

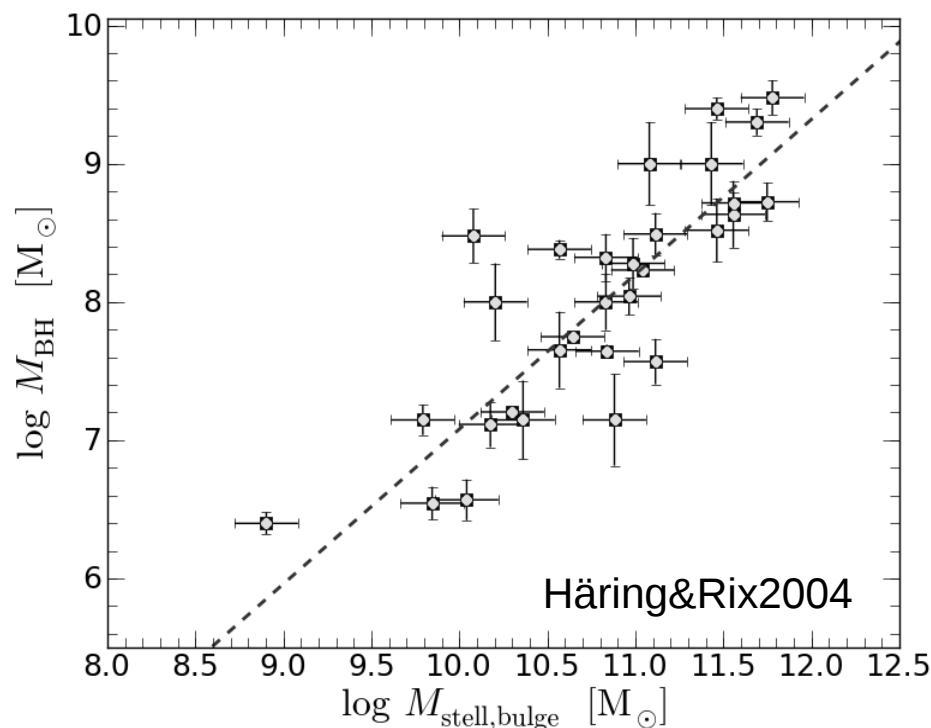
BH-Galaxy Co-Evolution at $z=3-4$: Latest Results from SUBARU & ALMA

Malte Schramm NAOJ
KEK 2017

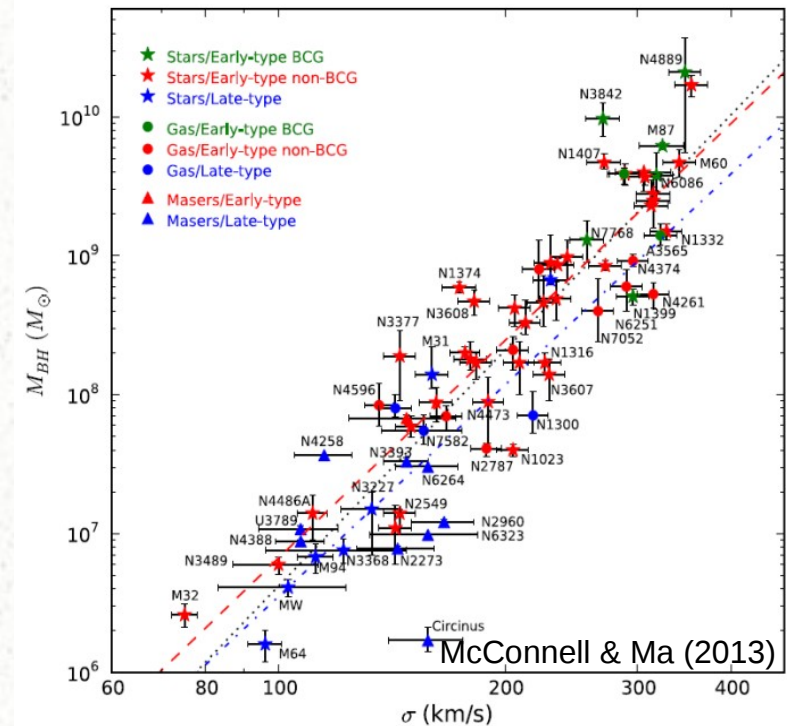
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Schulze (NAOJ), K. Ohta (Kyoto U.), John Silverman (IPMU), H.
Ikeda (NAOJ)

