Exploring Very Early Times

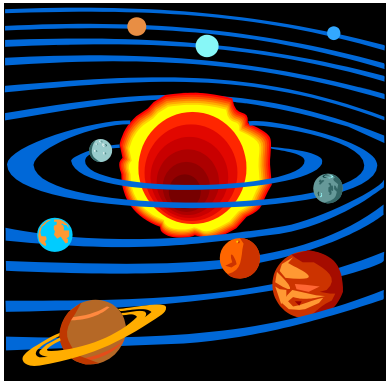
- "Fossil" evidence available to astronomy are remnants from the first few minutes and later after the Big Bang
- For earlier times → use physics
- Particle accelerators can briefly reproduce the Temperature of early times. The highest energy machine is equivalent to about 1 picosecond (.000000000001) after the universe began
- Understood earlier by extrapolation. Going back to the moment of Creation needs a complete knowledge of gravity and a more complete understanding of time itself
- Today's material won't be on exams

Unsolved Mysteries: Include

- Dark Matter earlier lecture
- Dark Energy earlier lecture
- Domination of Matter earlier lecture
- Weakness of Gravity → Extra Dimensions??
- Why the strength of the forces and the masses of particles seem to be "just right" → multiple universes - Multiverse??

Gravity and Extra Dimensions

- first force to be understood was gravity
- much much weaker then other 3 forces
- no quantum mechanical description of gravity (Einstein, Hawking, others have tried)



$$F = G\frac{mass_1 mass_2}{R^2}$$

Gravity vs Electric Force

- electric and gravitational forces →same form
- compare strengths for electron and proton in Hydrogen

$$F_{gravity} = G\frac{mass_1 mass_2}{R^2}$$

$$F_{electric} = E\frac{ch\arg e_1 ch\arg e_2}{R^2}$$

$$\frac{F_{gravity}}{F_{electric}}(Hydrogen) = 10^{-39}$$
$$= 0.000000000000000000000000000000000000001$$

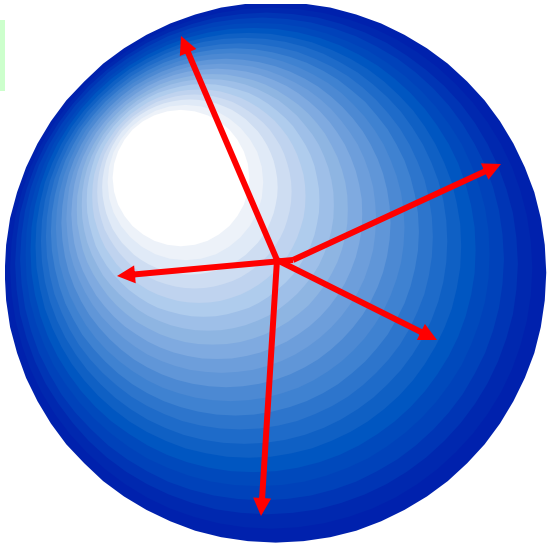
Gravity + Electric Force:Geometry

- $1/R^2$ → area of a surface of the sphere
- force carriers (photon or graviton) are spread out over this surface

