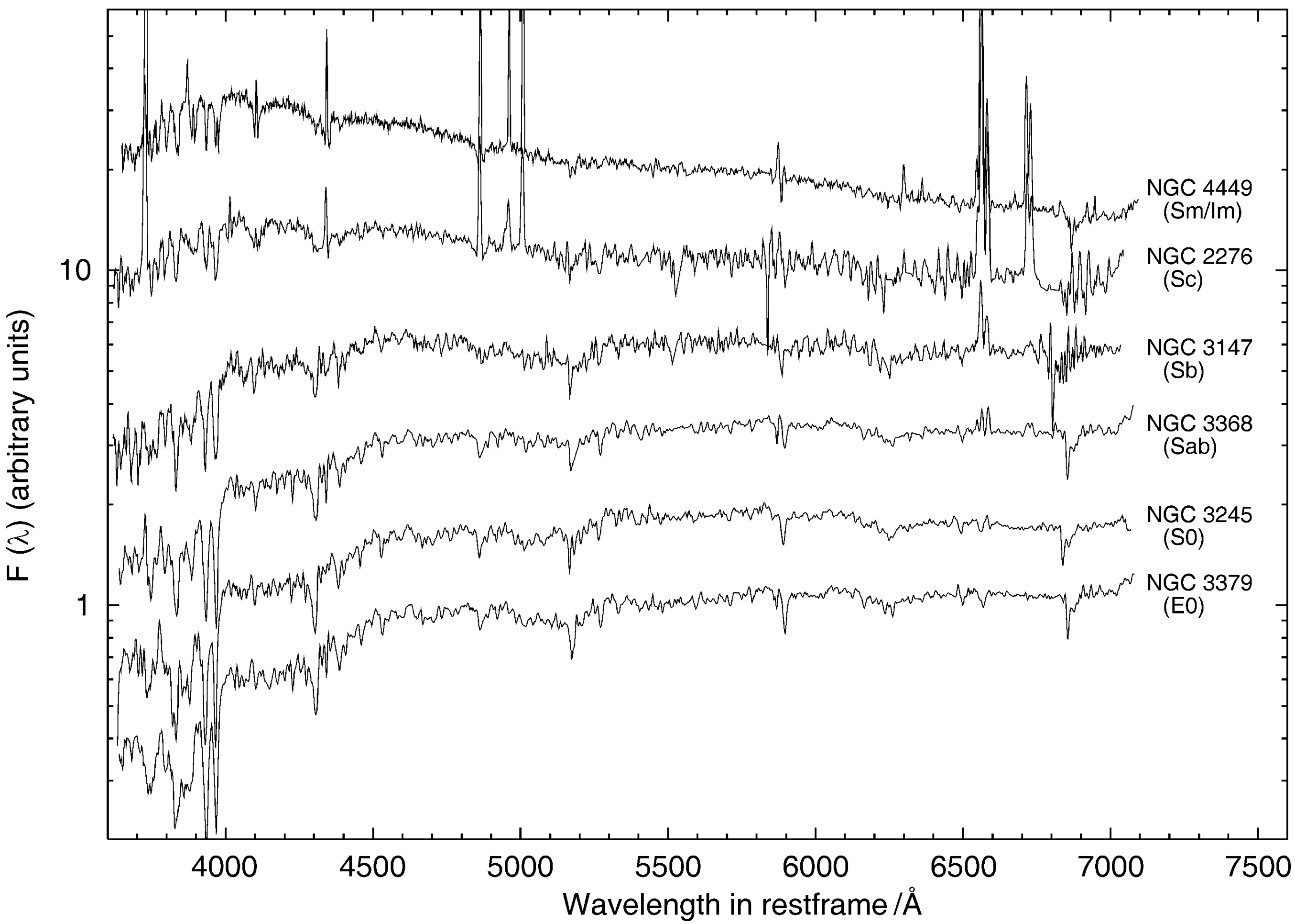
Stars in Galaxies

- Population synthesis – or how does one calculate the spectrum of a galaxy
- Chemical evolution

