(radio-mode) AGN feedback in semi-analytics

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Quenching & Quiescence

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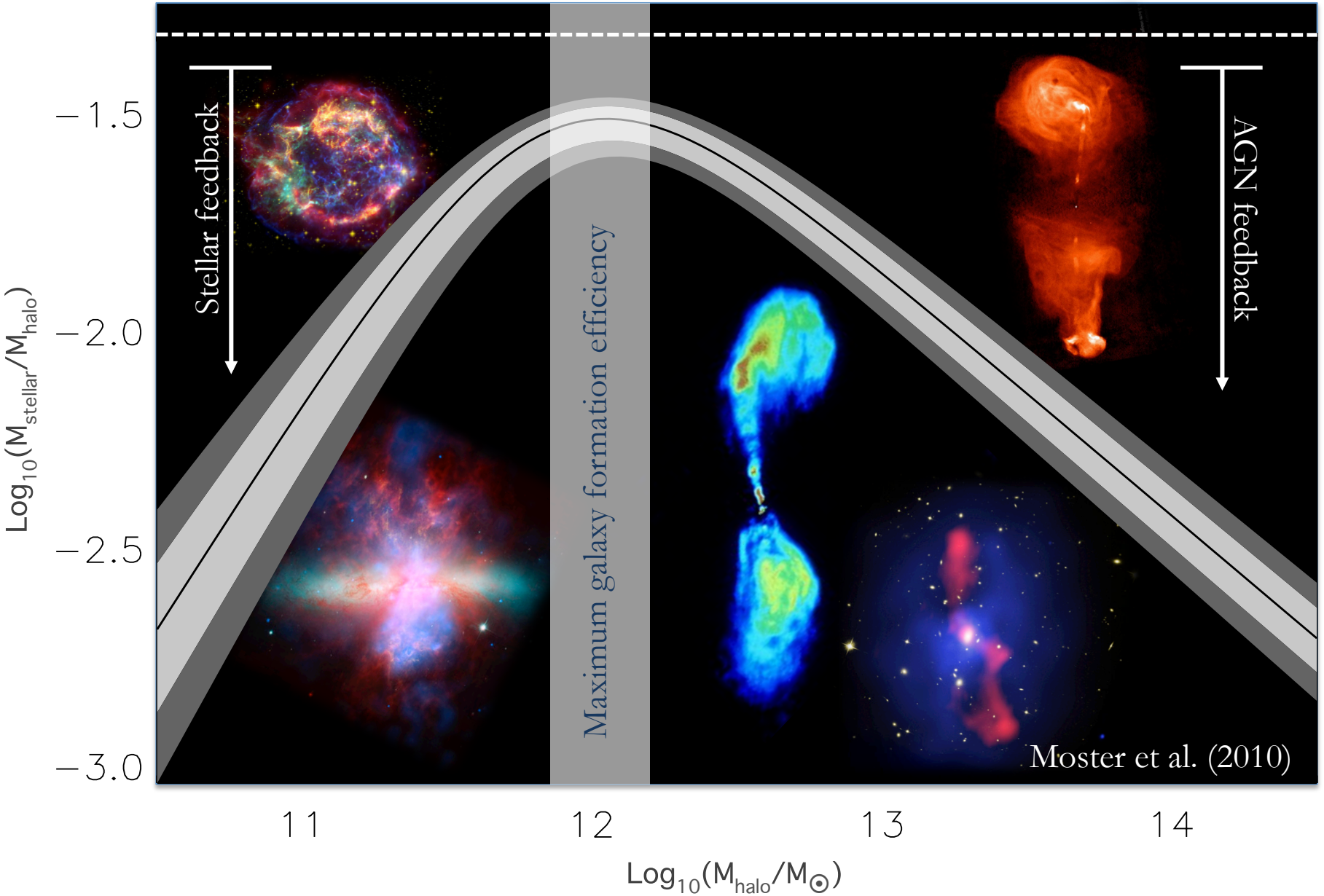
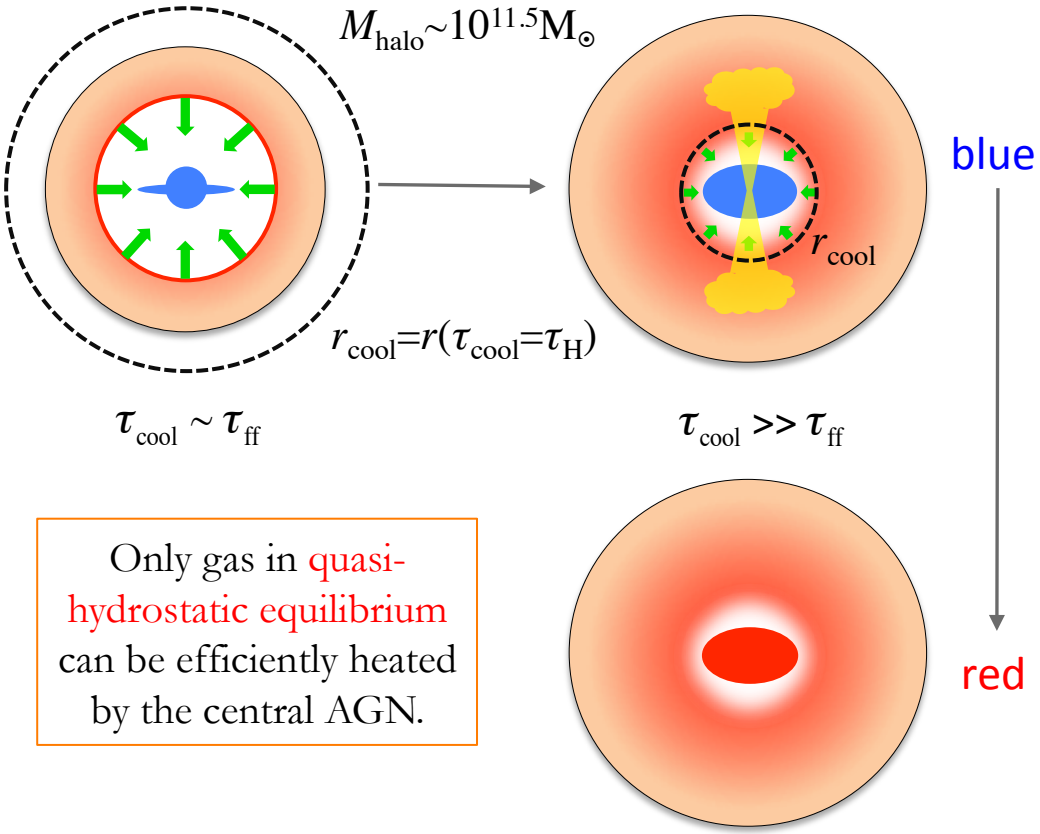
Motivation for introducing AGN feedback



Standard AGN feedback scheme in semi-analytics

Rapid-cooling regime

Static-halo regime



- Gas in $>10^{11.5}M_\odot$ haloes is in quasi-hydrostatic equilibrium.
- Outflows (jets?) driven by the central AGN heat the halo and supress the cooling of gas.

Only gas in quasi-hydrostatic equilibrium can be efficiently heated by the central AGN.

