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HEIGHT DISTRIBUTION OF THE RED AURORAL LINE IN POLAR AURORAE

BY LEIV HARANG

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Summary. Luminosity curves along vertical cross sections of auroral forms have been recorded by means of a photoelectric photometer of the lines 6300, 5577 and the band 4278. The intensity of 6300 shows a considerably slower decrease with height than the green line and the violet band. The character of the luminosity curves are demonstrated for various auroral forms. The effect is explained as due to a decrease in deactivation with height of the long-lived *D*-state of the O-atom.

1. Introduction. The height distributions of different emissions in auroral forms have been studied by various methods. For qualitative measurements, small spectrographs of high light power have been directed towards different angular heights of auroral forms in succession, and intensity effects have been recorded [1]. Filter photography in various colours has also been tried [2]. Of special interest is the height distribution of various spectral lines and within one single auroral form. Meinel [3] has published a photometric study of the height distribution of a number of bands and lines within an auroral arc. Here the image of the arc was projected into the vertical slit of a spectrograph, and photometer tracings were made along the lenght of each spectral line. The photometry showed a differing height distribution for the 5577 and 6300 *OI* lines. The red doublet exhibited a considerably slower decrease with height than the green line, and the intensity curves for the two lines were different.

2. Experimental Arrangement. In a previous paper [4], a chopping photometer and a splitbeam photometer were described which have been used for recording simultaneous intensity fluctuations of the 5577 line and the 4278 band, for determining the life-time of the *S*-state of the oxygen atom. The same shopping photometer can be used in the following ways during investigations:

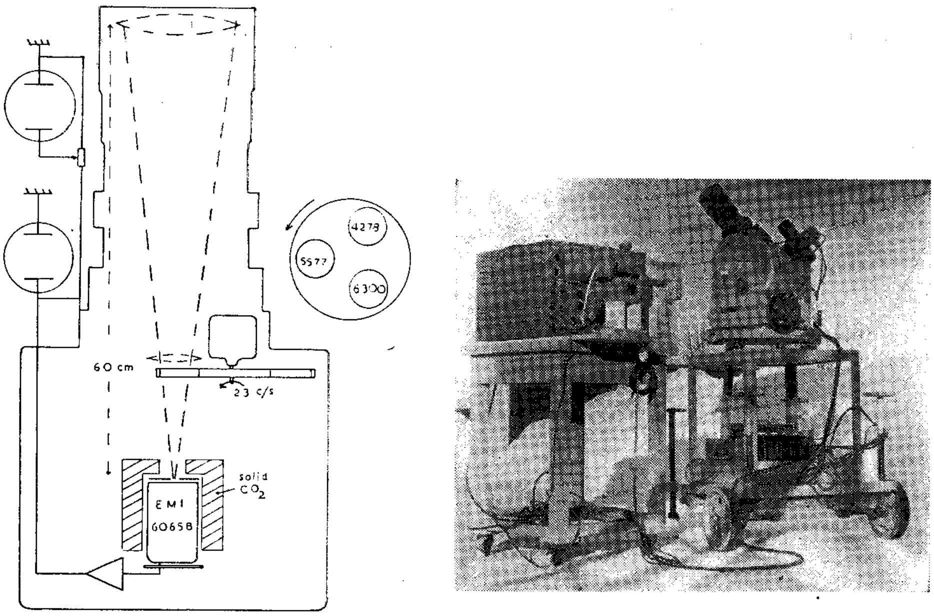

Fig. 1. The chopping photometer, left: principle of the photometer, right: photometer with oscillograph and camera.

a) the photometer is pointed at a *fixed* position in the sky, and auroral intensity fluctuations within a fixed angular column (usually of 1° × 1° width) are recorded. In this way it is possible to record the «life-history» of different spectral line intensities, and from such records the life-time of an auroral emission can be studied.
b) the photometer is swept vertically across a *quiet* auroral form (usually with an angular speed of 1° — 3°/sec) in order to record changes with increasing height of line and band intensities. Such measurements presuppose only minimum changes or movements in auroral form during the sweep time, and for many recordings this has been the case. Only the two oxygen lines 5577 and 6300 (and 6363) and the nitrogen band 4278 have been investigated.

