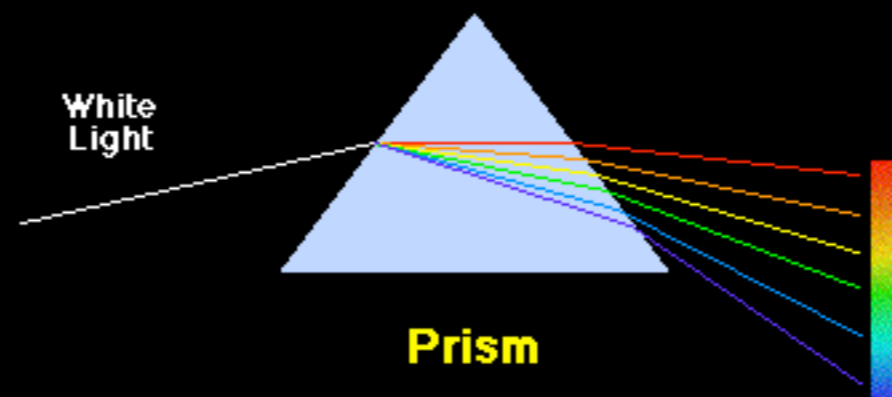


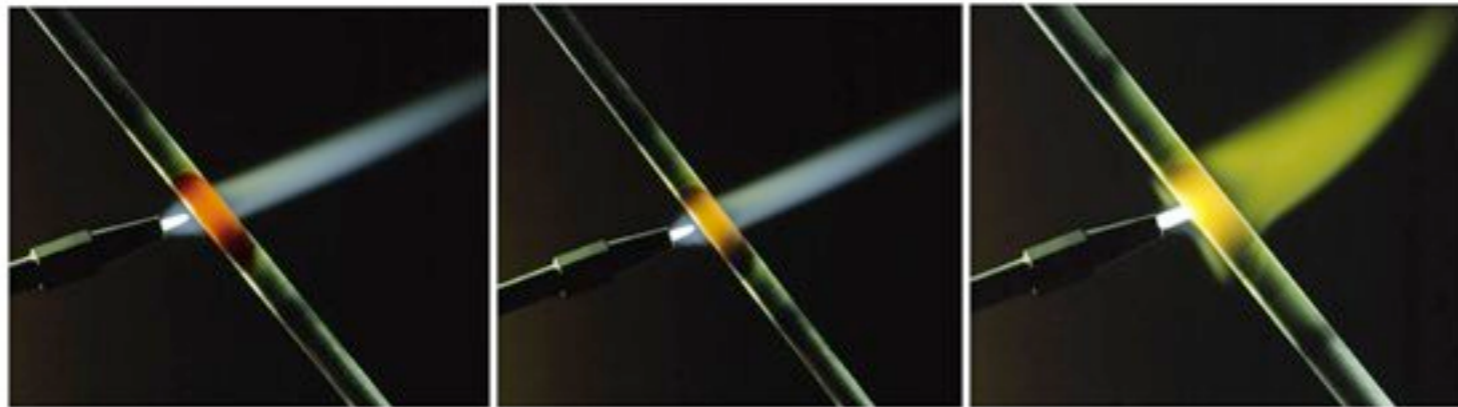
Light

Kirchhoff's Laws of Spectral Analysis

- To understand how stars and galaxies function, we must first understand how such objects produce the light that we observe with our telescopes - light is the only information that we can sample from most astronomical objects.
- In the last century, Gustav Kirchhoff (1824-1887) formulated 3 rules or laws which govern how light is produced by various states of matter. He stated that:
 - A dense, hot substance produces a **continuous** spectrum with all the rainbow colors. An example is a fireplace poker or the filament of a light bulb.
 - A low density, hot gas emits bright **emission lines**. An example is the gas around new stars like the Orion nebula.
 - If a continuous spectrum passes through a gas at a lower temperature, the cooler gas produces dark **absorption lines**.
- The Challenge: Explain these interesting rules for the production of light using our knowledge of matter.



Link :Blackbody Radiation



From left to right an iron bar is heated. As the temperature increases, the amount of energy radiated by the bar increases and so it appears brighter. The apparent color of the bar changes because as the temperature rises, the dominant wavelength of emitted light decreases. This behavior is explained by Black Body radiation theory.

