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Heights of the Airglow Emission Layers at Poona

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ABSTRACT. A specially designed and calibrated photoelectric photometer was used for the intensity measurements of the three principal airglow radiations λλ 5577, 5893 and 6300 at Poona during the period February-May 1962. Using the observed intensities at $Z=0°$ and $Z=75°$ and using the van Rhijn formula heights of emission layers were determined for 34 nights for each of these radiations. They ranged from 55 to 279 km with average values of 152, 176 and 168 km for the three radiations respectively. The results are discussed in relation to those obtained earlier at this station and also at other places in the U.S.A. The importance of extinction coefficients is stressed in the estimation of heights of the emission layers.

1. Introduction

With a view to determine the height of the λ5577 emission layer, photometric scanning of the whole dome of the sky was carried out in an almucantar manner on a few nights before and after every new moon, during the periods January-February 1956, December 1957 – January 1958 and December 1958 – March 1959. These estimates of height were reported in two previous communications by Chiplonkar and Kulkarni (1960) and Chiplonkar, Kulkarni and Agashe (1961). However, in view of the large discrepancy observed between the heights estimated at this station and those reported by other workers, especially from U.S.A., these measurements were continued at this station and extended further to the other two airglow radiations, *viz.*, λ5893 and λ6300. In the present communication are presented the results based on these new observations collected during the period February-May 1962, and also a revision of the older data in the light of new information gained since their publication.

2. Experimental

The details of the photometer used in our previous observations have already been described by Chiplonkar and Kulkarni (1958, 1960). It has now been modified to improve its performance substantially. For instance, in the new photometer we have replaced the photo-multiplier R.C.A. IP 28 by the DuMont 6291 and C.R.O. by a sensitive Multiflex galvanometer with a cathode follower D. C. Amplifier. Four interference filters which transmit narrow bands around λ5300, λ5577, λ5893 and λ6300 can be brought in turn in front of the photo-multiplier; λ5300 filter is used as a control for correcting the background radiation. The relative response of the photo-multiplier and spectral transmissions of the interference filters are shown in Fig. 1. The photometer covers a patch of the sky 6°·1 in diameter and is designed to scan the sky in an almucantar manner at the zenith distances – 0°, 15°, 30°, 45°, 60° and 75°.

3. Results

During the period February – May 1962 only on 34 clear nights observations for the height estimations could be carried out. The observed galvanometer deflections were first converted in terms of absolute intensities in Rayleigh by using the calibration constants of the present set up.* Next the background correction was applied and the residual intensities $I'(Z)$ representing the emission intensities received at the ground, were obtained for zenith distance Z. Using the residual intensities at zenith distances 0° and 75° ratios $V'(75) = I'(75)/I'(0)$ are obtained. They are presented in Table 1.

4. Processing the data

The determination of the height of an emission layer is an important aspect of the night airglow study. "In general there are two approaches to the problem of height determination — (*a*) To construct a family of theoretical curves corresponding to observations from the earth's surfrce, (*b*) to refer the observations to outside the scattering atmosphere for comparison with the universal curves of the van Rhijn function V against Z" (Roach and Meinel 1955). We have followed the first method in our analysis.

In order to obtain the predicted values of $V'(Z)$ at the base of the atmosphere, it is necessary to apply scattering and extinction corrections. Ashburn (1954) has given tables showing the intensity of light scattered by a hemisphere – illuminated by an emitting layer at various heights

*Note—The method of calibration was described by Chiplonkar and Kulkarni (1960)

TABLE 1

$V'(75) = I'(75)/I'(0)$ (Mean for entire night)

