AGN vs. SF in a universe with AGN feedback

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AGN vs. SF: Durham 28.08 – 01.09 2014

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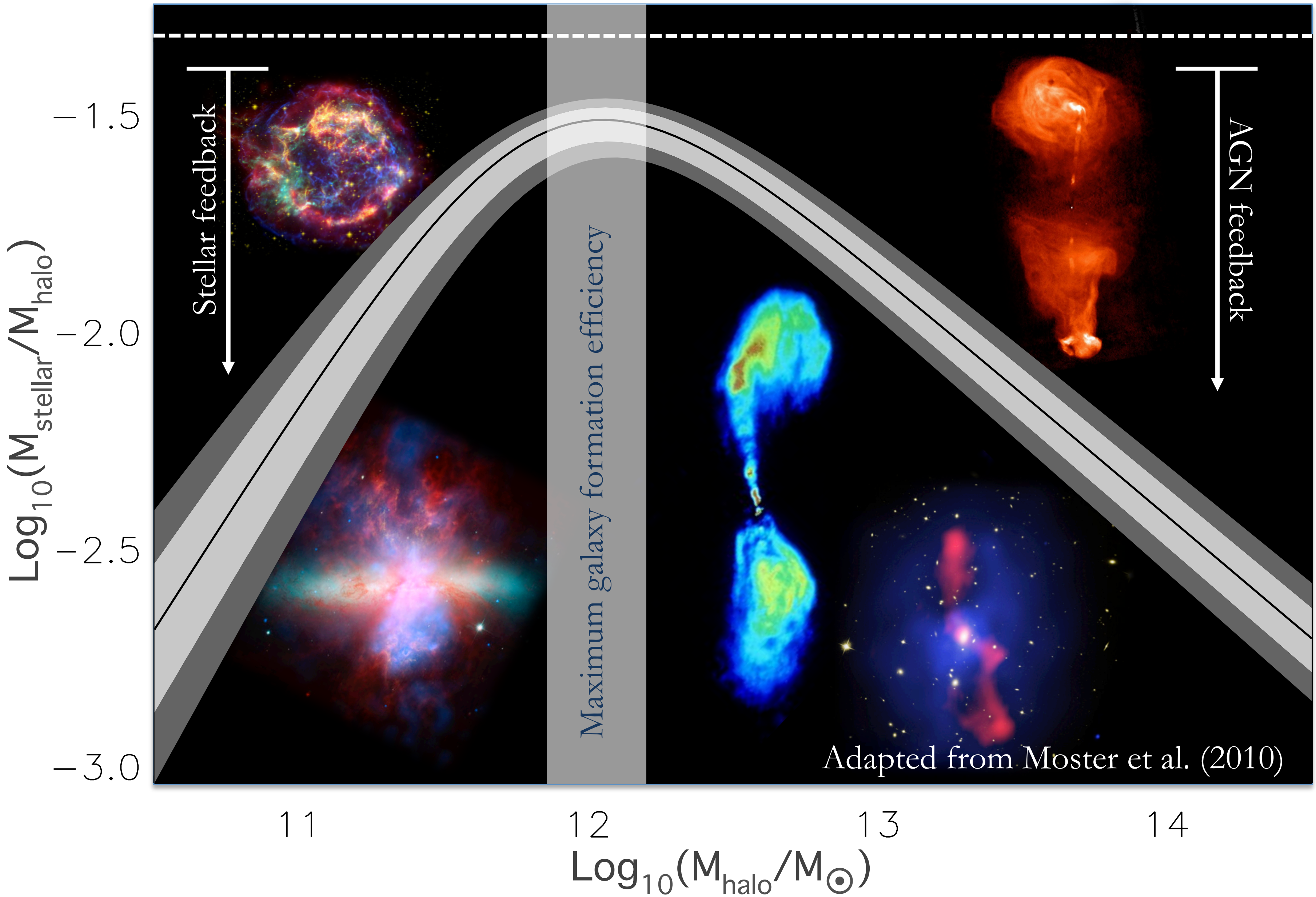
Today I am going to talk about:

1. Modelling Star Formation (SF) and AGN in the GALFORM semi-analytical model.
2. Predictions for SF vs. AGN.
3. Predictions for Radio Galaxies.

