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MAPS OF THE DISTRIBUTION OF ATOMIC HYDROGEN IN A REGION IN CENTAURUS

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ABSTRACT

We have made a survey of the region $302° \leq l \leq 310°$, $2° \leq b \leq 12°$ at the frequency of the hydrogen line. We have detected three elongated features that run parallel to the galactic plane at heights of about 200 pc above it, two of which may be associated with spiral arms in the plane. In addition, we have observed a number of very small clouds with negative radial velocities and one cloud with positive radial velocity.

I. INTRODUCTION

We present in this paper the results of a survey of neutral hydrogen in the region $302° \leq l \leq 310°$, $2° \leq b \leq 12°$. This region is part of a general survey at $b > 2°$ which is being carried out at the Instituto Argentino de Radioastronomía with the purpose of studying the distribution of neutral hydrogen away from the galactic plane, since relatively little information is available in this region in the longitude range visible only from the southern hemisphere.

One of the main reasons why this particular region was studied first was the discovery of profiles with one exceedingly narrow component. Such components are very interesting because an upper limit to the kinetic temperature can be derived from them. For example, Takakubo and van Woerden (1966) and Venugopal and Shuter (1969) obtained temperatures of about 120° K. More recently, Verschuur (1969), using the 300-foot telescope of the U.S. National Radio Astronomy Observatory and a frequency resolution of 2.5 kHz, deduced kinetic temperatures between 34° and 89° K. Unfortunately, with filter widths of 10 kHz we were unable to derive meaningful kinetic temperatures from our profiles.

Nevertheless, the region in question turned out to have several features of interest that justified its detailed study. Such features will be described in the following section.

II. OBSERVATIONAL DATA

The hydrogen profiles were obtained with the 30-m dish of the IAR-CIW Southern Radio Astronomy Station. The receiver is equipped with a parametric amplifier, and its back end consists of a bank of fifty-six filters with a half-width of 10 kHz. The angular resolution of the antenna at 1420 MHz is 0°.47.

Observations were spaced 0°.5 in l and b; the total number of points observed was 360 (including three outside the region; see § III*f*), and each of them was observed at least twice on different dates. The data were gathered in 1967 between July and December.

We use throughout this paper "new" galactic coordinates (l^{II}, b^{II}, hereafter written without superscripts). All radial velocities V_R are referred to the local standard of rest. After our reductions were completed, it was decided at IAR to use a temperature scale based on the profile at $l = 356°.00$, $b = -4°.00$ whose peak temperature is taken to be 80.0° K. In our contour diagrams, we use such a scale that is related to the "old" one by a factor 0.9.

Figure 1 shows a few typical profiles. The rms noise is about 0.7° K. In Figure 2 we

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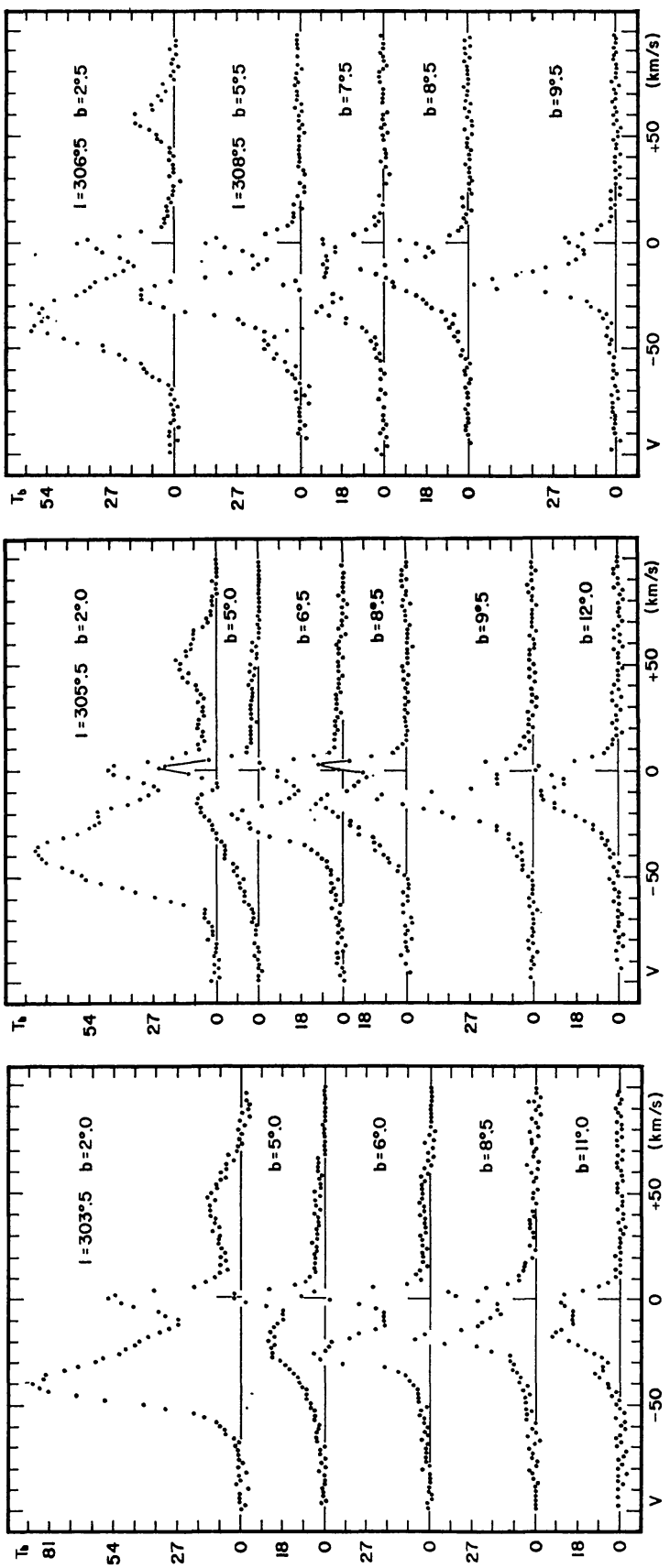


FIGS. 1*a*–1*c*.—Some typical profiles

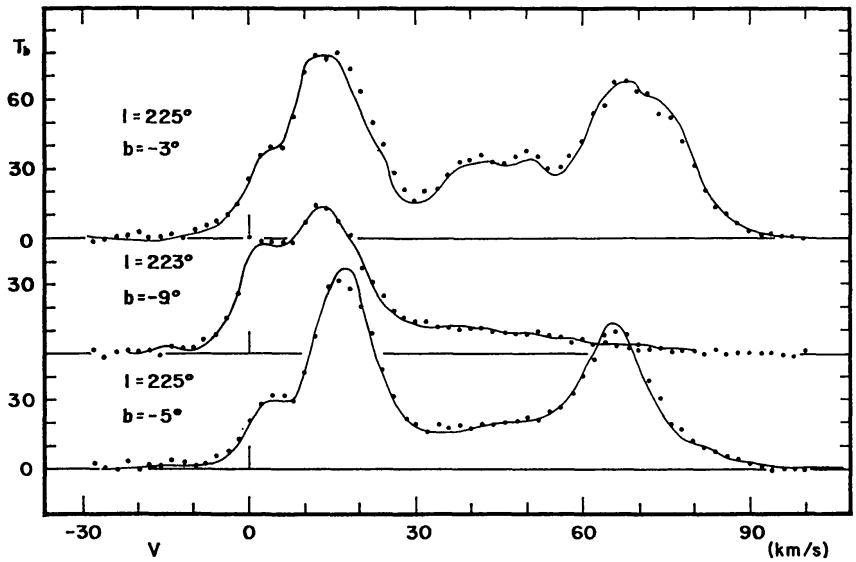


FIG. 2.—Comparison of our profiles (*points*) with those obtained with the 25-m telescope at Dwingeloo (*full lines*).

make a comparison between our profiles and those obtained with the Dutch 25-m dish at Dwingeloo. The agreement is excellent.

To analyze the data we prepared two kinds of contour diagrams of brightness temperature T_B. In one case we plotted T_B as a function of l and V_R at constant b, and in the other as a function of b and V_R at constant l. The range in radial velocity used was $-70 \leq V_R \leq 10$ km sec^{-1} (the observations themselves extended over the range $-100 \leq V_R \leq 100$ km sec^{-1}). In only one case was hydrogen found at $V_R > 10$ km sec^{-1}. This case was analyzed separately from the rest of the material. The temperature interval in the contour diagrams is 4.5° K. Figures 3 and 4 show both kinds of diagrams.

From such diagrams it is apparent that, in the region under study, there are three features clearly distinguishable in radial velocity. To visualize better the distribution of the gas belonging to each one of them, we plotted diagrams of l versus b for the velocities -13, -20, and -30 km sec^{-1} (see Figs. 5, 6, and 7).

