EVENING AND MORNING TWILIGHT ENHANCEMENT OF λ5577 Å ATOMIC OXYGEN LINE AT ALLAHABAD

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Abstract. A photometer for the observation of twilight airglow emissions has been fabricated. Intensity variation in morning and evening twilight of λ5577 Å line of atomic oxygen has been recorded at Allahabad for one year duration from 23rd March, 1987 to 22nd March, 1988. The enhancement in the intensity of the line is found to be irregular. Out of 40 clear evenings and 25 clear mornings from 23rd March, 1987 to 15th June, 1987 enhancement is observed in 24 evenings and 15 mornings. However, no enhancement is observed during the period from 15th September, 1987 to 15th October, 1987. It is found that rise and fall of intensity is exponential during twilight period. Considering different mechanism for the excitation of atomic oxygen green line, it is concluded that none of them are able to explain enhancement. More work is needed to be carried out for the better understanding of the problem.

1. Introduction

The presence of λ5577 Å line of atomic oxygen in twilight is well established. Dufay and Dufay (1948) first reported temporal variation in its intensity during twilight and observed an enhancement, which was at least a factor of two over the night time value. However other investigators (Berthier, 1956; Koomen Packer, 1956; Manring and Pettit, 1956; Hunten *et al.*, 1962) were not able to observe it for many years. Megill (1960) and Megill *et al.* (1960) carried out a systematic ground based study of λ5577 Å emission during twilight at Rapid City, South Dakota (44°02′ N, 103°03′ W) using birefringent photometer for over a period of one year. They observed an enhancement of few kilo-Rayleighs in sixteen evening and fourteen morning twilight periods. Deehr (1969) reported enhancement of several hundred Rayleighs at college of Alaska (64°51′ N, 147°50′ W). Schaffer (1975) observed slight increment in the intensity of atomic oxygen green line during evening and morning twilight periods at Fritz Peak Observatory (39°52′ N, 105°31′ W) using Fabry-Pérot interferometer. Ghosh *et al.* (1986, 1987) measured the intensity of this line for three years (1983–86) at Calcutta (22°39′ N, 88°27′ E) and reported clear enhancement in the intensity during morning and evening twilight period.

After reviewing the work it is noted that the observations made by different investigators differ from each other. The enhancement reported for different latitudes ranges from few kilo-Rayleighs to few Rayleighs only. Also, commencement time and duration of enhancement is different. Ghosh *et al.* (1987) reported start of evening enhancement at local SZA of 91° whereas Schaffer (1975) found it to be at local SZA of 100°. Further the enhancement is not a

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regular phenomenon. Deehr (1969) observed clear enhancement in summer while sporadic in winter, contrary to which Schaffer (1975) observed clear enhancement in winter while sporadic in summer. Thus in order to have better understanding of the phenomena more data should be collected at different places throughout the world. This will also help to establish a correlation of emission intensity with latitude; and to explain enhancement mechanism. In the present paper the observations taken at Allahabad (25°32′ N, 81°53′ E) from March 1987 to March 1988 are reported. It may be mentioned that no such observation has ever been taken at this place.

Experimental Set Up

The experimental setup for taking twilight airglow observation is shown in Figure 1. It is fully designed and fabricated in our laboratory. Radiations from the sky enter the photometer through the window W which are filtered by a Bousch and Lomb optical interference filter having its peak transmittance at λ5590 Å with 100 Å half intensity bandwidth (Figure 2). Filtered radiations are then allowed to fall on the photocathode of RCA 1P21 photo multiplier tube operated at 1000 V. Voltage is supplied by a highly stabilized power supply of Hewlett-Packard model No. 2116. The output of P.M. tube is measured by HIL's $4\frac{1}{2}$ digits Digital Multimeter Model No. 2665. Photometer is placed on a plateform which can be inclined to the horizon at different angles with the help of long screw S. This plateform was kept in a fixed Zenith angle of 75° and photometer was kept in a direction opposite to the sun through out the observation.

