scale the universe is the same to all observers *all the time*. In other words, if one took a movie film of the universe now, and compared it with films taken, say, 10^9 years ago and 10^9 years in the future, it would be impossible to pick out one from another: they would all look the same. One of the consequences of this is that in any given volume of space-time the amount of material is always the same, yet as the galaxies are moving apart, the density of material is not always static. To resolve this dilemma one can either say that galaxies are not moving outwards, that the increase of redshift with distance is due to something other than motion in the line of sight, or that new matter is being formed to replace that which is being removed by the expansion of the universe. In this theory the universe never had a beginning and will never have an end; galaxies condense and form all the time, move outwards, and ultimately reach velocities taking them beyond the boundary or horizon of the visible universe.

The Friedmann- and Lemaître-type models not only have a beginning, they also present us with two possible future states of the universe: the universe may be open or closed (see page 205). Also, in the Lemaître model cosmic repulsion could come in to play to cause a 'bounce' when the universe is again very dense so that it starts expanding once more. In that case the universe would be an oscillating one, having always existed (as in the case of the steady state model), going through alternate cycles of expansion and contraction (Fig. 8·12). although, there are strong reasons for believing that conditions could not be exactly reproduced with each cycle, and that the universe would 'grow' with each oscillation.

Observational evidence

The obvious hope is that observations will allow us to decide which of the models of the universe is the correct one; for instance, the model chosen will give a specific relationship between redshift, velocity and distance. At the moment there is not precise enough information to allow us to make a definite choice, but there is enough to allow some models to be rejected. First of all we know that the universe is expanding, that is that the distances between all the galaxies are increasing, and that this is giving rise to their observed redshifts and apparent velocities which increase with distance. Attempts have been made to find other explanations, but none have proved satisfactory. Yet, as pointed out on page 209, there is doubt among a few astronomers about whether the redshifts of quasars should be interpreted in this way.

Secondly, there is the evidence of the microwave background radiation, mentioned on page 206. This appears evenly spread in every direction and is hard if not impossible to explain on the basis of the steady state theory, at least as originally envisaged. Indeed, it presents such a stumbling block that it has led to the abandonment of the theory for the present. Almost all astronomers favour the theory of the big bang, the start of the universe from a concentrated superatom, and in particular accept the idea put

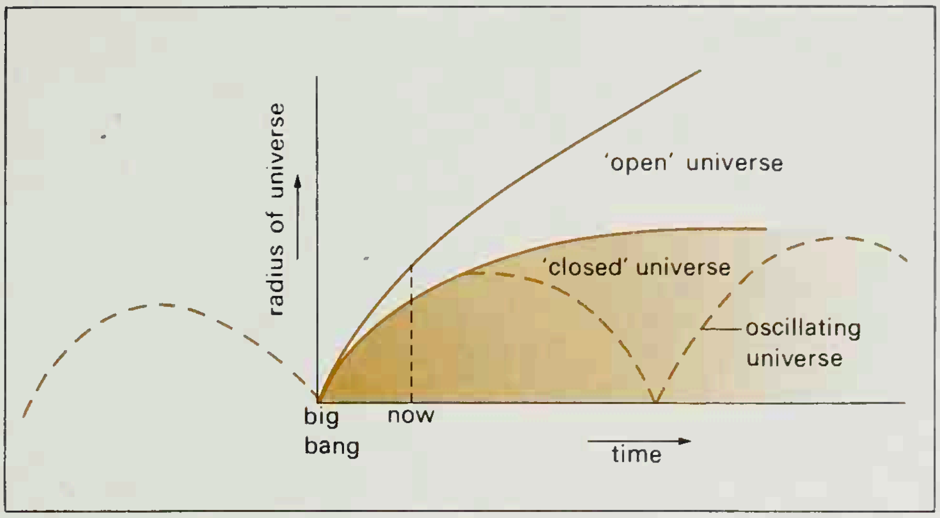

Fig. 8·12: According to the amount of matter in the universe, it can be 'open' (expanding for ever) or 'closed'. In the latter case there may be only one expansion and subsequent contraction, or an endless series of them, giving rise to an oscillating universe.

