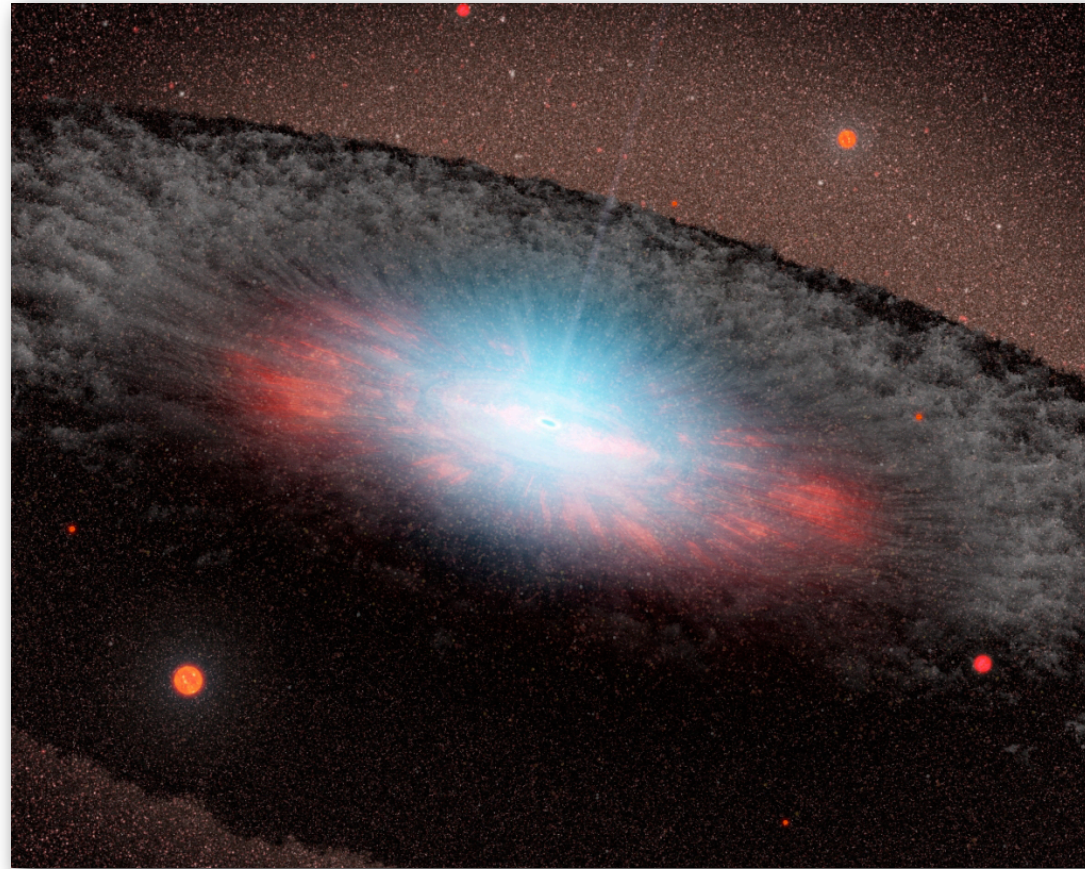


Black Hole Growth and its Connection to Host Galaxy Evolution



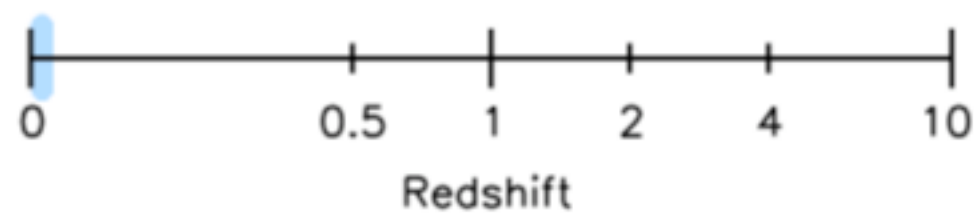
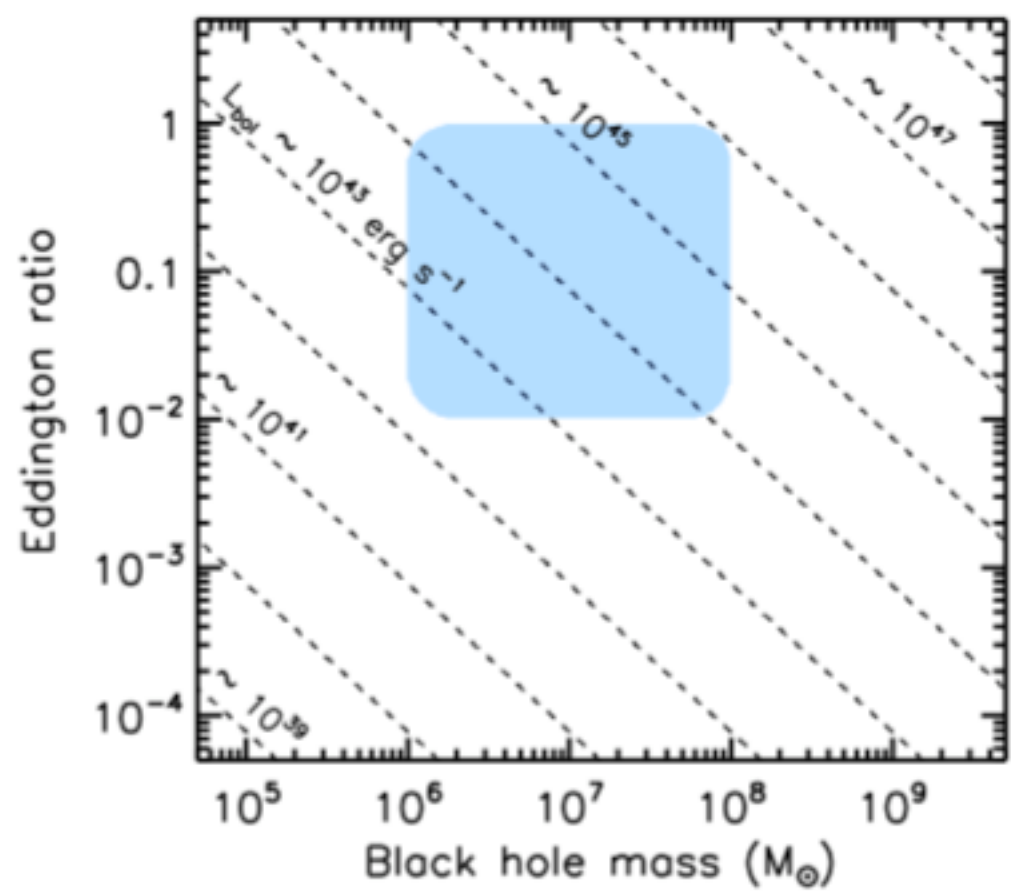
Kevin Schawinski

Einstein Fellow

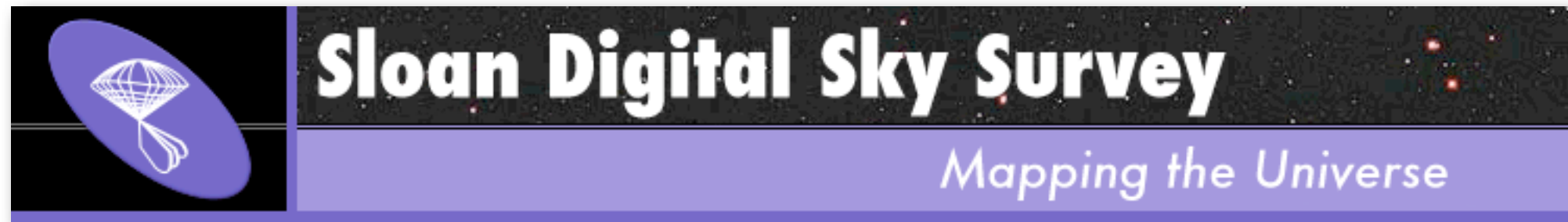
Yale Center for Astronomy & Astrophysics

Department of Physics

Yale University



Data



SDSS DR7 - photometry & spectra for galaxies & AGN



Galaxy Zoo 1 & 2 - detailed visual morphologies for
~1 million SDSS galaxies classified over 70 times *each*
Over 300,000 members of the public involved

Data now fully public: data.galaxyzoo.org

GALAXY ZOO.org

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The Science

How to Take Part

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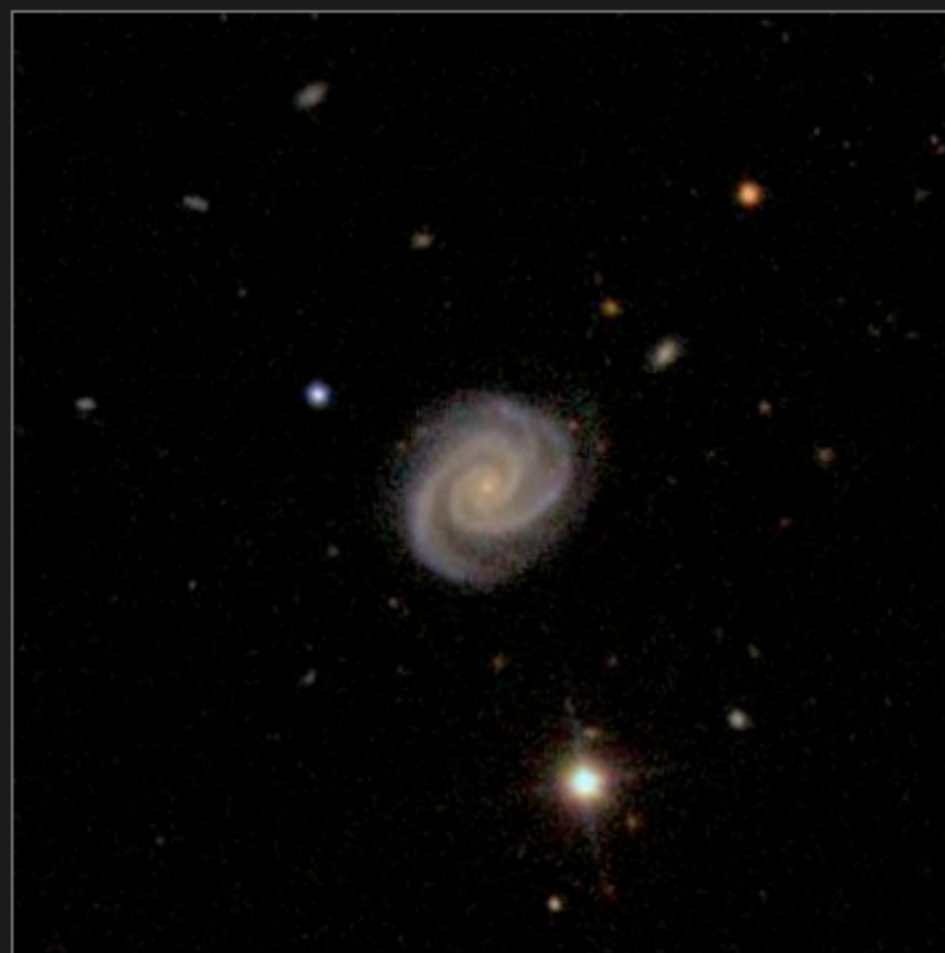
Galaxy Tutorial

Galaxy Analysis

Galaxy Zoo - Thank
You

Galaxy Analysis

Welcome to Galaxy Zoo's view of the Universe. If you're here you should already have seen the [Tutorial](#), but feel free to go and remind yourself. There's no need to agonise for too long over any one image, just make your best guess in each case.



Galaxy Ref:

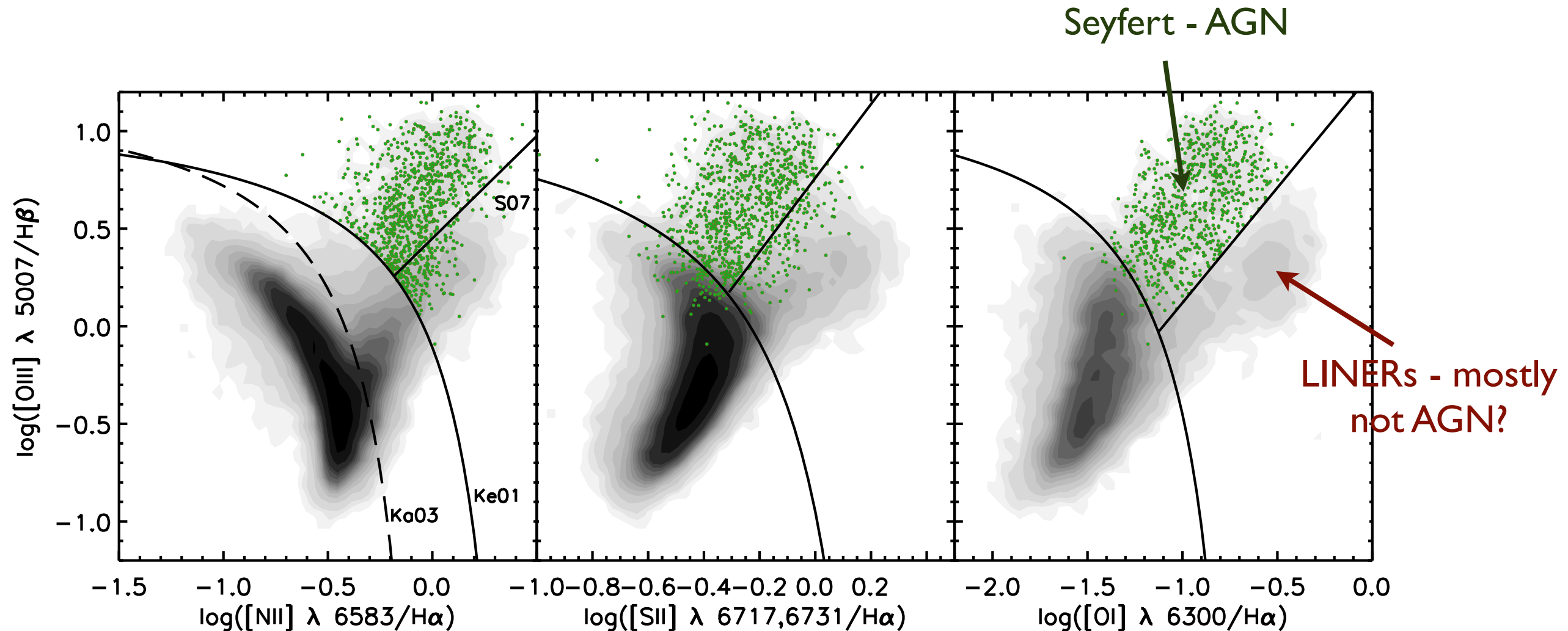
587741816777277606

Choose the Galaxy Profile
by clicking the buttons
below



■ Show Grid Overlay on the next Image

AGN Selection via emission line diagnostics

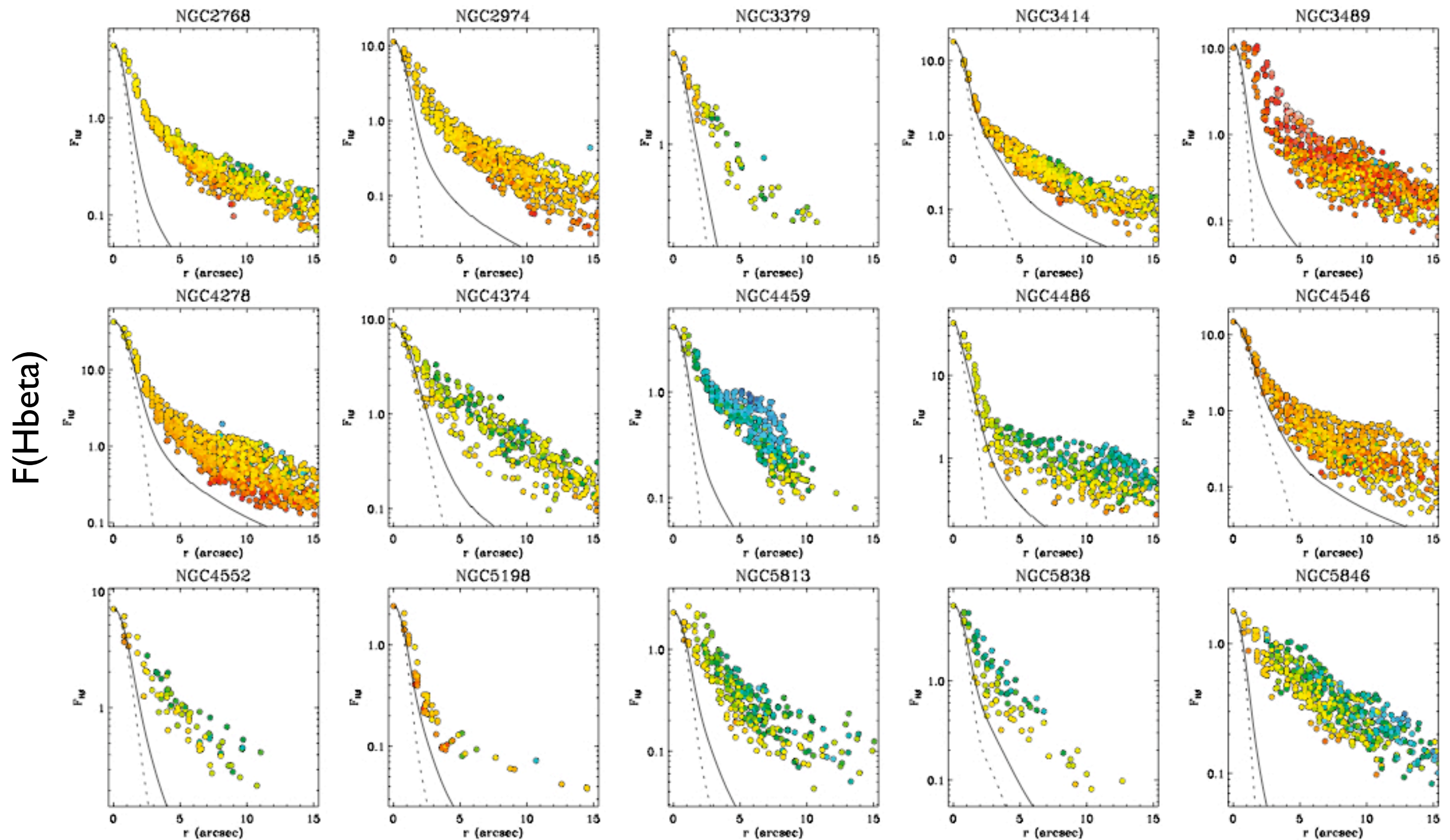


Emission line ratio diagrams (Baldwin, Philips & Terlevich 1981, Veilleux & Osterbrock 1987, Kewley+01,+06, Kauffmann+03, Schawinski+07)

Questions: completeness? bias? nuclear obscuration vs. host galaxy dilution? could we be missing a substantial population?

LINER emission in SAURON early-type galaxies:

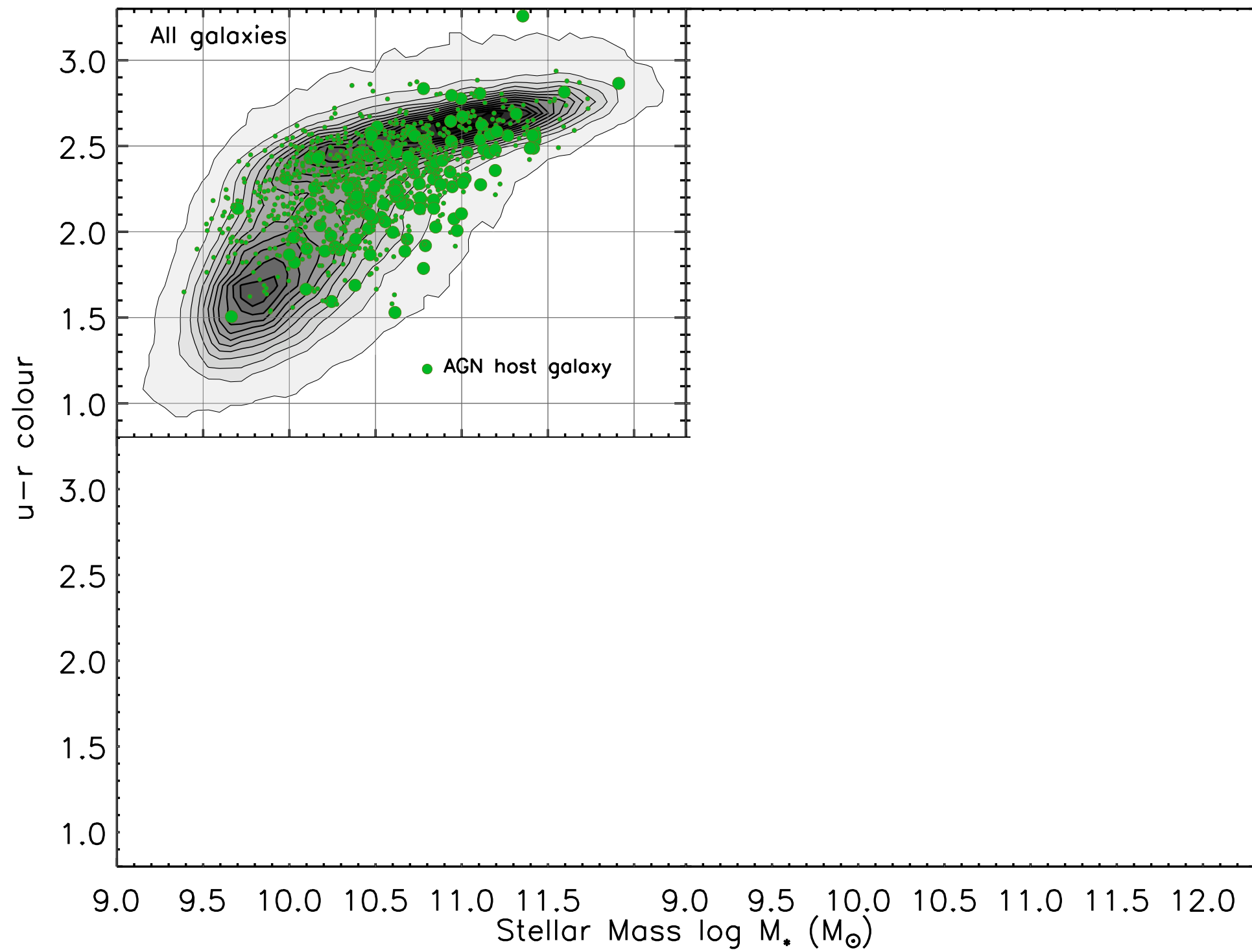
Caused by stellar source (pAGB stars?), not BH accretion



Radius (arcsec)

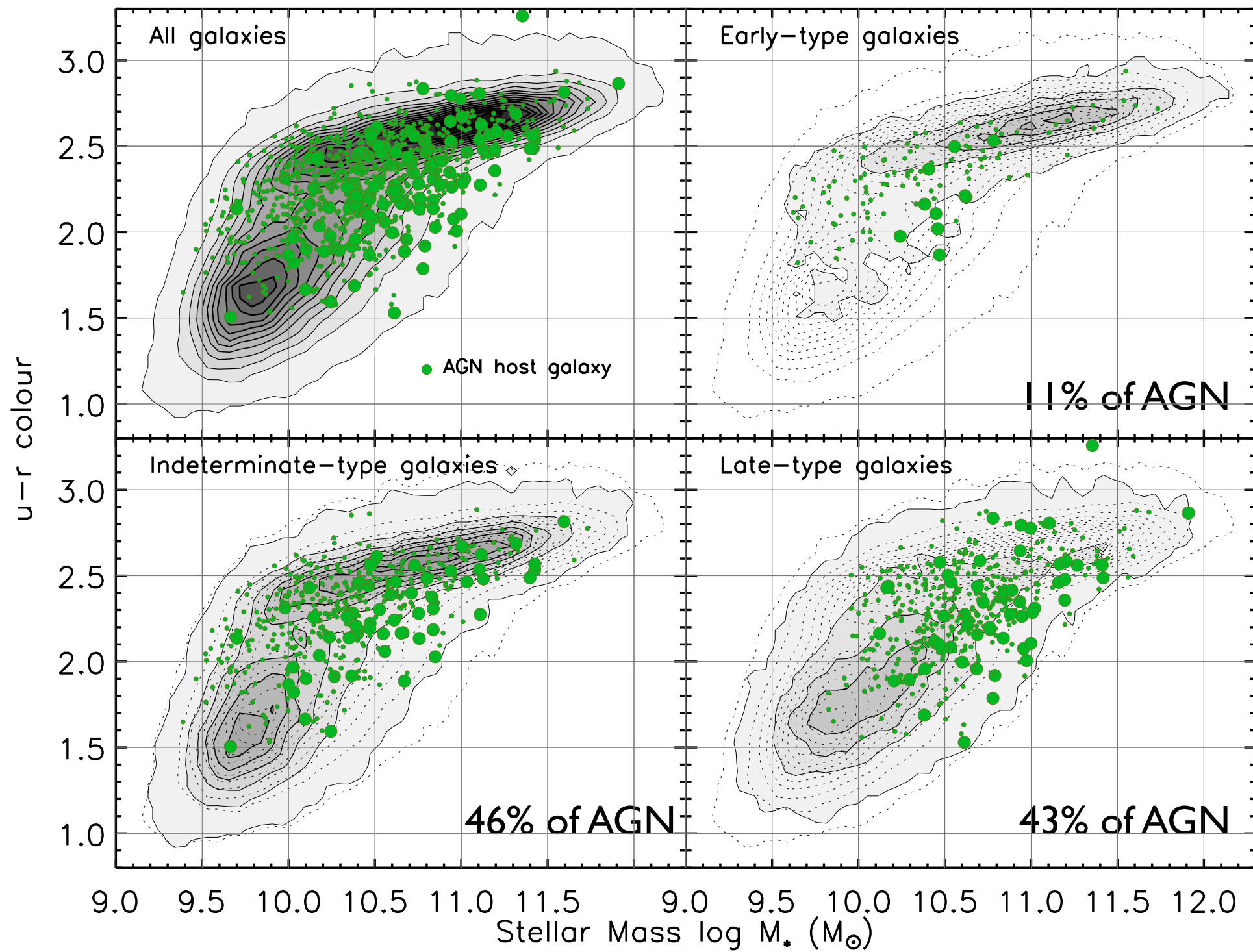
Sarzi, Shields, Schawinski & the SAURON team+10

