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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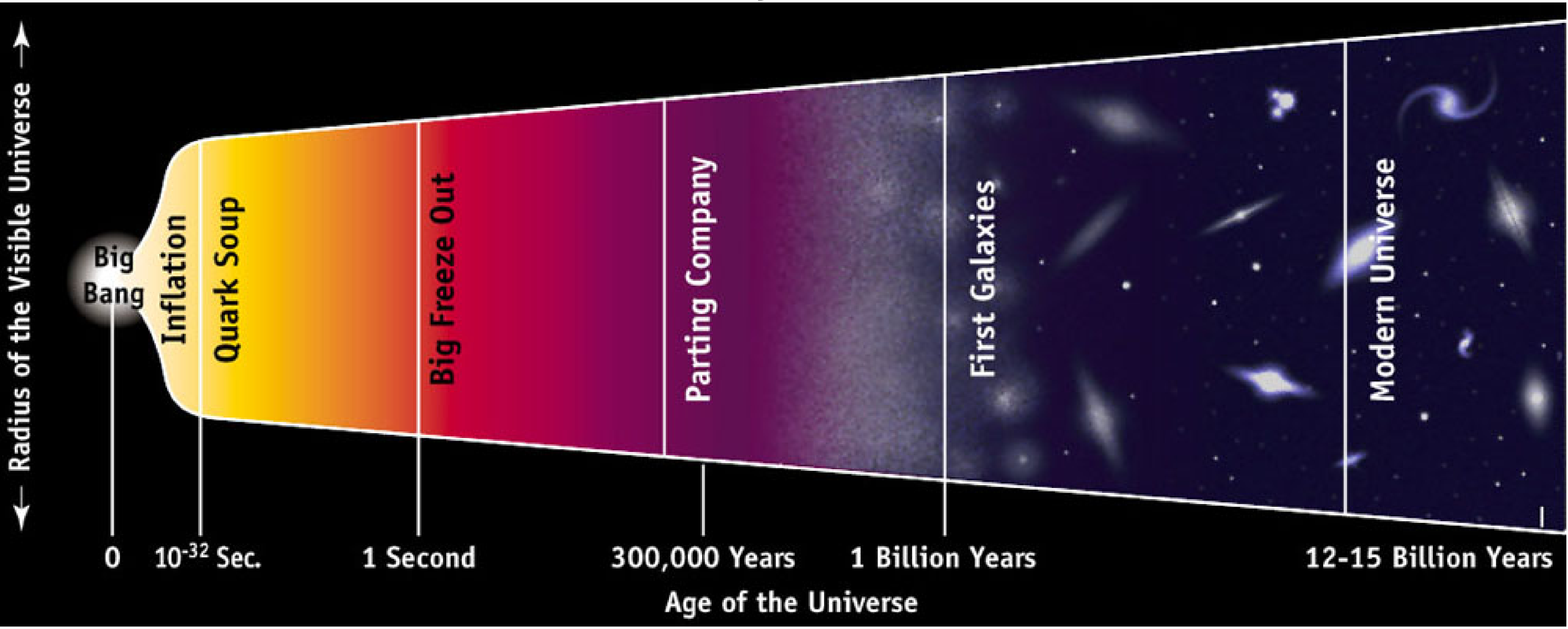
Timeline of the Big Bang