The principle of the chopping photometer is shown in Fig. 1. The filter plate is rotated at 23 c/s, with suitable time-constant of 10^{-3} sec in the amplification and display of the light-pips.

Interference type filters, with a half-width of 80—100 Å centred on the appropriate line or band have been used. For the purposes of this investigation it was desirable that the photomultiplier should have the greatest possible sensitivity in the red at about 6300, and the E.M.I. 6095B was found to be the most convenient type. As this cell is red sensitive the dark-current is considerable and has to be reduced by cooling with solid CO_2. The cell and filter arrangement has been mounted in an Askania phototheodolite, which can easily be adjusted for height and azimuth. The focal length

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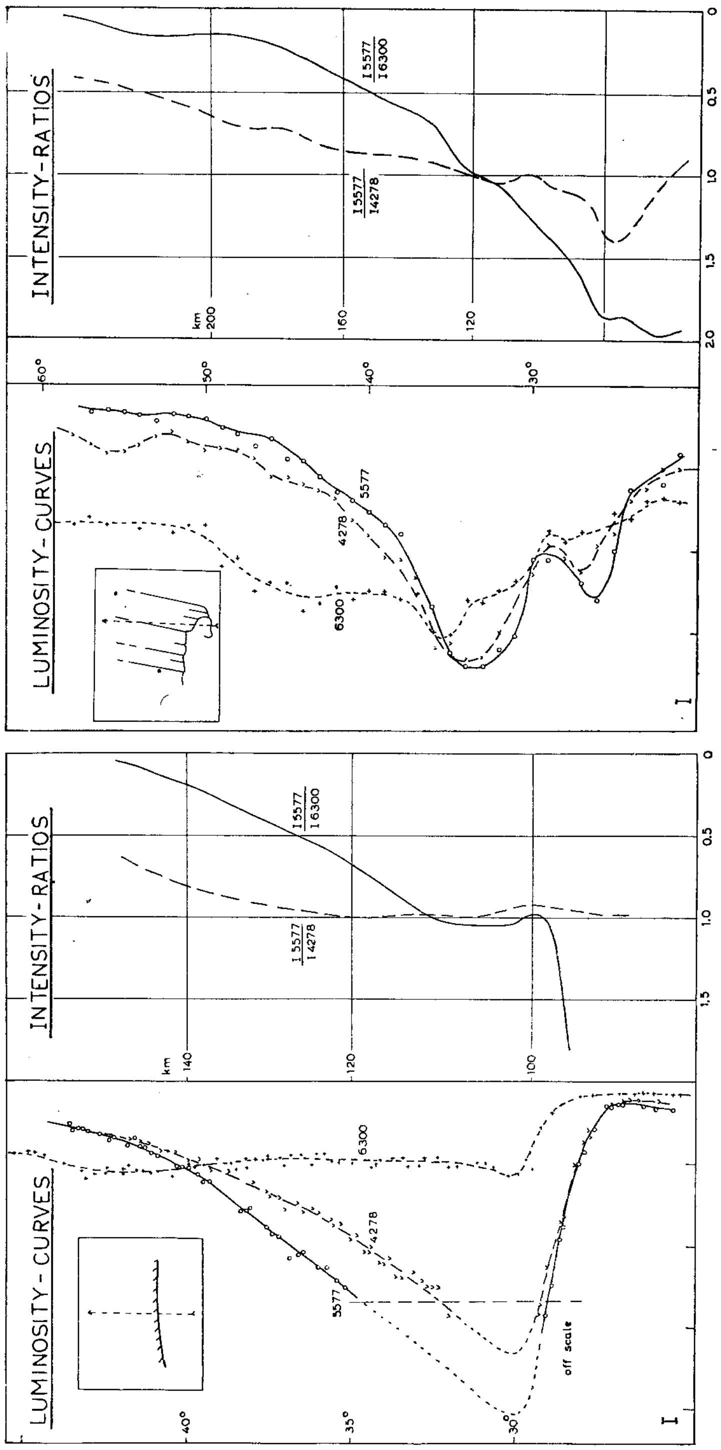