Motivation I

- Strong relations observed between BH mass and host properties



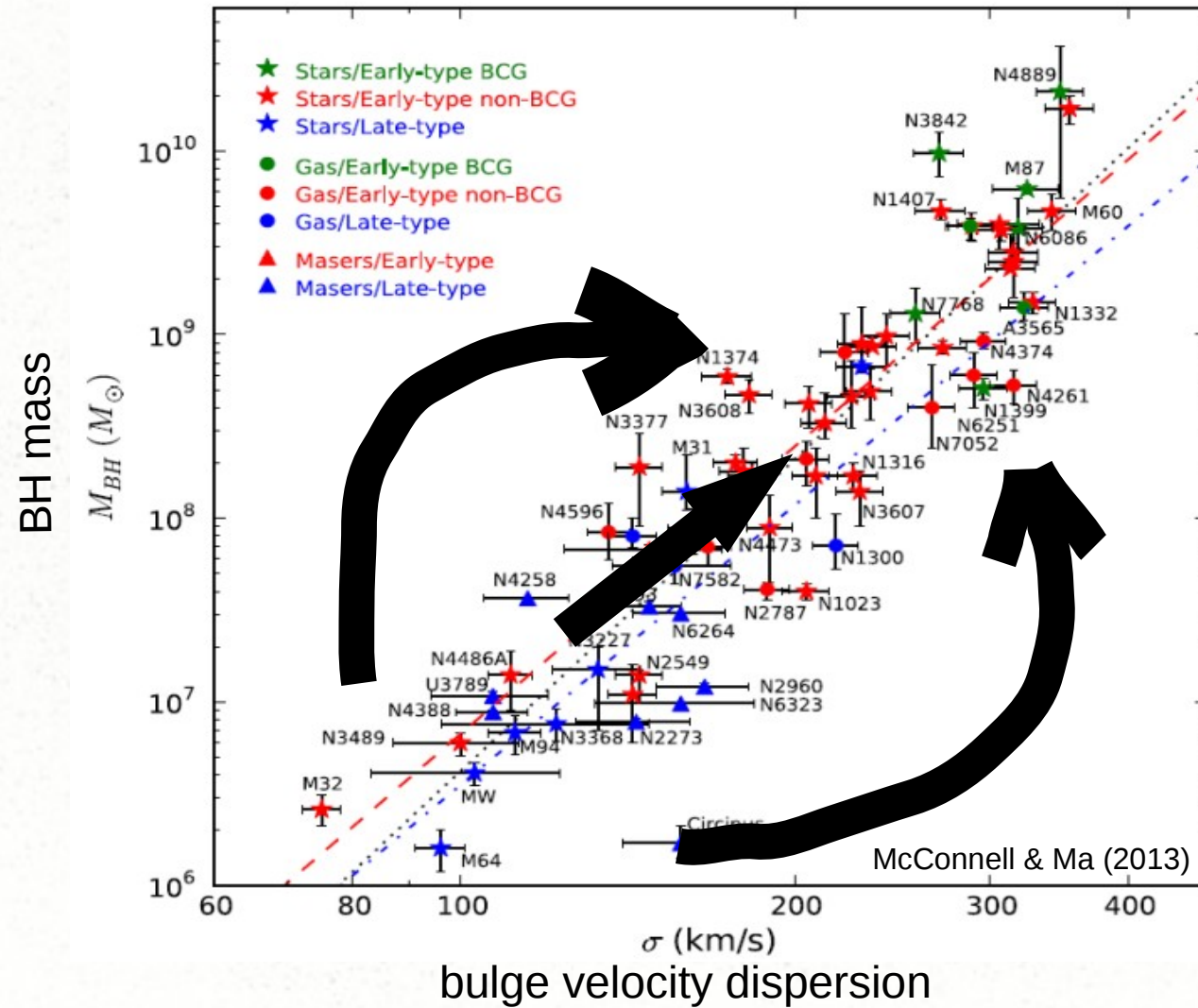
BH mass



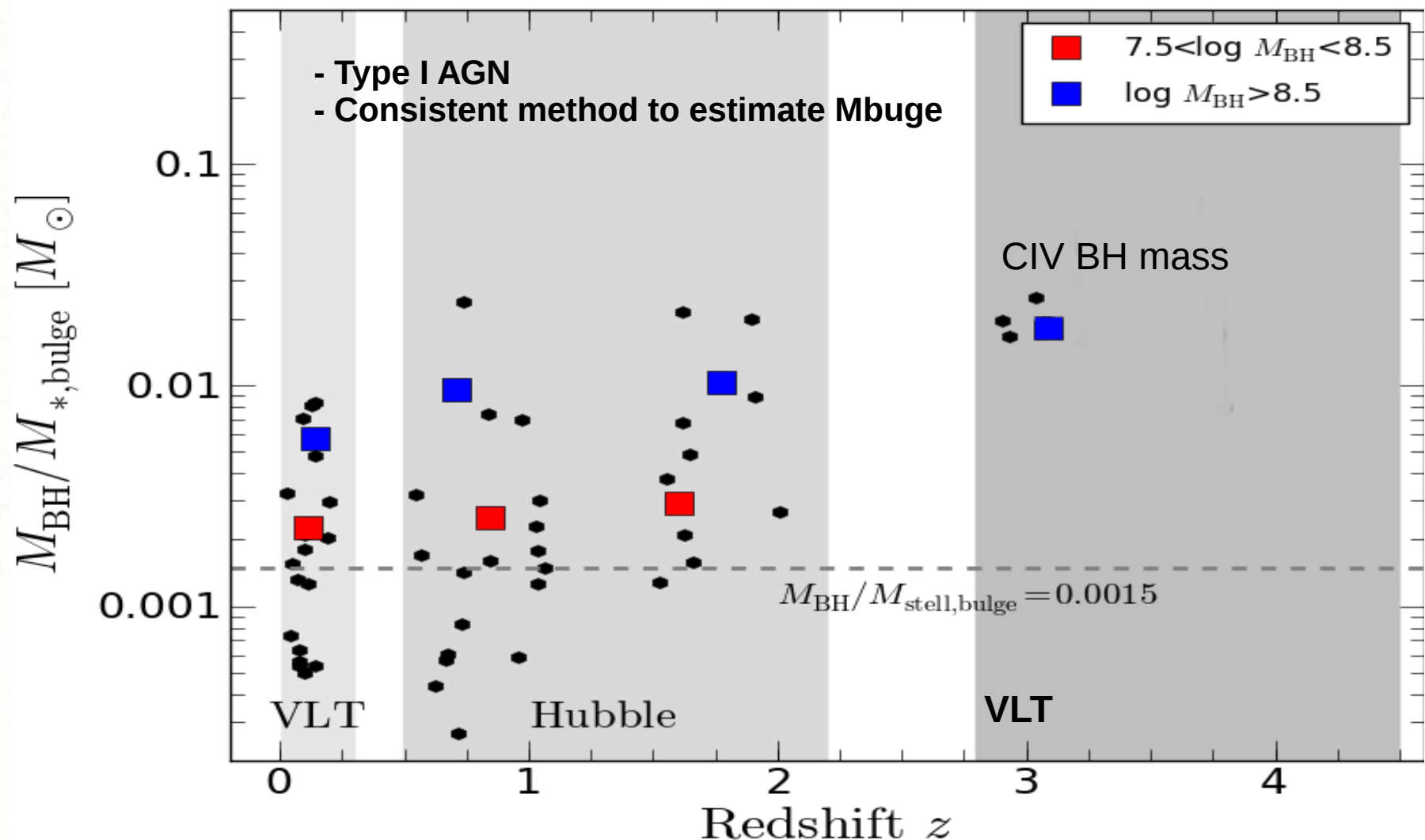
bulge velocity dispersion

So far: M-sigma only at $z < 1$

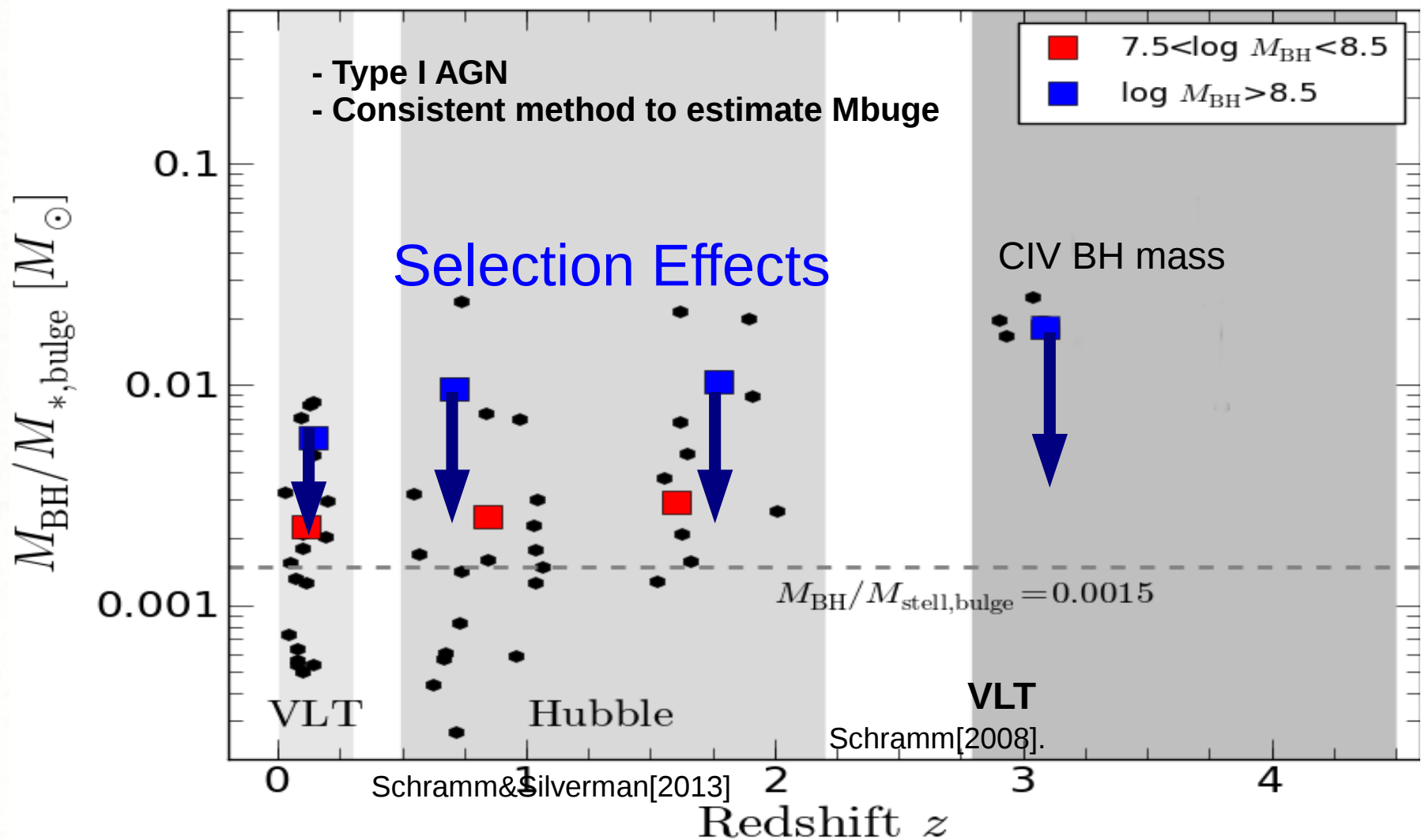
Who comes first BH or Host Galaxy?



