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TÍTULO: NIGHTGLOW OH (8,3) BAND INTENSITIES AND ROTATIONAL TEMPERATURE AT 23°S

AUTORES: H. Takahashi e B.R. Clemesha

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H. Takahashi and B.R. Clemesha

Instituto de Pesquisas Espaciais - INPE

São José dos Campos - São Paulo

Brazil

ABSTRACT

The OH (8,3) band airglow emission has been observed over 1 year at a latitude of 23°S. The average band intensity observed was 385 Rayleighs with a nocturnal range typically less than 100 R. The nocturnal variation in rotational temperature was usually less than 10°K, and the mean temperature was 179°K. The nocturnal variation of intensity is usually uncorrelated with that of the rotational temperature. Time average values of these parameters do, however, show some correlation. On some occasions large post-twilight and pre-dawn intensity enhancements are observed.

1. OBSERVATIONS

This paper presents the results of some observations of the vibration-rotation spectrum of the OH (8,3) band night airglow emission. The observations were made at São José dos Campos (23.2°S, 45.9°W) between July 1972 and April 1973, and at Cachoeira Paulista (22.7°S, 45.2°W) between May 1973 and July 1973.

A tilting filter photometer was employed, in conjunction with a ratemeter and pen recorder, to determine the zenith intensities of the P, Q and R branches of the OH (8,3) emission and the background continuum. An EMI 9558 B photomultiplier cooled to below 0°C was used. The characteristics of the photometer are given in Table 1.

Table 1 - Photometer Characteristics

Aperture	: 5 cm
Field of view	: 3° full angle
Filter bandwidth	: 20 Å (for normal incidence)
Center wavelength	: 7320 Å (P branch measurement)
	: 7281 Å (Q branch measurement)
	: 7242 Å (R branch measurement)
	: 7200 Å (Background measurement)
Absolute sensitivity:	≈ 10 counts sec^{-1} $Rayleigh^{-1}$.

Absolute calibration of the photometer was carried out using a calibrated radioactive standard light source, the filter transmission curves being determined experimentally for the various tilt angles. Calibration to check the photometer sensitivity variation was made several times during each night's observations. In subtracting the background light, we assumed its spectrum to be flat between 7200 and 7300 Å. This assumption should not cause more than 3% systematic error in the observed intensities, and $5^{o}K$ in the derived rotational temperature.

We believe that the absolute intensities measured are good to ± 10%, the relative intensities within ± 5% and the rotational temperatures to ± $5^{o}K$.

2.-DATA REDUCTION

The intensity of the ith emission line in a rotation-vibration band when thermal equilibrium exists (Herzberg, 1950) is given by

$$I_i(J) = C\,\nu_i^3\,S_J\,\exp.-\left(\frac{F_{(J)}\,hc}{k\,Trot.}\right) \qquad (1)$$

where, J is the total angular momentum quantum number in the upper rotational level, C is a constant, ν_i is the wave number of ith line, S_J is the line stregth, $F_{(J)}$ is the rotational term value of the upper vibrational level, Trot. is a rotational temperature, k, h and c are constants with their usual meanings.

When, as in our case, individual lines are not resolved, the measured intensity suitable corrected for the background continuum can be expressed as,

$$I = \sum_i \phi(\nu_i)\ I_i(J) \tag{2}$$

where $\phi(\nu_i)$ is an instrumental factor whose wavelength dependence is controlled mainly by the filter used. By suitable choice of filter and tilt angle it is arranged that the main contribution to I comes from the P, Q or R branches, according to the angle. On the basis of equation (2) and knowing the relative line intensity from equation (1), it is possible to calculate the expected intensities for the known different tilted filter transmission functions. The ratios of these intensities depend only on the rotational temperature, and thus this quantity can be determined. In calculating the $I_i(J)$ values we have used airglow data from Wallace (1960), laboratory data from Dieke and Crosswhite (1948) and Hill and Van Vleck's (1928) formula to determine the F(J) values, and Hönl and London's (1925) formula to determine the line strength.

