CHAPTER SEVEN

Extragalactic astronomy

Complete acceptance of the fact that some astronomical objects are outside the Milky Way system came only in the mid-1920s. During the previous seventy years it had been established that many nebulae have a spiral shape and the spectra of such objects suggested that they are collections of stars, but their distances were still unknown. Novae were recognized and their apparent brightness suggested that the distances are great, but just how great was uncertain since the distinction between novae and supernovae was not yet clear. Only with the advent in 1918 of the 100-inch (2·5-m) reflector on Mount Wilson was it possible to detect individual stars and for approximate distance measurements to become practical. The conclusive step came in 1924 when Edwin Hubble used observations of Cepheid variables (page 66) in several nearby nebulae to determine distances accurately. By this time, too, it was coming to be realized that the distribution of nebulae in the sky, avoiding the plane of the Milky Way, is an observational effect caused by interstellar obscuration and is not due to an uneven distribution in space, which would have required them to be attached to the Milky Way system. These results were related to the earlier concept of **island universes**, isolated separate star systems which later came to be called galaxies.

In spite of these discoveries, astronomers still refer to bright nebulae by their reference numbers in the 1784 catalogue of 103 objects drawn up by Charles Messier (M), or in Johann Dreyer's *New General Catalogue* (NGC) of 1888 which, with its later supplements, the *Index Catalogue* (IC), contains more than 13 000. These all list objects of extended appearance lying beyond the Solar System, objects which are of very different natures and distances so that, for instance, it turns out that only 34 of the items in Messier's catalogue are extragalactic.

The nearest external galaxies are the two Magellanic Clouds, satellites of our own Milky Way system, although they have never been regarded as nebulae and do not appear in the M or NGC catalogues. They are seen prominently in the southern sky and look like detached pieces of the Milky Way.

The word nebulae is now restricted to interstellar clouds of gas and dust, except sometimes colloquially in phrases such as extragalactic nebulae or the Andromeda nebula. The term island universes is not now used; the **universe** is defined as the totality of observable things and necessarily is unique.

It is now customary to write Galaxy, with capital G, for the Milky Way system and to use small g for other galaxies. Generally, although not quite always, use of the adjective **galactic** is restricted to our own Galaxy, with increasing use of the new word **galaxian** for another galaxy or galaxies in general. This convenient usage is followed here. Consistent with it, **extragalactic** means anything outside the Galaxy, including other galaxies, and, if not consistent, at least unambiguous, is the use of **intergalactic** to mean what is between the galaxies.

In the past thirty years, radioastronomy has become as important as optical astronomy in extragalactic studies; indeed the two are largely complementary. In general, optical observations show more detail, while spectral lines give information about motions, distances and chemical abundances. Radio signals, on the other hand, can be detected often from galaxies or parts of galaxies, which are too faint to be studied optically. Newer areas of observation in the infrared, ultraviolet and X-ray regions of the spectrum also contribute important information.

Classification of normal galaxies

Most galaxies are **normal**, in contrast to **active** galaxies, discussed later, which involve violent non-thermal processes in the central region or nucleus. Normal galaxies can be classified in a small number of basic types; the outer regions of galaxies with active nuclei can be classified in the same scheme.

Hubble's classification

The first classification was made by Edwin Hubble in the 1920s and, with modifications, is still in use. It is morphological, that is, based on the appearance of a galaxy in the sky, and contains three major classes: galaxies with no evident internal structure, which appear as ellipses (**elliptical galaxies**); those with a thin, flat disc containing a structure of spiral arms and a central condensation or nucleus (**spiral galaxies**); and those which are neither of these (**irregular galaxies**). These classes are subdivided, and there is also a sequence of **barred spirals**, SB, parallel to the spiral galaxies, S.

Elliptical galaxies are classified by the shape of the ellipse seen in the sky. Mathematically, if we take a and b as the axes of an ellipse, the ellipticity or flattening is given by $(a-b)/a$, which runs from zero for a circle towards 1 for a very flat system. The galaxies are classified by writing ten times this value, taken to the nearest whole number, after the letter