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Today

- Announcements:
  - HW#10 is due Wednesday Nov. 23.
  - Extra credit project on Intelligent Design is available it will be due Dec. 2nd at 5:00pm. Please don't wait till the last minute.
- Review of Big Bang
- The topics for today are Entropy, Black holes, Worm holes, and time.

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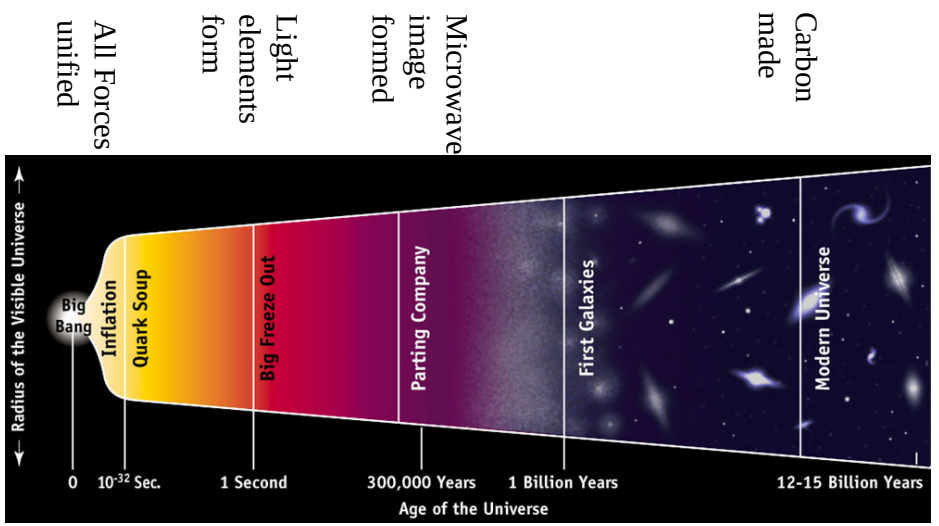
Timeline of the Big Bang



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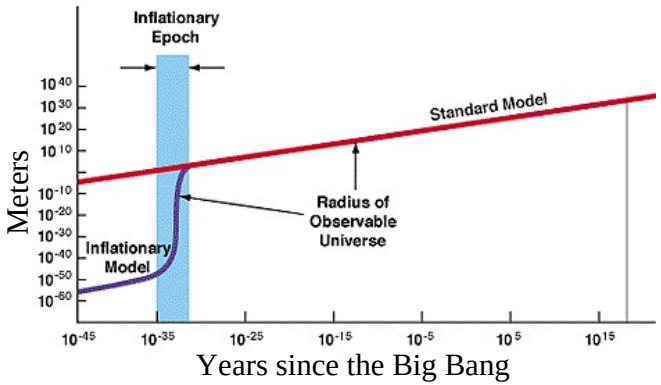
Inflation



The existence of an unknown scalar field caused the rapid inflation of the Universe

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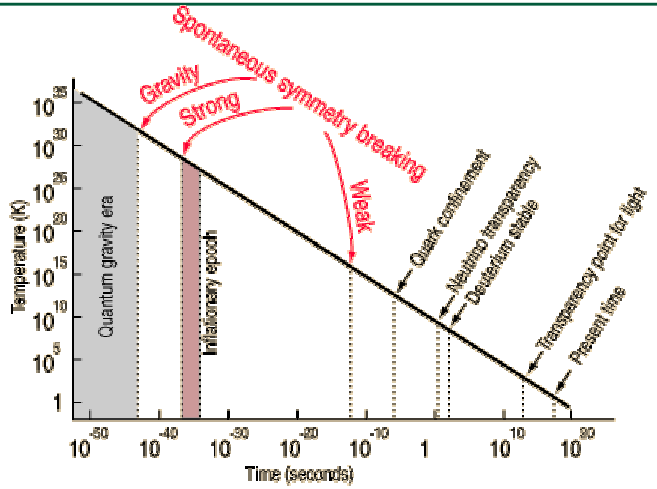
Big Bang Timeline (the early moments)