In practice we use the ratio of R to Q branches to determine the rotational temperature because this varies most rapidly with temperature. Figure 1 shows this intensity ratio and the ratio of P to Q branches as a function of Trot., and also shows the expected measured intensity ratio between the tilted filter positions.

These curves are not identical because the overlapping of branches is taken into account by carrying out the summation of equation (2) over all lines for which $\phi(\nu_i)$ is not negligible, rather than restricting it to a given branch. This method for determining rotational temperature was suggested by Meinel (1950).

The total band intensity is calculated by taking the measured intensity with the filter tilt corresponding to the R branch, and using the measured temperature to determine the fraction of the band intensity which this represents.

3. RESULTS AND DISCUSSION

3.1 - Band Intensity and Rotational Temperature

The average OH (8,3) band intensity for 20 nights of useful observations between July 1972 and July 1973 was 385 $\pm$ 40 Rayleighs. This value is less than the values (approximately 450 R) obtained by workers at middle latitudes in the northern hemisphere. The average rotational temperature during the period was 179 $\pm$ 5^{o}K. Figure 2 shows the daily mean values of the intensity and the rotational temperature. No pronounced systematic variation in intensity was observed over the period. A possible summer maximum in temperature is apparent, but more measurements are required to confirm this.

These results are consistent with Shefov's suggestion (Shefov, 1969) that OH intensity, rotational temperature and the seasonal variations of these parameters are probably minimum in the region of 20 ≈ 25^{o} latitude in the northern and southern hemispheres.

Figure 3 shows the mean rotational temperature measured by us (double circle), and the results of other workers at various latitudes. The continuous curves shows the summer and winter atmospheric temperature at 85 ~90 km altitude (after U.S. Standard Atmosphere Supplement, 1966). The solid bar shows the standard deviation of our daily mean value and the dashed line shows the total range. It can be seen that whilst most middle and high latitude measurements of rotational temperature have given values considerably greater than expected, our values do not differ significantly from the standard atmosphere temperature.

On the basis of the hydrogen-ozone reaction, generally assumed to be responsible for the production of excited OH, one would expect a correlation between temperature and intensity to occur as a result of the temperature dependence of the rate coefficient. Plotting the average band intensity against average temperature, such a correlation can be seen to exist, as shown in Figure 4. The averaging here has been carried out over periods of about 3 hours, before, around and after midnight.

In Figure 4 we also show a theoretical temperature dependence, calculated on the basis of the rate coefficient given by Bortner and Kummler (1970), $a = 2.6 \times 10^{-11}$ exp. (-500/T), and normalized to give 350 Reyleighs at 180^{o}K. The crosses in Figure 4 are for those nights when a large variation in intensity was observed. It may be seen that on these occasions the intensity is considerably higher than the average. Excluding these points, however, it does appear that part of the observed intensity variation is the result of temperature changes.

3.2 - Nocturnal Variations

The most frequently observed tendency is for a minimum intensity to occur near midnight. This type of variation has been observed by Nakamura (1961) and Shefov (1971). Figure 5.a shows some typical examples. On these nights, the rotational temperature variations are quite small and show no systematic trend, except for a slight increase or decrease during the course of a night. These observations do not agree with the results of Sivjee et al. (1972) and Dick (1972). Both of these groups, the former working at about 40^{o}N, and the latter at 32^{o}N, observed large variations in both intensity and temperature. On the other hand, Harrison et al. (1971), working at 51^{o}N, observe no systematic nocturnal variation in rotational temperature for the (4,1) and (5,2) bands.

There appears to be, then, a considerable lack of consistency between the results of various workers, a lack which can not be explained on the basis of a latitudinal effect.

The lack of correlation between the nocturnal variations in intensity and rotational temperature may be explained by changes in local concentration of the reacting species at a constant height, or by an additional OH production mechanism. Downward transport of atomic oxygen would result in an intensity increase without appreciable change in rotational temperature (Harrison et al., 1971 and Gattinger, 1971). Rao and Kulkarni (1971) measured a maximum OI5577 emission around midnight. This suggests that vertical transport of atomic oxygen may be responsible for both the OI5577 maximum and the OH minimum. Such transport could be due to atmospheric tides, but in this case a correlated temperature change would be expected. A variation in the eddy diffusion, perhaps itself resulting from tidal or gravity wave energy input, seems to be a more plausible explanation.

