

IDENTIFICATION OF EMISSION BANDS IN P/HALLEY

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ABSTRACT

Spectrophotometric studies of P/Halley ($r = 1.98$ AU, $\Delta = 1.19$ AU, $r = 1.97$, $\Delta = 1.16$ AU and $r = 1.95$ AU, $\Delta = 1.13$ AU) in the spectral range 3900 Å – 6450 Å 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

LARSON¹ and Wyckoff and Wehinger² observed the emission features of certain molecules in P/Halley on October 14.4 UT respectively. Larson¹ reports that there was no evidence of discrete coma features till October 15 but Wyckoff and Wehinger² 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 scanner³ used with this telescope included a 1800 lines mm^{-1} grating blazed at 5000 Å (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 Å, 5050–6050 Å and 6050–6450 Å at 2.99 Å, 2.67 Å and 2.54 Å intervals with an exit slit of 20 Å. On each night, before the comet observations were commenced, three standard stars, α Lyra, η Hya and χ^2 Ceti, 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 Å, 5377 Å and 6330 Å for the spectral regions 3900–5050 Å, 5050–6050 Å and 6050–6450 Å 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 Å 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 Å. 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 Å) is almost like the tail energy distribution of comets⁴. 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 Å and 5896 Å) 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

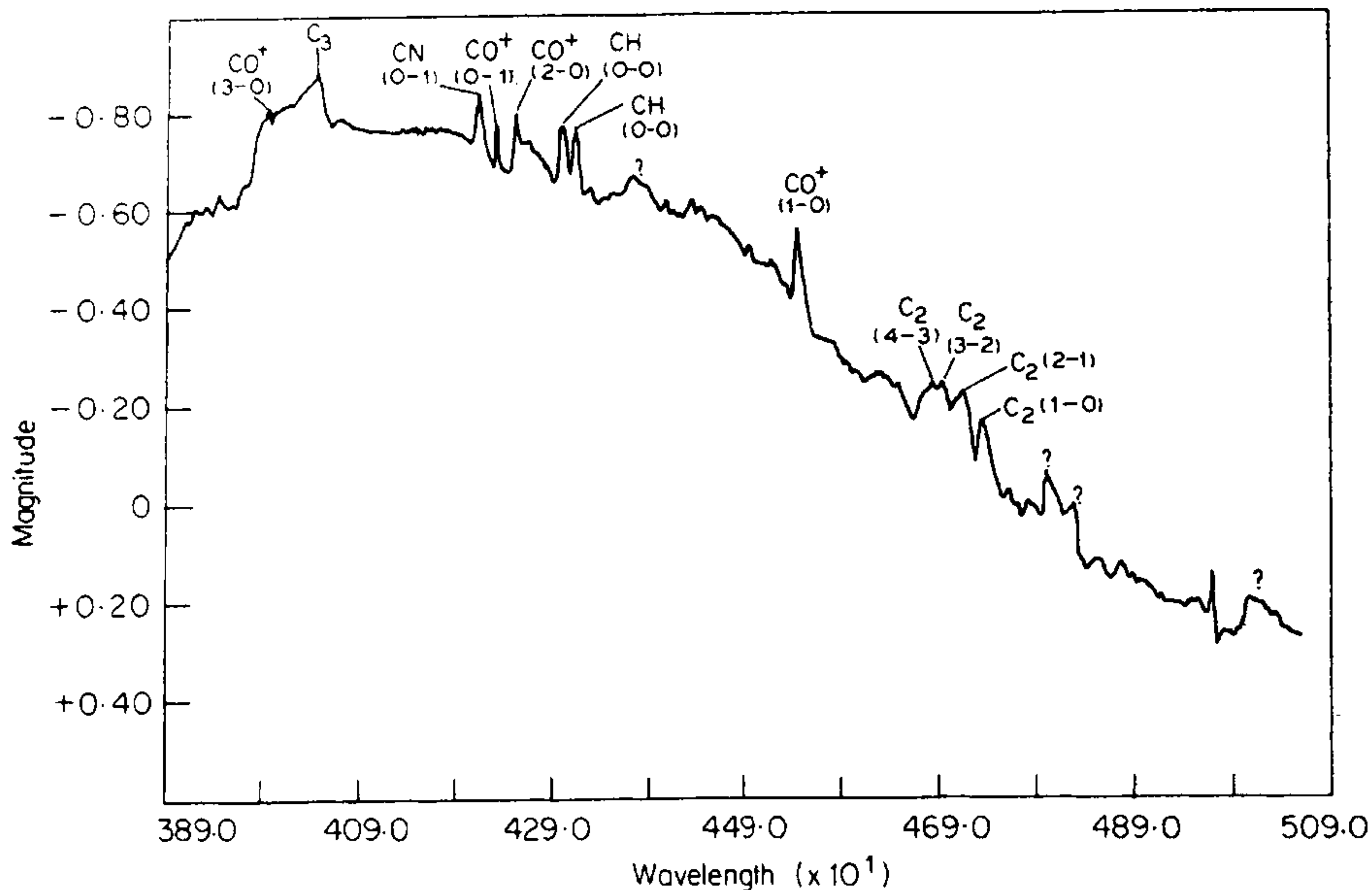


Figure 1. Spectra of P/Halley in the spectral region 3900–5050 Å and normalized at 4785 Å.

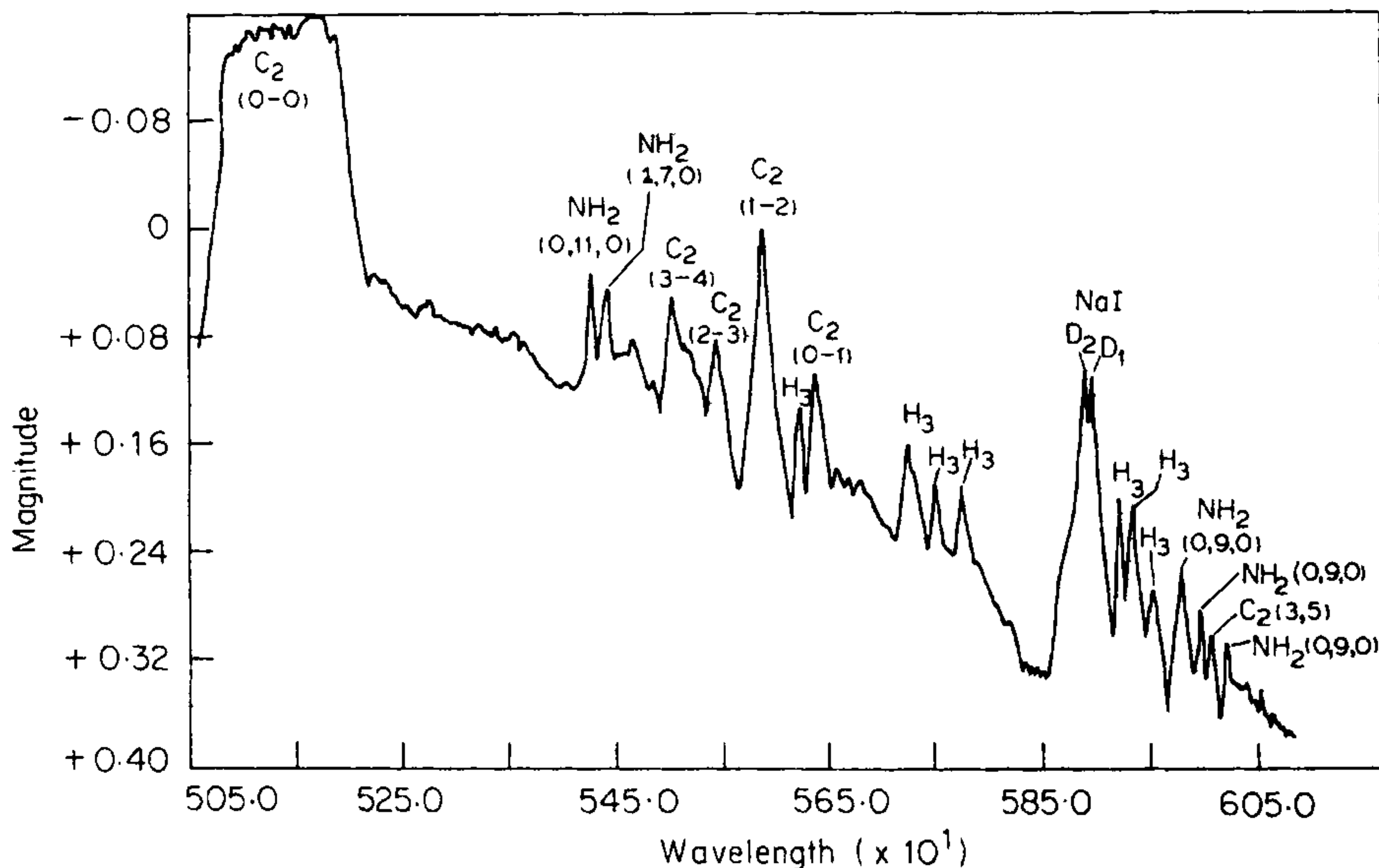


Figure 2. Spectra of P/Halley in the spectral region 5050–6050 Å and normalized at 5377 Å.

