Craig White

THE FATE OF THE UNIVERSE -- OPEN OR CLOSED?

Robert A. Ginskey

Albert Einstein once observed that "The most incomprehensible thing about the universe is that it is comprehensible." Not everyone would agree with that statement, for although man has been fascinated by the grandeur and mystery of the universe for many millennia, it's ultimate size, structure, and origin has remained an intriguing but unsolved riddle.

Historically, it appears that every culture has created a myth to explain the nature of the cosmos. The Greeks intertwined the creation of the world with the whims and family disputes of the gods. Our more sophisticated civilization may also have generated some myths of its own, impelled by our conviction that physical laws are universal and our hope that the universe, on a grand scale, is fundamentally simple and, as Einstein believed, comprehensible.

One is reminded of the words of Plato, when he wrote in the Timaeus, "If then, Socrates, in many respects concerning many things -- the gods and the generation of the universe -- we prove unable to render an account at all points entirely consistent with itself and exact, you must not be surprised. If we can furnish accounts no less likely than any other, we must be content."

A Static Universe

From ancient times until only half a century ago, the prevailing cosmological belief was that the universe must be unchanging. The universe, according to conventional wisdom, was essentially static -- a system of planets, stars, and nebulae which, in the large, was somehow held in a fixed and orderly arrangement. Indeed, when Einstein first propsed his relativistic model of the universe, he added a special factor known as the Cosmological Constant, which in effect, allowed the universe to remain static.

Then, in the late 1920's, astronomer Edwin Hubble discovered that in every direction all the distant galaxies appeared to be moving away from the earth. This conclusion was based on the famous "red shift" in the spectrum of the light coming from the galaxies -- a shift that was (and still is) most plausibly explained in terms of a corresponding velocity (i.e., a Doppler shift).*

When Hubble plotted the estimated distances to the various galaxies as a function of their apparent velocity (as implied by the "red shift"), he found an amazing correlation: the more distant a galaxy, the greater its velocity. The implication was clear. The universe was not static; the universe was expanding.

But if the universe was expanding, it must have been smaller in the past. By working backwards in time, it was easy to show that the universe must at one time have been highly compressed. From such reasoning came the concept that the universe started from a great explosion, some billions of years ago. George Gamow put it more aphoristically: the universe began with a Big Bang.

Steady State

Of course, other models for the expanding universe were also possible. Fred Hoyle, for example, accepted the expansion of the universe (the evidence seemed overwhelming), but he argued that new matter may be constantly introduced (by some as yet unknown process) so that new galaxies are constantly being formed. Thus creation was viewed as a "continuous process", and a specific unique "origin" of the entire universe was precluded.

Philosophically, Hoyle's Steady State cosmology had a great appeal. There was something very satisfying in the concept that the universe was eternal, having no beginning and no end. The theory also avoided the knotty problem of what the universe was like <u>before</u> the beginning, as well as the embarrassing conudrum of how the universe was able to achieve the highly compressed state needed for the Big Bang cosmology.

---

* The red shift $Z = \frac{\Delta\lambda}{\lambda} = \sqrt{\frac{1+v/c}{1-v/c}} - 1$ where λ is the wavelength, v is the velocity, and c is the velocity of light. For $v \leq 10^9$ cm/sec, $Z \approx \frac{v}{c}$, or $v=cZ$.

During the 1960's, however, the Steady State theory was severely discredited as a great deal of new evidence came to light.

First, an extension of Hubble's observations of the expanding universe clearly implied that the expansion must have begun at a definite time in the past about 10 billion years ago. Second, the older star clusters also seemed to be about 10 billion years old. And finally, radioactive elements appeared to have been in existence about 5 to 10 billion years. The agreement of three diverse methods appeared to be a striking corroboration of the Big Bang model.

Another major blow to the Steady State theory was the discovery, in 1956, of the so-called cosmic background radiation. This 2.7°K radiation appears to fill all of space in every direction. The radiation predicted by Robert Dicke as a remnant of the original Big Bang, and its discovery was a powerful confirmation that the Big Bang model is correct.