AGN host galaxies split by morphology



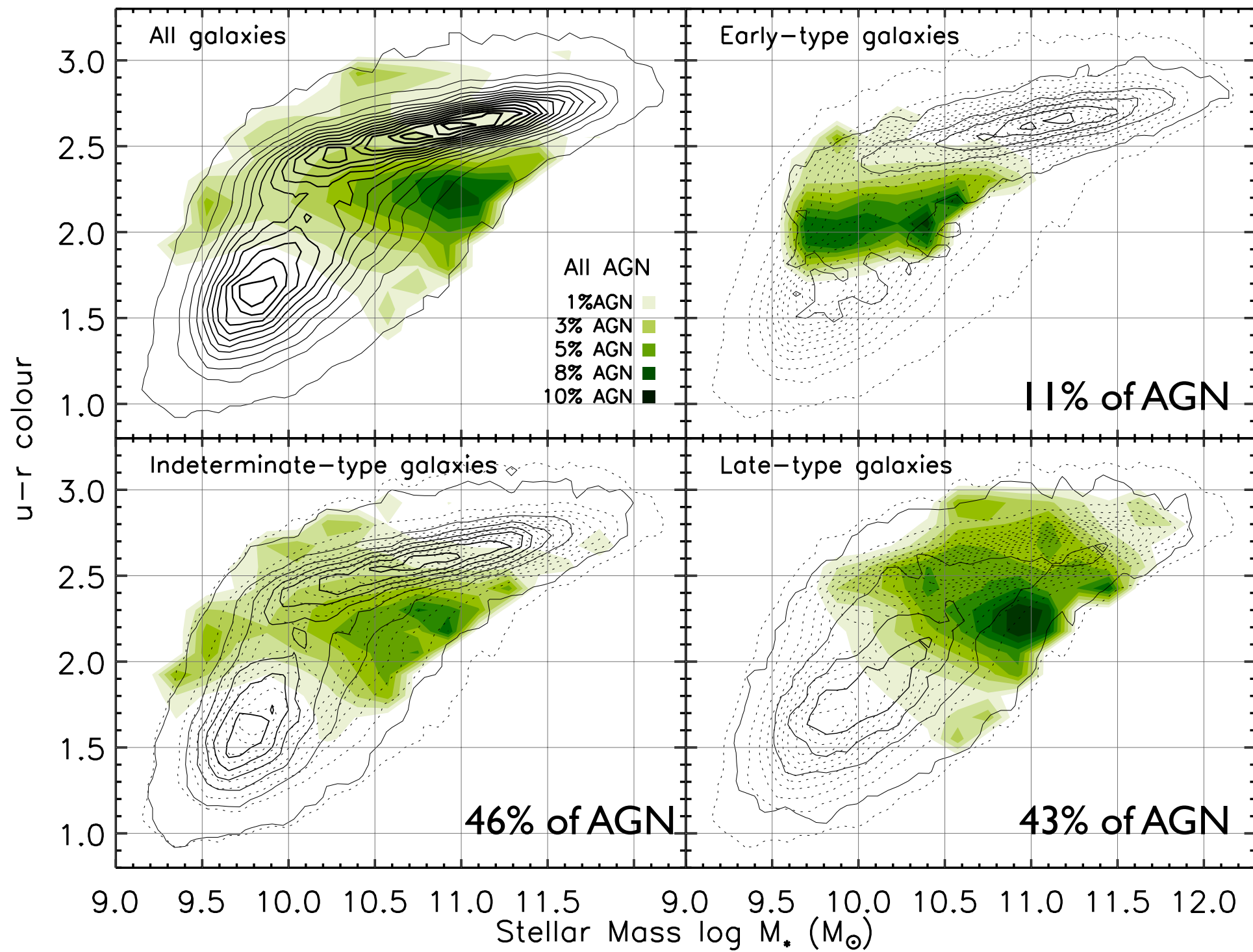
Schawinski+10a

AGN host galaxies split by morphology

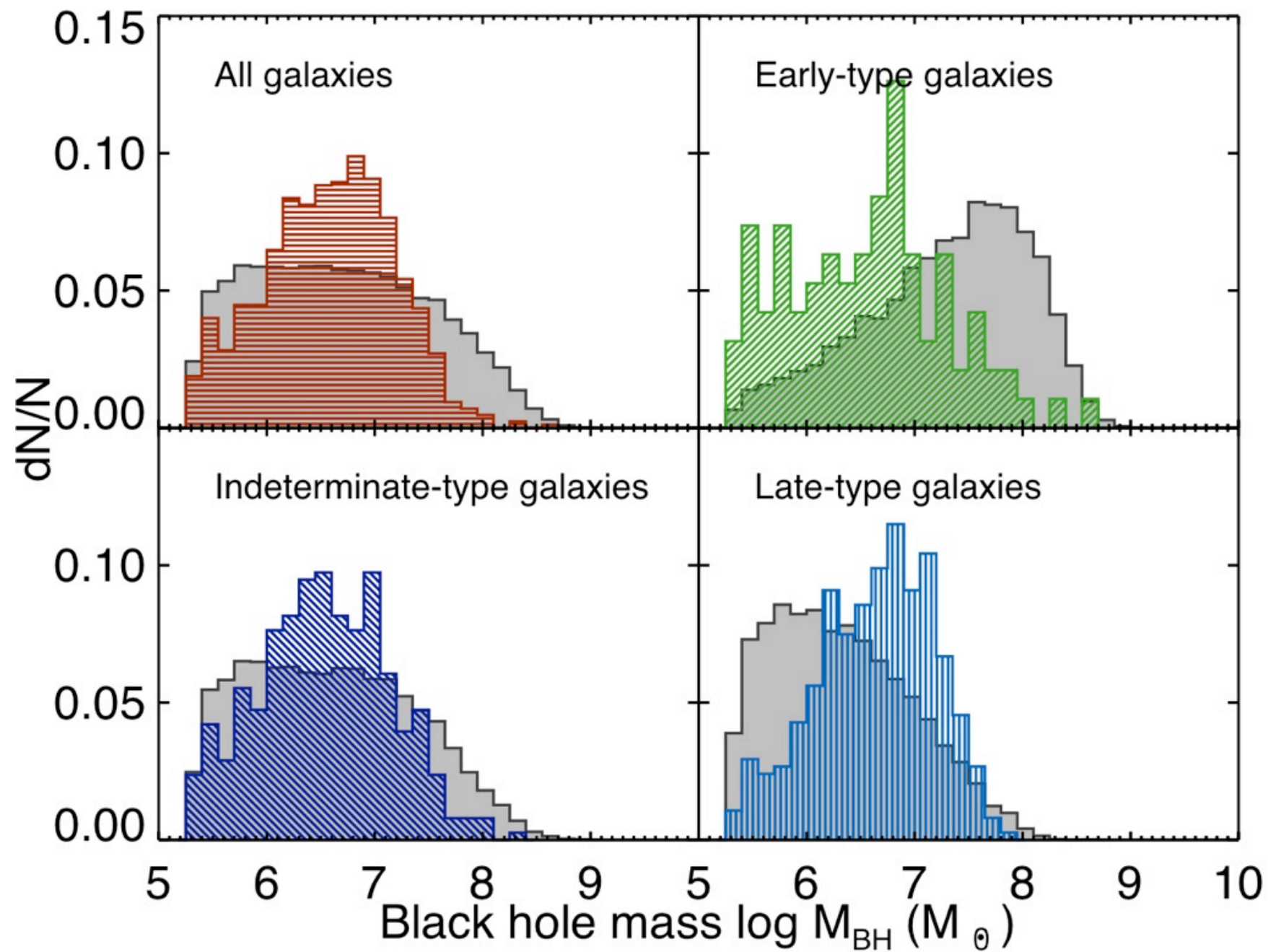


Schawinski+10a

AGN 'duty cycle' split by morphology

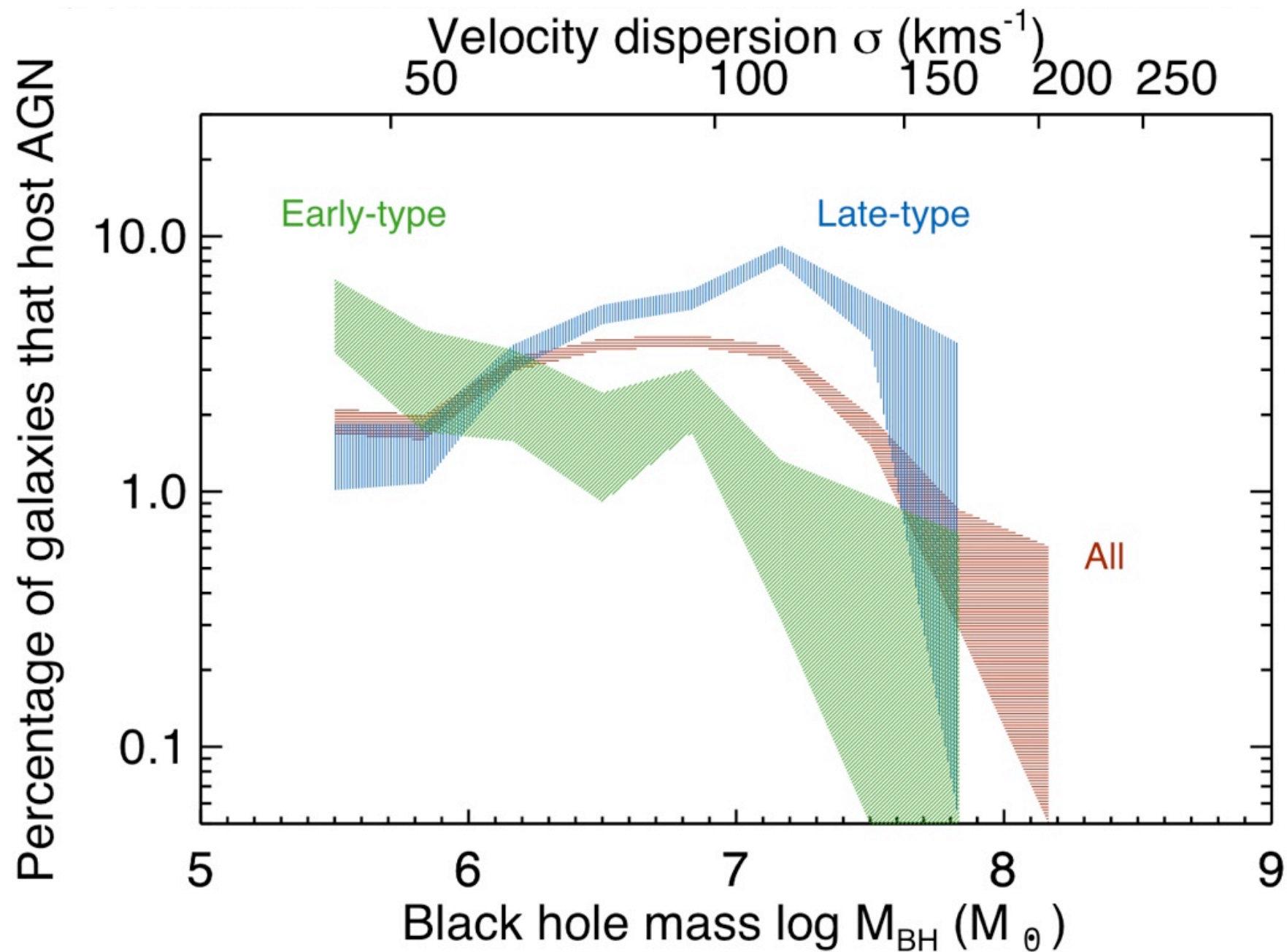


Which black holes are growing?



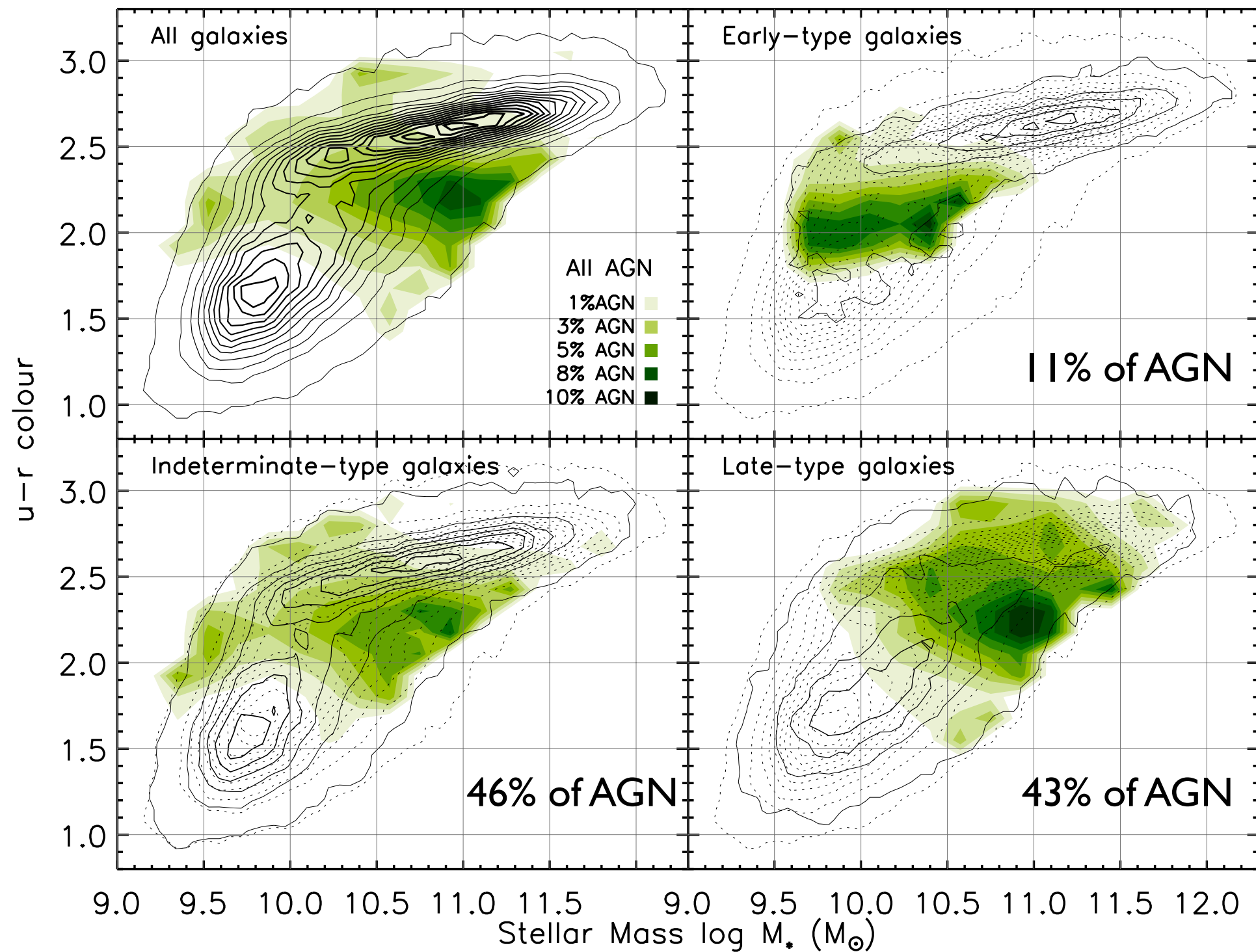
Schawinski+10a

Which black holes are growing?

