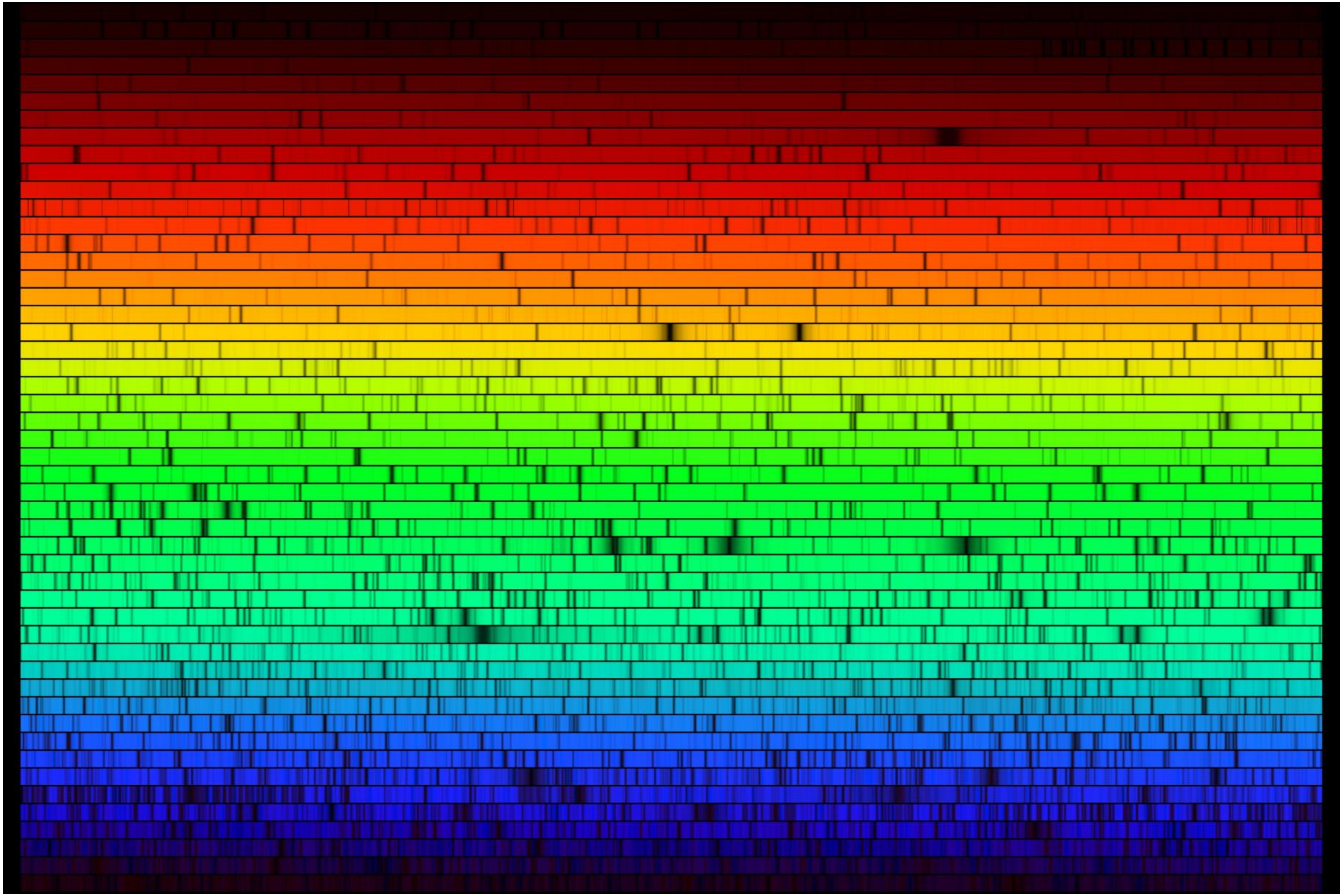
Stellar Spectra

- Absorption lines
  - cause
  - strength
- Temperature dependence
- Classification of stellar spectra

