SOME RESULTS OF OBSERVATIONS OF HYDROXYL EMISSION FROM THE UPPER ATMOSPHERE IN ABASTUMANI

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ABSTRACT: Variations in OH emission were obtained during a solar cycle. The minimum intensity for 1962-1963 had a greater amplitude than that for 1954-1955. The seasonal variations in rotational temperature have a greater amplitude for the bands from the upper vibrational levels. A study of the intensity variations in the OH bands, in relation to the zenith distance, shows that an increase in T (OH) corresponds to a lowering of the emitting layer.

During the International Quiet Solar Year, electrophotometrical and spectral observations of the OH emission in the airglow were conducted in Abastumani. /44

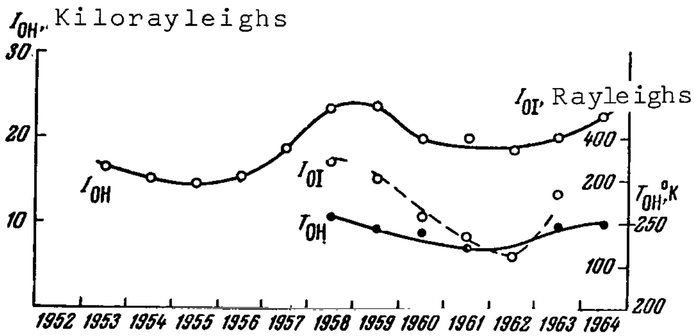

Fig. 1. Variations in the Average Annual Values for Intensity of the OH Bands, Intensity of the λ5577 Emission, and Rotational Temperature for the OH Band (9.3), during a Solar Cycle.

The electrophotometrical observations were accomplished with the aid of a wide-angle electrophotometer in the spectral region Δλ(9000-10,550) Å; the absolute total intensity of the OH bands (8.4), (3.0), (9.5), and (4.1) were measured at the zenith [1, 2]. The observations which were conducted in 1961-1964 confirm the results of previous years [3], that the intensity of the OH emission changes during a cycle of solar activity. Figure 1 shows the behavior of the average annual total intensities for these OH bands from 1953 to 1964. The maxima and the minima of activity for the hycroxyl emission of the upper atmosphere coincide with the periods of maximum and minimum solar activity. We should note that the second minimum in Figure 1, which corresponds to the last, nineteenth, cycle of solar activity, is shorter and of lesser amplitude for the illumination activity than is the minimum which corresponds to the preceding cycle. This circumstance confirms the concept that the new, twentieth, cycle of the solar activity began before the old one ended; in October, 1963, there already appeared a patch of the new cycle [4]. In 1963, the intensity of the OH emission increased /45 sharply, in comparison with 1962. Figure 1 also shows the curve for the variation in average annual intensities of the line 5577 [OI]; having reached a minimum in 1962, it also began to increase from 1963.

The variations in average annual values for the rotational temperature of hydroxyl emission, according to the spectral observations in Abastumani, are small throughout the course of the solar cycle. The minimum also occurs at the period for the minimum solar activity. The amplitude of these variations is small; for example, for $T(9.3)$, it is 18° K (Fig. 1), which is close to the error in determining T_{OH}, while, for $T(6.1)$, it does not exceed the error in the measurements. In the same way as during the preceding years, the maximum intensity of the OH emission and the rotational temperature is observed during November-December, while the minimum is observed during March-May. In comparing the seasonal variations of T_{OH} obtained for the bands (9.3), (6.1), and (5.2), it was found that the amplitude of the seasonal variations of T_{OH} is greater for the bands with a higher number for the vibrational levels. We can see from Figure 2 that the amplitude of the seasonal variations for $T(9.3)$ is almost twice that of the amplitude in seasonal variations for $T(6.1)$ and $T(5.2)$. In other words, during an increase in T_{OH} in the corresponding periods of the year, $T(9.3)$ increases more rapidly than does $T(6.1)$ or $T(5.2)$. This phenomenon conforms with the previously observed increase in the difference $T(9.3)$-$T(5.2)$ and $T(9.3)$-$T(6.1)$ for high rotational temperatures (T_{OH} > 250° K) [5, 6].

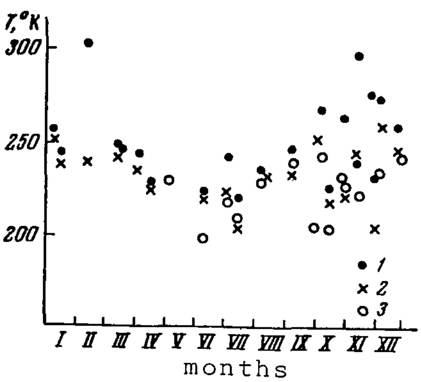

Fig. 2. Seasonal Variations in Rotational OH Temperature for 1964. The Average Values for Nights Which Are Rather Close in Time: (1) $T(9.3)$; (2) $T(6.1)$; (3) $T(5.2)$.

