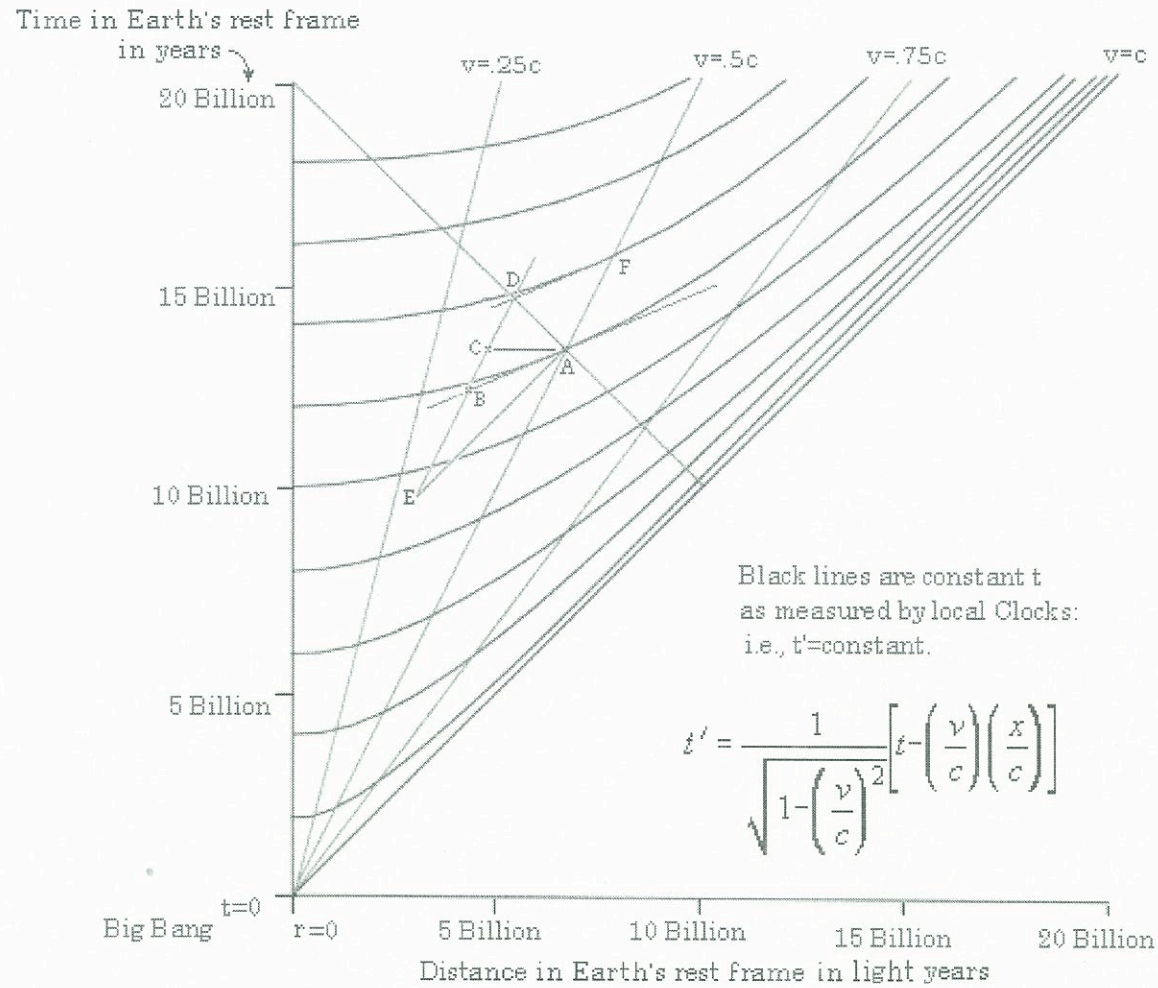
Home.

What we see when we look out in space.