III. ANALYSIS OF THE OBSERVATIONS

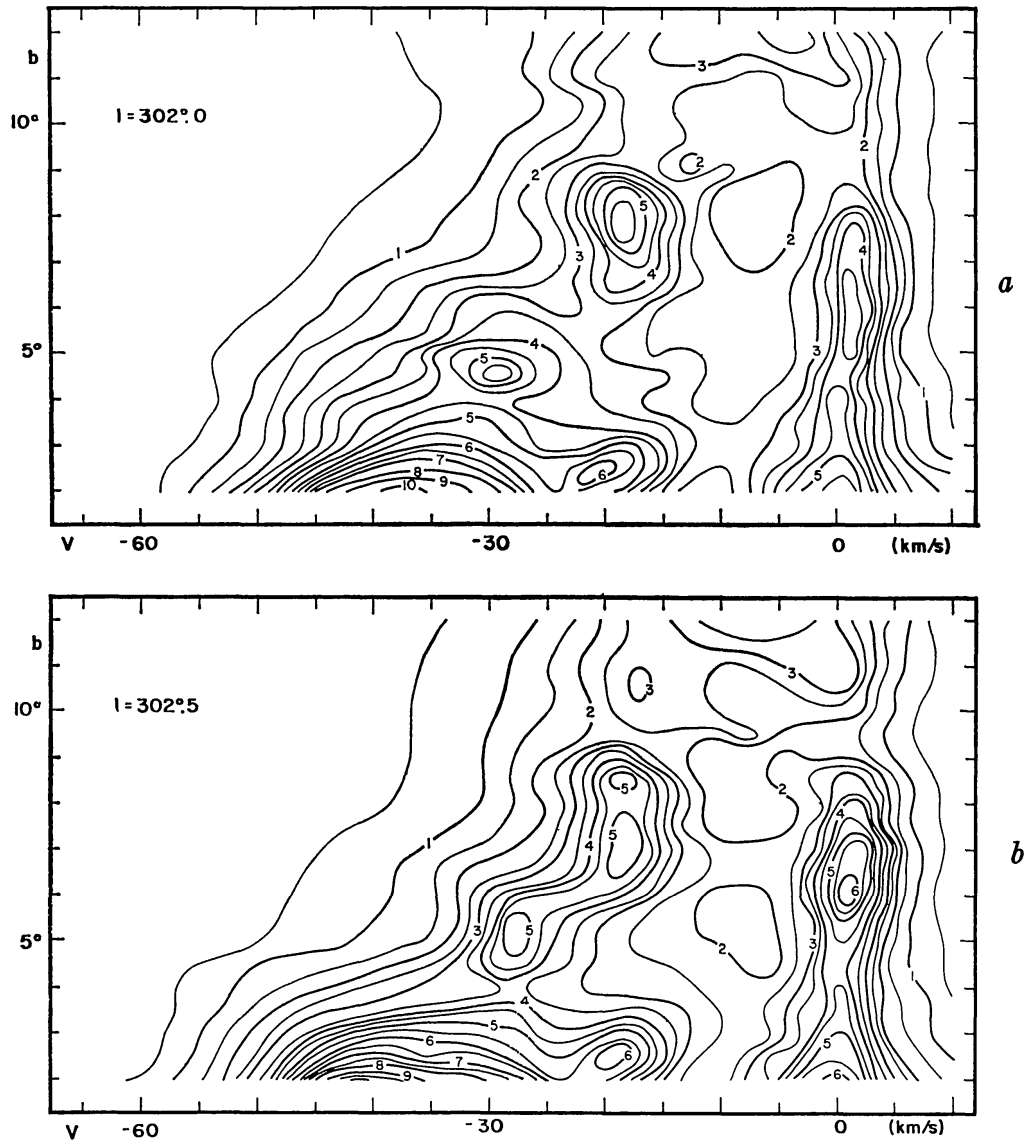
a) The Local Hydrogen

All profiles show a component, in most cases isolated from the rest of the profile, with radial velocity close to zero. We identify this component with hydrogen in the solar neighborhood. Assuming low optical depth, we computed column densities between 3.7 and 8.5 $\times$ 10^{20} atoms cm^{-2}. The velocity dispersion observed is 2.5 km sec^{-1}; if we correct for instrumental widening, the real dispersion turns out to be 2.3 km sec^{-1}.

On the basis of his observations in the range $90° \leq l \leq 250°$ Lindblad (1967) suggested the presence of an expanding shell, for which he derived a velocity model. For longitudes in the vicinity of $l = 310°$, this model predicts a radial velocity of 3 km sec^{-1}. This agrees very well with our observed values, which fall in the range $0.0 \leq V_R \leq 2.0$ km sec^{-1}.

b) The Feature at −13 km sec^{-1}

This feature can be clearly seen in the contour diagrams of brightness temperature as a function of radial velocity and either galactic coordinate. It appears at $l = 303°$,



FIGS. 3*a*–3*q*.—Contour diagrams of T_B as a function of b and V_R at constant l. Contour intervals are 4.5° K.

$b = 10°$, and can be followed up to $l = 310°$, $b = 8°.5$. It is somewhat inclined with respect to the galactic plane and reaches maximum intensity at $l = 305°.5$, $b = 9°.5$ (see Fig. 5).

It is obvious that this feature is not simply an extension of the galactic plane. The intensity of the hydrogen radiation decreases as we move away from the plane, and, at the velocity in question, it reaches a minimum at $b = 4°.5$. At about $b = 8°$ the intensity increases and reaches a maximum at values of b between 8°.5 and 10°. This increase in intensity does not appear in the survey of McGee and Murray (1961), probably because of its low resolution, both spatial and in frequency.

To see if we could relate this feature with some optical object, we went though the catalog of open clusters of Alter and Ruprecht (1963), but with negative results. We found in this region many stars in whose spectra interstellar lines of calcium have been identified (Feast, Thackeray, and Wesselink 1955, 1957; Feast and Thackeray 1963;