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

MUNICH model (Croton et al. 2006):

$$\dot{M}_{\rm BH} \propto M_{\rm BH} f_{\rm hot} V_{\rm vir}^3 \Rightarrow L_{\rm jet} = 0.1 \dot{M}_{\rm BH} c^2$$

$$\dot{m}'_{\rm cool} = \dot{m}_{\rm cool} - \frac{L_{jet}}{0.5 V_{\rm vir}^2}$$

See also Rachel Somerville's (2008) model and MORGANA model (Monaco et al. 2007)

GALFORM model (Bower et al 2006):

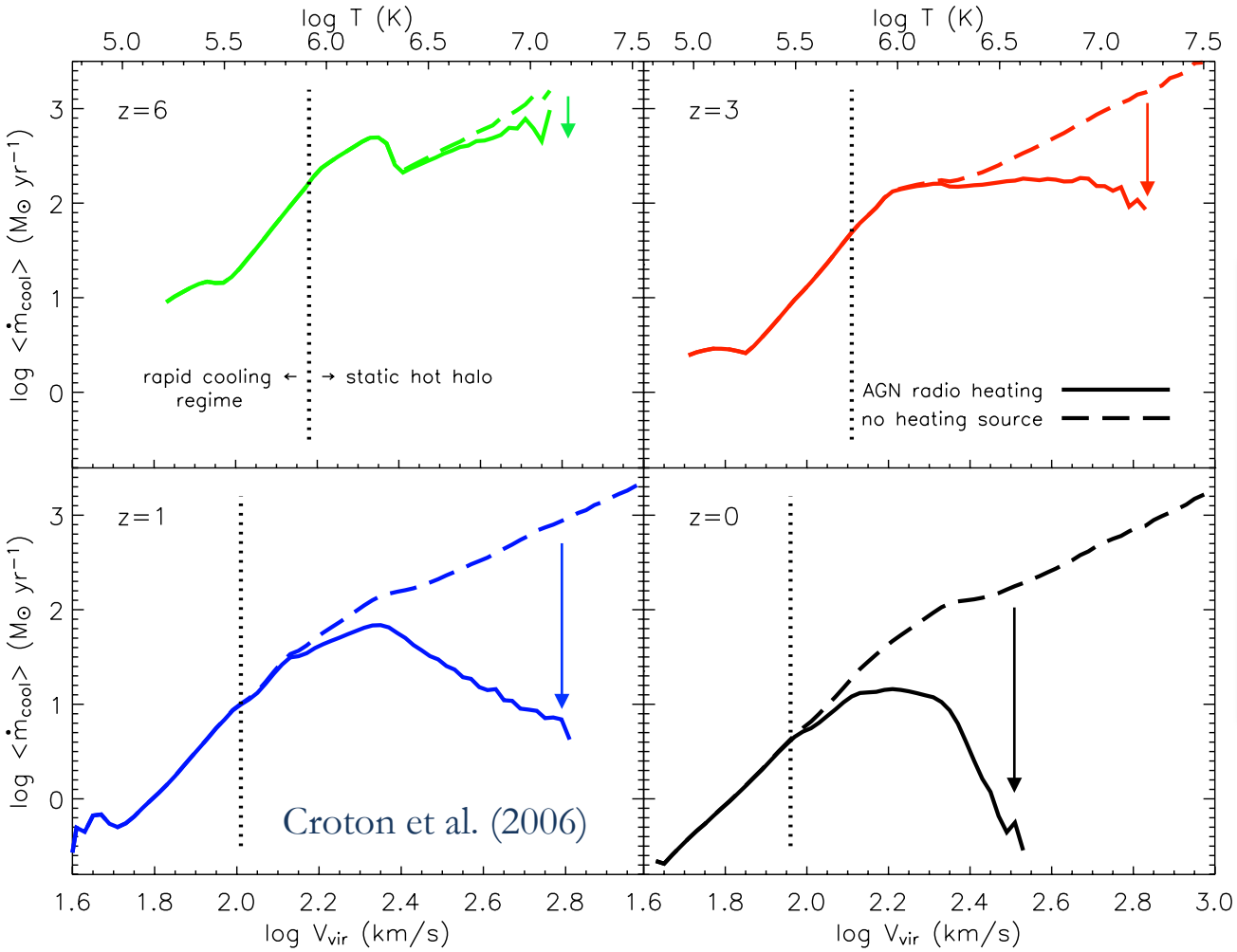
$$L_{\rm jet} = f_{\rm jet} L_{\rm Edd}, \; f_{\rm jet} \sim 0.04$$

Cooling in massive haloes is suppressed if:

$$L_{\rm jet} \geq L_{\rm cool} \Rightarrow \dot{M}_{\rm BH} = \frac{L_{\rm cool}}{\varepsilon_r c^2}$$

Typical accretion rates are below 1-10% of the Eddington accretion rate.

Effect on gas cooling

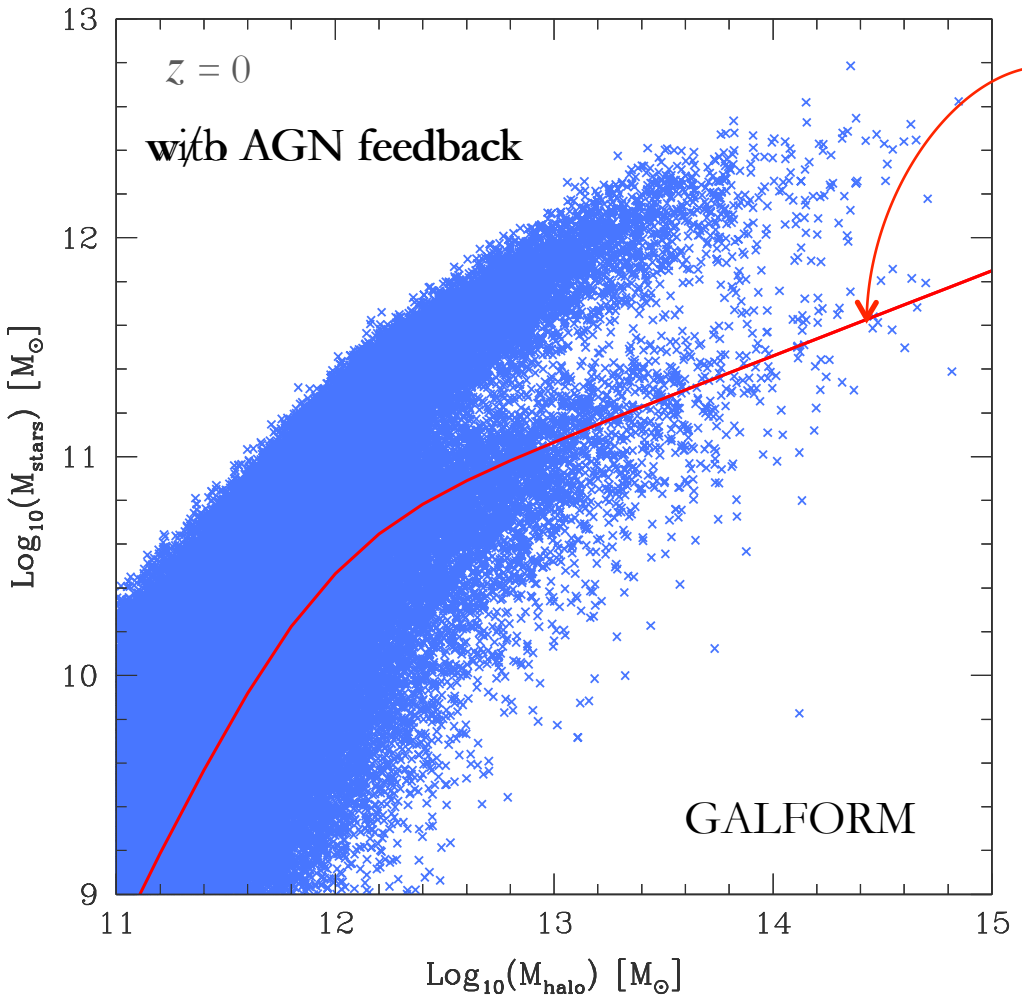


Average cooling rate

Cooling flow suppression is most efficient in massive haloes at late epochs.