Figure 5.b shows the results for two occasions when slow variations in intensity were accompanied by well correlated temperature changes. These variations could be the direct result of atmospheric tides. The previously quoted rate coefficient gives the right order of magnitude for the intensity variations, assuming that they are mainly due to the observed temperature changes, and the latter are of the same order as those predicted by Chapman and Lindzen (1970) for the solar diurnal tide. We would expect, of course, that the intensity should be affected not only by temperature variations, but also by tidal density changes, and in this context it should be noted that Kent et al. (1972) have measured density variations as large as 30% in the region of 90 km altitude.

Figure 5.c shows examples of atypical, short duration large intensity enhancements. On these nights, the rotational

A correlation is observed, however, between the long term variations of the time averaged values of these parameters. This correlation is explained on the basis of the temperature dependence of the Hydrogen-Ozone reaction.

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FIGURE CAPTIONS

Figure 1. - Calculated intensity ratios of R to Q branches and P to Q branches of the OH (8,3) band (dashed lines) and the expected measured intensity ratios, I(R)/I(Q) and I(P)/I(Q), as a function of rotational temperature.

Figure 2. - Long term variations of the OH (8,3) intensity and rotational temperature.

Figure 3. - OH rotational temperature vs. latitude. *Present work (◎) and the results of other workers; mean winter value (▲), mean summer value (●), mean value of several months (o) and mean value of less than 3 months (X). The continuous curves show the summer and winter atmospheric temperature at 85 ~ 90 km altitude (after U.S. Standard Atmosphere Supplement, 1966). The solid bar shows the standard deviation of our daily mean value and the dashed line shows the total range.*

Figure 4. - Measured OH (8,3) intensity vs. rotational temperature. *The circles show 3 hour mean values and the crosses are for the nights when a large intensity variation was observed.*

Figure 5.a, 5.b and 5.c - Nocturnal variation of the OH (8,3) band intensity and the rotational temperature.

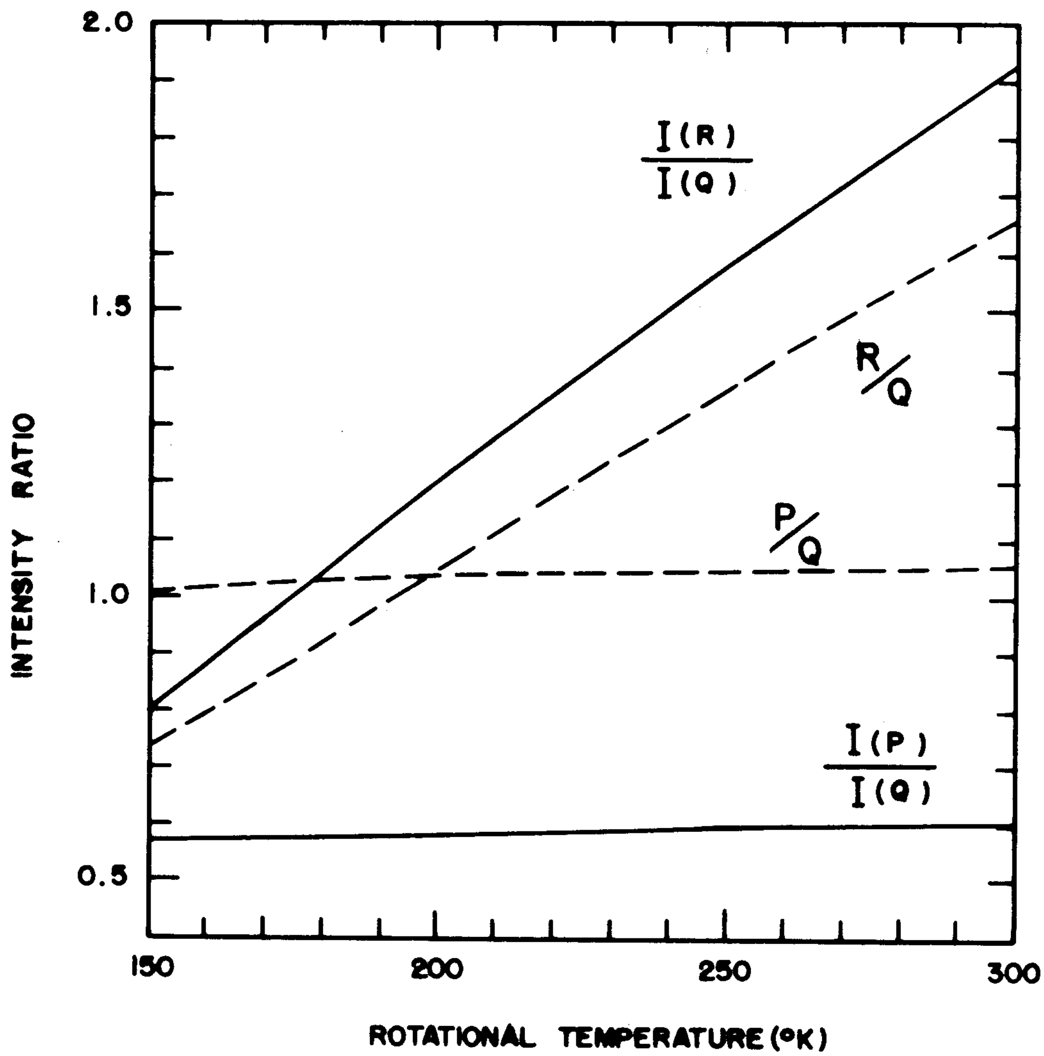
2.0
1.5
1.0
0.5
INTENSITY RATIO
I(R) / I(Q)
R/Q
P/Q
I(P) / I(Q)
150
200
250
300
ROTATIONAL TEMPERATURE (°K)

