AGN/Galaxy Co-Evolution

Fabio Fontanot (HITS)

AGN10 11/09/12

Heidelberger Institut für Theoretische Studien

HITS

Outline of review talk

- **AGNs in theoretical models of galaxy formation**

Outline of (biased) review talk

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- **AGNs in theoretical models of galaxy formation**
  - **Semi-Analytic Models of galaxy formation**
  - **SMBH growth**
  - **“Modes” of AGN feedback**
  - **“Popular” models**

Outline of (biased) review talk

- AGNs in theoretical models of galaxy formation
  - Semi-Analytic Models of galaxy formation
  - SMBH growth
  - “Modes” of AGN feedback
  - “Popular” models
- Testing evidences for co-evolution
  - Local Universe (z~0)
  - Intermediate Universe (z<5)
  - Early Universe (z>5)

Theory

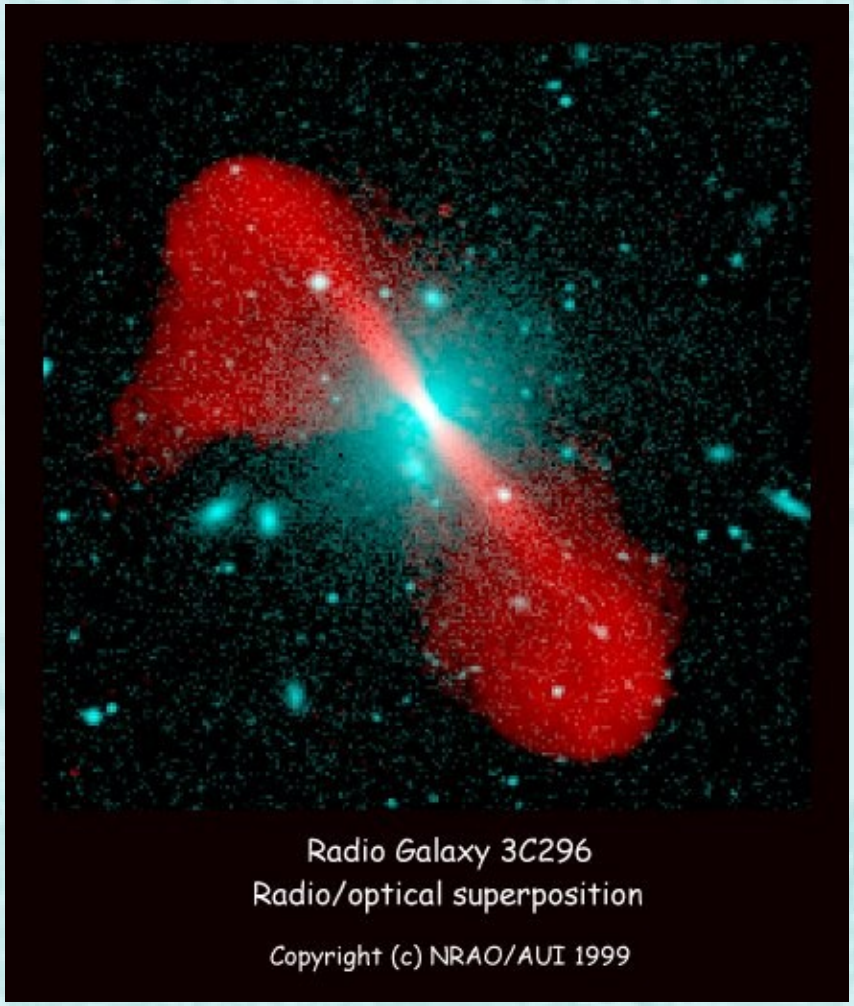
Different regimes for AGN feedback

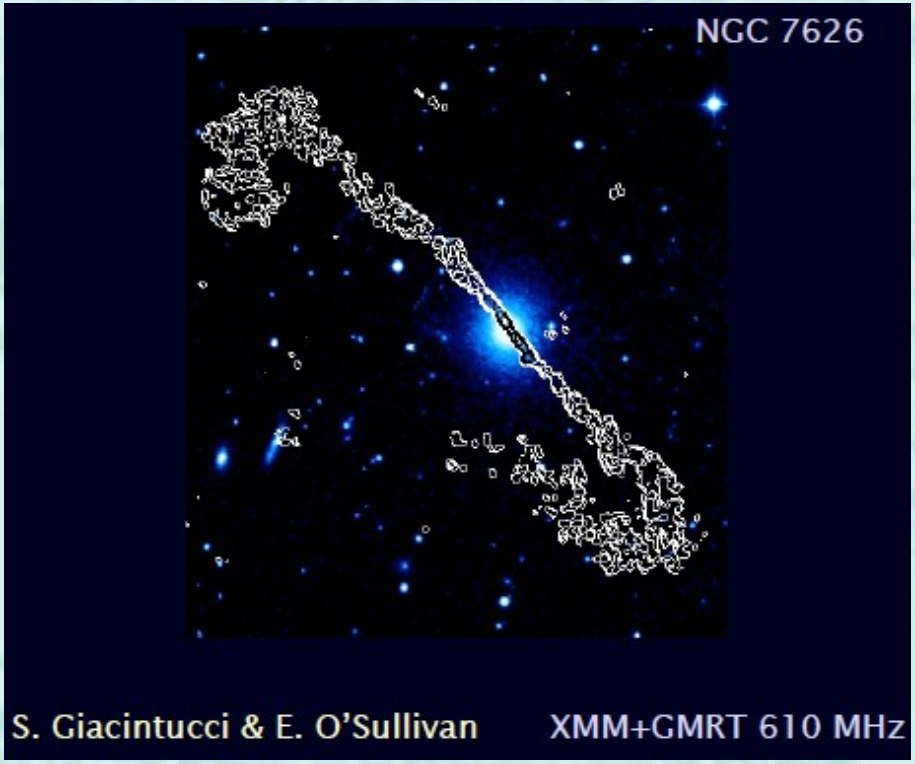
Different regimes

- **“Radio”-mode**
- **Low-accretion**

Different regimes

- **“Radio”-mode**
- **Low-accretion**
- **Development of radio jets**





Different regimes

- “Radio”-mode
- Low-accretion
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- Keep massive galaxies red
- Hot Haloes
  - Dry Mergers?
- LargeScales (DMH)

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Different regimes

- **“Quasar”-mode**
- **High-accretion**
- **Bright-phase**
- **Galaxy Mergers**

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Springel+05

Hopkins+05,06,07,08

Different regimes

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  - Secular processes?

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- Small Scales (~kpc)
  - Triggering galactic winds?
- Rapid

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- Rapid
- Regulates BH mass

SA Models

Wang+08

- **“Bright”-mode**
  - **Related to minor and major mergers**

$$\Delta m_{\rm QM}^{\rm C06} = f_{\rm BH}\,\zeta_m\,\frac{M_{\rm cold}}{1+\left(\frac{V_{\rm vir}}{280{\rm km/s}}\right)^{-2}}$$

- **“Radio”-mode**
  - **Accretion of hot gas from static atmosphere**
  - **Accretion rate proportional to halo mass**

$$\dot{m}_{\rm RM}^{\rm C06} = \kappa_{\rm C06}\left(\frac{M_{\rm BH}}{10^8 M_\odot}\right)\left(\frac{f_{\rm hot}}{0.1}\right)\left(\frac{V_{\rm vir}}{200{\rm km/s}}\right)^3$$

(See also Croton+06)

Menci+08

- **“Bright”-mode**
  - **Related to galaxy interactions**
  - **Mergers & Fly-bies**

$$f_{\rm acc} \approx 10^{-1} \left| \frac{\Delta j}{j} \right| = 10^{-1} \left\langle \frac{m'}{m} \frac{r_d}{b} \frac{v_d}{V_{\rm rel}} \right\rangle .$$

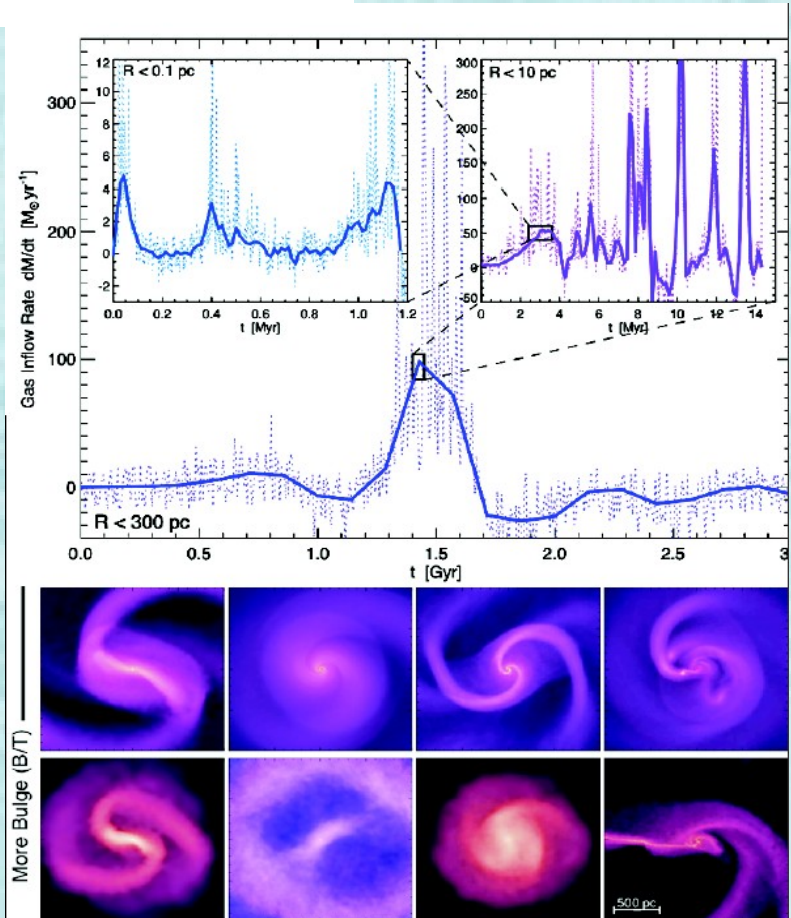
$$L = \frac{\eta c^2 \Delta m_{\rm acc}}{\tau} .$$

Somerville+08

- "Bright"-mode
  - QSO Light curve model for BH accretion
    Hopkins+05+07+09

$$\log(M_{\rm BH}/M_{\rm sph}) = -3.27 + 0.36\,{\rm erf}[(f_{\rm gas} - 0.4)/0.28]$$

$$M_{\rm BH,crit} = 1.07\,f_{\rm BH,crit}\,(M_{\rm BH}/10^9\,M_\odot)$$



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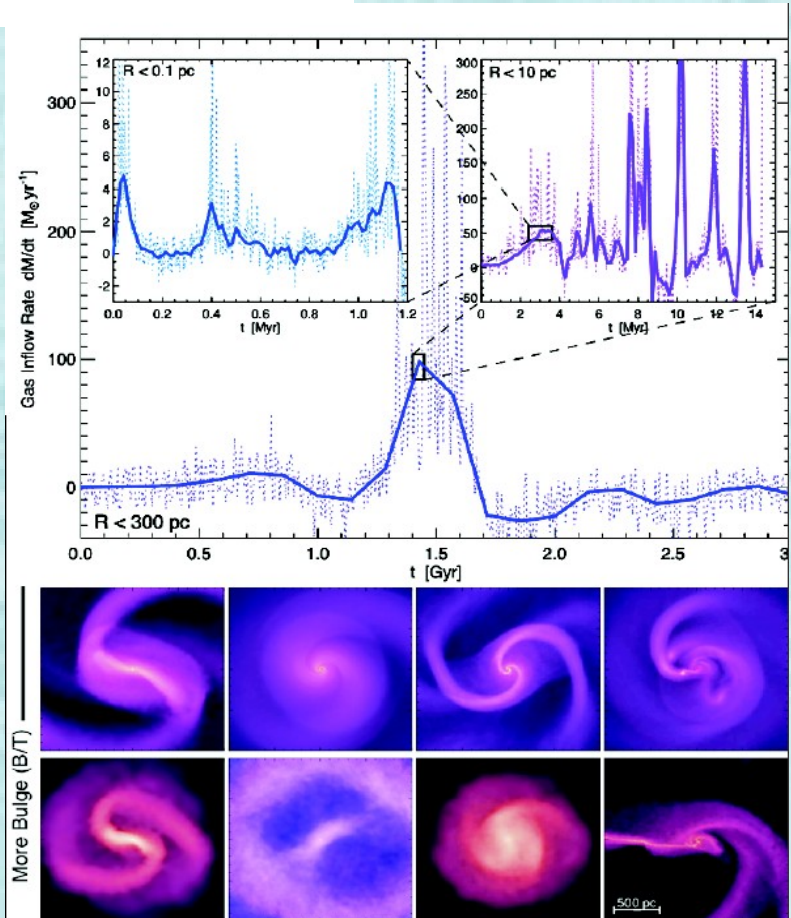
- **"Radio"-mode**
  - **Bondi-Hoyle Accretion**

$$\dot{m}_{\rm bondi} = \pi\, (G M_{\rm BH})\, \rho(r_{\rm A})\, c_s^{-3}$$

$$\dot{m}_{\rm RM}^{\rm S08} = \kappa_{\rm S08} \left(\frac{kT}{\Lambda(T, Z_h)}\right) \left(\frac{M_{\rm BH}}{10^8\, M_\odot}\right)$$



MORGANA

- **Unified accretion scheme**
  - **Based on Umemura+01 and Granato+04**
  - **Gas accretion from a reservoir by viscosity**

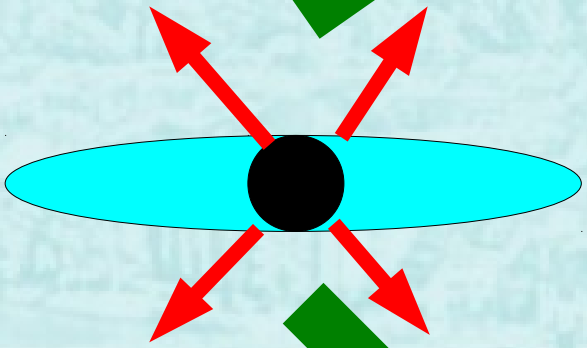
$$\dot{m}_{\rm resv} = f_{\rm resv}\,\dot{m}_{\star,B}\left(\frac{\dot{m}_{\star,B}}{100 M_\odot}\right)^{\alpha_{\rm resv}-1}$$

$$\dot{m}_{\rm BH}^{\rm M07} = \kappa_{\rm visc}\left(\frac{\sigma_B^3}{G}\right)\left(\frac{M_{\rm resv}}{M_{\rm BH}}\right)^{3/2}\left(1+\frac{M_{\rm BH}}{M_{\rm resv}}\right)^{1/2}$$

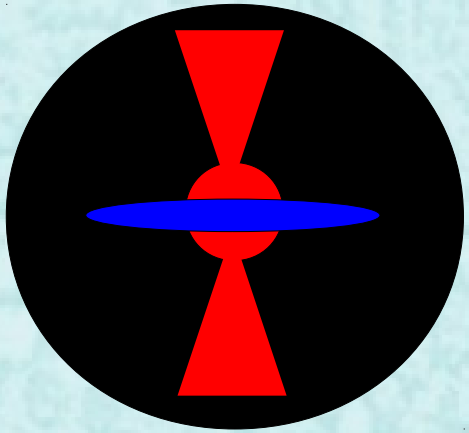
- **Accretion Rate determines feedback scheme**
  - **High accretion rates = “bright”-mode**
  - **Low accretion rates = “radio”-mode**

BRIGHT-MODE

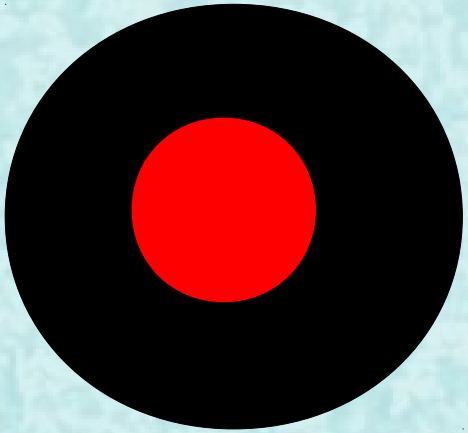
Coupling between AGN and stellar feedback may lead to ...



5) Triggering of Galactic Winds

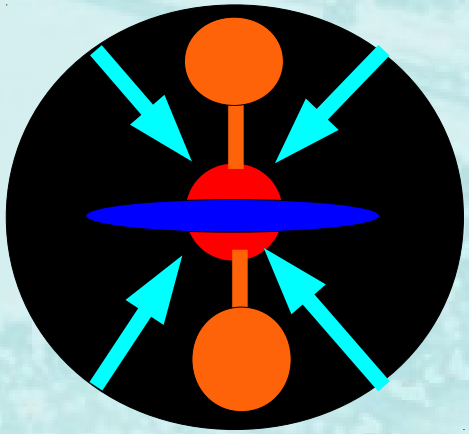


6) Quenching of Star Formation

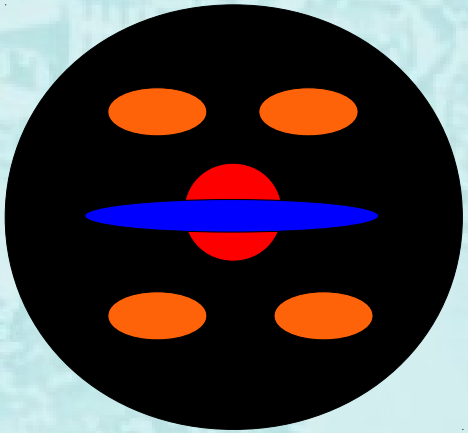


RADIO-MODE

5) Jet Development



6) Quenching of Cooling Flows



Malbon+07

- **“Bright”-mode**
  - **Related to mergers and disk instabilities**

$$\Delta M_{\rm stars} = \frac{(1 - {\rm e}^{-{\rm efold}})(1 - R_{\rm burst})}{(1 - R_{\rm burst}) + \beta_{\rm burst} + f_{\rm sw,burst}} M_{\rm cold}.$$

$$\Delta M_{\rm BH} = F_{\rm BH} \Delta M_{\rm stars},$$

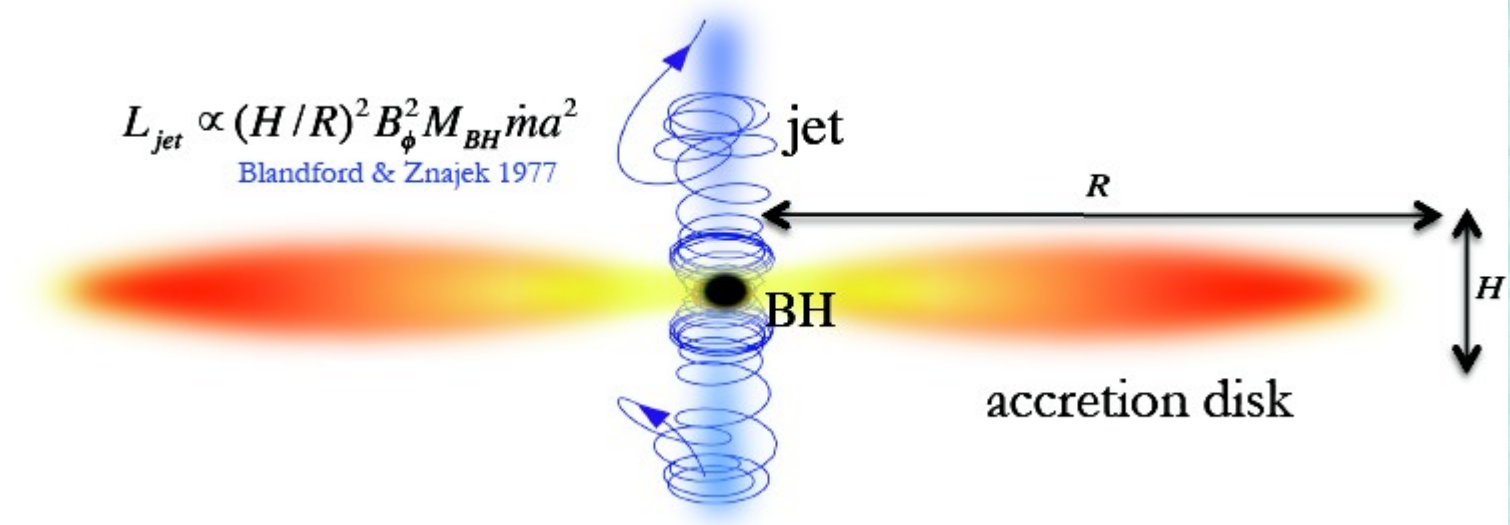
- **“Radio”-mode**

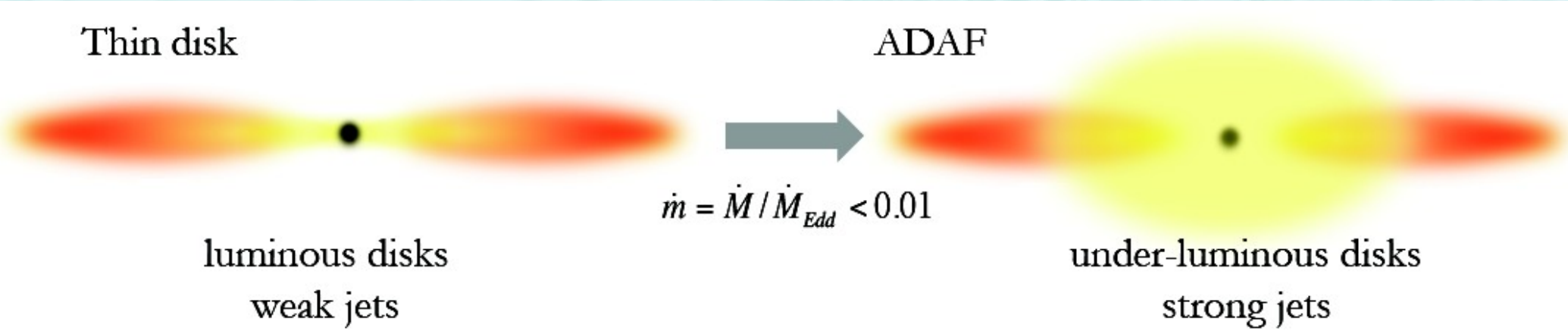
$$L_{\rm cool} < \epsilon_{\rm SMBH} L_{\rm Edd}.$$

