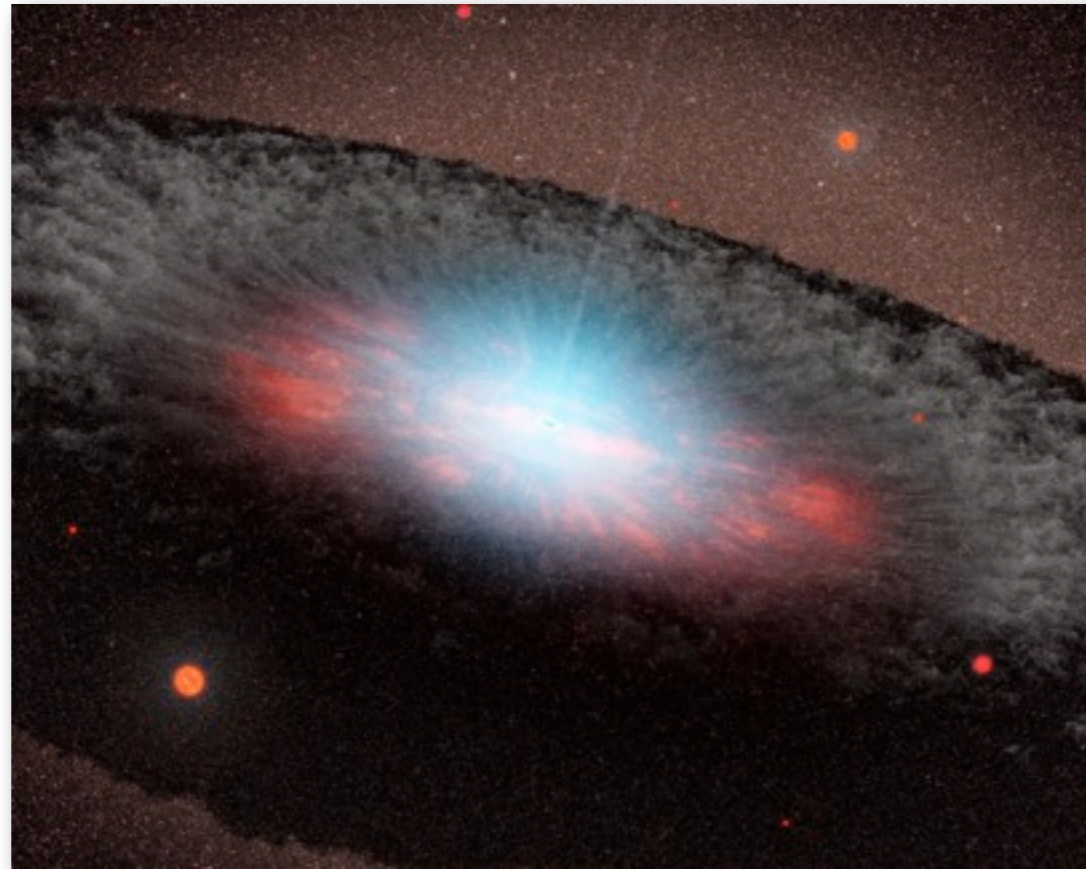# The co-evolution of black holes and their host galaxies

Kevin Schawinski

Yale Center for Astronomy & Astrophysics
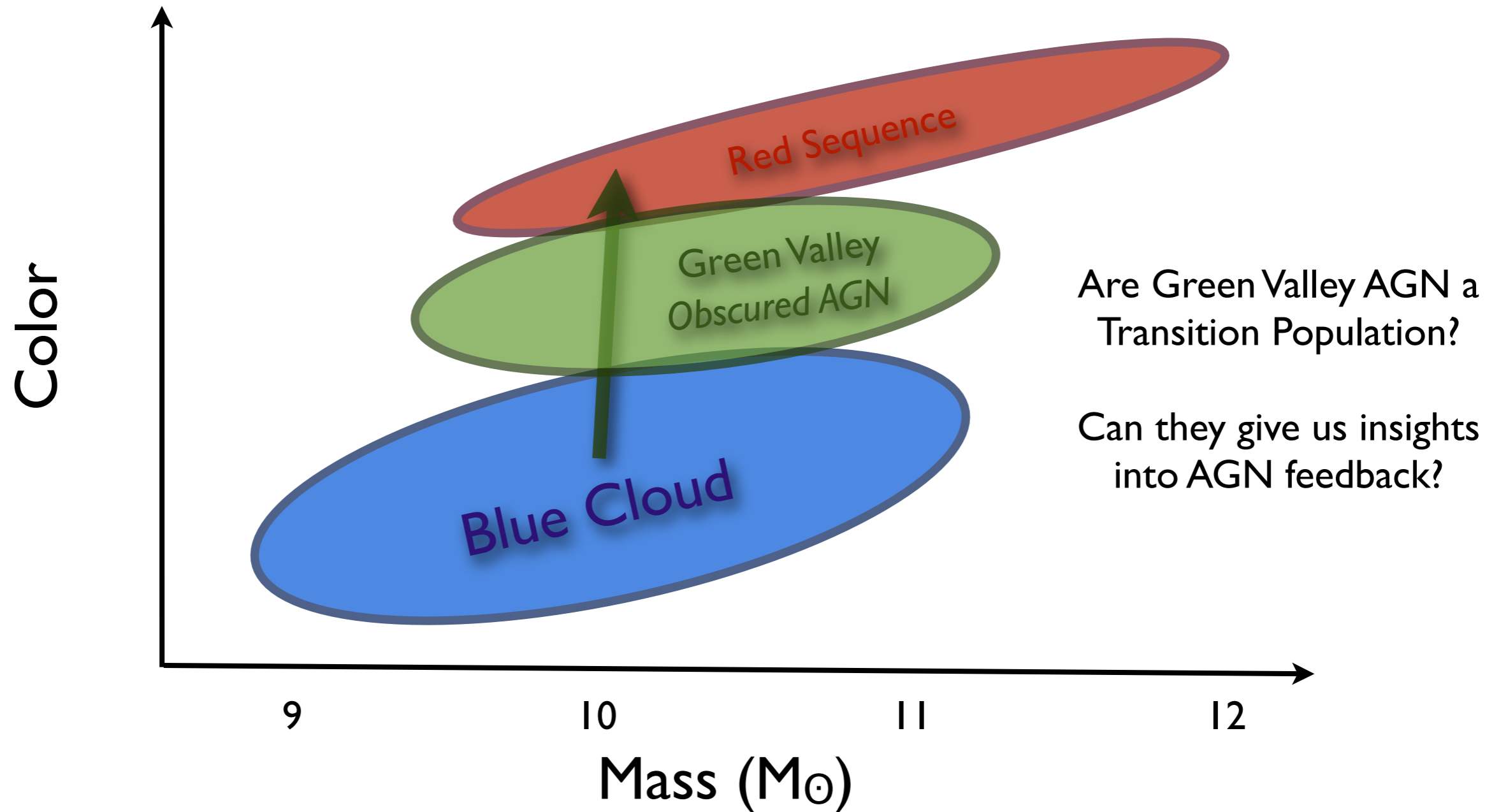Department of Physics
Yale University

Which galaxies host accreting black holes?

Does the energetic output from the black hole affect the host galaxy via *feedback*?

And if so, how?

Intriguingly, morphology may matter!

Migration from the blue cloud to the red sequence
...via an AGN phase in the green valley?

What does the Green Valley really mean?

Intermediate (`green') colours do not <u>necessarily</u> imply that star formation was recently shut down

but

If star formation has recently been suppressed, then intermediate colours imply a time delay on the order of the lifetime of OB stars