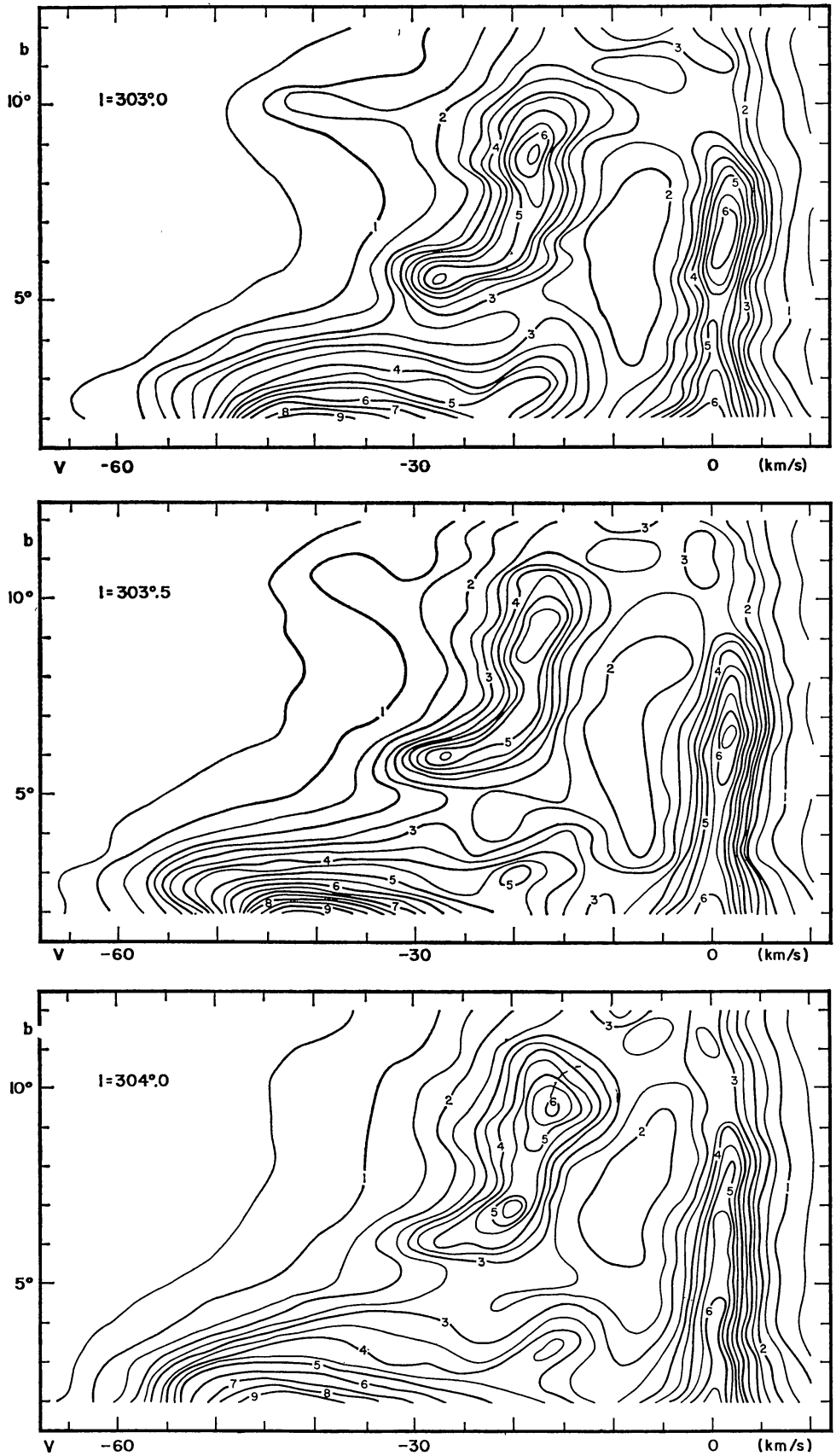
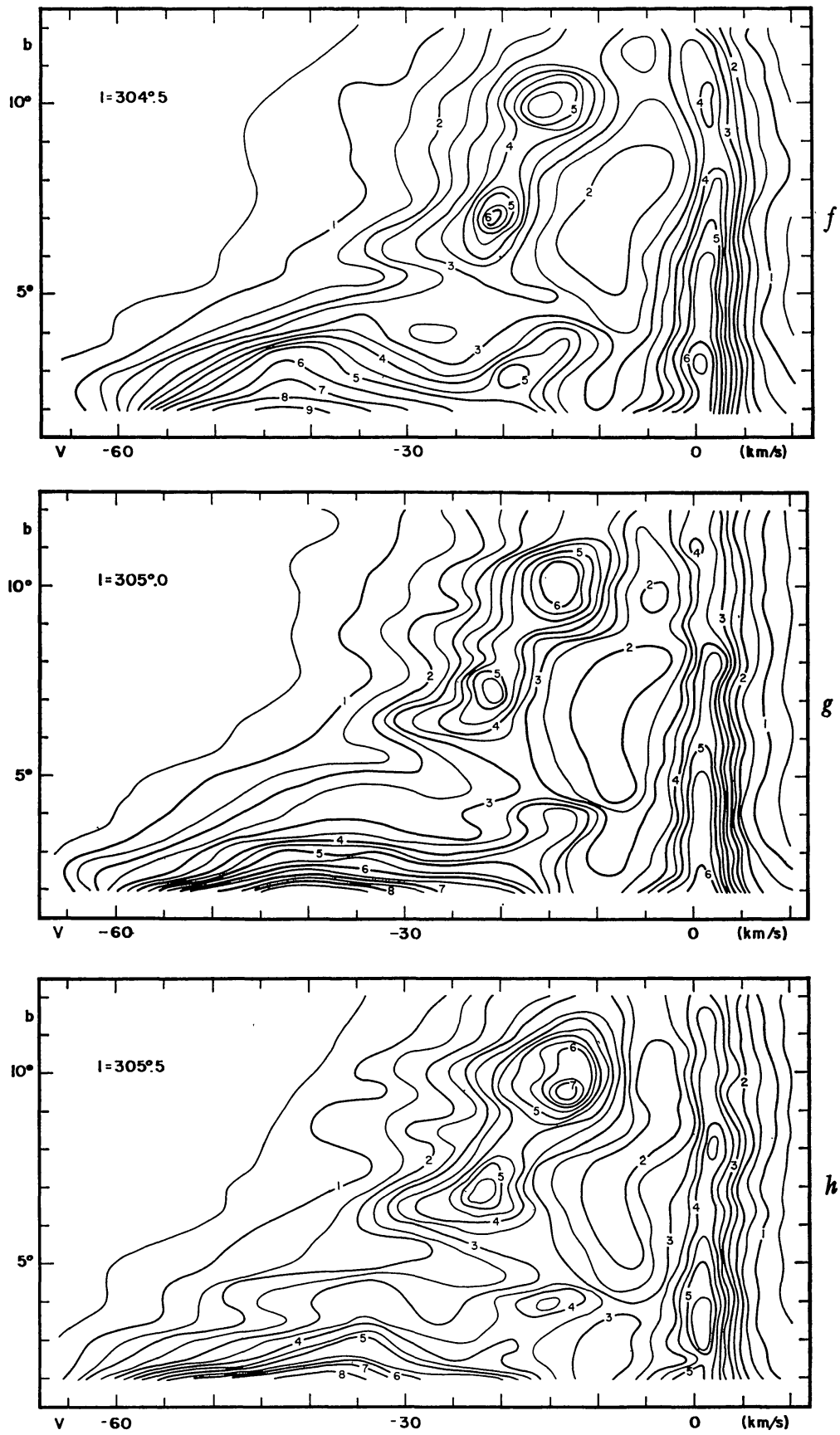


FIG. 3—*Continued*



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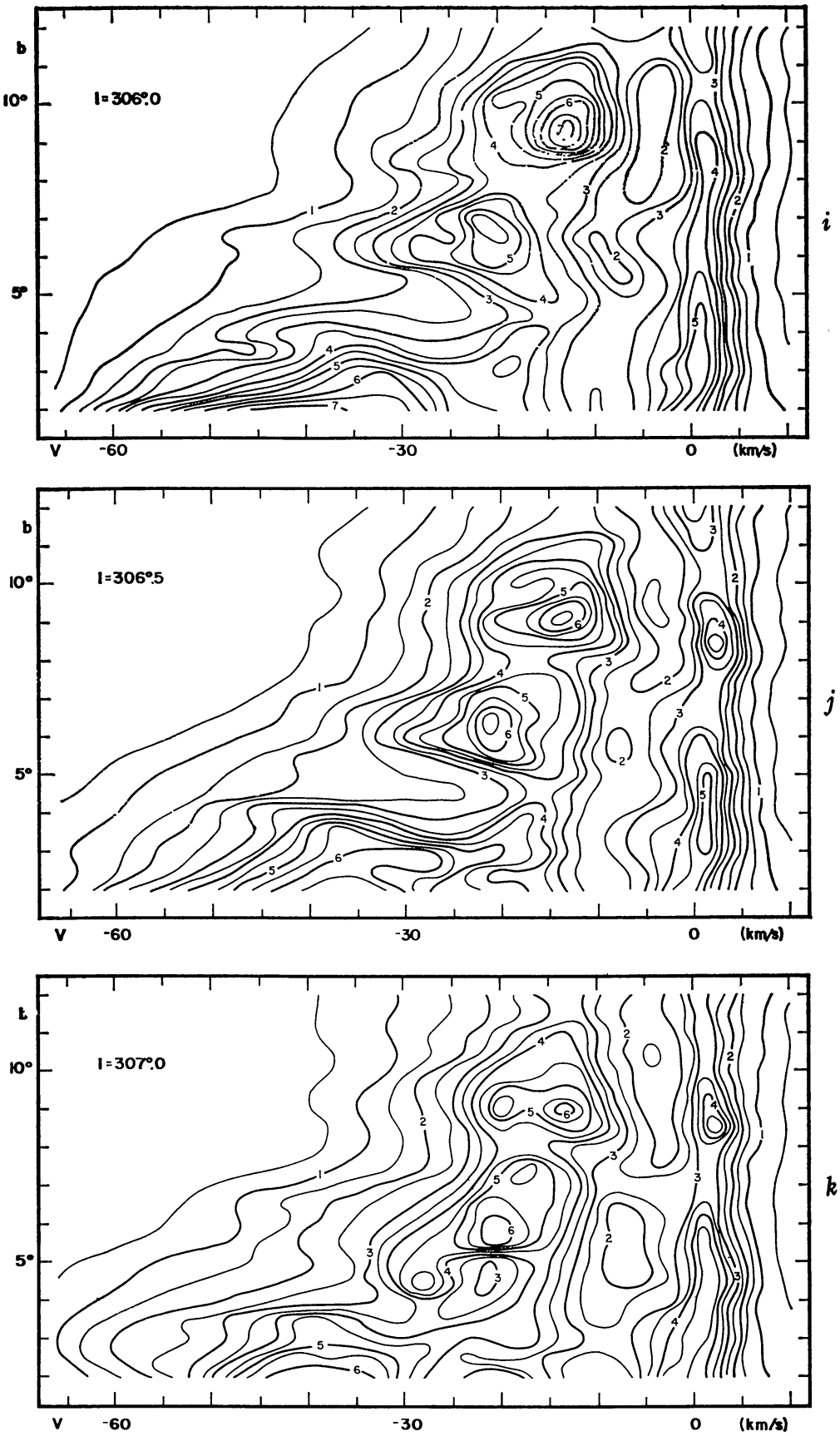

