Light & Telescopes

D.J. Pisano
Associate Professor of Physics & Astronomy

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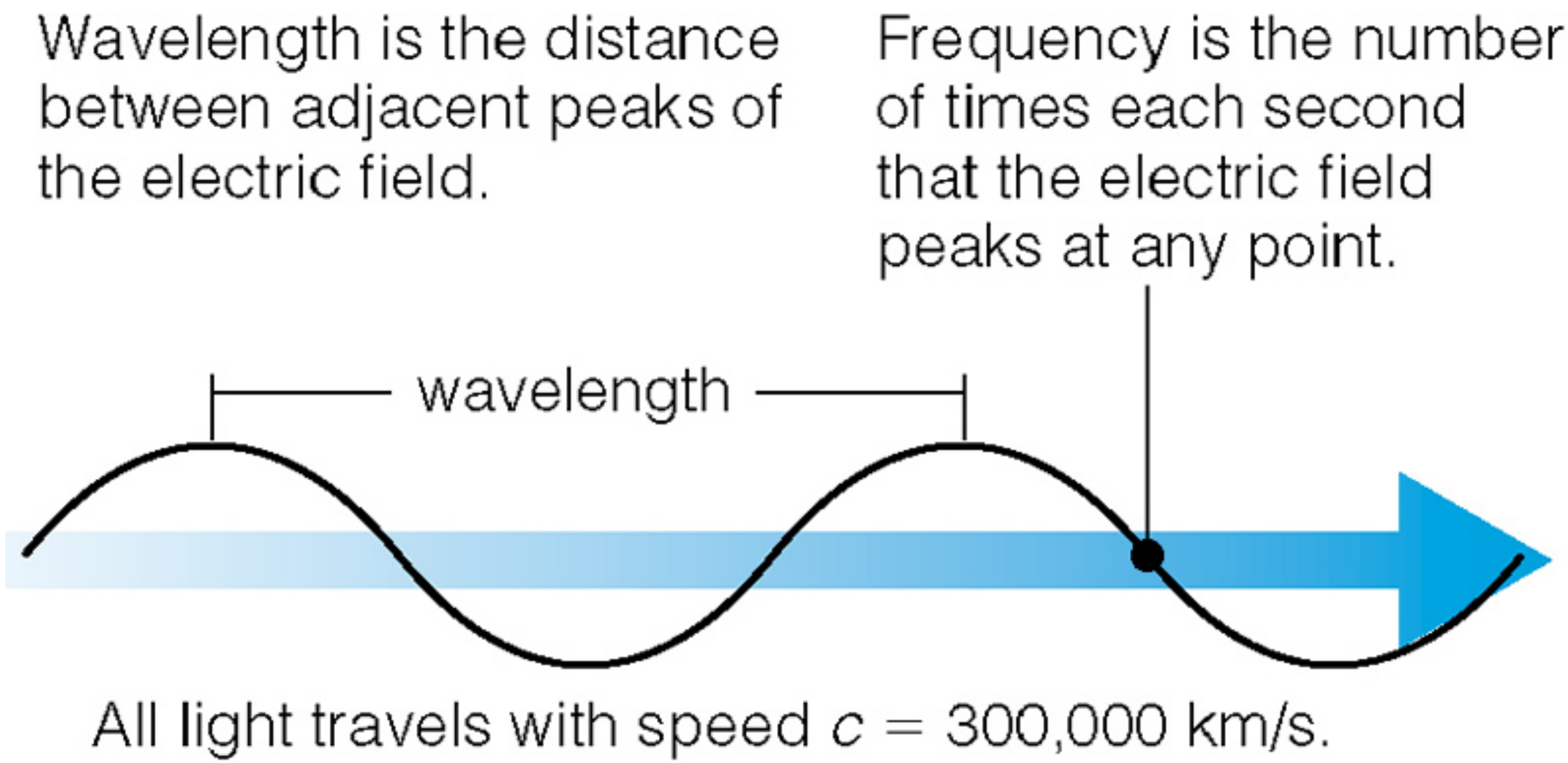
Light and Telescopes

With few exceptions, astronomers can only learn about the Universe by using *telescopes* to look at *light* from distant objects.

We can not do experiments on the Universe (or even small parts of it).

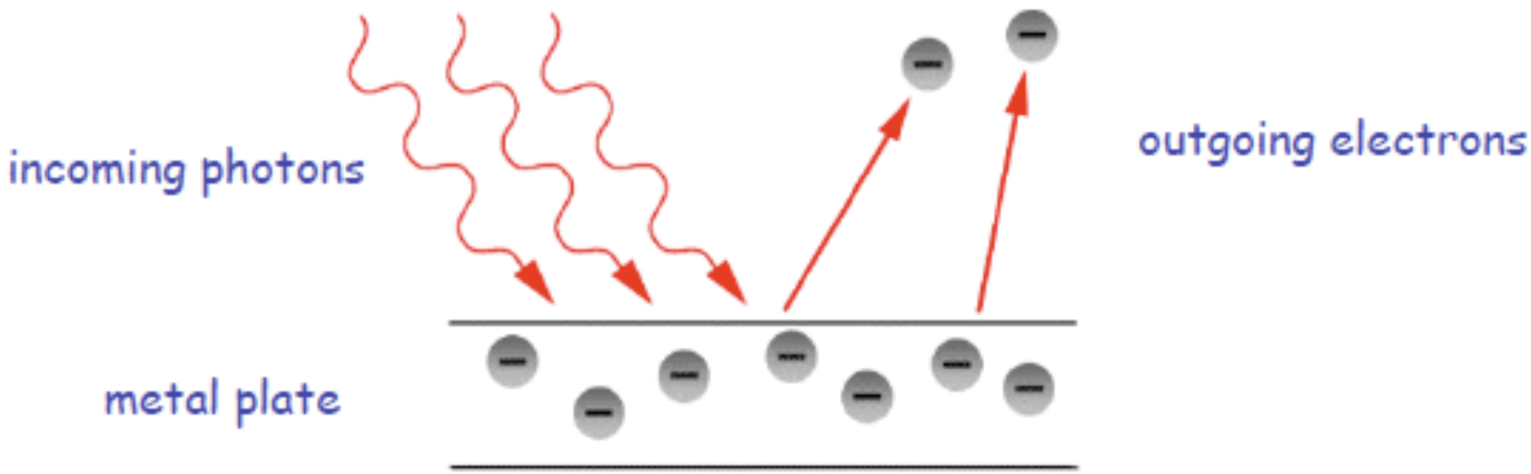
We must **observe** the Universe.

Light is a wave



Light is a particle

- In 1905, Einstein discovered that light had discrete energies ➔ light can appear as particles called *photons*.



This is called the *photoelectric effect*.

It is how light sensors for doors, toilets, etc. work.

Light as photons

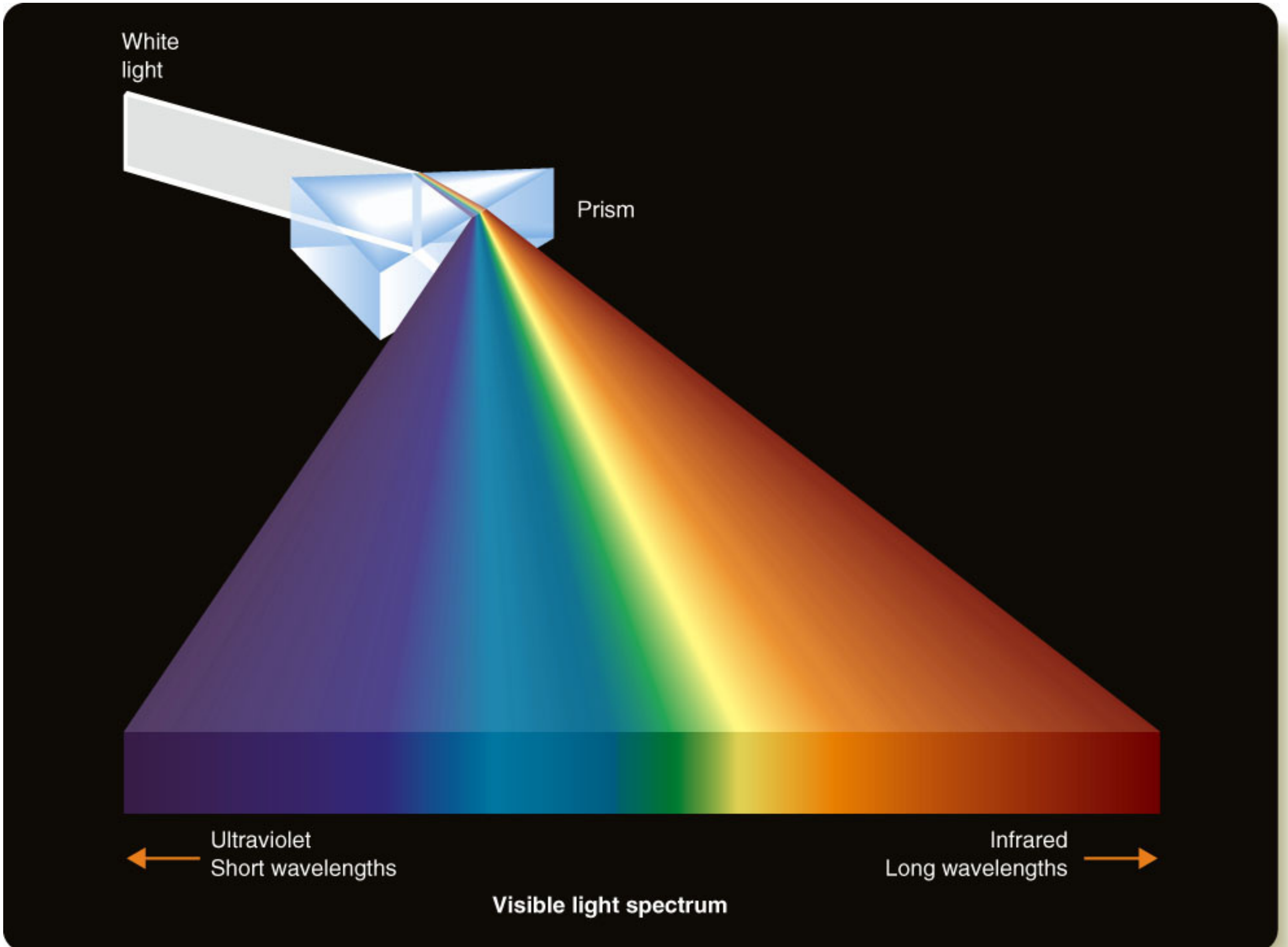
The *energy* of a *photon* is proportional to the *frequency* of the light.

Higher frequency means higher energy.

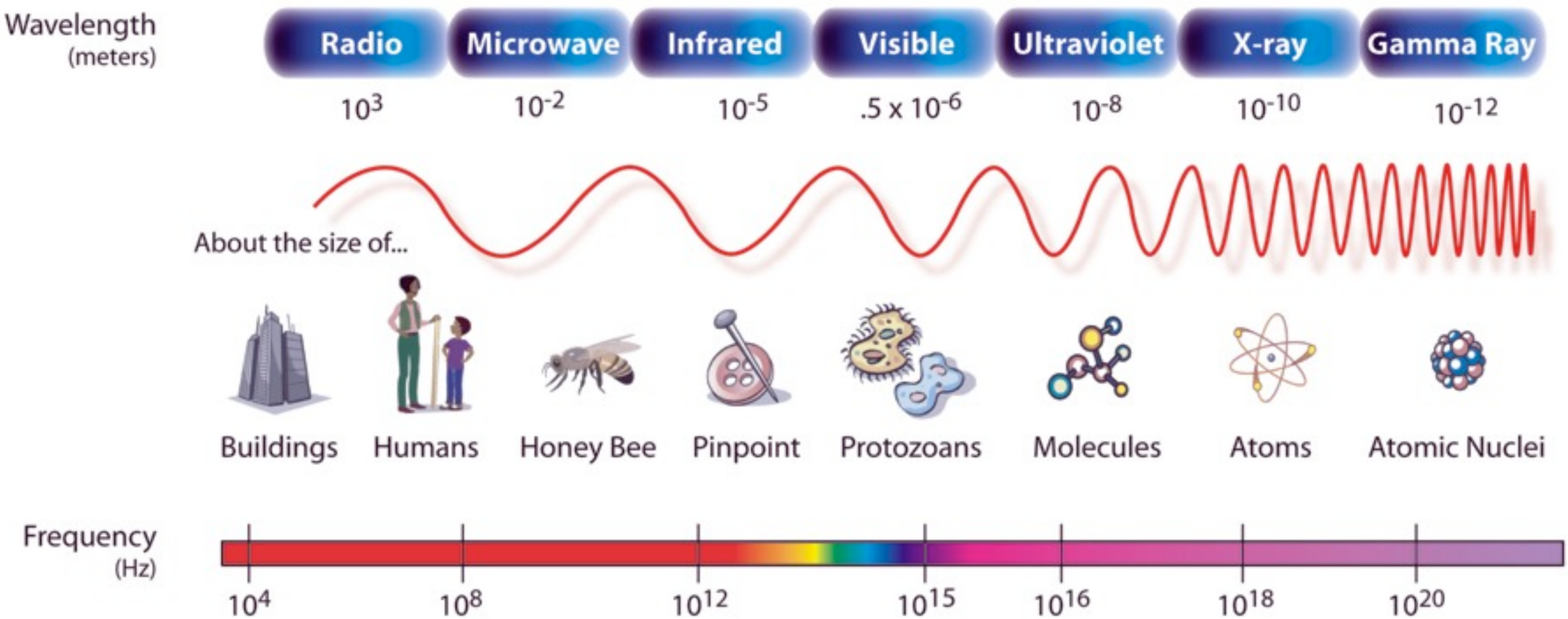
The energy of light is ***not*** related to *intensity* (how bright it is).

Higher intensities mean ***more*** photons mean brighter light.

The Electromagnetic Spectrum



The Electromagnetic Spectrum



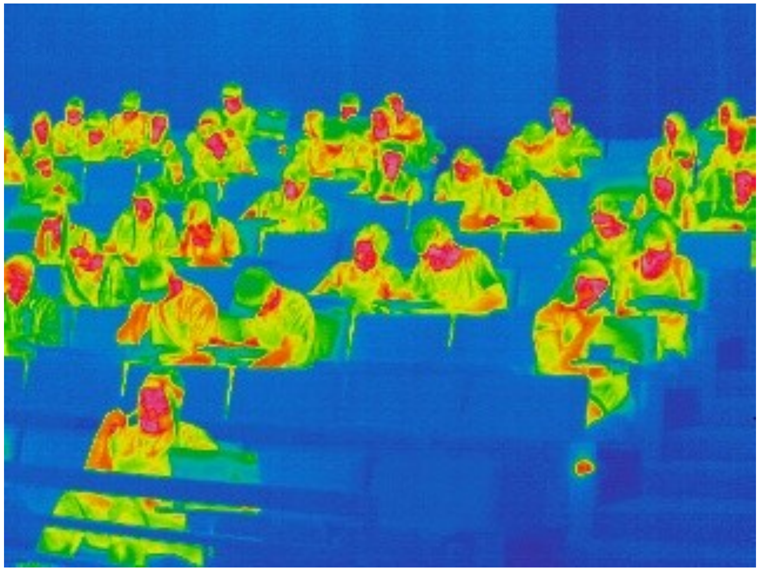
Lower Frequency = Longer Wavelength = Low Energy

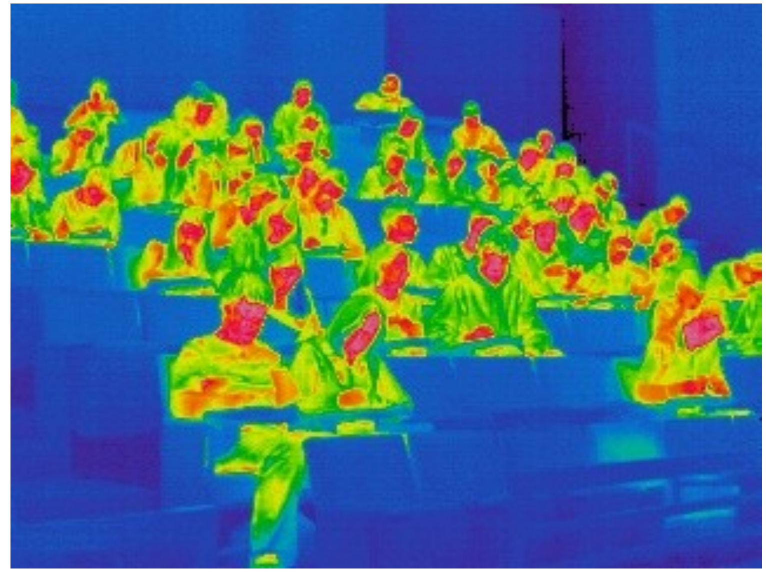
Higher Frequency = Shorter Wavelength = High Energy

