THE BIG BANG

Over billions of years gas clouds condensed into stars and planets. The primeval soup bubbled. Self-replicating organisms writhed. Fish struggled onto the land and took their first breath of air (dramatic stuff). The result of it all — A.S. Lipson. Here, in "Roots" (Part .001), he discusses how it all began.

ONE OF THE MANY QUESTIONS that has intrigued man since he first learned to speak is that of the origin of the universe. How did it all begin? Where did our world come from and what caused its existence) Scientists, being only human, (or so we are told) have not been immune to this type of curiosity — even Isaac Newton hypothesized about the origins of the stars. However, it is only fairly recently (during the second half of this century) that any research on this topic has been viewed as 'repectable', or fit material for a serious investigation. During this time, two main opposing theories as to the origin of the universe have developed; the Steady-state theory and the Big Bang theory. It is the latter which tends to be generally accepted these days, as we shall see later. But first we'll need to look at some of the background information

The Red Shifts Mystery ...

It was found during the 19th century that when light from the Sun was passed through a narrow slit and then split into a spectrum by a prism, the spectrum showed hundreds of tiny dark lines across it. The reason for this was not known until the advent of quantum mechanics this century, but it was noted that the lines always occurred in the same positions in the spectrum, corresponding to set frequencies or wavelengths of the light. In 1868, it was found by Sir William Huggins that not only were all the same lines found in the spectra of stars, but in some stars, the lines were shifted very slightly from their positions in the solar spectrum. Sometimes the shift was towards shorter wavelengths; the blue end of the spectrum, and sometimes to longer wavelengths; the red end of the spectrum. With a disappointing lack of originality these two changes became known as the blue shift and the red shift, respectively. In order to explain the shifts, Huggins used an analogy with sound. When you are standing still, and are suddenly passed by a fast moving car (of course Huggins, working in 1868, did not explain it in terms of cars, but anyway ...) which is emitting some sound, you may have noticed that as the car passes you the pitch of the sound drops. (Producing the eeeee-owwwww sound beloved of motor sport enthusiasts.) This change in pitch, or frequency of the sound waves is caused by the relative velocity between the car and yourself. It follows that light, which is also a wave, is affected in the same way by relative motion between the object emitting it and the object receiving it. In fact, the light from a star moving away from us at great speed is shifted slightly to the red end of the spectrum, and a star moving towards us has its light shifted very slightly to the blue end of the spectrum. This explains the red and blue shifts. Now, it so happens that the wavelength of the dark lines in a spectrum is one of those quantities which physicists find relatively easy to measure with extreme accuracy. by doing this, and comparing the wavelengths of dark lines in the spectra of stars to the wavelengths of dark lines in the spectra of stars to the wavelengths of the same lines in the spectrum of the Sun, it is possible to calculate fairly precisely just how fast a star is moving towards or away from the Earth.

In The Beginning ...

Things really began to get interesting, though, when astronomers looked at the shifts in the spectra of other galaxies. They discovered that the distant galaxies appear to be moving away from our own galaxy — the Milky Way. There are one or two exceptions; for instance, the Andromeda Nebula, the closest large galaxy to our own, appears to be moving towards us at about 300 kilometres per second. In general, however, the other galaxies seem to be moving away. In fact it appears that almost every galaxy we can see is rushing away from every other galaxy. This can be simply expressed by saying that 'the universe is expanding'. As a general rule, distant galaxies show a distinct red shift in their spectra and the further away the galaxy, the greater the red shift tends to be, indicating that the further away a galaxy is, the faster it is likely to be travelling away from us.

It began to look as though a long time in the past, all the galaxies were squashed up together and then a massive explosion sent them flying apart. This is the bare bones of what became known as the Big Bang theory and various calculations have shown that if this is indeed what happened, then the 'beginning' — the creation of the universe — took place about 10-20 billion years ago.

