Cosmic Accretion & Galaxy Co-Evolution:
Lessons from the Extended Chandra Deep Field South

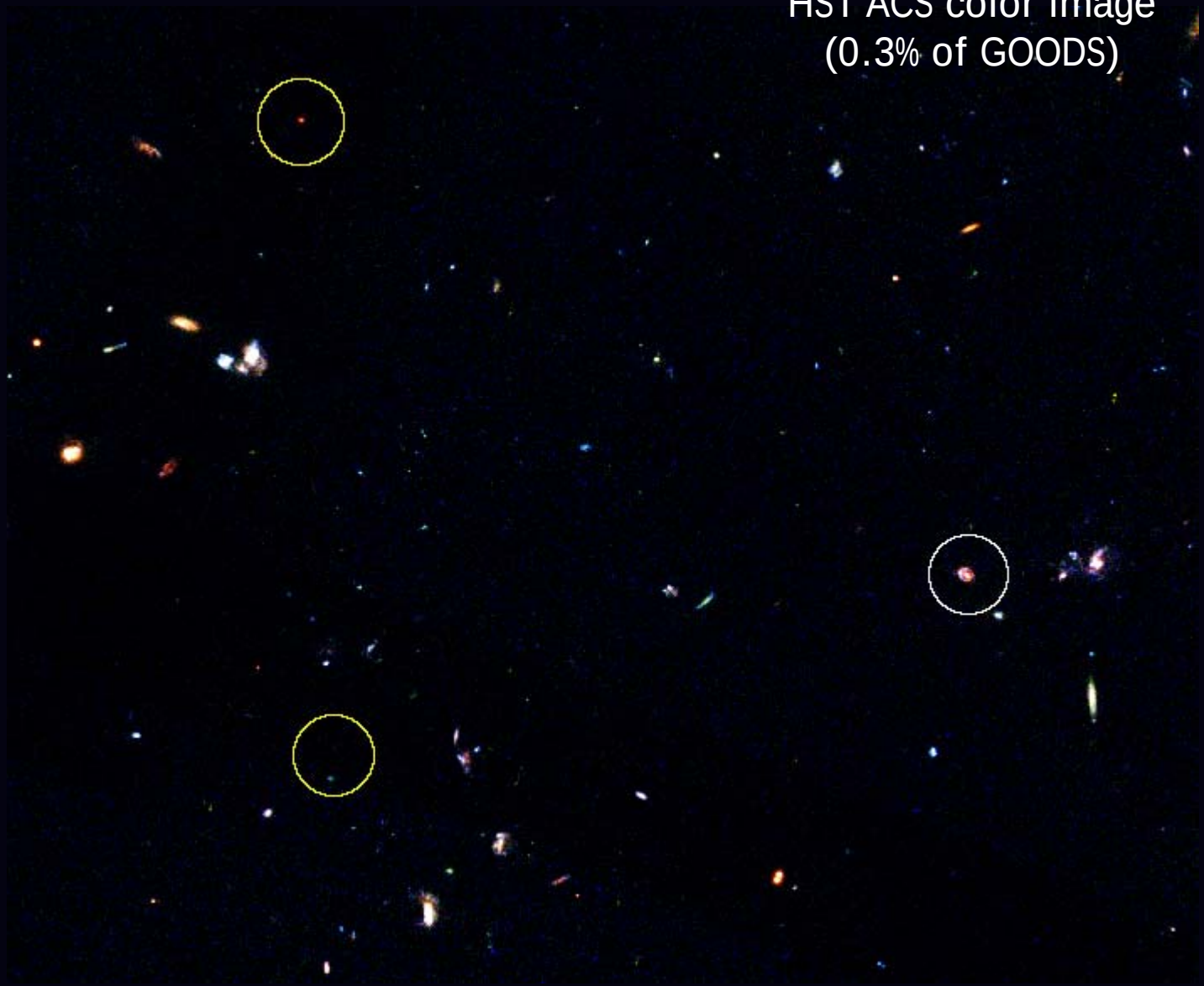
Meg Urry
Yale University

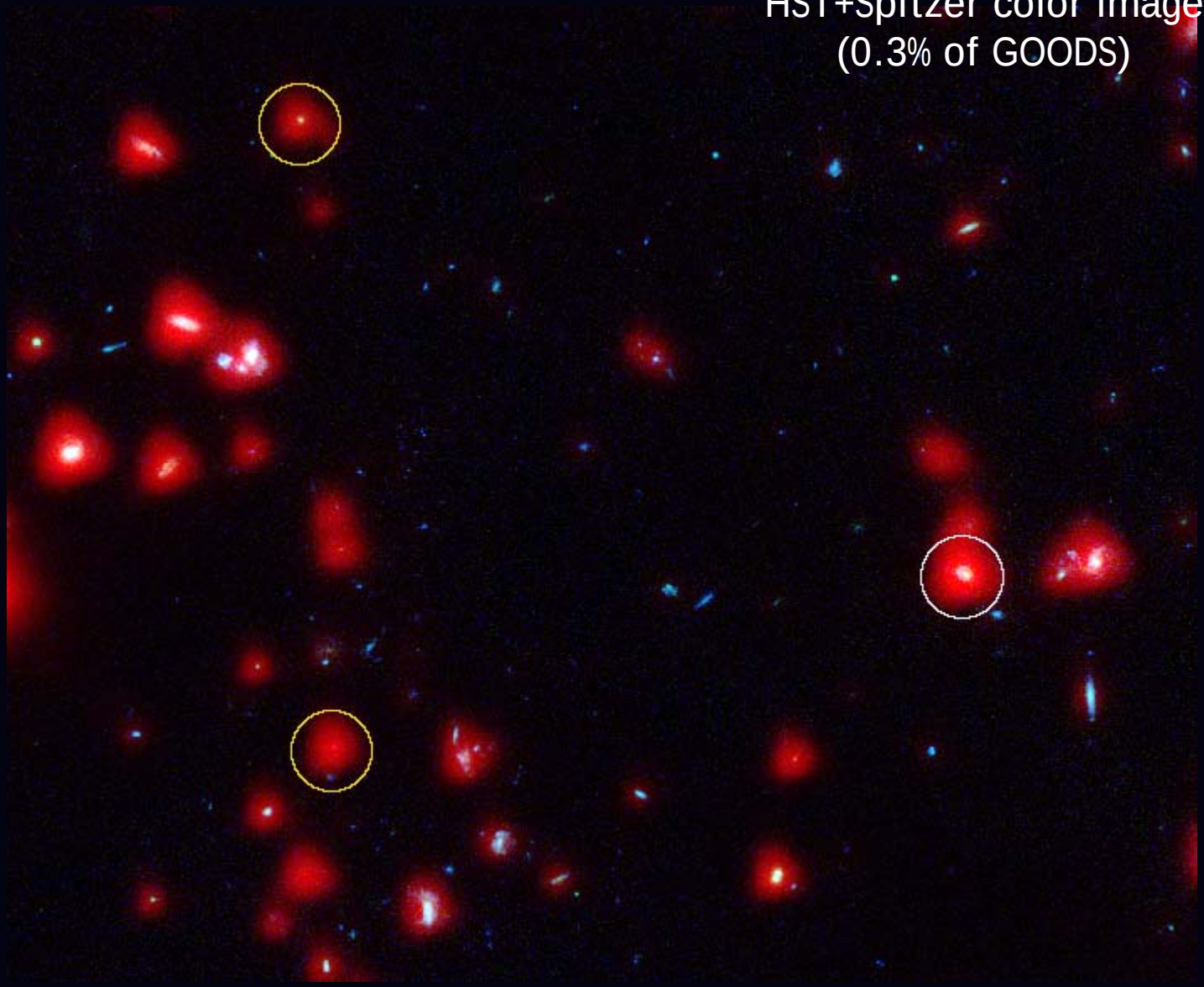
λλλ surveys → most BH growth obscured

- Faint red X-ray sources in GOODS, ECDFS, MUSYC, COSMOS, AEGIS, SWIRE, Lockman Hole, HDF-N/S, NDWFS, XBootes, ChaMP, …
- Treister et al. population synthesis model: *2004,2005,2006a,b, 2009a,b,2010a,b*
  - Fits LogN-LogS *infrared, optical, X-ray, γ-ray*
  - Fits local Seyfert SEDs L_X, N_H → *SED shape + normalization*
  - Fits AGN redshift distribution *optically faint "galaxies"*
  - Fits X-ray "background" *please see 2005, 2009 papers*
  - Obscuration increases w redshift N_H, *narrow lines, infrared*
  - Origin of quasars: mergers of gas rich galaxies *Science*
  - "Compton-thick AGN" poorly constrained beyond z~0 ***NuSTAR***
- Absorbed energy re-radiated in **infrared**

Also Fiore et al. 2008, 2009, Daddi et al. 2007, Georgantopoulos et al. 2008


GOODS
CMU, Giavalisco, Dickinson, Cesarsky, Giacconi, Bergeron ...


HST ACS color image
(0.3% of GOODS)

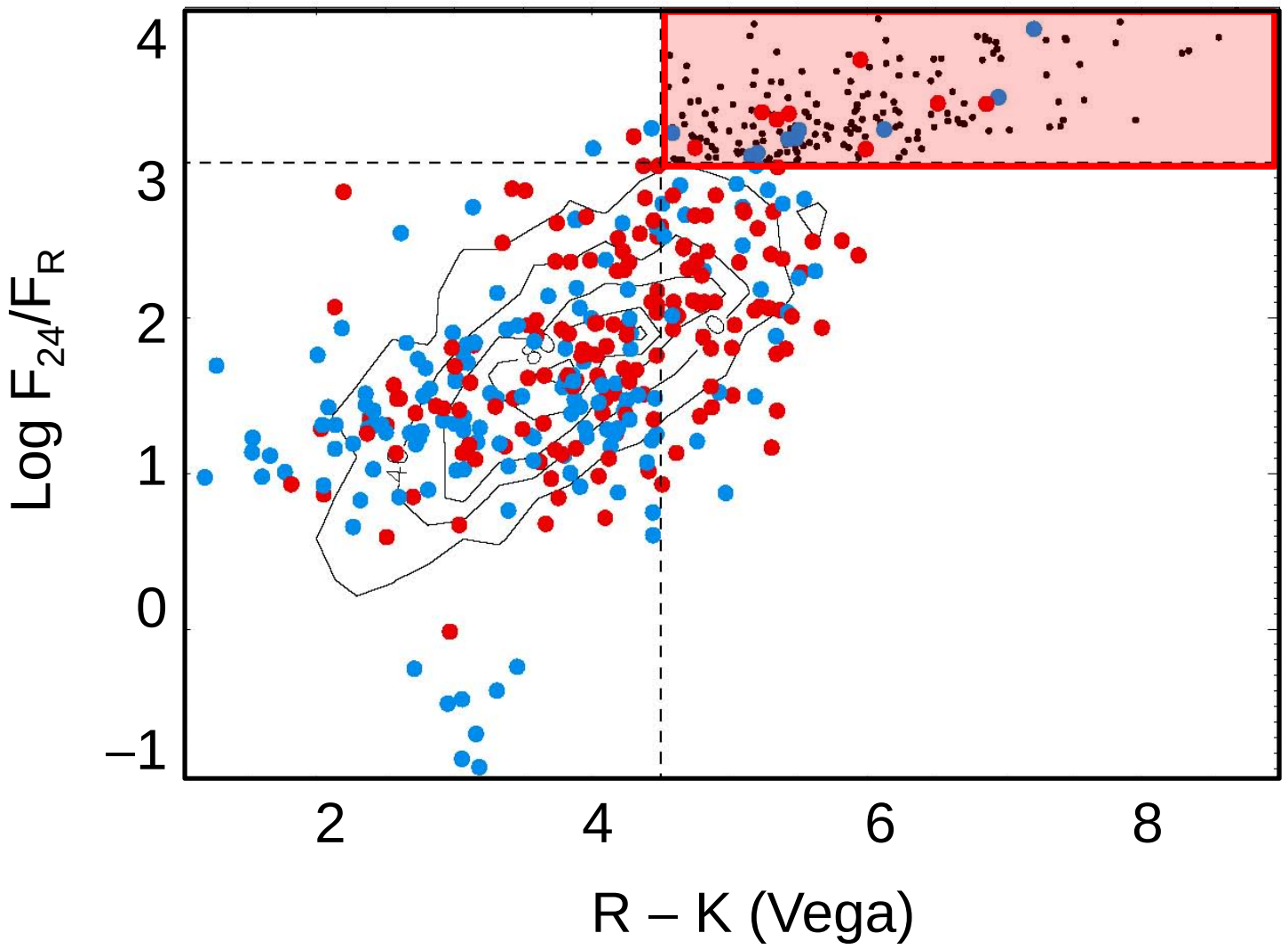

HST+Spitzer color image
(0.3% of GOODS)