Other observations on the numbers and locations of radio sources and quasars further undermined the credibility of the Steady State theory. The result was that by the 1970's, virtually all astronomers had concluded that the Steady State was wrong and that the Big Bang was essentially correct.

There remained, however, a perplexing question. Would the universe expand forever, or would it eventually stop expanding and collapse, perhaps to be reborn in another Big Bang?

Open vs Oscillating

If the universe expands forever, this obviously implies that the creation of the universe was a unique, one-shot affair. The universe was created at a definite time in the past -- some billions of years ago -- and is now in the process of expanding to infinity. We therefore, live at a unique moment in the history of the cosmos.

On the other hand, if every expanding phase of the universe is eventually succeeded by a contracting phase, which is followed with an expanding phase, *ad infinitum*, then the concept of a unique creation event loses all meaning. Such an "Oscillating Universe" has much the same philosophical attraction as the Steady State. Indeed, astronomers have found the Oscillating Universe theory so elegant, so attractive, and for some reason, so comforting, that they often comment on the compelling "theological" arguments for such a universe.

Actually, the implications of a perpetually Oscillating Universe are profound, especially as they relate to the Theory of Evolution. In effect, an Oscillating Universe would totally demolish all arguments against evolution which are based on probability.

The logic is as follows: (1) if the universe contains a finite amount of matter (or more correctly mass-energy), and (2) if the universe is endlessly oscillating (i.e., if the universe is infinitely old), then (3) since there is only a finite number of combinations for a finite number of atoms, it follows that (4) every conceivable combination must eventually be repeated an infinite number of times!

Eternal Recurrence

This is not a new concept. In fact, the philosopher Friedrich Nietzsche developed this principle in his "Doctrine of Eternal Recurrence," a notion which he had encountered in the Pythagoreans. Nonetheless, the point is that no matter how improbable an event, (other than "0" probability), if we consider an infinite number of relevant trials, the event becomes an absolute certainty.*

It is interesting that while secular astronomers may consider an Oscillating Universe a philosophical and even a theological necessity, religious fundamentalists must view the potential implications of an Oscillating Universe with a certain amount of skepticism if not consternation.

---

*For man (and perhaps other living systems) it could be argued that the probability of evolution by purely physical causes is, in fact, zero (cf. the spirit in man). In this case, the Doctrine of Eternal Recurrence would be clearly invalid.

Critical Parameters

We are faced, therefore, with a most intriguing question. Is the universe in fact "open", will it expand indefinitely? Or is the universe "closed", will it eventually fall back on itself? To resolve the question, two critical parameters must be known: (1) the rate at which the universe is presently expanding (i.e., the Hubble constant, H_o), and (2) the rate at which the expansion is changing (i.e., the deceleration parameter, q_o). If both these factors can be ascertained (assuming the Cosmological Constant is zero), then the past, present and future of the universe can be determined.

The rate at which the universe is presently expanding can be calculated if we know both the velocity and distance of a series of galaxies. The velocity is fairly easy to obtain, since all one need do is measure the spectrum of the galaxy and then calculate the corresponding velocity via the red shift.

By contrast, there is no straight forward way to measure the distance of a galaxy. Cepheid variable stars can be used for a few of the nearby galaxies. The luminosities of the very brightest stars in galaxies can also be used as distance indicators. Bright ionized hydrogen clouds found in many galaxies can be used to extend the distance yard stick still farther. And finally, the brightest galaxy in a cluster of galaxies may be used as a measure of distance. But none of these approaches is without its difficulties.

In the past few years, Sandage and others have painstakingly developed these distance estimating methods to a relatively high level of reliability. Plugging in the red shift determined velocities, a value of Hubble's constant equal to 55±5 kilometers per second per megaparsec is obtained.

It is interesting that this value is about 1/10 the original value obtained by Hubble some fifty years ago, a fact that has lead some observers to refer to "Hubble's variable."

