OI and N_2^+ Emissions Observed at Sanae

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Abstract

The general behaviour of the OI emissions at 6300 and 5577Å, as well as the N_2^+ emission at 4278Å, are discussed. The results concerning the twilight and midnight enhancements are reviewed. It is concluded that apart from the auroral enhancement near midnight due to the diurnal excursion of the auroral oval, there is a prevailing precipitation of soft electrons which may be related to the position of Sanae with regard to the southern radiation anomaly.

1. Introduction

Airglow observations have been made at Sanae (70°S, 2°W) since early 1964. Data for February to October, 1964 are tabulated in a M.Sc. thesis by *Robertson* (1965), and observations taken on six nights in June, 1967 are listed in a data bulletin. In view of the important position of the station, the general behaviour and some of the interesting features of these data are discussed. Both the observations and the data reduction were performed by the airglow group of the University of Stellenbosch under the direction of Professor P. Zeeman.

The observations were made using a zenith turret photometer with a 3° circular field of view, and the two-colour method of background correction was employed. The wavelengths of the filters used and their half-bandwidths (in brackets) are 6300 (29), 6240 (28,5), 5577 (22,5), 5537 (24,4), 4278 (33,5), 4180 (20,5) Å.

2. General Discussion of Observation

Figure 1 shows the medians of the monthly data obtained in 1964 for the three wavelengths 6300, 5577 and 4278Å. Typical night-time intensities for the period May to August, 1964 for magnetically quiet nights were of the order of 20 to 70 R for 6300Å, i.e. larger than those observed by *Eather* (1969) in the northern hemisphere in 1968, but in good agreement with the observations made by *Markham and Anctil* (1966) in the South Atlantic in 1964. This may possibly be due to Sanae's position with relation to the southern radiation anomaly (discussed in Section 5). Ionospheric traces for this period were largely absent owing to nondeviative absorption. On only four occasions during this four-month period was foF2 observable when an airglow observation was made. Using these data *Torr* (1971) has shown that the 6300 intensities on magnetically quiet nights when no enhancement occurred, can be accounted for by dissociative recombination.

Typical quiet night-time values of I5577 and I4278Å for 1964 are of the order of 150 and 40 R, respectively.

Times of sunrise and sunset at various altitudes at Sanae and at the magnetically conjugate point are indicated for June. Interesting features to be noted are the enhancements which appear to be associated with conjugate twilight (discussed in Section 3) and an enhancement in the vicinity of 0300 (discussed in Section 4).

Four of the six days available for June, 1967 were classified as international magnetically quiet days and so the median of these has been included in Figure 1. The magnitude of the intensities obtained in 1967 are in general far larger during enhancements than the 1964 values.

3. Twilight Enhancement

The I6300 curve for June, 1964 in Figure 1 shows a predawn enhancement which begins near conjugate point sunrise at 100 km. (The sun does not set above 200 km at the conjugate point in June and does not rise below 100 km at Sanae). This increase begins before local sunrise at 300 km. A similar effect can be seen after local sunset. (In the paper by *Torr and Torr* (1969), times of sunrise and sunset were calculated for 1st June, whereas it would have been better to use 15th June as has been done here).

Cole (1965) attributed the predawn enhancement in I6300 observed at Haute Province to heating of F region electrons by photoelectrons produced in the magnetically conjugate sunlit hemisphere. *Duboin et al* (1968) estimated that this heating could not result in the observed enhancement and proposed direct excitation of the 6300Å line by the photoelectron flux. *Bennett* (1969) examined the latitude dependence of the twilight enhancement in I6300 and found a lower limit of $L \sim 1,1$ and an upper limit of $L \sim 3,2$ to that region of the magnetosphere which permits the propagation of photoelectrons from one hemisphere to the other. This is contrary to observations by *Cogger and Shepherd* (1969), *Deehr* (1969) *Meier* (1971); and *Torr and Torr* (1969) who found evidence of a predawn enhancement at Sanae ($L = 4$).