Missing: heavily obscured AGN at high z

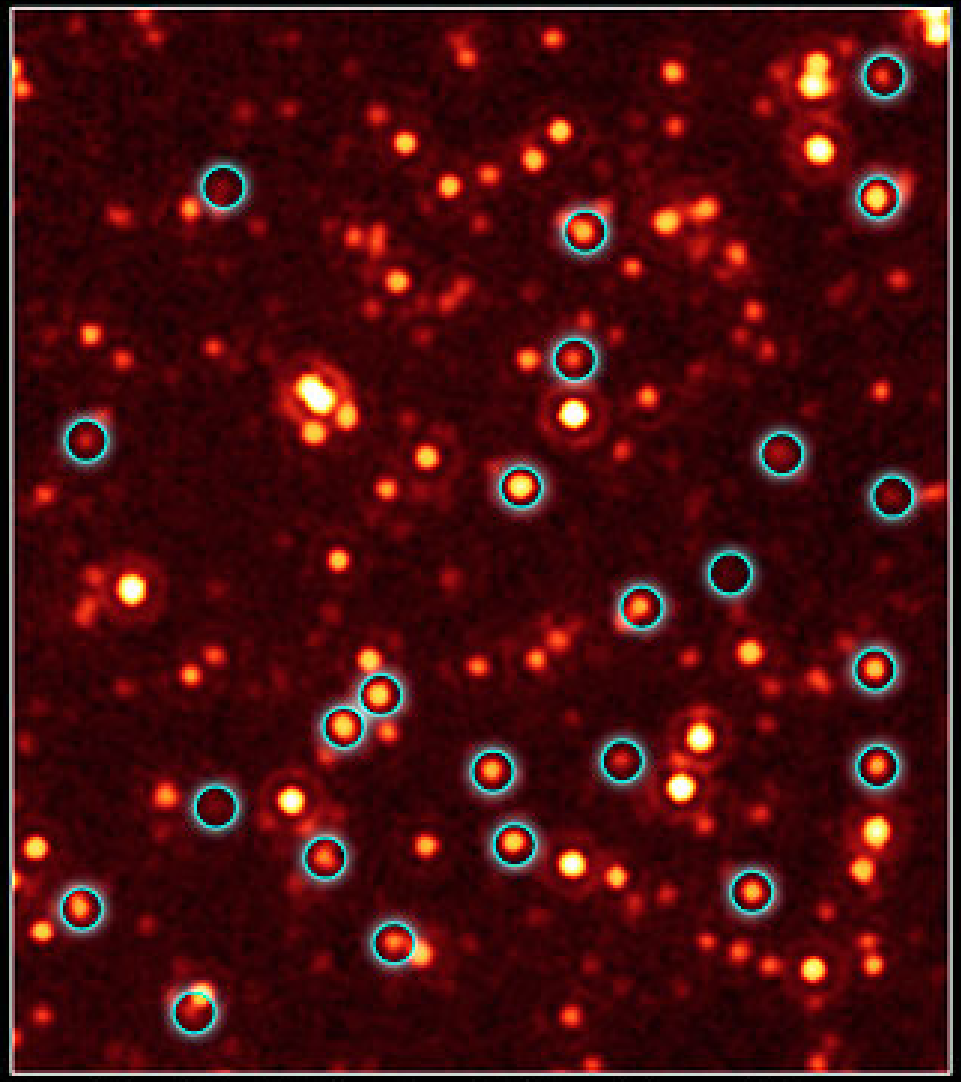
- Deep X-ray surveys can miss some
- Infrared-bright (high & low redshift)
- How to distinguish AGN from starbursts?
  → X-ray stacking

Fiore et al. 2008, 2009,Daddi et al. 2007,Georgantopoulos et al. 2008,Treister et al. 2009

Infrared-excess sources in ECDFS

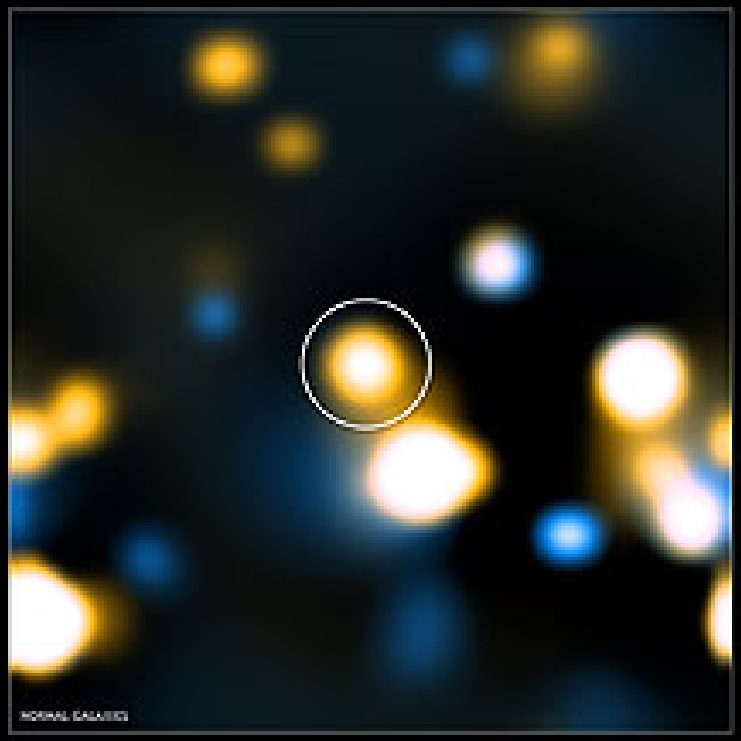


Fiore et al. 2008, 2009,Daddi et al. 2007,Georgantopoulos et al. 2008,Treister et al. 2009

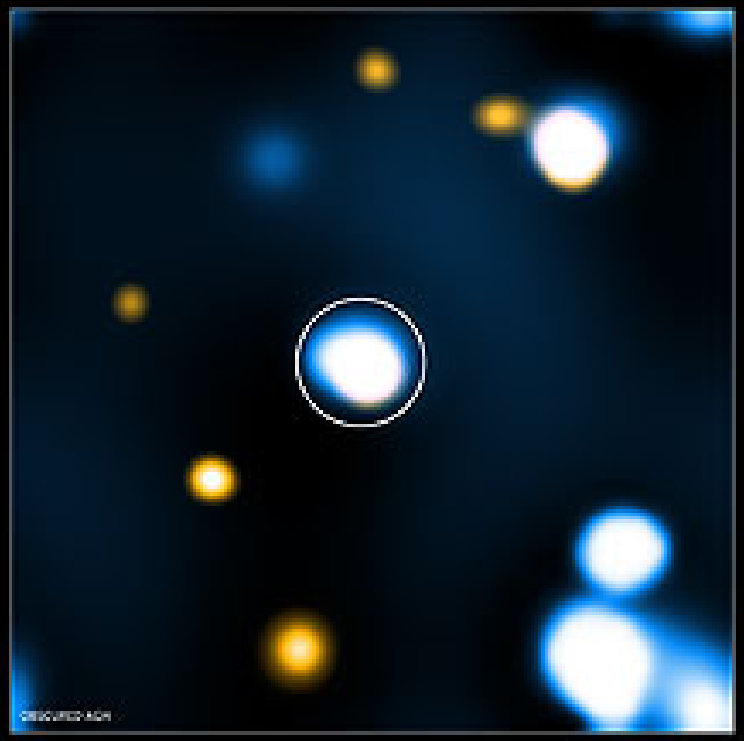


Daddi et al. 2007, Fiore et al. 2008

X-Ray Stacked Spectra



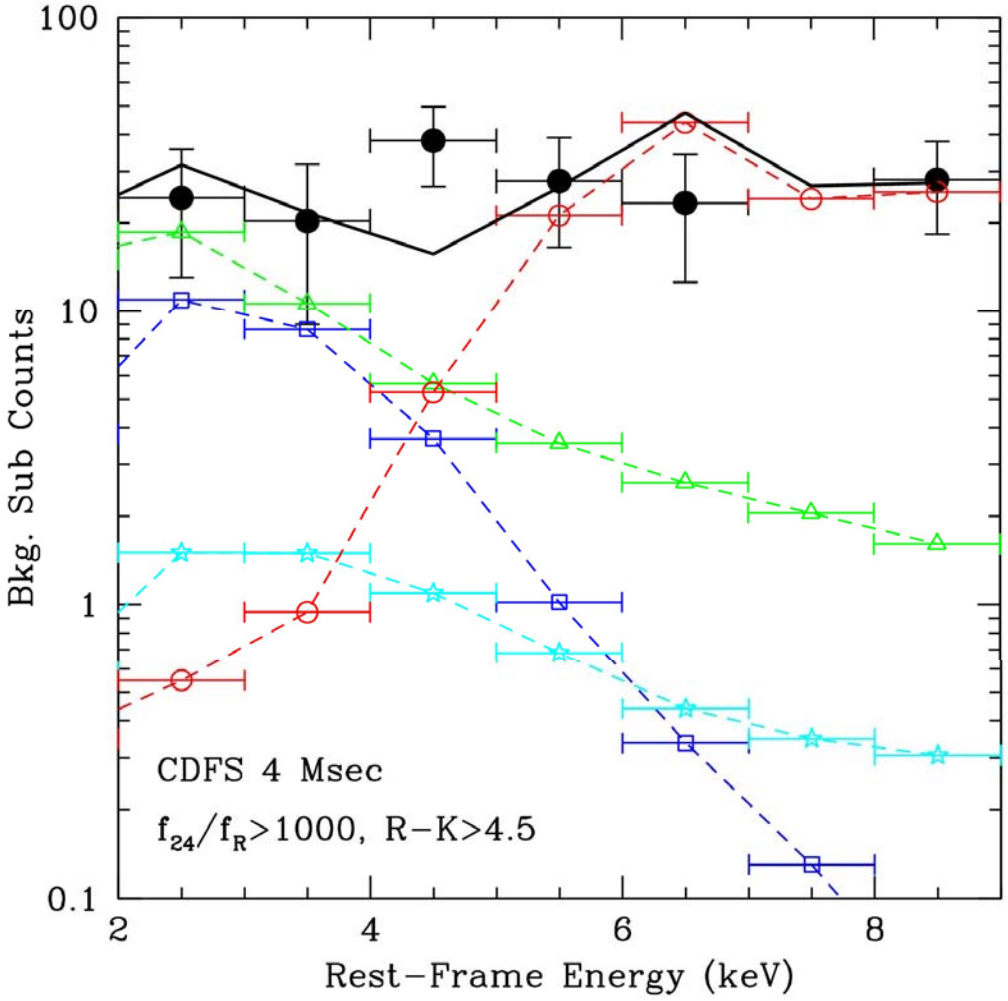
24 μm “normal”



24 μm “excess”

Daddi et al. 2007

Rest-Frame Stacking, all IR-excess sources

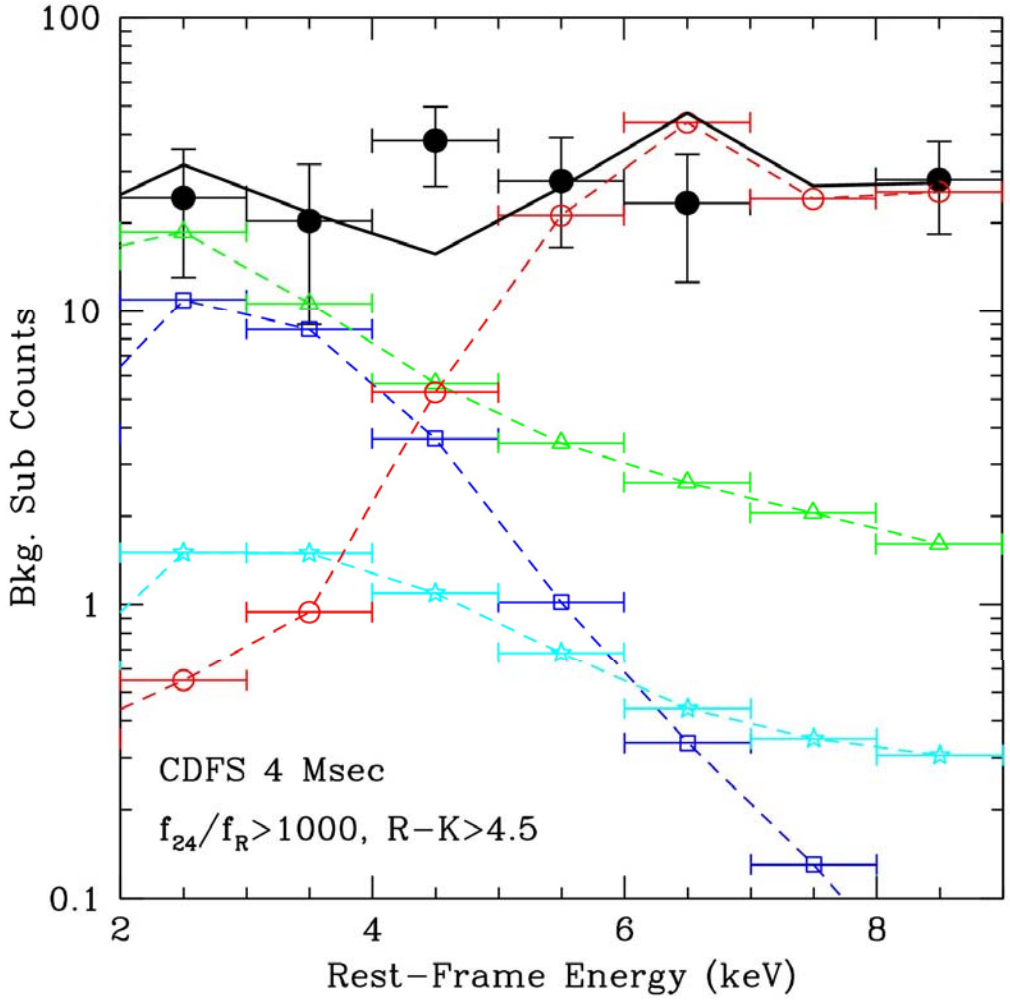


$N_H=10^{24}cm^{-2}$, $\Gamma=1.9$
$\Gamma=1.9$ (reflected)
Thermal kT=0.7 keV
HMXBs

