On the Filamentary Structure of the Solar Corona

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On good photographs of the solar corona the filamentary structure is clearly visible. Most theories, however, treat the corona as if it were a homogeneous medium.

In the present paper arguments are given for the view that the filamentary structure is produced by the existence of electric fields which give rise to currents. It is shown that currents above a certain strength should bunch the magnetic field, producing "magnetic ropes" or "filamentary currents." The magnetic field and the current density inside a rope is much higher than outside. The gas density and the temperature may also be different.

This leads to the view that the corona may consist of two parts, the *filaments* and the *interfilamentary medium,* having properties which are quite different. For the interpretation of optical and radio measurements it is important to specify to which of these constituents the measurements refer.

Since the sun has changing magnetic fields and motions perpendicular to the magnetic field, electromotive forces are produced and these forces should give rise to electric currents in the corona. The parallel conductivity in the corona is very high, and one may suppose that electric currents should flow uniformly over large regions of the corona. However, this is true only as long as the current density is so low that the magnetic fields from the currents are negligible in comparison to other fields in the corona. This is usually not the case.

It has been shown elsewhere (*1*) that at densities which are sufficiently low for the gas pressure to be neglected, an electric field parallel to a magnetic field produces a current which bunches the magnetic field lines into "ropes" in which almost the whole current flows. Outside the ropes the magnetic field is perpendicular to the electric field, and as the cross-conductivity is low, the current will be negligible. The ropes are force-free magnetic fields of a type which have some similarity to the fields studied by Lüst and Zirin (*2*), Jensen (*3*), Brown (*4*), Kippenhahn and Schlüter (*5*), and others, but the present model differs from these models in the respect that at large distances from the axis the magnetic field is perpendicular to the electric field and the current density is zero.

We shall discuss two simple models. In the *first model* the electromotive force is produced by motions in the photosphere. We assume that below a certain level, which is situated in the upper photosphere or the lower chromosphere, the conductivity is isotropic, whereas above this level the currents flow essentially parallel to the magnetic field. We consider a stationary state and assume that a magnetic field line ABC in the corona intersects the photosphere at two points A and C (Fig. 1). If

$$V = \int_A^C (\mathbf{v} \times \mathbf{H}) \cdot d\mathbf{s}$$

taken along ADC in the photosphere differs from zero, an electric current should be produced in the circuit $ADCBA$. The result may be a filamentary current in the corona along the line ABC.

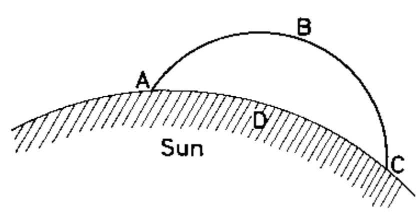

Fig. 1. A diagram showing the magnetic field line ABC in the corona intersecting the photosphere at points A and C.

If we want to identify this filamentary current or "magnetic rope" with some observable phenomenon, we must keep in mind that an electric current or a magnetic field cannot be observed directly but can be observed only by its effects on matter. Hence, only if matter is concentrated inside the magnetic rope can we observe it. It is possible that some types of filamentary prominences should be identified with the type of formation we have discussed.

In the *second model* we consider two magnetic field lines AB and

DC, both connecting the photosphere of the sun with a small cloud *BC* of matter in interplanetary space (Fig. 2). If we put

$$V = \int_A^D (\mathbf{v} \times \mathbf{H})\, \mathbf{ds} + \int_C^B (\mathbf{v} \times \mathbf{H})\, \mathbf{ds}$$

we find that if $V = 0$ there is no electromotive force active in the circuit *ABCD*. According to Ferraro's theorem this is the case when e.g., the cloud *BC* is at a constant distance from the sun and rotates around the axis of the sun with the solar angular velocity.

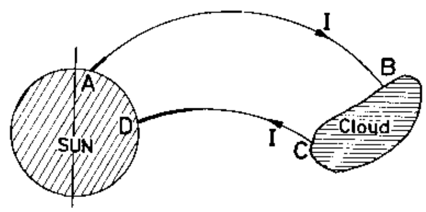

FIG. 2. A diagram showing the magnetic field lines *AB* and *DC* connecting the photosphere of the sun with a small cloud *BC* of matter in interplanetary space.

In the case when *BC* has a radial motion or does not co-rotate with the sun, *V* differs from zero and a current is produced in the circuit *ABCD*. For the same reasons as discussed above we should expect that current filaments are formed between *A* and *B* and also between *C* and *D*.

It is tentatively suggested that these filamentary currents are associated with the *polar plumes* and *equatorial streamers*. It seems also reasonable that they may be responsible for the filamentary structure far out in the corona (or "super-corona") which has been observed by radio methods.

A *third case* where filamentary currents may be of importance is the spicules. The hydromagnetic turbulence associated with the granulation should produce a varying electric voltage over the photosphere. Filamentary currents produced by this voltage may be a basic phenomenon in the chromosphere.

What has been said indicates that electric fields which are likely to be present in the solar atmosphere should bunch magnetic field lines. This process may take place on a very large scale—fields due to solar rotation producing bunches in the corona; on a medium scale—motions in sunspots producing prominences; and on a miniature scale—granulation producing spicules.

The result is that the solar atmosphere is strongly inhomogeneous.

Not only do the density and the temperature vary, as is obvious from observations, but also the magnetic field is strongly inhomogeneous. As the field lines are bunched, most of the solar atmosphere should have a weak magnetic field. Both optical and radio measurements of the magnetic field may refer more to the almost field-free regions than to the average field. This means that the possibility that the sun has a much stronger dipole moment than is generally believed cannot be excluded. Nor is it certain that this dipole moment varies in strength or changes its sign during the solar cycle. The observed variations may instead be due to a variation of the electric fields by which the bunching of field lines is produced.

References

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