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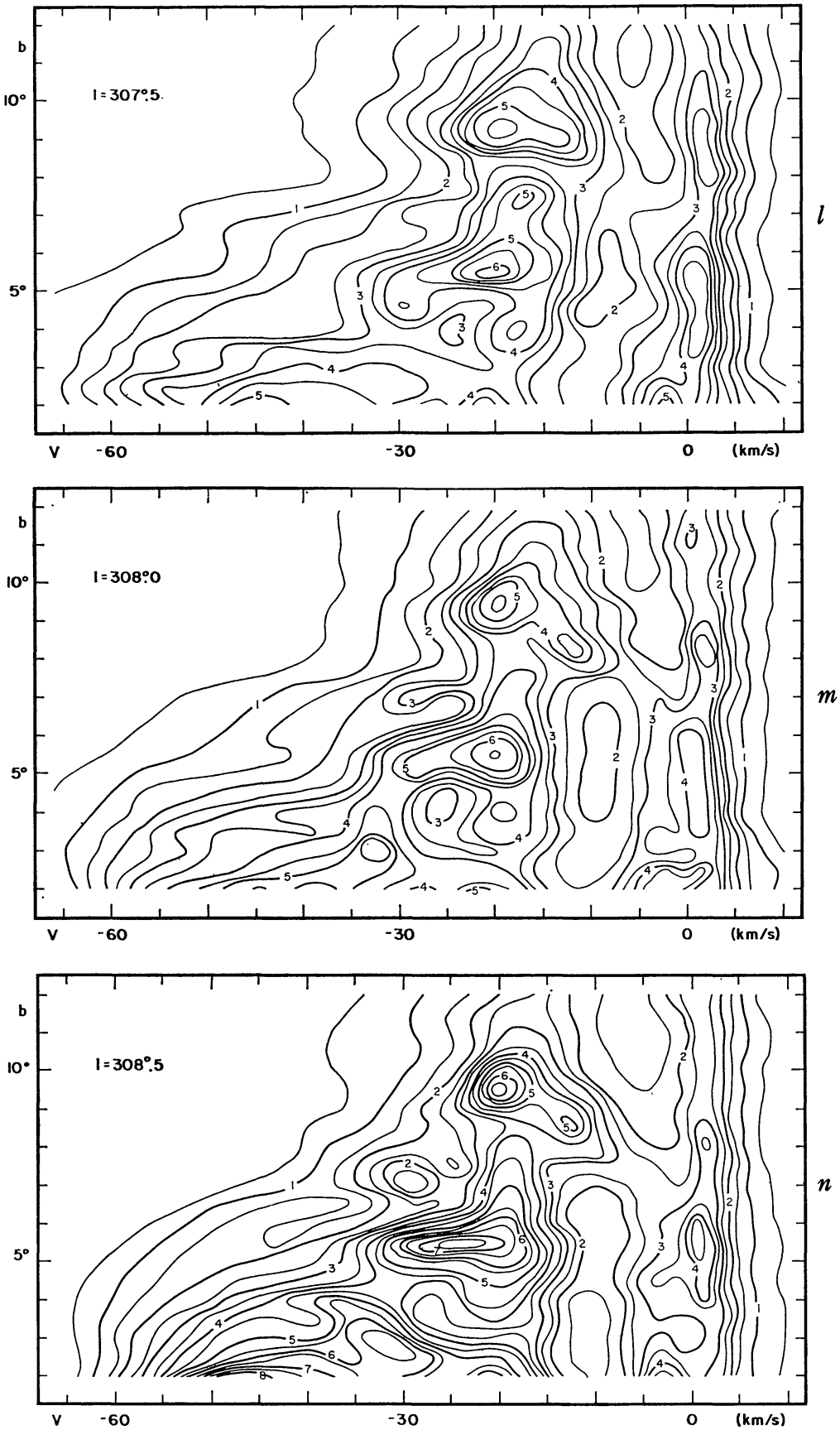

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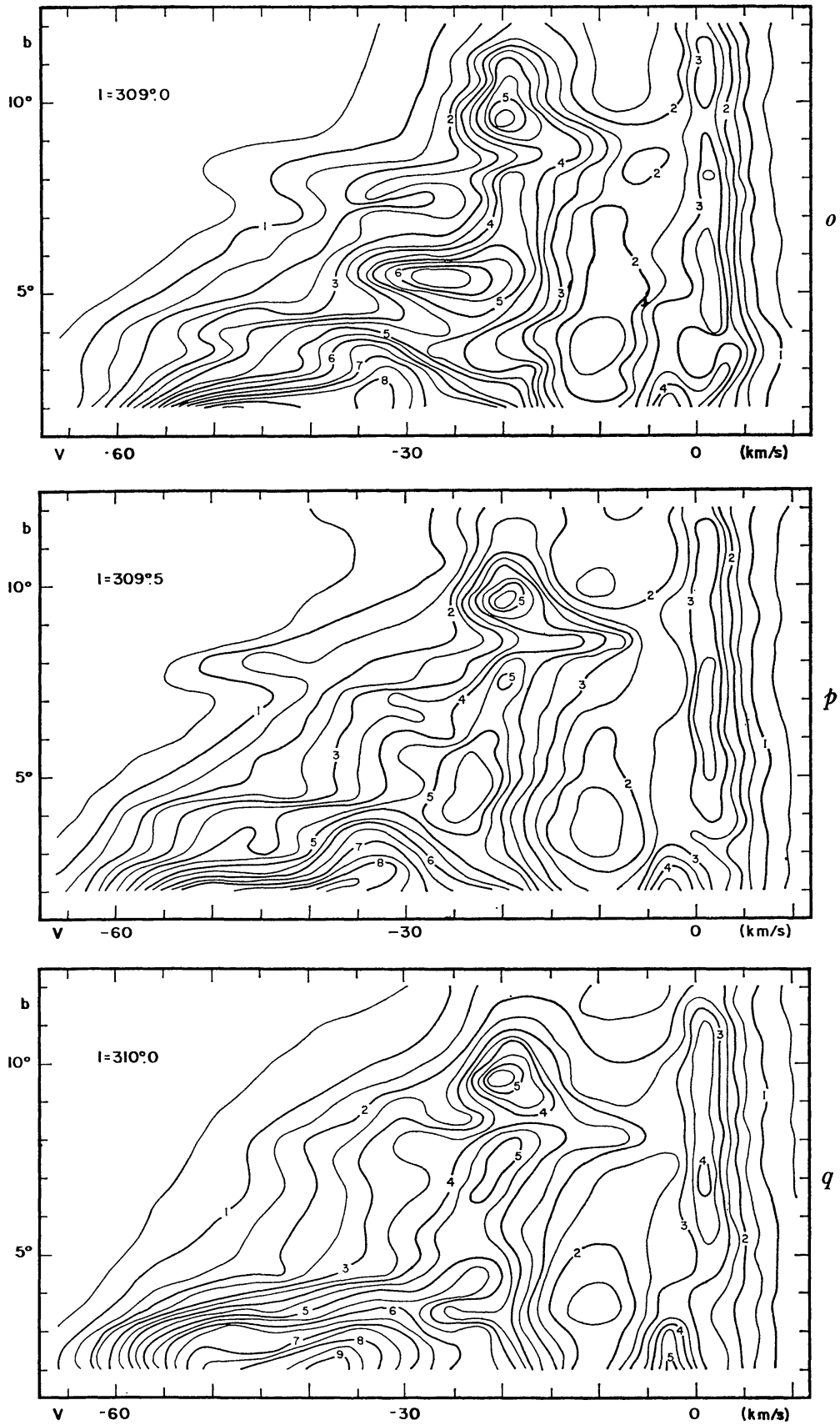
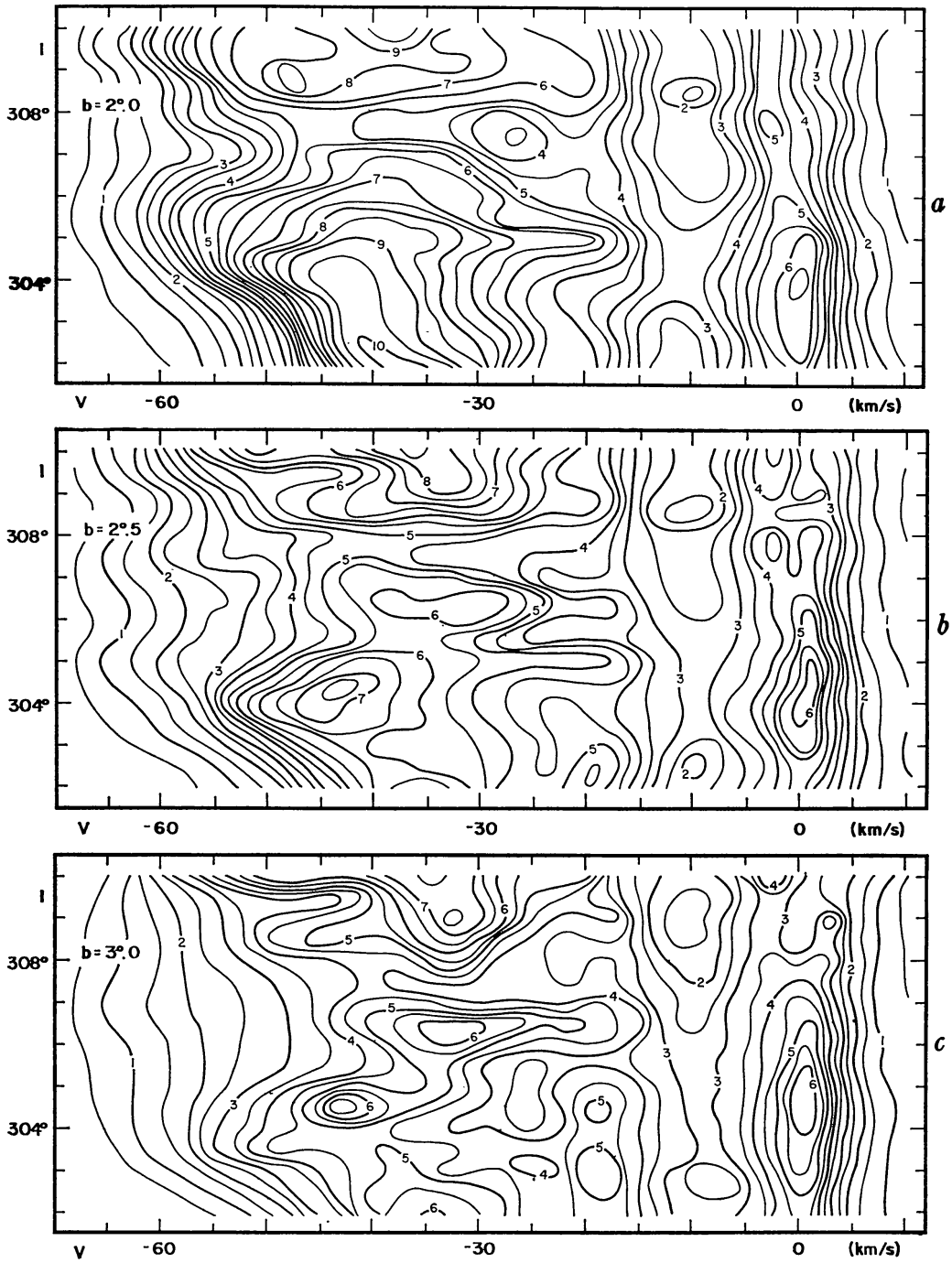