(See also Bower+06)

Fanidakis+11

- **Accretion mode related to BH spin**





Theory vs Observations

Different regimes

- "Radio"-mode
- Low-accretion
- Development of radio jets
- Keep massive galaxies red
- Hot Haloes
  - Dry Mergers?
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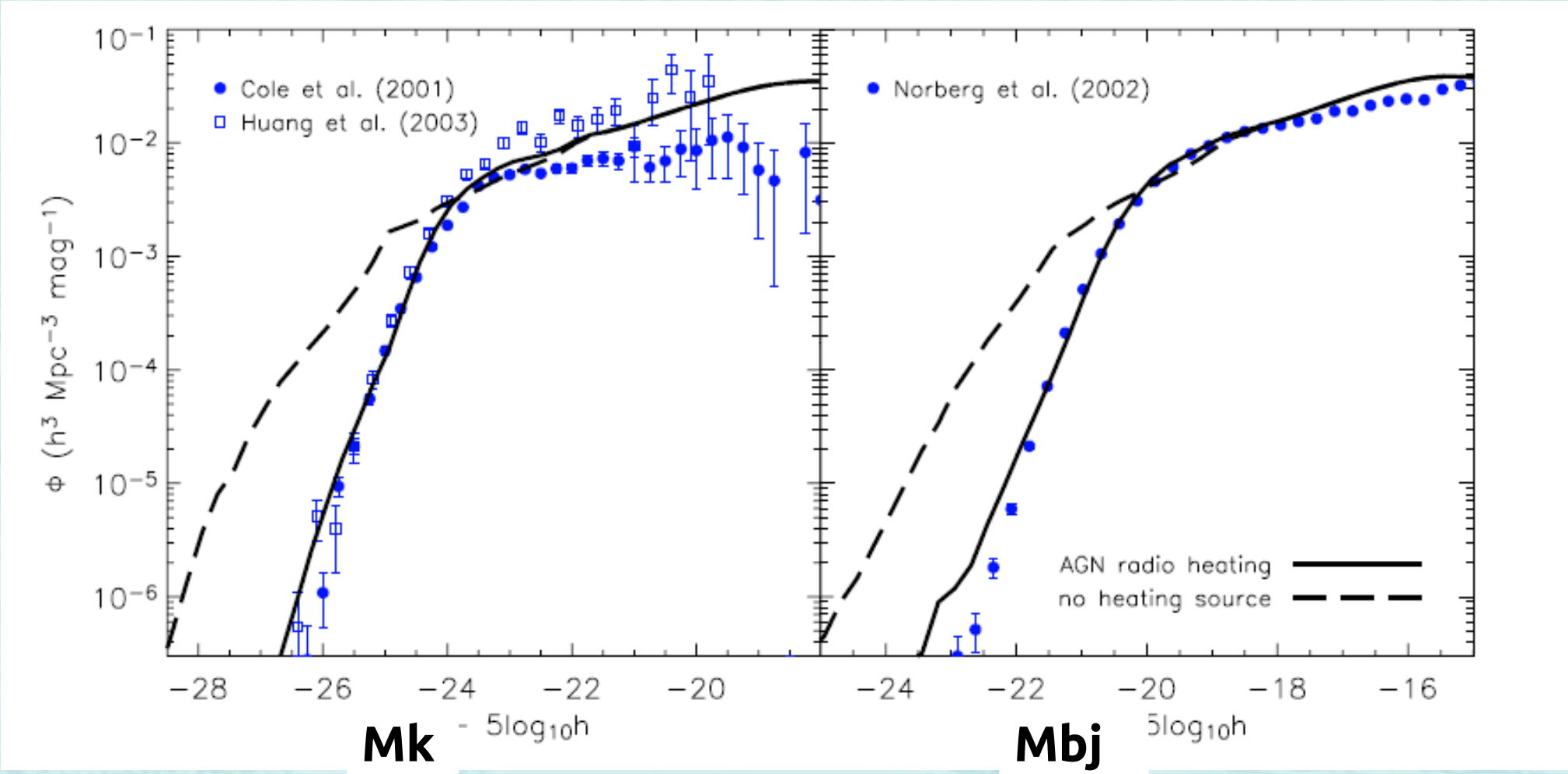
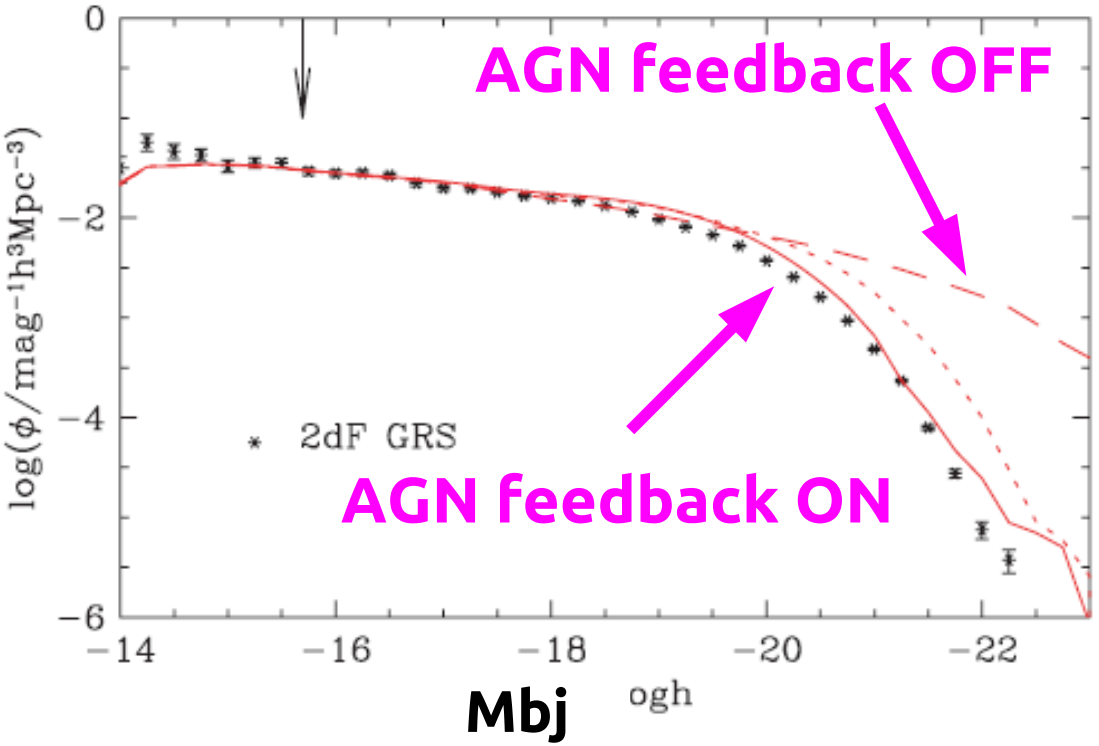
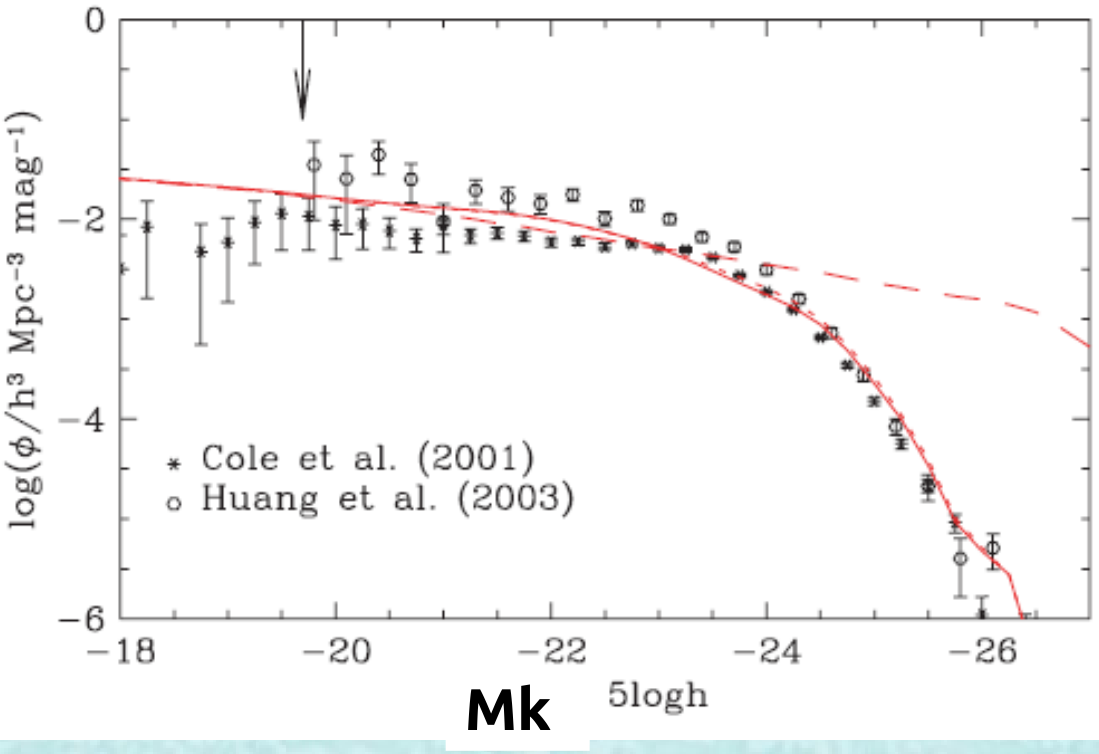
Galaxy Luminosity Functions



Croton+06

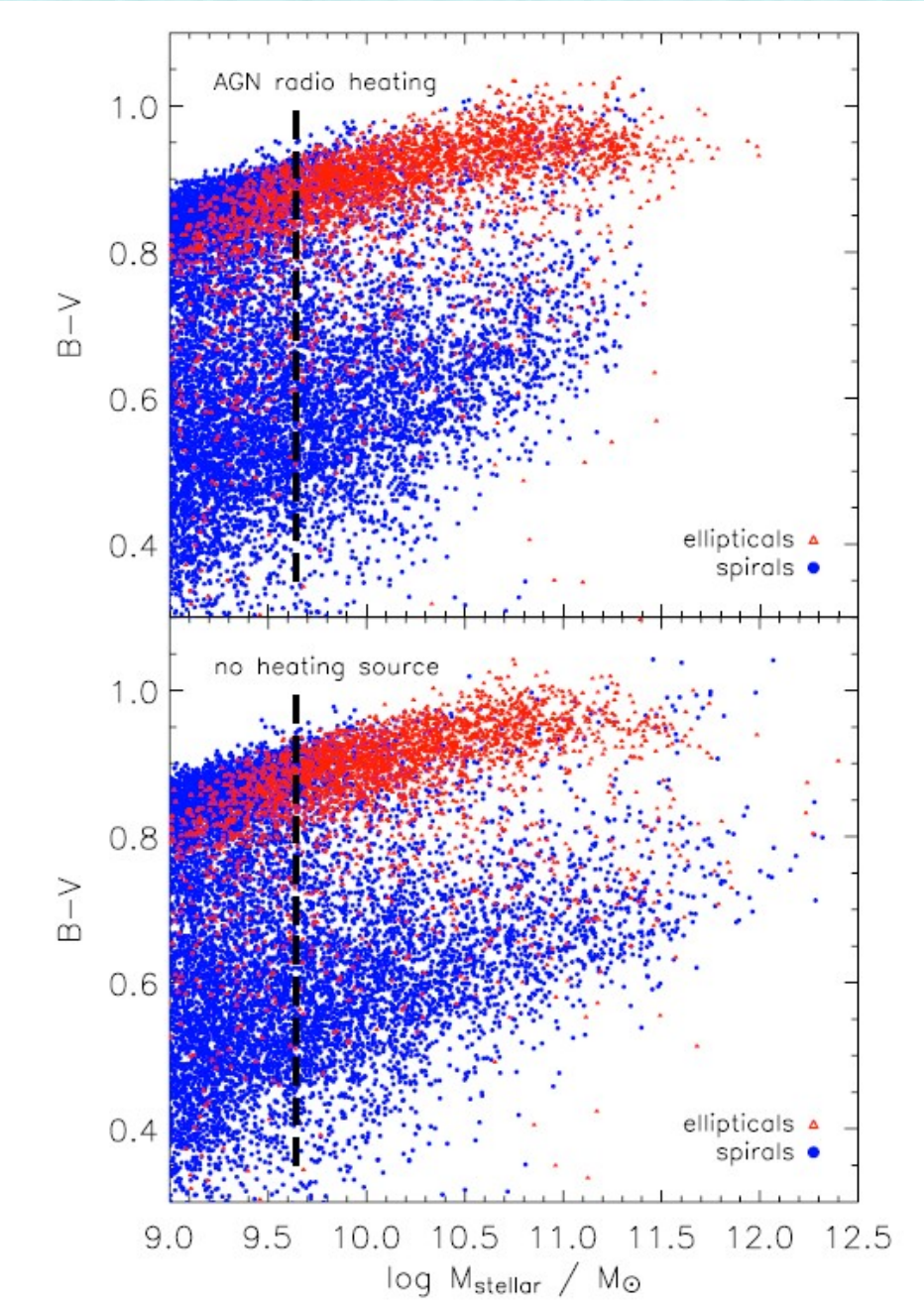
"Munich" group





Bower+06
"Durham" group

Bimodality



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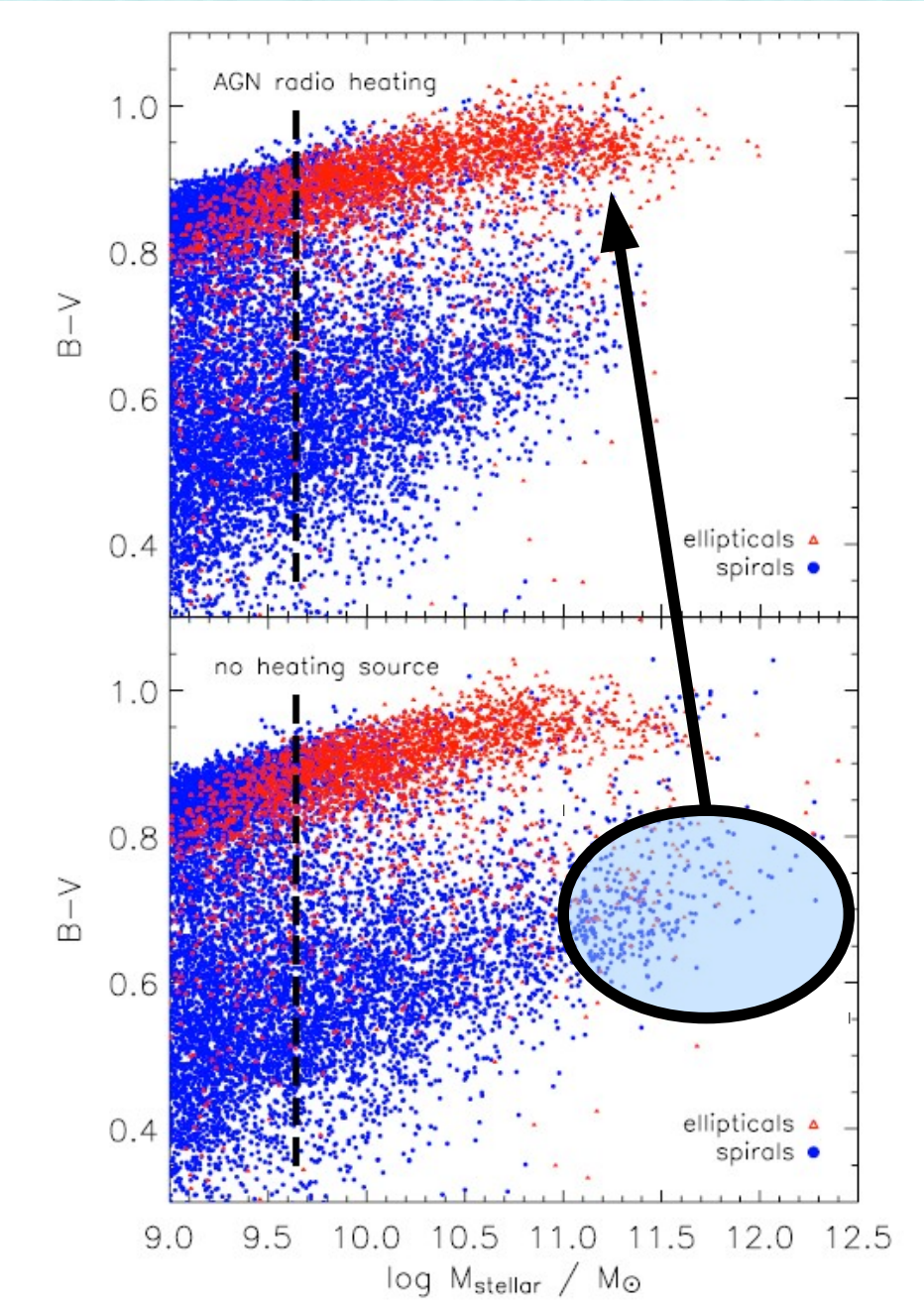

