

Comprehensive Stellar Population Models and the Disentanglement of Age and Metallicity Effects

Guy Worthey

1994, ApJS, 95, 107

Purpose

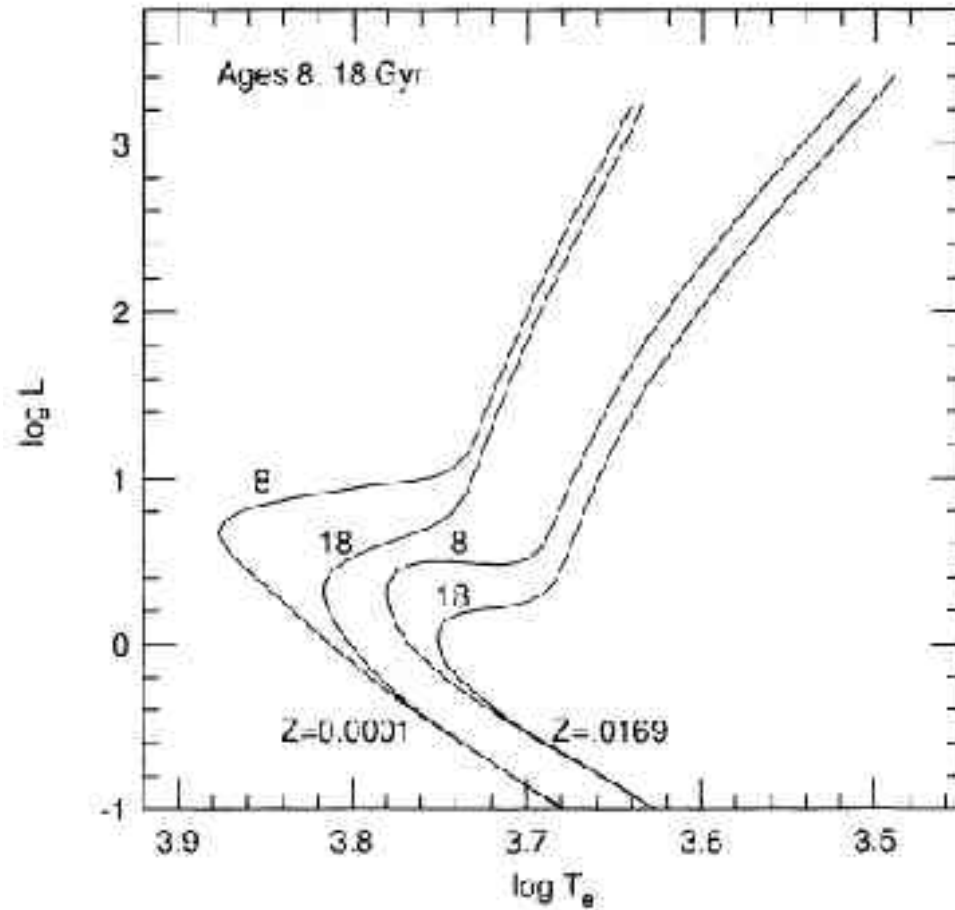
- Construct models for intermediate and old stellar populations.
 - Models output the following:
 - Broadband magnitudes
 - Spectral energy distributions
 - Surface brightness fluctuation magnitudes
 - 21 absorption feature indices
- Draw conclusions regarding abundances and other quantities.
- Separate age and metallicity effects.

Background

- Evolutionary population models build galaxies using knowledge of stellar evolution and physical input parameters.
 - These models are good in that there are few adjustable parameters.
 - Bad in that they rely on theory.
 - Often used to find out what galaxies looked like in the past.
 - This article introduces the use of a comprehensive array of absorption features.

Population Models

- Use stellar evolutionary isochrones from two different sources to cover different ages, masses, and metallicities.
 - Vandenberg and collaborators and Green et al. 1987.
- Conclude that effects due to age and metallicity are more similar for metal-rich stars.

