# ELLIPTICAL GALAXIES

Not as boring as your mother taught you

Matt Mechtley
2010.09.17

# THE RED SEQUENCE

When plotting a galaxy color-magnitude diagram, two main groups become evident.

Nearby, red galaxies are typically massive ellipticals. Blue galaxies are typically star-forming spirals

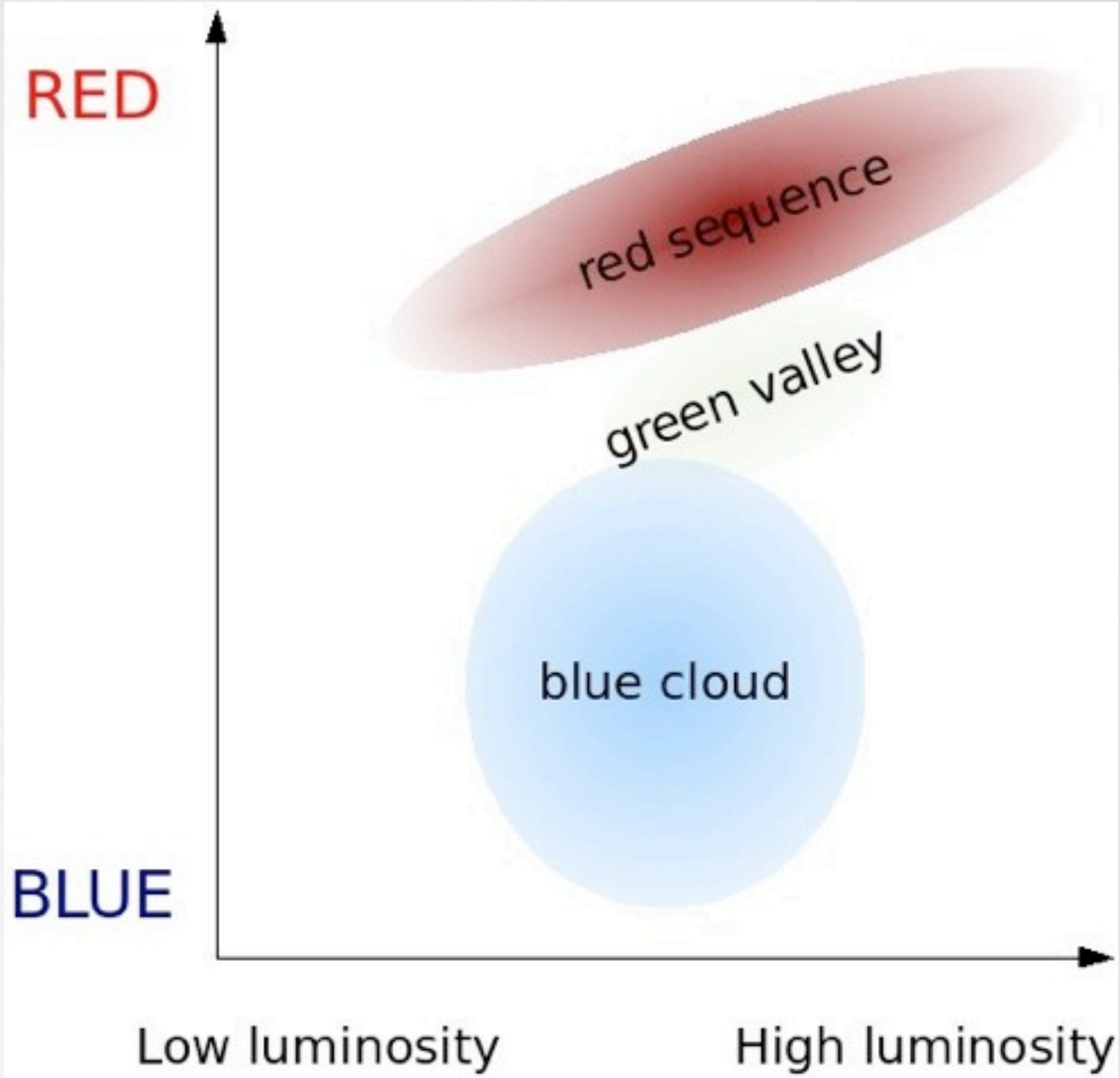
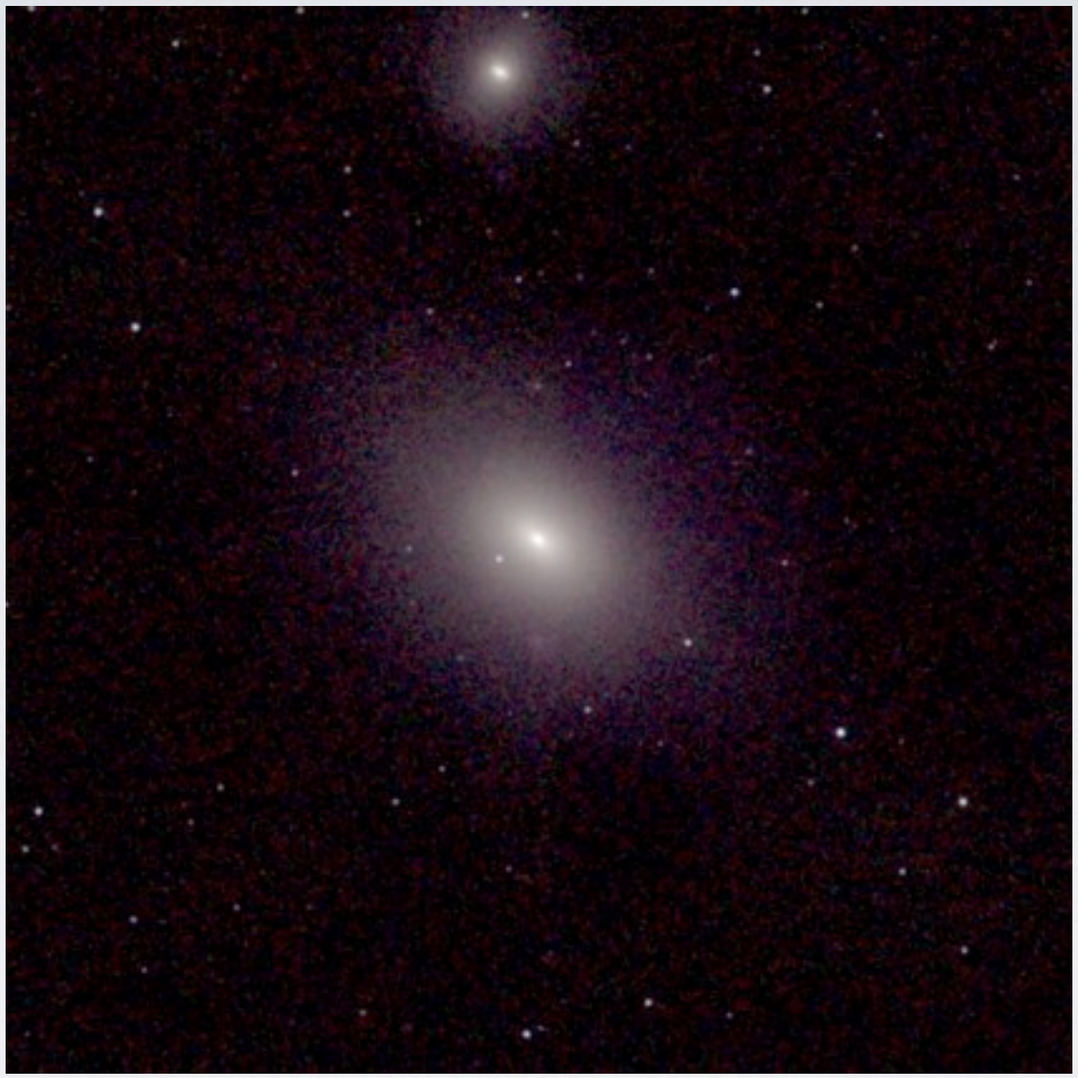



