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DIURNAL AND SEASONAL VARIATIONS IN THE OH (8,3) EMISSION AT A LOW LATITUDE STATION

by

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ABSTRACT

In this paper the results of OH (8,3) emission intensity and rotational temperature measurements made in the Brazilian sector (23°S) from 1972 to 1974 are presented. Diurnal variations of both parameters are found to fall into a number of distinct classes, showing significant seasonal effects. A correlative study with the OI 5577Å emission measured simultaneously is also presented. Possible effects of magnetic disturbances on the OH emission are discussed.

1. INTRODUCTION

In an earlier paper, Takahashi et al. (1974) discussed the nightglow OH (8,3) band intensities and rotational temperature measured at São José dos Campos (23.2°S, 45.9°W) and Cachoeira Paulista (22.7°S, 45.2°W) between the period July 1972 and July 1973. In this paper, we present additional observations obtained at Cachoeira Paulista up to October 1974 and discuss the diurnal and seasonal variations of the band intensities and rotational temperature. Also, on most of the nights of the OH (8,3) band observations, simultaneous measurements of the OI 6300Å and 5577Å emissions were carried out, and a correlative study of the OH (8,3) band and OI 5577Å is presented. Possible effects of magnetic disturbances on the observed OH (8,3) emission are discussed.

The details of the photometers and the data reduction techniques for the OH (8,3) band and the OI 6300 and 5577Å emission studies have been described in Takahashi et al. (1973, 1974) and Sahai et al. (1974), respectively.

2. OBSERVATIONS AND RESULTS

A total of 38 nights (245 hours) of useful observations were obtained during the period of July 1972 to October 1974. The average OH (8,3) band intensity was 408 ± 40 Rayleighs and the rotational temperature was $179^{o} \pm 5^{o}K$.

2.1 Nocturnal Variations

Different nocturnal variation patterns of the OH intensity and rotational temperature (Trot.) are tabulated in Table I. The classification is according to the scheme used by Nakamura (1961).

The most frequent type of intensity variation is a midnight minimum (Type A and B) with 43% occurence frequency. Independently, pre-midnight intensity decrease and post-midnight intensity increase show an occurence frequency of more than 50%. The variations in the rotational temperature are, in general, small (less than $10^{o}K$). Considering only variations of more than $5^{o}K$, Trot. decreases in the pre-midnight period for 32% of the observations while Trot. increases in the post-midnight period for 58% of the observations. No variation in Trot. in the pre-and post-midnight periods respectively, occurs in 49% and 30% of the observations.

It may be noted that there is a positive correlation between the intensity and rotational temperature variations. Visconti et al. (1971) have also reported similar variations from a mid-latitude station ($42^{o}N$, $23^{o}E$).

2.2 Seasonal effect on the Nocturnal Variation Patterns

It may be observed from Table 1 that the occurence frequencies of the intensity variations differ with season. Type A and B variations are more frequent in winter months, while in spring more frequent is type C. It is difficult to say anything about summer variations due to a lack of data. Autumn shows various types and the variations are larger. Trot. variations do not show any significant trend with season. However, it appears that the variations are small in spring and large in autumn.

Figure 1 shows the seasonally averaged nocturnal variations of the intensity and Trot.

The variation curves for each season show approximately the type of variation which most frequently occurs in the season. Also, Figure 1 shows the seasonally averaged nocturnal variations of the OI 5577Å emission.

At tropical latitudes, a portion of the OI 5577Å emission emanates from the F-region due to the dissociative recombination of O_2^+ and, therefore, for a correlative analysis of the OH and OI 5577Å emission, the E-region component was obtained by subtracting 20% of the OI 6300Å emission from the total observed OI 5577Å emission (see Silverman, 1970).

Wiens and Weill (1973) have presented a large amount of data for several OH bands from the Europe and African sectors and have observed some seasonal effect on the nocturnal variations of the intensities. Although the latitude of our observations is too far from their primary stations to permit a correlative study, it appears that the seasonal effects relating to the intensity variations observed by us are similar to those observed at Adi Ugri (14.9^{o}N, 38.8^{o}E). Also, the occurrence frequencies of pre-and post-midnight decreases observed by us are in some agreement with their results.

