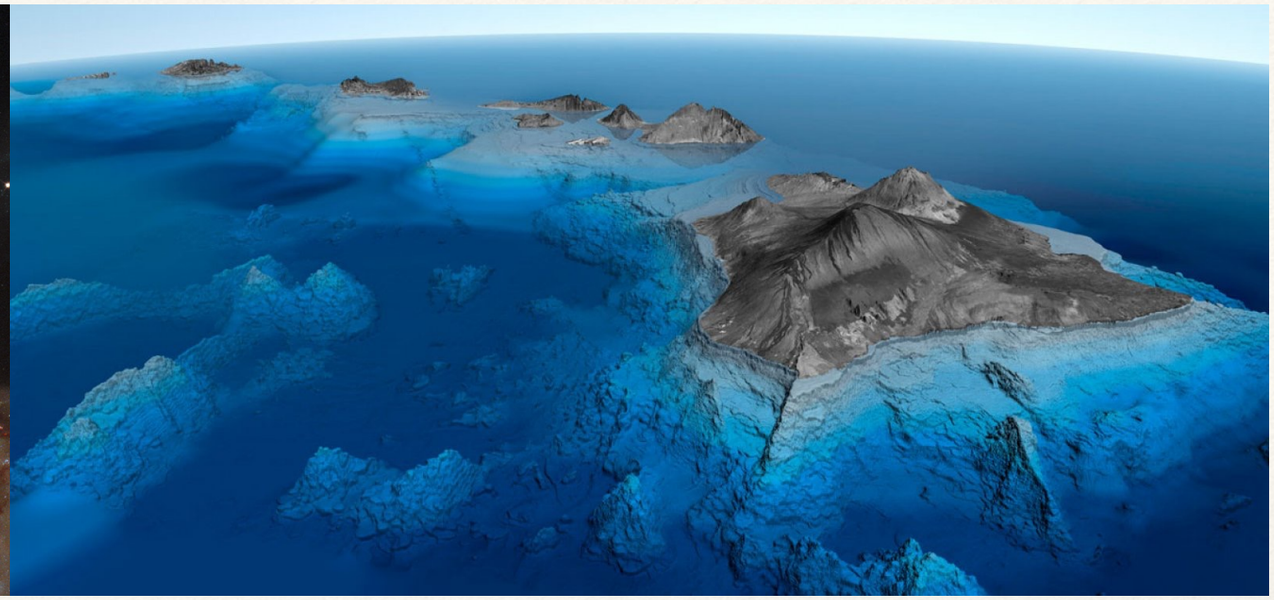


Getting to know the "island universes" out there.