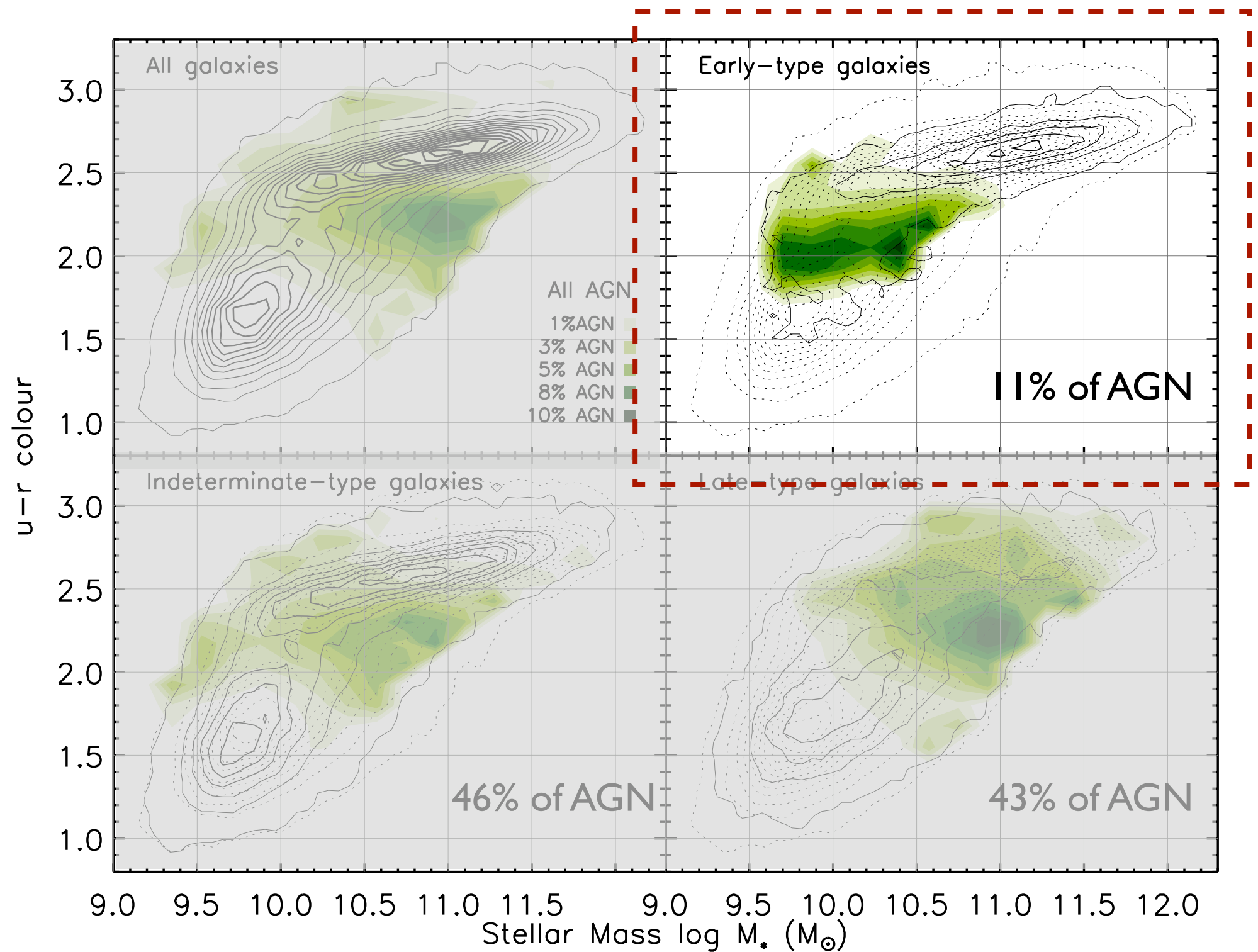


Schawinski+10a

Two modes of black hole growth in early- and late-type galaxies



Two modes of black hole growth in early- and late-type galaxies



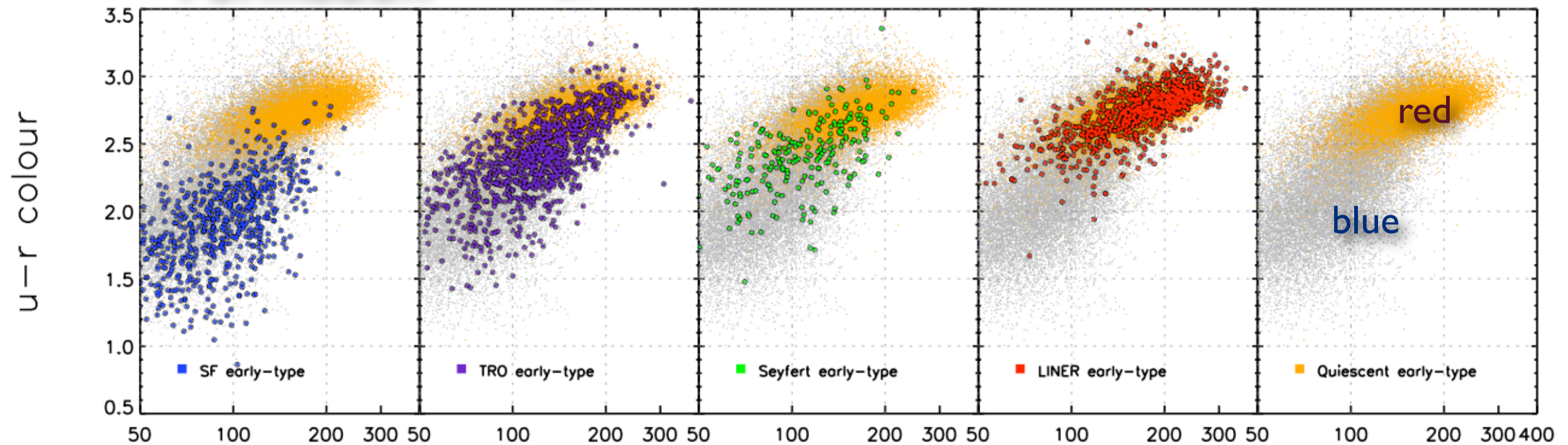
SDSS reveals an evolutionary sequence

Star
Formation

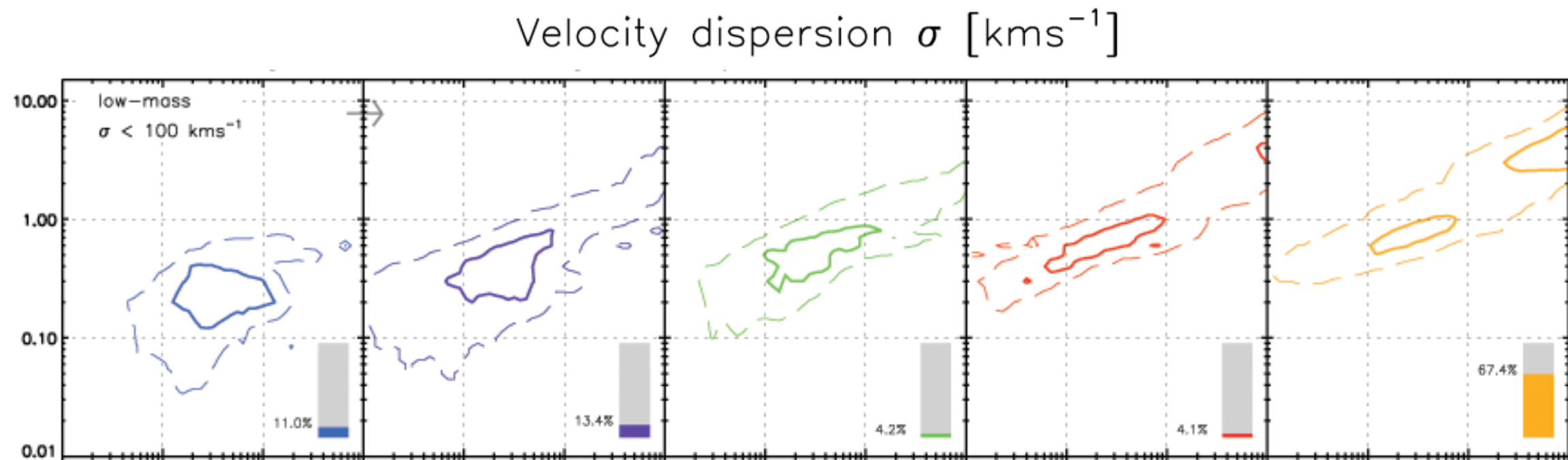
AGN
+SF

Seyfert
AGN

LINER



Age of most recent burst



Mass fraction formed in most recent burst

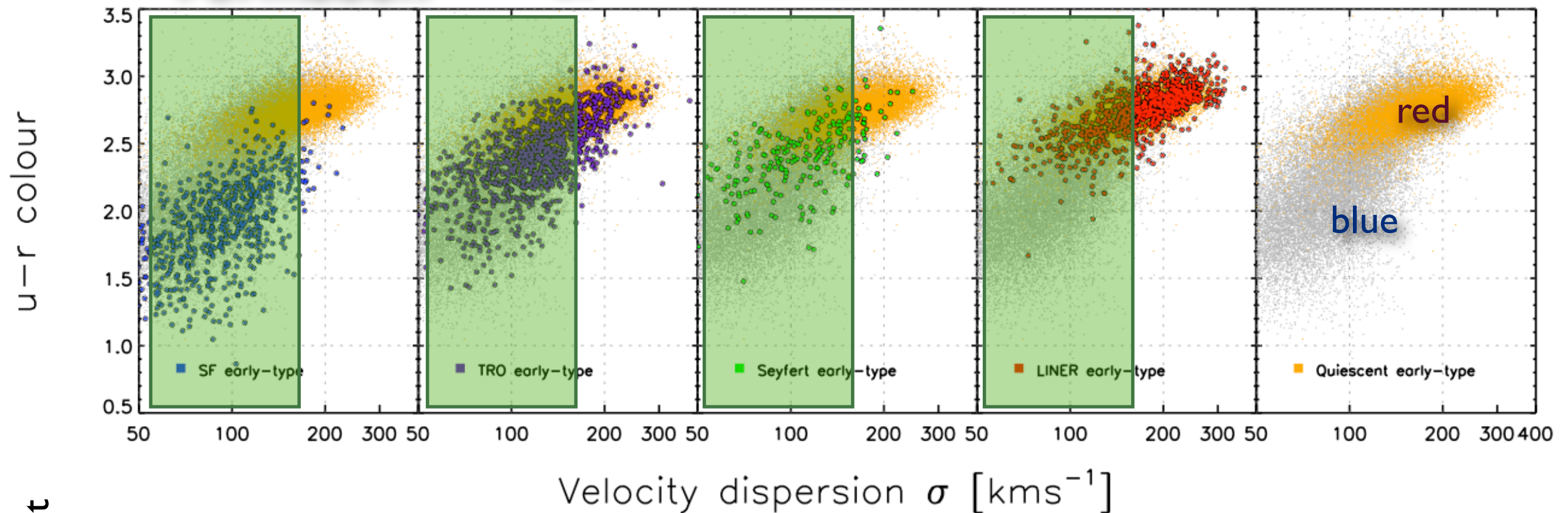
SDSS reveals an evolutionary sequence