Before Genesis

Some cosmologists, however, were womewhat unhappy with this explanation of the expansion of the universe. It involves a 'beginning' and therefore raises the awkard question of what was 'before'. In fact, it was reasoned, it would be much more satisfying philosophically if a theory could be found which did not involve a 'beginning' for the universe, (this idea, that a theory ought to be philosophically satisfying, is not quite as silly as might be thought. Time and again in physics, the theory which *feels* best has been the correct one). In the late forties Hoyle, Bondi and Gold proposed the Steady-state theory. This takes care of the expansion of the universe in a most ingenious manner; although the various galaxies are receding from each other all the time, new matter is continuously being created to 'fill up the gaps'. As more matter is created, it collapses by gravitational attraction to form new galaxies. Thus there is no need in this theory for there ever to have been a beginning — the universe is as it is simply because it has always been the same. According to the Steady-state theory, there never was a beginning to the universe, and presumably there will never be an end — it will just keep expanding, old galaxies dying, new ones forming. This theory does have a certain 'neatness' about it that is rather satisfying.

As a first impression it might seem that it would be impossible to tell which of the two main theories — Big Bang or Steady-state — is correct. The only real difference to the universe now would be that, if the Steady-state theory is correct, the rate of expansion would be constant, whereas if the Big Bang theory is correct, the expansion would be slowing down somewhat, as gravitational attraction attempts to pull the galaxies back together again. This slowing-down, however, is far to slight for us to be able to measure. So how can we decide which theory is correct?

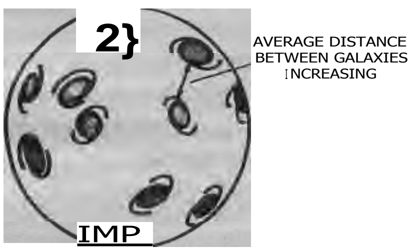

Fig. 1 **If you visualise our three-dimensional universe as being on the two-dimensional surface of an expanding balloon, you can see that, although the galaxies are getting further away from each other, the centre of expansion is not on the surface.**

Weil, for a start, there are one or two things which can only be explained interms of the Big Bang theory. One of these is the abundance of the element hulium in the universe — there is far too much of the stuff around for it to be explained in terms of the Steady-state theory (exactly why doesn't really concern us here). Another is the 'three degree Kelvin microwave background' — which we will consider later. Finally, there is this; according to the Steady-state theory, the universe has always been much the same as it is now, whereas according to the Big Bang theory, it has only evolved to its present state slowly, and it was different in the past. If only we had some way of looking at the past of the universe, we could compare it with the present. If the two were largely similar, we could conclude that the Steady-state theory is roughly correct. If, however, there was a noticeable difference in, say, the structures of galaxies then and now, we might conclude that the Big Bang theory is correct. But we can't look at the past. Or can we? When we look at the stars, we do not see them as they are, but as they were when they emitted the light we see. Light takes only about eight minutes to reach us from the Sun, but nearly four and a half years from even the closest star. When we look at the more distant galaxies, we see them as they were many millions of years ago. evidence is not 100% conclusive (it rarely is in cosmology) but weighing the facts one against the other, it seems it is the concept of the 'Big Bang' that is correct.

The Microwave Background

Now it is time, then, to elaborate a little on the Big Bang theory. A common misconception is that this theory states that about 15 billion years ago, a massive explosion occurred at one point in space, throwing out matter which eventually condensed into stars, galaxies, planets and (finally) us. In fact, this is not correct. The explosion is not imagined to have occurred at one particular point in space. It took place at every point in space, occupying the entire universe. It makes no sense, then, to ask "Where was the explosion?" The best way of understanding this is to imagine our universe as being on the two-dimensional surface of a balloon, which is being inflated. It makes no sense to ask where on the surface of the balloon is the centre of expansion; every point is just as much the centre as any other.