2.3 Annual Variation

Monthly mean values of the OH intensity, rotational temperature and OI 5577Å are plotted in Figure 2. Significant semi-annual variations are observed in the OI 5577Å emission with maxima in later autumn (April) and early summer (November). The OH intensity has no significant variations. A slight increase could be seen in autumn. Trot. has a spring minimum and autumn maximum but the variations are small. Visconti et al. (1971) have also presented results showing an enhancement of Trot. in autumn. Our observations are consistent with Shefov's suggestion (1969) that the variations in these parameter's should be a minimum at 20 - 25^{o} latitude.

Rao and Kulkarni (1971) have reported an opposite seasonal variation for the OH and OI 5577Å observed at Mt. Abu (24.6^{o}N, 72.7^{o}E). They suggested that atomic oxygen descends to lower heights in winter months and results in increasing the OH intensities while decreasing the OI 5577Å intensities. Our data do not show such an opposite correlation.

3. DISCUSSION

3.1 Nocturnal Variations and Seasonal Effect

The nocturnal variation of the OH intensity can be considered in two parts, pre and post-midnight. The OH intensity decrease in the pre-midnight period, which is the most frequent, can be explained on the basis of model calculations (Shimazaki and Laird, 1970; Hesstvedt, 1970; Gattinger, 1971). They assumed H-O_3 photochemical process for the excited OH production, with a constant atmospheric mixing ratio. The intensity increase in the post-midnight period, which is also very frequent, suggests some additional mechanism or an increase in atomic oxygen or hydrogen densities in the emission layer (Shimazaki and Laird, 1972). Moreels et al. (1974) obtained a reasonable sudden increase in the OH intensity in their model by increasing the eddy diffusion coefficient by a factor of 10 between 00 and 06 A.M.

An increase of the eddy diffusion coefficient after midnight could be due to tidal or gravity wave energy input. Clemesha (1975) observed that there is a tendency of downward propagation of wave like density profiles from Lidar measurements of the sodium layer near 23^{o}S. Alleyne et al. (1974) also observed downward phase propagation of the tidal field. Meteor radar measurements by Scholefield et al. (1975) at Jamaica (18^{o}N, 77^{o}W) show a sudden increase of meridional wind after midnight. These observations from low-latitude stations indicate considerable dynamic effects at mesospheric heights in the post-midnight period and the observed increase in the OH emission could be related to these effects.

The intensity increase after midnight is apparent in winter and autumn, but this effect is small in spring (Figure 1). Hesstvedt (1970) and Shimazaki and Laird (1972) have discussed the variability of the eddy diffusion coefficient with season wherein there is an increase in winter and a decrease in summer. The present observations are consistent with this.

Although the rotational temperature does not change much (almost constant throughout a night), it has a tendency to decrease from twilight to midnight and thereafter increases. The observed changes in Trot. can be explained on the basis of the changes in the OH vertical profile through a night (Shimazaki and Laird, 1970). After twilight, due to removal of H atoms, the bottomside of the OH profile rises, giving a decreasing tendency in Trot. During the later part of the night, possibly due to O atom injection from the upper region, the upper side of the OH profile rises giving an increasing tendency in Trot. The other possibility for increase in Trot. is direct energy input resulting from tides or gravity waves. The observed temperature variations $\Delta T \approx 5^{o}K$ are in reasonable agreement with that predicted by tidal theory (Chapman and Lindzen, 1970).

3.2 Correlation with the OI 5577Å Emission

In general, there is no correlation between the OH and OI 5577Å intensities if we consider the daily and monthly mean values (Figure 2). The correlation coefficient for daily mean values of the two emissions was less than 0.1. However, the seasonally averaged nocturnal variations show similar patterns (Figure 1) with a tendency for post-midnight enhancements of both the emissions. On a few occasions (see Figure 3a) an enhancement in the OI 5577Å was followed by an enhancement in the OH. Similar variations have also been reported by Rao and Kulkarni (1971) and are possibly due to vertical eddy transport of atomic oxygen. Figure 3b, however, shows that sometimes enhancements in one emission are un-correlated to the other emission and such enhancements are thus possibly due to localized effects in the respective emission layers.

