Synergy between LSS simulations and AGN clustering measurements: Part II

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AGN 2014: Clustering Measurements of Active Galactic Nuclei

With: Andrea Macciò (MPIA),

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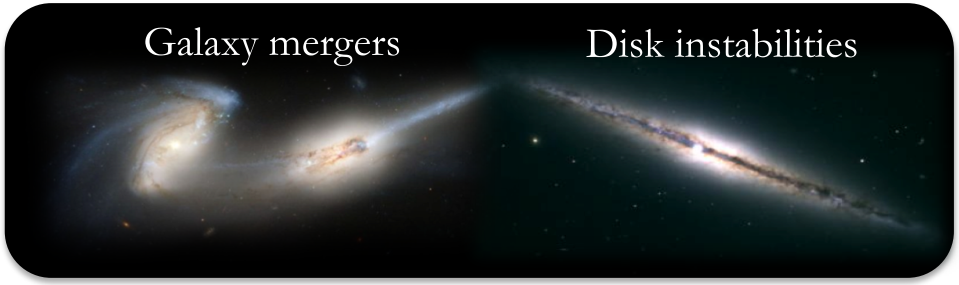
Today I am going to talk about:

1. Introduction on AGN clustering in semi-analytics
2. GALFORM & and the modelling of AGN
3. The halo environment of AGN & Radio Galaxies
4. Radio galaxies as tracers of massive structures
5. Over-densities around high-z QSOs
6. Conclusions
7. Future work

AGN activity in galaxy formation
is expected to be triggered by galaxy mergers
and disk instabilities.

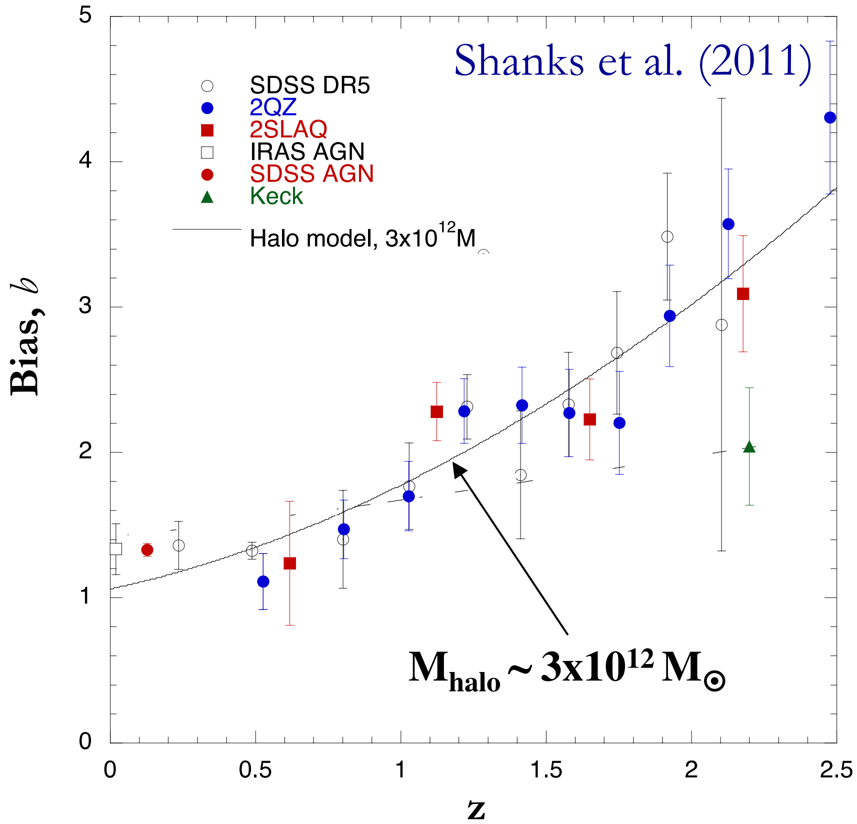


AGN

$$L_{\rm Bol} = \varepsilon_{\rm rad} \dot{M}_{\rm BH} c^2$$

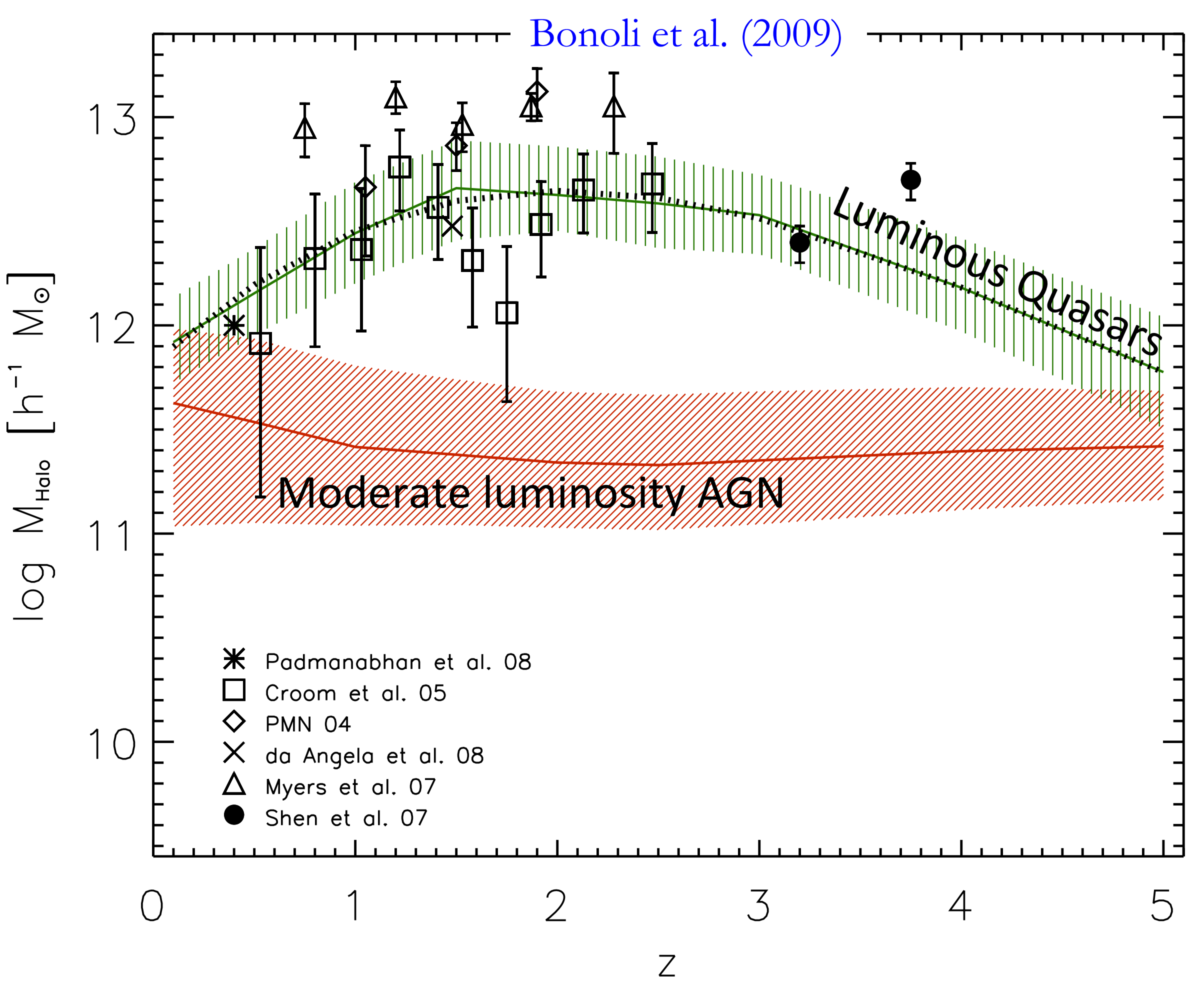
Springel et al. (2005),Di Matteo (2005, 2008), Hopkins et al. (200-), Marulli et al. (2008), NF et al. (2011, 2012), Hirschmann et al. (2012) etc.

Quasars selected in optical



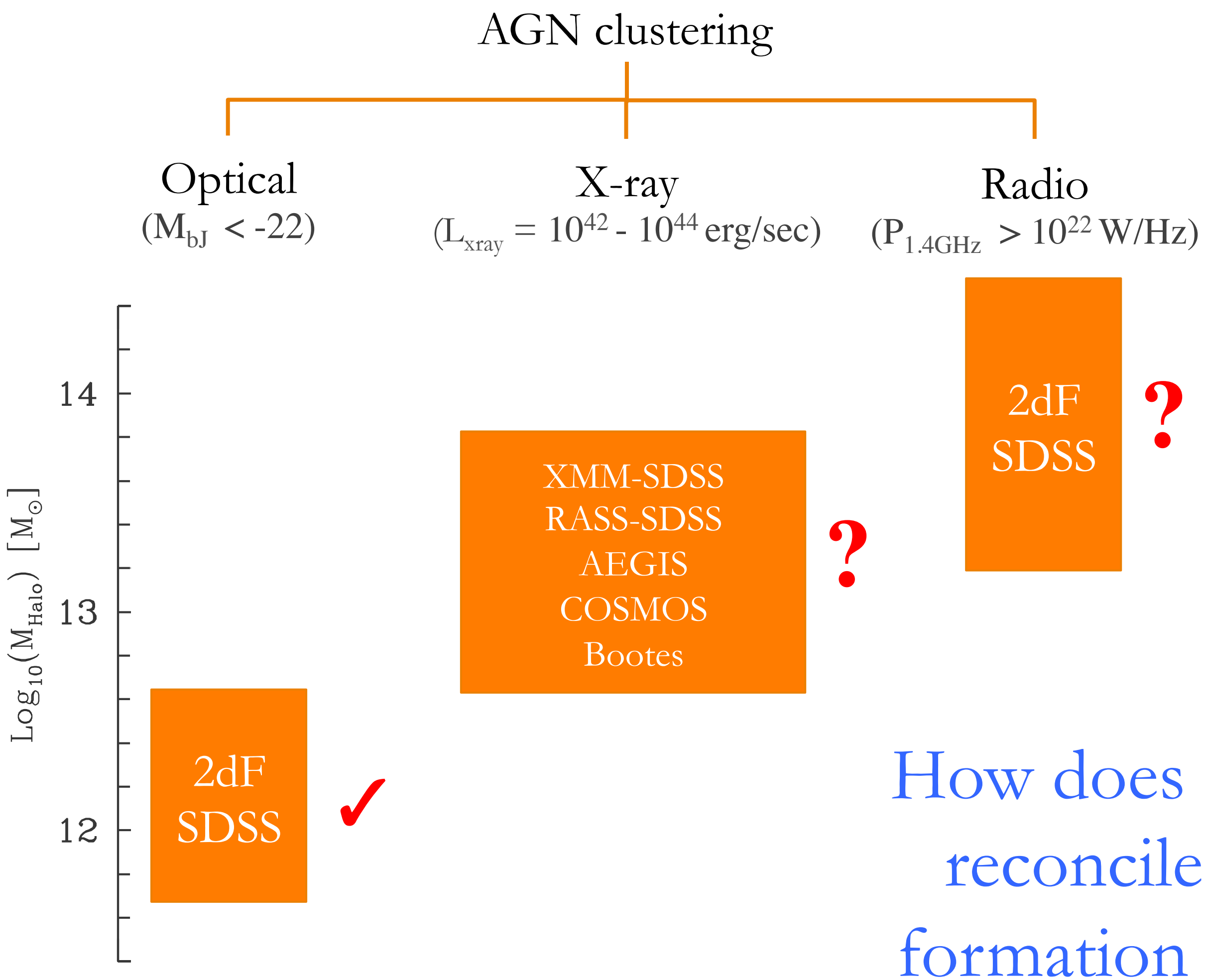
Clustering analyses show that quasar activity takes place in $\sim 10^{12}\,M_\odot$ haloes.

See: Croom et al. (2004), Ross et al. (2009), White et al. (2012), Shen et al. (2013), also Bonoli et al. (2009)



- Luminous quasars are found in the "correct" DM halo mass.
- Moderate luminosity AGN predicted to live in lower mass DM haloes.

