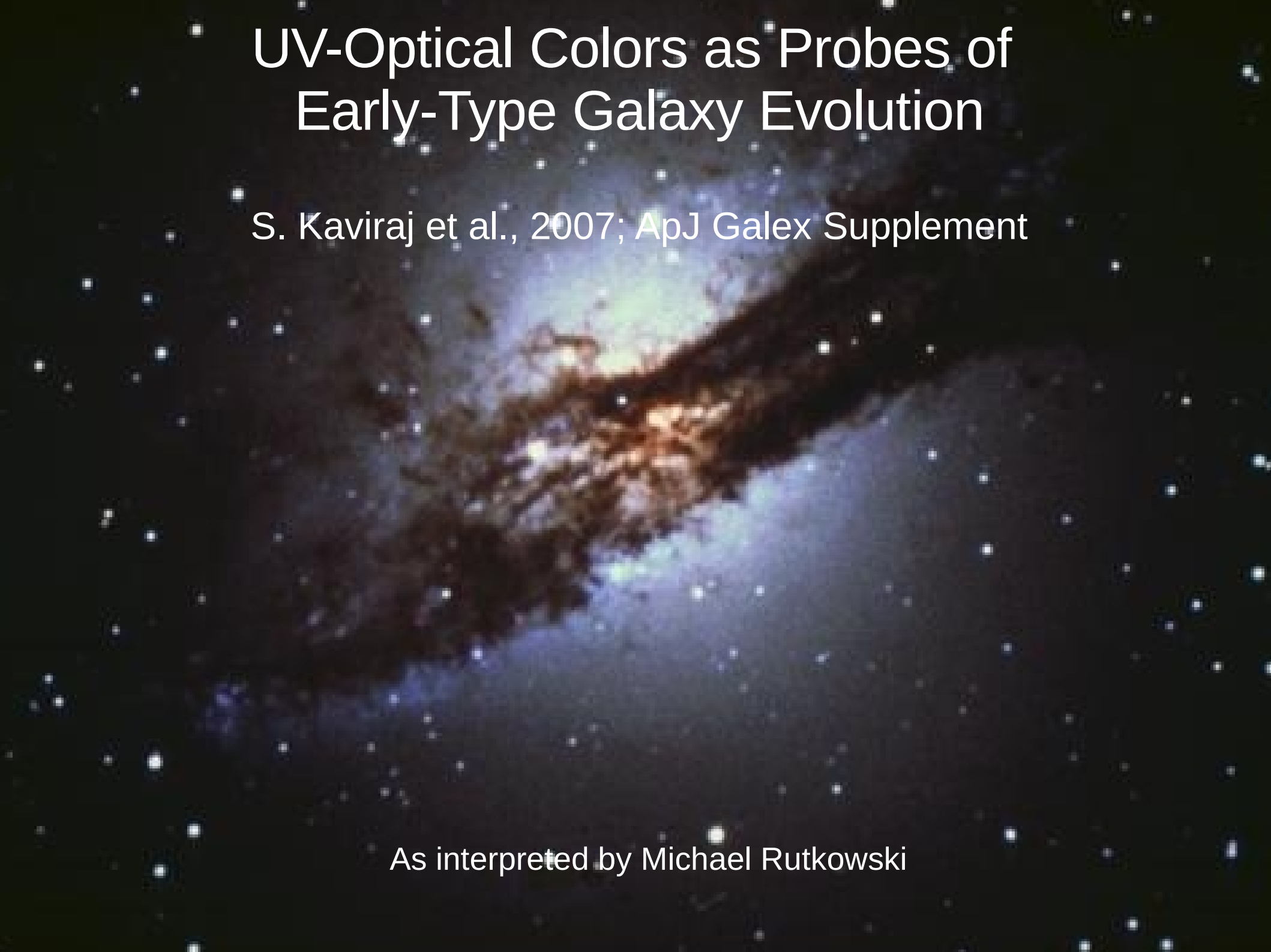
UV-Optical Colors as Probes of Early-Type Galaxy Evolution

S. Kaviraj et al., 2007; ApJ Galex Supplement



As interpreted by Michael Rutkowski

Where do galaxies come from?

- Monolithic Collapse: Efficient, singular episode of star formation at high (z >>1) redshift; the stellar populations passively age.
  - Support: Color-Mag Relations; little evolution with redshift of the slope and scatter in the optical
  - No longer a "strict" theory, cluster galaxies SFH suggest "quasi-monolithic" evolution
- Hierarchical Assembly: Accretion of gas from IGM to form disks and major merger events provide for a “bottom up” construction of galaxies
  - Support: We see mergers

