A Synthetic view of SMBH growth:
comparing and contrasting the radiative and mechanical sectors

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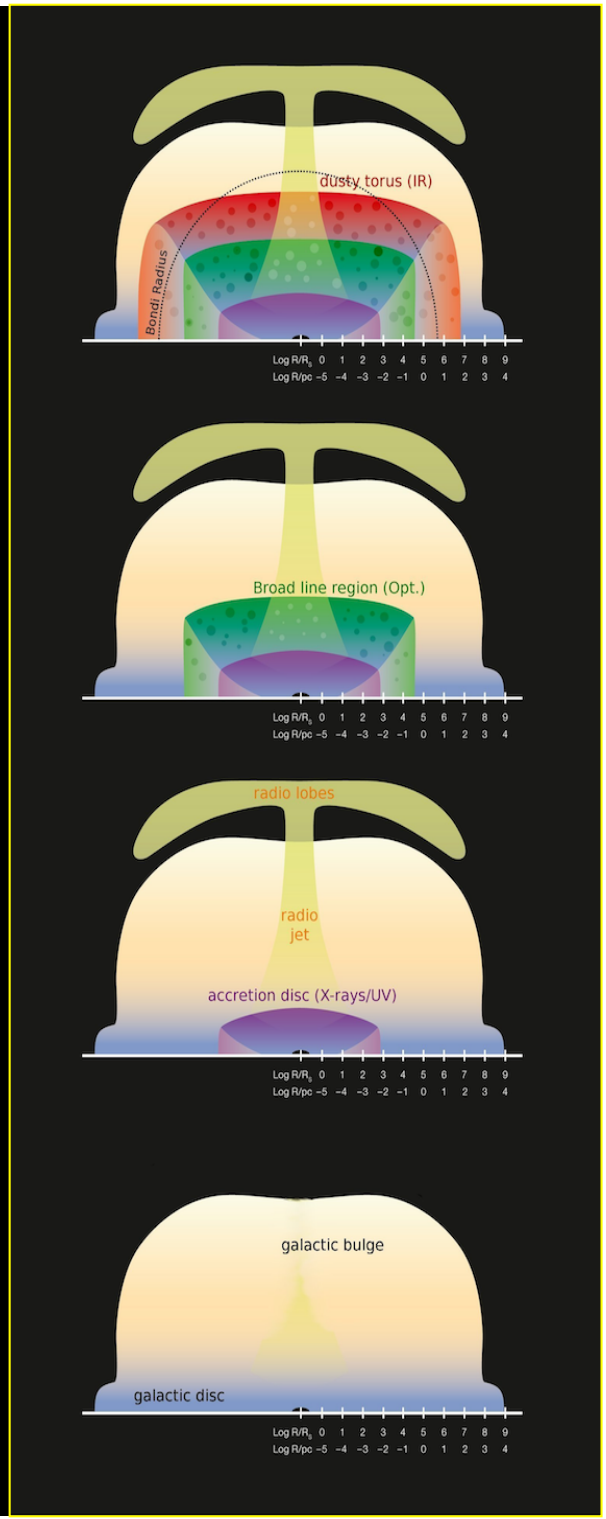
"A logarithmic view of an AGN/galaxy system" Merloni, Bonoli (ESO graphics)

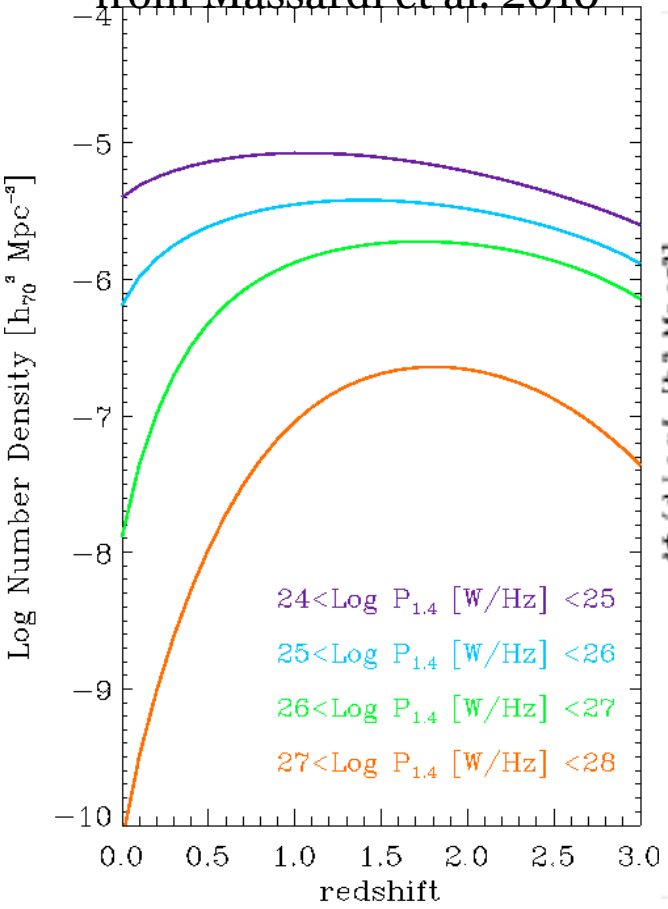


A synthetic view of SMBH growth: the “radiative” sector

AGN surveys: state of the art

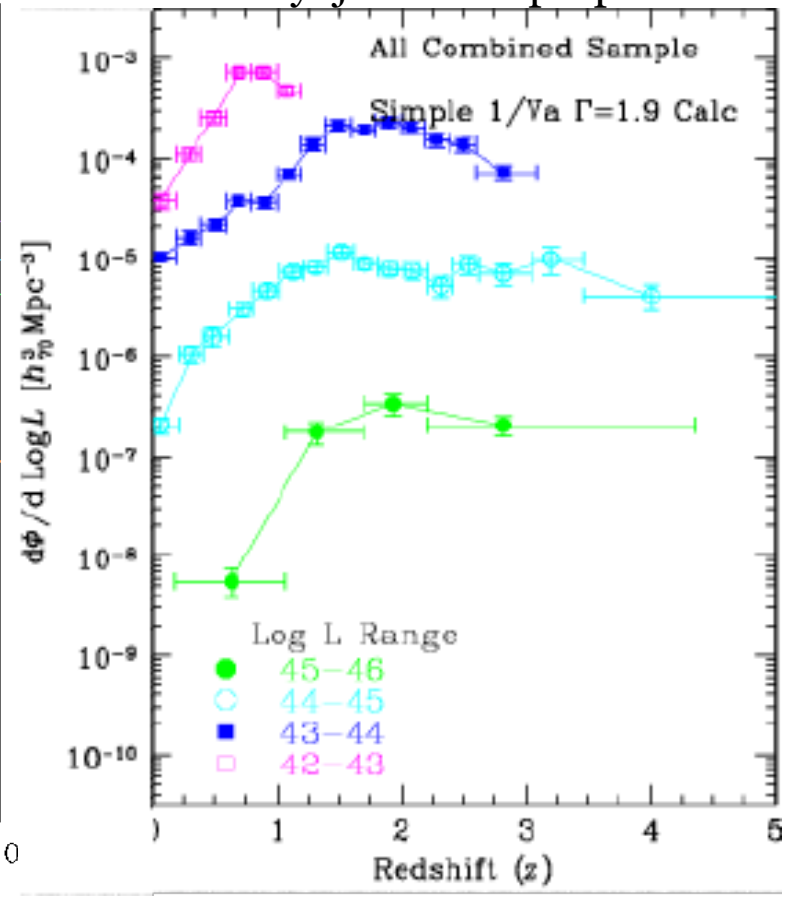
Radio (1.4 GHz)

from Massardi et al. 2010



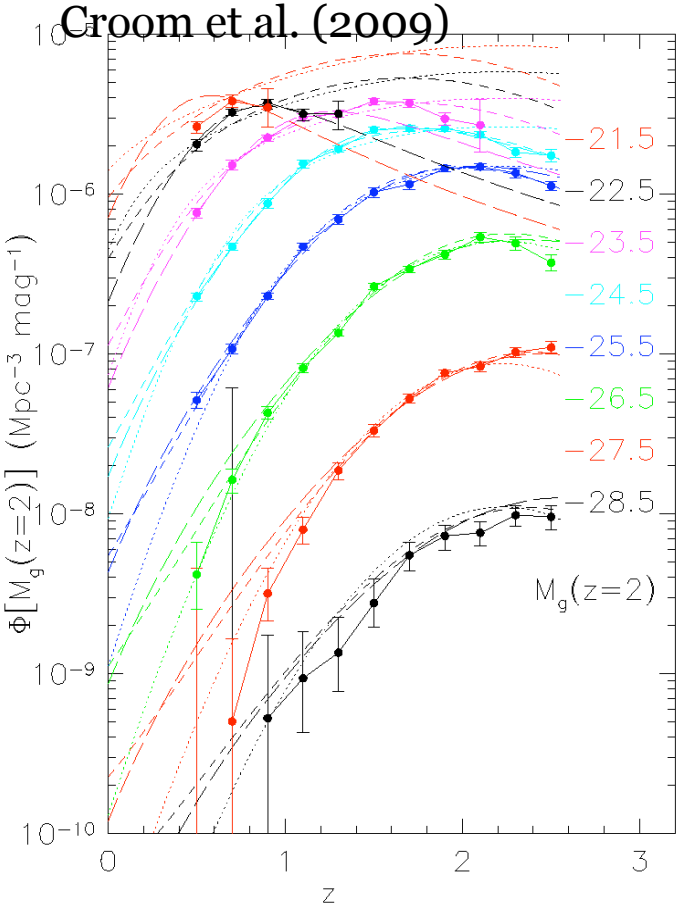
X-rays (2-10 keV)

Miyaji et al. in prep.



Optical (g-band) 2DF-SDSS

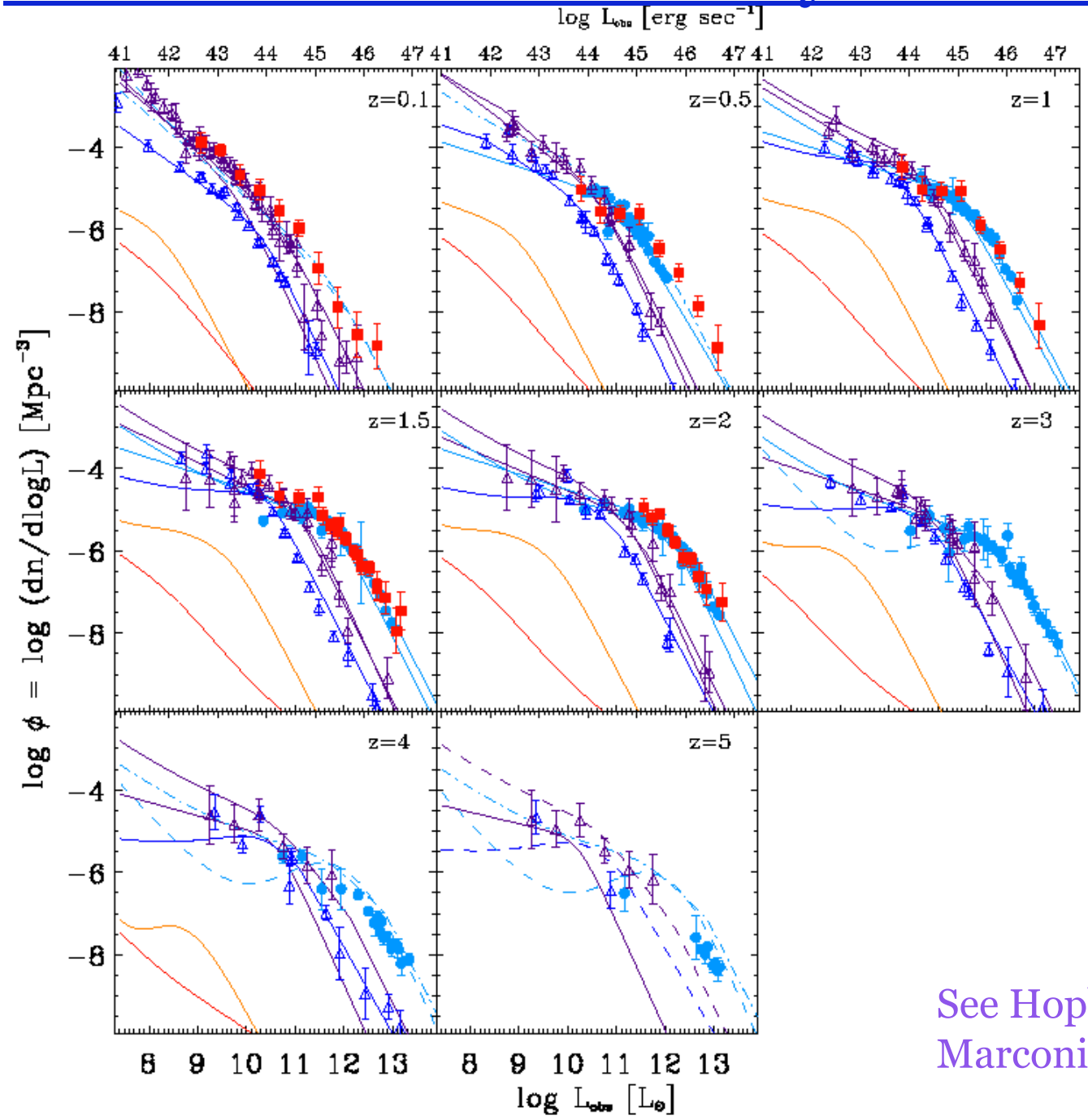
Croom et al. (2009)