Fig. 2. Luminosity curves across a very strong arc (left) and a drapery (right).

of the objective is 60 cm (alternatively 30 cm) with a light power of 1 : 4,5 Dumont double-beam oscillcgraph has been used for recording the light-pips. It is usually difficult to estimate the intensity of an auroral display and during the display there is little time for adjusting amplification of the light-pips. Consequently the two beams of the oscillograph have been used simultaneously with an amplification ratio of 1 : 5, in order to cover a wide intensity range. An ordinary polar aurora of medium intensity will produce light-pips for the 5577 and 4278 lines with amplitudes completely off-scale, whereas light-pips from the 6300 line have been of about noise amplitude. The transmissions of the green and violet filters have therefore been considerably reduced, and in order to increase the red sensitivity the dark-current has been reduced by cooling with solid CO_2. In this way consecutive light-pips in the three spectral regions could be measured simultaneously.

3. Observations. All observations have been made at Tromsø ($\varphi = 70°$N) of *polar* aurorae. The forms investigated appeared in the Northern horizon, and extended in some cases up to zenith. Preliminary tests showed that the intensity of the red line relative to the green line showed considerable variation from one auroral form to another, and also from one evening to another, depending on the main character of the auroral display. The relative red/green sensitivity of the photometer was changed from one evening to the next, and no attempt was made to establish an absolute value of the red/green sensitivity.

Observations have been made in the following way. After development of an auroral display, the photometer is directed at a point well below the lower edge of the aurora, and is then turned at a constant speed upwards. The light-pips for the three spectral regions 6300, 5577 and 4278 are recorded on a fast-moving film. The elevation of the photometer at the lower and upper points is noted, and at the same time photos, in some cases parallactic photos, are taken of the auroral form. From this material the luminosity curves in three spectral ranges can be constructed. Fig. 2 shows results obtained in this manner.

The 5577/4278 intensity ratio shows the well known decrease with height, but the 5577/6300 intensity ratio shows far greater decrease with height. In the auroral forms the red 6300 line shows only a slight absolute decrease with height. We further notice that at the lower auroral edge the red line shows a more rapid decrease than the green line.

In this discussion of luminosity curves no correction has been made for the effect of atmospheric extinction. A control calculation shows that in the height range involved (30°—55°), selective red and green extinction will not alter the character of the luminosity curves or change the effects already noted. Several examples of luminosity curves will now be presented.

In Fig. 3 are shown the luminosity curves of an arc and a drapery appearing at about the same elevation on the Northern sky. The are has a low *I 6300* which is con-