The world looks different at different wavelengths of light

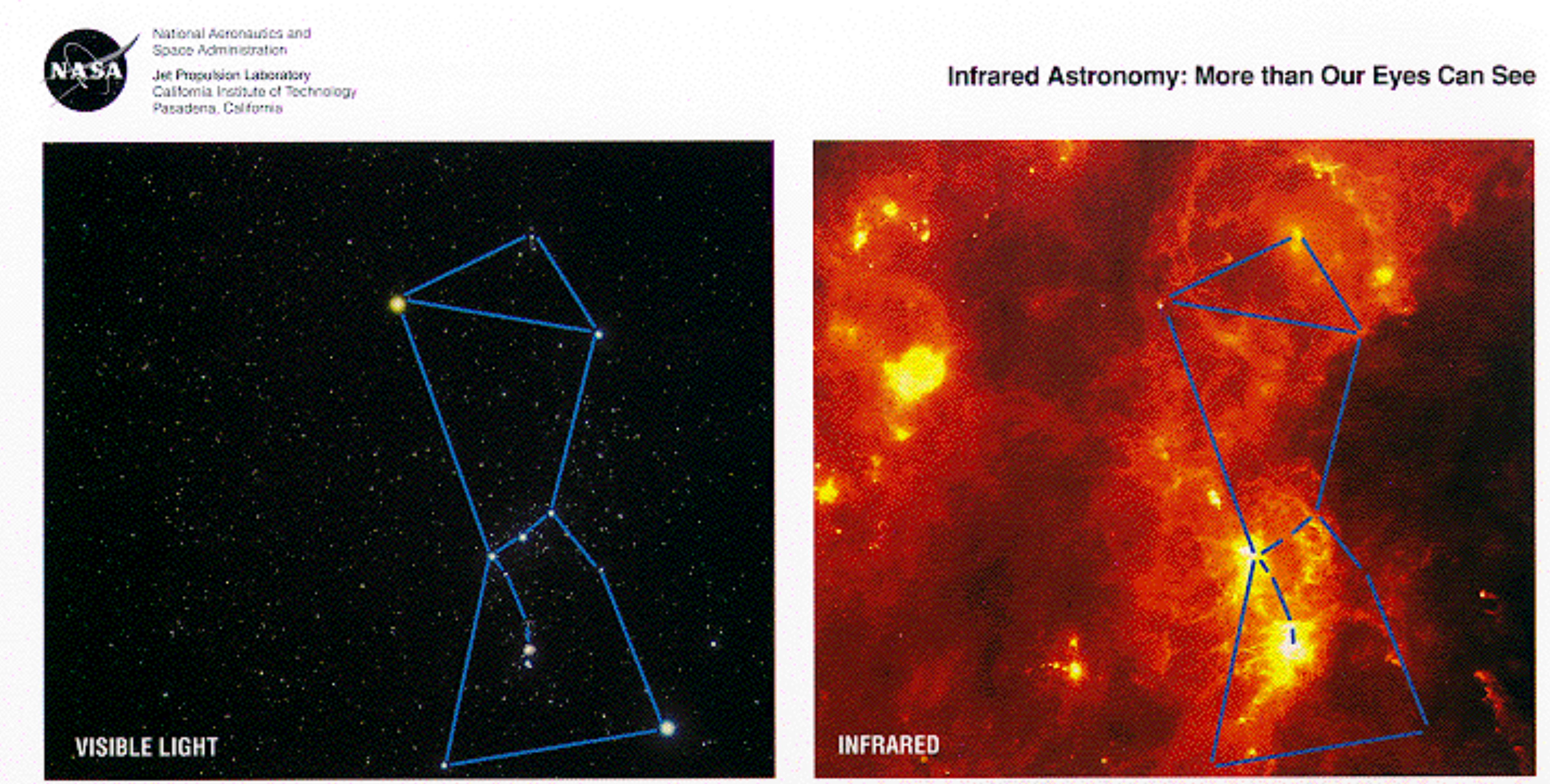
Consider infrared light...otherwise known as **heat**.

This is an astronomy class seen in infrared and visible light.





Consider Orion as Seen in Different Wavelengths of Light!



Review Questions

Question 1:

Light with a shorter wavelength has a _______ frequency.

A. higher
B. lower

Question 2:

Light with a higher frequency has a _______ energy.

A. higher
B. lower

Question 3:

Light with a higher frequency travels _______ light with a lower frequency.

A. faster than

B. slower than

C. at the same speed as

Question 4:

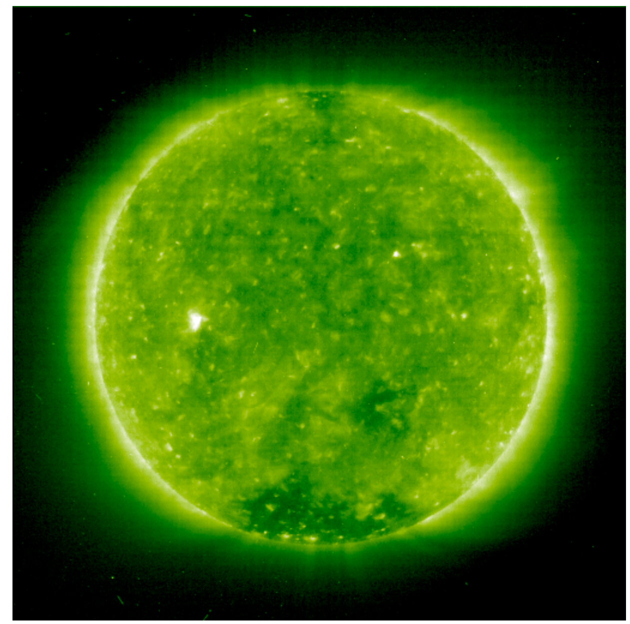
Which of the following does not emit light?

A. A light bulb
B. The Sun
C. People
D. A fire
E. All of the above emit light

Sunlight

By observing light from a star, we can learn about a star's:

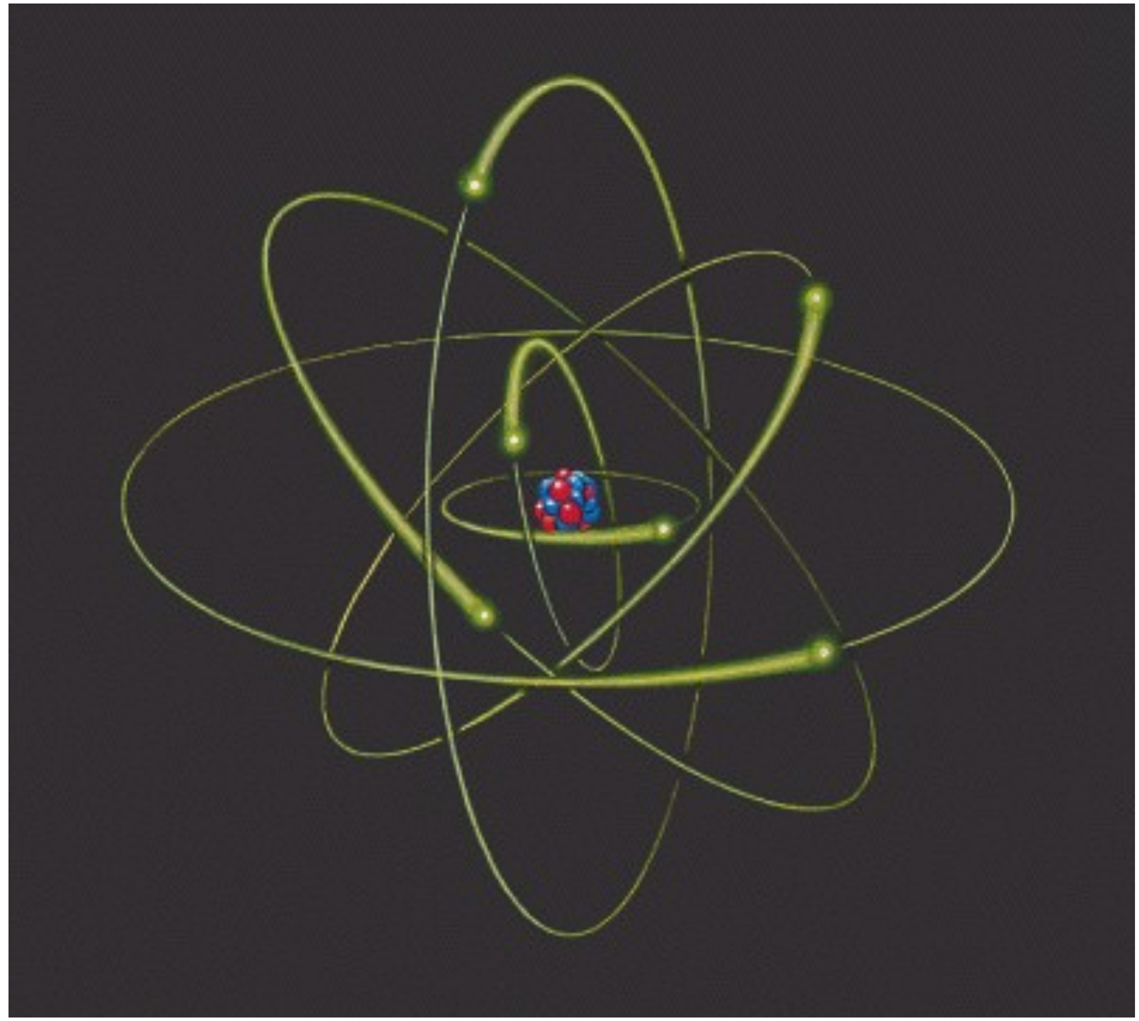
1. Total Energy Output
2. Surface Temperature
3. Radius
4. Chemical Composition
5. Velocity relative to Earth



And more…

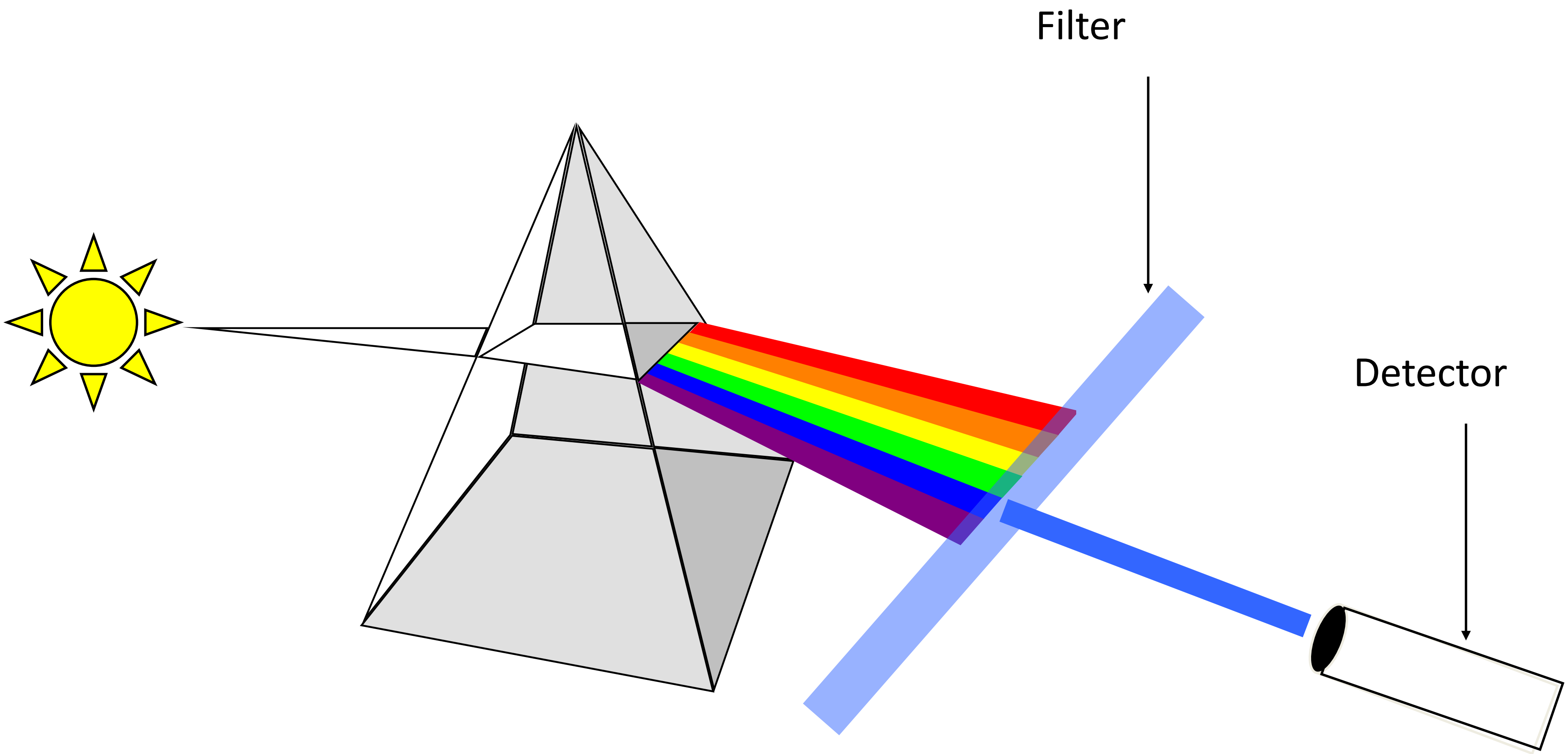
Everything is made of atoms

- All material is made up of *atoms*.
- Atoms are made from *protons*, *neutrons,* and *electrons.*
- Protons and neutrons are in the nucleus. Electrons move around the nucleus.

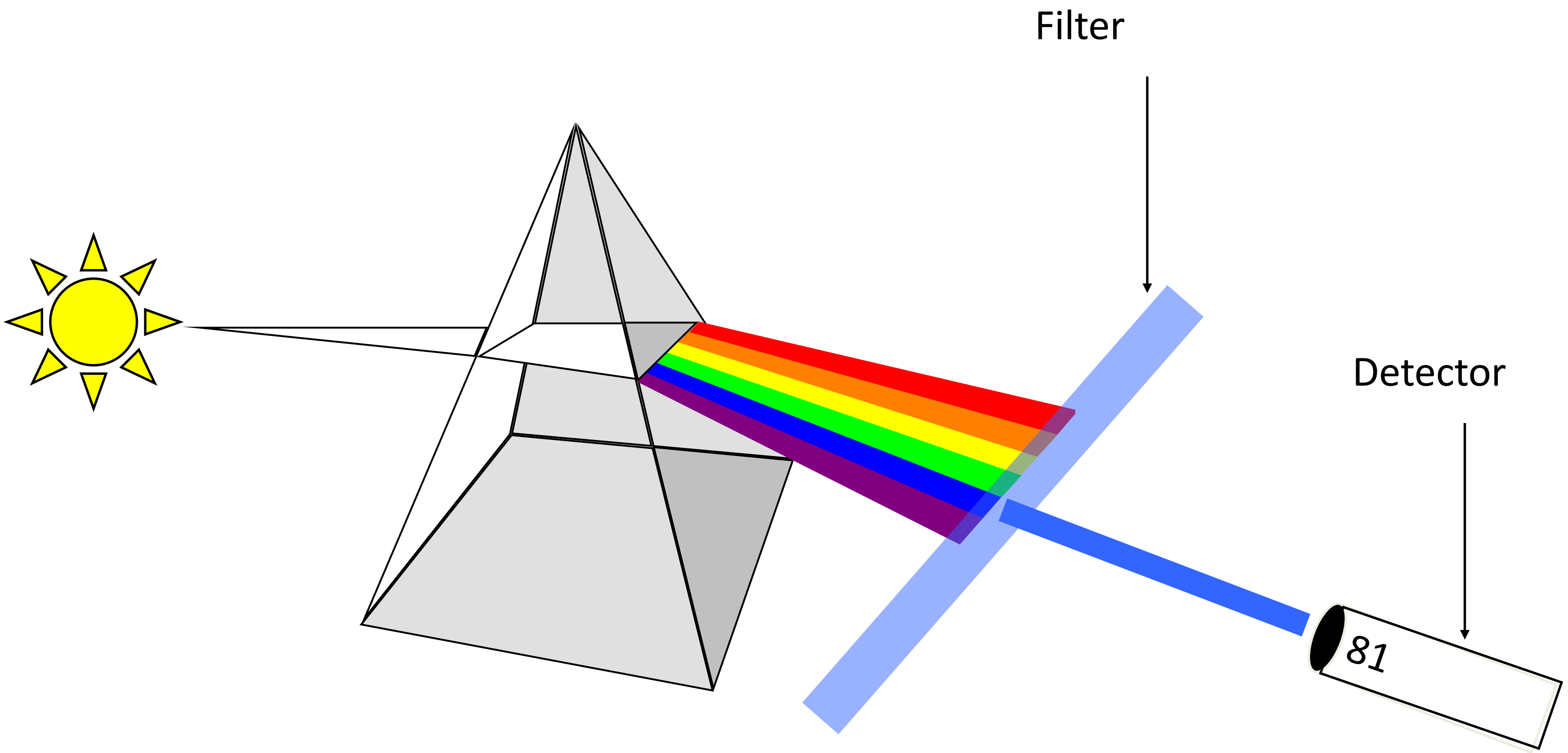


But where does the light come from?