Note also that Hubble's constant has units of reciprocal seconds. Its reciprocal thus gives an estimate of the age of the universe, a fact we will again encounter.

First, however, we must examine the second factor needed to determine the future fate of the universe. That factor is the deceleration parameter, q_o. In order to understand the significance of the deceleration parameter we need to remember that in the Big Bang model of the universe, the expansion is expected to slow down with the passage of time as the initial velocities of the different parts of the universe are slowed down by their mutual gravitational attraction. The universe acts somewhat as does a ball thrown upward from the surface of the earth. The ball slows down, stops, and eventually falls back to earth. If it is thrown with greater initial velocity, it travels farther before falling back. But, if the initial velocity is greater than what is called the "escape velocity", then the ball will never fall back but will travel upward forever, decelerating continually as it goes, but never coming back.*

If the planet from which the ball is thrown is more massive than the earth, we would expect its gravitational attraction to be greater and thus the escape velocity would be greater. For the expanding universe, a similar analysis applies: there is the possibility that the expansion will stop and eventually reverse itself, or, that it will continue indefinitely.

Obviously, the deciding factor is whether there is enough mass in the universe so that gravitational attraction will eventually overcome the expansion. The amount of mass in the universe is clearly related to the average density of the universe, which is in turn directly related to the deceleration parameter. It turns out that the "critical density" needed to eventually stop the universe's expansion is about 6×10^{-30} gm/cm^3 or about four hydrogen atoms per cubic meter. This number may seem incredibly small, and indeed, it represents a far better vacuum than the most sophisticated scientific instruments can produce. But the universe is inconceivably large, so the total amount of matter represented by such a density is very great. The point is this: if the density is smaller than the critical value, then the escape velocity is lower than the velocities we observe and the universe will

---

*Thus, we have an exception to the rule, "what goes up must come down."

expand forever; conversely, if the density is higher, the universe will eventually contract, and everything will be squeezed in what some astronomers call The Big Crunch!

Measuring the Mass of the Universe

But how do we find the mass or density of the universe and the value of the deceleration parameter? Probably the most obvious method is to simply count up all the galaxies we can see and estimate their mass. The astronomer J.H. Oort did just that about fifteen years ago, and found that the mass of all the matter in galaxies was only about 1% of the amount needed to "close" the universe. Since that time, many researchers have attempted to find "the missing mass."

However, before discussing their results, we need to note a very important relationship, namely, that the ratio of the observed density of the universe divided by the critical density is equal to twice the deceleration parameter. From this fact, it follows that when the observed density is equal to the critical density, the q_o is equal to 1/2. If the observed density is less than the critical density, the q_o will be smaller than 1/2, and the universe will be "open". On the other hand, if the observed density is larger than the critical density, q_o will be greater than 1/2, and the universe will then be "closed".

Using this relationship, we can appreciate the results of some fascinating work that astronomers have recently completed. J.R. Gott and others have made refined measurements of the mass of galaxies. Their "dynamical" method implies that galaxies may have a great deal of mass that telescopes cannot see. Yet, even with this more exact method, the density of the universe is still nowhere near the critical value. In fact, the density they find is only about 5% of the critical value, which means that q_o is 0.025 (well below the critical value of 1/2 or 0.50).

Other studies indicate that galaxies are associated with an amount of mass some ten times larger than the mass in the visible parts of the galaxies themselves, but that this mass is still at least ten times too small to stop the expansion of the universe. Of course, there is always the possibility that additional mass exists between the clusters of galaxies, but so far no one has been able to detect an appreciable amount.

Another method for estimating the mass and density of the universe makes use of the theory of nucleosynthesis of the elements in the high-temperature, high-density conditions that presumably prevailed in the very early history of the universe. The method is based on the concept that the element deuterium (a form of hydrogen with one proton and one neutron) was presumably made in the early history of the universe, as were a number of other elements. But the abundance of deuterium is highly sensitive to the density prevailing during nucleosynthesis. In other words, if we knew the present abundance of deuterium, we could calculate the original density of the universe, which would in turn give us a good idea of what the present density is. Schramm and others have used the Copernicus satellite to measure the amount of deuterium in interstellar space. They find that the density corresponding to the observed amount of deuterium is very low, yielding a value of q_0 between 0.03 and 0.05. Again, the experiments indicate that universe is open by a wide margin.