Building the case against strict monolithic formation

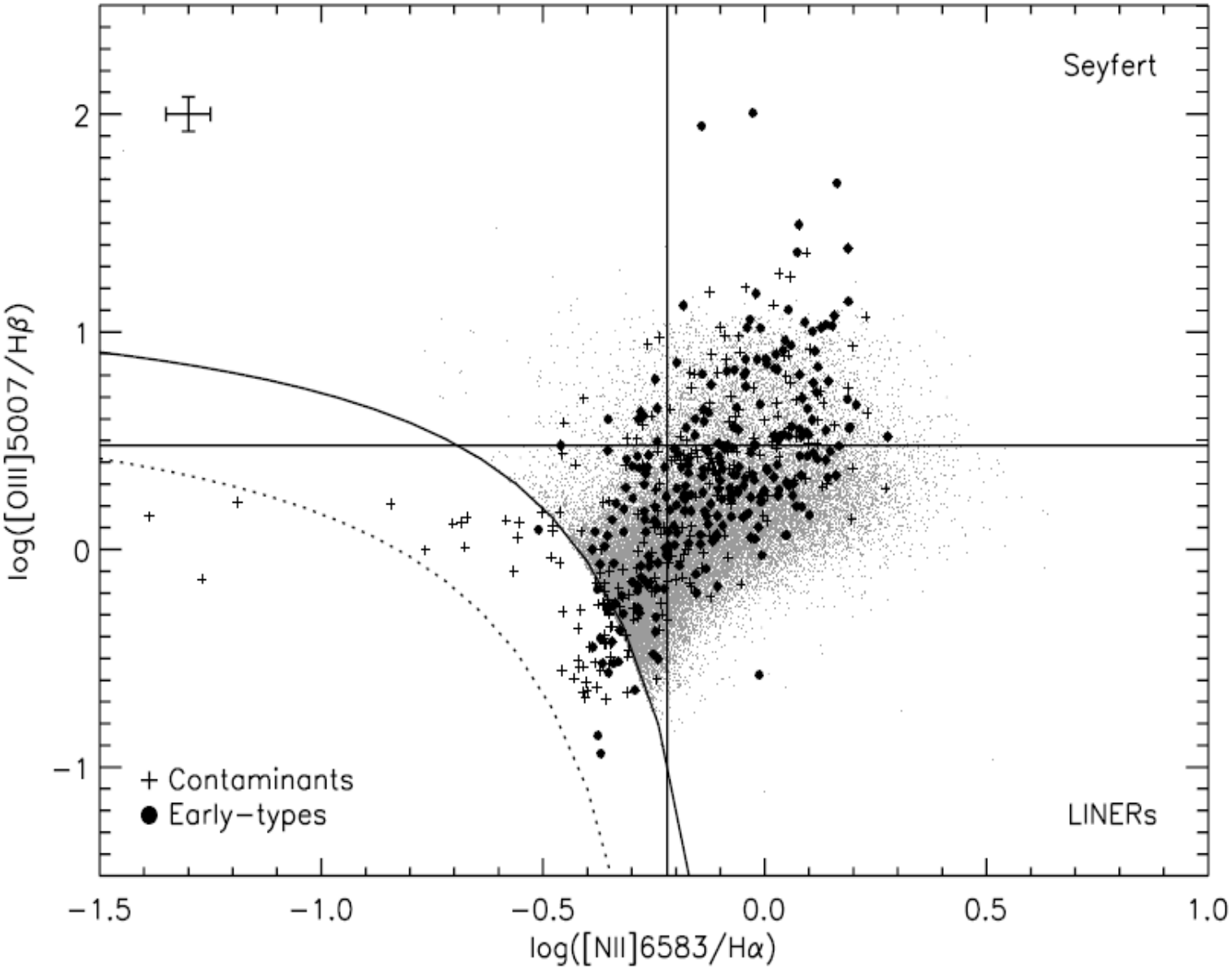
- Cold Gas found in many early-type galaxies
- CMRs (Ferraras and Silk 2000) for early-types in cluster A851 (t_{obs} = ~4.5 Ga) consistent with 10% of galaxy SF less than 500Ma
- UV-Upturn studies find blue colors in some early types can not be fully explained by old (EHB and later) stars
  - Deharveng et al. 2002
  - Bernardi et al. 2003 (B03)

Building the sample set

- B03 routine to find early types in catalogue from SDSS
  - Problem:
    - Visual Inspection shows contamination from late type spirals
    - Excludes recent SF early types
  - Solution:
    - Select on SDS parameter fracDev (1 => deVaucouleurs fit; 0 => exponential) in g',r',i'
    - Confirm by eye

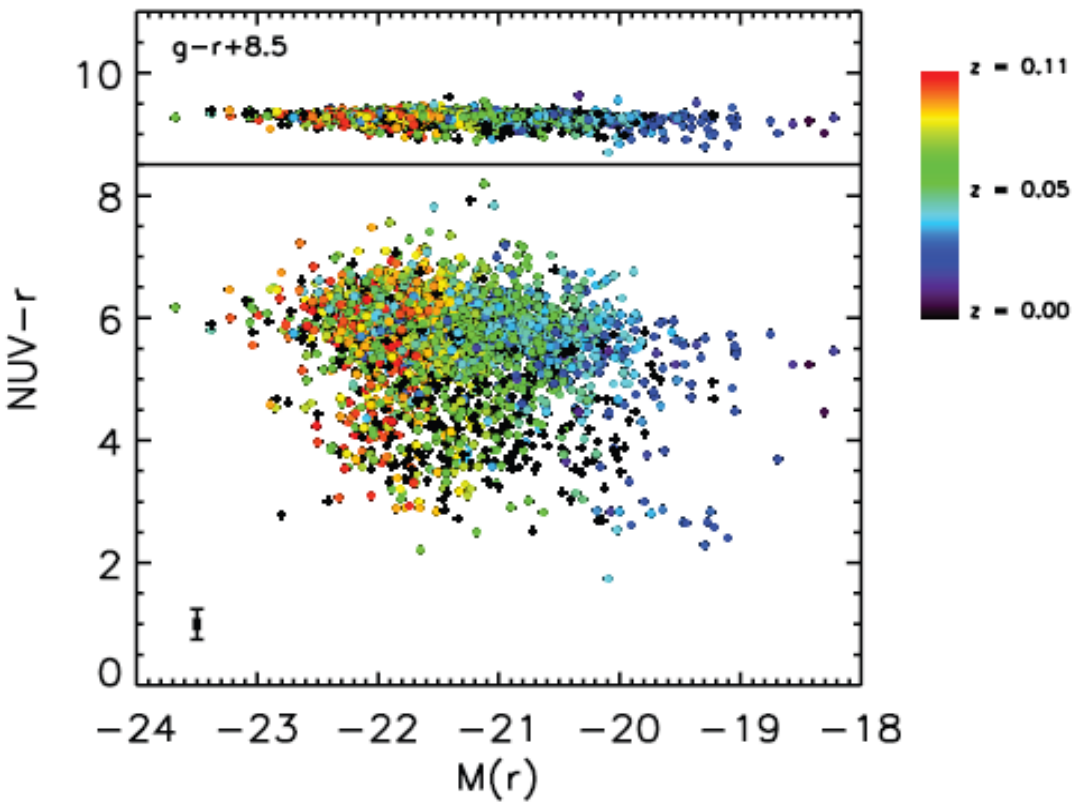
- Compensating for AGNs
  - Type II's identified by strength of metal emission lines
    - Reducing the sample by K03 method
      - Generated template spectra for 10,000 SF histories (Yi et al. 2003)
      - Minimize fit between template and observed spectra
      - Subtract model absorption from galactic spectra to produce emission spectra
      - Calculate emission line ratios (O[III]/HBeta, N[II]/HAlpha) in the emission regions
    - Reducing by comparison with Radio surveys
      - If SN too low or galaxies lack four emission lines, radio treatment is applied
      - Objects observed in the GALEX and overlapping radio surveys (FIRST,NVSS) with radio luminosities ~10^{22}W Hz^{-1} discarded as Type II AGN (empirical)