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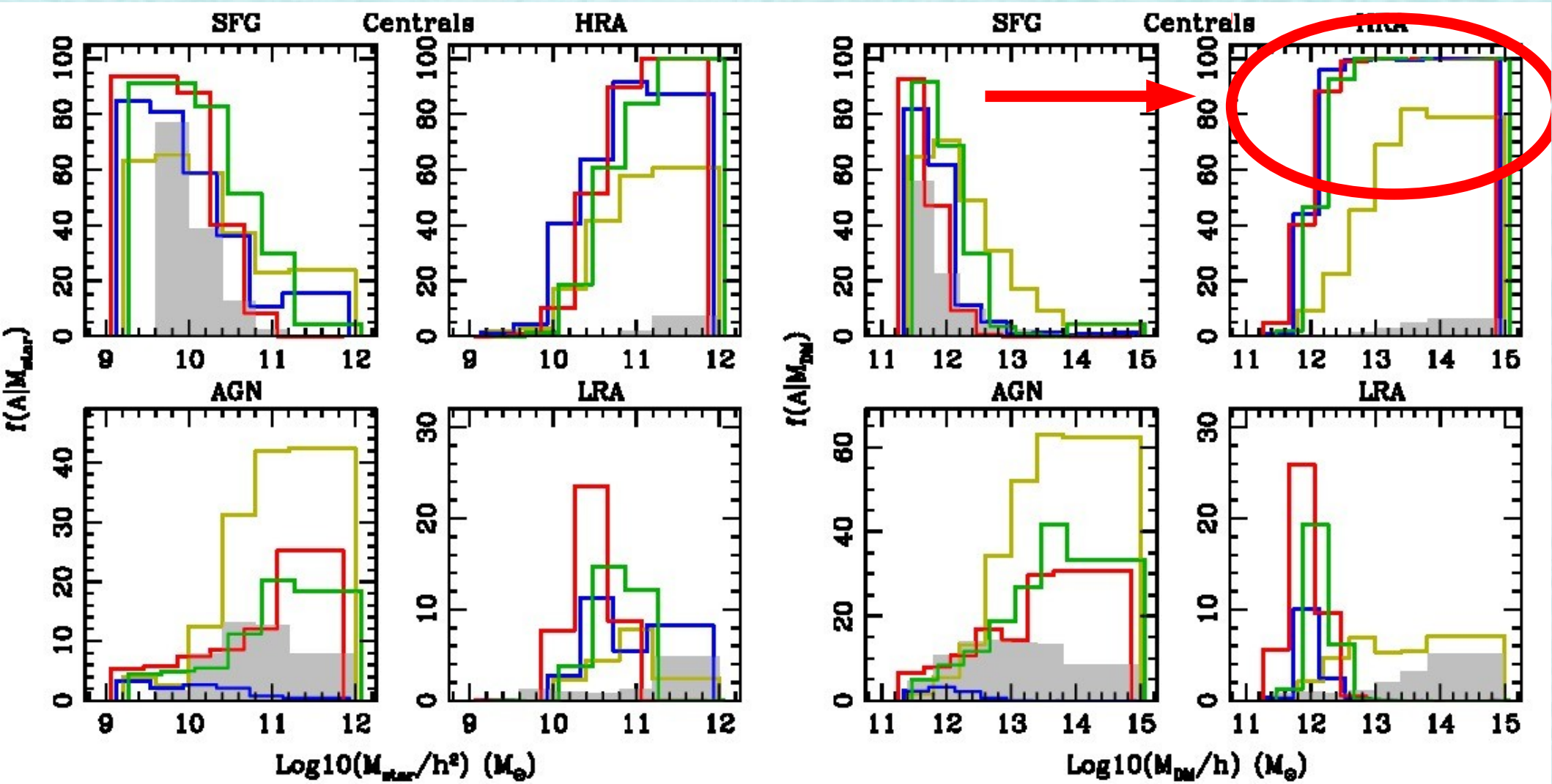
Central Galaxies

Fontanot+11

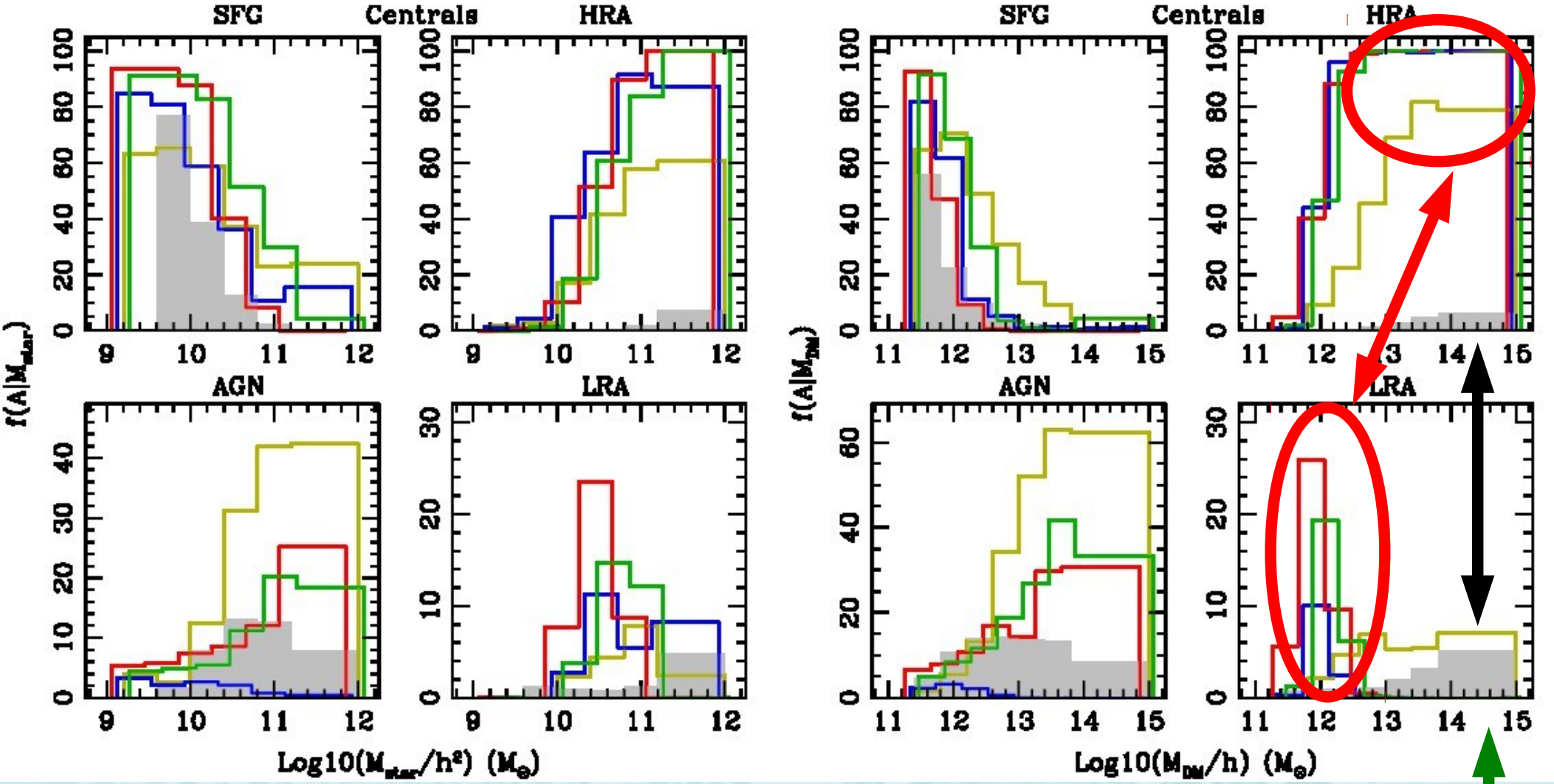


All Models

Central Galaxies

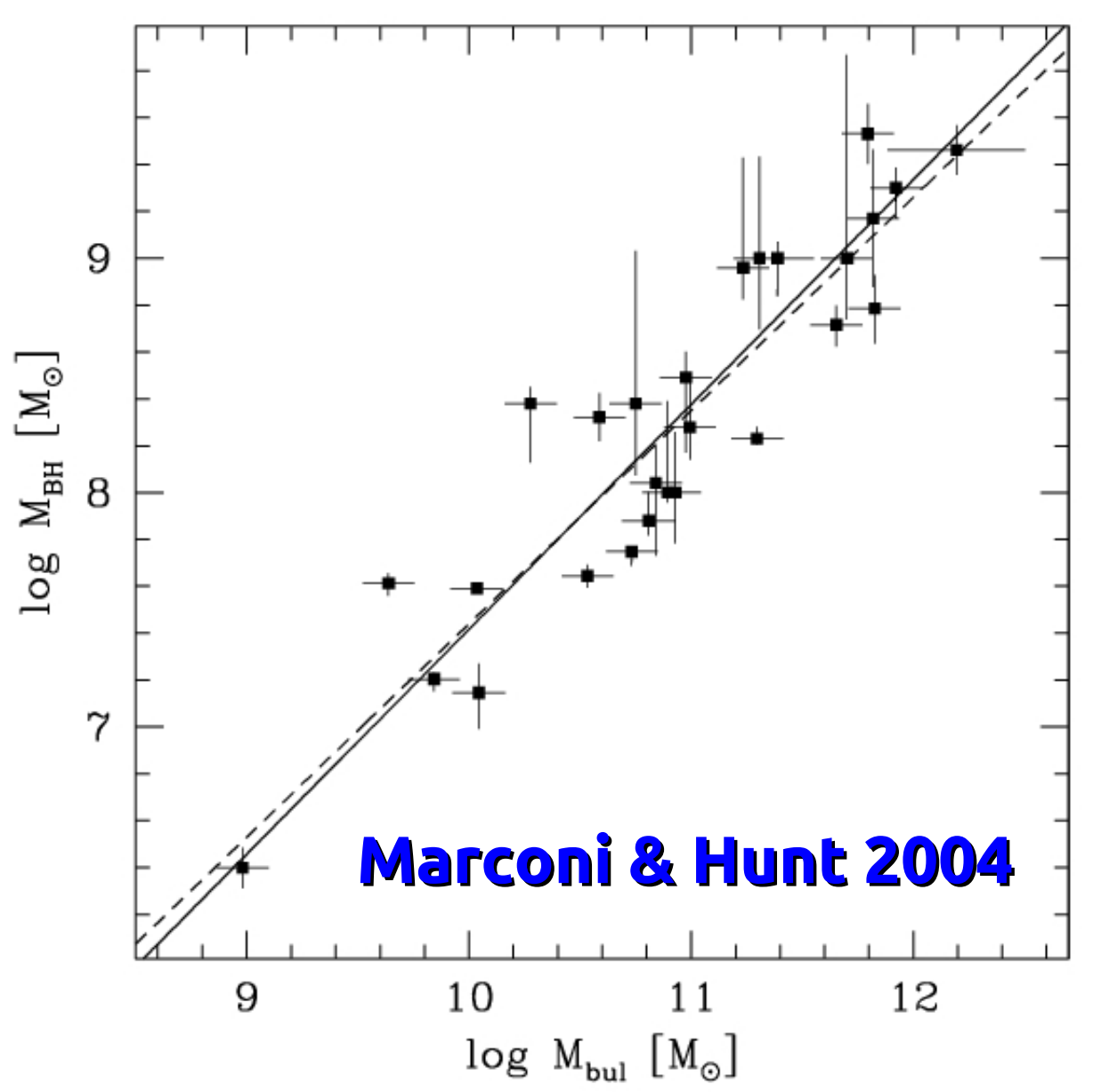
Fontanot+11

All Models



MORGANA

BH-bulge relation



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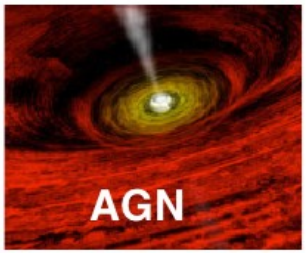
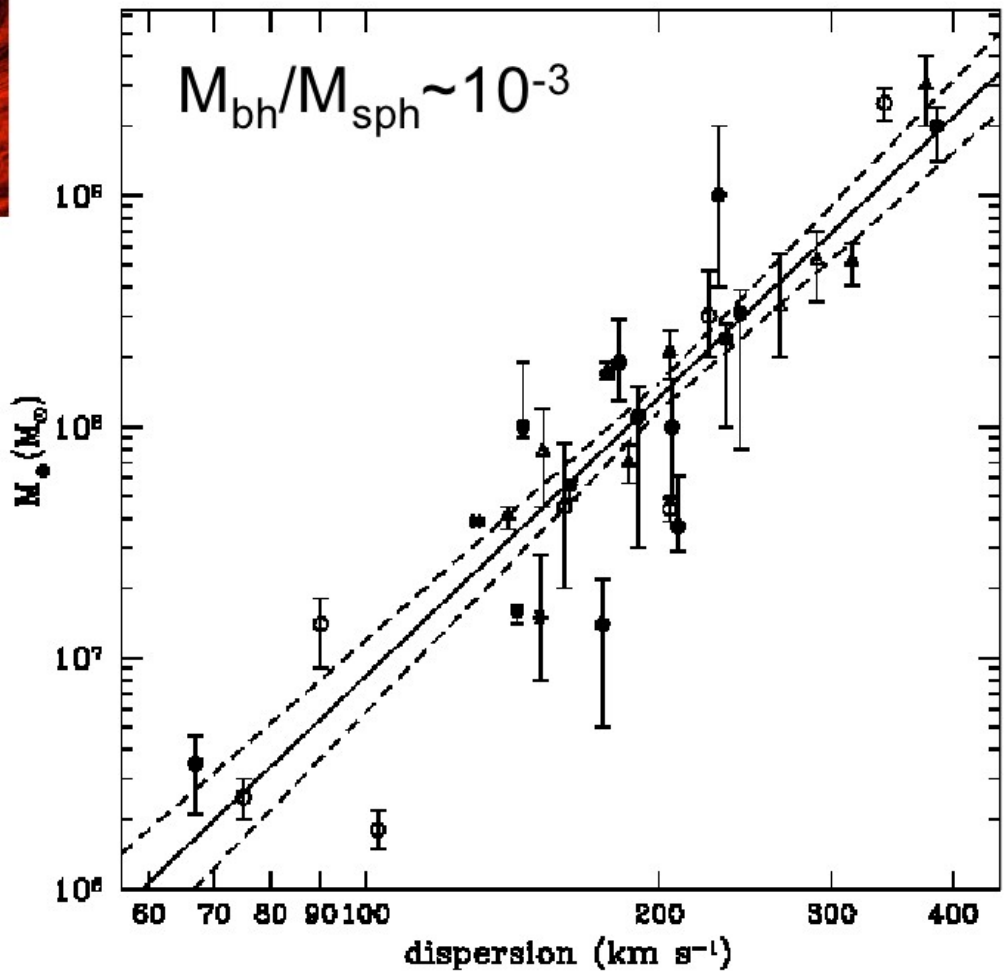


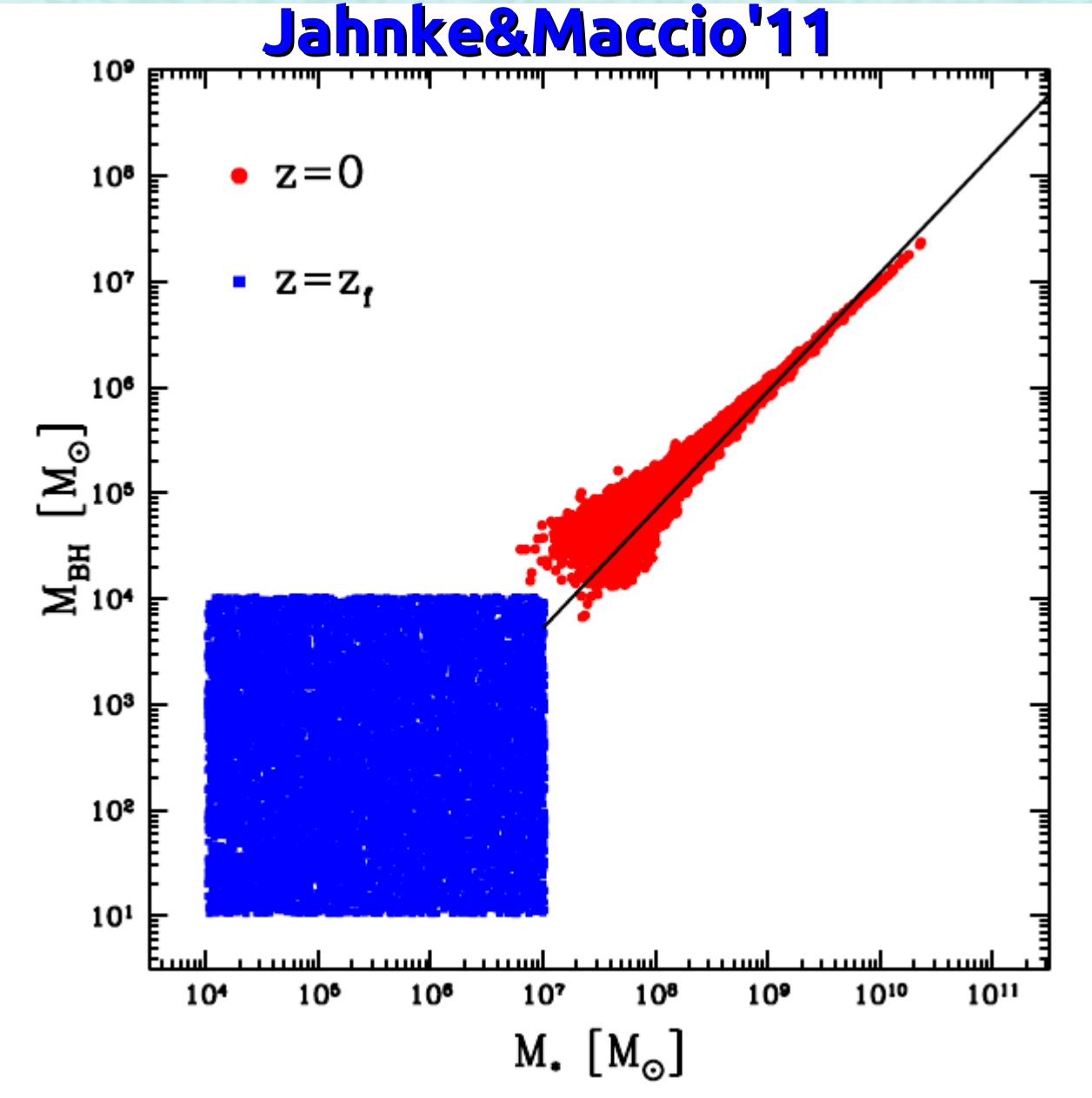
Driver: AGN activity



Driver: Star formation (gas accretion/mergers)