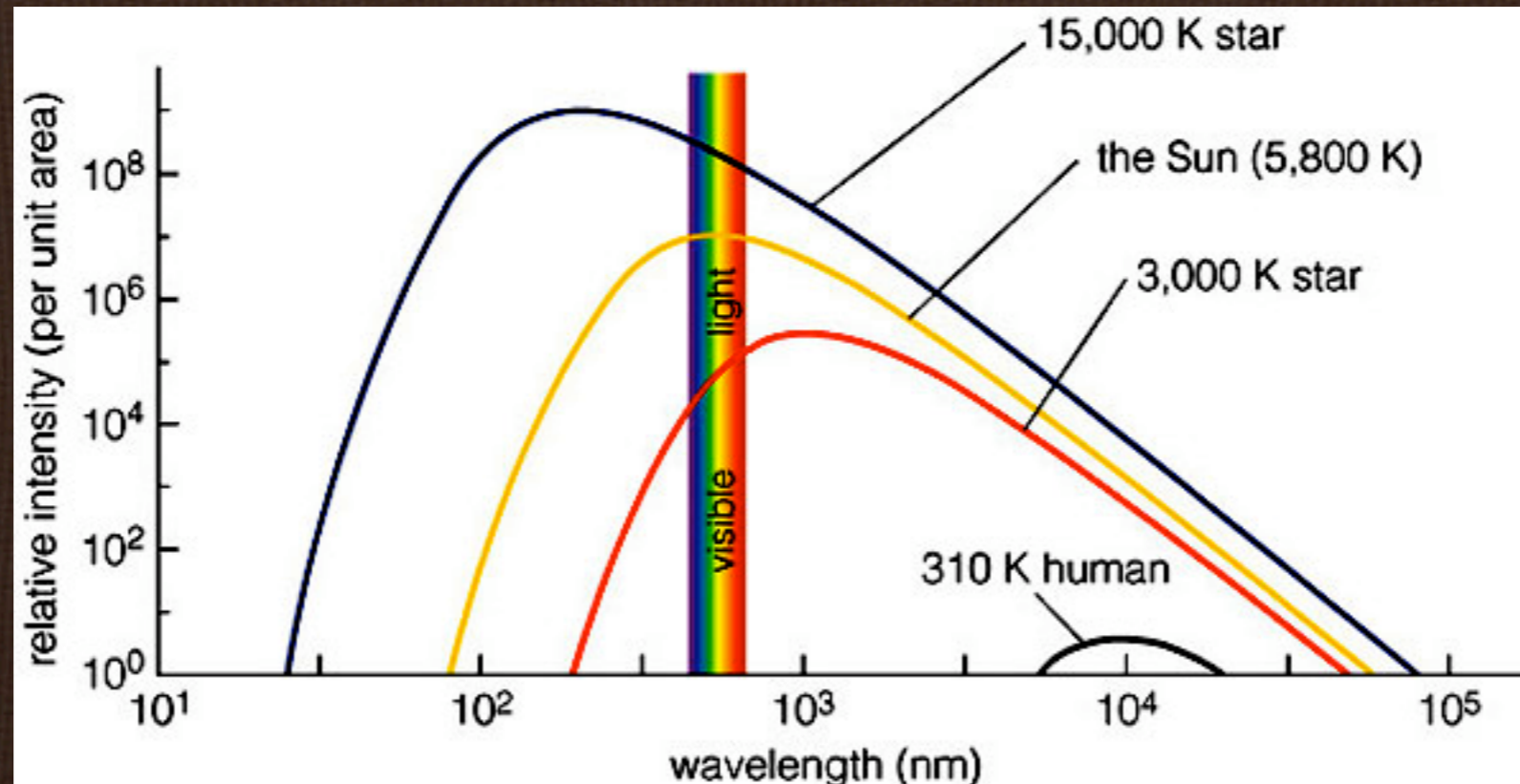


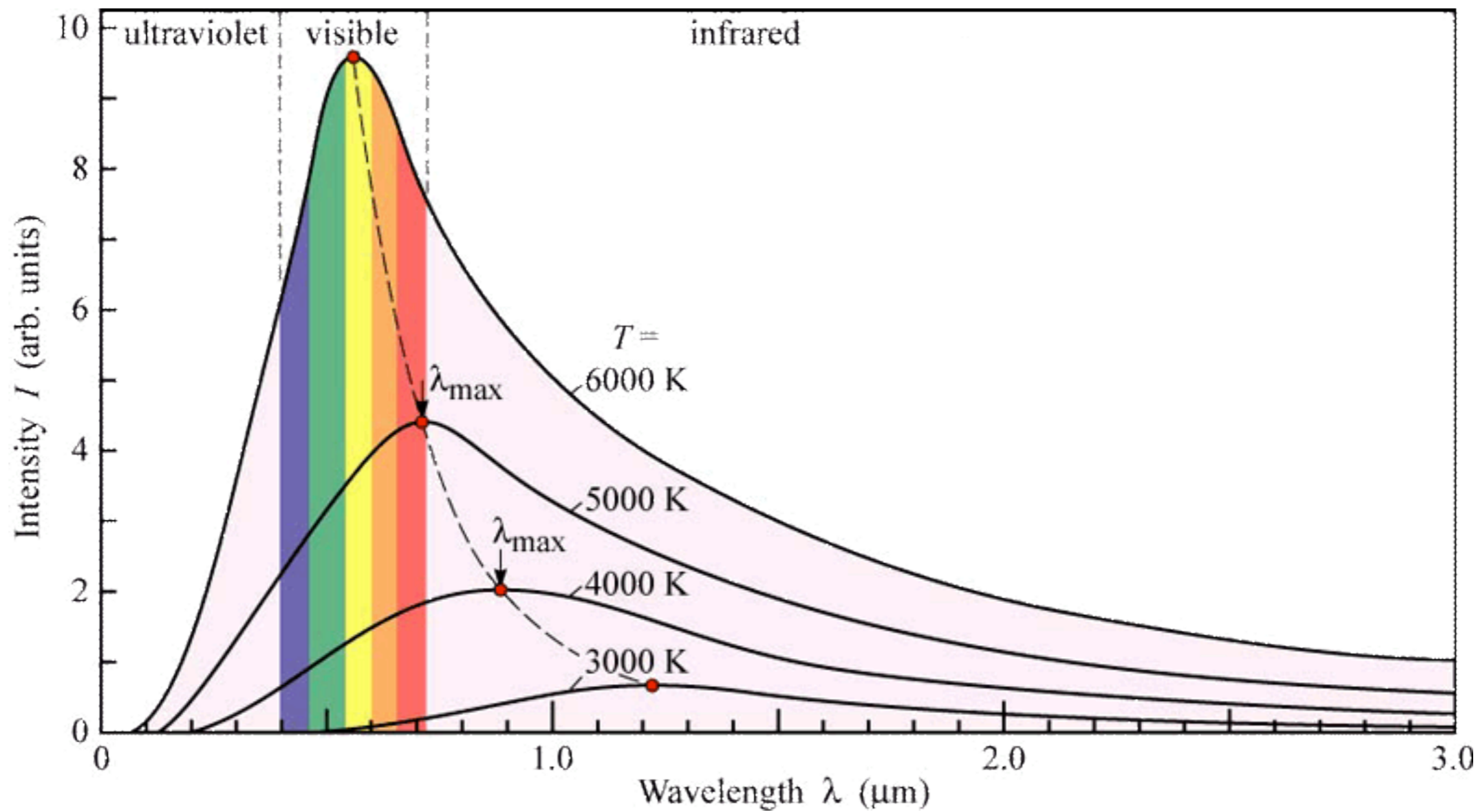
Max Planck: 1858

Graphs of idealized thermal radiation spectra.

Hotter objects emit more radiation per unit surface area (intensity) at every wavelength.

