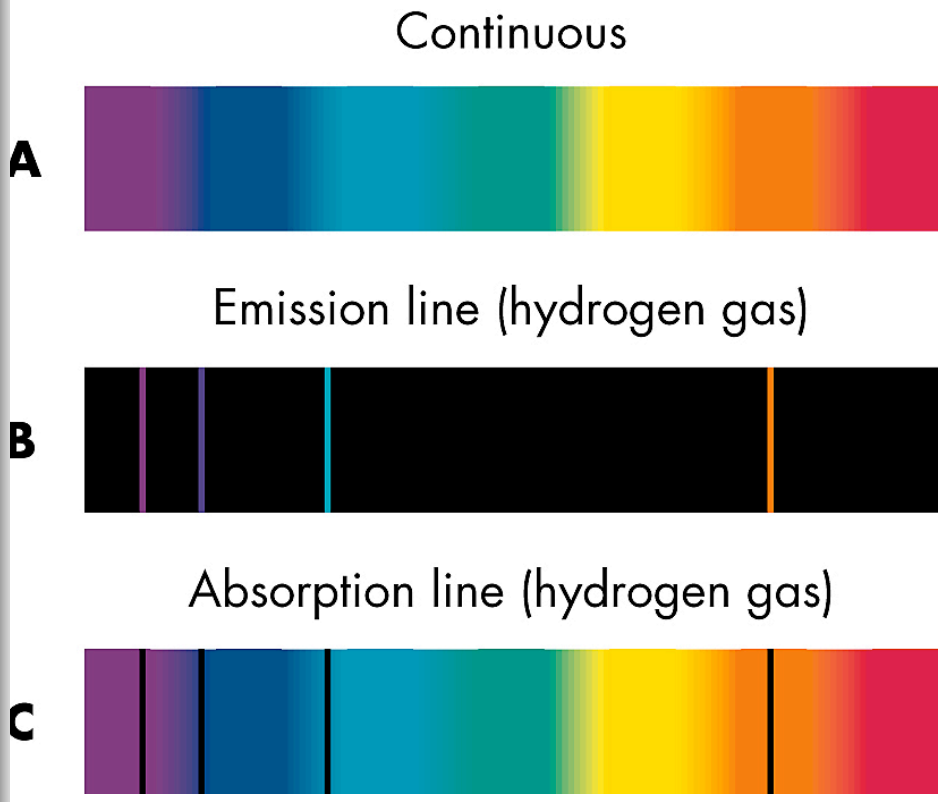
No homework for Wednesday

Read Chapter 8!

Next quiz: Monday, October 24

Chapter 7
Atoms and Starlight

Types of Spectra: Pictorial

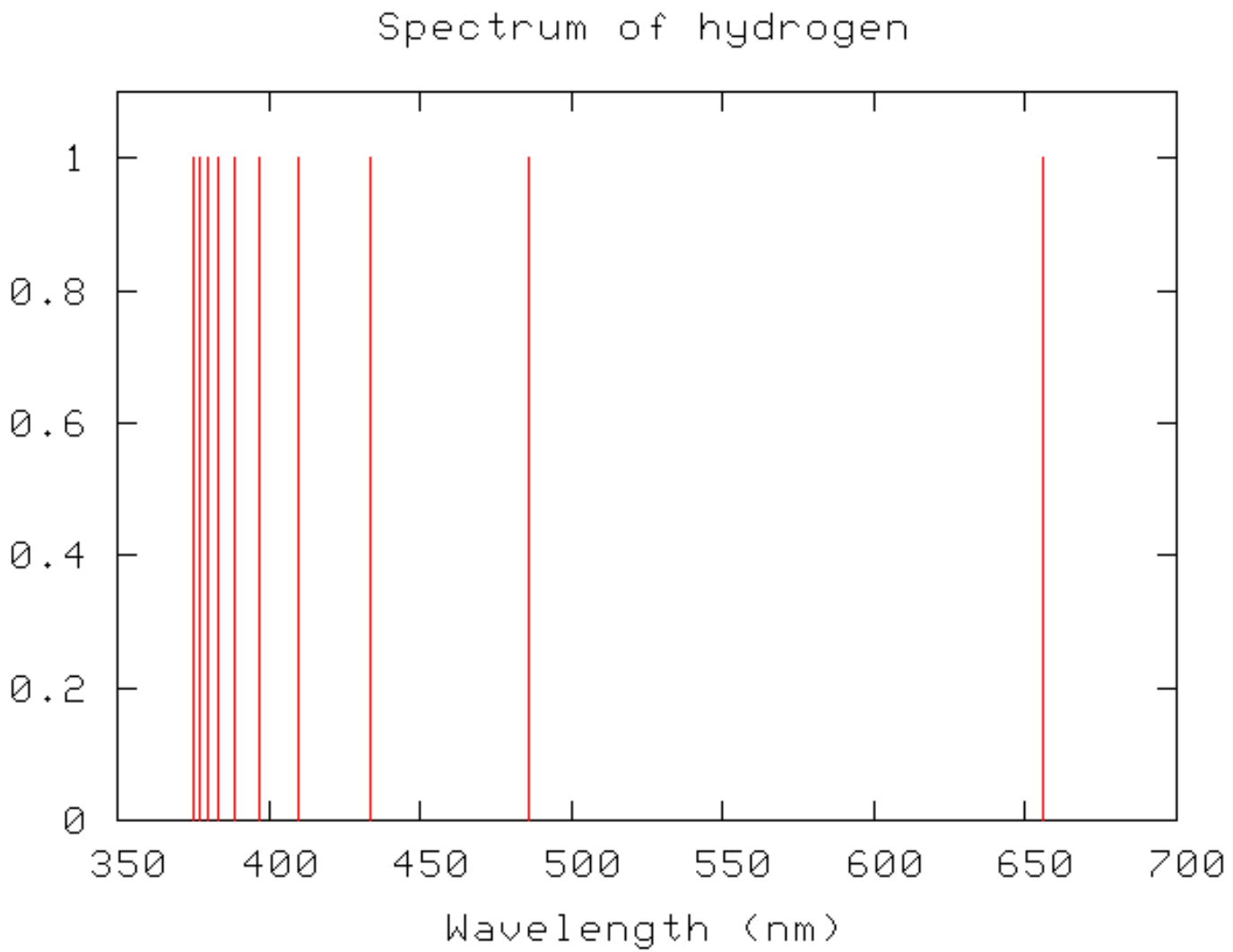


Some light sources are comprised of all colors (white light).

Other light sources contain just a few colors.

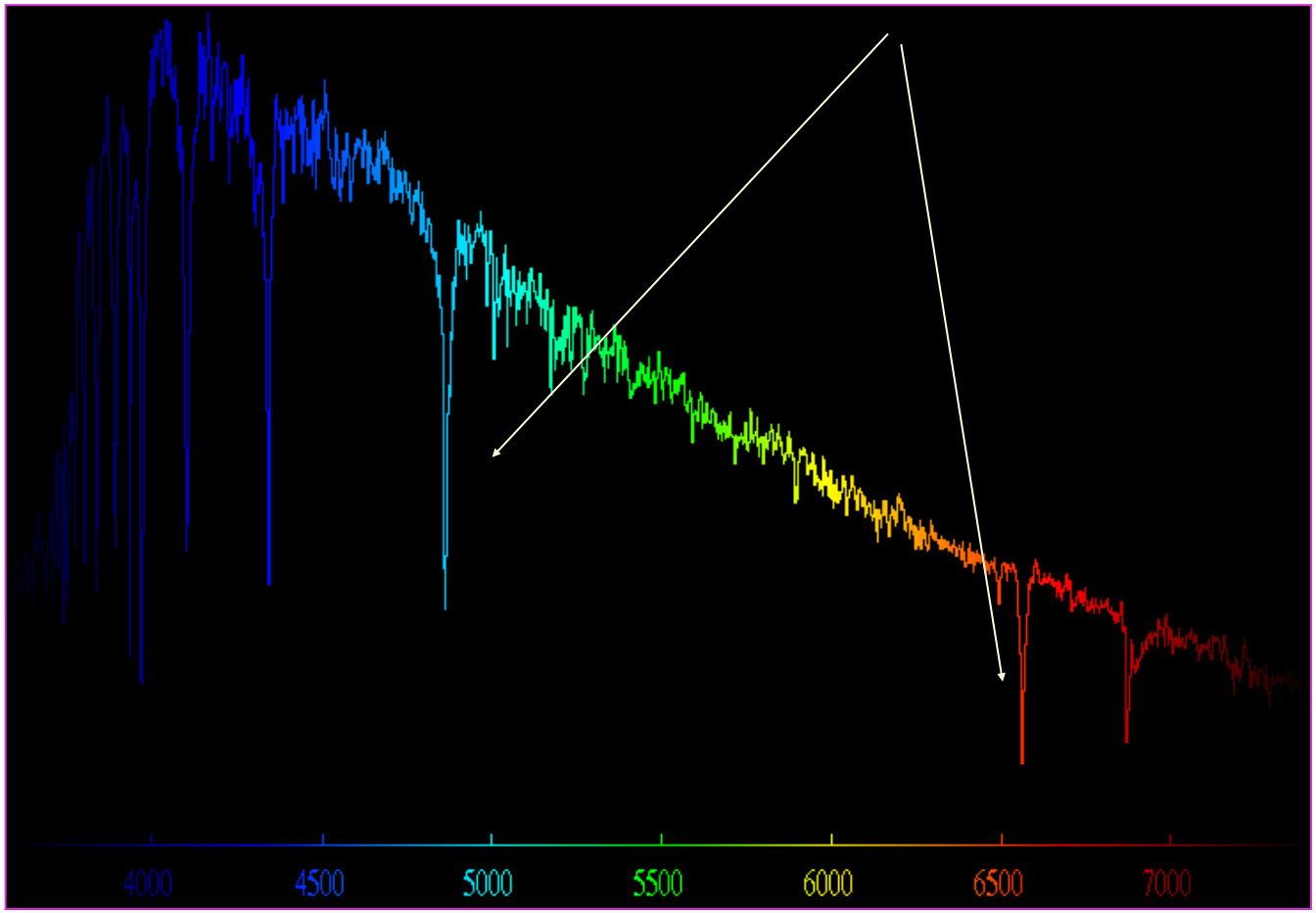
Some are missing just a few colors.

Emission Spectrum: Graphical



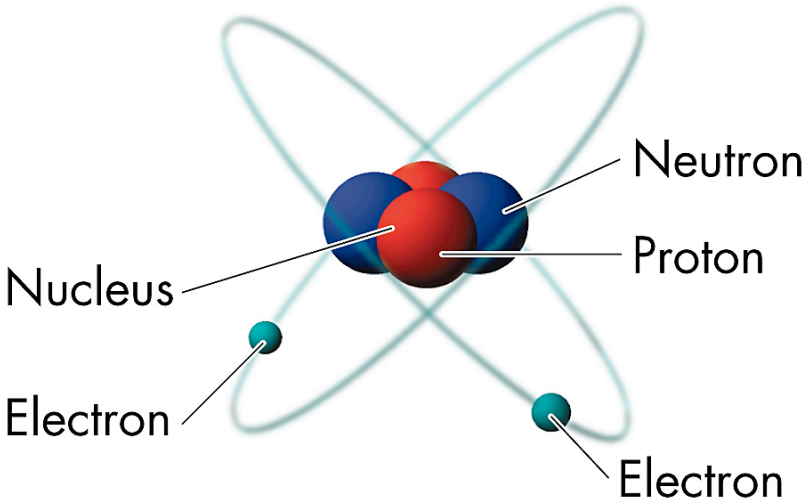
Absorption Spectrum: Graphical

Absorption lines



Atomic Structure

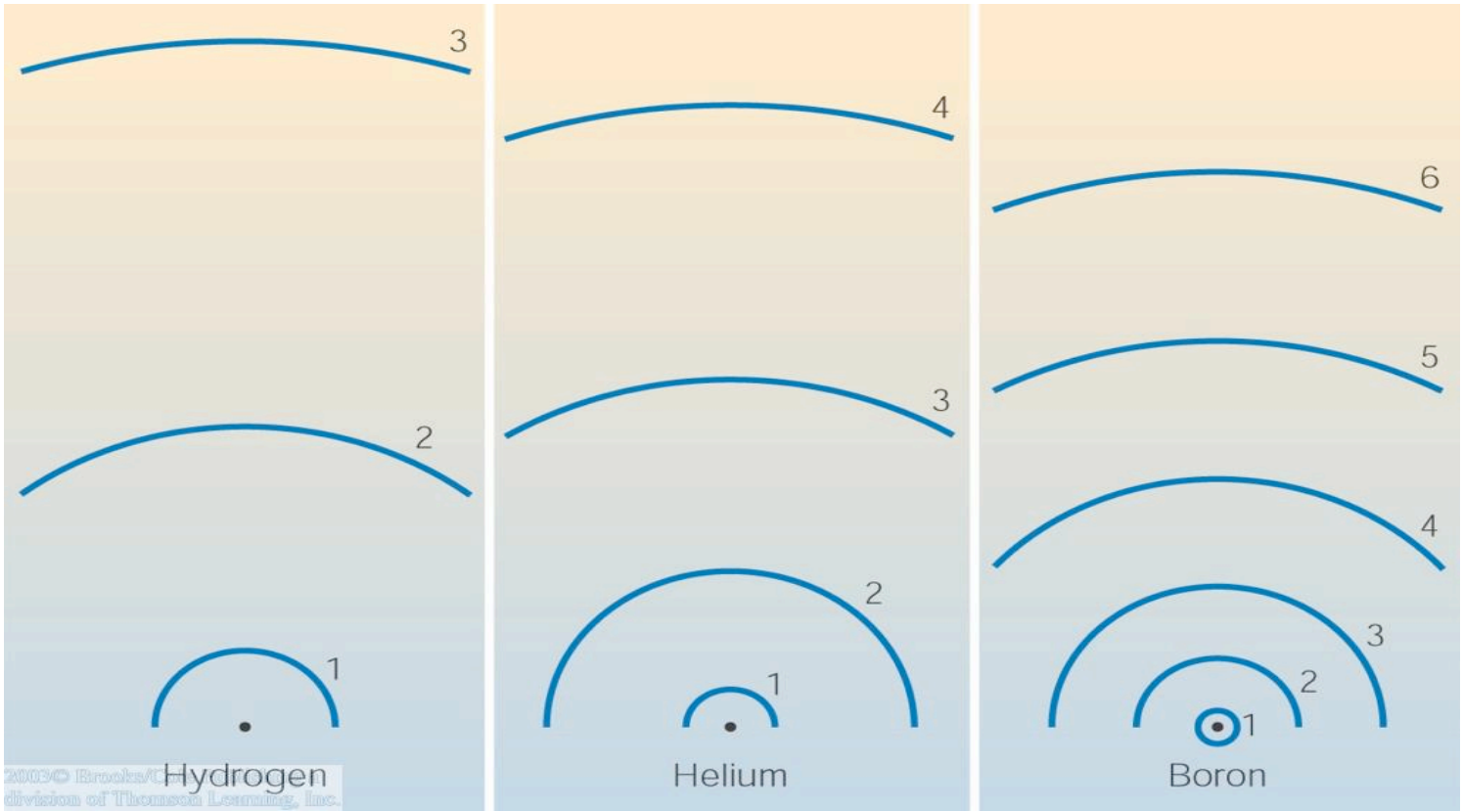
- An atom consists of an *atomic nucleus* (protons and neutrons) and a cloud of electrons surrounding it.
- Almost all of the mass is contained in the nucleus, while almost all of the space is occupied by the electron cloud.



Grapeseed in the middle of 4.5 football fields!

Electron Orbits

- *Electron orbits* in the electron cloud are restricted to very specific radii and energies.



- These characteristic electron energies are different for each individual element.

Electron Orbits

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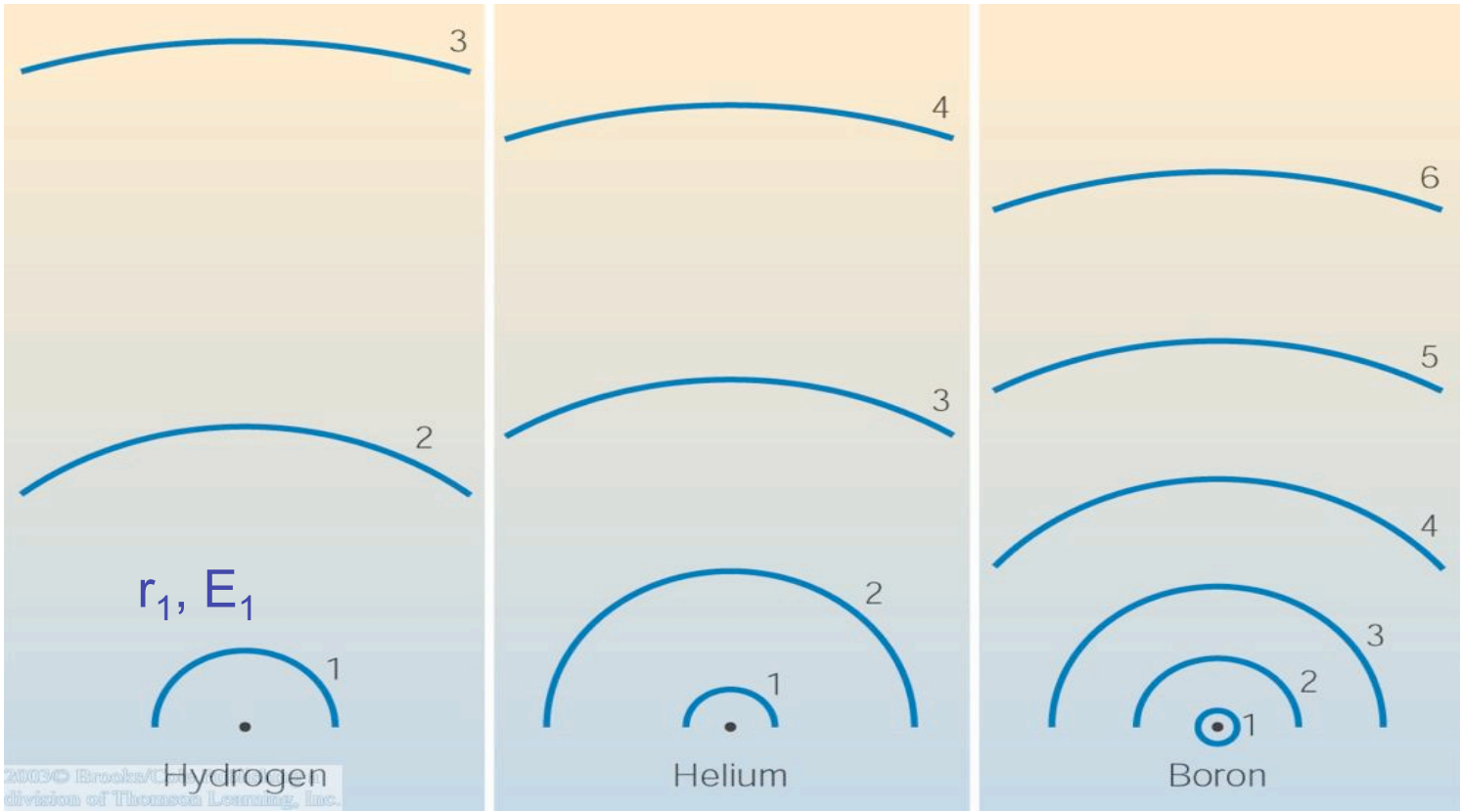

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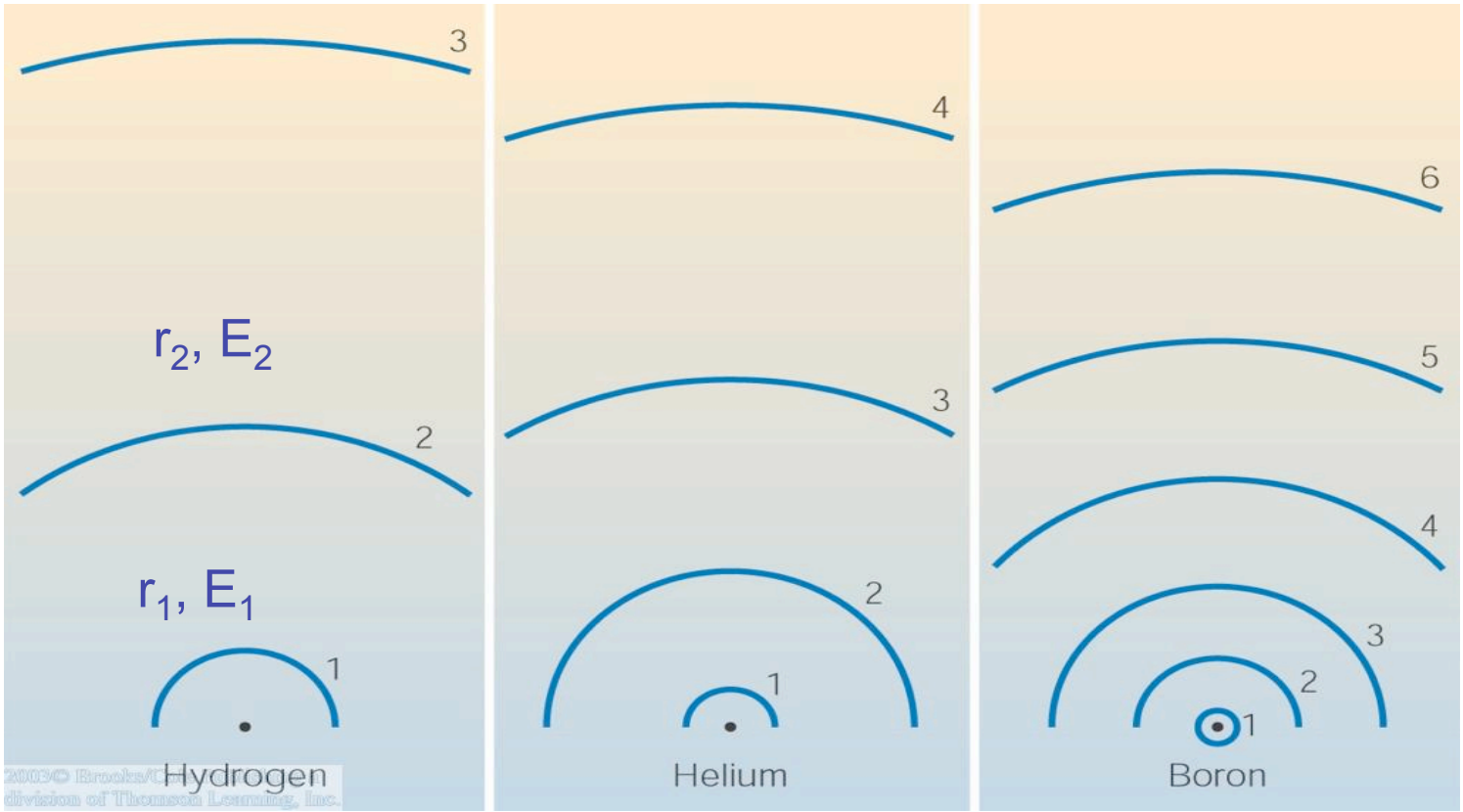

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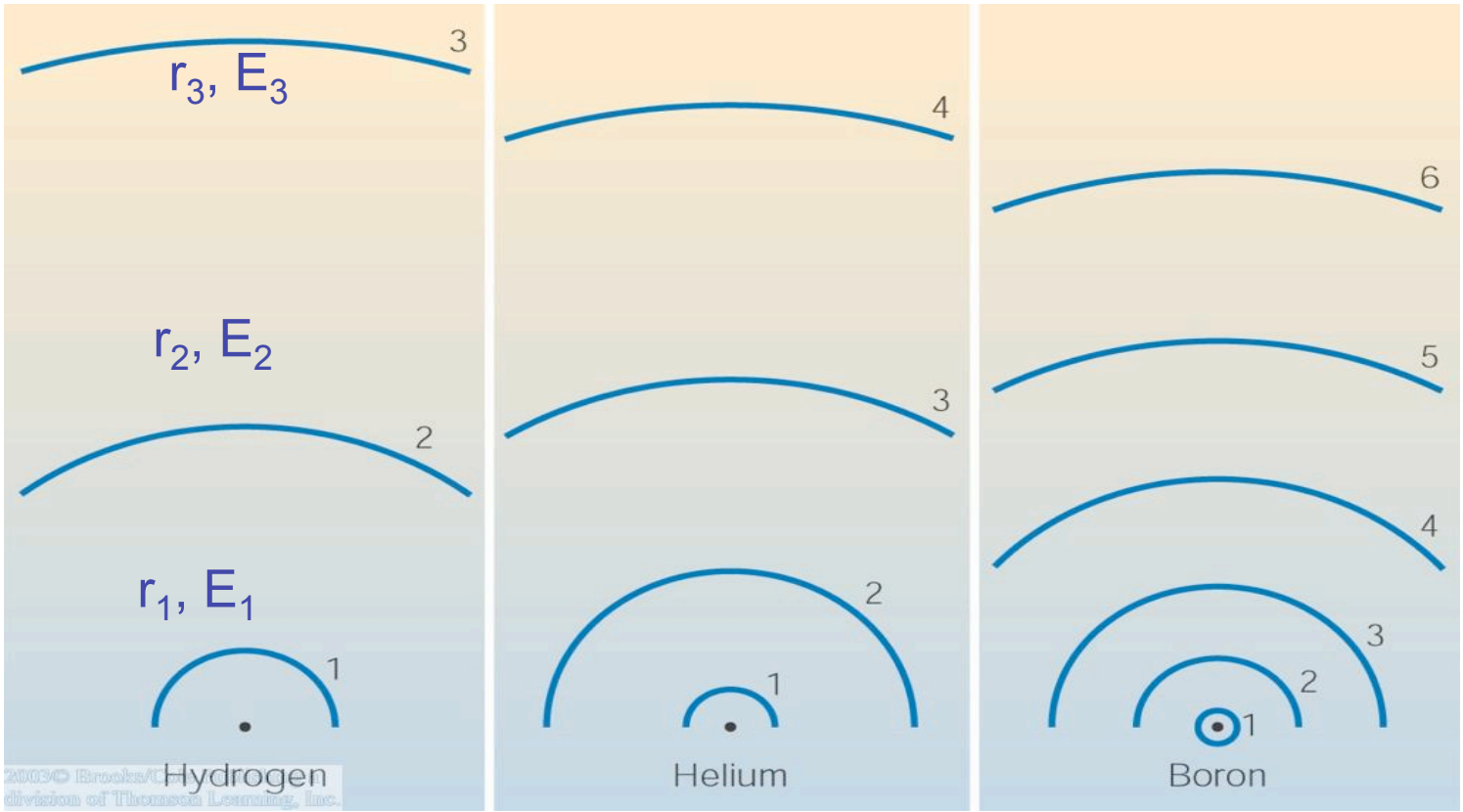
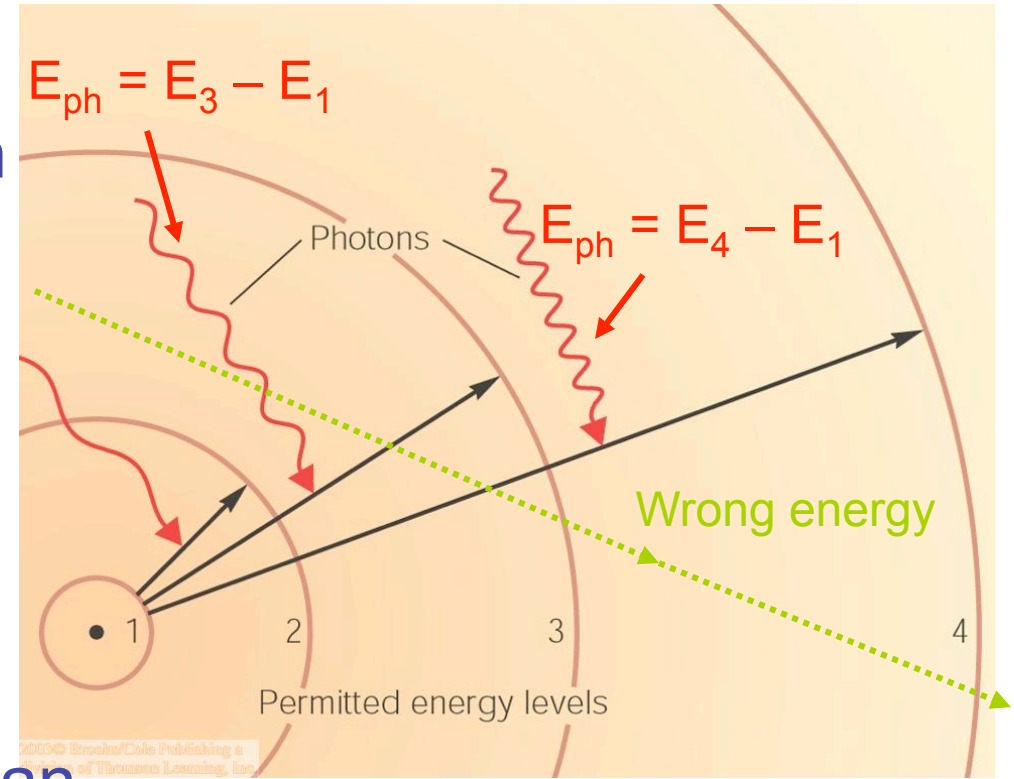


- These characteristic electron energies are different for each individual element.

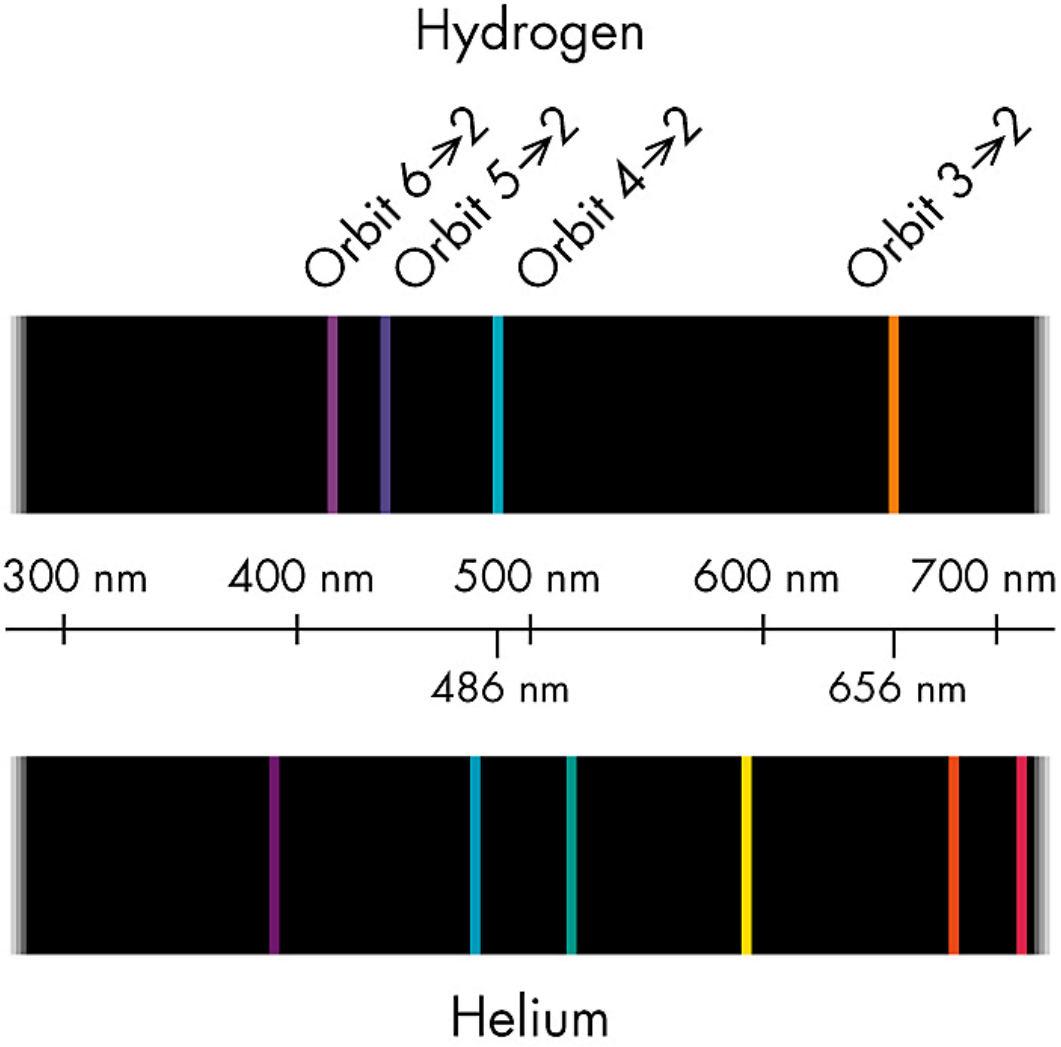
Atomic Transitions

- An electron can be kicked into a higher orbit when it absorbs a photon with exactly the right energy.
- The photon is absorbed, and the electron is in an excited state.
- All other photons pass by the atom unabsorbed.