Credits Dave Alexander

Warning


Jahnke&Maccio'11
z=0
z=z_f
M_BH [M_⊙]
M* [M_⊙]
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
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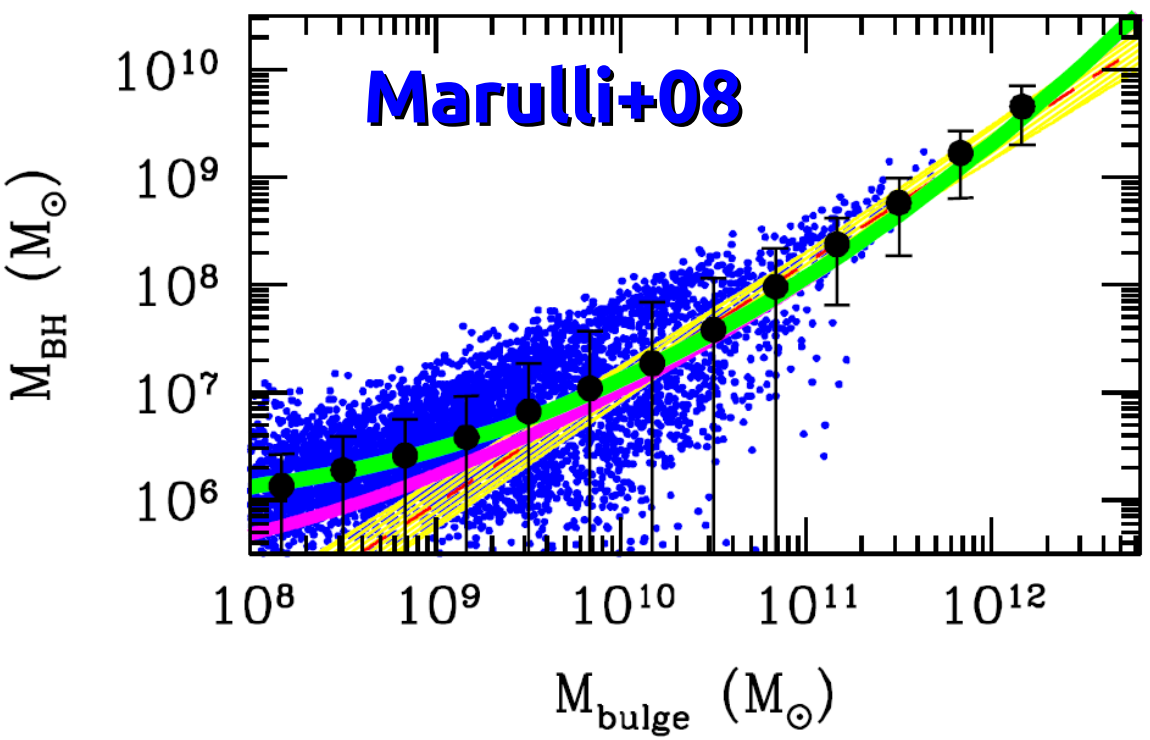
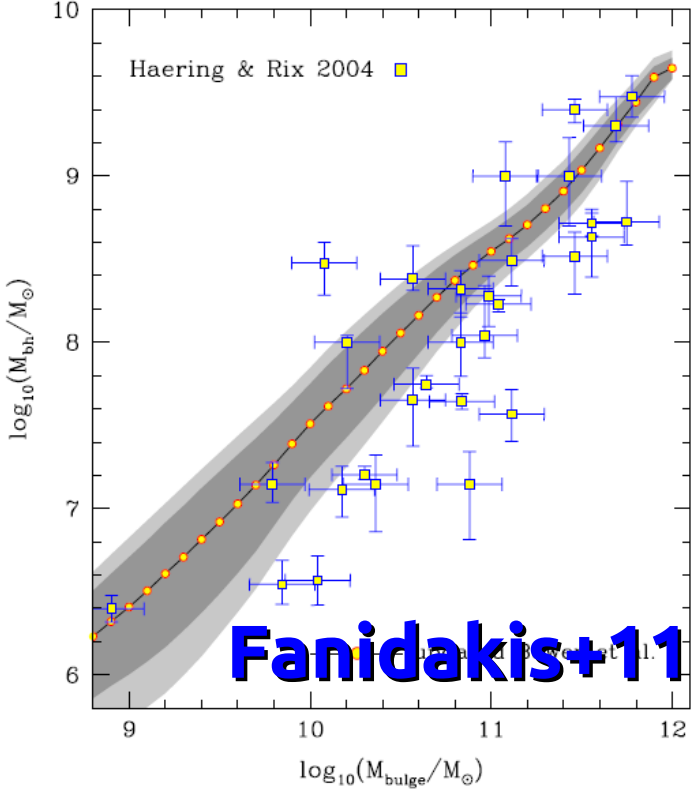
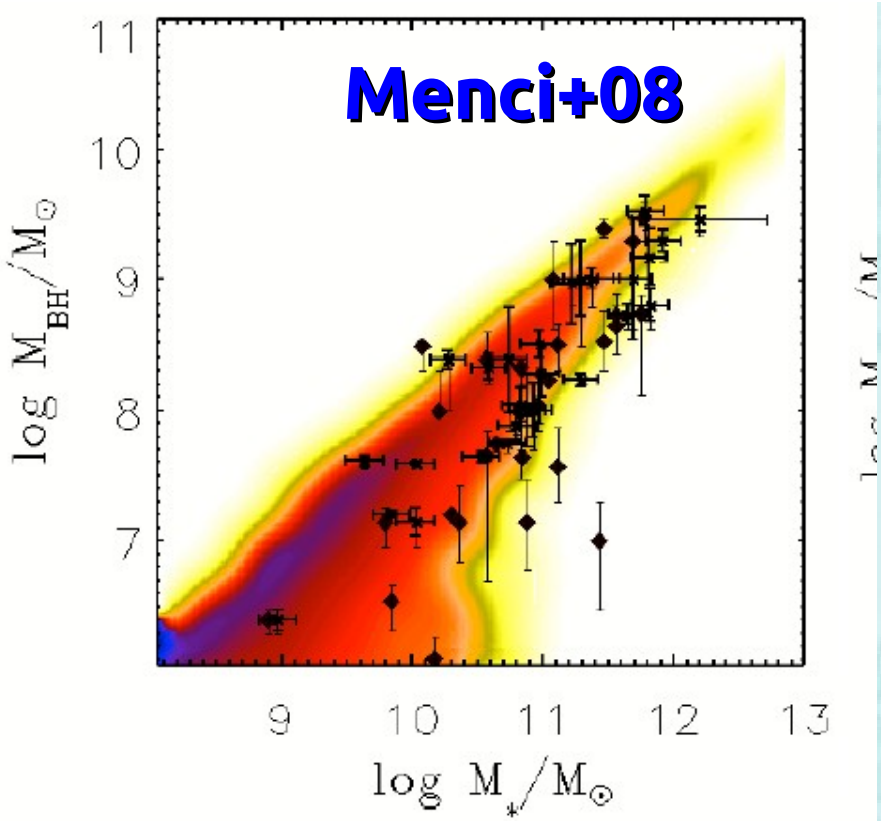
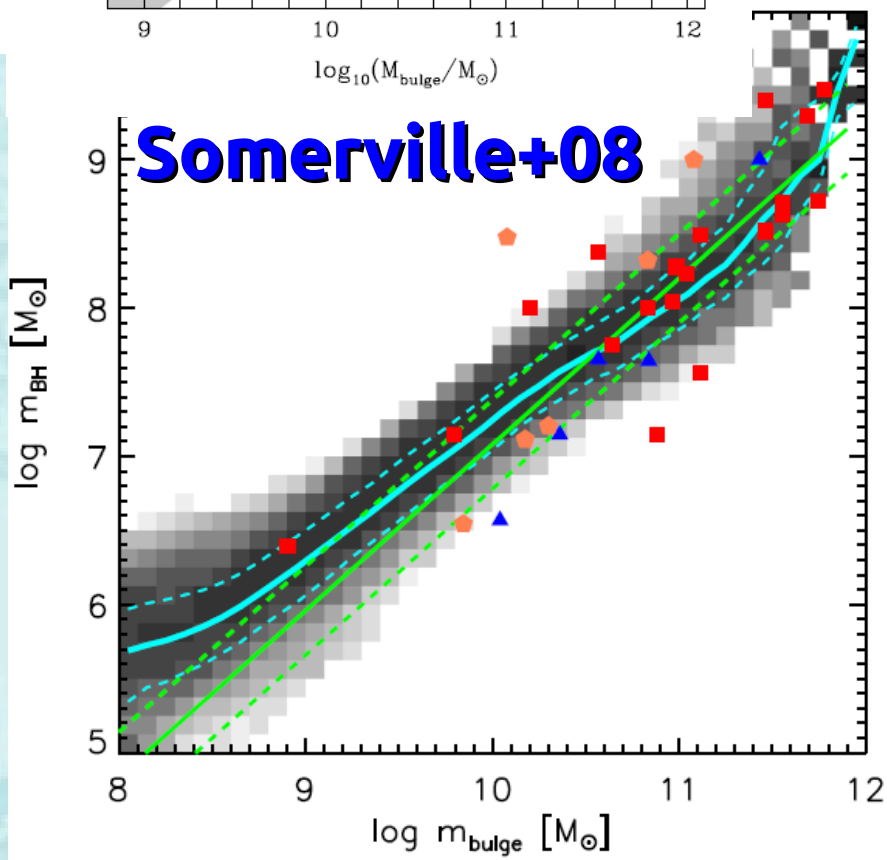
10^10
10^11

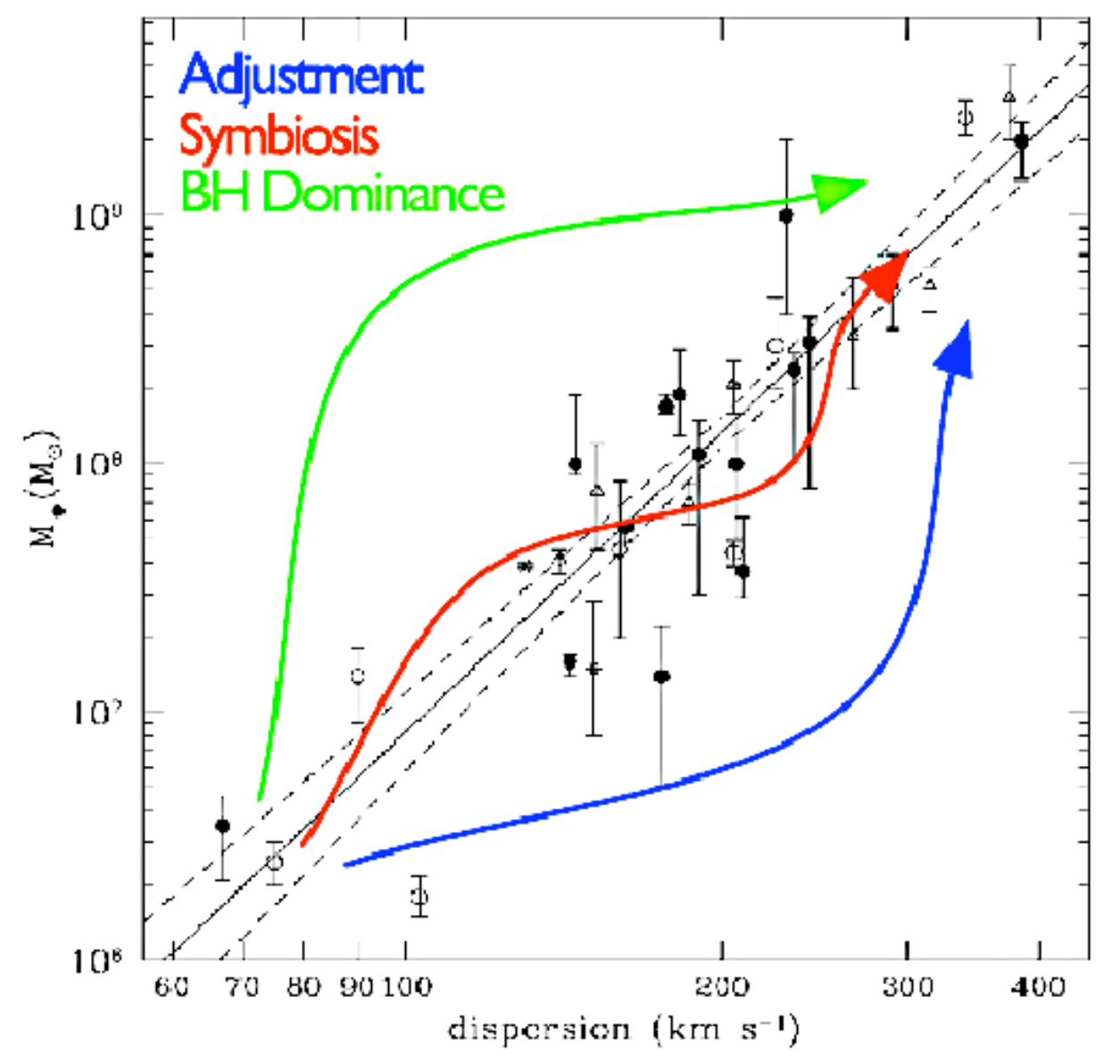

Marulli+08
M_{BH} ($M_\odot$)
M_{bulge} ($M_\odot$)


Haering & Rix 2004
Fanidakis+11
$\log_{10}(M_{bh}/M_\odot)$
$\log_{10}(M_{bulge}/M_\odot)$


Menci+08
log $M_{BH}/M_\odot$
log $M_*/M_\odot$

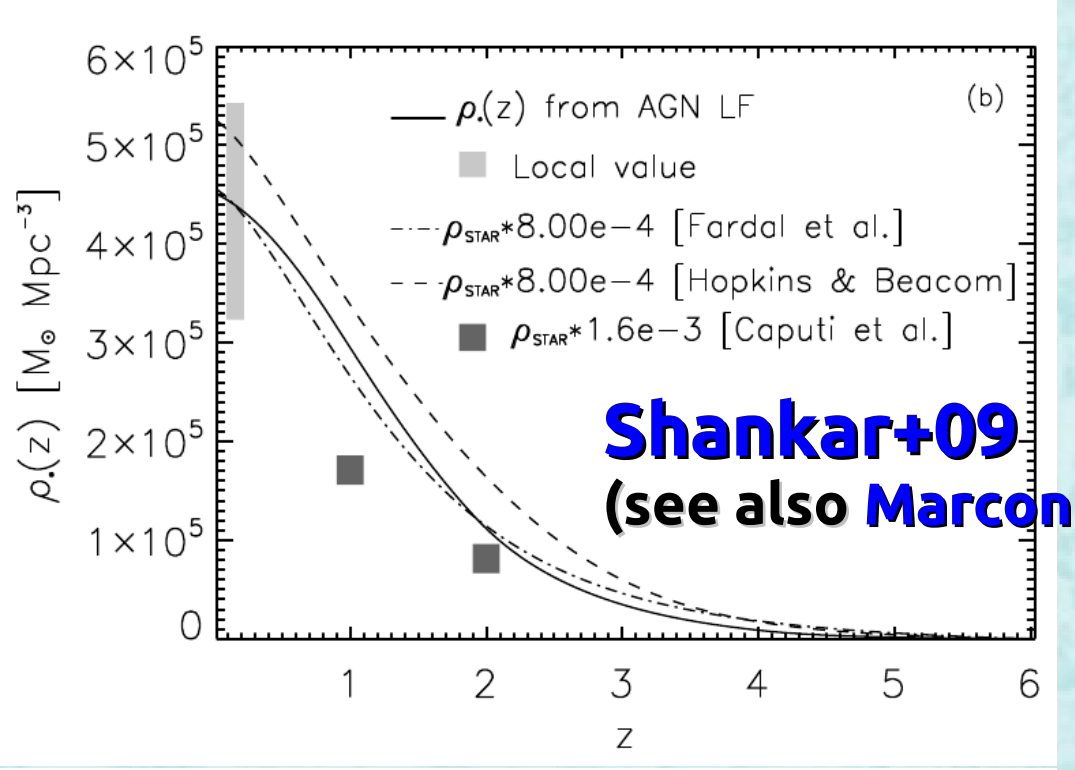

Somerville+08
log m_{BH} [$M_\odot$]
log m_{bulge} [$M_\odot$]

Assembly of BH-bulge relation

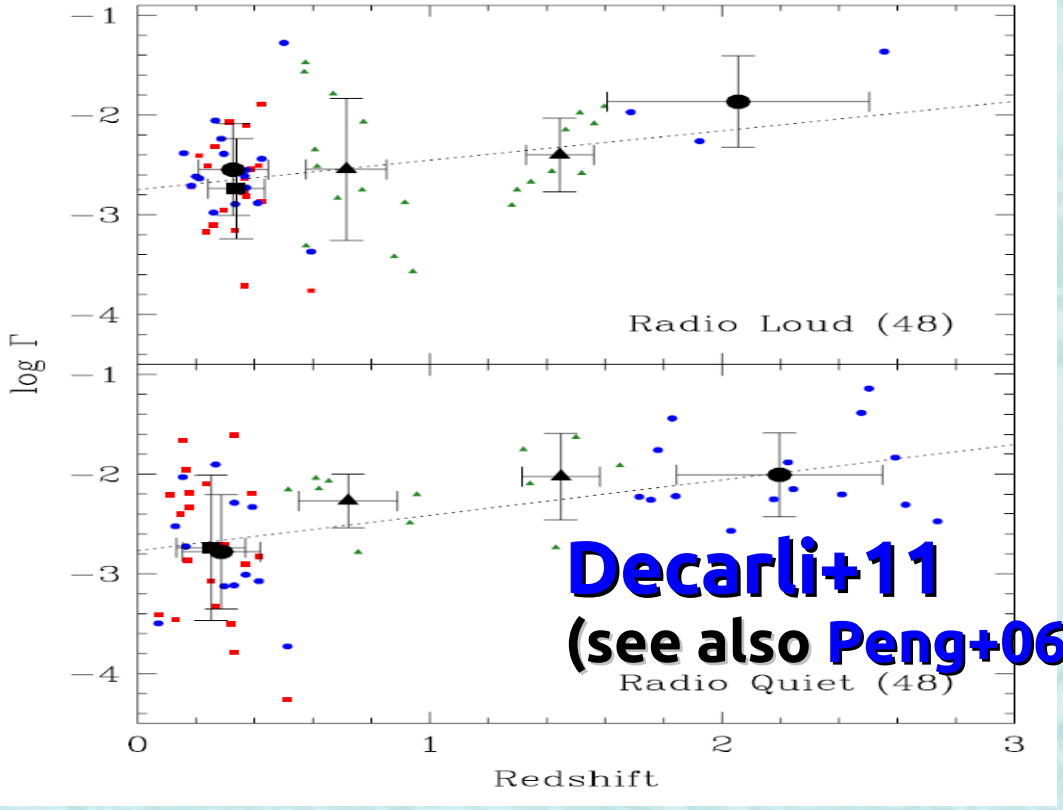


Colpi+07
Volonteri+10

Evolution of BH-bulge relation

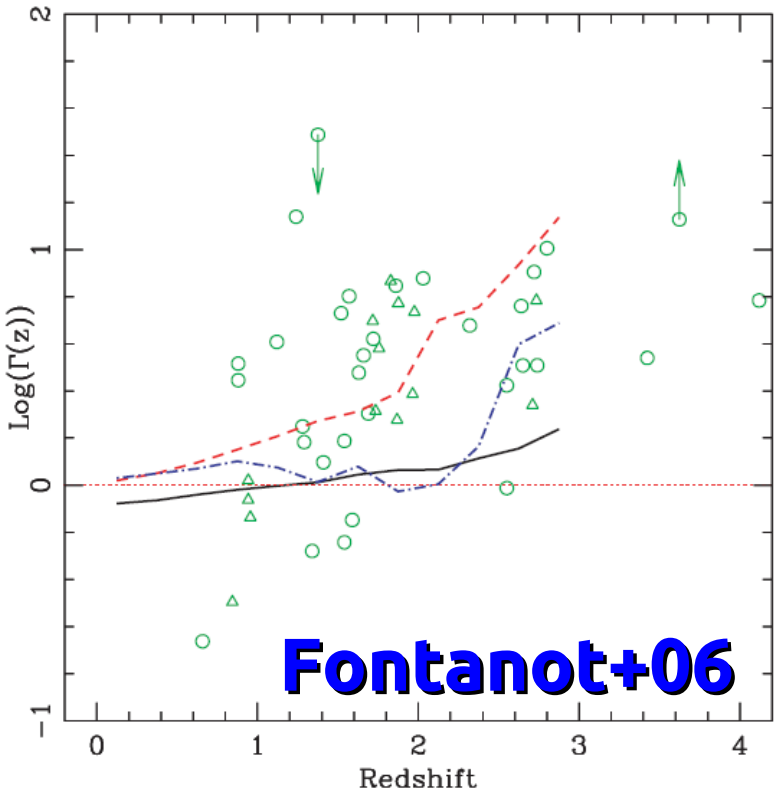


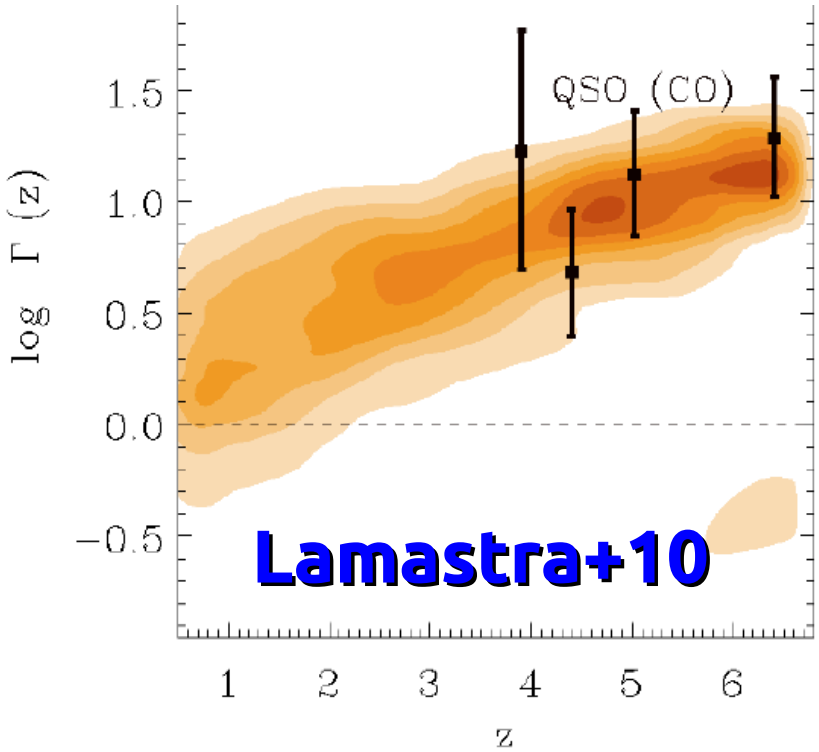
Shankar+09
(see also Marconi+04)

