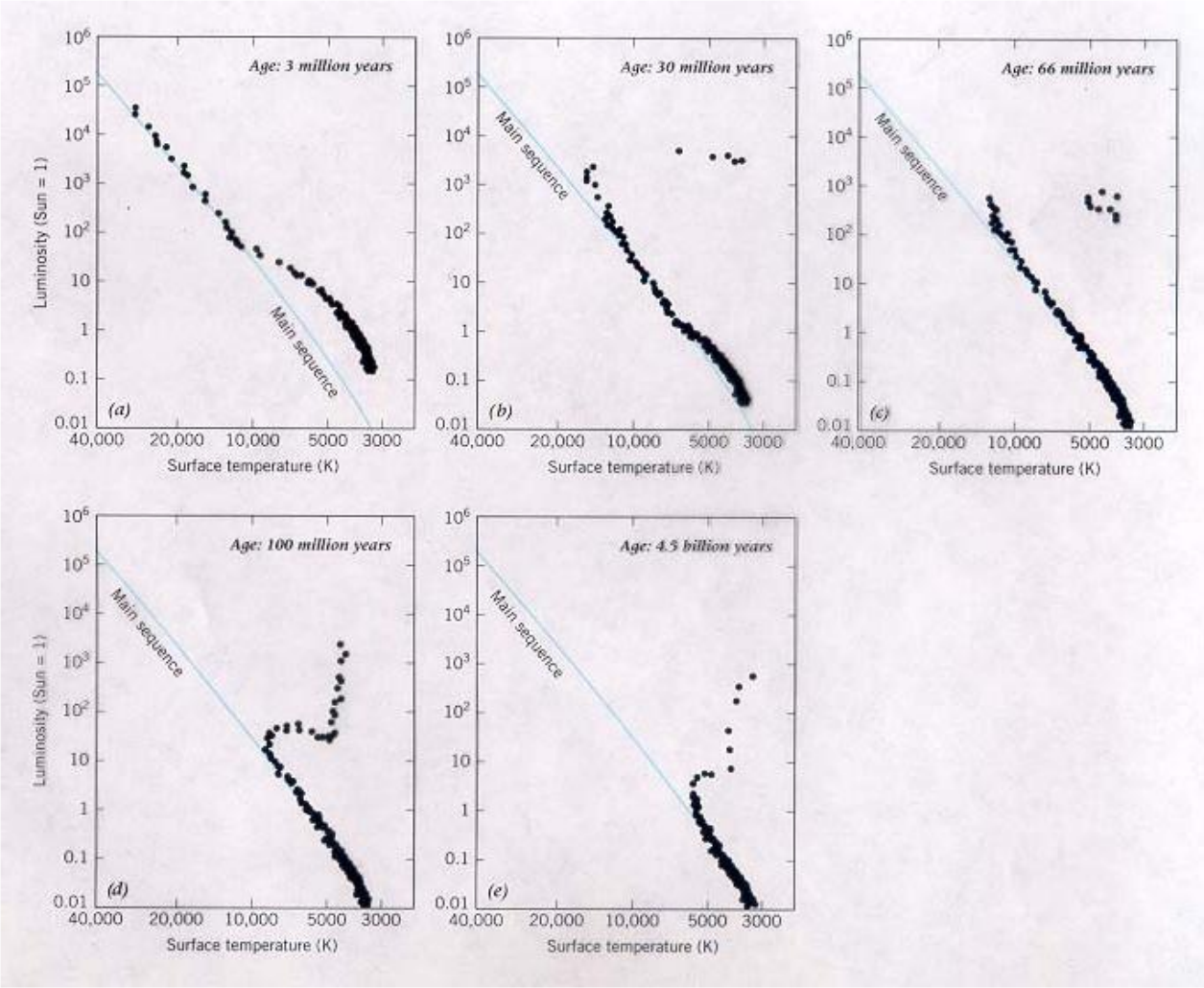
Studying galaxies via integrated light

- Almost all star clusters have, to a good approximation, a single age and metallicity
- Galaxies, by contrast, have a range of ages and metallicities in their stars
- Integrated light studies seek to disentangle the history of star formation and chemical evolution from the integrated light of galaxies via photometry (thru various filters) or spectra