Qualitatively similar evolution (“downsizing”)

Brightest objects at z<1 and z>3 still very uncertain (Area is KEY)

Panchromatic Luminosity Functions



See Hopkins et al. (2007); Marconi et al. (2004)

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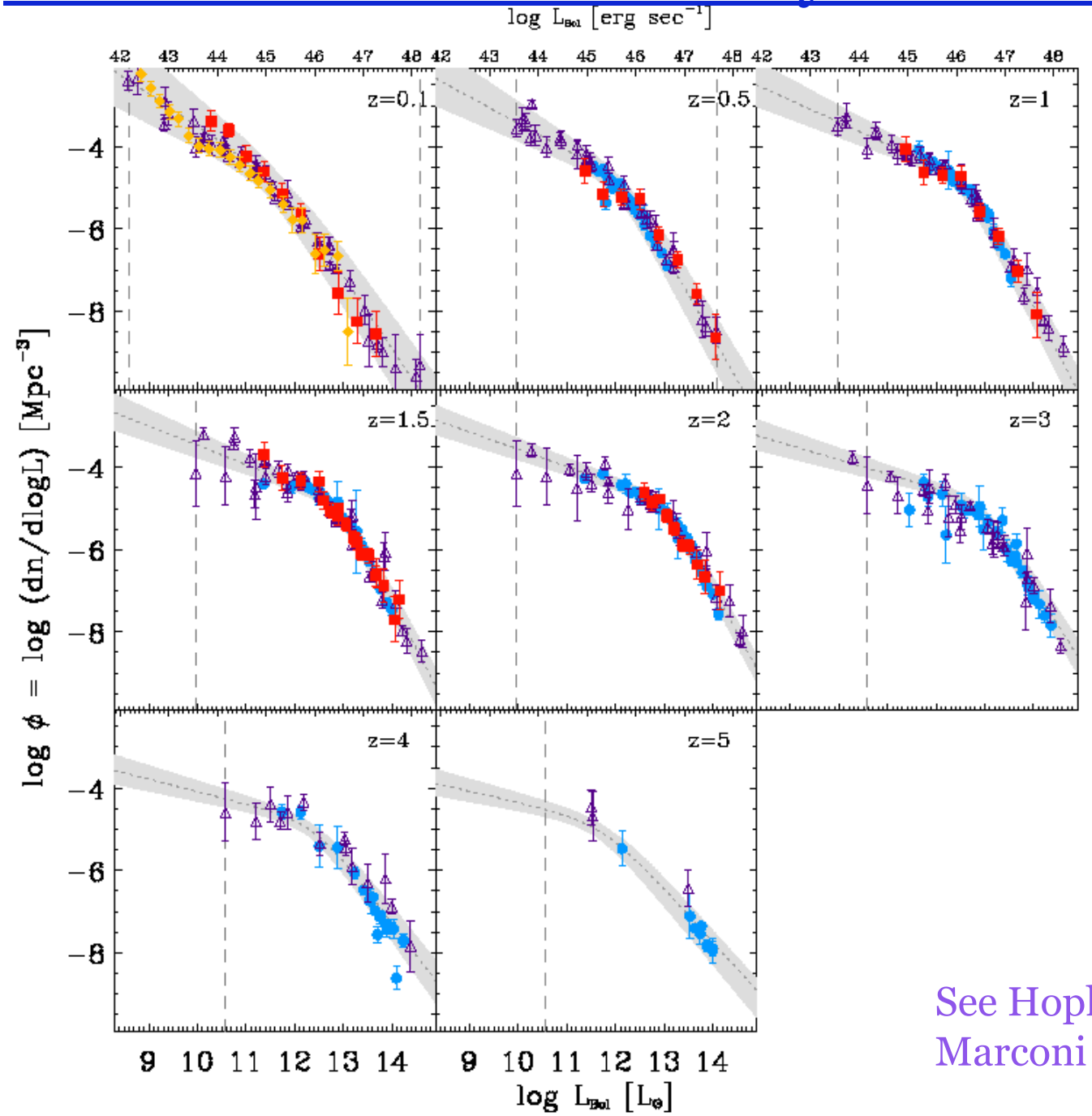


See Hopkins et al. (2007); Marconi et al. (2004)

Continuity equation for SMBH growth

Need to know simultaneously mass function $\Psi(M,t_o)$
and accretion rate distribution F(dM/dt,M,t) ["Fueling function"]

$$\frac{\partial \psi(M,t)}{\partial t} + \frac{\partial}{\partial M}\left(\psi(M,t) \int \dot{M} F(\dot{\mu}, \mu, t)\, \mathrm{d}\dot{\mu}\right) = 0$$

$$\mu = Log\, M$$

$$\phi(\ell, t) = \int F(\dot{\mu}, \mu, t)\psi(\mu, t)\, \mathrm{d}\mu$$

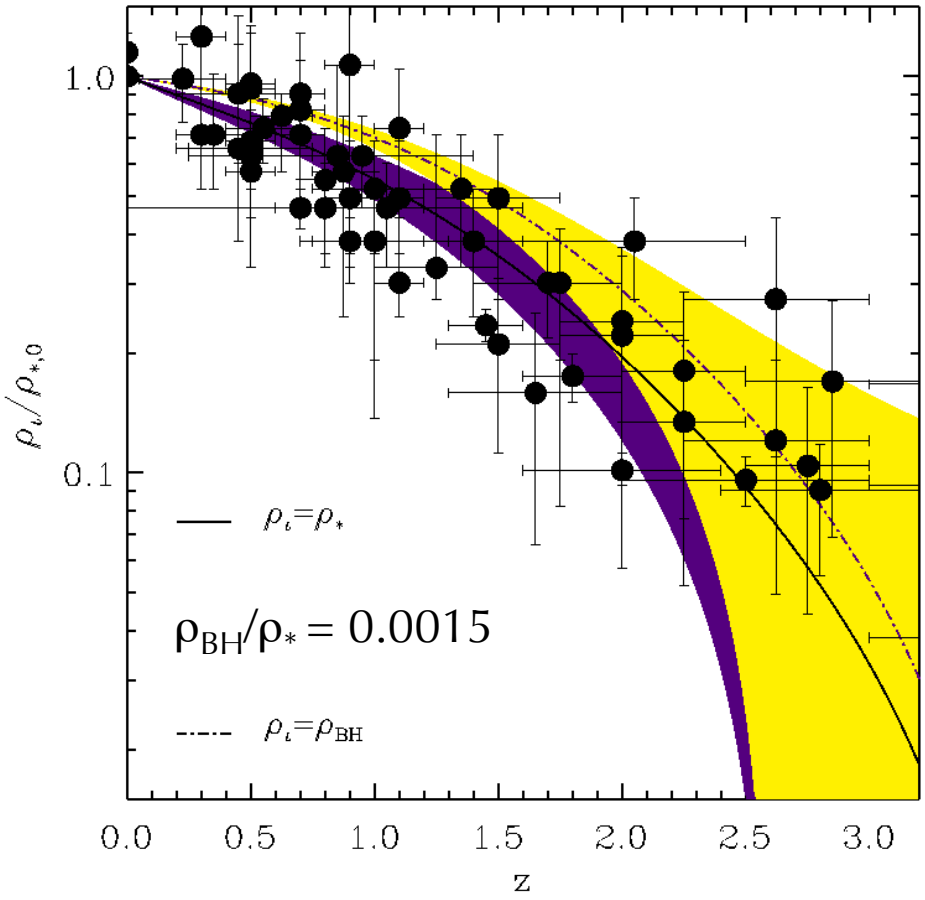
$$\ell = Log\, L_{bol}$$

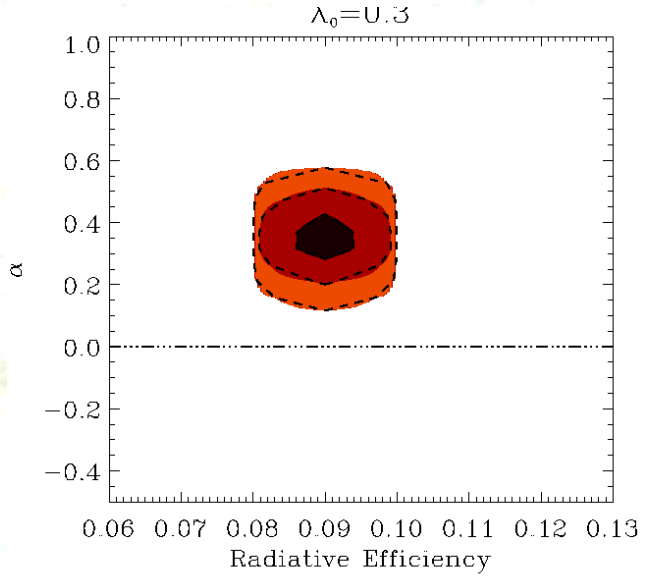
luminosity function **mass function**

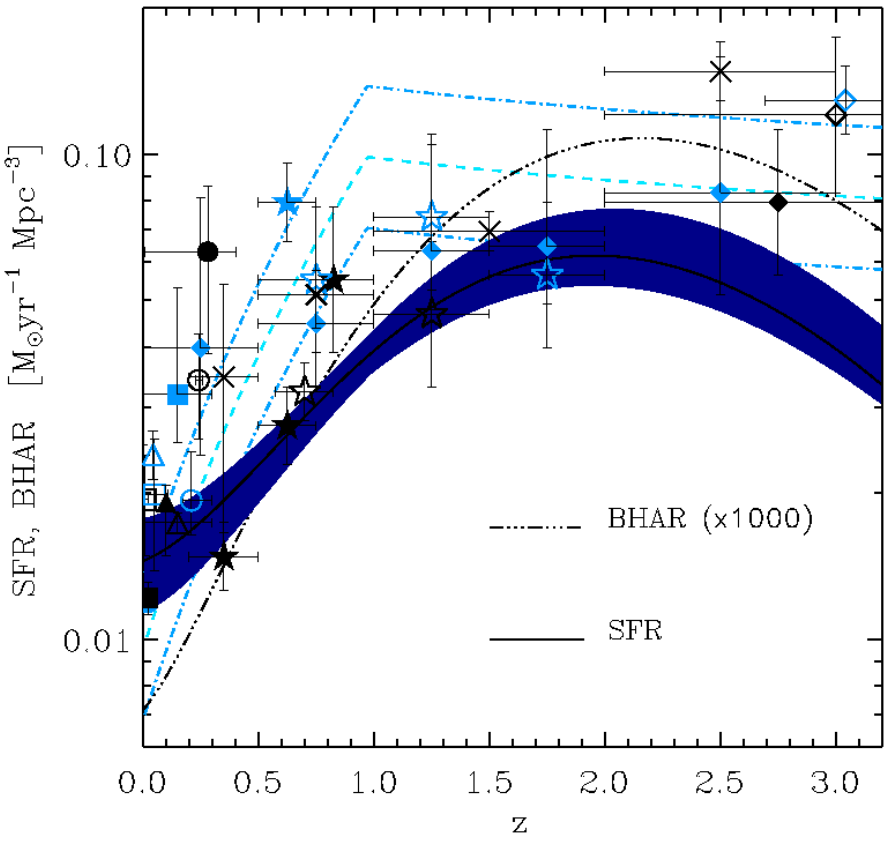
$$\dot{\mu} = Log\, \dot{M}$$

Cavaliere et al. (1973); Small & Blandford (1992); Merloni+ (2004; 2008; 2010)