$$\dot{m}_{\rm heat} \propto M_{\rm BH} V_{\rm vir}$$

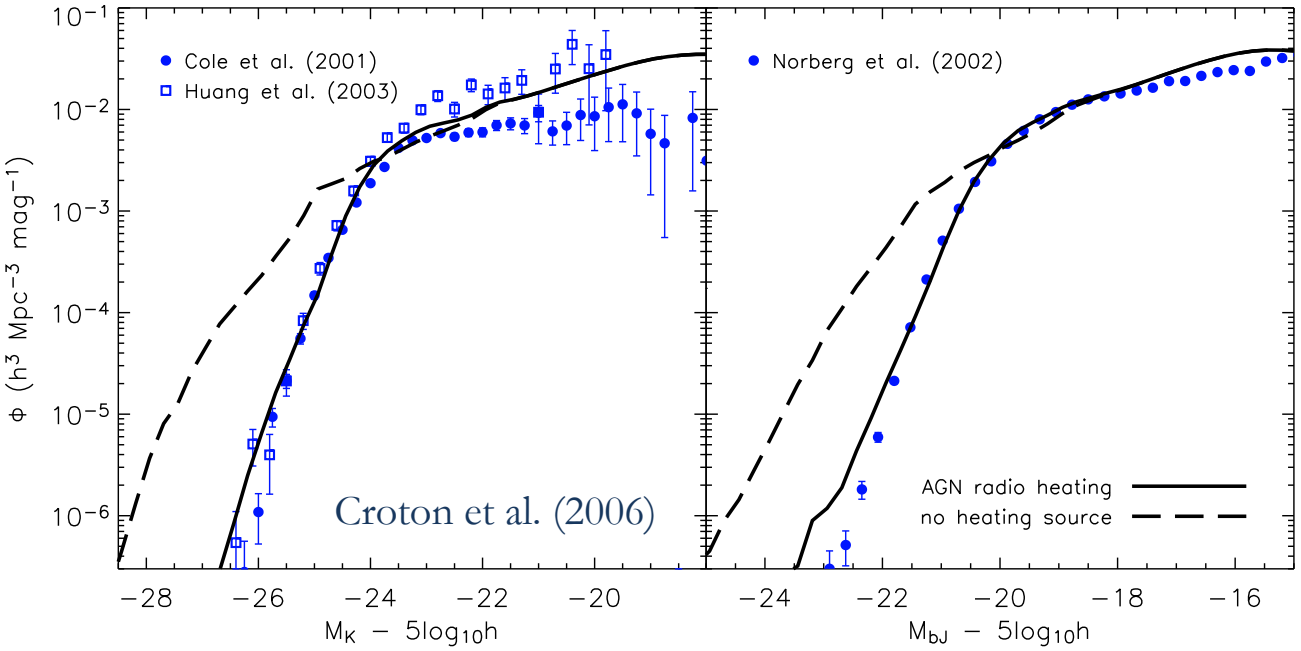
Effect on stellar mass



Moster et al. (2011)

AGN feedback is necessary for reproducing the correct stellar mass in massive haloes!

With AGN feedback we reproduce



① The paucity of galaxies in the bright end of the LF.

See also: Monaco et al. (2007), Lagos et al. (2008), Somerville et al. (2008)

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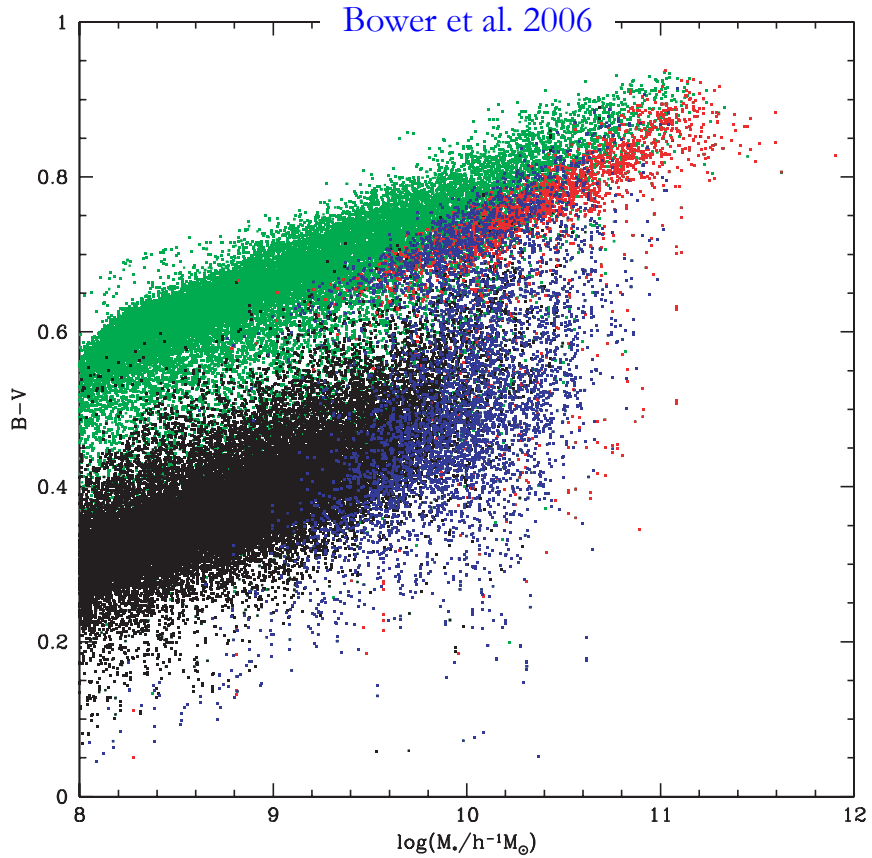


① The paucity of galaxies in the bright end of the LF.

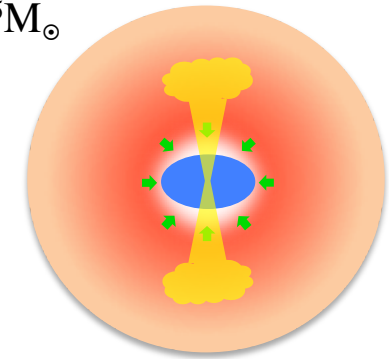
② The colour bimodality of galaxies.

