The Unity of the Universe

Remarks to the papers presented in Committee I
by Michael J. Higatsberger

The expressions "big bang" and "big crunch" are paraphrases for the singularities which appear when describing the universe the classical way. It became very soon clear that the classical theory does not extend to t=0 back since this would require an infinite density of the universe and an infinite temperature and thus energy. The big bang singularity occurs, because Einstein's theory of gravity does not hold in a universe of microscopic length and time. Quantum cosmology tries to combine phenomena of length scales from dimensions smaller than 10^{-12} m to lengths greater than 10^{18} m.

Table 1 shows the classical universe versus the quantum universe. The quantum universe does neither extend in time nor in length to absolute zero. From Heisenberg and Planck we know that there exist a smallest length and a smallest time called Planck length and Planck time. The first one is of the order of 10^{-35} m, while the Planck time is of the order of 10^{-43} s. Both can be derived from a combination of natural constants which include c (the speed of light), h (the Planck constant) and G_0 (the gravitational constant).

The Planck length for instance is

$$l_p = (G_0\hbar/c^3)^{1/2} = 1,61599.10^{-35} \text{ m},$$

the smallest time interval one can get by dividing the Planck length by c. A uniton mass and a uniton gravitational charge can be found using the three before-mentioned constants or only two of them.

Does quantum cosmology help to explain the genesis? Yes, because in the earliest moments of creation the universe was microscopic in size, much smaller than an atom. When the classical description has its initial singularities, the quantum universe has an expectation value of the area with l_p^2. 1,5.10^{10} years ago the universe was created. Figure 2 shows the logarithmic time scale from the big bang up to now.

The problems of the standard theory can be summarized as follows:

1. The singularity problem already touched upon.

2. The flatness problem. The only natural length we know is the Planck length 10^{-35} m. Our universe is about flat in a scale of 10^{26} m, the radius of the observable part of the universe. This distance is about 10^{61} times larger than l_p. One is tempted to ask the question, why is our universe so flat? Why is its geometry almost exactly euclidian?

3. The horizon problem confronts us with the fact that the maximum observational distance is limited by the velocity of light.

4. The problem of homogeneity and galaxy formation. Astronomical observations show that in a scale of 10^{10} light years, which is 10^{26} m, the distribution of matter departs from perfect homogeneity by less than one part in a thousand.

5. The uniqueness problem. This problem was formulated by Albert Einstein, who said: "What I am really interested in is whether God could have created the world differently." Small deviations from the natural constants would create different universes, most of them unfavourable for life and unstable.

It is known that Einstein's equations of general relativity have only a limited set of solutions. These equations can describe universes and their evolution with time. Astronomical observations confirm that we live in such a universe. We observe by the red shift a phenomenon for the majority of the stars that the universe is expanding and the space between them is stretching. One can simulate the situation by inflating a balloon with dots indicating galaxies. These dots do not move within the surface, but they move because the surface expands. In reality the matter is even more complicated, since we have to deal with a three-dimensional version of the balloon's surface. The question here is: Will the universe continue to expand for ever? This depends on the amount of matter in the universe. If there is enough matter, gravity will eventually slow down the expansion and return until the matter is compressed into a tiny volume which classically is called "big crunch".

Figure 3 shows

a) an expanding universe
b) an expanding universe with enough matter and
c) a steady-state situation.

Some discussion with respect to evolution was concentrated on the question of a non-transparent and a transparent universe. When it was cool enough for electrons and protons to form atoms (Figure 4), the universe became transparent. Photons which were before scattered by the free electrons could now fly without being scattered. As it has been said already the earliest reachable time in theory is 10^{-35} s, but the earliest reachable time in the laboratory is only 10^{-2} s.

At 10^{-35} s the temperature had a value of 10^{28} K. At this temperature colliding photons were able to produce particles of many orders of magnitude larger than protons. At the time of 10^{-2} seconds the universe had cooled down to a point which allowed the build-up of electrons, protons and neutrinos. Photons and neutrons were around already but not many of them. About one second after the big bang the temperature had fallen to 10^{10} degrees and photons could not easily produce particles any more.

