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The M_{BH}-M_{host} relation through Cosmic Time

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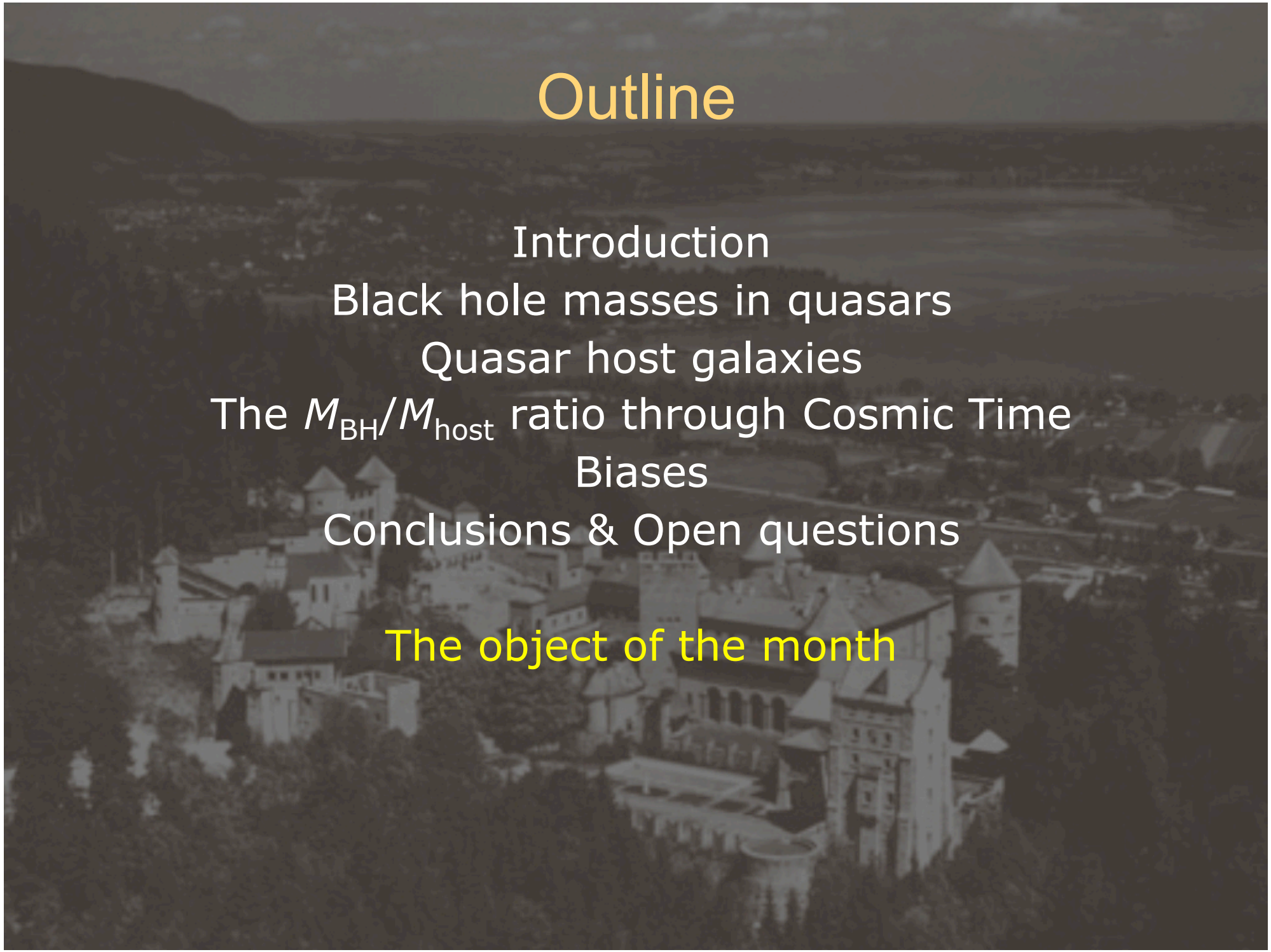
M. Dotti
F. Haardt
M. Volonteri
M. Colpi
C. Montuori

+ Many PGN09 speakers

Schloss Ringberg - June, 18, 2009



Outline

Introduction

Black hole masses in quasars

Quasar host galaxies

The M_{BH}/M_{host} ratio through Cosmic Time

Biases

Conclusions & Open questions

The object of the month

BHs and galaxies: clues of a common history

Massive BHs are ubiquitous

Quasar LFs – star formation density evolution
(Dunlop & Peacok 1990; Madau et al., 1998)

M_{BH} - L, M, s_* relations

Salpeter's time « Hubble time

Soltan's argument
(Soltan 1982)

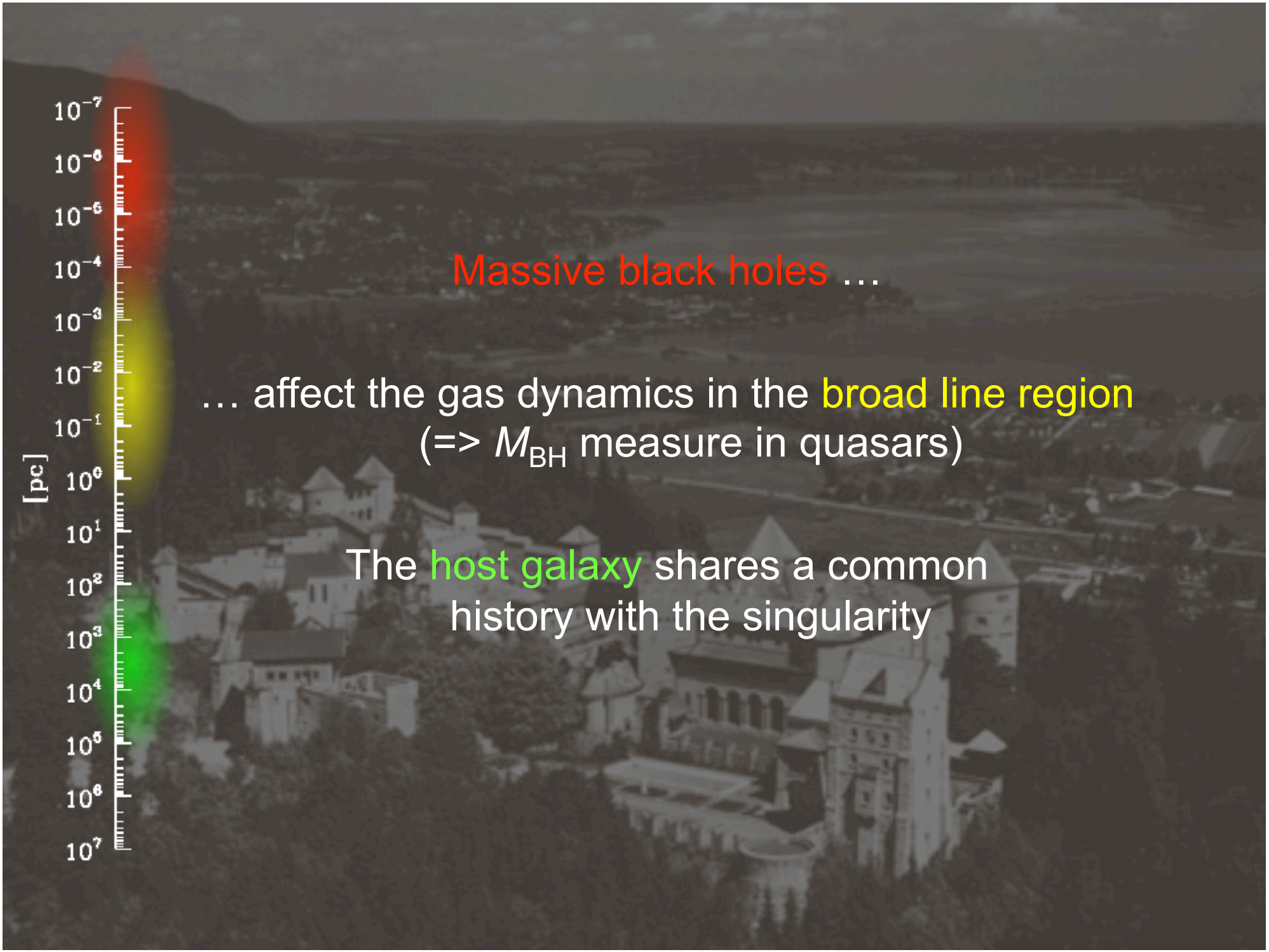
Massive black holes are responsible of quasar luminosities

Feedback

M_{BH} – core mass deficit – merger history
John's talk

Galaxy merger – nuclear activity
Nicola's talk (?)

Stephanie's talk



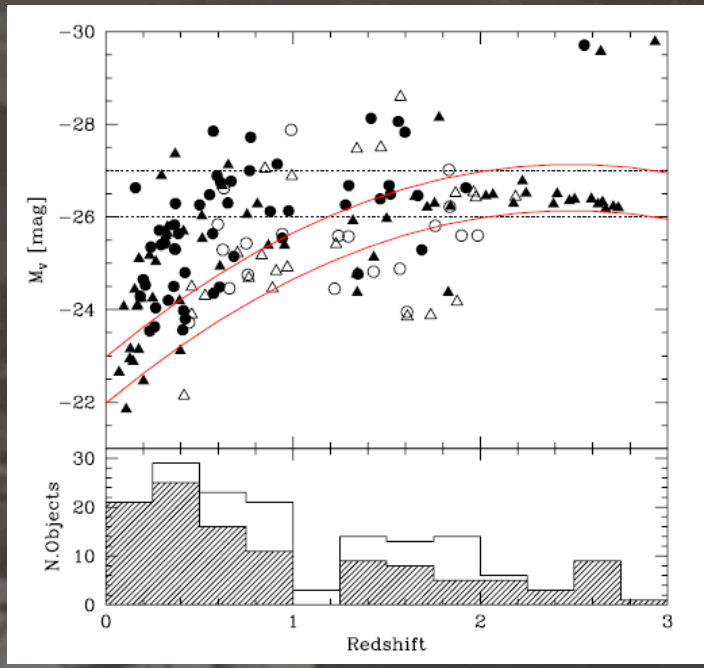
Massive black holes …

… affect the gas dynamics in the broad line region
(=> M_{BH} measure in quasars)

The host galaxy shares a common
history with the singularity

Our study

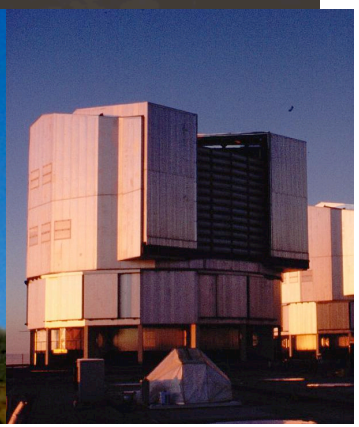
- **108** quasars (57 RQQs, 51 RLQs) from z=0 to z=3 (2x the samples by *Peng et al., 2006* and 3x *McLure et al., 2006*)
- Host galaxy luminosity from high res. images
- Black hole masses from good quality spectra



