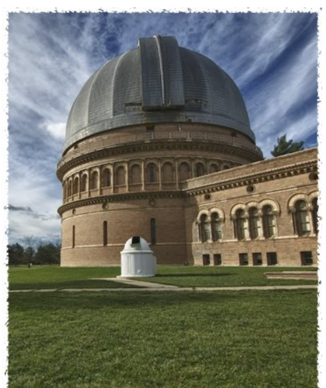
UWM Astronomy Club

First meeting September 22



UWM Astronomy Club
Meets Mondays at 4 pm, Physics 144
First meeting September 22

Discuss the latest astronomical discoveries and make some of your own! Control the world's largest radio telescope from the Arecibo Remote Command Center! Visit observatories near and far! Join the discussion, or work for $10/hour as part of UWM's pulsar search project.

Questions? Dawn Erb, erbd@uwm.edu

@UWMAstroClub

http://www.gravity.phys.uwm.edu/arcc/astronomy-club-meetings.html

Announcements

- Quiz 3 due Monday night
- Quiz 4 covers Chapters 2 & 3, due Monday, Sept 29th
- Problem set 4 is practice for Quiz 4

Announcements

- Planetarium session on Monday, Sept 22nd
  - Starts at 9.00 am, in Physics 139 (across the hall)
  - Doors close, so arrive early to pick best seat
- Planetarium assignment:
  - Write 150 words about your visit to the planetarium.
  - Include 1 point of something new you learned
  - Hand in on Wednesday, Sept 24th
  - Assignment counts for 5% of your total grade

Announcements

- Stargazing all nights next week:
  - starts at 8pm, 5th floor of Physics building
  - sign the sign-up sheet
  - Write a short summary on what you observed, what you liked and what you learned
  - Add 1 point to your final grade

Announcements

- First midterm is Wednesday October 1st
  - Will cover lectures through today (Lectures 1-8)
  - Textbook up to Chapter 2
  - Problems will be similar to those on quizzes
  - Problems on material through Chapter 2 – includes parts of quiz 4
  - No book, notes or calculator
  - Sheet of formulas will be given
  - Calculations will be doable without a calculator
- Review in class on Monday Sept 29th

Light and Matter

Please read Chapter 2

Today we will cover sections 2.4 to 2.8

Temperature

Temperature is a measure of how fast atoms or molecules are moving.

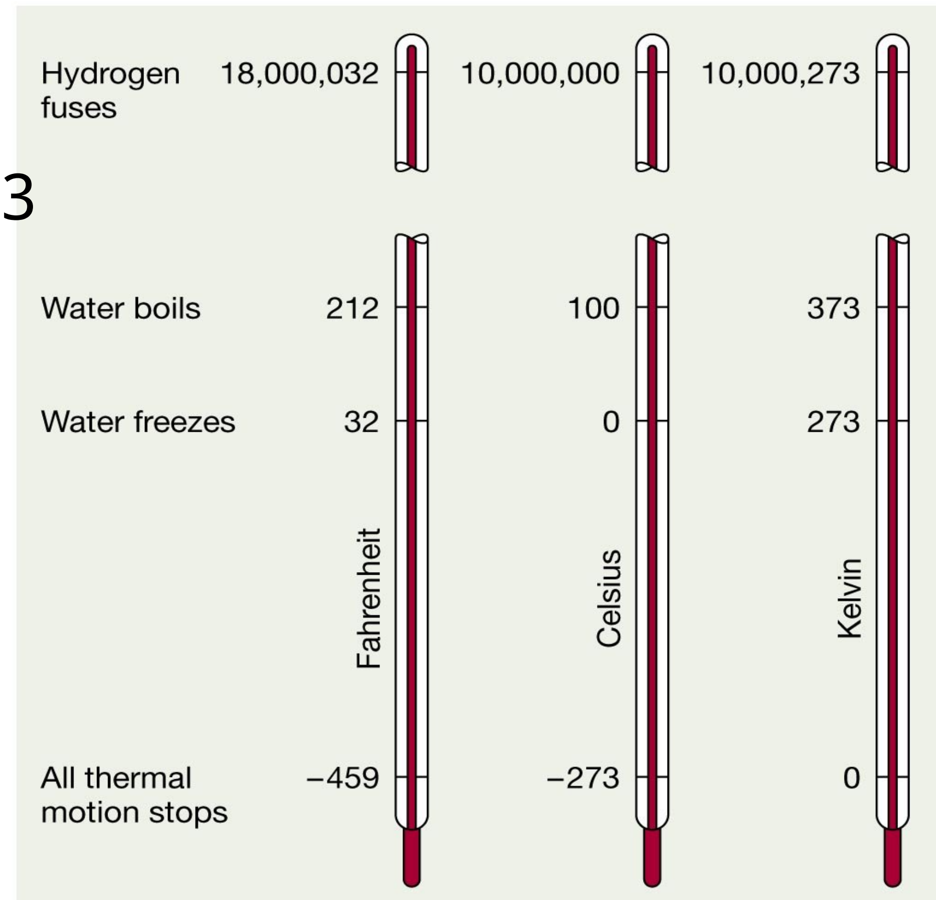
- Hot – atoms moving fast
- Cold – atoms moving slowly
- When atoms stop moving – lowest possible temperature.

This lowest temperature is called absolute zero, which is -273°C (-459°F).

You are familiar with the Fahrenheit and Celsius temperature scales.
A third temperature scale, the Kelvin scale, is designed to be identical to the Celsius scale, except that 0 K is the lowest possible temperature, absolute zero.

degrees Kelvin = degrees Celsius + 273

TK = TC+273.

