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Study of variations of the forbidden oxygen lines in the nightglow

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Abstract—The variations of the forbidden oxygen lines in the nightglow are investigated photoelectrically using a fixed orientation photometer set in a star free region near the north celestial pole. For the red lines our observations show that the slope of the evening twilight enhancement portion of the diurnal curve indicates a possible change with season; for the 5577 Å emission, the occurrence of a maximum around midnight is confirmed. Little correlation of these emissions with solar activity could be established.

Introduction

In the visible region of airglow emission spectra the prominent atomic lines are 5577 Å ($^1S \rightarrow {}^1D$), 6300–6364 Å ($^1D \rightarrow {}^3P$) and the *D*-lines of sodium. The diurnal and seasonal variations of forbidden oxygen lines in the green and red regions of the spectrum have been studied by Roach *et al.* (1953), Dufay and Tcheng Mao-lin (1946), Barbier (1959) and others. For 5577 Å a midnight maximum, first indicated by Dufay and Tcheng Mao-lin (1946) from spectrograms of moderate dispersion, has been established by Roach and Pettit (1951) by photoelectric techniques. For 6300–6364 Å Elvey and Farnsworth (1942) found a considerable evening twilight enhancement with a more or less steady level of radiation during the night and a slight enhancement towards morning hours. The "twilight flash" was first indicated by Slipher (1933).

The present investigation has been carried out at the Uttar Pradesh State Observatory, Naini Tal (latitude 29·5° N, longitude 79·5° E, height above sea level 6900 ft) with a view to examine further the nature of variations of these radiations.

Instrumental Technique

We have used a fixed orientation photometer for the purpose. Much useful information can be obtained by this technique. The greatest advantage of the method is that the background due to the unresolved faint stars does not change much and hence corrections for the illumination contribution from the varying galactic background would be unnecessary. The fixed orientation photometer also gives a higher time resolution for examining a single region of the sky in one radiation. The disadvantage of the fixed orientation photometer is that it misses the emission patches which can be picked up by the scanning photometers in all-sky surveys.

The observations reported herein were made photoelectrically using a 931-A photomultiplier tube and interference filters. The photometer had an altazimuth mounting and, being of the fixed orientation type, it was easy to set it on a region near the north celestial pole devoid of bright stars. An objective lens of 3 in. aperture and 17 in. focal length focussed an area of the sky onto a diaphragm of 7·5 mm diameter arranged to lie in the focal plane. The airglow radiations from an area of the sky equal to 0·80 square degrees thus fell on the photocathode after passing through a Fabry lens and an interference filter. We used interference filters manufactured by Baird Associates for isolating the emission lines and the continuum. These filters have a width at half intensity of about 55 Å and a peak transmission of 70 per cent and isolate the regions centred on 5300, 5577 and 6332 Å. Both 5577 Å and 6300–6364 Å, particularly the latter, are situated very near to the strong OH bands. The two bands are 5593 Å (intensity one-sixteenth of 5577 Å) and at 6257 Å (intensity almost equal to that of the red forbidden oxygen lines) (ROACH, 1957). From the filter transmission characteristics we find that the OH bands contribute 0·044 of the radiation at peak transmitted by the 5577 Å filter and an insignificant amount to radiation received by the photomultiplier through the red filter. We tilted the filters so that the transmission peaks would be centred to within 2 Å of the wavelengths of interest. This was done with the aid of sunlight and a medium dispersion monochromator available in our laboratory. The output of the photomultiplier was fed to a d.c. amplifier having highly linear characteristics and coupled to a 0–1 mA Esterline Angus recorder. A button of radium paint in the photometric apparatus was periodically used to check the overall stability of the electronics.

Observations were made on moonless nights and when the transparency of the sky was extremely stable. Photoelectric work carried out at this Observatory simultaneously on these nights indicated good stability of the values of atmospheric extinction on these nights. In general the altitude at which these observations were carried out ensured low extinction values with good stability.

NATURE OF VARIATIONS

For both 5577 Å and 6300 Å the nights can be isolated into two groups, one showing smooth variation and another characterized by small irregular fluctuations superposed on the general smooth variation. The variations of the ratio of intensity at 5577 Å to the intensity at 5300 Å expressed in magnitudes [$-2{\cdot}5 \log (I\ 5577/I\ 5300)$] are shown in Fig. 1. The variations on different nights are not identical. The ratio attains a maximum within 3 hr of midnight. This agrees well with data of ROACH and PETTIT (1951). The nights for which 5577 Å depicts smooth variation, show double maxima, one more prominent than the other. The shift of time of occurrence of maxima from midnight for various dates is given in Table 1. We see that the maxima occur before midnight from the middle of October to the beginning of March and after midnight during March and April. We have compared it with similar data obtained by ROACH *et al.* (1953) and find that in general during the period in which those observations were made the maxima occur after midnight between the middle of October and the beginning of March. We cannot emphasize this difference much since their study covers a much longer period than ours. The red lines 6300–6364 Å show considerable enhancement in evening twilight. The morning twilight enhancement also exists, but the relative change is comparatively less, which is explained as being caused by an unequal duration of illumination by sunlight of the upper atmosphere in the two cases (Fig. 2). In the night time the ratio $I\ 6300/I\ 5300$ either stays constant or shows a minimum near midnight. Our observations show that the slope of the evening twilight enhancement portion of the curve indicates a possible change with season. The