Image: Wikipedia

Cluster Abell S0740 (Image: Hubble Heritage Team)

# ELLIPTICAL GALAXIES

"Red and dead," characterized by old stellar populations



2MASS image of NGC 1316

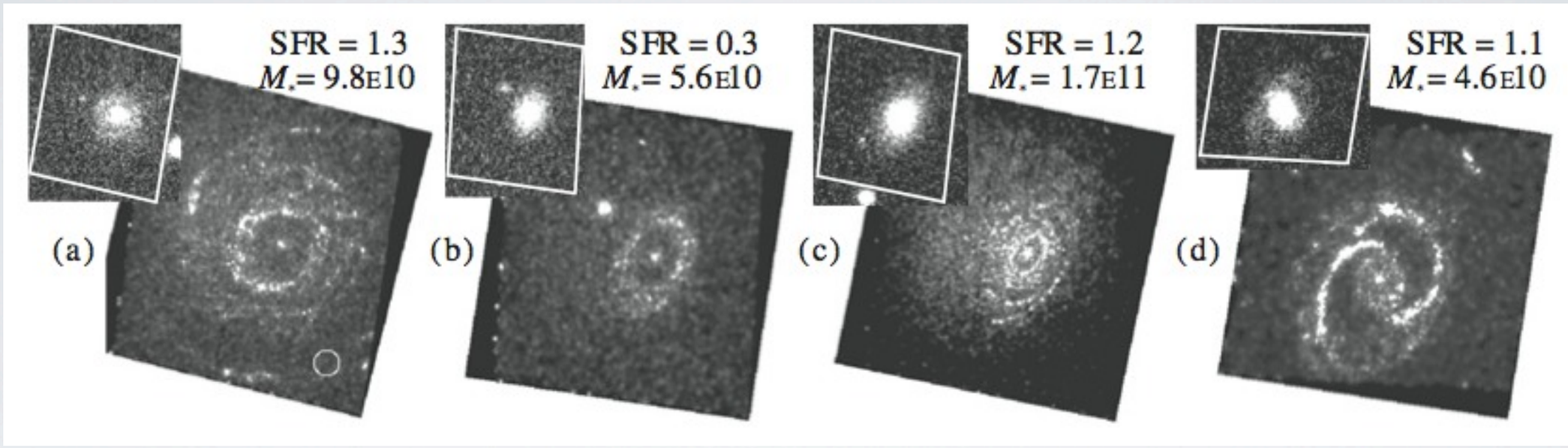
# RED AND DEAD...

## NGC 1316 in the IR

Optical image of NGC 1316 (Source: APOD)