- When something is hot, it’s atoms move around bumping into each other and the electrons in the material. The hotter it is, the more the atoms and electrons bump into each other.
- The electrons are accelerated when they are bumped and emit energy as *thermal radiation.*

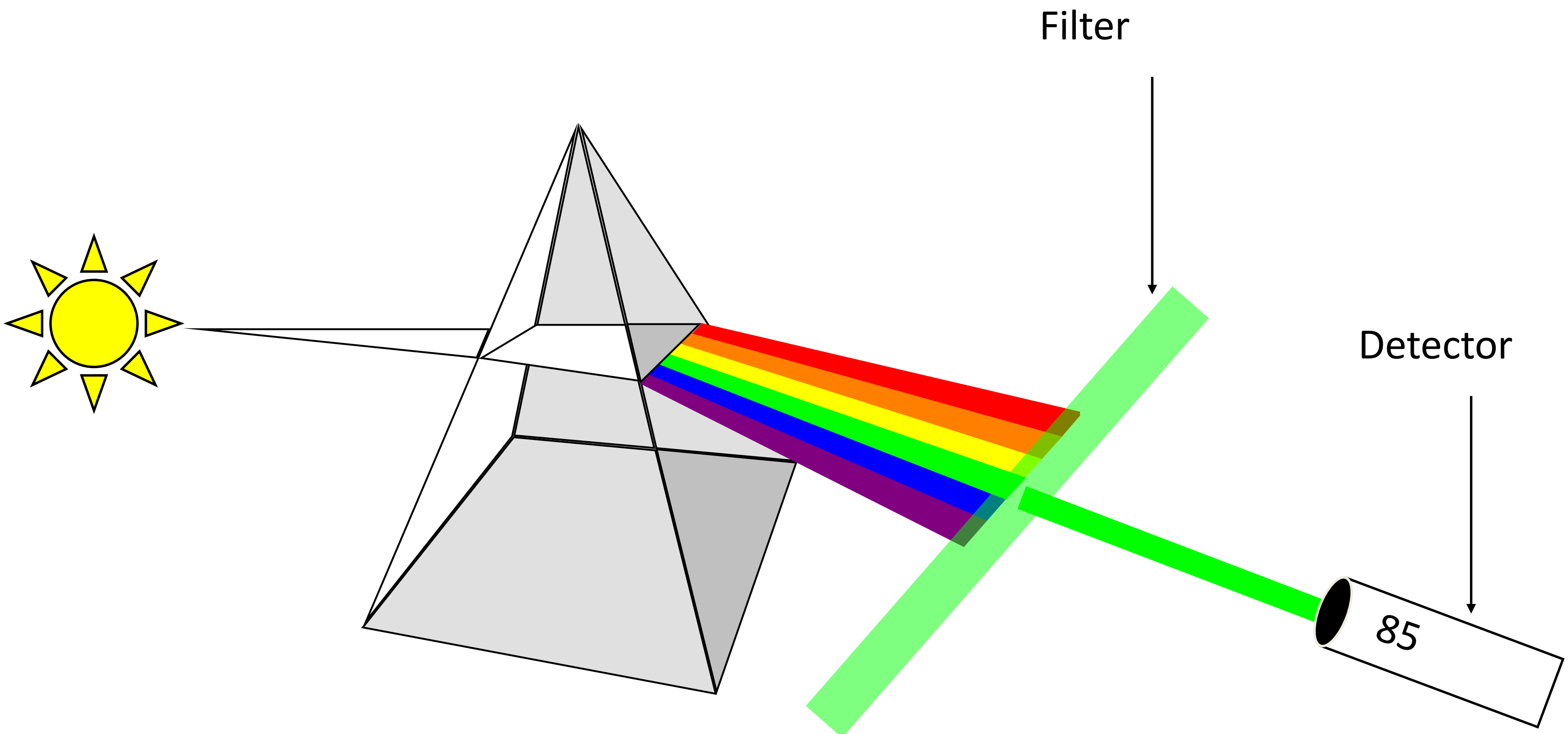

Filter
Detector

blue 4600 A 81



blue 4600 A 81

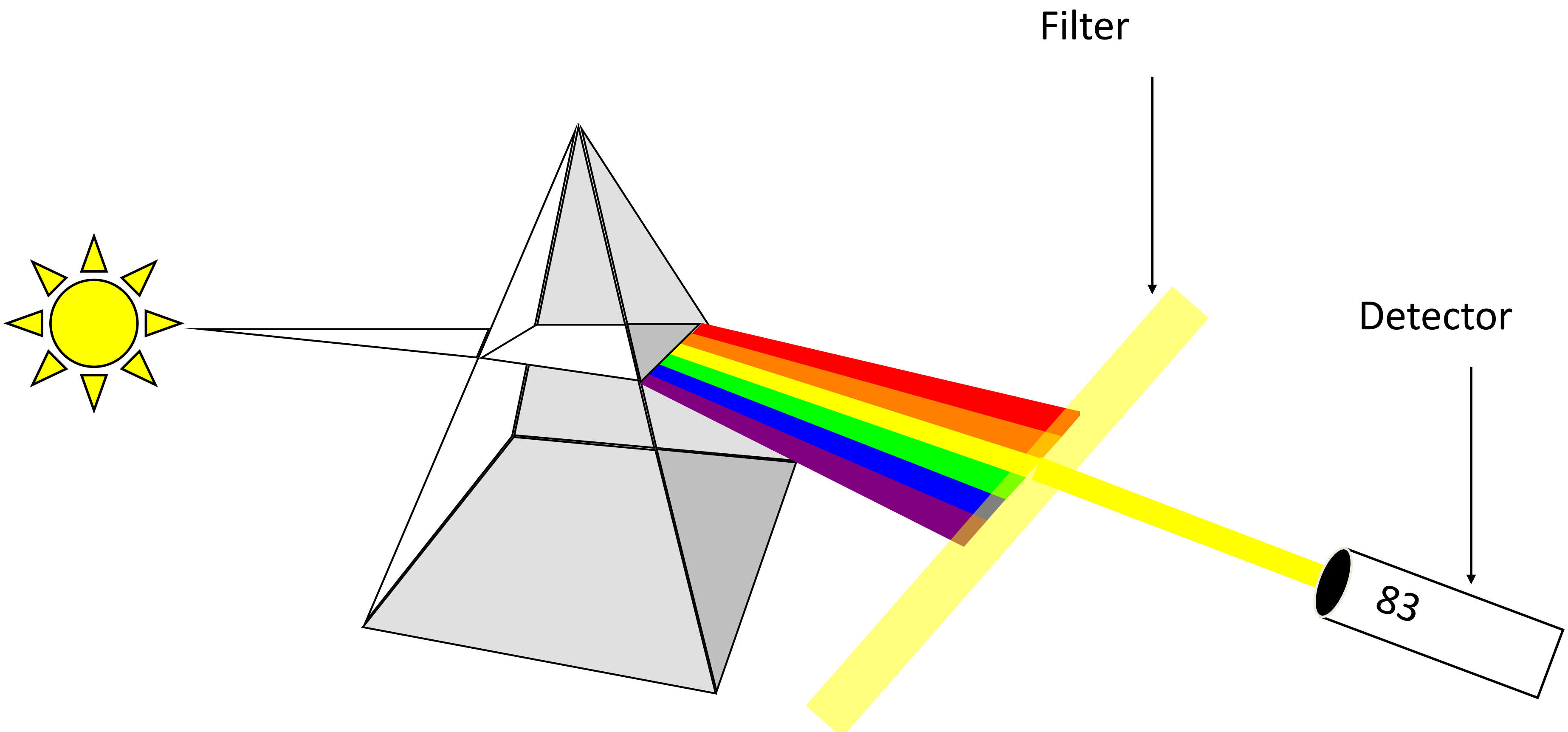
green 5300 A 85



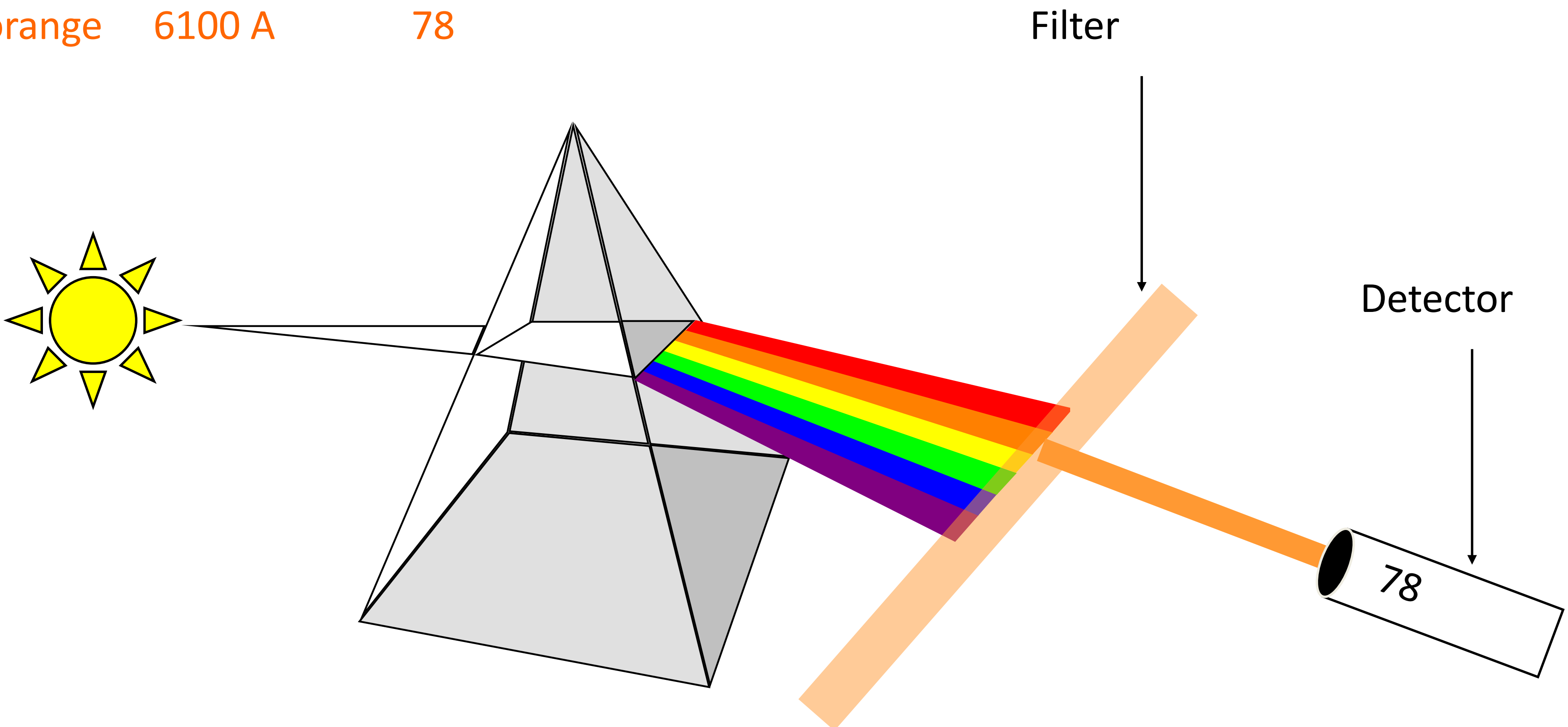
blue 4600 A 81

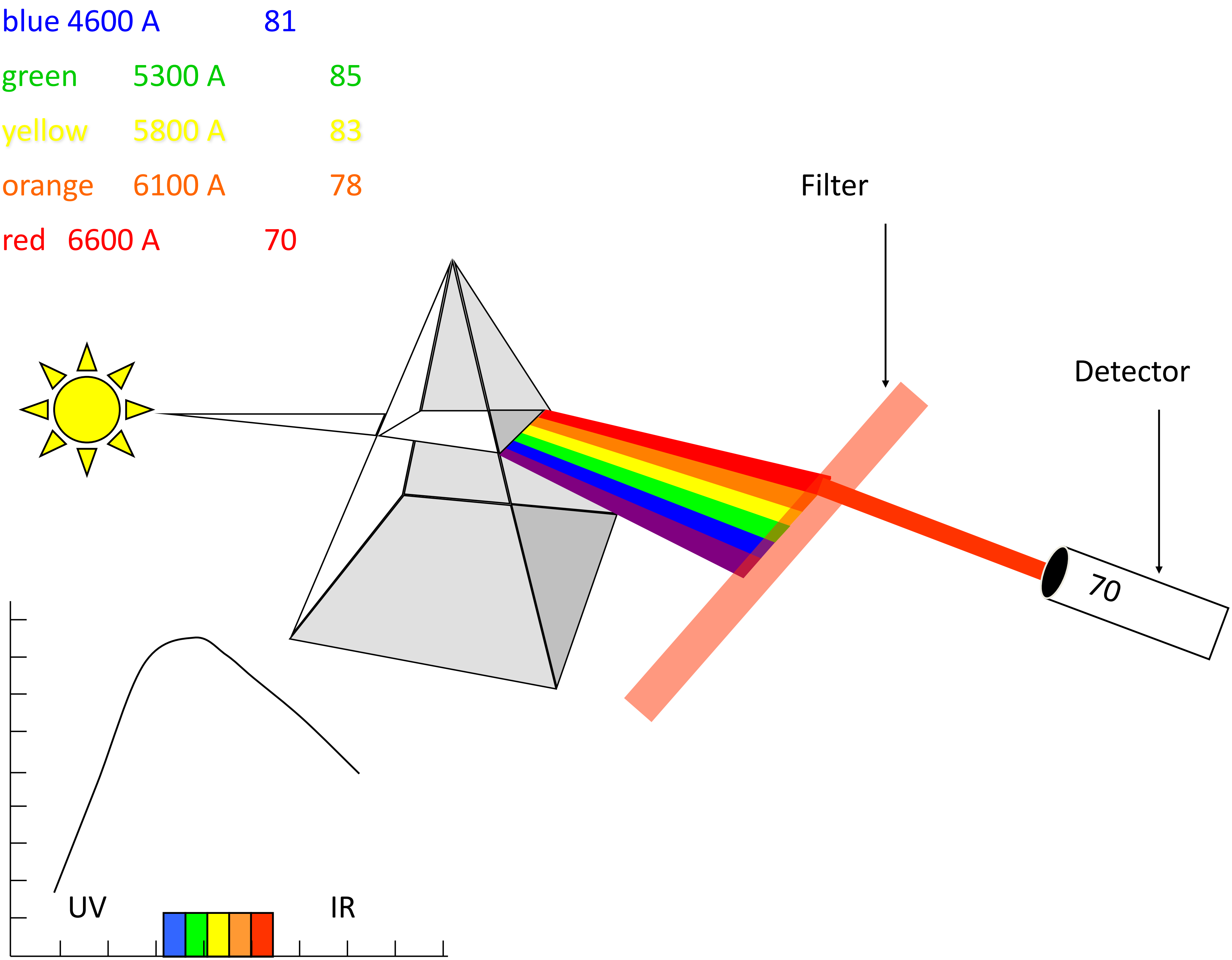
green 5300 A 85

yellow 5800 A 83



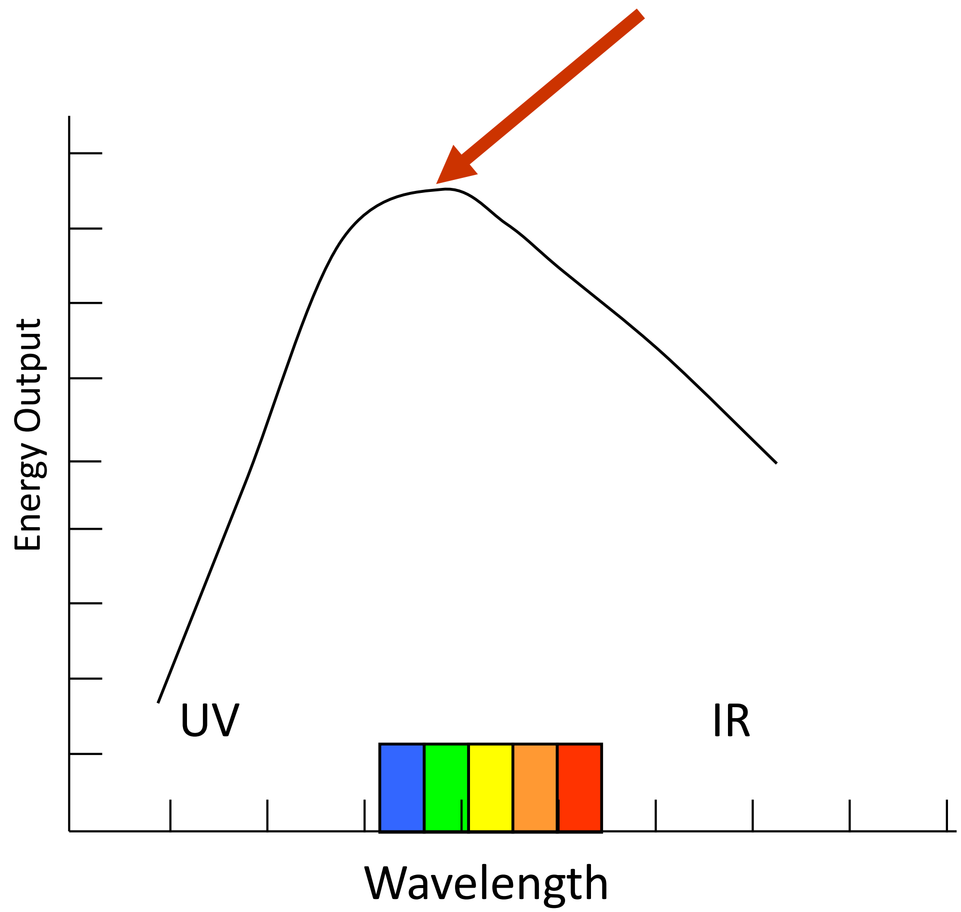
blue 4600 A		81
green	5300 A	85
yellow	5800 A	83
orange	6100 A	78



