Probing extreme BHs throughout cosmic time & the co-evolution picture

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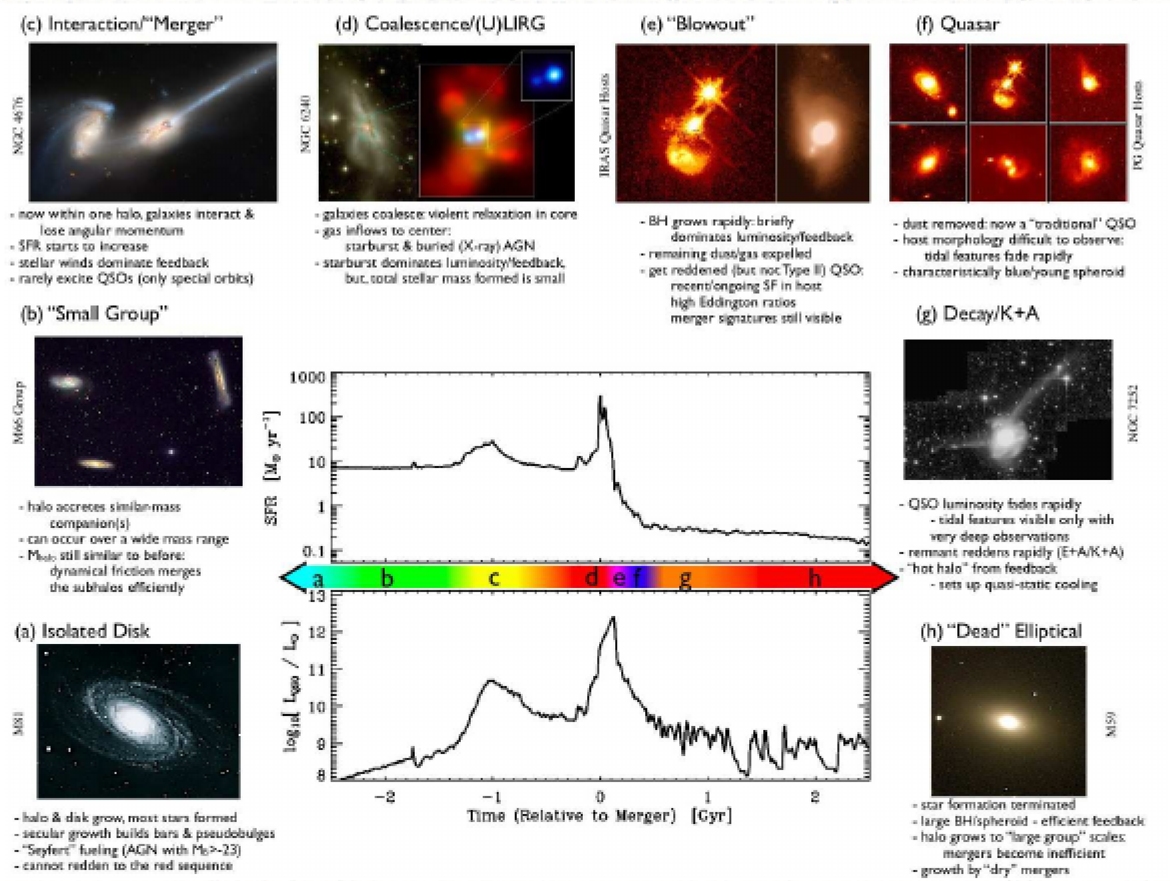
Thanks for the support of this contributed research program

Mainly based on Schulze, Schramm et al. 2017 ApJ...848..104S,
Schramm et al. 2018 to be subm to ApJL, Nitta, Schramm et al. 2018 to be subm.

INTRODUCTION

- Please see the nice talk from Tohru Nagao



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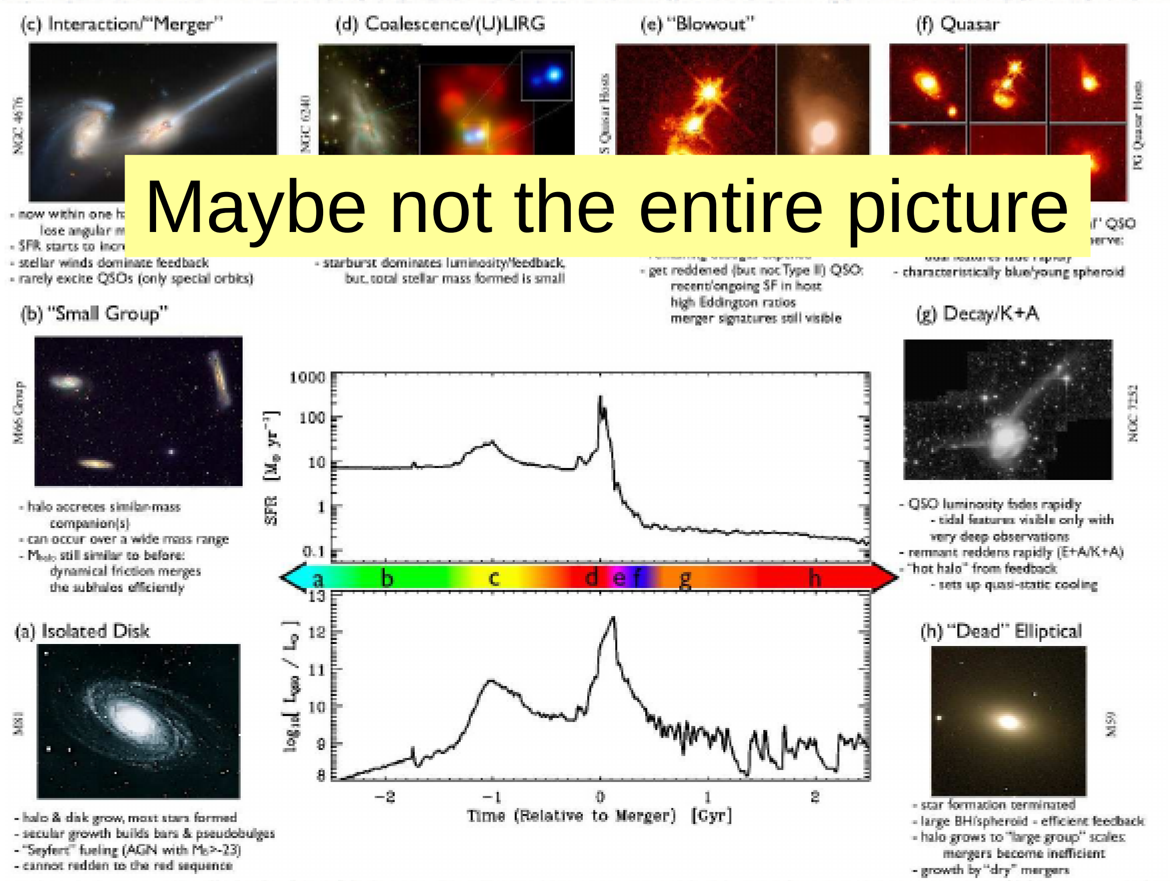

Maybe not the entire picture

INTRODUCTION

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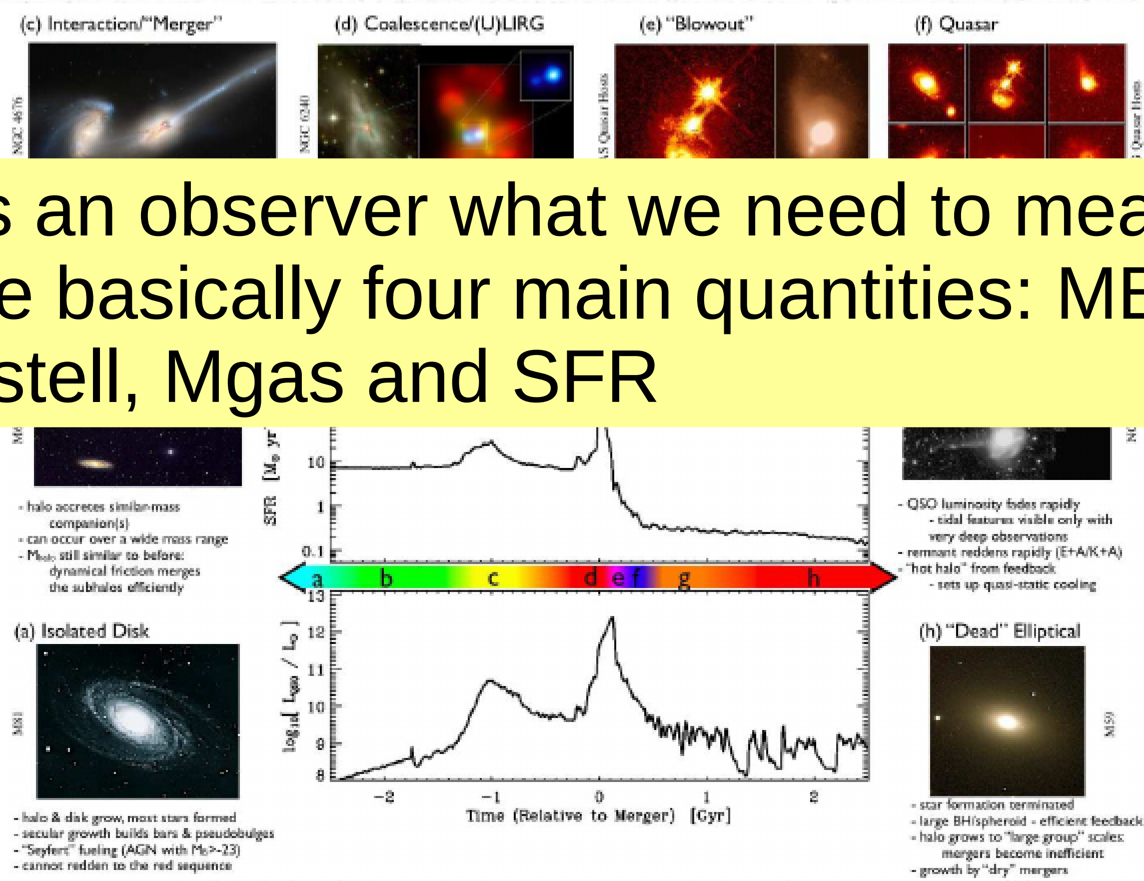
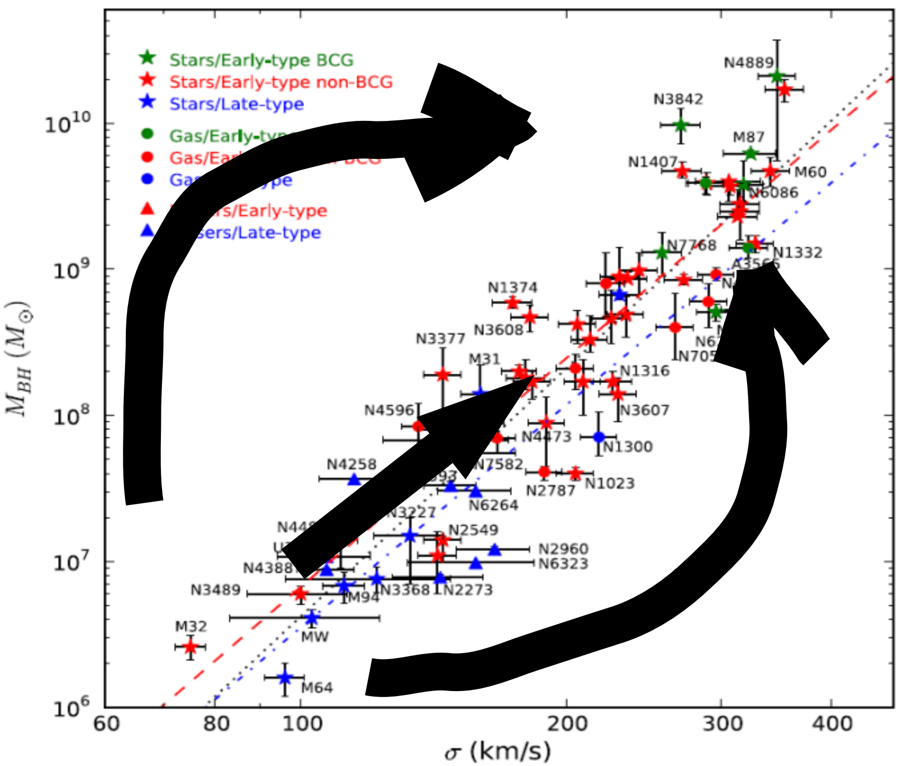


As an observer what we need to measure are basically four main quantities: MBH, Mstell, Mgas and SFR

My main motivation:
Who comes first BH or Host Galaxy?

