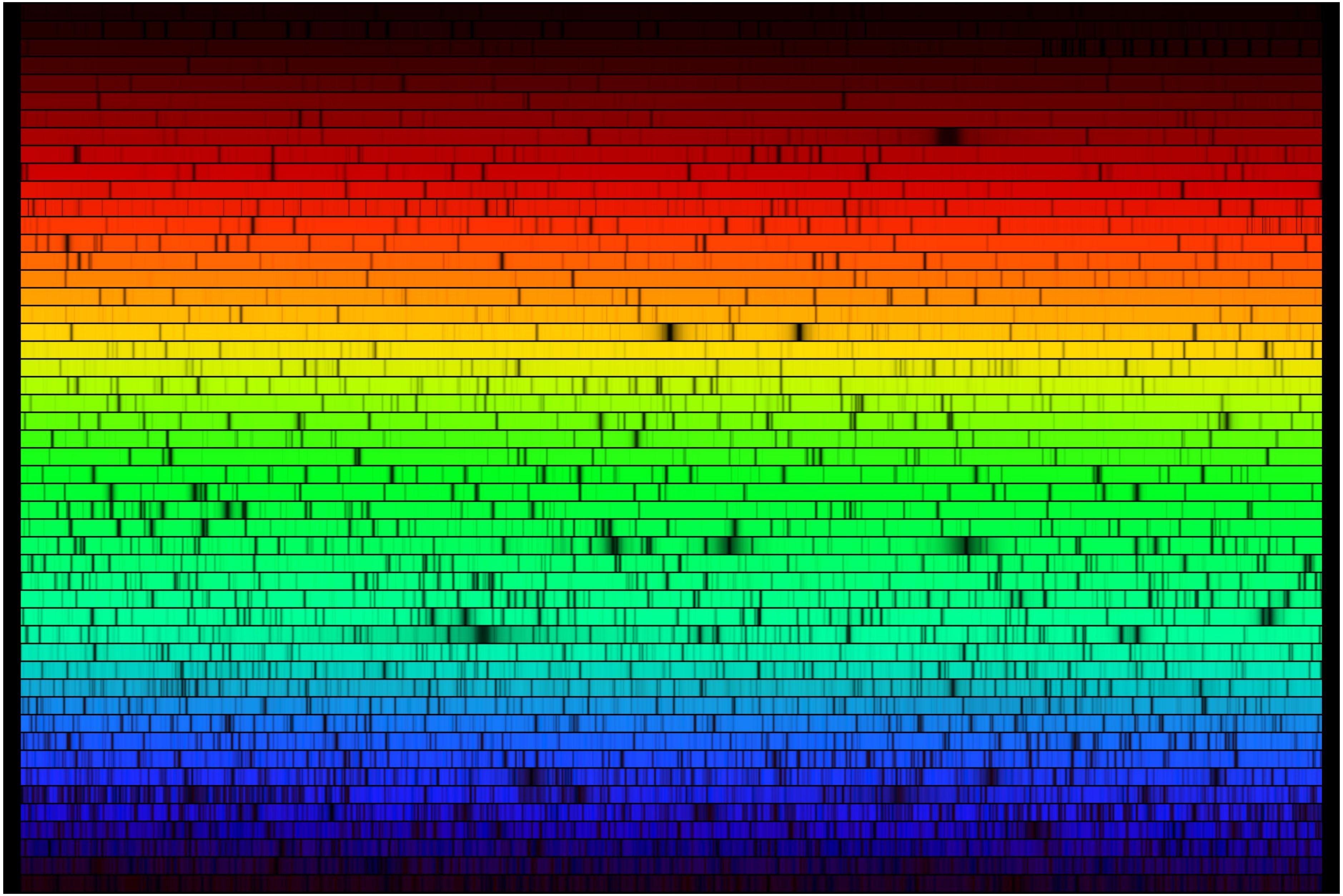
Stellar Spectra

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

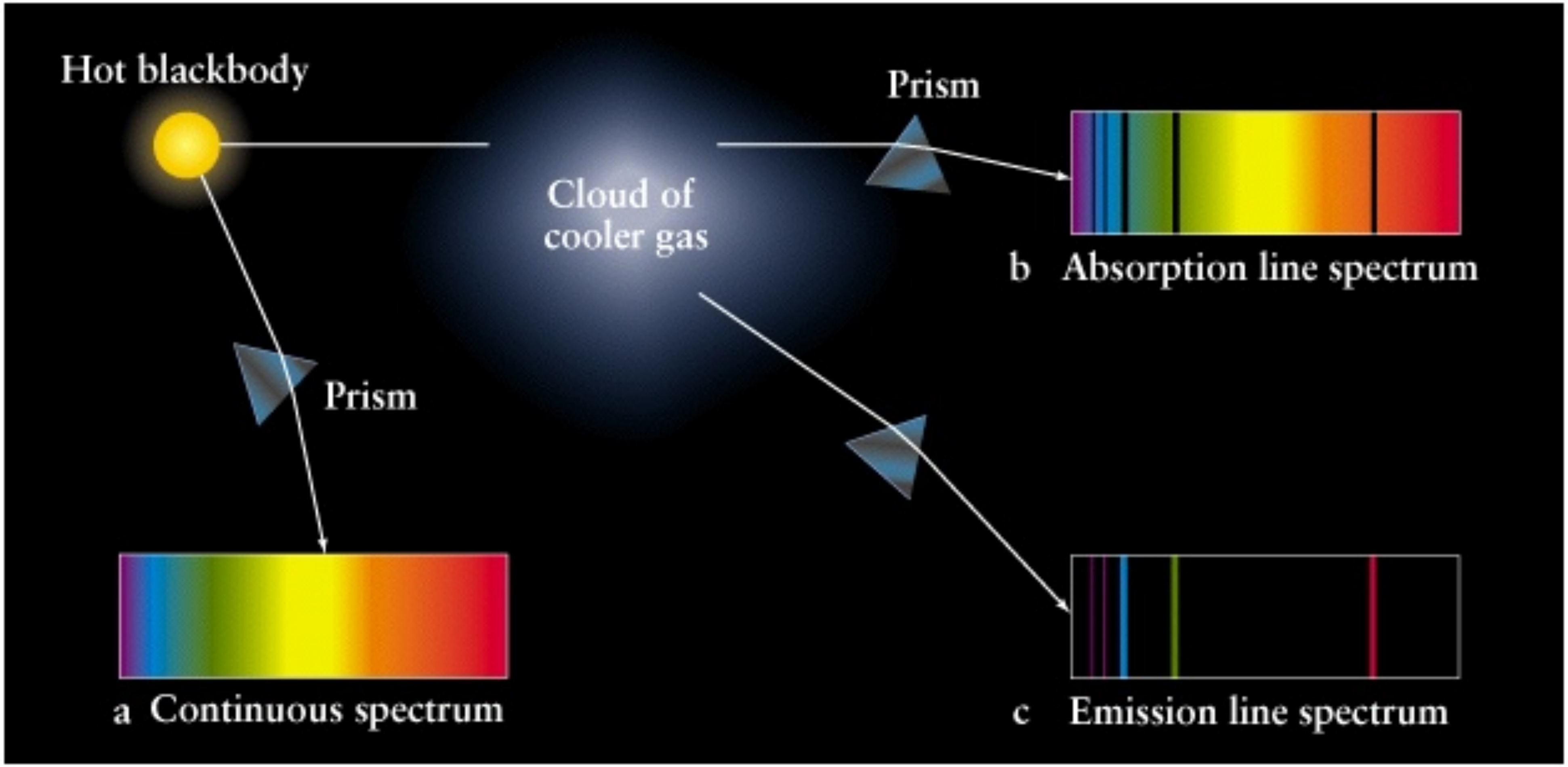
The Solar Spectrum



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

Absorption Lines

