THE SYMMETRY OF THE CORONA OF 1954 JUNE 30

T. Gold

(Communicated by the Astronomer Royal)

(Received 1955 March 2)

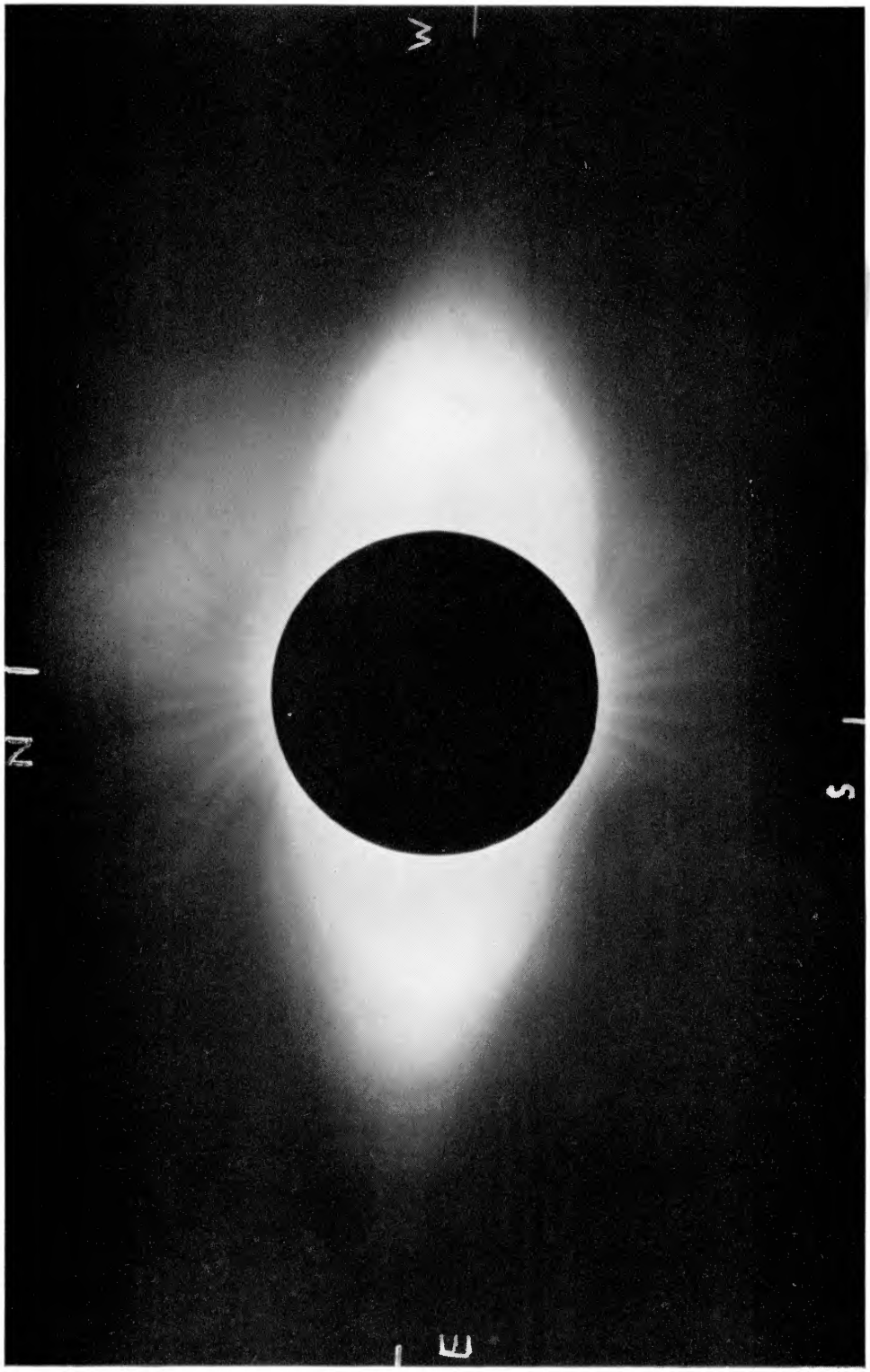
The corona seen during the total eclipse of 1954 June 30 was extraordinary for its regularity. The time of the eclipse was as nearly the sunspot minimum as can be determined, and no spot was seen at the Solar Observatory at Herstmonceux for 8 days preceding or 12 days following the eclipse. The corona did not possess any streamers extending out in odd directions as is normally the case, but was of a high degree of symmetry. In the equatorial direction there was the furthest extension, a little more to the east than to the west. In higher latitudes there were polar plumes fairly regularly spaced. There was a sharply defined position of changeover on the Sun's limb in each quadrant between the striated polar plume zone and the smooth zone associated with the equatorial extension.