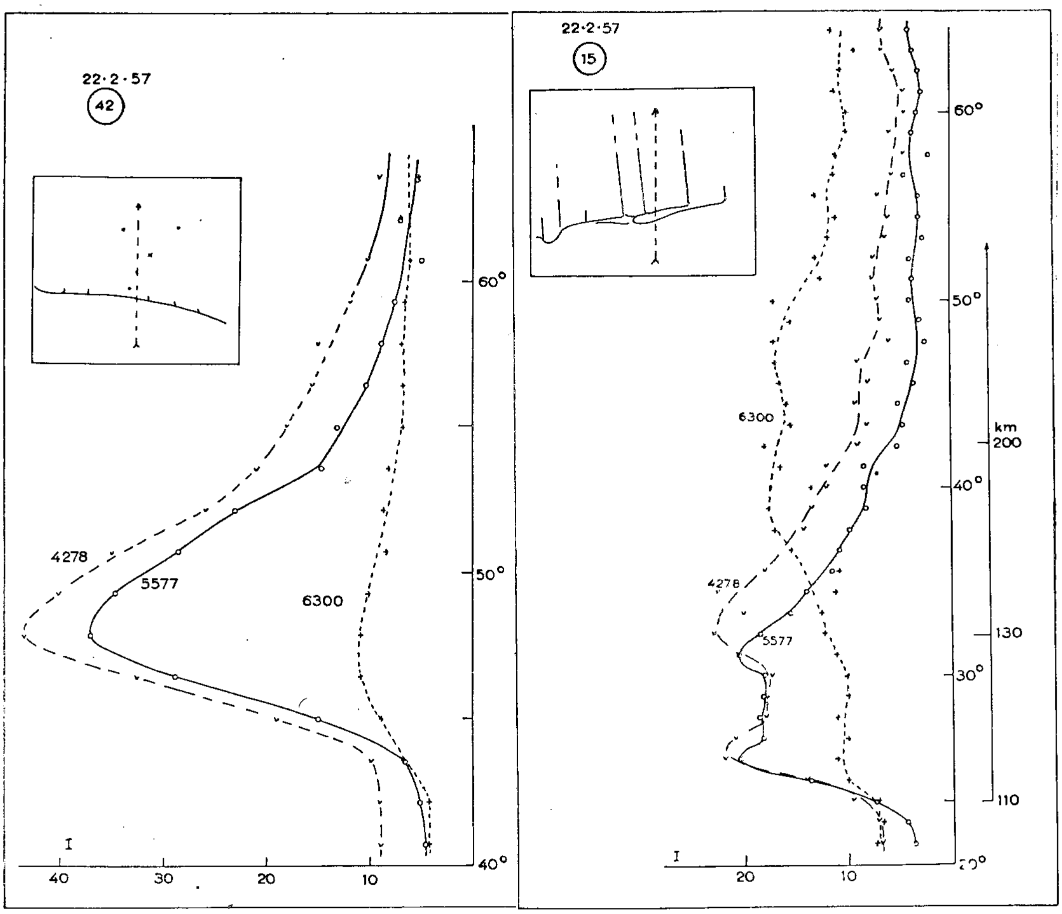


Fig. 3. Luminosity curves of an arc and a drapery.

fined to the main bulk of luminosity. The drapery with rays attaining great heights has a high *I 6300* even at the greatest heights.

Fig. 4 shows luminosity curves for two arcs, (2) (3), lying at great elevation (70°—85°), and for a long ray (21) appearing in the west. In this case a fourth filter isolating the region around H α (6574) has also been used. The arcs have a low *I 6300* value, the long ray a very high value which has a much slower decrease with height than *I 5577*. Although the mean value of *I 6300* across the arcs is low, the intensity in the upper part has a higher value. This effect appears systematically in recording made across arcs showing low *I 6300* values.

The intensity recording through the Hα-filter is very low, but there is no apparent general increase of intensity with height, as shown by *I 6300*.

Fig. 5 shows two Northern arcs, (7) (8), of low elevation. The low *I 6300* intensity