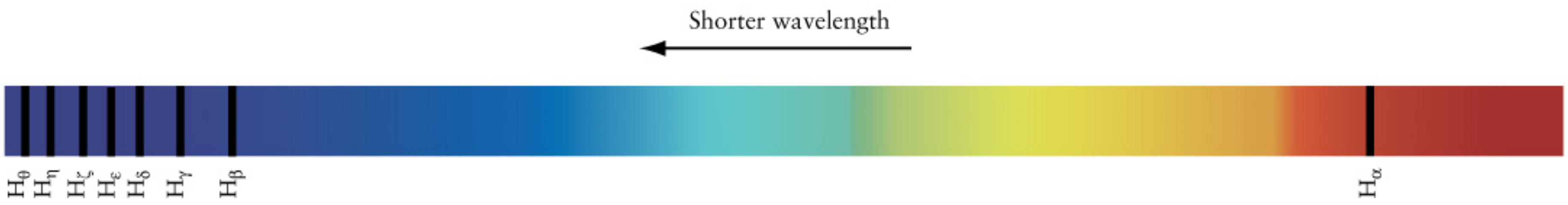
- Absorption lines arise when we view a hot source of continuum radiation through a cooler layer of gas
- Because the temperature drops with height in the atmospheres of stars we view cooler gas against a hotter background