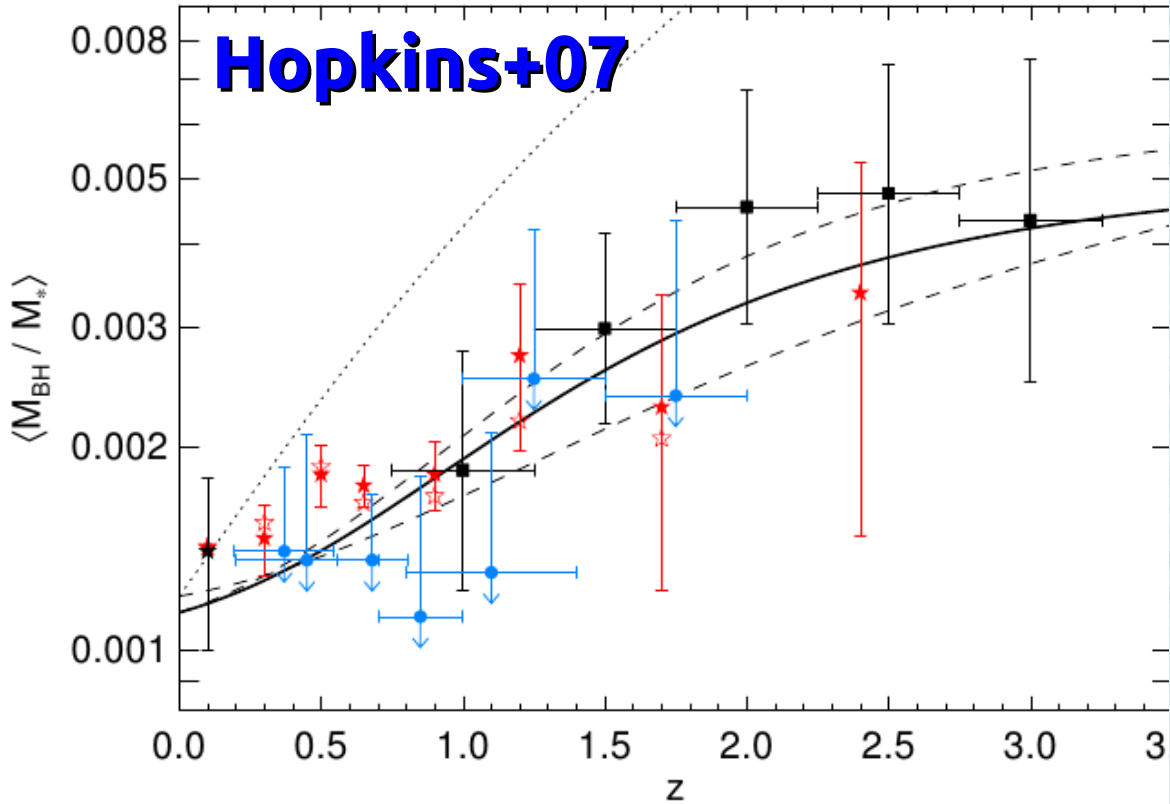


Decarli+11
(see also Peng+06)

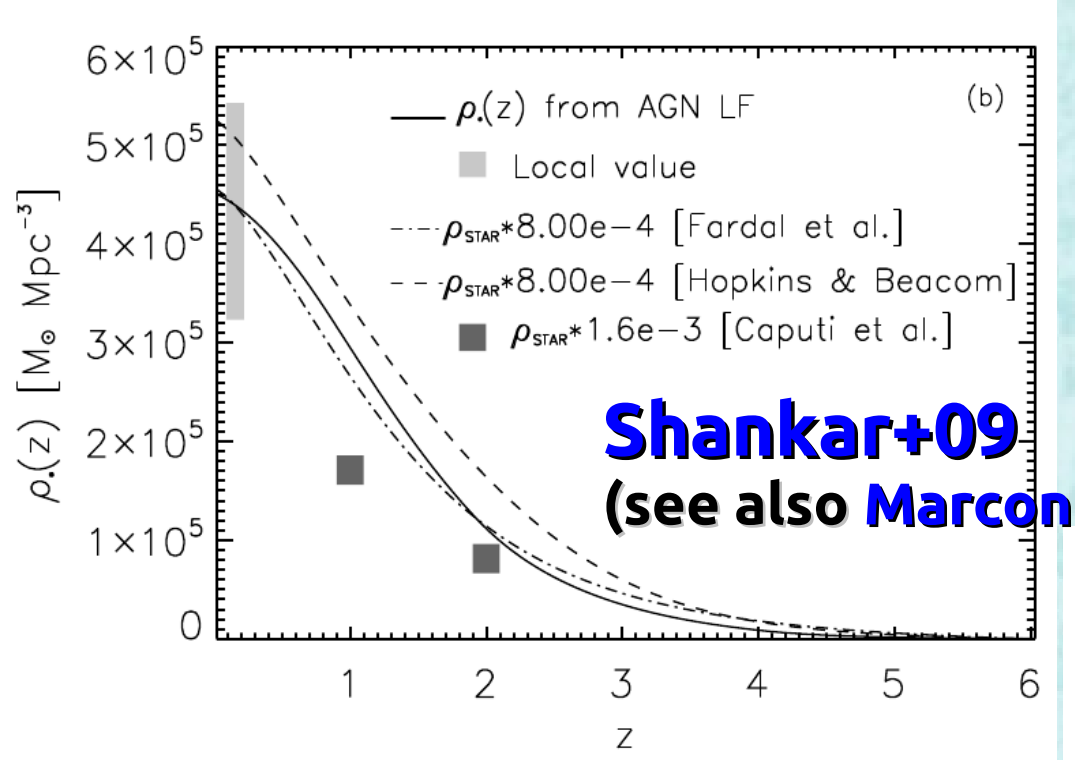
Evolution of BH-bulge relation







Evolution of BH-bulge relation



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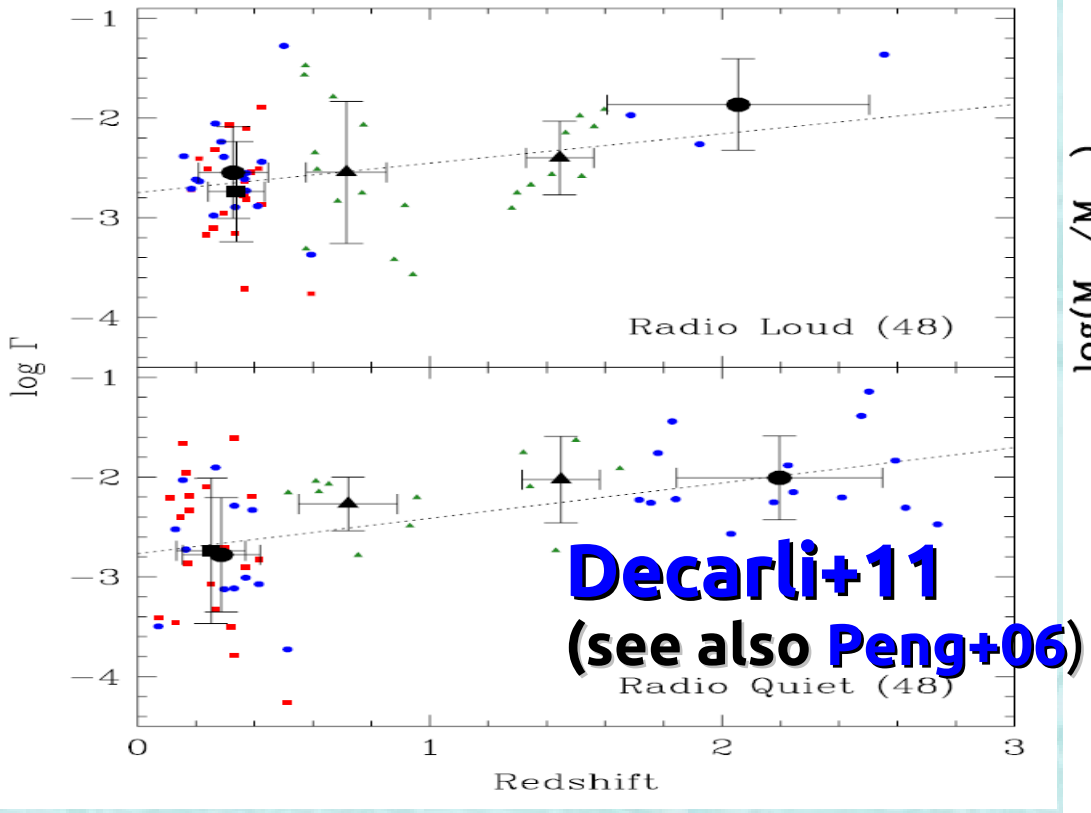

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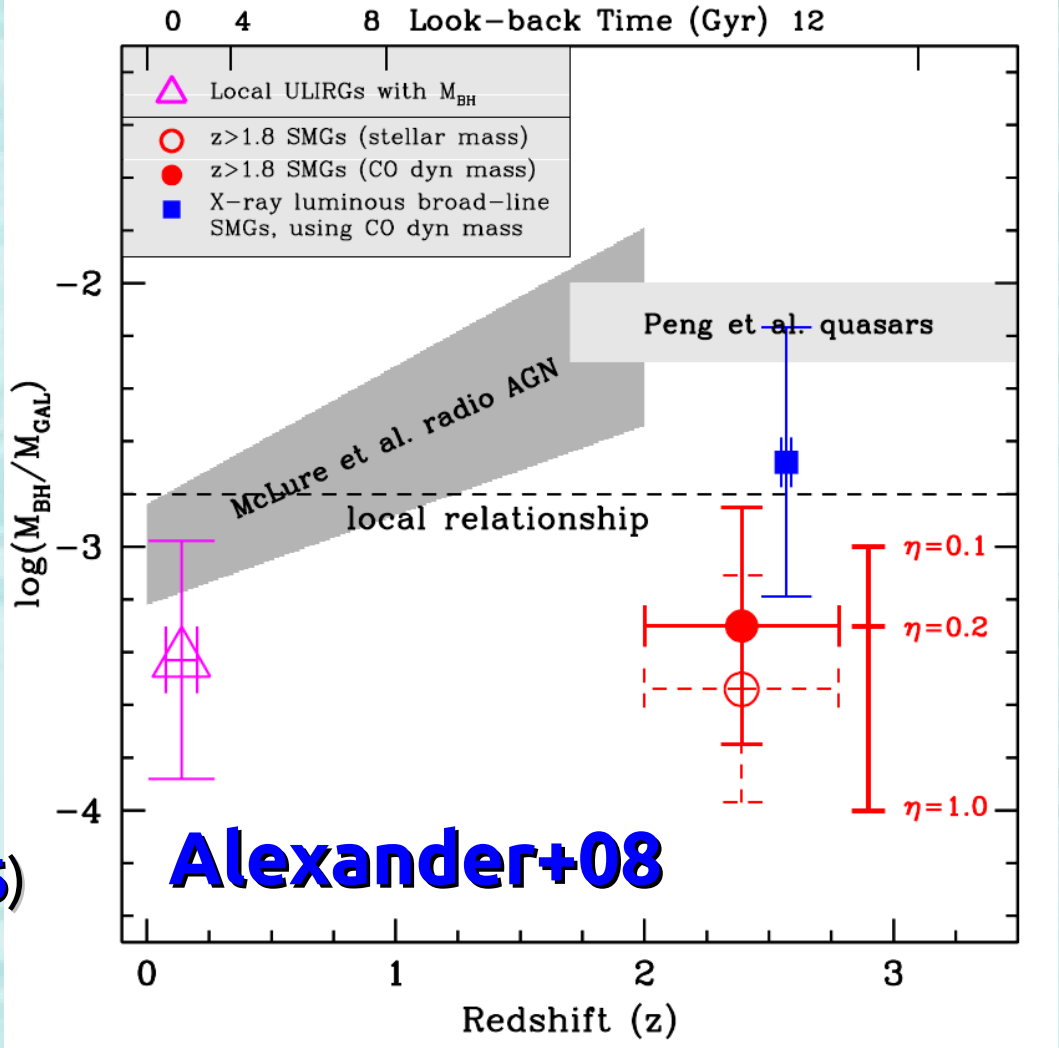
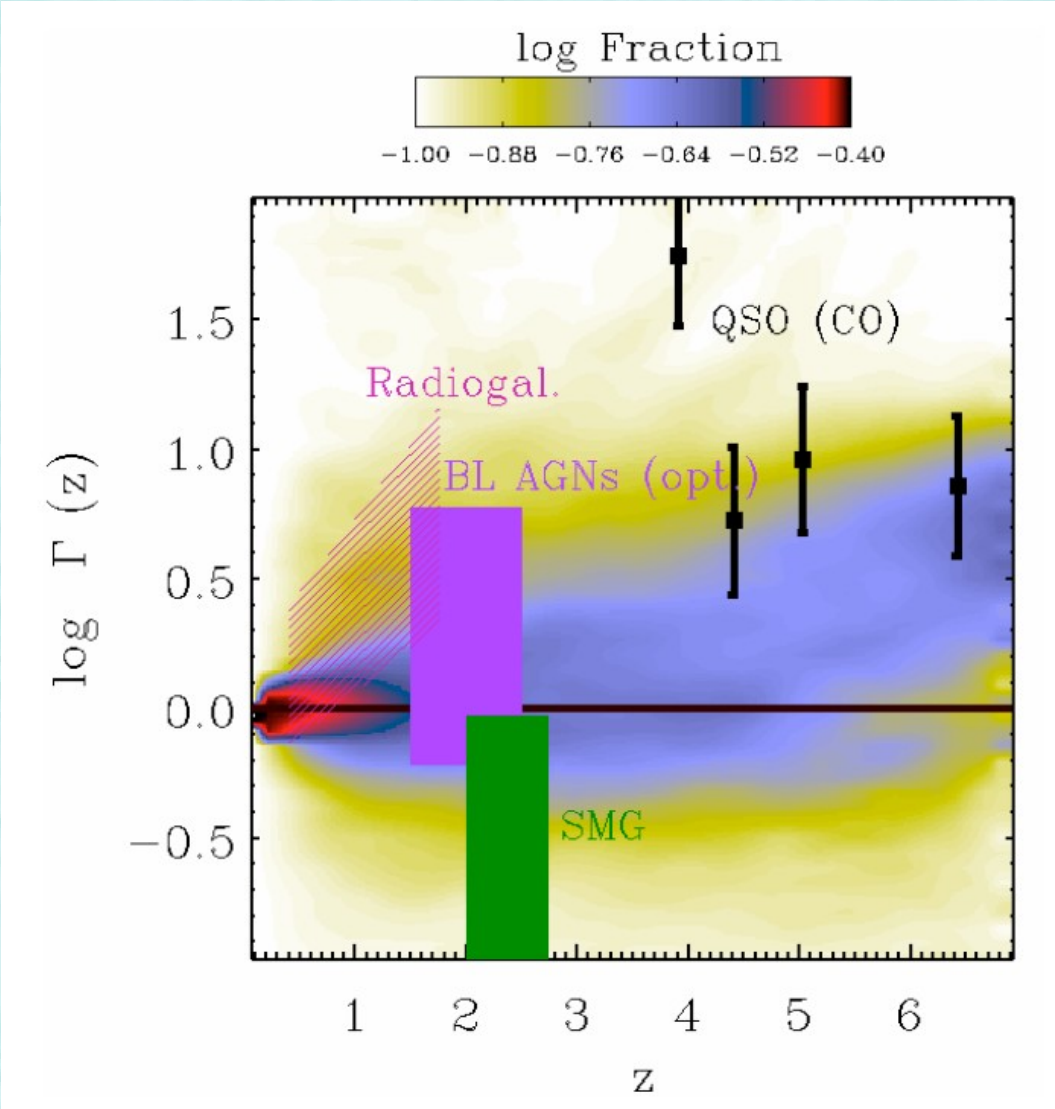
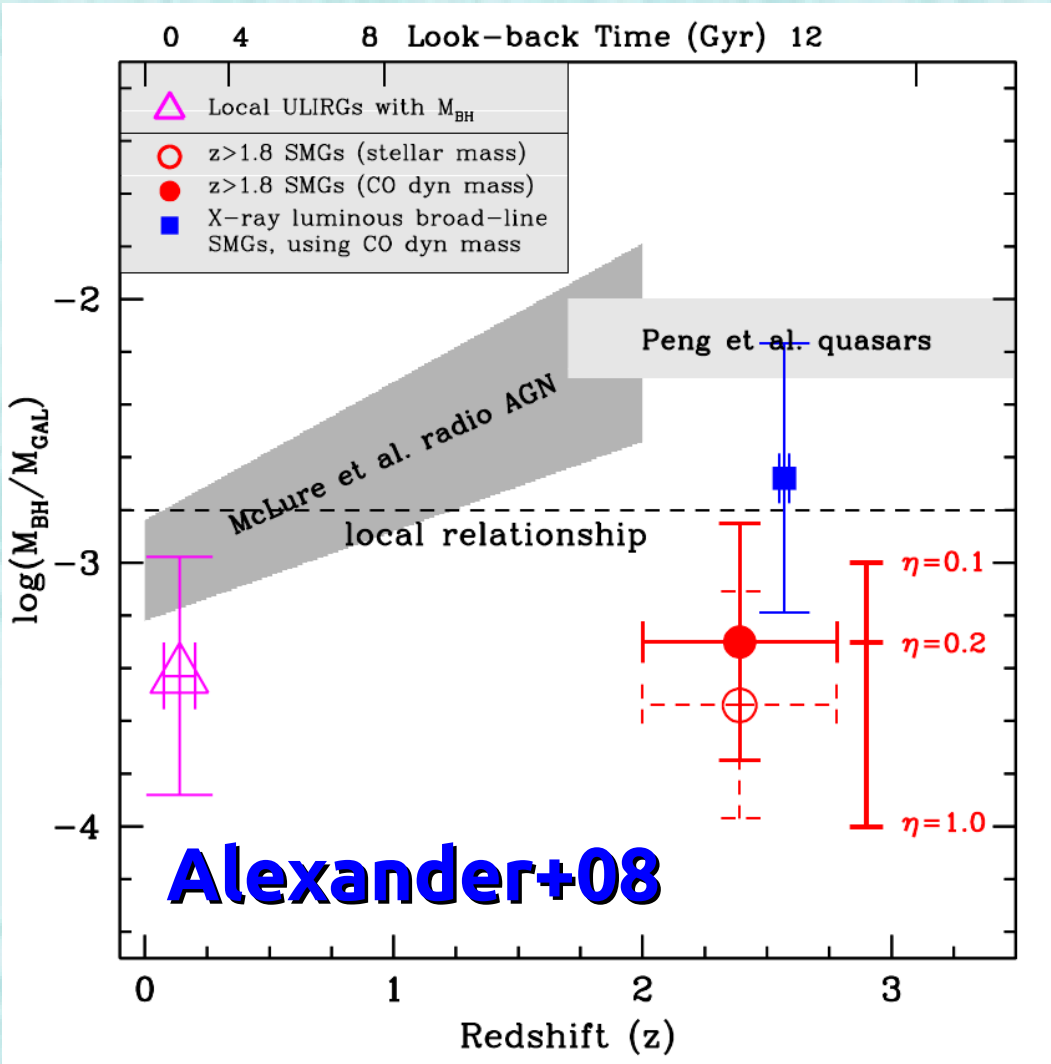


Alexander+08

Evolution of BH-bulge relation



Lamastra+10



Alexander+08

“Downsizing”

The Manifestations of “Downsizing”

- **DS in (specific) SFR**
  (Cowie+96,Zheng07,Noeske+07,Drory&Alvarez08,Dunne+08,Santini+09...)

- **DS in stellar mass**
  (Drory+05, Cimatti+06, Fontana+06, Pozzetti+07, Conselice+07,...)

- **Archeological DS**
  (Thomas+05, Gallazzi+05, Panter+07, ...)

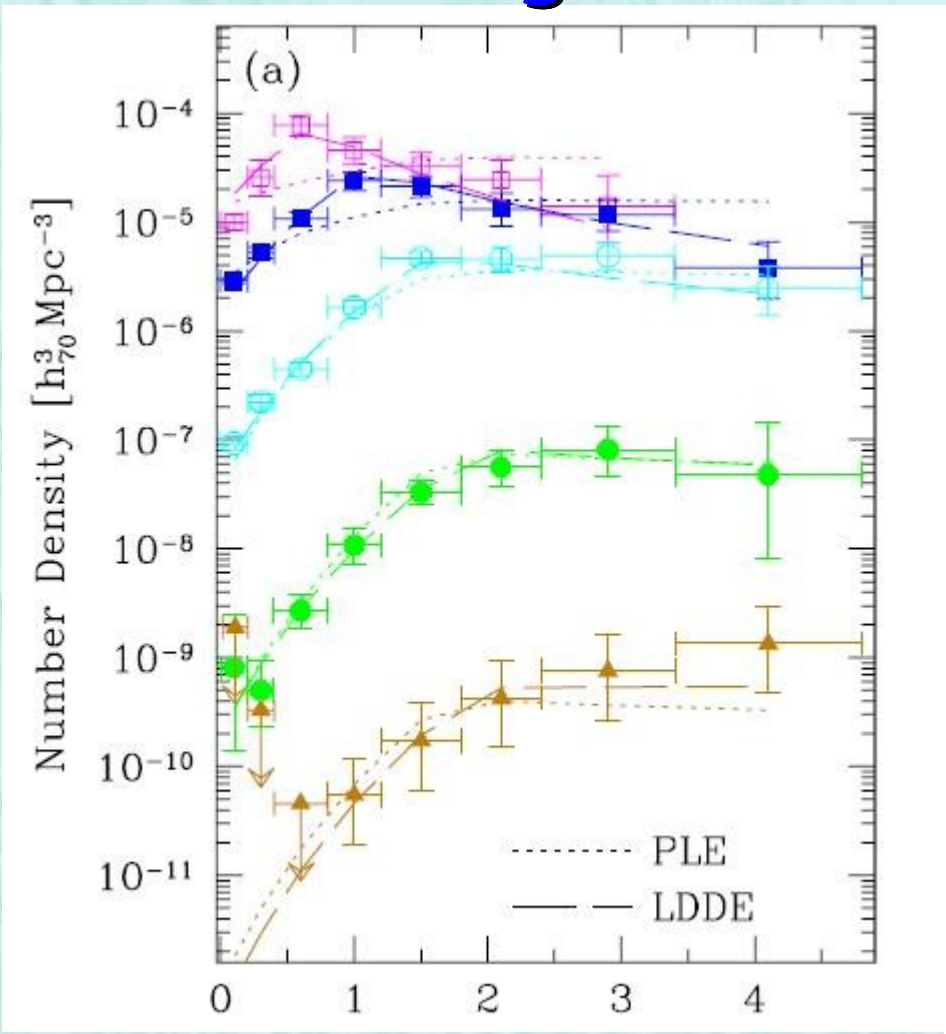
- **Chemo-Archeological DS**
  (Carollo+93,Trager+00,Matteucci+04,Thomas+05,...)

