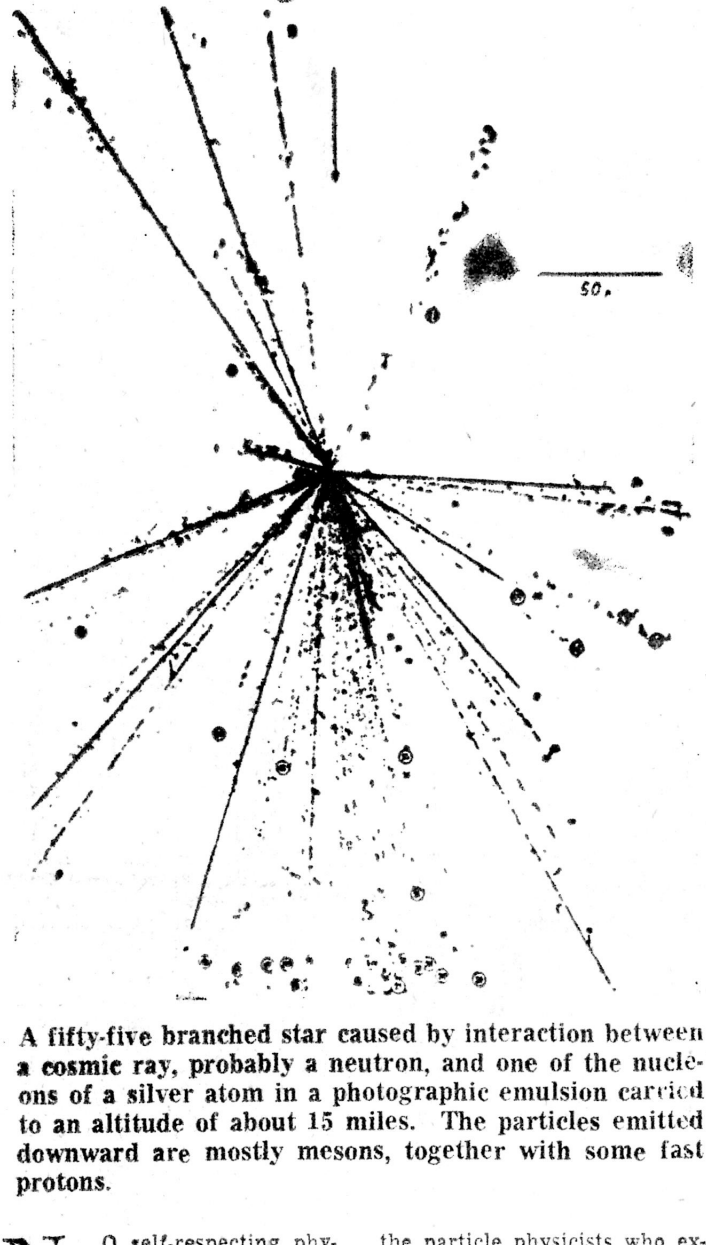
The aftermath of the 'big bang'



A fifty-five branched star caused by interaction between a cosmic ray, probably a neutron, and one of the nucleons of a silver atom in a photographic emulsion carried to an altitude of about 15 miles. The particles emitted downward are mostly mesons, together with some fast protons.

NO self-respecting physicist two decades ago would have predicted that particle physicists would one day join hands with cosmologists in attempting a solution of a profound scientific problem. For, particle physicists are concerned with the studies of very small systems, viz the subatomic particles, while the cosmologists study the largest system that is—the universe. Moreover, the former mainly rely on laboratory experiments and look upon the latter as speculators whose theories are based on flimsy evidence. What made the twain meet?

The change came about over the last five years, and it was the particle physicists who extended the hand for co-operation, in what has turned out to be a marriage of convenience. The gains to each side from the other are certainly big enough to justify the joint effort.

What motivated the particle physicists to condescend to take cosmology seriously? In the late sixties and the early seventies, the theory of electroweak interaction developed by Abdus Salam and Stephen Weinberg received increasing acceptance. The theory offered a way of unifying two basic interactions: those of electromagnetic effects and the so-called weak effects. The electro-magnetic theory, first ex-

pressed in a concise set of equations by the Scottish physicist James Clerk Maxwell in 1864 describes the behaviour of electricity and magnetism. From such small scale phenomena as the behaviour of atoms and molecules to the large scale ones like thunder and lightning, the underlying basic law is supplied by Maxwell's theory. The weak interaction is concerned with the behaviour of subatomic particles only. The merit of the Weinberg-Salam theory lies in providing a unified framework which brings together these apparently separate interactions. And this has prompted search for an even more ambitious theory that unifies all known basic interactions of physics.

The idea of unification of fundamental forces is not new. Albert Einstein spent most of his later life in search of a unified field theory, to bring together the forces of electromagnetism and gravity. He did not succeed and in his days the majority of physicists considered such attempts futile. However, fashions change even in physics. Today the construction of a unified theory is considered the most exciting area in fundamental physics. Moreover, in today's media-conscious world the physicists have found it expedient to replace Einstein's somewhat modest nomenclature by superlatives. Thus today's jargon talks of grand unified theories (GUTs), supersymmetric theories (SUSY) and supergravity theories.

