Announcements

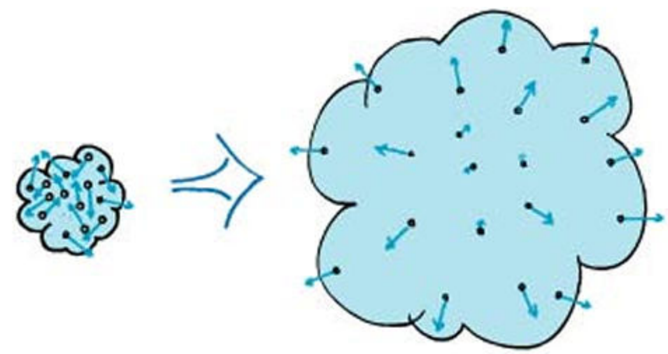
- Help room hours (1248 BPS)
  - Ian La Valley(TA)
  - Mon 4-6 PM (except not Monday Sept 17)
  - Tues 12-3 PM
  - Wed 6-9 PM
  - Fri 10 AM-noon
- Answers for exam 1 posted on course webpage
  - no scores returned from scoring office yet
- LON-CAPA #5 due Oct. 11
- Final Exam Tuesday Dec 11 7:45-9:45 AM

Back to thermodynamics: specific heat capacity

- The specific heat capacity (sometimes just called specific heat) of a substance is the quantity of heat required to change the temperature of a unit mass by 1 degree C
  - can think of it as thermal inertia since it signifies the resistance of a substance to a change in temperature
- Heat an oven up to 400^{o} F
- Would you stick your hand in the oven?
- Would you stick your hand on the metal rack inside the oven?
- Both are at the same temperature
- But the rack has a higher specific heat (more thermal energy stored)…that it's quite willing to transfer to your hand
- Take a piece of apple pie straight from the oven and eat it immediately
- The filling will burn your tongue while the crust will not
  - the filling has a larger specific heat
- Water has a high specific heat
  - it takes 8 times as much energy to raise the temperature of a gram of water by 1^{o} C than it does 1 gram of iron
  - the specific heat of water is 8 times that of iron
  - water is very useful for the cooling systems of cars because it absorbs a large amount of heat for a small increase in temperature

Joule-Kelvin effect

- Rapidly expanding gases get colder
- Used for producing the cold temperatures discussed in the video
- You can do an experiment at home; take a metal spray can; spray it for a while; the can will become noticeable colder
- Remember in the video where Dewar and Onnes were able to liquefy gases by first compressing them and then rapidly relieving the pressure
- This caused the gases to rapidly cool->liquify



Specific heat

- If the specific heat capacity c is known for a substance, then the heat transferred is equal to the specific heat capacity X mass X change in temperature

$$Q = cm\Delta T$$

  - where Q is the quantity of heat

- Suppose I mix 50 grams of 20° C water with 50 grams of 40° C water
- What is the final temperature of the water?
- The heat gained by the cooler water = the heat lost by the warmer water
  - conservation of energy again
- Since the masses are the same, the final temperature is midway
- We'll end up with 100 grams of 30° C water

Another example

- Suppose I mix 100 grams of 25° water and 50 grams of 40° C water
- Show that the final temperature is 31.4° C
- How would I approach this problem?

- Start by noting again that the heat gained by the cool water is equal to the heat lost by the hot water

$$cm_1\Delta T_1 = cm_2\Delta T_2$$

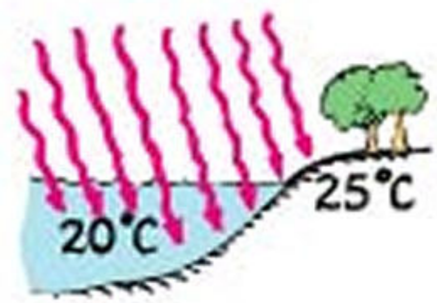
- Now ΔT_1 does not equal ΔT_2 because of the different masses of water
- Let T be the final temperature
  - T will be between 25° and 40°
  - $\Delta T_1 = T - 25^o$
  - $\Delta T_2 = 40^o - T$
- Then I can write

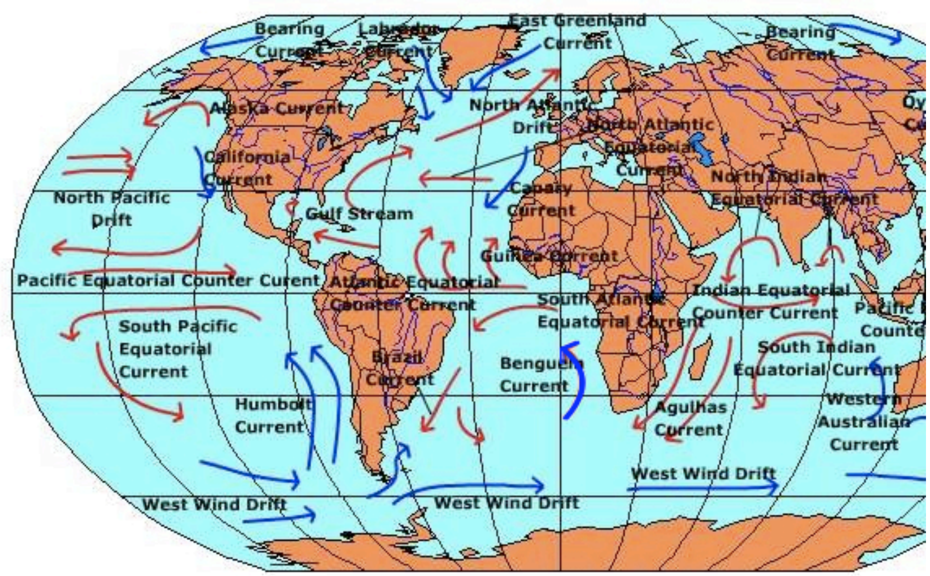
$$c(100g)(T-25) = c(75g)(40-T)$$

Our friend, water

- Water has a much higher capacity for storing energy than almost any other substance
  - because of the different ways that water molecules can store energy
  - in particular, in internal degrees of freedom such as rotation or vibration of the atoms inside a water molecule
- Water's high heat capacity affects the world's climate
- Northern Canada and northern Europe receive about the same amount of sunlight
  - Europe is warmer because of the Gulf Stream
  - 4.18 J for every g of water