Data
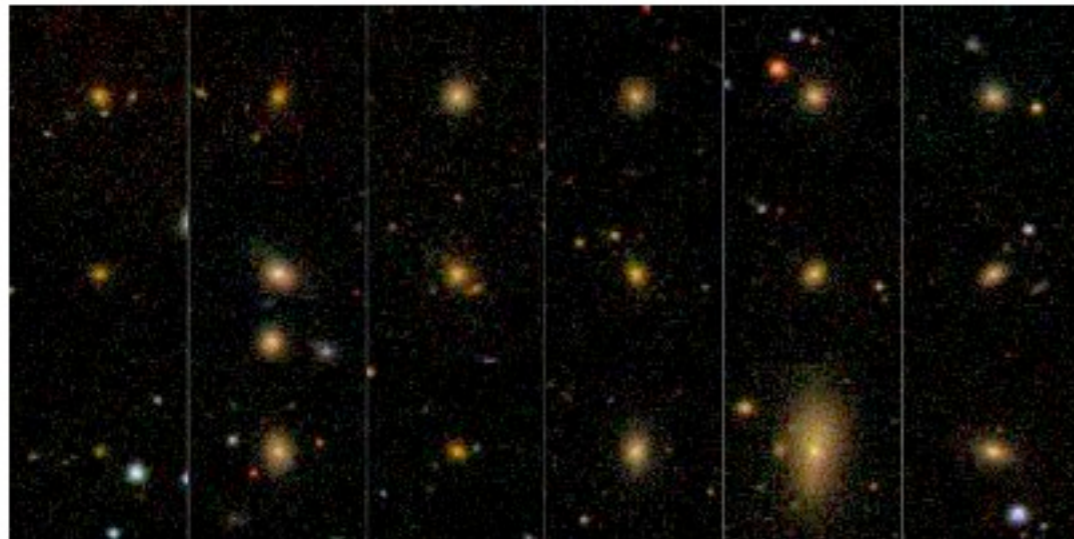

SDSS DR7 - photometry & spectra for galaxies & AGN

Galaxy Zoo 1 & 2 - detailed visual morphologies for ~1 million SDSS galaxies (publicly available soon!) Over 230,000 members of the public involved
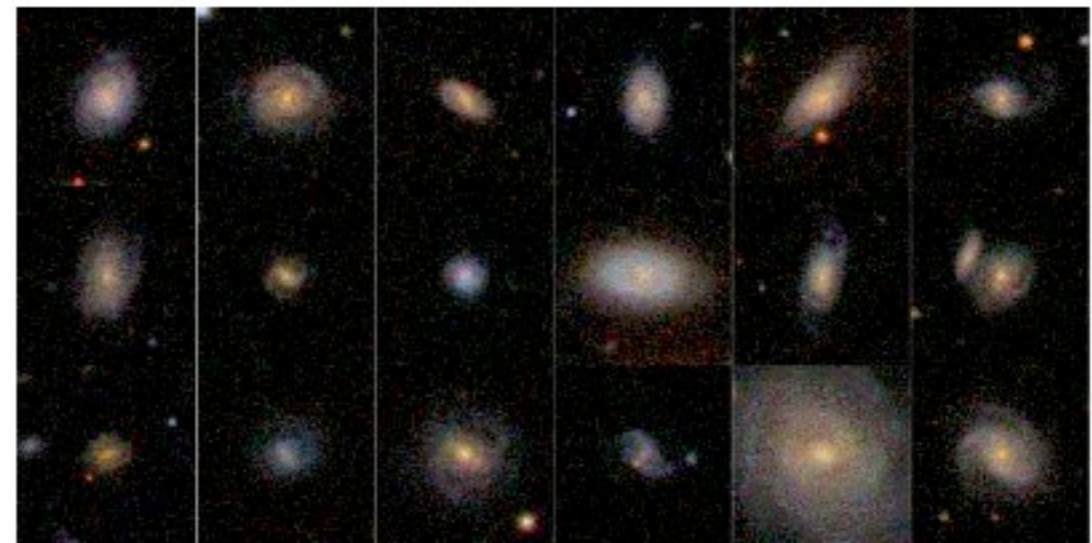
Kevin Schawinski

Galaxy Zoo Morphologies

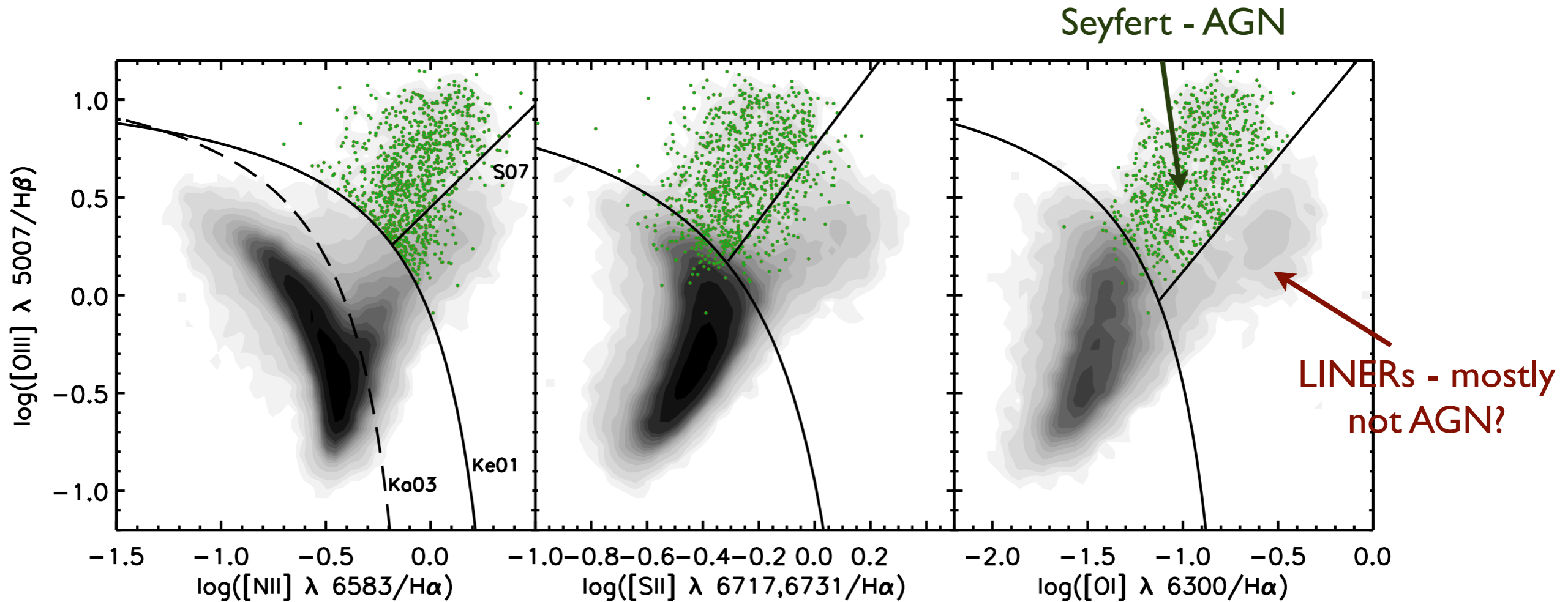Early-type

Face-on late-type

Lintott+08

At ~20 classifications per objects, the classifications from citizen scientists are as good as those from professionals.

Avoids biases that plague automated methods that use colour, spectral information or structural parameters as a proxy for morphology.

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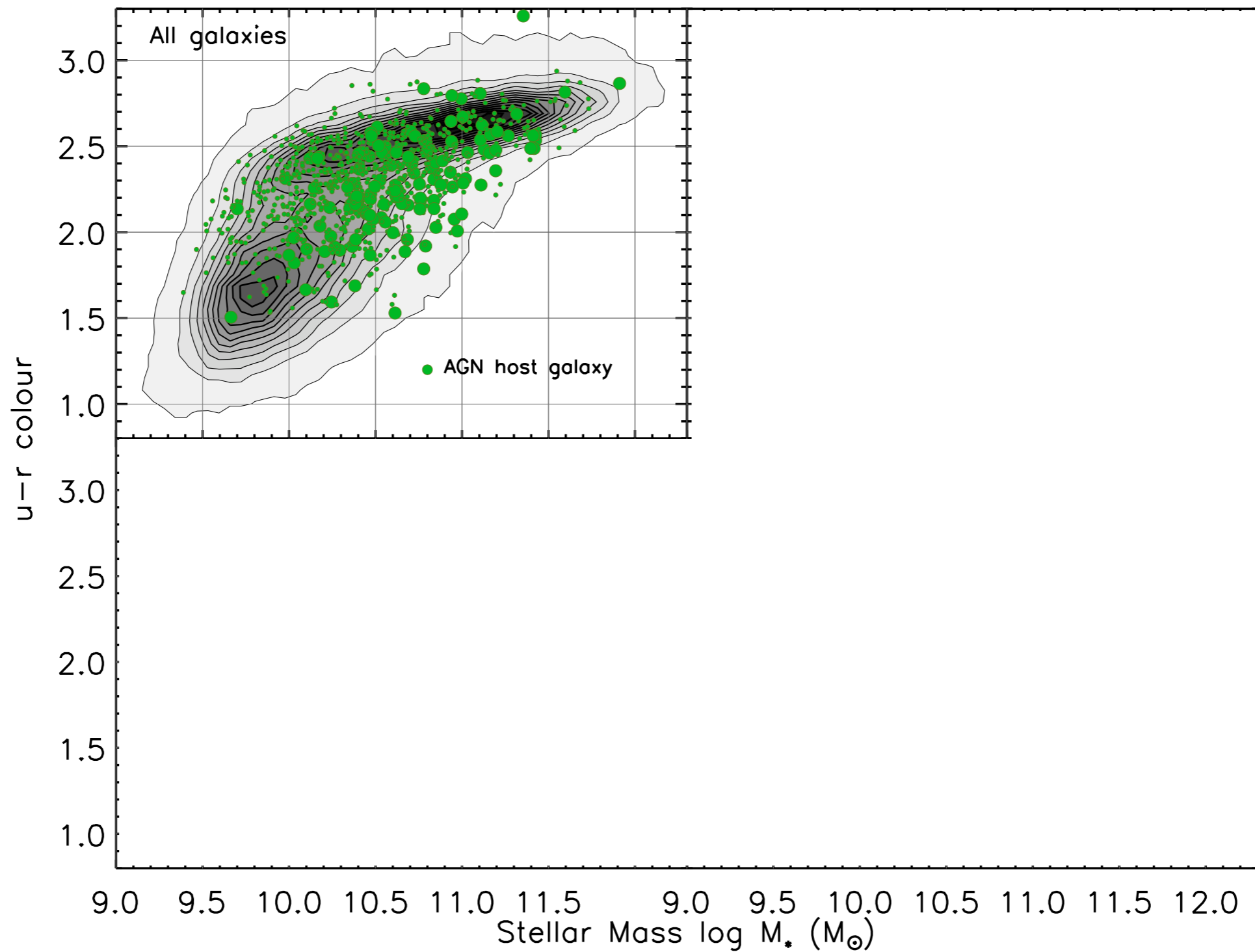# AGN Selection via emission line diagnostics