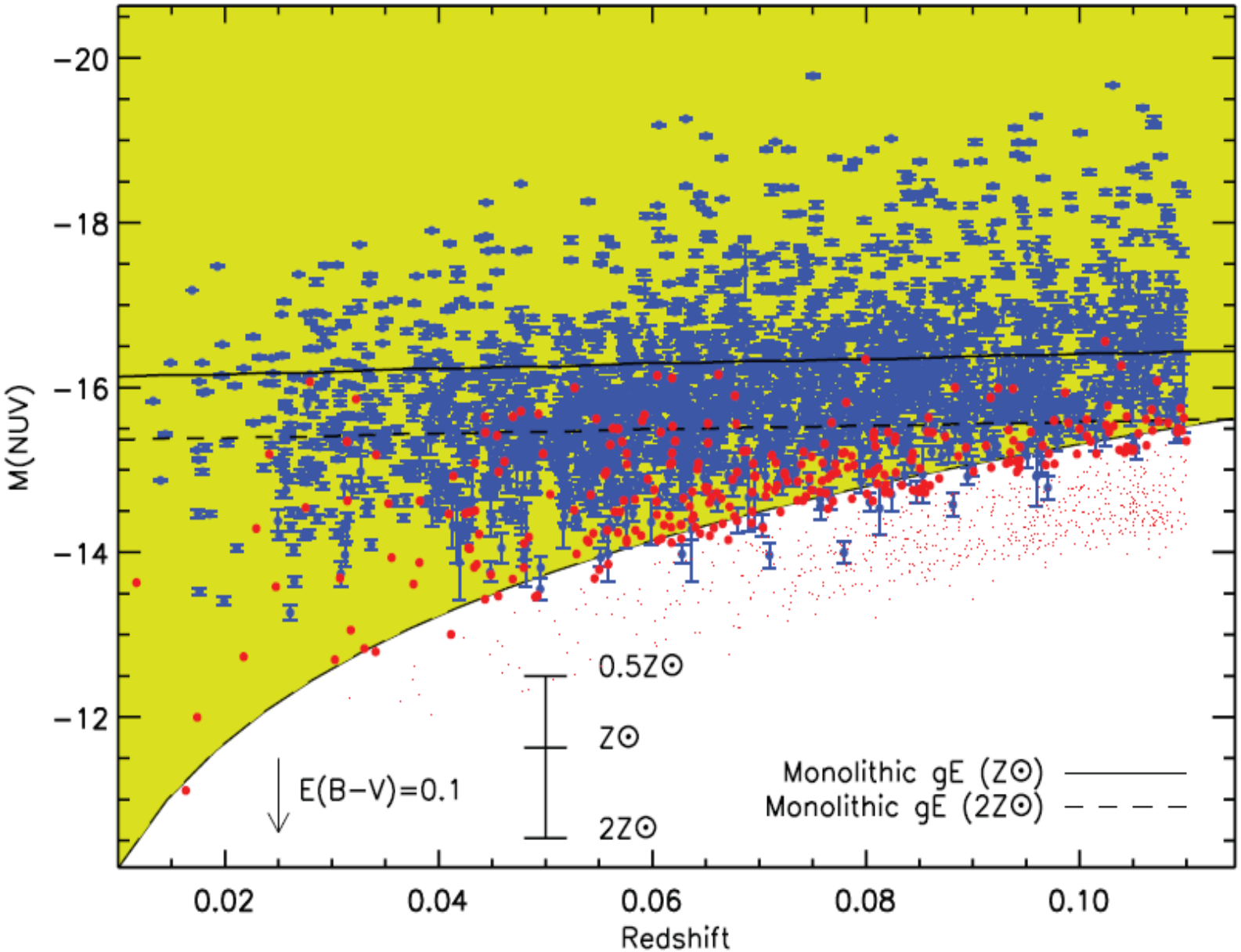
Building the sample set



The data set

- 2116 Galaxies
- Four magnitudes of scatter in the UV!
  - When considering UV-upturn blue-ing (from composite spectrum of NGC 4552) puts lower limit on NUV-R = 5.4 in monolithic model
- No red envelope-

