1. Introduction

This Atlas presents in graphical as well as digital form observations made with the Dwingeloo radio telescope of emission from neutral atomic hydrogen, HI, lying in our own Galaxy. Observations of HI provide information on a broad range of physical and morphological characteristics of the galactic interstellar environment, including information on temperature, density, and motion. HI contributes more mass than any other observed interstellar constituent. It is furthermore so widely spread that no direction devoid of HI has ever been observed. Under most circumstances, the interstellar medium is transparent enough to emission at 21-cm wavelength that HI investigations refer to much of the entire Galaxy, well beyond the optical horizon. Under less common circumstances, the optical depth of the HI line is high, so that information on the gas temperature is revealed. Because an intrinsically narrow spectral line is involved, the observations measure the kinematics of the interstellar medium in great detail.

Several recent reviews stressing the astrophysical relevance of HI data are available. The review by Dickey & Lockman (1990) discusses HI evidence regarding temperature and density, especially pertaining to the local, vertical variation of these parameters; the review by Kulkarni & Heiles (1988) discusses the differing temperature regimes represented in 21-cm spectra; and the reviews by Burton (1988, 1992) deal with aspects of galactic morphology amenable to studies using the HI tracer.

Almost three decades after the first major northern-sky surveys of galactic neutral atomic hydrogen were made with the former Hat Creek radio telescope, new material was needed to deepen understanding of the interstellar medium. The availability of high-quality all-sky surveys at other wavelengths, in particular in the far-infrared and in the X-ray regimes, prompted the undertaking of a new HI survey using modern equipment. The observational parameters of earlier surveys of the HI 21-cm emission line which have been used for general investigations of galactic morphology and of the galactic interstellar medium have been tabulated by Burton (1988, 1992). The principal parameters are the extent and resolution of the coverage of the sky, the extent and resolution of the coverage in velocity, and the sensitivity to weak emission. The Leiden/Dwingeloo survey presented here improves on the earlier material in each of these parameters.

The principal merits of the new data compared with those of the Hat Creek 85-ft survey of Weaver & Williams (1973) lie in the improved sensitivity and sky coverage; compared with the Hat Creek survey of Heiles & Habing (1974), in the improved sensitivity and velocity coverage; compared with the Leiden/Green Bank 140-ft survey of Burton (1985), in the improved sky coverage and resolution; compared with the Bell Labs survey of Stark *et al.* (1992), in the improved velocity and spatial resolution.

The surveys of galactic HI emission from the southern sky made by Kerr *et al.* (1986) using the Parkes 60-ft telescope at $|b|<10°$, and at higher $|b|$ by Cleary, Heiles, & Haslam (1979) using the Parkes 60-ft and by Colomb, Pöppel, & Heiles (1980) using the IAR 100-ft, remain the standards at $\delta<-30°$, although efforts are currently underway to map the southern sky with modern receivers.

Without attempting a complete listing of earlier 21-cm survey work, we mention two previous Dwingeloo surveys, namely that of Tolbert (1971; see also

Wesselius & Fejes 1973), which remained a prime source of information on the class of intermediate-velocity clouds seen at high latitudes until the appearance of the Bell Labs survey, and the high-velocity-cloud survey of Hulsbosch & Wakker (1988; see also Wakker 1990) which provided the first comprehensive sky coverage of this class of objects.

An older telescope can remain competitive if equipped with state-of-the-art receivers and if the project is such that the modest size of the telescope can be compensated for by a major investment in observing time. It is the case for optical as well as for radio telescopes that technological developments regarding mirrors or antennas, and the general supporting mechanics, have changed more slowly than the detector or receiver electronics. Furthermore, telescopes of modest size are the only ones practicable for survey work attempting coverage of major portions of the sky.

The observations in this Atlas utilized the Dwingeloo 25-meter radio telescope of the Netherlands Foundation for Research in Astronomy (NFRA) for a five-year period. The telescope structure itself had been little changed since its dedication in 1956; the antenna surface had been renewed in 1969 and little changed since then. The detector electronics were, however, of competitive modern design. Improvements in the velocity coverage were made possible by the new-generation DAS spectrometer whose prototype was installed on the Dwingeloo telescope as the project began; improvements in the sensitivity were made possible by the availability of a low-noise receiver of the same sort currently in use on the telescopes of the Westerbork Synthesis Radio Telescope (WSRT).

