2017

stellar population synthesis

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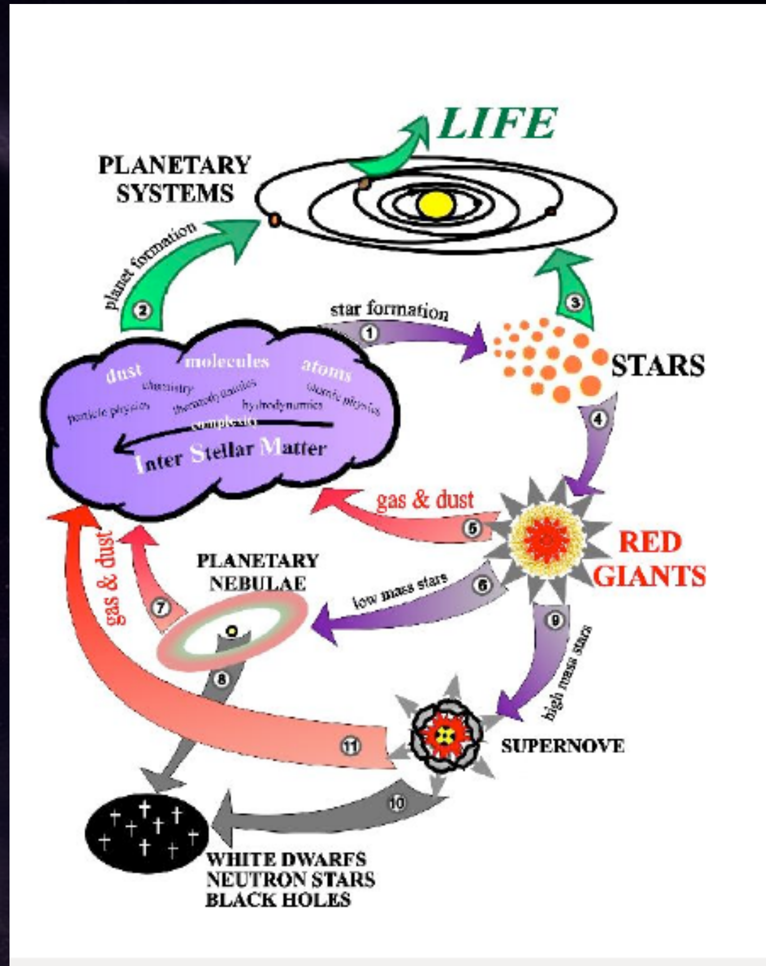
Outlines

- Overview of stellar population synthesis
  - Simple stellar population(SSP)
  - Composite Stellar Populations(CSP)
- Applications of stellar population synthesis
  - mass-to-light ratios
  - stellar metallicities
  - Dust

Overview of Stellar population synthesis

- Stellar population synthesis (SPS)

- SPS provides the fundamental link between theory/models and observations



History of Stellar population synthesis

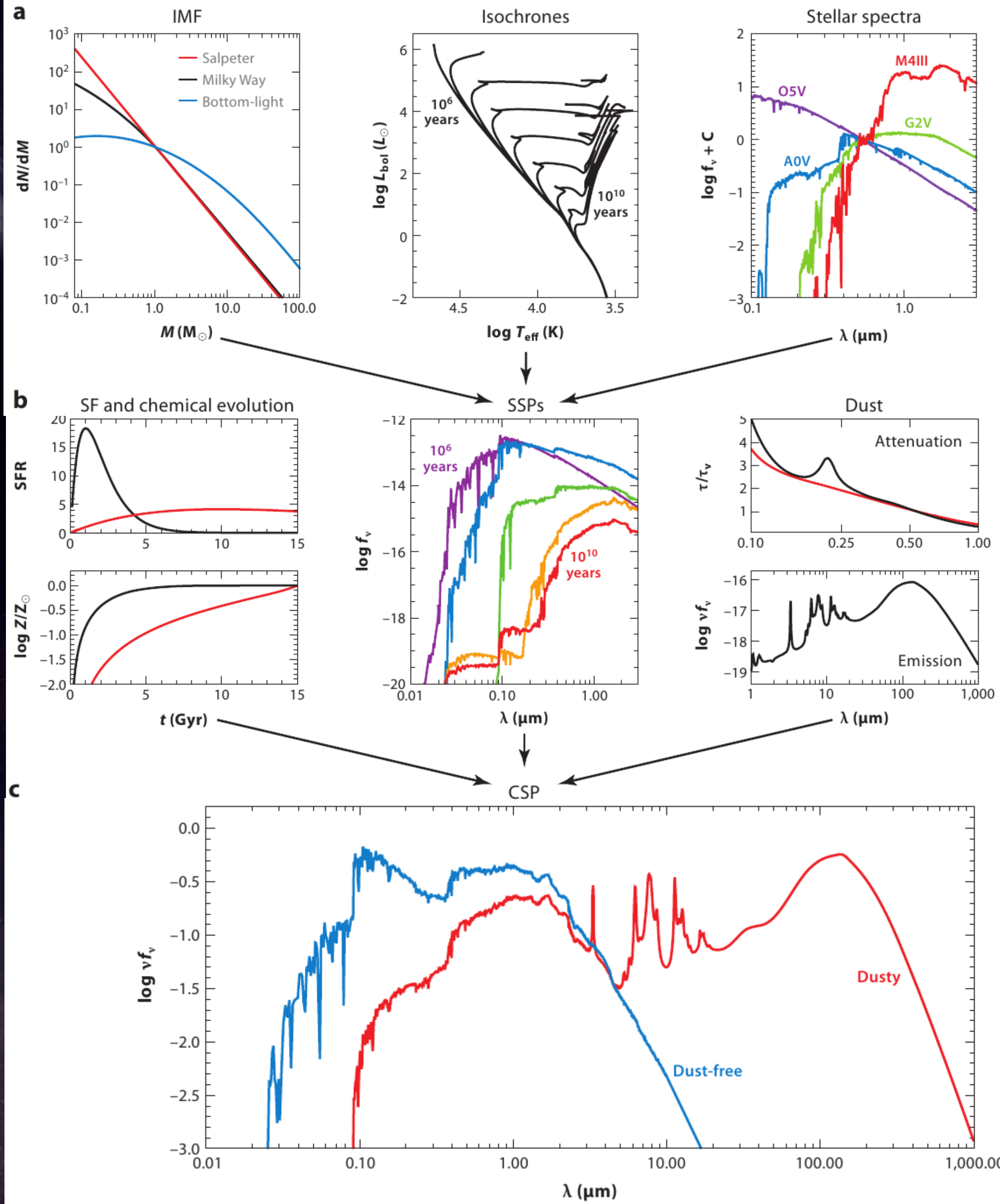
- Reproduces the integrated spectrum of a galaxy with a linear combination of individual stellar spectra of various types(Spinrad & Taylor 1971)
  - too large free parameters