All Forces unified

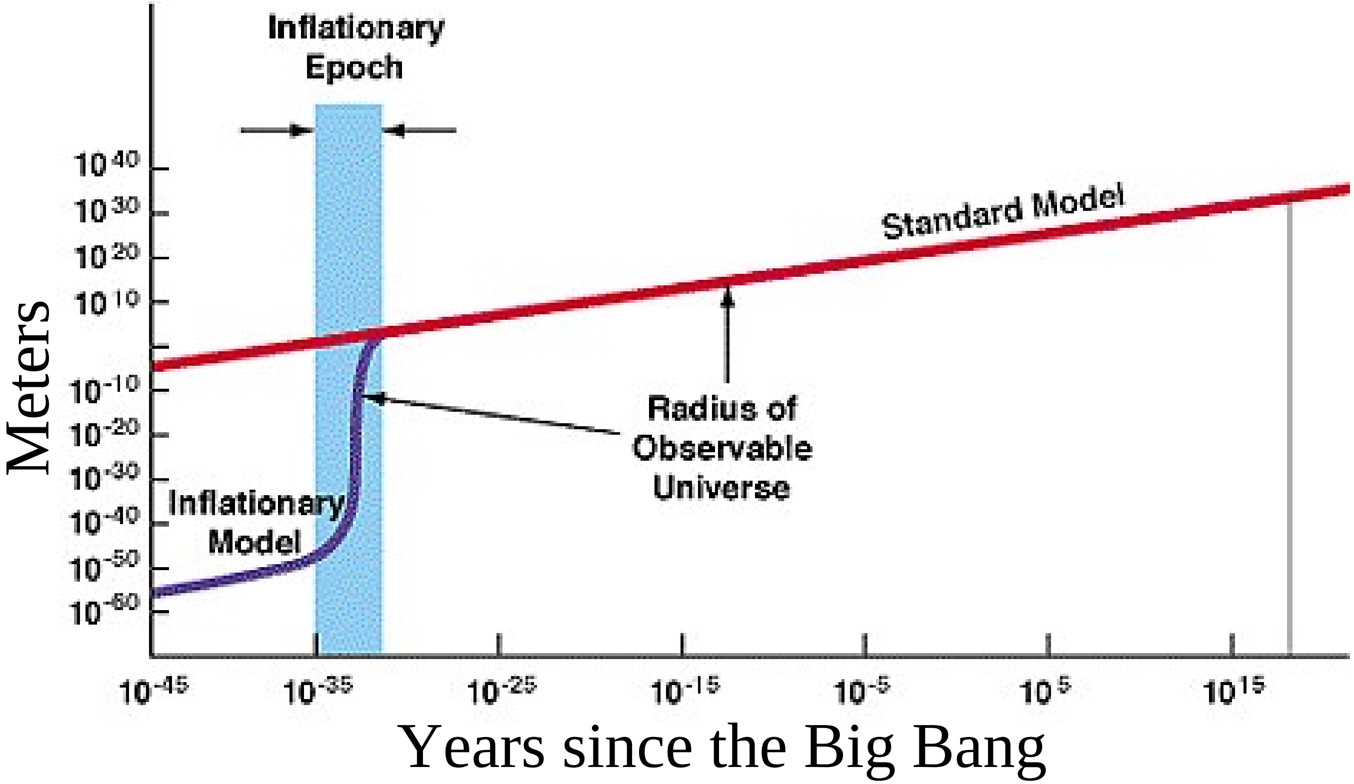
Light elements form

Microwave image formed

Carbon made

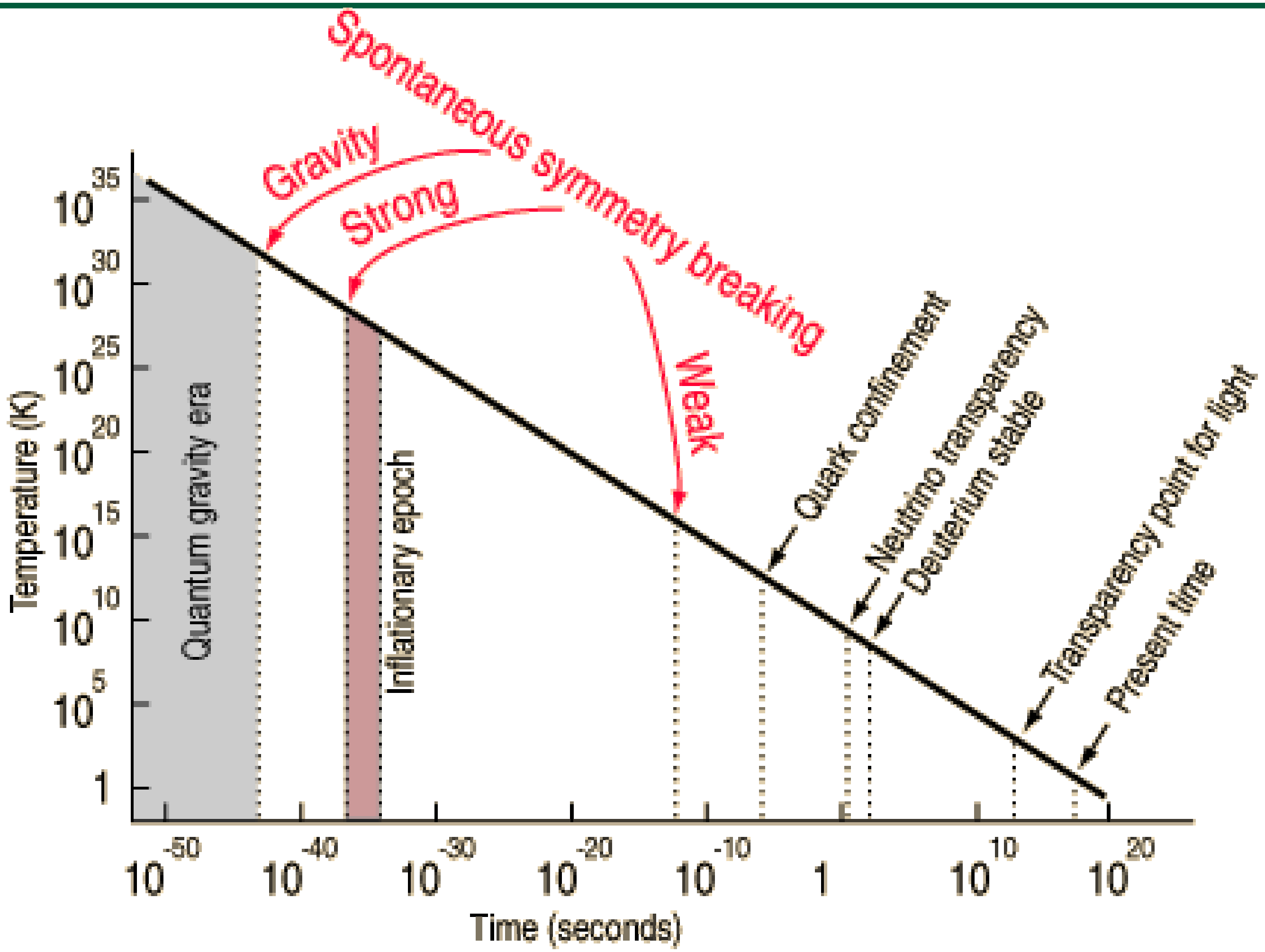


Inflation