2. Project motivation

When the Netherlands Foundation for Research in Astronomy was approached for support for the survey, including full-time use of the Dwingeloo radio telescope over a period of some years, our proposal stressed several particular uses of the data which we hoped to gather. Once completed, the new material would be valuable in addressing a range of scientific problems. Among the problems of most interest to us are the following:

1. Many interstellar cirrus dust features have gas counterparts traced by HI to the anomalous-velocity realm of intermediate-velocity clouds (IVCs, with velocities differing from the simply rotating, plane-parallel case, by some 40 to 70 $\mathrm{km\,s^{-1}}$). IVC structures, furthermore, are commonly found correlated with normal-velocity material. The all-sky topography of the IVC gas would be established and its relation to the normal-velocity HI explored. The link of HI at anomalous velocities with dust cirri had suggested the importance of exploring the possibility of some of the HI having been produced by star-formation processes, rather than being precursor to them; the IVC gas would then be material which has been processed near the galactic plane and subsequently accelerated away from the plane as a consequence of star-formation activity. The new data would reveal additional details of the high-velocity cloud (HVC) distribution. The HVC/IVC distinction still remains arbitrary; an effort would be made to establish if this distinction has a physical basis.
2. Regions of exceptionally low total N_{HI} in addition to the 'hole' studied by Lockman, Jahoda, & McCammon (1986) would be sought. Perhaps even more interesting would be regions in which the N_{HI} at *conventional* velocities (within, say, 20 $\mathrm{km\,s^{-1}}$ of $v_{\mathrm{lsr}}=0$ $\mathrm{km\,s^{-1}}$) is exceptionally low ($<7\times10^{19}$ $\mathrm{cm^{-2}}$), but where substantial densities do occur at *anomalous* velocities. Regions of low N_{HI} are par-

ticularly interesting because of the role of H I in obscuring X-rays. Indications would be pursued that X-ray shadows are cast by H I features in regions of low total N_{HI}.

3. The extension of velocity information beyond the coverage and resolution available earlier would enable analysis of the H I data in terms of the areal filling factor; derivation of the volume filling factor would be a more difficult matter, although important constraints could be put on this parameter even using the 0°.5 angular resolution of the new survey. The new material was expected to show many structures with velocity-width dispersions of the order of 1 km s^{-1} and less, and which are clearly isolated in velocity; the commonly accepted picture of high-latitude H I which attributes variations in N_{HI} largely to gradients in a generally smooth, diffuse distribution is one which the new data might well be able to refute. Determinations of filling factors (and, in general, of characteristic kinematic- and structural- scale lengths) are important to discussions of interstellar energetics, in particular of turbulence and scale-height maintenance, of radiation penetration, and of global H I optical depth.
4. The gas-to-dust interrelationships among H I column densities, Lick galaxy counts, and reddening of galactic and extragalactic objects had been analyzed by Burstein and Heiles (1978, 1982), leading to the establishment of correlations predicting galactic reddening. Their work raised important astrophysical questions which could not be verified with the data then at hand: a zero-point offset was found in the relation between reddening and N_{HI} (that is, regions with essentially no reddening showed nevertheless substantial H I intensities), and the H I gas-to-dust ratio was found to vary widely from region to region, for physical reasons not identified. The Burstein and Heiles work had been based on Berkeley H I data so confined in velocity that in many directions much of the gas was ignored (in particular the crucial contribution from the warped outer layer), as were spectra of sensitivity lower than what would characterize the proposed new data; the information on the diffuse dust is also richer now than when the 1978 analysis was carried out. The gas/dust/reddening problem would be re-analyzed, exploiting the qualities of the new H I survey and of the IRAS and other complementary data. Particular attention would be paid to the evident breakdown of the correlation between H I and dust emissivities, which is tight in the inner Galaxy and locally, but evidently not in the outer Galaxy, probably because of changing environmental conditions.
5. Much H I gas is marshalled in filamentary structures which have been variously named from a subjective lexicon as shells, supershells, bubbles, worms, chimneys, etc. The form and motions of such structures reveal aspects of the macroscopic energetics of the ISM. They have not yet been fully studied, largely because of limitations in the available H I data, the most important limitation being the narrow velocity extent of the $|b|>10°$ Berkeley data. A few shells have been traced to velocities well outside the range of the earlier survey data. The larger extent suggests an upward revision of the currently accepted energetics; if verified as general, this conclusion would be important to interpretation of the IVC class of objects, as well as to considerations of the energetics.

