COSMOLOGY

The Nature of the Universe

Ch.17

COSMOLOGY

- What is the nature of the universe?
- What is its past?
- What is its future?

THEOLOGY, PHILOSOPHY

- Other disciplines also try to answer these or similar questions
- Cosmology asks more limited questions:
  - Given the “rules of the game” and what we see, what models play by the rules of physics and can still describe what we see?
- We make no pretense as to answering “why”, or more immediate questions relating to humans such as the meaning of life, what happens when one dies, or good vs. evil

ROLE OF GOD?

- We don’t even try to answer that
  - God not scientifically testable
  - If omnipotent and trying to fool us, how could we tell?
- While religious literalists of all stripes find even asking these questions rather heretical, many scientists remain happily religious and scientific

HISTORY OF COSMOLOGY

- Where are we in the Universe has always been a big question
- Ptolemy – Geocentric universe
- Copernicus – Heliocentric
  - But stars still go about the Sun
- Newton proposes infinite universe
  - To prevent gravitational collapse
  - Not generally accepted, infinite is hard to wrap your brain around

HISTORY OF COSMOLOGY

- William Herschel maps out a lot of our own Galaxy (what we can see)
  - Has us in the middle of our galaxy (can't see too far with optical light)
  - But suggested that "spiral nebula" were other galaxies like our own
    - (This idea also not accepted, though Hubble proved him right in the 1920's)
  - Turn of the last century universe was no larger than the Milky Way

HISTORY OF COSMOLOGY

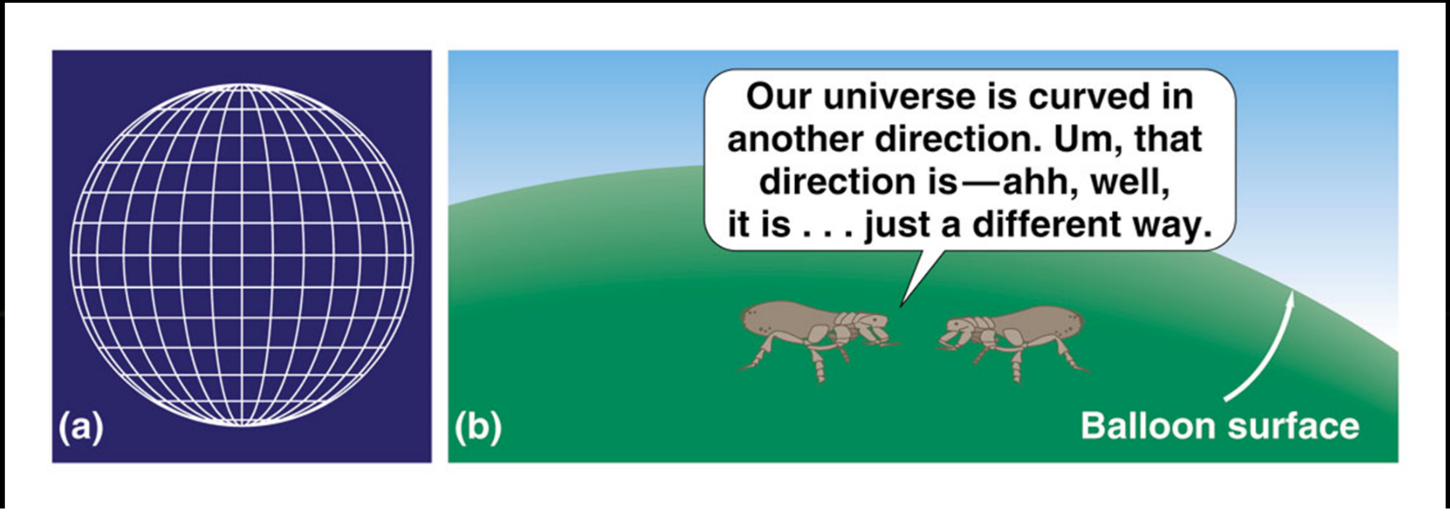
- 1917 – Harlow Shapley maps globular clusters, shows that we are not at the center of the Milky Way
- 1923 – Edwin Hubble finds Cepheids in other galaxies, shows that they are far-away collections of stars
- 1929 – Hubble uses redshifts to show that galaxies are all flying away from each other