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

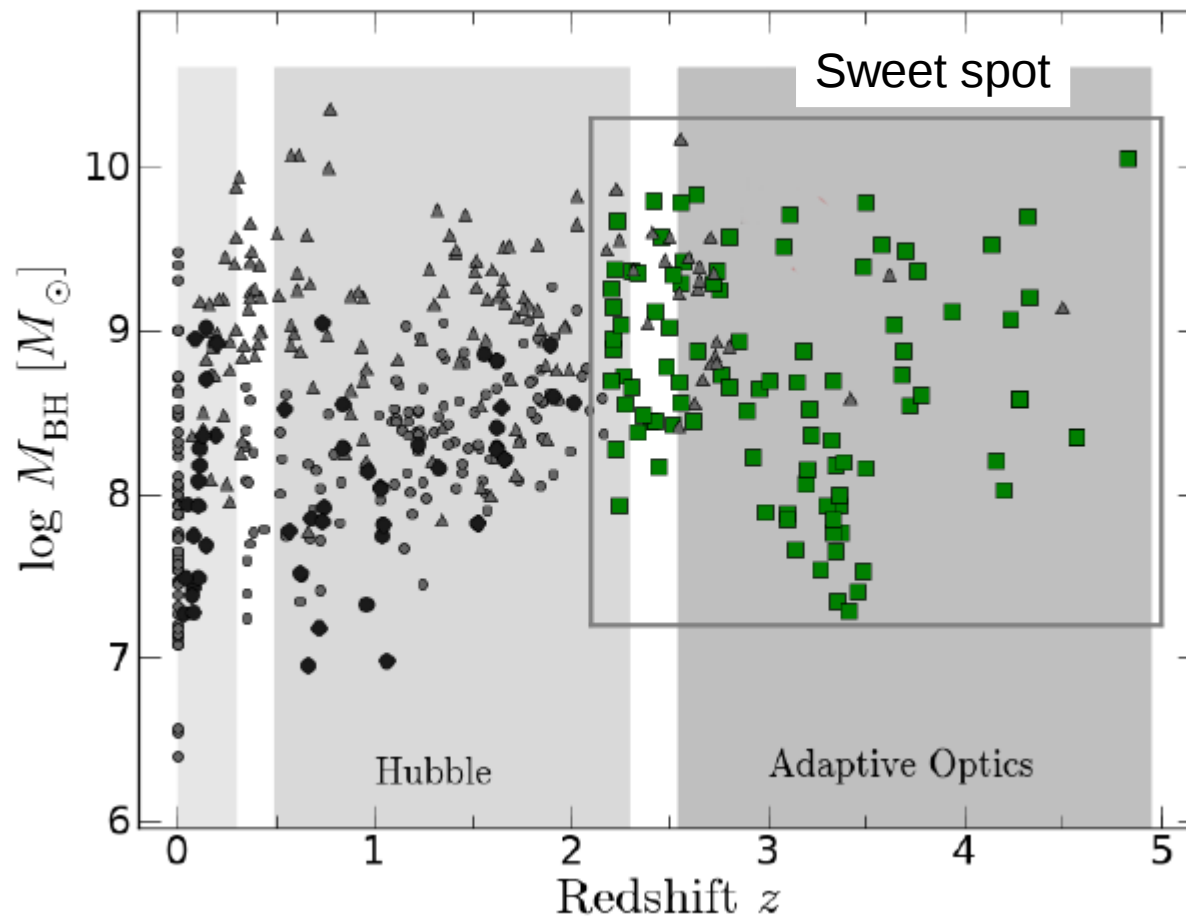


My Approach: Probing the redshift evolution of the BH mass – bulge mass relation



SUBRU IRCS+AO observations of high- z SDSS QSOs

Parent sample
Suitable for
AO: 70 QSOs

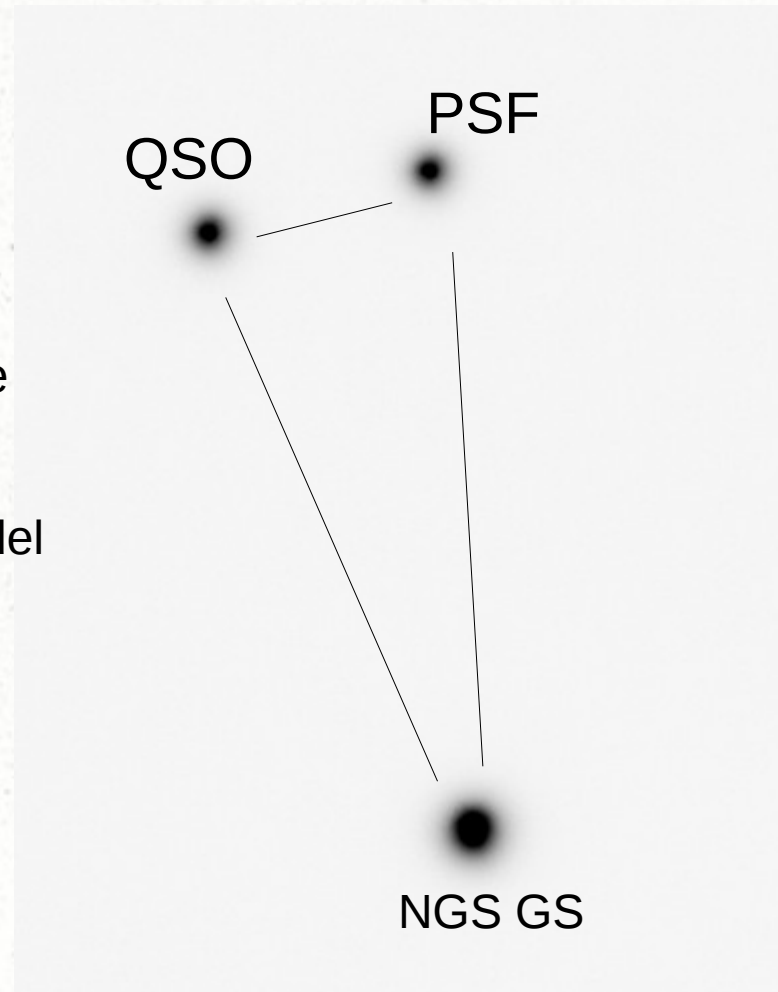


Lets try to be consistent with low-z!

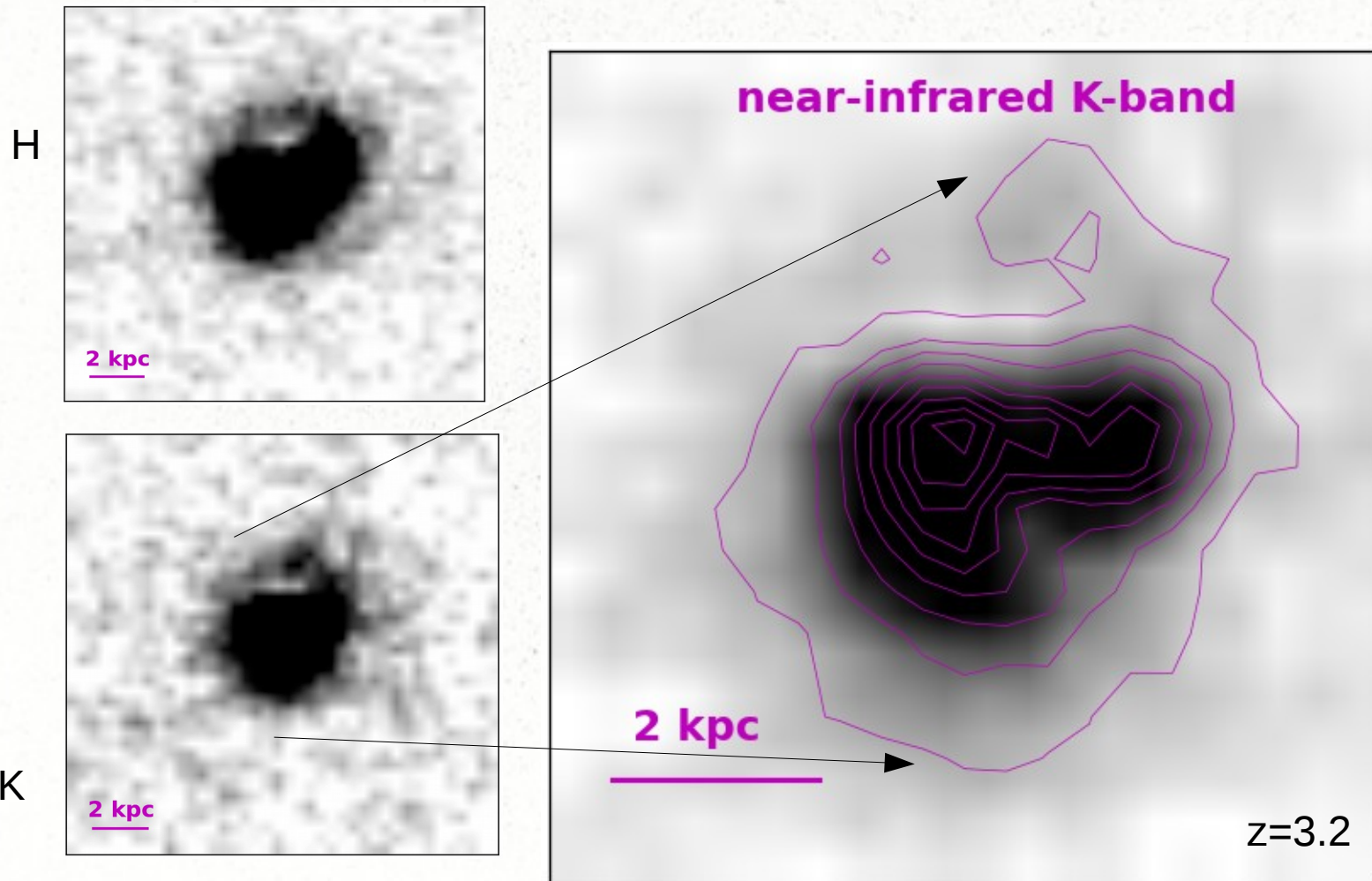
- Better BH mass estimates from Hbeta
- Better spatial resolution (0.1-0.3 arcsec) using SUBARU IRCS+AO188
- Have good control over the PSF
- Probe rest-frame B-V to cover region around 4000Å break for consistent M/L estimates

