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

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Purpose

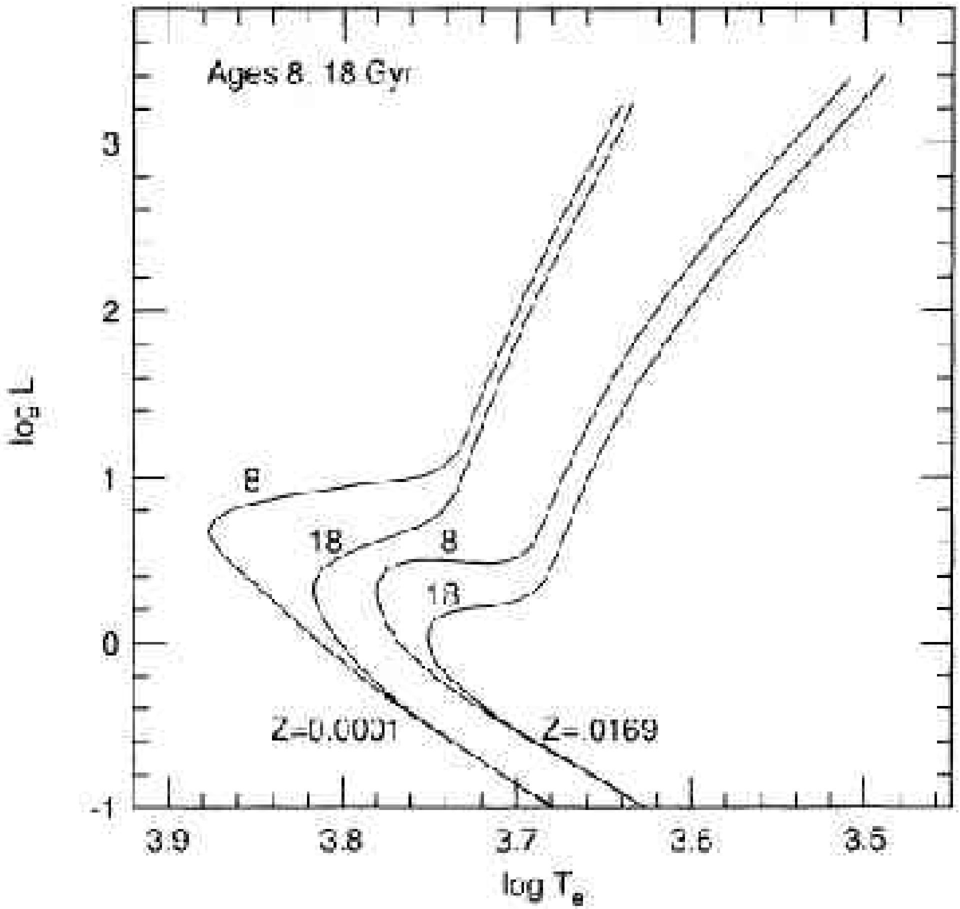
- Construct models for intermediate and old stellar populations.
  - Models output the following:
    - Broadband magnitudes
    - Spectral energy distributions
    - Surface brightness fluctuation magnitudes
    - 21 absorption feature indices
- Draw conclusions regarding abundances and other quantities.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

