Properties of a Finite Universe

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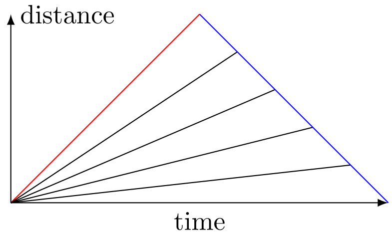
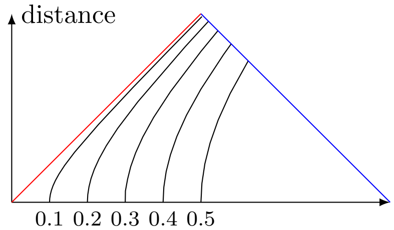
Hubble discovered that galaxies are moving away from us at speeds proportionate to their distances, at least over the range of distances for which one can observe individual Cepheid variable stars. Assuming relatively constant velocities over time, this is what the universe would look like if it had exploded 13.7 billion years ago, more or less. In order to originate from a single point and time, the velocities should actually be given by

$$v = \frac{d}{T - d/c} \quad \forall d < \tfrac{1}{2}cT$$

where T is the age of the universe and d is the observed distance. For the distances used by Hubble, the differences are insignificant.

This is illustrated in the following diagrams. The blue line corresponds to the observed universe, where the further away an object is the further back in time we see it. The other lines in the first graph represent the expanding universe, and the red line represents the upper limit on the size of the universe imposed by the speed of light. The curves in the second graph mark the age of the universe (as fractions of T) due to time dilation. The faster an object moves, the slower its clock runs (relative to us).





The next major discovery was the cosmic microwave background radiation. Once you remove the effects of our own galaxy and its velocity, this radiation is uniform in all directions, corresponding to a black body radiation of about 3° Kelvin. This radiation is supposed to come from when the universe first cooled to 3000° Kelvin and went from being a hot opaque plasma to a hot transparent gas. The red shift needed to achieve this change corresponds to a velocity of $v = 0.992c$.

At the time of this event, the universe was a 3000° oven. When you look at the sky, you are looking at the past, so you would have seen a transparent sphere expanding at the speed of light, surrounded by 3000° plasma. The way the inverse square law works, the universe would have remained a 3000° oven. It would only cool down due to two factors: red shift would lower the frequency and expansion would lower the intensity of the radiation.

Only a finite number of photons were released at the time of the cosmic background event, and the universe is much larger now than then. In fact by comparing the intensity of the microwave background to 3000° black body radiation one can determine how much larger the universe has become (minus those photons lost to absorption). Physicists tend to concentrate of the spectral frequency rather than the intensity, so i could find no data on the subject. Assuming the cosmic background intensity matches that of a 2.725° K black body results in a universe only 110 times larger by width, which would make the current universe far smaller than expected.

If the universe had a center, we should be able to locate it. Assuming the universe has a positive net mass, everything closer to the center of the universe should be red shifted and everything further from the center than us should be blue shifted. At the very least we should expect some sort of non-uniform distribution of galaxies with respect to distance from the center. Consequently, we assume a universe with no center or edges, where every observer sees themselves as being in the center.

At this point physicists generally start torturing general relativity to warp the universe into a shape which matches our observation. Frankly, it can't be done. General relativity was developed to explain gravitational fields, which have a center and extend to infinity. If anything, general relativity warps the universe the wrong way (concave verses convex).

So what sort of shape has no center and is finite in size? The usual analogy is that the universe is like the surface of a sphere. Taking this literally, let us assume a four dimensional space with dimensions d_1 through d_4 where the surface of the hypersphere is given by

$$d_1^2 + d_2^2 + d_3^2 + d_4^2 = r^2$$

where r is the radius of the hypersphere. The solution can be expressed in terms of three dimensions x, y and z using

$$\begin{aligned} d_1 &= r\cos(x/r) \\ d_2 &= r\sin(x/r)\cos(y/r) \\ d_3 &= r\sin(x/r)\sin(y/r)\cos(z/r) \\ d_4 &= r\sin(x/r)\sin(y/r)\sin(z/r) \end{aligned}$$

and the arc distance from any point on the hypersphere to its antipode is πr.

The most important consequence of this model is that the inverse square law falls apart at large distances. Specifically, the surface area of a "sphere" of radius d would be given by

$$A = 4\pi r^2 \sin^2(d/r) \quad .$$

(For light traveling through an expanding universe, use the current value of r.) If you measure distance using red shift, an object very far away should appear brighter than one would expect, which is opposite what was discovered recently for type 1 supernovae.

More interestingly, light from a given point should converge at its antipode. Therefore every object in the universe should create a real image of itself at its antipode as soon as light is able to cross the distance. At a distance, these would be indistinguishable from the original stars or galaxies except for their red shift and age. Close up they would appear much larger than the originals and transparent, so that objects behind an image would appear to be in front of it. These images would not just be slightly brighter than they should be based on red shift, they would look like close neighbors.

Obviously, we have not found any such images (excepting possibly quasars or as "gravity lensing"). Of course, if the universe is expanding close to the speed of light, space near the antipode could still be opaque (as observed by us).

It should also be noted that gravity or any other force with an inverse square characteristic will neither hinder nor help the expansion of the universe. Since every observer in the universe sees itself as being in the center of a relatively uniform mass, gravity cancels out. The net potential energy of the universe does not change as its size changes.