IDENTIFICATION OF EMISSION BANDS IN P/HALLEY

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ABSTBACT

Spectrophotometric studies of P/Halley (r = 1.98 AU, Δ = 1.19AU, r = 1.97, Δ = 1.16 AU and r = 1.95 AU, Δ = 1.13 AU) in the spectral range 3900 A – 6450 A were made on three nights and identifications of emission features include: CO^+, C_3, C_2, CN, CH, NH_2, H_3, NaI, OI and H_2O^+ molecules. For the first time H_3 molecule has been found in cometary atmospheres. Certain strong emission bands have been found in the spectra of P/Halley which are yet to be identified.

INTRODUCTION

Larson[1] and Wyckoff and Wehinger[2] observed the emission features of certain molecules in P/Halley on October 14.4 UT respectively. Larson[1] reports that there was no evidence of discrete coma features till October 15 but Wyckoff and Wehinger[2] report the emission bands of CO^+ and H_2O^+ ions, observed on October 18 and they have found only a few emission bands of certain molecules. The present paper reports the identifications of different radicals, molecules and ions in P/Halley. The principal aim of this investigation is to search for spectroscopic signature of H_3 molecule.

P/Halley was observed on three nights during pre-perihelion period between 1985 October 28–30 when the heliocentric distance varied from 1.97 to 1.95 AU and the geocentric distance varied between 1.19 and 1.13 AU. The observations were obtained with the 102 cm telescope of Vainu Bappu Observatory. The automated spectrum scanner[3] used with this telescope included a 1800 lines mm^{-1} grating blazed at 5000 A (first order) and a 51 cm focal length F/20 camera mirror, the detector was an EMI 9658 photomultiplier tube connected to a photon counting system. P/Halley was observed in the spectral regions 3900–5050 A, 5050–6050 A and 6050–6450 A at 2.99 A, 2.67 A and 2.54 A intervals with an exit slit of 20 A. On each night, before the comet observations were commenced, three standard stars, αLyra, ηHya and χ^2Ceti, were scanned to provide the nightly extinction values and the wavelength dependence of instrumental sensitivity. The sky brightness was measured immediately preceding and following the cometary scans. After correcting for this background sky brightness, the data were reduced on a VAX-11/780 using the spectrophotometric reduction package developed by A. V. Raveendran, to yield normalized magnitudes. We have normalized at 4785 A, 5377 A and 6330 A for the spectral regions 3900–5050 A, 5050–6050 A and 6050–6450 A respectively. The spectrum of P/Halley obtained was noisy and to improve it, with regard to signal-to-noise ratio, we have taken running average by 60 A over the entire range of the spectra and then superimposed many spectra of the same spectral region. The wavelength calibration of the scanner cannot be determined to better than 2 A. Since we have allowed the whole comet through the diaphragm, we are unable to isolate the head, coma and tail energy distributions. However, from figure 1 it is seen that the continuum energy distribution of P/Halley (3900–5050 A) is almost like the tail energy distribution of comets[4]. Relatively strong lines and bands of different atoms, molecules, radicals and ions detected in P/Halley are presented in table 1 and their spectra are shown in figures 1–3. Though we have not measured the intensities of each band sequence, the intensity of C_2 (0–0) band system is clearly seem to be the strongest one. Sodium emission lines are visible but are not sufficiently strong. Since the emission of NaI lines is a resonance fluorescence phenomena, their emission features (5890 A and 5896 A) proves that this phenomena has already started in P/Halley when it was at a heliocentric distance 1.98 AU. Figure 2 presents that there are H_3 molecule in the atmosphere of P/Halley. Herzberg and collaborators[5,6], detected and identified several prominent band systems in H_2 discharge spectra as being due to H_3 and they suggested that this molecule might be observed in some astrophysical sources. H_3O^+ ion, which has recently been detected in the atmosphere of