- Based on the evolutionary population synthesis technique
  - constrain the range of possible stellar types at a given age and metallicity

Overview of Stellar population synthesis

- Simple stellar population (SSP)
  - a single, coeval stellar population
  - single metallicity
  - abundance pattern

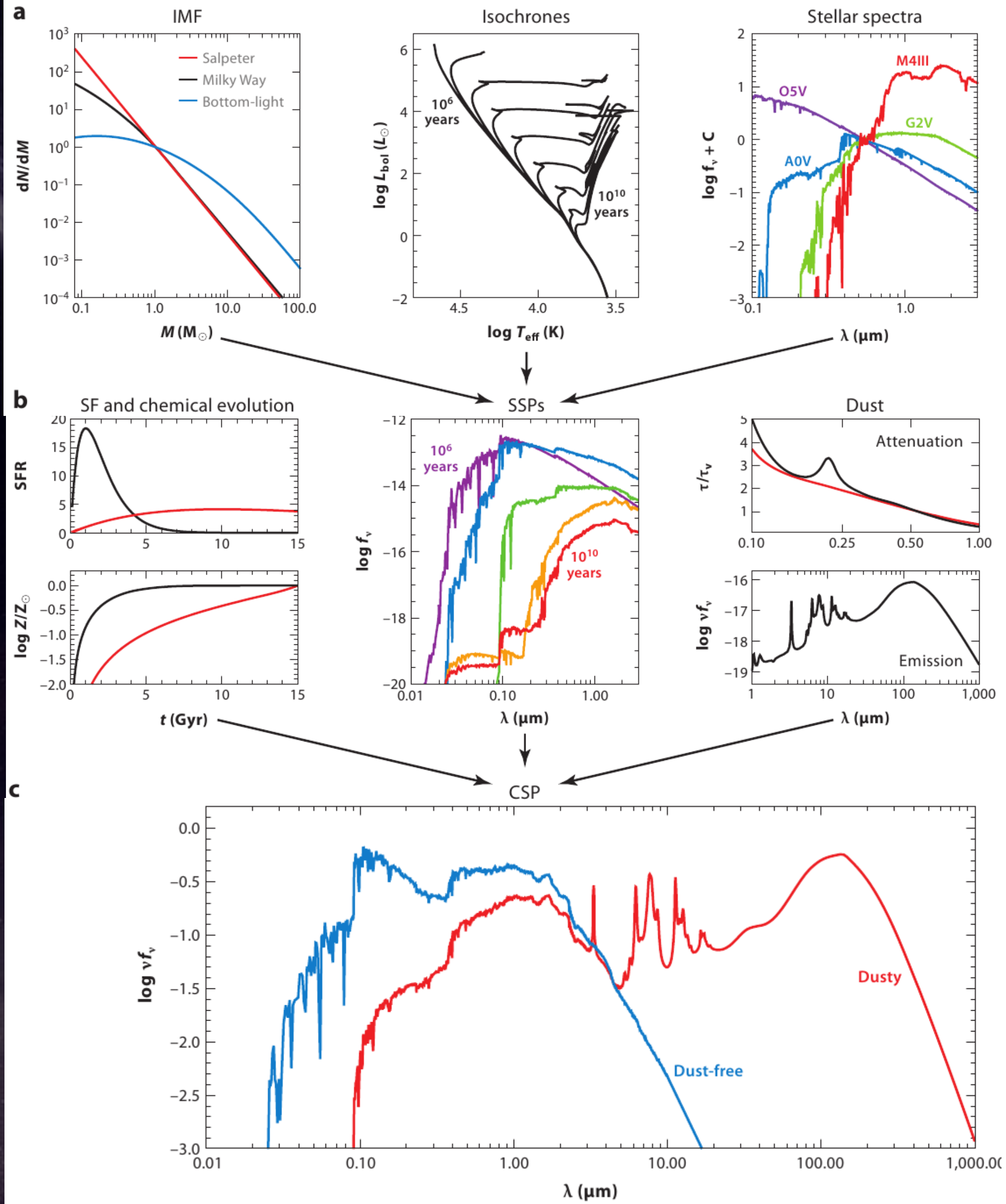
$$f_{\mathrm{SSP}}(t, Z) = \int_{m_{\mathrm{lo}}}^{m_{\mathrm{up}}(t)} f_{\mathrm{star}}[T_{\mathrm{eff}}(M), \log g(M)|t, Z]\, \Phi(M)\, \mathrm{d}M\,,$$