Star
Formation

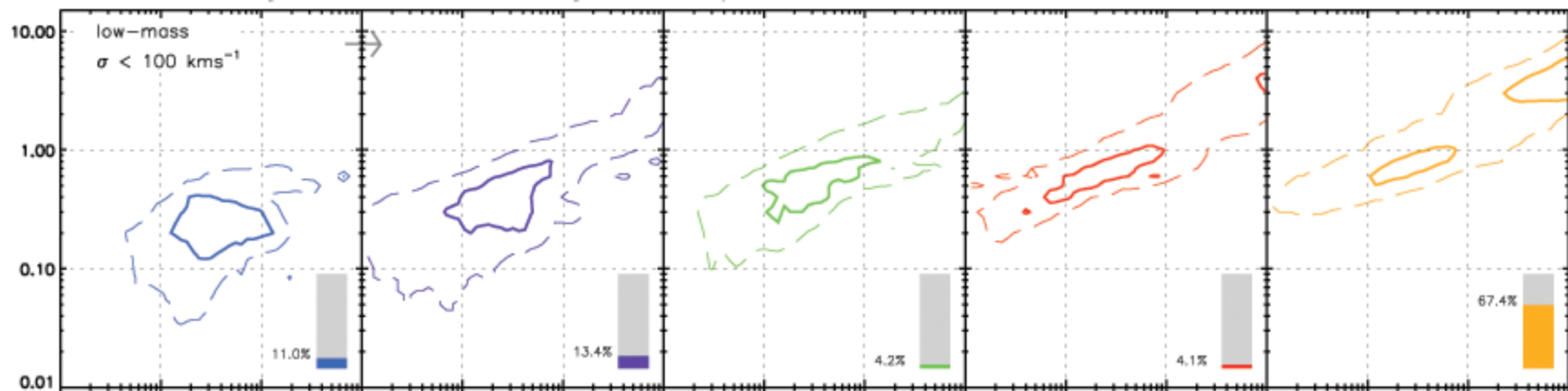
AGN
+SF

Seyfert
AGN

LINER



Age of most recent burst



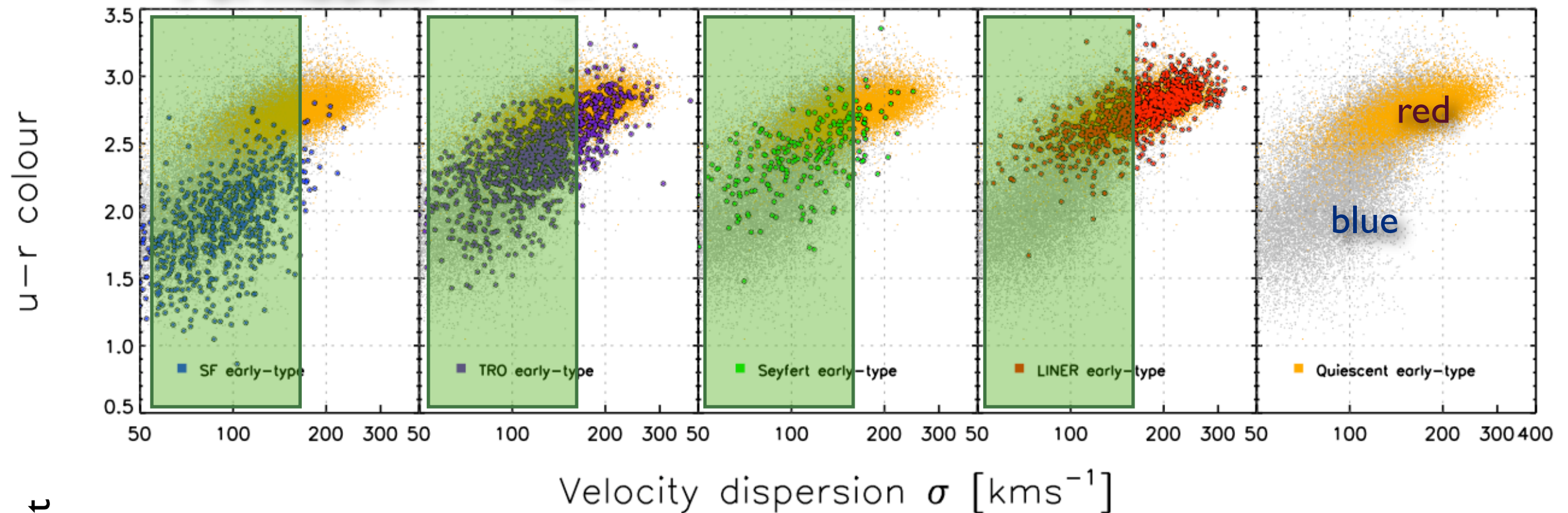
SDSS reveals an evolutionary sequence

Star
Formation

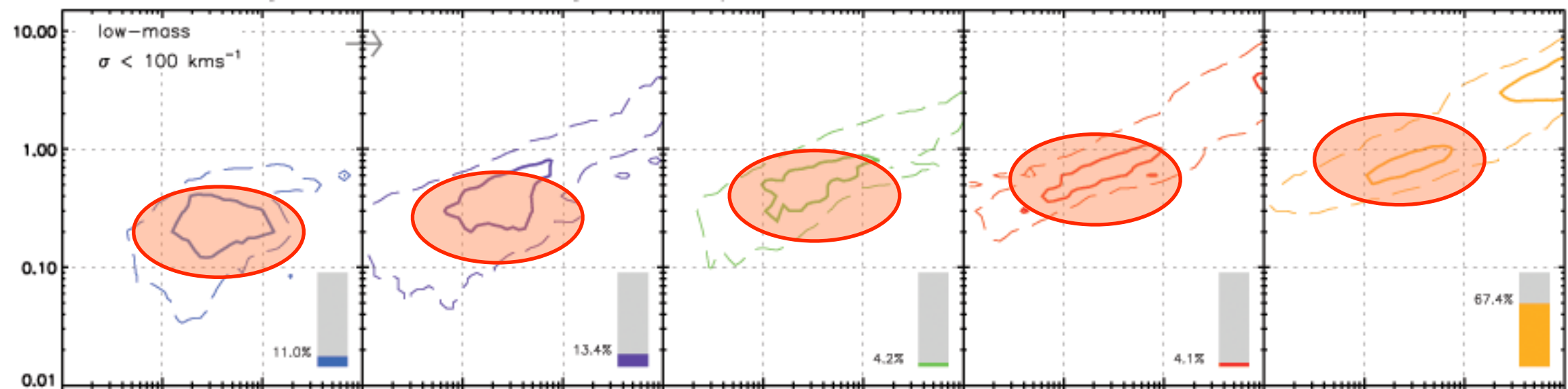
AGN
+SF

Seyfert
AGN

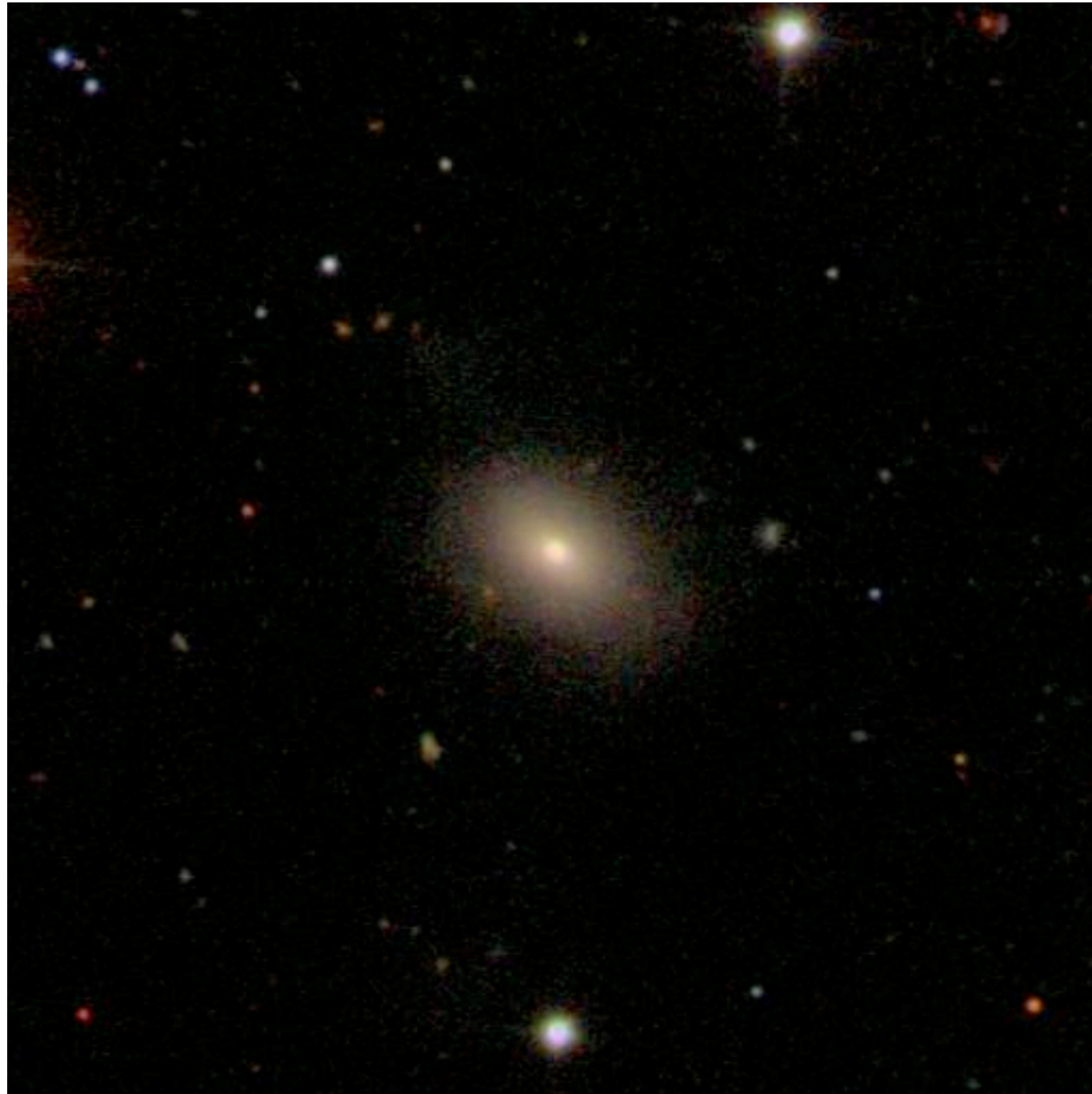
LINER



Age of most recent burst

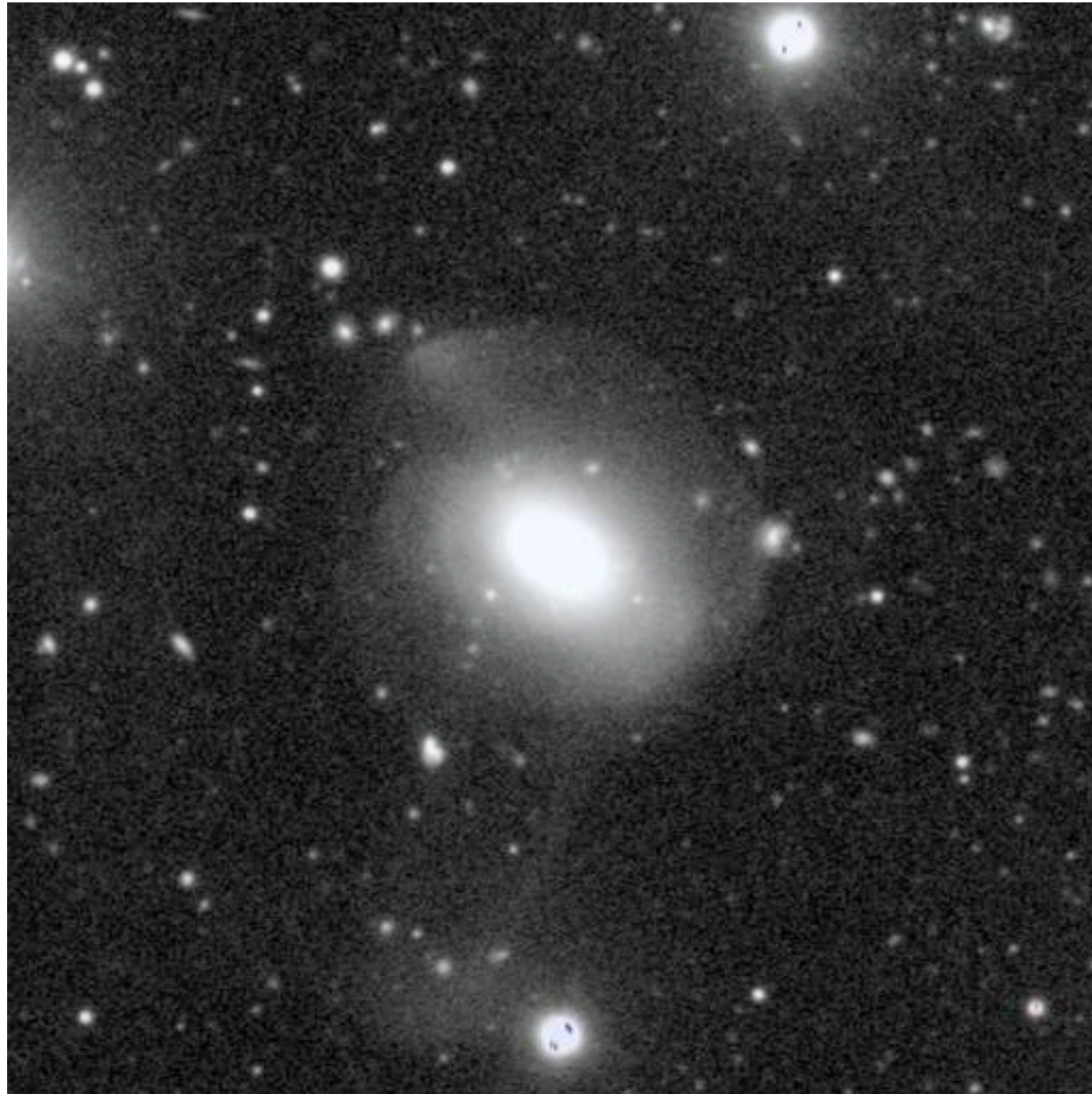


Mergers trigger the migration of low- mass early-type galaxies from the blue cloud to the red sequence