No.	Date	No. of sets	5577 Å	5893 Å	6300 Å	Sky conditions
1	1-2-62	13	1·976	2·105	2·173	Fair
2	2-2-62	16	2·127	2·269	2·188	,,
3	3-2-62	16	2·063	2·227	2·386	,,
4	4-2-62	16	1·934	2·021	2·122	,,
5	5-2-62	10	1·973	2·003	2·255	,,
6	6-2-62	13	2·121	2·120	2·365	,,
7	7-2-62	8	2·233	2·264	2·186	,,
8	27-2-62	8	2·373	2·577	2·436	,,
9	28-2-62	11	2·003	2·097	2·220	Excellent
10	1-3-62	12	2·131	2·105	2·238	Clear
11	2-3-62	13	1·988	2·085	2·190	,,
12	3-3-62	12	2·182	2·041	2·356	,,
13	4-3-62	15	2·151	2·300	2·329	,,
14	5-3-62	18	2·154	2·329	2·563	,,
15	6-3-62	18	2·361	2·217	2·504	Excellent
16	7-3-62	17	2·169	2·254	2·401	,,
17	8-3-62	12	2·353	2·257	2·343	,,
18	9-3-62	12	2·491	2·540	2·720	,,
19	31-3-62	10	2·025	2·126	2·173	,,
20	1-4-62	14	2·055	2·244	2·452	,,
21	2-4-62	16	2·036	2·527	2·538	,,
22	3-4-62	6	1·972	2·223	2·411	,,
23	4-4-62	16	2·456	2·174	2·200	,,
24	5-4-62	16	2·008	2·265	2·364	,,
25	28-4-62	9	2·343	2·244	2·190	Clear
26	29-4-62	13	2·433	2·387	2·515	,,
27	30-4-62	14	2·301	2·239	2·456	,,
28	1-5-62	15	2·286	2·370	2·368	Fair
29	2-5-62	7	2·327	2·283	2·373	,,
30	3-5-62	16	2·182	2·407	2·491	,,
31	4-5-62	10	2·193	2·232	2·487	,,
32	5-5-62	6	1·996	2·200	2·414	,,
33	6-5-62	7	2·089	2·186	2·324	,,
34	7-5-62	11	1·975	2·282	2·376	Clear
Mean	(Feb-May 1962)		2·156	2·217	2·346	

TABLE 2

Scattering Function*

Wavelength (Å)	mT	Z (degrees)	Height (km) of the emitting layer 100	200	300
5577	0·0834	0	0·0943	0·0867	0·0834
		75	0·3377	0·3290	0·3087
5893	0·0672	0	0·0772	0·0708	0·0678
		75	0·2841	0·2422	0·2273
6300	0·0510	0	0·0588	0·0554	0·0521
		75	0·2345	0·2134	0·1983

*Unit = Zenith intensity outside the atmosphere (0·25 cm of ozone; albedo of ground 0·25; for Poona, elevation 555 m)

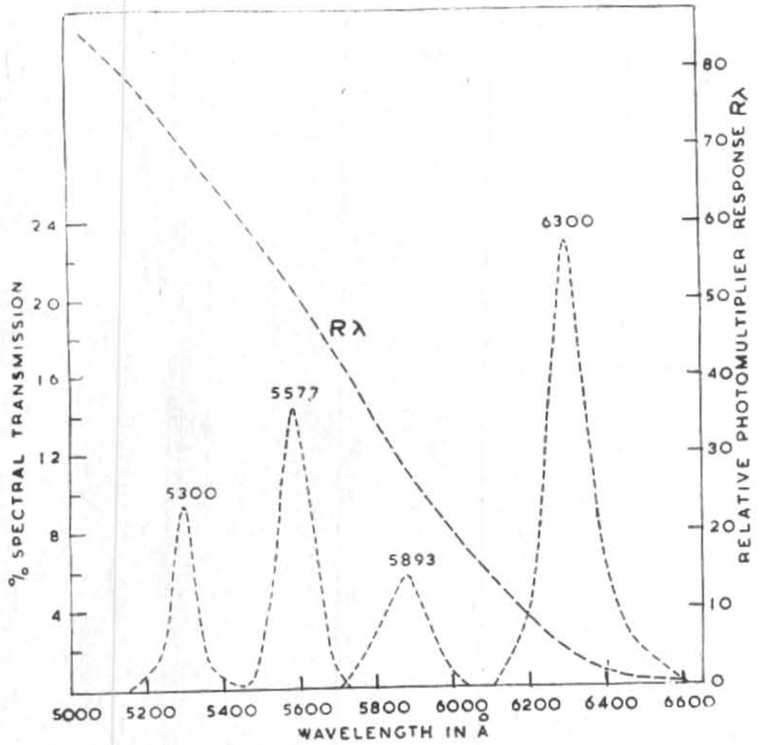

Fig. 1. Spectral transmission of the interference filters and relative response of the photomultiplier (Du Mont 6291) used in the investigation

in the earth's upper atmosphere. These tables were used to obtain the scattering corrections at our station. The numerical values of total scattering correction for the zenith distances 0° and 75° and for the three radiations under study are given in Table 2. The additional scattering of radiation reflected back into the atmosphere by the ground has been obtained— assuming a ground albedo of 0·25.