Favorable PSF configuration

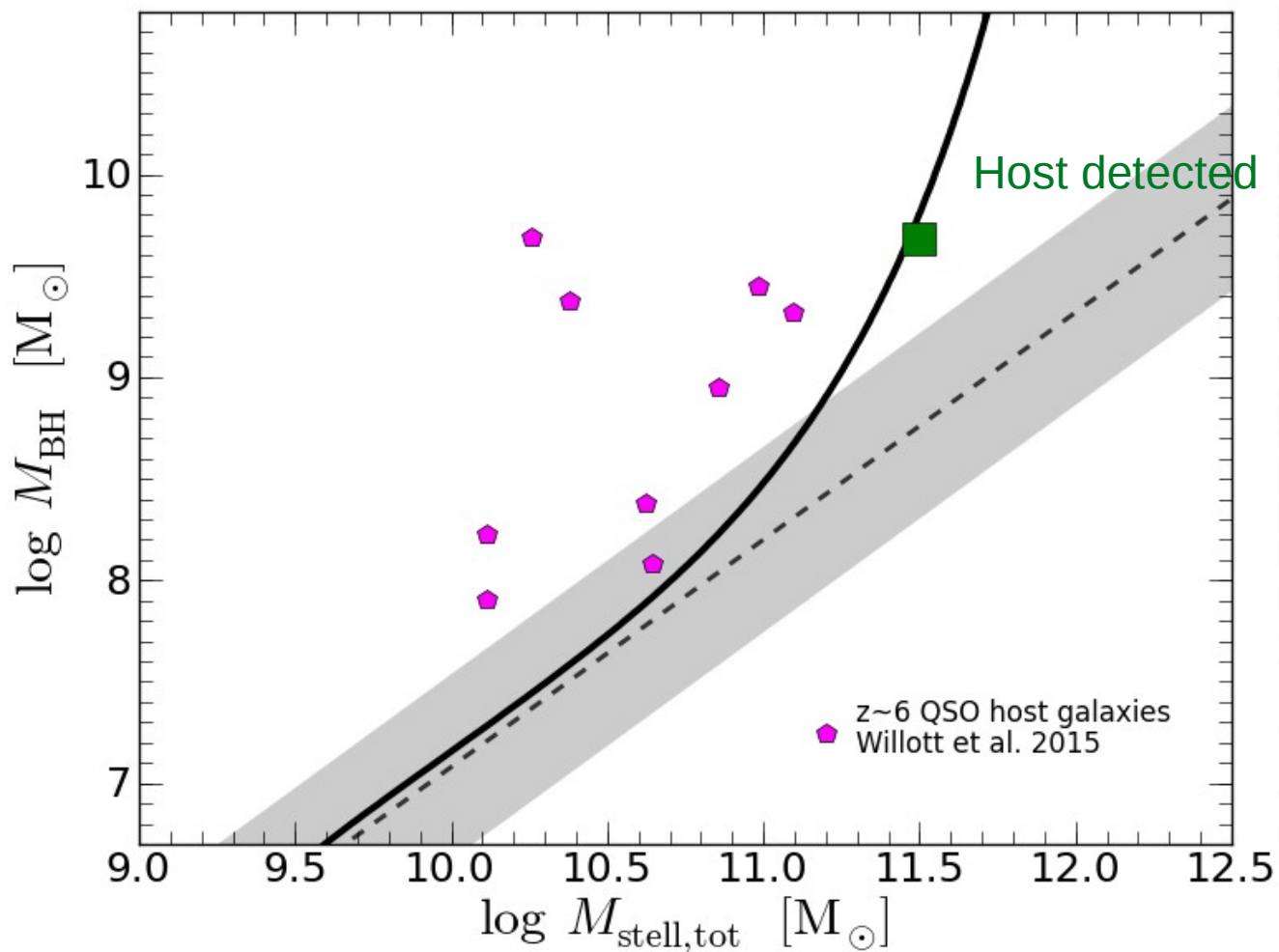
- resolving the host galaxy under the bright AGN still very difficult
- Minimize systematics in PSF control e.g. PSF degradation with increasing distance from guide star
- PSF shape can be difficult to model over full FoV with only few stars