The peaks of the spectra occur at shorter wavelengths



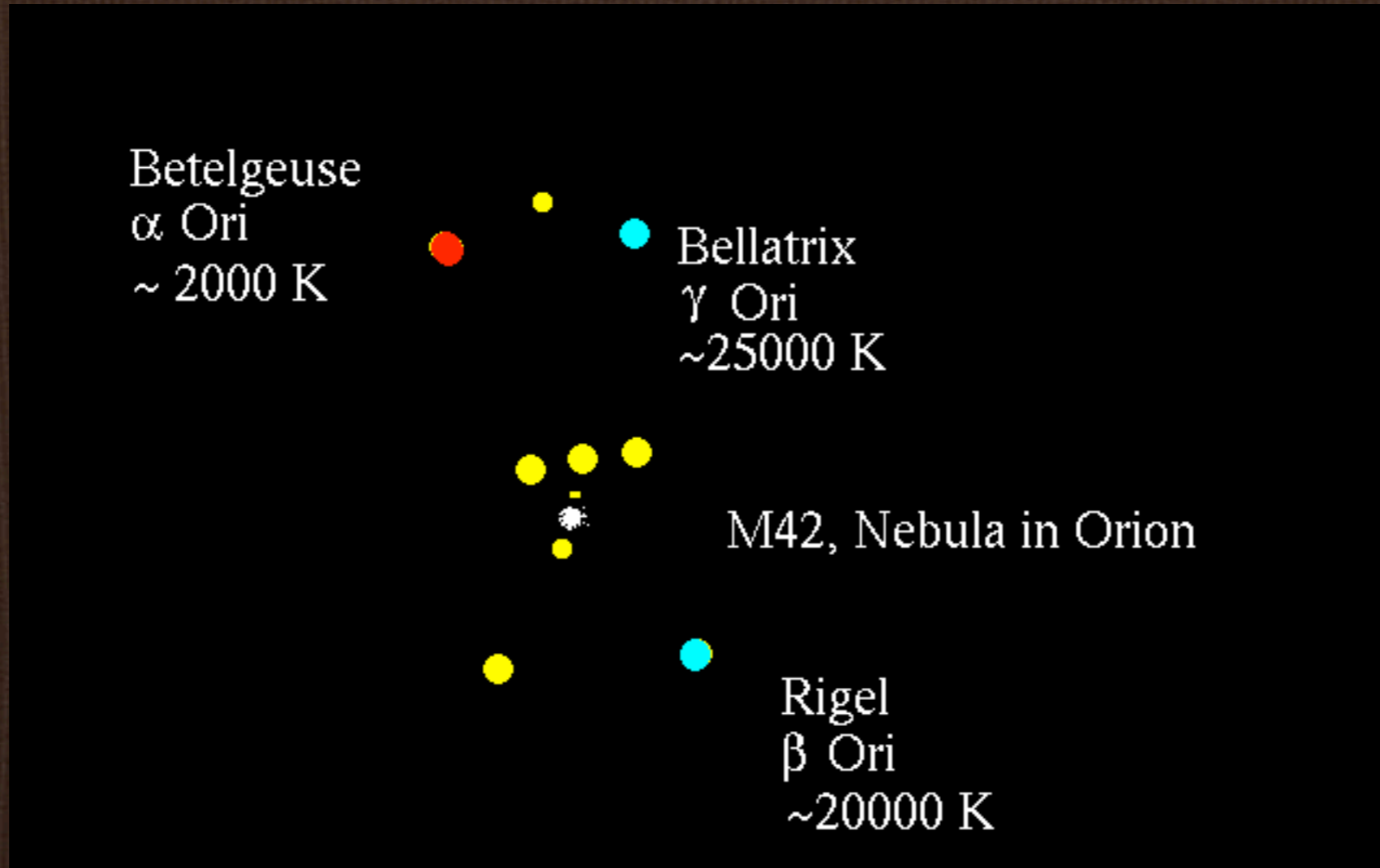


Betelgeuse
 α Ori
~ 2000 K

Bellatrix
 γ Ori
~25000 K

M42, Nebula in Orion

Rigel
 β Ori
~20000 K



Continuous Emission & Blackbody Radiation

A blackbody emits continuous radiation and meets the conditions outlined by Kirchhoff. The properties of a blackbody include:

- The electromagnetic radiation from a blackbody is strongly peaked at a particular wavelength that depends only on the temperature of the blackbody. A hot blackbody will appear to be blue and a cool blackbody will appear to be red. So, by just looking at the color of a star, you can get a pretty good idea of its temperature! A yellow star like the Sun has a temperature of 5500 K, whereas a red star like Betelgeuse has a temperature of only 3000 K.
- A blackbody emits some radiation at all wavelengths.
- The energy per area radiated by a blackbody will increase with temperature. In other words, for two stars at the same distance with the same radii, the star with the highest temperature will appear to be the brightest.

Spectral Lines & the Bohr Model

- Neils Bohr in the early part of this century first correctly described a working model for the hydrogen atom. He hypothesized that electrons can only occupy certain orbits at selected distances from the nucleus. They cannot lie between these particular orbits. Furthermore, each atom has a unique set of orbits which corresponds to different orbital energies. So, the electron orbits are said to be *quantized*.
 - The lowest orbit or energy level of an atom is called the *ground state*.
 - When an electron is in some orbit above the ground state, it is said to be *excited*.
- Next, Bohr recognized that when an electron jumps from a larger radius (or higher energy level) orbit to a lower radius orbit, it must give up energy. This energy is in the form of a photon which has exactly the energy that corresponds to the difference in energy between the two orbits. Such an electron transition produces an emission line.