During the IQSY, the electrophotometrical and spectral observations of the OH emission in Abastumani were conducted with the aid of the devices and methods which were developed and used during the IGY. A study was also made on a further refinement of the spectral and electrophotometrical observations of the airglow. In particular, a recording electrophotometer was designed which provides for recording continuously during the course of a night in a given direction; it records the absolute intensity of the OH band (6.2) λ8400 Å simultaneously with the absolute total intensity of the bands in the region λ9200-11,800 Å. The electrophotometer is a short-focus reflector with a parabolic mirror of 280 mm in diameter; the input block of the photoelectric section with the photomultiplier FEU-22 is located at the Nesmith focus. The recording is made on the three-channel recording machine EPP-09. The diameter of the field of vision for the electrophotometer is 3.5°. The circuit of the electrophotometer and the method of calibration in absolute units are described in detail in [7].

The electrophotometer has the following sensitivity: in the region λ8400 Å, divided by an interference light filter with a half-width for the transmission band of 90 Å, q_λ = 21 Rayleigh/division; in the region λ9200-11,800 Å, divided by a light filter IKS-3 with a thickness of 6 mm, q_λ = 43 Rayleigh/division. The light filters change automatically in step with change in channels on the EPP-09; the third channel is used for recording the dark background. The OH band (6.2) is included in the range of transmittance for the first light filter; the following six OH bands are included in that for the second: (8.4), (3.0), (9.5), (4.1), (5.2), and (6.3), and the contribution of the bands with $v' \leq 6$ is equal to 85%, while that for the bands with $v' \geq 8$ is 15%. Then, we can evaluate, in first approximation, the change in relative intensity of these bands, and, by the measurements of total absolute intensity, we can obtain the absolute intensity of each band, considering the relative intensity according to [8]. For example, the Table below shows the results of observations on the night of December 6-7, 1964: the ratio between I (6.2) and I (5.2) for each hour at the zenith, and in the directions North 67°/South 67°. The average measured intensity of the OH band (6.2) at the zenith is equal to 1600 Rayleighs, while that of the OH band (5.2), obtained on the basis of measurements for the total intensities, is equal to 11,000 Rayleighs. These values, and their ratio, correspond with the intensities shown in [9]. /46

VARIATIONS IN INTENSITIES OF THE OH BANDS DURING ONE NIGHT

Zone time	I (6,2) Rayleighs	$\frac{I^N (6,2)}{I^S (6,2)}$	I (5,2) Rayleighs	$\frac{I^N (5,2)}{I^S (5,2)}$	$\frac{I (6,2)}{I (5,2)}$
20^h15^m	1920	1,03	16 900	1,06	0,11
21 00	1840	1,05	13 200	1,06	0,14
22 00	1730	0,94	12 300	0,91	0,13
23 00	1600	1,08	10 500	1,09	0,15
0 00	1770	1,04	12 200	1,03	0,14
1 00	1490	0,92	10 000	0,95	0,15
2 00	1250	0,87	9 700	0,87	0,13
3 00	1270	0,81	9 400	0,80	0,14

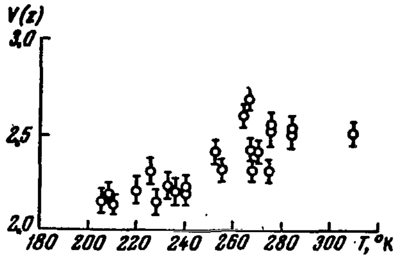

Fig. 3. Dependence of the Ratio Between Intensity of the OH Band (6.2) for z = 67° and the Same Intensity at the Zenith on the Rotational Temperature of OH (6.1).

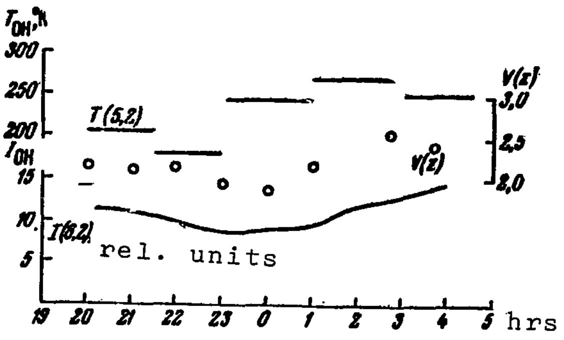

Fig. 4. Nocturnal Variation in Rotational Temperature T(5.2), and of the Ratio Between Intensity of the OH Band (6.2) for z = 67° and Its Intensity at the Zenith, and the Nocturnal Variation in OH (6.2) Intensity in Relative Units (December 4-5, 1964. /47

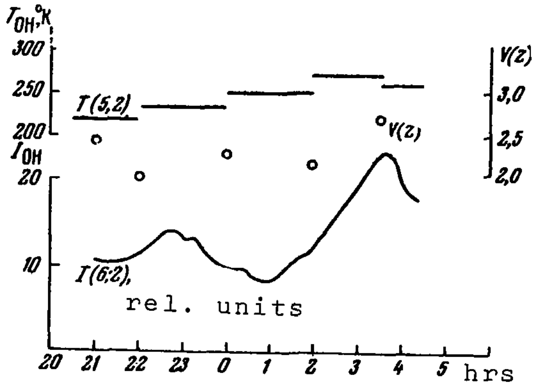

Fig. 5. Nocturnal Variation in Rotational Temperature T(5.2), and of the Ratio Between Intensity of the OH Band (6.2) for z = 67° and Its Intensity at the Zenith, and Nocturnal Variation of the OH (6.2) Intensity in Relative Units (January 4-5, 1965).