→obsc AGN+star formation

Treister et al. 2009b

Rest-Frame Stacking, all IR-excess sources



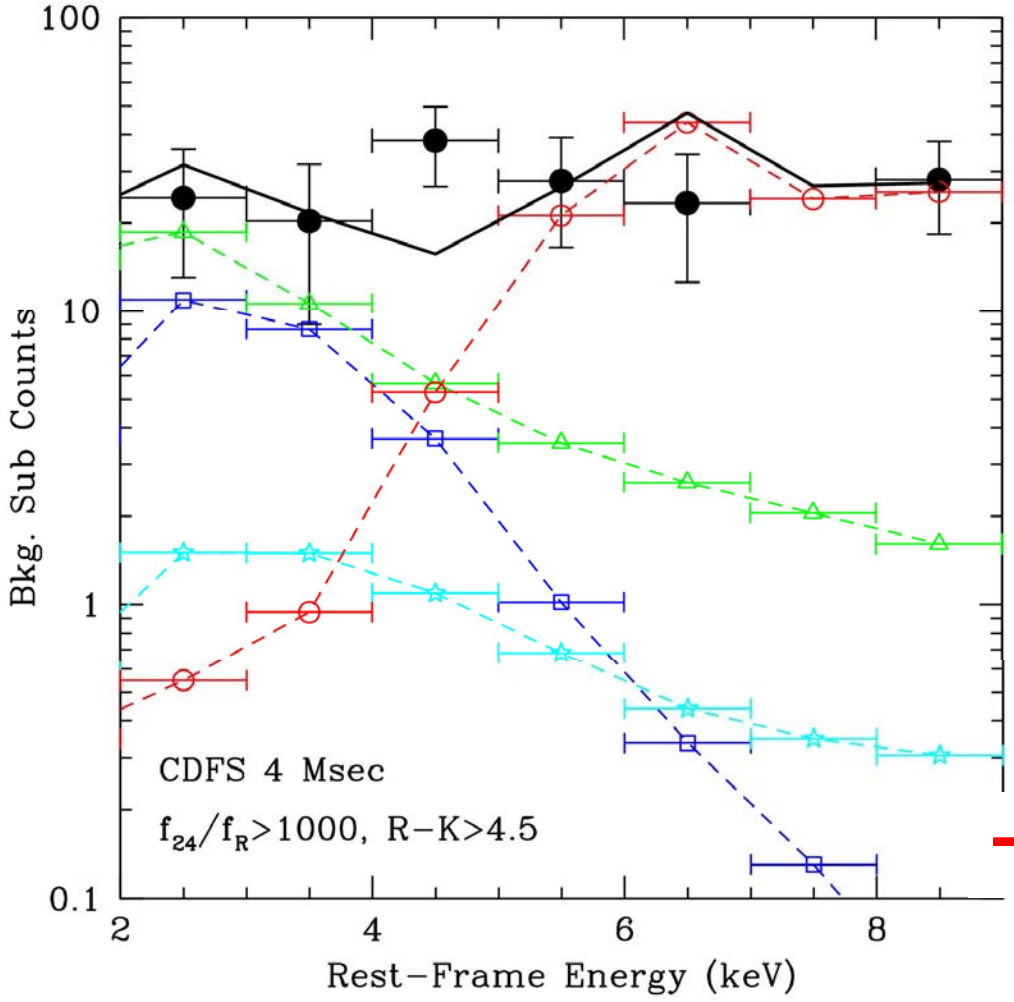
$N_H=10^{24}cm^{-2}$, $\Gamma=1.9$
$\Gamma=1.9$ (reflected)
Thermal kT=0.7 keV
HMXBs

→obsc AGN+star formation

Also:
Higher L → harder Γ
→ more AGN in stack

Treister et al. 2009b

Rest-Frame Stacking, all IR-excess sources



$N_H=10^{24}cm^{-2}$, $\Gamma=1.9$
$\Gamma=1.9$ (reflected)
Thermal kT=0.7 keV
HMXBs