Motivation for introducing feedback in galaxy formation

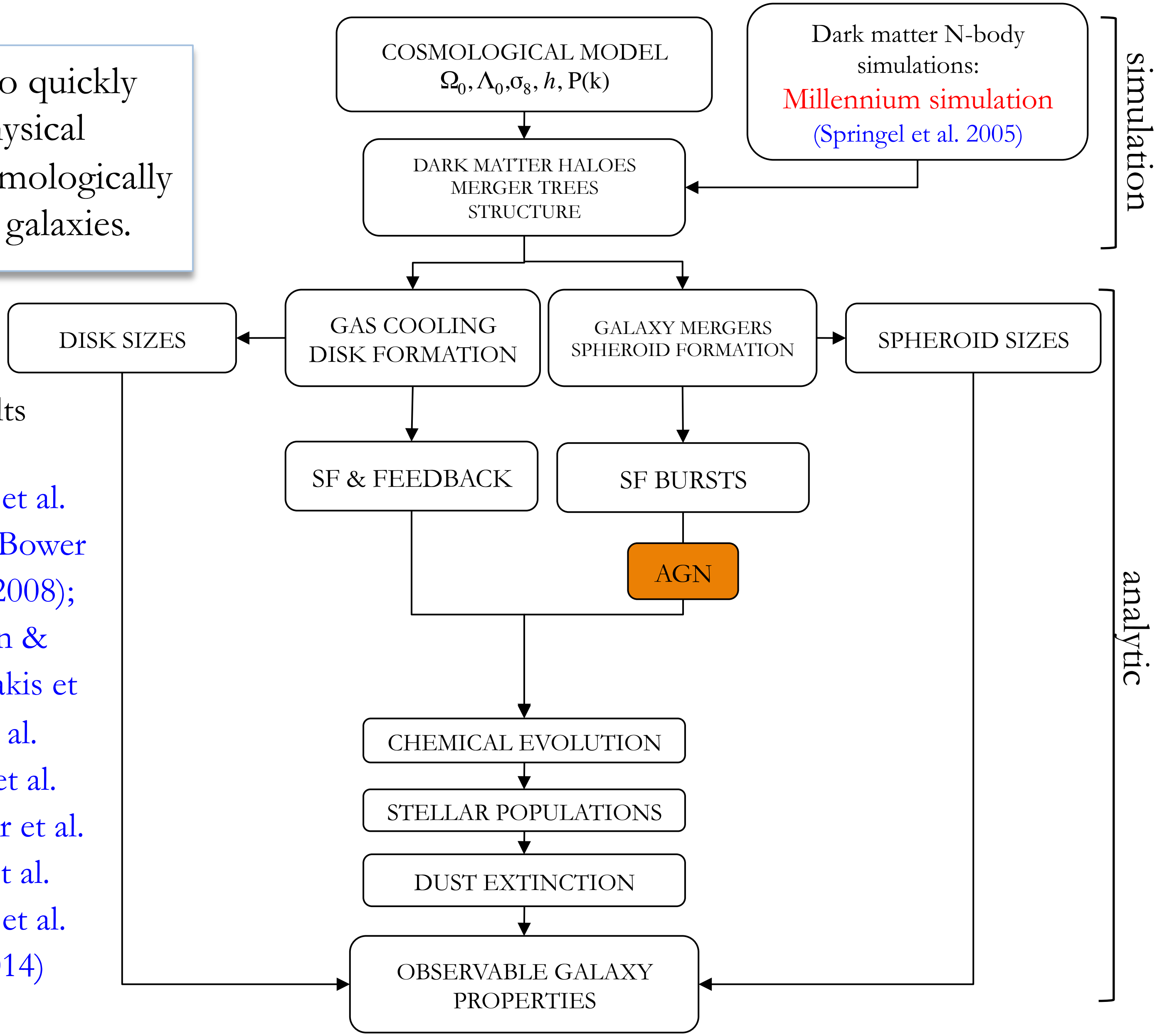


Insights from Semi-Analytics: The GALFORM model

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); Gonzalez-Perez et al. (2011,2013,2014), Cowley et al. (2014), Mitchell et al. (2014)

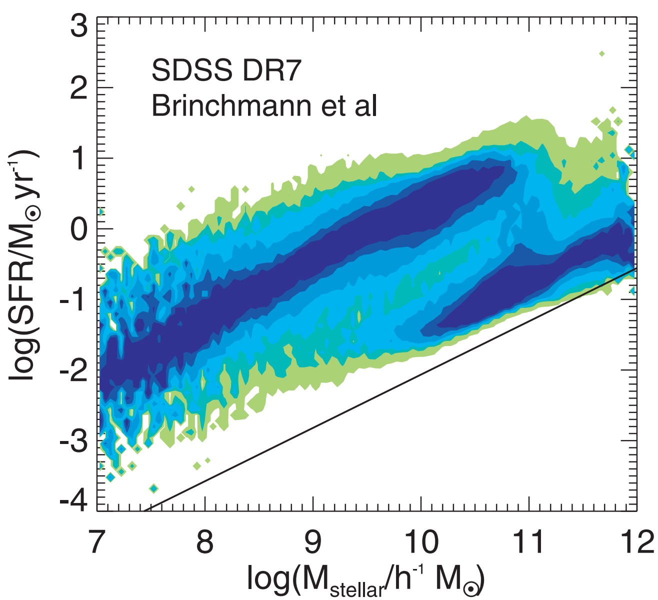


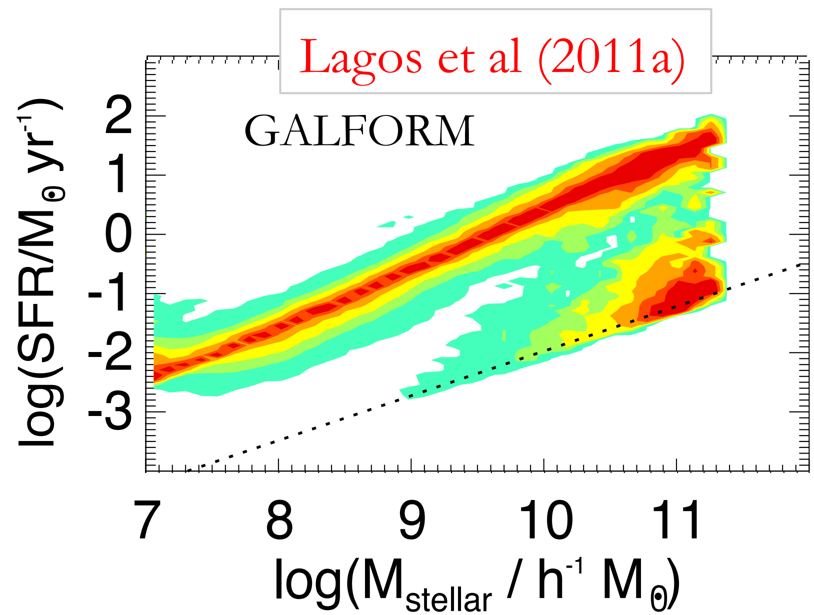
Lagos et al (2011a) Star Formation law implementation:

Blitz – Rosolowski (2006): $\Sigma_{SFR} = \nu_{SF} f_{mol} \Sigma_{gas}$ $\Rightarrow$ $SFR \propto H_2$

$$\frac{\Sigma(H_2)}{\Sigma(H\,I)} = \left(\frac{P_{ext}}{P_0}\right)^{\alpha}$$

H_2/H depends on ISM pressure Elmegreen (1993)

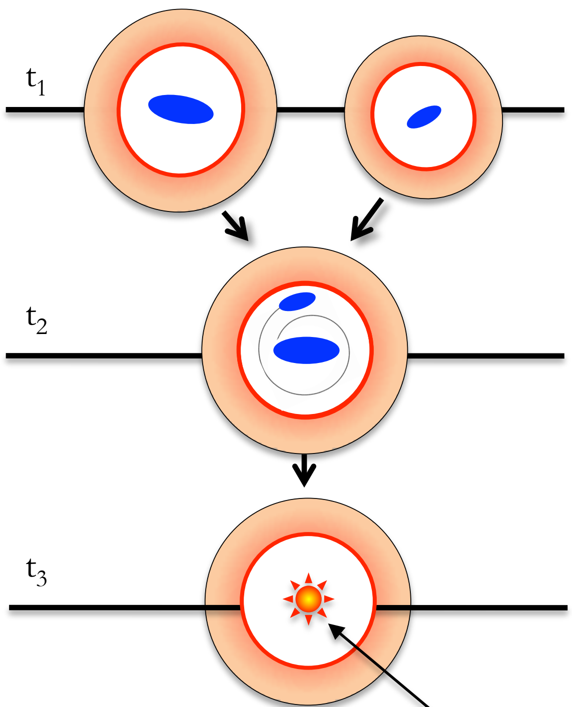




Model reproduces LFs (optical, Ly-break, IR), stellar & gas mass functions: **Lacey et al, in prep; Lagos et al. (2011ab, 2012, 2014); Gonzalez-Perez et al. (2014)**

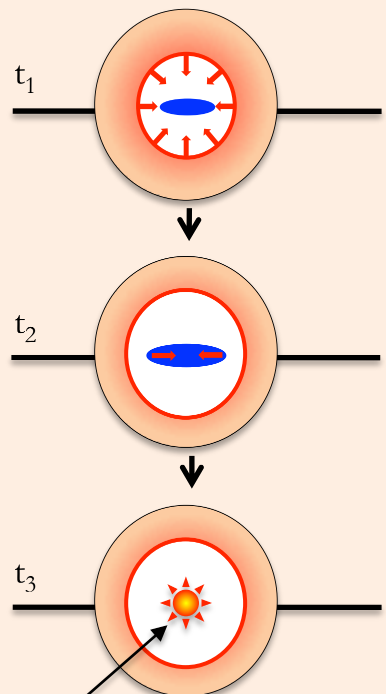
Black Hole (BH) growth in GALFORM

1. Galaxy mergers



$$\dot{M}_{\rm BH} = \frac{\Delta M_{\rm acc}}{f_{\rm q} t_{\rm dyn}}$$

2. Disk instabilities



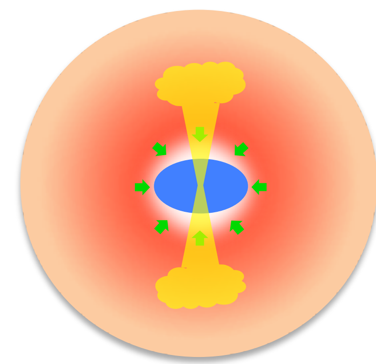
Dominant growth channel

Quasar

NF et al. (2011, 2012)