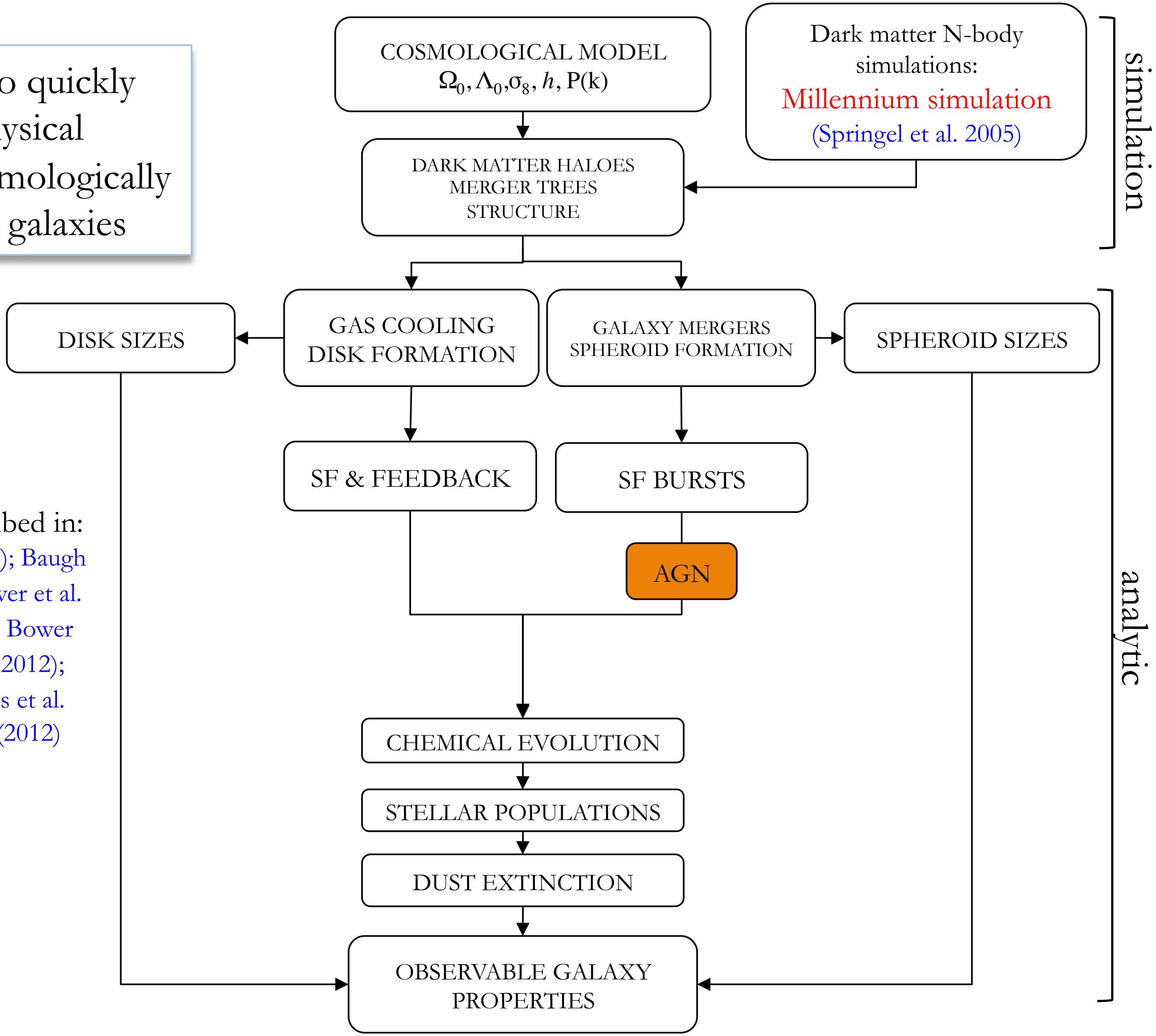
The Dark Matter halo mass of AGN at z < 2



How does this picture reconcile in galaxy formation modelling?

See also: Gilli et al. (2005), Croom et al. (2006), Bornancini et al. (2006), Wake et al. (2008), Donoso et al (2008), Coil et al. (2009), Cappelluti et al. (2010), Allevato et al. (2013), Mountrichas et al. (2012,2013), Krumpe et al. (2010,2012)

Semi-analytics allow to quickly probe different physical prescriptions with a cosmologically significant sample of galaxies

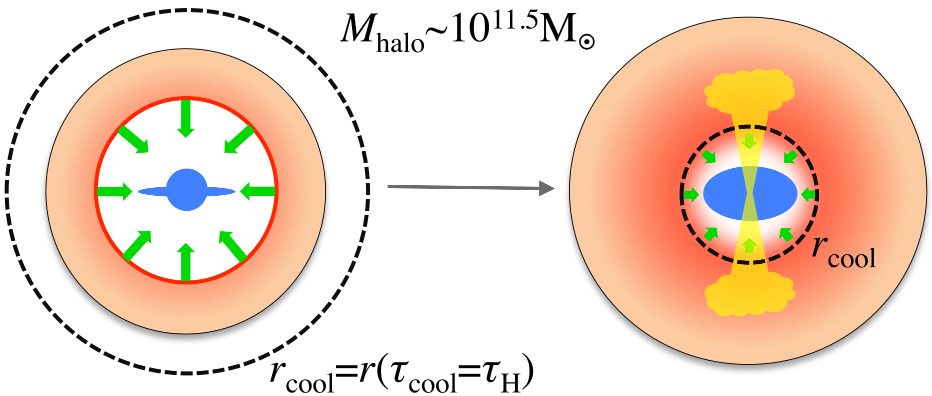


Main GALFORM results described in:
Cole et al. (2000); Benson et al. (2003); Baugh et al. (2005); Bower et al. (2006); Bower et al. (2008); Font et al. (2008); Benson & Bower (2010, 2011); Fanidakis et al. (2011,2012); Lacey et al. (2008,2010,2011), Lagos et al. (2011a, 2011b, 2012); Bower et al. (2012)

Standard cooling scheme in semi-analytics

Rapid-cooling regime

Static-halo regime



$\tau_{cool} \sim \tau_{ff}$

Rapid cooling
Intense SF
Stellar feedback
Strong AGN activity

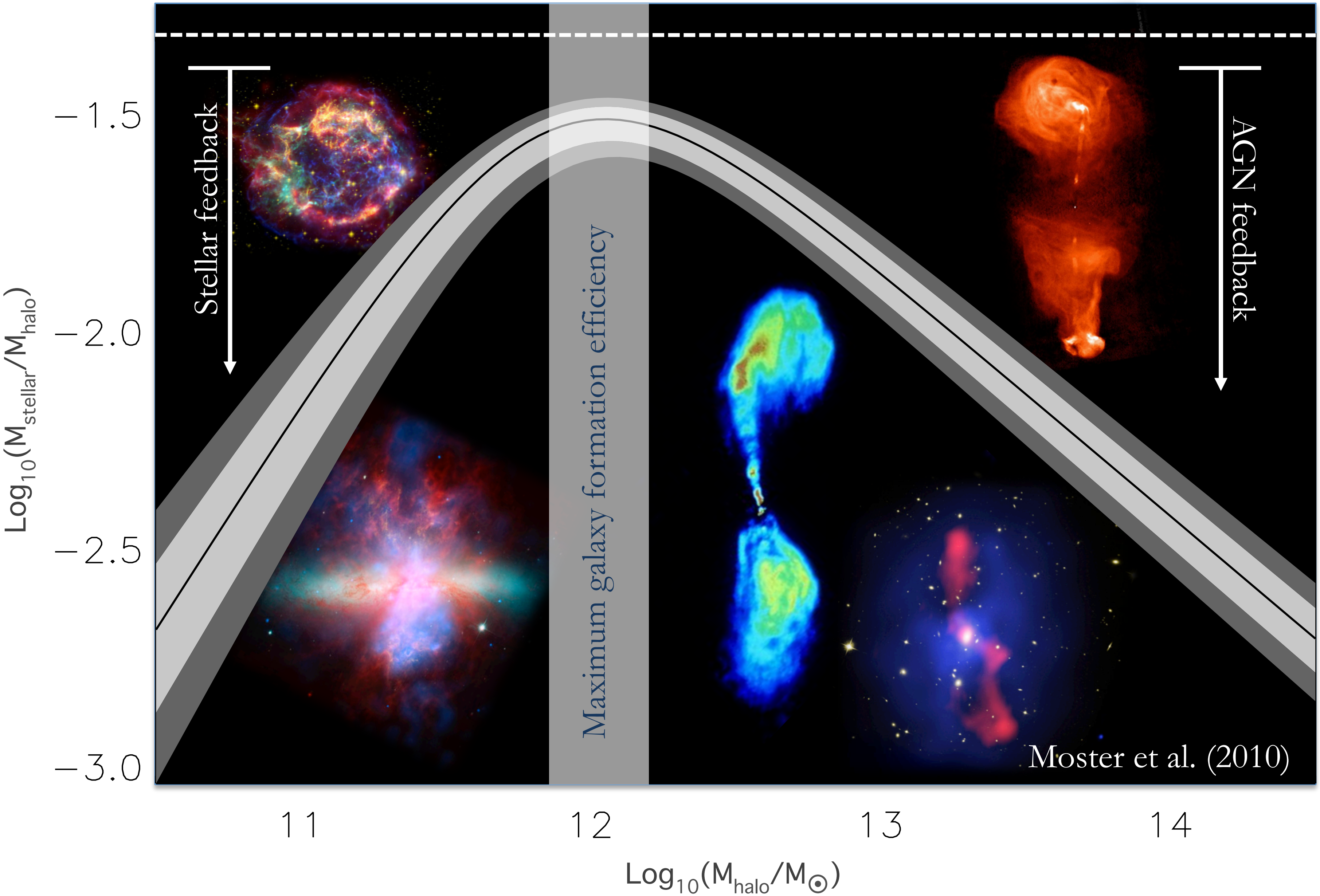
$\tau_{cool} >> \tau_{ff}$

Slow cooling
Weak SF
Radio mode feedback
Mild AGN activity

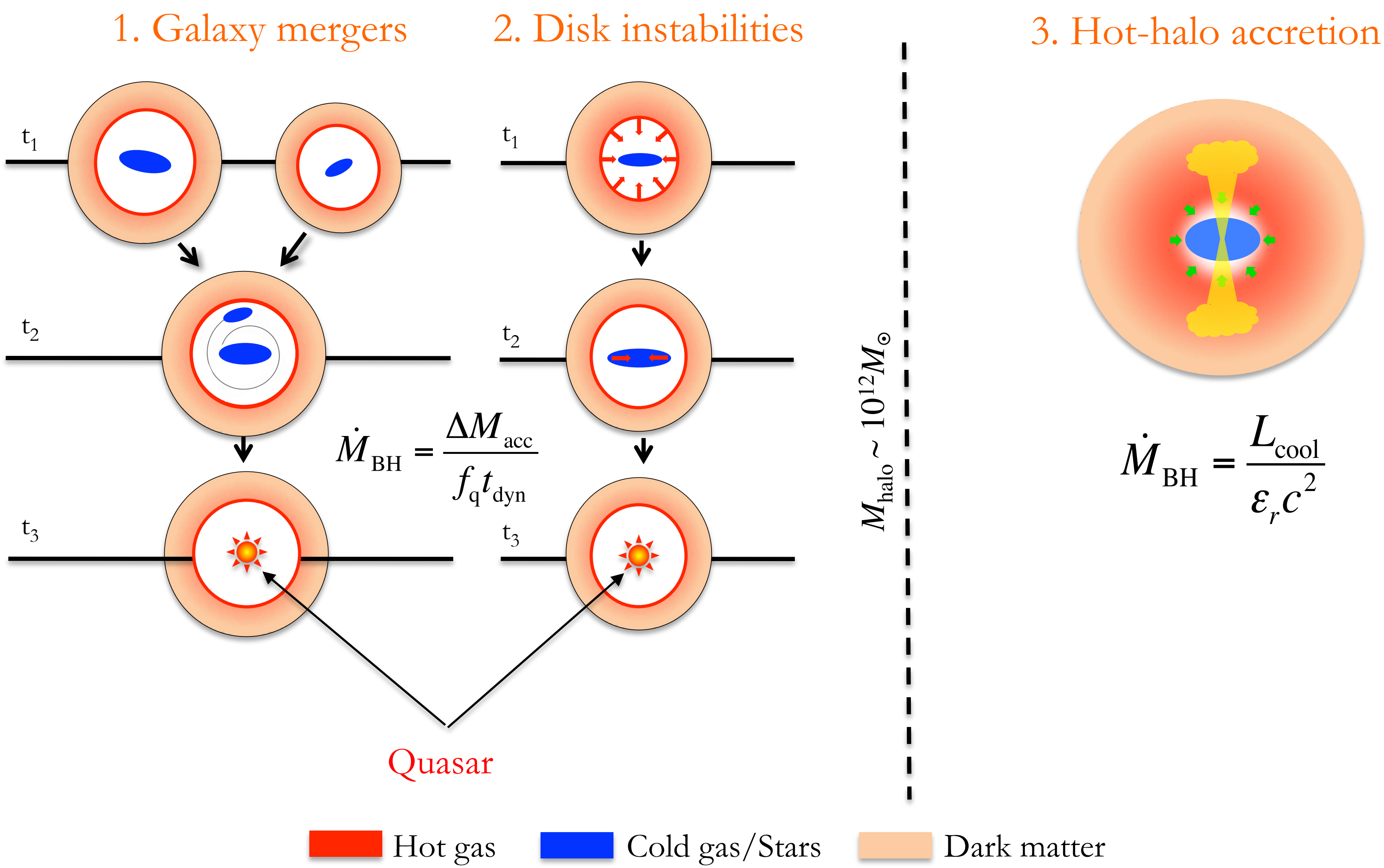
- Gas in $<10^{11.5} M_\odot$ haloes cools rapidly.
- Gas in $>10^{11.5} M_\odot$ haloes is in quasi-hydrostatic equilibrium.

