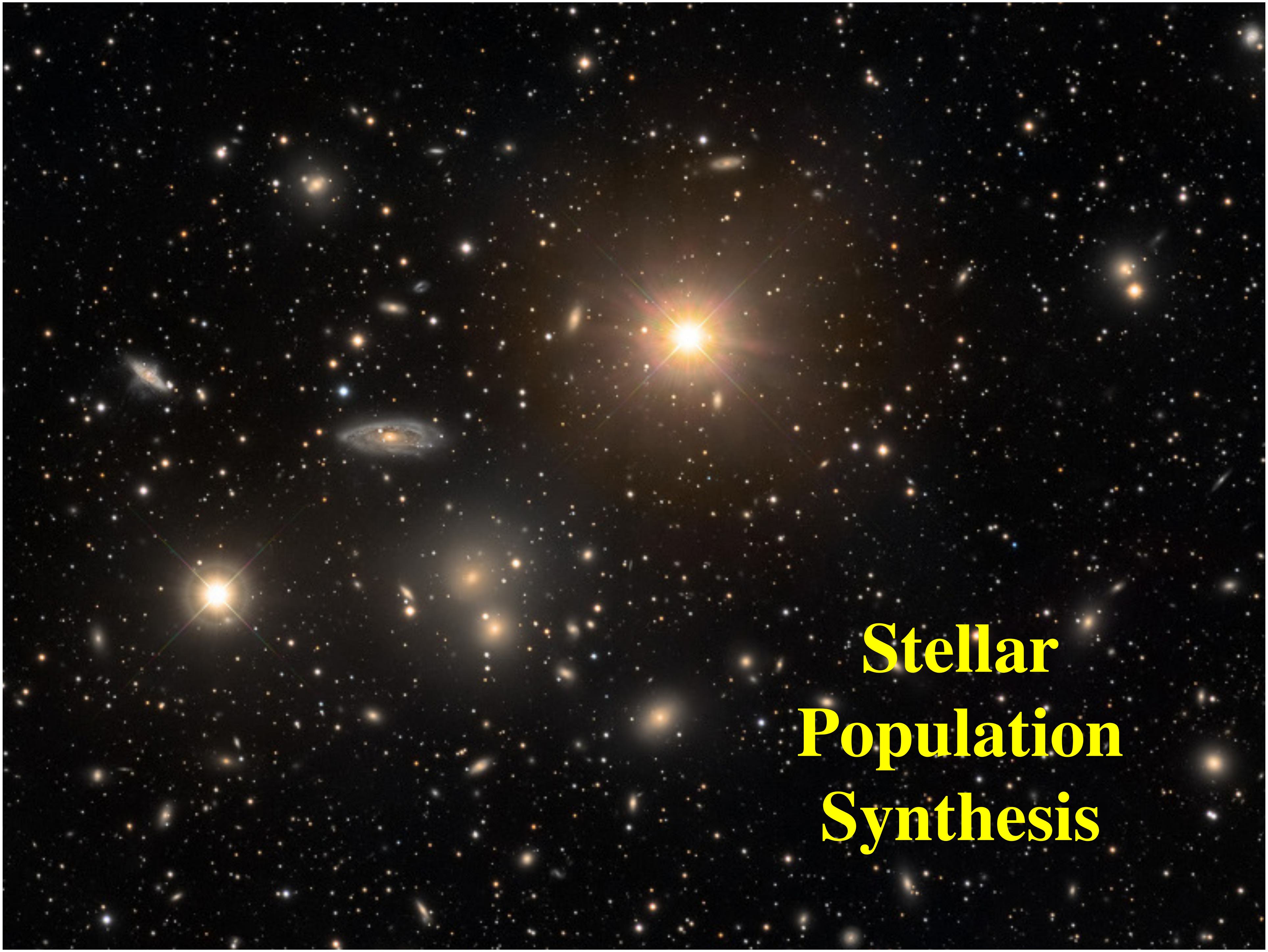
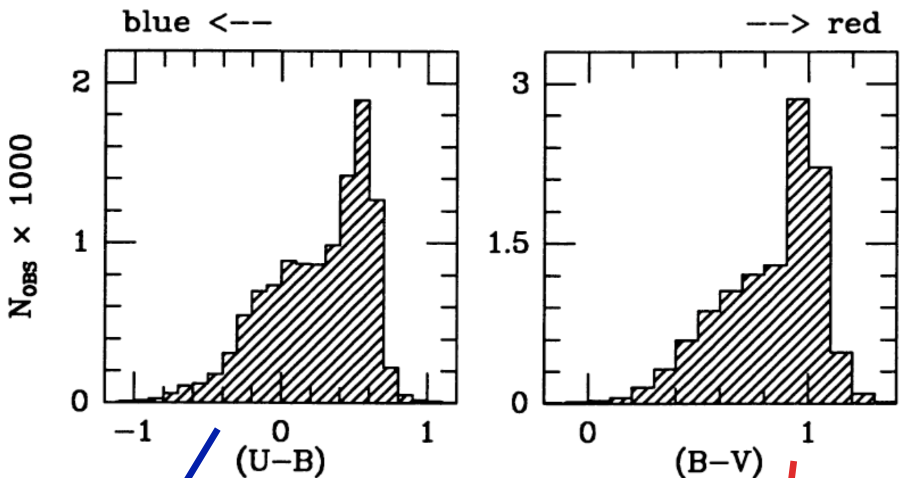