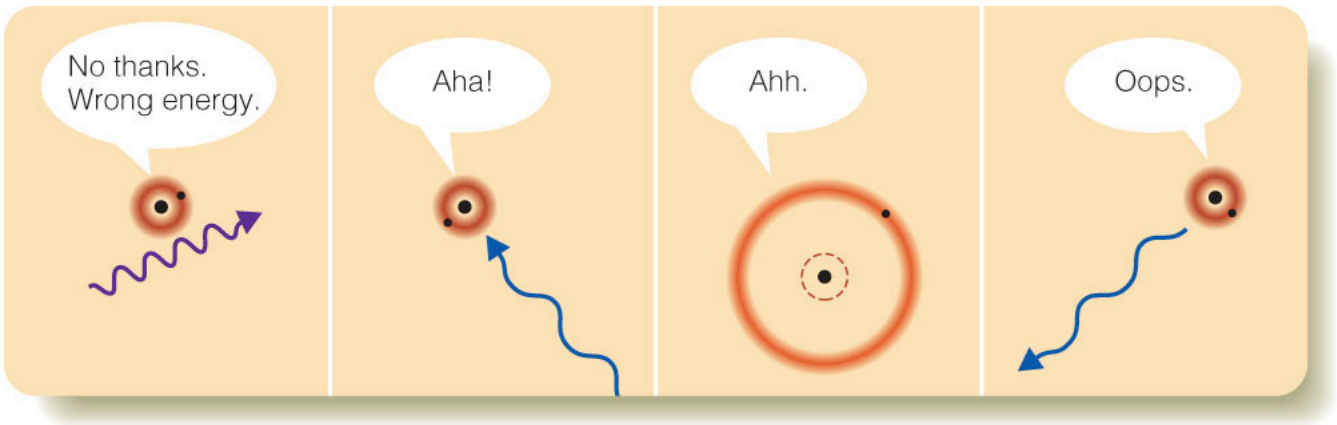


(Remember that $E_{ph} = h*f$)

Electron Orbits & Emission



Atomic Transitions

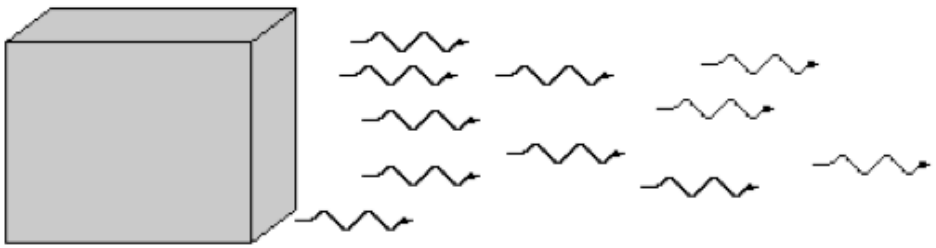


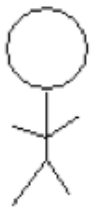
© Brooks/Cole, Cengage Learning

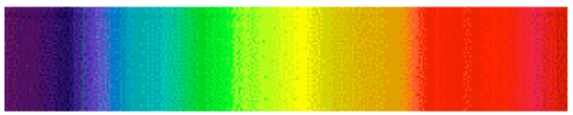
Electrons spontaneously decay back down to “ground” state

See animation at:
http://astro.unl.edu/classaction/animations/light/hydrogenatom.html

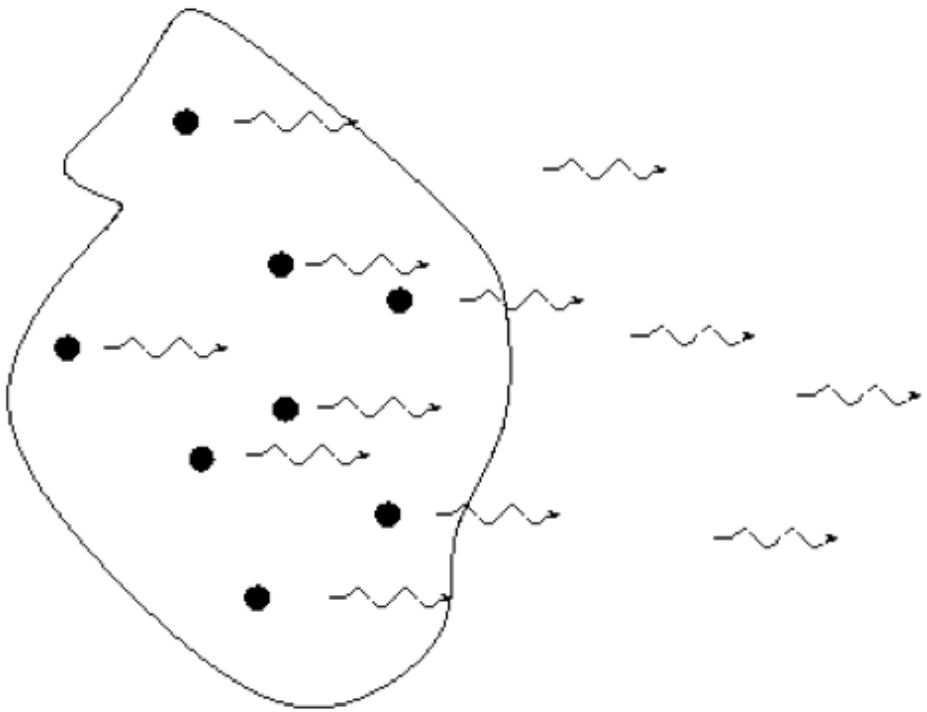
Continuous

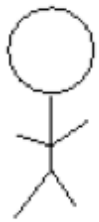




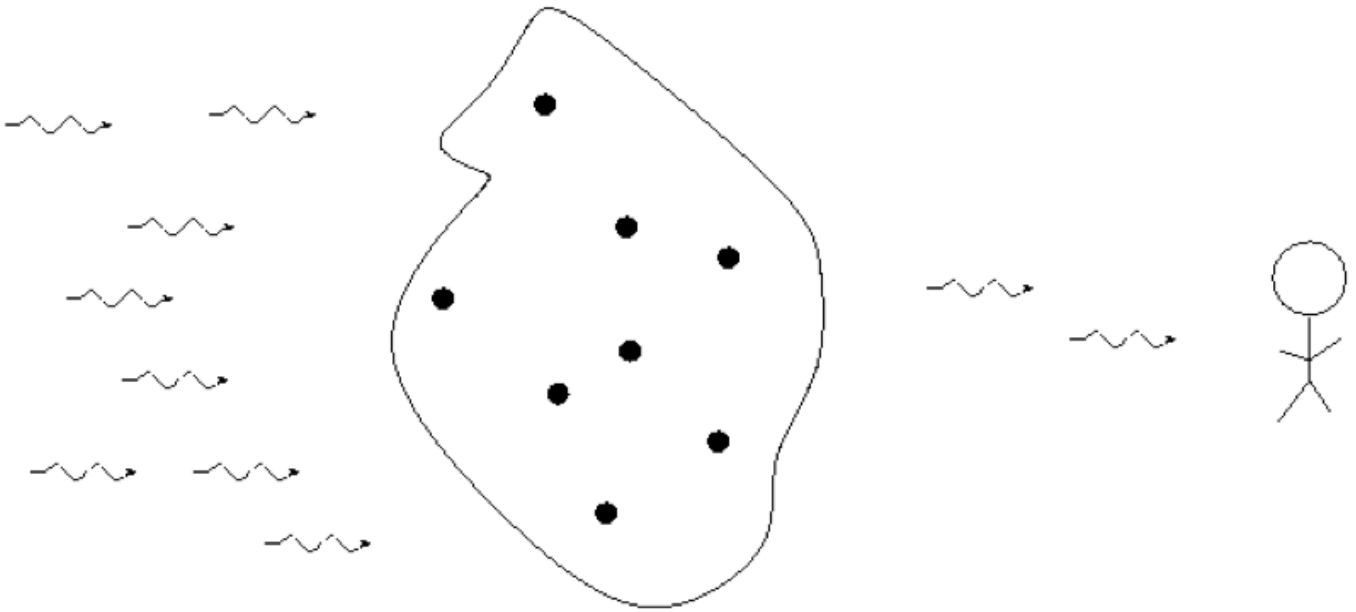


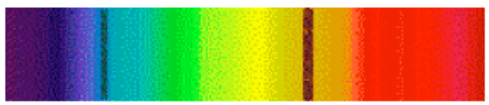
Emission





Absorption

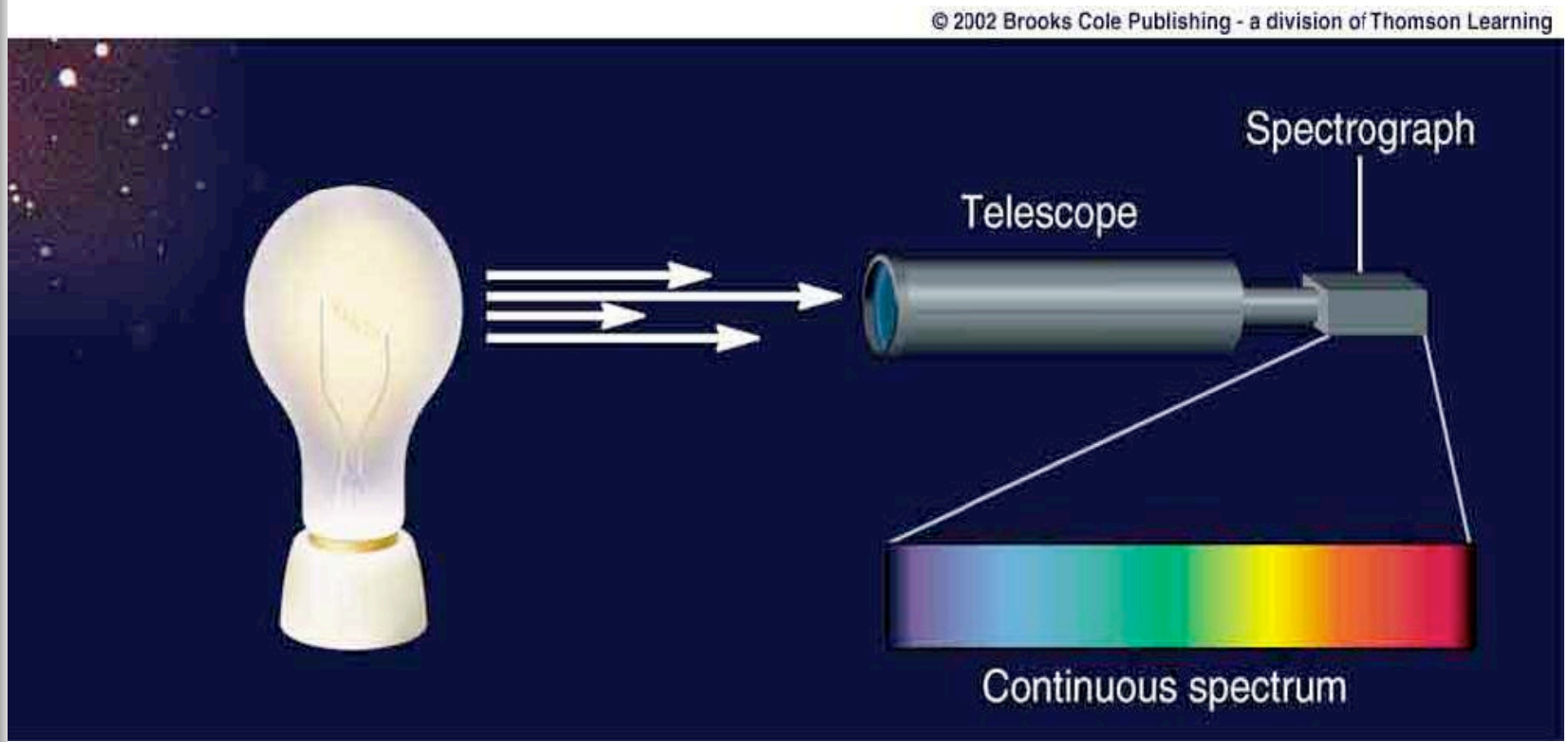




http://astro.unl.edu/classaction/animations/light/threeviewsspectra.html

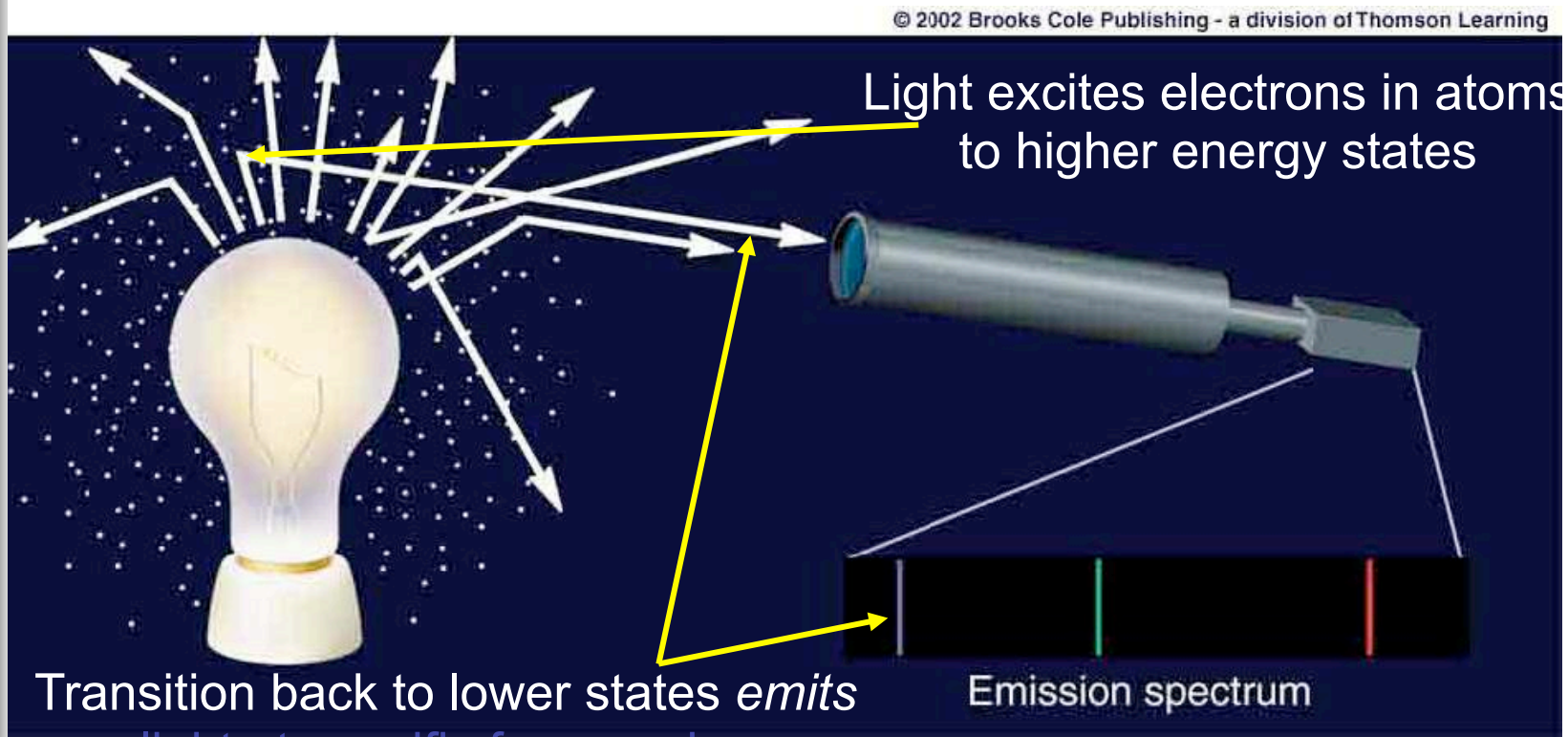
Kirchhoff's Laws of Radiation (1)

1. A solid, liquid, or dense gas at non-zero temperature will radiate at all wavelengths and thus produce a **continuous spectrum.**



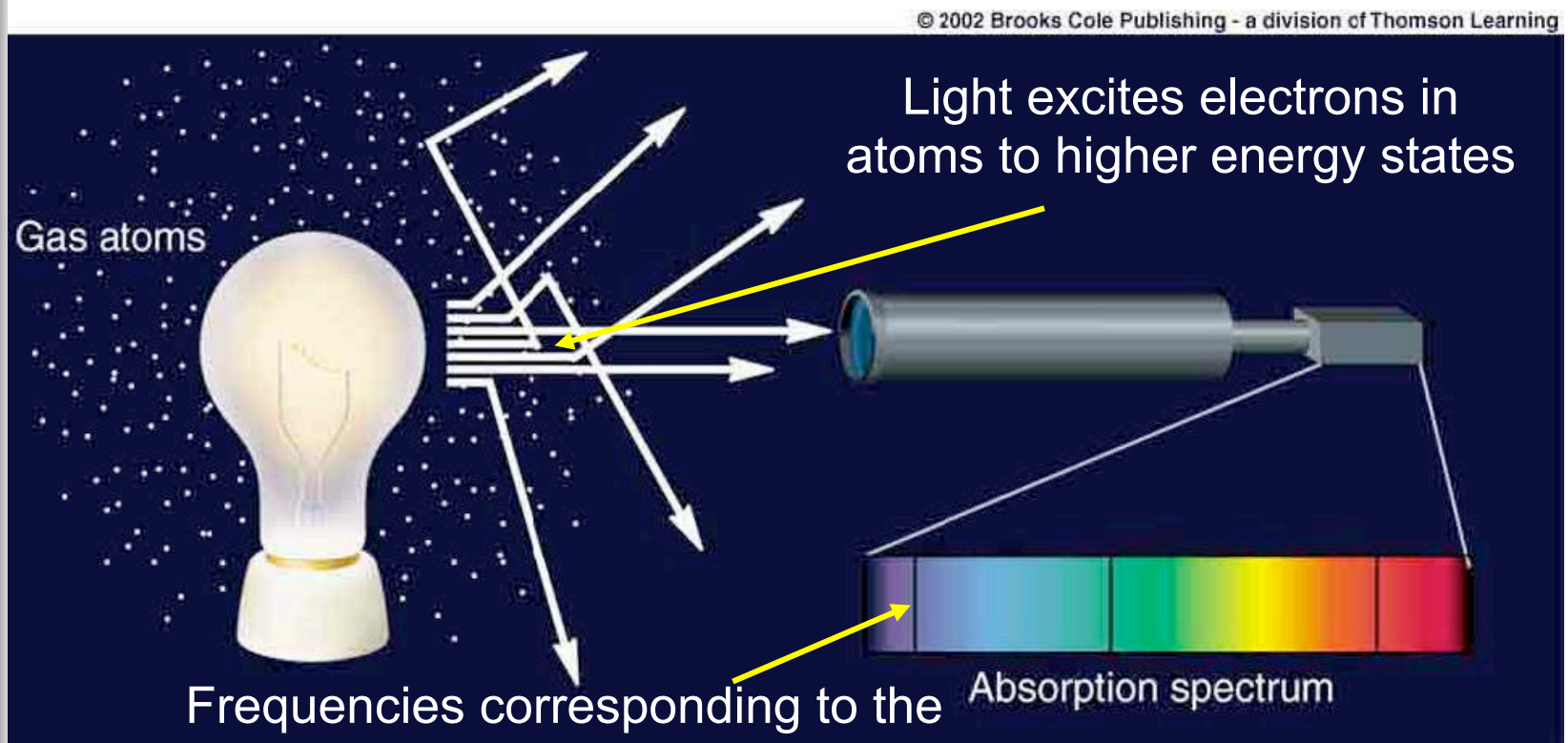
Kirchhoff's Laws of Radiation (2)

2. A low-density gas excited to emit light will do so at specific wavelengths and thus produce an **emission spectrum.**

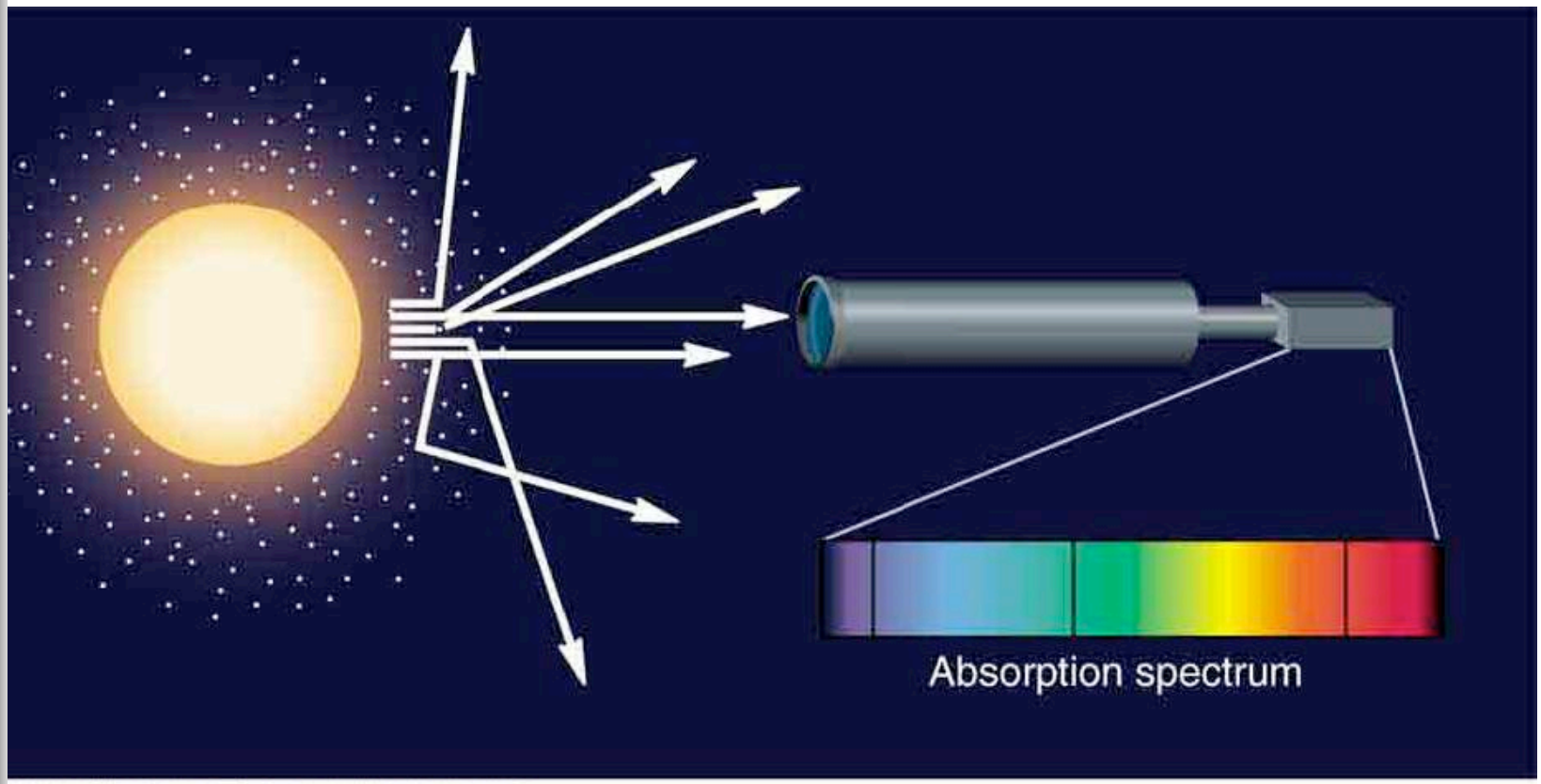


Kirchhoff's Laws of Radiation (3)

3. If light comprising a continuous spectrum passes through a cool, low-density gas, the result will be an absorption spectrum.



The Spectra of Stars



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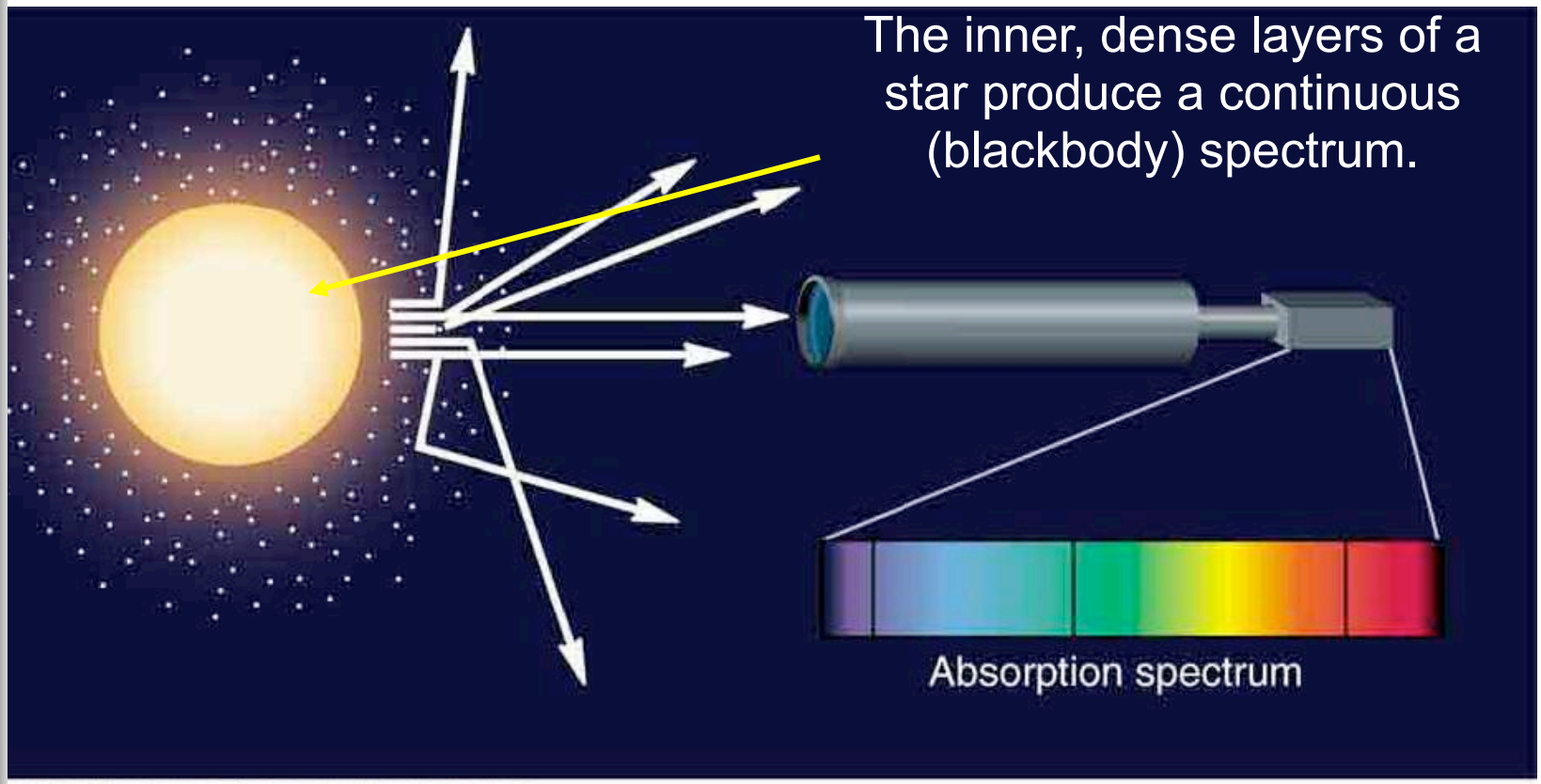
The Spectra of Stars



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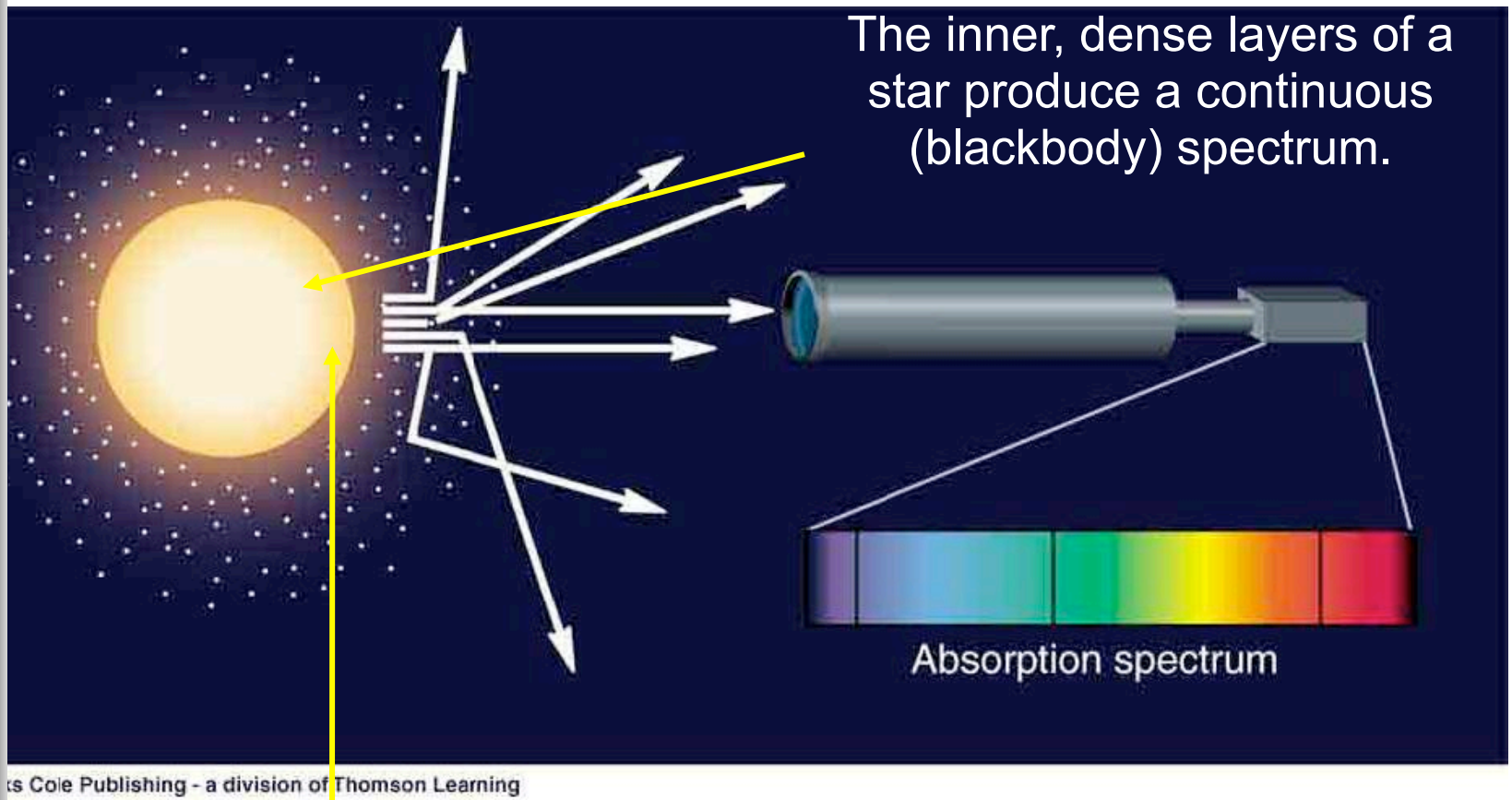
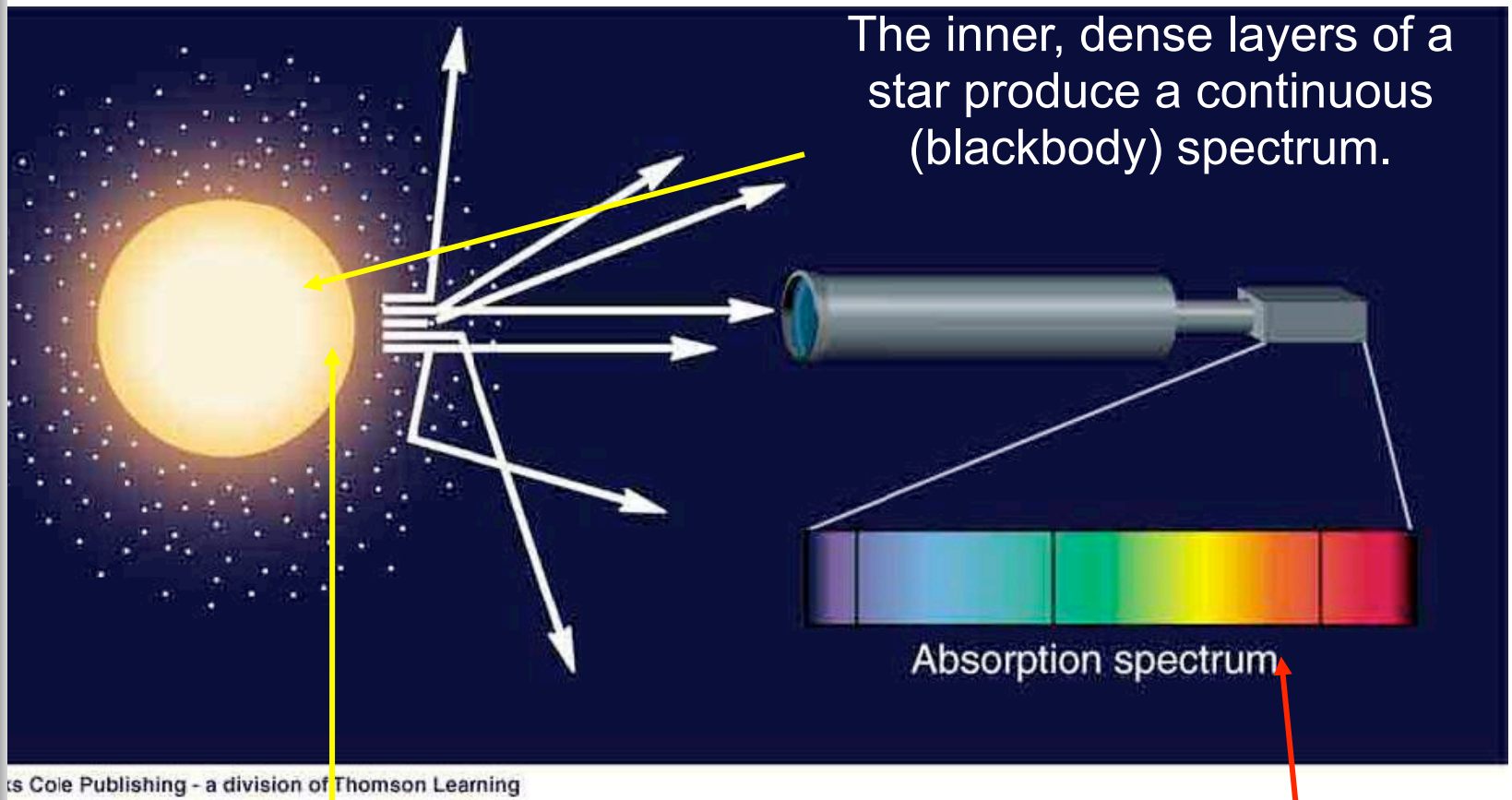
The Spectra of Stars



Cooler surface layers absorb light at specific frequencies.

The Spectra of Stars



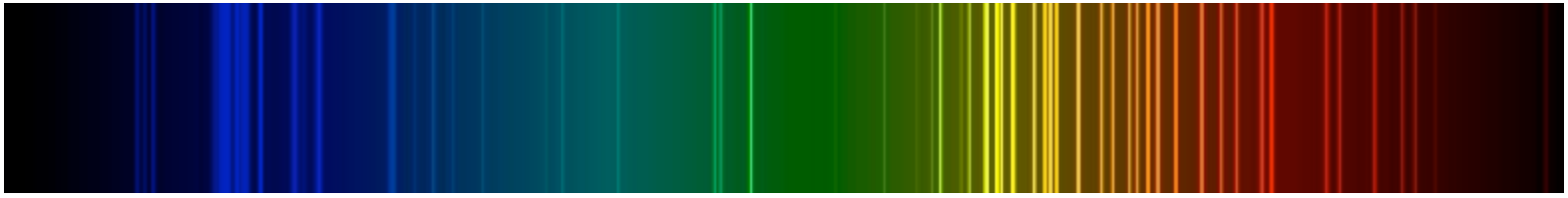
Cooler surface layers absorb light at specific frequencies.