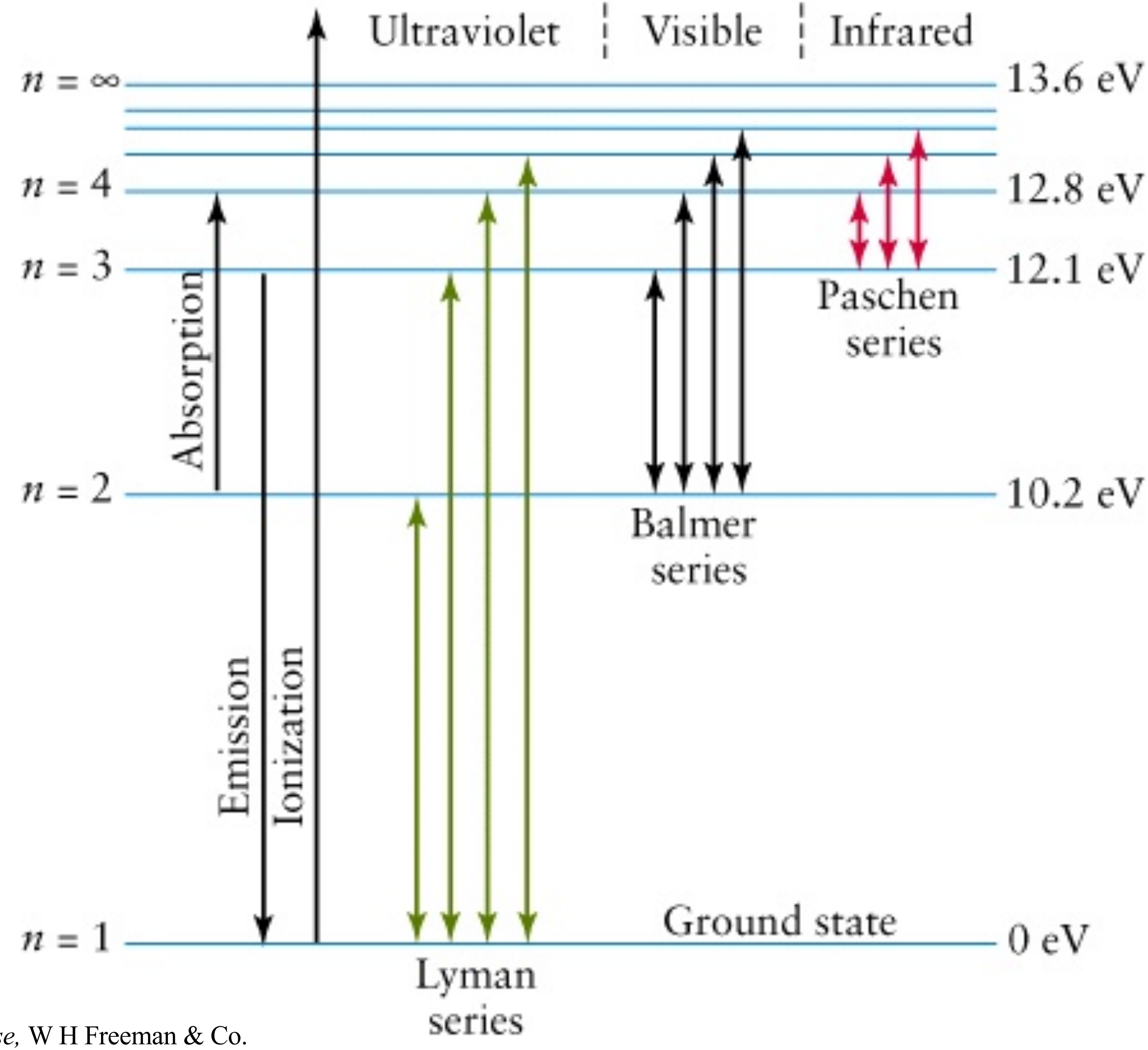


Hot blackbody
Prism
Cloud of
cooler gas
b Absorption line spectrum
Prism
a Continuous spectrum
c Emission line spectrum