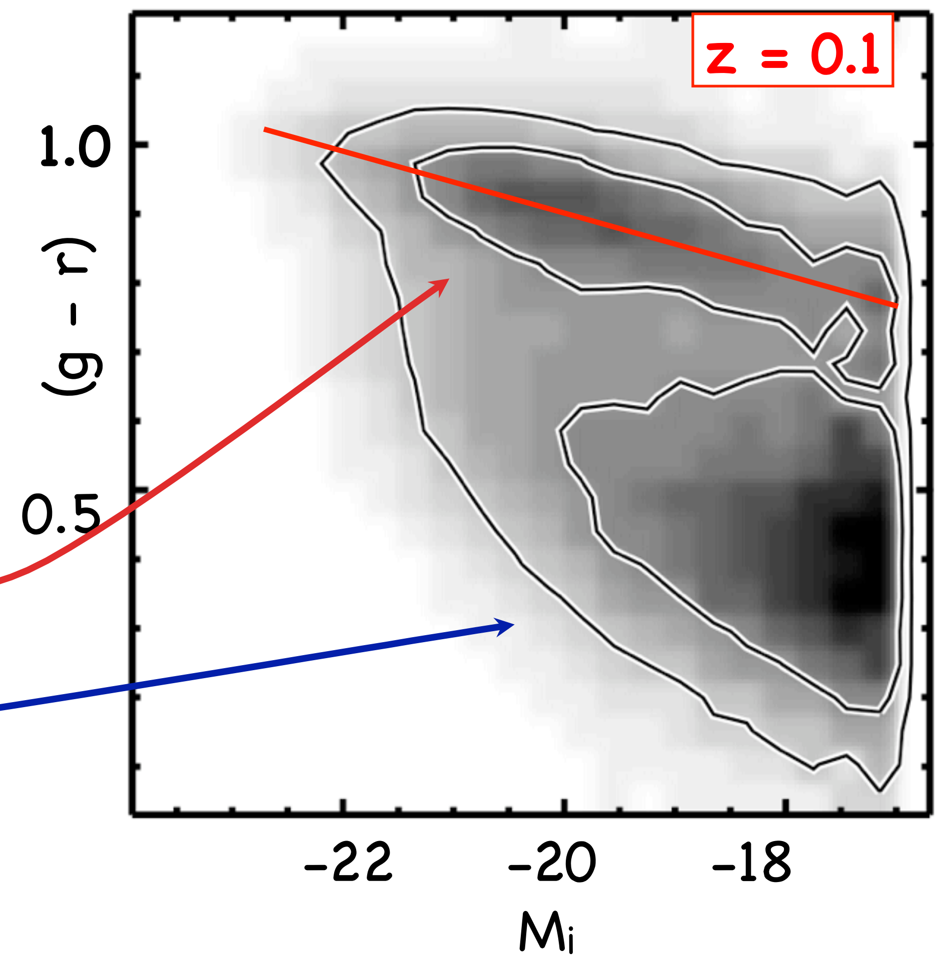