Overview of Stellar population synthesis

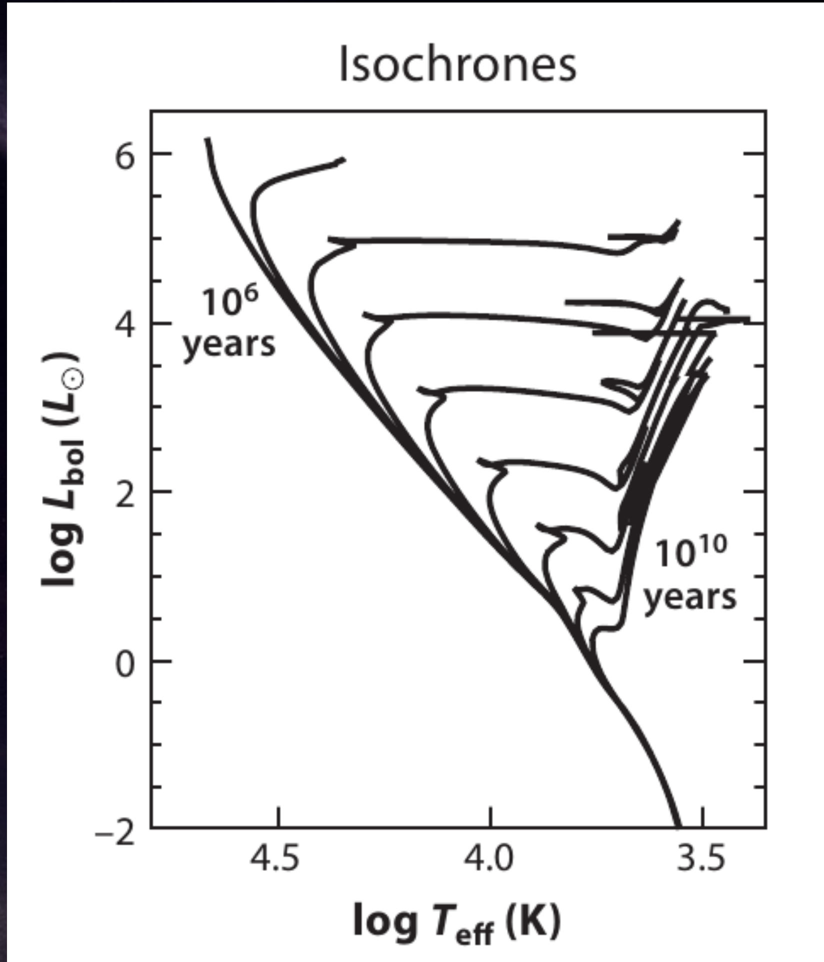
- Composite Stellar Populations(CSP)
  - ages given by SFH
  - metallicities as given by time-dependent metallicity distribution function
  - dust

$$f_{\mathrm{CSP}}(t) = \int_{t'=0}^{t'=t} \int_{Z=0}^{Z_{\max}} \left(\mathrm{SFR}(t-t')P(Z, t-t') f_{\mathrm{SSP}}(t', Z) e^{-\tau_d(t')} + A\, f_{\mathrm{dust}}(t', Z) \right) \mathrm{d}t'\, \mathrm{d}Z,$$



