NGC 1275: an outlier of the BH-host scaling relations

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Direct vs indirect M_{BH} estimates

Motions of *test* particles

★ Star proper motions and radial Velocities

★ Radial velocities of single gas clouds (masers)

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★ H_2O masers detected in few galaxies

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(spatially resolved)

★ Stellar Dynamics

V from Stellar Absorption Lines

★ Gas Kinematics

V from Gas Emission Lines

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(time resolved)

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V from line width, R from time variability

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★ Time consuming

Single Epoch Virial Relations

Assumptions

- ★ BLR is power by photoionization
- ★ Virialized BLR
- ★ Motions dominated by the BH

$$M_{BH} = f \frac{W^2 R}{G}$$

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Based on

- ★ The BLR-luminosity relation
- ★ The detection of BLR

$$\log(M_{SE}/M_{\odot}) = a \log(L/L_{\odot}) + b \log(FWHM/kms^{-1})$$

Calibrated

- ★ Reverberation mapping M_{BH}

- ★ Only for Type 1 AGN

Vestergaard 2002; McLure & Jarvis 2002; McLure & Dunlop 2004; Wu +2004; Greene & Ho 2005; Vestergaard & Peterson 2006; Kollmeier +2006; Onken & Kollmeier 2008; Landt +2008; Wang +2009; Vestergaard & Osmer 2009; Greene +2010b; Rafiee & Hall 2011b; Shen et al. 2011; Shen & Liu 2012; Trakhtenbrot & Netzer 2012, La Franca +2015, Mejia-Restrepo+16.

New Single Epoch Virial Relations

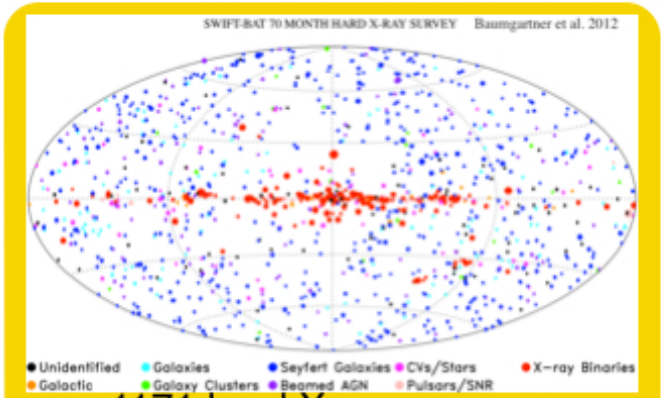
Optical (rest-frame):

- no broad line component → NIR (Paschen series, HeI)
- AGN continuum obscured and/or contaminated by host galaxy

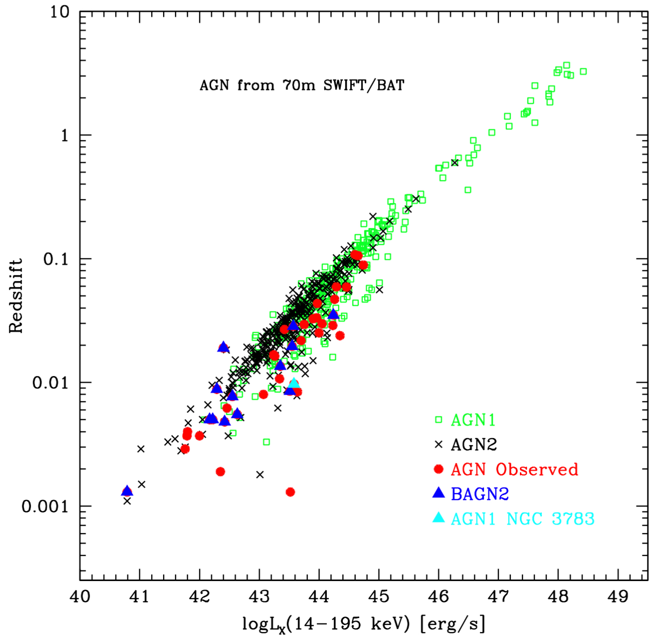
Swift BAT Hard X-ray selection:

- Complete sample of Compton thin AGN2 (log N_H >21), see also Koss +2017
- No contamination from the host galaxy to L_X

Onori +2017a



1171 hard X-ray sources
>700 AGN
41 AGN2 z<0.1 selected



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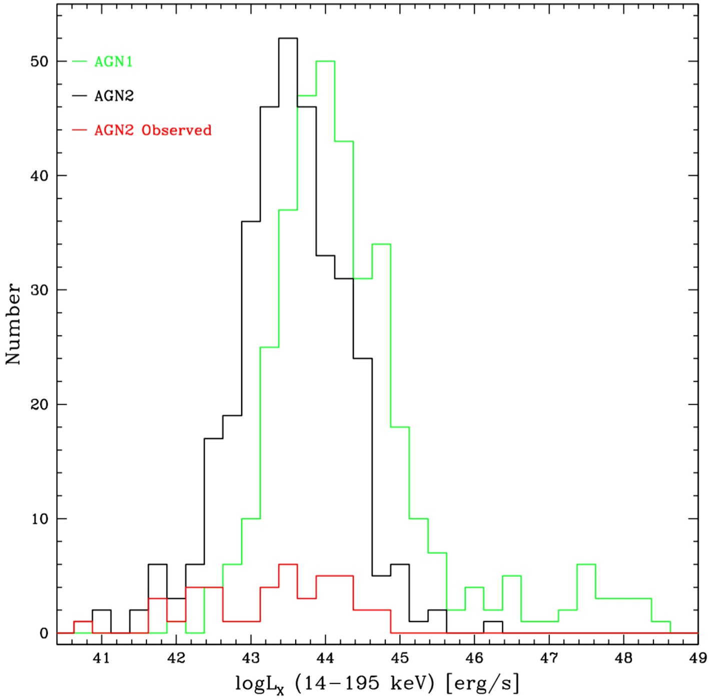
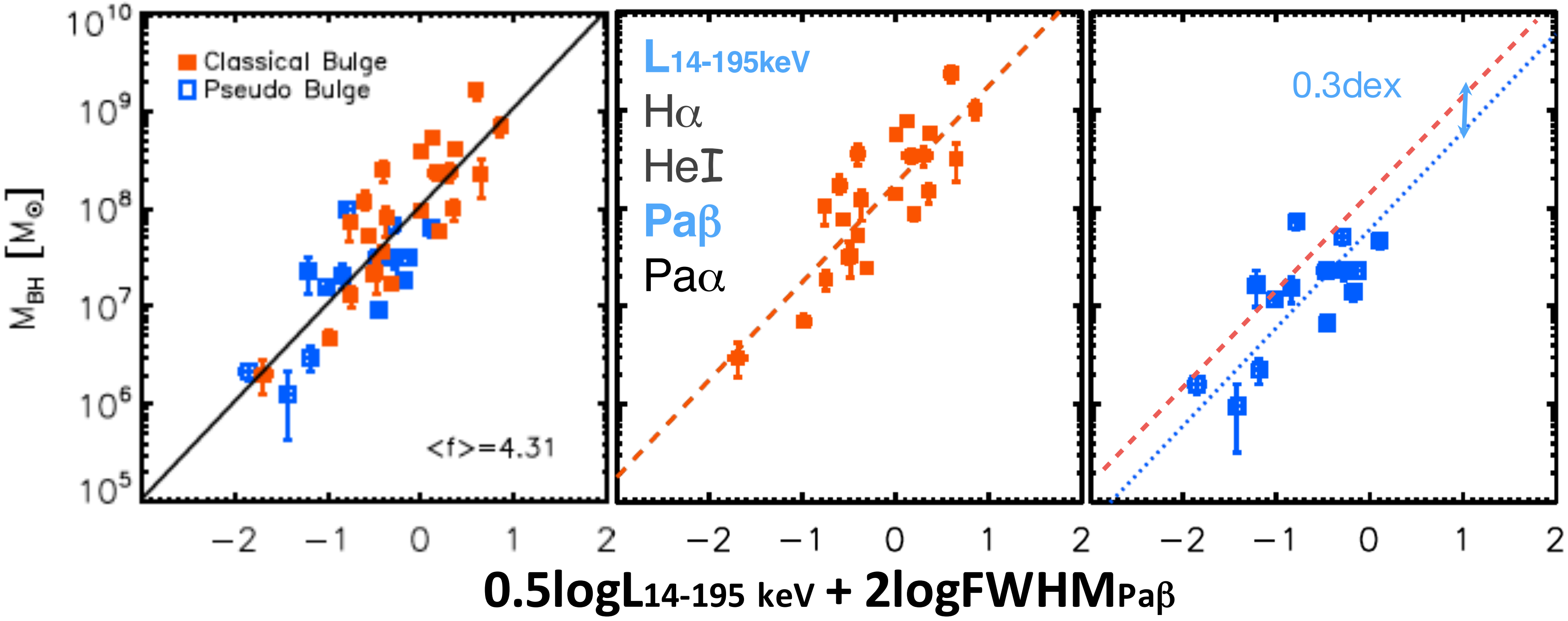


