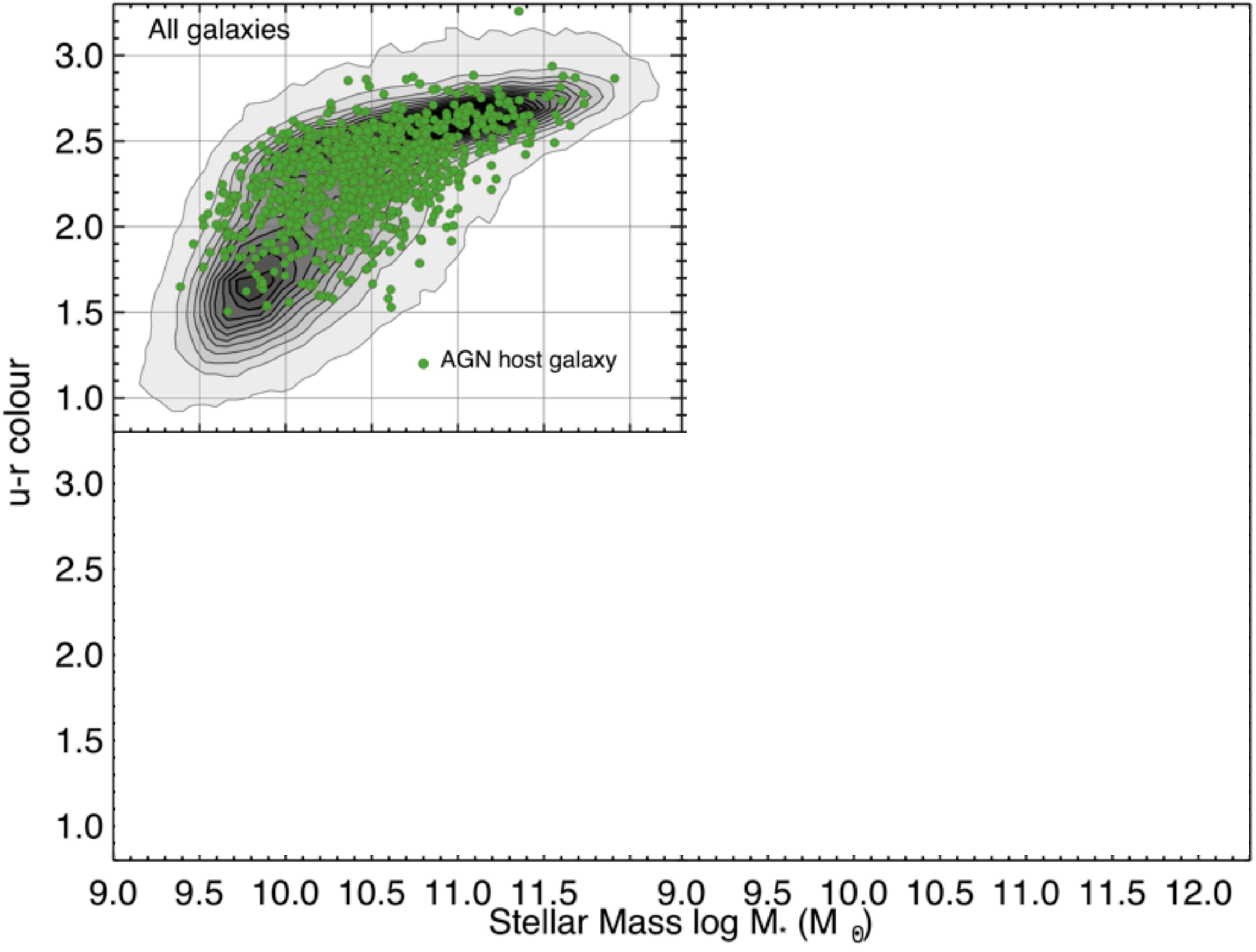
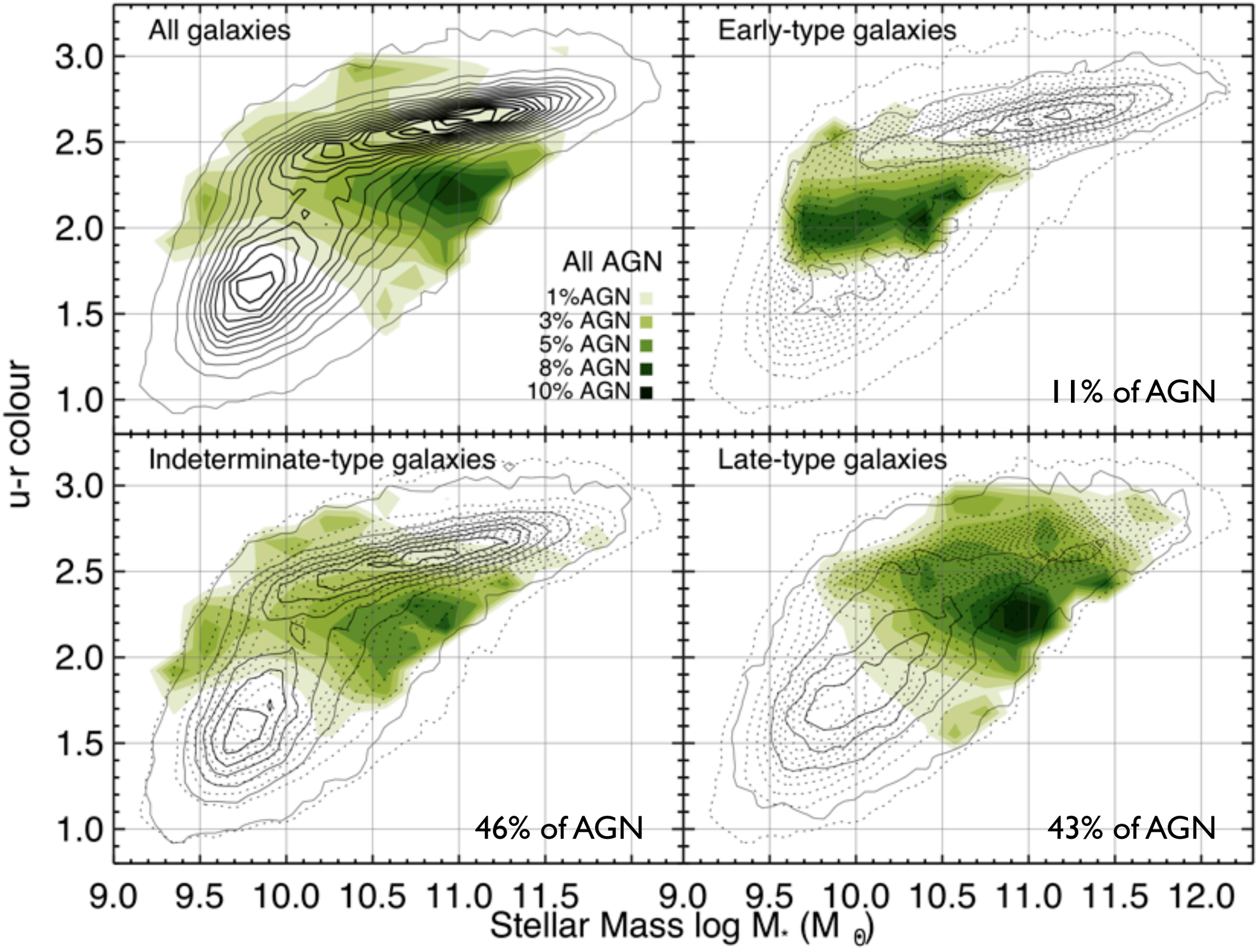
HST-WFC3/IR reveals the z~2* Universe:
secular black hole growth and first glimpses of seed black holes

