## Low Latitude Aurorae and *M*-arcs

It has been known for a long time that the main emission of low latitude aurorae is that of atomic oxygen at 6300 Å, so that low latitude aurorae are always red[1]. Some years ago Barbier[2] and Roach and Roach[3] reported low latitude arcs in emission at 6300 Å during intense geomagnetic storms, and called them *M*-arcs. This paper demonstrates that the *M*-arc is simply an extreme manifestation of the low latitude aurora during the more intense magnetic storms, because the red oxygen emission (6300 Å) develops a more pronounced peak in latitude with increasing magnetic disturbance ($D_{st}$).

While analysing zenith intensities of emission at 6300 Å obtained during the IGY and the IQSY I have shown[4] that the decimal logarithm of the average value of the intensity of this emission at zenith, log *I*, for cases when $I \geq 1$ kRayleigh may be represented by the following expression

$$\log I = \beta D_{st} + 0{\cdot}02 F_{10{\cdot}7} - 3{\cdot}17 \qquad (1)$$

where $D_{st}$ is an index characterizing the magnitude of geomagnetic disturbance[5], $F_{10{\cdot}7}$ is the magnitude of the solar radio flux at 10·7 cm in units $10^{-22}$ W m$^{-2}$ Hz$^{-1}$ and $\beta$ is a coefficient depending on the geomagnetic latitude, $\Phi$, of the observation point and determined for geomagnetic latitudes from 35 to 55 degrees by the expression

$$\beta = 6{\cdot}85 \times 10^{-4}(35° - \Phi) - 5 \times 10^{-4} \qquad (2)$$

Equation (1) is valid up to 55 to 60 degrees of geomagnetic latitude. Reliable data on this emission at higher latitudes are so far absent, although, as has been reported earlier[4], the intensity of this emission at high latitudes does not reach such large magnitudes as at medium latitudes. A ratio *K* between intensities at two adjacent latitudes $\Phi_1$ and $\Phi_2$, according to equation (1), may be represented by the expression

$$\log I_1/I_2 = \log K = D_{st}(\beta_1 - \beta_2) = \text{const} \qquad (3)$$

where $\beta_1$ and $\beta_2$ are coefficients for latitudes $\Phi_1$ and $\Phi_2$, respectively. A given intensity ratio *K* will therefore be obtained over a decreasing interval of latitude with increasing $D_{st}$ and, if we assume a well defined high latitude boundary, the most intense emission will become concentrated along a parallel of geomagnetic latitude.

In order to assess the extent to which emission becomes concentrated in latitude with increasing $D_{st}$ I shall define a latitude interval, 1/2 $\Delta\Phi$, such that (1) the maximum intensity of an aurora falls by a factor *e* at the lower latitude, or (2) the auroral intensity falls to the level of 1 kRayleigh. In the first case, from equations (2) and (3) the latitude interval, $\Delta\Phi$, will be determined by the expression

$$\Delta\Phi = 2{\cdot}9 \times 10^3 \frac{\log K}{-D_{st}} \qquad (4)$$

and in the second case by the expression

$$\Delta\Phi = 2(\Phi_m - \Phi^*) \qquad (5)$$

where $\Phi_m$ is the geomagnetic latitude of the maximum intensity of emission at 6300 Å and $\Phi^*$ is the latitude at which the zenith intensity of emission decreases to the magnitude of 1 kRayleigh. Comparing equations (4) and (5), the second method is less exact as equation (5) includes the value $\Phi_m$ for which, as mentioned earlier, reliable data have not yet been obtained. Fig. 1 (curves 1 and 2) presents $\Delta\Phi$, for the two cases defined earlier, as a function of $D_{st}$. $\Delta\Phi$ was determined by the second method on the assumption that $\Phi_m = 55$ degrees.

The points plotted in Fig. 1, which are from the available data on *M*-arcs[1,6], show clearly that the width of arcs the maximum intensity of which exceeds 1 kRayleigh varies with the $D_{st}$ index in good agreement with the relationship defined by curve 1. Thus there is every reason to believe that the red emission of low latitude

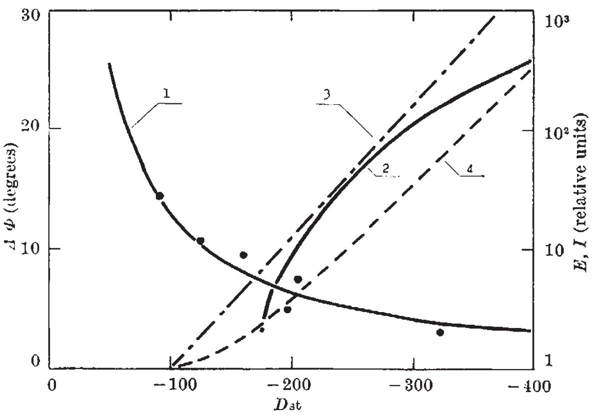


Fig. 1. Extent of auroral latitude versus $D_{st}$ indices. Curve 1 is determined by the first method and curve 2 by the second. The points are the extent of auroral latitude obtained from published data[1,6]. Also shown are the global energy release *E* (curve 3) and the local zenith intensity *I* at 6300 Å (curve 4) versus $D_{st}$ (right-hand scale).

aurorae, which has been known for a long time, and *M*-arcs, are the same phenomenon. *M*-arcs have their origin in the increase of latitude contrast during strong $D_{st}$.

The concentration of red emission in a narrow latitude interval during strong $D_{st}$ is probably an argument in favour of its excitation by hydromagnetic oscillations of magnetospheric plasma along geomagnetic lines of force of the same length. Such a concentration of emission during large $D_{st}$ leads to the fact that the increase of global energy release in red emission with the increase in $D_{st}$ takes place slower than the increase of local zenith intensities of emission. Fig. 1 (curve 3) shows global energy release versus $D_{st}$ on the basis of equation (1). Energy release during $D_{st} = -100$ gammas was assumed as the unit of the energy release scale. For comparison the relationship between the local zenith intensity of emission and $D_{st}$ is given (curve 4). The intensity during $D_{st} = -100$ gammas has been assumed as the unit of the intensity scale.

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[1] Chapman, S., in *Aurora and Airglow* (edit. by McCormac, B. M.), 23 (Reinhold Pub. Co., New York, 1967).
[2] Barbier, D., *Ann. Geophys.*, **16**, 544 (1960).
[3] Roach, F. E., and Roach, J. R., *Planet. Space Sci.*, **11**, 523 (1963).
[4] Truttse, Y. L., *Planet. Space Sci.*, **16**, 981 (1968).
[5] Sugiura, M., *Ann. IGY*, **35** (1964).
[6] Manring, E. R., and Pettit, H. B., *J. Geophys. Res.*, **64**, 149 (1959).

## Mechanism for the Auroral Emission of OI (6300 Å)

Various mechanisms have been proposed to explain the selectively enhanced emission of OI (6300 Å) from the auroral latitudes of the *F* region of the ionosphere. We discuss the enhanced OI emission in terms of a reaction between the major ion $O^+$ and the most abundant neutral constituent (O atoms) of the ionosphere at an altitude of about 400 km.

Among the mechanisms suggested for such optical emissions are (1) excitation of O atoms by thermal electrons[1], (2) conjugate photoelectron impact[2] and (3) dissociative recombination (DR) of $NO^+$ with electrons[3].