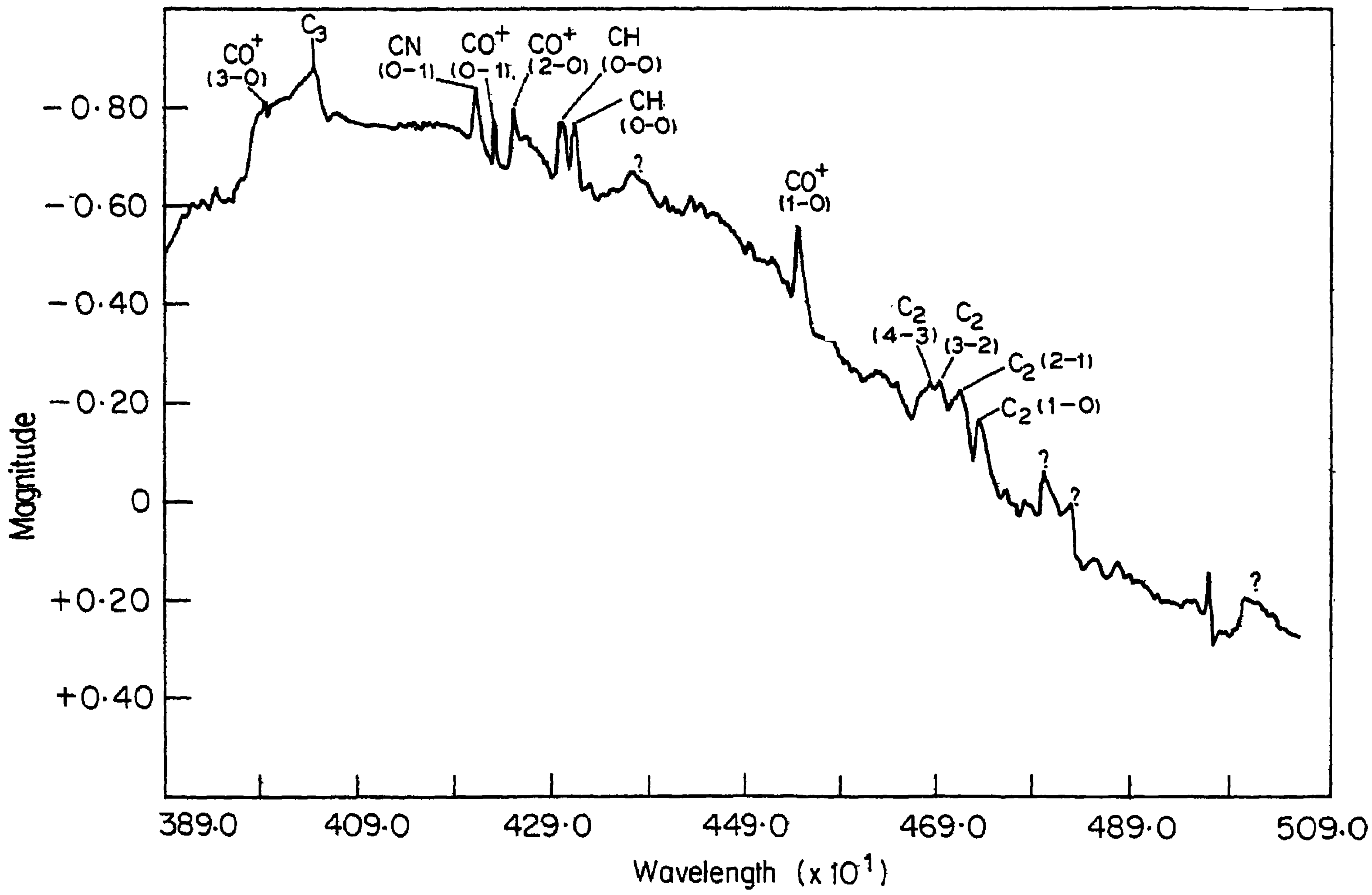

Figure 1. Spectra of P/Halley in the spectral region 3900–5050 A and normalized at 4785 A.