$$F_{gravity} = G\frac{mass_1 mass_2}{R^2}$$

$$F_{electric} = E\frac{charge_1 charge_2}{R^2}$$

$$Area = 4\pi R^2$$



What if – Extra Dimensions

- assume force carrier for electric force (photon) confined to "normal" 3D space

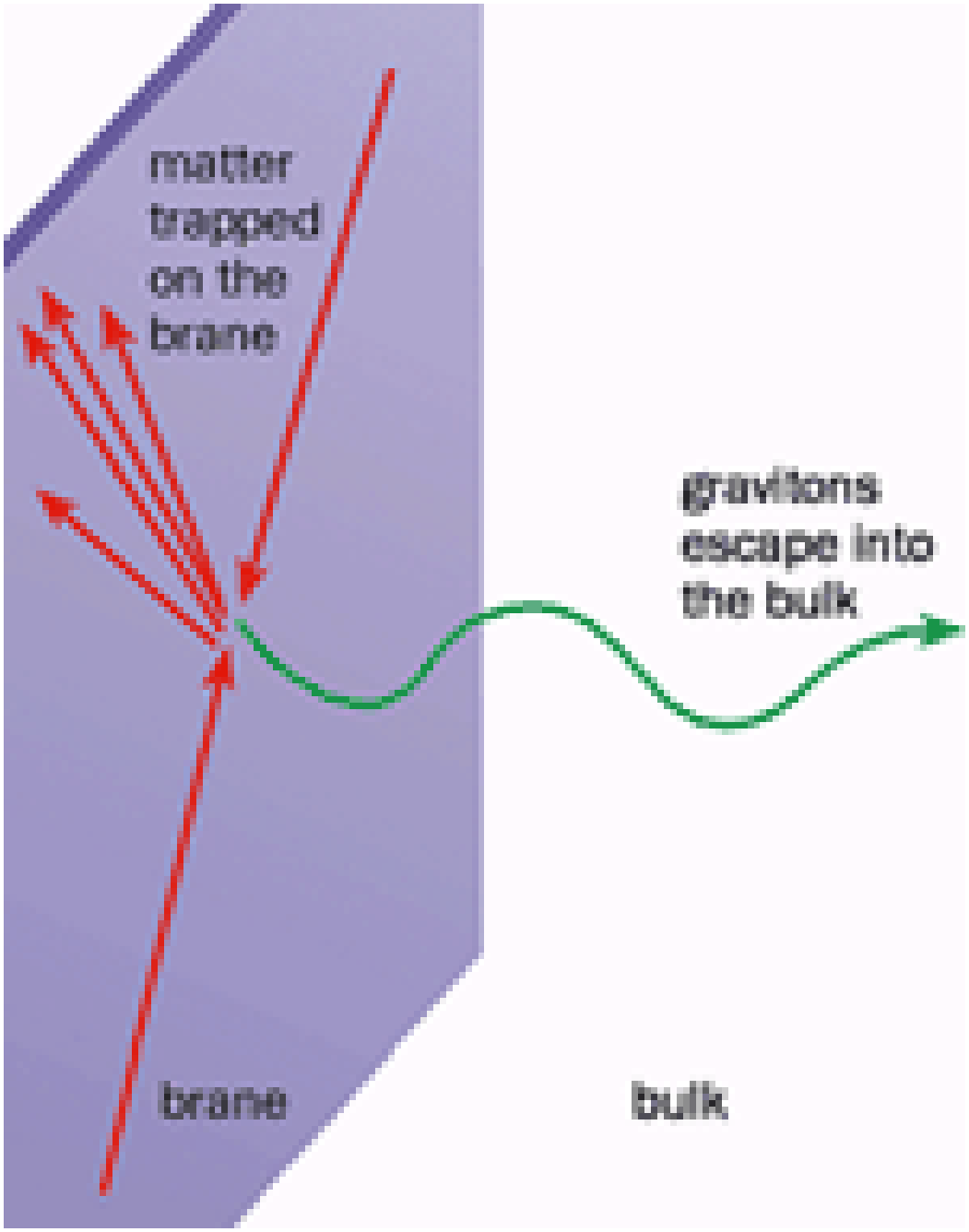
- exists extra dimensions: force carrier for gravity (graviton) can exist in

- gravity spreads itself out over more dimensions than electric force → appears weaker in normal 3D space

