Did the Universe Have a Beginning?

The big bang theory postulates that the entire universe originated in a cosmic explosion about 15 billion years ago. Such an idea had no serious constituency until Edwin Hubble discovered the redshift of light from galaxies in the 1920s, which seemed to imply an expanding universe. However, our ability to test cosmological theories has vastly improved, with modern telescopes covering all wavelengths, some of them in orbit. Despite the widespread acceptance of the big bang theory as a working model for interpreting new findings, not a single important prediction of the theory has yet been confirmed, and substantial evidence has accumulated against it. Here, we examine the evidence for the most fundamental postulate of the big bang, the expansion of the universe. We conclude that the evidence does not support the theory. It is time to stop patching up the theory to keep it viable, and to consider fundamentally new working models for the origin and nature of the universe in better agreement with the observations.

Introduction

For most of the existence of our species on this planet, mankind has believed that our home, the Earth, was located at the center of the universe. Copernicus's theory and the Scientific Method finally displaced this strongly held geocentric view with the humbler but more realistic perspective that we are no place special in the universe.

Because this basic perspective change was so difficult to achieve, modern science has since always insisted that any theory seeming to put humans in a special place in the universe was thereby automatically suspect. So when modern cosmologies were first formulated, they were required to obey the "cosmological principle", that the universe should have a uniform matter distribution on the largest scales (homogeneity), and look essentially the same for all observers viewing in all directions (isotropy).

With this background, it therefore came as a surprise in the 1920s when Edwin Hubble found that the light from galaxies appeared redshifted; and that the fainter (and therefore farther away, on average) a galaxy was, the more its light was redshifted. Here was an observable property of the universe that seemed centered on us, and changed uniformly with distance away from us, as if we were at the center of the universe.

The timing of this discovery was critical to further evolution of the theories. At just that time, Einstein's general theory of relativity had received observational support and was gaining in favor with physicists. But there was a serious problem in incorporating general relativity into cosmology. It appeared that gravity made the universe unstable, inducing it to collapse. Wherever galaxies or large assemblies of matter existed, other distant galaxies or assemblies would be attracted toward them; and these mutual attractions would cause all galaxies or large assemblies to be pulled toward one another, since they had insufficient velocity to resist the attraction. Simply put, all sufficiently large structures, including the universe as a whole, must collapse under the weight of mutual gravitation. Yet observations showed this did not happen.

To get around this difficulty, Einstein invented the "cosmological constant"—a hypothetical repulsive force operating on large scales that prevented the collapse of the universe. This was the unsatisfactory state of affairs when Hubble made his redshift discovery. Physicists of the day immediately knew that, if the redshift of galaxy light was caused by galaxies moving away from us, the implied expansion of the universe would serve to solve the "problem" with the stability of the universe in a far more elegant way.

Friedmann described three possible models in which the universe would appear homogeneous and isotropic, yet be seen as expanding, by all observers in it at the present time:

(1) The open universe, in which the rate of expansion everywhere exceeds the velocity of escape from the rest of the matter in the universe. Such an expansion would continue forever; and space in such a universe can be described as negatively curved.
(2) The closed universe, in which the expansion is eventually halted by gravity and becomes a collapse back to the origin. Such a universe has a finite lifetime unless it bounces and continues expanding and recollapsing forever. Space in this type of universe has positive curvature. As on a sphere, a straight line in any direction eventually returns to its starting point.
(3) The flat universe, in which the expansion is critically balanced at the threshold between open and closed. The expansion goes on forever, asymptotically approaching zero velocity after infinite time has elapsed and the universe has become infinitely large. Space therein has no curvature.

In principle, observations should allow us to determine which type of Friedmann expanding universe we inhabit. We simply measure the cosmic deceleration parameter, q. In a flat universe, the total matter in the universe is just enough to halt the expansion after an infinite time. This corresponds to a cosmic deceleration $q_o = 0.5$. If the observed value of q_o is larger than 0.5, the universe is closed. If q_o is less than 0.5, the universe is open. If there were no cosmic deceleration, $q_o = 0$; or if the expansion accelerates due to some hypothetical force of repulsion, $q_o < 0$. The most widely accepted form of the big bang theory predicts that $q_o = 0.5$.