New Single Epoch Virial Relations

NIR virial relations based on the Paβ FWHM (but also Hα, Paα, HeI1.083µm, see Greene&Ho+05, Landt+08, Shen&Liu+12, Mejia-Restrepo+16) and the hard-X $L_{14-195\,keV}$ therefore able to work with low-L AGN1 and AGN2



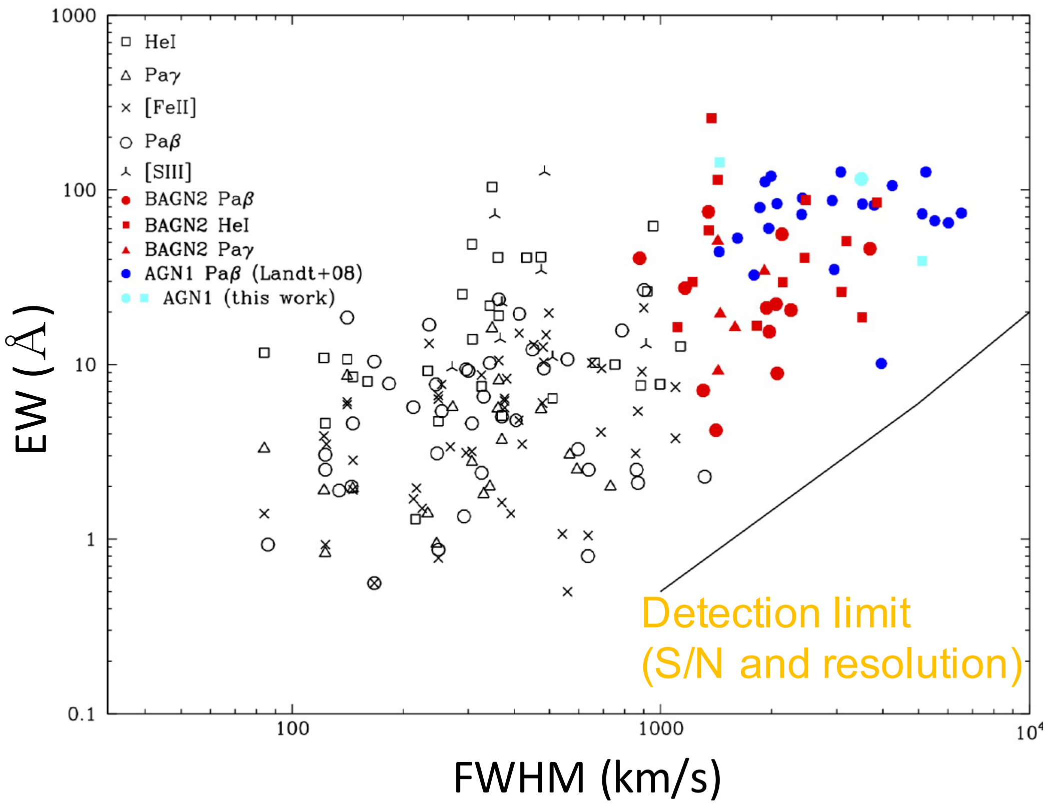
La Franca +2015
Ricci +2017

Sample of RM AGN1 to calibrate new virial M_{BH} estimators

FWHM of Hα Hβ Paα Paβ HeI all correlate each other

<f> for bulges and pseudobulges (Ho & Kim 2014) → M_{BH} in pseudobulge/AGN smaller than bulge/AGN

Local AGN2 vs AGN1

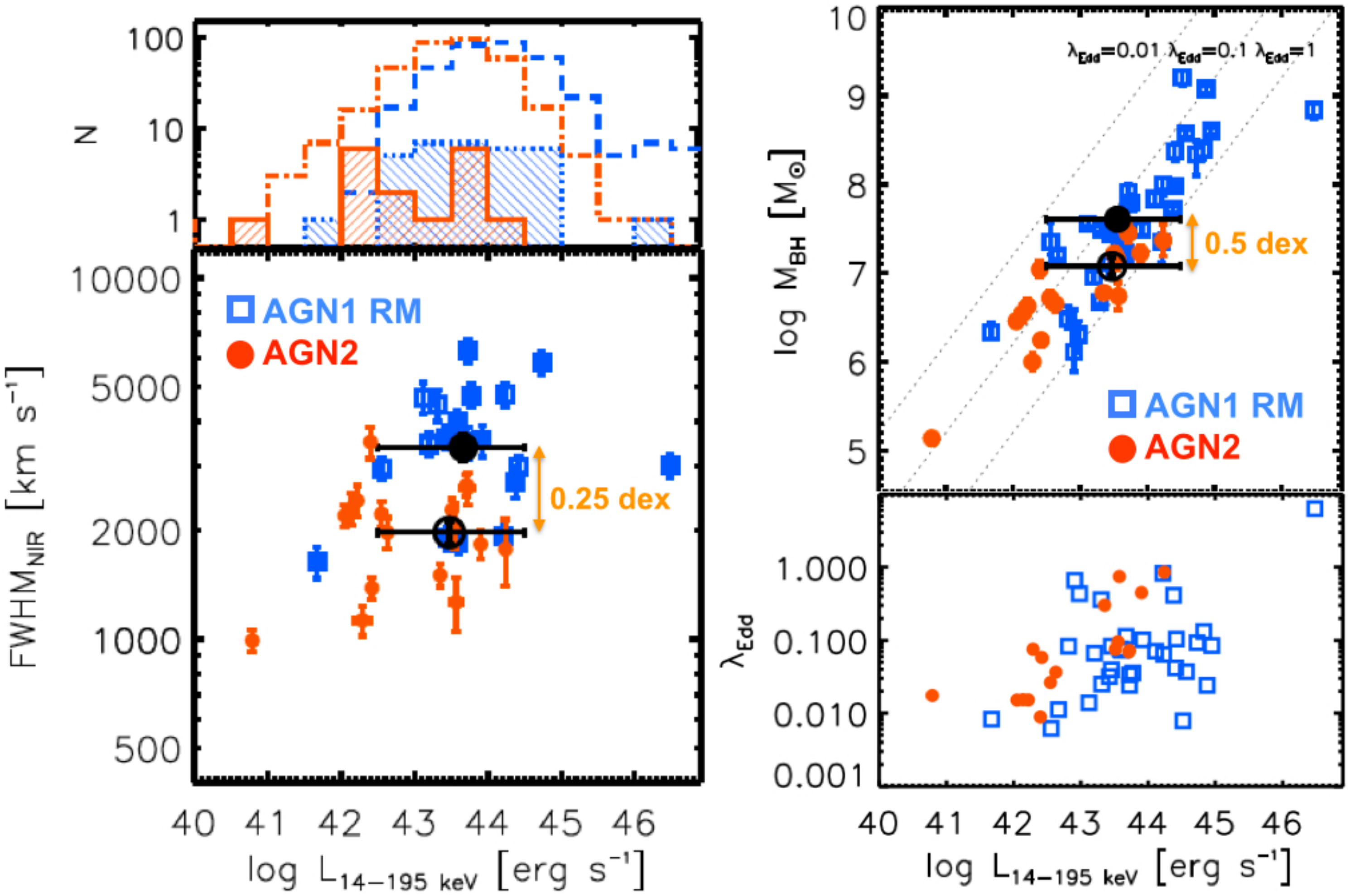


AGN1:FWHM ~ 3356 ± 310 km/s
EW ~ 80±6 Å
AGN2:FWHM ~ 1970 ± 145 km/s
EW ~ 44±9 Å

Onori +2017a

★ Broad lines in AGN2 are less wide and less intense than in AGN1
★ No biases against: S/N, IR flux, X-ray flux and L, N_H and host orientation