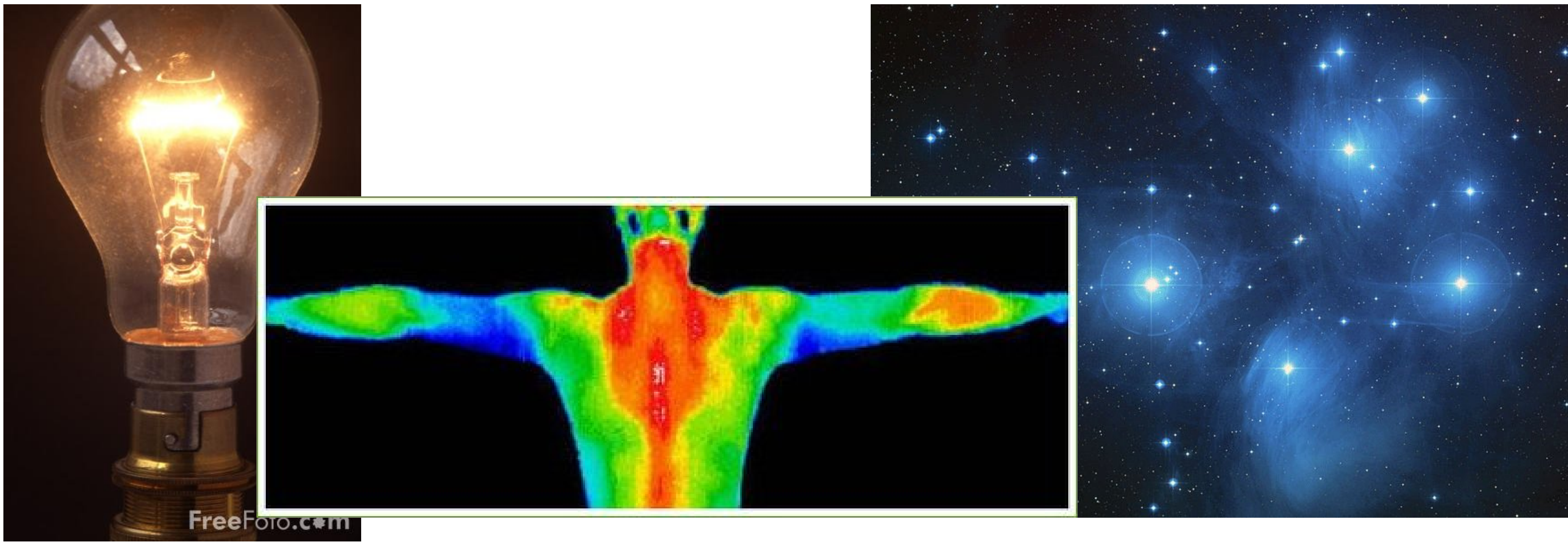


Centers of stars

Molecular clouds where stars form

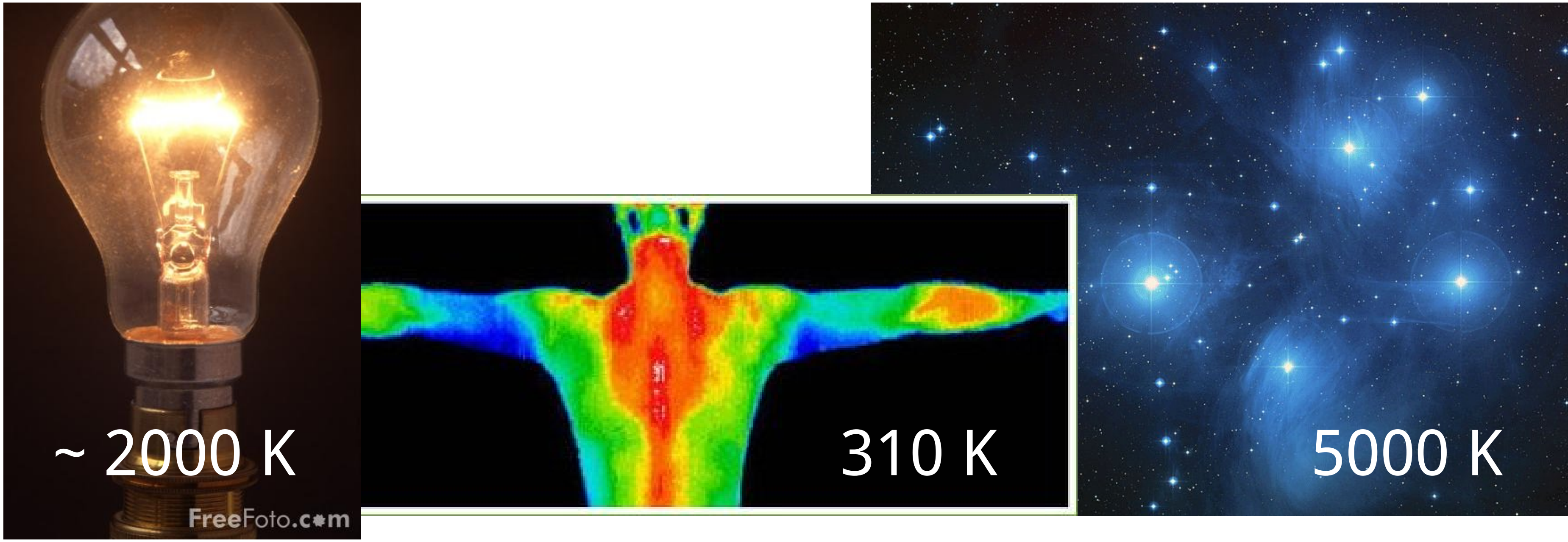
Thermal radiation:
The continuous blackbody spectrum

All objects with some temperature emit electromagnetic (EM) radiation – light



If you break up this radiation, you find some radiation at all wavelengths – it is continuous. So this is called a **continuous spectrum**

Radiation depends on temperature



The **hotter an object is, the brighter** it is (the more energy it emits per second).

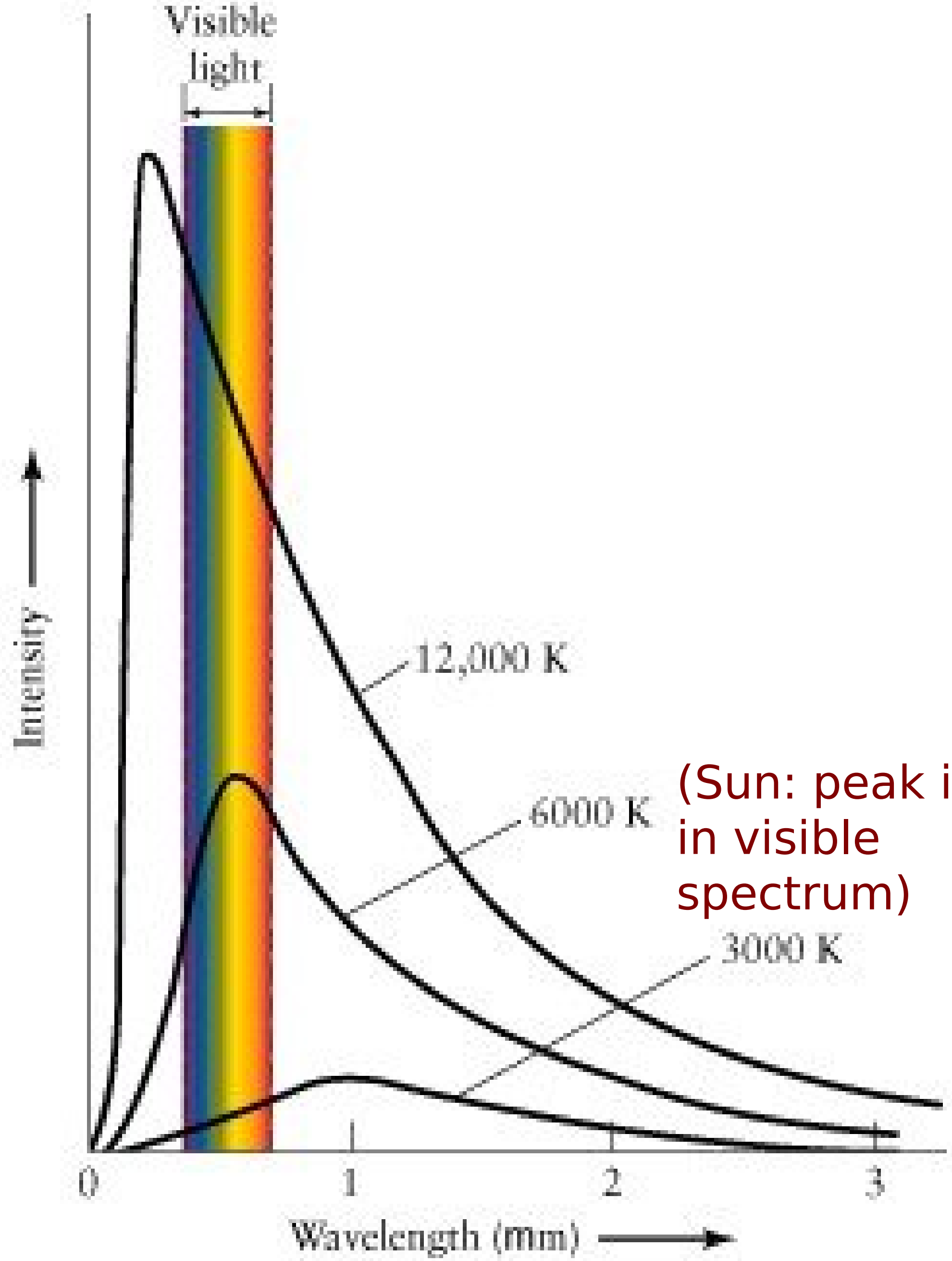
The **hotter an object is the shorter the average wavelength** of the light it emits