Observations

Intensity of atomic oxygen green line in the twilight airglow has been taken by the photometer described above at the latitude of Allahabad. The observation data for one year duration from 23rd March, 1987 to 22nd March, 1988 are

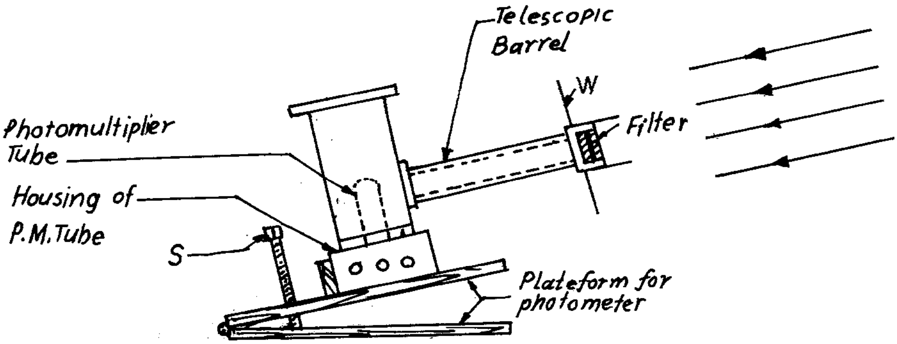

Fig. 1. Photometer used for the twilight observation.

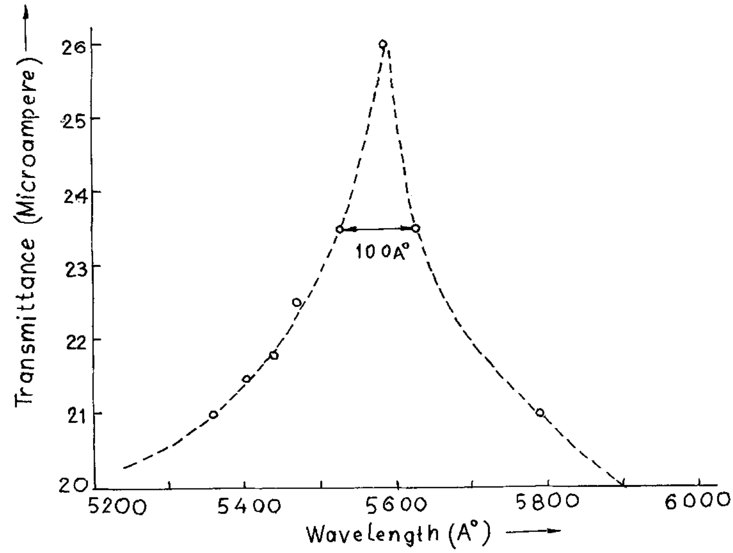

Fig. 2. Variation of transmittance of optical filter with wavelength.

analysed. Two distinct periods of suitable weather conditions for taking twilight airglow observation are in summer from 23rd March, 1987 to 15th June, 1987 and the other in winter from 25th September, 1987 to 15th October, 1987. Summer observations show clear enhancement in the intensity of λ5577 Å atomic oxygen line in morning and evening twilight, while winter observation do not show any enhancement in the intensity. Out of 40 clear evenings of summer duration enhancement was found on 24 occasions. Intensity starts rising at SZA 93.25° (13 min after sun set) and attains a peak 20 min after sunset at SZA 95°. After this, intensity falls. In the morning time out of 22 clear mornings 15 occasions of enhancement could be obtained. Intensity rises initially but decreases 19 min before sunrise time at SZA 94.75°, attains a minima after seven minutes at SZA 93° and then again increases. Rise and fall of intensity is found to be exponential for evening and morning summer twilight period (Figures 3 and 4). In winter duration of observation, evening twilight intensity decreases exponentially at first and then decrease becomes hyperbolic (Figure 5). In morning twilight of winter duration intensity rises hyperbolic at first and then rises exponentially (Figure 6). Peak intensity with dates are tabulated in Table I. Intensity rise time with dates during evening twilight is shown in Figure 7. Figure 8 shows intensity decrease time with dates in morning twilight. Commencement and termination time relative to sunset and sunrise time of intensity enhancement during evening and morning twilights with dates are shown respectively in Figures 9 and 10.