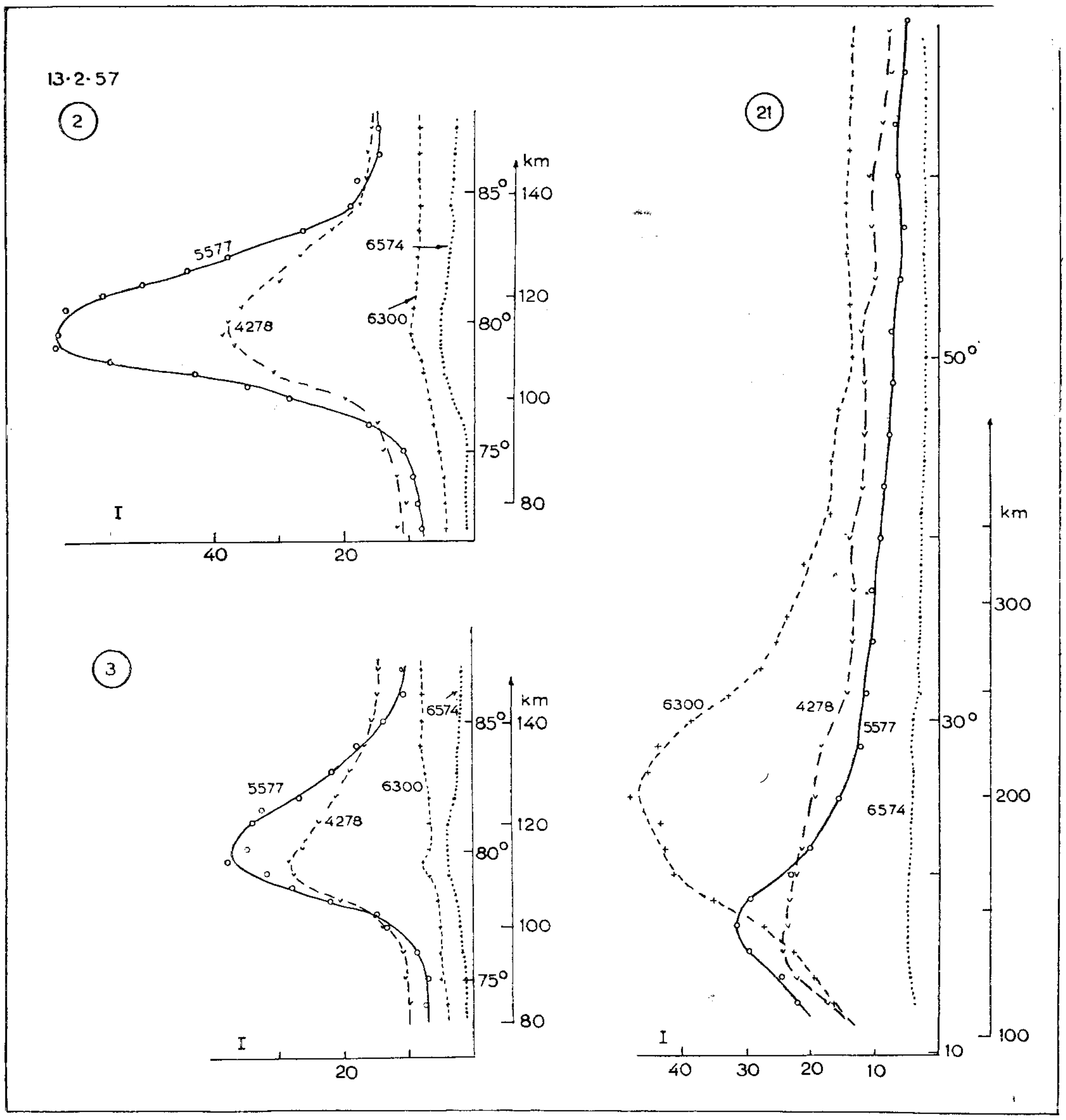


Fig. 4. Luminosity curves of two arcs and a long ray.

is apparent, although a slight increase may be seen in the upper part of the recordings. The two draperies (2), (48) and the long rays (39), (40) show the strong increase with height of *I 6300*.

The examples already shown have all been selected from examples of *normal* green-yellow polar aurorae. Luminosity curves for a group of *faint, greyish rays* appearing as long streamers in West are shown in Fig. 6.

