statistical point of view. But in reality we have some additional evidence pointing in favor of physical connections between the components of the same chain, namely, the similarity in color and the apparent connection with the dark filaments. This was also indicated recently by Martynov.[1]

If these systems are not accidental agglomerations of stars, they must be unstable and consequently very rare. Purely random arrangements of different kinds can surely appear in a dense star field. But their connection with dark filaments merits further attention.

Now a few words about the dark filaments, which are present in different parts of the sky, usually as some peculiarity of gaseous nebulae. It is to be noted that in the charts of the Palomar Atlas these filaments are much less distinguishable, because of numerous faint stars which appear in the area of the filaments.

[1] D. J. Martynov, Astron. Circ. N 149 (1954).

By comparing these features, photographed with different exposures up to different limiting stellar magnitudes, one can evaluate the apparent decrease in the number of stars and consequently the corresponding absorption. This absorption is not very great and generally does not surpass one stellar magnitude.

In the case of the aforementioned dark filaments in the region of McDonald 12 in Cygnus, their width at a distance of 1000 parsecs corresponds to nearly 0.3 pc. It is reasonable to assume that their thickness in the line of vision is substantially the same. Adopting now that general absorption of light in this region of space is some 2–3 mg per 1000 pc, which corresponds to a density of the order of 6.10^{-26} g/cm^3, one can reach the conclusion that the density of the dust in the dark filaments may attain a value as high as 10^{-22} g/cm^3, or nearly 1000 times greater than the average for interstellar space. The probable presence of gaseous matter must increase the density still more.

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Microstructure of the Galactic Magnetic Field

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The polarization of the stars in open clusters, explained on the basis of the Davis-Greenstein theory, gives some information on the microstructure of the galactic magnetic field.

The polarization is most conveniently described by the parameters Q, U, proportional to the Stokes parameters and defined by

$$Q=p\cos 2(\theta-\bar{\theta})$$
$$U=p\sin 2(\theta-\bar{\theta}),$$

where p is the amount of polarization, θ is the position angle of the electric vector, and $\bar{\theta}$ is the mean value of θ for the region under consideration.

The parameters Q, U may be represented as the integrals over the light path of some simple functions of the density and temperature of interstellar matter and of the components of the galactic magnetic field. We introduce two models: in the first model *isotropic* fluctuations are superimposed upon a homogeneous general magnetic field; in the second model fluctuations *perpendicular* to the mean direction of the field are superimposed upon a homogeneous field. The latter model might be correct if Alfvèn waves are running in the direction of the general field.

For each of these models the ratio of the variances of the parameters Q, U is computed for a group of stars lying at the same distance in a direction approximately perpendicular to the direction of the general field. In this way for the first model, we have

$$\sigma_Q^2/\sigma_U^2=1+C^2>1, \tag{1}$$

while for the second model

$$\sigma_Q^2/\sigma_U^2=\tfrac{1}{4}\alpha_1^2+C^2. \tag{2}$$

Here α_1 is the root-mean-square angular deviation of the magnetic lines of force from a uniform direction and C^2 is a positive constant.

The 92 stars within a radius of 2° around the Double Cluster in Perseus for which the polarization was measured by Hiltner[1(a)(d)], give

$$\sigma_Q^2/\sigma_U^2=0.60\pm 0.14(\text{m.e.}). \tag{3}$$

This value was obtained after eliminating the dependence of the polarization p on the galactic latitude b; this dependence was represented by the linear formula

$$p=0.^m115(\pm 0.007)-0.^m012(\pm 0.002)|b|. \tag{4}$$

Since the ratio (3) is smaller than unity it cannot be explained by the first model, assuming isotropic

[1] (a) W. A. Hiltner, Astrophys. J. **114**, 241 (1951); (b) *ibid.* **120**, 178 (1954); (c) *ibid.* **120**, 367 (1954); (d) *ibid.* **120**, 454 (1954); (e) Astrophys. J. Suppl. **2**, No. 24 (1956).

fluctuations of magnetic field. On the other hand, the ratio (3) can be represented by the formula (2) on the assumption that Alfvèn waves are running in the direction of the general field.

The distribution of the values of the parameters Q, U over the area of the Double Cluster was used to evaluate the microscale of the fluctuations in the factors responsible for the interstellar polarization. On the assumption that the properties of the interstellar medium are constant along the line of sight to the Double Cluster, a microscale of about 1.5 pc was obtained; this microscale is the distance over which the autocorrelation coefficient falls to $1/e$ (presented during the Stockholm Symposium on Electromagnetic Phenomena in Cosmical Physics).