- Answer always seemed to differ depending on the parameters we look at (Luminosity, vel. Dispersion, Mass) or sample

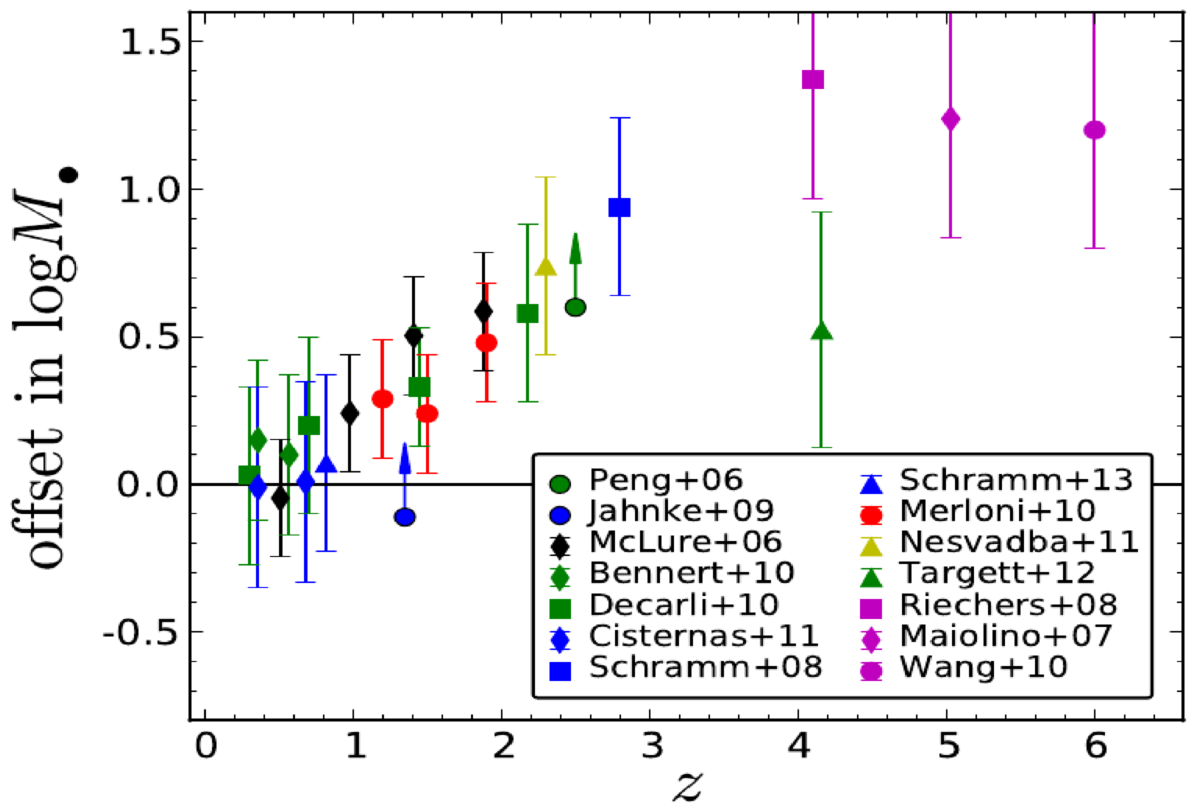
BH mass



Stellar bulge velocity dispersion

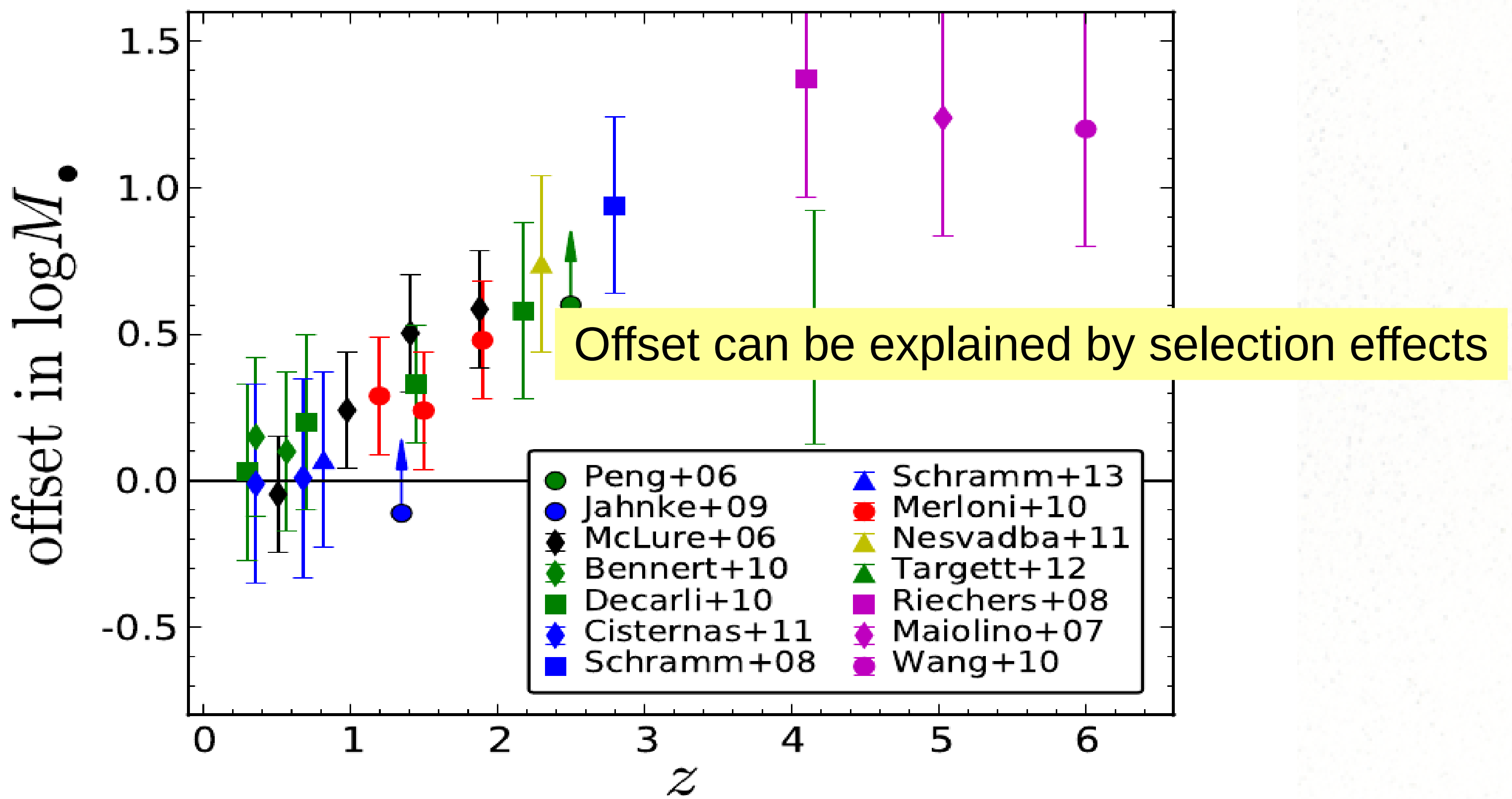
McConnell & Ma (2013)

Apparent Cosmic Eolution of M_{BH}/M_{BULGE} relation



Schulze&Wisotzki 2014

Apparent Cosmic Eolution of M_{BH}/M_{BULGE} relation



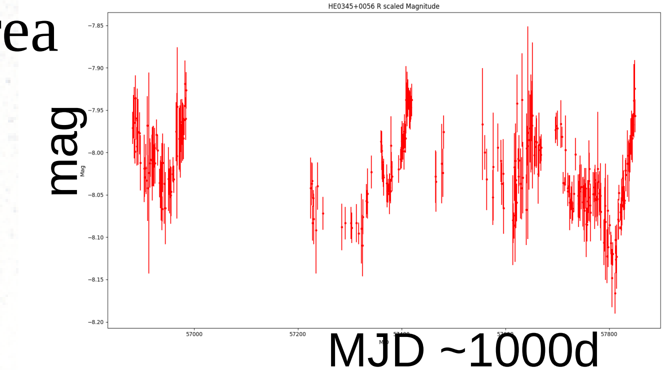
Schulze&Wisotzki 2014

Hunting for Extreme BHs

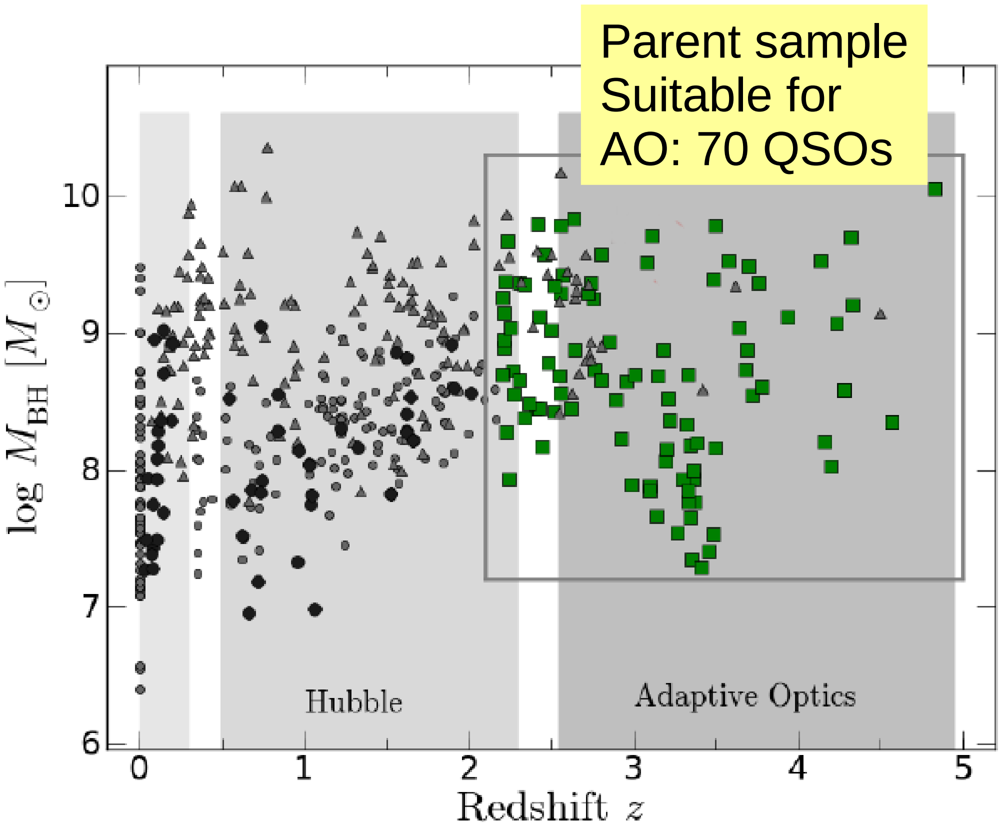
- Estimating reliable BH masses in Type 1 AGN:

  (1) Virial Method: Still on-going NIR spectroscopic campaign using mainly OAO,NOT & TNG to observe luminous quasars at z=2-4

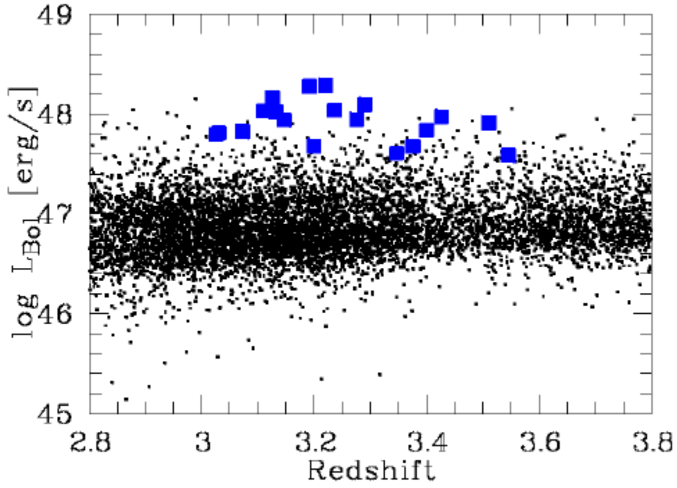
  (2) Direct Approach using RM on nearby AGN ranging from objects like NGC 4395 (lag few hours) to PG1116+216 (lag ~170d) through a large monitoring campaign with various small telescopes + spectroscopic followup: mostly handled by students in Thailand, Finland and Korea