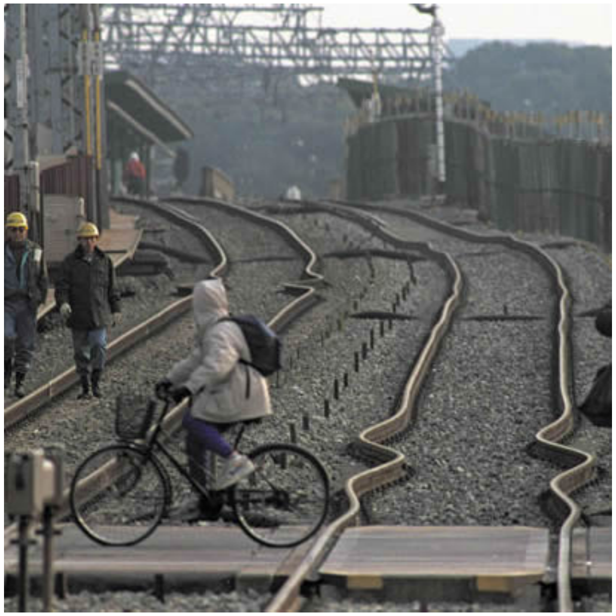
It takes a lot more energy to warm the water than to warm the land…and the water stays warmer longer





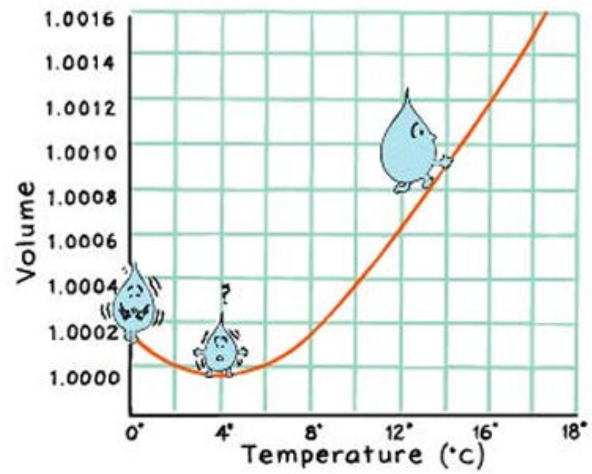
Thermal expansion

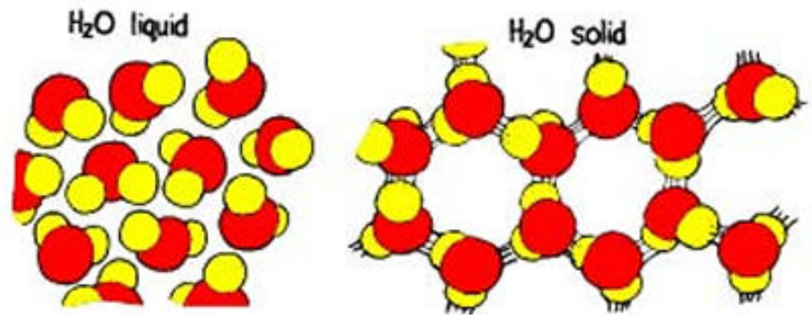
- As the temperature of a substance increases, the molecules vibrate faster and move further apart
- Most substances expand when heated and contract when cooled
- Railroad tracks laid on a cold winter day can buckle on a hot summer day
- If you look at a bridge closely, you can see expansion joints to prevent any damage from expansion/contraction

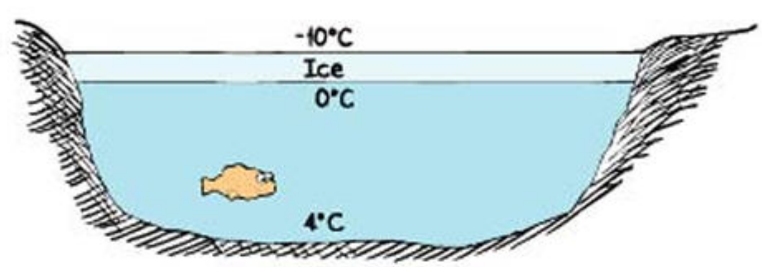


Water

- Water is an very unusual substance
- It expands when heated (normal), but it shrinks when cooled from 4º to 0º C
  - so 4º C water has the highest density, and therefore sinks to the bottom
- And it expands when it freezes
  - due to its crystalline structure
- So the density of ice is less than the density of water
  - so ice floats
  - and the bottoms of lakes tend to stay unfrozen
  - …and the fish are happy







Heat transfer

- Heat transfers from warmer to cooler things
- This process occurs in 3 ways
  - conduction
  - convection
  - radiation

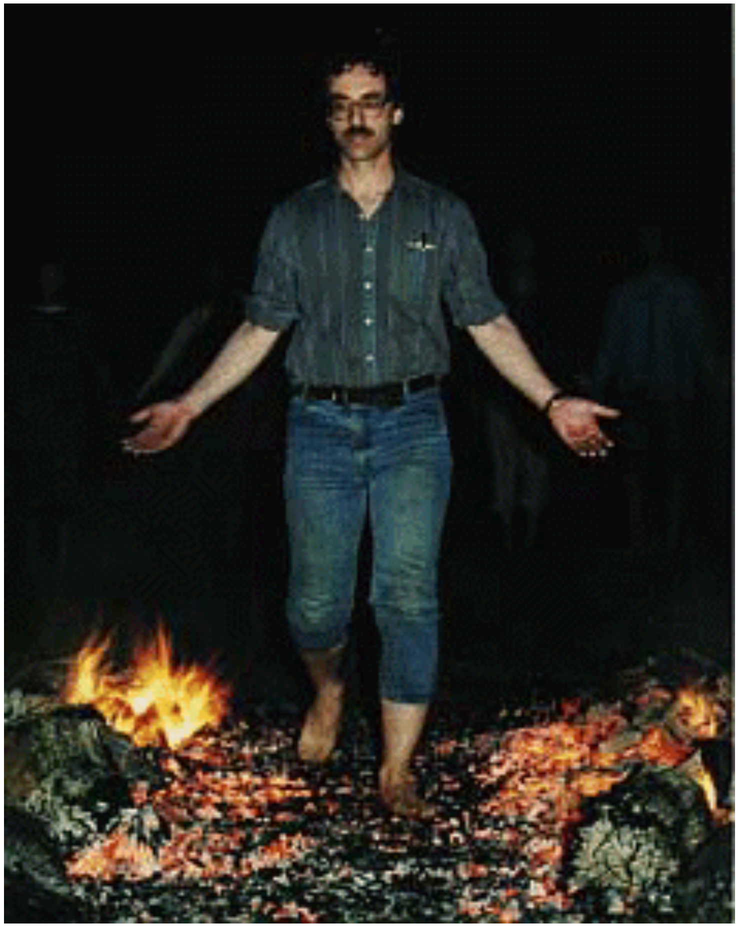
Conduction

- Thermal conduction occurs by collisions between particles and their immediate neighbors
- If you put one foot on a tile floor and one foot on a wooden floor, the tile feels cold, even though the two are at the same temperature
  - because the tiles are a better conductor of heat
- If the heat travels quickly through a material, we say that it is a good conductor of heat
- If the heat does not travel well, we say the material is a poor conductor, or a good insulator
- Good heat conductors have outer electrons that are loosely bound; good insulators have electrons that are tightly bound

We'll find the same is true for electrical conductors and insulators

Firewalking

- How does fire-walking work?
- Is it mental/psychic control?
- Luckily for the firewalkers, it's physics
- Wood, even hot coals, is a very poor conductor of heat, so even though the coals are hot, little heat is transferred to the feet



Pancakes

How to Make Pancakes – wikiHow

http://www.wikihow.com/Make-Pancakes | RSS | water droplets on hot griddle

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- Make French Toast
- Make Scrambled Eggs
- Make a Bowl of Cereal
- Make French Toast Waffles

How to Make Pancakes

Millions of people from all around the world love pancakes, and it's no surprise that many people prefer this filling, hearty breakfast as opposed to plain old cereal. This article will show you how to make these pancakes, step by step.