Stellar
Population
Synthesis

Colors of Stellar Populations: Differences in Star Formation Histories

z ~ 0 galaxies, Djorgovski 1992



SDSS, Blanton et al. 2002



The red sequence: mostly E's, no active star formation

The blue sequence: mostly Sp's, with active star formation

Stellar Population Synthesis Models

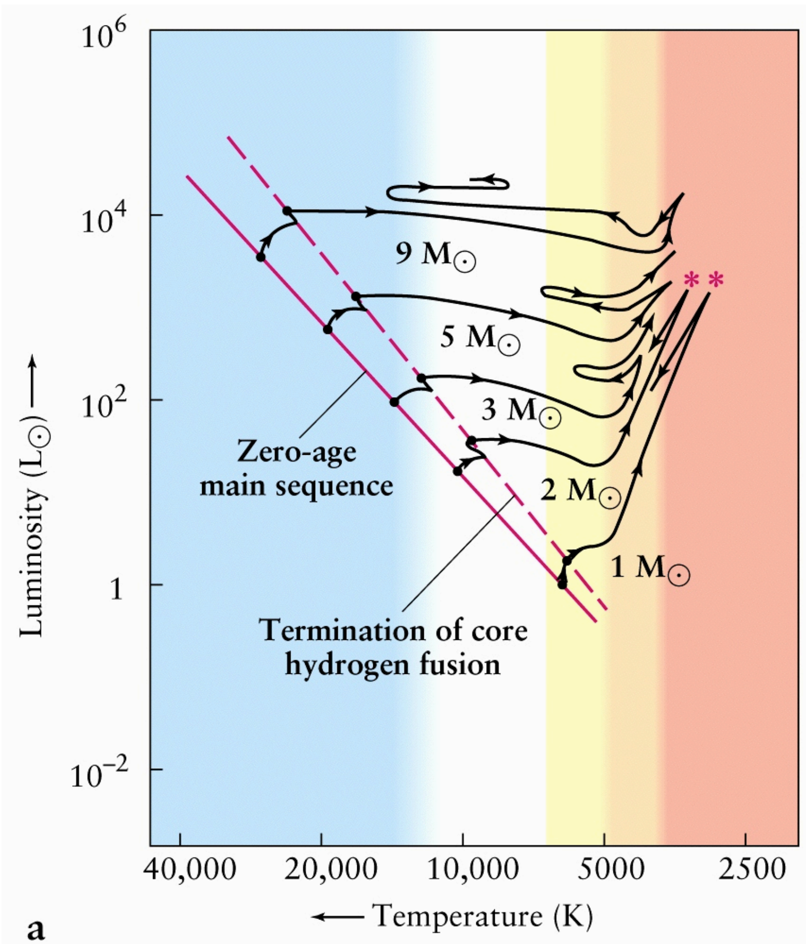
- We can synthesize predicted galaxy spectra as a function of time by assuming the following:
  - Star formation rate (as a function of time)
  - Initial mass function
  - Libraries of stellar spectra for stars of different masses and metallicities and ages, etc.
  - Stellar evolutionary tracks (isochrones)
- A simple stellar population (SSP) is the result of an instantaneous burst of star formation
- We can model more complex star formation histories by adding together multiple SSPs, parameterize star formation rate as a function of time as:
  - $dM/dt \sim \exp(-t/\tau)$ where t is the time since the start of star formation and τ is the star-formation time scale