Examples: a light bulb emits visible light, humans emit infrared light

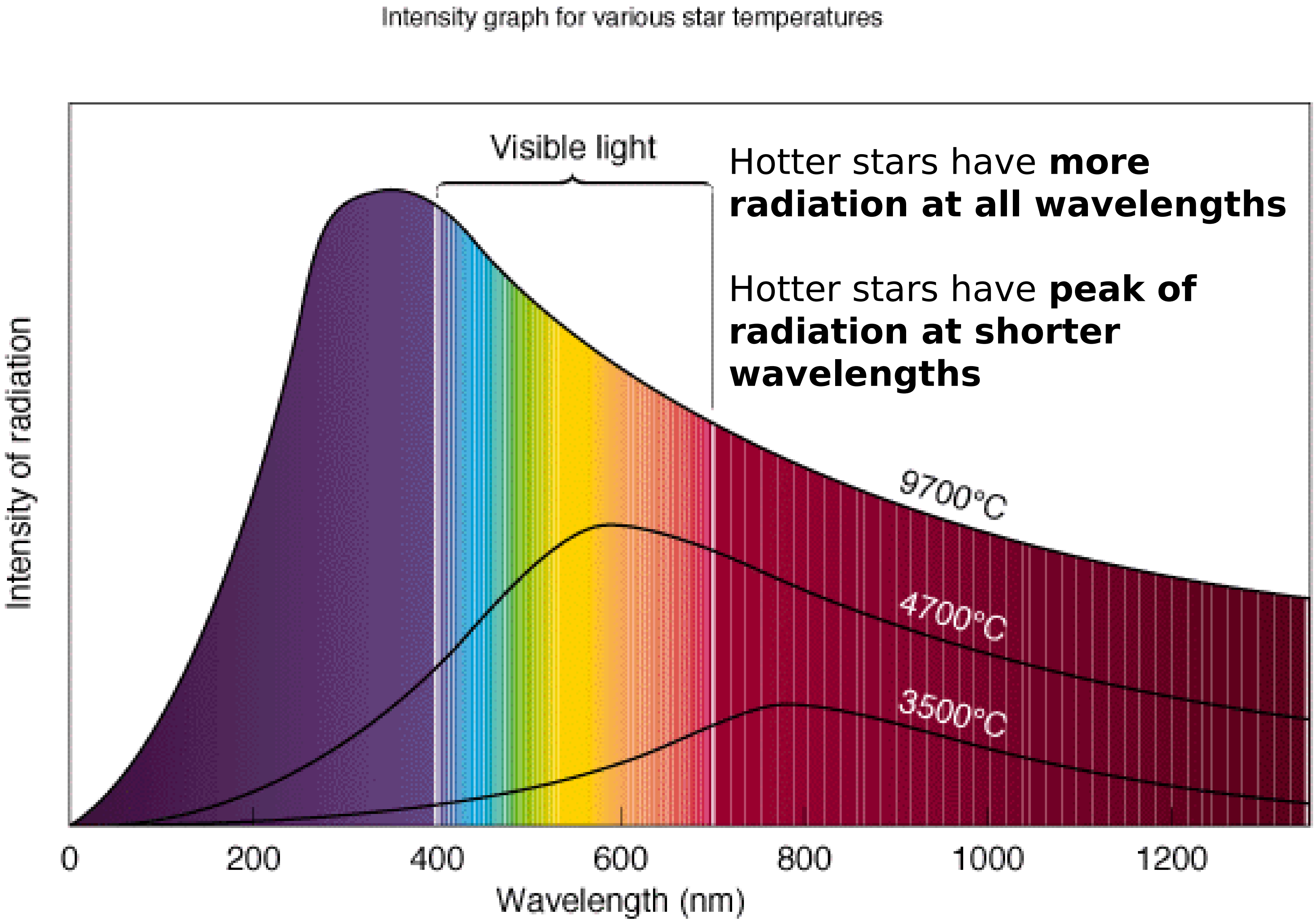
(Note: We're talking about traditional incandescent light bulbs, not the modern fluorescent kind! Fluorescent light bulbs emit another kind of radiation we'll talk about later.)

The peak intensity of light emitted by a star (or other hot object) depends on the temperature of the star.

Hotter objects are brighter and have shorter peak wavelengths.



(Sun: peak is in visible spectrum)

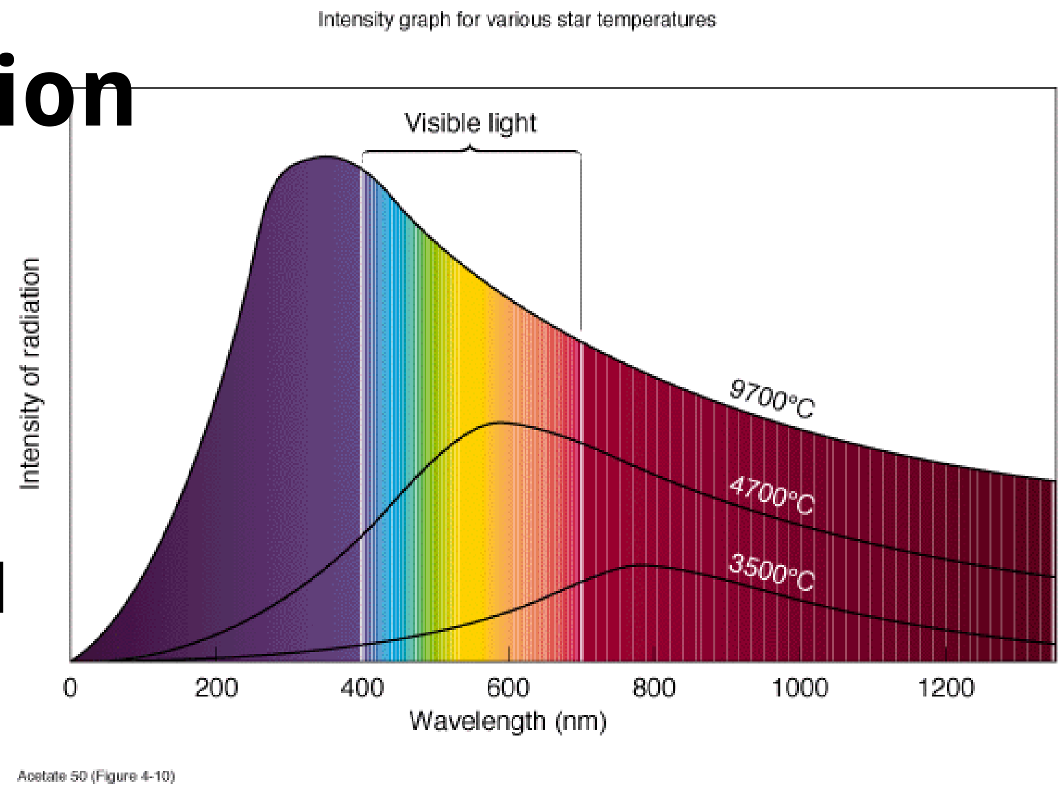


Hotter stars have **more radiation at all wavelengths**

Hotter stars have **peak of radiation at shorter wavelengths**

Acetate 50 (Figure 4-10)

Blackbody radiation



The radiation that something emits because of its temperature is called **thermal or blackbody radiation**, and we can use the peak wavelength of the blackbody curve to determine the temperature of an object.

Nothing radiates as a perfect blackbody, but stars come close!

So **hotter stars emit more radiation, and the radiation peaks at a shorter wavelength.**

With wavelength λ measured in nanometers and **T in degrees Kelvin**, the relation between the average wavelength of light emitted by a hot object and the temperature of the object is

$$\lambda = \frac{3 \times 10^6}{T} \text{ nm}$$

To 2 decimal-place accuracy and with λ measured in cm

$$\lambda = \frac{0.29}{T} \text{ cm}$$

Example: Milwaukee at 170 C = 290 K
Peak wavelength is 10,000 nm: infrared

$$\lambda = \frac{3\times10^6}{T}\ \mathrm{nm}$$

A star has a temperature of 2000 K. What is the peak wavelength of light that it emits?

$$\lambda = \frac{3\times10^6}{2000}\ \mathrm{nm} = 1500\ \mathrm{nm}$$

Recall that the peak wavelength of light from the Sun is at about 480 nm. Is a star with peak wavelength 1500 nm hotter or colder than the Sun?

A Hotter

B Colder

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A Hotter

B Colder

Longer peak wavelength = colder temperature

$$\lambda = \frac{3\times 10^6}{T}\,\mathrm{nm}$$

A star emits at a peak wavelength of 300 nm. What is the temperature of its surface?

A 0.9 K

B 9000 K

C 10,000 K

D 9 x 108 K

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A star emits at a peak wavelength of 300 nm. What is the temperature of its surface?