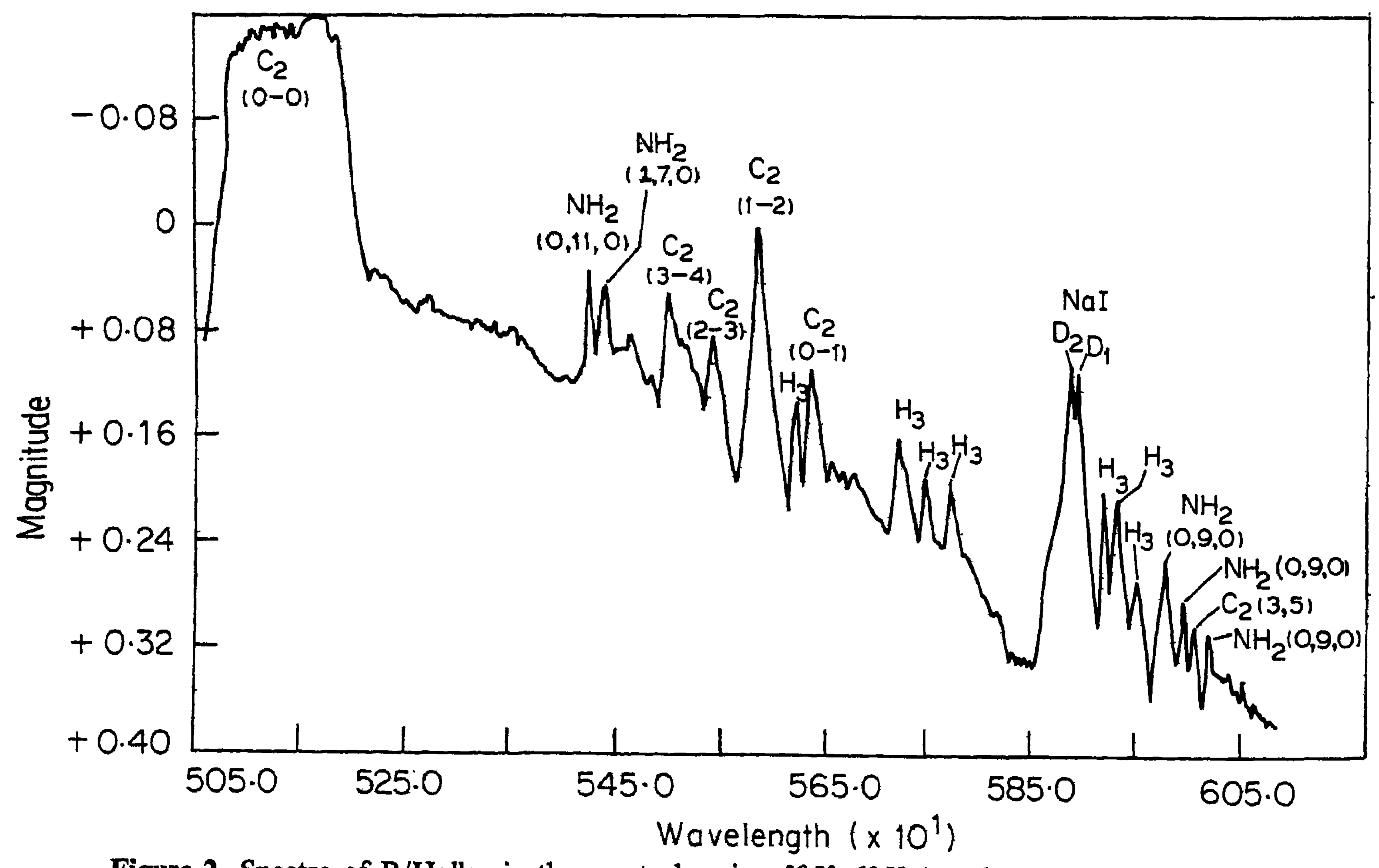

Figure 2. Spectra of P/Halley in the spectral region 5050–6050 A and normalized at 5377 A.