- **DS in metalicity**
  (Savaglio+05,Erb+06,Maiolino+08,...)

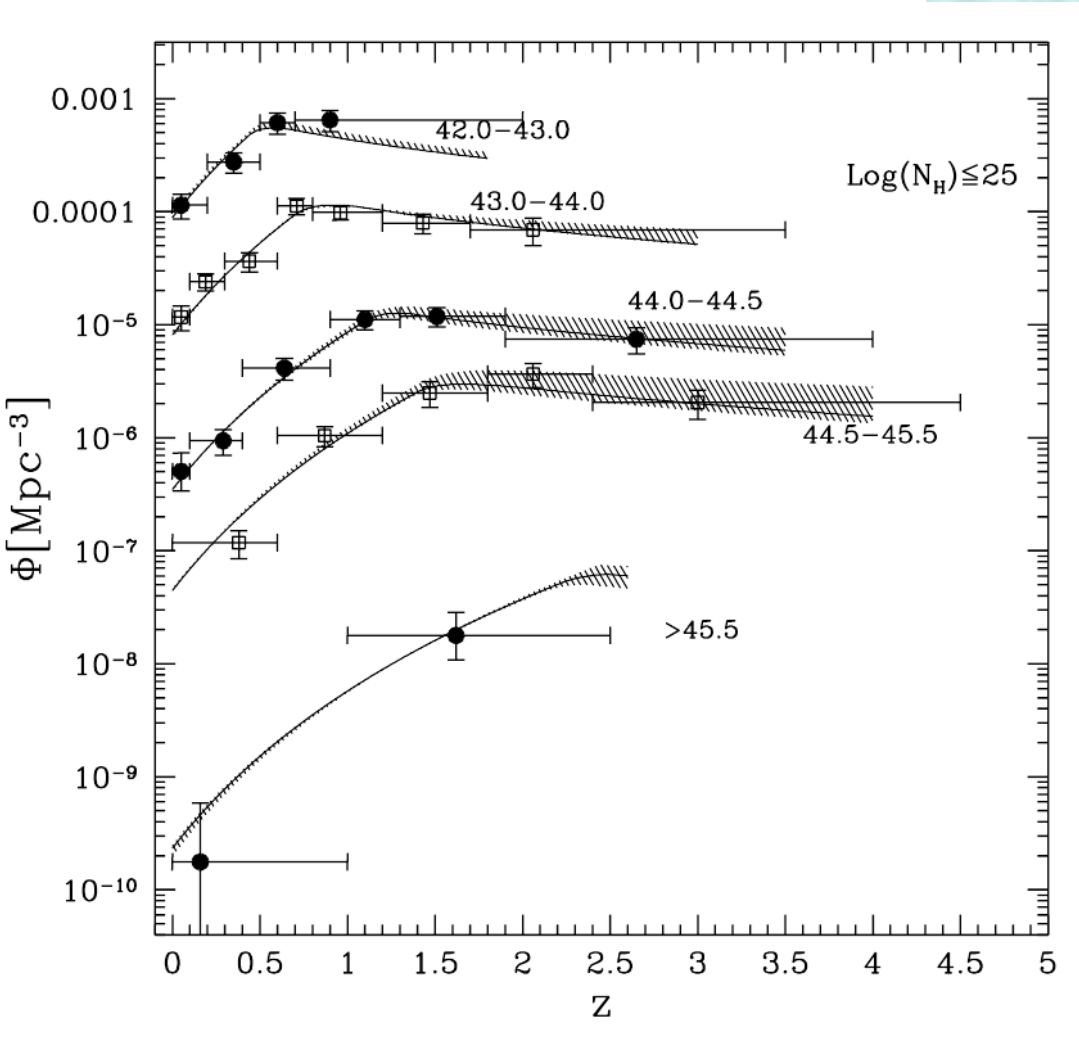
- **AGN DS**
  (Ueda+03,Hasinger+05,LaFranca+05,...)

AGN "Downsizing"