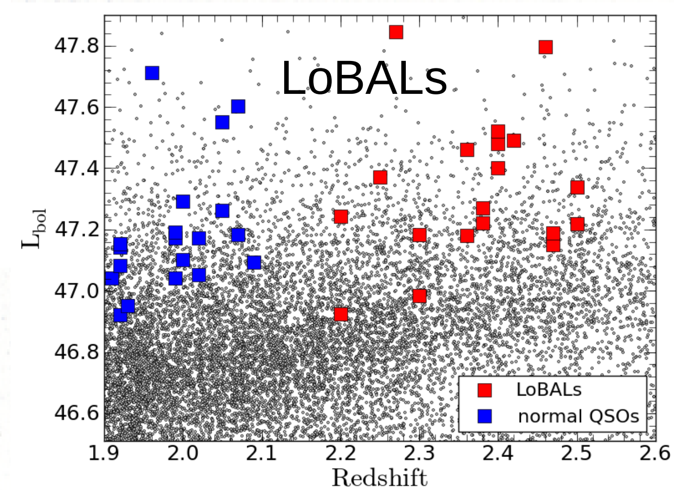


NIR Spectroscopy of QSOs at z=2-4

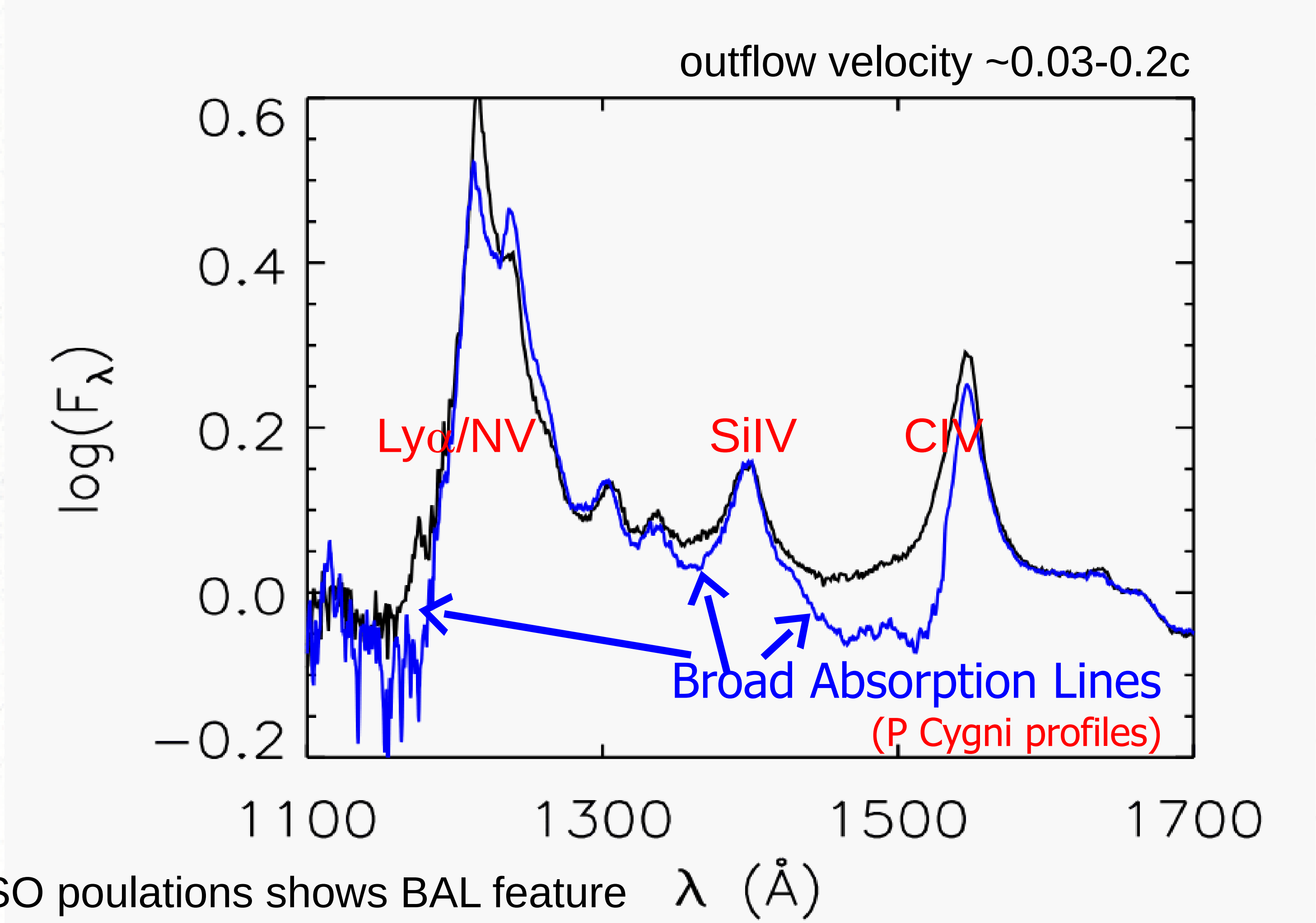


Interesting Subsamples





BAL QSOs: Quasars with Outflows



~15% of QSO poulations shows BAL feature

LoBAL 1-3% w/ absorption in Hi&Low Ionization lines

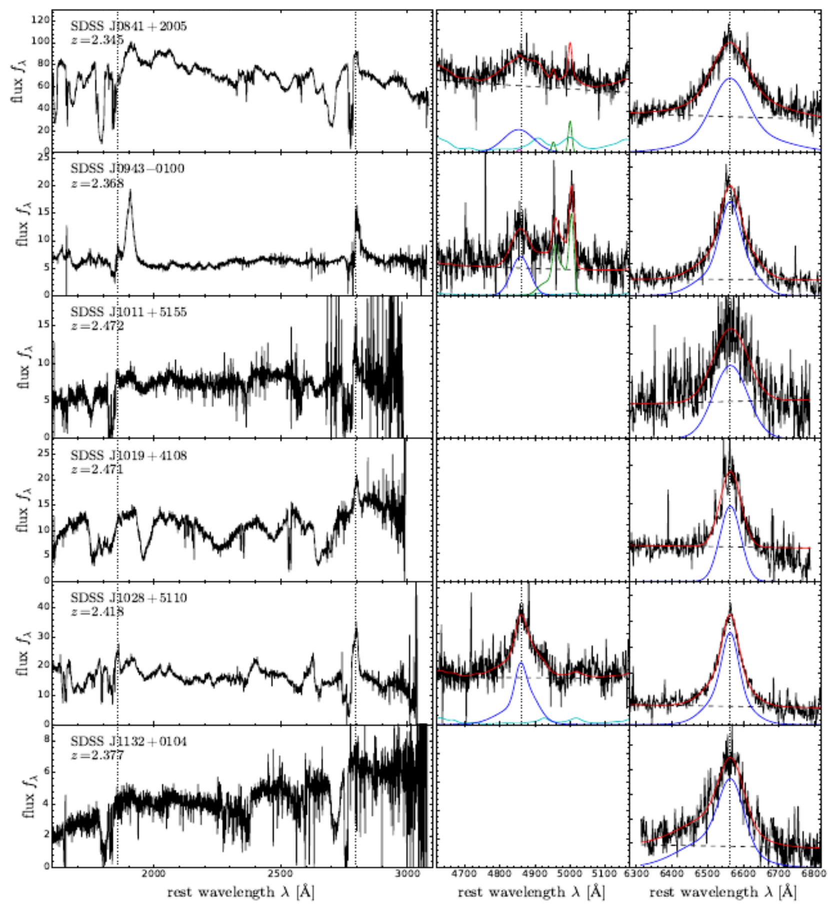
Two Scenarios for LoBALs

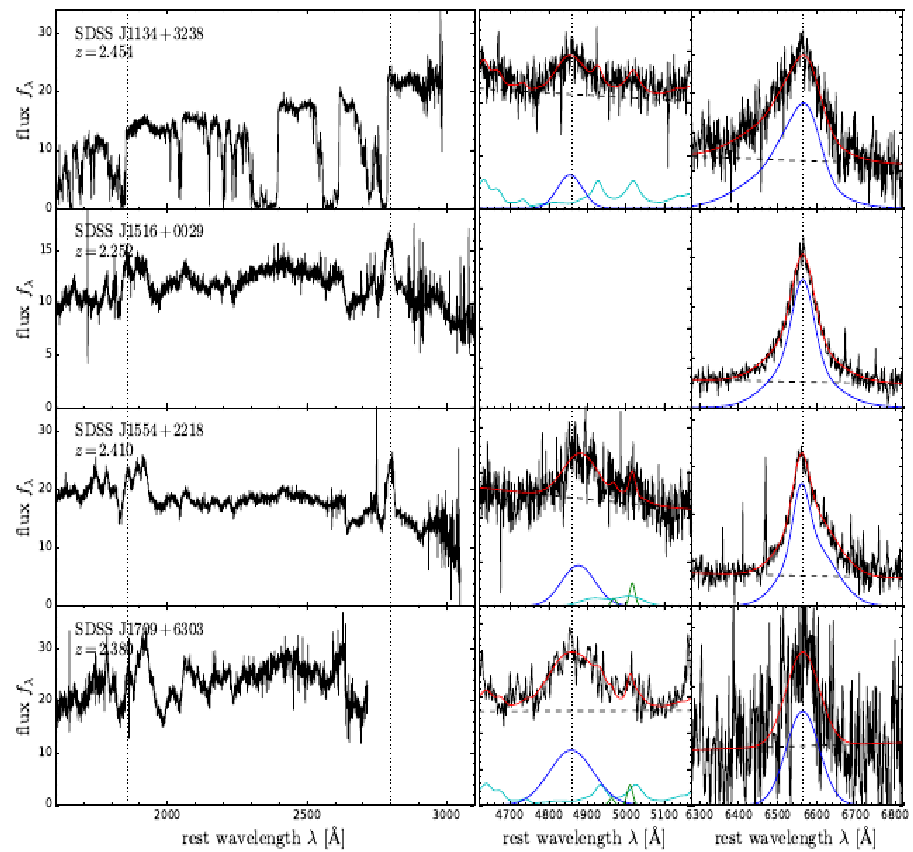
- I. The evolutionary scenario suggests LoBALs as a stage when a merger induced, young QSO, enclosed before by a dust rich cocoon and observed as a ULIRG, is ignited and blows out their dust envelope by a strong wind, accreting at a high rate
- II. Orientation effect, i.e. their occurrence is related to the observed line-of-sight

Scenario I implies: LoBAL QSOs should have high accretion rates, i.e. Eddington ratios compared to non-BALs

NIR Spectroscopy of LoBAL QSOs

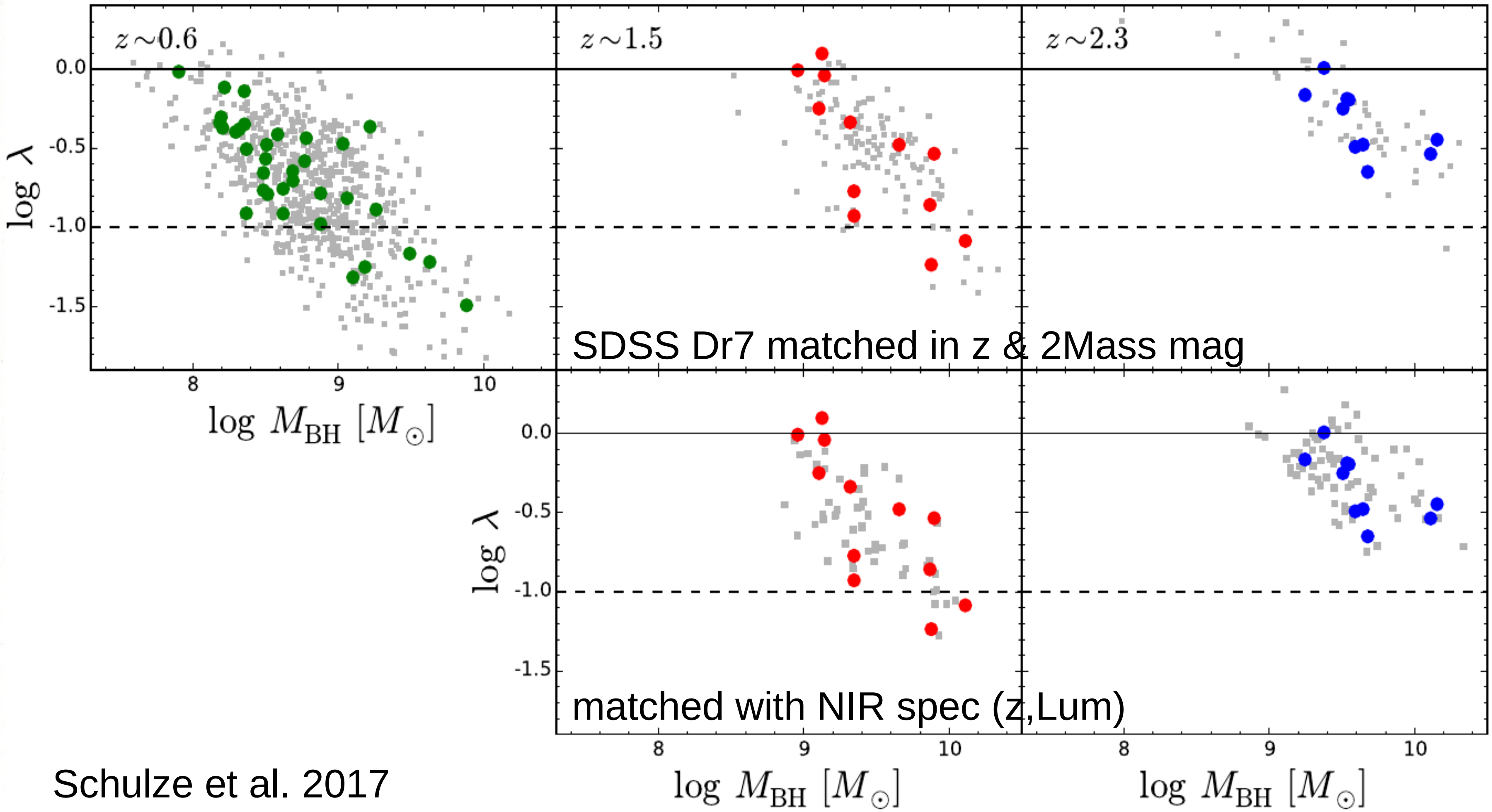
- Targeted the brightest (K<15.3 LoBALs at z~2.2) with OAO&NOT to probe Hα and Hβ regions and measure BH masses





Schulze et al. 2017

BH Mass vs. Eddington Ratio Distribution



Schulze et al. 2017

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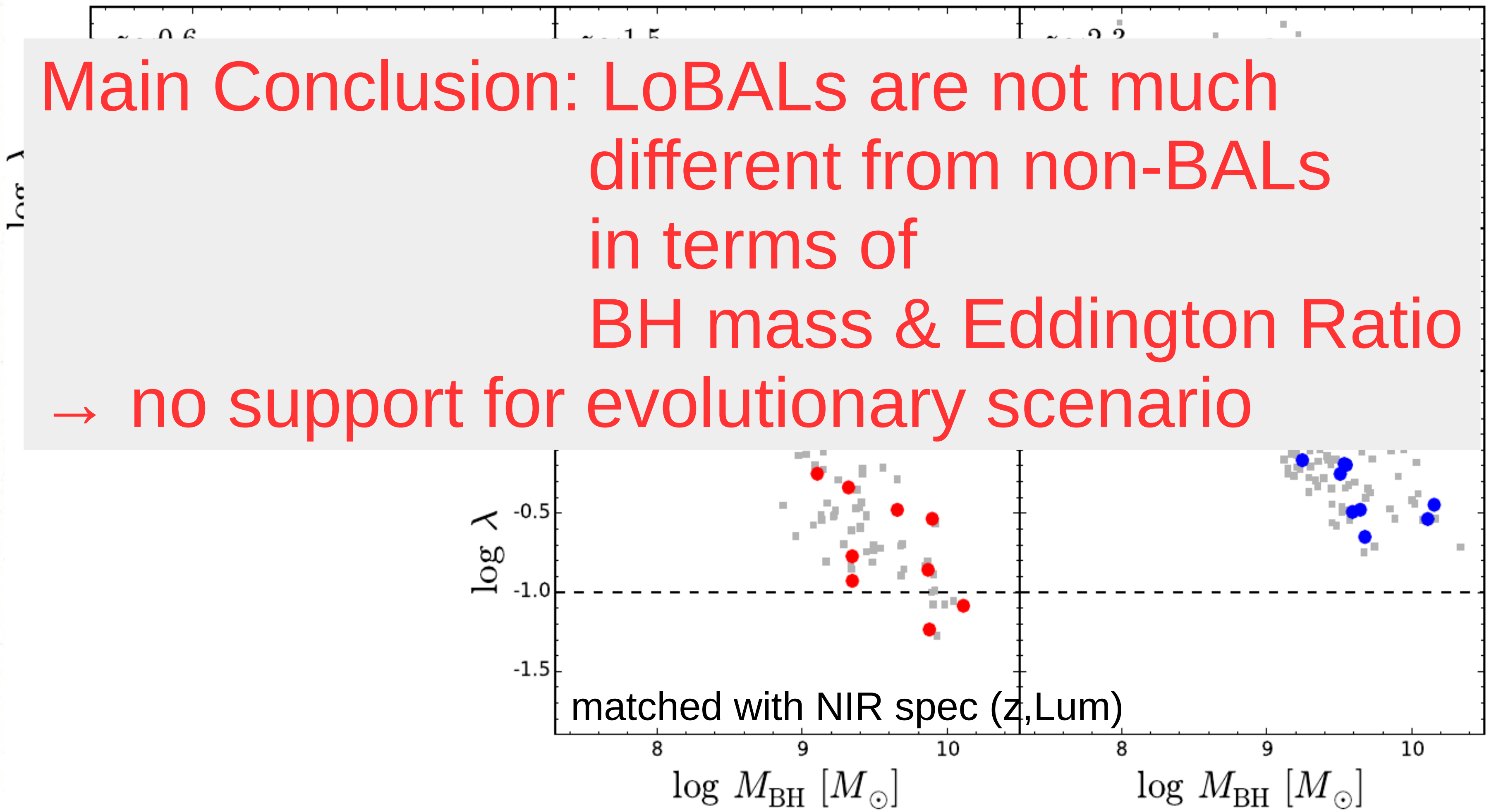
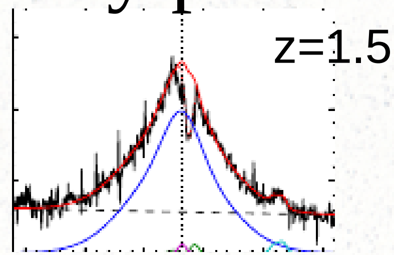