A 0.9 K

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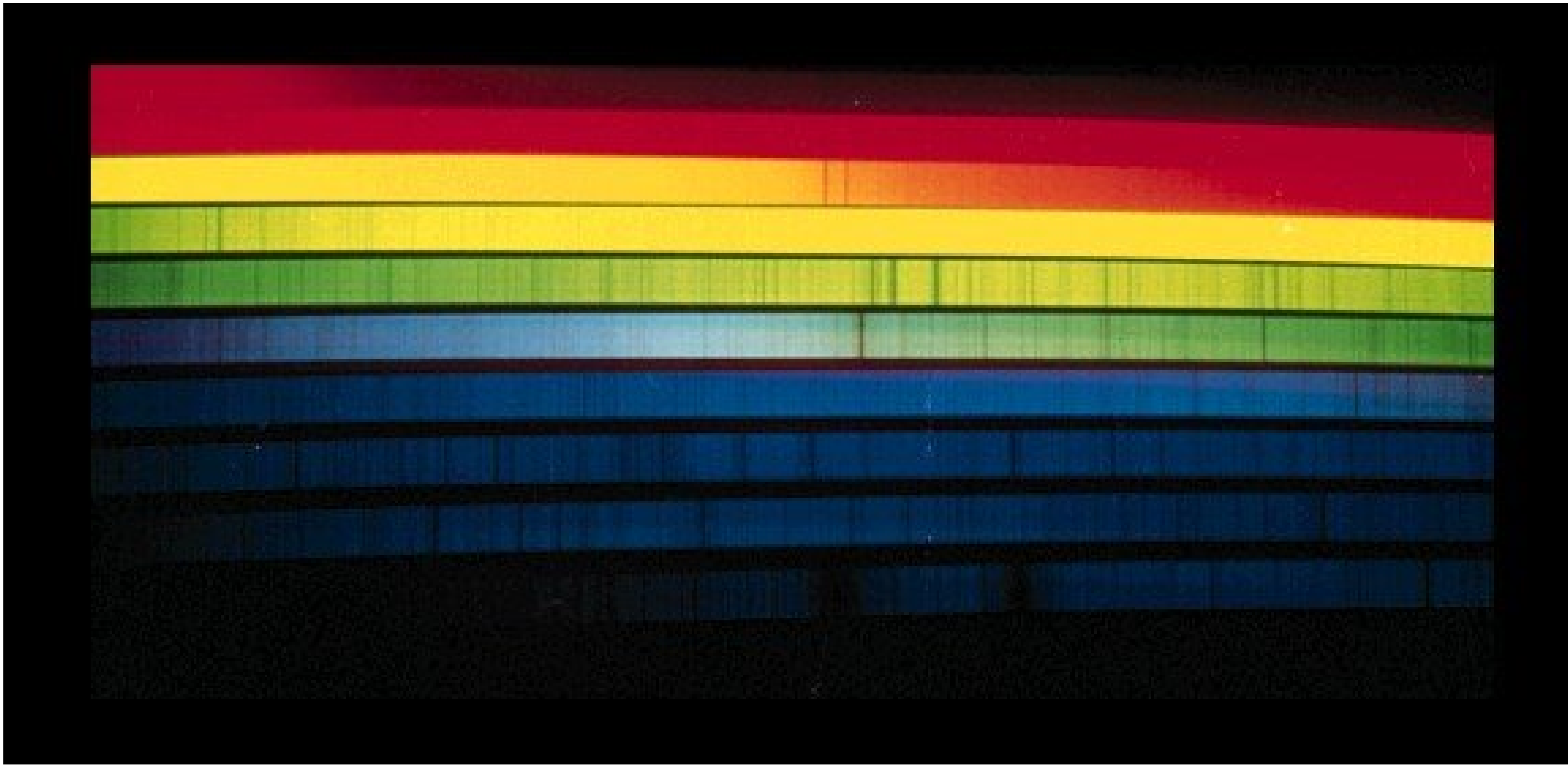
$$T = \frac{3 \times 10^6}{\lambda} \text{ K}$$

If wavelength in nm

Atoms and Spectroscopy

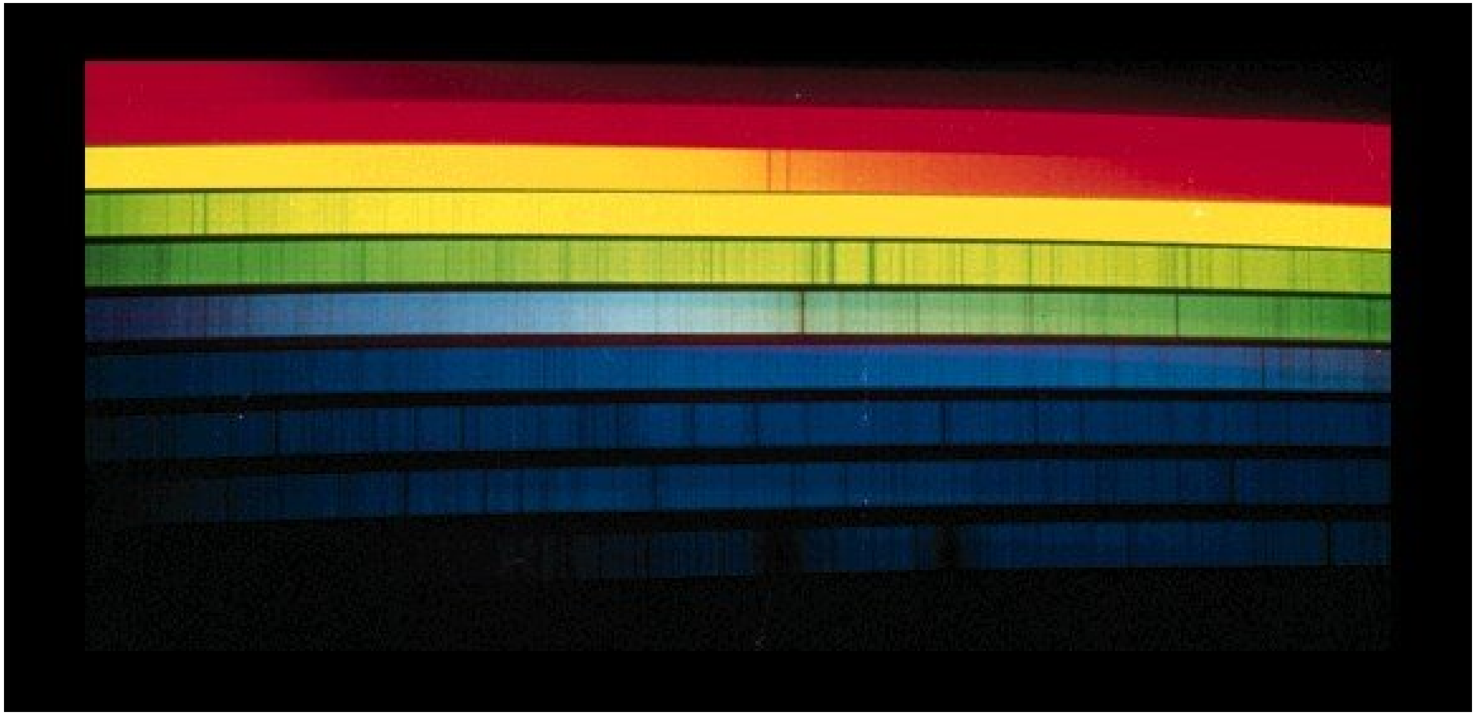
This is the spectrum of the Sun



Notice anything unusual or suprising?

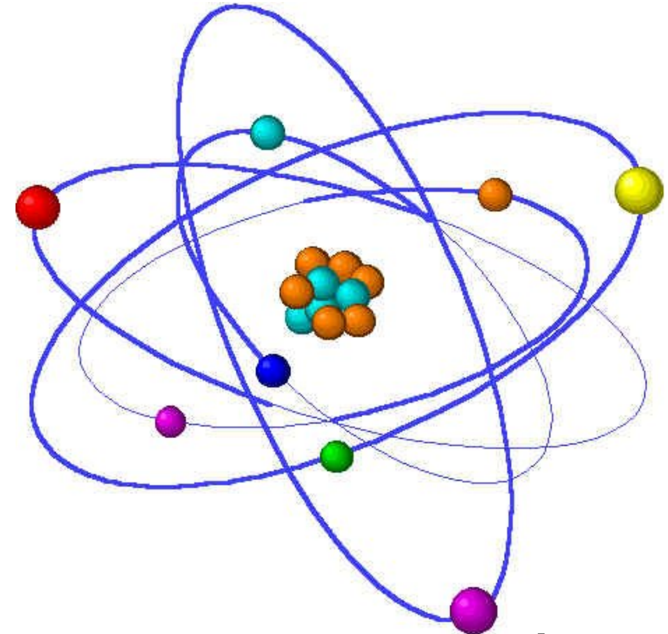
Light from the Sun looks like a continuous spectrum with a set of thin dark lines.