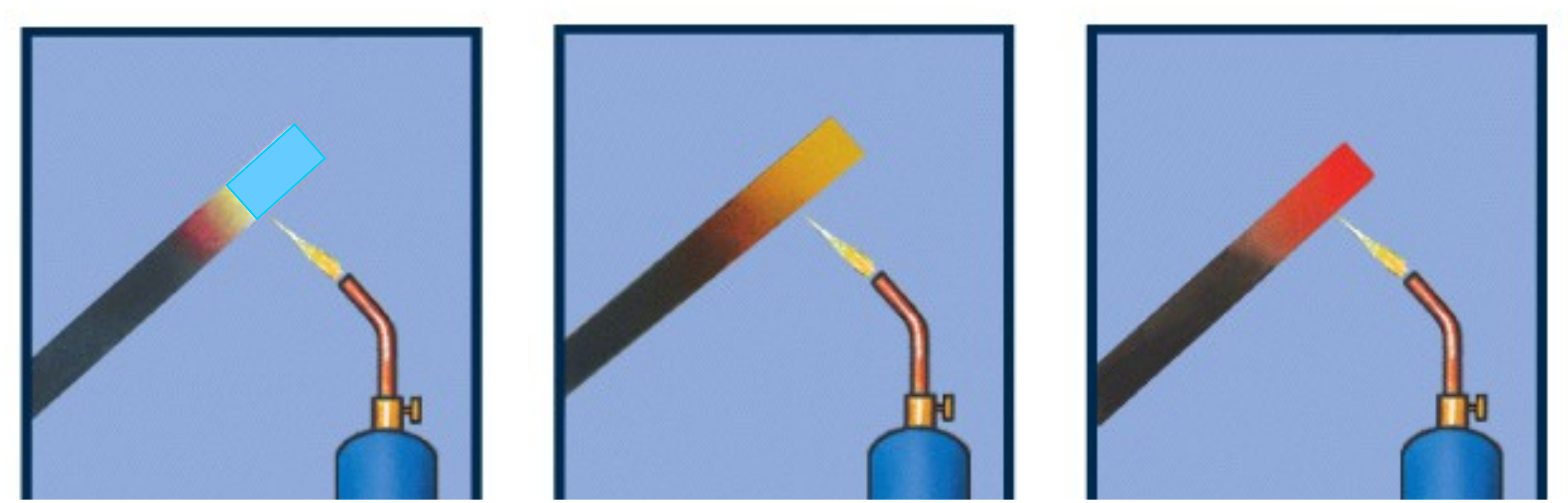

blue 4600 A 81
green 5300 A 85
yellow 5800 A 83
orange 6100 A 78
red 6600 A 70
Filter
Detector
70
UV
IR

“Blackbody Curve” - a graph of an object’s energy output versus wavelength.

The WAVELENGTH that the PEAK of this curve occurs at tells us about the object’s TEMPERATURE and COLOR.



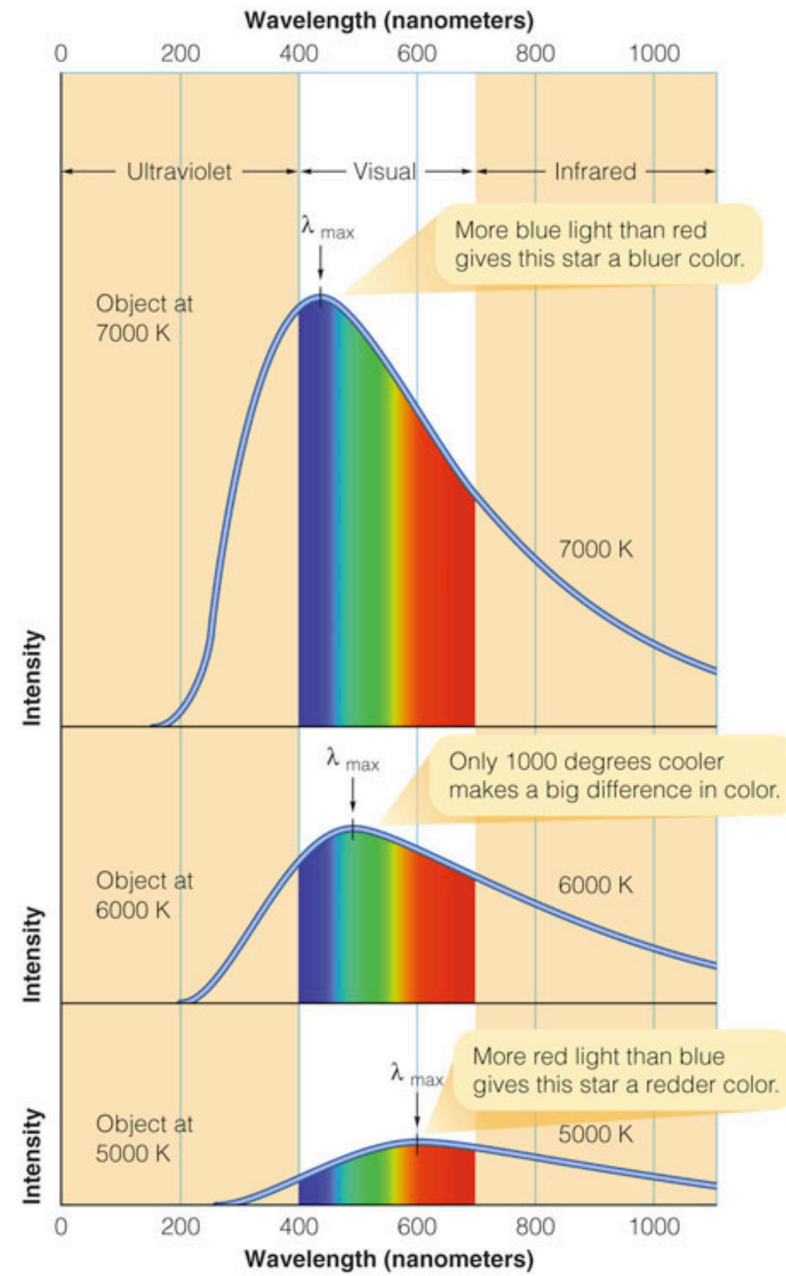
Which object is hotter, an object that is emitting mainly red light or mainly blue light?



Wien’s Law

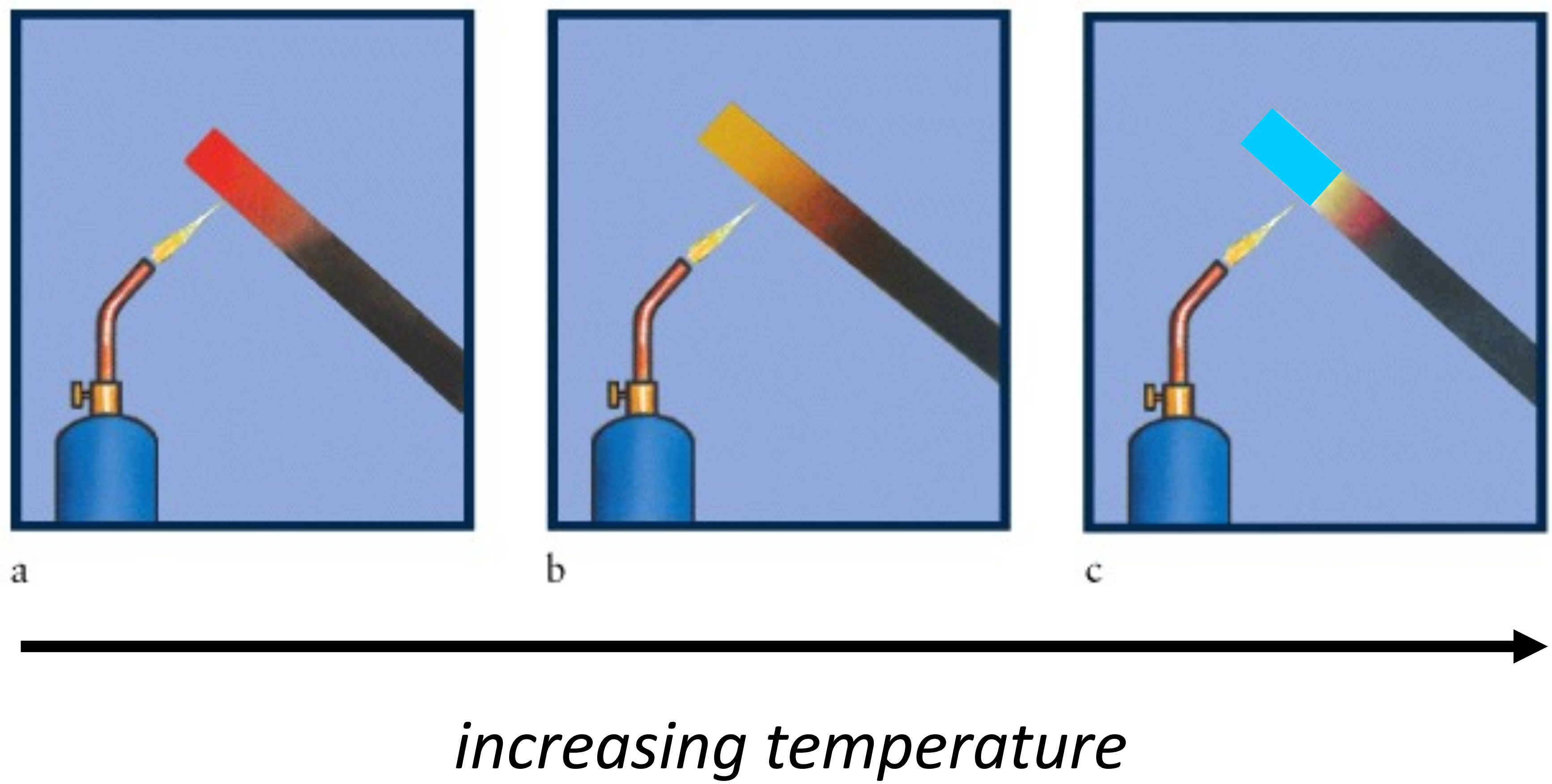
- The peak wavelength of a blackbody curve is *inversely proportional* to the temperature of the object.

$$\lambda_{max} = 0.289 \text{ cm} / T_K$$

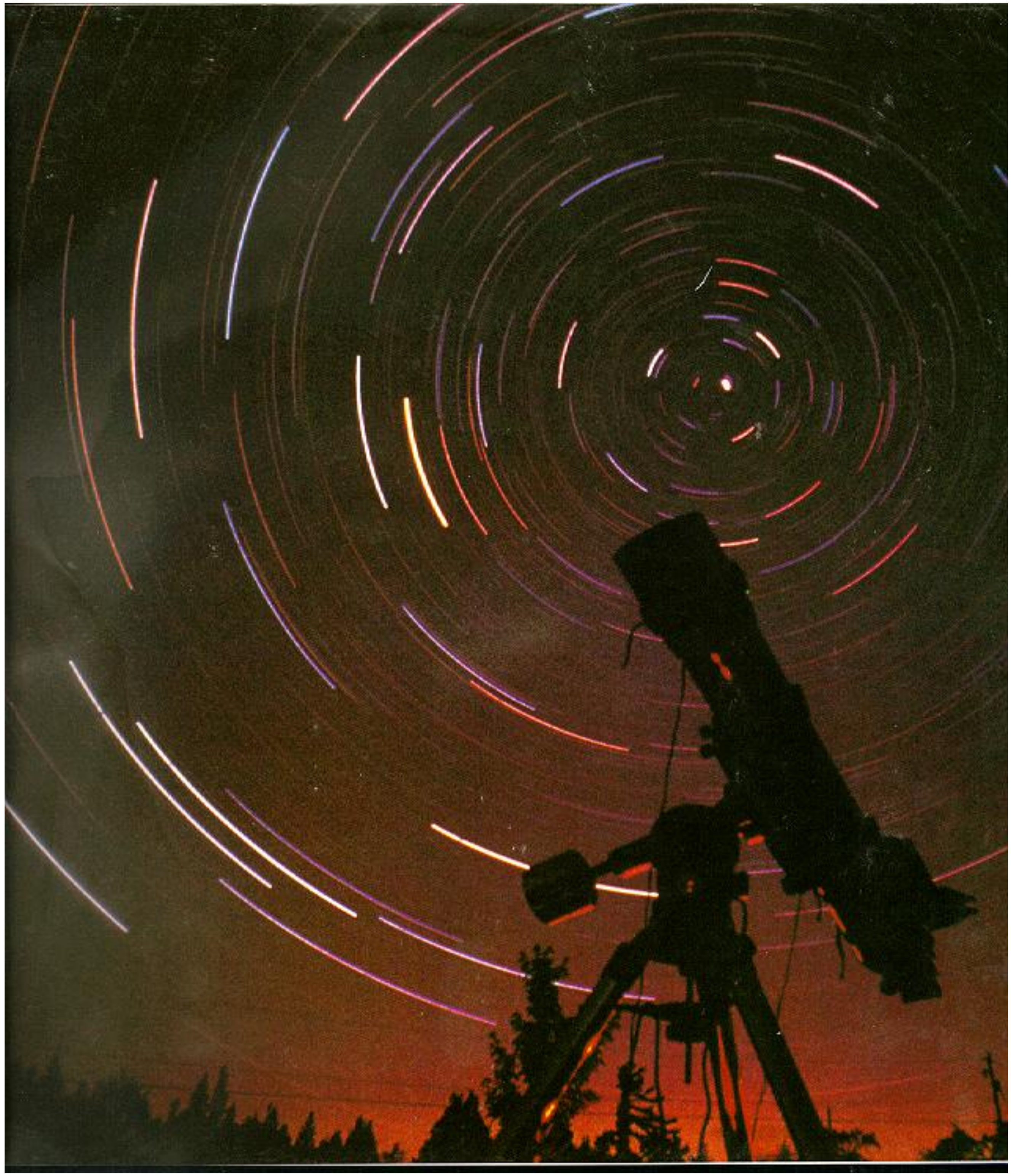


Hot objects emit light that **PEAKS** at **short wavelengths** (**blue**).