Main Conclusion: LoBALs are not much different from non-BALs in terms of BH mass & Eddington Ratio

→ no support for evolutionary scenario

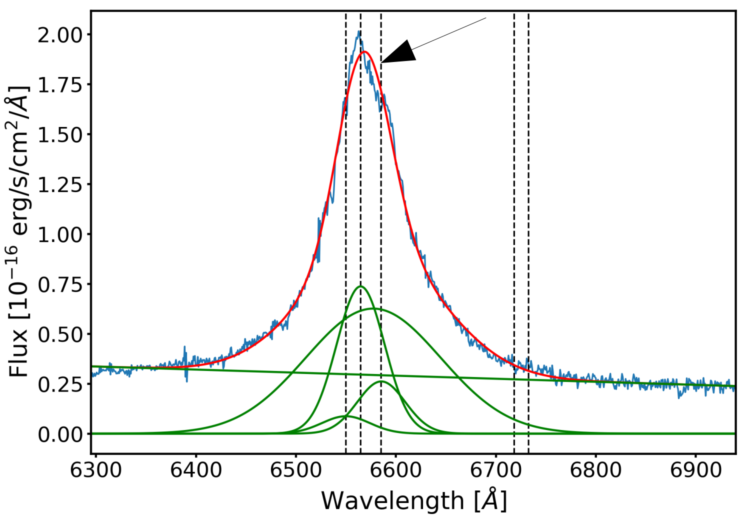
SINFONI IFU+AO Observations

- Very fresh and very preliminary data

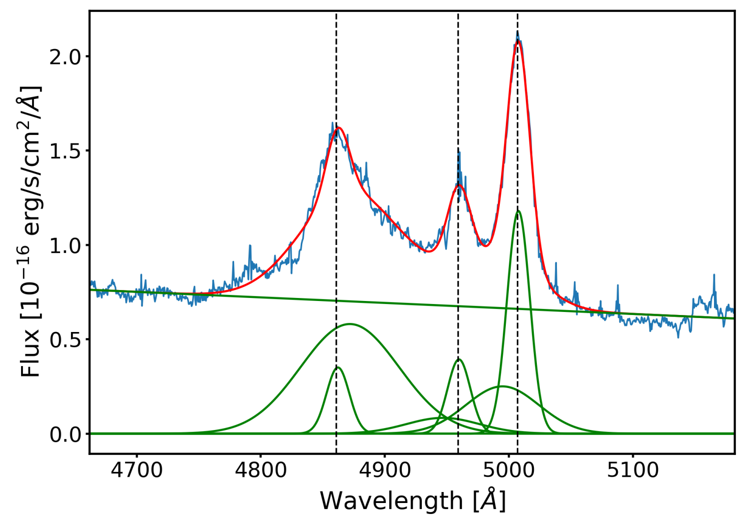


We were hoping for Balmer absorption

Hα



Hβ

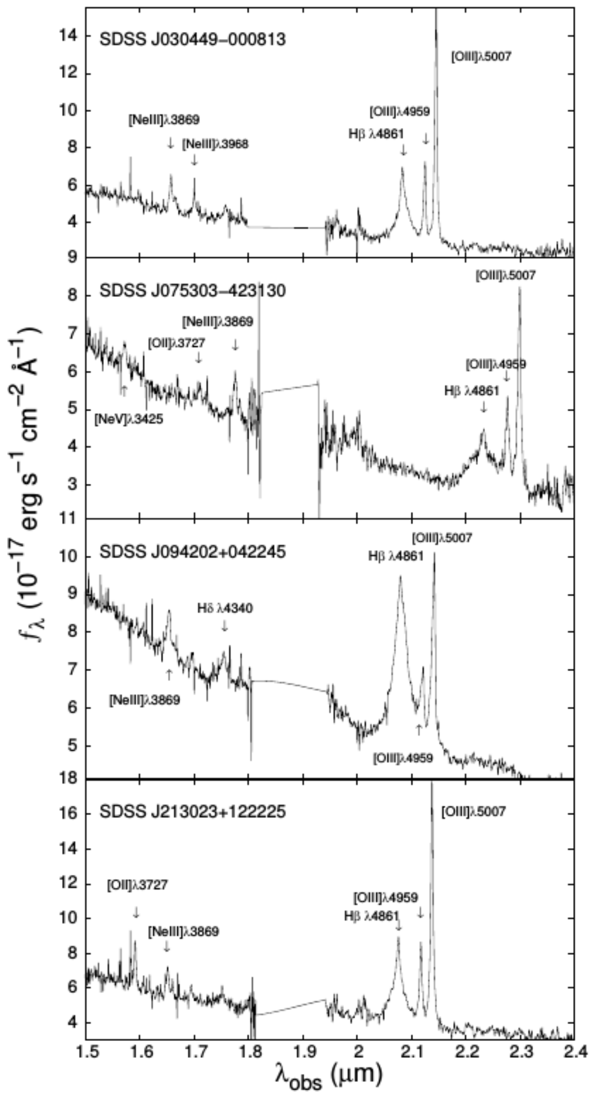


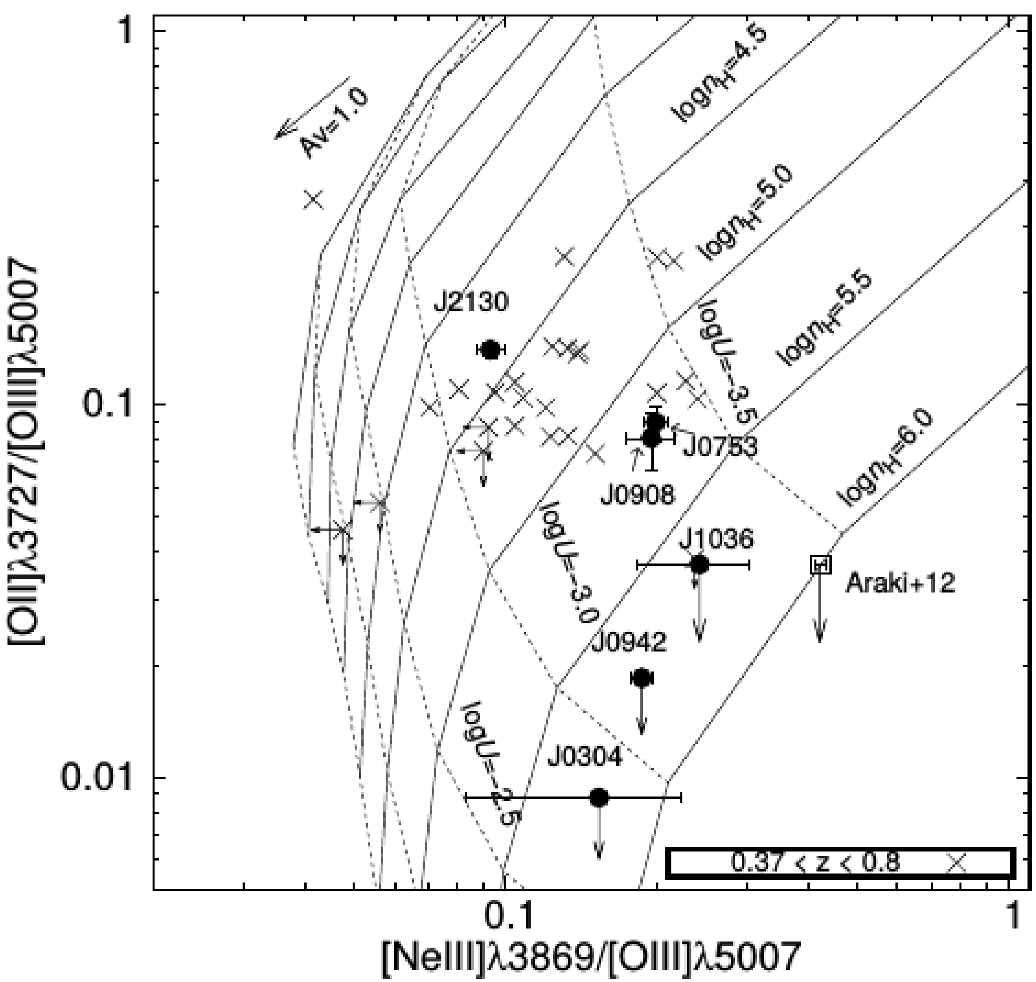
Fits need to be improved

Sorry I could not get the 2d maps (yet)

The NLR of high-z QSOs

- We can study the ISM of the host galaxies





Nitta et al 2018 to be submitted

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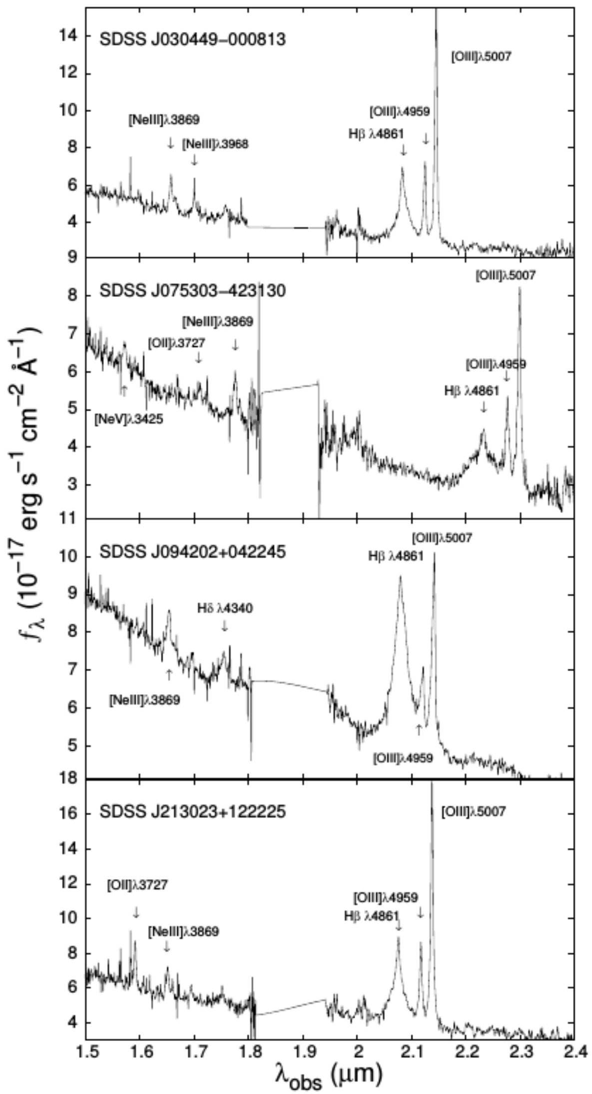
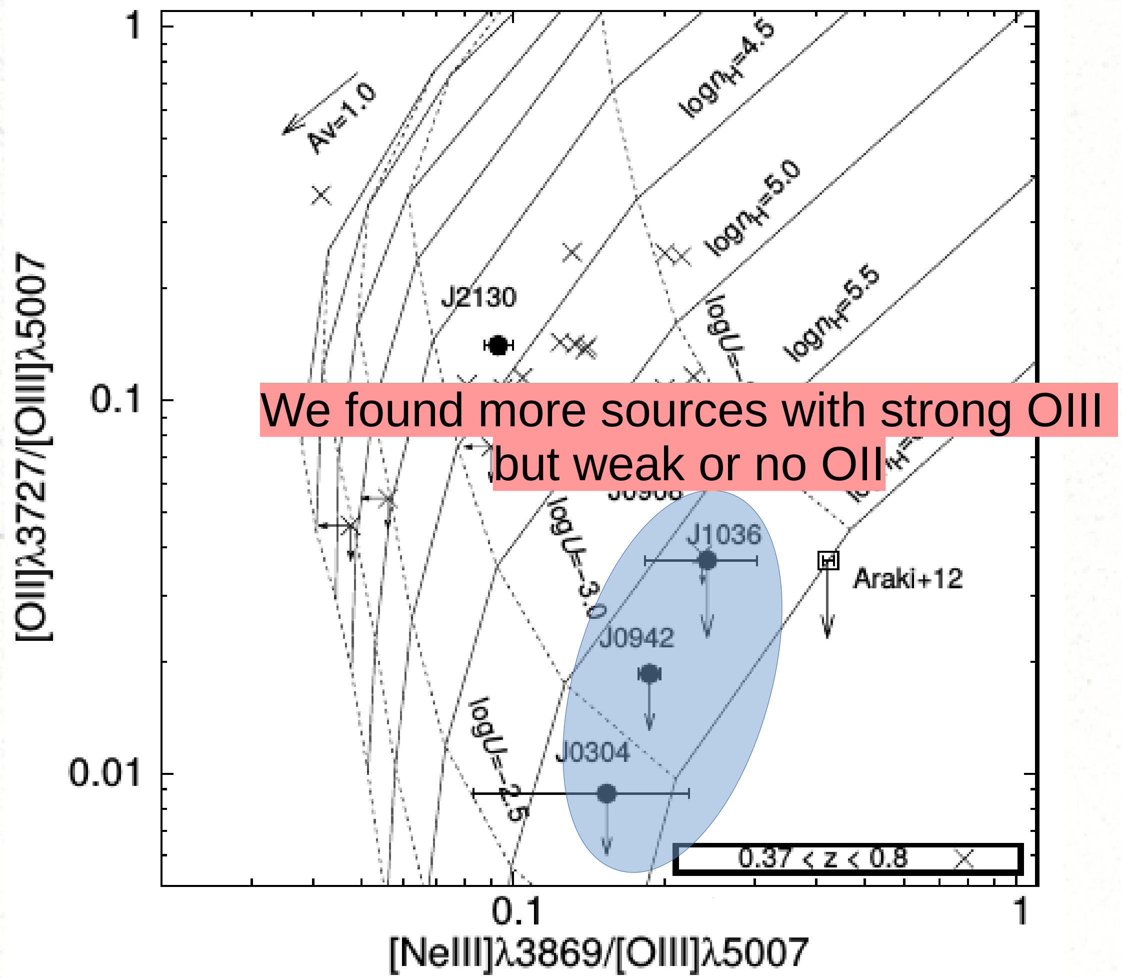