Stellar evolution and isochrones

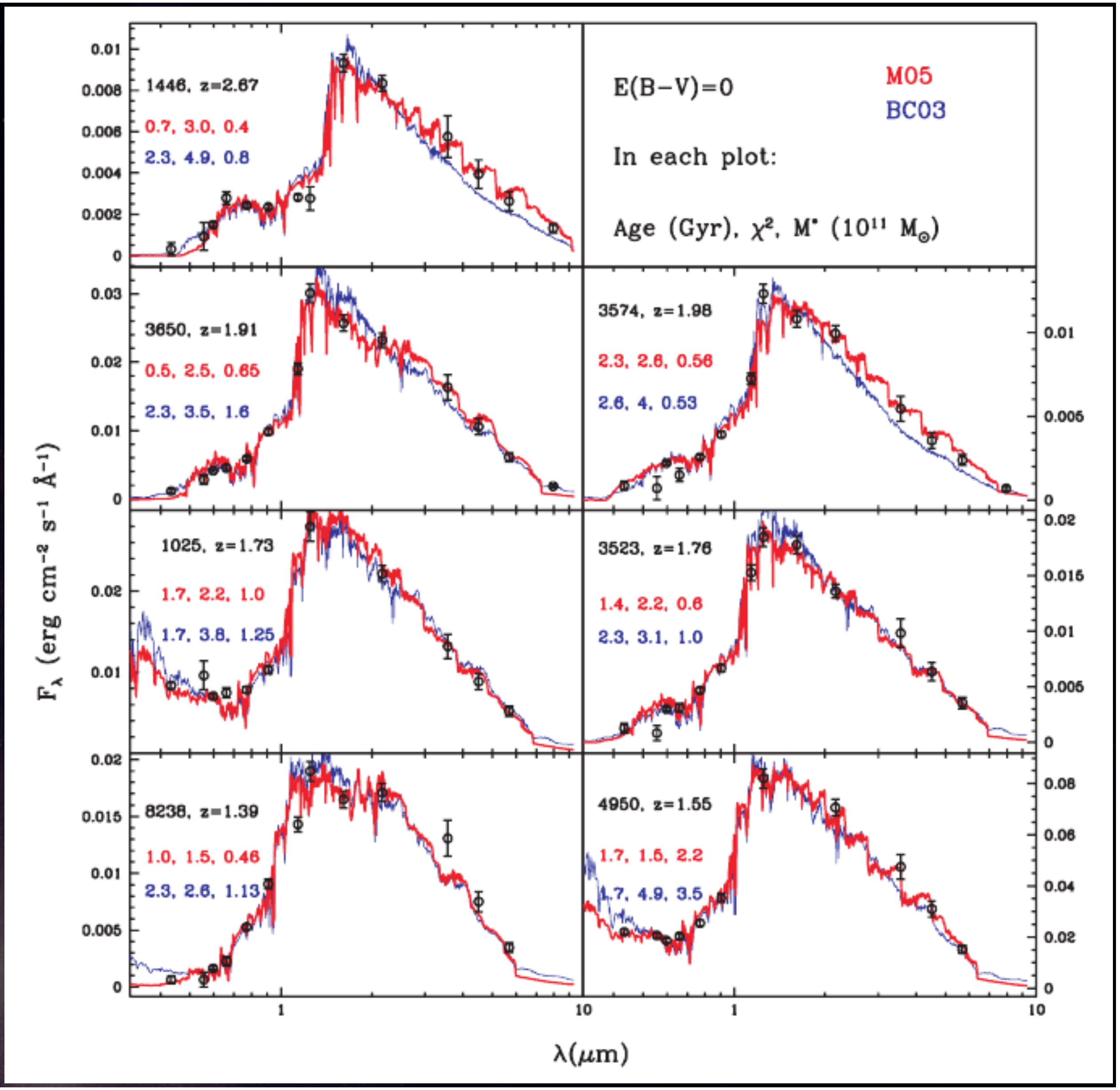
- Hertzsprung-Russell (HR) diagram of stars with a common age and metallicity.
- stars from the hydrogen burning limit (≈0.1 M_{sun}) to the maximum stellar mass (≈100 M_{sun}).
- models:
  - Padova models (Bertelli et al. 1994)
  - BaSTI models (Pietrinferni et al. 2004)
  - Geneva models (Schaller et al. 1992)



Stellar evolution and isochrones

- Lack of post-AGB evolutionary phase
- different assumptions of convection, rotation
- three-dimensional processes
- Lack of binary star evolution.
- Mass-loss problem
- Stellar remnants contribution
- thermally pulsating(TP)-AGB