See also: Monaco et al. (2007), Lagos et al. (2008), Somerville et al. (2008)

Linking feedback to AGN: BH growth in GALFORM

Hot-halo (radio) mode

$M_{\rm halo} > 10^{11.5} M_{\odot}$



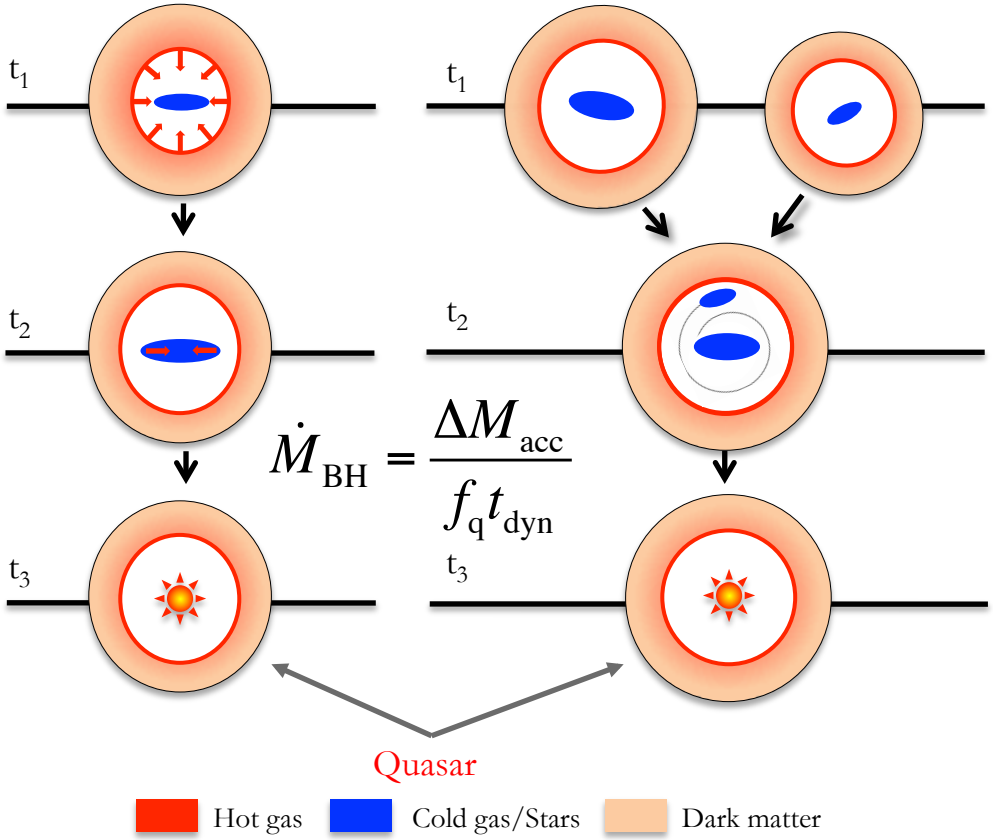
$$\dot{M}_{\rm BH} = \frac{L_{\rm cool}}{\varepsilon_r c^2}$$

We trace the evolution of BH mass, spin and accretion rate from z>>20 to z=0

Starburst (quasar) mode

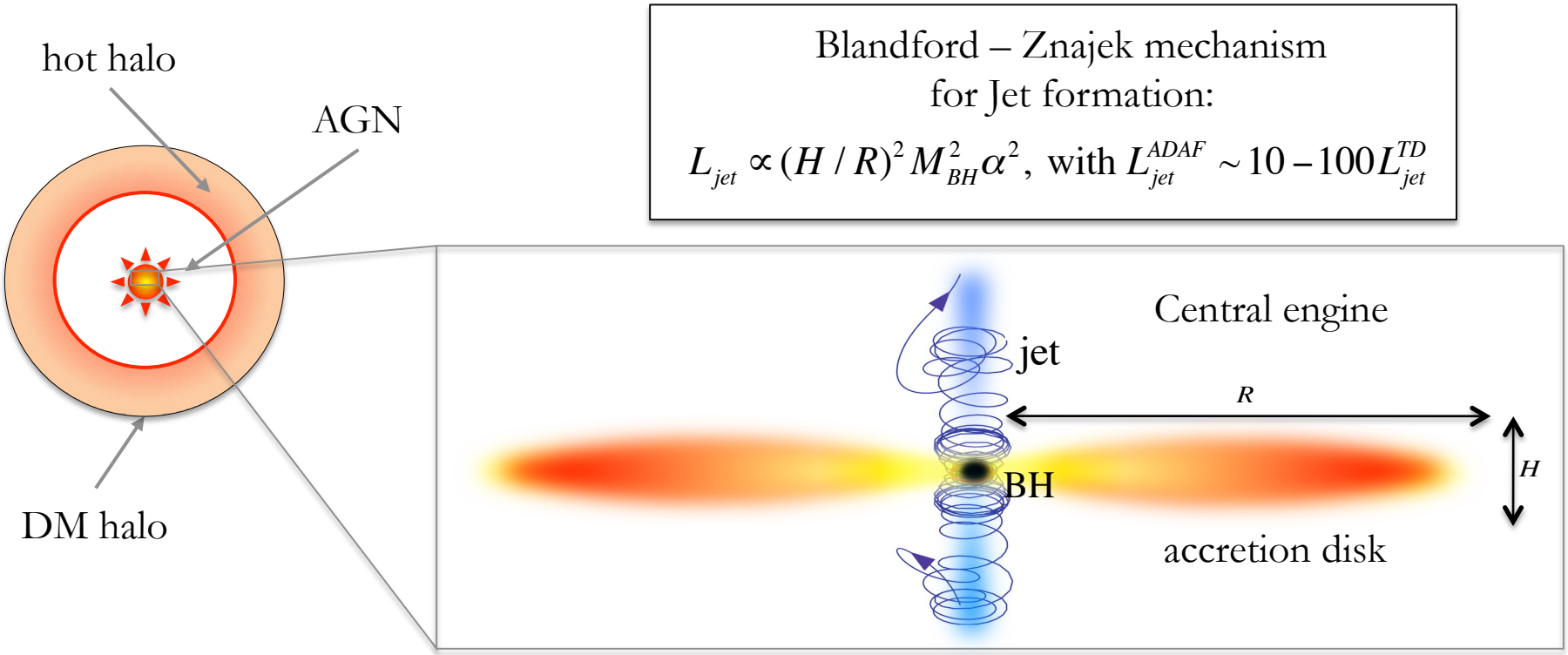
1. Disk instabilities

2. Galaxy mergers



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

Linking feedback to AGN: Modelling the accretion flow



Blandford – Znajek mechanism for Jet formation:

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

Thin disk → ADAF

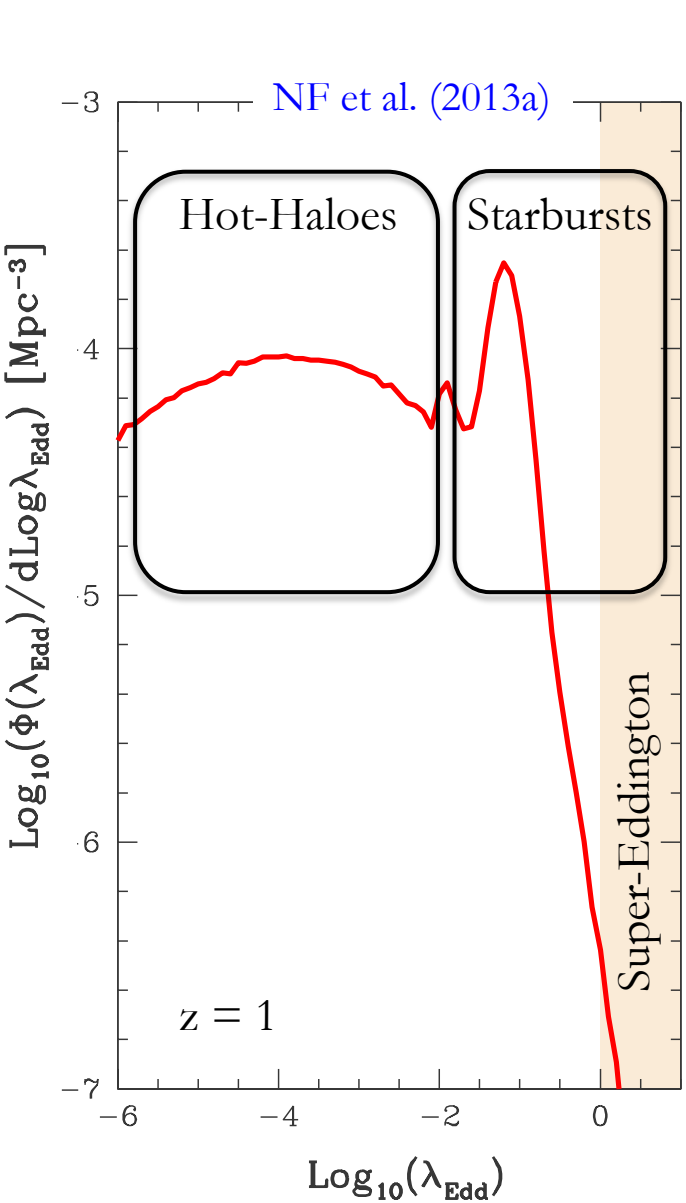
$$\dot{m} = \dot{M} / \dot{M}_{\text{Edd}} < 0.01$$