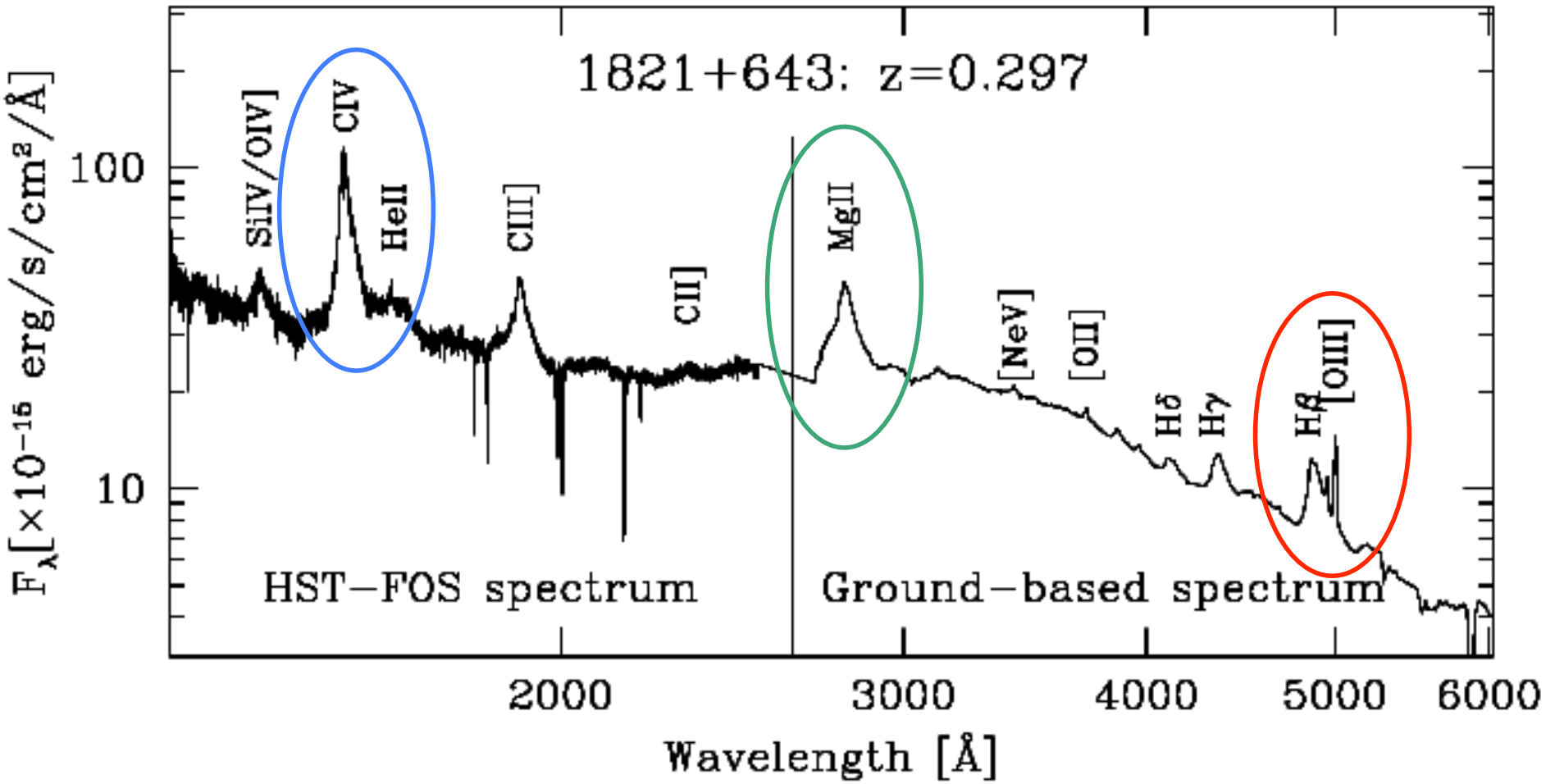
- For low-z quasars, images in the HST-WFPC2 archive, spectra from the SDSS and HST-FOS archives and from on-purpose observations at the Asiago 1.82m Telescope.
- For z>0.5 targets, images taken at the NOT and the ESO/VLT, spectra from the NOT and ESO/3.6m Telescope.





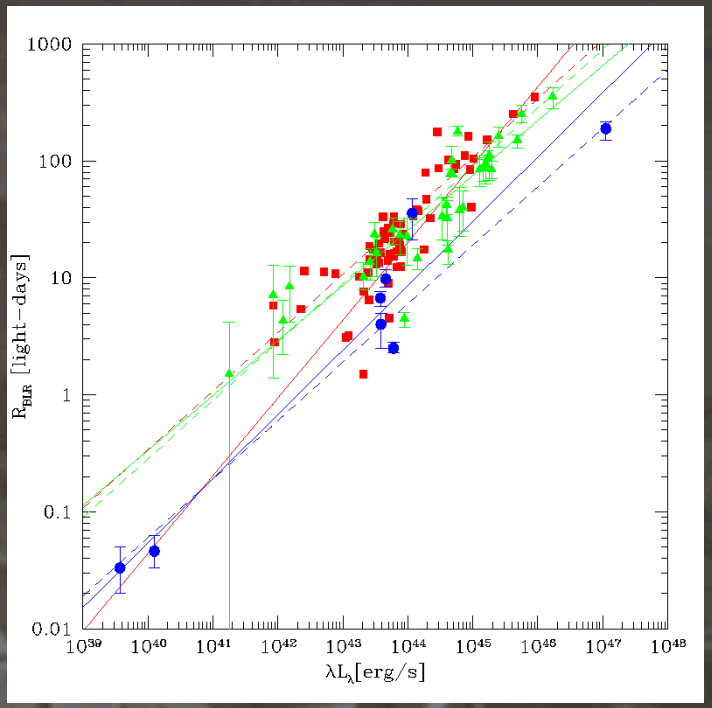



The FUV-to-V spectrum of low-z QSOs



Virial estimate of M_{BH}

- $M_{BH} = G^{-1} R_{BLR} v_{BLR}^2$
- $R_{BLR} \sim \lambda L_\lambda^a$ *(see Aaron's talk)*
- $v_{BLR} = f$ FWHM



But…

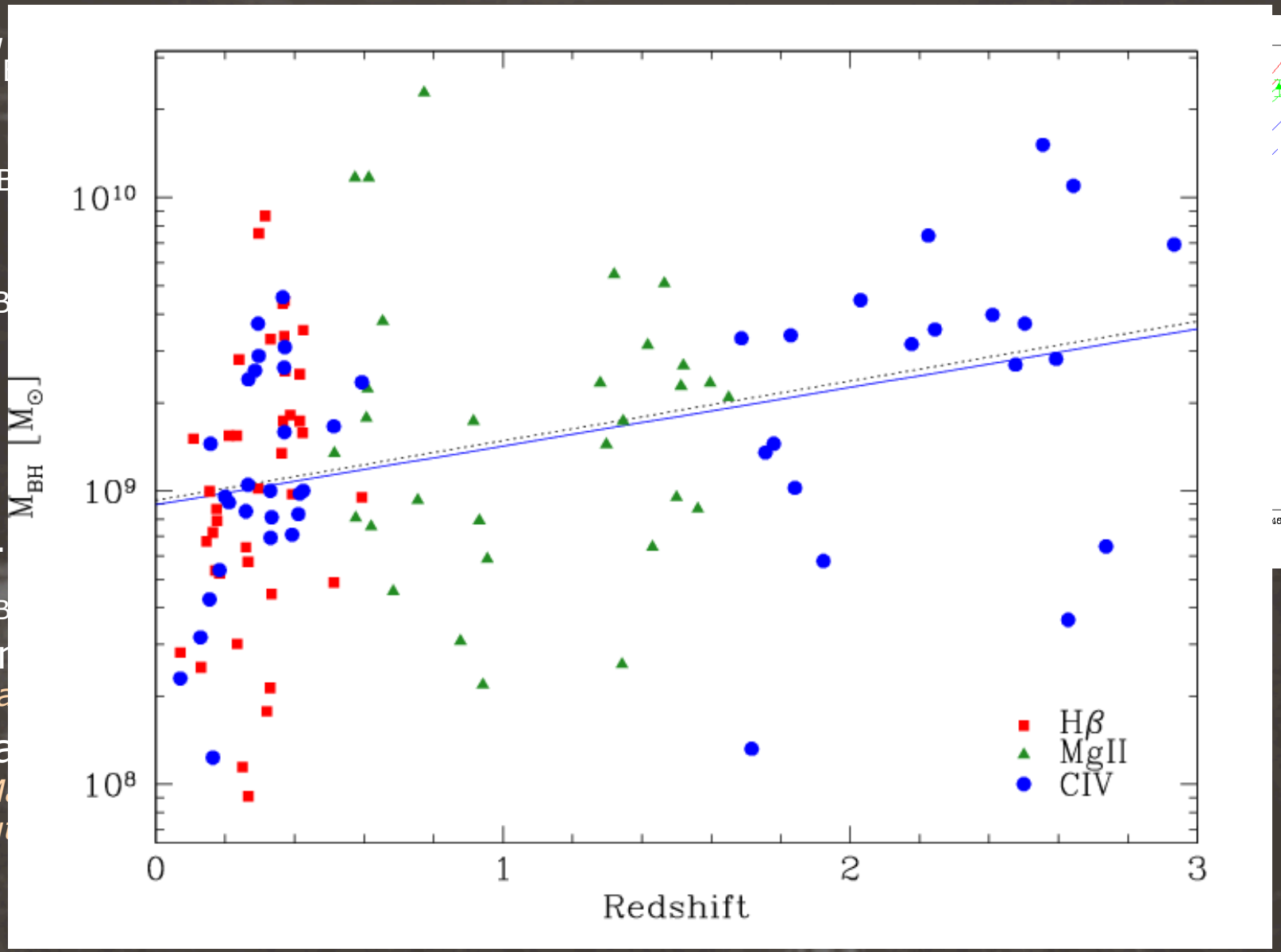
- R_{BLR}—λL_λ relations are poorly constrained
- Only the average value of f is known
  (Labita et al. 2006, Collin et al. 2006, Decarli et al. 2008)
- Radiation pressure => Underestimates of M_{BH}
  (Marconi et al. 2008, 2009 and Hagai, Shane, Moshe and Tigran's talks… but see also Netzer 2008)

