If the rise-time in the subsequent cycle is 3·8 years, the maximum $R_m$ in 1978 should be about 110.

The predictions may therefore be summarized as follows:

| | Cycle 20 | Cycle 21 |
|---|---|---|
| Date of maximum sunspot number | 1968·1 | 1978·5 |
| Intensity of maximum, $R_m$ | 140 | 110 |
| Date of subsequent minimum | 1974·7 | 1985·3 |

The validity of the prediction methods used here is of course disputable, and there can be no certainty that the predictions are even approximately correct. However, it is certain that the problem of predicting future sunspot numbers cannot be shirked, because the lifetimes of near-Earth satellites[9] are controlled by upper-atmosphere density, which is strongly affected by solar activity. The theory of satellite lifetime estimation cannot be placed on a sound basis until better predictions of solar activity are available, and the prediction of the date and intensity of the next sunspot maximum is also a matter of practical importance. For example, the U.K.3 satellite is intended to fly in a circular orbit at a height of 500 km, and its lifetime in orbit would be reduced by a factor of up to 10 if, at the time of launching (probably 1967), sunspot numbers were very high rather than slowly climbing towards a low maximum. As a second example, the *Echo* 1 satellite would probably not survive a vigorous sunspot maximum, but could last for 10 years longer if the next maximum is very weak. Plans are being made for geodetic triangulation programmes utilizing *Echo* 1, and the date of its decay affects the planning. For these and various other practical reasons (see, for example, refs. 5 and 10), the prediction of sunspot numbers must be attempted, and out of the chaos of discredited methods a correct one may well emerge.

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## ASTROPHYSICS

### Lightning, Solar Flares and Radio Galaxies

IN 1925, when it was still believed that a potential of $n \times 10^9$ V was necessary to cause a lightning flash[1a], C. T. R. Wilson put forward the suggestion that the soft cosmic rays up to about $10^9$ eV might be accounted for by runaway electrons in thundercloud fields[1b]. When it was pointed out that a lightning flash can occur with a total thundercloud potential of $n \times 10^7$ V (refs. 2[a,b]), the suggestion ceased to have much significance as applied to thunderclouds. However, in presenting a paper on these long leader strokes at the Belfast meeting of the British Association in 1952, I pointed out[2c] that the Wilson mechanism might apply in the much longer cosmic electrical discharges, in which relatively large electric fields must be built up by the short-circuiting of these much more extensive electric fields by the leader stroke of such discharges as solar flares.

In an earlier communication[2d], it was emphasized that temperatures of the order of $10^8$ °K must be reached in these last electrical discharges, and in a later communication[2e] it was pointed out that observational evidence had actually been obtained for the association of such temperatures with outbursts of solar flares.

The velocity of the jets of gas generated by these discharges is of the same order as that of the thermal velocities of the ions, namely, about $10^8$ cm/sec, and thus accounted for the delay of about 1 day between the solar outburst and the main magnetic storm at the Earth. The associated electron velocities will be about 40 times this value or about $4 \times 10^9$ cm/sec, and it is now suggested that some of these electrons become the runaway electrons which account for the arrival at the Earth of a soft cosmic ray component about half an hour after the observed solar outburst. Their average speed is thus about $10^{10}$ cm/sec, so they would only require to be accelerated by a factor of about 2 in the solar electric field.

This consideration would confirm the view arrived at from an investigation of cometary phenomena[2f] that the polarity of the solar field is the same as that of the thunderstorm field; that is, the regions farthest out in the gravitational field become positive.

This view of the existence of two major velocities of propagation of two different types of activity, a high-speed electron component and a plasma jet, has interesting possible applications in the investigation of radio galaxies, in which the same two components may be expected to occur. Observations on the gas velocities made by Seyfert[3] of about $4 \times 10^8$ cm/sec suggest the existence of plasma jets at temperatures of about $4 \times 10^8$ °K (ref. 2[g]). Associated with these we should expect to find active haloes due to the runaway electrons from the main discharges and reaching dimensions of the order of ten times the latter. This is just what is observed, and in the case of Virgo *A* (*NGC* 4486) "the general direction of the extension is the same as that of the 'jet' which optical observations have shown issuing from the nucleus of *NGC* 4486" (ref. 4*a*). Shain writes in the same contribution that "when angular sizes of a number of radio galaxies are determined, any optical search for associated galaxies must extend to galaxies having one-tenth or less of the radio diameters"[4b].

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## PHYSICS

### Formation of Straight Whiskers on Sublimating Single Potassium Chloride Crystal

NANNICHI has reported on the formation of silicon whiskers on a sublimating surface[1]. The specimen had in this case been kept at least 200 h at 1,000°–1,250° C in an initial vacuum of less than $10^{-8}$ torr. The whiskers were bent and whirled but their tips were at the height of the original surface. Matter is transported away from the neighbourhood of certain places by thermal erosion so that what is left is thin enough to be called a 'whisker'.

In an investigation of the effect of annealing on the cleavage surface, straight whiskers were found on single potassium chloride crystals annealed at 600° C for 5–23 h in a vacuum of about 0·1–1 torr. They were first found lying on the crystal surface (Fig. 1). A closer investigation revealed that there were also whiskers at right angles to the (100) surfaces (Fig. 2). The white dots marked with arrows in Fig. 1 are due to upright whiskers.

Different surface features are formed during the heat treatment[2,3]. Abnormal features, for example plateaux,