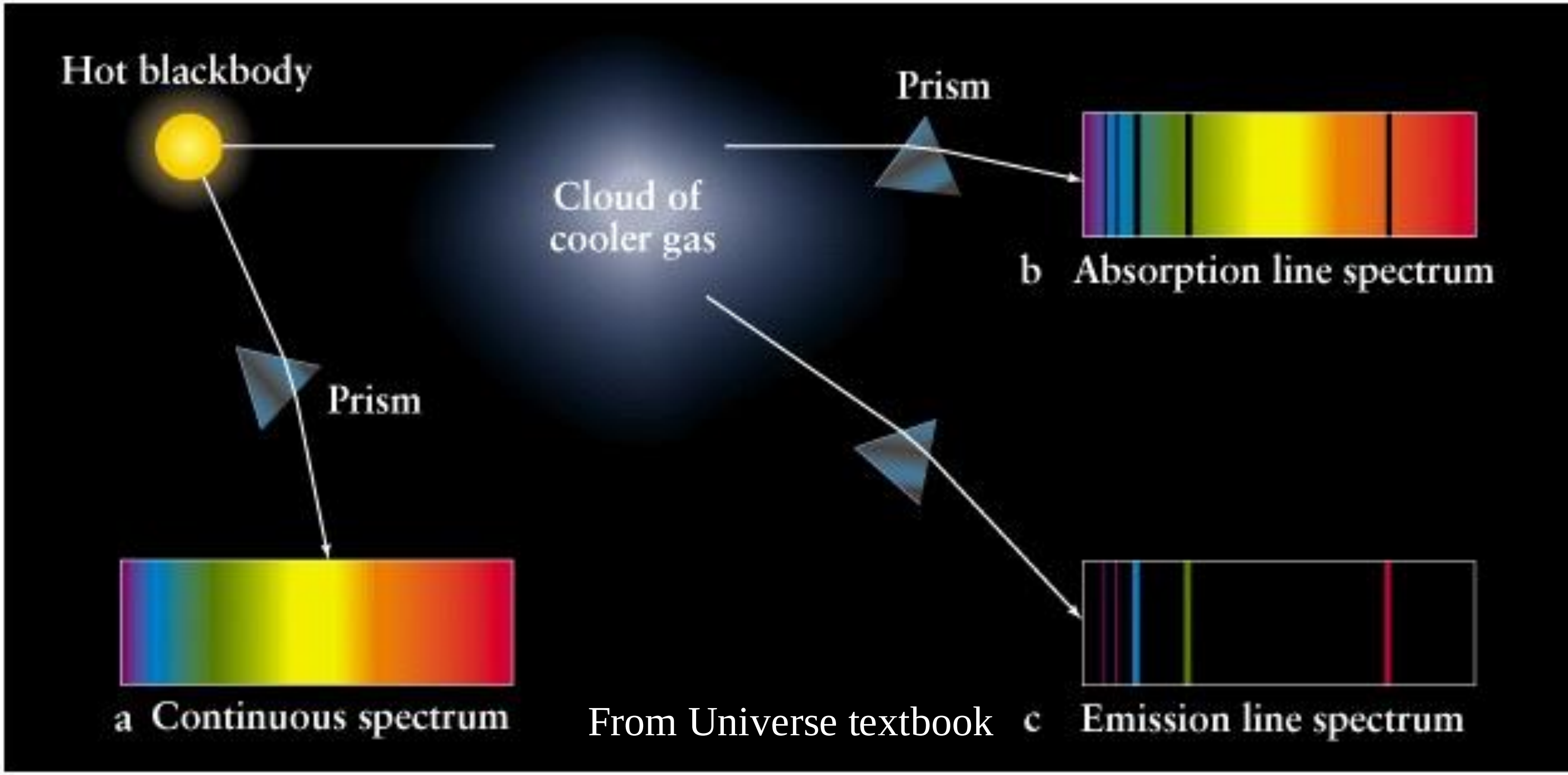
The Solar Spectrum

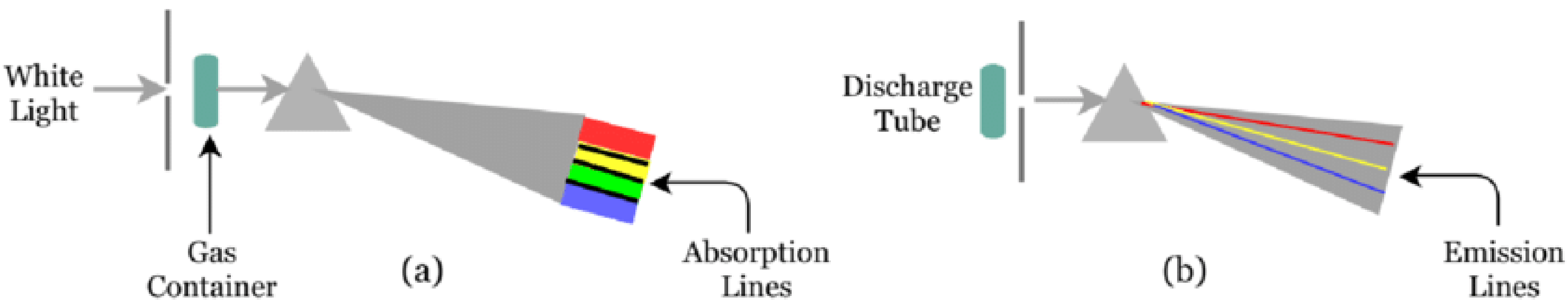


N.A.Sharp, NOAO/NSO/Kitt Peak FTS/AURA/NSF

Absorption Lines

- Absorption lines arise when we view a hot source of continuum radiation through a cooler layer of gas
