that the paper is a valuable contribution to our knowledge of Eastern Neolithic implements, and that our present remarks are, like those of Mr. Theobald, "merely tentative, and designed to elicit additional information."

J. EVANS

M. FIZEAU'S EXPERIMENTS ON "NEWTON'S RINGS"

A COMPARISON of the values given by Professor Ångström (in his magnificent *Recherches sur le spectre solaire*) for the wave-lengths corresponding to the two principal components of Fraunhofer's line D, with some observations made eight or nine years ago by M. Fizeau, not only reveals a remarkable agreement between the results of these two distinguished investigators, but yields one of the most striking confirmations of the truth of the undulatory theory of light that recent optical research has afforded.

The experiments of M. Fizeau to which we refer were, essentially, the following. He produced the phenomenon of "Newton's rings," by laying a convex lens of very long focus upon a piece of glass with plane parallel surfaces, and illuminating the combination by the yellow flame of spirit of wine containing a little common salt. The lens was so arranged that it could either be made to touch the glass plate or be separated a short distance from it, its position being regulated by a micrometer screw. On gradually separating the lens from the glass plate, the rings were seen to contract and move in towards the centre of the lens, where they successively disappeared, while their place was supplied by fresh rings which made their appearance at the circumference of the lens. So far, all was in accordance with what was well-known before. But M. Fizeau found that when the phenomenon was observed with sufficient care, nearly 500 rings could be counted, flowing inwards one after another, but that after about this number the rings ceased to be visible, the surface of the glass showing a nearly uniform illumination all over instead of a sharply defined alternation of light and dark bands. When, however, the distance between the lens and the glass plate was further increased the rings re-appeared, getting gradually more and more distinct, until when nearly another 500 had passed they had become as sharp as at first; but a still further increase of distance caused them again to become confused, and they ceased a second time to be discernible at about the 1,500th. With a still greater separation of the glasses, however, they reappeared again, and became quite sharp at about the 2,000th, after which they for a third time got gradually confused and became indistinguishable at about the 2,500th.

So the phenomenon went on, the stream of rings inwards towards the centre of the lens, followed by fresh ones from the circumference, continuing as the lens was moved further and further away from the glass plate; but the succession of rings was not uniform, but broken up into batches of about 1,000 each, separated by short intervals of confusion in the way that has been described. The rings did not finally cease to be distinguishable until *fifty-two* such batches had been counted, and the two glasses were at a distance of about fifteen millimetres (more than half an inch) from each other.

This remarkable phenomenon of the alternate periods of distinctness and confusion of the rings is easily explained, as M. Fizeau points out, when we remember that the light employed was not strictly homogeneous, but consisted of two portions of nearly, but not quite, equal degrees of refrangibility. If either of these two constituent parts of the light had been used by itself, it would have produced a set of rings, but the rings of one set would have been a very little larger than the corresponding rings of the other. Hence if the two sets of rings are put together (as they were in Fizeau's experiment), they will nearly, but not quite, fit each other. If we examine a few rings at the centre, when the two glasses are in contact, they will appear to coincide precisely; but if they are traced to a sufficient distance from the centre, the coincidence is seen not to be exact. For although the *twentieth* ring (say) of one set is not perceptibly bigger than the twentieth ring of the other set, the *five-hundredth* of one set is perceptibly bigger than the five-hundredth of the other, and, when put upon it, falls almost exactly halfway between the five-hundredth and five-hundred-and-first of this set. Consequently, at about this part of the phenomenon, the bright spaces of one set of rings will occupy the same position as the dark spaces of the other set, and they will mutually obliterate each other. But since the *thousandth* ring of one set is nearly the same size as the thousand-and-first of the other, the two sets of rings will appear to fit each other again about this point; the *fifteen-hundredth* of the first set, however, is larger than the fifteen-hundred-and-first of the second set, but not so large as the fifteen-hundred-and-second; and hence, at about the position of this ring, the rings of the two sets will overlap each other, and mutually efface each other's outlines. And, carrying such considerations further, it is evident that the apparent coincidence and overlapping of the two systems of rings would recur alternately at regular intervals.

In order to simplify this explanation, we have tacitly assumed the lens to be so large that several thousand rings could be seen between its centre and its circumference. Practically, this would be impossible; but, by gradually separating the lens from the plane glass, we can, as it were, draw in towards the middle the rings which, with a larger lens, would be formed at a great distance from the centre.

Now, according to the explanation which the undulatory theory gives of the formation of "Newton's rings," the distance by which the interval between the glasses must be increased, in order that a given ring may come into the position previously occupied by the next smaller ring, must be equal to half the wave-length of the kind of light used for the experiment; and the distance of 0·28945 millimetres, through which, as M. Fizeau found by actual measurement, it was necessary to vary the space between the glasses, in order to make the rings go through one of the recurrent periods above described, that is to say, pass from sharpness to confusion and become sharp again, must contain just one more half wave-length of one portion of the light by which the rings were formed than it does of the other.

This brings us to the point of contact between M. Fizeau's observations and those of Prof. Ångström, to which we referred at the beginning. According to the latter, the wave-lengths of the two principal constituents of the light emitted by a flame containing the vapour of sodium (such as the flame employed by M. Fizeau) are respectively—

Millimetres
0·000589513
and 0·000588912.

Now, if we divide 0·28945 by half the former of these numbers, we get as the quotient 982; and if we divide it by half the second, we get as the quotient 983. That is to say, we find, precisely as the undulatory theory requires, that the distance measured by M. Fizeau contains exactly one more half wave-length of the more refrangible constituent of the light of a sodium-flame than it does of the less refrangible part. And, moreover, if we calculate, from Ångström's determination of the wave-lengths, the number of rings which must intervene between the positions of greatest confusion and greatest distinctness, we find 491 of the one set and 491½ of the other, which agrees entirely with M. Fizeau's estimated round number 500.

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