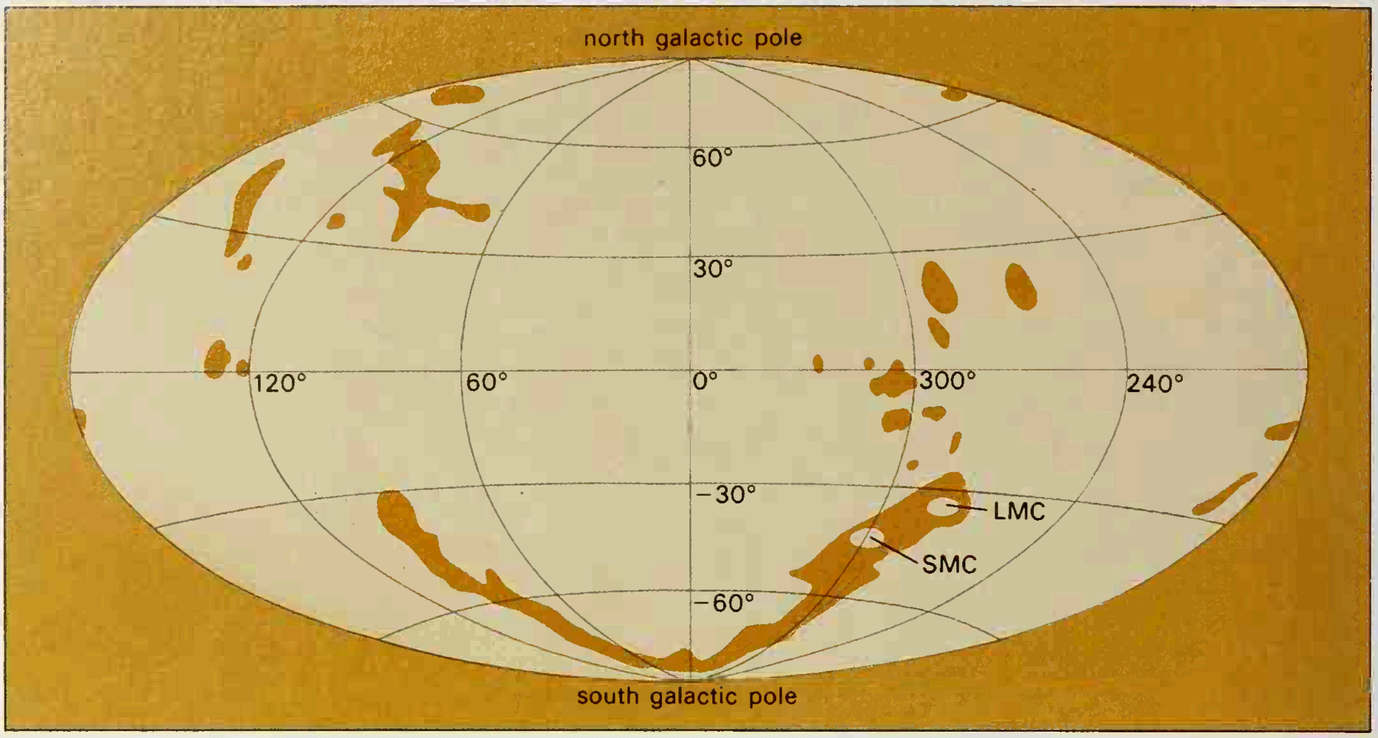

Fig. 7·6
Outline positions in the sky of the Magellanic Stream and other high velocity clouds, plotted in galactic co-ordinates with the centre of the Galaxy at the centre of the plot. The positions of the two Magellanic Clouds are indicated.

lanic Stream (Fig. 7·6), lies at the distance of the Clouds. There are two theories about it, one that the material was drawn out of the Clouds during a supposed recent close approach to the Galaxy, the other that it originated as an intergalactic gas cloud and never formed part of any galaxy. The existence of the Magellanic Stream makes it reasonable to think that at least some of the other high-velocity material also lies outside the Galaxy.

In addition, two clouds have been found, in directions near M 31 and M 33, which probably lie at the same distances as these galaxies. In a similar way, certain other intergalactic hydrogen clouds may be associated with galaxies in the Sculptor group. However, the possibility cannot be excluded that some or all of these are smaller clouds lying much nearer to us.

Stars in galaxies

In 1944, soon after the introduction to astronomy of a red-sensitive photographic emulsion, Walter Baade noticed that the bright stars in the spiral arms of the Andromeda galaxy are blue, while those in the nucleus are red; with only blue-sensitive plates this had not been observable. It led to the concept of population types. Population I contains interstellar gas and dust, blue stars and other essentially young objects, and is found in spiral arms. Population II contains evolved objects, in particular red supergiants, and is found in elliptical galaxies, globular clusters and the nuclei of spiral galaxies.

Even in the nearest galaxies only the very brightest individual stars can be studied, so the stellar content of a galaxy is investigated with the spectrum of the total light, **integrated starlight**. Galaxian colours change continuously through the sequence from E to Sm, reflecting an increase in numbers of Population I stars. Colour also varies (by a smaller amount) with radius in a galaxy and with galaxian size, indicating a higher abundance of heavy elements in the central regions of galaxies and in larger galaxies. These results are confirmed by the intensities of spectral lines in the integrated starlight. In regions of higher density, star formation is more rapid and so the total rate of processing of interstellar material through stars is faster there.

Recently, a few nearby elliptical galaxies have been found to contain small populations of blue giant stars. These observations disturb the conventional idea that ellipticals contain only old material.

Interstellar matter in galaxies

Spiral and irregular galaxies

Interstellar matter is observed in galaxies of later type in four main ways: optical obscuration by dust, optical spectral lines due to emission from H II regions, a radio background or **radio continuum** emission from ionized gas and spectral line emission at specific radio wavelengths from neutral gas. As in the Galaxy, dust and gas appear to be well mixed together. The dust is seen by the dark lanes which it produces in spiral arms and is conspicuous in some galaxies which are seen edge on. It can also produce significant reddening of starlight.

H II regions are brighter than individual stars and can be studied in more distant galaxies; but few spectral emission lines can be detected in the integrated light from a galaxy and HII regions are best studied individually. From theoretical considerations rather precise abundances may be derived for the atoms observed, atoms which, besides hydrogen and helium, include oxygen, nitrogen and sulphur. Heavy element abundances tend to decrease with distance from the galaxian centre, and this is consistent with the general picture obtained from the spectra in integrated starlight.

Continuum radio emission from normal galaxies comes from the electrons in ionized regions – H II regions, supernova remnants and more extended regions of lower density. As a free electron passes near a proton or other positive ion, it is accelerated and emits radiation. It is a type of thermal radiation (from the German often called **thermal bremsstrah-**