FIG. 3.—*Continued*

Thackeray 1966); but in no case did we find a component associated with our hydrogen feature. Therefore, the only way to estimate the distance to the cloud is by means of Schmidt's model of the Galaxy (Schimdt 1965). For $V_R = -13$ km sec^{-1}, $l = 307°$, the model gives two possible values: $r_1 = 1.2$ kpc and $r_2 = 11$ kpc. The low velocity dispersion shown by the profiles suggests that the shorter distance is the correct one, since one would expect a much higher dispersion for an object as large as 500 pc (see below).

From the profiles where the feature appeared more distinct we derived a mean



FIGS. 4*a*–4*u*.—Contour diagrams of T_B as a function of l and V_R at constant b. Contour intervals are 4.5° K.

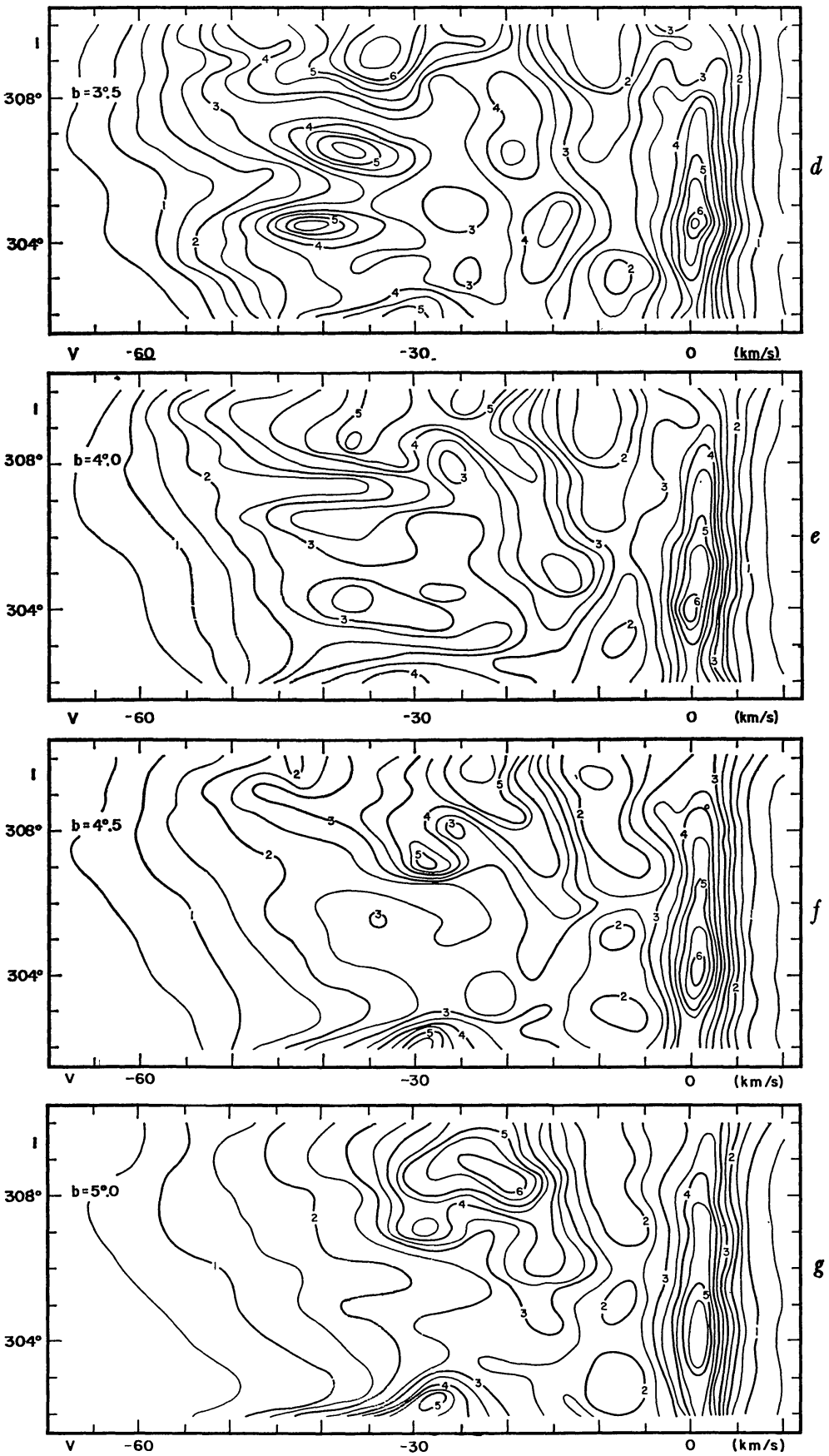


FIG. 4—*Continued*

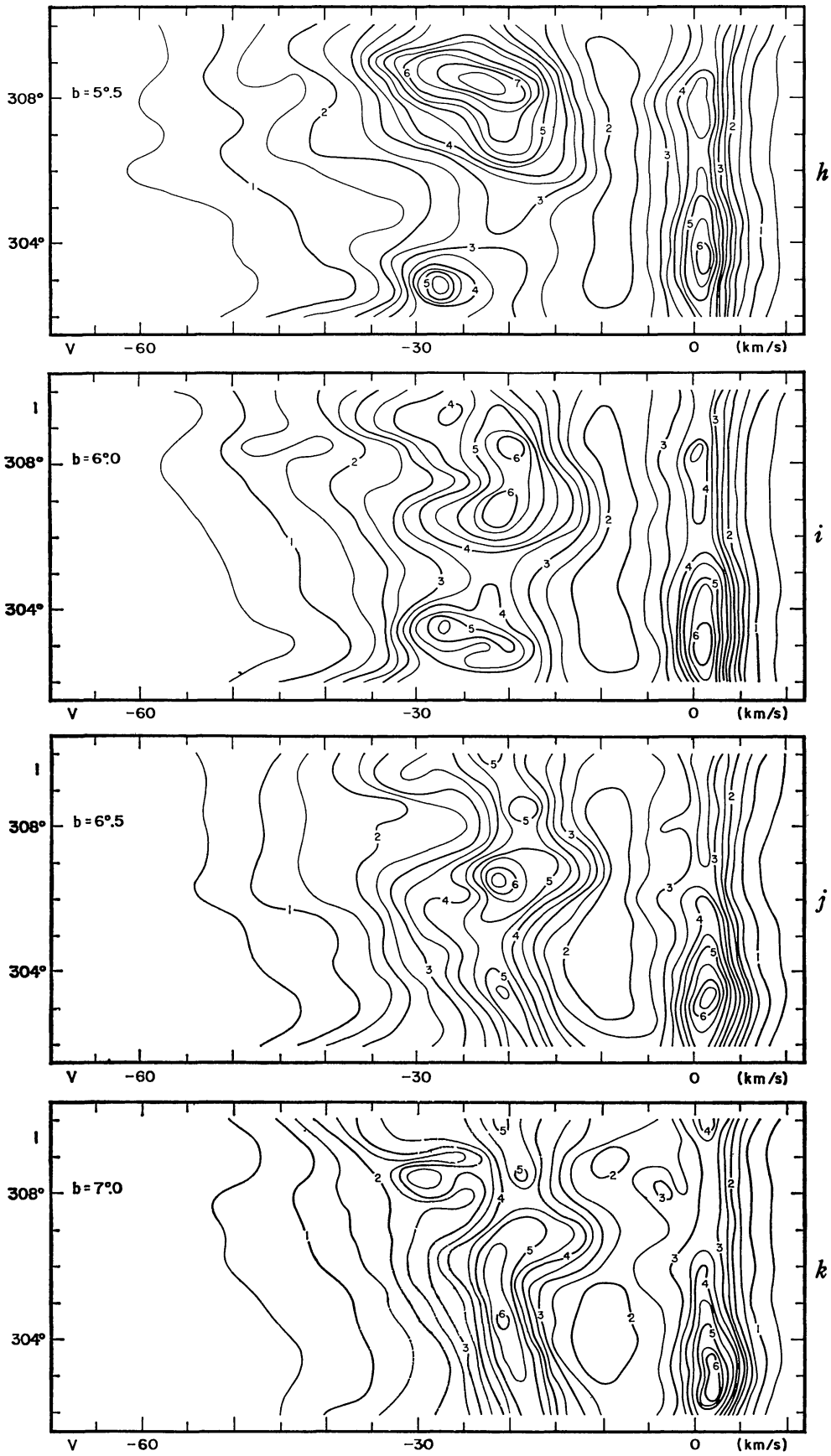
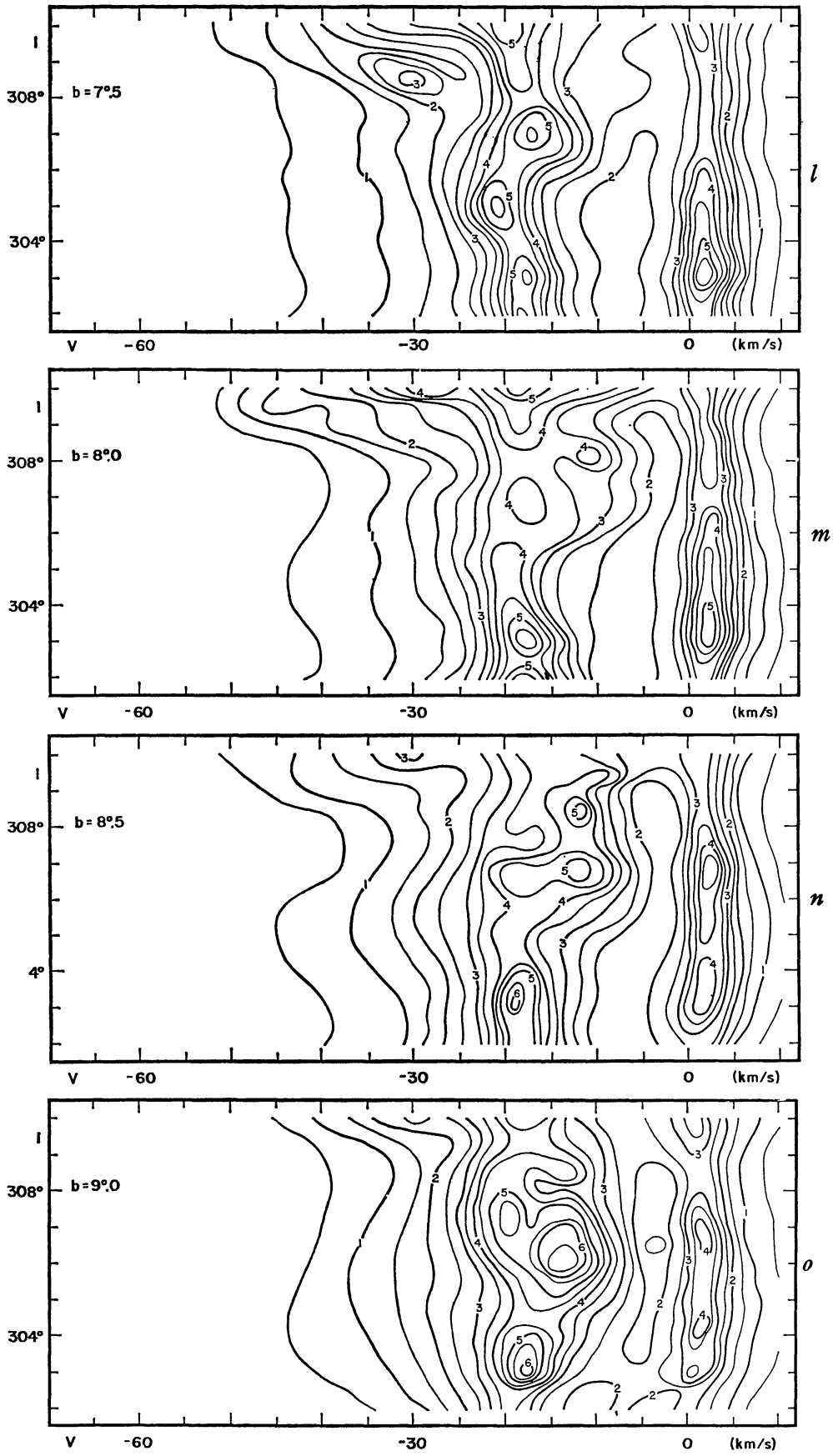


FIG. 4—*Continued*



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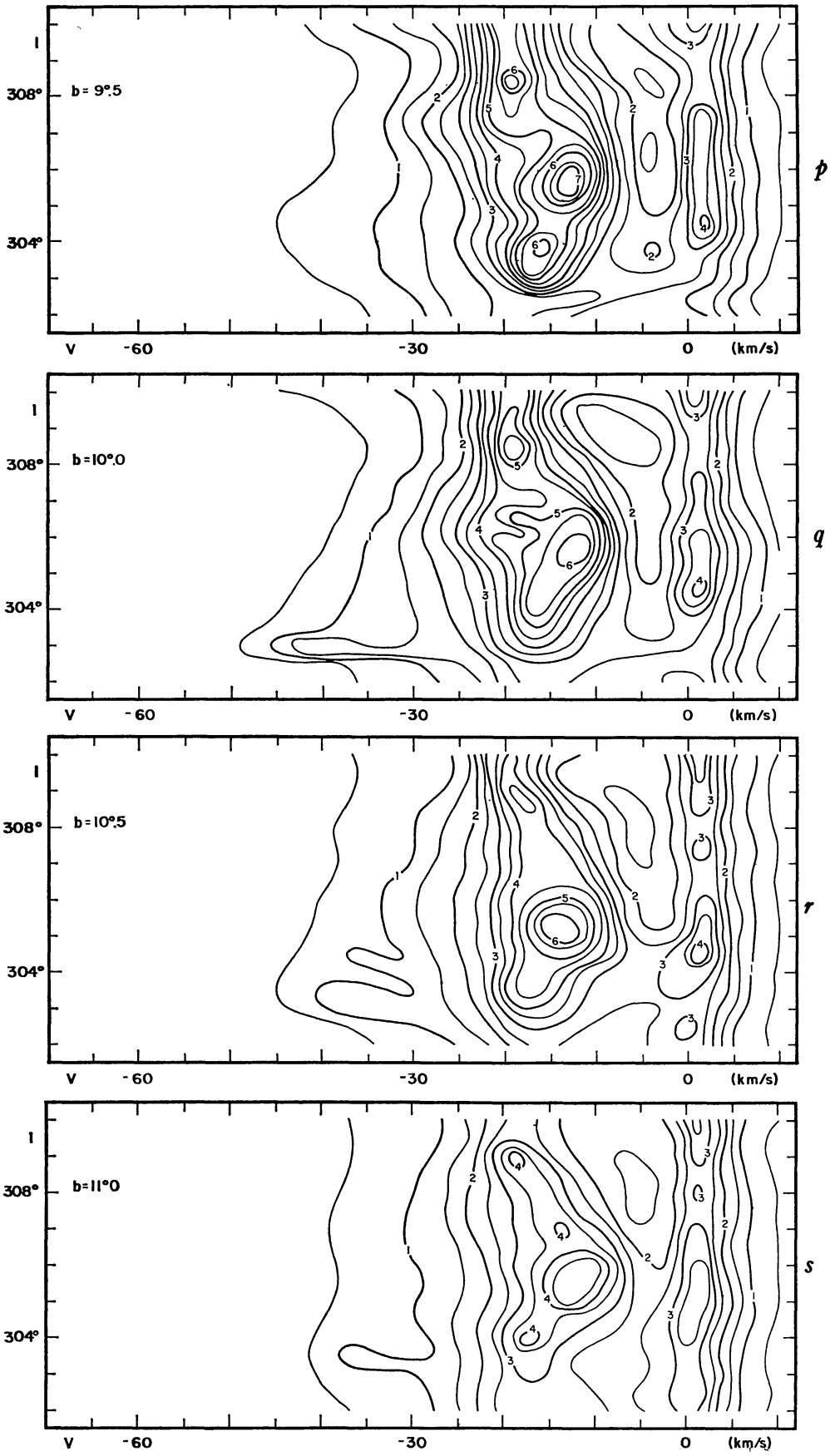

