8. INTERPRETATION OF THE OBSERVATIONS IN TERMS OF GAS DYNAMICS

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The new observations raise the following three problems, among others: (1) What is the origin of the clouds, particularly of the high-velocity clouds? (2) Are the interstellar clouds tied to the large-scale magnetic field which is revealed by the Faraday rotation? (3) Can small-scale structure of magnetic fields exist within clouds? If so, it can generate fine structure in the density distribution within the clouds, which should be important for the interpretation of the optical and radio emission and absorption lines.

1. Sweet (1) has recently investigated a gravitational interaction between interstellar gas and one or two star streams, the stars being treated as collisionless particles in analogy with plasma physics. The gas is unstable to density fluctuations if its speed relative to a star stream is comparable to or exceeds the speed of sound in the gas and if the velocity dispersion among the stars is less than their rate of streaming. If the high-velocity clouds discussed by Oort are falling into the galactic halo, this gravitational instability may well have been the cause for their condensation into clouds. In this case, they should also generate extensive shock structure in their surroundings. Computation of these shocks, taking into account the cloud compressibility and proximity to Mach 1, is a very formidable theoretical problem.

Sweet suggests that the double star stream near the Sun generates the local clouds. But condensation by gravitational instability leaves the gas and clouds tied to the magnetic field. Does this remain true after condensation?

2. The large-scale pattern in the direction of the Faraday rotation indicates that the magnetic field in H II regions (greater electron density than in H I clouds) has a preferred direction over regions sufficiently large to include at least several interstellar clouds. The alignment of the optical interstellar polarization indicates that cloud motions cannot significantly tangle the large-scale field, since this field is most probably the cause for the alignment. That the cloud motions do not tangle the field might be due to magnetic forces which control and correlate cloud motions over distances of the order of a kiloparsec, or due to the clouds being very short-lived, both explanations appearing rather improbable, or due to the clouds being magnetically detached from the surrounding large-scale magnetic field.

It appears to be the task of theory to explain interstellar reconnection of magnetic lines of force at a rate faster than has been believed so far. A promising recent approach is due to Petchek (2). He investigates the dynamics of a magnetic neutral point and argues that the reconnected lines of force near this neutral point achieve a structure involving switch-off shocks. The estimated maximum rate of magnetic field reconnection is determined mainly by the rate of flow away from the neutral point, at roughly the hydromagnetic velocity, and depends only logarithmically on the electrical conductivity.

If clouds can be separated from the surrounding magnetic field, their stability when moving through their surroundings should be investigated. The explanation of the aligned interstellar polarization should perhaps be sought in a flattening of the cloud by the surrounding magnetic field (3). Possibly clouds can pick up small magnetic flux loops which have been previously ejected from stars and have also been flattened by the large-scale field.

3. Could a cloud actually consist of several adjacent or intertwined flux loops, whatever their origin? If so, one would expect no measurable Zeeman splitting. Further, one would expect regions in the cloud where the gas pressure is comparable to magnetic pressure elsewhere in the cloud in order to maintain equilibrium. A reasonably low estimate of 5×10^{-6} gauss for the field strength then implies regions with densities of roughly 100 atoms per cm^3 at a temperature

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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-Hα stars were found mainly at Mount Wilson and at Tonantzintla.

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