Local AGN2 vs AGN1



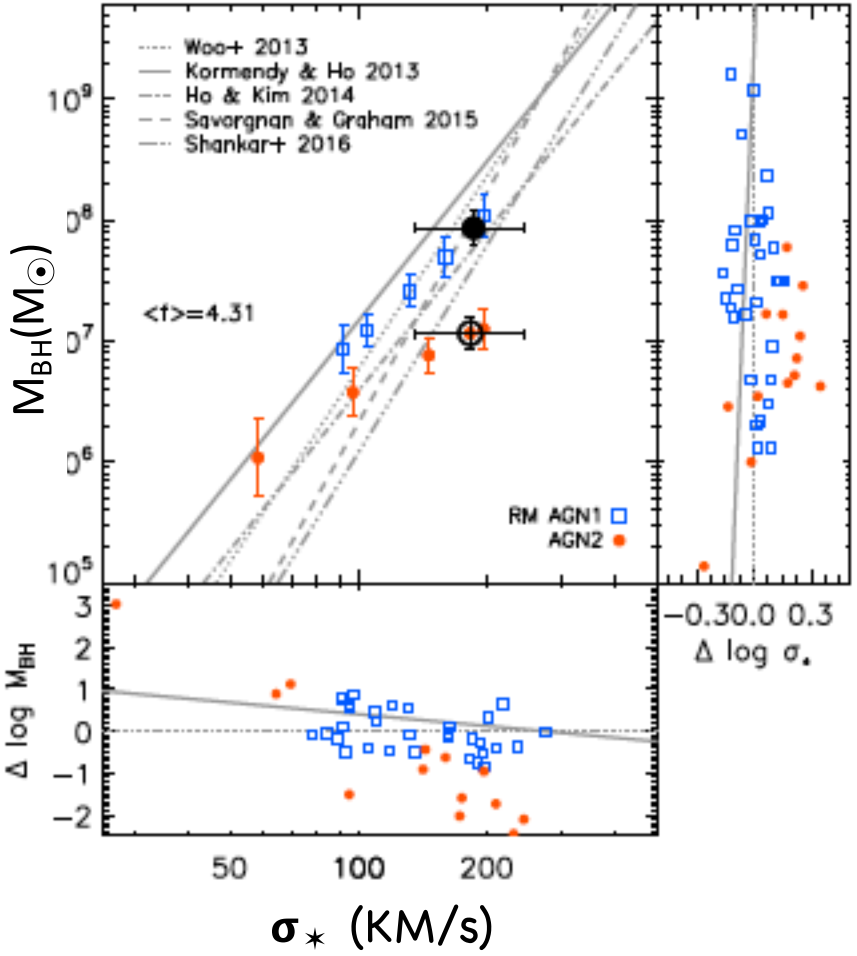
Onori +2017b MNRAS Letter

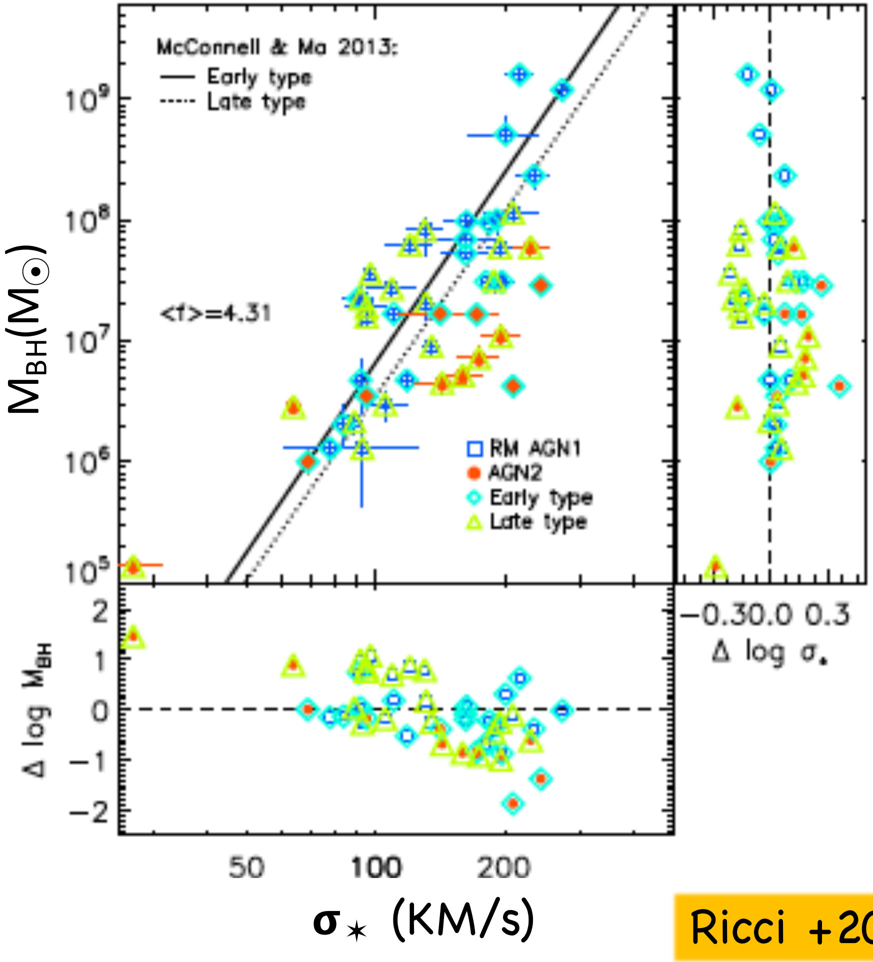
Over the same L_x range:

- M_{BH}(AGN2) < M_{BH}(AGN1) of ~0.5 dex
- λ_{Edd}(AGN2) > λ_{Edd}(AGN1) of ~0.3 dex

Note: <f> is the same for RM AGN1 and SE AGN2

Local AGN2 vs AGN1

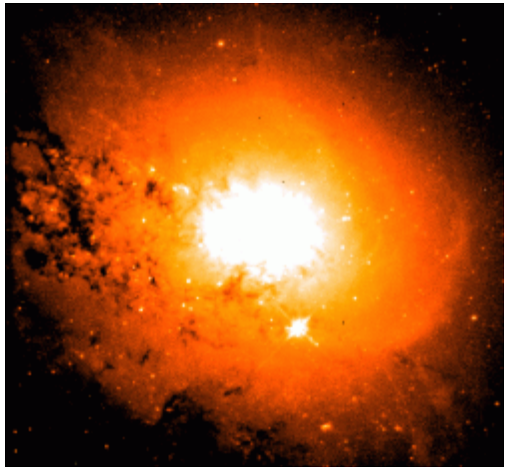




At a given $\sigma_\star$
M_{BH}(AGN2) < M_{BH}(AGN1)
of ~0.9 dex regardless the early/late type classification

Ricci +2017b MNRAS Letter

The Case of NGC1275: M_{BH} estimation



M_{BH}-$M_{\bigstar}$

$M_{\bigstar} \sim 2.4 \times 10^{11}\ M_{\odot}$ (Mathews +06)

→ $M_{BH} \sim 3 \times 10^{8}\ M_{\odot}$

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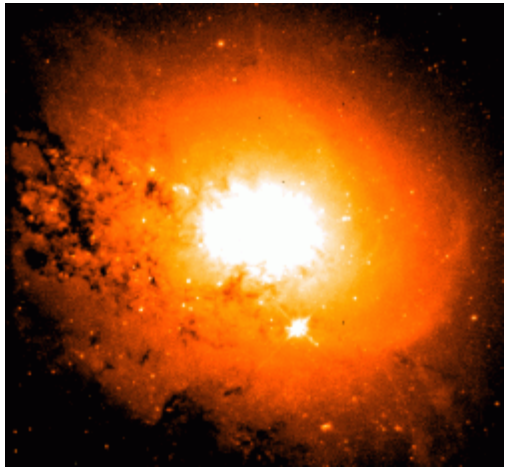