- Because the temperature drops with height in the atmospheres of stars we view cooler gas against a hotter background





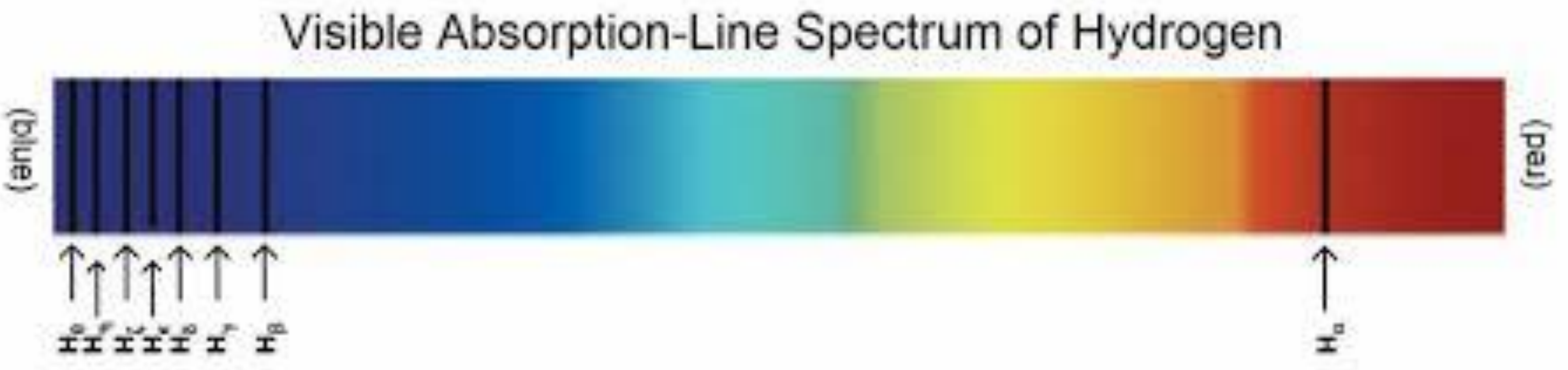
https://www.researchgate.net/publication/348212745

