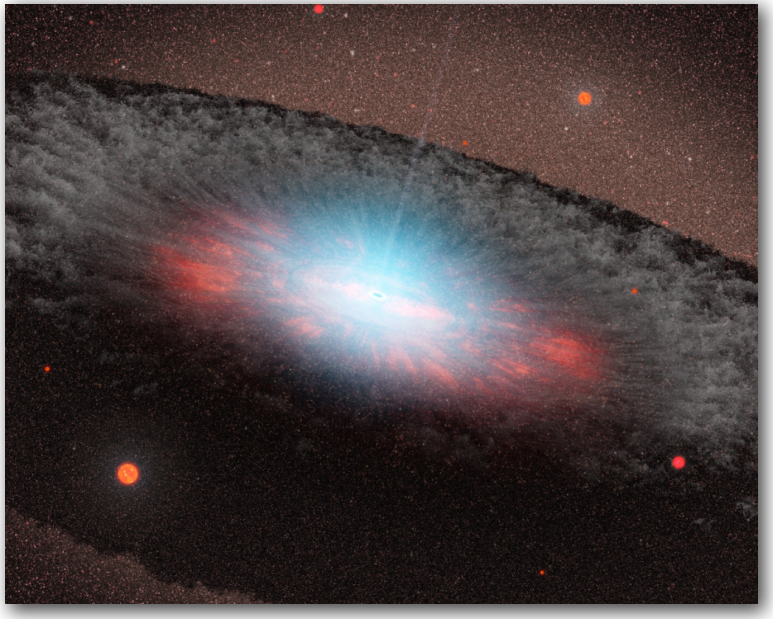
Black hole growth in the local universe



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

Why do galaxy and black hole growth trace each other?

Which galaxies host accreting black holes?

Do the AGN interact with their host galaxies?

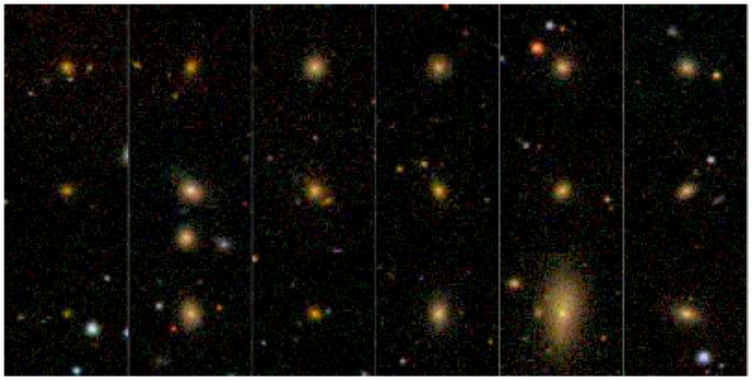
Data

SDSS DR7 - photometry & spectra for galaxies & AGN

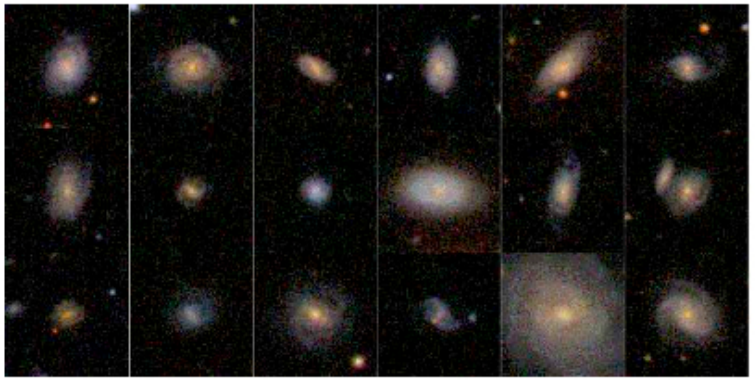
Galaxy Zoo 1 & 2 - detailed visual morphologies for
~1 million SDSS galaxies (publicly available soon!)
Over 230,000 members of the public involved

Galaxy Zoo Morphologies

Early-type



Face-on late-type

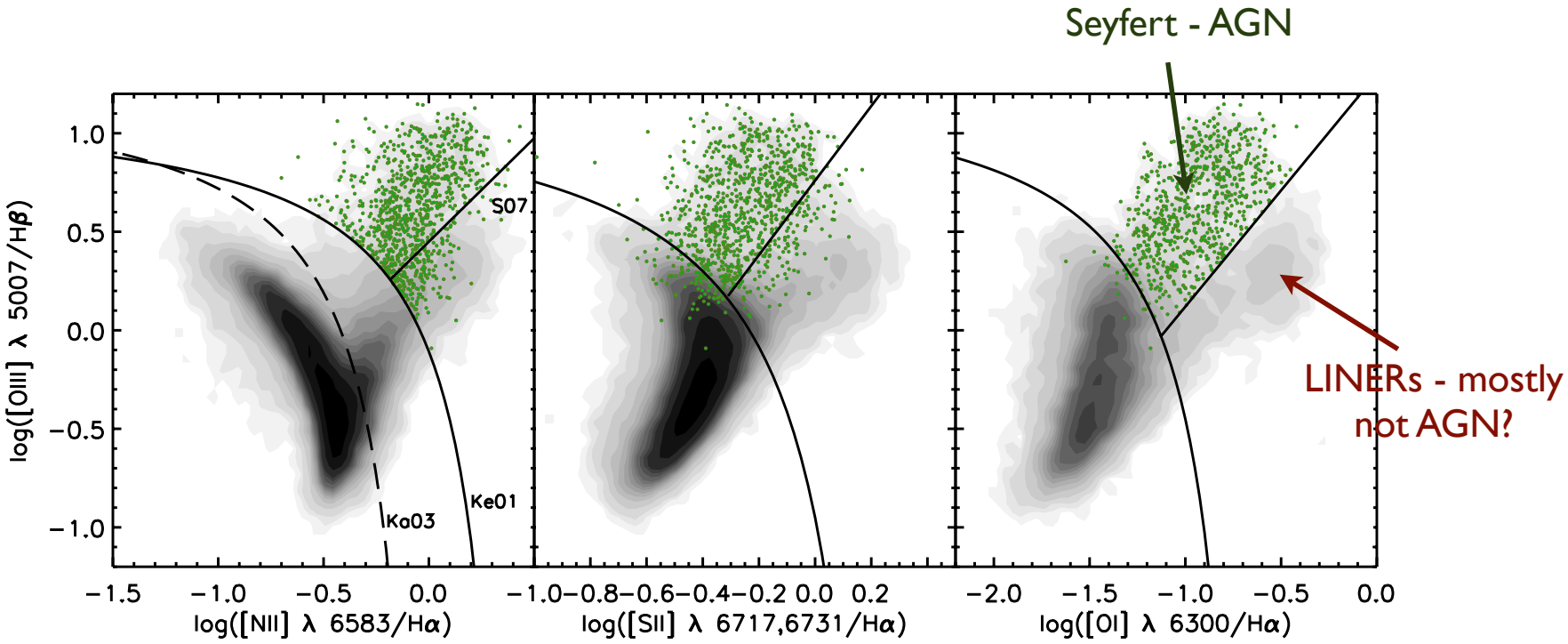


Lintott+08

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

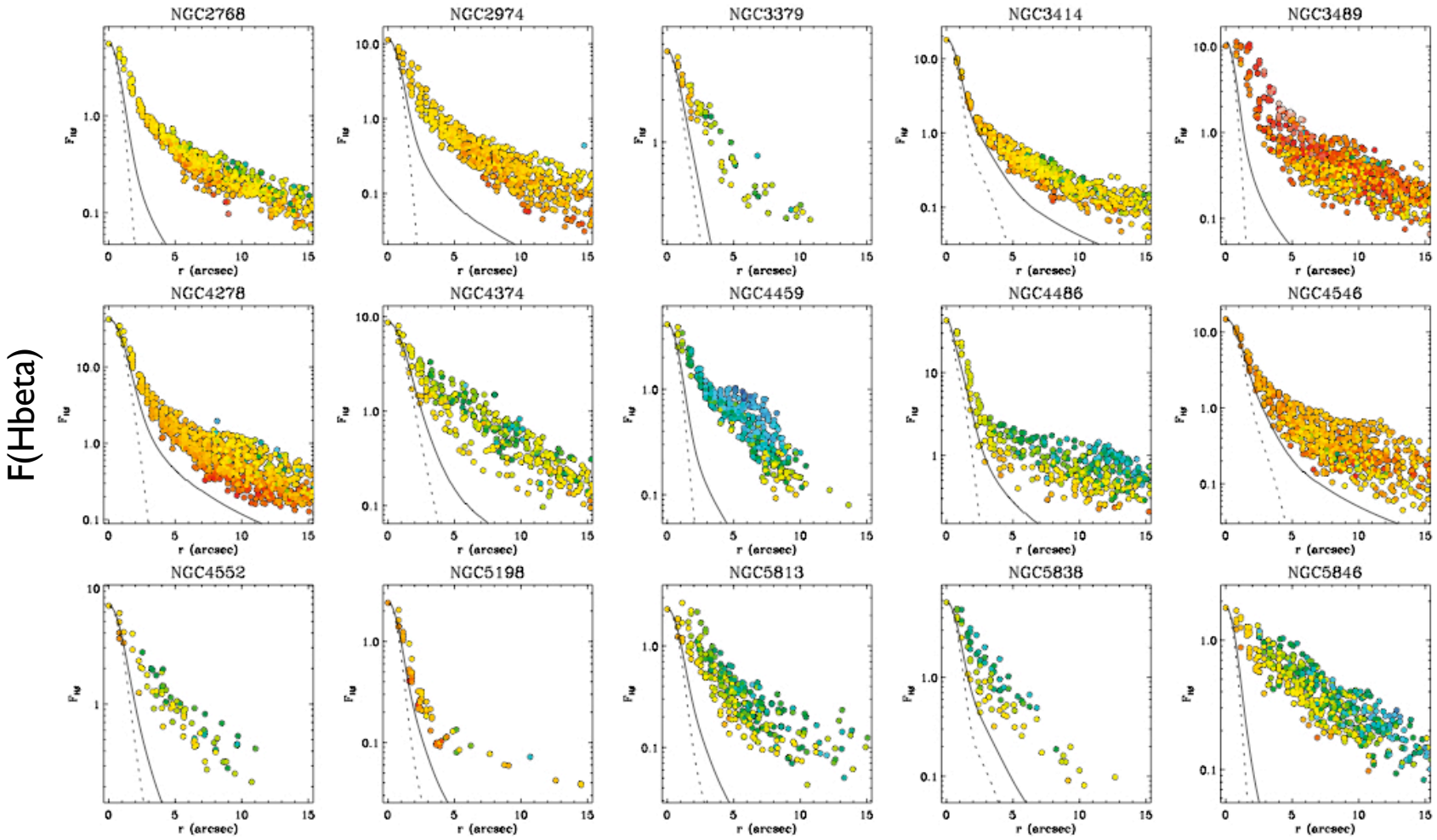
Avoids biases that plague automated methods that use colour, spectral information or structural parameters as a proxy for morphology.