What’s going on? What happened to the continuous spectrum?



Let’s review some important facts about matter.

Crash course : Atomic Physics in 10 slides



- All things are made of atoms.
- Atoms are about 1/10 nm (about 10^{-10} m) in diameter.
- Atoms are collections of neutrons, protons and electrons. The neutrons and protons form a very small, very dense nucleus. The electrons orbit the nucleus, bound by electric attraction to the protons.

  Opposite charges attract: electrons are negatively charged, and protons are positively charged. Neutrons have no charge.
- An atom is about 100,000 times larger than its nucleus

Spectra of isolated atoms

- Objects as small as atoms are described by **quantum mechanics**, and the quantum mechanical behavior of small objects is different in key ways from that of large objects.
- In contrast to planets orbiting the Sun, electrons orbiting the nucleus of an atom **are restricted to a discrete set of orbits**, at fixed distances from the nucleus. In particular, there is a closest allowed orbit.
- The closest allowed orbit of an electron is the one with lowest energy, called the ground state.

Spectra of isolated atoms

When light hits an electron in an atom, it can kick the electron outward to a more energetic orbit, called an excited state. An excited electron will spontaneously fall back down to a closer orbit, and the electron then emits light of a fixed wavelength that depends only on the difference in energy between the two orbits. Longer wavelength light corresponds to a smaller energy difference.

- **When an electron absorbs light, it moves from a closer to a more distant orbit.**
- **When an electron moves from a more distant to a closer orbit, it emits light.**

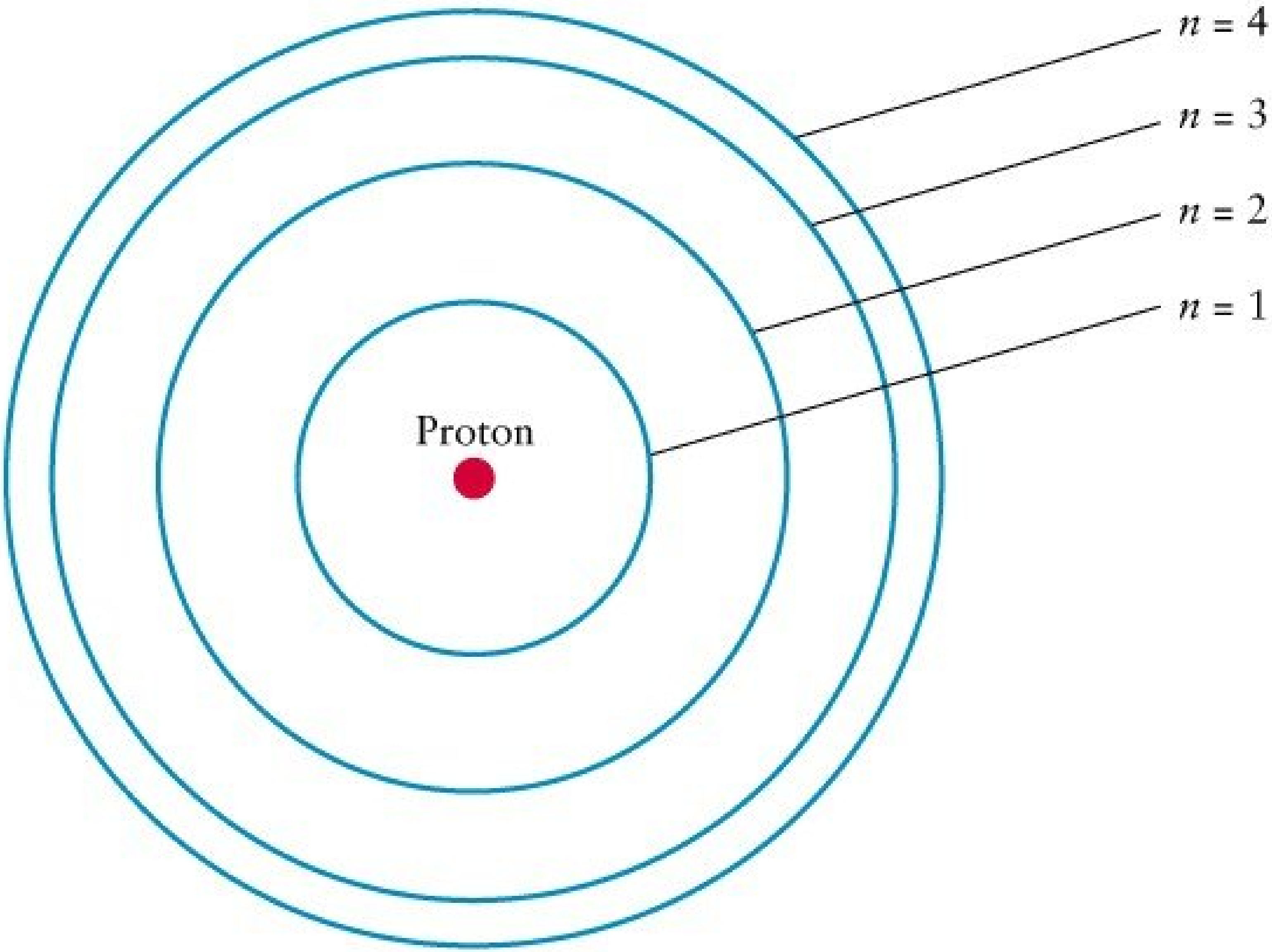
Spectra of isolated atoms

Atoms emit and absorb only those wavelengths of light that can correspond to the energy differences between orbits.

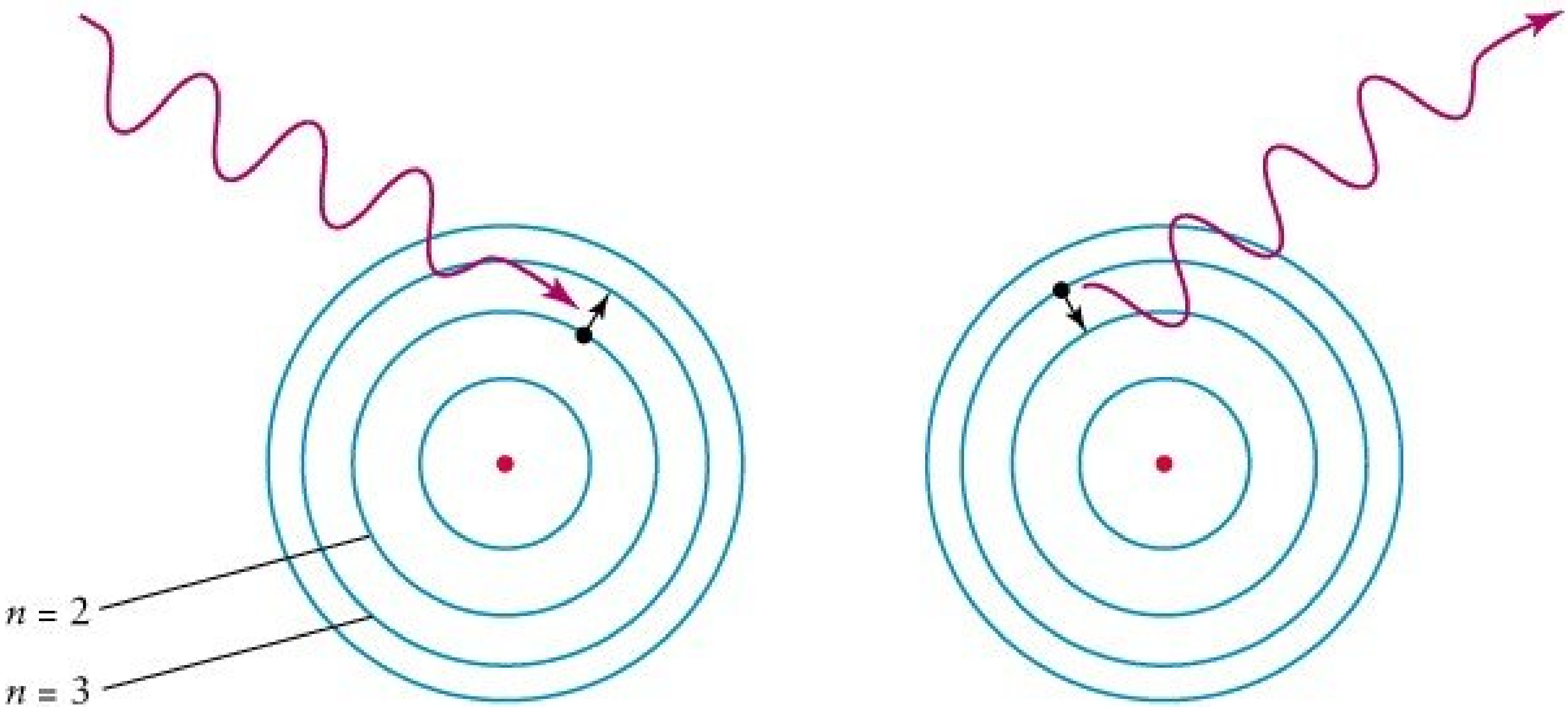
The light emitted or absorbed by isolated atoms is called a **discrete spectrum** because **only discrete wavelengths are emitted and absorbed**: one sees the spectrum as a set of distinct lines. Each type of atom (each element) has a different set of energy levels and therefore a different set of spectral lines.