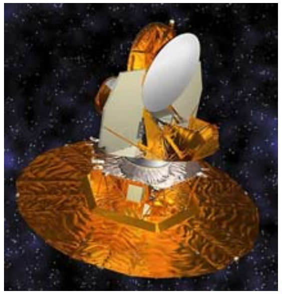


The existence of an unknown scalar field caused the rapid inflation of the Universe

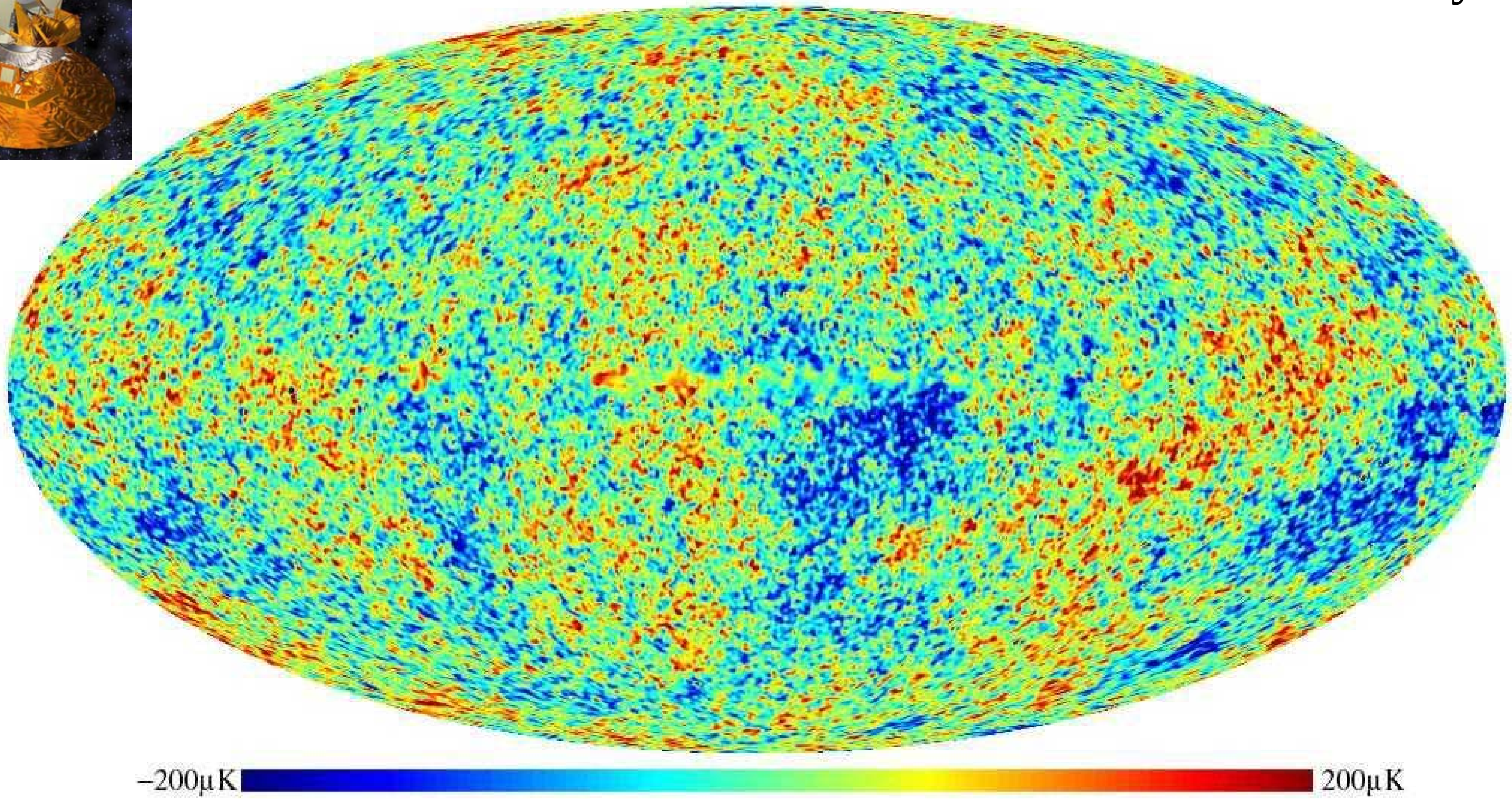
Big Bang Timeline (the early moments)