What is displayed above is a relativisticly correct space time diagram of the universe as seen along a line from the earth. The blue line represents the beam of light which is being used to see whatever is being observed (the line referred to in the previous sentence). I have set the age of the universe to 20 billion years for convenience. I don't think anyone should have any difficulty with that. If one wants to see the diagram as it should look now, all they need to do is find the correct age of the universe on the vertical scale and plot the line of sight at 45 degrees down to the right. Clearly I have omitted the right side below the line v=c as, if anything exists within that volume of space, it certainly cannot be observed as it must be expanding faster than the speed of light. I have explicitly shown three different "galaxies" (the orange lines) receding from us at .25c, .5c and .75c. This is the apparent Hubble velocity of recession of distant objects.

These galaxies were in the position indicated by the intersection of the blue line (the light we are using to observe them) and the orange lines (their positions in the space time diagram at rest with respect to the earth). The first thing you must be aware of is that they are moving with respect to the rest frame of the earth! This fact requires that their clocks must appear to be running slow when compared to the clocks on

the earth (or any clocks at rest with respect to the earth: i.e., the coordinate system in the above diagram). The correct relativistic equation for the conversion from t to t' is explicitly shown in the diagram, t' being the time as measured on the moving clocks. The hyperbolas plotted in black are lines of constant t' as measured from the "Big Bang" in the rest frame of the galaxy of interest under the approximation that variation from the Hubble recession velocity is entirely negligible (the reader should understand that, in our diagram, we could presume a galaxy at any point in space). Note that the black lines are spaced two billion years apart.

I know you have been told that events which are taken to be simultaneous in a given rest frame are not seen as simultaneous in a frame moving with respect to that frame. It is not difficult at all to show that events falling on a line tangent to the constant t' surface will appear to be simultaneous to observers at the point where the tangent is taken (note that I have shown a tangent at point A in the galaxy receding at .5c. There will also turn out to be an apparent Lorentz contraction in your space measurements. That distortion is exactly the same as what would be obtained by projecting measurements placed on the black lines in the direction of the orange lines (as if the black and orange lines were orthogonal). An observer on the moving galaxy would insist that the particular black and orange lines intersecting their position would be orthogonal in their rest frame. Line E-D is parallel to the path of the referenced galaxy and thus constitutes the path of an object at rest in the rest frame preferred by the observer at point A.

What I am getting at is the fact that the observer in that distant galaxy will set up his space time coordinates in a manner which he will call orthogonal but you (from the earth) will call skewed. In his coordinate system, he will see that same blue line as being 45 degrees off his space axis bisecting his space-time axes (thus he sees the same beam of light as traveling at the velocity c in his rest coordinate system). The speed of light is c in every inertial coordinate system. Please notice that, in my diagram, the blue line almost exactly bisects the intersection of the black and orange lines. The bisection would be exact if my plots were perfect but they are not as I merely sketched a smooth curve through some known points.

This document was originally composed to explain to a student of relativity exactly how we are able to see the state of the universe very close to the original Big Bang. The critical issue is the fact that, close to the limit of our observations, the local clocks appear to be running very slow. The light which we see (the blue line) may appear to have started towards us only 10 billion years ago (in our rest frame coordinate system) but, from the perspective of an observer close to the Big Bang itself, that exact same photon would appear to begin its trek to the earth only shortly after the Big Bang occurred. Thus the events we actually observe occurred during the very early phase of the life of the universe.

However, there are some other rather important phenomena which are certainly clarified by this same diagram. As I commented above, an observer at A would regard anything proceeding along a line parallel to the path of his galaxy to be at rest with respect to himself. I have drawn in one "square" (see the figure ABDF) of the coordinate system he would consider to be an orthogonal space time plot. Since he must see light as traveling at c in his coordinate system it should be clear that, by his measurement, he must see that "square" as two billion light years by two billion years. He will consider the two space time events (points) A and B as being simultaneous. On the other hand, an observer on the earth would define the two space time events (points) A and C to be simultaneous. Notice the earth observer would see the distance between the two objects (the observer at A and the object the observer says is at rest with respect to him at B) to be the line AC. Note that the line AC is considerably shorter than two light years. This is the relativistic contraction referred to in any treatise on relativity.