3.3 Effect of the Geomagnetic Activity

Thomas (1971) and Shefov and Toroshelidze (1974) have recently reviewed the effect of geomagnetic activity on the OH emission. Also, Rao and Kulkarni (1972) have observed an increase in the OH emission following magnetic storms at Mt. Abu. With a view to studying the possible effect of geomagnetic activity, correlation coefficients between the observed daily mean intensities of the OH and ΣK_p for various time lags in days were calculated (Figure 4a). It may be observed that between -1 and +3 days, the correlation coefficients are relatively higher. Figure 4b shows the scatter diagram of the daily means and ΣK_p for +2 days. It appears that there is an apparent increase in the OH intensity during magnetic disturbances.

4. CONCLUSIONS

There is some change in the excited OH production rate after midnight. This could be explained by a dynamic effect, i.e., a change in the rate of eddy diffusion (Moreels et al. 1974).

It appears that the dynamic effect varies with season, it is large in winter, small in spring and summer and large and irregular in autumn.

Nocturnal variation of Trot. is small, but the observed variations are in agreement with theoretical models.

The seasonally averaged nocturnal variations of the OH and OI 5577Å emissions exhibit similar patterns. However, there is no apparent correlation between these emissions if the daily and monthly mean values are considered. On a few occasions, enhancements in the OI 5577Å were followed by the OH.

There appears to be an increase in the OH intensity during enhanced magnetic activity.

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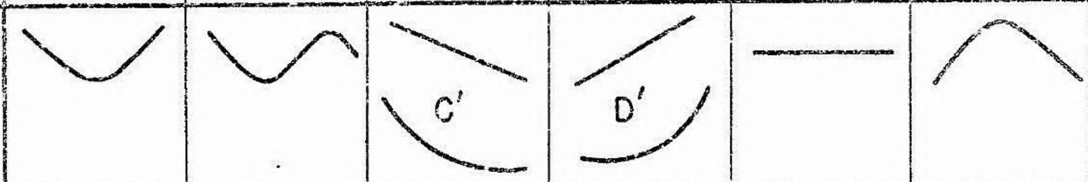
TYPE	A		B		C		D		E		F	
SHAPE OF DIURNAL VARIATION												
	INT.	TROT.	INT.	TROT.	INT.	TROT.	INT.	TROT.	INT.	TROT.	INT.	TROT.
WINTER	2	0	5	1	1	1	1	4	1	4	0	0
SPRING	2	2	0	0	4	1	2	1	1	5	0	0
SUMMER	0	0	0	0	0	1	0	1	3	1	0	0
AUTUMN	3	1	1	0	1	3	1	2	0	0	2	2
TOTAL	7	3	6	1	6	6	4	8	5	10	2	2
(%)	(23)	(10)	(20)	(3)	(20)	(20)	(13)	(27)	(17)	(30)	(7)	(7)

TABLE I — OCCURRENCE FREQUENCIES OF THE VARIOUS TYPES OF DIURNAL VARIATION OF OH(8.3) INTENSITY (INT.) AND ROTATIONAL TEMPERATURE (TROT.)