With the foregoing value of the microscale, and with the variances σ_Q^2, σ_U^2, obtained from the polarization measurements for the Double Cluster, the root-mean-square angular deviation of the magnetic lines of force from a uniform direction is

$$\alpha_1 = 0.71 \pm 0.06 \text{(m.e.) radians.} \quad (5)$$

The details of the determination of this quantity are described in another paper.[2]

If in the magnetohydrodynamic formula given by Davis[3] and by Chandrasekhar and Fermi,[4]

$$B = (4\pi\rho/3)^{\frac{1}{2}} v/\alpha_1 \text{ gauss,}$$

one takes the value (5) for α_1, the density of gas $\rho = 2\cdot10^{-24}$ g/cm^3 and its root-mean-square velocity $v = 12$ km/sec according to Spitzer,[5] one gets the strength of magnetic field

$$B = 5\cdot10^{-6} \text{ gauss,}$$

which is not discordant with the value $B = 3\cdot10^{-6}$ gauss obtained by Spitzer[5] from the condition that the gravitational pressure equals the sum of material and magnetic pressures.

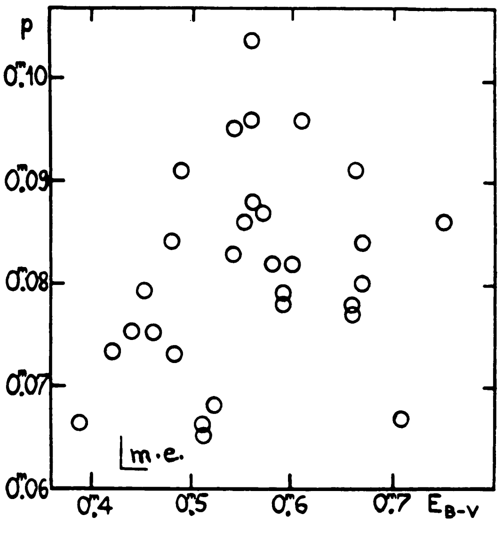

FIG. 1. Polarization *vs* reddening for the stars within a radius of 45′ around the Double Cluster in Perseus. The lines (m.e.) in the lower left of the diagram represent the mean errors of measurement.

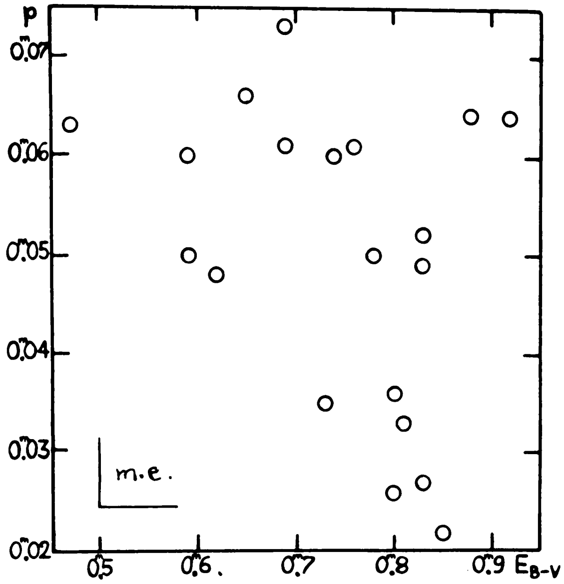

FIG. 2. Polarization *vs* reddening for the stars in the Stock cluster in Perseus.

If we consider the stars in a radius of, e.g., 45 min of arc around the Double Cluster, there is no correlation between the polarization and reddening (Fig. 1). The same result is obtained if all the stars in a radius of 2° around the center of the Double Cluster are considered, after eliminating the dependence of the polarization upon the galactic latitude by means of formula (4) and of the reddening E_{B-V} by means of the similar formula

$$E_{B-V} = 0.^m97 - 0.^m13|b|. \quad (6)$$
$$\pm4 \qquad \pm1$$

In this case the coefficient of correlation between p and E_{B-V} also equals zero within the limits of error.

A similar lack of correlation between polarization and reddening is stated for the heavily obscured association of OB stars in Cygnus observed by Hiltner[1(b)] (the peculiar star No. 12 being neglected) and also for the cluster in Perseus discovered by Stock[6] (see Fig. 2); the polarization of this cluster was measured photoelectrically by Larsson-Leander and myself.[7] Among the five clusters observed by Hoag[8] all except NGC 663 do not show any correlation between polarization and

[2] K. Serkowski, Acta astronomica (to be published).
[3] L. Davis, Phys. Rev. **81**, 890 (1951).
[4] S. Chandrasekhar and E. Fermi, Astrophys J. **118**, 113 (1953).
[5] L. Spitzer, Astrophys. J. **124**, 20 (1956).

