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TENTATIVE IDENTIFICATION OF THE HERZBERG BANDS OF O_2 IN THE ULTRAVIOLET SPECTRUM OF THE NIGHT SKY*

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As is well known, the identifications of the night-sky bands are still very unsatisfactory; even the strongest ultraviolet feature at λ 3556, which appears always in long spectroscopic exposures on faint nebulae, is still unidentified. Some time ago, I had the privilege of receiving from Dr. J. Dufay, of Lyons (France), a manuscript copy of an interesting paper in which a rather convincing identification is suggested for the strong ultraviolet bands, including λ 3556.[1] Dufay believes that these may be due to the "forbidden" transition $^3\Sigma_u^+ \rightarrow {}^3\Sigma_g^-$ (Herzberg system) of O_2. This band system has been observed only in absorption in the region λ 2400–λ 2900. The absorption consists of a progression $v'' = 0$, each $(v', 0)$ band having only a Q branch ($\Delta K = 0$) degraded to the red; the lower electronic level is the ground state of O_2. Dufay suggests that several night-sky emission bands are the $(v' \rightarrow v'' > 0)$ transitions of the Herzberg system.

The $v'' = 0$ progression, which was found in laboratory absorption by G. Herzberg,[2] has been measured by several authors[3] either in the laboratory or in atmospheric absorption. The measured wave lengths of the origins agree within about one angstrom unit for the bands of $\lambda \leqslant 2637$. Herman has measured three additional weak bands to the red of λ 2637, at λλ 2685.0, 2737.6, and 2795.2; and there may still be two more at approximately λ 2843 and λ 2912. Hence the actual v' designations are still in doubt, but the energies E' (v') are fairly well known.

To obtain the v' = constant progressions, Dufay determines the $\nu(v', v'')$ formula of the system by least-squares solutions, accepting for the v'' term a simplified expression obtained from the Schumann-Runge and the atmospheric O_2 bands, which have the same lower electronic level $^3\Sigma_g^-$. Then Dufay compares the calculated values of $\lambda(v', v'')$ with his wave lengths of the night-sky features and finds several cases in satisfactory agreement.

I have undertaken a similar discussion on the basis of the results on the night-sky spectrum obtained at the McDonald Observatory.[4] Instead of using least-squares solutions, I have simply taken for the upper state the "best" $\nu(v')$ corresponding to the observed Herzberg absorption bands.[5] For the ground electronic state I have used the formula, including the v''^3 and v''^4 terms, obtained by J. Curry and G. Herzberg,[6] which is better for large values of v'' than the simplified quadratic formula used by Dufay. More refined calculations are useless. The wave lengths of the night-sky spectrum are not accurately known, and we do not have accurate information on the widths or profiles of the bands. Moreover, we do not know what the rotational-intensity distribution should be in the night-sky bands of a specific molecule. From the observations we gather that the rotational-intensity distribution is of a low-temperature type. Yet we

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[1] Dufay's note has probably been published in the *Comptes rendus*, Paris. See Bull. 3 of the Committee for the Continued Distribution of Astronomical Literature, October, 1941.

[2] *Naturwissenschaften*, **20**, 577, 1932.

[3] Chalonge and Vassy, *C.R.*, **198**, 1318, 1934; Herman, *Ann. de Phys.* (11th ser.), **11**, 548, 1939; Miss N. Morguleff and Mrs. A. Vassy, *Ann. d. Ap.*, **1**, 427, 1939.

[4] Elvey, Swings, and Linke, *Ap. J.*, **93**, 337, 1941.

[5] The uncertain bands λ 2843 and λ 2912 are not retained; hence $v' = 0$ is adopted for λ 2795.2.

[6] *Ann. der Phys.*, **19**, 800, 1934.

cannot, a priori, determine the amount by which the observed rotational centers of gravity of specific bands should be shifted to the red, relative to the band origins. Such a temperature shift may even be different for different values of v'![7]

Taking into account the various sources of uncertainty, a number of coincidences are found, the majority of which are probably real. They are listed in Table 1: column 1

TABLE 1

HERZBERG BANDS OF O_2 IN THE NIGHT-SKY SPECTRUM

λ and Int. in Night Sky	O_2 Identification	
	Transition	λ (Calc.)
3110 (0)	(6,5)	3111
3145 (1)	(1,3) (3,4)	3141 3143
3157 (0)	((5,5)	3164)
3211 (3)	(7,6) (0,3) (2,4)	3205 3208 3209
3233 (θ)	(4,5)	3224
3263 (1)	(6,6)	3257
3298 (3)	(3,5)	3294
3321 (2)	(5,6)	3315
3378 (5)	(2,5) (0,4) (4,6)	3367 3368 3381
3425 (1)	((6,7)	3414)
3460 (2)	(1,5) (3,6)	3451 3459
3488 (3)	(5,7)	3478
3556 (10nn)	((2,6) (0,5) (4,7)	3539) 3542 3552
3598 (0)	((6,8)	3585)
3636 (2)	(1,6) (3,7)	3631 3637
3664 (1)	(5,8)	3656
3707 (3)	(7,9)	3702
3742 (4)	((0,6) (4,8)	3733) 3737
3834 (4)	(1,7) (3,8)	3828 3831
3948 (3)	(4,9) (0,7)	3939 3942
3984 (2)	((6,10)	3973)
4048 (2)	(1,8) (3,9)	4044 4044
4072 (5)	((5,10)	4060)
4174 (5)	((4,10) (0,8)	4160) 4172

contains the night-sky wave lengths and intensities, as found at the McDonald Observatory;[4] columns 2 and 3 contain the identifications which should be added to the ones previously given.[4] The v' values are uncertain, and they may possibly have to be increased by one or two units. The wave lengths in column 3 refer to the band origins, which should lie slightly to the violet of the observed maxima of the night-sky lines.

The O_2 bands provide probably the major contributions for all the lines of wave length $\lambda < 3598$, excepting possibly λ 3378 and λ 3425 but including the strong, unidentified lines. For $\lambda > 3598$ the influence of the Vegard-Kaplan system becomes important.

[7] This shows again the importance of renewed attempts to obtain the ultraviolet spectrum of the night sky with a better resolving power than has hitherto been available.

Assuming that the identification is correct, the average red shift of the observed bands, relative to the calculated band origins, corresponds to a temperature of the order of 150° K.

In a number of details the identifications given in Table 1 differ from the ones suggested by Dufay, but they favor his general hypothesis. As mentioned by Dufay, the excitation potential of the Herzberg bands is of the order of 4.5 volts; hence, it is not very different from the energy of the upper level of the green [*O* I] line (4.2 volts). The emission of the O_2 bands may be expected if the luminescence is excited according to Chapman's mechanism (recombination of two oxygen atoms). According to Herzberg,[8] the $^3\Sigma_u^+ \rightarrow {}^3\Sigma_g^-$ system is more likely to appear than the Schumann-Runge bands of O_2.

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[8] Private communication.