- only gravity communicates with extra dimensions →we can't "see" or "feel" them

brane = “normal” 3D space

bulk = extra dimensions

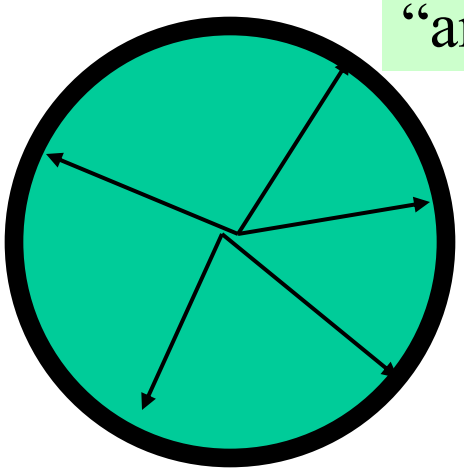


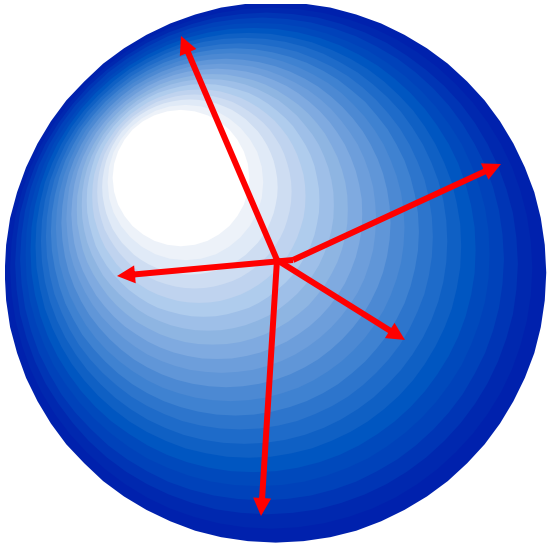
Extra Dimensions -- Geometry

- normal 3D space → $1/R^2$
- 2D space → $1/R$
- 3 extra dimensions → $1/R^5$

3D space
area=πR^2

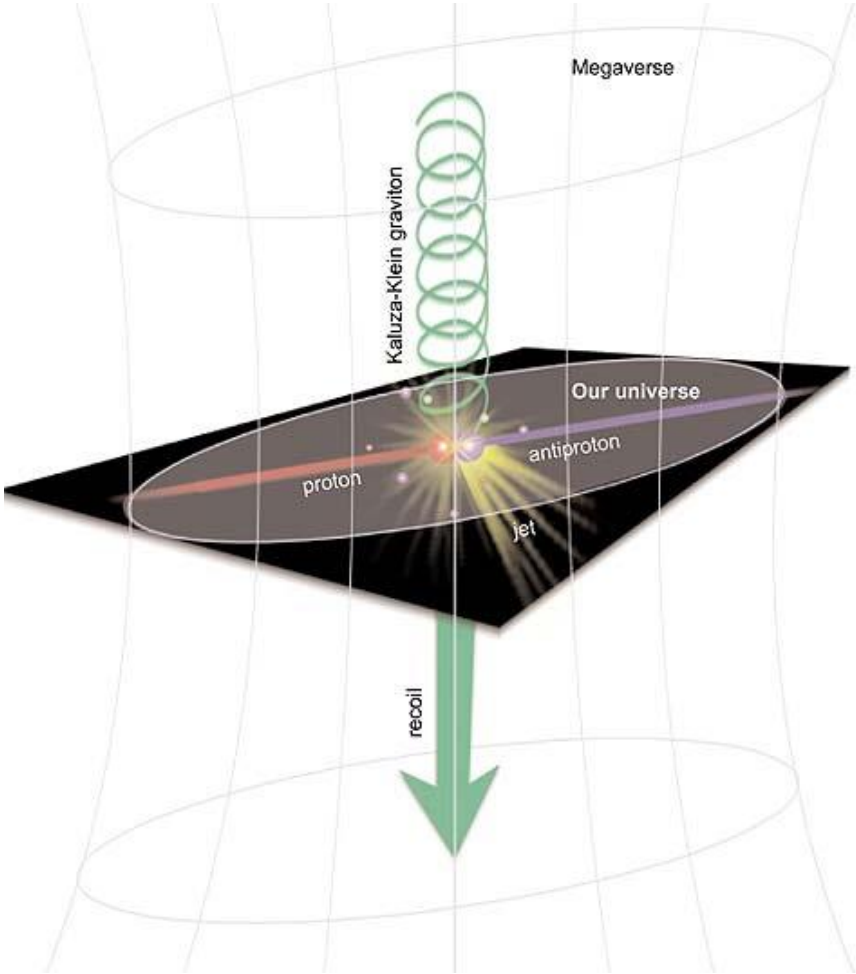
2D space
"area"=$2\pi R$





brane = our universe = “normal” 3D space

Megaverse = 3D plus extra dimensions



look for interactions at Fermilab+CERN → particles go into extra dimensions

Forces and Particles → Multiverse?

- the 4 forces and the particles (electrons, protons, etc) are "just right" for the formation of intelligent life