# OR NOT...

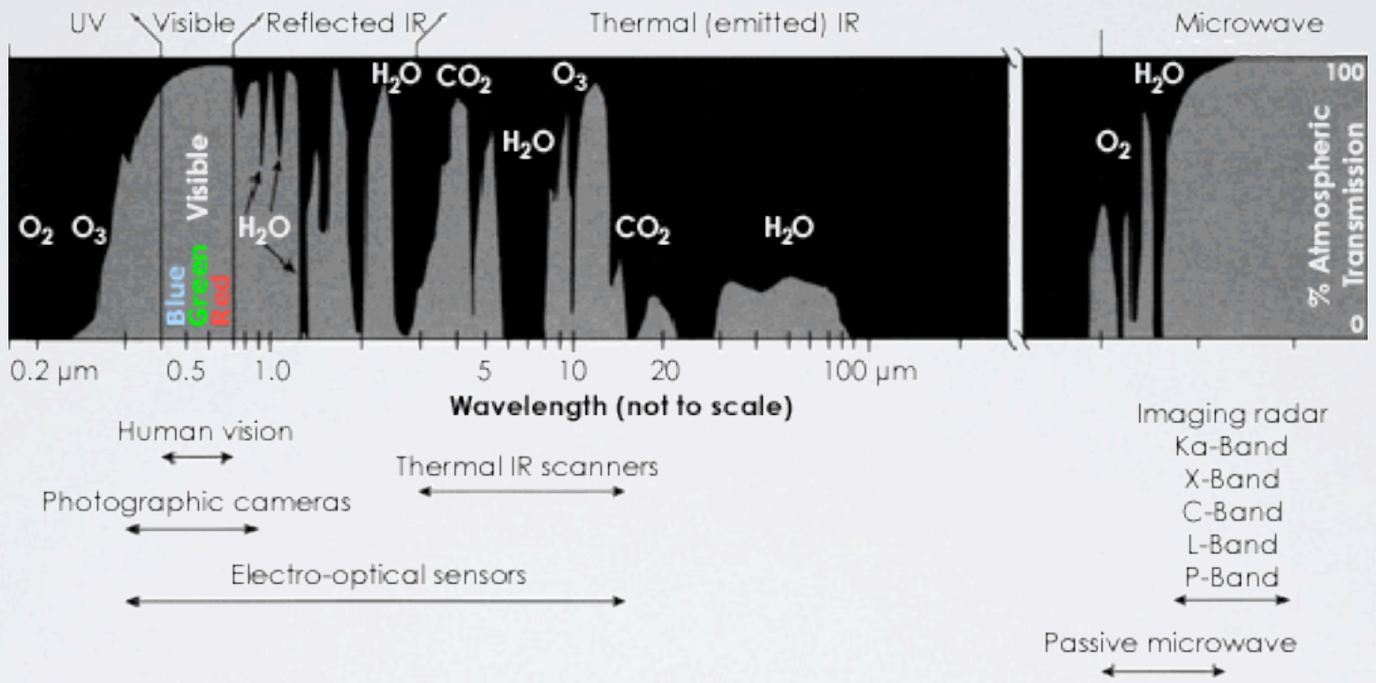
## NGC 1316 in the optical




Salim & Rich 2010

# WEIRDER STILL

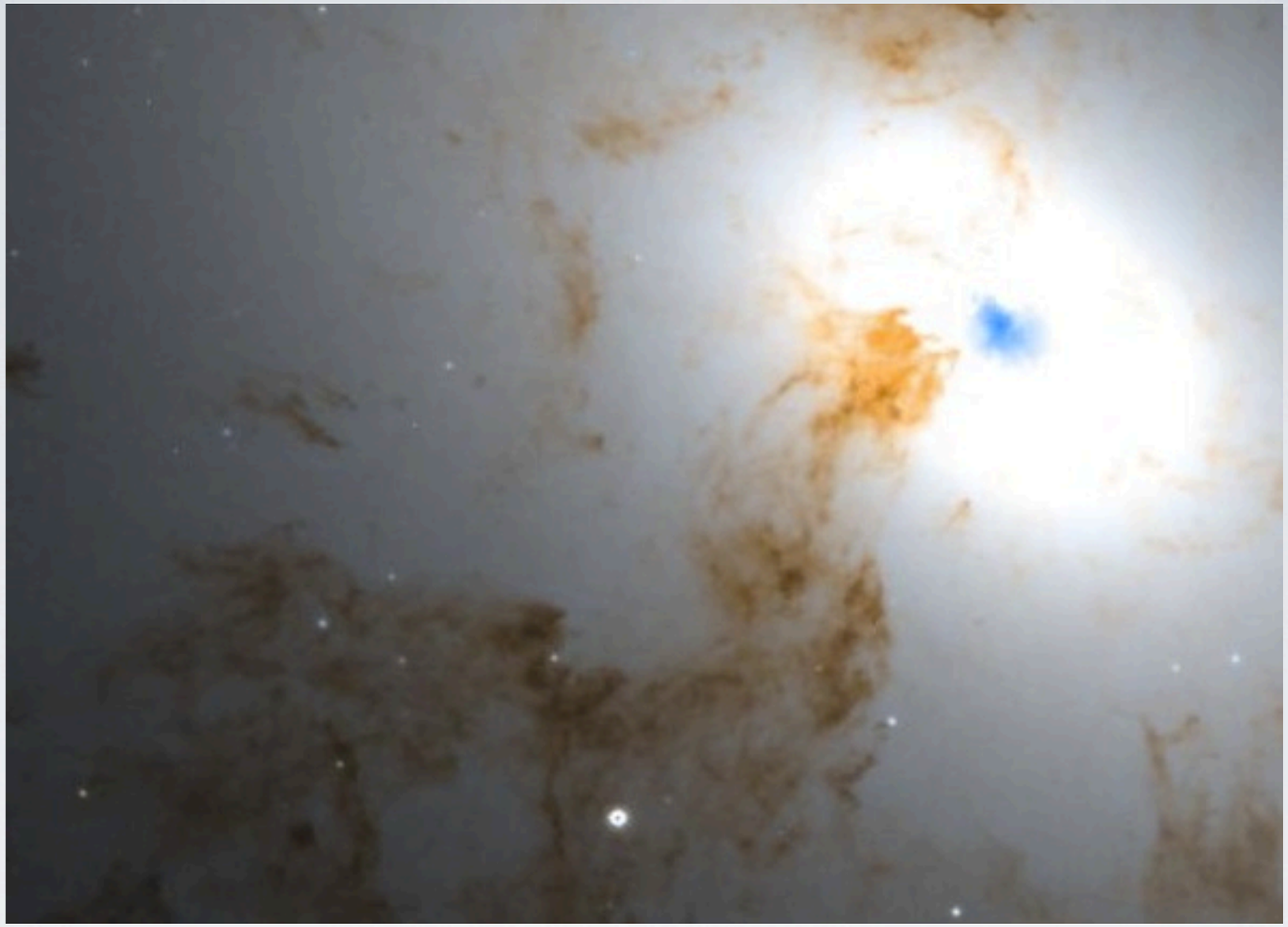
## HST ACS Solar-Blind Channel F125LP (Far-UV) images of "Quiescent" early-type galaxies




NASA Earth Observatory

# WHY SPACE?

## Wavelength – Far ultraviolet is inaccessible from Earth



Dust in NGC 1316 core – HST ACS/WFC F435W/F814W

# WHY SPACE?

Resolution – Features are too small to be seen with ground-based resolution

# STAR FORMATION IN ELLIPTICALS

Recent star formation in local, morphologically disturbed spheroidal galaxies on the optical red sequence

Sugata Kaviraj 2010

# SAMPLE DESCRIPTION

- Reddest, most luminous red galaxies by selection
- 126 galaxies (of which 101 have reliable SDSS/GALEX data)
- 86 Early-types (bulge dominated)
- 53% of total, 71% of early-types, show tidal disturbances