[6] J. Stock, Astrophys. J. **123**, 263 (1956).
[7] G. Larsson-Leander and K. Serkowski, Arkiv Astron. (to be published).
[8] A. A. Hoag, Astron. J. **58**, 42 (1953), and private communication.

reddening. The clusters NGC 663 and M 29 for which the polarization is strongly correlated with reddening, are probably (according to a suggestion by Hiltner[1(c)]) embedded in dense nebulae in which an appreciable part of the observed polarization and reddening is produced.

On the assumption that the same particles of dust are responsible both for the polarization and the reddening, and that the polarization introduced by a single dust grain is not dependent on the number of dust grains per cm^3, the correlation coefficient between the polarization and reddening in the cluster should be equal to

$$r = \left[\frac{\sigma_E}{\bar{E}}\right] \bigg/ \left[\frac{\sigma_p}{\bar{p}}\right], \tag{7}$$

where $\sigma_E/\bar{E}$ is the ratio of the root-mean-square deviation in reddening to the mean reddening, and $\sigma_p/\bar{p}$ is the corresponding ratio for the amount of polarization.

For the Double Cluster the observations show that $(\sigma_E/\bar{E}) > (\sigma_p/\bar{p})$; hence formula (7) gives a value greater than unity, while the observations show no correlation. This means that our assumptions were wrong and that the increase of the amount of polarization over the unit light path is independent from the number of dust grains per cm^3, at least in the HI regions where most of the reddening is produced.

The straight line joining us with the Double Cluster almost intersects the Stock Cluster mentioned above, which is situated in the Orion arm of the galaxy.

The Stock Cluster lies only 2° north from the Double Cluster but at a distance of about 300 pc, i.e., nearly 8 times smaller than the distance of the Double Cluster. Nevertheless, the reddening in the $B-V$ system is for the Stock Cluster $0.^m74$, thus greater than for the Double Cluster for which the corresponding value is $0.^m58$. On the other hand, the mean amount of polarization for the Stock Cluster is $0.^m050$, which is much smaller than for the Double Cluster for which $\bar{p} = 0.^m080$.

For the three stars (HD 13402, $BD+58°400$ and $BD+59°451$) lying at a distance of about 2 kpc behind the Stock Cluster, the mean reddening is $0.^m90$ and the mean polarization is $0.^m118$ according to Hiltner.[1(e)] Hence only about 20% of the observed reddening and nearly 60% of the observed polarization of these stars is produced at distances greater than the distance of the Stock Cluster, i.e., between the spiral arms of the galaxy. It may indicate that in the space between the spiral arms, where the interstellar gas is very rarefied and probably almost completely ionized, the ratio of polarization to reddening is very high. Thus *polarization is produced mainly in the HII regions while reddening in the HI regions.*

This conclusion is supported by the data on the latitude dependence of the ratio of polarization to reddening, given by Bielicka and myself,[9] who obtained that the ratio of polarization to reddening is distinctly smaller for stars near the galactic equator than for stars in higher galactic latitudes. This effect can be explained by the strong concentration in the galactic plane of the neutral hydrogen regions for which the ratio of polarization to reddening is supposed to be smaller than for the ionized regions.

[9] K. Bielicka and K. Serkowski, Warsaw Reprint No. 66 (1957).

DISCUSSION

L. Spitzer, Jr., *Princeton University Observatory, Princeton, New Jersey:* To what extent is it possible that polarization is produced in regions where there is no reddening? I had the impression that, at least in the infrared, the polarization was already about the maximum value that one could expect from the observed reddening, assuming that the extinction takes place in only one plane of polarization.

H. C. van de Hulst, *Leiden Observatory, Leiden, Netherlands:* The fundamental limit is that radiation cannot be changed from one polarization to the other; so if there is a strong polarization, at least half of that has to show up in the form of extinction. This limit would be reached if large polaroid filters would be put out into space.

L. Spitzer, Jr.: How close to this limit does Serkowski's suggestion come?

H. C. van de Hulst: This is in visual light, and in infrared one comes closer to the limit. The practical limit just depends on what assumptions one wishes to adopt about the particles in interstellar space.

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