GENERAL RELATIVITY

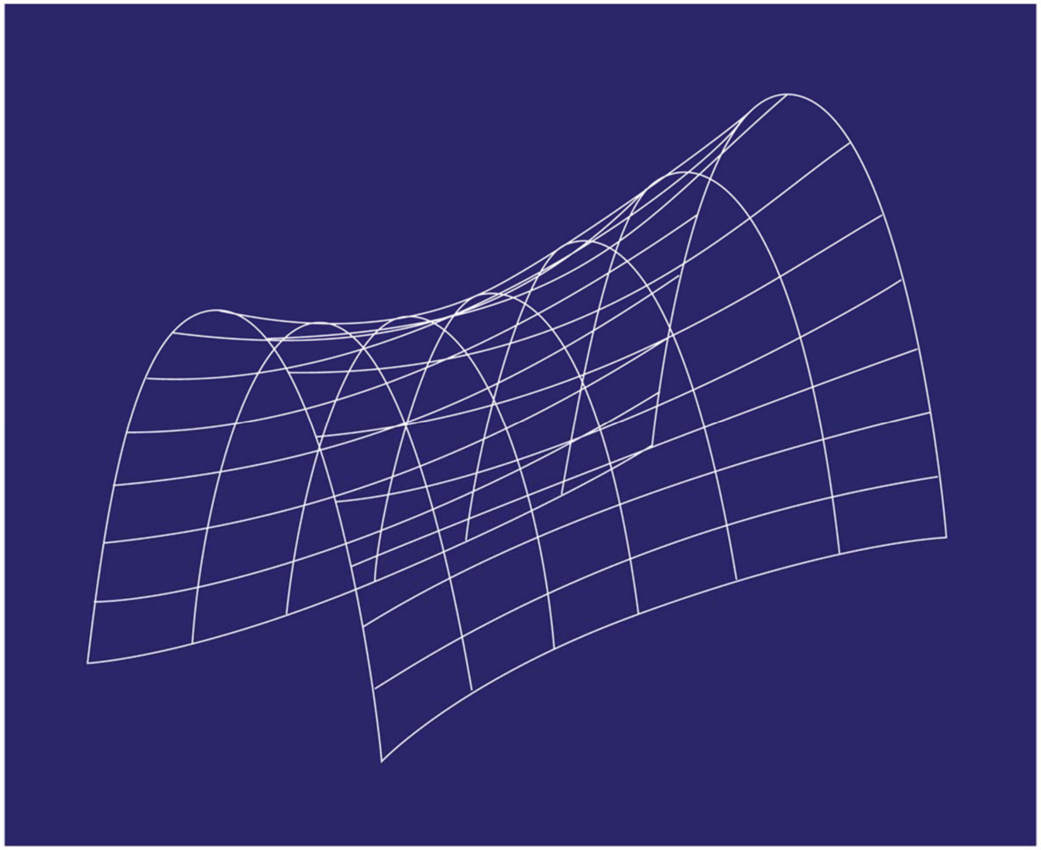
- If space itself curves when mass is present, what happens to the whole space of the universe due to all the mass in the universe?
- Newton knew a finite universe would collapse
- Conversely, enough mass bends space around on itself

A CLOSED UNIVERSE

- Such a finite, wrap-around universe is called "closed"
- Imagine a surface of a sphere – that's a two-D closed universe
  - Think of the lines as where a beam of light would go

