A search for atomic hydrogen in the II (ζ) Persei and the I Lacertae associations of O and B stars

Raimond, E.

A SEARCH FOR ATOMIC HYDROGEN IN THE II(ζ) PERSEI AND THE I LACERTAE ASSOCIATIONS OF O AND B STARS

BY E. RAIMOND

21-cm observations of the II Persei and I Lacertae associations of O and B stars have failed to reveal atomic hydrogen in these groups. An upper limit for the atomic hydrogen density in the Lacerta association is estimated.

Introduction.

Recent investigations [1] [2] have shown that the associations of early-type stars are generally very young groups; the stars in some of these groups must have originated from the interstellar gas only a few million years ago [2] [3]. One might expect to find considerable amounts of H left in these associations after the process of star formation. In many associations, including those considered in this paper, the presence of hydrogen is indeed shown by the occurrence of large Hα-emission regions.

The association around ζ Persei, with an age of about 1.5 million years [4], contains the emission nebula NGC 1499. Some rather pronounced dark clouds are also connected with the association.

The Lacerta group is 4.2 million years old. An emission region has been observed by JOHNSON [5] [6] [7] around the O9 star 10 Lac.

The present investigation is based on observations of the 21-cm line of atomic hydrogen in the regions of these associations.

Observations and reduction.

The observations cover areas of about 10° × 10° centred at $l = 129°$, $b = -15°$ (II Per) and $l = 65°$, $b = -15°$ (I Lac). The 48 line profiles, obtained with the 7.5-m Kootwijk paraboloid, are shown in Figures 1 and 2. For practical reasons the two line profiles at $l = 127°.9$, $b = -10°.8$ and $l = 128°.7$, $b = -10°.2$, which have been reduced separately, have been averaged to give the line profile $l = 128°.3$, $b = -10°.5$ of Figure 1.

The profiles have been observed and reduced in the manner described in the first paper of this series [8], and the scale of the reproduction is given on p. 161 of this *B.A.N.* Observations in a wider region would have been desirable; unfortunately, they could not be obtained, as the equipment had to be moved from Kootwijk to the new observing station at Dwingeloo.

The method by which the line profiles have been reduced to curves of optical depth, corrected for random cloud velocities, $\tau'(V)$, has been fully described by WESTERHOUT [9]. For every longitude the $\tau'(V)$ curves have been combined to a section of the Figures 3 and 4. Every section contains lines of equal optical depth in a diagram with the radial velocity and the galactic latitude as co-ordinates. The dots represent the members of the associations. All radial velocities are relative to the local standard of rest.

II Persei association.

It is clear from Figure 3 that the amount of atomic hydrogen with velocities near + 16 km/sec — the average radial velocity of the stars of the association — is very small.

It should, however, be noted that the velocity of the stars of the association coincides with the very steep parts of the line profile of general galactic hydrogen radiation. The adopted correction for random cloud motions at these velocities may be larger, numerically, than any weak 21-cm radiation from the association. Radiation of any importance should have been observed. For instance an increase of brightness temperature by 15°K over a velocity interval of 15 km/sec, which corresponds to 4×10^{20} hydrogen atoms per cm^2, should just have been detected.

Because of the inaccuracies, mentioned above, no upper limit for the density of atomic hydrogen in the II Per association can be given. The only conclusion from this observational material must be that the total amount of atomic hydrogen in the association near ζ Persei is very small. Observations with a larger radio telescope using a receiver with smaller bandwidth are necessary for further investigation.

I Lacertae association.

Figure 4 shows a general tendency of the optical depths to decrease with increasing distance from the galactic equator. An important increase of τ' towards the centre of the association is not seen. Apparently, the total amount of atomic hydrogen in the Lacerta