GUTs, for example, hope to unify the electroweak theory of Salam and Weinberg with the theory of strong interactions. Strong interaction, as its adjective implies, is the most powerful of all the basic interactions but it operates only on the subatomic scale. To study and verify the many properties of subatomic particles interacting via GUTs, it is necessary, however, to increase their speed enormously. Particle physicists are accustomed to studying particle interactions at high energies and the big accelerators at CERN and Fermilab have played key roles in establishing the vali-

dity of the Weinberg-Salam theory.

These man-made accelerators are, however, totally inadequate for testing GUTs. The energy needed for testing GUTs is a million million times more than what can be delivered from these accelerators. Since, a theory in order to be scientific has to be testable, it appeared therefore that GUTs do not fulfil this criterion, unless....

The saving grace is provided by cosmology. The currently favourite scenario for the structure and evolution of the universe envisages the universe as having originated in a gigantic explosion, often dubbed the 'big bang'. The state of matter in the universe soon after the big bang was believed to be very chaotic: it was a hot brew of particles at very high energy moving randomly. This state of affairs did not last very long; as the universe expanded it cooled down and the particles became less energetic. So, the clear message to particle physicists was: catch the universe when it was young enough to have particles energetic enough to feel the full impact of grand unified theories. How young should the universe have been? About a million-million-million millionth part of a second!

This explains why the big bang cosmology is taken seriously by particle physicists. The very early universe is the only high energy particle accelerator that could test their theories of unification of the basic forces of nature. What is the reason for cosmologists to welcome these high priests of physics with open arms?

If the universe did originate in a big bang then, cosmologists believe that most of the important decisions about its composition and subsequent evolution were made during the first three minutes or so. In the late forties and early fifties, George Gamow and his young colleagues Ralph Alpher and Robert Herman proposed a detailed framework in which the universe manufactured nuclei of most chemical elements found today. Later work by others showed that Gamow and Co. were over-optimistic: the conditions in the universe were suitable for the manufacture of only light nuclei like deuterium and helium. All heavier nuclei are believed to have been made deep inside stars.

Nevertheless one prediction of Gamow et al has been vindicated. They had predicted that the universe should retain relic radiation from those early hot epochs. The relic radiation was found in 1965 by Arno Penzias and Robert Wilson. As expected by Gamow, the temperature of the radiation is very small, about 270 degrees below zero on the celsius scale. It is mainly in the form of microwaves.

It was the discovery of microwave radiation background that boosted the astronomer's belief in the big bang theory. The cosmic abundances of deuterium and helium found by observations reinforced that belief. But in the footsteps of such confirmatory evidence came a whole host of problems which the cosmologists were unable to cope with, without inputs from fundamental physics. These problems are expressed by questions like the following.

When and how did the subatomic particles like the neutron and the proton come into existence? Why is there an apparent preponderance of matter over antimatter in the universe? What prevented the universe from stopping its expansion and recollapsing to a point like state (the big crunch!) long ago? What prevented its dispersal to infinity long ago? How did extended structures like galaxies and clusters of galaxies come into existence? Why is the microwave background so smooth and uniform in all directions? How much unseen matter lies between galaxies?

Can particle physicists with their unified theories—GUTs, SUSY, etc., find answers to these questions? Again, if the big bang scenario is correct, cosmologists have no alternative but to explore these various alternatives, however speculative they might appear.

The joint activity of cosmologists and particle physicists finds expression in a host of highly speculative papers in leading scientific journals and in symposia and workshops. The latest of these was held in Rome in mid-December, 1984.

The Rome meeting on cosmic background radiation and fundamental physics was attended by observational astronomers who reported on the latest data on the microwave background, by theoretical astrophysicists who reported on their attempts to understand how galaxies formed and by theoretical physicists who paraded the latest wares from GUTs, SUSY, quantum gravity, etc. Nobody expected that a consensus would emerge on what the very early universe was like just after the big bang. It did not, but it was interesting to watch the gulf that still separates the different disciplines.

For example, the astrophysicists argued that to form galaxies it may be necessary to have a lot of hidden matter, some of it in unusual particles like axions, gravitinos, photinos, etc., none of which have been detected in the laboratory. So they told the astrono-

A discordance still prevails on what the universe was like just after its origin in the 'big bang'. Hope of a breakthrough in knowledge coexists with frustration over years of ungainful efforts, notes Prof. J. V. NARLIKAR

mers that they were wasting their time by observing only the visible luminous matter. The astrophysicists were told in turn that they should beware of the exotic wares of particle physicists and that they were wasting their time in as yet fruitless attempts to understand galaxy formation. The particle physicists told others to be patient while they tried to figure out some sense from their attempts at unified theories. (After all, Rome was not built in a day!)

The Rome meeting typifies the prevailing excitement in this frontier area. On the one hand there is the expectation that a breakthrough will come any moment while on the other there is the frustration that there has been no tangible gain of insight about the post-big bang universe in spite of the concerted effort of so many big brains over several years. To the believers in big bang (and they are the majority) problems are inevitable in a frontier area and they indicate the liveliness of the subject. To the skeptics, the lack of success after so much effort suggests that the entire approach may be misdirected.

In the latter half of the nineteenth century many highly respected physicists believed that with the then available knowledge of physics most of nature's riddles would be solved and that no important problems would remain to be tackled. They were wrong, as the discovery of relativity and quantum theory so amply demonstrated. Likewise, the cosmologists who believe that the biggest problem, viz the origin of the universe is close to being solved or the particle physicists who believe that their holy grail of unification will soon be attained may well be in for disillusionment.

Meanwhile tackling the very early universe is lots of fun.

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