Nitta et al 2018 to be submitted

Stellar Component

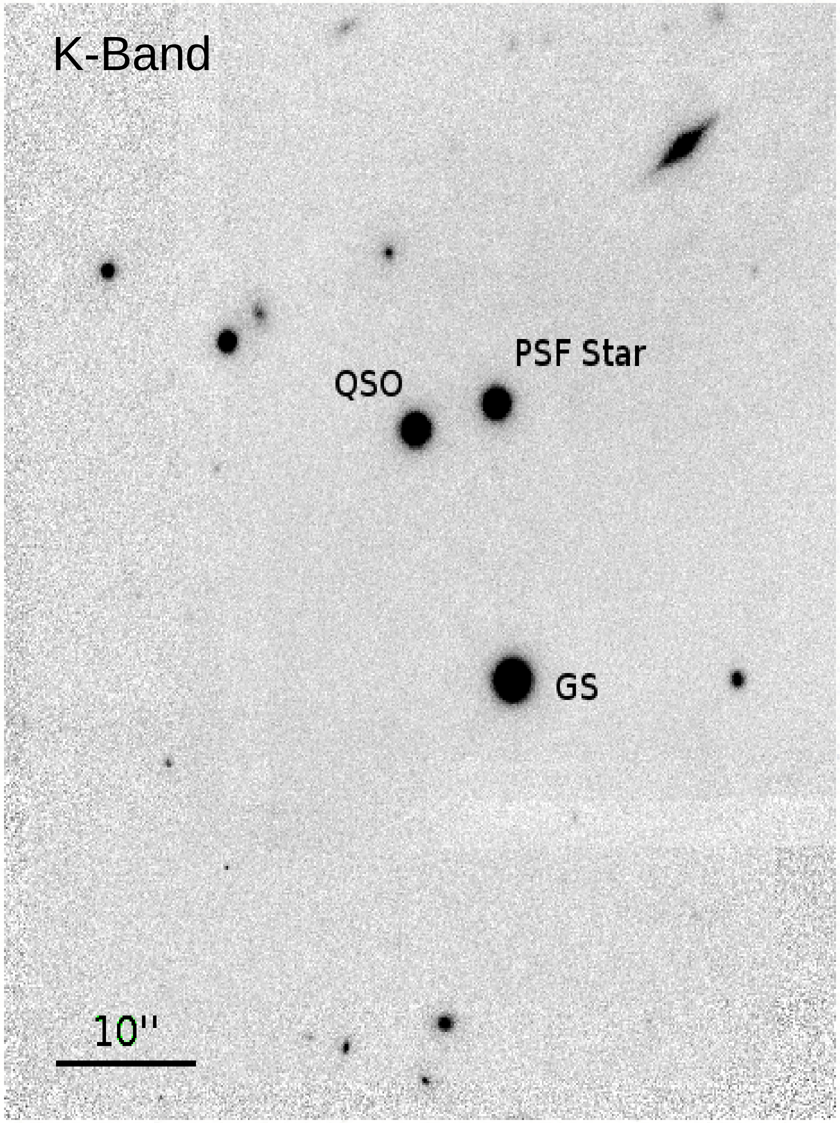
- Need high resolution in the rest-frame optical since host galaxies are getting more compact at high-z and the AGN is outshining its host

  2kpc at z=3 $\rightarrow$ ~0.25 arcsec

  typical natural seeing is more like >0.5 arcsec and best seeing nights are rare (as we heard from Miyazaki-san)

- Solution: Use AO supported NIR imaging

Stellar Component

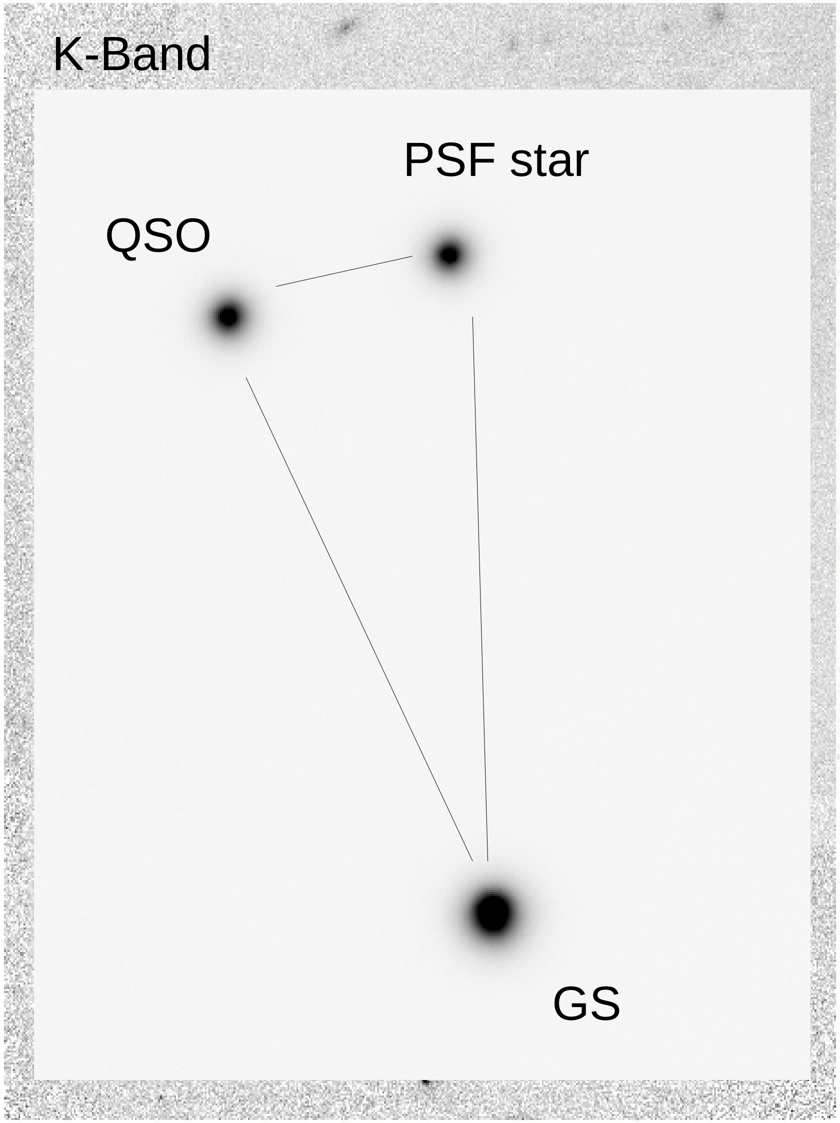


- With AO we can typically achieve 0.1-0.3 arcsec

- PSF shape can be difficult to model over full FoV with only few stars

SUBARU IRCS+AO188 total depth 4h

Stellar Component



- With AO we can typically achieve 0.1-0.3 arcsec

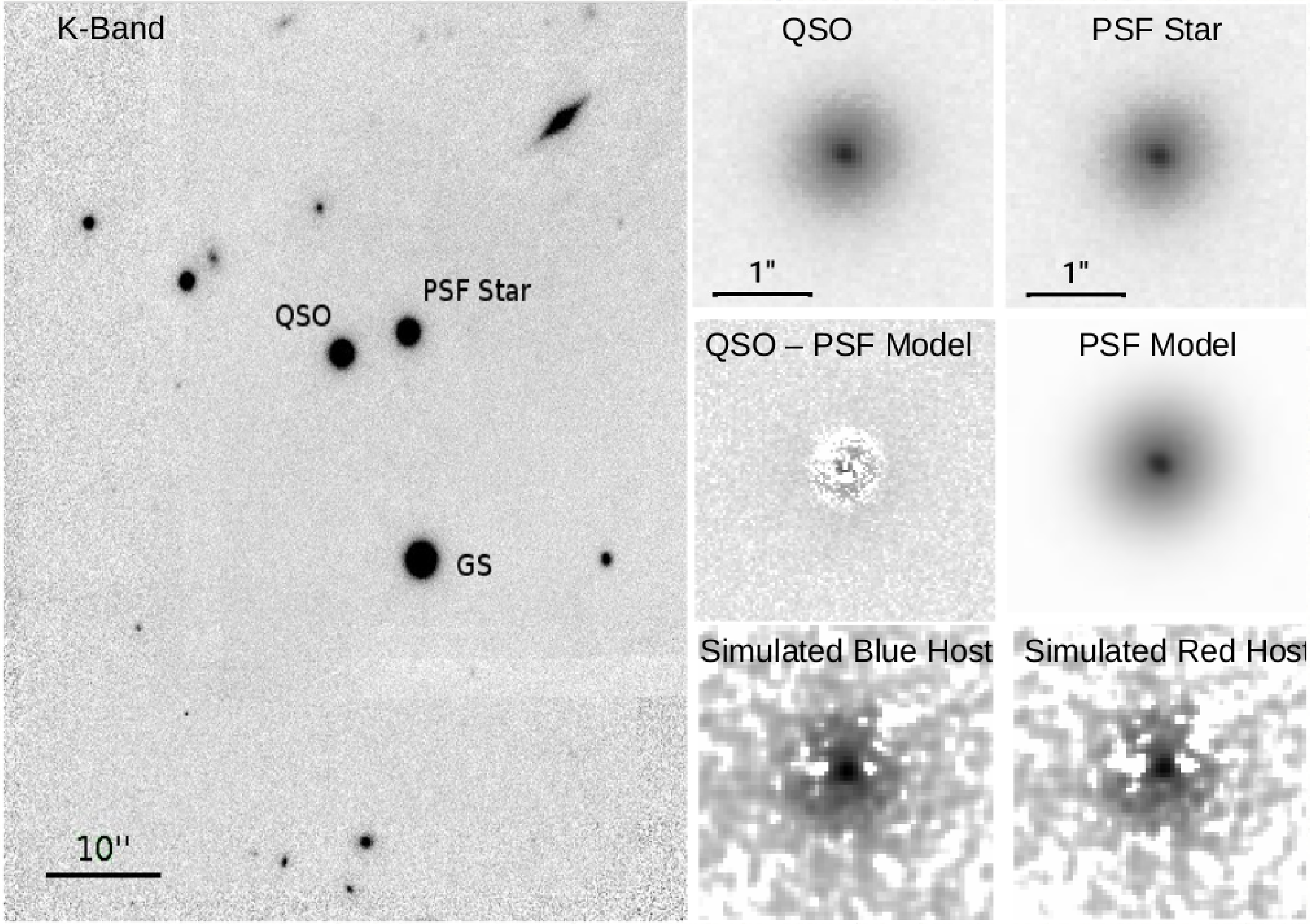
- PSF shape can be difficult to model over full FoV with only few stars

- Minimize systematics in PSF control e.g. PSF degradation with increasing distance from guide star by using favourable configuration beetween GS, QSO and PSF

THIS IS IMPORTANT for the modeling of the host galaxy and the AGN component

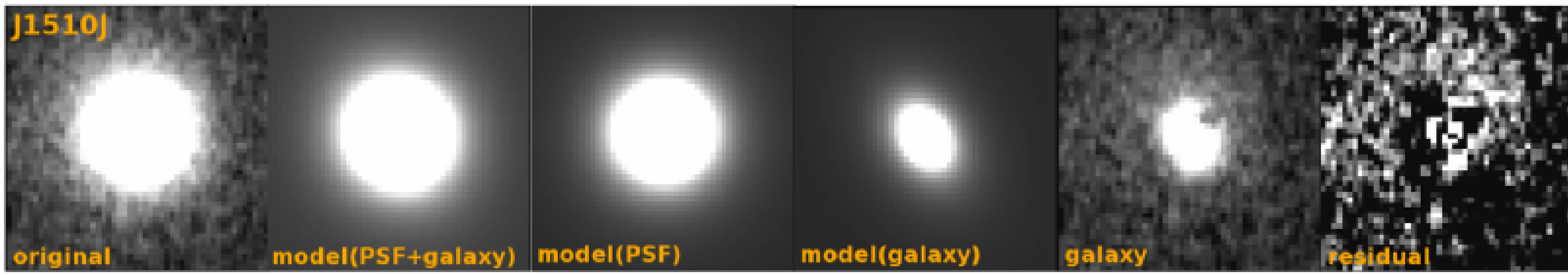
The Host Galaxy

- Even all is perfect we might not get anything



The Host Galaxy

- BUT in several cases we can resolve the host



- even see substructure if we are lucky

H-band

Title:psf_sub_nocontour.eps
Creator:matplotlib version 0.99.0, http:
CreationDate:Wed Jun 2 10:06:19 2010