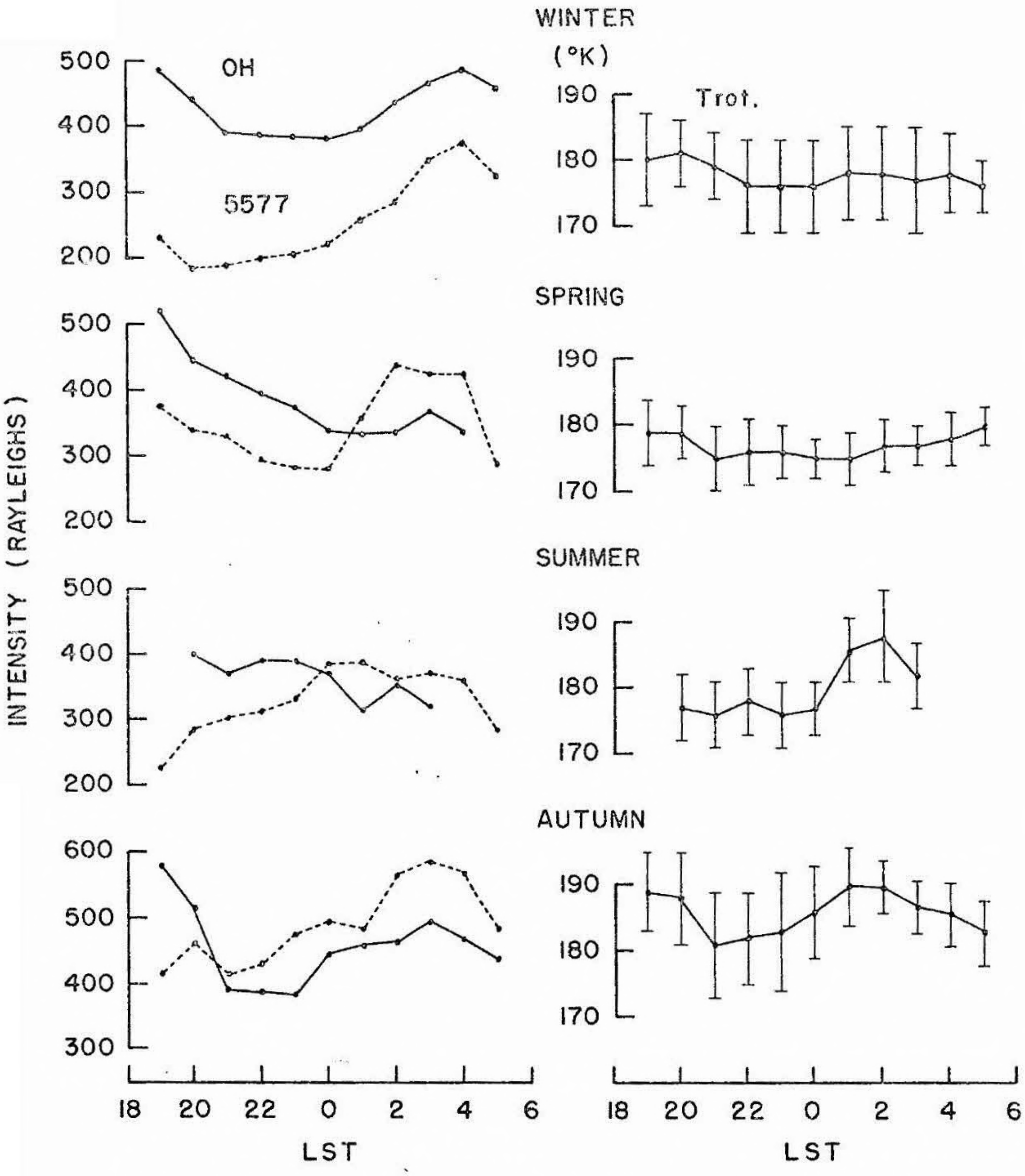


FIG. 1. SEASONALLY AVERAGED DIURNAL VARIATIONS OF OH (8.3) BAND INTENSITY (FULL LINES), OI 5577 (BROKEN LINES) AND ROTATIONAL TEMPERATURE. (JULY 1972-OCTOBER 1974)