AGN Selection via emission line diagnostics



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

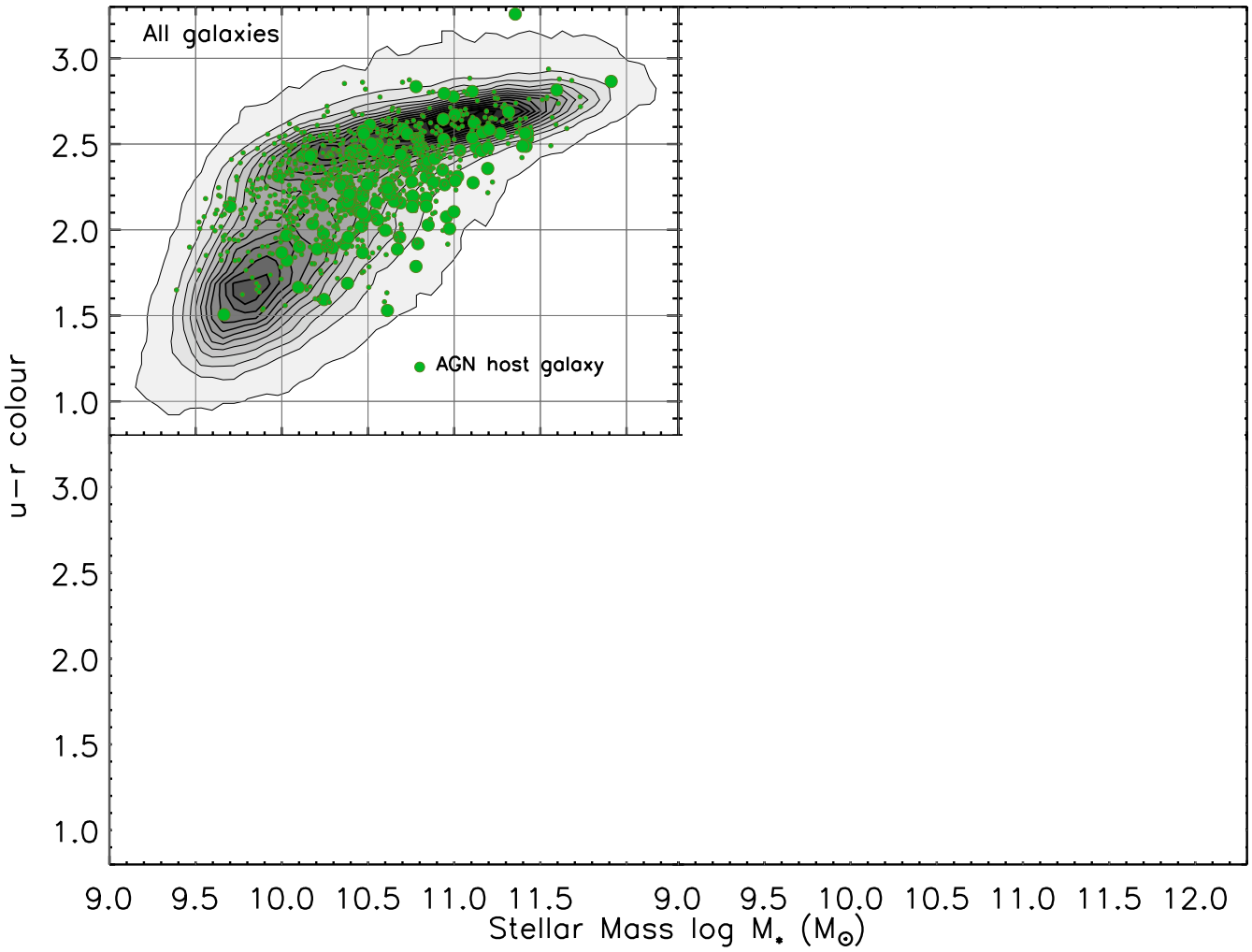
Extended LINER emission in SAURON early-type galaxies



Radius (arcsec)