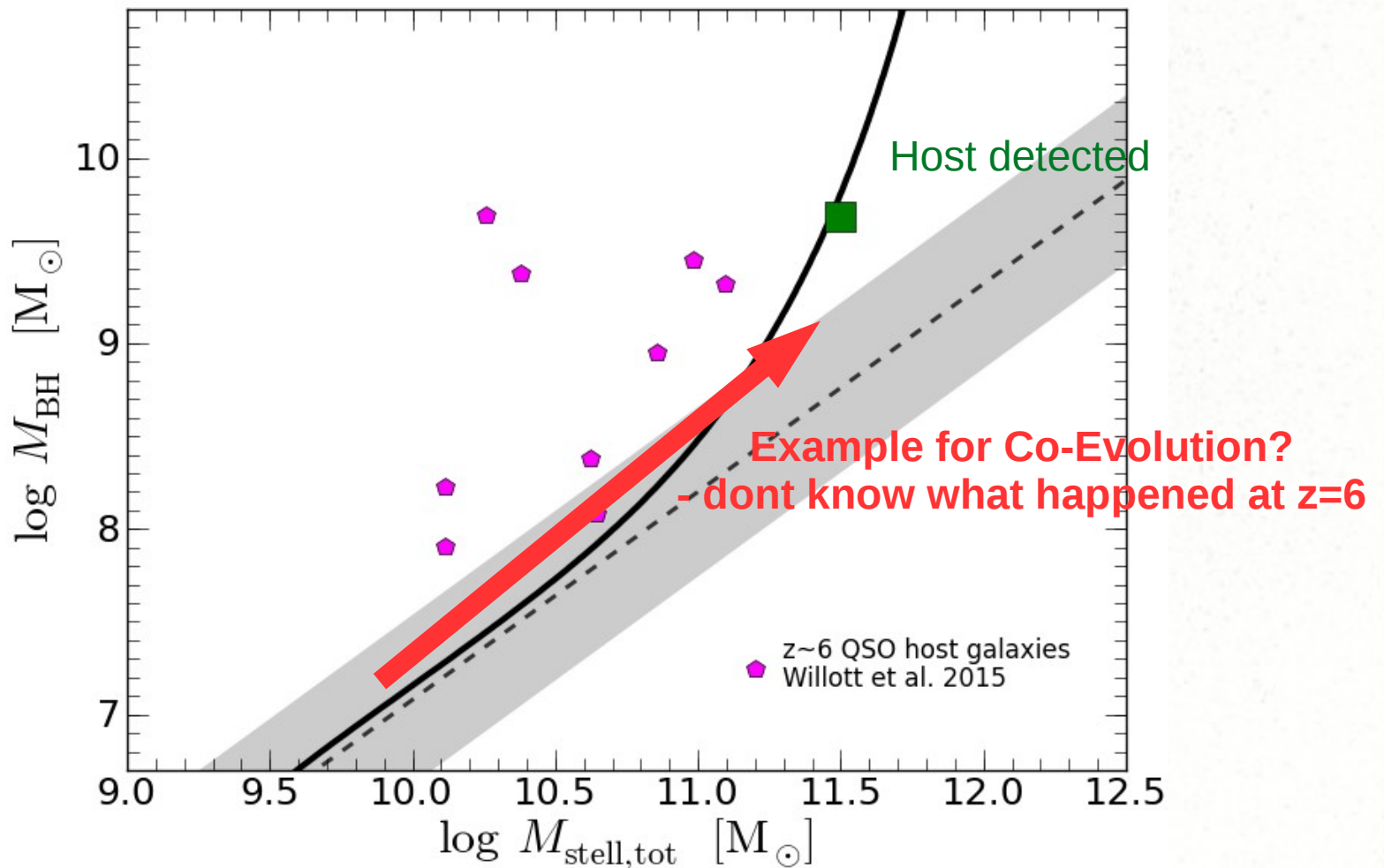
AGN host galaxy at $z=3.2$ wAO



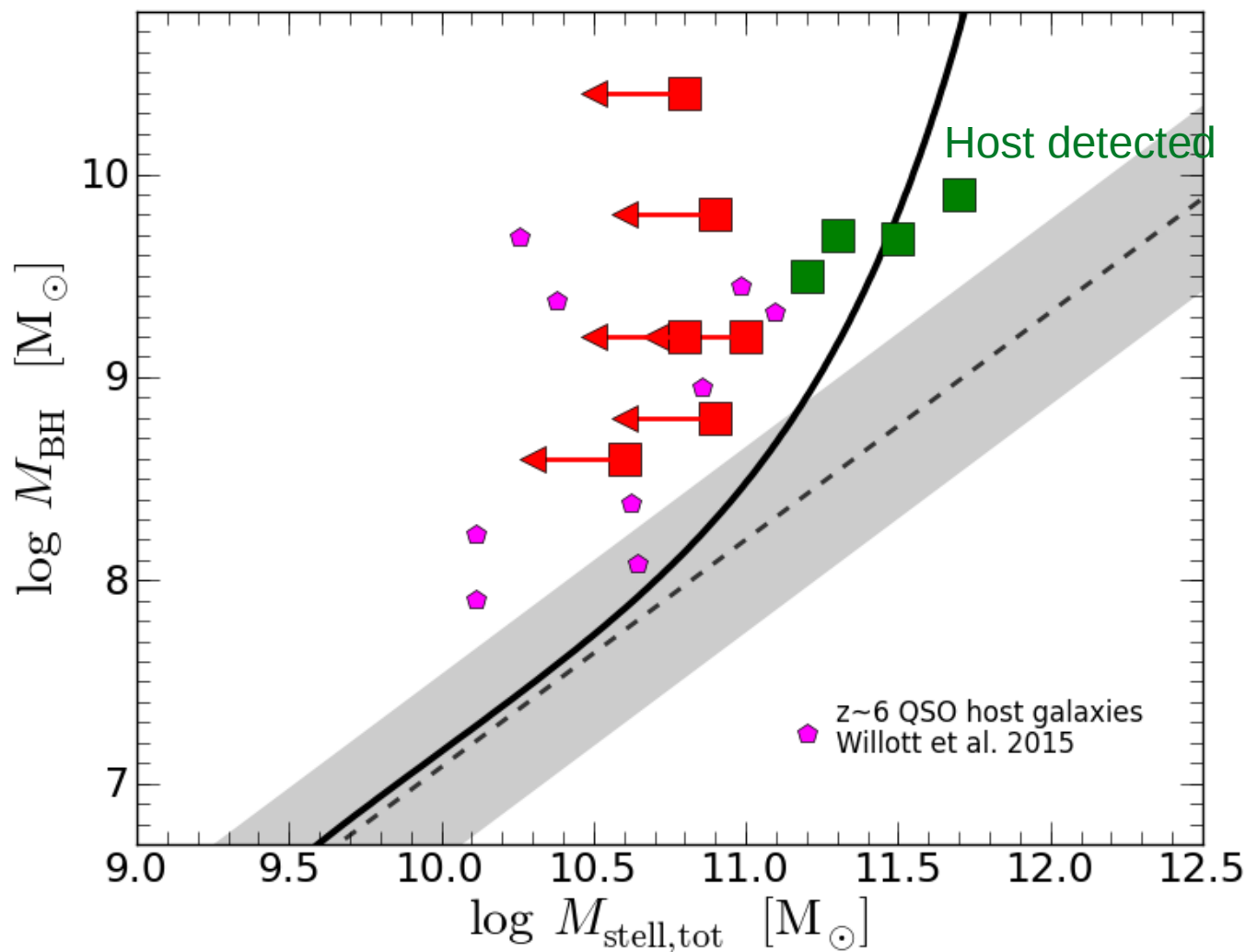
Scaling Relation at $z=3$



Scaling Relation at $z=3$



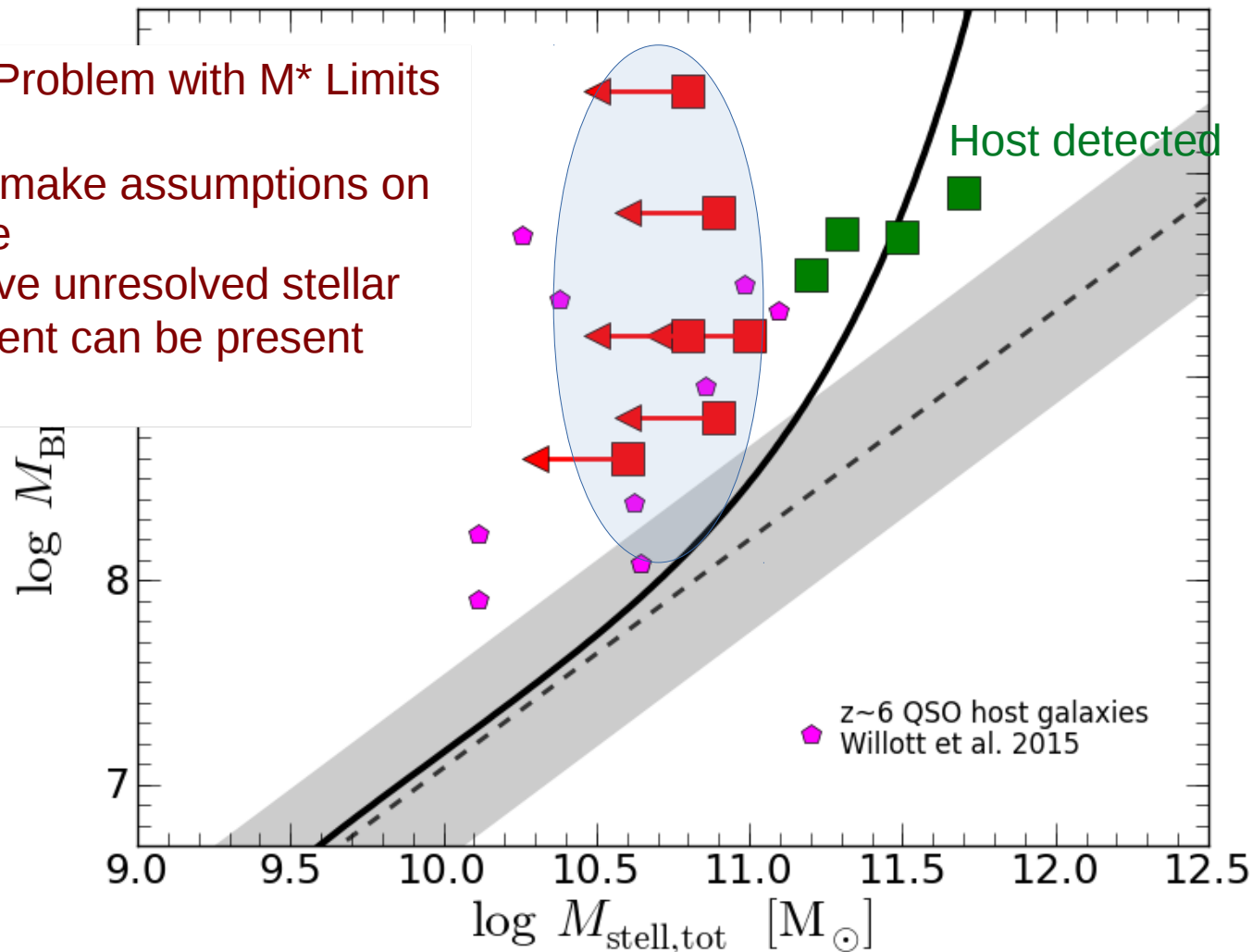
Scaling Relation at $z=3$



Scaling Relation at $z=3$

Possible Problem with M^* Limits

- * have to make assumptions on host size
- * a massive unresolved stellar component can be present



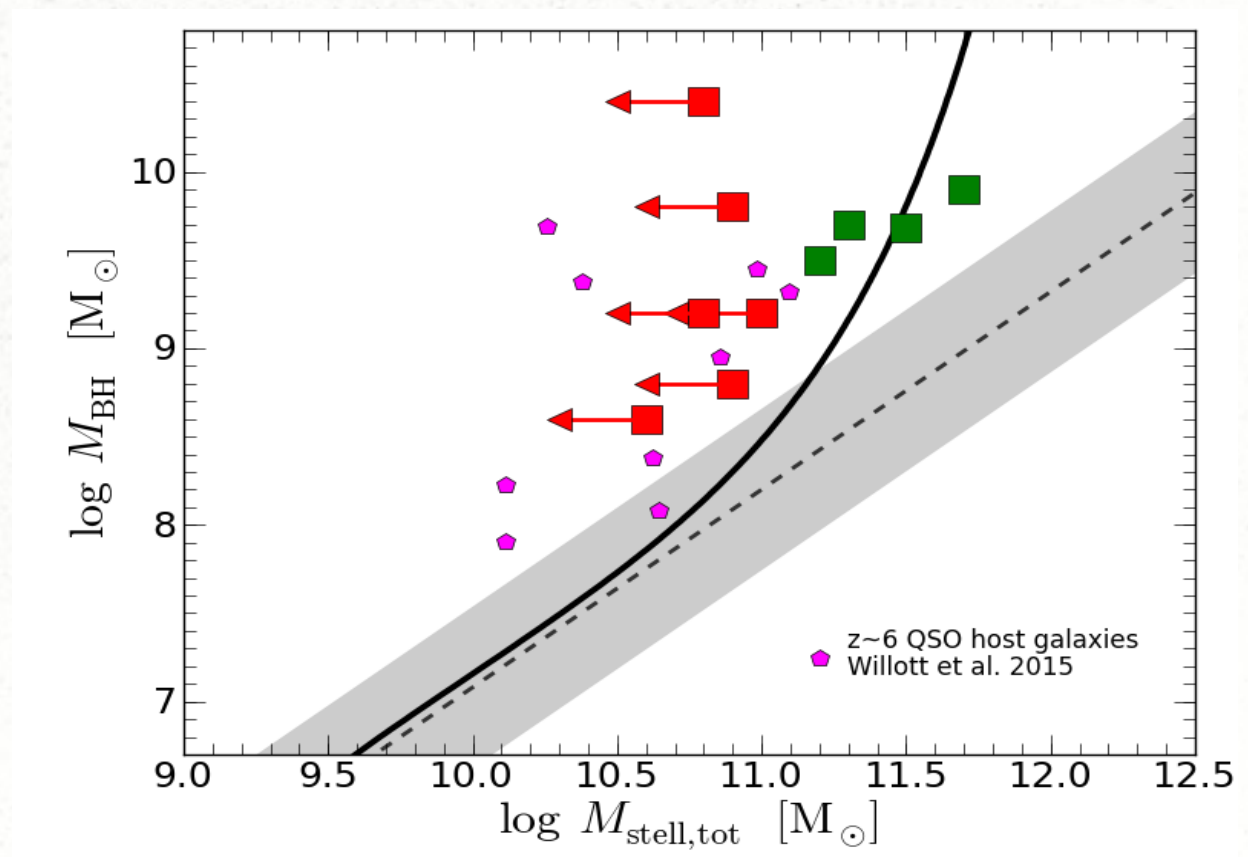
The next step: ALMA

- Two 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 $\rightarrow$ large gas reservoir
 $\longrightarrow$ only one clear detection at 9σ (2 non-detections)