Hasinger+05

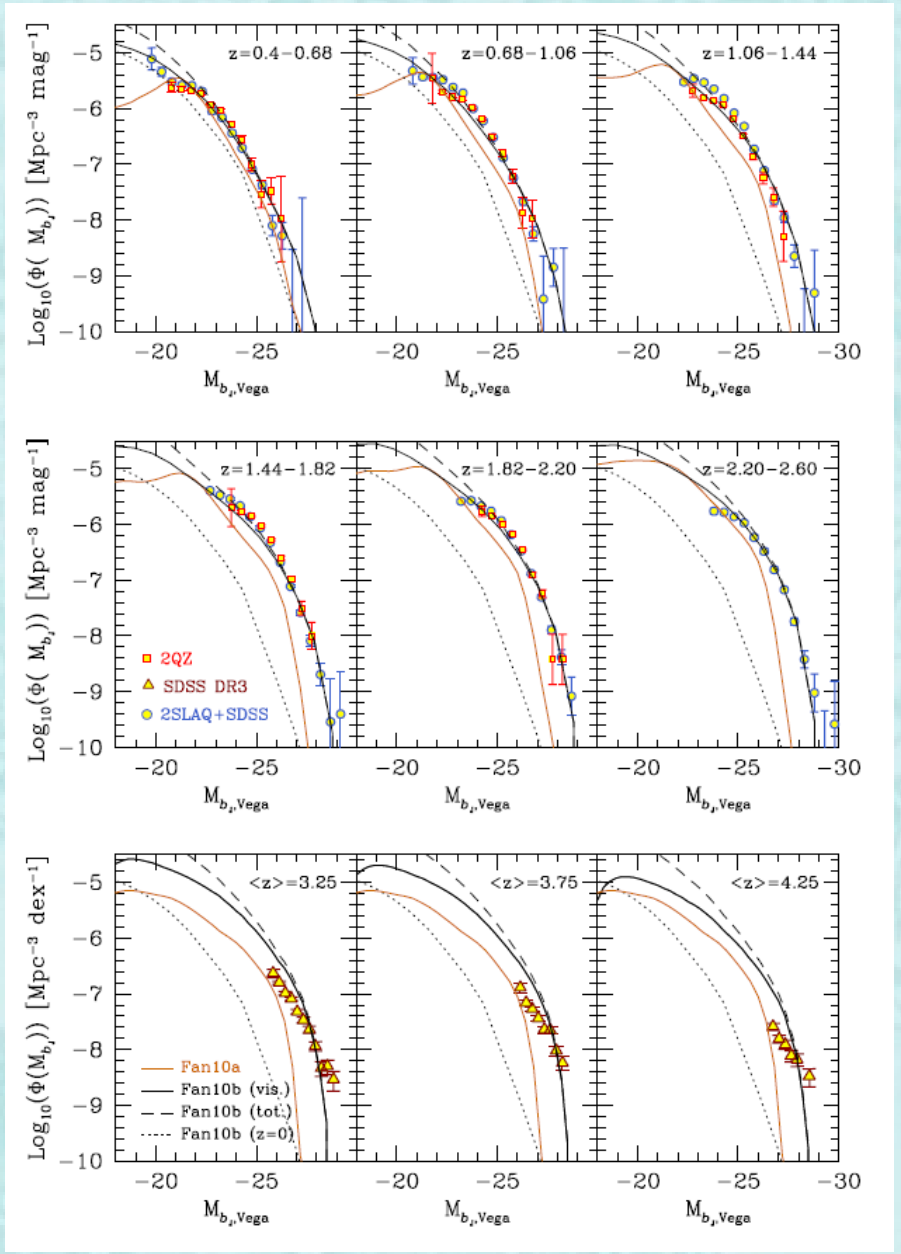


LaFranca+05

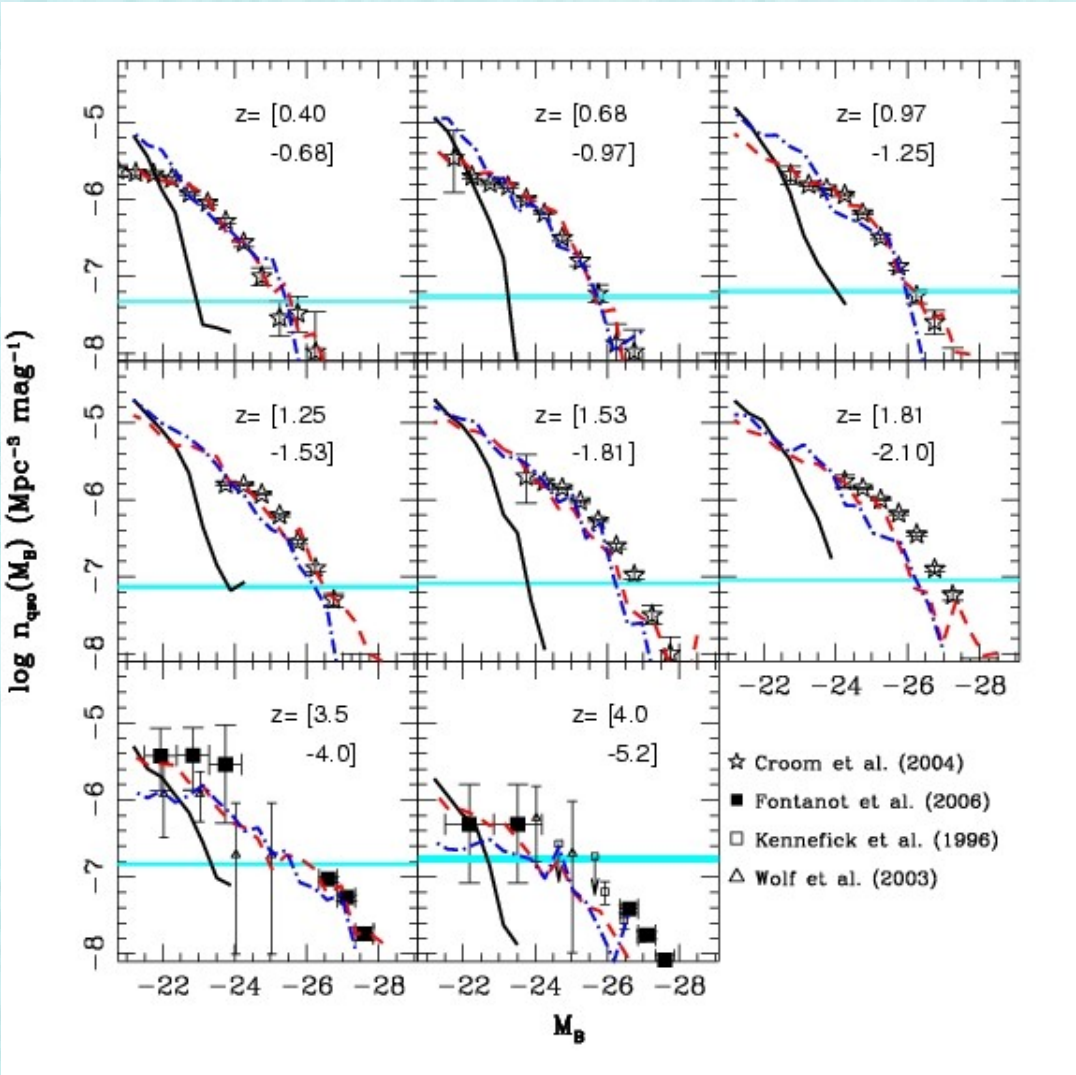


Optical QSO-LF

Fanidakis+11

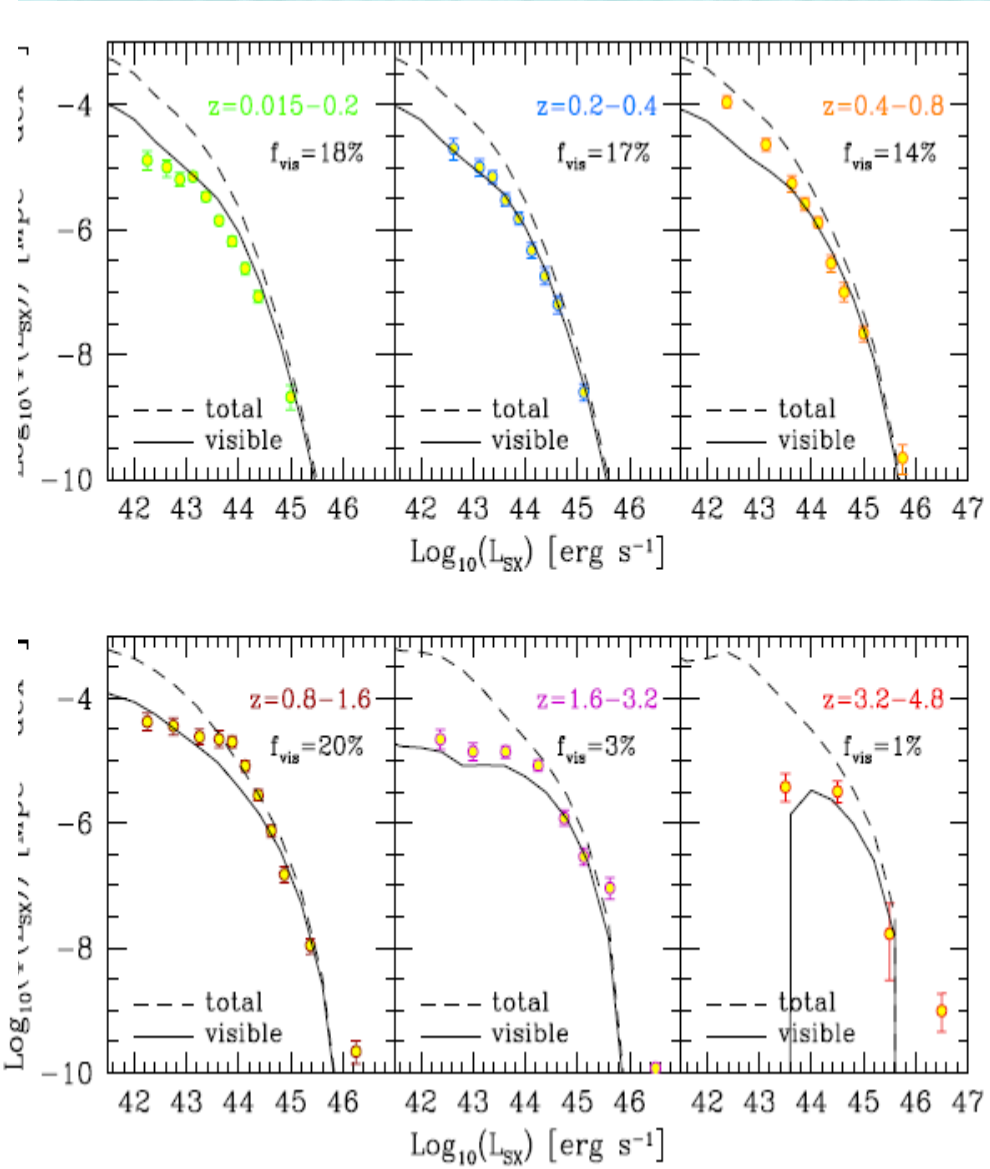


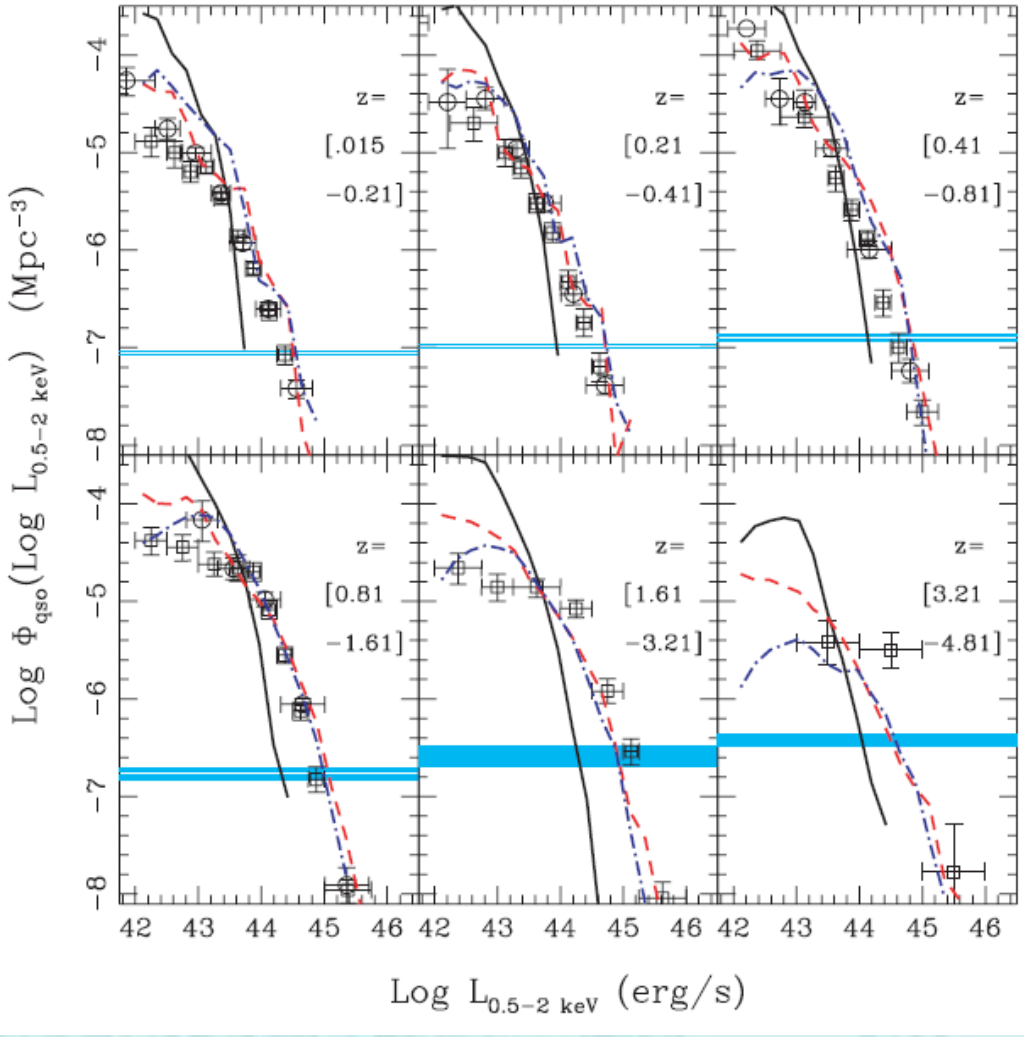
Fontanot+06



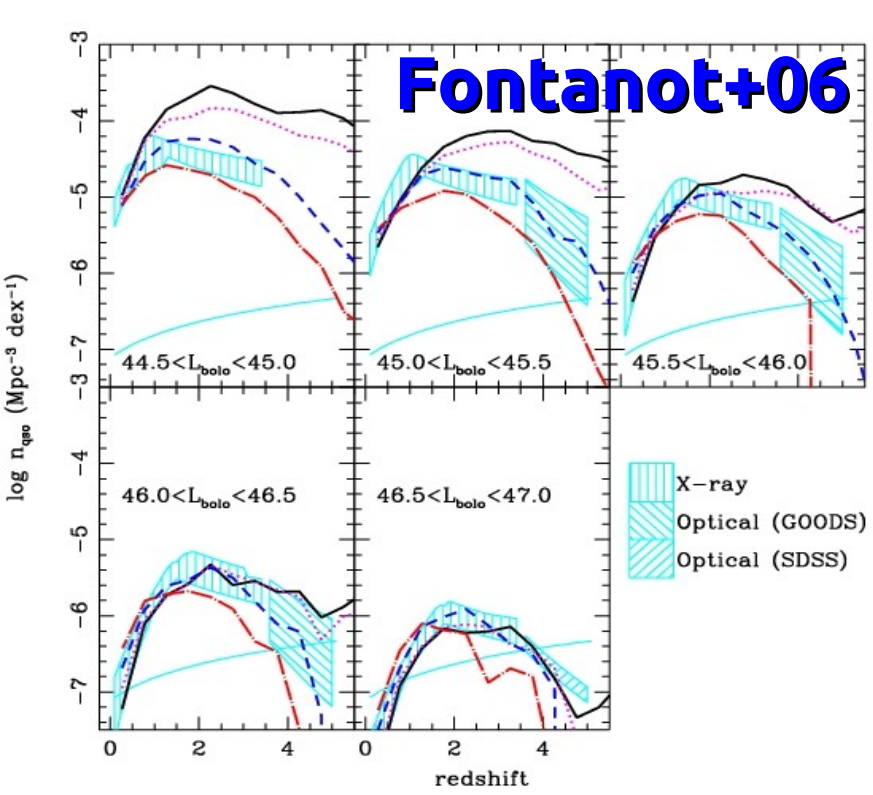
X-Ray QSO-LF

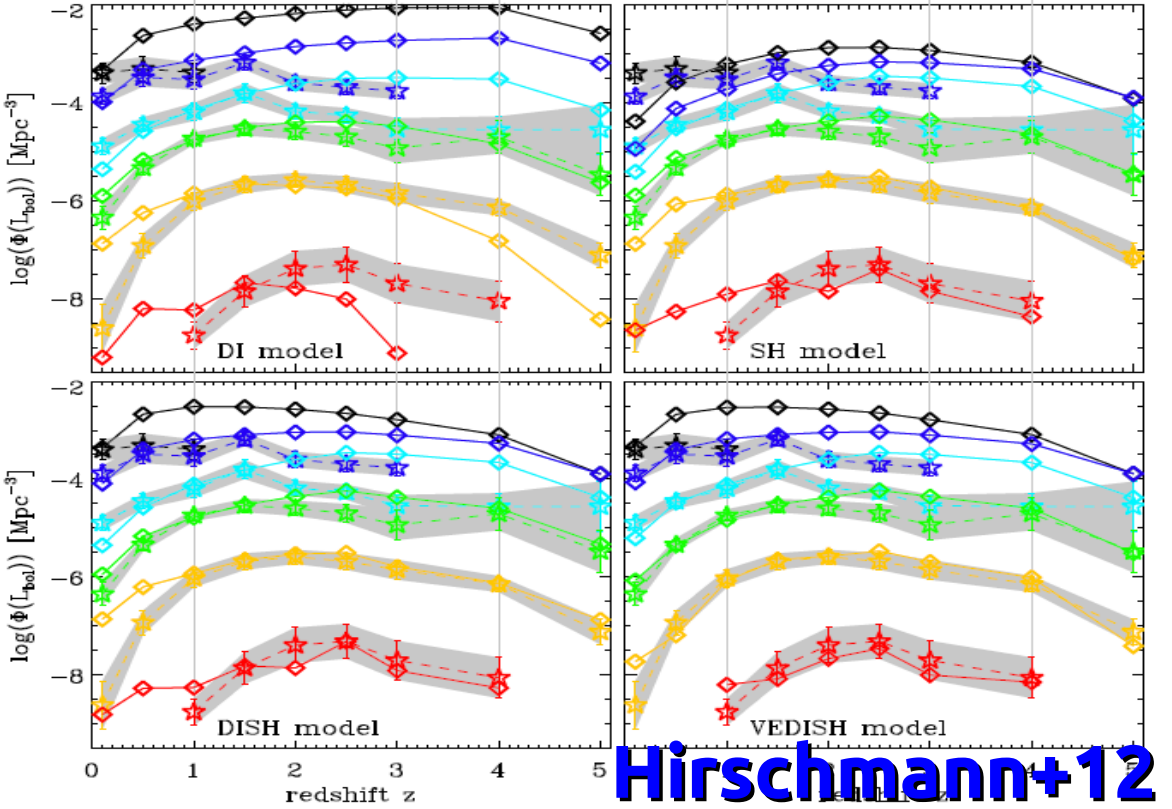
Fanidakis+11

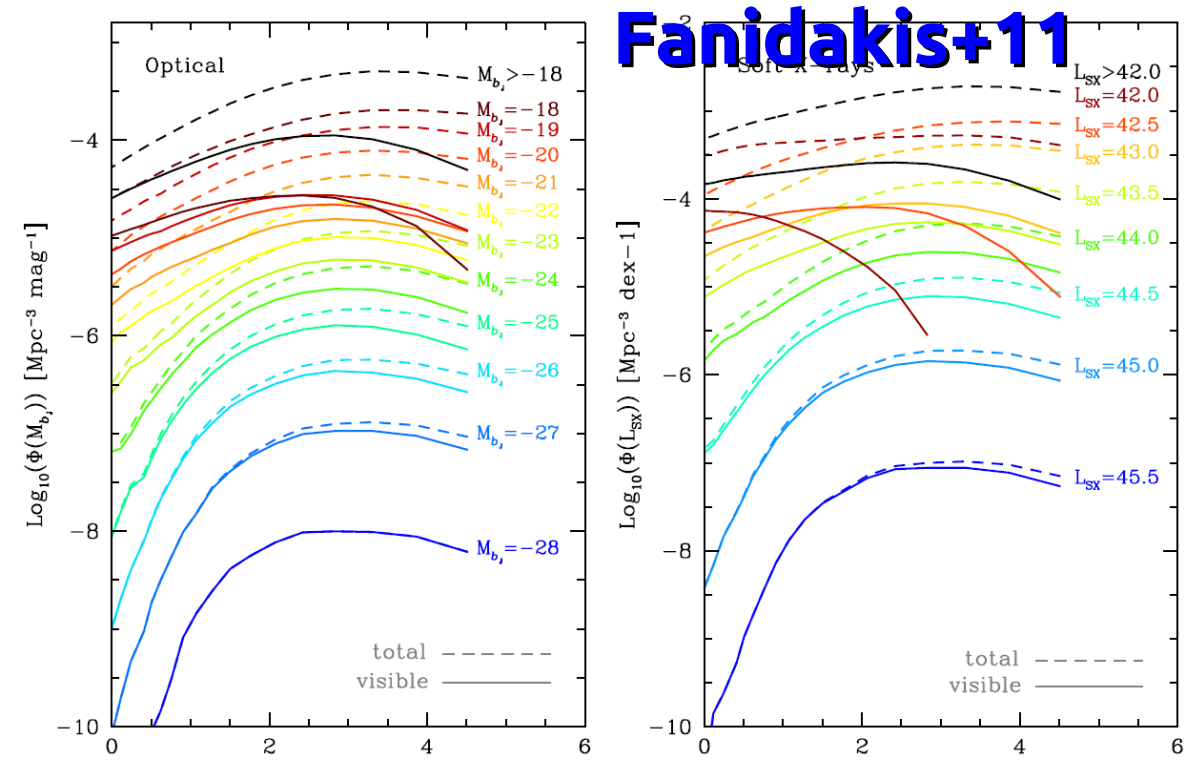


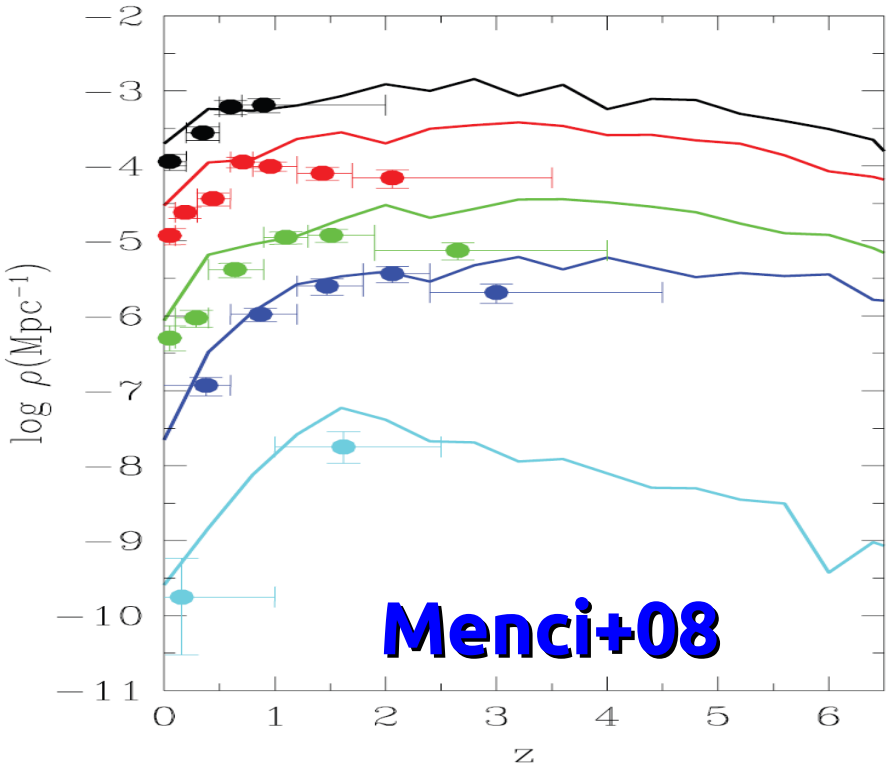


Fontanot+06

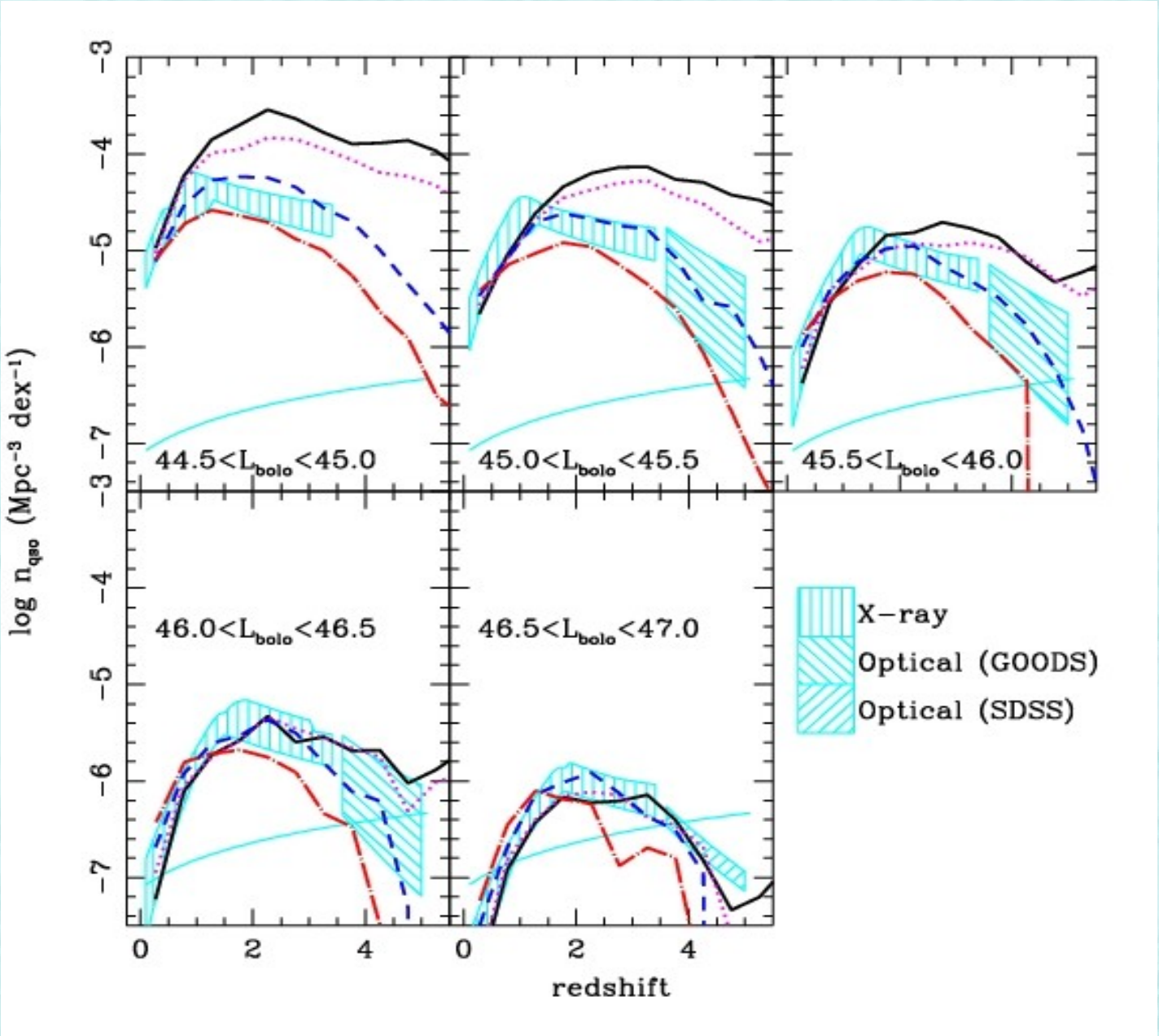

Fontanot+06
44.5<L_bolo<45.0
45.0<L_bolo<45.5
45.5<L_bolo<46.0
46.0<L_bolo<46.5
46.5<L_bolo<47.0
X-ray
Optical (GOODS)
Optical (SDSS)
log n_qso (Mpc^-3 dex^-1)
redshift

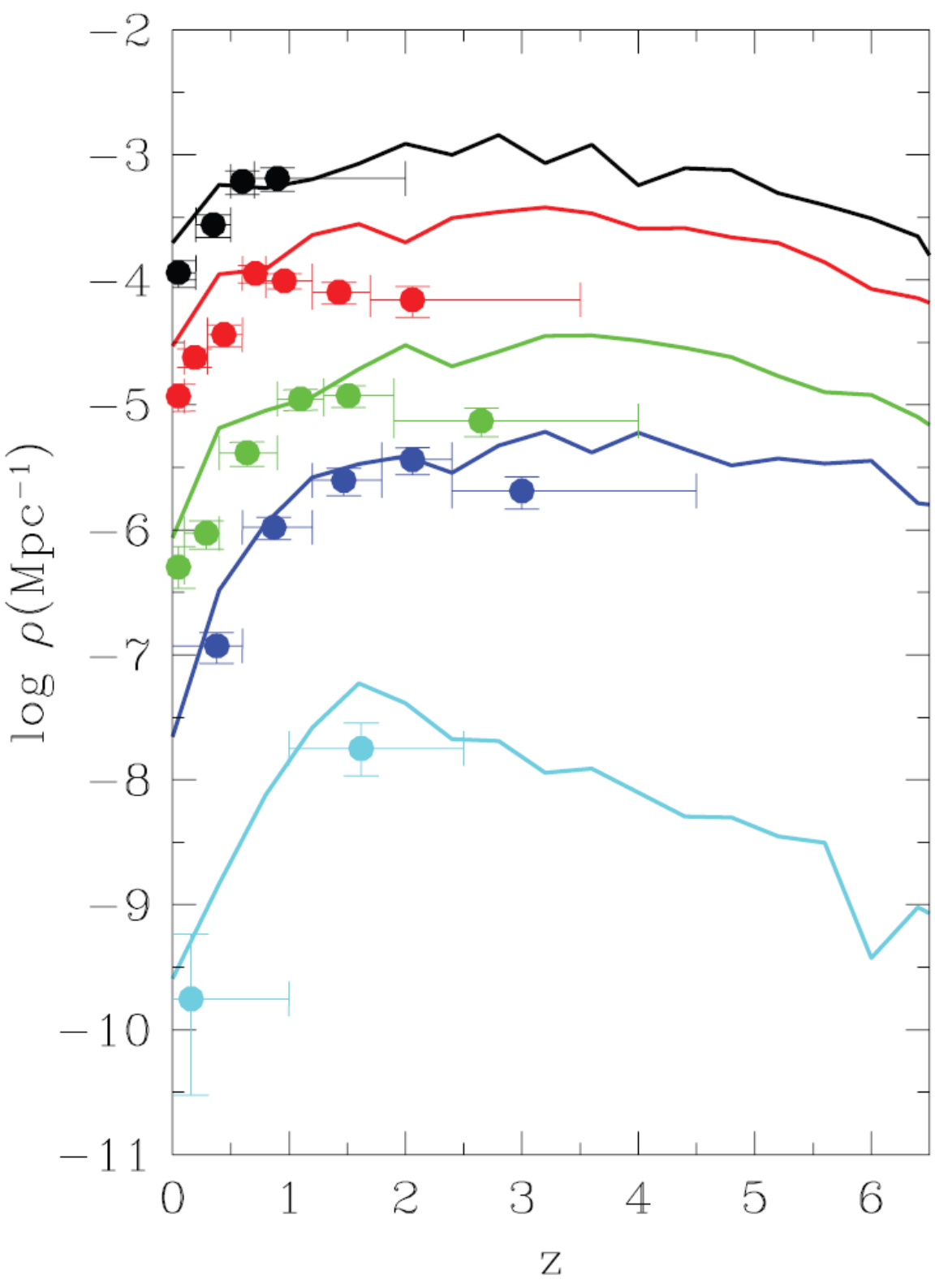

DI model
SH model
DISH model
VEDISH model
log(Φ(L_bol)) [Mpc^-3]
redshift z
Hirschmann+12


Fanidakis+11
Optical
Soft X-rays
M_bj>-18
M_bj=-18
M_bj=-19
M_bj=-20
M_bj=-21
M_bj=-22
M_bj=-23
M_bj=-24
M_bj=-25
M_bj=-26
M_bj=-27
M_bj=-28
L_SX>42.0
L_SX=42.0
L_SX=42.5
L_SX=43.0
L_SX=43.5
L_SX=44.0
L_SX=44.5
L_SX=45.0
L_SX=45.5
total
visible
Log10(Φ(M_bj)) [Mpc^-3 mag^-1]
Log10(Φ(L_SX)) [Mpc^-3 dex^-1]


Menci+08
log ρ(Mpc^-1)
z

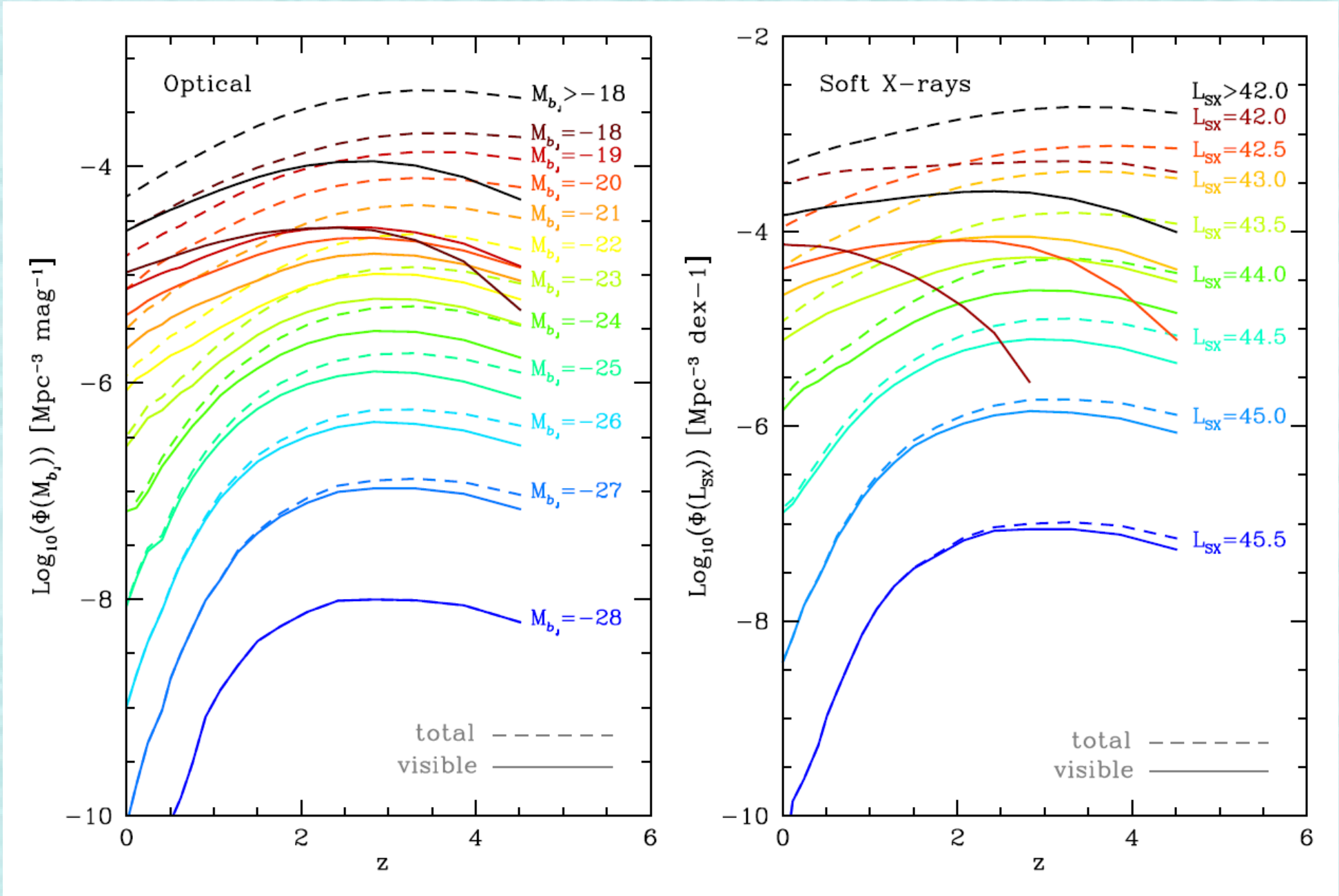
Fontanot+06


log n_{qso} (Mpc^{-3} dex^{-1})
redshift
44.5<L_{bolo}<45.0
45.0<L_{bolo}<45.5
45.5<L_{bolo}<46.0
46.0<L_{bolo}<46.5
46.5<L_{bolo}<47.0
X−ray
Optical (GOODS)
Optical (SDSS)