We will now see what it is thought the precise beginning of the universe was like. Nobody actually knows what the universe was like during the first few fractions of a second; our knowledge onlly starts after this. After the first tenth of a second or so, the vast and intense quantities of energy that had just sprung into existence with the universe were making the temperature of the universe an incredible 30 billion degrees on the Kelvin scale (at temperatures as high as this, the Kelvin and Centigrade scales are virtually identical). Apart from the pure energy in the form of photons, a lot of electrons and positrons were in existence, together with equally large numbers of particles called neutrinos. In addition, there was a slight contamination of heavier particles, like protons and neutrons. After a second or so, the temperature had dropped to only ten billion degrees or so and this was still far too hot for protons and neutrons to form atomic nuclei. This process didn't begin until three or four minutes after the beginning, when the temperature had dropped to a mere (...a mere.. I I .) 900 million degrees. Even though nuclei had been able to form, there was still far too much energy for electrons to be able to join up with the nuclei to form stable atoms. It took nearly three quarters of a million years for that to occur and by that time, most of the original electrons and positrons had vanished. (When an electron meets a positron, the two disappear, giving off energy. This is what is thought to have happened, leaving just a few particles behind.) Gradually, gravity clumped the atoms together, and then clumped the clumps, to form stars and galaxies. Eventually, life developed, but that happened much later.

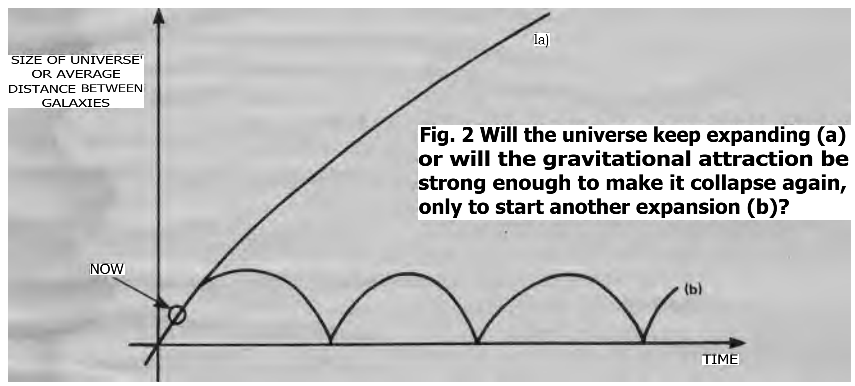

Fig. 2 Will the universe keep expanding (a) or will the gravitational attraction be strong enough to make it collapse again, only to start another expansion (b)?

Cold Radiators

So how can we test this theory? Well, if it is correct, there should still be some radiation hanging around from this beginning. The appropriate calculations have been performed, and it turns out that the radiation

Continued on page 70

C70

BIG BANG *Continued from* page *32*

ought to be roughly equivalent to that emitted by a perfect radiator at a temperature of about three degrees Kelvin (minus 270° Centigrade). This doesn't seem to be a lot, (things that cold don't radiate much heat) but despite this it is measurable. In the mid-sixties, Penzias and Wilson measured this 'three degrees Kelvin radiation background', more or less by accident. At first they blamed poor readings on their equipment and on a pair of pigeons which had nested inside the horn-shaped antenna they were using!

That's it then. It looks very much as though the Big Bang theory is in fact the correct explanation of the origin of the universe. There are still unanswered questions, however.

What's on Next?

We've seen an explanation of how the universe bagan, but how will it end? Will it just keep expanding, getting larger and larger and cooler and cooler, or will gravitational attraction pull the galaxies back together again, the expansion of the universe slowing and eventually stopping, then 'going into reverse'? This depends on exactly how much matter there is in the universe. If there is enough, then the gravitational pull will be strong enough to make the universe collapse back in again. If not, then the expansion will continue. In the former case, the universe is said to be 'closed', an din the latter case, 'open' Either way, the human race will certainly be long extinct' before it happens. So we may never know which is the case. Some evidence seems to indicate that the universe is closed; some that it is open. Until fairly recently, it seemed that the unvierse was probably closed. However, it is now thought possible that the sub-atomic particles known as neutrinos might have mass, contrary to what has been thought for many years. There are so many neutrinos in the universe that, if this is the case, it might be enough to make the difference between an open and a closed universe.

We will finish with one more fascinating possibility. It has been suggested that, if the universe does collapse back on itself, it would first return to its original state of intense heat, and then possibly explode outwards again, beginning the whole thing all over again. We can imagine the universe forever exploding outwards, contracting again, exploding, contracting ... Perhaps the universe we live in is formed from the remnants of the cycle before ... Sadly we shall never know ...

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4121