# Stellar Evolution,

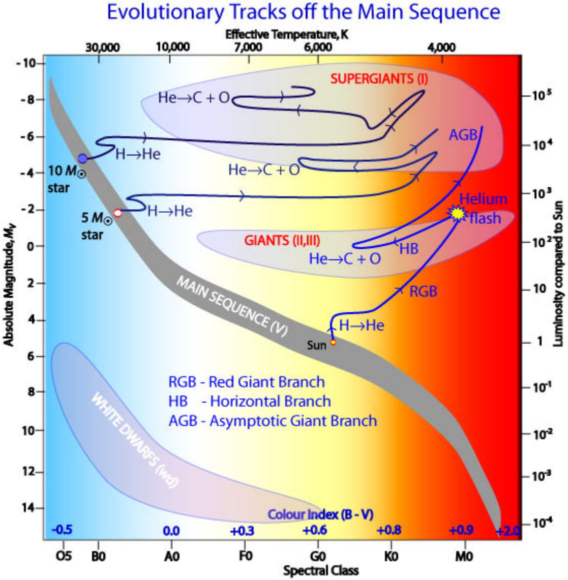
# Stellar Population Synthesis & the Chemical Evolution of Galaxies

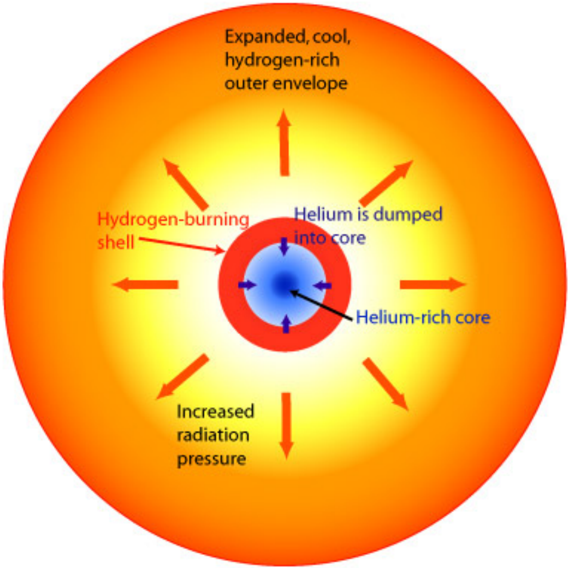
Stellar evolutionary tracks
Stellar spectra, Spectral synthesis
Stellar chemical production
Modeling chemical enrichment

September 26, 2024

University of Rochester

# Post-MS evolution



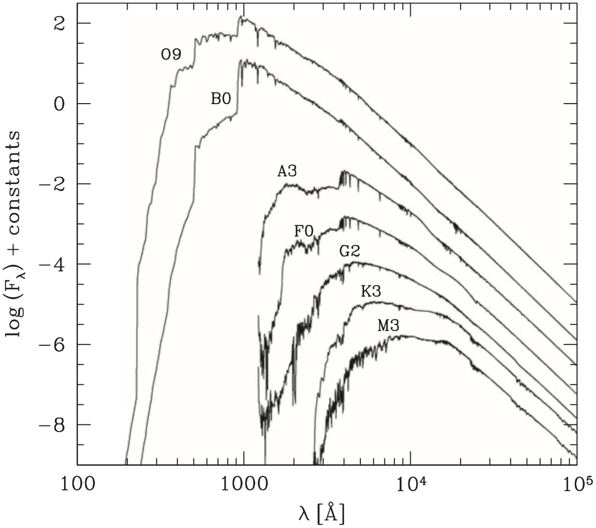




Hydrogen Shell Burning on the Red Giant Branch

# 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 $\lambda$ 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 $\tau$:

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

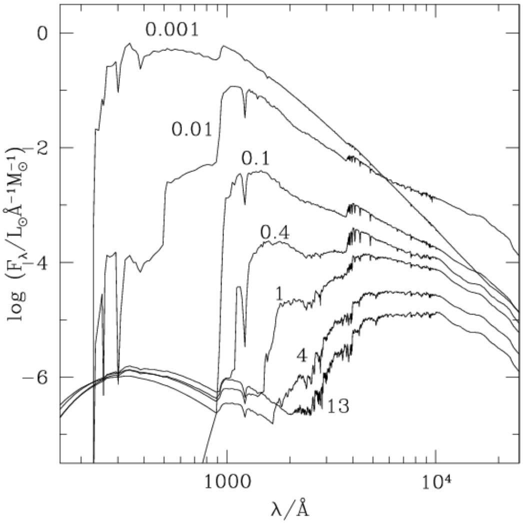
where

$m \equiv$ the mass of a star

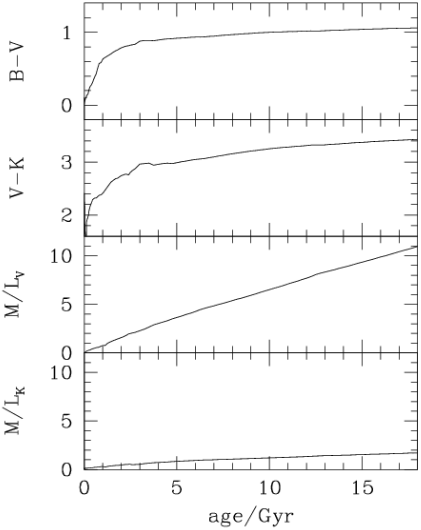
$\phi(m) \equiv$ the normalized IMF

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

# Stellar synthesis



# Passive evolution



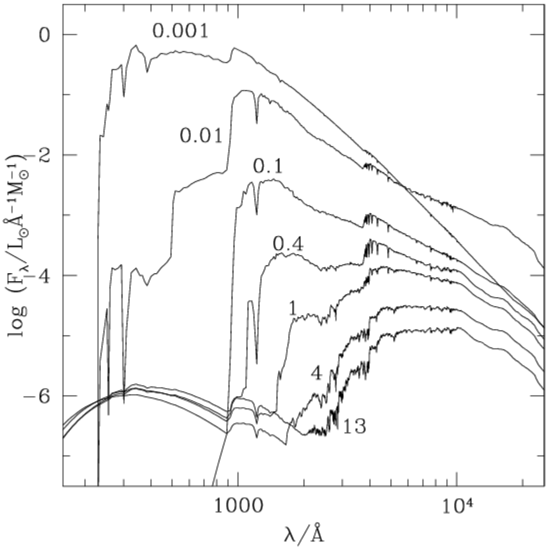
# Spectral discontinuities

Lyman break (912Å)

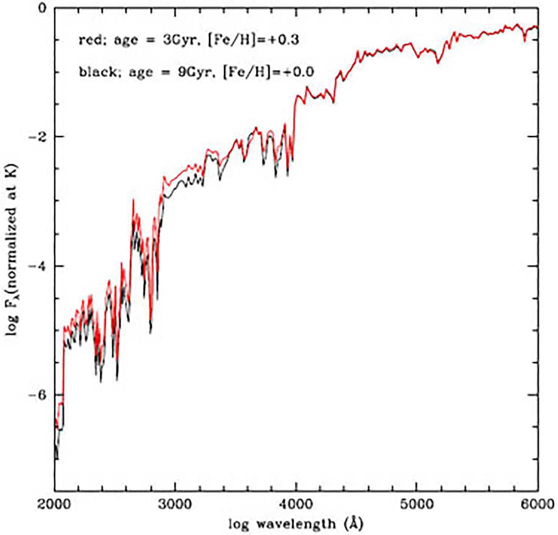
$$D(912) = \frac{\int_{1000}^{1100} F(\lambda)\, d\lambda}{\int_{800}^{900} F(\lambda)\, d\lambda}$$

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),

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

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

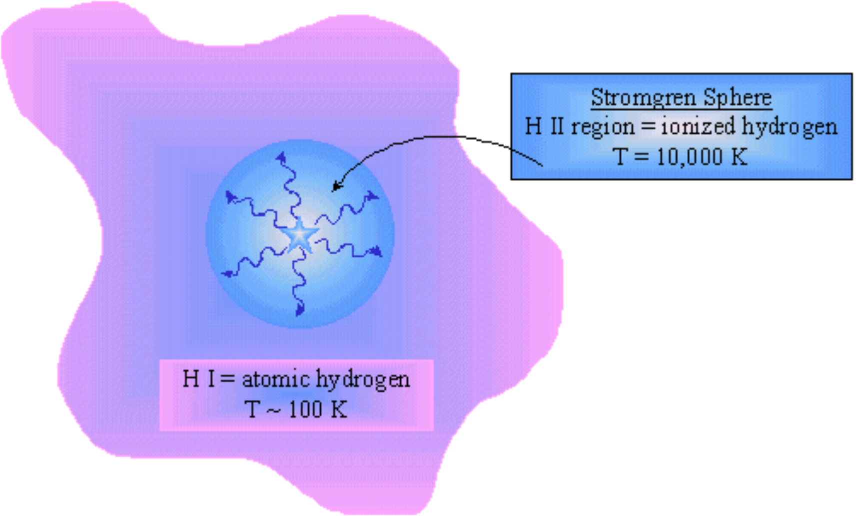
Therefore, for a photometric band $j$ centered at $\nu_0$, the corrected magnitude is

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

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

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

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

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