- Each element can be identified by its discrete spectrum.
- The spectral lines (wavelengths) that an atom emits are the same as the spectral lines it absorbs

Diagram of the four lowest energy levels (four closest orbits) of the electron in a hydrogen atom

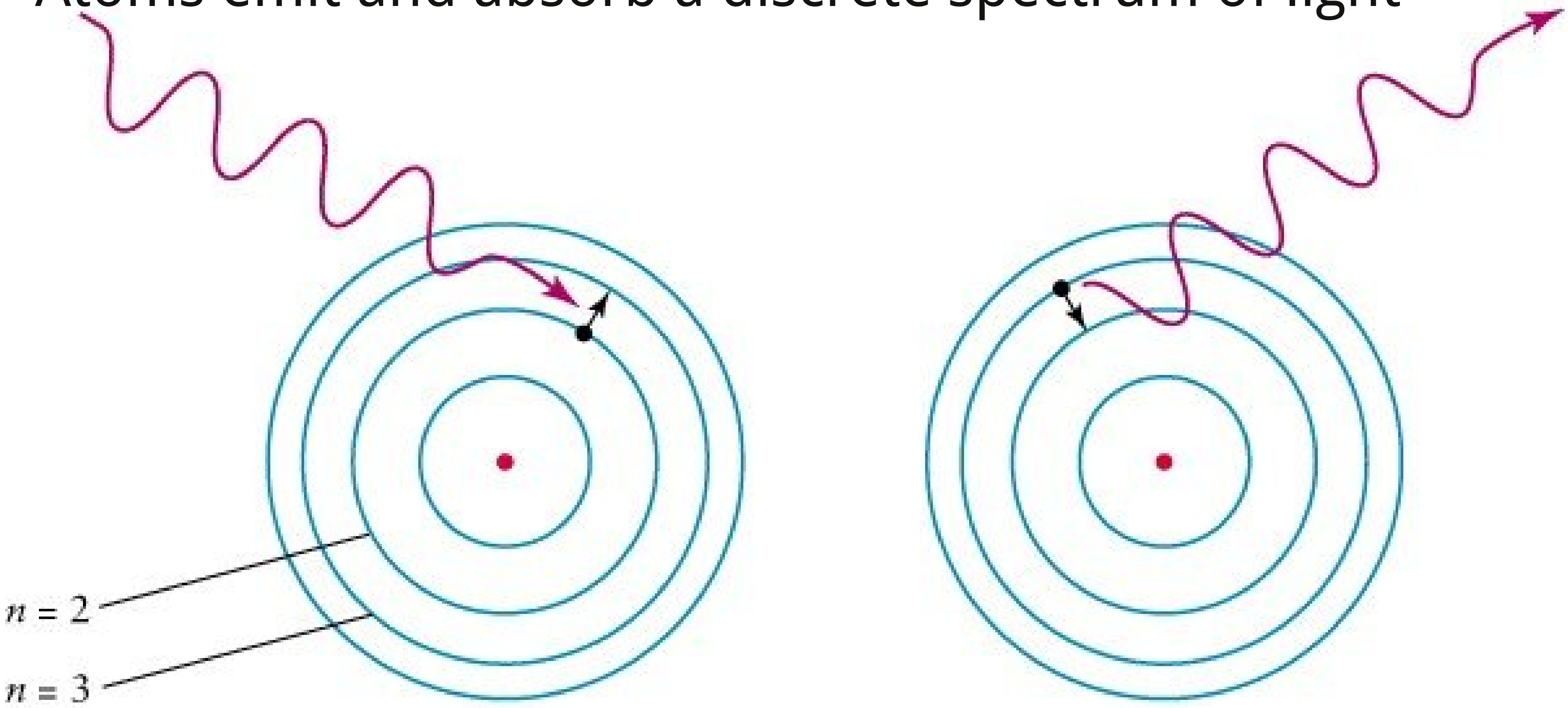


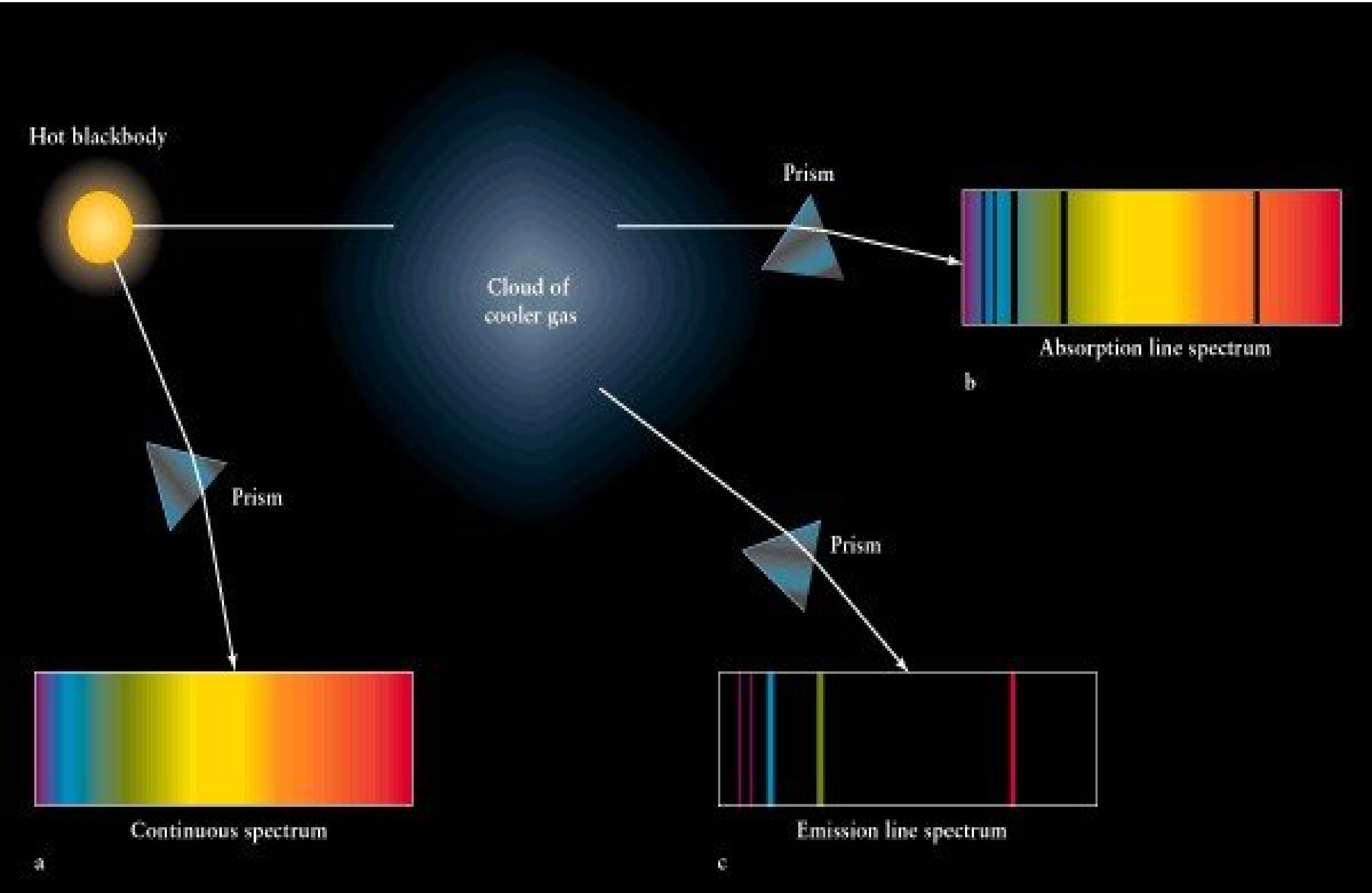
- When an electron absorbs light, it moves to a more distant orbit (unless the light is so energetic it knocks the electron off the atom)
- When it falls back to a closer orbit, an electron emits light