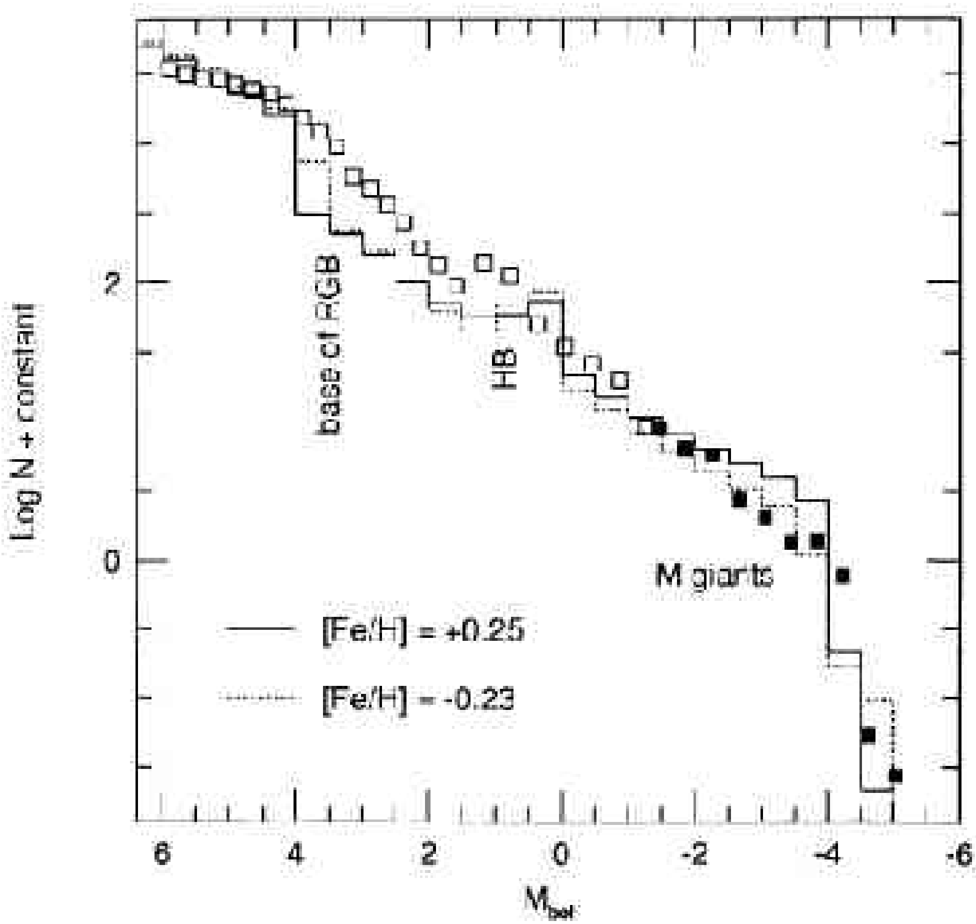


- Two sets of isochrones show that age and metallicity effects resemble each other more at higher metallicities.

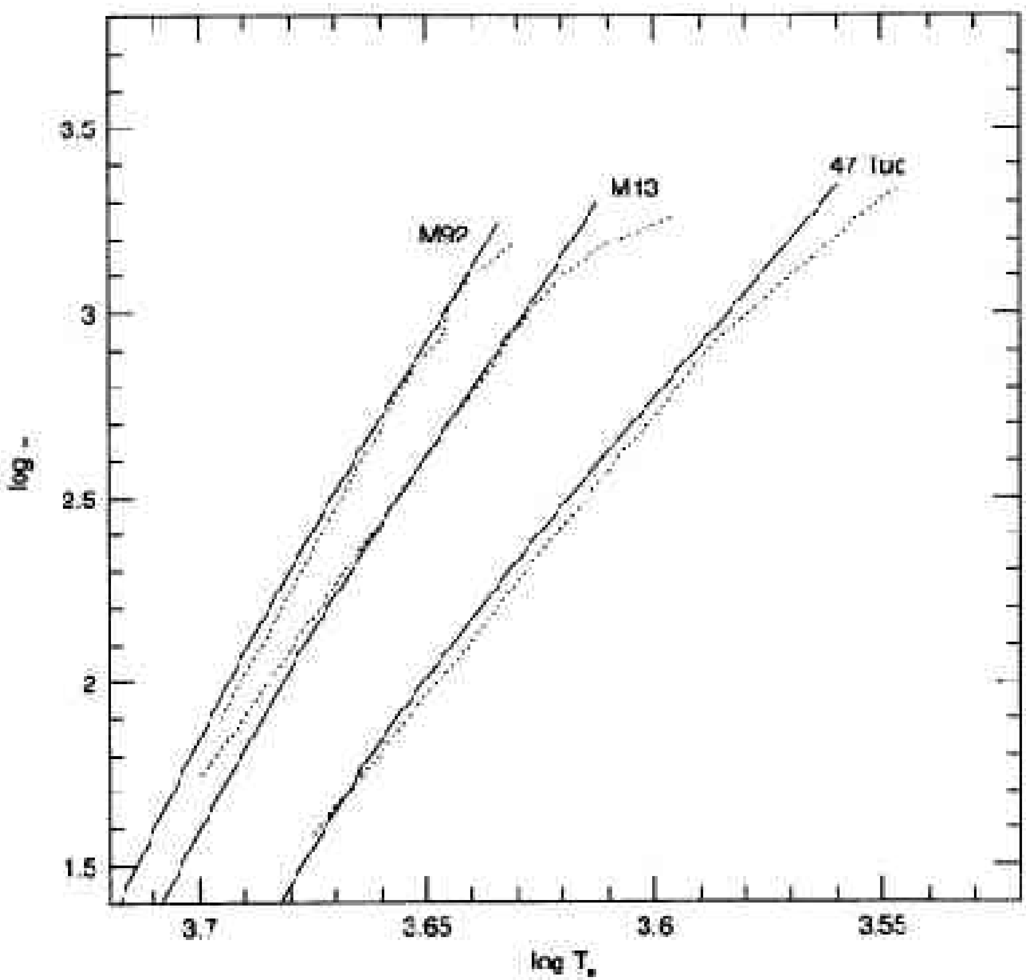
- Parcels of stars at different locations along the isochrones are summed up to obtain the total flux (as a function of wavelength).
- Integrated flux = $\sum_i n_i L_i F_{\lambda,i}$
  - *n* is the number of stars and *L* is the luminosity of the parcel.
  - Flux F_λ is normalized to 1 solar luminosity.
  - 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).