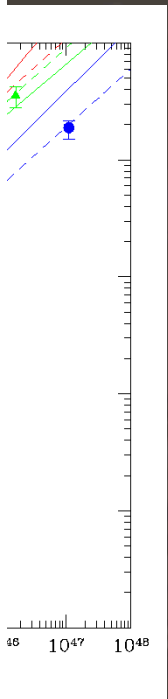
Virial estimate of M_{BH}

- M_{BH}
- R_{BLR}
- v_{BLR}

But…

- R_{BLR}
- Or
  (La
- Ra
  (M
  bu

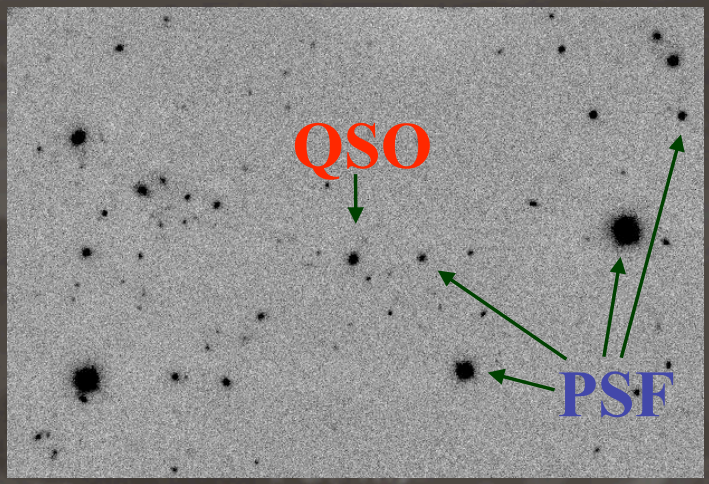


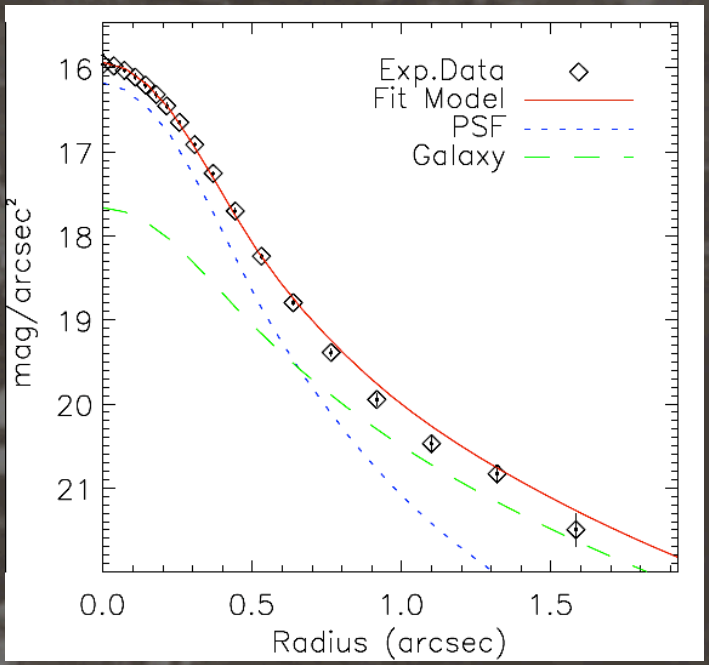


The host galaxy of high-z quasars

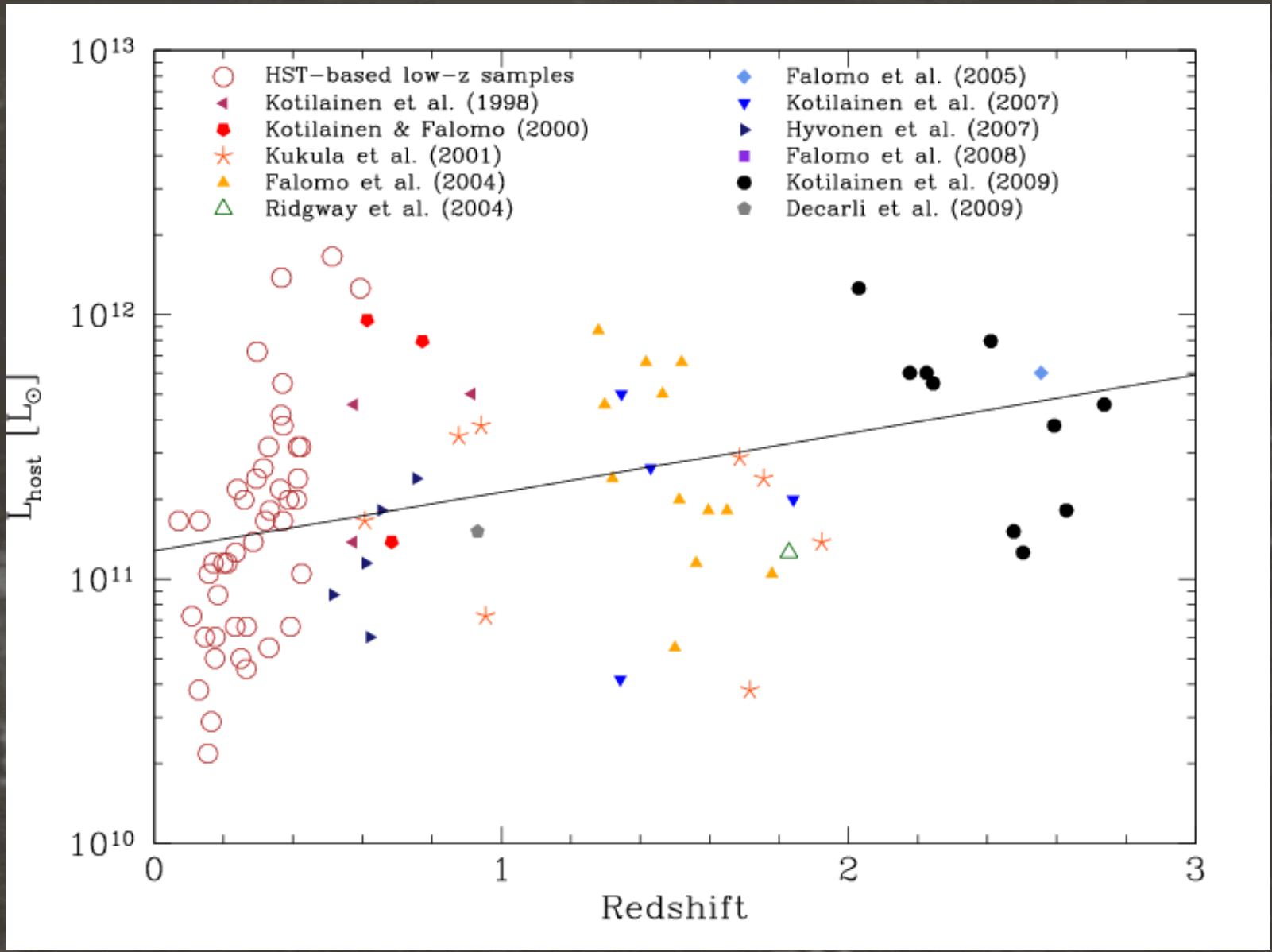
- In quasars, the nuclear light overwhelms the galaxy luminosity; the surface brightness is $\propto (1+z)^{-4}$
- The observed image is:

  (galaxy + nucleus) $\otimes$ PSF
- We use our Astronomical Image Decomposition and Analysis (AIDA) software in order to:
  - Model the PSF on the field stars;
  - Superimpose a nuclear point-like source to a galaxy model;
  - Convolve them with the PSF model and fit it to the observed quasar light profile.
- The host galaxy luminosity and morphology (according to the best-fitting galaxy model) are thus found.

