LETTERS TO THE EDITORS

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The Sun's Magnetic Field and Corpuscular Emission

A NEW instrument, the solar magnetograph[1], has been developed for measuring and recording weak photospheric magnetic fields. With it, more than 450 magnetograms showing the distribution, intensity and polarity of weak fields (greater than 0·3 gauss) on the sun have been obtained over a two-year period including the recent minimum of solar activity[2]. Most of the large-scale features of the magnetic pattern show a certain regularity; but there are pronounced random variations. There is also a partially resolved fluctuating fine structure showing changes of the order of 0·5 gauss in 30 min.

General Magnetic Field. Consistent evidence has been found for a dipolar component opposite in polarity to the field of the earth. The mean intensity near the poles is of the order of 1 gauss. This field is usually limited to heliographic latitudes greater than about $\pm 55°$; it has a varying fine structure and shows remarkable random fluctuations in effective intensity and extent. There seems to be no prevailing obliquity between the magnetic and rotational axes. The total flux is estimated to be nearly 10^{22} maxwells.

Bipolar Magnetic Regions. In the lower latitudes the stronger magnetic effects appear rather abruptly as contiguous areas of opposite polarity, as if loops of a submerged toroidal field were occasionally brought to the surface[3]. The bipolar magnetic regions obey Hale's laws of sunspot polarity[4]; but spots are comparatively rare, occurring when at all within such regions while they are young and active. Ca II *plages* are observed where the mean field intensity is greater than about 2 gauss. Hydrogen filaments occur around the borders of bipolar magnetic regions, or, alternatively, seem to divide the region into parts of opposite polarity. As the regions age, they generally expand, showing a decrease in field intensity, and disintegrate until lost in the background of irregular weak fields. There is much diversity in total magnetic flux, duration, area, and course of development.

Unipolar Magnetic Regions. Occasional extended areas of only one outstanding polarity were recognized on the magnetograms, but in no other way. The most prominent unipolar magnetic region of 1953 had a mean intensity of about 0·5 gauss and a duration of nine months or more; on each solar rotation its central passage on the disk preceded by about three days the onset of terrestrial magnetic storms in a prominent 27-day sequence. Unipolar magnetic regions may be remnants of disintegrating bipolar magnetic regions from which the lines of force have diffused outward through the corona. We suggest tentatively that unipolar magnetic regions may be identified with the hitherto hypothetical *M* regions of Bartels[5].

The observations provide objective evidence that magnetic fields are fundamental to sunspots, *plages*, prominences, chromospheric fine structure, bright coronal emissions, regions of strong radio emission and, perhaps, *M* regions. Several solar phenomena can be synthesized on the hypothesis that neutral streams of ions and electrons are being ejected more or less continually from all turbulent regions of the surface characterized by coherent magnetic fields of mean intensity 0·5 gauss or more. This corpuscular ejection is supposed to be associated with spicule activity, and to result in the acceleration of tenuous streams, individually intermittent, to velocities of some hundreds of kilometres a second in the upper chromosphere and the corona. Above the photosphere the ejected streams are guided by the magnetic lines of force over the bipolar, unipolar, or polar region, as the case may be. The streams above the spicules are composed largely of ionized hydrogen and hence are invisible except in so far as they excite the coronal radiations of the arches, rays and plumes outlining the lines of force. Corpuscular streams ascending both sides of the 'magnetic arches' above a bipolar magnetic region collide near the top, generating radio noise[6], and condense, forming visible prominences. With the emission of radio energy the material cools, the hydrogen becomes partly neutral, and the prominence begins a possibly lengthy but precarious existence under the combined influence of growth, gravity and magnetic forces. Finally, the material largely slides back down the magnetic lines of force or may be thrown outward by expansion of the arches. Above unipolar regions the streams move outward diffusely and more or less radially from the sun[7], without pronounced collisions, and hence are not generators of strong radio noise; if they interfere with the earth, they cause *M*-region phenomena. From the polar regions, where spicule activity is pronounced, corpuscular streams may recede to considerable distances. Much of the material may arrive in the vicinity of the equatorial plane, where the magnetic field is doubtless highly irregular. Through magnetic coupling, such material may carry away from high heliographic latitudes a share of angular momentum that is large in proportion to its mass.

A tentative model for corpuscular ejection involves local concentrations of the coherent magnetic field by random turbulent processes in the photosphere. Occasional attainment of equipartition of energy results in formation of concentric tubes of magnetic force of intensity ~ 500 gauss. Travelling hydromagnetic waves in the form of constrictions in the tubes of force are supposed to move upward with velocity $H/\sqrt{4\pi\rho}$. Owing to the decrease of density, ρ, by a factor 10^6 in less than 10,000 km., velocities of several hundred kilometres a second may be expected in the high chromosphere if H decreases moderately. Small tenuous clouds of ions and electrons are supposed to be squeezed up the magnetic tubes ahead of the constrictions at the wave velocity. H. Alfvén[8] has considered heating of the corona by hydromagnetic waves; we extend this idea with the concept of constrictive waves in magnetic tubes of force.

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