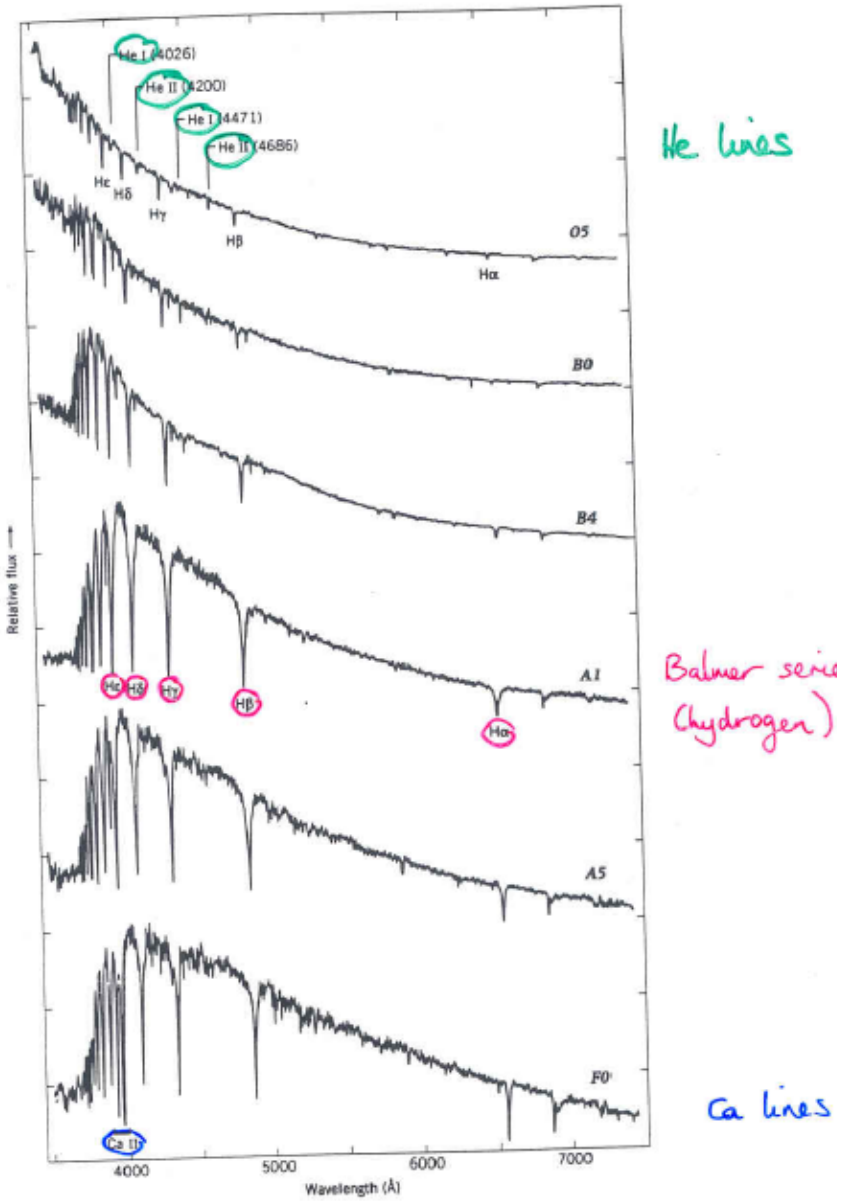
Integrated light of star clusters



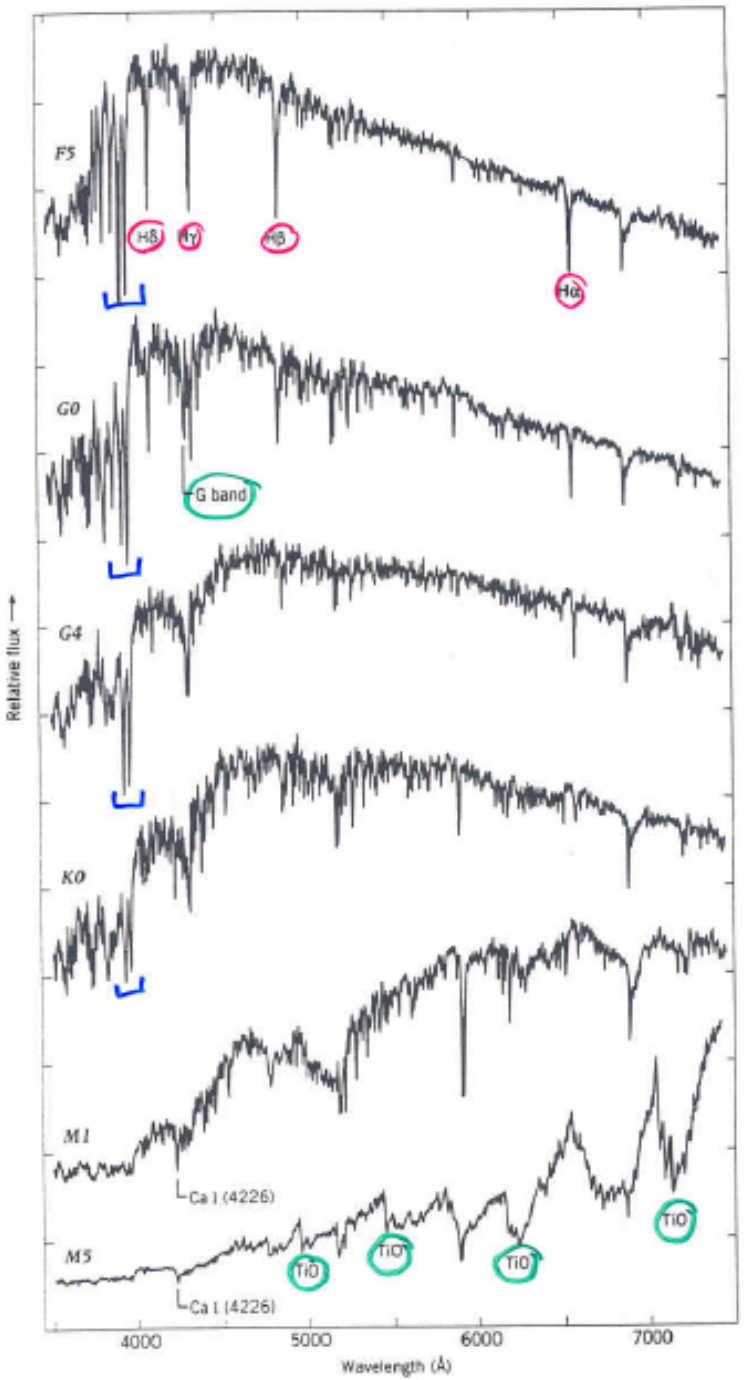
- Here we have an illustration of the CMD of a star cluster as it ages

- Q: How would you infer the spectrum of the star cluster at each age?