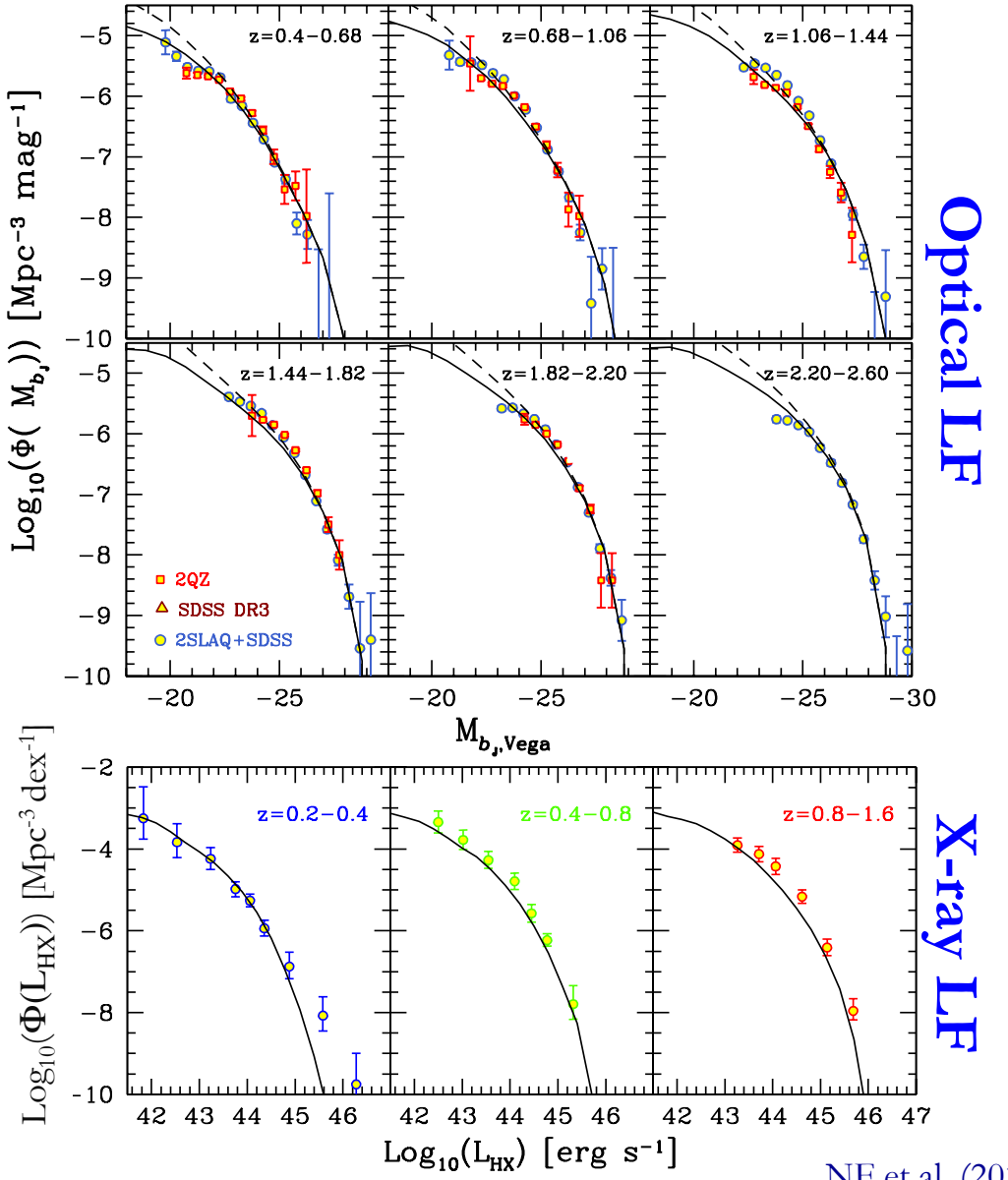
luminous disks → under-luminous disks

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

(NF et al 2011)