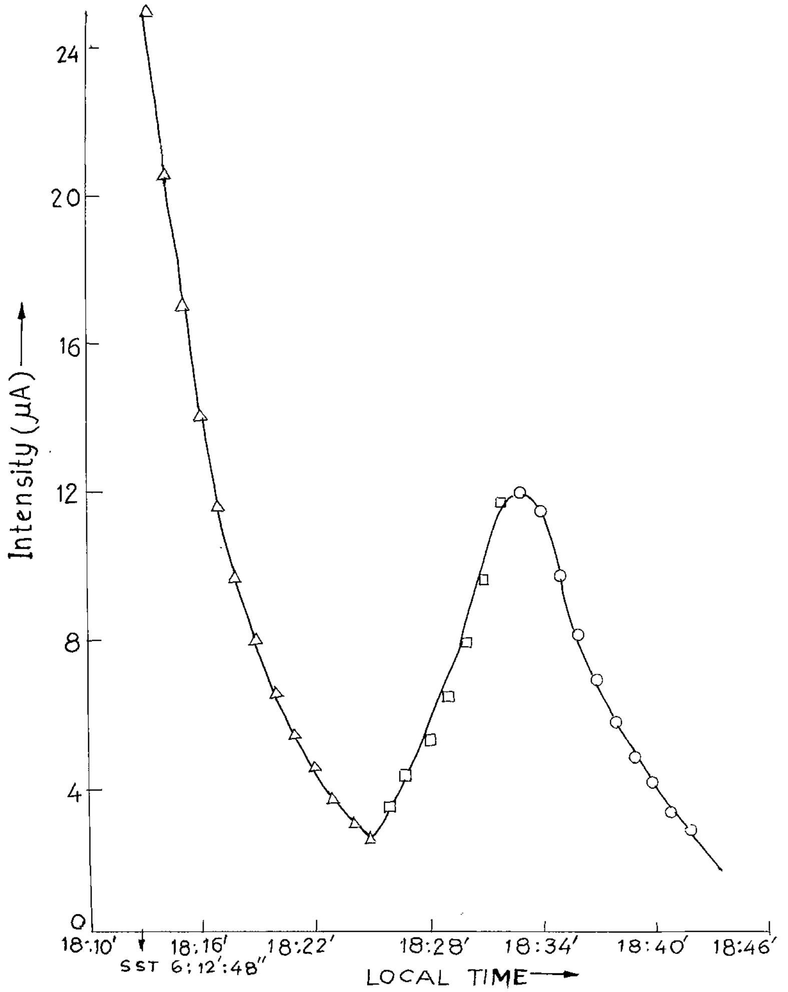

Fig. 3. Shows intensity variation of λ5577 Å emission line on 24.3.87 during evening twilight. Continuous curve represents the experimental data. △, □ and ○ follow the functions 30.09 exp. $(-0.188t)$; 2.42 exp. $(0.197t)$ and 16.29 exp. $(0.174t)$ during 18:13 to 18:25, 18:25 to 18:33 and 18:33 to 18:42 hours respectively.

4. Discussion

Photometer used in the present investigation is very simple. It uses an interference filter which has a pass band of 100 Å (half intensity band width, see Figure 2) with peak at λ5590 Å. It allows sufficient background radiation along with λ5577 Å line and OH(7.1) band. The background radiation is mainly due to scattering of solar rays by lower atmosphere. Before twilight time starts, the λ5577 Å line is completely masked by the scattered light; but as the local SZA