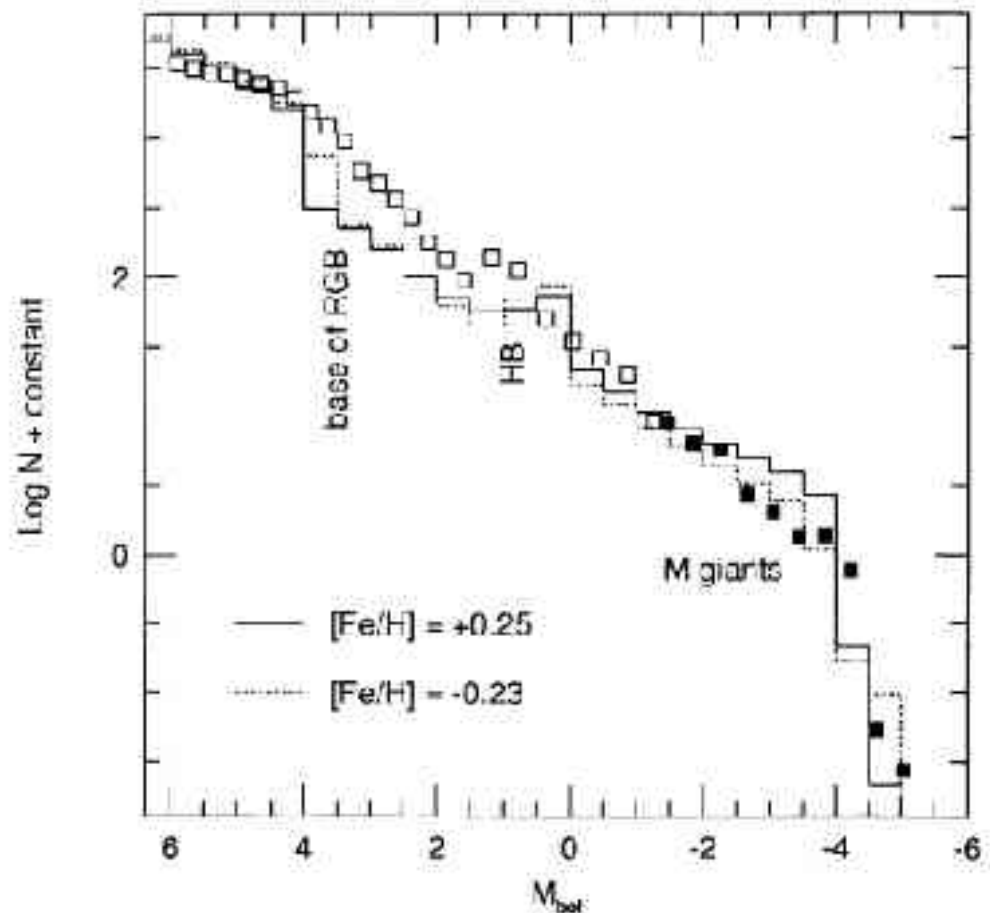


- Two sets of isochrones show that age and metallicity effects resemble each other more at higher metallicities.