See Croton et al (2006); Bower et al. (2006); Monaco et al. (2007); Somerville et al (2008); Lagos et al. (2008)

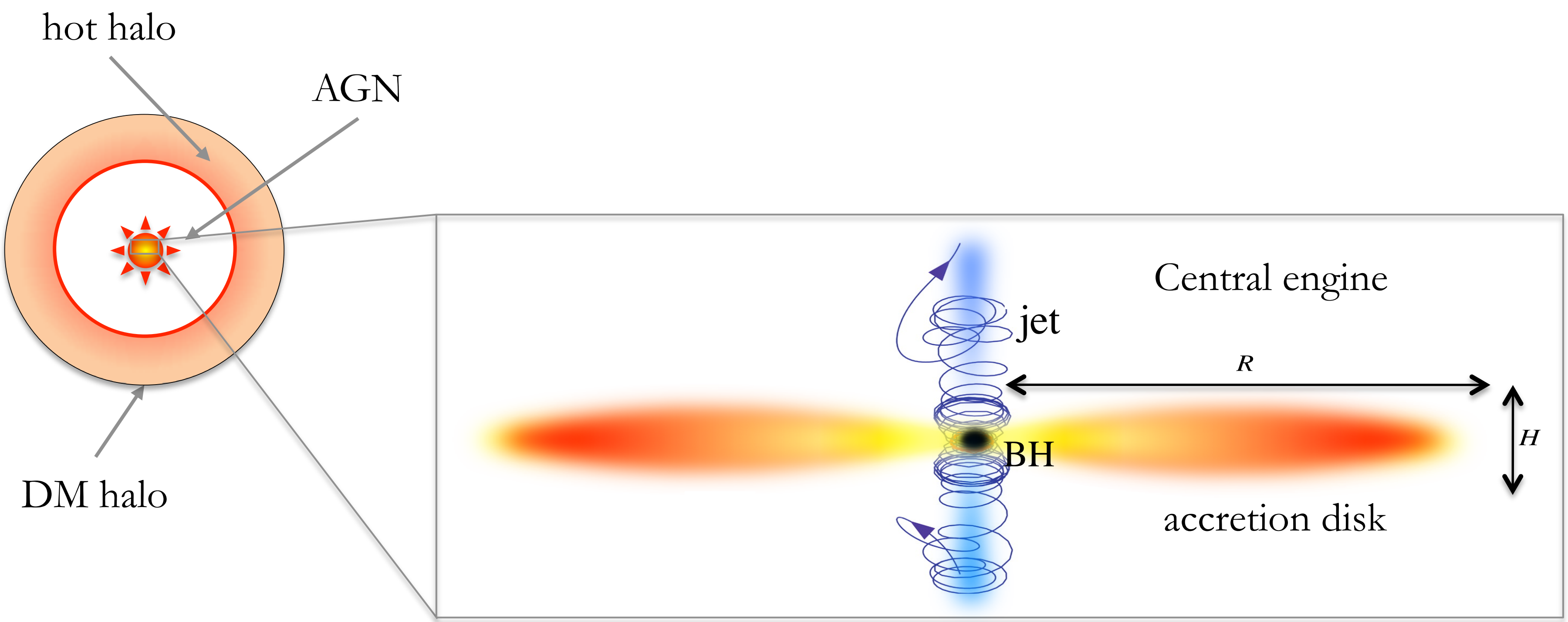
Motivation for introducing feedback in galaxy formation



Black Hole (BH) growth in GALFORM



NF et al. (2011, 2012) See also: Malbon et al. (2007), Marulli et al (2008), Somerville et al (2008), Hirschmann et al (2012)



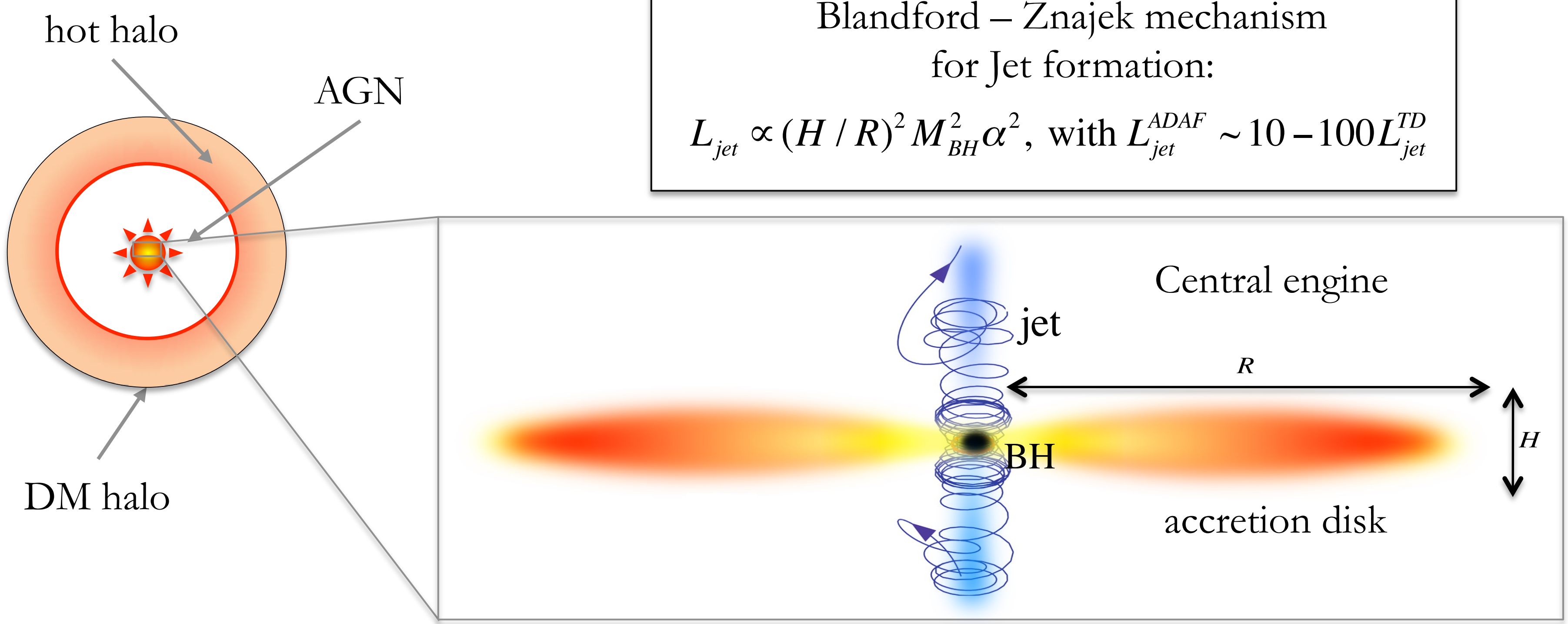
Basic ingredients

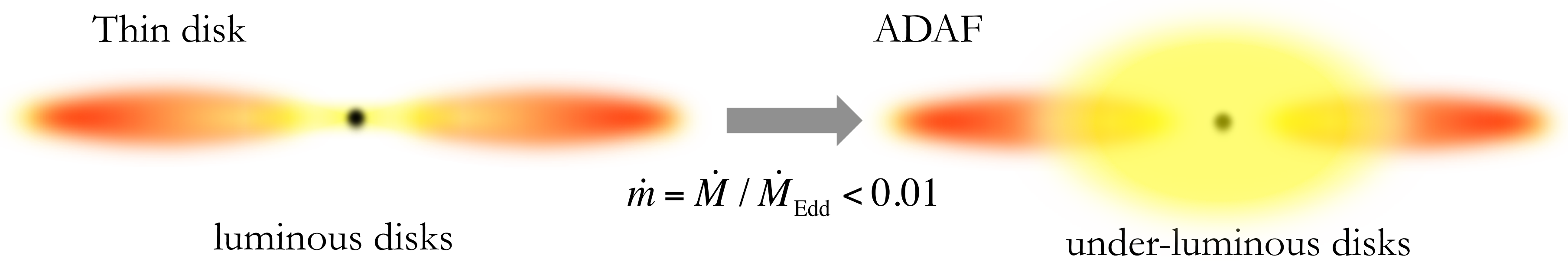
1) Accretion rate calculation
2) Disk structure (thin-disk/ADAF) Shakura & Sunyaev (1973); Mahadevan (1997)
3) BH spin evolution (accretion and BH-BH mergers) King et al. (2005)
4) Bolometric corrections for optical, x-ray, UV emission Marconi et al. 2005)
5) Empirical obscuration Hasinger (2008)
6) Jet total and radio luminosity Blandford & Znajek (1977)

(NF et al 2011)

Blandford – Znajek mechanism
for Jet formation:

$$L_{jet} \propto (H/R)^2 M_{BH}^2 \alpha^2, \text{ with } L_{jet}^{ADAF} \sim 10-100 L_{jet}^{TD}$$