=> Spectra of stars are absorption spectra.

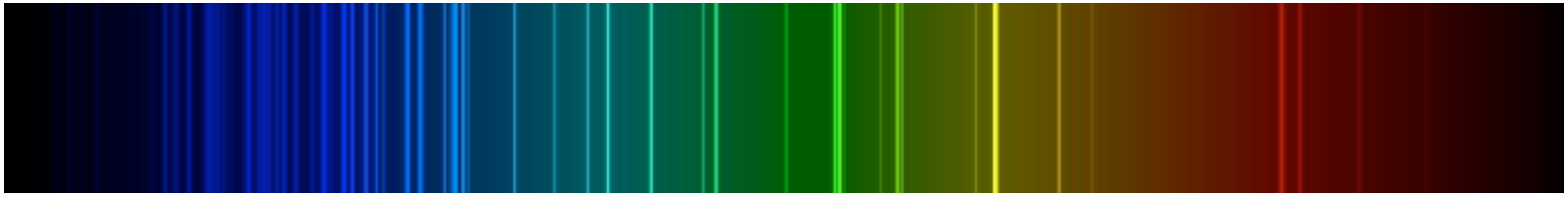
H

He

Ne



Kr

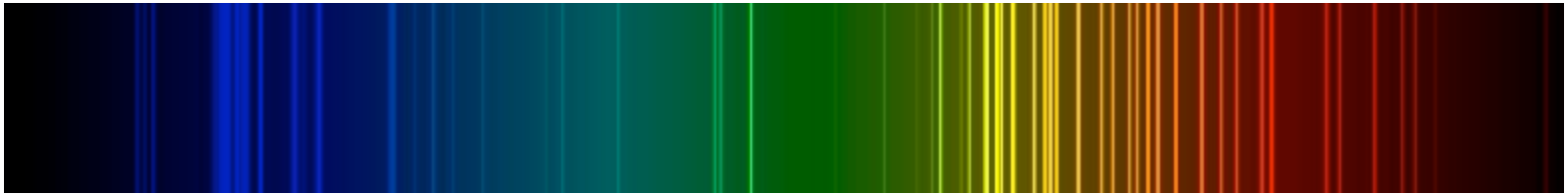


Since pattern is unique for every element, the emission spectrum serves as an atomic fingerprint, telling us about the composition of celestial objects.

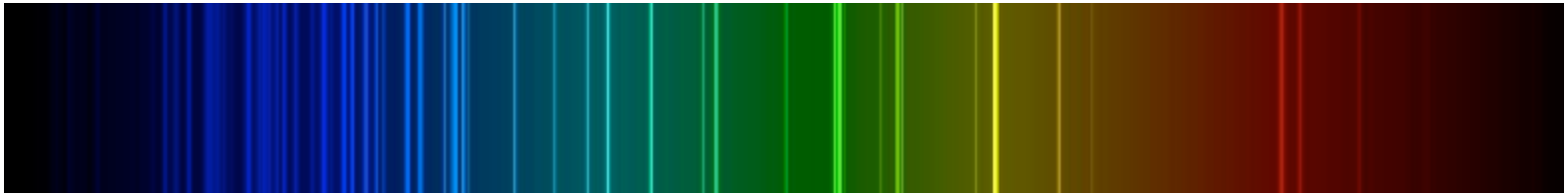
H

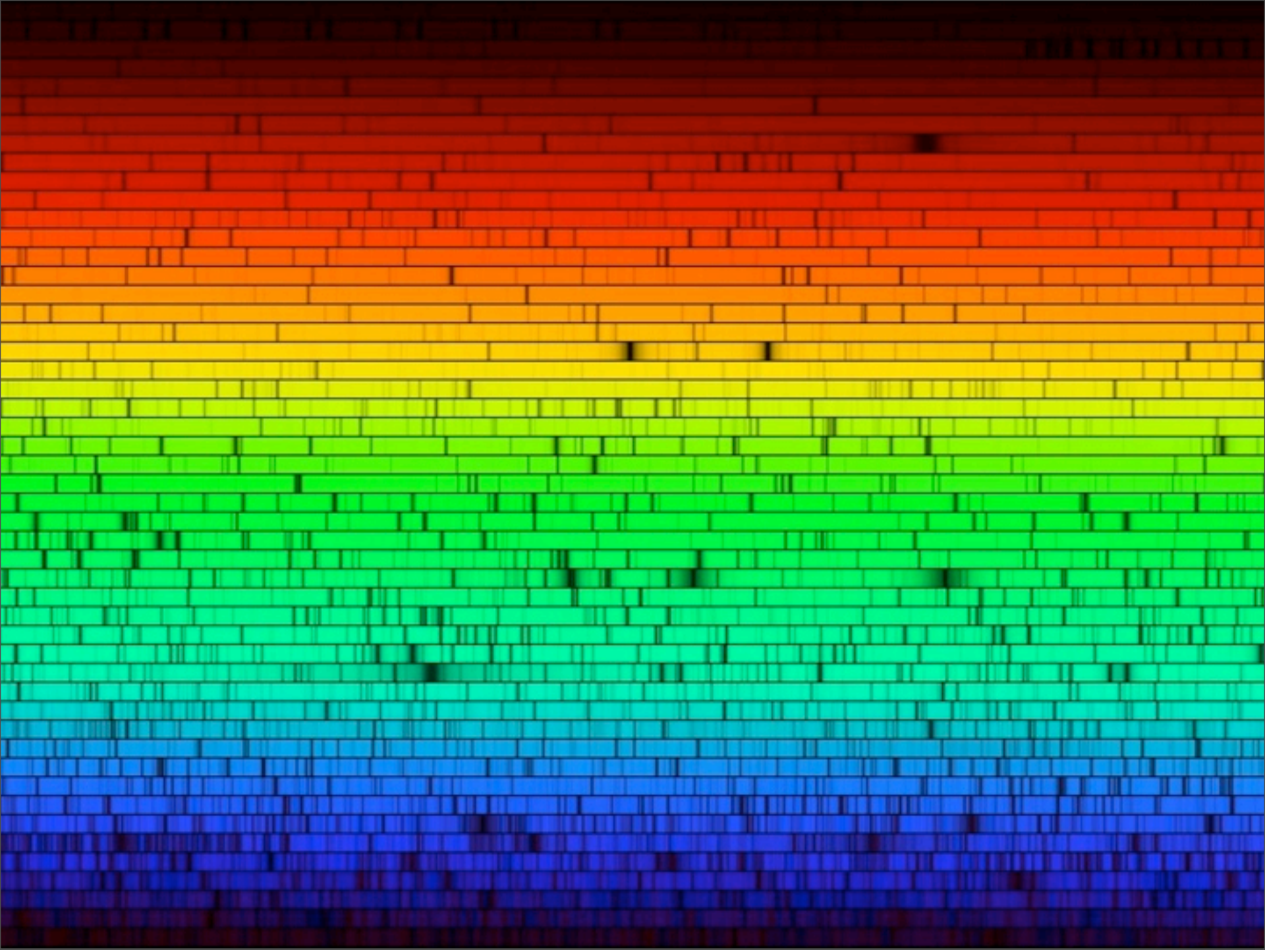
He

Ne



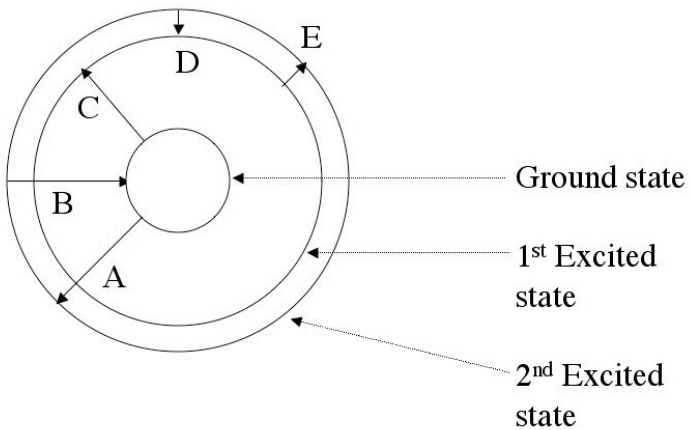
Kr

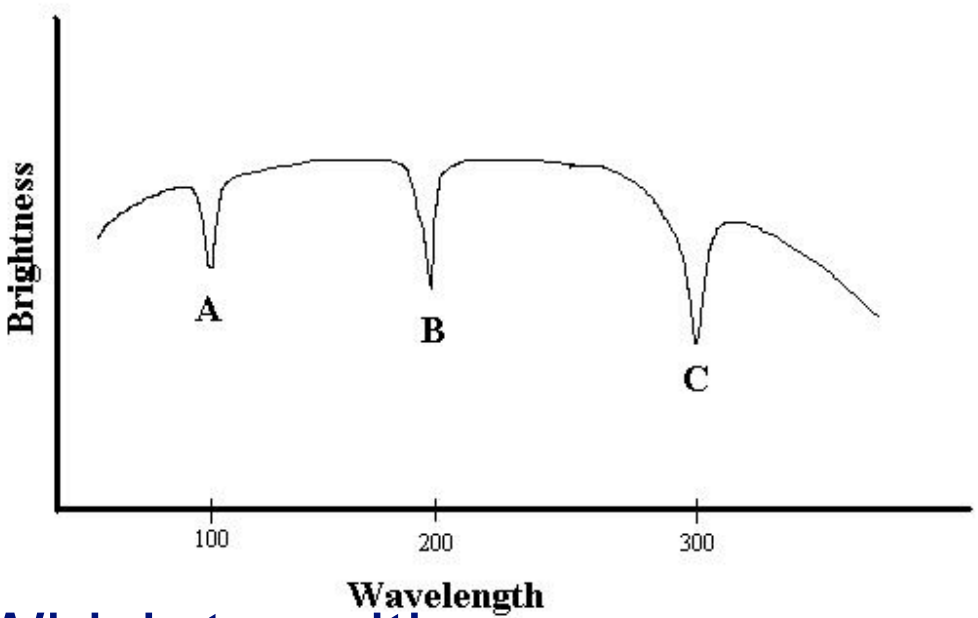


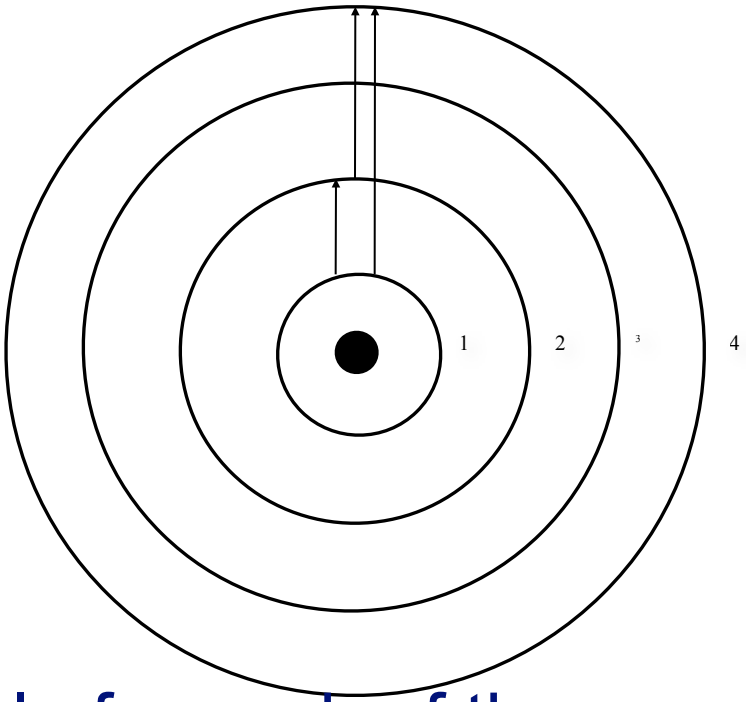


- The specific wavelengths seen in an emission line spectrum are due to
- A) photons dropping to lower energy orbits.
- B) photons jumping to higher energy orbits.
- C) electrons dropping to lower energy orbits.

- Below is a model 3-level hydrogen atom. Each of the circles represents an energy level/ orbit around the nucleus, from the ground state (n = 1) to the second excited state (n= 3). The spacing of each circle is proportional to the energy of each orbit. The arrows represent electron transitions. Which transition will result in the emission of the longest wavelength photon?
- A) A
- B) B
- C) C

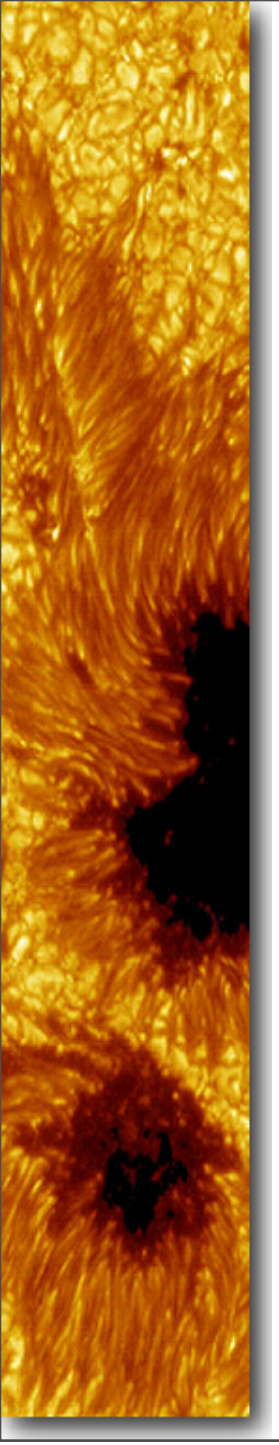






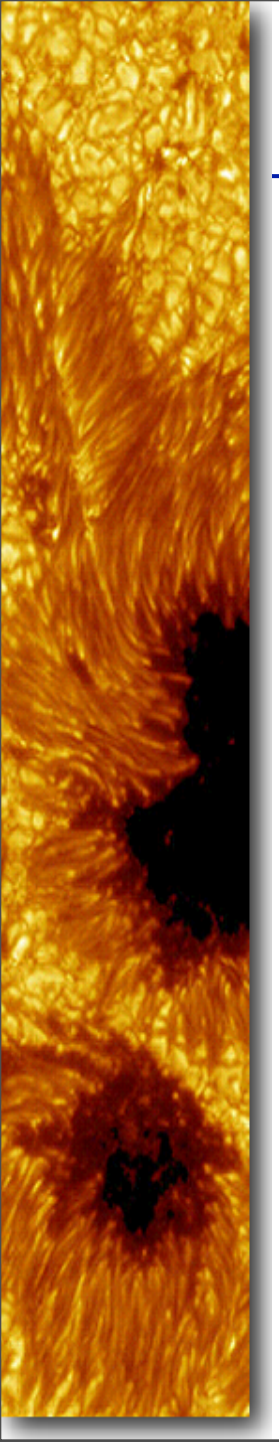
Which transitions were responsible for each of these absorption lines?

a) A: 1-2 B: 2-4 C: 1-4
b) A: 1-4 B: 2-4 C: 1-2
c) A: 4-1 B: 4-2 C: 2-1



Chapter 8

The Sun



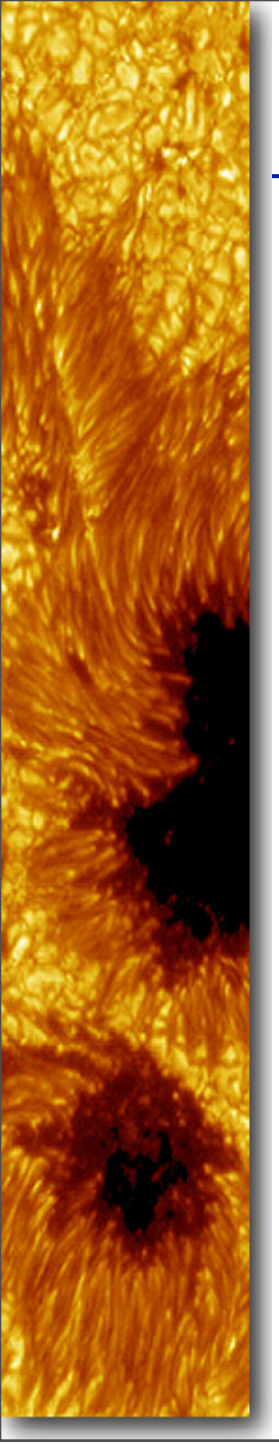
Guidepost

In this chapter, you can use the interaction of light and matter to reveal the secrets of the sun. Because the sun is a typical star, what you are about to learn are the secrets of the stars.

This chapter will help you answer three essential questions:

- *What do you see when you look at the sun?*
- *How does the sun make its energy?*
- *What causes sunspots and other forms of solar activity?*

The sun will give you a close-up look at a star.

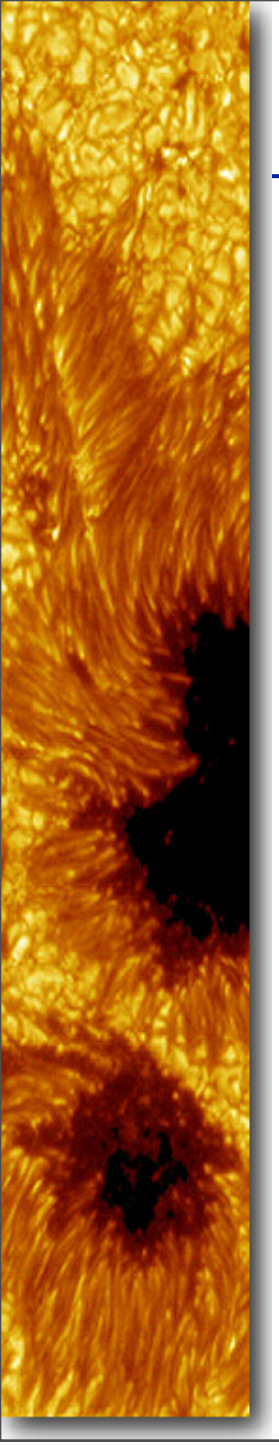


Outline

I. The Solar Atmosphere
- A. The Photosphere
- B. The Chromosphere
- C. The Solar Corona
- D. Helioseismology

II. Nuclear Fusion in the Sun

III. Solar Activity



Outline

I. The Solar Atmosphere
   A. The Photosphere
   B. The Chromosphere
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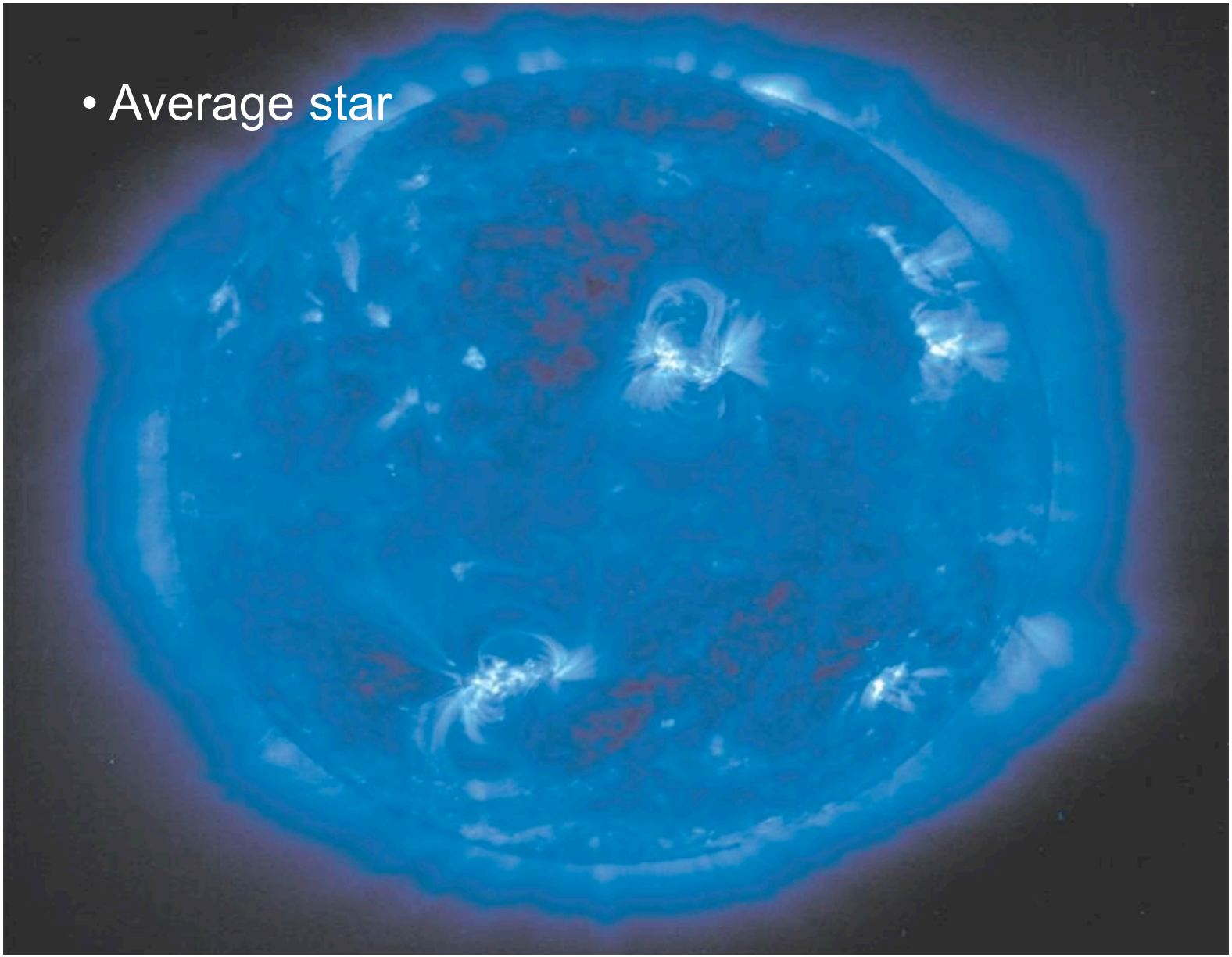
   D. Helioseismology

} Today!

II. Nuclear Fusion in the Sun

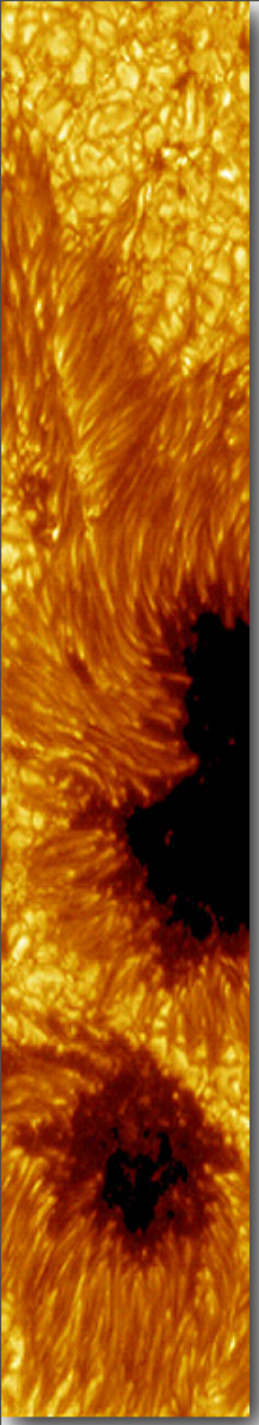
III. Solar Activity

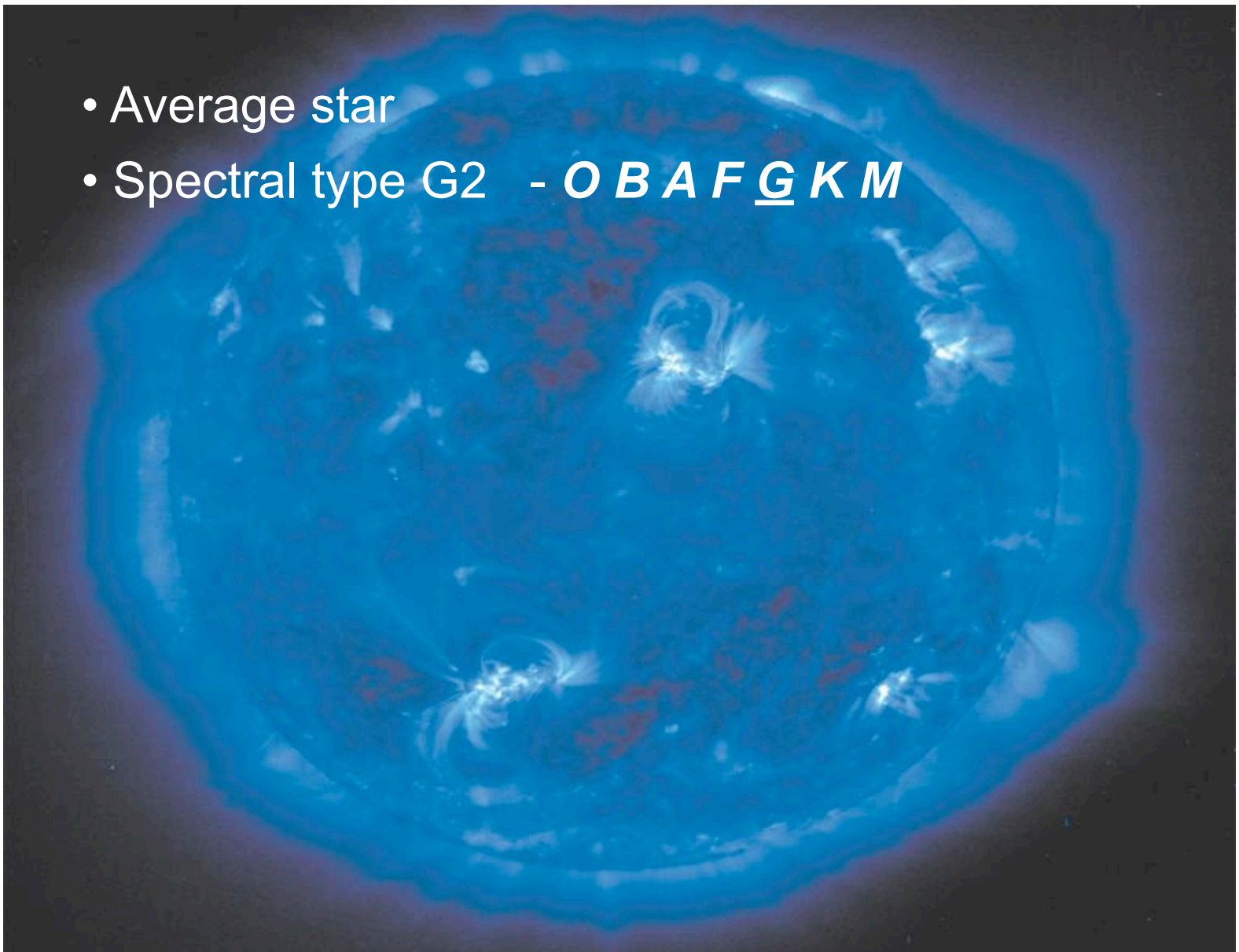
General Properties



- Average star

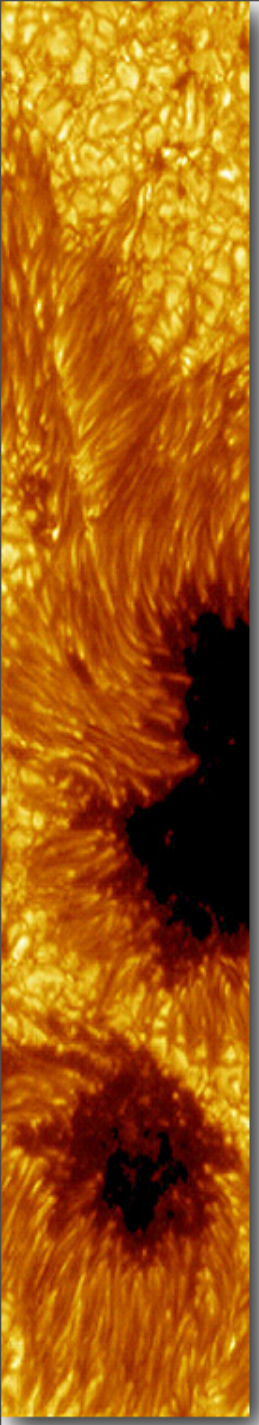
General Properties

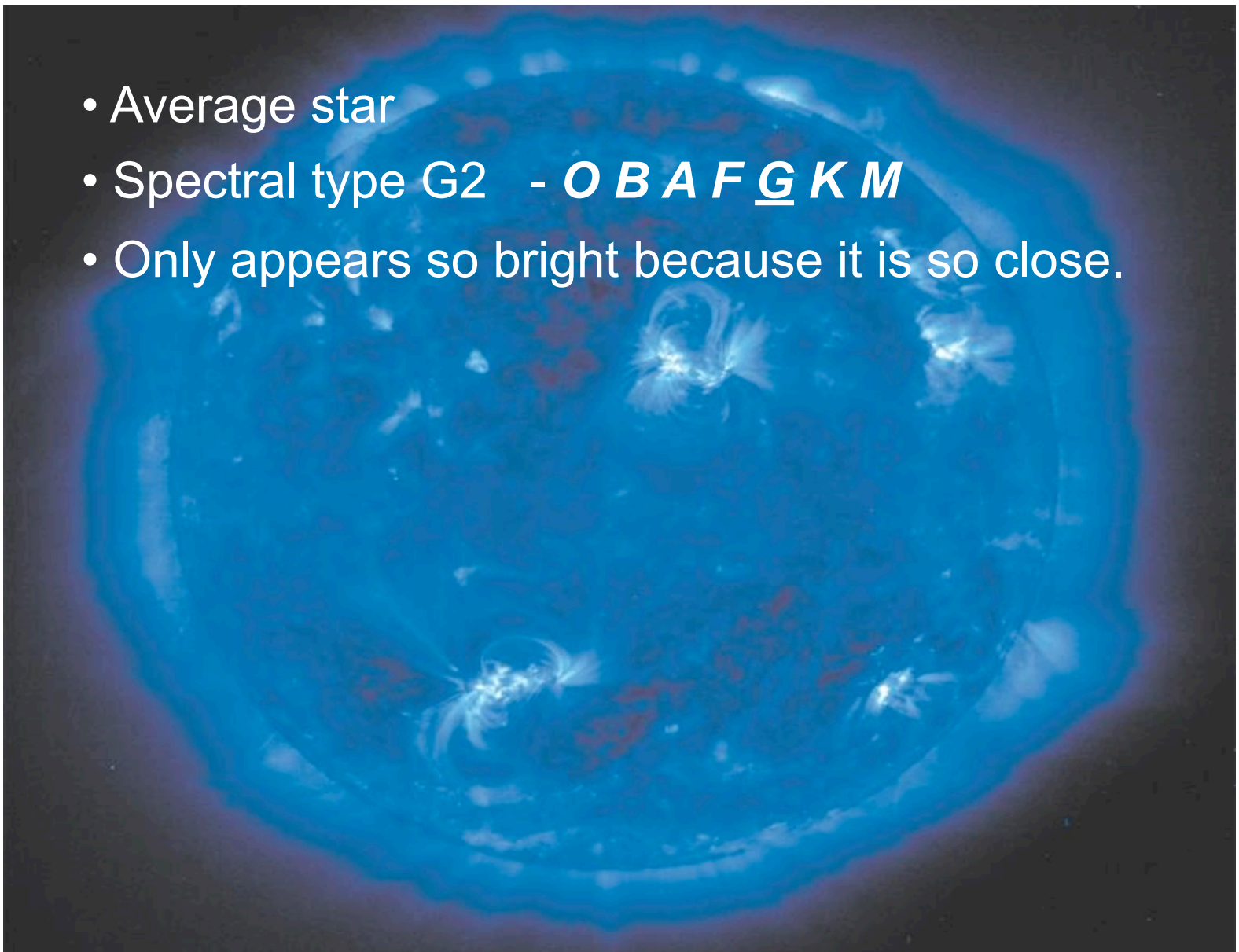




- Average star
- Spectral type G2 - ***O B A F <u>G</u> K M***

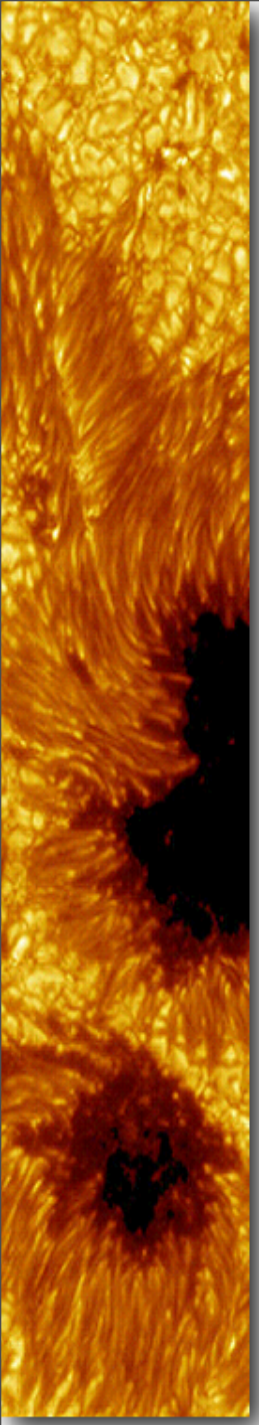
General Properties

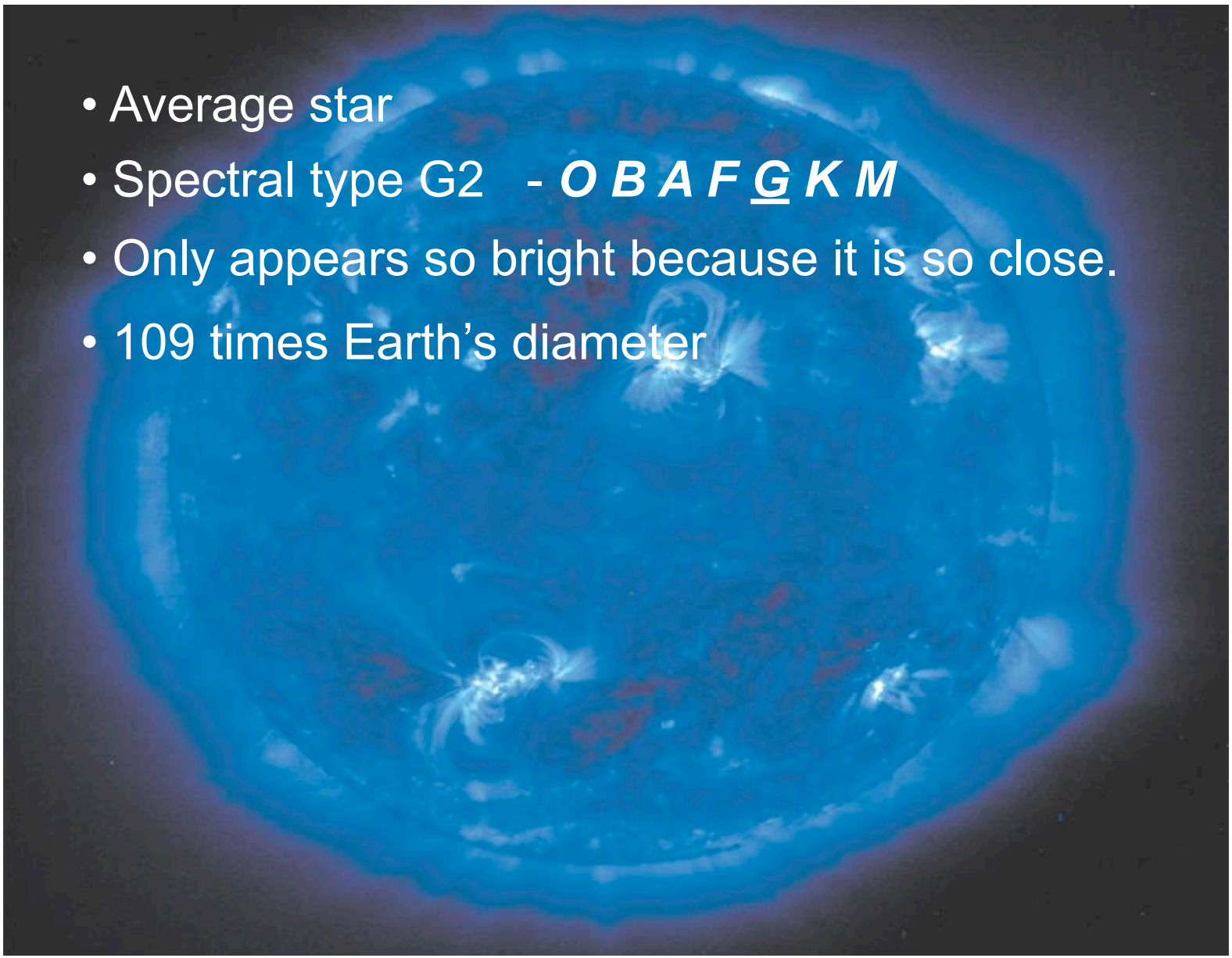




- Average star
- Spectral type G2 - ***O B A F <u>G</u> K M***
- Only appears so bright because it is so close.

