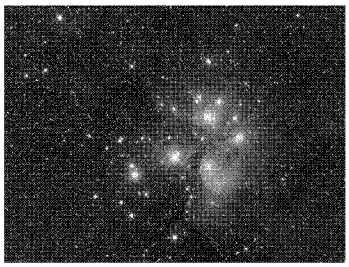
What is a Star?

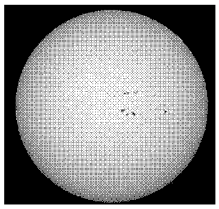


Wednesday, October 7

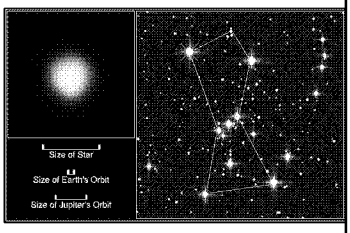
Next Planetarium Show: Tonight 7 pm

What is a star?

Examples of stars:



Sun



Betelgeuse

What is a star?

A large, hot, luminous ball of gas.

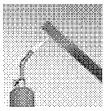
"Why do stars shine?"

Stars are dense (Sun is 40% denser than liquid water).

Stars are opaque (you can't see to the Sun's center).

Stars are hot.

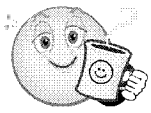
What happens when a dense, opaque object becomes hot?



It emits light.

What do I mean by **"HOT"**?

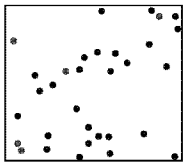
90°F



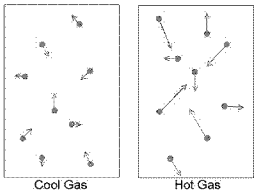
212°F

9980°F

At the submicroscopic level:
atoms in a gas

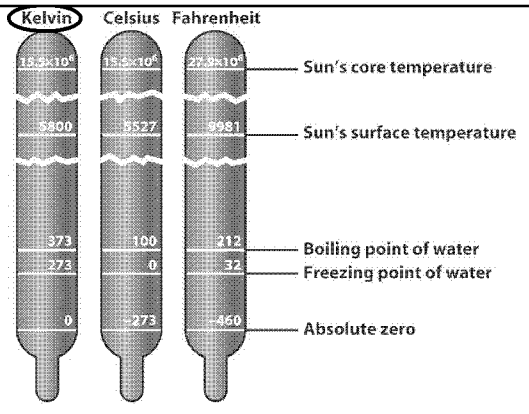


Object is **hot** when the atoms of which it's made are in rapid random motion.



Temperature: measure of typical speed of the atoms.

Random motions stop at **absolute zero** temperature.



Kelvin = Celsius + 273

Water boils: 373 Kelvin (K)

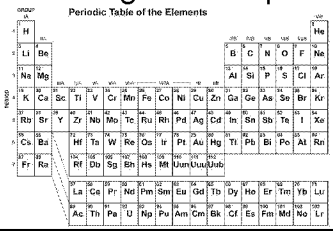
Water freezes: 273 K

Absolute zero: 0 K

Room temperature: ~300 K

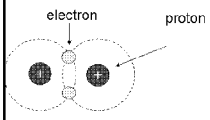
Surface of Sun: ~5800 K

Different elements respond in different ways to changes in temperature.



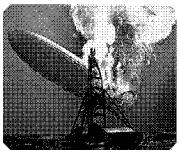
Rejoice! Spectra of stars & interstellar gas reveal they consist mostly of **hydrogen**, the simplest element.

At high density & low temperature, hydrogen is a gas of **molecules**.

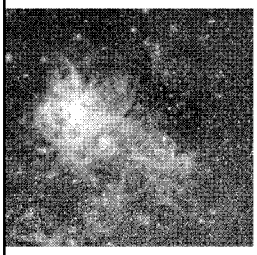


Molecular hydrogen (H_2) = two H atoms bonded together

(This assumes there's no oxygen for the hydrogen to bond with.)



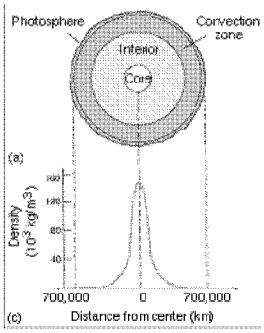
At low density & low temperature, hydrogen is a gas of **atoms**.



Much of the interstellar gas in our Galaxy is atomic hydrogen.

density ≈ 10^{-13} milligrams/m^3
T ≈ 100 K

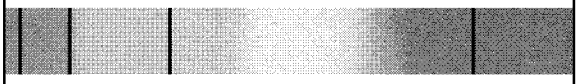
At high density & high temperature, hydrogen is an **ionized** gas (a.k.a. **plasma**)



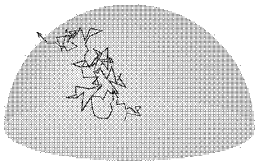
Much of the Sun's interior is ionized hydrogen.