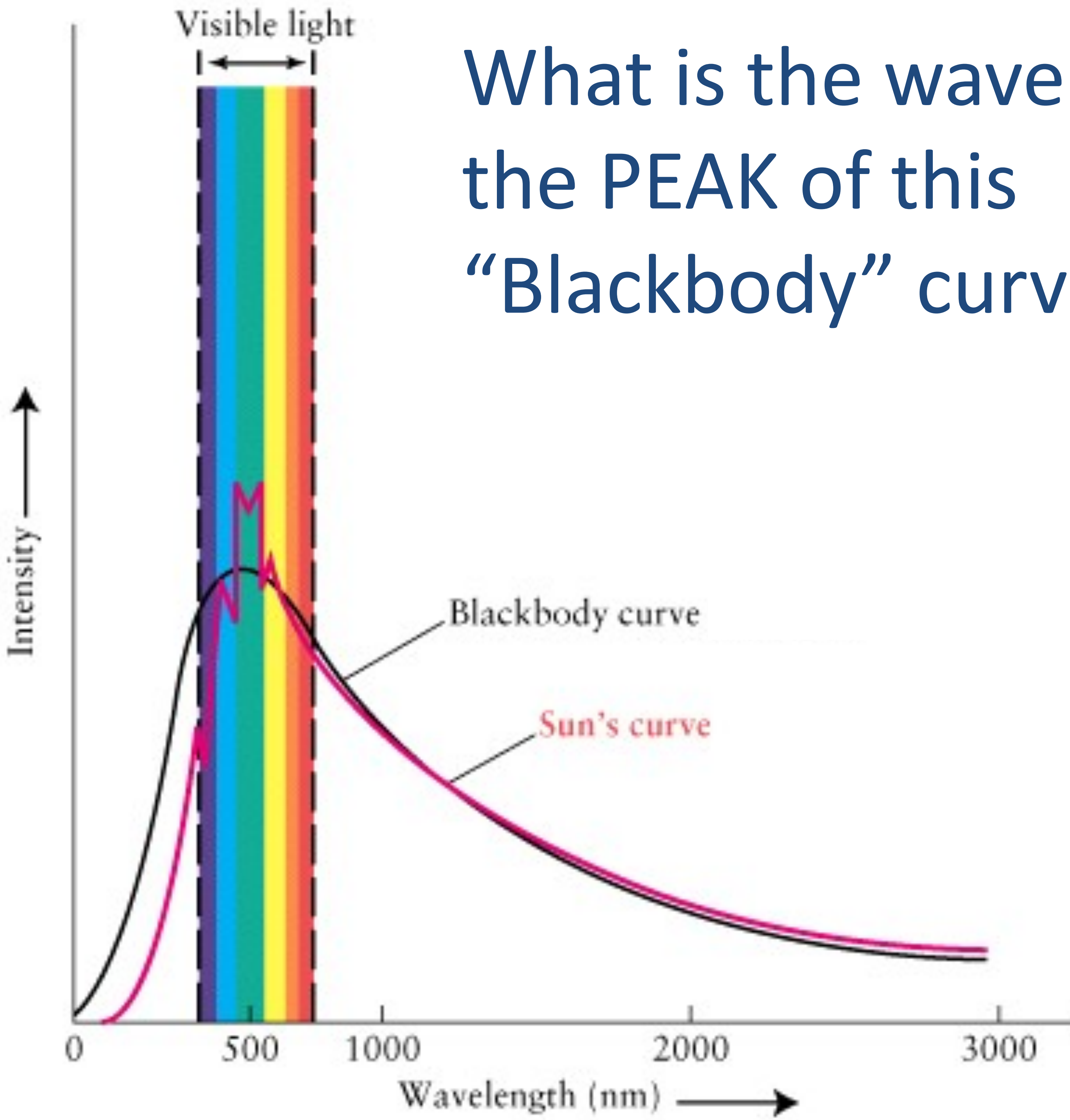
Cool objects emit light that **PEAKS** at **long wavelengths** (**red**)



Find the hottest star(s), how do you know ?

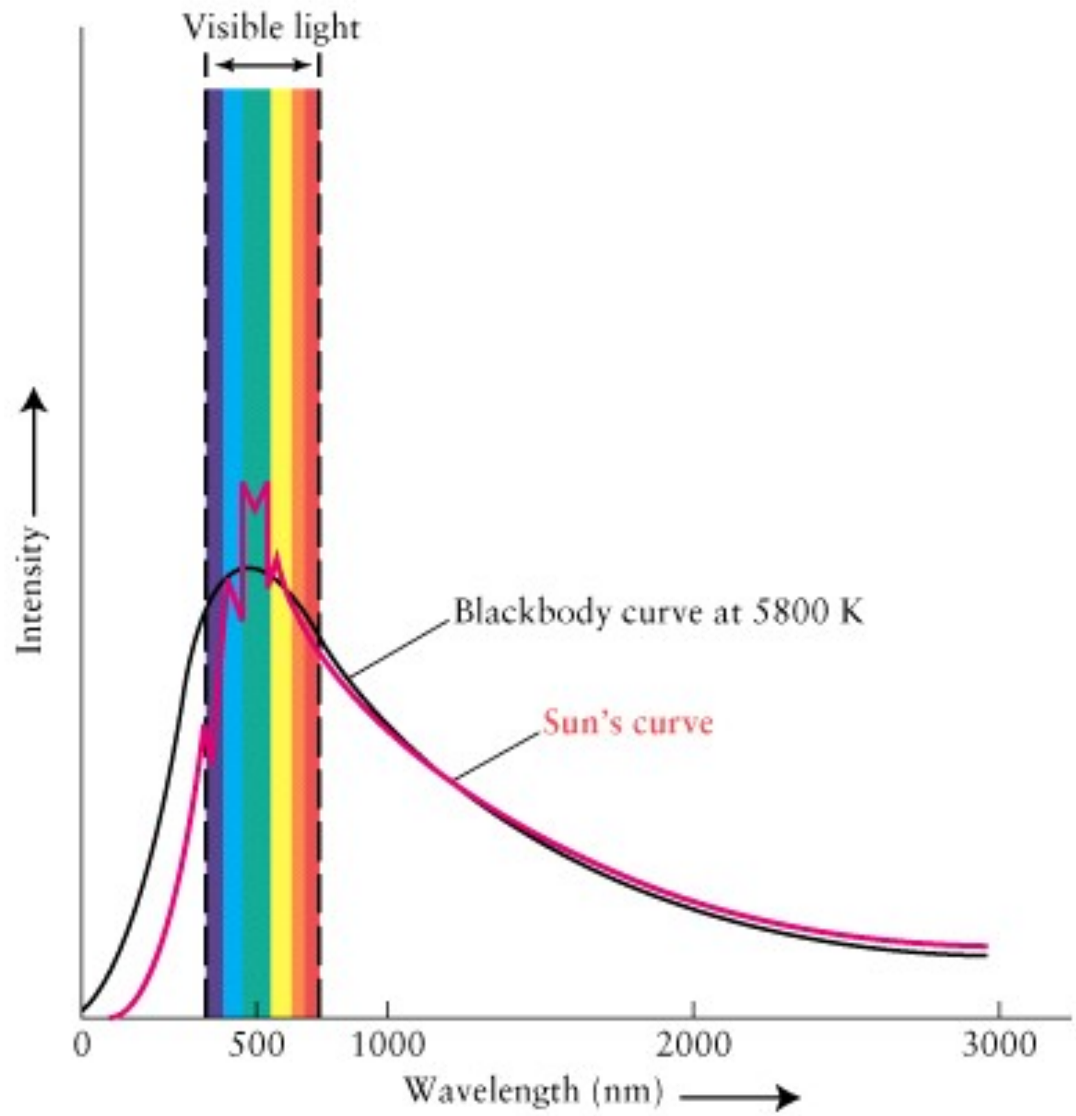


What is the wavelength of the PEAK of this "Blackbody" curve



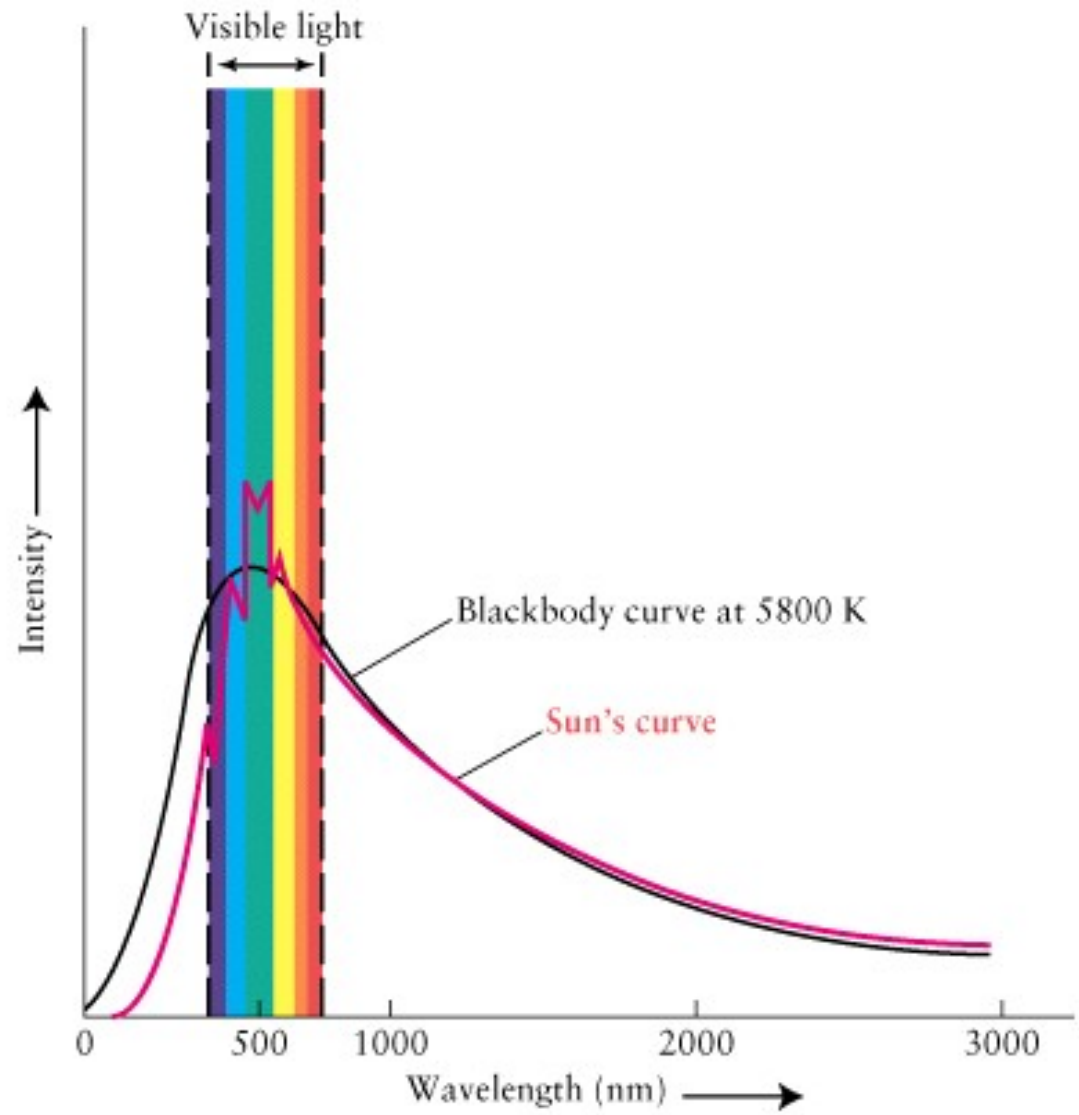
What color is our 5800K Sun?

The Sun emits all wavelengths of electromagnetic radiation (light); however, the wavelengths of light it emits most intensely are in the green/yellow part of the spectrum.

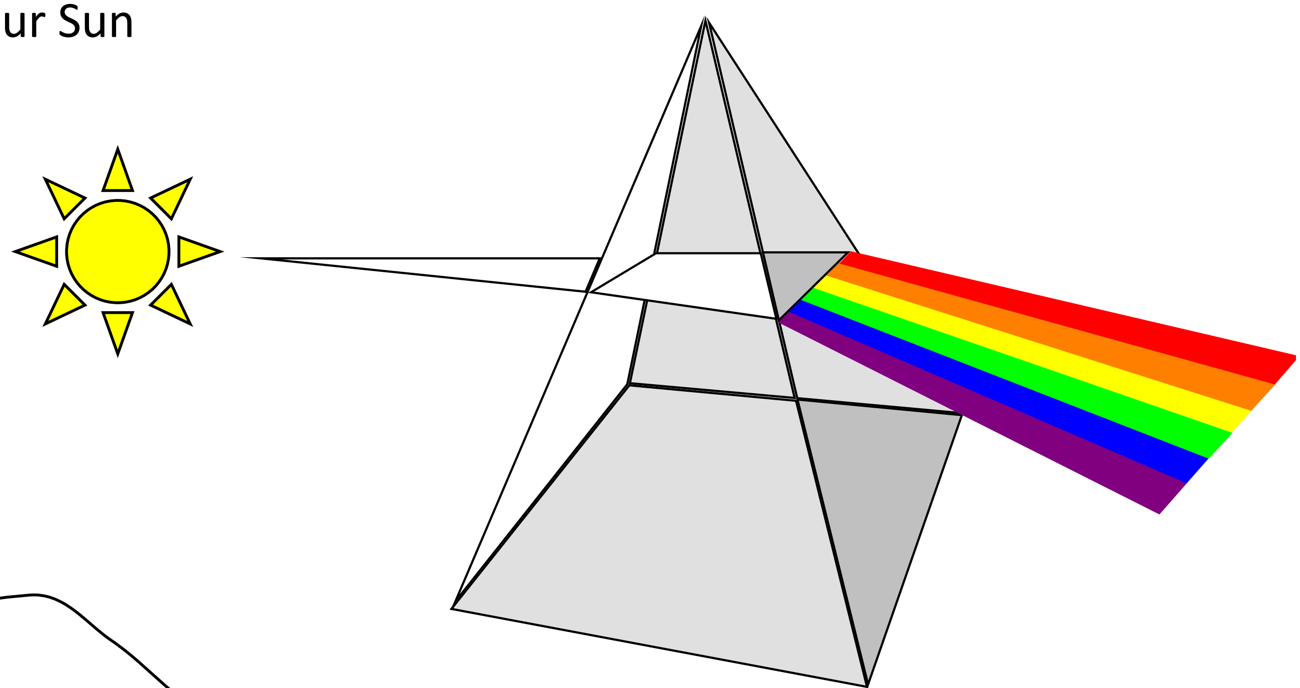


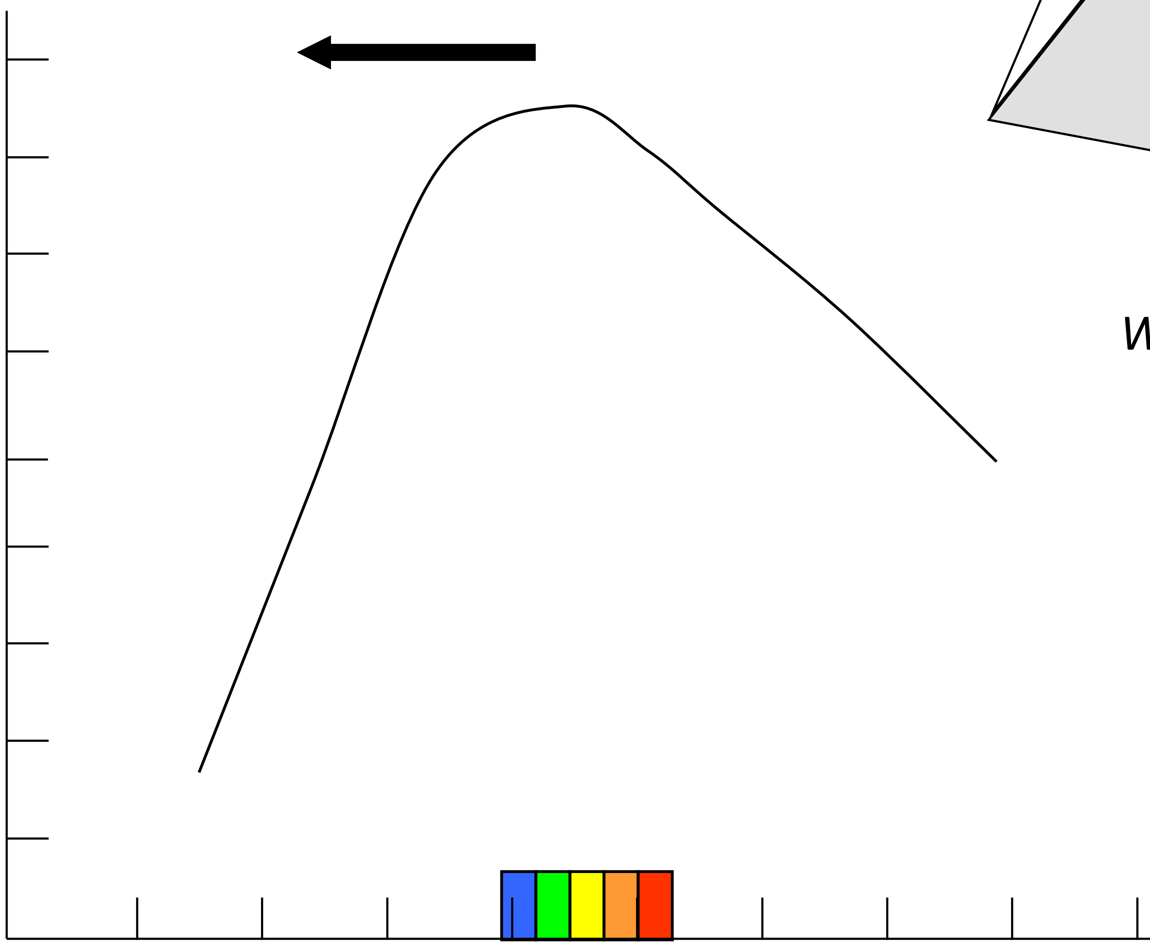
What color does the Sun appear? WHITE!!

