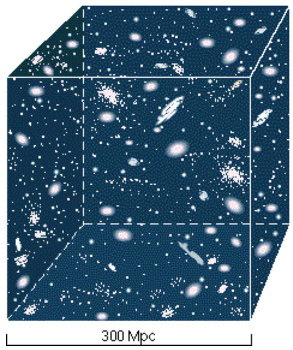
Cosmological Assumptions



Here is a typical chunk of universe at the current cosmological epoch. It is assumed that all chunks of this size will look and behave the same.

1. Homogeneity
   Matter is distributed evenly throughout the universe on the largest scales (~ 300 Mpc).

2. Isotropy
   The universe looks the same no matter where you are. Again, this is on the largest scales.

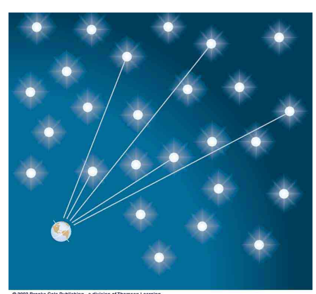
3. Universality
   The laws of physics as measured on Earth are everywhere the same. This also implies that these laws do not change with time.

4. Cosmological Principle
   A result of accepting both the homogeneity and (especially) the isotropy of the universe. This principle states that any observer in a any galaxy will see the same features of the universe. Since the universe changes with time, this principle applies only for observers living during the same cosmic epoch.

Olber's Paradox and defining the "Observable Universe"

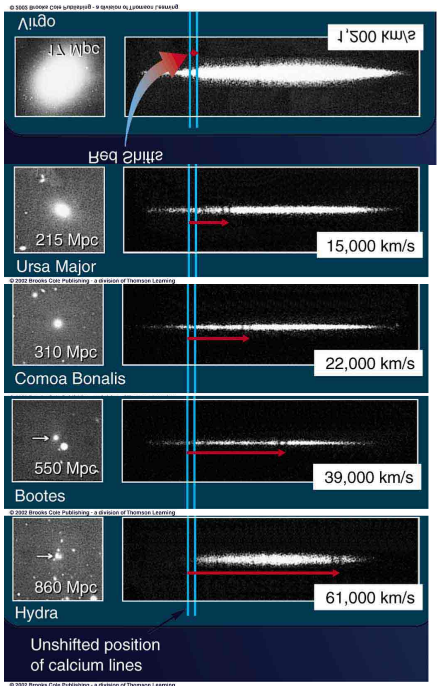
In a homogeneous and isotropic forest, no matter where you look, your line of sight will eventually intercept a tree.

You never see the "sky" behind the forest.

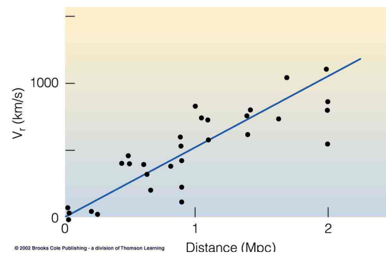


If homogeneity and isotropy apply in the universe, then the same should be true- your line of sight should always intercept a star and you would never see a dark patch of sky!

The observable universe is not infinite.



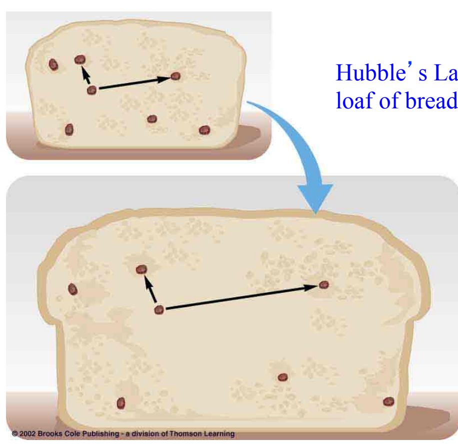
Hubble's Law Revisited
(it's interpretation)



Hubble's Law means that
the universe is expanding.

Think of space as made up of sugar cubed sized chunks. Each chunk is growing with time and all matter is being carried along.

The Raisin Bread Analogy

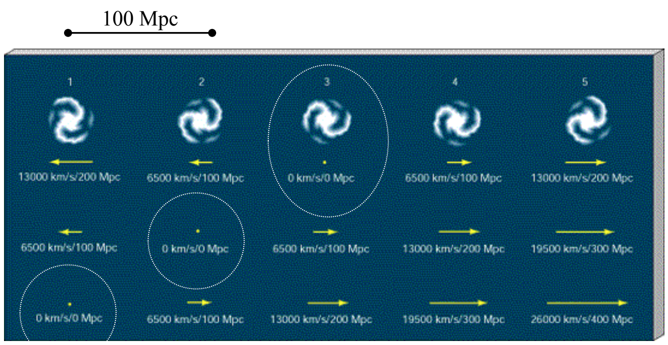


Hubble's Law in a loaf of bread!

Every grain of bread is expanding and the raisins are going along for the ride.