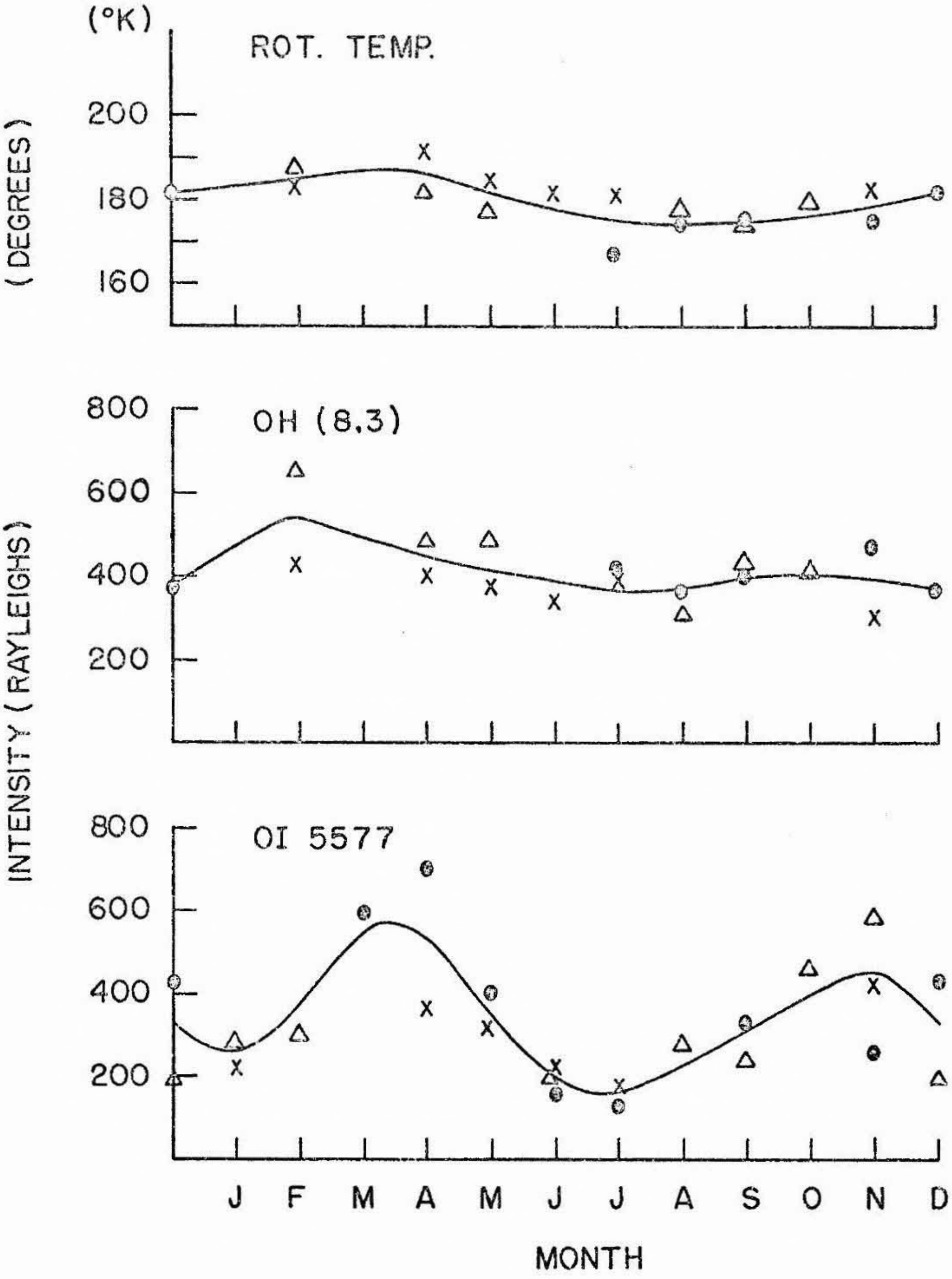


FIG. 2. ANNUAL VARIATIONS OF OH (8,3), OI5577 AND ROTATIONAL TEMPERATURE—(1972 - ●, 1973 - X AND 1974 - Δ)

