The Interstellar Hydrogen Line at 1,420 Mc./sec., and an Estimate of Galactic Rotation

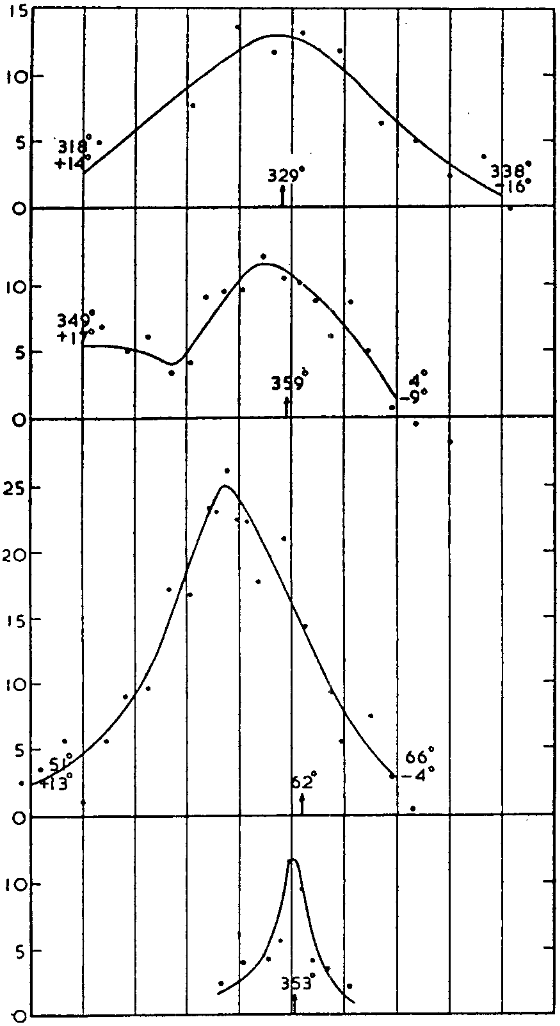
FOLLOWING a suggestion made by Dr. H. C. van de Hulst in 1944[1], attempts have been made to measure the radiation at 1,420 Mc./sec. (λ21 cm.) emitted by atomic interstellar hydrogen. The first experimental evidence for the presence of this interstellar emission line was obtained by Ewen and Purcell on March 25, 1951 (see the preceding communication). In the Netherlands, the first successful measurements were made on May 11.

The receiver consists of a double superheterodyne instrument, with a crystal-controlled first local oscillator, which is switched between two frequencies 110 kc. apart thirty times per second by a reactance modulator. By varying the frequency of the second local oscillator, the two frequencies can be moved together through a 4-Mc. wide pass band at 1,420 Mc. The pass band of the second i.f. channel is 25 kc. wide. Behind the usual phase-sensitive detector a narrow-band filter with a time constant of 12 sec. is used. So the difference between two frequency bands 110 kc. apart is measured. The noise factor of the receiver has not yet been measured. The losses in the coaxial antenna cable are rather high, and an effective noise factor of the whole receiving system of 25 has been deduced from other measurements with the sun as a source of noise. Important parts of the receiver have been constructed at the Philips Laboratory in Eindhoven under the supervision of Dr. F. L. Stumpers.

The receiver has been mounted behind a movable paraboloid of 7·5 m. aperture and 1·7 m. focal-length at the radio station at Kootwijk, which was kindly put at our disposal for these measurements by the Radio Department of the Post and Telegraph Service. The beam-width at half-power is 2·8°.

The results of the measurements made on a few of the first tracings are shown in the accompanying graphs. While these tracings were being made, the instrument was left in a fixed position relative to the earth, the motion across the sky being provided by the earth's rotation. The frequency of the second local oscillator is switched every 3 min. between positions in which either of the two pass bands coincides with the spectral line. The first position gives a positive, the other a negative, deflexion on the recording meter. The curves show the intensity as function of the right-ascension; the interval between successive vertical lines is 20 min. of time. The point at which each sweep crossed the galactic equator has been marked with an arrow, accompanied by a number giving the corresponding longitude. The galactic co-ordinates at the beginning and end of each tracing have also been indicated. The curves shown may be slightly distorted because the radial components of the orbital motion of the earth, of the sun's motion relative to the nearby interstellar clouds and of differential galactic rotation are different for the various directions. However, we do not believe that these effects will have seriously affected the general shapes of the records, except for latitudes less than 1½°, where in some directions the line is greatly widened by galactic rotation, and the measured intensities will be too small.

It is evident from the wide spread in galactic latitude that the clouds observed must be relatively close to the earth. From the width of the emission line observed in the region of the centre of the



Galaxy, where the rotation of the galactic system does not affect the line, it is found that the random velocities average about 5 km./sec. in one co-ordinate, which agrees approximately with what had been found from absorption lines in the visual region. With such small velocities it is unlikely that the gas extends to more than an average distance of about 50 parsecs from the galactic plane. With an average latitude of the order of 8°, the gas seen in the general direction of the centre cannot then be farther away than 300 or 400 parsecs. In Cygnus the distance may be twice this amount.

These small distances might be taken as an indication either that the more central parts of the Galaxy are devoid of atomic hydrogen, or else that within a distance of between 500 and 1,000 parsecs in the galactic plane the gas becomes optically thick in the wave-length of this line. Although we should like to reserve a definite judgment until more complete measures have been obtained, we believe the latter alternative is the more probable on the basis of the results so far available.

