SOLAR RADIO EMISSION AND THE ACCELERATION OF MAGNETIC-STORM PARTICLES

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The shift of the emitted frequencies towards lower frequencies during a solar outburst is usually interpreted as due to a progressive rarefaction of the emitting gas. If one assumes that the emitted frequency is identical with the plasma frequency and furthermore that the density of the emitting plasma is similar to the density of the solar corona at the location of the radiating material, then it follows that this material is subject to an acceleration throughout the solar corona which compensates or exceeds the effect of the gravitational field of the sun.

The existence of the general magnetic field of the sun, as observed by the Babcocks, seems to present a twofold difficulty to this interpretation. First, during the initial part of an outburst the radio-frequency emission is usually unpolarized, whereas it would be expected to be polarized in the presence of a magnetic field. Secondly, motion of ionized material across magnetic lines of force is impossible since the electrical conductivity is almost as high in the corona (due to the high temperature) as it is in ordinary metals; the so-called reduction of the conductivity across the magnetic lines of force (or more appropriately the Hall effect) does not affect this conclusion appreciably, as I have shown earlier. Therefore, if the ejected material is penetrated by the 'general' magnetic field of the sun, it has to drag this field along and overcome the Maxwell tensions which counteract any lengthening of the lines of force. Even if the accelerating mechanism were much stronger than required to compensate the gravitational field of the sun, ejection of material to infinity would seem almost impossible.

Both difficulties are circumvented if one assumes that the ejected material is *not* magnetized and moves *between* the magnetic lines of force, punching holes into the field. The material then behaves like a diamagnetic body and the Maxwell tensions of the magnetic field produce an accelerating

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force ('melon seed' mechanism). If one neglects the gas pressure of the *un*accelerated coronal gas and assumes a constant temperature of the ejected material, the magnitude and the direction of this force are proportional to $-\text{grad} \log H^2$, where H denotes the magnitude of the solar magnetic field that would exist at the considered place if no 'diamagnetic' matter were present. The logarithmic dependence is caused by the expansion of the ejected matter when it enters regions of smaller magnetic field strength. Therefore, the diamagnetic force is smaller than would be exerted upon a rigid body. (Only the latter possibility is usually considered in text-books.)

A closer analysis shows that the energy of acceleration stems from the heating mechanism of the corona while the magnetic field provides only the forces needed to balance gravitation and the change of momentum. All non-magnetized material, which is heated to a few million degrees (the exact value of the temperature depends on the structure of the magnetic field but not on its strength), will be accelerated and will reach the vicinity of the earth with a speed comparable to the velocity of escape at the point where the acceleration started. The speed of the particles which cause the ordinary magnetic disturbances on earth is usually thought to be of the order of the escape velocity near the surface of the sun. This seems to confirm the present theory. The increased speed of the particles during large magnetic storms could be explained by the assumption that these particles originate in locations on the sun where the magnetic field is considerably stronger than the 'general' magnetic field of the sun.

Discussion

Menzel: You do not mean to say that the dipole field can support everything? The force involved must be expressed as the divergence of the magnetic tensor, not as the gradient of the magnetic pressure.

Schlüter: I agree. The distortion component causes the support.