At about 10^{2} seconds helium atoms were formed using two protons and two neutrons. Free neutrons decay within about 11 minutes into protons and electrons and antineutrinos. One can calculate that roughly 10 protons were left over for every helium nucleus that was formed. These protons became later hydrogen atoms.

Isaac Newton's "principia" were formulated about three hundred years ago. Why is it so difficult to include gravity in the grand unified theories? A quantum mechanical treatment of the classical cosmological solution would have to combine the already complex quantum field theory with gravity. Quantum field theory deals with an infinite number of variables and assigns field strengths in all points in space. On the other hand quantum mechanics deals with a finite number only.

In quantum physics we have to accept that nothing is really certain. It is not possible to define the energy of a system precisely at a given time. However the product $\Delta E.\Delta t=h$. From this relation it can be seen that $\Delta E=0$ does not exist. One school of physics therefore assumes that the universe itself is governed by quantum fluctuations. Newton postulated the universe square-law of gravity while Einstein's description replaces action at a distance with a distortion of space-time. In some modern interpretations of relativity gravitational radiation with massless particles called gravitons exert the gravitational force at the speed of light.

In 1986 a fifth force was suggested acting besides the gravitational force only for a distance of about some 10 meters and this fifth force would slightly modify the inverse square-law. The main feature of this force would be a small difference in the gravitational constant over short ranges compared with the astronomical scale. It was suggested that the difference is the result that the gravitational force depends not only on the mass but also on the composition of the acting masses. No real proof exists so far for a fifth force.

At the moment the theories which allow to track us furthest back in time are the Grand Unified Theories called GUTs. These theories are governed by the three basic forces namely electromagnetic, strong and weak nuclear forces. Many physicists try to attempt that gravity too is a facet of a super force which did split apart the other three forces within the Planck time span of 10^{-43} s. But before one can unify the four forces one must be able to describe gravity by quantum mechanical methods.

In our Committee Joseph WEBER from the University of Maryland, one of the key-persons in the field, discusses gravitational antennas and the search for gravitational radiation with sophisticated instrumentation. Others have suggested a kind of Michelson-Morley experiment with laser beams and two end masses (Figure 5).

The contributions of the members of Committee I appear to be a very good mix of the leading ideas presently under discussion. Marcelo ALONSO contributed an excellent treaty on "Energy and the unity of the universe". He put the finger on the strong and weak points of the classical and advanced concepts on energy and mass, but also on energy and quantum theory and he apparently favours the concept of combining nuclear and elementary particle physics with cosmological physics. To make his paper readable for the non-specialists he added his calculations and diagrammatic representations in a special appendix for those who like to go in detail.