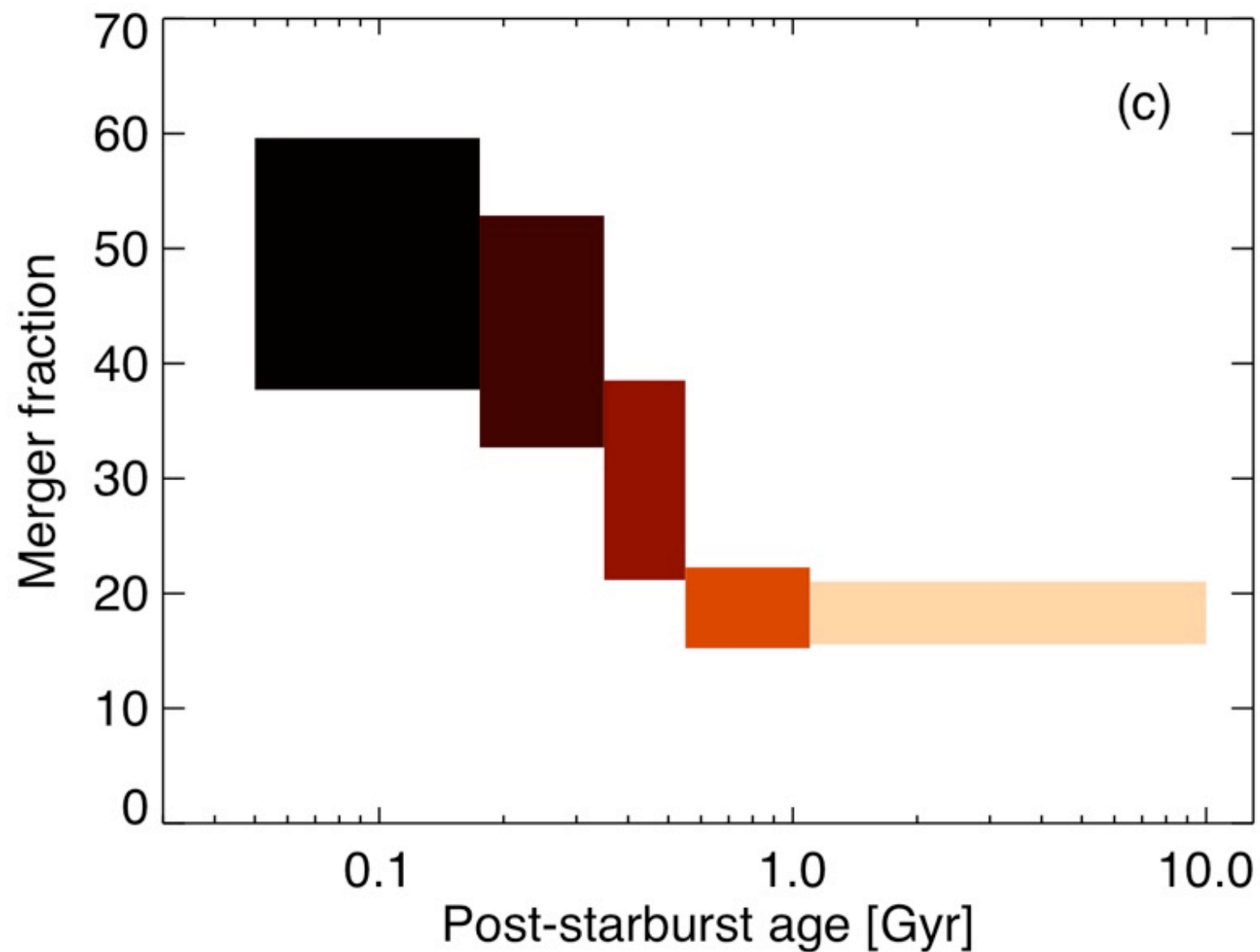
Schawinski+10b

Mergers trigger the migration of low- mass early-type galaxies from the blue cloud to the red sequence



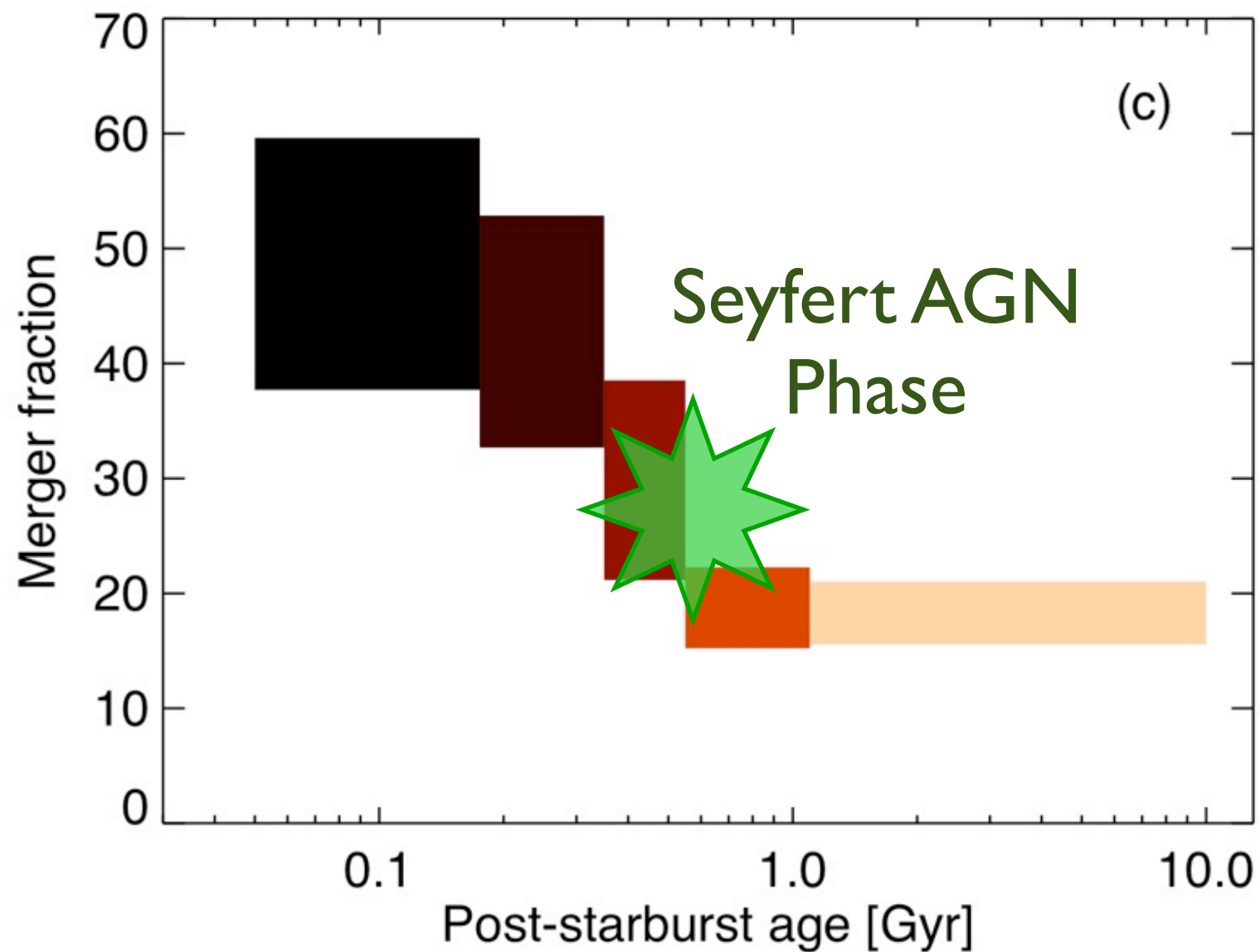
Schawinski+10b

Mergers trigger the migration of low-mass early-type galaxies from the blue cloud to the red sequence



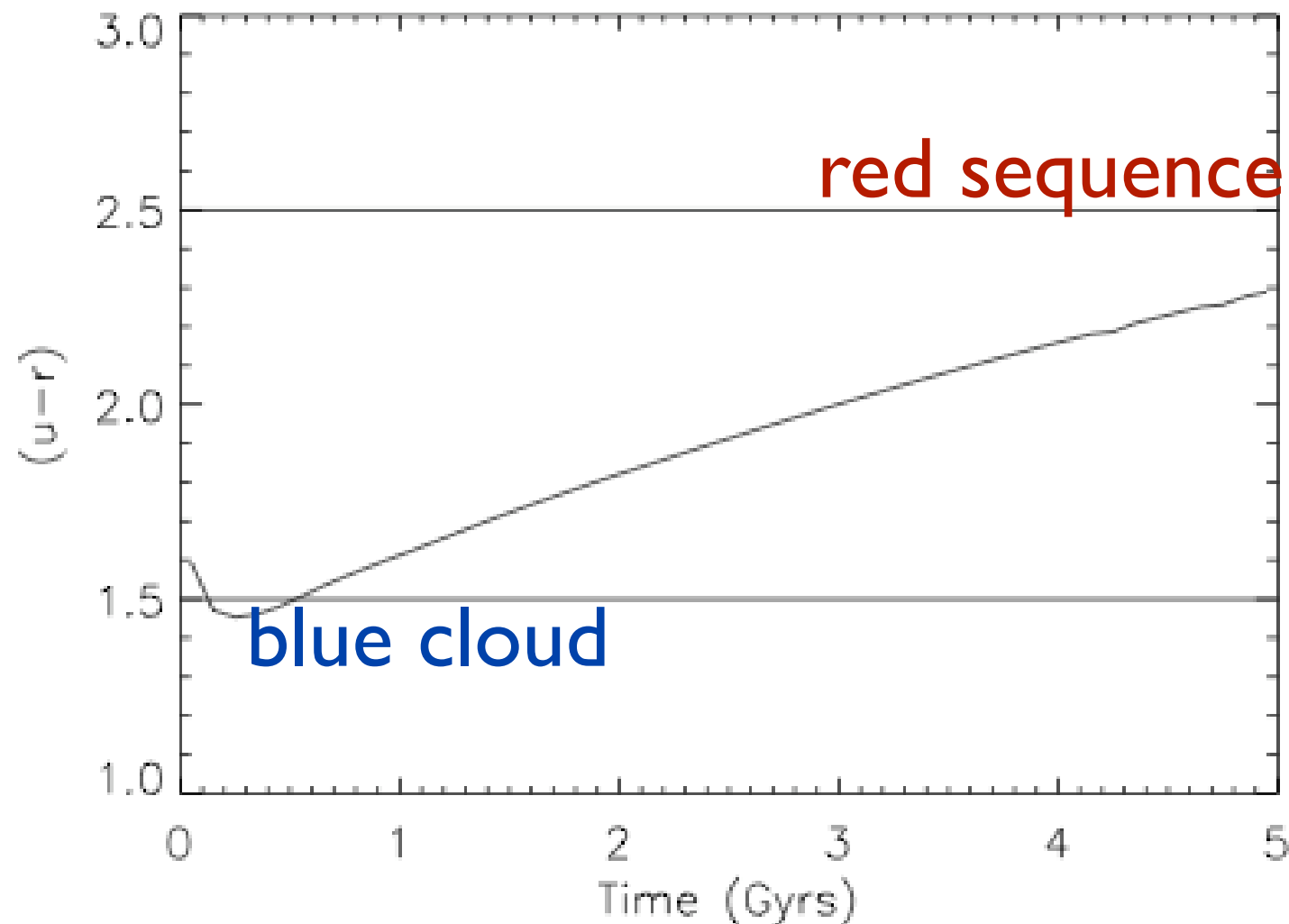
Schawinski+10b

Mergers trigger the migration of low-mass early-type galaxies from the blue cloud to the red sequence



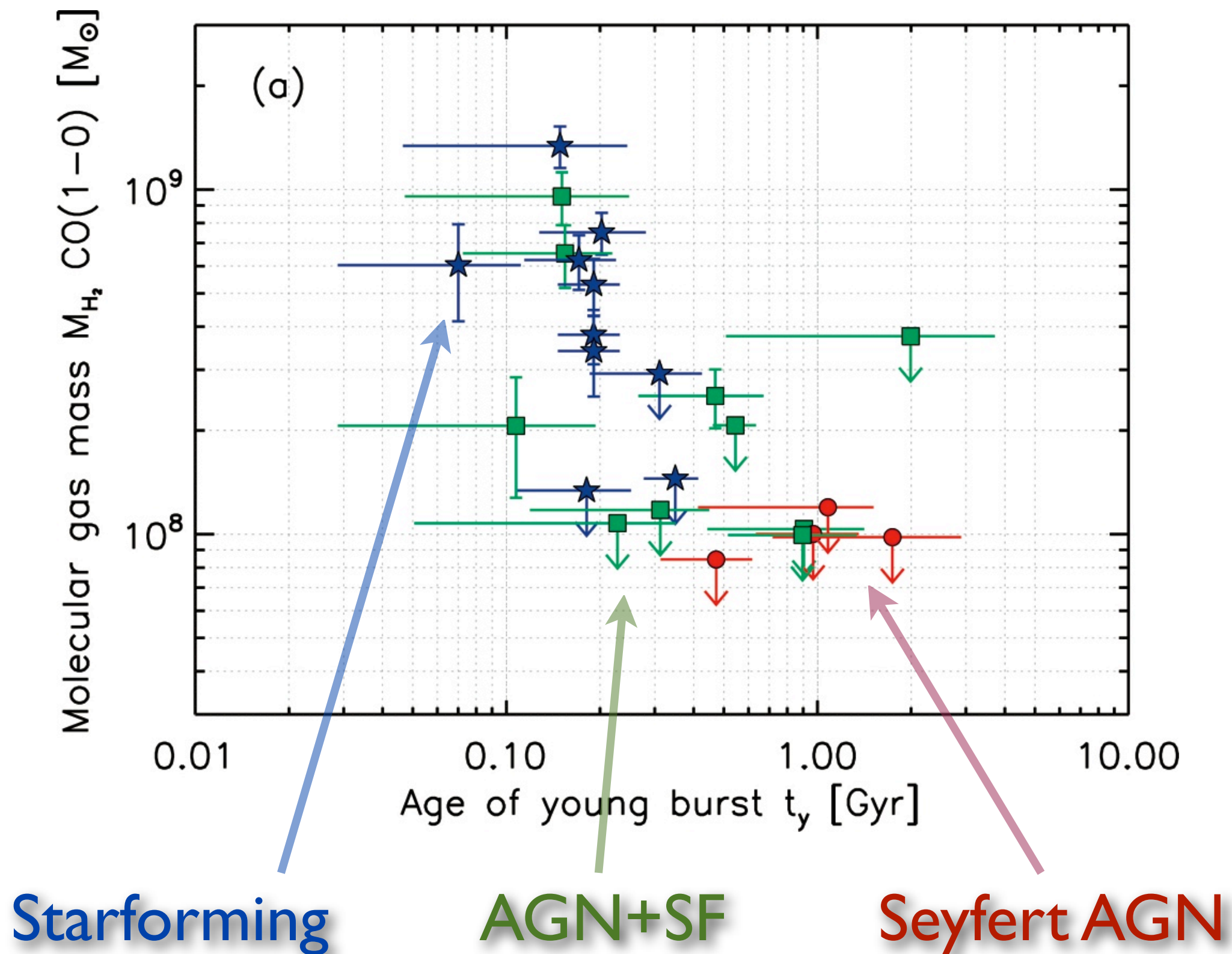
Deviations from the Schmidt Law: Clues to Feedback