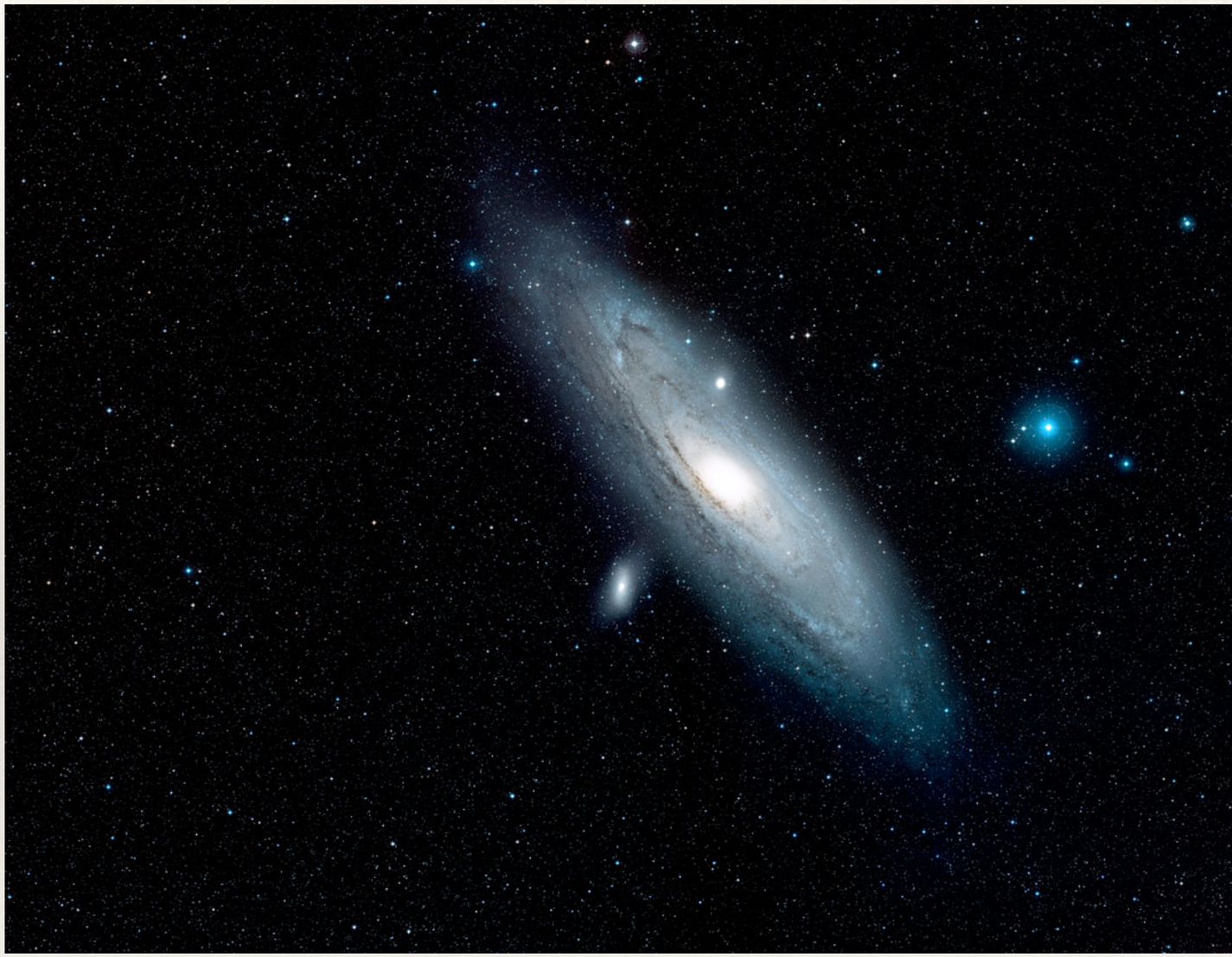
Galaxies I

ASTR 555

Dr. Jon Holtzman

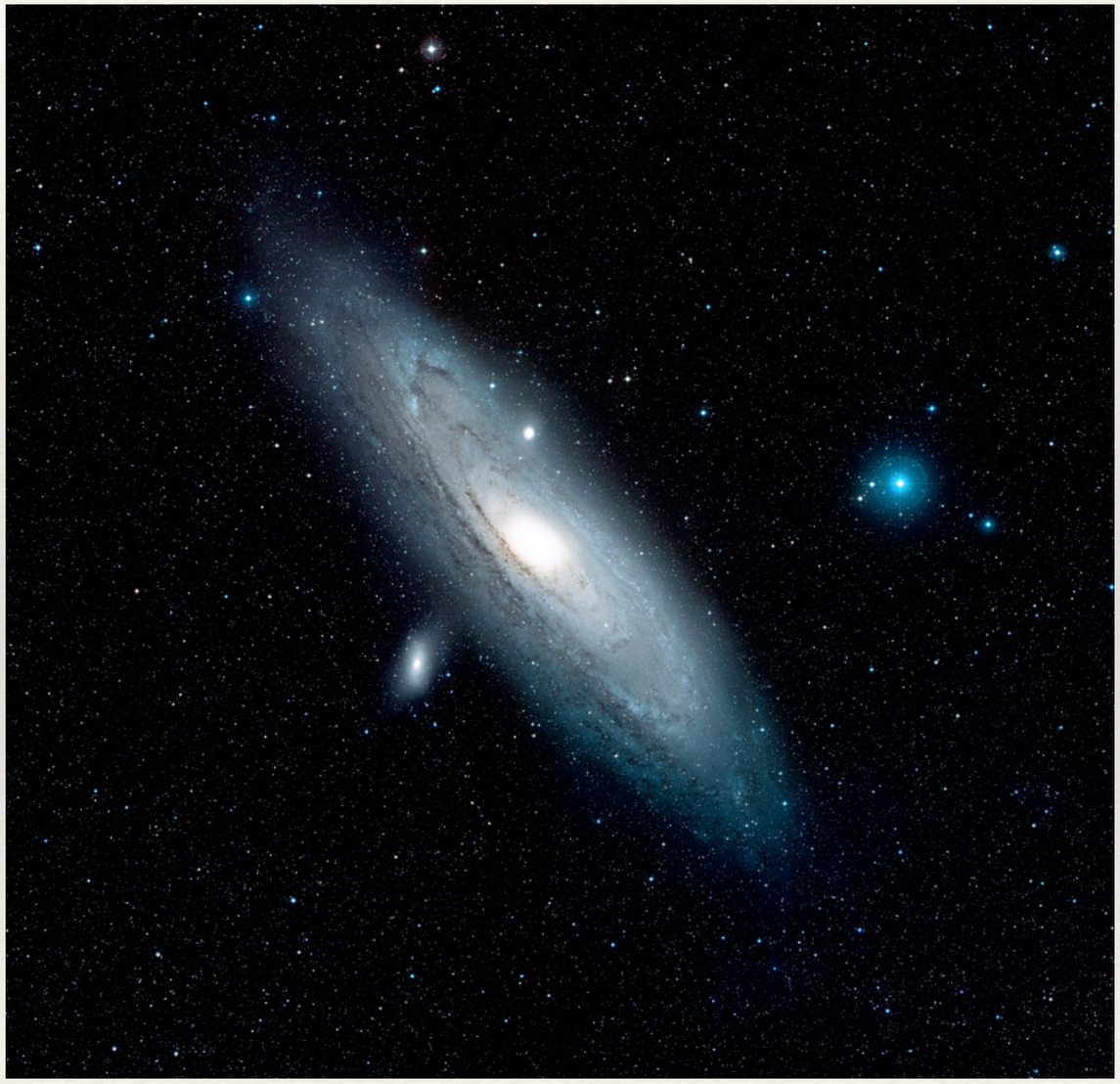
Outline for Today

- Building Blocks - Stars and Stellar Populations:
  - Star Formation Histories (SFH)
  - Unresolved Populations



Stars and Stellar Populations

- What affects the integrated light of an unresolved stellar population?
  - Which stars contribute the most light?
  - How does the integrated luminosity and color change in time?
- How do you go from luminosity to estimating stellar mass: the stellar mass-to-light ratio



Thought Questions

- How does the luminosity of a star scale with a star's mass on the Main Sequence?
- How does the number of stars scale with stellar mass?
- How does the contribution to **integrated** luminosity scale with star mass along the Main Sequence — in other words, which stars contribute the most light?

$L_\star(M) \propto M_\star^{3.5}$ along MS

$N_\star(M) \propto M_\star^{-2.35}$ for a Salpeter IMF

$L_{tot}(M) \sim L_\star(M)\, N_\star(M) \sim M_\star^{3.5}\, M_\star^{-2.35}$

$L_{tot}(M) \sim M_\star^{1.15}$

So high mass stars contribute more light

Thought Questions

- How about the contribution to total stellar mass?
- Which stars contribute the most mass?

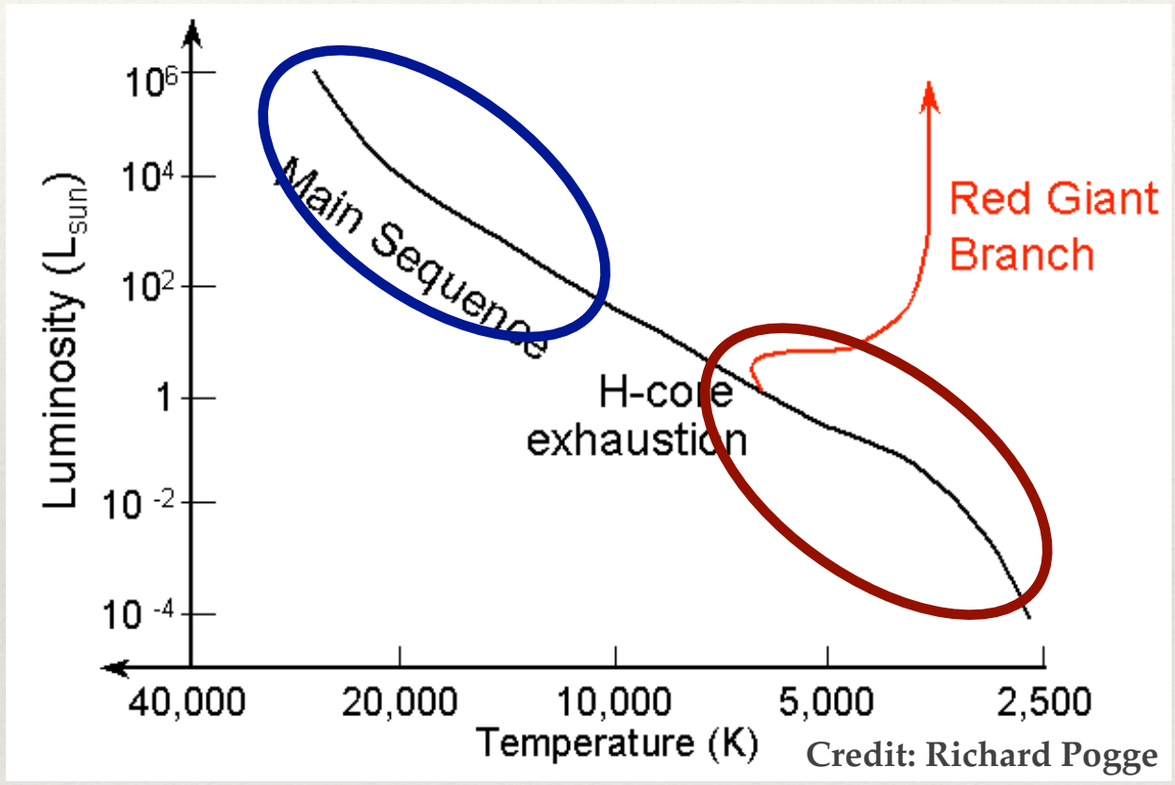
$$M_{tot}(M) \sim N_\star(M) \quad M_\star \sim M_\star^{-2.35} M_\star$$

$$M_{tot}(M) \sim M_\star^{-1.35}$$

So low mass stars contribute the most mass.