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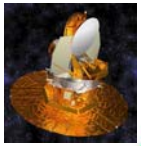
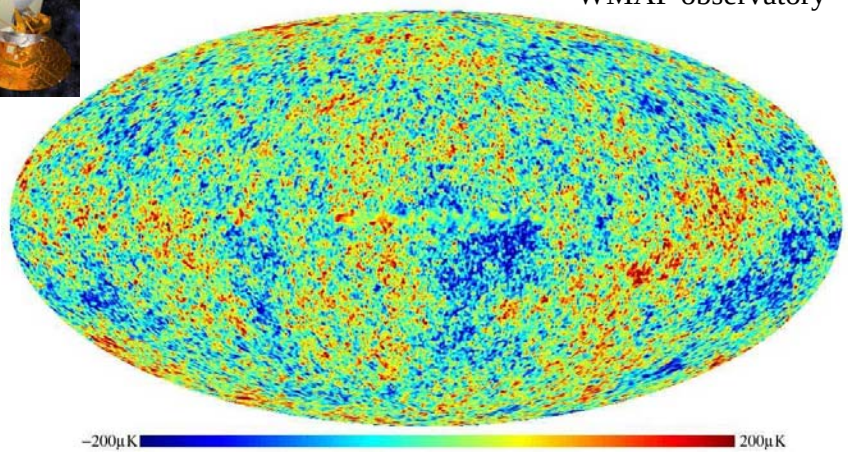
Map of the microwave sky



WMAP observatory



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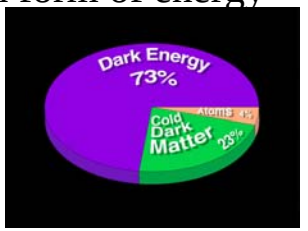
What we have learned from WMAP

- The Universe is 13.7 billion years old
- The Universe is Flat and will continue to expand forever – The mass of the universe is at the "critical mass".
- The Universe is made of mostly an unknown form of matter and an unknown form of energy (dark)



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What is the Ultimate Fate

- 10^{100} years – all the stars will have used their fuel
- 10^{100} to 10^{150} years "dark ages"
- 10^{150} years all black holes will have evaporated
- 10^{1000} years the Universe will reach its lowest energy state
- The current age of the Universe is 13.7 billion years 10^{10} years

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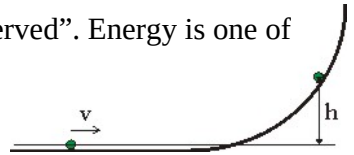
Conservation of Energy

In nature certain quantities are "conserved". Energy is one of these quantities.

Example: Ball on a hill



A 1.00 kg ball is rolled toward a hill with an initial speed of 5.00 m/s. If the ball roles without friction, how high, h, will the ball go?

$$KE = \frac{1}{2}mv^2 \quad PE = mgh\,;\; g = 9.80\frac{m}{s^2}$$

$$\frac{1}{2}mv^2 = mgh \rightarrow h = \frac{v^2}{2g} = \frac{(5\,m/s)^2}{2\cdot 9.80\frac{m}{s^2}} = 1.28\,m$$

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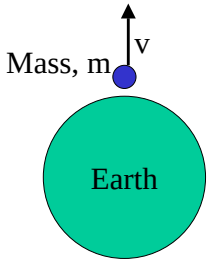
Escape Velocity



The velocity to completely escape the gravity of a planet is:

$$KE(leaving) = PE(far\ away)$$

$$\frac{1}{2}mv^2 = \frac{GmM_{planet}}{R_{planet}}$$

$$v = \sqrt{\frac{2GM_{planet}}{R_{planet}}}$$

The escape velocity for the Earth is about 11 km/s. See the homework problems for examples.

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Large Mass in a small region

What is the escape velocity for an object with the mass of the Sun and a radius of 10 km?

M_{sun}=1.99E+30 kg G=6.67E-11 Nm^2/kg^2

$$v = \sqrt{\frac{2GM}{R}} = \sqrt{\frac{2 \cdot 6.67E-11 \cdot 1.99E31}{10000}} = 5 \times 10^8 \frac{m}{s}$$

This is greater than the speed of light!

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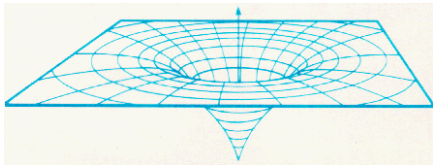
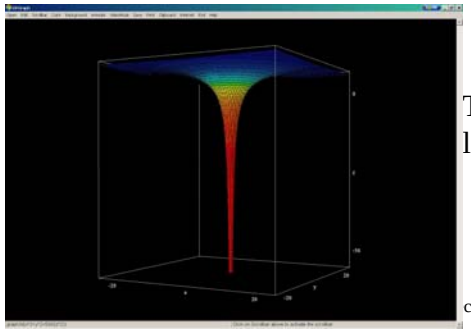
Black Holes





The "hole" in space is so deep that light can not escape.

