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C. RADIO-EMISSION FROM THE GALAXY

(prepared by C. Westerhout)

Polarization

Undoubtedly the most outstanding development in the last three years is the discovery of the background emission and the Faraday rotation of the polarized component of the radiation from discrete sources. Measurements of the polarization of the galactic background emission were started in 1957 and seemed to be partially successful, but so uncertain that not much weight was attached to them. Since late 1960, 408 Mc/s measurements of the polarization provided full sky surveys down to about 0·5 °K in the linearly polarized components (**7, 46, 53**). Recently, the first series of observations at 610 Mc/s were obtained (**1a, 35**). The degree of polarization in most parts of the sky is a few per cent or less, whereas we expect 50% or more if the interstellar Faraday rotation is small and the magnetic fields are aligned. In one region of high polarization (up to 10%) there is some correlation with the polarization of starlight, the Faraday rotation seems to be rather small, and there are indications that the line of sight is at right angles to the direction of the magnetic field (**35**). It seems likely that the small degree of polarization is due to the fact that the galactic magnetic fields are rather tangled, particularly in the galactic halo. Higher resolving powers and observations at several different frequencies are planned in the near future. The linearly polarized component of the radiation from discrete sources, both galactic and extragalactic, suffers little Faraday rotation at high galactic latitudes, much at lower latitudes, indicating that the product of electron density and magnetic field strength NH increases towards the galactic plane, given the same path lengths (**1a**).

Unpolarized Continuum

One of the most important data needed for the interpretation of the galactic background emission is its spectrum. Accurate measurements of the absolute intensity up to 400 Mc/s have been made by the Cambridge group (**43, 47, 49**). At this frequency, where the background intensity goes down to 20°K or less, background radiation in sidelobes makes a determination of the zero level very difficult. We may hope that with great effort and specialized antennas, eventually the background intensity down to 21 cm might be determined; it is only a few degrees K at that wavelength. The spectral index between 38 and 400 Mc/s is in the neighbourhood of 0·5 or 0·6. At the low-frequency end, measurements of the background emission, averaged over a large part of the visible sky, were made with ground-based (**12, 21**) and rocket-borne receivers (Haddock), down to 1·25 Mc/s. They indicate that the spectral index decreases to zero at the lower frequencies and possibly becomes negative at the low-frequency end. It may be shown that at least part of this is due to absorption by the ionized interstellar medium.

Several high-resolution maps have been produced recently such as those at 19 Mc/s (beam-width 1·4 × 1·4 square degrees) (**26, 45**), at 38 Mc/s (1 × 1) (**23**), at 178 Mc/s (4·5 × 0·2) (**48**), at 408 Mc/s (0·8 × 0·8) (**28**), at 960 Mc/s (0·9 × 0·9) (**55, 56**), at 1400 Mc/s (0·9 × 0·9) (**31**) for the southern hemisphere, completing the earlier northern hemisphere map, and 2700 Mc/s (0·3 × 0·4) (**3**). The mapping with high resolution is now really underway, and many details become visible. The question of whether the spiral arms are really visible as

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humps in the distribution of the non-thermal and the thermal emission along the plane, seems to be answered in the affirmative. The interpretation is less certain: is the thermal, and for that matter the non-thermal background also, entirely broken up into sources concentrated along the arms, or is there a continuous source medium of ionized hydrogen and non-thermal emitters as well (**1b, 11**)? The situation of the continuous emission from the galactic centre does not seem to be cleared up yet. There are clearly several bright sources at or very close to the centre, but not enough data with high resolution at various frequencies are available to accurately determine the spectrum of the various components (**1c, 30, 41**). There is clearly a mixture of ionized gas and non-thermal emitters.

The thermal sources in the Galaxy are now well understood, in particular the bright emission nebulae (see Commission 34). Recent high-resolution observations at 21 and 10 cm in Australia show that many of the unidentified thermal and non-thermal extended sources along the galactic plane are breaking up into several smaller sources (**1d**). There are now about 15 super-nova remnants known and both their spectra and their structure have been studied in detail (**18**). Most apparently are in the form of shells or parts of shells (**1e, 29**).