Using satellite measurements of conjugate photoelectron fluxes, *Noxon* (1969) and *Fontheim et al.* (1968) find the resulting I6300 to be 0,8 to 30R for conjugate solar-zenith angles from 100° to 85°. One could therefore not expect the 50 to 100R enhancement reported at some stations to be entirely due to conjugate photoelectrons. This appears to be supported by the Sanae data for 1967 in which the enhancements are far too large for conjugate photoelectrons to be the sole cause. Further, the data for 5577 and 4278Å which appear to show similar enhancements, require an energy spectrum which could not be provided by photoelectrons.

Silverman (1970) has reviewed existing results and has concluded that 'additional work is needed to separate out the contributions from photochemical reactions and corpuscular excitation, both direct and indirect'.

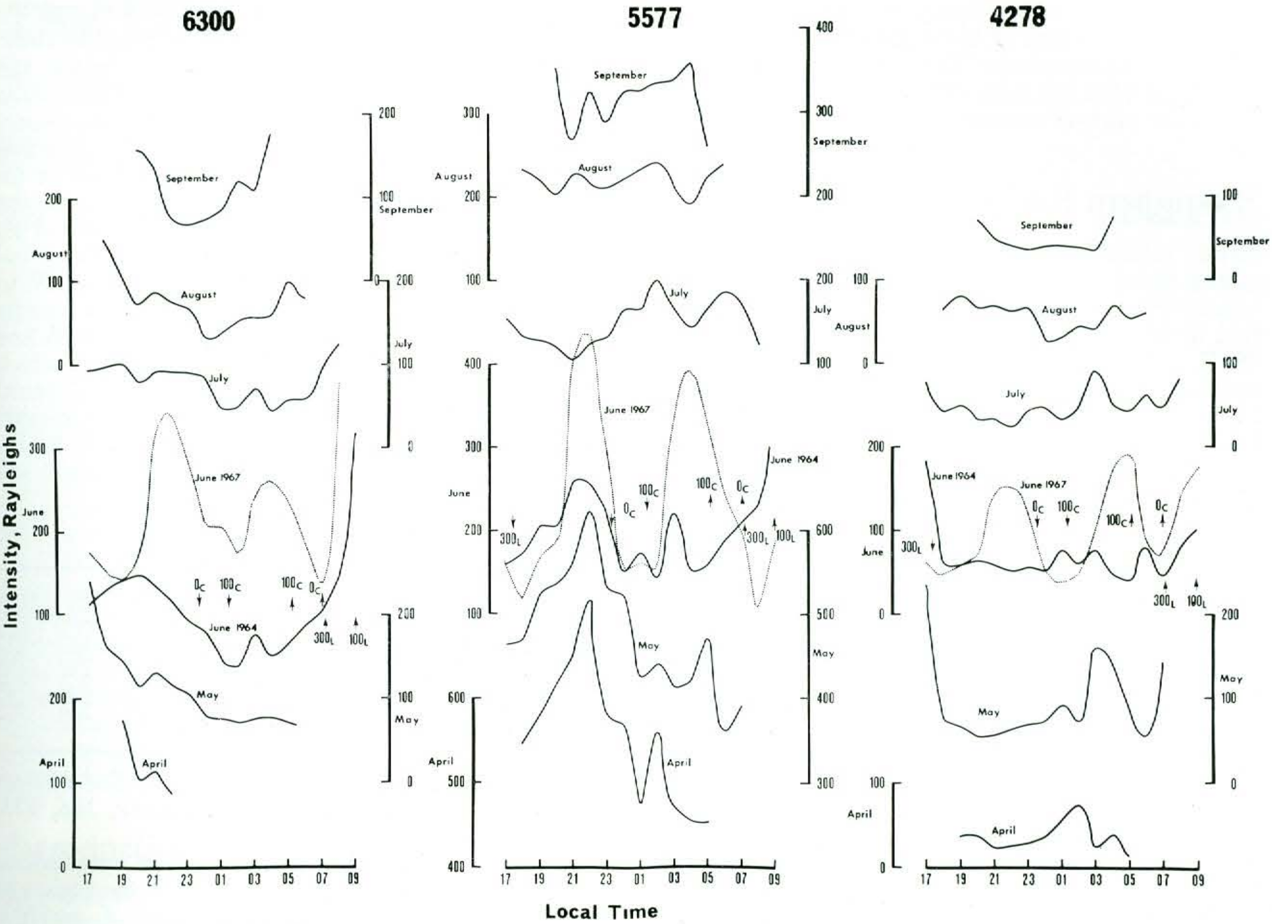

Fig. 1. Monthly medians of I6300, I5577 and I4278 at Sanae, 1964. The median (dotted curve) of 4 quiet days in June, 1967 is also shown. Time of local and conjugate (L and C) sunrise and sunset are indicated for various altitudes in km for 15th June.

4. Night-time Enhancements

Night-time enhancements in I6300 have been observed at several stations over a wide range of latitudes. Those occurring near the equator have been attributed to electric drifts (*van Zandt and Peterson*, 1968), those at middle latitudes still require explanation, while those at higher latitudes such as Sanae are due to auroral enhancements (*Torr*, 1971).