Map of the microwave sky

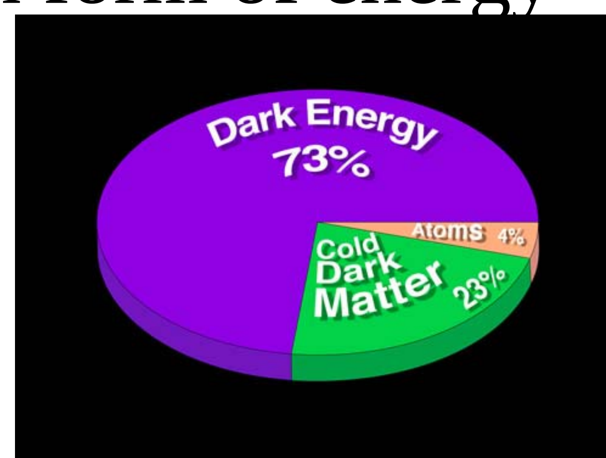


WMAP observatory



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)



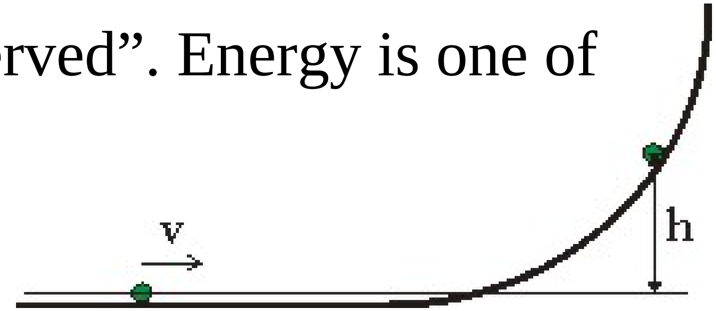
What is the Ultimate Fate

- 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

Conservation of Energy

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

Example: Ball on a hill

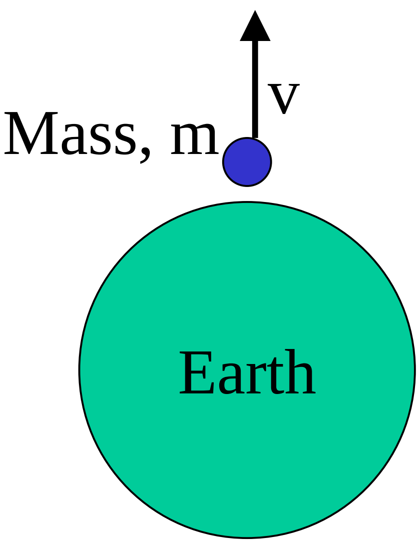


A 1.00 kg ball is rolled toward a hill with an initial speed of 5.00 m/s. If the ball roles without friction, how high, h, will the ball go?

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

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

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.

Large Mass in a small region

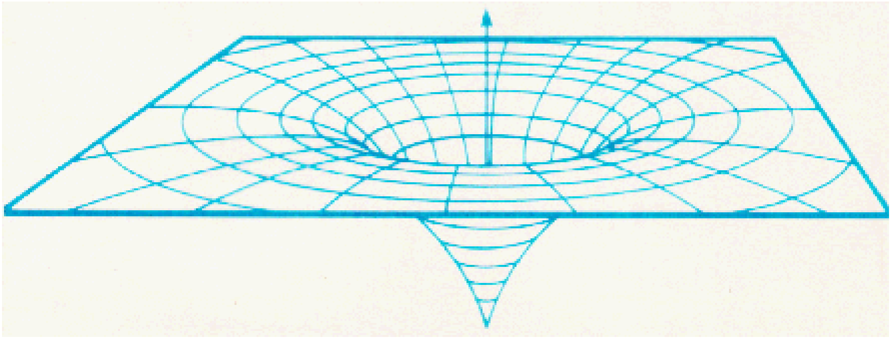
What is the escape velocity for an object with the mass of the Sun and a radius of 10 km?

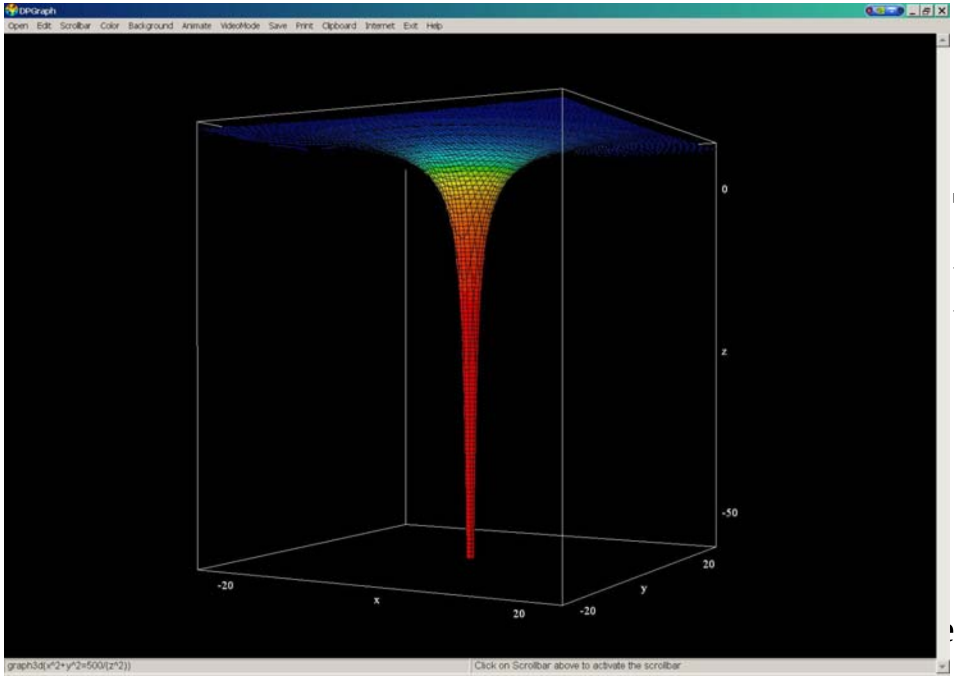
M_{sun}=1.99E+30 kg   G=6.67E-11 Nm^2/kg^2