Linking feedback to AGN: Luminosity functions

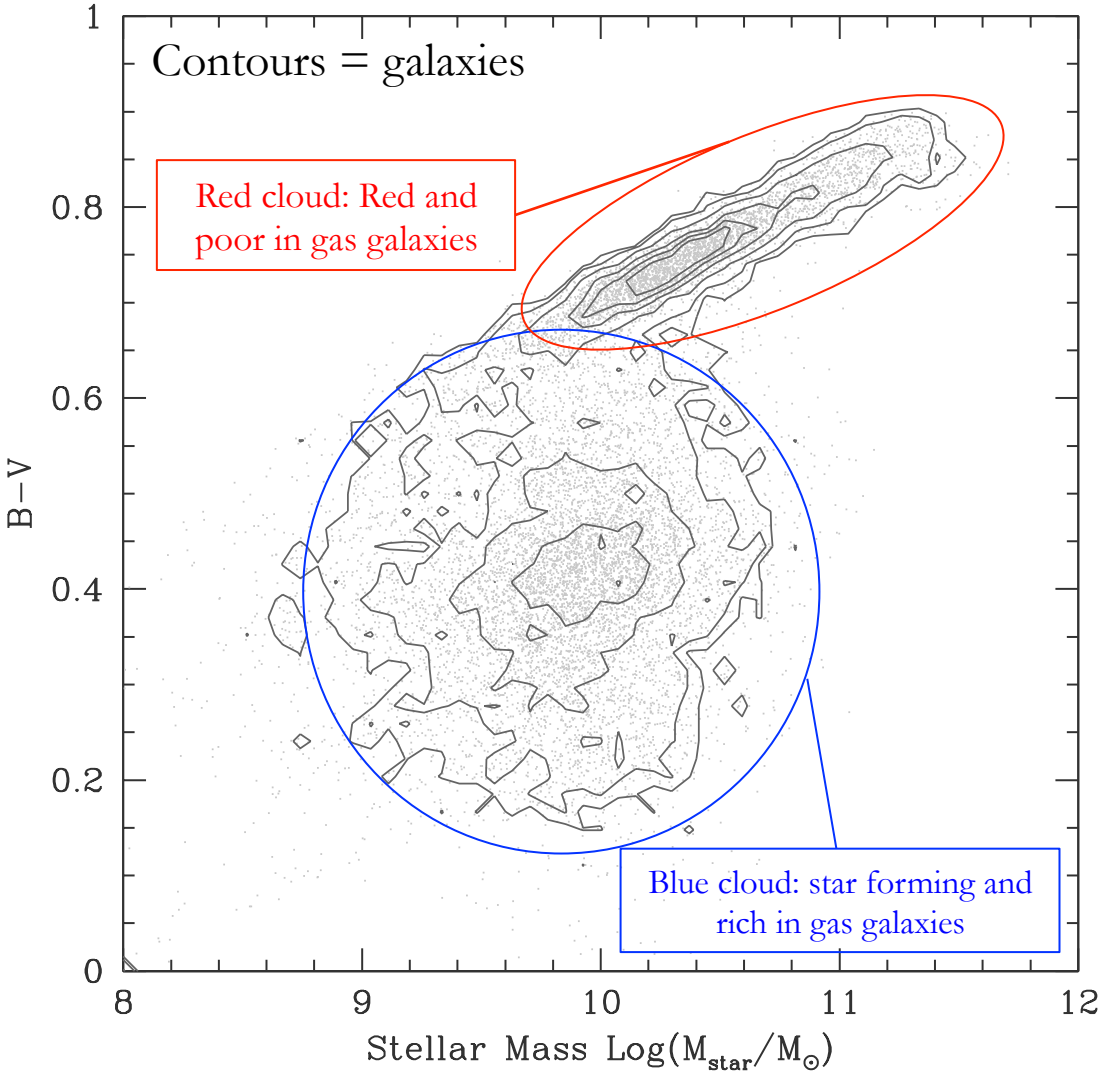




NF et al. (2012)

Effects of feedback on AGN: The AGN colour bimodality

The model predicts a bimodal distribution of AGN on the BV — stellar mass plane.



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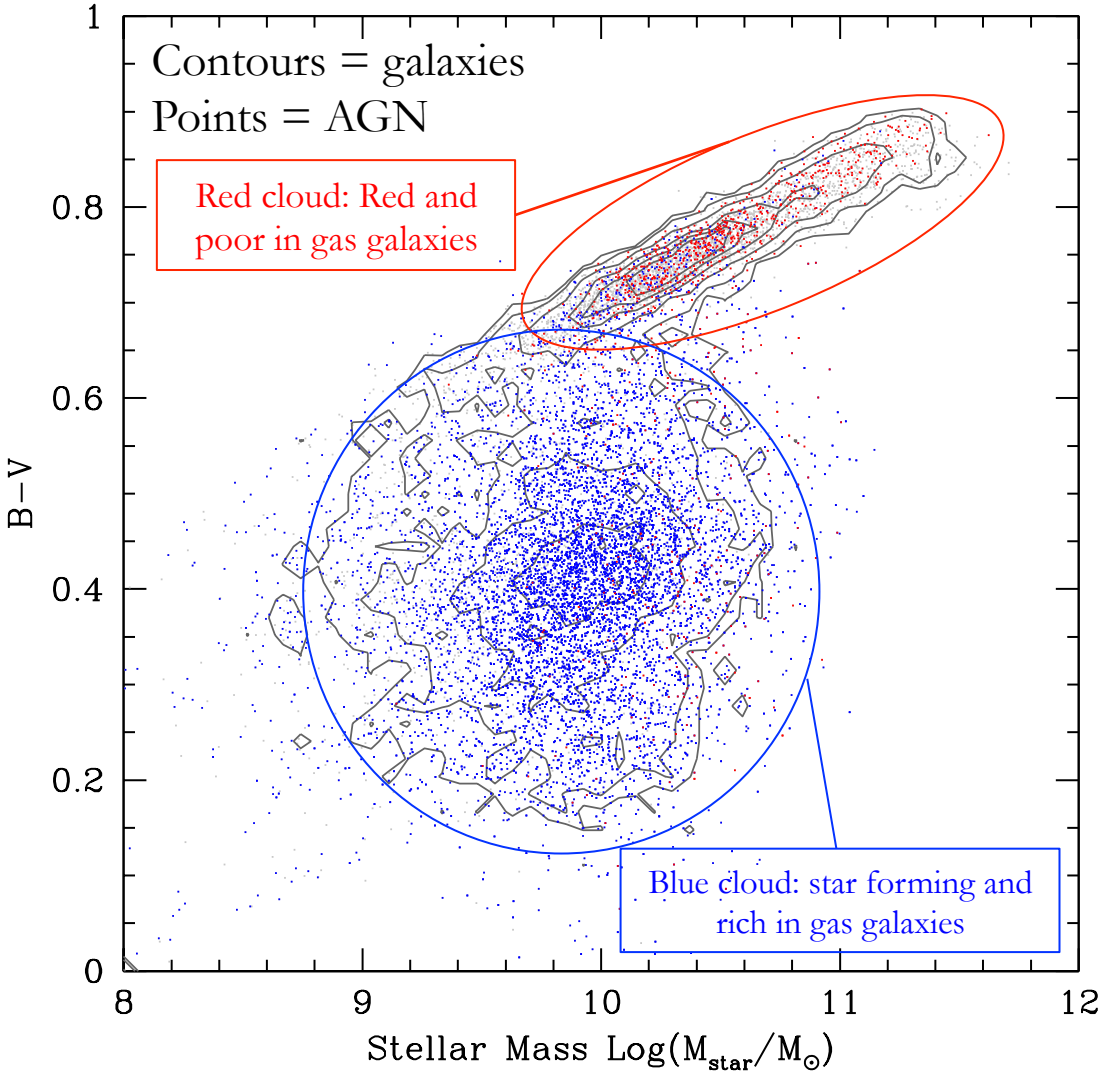
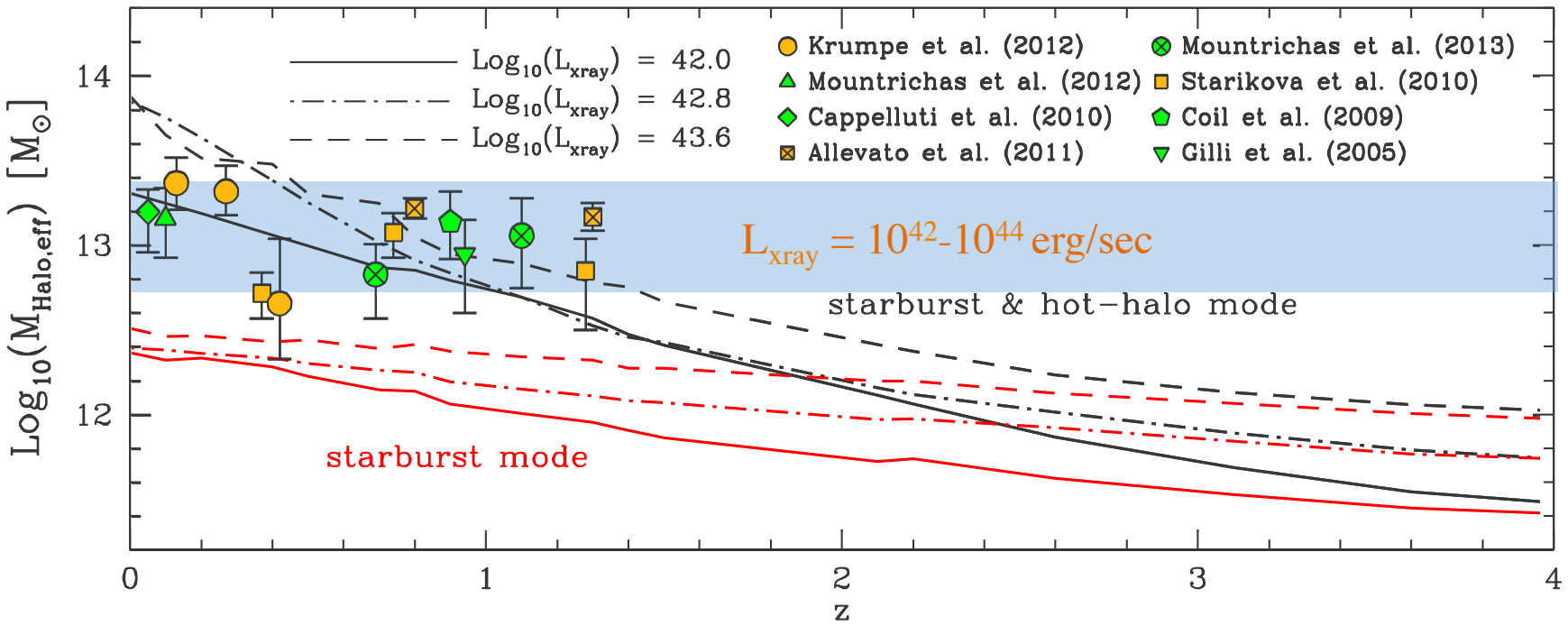