In entertaining new proposals in 1987, the NFRA Board had stipulated that future use of the Dwingeloo telescope would be granted only on a 'do-it-yourself' basis, with essential maintenance provided by the Foundation, but without routine operating or data-reduction support. Our proposal was granted, on this basis, for a 1988 start.

3. Background

During World War II, J.H. Oort, professor of astronomy at the Leiden Observatory, and H.C. van de Hulst, graduate student then at the University of Utrecht, discussed whether it would be possible to observe the general gaseous interstellar medium at radio wavelengths. Oort was fully aware of the pioneering work of Jansky and of Reber, which had demonstrated the presence of cosmic *continuum* radiation. He realized that observations of a radio *spectral line* would reveal the kinematics of the interstellar medium, and that distance measures, so notoriously difficult in astronomy, would follow from the kinematics. Van de Hulst set out to investigate which spectral lines might be observable at radio frequencies. At the 75th meeting of the Netherlands Astronomers' Club, which was held at the Leiden Observatory on 15 April, 1944, he presented the results of his calculations predicting that the hyperfine transition of neutral atomic hydrogen, emitting at a wavelength of 21.106 cm, should be observable (see van de Hulst 1945). The minutes of this meeting are reproduced in facsimile and in translation on pages 84-85. Van de Hulst's prediction was based on his realization that the number of hydrogen atoms in the ground state along a line of sight traversing the entire Milky Way would be very large. He also recognized that the density of atoms would be high enough for the hyperfine transition to be stimulated by encounters; indeed, transitions stimulated by encounters between atoms would occur much more frequently than spontaneous ones from isolated atoms.

The high expectations for the importance of radio astronomy led to the establishment, on 23 April, 1949, of the Netherlands Foundation for Radio Emission from Sun and Milky Way (Stichting Radiostraling Zon en Melkweg, SRZM), with Oort as the first chairman. In addition to astronomers, the founders of the SRZM included scientists from the Philips Physics Laboratory in Eindhoven, representatives of the Dutch Post- Telephone- and Telegraph- company (PTT) who were concerned with the effects of solar eruptions on the ionosphere, and meteorologists from the Royal Dutch Meteorology Institute (KNMI) who had similar interests. Several radar dishes of the Würzburg-Riesen class, which had been part of the German radar defenses deployed along the North Sea coast during the War, were transported from their locations in the dunes to the PTT central transmission station near the town of Kootwijk. One of these 7.5-m dishes was made available to the SRZM for use as a radio telescope.

The HI line was first detected by H.I. Ewen and E.M. Purcell in 1951 (on Easter morning) at Harvard University. Work in Kootwijk had proceeded diligently in early 1951, but had been delayed some months by a fire in the receiver cabin. When the receiver had been re-built, C.A. Muller and J.H. Oort succeeded in detecting the spectral line on 11 May, 1951. Within weeks, J.L. Pawsey confirmed Christiansen's and Hindman's measurement of the line in Australia. In an admirable display of scientific cooperation, all three early detections were published side-by-side in the same, 1 September, 1951, issue of *Nature*.

During the next five years, new receivers were developed in the laboratory at Kootwijk. Meanwhile, the 7.5-m telescope was used nearly full-time to make the first maps of neutral atomic hydrogen in the plane of the Galaxy, and to demonstrate fundamental aspects of galactic rotation. The first results of this pioneering work were published in 1954 (see van de Hulst, Muller, & Oort, and Kwee, Muller, & Westerhout, as well as other articles in Vols. 12 and 13 of the *Bulletin of the Astronomical Institutes of the Netherlands*). Before the Kootwijk telescope was effectively superseded by larger facilities, it had also provided important data supporting the first estimates of the thickness of the gaseous disk of the Milky Way, had led to measures of the characteristic optical depth and gas temperature of the interstellar HI, and had contributed to the determination of the direction of the center of the Milky Way and of the fundamental planes of galactic longitude and latitude.

As early as 1945, Oort had argued to the Royal Dutch Academy of Sciences that a radio telescope with a diameter as large as 25 meters should be built to map the Galaxy thoroughly in the 21-cm line. At that time the War had only recently ended, and such an ambitious project could not be realized. But a decade later, after the successful work done with the Kootwijk telescope, Oort, as chairman of the SRZM, did manage to obtain a grant for building a 25-m telescope.