with: Meg Urry, Ezequiel Treister, Carie Cardamone, Brooke Simmons, Priyamvada Natarajan, Marta Volonteri, Chris Lintott, Shanil Virani and ~440,000 citizen scientists

Kevin Schawinski
Einstein Fellow
Yale Center for Astronomy & Astrophysics
Department of Physics
Yale University



AGN host galaxies at z~0 (Schawinski et al. 2010)



AGN host galaxies at z~0 (Schawinski et al. 2010)

All galaxies

Early-type galaxies

AGN with
$L/L_{Edd} > 0.1$
1%AGN
3% AGN
5% AGN
8% AGN
10% AGN

11% of AGN

Indeterminate-type galaxies

Late-type galaxies

u-r colour

3.0
2.5
2.0
1.5
1.0

9.0 9.5 10.0 10.5 11.0 11.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0

Stellar Mass log M* ($M_\odot$)

10% AGN

11% of AGN

Indeterminate-type galaxies

Late-type galaxies

Milky Way

46% of AGN

43% of AGN

u-r colour

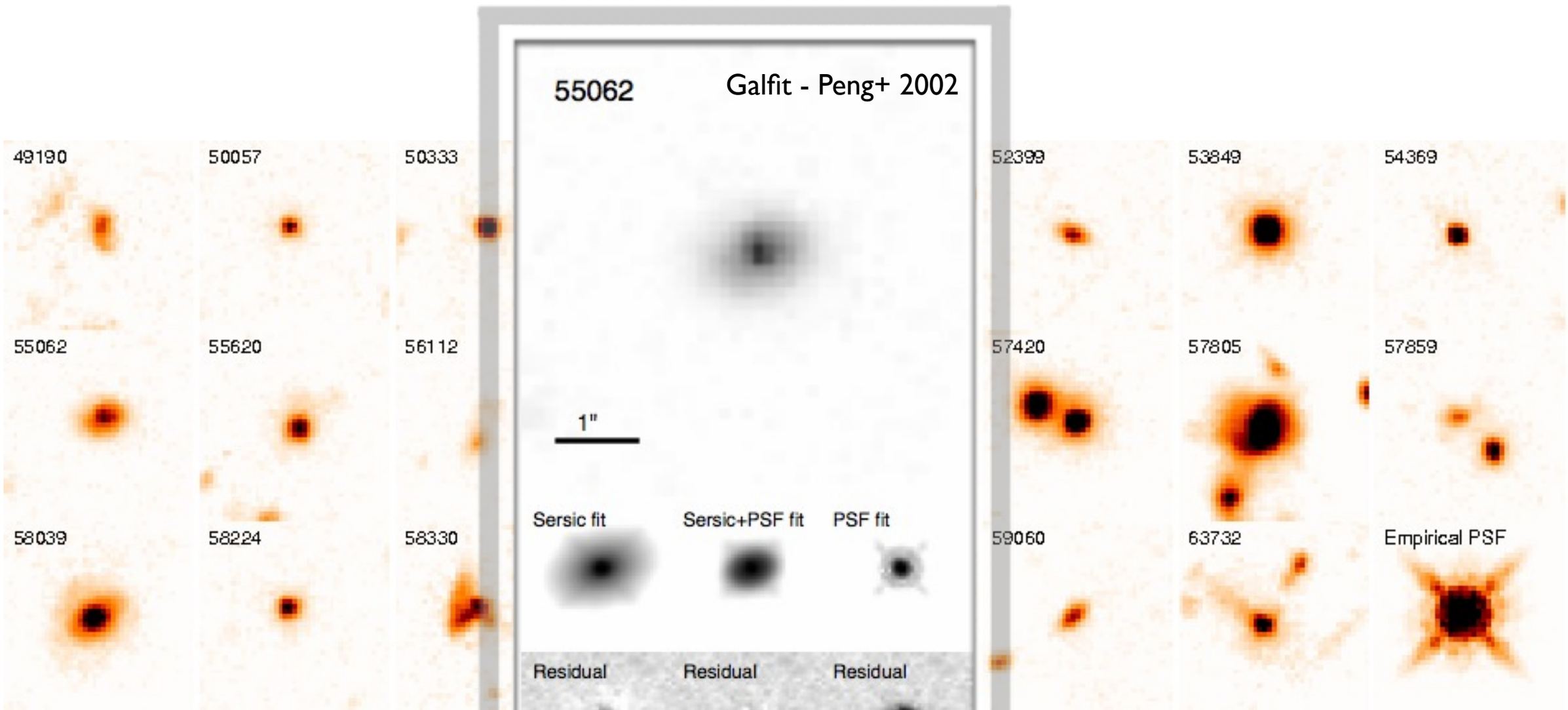
3.0
2.5
2.0
1.5
1.0

9.0 9.5 10.0 10.5 11.0 11.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0

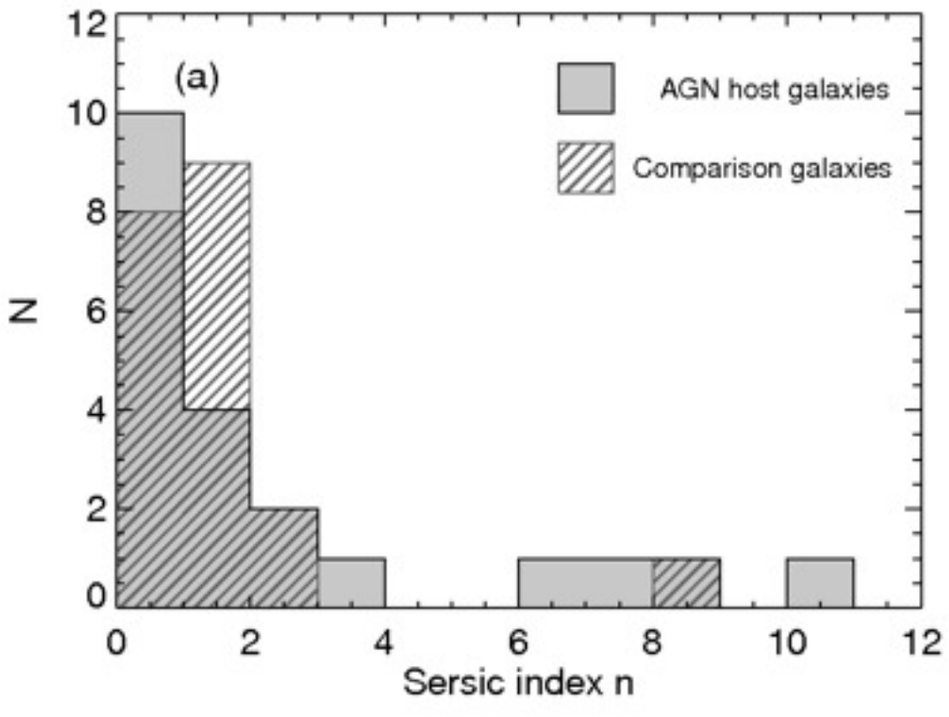
Stellar Mass log M. ($M_\odot$)

WFC3/IR (*YJH*) imaging of *Chandra* X-ray AGN

Typical AGN host galaxies at z ~ 2



Typical AGN host galaxies at z ~ 2

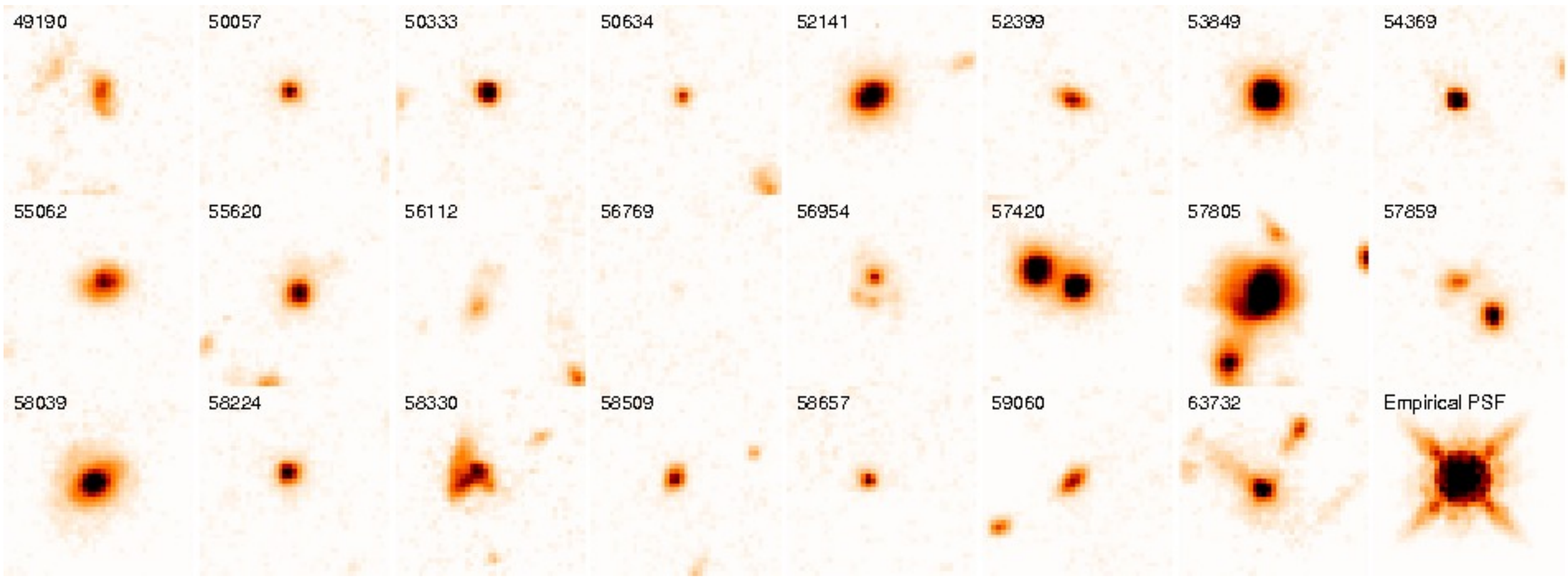


80% have low Sersic indices - disk-dominated, not bulges, not mergers.