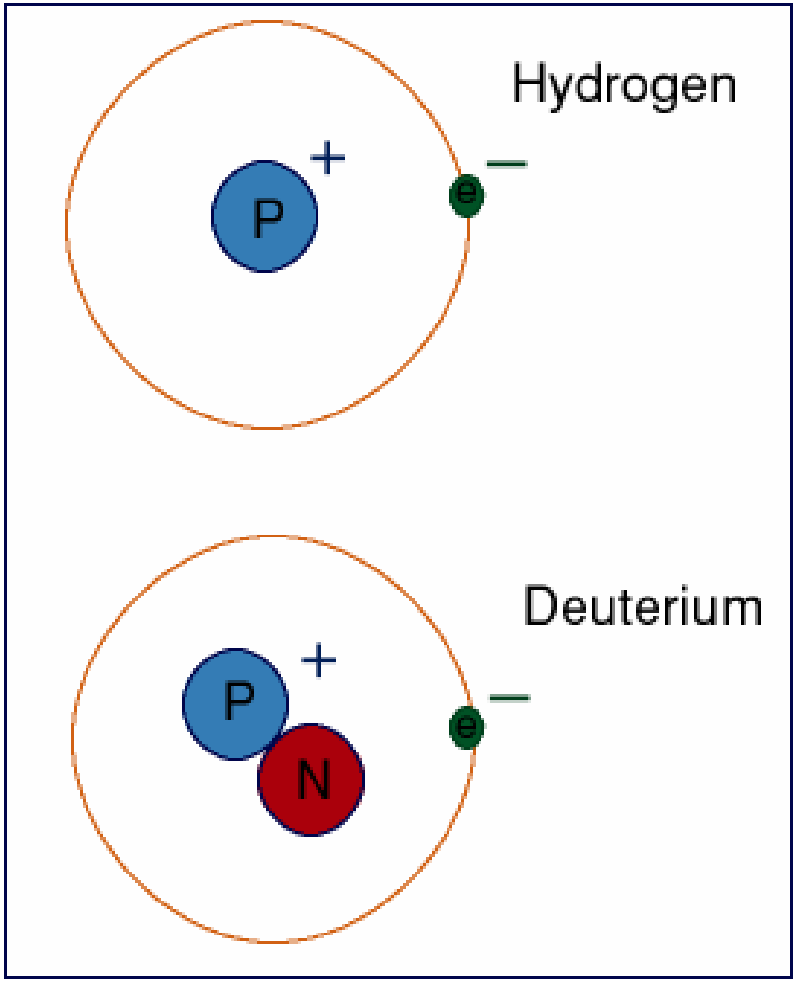
EXAMPLES

- if gravity were stronger then stars' lifetimes would be shorter
- if the neutron mass were lighter then the proton mass then normal Hydrogen would be unstable and rare → let's look at this in greater detail

Hydrogen

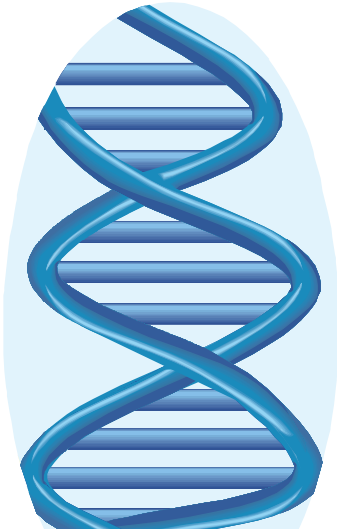
- Simplest atom – just one electron and one proton

- "heavy" hydrogen or deuterium adds one neutron to the nucleus



Hydrogen → Life

- Hydrogen bonding allows complicated molecules to form and readily change forms



- amino acids, proteins, RNA, DNA etc

- "pure" Carbon is biologically inert; need hydrocarbons, water, ammonia for biology
- CH_2 CH_4 H_2O NH_3

Neutrons and Protons

- Neutron's mass is slightly more than proton's mass
- → neutrons decay, lifetime of 15 minutes

$$m_p = 938.3\,MeV/c^2$$

$$m_n = 939.6\,MeV/c^2$$

$$m_e = 0.5\,MeV/c^2$$

$$n \rightarrow p + e^- + \bar{\nu}_e$$

Neutrons and Protons

- all the protons and neutron were formed in the first minute after the Big Bang.
- Neutrons decayed to protons or combined with protons to make Helium.
- Our Universe is 90% H + 9% He+1% heavy
- 7/1 p/n ratio Hydrogen dominates