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Bulk motions: gas kinematics

$M_{BH} \sim 8 \times 10^{8}\ M_{sun}$ (Wilman +05, Scharwächter +13)

- ★ No circular motions (bulk motions, gas streams)
- ★ H_2 mass not negligible
- ★ BH sphere of influence not resolved
- ★ Disk inclination unknown

- ★ Upper limit → $4 \times 10^{8}\ M_{sun}$

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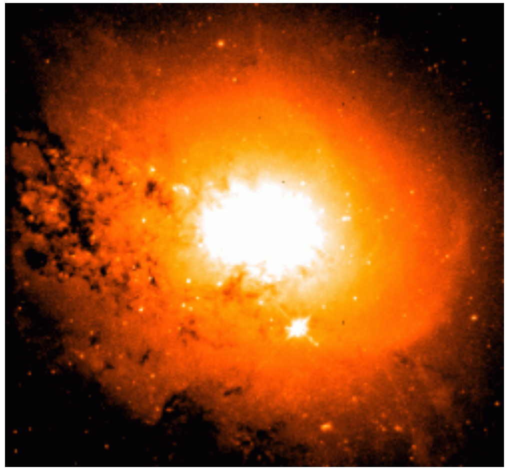

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Virial method: SE scaling relations

- ★ FWHM(Hα), L_{5100} → $M_{BH} \sim 1.4 \times 10^7\ M_\odot$ (Koss +17, BASS collaboration)

- ★ Balmer series dimmed by absorption
- ★ (log $N_H \sim 21.2$ Tueller +08)
- ★ FeII pollution

The Case of NGC1275: M_{BH} estimation

Virial method: SE scaling relations

★ FWHM(Paβ) = 2824 km/s

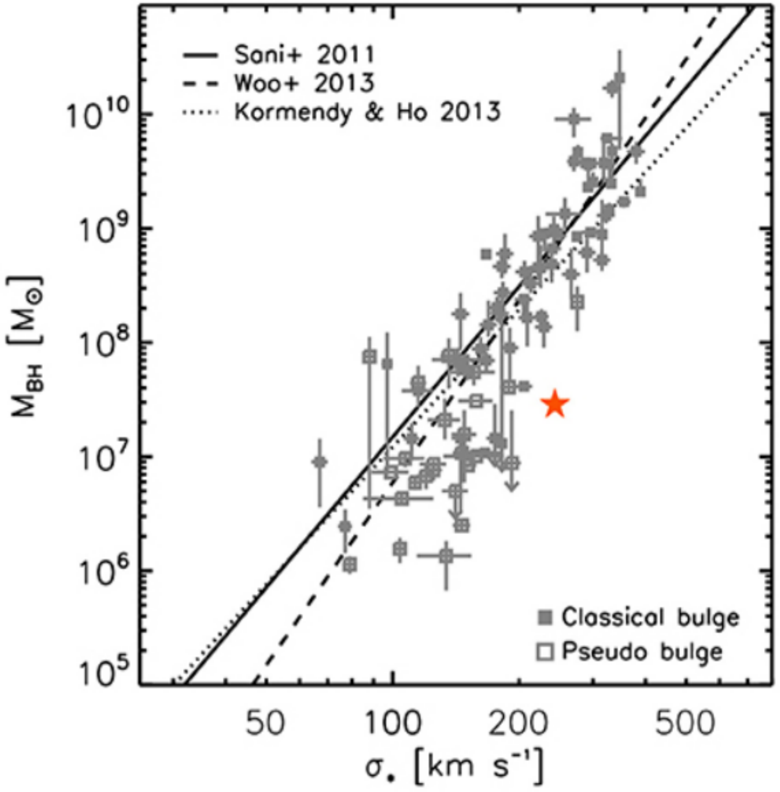
★ $L_{14\text{-}145keV}$ = 5.13 x 10^{43} $L_{\odot}$

Onori +2017b

★ M_{BH} = (2.9±0.4) x 10^{7} $M_{\odot}$

NGC 1275 cD gal of Perseus, archetypal system that is supposed to *fit well* the BH-host scaling relations, BUT…

- 1.2 dex displaced in the M_{BH} - $\sigma_{\star}$ ≳ 30% than observed in AGN2



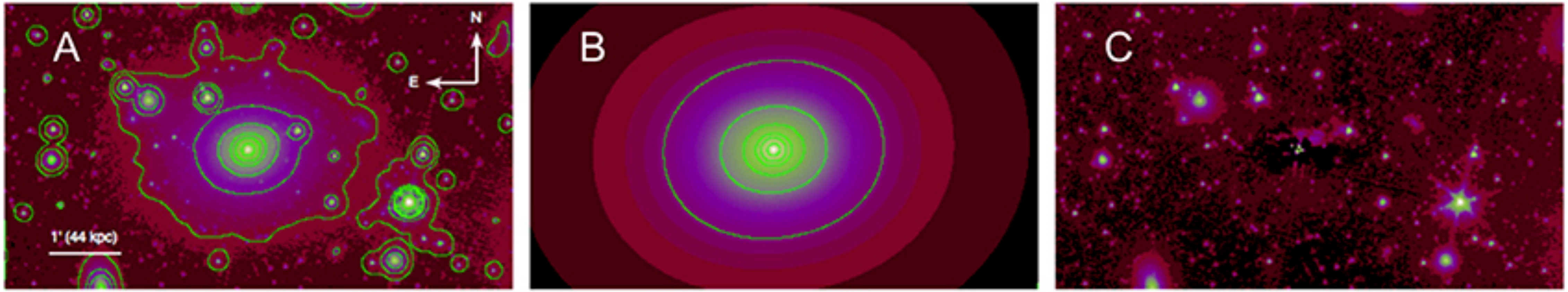
Ricci +2017b
Sani +2018

The Case of NGC1275: morphology

Decomposition of *Spitzer*/RAC images with GALFIT

Control:

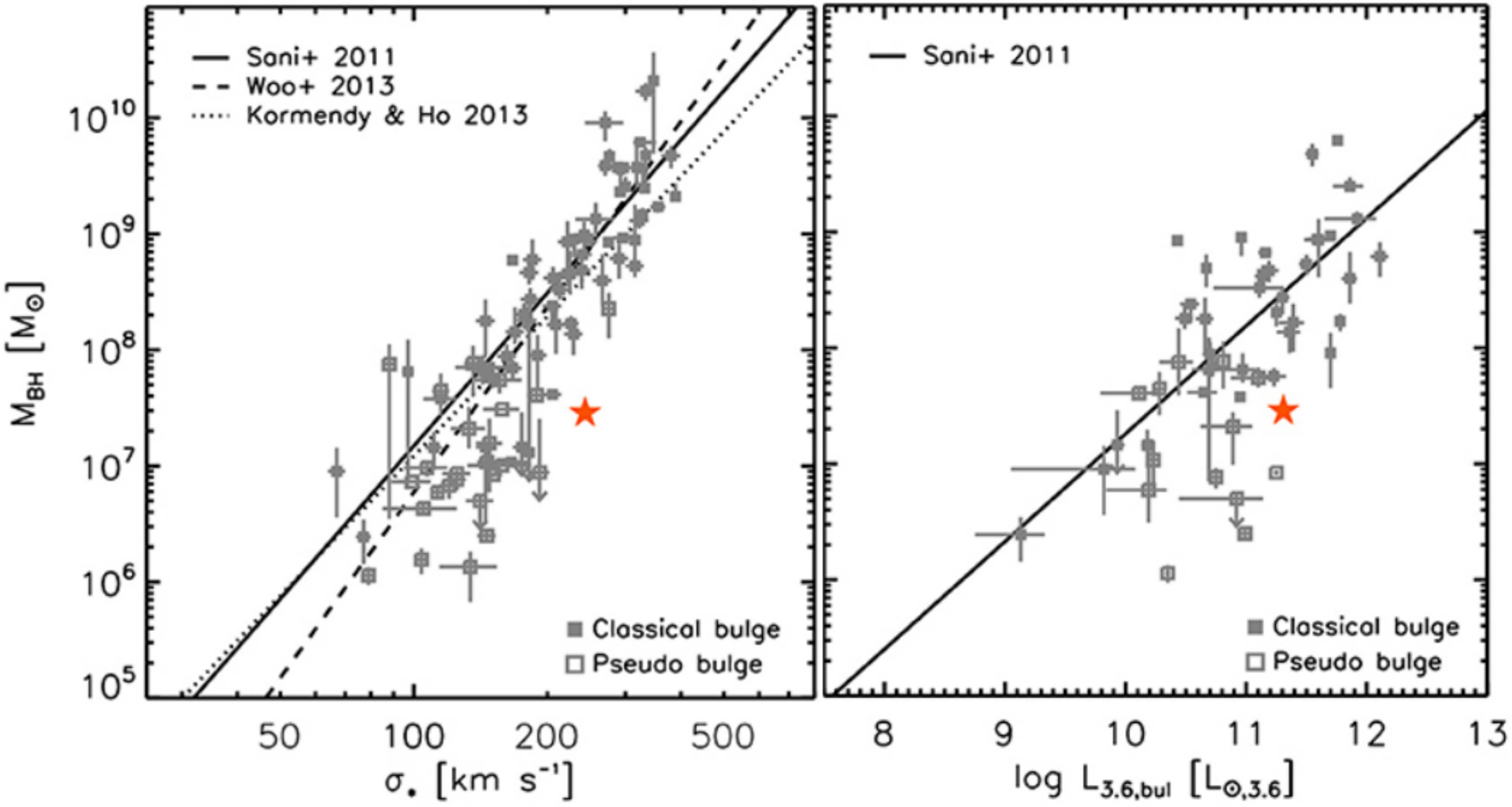
- the n_{ser} – R_e degeneracy
- Sky flux → Grid of 4 nser and 3 sky values
- Underestimated statistical errors