Thus, the big bang theory was born from the adoption of Friedmann's premises as the explanation for Einstein's quandary about the collapse of galaxies and Hubble's redshift data. However, in their eagerness to solve these dilemmas, astronomers and physicists were induced to accept a new, if less distressing, way of accepting that the observer was special. It is true that the Earth would occupy no special *place* in a Friedmann-type universe, and everything would look basically the same in all directions as seen by anyone anywhere. However, everything in the universe would always be at a special *time*, a finite number of years from the beginning or end of the universe, and evolving accordingly. The universe looked rather different at any two widely spaced moments of time. The Friedmann models still obeyed the original cosmological principle; but they violated the new "perfect" cosmological principle, in which the universe should look essentially the same to any observer at any *time* as well.

This development was ironic, because one of the accomplishments of the theory of relativity was to show the large extent to which space and time were similar and interchangeable. That symmetry had to be abandoned by the big bang when the perfect cosmological principle was abandoned. As we will discuss, this pragmatic decision to once again allow the observer to be special (observing at a special time) was probably a wrong turn for science.

What Does Expansion Mean?

The essence of the big bang cosmology is an expanding universe. The redshift of the light from galaxies is proportional to their distance (as inferred from brightness). No cause of galaxy redshift other than a velocity away from the observer was considered plausible, so Hubble's result was taken to mean that, the farther away from us a galaxy is, the faster it moves away from us. Hence, the overall universe had to be expanding.

Of course, the redshift still *might* be caused by something other than velocity. The only way to be sure is to perform observational tests. When considering tests for expansion, it is important to know what expansion really means in the big bang theory. The three Friedmann models described ways in which the expansion would appear the same from everywhere within the universe. But if this expansion meant that all matter in the universe was at one time located at a point in space, then the universe would have a center and an edge. That would make every point in it "special" with respect to the origin point and with respect to the void beyond the edge. The view would not be the same from everywhere.

To understand expansion in the big bang theory, we are asked to visualize an expanding balloon as a 2-dimensional analogy of our 3-dimensional universe. Every point on the surface of the balloon gets farther away from every other point as the balloon expands. Yet no point on the surface serves as the center, and there is no edge. The expansion is slowed by gravity and may eventually halt and begin to contract back to its origin point; or the expansion rate may be too high to ever halt the expansion. It is up to observations to tell us which kind of Friedmann universe we inhabit by allowing us to measure the cosmic deceleration parameter, q.

But all these Friedmann universes are very different from the kind of expansion one would get if the universe originated in an explosion into pre-existing empty space. This is because the big bang is an explosion *of* space and time, not an explosion *into* space and time. A recent paper by Harrison (1993) explains:

> *From a purist point of view one cannot help but deplore the expression 'big bang', loaded within appropriate connotations ..., which conjures up a false picture of a bounded universe expanding from a center in space. In modern cosmology, the universe does not expand in space, but consists of expanding space. And this correct picture leads naturally to a distinction between the redshift-distance and velocity-distance laws.*

Odenwald and Fienberg (1993) state the point in more detail:

> *This [cosmological] redshift, which again is* not *a Doppler shift, arises from the expansion of space-time itself. Light waves literally stretch as the universe expands between the time the light was emitted and today, when it finally reaches us. ... Now galaxies are located at fixed positions in space. They might perform small dances about these positions in accordance with special relativity and local gravitational fields, but the real 'motion' is in the literal expansion of the space between them. ...*
>
> *This is not a form of motion that any human being has ever experienced, in that it does not involve travel* through *space. So it is not surprising that our intuition reels at its implications and seeks less radical interpretations.*

So the big bang postulates that the cosmological expansion occurs, not because galaxies move apart through space, but because more space is being continually added between them. This continual creation of space *ex nihilo* is an integral part of the theory. Without it, the cosmological principle would be violated.

> *"And in the beginning there was nothing. And God said, 'Let there be light.'*
> *And there was still nothing, but now you could SEE it!"*
> *—Anonymous*

Does the Universe Really Expand?

One might be inclined to think, given the popularity of the big bang theory today, that we must by now have solid evidence that the universe is indeed expanding. But in truth, that most fundamental premise to the big bang cosmology remains an assumption. Attempts to show its truth observationally have frustrated astronomers for decades. Moles (1991) recently summarized the four classical tests for expansion. These involve the relationships between the redshift of galaxies on the one hand, and apparent magnitude, surface brightness, number counts, or angular size of galaxies on the other hand. The redshift of galaxy light is *assumed* to be caused by the velocity of the galaxy away from us. We are here examining tests of the correctness of that assumption. In the next section we will mention some alternative interpretations of redshift for galaxies. To be clear on this point, it is well established that the redshift of ordinary galaxies (although not radio galaxies, Seyfert galaxies, "active galactic nuclei", or quasars) is closely correlated with the distance of those galaxies. But is not well established that the redshift is caused by an increase in that distance.