A star, like the Sun, which peaks in the middle of the visible part of the spectrum (green/yellow light) will appear WHITE to the human eye because it is giving off nearly equal amounts of all the visible colors of light.

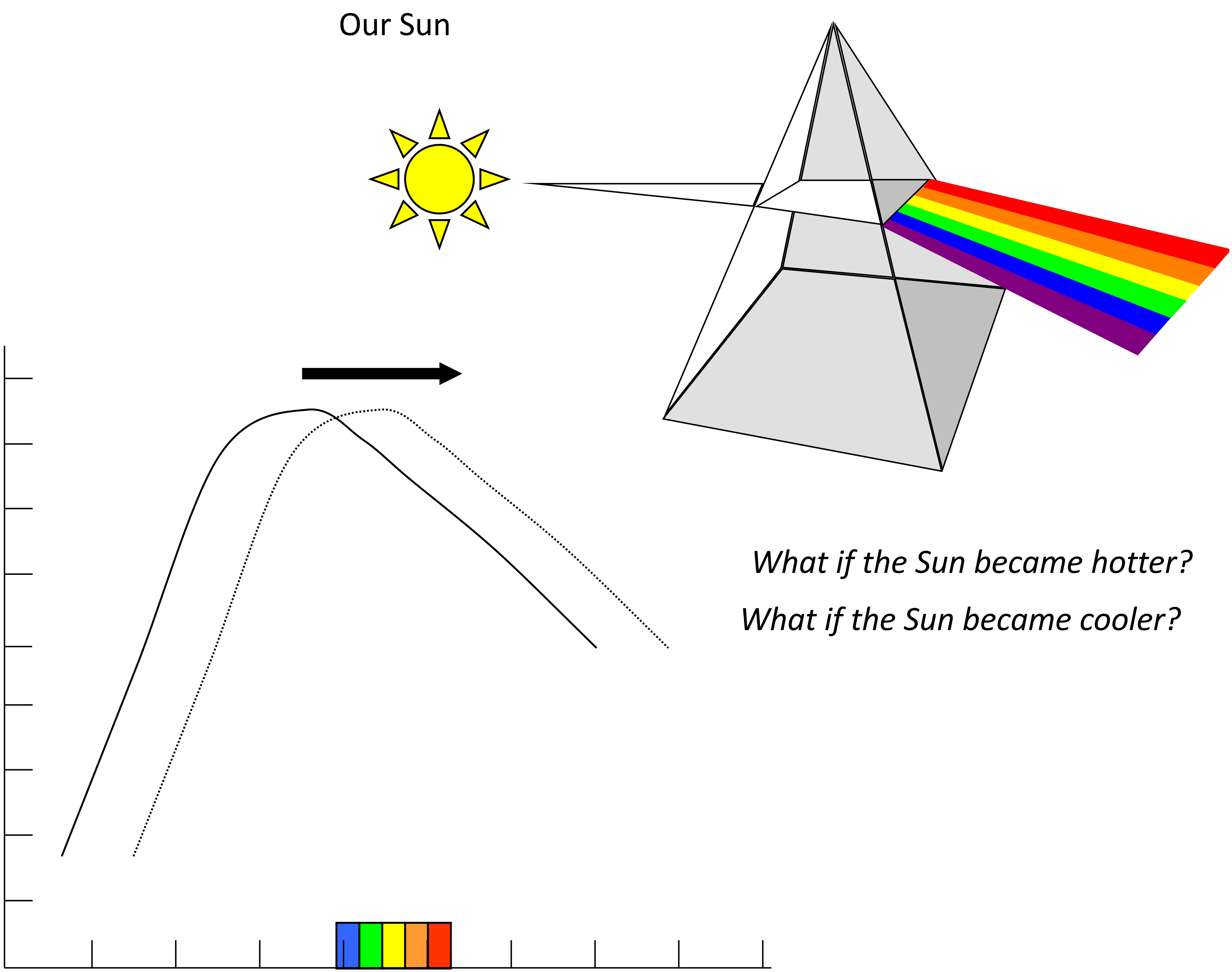


Our Sun



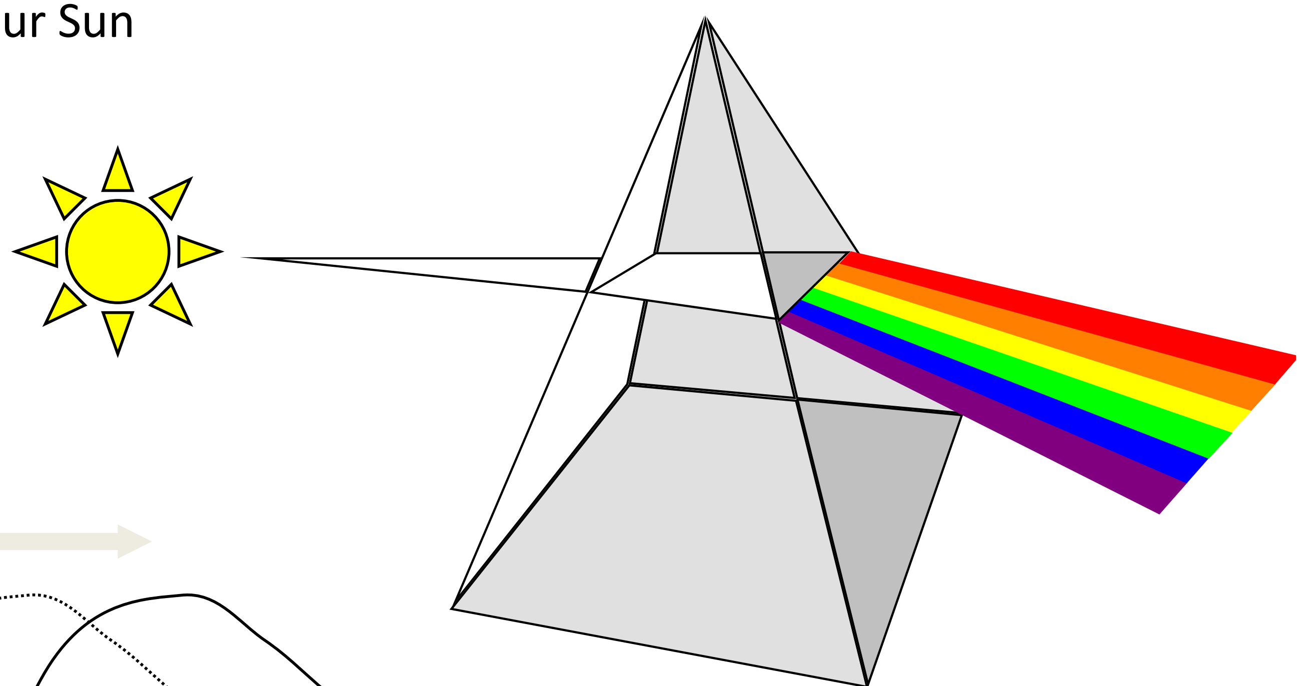


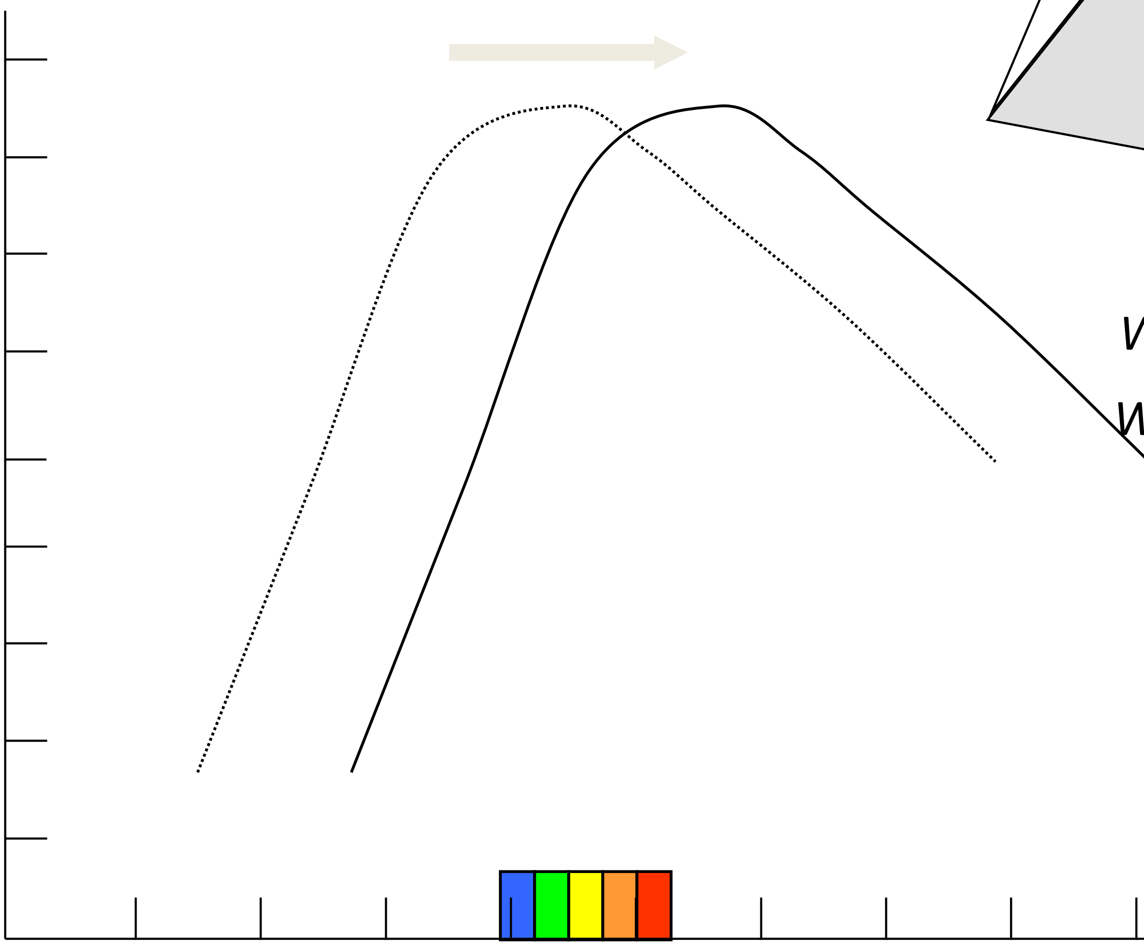
What if the Sun became hotter?



Our Sun
What if the Sun became hotter?
What if the Sun became cooler?

Our Sun





What if the Sun became hotter?

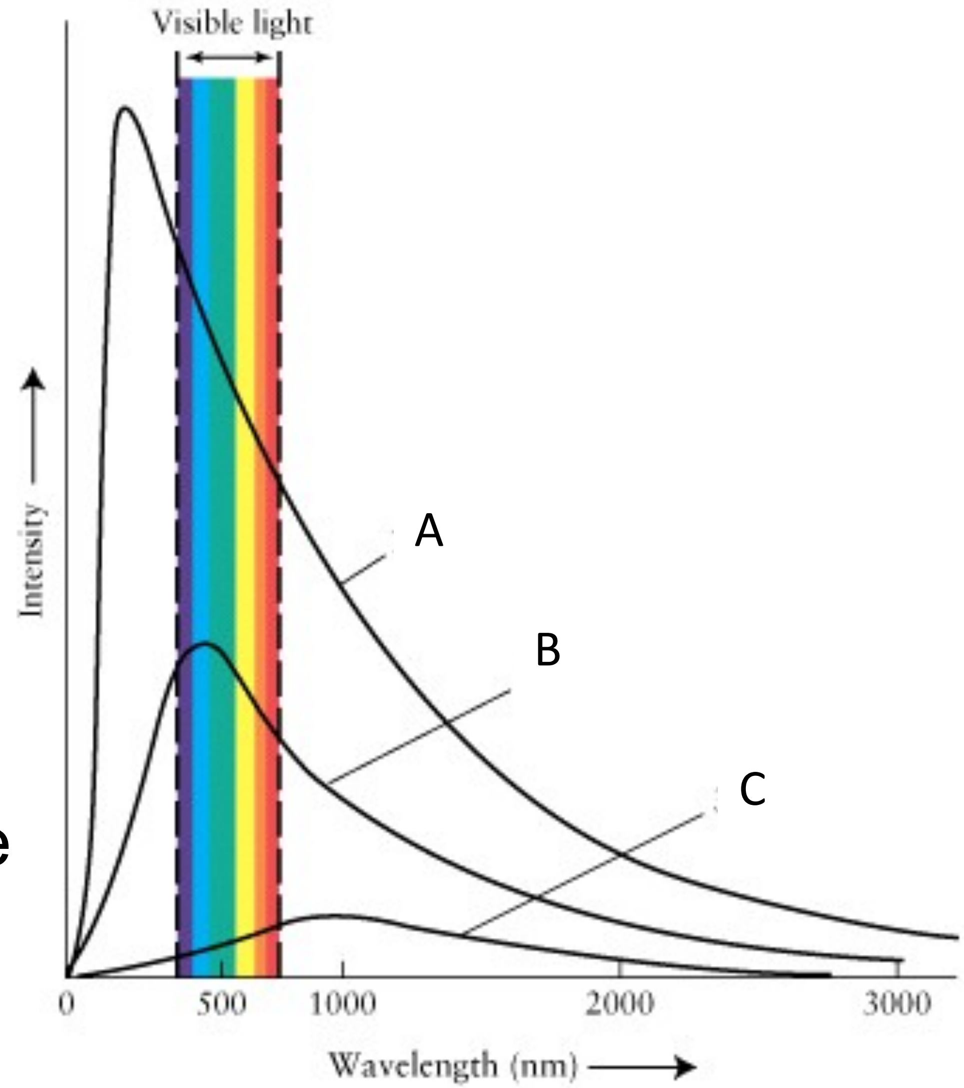
What if the Sun became cooler?

1. Which object gives off the greatest amount of Blue light?

2. Which object gives off the greatest amount of Red light?

3. Which object would appear Red?

4. Which object would have the lowest temperature?



But wait, what about how bright something looks?

Stefan-Boltzmann Law

- The luminosity (brightness) of an object is proportional to its *size* and *temperature*:

$$L = 5.67\text{x}10^{-8}\ R^2T^4$$

- Big and hot objects are brighter than small and cool objects.
- Two objects with the same brightness and different temperatures will have different sizes (and vice-versa).

Consider the following...

Which of these two stovetops is brighter?

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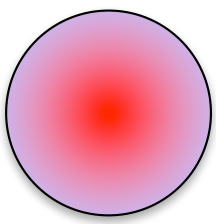
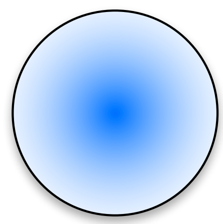
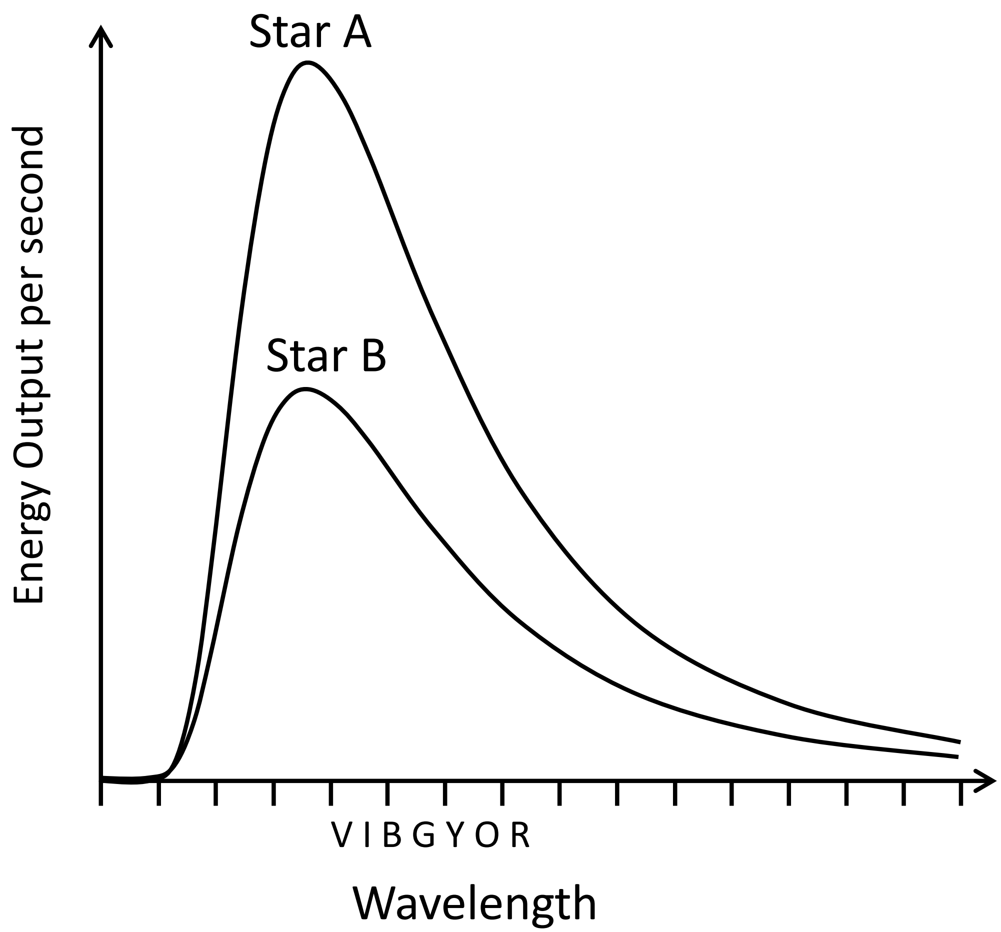
Which of these two stovetops is brighter?