An Oscillating Universe?

But if all these measurements indicate that the density of the universe is small, and that q_0 is small, and that the universe will thus expand forever, then why is it that astronomers have often considered the universe to be "oscillating" and thus "closed"?

The answer is that for years, Sandage and other astronomers used the so-called "classical" method of determining q_0. This method was simply a plot of dimness (distance) of galaxies against red shift (velocity). If the universe acts like an explosion, we would expect a straight line for such a plot, the dimmest objects -- those farthest away -- having the greatest velocity (red shift).

However, when we view distant galaxies, we are actually looking back in time. We see the galaxies as they were billions of years ago, travelling at very high velocities because they haven't yet been slowed down by the gravitational attraction of the rest of the universe. Therefore, the distant galaxies should show a deviation from the expected red shift, i.e. their red shifts should be too high for their distance, when compared with nearby galaxies.

By measuring these deviations, Sandage was able to calculate the amount of deceleration the universe has experienced. Sandage obtained values of q_o greater than 1/2, or more specifically 1.0 ± 0.5. In other words, the universe appeared to be slowing down rapidly, and ultimately it was expected to reverse its motion and collapse (and possibly begin another oscillation).*

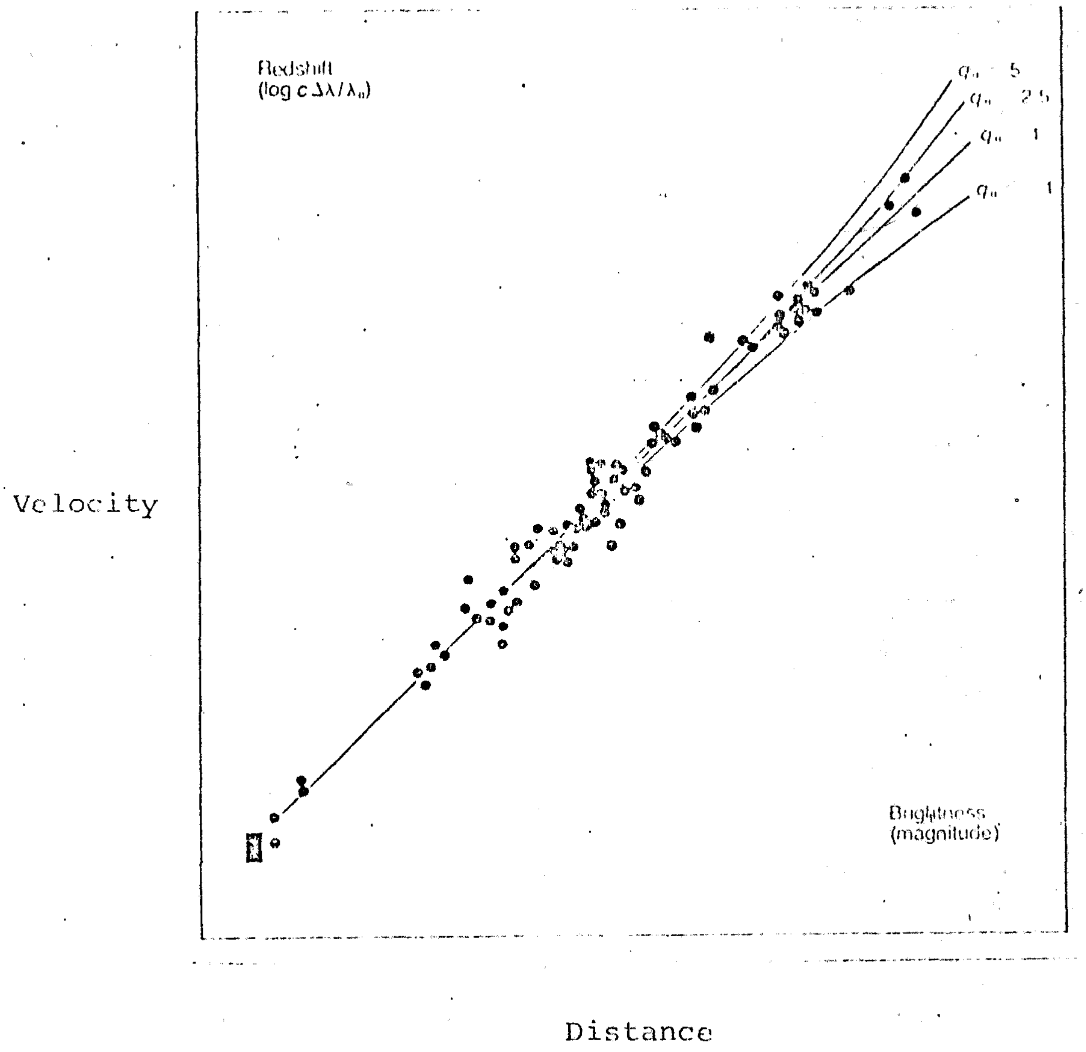
Unfortunately, Sandage's method makes a very tenuous assumption: it assumes that the brightness of galaxies does NOT change over their lifetimes. But if galaxies evolve and get old, then they were probably brighter in the past, when their stars were still young and bright. Therefore, the distant galaxies we see may actually be farther away than we thought. This implies that their red shifts may not be disproportionately higher than nearby galaxies and that the universe has NOT been slowing down appreciably. When we adjust Sandage's calculations to take this effect into account, we obtain a value for the deceleration near 0. Again, the universe appears to be open.**