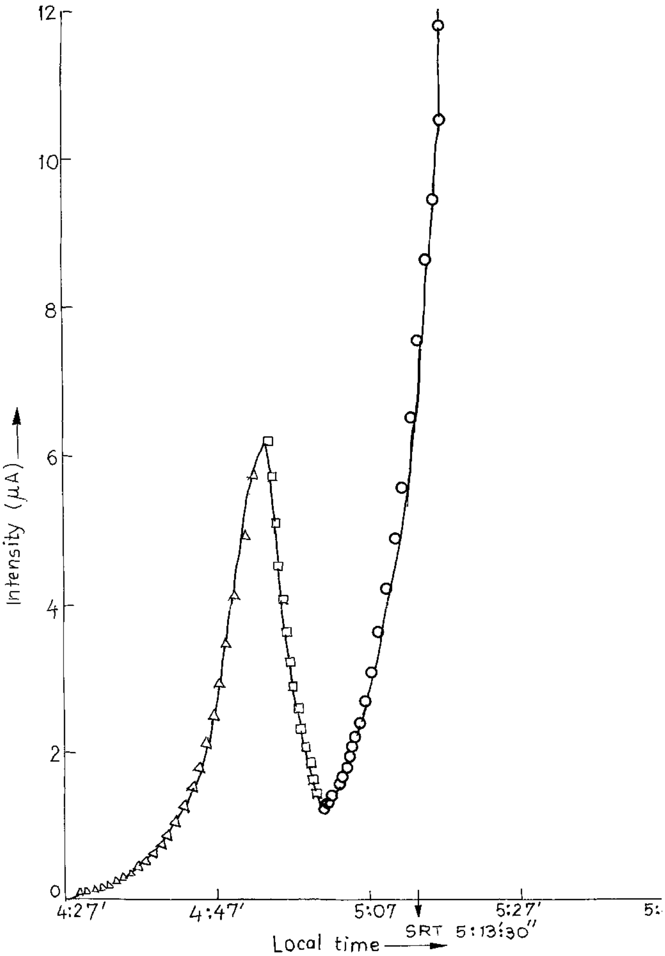

Fig. 4. Shows intensity variation of λ5577 Å emission line on 20.5.87 during morning twilight. Continuous curve represents the experimental data. △, □ and ○ follow 0.849 exp. $(0.159t)$, 7.22 exp. $(-0.113t)$ and 1.126 exp. $(0.146t)$ during 4:30 to 4:56; 4:56 to 5:04 and 5:04 to 5:20 hours respectively.

further increases the shadow height increases which causes the decrease of scattered radiation to a very low level and λ5577 Å line becomes prominent (Figure 3). One can also see from Figure 11 that the contribution due to OH(7, 1) band is very small compared to λ5577 Å line. Enhancement of OH bands occurs only in the infrared region (Berthier, 1953, 1956). From the above consideration it may be concluded that radiation recorded by the above photometer is mainly λ5577 Å line.

Various mechanism for the excitation of green line in the twilight glow have been proposed (Table II). From above table it is clear that there are three layers

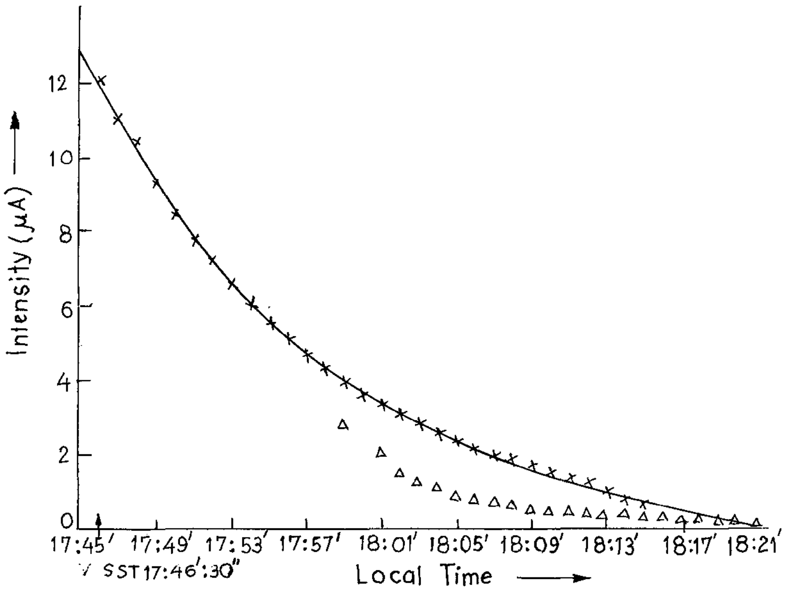

Fig. 5. Intensity variation of $\lambda 5577$ Å line on 4.10.87 during evening twilight. There is no intensity enhancement. Continuous curve represent, the experimental data. $\triangle$ and $\times$ follow the functions $1/(61.31+2108.04t)$ and 13.15 exp. $(-8.632t)$ for 17:42 to 18:21 and 17:42 to 18:15 hours respectively.