Spectra of Galaxies

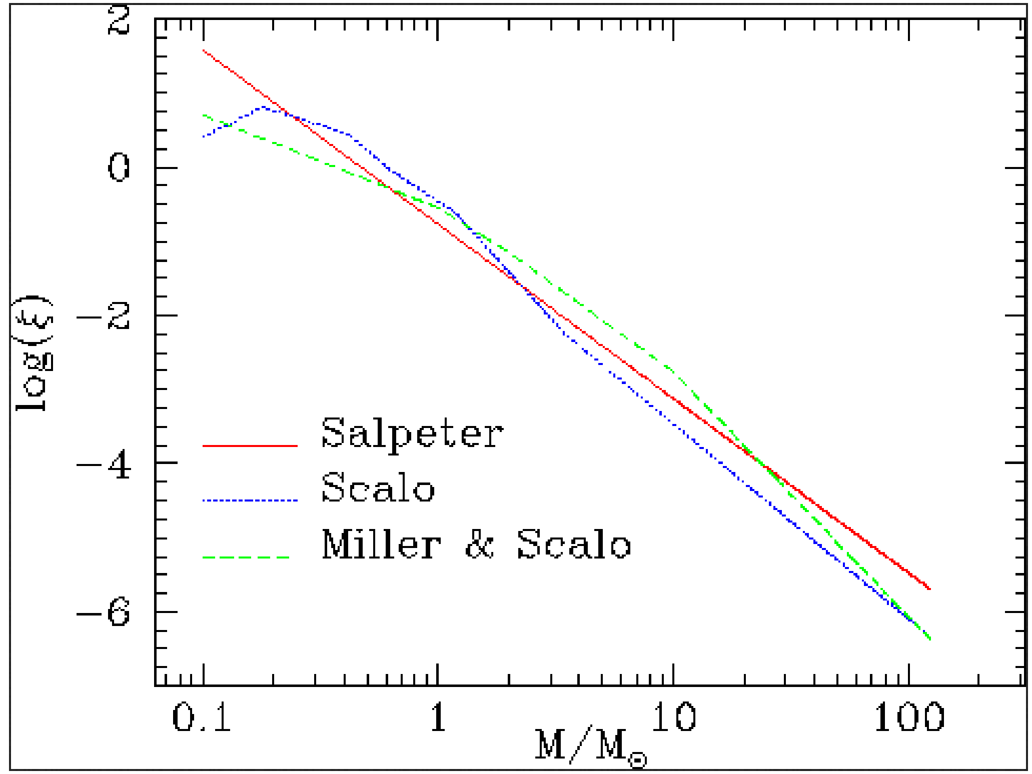


How can we understand these spectra?