K-band

Title:K_psf_sub_nocontour.eps
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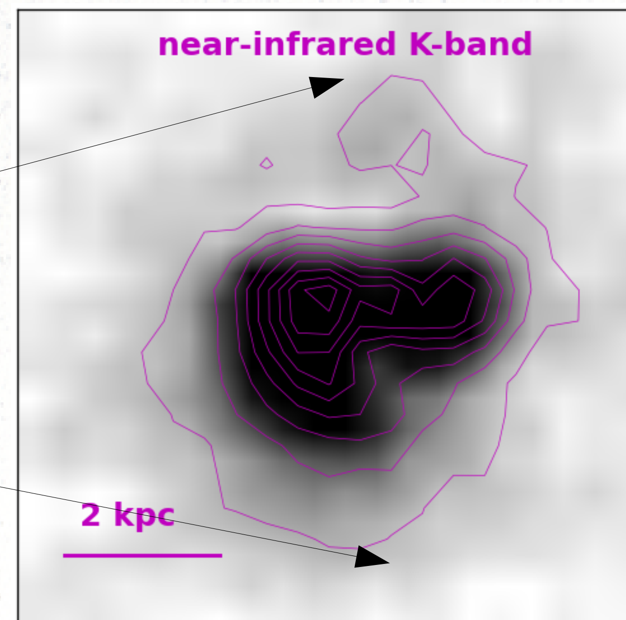
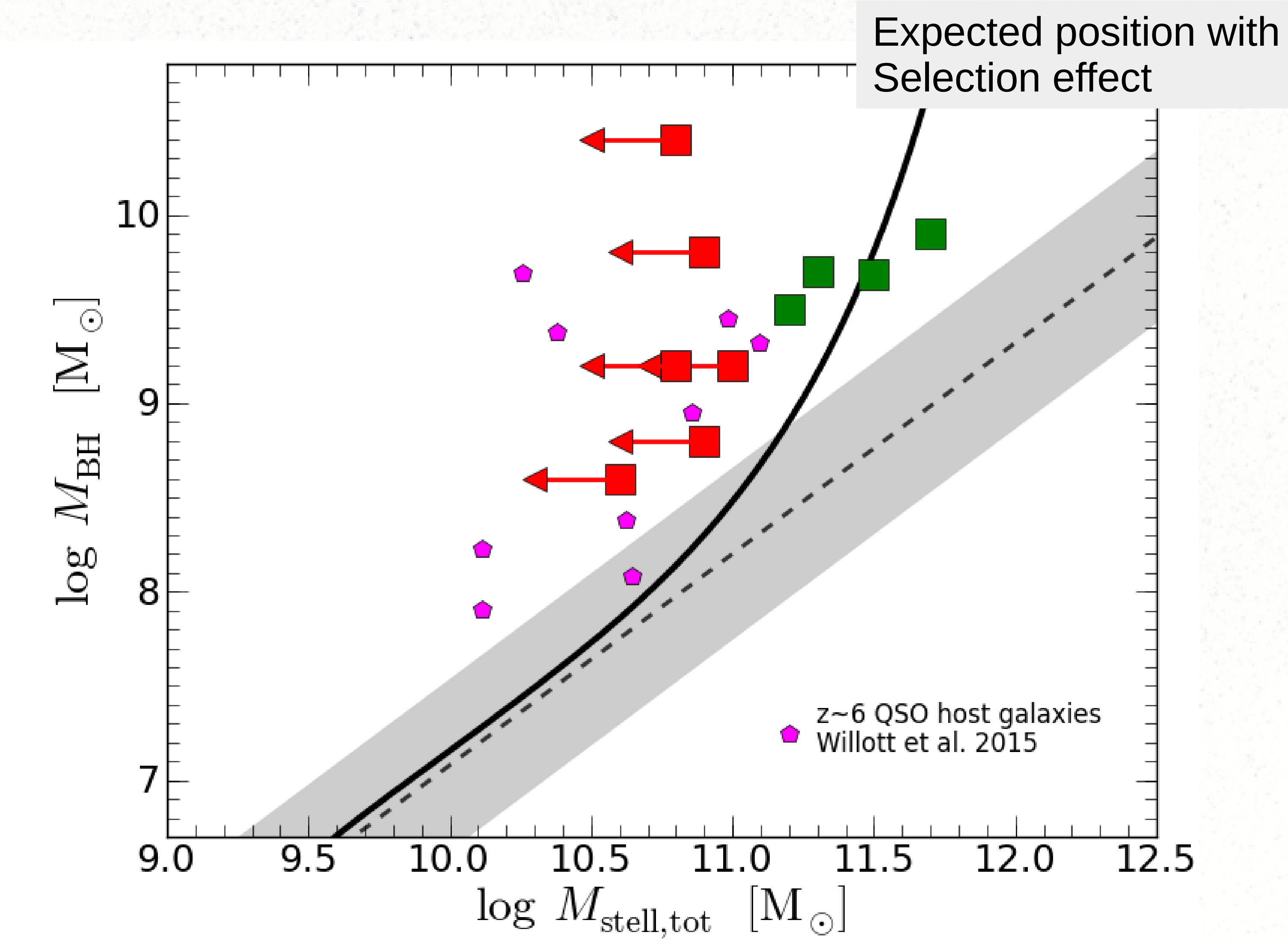
CreationDate:Wed Jun 2 10:11:23 2010



Host galaxy after removing AGN

BH Mass – Mstell relation at z=3



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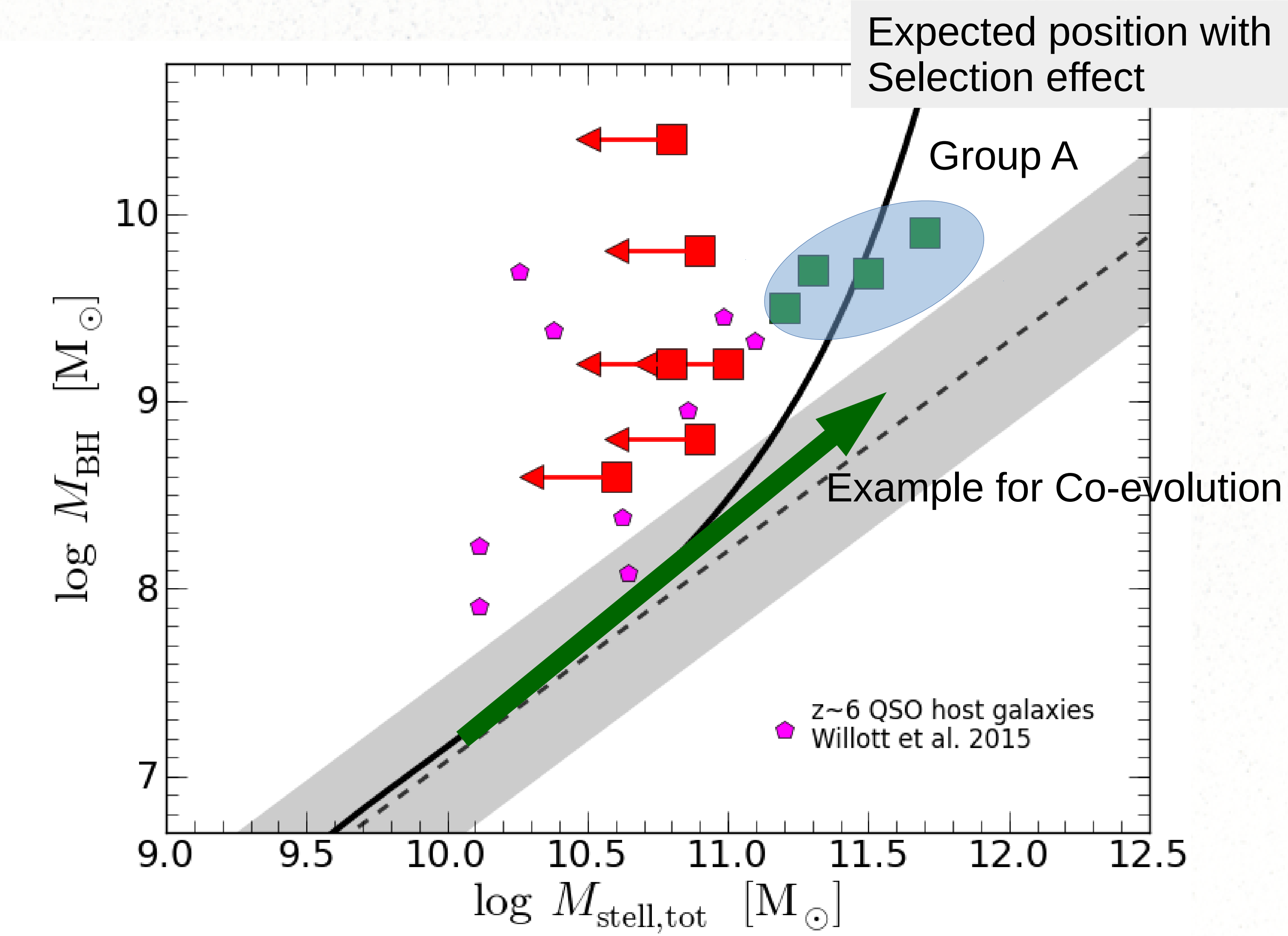

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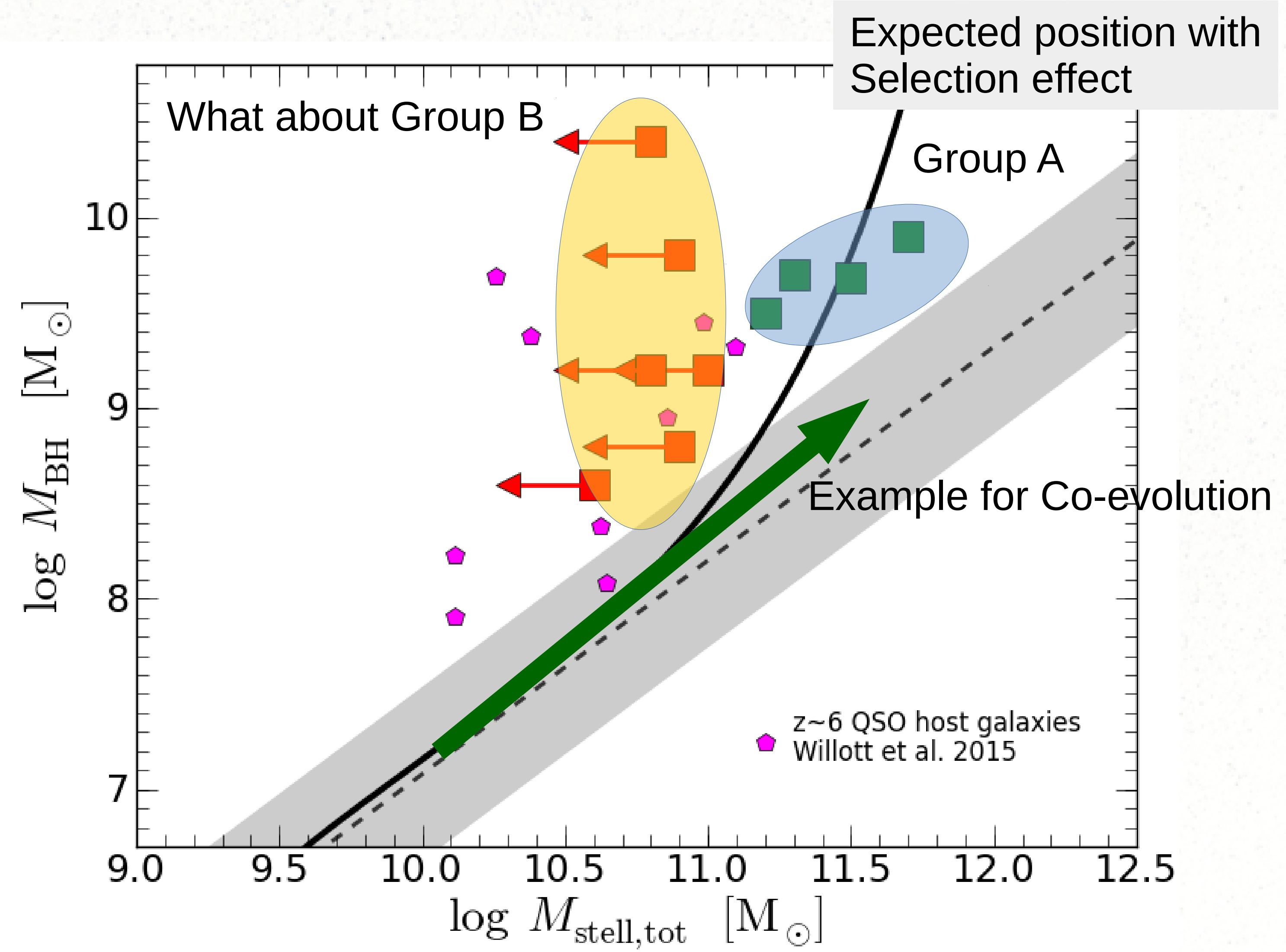

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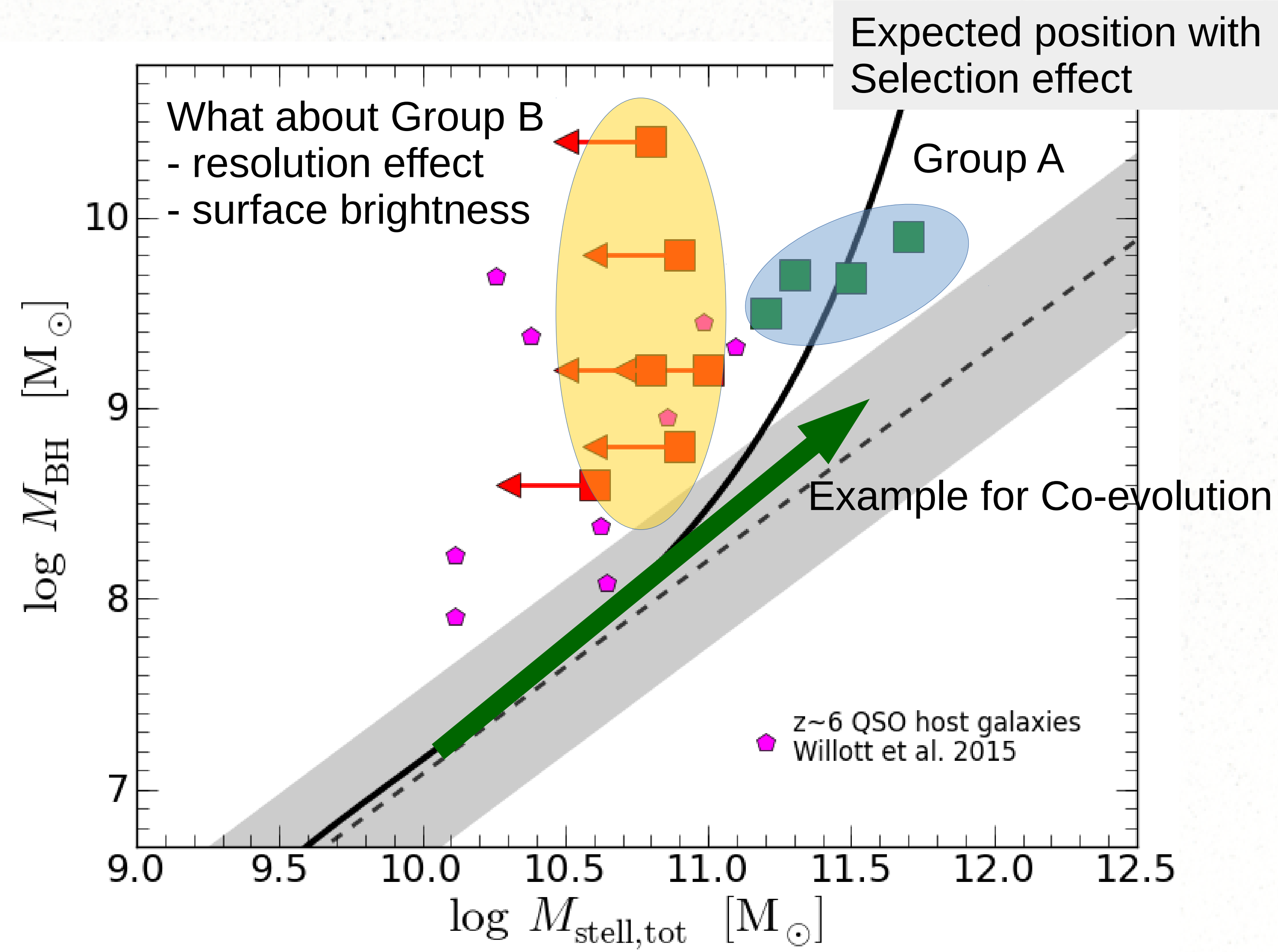