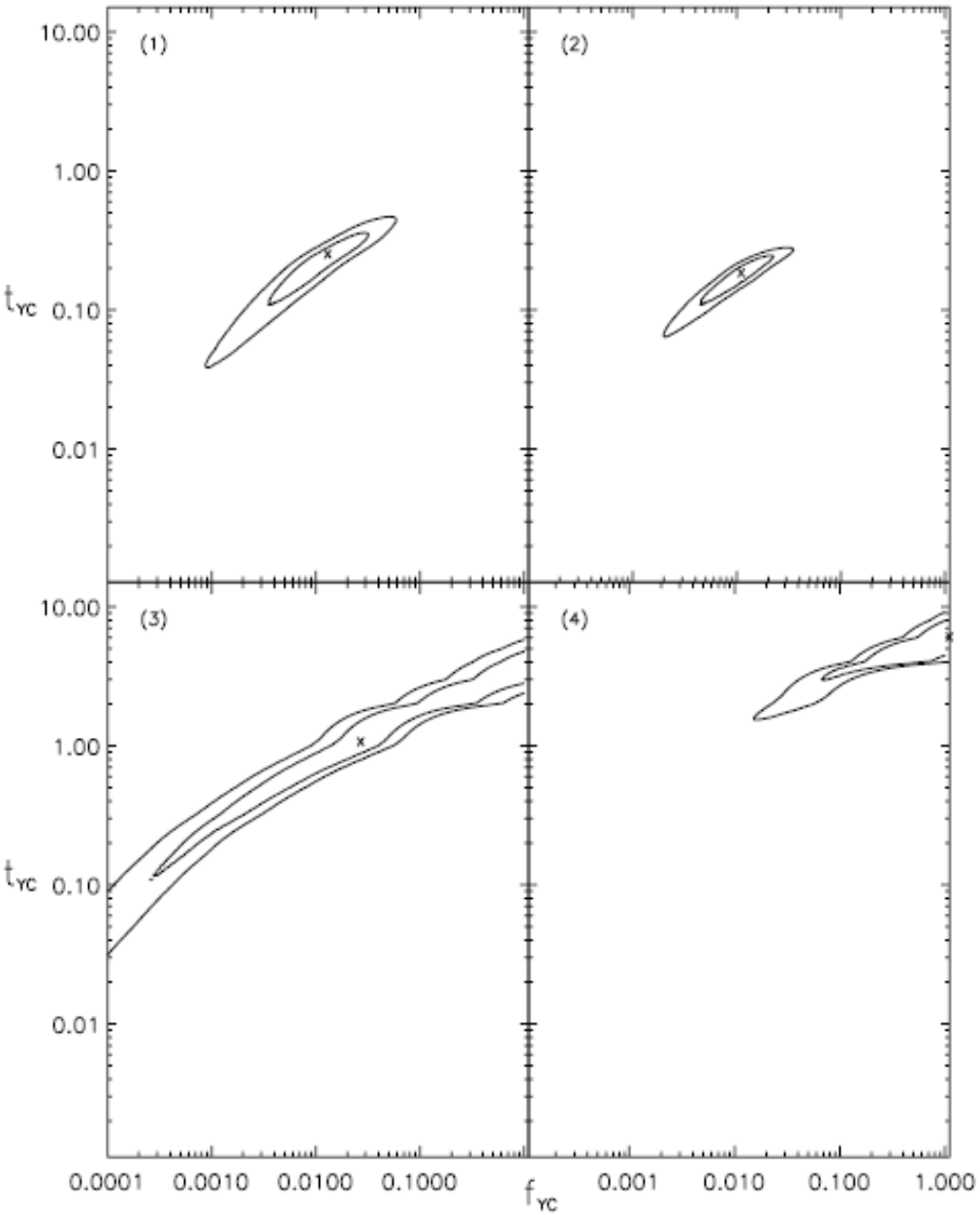




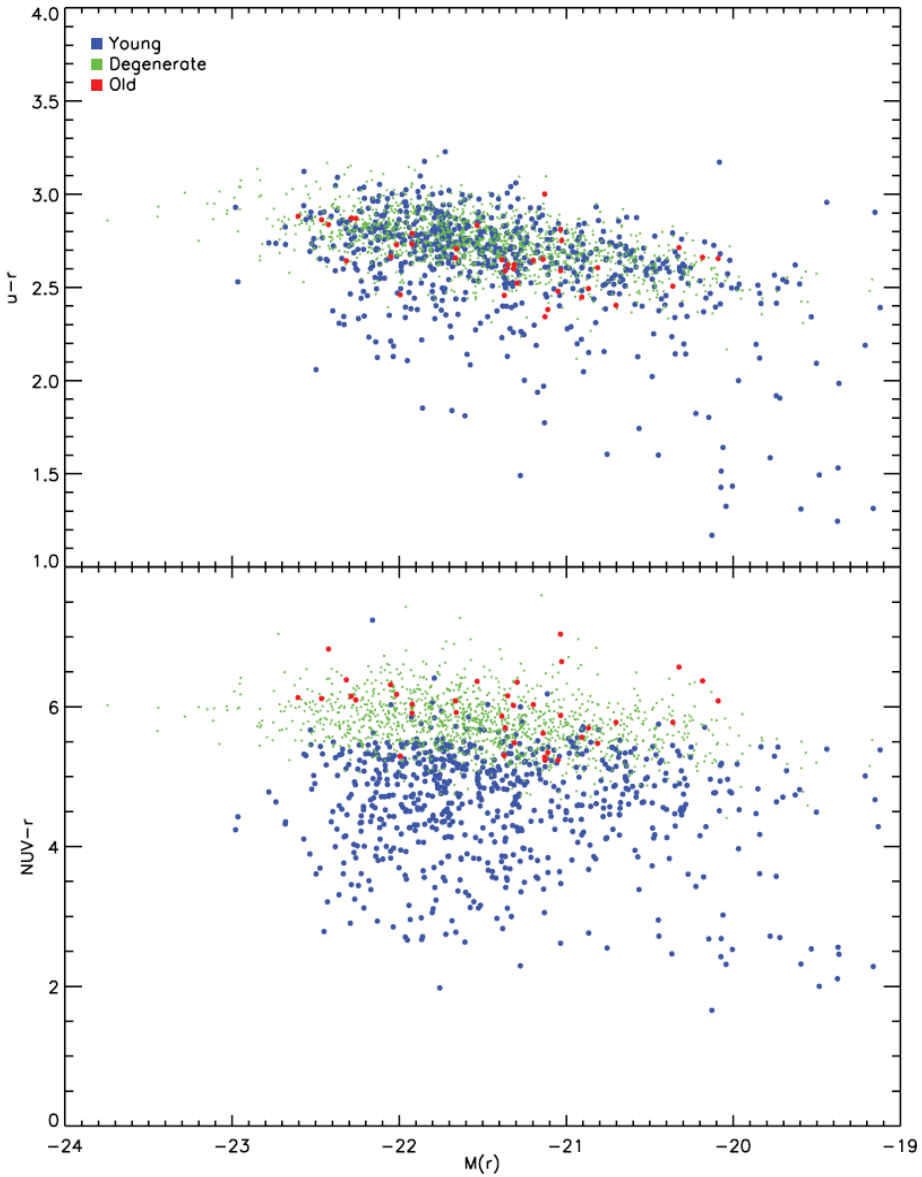
All signs point to a SFH for early type galaxies more complex than strictly passive evolution after monolithic collapse

Fit Results

- Fitting observed SEDs to two stage SFH
- Parameters
  - Initial Burst at z = 3 (11Ga); instantaneous
  - t_{YC}: Second Burst 10^{-2} to 15 (?) Ga; instantaneous
  - f_{YC}: mass fraction of new stars produced at secondary burst; variable 10^{-4} and 1(?)
  - Metallicity: variable 0.5-2.5Solar
  - Extinction: variable 0-0.15 with Calzetti Reddening Prescription (empirically derived, 40 galaxies at z < 0.03 in Calzetti et al. 2000)