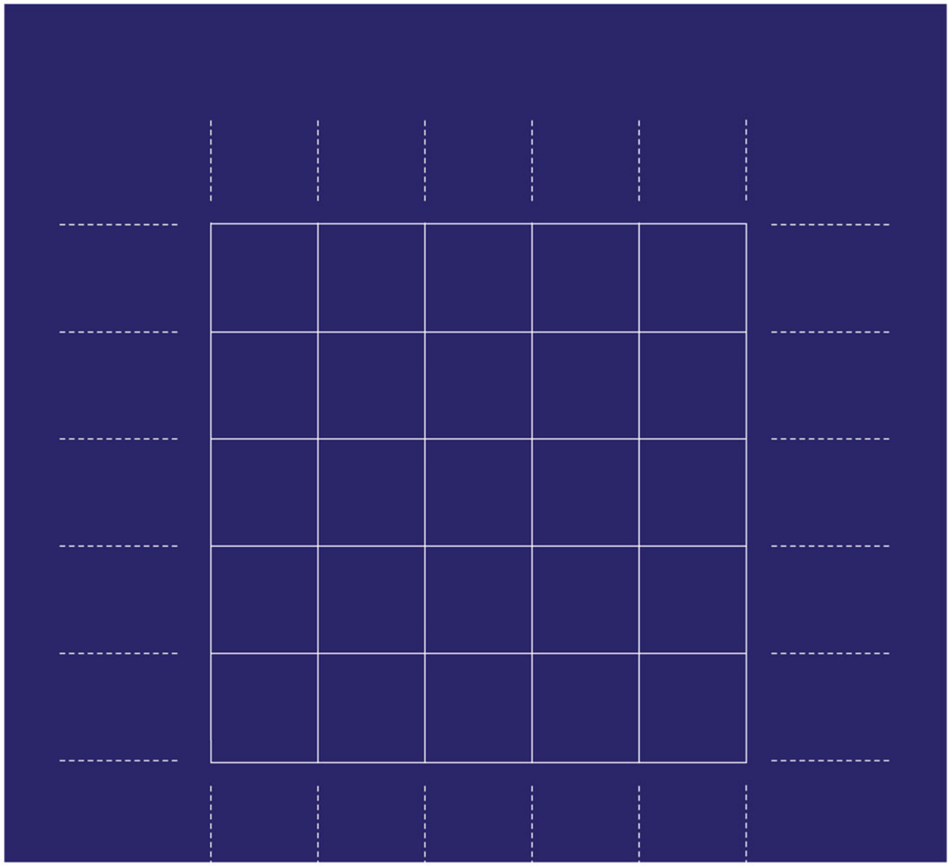


AN OPEN UNIVERSE



- With not enough total mass to bend space around on itself, the universe is termed “open”
- The 2-D analog of this is a saddle-shape

A FLAT UNIVERSE



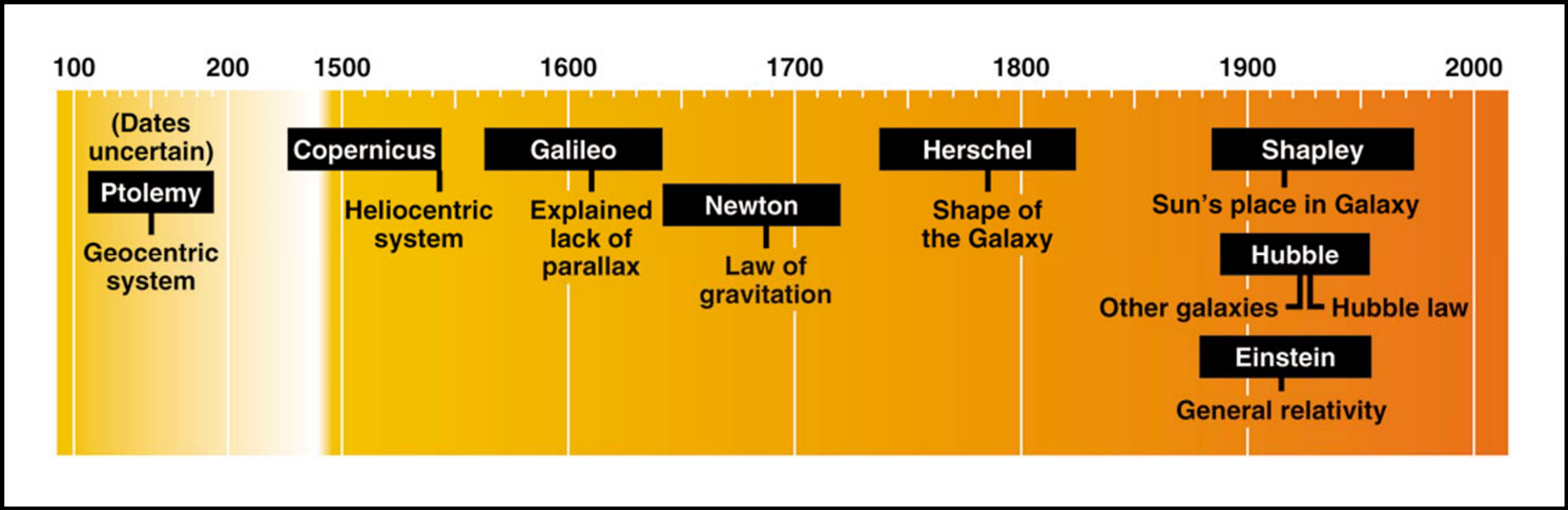
- The special case of just barely enough mass to balance between open and closed is “flat”
- The geometry is familiar, Euclidian