Stars and Stellar Populations

- Integrated light from unresolved simple/single stellar population (SSP) — which stars contribute the most light?



Credit: Richard Pogge

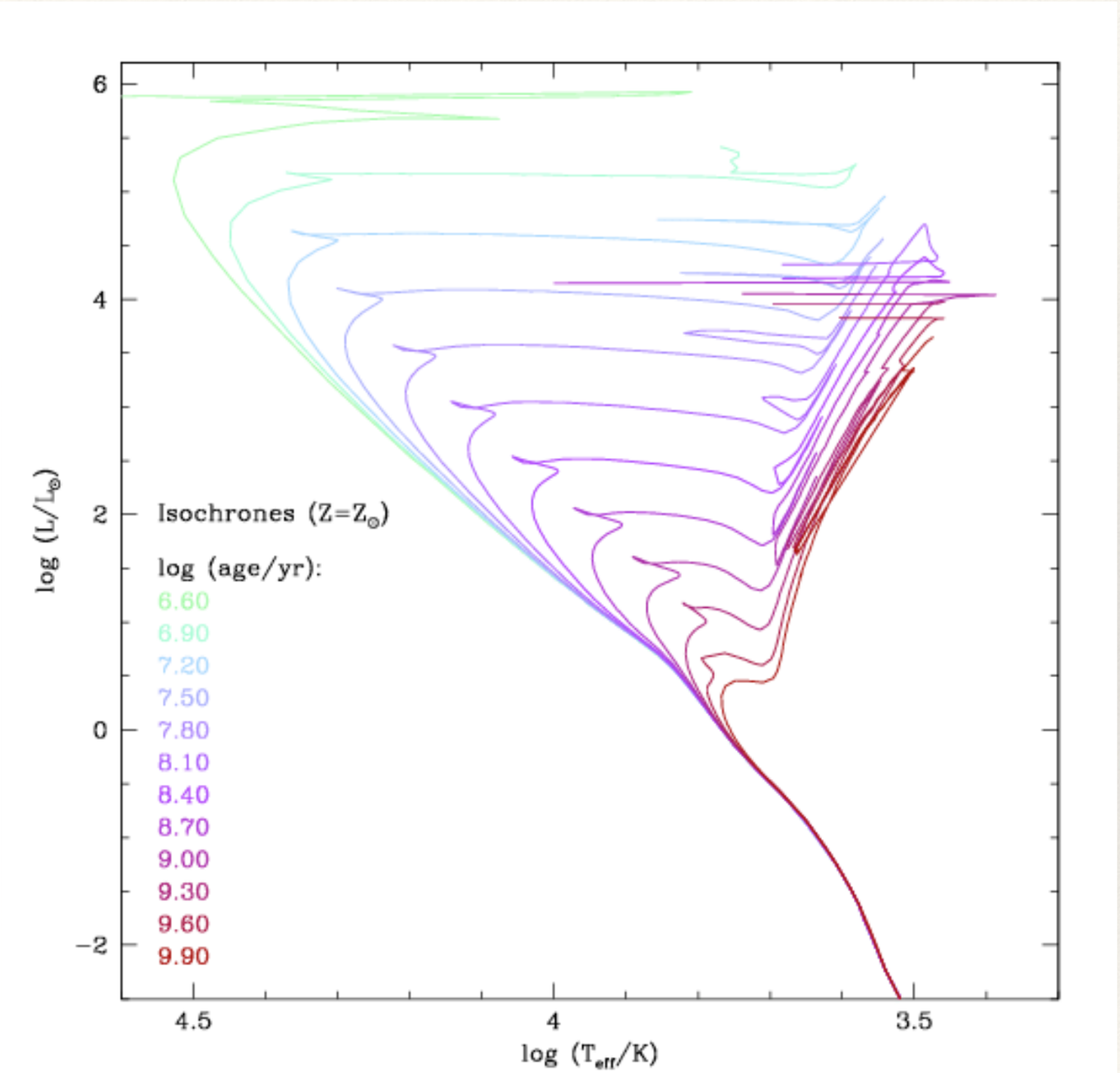
- On the Main Sequence, **much more mass in low mass stars — $M_{tot} \propto M^{-1.35}$**

- However, **more luminosity from high mass stars — $L_{tot} \propto M^{1.15}$**

Massive (young) stars dominate light if they exist

Stars and Stellar Populations

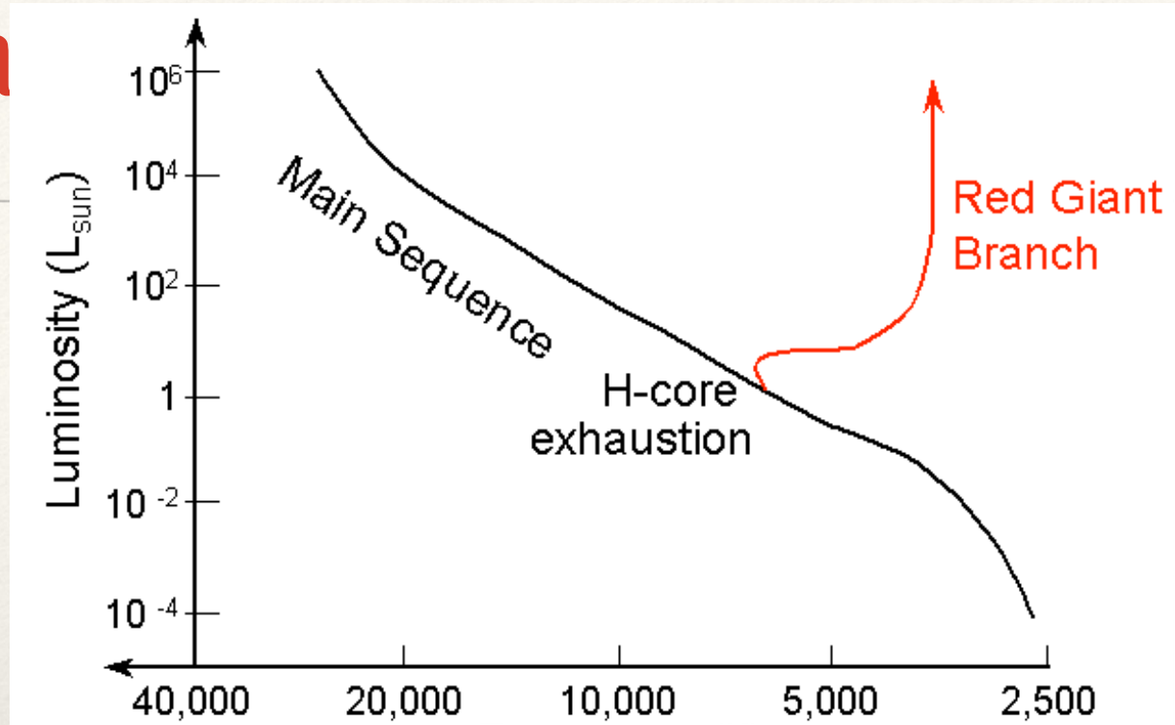
- What about older populations>
- After Main Sequence Turn-Off (MSTO):
  - Initially, massive stars “peel off” MS and change color
  - However, still very luminous (supergiants!)