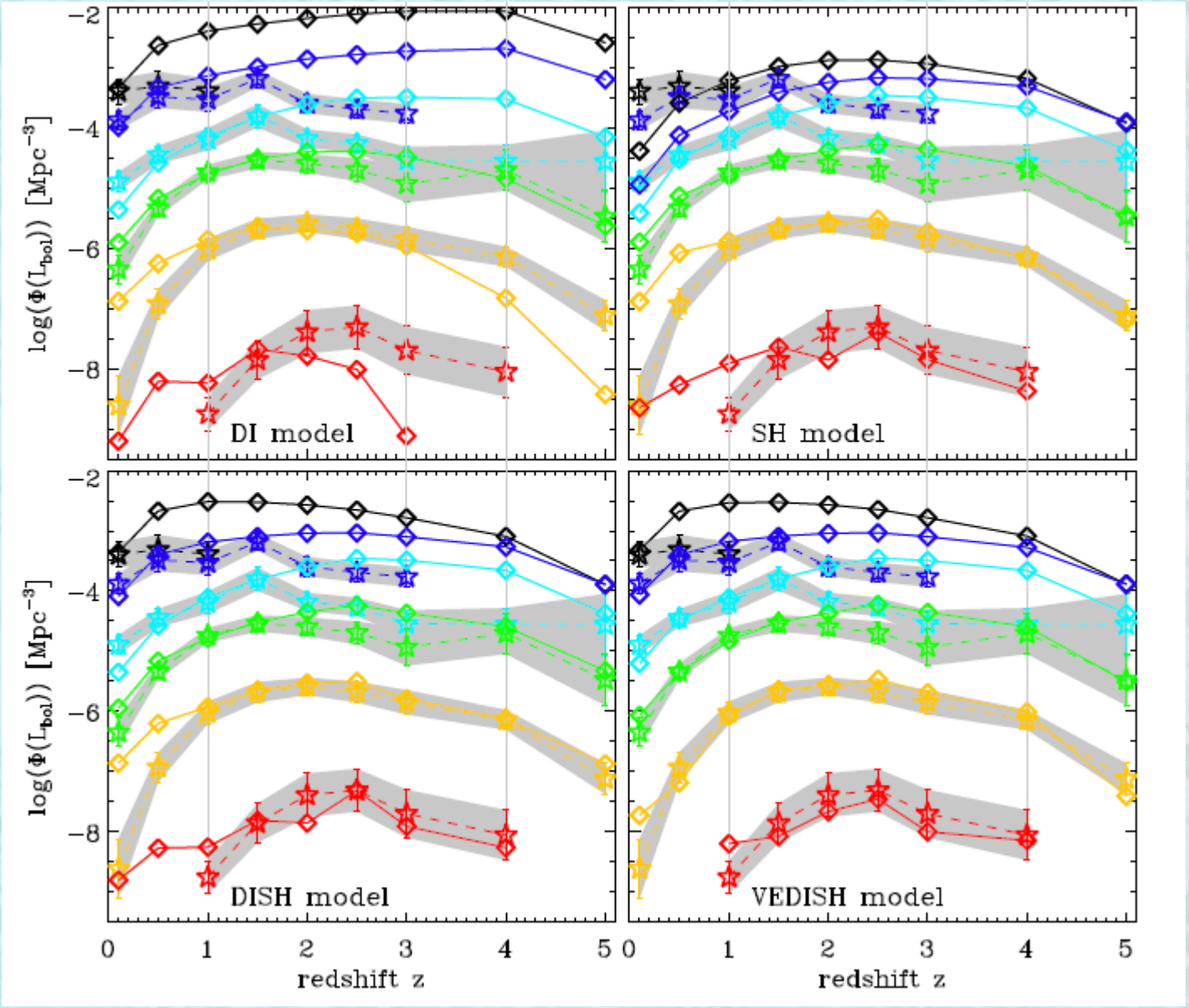


Menci+08

Fanidakis+11



Hirschmann+12



AGN “Downsizing”

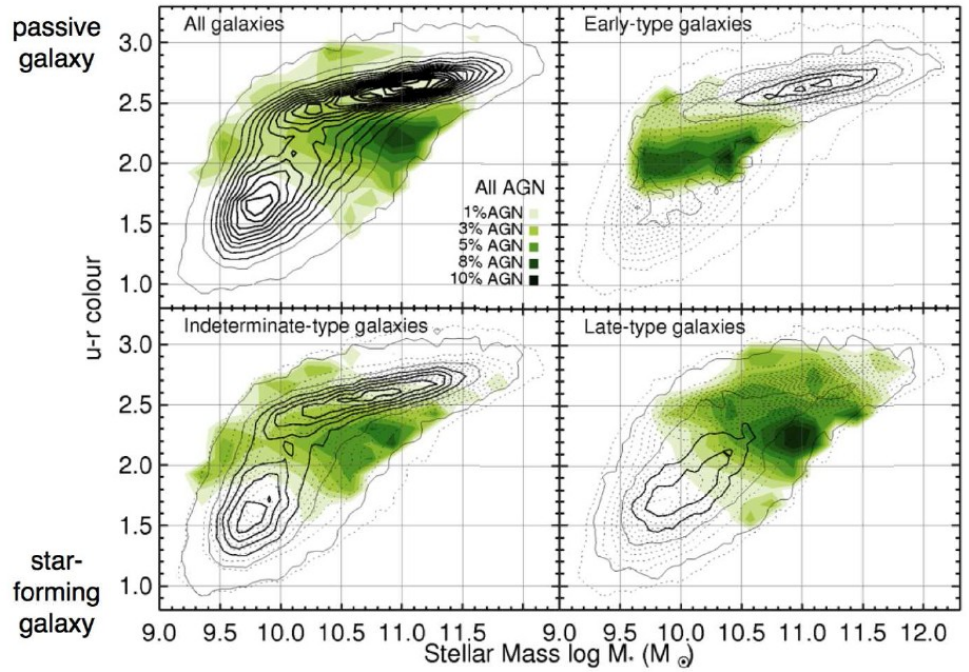
- Different Explanations
  - Coupling of AGN and stellar feedback Fontanot+06
  - Galaxy Interactions Menci+08
  - Dust Obscuration Fanidakis+11
  - Heavy BH seeds & major role of disk instabilities Hirschmann+12

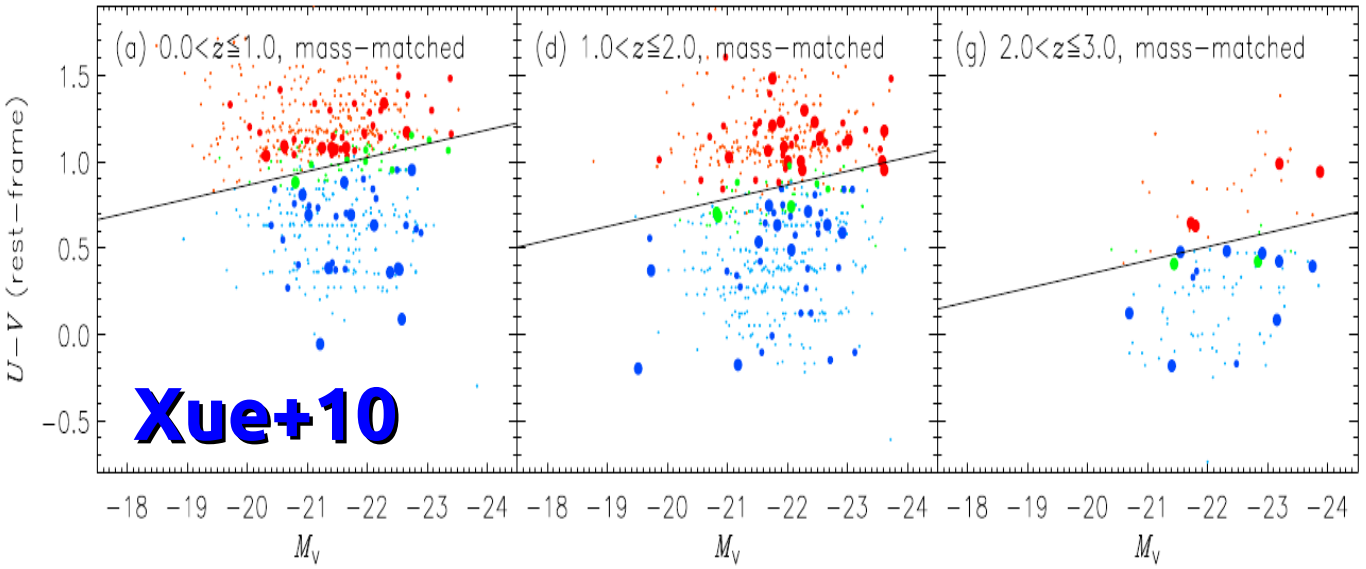
Different regimes

- "Quasar"-mode
- High-accretion
- Bright-phase
- From blue to red
- Galaxy Mergers
  - Secular processes?
- Small Scales (~kpc)
  - Triggering galactic winds?
- Rapid

Warning: AGN hosts

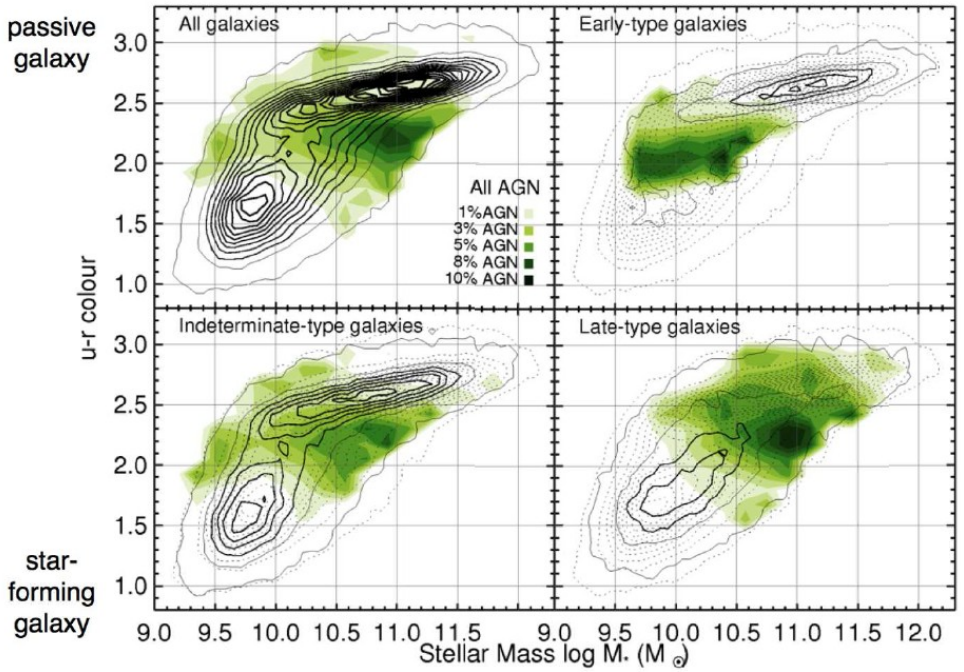
Schawinski+10;12



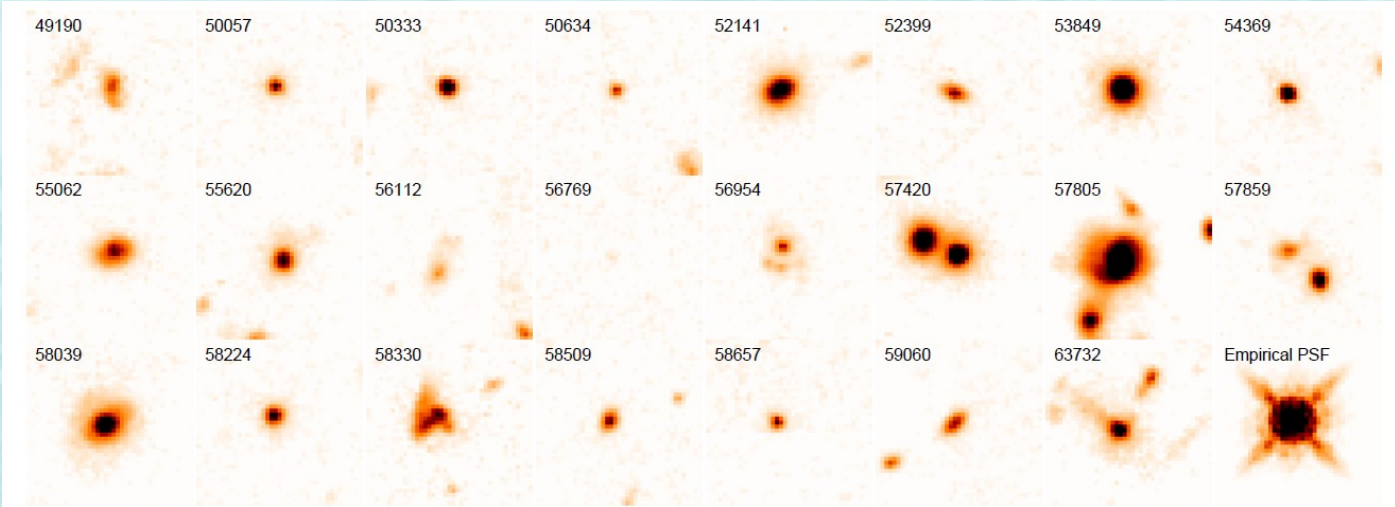


Xue+10

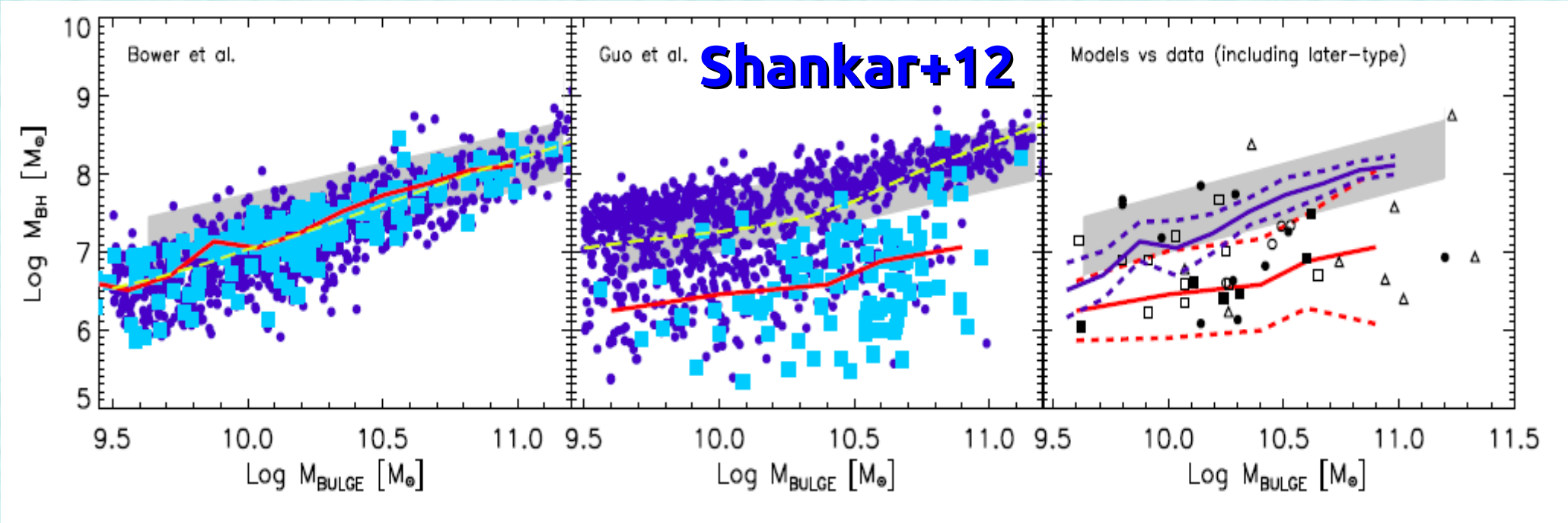
Warning: AGN hosts



Schawinski+10;12

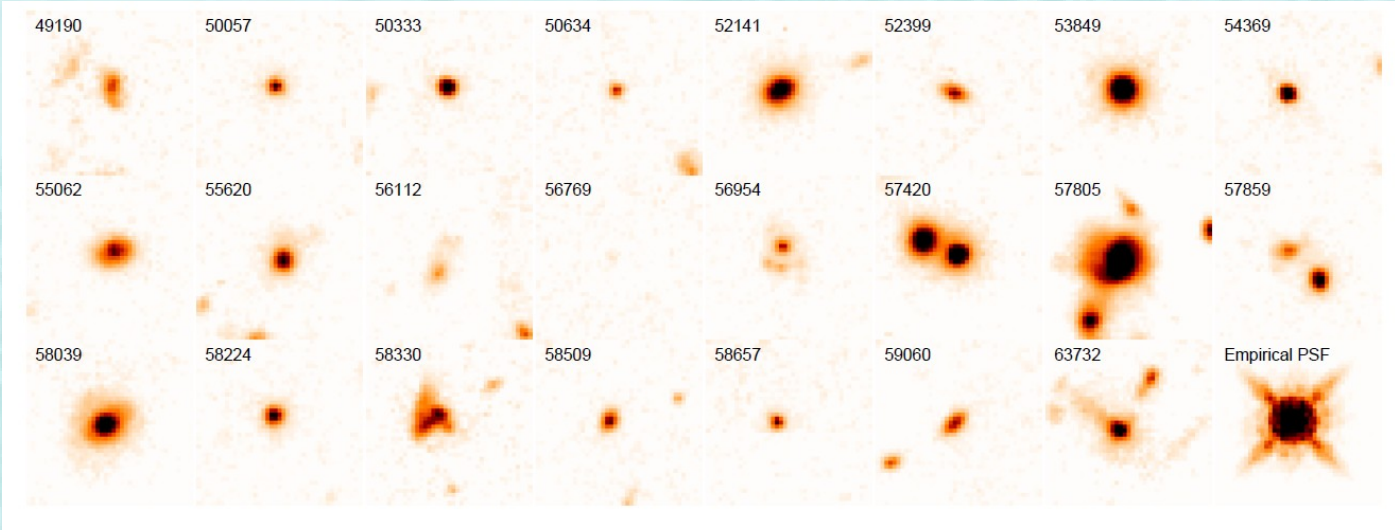


Mergers vs Secular



Shankar+12

Schawinski+10;12



Conclusions

- Joint Evolution of Galaxy and AGNs
  - **Consensus:** Key aspect for setting up both galactic and SMBH properties
  - **Disagreement:** how does it happen?
- Data vs Models
  - **Good News:** models (somehow) reproduce the data
  - **Bad News:** models (somehow) reproduce the data
- Call for observational tests able to disentagle between the different proposed models
  - Better knowledge of host galaxy properties
  - Detailed knowledge of accretion physics
  - Different calibration sets