Ingredients [edit]

The following ingredients will make between 4-8, depending on the size. You may change the amounts of ingredients according to the amount of which you wish to serve.

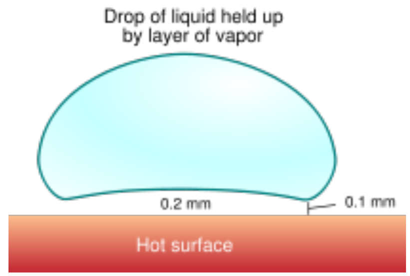
- 2 cups Self rising flour (All Purpose can work, too)
- 2 eggs
- 2 3/4 cups of milk
- 1/4 cup olive oil
- 2 tablespoons butter
- 3 tablespoons sugar
- 1 1/2 tablespoons of baking powder
- 1 teaspoon salt

Steps [edit]

1. Beat eggs until fluffy. Add dry ingredients, followed by milk, and oil.
2. Melt butter and add to mix. Stir gently, leave some small clumps in the batter. DO NOT BLEND UNTIL SMOOTH, your pancakes will be tough and flat as opposed to fluffy. THIS IS VERY IMPORTANT
3. Heat frying pan to a medium low flame. If you have an inital 'pancake' setting on your stove, use that. Be
4. To be sure the pan is hot enough, sprinkle some water on it. If it 'dances', it is ready.

Leidenfrost effect

- If a drop of liquid is in contact with a surface significantly hotter than the boiling point of the liquid, then a vapor layer forms between the drop and the surface
- The heat conductivity of the vapor is poor, causing the drop to take longer to vaporize than at lower temperatures
- Also works with molten lead
    - but don’t try this at home



#96-b (3/25/2006)

http://www.ripleys.com/
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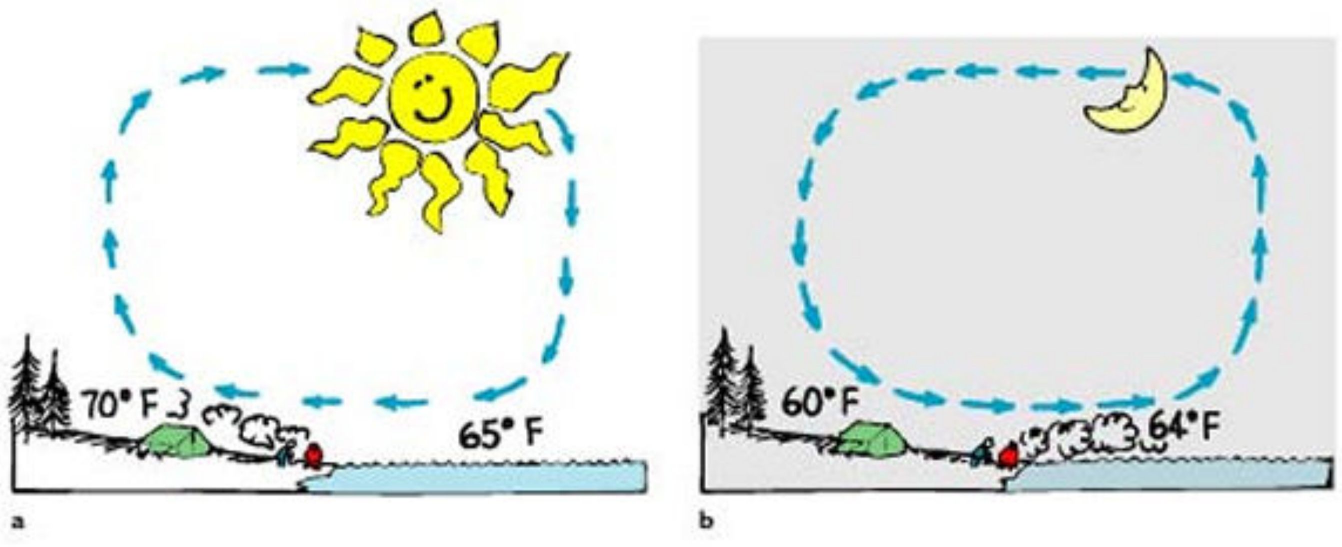
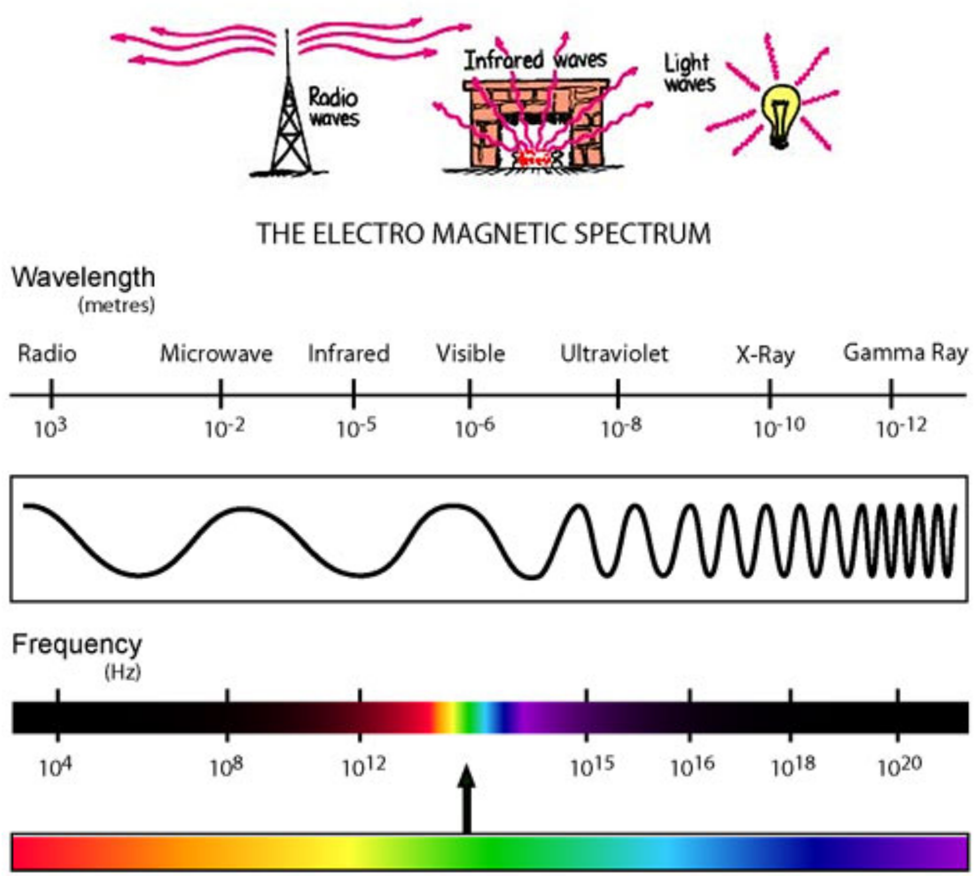
Convection