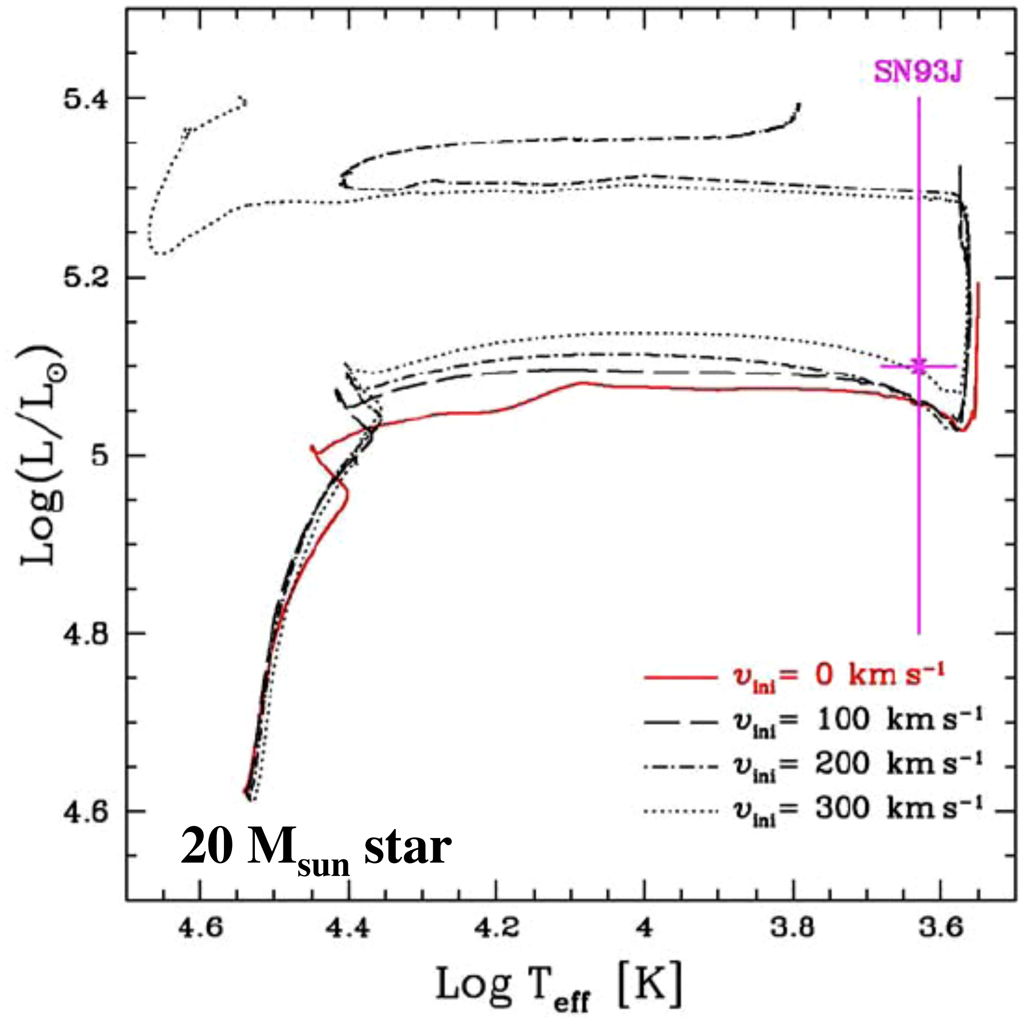
Modeling Evolution of Stellar Pop's

- Stellar evolution is relatively well understood both observationally and theoretically; the key points to remember:
  - Massive stars are very hot, blue, very luminous, and have very short lives; they dominate the restframe UV light
  - Thus we expect largest effects in the bluer parts of the spectrum
  - But there are still some modest disagreements among the models
- Star formation histories are a key assumption:
  - Ellipticals are best fit by a burst of early star formation followed by "passive evolution" where they fade and get redder with time $\tau \sim 1$ Gyr or less
  - Spirals are best fit by $\tau \sim 3$-10 Gyr – they stay bluer and don't fade as much
  - Irregulars are best fit by constant star formation rates

Stellar Evolution Tracks

Well understood at low stellar masses and near-Solar metallicities, but uncertainties grow at high masses and very low metallicities