Parallel lives



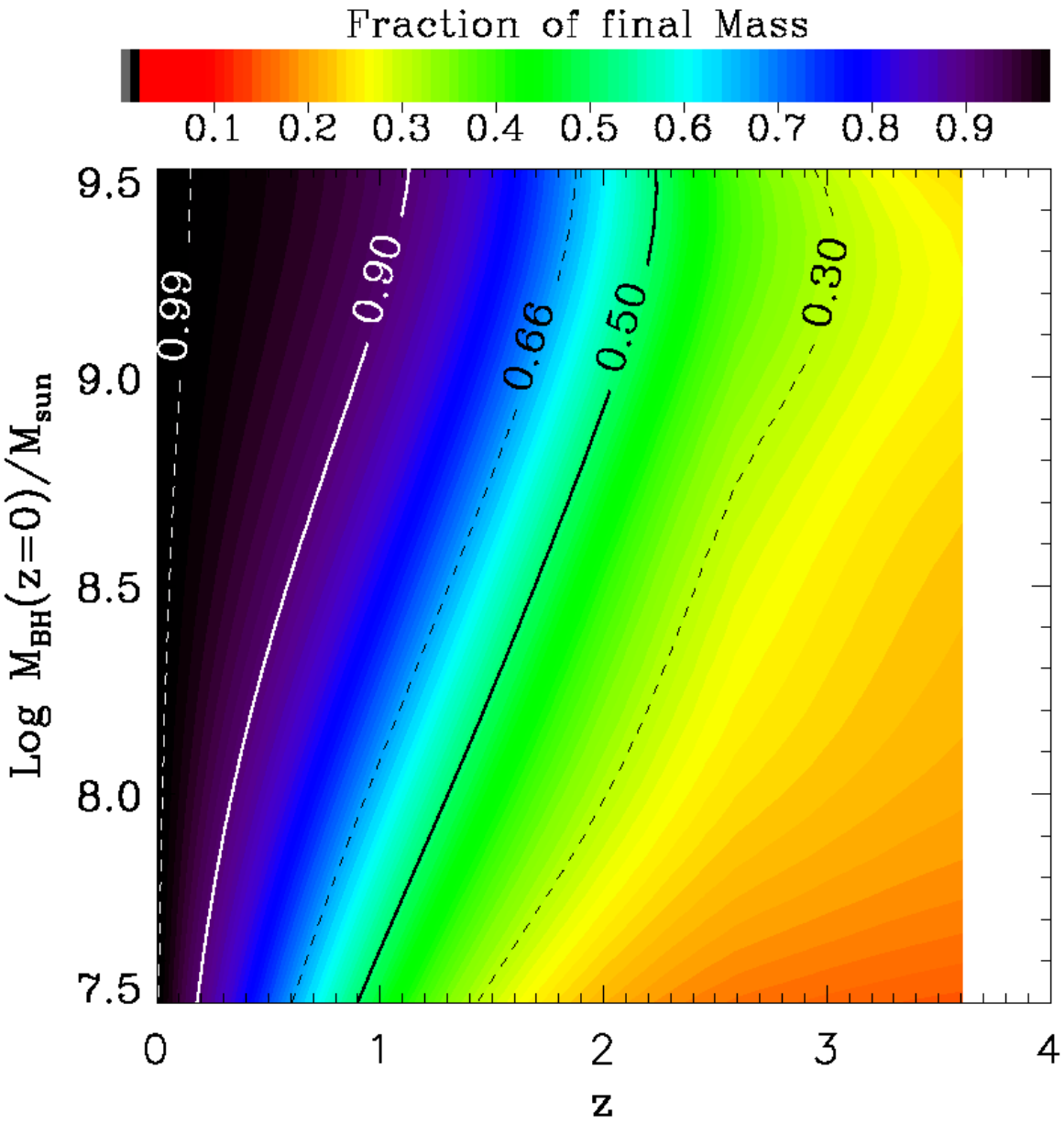




Mild evolution $\langle M_{BH}/M_{*,bulge}\rangle \sim (1+z)^{0.4}$
Avg. radiative efficiency ~ 0.09

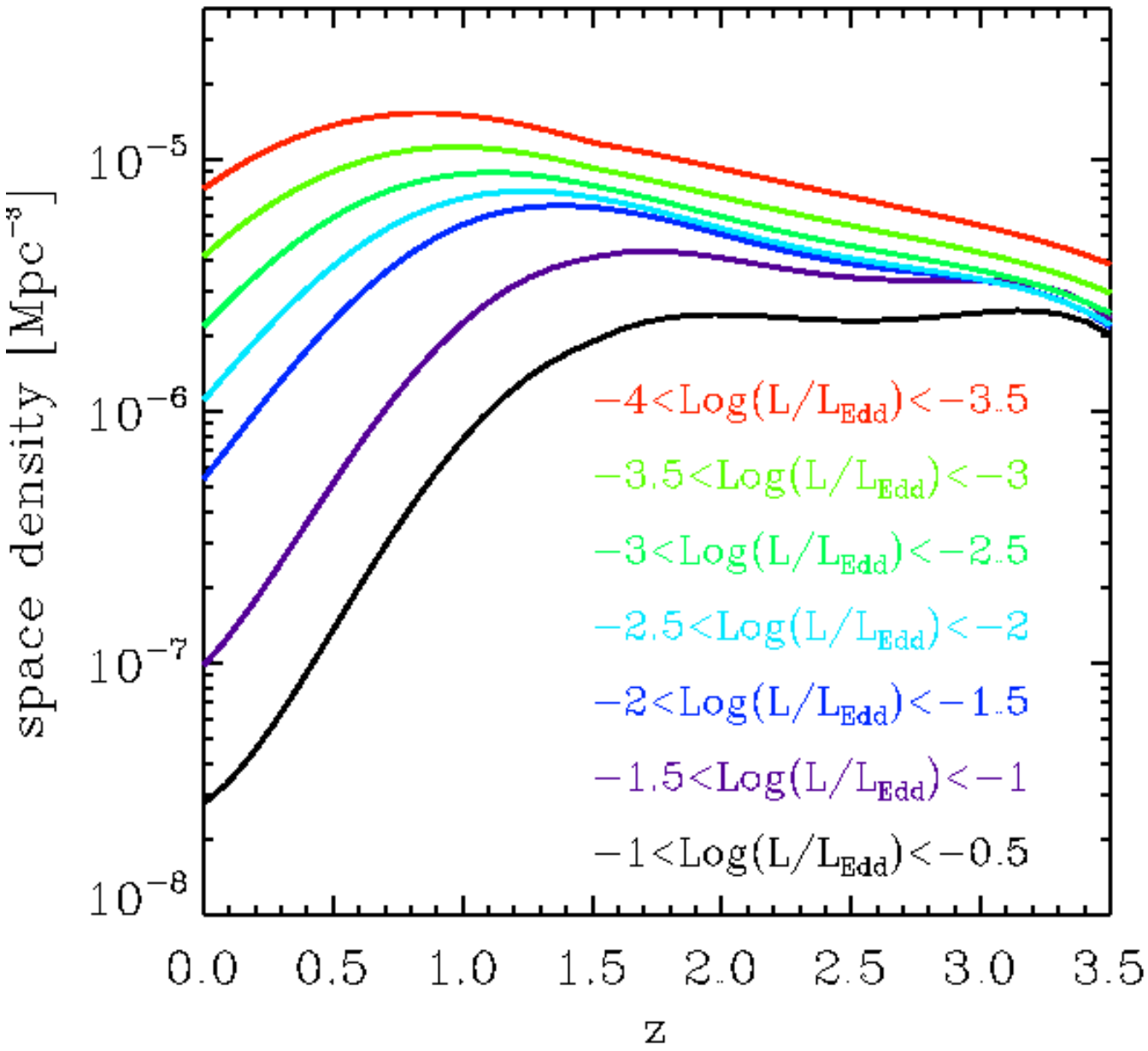
See Merloni, Rudnick, Di Matteo (2004)