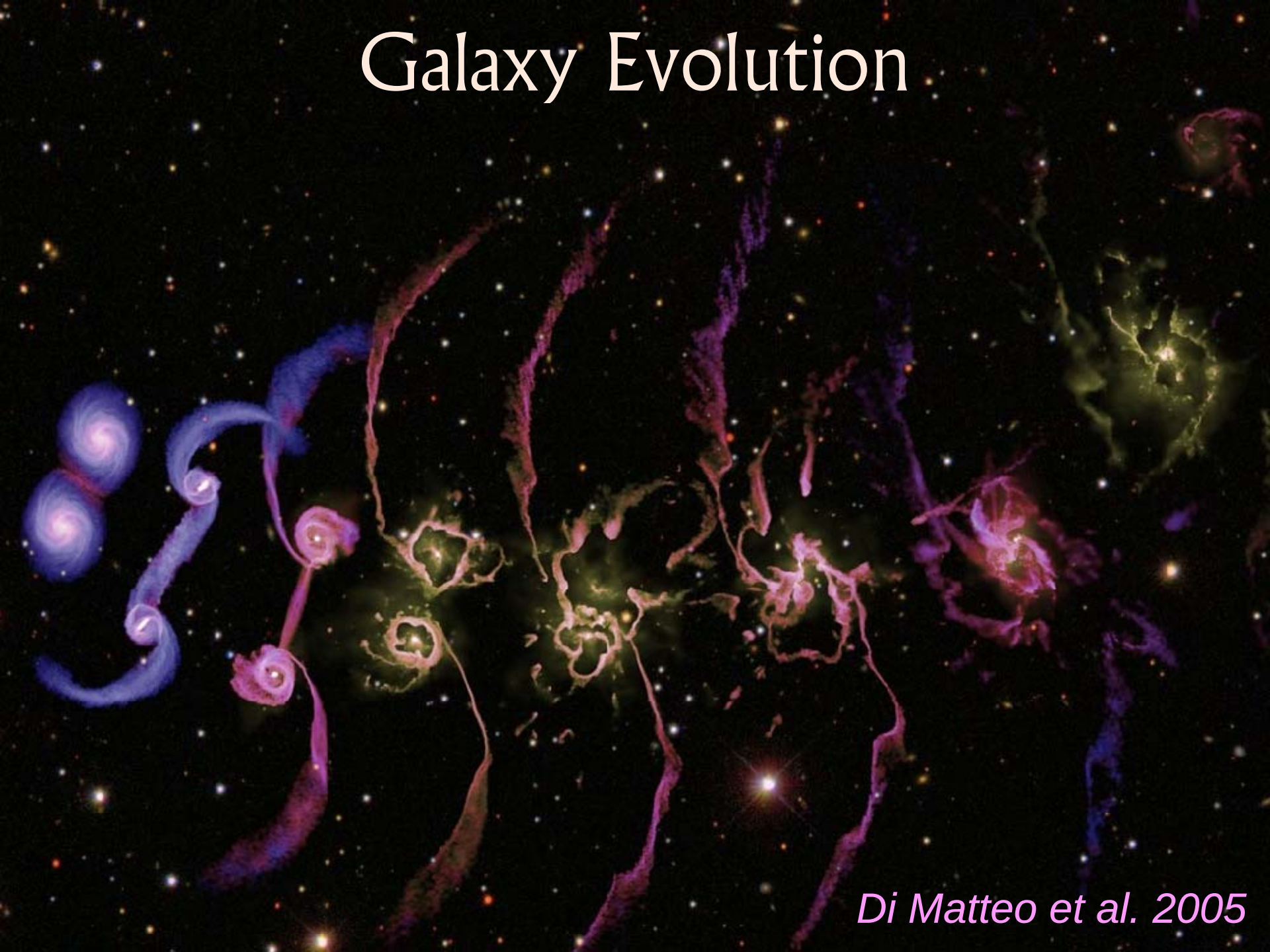
→obsc AGN+star formation

Also:
Higher L → harder Γ
→ more AGN in stack

→deep/wide X-ray surveys

Treister et al. 2009b

Galaxy Evolution

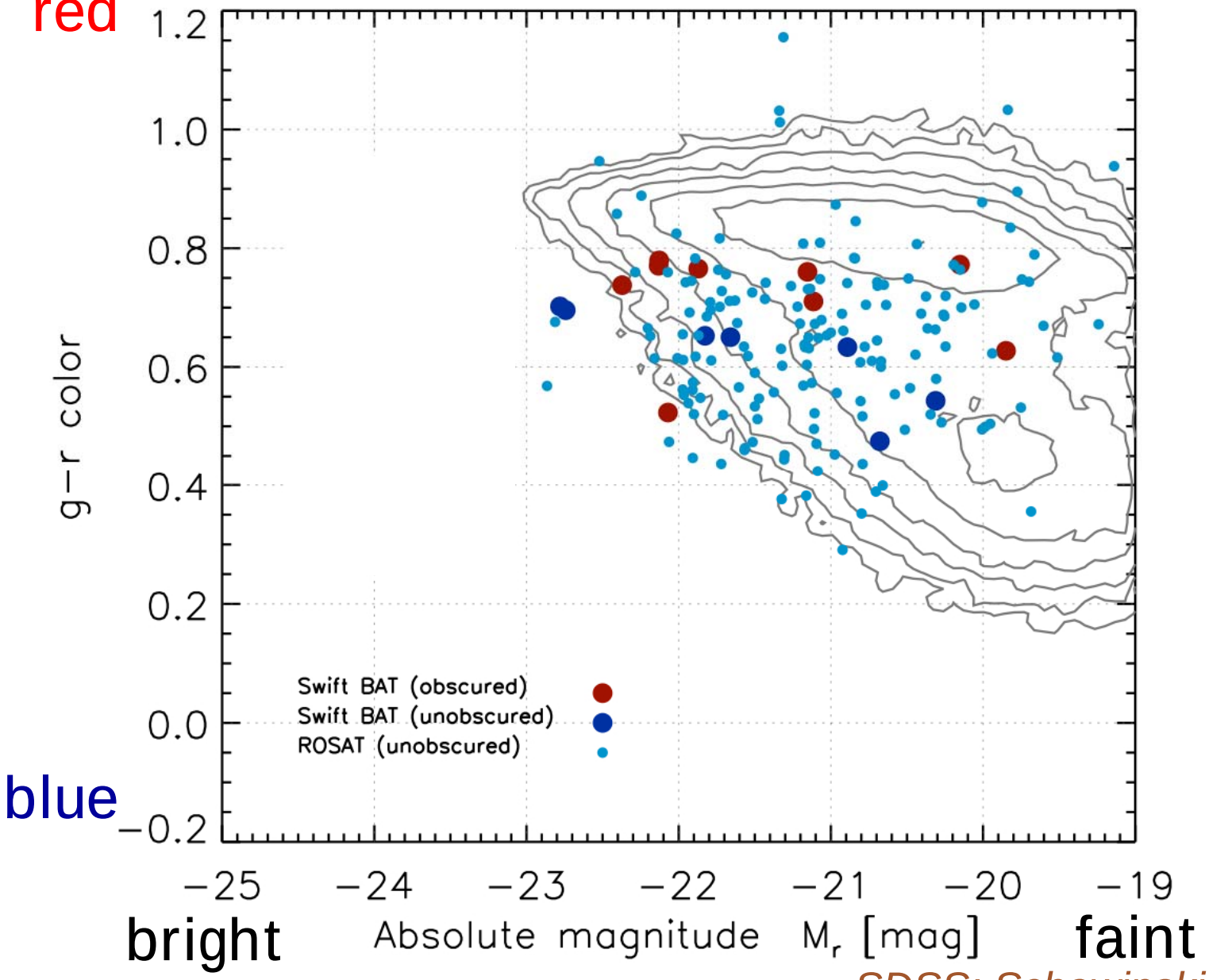


Di Matteo et al. 2005

Galaxy evolution scenario

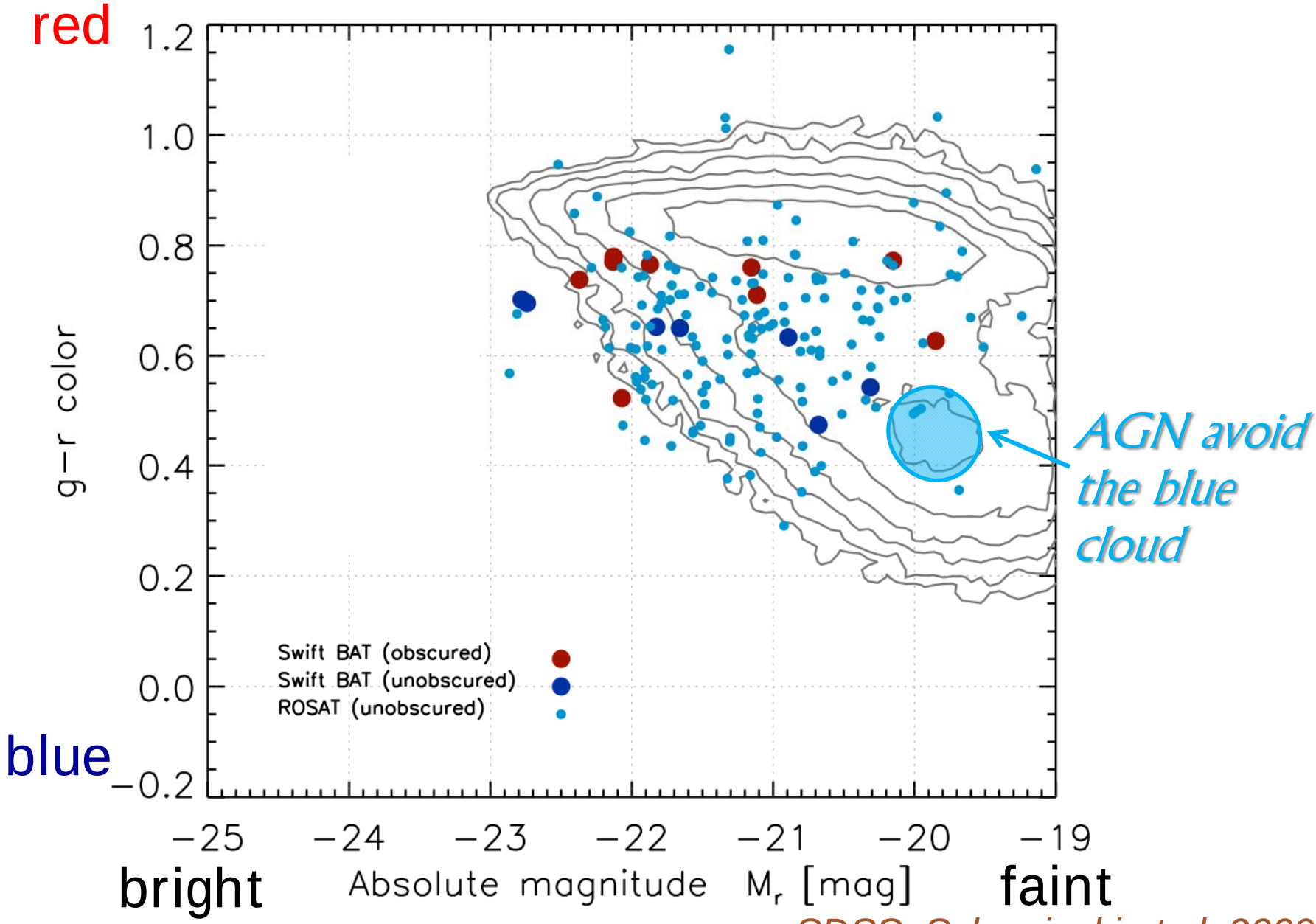
- Common trigger (e.g., merger)
- Star formation starts
- BH accretion delayed (angular momentum)
- AGN turns on, heats ISM/IGM
- Star formation turns off
- Stellar population ages from blue to red

AGN Host Colors at z~0



SDSS: Schawinski et al. 2009

AGN Host Colors at z~0



SDSS: Schawinski et al. 2009

Actual feedback at z~0

- Stars turn off
- Stars age from blue to green
- *Then* AGN turns on (BH accretes)
- Stars age to red

SDSS: Schawinski et al. 2009

Actual feedback at z~0

- Stars turn off
- Stars age from blue to green
- *Then* AGN turns on (BH accretes)
- Stars age to red

What happens at z > 1?

Actual feedback at z~0

- Stars turn off
- Stars age from blue to green
- *Then* AGN turns on (BH accretes)
- Stars age to red

What happens at z > 1?

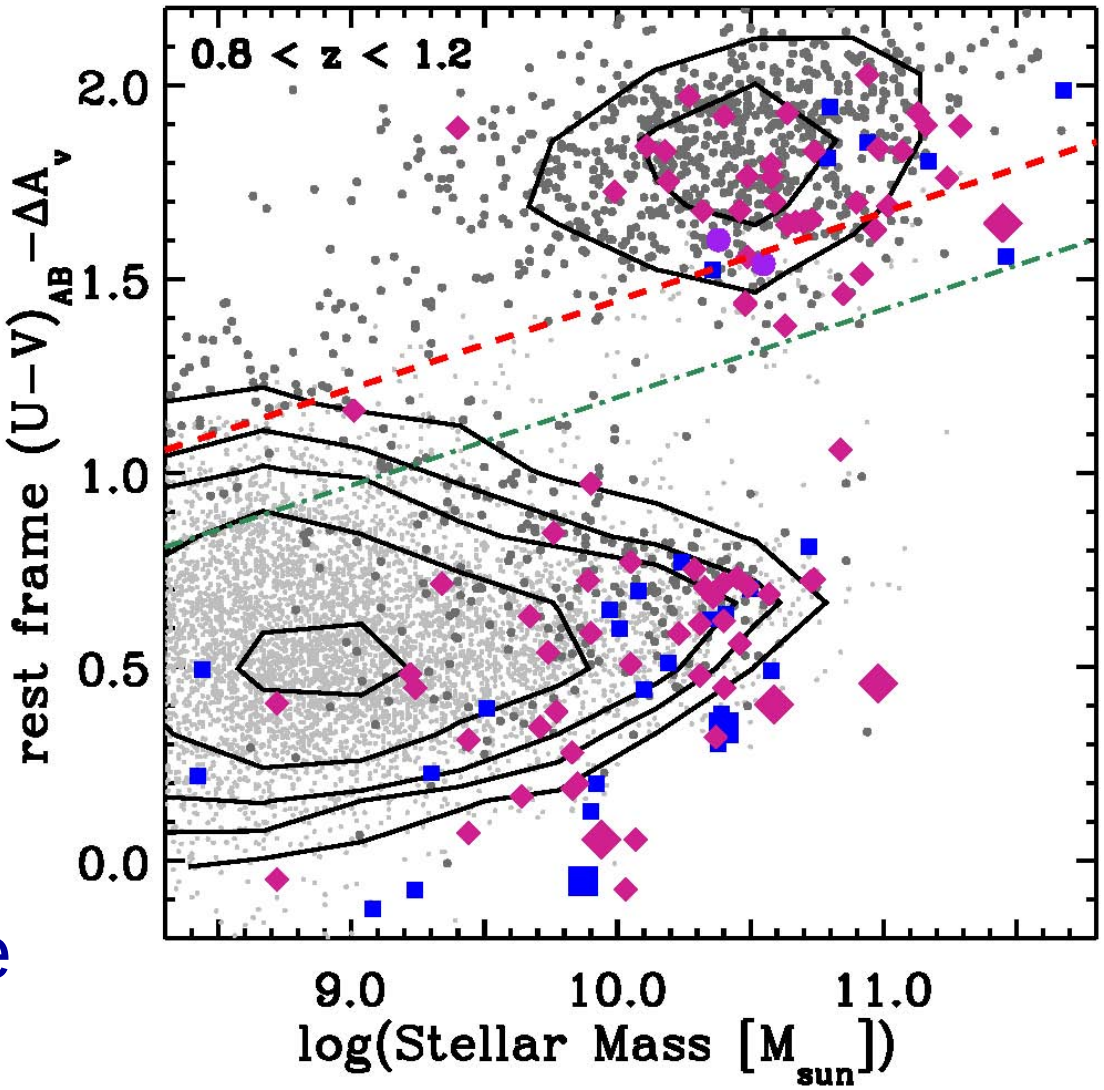
ECDFS: Subaru imaging in 18 medium-bands

- 1% photz's, 30-band SEDs 24 μm – 8 keV
- stellar masses, reddening, emission lines

Cardamone et al. 2010a,b

De-reddened galaxy colors at z~1

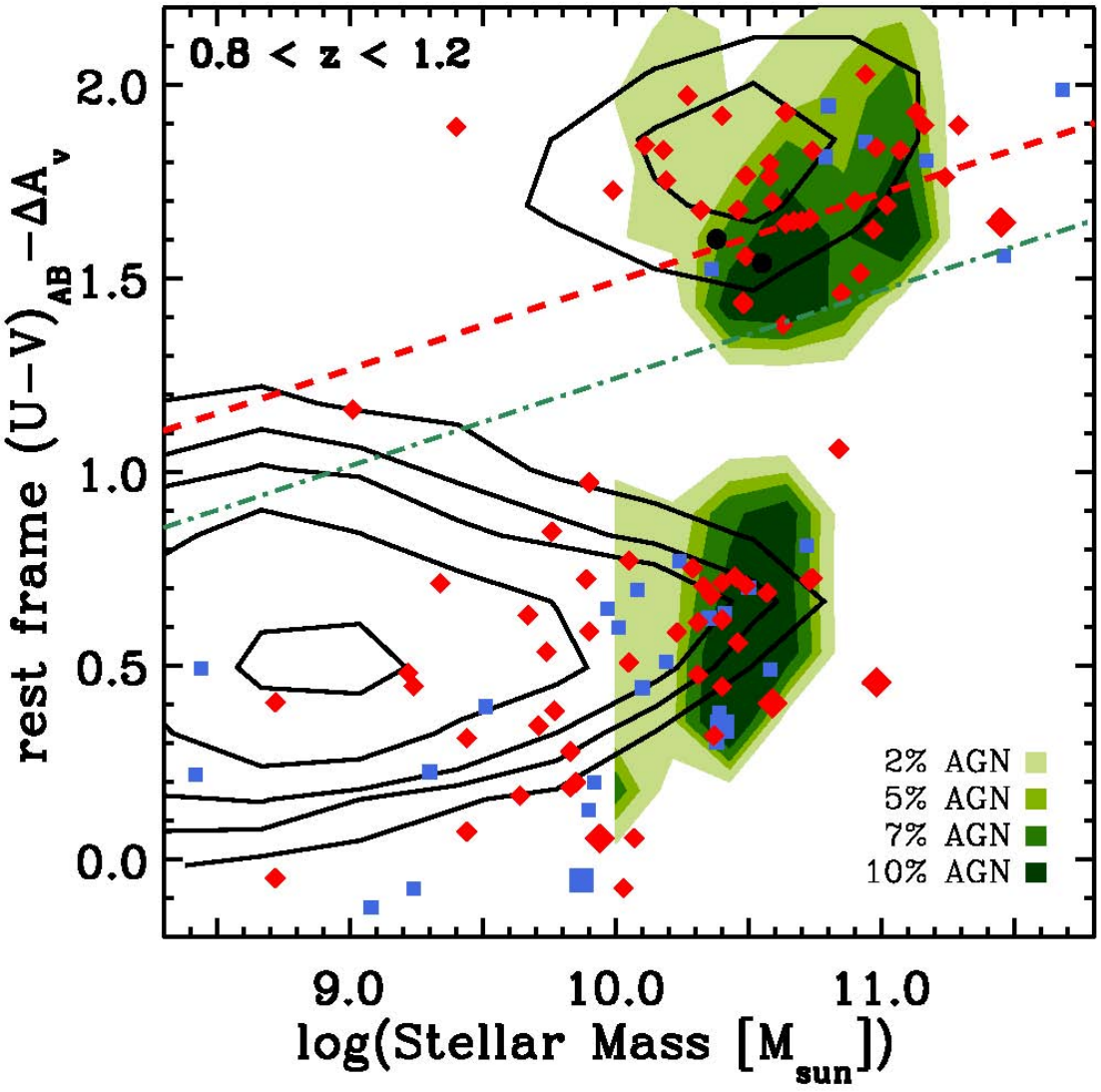
red



blue

Cardamone et al. 2010b (PhD thesis)