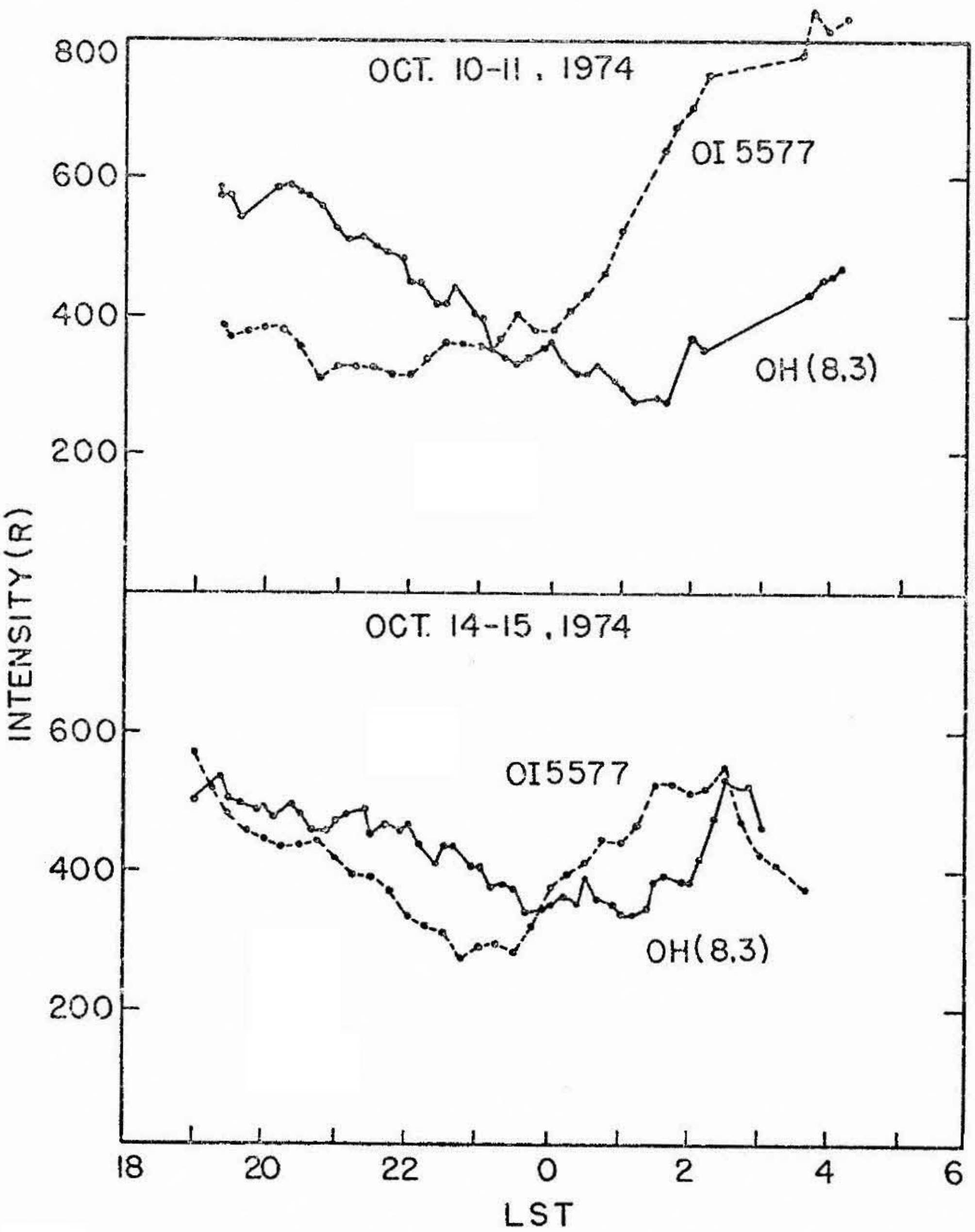


FIG.3.a NOCTURNAL VARIATIONS OF OH(8,3) AND OI5577, SHOWING ENHANCEMENTS OF OI5577 FOLLOWED BY OH.