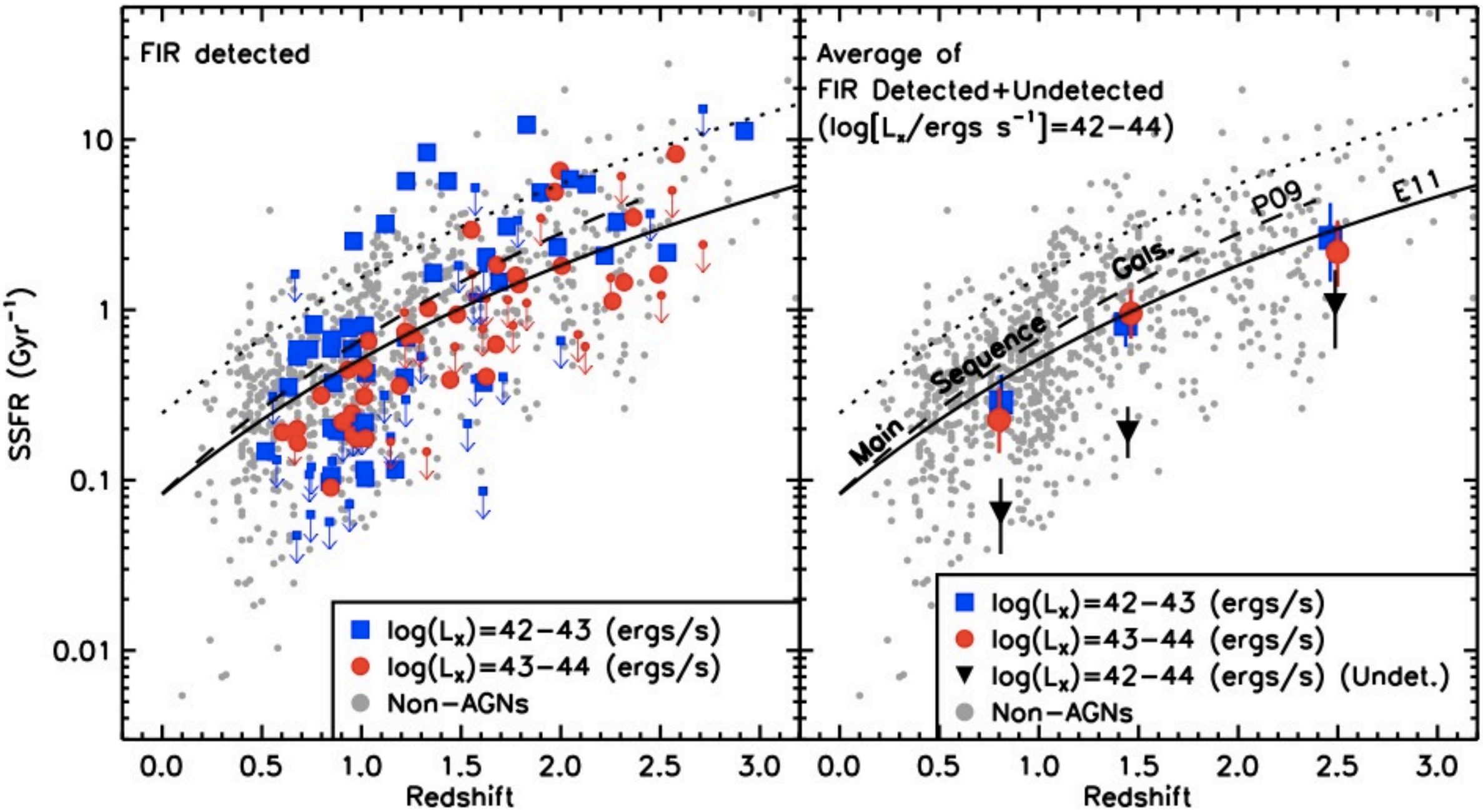
Possibly high Eddington ratios!

Very similar morphological mix as at z~0 - but *caveat emptor*!

Similar to Cisternas+11 at z<1
Now also Allevato+11(clustering), Mullaney+11 and Dale Kocevski's talk