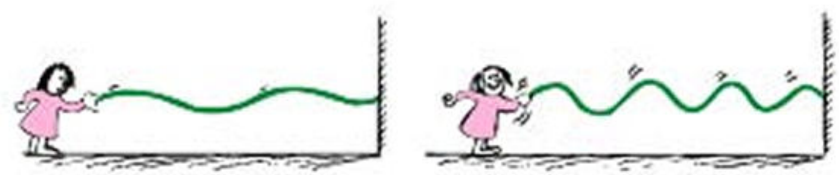
- On a hot day, you can see ripples in the air as hot air rises from an asphalt road
- Transfer of heat by the motion of fluid as it rises or sinks is called convection
- Convection involves bulk motion of a fluid
- Convection currents stir the atmosphere and produce winds



Radiation

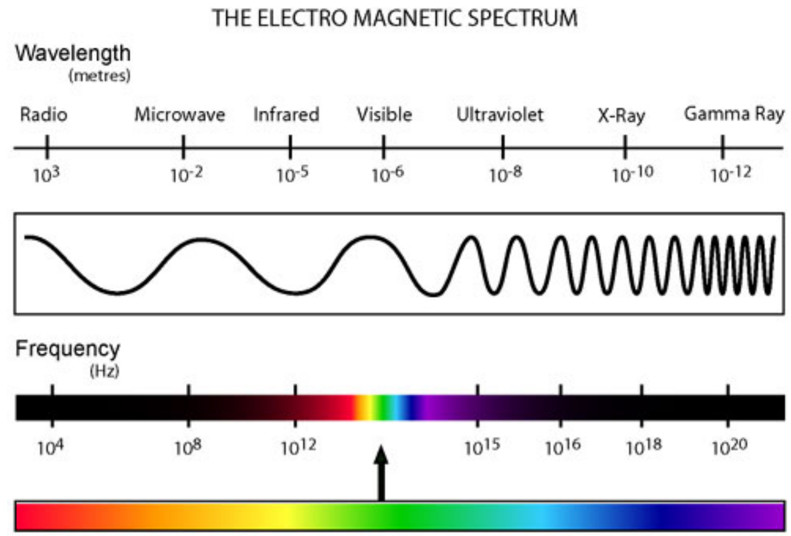
- Energy travels from the Sun through space and then through the Earth's atmosphere to warm the Earth's surface
- This can't involve conduction or convection, so it must involve another mechanism: radiation
- Radiant energy exists in the form of electromagnetic waves, ranging from the longest wavelengths to the shortest
    - radio waves
    - microwaves
    - infrared waves
    - visible waves
    - X-rays
    - gamma rays
- The wavelength of a wave is related to its frequency
- If I shake a rope at a high frequency, I get a shorter wavelength





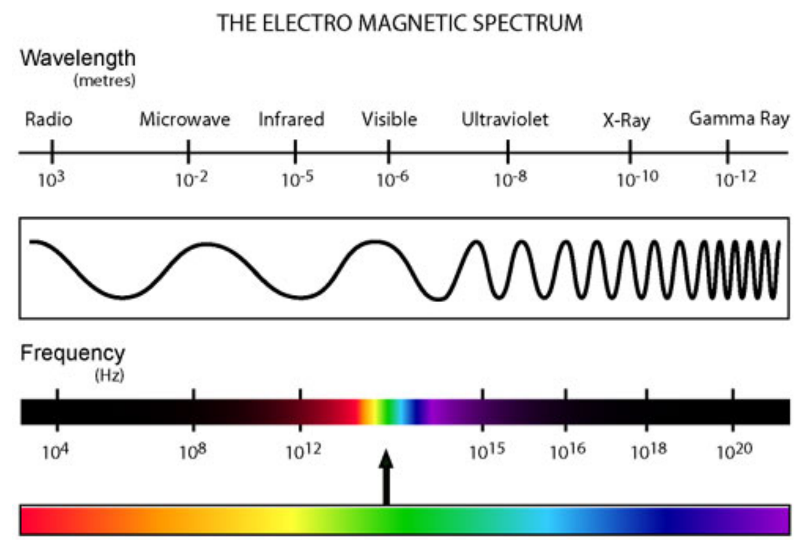
Radiation

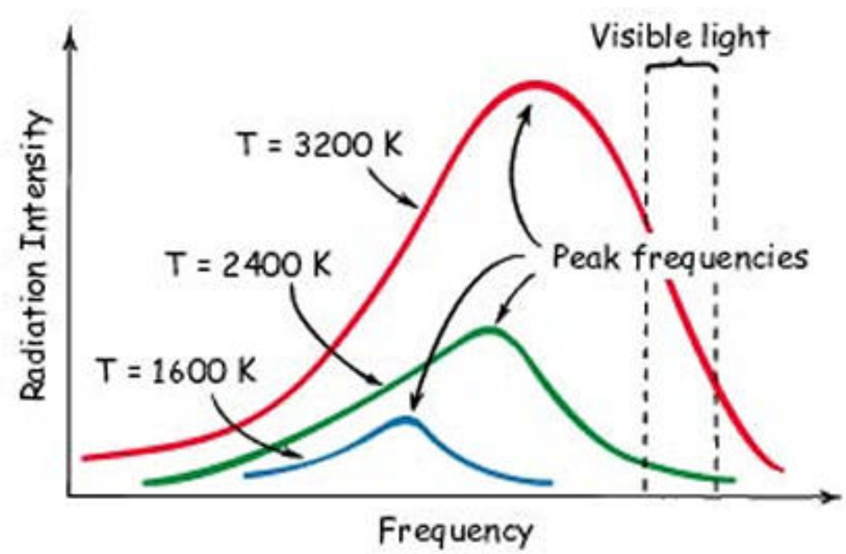
- Every object above absolute zero emits radiant energy
- The peak frequency for the radiation is proportional to the temperature
- If an object is hot enough, it emits light in the visible range of the spectrum
- If an object is at a temperature of 500° C, it emits enough radiation in the visible region of the spectrum to appear to be 'red-hot'
- Higher temperatures produce a yellowish light
- At still higher temperatures, all the visible wavelengths are present and the object appears 'white-hot'