Niels Bohr was born in Copenhagen on October 7, 1885

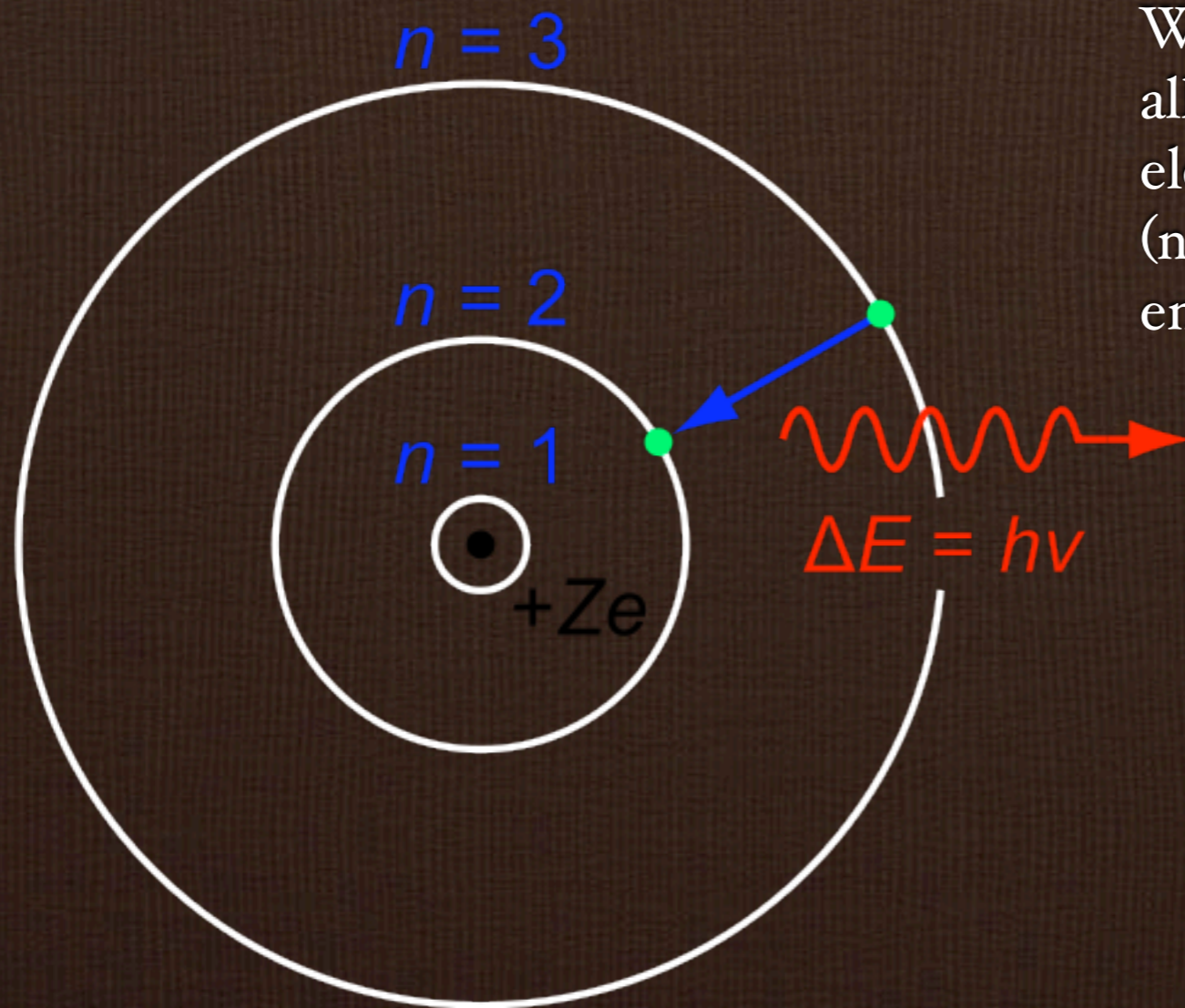
During the Nazi occupation of Denmark in World War II, Bohr escaped to Sweden and spent the last two years of the war in England and America, where he became associated with the Atomic Energy Project

In 1943, under threat of immediate arrest because of his Jewish ancestry and the anti-Nazi views he made no effort to conceal, Bohr, together with his wife and some other family members, was transported to Sweden by fishing boat in the dead of night by the Danish resistance movement. A few days later the British government sent an unarmed Mosquito bomber to Sweden, and Bohr was flown to England in a dramatic flight that almost cost him his life.

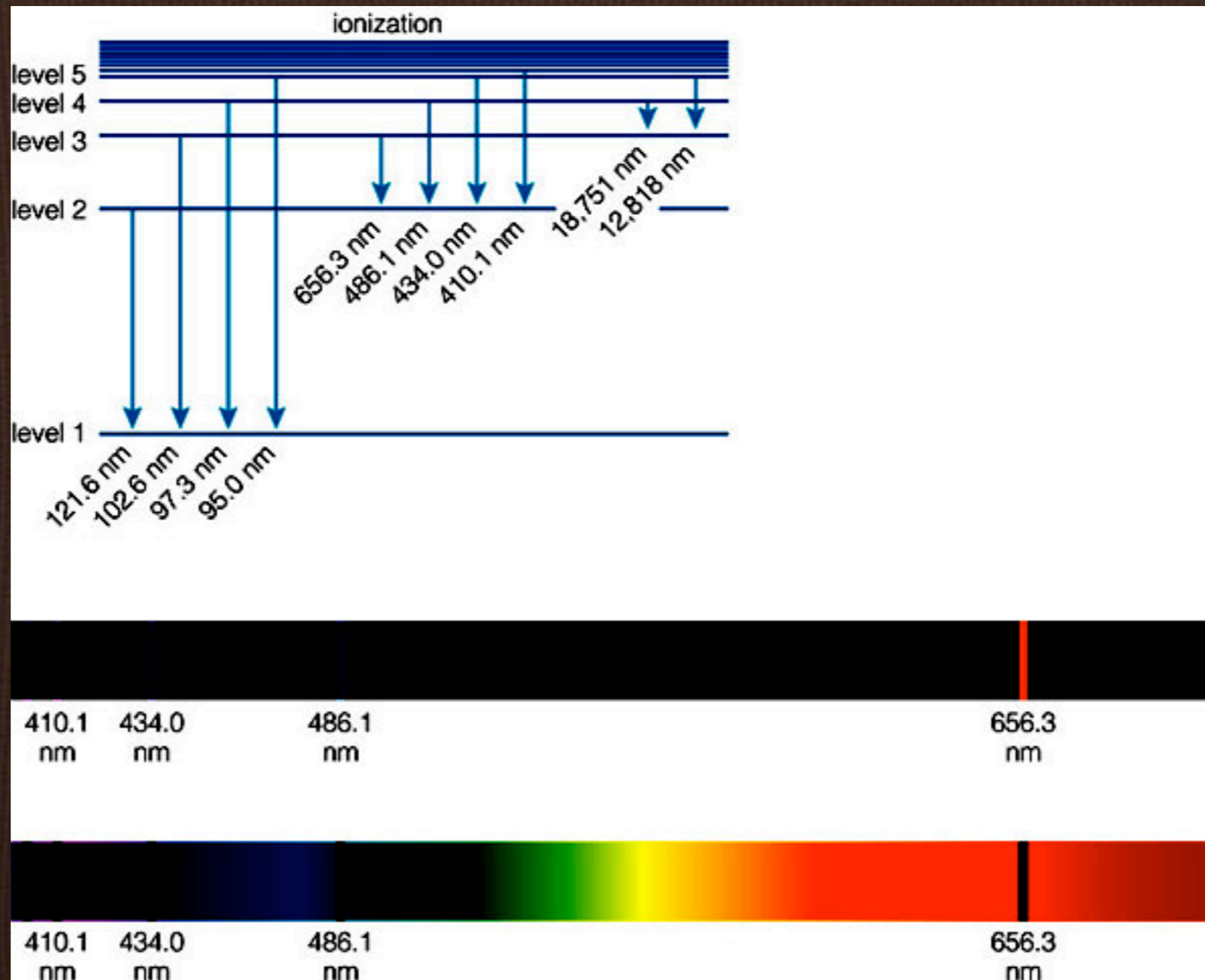
Niels Bohr died in Copenhagen on November 18, 1962.

