of about 100°K. This fine structure in the density distribution within a cloud would greatly influence the ratios of the various emission and absorption processes. Theoretically, Parker (3) has shown that a cloud in equilbrium must have a 'tangled' field. Furthermore, there is no well-known process by which the field could be dissipated and simplified. For a field scale of $L = 1$ pc, ohmic dissipation requires $t(\mathrm{Ohm}) = 4\pi\sigma L^2 \simeq 10^{20}$ years, ambipolar diffusion increases the field gradients (without reconnecting the lines of force) in $t(\mathrm{a.d.}) = \mathrm{const.} \times n^2L^2/H^2 \simeq 10^6$ years and causes dissipation in $[t(\mathrm{Ohm})t(\mathrm{a.d.})]^{1/2} \simeq 10^{13}$ years (4). Cloud collisions reduce only $L$ and the available time, but not $n/H$, hence do not help. Various instabilities might be invoked for more rapid dissipation. For instance, the above time of $10^{13}$ years is based on the hydrodynamic approximation, but the same computation yields dissipation by high field gradients over an impossibly small scale of only a few cm. Therefore, the full details of plasma physics should be invoked. But most instabilities are likely to involve gas motions at hydromagnetic velocities, and such violent dissipation appears somewhat implausible in clouds corresponding to the frequently observed narrow emission and absorption lines. Nevertheless, dissipation may be occurring in clouds with wide lines, and these may be good candidates for star formation when the dissipation is completed.

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## II. INTERSTELLAR MATTER AND YOUNG STARS

### 9. THE DISTRIBUTION OF EMISSION-LINE STARS IN THE TAURUS DARK NEBULAE

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The time is past when we examined the distribution of the T Tauri stars in an effort to establish the reality of their association with interstellar material. Today, that point is beyond question, and now we should look again and, armed with new insight, attempt to learn what the observations might tell us about the deeper nature of this association.

The most promising region to begin such a study is that of the dark clouds in Taurus, and I wish here only to outline a few aspects of the problem in that region. Taurus is a particularly suitable place to begin such a study because much of the necessary data is already available, and also because in the main it is free from the complications arising from the presence of emission nebulae and their very hot stars; in the region discussed here, the earliest type star associated with the dark material is about type B5. Fig. 1 is a somewhat schematic diagram of the boundaries of the dark clouds as indicated by simple inspection of direct photographs. Superimposed on the clouds are the positions of about 70 T Tauri stars (including 5 flash variables) within the boundaries of the region studied, an irregular region of about 50 square degrees centered at about $4^h\ 29^m$, $+25°$ (1950). (Star counts indicate that the cloud boundaries shown are the contours of photographic extinction $= \sim 1{\cdot}5$ mag with respect to the neighboring clear region.) The emission-H$\alpha$ stars were found mainly at Mount Wilson and at Tonantzintla.