[1] V. A. AMBARTSUMIAN, *A.J. U.S.S.R.* **26**, 3, 1949; *Izv. Ak. Nauk U.S.S.R. Phys. Ser.* XIV, 15, 1950.
[2] A. BLAAUW, *B.A.N.* **11**, 405 (No. 433), 1952.
[3] A. BLAAUW and W. W. MORGAN, *Ap. J.* **117**, 256, 1953. See also J. H. OORT, *B.A.N.* **12**, 177 (No. 455), 1954.
[4] A. BLAAUW and J. DELHAYE, *B.A.N.* **12**, 72 (No. 448), 1953.
[5] H. M. JOHNSON, *Ap. J.* **118**, 162, 1953.
[6] H. M. JOHNSON, *Ap. J.* **118**, 370, 1953.
[7] W. W. MORGAN, B. STRÖMGREN and H. M. JOHNSON, *Ap. J.* **121**, 611, 1955.
[8] C. A. MULLER and G. WESTERHOUT, *B.A.N.* **13**, 151 (No. 475, first paper), 1957.
[9] G. WESTERHOUT, *B.A.N.* **13**, 201 (No. 475, third paper), 1957.

association is small compared to the amount of hydrogen observed in the Lacerta direction.

Dense clouds, which are small with respect to the beamwidth, may not have been resolved, but they cannot be very numerous unless they cover the observed area almost homogeneously. As the dimensions of the Lacerta aggregate are about 15° × 9°, this possibility cannot be absolutely excluded. For this reason, additional observations in a wider area including positive galactic latitudes at the same longitudes would have been helpful. It is, however, not to be expected that the association would contain a large amount of atomic hydrogen showing little or no concentration to the centre of the group.

To obtain at least a rough estimate of the H-density in the association, the differences ($\Delta\tau'$) between the optical depths at $l = 65°$ and the average of the optical depths at $l = 62°.5$ and $l = 67°.5$ at corresponding latitudes and velocities have been computed. Table 1 gives the values $\Delta\tau'$ averaged over the velocities between — 9.5 km/sec and + 3.1 km/sec, which is about the velocity interval of the association members.

TABLE 1

b	— 10°	— 12°.5	— 15°	— 17°.5	— 20°
$\Delta\tau'$	+.048	+.008	+.010	+.032	+.015

The average difference at these five latitudes is $\Delta\tau' = .023$. The longitudes 62°.5 and 67°.5 are far inside the boundaries of the association; a comparison of $l = 65°$ with $l = 60°$ and $l = 70°$ would therefore have been better. But the non-linear increase of optical depths towards the spiral arm at $l = 45°$ makes this comparison useless. The amount by which the total optical depth, including the association, surpasses the total optical depth without the association may be higher than .02, but probably does not exceed .10.

The number of H-atoms in a cylinder of 1 cm² diameter belonging to the association, may be computed by the equation:

$$N_H = 1.835 \times 10^{13}\, T \Delta V \Delta\tau,$$

which is an integration of eq. 12 of *B.A.N.* No. 452 over the full velocity interval of the line, ΔV, in which $\Delta\tau$ is assumed to be constant. All quantities are expressed in c.g.s. units. We have to assume $T = 125$°K, as this value was adopted in deriving $\Delta\tau$ (the actual value of T is irrelevant for small optical depths). Taking $\Delta V = 12$ km/sec, the velocity range of the stars of the association, and $\Delta\tau = 0.1$, we find $N_H = 2.75 \times 10^{20}$ cm^{-2}.

The distance of the association being about 500 pc [1]), the linear dimensions perpendicular to the line of sight are 130 pc × 80 pc (15° × 9°). The dimension in the line of sight might be between 50 and 100 pc [1]). Assuming 70 pc for this value, the average density of atomic hydrogen is $n_H = 1.2$ cm^{-3}. Unless the temperature of the gas is much higher, which is not improbable as a result of heating by hot stars, or the thickness is much smaller, this figure will be an upper limit.

More information about the interstellar gas in the I Lac association is given by the emission region near 10 Lac [2]). From the emission measure in different parts of the emission region, the densities of the ionized hydrogen are found to range from 4 cm^{-3}, between 10 Lac and the bright rim west of 10 Lac, to 10 cm^{-3} in this rim. As it is uncertain whether the emission region is limited by the ionizing power of 10 Lac — which is the only O star in this region — or by a decrease of H-density near the edges, the values given are upper limits. In the former case neutral hydrogen might be present outside the emission region. It may be noted that the optical depths in the 21-cm line are slightly smaller near the position and velocity of 10 Lac (+ 1.6 km/sec) than in its surroundings (see Figure 4, $l = 62°.5$, $l = 65°$, $l = 67°.5$). This might be an indication that some atomic hydrogen is present in the Lac association. The "hole" in the optical depths would then be due to ionization of the hydrogen by 10 Lac. It should be emphasized that these considerations are rather speculative.