for the emission of atomic oxygen green line in the twilight glow; and the main emitting layer lies above 200 km. To settle the question of mechanism responsible for the enhancement, different investigators have proposed different excitation mechanism. Deehr (1969) suggested that the photo dissociation of O_2 molecules in Schuman-Runge continuum is responsible for the enhancement. But rocket borne measurements (Hays and Sharp, 1973) and analysis of ground based observations by triangulation method (Schaffer, 1975) showed that the enhancement in intensity is due to layer above 200 km. A number of investigators (Hunten, 1969; Schaffer, 1975) suggested that the cause of enhancement is dissociative recombination of O_2 ions with F region electrons. Ghosh *et al.* (1986) has concluded that enhancement is due to increase in the concentration of ozone density just after sunset. As mentioned earlier, observations reported by different investigators show that enhancement is not a regular phenomena. While according to excitation mechanism proposed above, enhancement in the intensity must occur regularly. This simply indicates that none of the excitation mechanism proposed above explains irregular enhancement of $\lambda 5577$ Å line during twilight. In order to have a better understanding of the problem related to the enhancement in twilight airglow of OI green line more work is to be carried out.

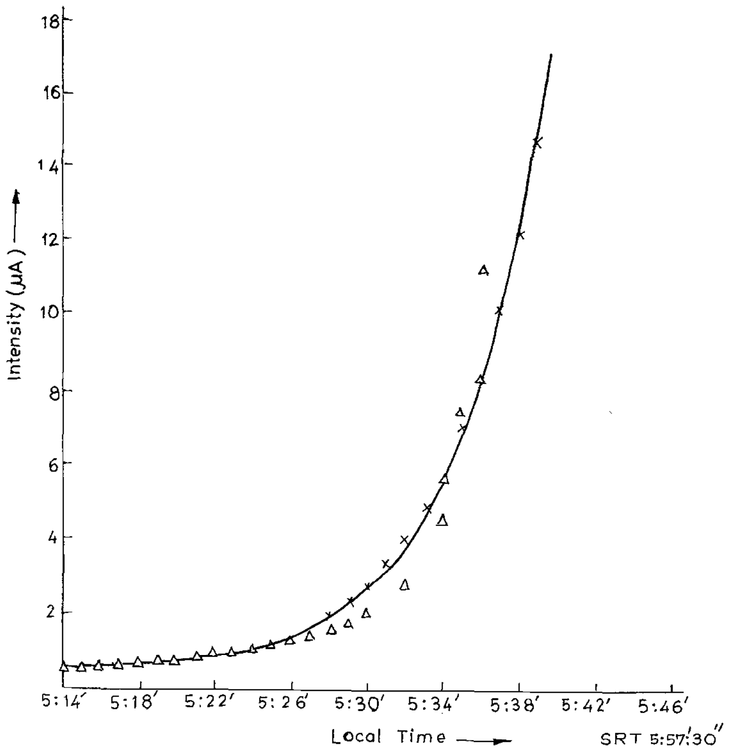

Fig. 6. Intensity variation of λ5577 Å line on 13.10.87 during morning twilight. There is no intensity enhancement. Continuous curve represent, the experimental data. △ and × follow the functions $1/(16.86+134.59t)$ and 9.25 exp. $(0.185t)$ for 5:14 to 6:39 and 6:25 to 6:39 hours, respectively.

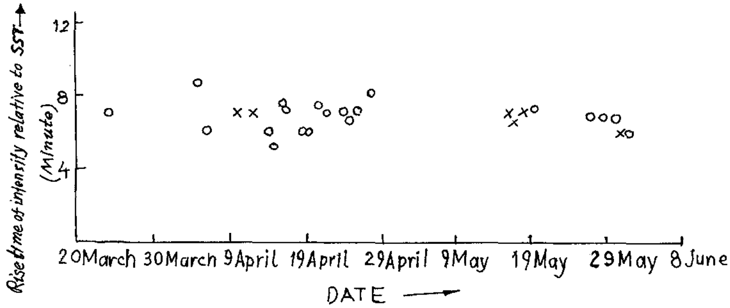

Fig. 7. Intensity rise time relative to the Sun set time with date for evening twilight. x represents that the sky was not fully clear.

