NOTES

PHOTOMETRIC OBSERVATIONS OF RAYED AND PULSATING AURORAE*

During those stages of an auroral display when rays and pulsating aurorae occur, there seems frequently to be a certain background of auroral light showing little or no structure. Therefore, when conventional spectrographs or scanning spectrophotometers are applied to rayed and pulsating auroral forms, it is not evident how large a fraction of the light originates in these forms, so that the results are somewhat ambiguous. In fact, the measurements reported in this note show that more than half the light recorded by a spectrograph may come from the smooth background. These new measurements were made with a two-color photoelectric photometer, using interference filters. The photometer is similar to the "split-beam" type described by Omholt and Harang (1955), but the aurora is focused on two diaphragms. Each of these is fitted with a field lens, which in turn focuses the objective on the photocathode. This insures that the photocathode is identically illuminated by every point in the aurora within the area selected by the diaphragms. A two-pen Brush recorder with amplifier was adapted to the photometer. The main feature of this photometer is that it records the aurora simultaneously on two wave lengths. These are selected by interference filters, and only the light appearing within a circular area of about 0.5 square degree of the sky is recorded. This area is identical for the two wave lengths. When pulsating aurorae appear or moving rays pass the sight-line of the fixed photometer, it records light-pulses which are certainly due to the pulsating or moving form.

Measurements have been made of Hβ simultaneously with the negative N_2^+ band λ 4709 and also of the [O I] line λ 5577 simultaneously with the negative N_2^+ band λ 3914. For Hβ/4709 the results given here are mainly from the aurora on March 27 but are in agreement with previous results obtained with filters of lower quality and with results obtained on April 9, when moonlight precluded the achievement of high accuracy. The results can be summarized as follows: Just after the first arc broke up and showed ray structure, the intensity ratio $R(\text{H}\beta) = I(\text{H}\beta)/I(\lambda\, 4709)$, I being the absolute intensity, was about 0.25 for the more homogeneous auroral "background." This intensity ratio decreased slowly (in about $\frac{1}{2}$ hour) to a value around 0.15–0.10. The ray structure itself and also the flaming and pulsating aurorae which appeared in the later stages of the display showed a very low intensity of Hβ, with $R(\text{H}\beta) \leq 0.05$. Some light definitely passed through the Hβ filter in these cases, but this might have been other radiations, so that $R(\text{H}\beta)$ could actually have been zero. The transmission of the Hβ filter at 4709 A is about 2 per cent of the maximum transmission, and there are also other, although very weak, auroral radiations in the wave-length range passed by the filter (the pass band is about 40 A). Also, the intensity of the light-pulses through the Hβ filter was often so low that they were barely detectable. The Hβ line was undoubtedly present in the smooth "background" of auroral light throughout the display, although weak ($R \approx 0.15$),[1] but was always absent or extremely weak ($R < 0.05$)

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[1] This is also in agreement with heavily exposed spectrograms obtained at Yerkes Observatory with the I.G.Y. patrol spectrograph during periods of auroral displays when rays and pulsating forms were dominant.

in the rays and in pulsating forms. The initial arc was not measured, but measurements on other arcs have given values of $R(H\beta)$ varying from 0.2 to 0.7. From spectrographic work (cf. collected data by Omholt 1956*a*) it seems that $R(H\beta)$ may occasionally be about 1 in arcs at low latitudes.

The results reported here appear to support the theory that rays and flaming aurorae are discharge phenomena. Protons may come in over a wide area and the accumulated charge be discharged through rays and flaming aurorae (cf. Chamberlain 1956). However, observations of the intensity ratio $I(\lambda\, 5577)/I(\lambda\, 3914)$, obtained with the same photometer, are more difficult to reconcile with this theory. This ratio seems to be almost constant (within ± 20 per cent) in all types of aurora. In rays and flaming aurorae the time delay between λ 3914 and λ 5577 is consistent with the assumption of simultaneous and proportional excitation of both radiations and with a lifetime for the O I atoms in the ^1S term of about 0.6–0.7 sec, in agreement with earlier results (Omholt 1956*b*). Since λ 5577 and λ 3914 have very different excitation potentials (4 and 19 ev, respectively) their relative intensity is very sensitive to the excitation conditions. As shown by Chamberlain (1956), the excitation ratio of the two emissions is expected to vary strongly along rays if these are discharge phenomena. As Chamberlain pointed out, his quantitative computations are not very accurate, since only some of the most important of the various inelastic collisions were considered in computing the energy distribution-curves for the electrons.[2] The general behavior of the excitation ratio along a ray is probably correctly described, however, as seems reasonable from qualitative arguments. The observational evidence is thus not favorable to the discharge theory in its present form. It should be emphasized, however, that measurements of red rays have not yet been obtained.

The intensity and behavior of the hydrogen lines seem to vary with latitude and from time to time, and results obtained by different observers are apparently somewhat contradictory (cf. Fan and Schulte 1954; Vegard and Kvifte 1954; Hunten 1955; Vegard 1955). If both the ionization cross-section for N_2^+ given by Tate and Smith (1932) and the excitation cross-section for the first negative bands given by Stewart (1956) are correct (the former being about thirty times larger than the latter), it seems doubtful whether protons can be the sole source of ionization in any aurora, even when the hydrogen lines are at their strongest. The total rate of ionization would then be about 1×10^3 times the emission rate of λ 4709, whereas, for an auroral arc with its lower limit at 105 km, the best data available yield a rate of ionization by protons which is about 4×10^2 times the emission rate of $H\beta$ (cf. Omholt 1956*a*). From our present knowledge of the auroral spectrum and its variation, it seems more satisfactory to assume that aurorae are caused primarily by other types of fast incident particles, which may be electrons. Protons do contribute but more regularly and to a greater extent at lower latitudes than in the auroral zone. The old idea of incident electrons involves, of course, more difficulties regarding the acceleration mechanism, since the electrons would have to enter the earth's atmosphere together with the protons. However, evidence of X-rays in the auroral zone, interpreted as bremsstrahlung from electrons, may favor this assumption (Van Allen 1957). This does not mean that the general idea of discharge processes has to be abandoned, but an acceptable process would have to yield a spectrum which does not vary very much with altitude and which is very similar to that emitted during proton impact.

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[2] In this connection it should be pointed out that electronic excitation of N_2 and N may be very important and that, at low energies, rotational excitation of N_2 is much more important than elastic collisions (cf. Anderson and Goldstein 1956).