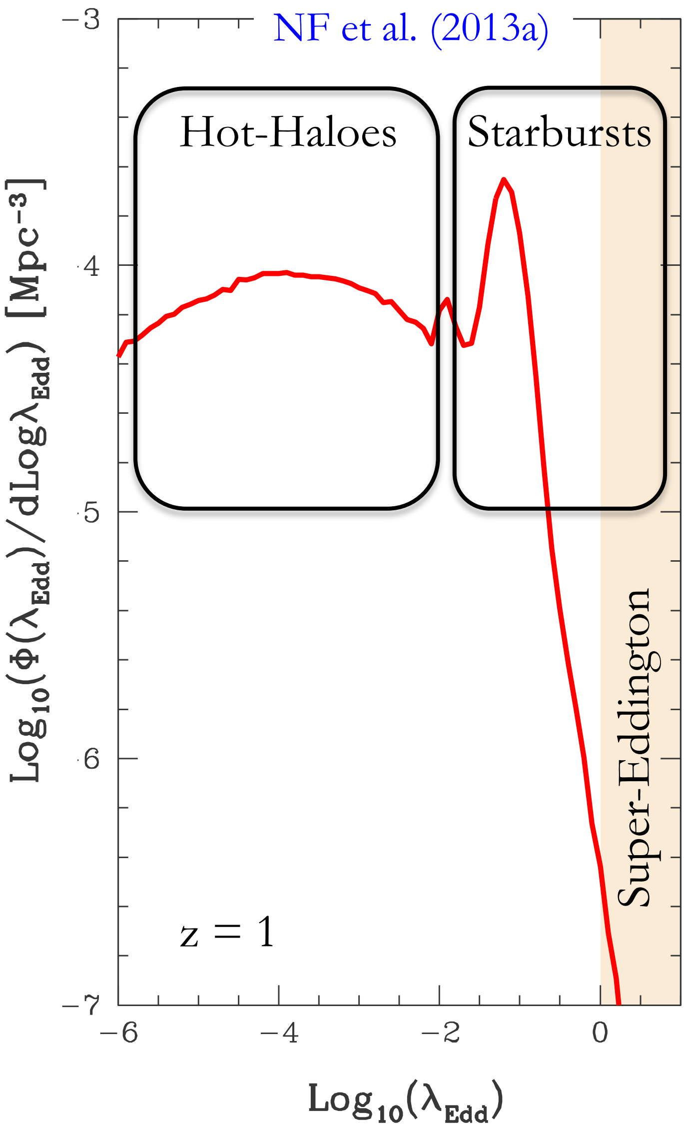


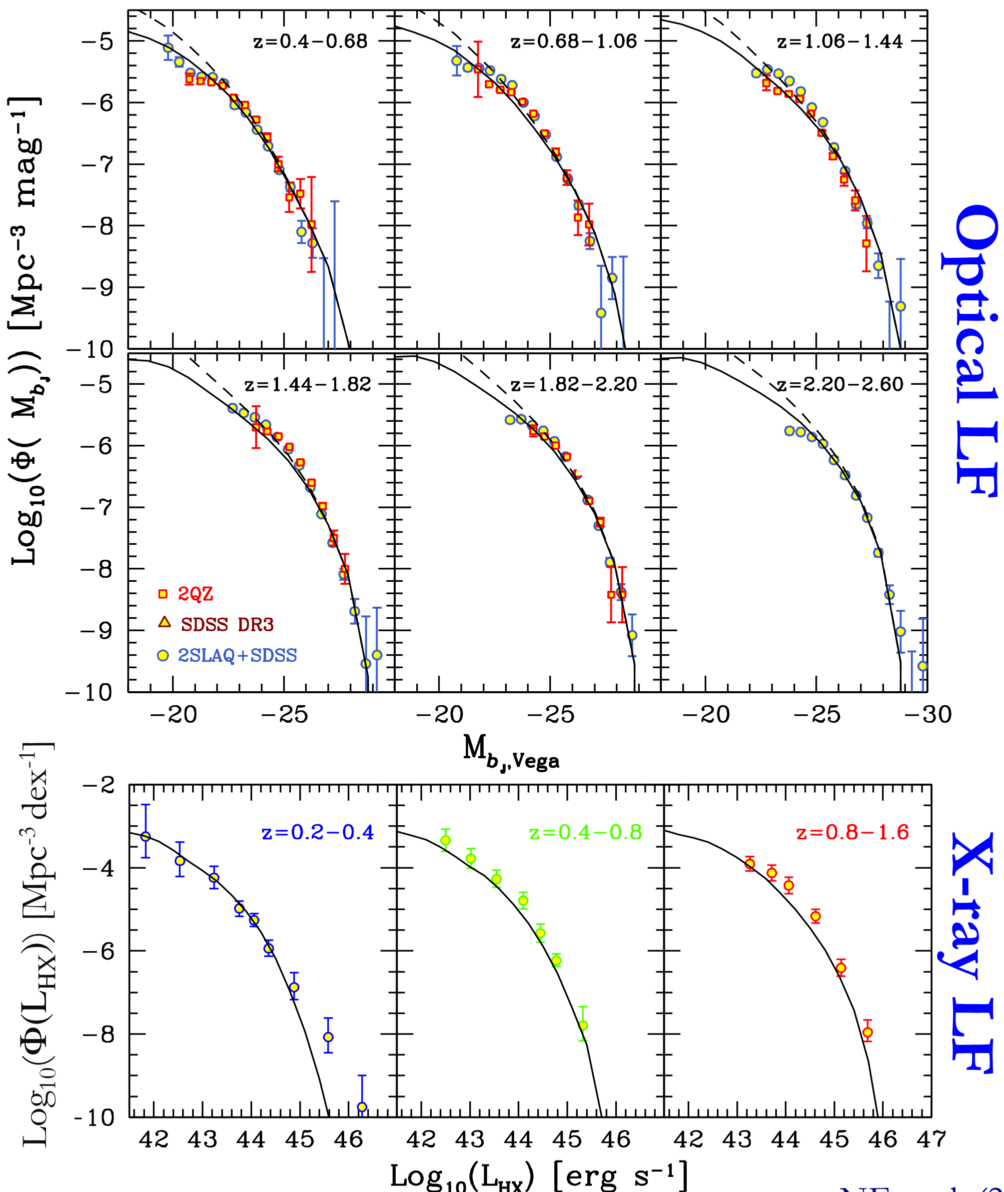


$$\dot{m} = \dot{M} / \dot{M}_{\rm Edd} < 0.01$$

$$L_{disk}^{ADAF} = \varepsilon_{ADAF} L_{disk}^{TD}, \quad \varepsilon_{ADAF} = 0.01-0.1$$

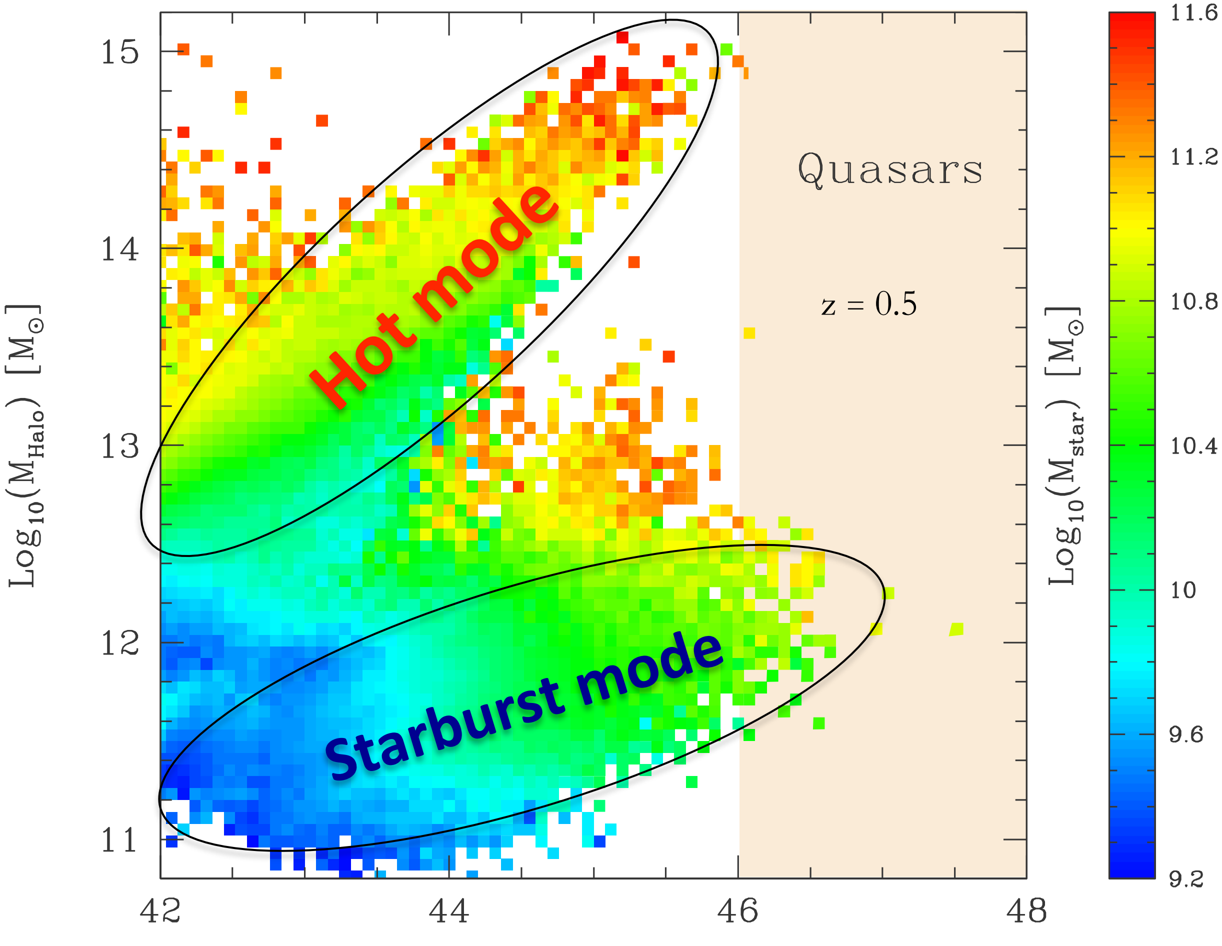
(NF et al 2011)


NF et al. (2013a)
Hot-Haloes
Starbursts
Super-Eddington
z = 1
$\mathrm{Log_{10}(\Phi(\lambda_{Edd})/dLog\lambda_{Edd})}$ [Mpc^{-3}]
$\mathrm{Log_{10}(\lambda_{Edd})}$


z=0.4−0.68
z=0.68−1.06
z=1.06−1.44
z=1.44−1.82
z=1.82−2.20
z=2.20−2.60
2QZ
SDSS DR3
2SLAQ+SDSS
$\mathrm{Log_{10}(\Phi(M_{b_J}))}$ [Mpc^{-3} mag^{-1}]
$M_{b_J,\mathrm{Vega}}$
Optical LF
z=0.2−0.4
z=0.4−0.8
z=0.8−1.6
$\mathrm{Log_{10}(\Phi(L_{HX}))}$ [Mpc^{-3} dex^{-1}]
$\mathrm{Log_{10}(L_{HX})}$ [erg s^{-1}]
X-ray LF

NF et al. (2012)

BH accretion modes vs. Dark Matter halo mass



NF+(2013b)

Starburst mode:

- Disk galaxies rich in gas.
- Luminosity correlates with $M_\star$.
- Quasars = L > 10^{46} erg/s AGN.
- Average halo environments.

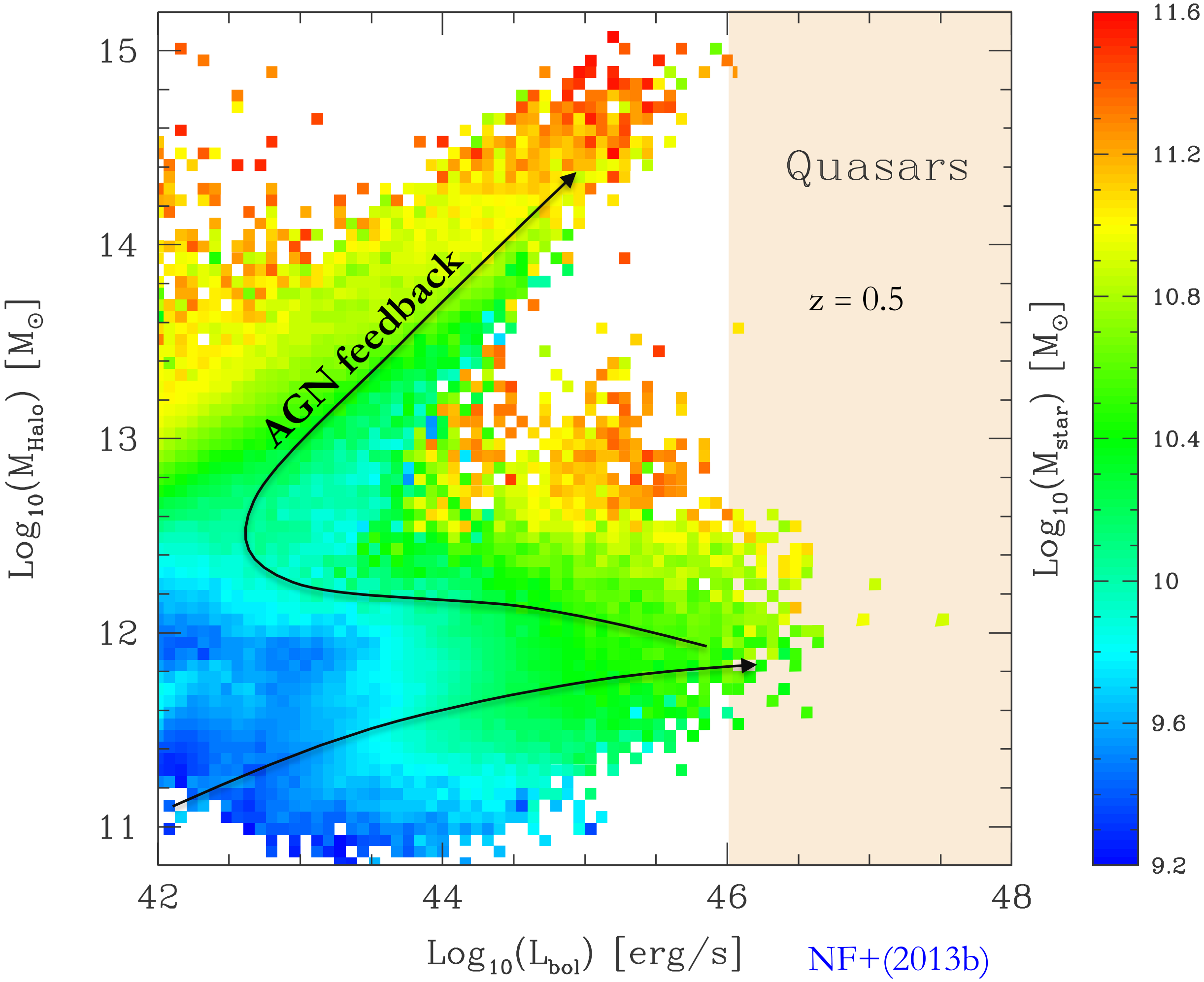
Hot-halo mode:

- Spheroids poor in gas.
- Luminosity correlates with M_{halo}:

$$\dot{M}_{BH} = L_{cool} / \varepsilon_r c^2$$

- Luminosity correlates with $M_\star$.
- Massive halo environments.