A very simplified Borh's model of atom

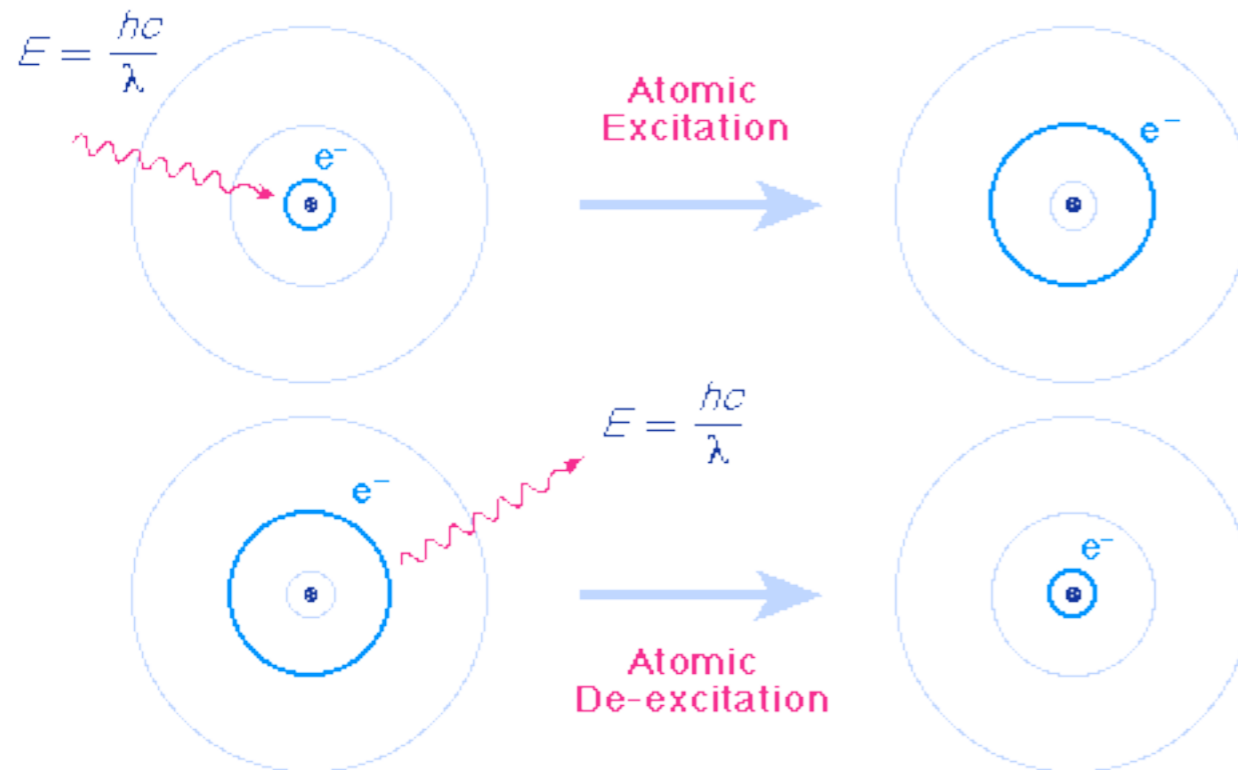
Electrons orbiting nucleus can occupy only discrete energy states. In this diagram nucleus is the black circle in the center. It has positive charge Z measured in unit of the charge of an electron. White circles schematically show allowed positions of electrons. When an electron jumps from high energy state ($n=3$) to lower energy ($n=2$) a photon is emitted.



An atom emits or absorbs light only at specific wavelengths that correspond to changes in the atom's energy as an electron jumps between its allowed energy levels.