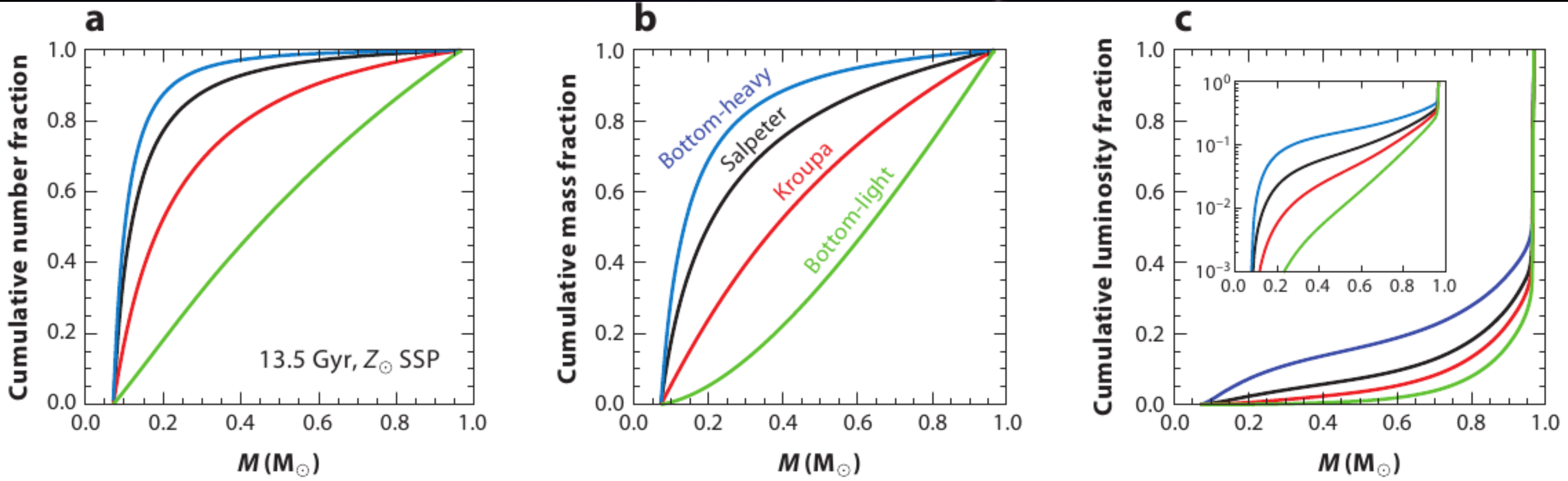
Maraston et al. (2006)



Initial Mass Function(IMF)

$$dN/dM \propto M^{-x}$$

- The initial distribution of stellar masses along the main sequence

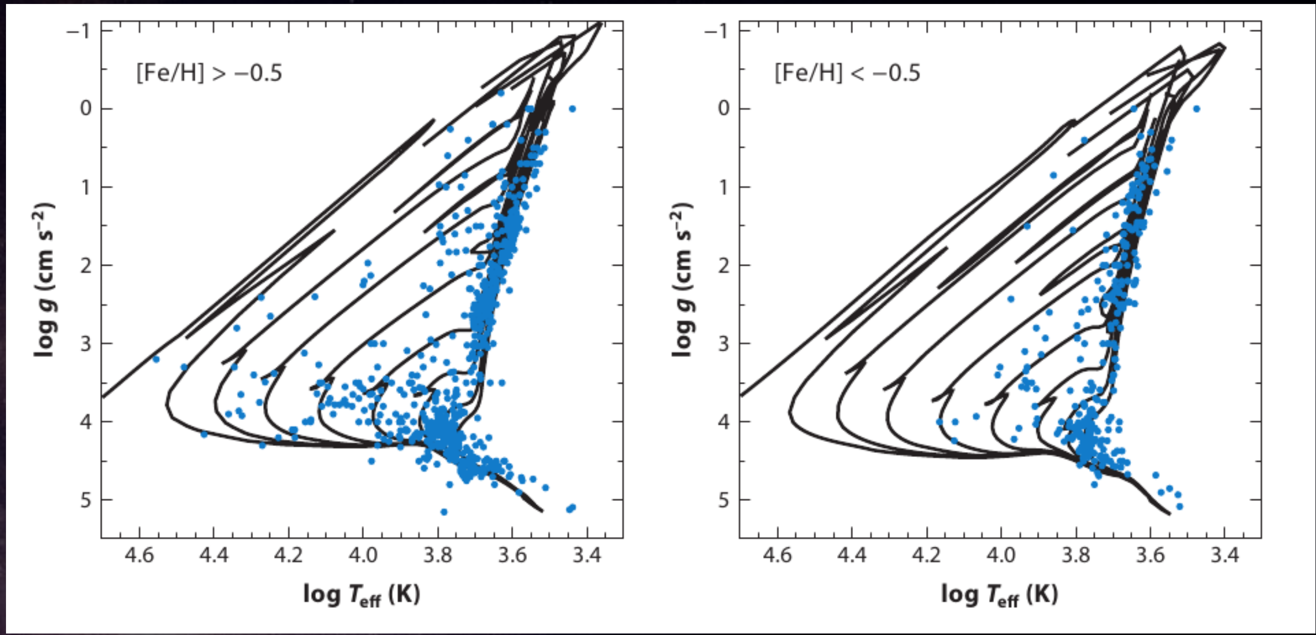


Stellar spectral libraries

- Theoretical libraries
  - densely covering parameter space
  - producing spectra

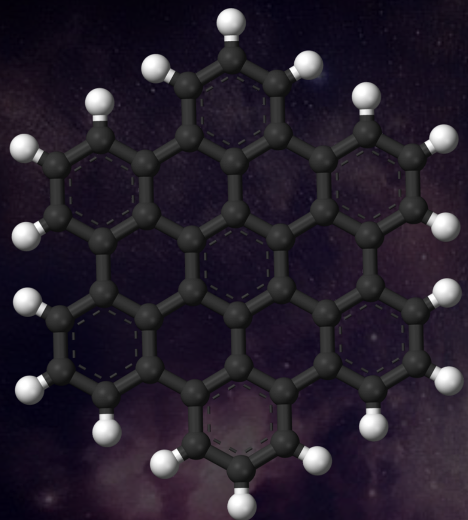
  that are not subject to observational issues such as flux calibration and atmospheric absorption.