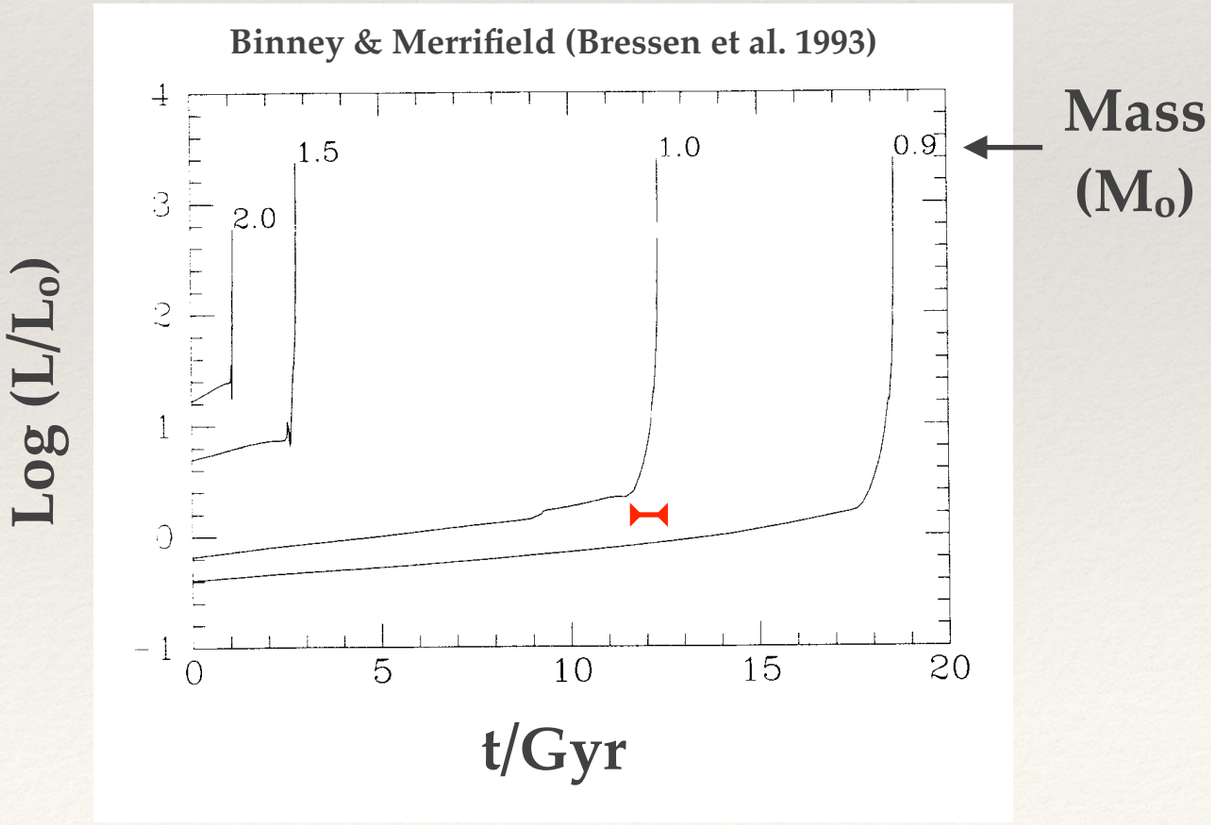


da Cunha 2008

Stars and Stellar Popula

- After Main Sequence Turn-Off (MSTO):
  - All lower mass stars reach comparable luminosity (TRGB)
  - Post-MS evolution is fast — luminosity of evolved stars at a given time from (nearly) a single mass
- **RGB** stars have nearly same mass as **MSTO** stars, but significantly more luminous





Stars and Stellar Popula

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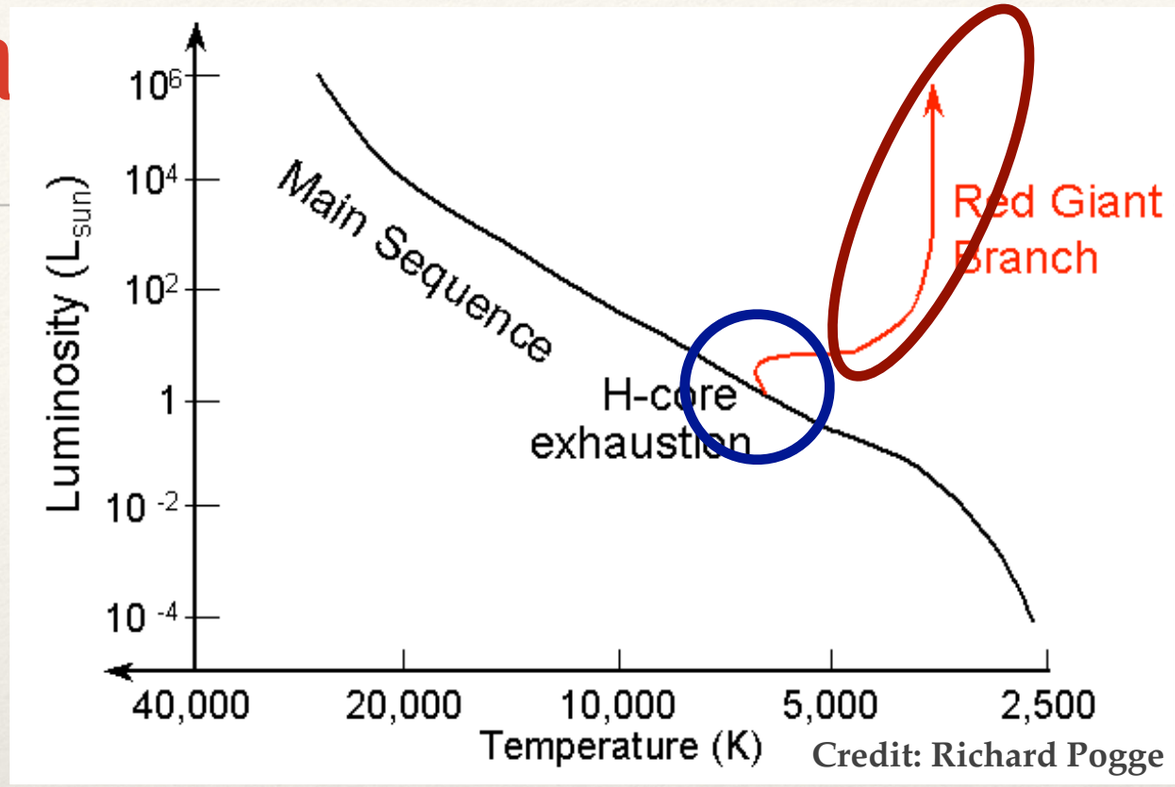
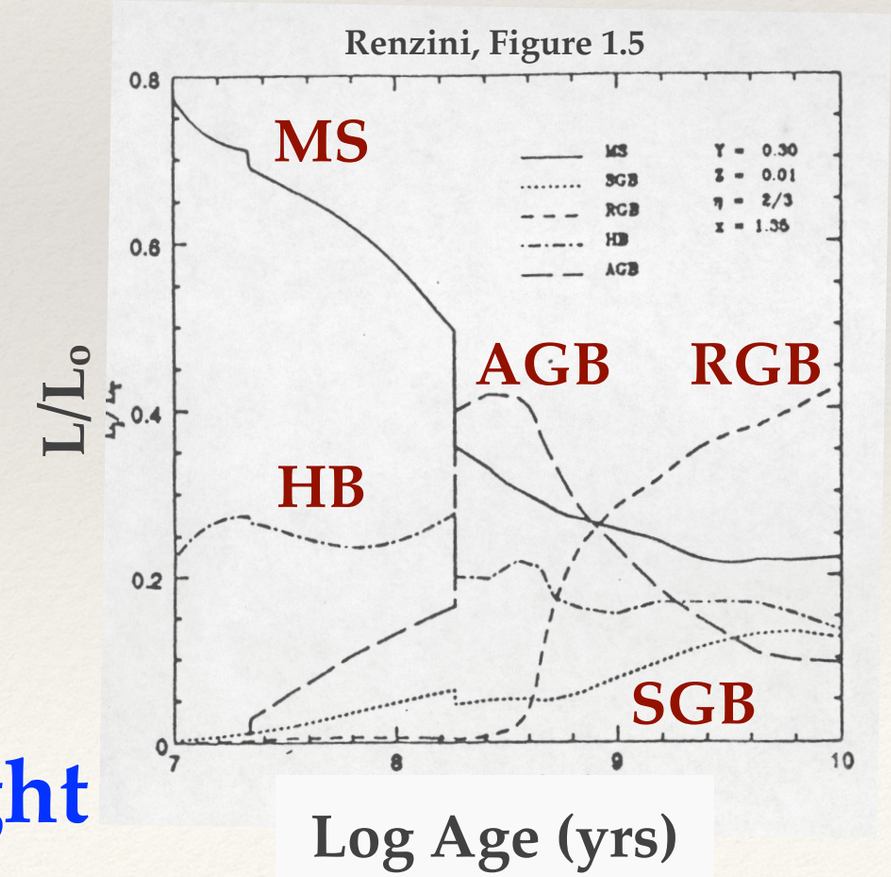