Emission line ratio diagrams (Kewley+01,+06, Kauffmann+03, Schawinski+07)

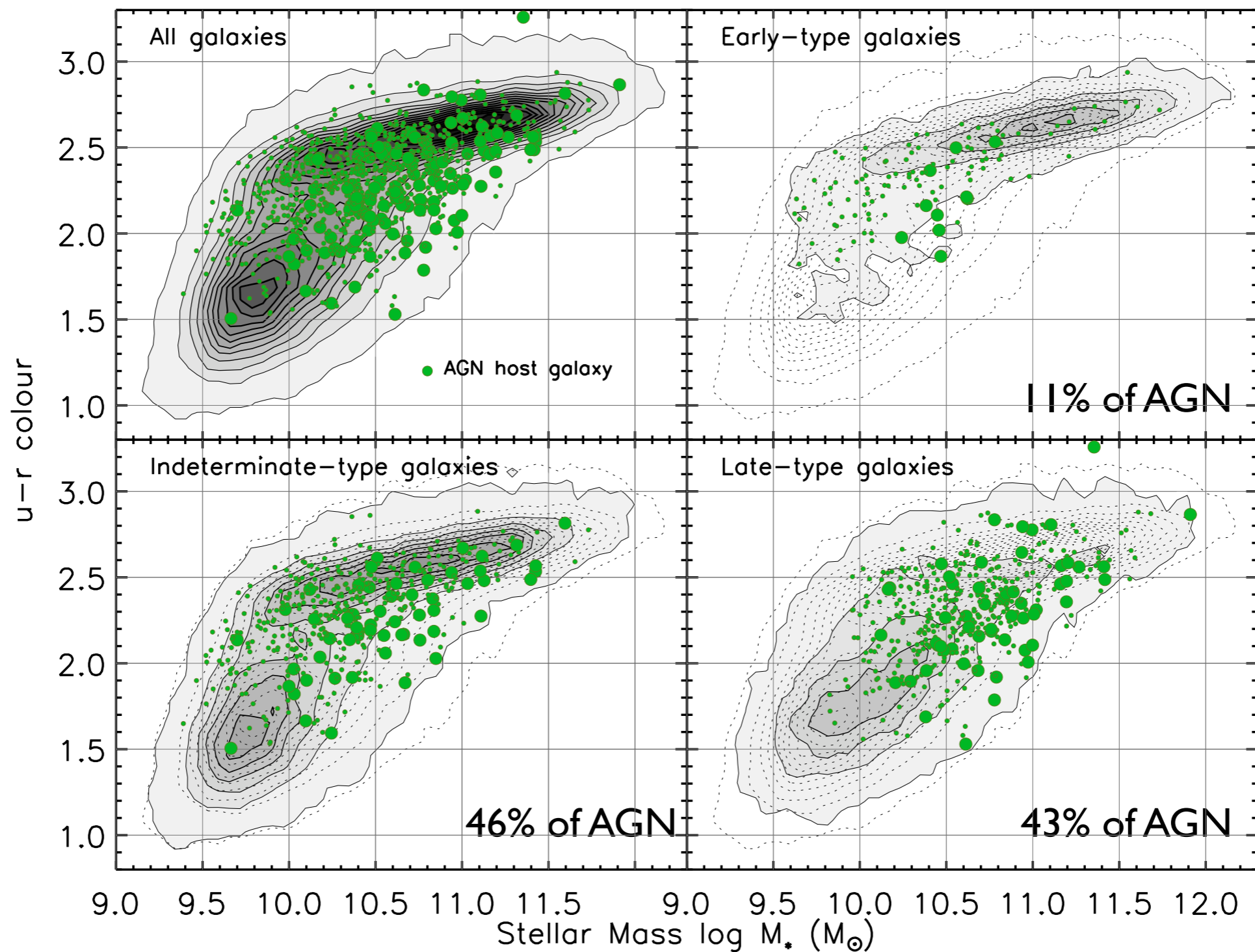Seyfert - LINER divide corresponds almost exactly to "Eddington ratio" cut, and approximately to L[OIII] 5007 cut.

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AGN host galaxies split by morphology

Schawinski+09, submitted

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AGN host galaxies split by morphology

Schawinski+09, submitted

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The absolute distribution of AGN host galaxies
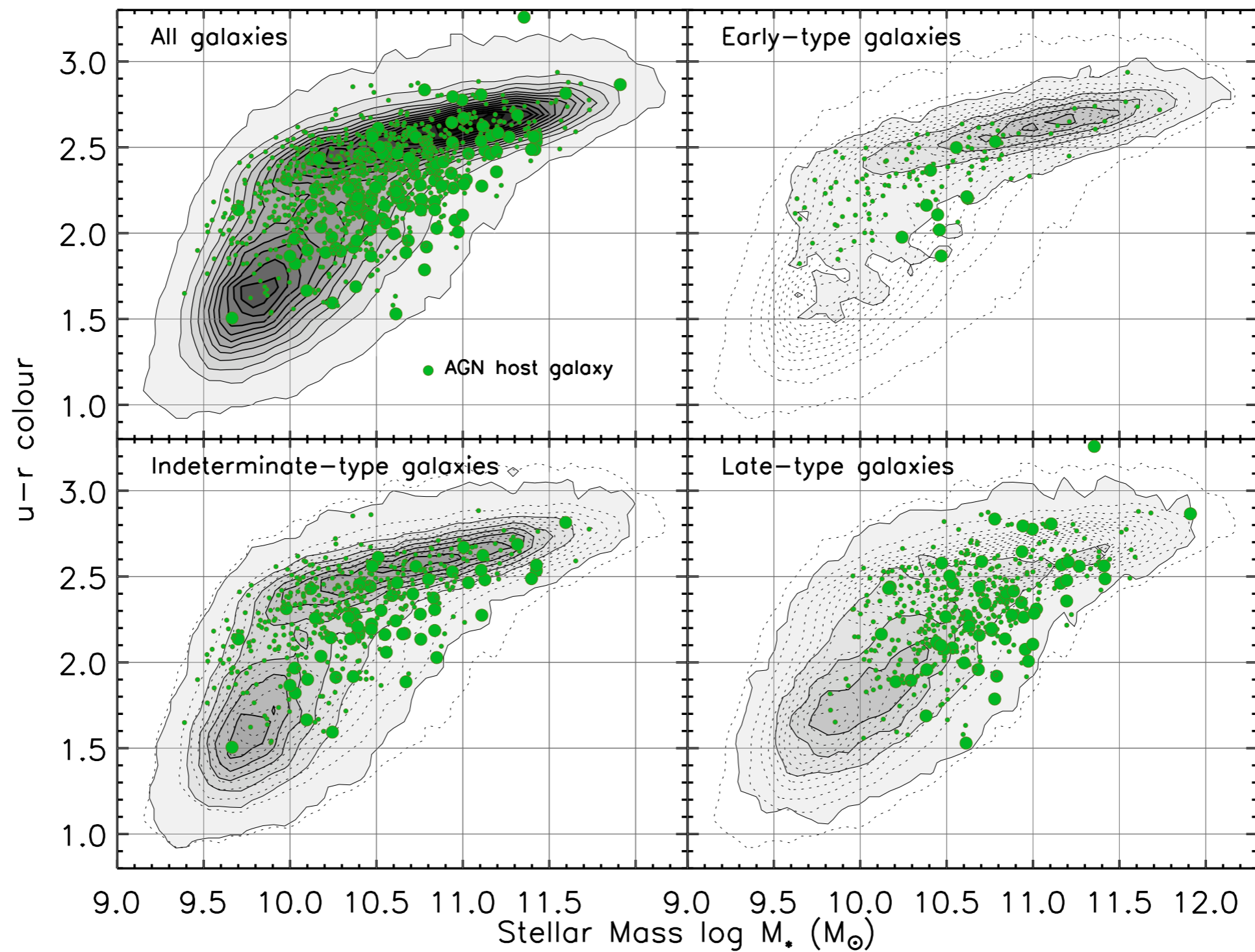doesn't tell us everything,

AGN fraction in a population is a rough proxy
for the duty cycle.

But, we need to consider the right sub-population...