Fractional Mass evolution: Downsizing

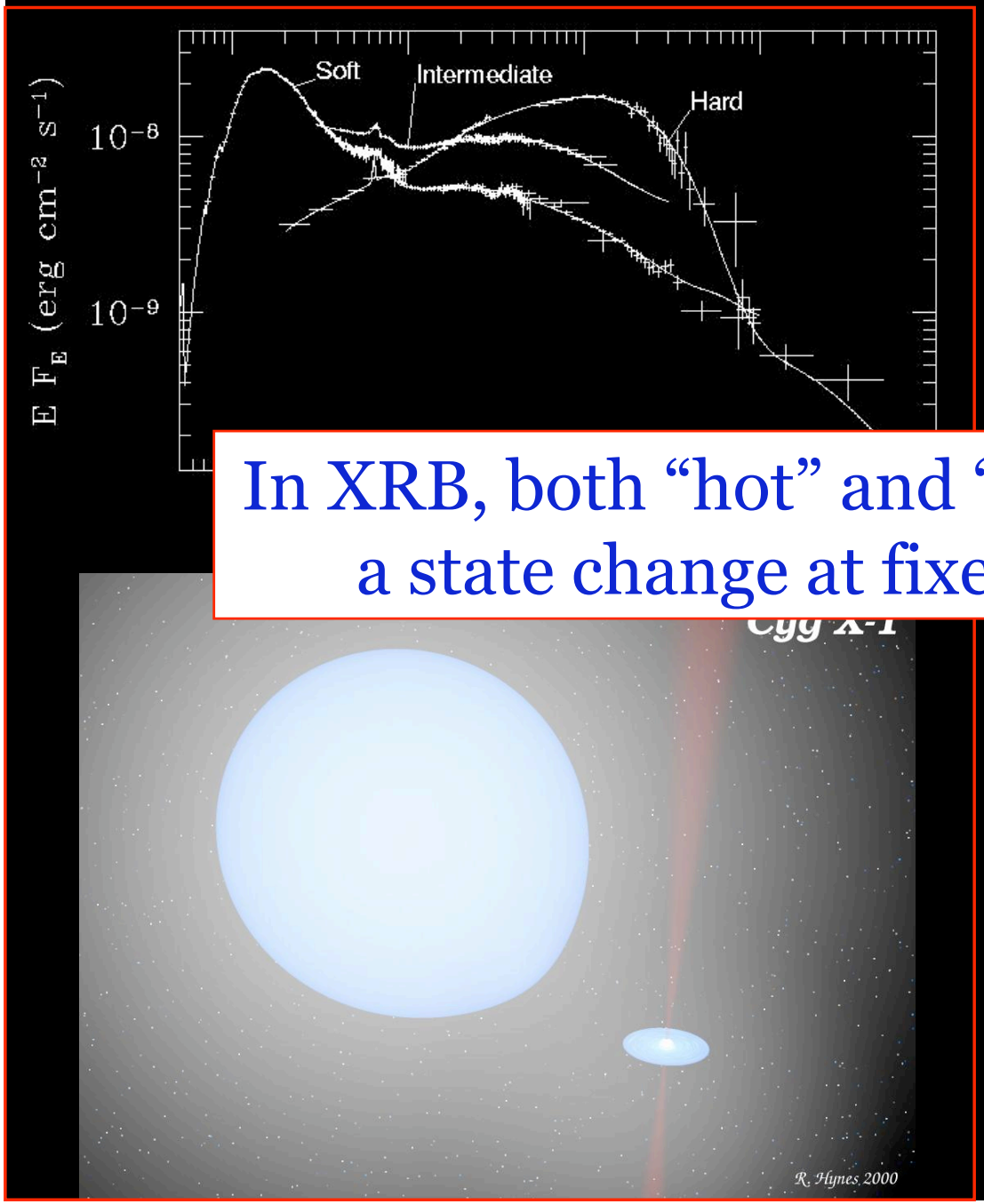


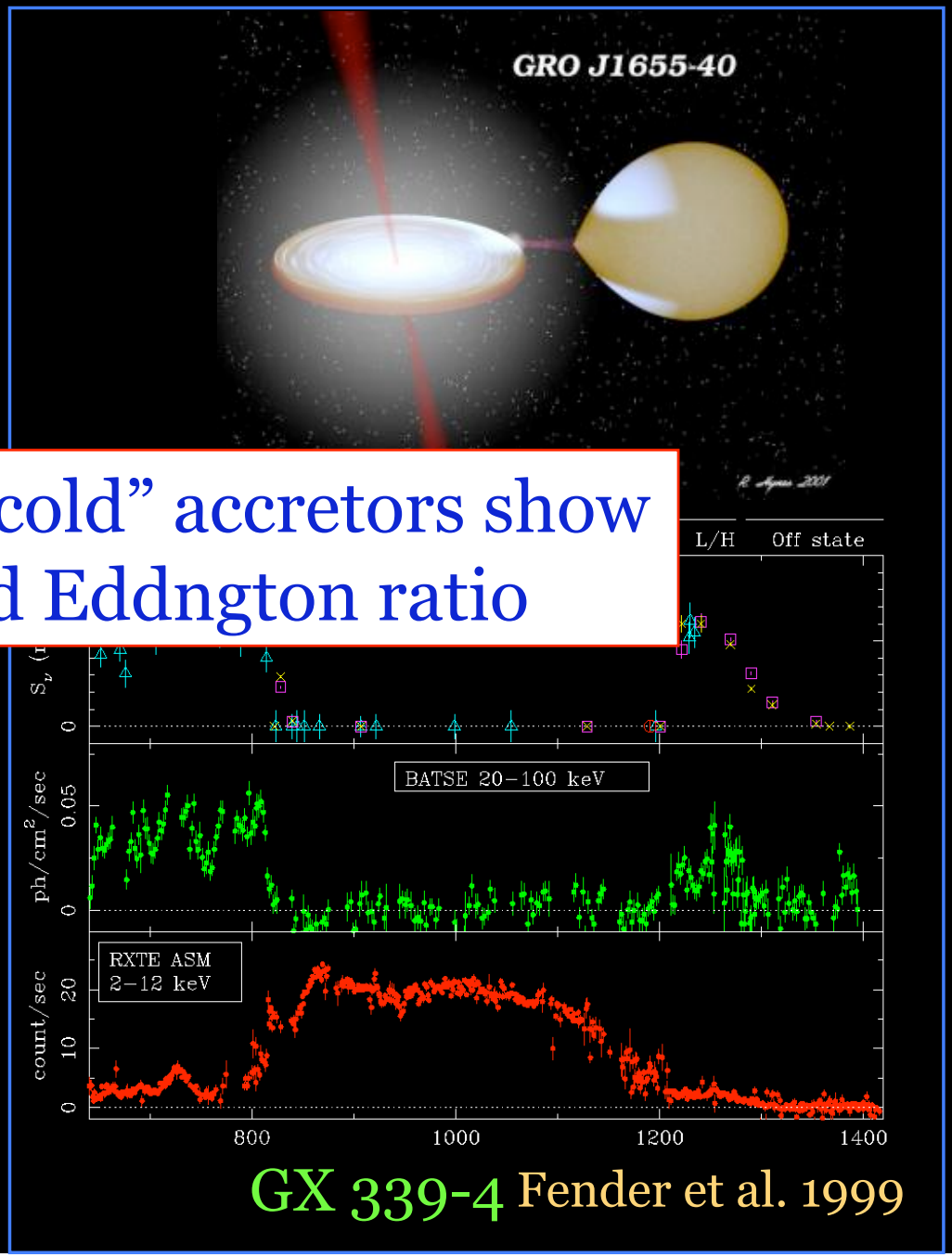
Merloni+ 2010; Lamastra et al. 2010

AGN number densities vs. L/L_{Edd}



Hot vs. cold? Low vs. high mdot? XRB examples





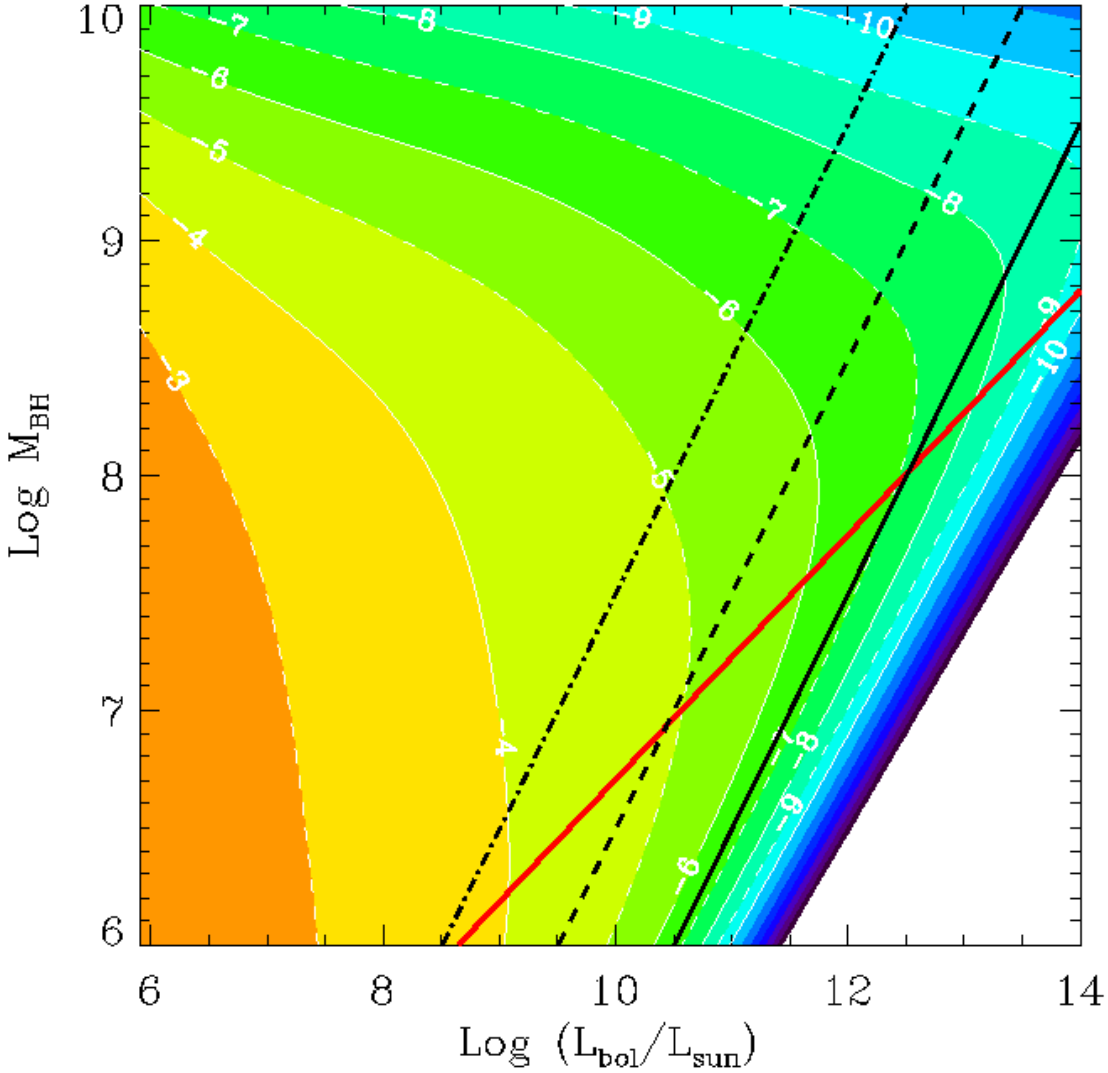
In XRB, both “hot” and “cold” accretors show a state change at fixed Eddngton ratio