The location of the site for the new observatory was partly motivated by the requirement of radio silence. A nature reserve near the village of Dwingeloo (in the relatively sparsely populated province of Drenthe in the northern Netherlands) was expected to remain undisturbed by radio interference in the foreseeable future. The telescope was built at the edge of this reserve, where the forest meets the heath. An important consideration behind approval of the project by the authorities of the nature reserve was the observatory's intent to minimize the presence of motorized vehicles in the area.

The Dwingeloo telescope received 'first light' in November, 1955, when a rare lunar occultation of the Crab Nebula (Tau A) occurred. Although the telescope was then not yet fully operational, the occultation was successfully observed at a frequency of 400 MHz, with pointing and tracking done manually. The official opening of the telescope took place on 16 April, 1956, when Queen Juliana pressed a button setting in motion what was then the largest telescope in the world. The Dwingeloo telescope has now been in continuous operation for almost 40 years, longer than any other radio telescope.

4. The Dwingeloo Telescope

Accounts of various aspects of the background of the Dwingeloo 25-m telescope and its scientific achievements have been given by Kleibrink (1957), Westerhout (1961), van Woerden, Brouw, & van de Hulst (1980), Spoelstra (1981), Sullivan III (1982), van Herk, Kleibrink, & Bijleveld (1983), and Hartmann (1994), as well as in the annual reports of the Netherlands Foundation for Radio Emission from Sun and Milky Way, now renamed the Netherlands Foundation for Research in Astronomy.

The Dwingeloo telescope has contributed to a wide range of astronomical research. Among its principal contributions made in 21-cm studies of our own Galaxy include the discovery of the 3-kpc arm, studies of the galactic center, work directed at mapping the Galaxy-at-large and determining its rotation and general kinematic structure, discovery of the high-velocity-cloud and intermediate-velocity-cloud classes of objects, as well as studies of individual regions of particular astrophysical interest. Hartmann (1994) has listed the Ph.D. theses which were based on observations made with the 25-m telescope.

The Dwingeloo radio telescope has a reflecting mirror with a diameter of 25 meters and a focal length of 12 meters. The antenna surface is constructed of 372 triangular frames each with sides 1.8-m long. Each frame was covered originally with a 15×15 mm wire mesh, woven from steel wire with a diameter of 1.5 mm. Crossing wires were welded together and the entire surface galvanized. The dish moves up and down in elevation in a horizontally-mounted support structure. The support structure is constructed as a robust steel frame resting on four wheels, each 80 cm in diameter. It can rotate in azimuth over a circular steel track 16 meters in diameter. The weight of the dish alone is 18 tonnes. The total weight of the telescope is 120 tonnes, half of which is carried by a central pivot bearing. When constructed,