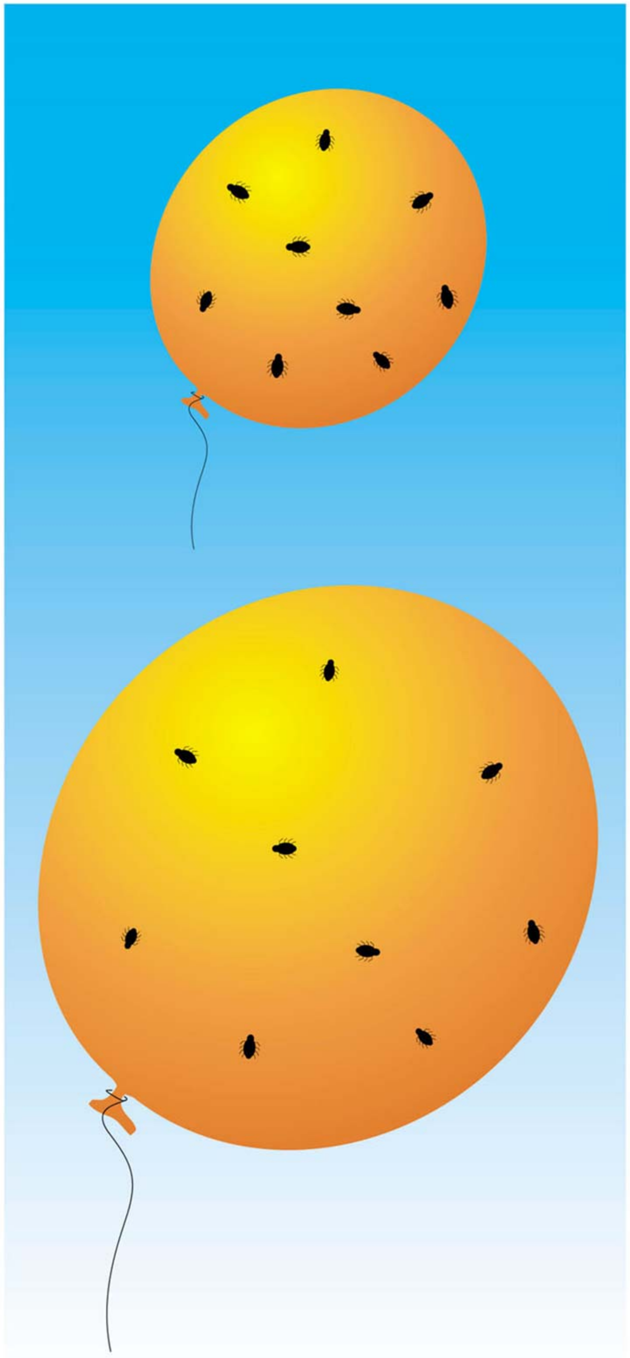
WHICH IS OUR UNIVERSE?

- One of the big questions Cosmologists hope to answer
- Can be accomplished by comparing
  - The total amount of mass in the universe
  - The speed at which things are flying apart
- Is there enough mass to produce enough gravity to eventually halt the expansion (flat) and/or pull it back (closed). Not enough mass would mean an open universe

THE EXPANDING UNIVERSE

- Hubble observed that the further away things were the faster they were moving away from us
- Einstein figured out the General Relativity that allows calculations of the shape of space-time