Figure 1

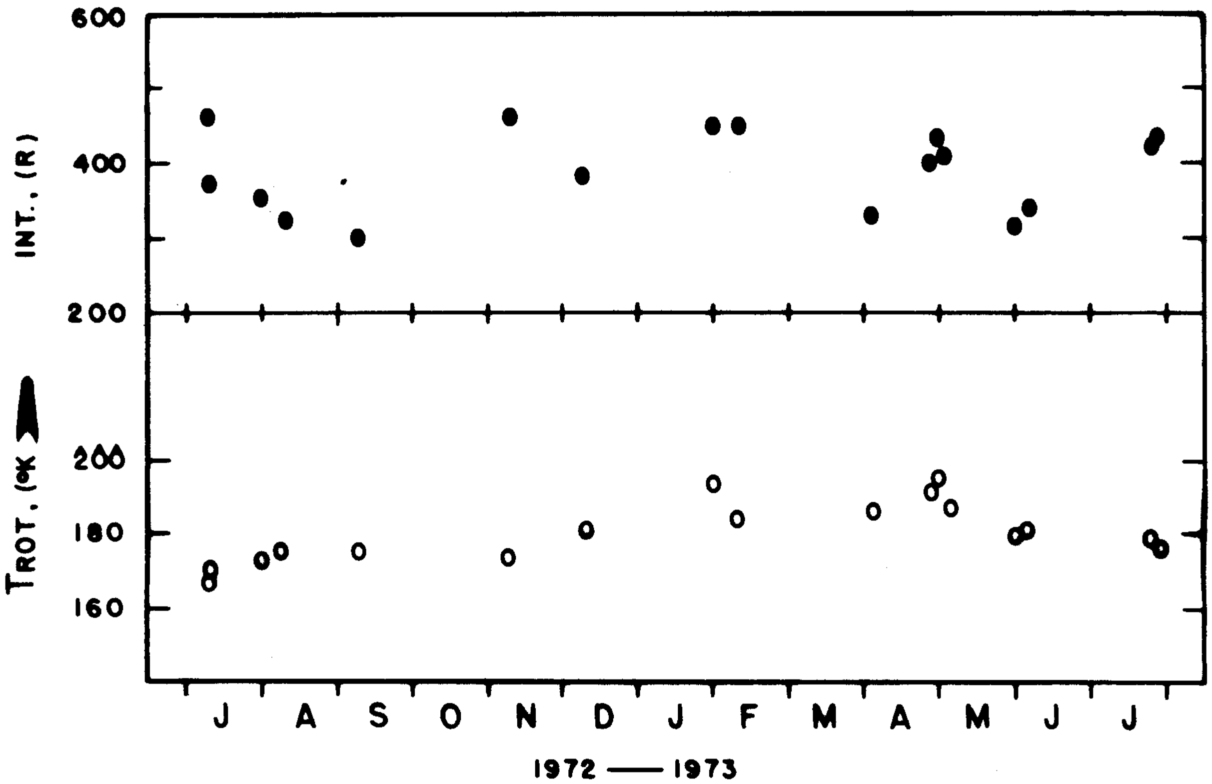

Figure 2

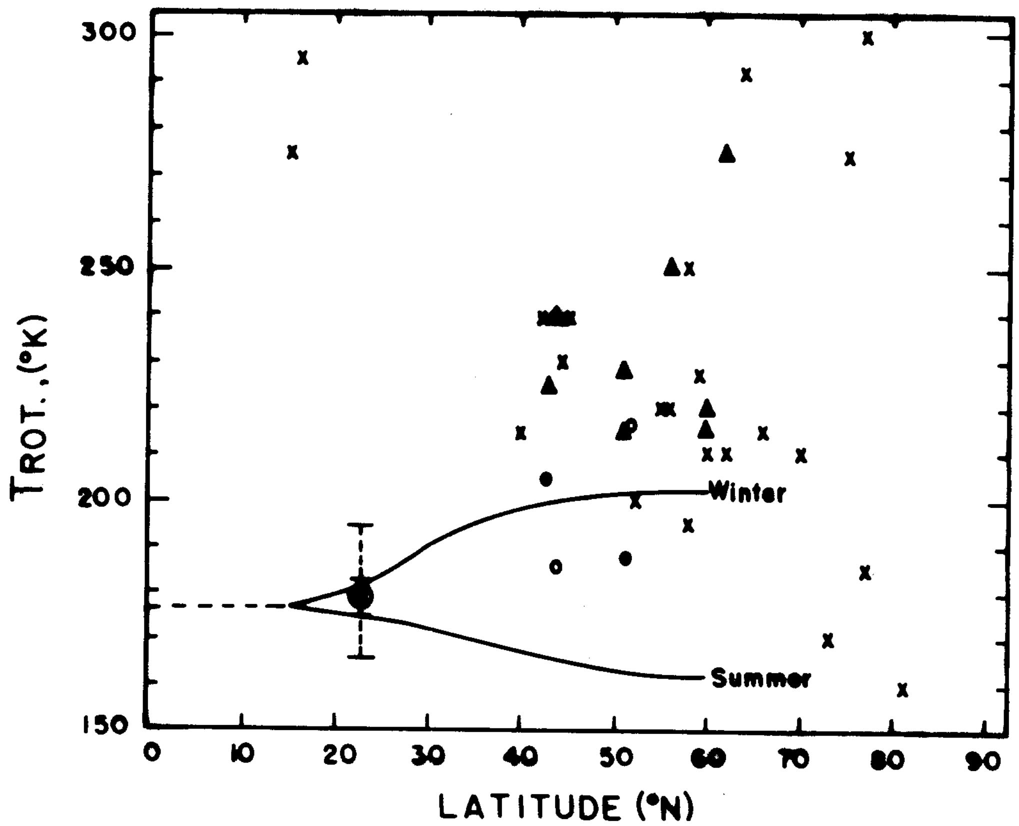
300
250
200
150
$T_{ROT.}$ (°K)
0
10
20
30
40
50
60
70
80
90
LATITUDE (°N)
Winter
Summer