The intensity of a light beam is weakened as a result of extinction due to the impurity of the atmosphere existing at the time and place of observation as also due to molecular scattering. The different components responsible for this extinction are given in col. 1 of Table 3. Since these quantities were not measured experimentally at this station simultaneously with the intensity measurements their most probable values from the tables compiled by Allen (1955) were selected as given in columns 2, 3 and 4 of the same table.

In Table 4 are given the predicted values of $V'(Z)$ for the three radiations; and finally the results of height determination are given in Table 5.

5. Revaluation of the old data

Such calculations of the height of emitting layer were also carried out in the past at this station using different corrections for scattering and attenuation which were either chosen for the station on certain assumptions or accepted on the recommendations in this behalf of the I.G.Y. Committee. All these calculations have now been repeated with the new scattering and extinction coefficients based on more recent information and used in calculating the heights in Table 5. The results are shown in Table 6. Measurements for λ5893 and λ6300 emissions were not made during the earlier periods. A comparison of the average of the values in col. 5 of Table 6 and those in col. 3 of Table 5 shows that the old data give for the height an average value which is not very much different from that obtained from the 1962 data.

6. Discussion

The importance of the choice of scattering and extinction coefficients is clearly brought out by the results of these calculations of the old data. In the past, scattering was taken to be proportional to $1-\exp(-m_z\,\beta)$ as a first approximation, where ($\beta = 0{\cdot}125$) is the co-efficient of molecular scattering and m_z the airmass along the direction of zenith distance Z. Extinction was taken to be proportional to $\exp(-m_z\,T)$ where T the extinction coefficient has a value of 0·150. The correctness of the choice of our new coefficients

TABLE 3

Extinction coefficients referred to sea level

Component	Wavelength (Å)		
	5577	5893	6300
Molecular scattering	0·0912	0·0735	0·0560
1 cm water vapour absorption	0·0021	0·0019	0·0017
0·25 cm ozone absorption	0·0287	0·0342	0·0300
Dust scattering (per atmosphere)	0·0370	0·0298	0·0270
Total	0·1590	0·1394	0·1147

TABLE 4

Predicted $I'(75)/I'(0)$ values for Poona, elevation 555 m (above m.s.l.)

Wavelength (Å)	Height (km)					
	50	100	150	200	250	300
5577	2·458	2·298	2·163	2·053	1·958	1·883
5893	2·618	2·430	2·280	2·160	2·077	1·973
6300	2·749	2·552	2·393	2·264	2·152	2·062

is thus proved by the greater consistency in the results obtained, if consistency is a true criterion, here.

The variation in height from night to night may be due to variability of the extinction as well as due to intrinsic changes in the emission heights. Extinction coefficient used in this investigation is an adapted and a constant value. The dependence of height on extinction is shown in Fig. 2, wherein the minimum and maximum values of extinction coefficient excluding and including dust are 0·122 and 0·188 respectively. Hence it can be seen that the range of observed heights lies within the limits determined by the extreme values of extinction. This perhaps indicates that the height of emission layer may remain the same and yet changes in extinction alone would produce the observed changes in its height.

The new heights are more in agreement with those obtained at other stations by Roach and others (1955). Very recently, Kulkarni (1965) has reported almost identical value (*viz.*, 145$\pm$14 km) for the height at Mt. Haleakala (Hawaii), a station in the Pacific tropics.

In the same communication Kulkarni has discussed the merits of using intensity ratios at $Z=80°$, 75° and 70° in the height calculations and has come to the conclusion that the probable error in height determination for zenith distance 75° is the smallest while for both 70° and 80° it is larger. Incidentally it may be noted that at this station observations at $Z=75°$ have always been used for the height determination after carrying out such trial calculations earlier.

Further from an analysis of correlation between the intensities of λ6300 and λ5577 Kulkarni has proposed in the same paper the existence of two layers emitting λ5577 radiation. Of these one is at 100 km giving no correlation with λ6300 intensity and the other is in the vicinity of *F*-layer of the ionosphere giving a high correlation with λ6300 intensity. From our data of February—May 1962 we find a low value for the correlation coefficient (*viz.*, 0·38) between the intensities of λ5577 and λ6300. The height obtained from the van Rhijn method is the height of the optical centre of gravity of the two layers. This was in fact suggested much earlier by Abadi, Vassy and Vassy (1944) on somewhat different grounds.