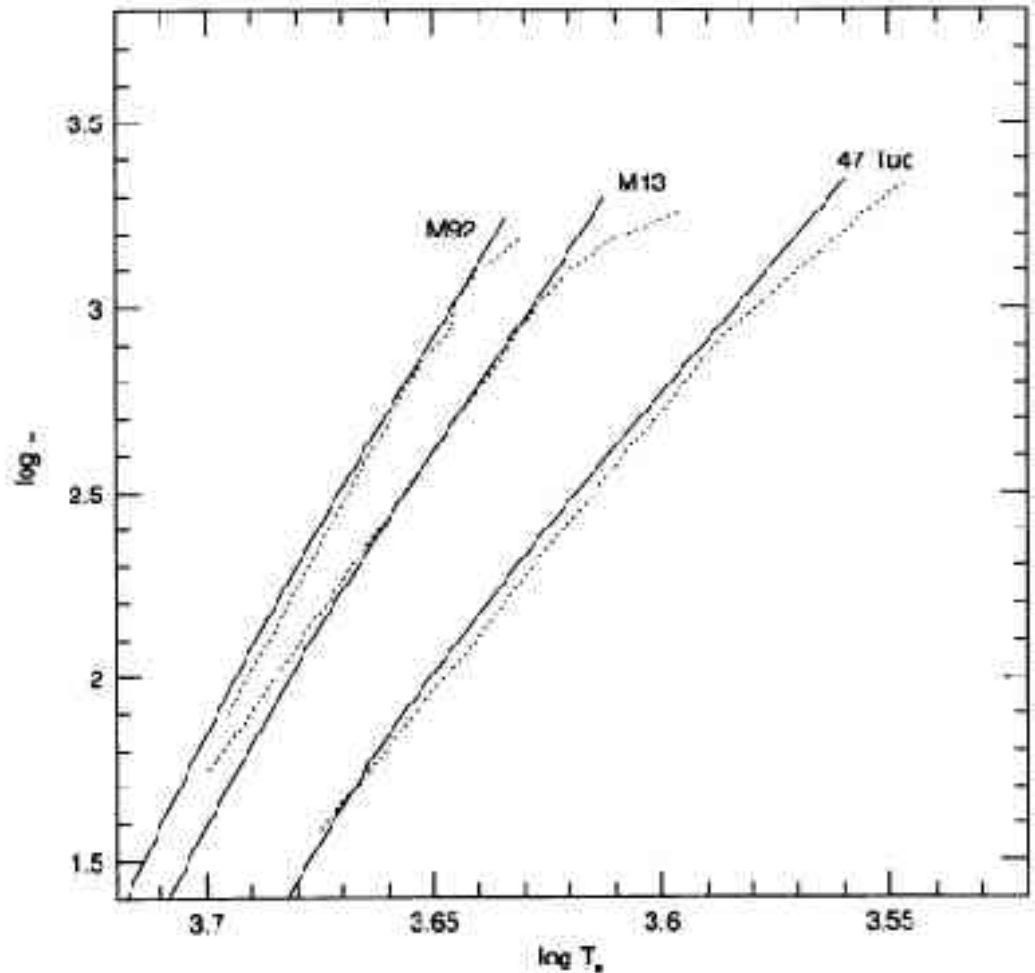
- Parcels of stars at different locations along the isochrones are summed up to obtain the total flux (as a function of wavelength).
- Integrated flux = $\sum_i n_i L_i F_{\lambda,i}$
 - n is the number of stars and L is the luminosity of the parcel.
 - Flux F_{λ} is normalized to 1 solar luminosity.
 - Index i represents the bins in the isochrone.
- This also gives colors and absorption features.

Comparison to observed clusters

- Comparison to observed luminosity functions.
 - Horizontal branch is 0.5 mag fainter than predicted by model.
 - Otherwise good agreement.



- The isochrones are compared to color-magnitude diagrams.
 - Isochrones deviate near the tip of observed giant branches.
 - Solid curve: 15 Gyr model isochrones.
 - Dotted: observed populations (Frogel, Persson, & Cohen, 1981).
 - Isochrones are matched with $[Fe/H]$ to clusters.
 - Globular and open clusters are generally in good agreement with model sequences.



Model output

- Initial mass function
- Output tables
- Initial mass at RGB tip
- Luminosity
- Influence of model parameters
- Spectral energy distributions
- Age and metallicity sensitivity

Initial mass function

- Power law (Salpeter 1955).