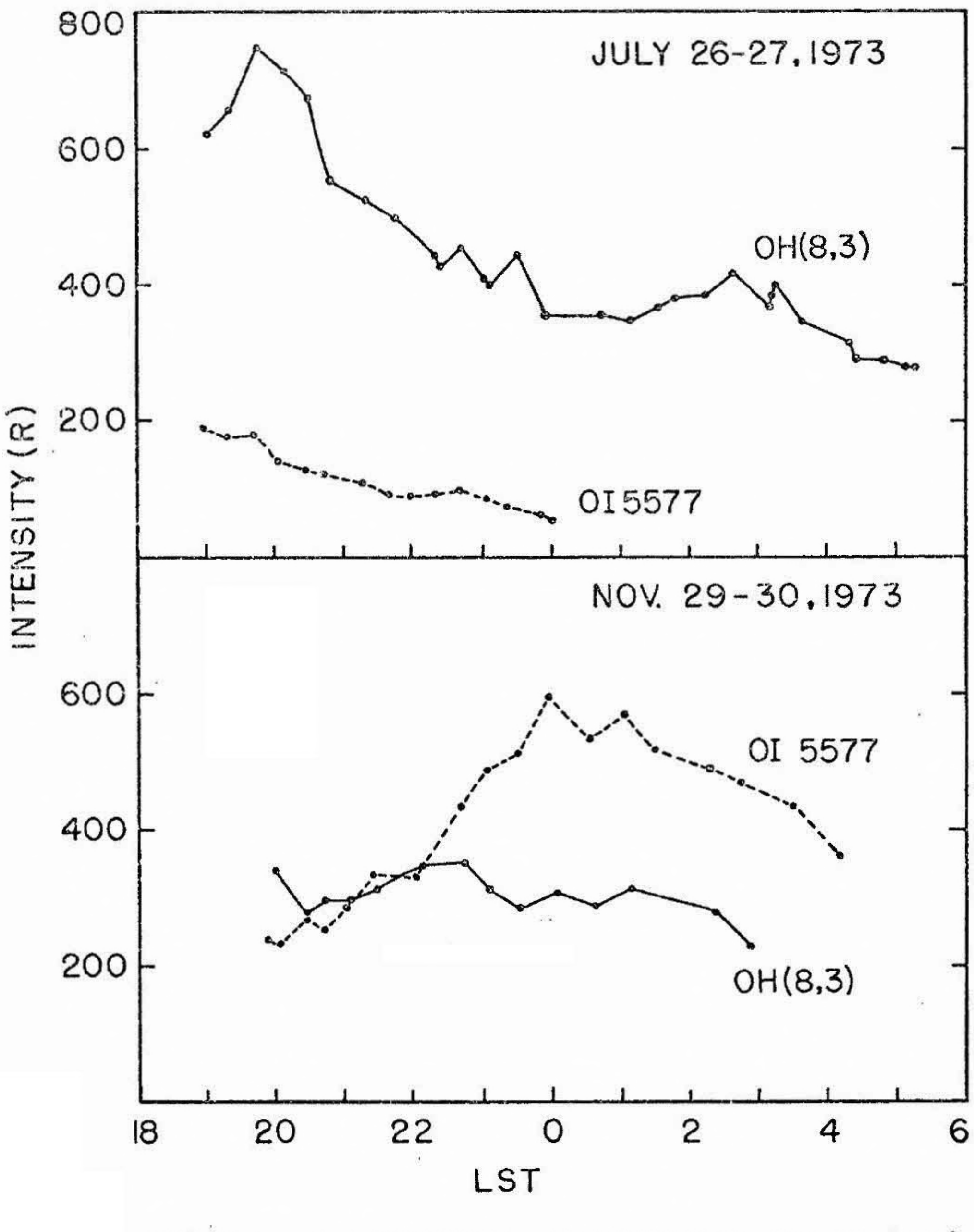


FIG. 3. b. NOCTURNAL VARIATIONS OF OH(8,3) AND OI5577, SHOWING DIFFERENT BEHAVIOUR OF THE TWO EMISSIONS.