Stellar population synthesis

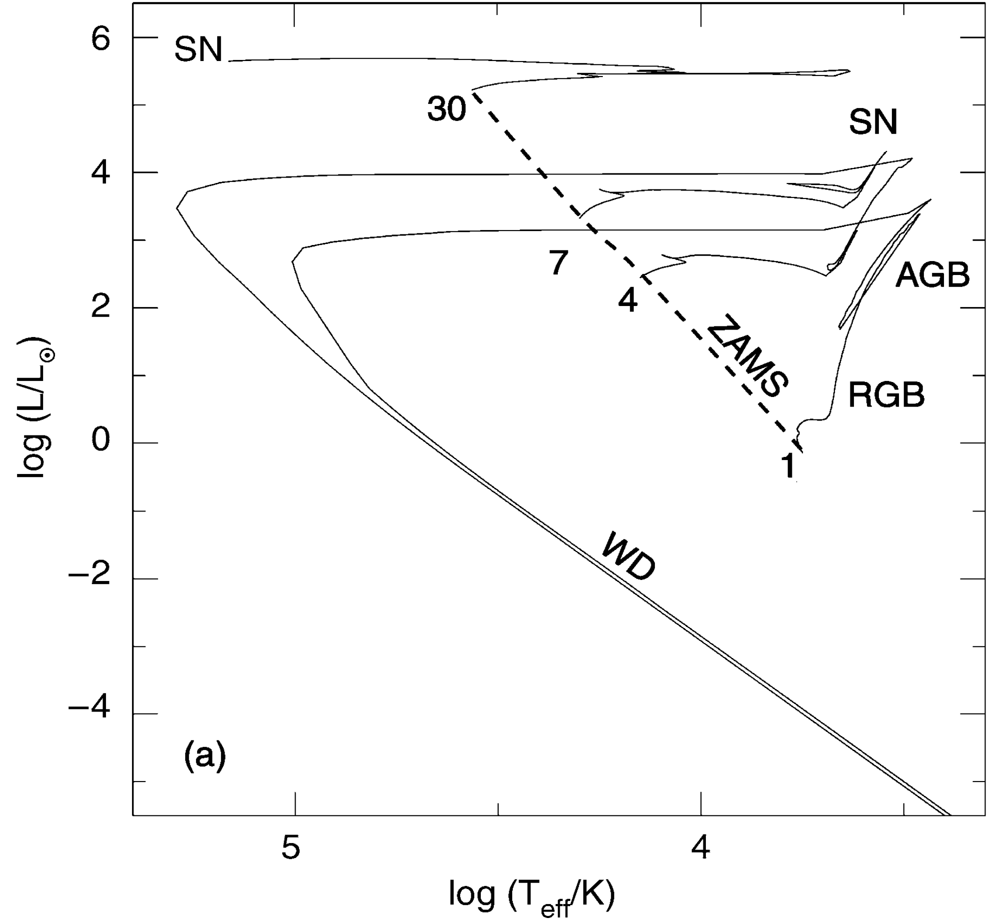
- The light from normal galaxies is mainly from stars.
- The spectrum (and colors) of a star depend on its mass and age.
- The spectrum of a normal galaxy is (mostly) the sum of the spectra of all its stars.
- Population synthesis:
  - starts with star formation
  - models the distribution of stars formed at different masses
  - follows each mass range through its evolution
  - finds the summed spectrum or colors of the resulting stellar population.

Initial mass function



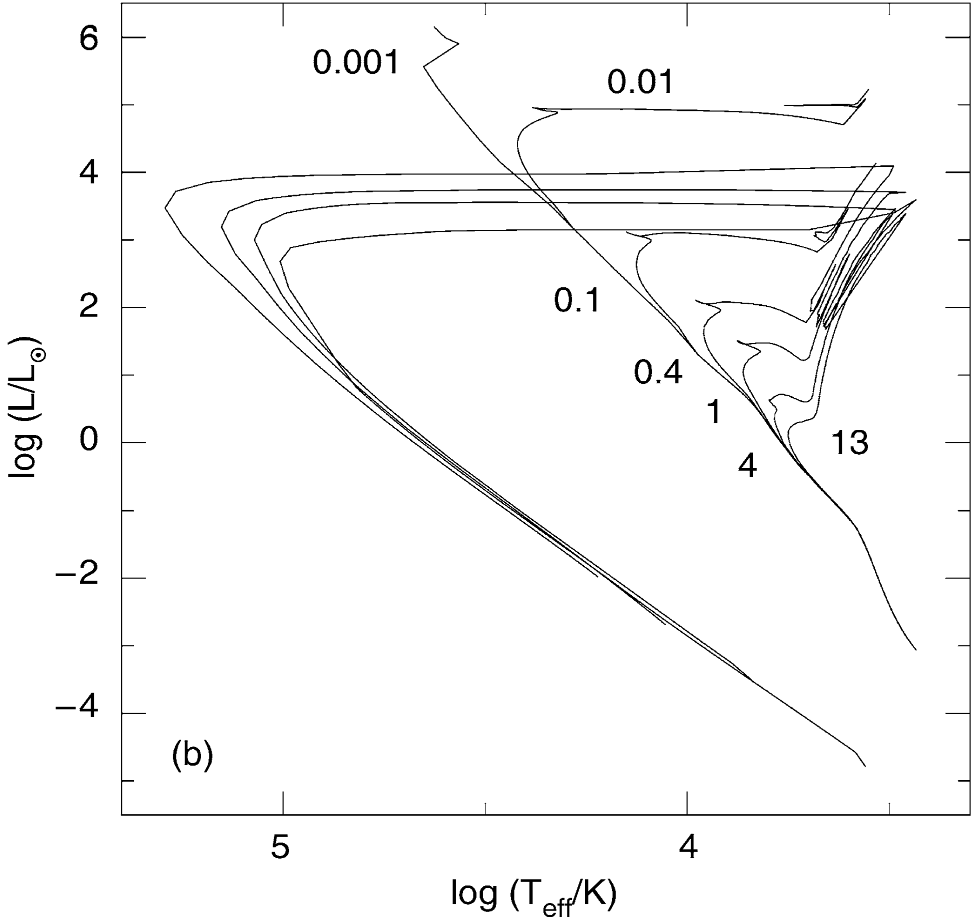
- Given a star formation rate (SFR) or how much gas is converted to stars in a specific time (usually quoted as solar masses/year), what stars will be formed?
- Initial mass function (IMF) gives number of stars as a function of mass (0.1-125 solar masses).
- Salpeter IMF says $n(m) \sim m^{-2.35}$. There are also other IMFs in the literature.