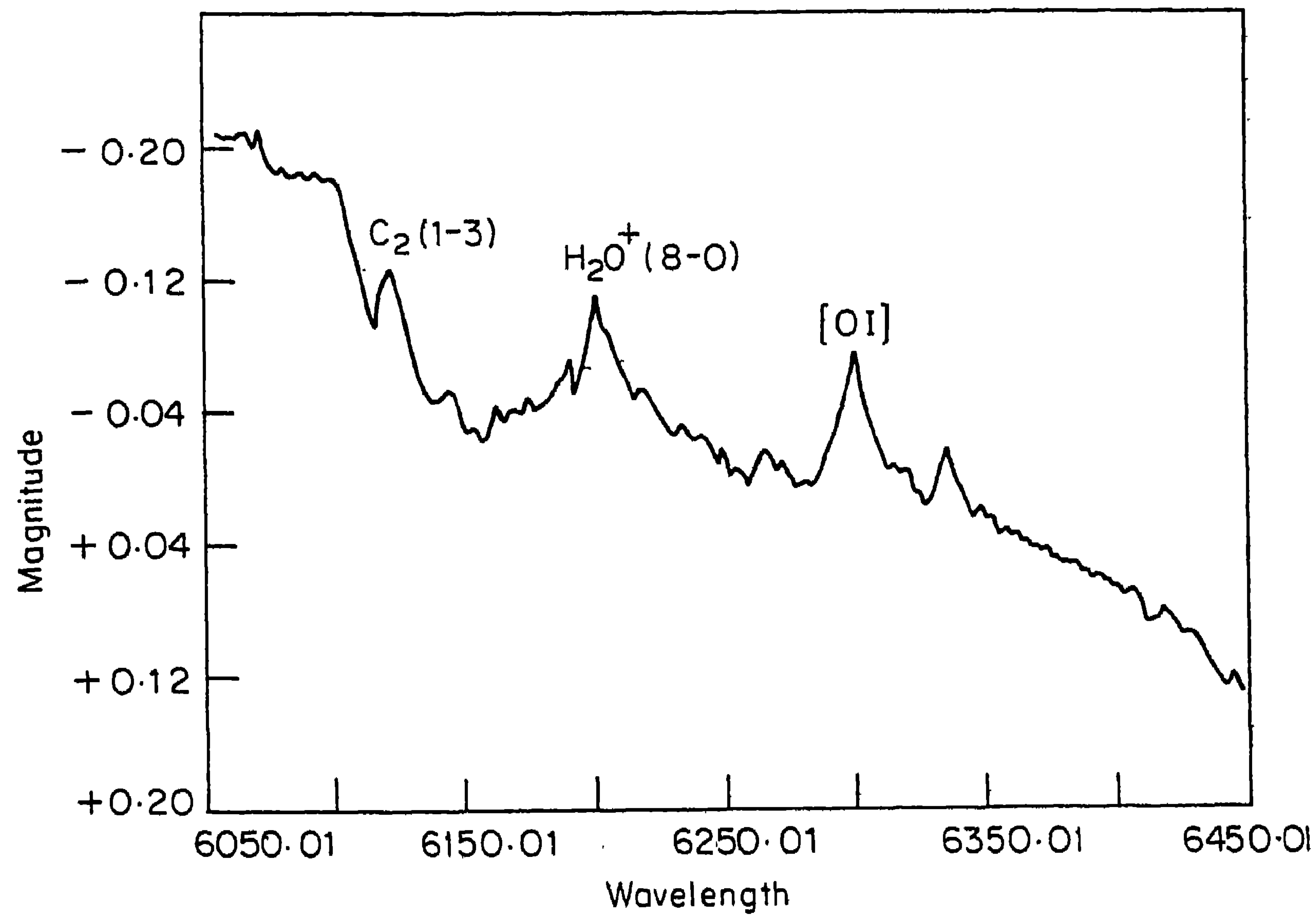

Figure 3. Spectra of P/Halley in the spectral region 6050–6450 A and normalized at 6330 A.