Assumption: high AGN fraction/duty cycle
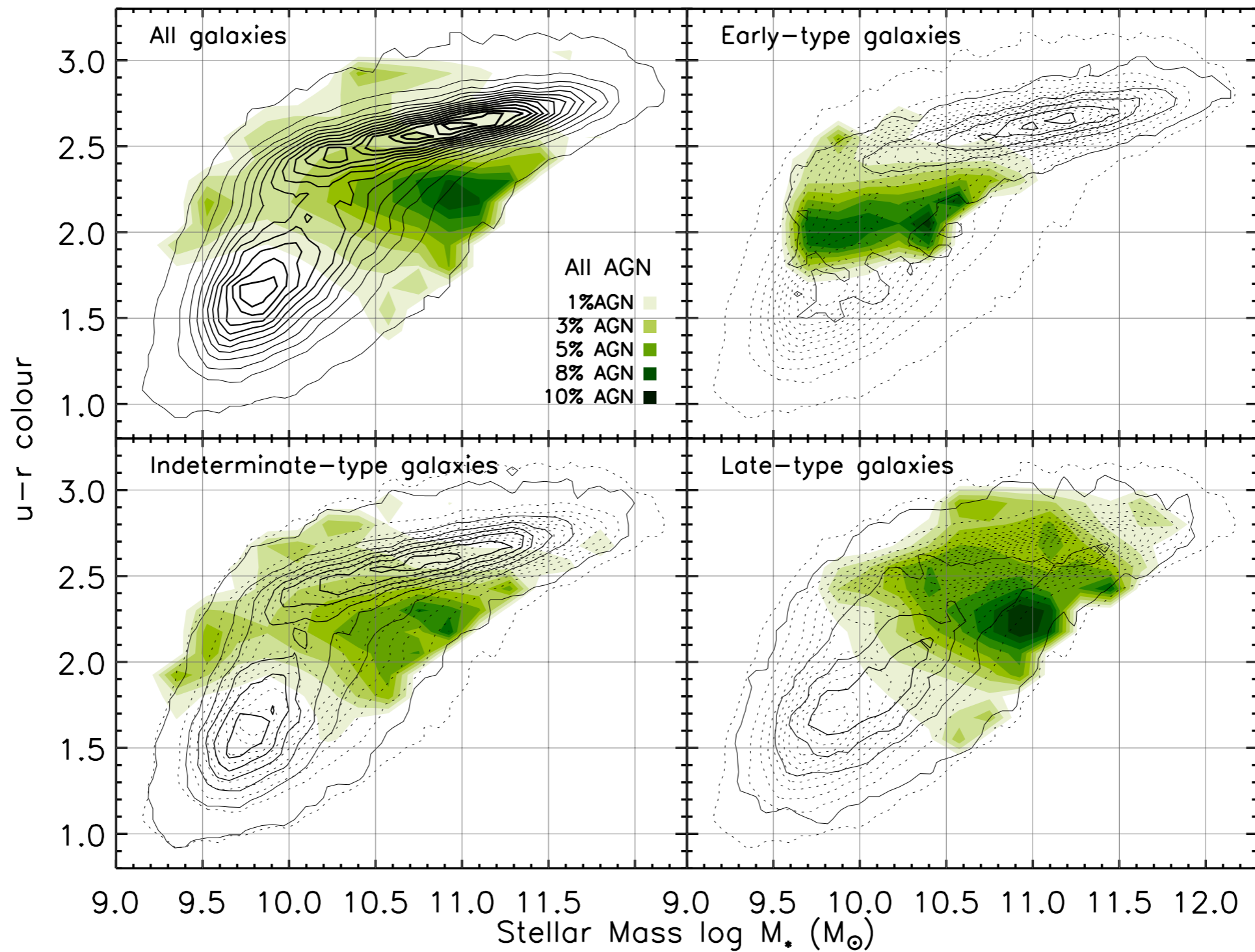implies bigger impact on host galaxy

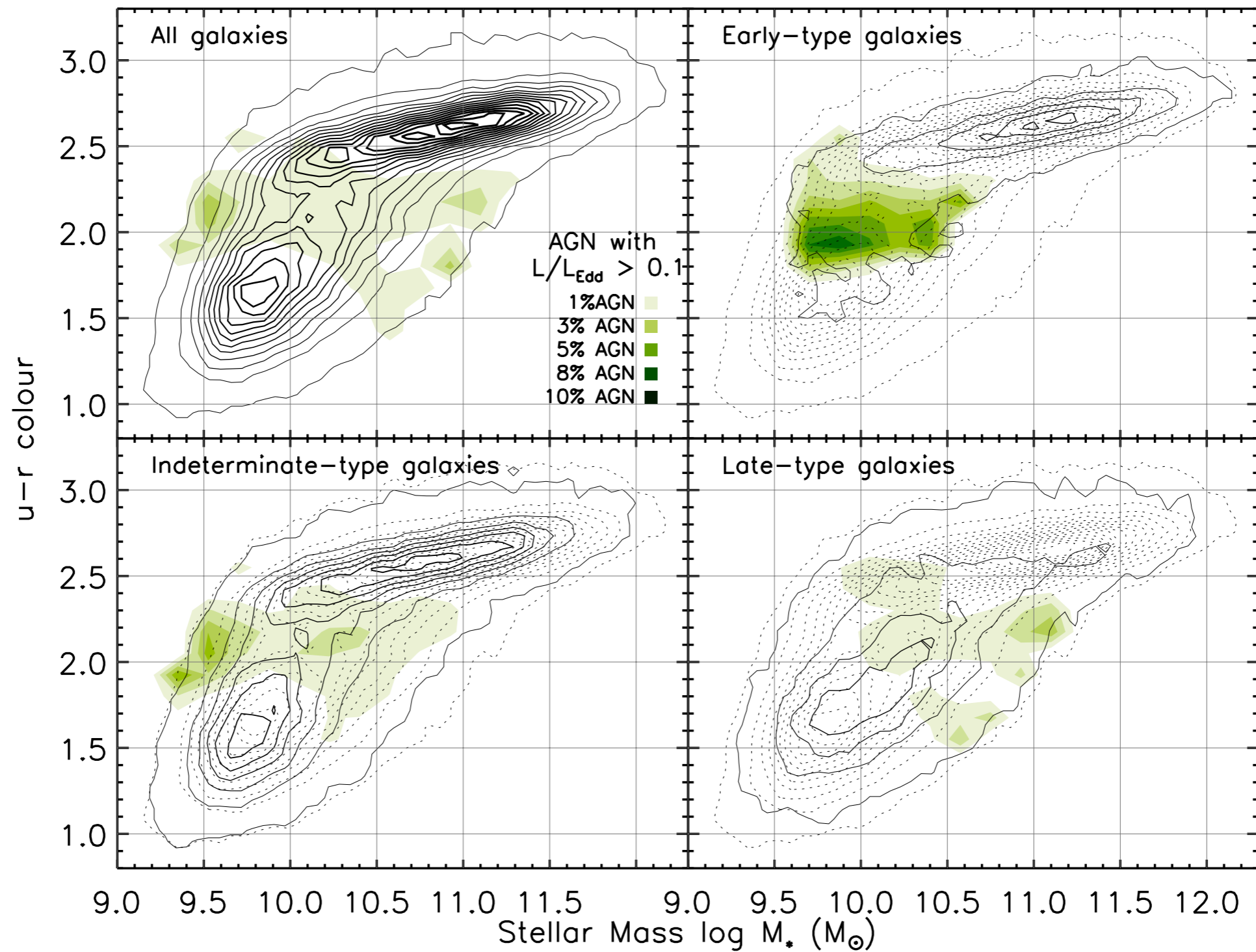# Computing the AGN fraction...

Schawinski+09, submitted

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AGN duty cycle split by morphology

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AGN duty cycle split by morphology
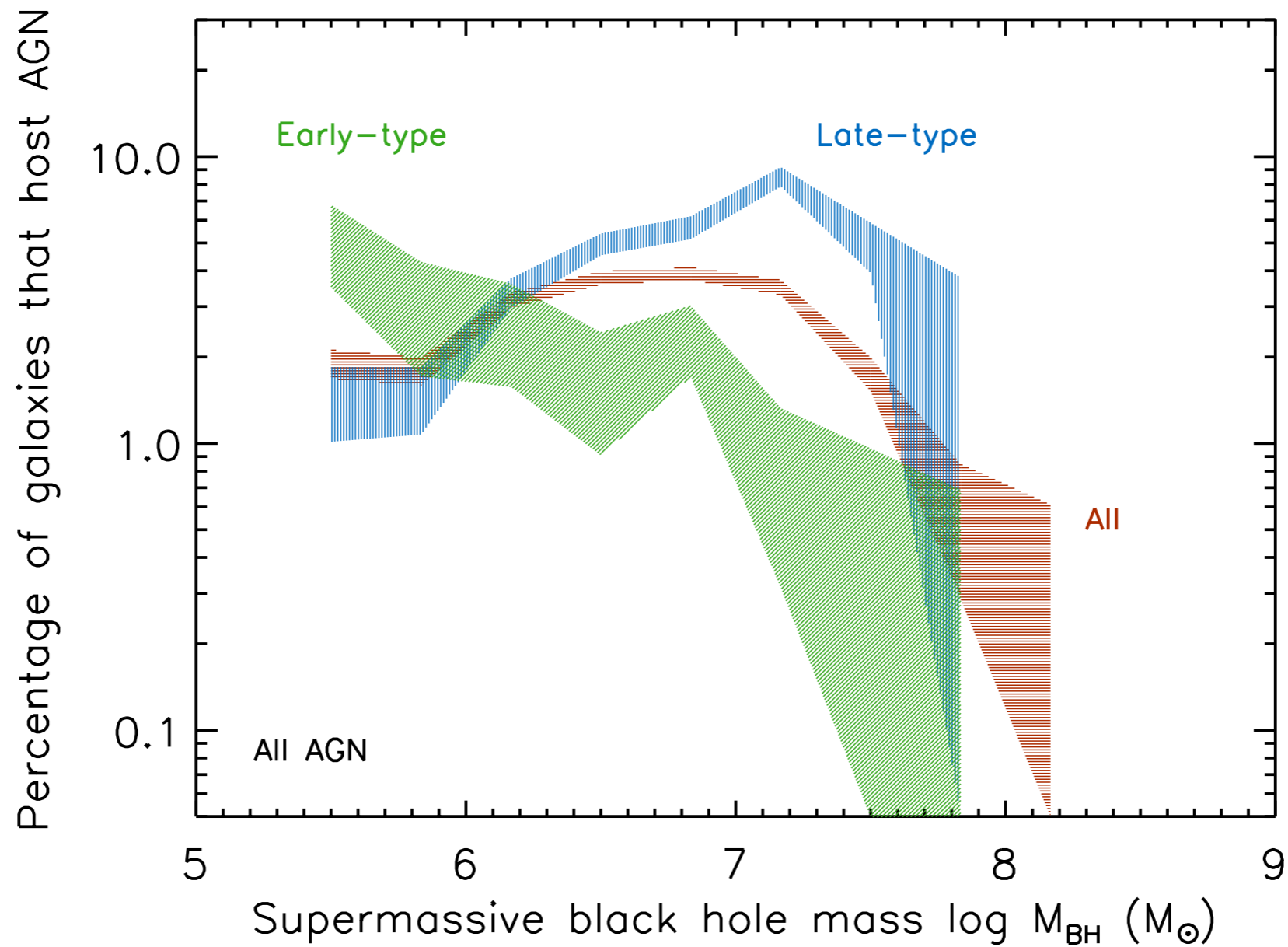
High Eddington ratio *only*