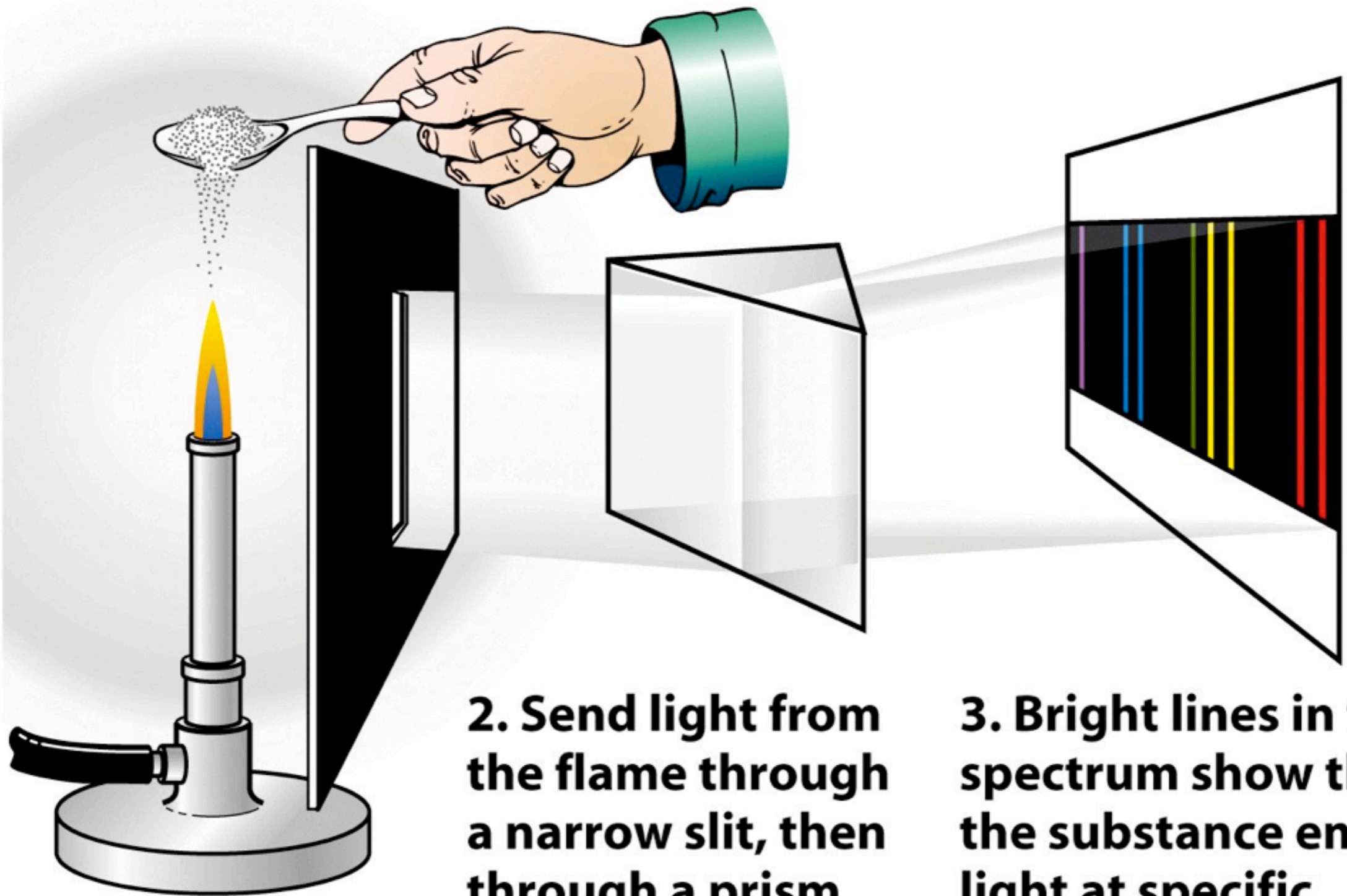
A very simplified Borh's model of atom



When a photon with energy equal to the energy of one of allowed transitions is absorbed, electron receives the energy and gets into high energy state.

After some time the electron spontaneously jumps back to lower energy state and emits a photon. Energy of the photon is exactly the same as the energy of the photon, with produced the excitation. However, direction of the emitted photon is totally random.

1. Add a chemical substance to a flame



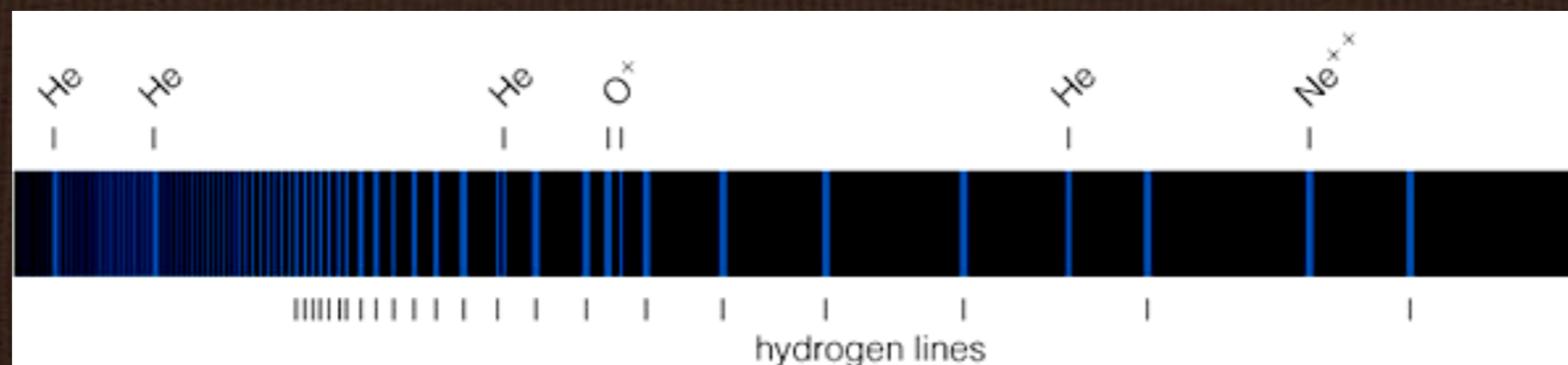
2. Send light from the flame through a narrow slit, then through a prism