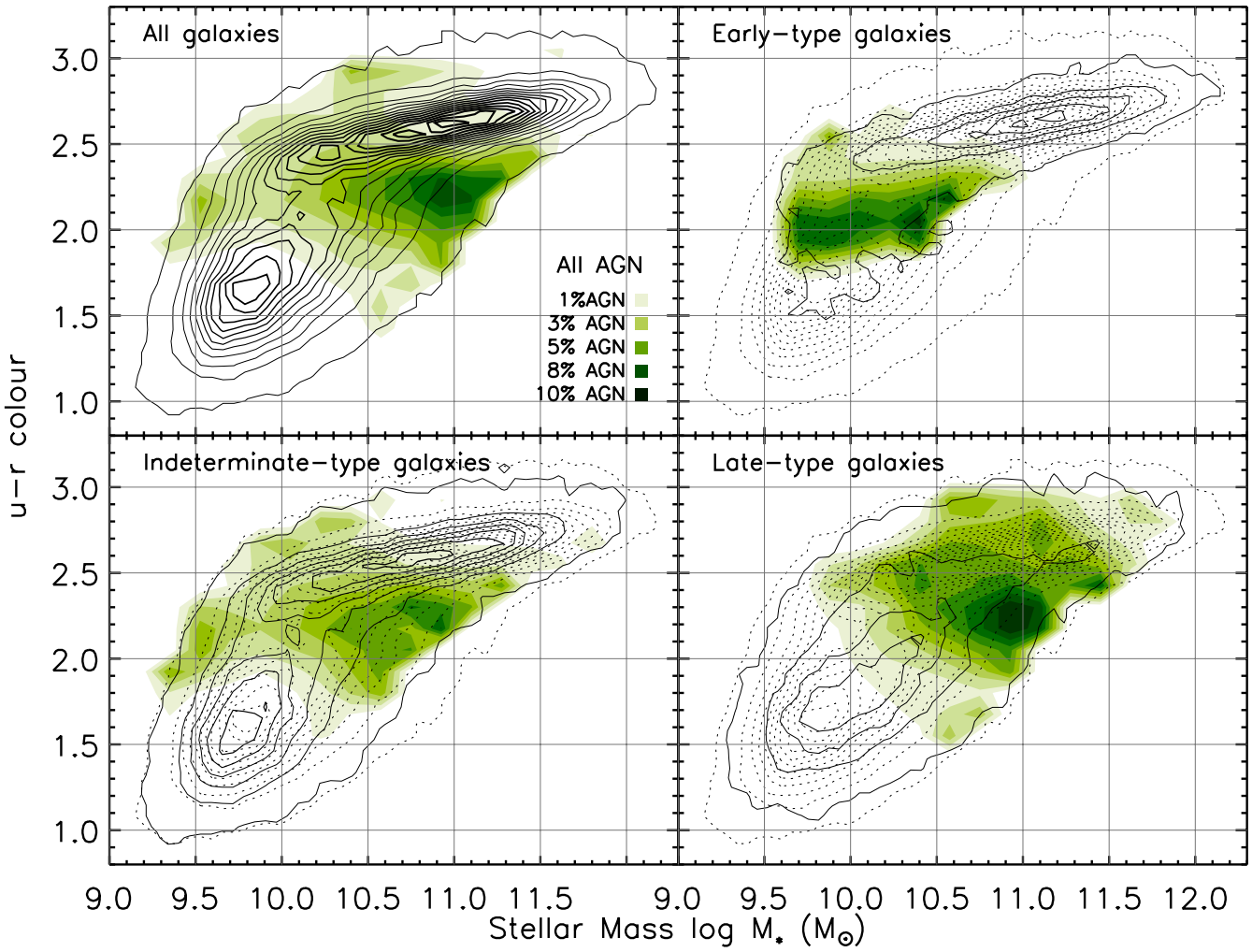
Sarzi, Shields, Schawinski+10

AGN host galaxies split by morphology



Schawinski+10a

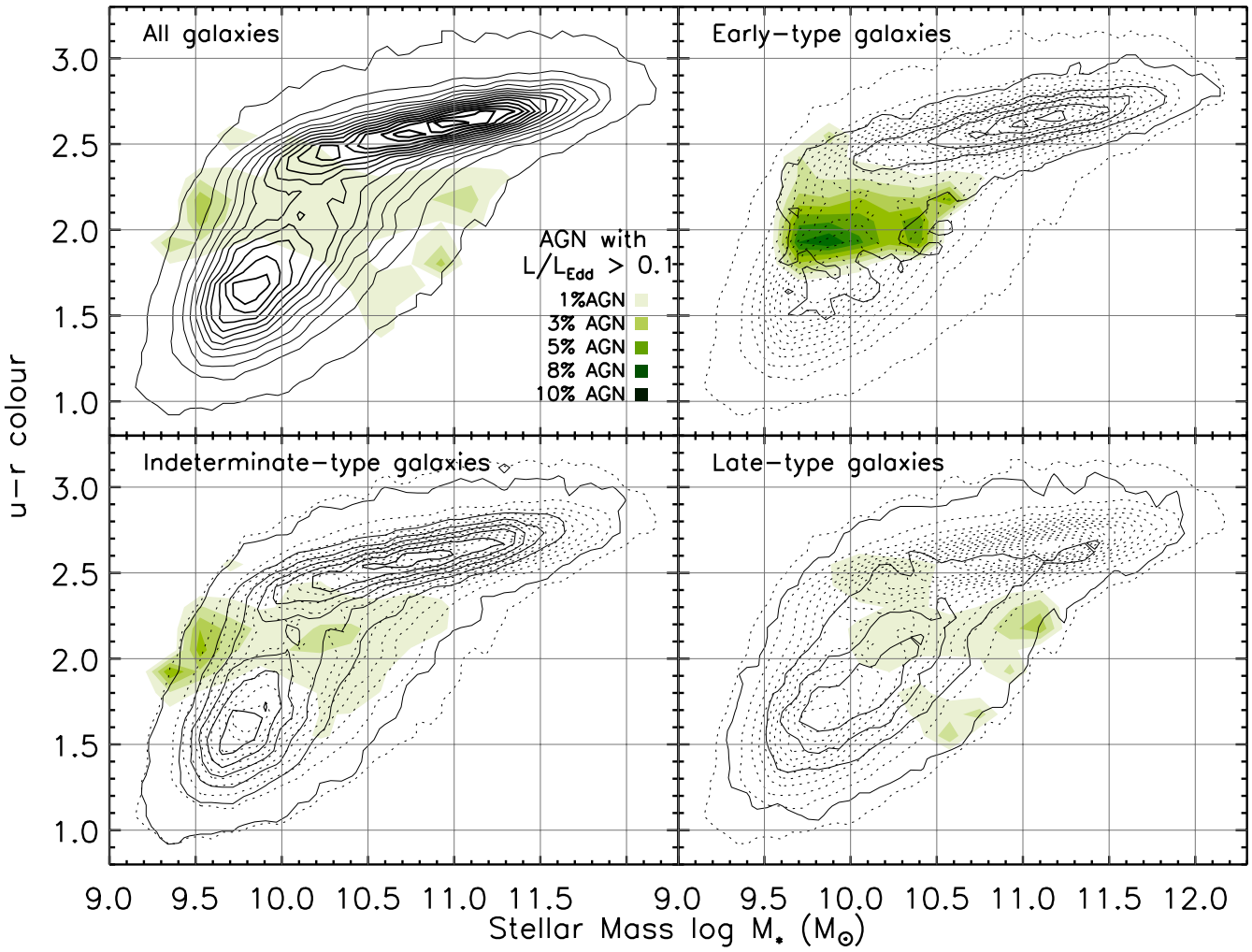
AGN duty cycle split by morphology



Schawinski+10a

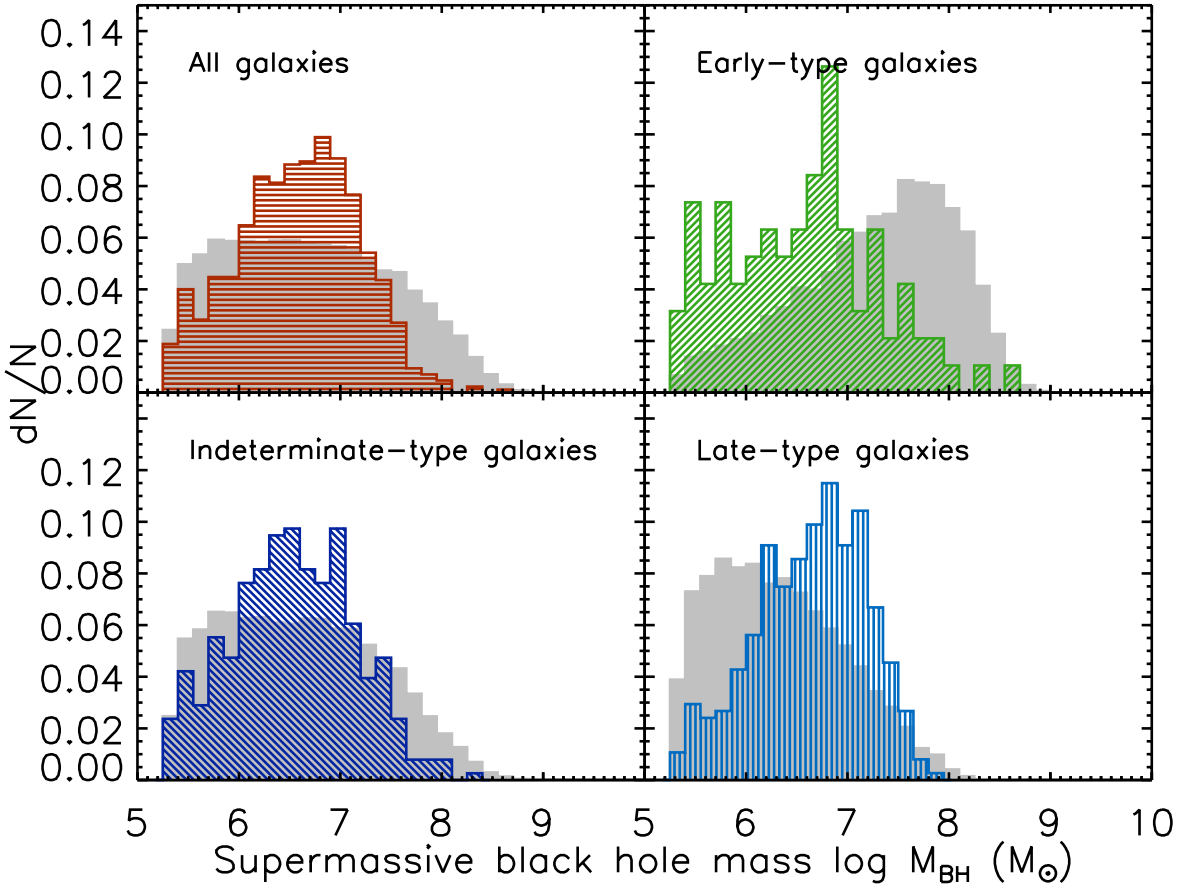
AGN duty cycle split by morphology

High Eddington ratio *only*



Schawinski+10a

Which black holes are growing?