BH accretion modes vs. Dark Matter halo mass



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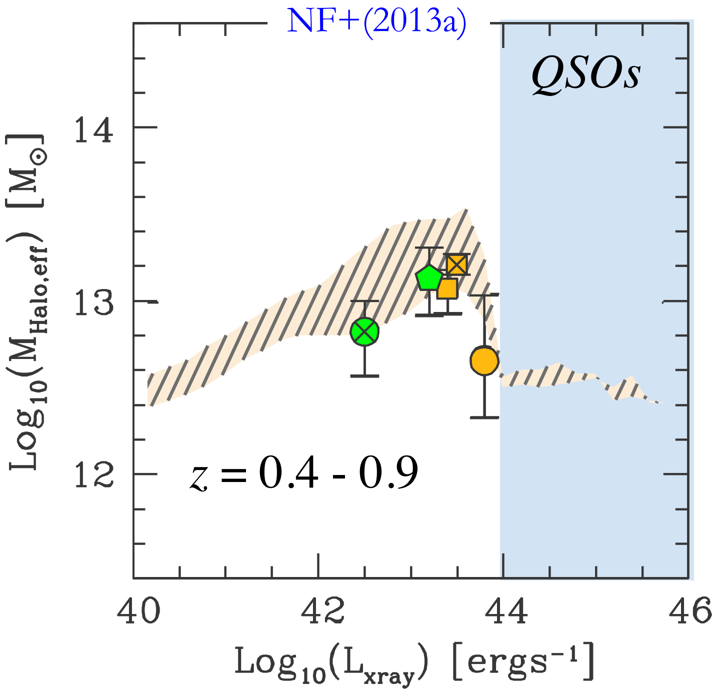
The clustering of moderate luminosity AGN

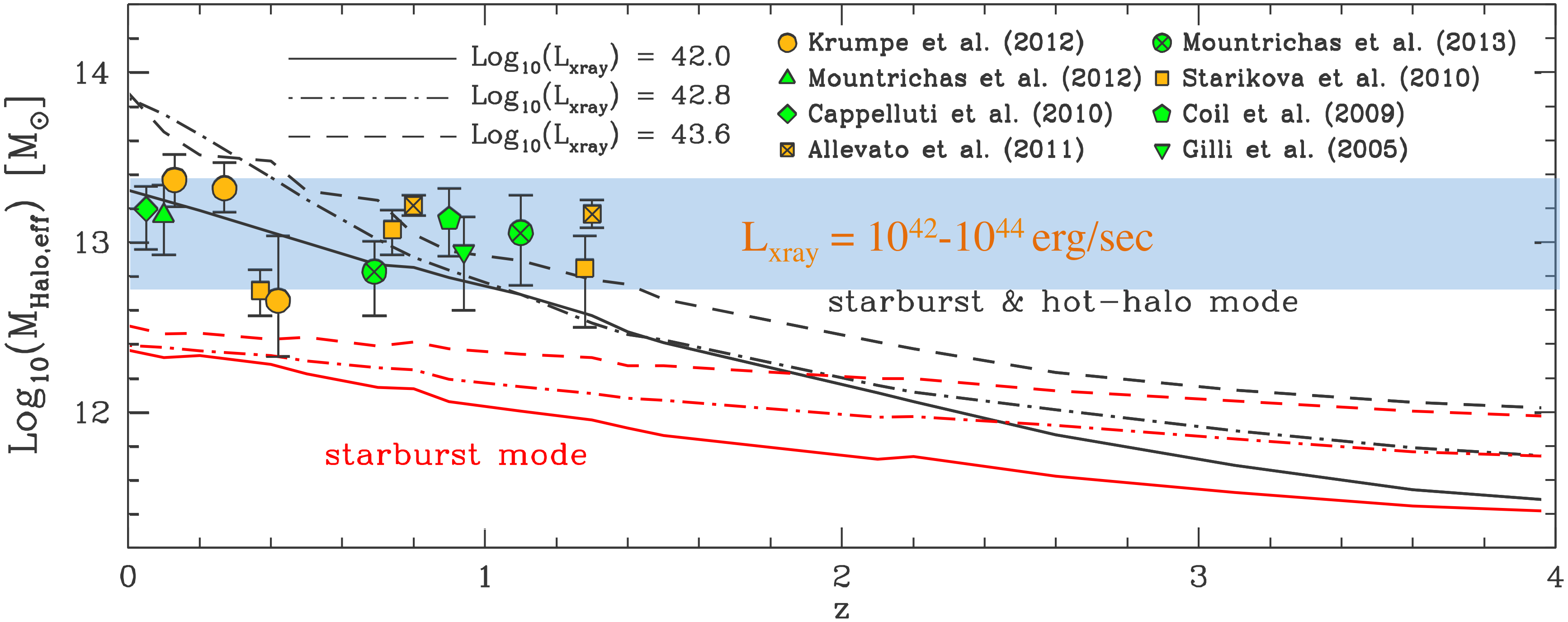


$M_{\mathrm{halo,eff}}$ from $b_{\mathrm{eff}}(z)$ using the ellipsoidal collapse model of Sheth & Tormen (1999)

$$b_{\mathrm{eff}}(z) = \frac{\int b(M_{\mathrm{Halo}}, z) N_{\mathrm{q}}(M_{\mathrm{Halo}}, z) n(M_{\mathrm{Halo}}, z) \mathrm{d} \log M_{\mathrm{Halo}}}{\int N_{\mathrm{q}}(M_{\mathrm{Halo}}, z) n(M_{\mathrm{Halo}}, z) \mathrm{d} \log M_{\mathrm{Halo}}}$$

Baugh et al. (1999)

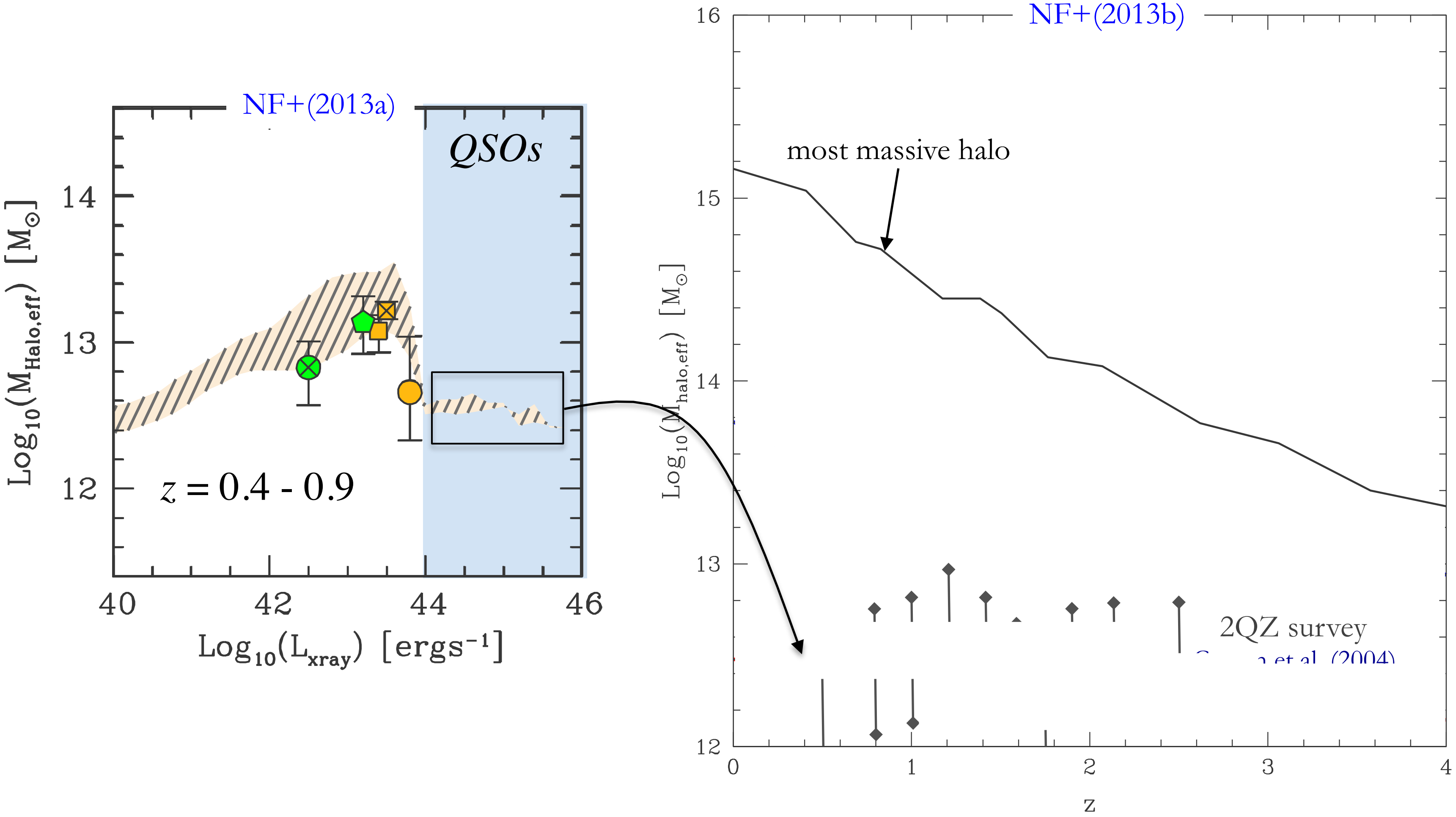
Hot-halo accretion is essential for reproducing the halo mass of moderate luminosity AGN!



NF+(2013a)

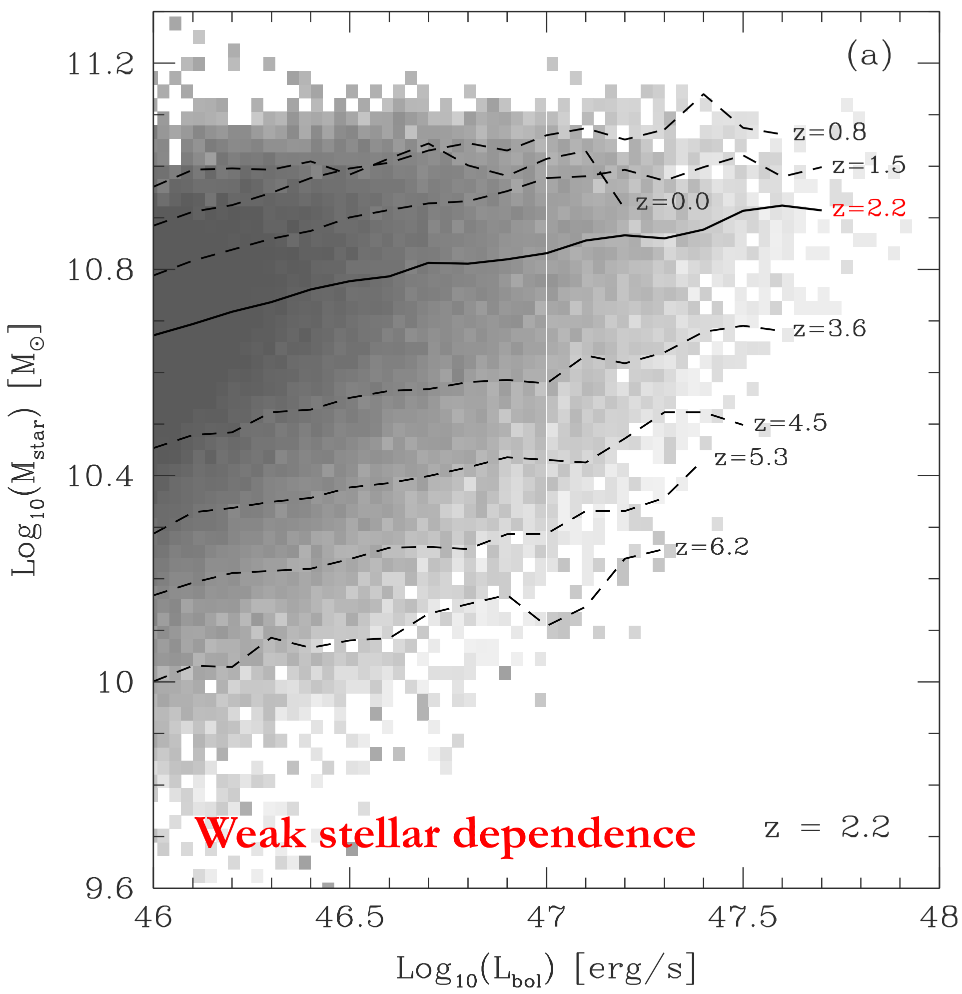
Dark Matter halo mass of luminous Quasars