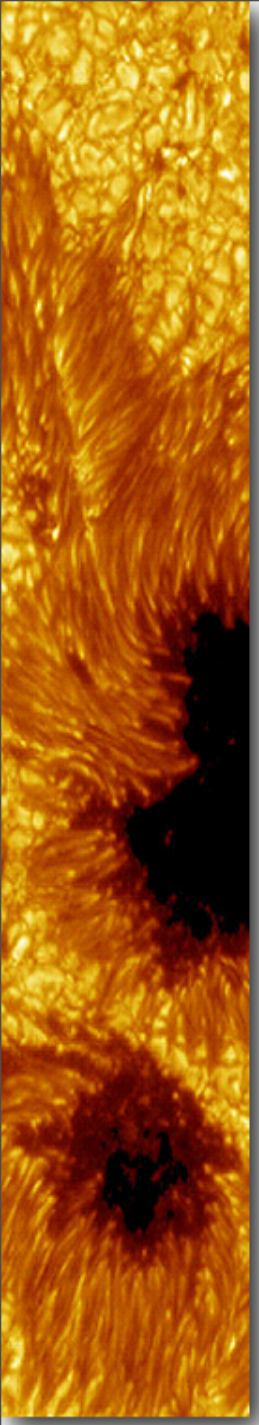
General Properties

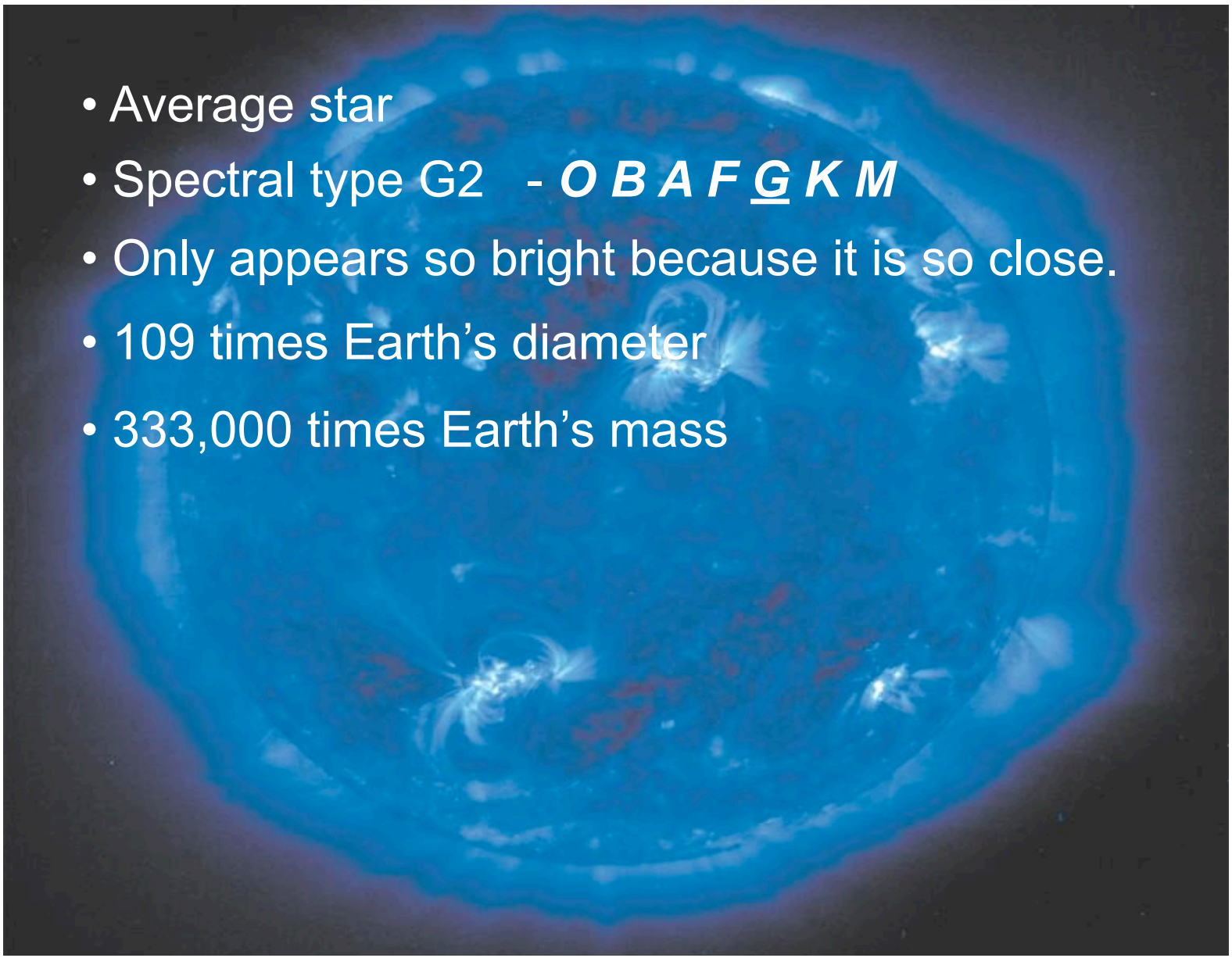




- Average star
- Spectral type G2 - ***O B A F <u>G</u> K M***
- Only appears so bright because it is so close.
- 109 times Earth's diameter

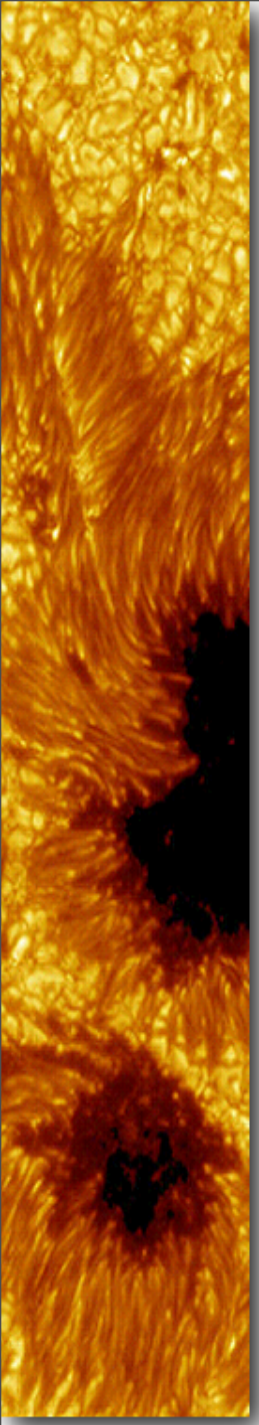
General Properties





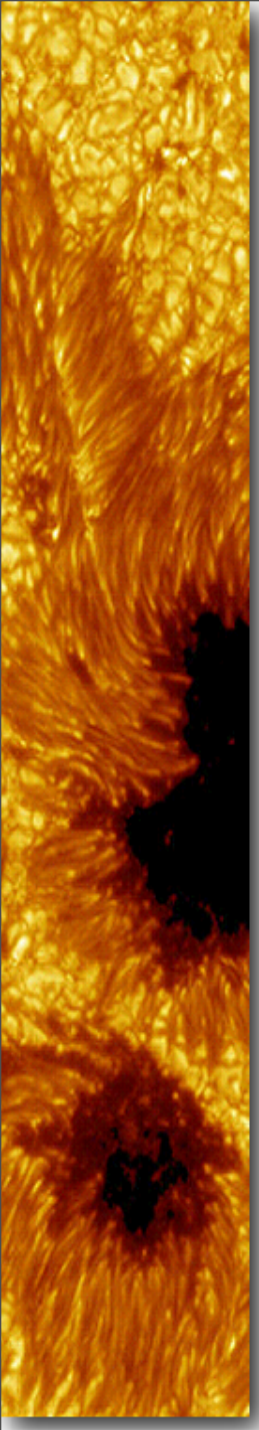
- Average star
- Spectral type G2 - ***O B A F <u>G</u> K M***
- Only appears so bright because it is so close.
- 109 times Earth's diameter
- 333,000 times Earth's mass

General Properties



- Average star
- Spectral type G2 - ***O B A F <u>G</u> K M***
- Only appears so bright because it is so close.
- 109 times Earth's diameter
- 333,000 times Earth's mass
- Consists entirely of gas (av. density = 1.4 g/cm^3)

General Properties



- Average star
- Spectral type G2 - ***O B A F <u>G</u> K M***
- Only appears so bright because it is so close.
- 109 times Earth's diameter
- 333,000 times Earth's mass
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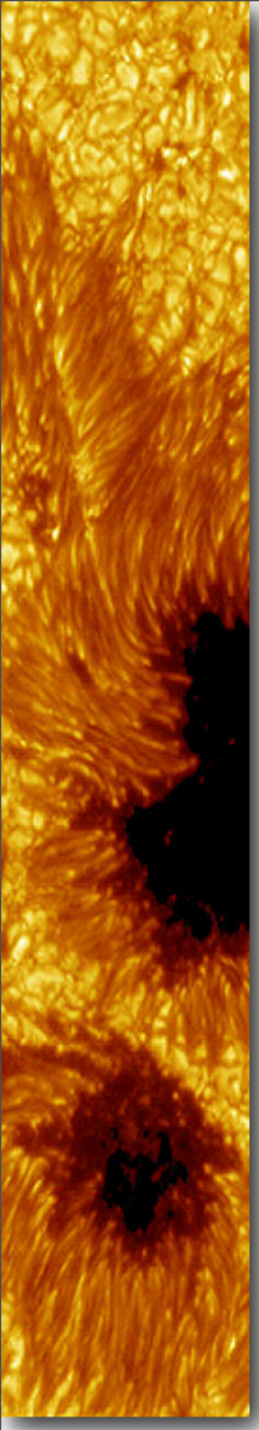

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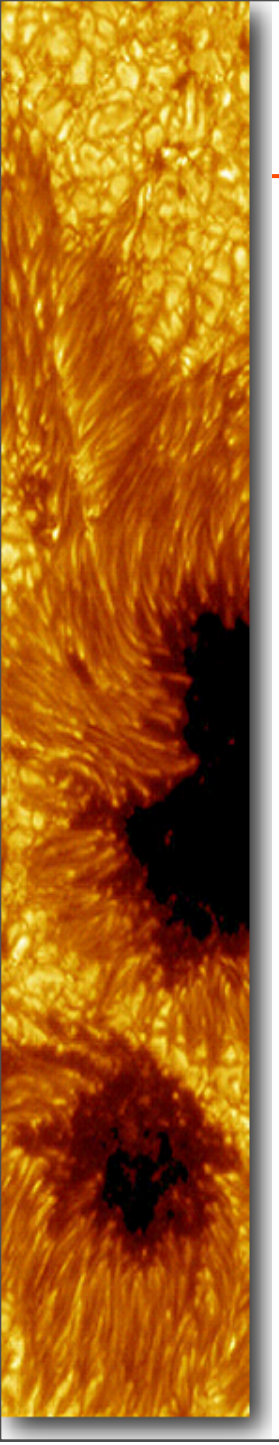
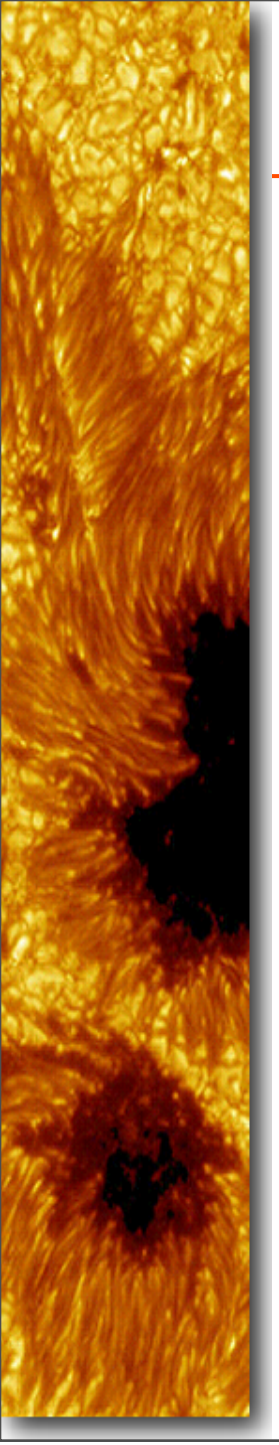


Very Important Warning:

Never look directly at the sun through a telescope or binoculars!!!



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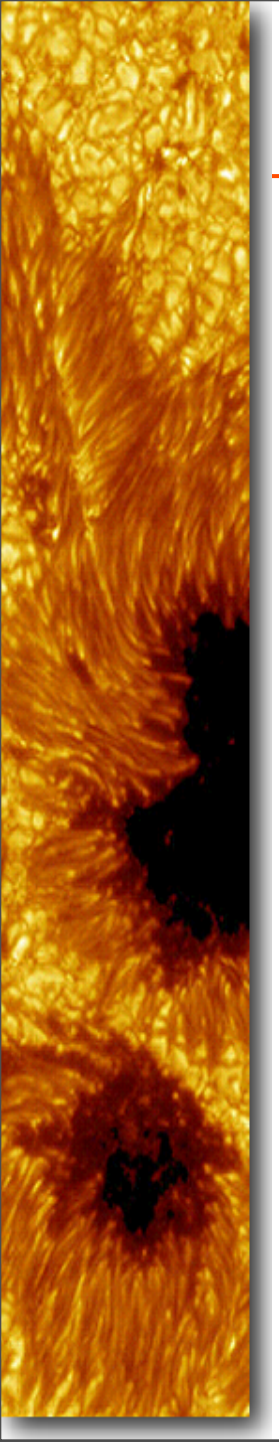

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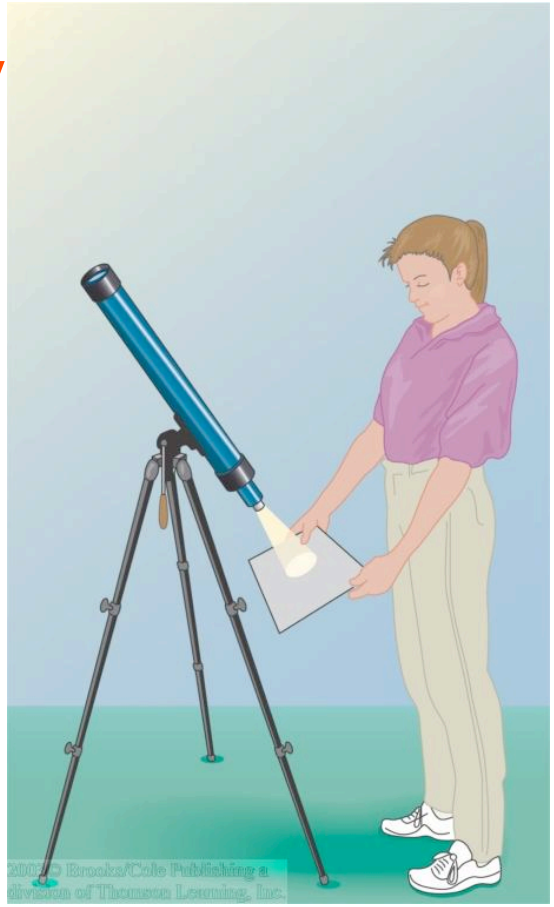

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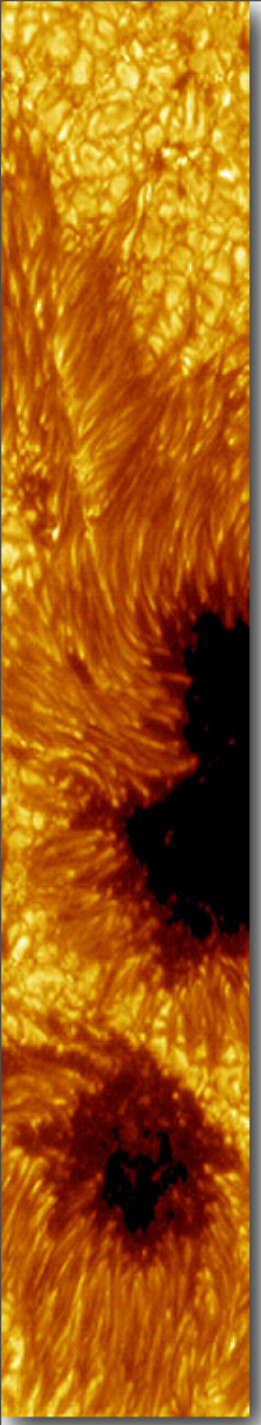
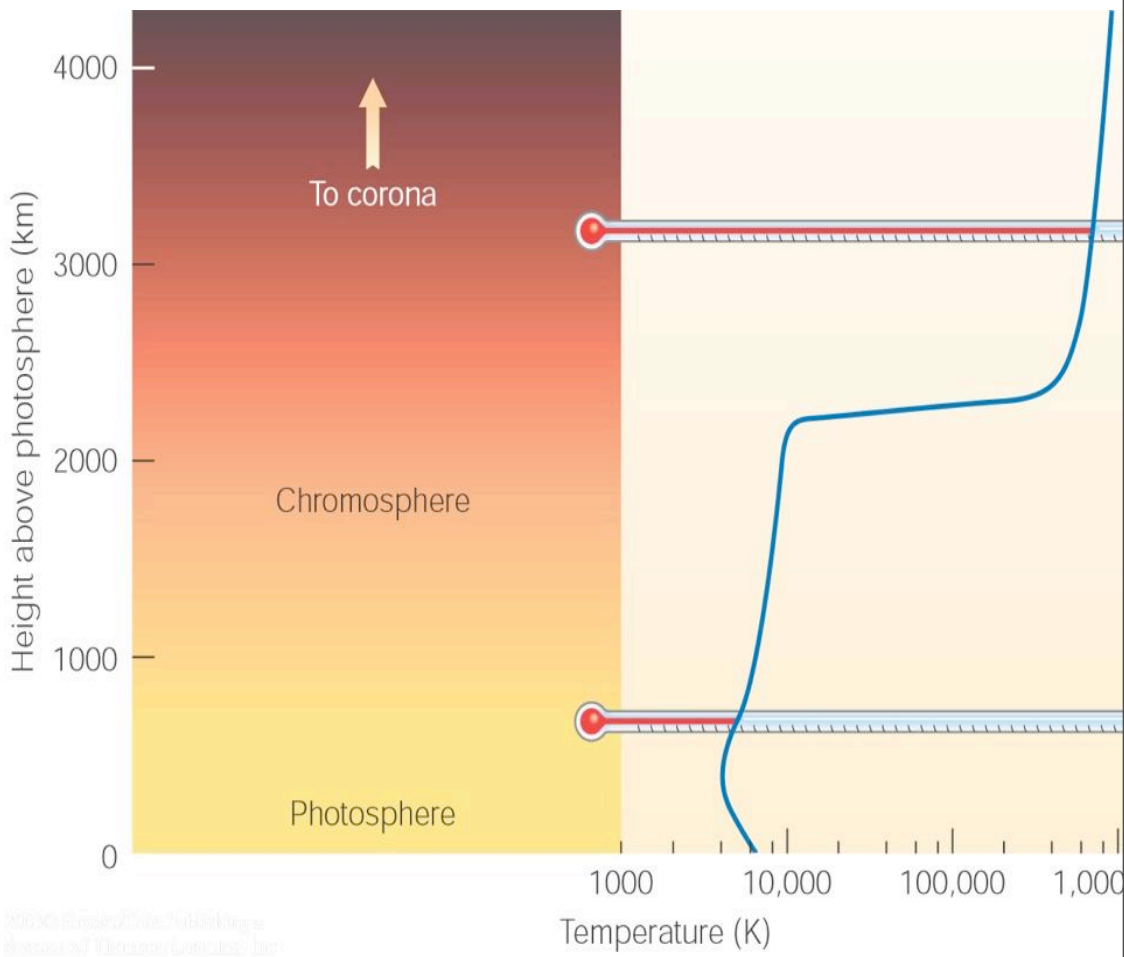
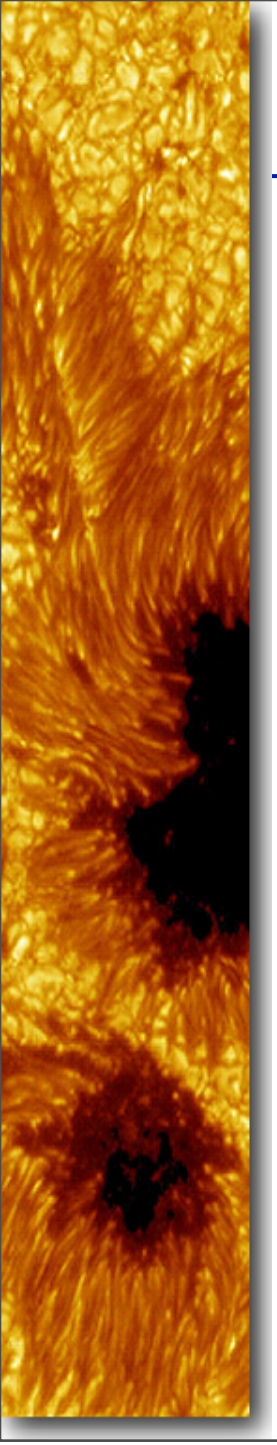
Use a projection technique or a special sun viewing filter.

The Solar Atmosphere

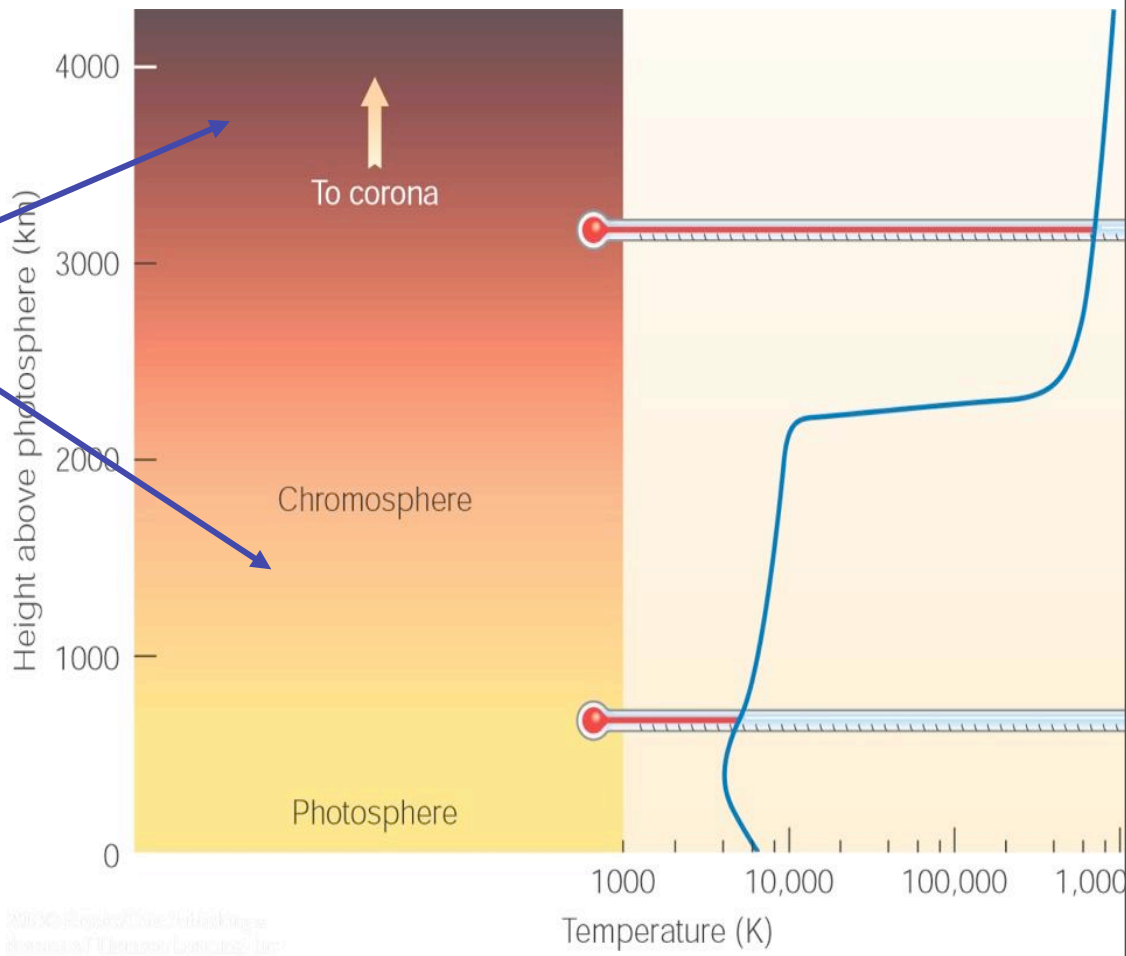






The Solar Atmosphere

Only visible during solar eclipses



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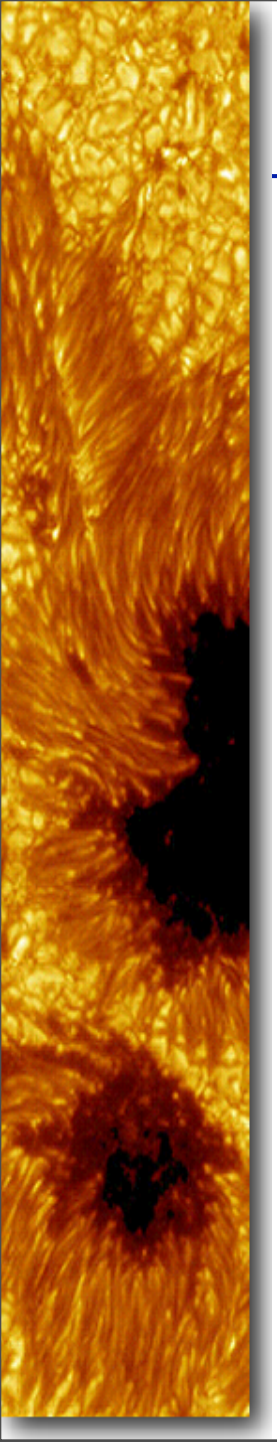

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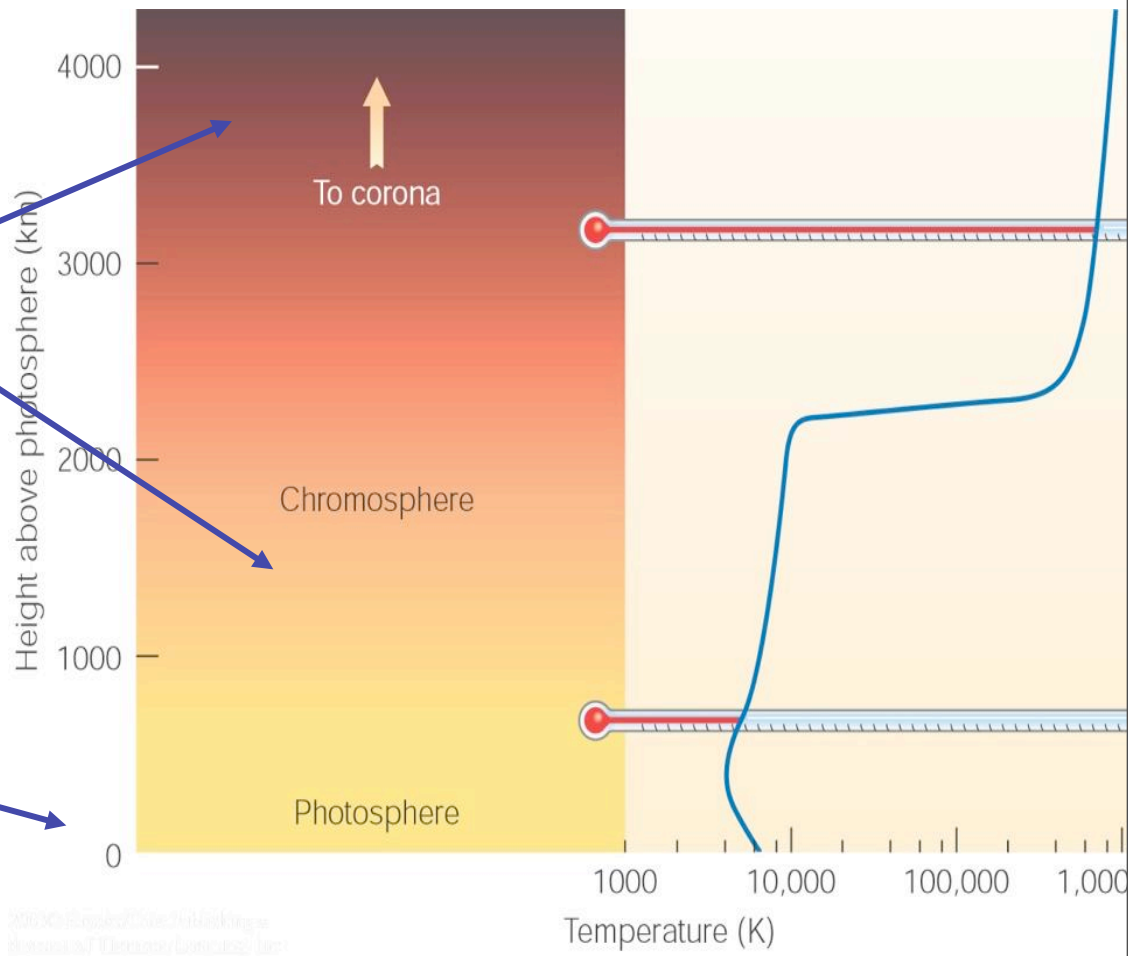
Apparent surface of the sun



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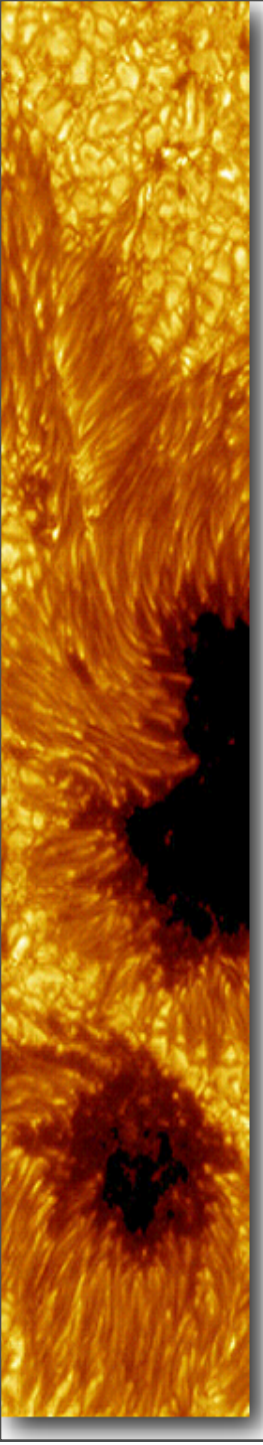