Stellar Spectra

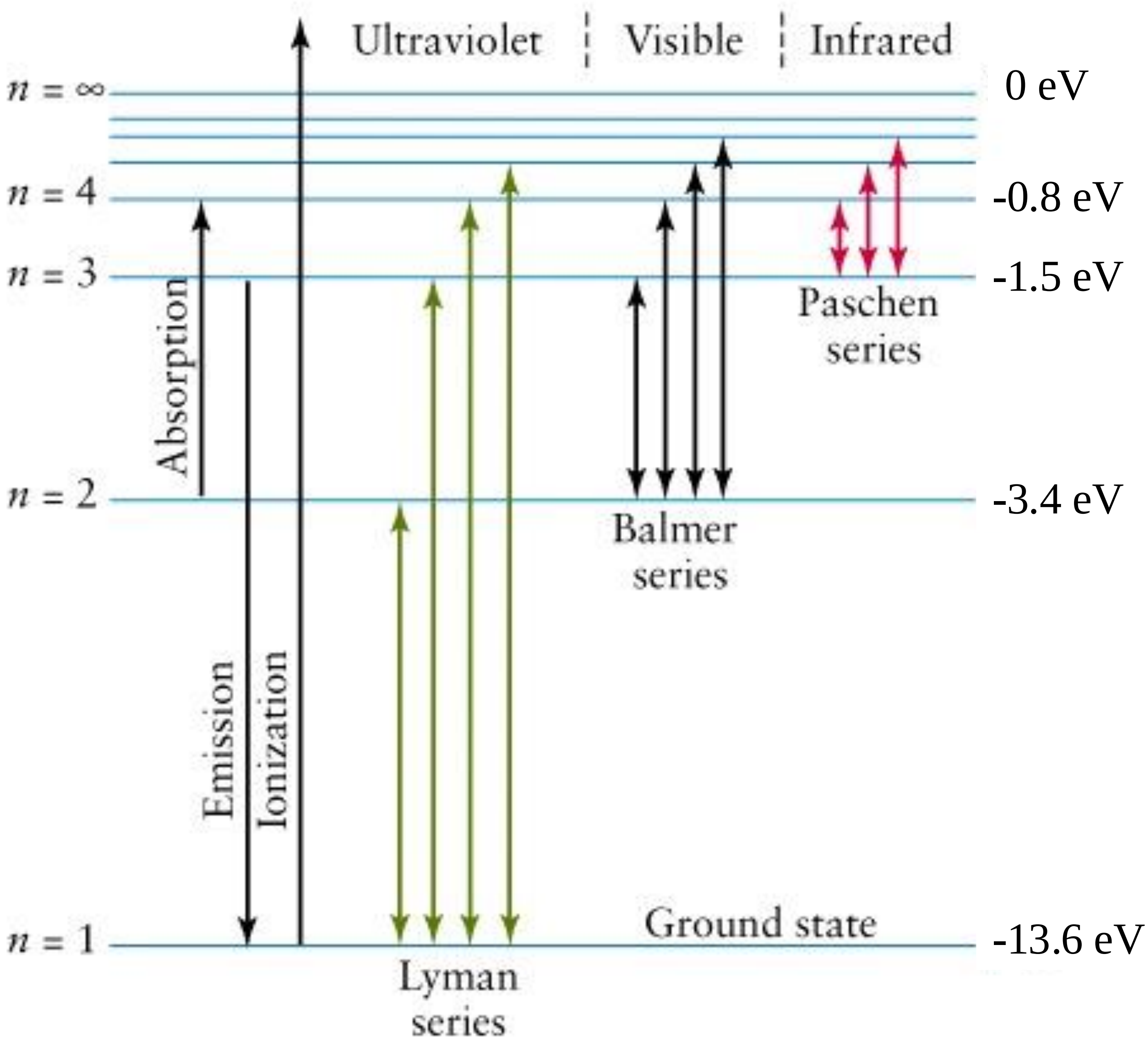
- Spectra of stars consist of a vast number of absorption lines from different species
- One of the most recognizable is the Balmer series due to atomic hydrogen (H I)

Balmer Series

- This series arises from transitions from the n=2 level in H I



From www.phys.lsu.edu



From Universe textbook

Class Example

- An electron in the n=2 level of hydrogen requires 3.4 eV of energy to become ionized. What temperature blackbody would give a peak of emission at the wavelength corresponding to an energy of 3.4 eV?