★ $m_{3:6;psf}$ = 12.12

★ $m_{3:6;bul}$ = 9.42 ± 0.21, R_e = 42 ± 15 kpc, n_{sers} = 4 ± 0.5 → De Vaucouleurs law, no pseudobulge
no signs of merger remanence
nor of star formation

NGC1275: an outlier of the BH-scaling relations

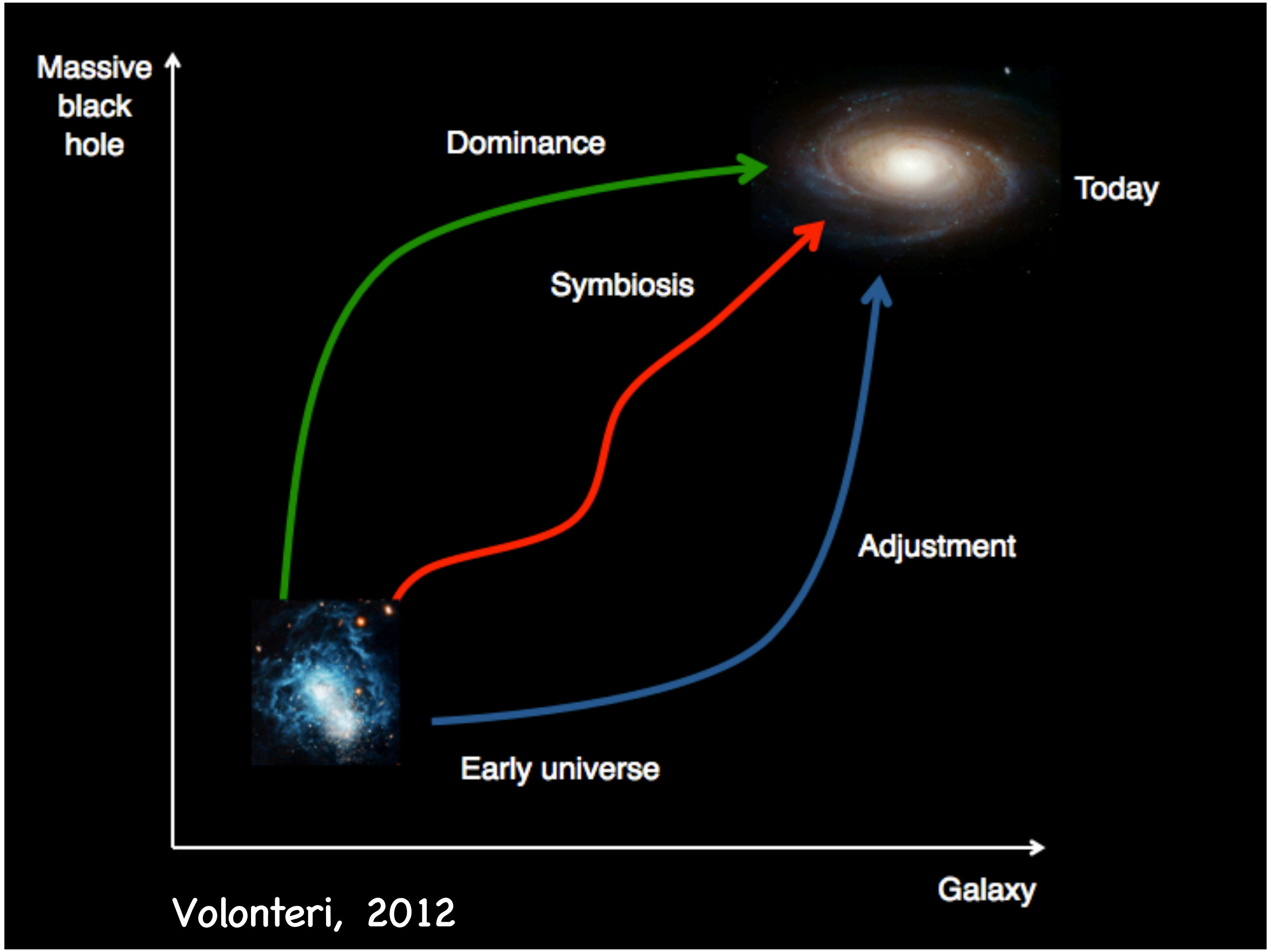


NGC 1275 cD gal of Perseus, archetypal system that is supposed to ***fit well*** the BH-host scaling relations, BUT….

1. **1.2 dex** displaced in the M_{BH} - $\sigma_\star$ ≳30% than observed in AGN2
2. **~15 times under-massive** than expected for quiescent galaxies that lie within the intrinsic scatter of the M_{BH} - $L_{3.6,bul}$