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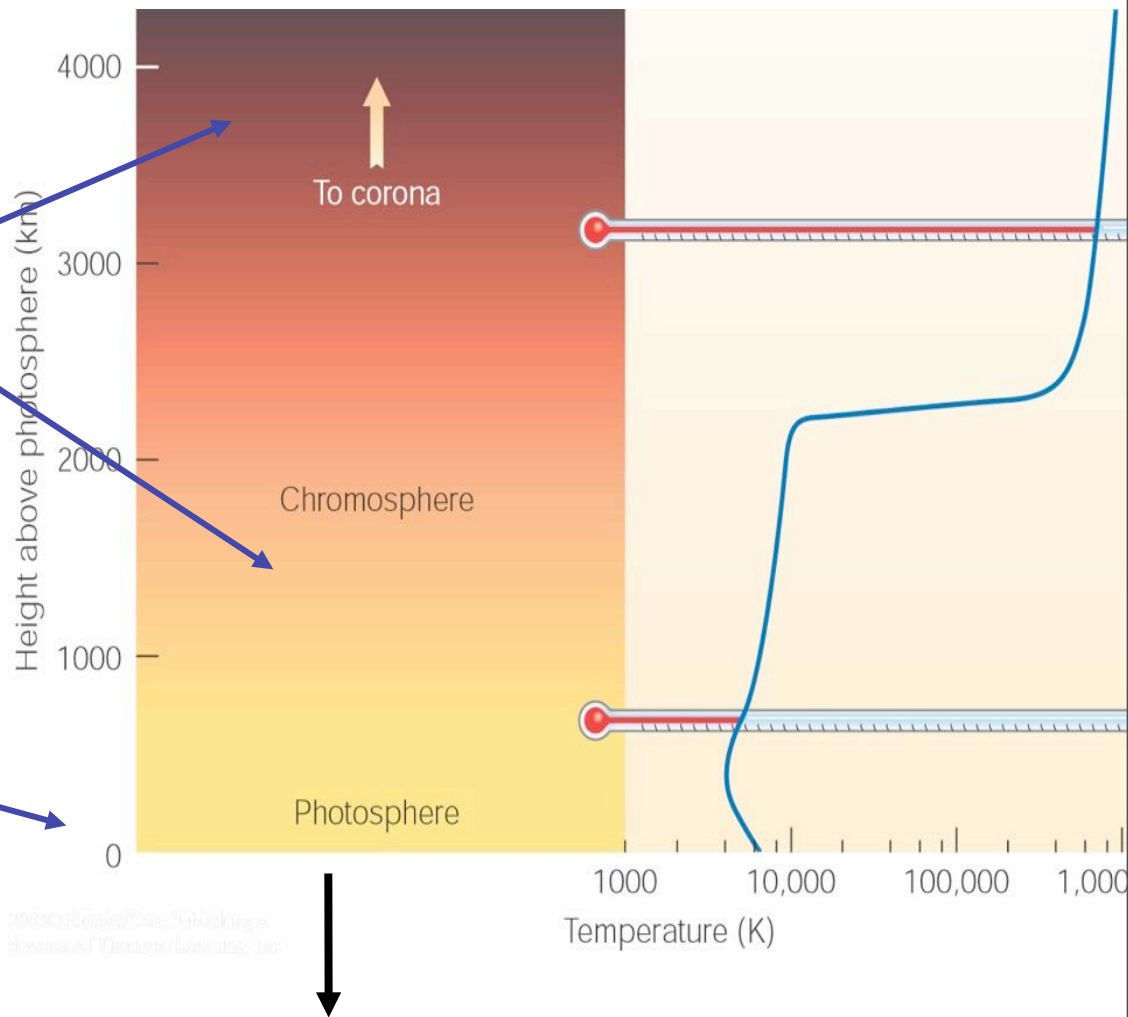
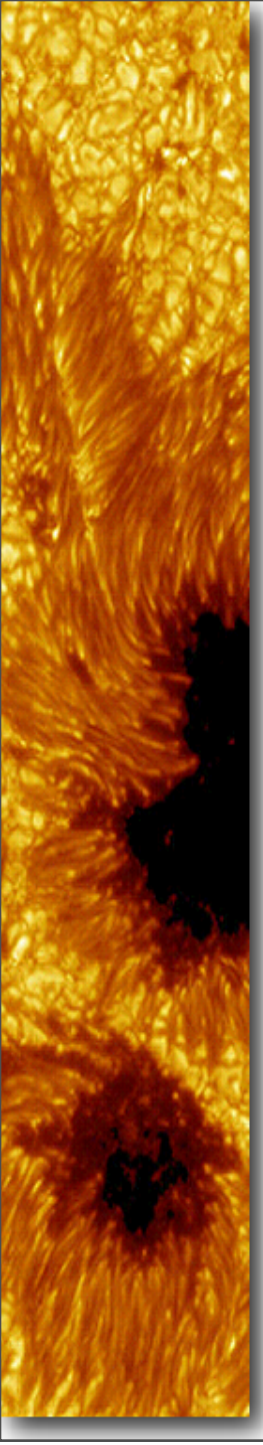


Solar interior

The Solar Atmosphere



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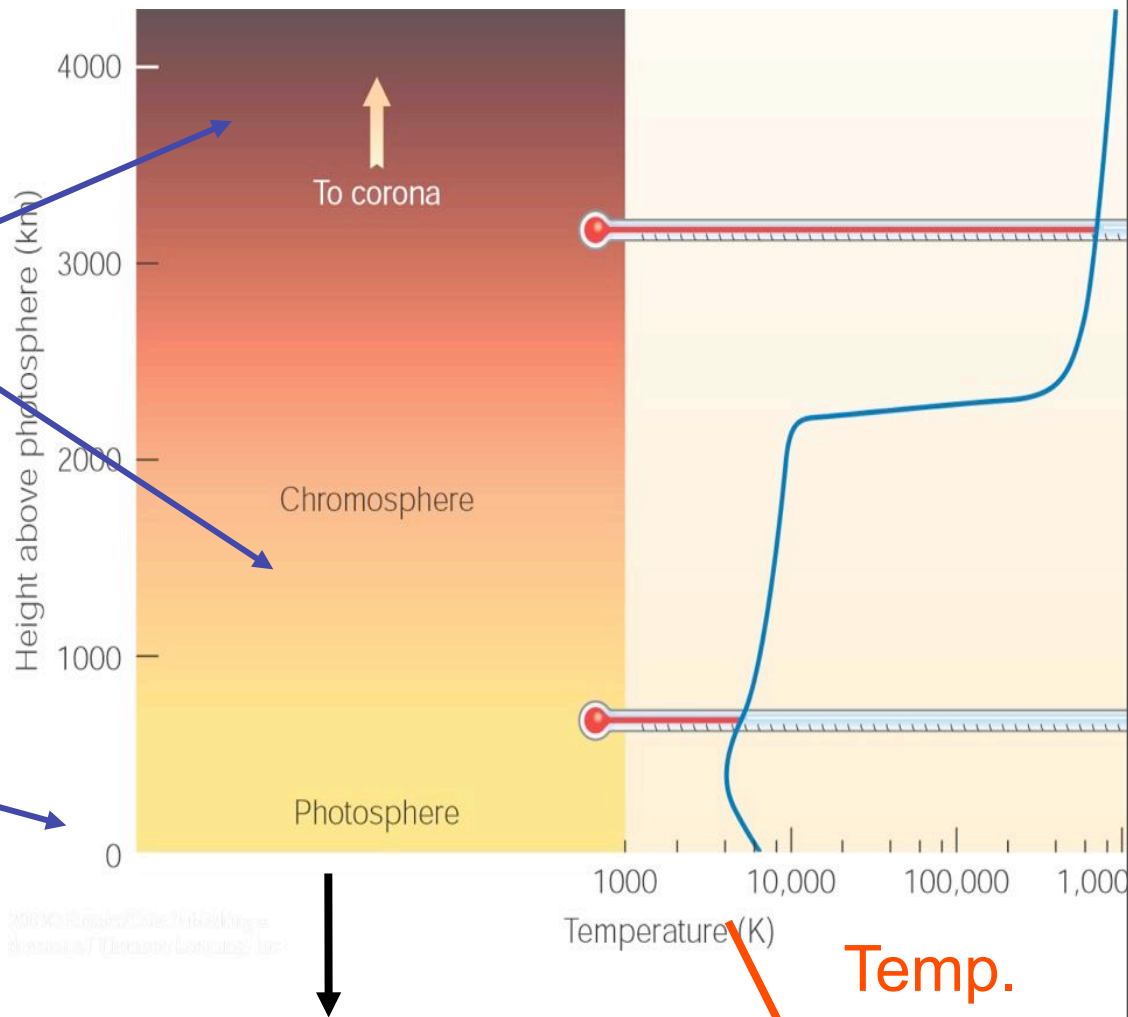
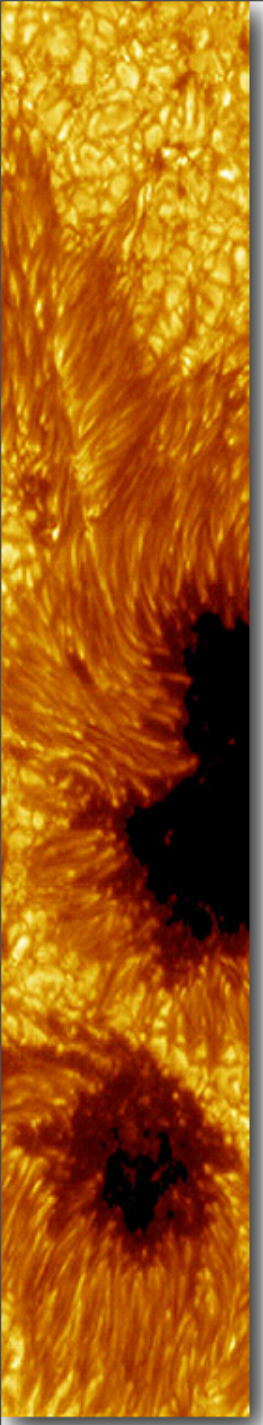


Solar interior

Temp. incr. inward

The Solar Atmosphere



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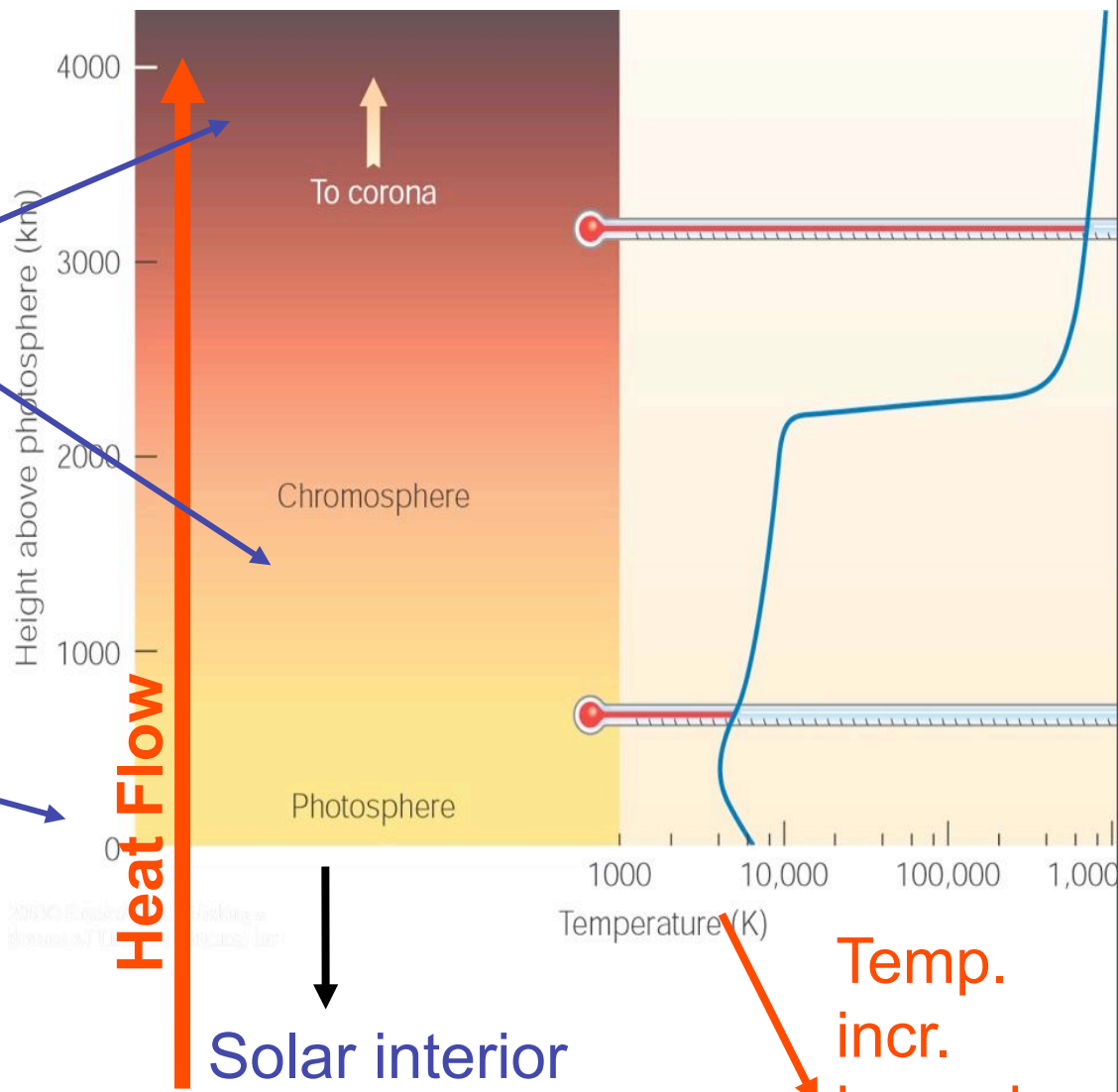

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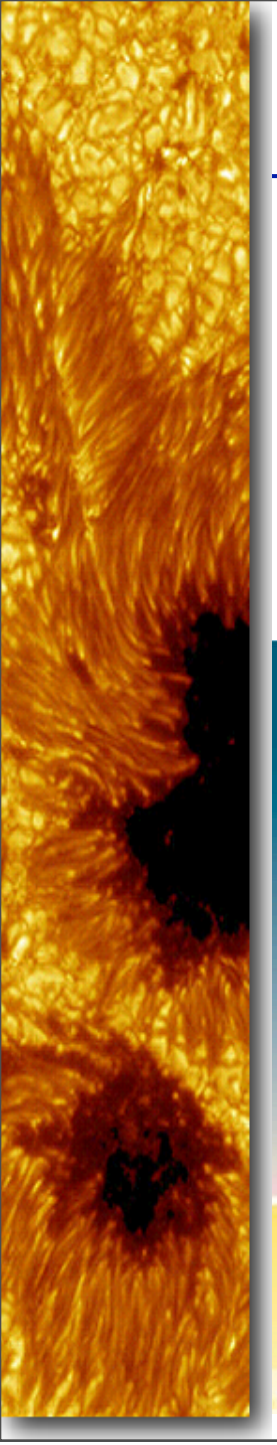
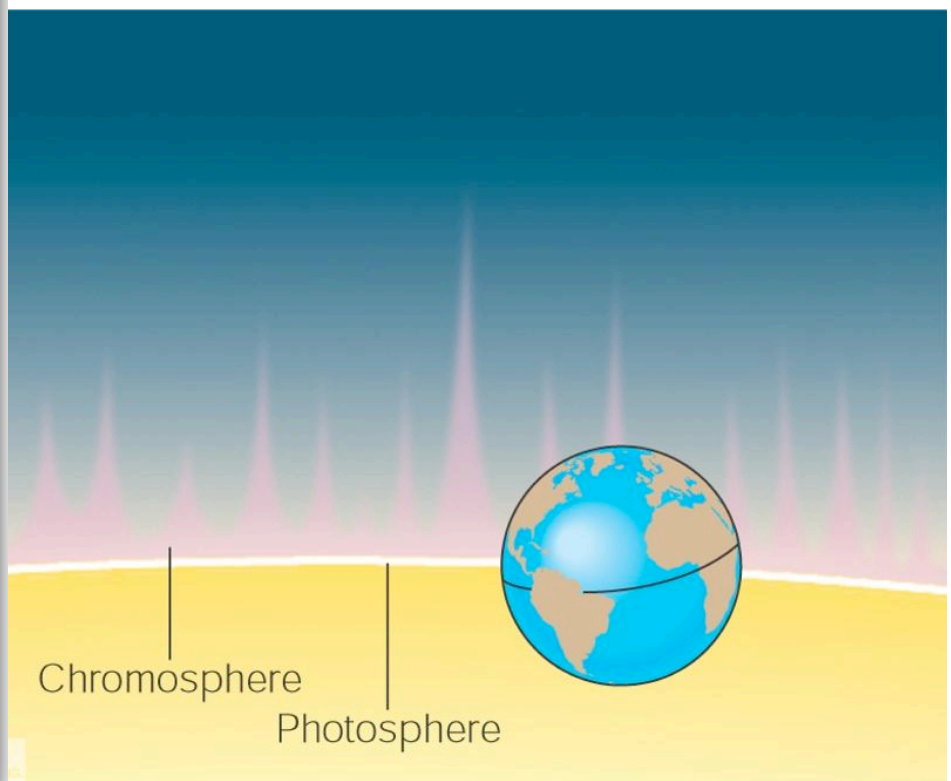
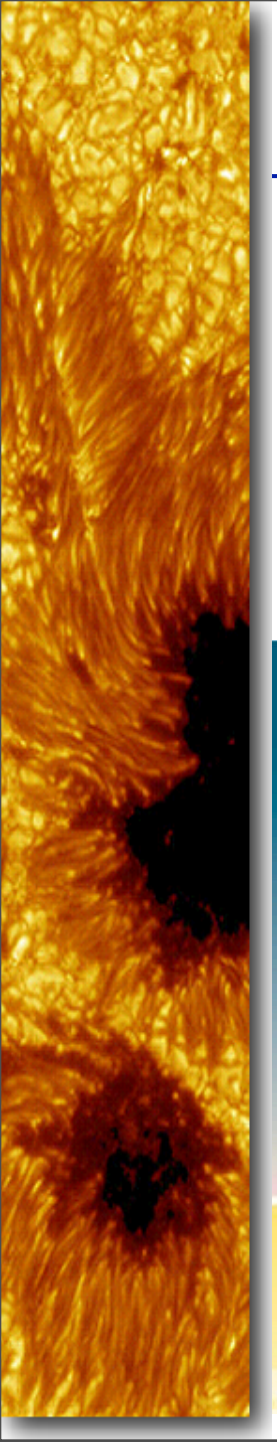


The Photosphere

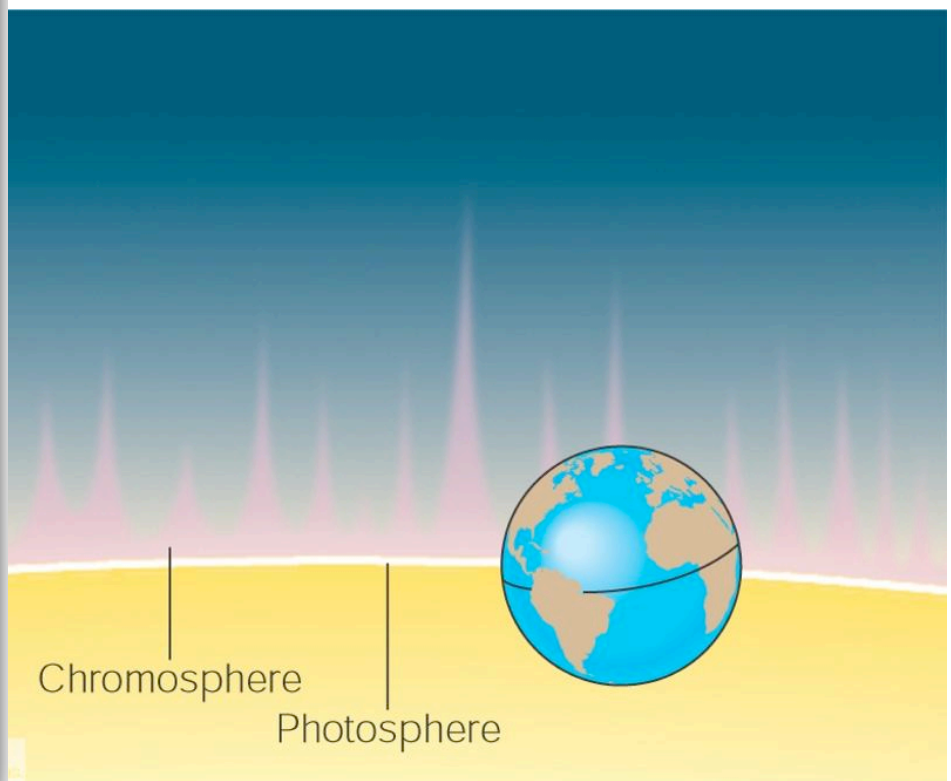
- Apparent surface layer of the sun

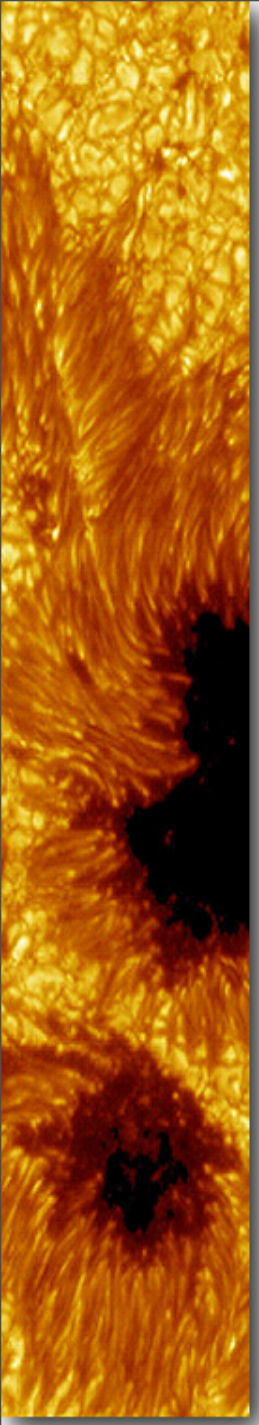




The Photosphere

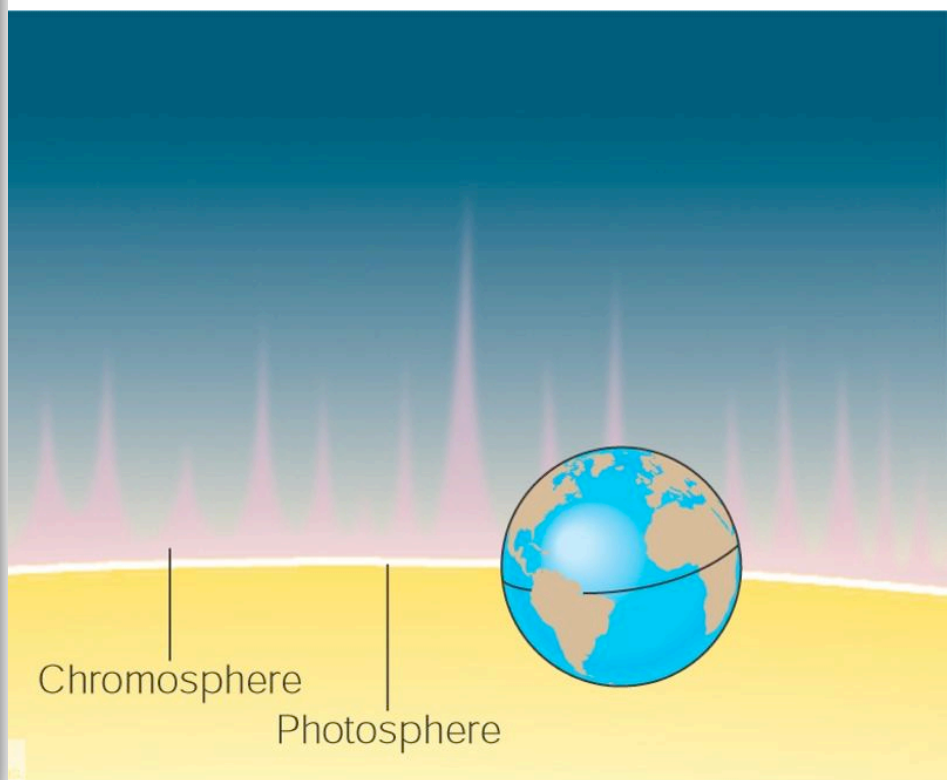
- Apparent surface layer of the sun
- Depth ≈ 500 km

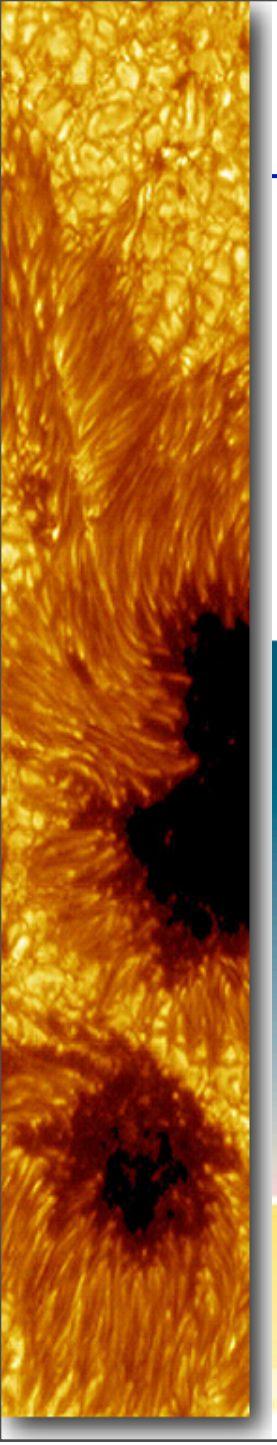




The Photosphere

- Apparent surface layer of the sun
- Depth ≈ 500 km
- Temperature ≈ 5800 ^{o}K





The Photosphere

- Apparent surface layer of the sun
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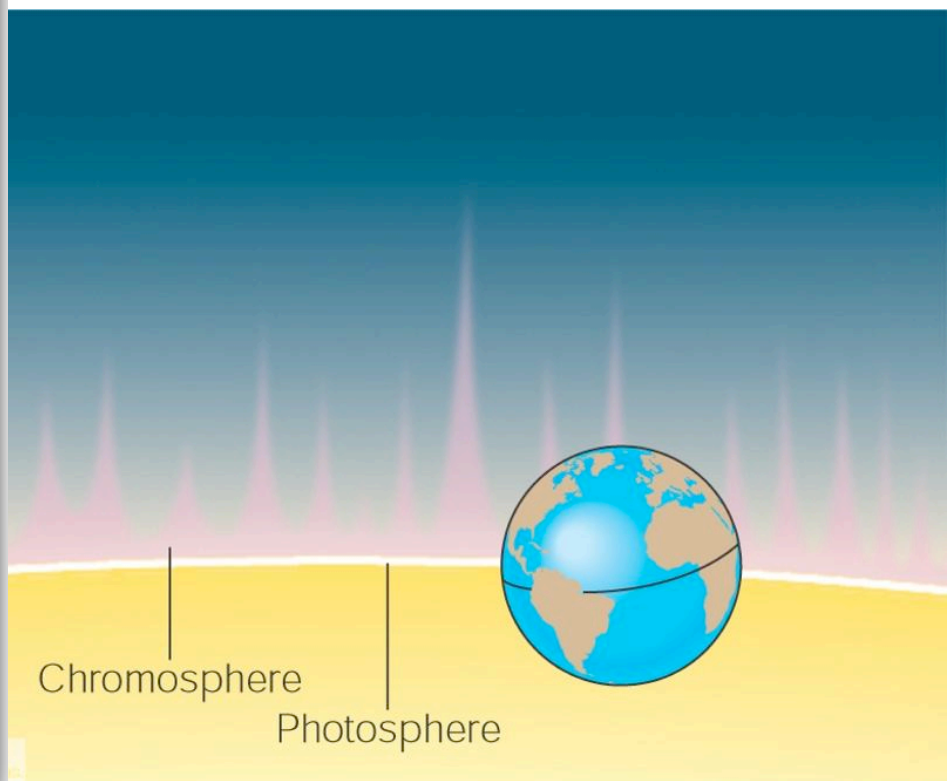
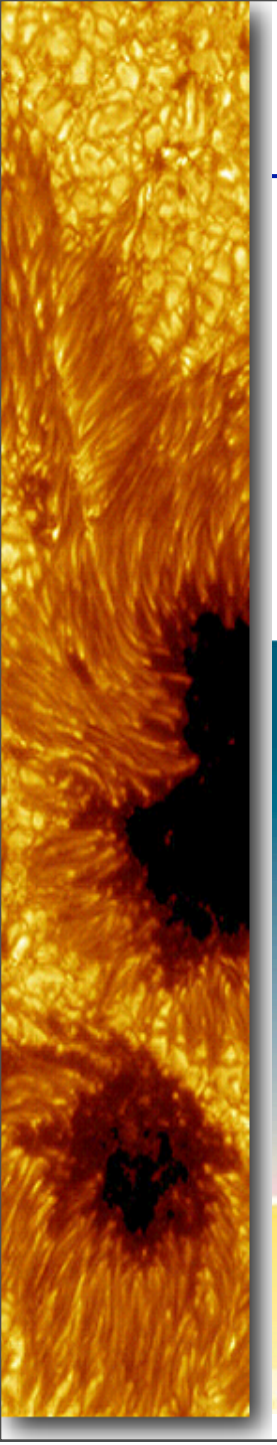
- Temperature ≈ 5800 ^{o}K
- Highly opaque (H^- ions)





The Photosphere

- Apparent surface layer of the sun
- Depth ≈ 500 km
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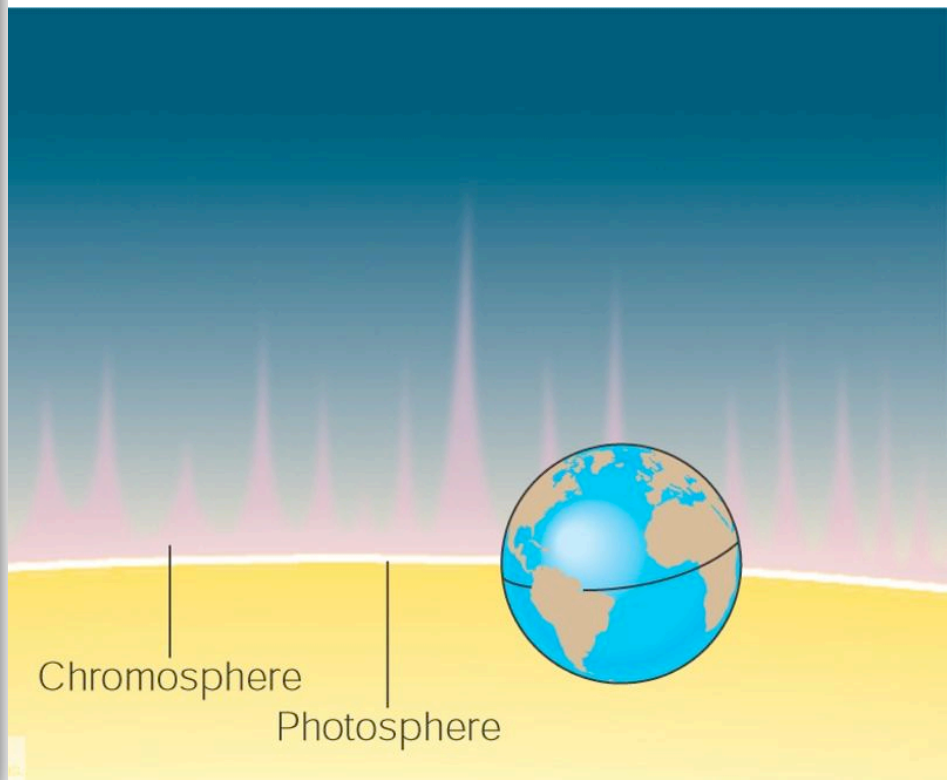
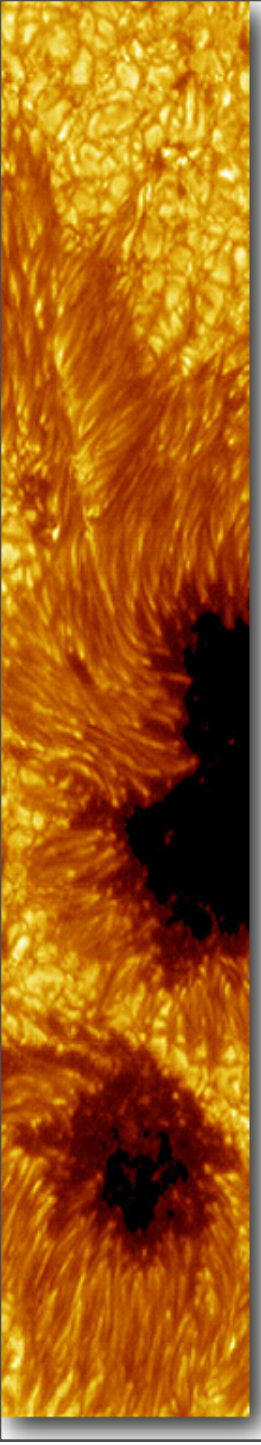
- Highly opaque (H^- ions)
- Absorbs and re-emits radiation produced in the sun





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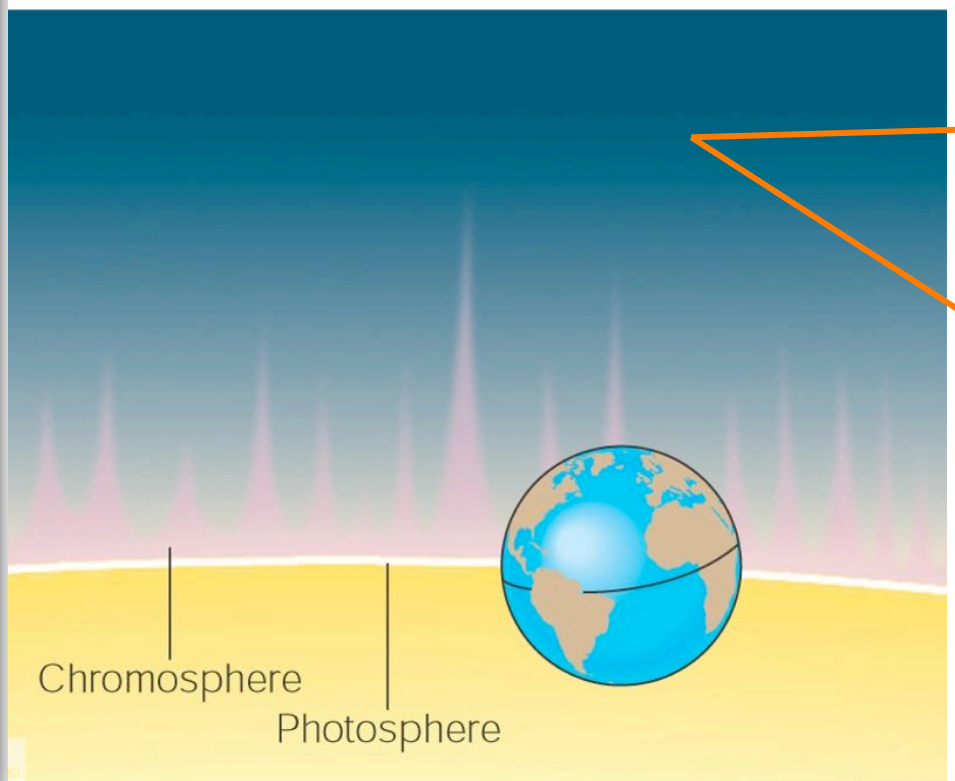
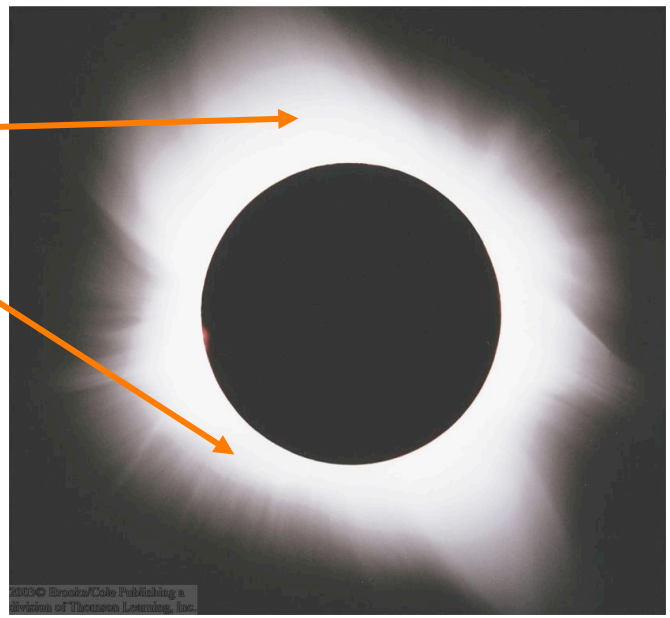
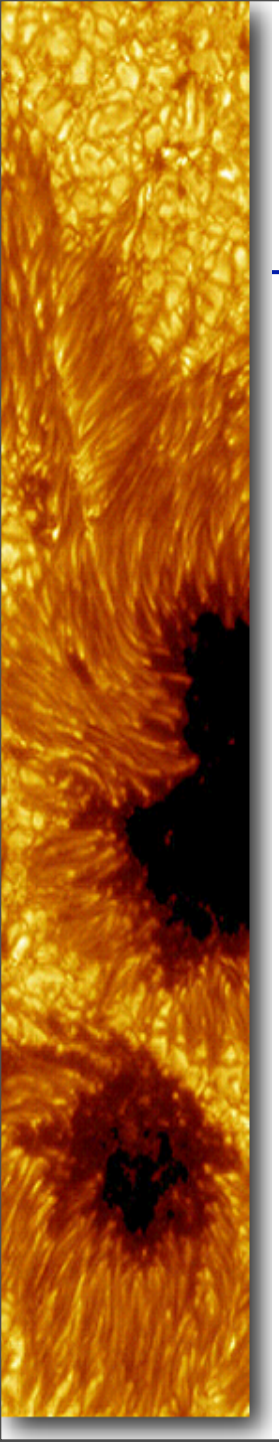


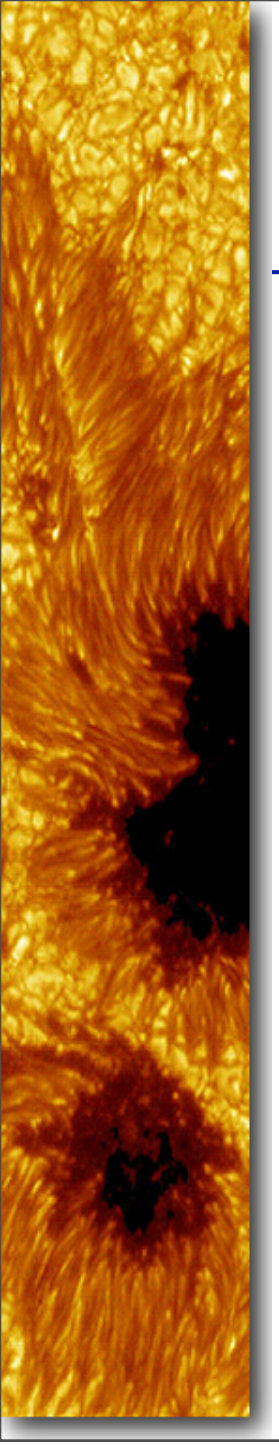


The solar corona



Energy Transport in the Photosphere

Energy generated in the sun's center must be transported outward.