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

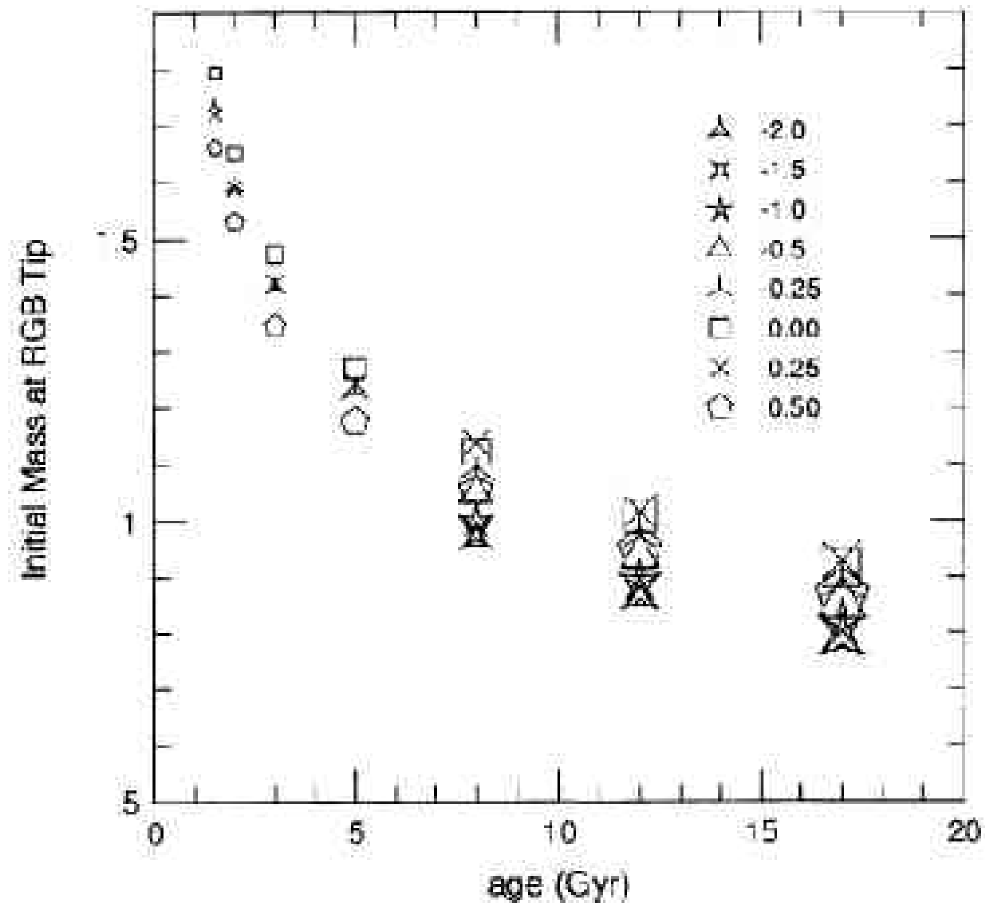
  - *N* is number of stars, *C* is a constant, *M* is the stellar mass, and *x* is a parameter.
  - *C* is defined such that total mass $M_{tot} = 10^6$ solar masses.
    - Results can be scaled for more or less massive systems.
  - Limits are 0.1 and 2 solar masses.
    - 2 since young stars are not included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