Stellar spectra: warm stars



- Q: which age cluster will have its spectrum dominated by O and B stars? Why?



Balmer lines weaker

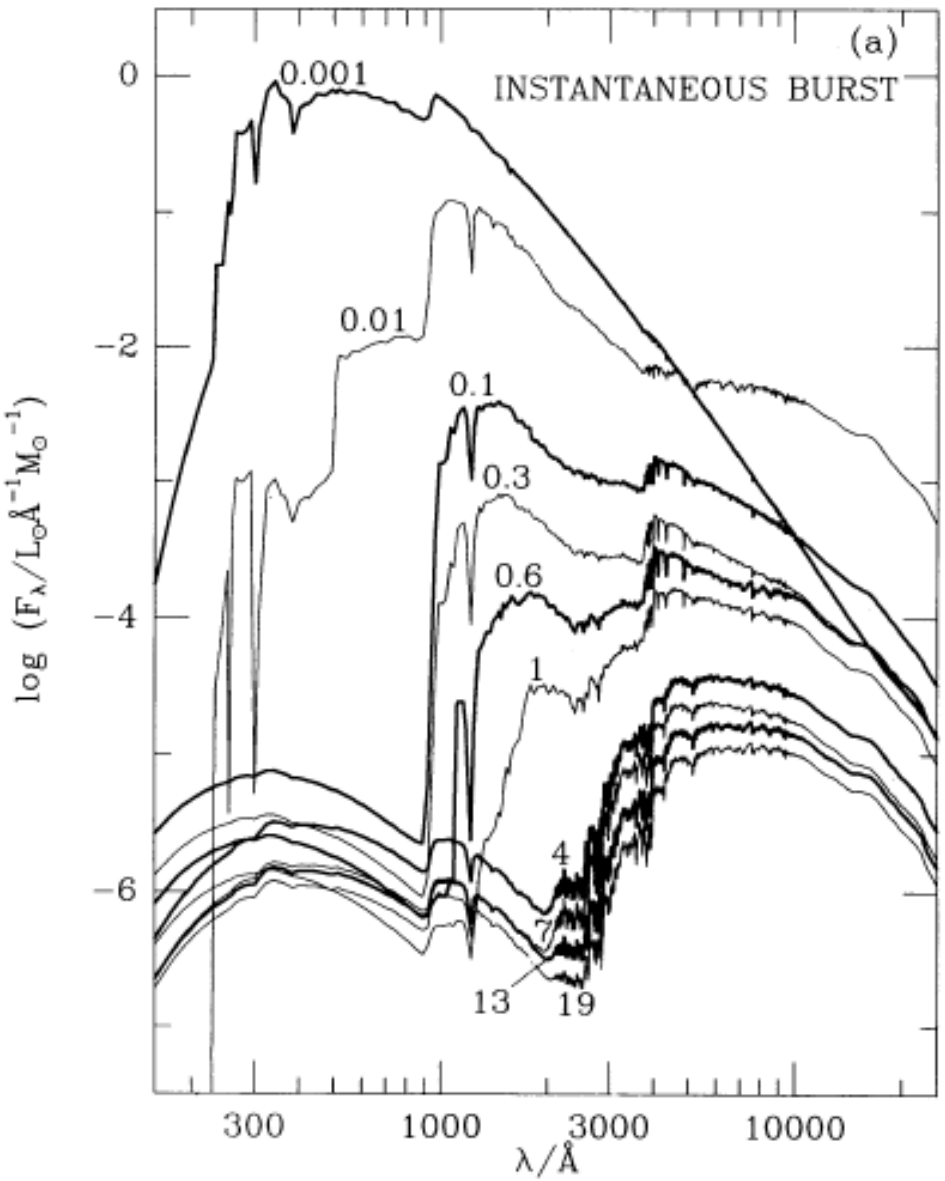
G band – not just a single line

Ca lines strong

TiO and other molecules cause bands of absorption

Stellar spectra: cool stars

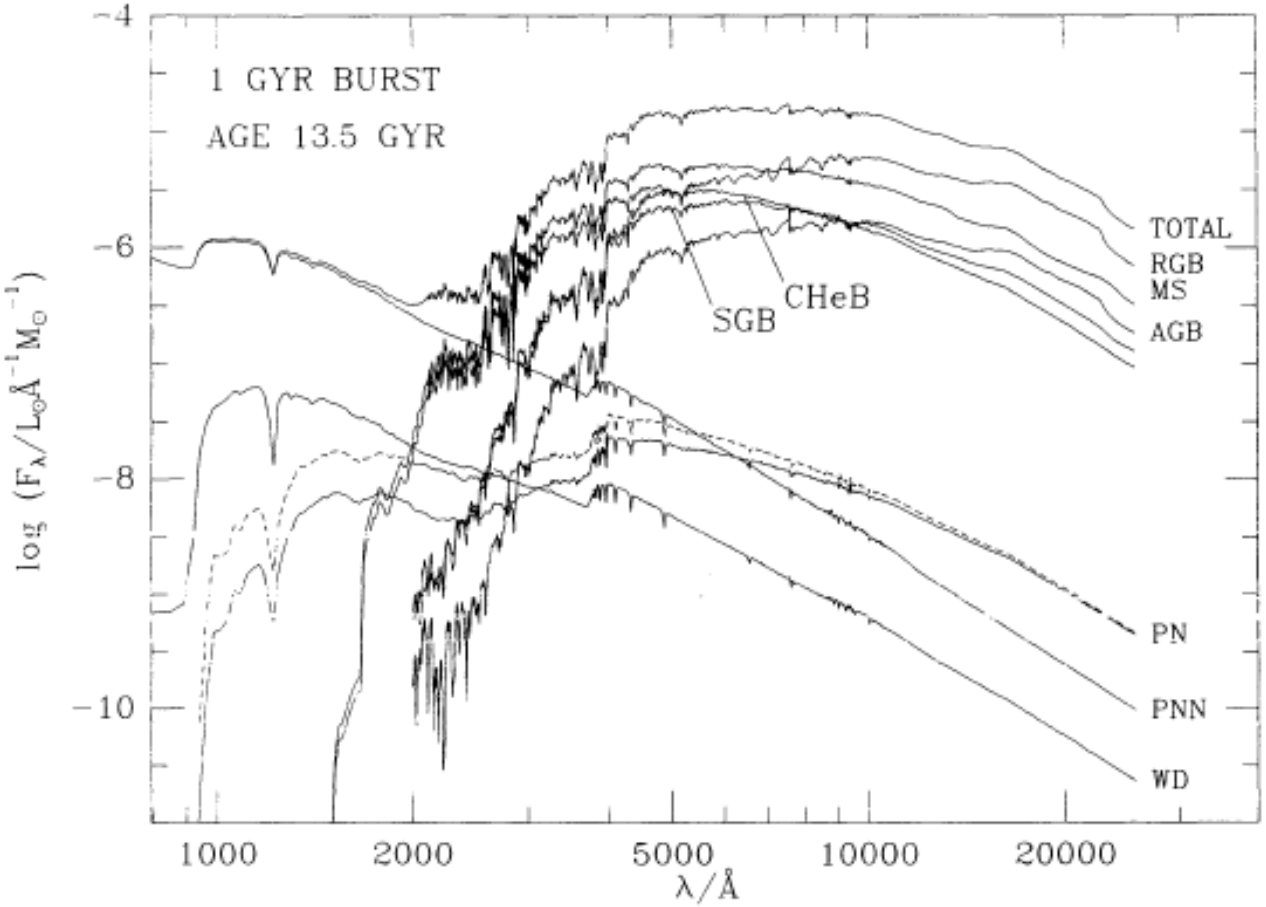
- Q: which cluster will have its spectrum dominated by G stars?
- K stars?
- Why?



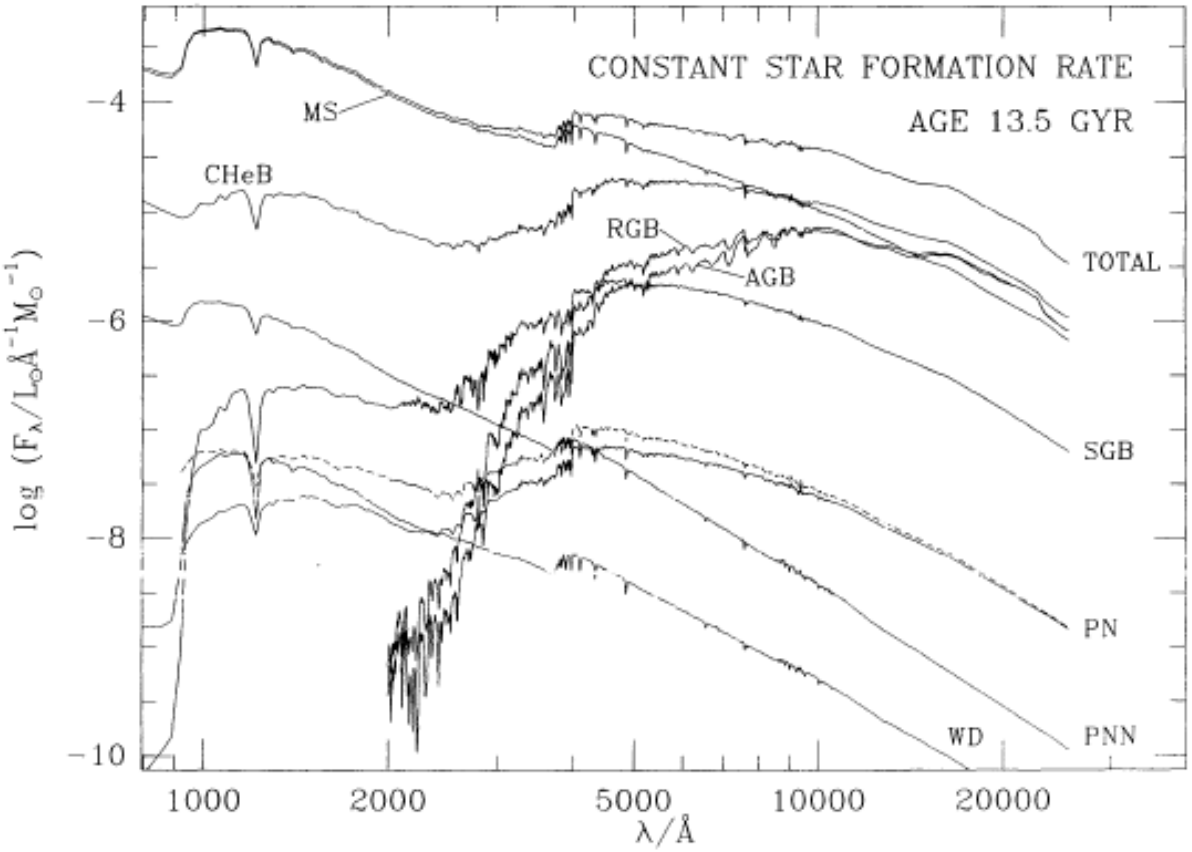
Spectral changes with age

- From Bruzual and Charlot (1993): widely used models for spectral synthesis (also BC03)
- Note spectral coverage: vacuum UV (300 A) to near IR (2 microns)
- These BC93 models synthesize spectra of different age and metallicity using model atmospheres and then add them in the correct proportion using stellar evolution models
- This plot shows the aging of a single starbust
- Note that older populations are harder to distinguish