Fit Results



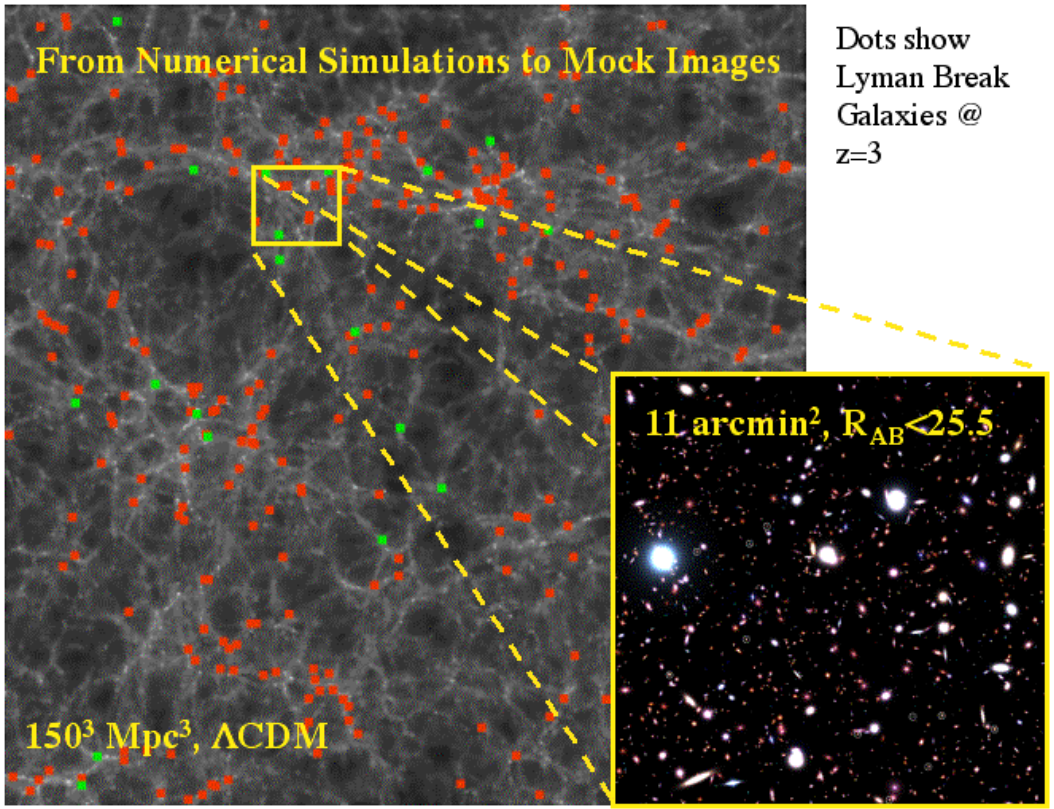
- Optical
  - Low scatter
  - Non-Distinct CM regime
- UV
  - High Scatter
  - “Young” SF confined to NUV-r < 5.5
  - Does degeneracy imply large fraction above NUV-r = 5.5?
- Stacked Blue Galaxies:
  - likely SFH peaked at f_{YC} = .01 and t_{YC} = 0.5 Ga

Formation of the blue fraction

GALICS:*G*alaxies *I*n *C*osmological *S*imulations

"The GalICS model developed at the IAP explicitly intends to address the issue of the high-redshift star formation rate history in a multi-wavelength prospect, from the ultraviolet to the submillimetre range."

Project site at: http://galics.cosmologie.fr/



Formation of the blue fraction

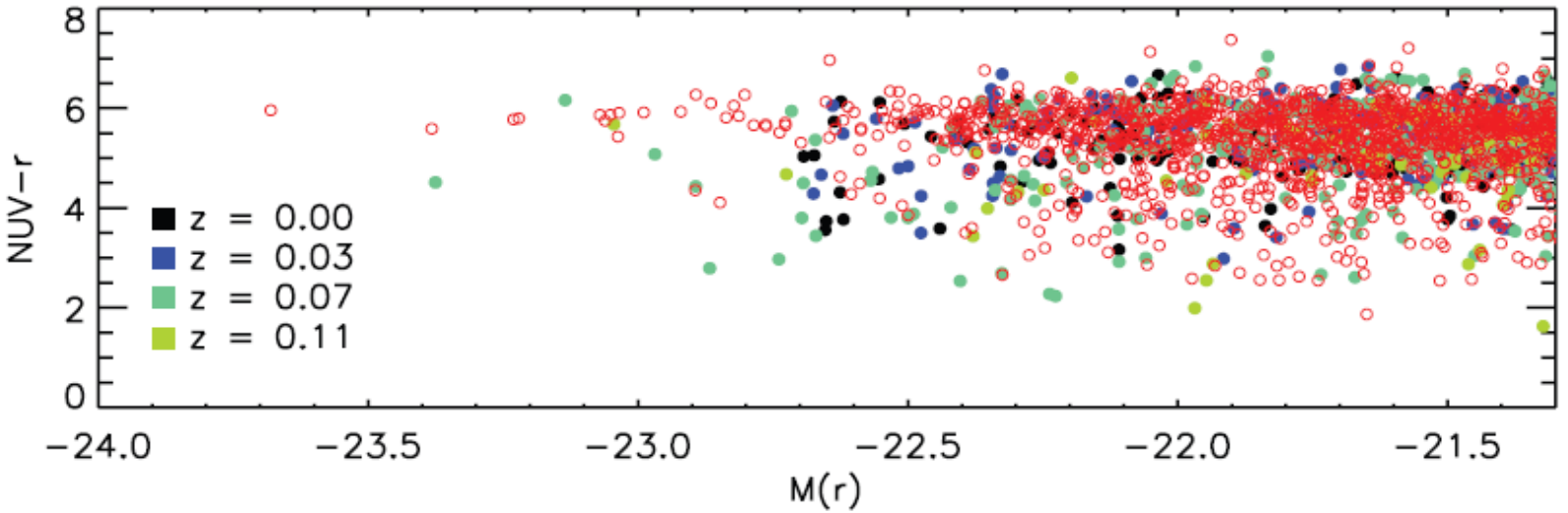
- Comparison between GALICS simulations and observations will provide insight into the formation of young stellar populations in the early-type galaxies
- Free Parameters:
    - Extinction by Birth Clouds
        - BCs are thick, opaque, molecular
        - Optical depth potentially many x's greater than ISM
        - BCs may obscure young stars ~ 100 Myr
            - UV is ~4x more sensitive to dust than Optical
        - Work Around:
            - Vary obscuration age between 10 and 100 Myr
            - Locally increase extinction by factor μ