---

*It has been argued that an oscillating universe cannot exist because if the universe collapses, it will disappear down its own black hole and never reappear. Recently, however, theoreticians have asked whether quantum phenomena might not play the role of a _deus ex machina_ who saves the universe from its ultimate fate. They further speculate that a cosmic uncertainty principle may be operative at the near infinite densities encountered in universal collapse, and that such phenomena could result in totally different laws of nature when the universe re-emerges.

**M. Schmidt and others have argued that large galaxies "eat" small galaxies, thus counteracting the evolutionary dimming described above. At present, however, the dimming hypothesis seems more plausible.

THE MODERN HUBBLE DIAGRAM



Shown above is an illustration of Hubble's red shift-distance relationship, as extended by Sandage to the brightest galaxy in each of 84 galaxy clusters. (The original Hubble data would lie within the small box in the lower left-hand corner!) In principle, the velocity-distance relationship so determined allows the value of the deceleration parameter, q_0, to be deduced. If q_0 is less than 1/2, the universe is open; if q_0 is greater than 1/2, the universe is closed. However, theoretical as well as experimental uncertainties make any such determination extremely difficult.

More recently, Sandage has measured the effect of local anisotrophy in the distribution of galaxies: there are up to four times as many galaxies brighter than magnitude 13 in the direction of the north galactic pole as there are in the south. If the matter in the universe really does affect the expansion rate, then we might expect the rate to be smaller in the direction where the density is higher. Sandage has measured the Hubble constant in both directions, however, and finds no measurable difference. Thus, he concludes that the expansion of the universe is too rapid to be noticeably decelerated by gravitation, and he infers that q_o is equal to or less than 0.28. Once again, the universe appears to be open.

Still another approach is to see whether the age of the universe as estimated from Hubble's constant is larger than the age of the universe based on other methods. The "Hubble age" of the universe is about 18 billion years (the reciprocal of H_o). But the expansion of the universe was presumably faster in the past and therefore, the true age of the universe is smaller than the Hubble age. The ratio of these two ages is a measure of q_o. Thus, if the true age of the universe were known, it would be possible to estimate q_o. As a lower limit for the age of the universe, astronomers use the age of the oldest globular clusters in our galaxy, which are estimated to be about 14 billion years old. On this basis, q_o is 0.35 -- still too small to close the universe.