Contribution of different evolutionary states in old population like an elliptical galaxy



Now for a population with a constant star formation rate: like a disk galaxy



The effect of metallicity on optical spectra

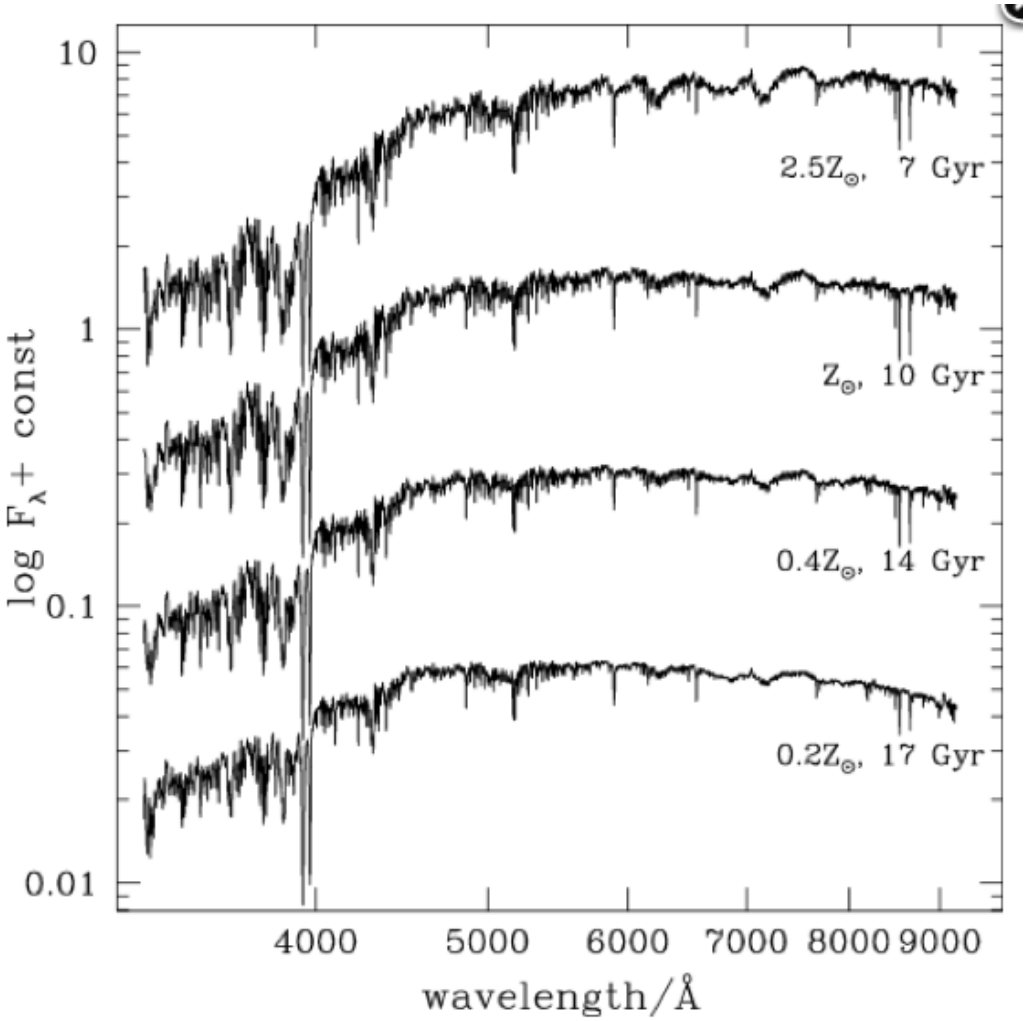
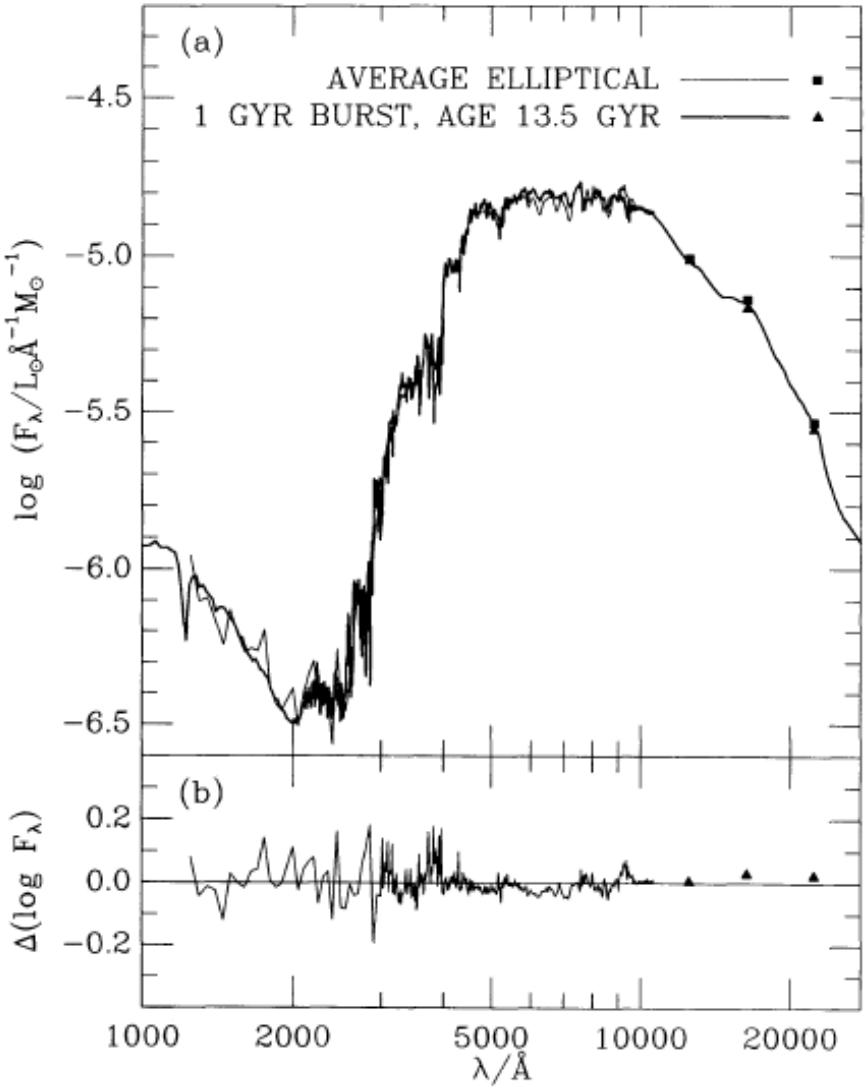


