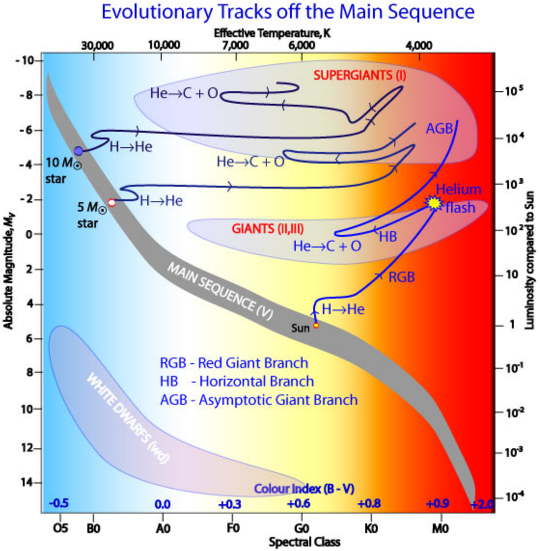
Stellar Population Synthesis & the Chemical Evolution of Galaxies

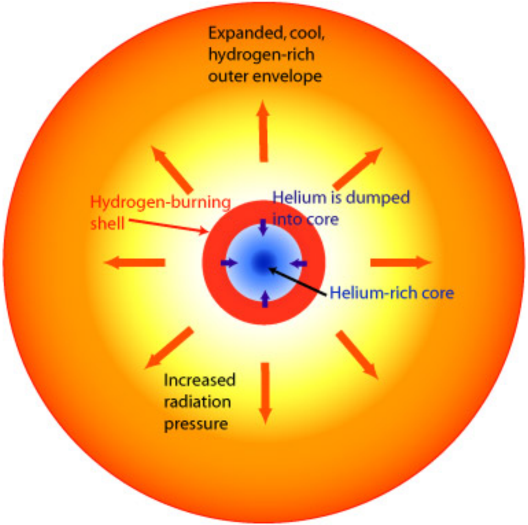
Stellar spectra, Spectral synthesis
Stellar chemical production
Modeling chemical enrichment

October 4, 2022

University of Rochester

Post-MS evolution



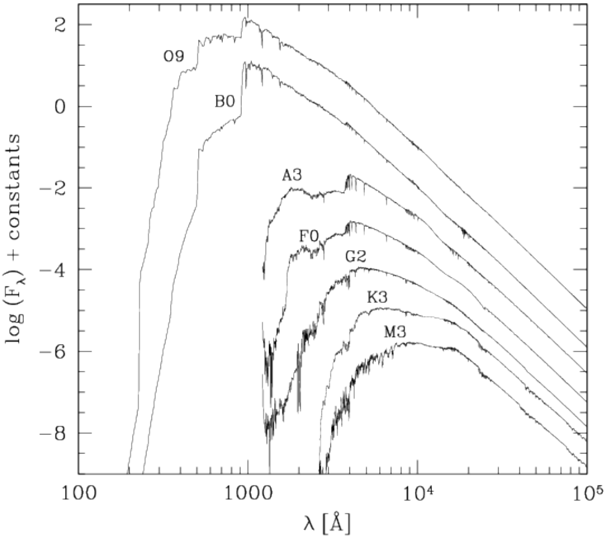


Hydrogen Shell Burning on the Red Giant Branch

Supernovae

Type	Spectral features	Galaxy type	Location within galaxy
Ia	significant Si^+ absorption	All galaxies	Everywhere
Ib	no H emission or significant Si^+ absorption	Rare in early-types	Spiral arms
II	H emission	Rare in early-types	Spiral arms