$M_{\rm halo} \sim 10^{12} M_{\odot}$

3. Hot-halo accretion



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

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

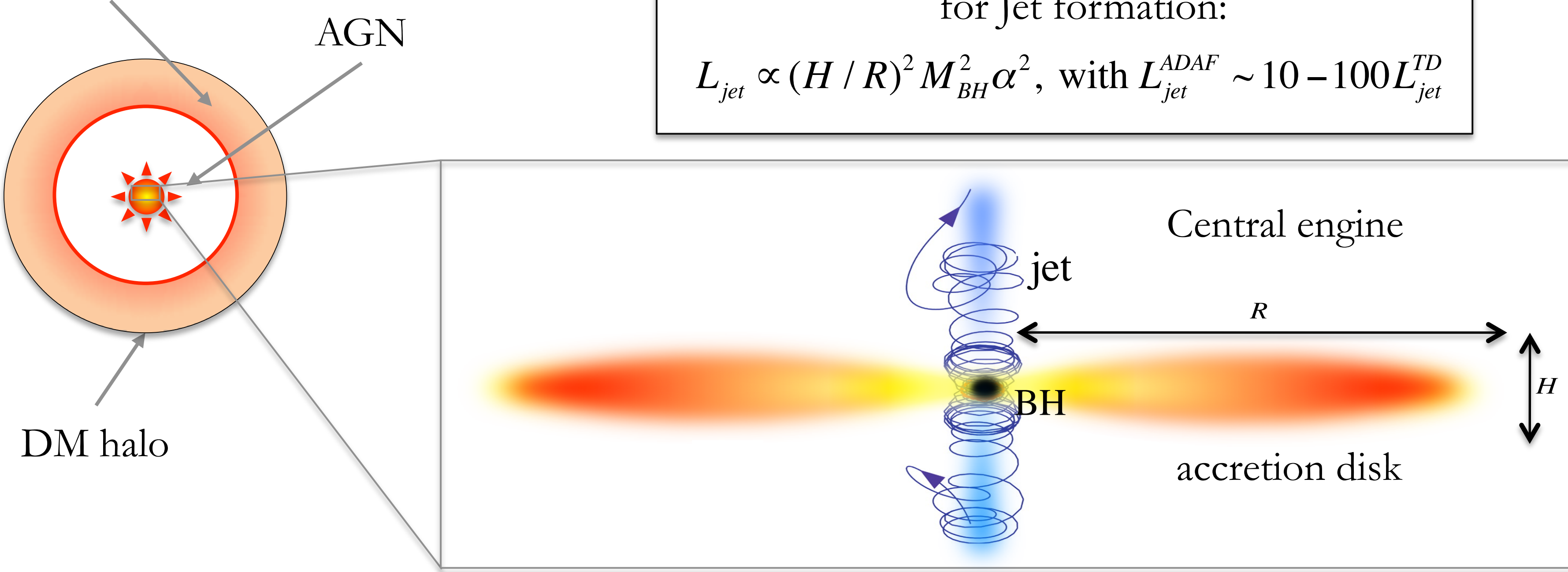
Hot gas | Cold gas/Stars | Dark matter

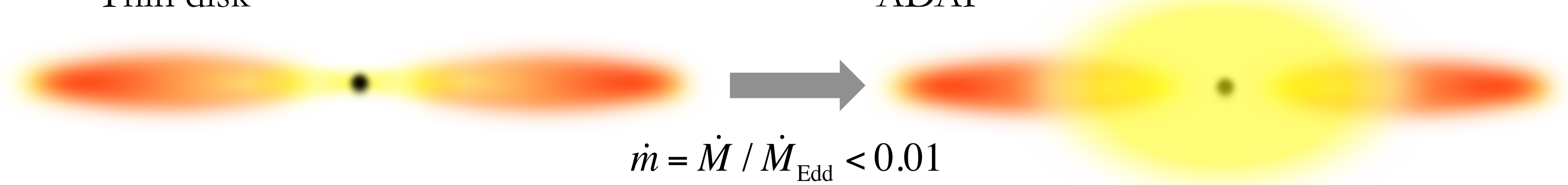
See also: Bower et al. (2006), Malbon et al. (2007), Marulli et al (2008), Somerville et al (2008), Hirschmann et al (2012)

The accretion flow

Blandford – Znajek mechanism
for Jet formation:

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



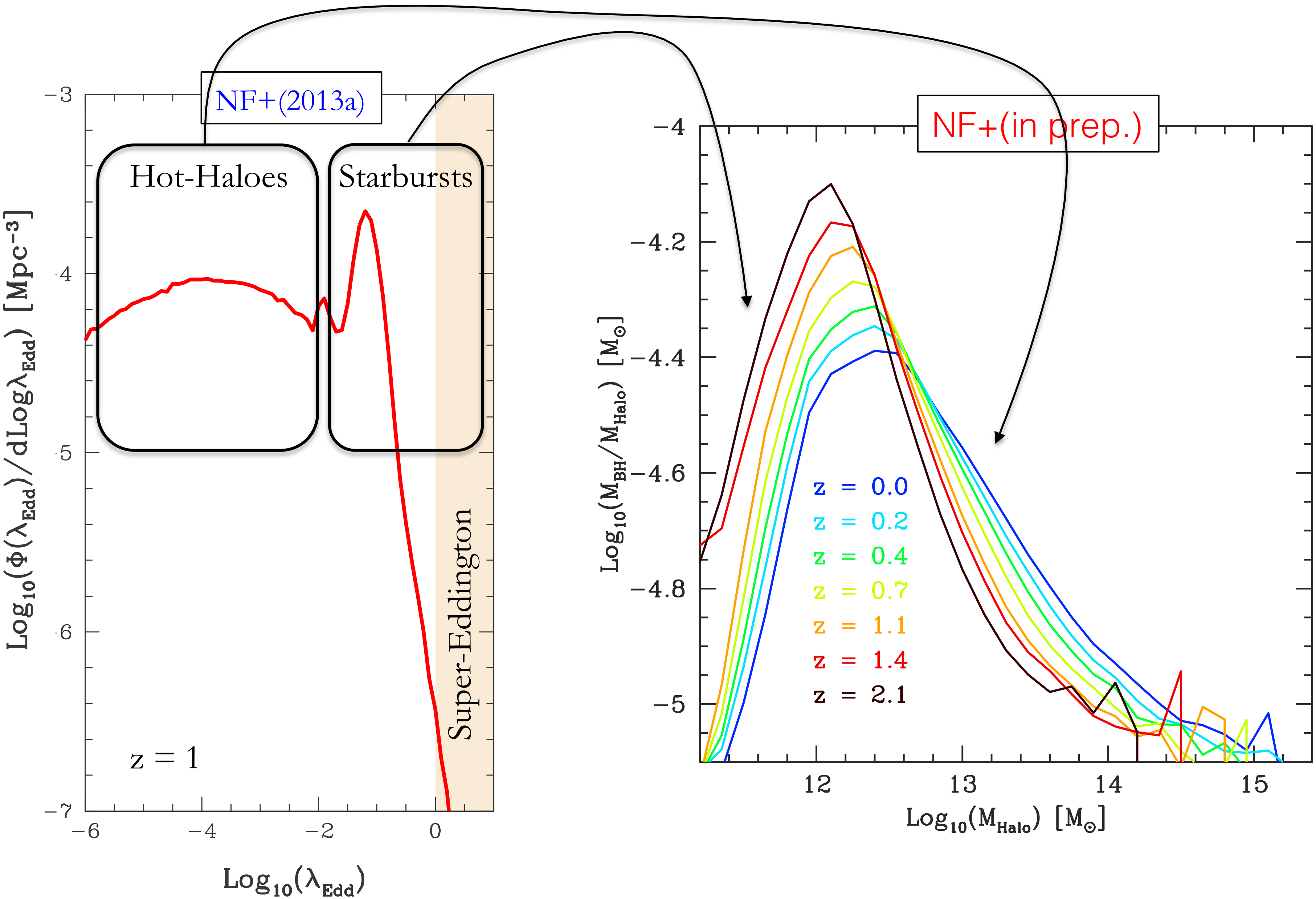


$$\dot{m} = \dot{M} / \dot{M}_{\rm Edd} < 0.01$$

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

NF+(2011)