Schawinski+10a

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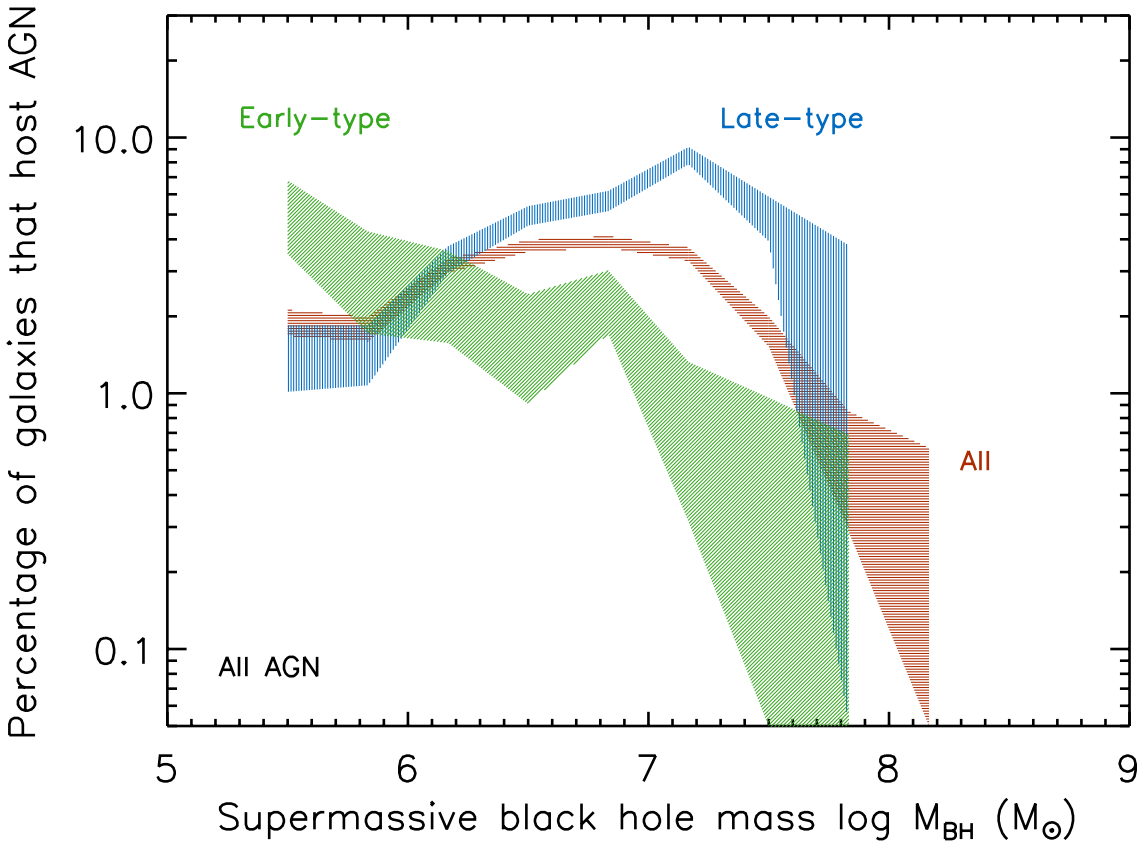
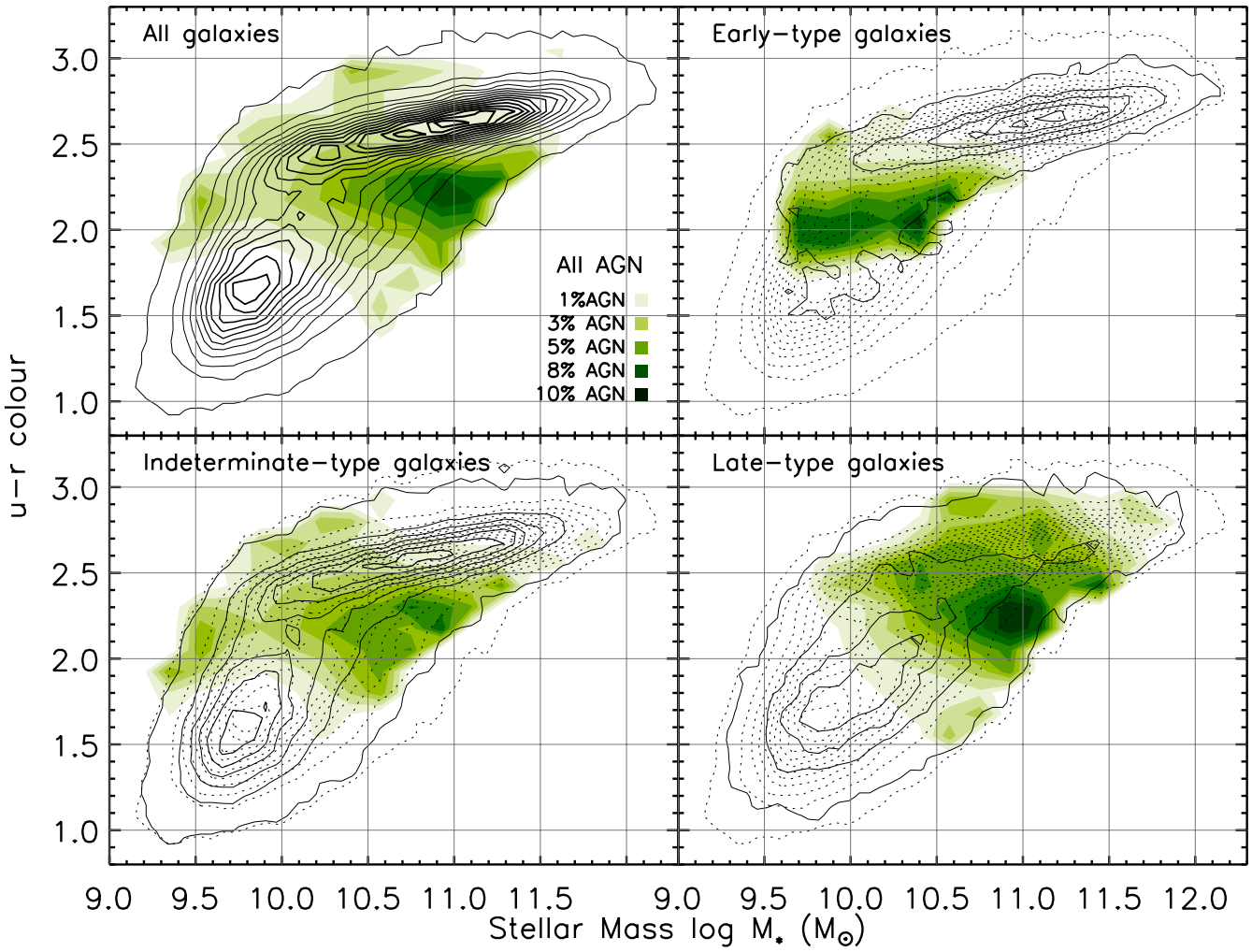


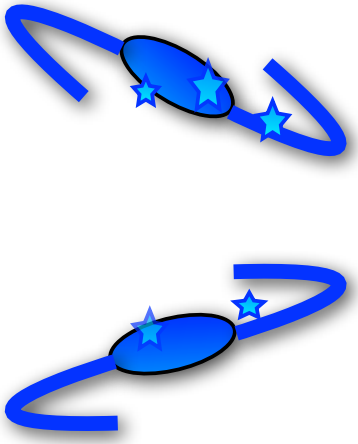
Schawinski+10a

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



Schawinski+10a

A Sequence of Events for AGN Feedback in the formation of early-type galaxies

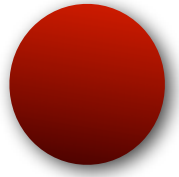


1. Initial approach triggered star formation

2. Violent relaxation major starburst

3. SMBH begins feeding, AGN sweeps up gas & dust

4. Post-starburst galaxy

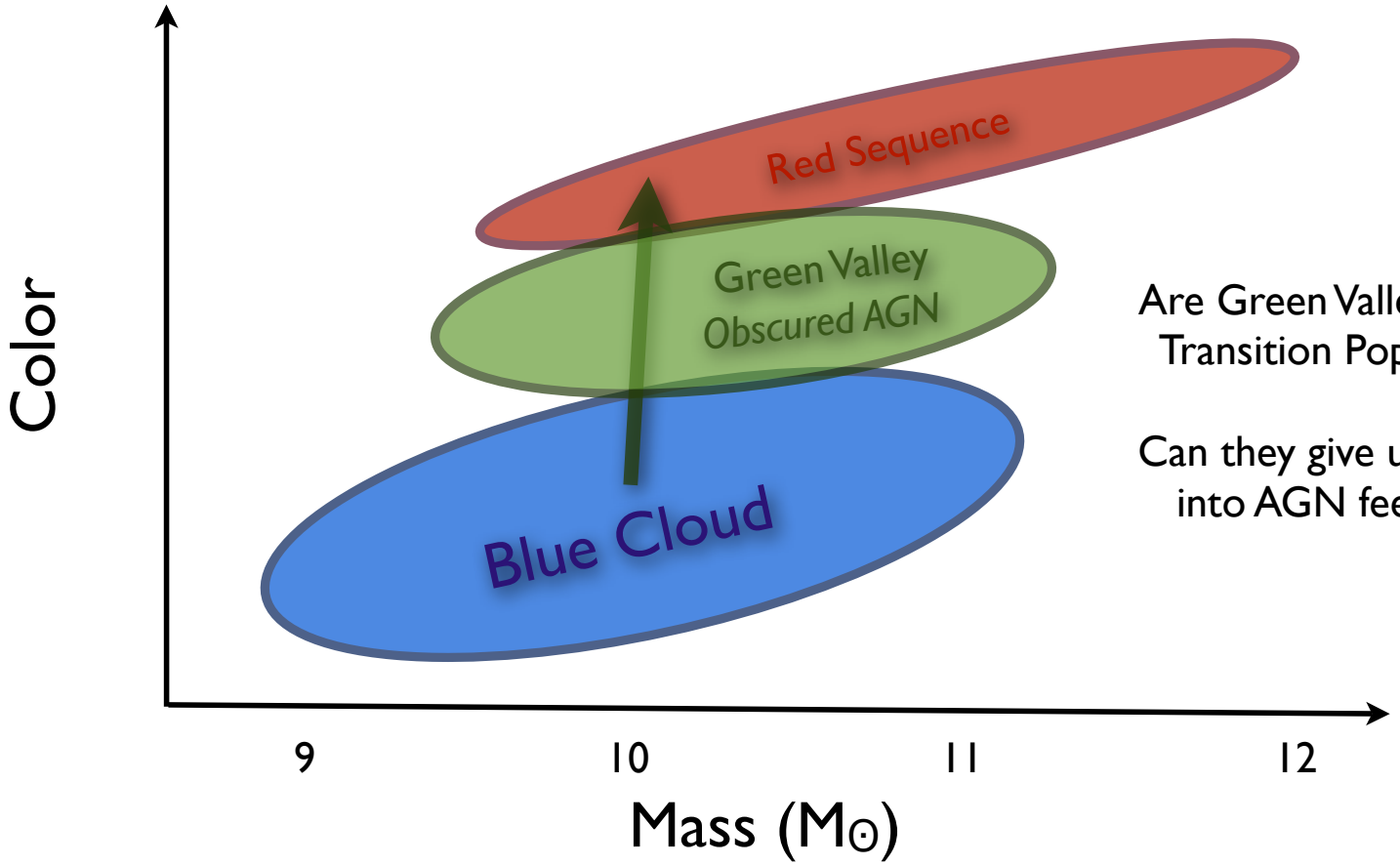


5. Passive early-type

Sanders et al. (1988), di Matteo et al. (2005), Springel et al. (2005), Hopkins et al. (2006), Johansson et al. (2009)

Observational Evidence forMigration from the blue cloud to the red sequence

...via an AGN phase in the green valley?



Are Green Valley AGN a Transition Population?

Can they give us insights into AGN feedback?