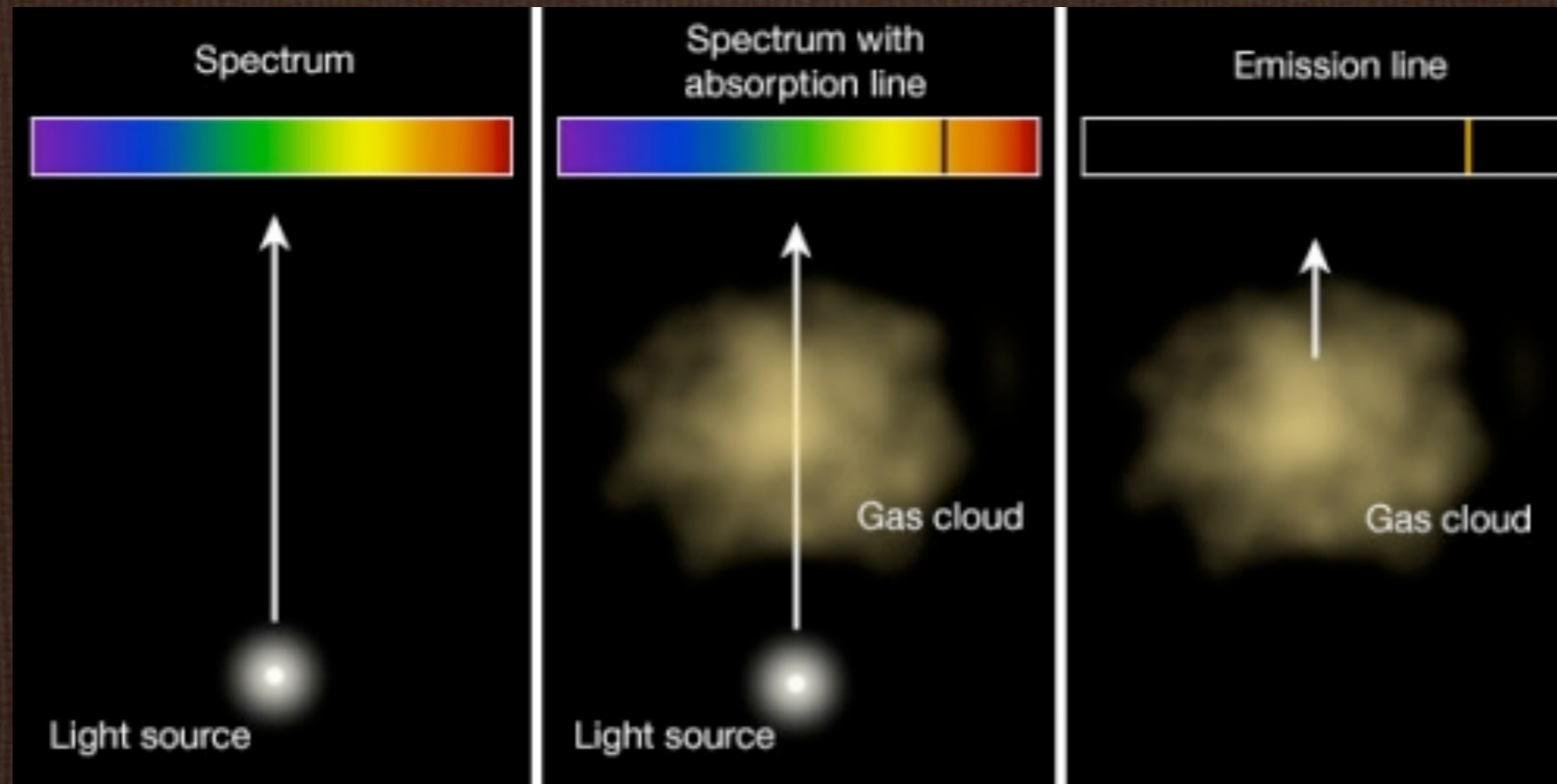
3. Bright lines in the spectrum show that the substance emits light at specific wavelengths only

Visible-light emission line spectra for helium, sodium, and neon. The patterns and wavelengths of lines are different for each element, giving each a unique spectral fingerprint.



The emission line spectrum of the Orion Nebula in a portion of the ultraviolet (about 350–400 nm). The lines are identified with the chemical elements or ions that produce them (He = helium; O = oxygen; Ne = neon).





(a) An opaque object produces a continuous spectrum of thermal radiation.

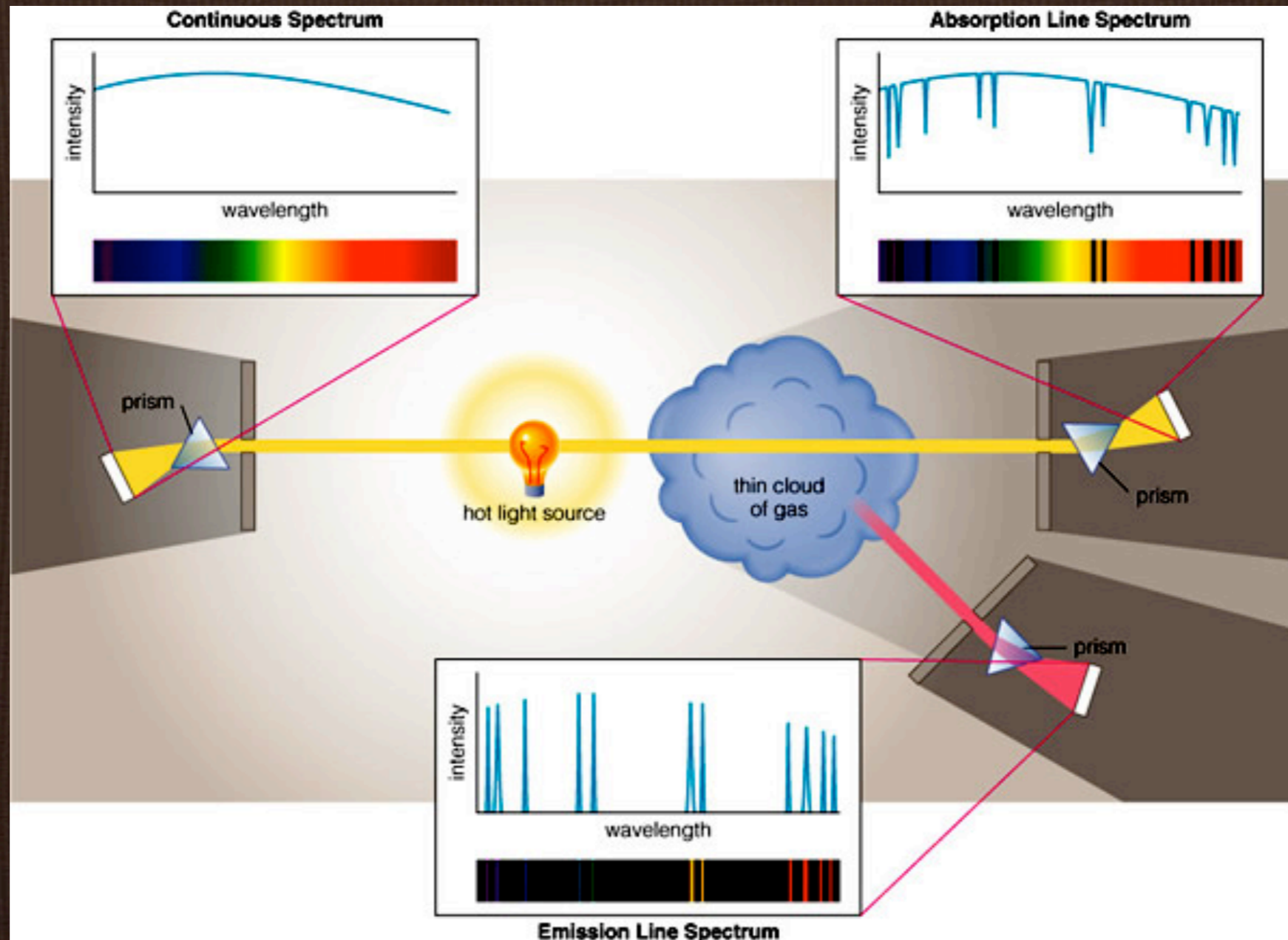
(b) If thermal radiation passes through a thin (transparent) gas, dark absorption lines are superimposed on the continuous spectrum.