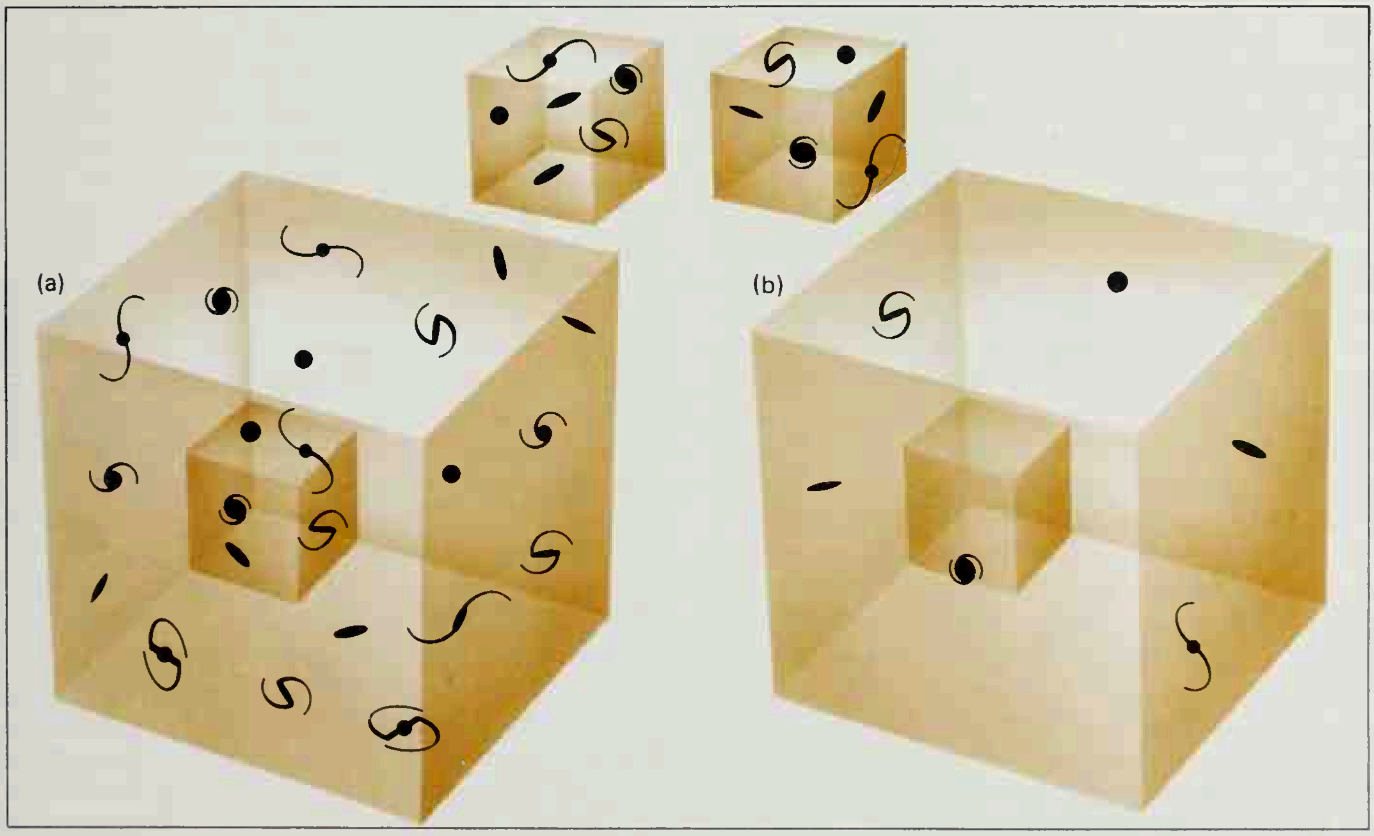

Fig. 8·11 Differences over a long time between the steady state (a) and big bang (b) universes. In the steady state, although material (galaxies) spread out with time, new ones are created to take their space, and the general appearance of a volume of space remains the same. This is not so with a big bang universe; the material becomes increasingly separated with time.