19. A MOTION PICTURE FILM OF GALACTIC 21-CM LINE EMISSION

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Since 1964 we have been observing 21-cm line profiles in a new survey of the neutral hydrogen distribution in the neighborhood of the galactic plane with the 300-foot radio telescope of the National Radio Astronomy Observatory* in Green Bank, W.Va. This is the largest telescope available for 21-cm line work; it has a beamwidth of 10 min of arc and is equipped with an excellent line receiver. Since it seems unlikely that an extensive hydrogen-line survey will be made with any larger telescope, we felt that for reference purposes a concerted effort should be made to obtain as many 21-cm data as possible pertaining to the structure of the Galaxy with this telescope. The data have been presented in the form of contour maps giving the intensity of the 21-cm line radiation as a function of right-ascension and velocity at constant declination. A series of contour maps was distributed to the astronomical community in 1966 as the first edition of the *Maryland–Green Bank Galactic 21-cm Line Survey*. The second edition, containing 1200 pages and approximately 1800 maps, was distributed in the summer and fall of 1969. It is expected that additional contour maps, completing the survey as originally planned, covering a latitude range from $b^{\mathrm{II}} = +1°$ to $-1°$, $l^{\mathrm{II}} = 11°$ to $235°$ ($b^{\mathrm{II}} = +3°$ to $-3°$ between $l^{\mathrm{II}} = 100°$ and $145°$), will be finished by the summer of 1970. Scans were made across the galactic equator with a stationary telescope, so that the declination is constant through each scan; the declination intervals varied from 4 to 6 min of arc. Eventually, we plan to cover a strip from $b^{\mathrm{II}} = +5°$ to $-5°$ between $l^{\mathrm{II}} = 11°$ and $235°$, containing 225000 independent points at intervals of 6 min of arc, with an effective beamwidth of 12.5 min of arc, a velocity resolution of 2 km s^{-1}, and a total of 1.2×10^8 individual intensities.

In our search for a way to examine this mass of data in a convenient form, we have found the contour maps excellent for the study of small-scale features. But by presenting them in the form of motion picture film, one will obtain an overall view of a large section of sky and its variations in a reasonably short amount of time. A section of such a film, covering a region $30° \times 6°$, was shown at the Symposium. In order to produce the film, we converted the survey data into contour maps in galactic latitude and velocity, so that each frame of the film gives intensity as a function of b and v for constant l. The contour maps from which the film was constructed were produced by computer and photographed from the face of a cathode-ray tube. Each frame was photographed 7 times, so that when the film is shown at a speed of 24 frames per sec, one beamwidth in longitude passes by in approximately 2.5 sec. Three frames of the film are reproduced in Figure 1. The successful production of this film is mainly due

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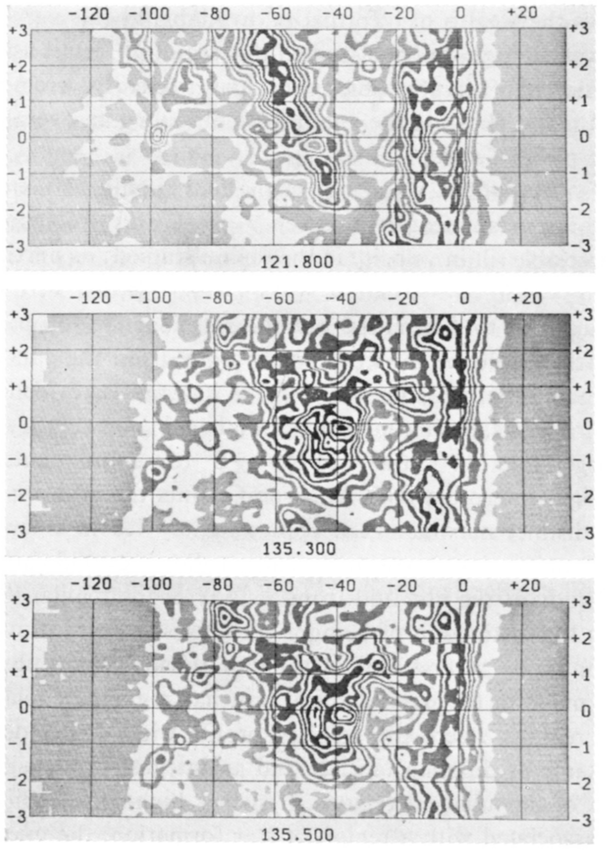

Fig. 1. A sample of three frames from the motion picture film for galactic longitudes 121.8, 135.3 and 135.5. Coordinates are radial velocity with respect to the local standard of rest, and galactic latitude. The contour intervals are approximately 14 K in brightness temperature. Contour lines with higher temperatures are darker.

to the extremely competent computer programming, data analysis and organization of the reductions by Mr. H. U. Wendlandt.