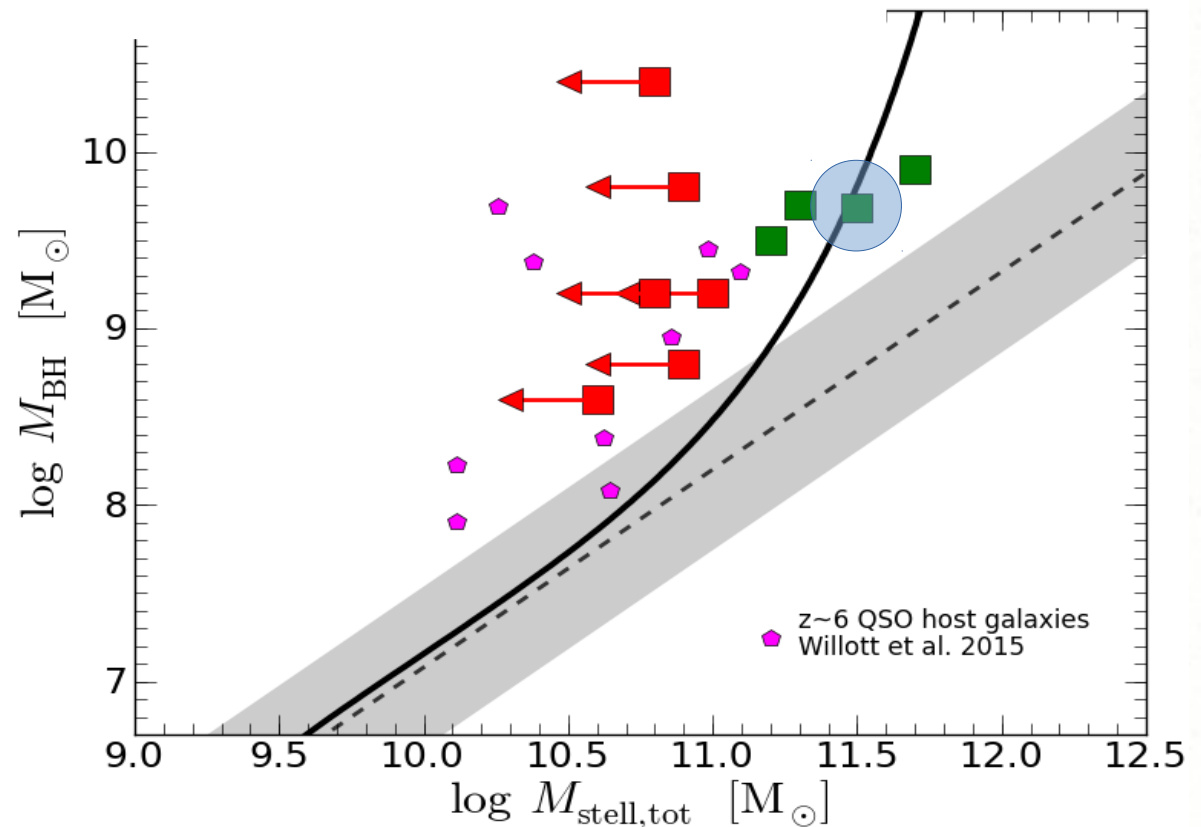
- On-going Cycle 4 ALMA program (3/4 targets observed) on quasars with different OIII properties in band 4
 $\longrightarrow$ 2/4 targets delivered (1 detection)