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





Ultraviolet
Visible
Infrared
n = ∞
13.6 eV
n = 4
12.8 eV
n = 3
12.1 eV
n = 2
10.2 eV
n = 1
0 eV
Absorption
Emission
Ionization
Paschen series
Balmer series
Ground state
Lyman series

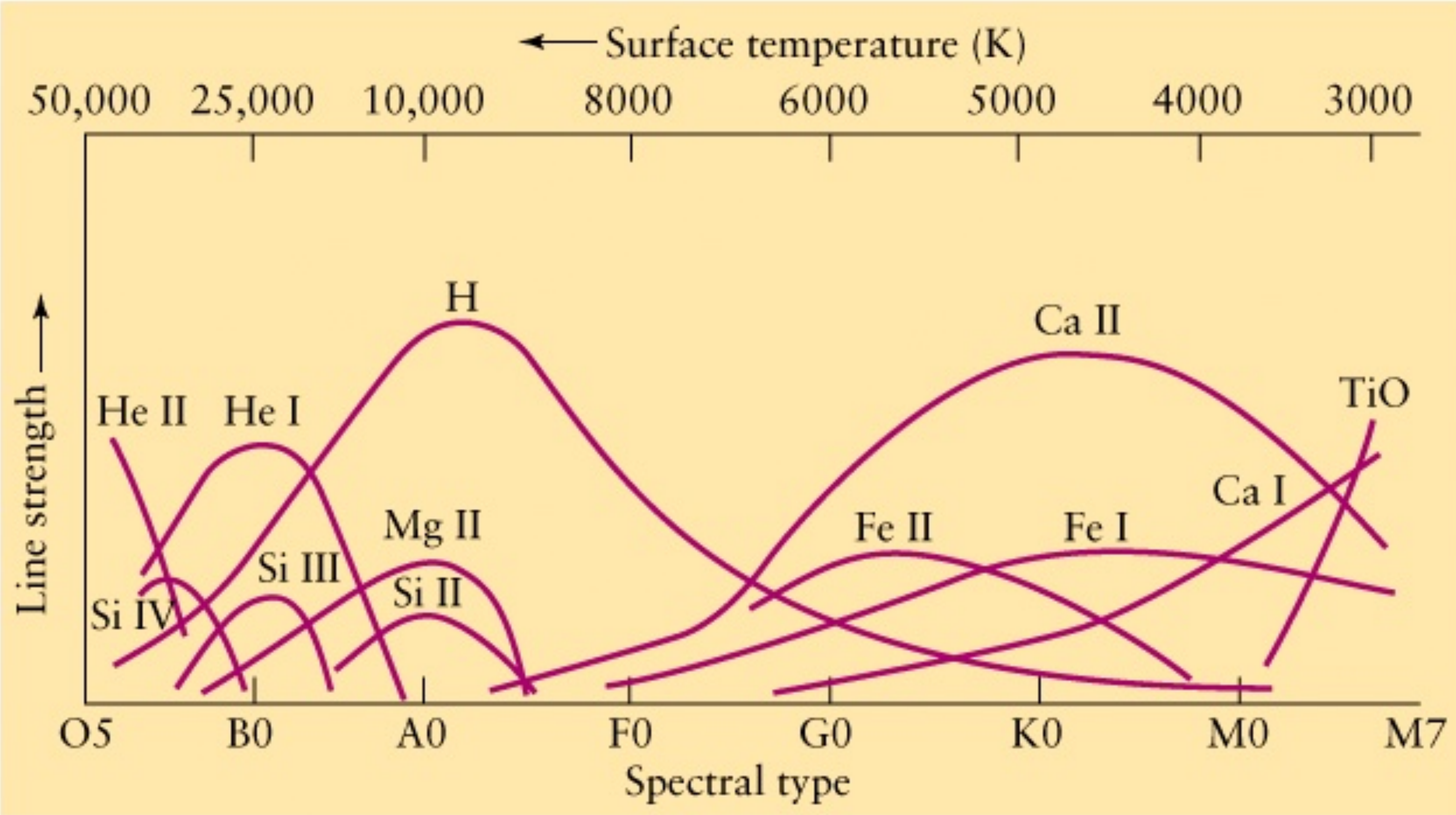
Absorption Line Strength