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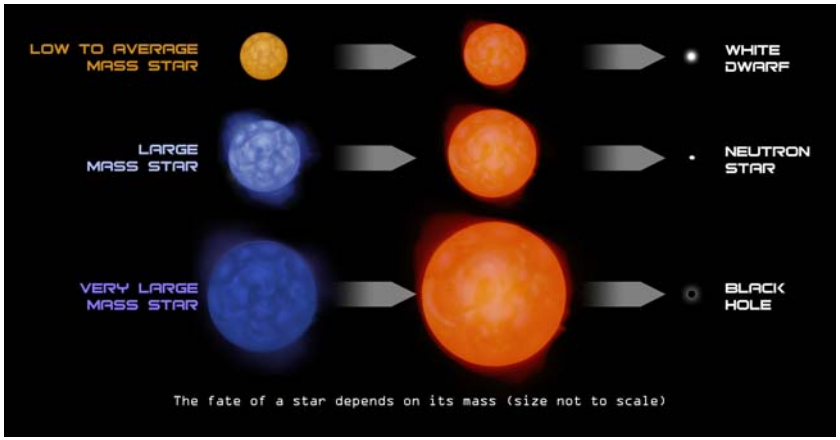
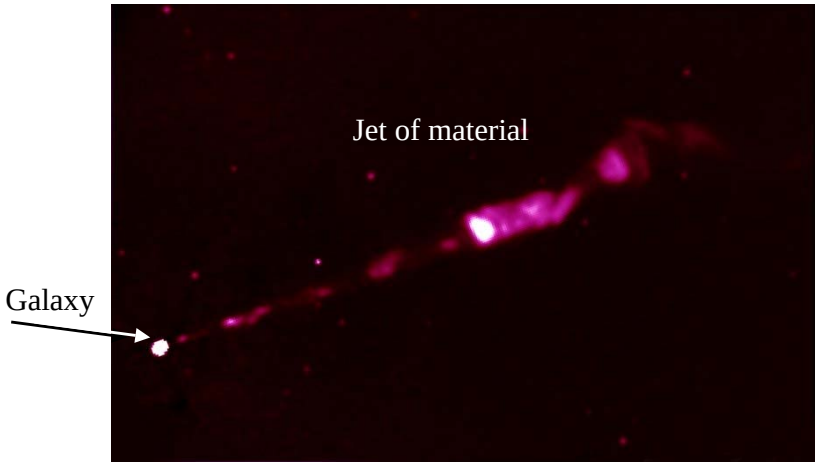
Black Holes

- Black holes act as a lens and we see light from stars behind. They don't necessarily look "black".
- They range from 3 solar masses to more than a billion solar masses.
  - Small ones are formed by the collapse of a large star
  - Larger ones form at the center of galaxies
- We can tell they exist because of thing orbiting nothing, and the radiation given off as things fall into them.
- Black holes are not cosmic vacuum cleaners. If the Sun were a black hole (with the same mass) the Earth would still orbit it.

Where do black holes come from?

