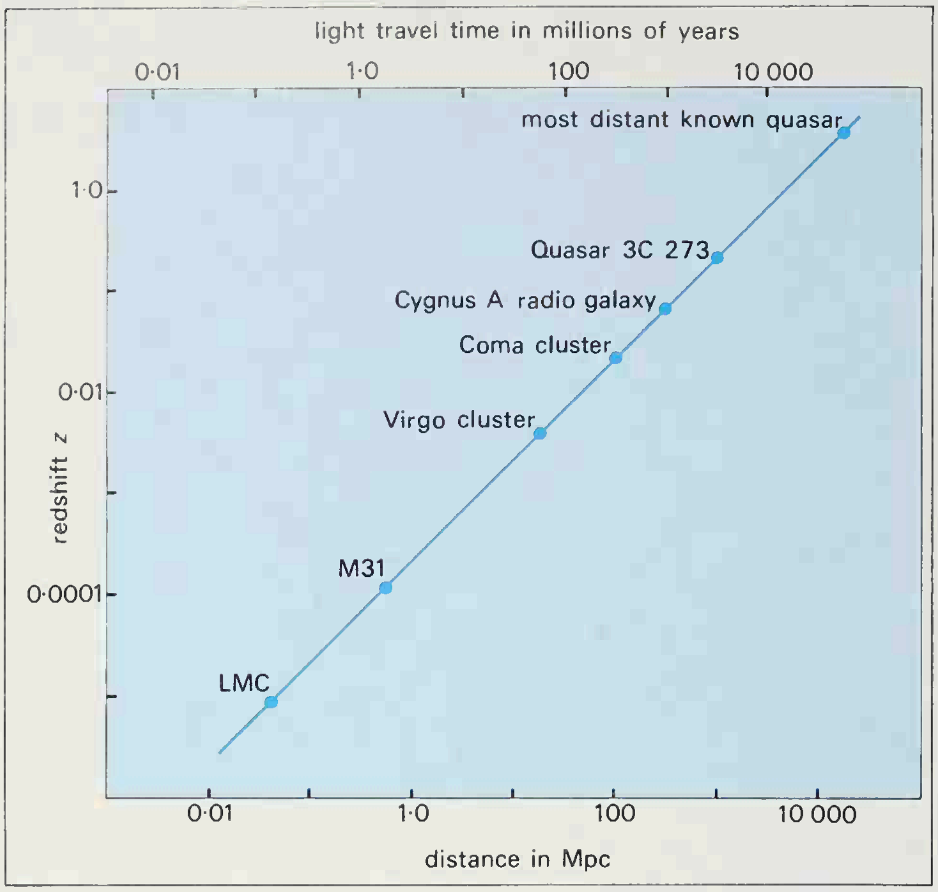

Fig. 7·5
The relation between redshift, distance and light travel time, using a very simple theory. A value 55 has been adopted for Hubble's constant H_0.

main sequence stars, for which absolute magnitudes are well established. Again, supernovae can be observed at large distances, up to about 400 Mpc, and all reach about the same maximum luminosity, but it is difficult to calibrate them accurately. A recent study using supernovae gives H_0 as 60 km per s per Mpc but with a large probable error, ± 15 km per s per Mpc. Another method uses the third brightest galaxies in small clusters of galaxies, presuming that they all have about the same luminosity; for some reason, this is truer for third brightest than for brightest galaxies in clusters. In 1974, van den Bergh analysed results from these and several other methods and found H_0 = 93 km per s per Mpc, with probable error ± 7 km per s per Mpc. An only slightly smaller value, 86 km per s per Mpc, has been suggested by recent work of de Vaucouleurs, based on the brightest globular clusters associated with different galaxies; and the same author has also obtained a similar value from various other methods.

A method using radioastronomy has been proposed recently by Brent Tully and Richard Fisher, who find a close relationship between the total width of the hydrogen 21-cm line emitted by a galaxy and its absolute magnitude in blue light. With this method, they obtain H_0 = 75 km per s per Mpc, but Sandage and Tammann obtain H_0 = 50 km per s per Mpc, consistent with their own other value. The point of disagreement is different from the one which concerns the optical determination by Sandage and Tammann, and so, if they are wrong on both counts, this method would give a value of about 100 km per s per Mpc.

At present there remains a considerable divergence of view between those who favour a small value of H_0, and those who believe that the true value is nearer to 85–100 km per s per Mpc. We retain the value of 55 km per s per Mpc in this discussion, but must bear in mind that a revision to a higher value would require all the distances and masses mentioned to be adjusted in the ratio of 55:85, or 55:100, or in accordance with whatever value is finally adopted. Any such adjustment would of course affect the calculations which can be made concerning the mean density of the universe, for example, as will be discussed later (page 205).

Variation of H_0

In 1973, Vera Rubin, Kent Ford and Judith Rubin, using a sample of distant Sc I galaxies, presented evidence for a variation of H_0 with direction in the sky, but their interpretation was questioned. More recently, Vera Rubin and Ford, with other colleagues, have studied a larger sample of galaxies and confirmed their earlier result.

Different values of H_0 in different directions could be produced by different rates of expansion of the universe in different directions, by large random velocities of groups and clusters of galaxies, or by a large random velocity of the Galaxy and the Local Group. In the last case, the effect of our motion would be that the apparent velocity of recession of galaxies towards which we are moving is less, producing the appearance of a smaller H_0 there than in other directions. Rubin and her colleagues favour this third interpretation, and conclude that the Sun is moving at 600 ± 125 km per s relative to the distant galaxies. After allowing for the Sun's motion around the centre of the Galaxy and the motion of the Galaxy itself, the velocity of the Local Group is found to be 454 km per s.

This result is not yet accepted without question, for the observations could be interpreted in other ways. For example, an effect similar to what is observed might be produced by unexpected fluctuations of interstellar absorption in different directions within the Galaxy. It is also possible that there is still something special about the sample of galaxies being used.

There is some evidence for systematic differences in the motions of relatively nearby galaxies seen in different directions, an effect which can be interpreted as due to systematic motions within what is called the local Supercluster.

The Local Group

The Milky Way Galaxy forms an association with the nearest other galaxies, called the Local Group, which has nearly thirty known members. Most of their distances are known accurately from measurements of Cepheid variables. The Group contains a reasonably mixed sample of galaxy types, except that there are no conspicuous giant ellipticals or barred spirals.

It is hard to establish the precise Hubble class for our Galaxy because we are inside it and so do not easily see its large-scale structure. The Galaxy has several small satellite companions, of which the Large and Small Magellanic Clouds are the most prominent, being clearly visible to the naked eye in the southern sky. Satellites of our Galaxy also include