First ALMA Results



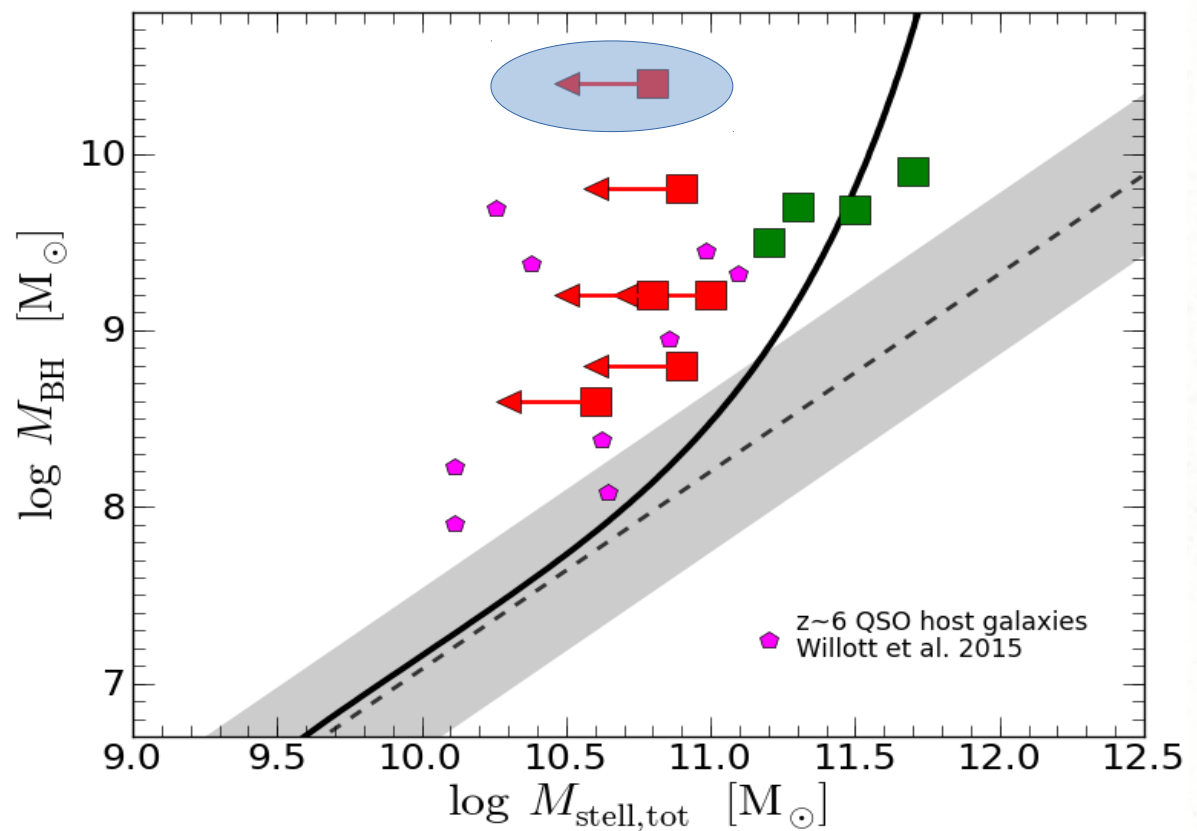
First ALMA Results

**Quasar with resolved stellar host galaxy:
NO Detection with ALMA
all gas into stars?**



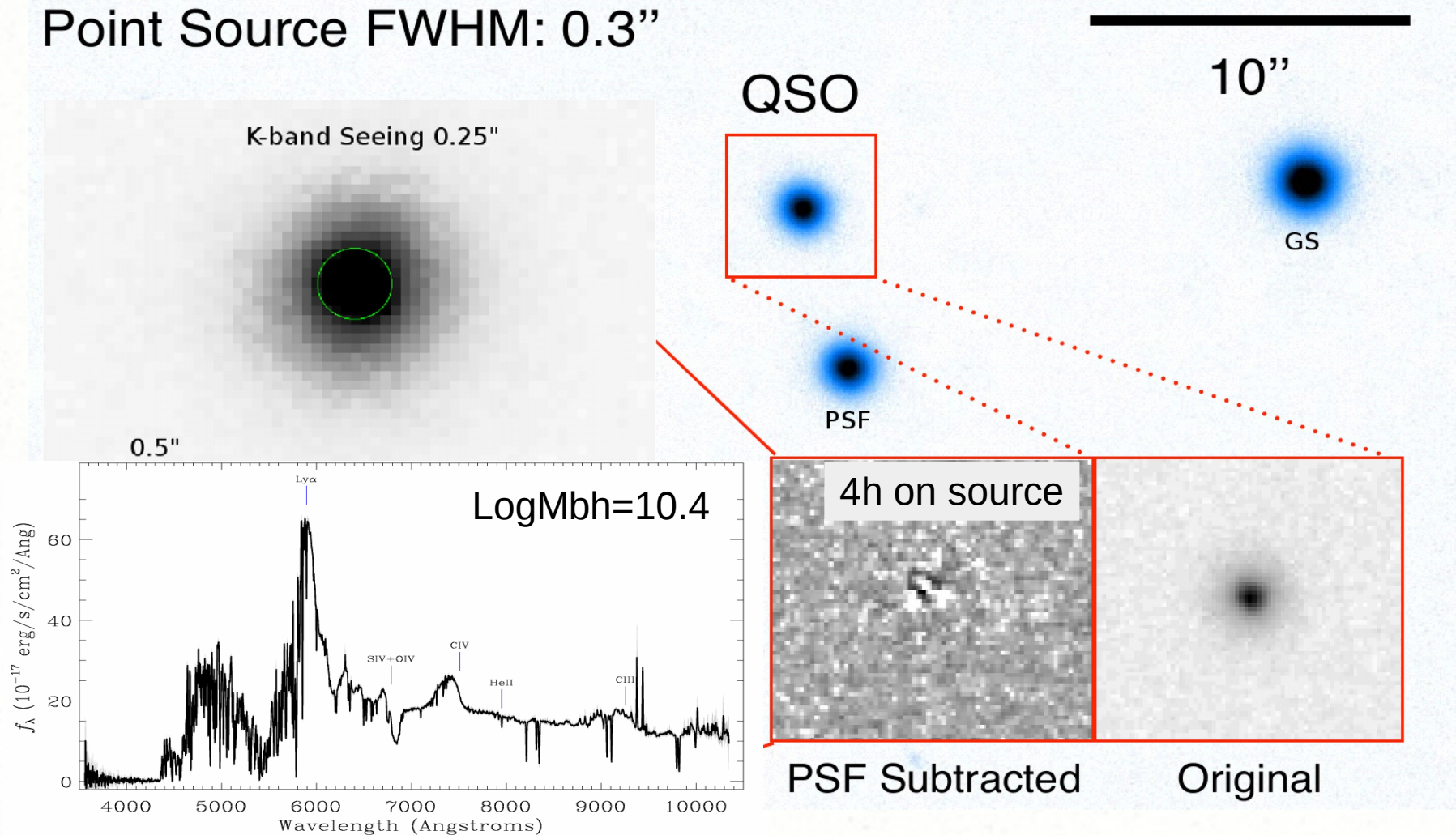
First ALMA Results

Most interesting Case Study of a $z = 3.8$ Quasar

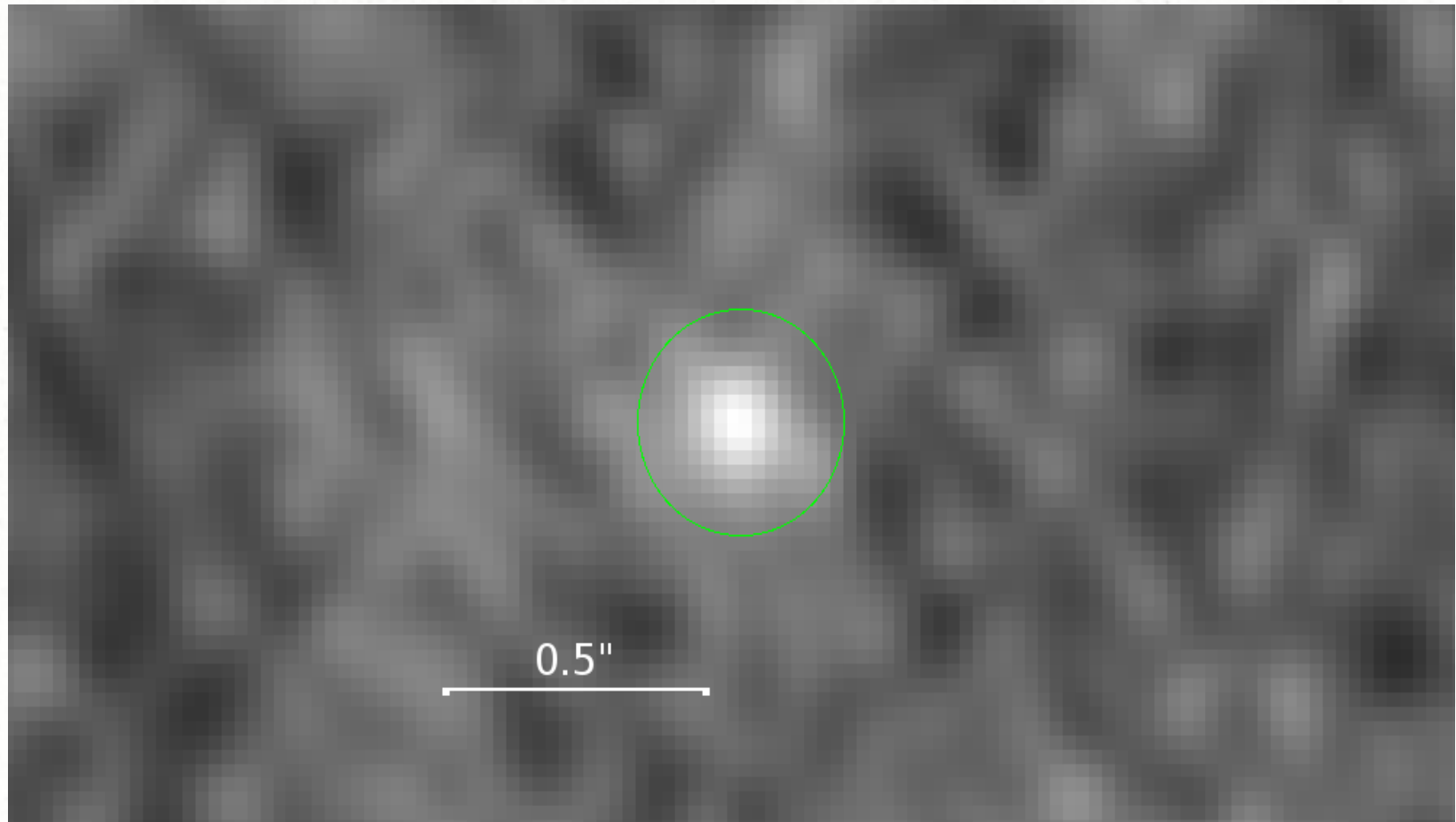


Case study of J16+28

Point Source FWHM: 0.3''



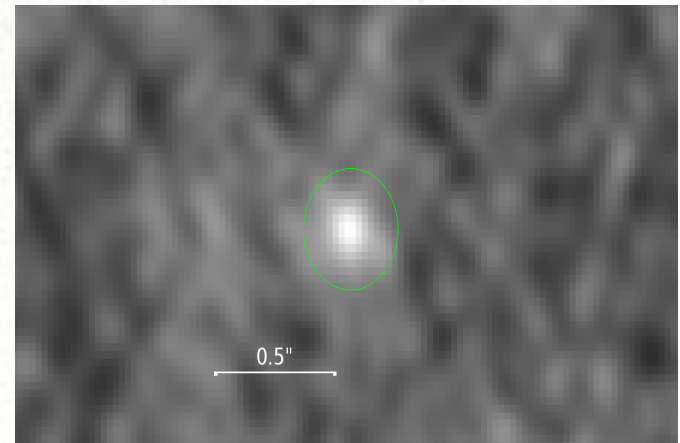
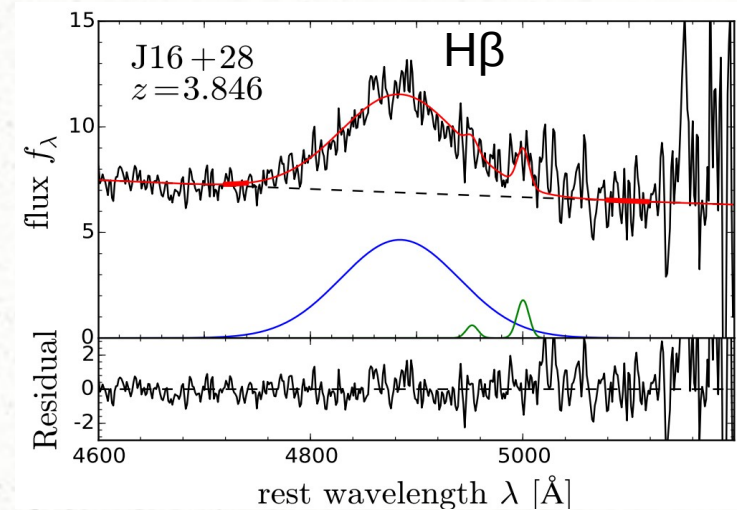
ALMA reveals the gas!



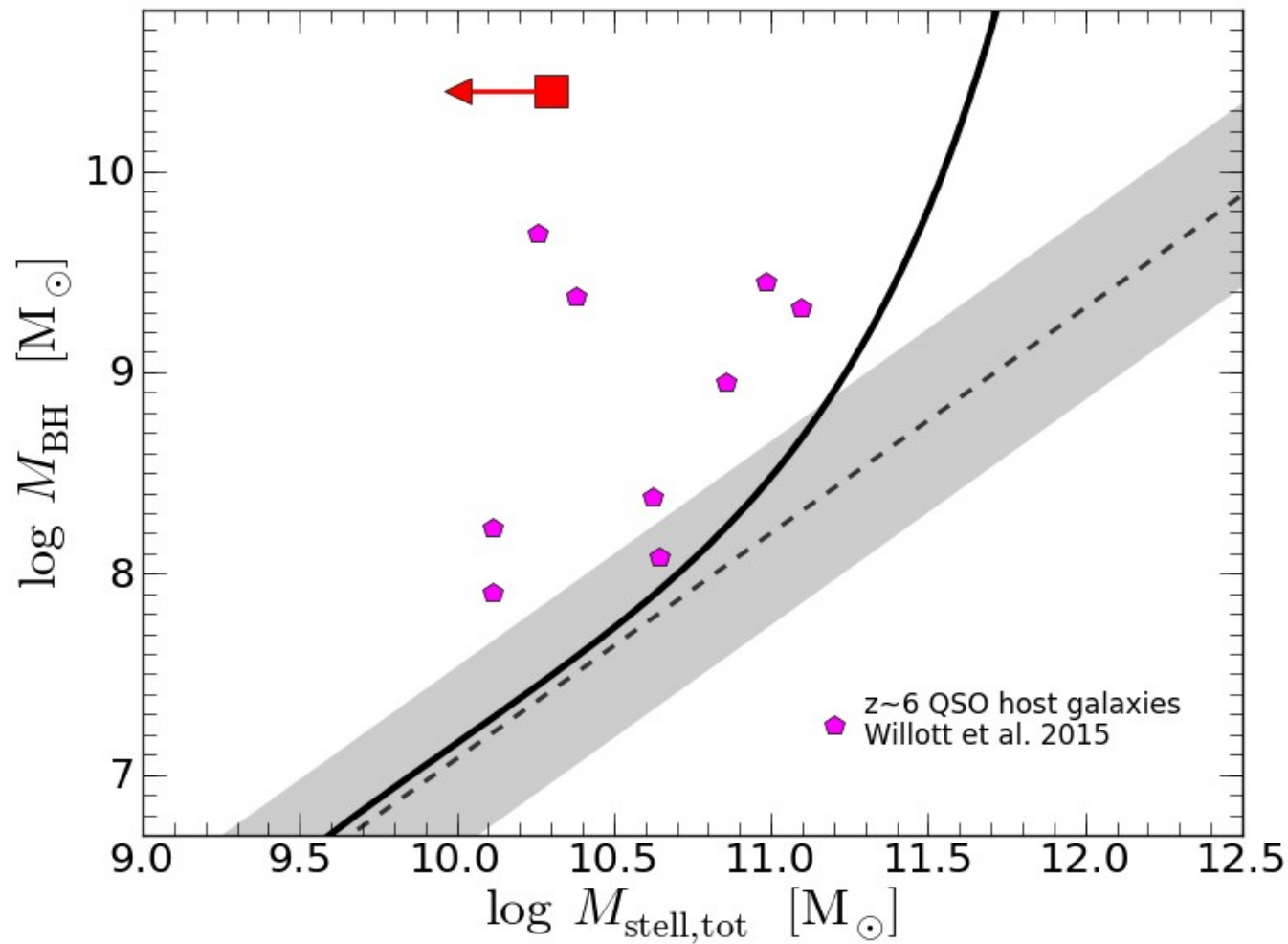
ALMA reveals very compact CO4-3 (<1.5 kpc) ALMA resolution $<0.1''$