Fraction of galaxies that are active at z~1



Cardamone et al. 2010b (PhD thesis)

AGN Hosts at z~1

- Hosts are massive galaxies
- Half *are* blue & star-forming
  - 2/3 of these are dusty
  - Plenty of gas remaining
  - Vigorous accretion "quasar mode"
- Half are evolving passively
  - On young edge of red sequence
  - Same age as "green valley" hosts at z~0
  - Moderate accretion "maintenance mode"

Cardamone et al. 2010b (PhD thesis)

"Standard" feedback at z~1

- "Quasar mode:" AGN shuts down SF?
- Stars age from blue to green
- Stars age to red
- "Maintenance mode:" little SF, small BH growth

"Standard" feedback at z~1

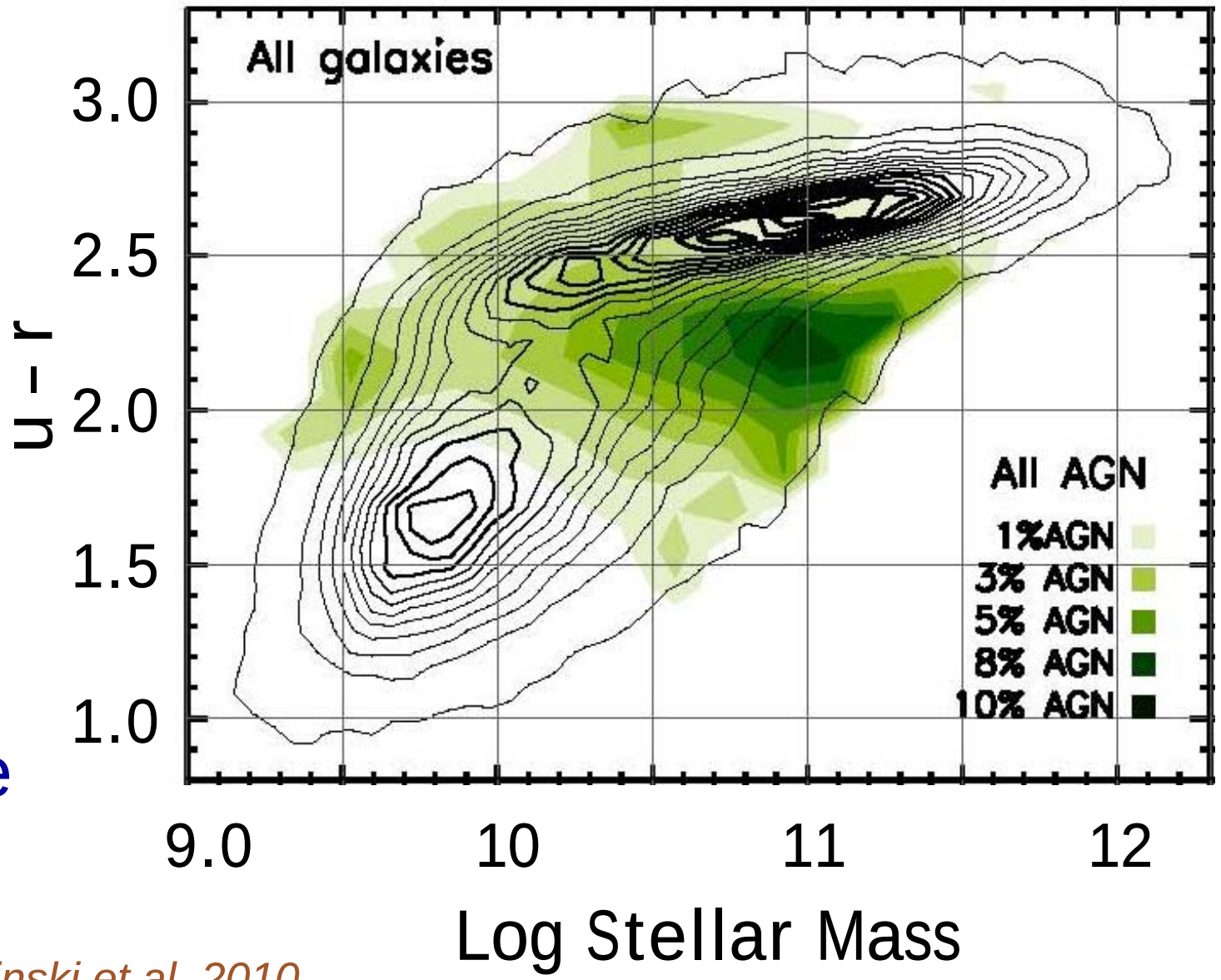
- "Quasar mode:" AGN shuts down SF?
- Stars age from blue to green
- Stars age to red
- "Maintenance mode:" little SF, small BH growth