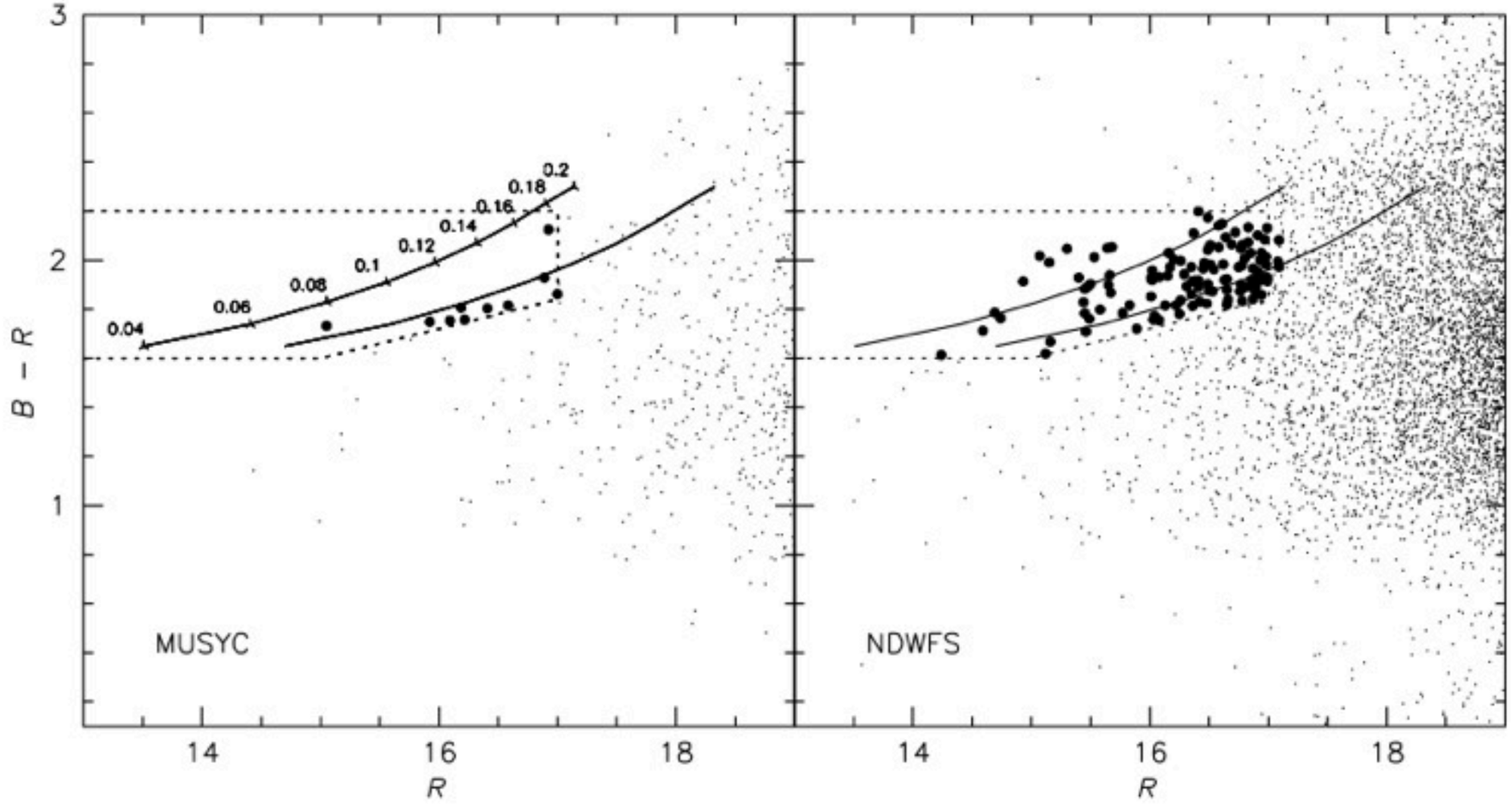



FIG. 2.—Sample selection. Solid lines show the expected $B - R$ colors and $R$ magnitudes for $L_*$ and $3L_*$ elliptical galaxies at redshifts $0.04 \leq z \leq 0.20$. The dashed lines show the selection region in color and magnitude. MUSYC consists of four 0.3 deg$^2$ fields, including the areas around the ECDF-S and the EHDF-S. The NDWFS covers a contiguous area of 9.3 deg$^2$.

# SAMPLE CRITERIA

Color/mag cuts (loosely?) based on L>L* models of elliptical galaxies from z = 0.04 to 0.20


# SAMPLE GALAXIES

Example tidally-disturbed early-type galaxies from the vD05 sample

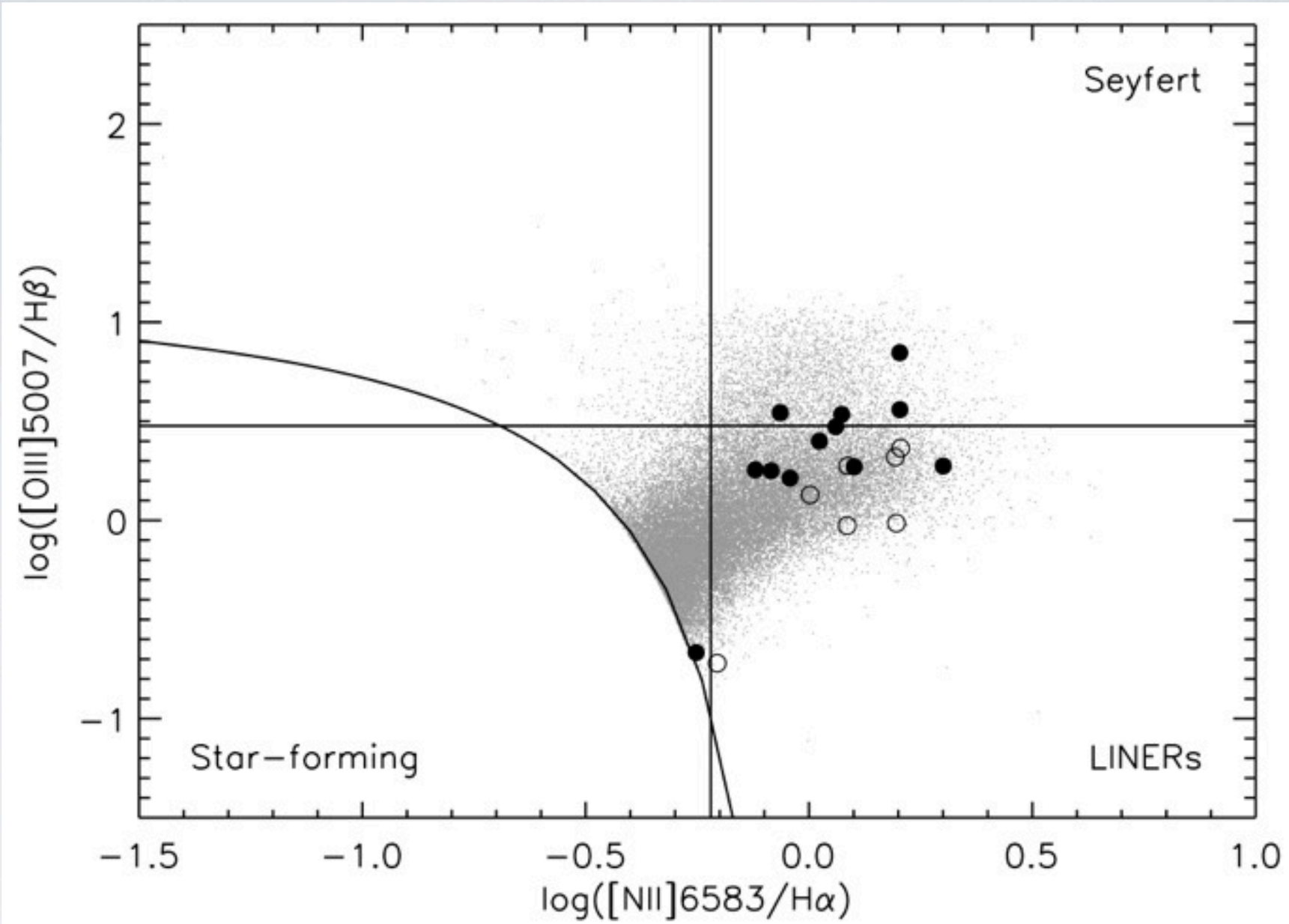
# OVERVIEW

- Use a relatively unambiguous method of measuring recent star formation in ellipticals (UV light)
- Compare to a measurement of tidal disturbance
- Profit?

