from circular motion can lead to large errors in distance estimates. Also the very transparency which makes the whole Galaxy accessible to radio investigations can prove an embarrassment in the study of near-by individual objects, which are difficult to isolate from their background.

A great deal of work remains to be done in tying together the detailed optical information on stars, clusters, etc., in the first few kiloparsecs, and the more smoothed out radio picture of the hydrogen over a much larger area.

Distribution and Motions

The overall distribution and motions of the hydrogen were then discussed, but this account will not be reproduced here, as the subject has recently been extensively reviewed by Kerr and Westerhout (1965). Some current problems will be mentioned briefly.

Current Problems

The present diagram of hydrogen spiral structure is still based on old low-resolution observations from Leiden and Sydney. The production of a new version will be difficult, because much more detail is present in recent observations, and also there is more realization of the complexity of the kinematical pattern.

There is evidence from various sources that spiral arms are broken up into 'patches', 500–1000 pc in length. Further, these individual patches seem to have small deviations from circular motion, some inwards and some outwards.

The rotation curves derived from 21-cm observations show a substantial difference between the northern and southern galactic hemispheres, and also considerable irregularity (Kerr 1963, Shane 1965). These effects are presumably related to asymmetries and irregularities in the hydrogen distribution, and also the local deviations from circular motion must have their effect on the apparent rotation curve. In his discussion, Shane has drawn attention to the gravitational distortion of the rotational pattern which would be produced by the mass in spiral arms.

It is clear that a smoothly-varying circular-orbit model of galactic rotation can no longer be used, and the overall picture of gas distribution and motions will be a quite complex one.

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3. CLOUD STRUCTURE AND LOCAL KINEMATICAL PROPERTIES OF THE INTERSTELLAR MATTER

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The structure of the interstellar medium has been the subject of considerable controversy. Most workers in the field favour the discrete-cloud model, but others prefer to think of a relatively smooth medium with only minor density fluctuations. Obviously, in any model density and velocity are functions of position; the character of these functions determines whether the word 'cloudiness' is a suitable description.

Structural Information from Direct Photographs

The dark areas on sky photographs like those in Barnard's atlas, with their irregular shapes and sharp boundaries, probably are the origin of the cloud concept. Counts of stars and of extra-galactic nebulae supply quantitative data on these obscuring clouds; so do measurements of colour excesses. A near-by star may illuminate such a cloud and turn it into a reflexion nebula. Some reflexion nebulae, e.g. that in the Pleiades, show very intricate detail reminiscent of cirrus clouds in our atmosphere.

Other objects visible on photographs are the supernova remnants, like the Cygnus loop with its complex filamentary structure, and the emission nebulae (H II regions). We refrain from detailed discussion. Sizes and densities have been summarized by van de Hulst (1958, section 4) and by Spitzer (1963, section 2.1).

Structural Information from Spectra

The absorption lines produced by interstellar Ca^+ and Na in the spectra of many early-type stars are—under sufficiently high dispersion—often observed to contain two or more narrow components. Adams (1949) and others have called these 'clouds'. In principle, it would be better to give these spectral features the name 'currents', but consideration of the mean free path shows that such currents must be separate in space, so that the word 'clouds' is entirely appropriate. It is, however, not at all obvious that these clouds defined as spectral features will correspond directly to structures visible on photographs.

By establishing the presence or absence of the same component in the spectra of neighbouring stars, one can determine the angular extent of a cloud. Differential galactic rotation, or the location of stars in the foreground and background, may furnish an estimate of the distance, and hence of the linear size. The strength of the component (equivalent width) supplies the number of absorbing atoms in a column of 1 cm^2 cross-section; the average density in the cloud then follows directly. Given the stellar distances, one may immediately derive the average number of clouds cut by a line of 1 kpc length, if the amount of blending of components can be estimated. Results again have been summarized by van de Hulst (1958, section 3B) and Spitzer (1963, section 2.1).

Only a few hundred early-type stars are bright enough for these high-dispersion observations. Consequently, our knowledge of the Ca^+- and Na-clouds has remained quite scanty. A similar limitation applies to the study of neutral hydrogen from its absorption at 21-cm wavelength of radio radiation from discrete sources. Clark, Radhakrishnan and Wilson (1962) have analysed the absorption spectra of 20 sources. With the large radio-telescopes at Green Bank and Parkes, many more sources are of sufficient strength, and extensive investigations are now under way.