The film displays a part of the sky in which our coverage in latitude is already considerably larger than $b^{\text{II}} = +1°$ to $-1°$, namely the region from $l^{\text{II}} = 108°$ to $138°$, $b^{\text{II}} = +3°$ to $-3°$. The contour maps shown in the film are corrected for the effect of the far-out sidelobes of the antenna, caused by irregularities in the telescope surface (the 'error beam'; a considerable fraction of the radiation comes from a region about 6° in diameter centered on the main beam of the antenna). This correction results mainly in an enhancement of small details with respect to the overall background, but does not produce major changes in the overall pattern. We found that for studies of large-scale galactic structure, the uncorrected maps in the published survey are more than adequate, as long as one is not interested specifically in detailed intensity comparisons.

The film shows the wealth of information available in this survey. In particular, we found that even though we have studied this region in detail using the published survey maps, a number of features which show up very clearly were not seen previously on the published maps, showing the importance of having an overall rapid view over a relatively large piece of sky.

Some of the features which stand out in the film should be mentioned here. The Perseus arm, the important feature between $v=-40$ and -60 km s^{-1}, appears to have a very appreciable tilt in velocity in the region studied: its maximum varies from -60 km s^{-1} at $b^{\mathrm{II}}=+3°$ to -40 km s^{-1} at $b^{\mathrm{II}}=-3°$. If this were to be interpreted as a distance effect due to differential galactic rotation, the top part of this section of the Perseus arm would be 2.5 kpc further away from the sun than the bottom part. As Kerr mentions in his review, there is substantial evidence for a 'rolling' motion in the spiral arms; in this interpretation, the 'circular velocity of rolling' would be somewhat larger than 10 km s^{-1} at $b^{\mathrm{II}}=\pm 3°$ (or approximately $z=\pm 200$ pc). But is this the right interpretation? At several points the arm appears to break up into three very distinct maxima, each approximately 1°.5 in extent, and each at a different latitude and velocity. Are these really 'rolling' around each other?

Both from a study of the film and from a study of the regular contour maps, the Perseus arm has the distinction of being a very massive feature over at least 90° in galactocentric longitude. A first look at the film already makes obvious a statement which has been made in the past: a spiral arm has regions of relative 'quiescence', interspersed by regions where the velocity profile widens considerably, has many maxima at the same or different latitude and an integrated intensity which is much higher than that of the adjacent regions. If such a high-density, high-velocity-width region is to be associated with a region of star formation, the question needs to be answered why such regions occur over only limited portions of spiral arms, typically of the order of 1 kpc in length.

From a study of both the contour maps and the film, it is clear that the intensities of inter-arm regions can be extremely low, often more than 10 times lower than the peak intensities in the arms. But a very interesting phenomenon is the formation of connections between arms in the 30° strip covered by the film. Two such connections form, and remain over longitude ranges of approximately 5°, between the Orion arm and the Perseus arm, and at least one such connection forms between the Perseus arm and the so-called Outer arm. At one point, all three arms appear to be joined by a collection of inter-connected intensity peaks. The frequency of these inter-connections and their variation with longitude give the impression that we might well be dealing here with the 'feathers' observed relatively frequently in the photographs of other galaxies.

Finally, a few remarks about the work in progress at Maryland connected with this survey. We plan to convert the entire survey into a collection of contour maps, each at constant longitude, and corrected for the effect of the far-out (error-beam) sidelobes. These maps will then likewise be put in the form of a motion picture film. A statistical study is underway of small-scale features in several different regions of the Galaxy. Preliminary results indicate that there is a preponderance of small peaks with sizes close to the resolution limit of the telescope, more or less independent of the distance to the sun. This raises the question whether or not the entire interstellar medium is broken up into individual small 'clumps', together blending into the spiral arms. Or do we see here the cool condensations in a hot medium?

Mr. R. H. Harten is studying the large-scale streaming characteristics of the gas in the arms. Examination of the existing data gives evidence for several distinct types of motion: a 5 km s^{-1} streaming motion in the direction of galactic rotation, a helical magnetic field and its implied motion, and a general 'tumbling' of the spiral arms. All of these put together might indicate a helical streaming of the gas with a velocity of the order of 10 km s^{-1} and a skew angle of about 30°, in the direction of galactic rotation. Smaller features seem to indicate the presence of rope-like structures wound around the main body of the arms and streaming some 5 km s^{-1} faster again than these arms.

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