The Next Step: ALMA

- Three Successful Programs
- Cycle 3 ALMA program to look at 4 QSOs with NO host detection in band 3 to detect CO at best possible resolution <0.1 arcsec

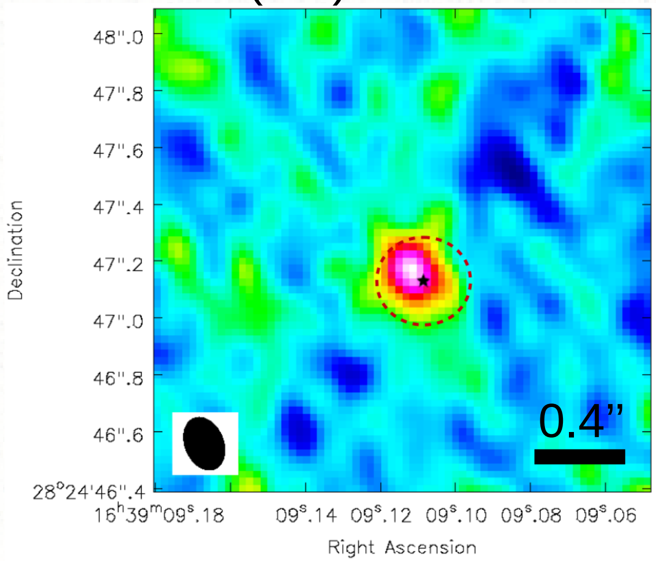
  assumption: 'no' stars but massive BH → large gas reservoir

  only one clear detection at 9σ (1 weak & 2 non-detections)

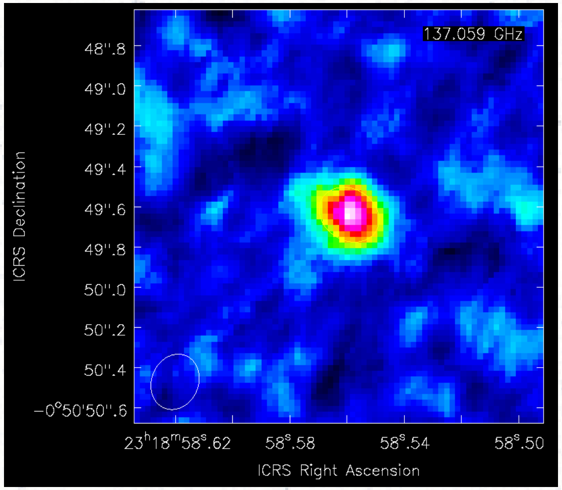
- Cycle 4 ALMA program on quasars with different OIII properties in band 4 1 clear detection / 3 targets
- Cycle 5 ALMA 7 quasars in band 3 to detect CO (all observed – waiting for final deliveries)

ALMAs View on the Gas

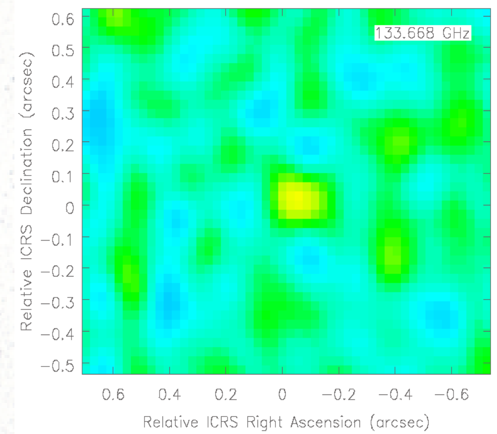
CO(4-3) at z=3.8



CO(5-4) at z=3.2

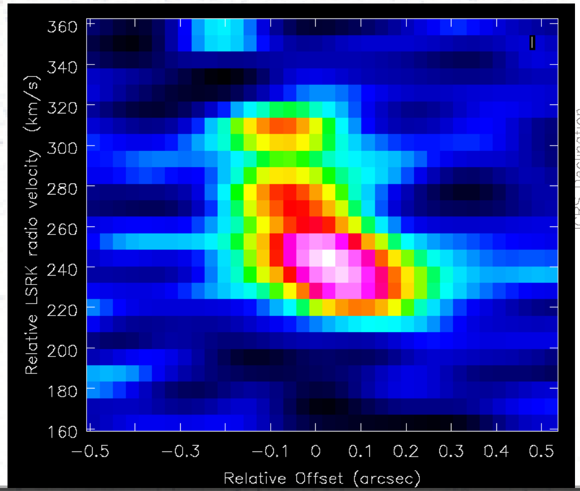


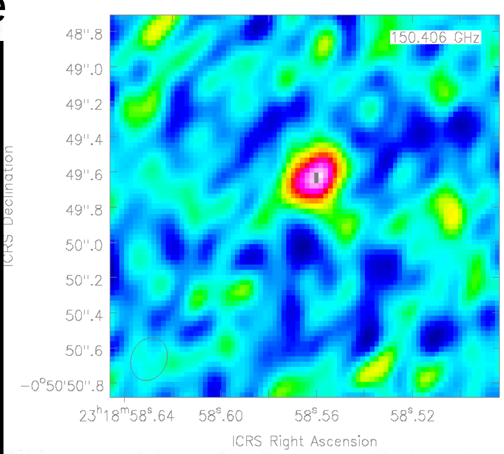
Sometimes only Continuum



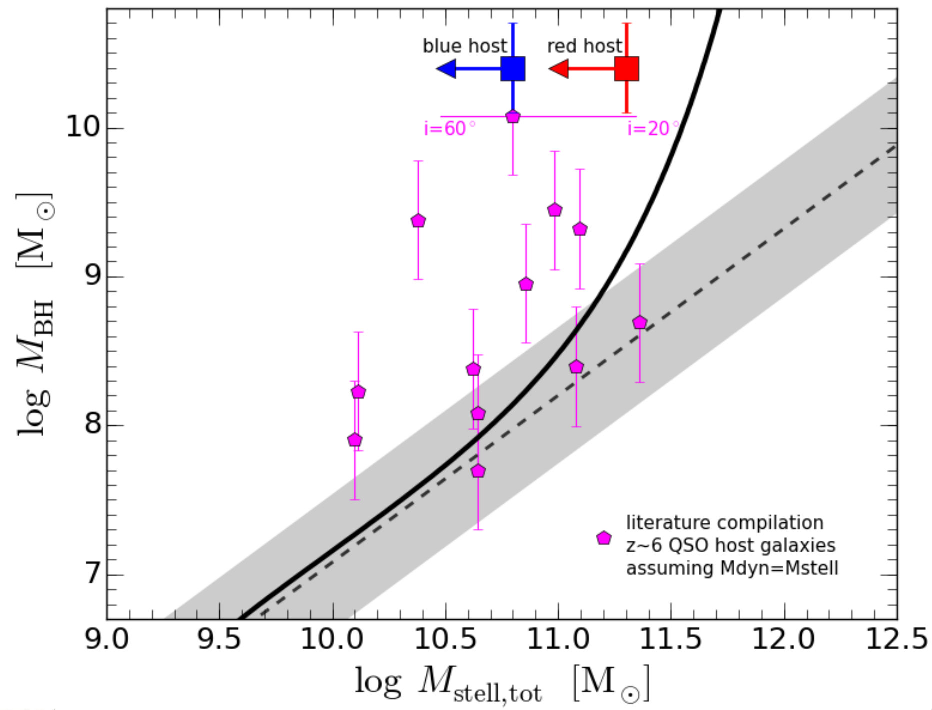
Resolved CO is great:
We get dynamical masses

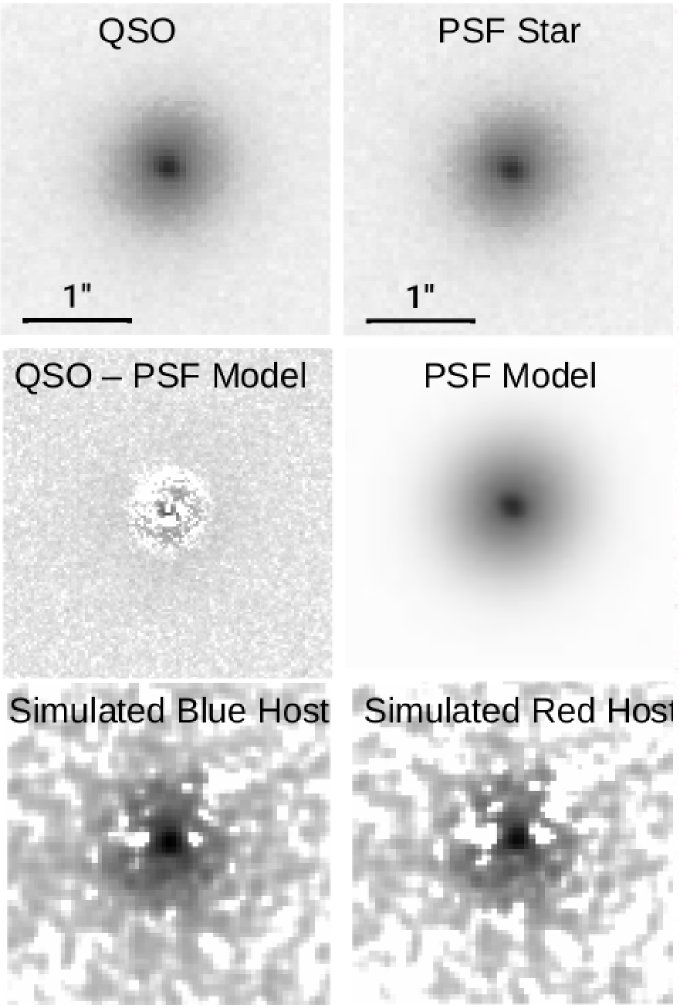
Even some rotation visible





Case Study of J16+28 at z=3.8





Possible Problem with M* Limits
* have to make assumptions on host size
* a massive unresolved stellar component can be present

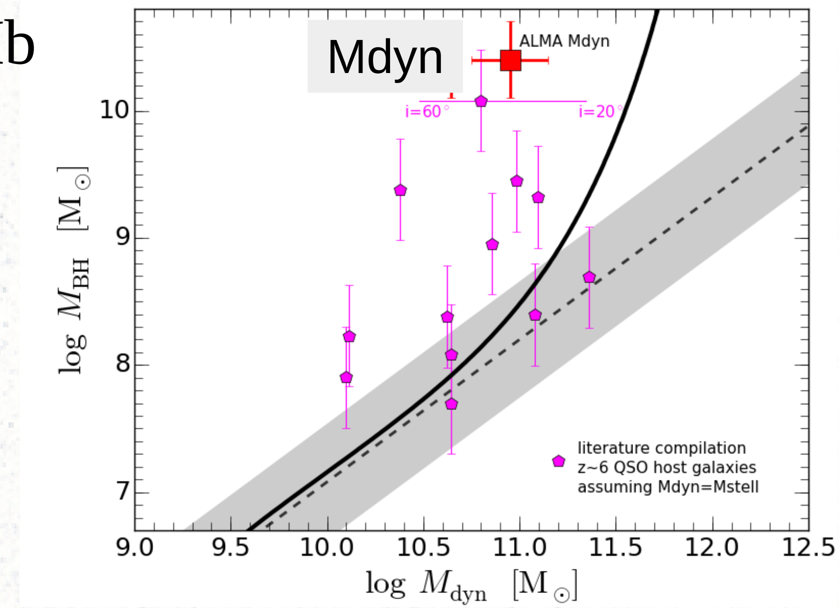
Schramm et al. 2018 to be subm

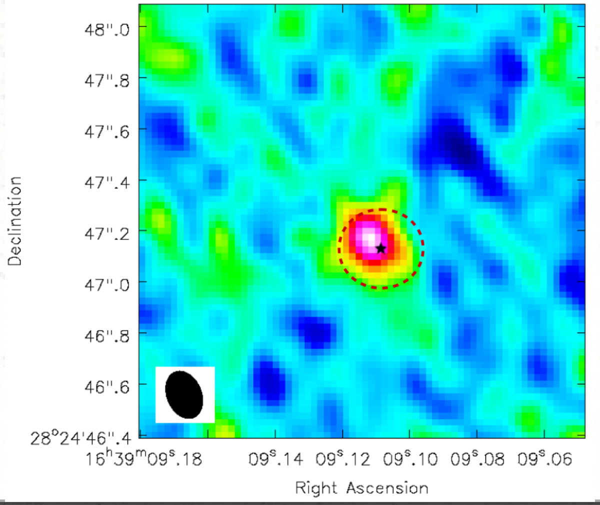
Case Study of J16+28 at z=3.8

- BH mass: log MBH=10.4 from Hb consistent with CIV, ER: 60%
- Upper limit of the stellar mass logM*<10.8 (blue host)
- Mol. gas mass logMgas=10.3
- limit on dynamical mass logMdyn=10.8 (i~50°) from CO