TABLE 5

Estimated heights of the three airglow emission layers at Poona

Date	No. of sets	5577 Å	5893 Å	6300 Å	Sky conditions
1-2-62	13	241	225	239	Fair
2-2-62	16	165	188	198	,,
3-2-62	16	195	171	152	,,
4-2-62	16	265	267	235	,,
5-2-62	10	249	279	204	,,
6-2-62	13	167	218	160	,,
7-2-62	8	124	156	232	,,
27-2-62	8	77	61	132	,,
28-2-62	11	244	228	217	Excellent
1-3-62	12	164	225	171	Clear
2-3-62	13	232	234	239	,,
3-3-62	12	141	257	164	,,
4-3-62	15	155	142	174	,,
5-3-62	18	153	130	98	,,
6-3-62	18	90	176	112	Excellent
7-3-62	17	146	160	146	,,
8-3-62	12	83	159	169	,,
9-3-62	12	55	71	57	,,
31-3-62	10	213	215	239	,,
1-4-62	14	199	164	125	,,
2-4-62	16	208	74	104	,,
3-4-62	6	240	173	142	,,
4-4-62	16	152	194	226	,,
5-4-62	16	221	156	160	,,
28-4-62	9	86	164	231	Clear
29-4-62	13	59	112	109	,,
30-4-62	14	99	166	124	,,
1-5-62	15	104	116	159	Fair
2-5-62	7	91	148	157	,,
3-5-62	16	141	106	115	,,
4-5-62	10	135	169	115	,,
5-5-62	6	227	182	141	,,
6-5-62	7	183	189	176	,,
7-5-62	11	239	149	156	Clear
Total	426				
Average		152	176	168	

Further the heights determined by the rocket experiments on three occasions are round about 100 km only (Berg, Koomen, Meredith, Scolnik 1956; Koomen, Scolnik, Tousey 1956; Heppner, Stolarik, Meredith 1957). Their results do not necessarily indicate that this is only a single layer that exists and the higher one does not. In fact there could also be a second layer heigher up as suggested by Abadi, Vassy and Vassy (1944) and Kulkarni (1965) which the rocket experiments may not have investigated. Thus our results of higher heights are then significant and possibly indicate the positions of centre of gravity of two layers on each individual night.

Finally it may also be pointed out that heights of λ6300 and λ5893 emission layers have also been carried out recently for the first time at this station which are included in Table 5. These heights obtained for λ6300 emission layer are generally much lower than those obtained by a few workers at other stations who report average heights of over 250 km. They, however, deduced these heights from

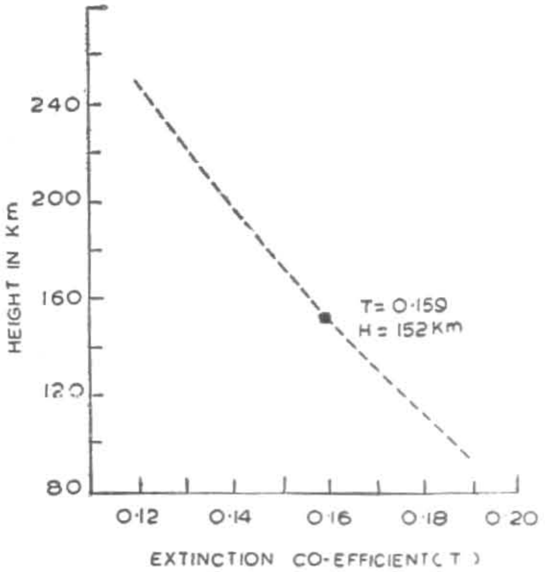

Fig .2. Dependence of mean height on the assumed value of extinction coefficient

TABLE 6

Revaluation of the older data for the height of night airglow λ5577 emission layer

Date	No. of sets	Mean height of the night	
		Old values	New values
13-1-1956	7	235	123
14-1-1956	6	245	205
9-2-1956	4	229	185
27-12-1957	17	105	85
13-1-1958	6	256	224
14-1-1958	13	183	127
15-1-1958	18	232	166
18-2-1958	10	239	210
19-2-1958	9	227	160
12-1-1959	14	200	170
Mean		204	155

a consideration of a correlation of λ6300 intensity and the characteristics of the *F*-layer (Barbier, Roach and Steiger 1962). Method of triangulation (Barbier, Weill and Glaume 1961) based on observations from an airplane and a ground station at Tamanarasset indicates that the height varies between 240 and 400 km.

7. Acknowledgements

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