Figure 3

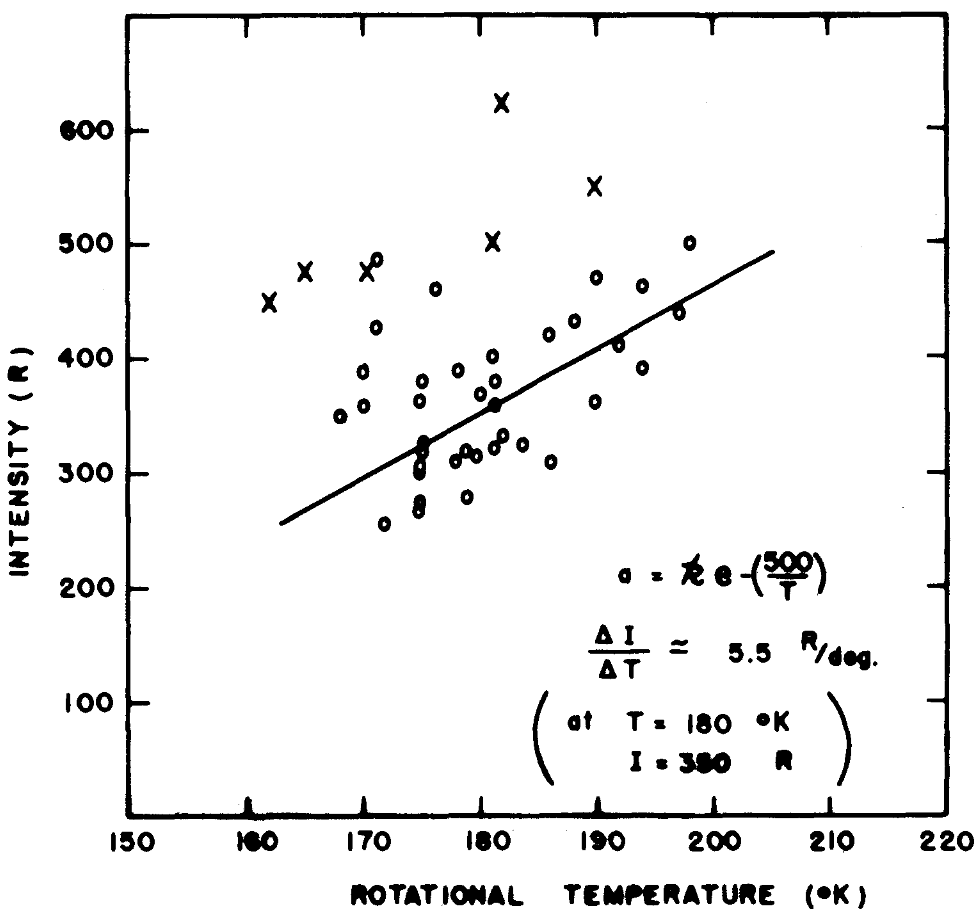
600
500
400
300
200
100
INTENSITY (R)
150
160
170
180
190
200
210
220
ROTATIONAL TEMPERATURE (°K)
ΔI/ΔT ≃ 5.5 R/deg.
at T = 180 °K

