COMMITTEE VI
The Universe and Its Origin:
From Ancient Myth to Present Reality
and Fantasy

DRAFT - 11/15/85
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COSMOLOGY: OUR KNOWLEDGE AND IGNORANCE

by

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DISCUSSION PAPER

on

Hong-Yee Chiu's

COSMOLOGY - MODERN VIEWS

The Fourteenth International Conference on the Unity of the Sciences
Houston, Texas   November 28-December 1, 1985

Hong-Yee Chiu's paper about modern cosmology is very good. It is a summary of the prevailing picture of the universe, shared by most of the present workers in this fascinating field, and it includes some brief background about history and observations. The paper needs only few critical remarks, thus I want mainly to give some additional comments and different view points.

In their attitude toward cosmology we have three groups of scientists. First, the daring spirits who ask what kind of universe is possible on general grounds, yielding various model universes. Second, the observers want to stay a bit closer to what can actually be seen, but trying hard to push our observational limits ever further out. Third, some sceptics choose to regard the results of the first group as mere speculations, and those of the second one as misinterpretations of observing errors. In the end, all three attitudes and their interaction are needed in our search for the truth. Since I know Chiu as a good theoretician of the first group, I will put more emphasis on the difficult, the unknown, and the odd sides of cosmology.

The difficulties are fourfold (partly mentioned by Chiu, too). First, our observation has technical (or financial) limitations: limited size and quality of telescopes and equipment, and either severe degradations by looking through our atmosphere, or extreme expenses for space telescopes. Second, the universe has basic observational limts: cosmic background noise (galactic, finite energy of single photon, three-degree, faint background sources); and most world models have a finite "particle horizon", which is the maximum distance a photon can have travelled, from the beginning to the present. Obviously, nothing is observable beyond our horizon, and even nothing near it, since objects close to our horizon approach infinite redshift and zero brightness. Third, we want to ask well defined single questions, but the observational answers are always an odd threefold mixture: looking far out into space (asking for its curvature for example) we necessarily look far back into the past (where all may have been very different), and we do not observe the universe but only its objects (which usually had quite a history of their own). Disentangling this mixture is one of our main problems. Fourth, although it is reassuring and by no means trivial that we see the same kind of matter obeying the same laws of physics as here on Earth, as far out in space as we can see, we do know that all this cannot be applied to the very early phase of the big-bang with its so extremely high density, temperature and pressure. New laws and states of matter must be guessed, with more or less confidence but no certainty. I would like to add that the very beginning of the big-bang, as a "singularity", is just as little understandable as the internal state of a black hole (for a co-moving observer) after the gravitational collapse is finished.

Because of these and some more difficulties, we actually know only rather little about our universe. We know it expands, but the rate of expansion versus distance, the Hubble parameter, is not just 75 km/sec per megaparsec as quoted by Chiu, our best observers still disagree whether it is only 50 or even 120. This uncertainty of the cosmic distance scale, of a factor two, yields by itself an uncertainty of a factor $2^3=8$ for the cosmic density, regarding the observed galaxies. But the average galactic mass is also uncertain by at least a factor four (curves of rotational velocity indicate a lot of thinly distributed mass in the outer parts), making such a simple question as the observed average density uncertain by at least a factor 30. And on top of that we have the indication for, and uncertainty of, the "missing" dark mass as discussed well by Chiu.

It gets even worse if we go one step further, asking for the change of the expansion, the deceleration parameter q. Present observations of redshift versus distance can limit it at best to about $0\leq q\leq 1$, a large range of uncertainty.

The next question, omitted by Chiu (and by some but not all experts), is that of the "cosmological constant", Λ. It was introduced by Einstein for two independent reasons: to enable a static universe (not needed any more after Hubble discovered the expansion), and to enforce Mach's principle in a closed universe (not possible as shown by de Sitter). Although not directly needed, Λ cannot simply be omitted either, because it just is a constant of integration of Einstein's field equations. The only and maybe legitimate reason for letting $\Lambda=0$ is simplicity, but the only solid statement could come from observation. If density, Hubble and deceleration paramter were accurately measured, then the value of Λ would follow from a simple equation. But this is far beyond our present observational possibilities. I should add that the most simple of all world models is the Einstein-de Sitter model, with Λ=0 and q=1/2, and the critical density for parabolic expansion in a flat (uncurved) space.