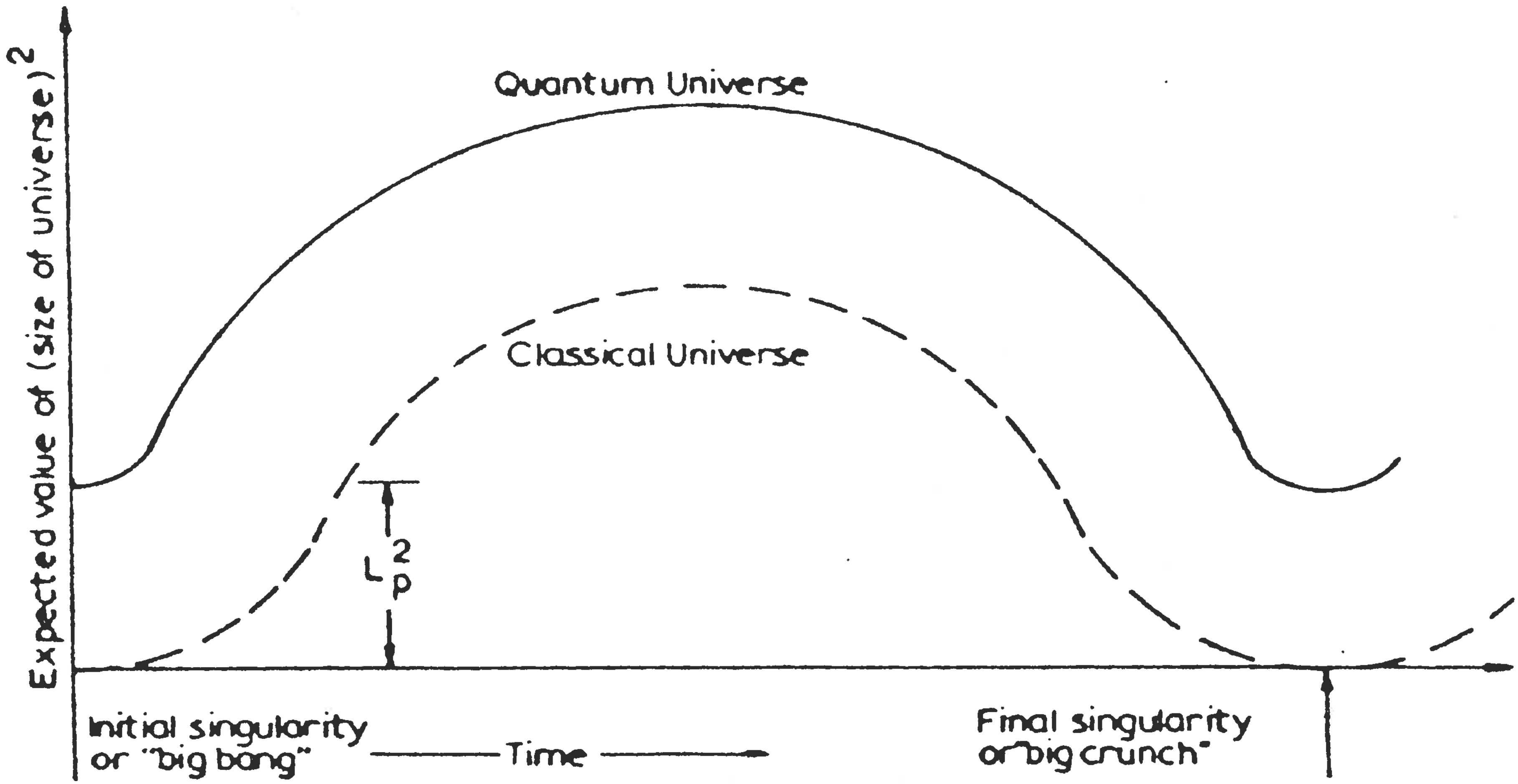
A very original and interesting contribution is given by Lloyd MOTZ, who already in 1983 published a paper entitled "Cosmological consequences of the existence of a unit gravitational charge $(\hbar c/4)^{1/2}$", which leads to the unit gravitational mass $(\hbar c/4G_0)^{1/2} = 1{,}08841.10^{-8}$ kg called uniton. With this unit mass a simple picture of the "big bang" can be drawn. The unitons exist in triplet form and as a consequence of the gravitational collapse of the triplet uniton nucleons are formed.

To circumvent the singularity problem to which also Einstein's cosmological differential equations lead to, he assumes that if the quarks that constitute baryons are not infinitely confined but bound by a very large potential energy of the order of 10^{19} times the proton mass, these quarks are unitons. The baryon model eliminates the initial singularity in the history of the universe and leads to two simple simultaneous algebraic equations, whose solutions are the number of baryons now in the universe with about 10^{80} and an initial radius of about 10^{10} m. The total number of baryons is calculated also by several other authors at about 10^{80}. The problem of the hidden mass is solved, since the mass of a free uniton is of the order of 10^{19} times the mass of a proton, only one such uniton per 10^{17} protons accounts for the hidden mass. Other interesting conclusions can be drawn such as the existence of the presently observed photons versus protons with 10^{10} photons/proton.