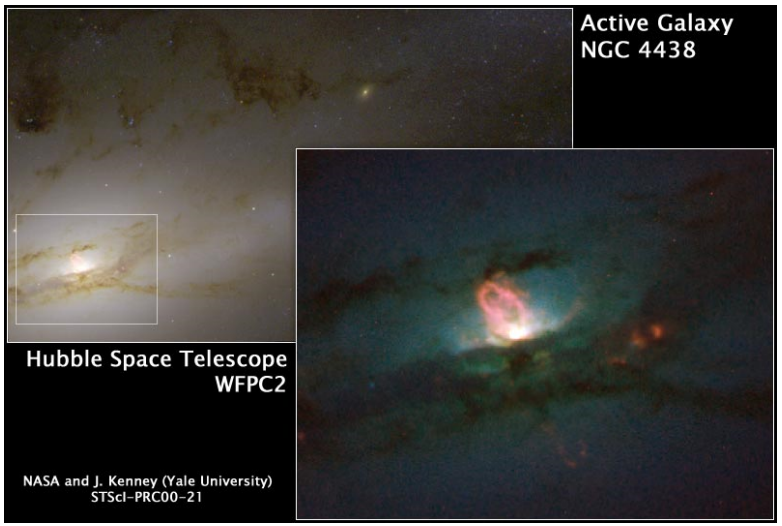


Active Galaxies/ Quasars

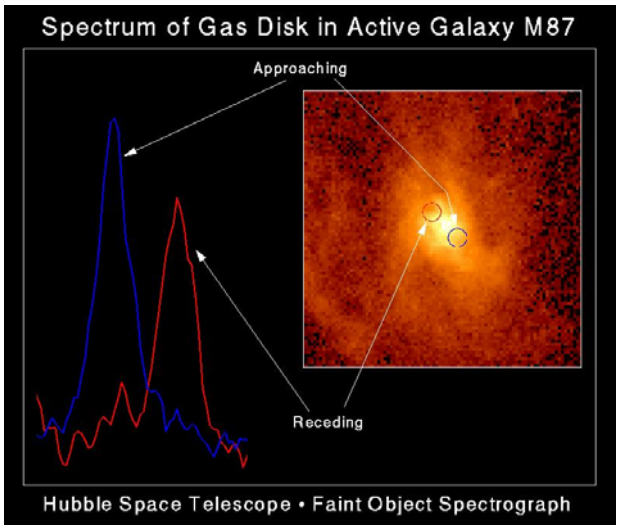


At the center is a billion solar mass black hole

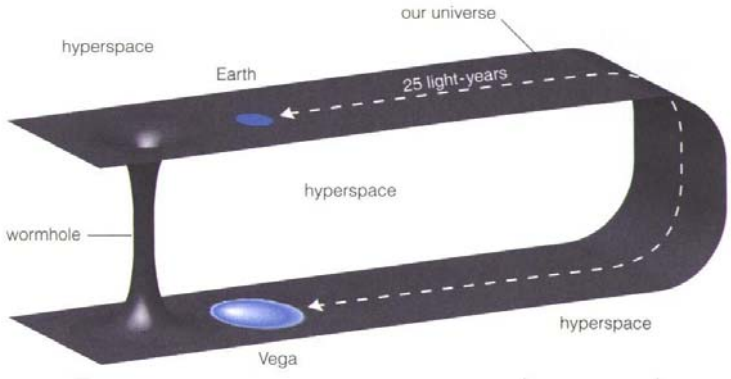
Picture of an Active Galaxy (quasar)



Rotation around a Supermassive Black Hole



Wormholes



Wormholes

- Wormholes are not stable. Some type of exotic material (that acts as antigravity) is necessary to keep one end open.
- If there are wormholes, there must be white holes. No white hole has ever been observed.
- A white hole would violate the second law of thermodynamics.

The Second Law of Thermodynamics

- Statement: No device can transform a given amount of heat completely into work.
- Statement: The entropy of an isolated system never decreases.
- Statement: Natural process tend to move toward a state of greater disorder.
- Consequence: Time appears to have a direction.

Entropy

- Entropy is a measure of disorder. We usually use the symbol S.
- The unit is J/K (*joules/Kelvin*)
- Formula: S = k ln(W), where k=1.38E-23 J/K and W is the number of possible states of a system.
- Alternative formula: S = heat/temperature

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Two examples

What is the entropy of a deck of cards that has one pair?
Data: there are 1,098,240 to order such a deck.

S = 1.38E-23 J/K ln(1,098,240)= 1.92E-22 J/K

How much is the entropy of a glass of water increased if 1.0 J of heat is added when the water is at 295 K. Assume the temperature rise of the water is small.

S = 1.0 J / 295 K = 3.39E-3 J/K

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Coin Tosses

- Suppose we have 20 coins: HHHHHHHHHH
  S = k ln(1) = 0

Heads	Number of ways	Entropy (J/K) $*10^{-23}$
9	10	3.18
8	45	5.25
7	120	6.61
6	210	7.38
5	252	7.63
4	210	7.38
3	120	6.61
2	45	5.25
1	10	3.18

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Why does time always move in one direction?

- Inflation during the Big Bang resulted in a universe that had a very low entropy. Much too low for its size. It is like the Universe started with all heads.
- Hence, everything in the Universe moves toward reaching the correct amount of entropy.
- Time has a direction because going back in time would imply the entropy could be decreased. That is very improbable.
- The Universe tends toward increasing entropy.
- What is time?