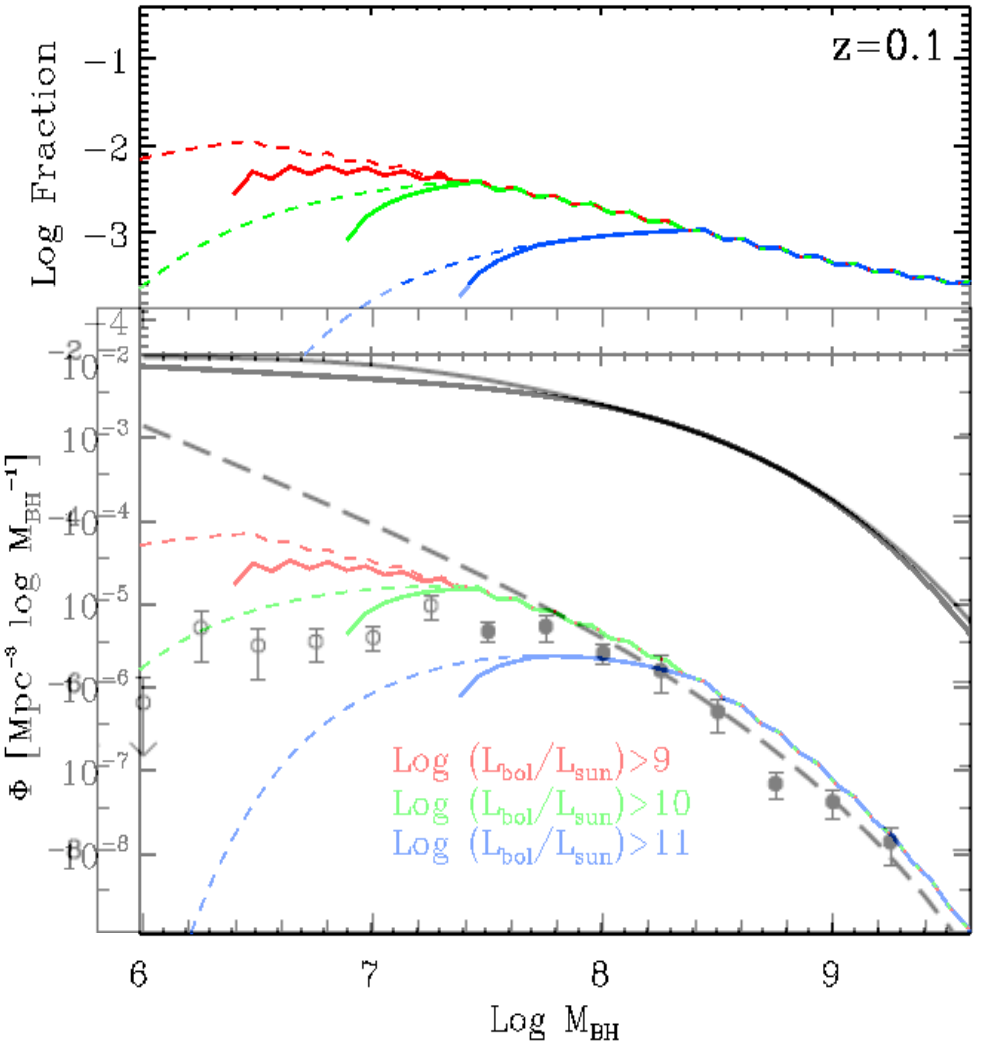
GX 339-4 Fender et al. 1999

Bivariate distributions

z=0.1

Optical BLAGN Mass function,
Schulze and Wisotzki 2010

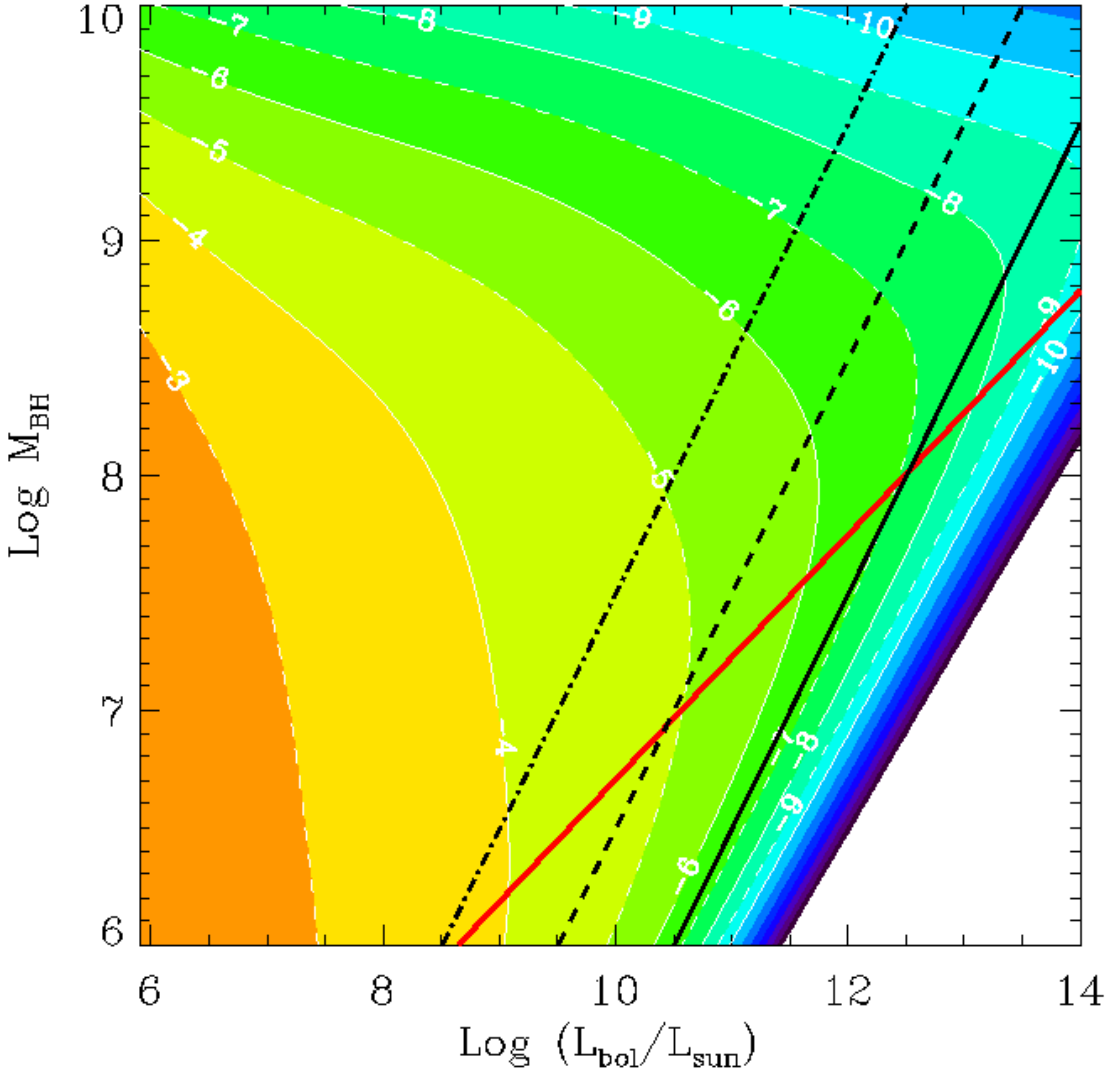


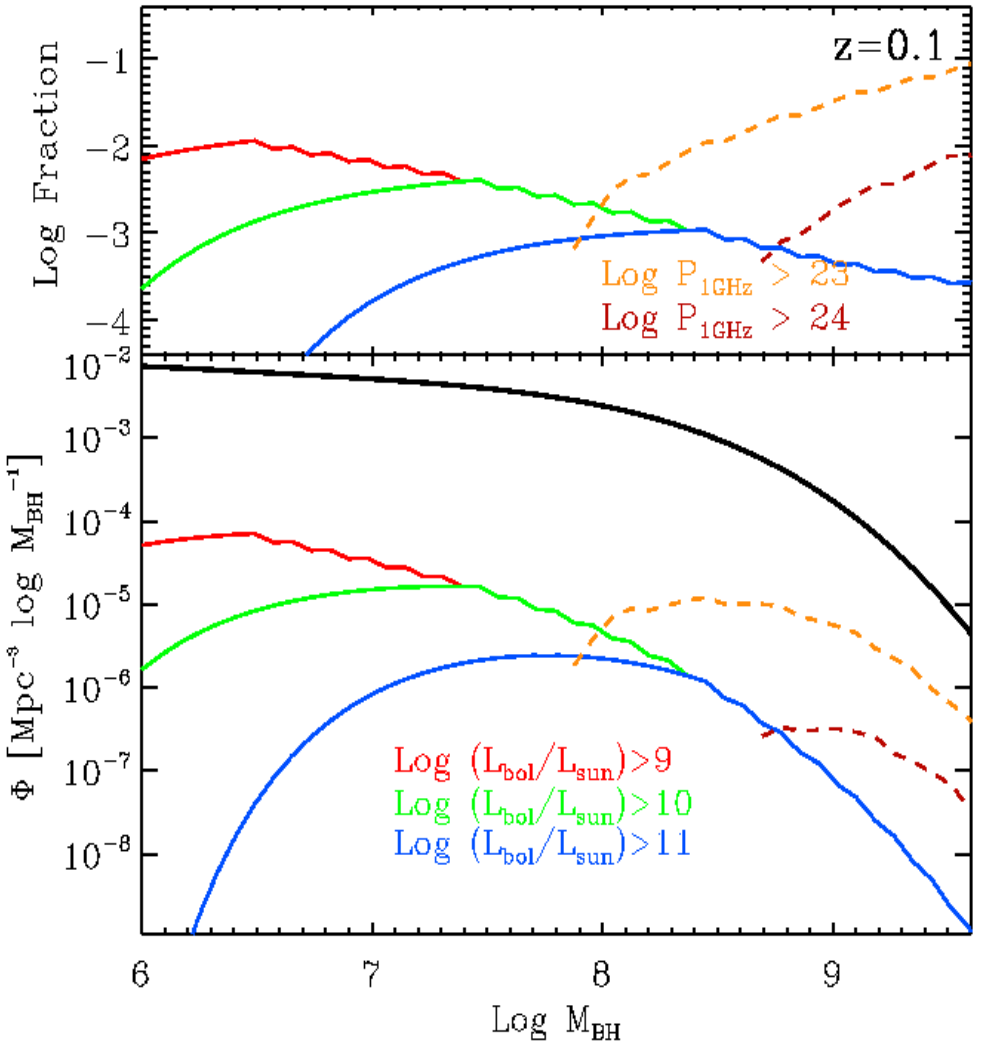


Bivariate distributions

z=0.1

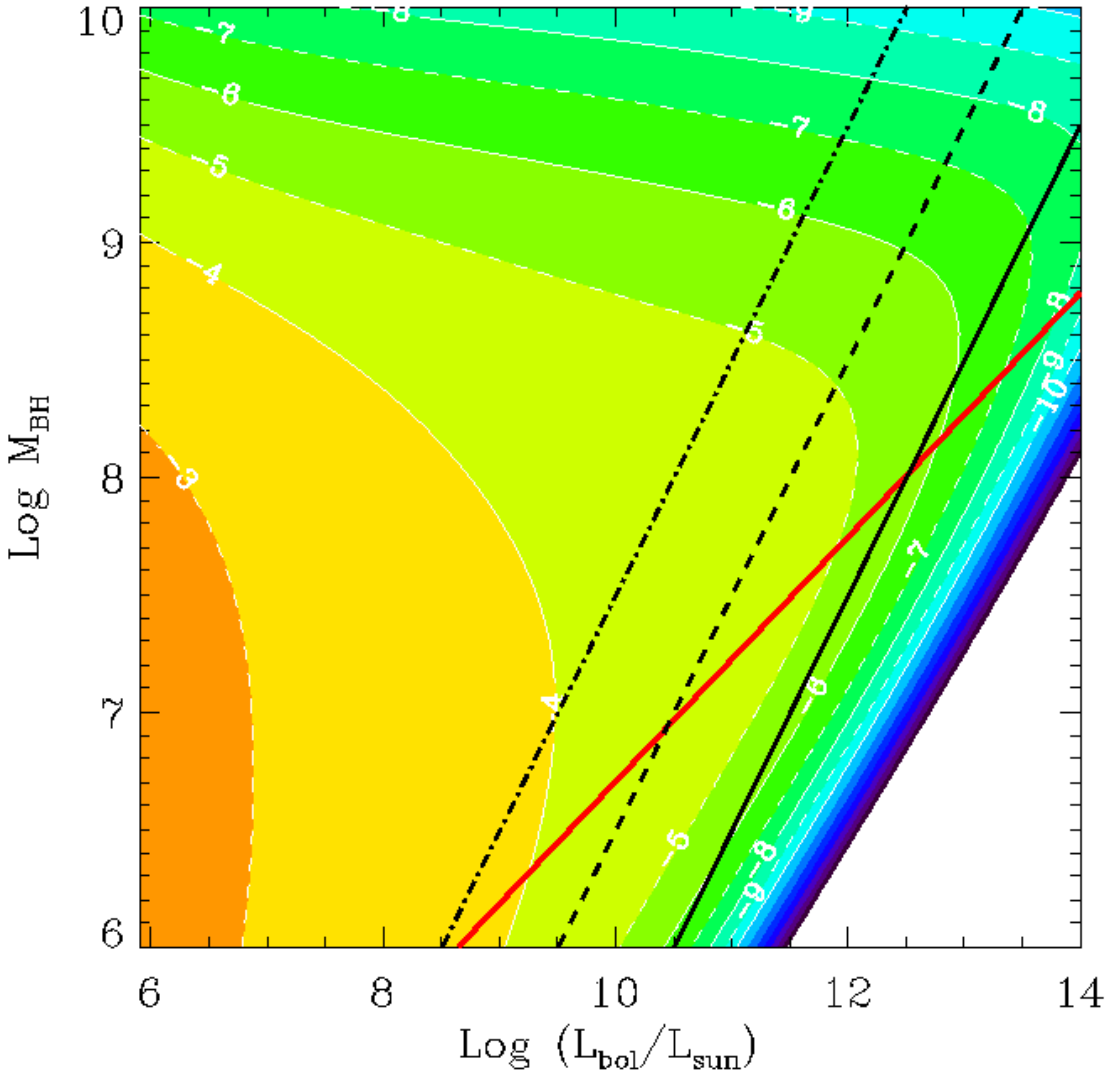
Using the "fundamental plane" relation to infer L_R below $L/L_{edd}=0.01$