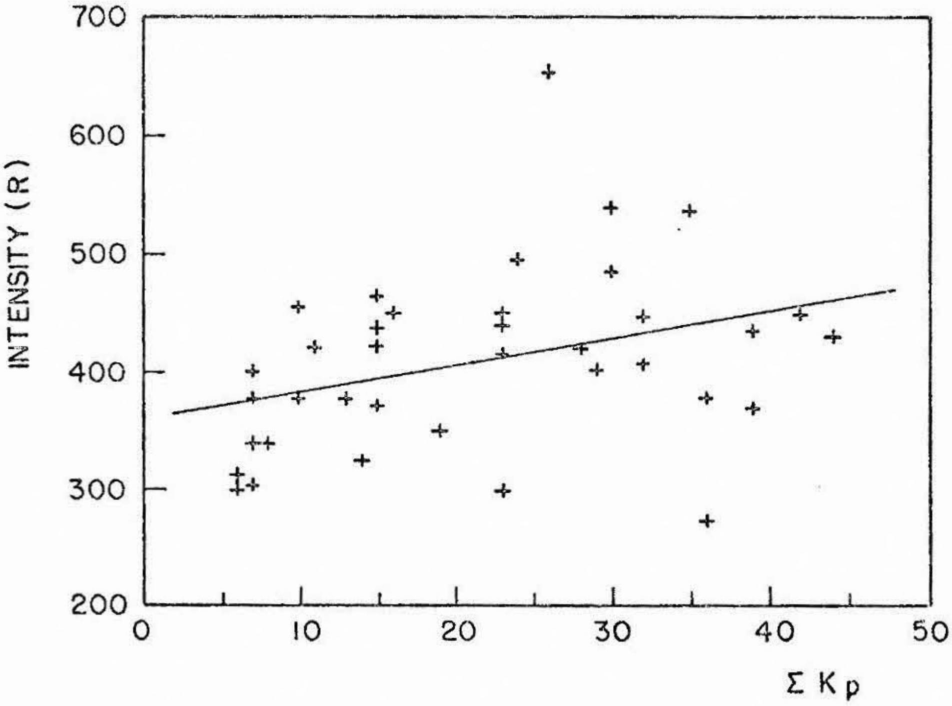


FIG. 4.b. DAILY MEANS OF OH (8,3) VERSUS Σ Kp 2 DAYS AFTER THE OBSERVATION (CORRELATION COEFFICIENT, 0.35).

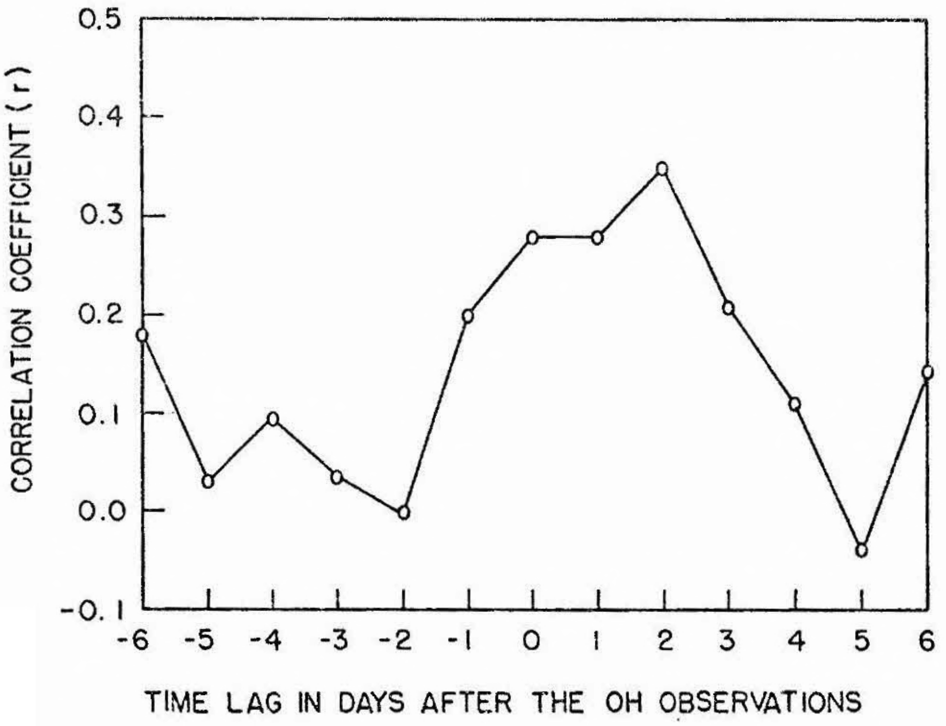


FIG. 4.a. VARIATION OF CORRELATION COEFFICIENT (r) BETWEEN THE OBSERVED DAILY MEANS OF OH(8,3) AND Σ Kp FOR DIFFERENT DAYS.