The 6300Å enhancements at Sanae ($>$50R) are usually accompanied by Es and increases in the 30 MHz riometer absorption, indicating that energetic electrons ($>$10keV) are precipitating into the ionosphere. A lower energy component ($\lesssim$2keV) produces the 6300Å enhancements. The enhancements occur shortly after midnight (see *Torr* (1971), figure 2), and reach a maximum at about 0200 L.T. Their duration is 2 to 3 hours. The 6300Å line is apparently being enhanced by the diurnal excursion of the auroral oval which is furthest equatorwards, near or shortly after midnight (*Davis*, 1962). The processes involved in the excitation of auroral O(^{1}D) have been discussed by *Rees et al.* (1967). They have shown that secondary electron impact dominates up to $\sim$250 km while excitation by the thermal electron gas dominates above this altitude.

At Sanae it was found (*Torr*, 1971) that of the 40 nights examined during magnetically quiet times $\sim \frac{1}{3}$ show a midnight enhancement; when Σ Kp increases above a threshold, the probability of an enhancement increases to almost certainty. This is consistent with the movement of the auroral oval. Sanae lies at an invariant latitude of 59,7°. During magnetically quiet periods, the auroral oval lies at an invariant latitude of $\sim$ 70° at night. However, the oval moves to $\sim$ 60° invariant latitude when Kp increases beyond 5 (*Feldstein*, 1966).

Of the 40 nights examined in this period, 29 showed enhancements in I6300, 25 in I5577 and 20 in I4278.

