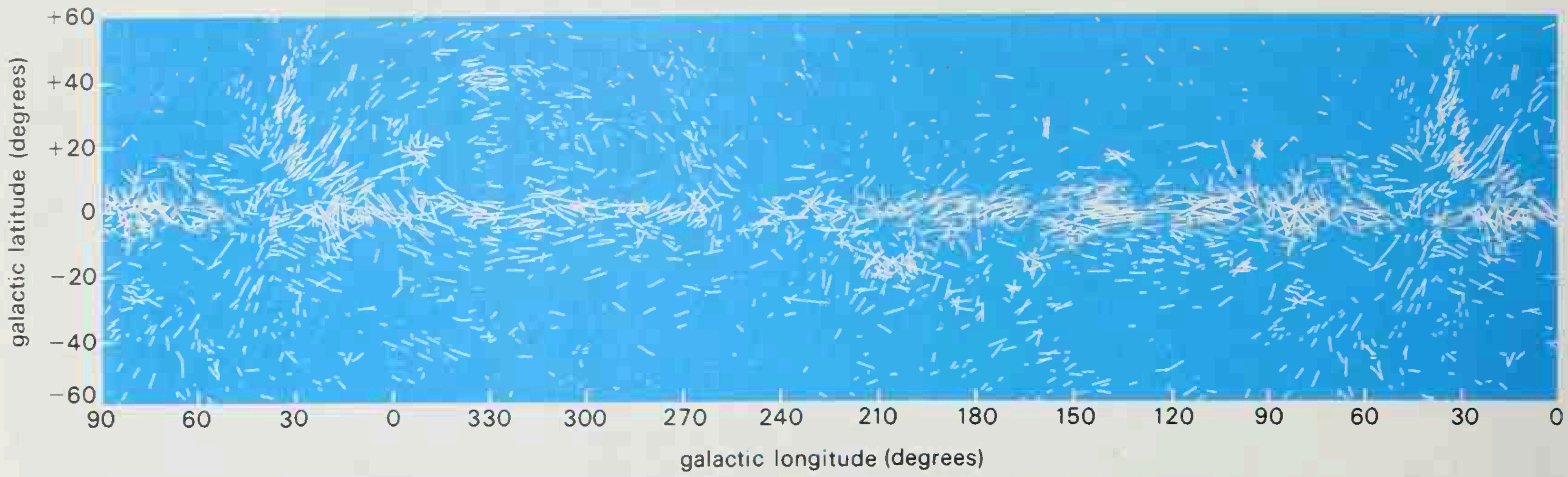
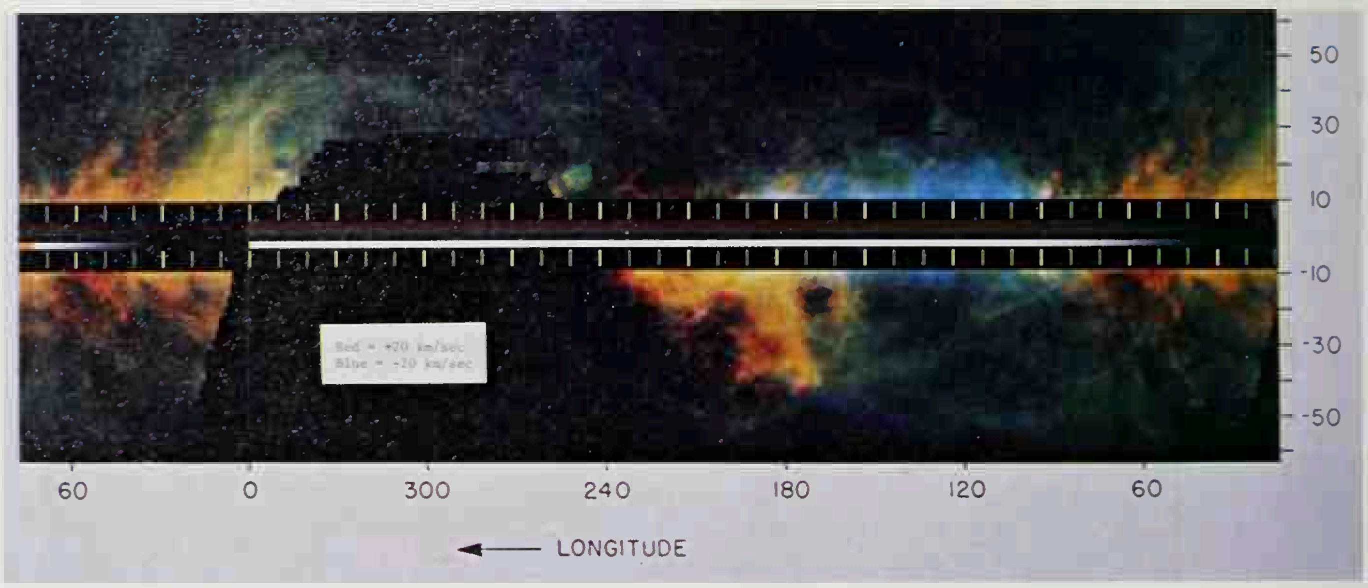