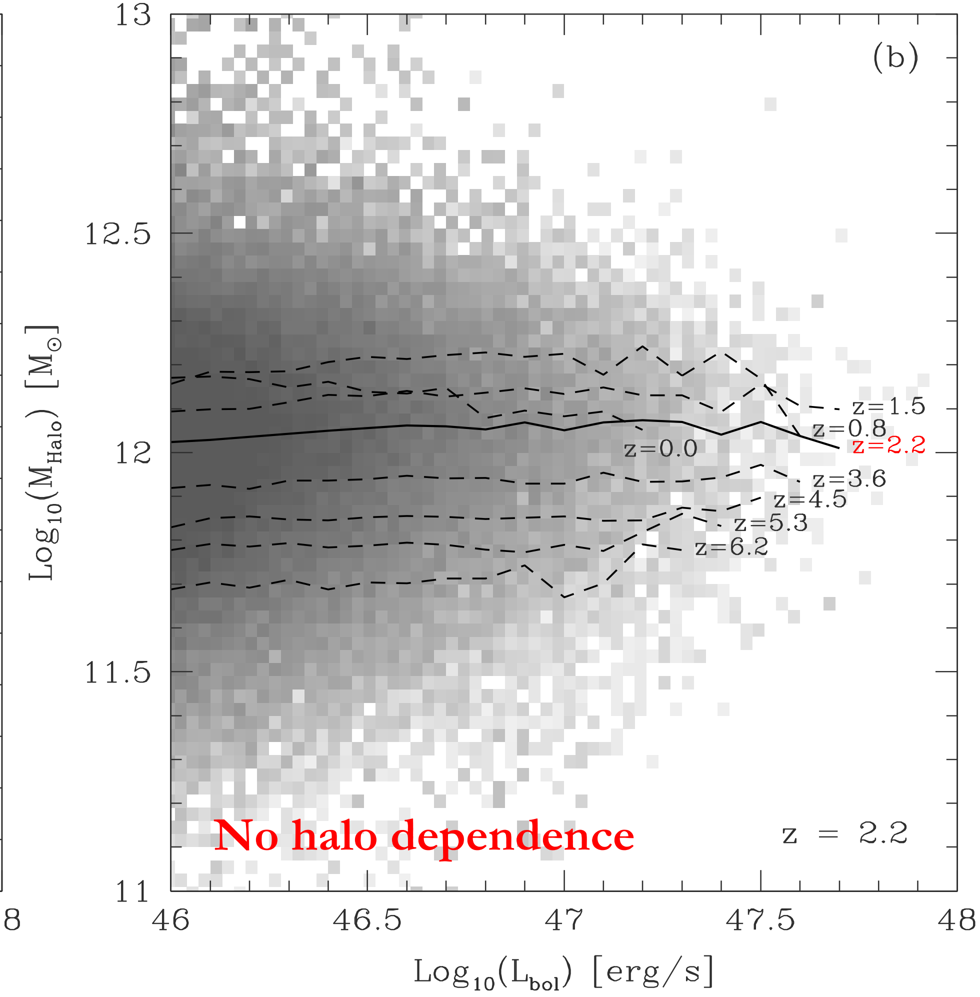
The starburst mode shapes the halo environment of luminous Quasars!



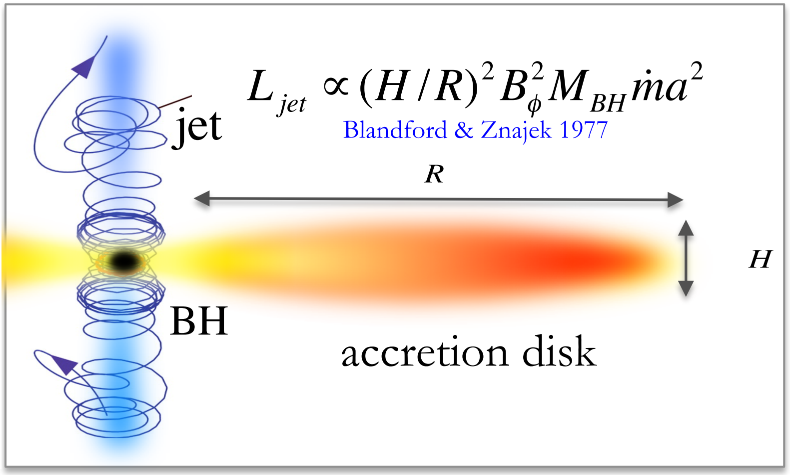
See also: Ross et al. (2009), White et al. (2012), Shen et al. (2013)

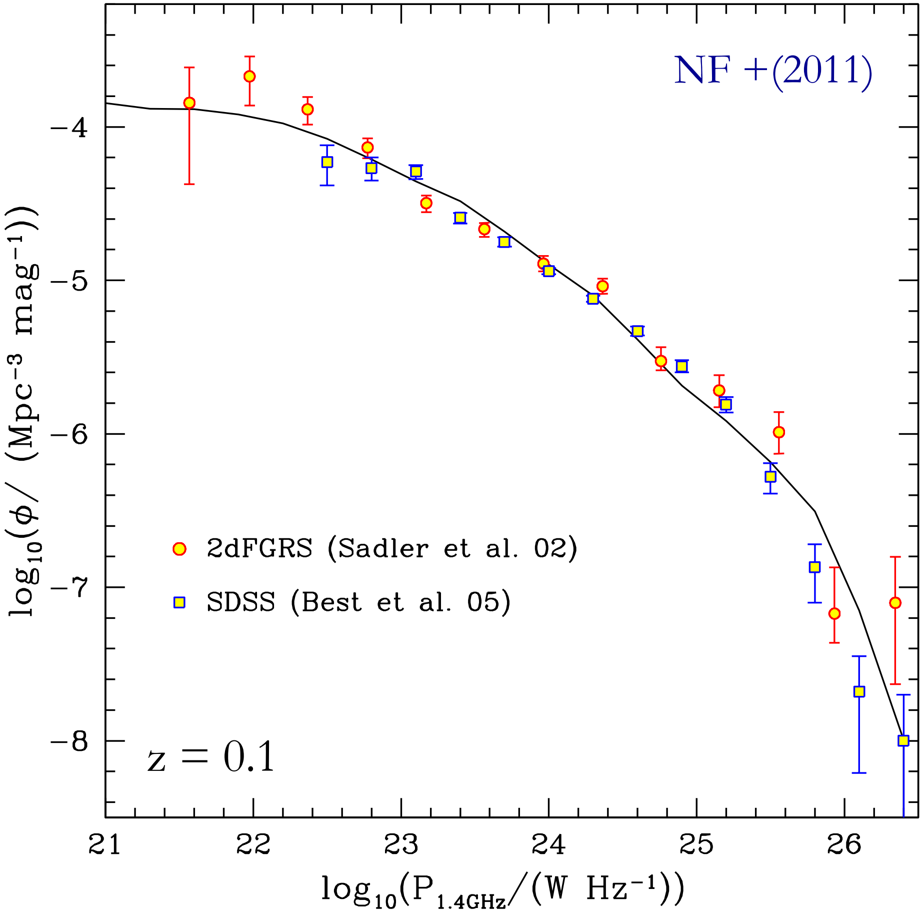
Stellar and halo mass of luminous Quasars





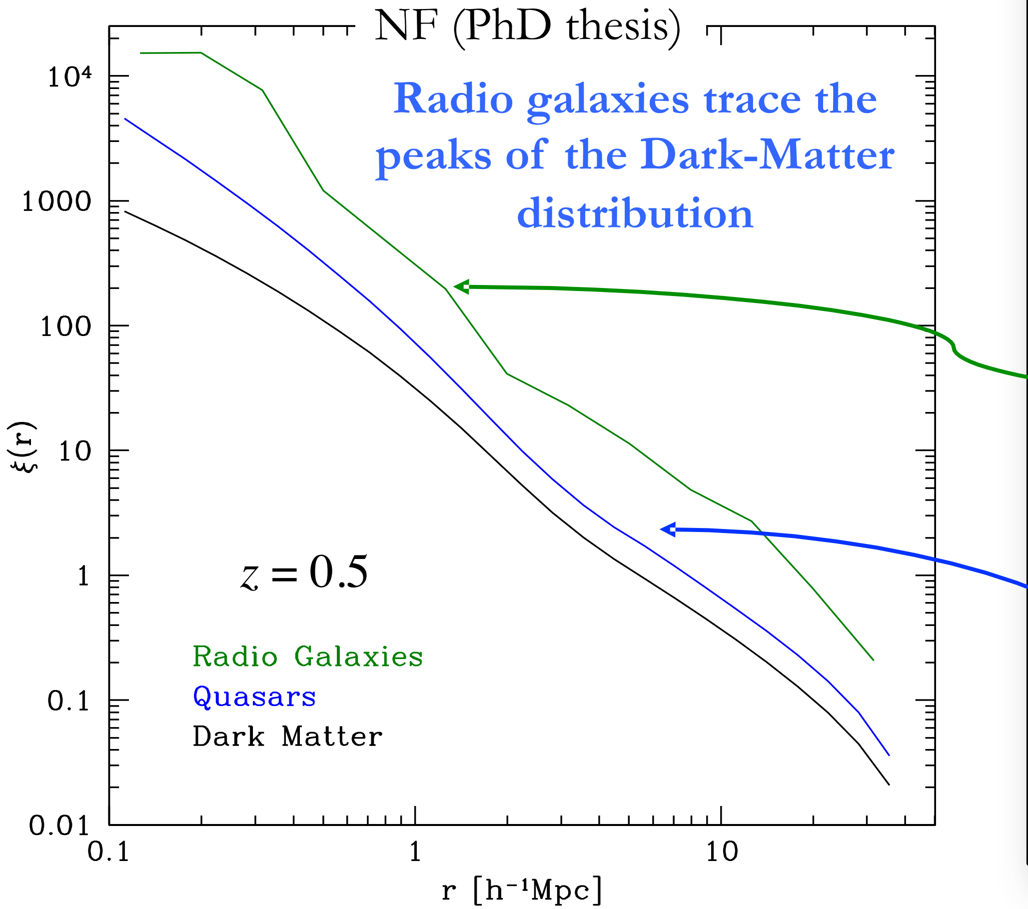
We couple the spin, mass and accretion rate to the Blandford – Znajek jet mechanism.