=> in this case BH accounts for 40% of Mdyn

=> BH+gas account for 75% of Mdyn





Case Study of J16+28 at z=3.8

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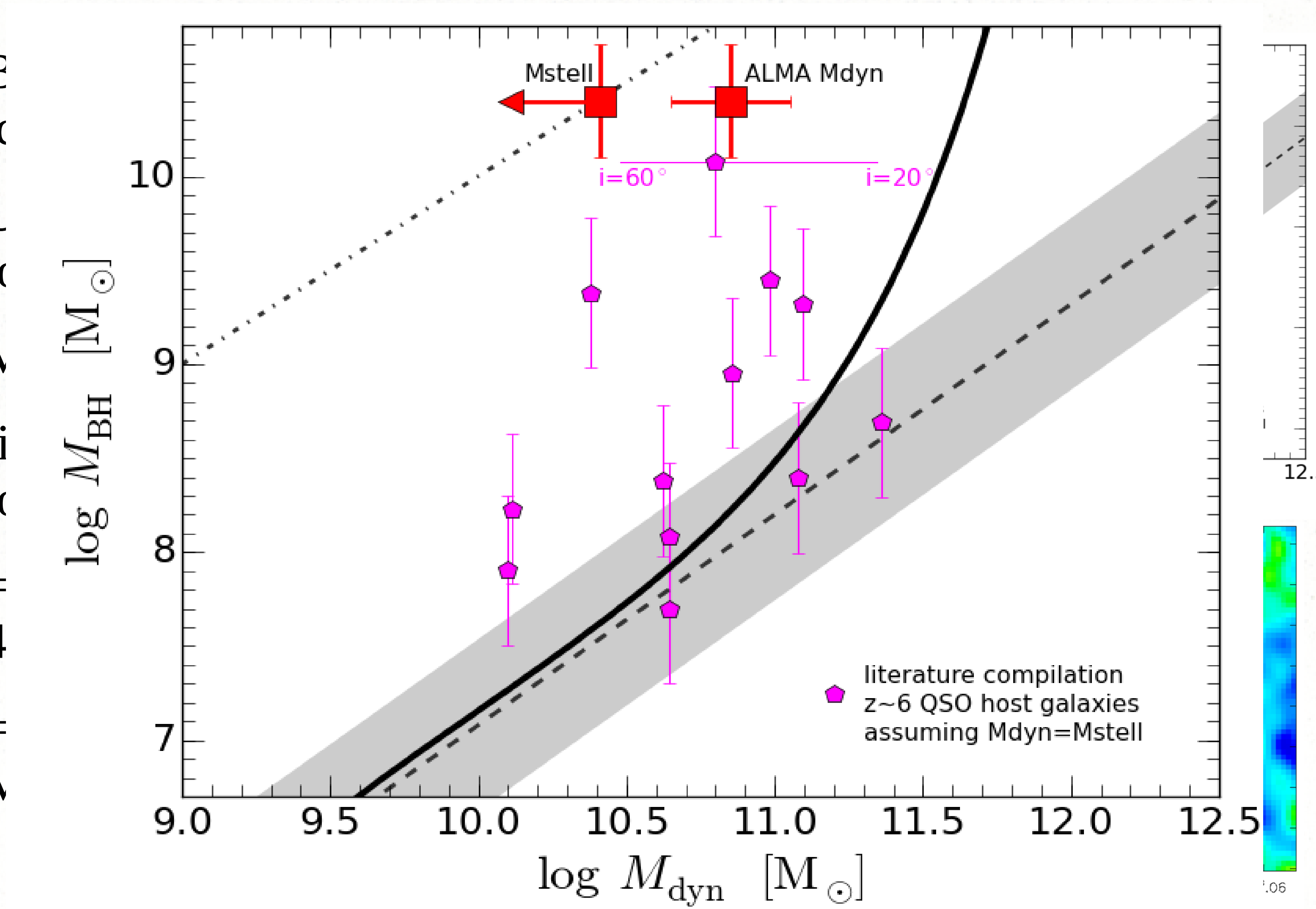

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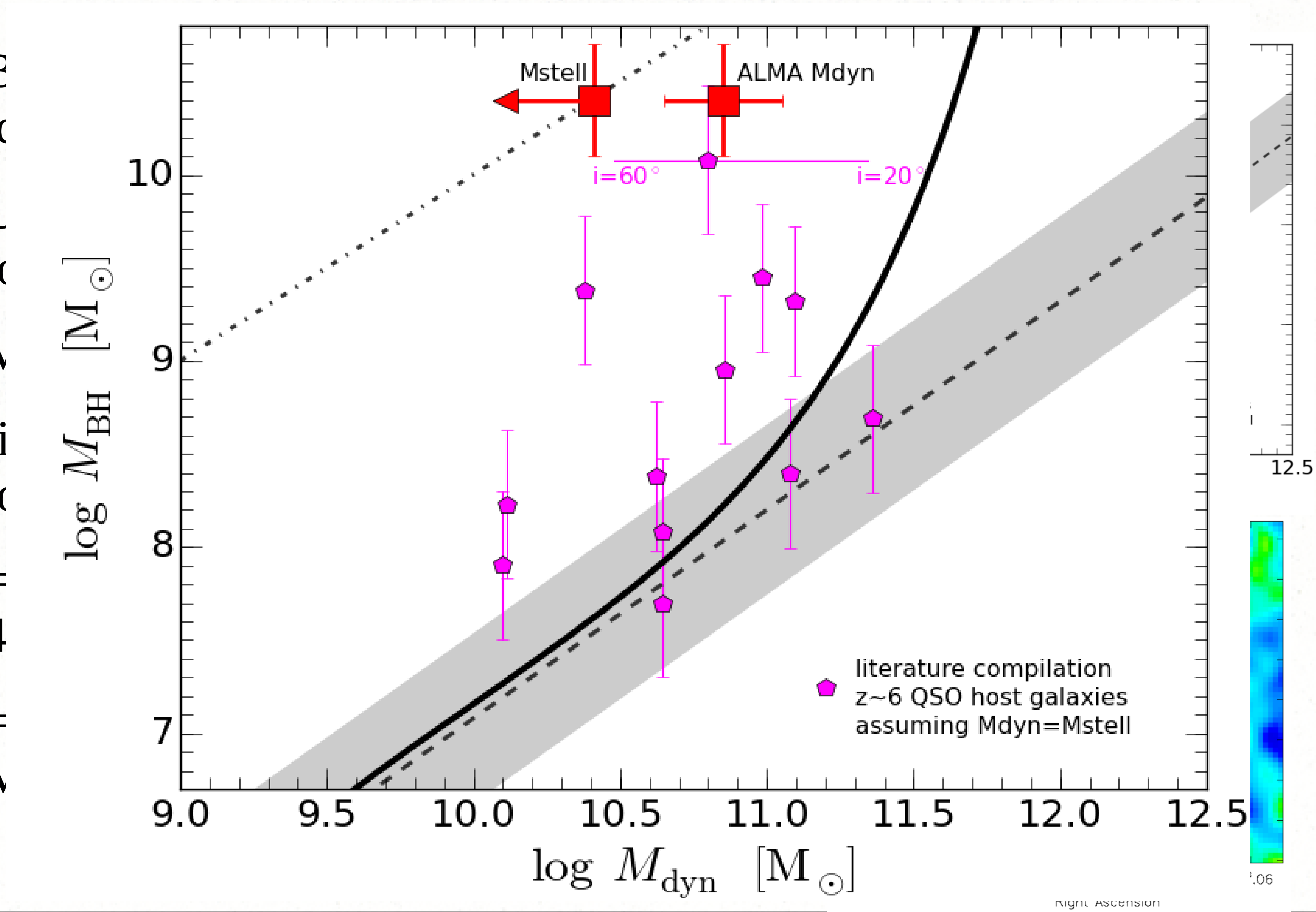

Case Study of J16+28 at z=3.8

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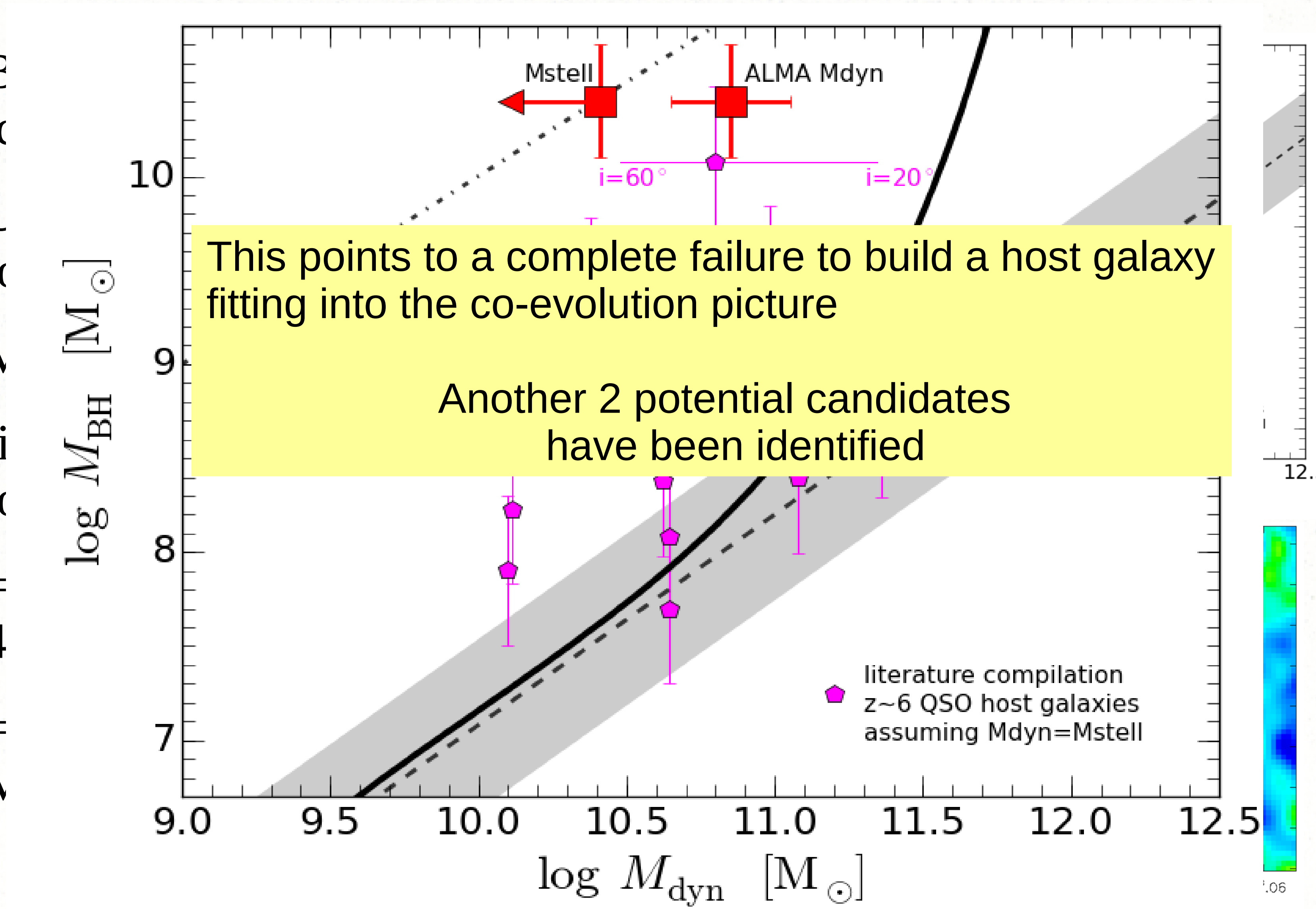
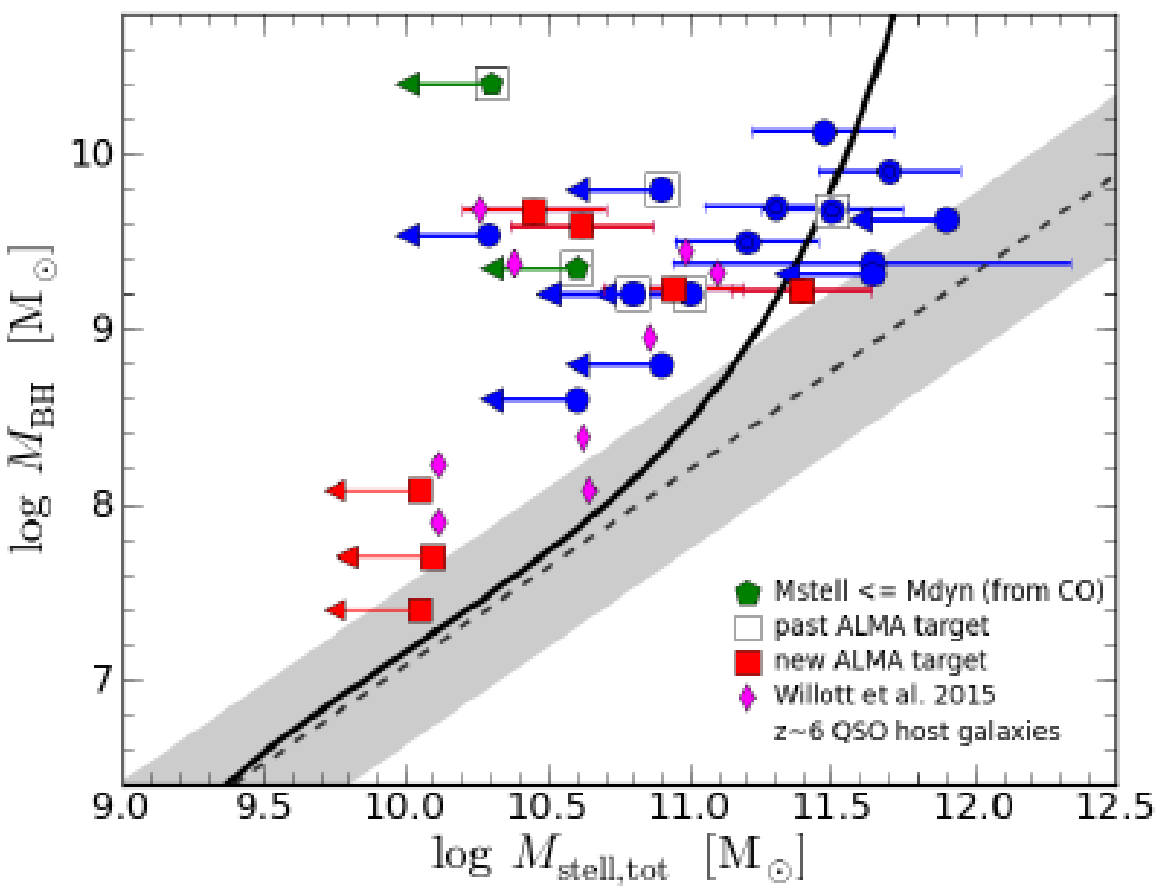


This points to a complete failure to build a host galaxy fitting into the co-evolution picture

Another 2 potential candidates have been identified

BH Mass – Mstell relation at z=3
Current Situation



Summary

- Observations (take time but) are going really well NIR spectroscopy, monitoring and ALMA follow-up (part published or to be subm.)
- We can constrain Stellar Mass either directly from imaging or from dynamical mass using ALMA
- We find very unique case of quasar host galaxy showing almost no stellar component

Thanks a lot for the great symposium

My Approach: Probing the redshift evolution of the BH mass – bulge mass relation