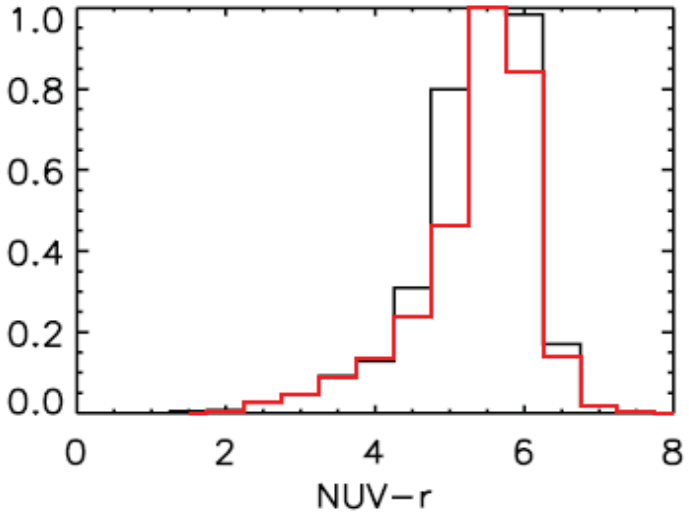
Formation of the blue fraction

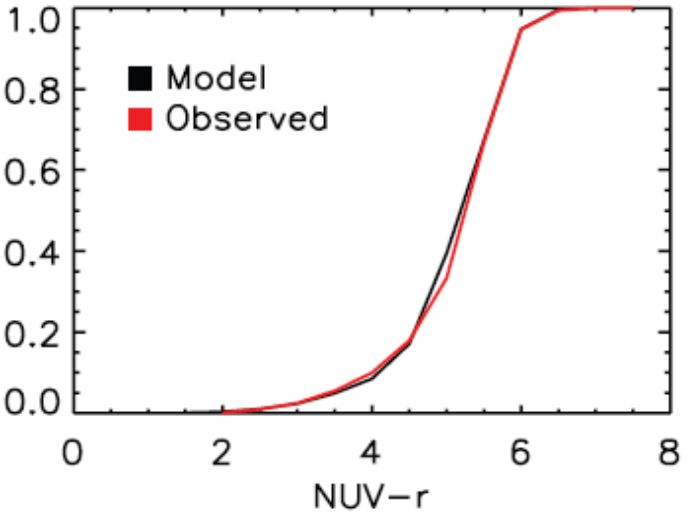
- Free Parameters (cont.)
  - Onset of Star Formation
    - Questions standard SF paradigm; gas = stars
    - Work Around
      - Instantaneous formation instead considered as discrete, random (Poisson in time)
      - Motivated by observations of NGC 205, with bursts at 50 and 100 Ma
      - Allow distribution weighted by κ, number of iterations in burst period
        - Assumed here equal to 10 => 10 bursts per Gyr
      - Define 0 < lmin 0.05 Myr and 0.2 < lmax < 0.5 Myr to bound distribution

Formation of the blue fraction

Best fit model: Mu = 3, tau = 30 Myr, lmin = 20; lmax=200 Myr

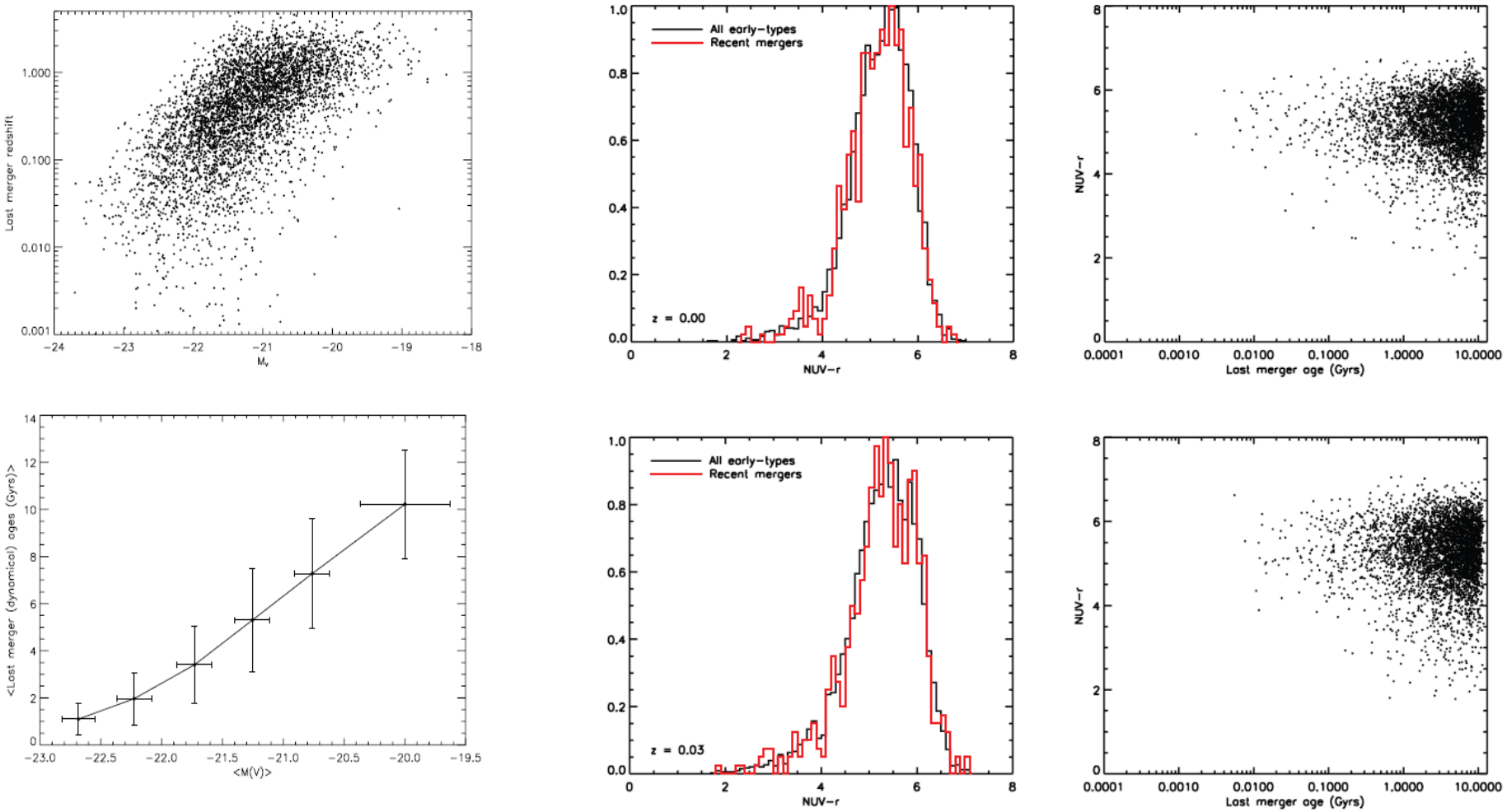






Particulars within the blue fraction

- Hierarchical Paradigm defined by quiescent star formation (More cold gas, more stars) and Mergers (dynamical interactions between stellar systems)
    - Does either dominate the evolution history?