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

This is greater than the speed of light!

Black Holes



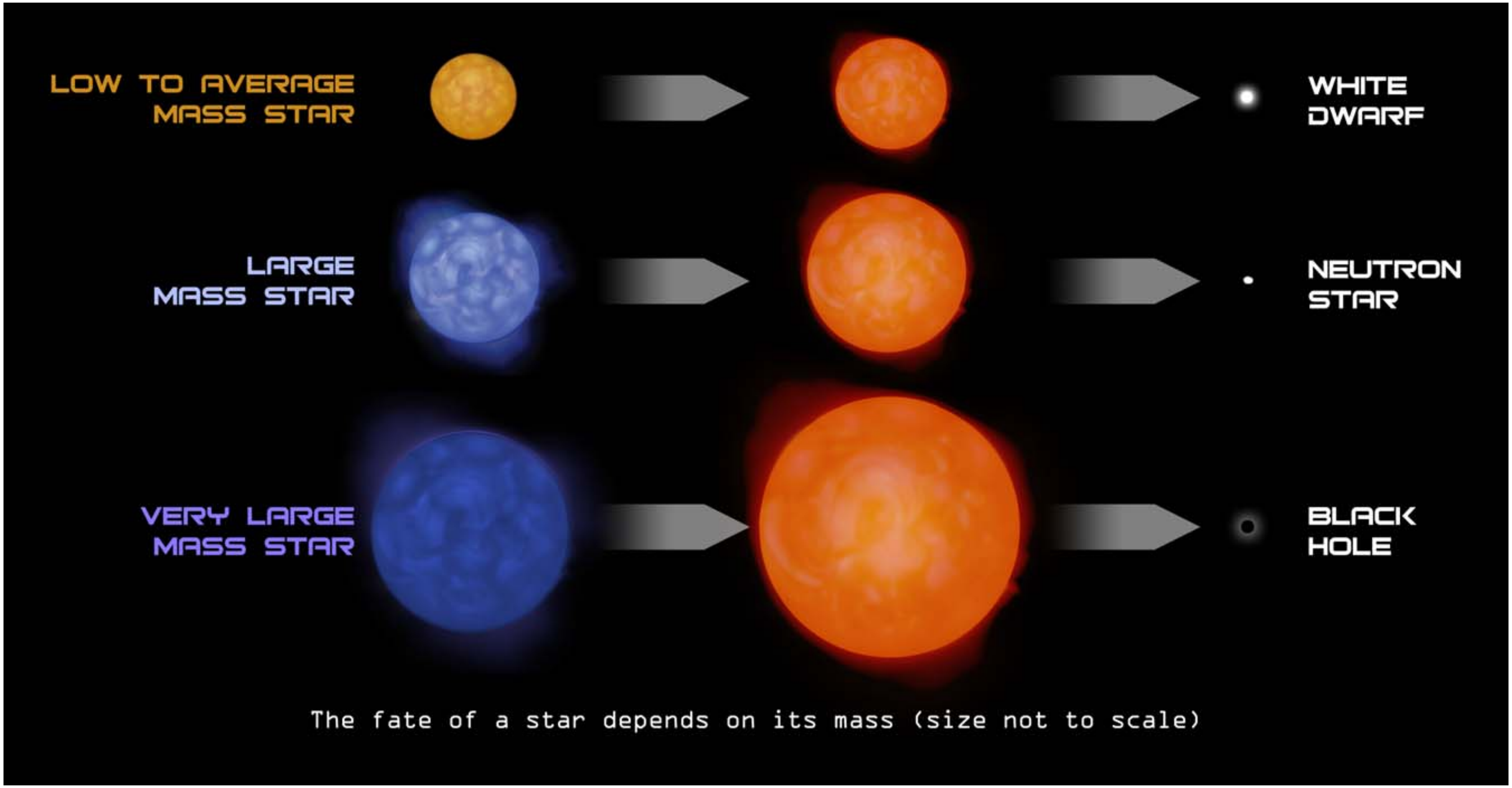


The “hole” in space is so deep that light can not escape.