- What temperature blackbody would give a peak of emission at the wavelength corresponding to an energy of 3.4 eV?

$$E = 3.4\ \text{eV} = 3.4 \times 1.6 \times 10^{-19}\ \text{J} = 5.4 \times 10^{-19}\ \text{J}$$

$$E = h\nu = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{E} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{5.4 \times 10^{-19}}$$

$$= 3.6 \times 10^{-7}\ \text{m} = 360\ \text{nm}$$

$$T = \frac{3 \times 10^{-3}}{3.6 \times 10^{-7}} = 8000\ \text{K}$$

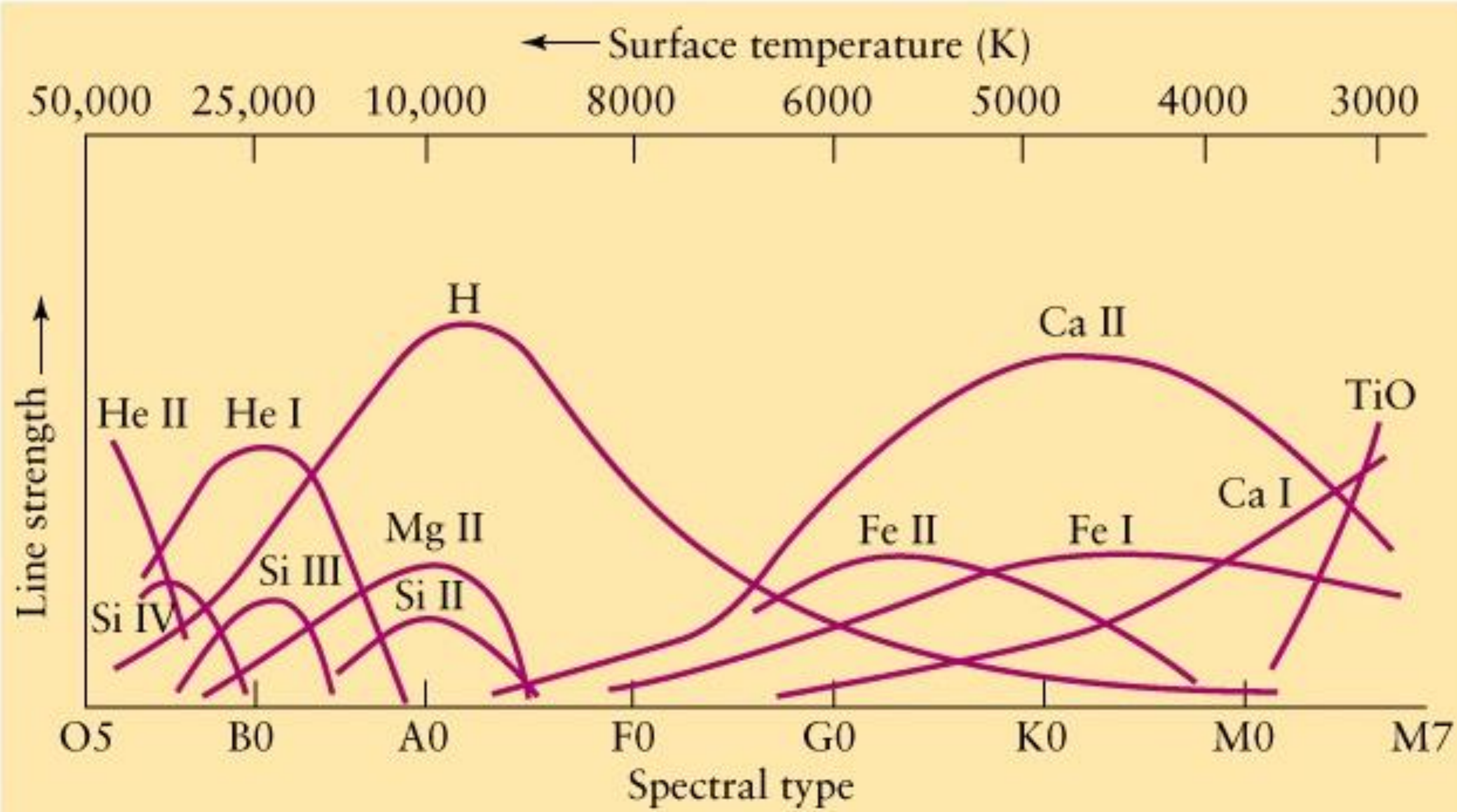
Absorption Line Strength

- Strength of an absorption line depends on:
  - strength of the particular transition (absorption cross-section), i.e. depends on atomic physics
  - number of particles in the lower state of the transition, i.e. depends on abundance, temperature and density