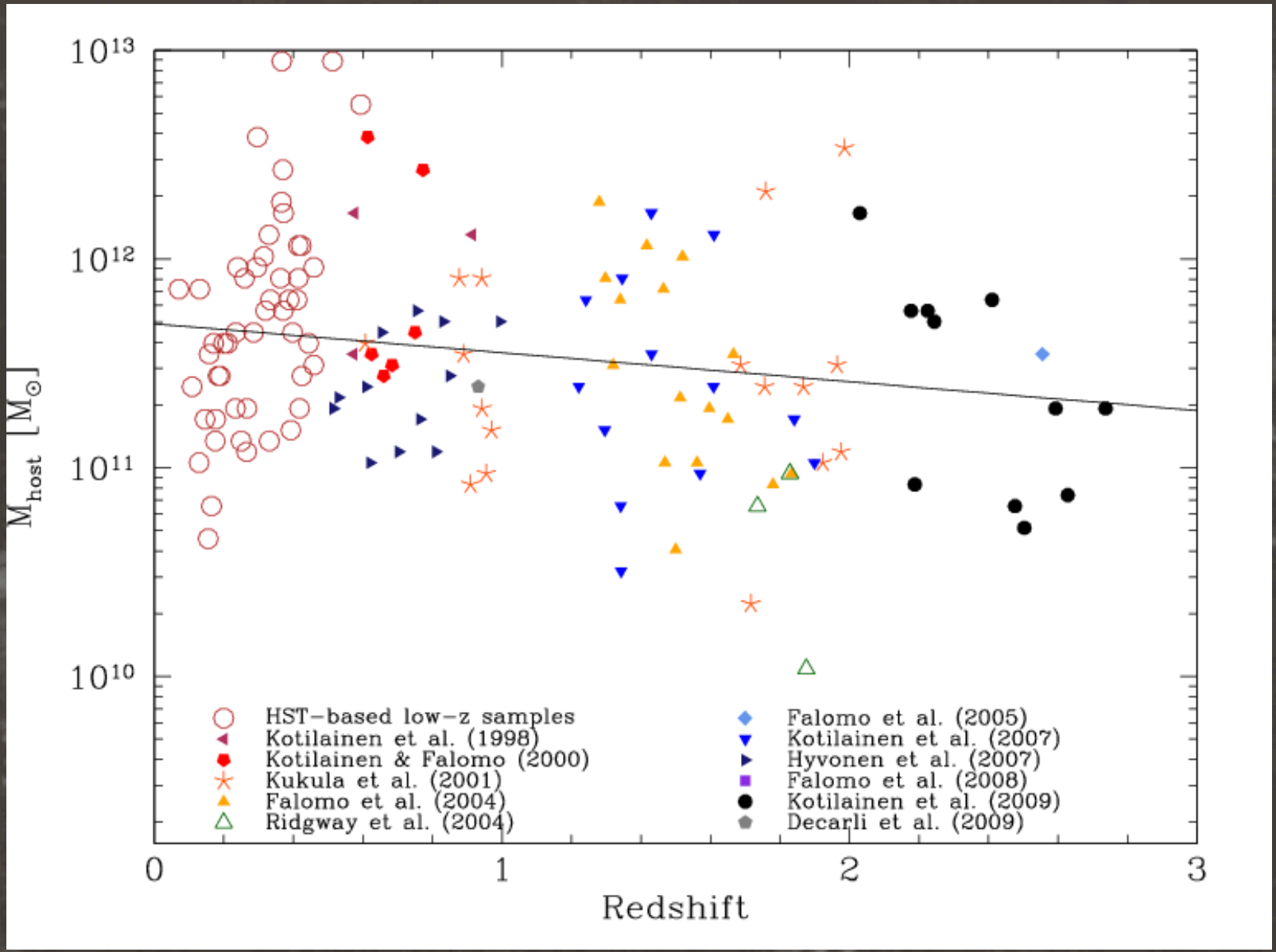




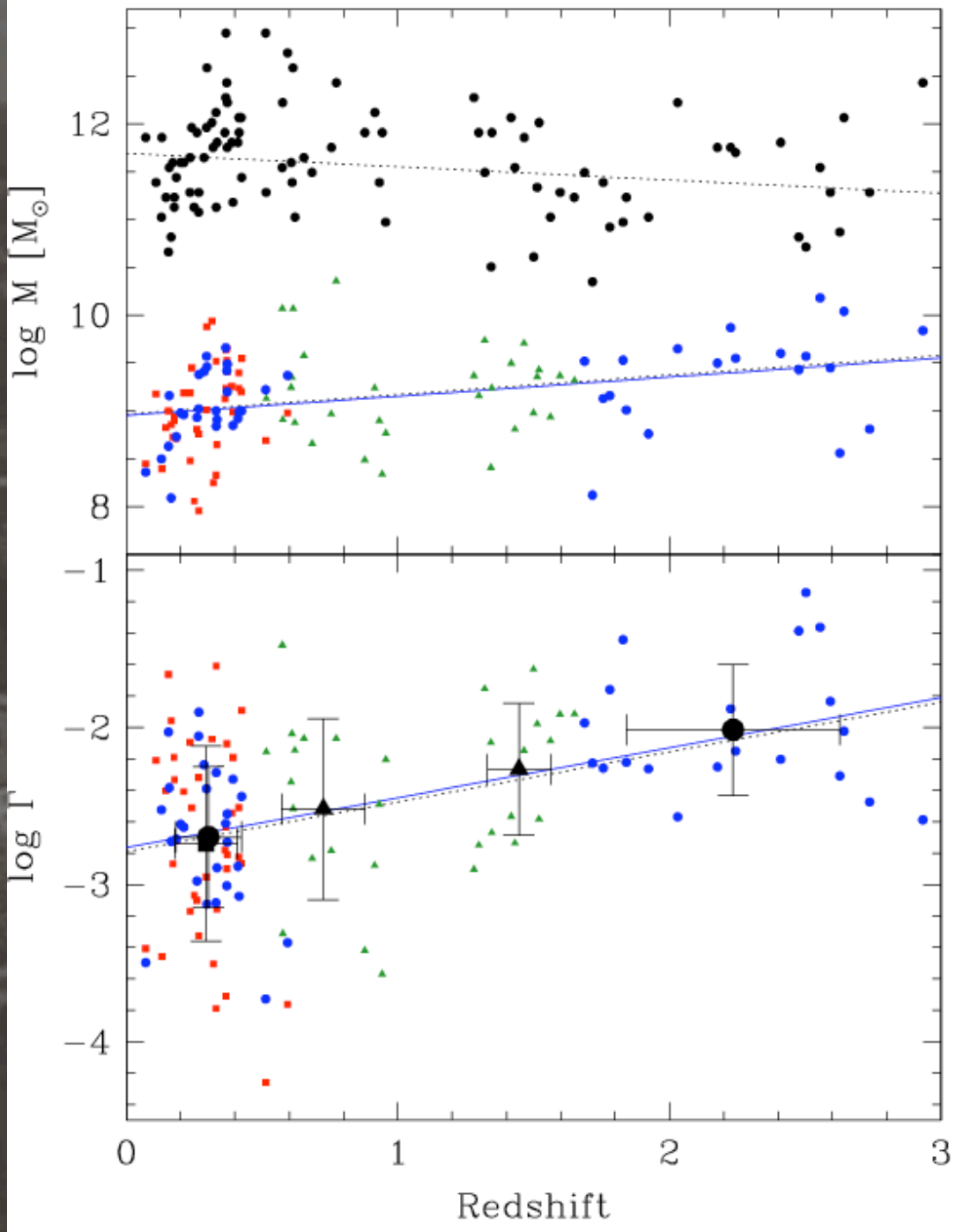
L_{host} as a function of redshift



M_{host} as a function of redshift



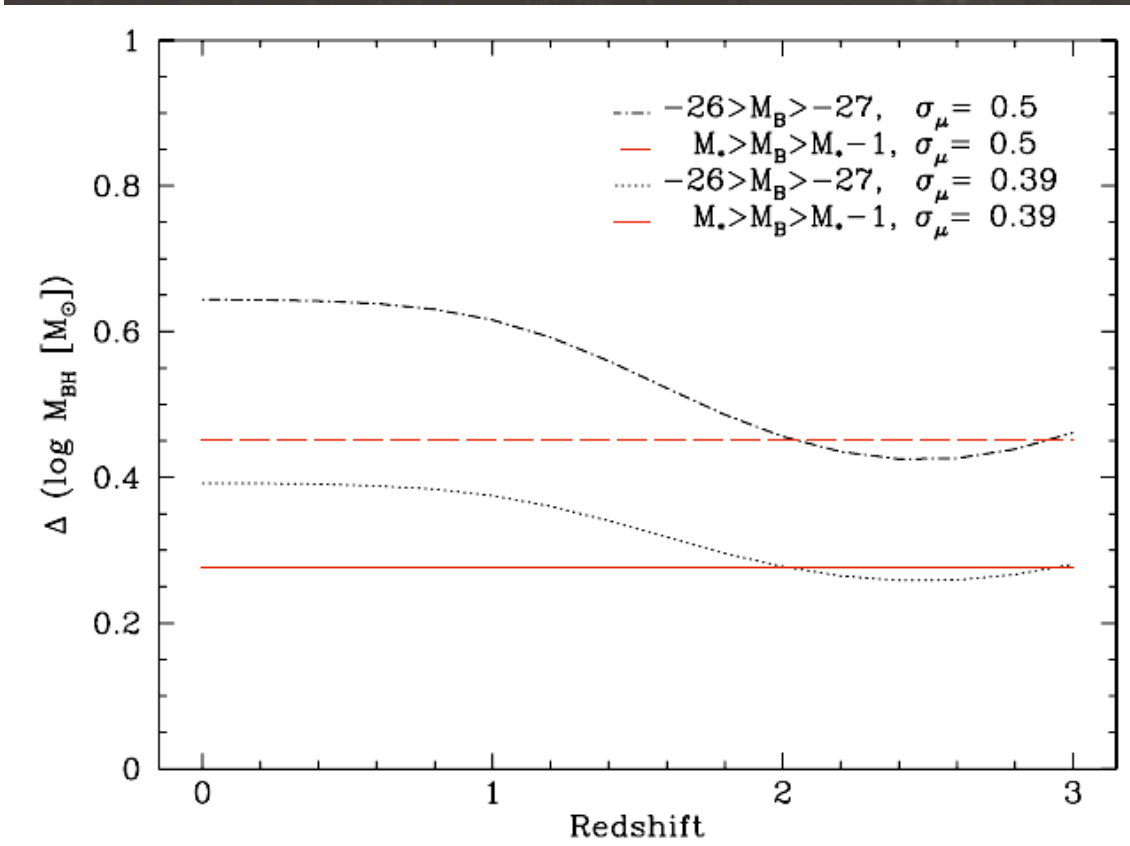
The M_{BH}–M_{host} ratio as a function of z

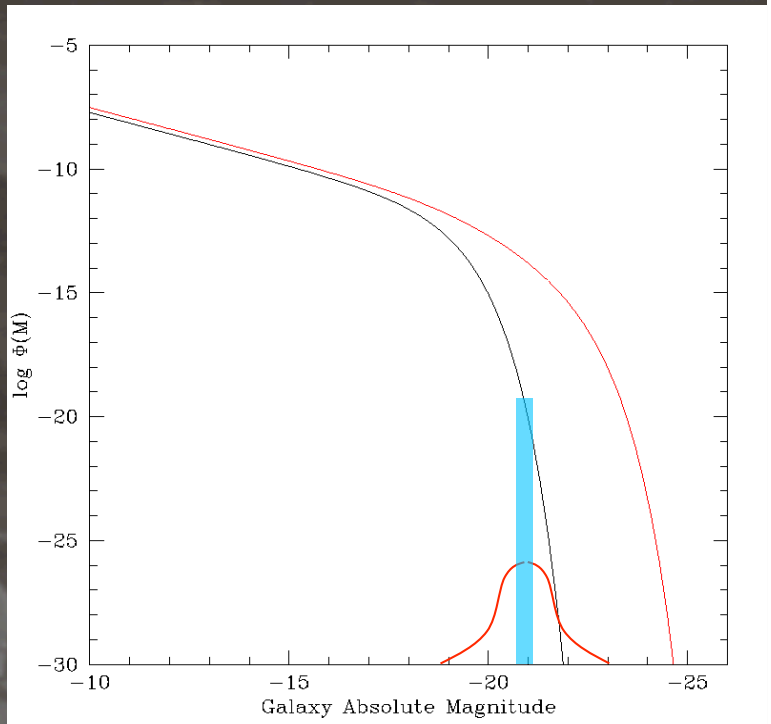


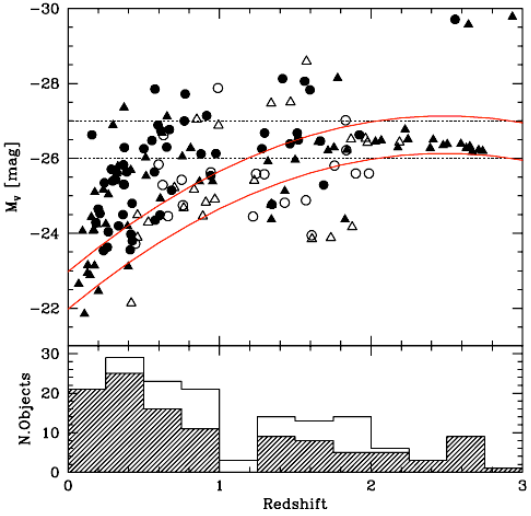
Decarli et al (in preparation)

Luminosity Function bias

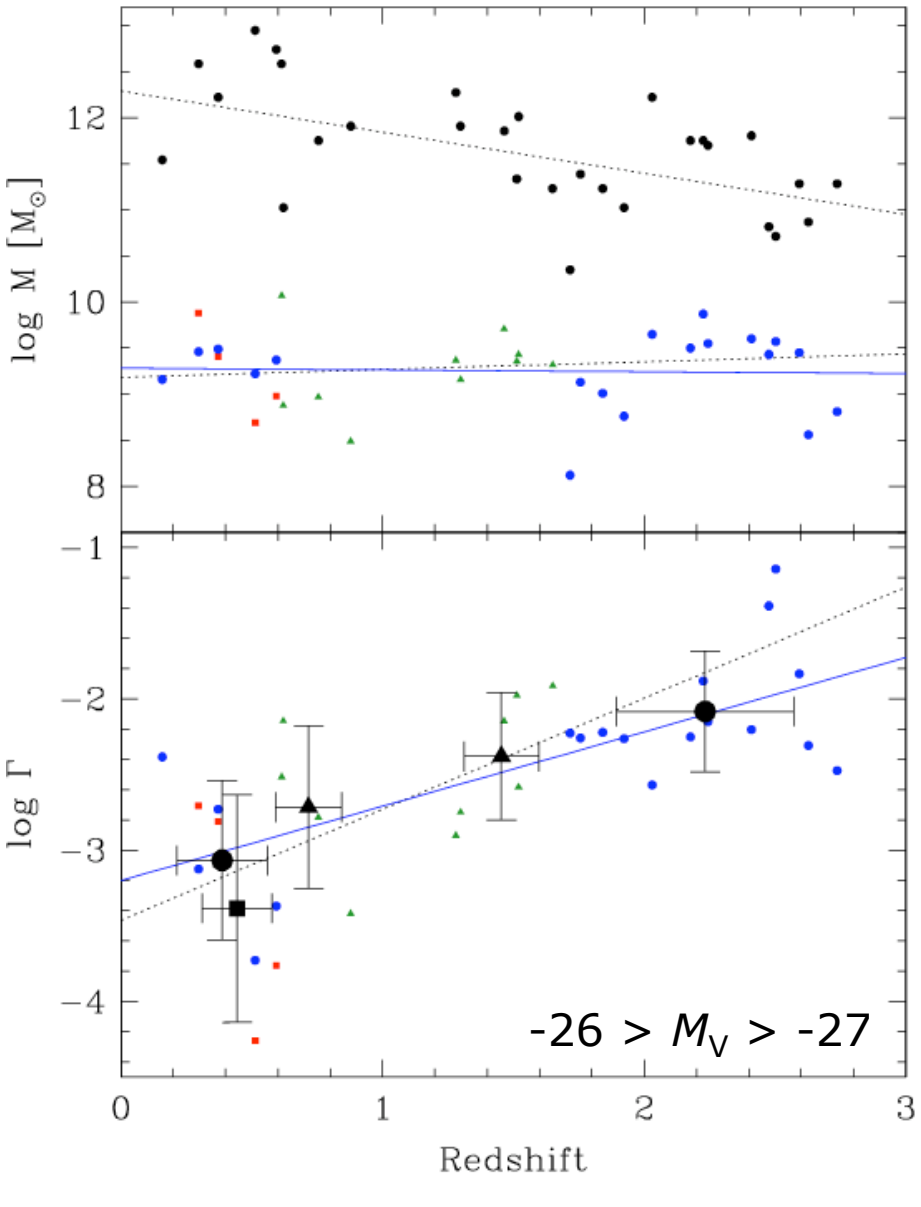
- The scatter in the M_{BH}-M_{host} (L_{host}, σ_*, etc) relation introduces a bias *(Lauer et al., 2007)*.
- The steeper is the luminosity function, the larger is the bias.
- $\Delta \log M_{BH} = \int_{\Phi(M1)}^{\Phi(M2)} (\Phi(M2)-\Phi(M1)) / \int_{M1}^{M2} \Phi(M)dM$