$$dN = CM^{-x}dM$$

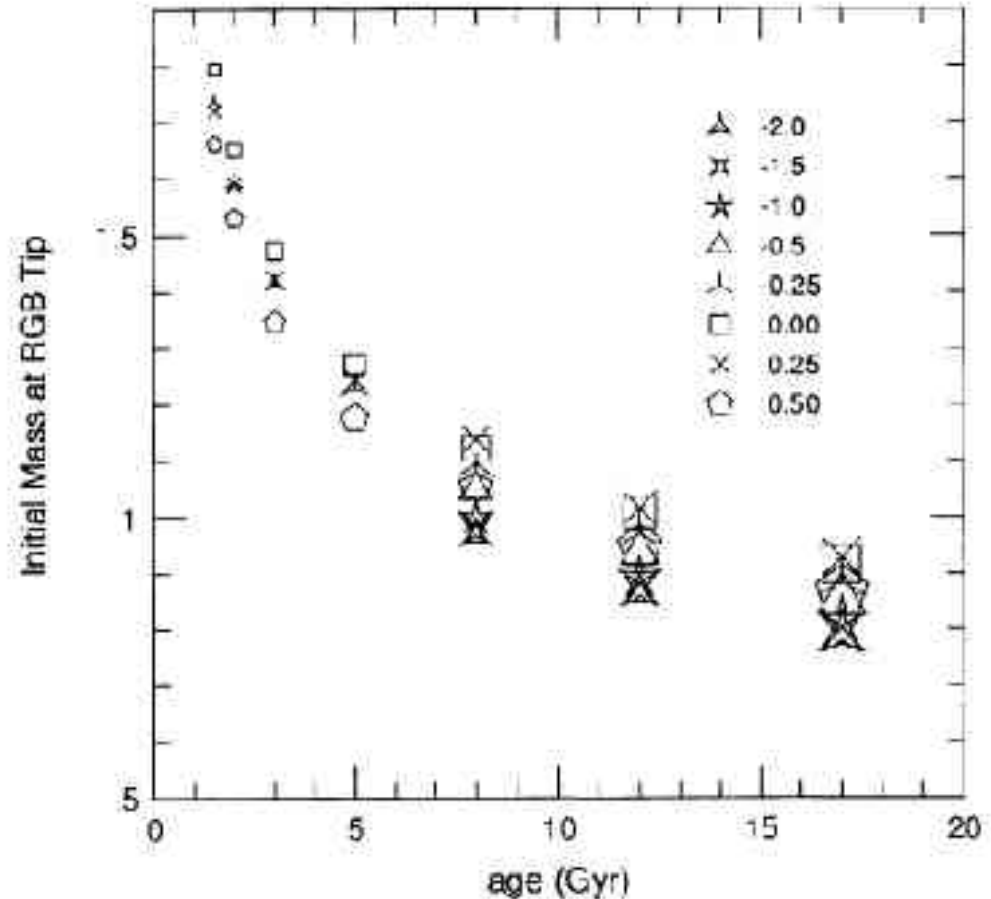
- N is number of stars, C is a constant, M is the stellar mass, and x is a parameter.
- C is defined such that total mass $M_{tot} = 10^6$ solar masses.
 - Results can be scaled for more or less massive systems.
- Limits are 0.1 and 2 solar masses.
 - 2 since young stars are not included here.

Output tables

- The models output the following quantities for different ages and metallicities:
 - Initial mass at the tip of the RGB
 - Bolometric luminosity
 - V-band bolometric correction
 - Absolute magnitudes
 - M/L ratios
 - Broad-band colors
 - Absorption feature indices
 - D(4000) index
 - Fluctuation magnitudes
 - Fluctuation colors