Stephan's Quintet – HST WFC3

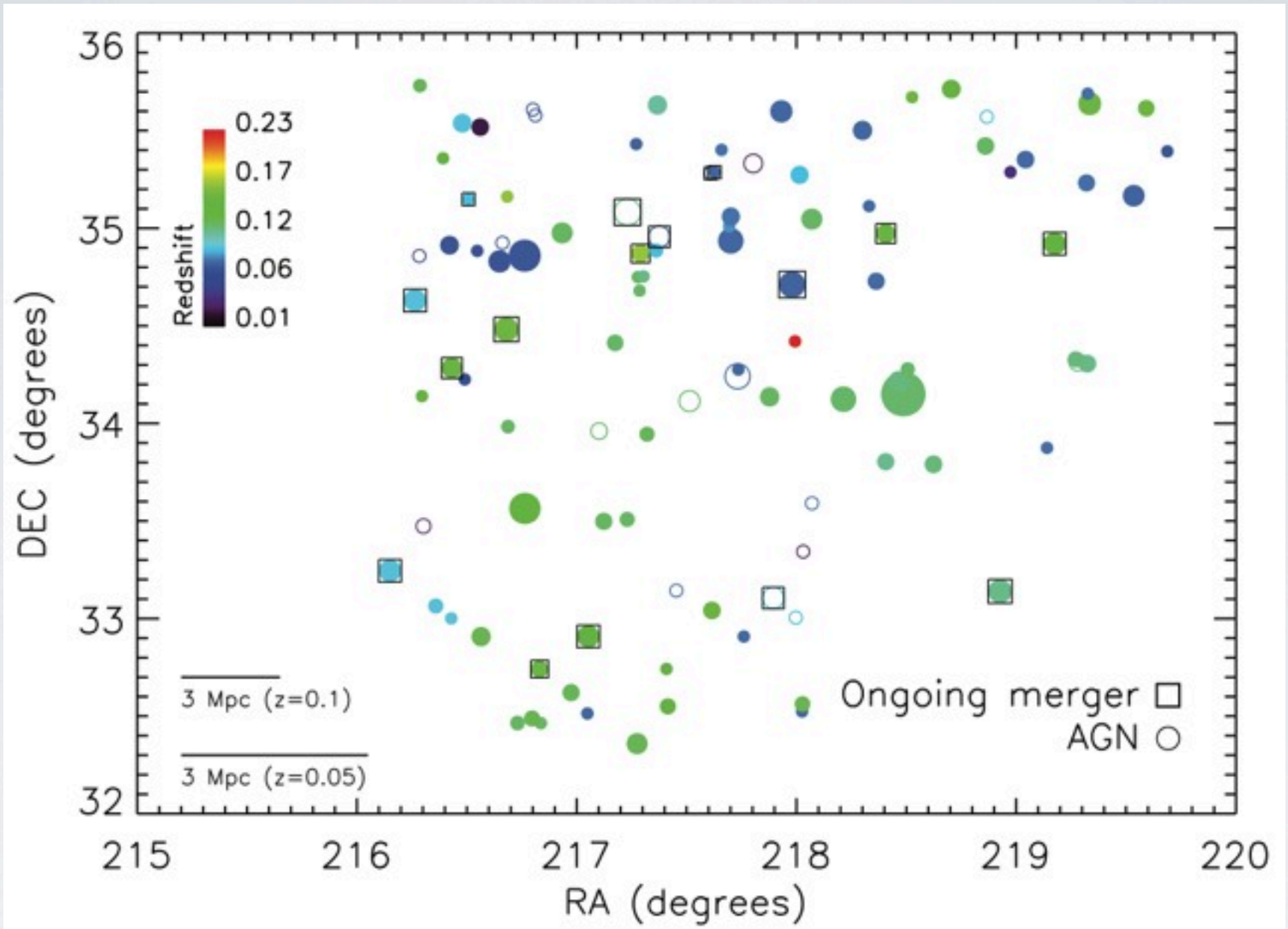
# MERGER-DRIVEN SF

Mergers can compress existing gas, triggering a star formation episode.




# AGN

BPT plot, comparing line emission ratios as a diagnostic of Active Galactic Nucleus activity. AGN emit UV, also.

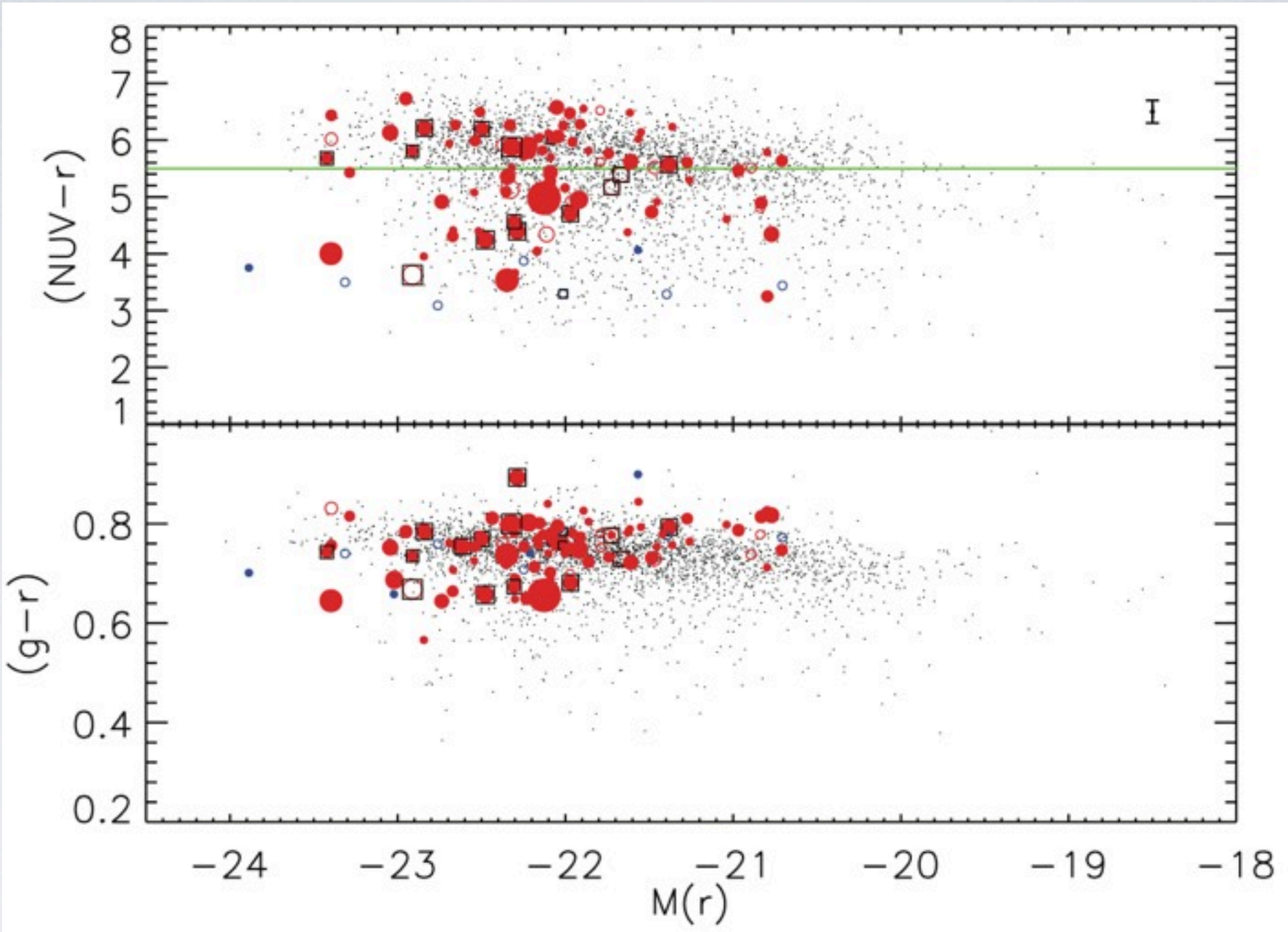



# SPATIAL DISTRIBUTION

Upshot – Sample isn't from particularly dense regions, so tidal features are common among field ellipticals.



Symbol sizes = tidality parameter.
Open symbols = AGN.
Boxes = Ongoing merger.