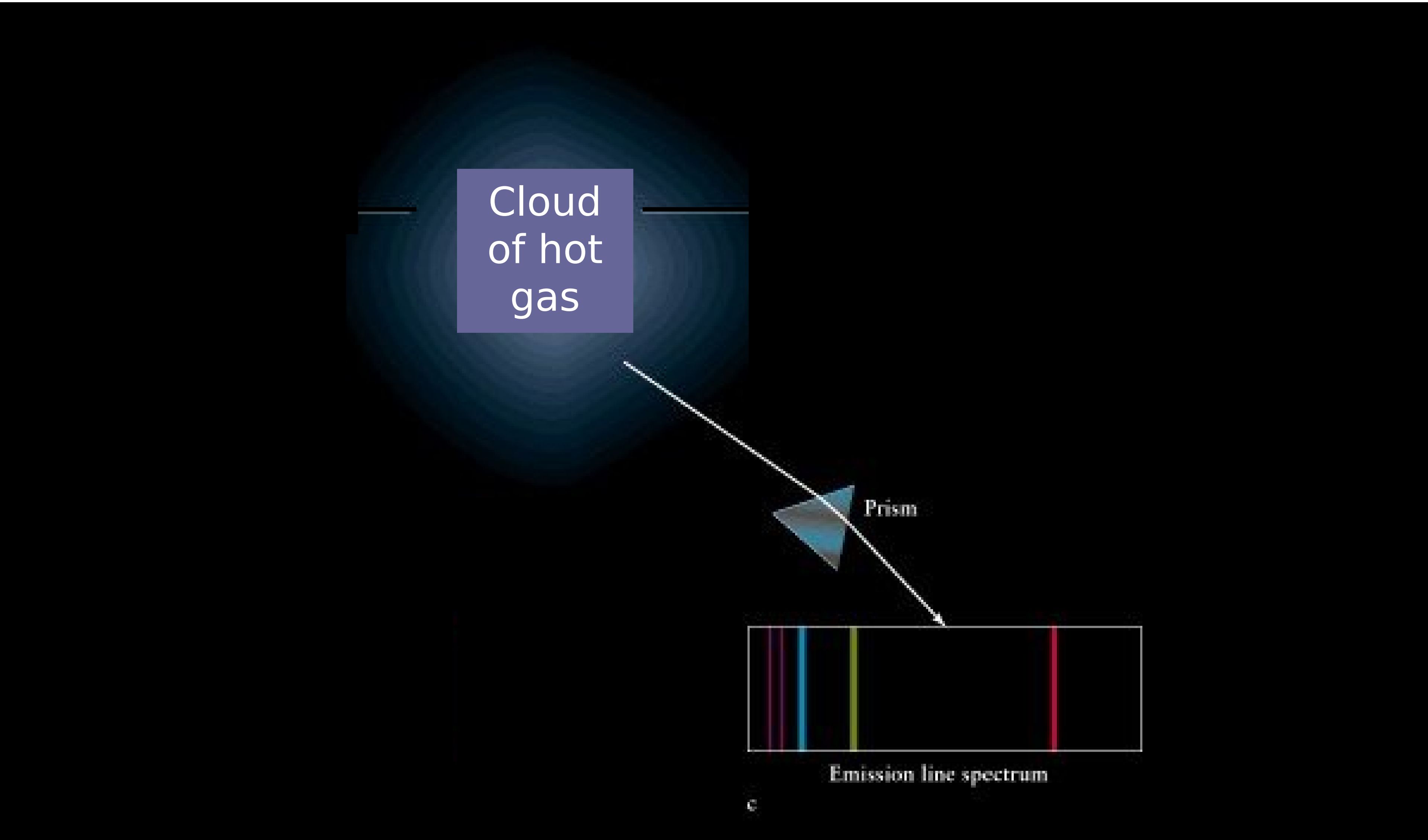
a Absorption b Emission

- The energy of the emitted or absorbed light is equal to the difference in energy between the two orbits.
- The wavelengths that an atom emits are the same as the wavelengths it absorbs:
  → The absorption lines and the emission lines of an atom have the same wavelengths.
- Atoms emit and absorb a discrete spectrum of light

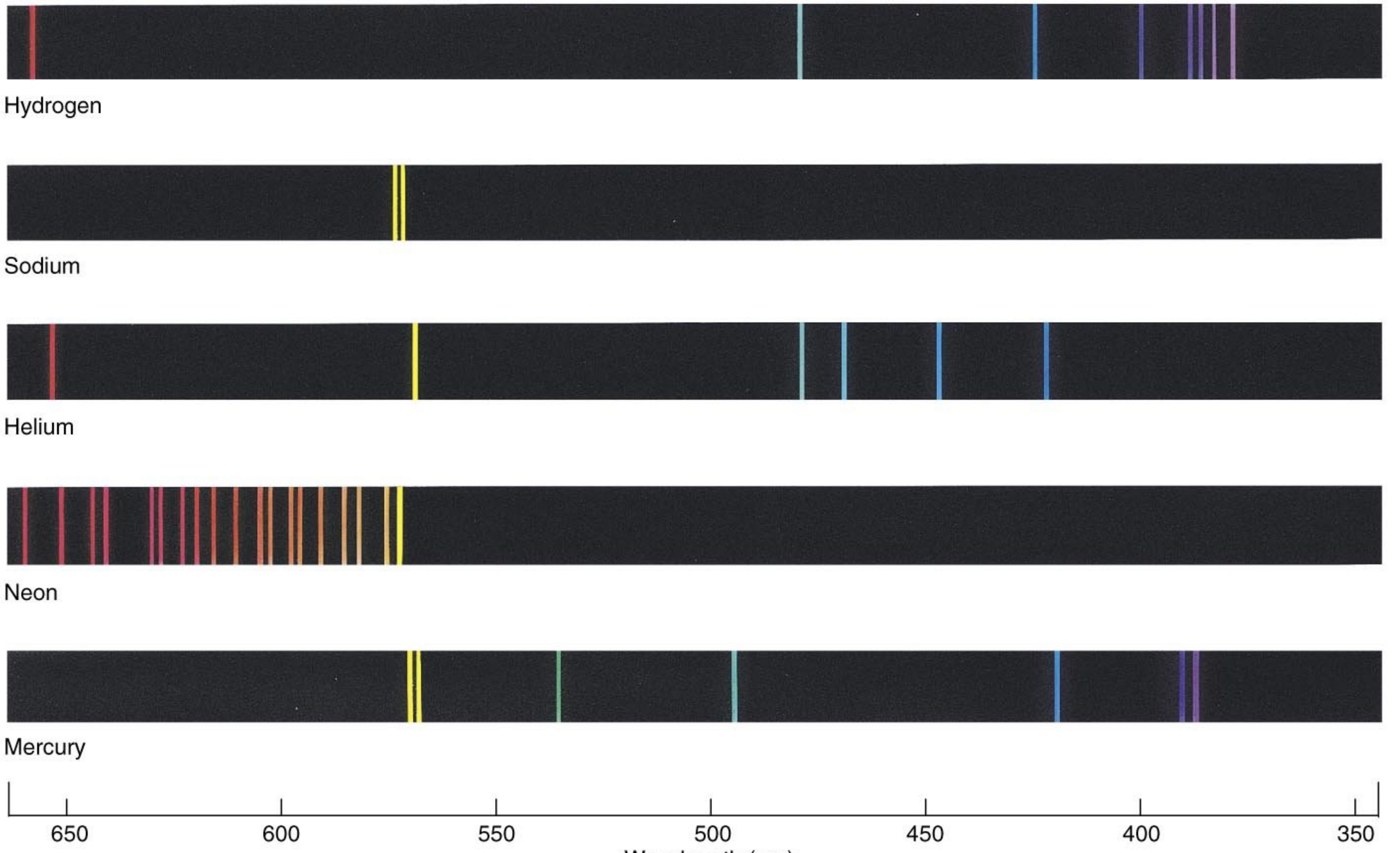



Hot blackbody
Cloud of
cooler gas
Prism
Absorption line spectrum
b
Prism
Prism
Continuous spectrum
a
Emission line spectrum
c