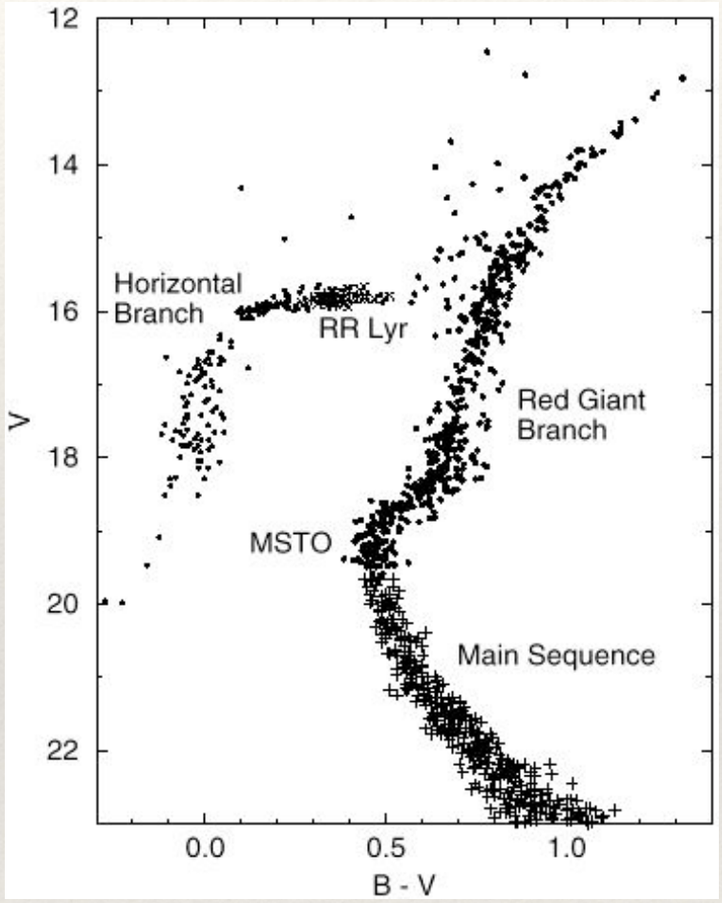


Later on, evolved stars dominate light

Thought Question

- The luminosity of an evolved SSP will depend primarily on the **number of red giant stars**.

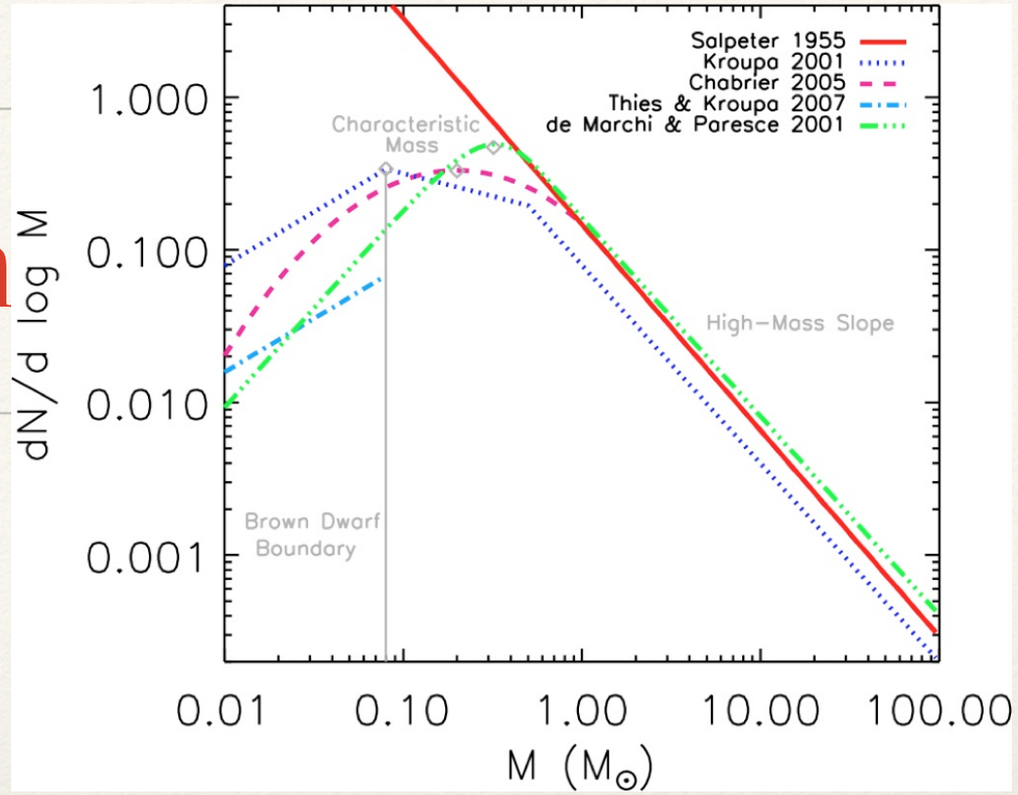
- How will the **number of red giant stars change with time**?
  - Note that there are two factors that will enter into this!