Typical AGN host galaxies at z ~ 2



Mullaney+11 - SSFR of X-ray selected AGN indistinguishable from galaxies

No link to mergers? Not so fast...
Mid-IR-selected CT-quasars at z>2 are a mess

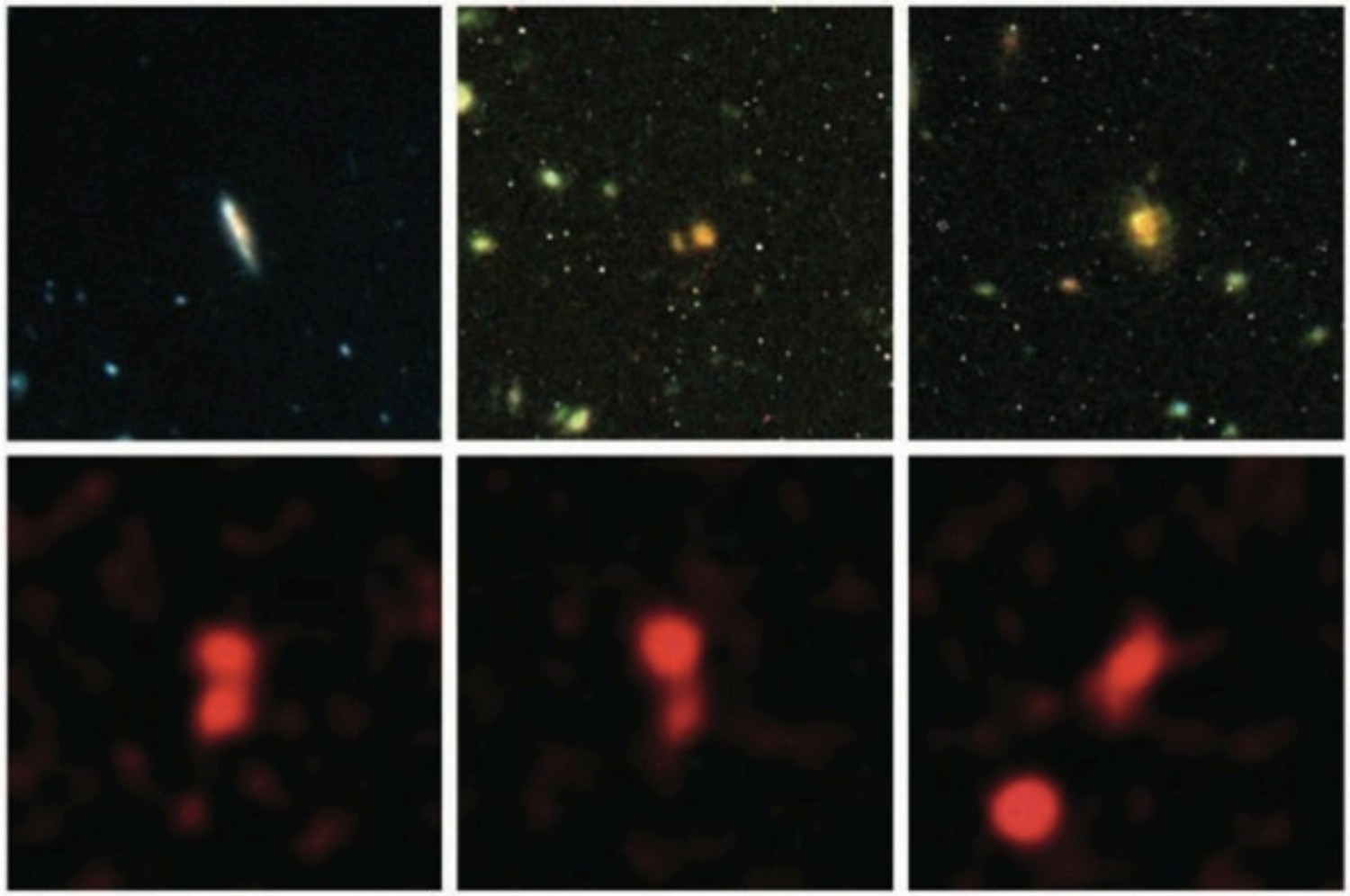


Fig. 3. Rest-frame optical images of six mid-IR–selected heavily obscured quasars at $z \sim 2$ in the Extended Chandra Deep Field-South region. Top images were obtained with the HST-WFC3 (Wide Field Camera 3) camera using the *Y*, *J*, and *H* observations of the Ultra-Deep (left) and GOODS fields. The bottom images were made by combining data in the *R*, *J*, and *K* bands obtained from ground-based telescopes, hence with a spatial resolution about 10 times as large as that of the HST images. All images are 15 arc sec by 15 arc sec.

Treister+10, *Science*

Implications/Questions/Worries

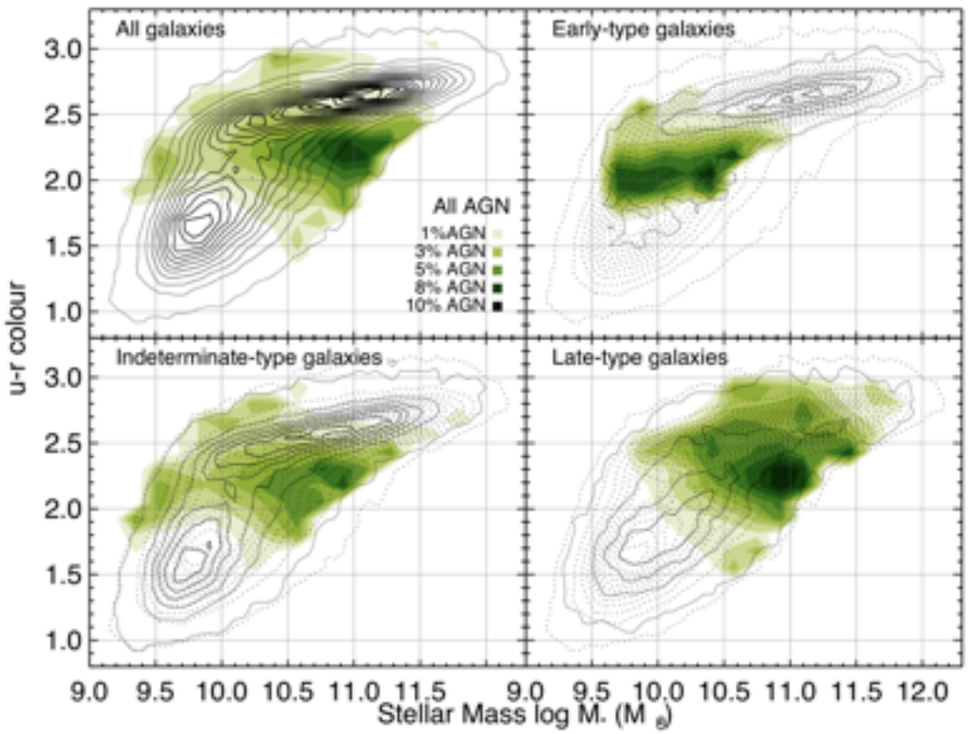
Do `secular' modes seem to dominate cosmic black hole growth?