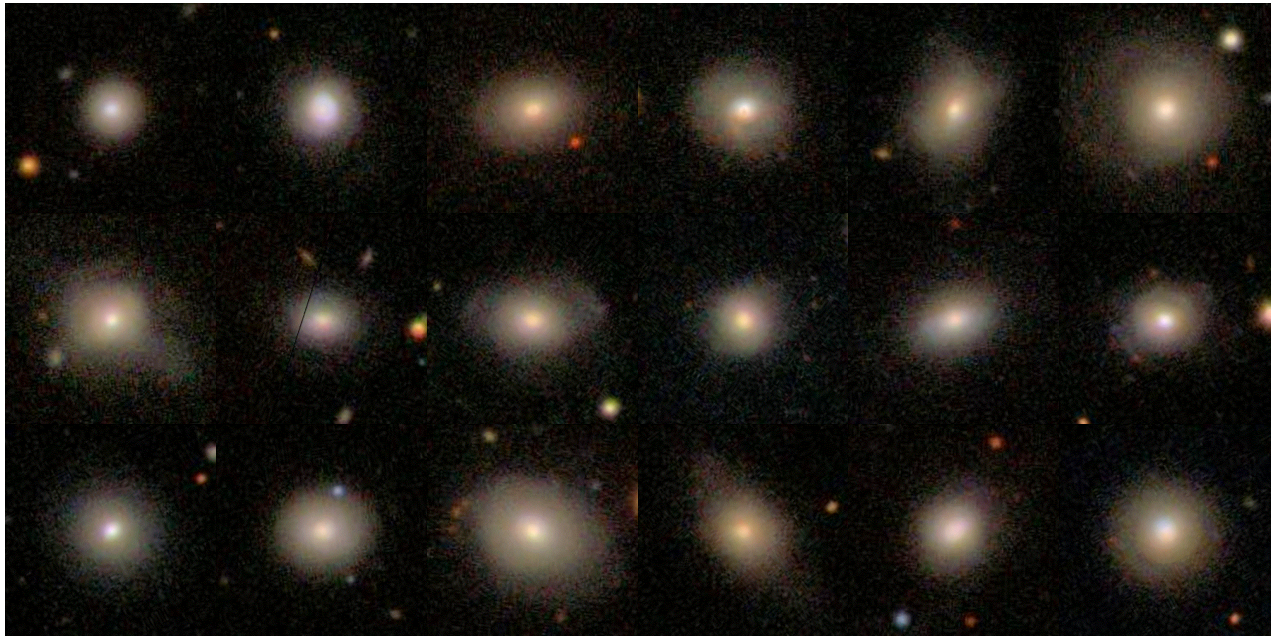
What does the Green Valley really mean?

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

but

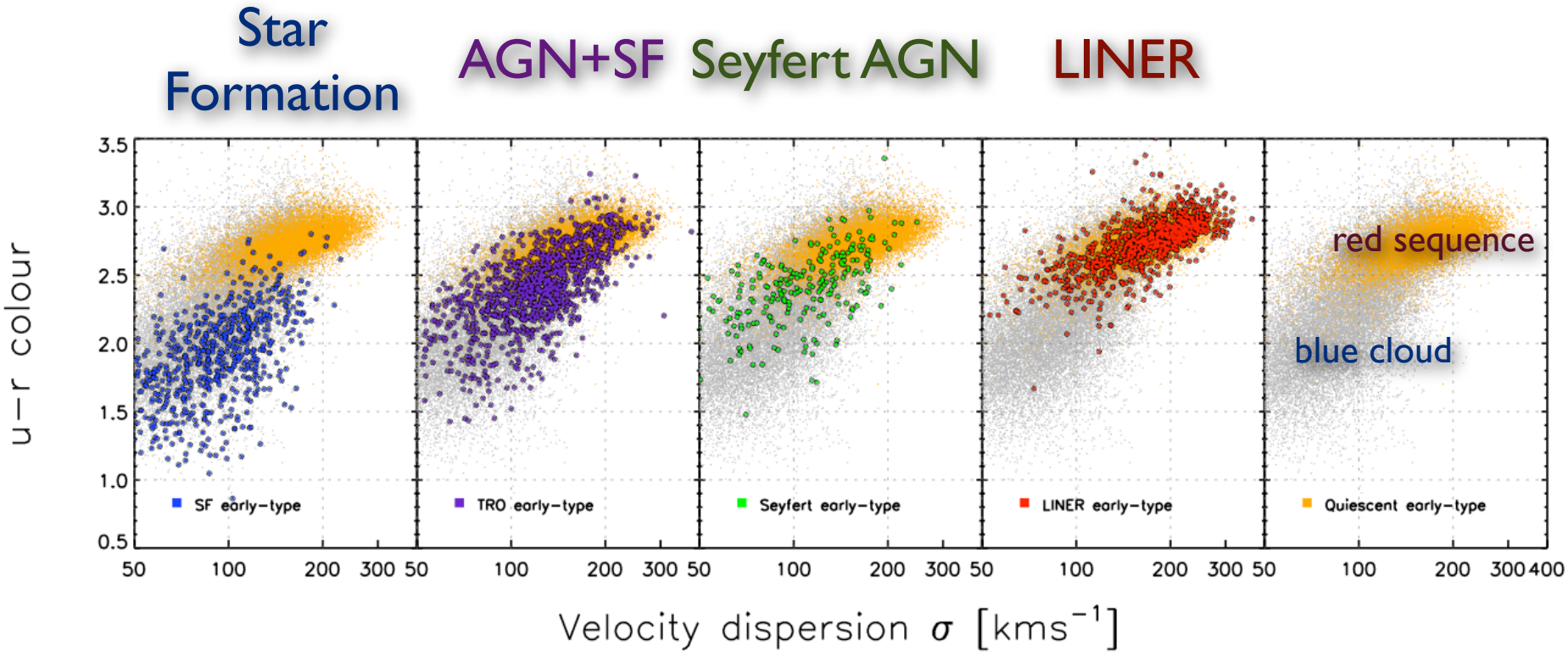
If star formation has recently been suppressed, then intermediate colours imply a time delay on the order of the lifetime of OB stars

Low-mass active early-types in SDSS



Schawinski et al. 2009, MNRAS

SDSS reveals an evolutionary sequence



Schawinski+07

Is this a genuine sequence? Are the AGN a part of it?

A Method for Recovering Star Formation Histories

Breaking degeneracies

1. Parameterisation

Describe the SFH as a two-component model

Derive age & mass-fraction of most recent burst.

- Old component – SSP (Maraston 2005)
- Young Component – CSP (exponential, t=100 Myr)
- Dust (Calzetti 2001)
- Metallicity from -1.3 < [Z/H] < +0.67 including asymmetric internal distribution

2a. Fitting Broad-band Photometry

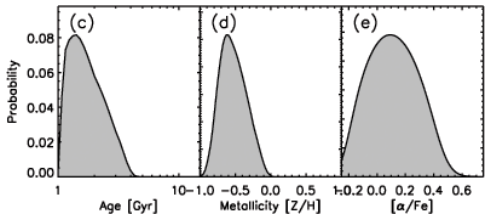
Fit the photometry: FUV, NUV, u, g, r, i, z, J, H, K

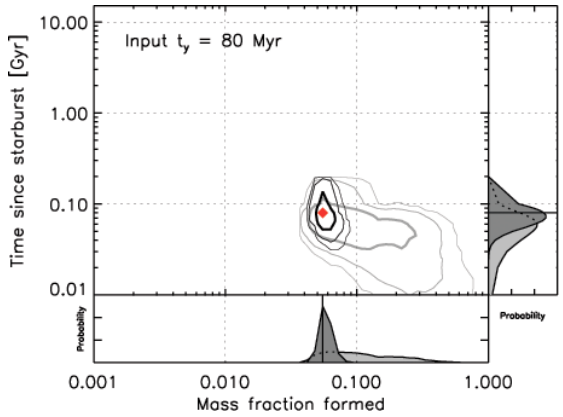
Compute χ^2 for 5-d array. Total of ~5 million SFHs.

2b. Lick indices

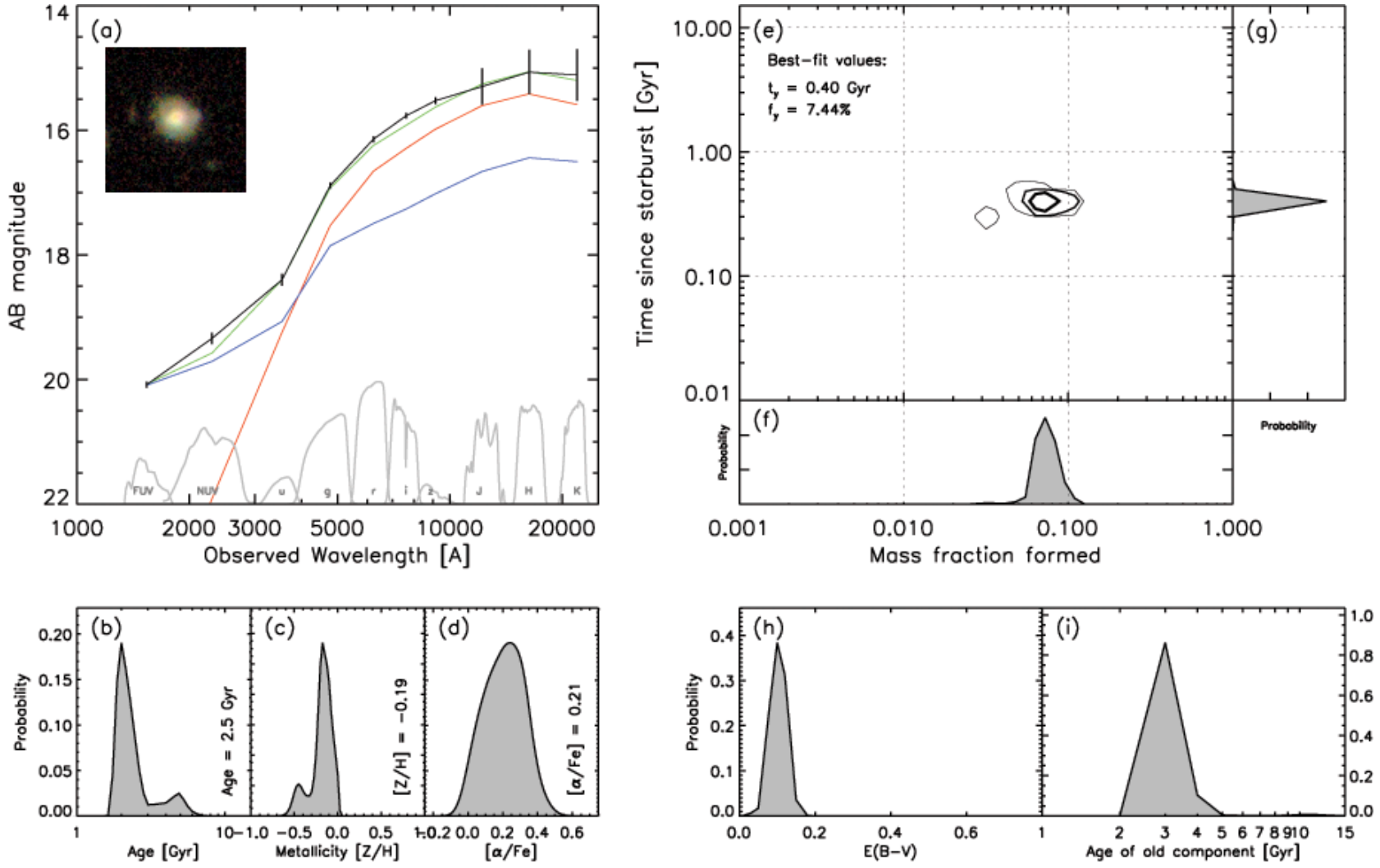
Fit the 25 stellar absorption indices (Lick system) to models (Thomas, Maraston & Bender 2003) to get *spectroscopic* age & metallicity.