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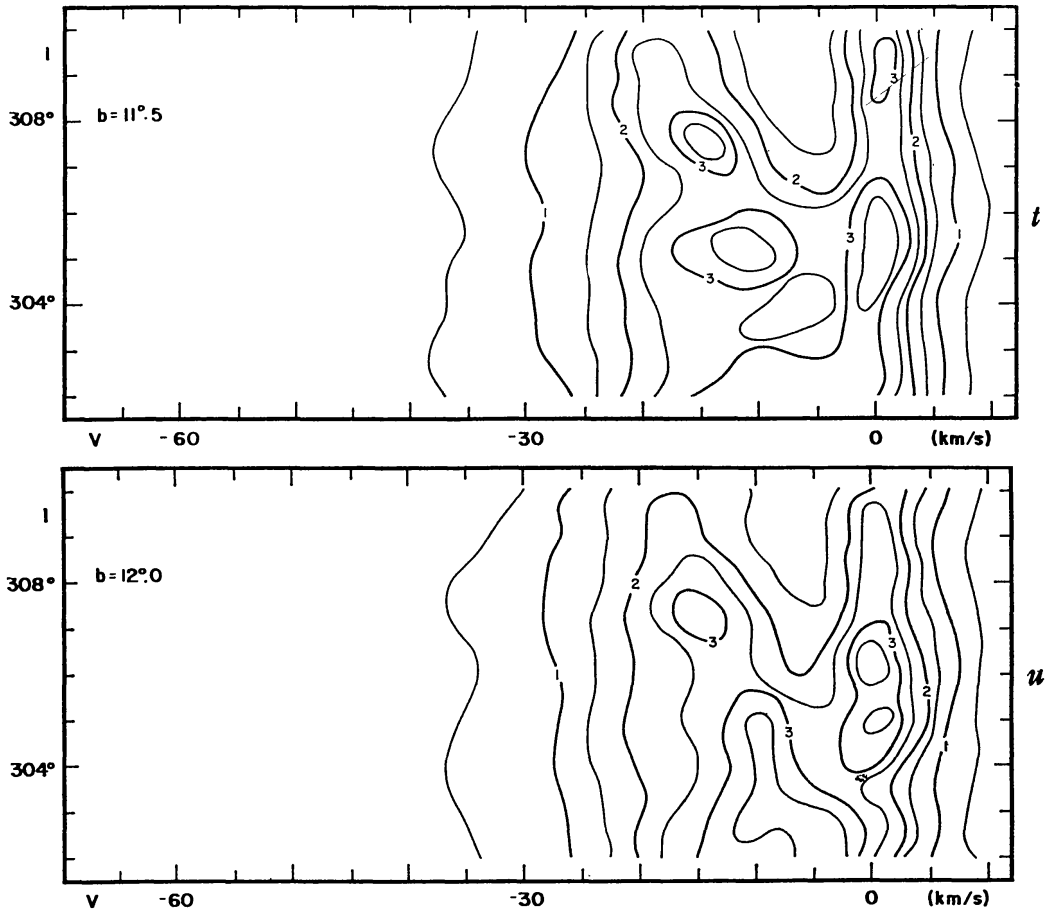


FIG. 4—*Continued*

velocity dispersion $\langle\sigma\rangle = 3.0$ km sec^{-1} and a mean column density $\langle N_H\rangle \approx 1.13 \times 10^{21}$ atoms cm^{-2}. If the distance r is correct, then the height of the feature above the galactic plane is $z = 160$ pc, and its linear size is $d = 50$ pc. If we assume a spherical cloud, the mean density volume turns out to be $\langle n_H\rangle = 7$ atoms cm^{-3}. Figure 8*a* shows a sketch of the feature just described.

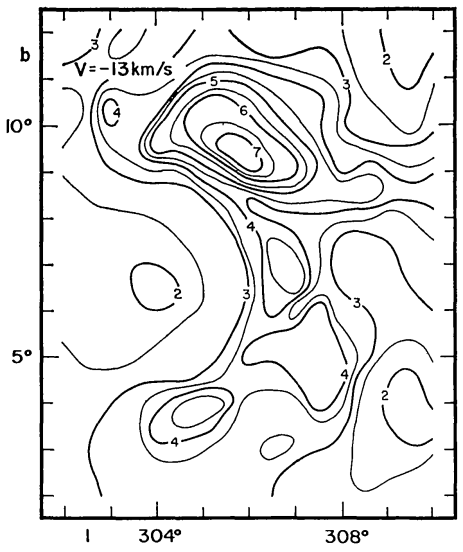
c) The Feature at −20 km sec^{-1}

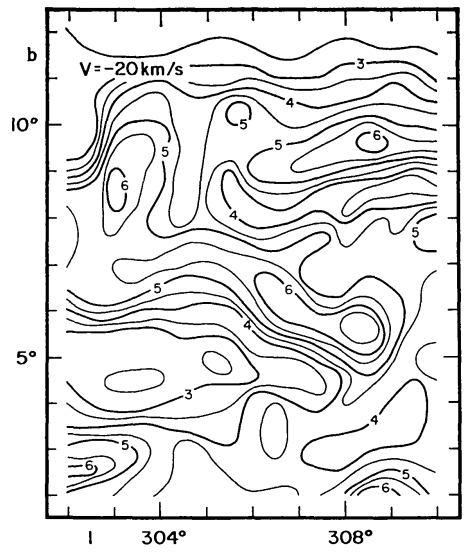
This feature appears as double. One hydrogen concentration appears at $l = 302°$, $b = 7°$, and extends up to $l = 310°$, $b = 5°$; the other runs along $b \geq 9°$ for all longitudes. The two concentrations seem to merge near $l = 302°$.

Again no connection was found between this feature and young optical objects or interstellar lines of calcium. If we make use of Schmidt's model, the possible distances are $r_1 = 1.5$ kpc and $r_2 = 10.5$ kpc. Since $\langle\sigma\rangle = 3.6$ km sec^{-1}, we again take the short distance as the more likely one.

The heights above the plane of the two concentrations are between 140 and 180 pc for one and about 240 pc for the other. The mean column density from both features is $\langle N_H\rangle = 0.79 \times 10^{21}$ atoms cm^{-2}, and, if we assume a spherical cloud at a distance of 1.5 kpc, the volume density is $\langle n_H\rangle = 4.9$ atoms cm^{-3}.

A sketch of this feature is shown in Figure 8*b*.





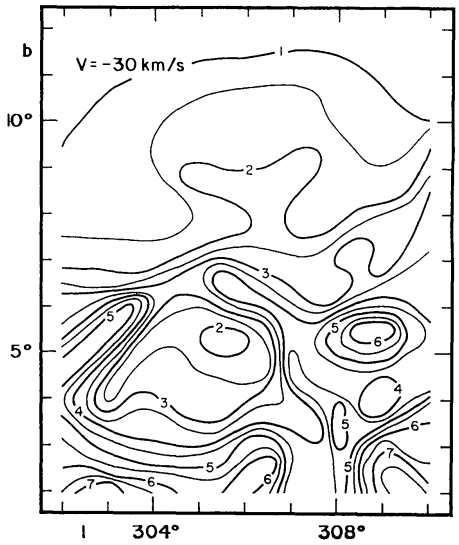


FIG. 5 (*top left*).—Contour diagrams of T_B as a function of l and b for $V_R = -13$ km sec^{-1}. Contour intervals are 4.5° K.

FIG. 6 (*top right*).—Contour diagrams of T_B as a function of l and b for $V = -20$ km sec^{-1}. Contour intervals are 4.5° K.