Sani +2018

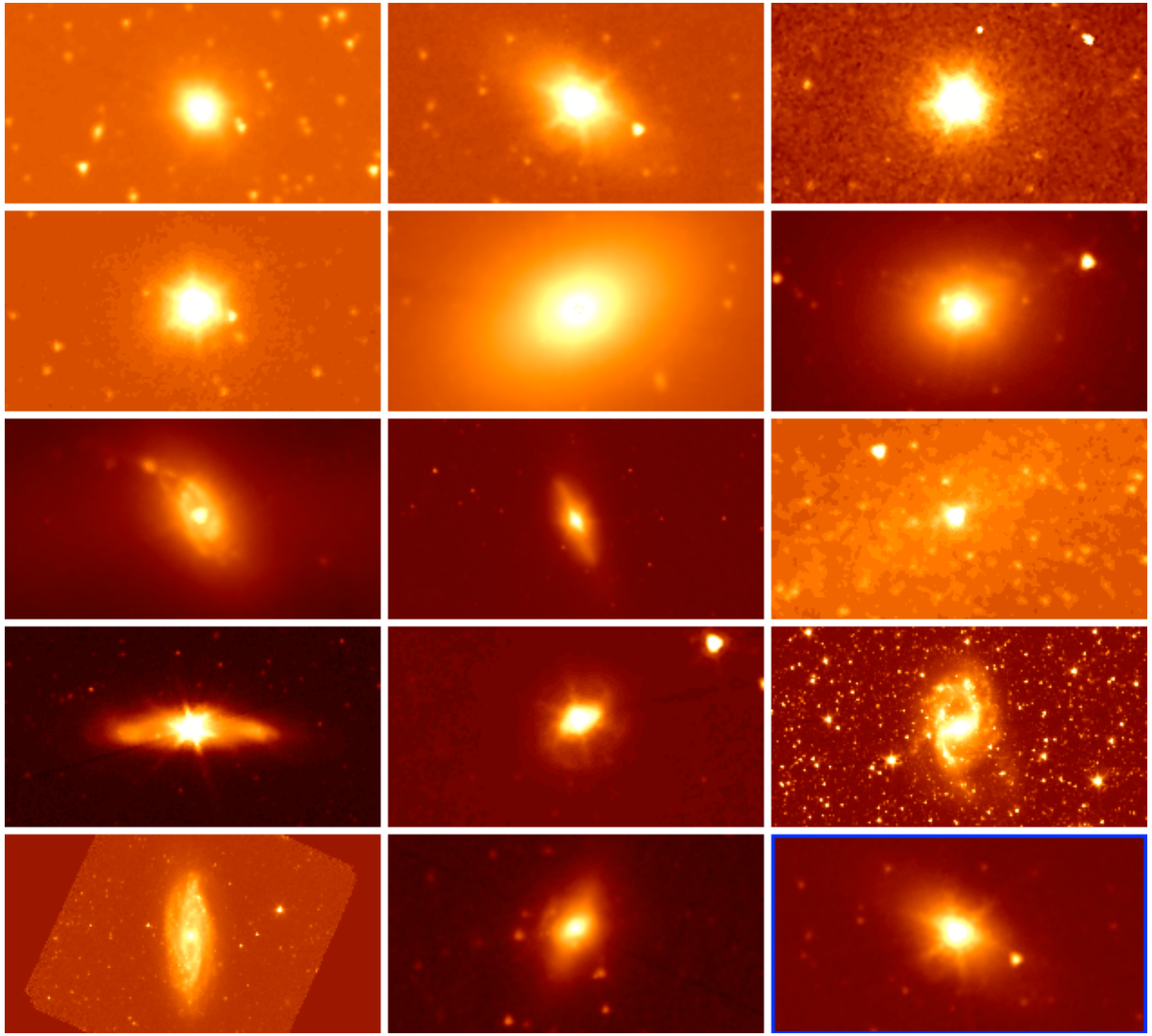
NGC1275: an outlier of the BH-scaling relations



Even though there is no trace of a pseudo-bulge from the 2D Spitzer image analysis, it hosts a relatively small AGN2 → observational link between **secular evolution** and **merger**

Evolutionary path where the galaxy grew first, and the black hole is adjusting to its host.

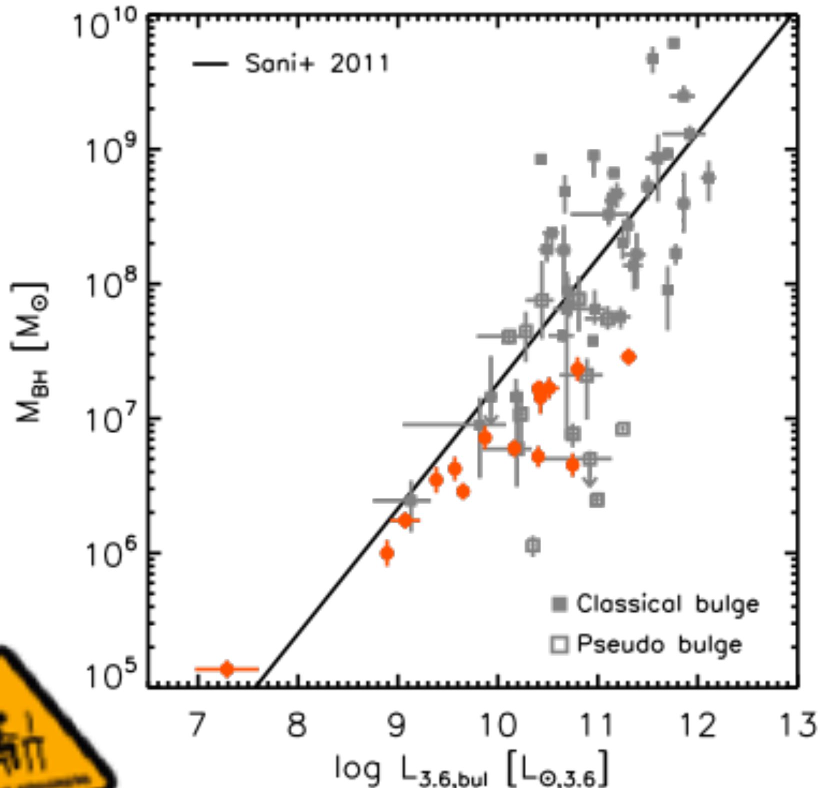
M_{BH} - host coevolution in AGN2: M_{BH} - $L_{3.6,bul}$



Active Galaxies in Spitzer/IRAC:

- 15 AGN2 with M_{BH} (NIR detect)
- 16 AGN2 (NIR non-detect)
- 19 RM AGN

+ Dynamical M_{BH}: 50



Conclusions & Summary

- New virial estimators for M_{BH} in faint and obscured AGN
- Broad emission lines detected in AGN2 and intermediate AGN → are narrower and fainter than in AGN1
- AGN2 harbour on average smaller BHs accreting at higher Eddington ratios than the AGN1 control population (with the same luminosity)
- At a given $\sigma_\star$, BHs are smaller in AGN2 than in AGN1 regardless the host morphology

NGC 1275:

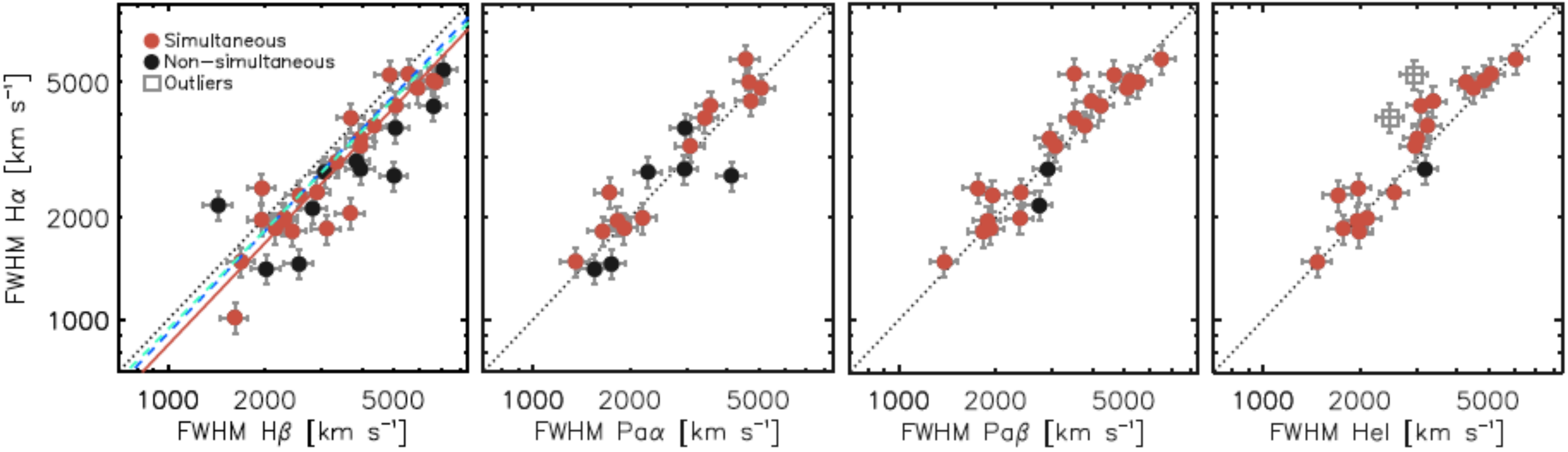
- $M_{BH} \sim 3 \times 10^7 M_\odot$, based on SE virial relations
- Displaced on M_{BH}- $\sigma_\star$ more than other dimmed AGN
- Dust is mainly heated by the AGN
- Host follows a de Vaucouleurs profile, no merger remanences, no strong SF
- $L_{3.6,bul} \sim 2 \times 10^{11} L_\odot$, NGC 1275 harbors a black holes 15 times under-massive than what expected for quiescent galaxies