TABLE I
Peak intensity with date for morning and evening twilight

Evening twilight		Morning twilight	
Date	Peak intensity	Date	Peak intensity
24.03.87	12.0	05.04.87	6.87
05.04.87	0.57	06.04.87	9.36
06.04.87	45.33	14.04.87	15.34
10.04.87[a]	23.58	15.04.87[a]	2.28
12.04.87[a]	19.87	16.04.87	15.89
14.04.87	1.02	17.04.87	17.25
15.04.87	0.17	21.04.87	7.56
16.04.87	17.97	22.04.87	15.10
17.04.87	0.78	12.05.87	2.14
19.04.87	57.85	18.05.87	1.99
20.04.87	65.60	19.05.87	3.33
21.04.87	36.24	20.05.87	5.88
22.04.87	26.66	21.05.87[a]	4.09
24.04.87	3.99	27.05.87[a]	3.27
25.04.87	0.43	28.05.87	1.54
26.04.87	14.31		
28.04.87	7.11		
16.05.87[a]	3.05		
17.05.87[a]	11.65		
18.05.87[a]	29.79		
20.05.87	10.30		
27.05.87	10.40		
29.05.87	9.27		
30.05.87	7.28		
31.05.87[a]	3.04		
01.06.87	2.01		

[a]Sky was not fully clear.

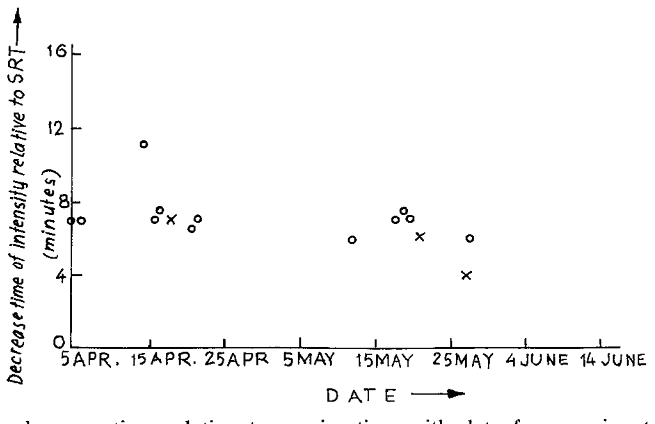

Fig. 8. Intensity decrease time relative to sunrise time with date for morning twilight time. x represents that the sky was not fully clear.

TABLE II
Excitation mechanism for the production of λ5577 Å line in the twilight airglow emission

Sl. No.	Excitation mechanism	Reaction	Height of emitting layer	Remark
1.	Chapman mechanism	$O+O+O \rightarrow O_2+O(^1S)$	100 km	It is an important source for the excitation of the green line in the night glow. Its contribution in twilight glow is small.
2.	Barth mechanism	$O+O+M \rightarrow O_2^*+M$ $O_2^*+O \rightarrow O_2+O(^1S)$	100 km	It is also proposed to explain night glow excitation and is faster mechanism compared to Chapman's one. It also contributes little in the twilight glow.
3.	Photodissociation of O_2 molecules	$O_2+h\nu \xrightarrow{1293\,Å} O(^1S)+O(^3P)$	140 km	It is very important mechanism for the day glow but its contribution in the twilight glow is low.
4.	Photoelectron impact on O^+ atoms	$O^+ + e \rightarrow O(^1S)+h\nu$	above 200 km	It is also important in the day glow. Its contribution in the twilight glow is negligibly small.
5.	Dissociative recombination of O_2^+ with F region electrons	$O_2^+ + e \rightarrow O(^1S)+O(^1D)$	200 km	It is an important source of excitation and has major contribution in twilight time

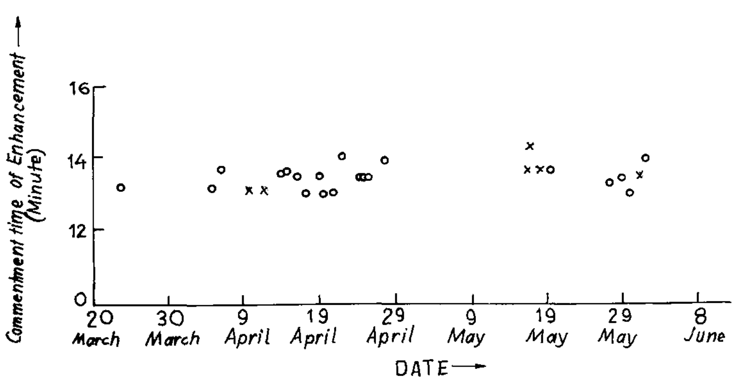

Fig. 9. Commencement time of enhancement after sunset with date (evening twilight).