# UV/OPTICAL CMRS

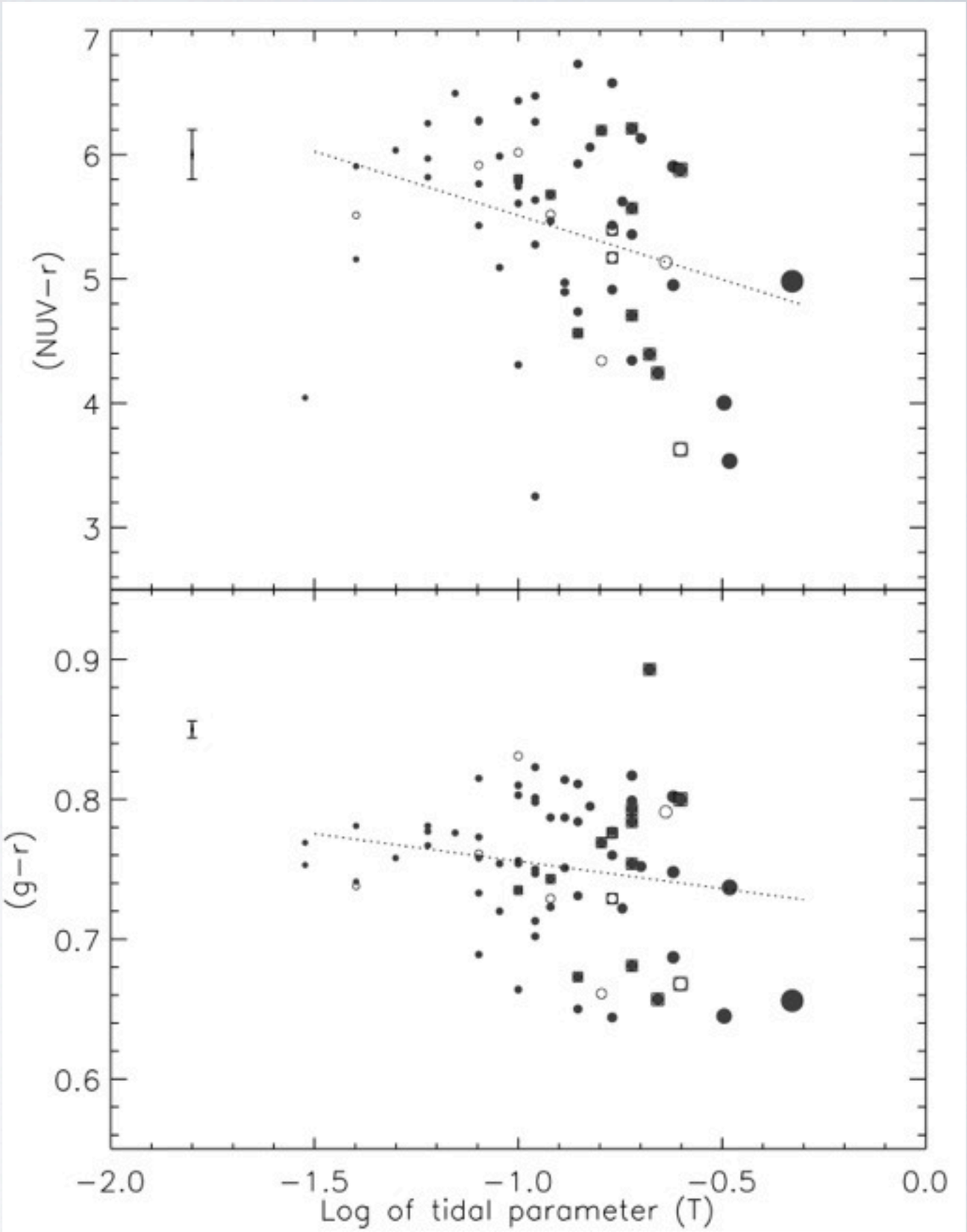
Small spread in g–r color, large spread in NUV–r color. Below the green line, are likely to have recent star formation.



blue symbols = spirals, red = ellipticals

# COLOR-TIDAL PARAMETER RELATION

Statistically significant correlation in both g-r and NUV–r, with a stronger, higher-confidence correlation in NUV–r.



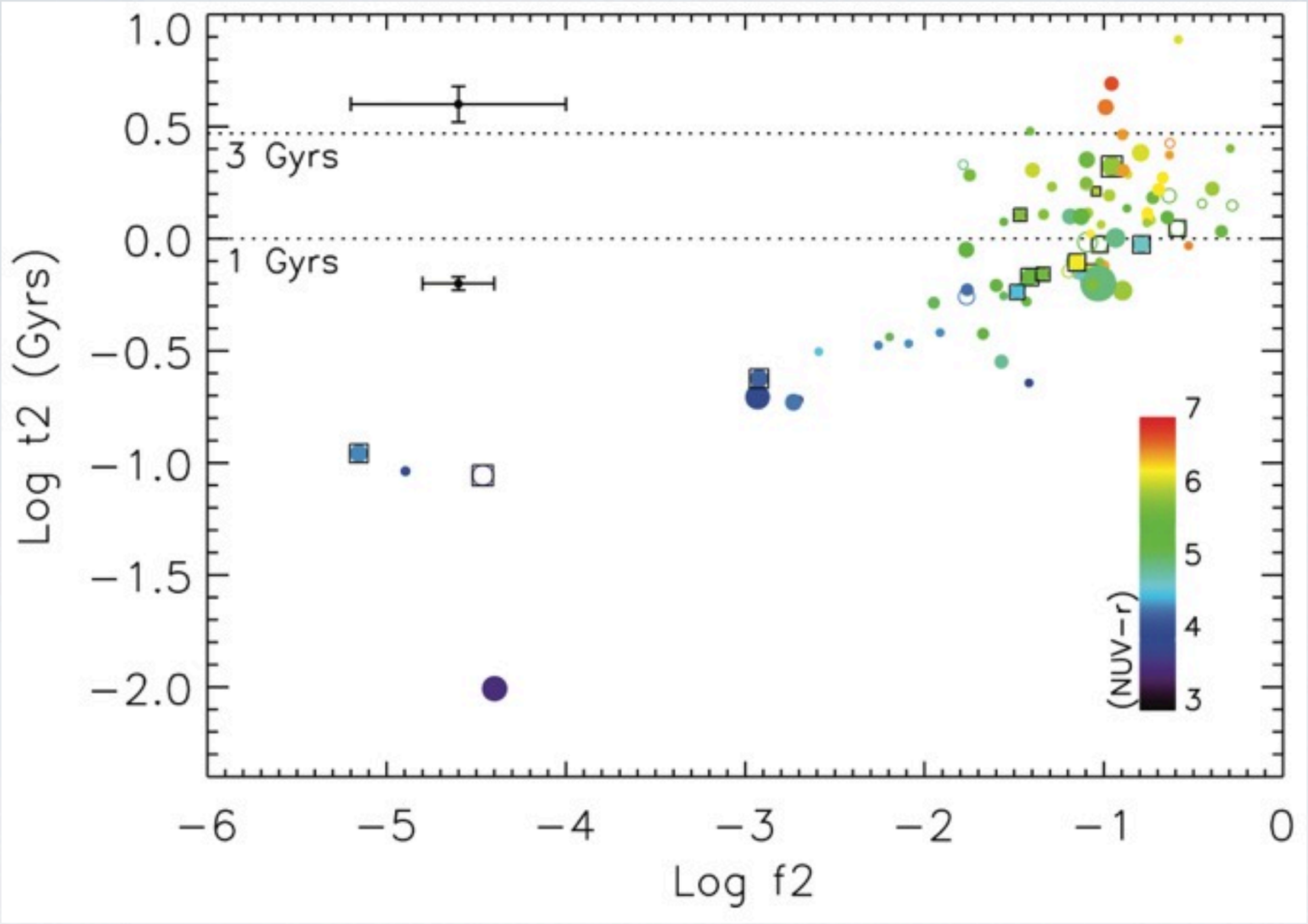
# A NOTE ON THE COLOR-TIDAL PARAMETER RELATION

- Strictly speaking, different underlying populations are responsible for these two measurements

- Tidal distortion is mostly in the existing red population

- NUV color is a contribution from recent star formation

- Likely same underlying physical process (merger). Relative gas content may be responsible for scatter in the correlation.