FIG. 7 (*bottom*).—Contour diagrams of T_B as a function of l and b for $V = -30$ km sec^{-1}. Contour intervals are 4.5° K.

d) The Feature at −30 km sec^{-1}

This feature has a semicircular shape, starting at $l = 302°$, $b = 5°$, then going up in latitude as l increases (going through $l = 305°$, $b = 6°.5$), and finally returning to $b = 5°$ at $l = 310°$. The possible distances for this feature are $r_1 = 2.2$ kpc and $r_2 = 9.5$ kpc. Since $\langle\sigma\rangle = 3.8$ km sec^{-1}, we accept the shorter distance. The column and volume densities (with the same assumptions as before) are $\langle N_{\rm H}\rangle = 0.96 \times 10^{21}$ atoms cm^{-2} and $\langle n_{\rm H}\rangle = 5.5$ atoms cm^{-3}. Its height above the plane runs between 190 and 250 pc; a sketch is shown in Figure 8*c*.

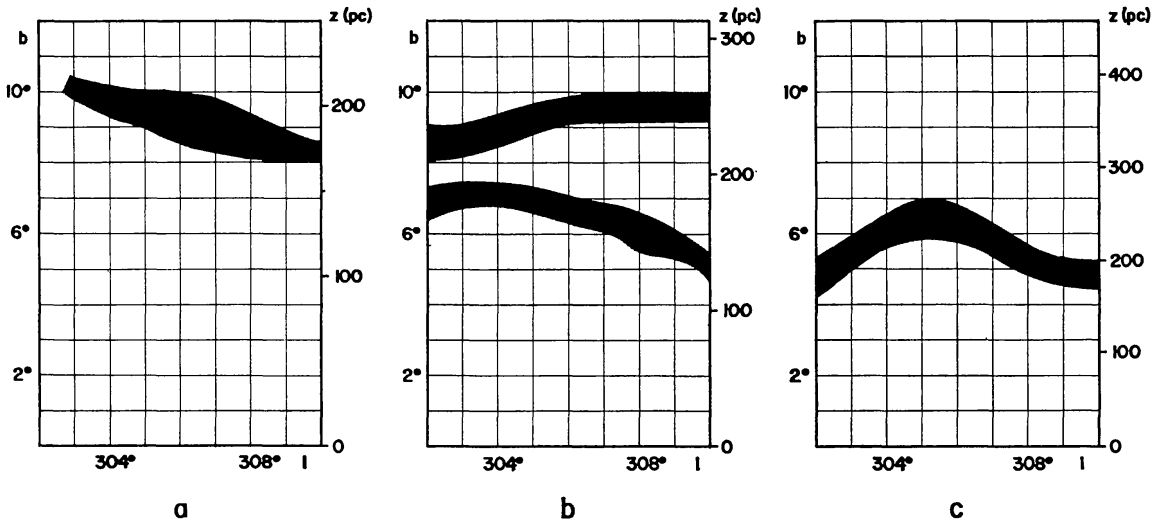


FIG. 8.—Sketch of the location of the features at −13, −20, and −30 km sec^{-1} (*a*, *b*, *c*, respectively), where distances given by Schmidt's model of the Galaxy are assumed.

e) Clouds of Small Angular Extent

In addition to the extended features described above, we have detected a fair number of clouds with negative radial velocities, whose extensions are comparable to the resolving power of our telescope (0°.5). Table 1 lists the clouds that could be clearly separated from the other features.

f) A Cloud with Positive Velocity

Many investigators have found clouds at intermediate negative velocities (e.g., Erickson, Helfer, and Tatel 1959; McGee and Murray 1961; Blaauw and Tolbert 1966; Dieter 1964, 1965; Hulsbosch and Raimond 1966). On the other hand, clouds with intermediate positive velocities seem to be rather rare objects. Some examples are given by Smith (1963), Prata (1964), and Cugnon (1967). In the present work we have found one example around $l = 306°.5$, $V_R = 57$ km sec^{-1}, with maximum temperature around

TABLE 1

CLOUDS OF SMALL ANGULAR EXTENT

V (km sec^{-1})	l	b
−46	308°.5	5°.5
	308°.5	6°.0
	308°.5	6°.5
−44	309°.5	8°.0
−37	303°.0	10°.0
	303°.0	10°.5
	303°.5	10°.5
	303°.5	11°.0
−35	304°.5	10°.5
−33	308°.0	7°.0
	308°.5	7°.5
	309°.0	7°.5

$b = 2°.5$. To make sure that this cloud was not connected to the galactic plane we obtained profiles at $l = 306°.5$ and $b = 0°.5$, $1°.0$, and $1°.5$. Figures 9 and 10 clearly show that the feature at $V_R = 57$ km sec^{-1} is isolated from the plane (the feature at $V_R = 45$ km sec^{-1}, on the other hand, is obviously part of the plane). Table 2 gives a comparison between this cloud and similar ones found by other authors; perhaps the most remarkable

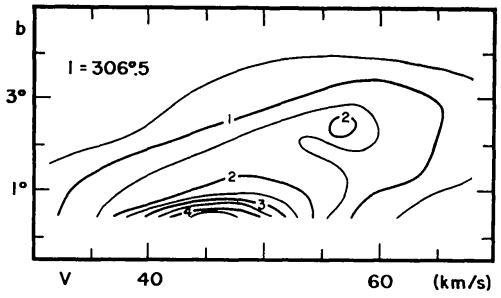


FIG. 9

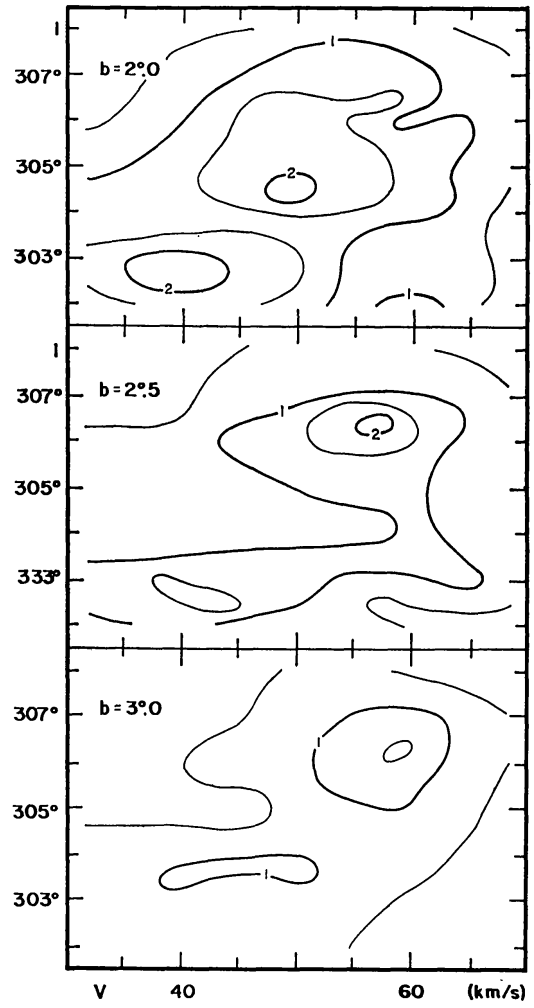


FIG. 10

FIG. 9.—A cloud with positive radial velocity at $l = 306°.5$, T_B diagram. Contour intervals are 4.5° K.

FIG. 10.—Contour diagram of T_B, for three values of b, showing the cloud with positive radial velocity. Contour-diagram intervals are 4.5° K.

TABLE 2

SOME CLOUDS WITH POSITIVE VELOCITIES

Investigator	l	b	σ (km sec^{-1})	V_R (km sec^{-1})	$N_H \times 10^{-20}$ Atoms cm^{-2}
Smith.....	40°.5	−15°.0	16.4	90.8	2.18
Prata.....	22°.0	− 4°.0	10.1	114.6	1.86
Cugnon.....	349°.0	+ 3°.0	11.2	52.4	4.25
This work.....	306°.5	+ 2°.5	5.5	57.0	4.74

characteristic of the cloud described here is its low velocity dispersion, which would indicate that the cloud is relatively near the Sun. From Schmidt's model, however, the distance to the cloud would be 16 kpc, and its height above the plane 700 pc.

IV. CONCLUSIONS

We have searched for atomic hydrogen at positive galactic latitudes in a region where the galactic plane is known to bend toward negative latitudes. Nevertheless, near the Sun we have found a considerable amount of matter, some in the form of small clouds and some in the form of three continuous features. Two of the latter, with radial velocities around -13 and -30 km sec^{-1}, seem to run exactly above two arms that lie in the plane, identified by Garzoli (1970) as features *A* and *P* (*A* is referred to in the literature as the "Carina arm"). Oort (1970) has also found that in the eastern galactic hemisphere some arms show extensions at considerable distances from the galactic plane. On the other hand, our feature at -20 km sec^{-1} does not correspond to any hydrogen concentration in the plane.

No hydrogen was found at large distances from the Sun, except for one cloud that could possibly be associated with feature *H* of Garzoli. This should be contrasted with the large amount of hydrogen found by Garzoli at negative latitudes.

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