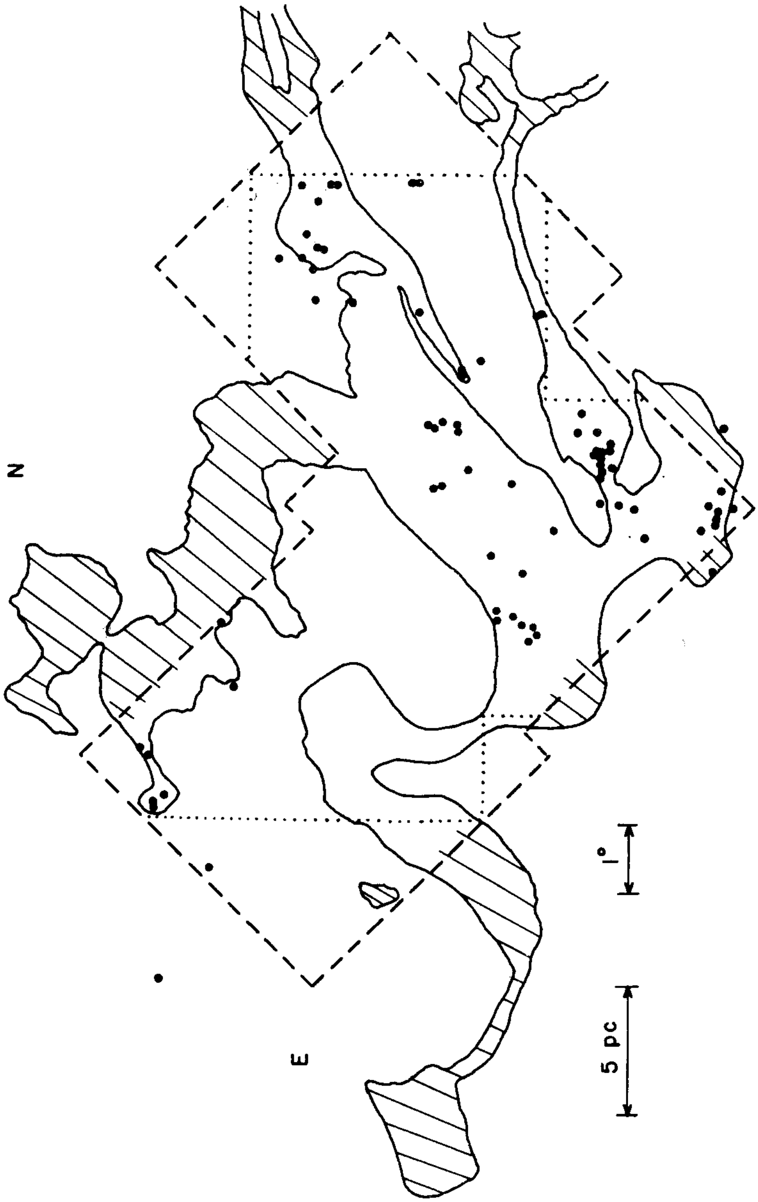


Fig. 1. Boundaries of Taurus dark clouds, with positions of T Tauri stars.

The concentration of the T Tauri stars to the dark lanes is striking, but it will be noted that there are a few which lie in the relatively clear regions outside the indicated cloud boundaries, i.e. where $A_{pg} - A_{pg}$ (background) $< 1{\cdot}5$ mag. We return to these stars presently.

The $A_{pg}$'s in this region have been derived from star counts to about $m_{pg} = 18$ on Lick 20-inch Astrograph photographs, which in turn have been reduced to the system of photographic absorptions of Bok (1) which are based on star counts to about magnitude 20 on 48-inch Schmidt plates. In particular, the $A_{pg}$ at the position of each emission-line star has been obtained from star counts in an $8' \times 12'$ area centered on the star. After reduction to equal projected area (of 1 $pc^2$), the summary is as follows:

| $A_{pg}$: Photographic absorption over the background | Number of all stars per projected 1 $pc^2$ | Number of emission stars per projected 1 $pc^2$ | Actual number of emission stars counted |
|---|---|---|---|
| 0–1 mag | 310· | 0·05 | 8 |
| 1–2 | 155· | 0·12 | 12 |
| 2–3 | 78· | 0·24 | 10 |
| 3–4 | 36· | 0·56 | 14 |
| > 4 | 12· | 1·4 | 26 |

The number of emission stars actually counted, before correction to equal area, is shown in the last column. The preference of the T Tauri stars for the heavily obscured regions is displayed again. For those concerned with star counts, it is of interest to note that in the most heavily obscured regions in this field ($A_{pg} > 4$ mag), down to $m_{pg} = 18$ about one star in eight is an emission-line star, and if the ratio of 2·5:1 between emission + non-emission variables and emission stars alone that is found in other nebulae holds here, then about one star in three is physically associated with the dark cloud. Such a direct comparison of the second and third colums of the table assumes that the limiting magnitudes are the same in the two cases. We are not sure that this is precisely so: the emission-star counts may correspond to a limit about 0·5 magnitude brighter than the star counts.