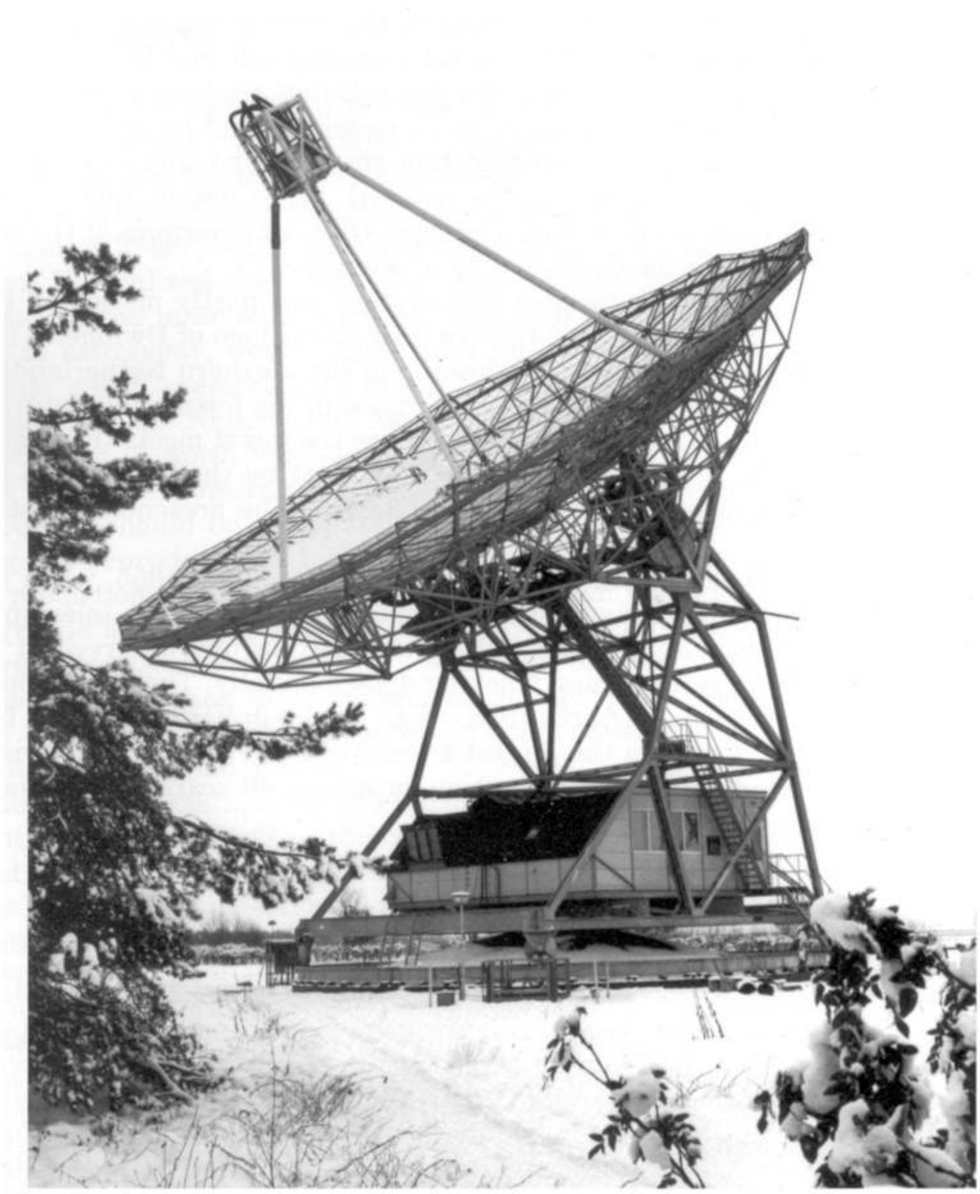

Figure 1. *The 25-meter Dwingeloo radio telescope of the Netherlands Foundation for Research in Astronomy. The observations in this Atlas utilized this telescope for a continuous five-year period, compensating for the modest size of the antenna by a substantial investment in time.*

the receiver feed was suspended at the focus of the telescope by a single central pole of 15 cm diameter, guyed with three steel wires to the edge of the dish. The single-channel Dicke-switched receiver weighed 25 kg; it was not cooled, and had a system temperature of about 400 K.

During the 20 years following its official opening, three major modifications were made to the telescope structure. The first modification was required by the new front-ends which had been developed with feeds that better illuminated the mirror and had lower sidelobe responses. They were, however, bigger (blocking more of the beam) and heavier (weighing about 150 kg) than the old front-end and could not be supported by the single pole. In late 1961, the single pole supporting the receiver was replaced by a more stable tripod construction.

The second structural modification involved re-surfacing the antenna in order that research carried out using the telescope could be extended to wavelength regimes shorter than the 21-cm one. In 1969 a new 7.7×7.7 mm mesh made from 0.8-mm diameter stainless-steel wire was applied to the triangular panels, allowing observations at wavelengths as short as 6 cm. To stabilize the parabolic shape of the dish, the frame of each panel was kinked in the middle of each side. Deviations from a perfect parabolic shape were now less than 1 mm.

The third modification followed the development of cryogenically cooled receivers, which again increased the size and weight of the front-ends beyond the capacity of the feed-support structure. In 1973–74, the tripod was replaced by a quadripod. The Dwingeloo telescope was now also suited to test front-ends for the Westerbork Synthesis Radio Telescope. The relevance of these structural modifications to the HI survey presented in this Atlas is discussed below.