It is clear that observations with a smaller beam- and bandwidth could be helpful. These would make the detection of small clouds with rather large densities possible.

My thanks are due to Dr A. BLAAUW for some valuable correspondence on this subject and to Mr H. VAN WOERDEN, with whom I had many helpful discussions.

Note added in proof.

In an investigation of the distribution of neutral hydrogen at galactic latitude −15°, MATTHEWS[3]) finds a sudden increase of the H density near the longitudes of the II Per and I Lac associations. Altough there are small differences between the velocities and the coordinates of the hydrogen clouds and the average of the association members, a relation between the hydrogen and theassociatons seems probable.

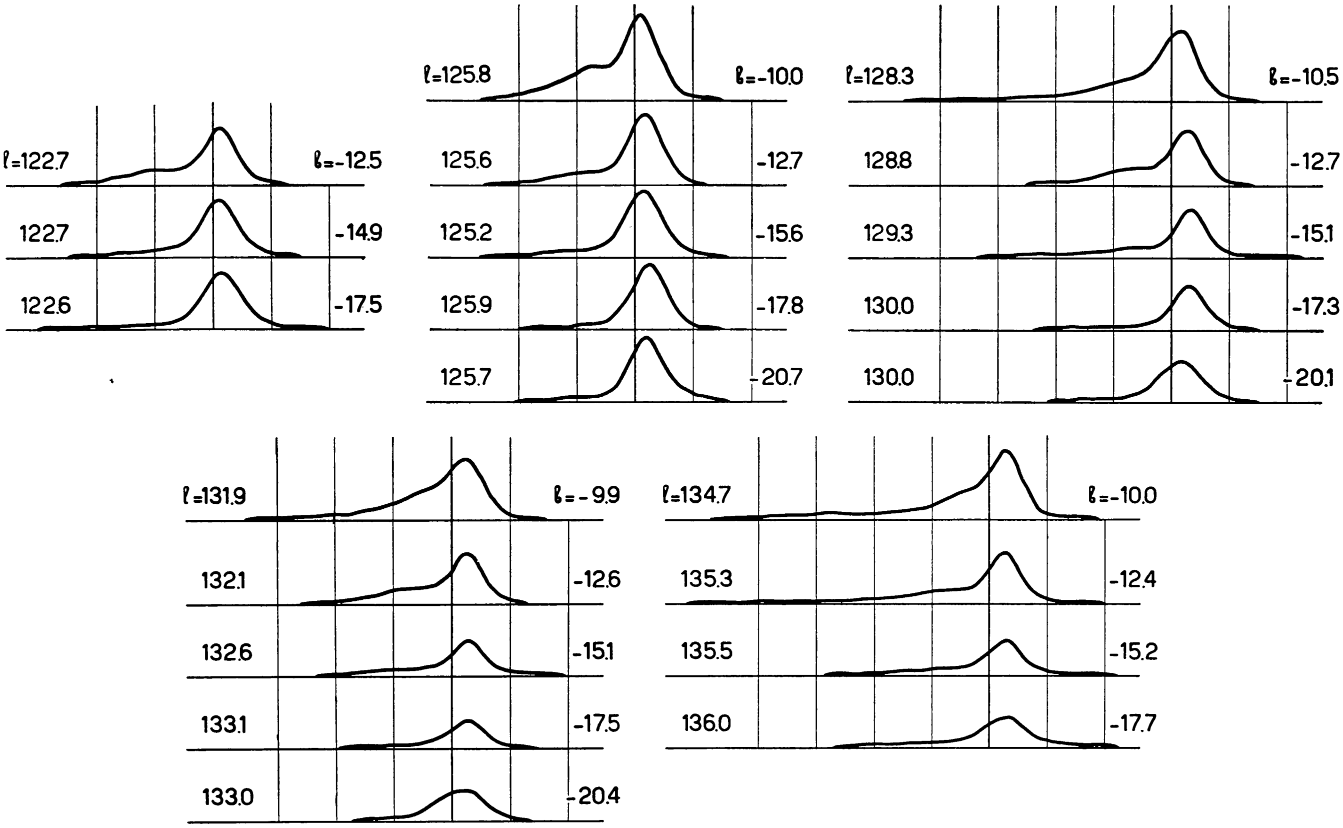
More detailed investigations are needed.