A question of interest to the evolutionists is whether anything can be said about the density dependence of star formation. The answer seems to be: nothing very definite, but there is the following interesting point. Assume that these stars have not moved a significant distance from their points of origin. At a given total absorption $A$, the total number of emission-line stars counted per unit projected area to limiting magnitude $m = 17{\cdot}5$ or $18{\cdot}0$ is $N_T$:

$$N_T(A) = \int^{m_{\lim}} n_T(m)\,\mathrm{d}m \leqslant \int n_T(z)\,\mathrm{d}z$$

while

$$A_{pg} = 1{\cdot}09 \int \kappa\rho_{\mathrm{dust}}(z)\,\mathrm{d}z,$$

where $z$ is the coordinate in the line of sight. Now if $n_T(z)$ is directly proportional to the total local density $\rho(z)$, i.e. if the rate of star formation at a point in the cloud is proportional to the first power of the local cloud density, then at two absorptions $A_1$ and $A_2$, if $A_1 > A_2$, and if $\rho$ and $\rho_{\mathrm{dust}}$ are everywhere in the same proportion:

$$\frac{N_T(A_1)}{N_T(A_2)} \leqslant \frac{A_1}{A_2},$$

and this linear relation is shown by the straight line in Fig. 2, where $N_T$ is plotted against $A_{pg}$. Now of course, the large assumption that stars do not move significantly from their points of formation is not fulfilled, since there are times of the order of $10^6$ to $10^7$ years available. Furthermore, we expect the emission-star counts to be increasingly incomplete at the higher absorptions. But despite this last, one sees that there is a considerable excess of T Tauri stars in the most heavily obscured regions over that expected on the above simple picture; presumably the true excess at the largest $A_{pg}$'s is even larger.

Finally, to the question of the T Tauri stars lying outside the apparent boundaries of the obscured lanes. RW Aurigae, the most striking case, has a projected separation of about 7 pc from the nearest heavy obscuration (although there are patches of lighter obscuration near by); none of the other stars are farther than about 3 pc from the nearest dark material. Should this give concern to the evolutionary interpretation of the T Tauri stars? The answer is probably no,

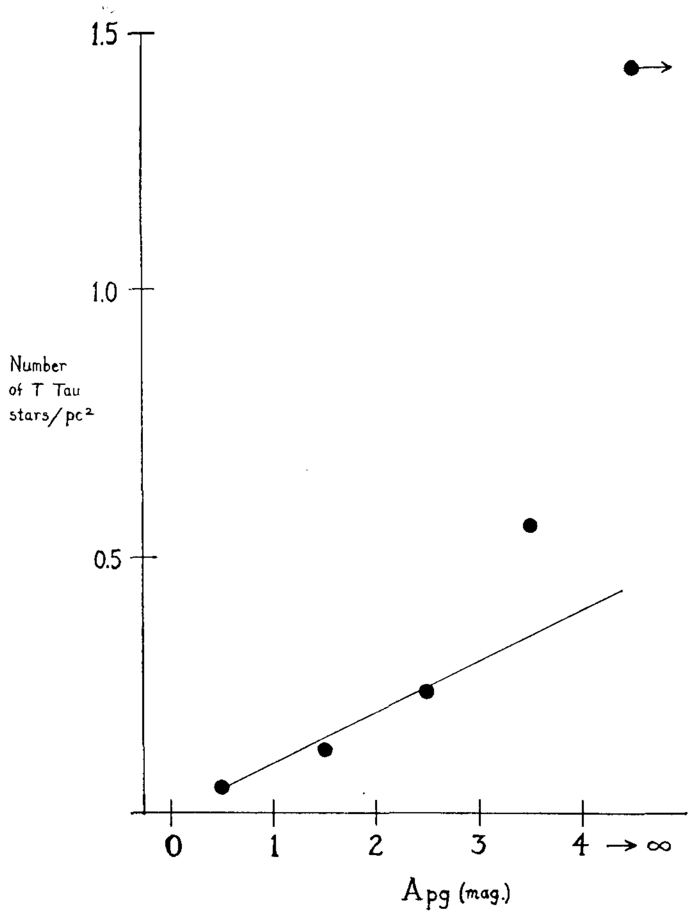


Fig. 2. Relation between surface density of T Tauri stars and total absorption *A*.