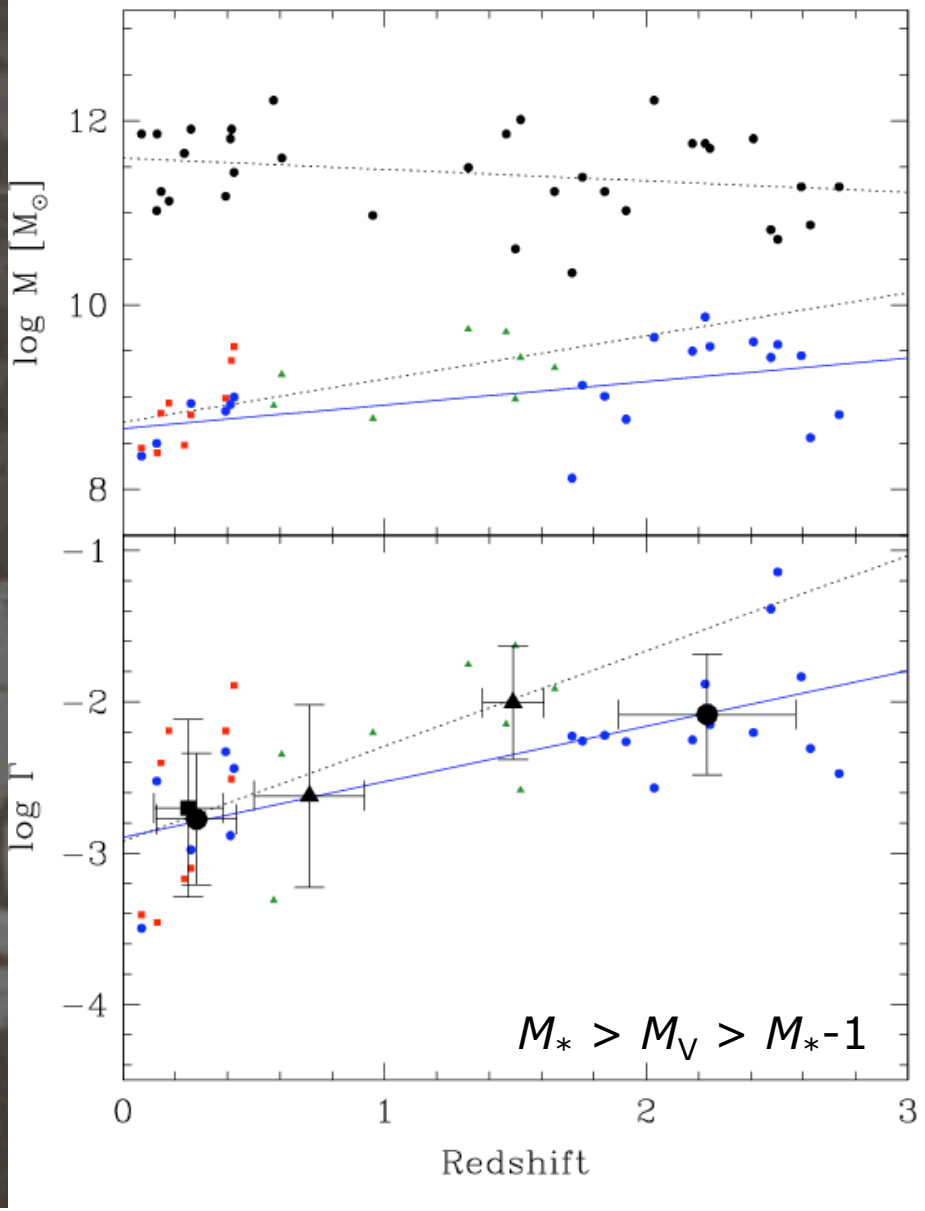




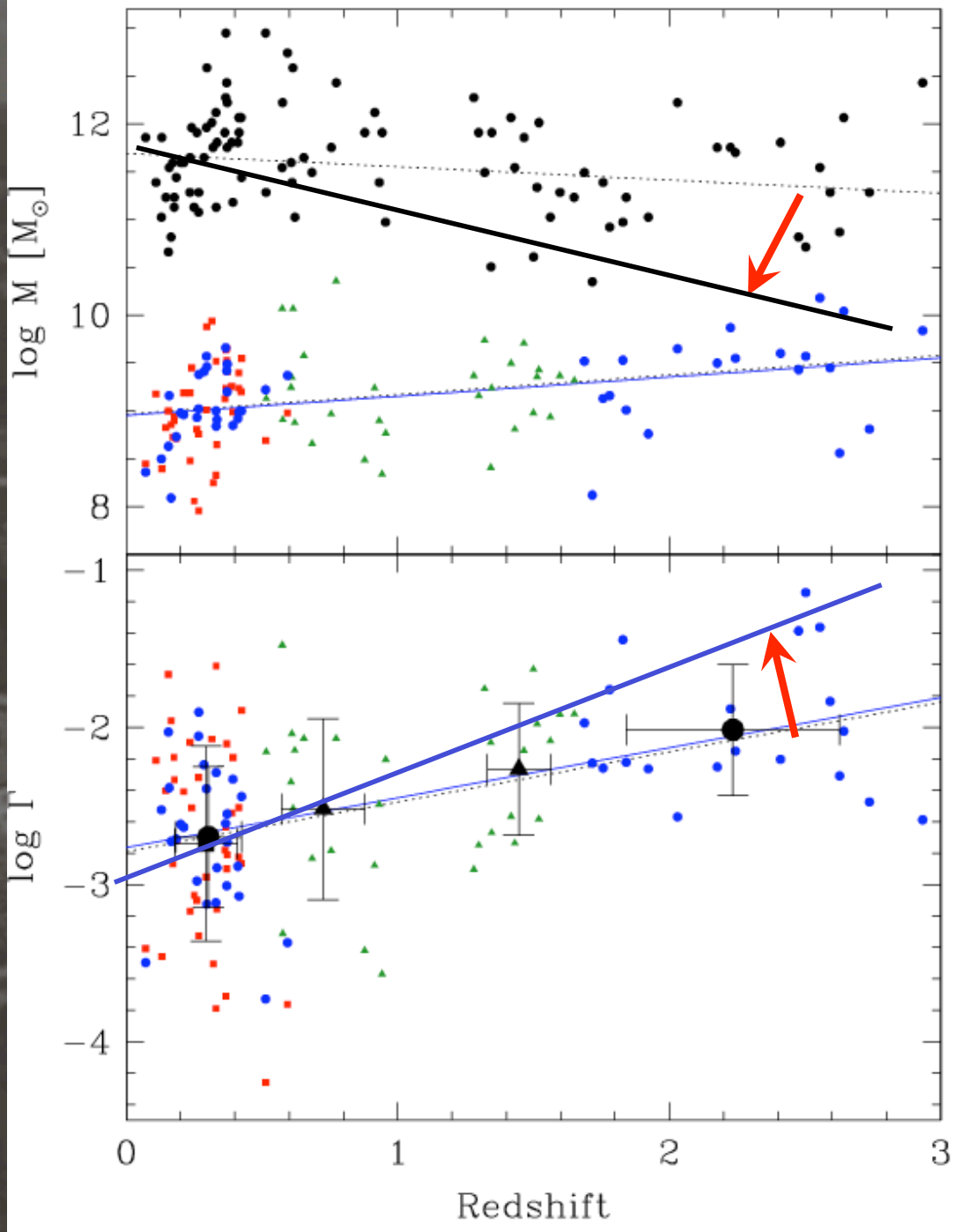


Luminosity cuts

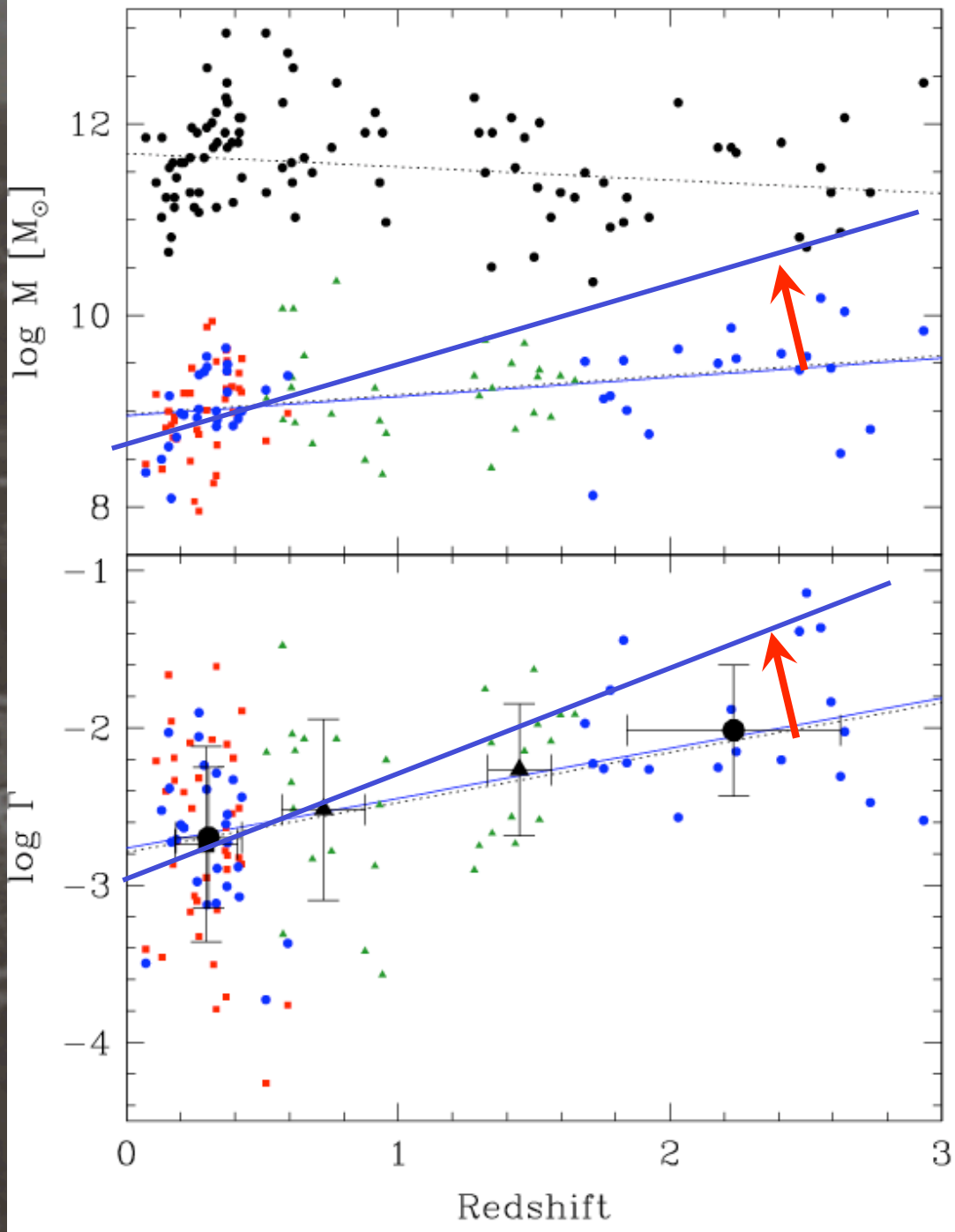