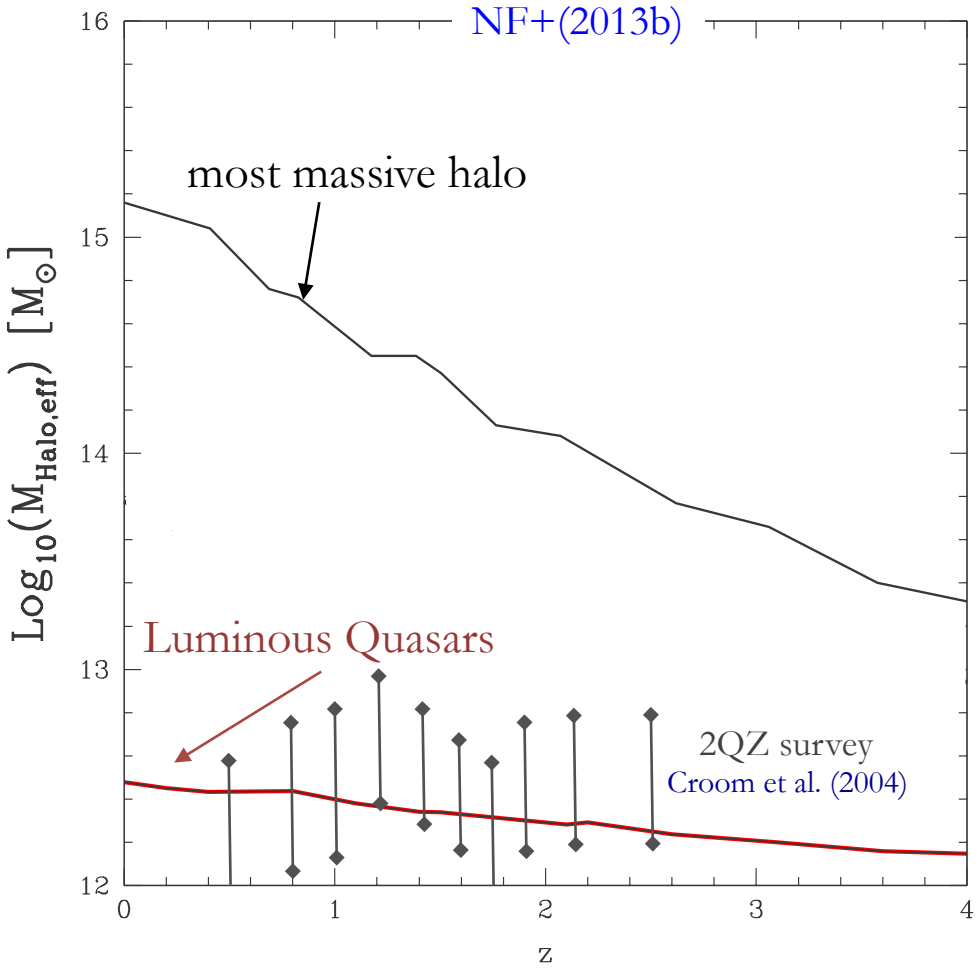
NF & Georgakakis (in prep)

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



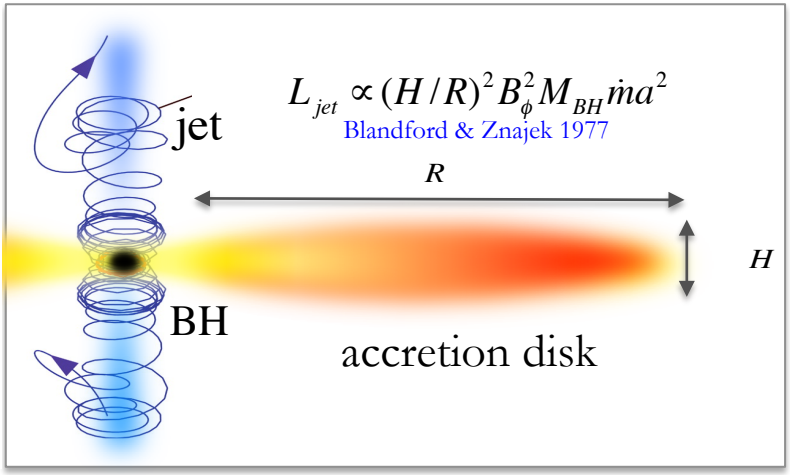
NF+(2013a)

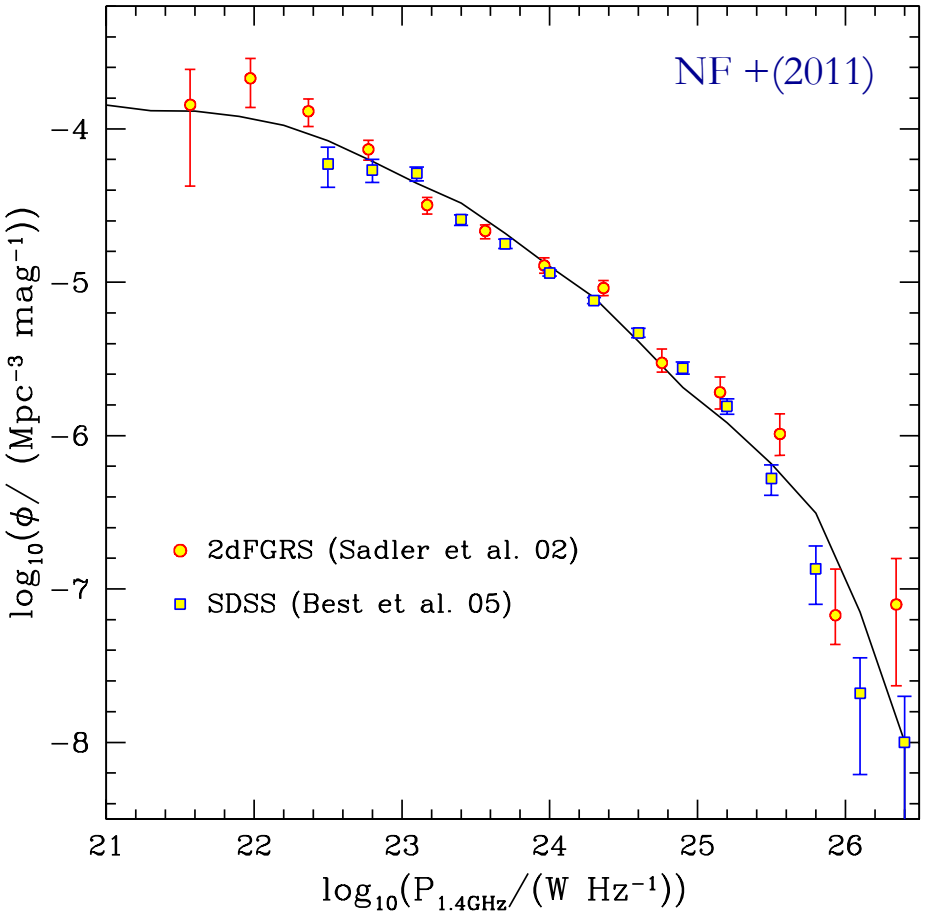
The AGN feedback shapes the halo environment of luminous Quasars!