Stellar evolution



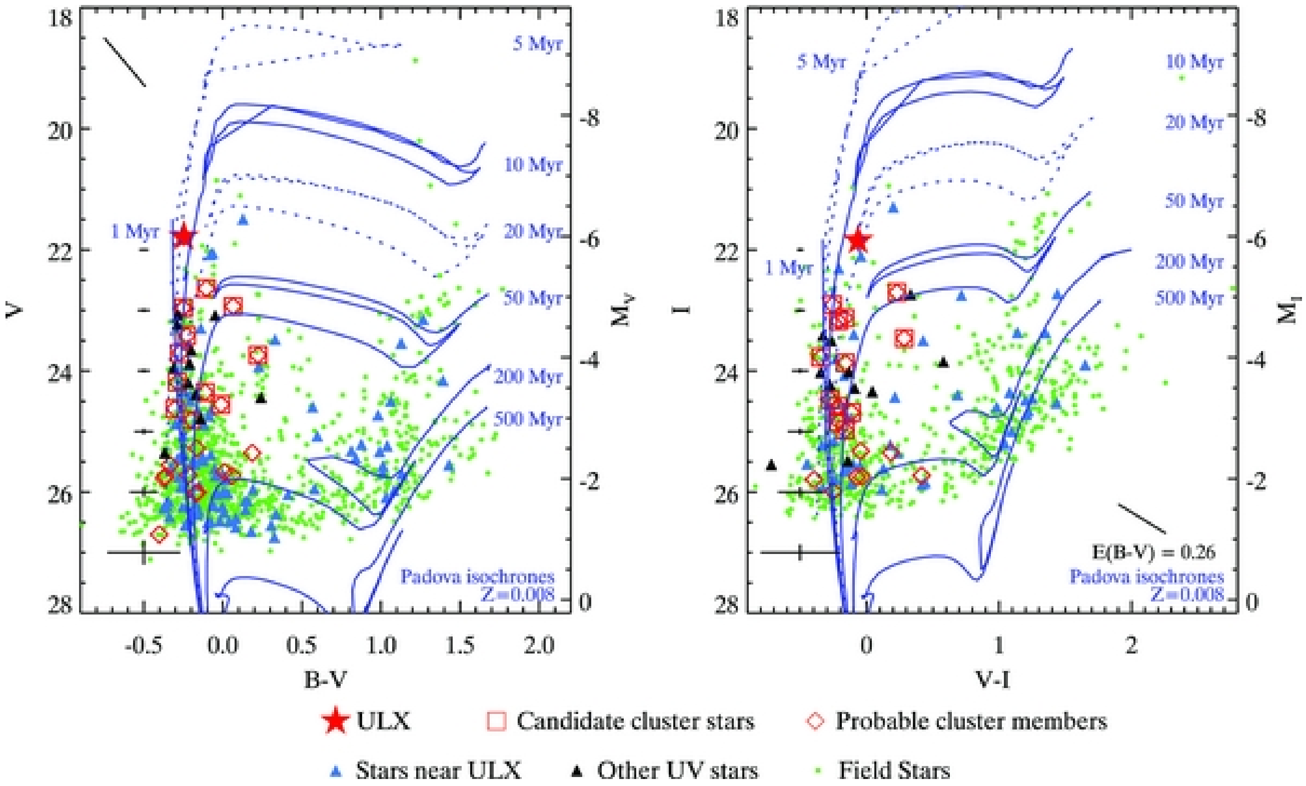
- Newly formed stars lie on the zero-age main sequence (ZAMS).
- Stars will then evolve: through their main sequence lifetime, onto the giant branch, ending as supernova or white dwarf.
- Rate of evolution depends on mass (and metallicity).
- Visualize evolution on HR diagram.