3. Combine the two Results



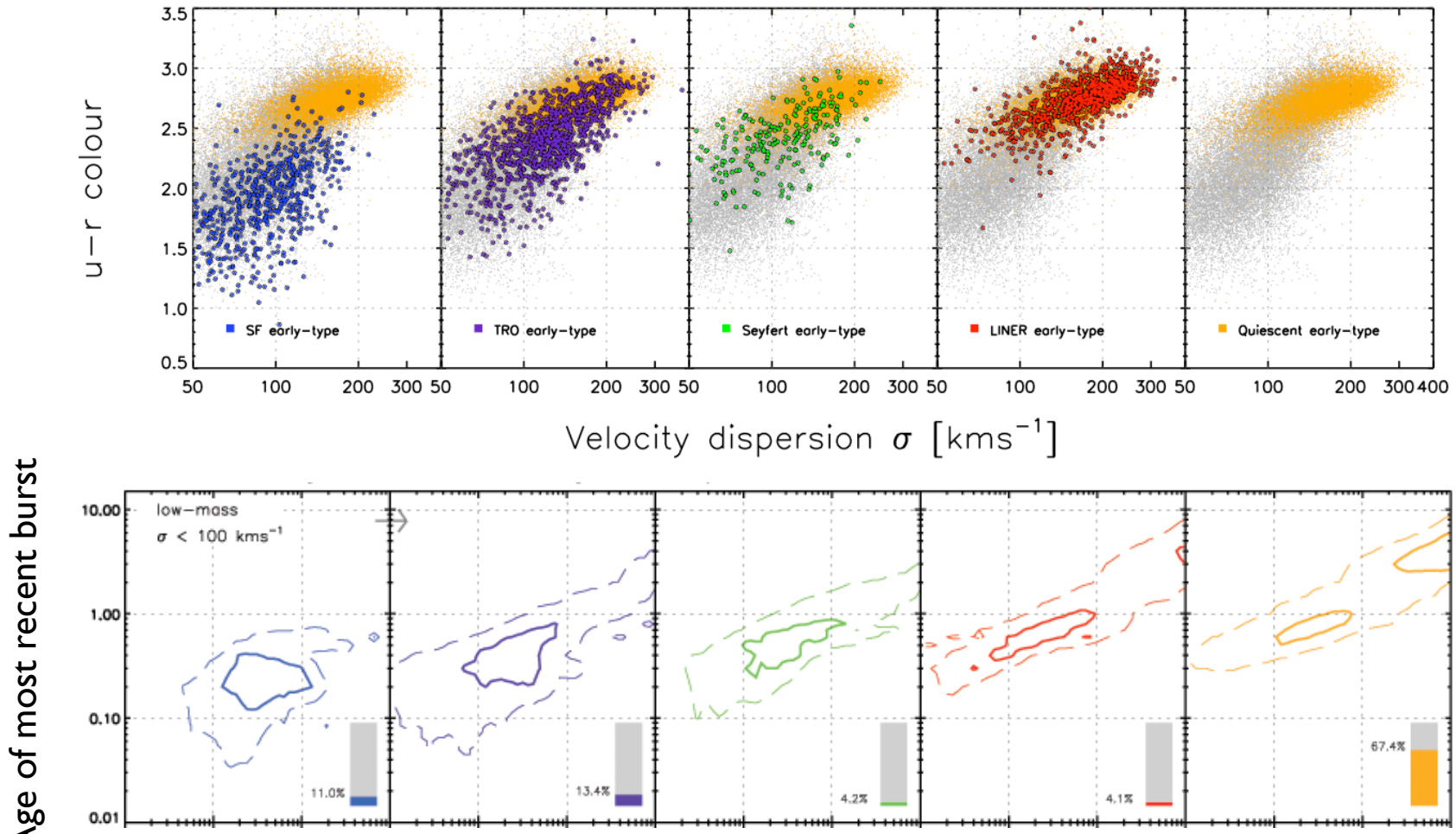


Application to Real Galaxies



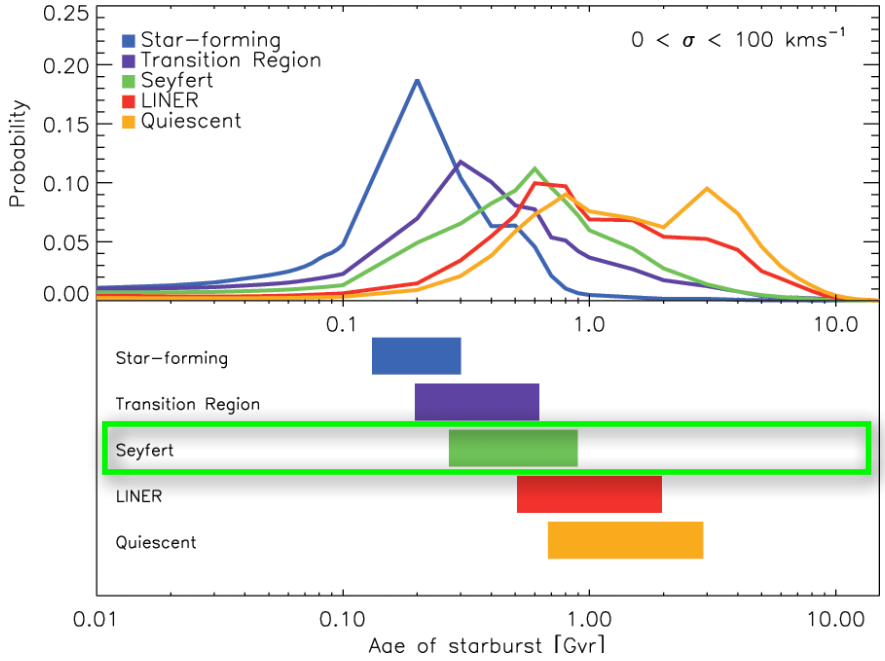
Schawinski+07

Recovered Star Formation Histories



Schawinski+07

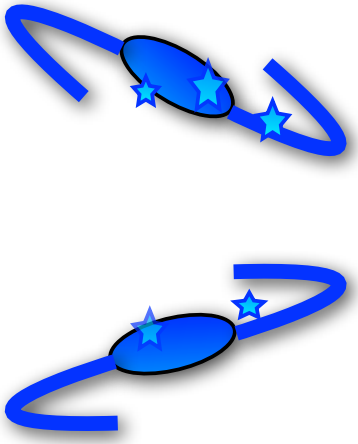
So, are we seeing AGN feedback suppressing star formation?



Transition time scales pose challenge!

Seyfert (moderate-luminosity obscured AGN) only become important ~0.5 Gyr after shutdown of star formation.