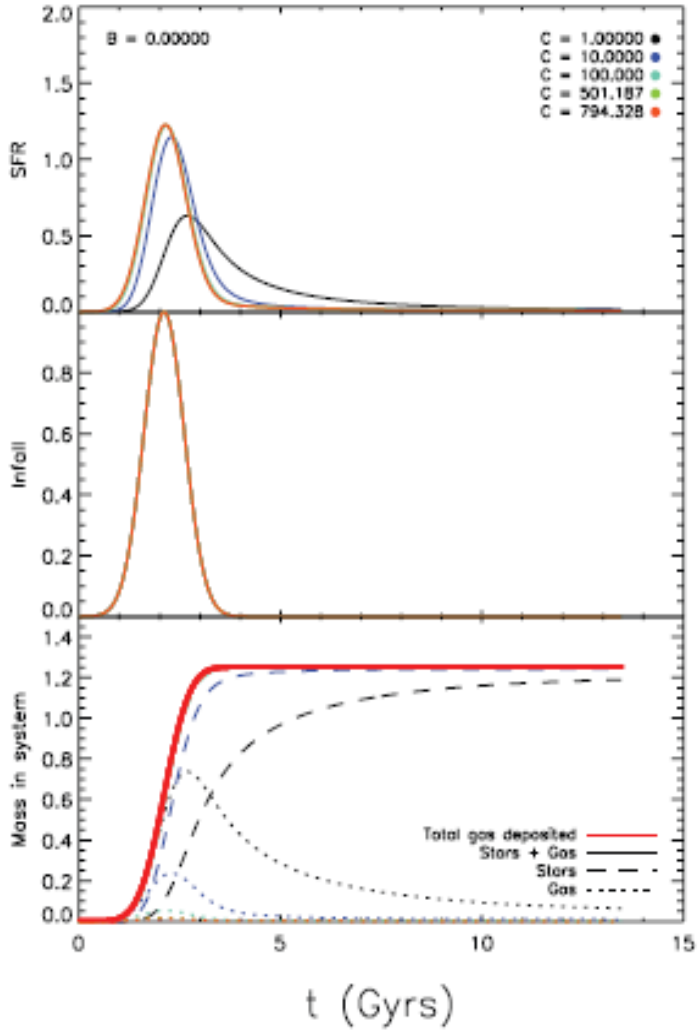


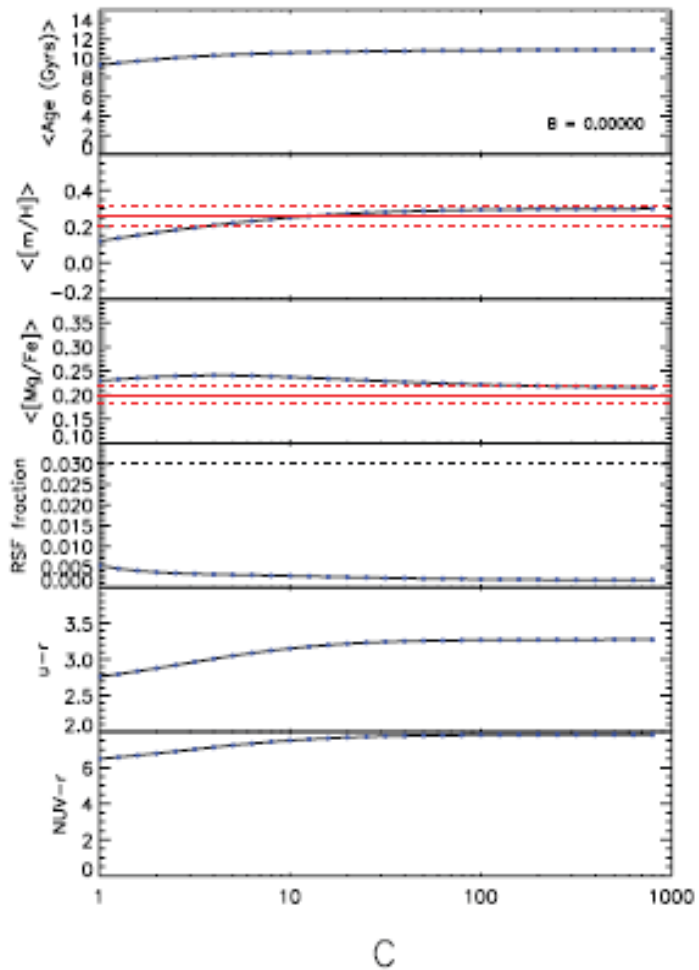
One last look at Monolithic Collapse

- Monolithic burst fuels nearly instantaneous burst of SF, most gas would be recycled
- Could recycled fuel promote continual SF ?
- Simulating monolithic model , attempt to reproduce the photometry of the blue fraction
  - Model Parameters:
    - Chemical Enrichment first outlined by Ferreras and Silk
    - Yields from Thielemann et al. (>10 M_Sun) and van den Hoek and Groenewegen (< 10 M_Sun)
    - Salpter IMF
    - Instantaneous recycling, but not instantaneous mass loss
    - Infall is Gaussian at high redshift (~ 3)
    - SFR by Schmidt Law
    - Free Parameters: C and B (Wind fraction) $\Psi = Cg^{\alpha}$