Temperature dependence

- the distribution of populations among the energy levels within an atom or ion depends on the temperature
- higher temperatures populate higher levels - excitation
- higher temperatures can also ionize a species, e.g. $He^0 \rightarrow He^+$ or He I $\rightarrow$ He II - ionization

- an absorption line for a species will have a maximum strength at a particular temperature
- at lower temperatures most of the species will be in the ground state
- at higher temperatures most species will become ionized to the next ionization stage



From Universe textbook

Class Example

- The He II ion is a hydrogen-like ion where the energy levels

$$E \mu - \frac{Z^2}{n^2}$$

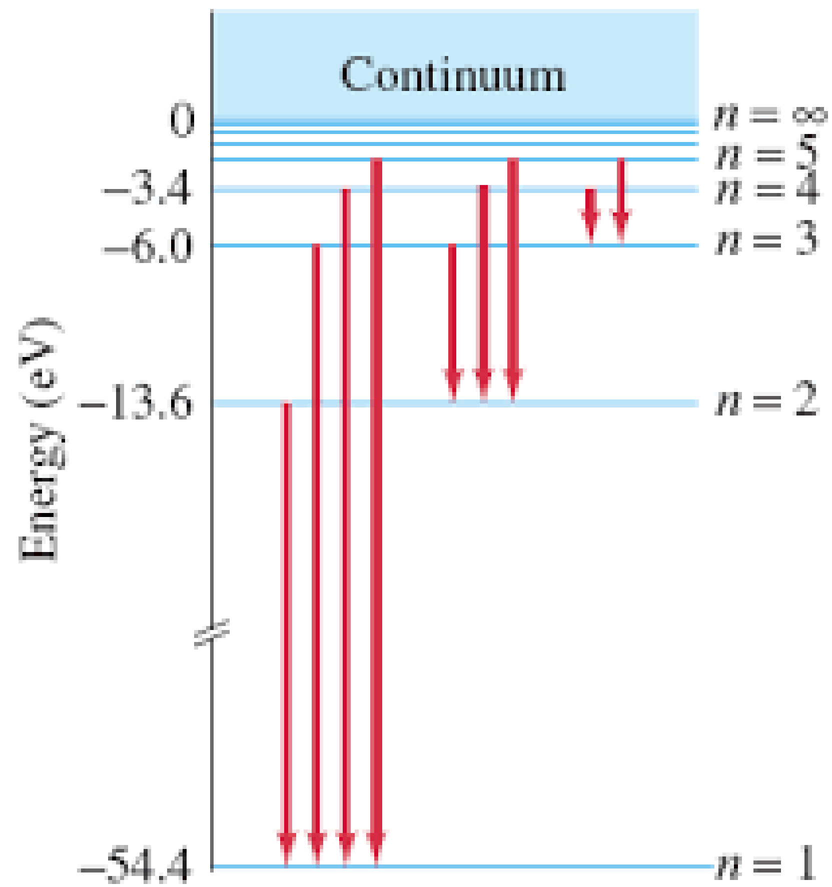
where Z is atomic number and n is the level number. Why does this explain the high temperatures needed for the He II lines?