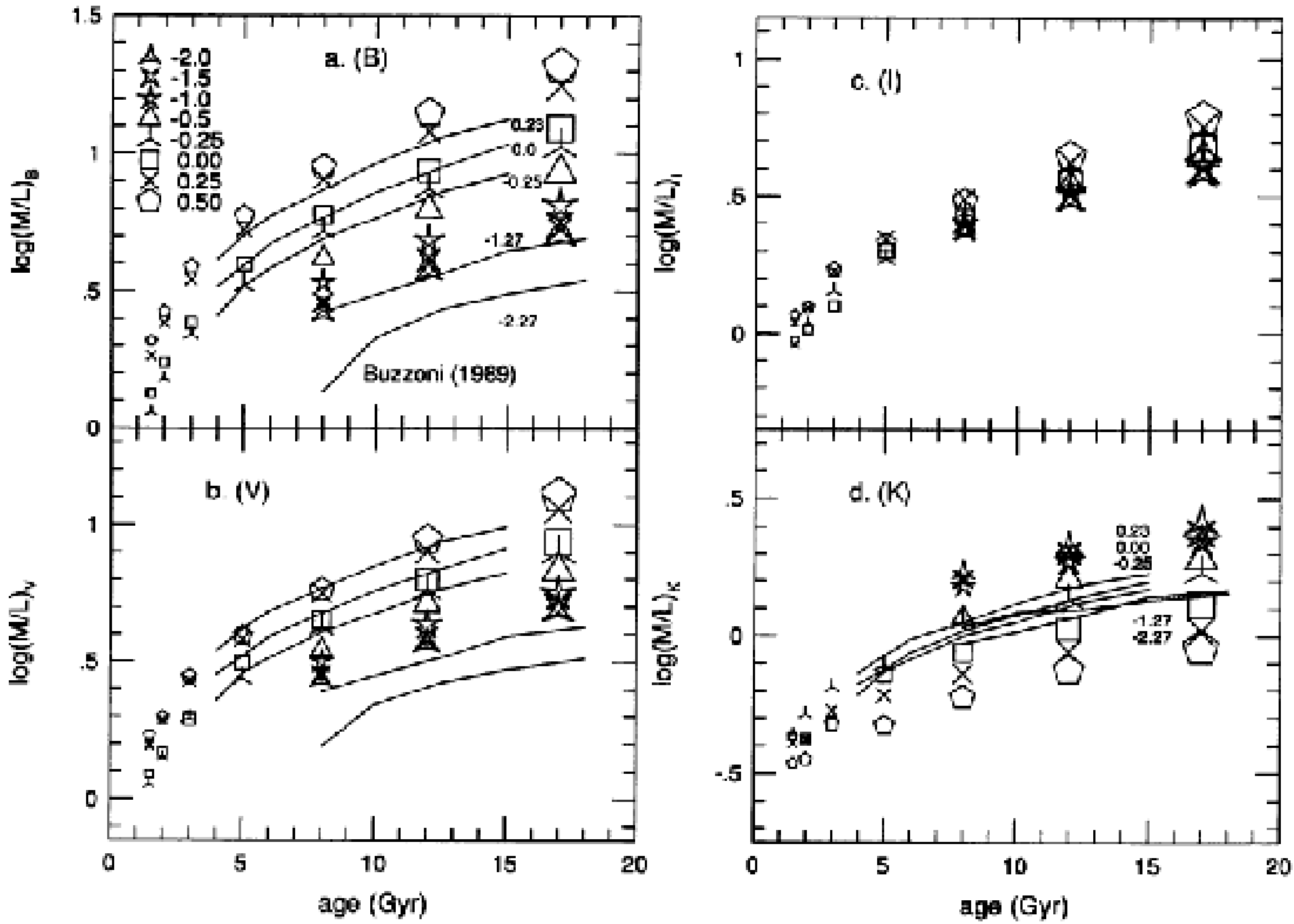
- Important for determining number of post-RGB stars.
- The different symbols and their sizes represent different values of [Fe/H] and age hereafter.



