WHAT IF THE BIG BANG DIDN'T HAPPEN?

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Most astronomers believe that the Universe is expanding and that it was created in a hot big bang. Indeed, much of modern physics rests on the concept that all known fundamental particles and forces came into being seconds after the big bang. But what evidence do we have in favor of the big bang? In fact, the big bang hypothesis (BBH) rests only on three observations: (i) the red shift (RS), (ii) the spectrum of the microwave background (MB), and (iii) the light element abundances.

Hubble's law (HL) observes that the RS of a galaxy is directly proportional to its distance. Before Hubble, Friedman had used Einstein's equations to propose that the Universe is expanding. Hubble's observations, therefore, provided dramatic confirmation of the prediction based on general relativity. The notion of the BBH is based on Friedman's model.

In the early 1950's, Gamow, Alpher and Herman suggested that the BBH implies that there should be a relic black body radiation with $5<T<7$K from the early hot epoch when the Universe was barely a second old. In 1965, Penzias and Wilson came across this MB at 3K, thus confirming a theoretical prediction.

The final observation in support of the BBH is that the amounts of He, D and the light elements in the Universe agree with predictions based upon a hot big bang.

However, it may not be foolhardy to question the validity of the BBH. About a year ago, Arp, G. Burbidge, Hoyle, Wickramasinghe and I met in Cardiff to review the current status of the BBH (see Nature, August 1990). We first examined the HL. There is no unambiguous way of estimating the distance of a galaxy. Sandage has shown that the surface brightness of a sample of nearby galaxies related to the RS confirms HL. The quasars, most of which have much higher RS's, however, raise new questions.

A plot of apparent faintness versus RS for quasars reveals no linear correlation. To verify this, it is necessary to directly measure the distances to the quasars. Some quasars appear to be physically attached to a galaxy, perhaps by a "bridge" of gas and dust. If a galaxy obeys HL, then its companion quasar should do so as well. Indeed, some quasars seem to lie at the centers of the galaxies and, according to conventional theory all quasars are the active nuclei of galaxies. But it is very difficult to measure the RS of a galaxy surrounded by a quasar because the instruments are swamped by light from the quasar itself. It is easier to compare the two RS's if the quasar and the galaxy lie side by side. Stockton (1979) chose 25 nearby quasars, and looked for galaxies near them. He measured the RS of the galaxy (if found) and called it a "success" if its RS was similar to that of its neighboring quasar. He recorded 13 successes with a probability that the two are chance juxtapositions at 1.5×10^{-6}.

The RS's of the quasars and the galaxies were quite different for the 12 "failures" that Stockton ignored, which illustrates the weakness in this line of approach both for and against HL. Over the years, many such discrepant cases have been reported and ignored until a new phenomenon called gravitational lensing seemed to offer a plausible explanation. The lensing can occur on a "large" scale where the light bending agent is a galaxy or on a "micro" scale where it may be a star in a galaxy. In spite of early hopes, it is now becoming difficult to explain these anomalies with lensing.

Another more serious difficulty is that the MB is much too smooth. Observations show that matter in the Universe is in the form of galaxies grouped into clusters and superclusters with long filamentary stretches and giant voids in between. When these structures formed in the early Universe, they should have left an imprint on the MB. So far, COBE, the satellite currently studying the MB, has found no unevenness in the MB. These observations pose a serious problem for the BBH. Avoiding confrontation with observations is scarcely the hallmark of a good theory.

Another aspect is that the big bang cosmologists have invoked the notion of dark matter in the early Universe to provide the gravitational force necessary to cause matter to coalesce into galaxies and clusters of galaxies. Theoretical particle physics has provided a rich menu of dark matter candidates, none of which has been detected in accelerators on Earth.

Current BBH also requires the Universe to have undergone an "inflationary" phase at age $t \approx 10^{-36}$ s. This phase sets the initial conditions for the Universe. In particular, it gives the present age of the Universe to be 6.5-13 billion years. This may be compared with the ages of the oldest stars, 13-17 billion years, and ages of the elements, 12-16 billion years. It seems that the Universe is just not "old enough" to accommodate its constituents. There is also a problem at the "young" end of the galactic age range. As we saw earlier, in discussing dark matter, the BH is still grappling with the problem of how galaxies and galaxy clusters are formed. Most theories predict that they formed within a relatively short period and are about 10-15 billion years old, implying that we should not be seeing any young galaxies now. The surveys of the Infra Red Astronomy Satellite (IRAS), however, show several cases of galaxies that are "young" in terms of stars found within them. The BBH offers no explanation of why the galaxies should still be forming. Rather, the notion of young galaxies co-existing with older ones fits more naturally into the framework of the steady state hypothesis (SSH), in which matter is continually created and new galaxies form all the time.

The debate between the SSH and the BBH has centered mainly on the concept of evolution. We might consider using the RS to decide the issue, provided it is an indicator of cosmological time. The RS's of the quasar population do appear to show evidence of evolution. But if the RS of a quasar is not entirely due to the expansion of the Universe, it cannot be used as a basis for asserting evolution. So it is significant that recent work of DasGupta shows that the SSH is consistent with the results obtained from counting radio galaxies (RG's), ie, the number of RG's detected in any chosen volume of space is constant. Because light travels at a finite speed, this means that the density of RG's was the same long time ago as it is now, ie, the Universe is not evolving. Given these problems we should

explore other possibilities for a healthy growth of cosmology. Let us consider some alternatives.

First, the MB could have been of more recent origin. What it requires is a population of particles that absorb microwaves but are nearly transparent to optical and radio waves. These particles, distributed throughout intergalactic space, serve to absorb and redistribute any radiation in the MB. Recent work on cosmic grains, small particles of iron, carbon and the like found in interstellar space, has turned up a promising candidate. Calculations show that such particles could very efficiently wipe out any unevenness in radiation.

The anomalous RS's of the quasars can be explained using a theory of relativity that Hoyle and I developed. This theory depends on Mach's principle, whereby inertia of matter arises from its interaction with other matter in the Universe, and may increase with the age of matter. Thus, any particle just created starts with zero inertial mass and acquires mass as it grows older via interactions with increasingly many particles in the Universe. Because the effect is universal, a hydrogen atom of young matter will have a smaller inertial mass and so its spectral lines will be red shifted. This approach could explain why some quasars have much larger RS's than their galactic partners. The quasars could have been created from an older galaxy in a process of "mininucleation". As the quasars grow old, the discrepancy in RS gradually diminishes.

On a larger scale, clusters and superclusters of galaxies form through local creation events. This scenario forms a bridge between the BBH and the SSH. It has the advantage of a natural link between the local explosions observed in quasars, galaxies where stars are actively forming, and cosmology. Perhaps the strongest point in favor of this alternative is that it brings cosmology within the scope of the physics and astrophysics of the Universe as it is today. By contrast, the BBH relegates most observable features of the Universe such as the MB and formation of galaxies to remote past. The BBH relies upon esoteric forms of matter not found in the laboratory to explain how the Universe got to be the way it is. Most disturbing is that the scenarios proposed are supposed to have happened only once, not being repeatable as required by the norms of science. Our alternative scenario does not claim to be the last word but it deserves further critical appraisal as an alternative to the BBH.