$$\text{SFR} = \epsilon M_{\text{gas}}/t_{\text{dyn}}$$

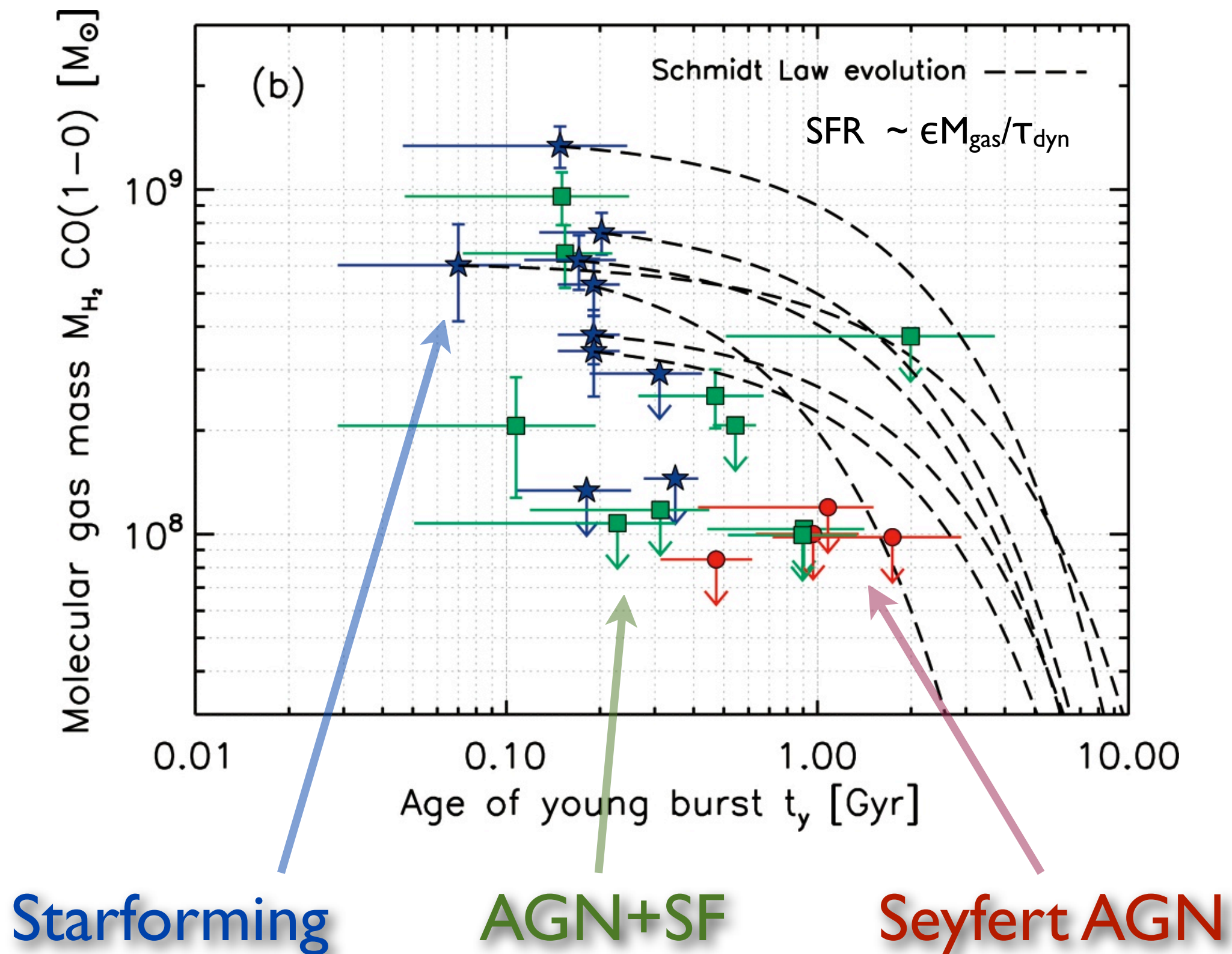


Evolution of an (early-type) galaxy following the Schmidt Law with typical dynamical time and gas fraction and a standard efficiency of 2%. No further outside gas accretion, no minor mergers and no mass loss allowed to replenish the gas reservoir.

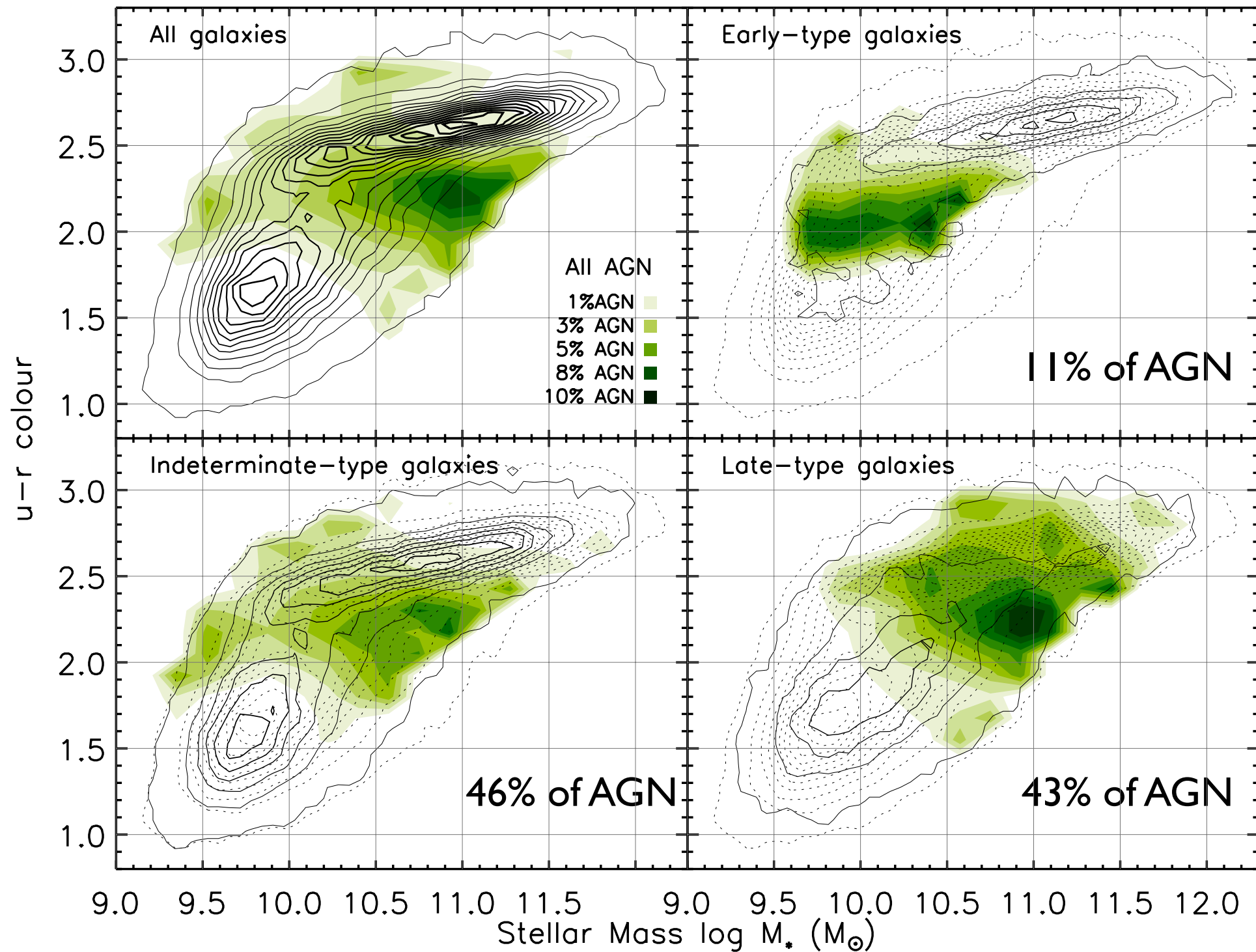
Deviations from the Schmidt Law: Clues to Feedback



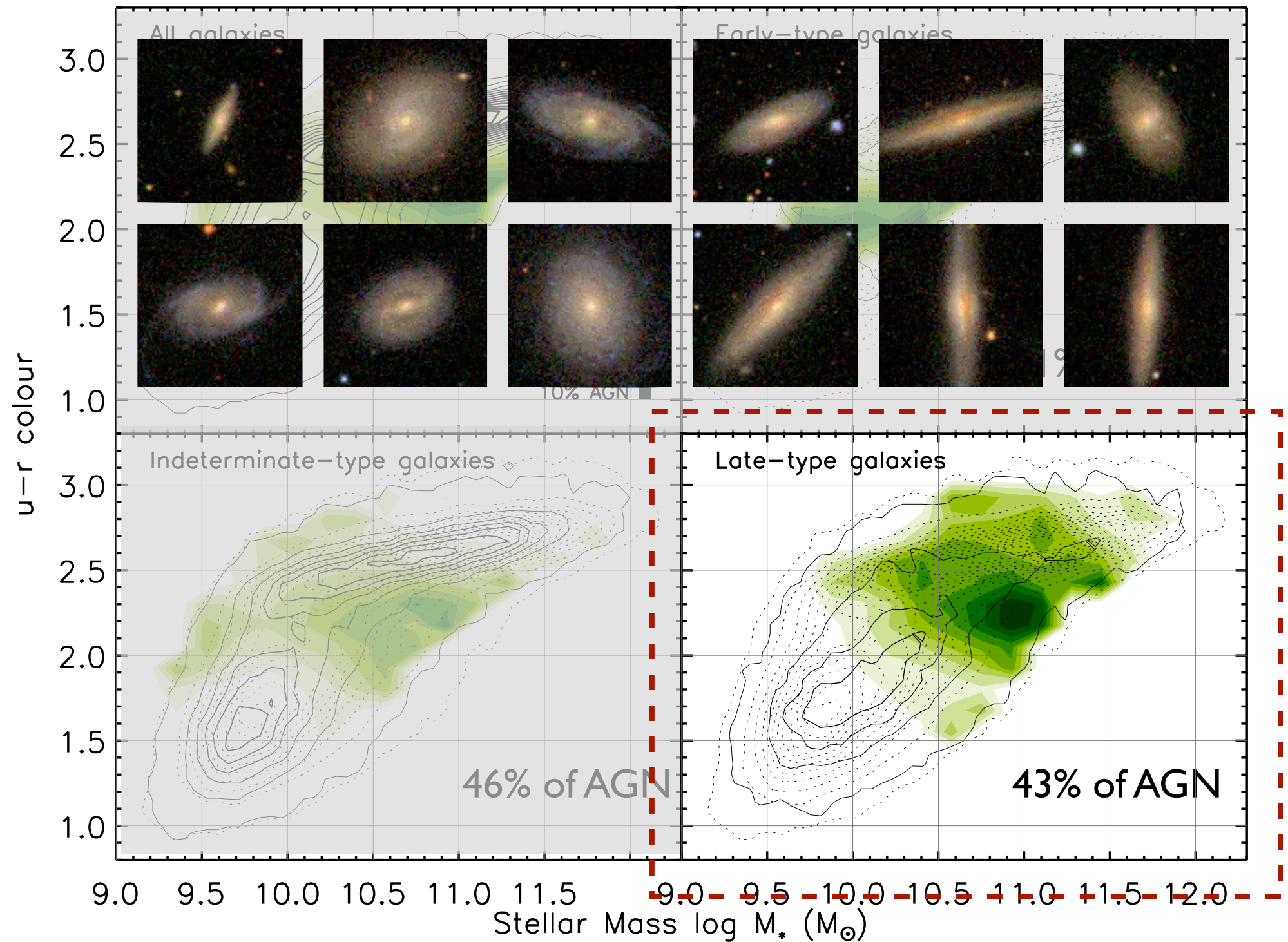
Deviations from the Schmidt Law: Clues to Feedback



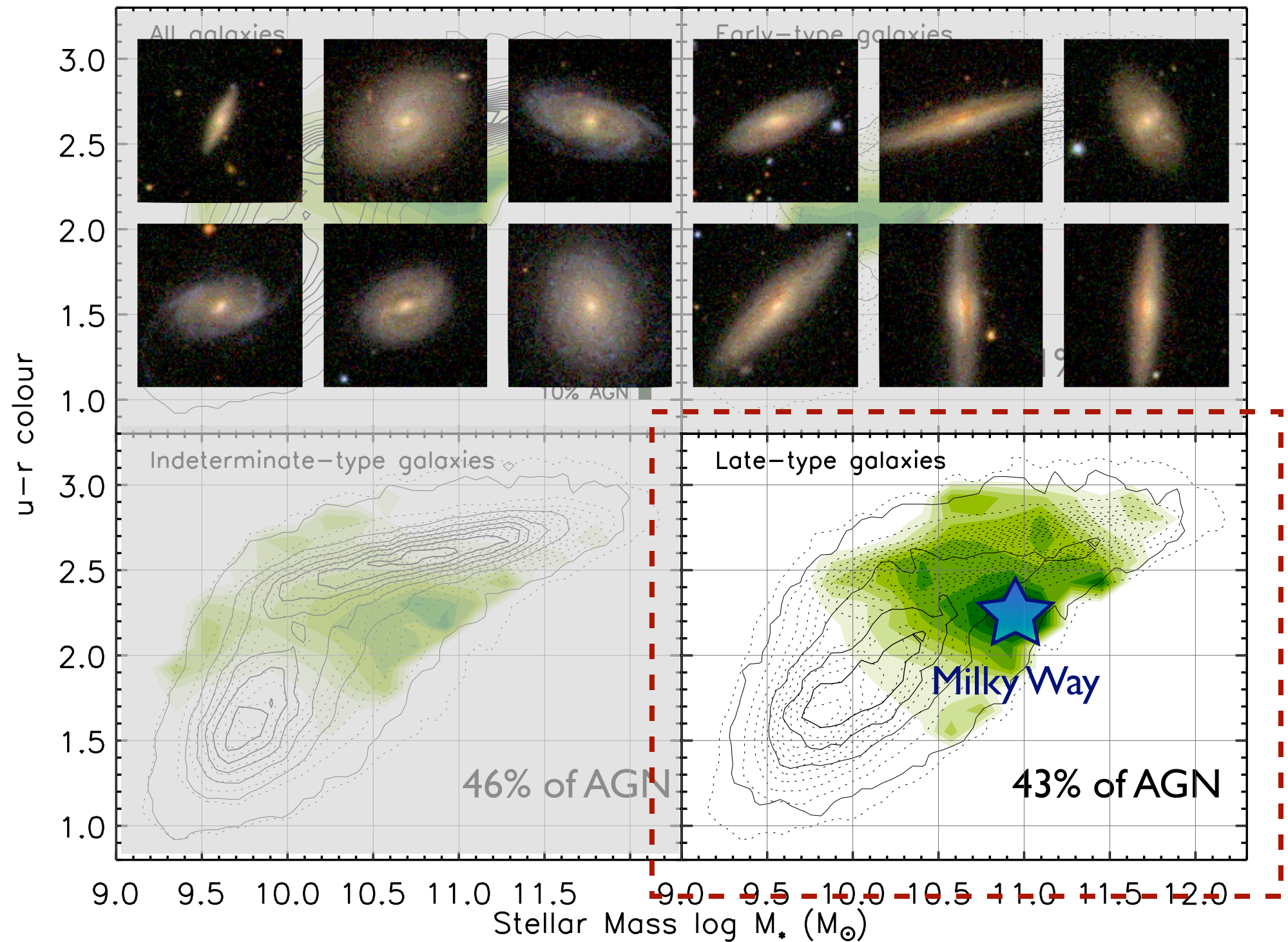
Two modes of black hole growth in early- and late-type galaxies