In order to test the presence of radiating hydrogen in the inner regions of the Galaxy, measures have been made across the Milky Way at $l = 355°$, 30° from the centre, where the change of frequency due to differential galactic rotation should make it possible to observe the gas up to large distances. Provisional measures indicate that the emission line in this direction has an effective width of about 330 kc./sec., or 70 km./sec., and that the rotational velocity of the galactic system at a distance from the centre equal to half the sun's distance from the centre is approximately 190 km./sec. This agrees well enough with the rotational velocity of 205 km./sec. computed from a schematic model of the galactic system[2]. (In both cases a value of 270 km./sec. has been assumed for the rotation near the sun.)

The graph at the bottom shows the results of a registration across the Milky Way at 355° longitude and at a frequency 250 kc./sec. lower than the normal frequency of the line, corresponding to a differential radial velocity of +55 km./sec. The gas clouds observed at this frequency are presumably situated at an average distance of about 8 kiloparsecs. It may be noted that the spread in latitude is quite small, and may roughly correspond to the beam-width of the instrument, as would be expected for these large distances.

The tracings reveal many irregularities in distribution. The extension to high positive latitudes in the second graph may possibly be connected with the well-known dense clouds in Ophiuchus. The maxima in the Cygnus region lie systematically about 2½° south of the galactic circle at longitudes between 40° and 45°, while between 56° and 62° they occur roughly 3° north of the plane. Though no weight should be attached to the exact differences in height of the various sweeps, the intensities in Cygnus appear to be definitely higher than in other regions (except in that opposite the centre). This may be ascribed to the effects of galactic rotation. The fact that the intensity is also lower in the direction towards the centre, where these effects are presumably negligible, is possibly due to the superposition of continuous background radiation, which has probably a considerable intensity in this direction.

The measurements reported in this communication are of a provisional nature. Improvements in the receiver are possible, and are now being made in preparation for more systematic measurements.

The investigation has been made possible by grants from the Netherlands Organization for Pure Research (Z.W.O.).

C. A. Muller
J. H. Oort

Netherlands Foundation for Radio Astronomy,
Kootwijk Radio Station.
Observatory,
Leyden.
June 26.

[1] Van de Hulst, H. C., *Nederl. Tij. Natuurkunde*, 11, 201 (1945).
[2] Oort, J. H., *Bull. Astro. Inst. Netherlands*, 9, 193 (1941).

The following cable dated July 12 has been received from Sydney, N.S.W.:

Referring Prof. Purcell's letter of June 14 announcing the discovery of hyperfine structure of the hydrogen line in galactic radio spectrum, confirmation of this has been obtained by Christiansen and Hindman, of the Radio Physics Laboratory, Commonwealth Scientific and Industrial Research Organization, using narrow-beam aerial. Intensity and line-width are of same order as reported, and observations near declination 20° S. show similar extent about galactic equator. J. L. Pawsey

VARIATIONS IN THE CHEMICAL COMPOSITION OF STRATOSPHERE AIR

By Dr. K. F. CHACKETT, Prof. F. A. PANETH, F.R.S., P. REASBECK and B. S. WIBORG

Londonderry Laboratory for Radiochemistry, University of Durham

In a previous article[1] analyses of upper air samples obtained from 52–66·5 km. height by means of *V*2 and Aerobee rockets were described, and it was shown that in all cases the composition of the samples was nearly the same as at ground-level, with respect to the ratio of helium, neon and argon to nitrogen. At the same time it was pointed out that some uncertainty must be attached to the helium values because the air was sent to us in glass vessels. Recently, we received, from the University of Michigan, stratosphere air in the original steel bottles in which the samples had been collected; a new and improved sampling technique had been employed, and in the meantime our method of analysis had also been further developed. We now wish to communicate our latest results, which provide evidence for gravitational separation between 64·3 and 71·8 km. height (M.S.L.). Details of the experimental procedure will be published later.

We owe the following information about the new sampling arrangements to the scientific workers of the Department of Aeronautical Engineering, University of Michigan[2]. Three evacuated steel bottles were located immediately behind the hollow nose cone of an 'Aerobee' rocket. The bottles were soldered to thin copper tubes, one inch in diameter, the sealed-off ends of which projected into the cone. The latter was ejected automatically just before sampling. At a predetermined instant a steel knife was arranged to cut through one tube, and five seconds later this was squeezed shut at a lower point by a pyrotechnically operated vice. The second and third bottles were opened and shut at successively later times. Control experiments had shown that the sealing mechanism gave satisfactory vacuum-tight seals without the use of solder.

A successful flight took place from the White Sands Proving Ground in New Mexico on December 19, 1950. After recovery, the three steel bottles were dispatched to us and their contents analysed by our micro-method for oxygen, nitrogen and the inert gases helium, neon and argon. Since our previous work, an entirely new apparatus had been built with several improvements over the old model. Thus, the air pipette was of smaller volume, enabling us to take smaller amounts of gas (between 0·07 and 0·10 c.c. s.t.p. for each analysis); the same pipette was used for the helium–neon analysis and for the nitrogen–argon analysis; and the fractionating column consisted now of fifteen units instead of twelve, each smaller than formerly, and operated by means of a mechanical device which could be set to perform any number of fractionations and then stop.

In general, runs on the stratosphere air were sandwiched between runs on ground-level air, so that a good check could be kept on the satisfactory working of the apparatus. As we found in the earlier work, the oxygen content of the samples was much below normal in spite of the fact that the sampling vessels were always cold. It is impossible to assume that there really is this deficit of oxygen in the