CHAPTER VI

THE OCCASIONAL COVARIATION OF 6300 Å AND 5577 Å EMISSIONS
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6.1 Introduction

The airglow observations at Mt. Abu indicate in general an absence of covariation between 6300 Å and 5577 Å emissions. The 5577 Å emission generally shows a peak around midnight, and 6300 Å shows a minimum around midnight. The variations on three general nights are presented in Fig. 6.1. There are however a few occasions when covariation in the two emissions has been observed. On such nights, both red and green emissions show a general covariation on which is superposed abnormal enhancements lasting for an hour or so.

In Figs. 6.2a, b, c pronounced peaks occur around 2100 IST in both 5577 Å and 6300 Å and are superposed on the dotted curve which may be considered as the 'general variation' of the two radiations. In Figs. 6.3a, b, c and 6.4 are represented curves of intensity on a few nights on which there was covariation of the two emissions during March 1967 and December-January-February, 1964-65. Such occasions, having peak to peak covariation in the two emissions are however not very frequent.
FIG. 6.1. Nights showing general nocturnal variation of 6300 A and 5577 A at Mt. Abu.
FIGS. 6.2, 6.3. Showing occasions when enhancement and covariation in 6300 A and 5577 A emissions were observed.
FIG. 6.4. The occasions when 6300 A and 5577 A emissions had covariation.
6.2 Photochemical reactions

Normally 5577 Å emission is from the 100 km region of the atmosphere and 6300 Å is from 250-300 km region, which is associated with the ionization of the night time F-layer. The study of the covariation in the two emissions may be expected to elucidate the mechanism of the emissions.

The dissociative recombination reactions in night time F-region, which are important in this respect are the following

\[
\begin{align*}
\text{NO}^+ + e^- &= N^* + O^* \quad (2.76 \text{ ev}) \\
O_2^+ + e^- &= O^* + O^* \quad (6.96 \text{ ev})
\end{align*}
\]

\(^1S_0\) term production is not possible in reaction (1) as an energy 4.17 ev is required for this excitation. Only 6300 Å emission (1.96 ev) is possible. The energy available in the excited oxygen atoms in reaction (2) is sufficient for the production of 5577 Å (4.17 ev) line. Thus the green and red emission covariation may be possible when reaction (2) is operative.

The observations indicate that the covariation in the two emissions are not very frequent and therefore the mechanism of reaction (2) taking place in the F-region may be operative only infrequently. Normally, if reaction (2) were operative like (1), the yield in 5577 Å radiation will be much smaller.
than in 6300 Å radiation (Peterson et al 1966, referring $I_{6300}/I_{5577}$). Gulledge et al (1966) showed that the intensity of the green emission from the layer at 250 km was about 0.2 that of the red line. Therefore, for a good and a point-to-point covariation in two emissions, the mechanism (2) must be enhanced or a different mechanism producing $1S_0$ term should operate.

The OSO-B2 satellite observations (Sparrow et al 1968) showed that this high altitude 5577 Å emission layer could not be detected at middle latitudes but was readily seen within $20^\circ$ of the equator. The observations at our station ($30^\circ$N) did not in general show a covariation of the two emissions, and if there was a small component of 5577 emission from 250 km layer, it was masked by the independent and stronger emission of 5577 Å at 100 km region.

The covariation if observed in the two emissions could be interpreted to mean that when there is an enhancement of emission from F-region, the 5577 Å emission could extend occasionally from equator to $30^\circ$.

Then it can be conceived that on nights, on which both the emissions are enhanced for a short period and, later covary for a few hours, conditions are favourable for reaction (2). The point-to-point covariations observed in the two emissions on January 5, 7, 10, 1967 and March 1, 4, 5, 1967 (Figs.6.2, 6.3) are interesting examples in this regard.
One can observe a covariation in the two emissions in the pre-midnight period when the phenomenon is very pronounced. It is also seen that in some cases there may or may not be a peak-to-peak covariation in the two emissions, after the initial period of enhancement.

An examination of magnetic index $K_p$ and the total magnetic field recorded at Ahmedabad showed that there was no relation of these enhancements with magnetic activity.

Ionospheric data indicate that such events occurred with $h_pF_2$ relatively high during the enhancements of 6300 Å and 5577 Å at 2100 IST and that the high value of $f_oF_2$ with the presence of spread F was the speciality of such events.