A Sequence of Events for AGN Feedback in the formation of early-type galaxies



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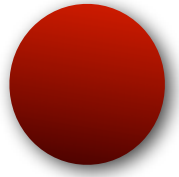
2. Violent relaxation major starburst

3. ~~SMBH begins feeding, AGN sweeps up gas & dust~~

SF shuts down

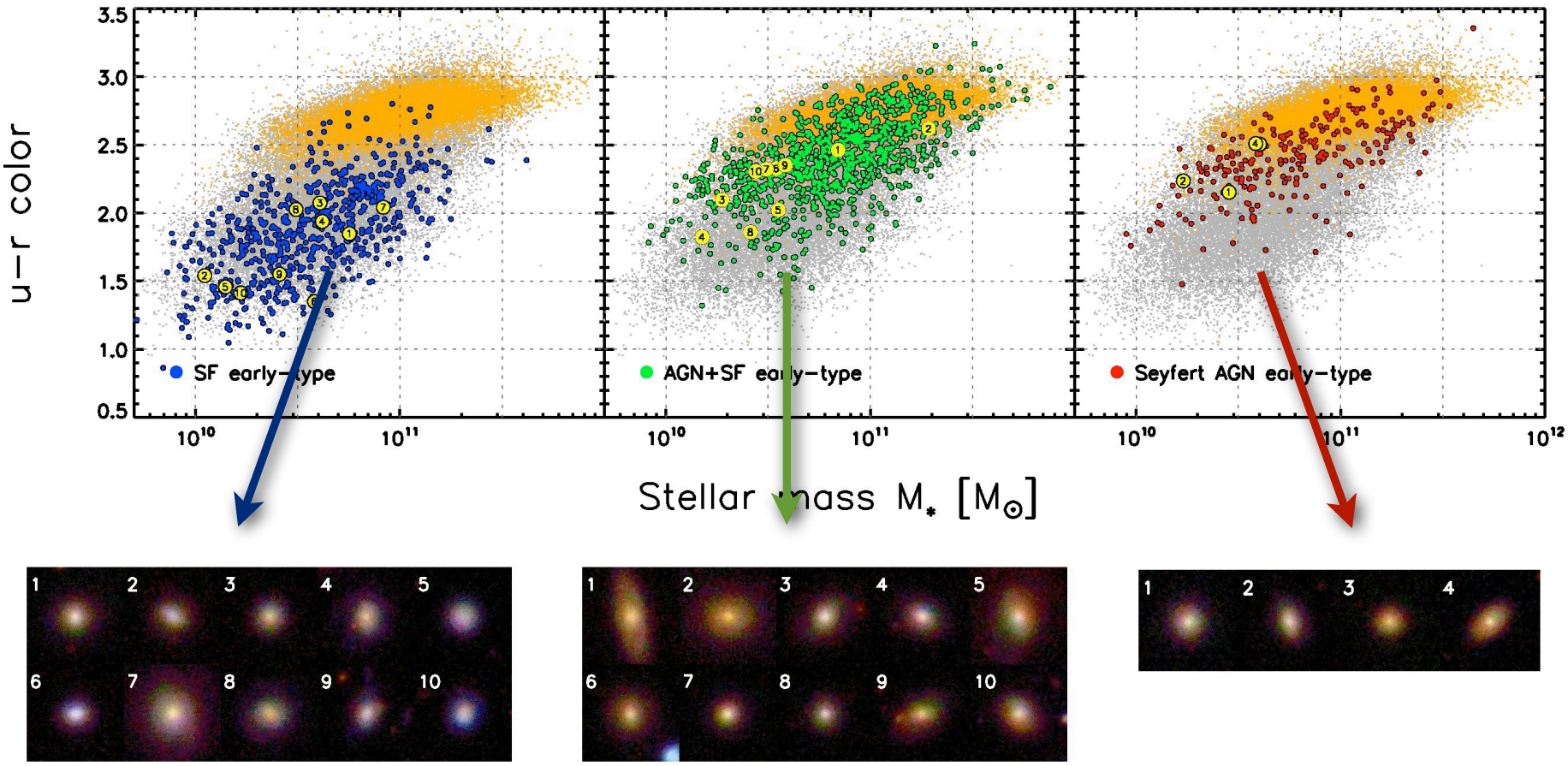
4. Post-starburst galaxy

+ AGN



5. Passive early-type

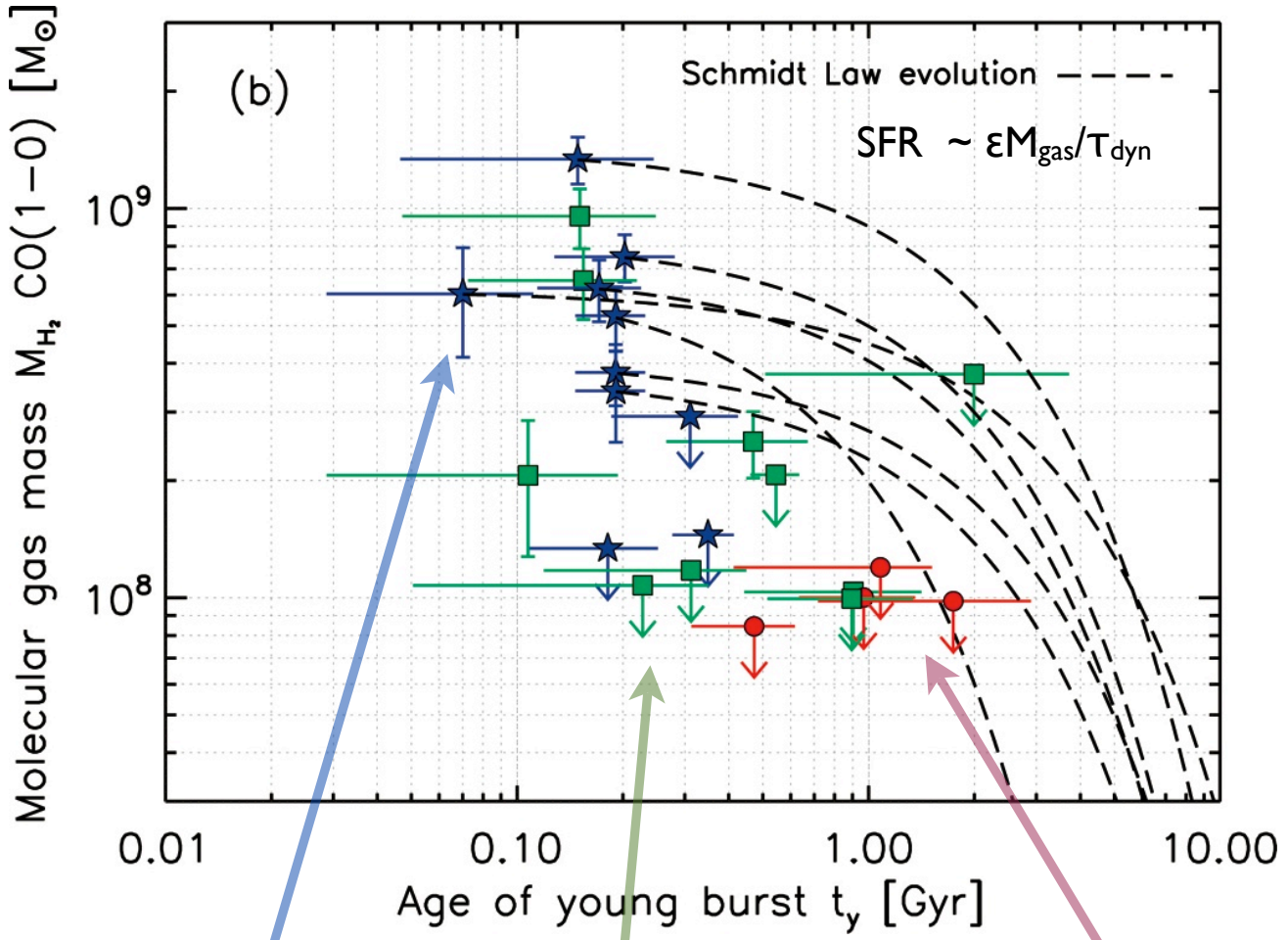
Tracing the fate of molecular gas



Starforming AGN+SF Seyfert AGN

Schawinski et al. 2009, ApJ, 690, 1672

Can we rescue AGN feedback?



Starforming

AGN+SF

Seyfert AGN

Schawinski et al. 2009, ApJ, 690, 1672

A Sequence of Events for AGN Feedback in the formation of early-type galaxies

Could there be AGN hiding here already?