In 1974, the Dwingeloo telescope was equipped with a prototype of the WSRT multi-frequency front-end receiver (Casse, Woestenburg, & Visser 1982). It was a cryogenically-cooled system, with a 256-channel digital auto-correlator spectrometer back-end, which also was a prototype of a new WSRT instrument. A wide range of bandwidths could be selected. The system temperature was about 40 K, half that of the previous front-end. The receiver was improved in 1981, when the two-step parametric amplifier was replaced by a helium-cooled FET amplifier with a noise temperature of 13 K. The total system temperature is now about 35 K when observing directions of low HI column density. The receiver is equipped with a single channel which is matched to the linearly polarized dipole antenna.

The 256-channel spectrometer was replaced in 1988 by the 1024-channel prototype of the Dwingeloo Auto-correlation Spectrometer (DAS; see Bos 1989), which had been developed at the NFRA as the common-user spectrometer for the British/Dutch/Canadian James Clerk Maxwell Telescope on Hawaii. Equipped with a receiver of the WSRT class and with the DAS back-end, the Dwingeloo telescope was thus outfitted with state-of-the-art electronics; this was the instrumental setup pertaining at the time of our survey.

5. Observing strategy and parameters

The availability of a 1024-channel back-end guided the choice of the bandwidth. To cover the entire velocity range expected from galactic HI, including all but the most extreme high-velocity clouds, we observed at 5-MHz bandwidth, covering a velocity interval of 1055 km s^{-1} centered at $v_{\rm lsr}$=0 km s^{-1} (central channel). After reduction, the effective useful velocity range was $-450<v_{\rm lsr}<+400$ km s^{-1}, sampled at an interval of 1.03 km s^{-1} between channels. (Radial velocities in this project were expressed relative to the Local Standard of Rest, defined in terms of the Standard Solar Motion of 20 km s^{-1} toward $(\alpha,\delta)_{1900}=(18^{\rm h}, 30°)$.)

The half-power beam width (HPBW) of the Dwingeloo telescope at 1420 MHz is 36 arcminutes, or 0°.6. A fully sampled survey would require positional spacings of 0°.3. A 5°×5° region would then contain about 300 pointed observations, and the total number of observations for the survey would have exceeded 550,000. We decided instead to sample the sky with a 0°.5 (true-angle) spacing. At 85% of the HPBW, or 60% Nyquist sampling, the estimated total number of grid points was reduced by a factor of 2.8.

The choice of the integration time, $t_{\rm int}$, was influenced by two principal factors. The integration time was to be long enough to improve the signal-to-noise ratio over that of earlier work. The completed survey is characterized by an *rms* noise of about 0.07 K. On the other hand, the integration time was to be short enough to allow mapping the entire accessible sky in a reasonable amount of time. The expected number of observations was of the order 2×10^5. This implied a net total integration time of about 140 days per net minute of integration time per spectrum. An additional overhead time for each spectrum was about 90 seconds. We were thus led to a choice of $t_{\rm int}$=180 seconds, implying an estimated net telescope time of 625 days. As the survey progressed, we realized the importance of repeated observations of single positions, particularly for adequate tuning of the stray-radiation correction procedure. In addition, a variety of unforeseen software, hardware, and weather problems lengthened the expected time commitment. As it turned out, the Dwingeloo telescope was dedicated to this project for a period of five years.

The HI spectral line contributes only a small fraction of the total power received and recorded by the telescope system during an observation. Most of the power originates from instrumental noise, from the far sidelobes of the antenna looking at the ground, and from true cosmic background continuum radiation. The various amplifiers and filters in the receiver system introduce frequency-dependent gain variations, shaping the bandpass of the signal that enters the spectrometer. Removing the bandpass characteristics from the observations requires determining what the bandpass shape would be if *no* spectral-line emission were present. There are three general observing modes designed to accomplish this: beam-switching, load-switching, and frequency-switching.

In the *beam-switching* mode, a signal spectrum ('on source') is compared with a reference spectrum ('off source') close by in position (typically a few beam widths away) and hopefully devoid of emission. For 21-cm spectral-line observations this method generally is not useful, as not a single line of sight has ever been found devoid of HI emission.

In the *load-switching* mode, instead of switching to a patch of emission-free sky, a reference spectrum is obtained from a cold matched resistor in a cryogenic system. A white-noise signal is added to balance the output power with that of the signal spectrum. However, gain variations over the frequency band are likely to be different in the reference spectrum than in the signal spectrum, introducing baseline problems in the combined spectrum.