The before-mentioned conclusions and results are developed out of the solution of Einstein's two cosmological equations which apparently have been overlooked until now. The uniton concept gives a singularity free universe, but of course does not answer the questions what did lead to the uniton creation and what was the governing process before. MOTZ identifies his unitons with the Gell-Mann quarks particle concept. MOTZ's thesis started from the point that singularities are unphysical concepts and should not be part of any theoretical model which attempt to describe nature. In order to fully grasp the idea of this new concept, MOTZ's papers in this context published in the last four or five years are recommended to be studied.

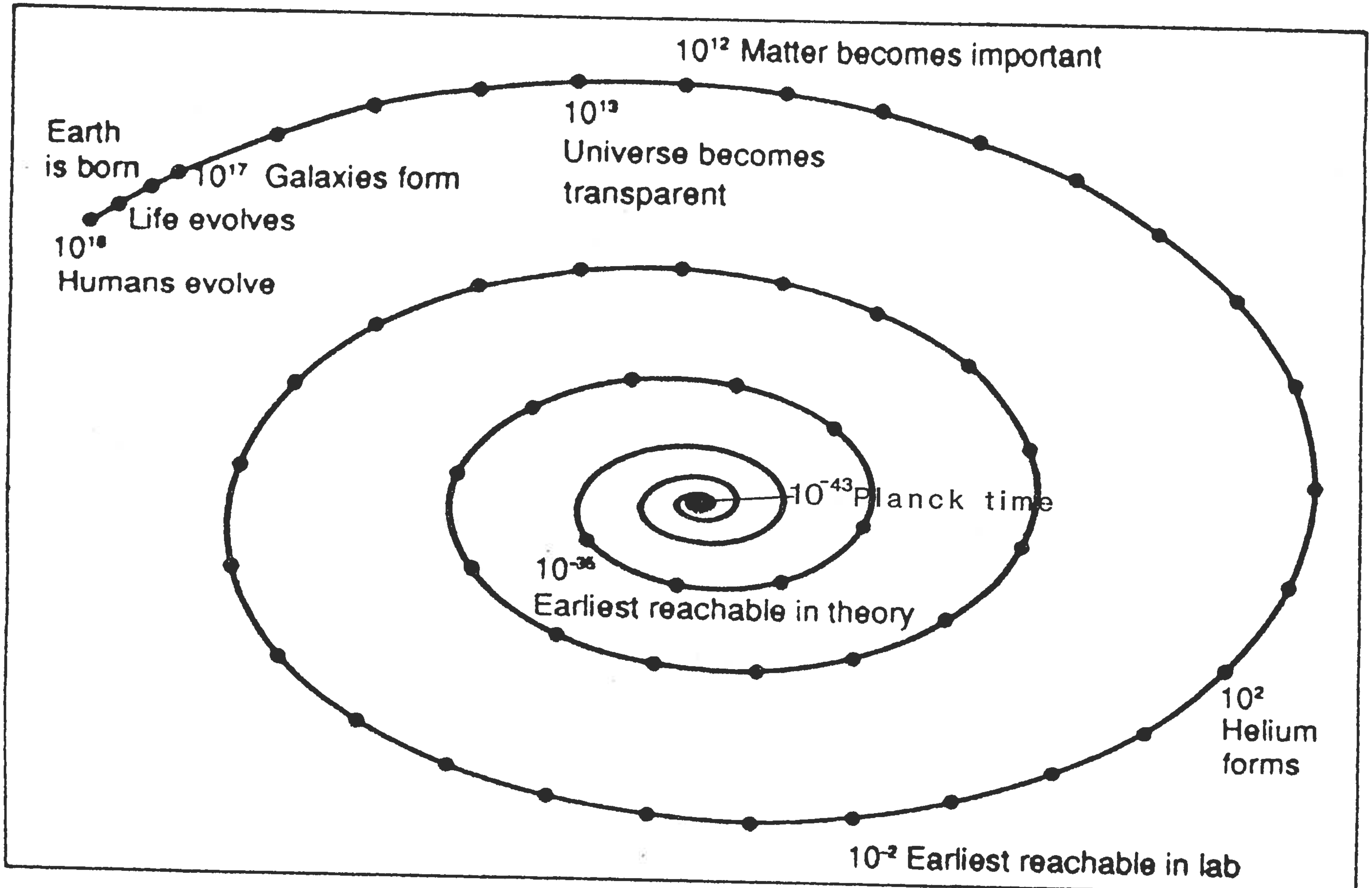
The other contributors Fred M. JOHNSON, Michael D. PAPAGIANNIS and Virginia TRIMBLE discuss the creation of organic molecules and the anthropic principle as well as life and intelligence in the universe.