These classical tests are somewhat complicated with respect to proving or disproving the expansion hypothesis by the influence of unknown evolutionary effects. But these galactic evolutionary effects themselves, and also supernova light curves and the ages of globular clusters and galaxy super clusters, each offer the possibility of specialized tests of the expansion hypothesis. We can also easily test non-expanding (static) models, since these generally have no evolutionary effects.

One great difficulty in applying observational tests to galaxy samples is the influence of Malmquist bias. Galaxy sizes do not seem to have any definite maximum, but very large galaxies are rare compared to those of average size. So if we take a small sample of galaxies, it probably will not contain any galaxies very much larger than normal. But the larger our sample becomes, the more extreme the largest galaxy in it is likely to be.

So as we look farther out into the universe, two things happen simultaneously: We start to lose the smaller galaxies from our samples because they are too faint to be seen; and the total number of galaxies increases with roughly the cube of distance. The first fact tends to push the average galaxy in our samples toward the brighter, and therefore larger, galaxies. The second fact implies that the brightest galaxies in our samples will tend to get brighter with distance simply because a larger sample will tend to find more abnormally large galaxies than a smaller sample would. Both effects bias our samples toward larger, brighter galaxies as distance increases. Astronomers must make the effort to compensate for this using appropriate sampling techniques, or the observational test results may become misleading.

For the equations underlying these tests and more details of the analyses, see Moles (1991).

Test #1: ***Apparent magnitude versus redshift for galaxies:*** Applications of this test potentially suffer not only from Malmquist bias, but also because of extinction due to the intergalactic medium, making distant galaxies appear fainter than they otherwise would. But when these biases are compensated to the best of our ability, the observed relationship seems to agree well with expansion models that have a cosmic deceleration parameter $q_o = 1$ or slightly larger (closed universe). Of course, given that q_o is a free parameter, some form of the expansion hypothesis was sure to agree with observations. It is interesting to note that the static universe model, with no free parameters, also agrees with these observations. Taken in isolation, this test would therefore favor static universe models because they are simpler theories in the sense of Occam's Razor ("Invent no unnecessary hypotheses") or in the sense of Beysian analysis —models with fewer free parameters are preferred, other things being equal.

Test #2: ***Galaxy number counts versus redshift:*** Results of this test (LaViolette 1986), taken at face value, do not agree with expansion models unless *ad hoc* evolutionary corrections are applied, and the universe is open. $q_o \leq 0$ is implied for the cosmic deceleration parameter. These results do, however, agree with static models. As before, the static models are without benefit of extra parameters. In expansion models, the evolutionary corrections must already be important at a redshift of 0.4, where galaxies were thought to be only very mildly different from those in the present universe, according to the big bang model. So this test, too, favors static models over expanding ones.

Test #3: ***Surface brightness versus redshift for galaxies:*** The surface brightness versus redshift testis the most difficult to correct for observational bias effects such as Malmquist bias. It is, therefore, the least conclusive test. The best available results are broadly consistent with both expansion and static models, but give better agreement with expanding models.

Test #4: ***Angular size versus redshift for galaxies and radio sources:*** This test predicts the most drastic difference between expanding and static models, since expansion requires a minimum angular size near roughly redshift $z = 1.2$, whereas static models usually predict no minimum in the observable range. The test is also the most observational-bias-free among the four classical tests. Results from observations of galaxy cluster radii, and (independently) from the sizes of brightest cluster members (Dorgovski and Spinrad 1981), both disagree strongly with predictions of any form of the Friedmann expanding universe models, since no such minimum angular size is seen, but agree reasonably well with static universe models. Results from the largest angular sizes of double radio sources are less consistent with static models, but still disagree strongly with all expansion models. Results showing a lack of small radio sources give cosmological parameters inconsistent with any of the preceding, but may themselves be explained by interplanetary scintillation effects (Hajivassiliou 1991).

To defend expanding models it is necessary to postulate strong evolutionary effects, sometimes counter-intuitive ones. For example, the most powerful radio sources must also be the intrinsically smallest ones. It is also necessary to have little or no deceleration of the universe, or even an acceleration of the expansion; i.e., the universe must be strongly open; except for the small radio source observations, which seem to imply the universe must be strongly closed unless the lack of small sources is a scintillation effect. In most static models, redshift is not a distance indicator for radio sources such as quasars and most radio galaxies, so only the galaxy results (which agree) should be considered significant. Therefore, three of four independent applications of this testfavor static universe models over expanding models—two of them strongly—and the fourth test is inapplicable to most static models.