1) I am indebted to Dr A. BLAAUW, Yerkes Observatory, for these values.

2) H. M. JOHNSON c.s., *loc. cit.*

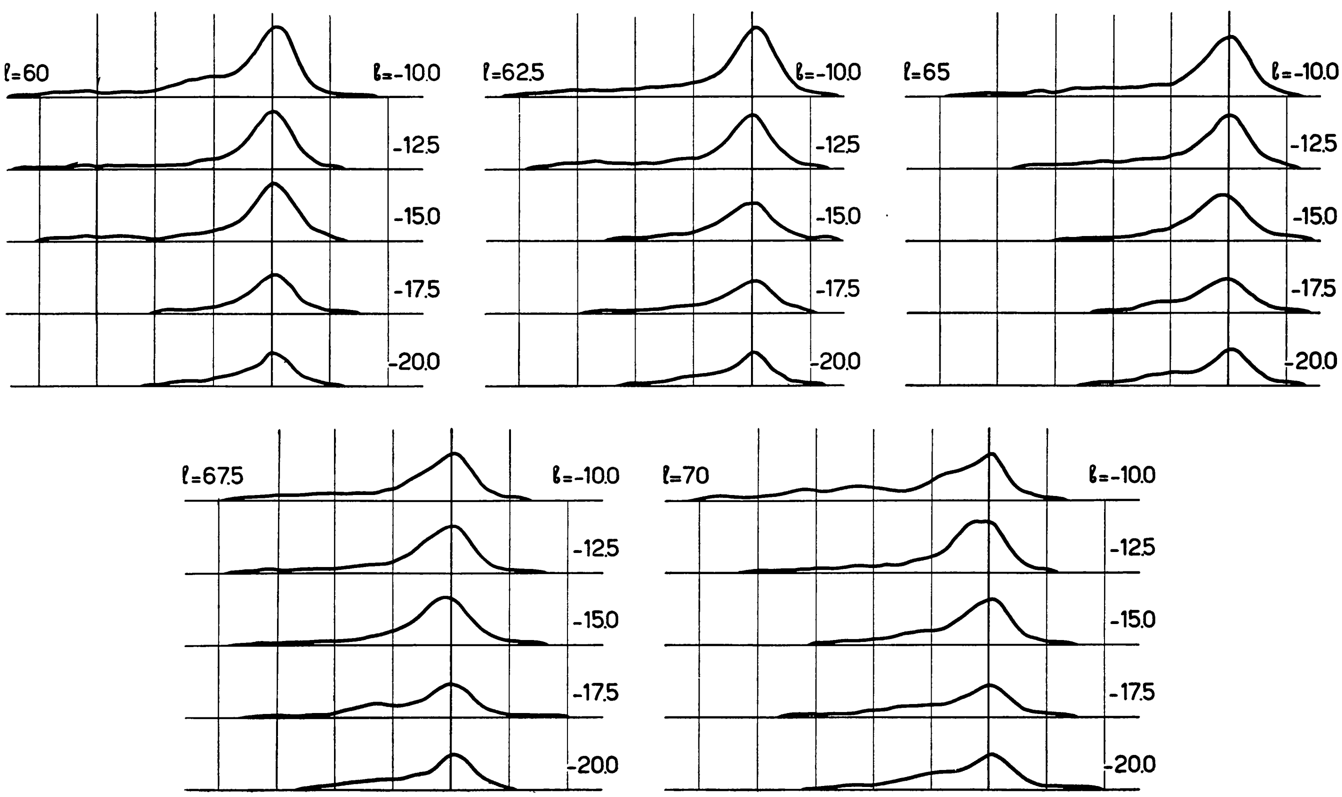
3) A. TH. MATTHEWS, "The distribution of neutral hydrogen between galactic longitudes 60° and 135°", *doctoral thesis*, Harvard University, 1956.