Stellar spectra



Spectral synthesis

The luminosity of an ensemble of stars at a wavelength λ is

$$L_\lambda(t) = \int_0^t \mathcal{L}_\lambda^{(\mathrm{cp})}(t - t')\Psi(t')\,dt'$$

where

$\Psi(t) \equiv$ the star formation rate

$\mathcal{L}_\lambda^{(\mathrm{cp})}(\tau) \equiv$ the luminosity per unit stellar mass of all stars of a coeval population of age τ:

$$\mathcal{L}_\lambda^{(\mathrm{cp})}(\tau) = \int \mathcal{L}_\lambda(m,\tau)\frac{\phi(m)}{M_\odot}\,dm$$

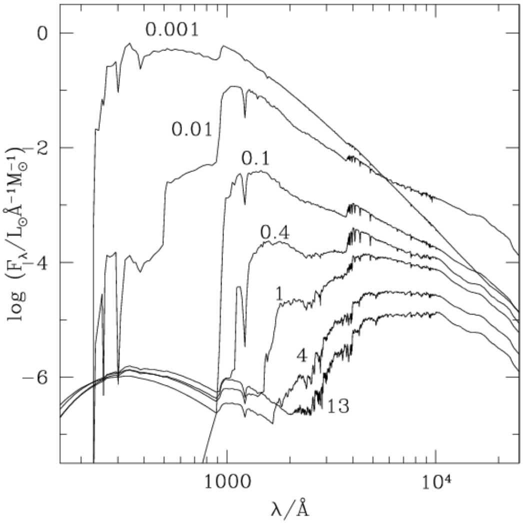
where

$m \equiv$ the mass of a star

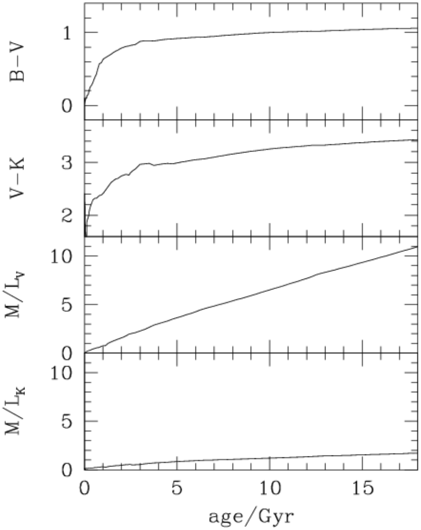
$\phi(m) \equiv$ the normalized IMF

$\mathcal{L}_\lambda(m,\tau) \equiv$ the luminosity of a star at age τ with an initial mass m

Stellar synthesis



Passive evolution



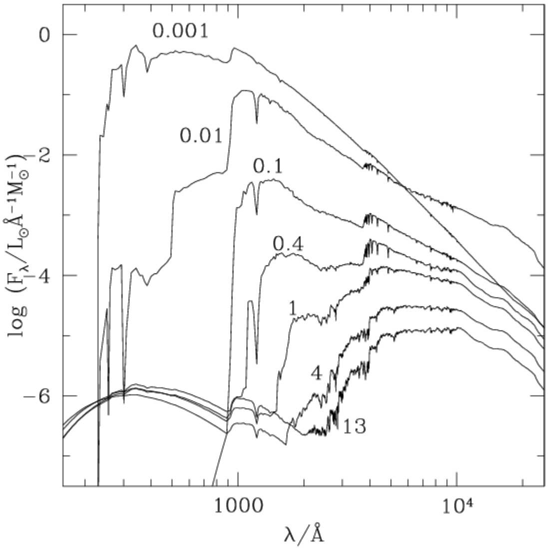
Spectral discontinuities

Lyman break (912Å)