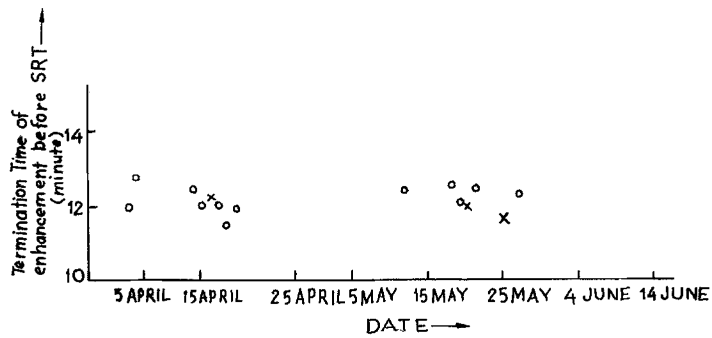

Fig. 10. Termination time of enhancement before sunrise time with data (morning twilight).

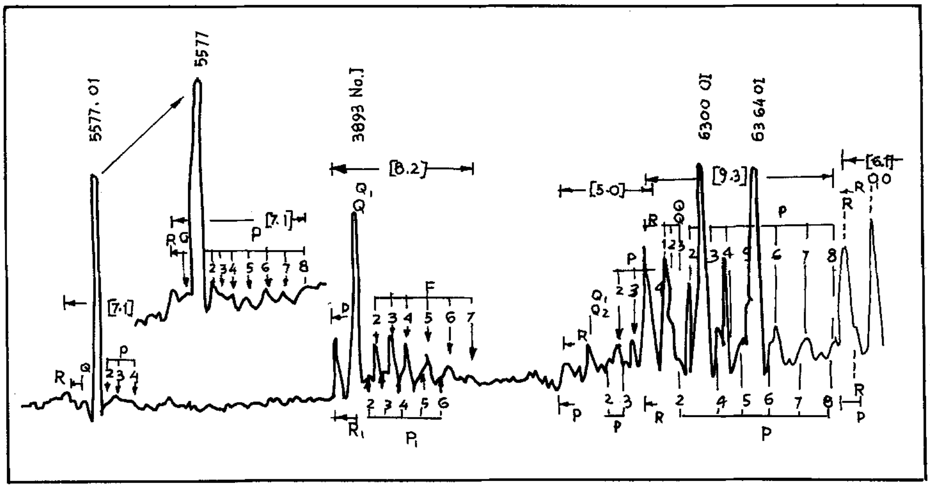

Fig. 11. Microphotometer tracing of night glow spectrum depicting the presence of λ5577 Å line of atomic oxygen and (7, 1)OH band (Chamberlain, 1961).

References

Berthier, P.: 1956, *Ann. Geo. Phys.* **12**, 113.
Chamberlain, J. W.: 1961, *Physics of Aurora and Airglow*, Academic Press, New York.
Deehr, C. S.: 1969, *Ann. Geo. Phys.* **25**, 881.
Dufay, J. and Dufay, M.: 1948, *Compt. Rend.* **226**, 1208.
Ghosh, S. N. and Midya, S. K.: 1987, *Indian J. of Radio and Space Phys.* **16**, 277.
Ghosh, S. N. and Midya, S. K.: 1986, *Indian J. Phys.* **60B**, 413.
Ghosh, S. N. and Midya, S. K.: 1980, *Mahavishwa* **3**, 31.
Hays, P. B. and Sharp, W. E.: 1973, *J. Geophys. Res.* **78**, 1153.
Hunten, D. M.: 1962, *J. Atmospher. Terr. Physics* **24**, 333.
Hunten, D. M.: 1967, *Space Sci. Rev.* **6**, 493.
Koomen, M. J., Packer, E. M., and Tousey, R.: 1956, in *The Airglow and Aurora*, E. B. Armstrong and A. D. Dalgarno (eds.), p. 355.
Manring, E. R. and Pettit, H. B.: 1956, *ibid.*, p. 29.
Megill, L. R.: 1960, *J. Atmospher. Terr. Phys.* **17**, 276.
Megill, L. R., Jamnic, P. M., and Crutz, J. E.: 1960, *J. Atmospher. Terr. Phys.* **18**, 309.
Schaffer, R. C.: 1975, *J. Geophys. Res.* **80**, 154.