Figure 4

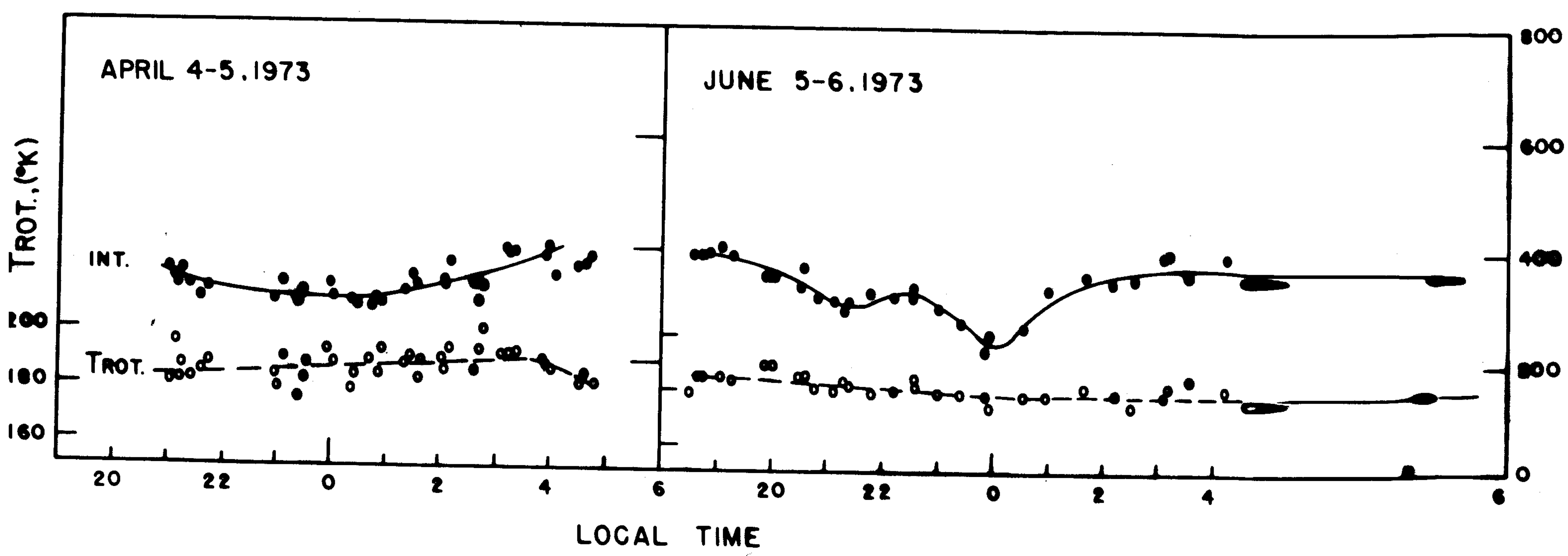
APRIL 4-5, 1973
JUNE 5-6, 1973
INT.
TROT.
TROT.,(°K)
200
180
160
INT., (R)
800
600
400
200
0
20
22
0
2
4
6
LOCAL TIME