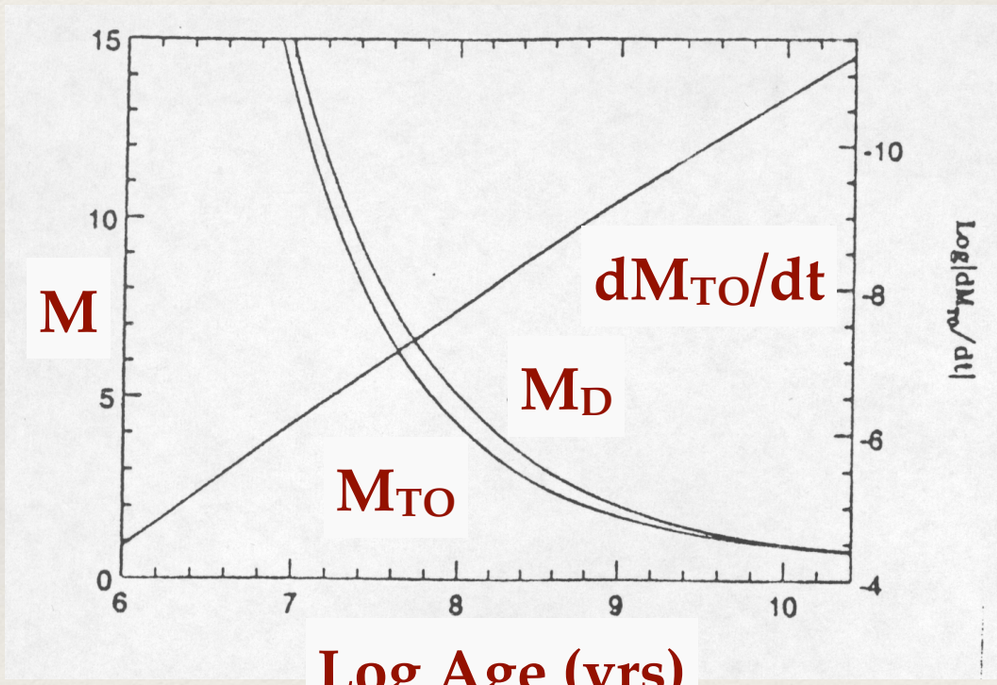
M15 (Krauss 2000)

Stars and Stellar Population

- How does the **integrated luminosity** of an SSP evolve over time?
  - Depends on the **number of red giants**, (roughly the same as the **number of stars evolving off the MS**):
    - how many stars of a given mass formed (IMF)
    - how quickly stars of a given mass turn off the MS
- Competing effects — lower mass stars are more numerous but peel off MS more slowly



Offner et al. 2014



Renzini, Figure 1.5

Given a typical IMF, SSP will fade slowly over time

Stars and Stellar Populations

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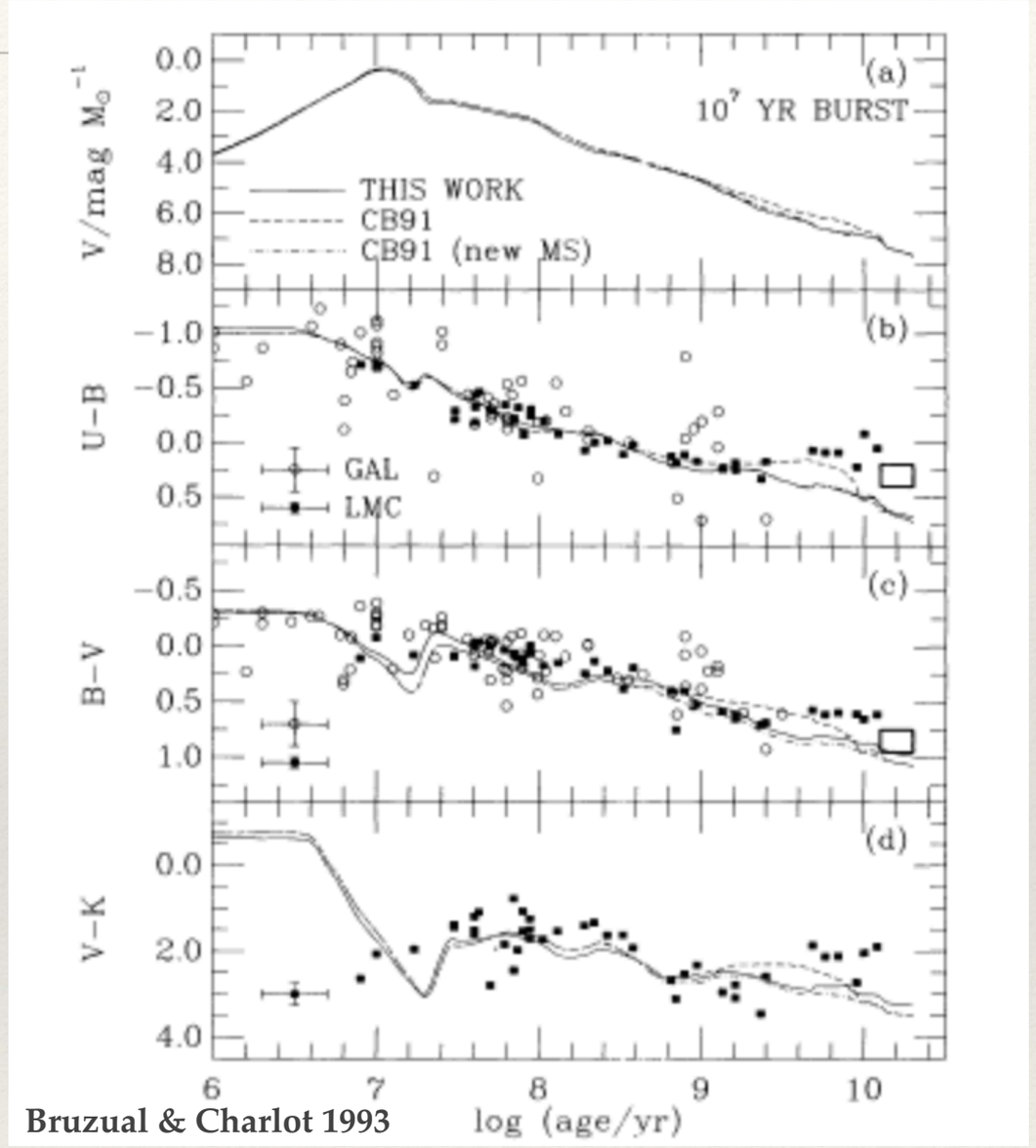
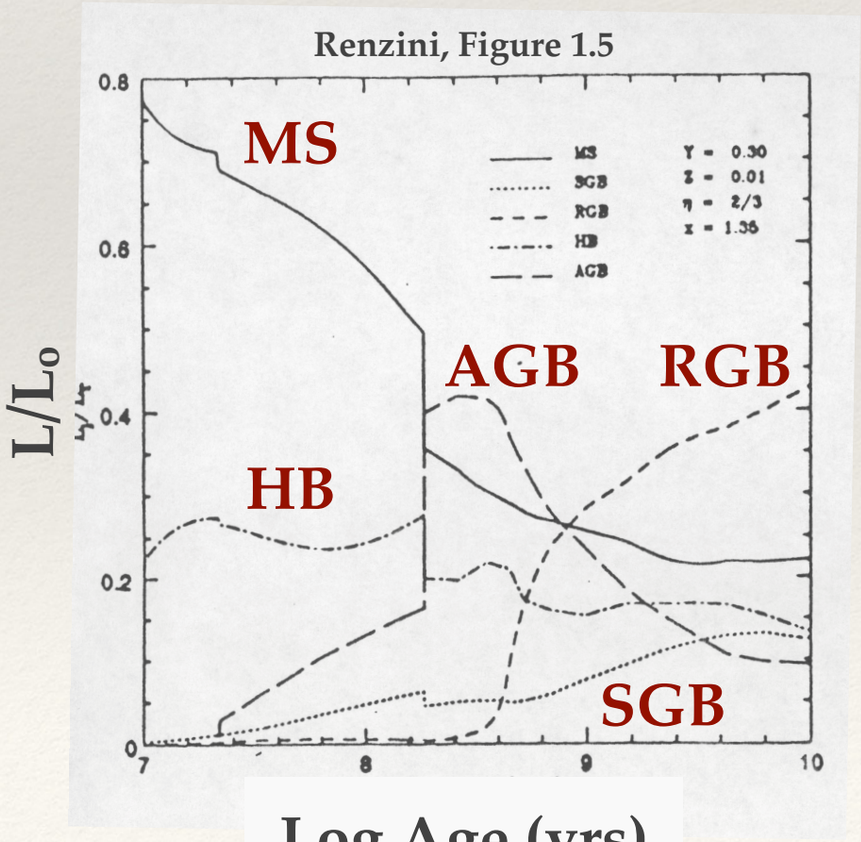