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.



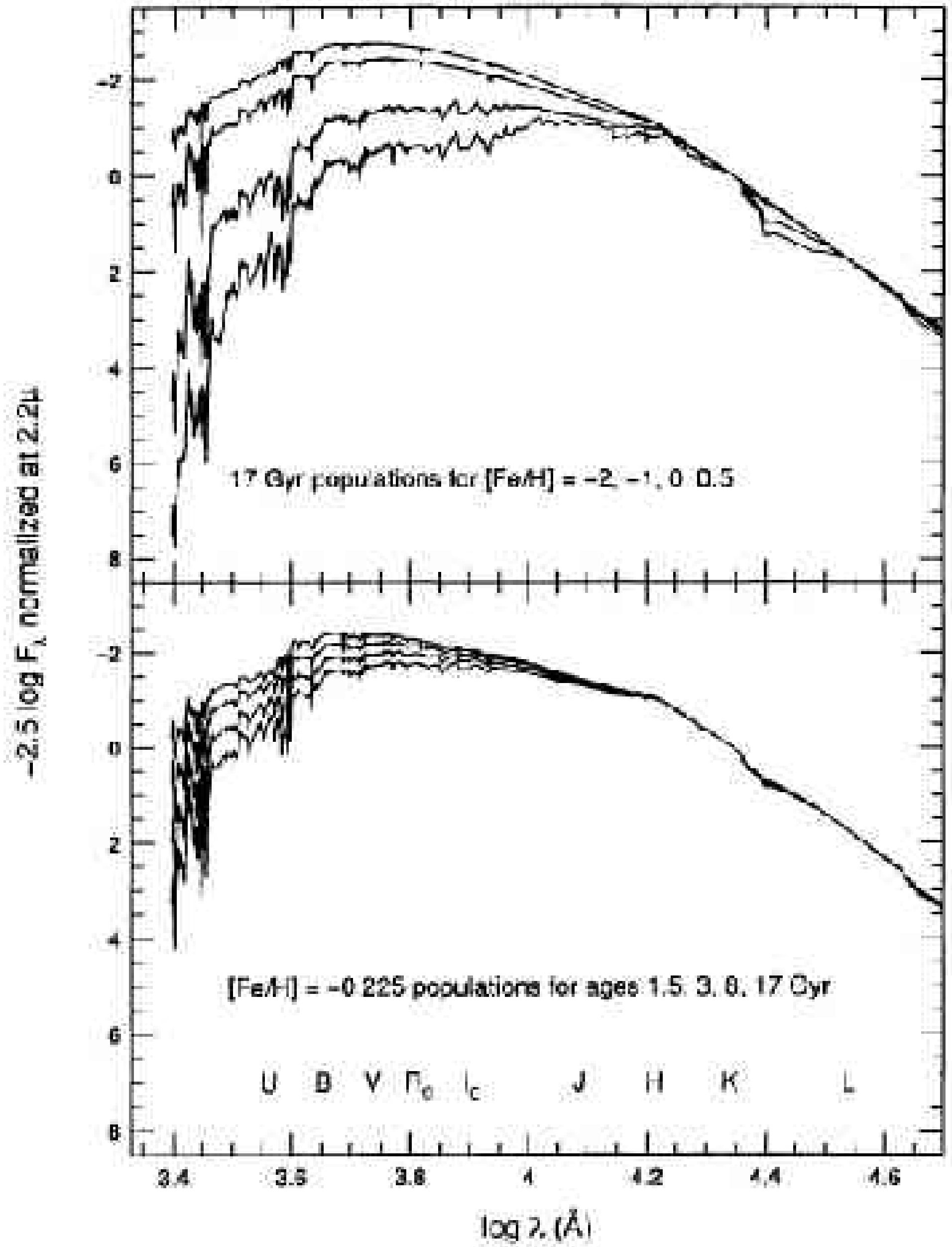
- M/L as a function of age for four different passbands.

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
- Hβ 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 Hβ
  - 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.