Finally N. Chandra WICKRAMASINGHE presents a well-founded documentation on observations with respect to interstellar dust, comets and panspermia. It will be up to other paper discussants to comment in detail about their papers.



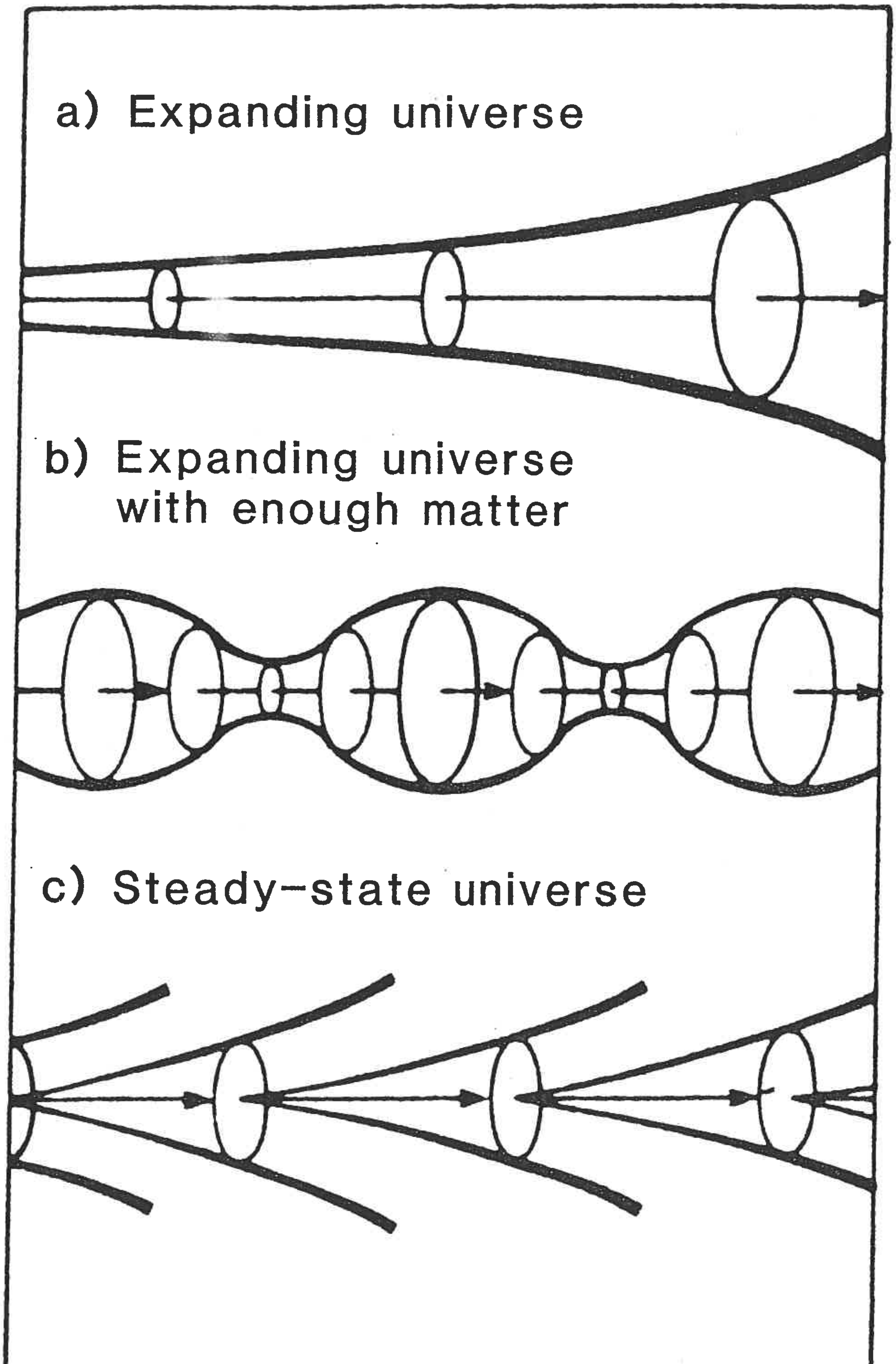
"Quantum universe" versus "classical universe"