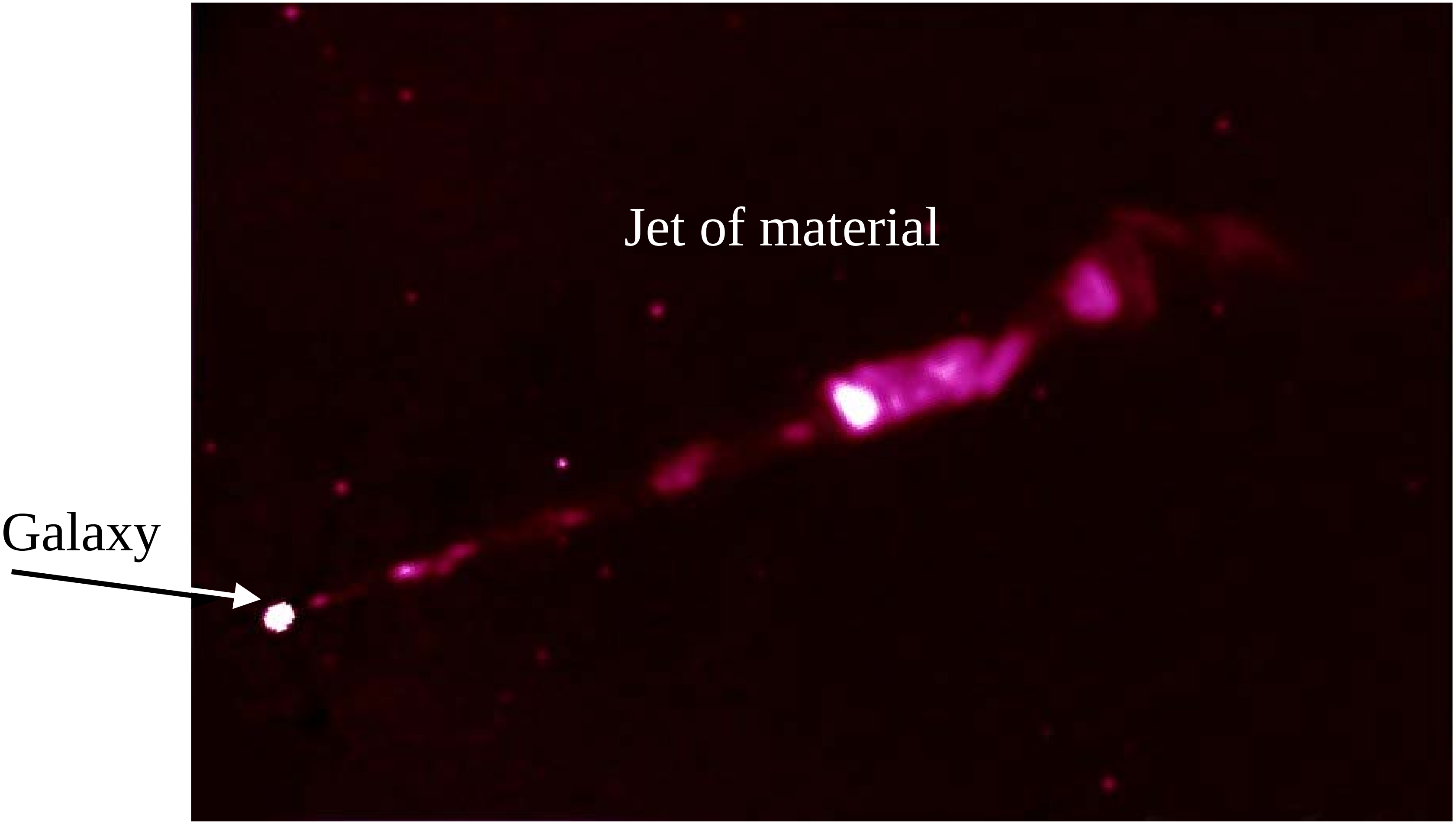
Black Holes

- 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?