FIGURE 1



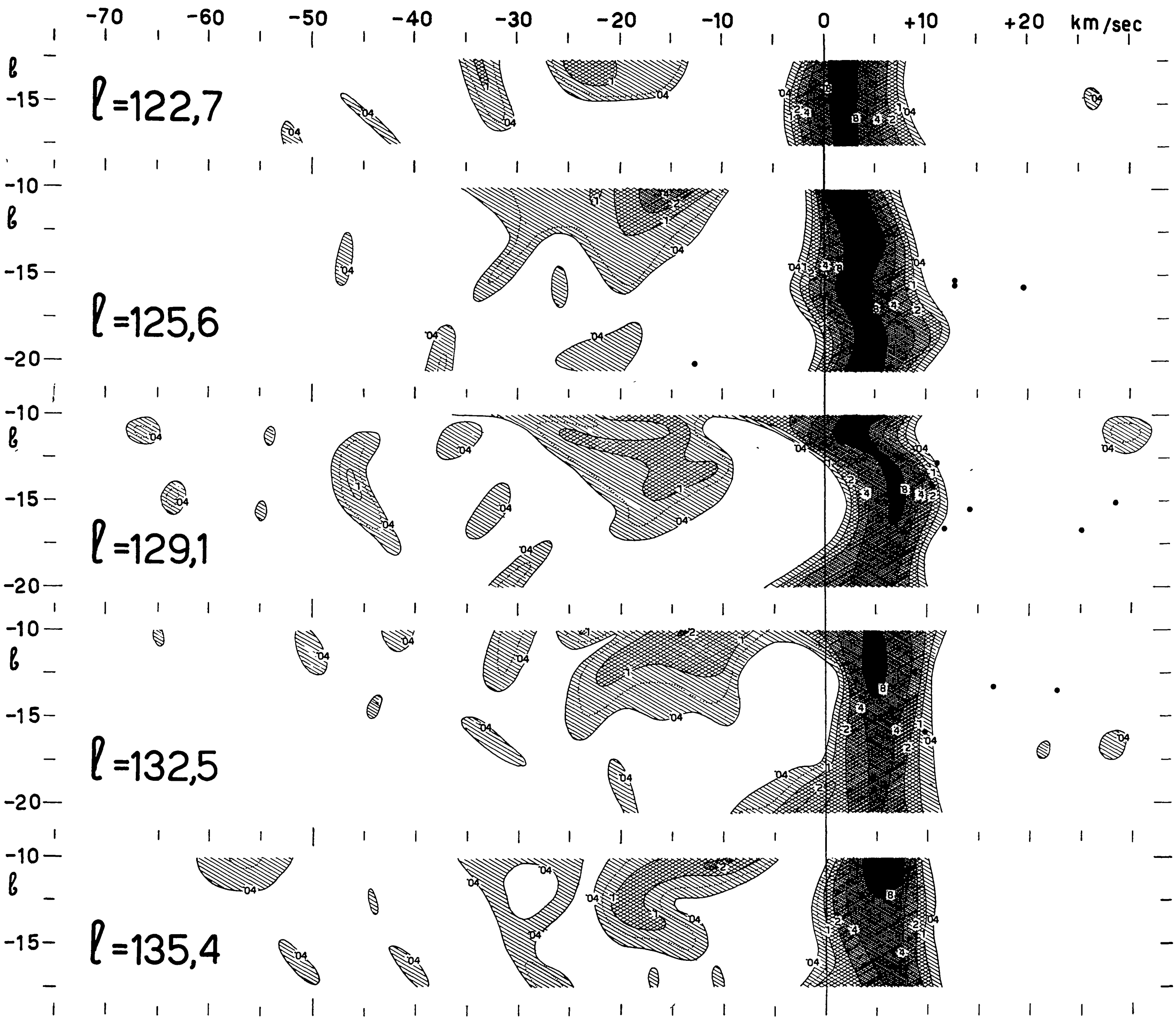
Line profiles in the II Persei association.