z ~ 2 ? in progress

Fraction of galaxies that are AGN z~0

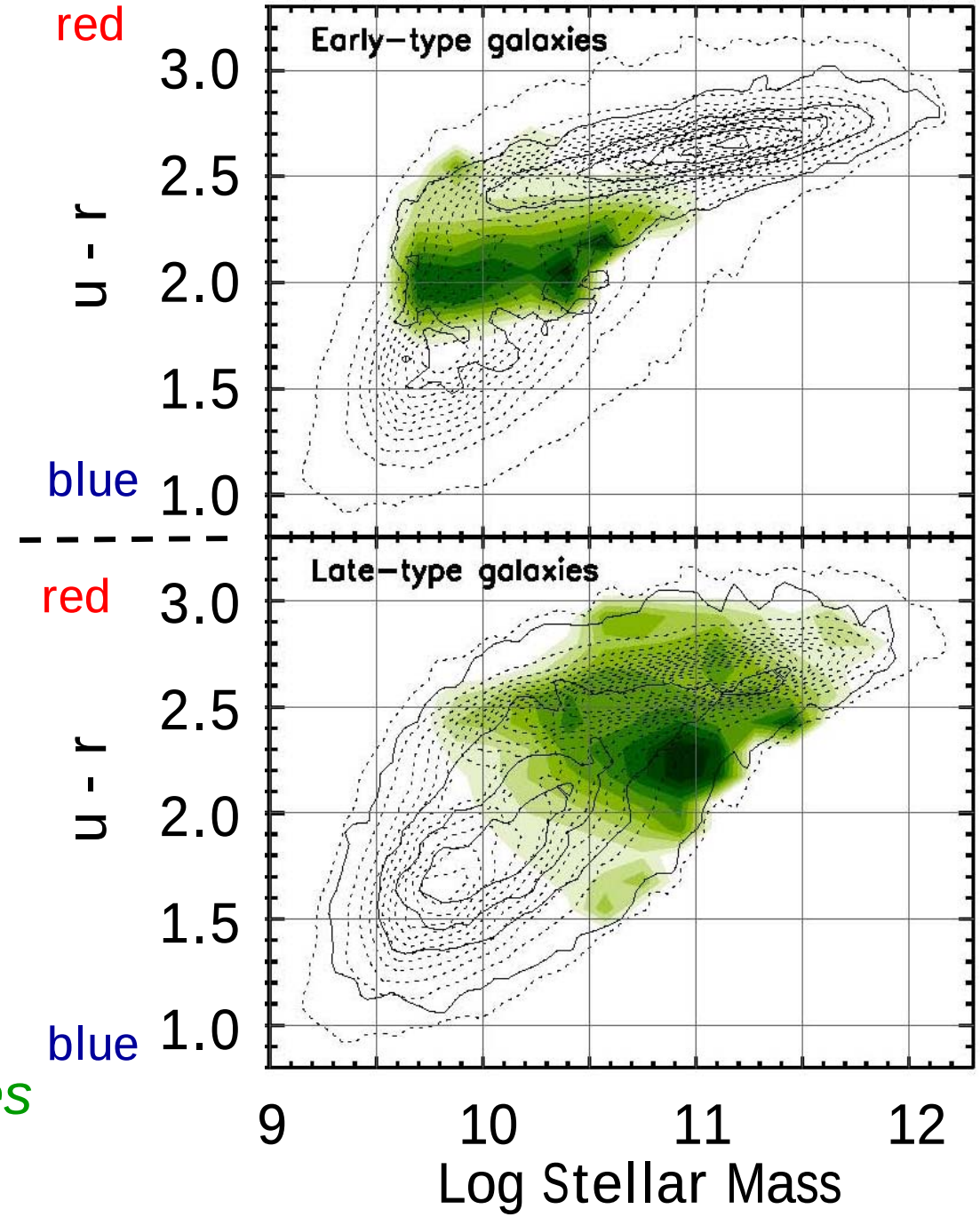
red

blue



Schawinski et al. 2010

Relation of morphology and BH growth



Galaxy Zoo morphologies

Schawinski et al. 2010

Relation of morphology and BH growth

low L/L_{Edd}

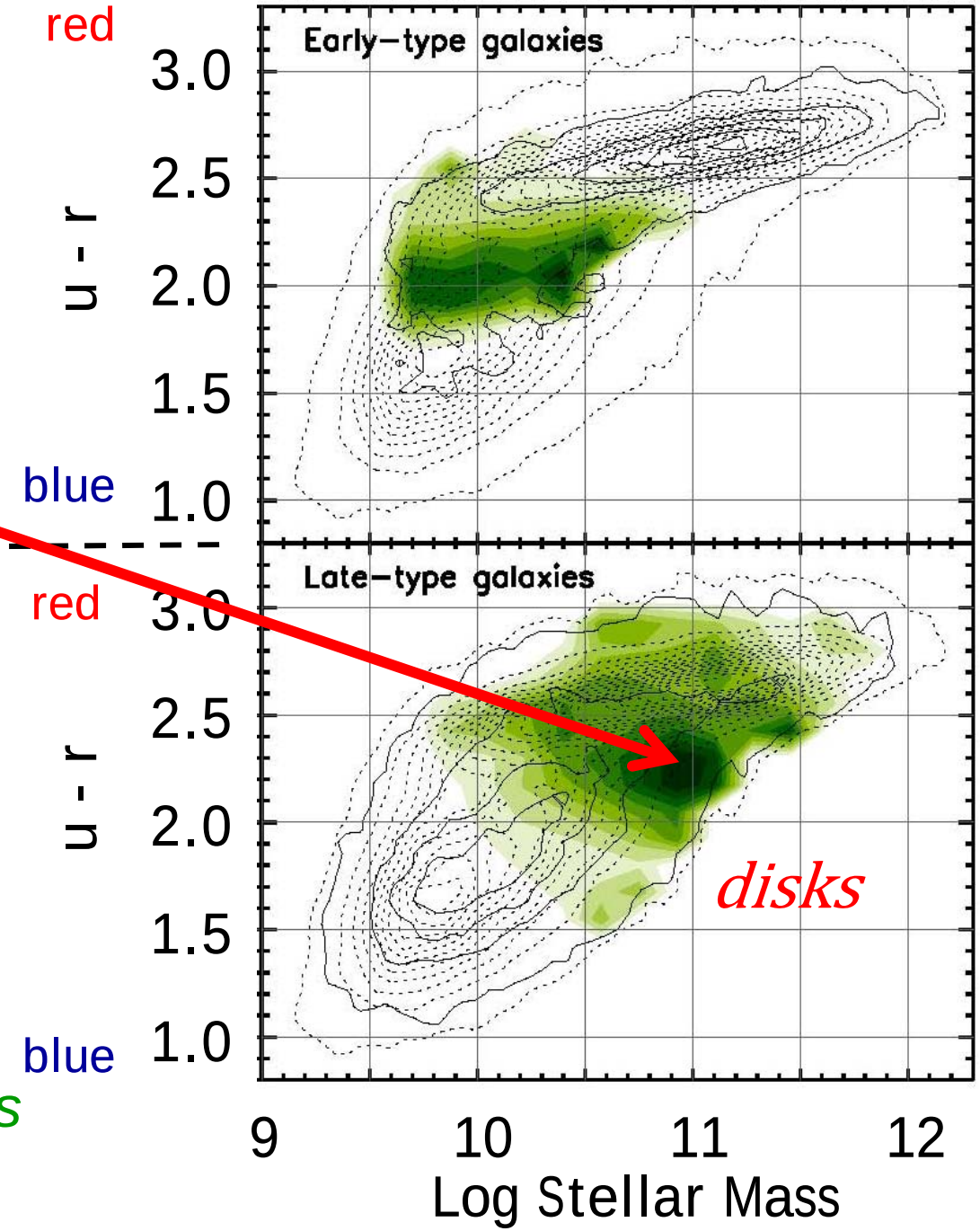
$0 < z < 1.25$

Simmons et al. 2011

Cardamone et al. 2010a

Galaxy Zoo morphologies

Schawinski et al. 2010



Relation of morphology and BH growth

low L/L_{Edd}

$0 < z < 1.25$

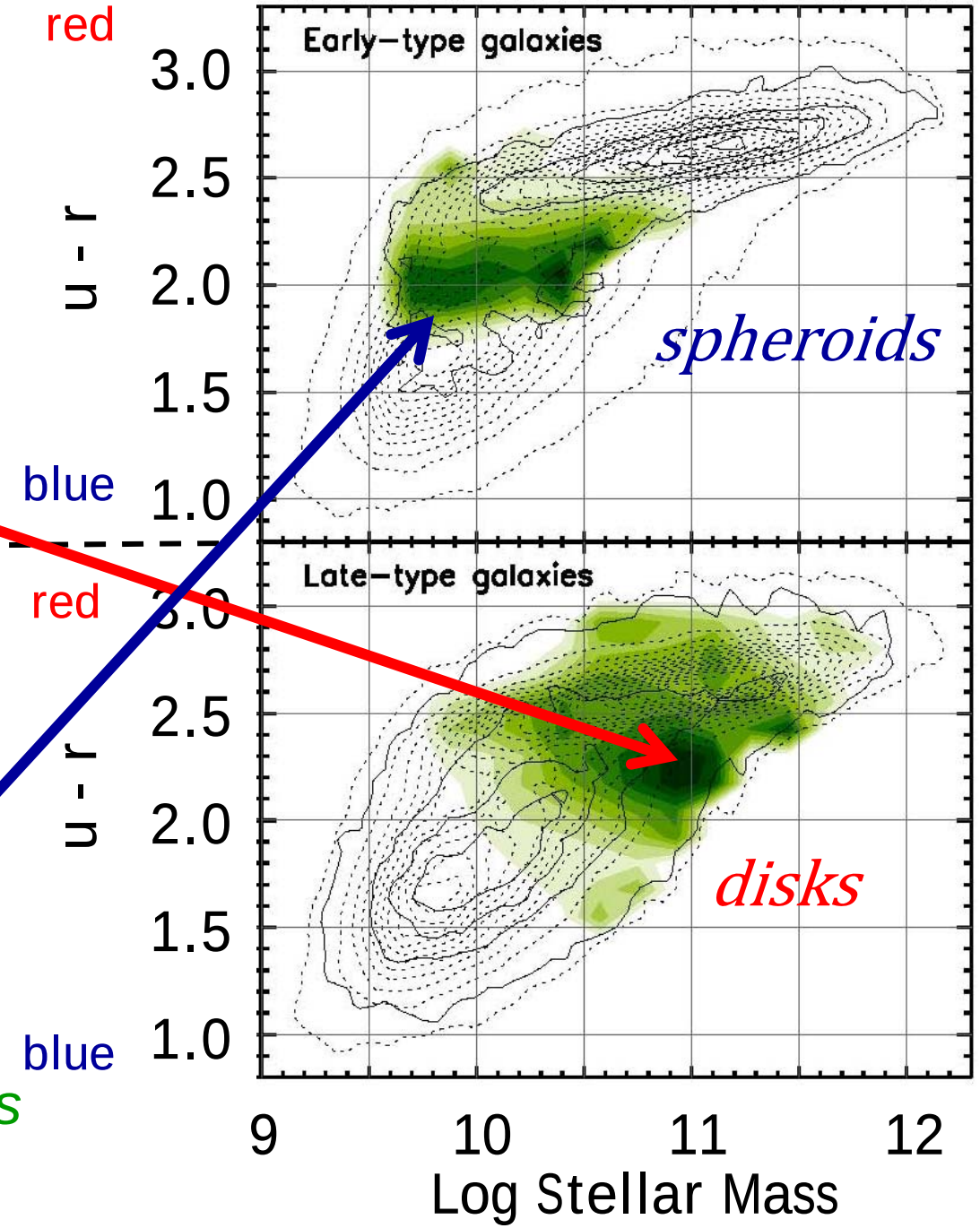
Simmons et al. 2011

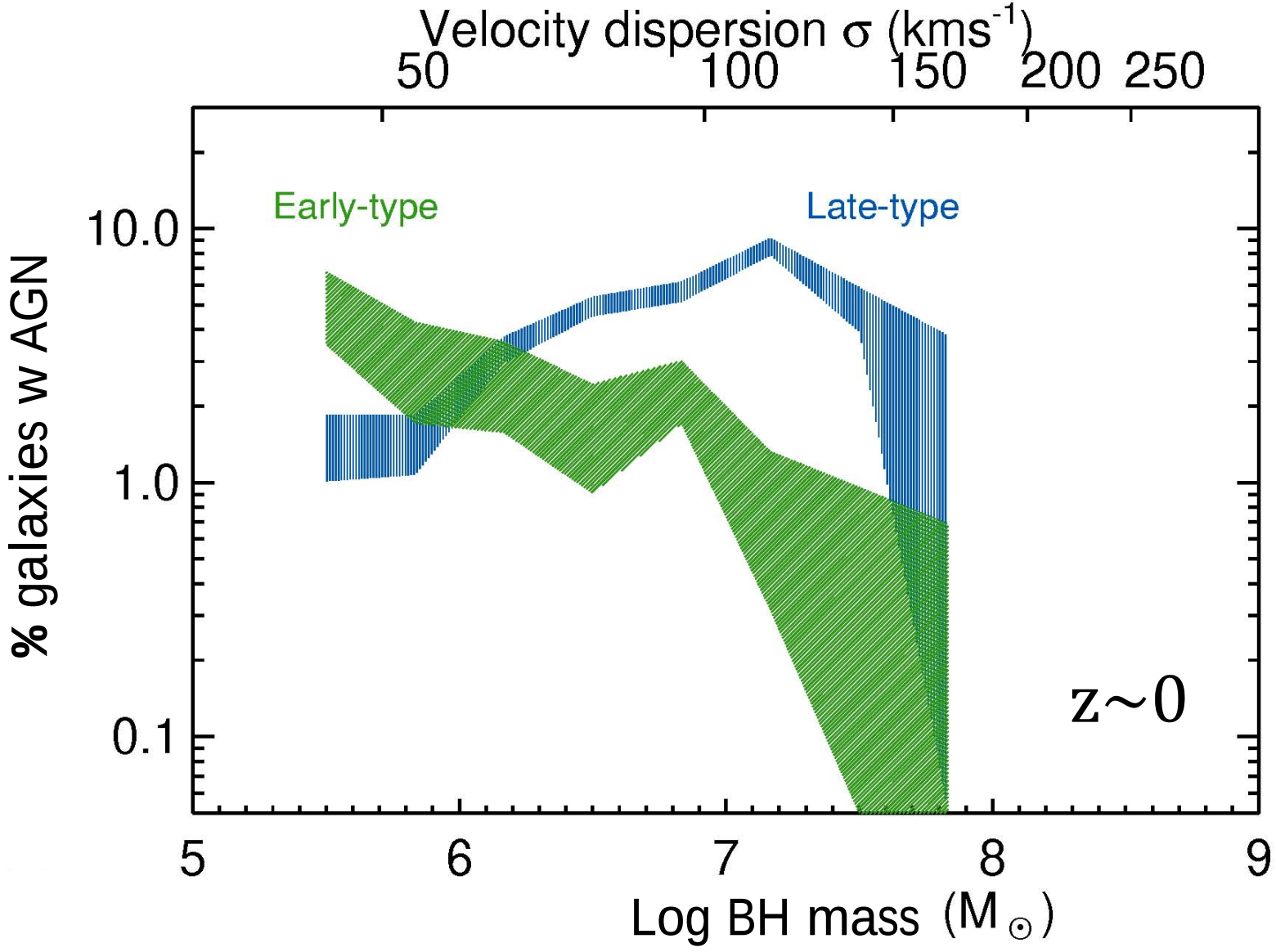
Cardamone et al. 2010a

higher L/L_{Edd}, $z \sim 0$

Galaxy Zoo morphologies