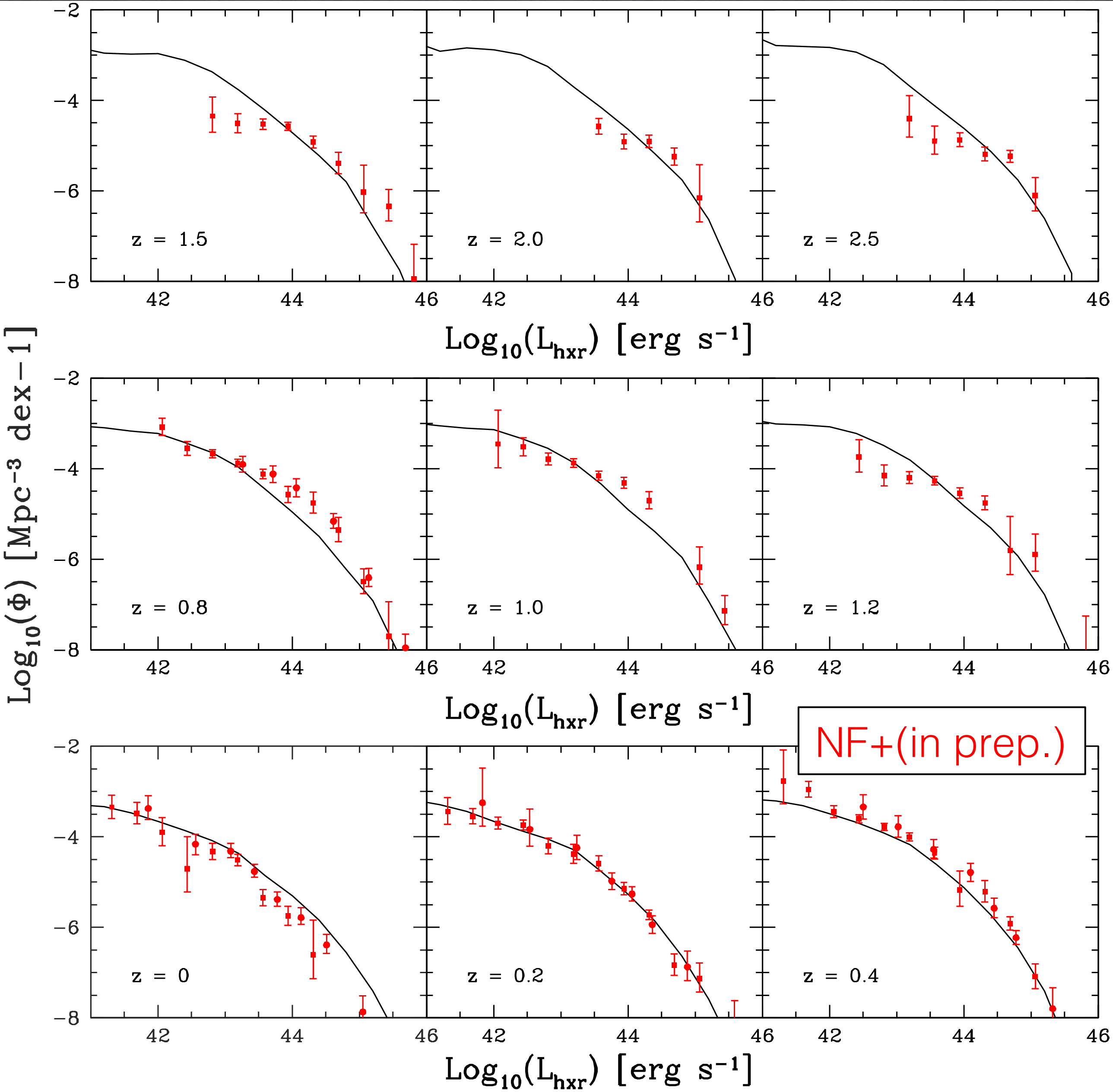
Eddington ratios and growth efficiency



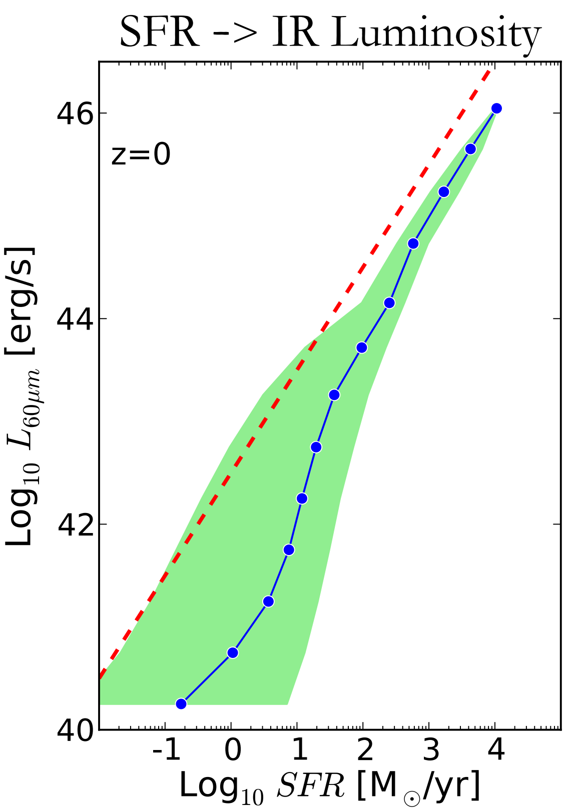
AGN Luminosity functions

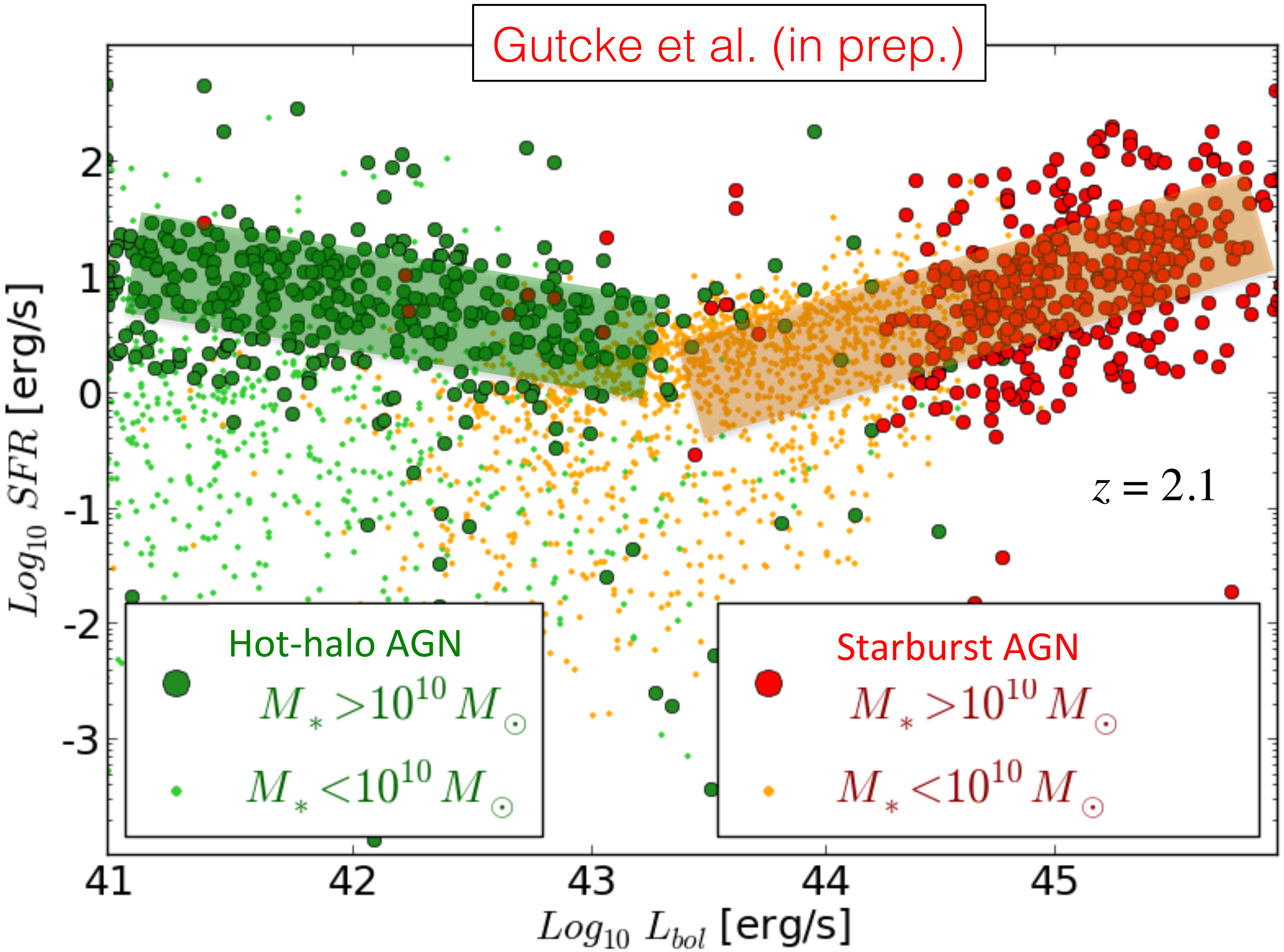
LFs

- Good agreement with 0<z<6 LFs in optical, soft and hard X-ray.
- Model also reproduces BH (active & relic) mass function, and clustering properties of AGN.