Stellar evolution



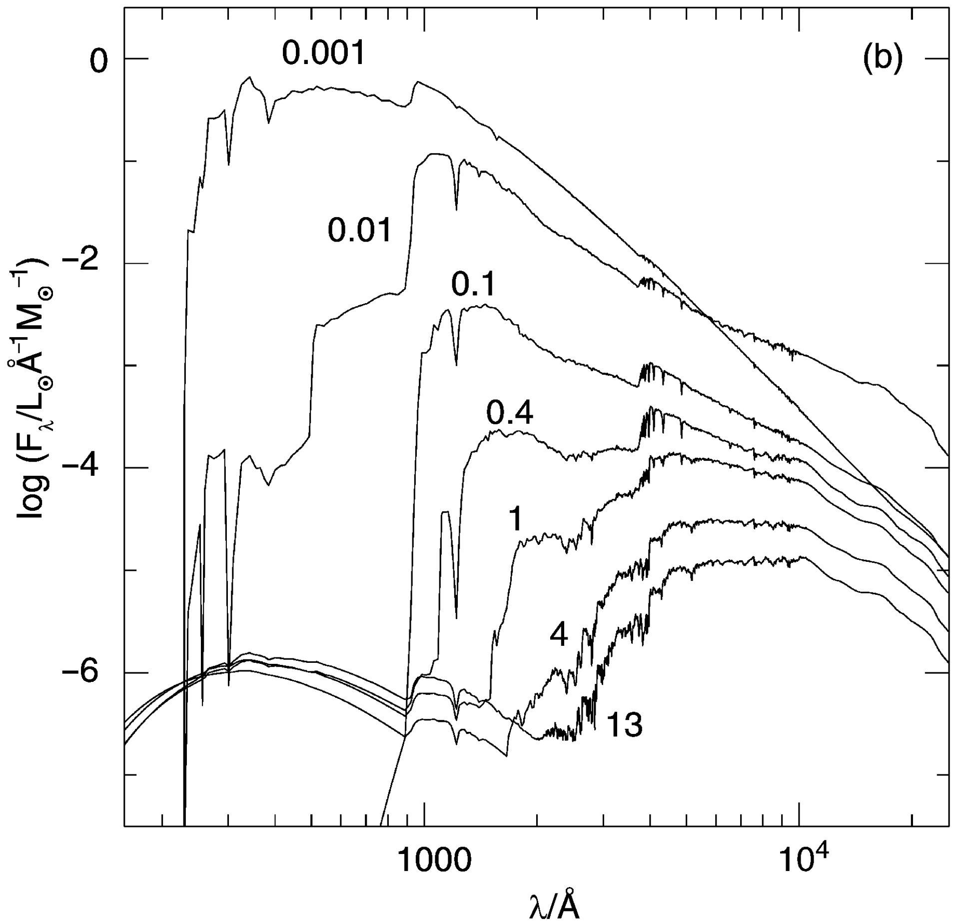
- An isochrone is a snapshot at a given time of a population of stars all born at the same time (ages in Gyr).
- Information is evolutionary stage of each different mass of star. One then finds the spectrum for each star and calculates luminosity and temperature, colors in specific bands, or summed spectrum.