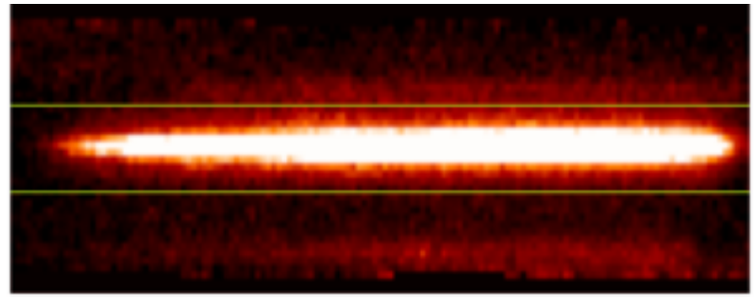
Is there a luminosity (read: black hole mass) dependence? Do mergers only trigger "quasar" events while normal black holes grow in disk galaxies?

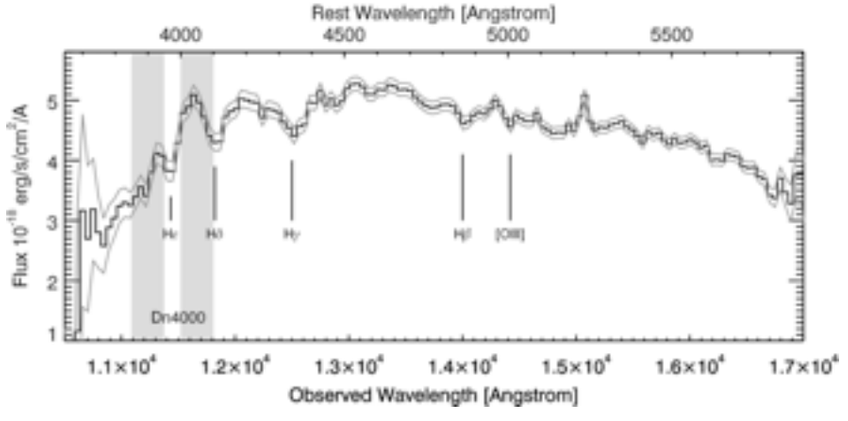
If so, quo vadis, M-sigma?

Are the z~0 early-types just `downsized' quasar? If so, what kind of clues do they hold?

Key next step: accurate SFHs for z~2 AGN host galaxies!

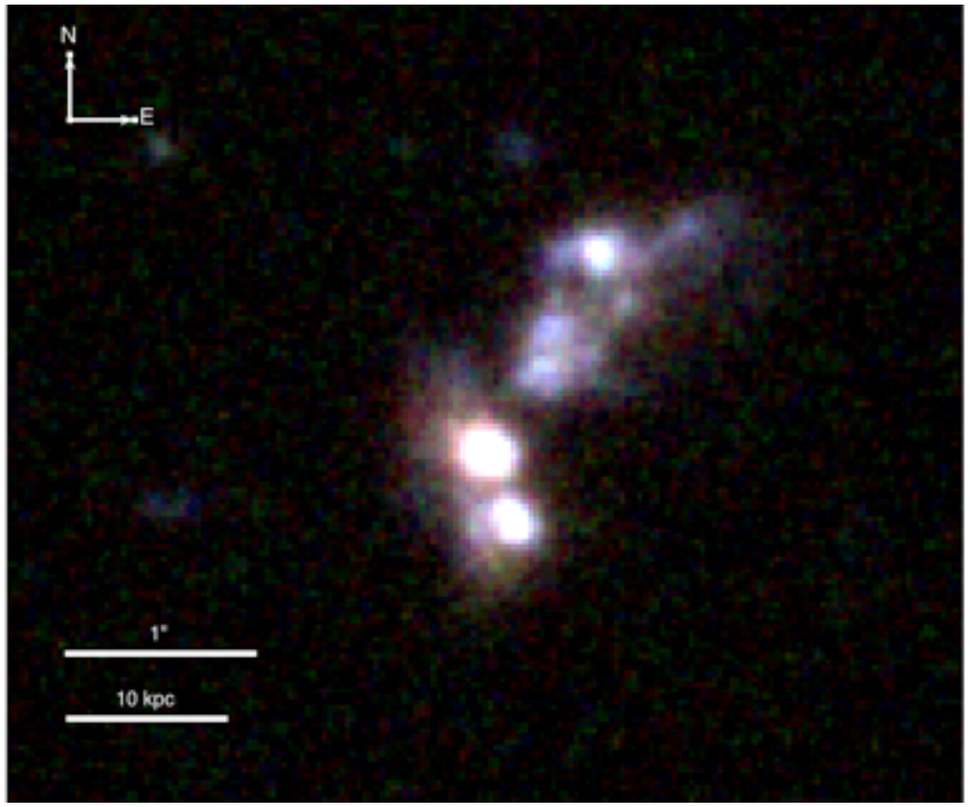






First glimpse of seed black holes?

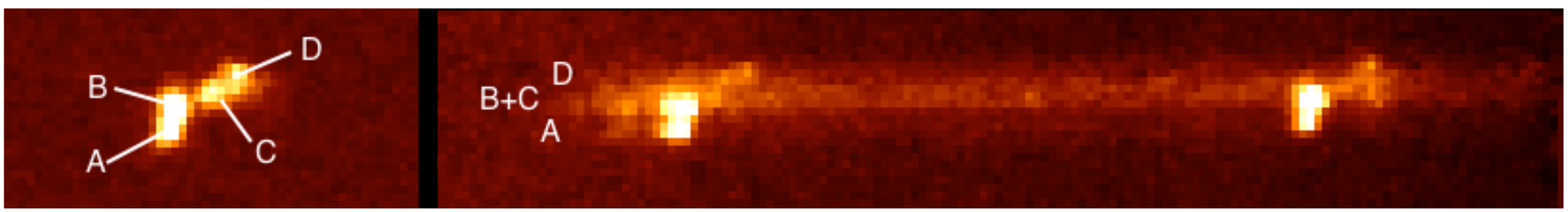
HST WFC3/IR grism - spatially resolved spectroscopy at z~1.3



Could be a merger?