The Royal Greenwich Observatory expedition to Syd Koster island, Sweden, (T. Gold, A. Hunter, E. W. Bastin, D. W. Sciama) had intended to photograph the eclipse star field with a telescope of 21 ft focal length, for the purpose of a measurement of the Einstein deflection of light. Thin cloud prevented this, but a good picture of the corona was obtained, marred by cloud only in the north-west quadrant. The negative contains a very large range of density and this renders it unsuitable for direct reproduction in print. The print shown was obtained from the negative by a process involving the subtraction of intensity by an amount which was a suitable function of radius only. The real isophotes are much more nearly circular than appears in the reproduction; but the reproduction serves to show some of the coronal pattern. On the negative the following measurements were carried out.

1. *The direction of the equatorial extension.*—A line was drawn through the equatorial extension splitting it as symmetrically as possible into the northern and southern parts. On the east side this required drawing it through the furthest extension that could be seen on the plate (about 4 solar radii from the limb) while on the west side the extension was clearly and quite symmetrically bifurcated, and the line had to be drawn through the middle of that. This line, defined solely by the outer corona, passed accurately through the centre of the Sun. Its direction seemed indeterminate by not more than $\pm\frac{1}{2}$ degree. The angle that this line made with the normal to the projection of the Sun's axis was 0·8 degrees.

2. *The changeover between the polar and the equatorial type of corona.*—The lines separating the striated polar regions from the smooth equatorial ones can be seen right in to the Sun's limb. The heliographic latitudes of these changeover points on the four quadrants of the limb are very similar and do not appear to be uncertain to more than about one degree. They are:

N.E. 60°
N.W. $59\frac{1}{2}$°
S.W. 60°
S.E. $63\frac{1}{2}$°



T. Gold, The symmetry of the corona of 1954 June 30

The symmetry of shape of the corona was considerably more marked between north and south than between east and west, both so far as the inner features are concerned, and also the furthest equatorial extensions. This symmetry is known to be absent at other phases of the sunspot cycle, when disturbances on the surface of the Sun appear to influence or even to determine the coronal appearance. The corona at sunspot minimum would therefore appear to have the special interest that it reveals the shape that the system settles down to when not subjected to the erratic disturbances marking periods that are richer in sunspots.

The implication of this high degree of symmetry would seem to be that the equatorial regions of the corona, even out to a distance of 4 radii, are very much under the control of the Sun. The relaxation time in which the corona settles down to this symmetrical condition is not likely to be more than a few months, judging from the evidence of previous near-minimum eclipses which still showed great disturbances. The mechanism which transfers this precise information about the rotation of the Sun out to that distance is not clear, but it seems likely that any explanation will require an outward flow of material in the equatorial region. Any suggested pattern of flow involving an inward flow in the equatorial zone would greatly augment the difficulties, for it would then be necessary to find a mechanism capable of pulling the incoming material into a shape determined by the Sun, while it is still at such a great distance.

The polar plumes, on the other hand, do not require an outward flow for their explanation. Most patchy distributions of material at some distance from the Sun would be drawn into such shapes by falling under the combined effect of gravitation and a magnetic field, whose lines of force would thereby be made visible. If, as seems very likely, the polar plumes are indicators of magnetic lines of force, then another consideration is of interest. The shapes of the plumes form an ordered sequence (as would be expected from lines of force resulting from electric currents in the Sun) and the boundary of the plume zone, namely an edge of the equatorial extension, is clearly an adjacent shape in that sequence. If the plumes are the lines of force, then the outlines of the equatorial extension, at any rate the parts within the range where the plumes can be seen, must also be lines of force. In searching for the physical difference that underlies the clear distinction in the appearance of the two zones we are again led to a hydrodynamical explanation, not only because of the difficulty of invoking another physical effect, but also because any streaming has to occur along lines of force in a system such as this, where ohmic dissipation plays no essential part, and a changeover in the direction of flow must therefore be on a surface defined by lines of force.

The greatest departure from the shape of a dipole field that can be seen in any of these outlines is in the edge of the equatorial extension and the nearby plumes. While there would be no need to suppose the currents in the Sun to be just those that make an external dipole-like field, the departure in shape is in the sense of making the loops of the lines of force stretch out very much further than a solar dipole field would. This is very unlikely to result from currents in the Sun (where sets of nearby opposing current rings would be required) but would result from the outward convection of the field due to an outward flow in the equatorial zone.

Estimates of the surface field of the Sun and of the conductivity of the corona at different ranges from the Sun will enable an estimate to be made of the strength

of the magnetic forces that the coronal material has to bear to uphold this deformation of the field; and with a knowledge of the densities this would specify the order of magnitude of the streaming velocities.

I should like to acknowledge the skilled work of Dr Hunter, and the valuable assistance of the volunteer members of the expedition, Dr E. W. Bastin and Dr D. W. Sciama.

Royal Greenwich Observatory,
Herstmonceux :
1955 *February.*