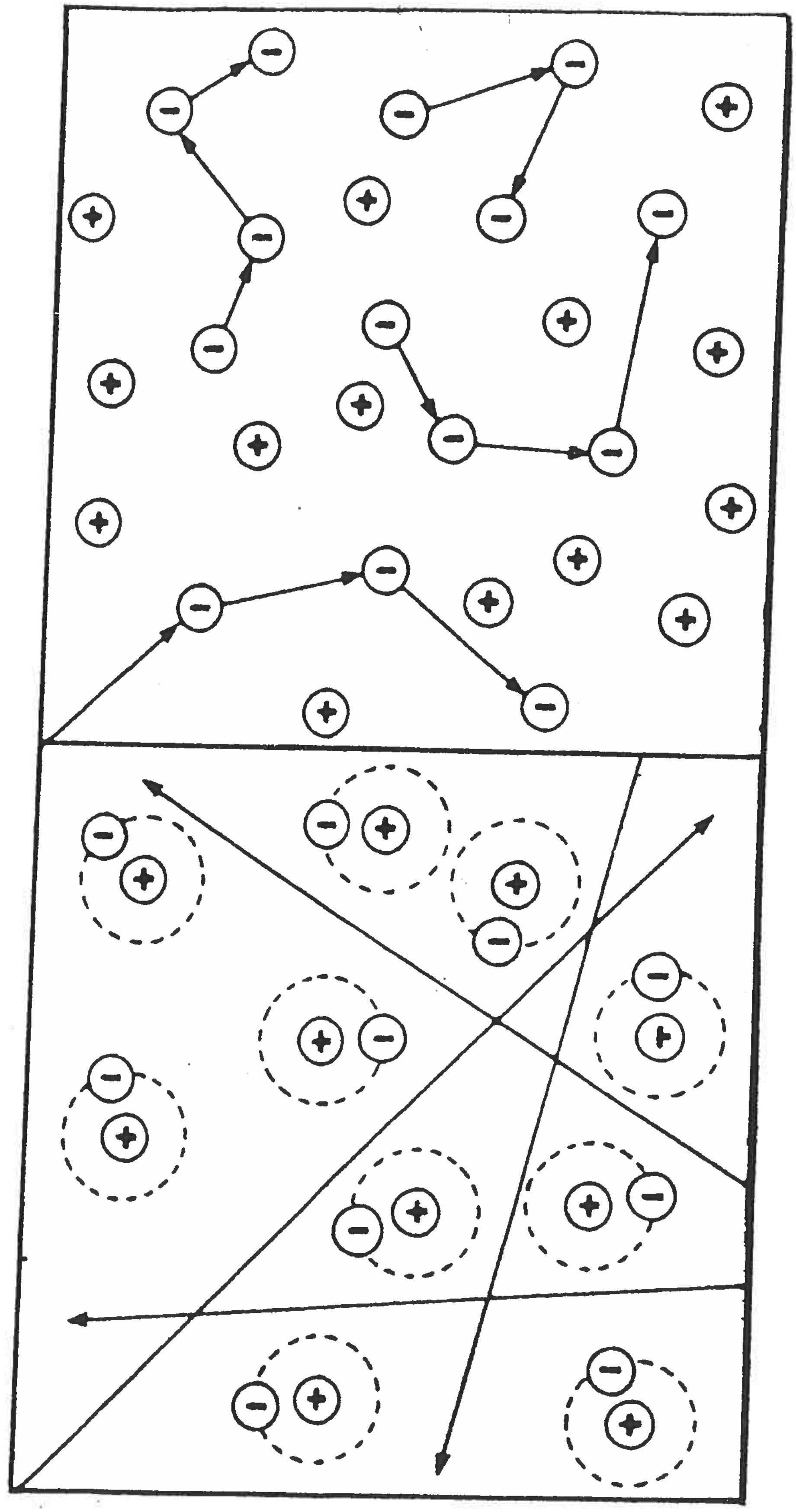
Table 1



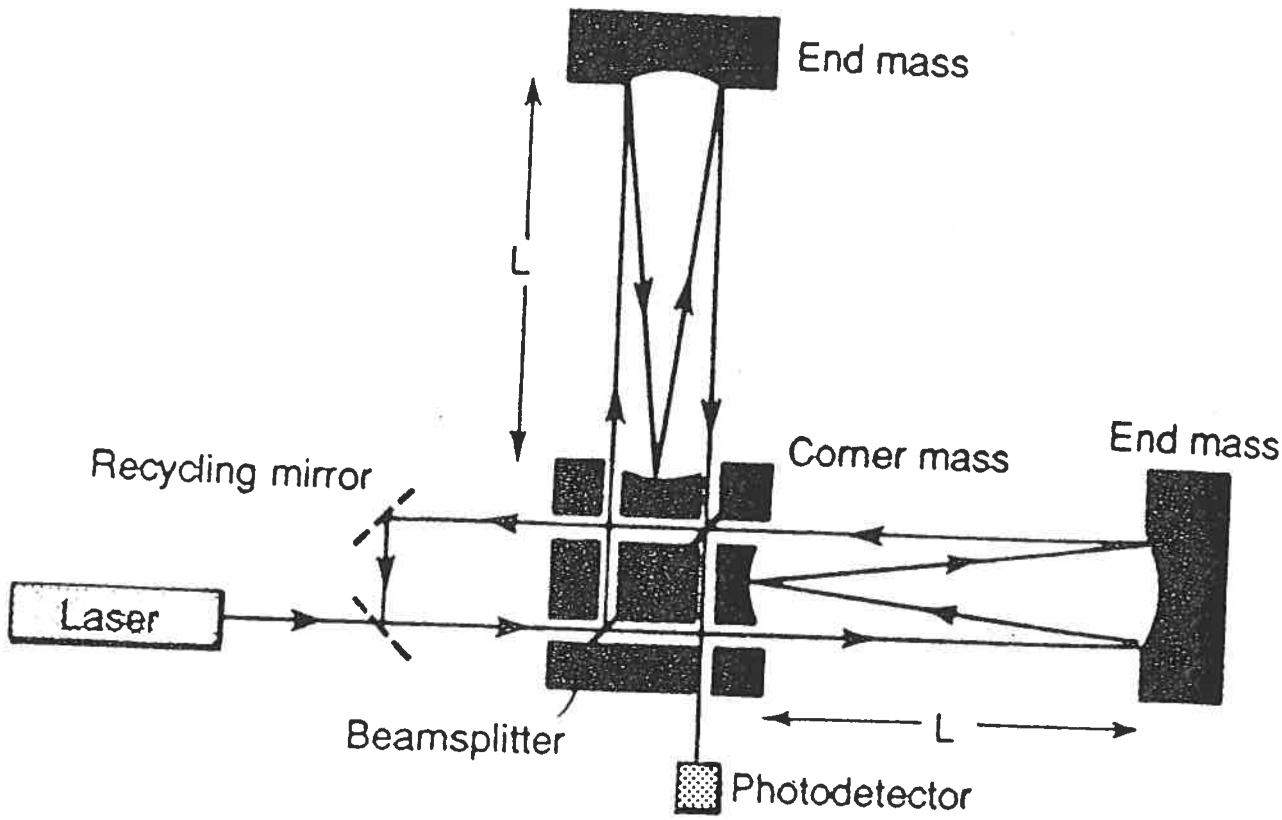
Time-scale from big bang up to now

Table 2


a) Expanding universe
b) Expanding universe
with enough matter
c) Steady-state universe



Non-transparent and transparent universe



Gravity waves testing set-up