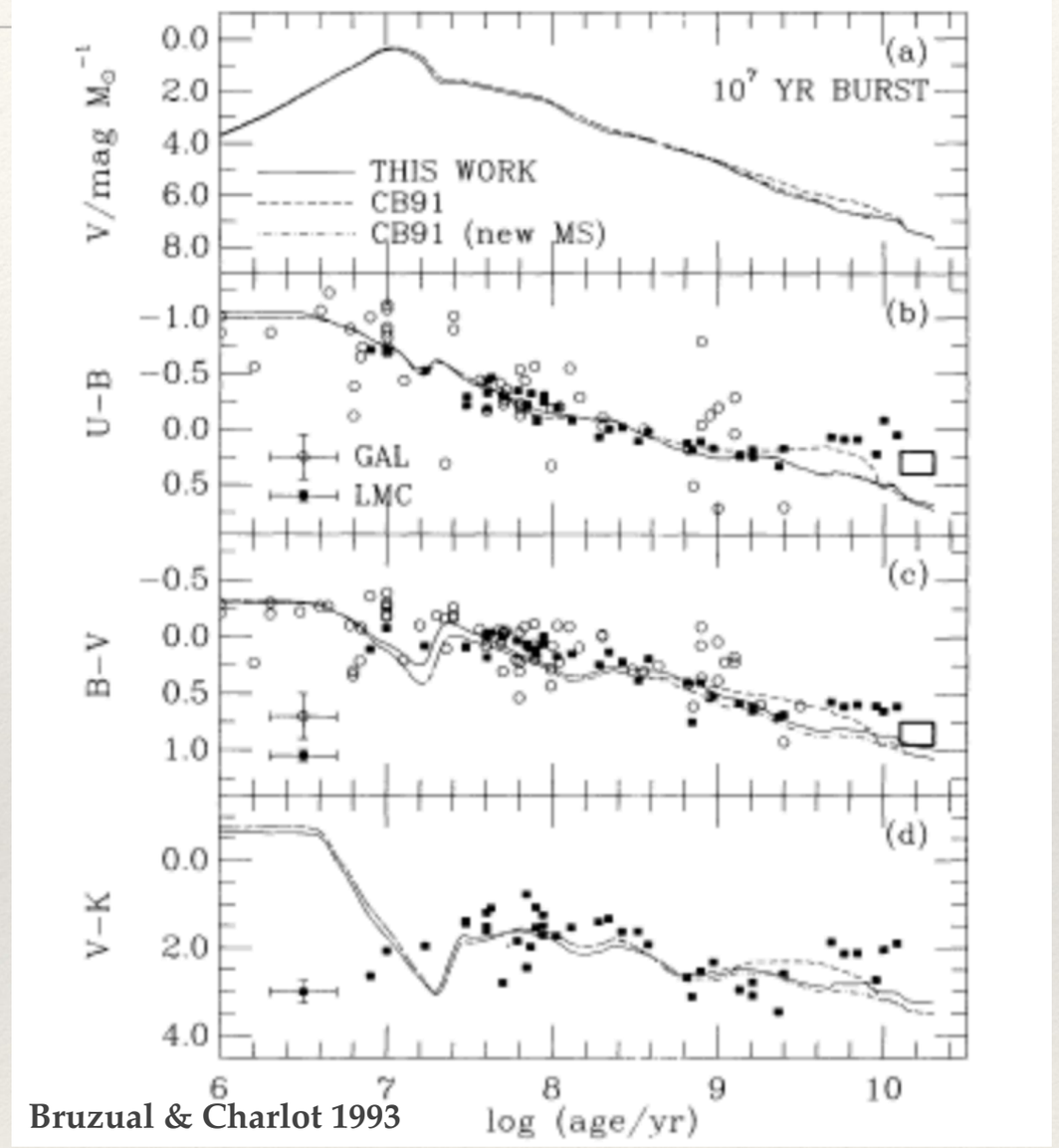
Bruzual & Charlot 1993

Given a typical IMF, SSP will fade slowly over time

Stars and Stellar Populations

- How does the **integrated color** of an SSP evolve over time?
  - Over time, larger fraction of stars have evolved off the Main Sequence
    - Less evolution at long wavelengths