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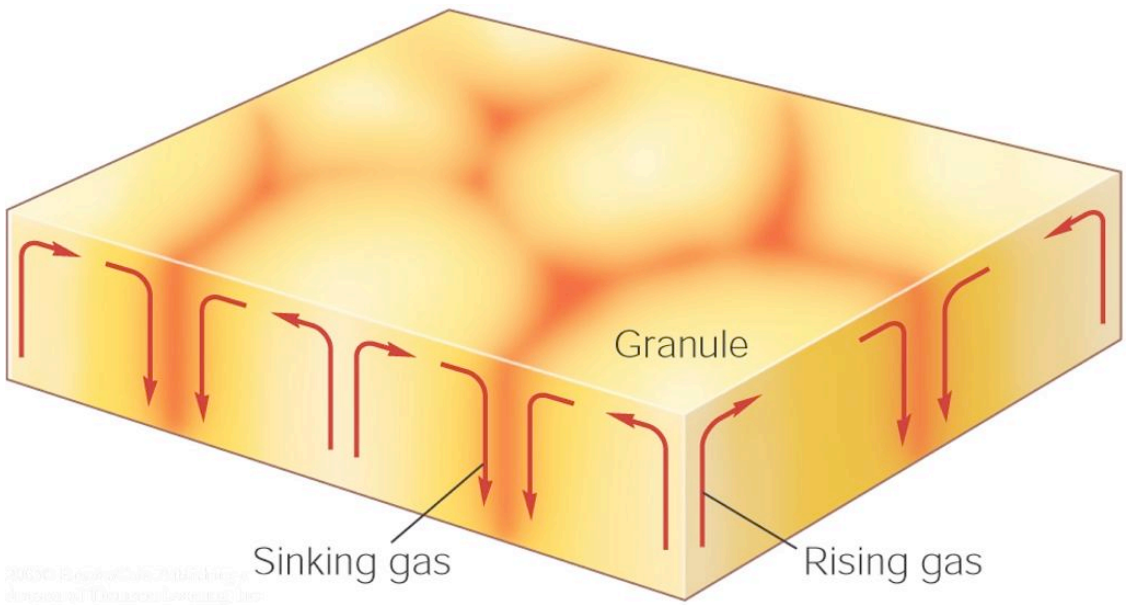
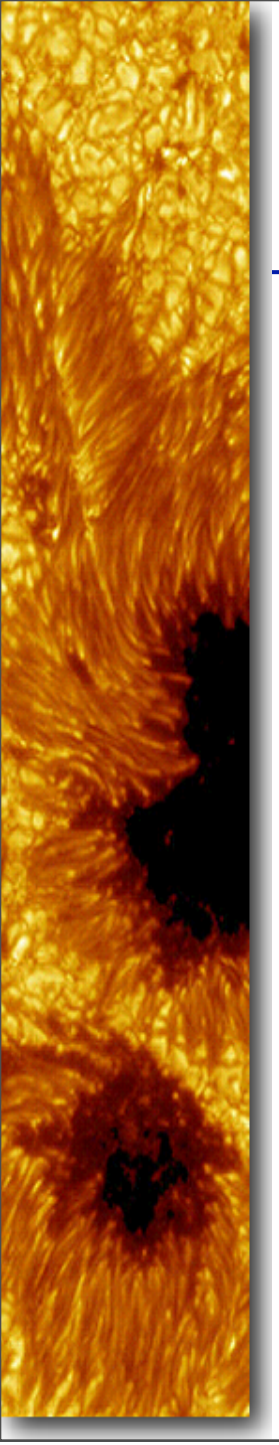
Convection:





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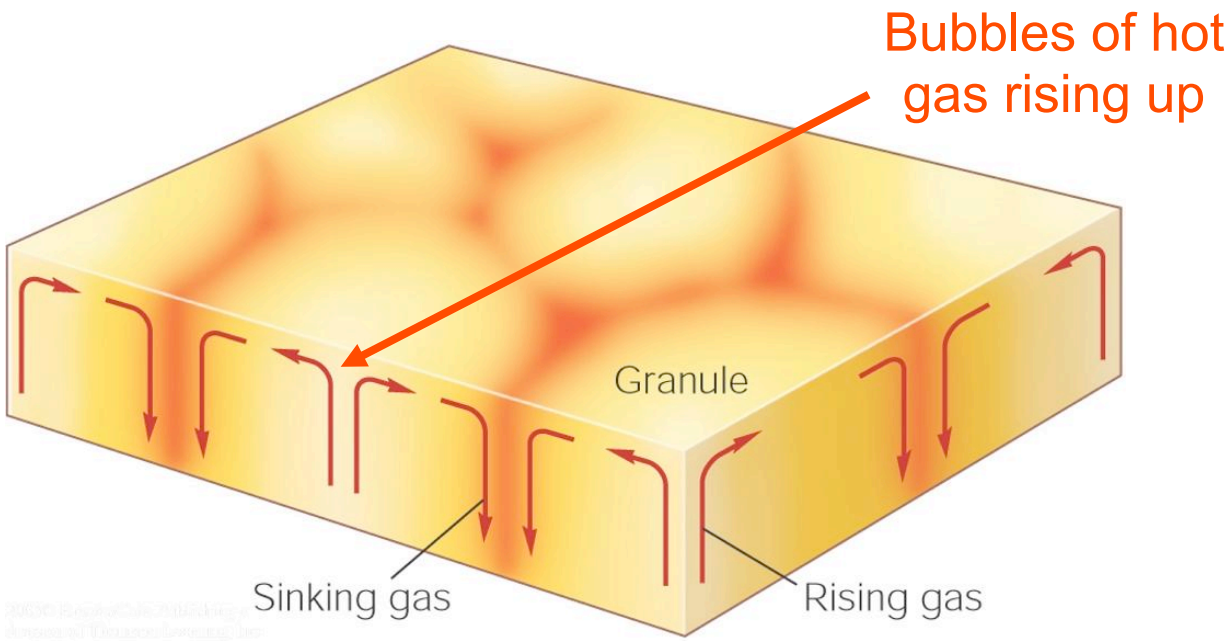

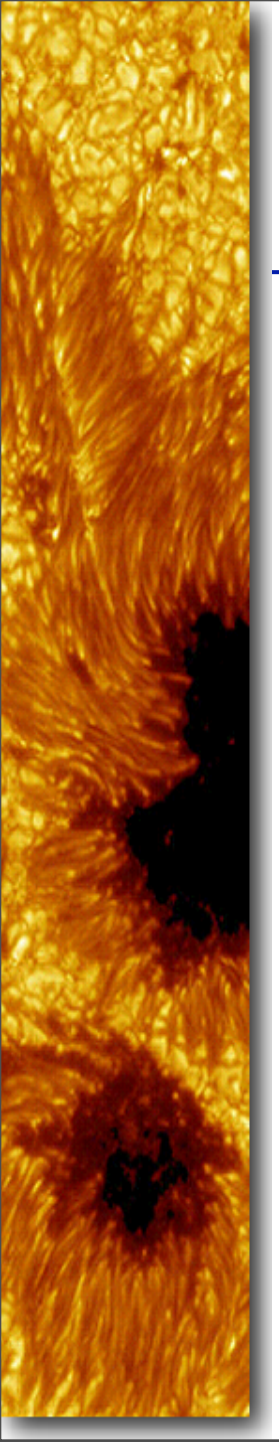

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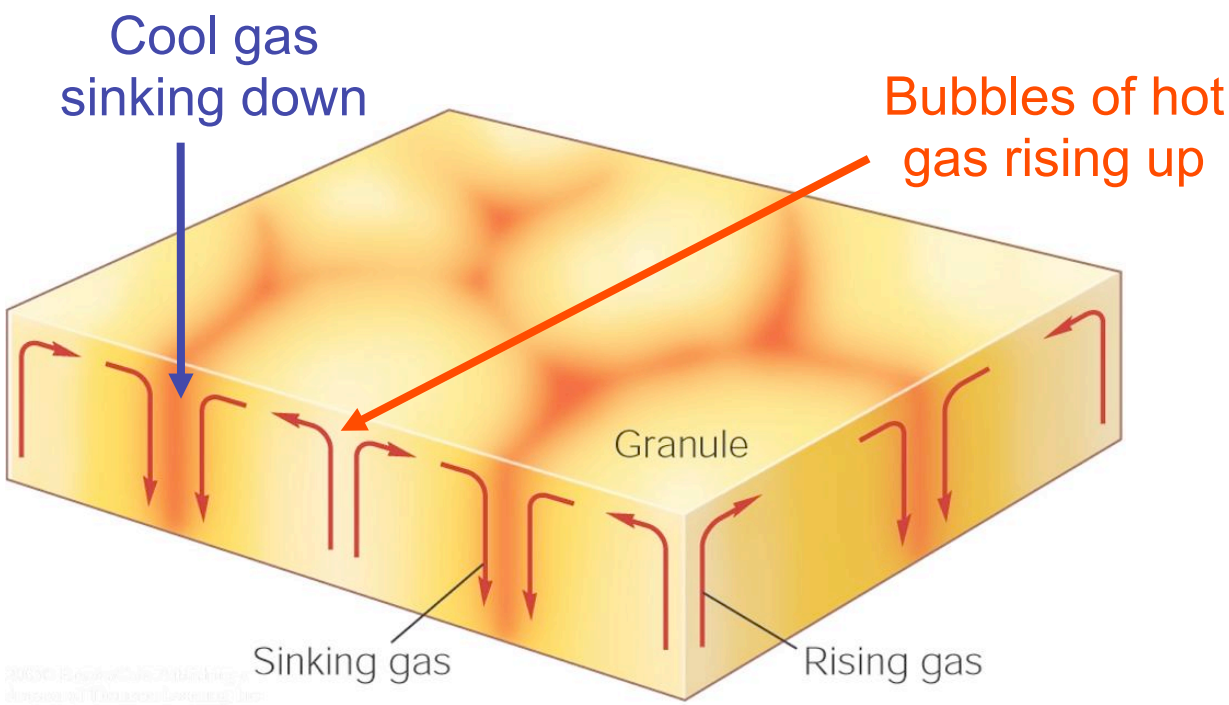

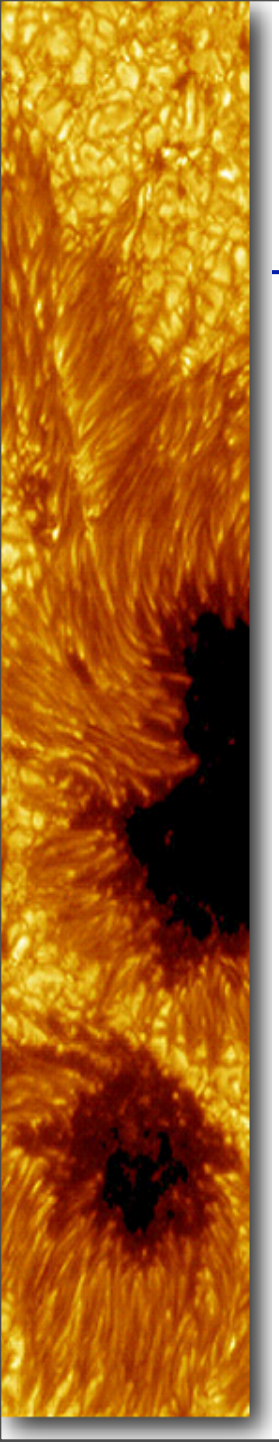

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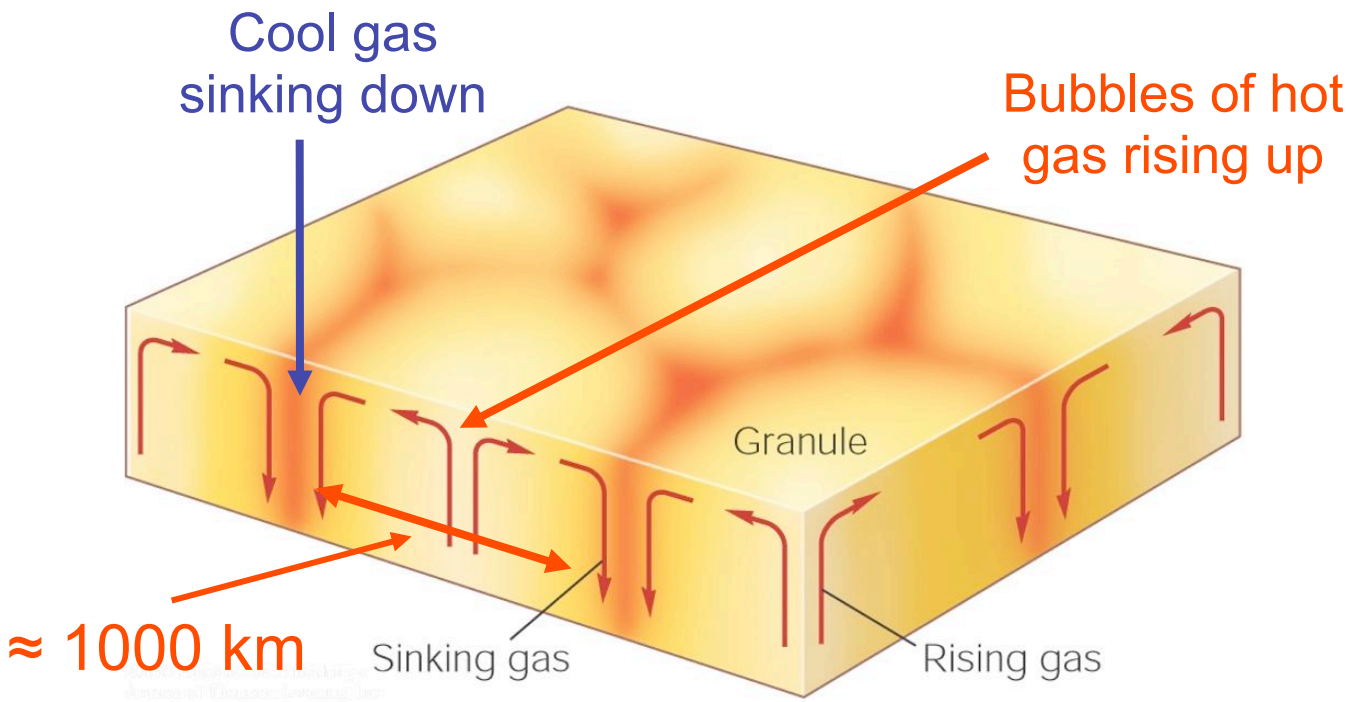

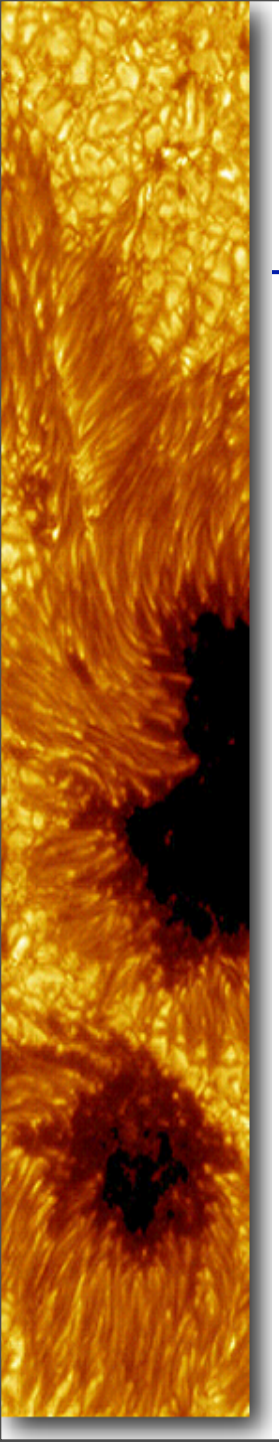

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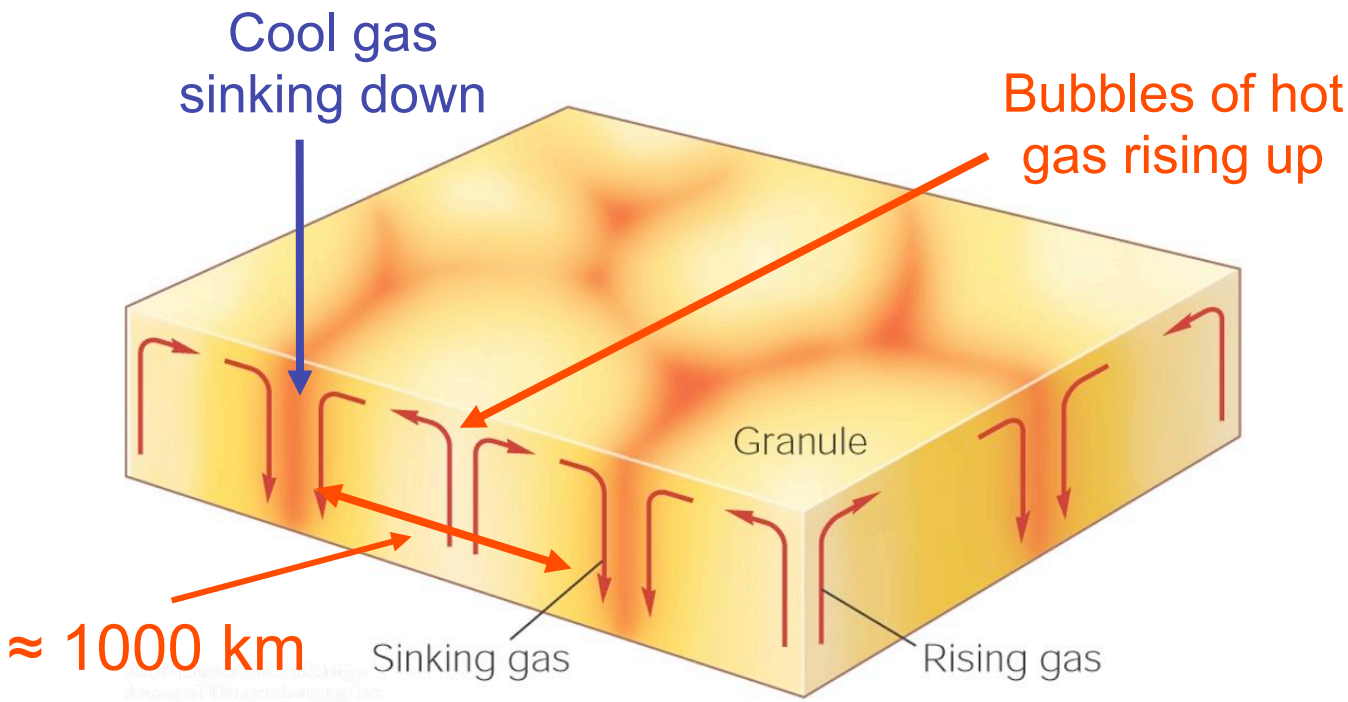
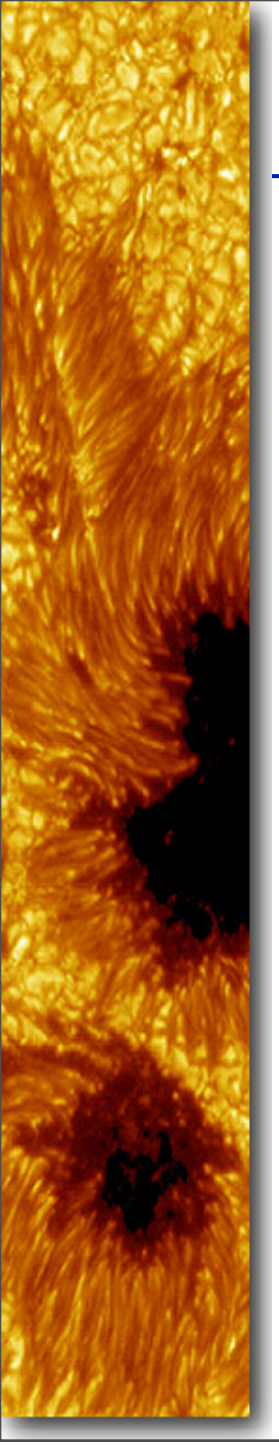
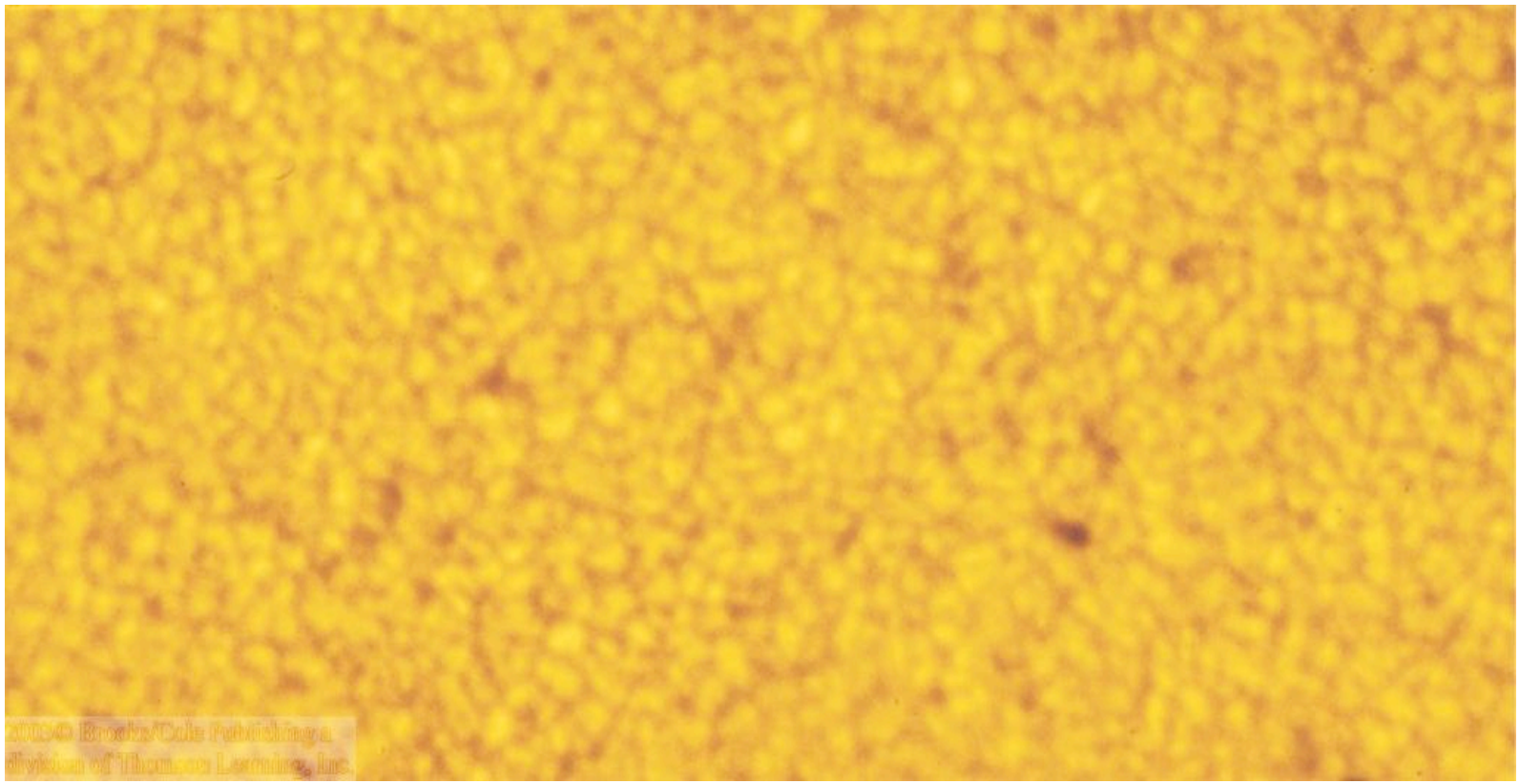


Bubbles last for ≈ 10 – 20 min

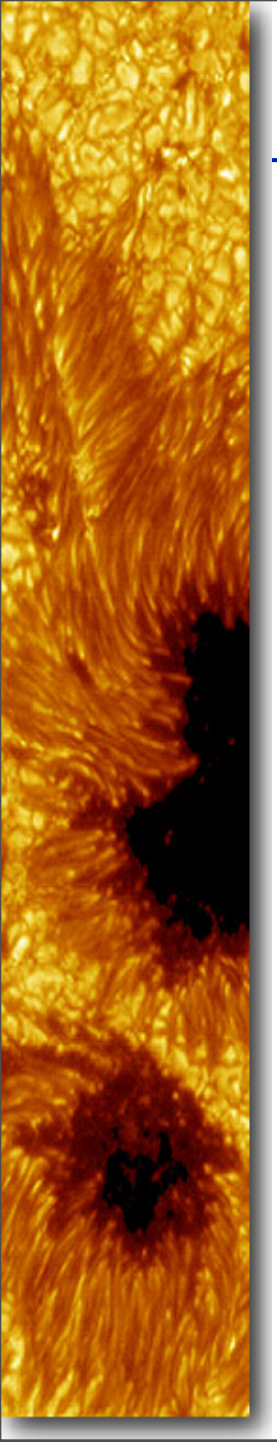


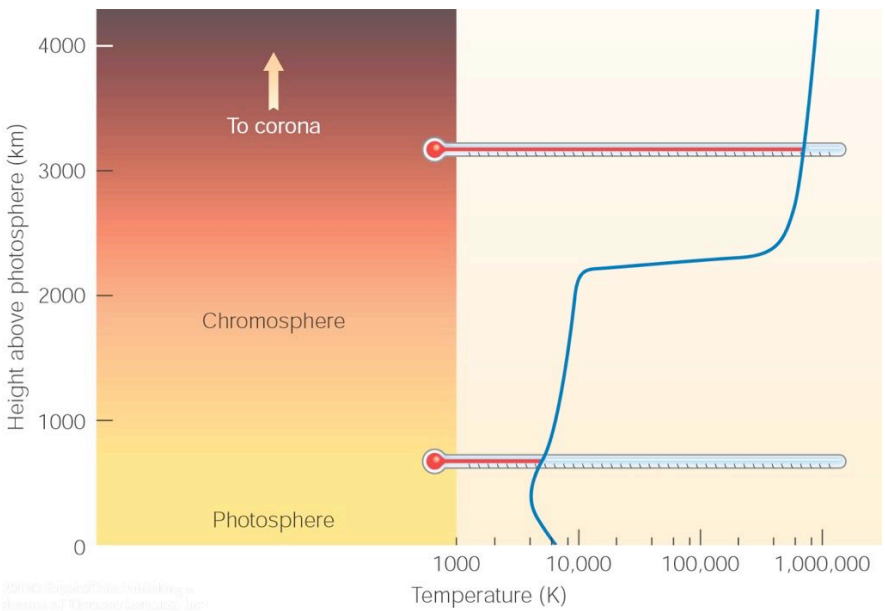
Granulation

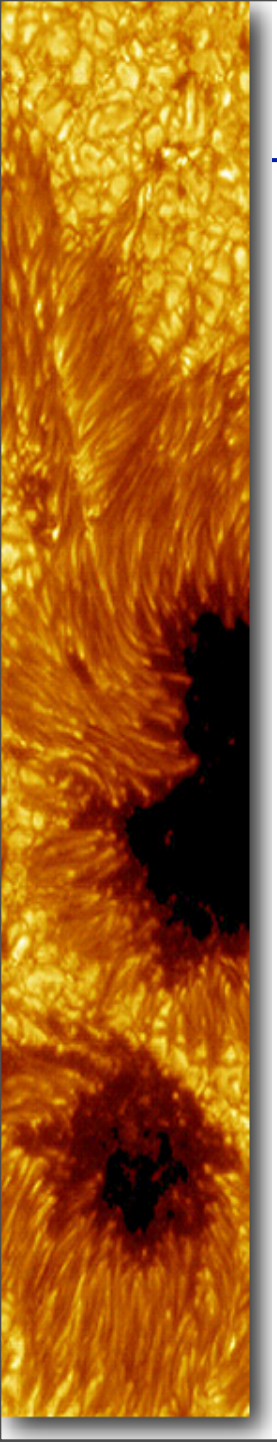


… is the visible consequence of convection.