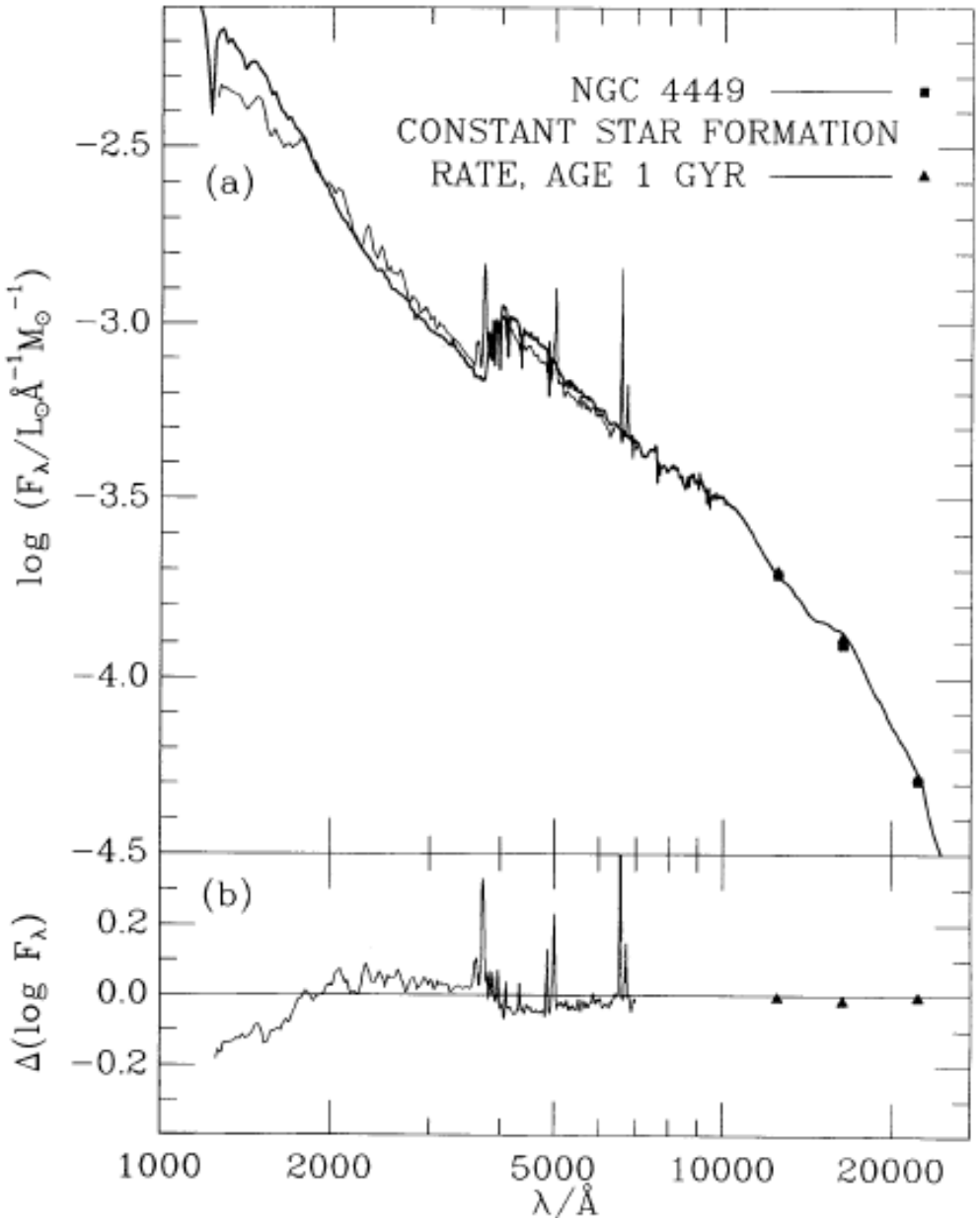
Figure 10. Spectra of the standard SSP model of Section 3 at different ages for different metallicities, as indicated. The prominent metallic features show a clear strengthening from the most metal-poor to the most metal-rich models, even though the shape of the spectral continuum is roughly similar in all models.

