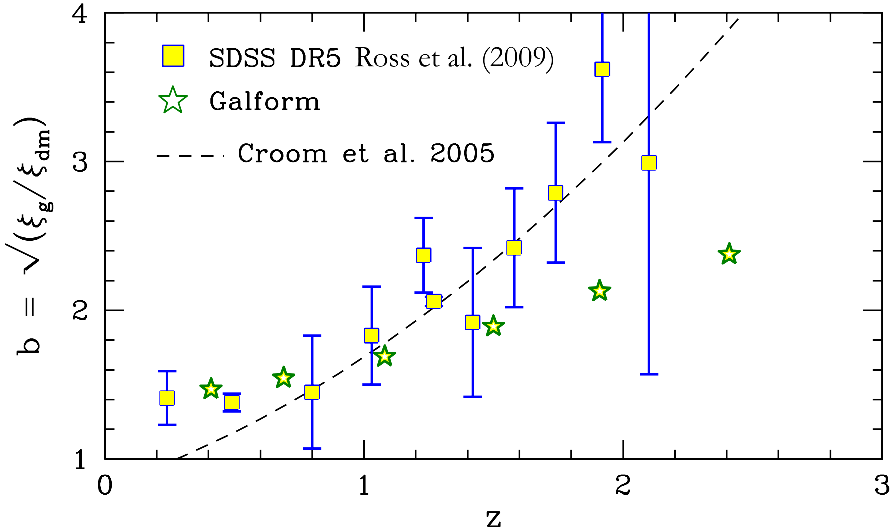
Fanidakis et al. (b), in prep.

Quasar clustering



QSO bias, b

$$b^2 = \frac{\xi_{QSO}}{\xi_{dm}}$$



Fanidakis et al. (b), in prep.

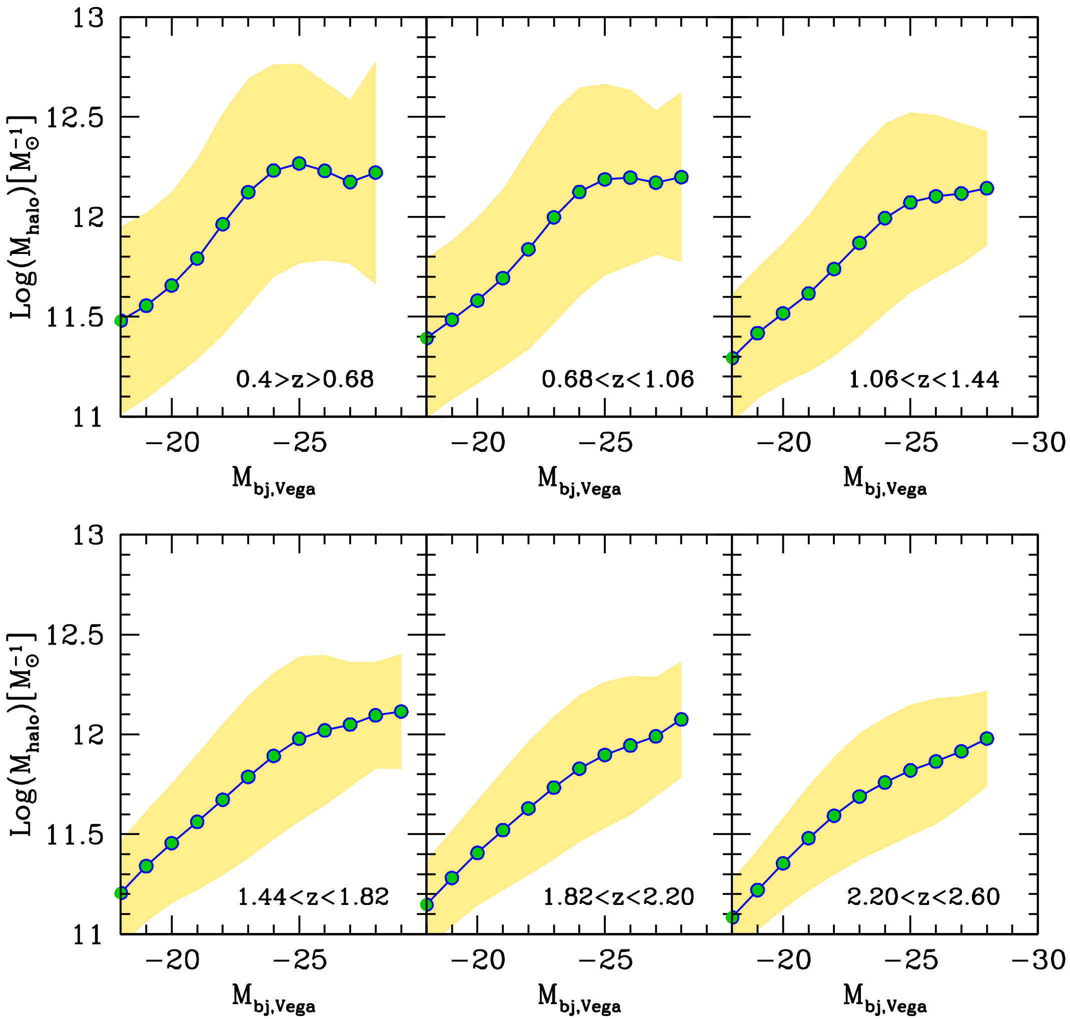
Halo mass vs. M_{bj} luminosity

$M_{bj}>-24$

Strong correlation of M_{halo} with M_{bj}.

$M_{bj}<-24$

Flat M_{halo}-M_{bj} trend (AGN feedback) -> Bright quasars live in ~$10^{12}M_{\odot}$ haloes, independent of their luminosity.



Fanidakis et al. (b), in prep.

Summary

- We have used the semi-analytical model GALFORM to study the cosmological evolution of SMBHs in a LCDM universe.
- We find that:
  - SMBH spins at z=0 have a bimodal distribution: low (high) mass SMBHs — low (high) spins.
  - The accretion efficiency is kept low (=0.062) over cosmic history.
  - The density of quasars evolves strongly with redshift -> quasar activity was more intense at high redshifts (more gas available).
  - Radio galaxies are more clustered than quasars at z=0.
  - The dependence of clustering on quasar luminosity becomes significant for z>1.5.
  - The model predicts a strong correlation of halo mass and quasar luminosity. That correlation flattens at low redshifts for quasars brighter than $m_{bj}<-24$ (AGN feedback).
  - A typical halo mass for a $m_{bj}<-24$ quasar is $\sim 5\times10^{12} M_{\odot}$.
- Future work: comparison with observations, cross-correlations with LRGs, z=6 quasar properties, morphological properties of radio galaxies, etc...