The Chromosphere

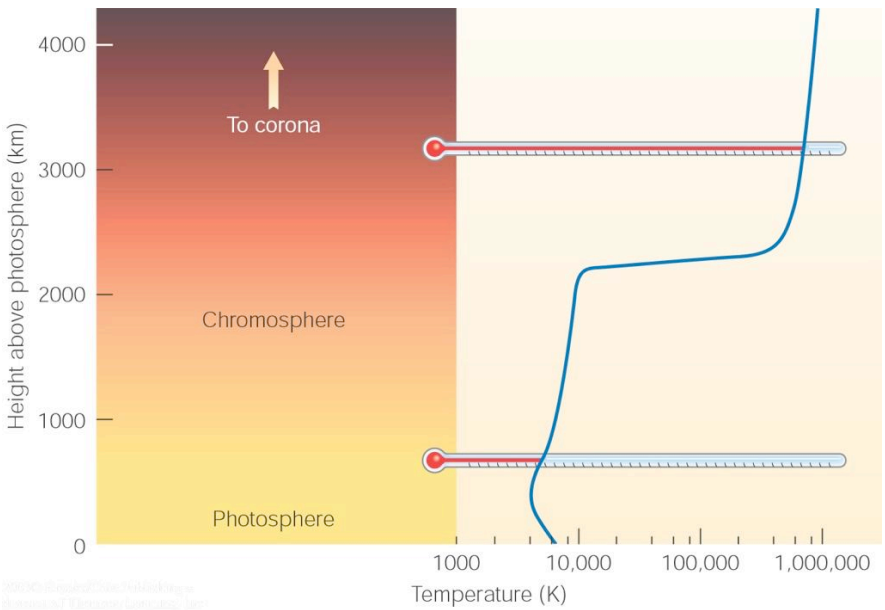






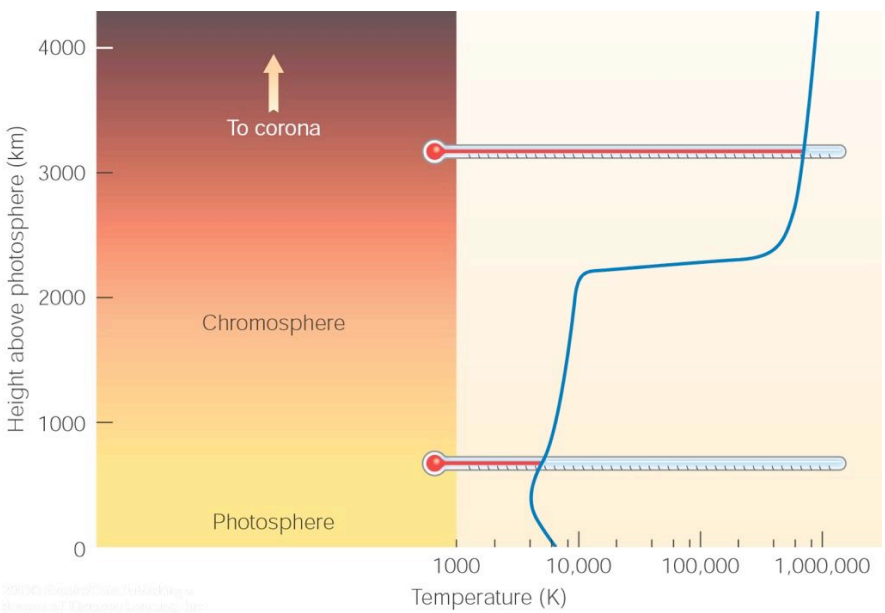
The Chromosphere

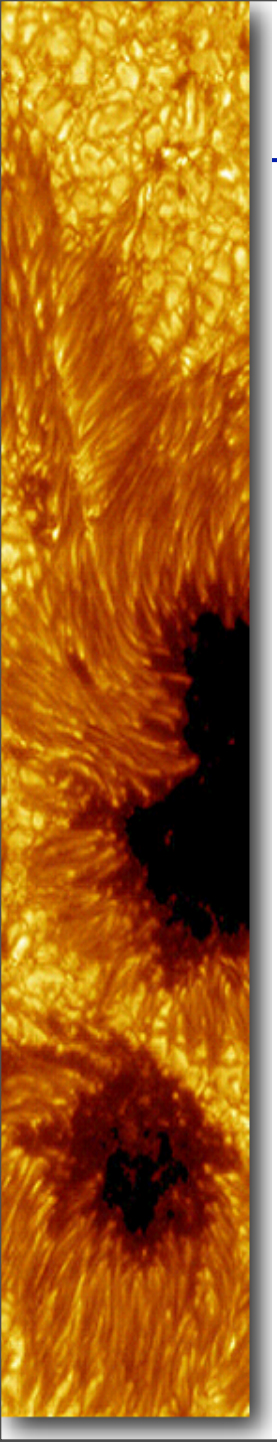
- Region of sun's atmosphere just above the photosphere



The Chromosphere

- Region of sun's atmosphere just above the photosphere
- Visible, UV, and X-ray lines from highly ionized gases





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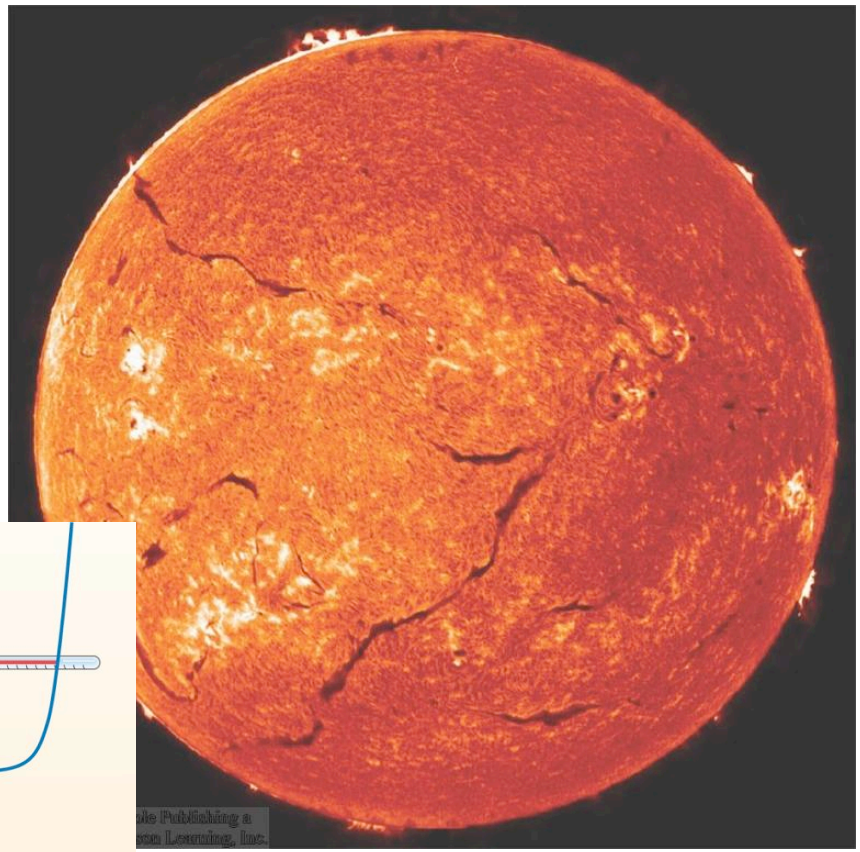
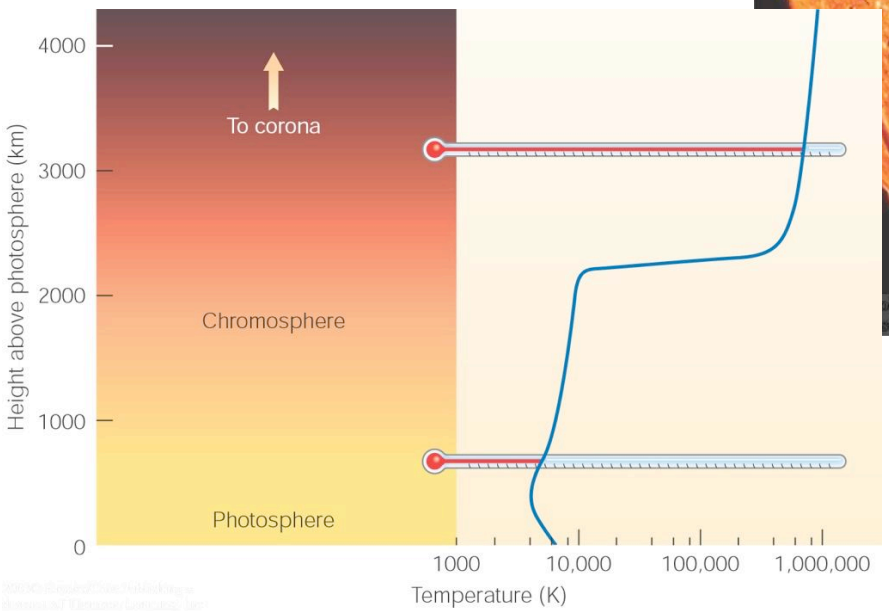
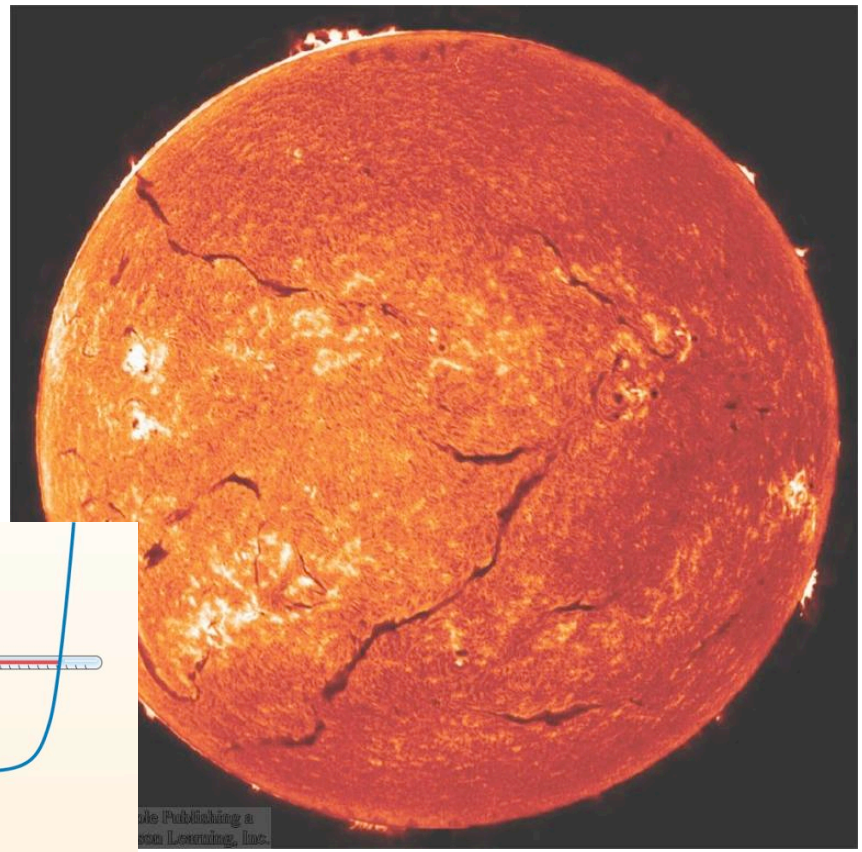


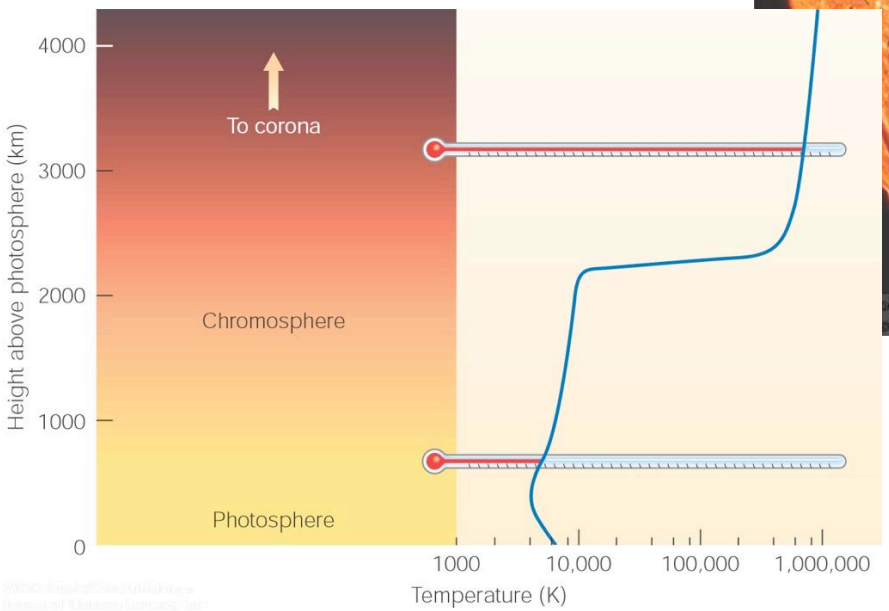


Chromospheric structures visible in Hα emission (filtergram)

The Chromosphere

- Region of sun's atmosphere just above the photosphere
- Visible, UV, and X-ray lines from highly ionized gases
- Temperature increases gradually from ≈ 4500 °K to ≈ 10,000 °K, then jumps to ≈ 1 million °K





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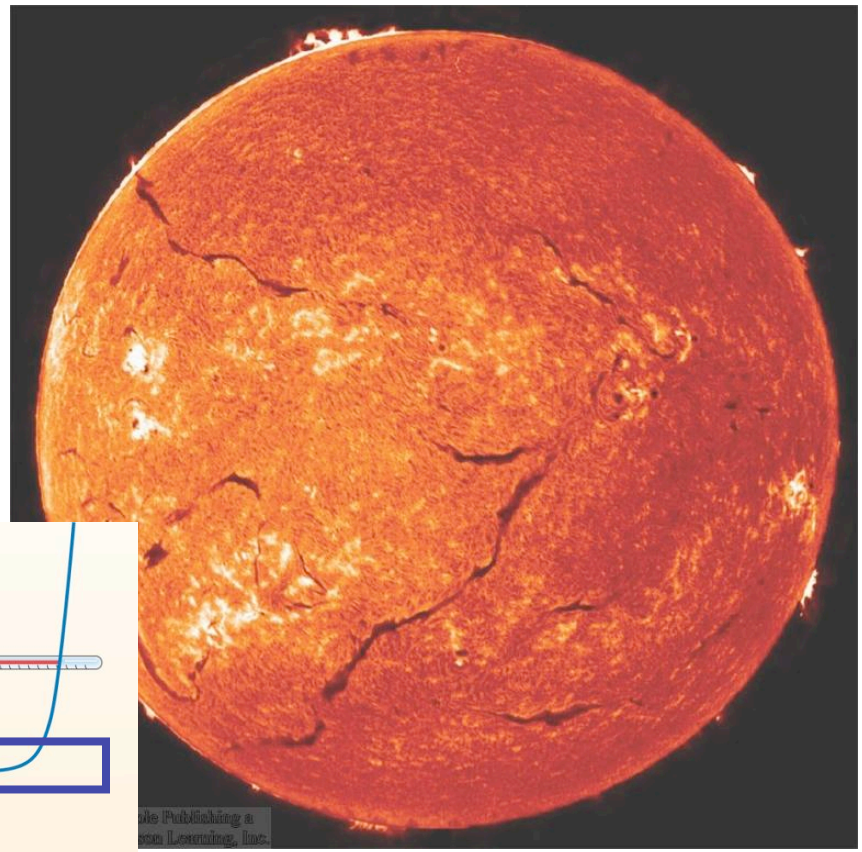

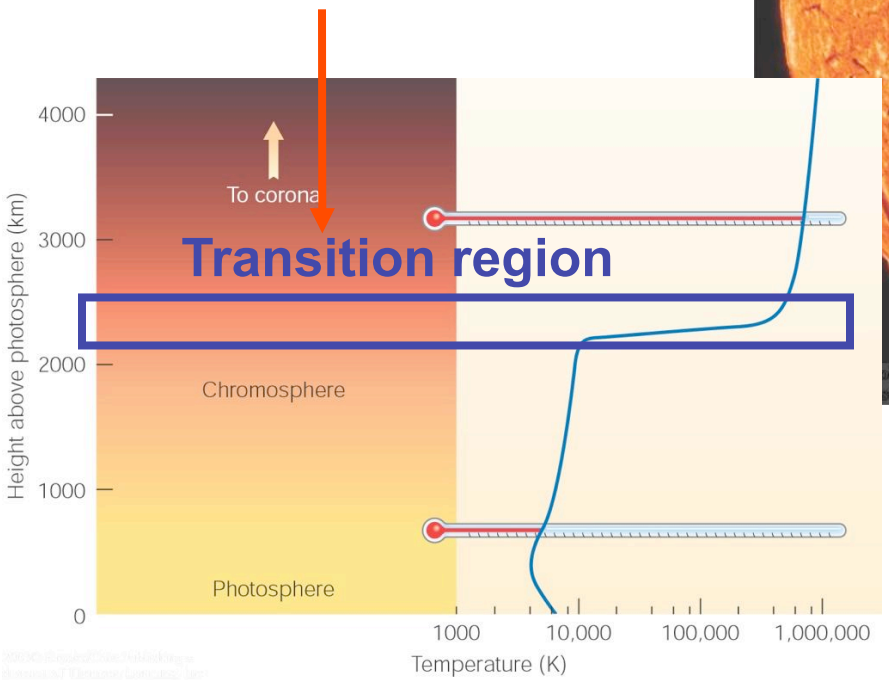

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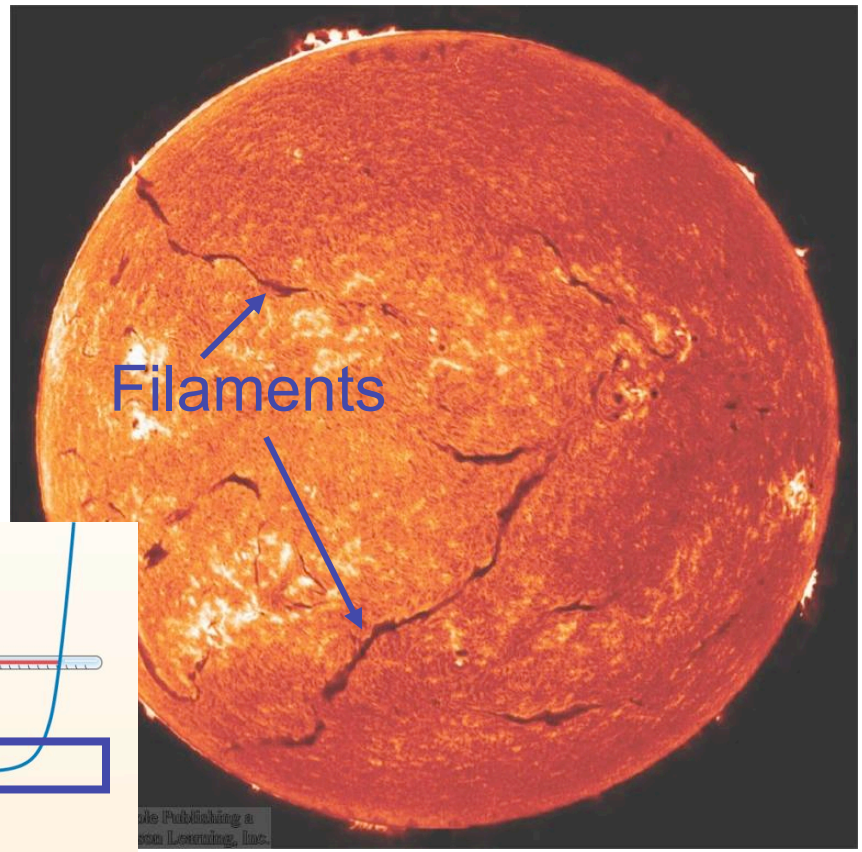

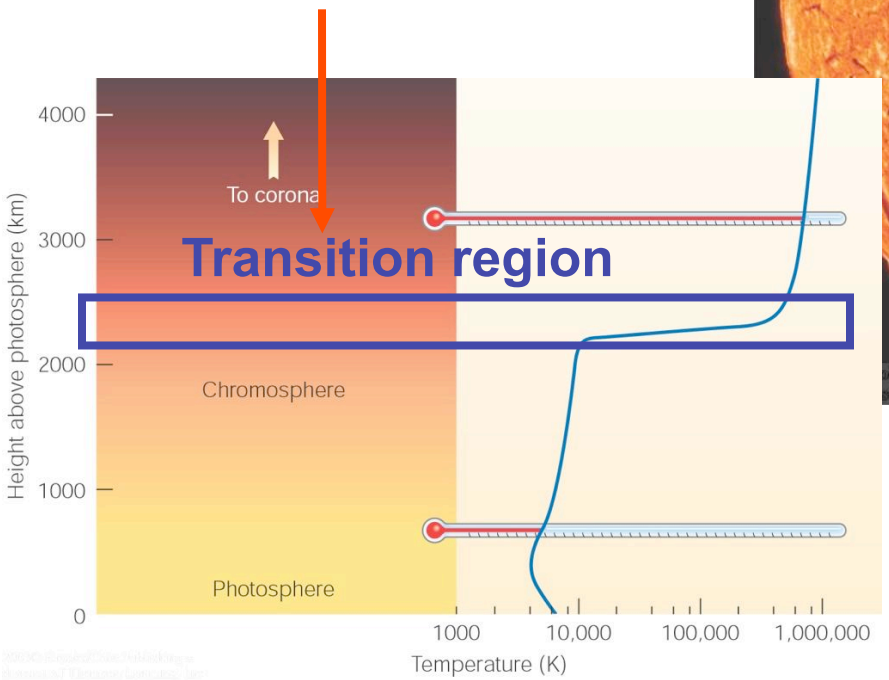

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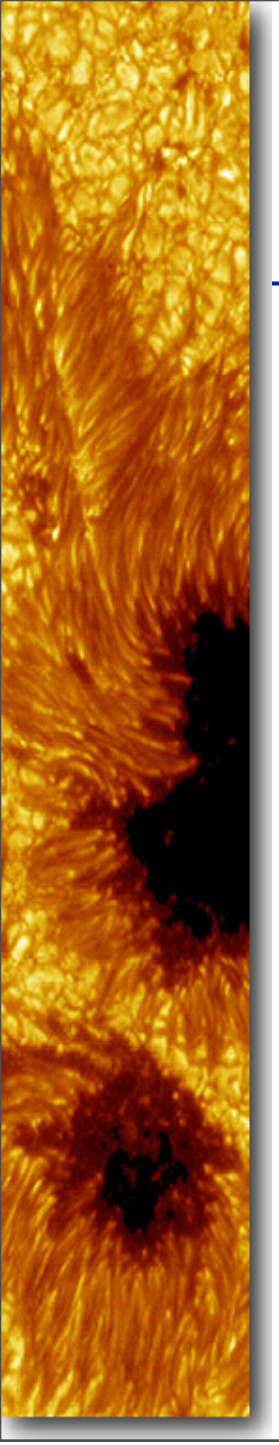

The Layers of the Solar Atmosphere

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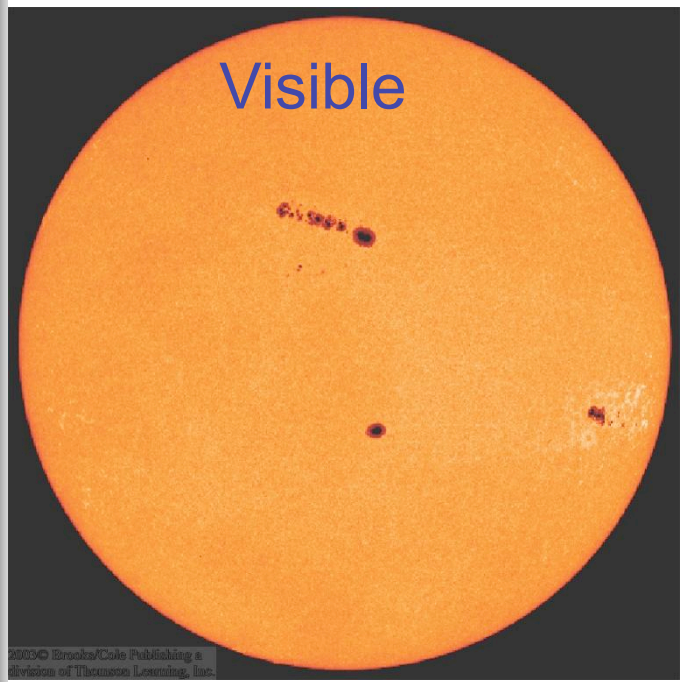

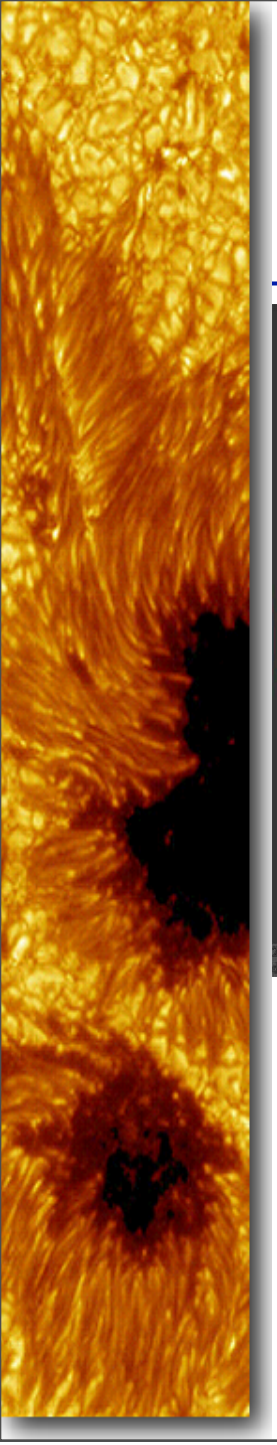

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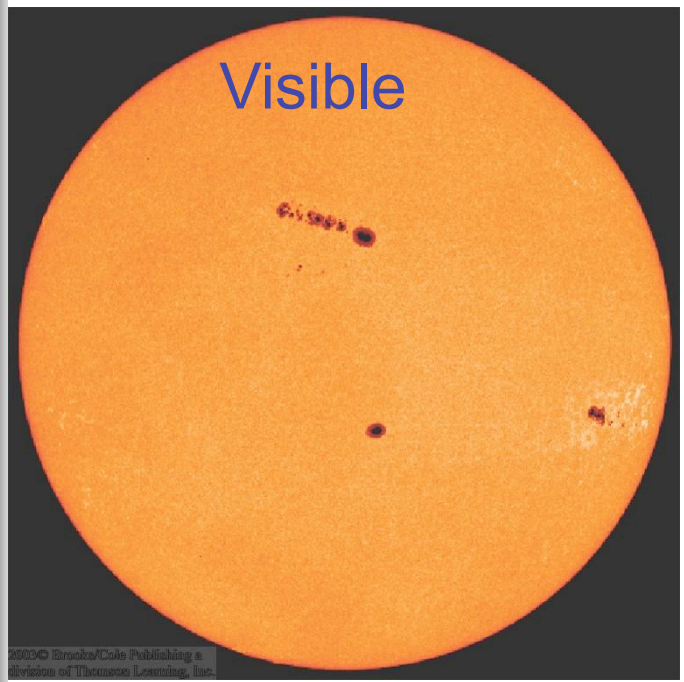

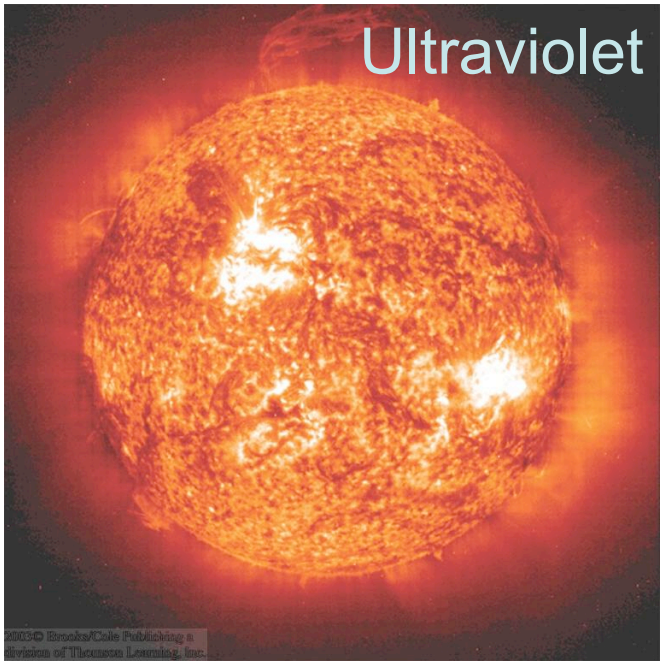

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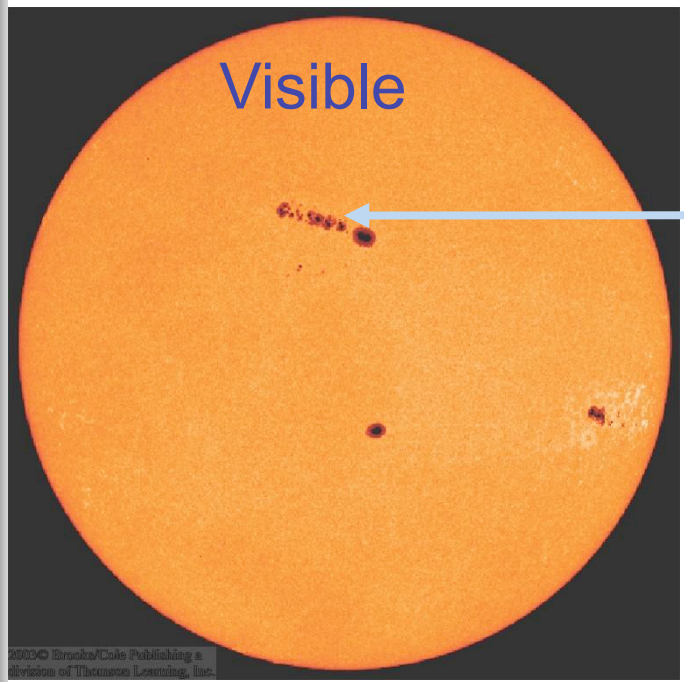
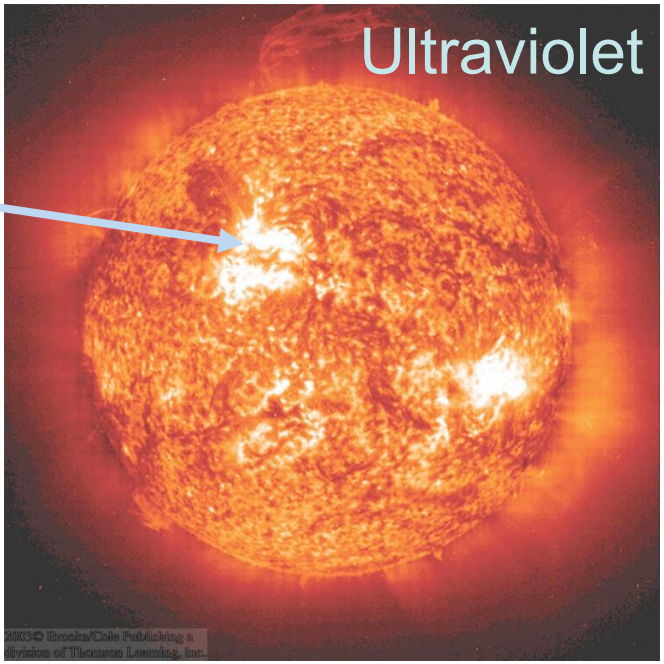


Sun Spot Regions



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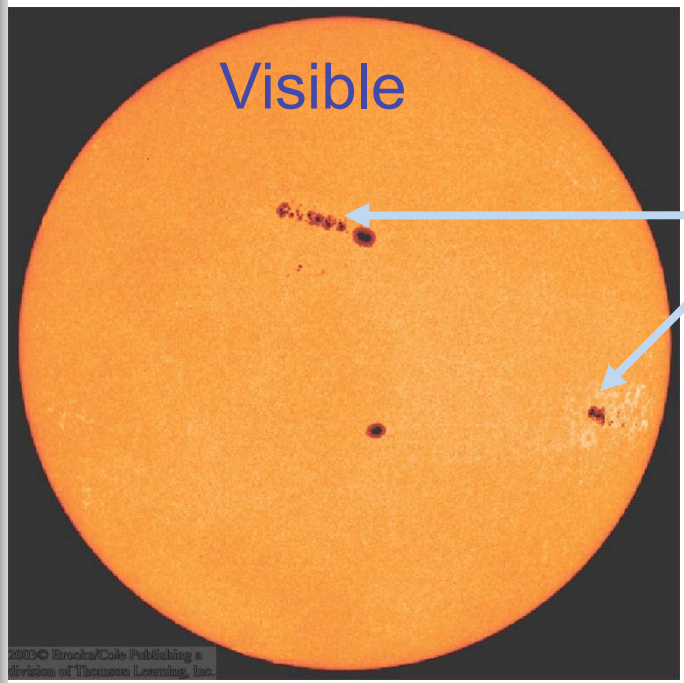

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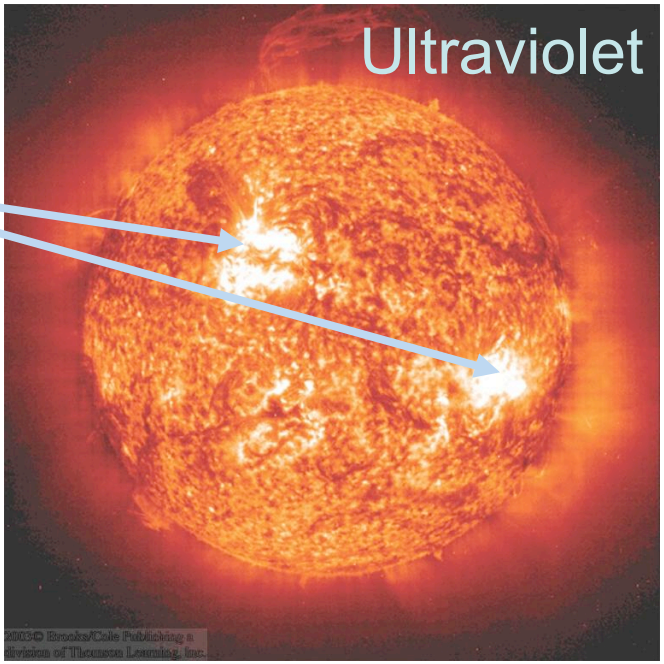

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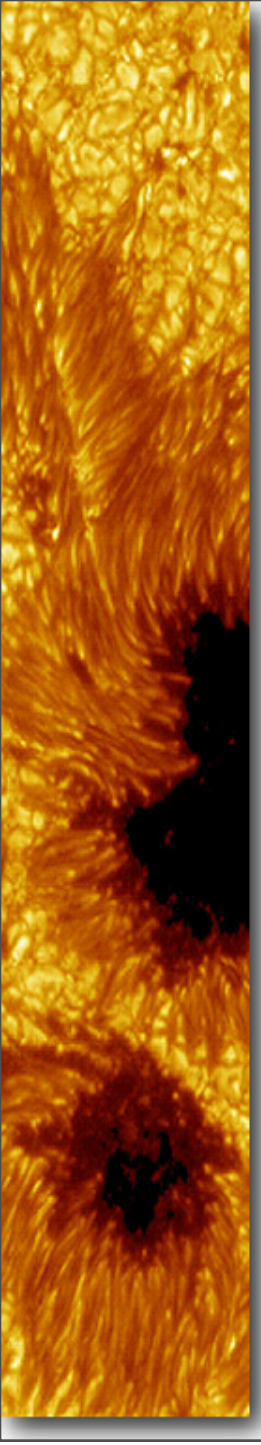