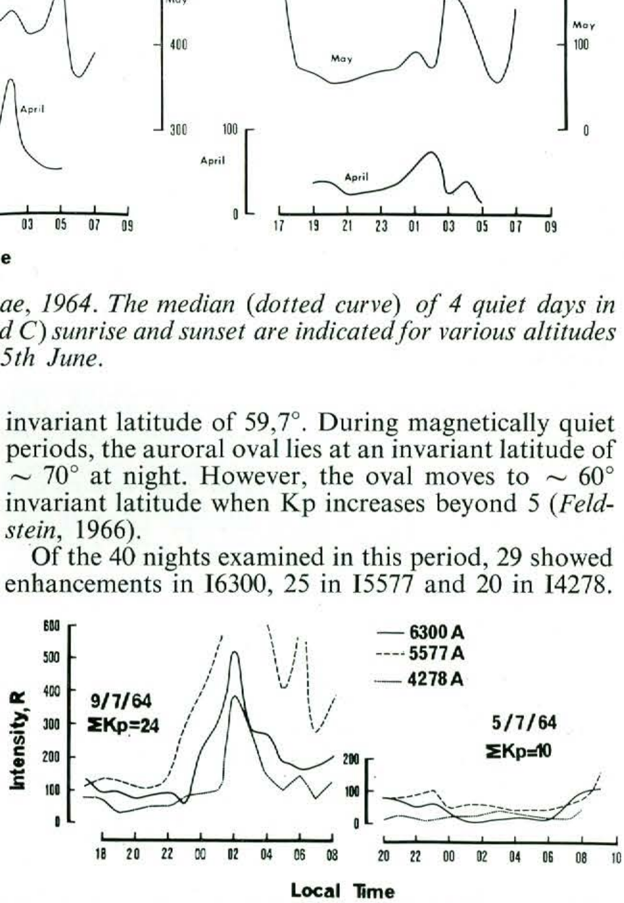

*Fig. 2. Variation of 6300, I5577 and 4278*A *on a night when all three showed auroral enhancements and on a night when none did.*

Figure 2 shows an example of a night when there was no enhancement in any of the wavelengths and a night when there was an enhancement in all three.

Table 1 shows the ratio's I6300/I5577 and I6300/I4278 of the hourly medians for June and July, 1964. It is interesting to note how this ratio decreases during the auroral enhancements, indicating an increase in the higher energy component. During the pre-midnight hours, I6300/I5577 is $\sim$ 0,7 while during the enhancement the ratio is $\sim$ 0,3. The latter is fairly typical for aurorae. Similarly, I6300/I4278 is ~ 2,3 during the early part of the night, changing to ~ 0,8 during the enhancement. This latter figure also is in agreement with the ratio of 0,5–0,9 found by *Eather* (1969) for normal aurorae.

5. Southern Radiation Anomaly

It was originally anticipated that airglow intensities in the vicinity of Sanae would be considerably enhanced over the airglow in regions outside the radiation anomaly (*Cole*, 1961; *Gledhill and van Rooyen*, 1962). *Silverman* (1970) has reviewed ship and airborne observations somewhat north of this area. *Greenspan and Stone* (1964) found a region in which I5577 increased from 200-300R to 600R. *Van der Walt et al.* (1966) found an enhancement in I5577 but not in N_2^+ emission. *Markham and Anctil* (1966) and *Eather and O'Brien* (1968) failed to find any enhancement. However, the intensities reported by these observers, although much lower than anticipated, are far larger than those observed by *Eather* (1969) at the same invariant latitude in the nothern hemisphere. This is certainly true of Sanae. Hence, apart from the auroral oval enhancements, there appears to be an almost permanent corpuscular enhancement at the station. *Schield and Frank* (1970) have measured an energy flux of 0,49 ergs cm $^{-2}$ sec $^{-1}$ ster. $^{-1}$ near local midnight in the plasmasphere near L = 4 (100eV to 50keV). The energy spectrum has a lower energy component ($\lesssim$ 2keV) which enhances the 6300Å line and a higher energy component (> 10keV) which caused the Es, enhanced absorption and enhanced I5577 and I4278. These two components are usually, but not always present together and there is an increase in the harder component during auroral enhancements.

Table 1

		18	19	20	21	22	23	00	01	02	03	04	05	06	07	08
Local Time																
I6300/	June	0,7	0,7	0,7	0,5	0,5	0,4	0,5	0,3	0,3	0,4	0,3	0,4	0,5	0,5	0,6
I5577	July	0,7	0,8	0,7	0,9	0,7	0,7	0,5	0,3	0,2	0,4	0,3	0,3	0,3	0,5	1,0
I6300/	June	2,0	2,4	2,3	2,3	2,2	1,7	1,5	0,6	0,6	1,0	1,0	1,6	1,1	2,3	1,8
I4278	July	2,3	2,0	2,4	2,7	4,0	2,2	1,8	1,5	1,1	0,8	1,9	1,4	0,9	2,0	1,5

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