ISSN: 2641-886X

International Journal of Cosmology, Astronomy and Astrophysics

Opinion Article

Open Access

Why can't Cosmology be more open?

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Article Info

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Received: November 5, 2018
Accepted: November 15, 2018
Published: January 2, 2019

Citation: Narlikar J. Why can't Cosmology be more open? *Int J Cosmol Astron Astrophys.* 2019; 1(1): 1-3.
doi: 10.18689/ijcaa-1000101

Keywords: Cosmology, Galaxy, Big Bang, Spectrum

More than two millennia back, Pythagoreans believed that the Earth went round a central fire, with the Sun lying well outside its orbit. When sceptics asked," Why can't we see the fire?", theorists had to postulate that there was a 'counter-Earth' going around the central fire in an inner orbit that blocked our view of the fire. The sceptics asked again: why don't we see this 'counter-Earth'? The theorists replied that this happened because Greece was facing away from it. In due course this explanation too was also shot down by people sailing around and looking from other directions.

I have elaborated this ancient episode because it holds a moral for scientists. When you are on the wrong track, you may have to invoke additional assumptions, like the counter-Earth, to prop up your original theory against an observed fact. If there is no other independent support for these assumptions, the entire structure becomes suspect. The scientific approach then requires a critical re-examination of the basic paradigm.

Begin at the beginning

By mid-1920s astronomers had begun to appreciate the fact that our Milky Way Galaxy has more than a hundred billion stars and that the universe observed through the best available telescopes has many such galaxies. A daring attempt to mathematically model this large system was made by Albert Einstein through his 1917 paper [1]. He believed that the universe is static with its major components at rest. In order to arrive at this, he had to modify his equations of general relativity to include a *cosmic force of repulsion*. However, Alexander Friedmann [2] during 1922-24 and Abbe Lemaitre [3] in 1927 independently arrived at models of the *expanding universe* using Einstein's equations.

Is the universe static or expanding?

A major observational advance resolved this question when Edwin Hubble [4], used the then largest telescope (2.5 metre) from Mount Wilson in California, to find that almost all galaxies observed seemed to be receding from the Milky Way in a systematic fashion with radial recession velocity of a galaxy increasing in proportion to its distance from us. In short, the universe was not static; it seemed to expand exactly as suggested by the models of Friedmann and Lemaitre.

Given the success of the expanding universe picture, scientists followed it further to suggest that the universe had a beginning in a gigantic explosion. This explosion was concentrated within a very small volume, literally a point, and the expansion was the aftermath of this primordial event. That event is popularly known as the *big bang*. The laws of science so far understood were then applied to this system. However, this exercise has met with mixed success.

As first argued by nuclear astrophysicist George Gamow [5] in the 1940s, the closer the universe is to the big bang, the hotter and denser is it. This led Gamow to propose that during the period around 1-200 seconds after the big bang, the universe was hot enough to serve as a nuclear fusion reactor. Gamow hoped to show that most chemical elements we see today were synthesized in that period as neutrons and protons came together.

However, this hope was not translated into reality. Constraints of nuclear physics and the rapidly changing conditions of the expanding universe allow only some light nuclei like deuterium, helium and lithium to form [6]. That too is possible only if the neutrons and protons satisfy certain physical conditions.

Even so, the abundance of light nuclei in the universe is consistent with these theoretical estimates. Moreover, as Gamow's younger colleagues Ralph Alpher and Robert Herman [7] predicted, the hot radiation then present would leave behind a relic background, albeit very cool today owing to the continued expansion of the universe. This 1948 prediction was borne out in 1965 by the discovery of the microwave background by Arno Penzias and Robert Wilson [8]. This background has been extensively studied and it shows (as predicted) a black body spectrum with a temperature of 2.73 Kelvin. In hindsight, however, one can say that this background had been observed as early as 1941 by McKellar [9] through stellar spectroscopy.

Thus by the late 1960s most cosmologists were convinced that the big bang model is basically a correct description of the universe. Most work in cosmology in the last three decades has centred on establishing this belief as fact. To this end cosmologists have concentrated their efforts in many 'problem areas', building on Gamow's pioneering work. These problem areas include an understanding of the large scale structure observed in the universe, the early physical processes that left their imprints on the microwave background, the origin of subatomic particles, knowing why the universe today is dominated by matter over antimatter, knowing why it is so homogeneous and isotropic and above all trying to assess the physical conditions in the very early stages when many physicists believe the basic forces of nature acted in a unified framework [10].

From facts to speculation

This ambitious agenda presented a challenge to the best intellects available today. Theoretically, a unified framework for physics lies in the realm of speculation. For, the particle energies (1000 GeV) produced by the best man-made accelerators today fall well short of the high energies (10^{16} GeV) needed to test such grand unified theories. Direct astronomical observations of the distant universe go back to epochs when the linear size of the (expanding) universe was about a tenth of the present size.

Theory tells us that even if we had far more efficient telescopes, we would hit against an optically opaque wall erected by the radiation background at past epochs when the linear size of the universe was smaller than a thousandth of its present size. The current theories about the very early universe take us back to epochs when the universe was 10^{-28} of its present linear size! In short, cosmologists are speculating about the state of the universe that is not only astronomically unobservable, but to which no tested physics can be applied. One may still indulge in a study of the very early universe, as an intellectual feat. But one must be conscious that such an exercise is highly speculative and not testable as most standard physical theories are.

Unfortunately, by describing the present model of the universe as a 'precision' or 'concordance' model [11] an impression is created that the model with its various parameters is the confirmed last word in the subject. Let us take one example. The concordance model describes the breakup of matter-energy content of the universe as 4% ordinary (baryonic) matter that is familiar to us, 23% non-baryonic dark matter and 73% dark energy. All astronomy from planets to clusters of galaxies to date has grown on observations of the baryonic part: there is no direct evidence for the remaining 96%. Certainly there is good astronomical evidence for dark matter; but if it were taken to be all baryonic, then the big bang model faces two serious problems: (1) It cannot explain the observed deuterium in the universe and (2) the microwave background would show far stronger inhomogeneities than actually observed. So to sustain the model one is forced to postulate non-baryonic dark matter for which there is no independent evidence either in astronomy or in the physics labs. Is this not a modern example of the Pythagorean counter-Earth?

Emperor's New Clothes

Likewise, for dark energy there is no independent evidence. It was invoked as a solution for understanding why distant supernovae look dimmer than expected. Have other, more mundane and familiar options to arrive at the results been really exhausted? Or, are theoreticians indulging in an exercise reminiscent of Hans Andersen's satire 'The Emperor's new clothes'?

In the Vatican Conference held in the late 1960s, Fred Hoyle [12], the most imaginative astrophysicist of the twentieth century, wondered if the human brain was capable of understanding all the intricacies of physics and even if it was, whether that stage had been reached in the decade ending in 1970. He made this cautionary comment, because the big bang cosmologists at the conference were making very definitive claims about what the universe is like.

In retrospect, Hoyle's caution seems justified, since the so called last word on cosmology of the 1960s was innocent of non-baryonic dark matter, dark energy, inflation, and all the rest of the paraphernalia that go to make up the present 'last word' on cosmology.

Surely, such a fundamental issue as the origin of the universe requires more careful discussion of the standard model, making room for alternative ideas!

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