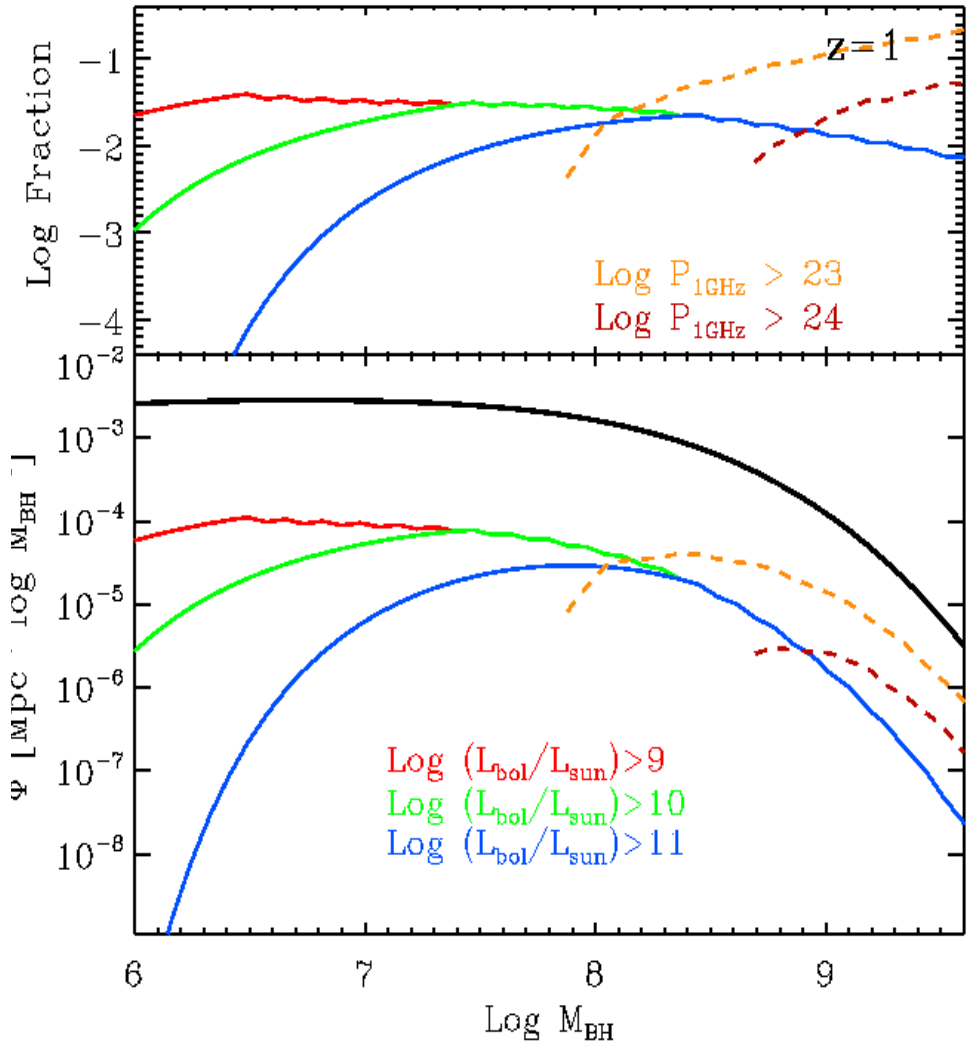




Bivariate distributions

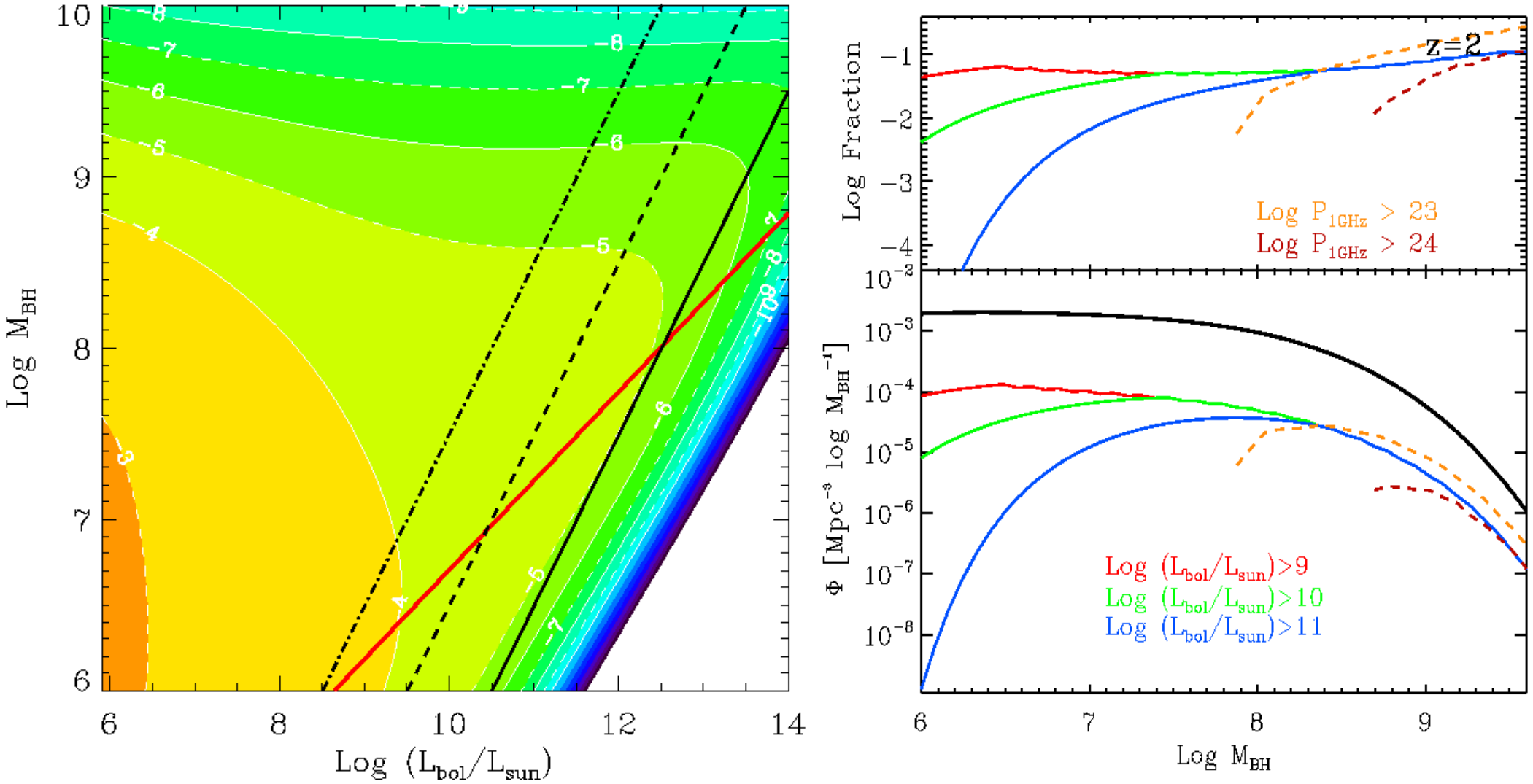
Z=1





Bivariate distributions

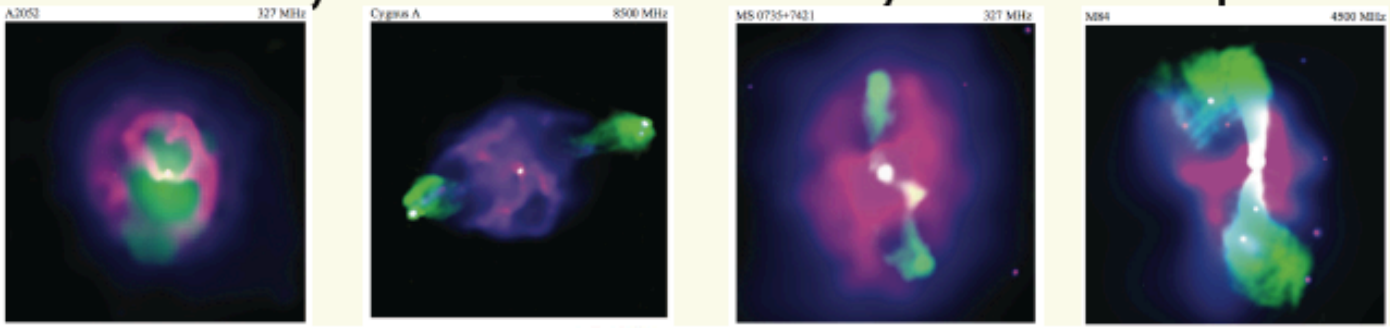
Z=2; Strong increase in AGN fraction/duty cycle