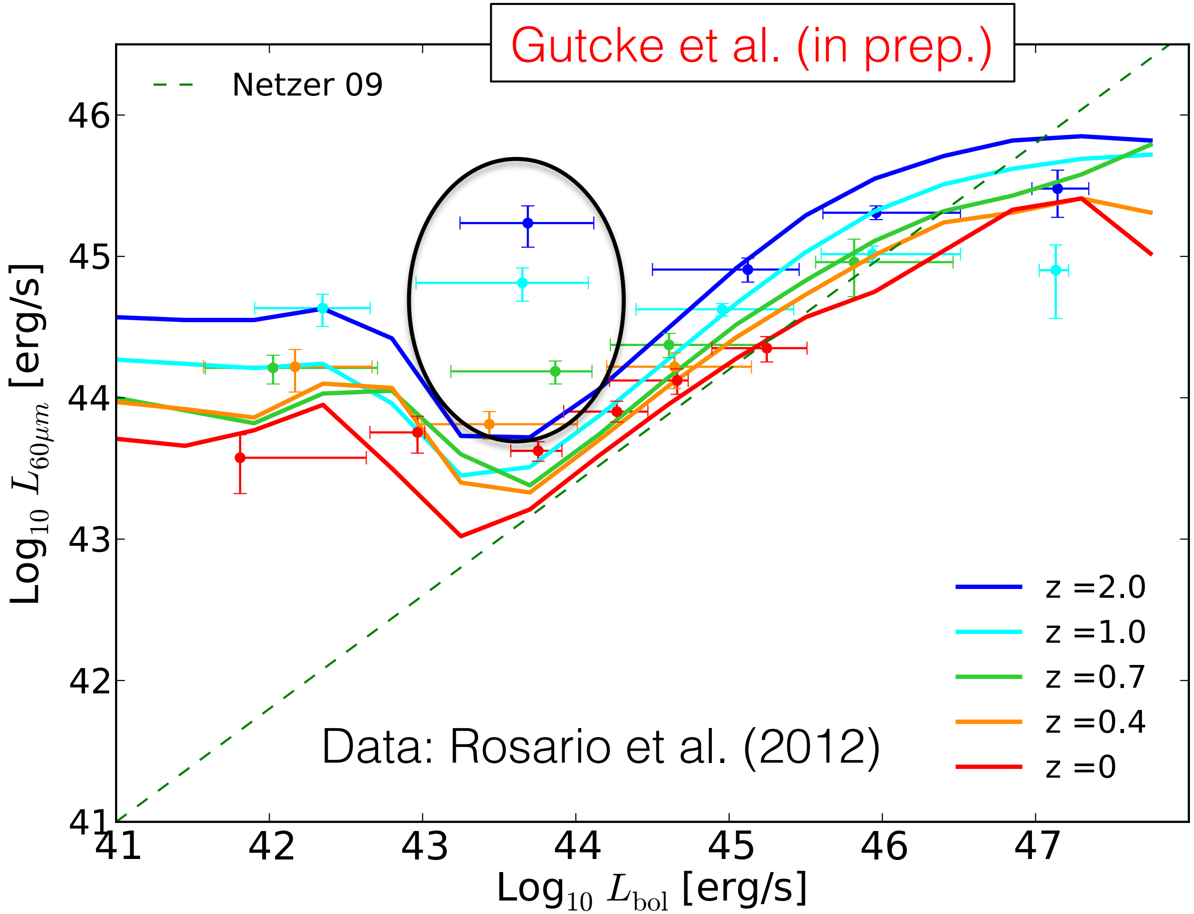


SFR vs Bolometric AGN luminosity



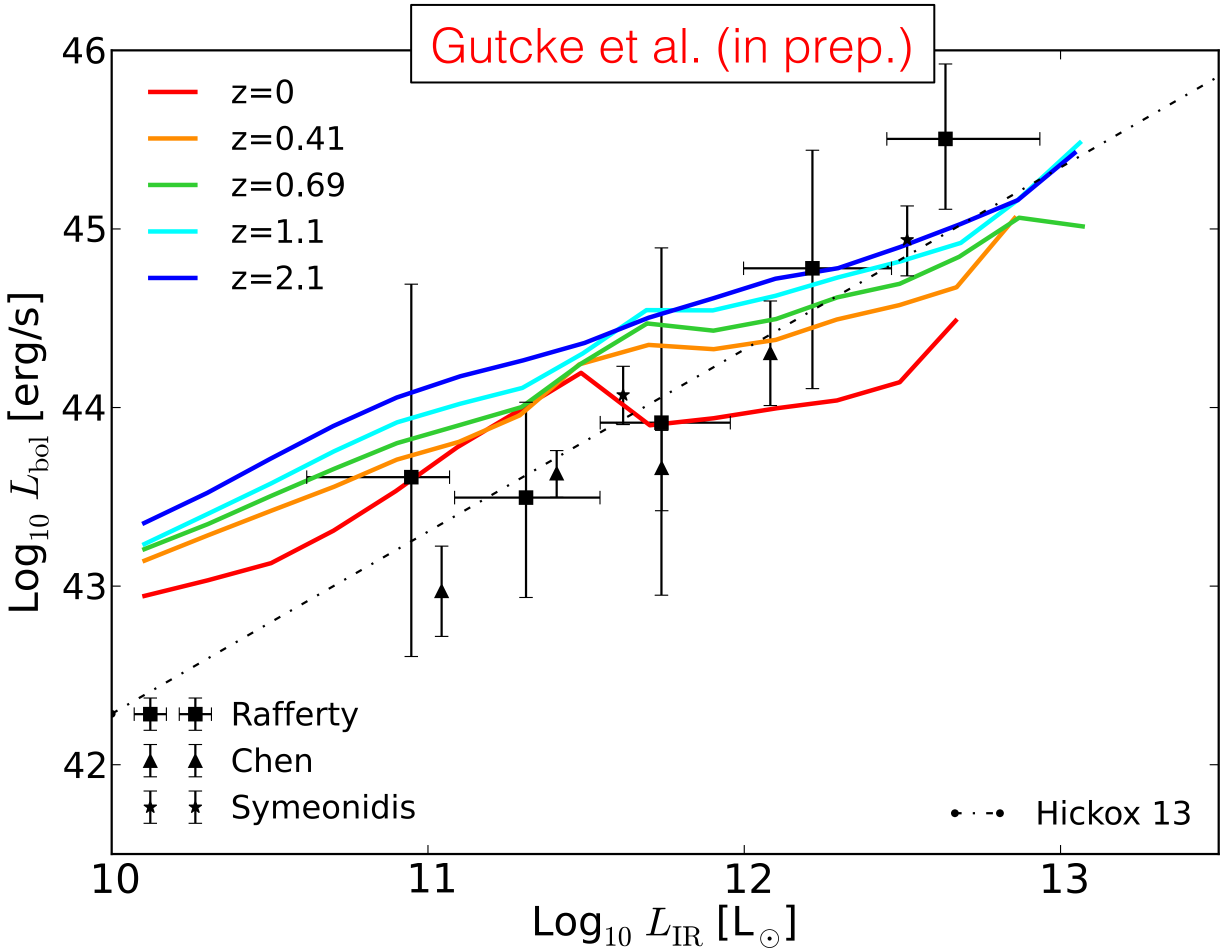


Comparing to data



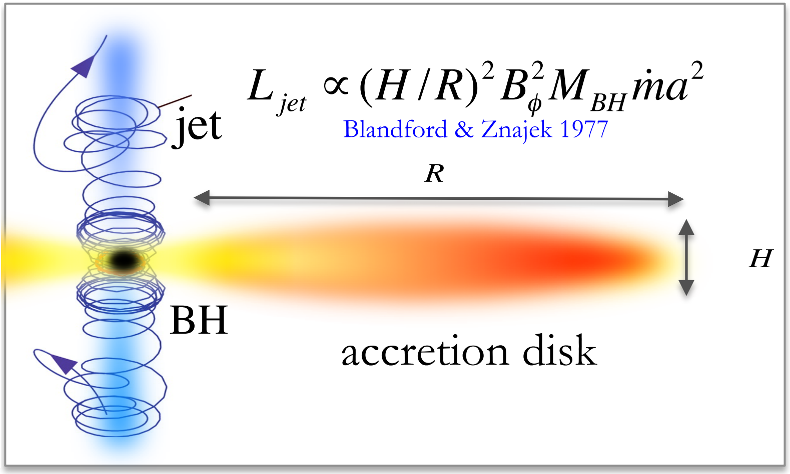
- Strong tension at ~10^{43}-10^{44} erg/sec.
- Disagreement may indicate the need for AGN variability and/or AGN-SF delay.