Isochrones



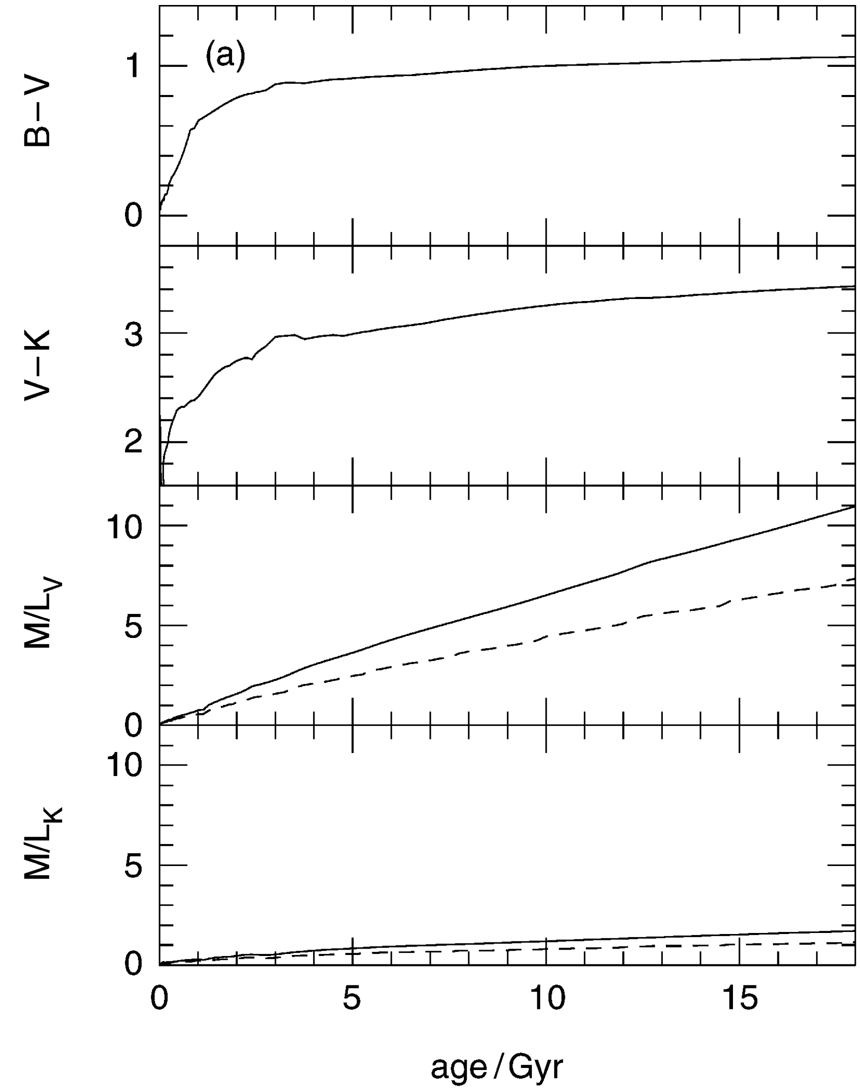
- Isochrones can be used to determine the date of recent star formation events.
- Plots show CMD for stars near Holmberg IX X-1 (Grise et al. 2011).
- There is a 10-20 Myr old cluster near the ULX while the field stars are mostly 200-500 Myr old.

Stellar evolution



- For an unresolved stellar population, can calculate summed spectrum weighting according to number of stars at each mass.
- Young populations produce lots of UV/blue light. As population ages, spectrum moves to the red.
- Spectral break at 4000 Ang will be important later.