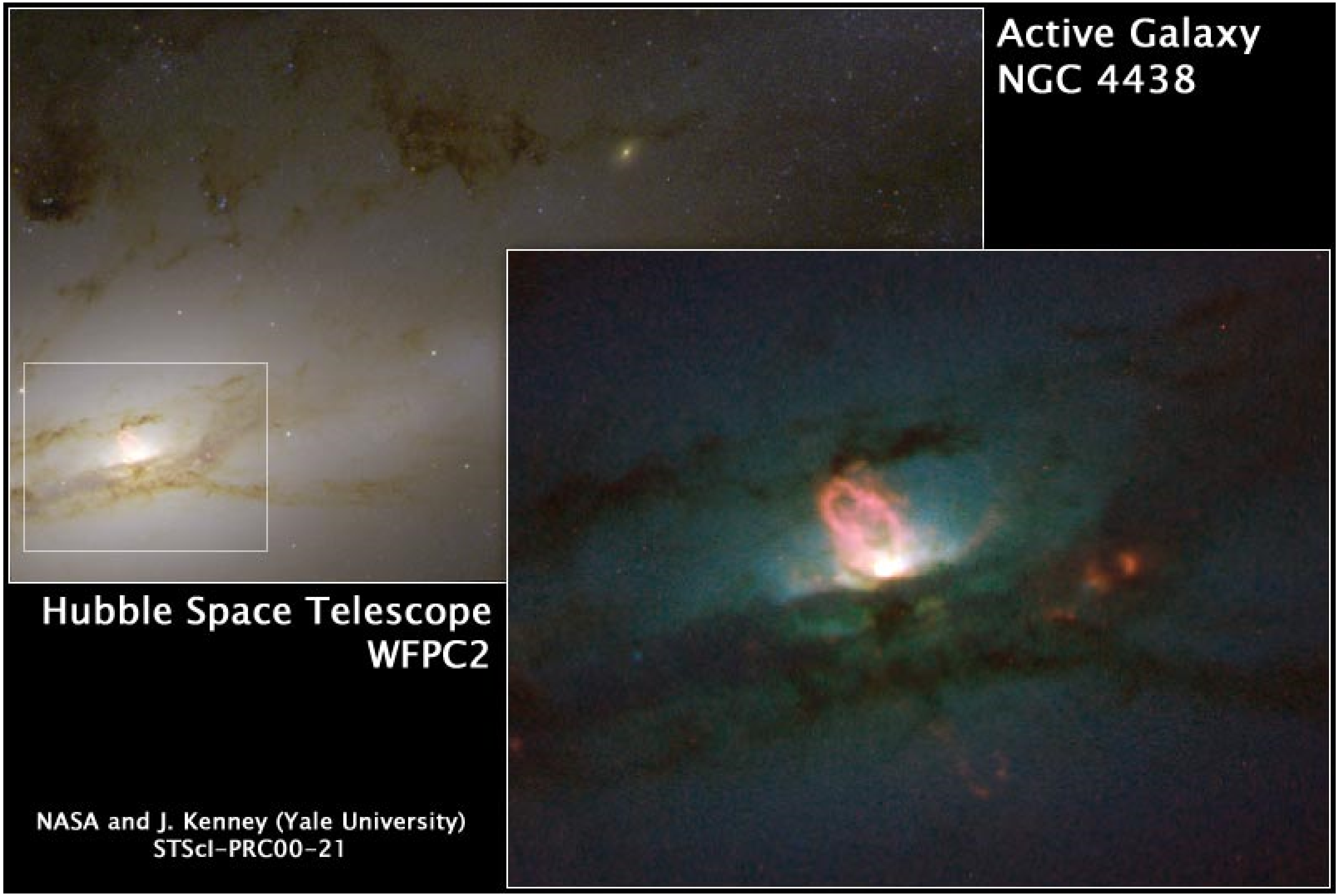


Active Galaxies/ Quasars

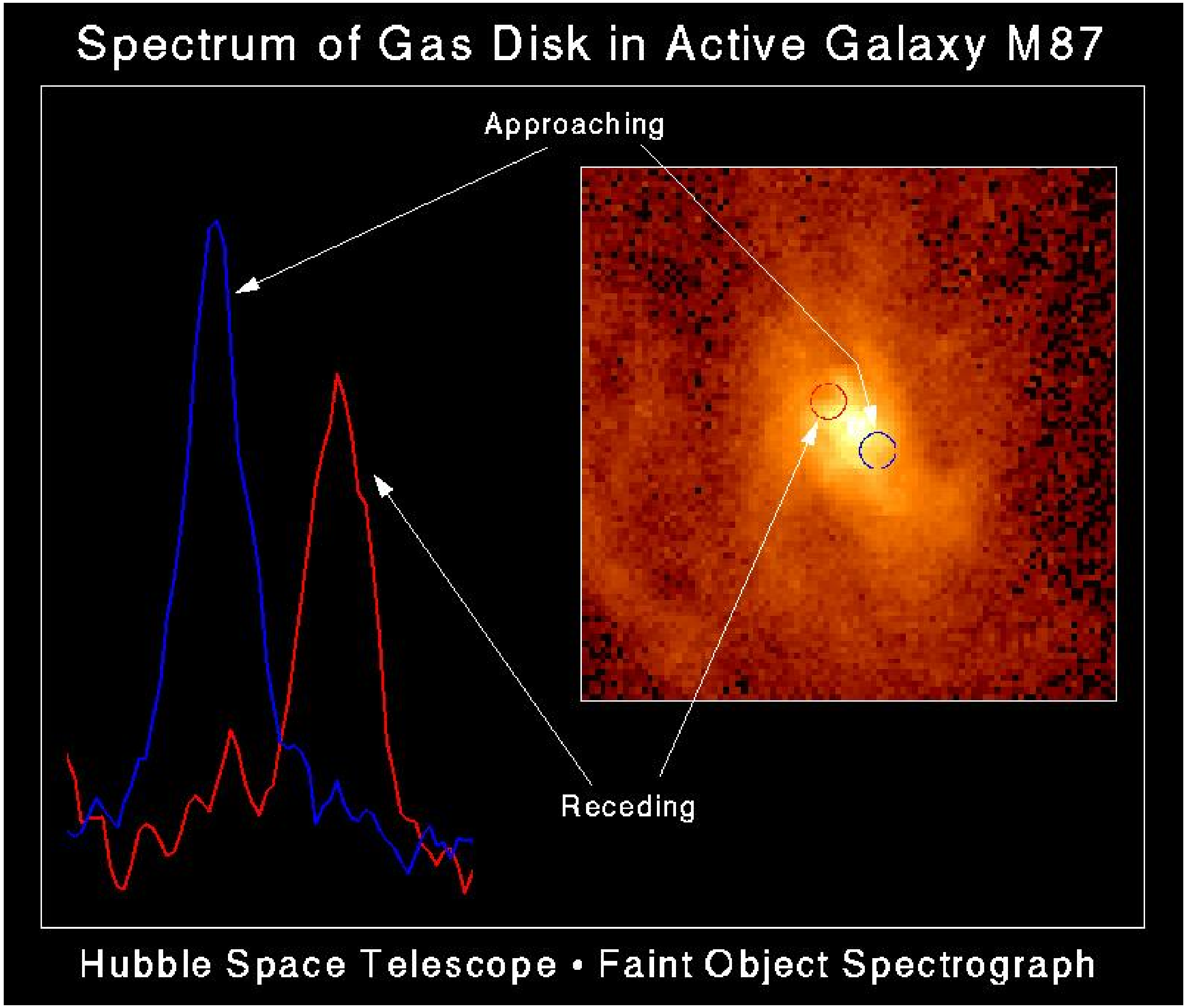


At the center is a billion solar mass black hole

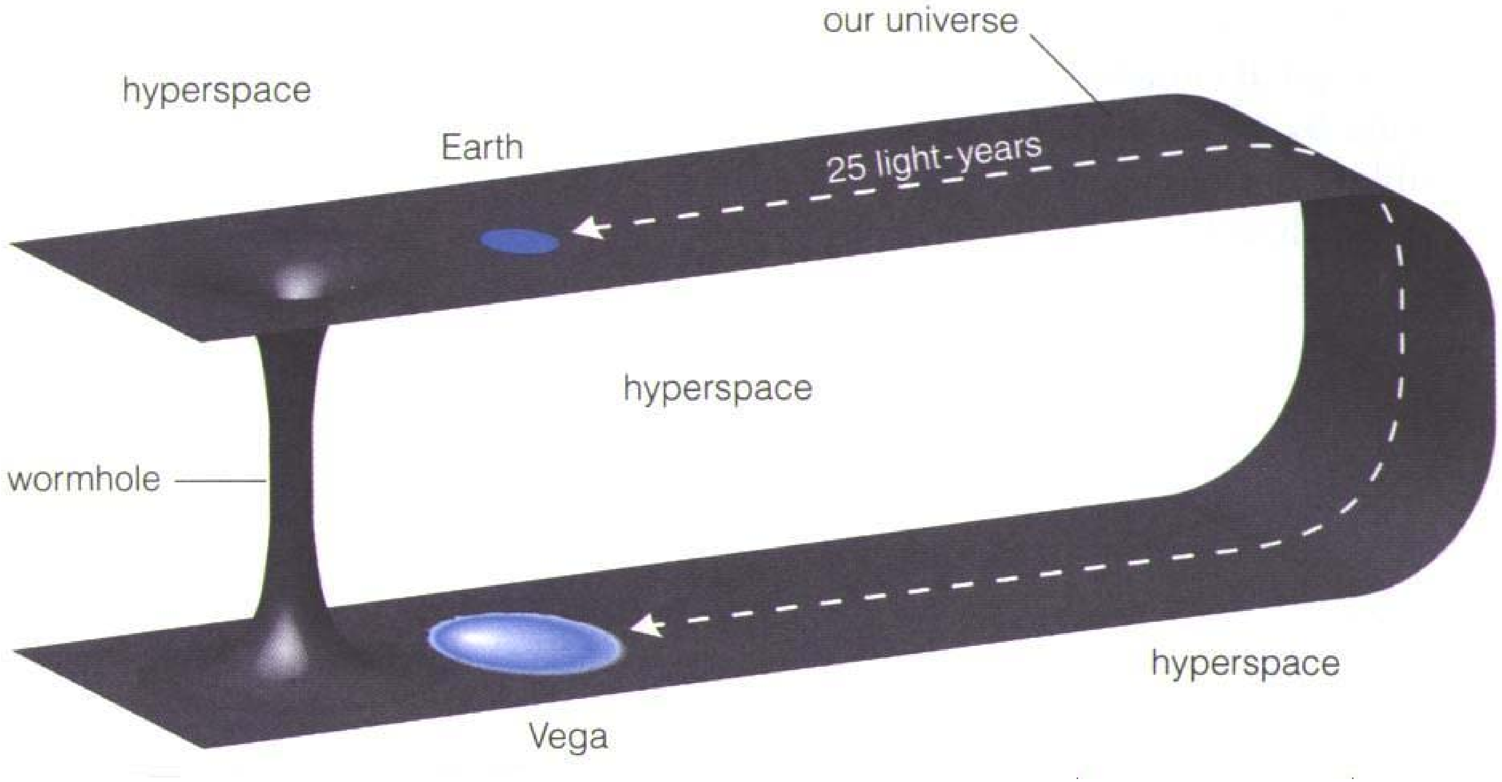
Picture of an Active Galaxy (quasar)



Rotation around a Supermassive Black Hole



Wormholes


our universe
hyperspace
Earth
25 light-years
hyperspace
wormhole
hyperspace
Vega

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

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

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

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?