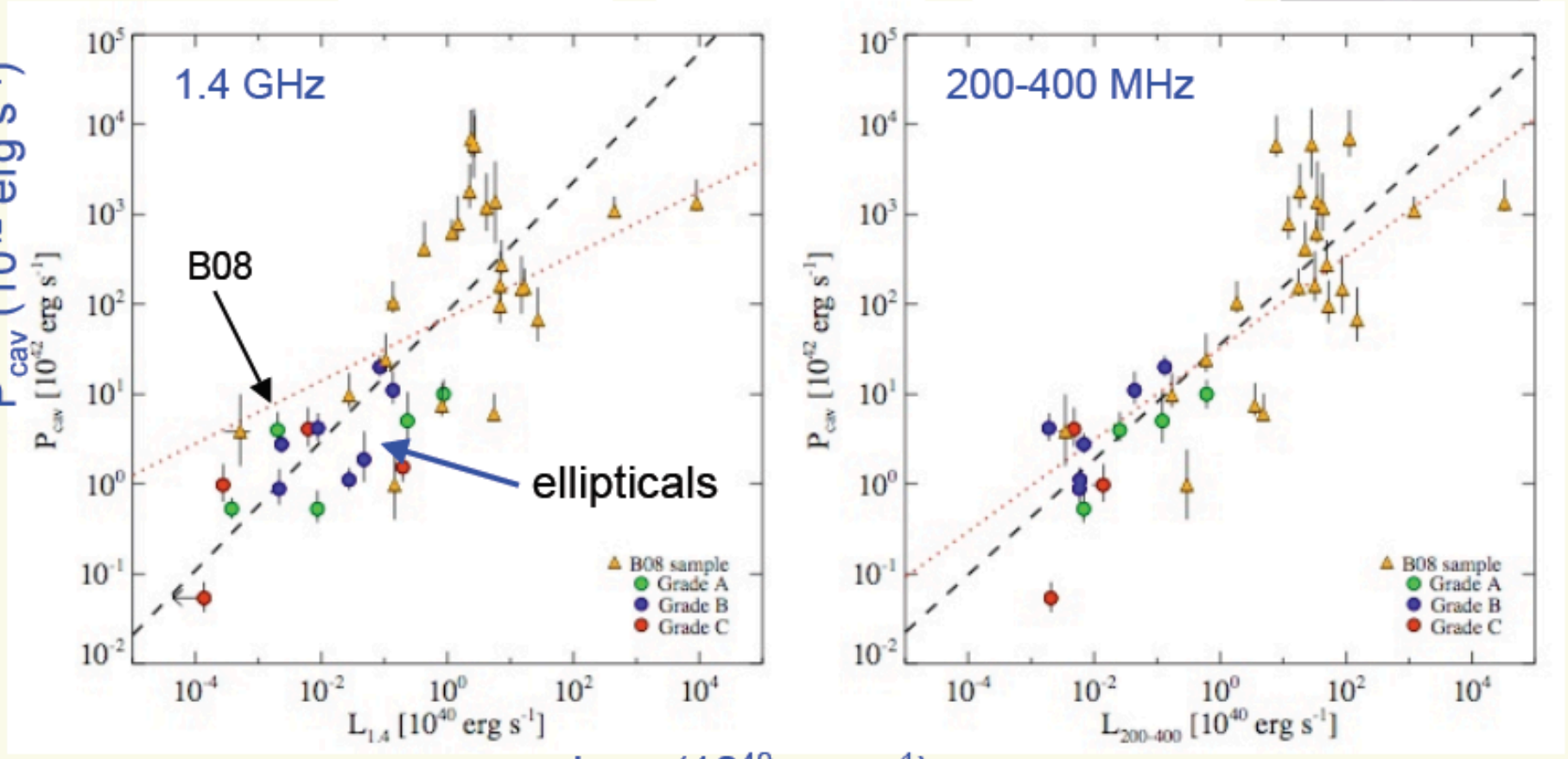


A synthetic view of SMBH growth: the “kinetic” sector

New Jet Power vs Synchrotron luminosity relationships

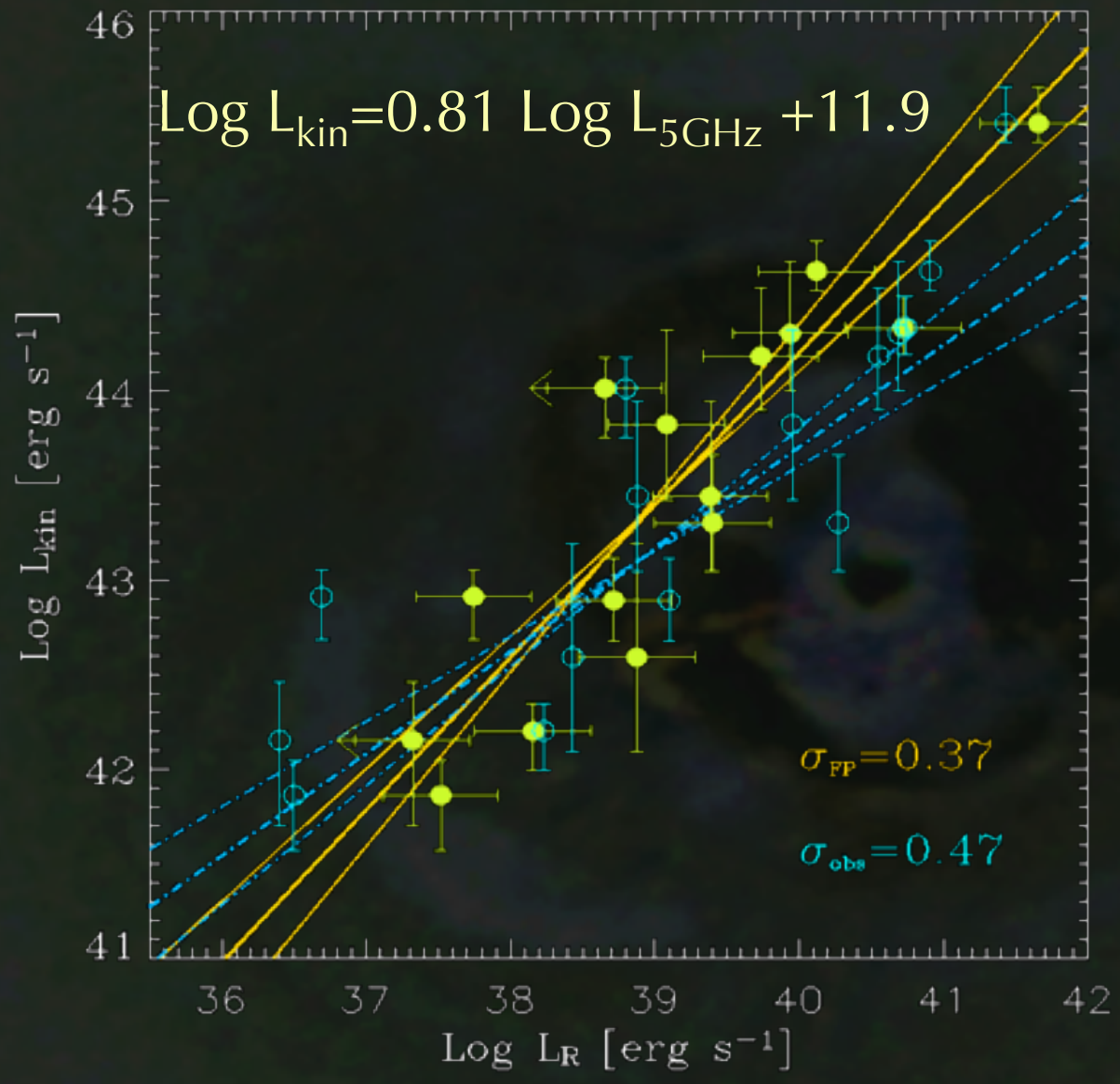
$$P_{cavity} \propto L_{radio}^{0.7}$$





Cavagnolo + 10, Birzan + 08

Core Radio/L_{Kin} relation



Slope=0.81

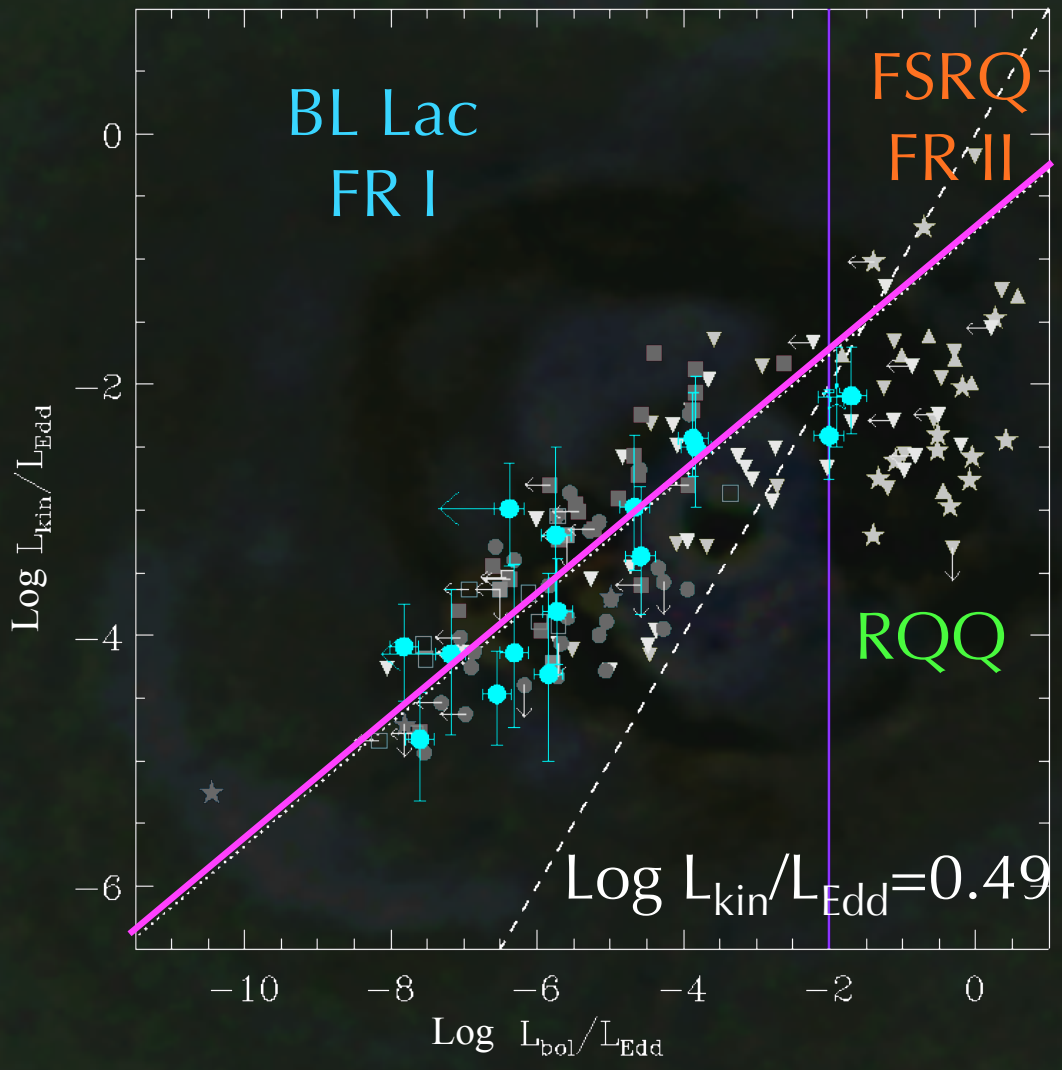
Observed L_R (beaming)
Derived from FP relation

Monte Carlo simulation:
Statistical estimates of
mean Lorentz Factor $\Gamma \sim 7$

Not a distance effect:
partial correlation analysis
$P_{nul}=2 \times 10^{-4}$

Merloni and Heinz (2007)

Low Power AGN are jet dominated



- The observed slope (0.49 ±0.06) is consistent with radiatively inefficient "jet dominated" models

$$\text{Log } L_{kin}/L_{Edd} = 0.49 \text{ Log } L_{bol}/L_{edd} - 0.78$$

Merloni and Heinz (2007)

Basic scaling laws (working hypothesis)

LLAGN ($L/L_{edd}<0.01$); No BLR

$$L_R \propto L_X^{0.6\text{-}0.7} M^{0.7\text{-}0.8}$$

$$L_{KIN} \propto L_R^{0.7\text{-}0.8}$$

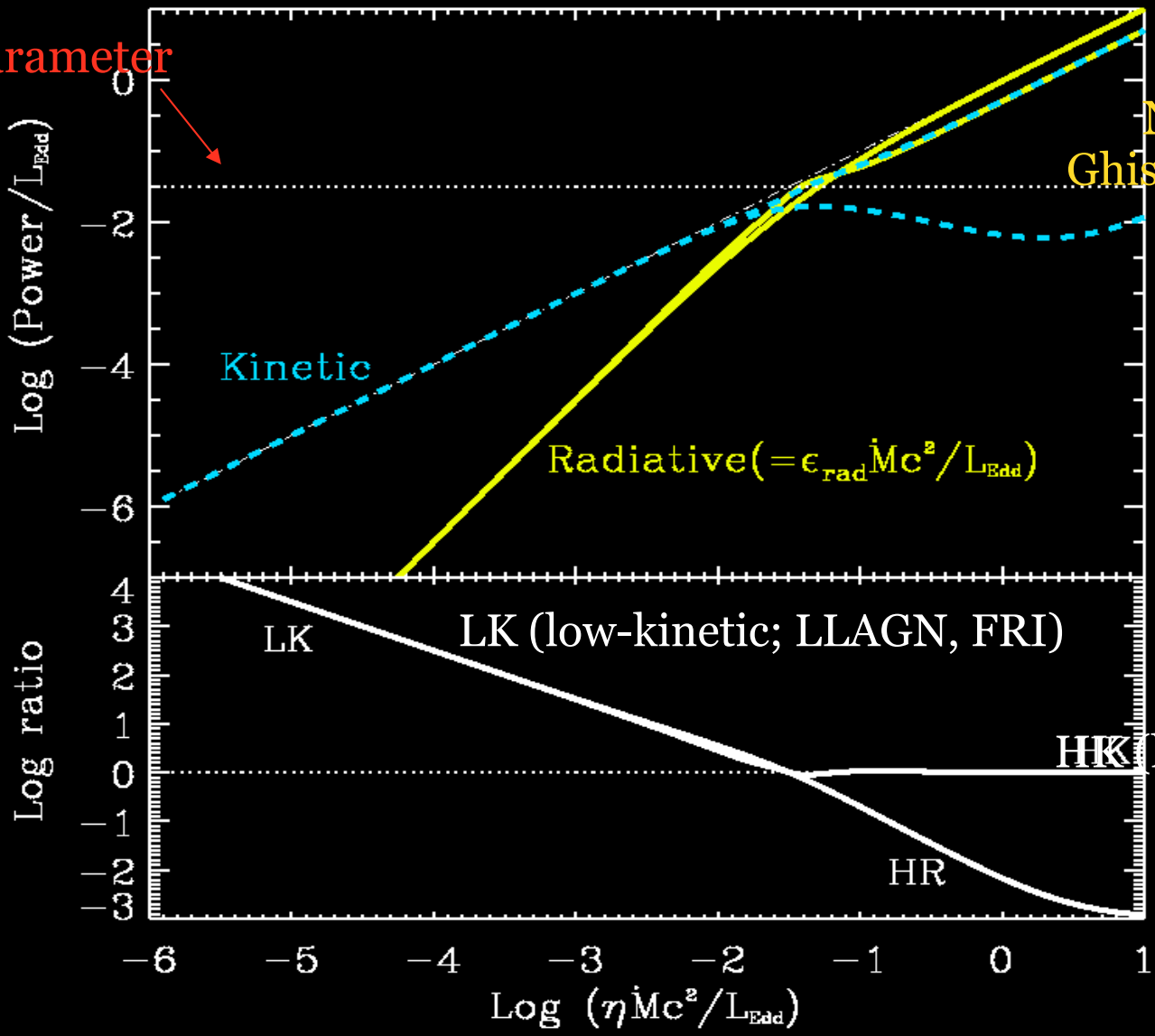
$$L_{KIN}/L_{EDD} \propto L_X/L_{EDD}^{0.5}$$