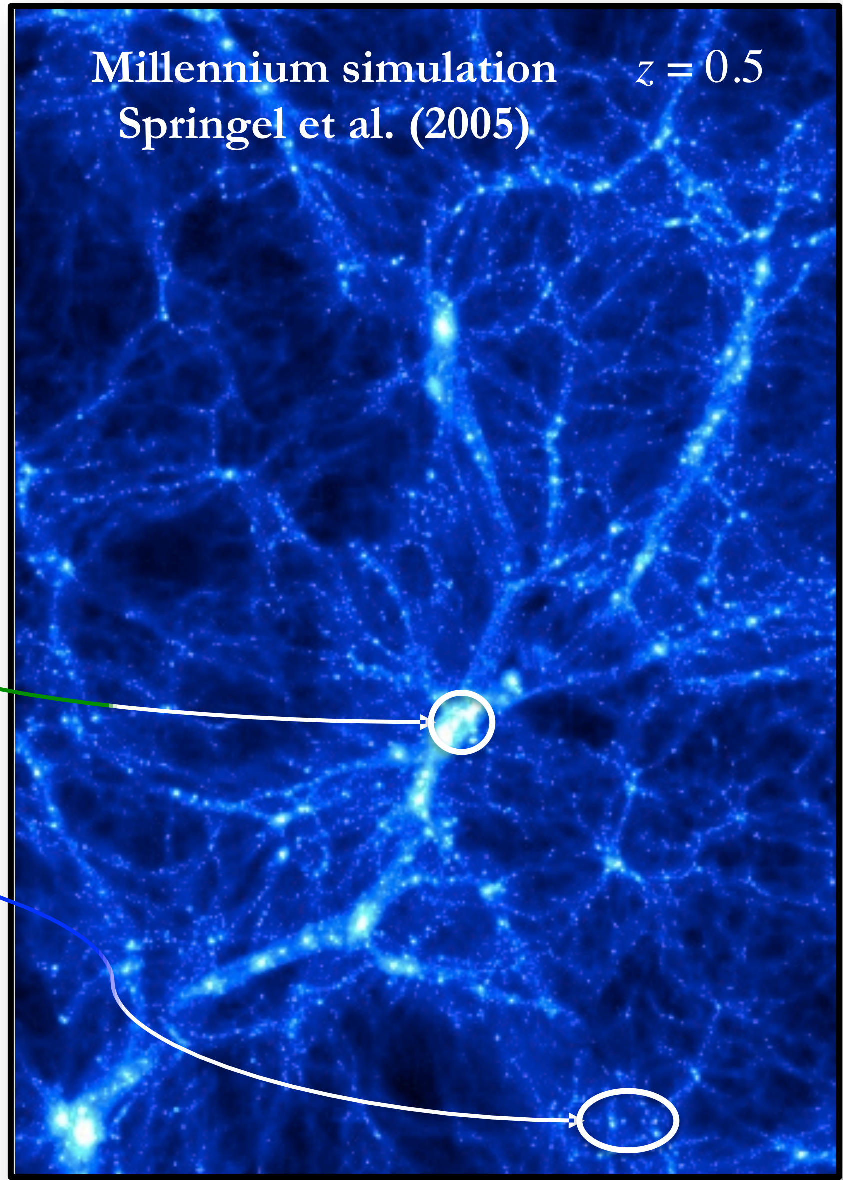




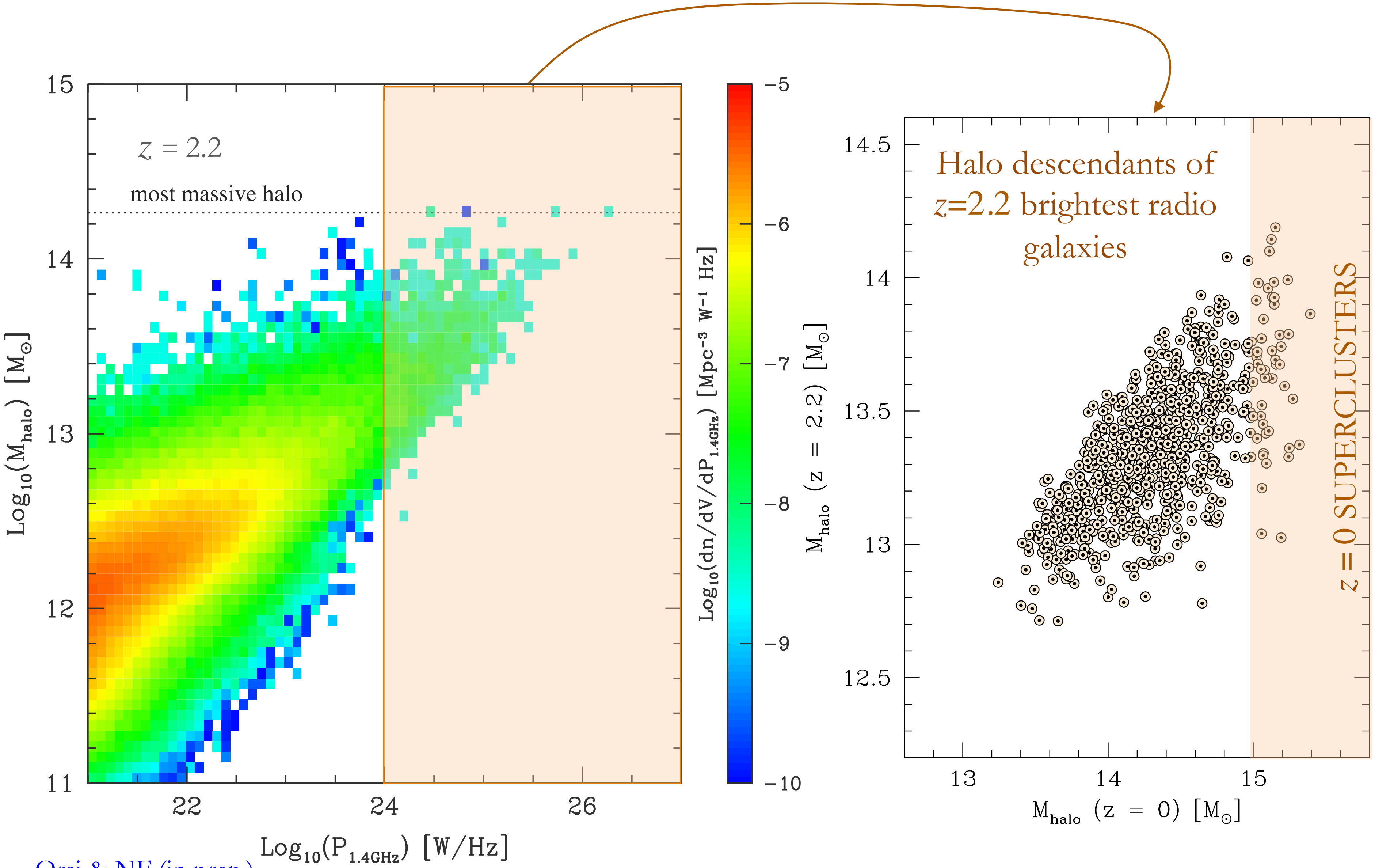
The clustering of Radio Galaxies

The dependence of BH parameters on the environment creates the right conditions for reproducing the clustering of Radio Galaxies



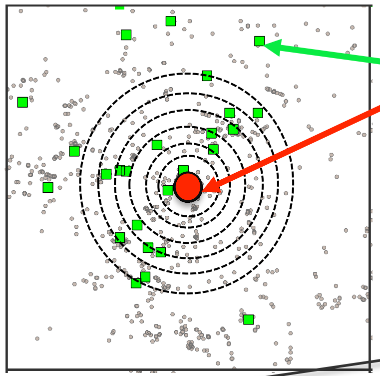


High-z Radio Galaxies (HzRGs) as tracers of proto-clusters

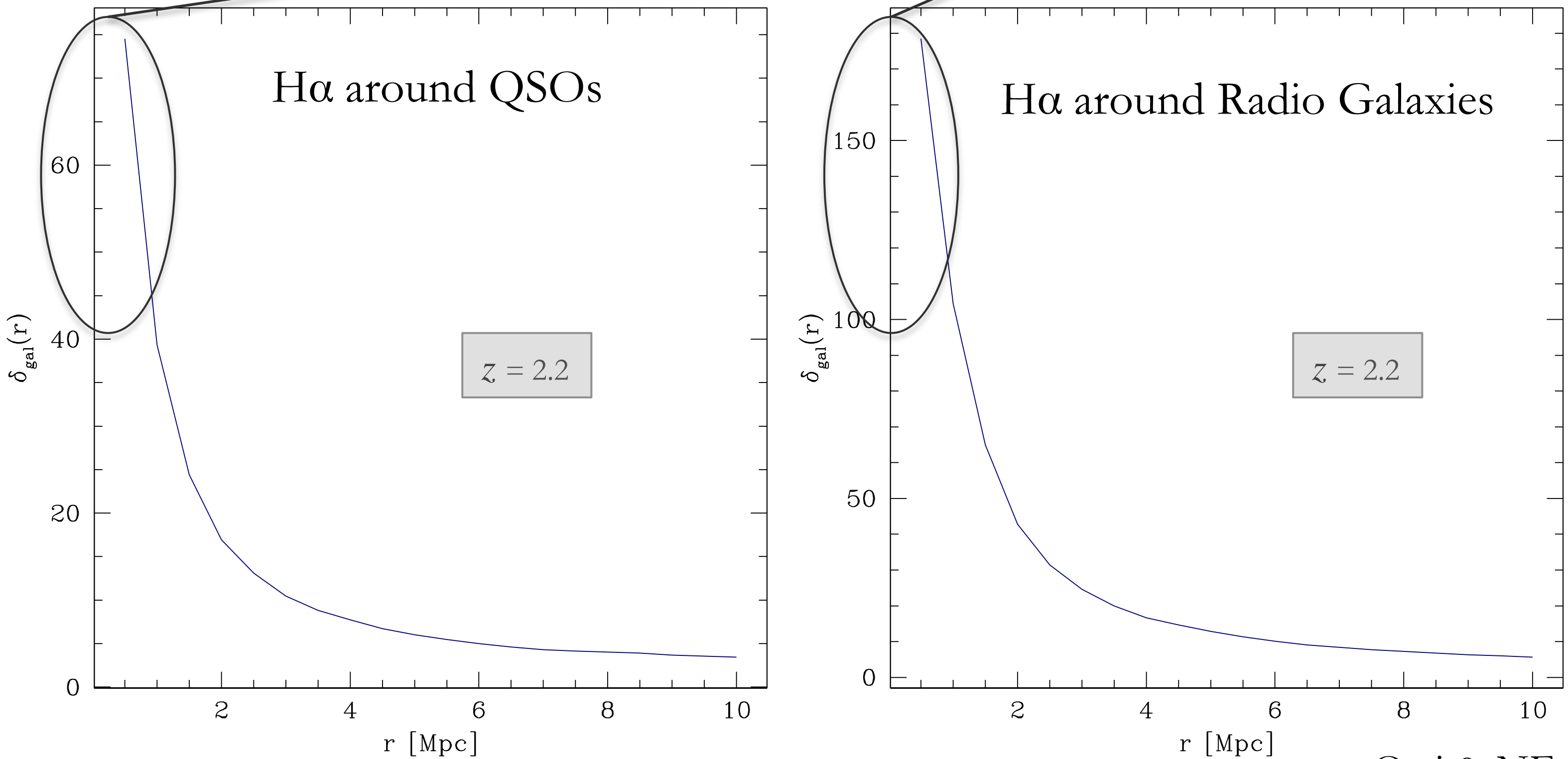


Orsi & NF (in prep.)

$$\delta_{gal}(r) = \frac{\langle N(r) - \tilde{N}(r) \rangle}{\tilde{N}(r)}$$



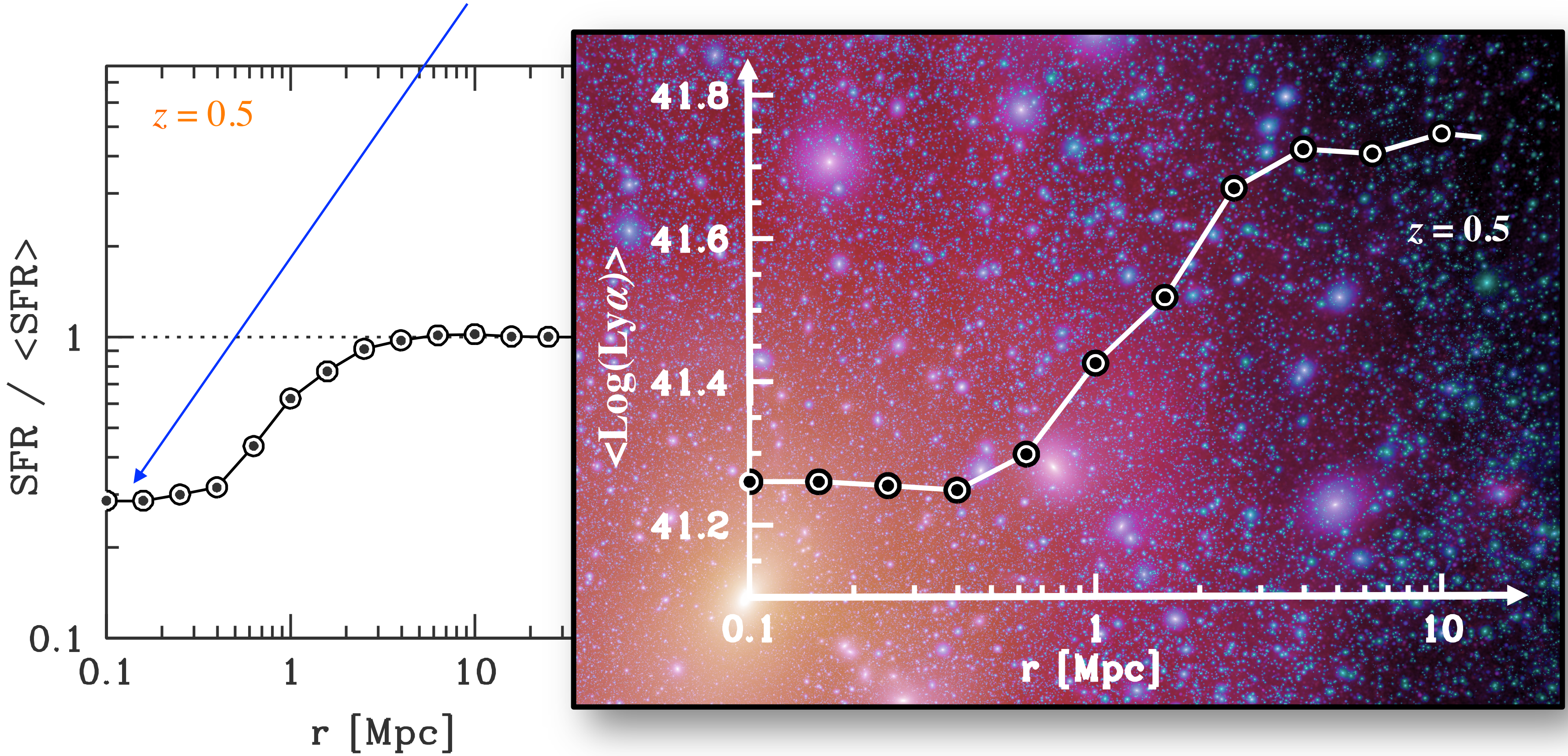
Line emitting galaxies cluster strongly around radio galaxies



Orsi & NF (in prep)