A 

B 

Which star is larger?

A. Star A
B. Star B
C. Same



Which star is larger Star A or Star B?

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B. Star B
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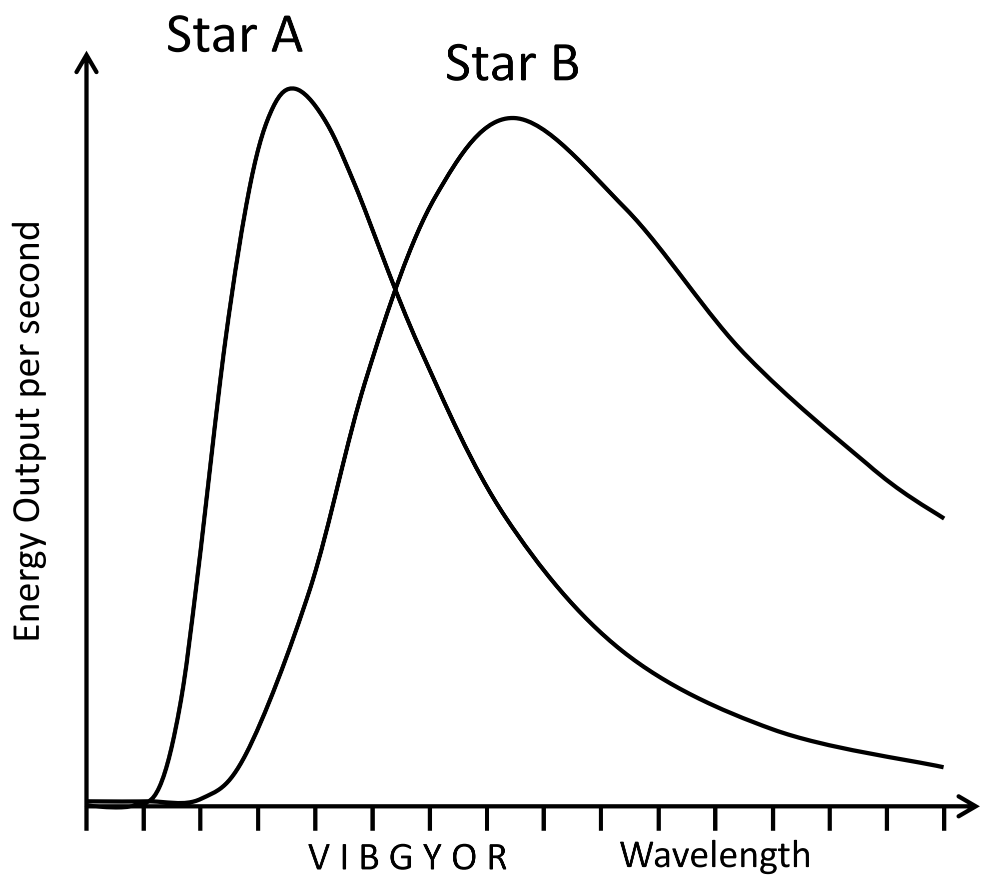
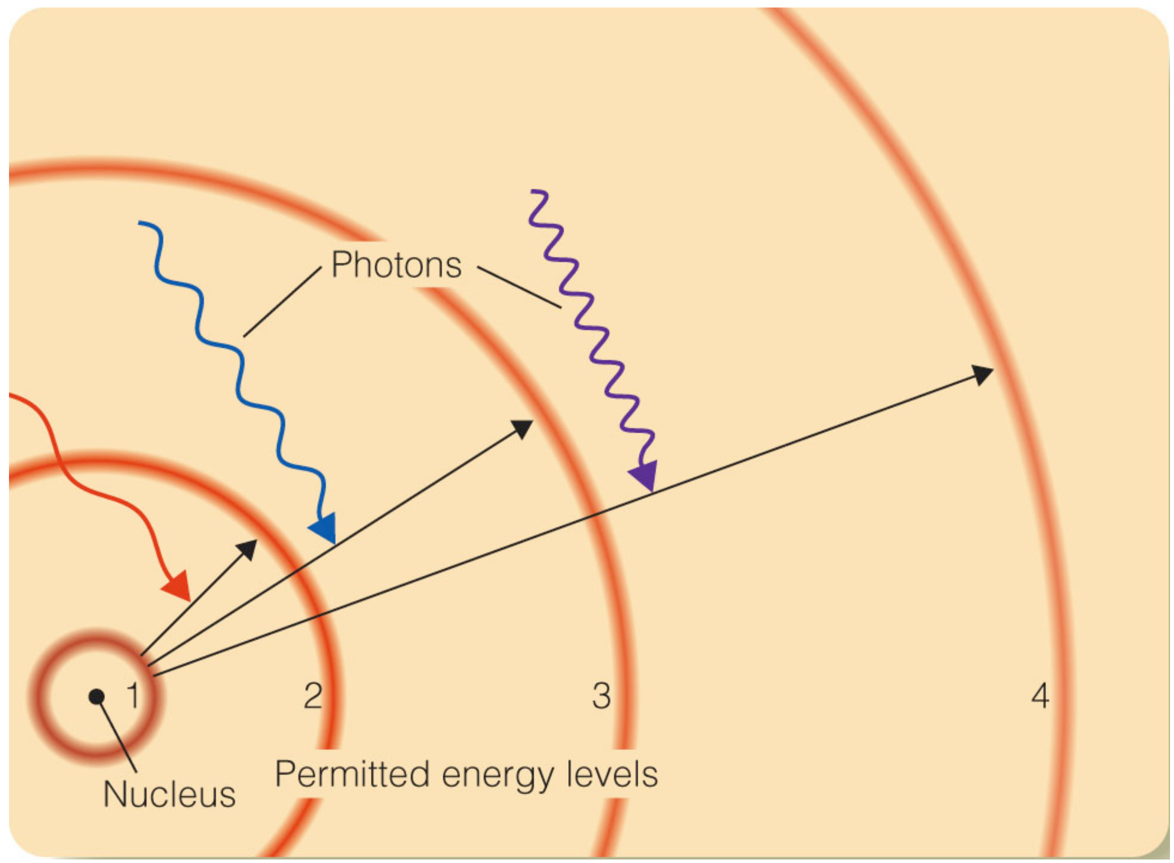


But where does the light come from?

- When something is hot, it's atoms move around bumping into each other and the electrons in the material. The hotter it is, the more the atoms and electrons bump into each other.
- The electrons are accelerated when they are bumped and emit energy as *thermal radiation.*
- **But there is also another way for atoms to emit light…**

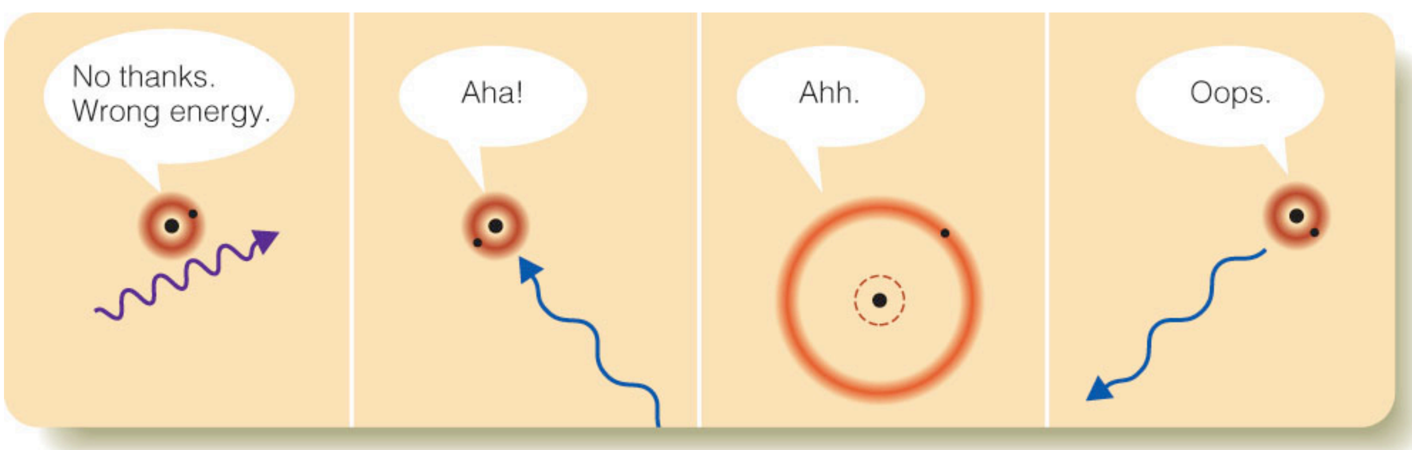
Energy Levels

Electrons can only "orbit" at very specific *energy levels.* The energies of these levels correspond to the energy of specific wavelengths (frequencies) of light. These levels are discrete or *quantized*.

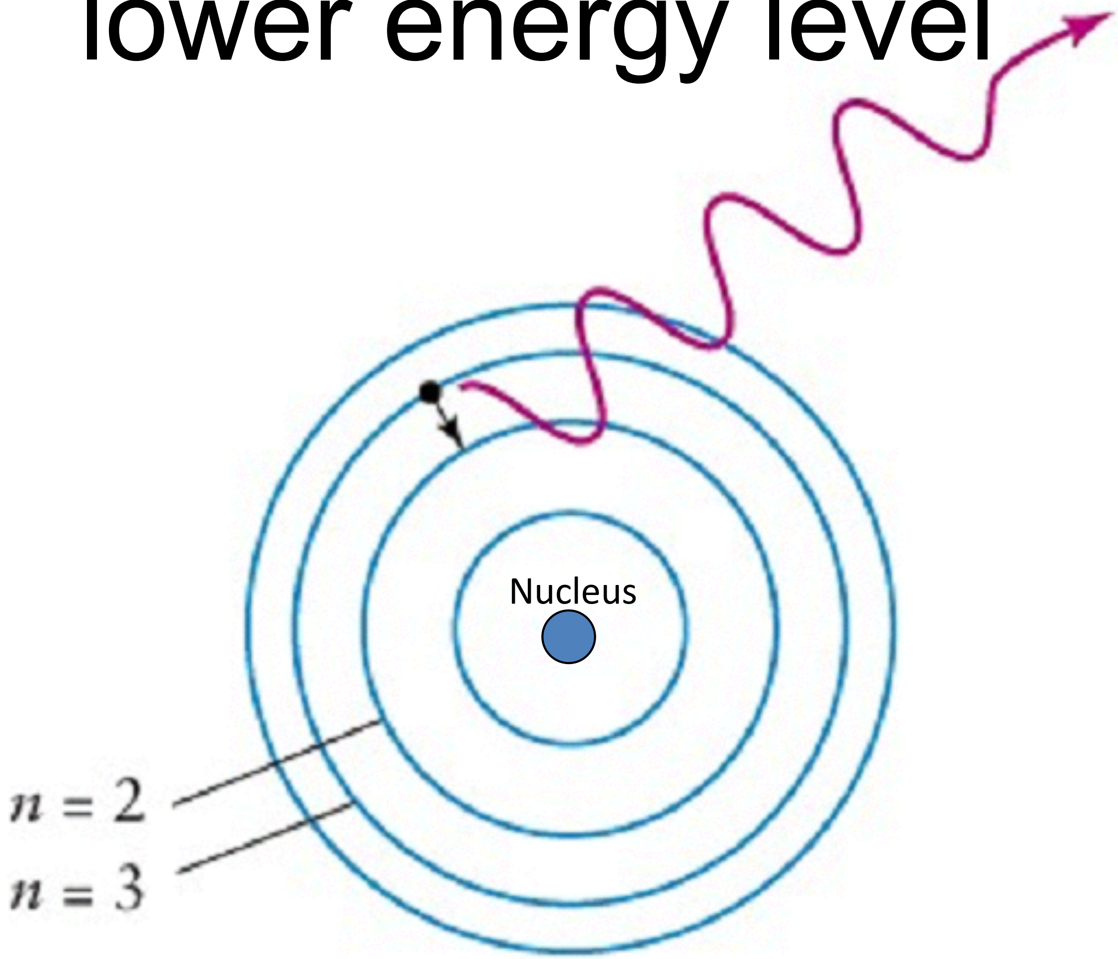


Emission and Absorption

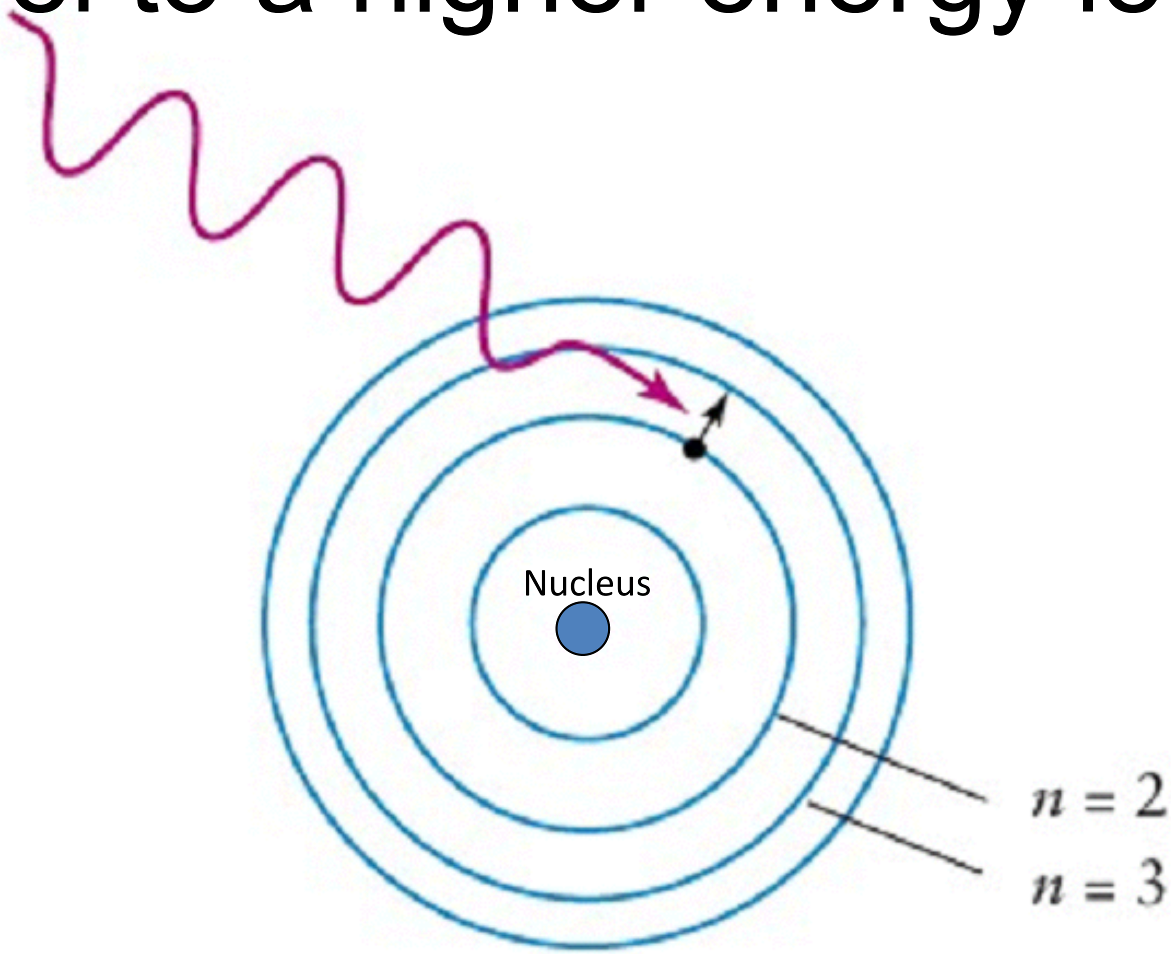
Imagine that the atom below has a single electron in its lowest energy state (the *ground* state). It can only move up a level if it absorbs a blue photon. If it is in a higher energy (excited) state, then it can suddenly decide to emit a blue photon (and only a blue photon).