Schawinski et al. 2010





Schawinski et al. 2010

New Data Coming Soon

"Hubble Zoo" morphologies, mergers *z≳1*

WFC3 data *ERS=1/3 GOODS*

Wide-area λλλ surveys

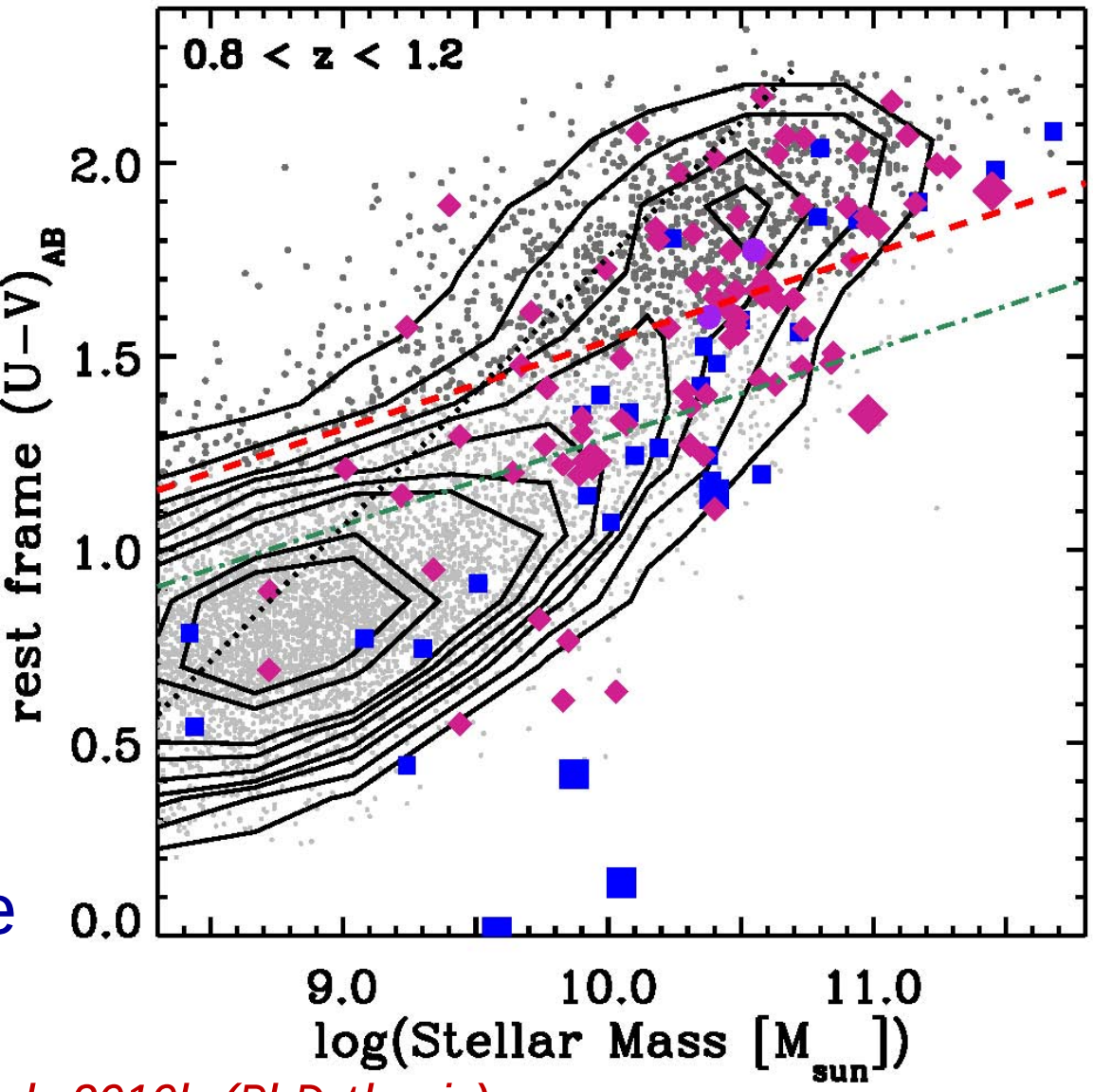
Far-infrared, submm *Herschel, ALMA*

X-ray surveys *Stripe 82, NuSTAR, Astro-H*

Galaxy colors at z~1

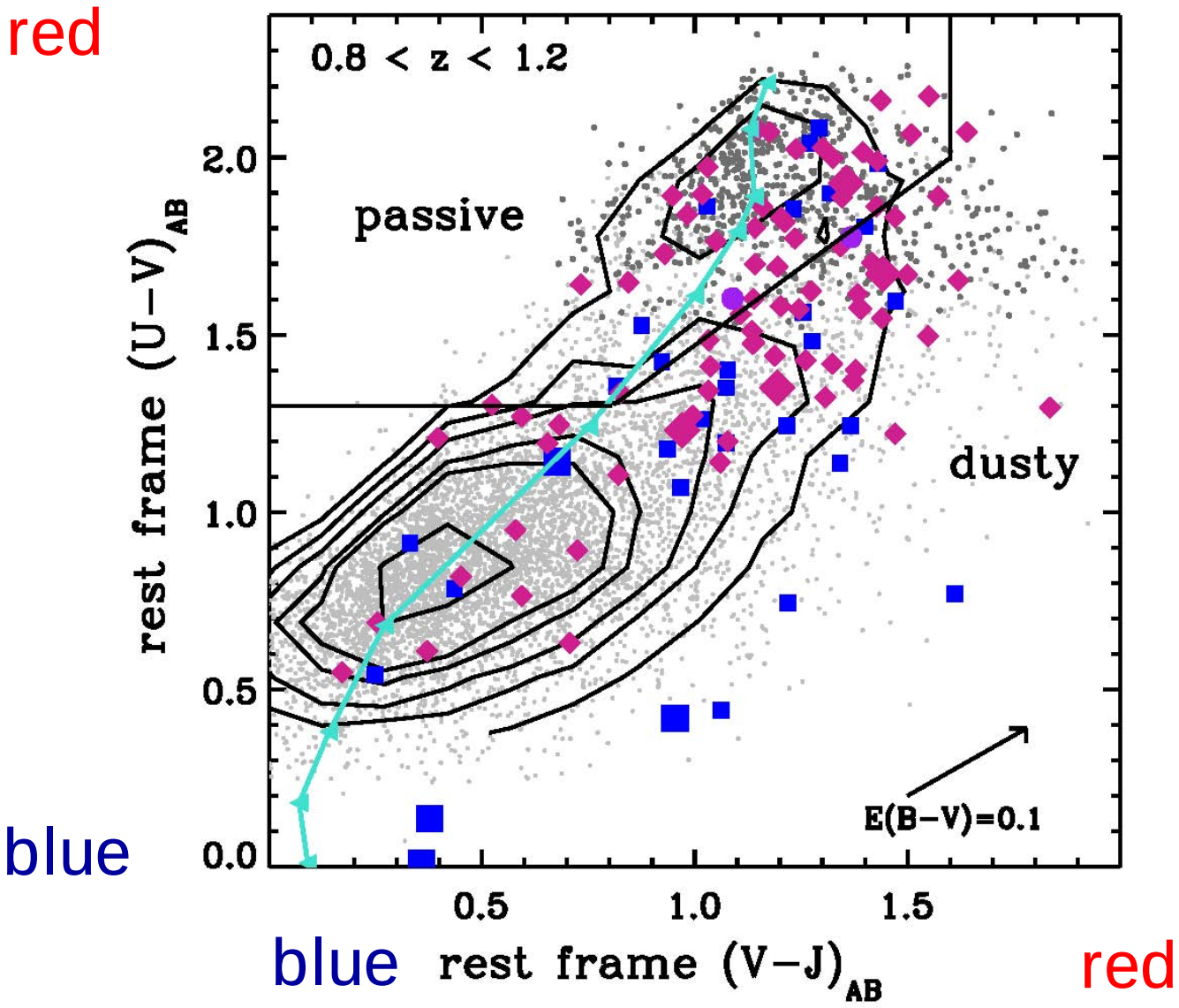
red

blue



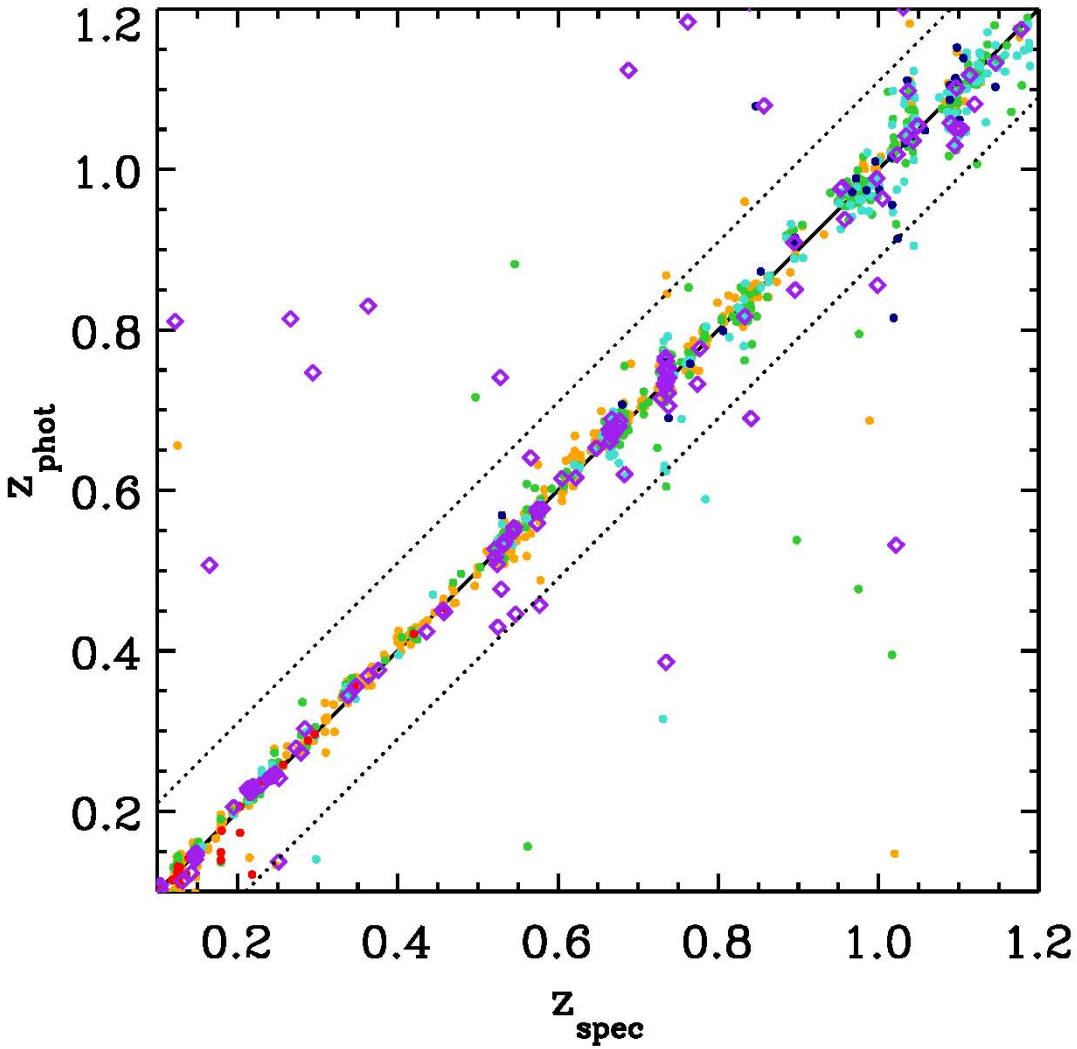
Cardamone et al. 2010b (PhD thesis)

Dusty vs. passive red galaxies



Cardamone et al. 2010b (PhD thesis)

Photometric Redshifts



$\Delta z/(1+z) \sim 0.007$

galaxies (<10% outliers)

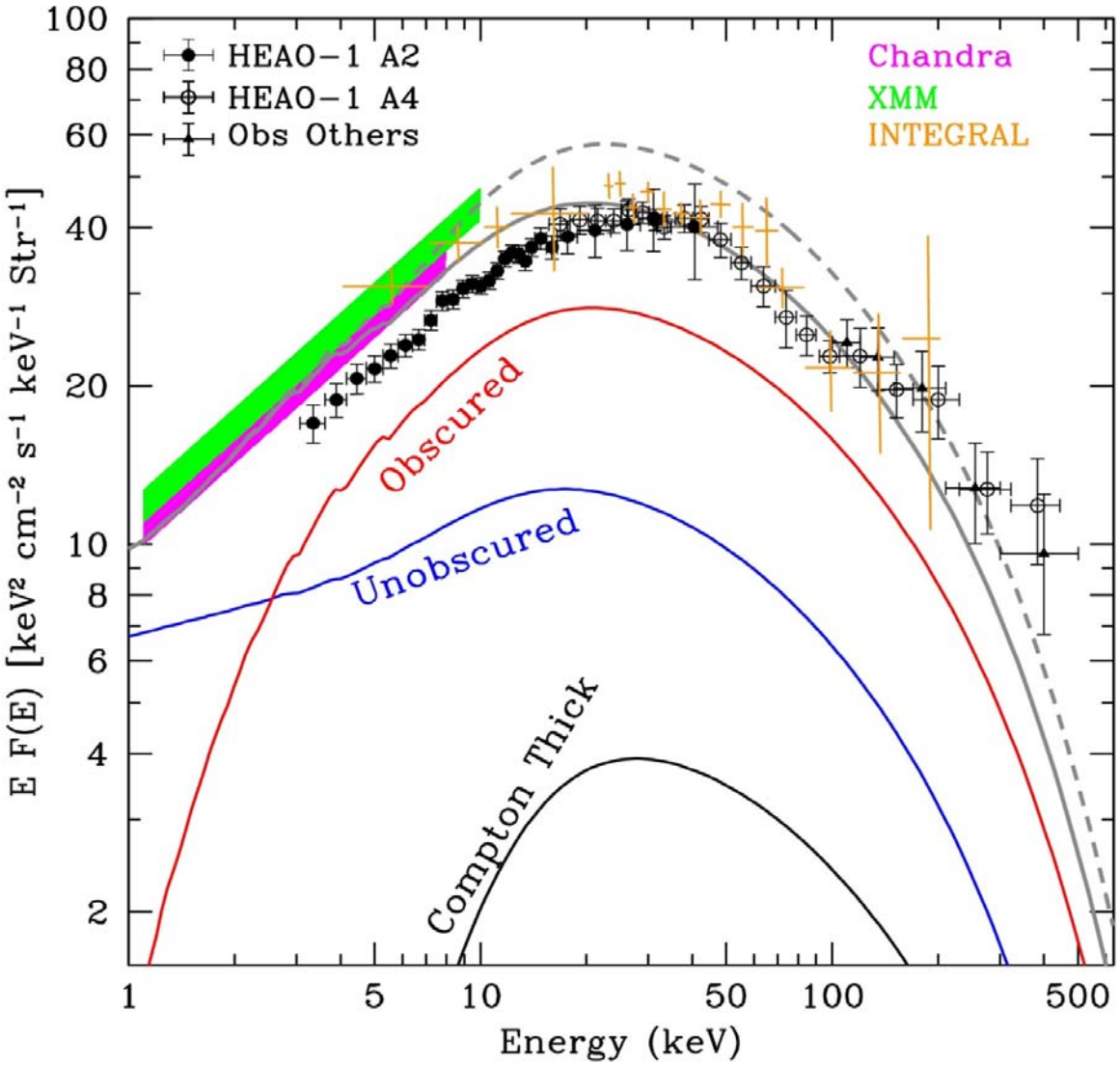
$\Delta z/(1+z) \sim 0.01$

AGN (~15% outliers)