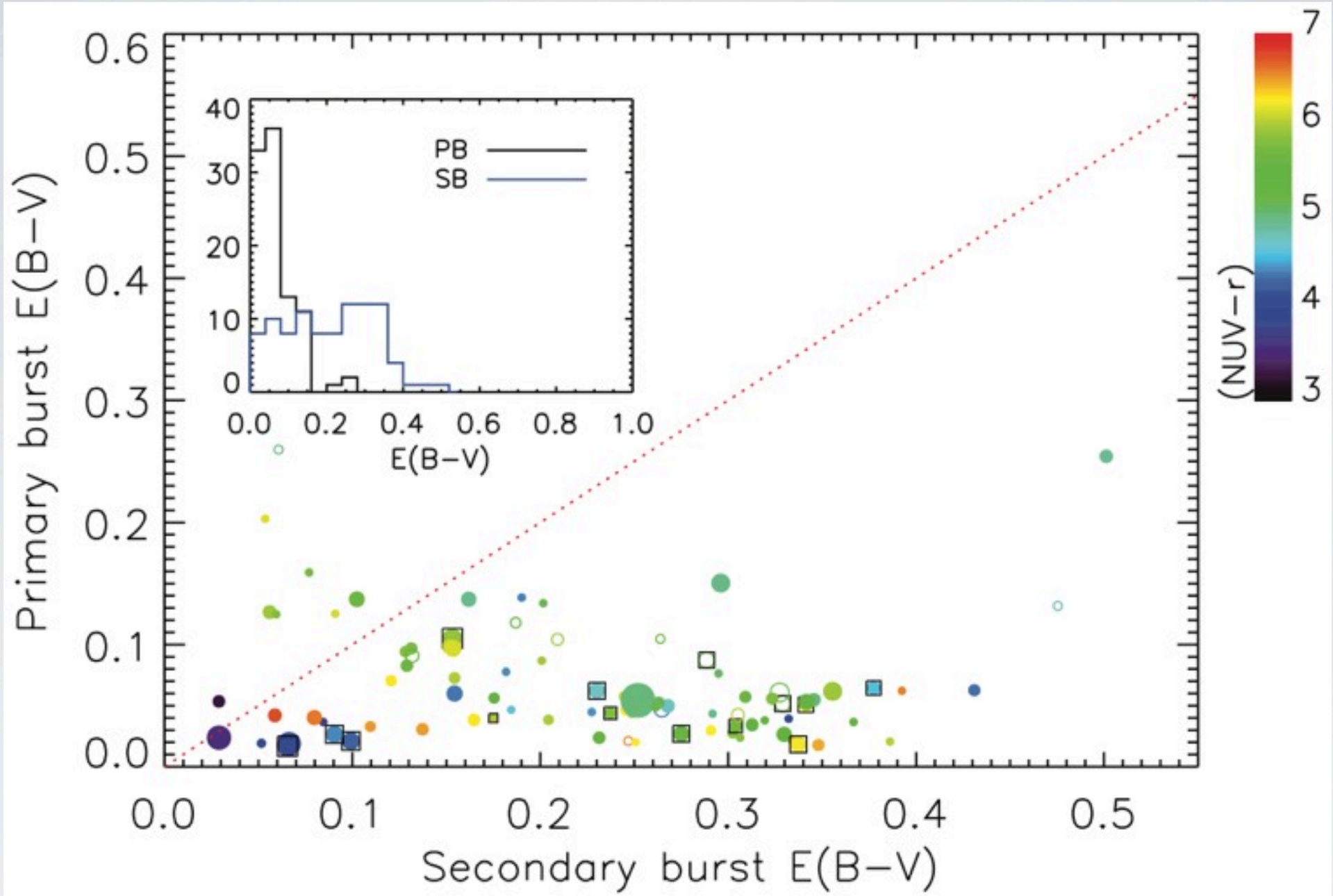

# STAR-FORMATION HISTORIES

Time vs. mass fraction of second star-formation episode, derived from model fits.

"The leverage in $t_2$ and the quality of the $t_2$ fits depends critically on our access to the rest-frame UV, which hosts most of the flux from hot, young main-sequence stars."

# AS MERGER PROCEEDS...

- $t_2$, the lookback time to the last star-formation event, increases
- Remnant relaxes, so tidal parameter decreases
- Gas is expended, so star formation activity decreases, and colors redden
- Mass fraction of the secondary star formation episode increases