- 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

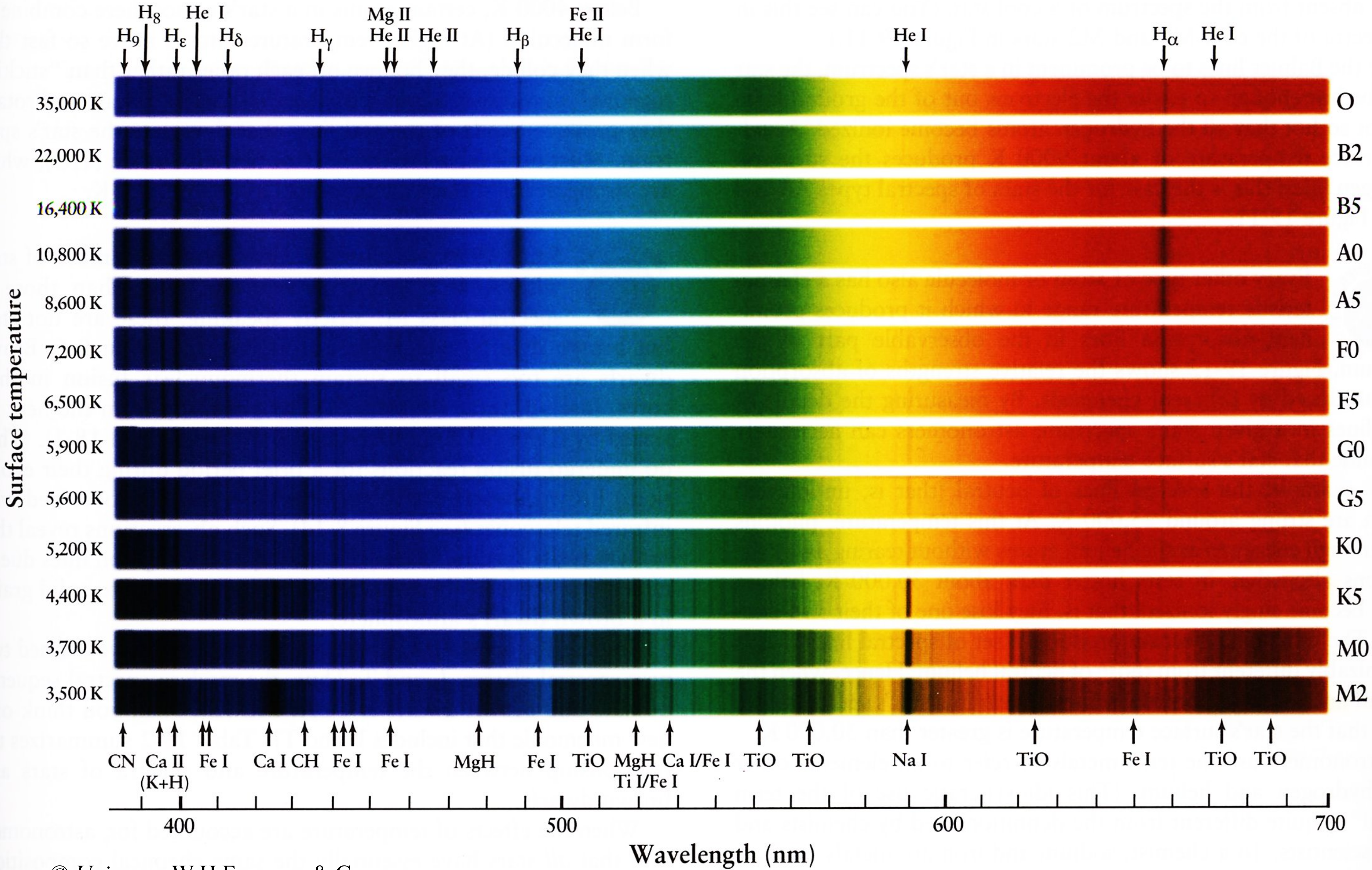

← Surface temperature (K)
50,000
25,000
10,000
8000
6000
5000
4000
3000
Line strength →
H
Ca II
He II
He I
TiO
Ca I
Mg II
Fe II
Fe I
Si III
Si II
Si IV
O5
B0
A0
F0
G0
K0
M0
M7
Spectral type