Sun's center:
density ≈ 150 **tons**/m^3
T ≈ 15 million K

Electrons in a neutral atom can absorb photons at a few special energies.



Free electrons in an ionized gas can scatter photons of **any** energy.



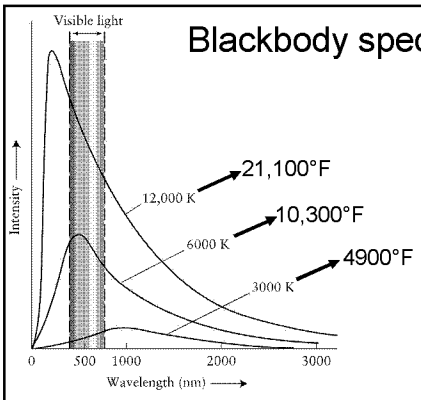
A star is an approximate **blackbody.**

A blackbody is an object that absorbs **all** the light that hits it.

Heat a blackbody: it emits light of all wavelengths (a **continuous** spectrum).

Wavelength at which spectrum peaks depends **only on temperature**.

Blackbody spectra



Wavelength of peak emission for a blackbody is **inversely** related to temperature.

$$\lambda_{\text{peak}} = \frac{2{,}900{,}000\ \text{nm} \cdot \text{Kelvin}}{T}$$

λ_{peak} = wavelength of maximum emission

T = temperature (Kelvin)

Examples:

You:

$$T = 98.6^\circ\,\mathrm{F} = 37^\circ\,\mathrm{C} = 310\,\mathrm{K}$$

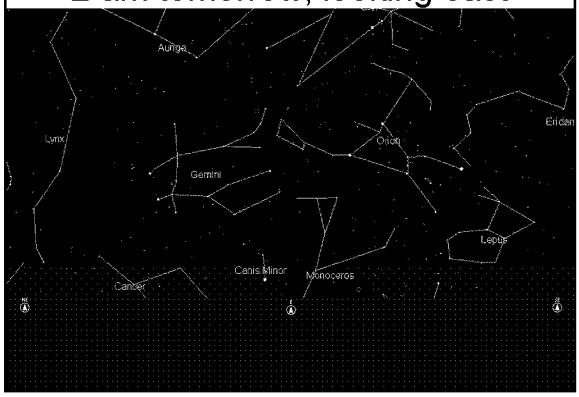
$$\lambda_{\text{peak}} = \frac{2{,}900{,}000\,\mathrm{nm}\cdot\mathrm{K}}{310\,\mathrm{K}} =$$

Sun's surface:

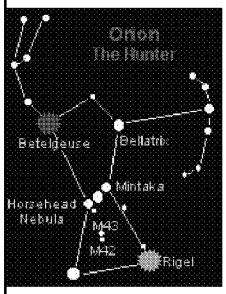
$$T = 5800\,\mathrm{K}$$

$$\lambda_{\text{peak}} = \frac{2{,}900{,}000\,\mathrm{nm}\cdot\mathrm{K}}{5800\,\mathrm{K}} =$$

2 am tomorrow, looking east



Another example: taking the temperature of a star!



Betelgeuse is **red**.

(Hard to see colors with the naked eye – binoculars help!)

Rigel is blue.

Betelgeuse:

$$\lambda_{peak} = 1000\,\text{nm}$$

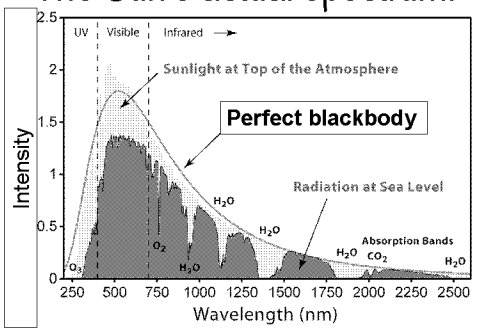
$$T = \frac{2{,}900{,}000\,\text{nm}\cdot\text{K}}{1000\,\text{nm}} =$$

Rigel:

$$\lambda_{peak} = 200\,\text{nm}$$

$$T = \frac{2{,}900{,}000\,\text{nm}\cdot\text{K}}{200\,\text{nm}} =$$

The Sun's actual spectrum:



Close to a blackbody, but not perfect.

Friday's Lecture:

What is a galaxy?

Reminders:

Have you read chapters 1 – 3 ?
Problem Set 2 is due **Wed, Oct 14**.
Planetarium show **Tonight.**