- Why are high temperatures needed for the He II lines?

$$E \mu - \frac{Z^2}{n^2}$$

$$E \mu - \frac{1}{n^2} \text{ for hydrogen}$$

$$E \mu - \frac{4}{n^2} \text{ for helium}$$

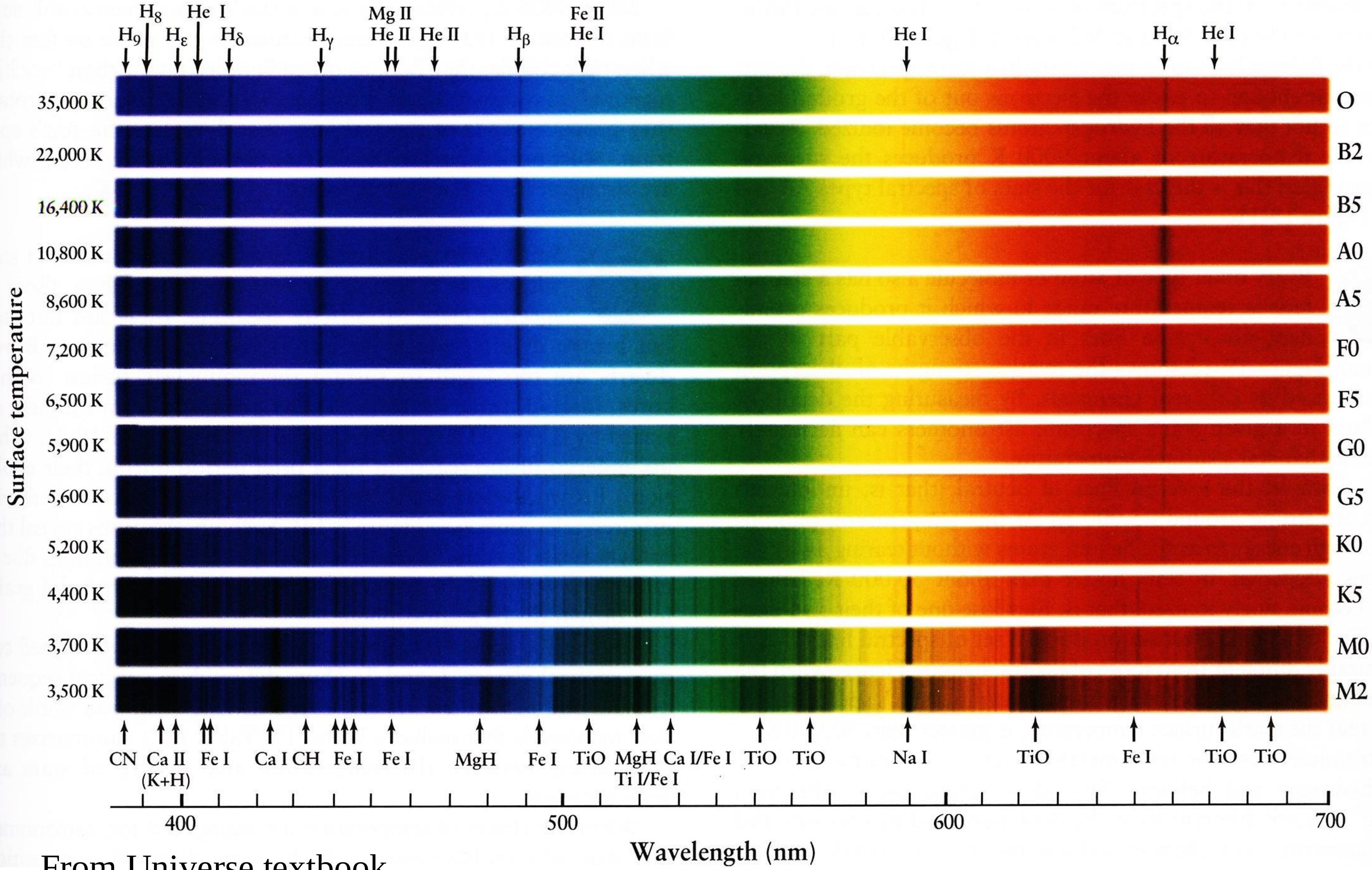


Spectral Classification

- stellar spectra can be classified into a temperature sequence based on the relative strengths of the various lines present
- Balmer lines strongest for T_{eff}=10 000 K, e.g. Vega