Project: measure BH masses of AGN2

Hα probes a velocity field in the BLR consistent with the Hβ and the other NIR lines Paα, Paβ and He

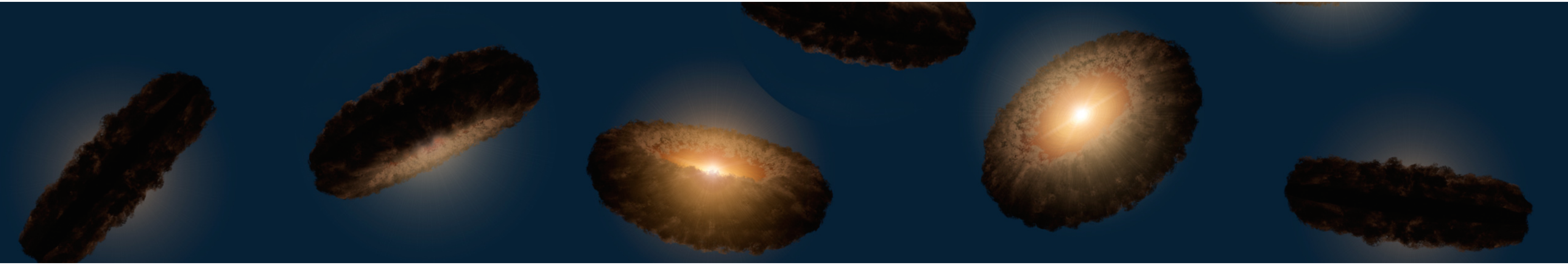
Assuming the virialization of the clouds emitting the Hβ implies the virialization also of the other lines → can be valuable tools to estimate the velocity of the gas residing in the BLR also for intermediate (e.g. Seyfert 1.8-1.9) and reddened AGN classes, where the Hβ measurement is impossible by definition

Ricci et al. 2017a



Project: measure BH masses of AGN2

In order to have a direct view of the BLR also in obscured systems, we need to penetrate the obscuring material → NIR Paschen lines



1. NIR observations of high-R and high-S/N have revealed broad Paschen lines in type 2 AGN (Veilleux+97, Riffel+06, Cai+10)
2. the dust absorption is less severe (~10 times) than in the optical (Veilleux+02)
3. Paα and Paβ are the strongest emission lines observed in the NIR, and are almost unblended (Landt+08)

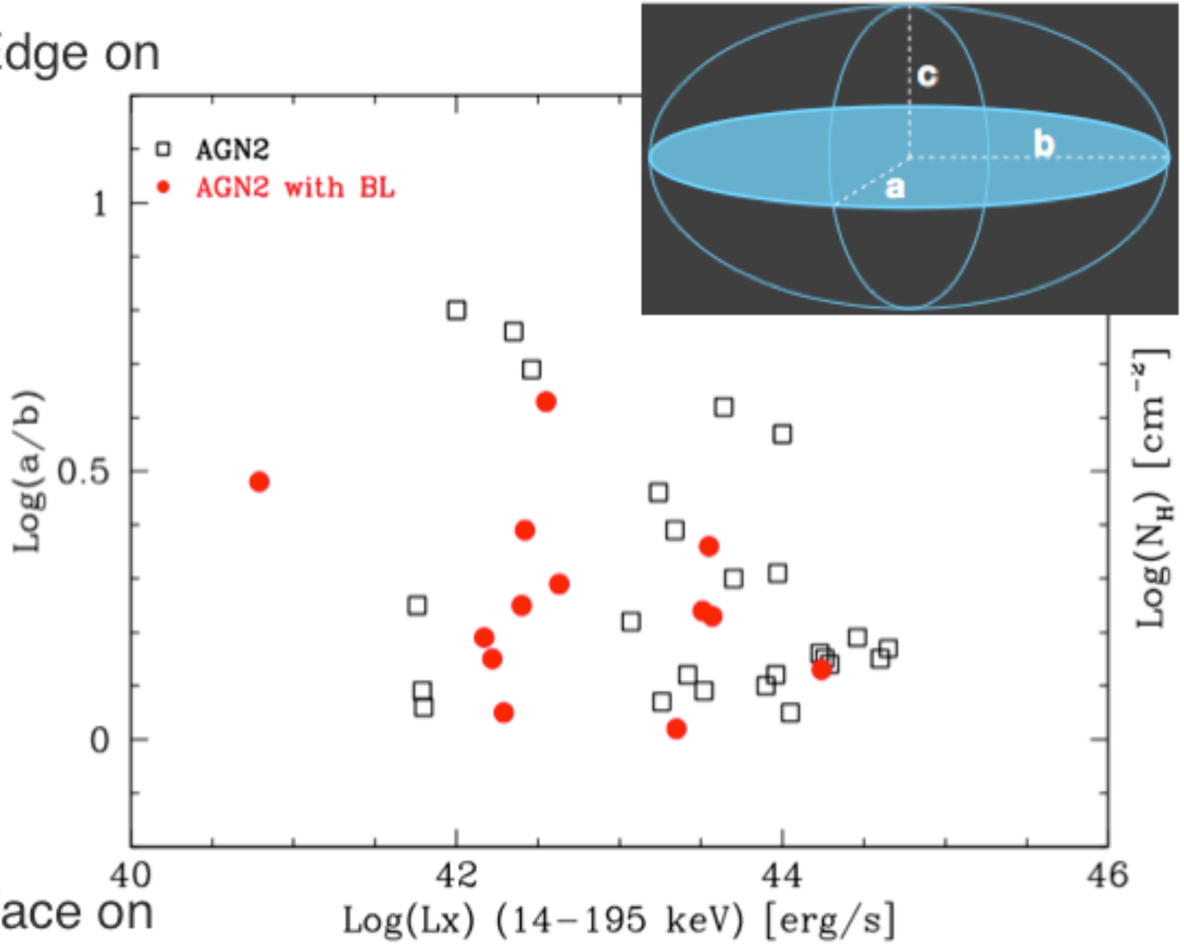
Possible selection effects

1. L_X - (a/b) and L_X - N_H planes

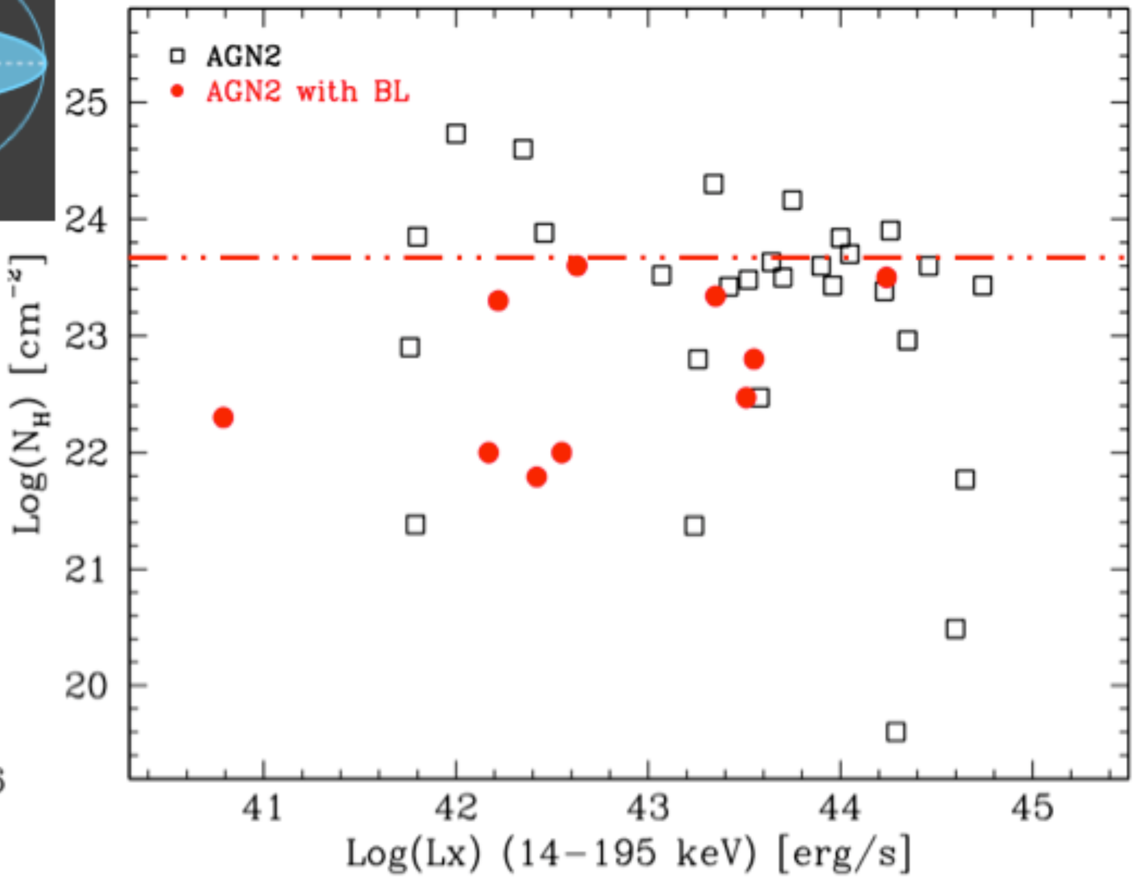
- No dependence on galaxy orientation
- No dependence on the N_H, but no BLR components found for log N_H > 23.6 (no statistical difference among the averages, even though smaller N_H for broad AGN2)