Test #5: ***Supernova lightcurves:*** Type Ia supernova light curves have a characteristic shape and rate of decline. If the universe were expanding, supernova light curves in high redshift galaxies would be stretched out in time due to the rapid recession of the parent galaxy. In a static universe, no such stretching would occur. The best case so far is for a supernova in a redshift $z = 0.31$ galaxy seen only after the explosion reached its maximum brightness and begun its decline. Model-dependent assumptions about the time and intensity of the maximum brightness must be made. The observations can then be fit with an expanding universe model (Norgaard-Nielsen 1989). But expansion is not required for a good fit to the observations because the light maximum was not seen, so static models work too. The results of this test are therefore presently ambiguous. In 1993, another supernova was seen in a galaxy at redshift $z = 0.43$. Details of an analysis of those observations are eagerly awaited.

Test #6: ***The ages of globular clusters and of superclusters of galaxies:*** If the universe originated 10-15 billion years ago, then no objects within it can be older than that. Yet the deduced ages of globular clusters of stars in our own galaxy do appear somewhat older than that, perhaps 16-18 billion years old. It is usually assumed that either something is wrong with stellar evolution theory, making the calculations come out too large; or that the universe is actually more like 20 billion years old, as Allan Sandage has argued. So the age of globular clusters is not presently a strong argument for any model of the universe.

The age problem is a bit more severe in the case of super clusters of galaxies. These huge structures would take perhaps 100 billion years to form, given the typical relative speed of galaxies (Lerner 1991). The same problem applies to "great walls" of galaxies, which are even vaster structures. There is no clear way to form structures on such large scales in the time available unless relative velocities were much higher in the past. But higher past velocities would require a dissipation mechanism which would have released tremendous energy. There is no credible evidence at present for the operation of such an enormous energy sink as would be required to resolve this dilemma. Therefore, this test presently favors static universe models, which have essentially unlimited time to form the observed structures through normal processes.

Test #7: ***Galaxy evolution:*** If the universe originated just 10-15 billion years ago, galaxies are a recent phenomenon, and galaxy evolution would be a strong feature of the early universe. If the universe is not expanding, then presumably galaxies today are of the same character as those of 10-15 billion years ago. It is argued that, in a non-expanding universe, the radio galaxy 3C 65 at a redshift of 1.2 would be larger and fainter than any known galaxy in the local universe at the present epoch (Rigler and Lilly 1994), which seemingly implies the need for evolutionary effects. However, as already noted, in many static universe cosmologies, redshift is not a distance indicator for quasars and most types of radio galaxies. So inferences about the true size and intrinsic brightness of the radio galaxy would not be applicable. Indeed, the entire progression from quasars to ordinary galaxies, postulated in the big bang, is interpreted quite differently in static models, so that no clear distinguishing test of models appears possible using these exotic objects.

In recent years it has been popular to point to the so-called "Butcher-Oemler effect" as evidence that galaxies do evolve with time. This is an observation that faint blue galaxies are far more abundant at redshifts of 0.4 and up than they appear to be in the local universe. However, in the most recent findings it now appears that low-surface-brightness (LSB) galaxies may be the local counterpart of these faint blue distant galaxies (McGaugh 1994). LSB galaxies are difficult to discover locally because we tend to look right through them. But in a recent survey specially designed to detect such objects, they appeared to be as abundant as normal spiral galaxies. However, like their possible distant cousins, they are much bluer than spiral galaxies, making them good candidates to be the local counterparts of the Butcher-Oemler faint blue galaxies. If that identification is correct, this strongest remaining argument for the evolution of galaxies as a class with time would be invalidated.

Conclusions

A summary of the seven tests is shown in the table. For an expanding universe model to be consistent with the observations, a solution must be found to the unexpected existence of extremely large structures in the universe, such as super clusters of galaxies and great walls, which have had insufficient time to form since the origin of the universe; *ad hoc* evolutionary effects must be postulated to explain some test results, especially the absence of the predicted minimum angular size for large-redshift objects; and a solution must be found to the apparent contradiction between the results of test #1 and those of tests #2 & #4 for the implied value of the cosmic deceleration parameter q_o.

Test	Description	Consistent with Friedmann models?	Consistent with Static universe models?
1	mag. *vs. z*	if $q_o \geq 1$	yes
2	# *vs. z*	if $q_o \leq 0$	yes
3	SB *vs. z*	yes	yes?
4	ang. size *vs. z*	if $q_o \leq 0$	yes
5	supernovas	yes	yes
6	ages	no?	yes
7	evolution	yes	yes

These difficulties for the Friedmann models cannot be rescued by Einstein's cosmological constant because incompatible values would be required by different tests, and because the scarcity of observed gravitational lenses severely limits any non-zero value for this parameter to be too small to help the big bang theory (Maoz and Rix 1993).