Stellar evolution

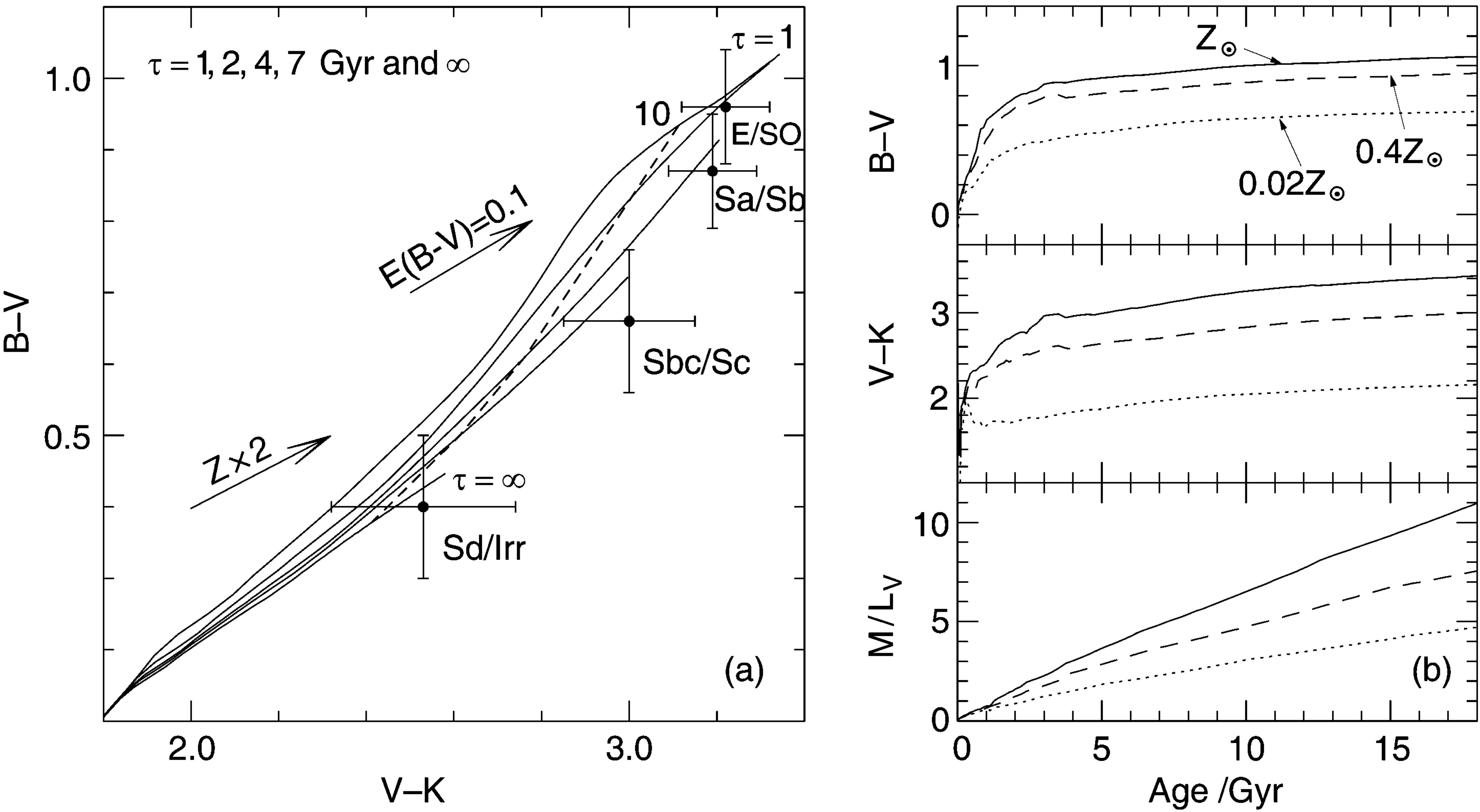


- Younger populations are bluer and more luminous.