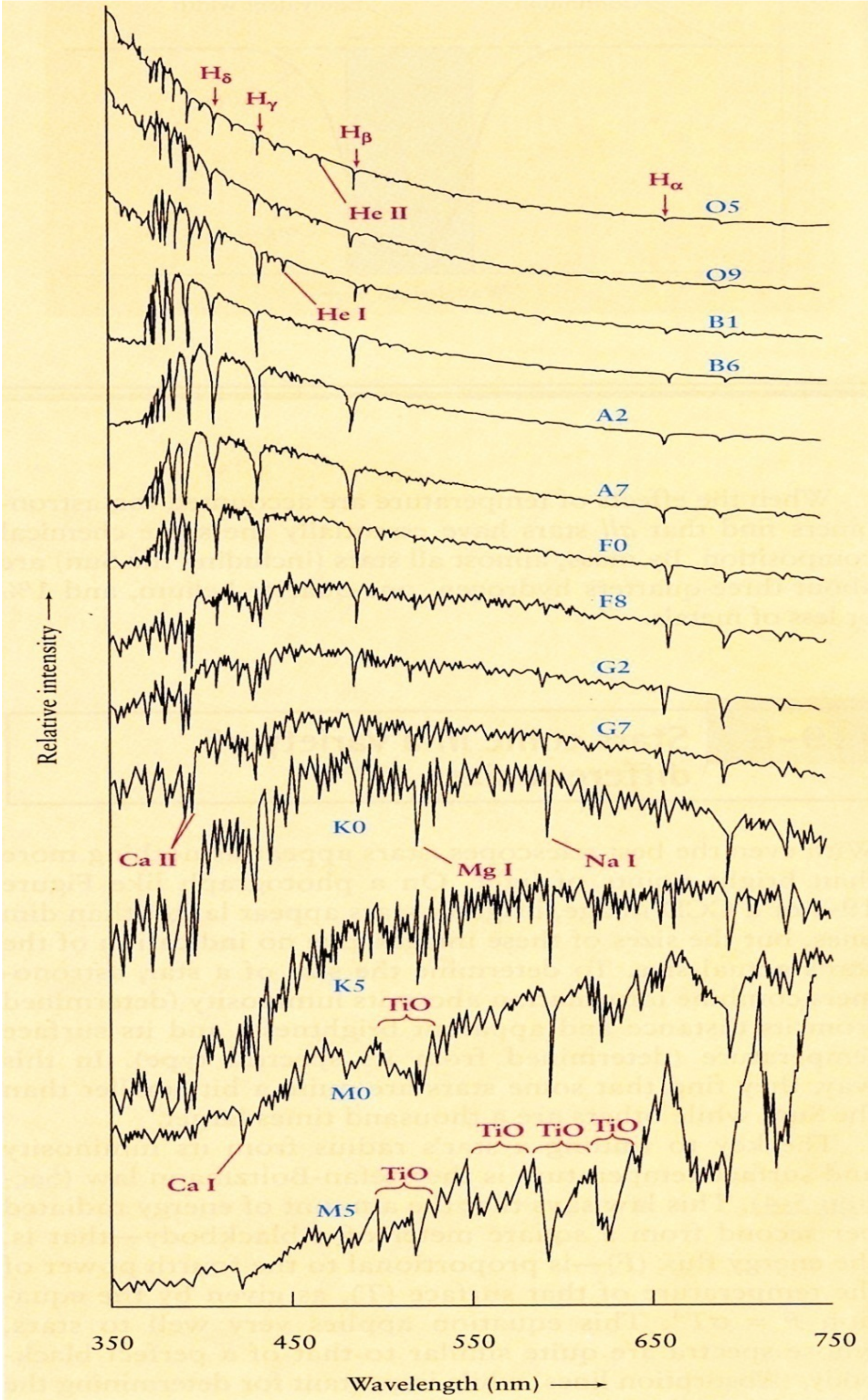
Spectral Classification

- stellar spectra can be classified into a temperature sequence
- spectral type is denoted by the sequence of letters:

O B A F G K M

early type late type


H9
H8
Hε
He I
Hδ
Hγ
Mg II
He II
He II
Hβ
Fe II
He I
He I
Hα
He I
35,000 K
22,000 K
16,400 K
10,800 K
8,600 K
7,200 K
6,500 K
5,900 K
5,600 K
5,200 K
4,400 K
3,700 K
3,500 K
Surface temperature
O
B2
B5
A0
A5
F0
F5
G0
G5
K0
K5
M0
M2
CN
Ca II (K+H)
Fe I
Ca I
CH
Fe I
Fe I
MgH
Fe I
TiO
MgH Ti I/Fe I
Ca I/Fe I
TiO
TiO
Na I
TiO
Fe I
TiO
TiO
400
500
600
700
Wavelength (nm)


Hδ
Hγ
Hβ
Hα
He II
He I
O5
O9
B1
B6
A2
A7
F0
F8
G2
G7
K0
Ca II
Mg I
Na I
K5
TiO
M0
Ca I
TiO
TiO
TiO
TiO
M5
Relative intensity
350
450
550
650
750
Wavelength (nm)

- each spectral class is subdivided into 10 subclasses denoted $0 \rightarrow 9$
- Sun has spectral type G2
- Balmer lines strongest at A0
- A0 stars have T_{eff}=10 000 K, e.g. Vega

Luminosity Classification

- More luminous stars with the same temperature must be larger
- if also of similar mass then average density must be lower
- lower density means the width of spectral lines are narrower due to less collisions between atoms
- line widths used for luminosity classification

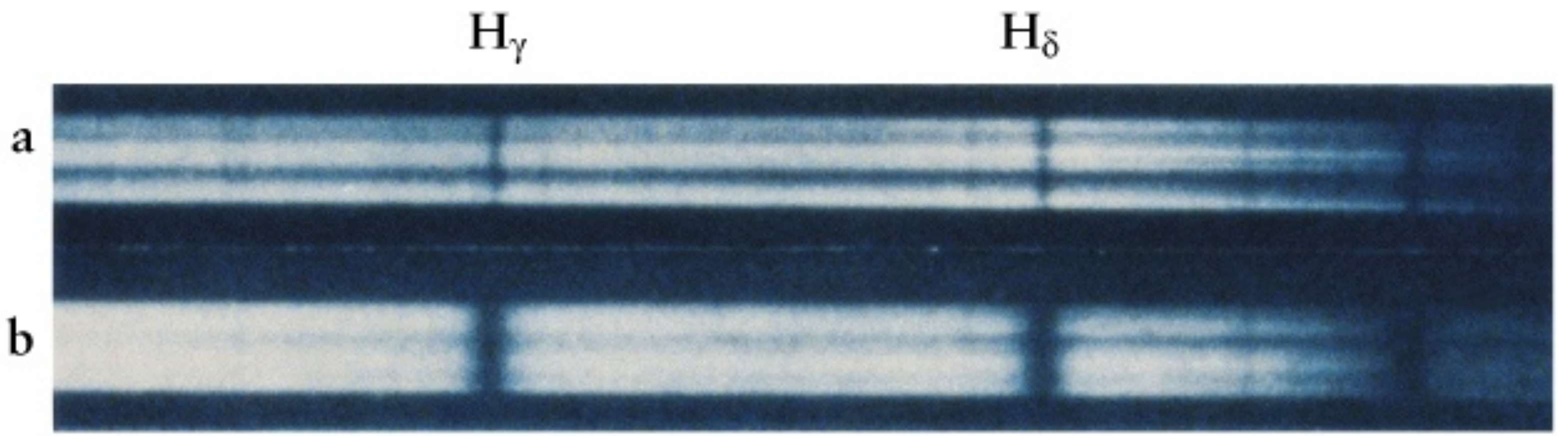
- Roman numerals used for luminosity classes

I	II	III	IV	V	VI
super-giants	bright giants	giants	sub-giants	MS (dwarfs)	sub-dwarfs

- Sun is a G2 V star

B8 I

B8 V



Summary

- absorption lines in stellar spectra can be used to classify stars
- spectral type is primarily a measure of the effective temperature of the star
- linewidths also indicate whether the star is a dwarf, giant or supergiant