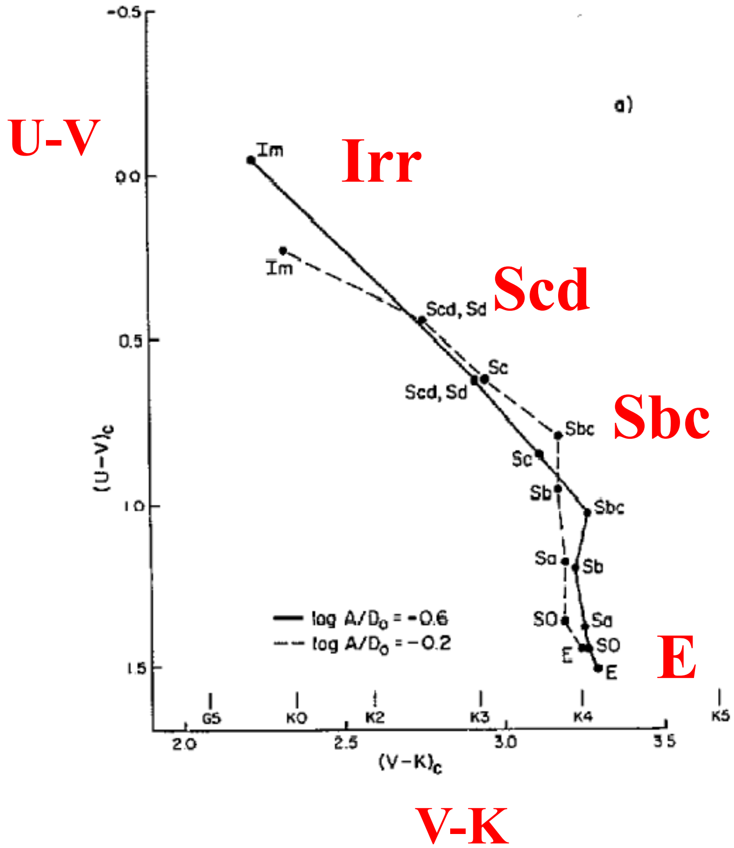


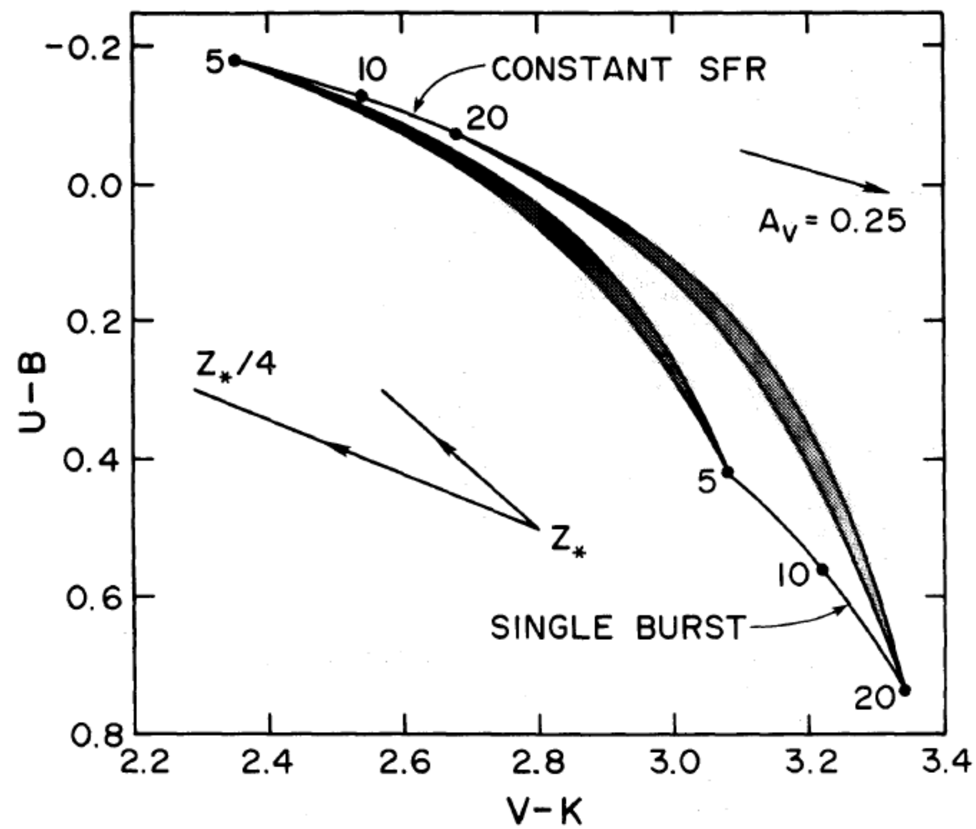
What We Need

- Stellar theory predicts the evolution or (***stellar tracks***) or stars of a given mass. There is some variation among different theoretical models
- Observations give us ***libraries of stellar spectra*** as a function of age, mass, metallicity, etc.
- We need the ***initial mass function (IMF)*** of stars
- All of these are uncertain at very low metallicities and high stellar masses
- We have to assume some ***star formation rate (SFR)*** as a function of time. Popular choices include a sharp burst, a constant SFR, or an exponentially declining one:

$$\frac{\partial M}{\partial t} \propto \exp\left(-\frac{t}{\tau}\right)$$

Colors and Star Formation Histories

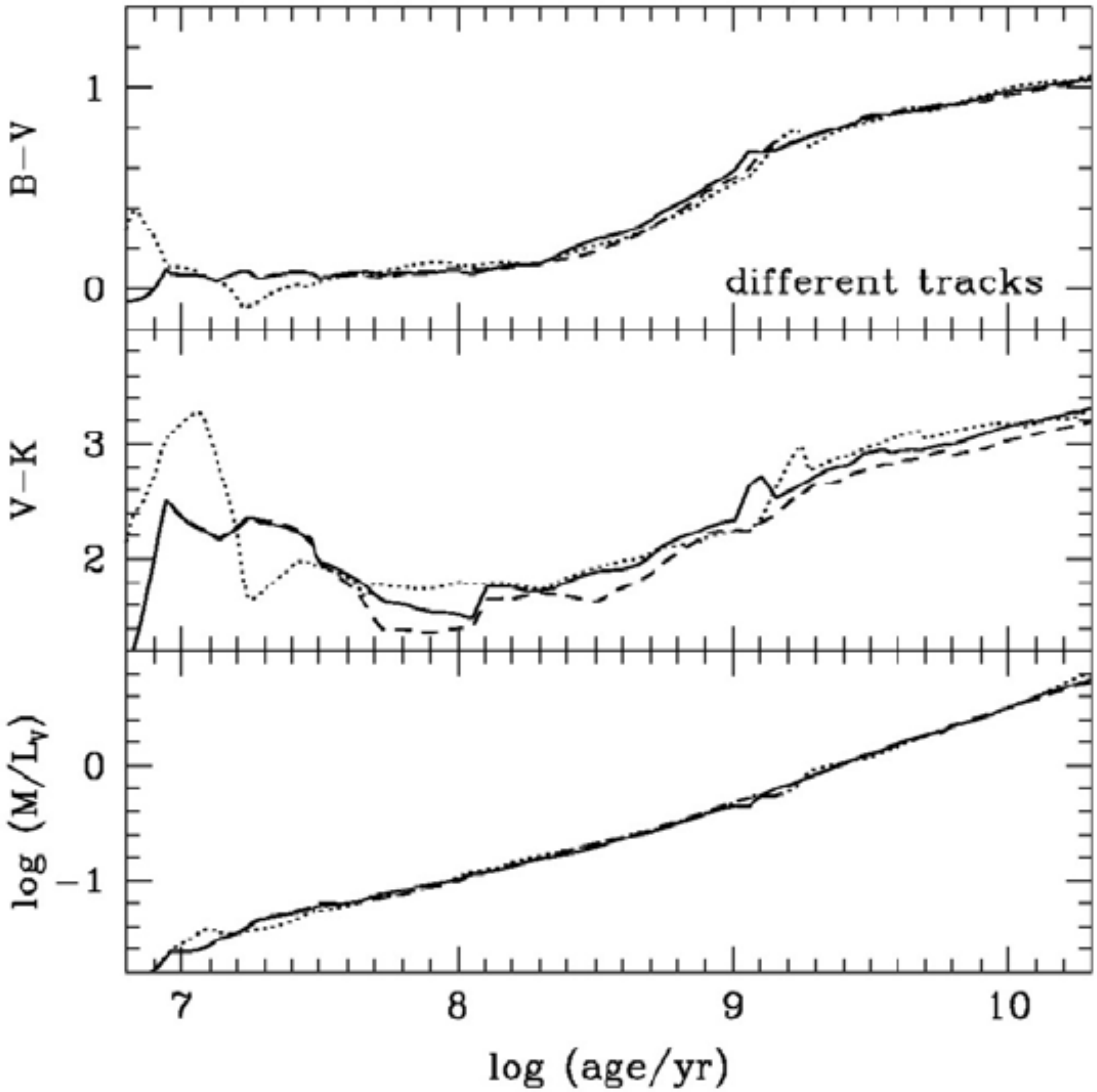




• Ellipticals and bulges: old stellar systems following an initial burst of star formation; modest ‘monolithic’ collapse

• Spiral disks: significant dissipation during collapse, continuous star formation and younger mean stellar age