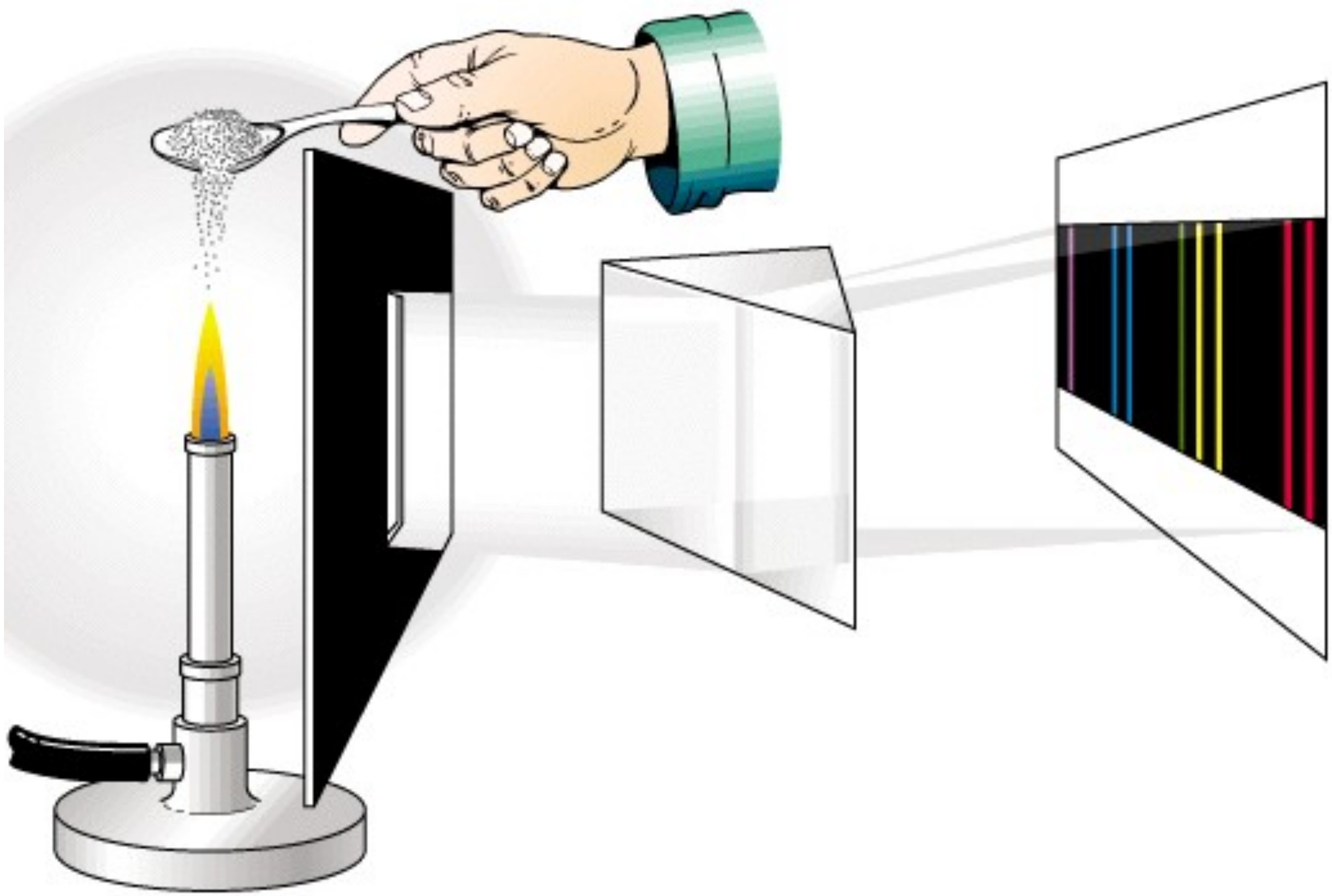
Photons (light-waves) are emitted from an atom when an electron moves from a higher energy level to a lower energy level



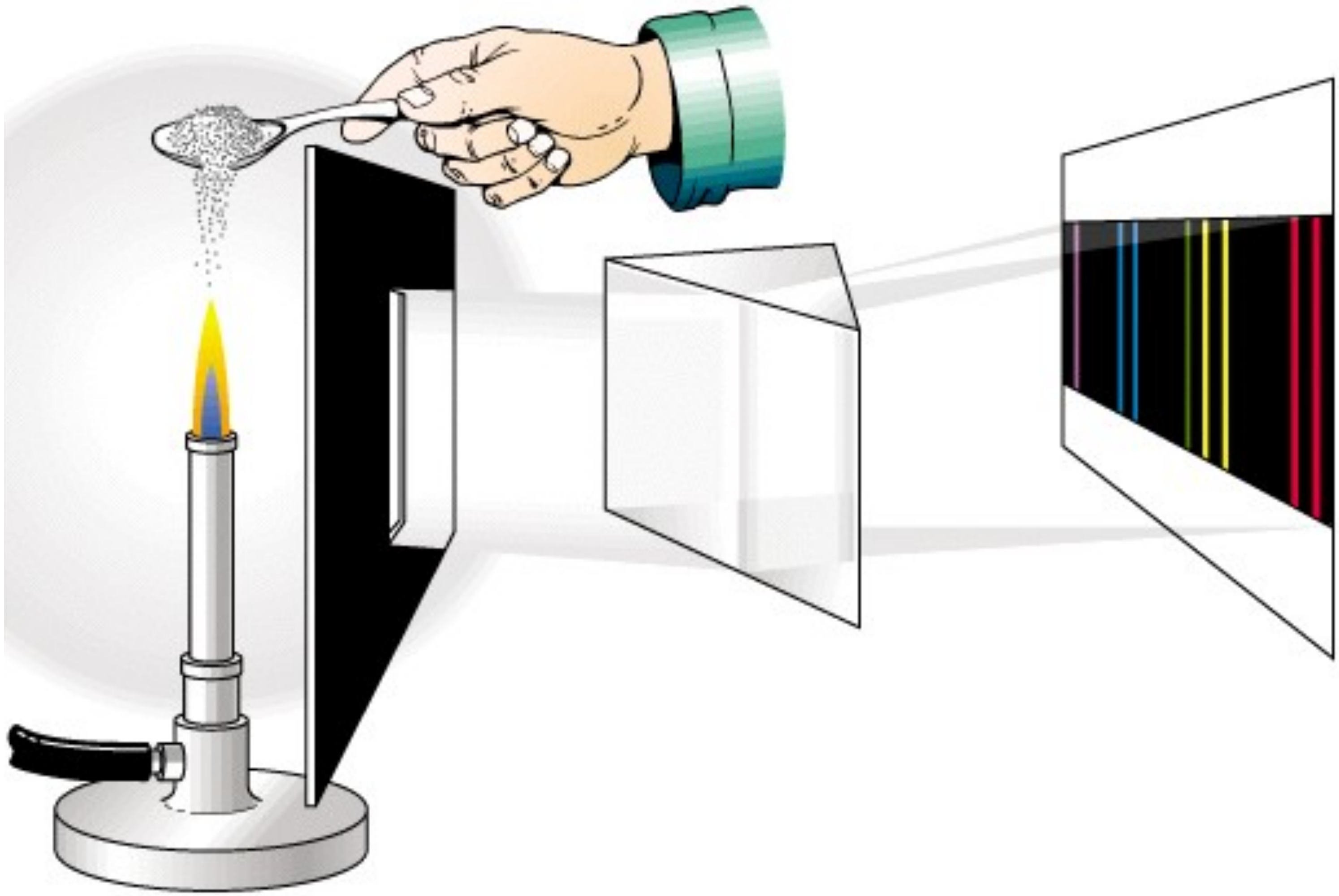
Photons (light-waves) can also be absorbed by an atom when an electron moves from a lower energy level to a higher energy level



Each chemical element produces its own unique set of spectral lines when it is excited



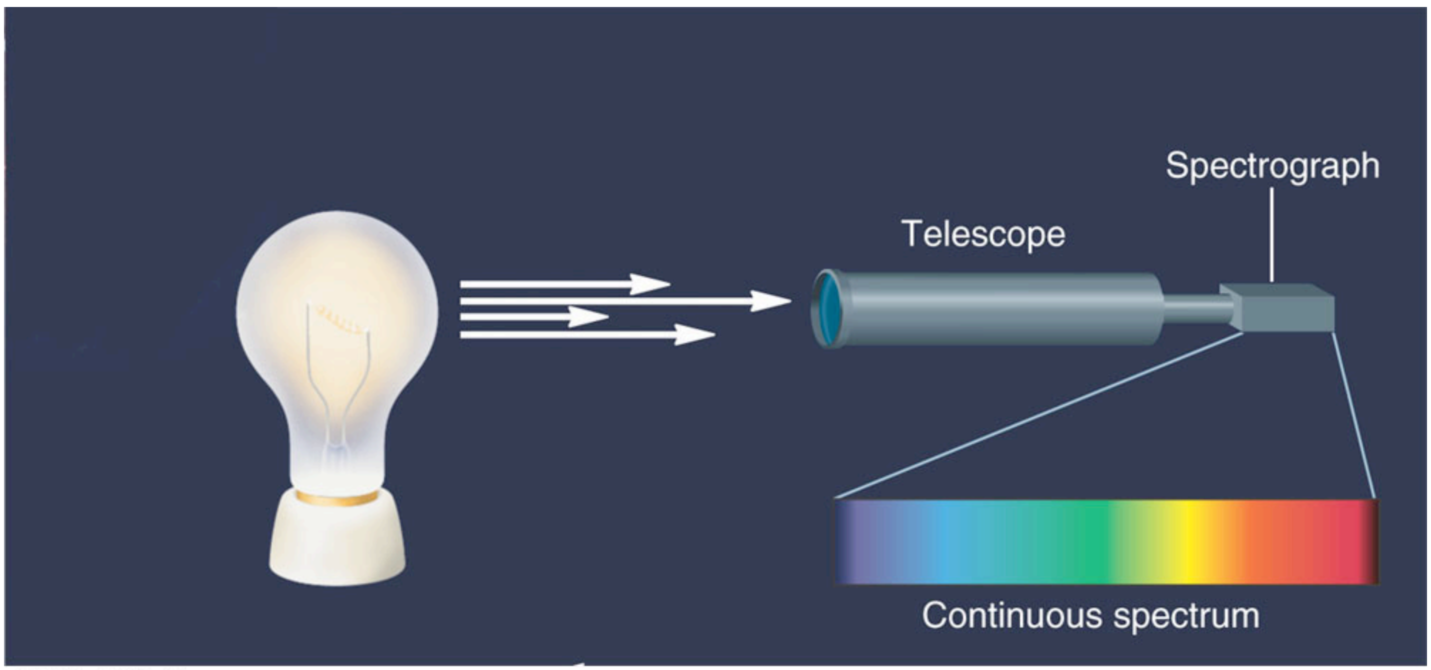
We can use these lines to determine the chemical composition of a star.



There are three laws that govern the types of spectra we see in the Universe.

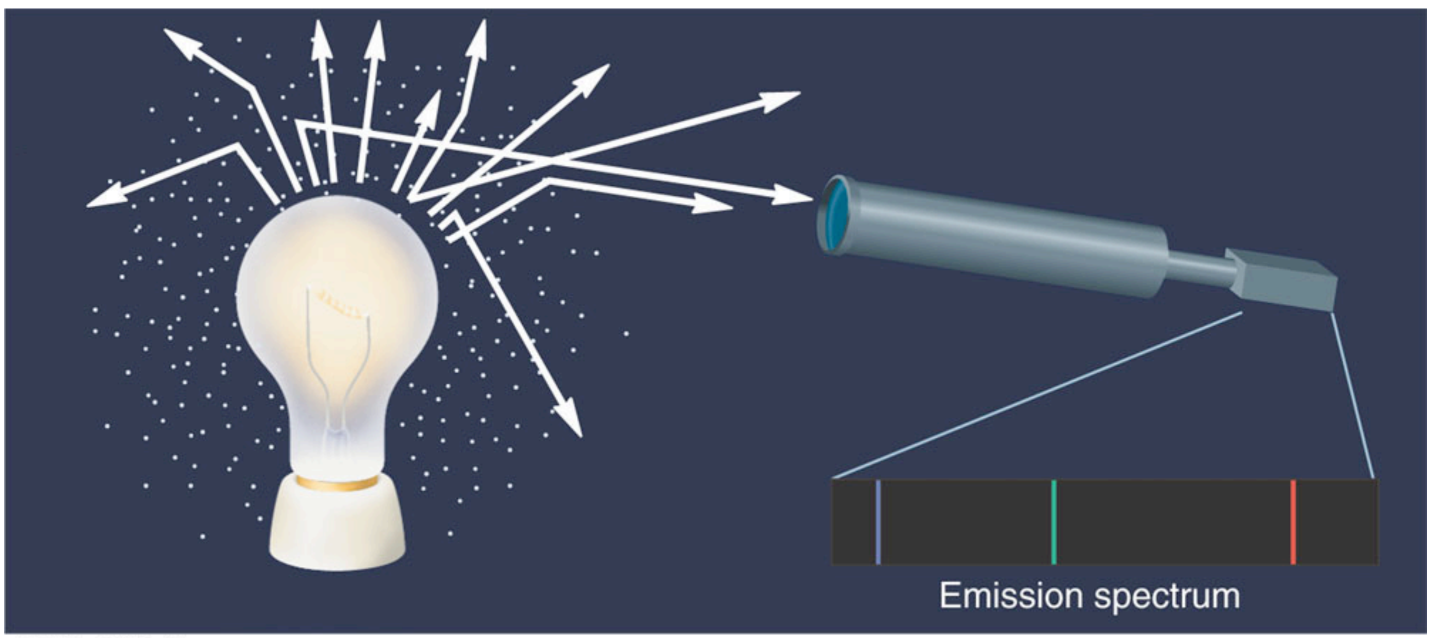
Kirchoff's Law #1

A hot, dense material will emit light at all wavelengths to produce a *continuous* spectrum.



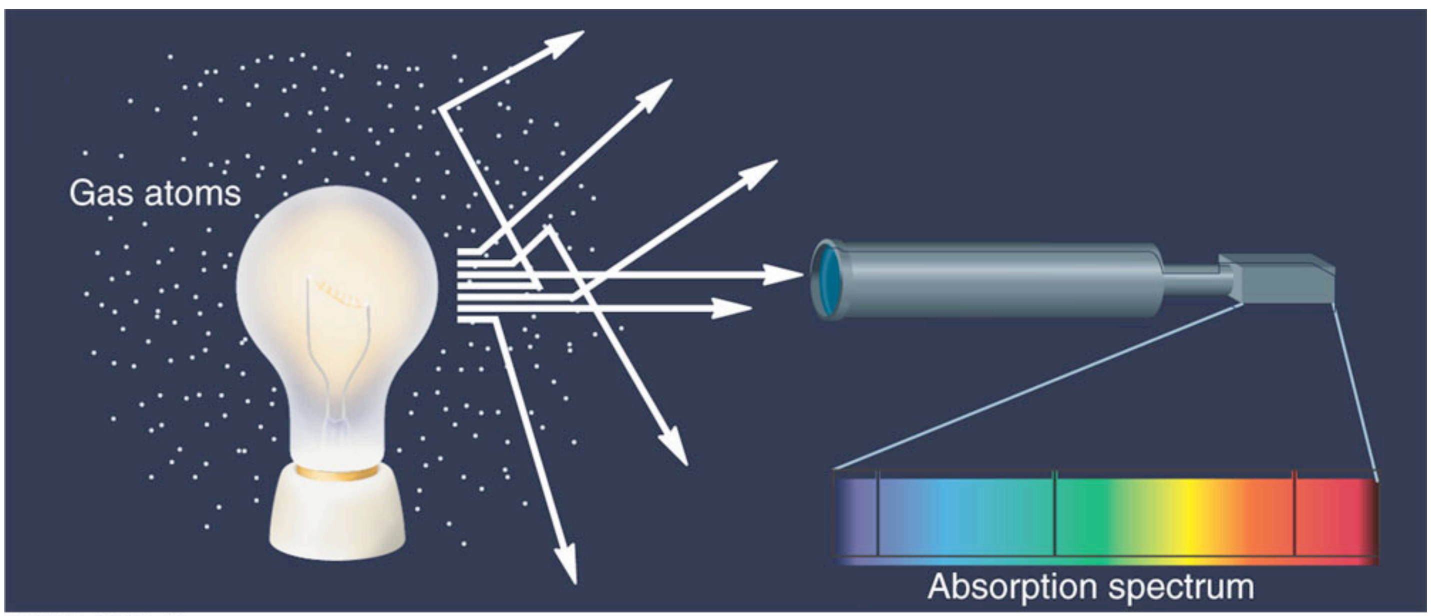
Kirchoff's Law #2

A hot, low-density gas will emit light at only at specific wavelengths producing an *emission spectrum.*



Kirchoff's Law #3

When light from a hot, dense object passes through a cooler, low density gas, the result is an *absorption spectrum.* The absorption lines are at the same location as the emission lines would be.



Let’s look at some examples of these laws in action.