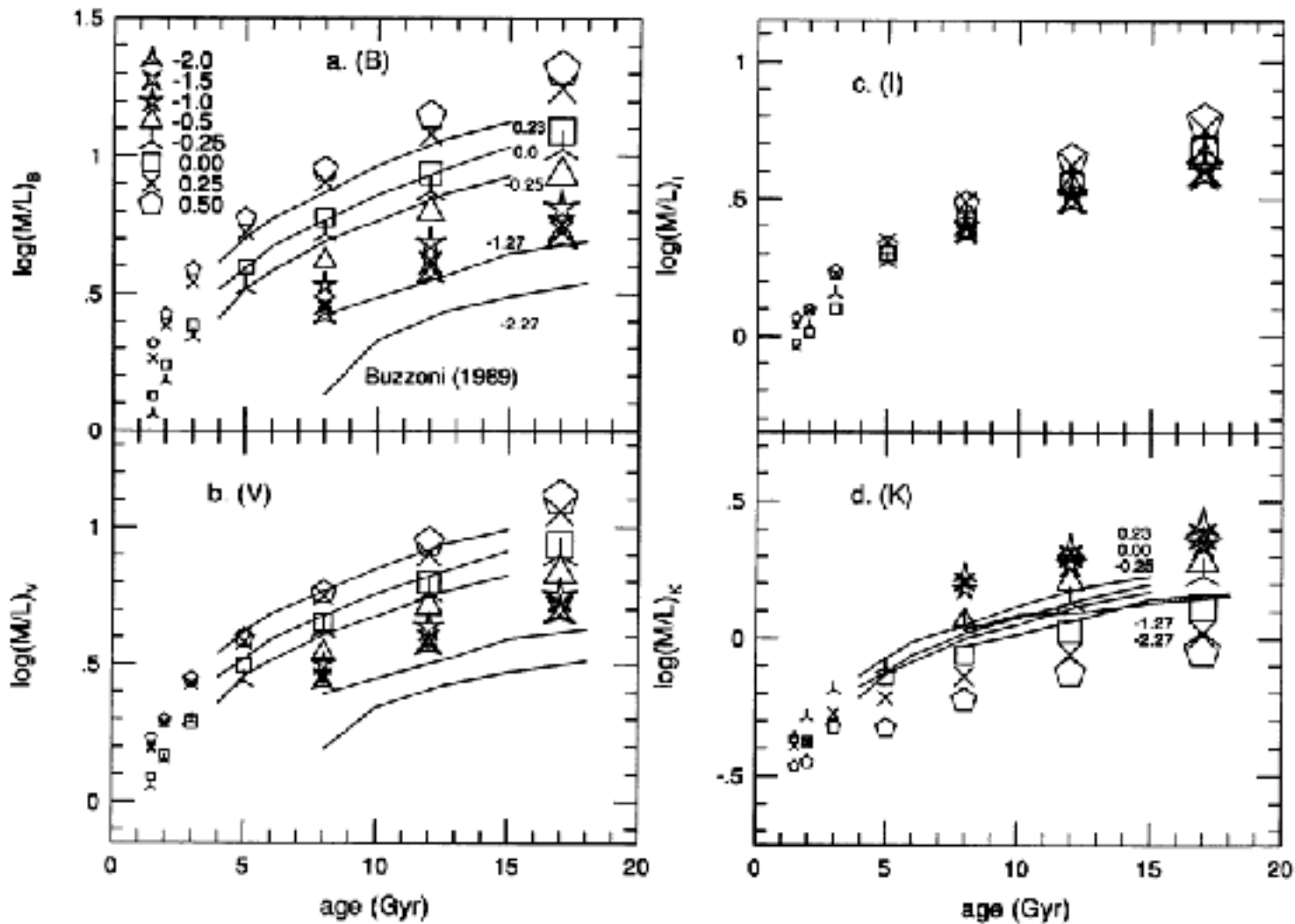
Initial mass at RGB tip

- Important for determining number of post-RGB stars.
- The different symbols and their sizes represent different values of $[Fe/H]$ and age hereafter.



Luminosity

- Expressed in M/L for different passbands.
- Trend of M/L with metallicity reverses near I -band (see following figure).
- M/L_I has weakest metallicity dependence, and also depends more weakly on age than traditionally used M/L_B .
- Should be used for studies in M/L and standard candles.
 - J -band is nearly as good in this respect.