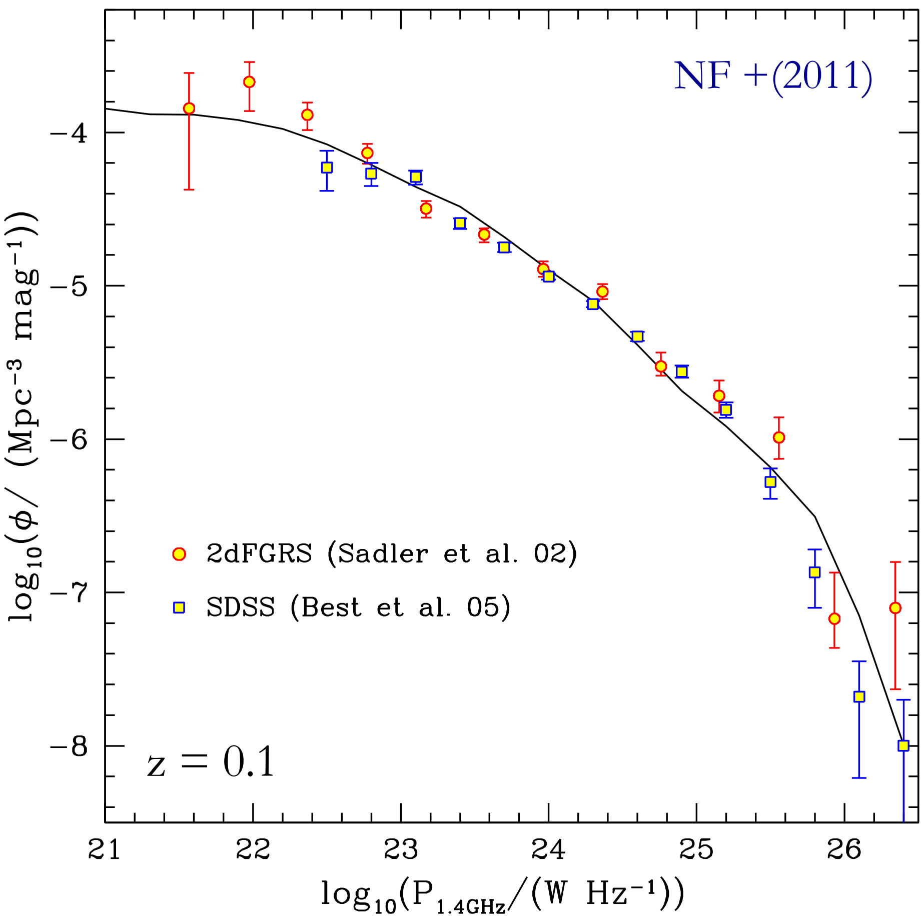
Inverting the axes



The abundance of Radio Galaxies

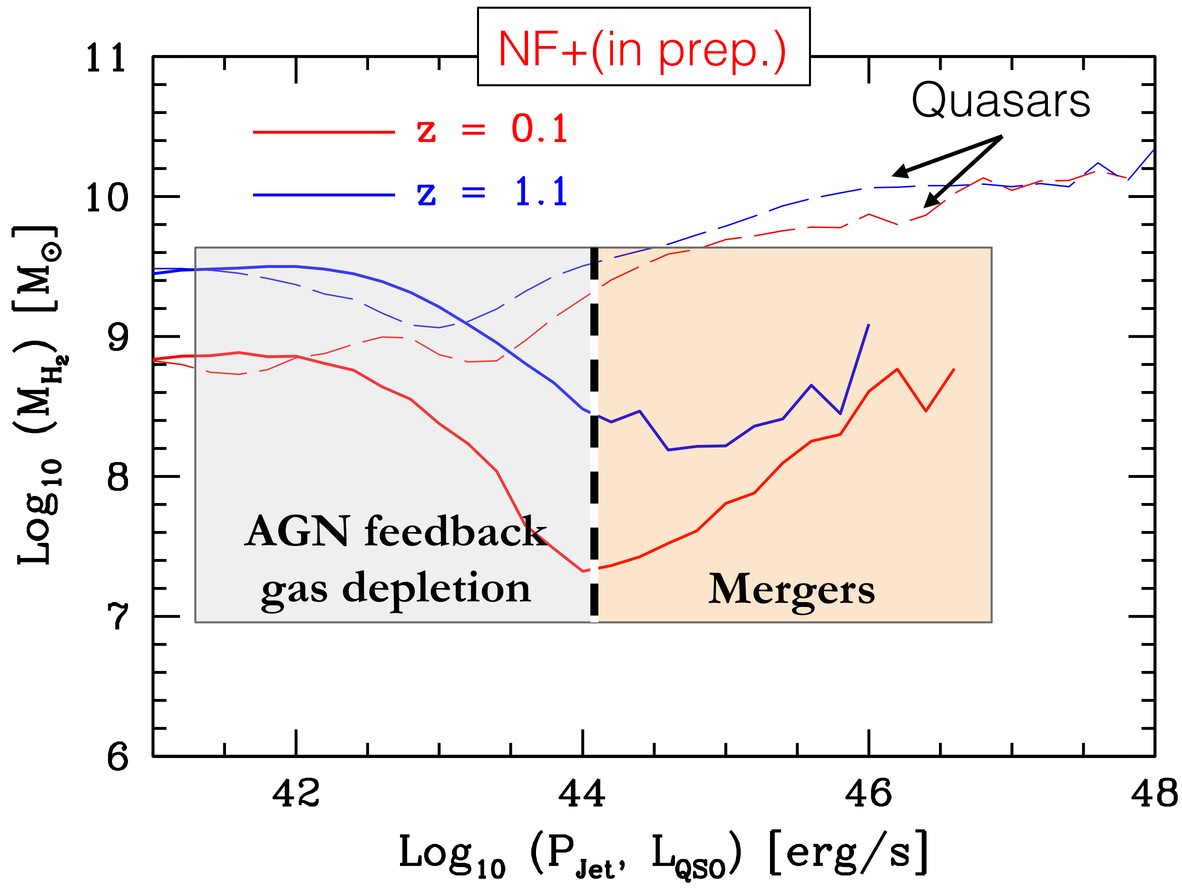
We couple the spin, mass and accretion rate to the Blandford – Znajek jet mechanism.





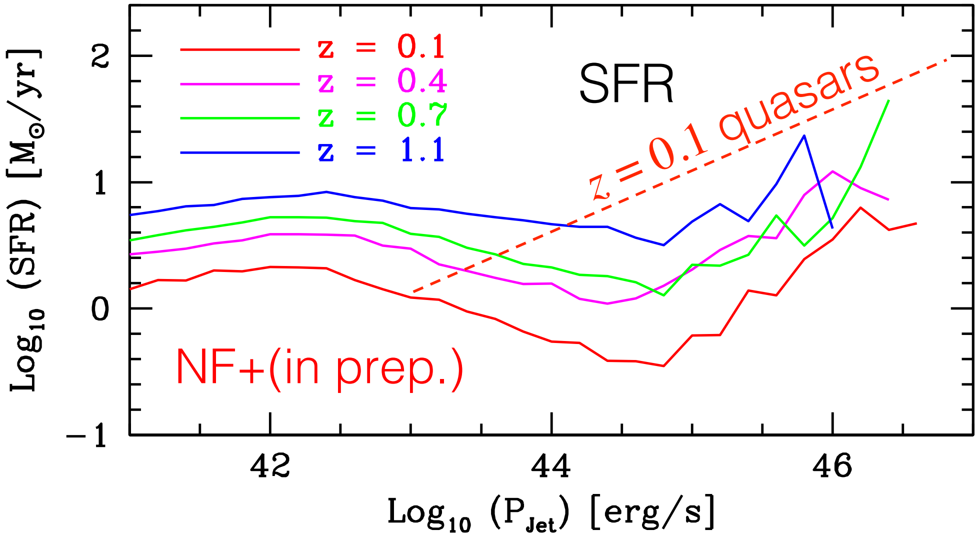
Radio Galaxies

- Radio Galaxies appear to have non-negligible molecular gas reservoirs
- Two regimes: gas depletion & major mergers regime.
- ~60% of luminous Radio Galaxy hosts receive their cold gas via mergers.