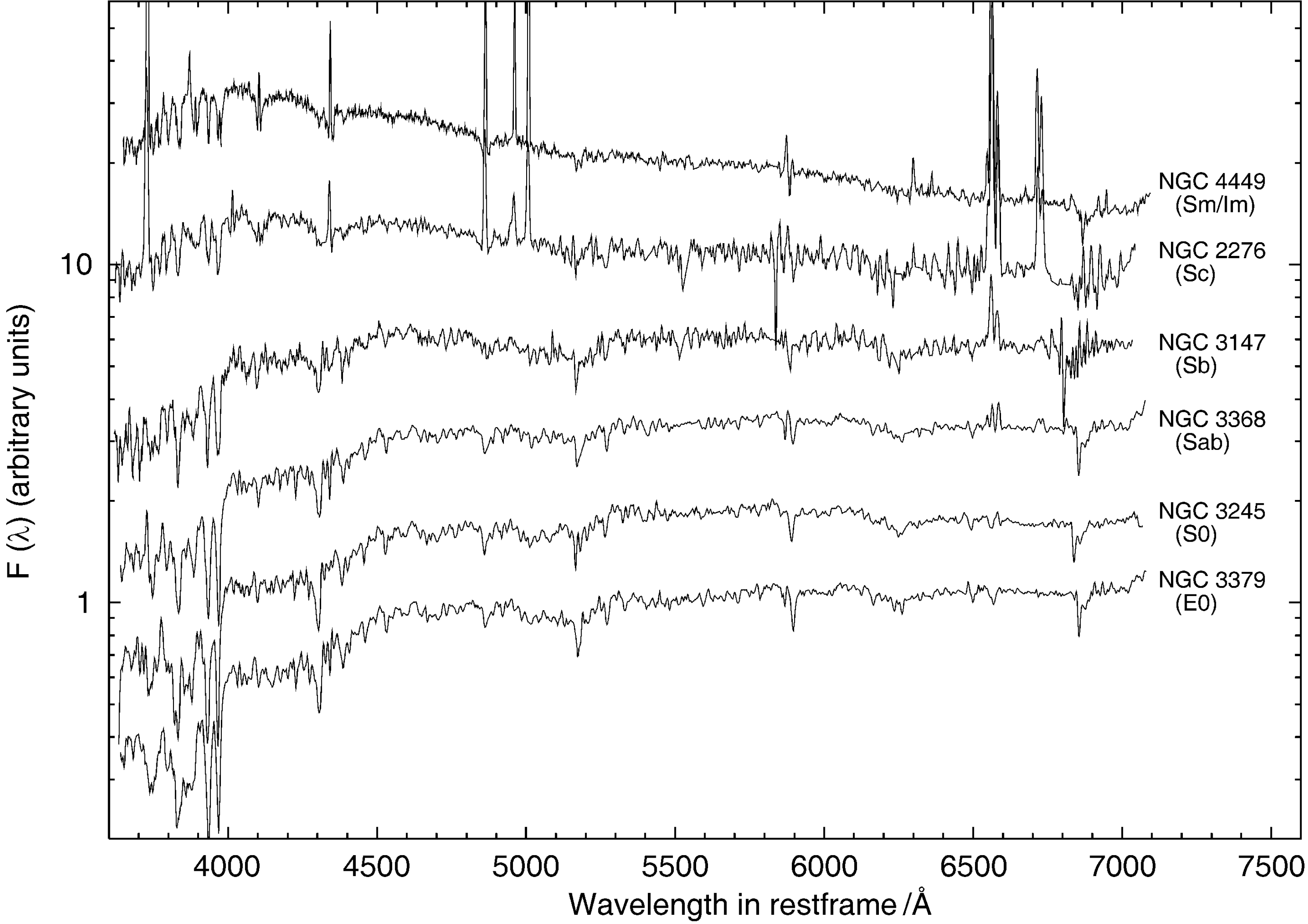
Population synthesis

- Star formation is generally spread out of the history of a galaxy, describe as $\psi(t)$.
- To estimate spectrum at time t, do a convolution of evolution of stars formed at each time t' that have aged for t-t' years.
- Note that metallicity will change over time, so need to keep track of that as well.

- In general $\psi(t)$ can be a complicated function: multiple epochs of star formation that lead to stellar populations of different ages.
- Also different $\psi(t)$ can lead to the same current total spectrum.



- Use toy model $\psi(t) \sim \exp(-t/\tau)$.
- Galaxies with more old stars will be redder and less luminous.



- Galaxies with older stars are redder.
- Galaxies with current star formation have hydrogen emission lines due to HII regions (gas ionized by UV from young star), but dust absorption decreases UV/blue emission.

Chemical evolution

- Stars convert H and He to heavier elements. Some of the heavier elements is recycled to the ISM, so the metallicity of gas in a galaxy will change over time.
- "Yield" (y) is the mass in metals returned to the ISM divided by the mass that stays in stars.
- If the gas in a galaxy starts with no metals, $Z(t = 0) = 0$, and the galaxy is a closed box, then
  $$Z(t) = -y \ln(\text{gas mass/gas + stars mass}).$$
- $Z(t) = -y$ when most gas has been converted to stars.
- Model predicts too low Z for oldest stars in Milky Way.

For next class

- Read 4.1-4.3.
- Keep a list of terms you don't understand and e-mail it to philip-kaaret@uiowa.edu noting section or page where the term was used.