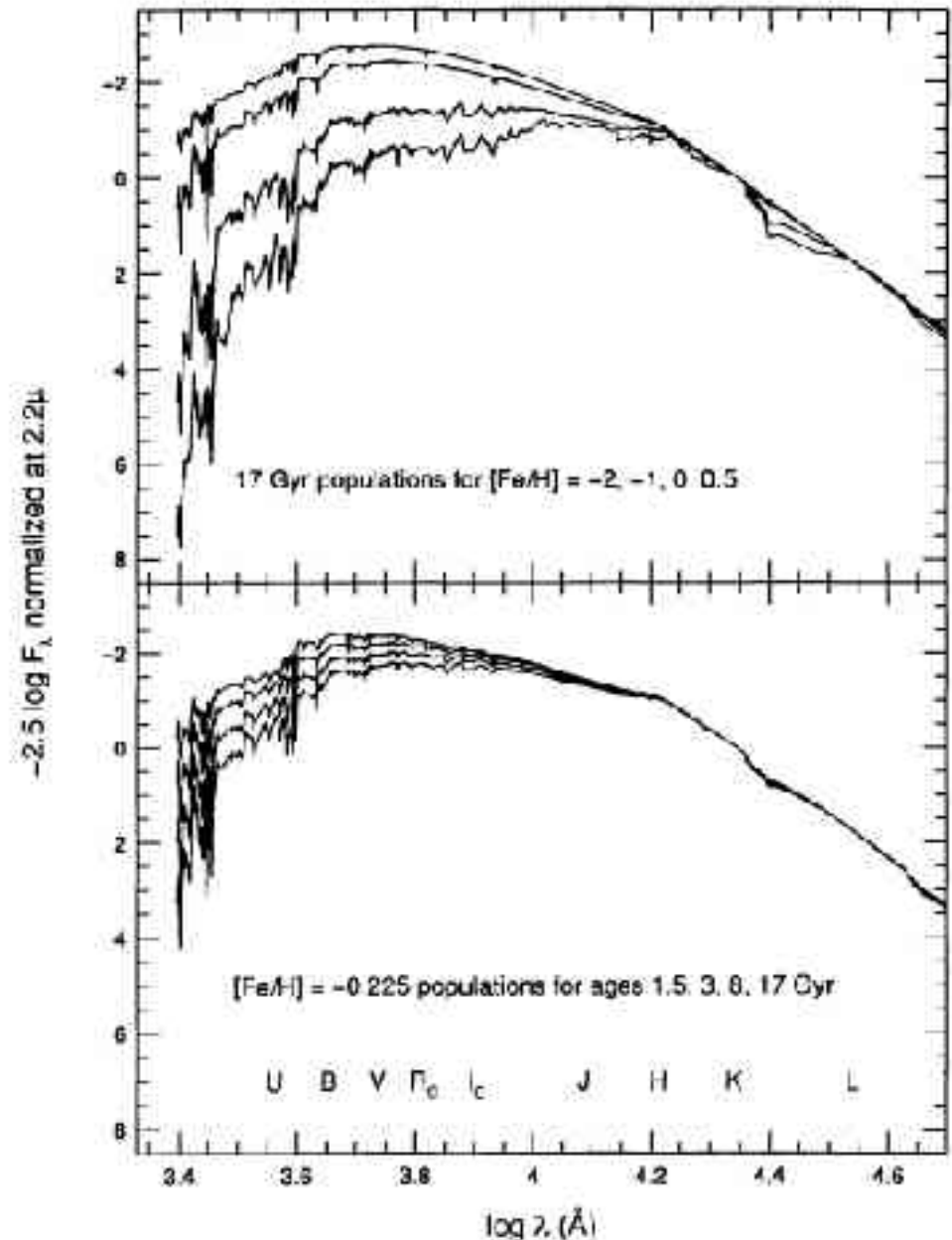
- M/L as a function of age for four different passbands.

Influence of model parameters

- Metallicity and age produce the greatest variations among old populations.
- Other variables such as IMF slope x have an effect of the same magnitude as model uncertainties.
- Some index-index diagrams are highly degenerate and ambiguous.

Spectral energy distributions

- “Modeling of metal rich populations at wavelengths redder than V requires careful modeling of M-giant light.”



Age and metallicity sensitivity

- Fe4668, Fe5015, Fe5709, and Fe5782 are good metallicity indicators.
 - 2 to 3 times better than commonly used Mg_2
- $H\beta$ and G4300 are not sensitive to metallicity and are good age indicators.
- In the future, higher order Balmer lines might be used.
 - Less affected by emission than $H\beta$
 - Less diluted by light from giants
- Broad-band colors are not useful in separating age and metallicity effects.

- If symbols are separated in a grid-like fashion, an age indicator has been found.
 - Otherwise, there is degeneracy and it will be hard to separate age and metallicity effects.