$$n \rightarrow p + e^{-} + \bar{\nu}_e$$

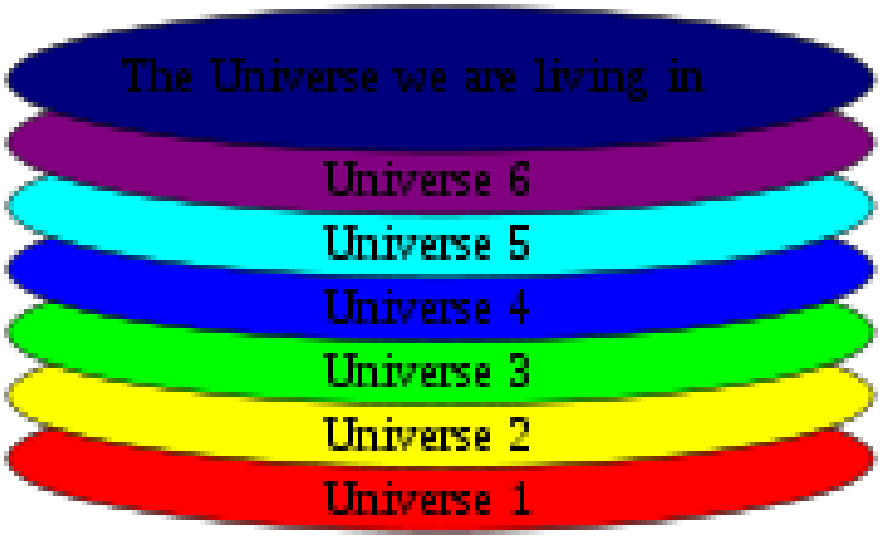
$$2n + 2p \rightarrow He$$

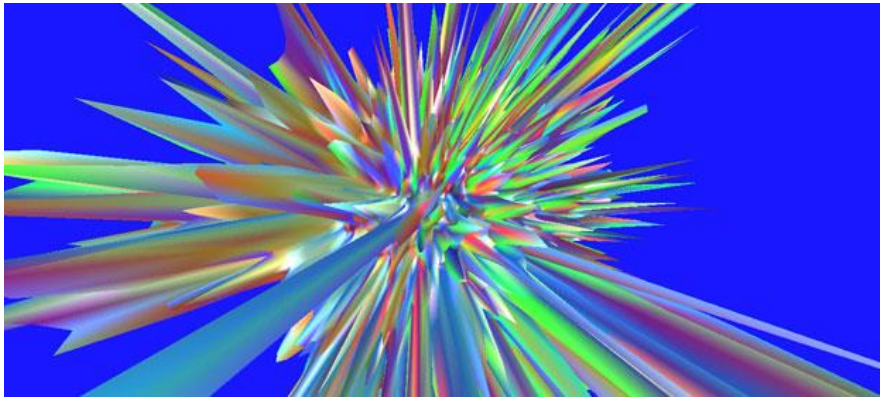
Masses of Neutrons and Protons

- Why is the neutron heavier than the proton? **We don't know why.** Could be due to a random condition at the very start of the Big Bang
- How would our universe look if these masses were different? For instance, if the proton were heavier then the neutron
- Can different Universes exist? Will they have the same physics? In this case the neutron and proton masses

What if Multiverse

- many (infinite??) universes in a multiverse
- not really "next" to each other. "nothingness" separates
- no communication between universes





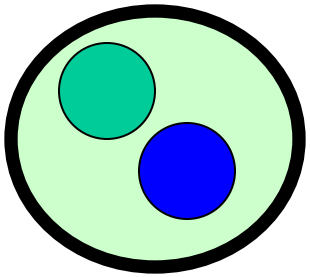
two artist conceptions – mostly meaningless

Snowflakes

- each snowflake is unique do to the slight variations in the conditions when they formed

What if in different universe

- proton is unstable and decays to neutrons
- still have stable heavy Hydrogen (Deuterium pn nucleus) but is very rare. D/He~.0005
- in early universe, He forms and then extra neutrons easily attach to He and then decays making Li, Be, B, C
- some free neutrons remain



Deuterium

What if in different universe

very small amount of Hydrogen (and all Deuterium)

→ different type of Stars and planets but with little water and Hydrogen : needed for biochemistry (proton bonds, DNA, etc)

→ no life

Anthropic Principle and Multiverse

- intelligent life in our universe depends on having the physics "just right". Why?

→ anthropic principle holds that with an infinite number of universes, there is a non-zero probability that one is "just right"

→ That's ours where the masses of the neutron, proton and electron, and the strengths of the forces are "just right"

Goldilocks and the Three Bears

This universe has the matter-antimatter variation too small

This universe has the proton mass too large

This universe has the strong nuclear force too strong

This universe has the electron mass too small

This universe has the weak nuclear force too weak

Our Universe is just right

PHYS 162 Conclusions

- the Universe is an extraordinary place much of which (stars, supernovas, neutron stars) are understood by our knowledge of physics
- But many unanswered questions
- what is dark matter and dark energy
- what is the origin of the Universe
- Are there Extra Dimensions or an infinite number of Universes
- How probable is the development of intelligent life