Schawinski+09, submitted

Kevin Schawinski
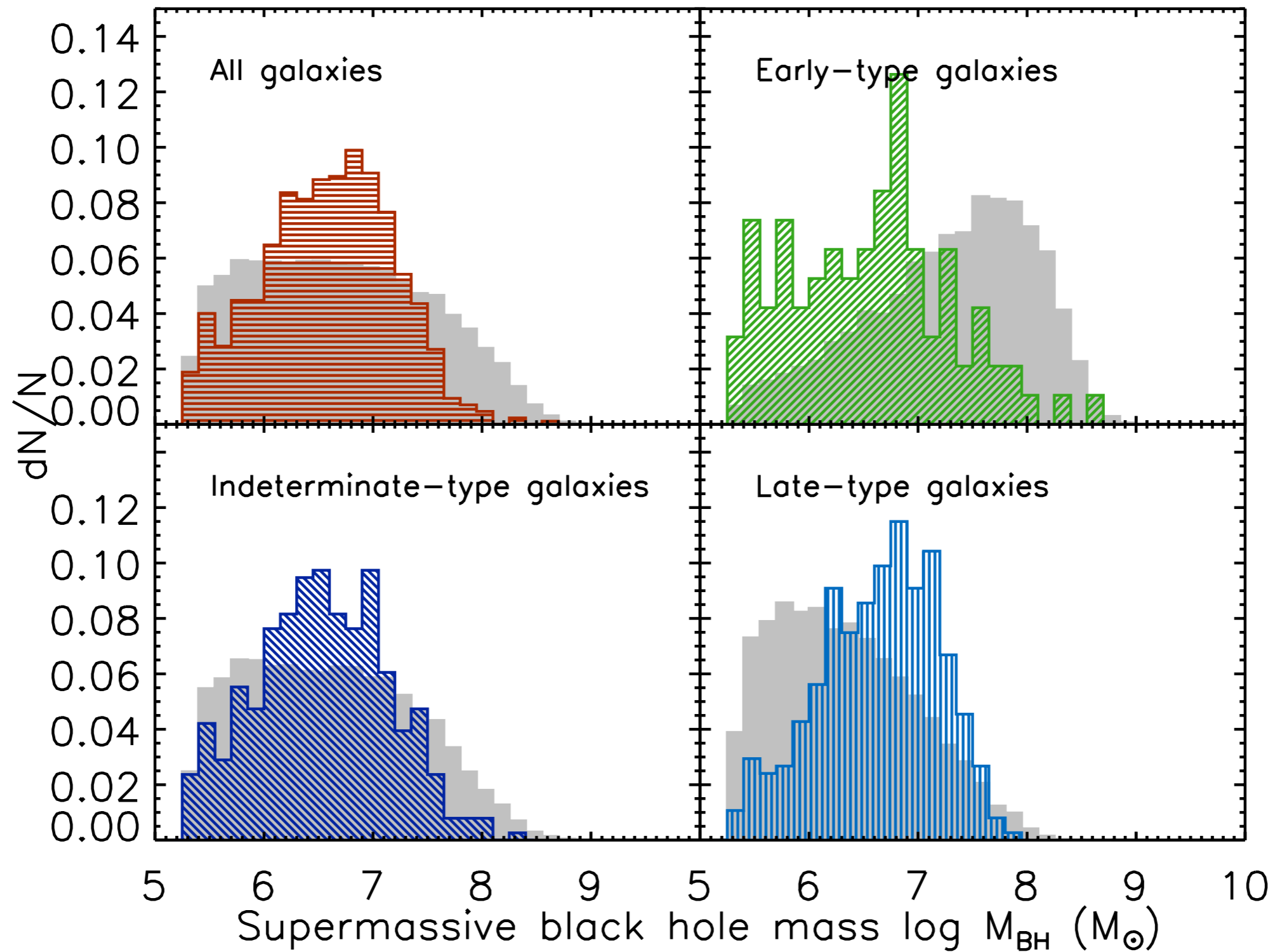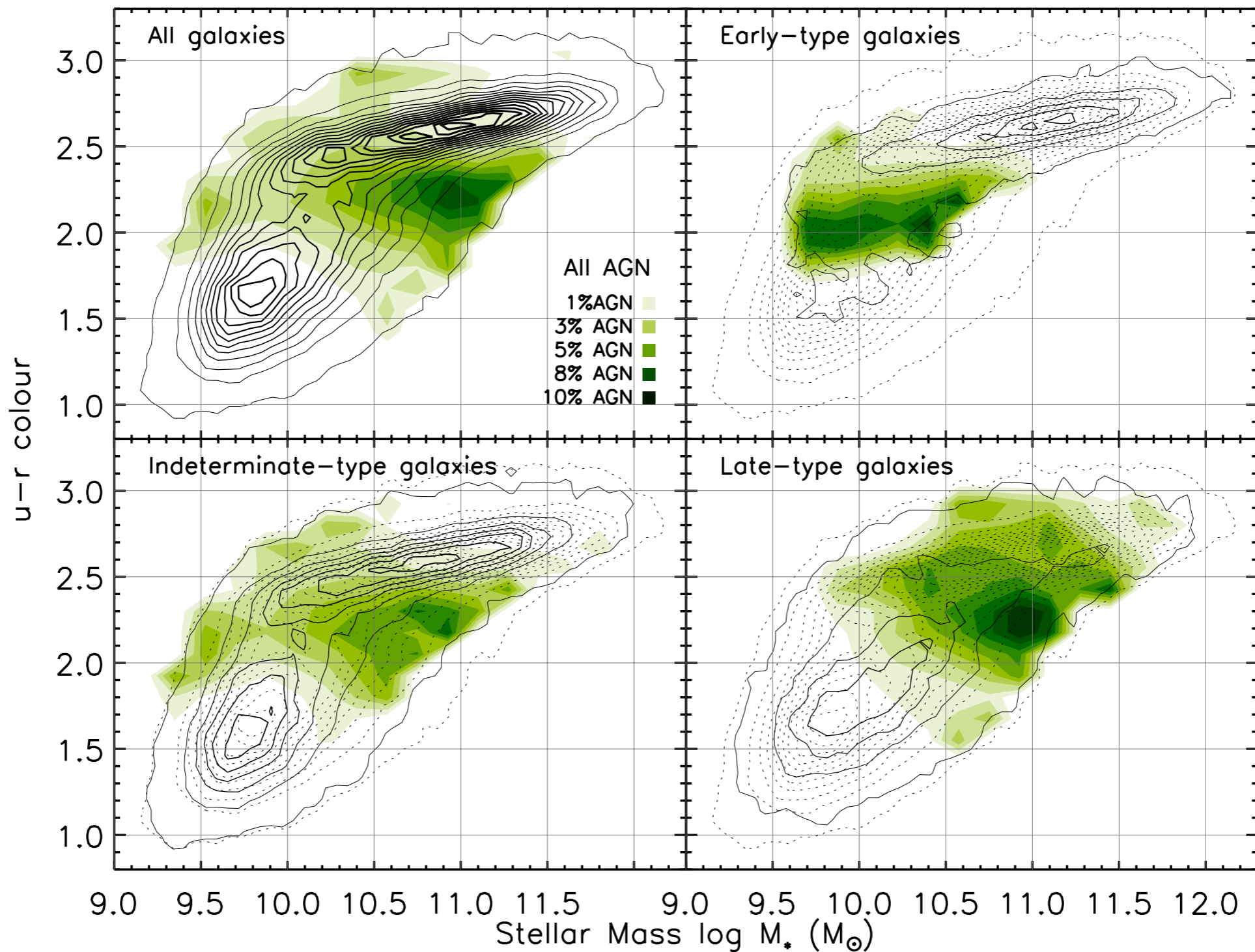
Which black holes are growing?

Schawinski+09, submitted

Kevin Schawinski

Which black holes are growing?