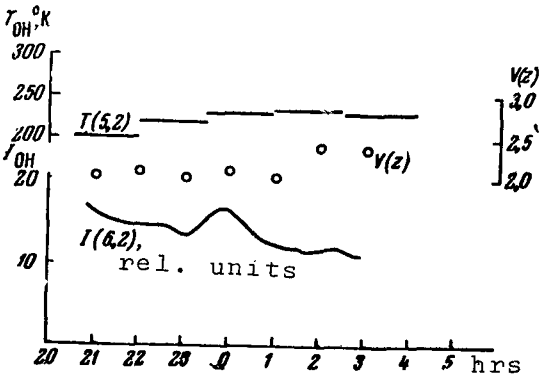

Fig. 6. Nocturnal Variation of the Rotational Temperature T (5.2), and of the Ratio Between Intensity of the OH Band (6.2) for z = 67° and Its Intensity at the Zenith, and Nocturnal Variation of the OH (6.2) Intensity in Relative Units (December 6-7, 1964).

Observations in three directions (z = 0°, z = 67° N, and z = 67° S) showed that the OH emission, generally speaking, is not distributed uniformly over the sky, and that in most cases, the ratio North 67°/South 67° is more or less one unit, and varies during the night. We should mention here that, in order to examine the patchiness and the spatial variations of the illumination, the infrared region of the spectrum can be used so that the effect of the continuous background, including the stellar component, is insignificant in it. Keeping in mind the latter circumstance, as well as the small field of vision of the recording electrophotometer, we attempted to study the distribution of intensity for the OH band (6.2) along the meridian, in relation to z, for all those nights when the emission was distributed uniformly over the sky, i.e., when the ratio North/South did not change during the course of the night and remained approximately equal to 1. We selected nights with a high and stable /48 transmissivity. We found 23 nights in all which satisfied these conditions. We determined the value (Van Ryan function) $V = (z) = I_z/I_0$ for z = 67°. The value for $V(z)$ depends on the altitude of the emitting layer. However, for precise determinations of the altitude of the emission, the Van Ryan method was ineffective, because of the non-uniformity of the emission over the sky and the sensitivity of the method to measurement accuracy for the transmission coefficient and a consideration of the scattering in the troposphere. The second argument against the Van Ryan method is, possible, not as serious for those segments of the infrared spectrum in which there are no bands of water absorption. In any case, for these 23 nights with a homogenous distribution of the emission over the sky, we obtained a value for this ratio of $V(z) = 2.4 \pm 0.2$, which is within the interval of values $V(z)$ corresponding to an emission of OH at an altitude of 60-100 km [10, 11]. However, the error in determining $V(z)$ is very high. This does not allow for making an accurate determination of the variations in height of the OH emission by using this method. Therefore, we were limited to only relative comparisons of the variations in the ratio $V(z)$ from night to night, and during the course of one night. These variations can be of interest in relation to the variations in rotational temperature of the hydroxyl emission. The $V(z)$ which was obtained with the aid of the recording electrophotometer for the OH band (6.2) was compared to the rotational temperature T_{OH} determined during the same nights for the OH bands (6.1) and (5.2) with the aid of the spectrographic method, in the direction z = 67° N.

Figure 3 shows values of $V(z)$ averaged per night, in relation to T(6.1). We can see from the figure that $V(z)$ increases with an increase in T_{OH}. The same relationship was obtained in attempting to compare the variation of T_{OH} during the course of one night with the variation of $V(z)$ and the intensity of the OH band (6.2). The nocturnal variation of the rotational temperature obtained for the OH band (5.2) with 2- and 1.5-hour exposures was compared with the nocturnal variations of $V(z)$ and I(6.2) obtained from electrophotometrical data (Figs. 4 to 6). It was found that the increase in T_{OH} is accompanied by an increase in $V(z)$ in all three cases, and with an increase in the intensity, in two cases (when T_{OH} > 250° K [12]).

Thus, $V(z)$, in relation to T_{OH}, behaves as if the increase in the rotational OH temperature were accompanied by a lowering of the emitting layer. Although, for reliable conclusions, the accuracy and the quantity of the data presented here are insufficient, it is possible that a relationship between $V(z)$ and T_{OH} is real. The variations in rotational temperature of OH observed up to now - seasonal, from night to night, and during the course of one night - are most probably the result of a change in the height of the emitting layer and of the variations in the non-uniformity of the emitting layer by height, in relation to the dynamic processes in the upper atmosphere [13]. Rocket measurements of the temperature in the upper atmosphere show that, at altitudes of 60-100 km at middle latitudes, the temperature changes within the range of 250-300° K at 60-65 km, within 170-200° K at 80-85 km, within 200-240° K at 90-100 km [14]. Therefore, we can assume that the rotational temperature T_{rot} > 250° K actually corresponds to a lowering of the maximum emitting layer to an altitude lower than 70 km.

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