Figure 5.a

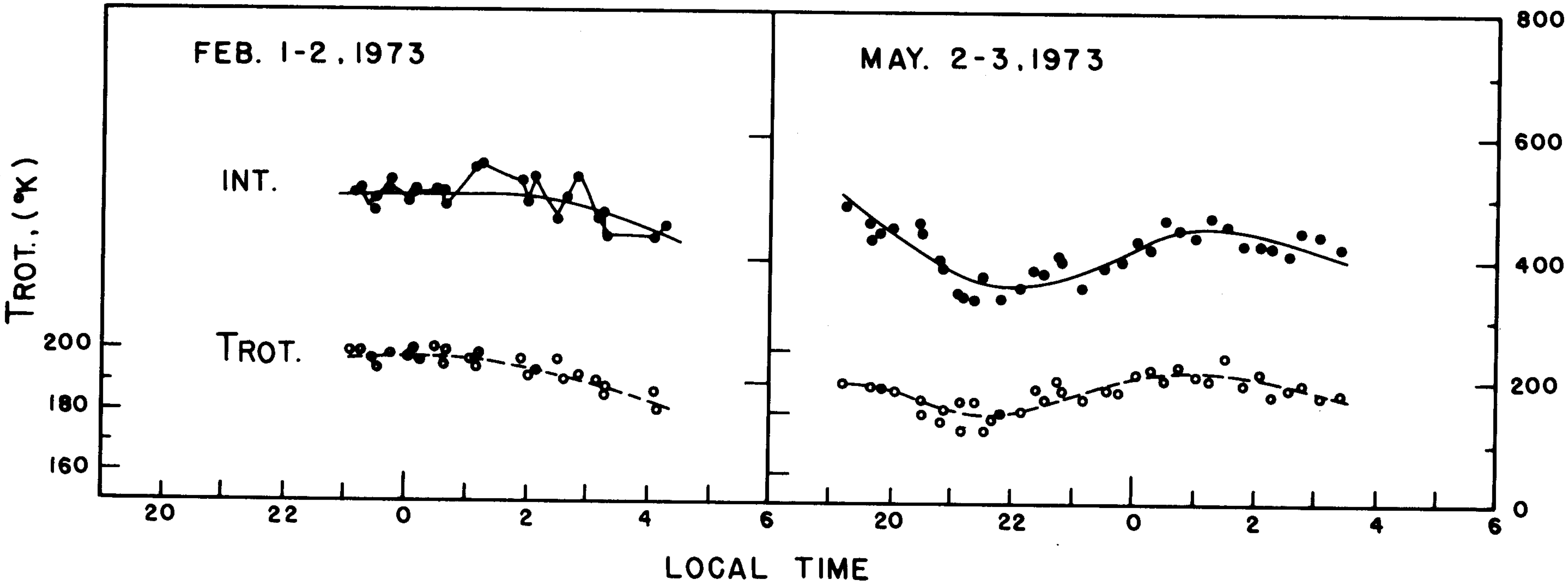
FEB. 1-2, 1973
MAY. 2-3, 1973
INT.
TROT.
TROT., (°K)
200
180
160
INT., (R)
800
600
400
200
0
20
22
0
2
4
6
LOCAL TIME