Radiation

- Every object above absolute zero emits radiant energy
- The peak frequency for the radiation is proportional to the temperature
- If an object is hot enough, it emits light in the visible range of the spectrum
- The Sun is very hot, on the order of 6000° K; it emits most of its radiation in the visible portion of the electromagnetic spectrum, with the peak at wavelengths corresponding to yellow light
- It should be no surprise that our eyes have evolved to have maximum sensitivity to the yellow portion of the spectrum

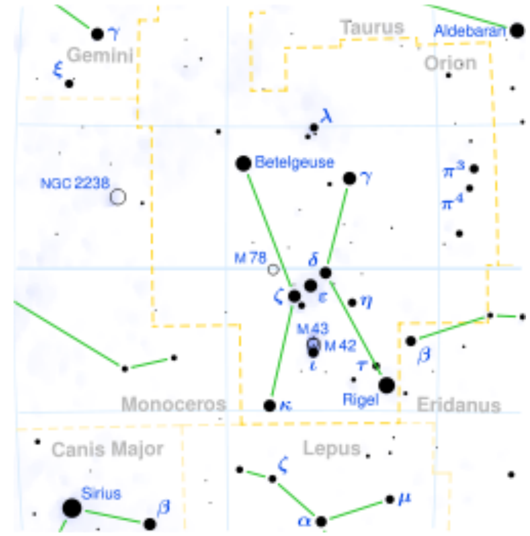




Different stars have different colors

…in the constellation Orion

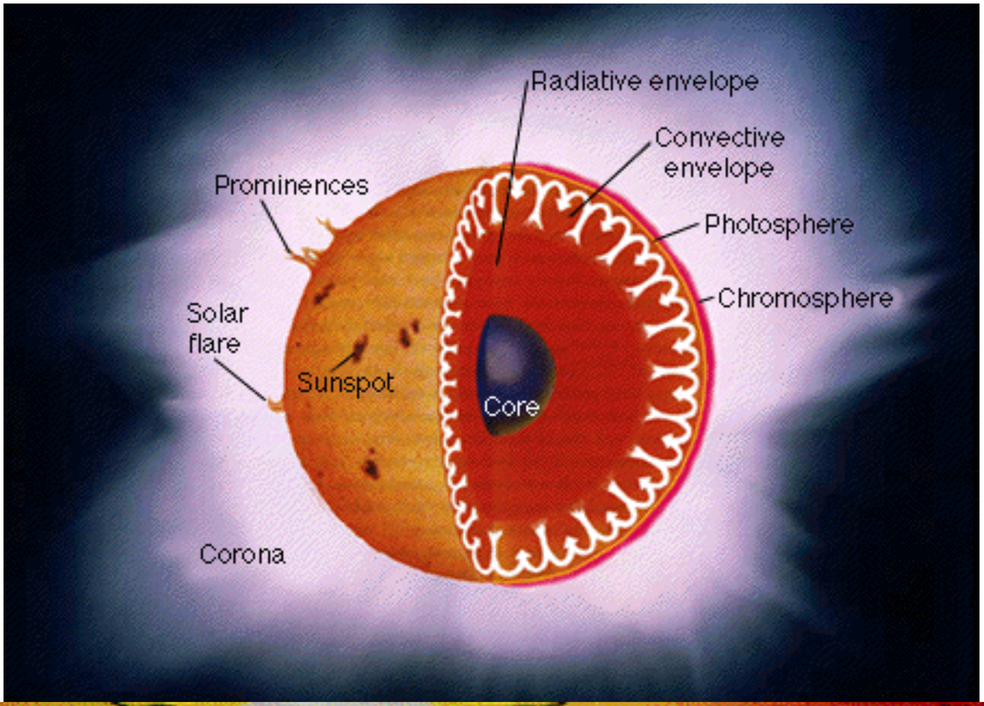
Betelgeuse (noticeably red; it's a red supergiant star)

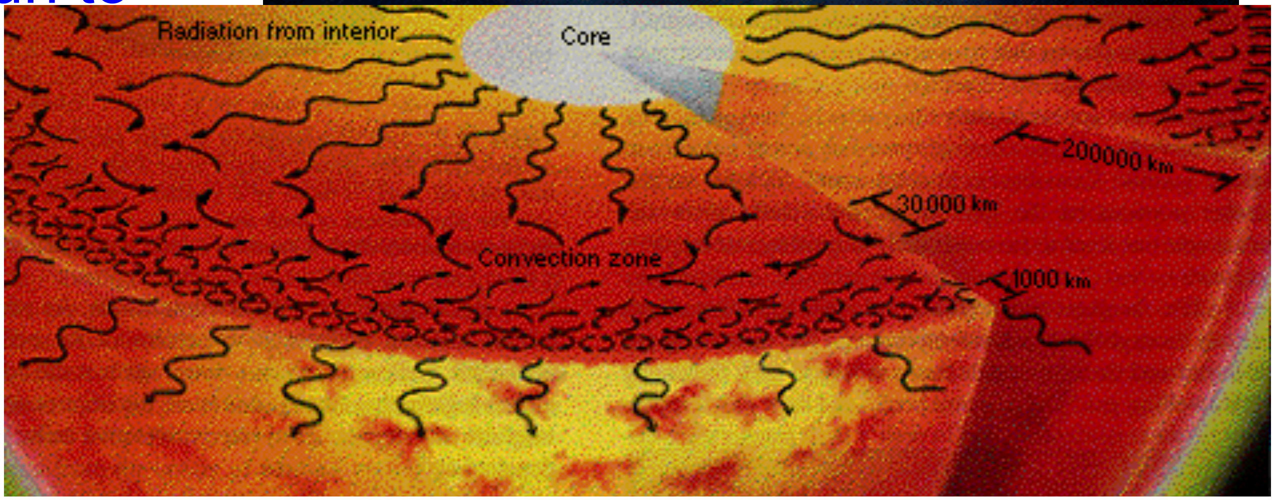


Rigel (it's much hotter than the Sun, noticeably blue)

Back to the Sun

- Energy is transported in the Sun both by radiation and by convection
- It takes about 20 million years for the energy produced by nuclear fusion in the interior of the Sun to come to the surface



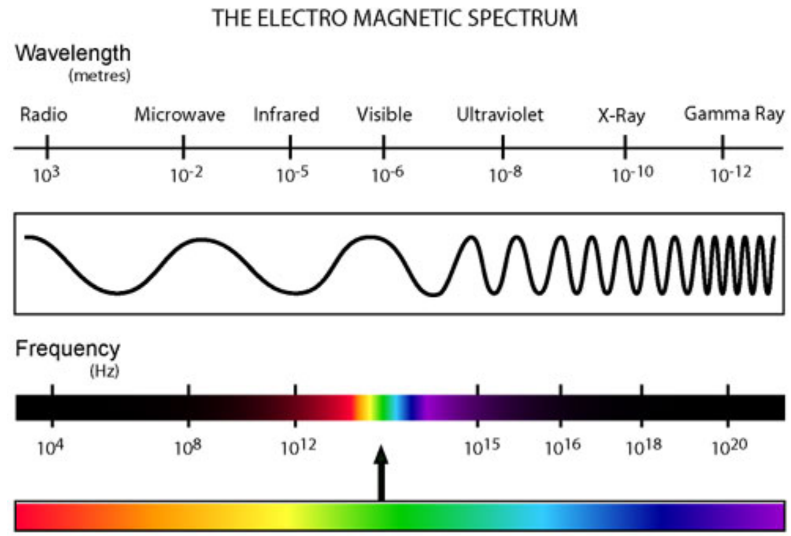


iclicker question

- By what means of energy transport does light from the Sun reach the Earth?
  - a) conduction
  - b) convection
  - c) radiation
  - e) transduction
  - e) CATA