See the line blanketing increase in the blue as the metallicity increases

Real galaxy spectrum with derived SFR and age



- Star formation starts 13.5 Gyr ago and continues for one Gyr
- Note infrared passbands J,H and K



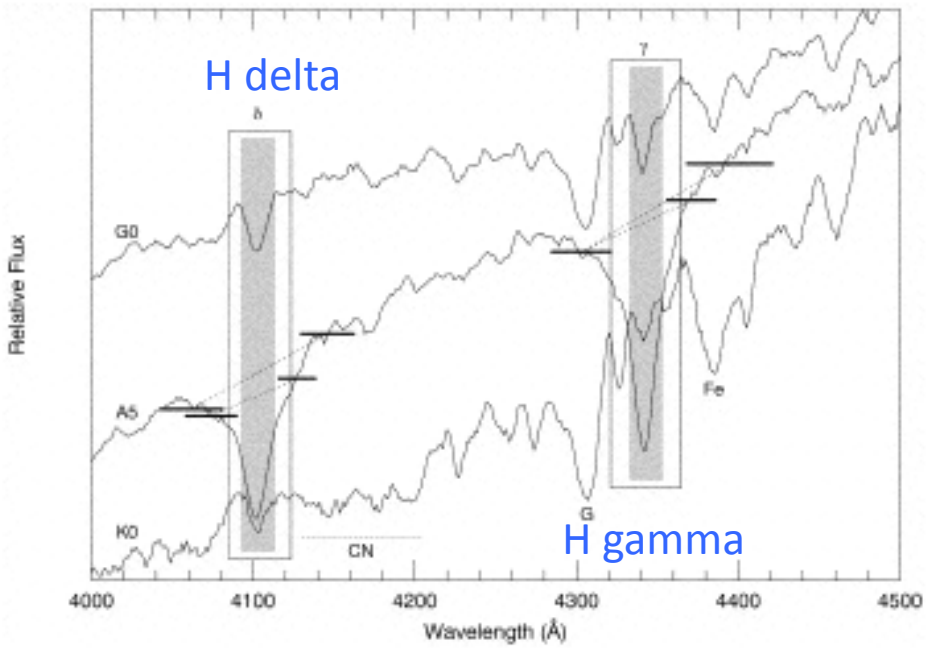
dwarf Irregular

NGC 4449

Q: do you think there are any old stars (~10 Gyr) in this galaxy?

Quantifying agreement with models

- The spectral synthesis codes provide the synthetic spectra themselves and colors in various passbands
- Comparison of measured colors with predictions are straightforward (see Homework 3) but spectral comparisons are more difficult



Worthey and Ottaviani 1997

Pseudo equivalent widths are a common way of measuring the strength of important spectral features