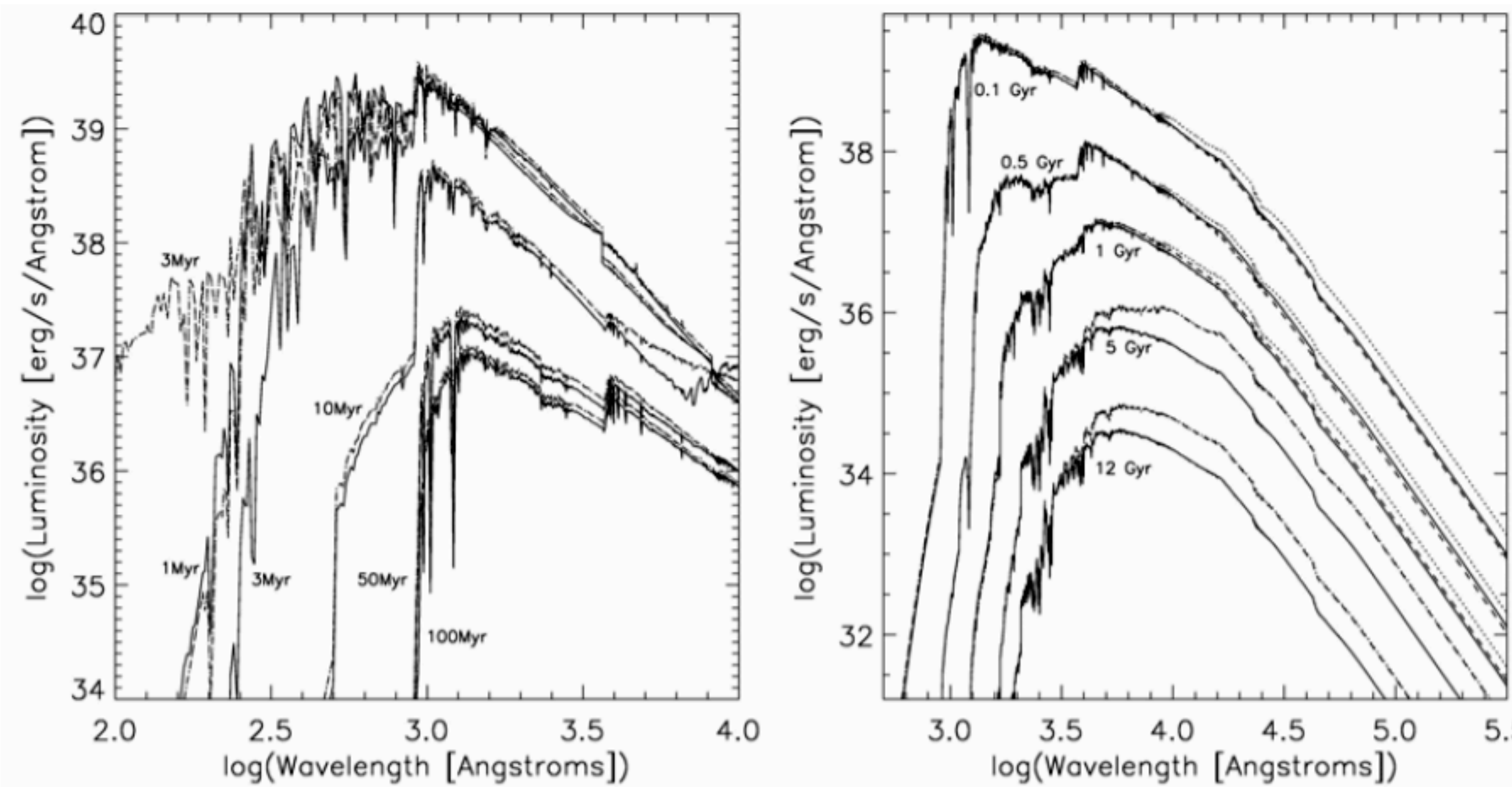
Different Models Agree Reasonably Well



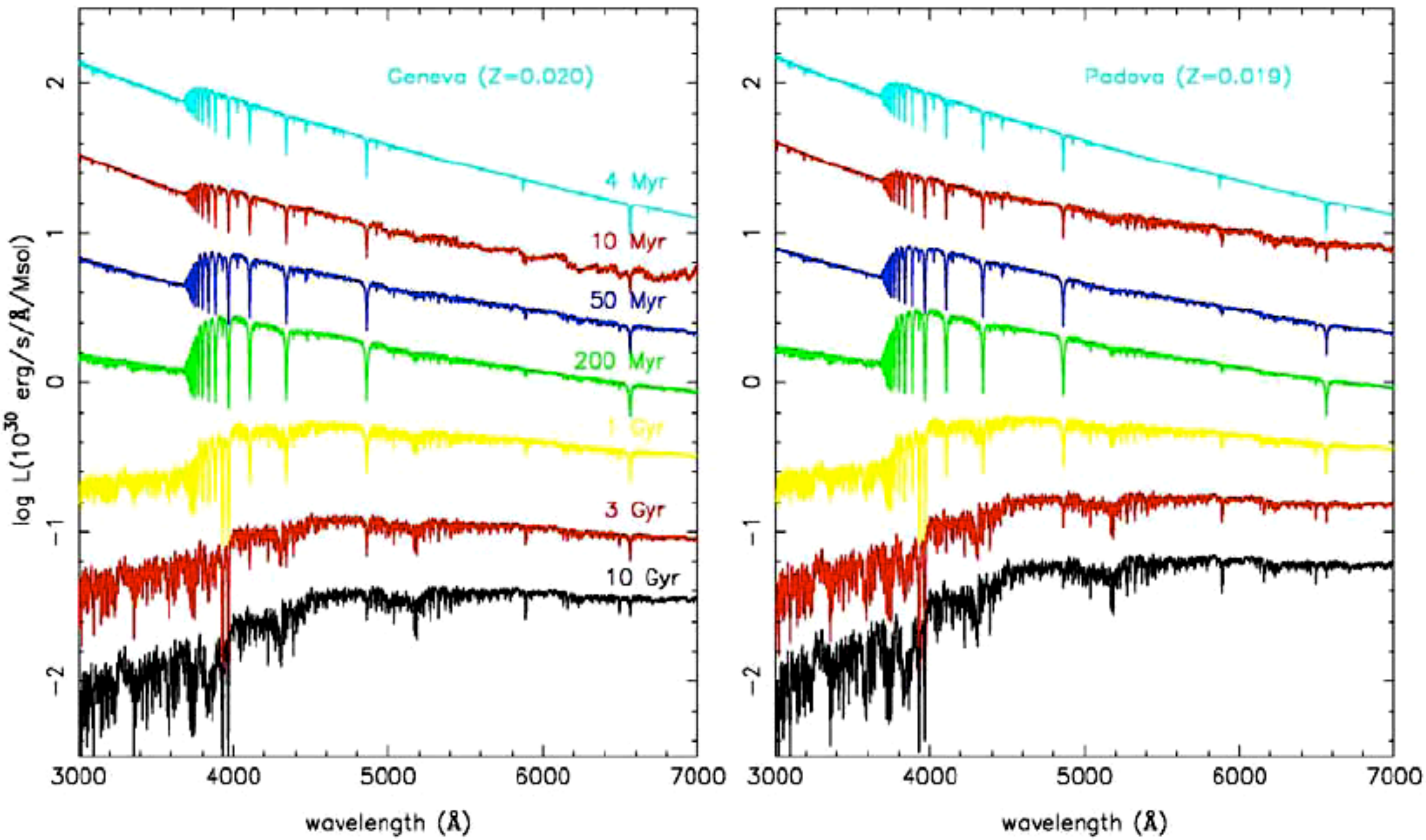
… and produce the right range of galaxy colors, luminosities, and (M/L) ratios today