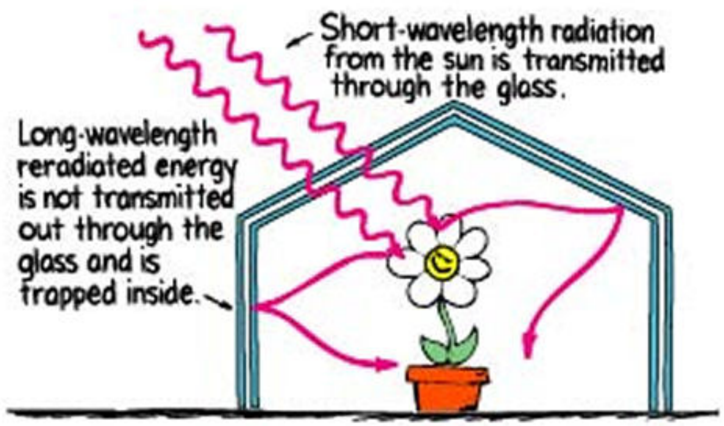
Infrared (or night vision) goggles

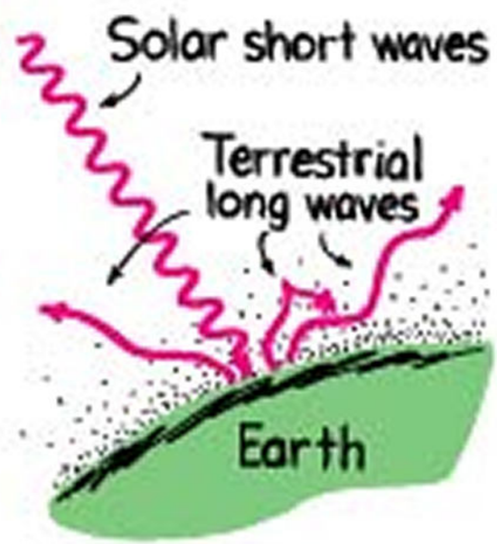
- As stated before, every object above absolute zero emits electromagnetic radiation
- The Sun emits mostly in the visible region of the spectrum (but also infrared and ultraviolet)
- Our bodies, at 300°K, emit mostly in the infrared portion of the spectrum
- The Earth absorbs the (mostly visible) solar radiation and emits it as IR (since it is at a much lower temperature than the Sun)



Greenhouse effect

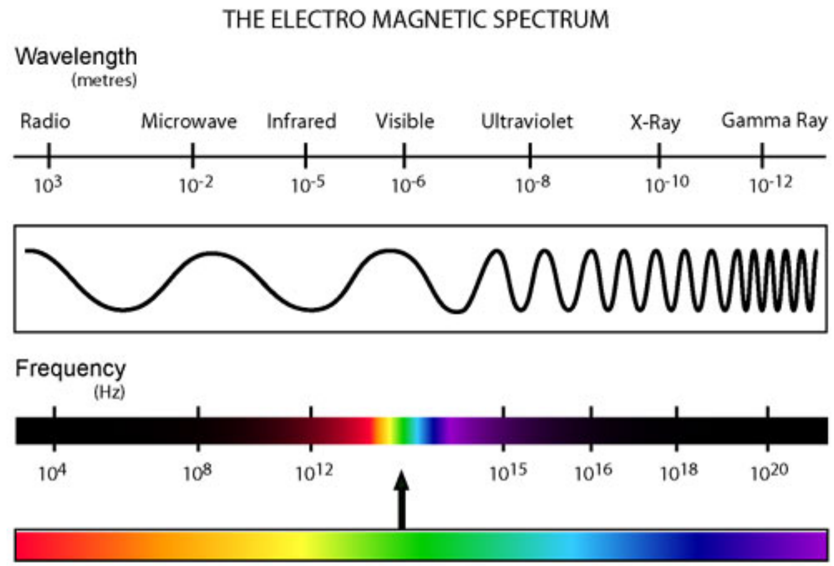
- Why is a greenhouse hot? Short wavelength light is transmitted through the glass, absorbed by soil and plants inside and is re-radiated as longer wavelength radiation (which is reflected by the glass and stays inside)
- Same thing happens with the Earth's atmosphere
  - because of greenhouse gases such as carbon dioxide
- Responsible for increasing Earth's average temperature
- With the greenhouse effect, the average temperature is 14°C; without it would be -18°C





Penzias and Wilson

- Penzias and Wilson were two physicists working for Bell Labs in the 1960's
- One of their assignments was to try to understand the source of the background noise (hiss) on transatlantic phone calls
- They used a radio telescope sensitive to microwave frequencies
- They found the radiation was everywhere they pointed in the sky
- It was then realized that they were observing radiation left over from the Big Bang (or actually 400,000 years after the Big Bang, when the universe became transparent)
- Originally corresponding to a temperature of millions of degrees (with the radiation consisting of gamma rays), it had since cooled down to 3°K (microwave region)
- This had been predicted