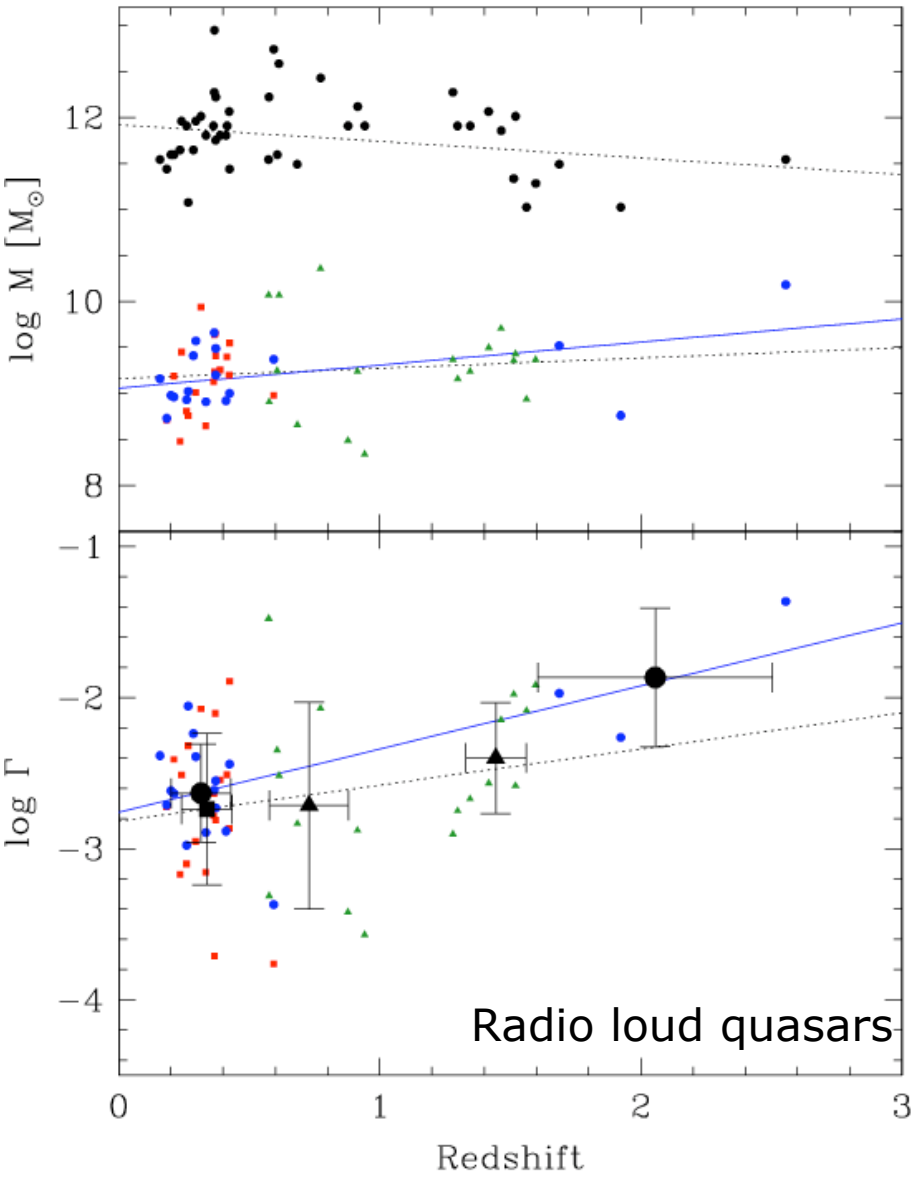
Contaminations from disc-dominated and/or unresolved galaxies?

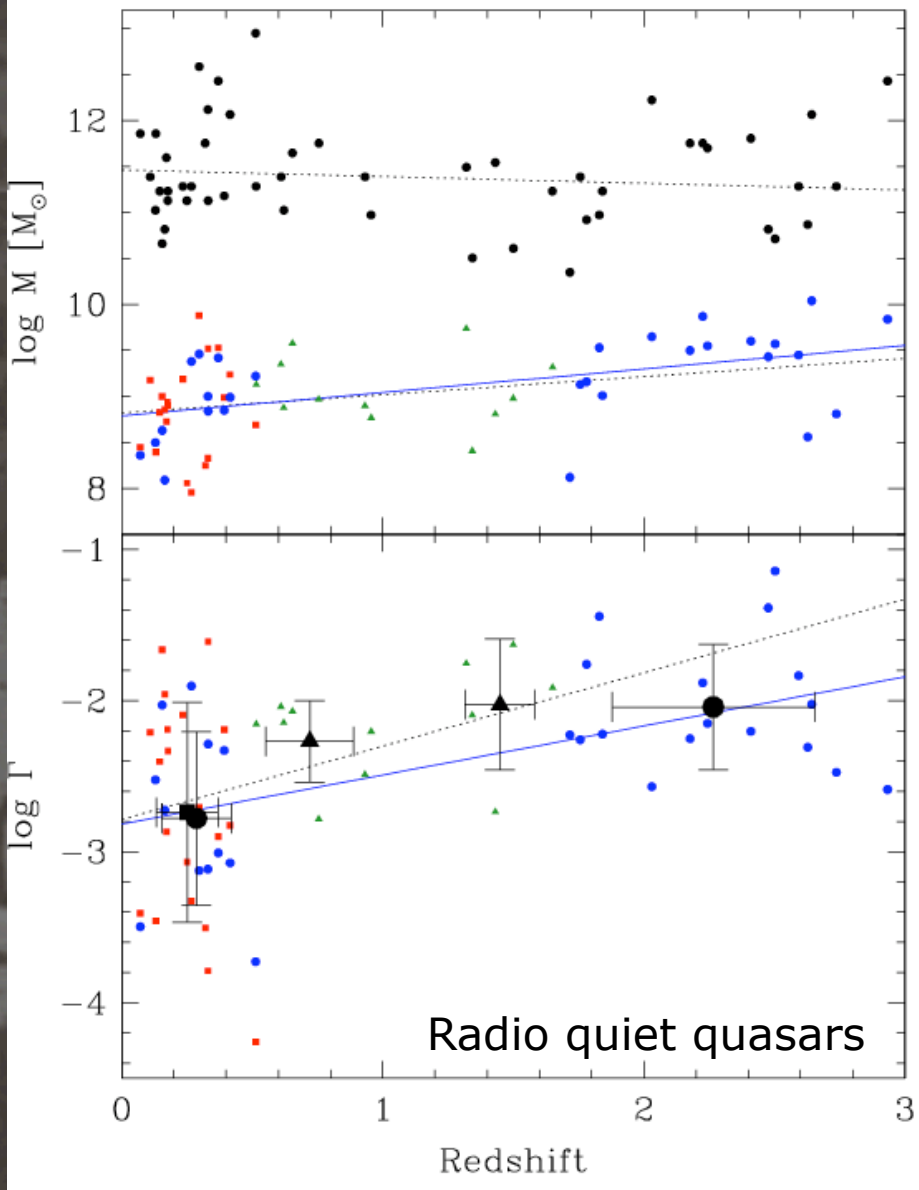


Radiation pressure?