Also, big bang models now use an ever-increasing variety of free parameters to maintain consistency with various observational constraints. Related to origin and expansion conditions alone, we now have the Hubble constant H (= expansion rate); the cosmological constant Λ (= pressure resisting gravity); the cosmic deceleration parameter q_o (= expansion deceleration); the density parameter Ω (= ratio of actual matter density to density needed for flat universe),subdivided into the density for ordinary matter and that for invisible dark matter; and the bias parameter b (= measures lumpiness of matter distribution). The hypothetical dark matter is itself a fudge factor required to obtain agreement with observations that were not in accord with big bang expectations, and it comes in three flavors: hot, cold, or mixed. So even if the difficulties shown in the table were solved elegantly, Occam's Razor (a part of Scientific Method) tells us that we should still prefer the model with fewer free parameters.

If the field of astronomy were not presently over-invested in the expanding universe paradigm, it is clear that modern observations would now compel us to adopt a static universe model as the basis of any sound cosmological theory.

What Else Can Cause Redshift?

If the redshift of galaxies is not due to expansion velocity, then what might cause the redshift? Over the years, a surprising number of proposals have been made. A recent summary article lists 20 non-velocity redshift mechanisms (Ghosh 1991). Basically, anything that causes light to lose energy will cause it to redshift. The trick is to have an energy loss mechanism that doesn't scatter the light. The absence of observed scattering is the main objection to the so-called "tired light "theory, in which intergalactic matter is supposed to be responsible for the energy loss of light.

One of many possibilities (the one favored by this author) is that one day we will discover the particle or wave serving as the carrier of the gravitational force. If such entities, dubbed "gravitons", exist, they must necessarily be of a much finer scale than current quantum particles. It therefore seems likely that they would have negligible scattering effects on light over cosmological distances, although light traveling through such a resisting medium of gravitons would necessarily lose energy and be redshifted. In such a case, we would expect to see light from galaxies redshifted in proportion to their distances from us, just as observed; yet there would be no expansion of the universe. The perfect cosmological principle would be obeyed.

This particular notion of gravitons also answers the dilemma for general relativity faced by Einstein —Why doesn't the universe collapse from its own gravity? If these hypothetical gravitons have a finite cross-sectional area, then they can only travel a finite distance, however great, before colliding with another graviton. So the range of the force of gravity would necessarily be limited in this way. Curiously, if the mean flight distance between collisions for gravitons was about 2 kiloparsecs (about the diameter of the core of many galaxies), then the limited range of the force of gravity would give rise to a change in the inverse square force law over distances larger than 2 kiloparsecs. The predicted form of this change happens to imitate just what we observe in the behavior of galaxies that has led big bang astronomers to hypothesize the existence of "dark matter" in ever greater quantities to account for the rotation and clustering of galaxies on these large scales. In other words, if this graviton conjecture is correct, there would be no need of invisible dark matter to explain large-scale behavior of dynamical systems. More details of this alternative model are published elsewhere by this author (Van Flandern 1993a).

What of the cosmic microwave radiation and the light element abundance predictions, often touted as successful predictions of the big bang model? These points have been critiqued in detail elsewhere (Van Flandern 1993b), and that discussion is beyond the scope of this paper. To make a one-sentence summary about each point: The big bang made no quantitative prediction that the "background" radiation would have a temperature of 3 degrees Kelvin (in fact its initial prediction was 30 degrees Kelvin); whereas Eddington in 1926 (Eddington 1926) had already calculated that the "temperature of space" produced by the radiation of starlight would be found to be 3 degrees Kelvin. And no element abundance prediction of the big bang was successful without some *ad hoc* parametrization to "adjust" predictions that otherwise would have been judged as failures.

As a final note on the question of the universe's expansion, it should not be forgotten that it is not even certain that the universe is presently expanding (as opposed to contracting) even within the context of the big bang theory. Sumner (1994) has recently argued that the new space introduced by the expansion must dilute the permittivity of the vacuum, which in turn must alter the frequency of electrons around atoms. This affects observed redshifts twice as strongly as the speed of expansion. When this consideration is factored into the equations, it turns out that the present universe is actually collapsing, not expanding, under big bang premises!

So we see that, despite the widespread popularity of the big bang model, even its most basic premise, the expansion of the universe, is of dubious validity, both observationally and theoretically.

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