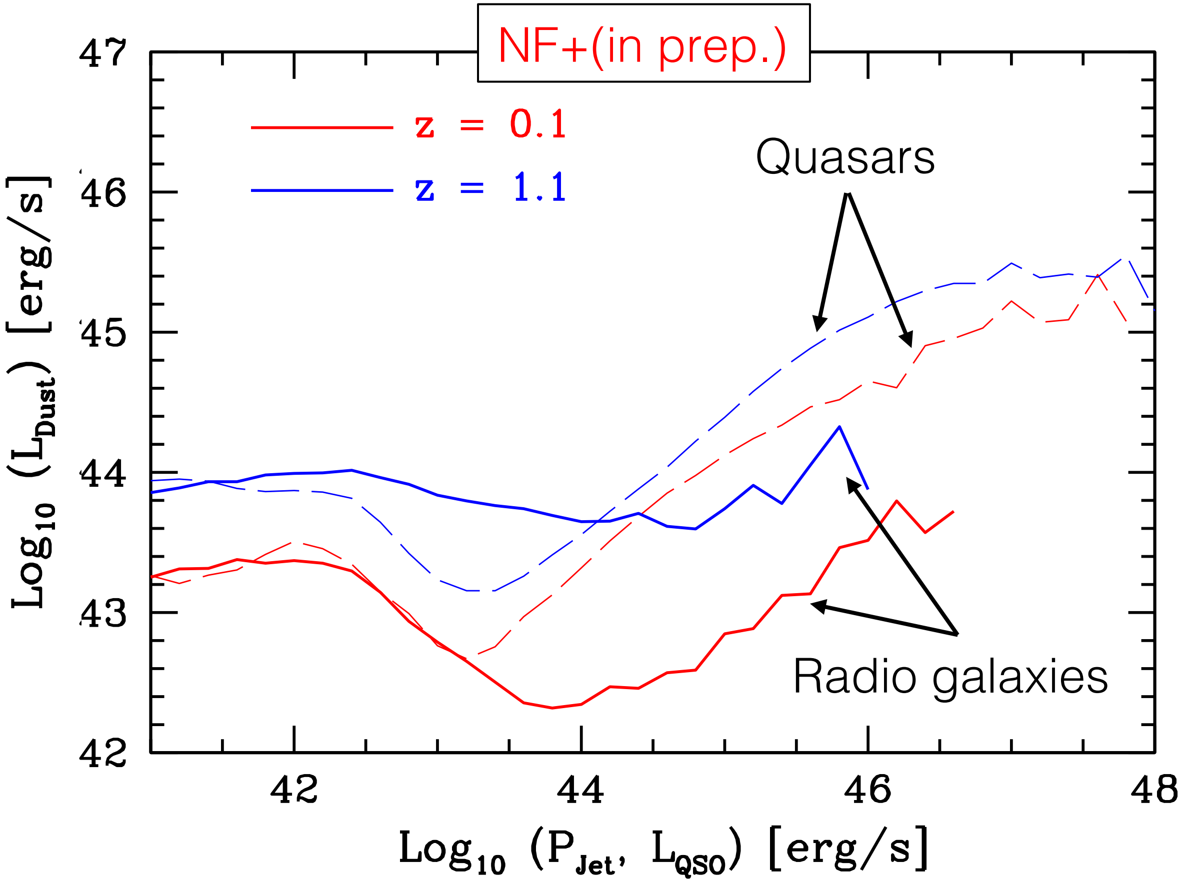
Radio Galaxies

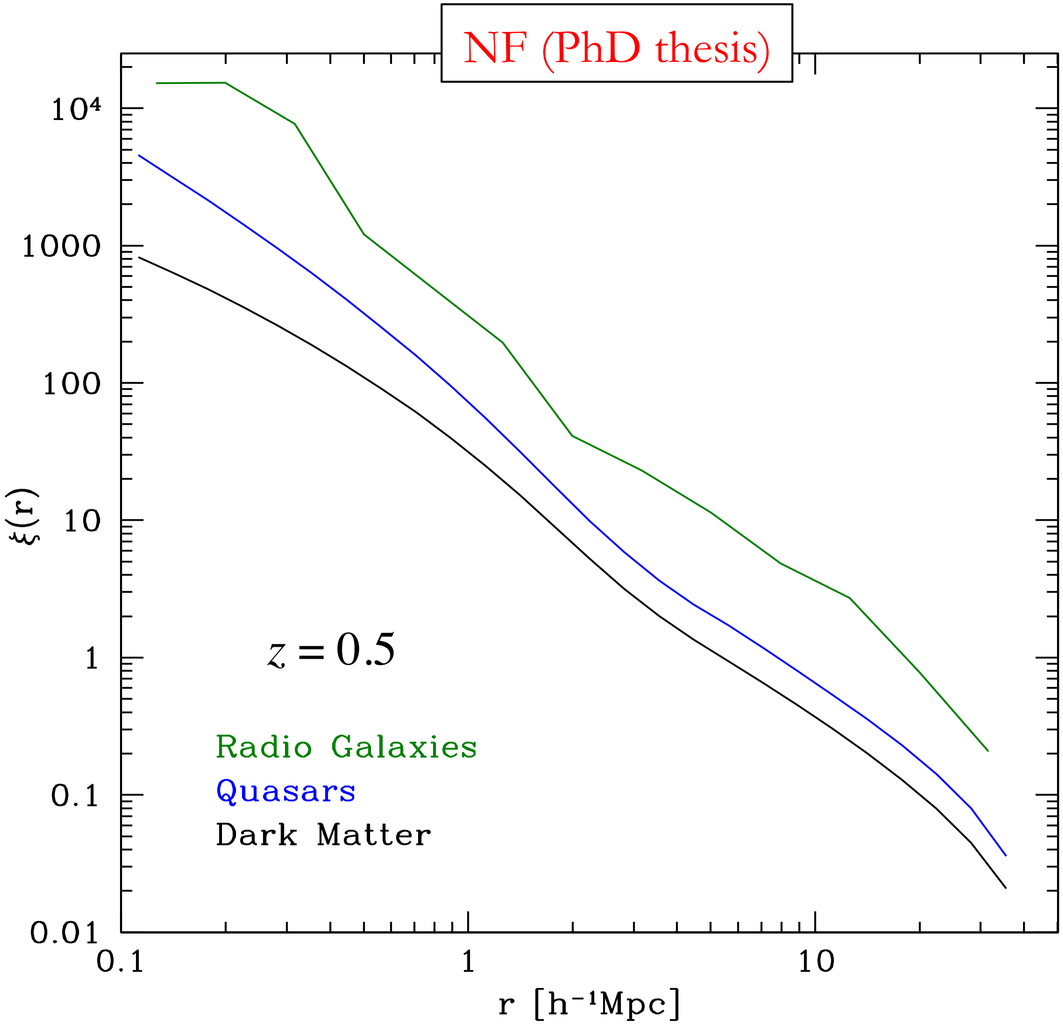
- Radio Galaxy hosts are not dead!
- sSFR's though are still relatively low.



Radio Galaxies

- Dust emission is also considerably high.
- Still below typical dust emission of quasar hosts.





Radio Galaxies still remain more clustered than Quasars!

Conclusions

A galaxy formation model with AGN feedback predicts:

1. Two regimes of BH growth – similar to stellar mass growth.
2. Bulk of AGN activity driven by secular processes.
3. Two modes of accretion define the AGN-SFR plane (two slopes).
4. Predictions for the mean IR luminosity of AGN show strong tension at moderate luminosities (need for variability?)
5. Radio Galaxies show strong signs of SF and IR emission.
6. Most of the luminous Radio Galaxy hosts receive their cold gas via mergers.