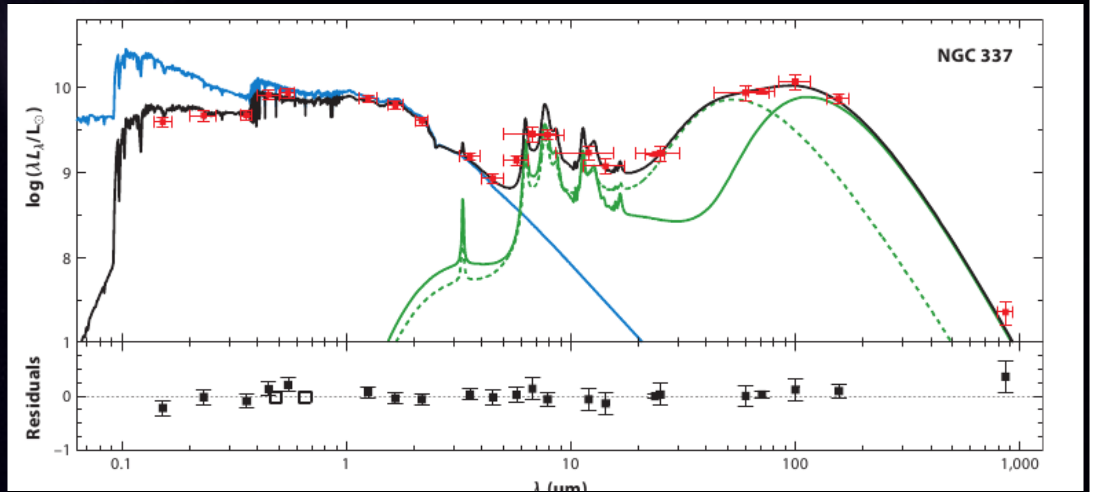
- Empirical libraries
  - do not suffer from issues with line lists, treatment of convection



Dust

- Attenuation
  - sensitive to geometry
  - absorbing and scattering starlight
  - scattered both out of and into a given line of sight
  - geometrical distribution



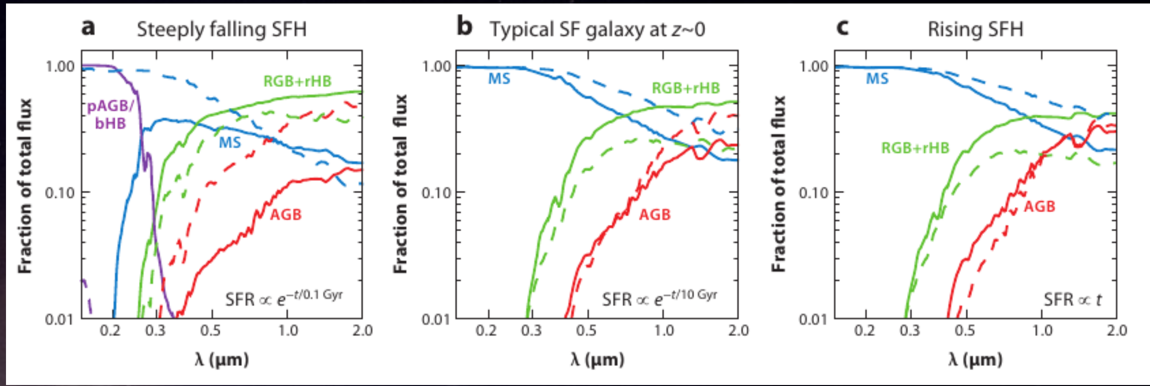


- Emission
  - sensitive to the interstellar radiation fielde
  - > 50µm , ~2/3 of the total IR luminosity
  - shorter wavelength, ~1/3 of the total IR emission
  - <12µm,supplied almost entirely by PAHs

Stellar Formation History

$$f_{\rm CSP}(t) = \int_{t'=0}^{t'=t} \int_{Z=0}^{Z_{\rm max}} \left(\mathrm{SFR}(t-t')P(Z,t-t')f_{\rm SSP}(t',Z)e^{-\tau_d(t')} + A\,f_{\rm dust}(t',Z)\right) \mathrm{d}t'\,\mathrm{d}Z,$$

- τ-model, SFR $\propto$ $e^{-t/\tau}$
  - SFR depends linearly on the gas density
- rising SFH, SFR $\propto$ t
  - explain the SEDs of high-redshift galaxies
- more popular: SFR $\propto$ $t^{\beta}e^{-t/\tau}$
  - an early phase of rising SFRs with late-time decay