Predicted Spectral Evolution

for a simple stellar population (SSP):
a δ-function burst with a fixed metallicity and IMF



Predicted Spectral Evolution

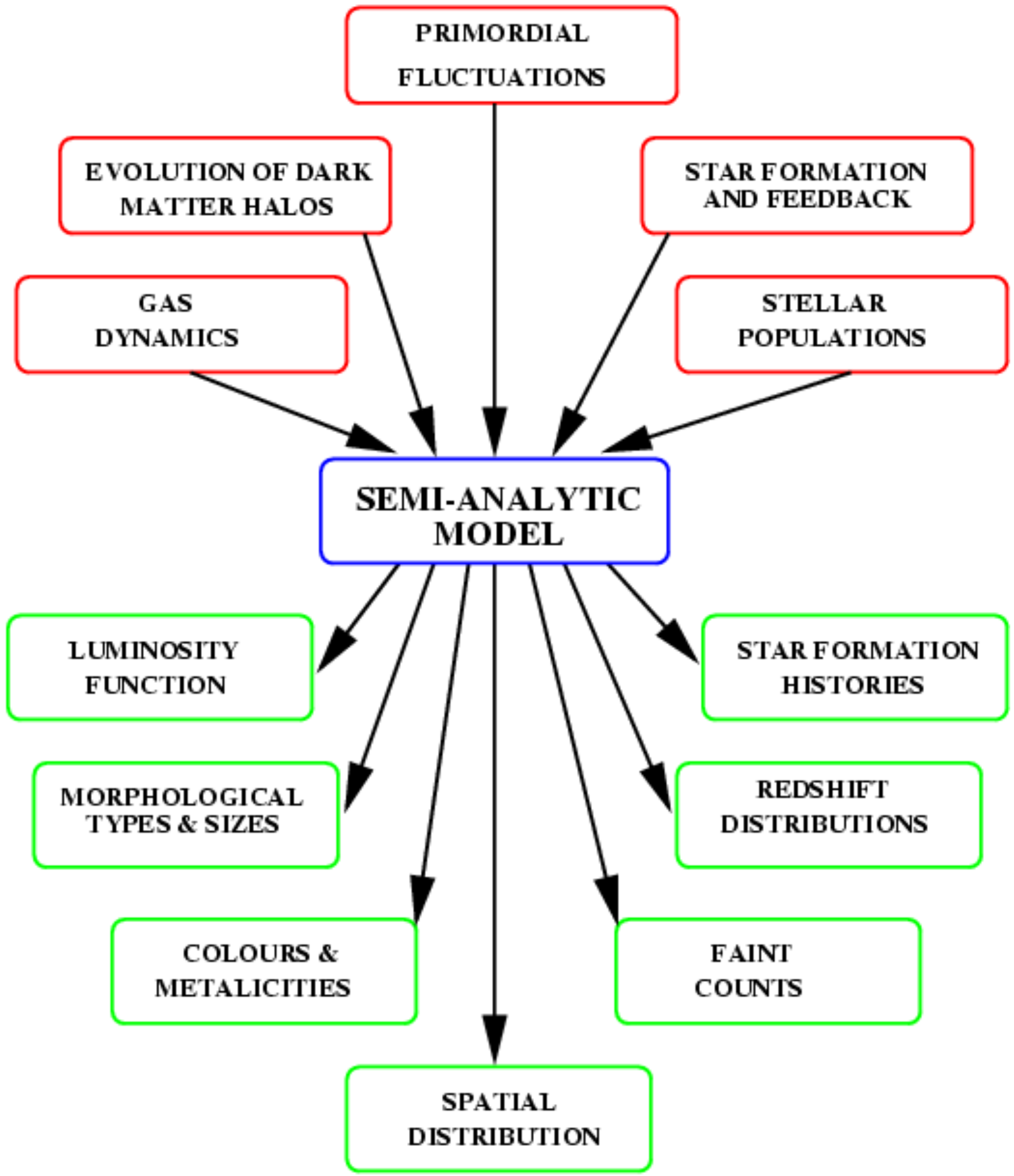


Generally, models fade in time, and faster in the UV than in the IR

Semi-Analytical Models

Semi-analytical models claim to match observations using prescriptive methods for star formation and morphological assembly

Warning: Star formation is a complex, poorly-constrained phenomenon: provides a weak test of the theory (age of stars ≠ age of structures)



Next:
Observing Galaxy Evolution