Percentage of galaxies that host AGN (y-axis)

Supermassive black hole mass log M_{BH} ($M_\odot$) (x-axis)

Early-type, Late-type, All, All AGN

What does this mean for the role of the AGN for the host galaxy?
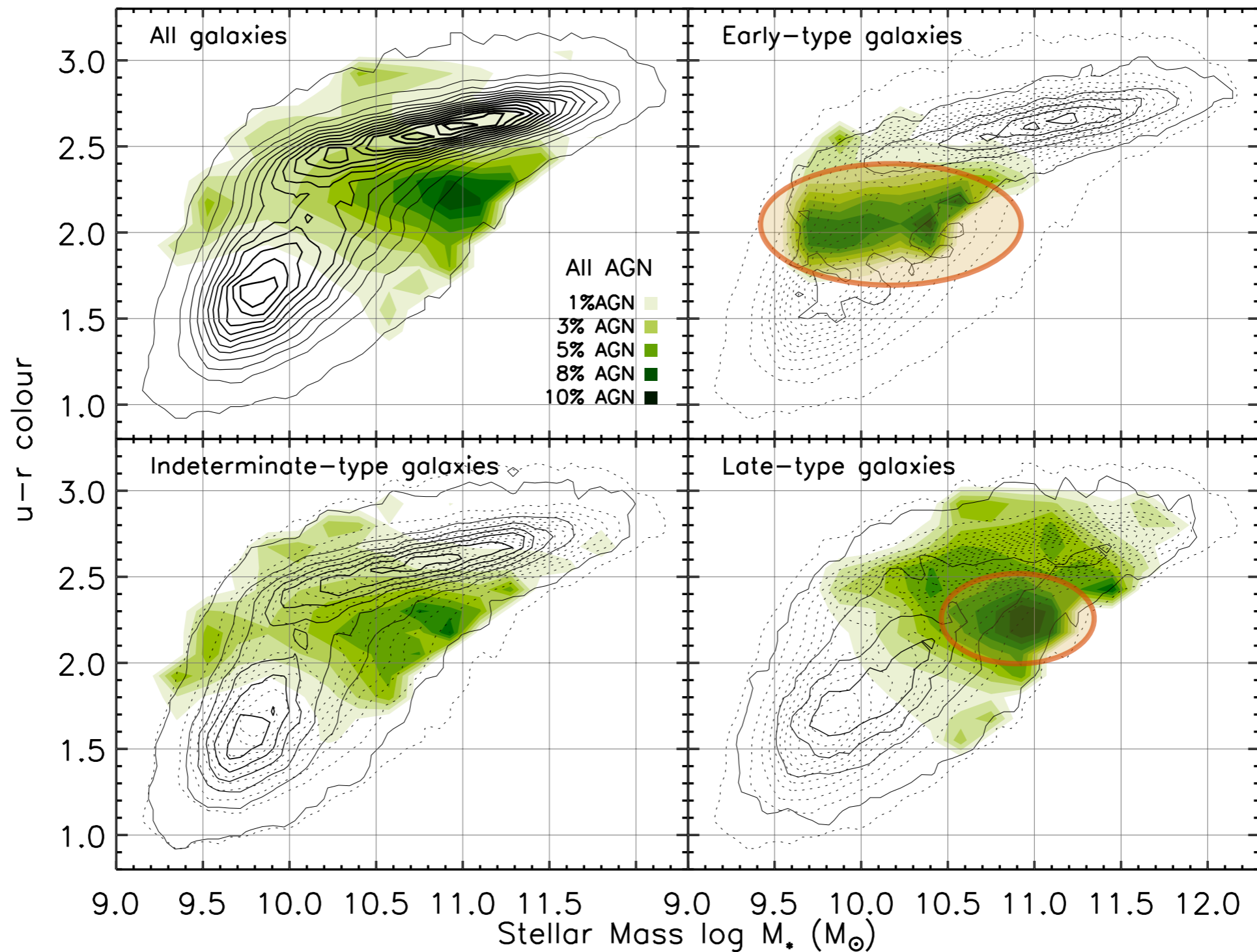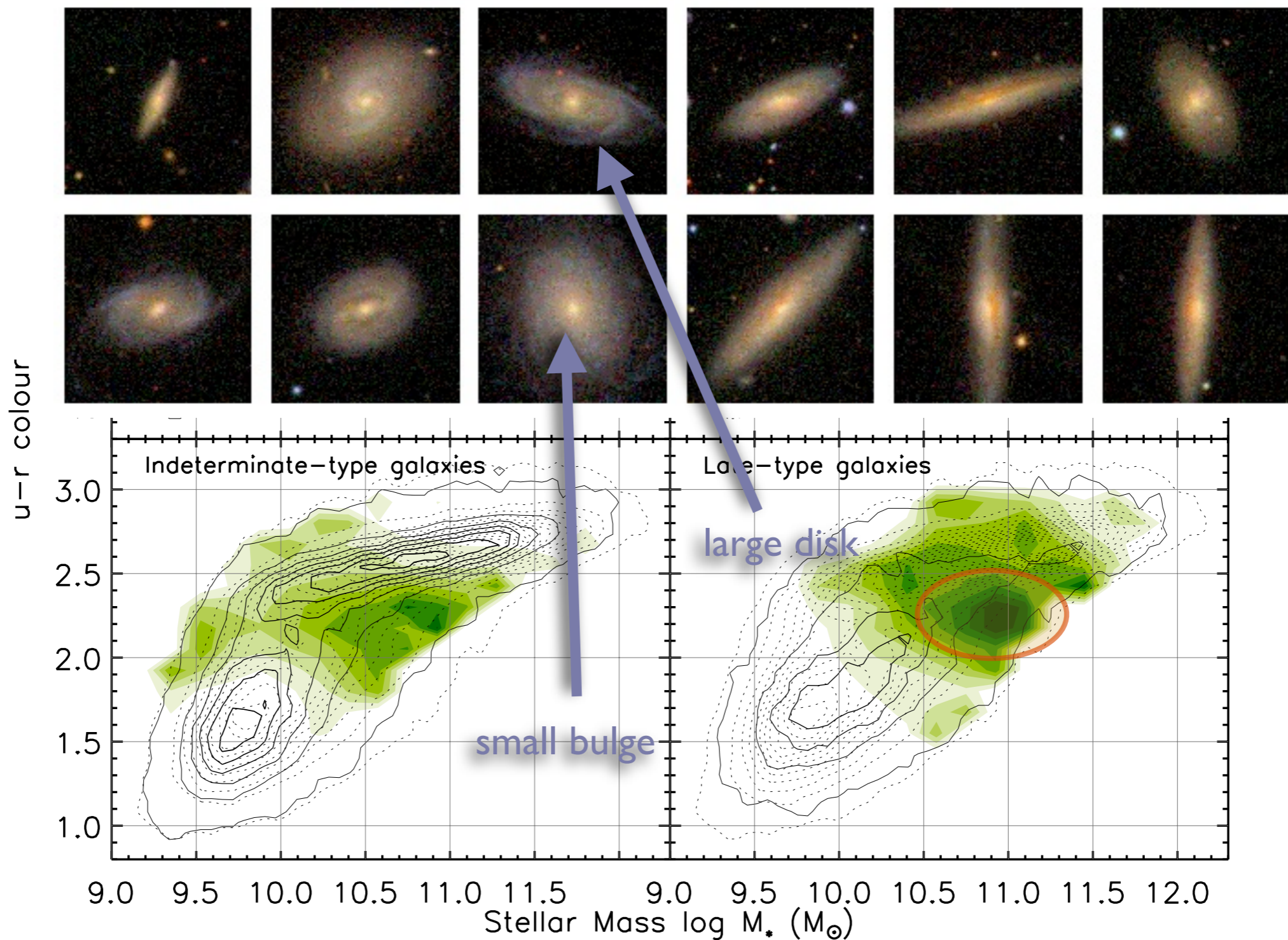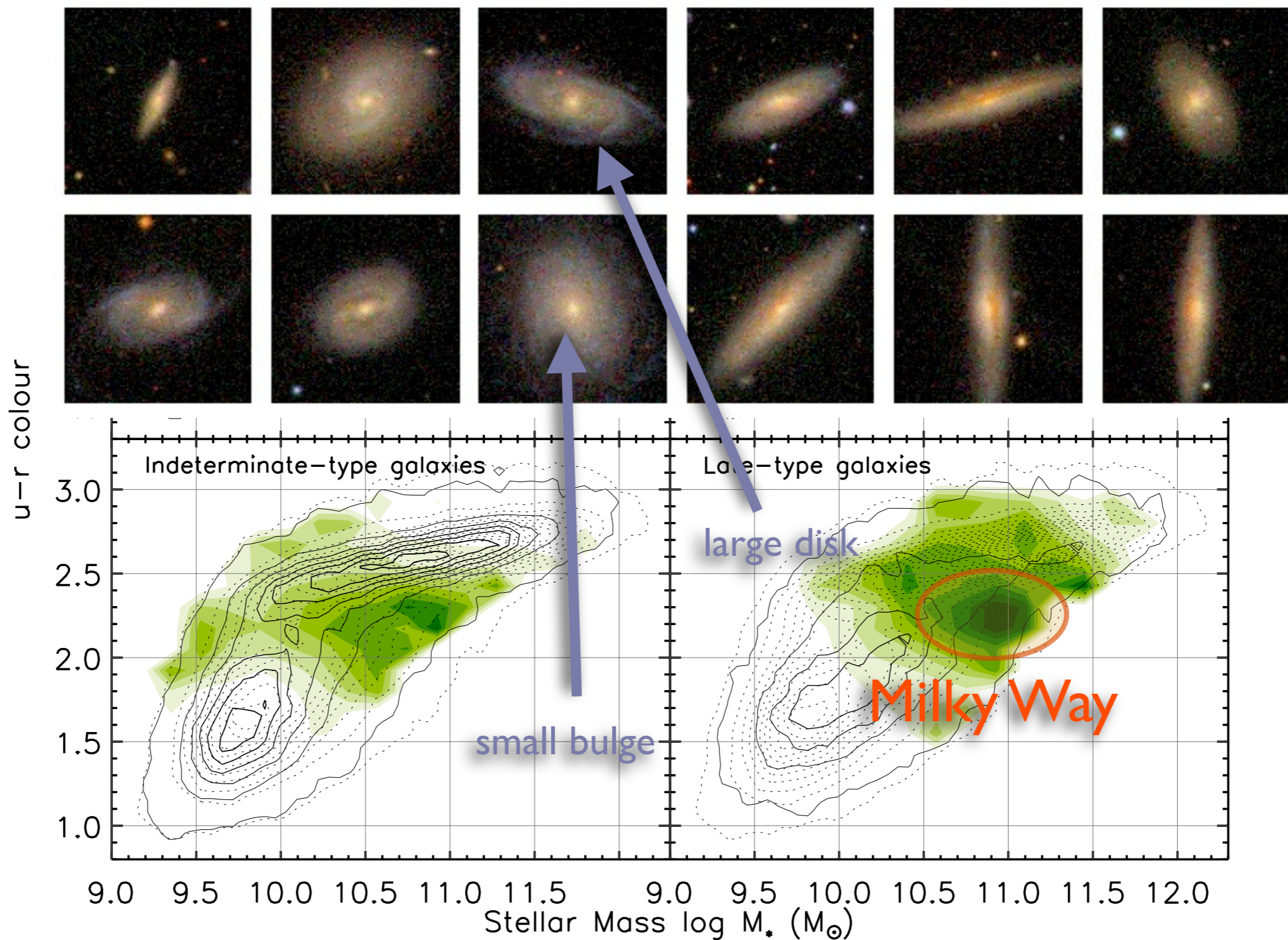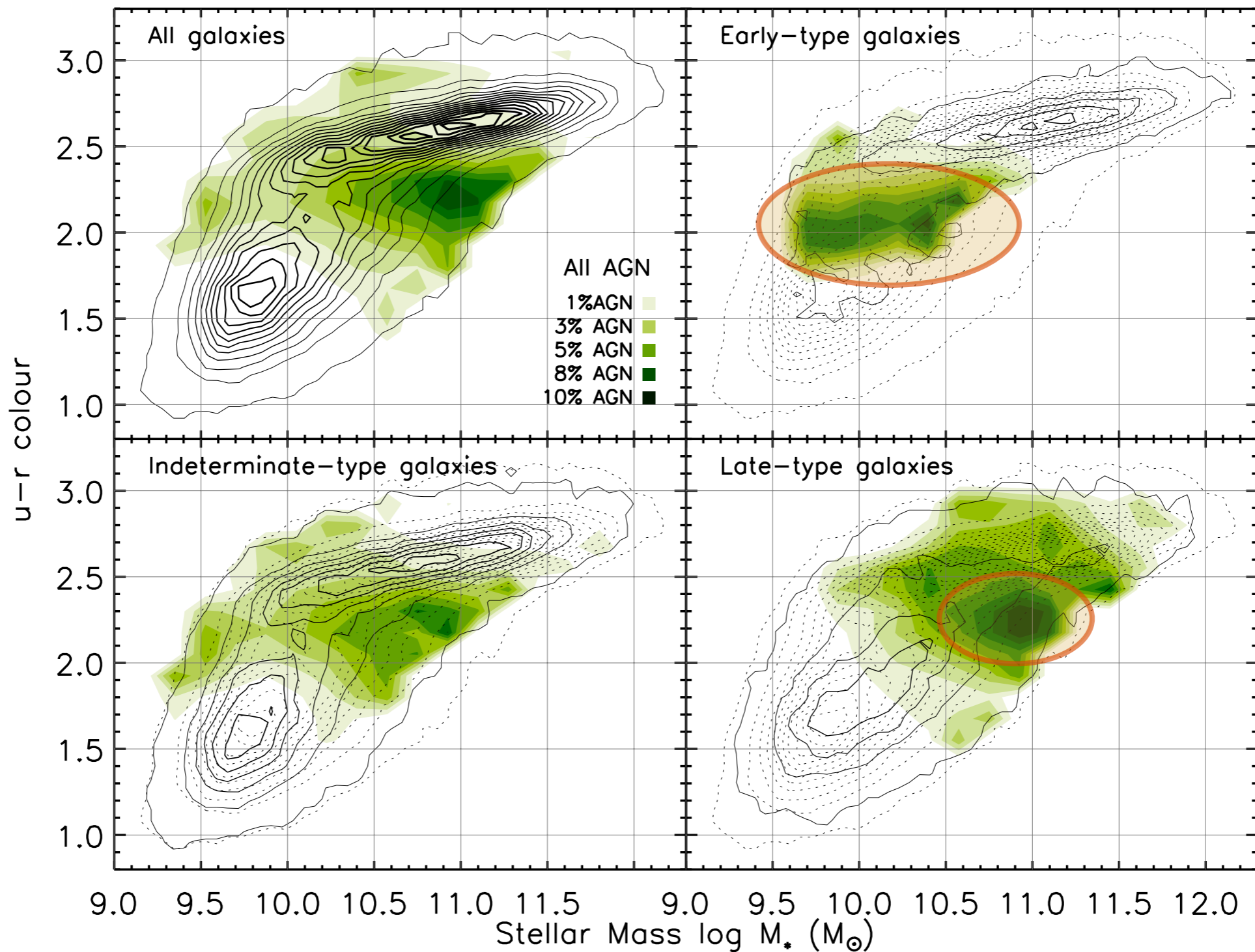