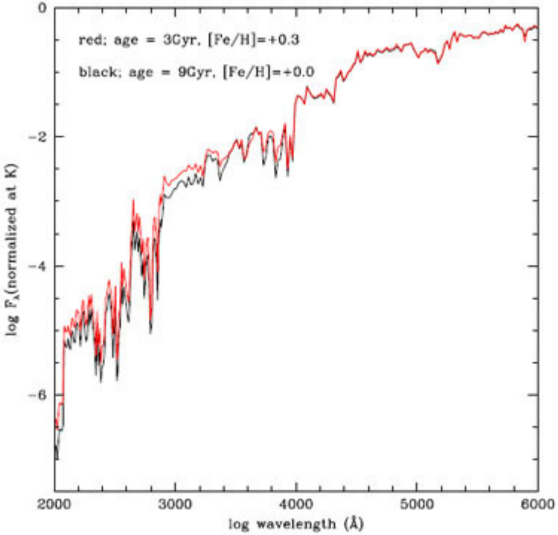
$$D(912) = \frac{\int_{1000}^{1100} F(\lambda)\, d\lambda}{\int_{800}^{900} F(\lambda)\, d\lambda}$$

D(4000) break (4000Å)

$$D(4000) = \frac{\int_{4050}^{4250} F(\lambda)\, d\lambda}{\int_{3750}^{3950} F(\lambda)\, d\lambda}$$



Age-metallicity degeneracy



K-corrections

If a galaxy's restframe SED is $L(\nu_e)$ so that $L(\nu_e)\,d\nu_e$ is the energy emitted by a galaxy in the frequency range $\nu_e \to \nu_e + d\nu_e$, and the galaxy's observed flux is $f(\nu_0)\,d\nu_0$, then (ignoring absorption),

$$f(\nu_0)\,d\nu_0 = \frac{L(\nu_e)\,d\nu_e}{4\pi d_L^2} \qquad \text{where } \nu_e = \nu_0(1+z)$$

$$f(\nu_0) = \frac{L(\nu_e)}{L(\nu_0)}(1+z)\frac{L(\nu_0)}{4\pi d_L^2}$$

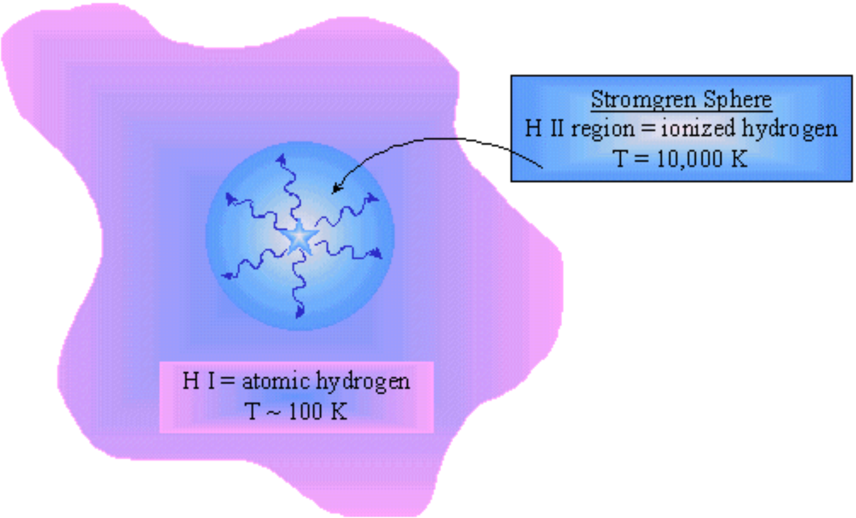
Therefore, for a photometric band j centered at ν_0, the corrected magnitude is

$$m_j = M_j + 5\log\left(\frac{d_L(z)}{10\text{ pc}}\right) + K_j(z)$$

where

$$K_j(z) = -2.5\log(1+z) - 2.5\log\left(\frac{L(\nu_e)}{L(\nu_0)}\right)$$

Emission from HII regions



Dust extinction

The strength of the dust extinction along the line of sight is

$$I_\lambda = I_{\lambda 0} e^{-\tau_\lambda}$$

The empirical extinction law

$$k(\lambda) \equiv \frac{A_\lambda}{E(B-V)} = R_V \frac{A_\lambda}{A_V}$$

where

$$A_\lambda = (2.5 \log e)\tau_\lambda$$

E(B - V) $\equiv A_B - A_V$ is the color excess

$$R_V \equiv \frac{A_V}{E(B-V)}$$