Radio loudness



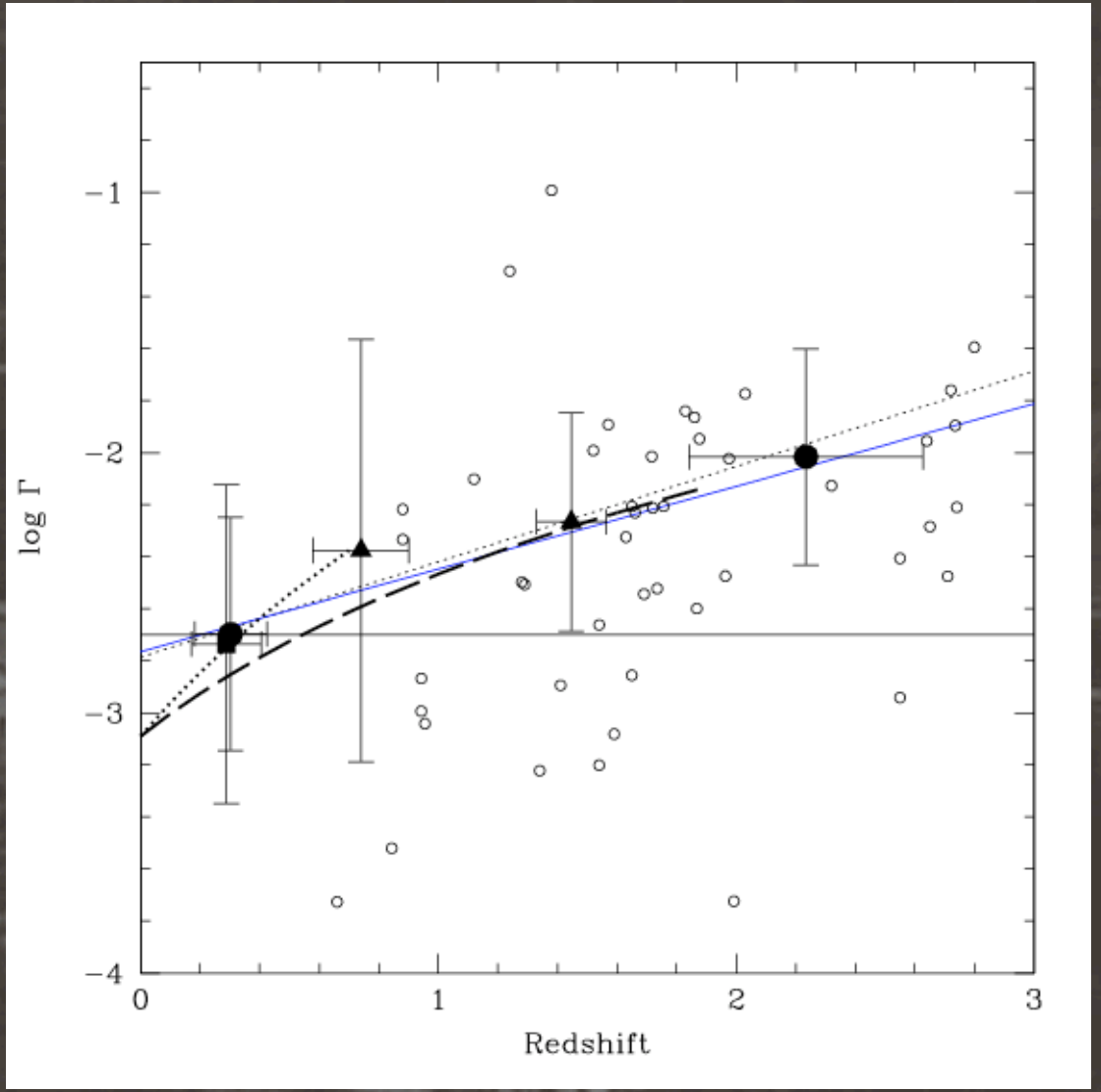


The M_{BH}–M_{host} ratio as a function of z

- We confirm the trend observed by *McLure et al. (2006)* for z<2 radio loud AGNs and extend it to 2<z<3 quasars, both for RLQs and RQQs

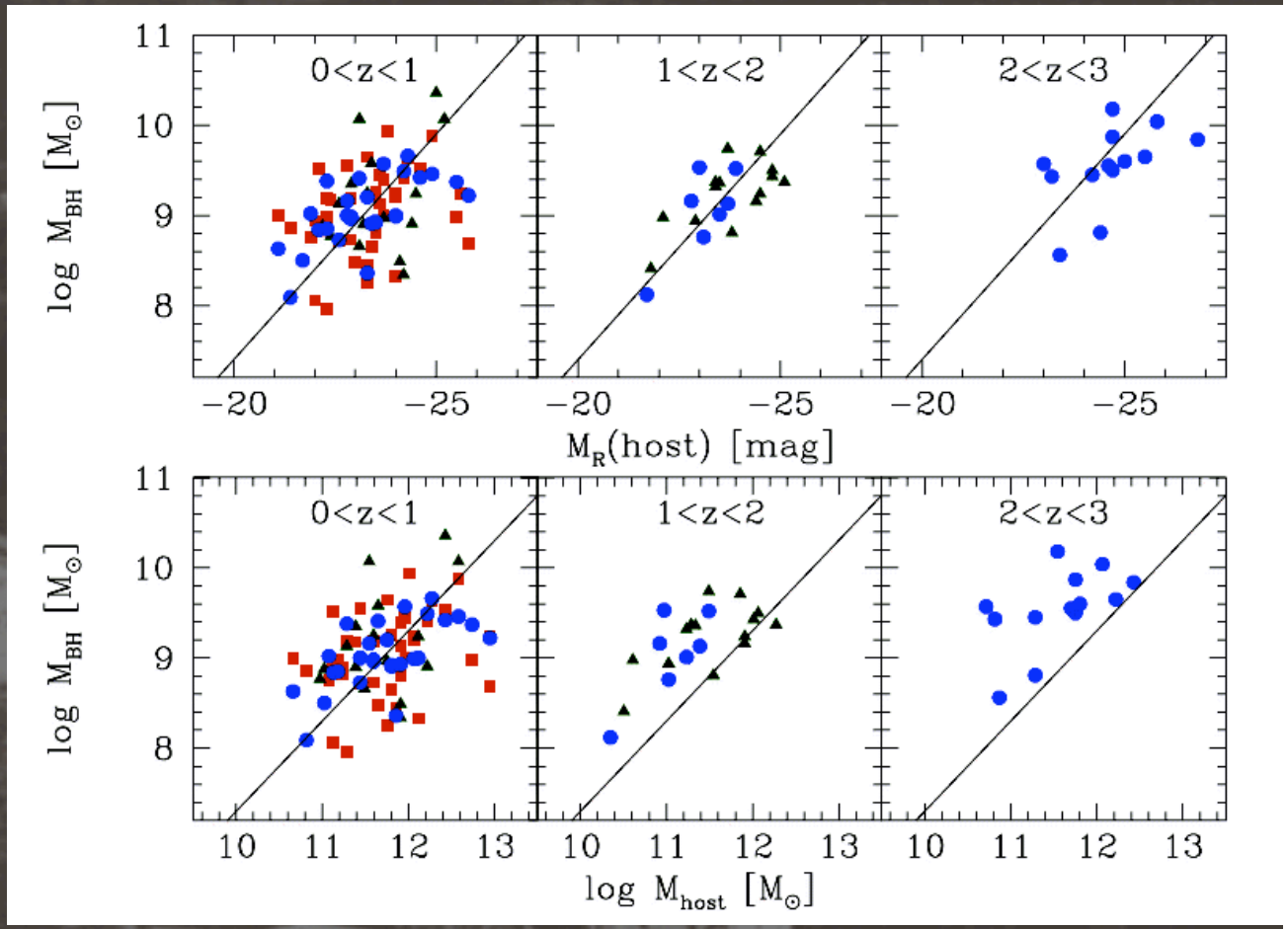
- Our results are also qualitatively in agreement with those by *Peng et al. (2006)* and *Woo et al. (2006)*

- SDSS1148+5251:
  $z = 6.41$
  $M_{BH}=3 \cdot 10^9\ M_o$
  (Barth et al. 2003)
  $M_{dyn}= 5 \cdot 10^{10}\ M_o$
  (Walter et al. 2004)
  $M_{BH}/M_{host} > 0.06$
  Extrapolating our result:
  $M_{BH}/M_{host}=0.14$



Conclusions

- We now probe the M_{BH}-M_{host} relation up to z=3
- The M_{BH}/L_{host} is almost constant up to z=3
- Once we correct for the evolution of the (fading) *M/L* ratio of the host galaxy stellar component, the M_{BH}/M_{host} ≡ G ratio increases of a factor ~8 from z=0 to z=3
- Is the stellar *M/L* evolution correct?



Open questions

- What does it mean?

- What about: M_{dyn}, s_*, the gas fraction, the DM component? (=> fundamental plane evolution…)

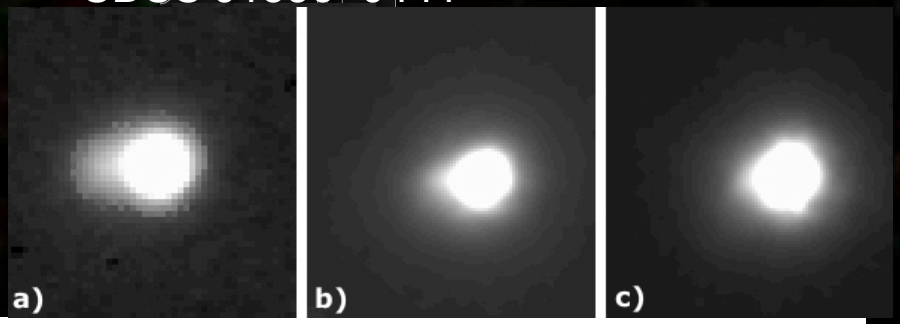
- What is the role of major/minor and dry/wet mergers?

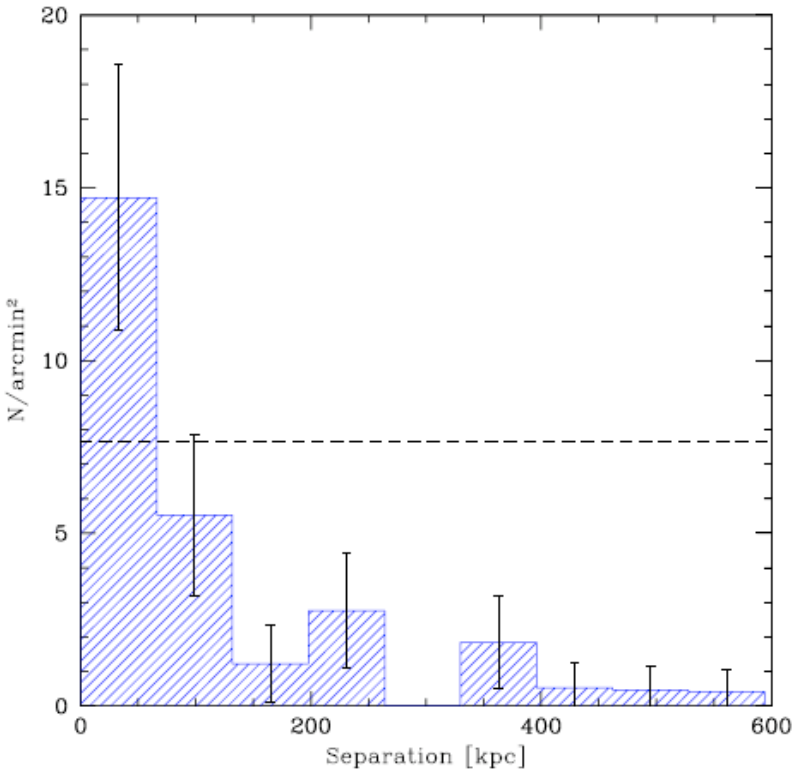
- What about spiral galaxies?

… up to the afternoon talks!