J16+28 character sheet

- BH mass: $\log M_{\text{BH}}=10.4$ from H β consistent with CIV
 - ER: 60%
 - Upper limit of the stellar component $\log M^* < 10.8$
 - Gas mass $\log M_{\text{gas}}=10.3$
 - limit on dynamical mass $\log M_{\text{dyn}}=10.8$ ($i \sim 50^\circ$) from CO
- => in this case BH accounts for 40% of M_{dyn}
- => BH+gas account for 75% of M_{dyn}



Implication on Scaling Relation



Implication on Scaling Relation

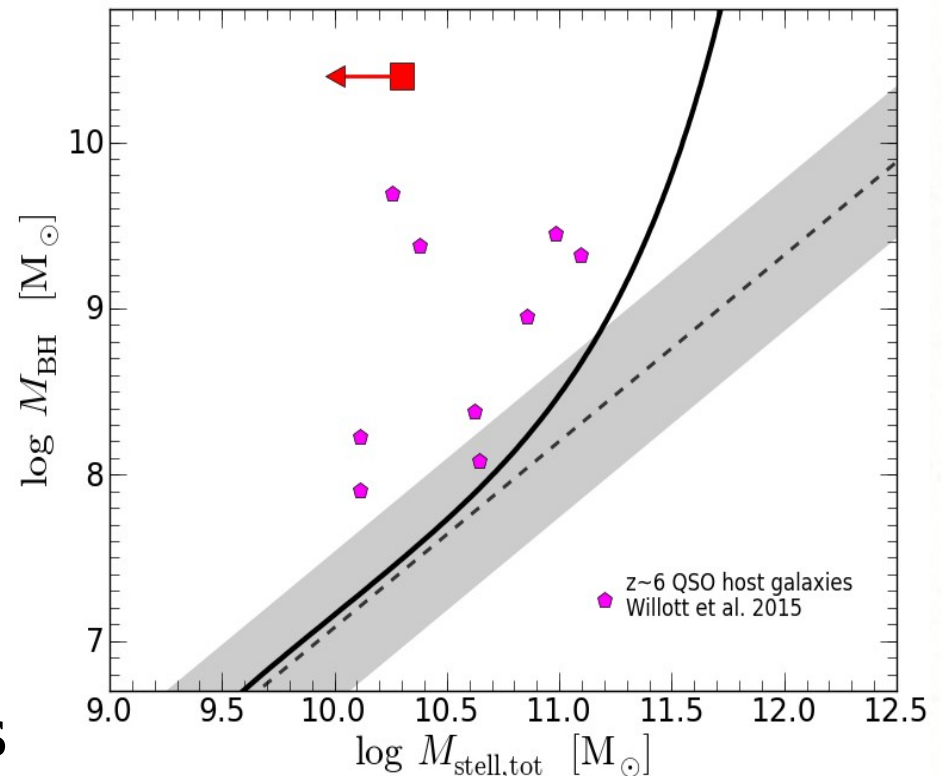
- Currently no way to gain some weight for the host

Is there gas hidden somewhere?

- Maybe ionized gas on larger scale?

Needs to be tested
(preliminary results reveal no large scale ionized gas - Ly α)

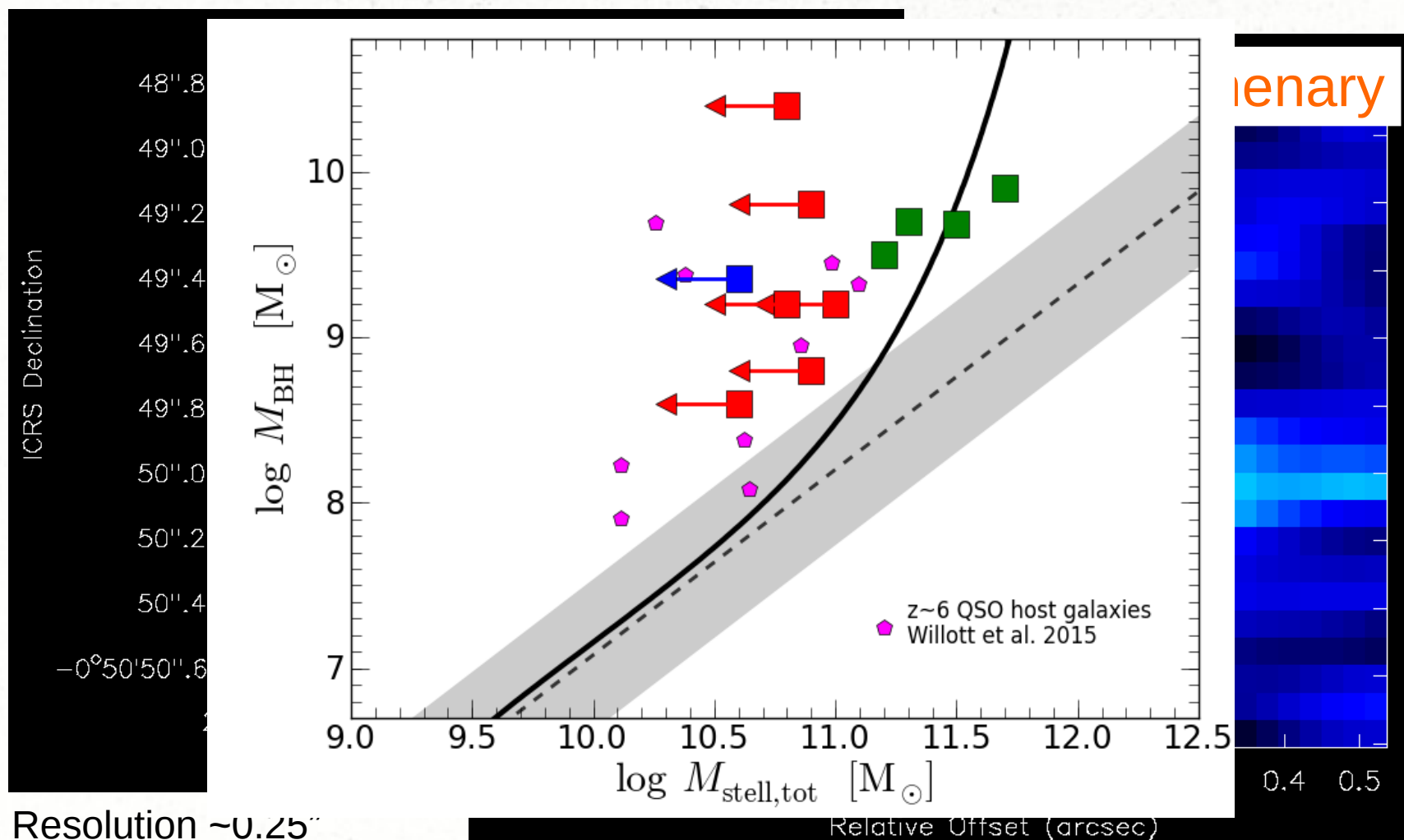
- Host can only grow through external processes



How to interpret this?

- We can still hide some gas (tested only CO(3-4), and need to test Lya on 100 kpc scale)
- If no further gas is found: this might be an interesting case study for very efficient accretion & Direct Collapse Model????
- Our other 3 QSOs with no ALMA detection might be gas poor but difficult to interpret since we have no detection – could be sb issue

Another Interesting Case Study from ALMA Cycle 4



Future/Summary

- Still 2 objects missing from ALMA Cycle 4
- Systematically study Bhs with $MBH > 10^{10} M_{\text{sun}}$
- Use HSC to study the local environment – improve photo-zs by our deep H/K-band imaging
- Study extended narrow-line region – look for Ly α halos

My Question: How to grow Objects like J1639
with very dominant BH growth?