Full sky coverage is available through observation of the 21-cm line in emission. The major limitation here is that of resolution on the sky. Typical beamwidths are: about 2° for the galactic-belt surveys made at Kootwijk and Sydney, $0\overset{\circ}{.}6$ for the 85-foot telescopes now in use at many observatories, $0\overset{\circ}{.}2$ for Parkes and Green Bank. These correspond to solid angles 10^{15} to 10^{13} times larger than that subtended by a B0-star at 400 pc distance! Whether this difference makes the hydrogen clouds unobservable as components of a 21-cm emission profile, depends on their angular size. The Dwingeloo–Groningen survey (van Woerden, Takakubo and Braes, 1962) of neutral hydrogen at intermediate galactic latitudes (10° to 25°) indicates a considerable amount of profile structure. Aiming at reproducible resolution of this structure, Takakubo and van Woerden (1964) have used an electronic computer to make least-squares fits of sets of components to their profiles. Girnstein and Rohlfs (1964) and Dieter (1964) have followed similar methods. In these analyses, some type of velocity distribution within a component must be assumed. We therefore now turn to a discussion of motions.

Velocities of Interstellar Clouds

In what follows we shall have to use the kinematical definition of an interstellar cloud as a component of the profile of an interstellar absorption or emission line. We further shall distinguish internal motions within a cloud (see next section) from the motion of a cloud as a whole, i.e. of its centre of gravity. The latter (cf. van de Hulst 1958, section 3A) is a superposition of general galactic rotation, the systematic motion of a local group of clouds, and the peculiar motion of a cloud in a group. In this discussion of local interstellar matter, we shall only be concerned with the peculiar ('random') motions.

The velocities of interstellar Ca$^+$-clouds measured by Adams (1949) have been analysed by, among others, Blaauw (1952) and Takakubo (1958). Both conclude that the distribution of velocities is best represented by an exponential function: $\exp\left(-\frac{|V - V_0|}{\eta}\right)$, with η between 5 and 7 km/sec. Münch (1957) finds $\eta = 5$ km/sec from the intensity ratios in the Ca$^+$-doublet, $\eta = 3{\cdot}3$ km/sec from the Na-doublet. According to 21-cm workers, other types of distribution may be equally good, but we shall summarize their results in terms of the exponential function. The discussion of galactic-belt profiles by Westerhout (1957) indicates $\eta = 4$ to 6 km/sec. From the profile components in the intermediate-latitude survey, Takakubo (1964) obtains $\eta = 4{\cdot}5$ km/sec. It appears that $\eta = 5$ km/sec, corresponding to a root-mean-square velocity of 7 km/sec, is a very good average.

Internal Motions within Interstellar Clouds

Spitzer and Skumanich (1952) made an early attempt to determine motions within clouds. Assuming a gaussian velocity distribution, $\exp\left\{-\frac{(V - V_0)^2}{2\sigma^2}\right\}$, and correcting for instrumental broadening, they found velocity dispersions, σ, of 2 to 5 km/sec for a few selected Ca$^+$-components from Adams material. These results are rather uncertain, since they depend strongly on the instrumental profile assumed, which has a width similar to that of the corrected components.

Much better velocity resolution has been obtained in the 21-cm line. Muller (1959) fitted gaussian components to the absorption spectra of four bright radio sources; the velocity dispersions (after correction for an instrumental broadening $\sigma_{\text{instr}} = 0{\cdot}4$ km/sec) range from 1·0 to 2·6 km/sec, with 1·9 km/sec, as average. The interferometric observations of seven sources by Clark, Radhakrishnan and Wilson (1962), with $\sigma_{\text{instr}} = 0{\cdot}5$ km/sec, yielded velocity dispersions from 0·8 to 5 km/sec. averaging 2 km/sec. The hydrogen line in emission gives similar results, if observed at sufficiently high latitude and with a narrow passband. Takakubo and van Woerden (1964) have analysed nearly 200 intermediate-latitude profiles into gaussian components. Correcting for $\sigma_{\text{instr}} = 0{\cdot}8$ km/sec, they find velocity dispersions ranging upwards from 1 km/sec; this lower limit was confirmed by measurements with a narrower band. Van Woerden and Schwarz, in an unpublished discussion of several hundred profiles in the Orion region, obtain a distribution of velocity dispersions with a pronounced maximum at 2 to 3 km/sec, dropping sharply to zero at 1 km/sec. Also Mrs Dieter, operating with a very narrow band ($\sigma_{\text{instr}} = 0{\cdot}2$ km/sec) in the region of the north galactic pole, derives velocity dispersions between 1·0 and 5 km/sec, averaging 2·4 km/sec. All these authors find that the 21-cm profiles can be well represented by gaussian components. The consistent conclusion appears to be that the internal motions in hydrogen clouds closely follow a gaussian distribution, with a velocity dispersion (in one co-ordinate) varying from cloud to cloud, but rarely if ever smaller than 1 km/sec. The corresponding kinetic temperatures would range upwards from 120°K. Of course, differential mass motions in a cloud may contribute appreciably to the dispersions found. This can best be evaluated by comparison of results obtained with various aerial beams.

Resolution on the sky at present is the major limiting factor. Velocity resolution does not appear to have been a severe limitation, although this ought to be checked by more extensive observations with very narrow passbands.