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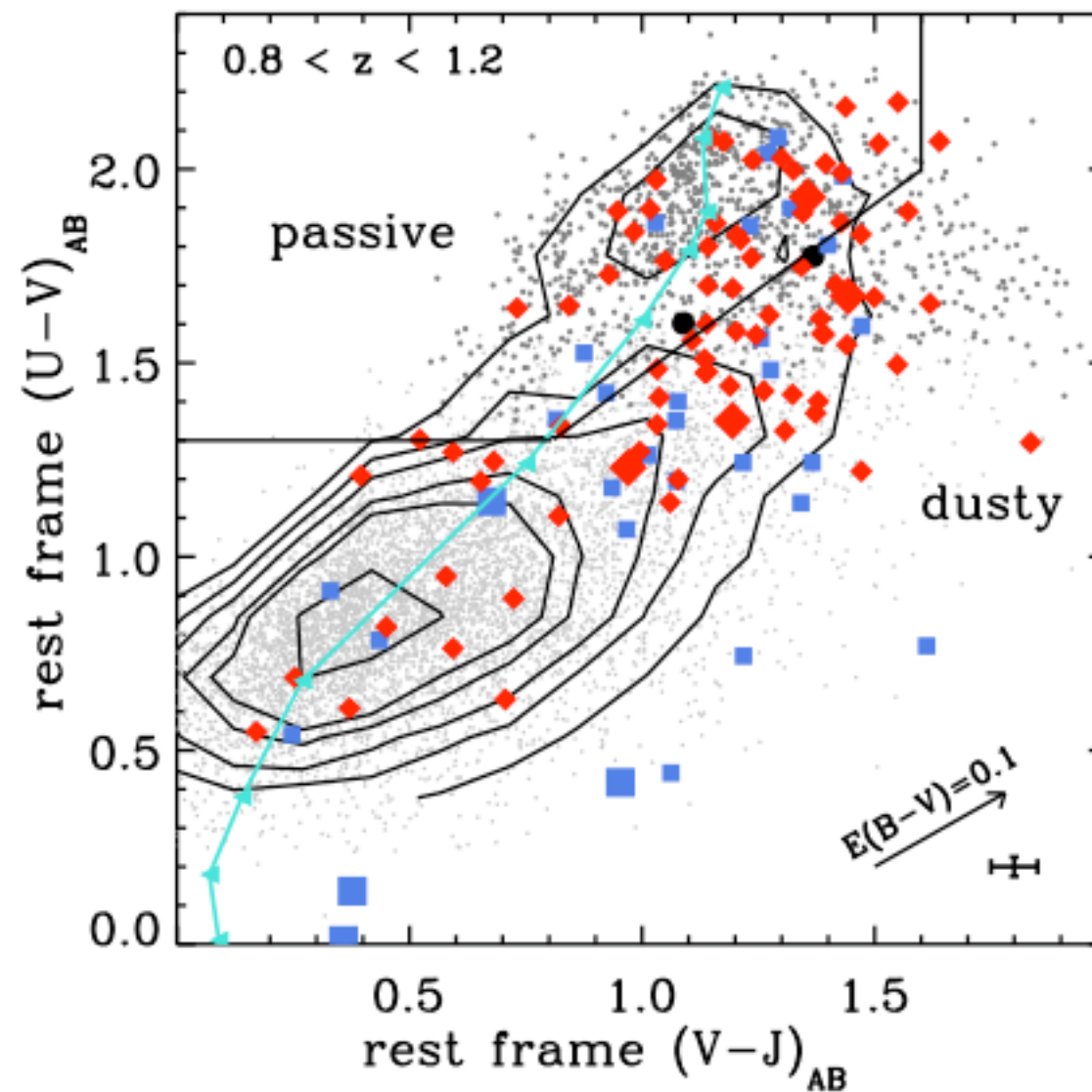
Early-type galaxies (11% of AGN)

- Least massive black holes most likely to accrete.
- Triggered (indirectly) by (major?) merger.
- Host galaxies have post-starburst stellar populations (blue>green>red).
- Are building low-mass end of the red sequence.
- Phasing with merger/starburst still hard to understand.

Late-type galaxies (43% of AGN +46% indeterminates?)

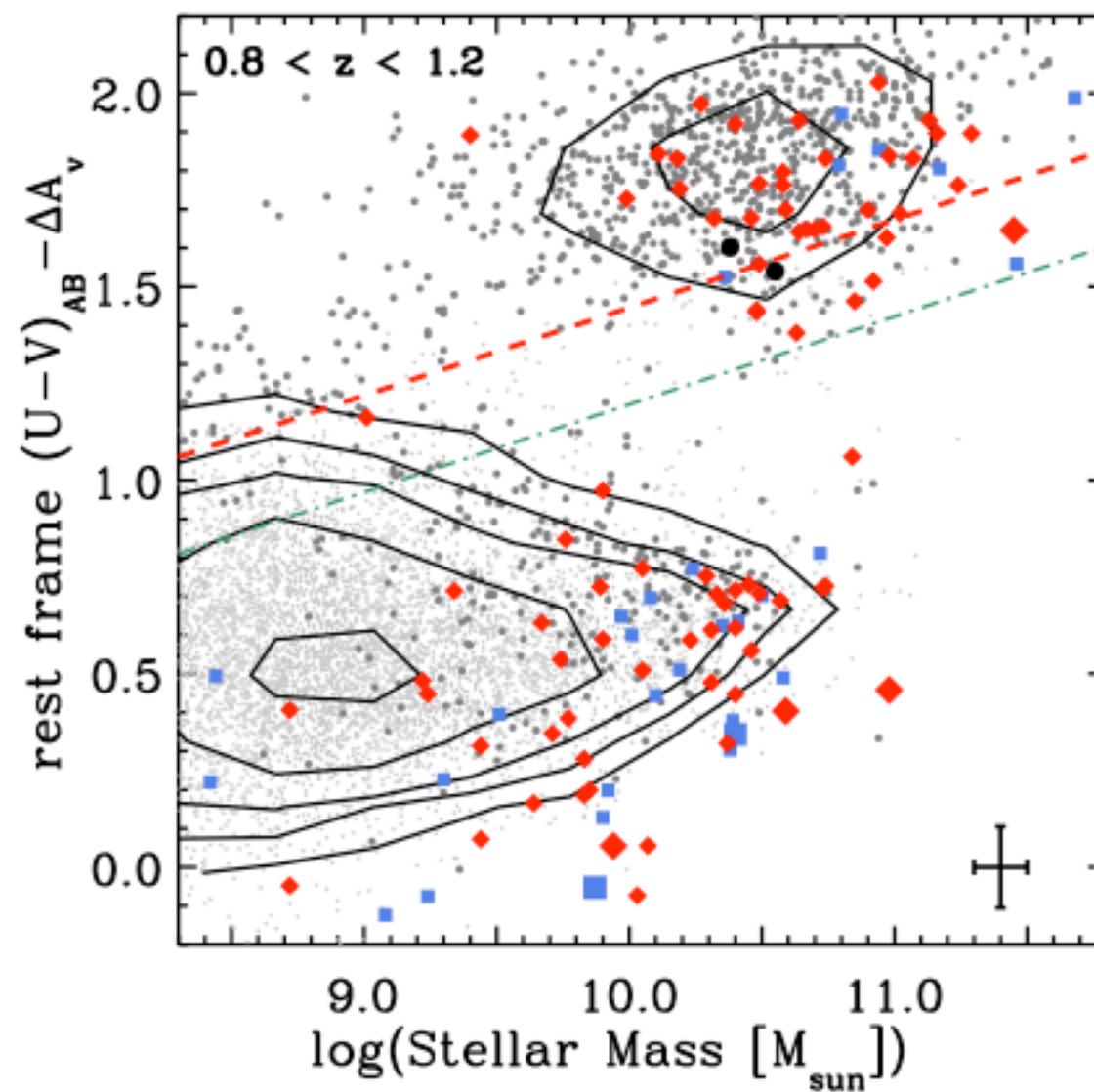
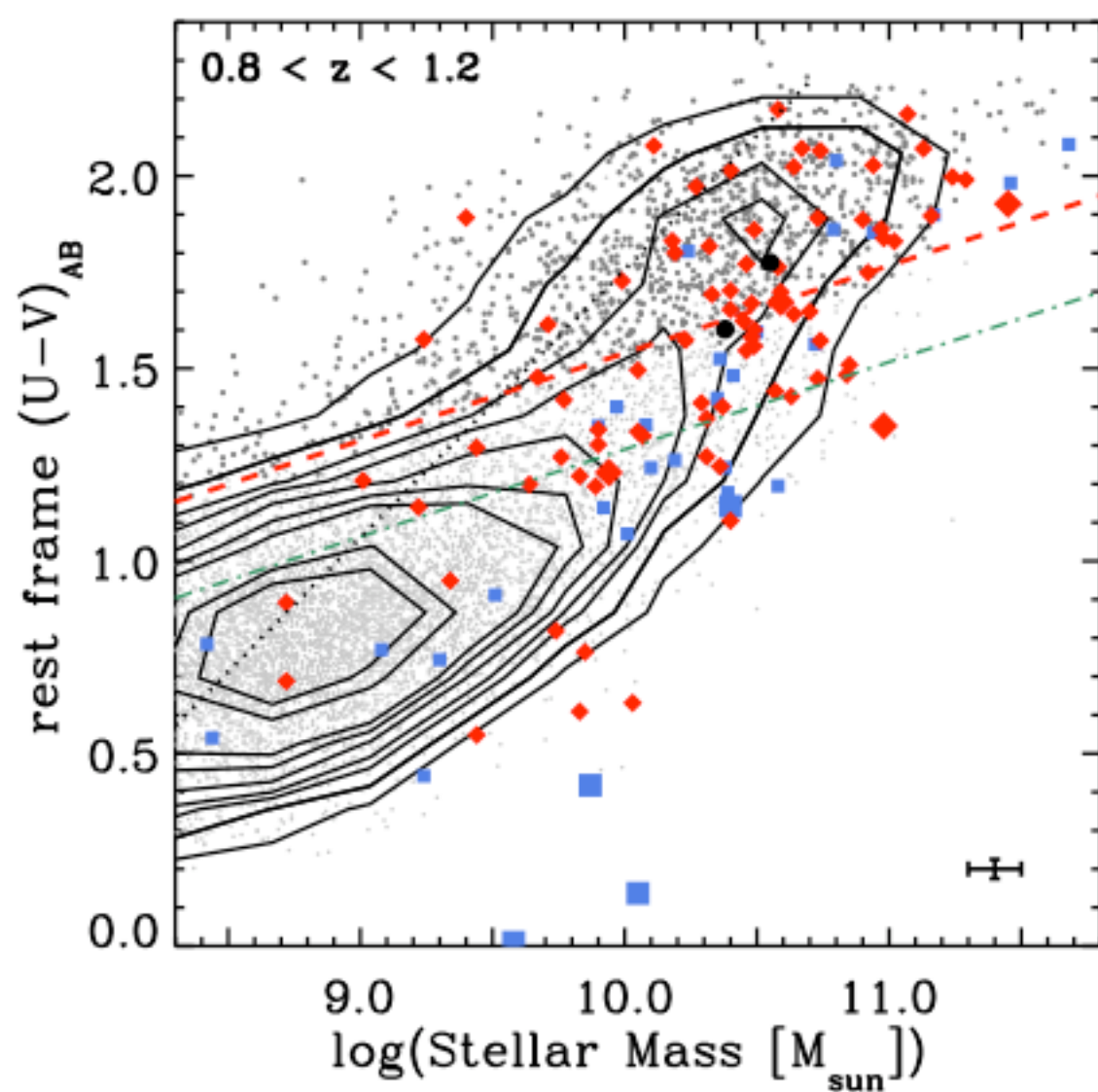
- Most massive black holes most likely to accrete.
- Unlikely to be triggered by merger - disks are stable.
- Host galaxies do NOT post-starburst stellar populations, but low SSFR?
- Are not transitioning from blue to red.
- Fuelling likely to be stochastic.
- Milky Way is archetype.

What about high redshift?



Cardamone et al. 2010, submitted - See Poster!

What about high redshift?



Cardamone et al. 2010, submitted - See Poster!