21-cm Line

An almost complete low resolution ($2^\circ\cdot5$) survey of the whole sky is now available (**13, 32, 33**). The velocity pattern in the solar neighbourhood derived from this shows that most of the hydrogen at higher galactic latitudes is moving towards the plane (**19, 33**). The galactic rotation curve in the southern hemisphere has been compared with the older northern hemisphere curve and shows lower velocities (**25**). This was tentatively explained as due to radial motion of the local standard of rest, and a velocity model was proposed which included an expansion term going as $1/R^2$. Recent observations have shown this latter assumption to be invalid (**1f, 6**): general expansion, if present at all, does not seem to be larger than 5 to 10 km/sec throughout the Galaxy. Further work on the central regions of the Galaxy indicates that the very central part can be described as a rapidly rotating disk (solid-body rotation) with a diameter of 600 pc, and a ring with a diameter of 1200 pc (**1g**; Oort, in **2, 44**). The 3-kpc arm is shown to break up into various parts at greater angular distances from the centre (**1h**). Further away from the centre, between 3 and 6 kpc, it appears that the spiral structure might be described as a condensation in a rather smooth layer of neutral hydrogen (Oort in **2**). The far outer arm, at about $R = 12$ kpc, is shown to extend up to several kpc above the galactic plane (Blaauw, in **2**). In several regions both near the Perseus arm and in the more central regions of the Galaxy neutral hydrogen concentrations have been found at many hundreds of parsecs from the galactic plane (Blaauw, in **2**). Recently, hydrogen clouds at high galactic latitudes with radial velocities larger than 100 km/sec have been found (**36**). It seems likely that they are situated in the galactic halo. Investigations of hydrogen in various restricted areas of sky are underway. These include studies of associations, such as Orion, Sco II, Per I (Groningen), I and II Mon (**15**, Leiden); IC 443, the anticentre region (Penticton), and many others. These studies lead to dynamical models of the hydrogen in some of the associations, and to detailed density distributions. The anticentre observations are aimed at a study of the large-scale motions beyond the Sun (**20**). Individual hydrogen clouds have been studied by resolving the line profiles into Gaussian components (**50**, Takakubo, **54**). The observations may be reproduced by uniform spherical clouds with 3 pc radius, a density of 14 cm^{-3}, a number density in the galactic plane of 3×10^5 clouds per kpc, and a mass of 55 $M_\odot$. Reconsideration of the original Leiden catalogue of line profiles in combination with new observations, has led van Woerden to calculate a total neutral hydrogen mass of between 3 and 4×10^9 $M_\odot$. Changing $R_\odot$ from 8·2 to 10 kpc will increase the hydrogen mass to 5 to 7×10^9 $M_\odot$. The largest amount of hydrogen is found in the Perseus arm, enhancing the similarity with the Andromeda nebula. Several studies of the 21-cm line absorption have been made or are in progress, confirming the earlier conclusions that these absorption lines are, in general, very much narrower than the emission lines (**10**). Of several attempts to measure the Zeeman splitting in the 21-cm line, only one has yielded positive results, indicating a field of the order of 2×10^{-5} gauss in one cloud, and a general field of the order of 5×10^{-6} gauss (**1i**). The upper limits of the investigations giving negative results are about 5×10^{-6} gauss (**51**).

Theoretical

A number of theoretical papers on the non-thermal emission from the Galaxy discuss the emission mechanism (**14, 42**), the distribution of the magnetic field (**57**) and the galactic 'spur' (**37, 38**). A review of the theoretical work on magnetic fields and spiral structure is given in (**52**). The expansion of hydrogen near the galactic centre and the existence of a galactic halo suggest phenomena similar to those in the very bright radio galaxies, but on a much smaller scale (**8**). The thermal emission mechanism is now well understood and formulated in various papers (for example **39**). Measurement of the gravitational redshift in the 21-cm line due to the mass of the Galaxy was shown to be impossible due to the large random and systematic motions of the hydrogen (**24, 27**).

Attempts at measuring the deuterium and OH lines were unsuccessful. Several other lines, notably those of H_2^+, are discussed (**9, 22, 34**).

Galactic Pole and Scale of the Galaxy

The evidence on which the choice of a new galactic co-ordinate system was based (21-cm line, radio continuum, galactic centre, and optical determinations) was published (**4, 5, 16, 17, 40**). The new galactic co-ordinates are now being used in most recent publications. For the reductions of 21-cm line data, a value for the distance Sun-centre of 8·2 kpc was used up until 1963. It is recommended that, in view of present evidence, the values $R_0 = 10$ kpc, $\theta_0 = 250$ km sec^{-1}, $A = 15$ km sec^{-1} kpc^{-1} and $B = -10$ km sec^{-1} kpc^{-1} be used for 21-cm line work (**58**).

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