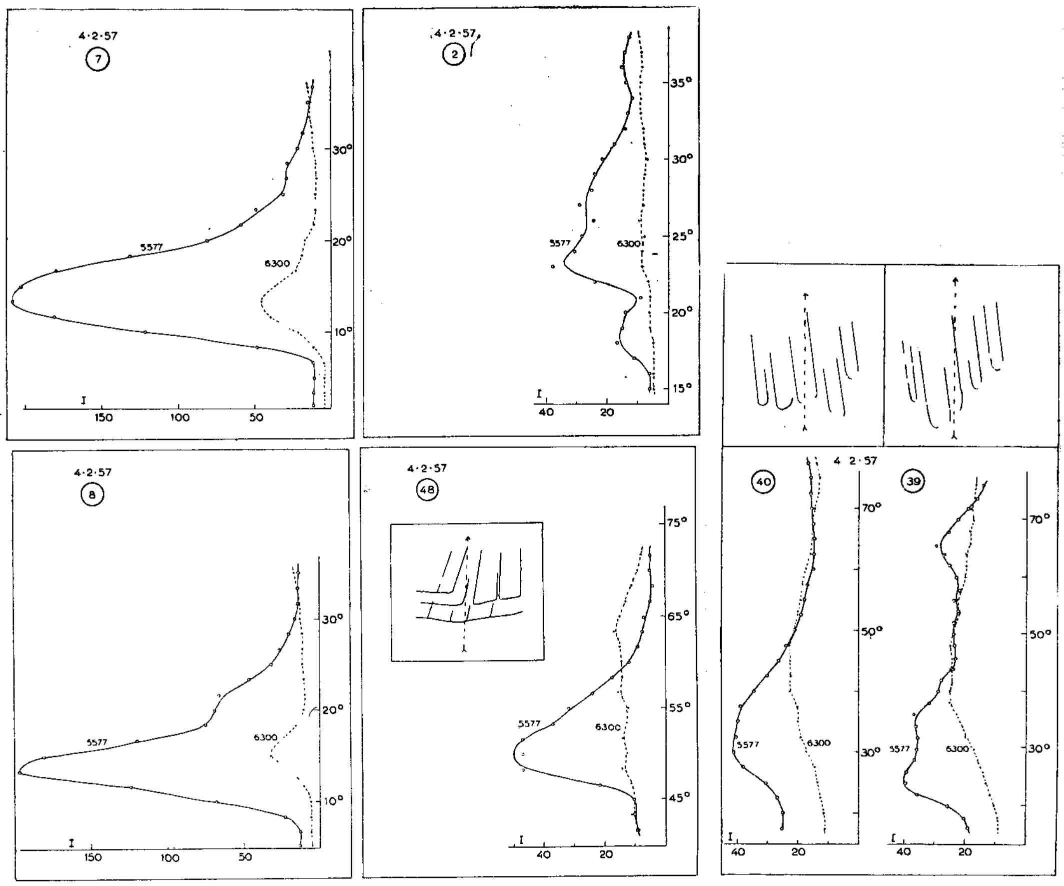


Fig. 5. Luminosity curves of arcs, draperies and rays.

The streamers rested quietly as long, faint curtains on the Western sky, appearing after a series of strong auroral displays. Parrallactic photos were not taken, but as the streamers appeared in the West and extended uniformly upwards along the geomagnetic lines of force, it is easy to calculate the total length of the rays, from single photos, by assuming a lower boundary at 120 km. Compared with the usual arcs and bands the *I 6300* value for these rays has increased enormously. The *I 5577* and *I 4278* luminosity curves show similar trends, but the *I 6300* curve is displaced towards greater heights and shows a different character. The three recordings were taken at 3—5 minute intervals and the streamers changed slowly.

4. Discussion. In a previous paper [4] a value for the lifetime of the *S* level of 0.7 sec has been determined from the 5577 intensity fluctuations in relative to the 4278 nitrogen band. The recordings also indicate that a probability of collisional deacti-

