polar region and depends also on the phase of the sunspot cycle. The measurements of the inclination have been obtained from large-scale photographs of the corona at the eclipses of 1952, 1954, 1955 and 1961. The following mean values of c have been observed:

Year	1952	1954	1955	1961
c	0·69	1·23	0·90	0·90

The measurements refer to the distances $r = 1 \cdot 1$ and $1 \cdot 3$ from the Sun's centre, and to both the northern as well as to the southern hemisphere, except for the 1961 corona which has shown the polar streamers in the northern polar region only. From the figures given, one may conclude that the inclination of the polar streamers increases as the sunspot minimum (1954) is approached and decreases again after sunspot minimum.

DISCUSSION

V. V. Vitkevitch: I wish to call attention to the Russian eclipse expedition back in 1936. Detailed description of the polar rays have been published in 1939 by E. J. Bugoslavskaya (Sternberg Dissertation). In Kiev further studies have been made of the polar and the equatorial rays and their connection with the Sun's magnetic field. I shall report about them at the Cloudcroft symposium.

7. FILAMENTARY CURRENTS AND THE MAGNETIC CONDITIONS ON THE SUN

H. Alfvén

It is an observed fact that cosmical plasmas often exhibit filamentary structures. Examples of such structures are prominences, polar plumes, coronal rays, supercorona (**1, 2, 3**) and filaments in interstellar clouds. Structures of these kinds have been studied recently by Kippenhahn and Schlüter (**4**), Jensen (**5**), Lüst and Zirin (**6**) and others.

Filamentary structure may be an essential and general property of low-density cosmical plasmas. This view can be supported by theoretical arguments. From analysis of a simple model, it has recently been concluded (**7**) that currents in a low-density plasma tend to approach

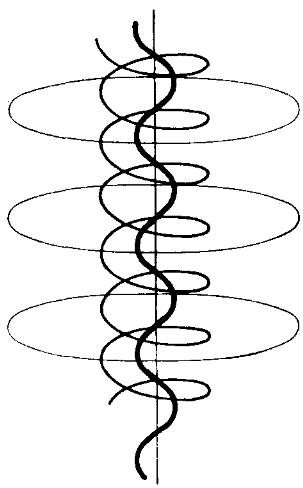

FIG. 1. Magnetic lines of force in a 'magnetic rope'.

a special configuration called 'filamentary current'. By the action of the filamentary current magnetic field lines are bunched into what may be called 'magnetic ropes', a term which is meant to draw attention to the twisted structure of the bunches.

A simple axially symmetric model is discussed in order to show what happens if in the presence of a magnetic flux ϕ_0 in the z-direction there is an electric current parallel to the z-axis. It is shown that the steady state is characterized by the presence of azimuthal currents

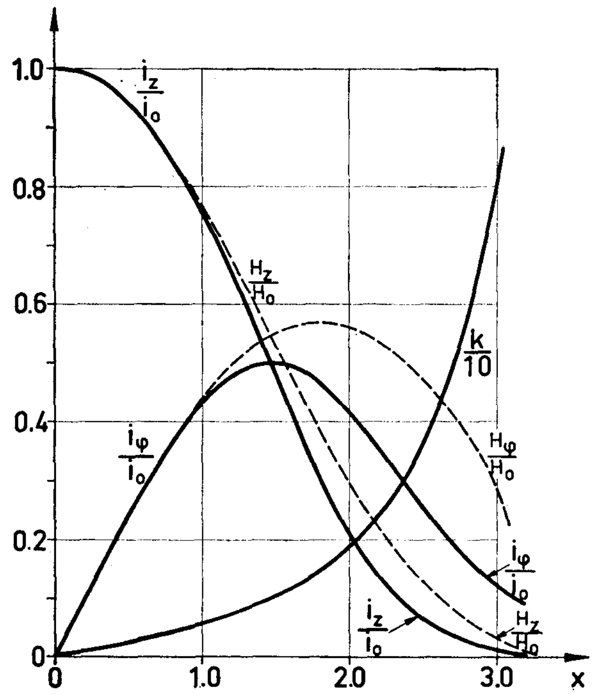

FIG. 2. Axial and azimuthal components of the magnetic field, H_z, H_ϕ, of the currents, i_z, i_ϕ, and the ratio $k = H_\phi/H_z$ as functions of the normalized radius $x = r/b$.

by which the whole flux is confined to a region around the axis. The pressure is assumed to be negligible so that only currents along the magnetic field need to be considered (force-free magnetic field). It is then found that in the steady state the magnetic lines of force form spirals that have a pitch angle which decreases with radius, so that far out the field lines are nearly circular (Figure 1). The total magnetic flux ϕ_0 in the z-direction is thus essentially concentrated within a certain radius from the axis. This radius is

$$b = \left(\frac{\phi_0 c}{4\pi^2 \gamma i_0}\right)^{1/3}$$

where γ is a numerical constant close to 3·1 and i_0 is the current density at the axis. The configuration is in some respects similar to certain types of pinches studied in plasma experiments. Figure 2 shows the components of current and magnetic field as well as the quotient H_ϕ/H_z, which is a measure of the inclination of the field.

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The time necessary for formation of a filamentary current may in some cases be very long, and in cosmical plasmas we should expect not only configurations like that in the above model but also non-stationary configurations approaching the steady state or decaying from it after the electromotive forces producing them have disappeared.

The filamentary current has, especially during its formation, a tendency to collect matter towards the axis. Hence we should expect the formation of a filamentary current, which is not itself observable, to be accompanied by a formation of a filament of gas, which is observable.

In the cosmical applications the boundary conditions are generally much more complicated than in the simple model and correspondingly complicated magnetic patterns are to be expected. For example, when the magnetic lines of force from a sunspot branch to various parts of the surrounding photosphere or to adjacent spots, electric fields may produce a number of filamentary currents. The corresponding gas filaments collected by the currents may perhaps be identified with certain types of filamentary prominences (**8**).

Other filamentary structures in the corona are polar plumes, equatorial streamers and filaments in the outermost parts of the corona. It is conceivable that all these structures are associated with filamentary currents, which bunch the Sun's general field into magnetic ropes. If a bunching of field lines takes place also in or near the photosphere, the main magnetic flux may pass the photosphere in a number of thin bunches which are difficult to detect with Zeeman effect measurements. This would add another objection (**9**) to the earlier objections against the usual interpretation (**10, 11**) of these measurements.

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DISCUSSION

L. Biermann. For the sake of the audience I raise the question of the origin of the electric fields parallel to the magnetic field **H,** the [$\mathbf{v} \times \mathbf{H}$] fields being always perpendicular to the magnetic field.

H. Alfvén. With the example of a growing sunspot one can show that induced electric fields will easily form along the lines of force, the electric conductivity across the lines of force being negligible.