wavelengths of 2 mm and shorter can not penetrate the Earth's atmosphere. Nevertheless, observations made at wavelengths throughout the range detectable from the ground (from a few mm to nearly 1 m) are consistent with a uniform-temperature, black-body radiation.

At each wavelength observable from Earth, the radiation is found to be independent of direction within about 0·1 per cent. This has been done both for small areas up to about 1° across and for widely separated regions of the sky, and the results clearly exclude the possibility that the radiation is produced by a very large number of discrete sources, not otherwise detected: to produce what is observed, such sources would need to be far more numerous than galaxies.

Recently, a very small difference of intensity has been measured between opposite directions in the sky. It is believed to be caused by motion of the Sun relative to the material which last scattered the radiation, in the very earliest stages of the history of the universe.

Measurement at shorter wavelength

First attempts to obtain measurements at wavelengths which cannot penetrate the Earth's atmosphere were indirect, and were based on optical observations of the interstellar molecules CH, CH^+ and CN, first detected in 1937–41. This was possible because in low density interstellar clouds, excited molecular states are energized by radiation from the microwave background. The relative strength of optical absorption by excited CN molecules gave a measure of the intensity of the background radiation at wavelength 2·64 mm, while failure to detect any absorption from other excited molecules gave upper limits to the intensity at several particular shorter wavelengths. Unfortunately, the results were not accurate enough to make certain that the curve reached a maximum.

However, direct observations have now been made, from both rockets and balloons. The first observations, carried out around 1969, disagreed, but this was later found to be caused by instrumental errors; more recent results, obtained by astronomers from London, England, in 1974 and Berkeley, U.S.A., in 1975, show very clearly the maximum and the descending part of the curve. The results are quite accurately consistent with a black body curve at about 2·8 K.

It has now been established that the background radiation is not perfectly isotropic a (i.e. it does not come perfectly evenly from all parts of the sky, being slightly 'hotter' in one direction and 'cooler' in the opposite region). This is taken to indicate the motion of the Local Group, at a velocity of about 600 km per second with respect to the 'primordial' radiation. This was not entirely unexpected, and indeed would have caused some concern if it had not been discovered. The motion of 600 km per second can only be reconciled with the peculiar motion of about 450 km per second found by Rubin and Ford (page 198) if it is assumed that the galaxies which they used themselves share a common motion of some 800 km per second in a different direction. This could be taken to indicate large-scale turbulent motions in the universe, but in view of the reservations expressed about the Rubin-Ford value (as discussed earlier), such conclusions must await further research.

The background radiation has very important consequences for cosmology, because its presence has to be explained for any theory to be acceptable. Its significance in this respect is discussed in the next chapter.

An optical photograph of M33, a nearby spiral galaxy, image-processed to accentuate the difference between the young blue stars in the arms and the older, red stars in the nucleus.

Active galaxies

In a normal galaxy, everything seems to be stable and in equilibrium. By contrast, an active galaxy is one where there is strong non-thermal emission, and where rapid variations of intensity are observed.

Active galaxies have been found in two different ways, by being strong radio sources or by having a peculiar optical appearance. These two groups overlap but do not coincide: strong radio sources may be optically normal or optically peculiar; and some peculiar galaxies are not strong radio sources.

Seyfert galaxies

In 1943, Carl Seyfert published a list of six unusual galaxies, with a small nucleus which was bright compared with the rest of the galaxy, and now about 100 galaxies are classified as **Seyfert galaxies**. The optical spectrum of the nucleus contains emission lines not seen at all strongly in normal galaxies, but commonly observed in galactic gaseous nebulae. The lines are particularly broad, implying expansion out from the nucleus at rather high velocities, around 500 km per s.

Daniel Weedman has identified two classes of Seyferts. In Class 1, the hydrogen lines are broader than the forbidden lines (page 178), so emission is from different regions; in Class 2 the lines have the same width. In Class 1, the emission lines are weak compared with the continuum emission from the nucleus, in Class 2 they are strong. The nucleus appears smaller in Class 1. In many ways the nuclei of Class 1 Seyferts resemble quasars, which we shall