The object of the month

SDSS J1536+0441



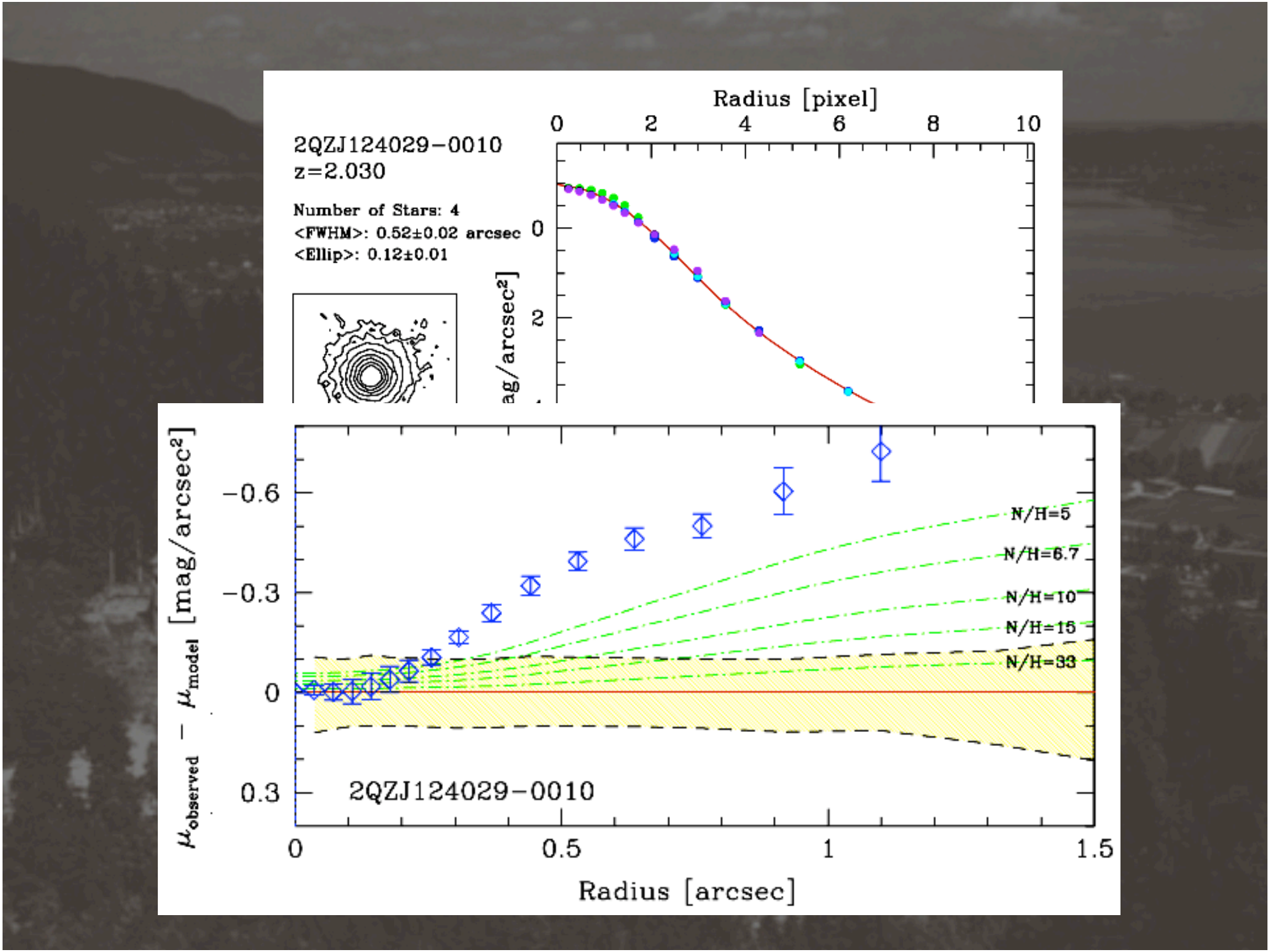


- **A z=8.1 GRB?**
  (Salvaterra et al., Tanvir et al.)

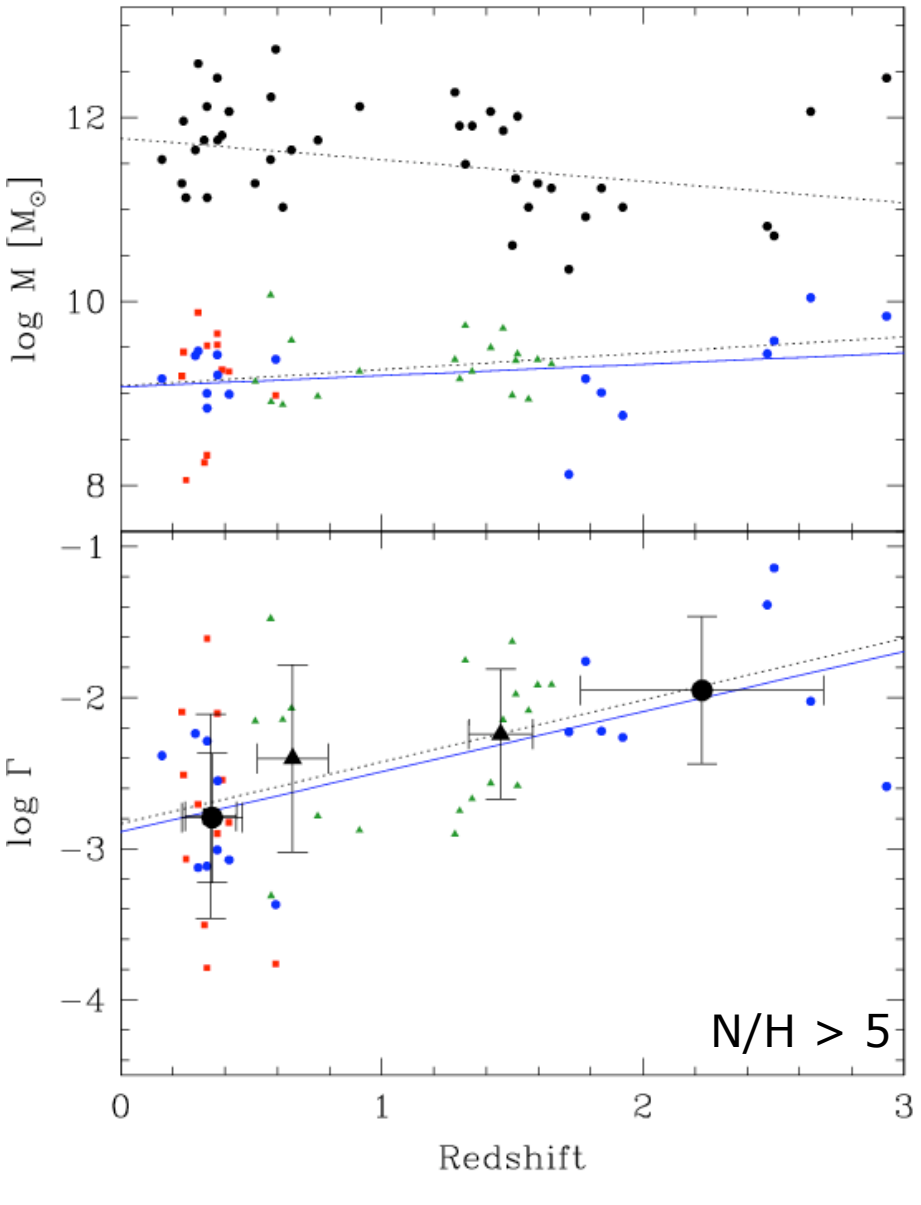
- Boroson & Lauer (SDSS) — Jan, 23
- Chornock et al. — Mar, 9
  Gaskell — Mar, 25

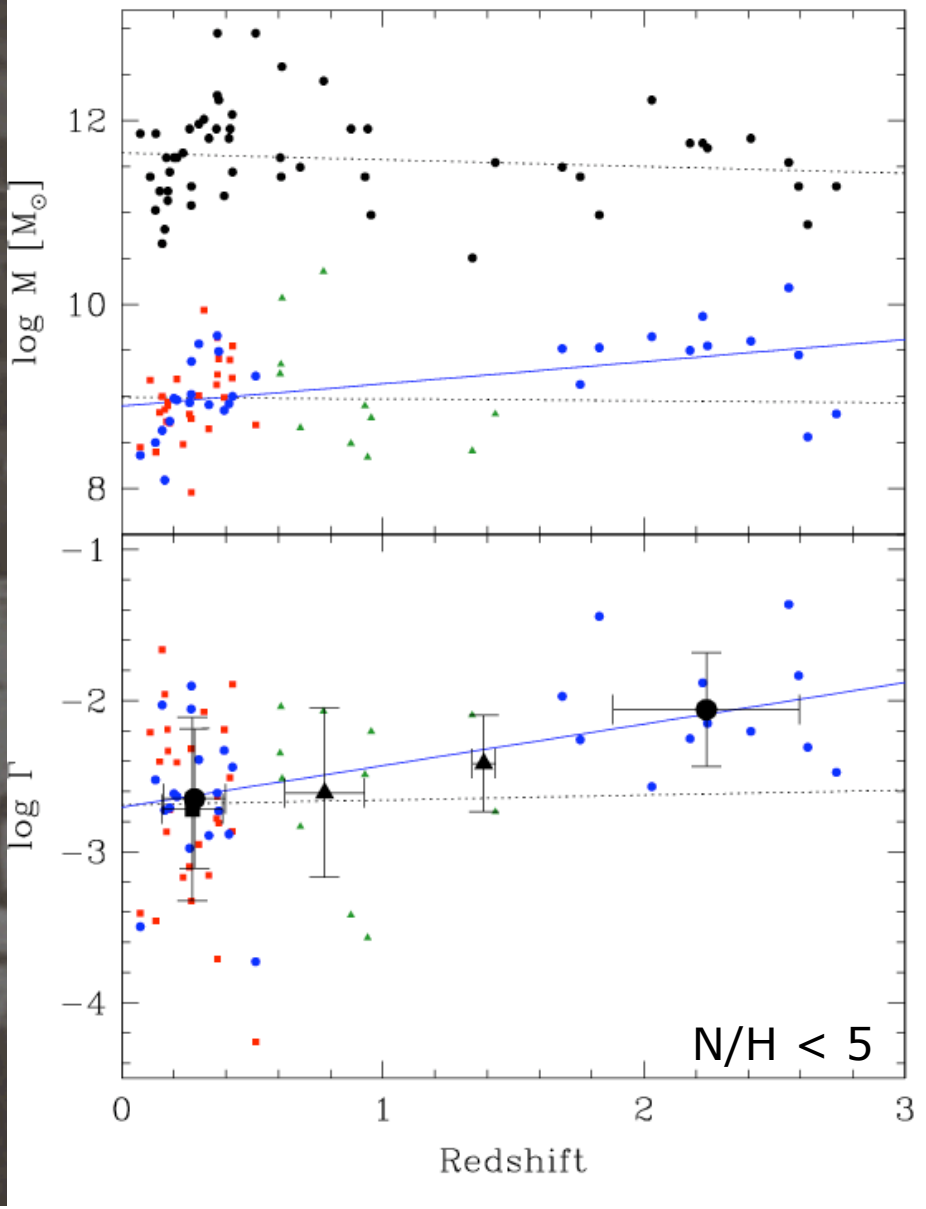
- Wrobel & Laor — May, 25 (VLA)
- Decarli et al. — May, 27 (VLT)
- Lauer & Boroson — Jun, 2 (HST)
- Chornock et al. — Jun, 5 (KECK)
- Decarli et al. (VLT) — …

- The companion probably hosts an AGN
- The quasar lies in a galaxy cluster
- Most of its peculiar spectral features


2QZJ124029−0010
z=2.030
Number of Stars: 4
<FWHM>: 0.52±0.02 arcsec
<Ellip>: 0.12±0.01
Radius [pixel]
0
2
4
6
8
10
0
2
ag/arcsec²]
$\mu_{observed} - \mu_{model}$ [mag/arcsec²]
−0.6
−0.3
0
0.3
N/H=5
N/H=6.7
N/H=10
N/H=15
N/H=33
2QZJ124029−0010
0
0.5
1
1.5
Radius [arcsec]

N/H ratio


log M [M⊙]
12
10
8
log Γ
−1
−2
−3
−4
0
1
2
3
Redshift
N/H > 5


log M [M⊙]
12
10
8
log Γ
−1
−2
−3
−4
0
1
2
3
Redshift
N/H < 5