- (spectral type is denoted by the sequence of letters: OBAFGKM with sub-classes of numbers 0-9)

The women of Harvard College Observatory classifying stellar spectra.
From https://cas.sdss.org/dr7/en/proj/basic/spectraltypes/history.asp



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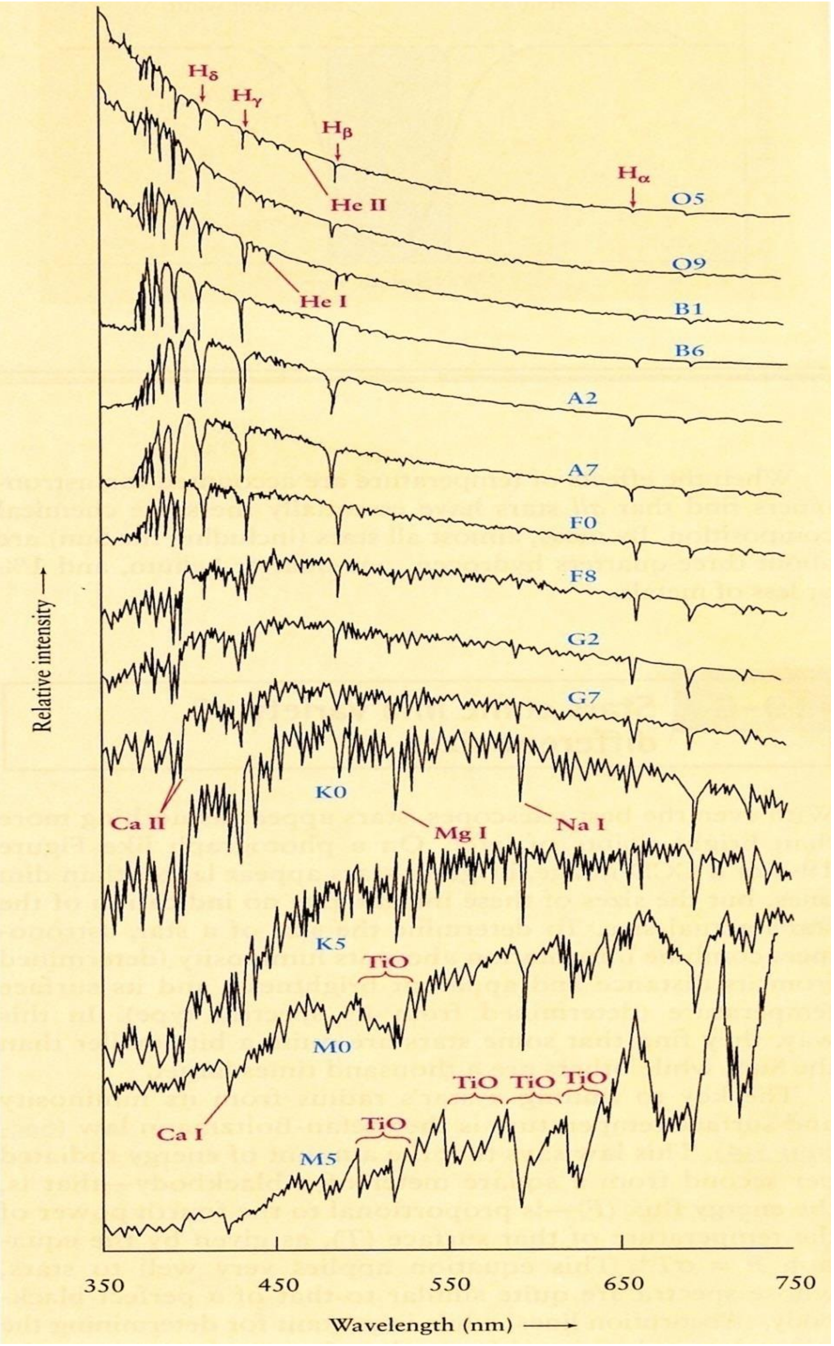

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Summary

- Absorption lines in stellar spectra can be used to classify stars
- The spectral sequence is primarily a measure of the effective temperature of the star