Due to changing stellar population mix, SSP will slowly redden over time

Thought Question

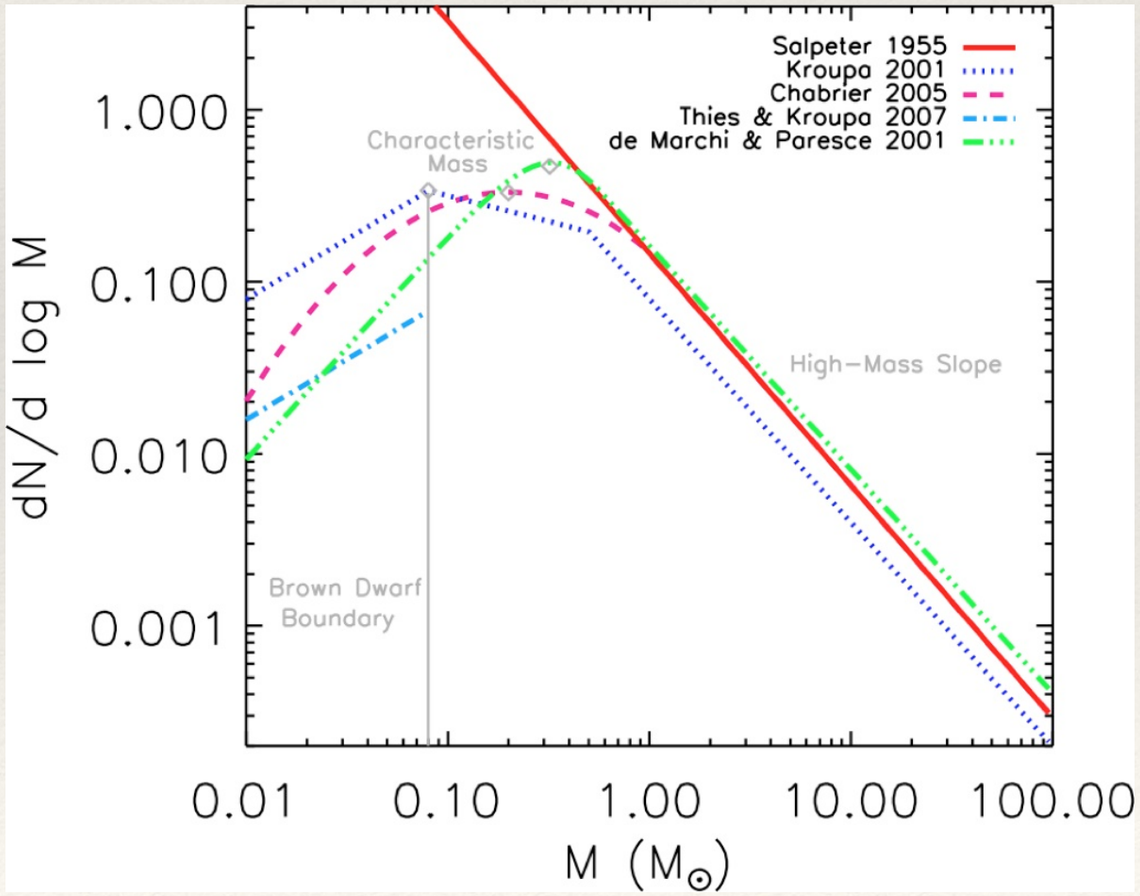
- Suppose we want to estimate the stellar mass of a galaxy based on its observed magnitude and integrated light spectrum:
  - What do you need to consider to do this?

Stars and Stellar Populations

- How can we estimate the stellar mass from integrated light?
  - Consider the **stellar mass-to-light** ratio:

$$M/L \equiv \frac{(M/M_{sun})}{(L/L_{sun})}$$

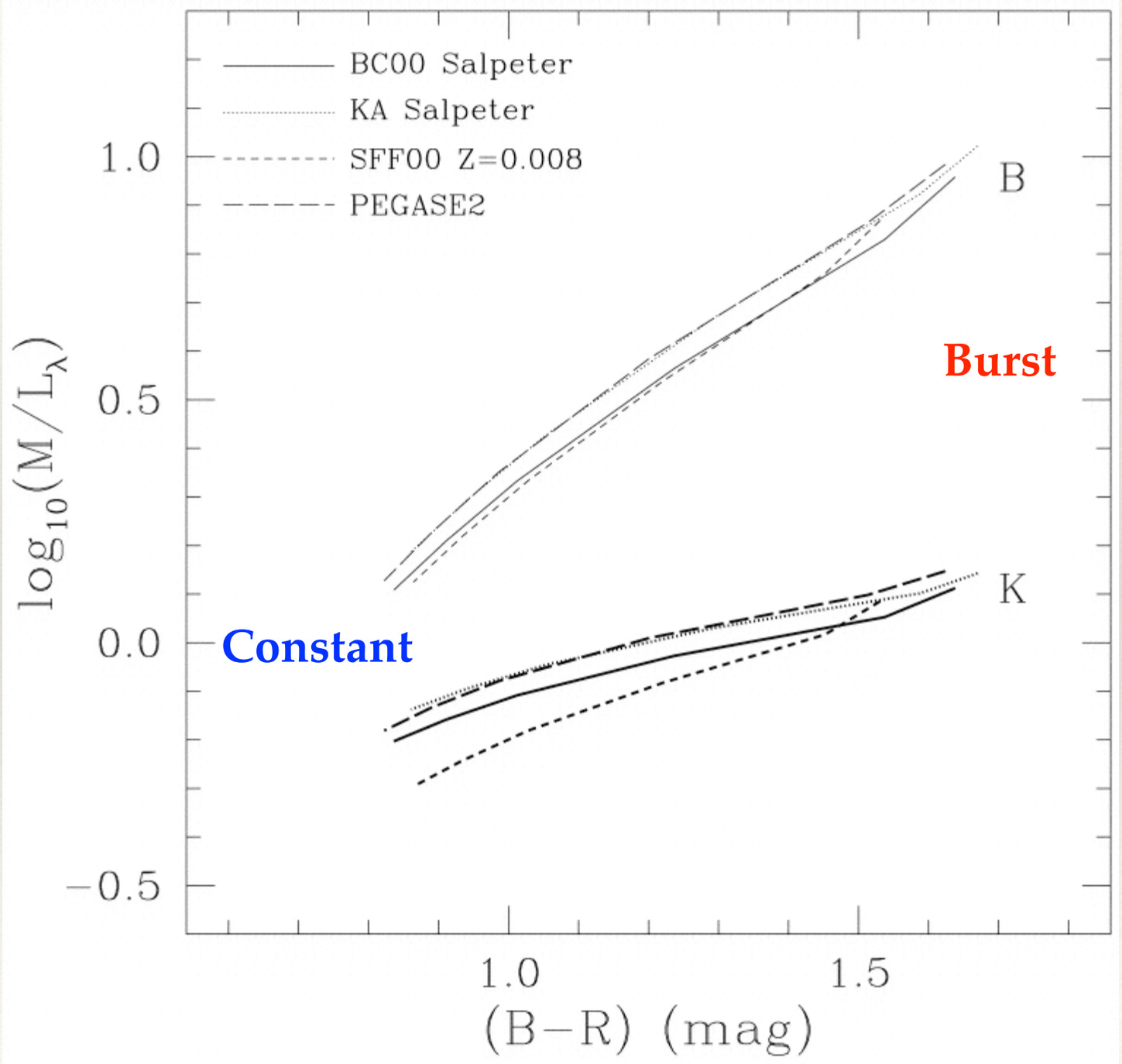
- For individual stars, the M/L decreases as mass increases — **$L \propto M^{3.5}$ on MS so $M/L \propto M^{-2.5}$**
- For a population, M/L depends strongly on IMF



Offner et al. 2014

Stars and Stellar Populations

- Estimate stellar M/L from broadband color or from spectrum
- Luminosity + stellar M/L gives stellar mass
- Stellar M/L depends on bandpass and SFH
  - Less variation in near-IR (less sensitive to younger stars)
  - K-band luminosity often used as a rough proxy for stellar mass
- Absolute value of M/L of a population depends strongly on IMF. Relative values characterize different stellar pops for fixed IMF.



Bell & de Jong 2001