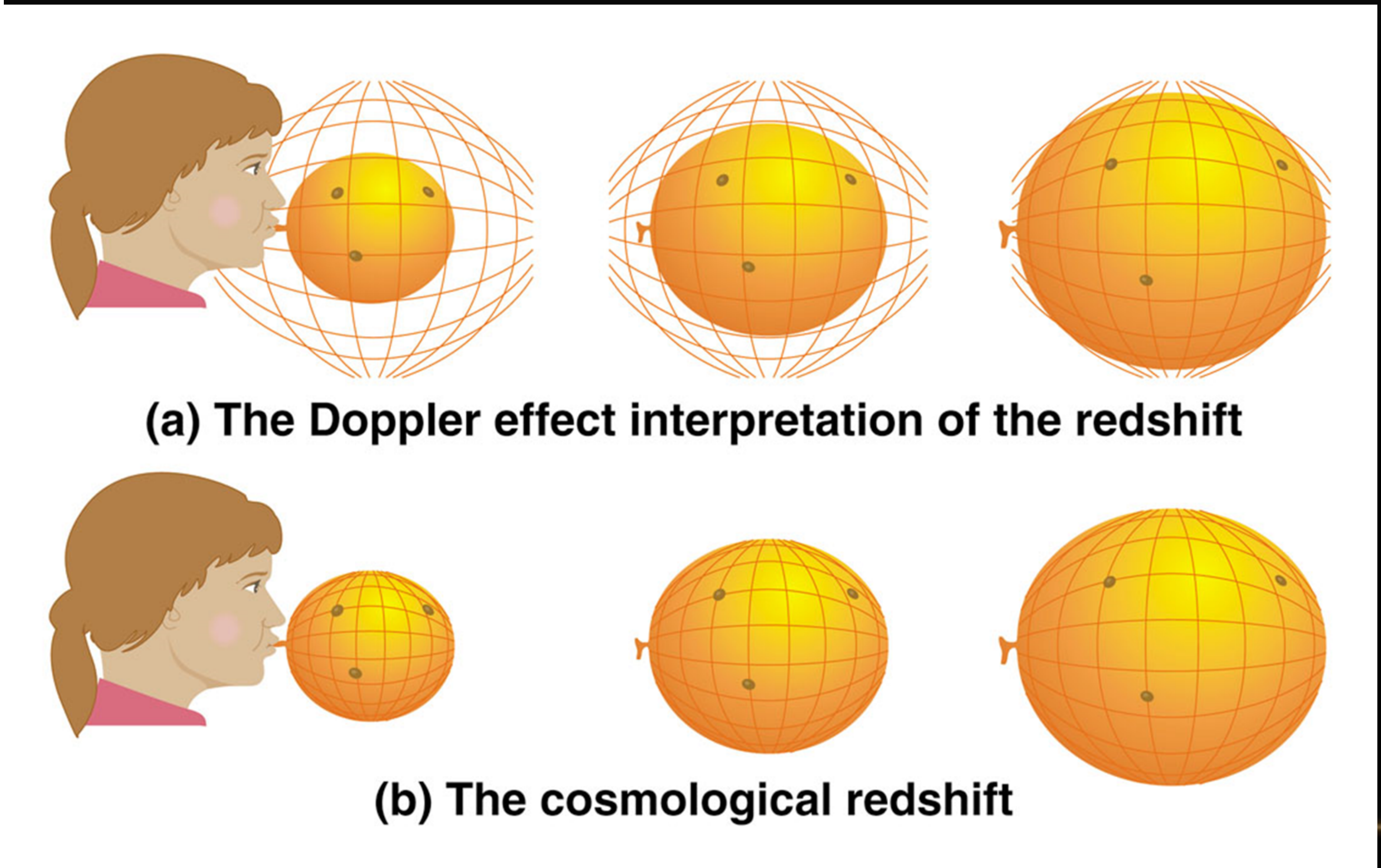




EXPANSION?