Light emitted by a hot gas of atoms has only those wavelengths that correspond to the energy differences between allowed electron orbits



Elements in stars can be identified by recognizing the patterns of their spectral lines.



We experience this in our everyday lives.

- Different elements differ only in the number of protons in their nuclei.
- The lightest elements have the smallest number of protons:
  - Hydrogen (H) has 1 proton (and most commonly no neutrons)
  - Helium (He) has 2 protons (and most commonly 2 neutrons)
- The heaviest elements have many more protons
  - Iron: 26 – Lead: 82 – Uranium: 92

Periodic table of elements

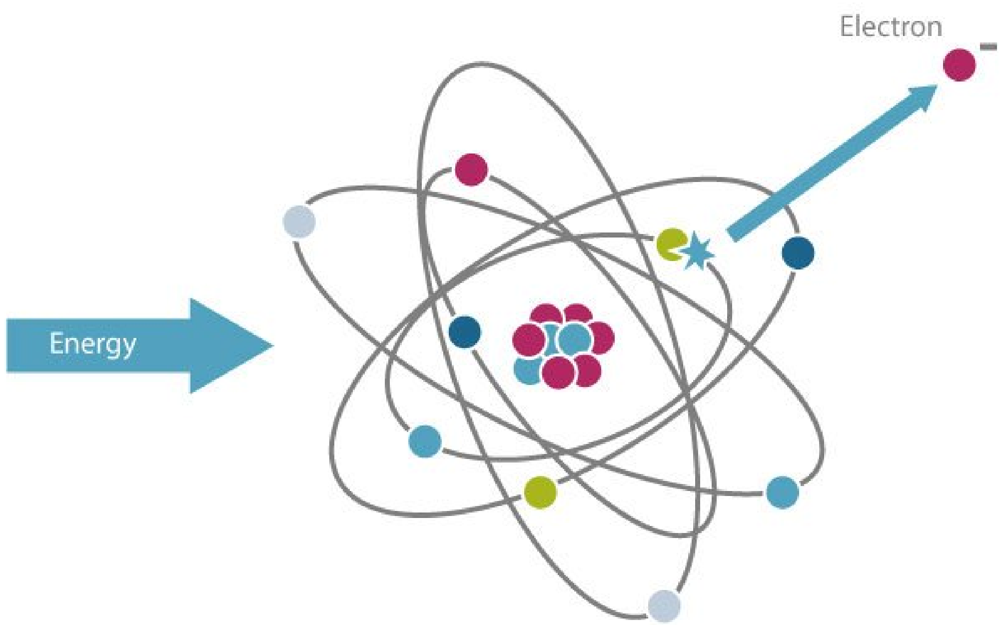
Here is a table of the atoms, listed by the number of protons in their nucleus (equal to the number of electrons orbiting the nucleus).

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Uun	111 Uuu	112 Uub						

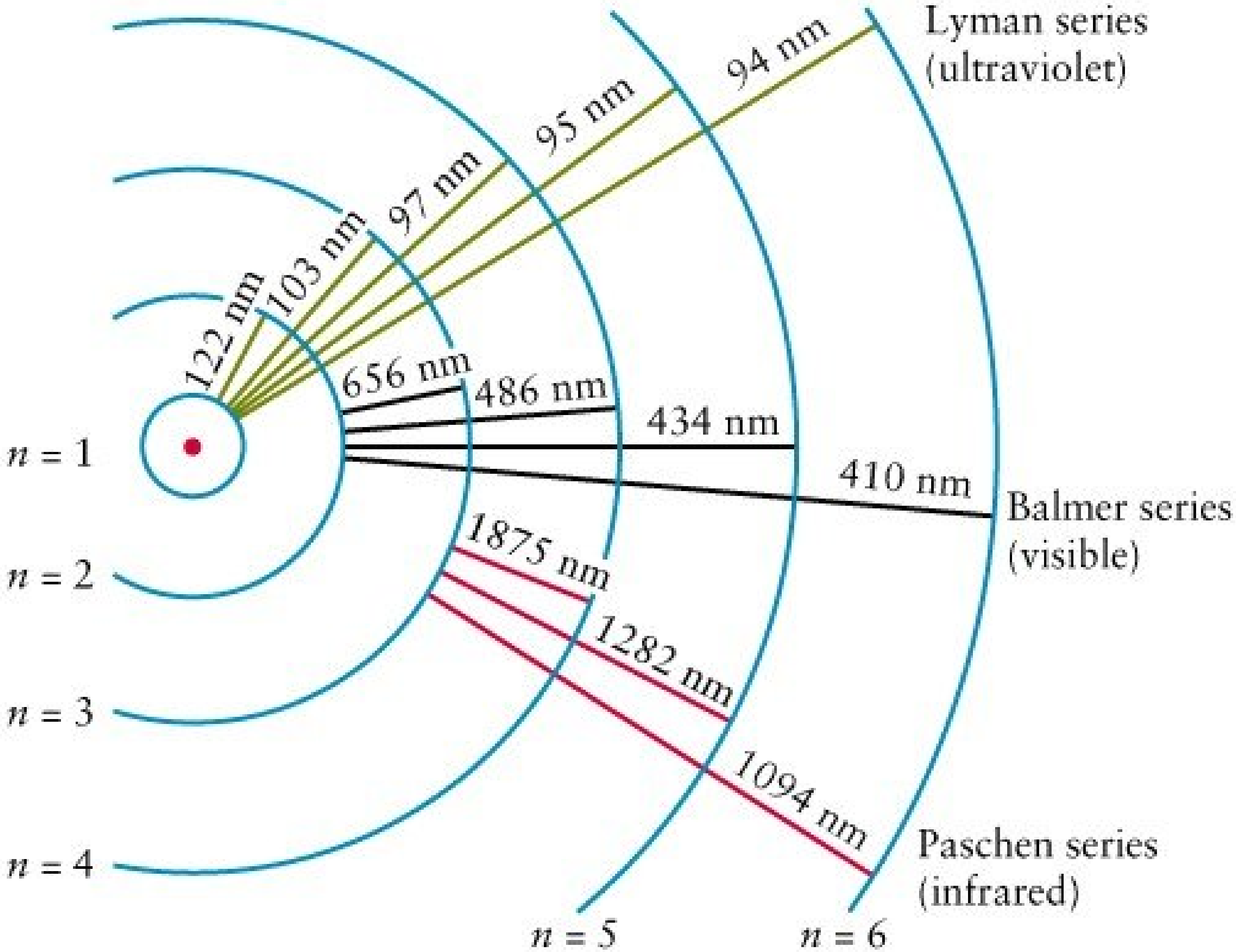
57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No

Ionization

- A neutral atom has the same number of protons and electrons. But if you hit its electrons hard enough (e.g. in collisions with other atoms in a hot gas) or if you hit its electrons with energetic enough light (short wavelength light), you can knock them entirely off the atom.
- Knocking electrons off an atom is called **ionizing the atom**



This is very closely related to the "photoelectric effect" for which Albert Einstein was awarded the Nobel Prize in 1921: http://www.nobelprize.org/nobel_prizes/physics/laureates/1921/press.html



Atomic transitions in hydrogen