Fig. 6·7 above: Polarization observed in the light from distant stars reveals that there is a magnetic field in our Galaxy which aligns the dust grains. Measurements such as this tell of both the strength and direction of this magnetic field, and the composition of the grains.



Above right: *Half a million observations with radio telescopes were combined in a computer to construct this map of the distribution of neutral hydrogen (HI) in our Galaxy. The plane of the Galaxy (where the hydrogen is densest) is blanked out in order to reveal the higher-latitude gas. Colours indicate motion: blue towards us, red away.*

Radio studies and hydrogen distribution

The transparency of the interstellar medium to radio waves, and the sophistication of modern radio-telescopes make these frequencies ideal for studying the large-scale structure of the Galaxy. Most useful of all, neutral hydrogen (H I) atoms emit a spectral line in the radio region, the famous 21-cm line. Hydrogen makes up 70 per cent (by mass) of the interstellar gas, and so it is ideal for mapping the interstellar medium; moreover, slight deviations from this frequency due to the Doppler effect reveal motions of the gas along the line of sight (its radial velocity).

A hydrogen atom consists of a single electron orbiting a proton, and each of these particles is spinning about its own axis. The laws of quantum mechanics insist that the spin axes of proton and electron be parallel, and so the hydrogen atom can exist in only two states: either with both particles spinning the same way (higher energy state), or spinning in opposite directions (lower energy state). In an interstellar hydrogen cloud, atoms are continually colliding, and once in a few hundred years the electron in any given atom will flip over during the collision, and hence change the atom's spin-state. There is a very small chance (about one in 10^5) that the electron will flip spontaneously from having the same spin as the proton to the opposed spin state, and in this case it emits the excess energy as a radio wave at 21-cm wavelength. Despite the very low emission rate – any given atom emits this radiation once in 11×10^6 years, on average – the vast amount of hydrogen in space makes the radiation readily detectable.

Although other lines, for example those of OH, also occur in the interstellar medium, the hydrogen line is the most generally useful. Careful study of the H I emission from a cloud reveals its extent, its velocity, whether it is rotating, its density and its mass. If it happens to lie in front of a bright background source giving a continuous radio spectrum, the cloud's H I line can be see in absorption, and its temperature can then be determined.

From these observations, the interstellar medium seems to be extremely non-uniform. The simplest interpretation is that the hydrogen is clumped together in clouds about 10 pc across, with a density of some 2×10^7 per m^3 and a temperature of around 100 K. These clouds occupy only a few per cent of the disc's volume, and they are separated by a much hotter, more tenuous **intercloud medium** with a density 100 times lower and a temperature of about 3 000 K. These parameters are only rough, for individual clouds and patches of intercloud medium vary considerably. The clumping into clouds may well have been caused by the expansion of old supernova remnants, which eventually sweep up thin dense shells of cool gas. The centres of old supernova remnants are even hotter and more tenuous than the intercloud gas.

It is now thought that extreme heating by supernovae has given rise to the exceptionally hot gas observed at considerable distances from the galactic plane. The so-called high-velocity clouds have been