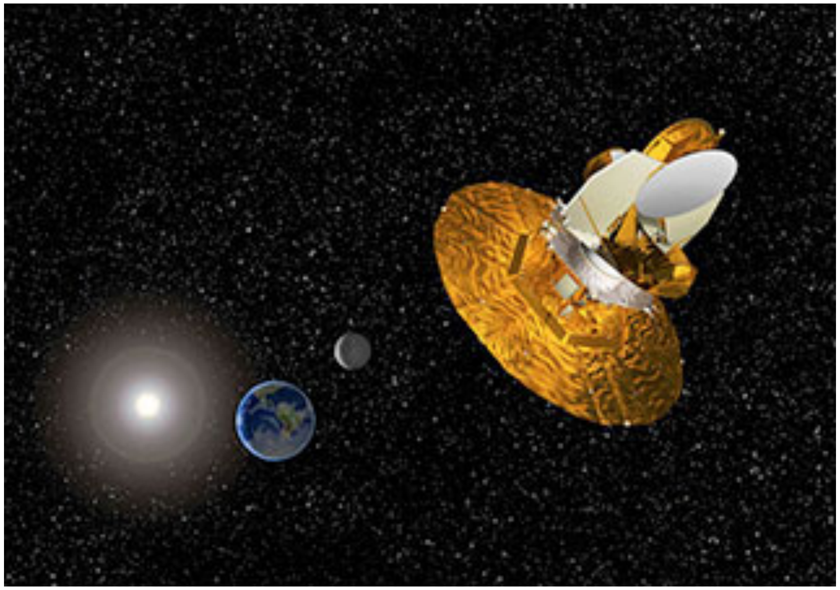


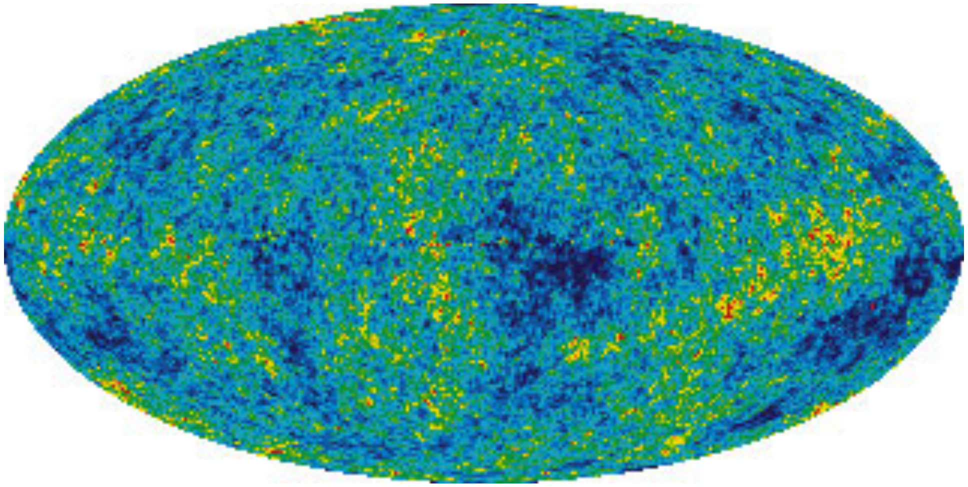
Your very own Big Bang Radiation detector

- The remnant radiation from the Big Bang fills all of the universe
- It's been cooled down to microwave wavelengths
- Take your tv, disconnect the cable (and antenna)
- The screen is filled with static
- About 2% of that static is radiation from the Big Bang

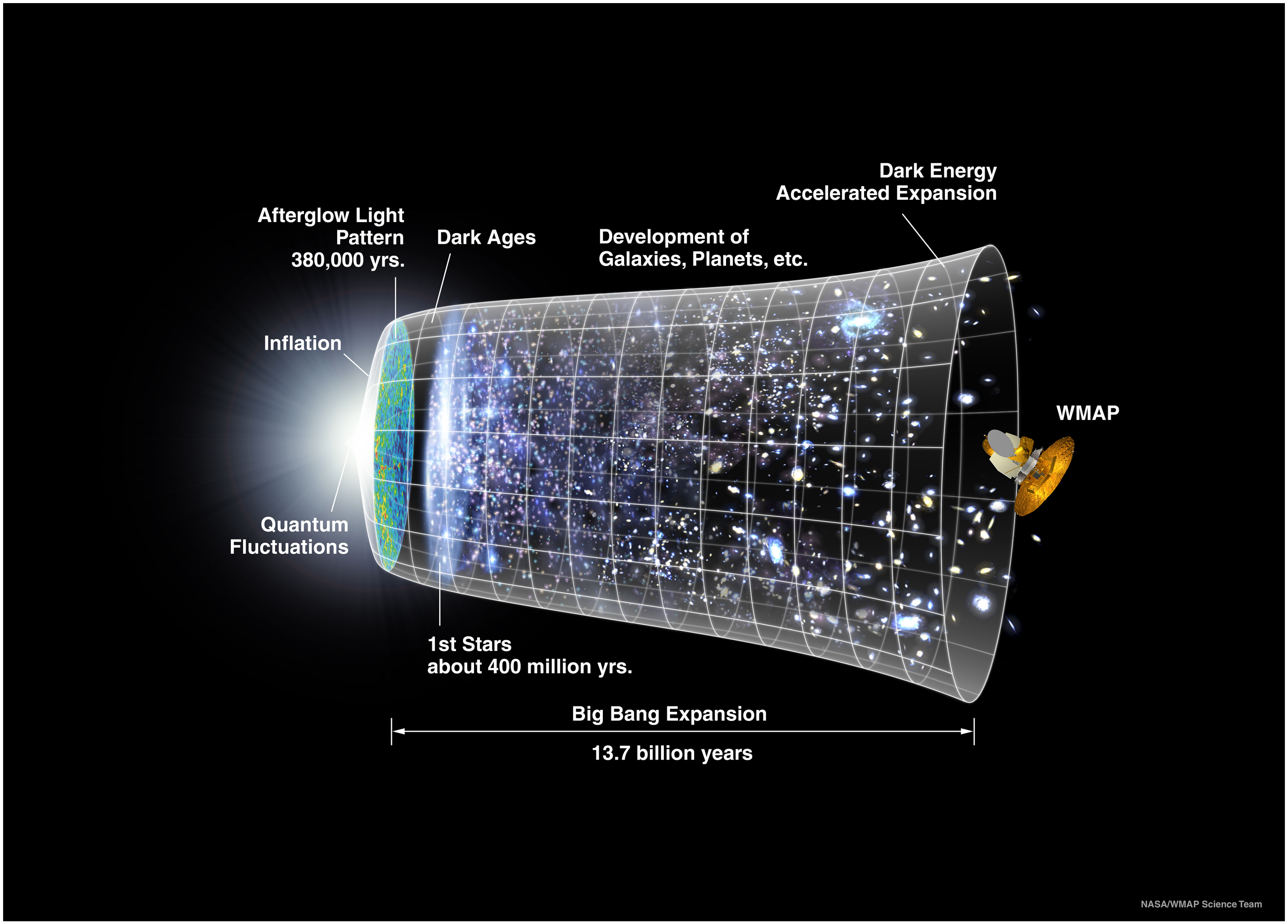
WMAP

- The mission of the WMAP spacecraft was to make a detailed map of the temperature variations for the microwave radiation left over from the Big Bang
- The map on the right is one of the results
- Blue indicates cooler regions of the sky and yellow warmer regions
  - but the temperature differences are small, of the order of a few hundred millionths of a degree
- It's these fluctuations/ variations that allowed galaxies to form