One thing should be very obvious to anyone examining this diagram. That is the fact that the entire issue of special relativistic transformations revolve totally on the inability of the observers to agree on what events are "simultaneous". This is a fact and anyone who holds that it is not a fact does not understand what is going on. To a certain extent we owe some of the confusion surrounding relativity to the scientists who, in the face of this problem, define "simultaneous" in a manner which they felt was the most obvious: they define it in a manner which is consistent with the standard Newtonian space time diagram. We can't really fault them as such an attack at least allows relativistic phenomena to reduce to the Newtonian result when the finite speed of light becomes inconsequential. However, they shortchange the customer when they hold that such is the only possible definition of "simultaneity".

Note that the opening arguments of any presentation of relativity immediately make the assumption they are at rest in the frame of reference where the speed of light is c. I point out that this is a required assumption if one wishes to obtain the standard relativistic results; however, I still insist it is an assumption and anyone who holds that it is not, does not understand relativity (a very common problem). I will admit that the attack does yield a particularly convenient development of relativity, but certainly any calculation which can be done in the Earth's rest frame can just as well be done in A's coordinate system. That is, A's definition of simultaneous is just as valid as ours; it just complicates our life considerably to use his. The fact that either can be used is in fact the central pillar of relativity.

Therein lies another significant issue seldom brought forth in standard presentations of relativity. The standard definition of simultaneity is not at all what is seen when one observes the universe. As is shown clearly in the diagram above, neither the earth scientist's position that space time events C and A are simultaneous or the observer at A's position that B and A are simultaneous reflect what is actually seen when either party looks in a telescope. The observer on the earth will see events D and A as occurring simultaneously (the light from those two events arrive at his observation point at exactly the same time) and the observer at A will see the events E and A as occurring simultaneously (again, the light from those two events will arrive at his observation point at exactly the same time).

This is an issue which many scientists overlook when they talk about how things appear to be when relativity is properly accounted for. That is to say, the common scientific representation of events usually corrects for the finite time it takes for the light to arrive. Or another way to look at the situation is that scientists, when they talk about how things appear, usually fail to take into account the complications which the finite speed of light generate in the actual optical image seen.

Well, since the only fact that we can actually agree upon is that different observers will see different space time events as simultaneous, why don't we just make life easy for the ignorant observer and define "simultaneous" to indicate that the light arrives at our observation at exactly the same time? Sure it complicates calculations for the scientists but most of them are pretty good at mathematics anyway and I am sure there are very few who are so backward as to be incapable of adjusting their results to such a definition. One very important aspect of such a definition is that "simultaneous collapse of a wave function" becomes strictly dependent on the observer and is consistent with many other ideas basic to quantum mechanics.

Finally, there is one last fact evident in the diagram presented which is actually quite astounding considering the fact that we are discussing the consequences of special relativity only. Keep in mind the fact that all coordinate systems being referred to here are conventional Euclidean constructs. The issue of relativity concerns only how the various coordinate systems are transformed one into another. Bearing that in mind, notice that, since observing light coming from great distances amounts to looking at an image of the universe as it was not only long ago but, because the clocks far away appear to be running quite slow, the image must be substantially identical to the state of the universe very close to the big bang itself.

Now the issue here is the surface area of the sphere being observed this great distance away. By special relativity, the objects being observed will display contraction only in the direction of the motion which in this case is radial. If one were to use Euclidean geometry to calculate the surface area of the sphere being observed one would obtain quite a large number. On the other hand, if one were to estimate the surface area of that same sphere using the phenomena observed taking place on that sphere one should obtain exactly the same answer which would have been obtained by an observer resident in the universe at the time when the universe was young, Therein lies the difficulty. That number should be considerably smaller than the number obtained in the geometrical calculation. The only conclusion one can reach is that, in spite of the fact that our geometry here is explicitly Euclidean, the actual appearance will be non-Euclidean: i.e., if we could see the actual big bang, the point that it is understood to be would be spread over the entire spherical view.

This suggests that special relativity together with the acceptance of the big bang introduces an optical distortion of space at large radii even without any general relativistic effects. Life is certainly more complex than it first appears to be when one goes to make predictions as to what will be seen when one looks.

I hope you enjoyed the thoughts -- Richard D. Stafford, Ph.D.