Schawinski+09, submitted

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What does this mean for the role of the AGN for the host galaxy?

Kevin Schawinski

What does this mean for the role of the AGN for the host galaxy?

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What does this mean for the role of the AGN for the host galaxy?

large disk

small bulge

Milky Way

Indeterminate-type galaxies

Late-type galaxies

u−r colour

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

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What does this mean for the role of the AGN for the host galaxy?

Schawinski+09, submitted

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Low-mass <u>active</u> early-types in SDSS

Recovered Star Formation Histories
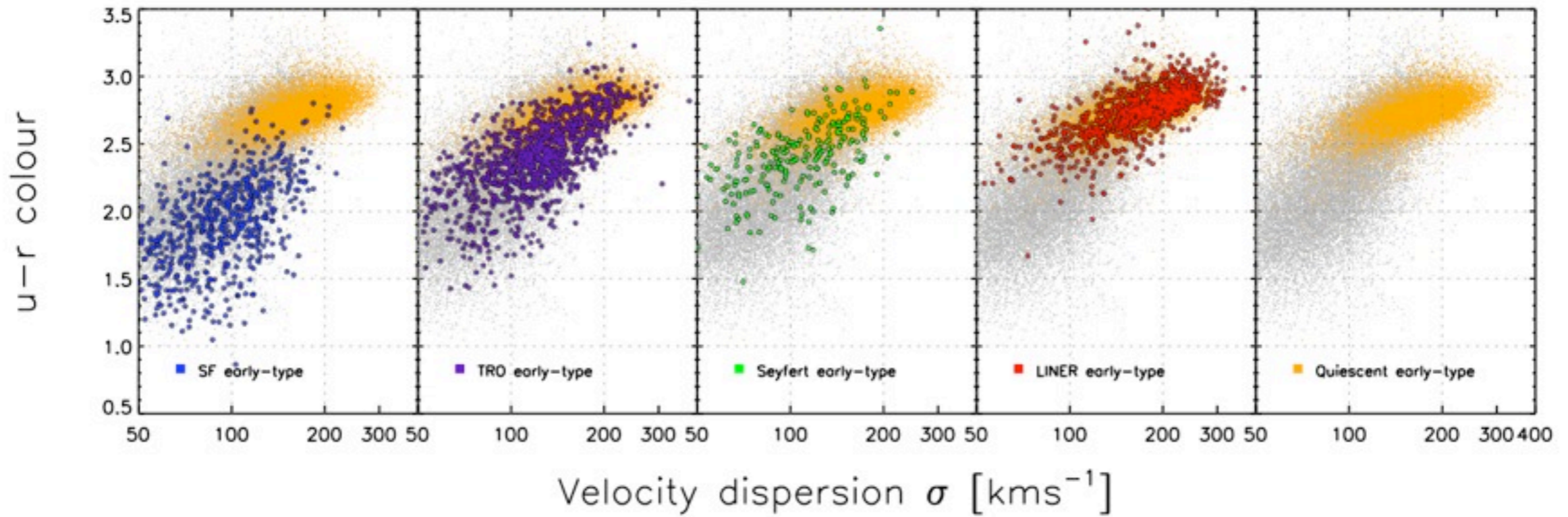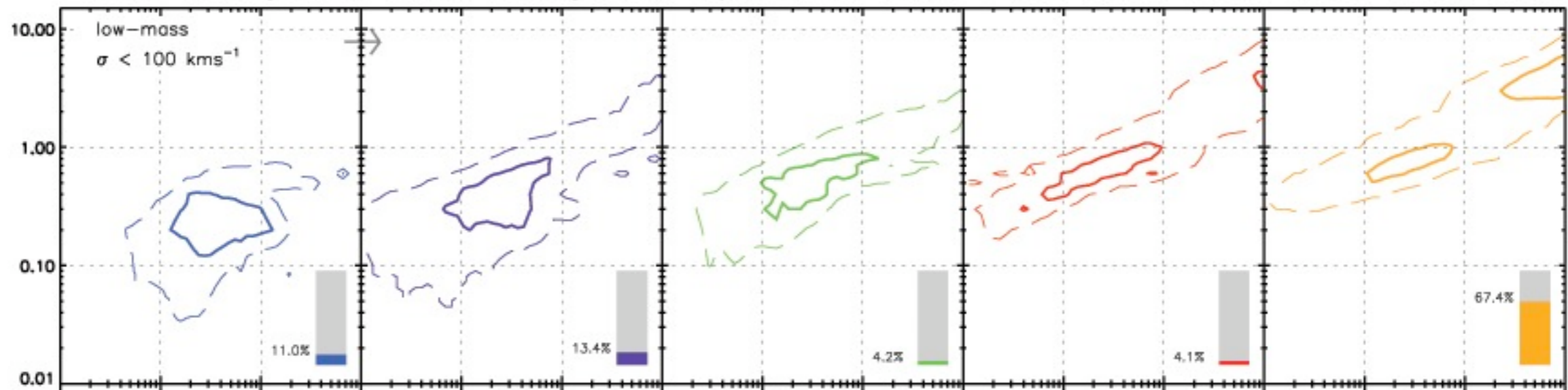
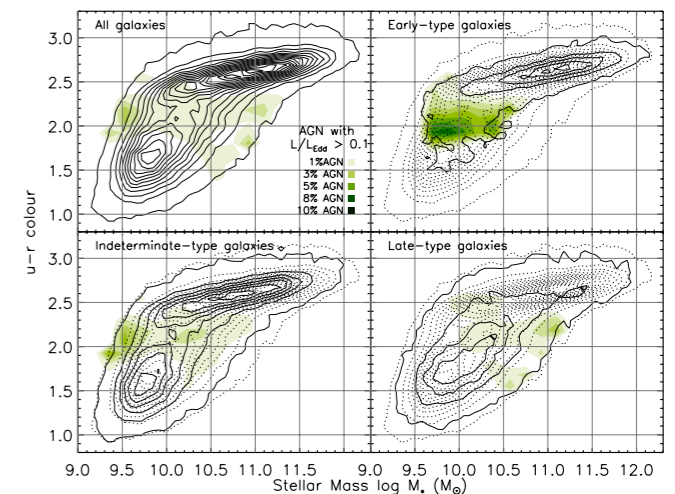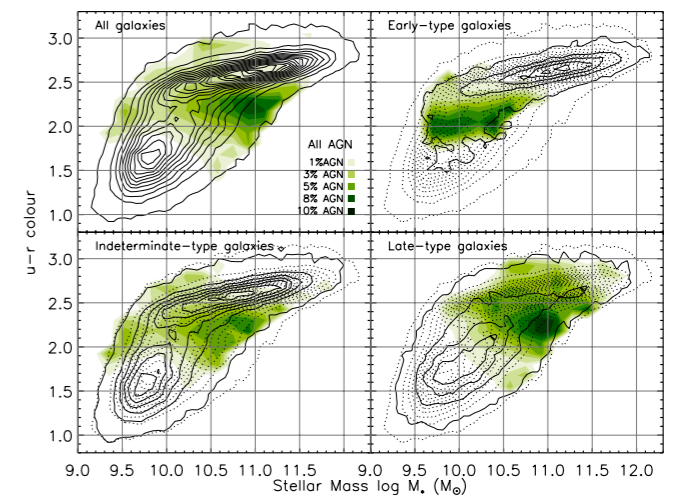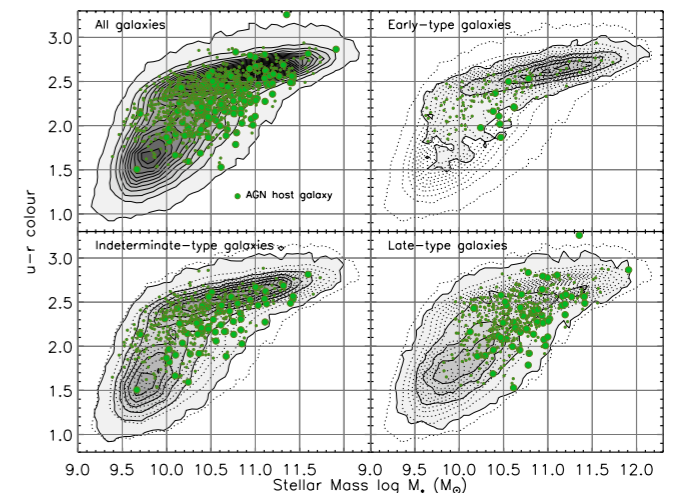# Summary

AGN host galaxies in the local universe are *not* a homogeneous class
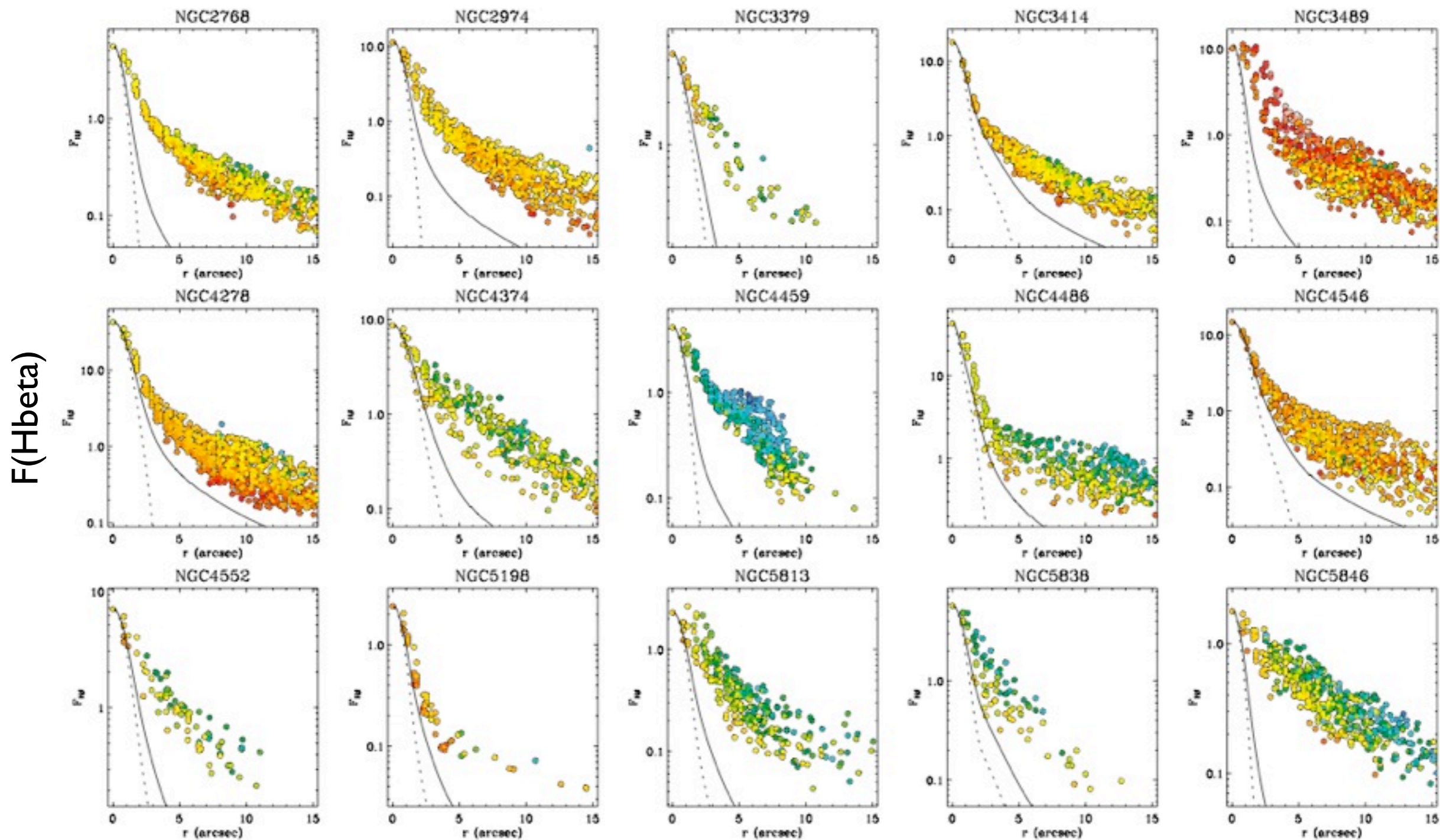
Black hole growth in early- and late-type galaxies is fundamentally different

Role of AGN on star formation history in early- and late-type galaxies likely also very different

Future: X-ray-selected AGN at z ~ 1 and beyond (Hubble Zoo!)

Extended LINER emission in SAURON early-type galaxies

F(Hbeta)

Radius (arcsec)

Sarzi+09, submitted

Kevin Schawinski