for the following reason. Proper motion studies by Blaauw and Pels (unpublished) and by Wenzel (**2**) indicate that the velocity dispersion of the T Tauri stars in this region is probably no greater than 1–2 km/sec. Such radial velocity information as is available supports this very small value. But the (Hayashi) contraction time of an early G dwarf along its vertical evolutionary track is about $10^7$ years, which is large enough for a slow-moving star to travel 10–20 pc, provided of course that it is able to escape from its parent cloud in the first place. So there is nothing alarming about the location of RW Aurigae and a few other similar stars.

Certainly the next question is whether the problem can be inverted and used to study the kinematics of young stars and their parent clouds from the distribution of emission-line stars. But that is still a question for the future.

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DISCUSSION

*Bok.* Is there any information on the concentration of H I in these very dark regions?

*Herbig.* We have no new information, and hence did not consider the point.

## 10. LARGER-SCALE PHENOMENA IN DISTRIBUTION AND MOTIONS OF STARS AS COMPARED TO THOSE OF THE GAS

*Th. Schmidt-Kaler*

The term 'larger scale' serves as a contrast to structures with dimensions of the order of 100 pc, but should remain within the local domain, that is within 2-3 kpc distance from the Sun. Within this domain we know of only one dominating structure, the spiral filaments of our Galaxy. Apparently optical work in the last 2 years leads to a consistent, unified picture of this structure within the local domain.

First, let me give a short review of the methods for determining spiral structure in our Galaxy:

1. *Position and distance.* The most direct method, applied to individual spiral tracers (H II-regions, early-type clusters, associations) and in stellar-statistical investigations (OB-stars, selected fields). In a modified version it can be applied to H I-absorption-lines on thermal sources and to calcium-emission-lines in distant stars by simple *ordering* along the line of sight.

2. *Position and intensity:* looking along a spiral feature we expect to observe intensity (or frequency) maxima. Applied to the surface photometry of the Milky Way, to the thermal radio emission continuum and the frequency distribution of distant objects (M-giants, WR-stars).

3. *Position and direction* (form of dark clouds and details in emission nebulae, interstellar polarization of star-light, measurements of magnetic fields in the Galaxy). The interpretation is not so straightforward as in the first two methods.

4. *Position and velocity* (interstellar calcium-lines, radial velocities of distant OB-stars and supergiants, interferometric velocities for faint emission nebulae, and especially the analysis of the 21 cm-line-profiles). This method implies knowledge of a dynamical model of the Galaxy.

The objects to be discussed should meet two additional conditions: (1) they should represent a statistically homogeneous and complete sample within the local domain covering a full band along the galactic equator, (2) they should be very young since the random velocities tend to smear out objects which originated in the spiral filaments over the plane within *ca.* $10^8$ years. So we are finally left with only a few types of objects. It should, however, be emphasized that there is a great number of additional investigations which do not contradict the general picture derived here.

A. Early-type open clusters (with earliest type O5–B2). The distance moduli have been taken from Becker (1963, 1964) and Hoag, Johnson *et al.* (1961), giving double weight to Becker's values. For four clusters with strongly discrepant values the modulus has been determined anew, and four southern clusters have been added on the basis of unpublished work of Graham and H. Schmidt (50 objects).

B. OB-aggregates. From K. H. Schmidt's (1958) list all objects were selected with

(*a*) earliest spectral type O–B0
(*b*) overall diameter between 15 and 180 pc
(*c*) minimum number of 10 members with accurately known MK-classification and photoelectric (U) *BV*-photometry
(*d*) dispersion of distance moduli (determined with the luminosity calibration of Schmidt-Kaler (1963)) $\leqq 0\overset{m}{.}8$.

https://doi.org/10.1017/S0251107X00019301 Published online by Cambridge University Press