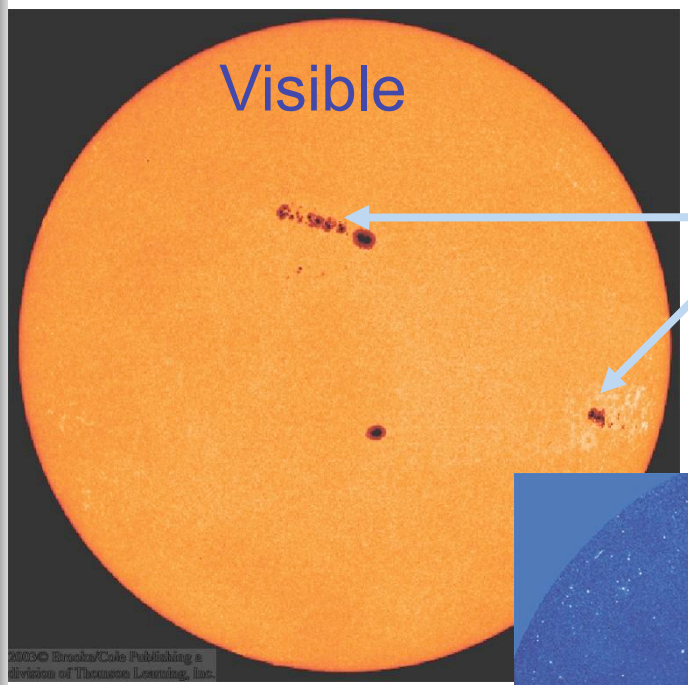

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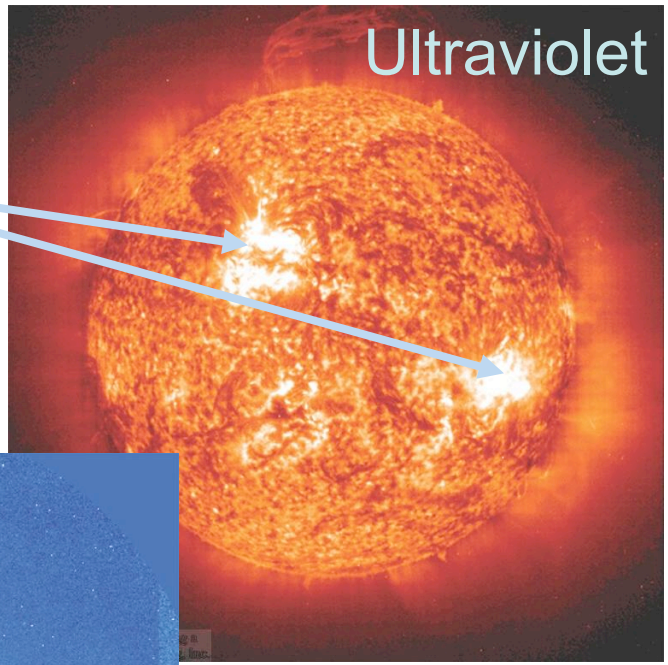

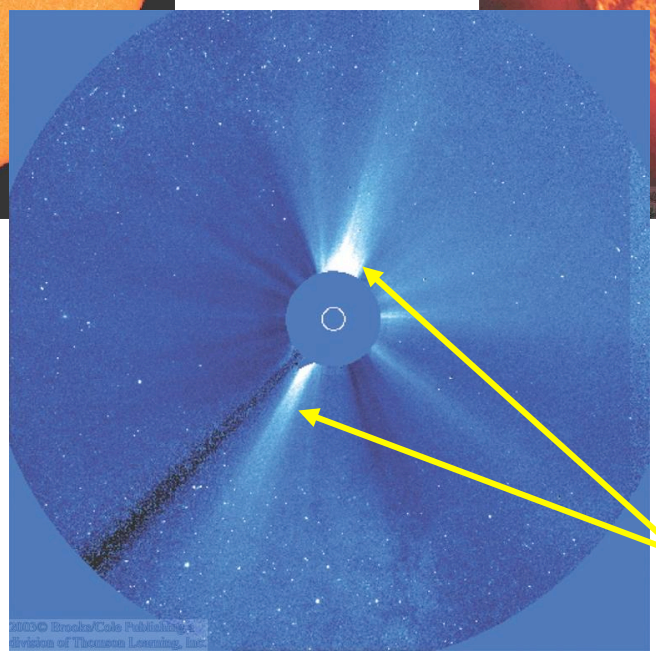

Coronal activity, seen in visible light

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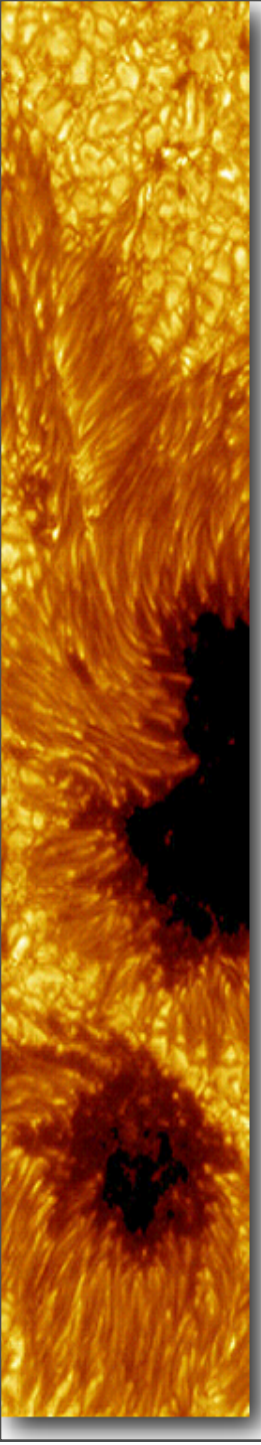

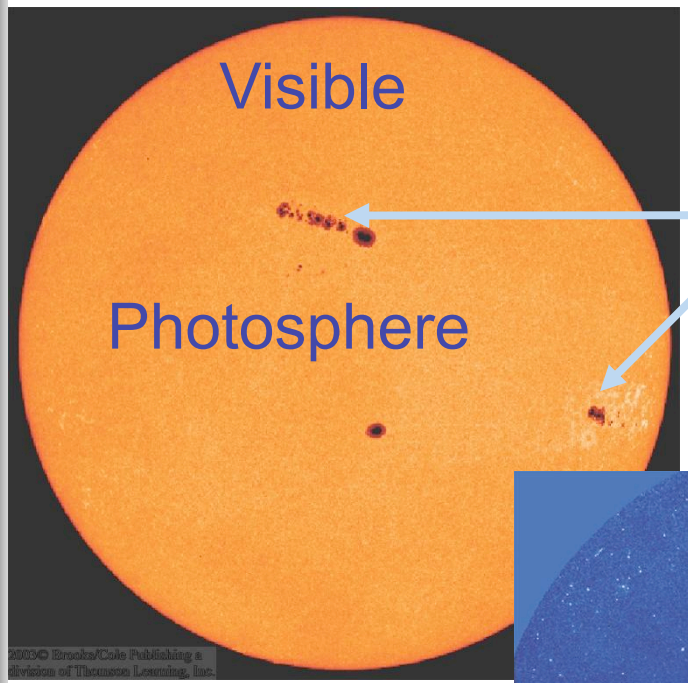

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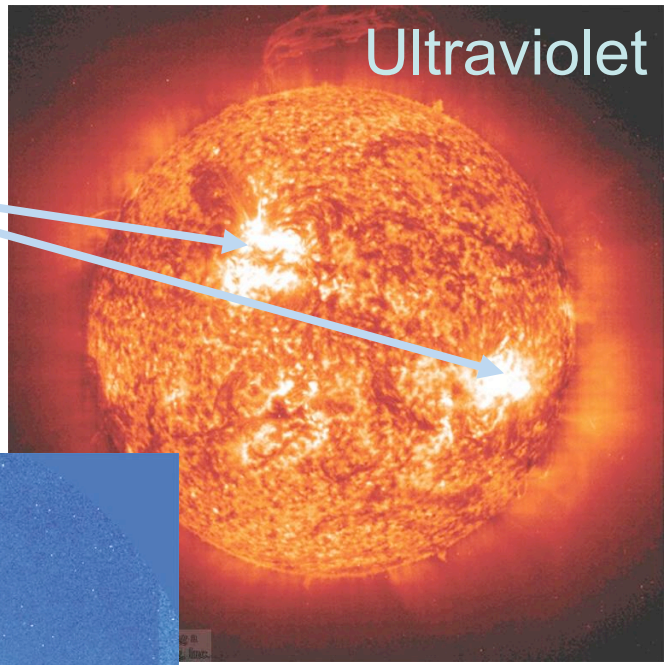

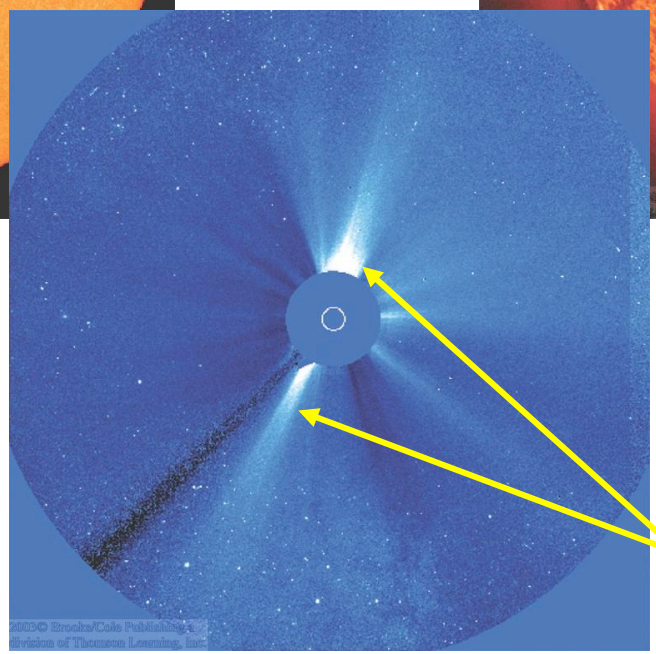

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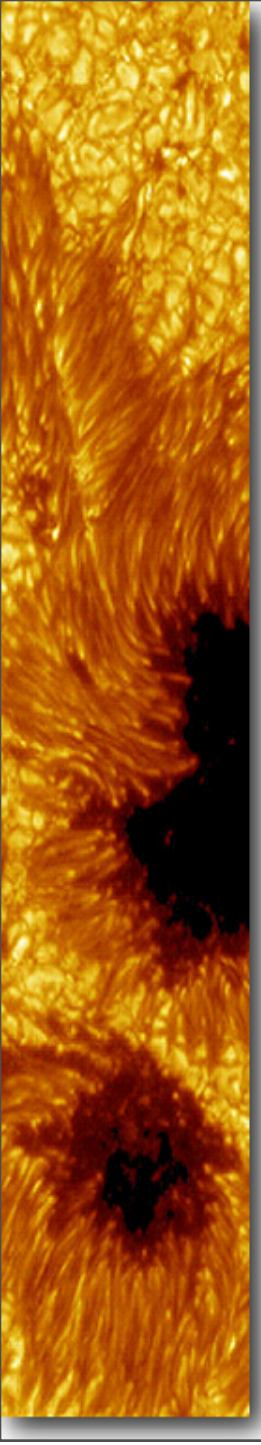

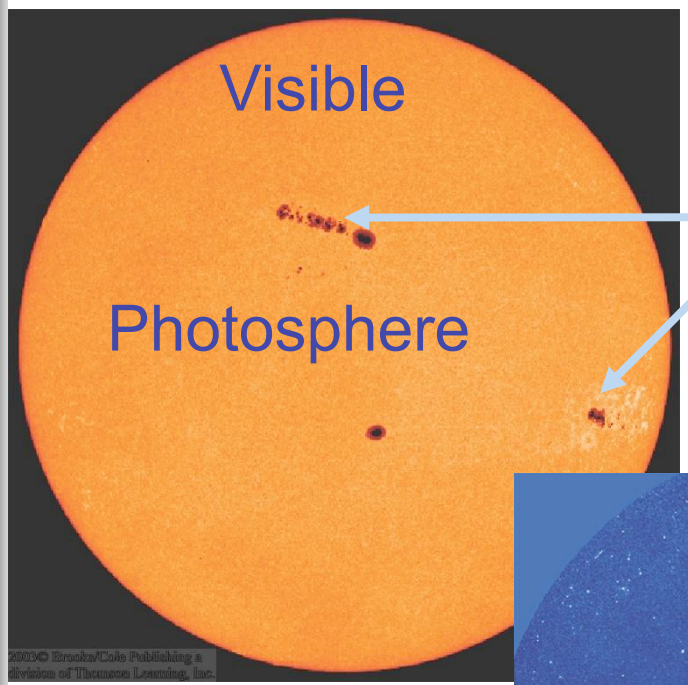

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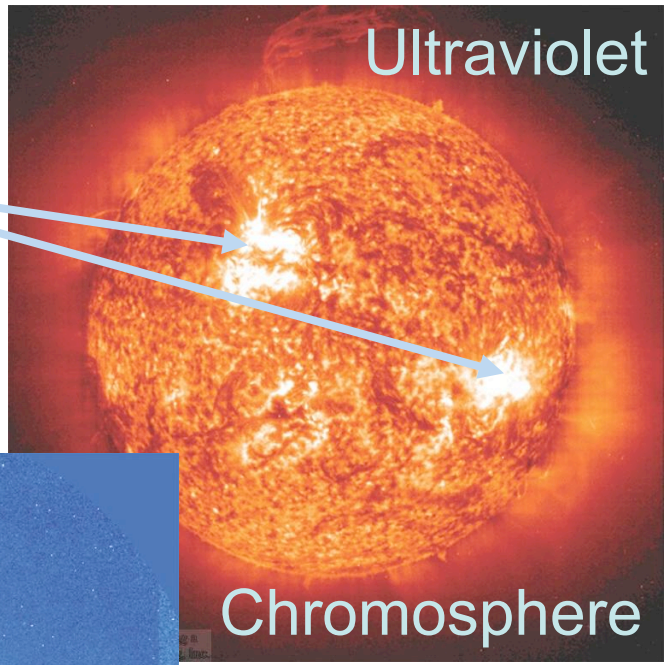

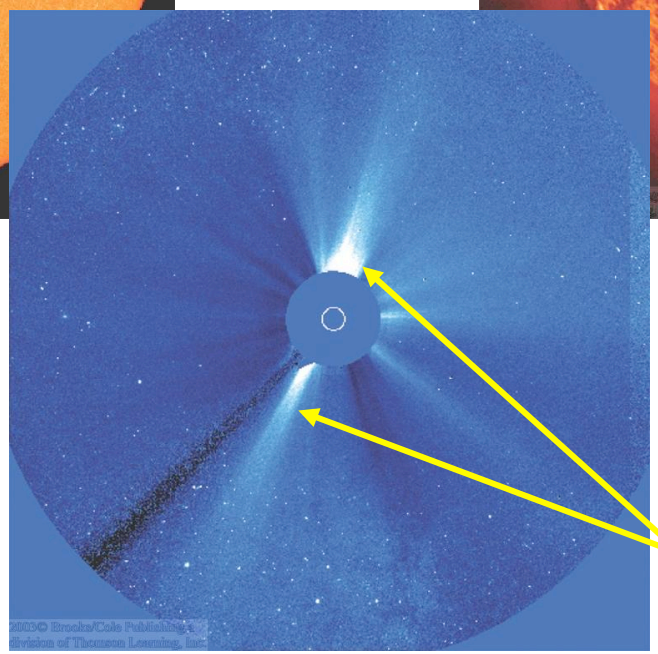

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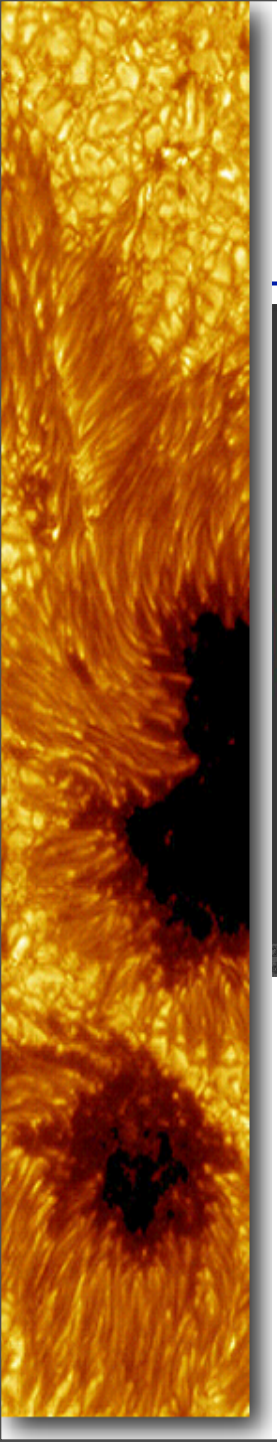

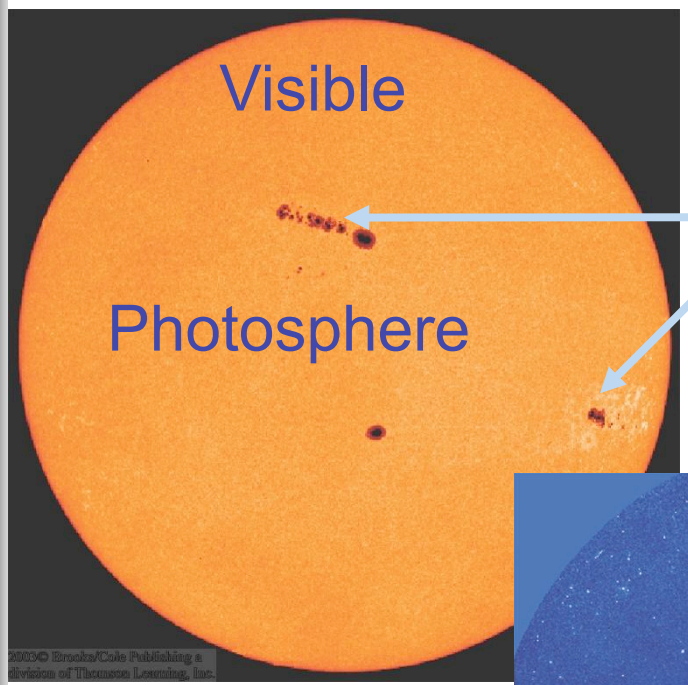

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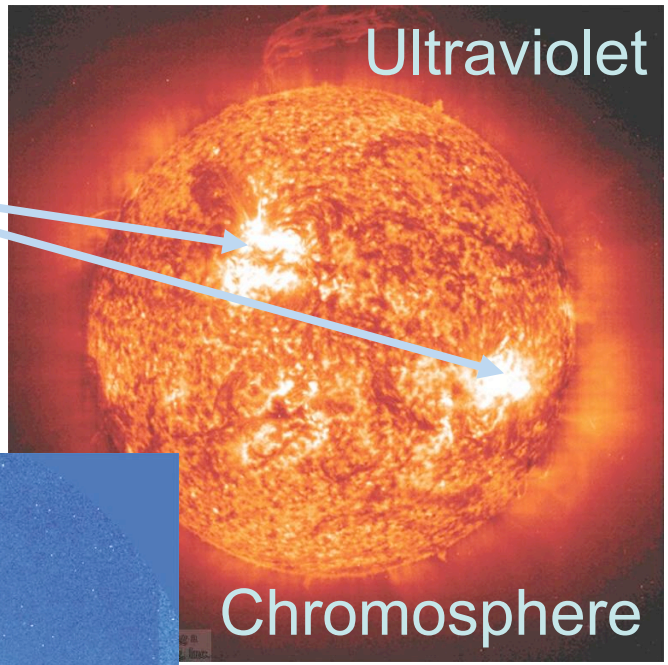

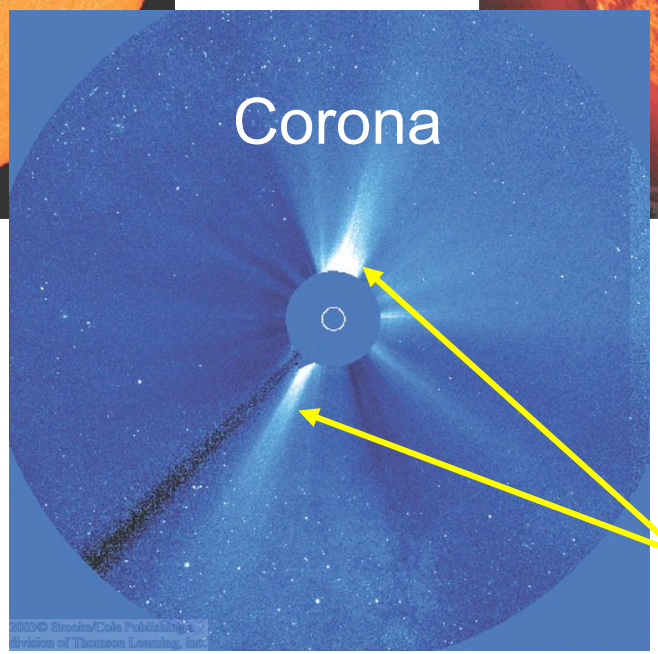

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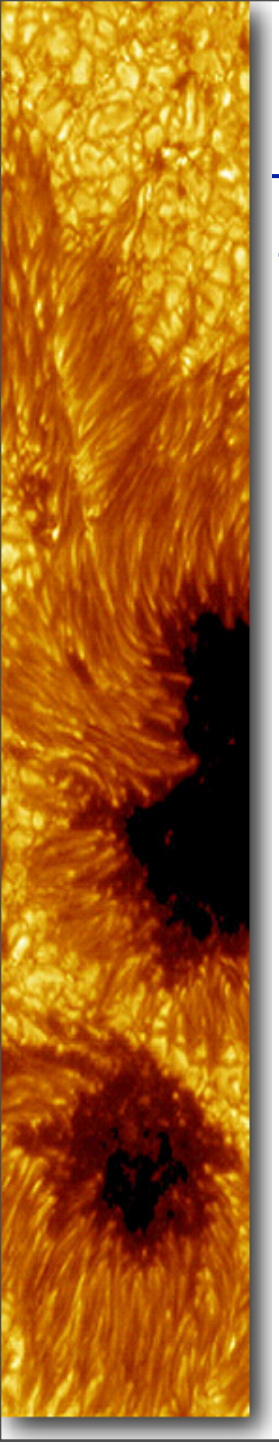
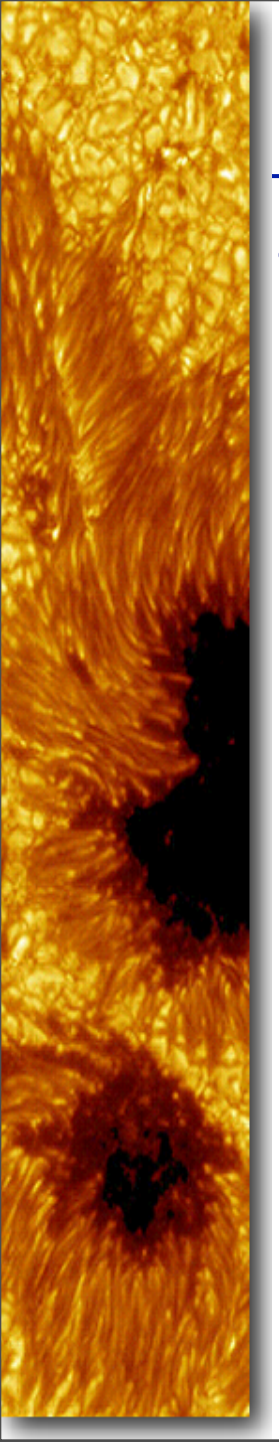


The Magnetic Carpet of the Corona

- Corona contains very low-density, very hot (1 million ^{o}K) gas



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- Corona contains very low-density, very hot (1 million ^{o}K) gas
- Coronal gas is heated through motions of magnetic fields anchored in the photosphere below ("magnetic carpet")

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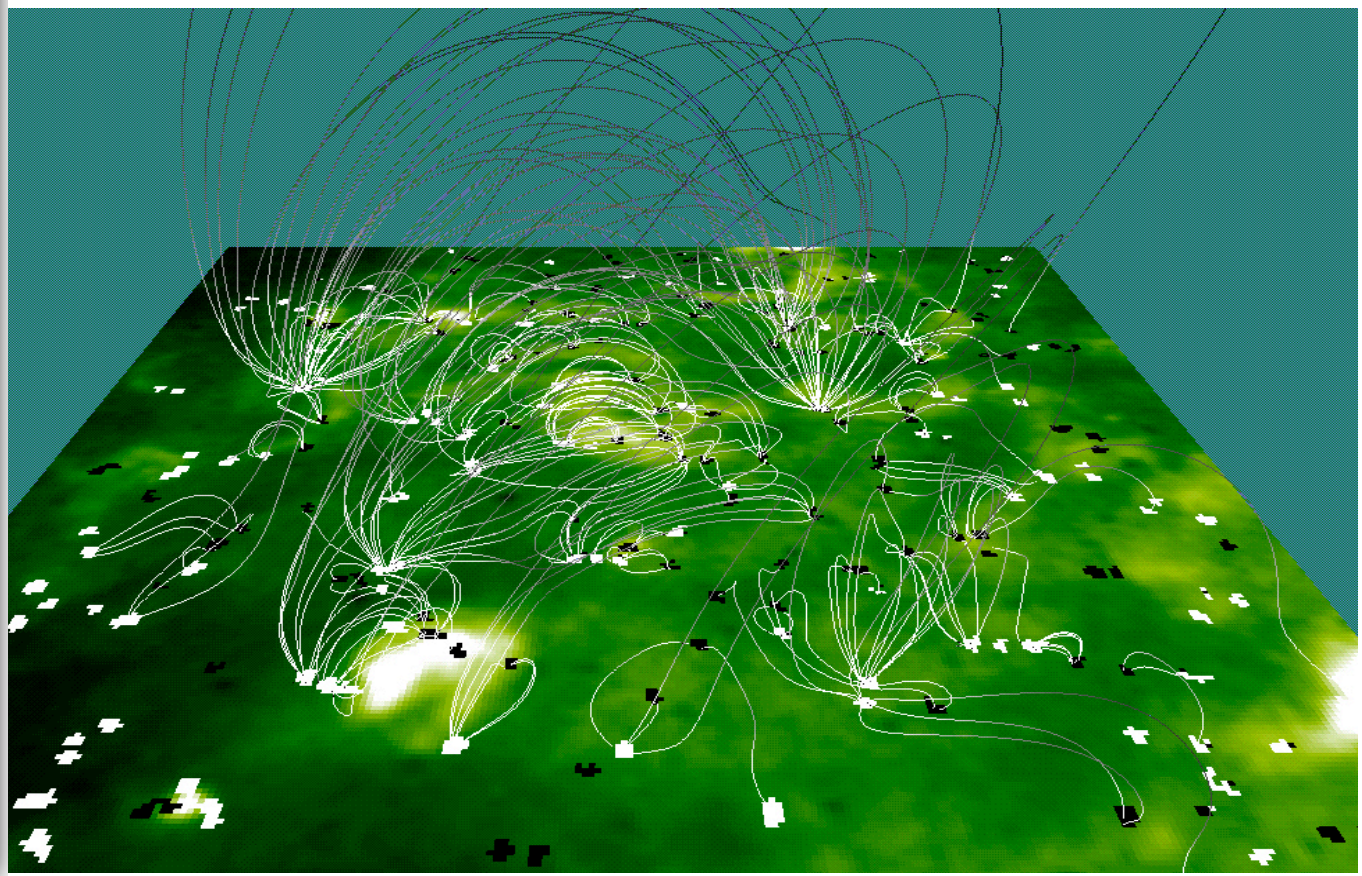
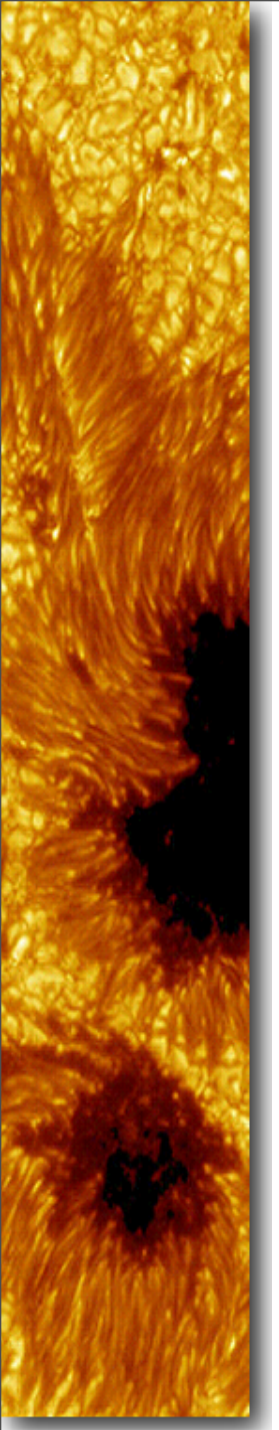


Computer model of the magnetic carpet



What effect does the formation of negative hydrogen ions in the sun's photosphere have on solar observations?

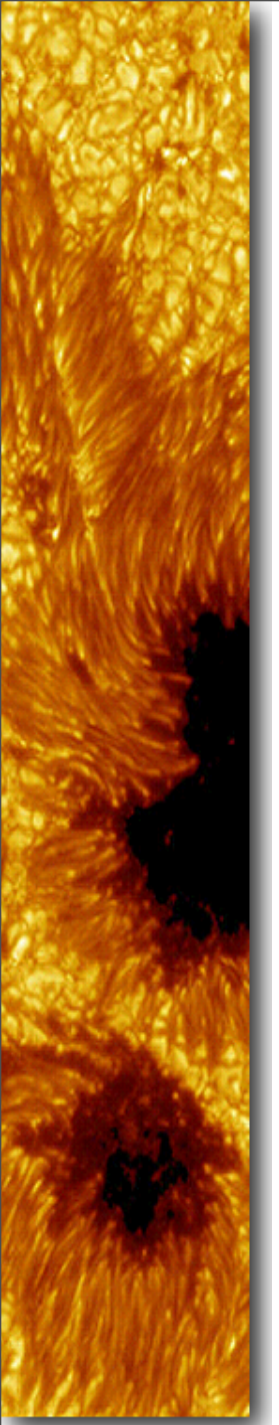
1. We can view the sun's interior through special filters set to the wavelength of the absorption lines created by such ions.

- Concentrations of such ions form sunspots that allow us to track solar rotation.

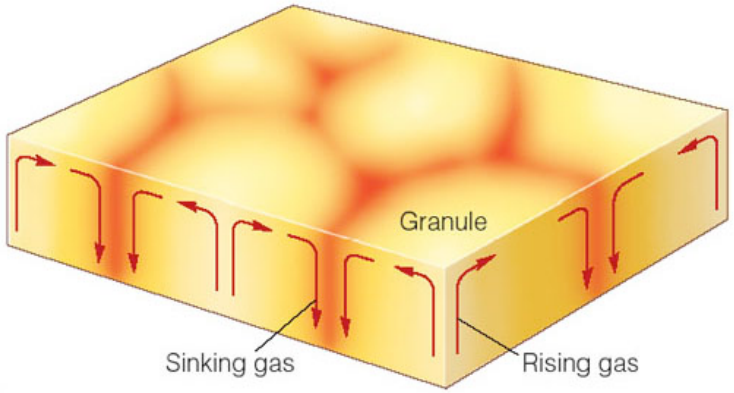
- It divides the sun's atmosphere into three distinct, easily observable layers.

- The extra electron absorbs different wavelength photons making the photosphere opaque.

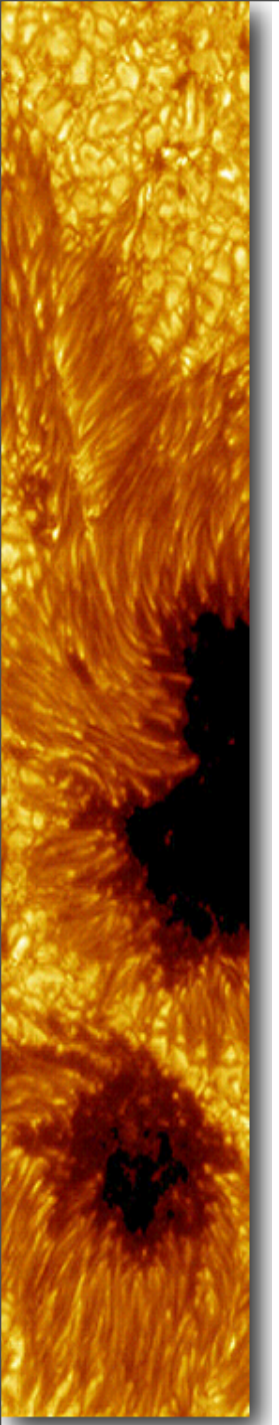
- These ions produce the "diamond ring" effect that is seen during total solar eclipses.



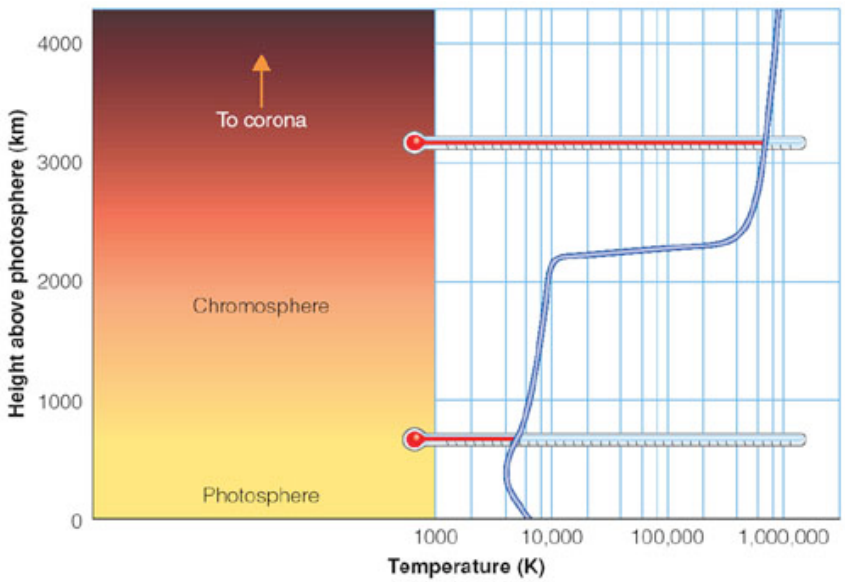
This diagram explains the structure of solar granules. Why is the center of a granule brighter than its edges?



1. The surface elevation is higher at the center.
2. The surface elevation is lower at the center.
3. The temperature is higher at the center.
4. The temperature is lower at the center.
5. The surface elevation is lower at the center.



The sun's atmospheric layers are all less dense than its interior. Based on this figure, which layer of the sun is responsible for the absorption lines in the solar spectrum?



1. Corona
2. Chromosphere
3. Photosphere
4. All the layers are responsible.
5. Both corona and chromosphere