(c) If the cloud of gas is viewed against a dark background, it produces an emission line spectrum.

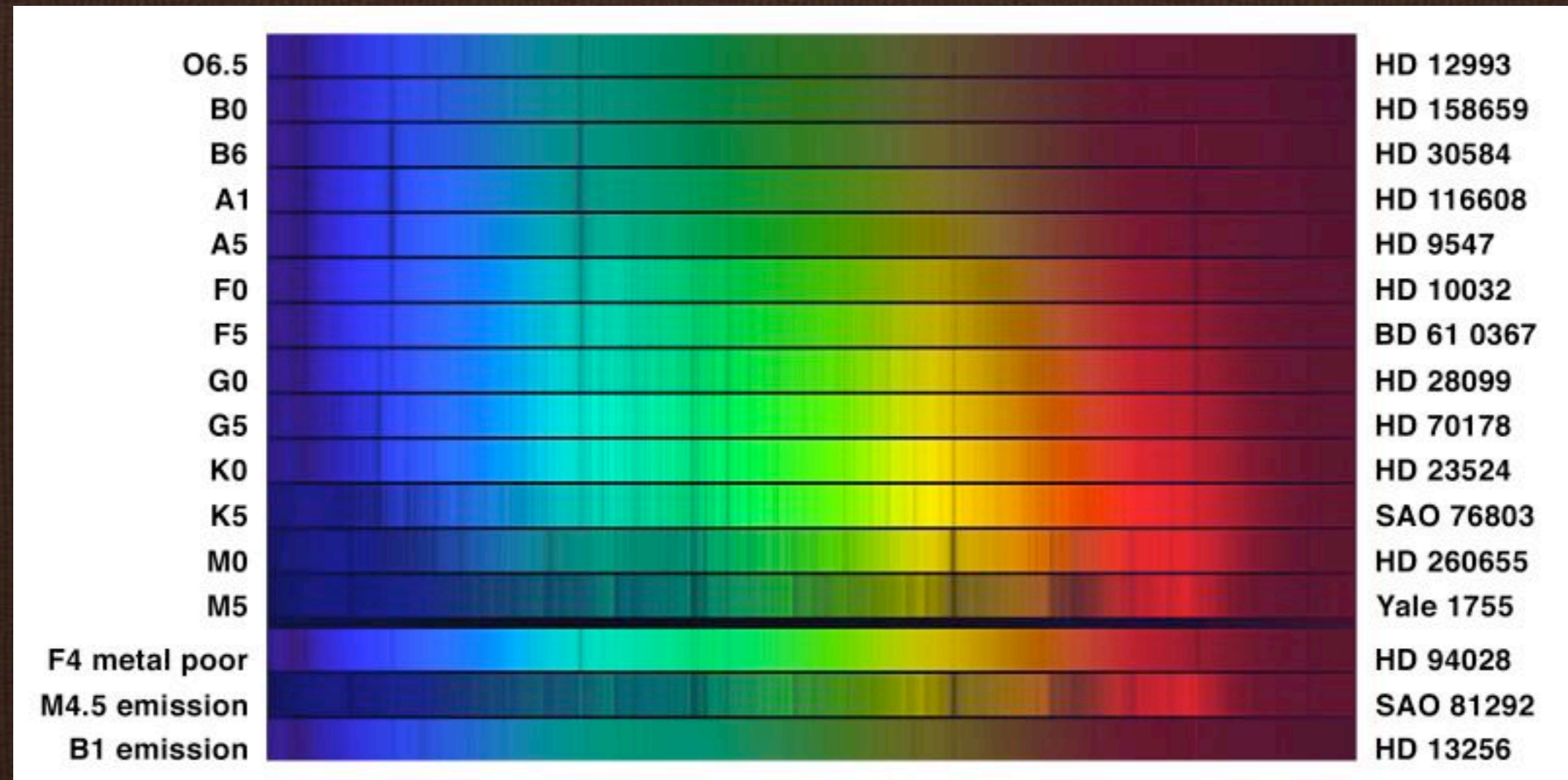
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Spectra of different Stars



Spectrum of our Sun