Powerful Jets ($L/L_{edd}>0.01$)

$$L_{KIN,JEt} \sim L_{bol}$$

Accretion diagram for LMXB & AGN

Model parameter



New "Blazar Sequence"
Ghisellini and Tavecchio (2009)

LK (low-kinetic; LLAGN, FRI)

HK (high-kinetic; RLQ, FRII)

HR (high-radiative; RQQ)

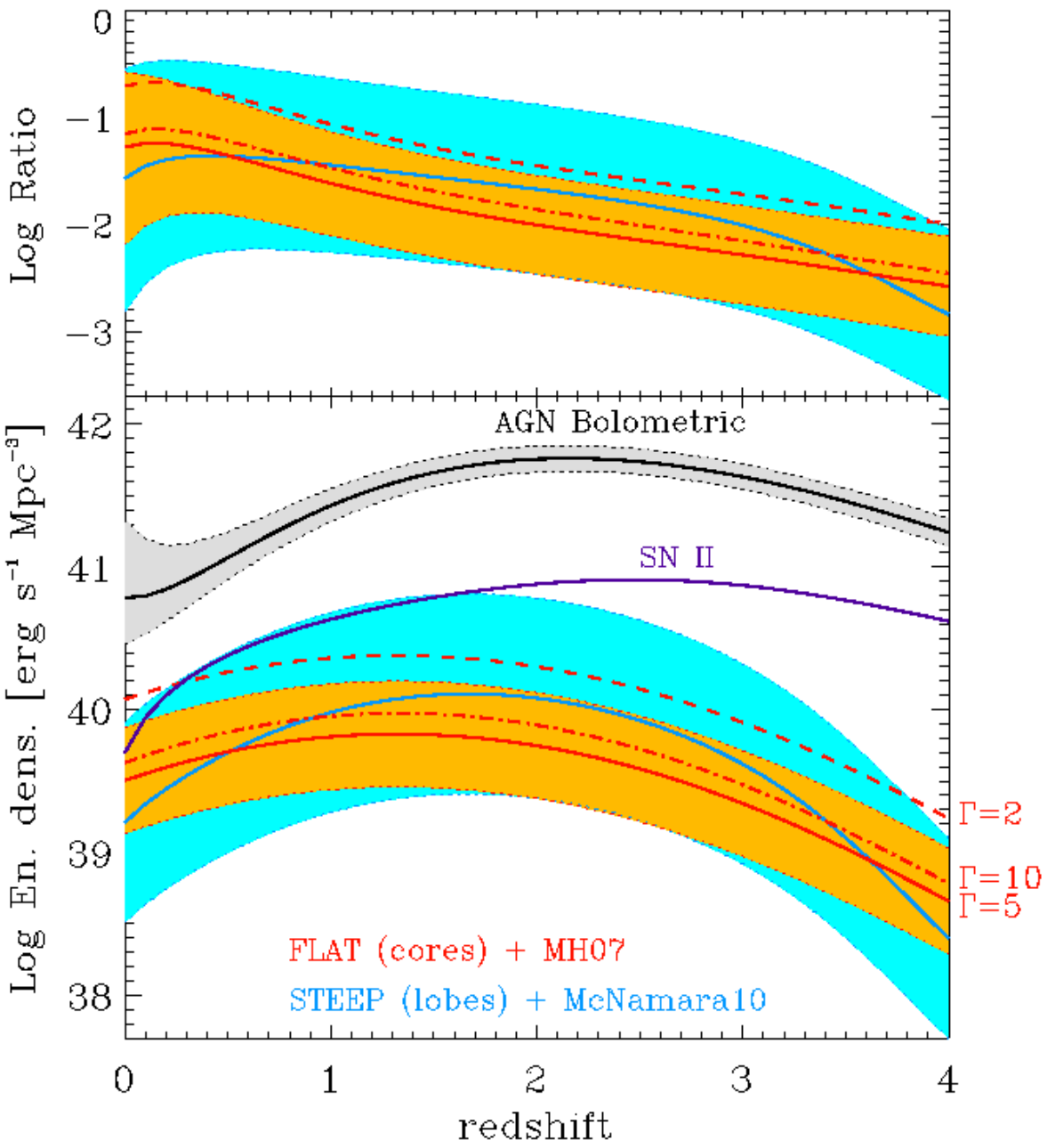
(Blandford & Begelman 1999, Körding et al. 2007, Merloni and Heinz 2008)

SMBH growth: weighting modes

Log L_{kin}= 45.2 x 0.81 Log ($P_{1.4,core}$ /10^{25})
(Merloni & Heinz 2007)

Log L_{kin}= 44.6 x 0.7 Log ($P_{1.4}$ /10^{25})
(Cavagnolo 2010, "cavity power")

Heinz, Merloni and Schwaab (2007); Körding, Jester and Fender (2007); Cattaneo and Best (2009); See Poster by La Franca



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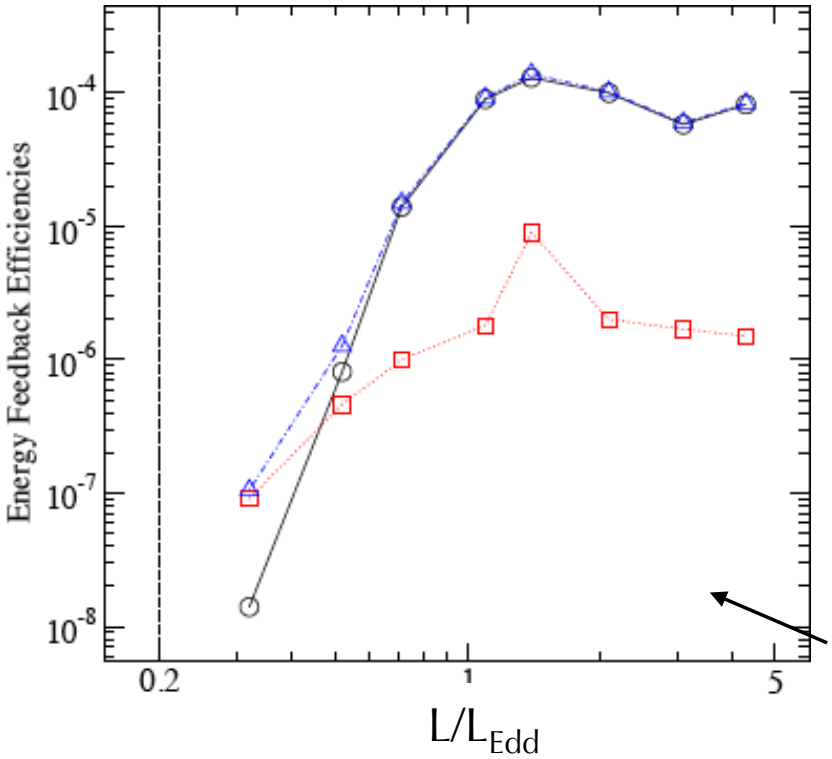

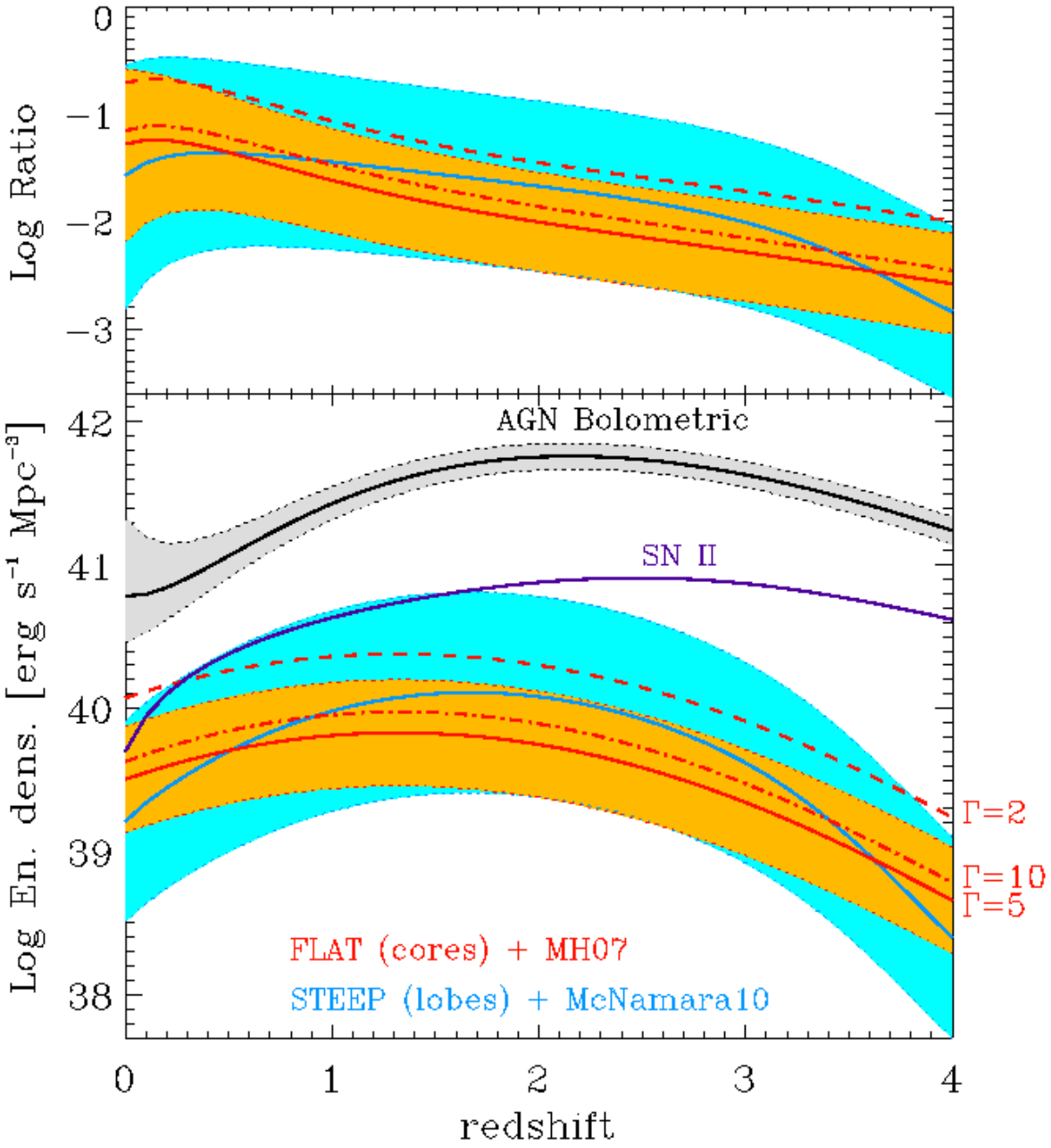

Energy efficiency of winds in ~Eddington accretion
Kurosawa et al. 2009

Conclusions and Outlook

- Most of SMBH mass density has been accumulated in radiatively efficient (e~0.1) episodes, likely with L/Ledd>0.01
- AGN energy output is regulated by an accretion mode switch
- The kinetic efficiency of AGN depends on BH mass and redshift. Its average value is close to 0.5%
- We need:
  - Robust calibrators of kinetic power in radio AGN
  - A clear idea of the role of AGN winds is radiatively efficient QSOs