A Lyα luminosity gradient near HzRGs

LAEs deeper in the potential well have depleted most of their gas reservoirs



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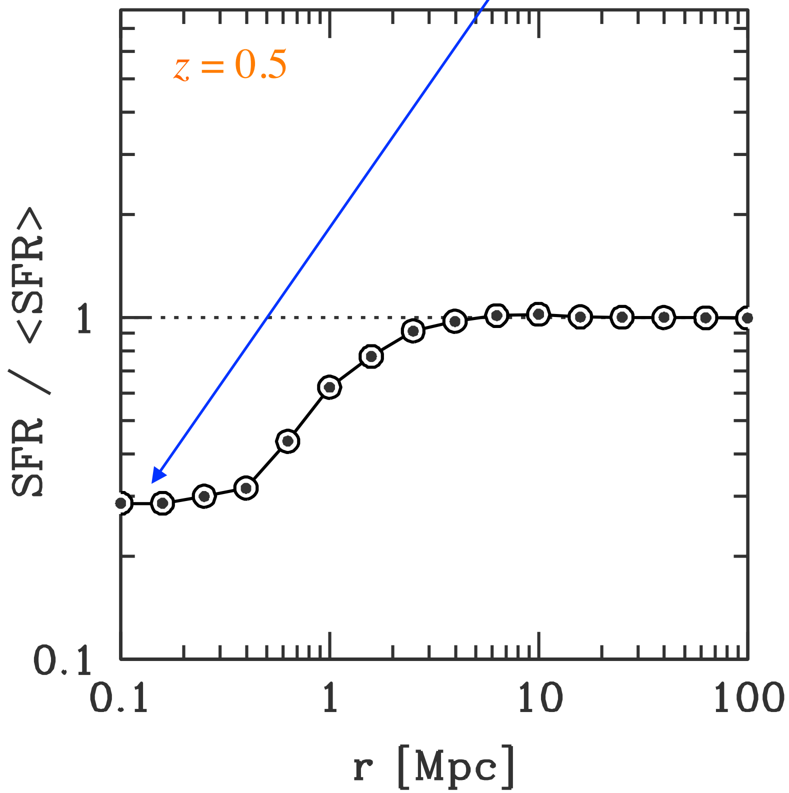
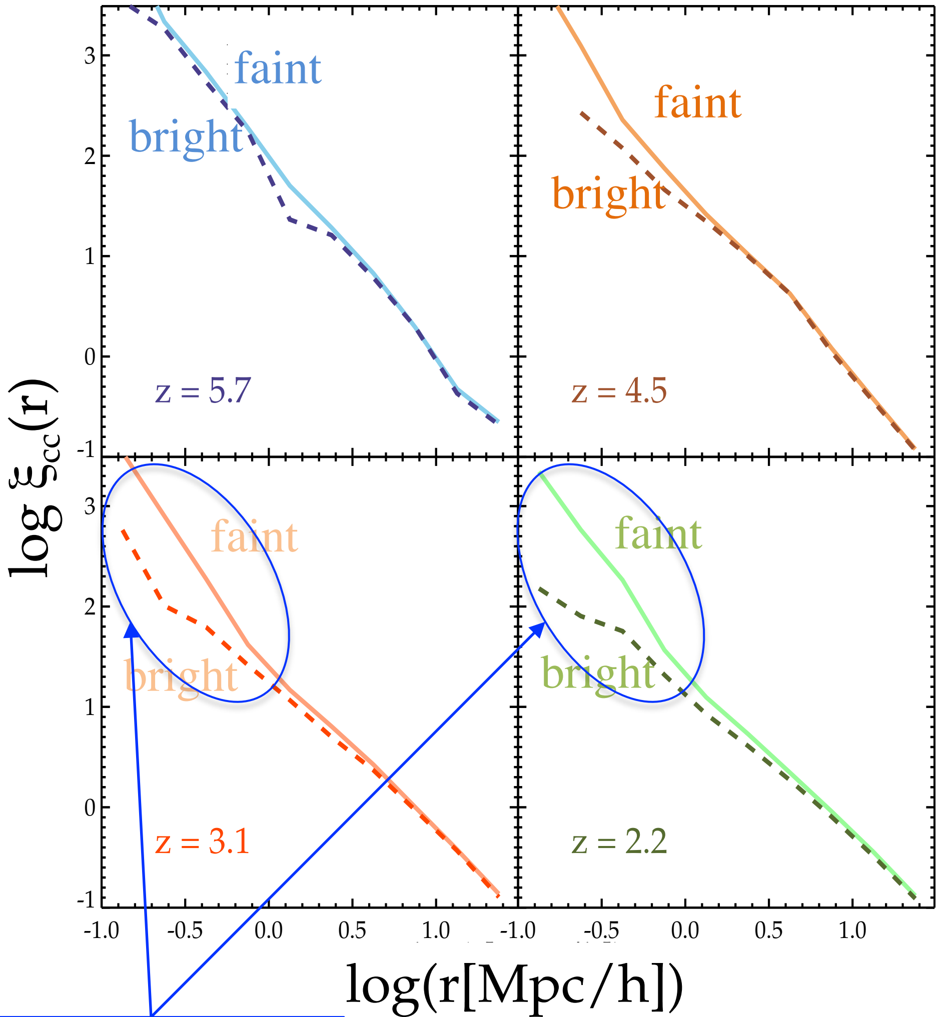


LAEs – HzRGs cross correlation



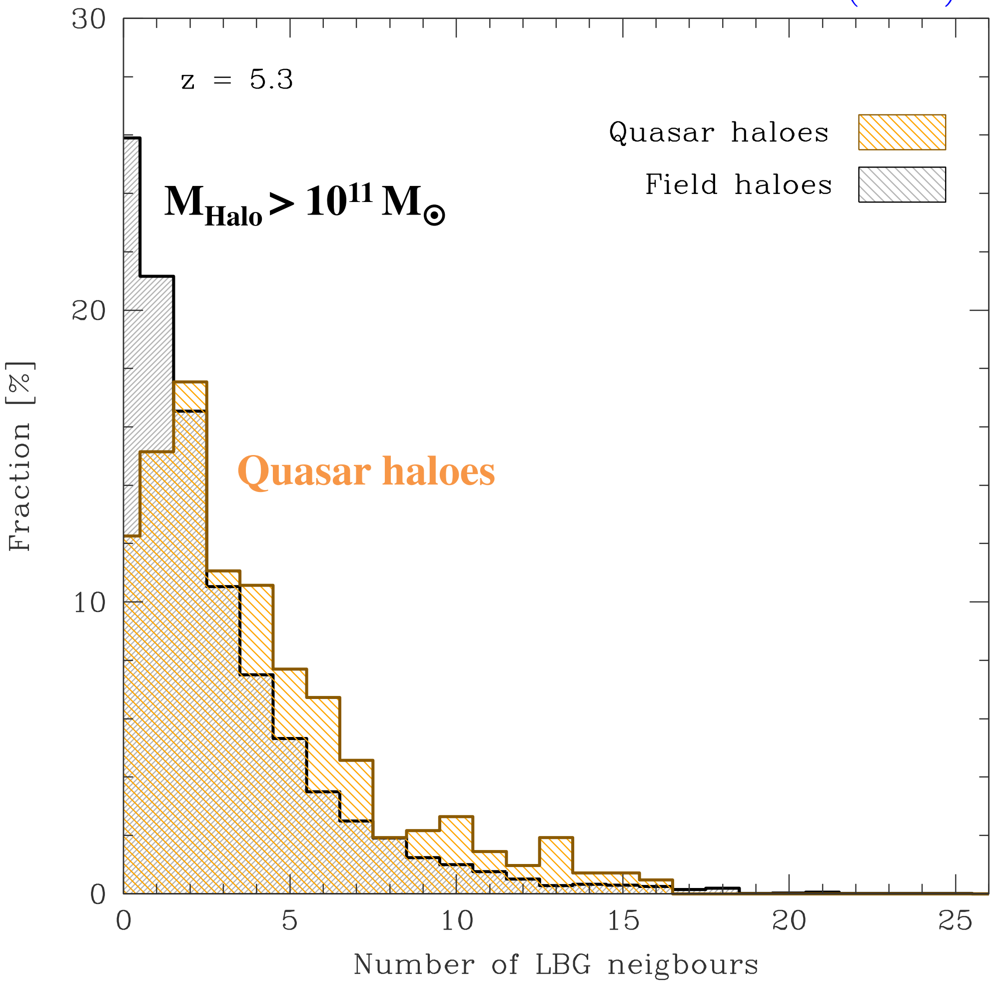
AGN feedback

Orsi & NF (in prep)

Do high-z Quasars live in over-densities?

A similar analysis for QSOs shows that there is a non-negligible probability to find an overabundance of LBGs around high-z Quasar

NF+(2013b)



See: Stiavelli et al. (2005), Zheng et al. (2006), Priddey et al. (2008), Cantalupo et al. (2012), but also: Francis & Bland-Hawthorn (2004), Willott et al. (2005), Kashikawa et al. (2007), Swinbank et al. (2012), Bañados et al. (2013)

Do high-z Quasars live in over-densities?

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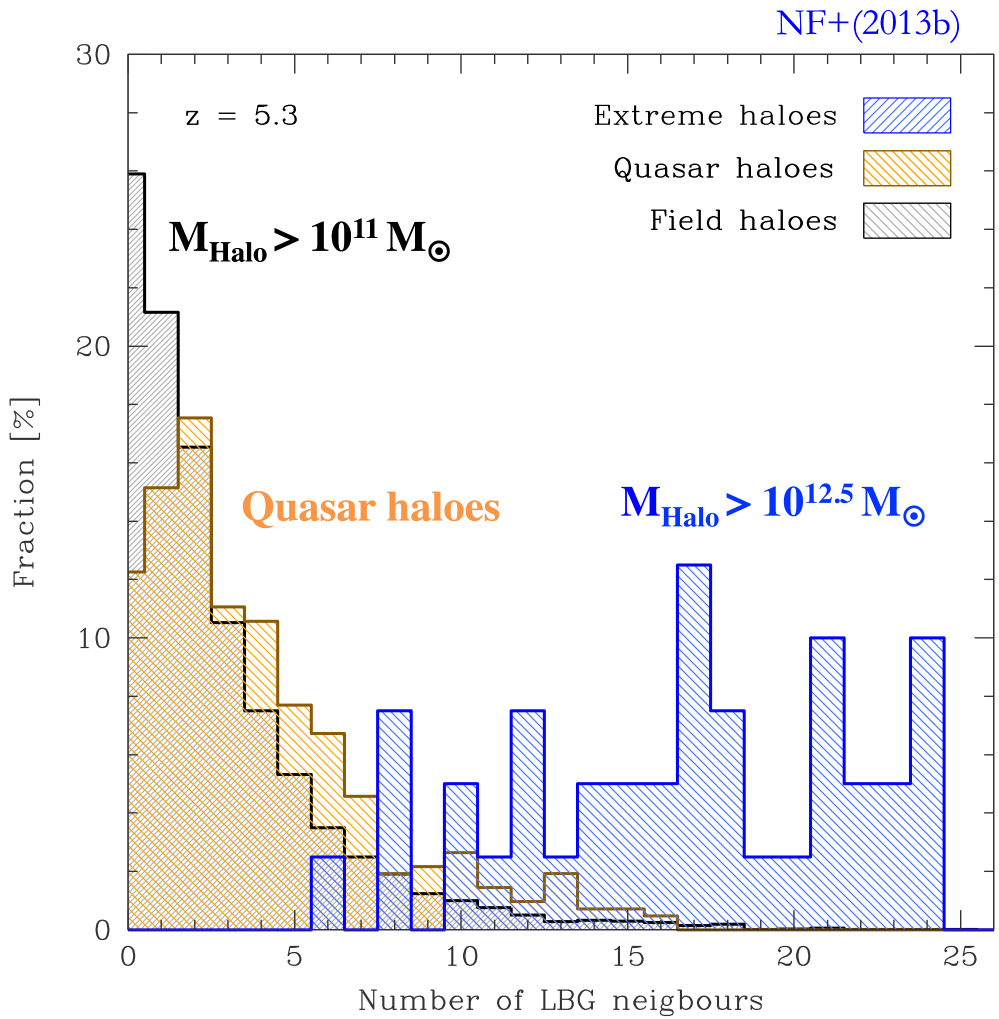
However, these overdensities are moderate compared to the ones expected in most massive DM haloes.



See: Stiavelli et al. (2005), Zheng et al. (2006), Priddey et al. (2008), Cantalupo et al. (2012), but also: Francis & Bland-Hawthorn (2004), Willott et al. (2005), Kashikawa et al. (2007), Swinbank et al. (2012), Bañados et al. (2013)

Conclusions

The environment of AGN is determined by the accretion channel.

Starburst mode (disk instabilities/mergers):

- Fuelling channel of quasars
- Typical halo mass of $\sim 10^{12}\, M_{\odot}$

Hot-halo mode (AGN feedback):

- Dominates faint AGN
- Typical halo mass of $\sim 10^{13}\, M_{\odot}$
- Main fuelling channel of Radio Galaxies

Also:

1. Bulk of AGN activity driven by secular processes
2. X-ray AGN halo mass: mild dependence on *L* – Luminous Quasars: no dependence on *L*
3. Radio galaxies trace the most bound structures (BH spin & mass correlates with DM mass).
4. Radio galaxies trace the location of proto-clusters in the high-z universe.
5. The clustering of line-emitting galaxies near Radio Galaxies is strongly luminosity dependent.
6. $z \sim 5 - 6$ Quasars can be found in mild (but not extreme) over-densities.

1. **Compare correlation function of AGN to available data**
2. **Evolution of Radio Galaxies and Radio Loud Quasars (?)**
3. **Clustering of Radio Galaxies (2PCF+HOD)**
4. **Calculate optical/Xray AGN HOD**
5. **Test effects of AGN variability on clustering**
6. **BAO calculation for radio, X-ray and luminous QSOs**