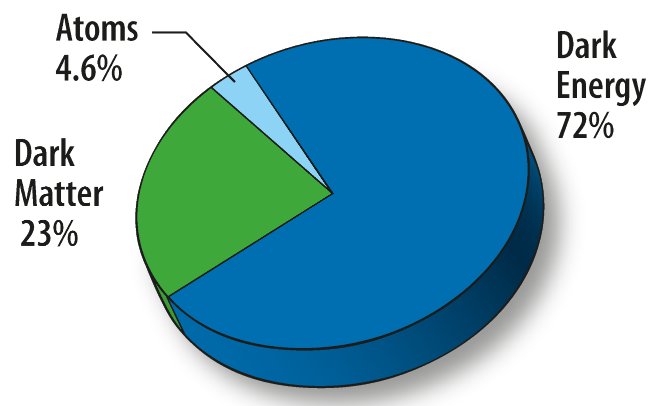


Timeline of the universe

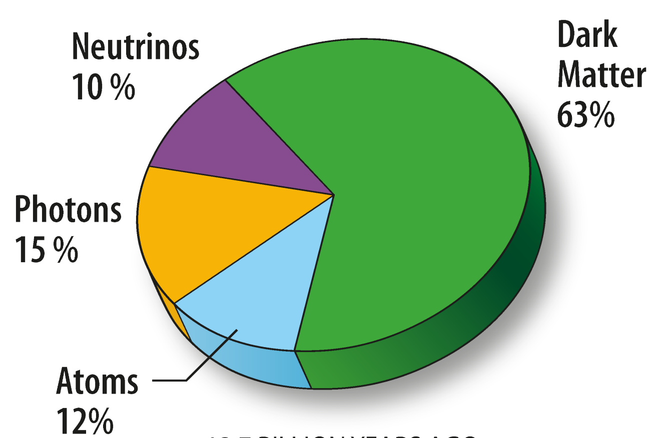


Conclusions from WMAP

- Most of the universe is composed of stuff we don't understand
- Dark matter and dark energy
- The dark energy is the stuff that trying to pull the universe apart
- We'll talk about it more towards the end of the semester



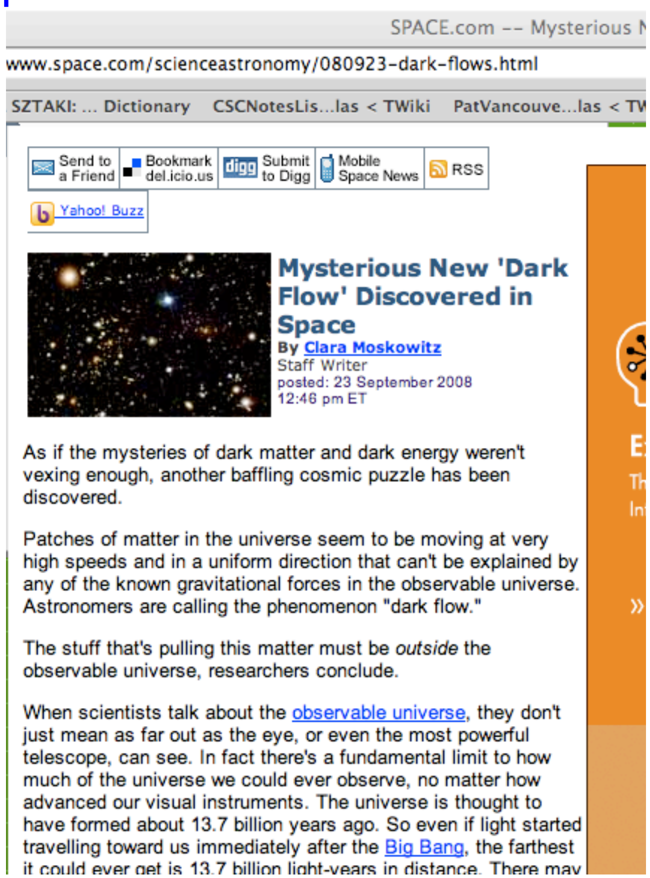
TODAY



13.7 BILLION YEARS AGO
(Universe 380,000 years old)

It gets weirder

- There's something incredibly massive beyond the observable universe that is exerting a gravitational attraction on some parts of the universe



SPACE.com -- Mysterious N

www.space.com/scienceastronomy/080923-dark-flows.html

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Mysterious New 'Dark Flow' Discovered in Space

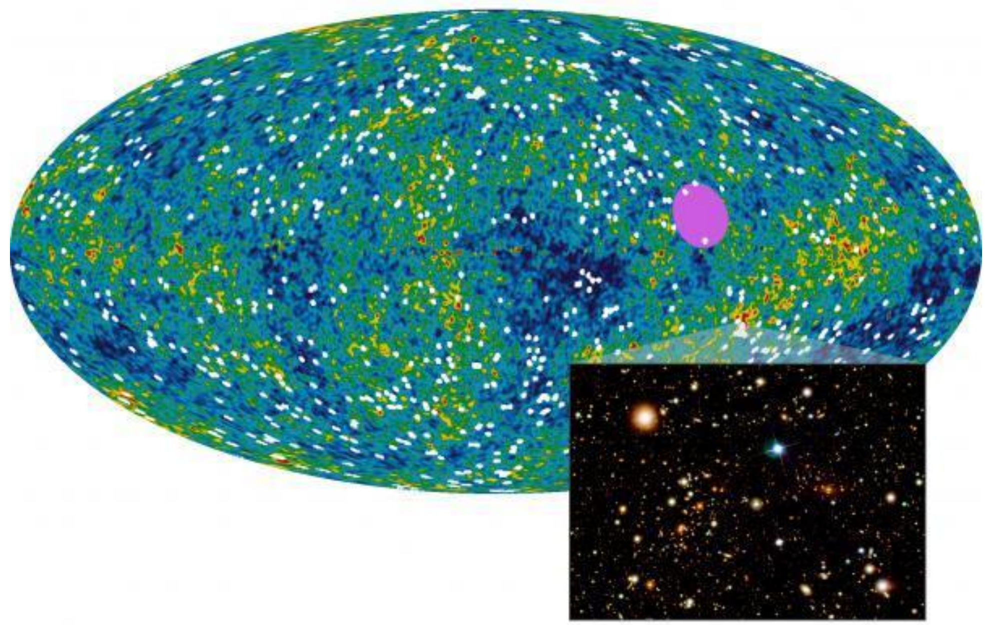
By Clara Moskowitz
Staff Writer
posted: 23 September 2008
12:46 pm ET

As if the mysteries of dark matter and dark energy weren't vexing enough, another baffling cosmic puzzle has been discovered.

Patches of matter in the universe seem to be moving at very high speeds and in a uniform direction that can't be explained by any of the known gravitational forces in the observable universe. Astronomers are calling the phenomenon "dark flow."

The stuff that's pulling this matter must be *outside* the observable universe, researchers conclude.

When scientists talk about the observable universe, they don't just mean as far out as the eye, or even the most powerful telescope, can see. In fact there's a fundamental limit to how much of the universe we could ever observe, no matter how advanced our visual instruments. The universe is thought to have formed about 13.7 billion years ago. So even if light started travelling toward us immediately after the Big Bang, the farthest it could ever get is 13.7 billion light-years in distance. There may



"Most likely to create such a coherent flow they would have to be some very strange structures, maybe some warped space-time."

Maybe another universe, somehow intersecting with our own.