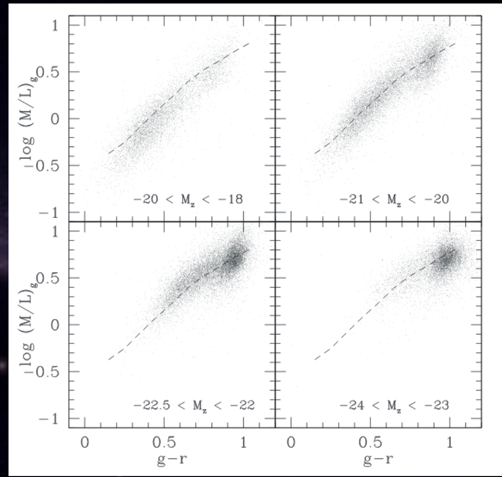


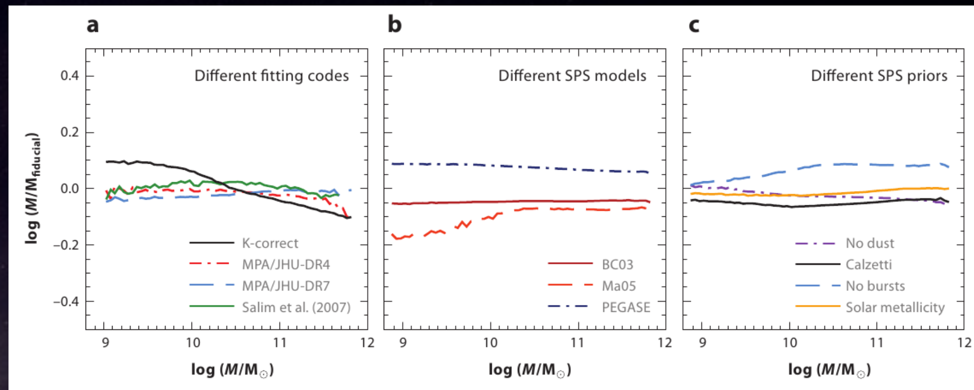
Applications of stellar population synthiese

- mass-to-light ratios and stellar masses
- star-formation rates, histories and stellar ages
- stellar metallicities and abundance patterns
- dust
- initial mass function

MASS-TO-LIGHT RATIOS

- MASS-TO-LIGHT RATIOS
  - Color-based M/L ratios.
    - B−R vs M/L_B (Bell & de Jong (2001))
    - M/L_H vs i−H (Zibetti, Charlot & Rix (2009))
  - M/L from broadband and spectral fitting techniques.
    - The consideration of the Balmer lines with other age and metallicity-sensitive features, such as the 4,000-Å break (Dn4000), can constrain the burstiness of the SFH. Optical spectra therefore offer the possibility of providing stronger constraints on the M/L ratio

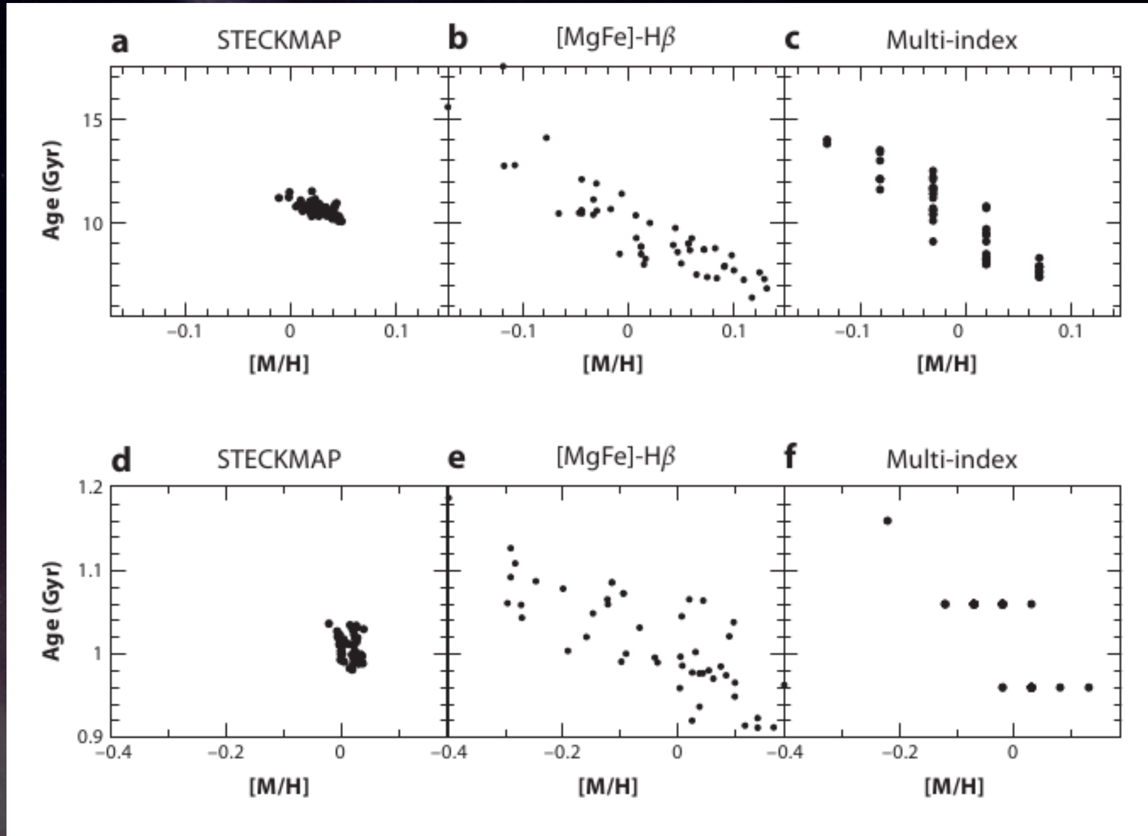




SDSS photometry
SDSS spectral indices
SDSS and GALEX photometry

STELLAR METALLICITIES

- The Age-Metallicity Degeneracy
  - an increase in metallicity results in a cooler main sequence and giant branch,
  - increase in metallicity results in redder colors
- CSPs could separate age and metallicity effects.
  - Photometric Metallicities
  - Spectroscopic Metallicities



