HARALD FRITZSCH ON COSMOLOGY
(Dr. H. Yilmaz, Discussant)

Professor Harald Fritzsch, one of the originators of modern theory of strong interactions, explores the interface of today's elementary particle physics with cosmology. His aim is to elucidate as much as possible what can be said about the early history and the present state of the universe on the basis of present day physical knowledge, and without resorting to wild speculation.

At any given stage of science, man has a right to construct a unified picture of the universe we call cosmology. This has been attemped innumerable times since the earliest history of man. Early attempts were mostly based on certain beliefs and speculations. Recently, however, advances in elementary particle physics, in combination with well regarded theories of space and time, appears to provide a less speculative cosmology. If the present theories of elementary particles are essentially correct and if the spacetime theories in existence are valid under the extreme conditions characteristic of the subject, then cosmology may be on its way to become a positive science. Professor Fritzsch makes the best of such a combination and describes a plausible scenario in which our present knowledge may be applicable to the past history of the universe from just 10^{-11} seconds after its creation to the present. The scenario aims at explaining the evolution and the overall structure of the universe as a logical development based on science.

The universe is assumed to begin with an explosion and its history before 10^{-11} seconds is highly speculative. The 10^{-11} seconds corresponds to ~ 100 GeV in temperature. This is the energy scale of present day elementary particle physics up to which the phenomena seem well understood. This gives one a right to scientifically extrapolate from present to 10^{-11} seconds. Of course one must also assume that all other theories are likewise applicable to such early times. The system of theories on which one relies are:

1. Unified Electroweak Interaction
2. Quantum Theory of Colored Quarks
3. General Theory of Relativity

The application is fairly successful and helps us to undertand the following observable features:

a) The Hubble Expansion of the Universe
b) Existence of (distant) Old Galaxies
c) Large Helium Content of the Universe
d) Existence of 3° K Thermal Background.

However, if we restrict ourselves only to what seems to be solid knowledge, many important problems remain unintelligable. Some of these are:

a) Isotropy of 3° K Background (Horizon Prob.)
b) Non-Existence of Antimatter (Antimatter Prob.)

c) Galaxy Formation (Initial Cond. Prob.)

d) Density of Matter (Flatness Prob.)

To overcome such problems one might consider a fourth and rather speculative theory, namely,

4. SU(5) Grand Unified Theory

which implies higher energies, hence times earlier than 10^{-11} seconds. This theory assumes a symmetry breaking via Higgs fields. The hope is that a rapid phase transition at a very early stage ($\sim 10^{-35}$ seconds) leads to an inflation and makes 3° K radiation isotropic. Such a process could have other advantages. For example, the present state of the universe could become independent of special initial conditions or defects formed during the phase transition may nucleate galaxy formation.

Dr. Fritzsch is unwilling to enter such speculation and rightly so. He remarks: a) SU(5) great unified theory predicts a proton lifetime of 10^{31} years which is not confirmed by experiment b) It predicts a weak unification angle, $\sin\theta_W = 0.37$ which is at variance with the observed value 0.20 c) It assumes Higgs bosons which are not observed.

So Dr. Fritzsch considers extrapolations to times much earlier than 10^{-11} seconds pure speculation. However, conceding that in the future, such extropolations might become plausible e.g., on the basis of a successful composite model of elementary particles and a successful quantum theory of gravity, he is willing to extend his evolutionary viewpoint all the way to the instant of creation. Of course he is willing to do this only for the sake of completeness. This results in a view of the universe which starts with an explosion and, passing .pa

through 8 discernible stages, evolves into our present universe with its stars, galaxies and sentient life.

1) $t = 0 - 10^{-43}$ sec.: (Quantum Gravity?)

2) $10^{-43} - 10^{-33}$ sec: (SU(5), Inflation?)

3) $10^{-33} - 10^{-6}$ sec: (Quartes? 10^{-11} sec. / Electroweak 10^{-11} sec.)

4) $10^{-6} - 10^{-3}$ sec: (Nucleons, mesons)

5) $10^{-3} - 10^{2}$ sec: (Electrons, Neutrines)

6) $10^{2} - 10^{3}$ sec: (Atomic Nuelei)

7) $10^{3} - 3\ 10^{13}$ sec: (Atoms, Molecules)

8) $10^{6} - 2\ 10^{10}$ yrs: (Galaxies...Life)

This is a remarkable organization.[1] The clear separation of what is based on reasonable knowledge and what is based on speculation is a characteristic of Dr. Fritzsch's presentation. Dr. Fritzsch deftly weaves into the discussion a truly scientific chain of arguments which makes the topic all the more interesting for those of us who crave for such a comprehensive theory of the Universe.

My own view of the subject is quite similar to that of Dr. Fritzsch but differs somewhat on certain premises and interpretations. Since as a discussant I am required to attempt a critical assessment of this admirable work, I may briefly mention where certain considerations in the premises might possibly lead to a somewhat improved version of the picture:

1. The usual general relativity is not necessarily the final theory of gravity. A new theory of gravity is formulated which is automatically isotropic and possesses no cosmological constant.[2] This theory is highly successful and may help us to observe the horizon problem or clarify the vanishingly small value of the cosmological constant.

2. In this new theory the compatibility with quantum mechanics is explicitly demonstrable whereas in the usual theory this is problematic. Thus a satisfactory quantum gravity and a truly grand unification might be attainable via this theory, giving a more palpable basis for an extropolation to times prior to 10^{-11} seconds.

3. Even so, other possibilities should not be ignored. For example, the 3° K background radiation might be thermalized starlight and Helium abundance (as well as galaxy evolution) might have other explanations.[3] Such possibilities are being considered by a small but respectable minority as an alternative to the Big Bang.

With these ancillary remarks we thank Dr. Fritzsch for presenting us with a highly plausible view of the Universe and its evolution, based on the most reliable physical knowledge that can be extracted from contemporary particle physics.

REFERENCES

1. H. Fritzsch, "The Creation of Matter", Basic Books Inc., New York, p. 234 (1984)

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3. D. Layzer, "Constructing the Universe", Scientific American Books, Inc., New York, p. 262 (1984)