Without commenting on the mechanism of enhanced peaks in both the emissions at 2100 IST we proceed to study the nature of both emissions in their 'general background curves' (enhanced peaks excluded over dotted interpolation, Figs.6.2).

6.3 The study of covariation in normal curves on January 5-6 and January 10-11, 1967

It is found in the general background curves that both emissions decay simultaneously. It is our object here to study the variation of red to green intensity ratio during the decay of both emissions. The red to green intensity ratios
for these two nights show a definite trend of variation as can be seen from Fig. 6.5. This trend of variation is interpreted on the basis of the dissociative recombination theory of forbidden transitions of atomic oxygen (both 5577 Å and 6300 Å) as put forward by Peterson et al (1966).

The relevant part of the theory and its use in the present context is reproduced below.

In their theory, Peterson et al (1966), considering the contribution of dissociative recombination reactions, have derived the following expression for red to green emission ratio,

$$\frac{\varepsilon(6300)}{\varepsilon(5577)} = \frac{k_D}{k_{S_1}} \frac{0.81}{1 + \frac{d_D}{\lambda_D}}$$

(3)

where $k_D$ is a factor dependent on the efficiency of the reactions, in producing the forbidden terms of atomic oxygen and is weakly height-dependent through the ratio of recombination coefficients. $k_{S_1}$ is the efficiency of reaction (2) in producing $^1S_0$ term per recombination. Its value lies somewhere between the limits zero to one. The collisional deactivation coefficient $d_D$ has a strong height-dependence through the molecular oxygen concentration as it is related to the latter in the form $d_D = S_D(0_2)$, where $S_D$ is the specific reaction rate. $\lambda_D = 0.0091$ sec$^{-1}$ is the Einstein transition coefficient for the $^1D$ level. Equation (3) shows therefore that the red-to-green emission ratio is proportional
FIG. 6.5. The time variation of the intensity ratio of 6300 Å to 5577 Å observed at Mt. Abu. The ratio is proportional to the factor $1/(1 + d_D/A_D)$. 
to the factor \(1/(1 + \frac{d_D}{A_D})\). Peterson and others (1966), assuming three values of the specific reaction rate \(S_D\), have plotted \(1/(1 + \frac{d_D}{A_D})\). Their diagram is shown here as Fig.6.6.

When the reaction (2) which is capable of producing 5577 Å does not remain effective, which may result in no covariation of two emissions, the ratio \(\varepsilon(6300)/\varepsilon(5577)\) loses its significance. But when the covariation continues through a considerable part of the night the ratio \(\varepsilon(6300)/\varepsilon(5577)\) remains proportional to the factor \(1/(1 + \frac{d_D}{A_D})\).

For testing this inference the observed ratio \(I_{6300}/I_{5577}\) on the two nights reported, has been computed at intervals of 20 minutes. Now again, it is difficult to locate the height where the emission mechanism is predominantly present. Therefore a plot of \(I_{6300}/I_{5577}\) versus height could not be obtained. On the other hand, a checking of \(h_{F_2}\) values over Ahmedabad indicated that ionization maximum was confined to higher levels in the beginning of these two nights and came down steadily to lower levels as the night progressed. For illustrative purpose therefore, the height scale was replaced by a linear time scale, for plotting \(I_{6300}/I_{5577}\) in Fig.6.5.

The observed curves of Fig.6.5 resemble the curves of Fig.6.6. It was not possible to separate from ground based observations, the contribution from the lower green layer at
FIG. 6.6. The height dependence of the collisional deactivation factor \( \frac{1}{1 + \frac{d_D}{A_D}} \), (after Peterson et al 1966).
100 km. But as we saw a good covariation in the two 'general background curves' of the two emissions on these two nights, we have assumed that the variation in 5577 Å intensity was mainly due to dissociative recombination processes making the two emissions to covary.

6.4 Conclusion

The resemblance of the calculated curves with the theoretical curve indicates that on the nights studied here, there is a considerable 5577 Å emission produced by dissociative recombination process in the night time F-layer of ionosphere. Further more, the processes are confined at higher levels in the beginning and then descend as the night progresses. Thus a high level confinement of F-layer with higher electron density (as is observed on these occasions) would favour covariation of two emissions.

On such occasions as studied in the present text the occurrence of spread F is a matter of interest and further investigation is needed in this regard.