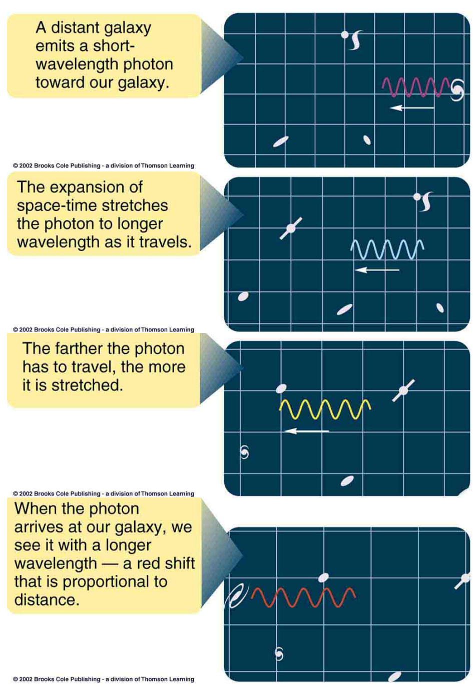
The further apart two raisins, the more grains between them, the faster they are "carried" away from one another. Its an additive effect by summing up all grains between the raisins.

Galaxy Raisins



No matter which galaxy you are on, all other galaxies are moving away.

The further away the galaxy, the faster the galaxy is moving away from you!



The photon has a well defined wavelength of "3" (peak to peak) on imaginary grid of space.

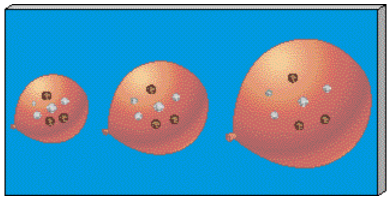
That wavelength does not change relative to the imaginary grid. It always is "3" from peak to peak.

As the grid size stretches, because the area of space inside each grid is expanding, the photon also stretches.

The color changes. A photon that was very blue when it was emitted eons ago, would now be very red!

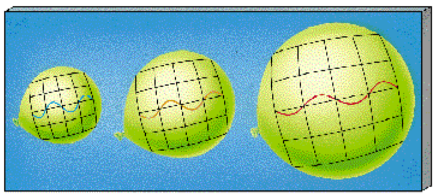
Since the speed of light is constant, the distance the photon traveled is directly related to its travel time.

The Balloon Analogy



Objects on the surface are carried along as each location on the balloon stretches

Hubble's Law on a big fat ballon!

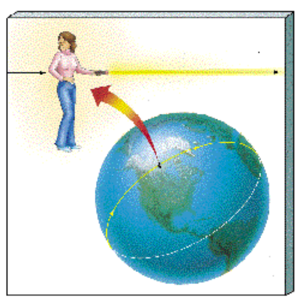


Photons are stretched as well. Since the color is defined by wavelength, the color changes! Photons get "redder".

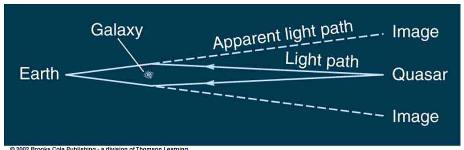
Cosmological Redshift.

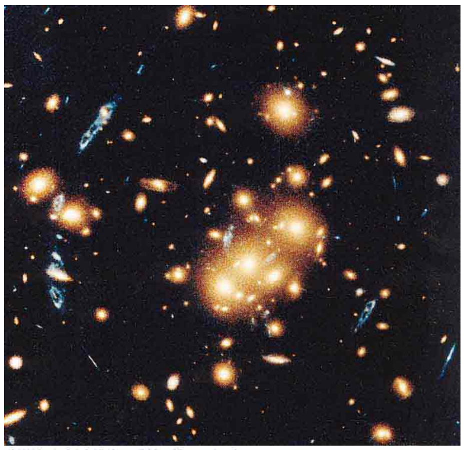
This stretching of the wavelength causes a reddening of the light. This is a redshift (just like the Doppler redshift), but it is not due to the motion of the object, but to the stretching of the photon.

Is space flat, or curved like the surface of the Earth?



To check this out, you must define some sort of measuring technique and some way to define the shape of space. On the Earth, we use "great circles", as shown with the bending light ray in the picture above.

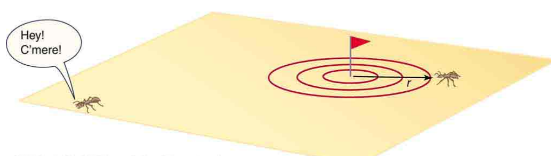




GRAVITATIONAL LENSING

Provides a way to look at curvature of space through the curvature of light paths.

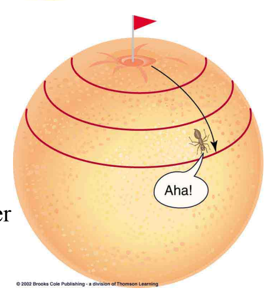
The space around this giant cluster is "bent", not flat. The curvature of the light paths is just the light traveling on the "great circles" in the universe.



FLAT SPACE

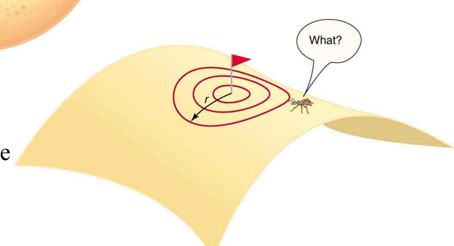
The relation between the radius, r, and the length around the circle, the circumference, C, is a well known constant called $\pi = 3.1415$

$$C = \pi r$$



POSITIVE CURVED

The relation between the radius and the circumference, is no longer $\pi = 3.1415$, but a number larger than π.



NEGATIVE CURVED

The relation between the radius and the circumference, C, is no longer $\pi = 3.1415$, but a number smaller than π.