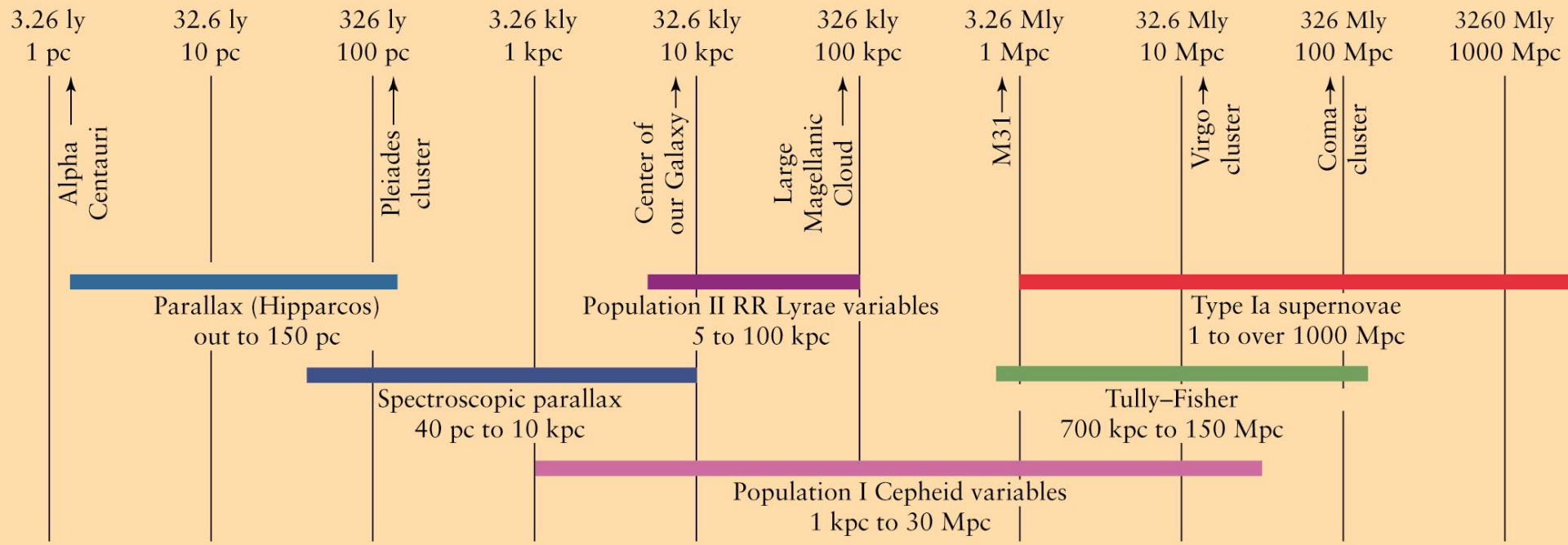
Test 3 Overview

- Formation of planets. temperature of solar nebula, and how it varies with distance → type of planet formed. Heavy elements freeze out first. Extrasolar planets detected in a number of ways (motion of stars, planet eclipsing star, directly). Planetary atmospheres: high temp and/or low surface gravity prevent the planet from holding on to light gases like hydrogen.
- Life in the Universe. Need star to be long-lived and not in binary system. Need planet to be the right distance from its star. Communicate with ET by radio with Drake equation giving estimate of number of possible civilizations in Milky Way.

Galaxies. Ellipticals:little rotation, little gas/dust or active star formation Spiral: rotation/gas/dust and active star formation, and irregulars active star formation but indistinct shape. Galaxies are moving away from us with v=Hd v=velocity, d=distance, and H=Hubble constant. Milky Way has inner nucleus, spiral arms (active star formation, halo of old stars (early shape)

Cosmology. Hubble law → Universe is expanding, gives universe's age, depends on Hubble "constant" changes with time. Closed universe has gravity slowing the expansion so it starts to contract. Open universe expands forever. Early universe was very hot and when matter was created. First electrons, protons and neutrons, then protons and neutrons give hydrogen and helium nuclei minutes after the Big Bang. 400,000 years later atoms form, Universe became transparent, and light appeared, seen as the cosmic microwave blackbody radiation temperature of 3 degrees K.

Measuring Distances – summary



- Type Ia supernovas (white dwarves which hit the Chandrashekar limit) are best for distant objects. Once understood, use Hubble Law v=Hd to measure distance (measure v get d).