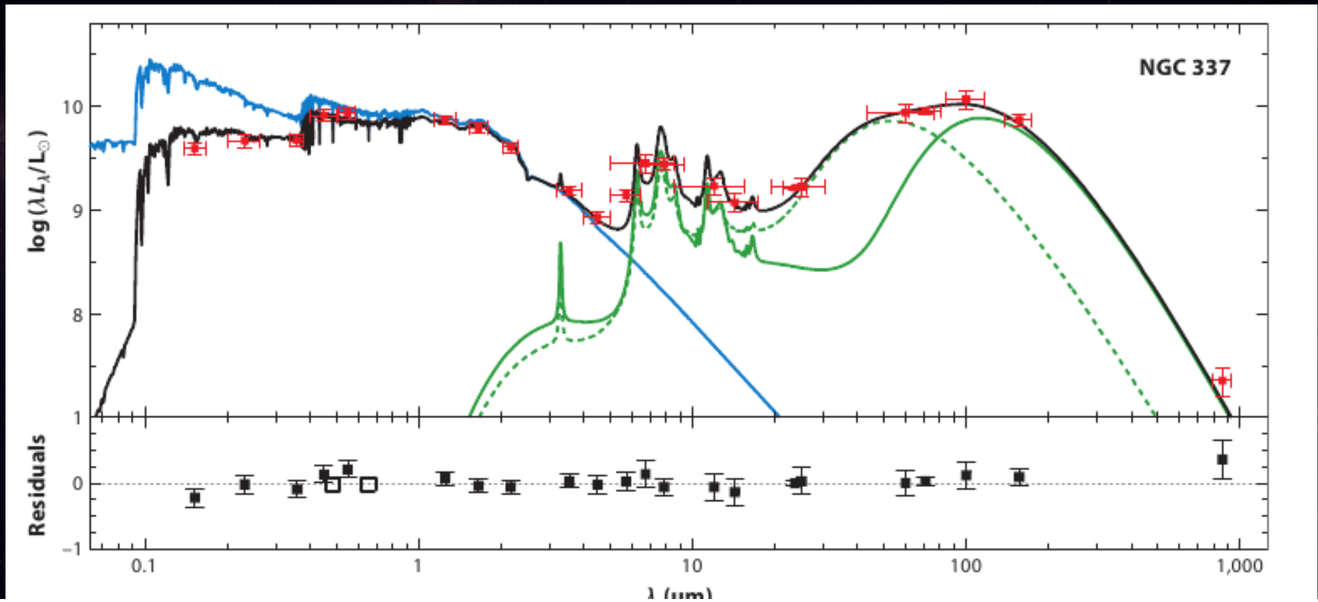
Dust

- four primary techniques:
  - UV-NIR SED
  - the Balmer line ratio Hα/Hβ
  - Energy conservation
  - known intrinsic spectrum

Physical Dust Properties

- empirical spectrum for the PAH emission,
- warm and cold thermal dust emission,
- emission from stochastically heated grains

da Cunha, Charlot & Elbaz (2008)



Summary

- The principal goal of stellar population synthesis (SPS) is to extract physical properties(eg:star-formation history,metal content, dust mass, star-dust geometry,) from observed galaxy SEDs
- The starting point of any SPS model is the simple stellar population (SSP), requires three basic inputs: stellar evolution theory in theform of isochrones, stellar spectral libraries, and an IMF
- Composite stellar populations (CSPs) differ from simple ones in three respects: (a) they contain stars with a range of ages given by their SFH; (b) they contain stars with a range in metallicities as given by their time-dependent metallicity distribution function,(c) they contain dust
- The construction of models for simple and composite stellar populations (CSPs) is conceptually straightforward to deal with incomplete isochrone tables, incomplete empirical stellar libraries,poorly calibrated physics, etc

References

- Charlie Conroy, Modeling the Panchromatic Spectral Energy Distributions of Galaxies, Annual Review of Astronomy and Astrophysics, vol. 51, issue 1, pp. 393-455

- Bruzual, G.; Charlot, S. Stellar population synthesis at the resolution of 2003.MNRAS Volume 344, Issue 4, pp. 1000-1028

- C. Maraston et al. EVIDENCE FOR TP-AGB STARS IN HIGH-REDSHIFT GALAXIES, AND THEIR EFFECT ON DERIVING STELLAR POPULATION PARAMETERS. The Astrophysical Journal, 652:85Y96, 2006 November 20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