

this and shorter wave-lengths and, consequently, the effect is much greater. Since our discovery of the anomalously reflected iodine rays from potassium iodide, several cases of anomalous reflection have been reported and explanations suggested by McKeehan⁶ on several metals, Dickinson⁷ on potassium iodide and tin tetra-iodide, and Mie² on bismuth, etc. Apparently, the explanations are not adequate, however, for the particular cases discussed here.

The excitation of X-rays characteristic of constituent elements and their regular reflection by the same crystal seems to be reasonably well explained on the basis of the principle of the transfer of radiation momenta in quanta.⁸ This analysis alone accounts for the facts, including the peculiar relative intensities, the diffuse nature of the lines, etc. Mie² considers the phenomenon as true optical resonance. If this is true, it should be possible, by using a voltage between 28,250 and 31,800, to produce an α peak without a β or γ peak. There is every reason to believe from our previous researches that the α line cannot be produced without the β and γ , just as it cannot be produced alone by the target. Furthermore, if spherical characteristic wave-trains spreading out from atoms in the crystal and reflected from other atoms produced these effects, then they ought not to depend much upon the angle of incidence of the primary X-ray, which they do, according to our experiments.

¹ Clark and Duane, These PROCEEDINGS, 8, 90 (1922); 9, 117, 126, 131 (1923); *J. Optical Soc. Amer.*, 7, 455 (1923); *Science*, 58, 398 (Nov. 13, 1923).

² *Zeit. Physik*, 15, 56; 18, 105 (1923).

³ Duane and Stenström, these PROCEEDINGS, 6, 477 (1920).

⁴ Wyckoff, *Science*, July 20, 1923.

⁵ Clark and Duane, *Science*, Nov. 13, 1923.

⁶ McKeehan, *J. Optical Soc. Amer.*, 6, 989 (1922).

⁷ Dickinson, *Phys. Rev.*, Aug. 1923, p. 199.

⁸ Duane, these PROCEEDINGS, 9, 158 (1923).

THE LAW OF SUN-SPOT POLARITY

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In a paper on "The Direction of Rotation of Sun-spot Vortices," published in the *Proceedings of the National Academy of Sciences* in June, 1915, I described the general reversal of the magnetic polarity of sun-spots observed at the minimum of solar activity in 1912. After the usual interval of about eleven years another minimum has occurred, and the incoming

spots of the new cycle following it show another reversal of polarity. It therefore becomes possible to formulate a polarity law based on observations by Hale, Ellerman, Nicholson, Joy, Pettit and others of the Zeeman effect in 2136 sun-spot groups during the period 1908-1923.*

About 60 per cent of all sun-spots are bipolar, consisting of two spots or groups of spots of opposite magnetic polarity. In classifying the observations we give chief weight to these, and treat single spots followed by flocculi as the preceding members of incomplete bipolar groups, and single spots preceded by flocculi as the following members of such groups. Before the minimum of 1912 the polarity of preceding spots in the northern hemisphere was S (south seeking pole) or negative, and that of following spots N or positive. The spots of the southern hemisphere gave opposite polarities, i.e., N for the preceding and S for the following members.

As is well known, the last spots of a cycle occur in low latitudes, ranging from 0° to about 18° . The first spots of a new cycle appear in high lati-

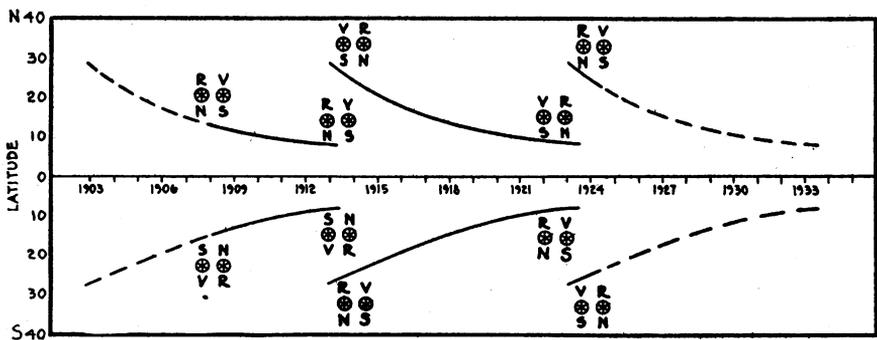


FIGURE 1

tudes, sometimes exceeding 40° . As the cycle progresses, the average latitude of all spots decreases steadily, as shown by the curves in Fig. 1.

To our surprise, the high latitude spots of the new cycle, which began in 1912 when spots were very few, were opposite in polarity to the low latitude spots of the previous cycle. As this cycle advanced and the spots became more and more numerous, the new polarities were found to characterize all spots observed, with only 4 per cent of exceptions. The average latitude of the spots gradually decreased, in the customary way, and the recent spots marking the end of the cycle have been near the equator, though several of them observed in 1923 reached latitudes as high as 15° .

The first spot of the next (third) cycle appeared on June 24, 1922, at latitude 31° N. After a long interval several other spots of this cycle have been observed, including a number of bipolar groups. They again show a reversal of polarity, back to the conditions existing in the first cycle before the minimum of 1913. The results are shown graphically in Figs. 1 and 2.

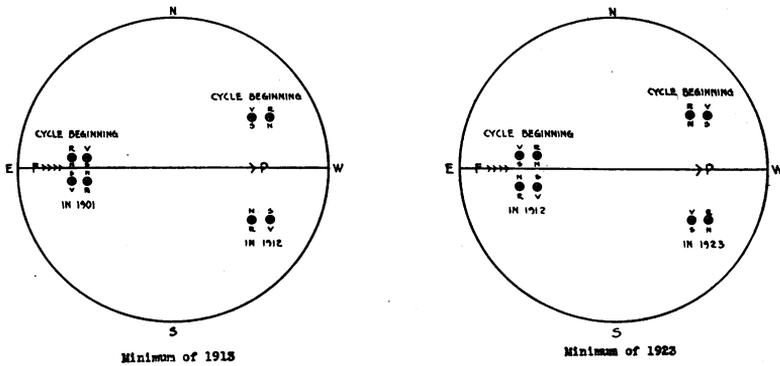


FIGURE 2

It thus appears that near the time of minimum solar activity four spot zones, characterized by distinct magnetic polarities, may co-exist on the sun. This condition lasts only two or three years, after which the last low-latitude spots of the old cycle disappear.

We cannot yet determine with certainty the sign of the dominant electric charge in the spot vortex. If it is always the same, the vortices of the preceding and following spots of bipolar groups must whirl in opposite directions. Moreover, the reversed polarities of corresponding spots (preceding or following) in the same hemisphere of successive cycles must also mean opposite directions of whirl. A series of observations of the Evershed effect at low levels in bipolar spots is needed to settle this question and thus to determine the sign of the dominant charge.

The sun-spot period, if defined in the usual way as representing the variation in the number or total area of all spots on the sun, is about 11.1 years. But if we regard the period as the interval between successive appearances of spots of the same magnetic polarity, the present results indicate that it is twice as long.

The details of this investigation will be published in the *Astrophysical Journal*.

* For the methods employed, see "The Magnetic Polarity of Sun-spots," Contributions from the Mount Wilson Observatory No. 165. *Astrophys. J., Chicago*, 49, 1919 (153-178).