Furthermore, it is unlikely that globular clusters formed immediately after the Big Bang. From observations of distant quasars (objects apparently at the very edge of the observable universe), the conclusion can be tentatively drawn that about 4 billion years elapsed between the beginning of the expansion of the universe, and the formation of the oldest globular clusters. Thus, the universe is at least 18 billion years old, or roughly the same age as the Hubble constant would indicate. Sandage and Tammann derive a value of q_o equal to 0.03. Such studies point to one conclusion: the universe will end not with a Big Bang, but with a whimper.*

---

*Indeed, recent data indicate the universe is not only open, but accelerating in its expansion! This implies that Einstein's (repulsive) Comological Constant may not be zero afterall. Says James Gunn, "most relativists find it [the Cosmological Constant] repulsive on principle rather than by observation."

A Caveat

Yet in spite of the impressive evidence, a caveat must be made. Although many cosmologists are now tilting toward the open universe, it seems premature to close the case! We cannot insist that the universe MUST be open. There are so many uncertainties and assumptions that must be applied to even the best data, that no one can yet be dogmatic. Indeed, with so many of the conclusions resting on observations at the very limits of our ability to measure the universe, it should not come as a surprise if new data dramatically alter our present conclusions.

On the other hand, we cannot escape the fact that, at present, a wide variety of arguments strongly suggest that the density of the universe is no more than a tenth of the value required for closure. If, indeed, the universe is open;. if, without God's intervention, the universe will expand indefinitely; and if therefore, the universe had a definite beginning at a unique creation event; then it follows that probabilistic arguments against the theory of biological evolution are indeed valid.

Man's Inheritance

In addition, an open, ever expanding universe is highly suggestive of man's inheritance and his ultimate potential, as revealed in scripture. Unless we wish to eventually stop the expansion of the God family, and limit its scope, the concept of an infinite and growing universe would seem essential. If man's ultimate inheritance is to inhabit and govern an infinite universe, then perhaps we can perceive an added dimension in the words, "Come, inherit the kingdom, prepared for you from the foundation of the world."

BIBLIOGRAPHY

Gott, J.R. et al, "An Unbound Universe?", *Astrophysical Journal*, *194*, 543, 1974.

Gunn, J.E., "Will the Universe Expand Forever?", *Mercury*, p. 4, November/December, 1975.

Gunn, J.E., and Tinsley, B.M., "An Accelerating Universe," *Nature*, *257*, 53, 1975.

Hodge, P.W., *Concepts of the Universe*, McGraw-Hill, 1969.

Hubble, E.P., *The Realm of the Nebulae*, Yale University Press, 1936.

Kaufmann, W.J. *Relativity and Cosmology*, Harper and Row, 1973.

Morrison, D., and Morrison, N.D., "An Infinitely Expanding Universe," *Mercury*, September/October, 27, 1975.

Morrison, D., and Morrison, N.D., "The Expansion of the Universe," *Mercury*, p. 22, July/August 1975.

Partridge, R.B. "The Beginning and the End of the Universe," *Science Teacher*, p. 24, May 1975.

Sandage, A.R., "Cosmology: A Search for Two Numbers," *Physics Today*, February 1970.

Sandage, A.R., and Tammann, G.A., and Hardy, E., *Astrophysical Journal*, *172*, 253, 1972.

Sciama, D.W., *Modern Cosmology*, Cambridge University Press, 1971.

Shapiro, I.I., "The Universe: An Open or Close Case?", *Technology Review*, p. 65, December 1975.

"The Infinite Universe," *Time*, p. 48, December 30, 1974.

Thilly, F., and Wood, L., *A History of Philosophy*, Holt, 1959.

"Universe Expansion; Accelerating?", *Science News*, *107*, 285, 1975.

Weiss, R., "The Oldest Fossil," *Technology Review*, p. 57, December 1975.