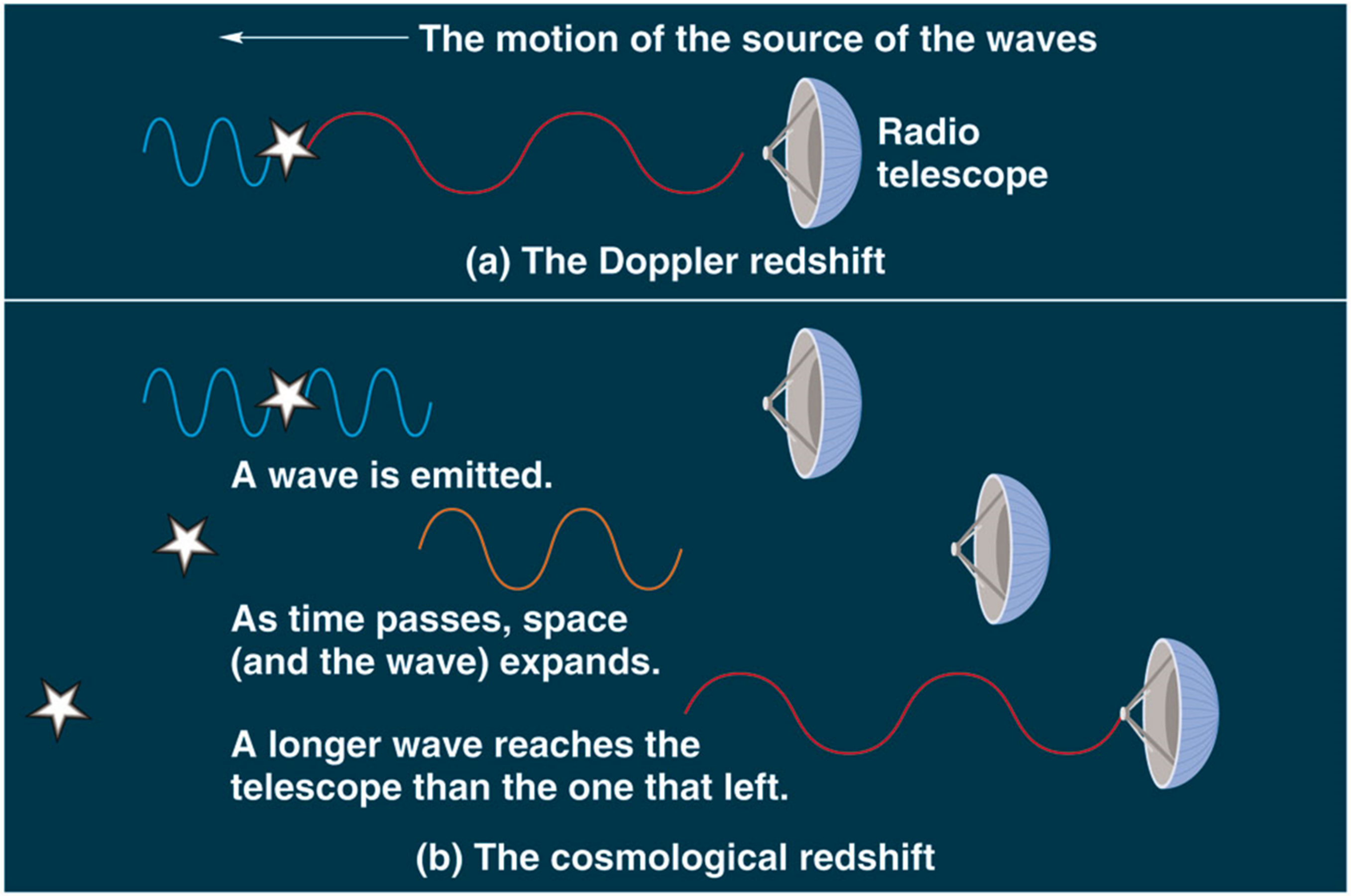
- Back to the 2-D fleas on the balloon
- If the balloon is expanding, every flea is getting further from every other flea
- A better 3-D analogy would be raisins in a rising loaf of bread

COSMOLOGICAL VS. DOPPLER REDSHIFTS



- Things moving apart
- Or space itself is stretching

STRETCHING SPACE



- General Relativity tells us that space itself is stretching
- Waves get stretched out
  - Longer waves are more red

LOCAL SPACE STRETCHING?

- Does this apply to stuff nearby?
- Two parts to this answer:
  1) Yes, but it's a small fraction so is hard to notice
  2) Plus all the mass nearby (say, in our galaxy) distorts space locally more than does the small amount from the expanding universe
- So, we don't see stars on the other side of the Milky Way moving away due to the expanding universe

OLBER'S PARADOX

- Why is the sky dark at night?
- If the universe is infinitely large (and/or infinitely old), everywhere we would look we would eventually see some star somewhere
  - Maybe far away, but somewhere
  - So the sky would be very crowded and bright!

a In a large forest, a tree will block your view no matter where you look. Similarly, in an unchanging universe with an infinite number of stars, we would expect to see stars in every direction, making the sky bright even at night.