Table 1 *Identified atoms, molecules and ions in the atmosphere of P/Halley*

Observed wavelength (A)	Laboratory identification		Observed wavelength (A)	Laboratory identification
4000	CO^+	(3–0) Head	5542	C_2(2–3) Head
4052	C_3			P_3 (17), P_1 (18),
4216	CN	$(B^2\Sigma - X^2\Sigma)$ (0–1)		P_2 (17), . . .
		Head P (17), P (18)	5585	C_2(1–2) Head
				P_1 (18), P_1 (17), . . .
4231	CO^+	$(B^2\Sigma - X^2\pi)$ (0–1)		$H_3(\lambda_{Lab} = 5621.0)$
		Head	5623	
4252	CO^+	$(A^2\pi - X^2\Sigma)$ (2–0)		
		Head	5635	C_2(0–1) Head
				P_3 (14), P_3 (15), . .
4304	CH	$(A^2\Delta - X^2\pi)$ (0–0)		
		R_1 cd(1), R_1 dc (1)	5723	$H_3(\lambda_{Lab} = 5722.0)$
4313	CH	$(A^2\Delta - X^2\pi)$ (0–0)	5751	$H_3(\lambda_{Lab} = 5750.3)$
		Q_2d(3), Q_2d(2), . . .		
			5774	$H_3(\lambda_{Lab} = 5773.4)$
		Q_1c(2), Q_1d(2)	5890	NaI D_2
4545	CD^+	$(A^2\pi - X^2\Sigma)$ (1–0)		
		Head	5897	NaI D_1
4685	C_2	(4–3) Head	5922	$H_3(\lambda_{Lab} = 5920.2)$
4697	C_2	(3–2) Head	5932	$H_3(\lambda_{Lab} = 5931.5)$
4715	C_2	(2–1) Head	5953	$H_3(\lambda_{Lab} = 5953.1)$
4737	C_2	(1–0) Head	5977	NH_2(0, 9, 0) 3_{03}–3_{13}
5165	C_2	(0–0) Head		5_{05}–5_{15}, 1_{01}–1_{11}
		P_3 (18), P_1 (19)		
			5994	NH_2(0, 9, 0) 1_{01}–2_{11},
		P_2 (18), . . .	6004	C_2(3–5) Head
5428	NH_2	(0, 11, 0)		
		2_{02}–2_{12}, 4_{04}–4_{14},	6021	NH_2(0, 9, 0) 3_{03}–4_{13},
		3_{03}–3_{13}, 1_{01}–1_{11},	6122	C_2(1–3) Head
5443	NH_2	(1, 7, 0) 2_{21}–1_{11},	6200	H_2O^+ (8–0), P
				P_2, N-$2^{(2)}$
5502	C_2	(3–4) Head	6300	[O I]

P/Halley[7] may be the important constituent for the formation of H_3 molecule. The excitation mechanism of H_3 molecule may be as follows:

$$H_3O^+ + e \rightarrow H_2O + H, \quad (1)$$
$$\rightarrow H_2 + OH, \quad (2)$$
$$\rightarrow H_3^* + O \rightarrow H_2 + H + O. \quad (3)$$

Reactions (1) and (2) may be the dominant channels for reaction between H_3O^+ and e. However, reaction (3) may produce metastable H_3^* molecule (H_3) and it may emit radiation in different band systems of H_3. From the laboratory results of similar type of reactions between H_2O^+ and e, which are as follows[8]

$$H_2O^+ + e \rightarrow OH + H \quad (4)$$
$$\rightarrow H_2^* + O \rightarrow 0 + H + H, \quad (5)$$

it can be expected that reaction (3) is also probable. Detected band systems of H_3 are presented in table 1 and their apparent relative intensities and the laboratory results are in good agreement. Many strong emission bands have been found in the spectra of P/Halley which are yet to be identified. It is difficult at present to indicate the detailed excitation mechanism of H_3 molecule in the neutral atmosphere of P/Halley. It is, therefoere, necessary to accumulate more observations on P/Halley for a better insight into the excitation mechanisms of different molecules, radical and ions in its atmosphere.

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