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

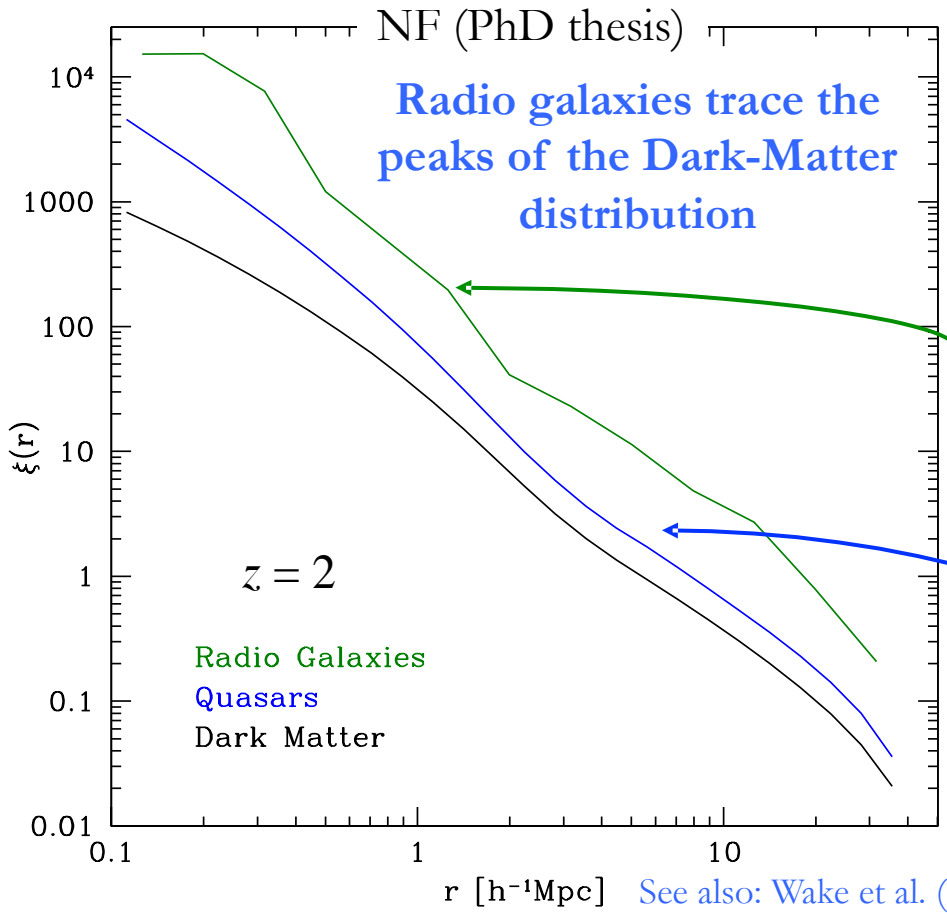
Radio LF dominated by rapidly rotating BHs accreting in the hot-halo mode!

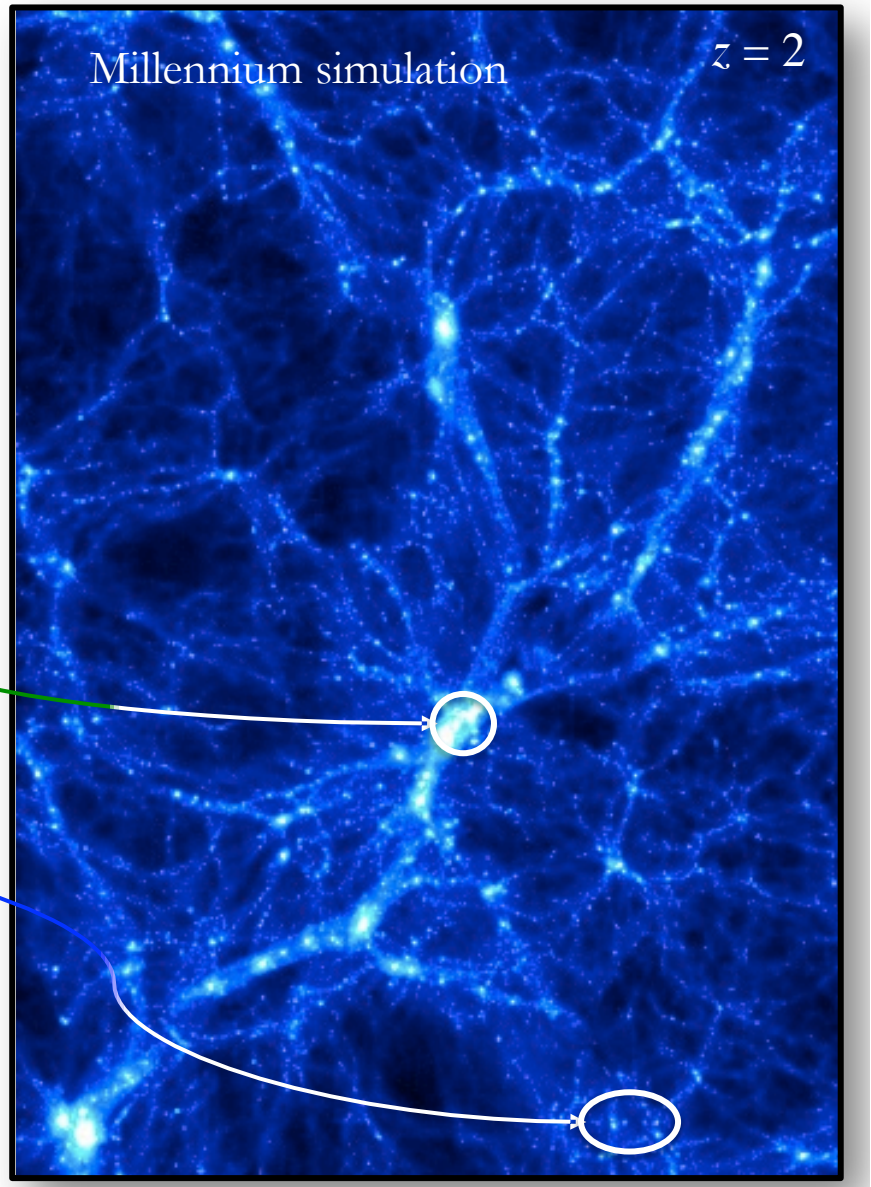




Effects of feedback on AGN: The clustering of Radio Galaxies

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





See also: Wake et al. (2008); Donoso et al. (2008)

Summary

With a phenomenological calculation for the accretion rate that is linked to AGN feedback we get:

1. The correct evolution of AGN
2. The colour bimodality of AGN
3. The clustering of moderate luminosity AGN and luminous Quasars
4. The abundance & clustering of Radio Galaxies

Take away message: AGN feedback & associated growth mode crucial for reproducing key AGN properties