Onori et al. 2017a

Edge on



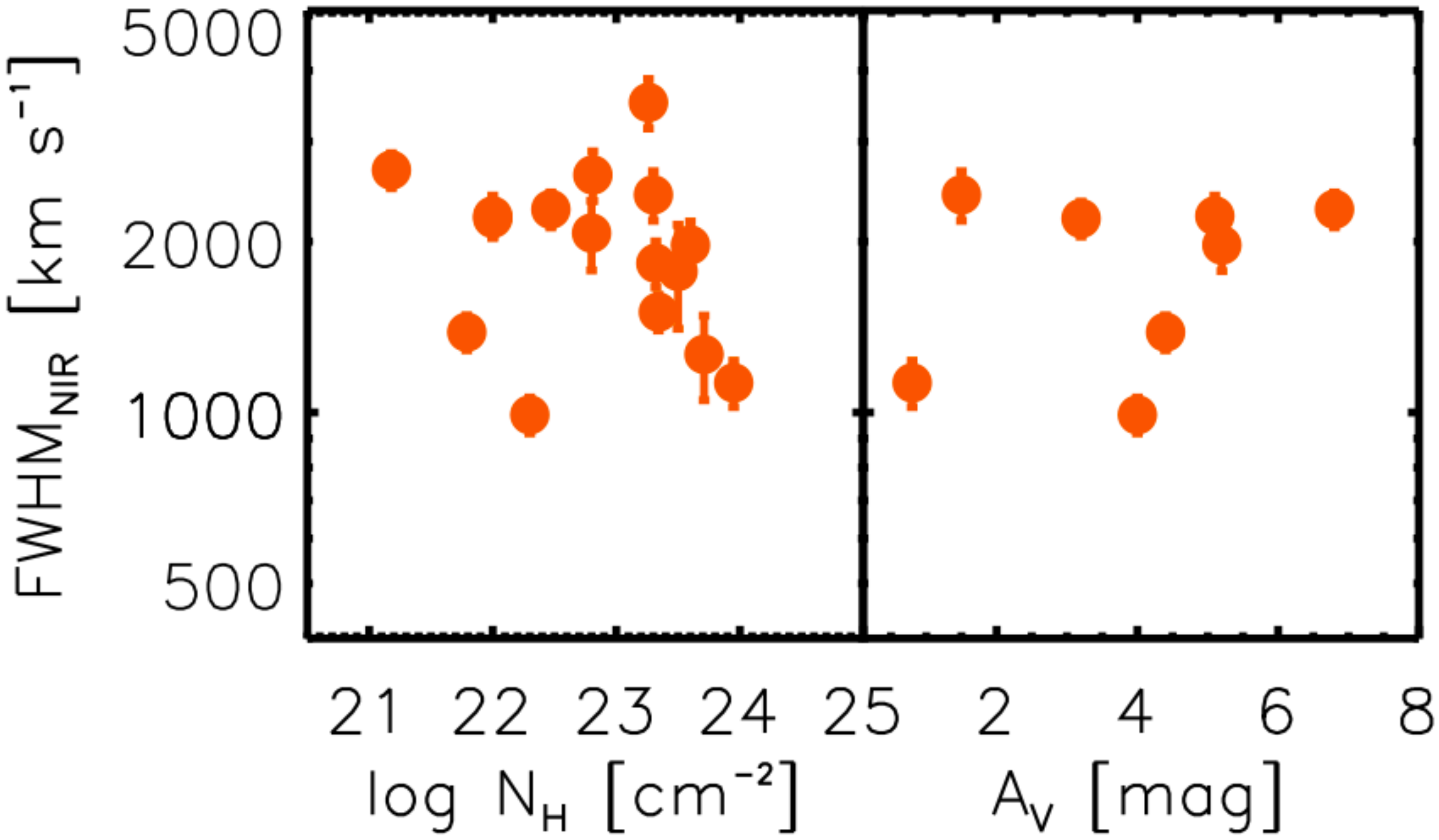
Face on



Possible selection effects

2. FWHM vs N_H and A_V

- No dependence on column density nor extinction, excluded a scenario in which we are detecting the outer part of the BLR



The subsample of AGN2 with NIR broad lines has no clear difference with the
other observed AGN2 → representative sample of local Compton thin X-ray selected AGN2

Onori2017b

Why only 30% success rate?

- Not uncommon! Other NIR surveys found similar success rates (Veilleux+97, Lamperti+17)
- possible reasons for NIR non-detection
  1. true Seyfert 2 (Tran+01, Elitzur&Ho+09)
  2. AGN variability in line emission
  3. stochastic variability in obscuration → in clumpy torus model the AGN 1-2 classification is probabilistic and depends on whether there or not there is a clump along the line of sight
  4. for the more obscured sources (log $N_H > 24$ cm^{-2}) it could be that the NIR did not allowed us to completely penetrate the strong nuclear obscuration
- How to supersede or test these ideas?
  1. longer wavelengths (less affected by obscuration)
  2. high R IFU
  3. spectropolarimetry

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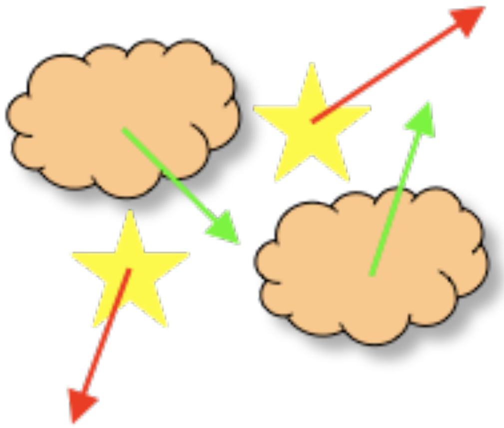

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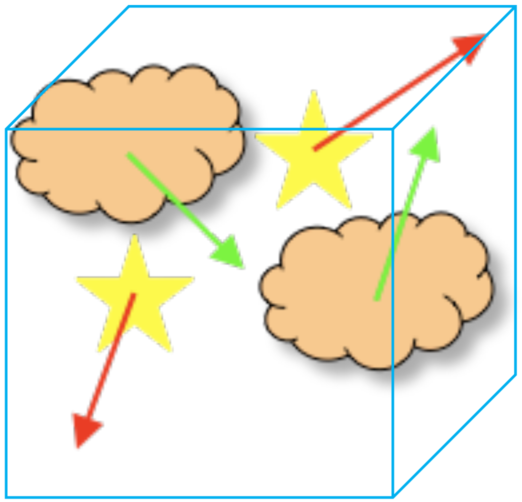

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(time resolved)

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V from line width, R from time variability