FIGURE 2



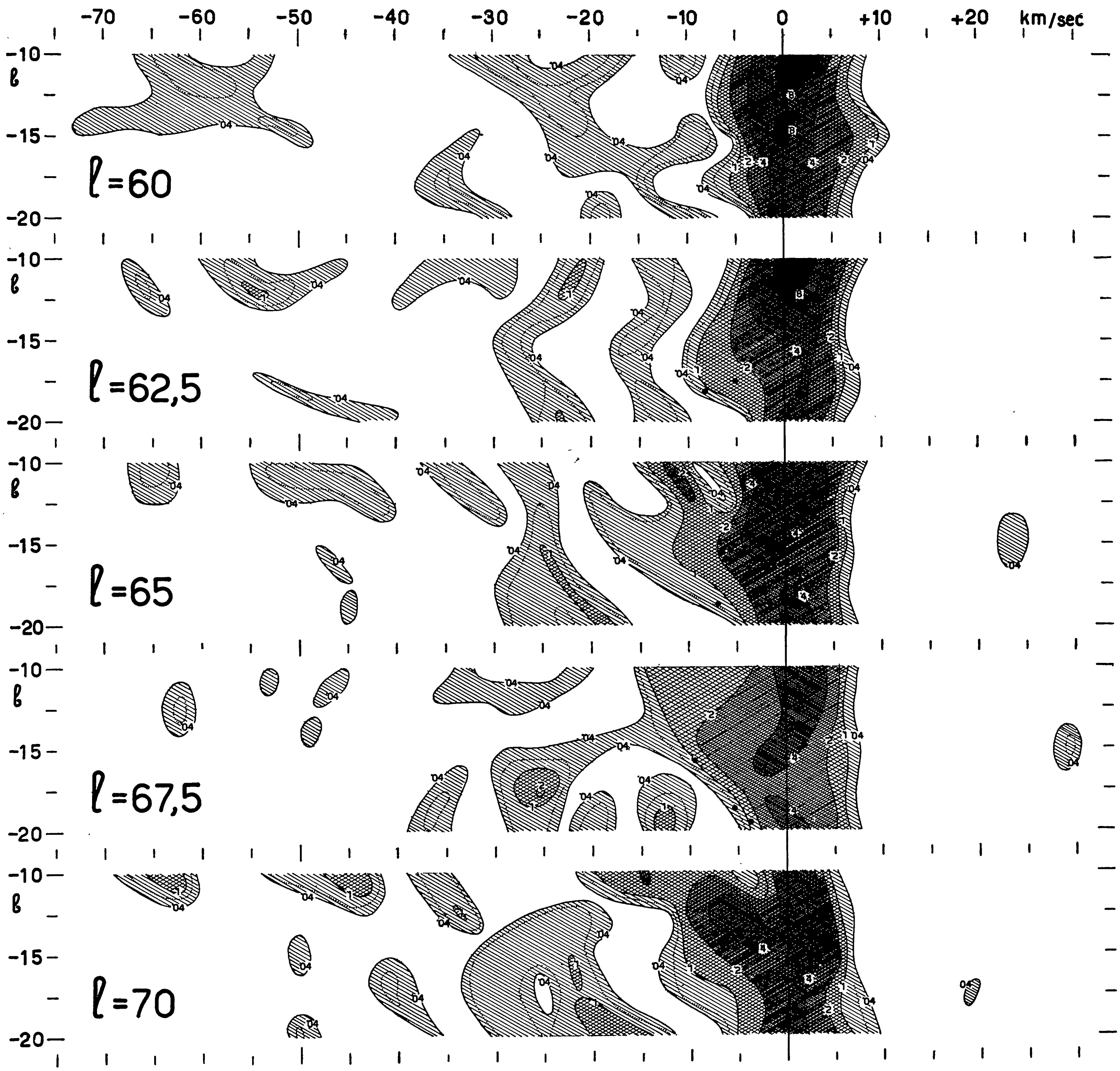
Line profiles in the I Lacertae association.

FIGURE 3



II Persei association: Optical depth, corrected for cloud velocities, in planes perpendicular to the galactic plane, as a function of radial velocity and latitude. Lowest contour is $\tau' = 0.04$, highest is $\tau' = 0.8$.

FIGURE 4



I Lacertae association: Contours of optical depth (see Figure 3).