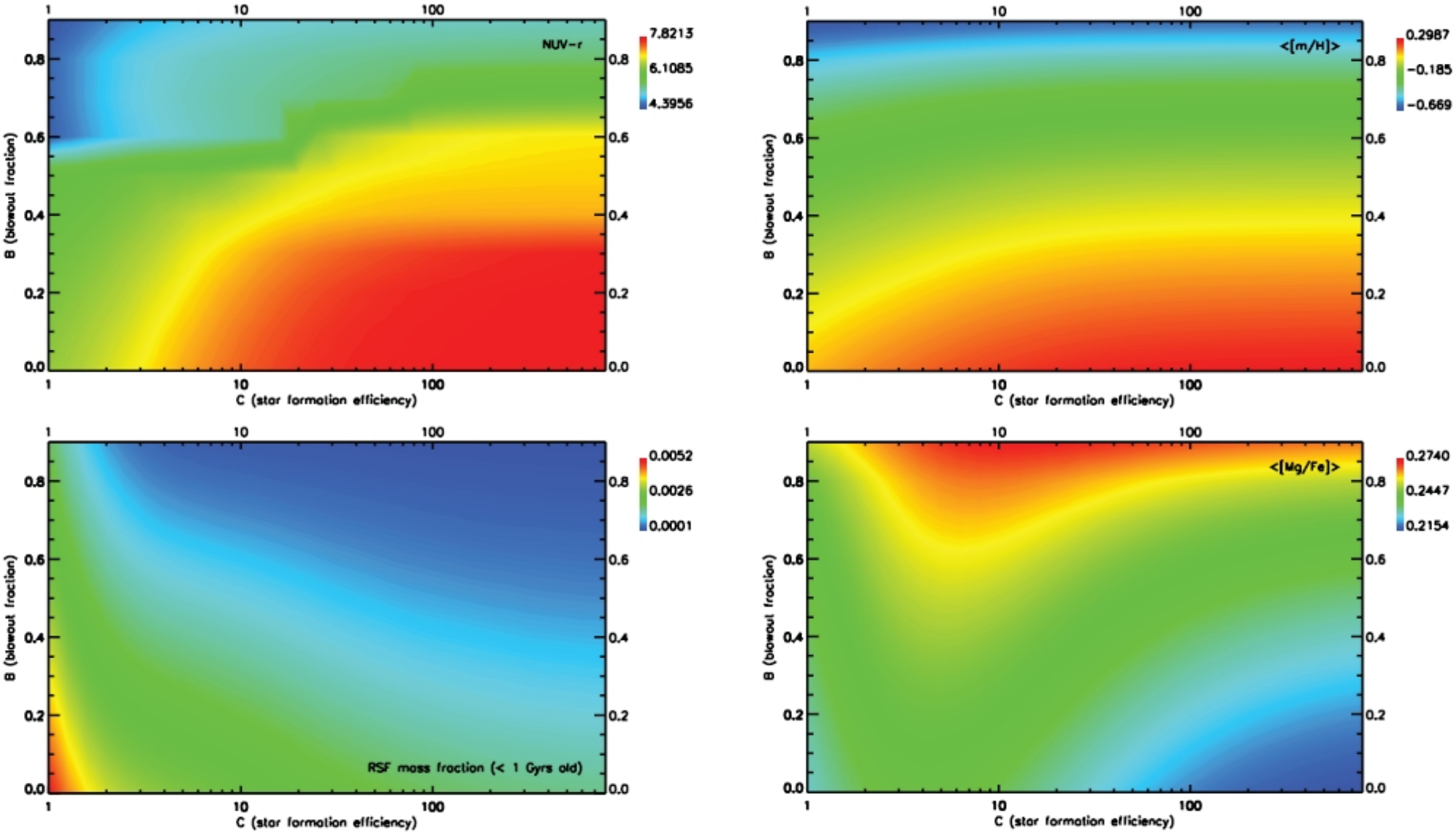
Model Results

- With no winds: Prediction of late time RSF < 0.005; Merger models predict RSF ~ 0.03
- C=1: 1 Gyr delay in SF. C>100: small delay. 10-11 Gyr later...SFR and axis indistinguishable





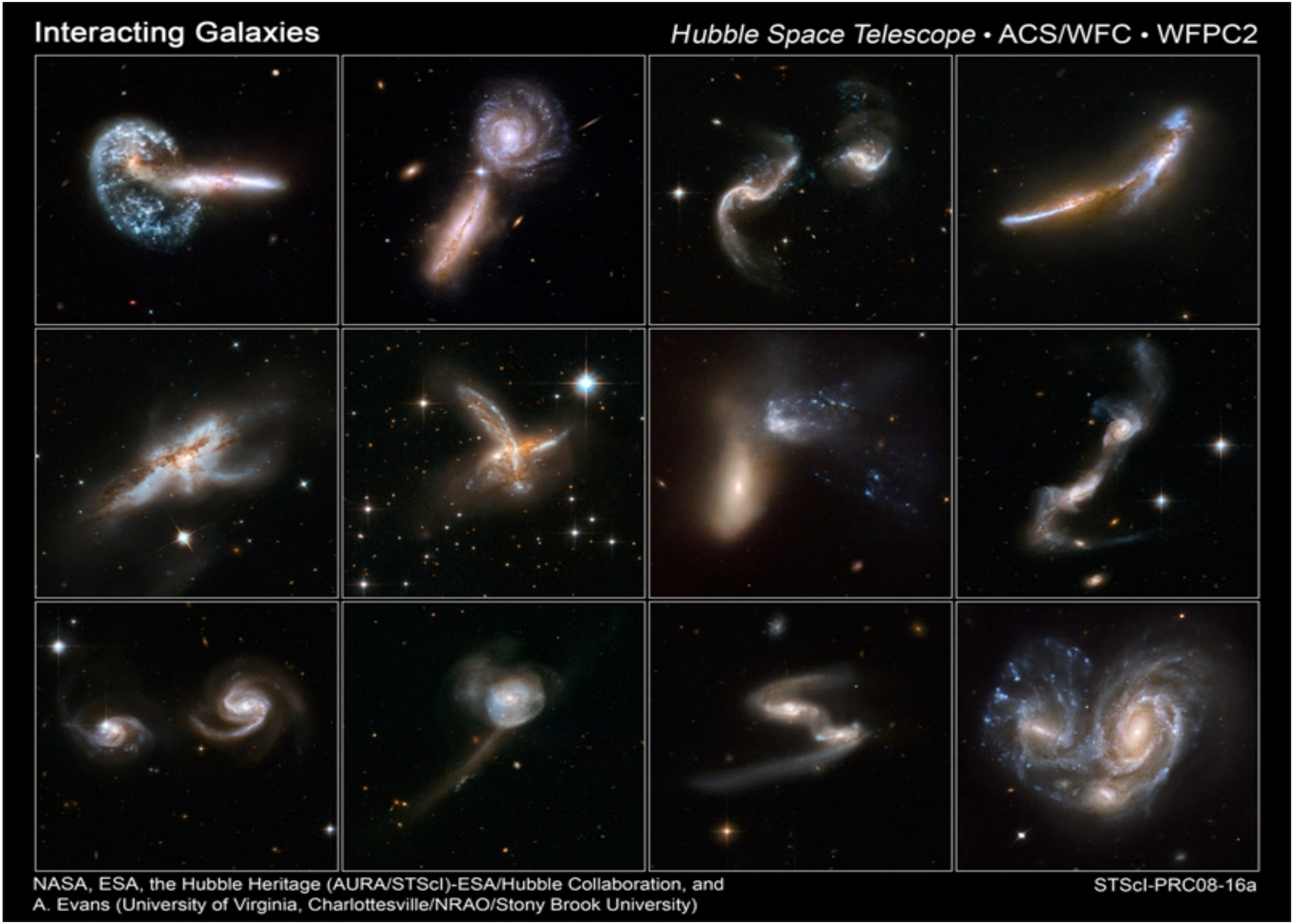
Model Results



Low escape efficiencies B < 0.3 match the metallcities but are too red
To get the blue colors must invoke high winds--> unobserved metallicities/alpha enhancements

Conclusions

- 2100 Galaxies in the SDSS DR3 and GALEX MI surveyed
- 30% of RSF of nearby ($0 < z < 0.11$) early types is quite recent, less than 1Gyr
- Optical CMRs can not determine RSF on this timescale
- Hierarchical Merger with observation, with assumptions:
  - BCs of young stars extinct light 3x ISM
  - Formation is not instantaneous; time lag exists between formation and observation


Interacting Galaxies
Hubble Space Telescope • ACS/WFC • WFPC2
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