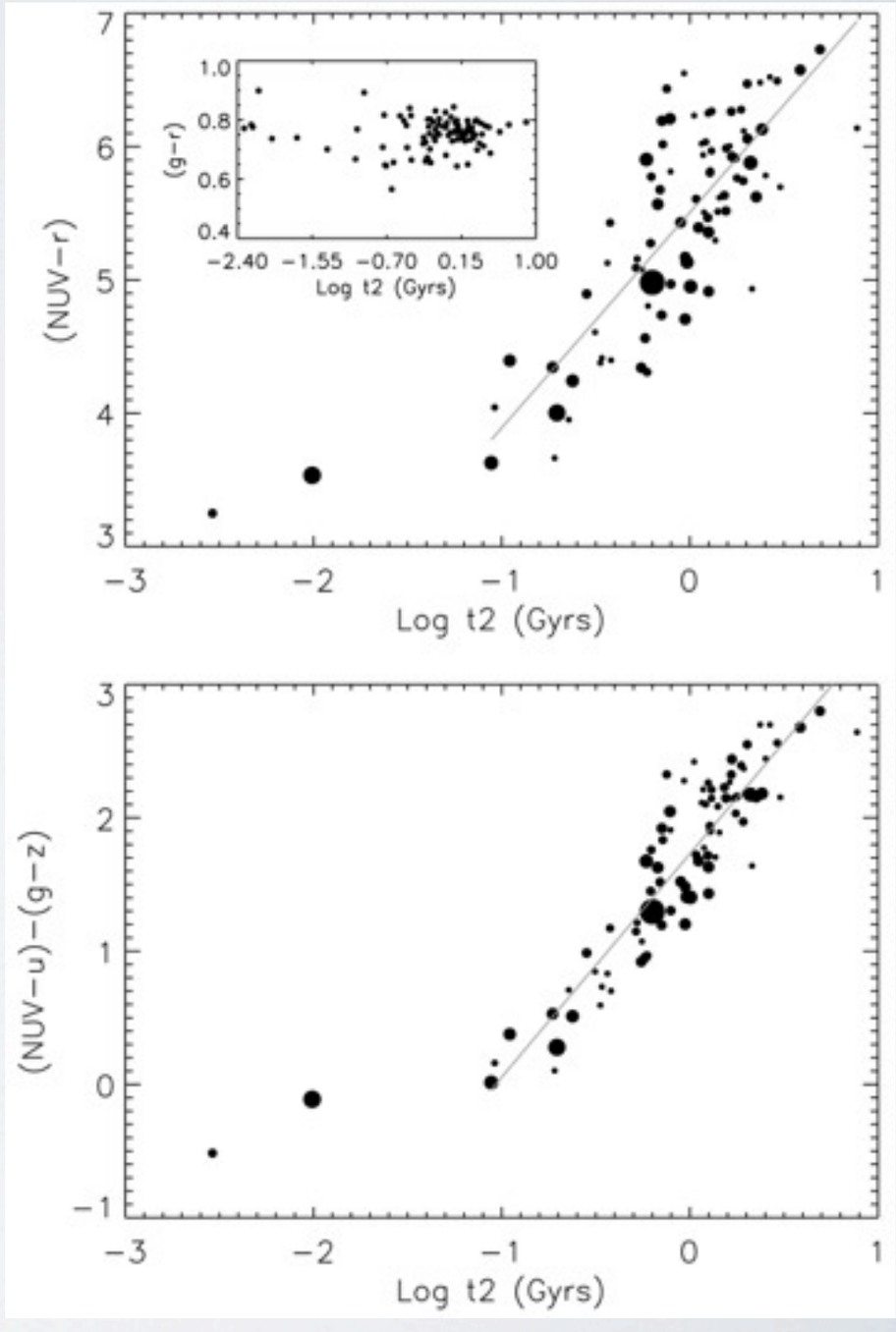

# DERIVED PARAMETER: DUST

Derived dust content of primary burst is low (consistent with early-types). Secondary (merger) burst shows a larger scatter.

# AGE OF LAST STAR FORMATION

- Top panel shows sensitivity of UV in quantifying age of recent star formation

- Using the double color (NUV–u)–(g–z) reduces sensitivity to extinction, and decreases scatter in the relation.

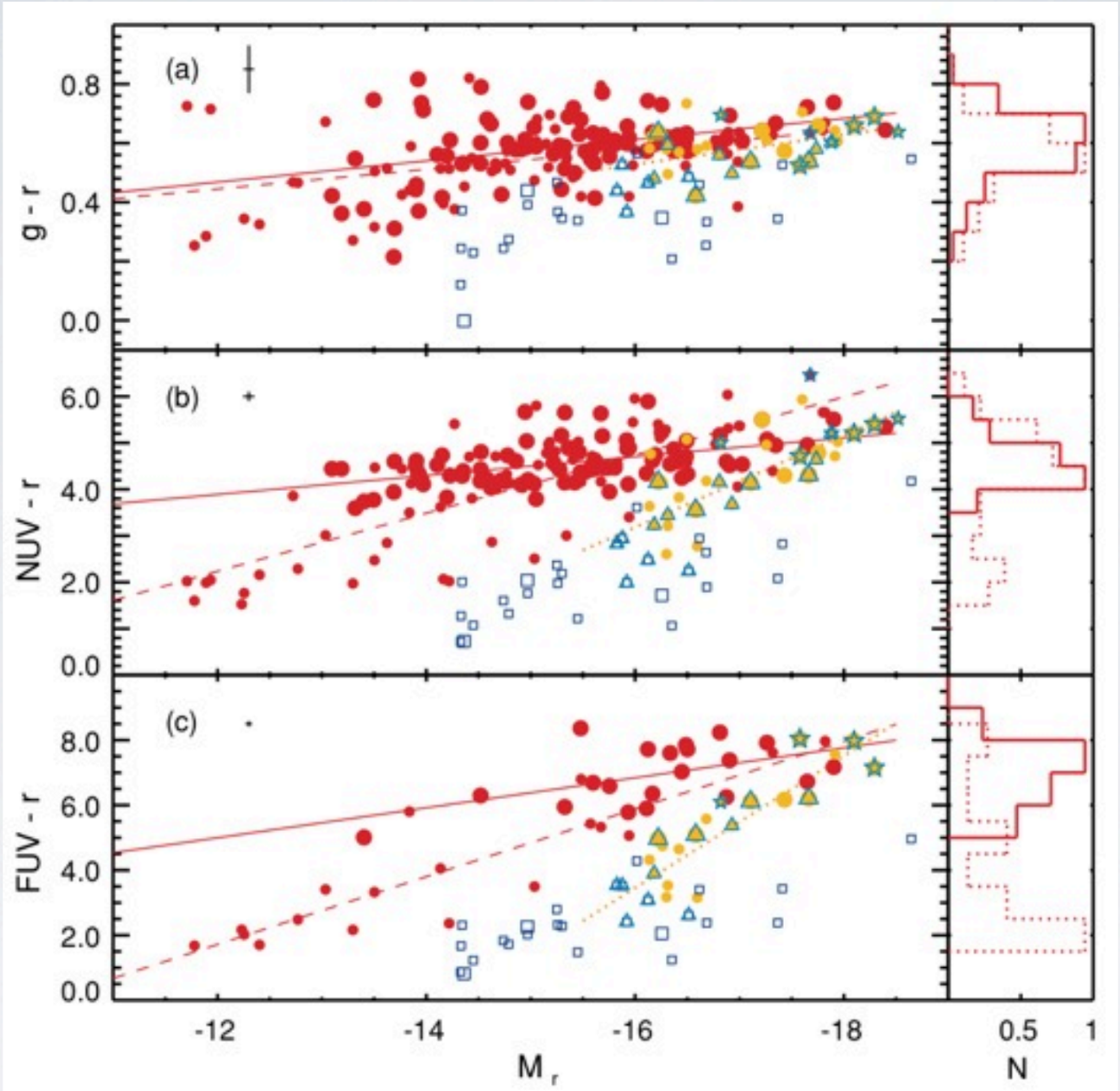


# SPACE-BASED TELESCOPES UNIQUELY ENABLE THIS

- NUV observations used (~2300Å) cannot be made from the ground.

- High-resolution imaging could potentially confirm the spatial extent of the NUV flux within the galaxies. GALEX PSF has FWHM of 5 arcsec, too large to resolve the source.

- Rings such as in the Salim & Rich sample? Associated with the tidal features?




Kim et al. 2010

# OTHER UV PROPERTIES

Discriminating between dwarf early-type galaxies – UV colors as a function of cluster location and Hubble type.



Solid lines, lg. symbols – cluster core, dashed, small symbols – outer cluster, dotted – dS0
dE – red circles, dS0 – yellow circles, dE with disk – stars, dE with blue center – triangle, blue compact dwarf – square

# TAKE-AWAY

If you want to study recent star formation, whether in the most massive galaxies, the smallest dwarfs, or our own, ultraviolet observations are your pal!