ECDFS
Subaru Medium-Band + UBVRIzJHK

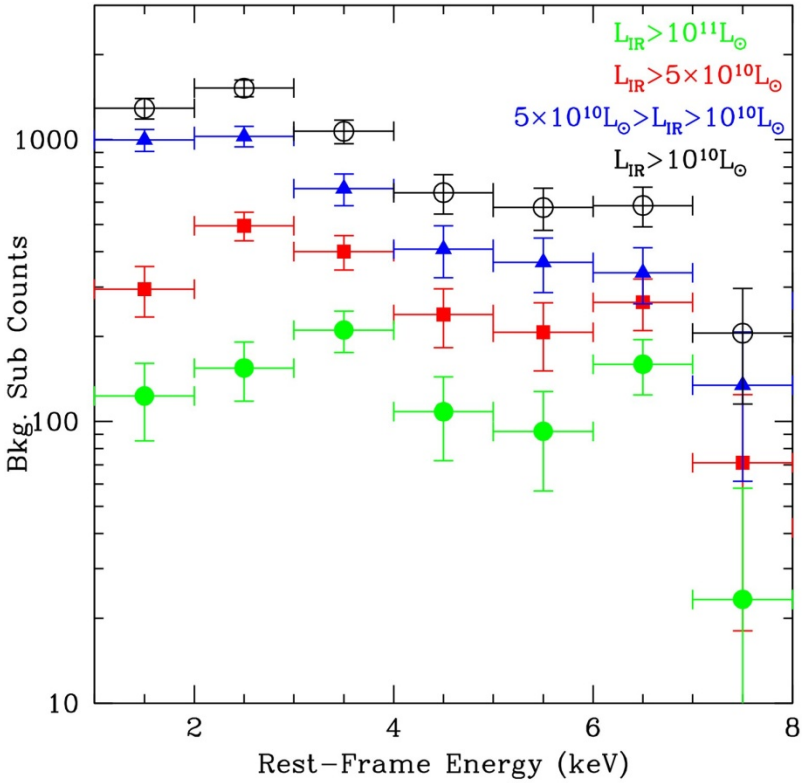
Cardamone et al. 2010a,b

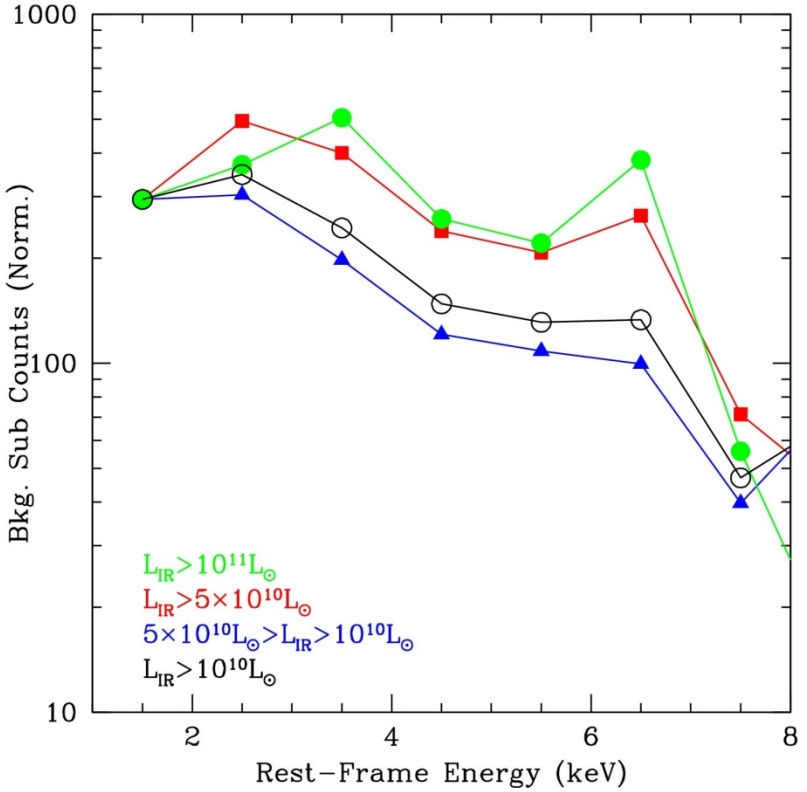
X-ray “background”



Treister & Urry 2005, Treister, Urry & Virani 2009

Rest-frame stacking, by L_{IR}



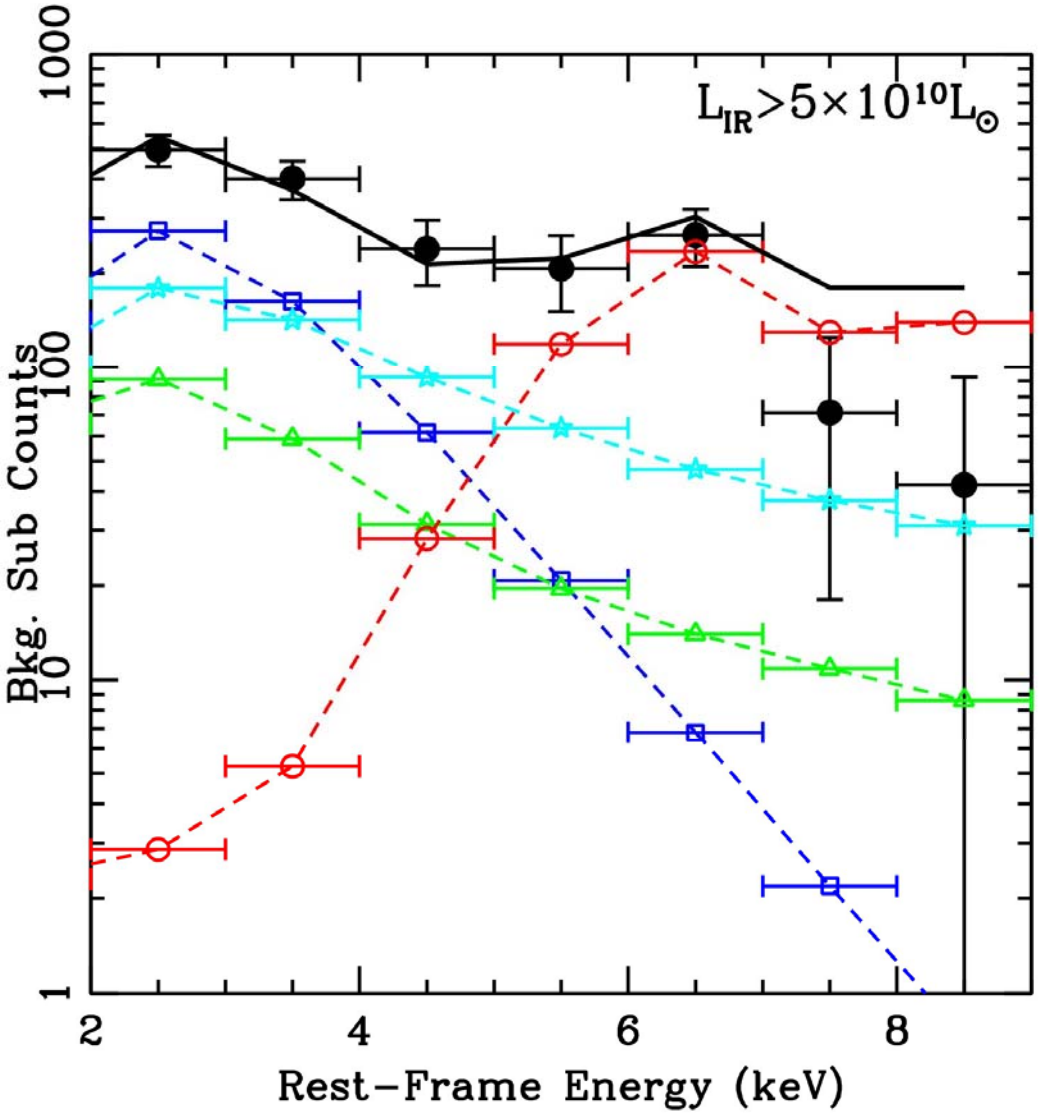


Higher luminosity → harder X-ray spectrum

→ higher fraction AGN

Treister et al. 2010b

Spectral Analysis of stacked X-ray spectra



$N_H=10^{24}cm^{-2}$, $\Gamma=1.9$

$\Gamma=1.9$ (reflected)

Thermal kT=0.7 keV

HMXBs

→obsc AGN+star formation

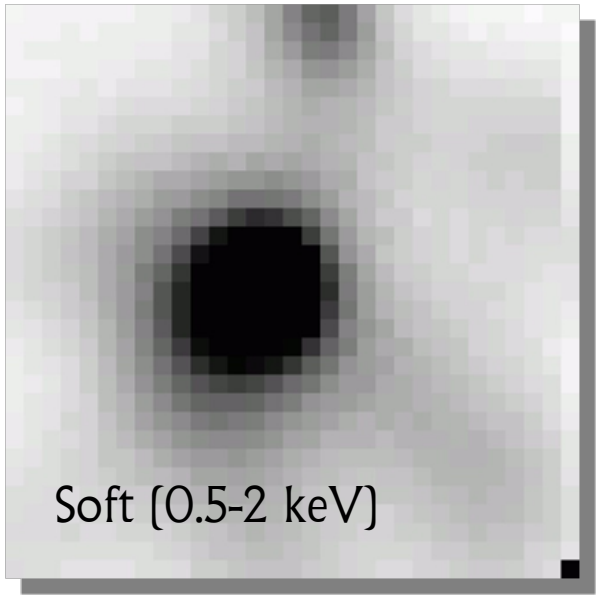
Average AGN Luminosity

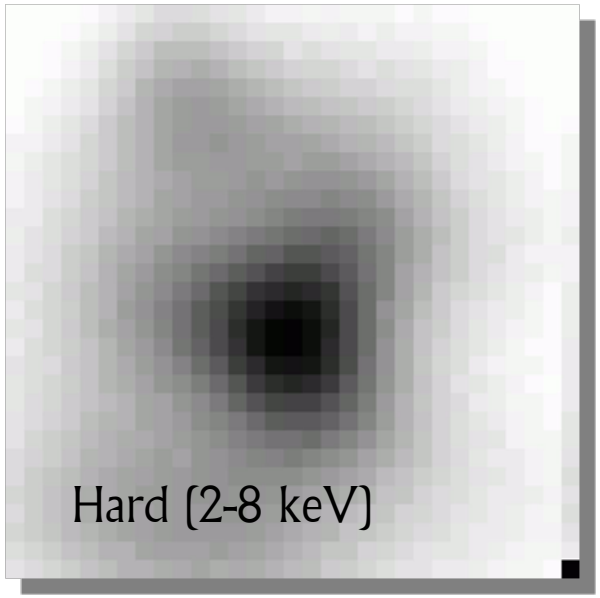
3×10^{42} erg/s

flatter evolution than quasars

Treister et al. 2009, 2010

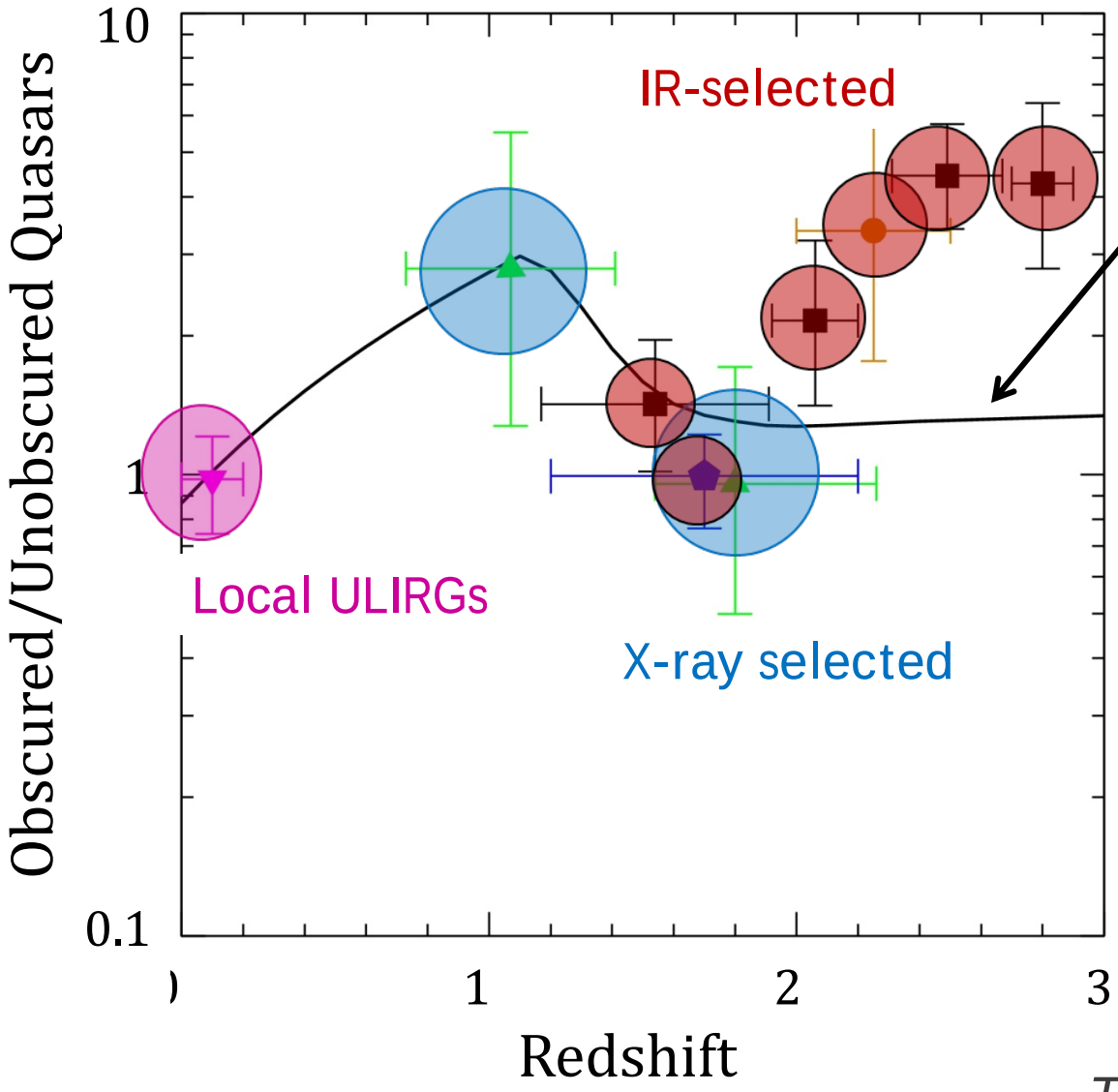
Stacking of $f_{24}/f_R>10^3$ Sources





- ~4σ detection in each band
- $f_{soft}=2.1\times10^{-17}$erg cm^{-2} s^{-1}, $f_{hard}= 8\times10^{-17}$erg cm^{-2}s^{-1}
- Sources would be detected individually in ~10 Msec

Evolution of obscured accretion



Treister et al. 2010