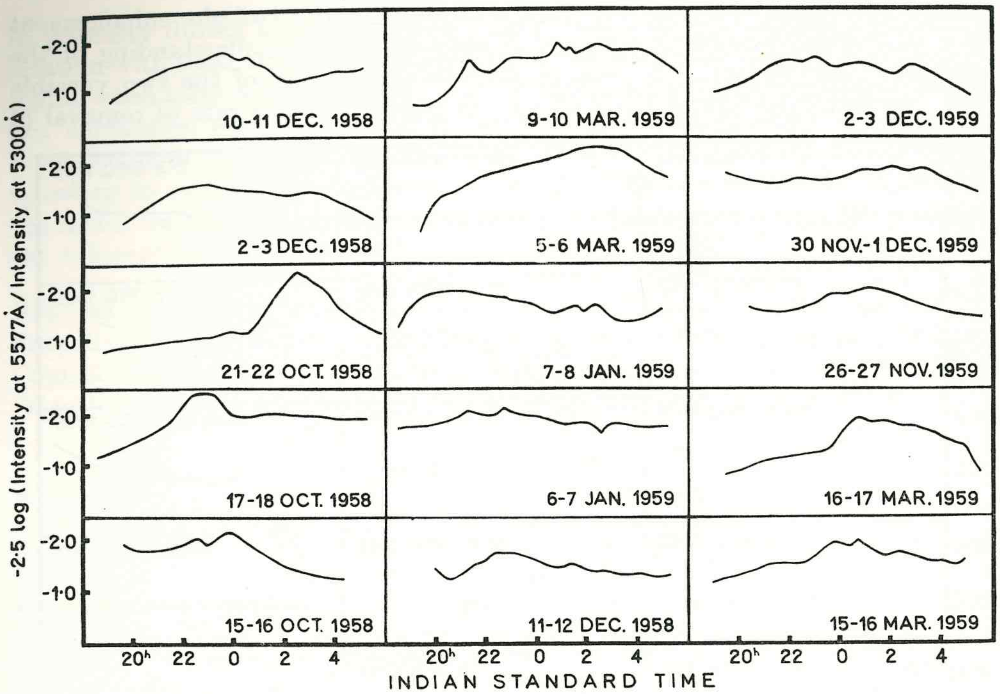

Fig. 1. Variation of the intensity of 5577 Å radiation in the night airglow at Naini Tal.

Table 1.

Date	Nature of solar activity	Intensity of 5577 Å	Shift* of time of maximum of 5577 Å radiation from mid-night (hr)
15/16.x.58	Normal	Normal	+2·5
17/18.x.58	Active	Abnormal	−1·5
22/23.x.58	Active (SWI)	Abnormal	−1·5
2/3.xii.58	Active (alert)	Normal	−2·3
7/8.xii.58	Normal	Normal	−2·0
10/11.xii.58	Active (alert)	Normal	−0·5
11/12.xii.58	Active (alert)	Normal	−1·3
6/7.i.59	Normal	Normal	−3·0
7/8.i.59	Normal	Normal	−2·5
5/6.iii.59	Normal	Normal	+2·5
10/11.iii.59	Normal	Normal	+0·75
16/17.iii.59	Normal	Normal	+0·75
17/18.iii.59	Normal	Normal	+0·75
31.xi/1.xii.59	Normal	Normal	+2·00
2/3.xii.59	Normal	Normal	−1·00

* (+) indicates a shift towards later hours.

slopes are given in Table 2. The change in slope of the twilight enhancement portion of the curve is significant and it may help in an understanding of the enhancement mechanism. The change may be due to any of the two variable factors, the concentration of the reactants or more likely the rate of removal of