Clumpy galaxies, gas-rich disks - secular growth...

See talks by:
Forster-Schreiber, Genzel, Combes & many others



Schawinski+11, submitted

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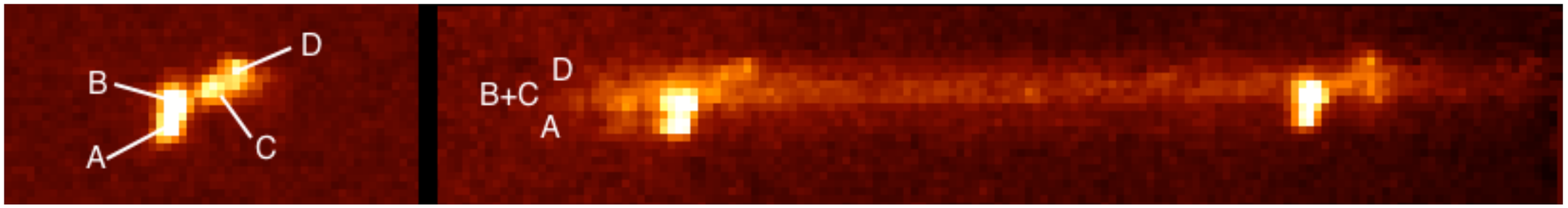
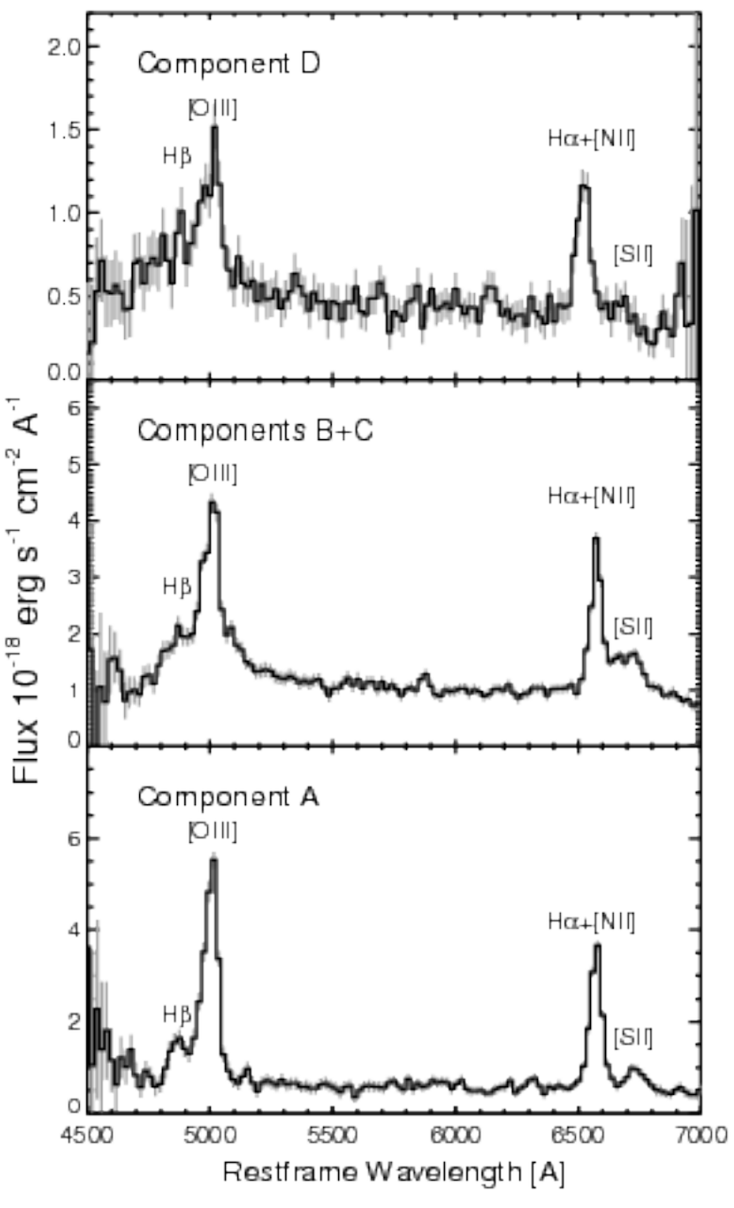
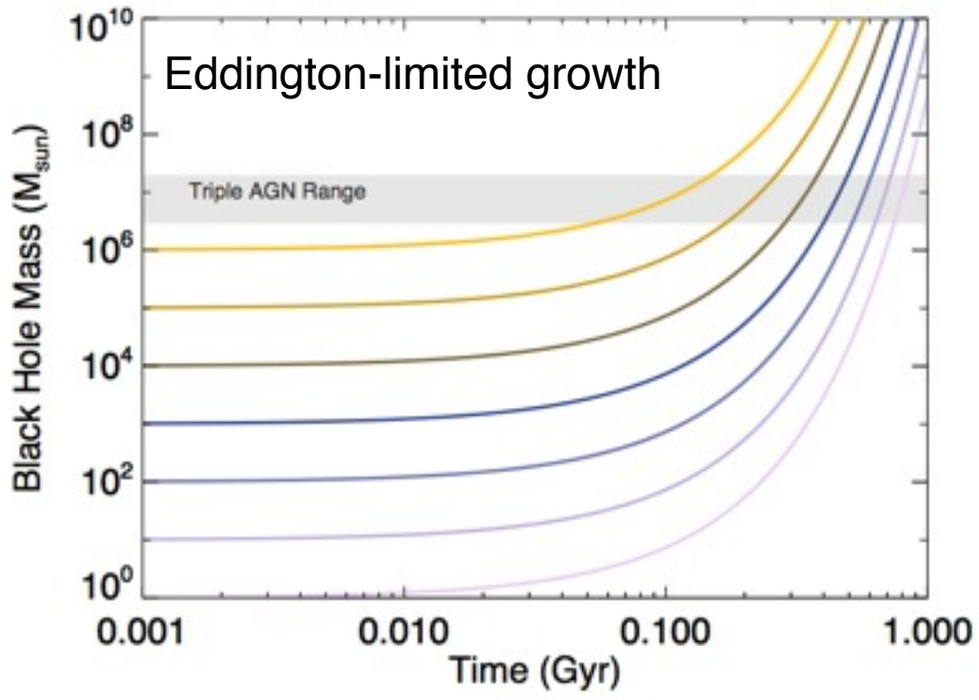