This calls for a side-remark. Our preference for simplicity and beauty may be a good guideline (especially in lieu of more solid arguments) but its conclusions must be regarded with caution. I do not understand why Chiu dismisses an unbound open universe, with its infinities, as "aestetically unacceptable". The ancient Greeks found nothing but circles aestetically accetable for planetary movements, and steady-state theory was developed for its beauty. Whereas the infinite original density of the big-bang looks to me not more aestetic than an open universe. And, by the way, why talk always only of "total" models? Why not of an open universe, of finite size but so very large that we see only a tiny fraction of it? But back to our observational uncertainties:

We know now fairly sure that radio galaxies at early times were more numerous or more luminous or both, and there also were more quasars. These object-evolutions make the disentangling of the universe from its objects very difficult indeed. But they also yield a strong argument against the steady-state theory, in addition to that from the three-degree background mentioned by Chiu.

Clusters of galaxies are more important than indicated by Chiu, and the degree of clustering of clusters is still being discussed. Latest observations seem to suggest that the largest cosmic features have more the form of filaments, surrounding empty blobs.

In addition to obervational uncertainties, we also have some rather uncomfortable observations which deserve to be at least discussed before being pushed under the rug. Chip Arp has collected a number of close pairs of quasars and galaxies (both mixed and one-typed pairs) which have very different large redshifts. Large redshifts are always taken as a measure of distance, via the cosmic Hubble-expansion, and the two members of such pair then would have very different distances along the line of sight; whereas the closeness of such pair would then only be an apparent one, a chance effect after their projection on the sky. But Arp claims, and his data seem to support it, that the closeness of these pairs and their numbers go far beyond any reasonable chance expectation. This would mean that redshifts are not (or not always) a measure of distance, maybe not even of velocity. Quasars could be nearby and less luminous, but all detailed explanations and models so far have failed. I must leave this an open question.

We have more oddities to deal with. In all our terrestrial experiments, and observations of cosmic rays: if ever matter is created, it is always created absolutely symmetrically with matter and antimatter in equal numbers, each particle simultaneously with its antiparticle. Since we always extrapolate from the lab to the universe, mostly with good success, and since symmetries have high aestetic value, we should assume the same symmetry for the big-bang: simultaneous creation of particles and their antiparticles. But then we have to explain why not just our Earth and solar system, but certainly the whole Galaxy and at least all the local group galaxies, are definitely made up of matter only. Some explanations with a separation of matter and antimatter in large blobs at an early phase have not been satisfactory, but neither is a slight asymmetry at creation. Again an open question.

The origin of the homogeneity and isotropy has been discussed by Chiu: "If we mix a number of different ingredients in a vessel, it takes great efforts to obtain a homogeneous mixture". Since big-bang models have a finite horizon, the earlier the smaller and even going to zero at time zero, there was no time for effective mixing. Chiu then mentions a new "inflationary theory" by Alan Guth, which allows enough mixing during a very early and fast expanding phase of the universe. This, as well as earlier treatments of this so-called mixmaster-problem, tries, in my opinion, only to remove the symptoms of a more basic illness: the zero-horizon at start, which means no causal connection between any two parts of the new-born universe, thus leading to the concept of different ingredients at different places, thus needing mixing. The real problem is not the need for mixing, it is this "common but unrelated origin of all things" as I once called it. It results from zero-horizon, which results from starting the big-bang with infinite velocity. We should look for a model without extreme start velocity. Then a common origin may causally be connected (as it well should) and may produce the "same ingredients" any place in a natural way.

One more oddity, if I may. Before Einstein, a classical or Newtonian cosmology was developed, considering the potential energy (of gravity) and the kinetic energy (expanding universe) of an arbitrary volume of the universe. It was found, depending on the total energy being either positive, or zero, or negative, that there are three types of possible universes: either expanding forever, or coming to a halt after infinite time, or reaching a maximum expansion and then collapsing again. The odd thing is that the results of Newtonian and relativistic models are strikingly similar (at least if $=0$); whereas the basic considerations are completely different. Einstein considers only the rest-mass energy ($E=mc^2$) and the thermal energy (pressure) which both are omitted in Newtonian cosmology, while Einstein omits both potential and kinetic energy, which can be seen from his field equations and the energy-momentum tensor. Let me try a simple explanation: if we compare energies in an arbitrary volume, say a sphere of radius r, then this seems possible only if all considered energies go with the same power of r. Now, the Newtonian potential and kinetic energies go both with r^5, whereas the relativistic rest-mass and thermal energies both go with r^3. Thus, one may do it either way (but should have bad feelings about the omitted parts). The only case where I think no omission is needed is if we consider the total energies of a closed finite universe.

Finally, our inability to answer the basic questions, about space curvature, expansion type and cosmological constant, implies a non-trivial statement: our universe is not too different from the simplest one, the Einstein-de Sitter model, the only one where Newton and Einstein give the same results.