Figure 5.b

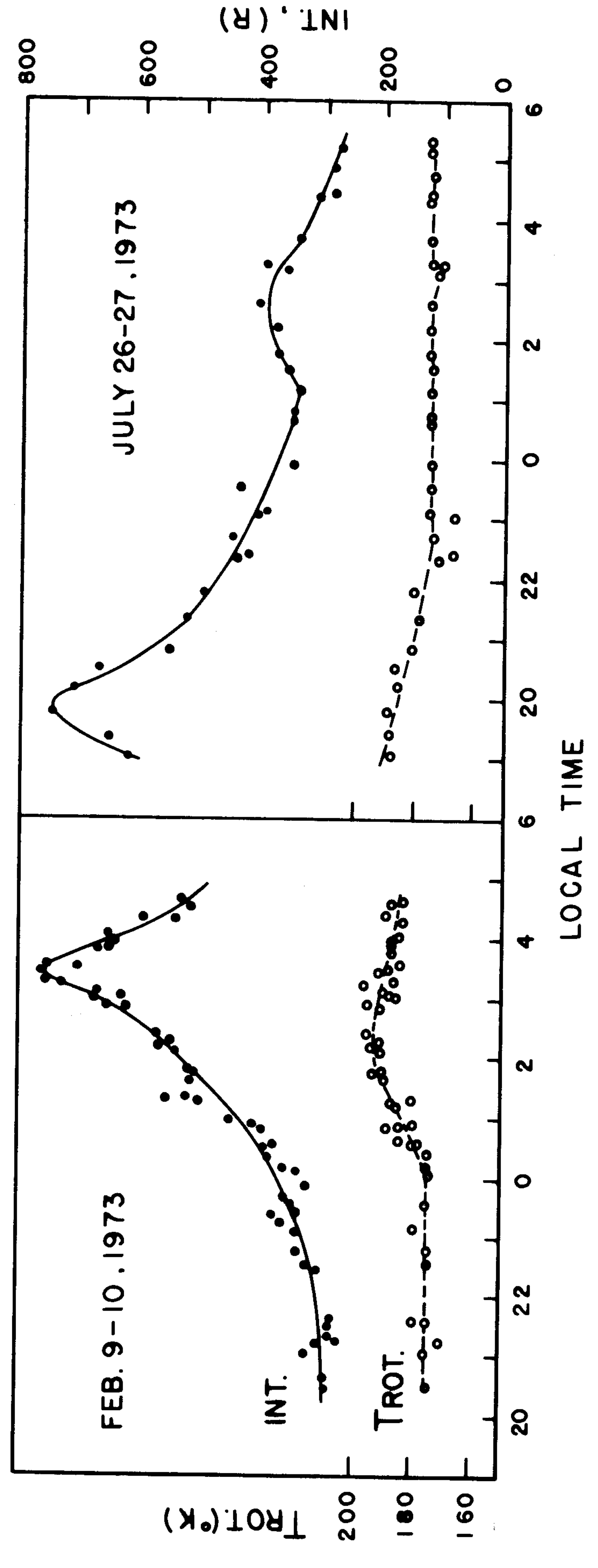
FEB. 9-10.1973
JULY 26-27.1973
INT.
TROT.
INT., (R)
TROT.(°K)
LOCAL TIME
800
600
400
200
0
200
180
160
20
22
0
2
4
6

Figure 5.c