Location at the center of clump and rapid growth (that is, recent birth?) makes this plausible site for seed formation.

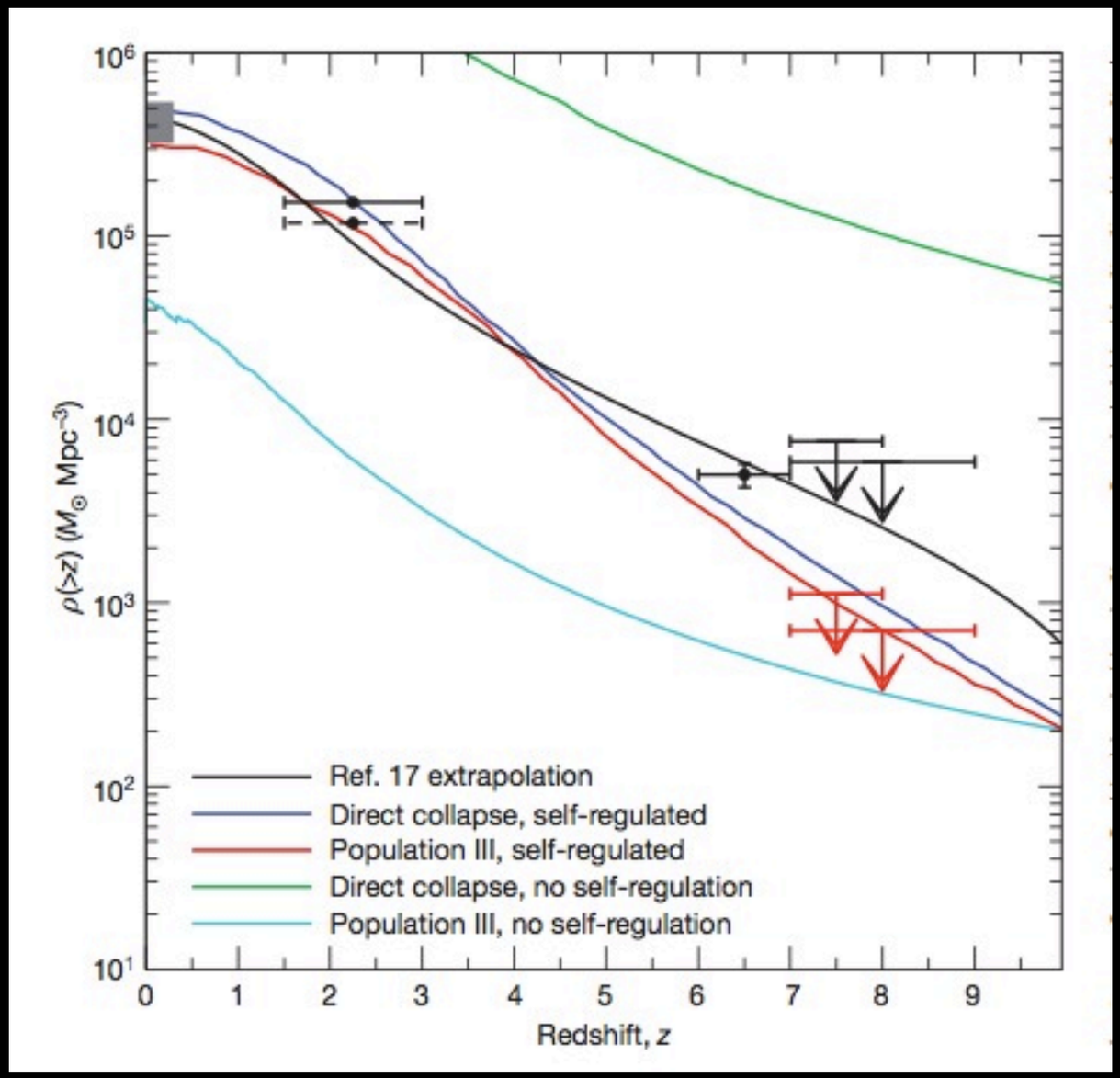
Models - direct collapse (Lodato & Natarajan 06, 07), runaway collapse of stellar mass BHs (Devecchi & Volonteri 09), etc.

Also - implications for central SMBH/bulge formation: Elmegreen +07,08, Bournaud+07,11, Noguchi+99, Immeli+04, Genzel+08, etc.

Talk by Abel

Clues to co-evolution from first black holes at z>6
Chandra stack of z~6,7 and 8 dropouts

Treister, Schawinski, Volonteri, Natarajan & Gawiser, 2011, Nature



Models without `self-regulation' fail - link between galaxy and black hole goes back to z~8!?

Treister, Schawinski, Volonteri, Natarajan & Gawiser, 2011, Nature

Summary

Secular growth is important both at z~0 and z~2

Multiple modes (mergers/spheroids vs. disks) obvious at z~0, perhaps also z~2 (large multi-lambda samples needed to see!)

Seed black holes may continue to be built in star-forming galaxies and yield clues to seed formation models

Self-regulation/co-evolution may go back to first black holes and first galaxies at z~8