1. Initial approach triggered star formation

2. Violent relaxation major starburst

3. ~~SMBH begins feeding, AGN sweeps up gas & dust~~

SF shuts down

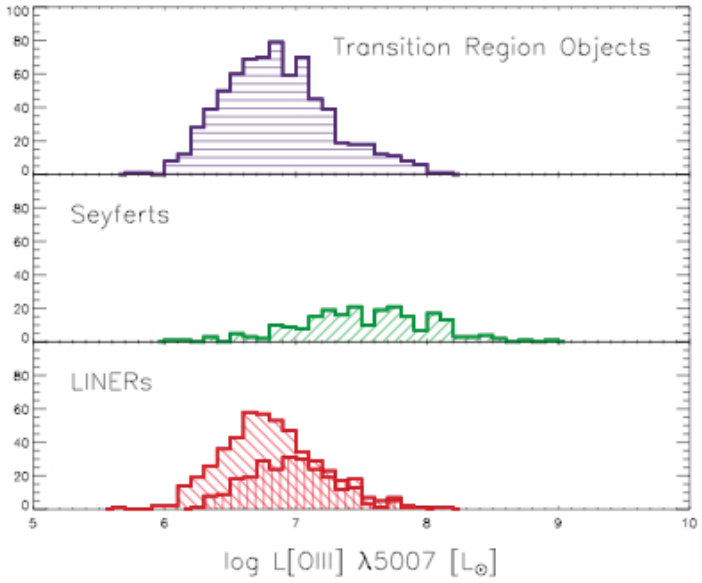
LL AGN switches on... *Coincidence?*

4. Post-starburst galaxy

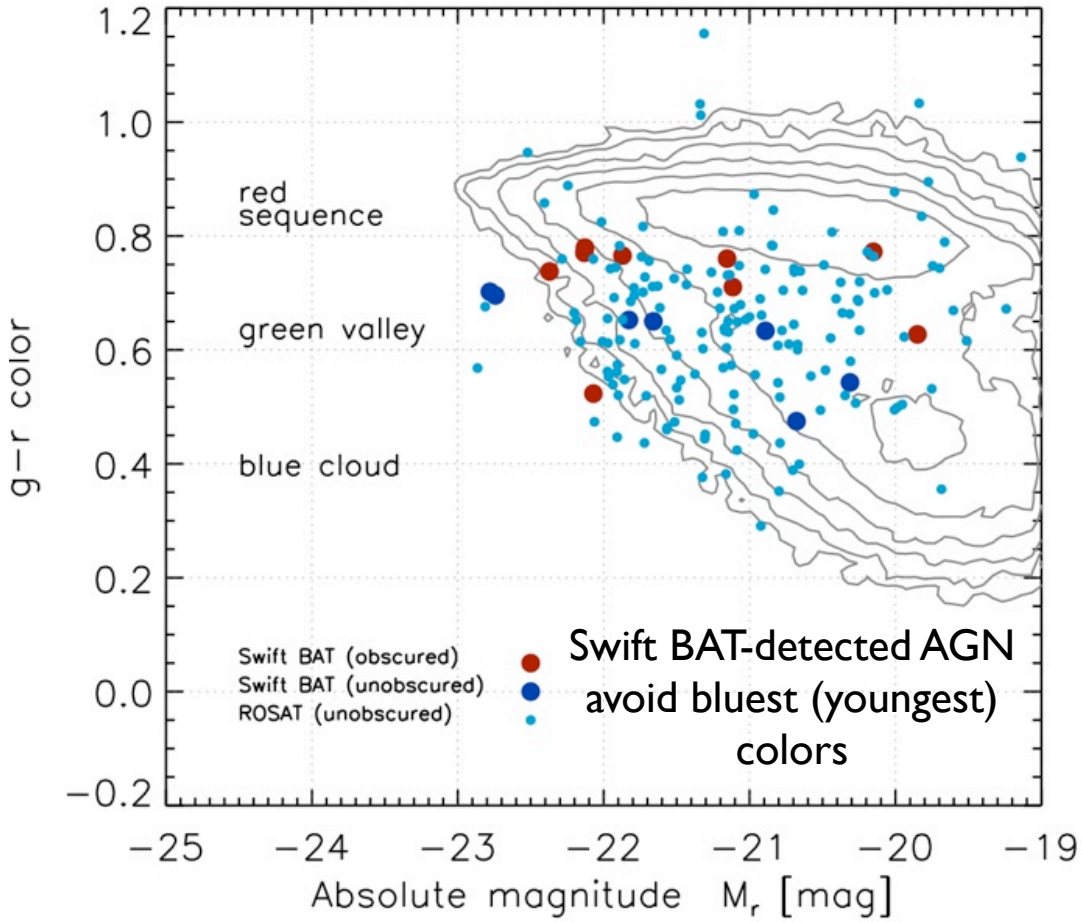
+ AGN

5. Passive early-type

Unlikely!



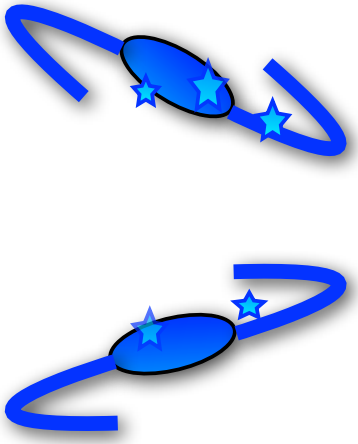
L[OIII] increases w/ time



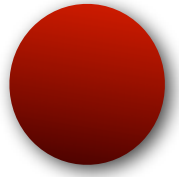
Swift BAT-detected AGN avoid bluest (youngest) colors

A Sequence of Events for AGN Feedback in the formation of early-type galaxies

What about the trigger?



No luminous AGN present



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3. ~~SMBH begins feeding, AGN sweeps up gas & dust~~

SF shuts down

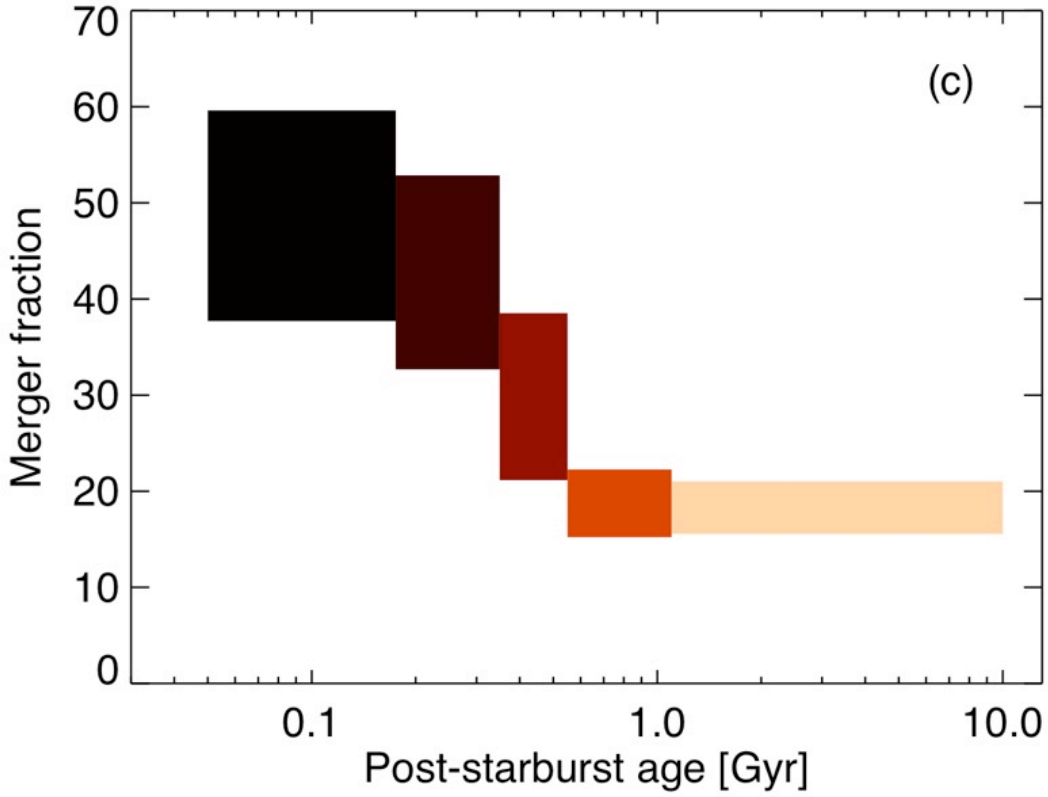
LL AGN switches on... *Coincidence?*

4. Post-starburst galaxy

+ AGN

5. Passive early-type

Mergers trigger the migration from the blue cloud to the red sequence



Schawinski+10b

Summary

Early-type galaxies **continue to build** or return to the low-mass end of the red sequence.

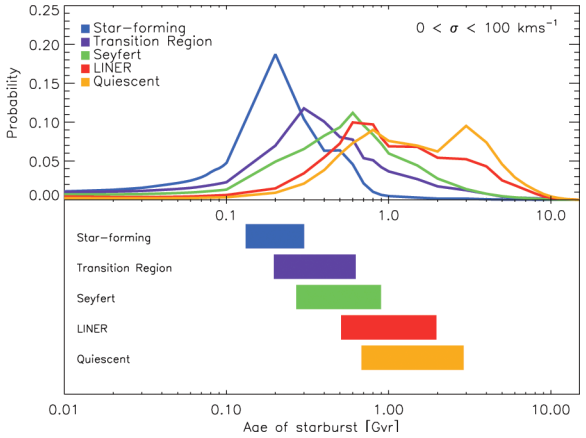
Time sequence of events includes a slow rise of AGN peaking in the green valley **~0.5 Gyr after shutdown**.

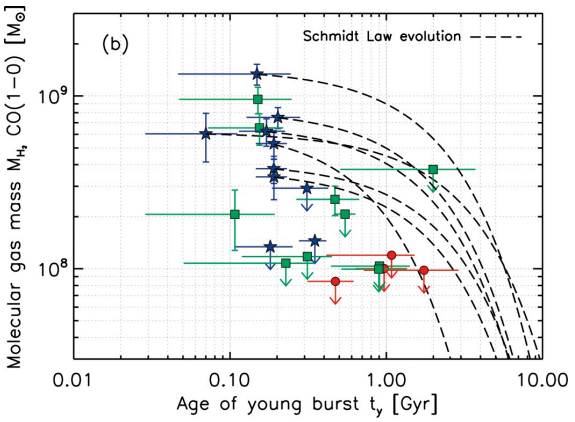
Molecular gas disappears **extremely rapidly** ~200 Myr after start of current starburst and **coincides with low-L AGN phase** -> kinetic feedback?

High-L AGN phase **too late** for suppression and cannot be responsible for shutdown of SF.

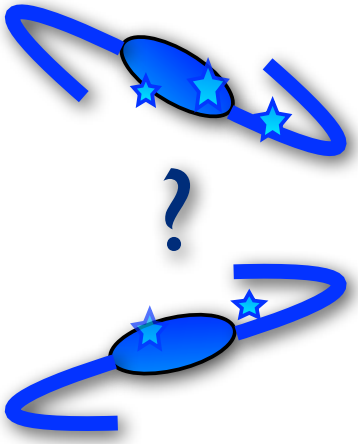
Up to 90% of local black hole growth is **not associated** with this movement of spheroidal galaxies to the red sequence - what do AGN do in late-type galaxies?

<u>Time scales are a major puzzle!</u>





A Sequence of Events for AGN Feedback in the formation of early-type galaxies

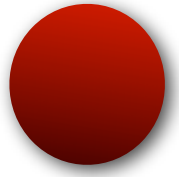


1. Initial approach triggered star formation

2. Violent relaxation major starburst

3. LL AGN switches on
-
at the same time SF is shut down as H_2 reservoir is destroyed

4. Post-starburst galaxy hosting Seyfert AGN



5. Passive early-type

Thank you!