The *frequency-switching* mode is the most commonly-used technique for galactic 21-cm spectral-line observing. Tuning the receiver away from the spectral window containing the HI line, a reference spectrum may be obtained; as the frequency switch takes place at the first local oscillator, the shape of the bandpass is affected by the consequent amplifiers, filters, and oscillators in very much the same way as the signal spectrum. An important disadvantage of the frequency-switching mode is that this mode doubles the required integration time.

We chose the so-called total-power variation of the frequency-switching mode. The local oscillator was tuned to set the frequency for the central channel to that corresponding to $v_{\rm lsr}$=0 km s^{-1}. A total-power measurement consists of two cycles, S and (S+N), yielding a correlation function and total power for the signal cycle, S, for the duration of $t_{\rm int}$, and a total power for the signal+noise cycle, S+N, for the duration of $t_{\rm noise}$. Reference spectra were obtained by regularly observing total-power spectra toward selected grid points at a central frequency that was a full bandwidth (5 MHz) higher than the $v_{\rm lsr}$=0 km s^{-1} setting. The instrumental baseline of a number of survey spectra could then be accounted for by a single reference spectrum.

About 10% of all survey grid points measured were such references. In addition to the observations made on the survey grid, certain standard directions were observed in frequency-switching mode. These standards served as stability calibrators for the absolute intensity-scale conversion, from antenna temperature to brightness temperature, and as consistency calibrators for the stray-radiation cor-