Dn(4000) H delta

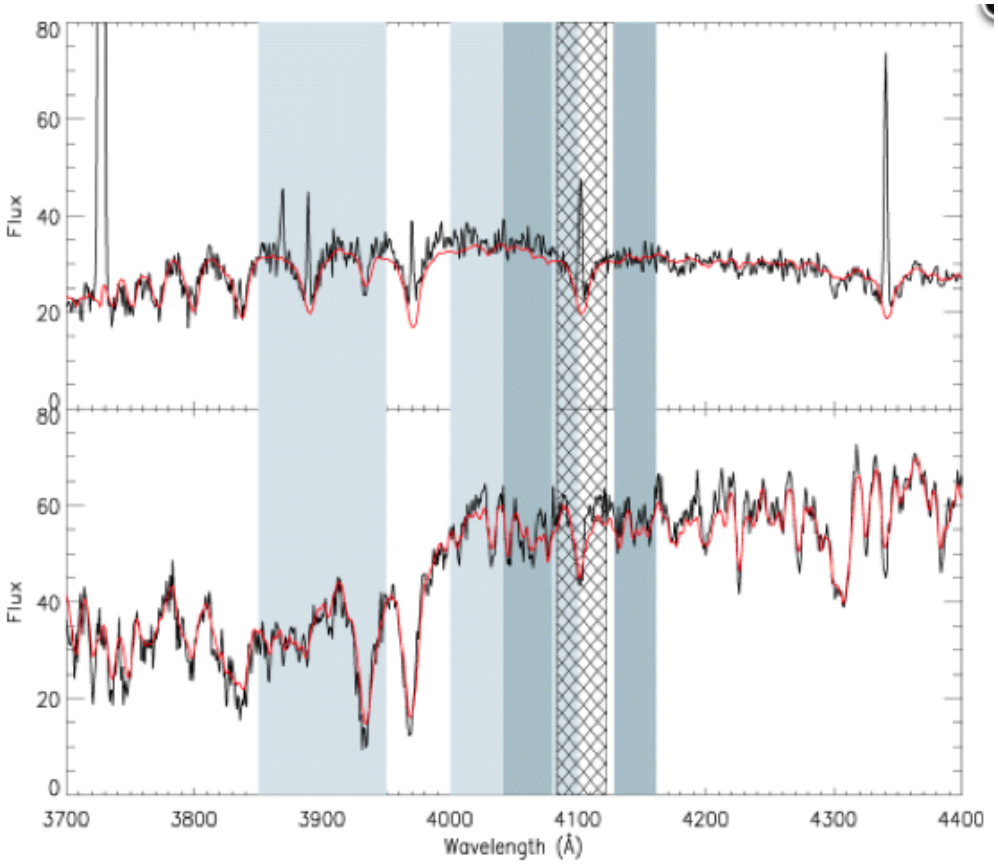


Figure 1. SDSS spectra of a late-type galaxy (top) and an early-type galaxy (bottom) are plotted over the interval 3700–4400 Å in the restframe. The red line shows our best-fitting BC2003 model spectrum. The light grey-shaded regions indicate the bandpasses over which the $D_n(4000)$ index is measured. The dark grey regions show the pseudocontinua for the $H\delta_A$ index, while the hatched region shows the $H\delta_A$ bandpass.

Kauffmann et al 2003

How age and metallicity are measured in SDSS spectra

First, remove the emission lines from the spectra
Then measure Dn(4000) which quantifies the 4000 A break, and H delta index, using continuum bands shown in the diagram

Q: what will affect the 4000A break? Age? Metallicity? How about H delta?

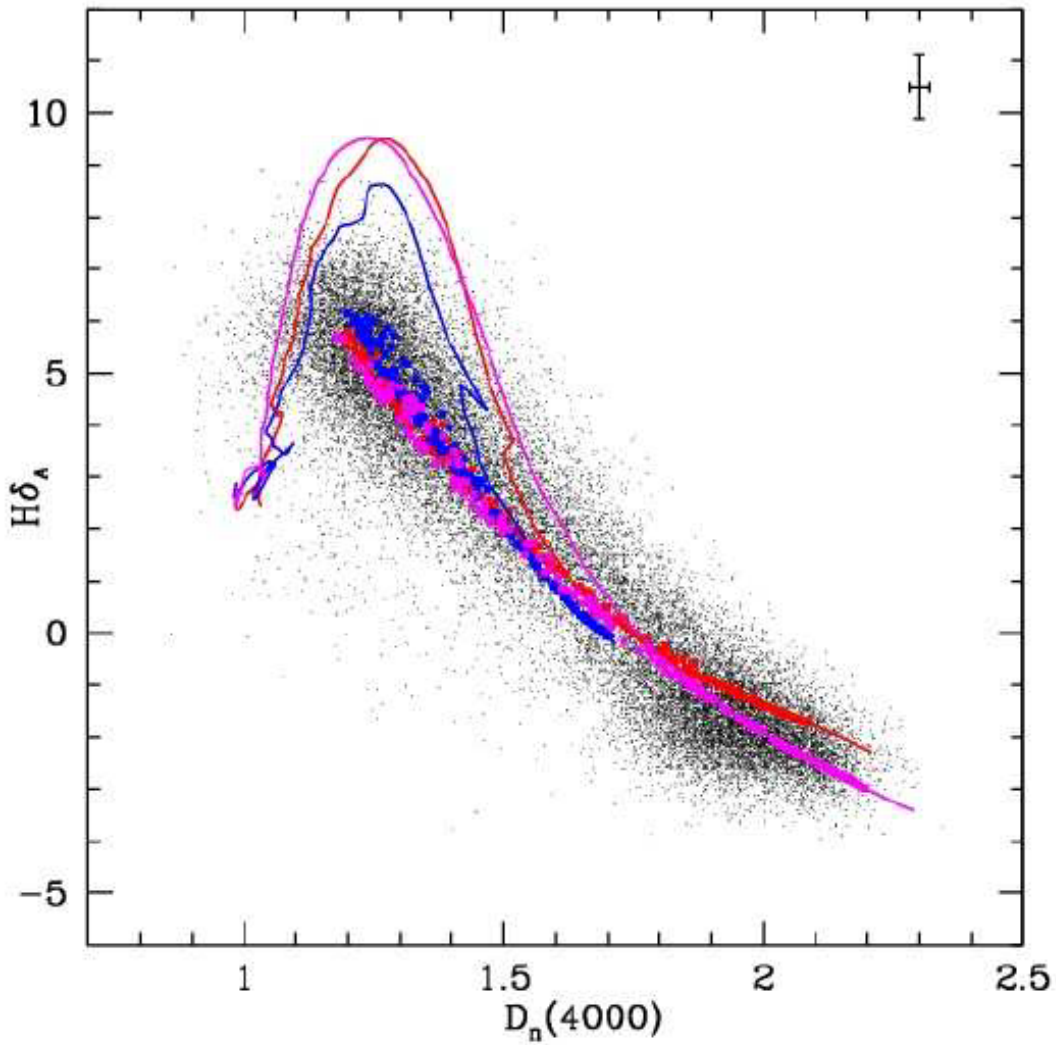


Figure 3: $H\delta_A$ is plotted as a function of $D_n(4000)$ for 20% solar, solar and 2.5 times solar metallicity bursts (blue, red and magenta lines), and for 20% solar, solar and 2.5 solar continuous star formation histories (blue, red and magenta symbols). A subset of the SDSS data points with small errors are plotted as black dots. The typical error bar on the observed indices is shown in the top right-hand corner of the plot.

Kauffmann et al 2003