Fig.17.17a

WE DON'T SEE THAT

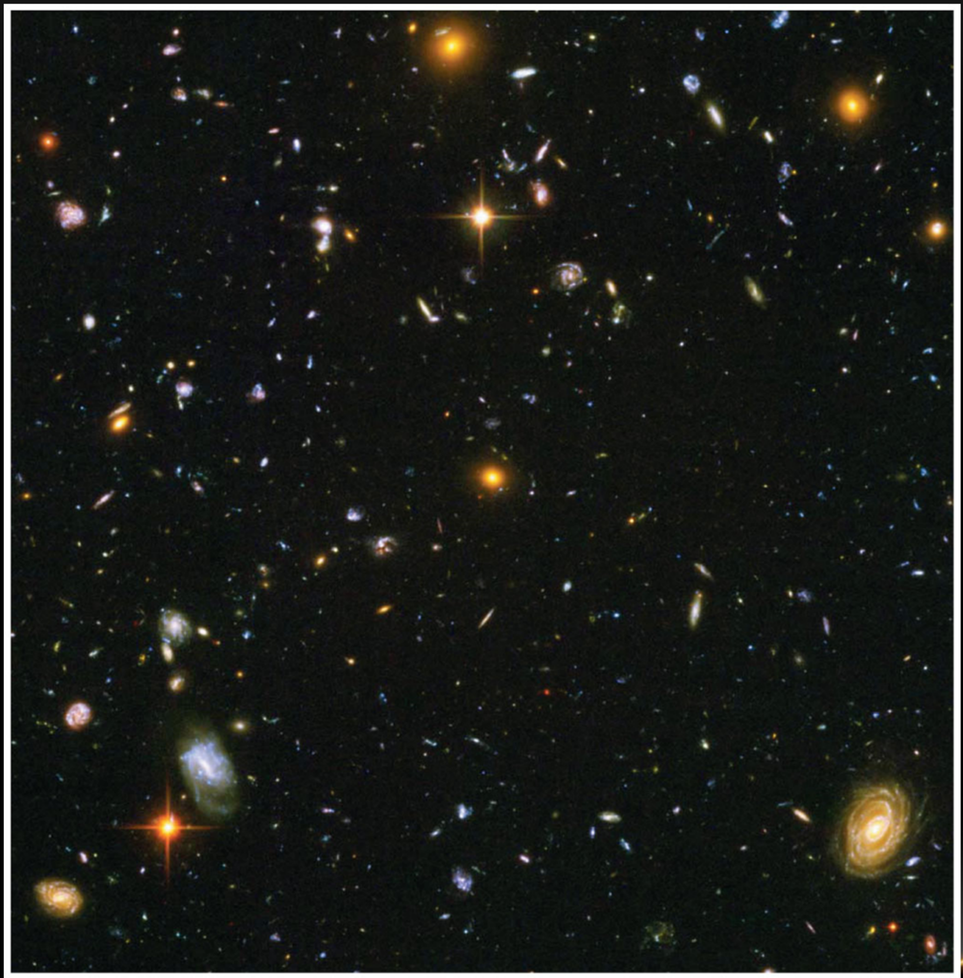


Fig.17.17b

b In a small forest with a smaller number of trees, you can see open spaces beyond the trees. Because the night sky is dark, the universe must similarly have spaces in which we see nothing beyond the stars, which means either that the number of stars is finite or that the universe changes in a way that prevents us from seeing an infinite number of them.

A DARK SKY

- If the universe is not infinitely old, then we can only see as far away as light has had a chance to travel
  - Say, 13 billion years or so
- So, our line of sight in some random direction can only go so far out
  - If it does not hit a star in 13 billion ly, that patch of sky is dark
  - We are seeing back to a time when there were no stars

COSMOLOGICAL ASSUMPTIONS

- Things cosmological calculations assume:
  - The universe is Homogenous
  - The universe is Isotropic
- Together they're called the "Cosmological Principle"
- Also, we assume "Universality"
  - The same physical rules apply everywhere

HOMOGENEITY

- This means that the universe has uniform properties throughout
  - Made of the same stuff
- Doesn't work well on the small scales
  - This room has air and concrete
  - Very non-homogenous!
- Works ok on bigger scales
  - Average over a bigger area of space, it's all H and He and a little bit of other stuff
- Cosmology cares about the Really Big, so this is OK

ISOTROPY

- This means that the universe looks the same in every direction
- Again, doesn't work well in small scales
  - We see lots of stars in the galactic plane, fewer looking up out of the disk
  - Even larger, still has problems – galactic clusters
- But is ok on really big, cosmological scales
  - The maps of all the galaxies known show dots spread out pretty smoothly

GALAXIES

- For example, a galaxy map