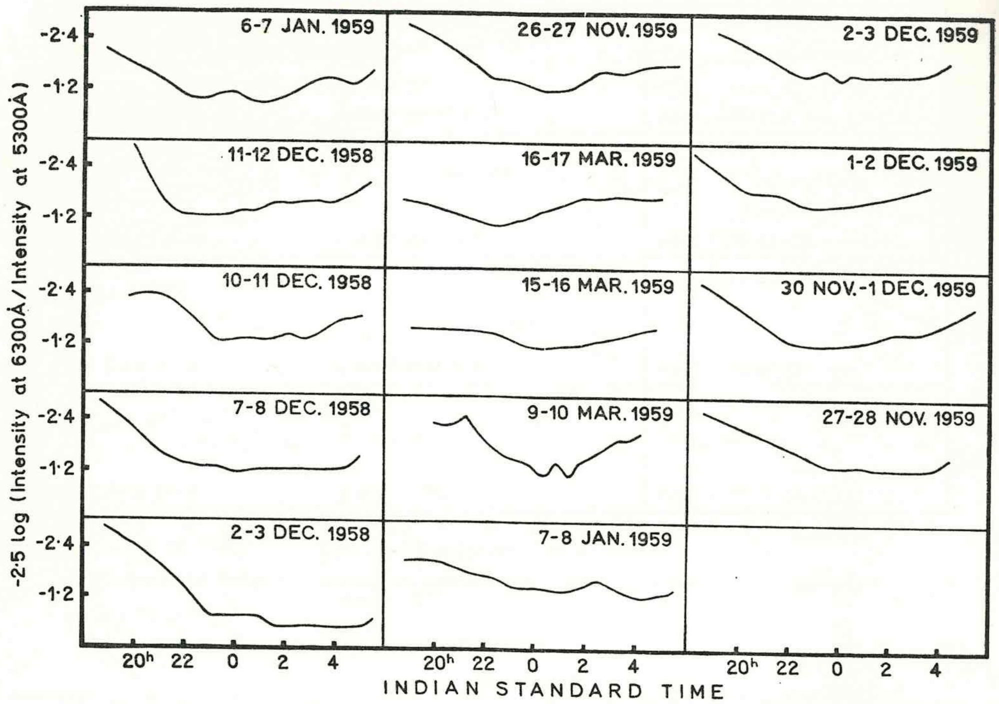

Fig. 2. Variation of the intensity of 6300 Å radiation in the night airglow at Naini Tal.

Table 2. Slope of the evening twilight enhancement potion of the diurnal variation curve for red lines

Date	Slope	Date	Slope
2/3.xii.58	1·38	15/16.iii.59	0·23
7/8.xii.58	1·46	16/17.iii.59	0·17
10/11.xii.58	1·20	26/27.xi.59	1·24
11/12.xii.58	4·53	27/28.xi.59	0·83
6/7.i.59	0·58	1/2.xii.59	1·55
7/8.i.59	0·46	2/3.xii.59	0·84

solar ultra-violet. Both these factors may vary with the season in such a manner that the evening twilight enhancement portion of the curve for summer is comparatively flatter than that during winter. The morning twilight enhancement portion during summer has a larger gradient. This point, however, needs further study.

EFFECT OF SOLAR ACTIVITY

Since low latitude aurorae are expected to occur in periods of increased solar activity (as it was during 1957–1958), 5577 Å and 6300 Å may indicate an increase

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sponding to each night is indicated in Table 1. The criteria for the distinction are
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the International Geophysical Year.

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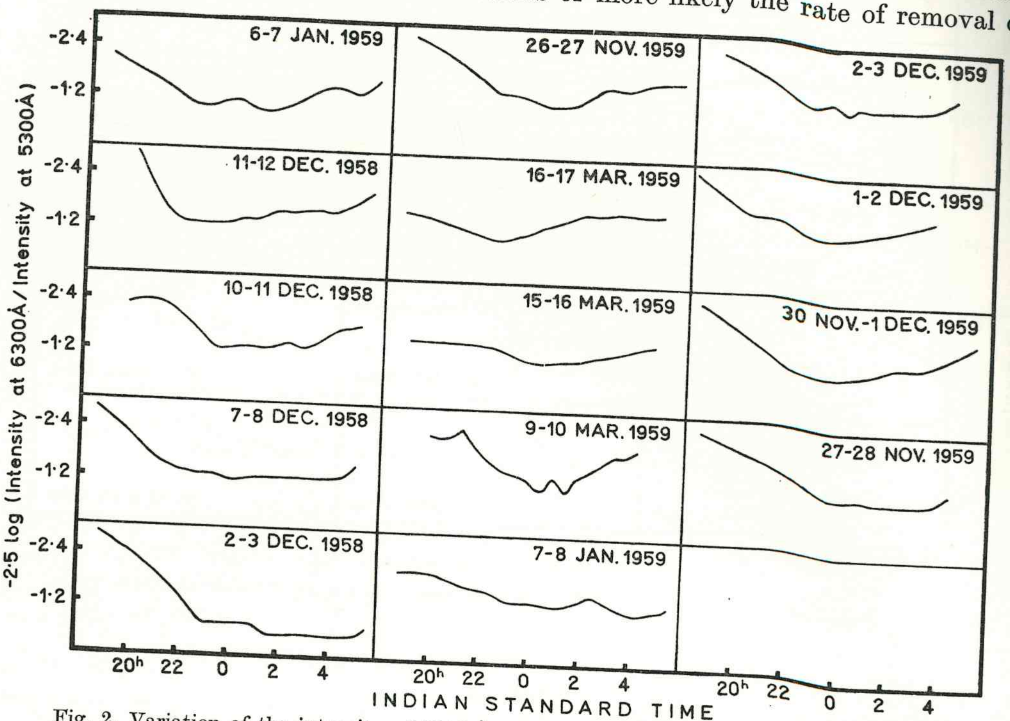

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