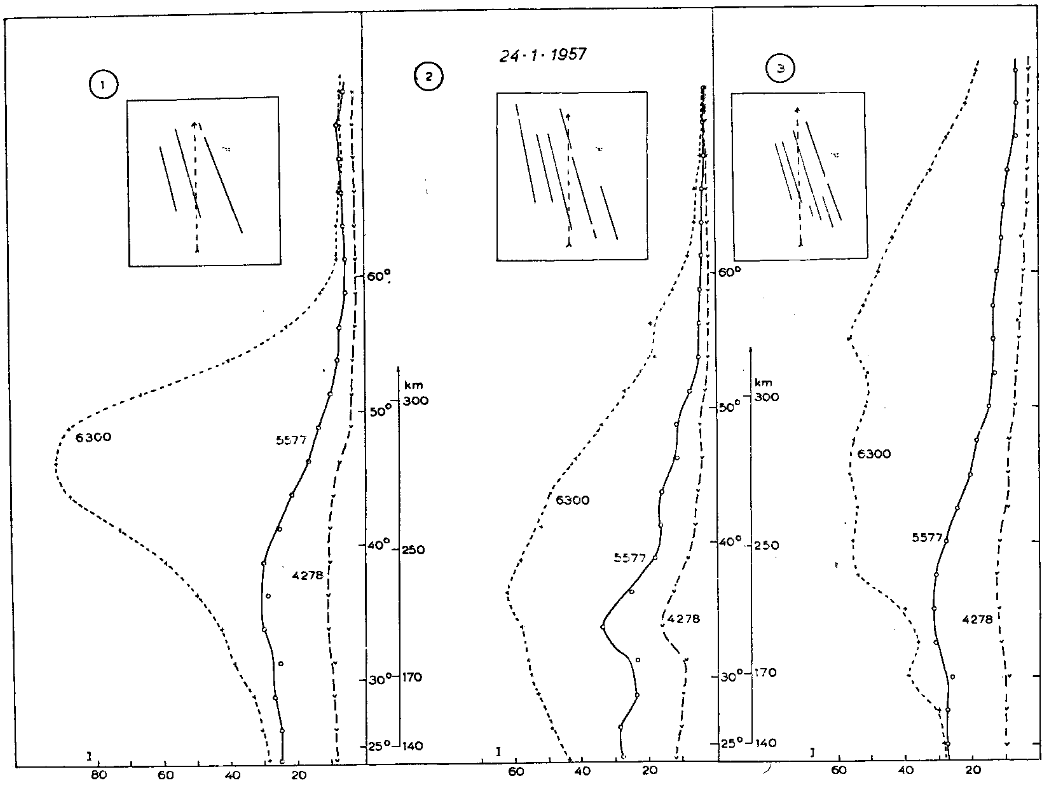


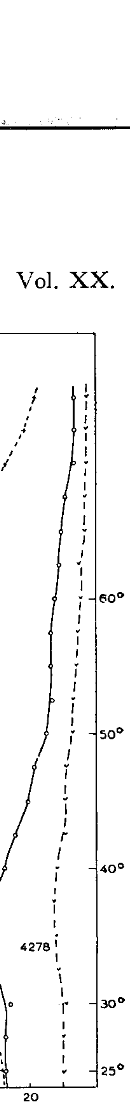
Fig. 6. Luminosity curves of faint, grey rays extending up to great heights.

vation of the S level of the order 0—1 sec.$^{-1}$ may appear. For the D level one must assume a lifetime of the order of 100 sec: the effect of collisional deactivation will therefore here be more pronounced than for the shortlived S level. The diverging character of the height distribution of 6300 can be considered as being due to a strong increase in collisional deactivation of the D level with decreasing heights.

Following Seaton [5] the intensity ratio R between the red doublet and the green line is given by

$$(1) \qquad R = \frac{I\,(6300 + 64)}{I\,(5577)} = \left(\frac{A_{31} + A_{32} + d_3}{A_{21} + d_2}\right) \left[\frac{S_2}{S_3} + \frac{A_{32} + d_{32}}{A_{31} + A_{32} + d_3}\right]$$

Here A_{31}, A_{32}, and A_{21} are the spontaneous transition probabilities from respectively the S to the P level, the S to the D level, and the D to the P level. S_3 and S_2 are the total numbers of atoms entering the S and D levels respectively: cascading from S to D, d_{32} is the probability of collisional deactivation from the S to the D level; d_3 and d_2 are the probabilities of collisional deactivation per sec of an atom in the S and D state respectively.



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Assuming now S_2/S_3 to be constant with height, neglecting d_3 and d_{32} and using the theoretical values for $A_{nm,}$ the following simplified expression of (1) is obtained.

$$(2) \qquad 1/R = \frac{I\ (5577)}{I\,(6300 + 64)} = \text{const}\ (1 + 110\text{d}_2)$$

Considering now Fig. 2 (left) it can be seen that the slope of the intensity I *(5577)*/I(6300 + 64) is fairly constant with height within the height-interval 110—150 km. According to (2) this should indicate an approximately linear decrease in collisional deactivation d_2 of the D state with height. At the lower border of the arc, in the height-interval 90—100 km, one must assume a very strong deactivation of the D state which strongly diminishes the intensity of the red doublet.

The intensity ratios of the drapery shown in Fig. 2 indicate the same effects, but in this case the 6300 intensity reaches a greater height.

The intensity curves across the faint, grey rays in fig. 6 exaggerate this *I 6300* increase even more and its displacement towards greater heights. Auroral rays and draperies of this type are most frequently seen at lower latitudes, for instance at Oslo they may be lying 10°—12° from the auroral zone.

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Institute of Theoretical Astrophysics, Blindern, Oslo.

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