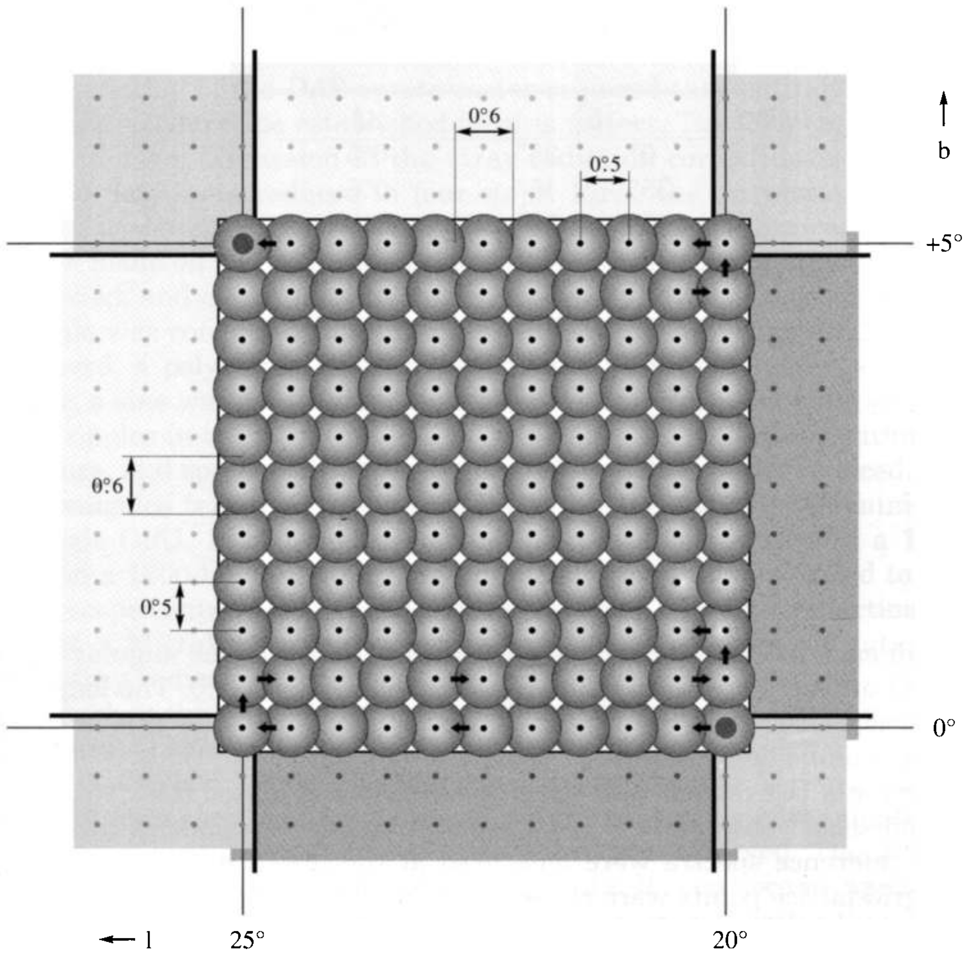

Figure 2. *Distribution of survey grid points in a 5°×5° box. In this particular example, l_{min}=20° and b_{min}=0°. The longitude spacing here is Δl=0°.5 (see Table 1); Δb is equal to 0°.5, as for all boxes. Each grid point is marked by a dot surrounded by a circle indicating the size of the HPBW. The arrows and the overlap of the circles indicate the direction in which the grid was traversed. Reference spectra were observed at the first and last grid points (indicated by the large dots). In this example, eight References and 121 Sources were measured. This box has 40 grid points in common with its four neighboring boxes; these positions were subsequently measured again, yielding a total of 36 doubly and four quadruply observed directions.*

rection procedure described below. They also provided a safeguard against general problems such as pointing errors and gain variations.

Code was written to schedule the observations optimally. The entire sky accessible from Dwingeloo (longitude $6^h23^m48^s$ east, latitude +52°48′48″) was divided into galactic-coordinate 'boxes', each measuring 5°× 5°. If the center of a box was north of declination −32°.5 , it was marked for observing. The strategy was to observe low-declination boxes as early during the survey as possible. In the final stages of the data taking, remaining boxes were largely circumpolar; these were scheduled by hand, as were the galactic polar-cap regions (at $|b|$>85°) and the positions that for some reason needed to be re-observed.

Within each marked box a uniform rectangular grid was specified, as illustrated in Figure 2. The objective was to observe all the grid points in a particular box in a single contiguous run. The latitude separation, Δb, was constant for all boxes, and equal to 0°.5 (85% of the *HPBW*). The longitude separation, Δl, was con-

Table 1. *Longitude separation of the grid points in an observing 'box', as function of the galactic latitude of the center of the box*

$\lvert b \rvert$	Δl
0° ... 35°	0°.5
35° ... 45°	0°.6
45° ... 55°	0°.7
55° ... 60°	0°.8
60° ... 65°	1°.0
65° ... 70°	1°.1
70° ... 75°	1°.4
75° ... 80°	1°.9
80° ... 85°	2°.8
85° ... 90°	5°.0

stant within each individual box, and chosen such that the true angular sky separation was 0°.5 or less. For $|b|>85°$, the longitude interval was 5°.0. The longitude sampling interval for the different latitude strips is given in Table 1. A box at $|b|<35°$ had 121 grid points; boxes at $|b|>35°$, fewer.

Observing a box consisted of the following steps. Pointed (i.e., 'stop-and-stare', or 'point-and-shoot') observations in total-power mode were made at each grid point. First, four reference spectra were measured at the initial grid position ($l_{\rm min}$, $b_{\rm min}$). Next, the grid lattice points were observed, increasing galactic longitude before latitude. On moving to the next latitude, the longitude direction was reversed to reduce the slewing time of the telescope. After taking the last spectrum at ($l_{\rm max}$, $b_{\rm max}$), four reference spectra were again taken. The scheduling code avoided observing positions lying closer than 25° to the Sun, or closer than 10° to the Moon. Before initiating observations of a new box, selected standard sources were scheduled. In addition, once every 24 hours, an observation of either Virgo A or Taurus A was scheduled.

An observation of a single grid point required about 270 seconds. The noise cycle time and the overhead added 90 seconds to the net integration time of 180 seconds. The overhead time included the telescope slewing time between grid points, and telescope settling time, but was largely due to the initialization procedure of the auto-correlator. Steering the telescope to the first grid point in a box proceeded at about 0°.5 per second. The total overhead time required was thus substantial, namely about 50% of the net integration time. Observing an entire box, involving 121 lattice points plus eight references, required about 10 hours to complete if the system operated optimally.

It was convenient for a variety of practical reasons to schedule the observing for periods of about a week's duration; we called observations made during a single such period a 'batch'. Routine observing began in November, 1989, about a year had been spent debugging the DAS and preparing the telescope and the observing and operating procedures. Between November, 1989, and November, 1992, 126 batches were completed. During these three years, the telescope was fully devoted to the survey; periods of maintenance, system failure, and poor weather conditions increased the gross observing time. In May, August, and September, 1993, three additional batches were observed to complete the data-taking phase of the project.