Clearly, studies of the Ca$^+$- and Na-lines with similar velocity resolution are urgently needed. The large survey by Adams (1949) included 300 stars, but had insufficient resolution (σ_{instr} = 3 to 4 km/sec). Since 1958, the 100-inch coudé at Mount Wilson has a grating allowing 1·1 instead of 2·9 Å/mm in the violet. On IIa-O plates, the instrumental dispersion σ_{instr} comes close to 1 km/sec. Following earlier work by Oke (1959) and Münch, van Woerden has in 1962–64 made extensive use of these facilities. In the Orion region alone, 20 stars have been observed with this high velocity resolution, and 20 more with slightly lower. Preliminary results indicate that here again components are found with (corrected) velocity dispersions of 1 km/sec. With the Okayama 74-inch telescope and similar resolution, Takakubo (1963) has measured in the spectrum of ϵ Ori four components with velocity dispersions ranging from 1·0 to 3·3 km/sec. These values for the Ca$^+$-components agree substantially with those found above for hydrogen, suggesting that thermal motions are not the main broadening agent. Since, however, the narrowest components are about as wide as the instrumental profile, caution is required until even better velocity resolution is achieved. Only very recently Livingston and Lynds (1964), using the Kitt Peak solar telescope with an image tube, have gained another large factor in resolution. Their spectra appear to contain components with velocity dispersions even smaller than 1 km/sec. Further results of this technique will be eagerly awaited; they will be of decisive importance to our understanding of motions inside interstellar clouds.

A success in the separation of thermal and non-thermal ('turbulent') motion has been scored by Barrett, Meeks and Weinreb (1964), who compared the absorption features of OH (at 18 cm) and H (at 21 cm) in the spectrum of Cas A. They find kinetic temperatures of 90°K and 120°K, and turbulent motions of about 0·25 km/sec (r.m.s.). These results depend on the assumption that H and OH have the same density distribution, kinetic temperature and mass motions.

Great advances have indeed been made in our knowledge of internal motions in interstellar clouds during the last few years. Careful component analysis of profiles at neighbouring points on the sky should soon provide us with detailed and reliable data on the sizes, densities and structure of interstellar clouds. Takakubo (1963*b*) has studied a region close to the north celestial pole; this work is being extended by Schwarz. Mrs Dieter is analysing the regions around the galactic poles. Heiles (Princeton) is embarking on a massive programme of this nature with the Green Bank 300-foot telescope. Van Woerden and Schwarz are discussing hydrogen- and calcium-data in the Orion, Scorpius and $h + \chi$ Per associations. Early results indicate a variety of structural detail. We should hope to obtain a quantitative spectrum of sizes and densities to replace the overworked 'standard cloud'.

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DISCUSSION

Davies. Shuter and Verschuur (*Mon. Not. R. astr. Soc.*, **127** 387, 1964) have made a high resolution study with 3 and 5 kc/sec bandwidths of the absorption spectra of the intense radio sources. Such measurements have an angular resolution equal to the angular size of the sources themselves and are less confused than emission spectra. Dispersions were typically 0·5 to 0·8 km/sec and correspond to kinetic temperatures in the range 30 to 100°K.

Grahl. At Bonn Observatory we observed a 21-cm line programme at higher galactic latitude in the vicinity of the north celestial pole. In a region around the position $l^{\mathrm{II}} = 125\overset{\circ}{.}5$, $b^{\mathrm{II}} = 31\overset{\circ}{.}5$ we found profiles with simple shapes. The main component with standard deviation about $\sigma = 2{\cdot}3$ km/sec predominated. In the isophote map of maximum temperature we find a cloud-structure with a total half-power width of $2\overset{\circ}{.}6$ and high gradients on some edges. With an estimated distance of 100 pc the linear diameter is about 10 pc, and we get a total mass of about 250 solar masses by integration over the solid angle. Some simple model calculations for best fitting of the results will be completed soon.

Fehrenbach. What is the radial velocity of this cloud?

Grahl. Zero.

4. HIGH-LATITUDE, HIGH-VELOCITY CLOUDS

J. H. Oort

The clouds with velocities higher than 70 km/sec with respect to the local standard of rest which were found in a Leiden-Dwingeloo survey for high-velocity features in high galactic latitudes, show a remarkably systematic distribution. They are concentrated between 72° and 167° new longitude and between +15° and +50° latitude. Moreover, their velocities are all negative. They range from −70 to −174 km/sec, with an average of −115 km/sec.

It should be emphasized that the survey is still quite incomplete; it is to be expected in particular that further observations at somewhat lower latitudes will yield many more features of this sort. It should also be pointed out that in the course of W. W. Shane's survey of the galactic structure between 22° and 42° longitude some objects with high *positive* velocity were found. One of these, with a velocity of +90 km/sec, is situated at −15° latitude; the others are closer to the galactic equator. We do not yet know whether these objects are of a different nature.

For most of the high-velocity clouds the structure has not yet been determined. From the few cases studied so far it may be inferred that they are irregular and of widely different angular