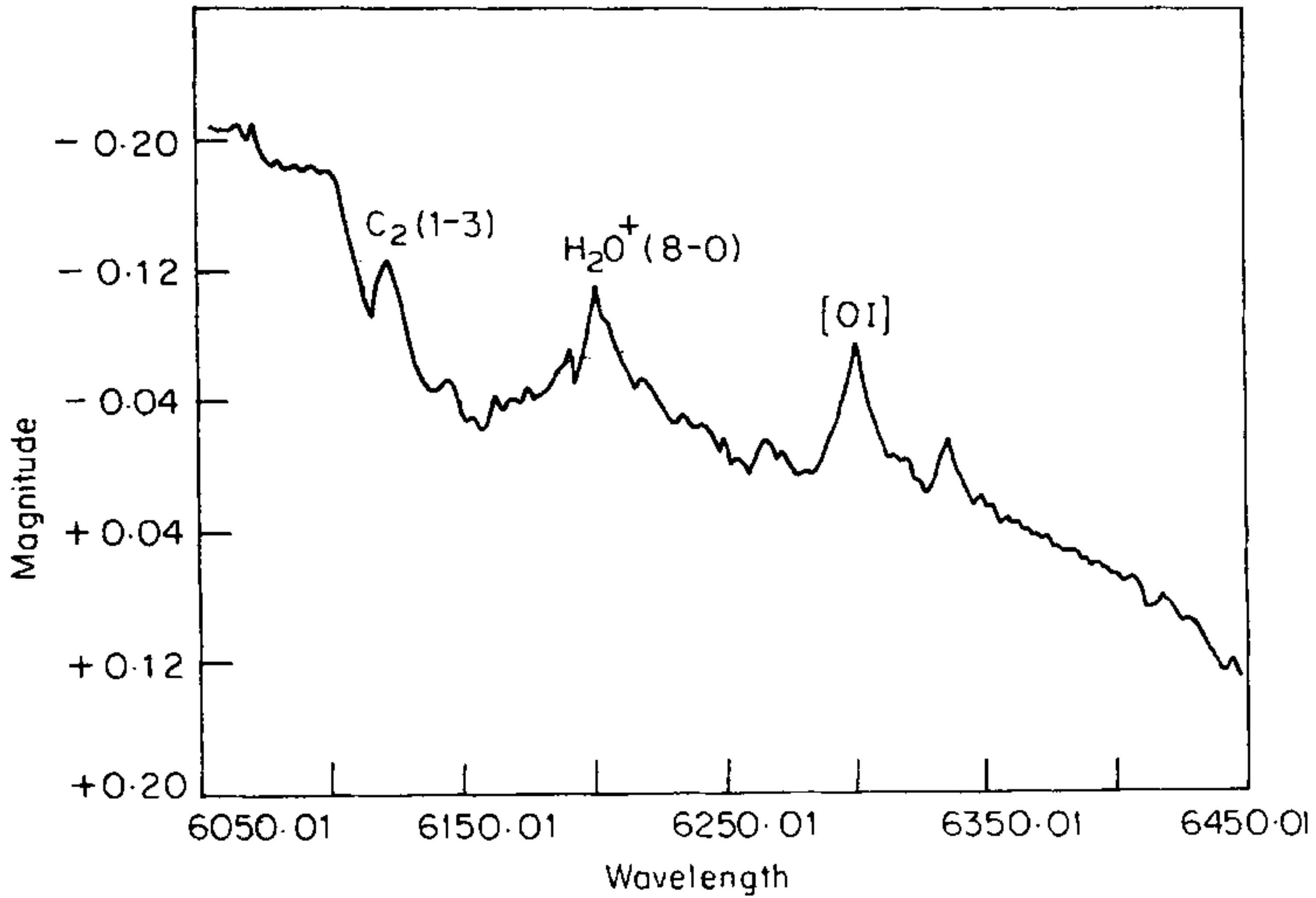
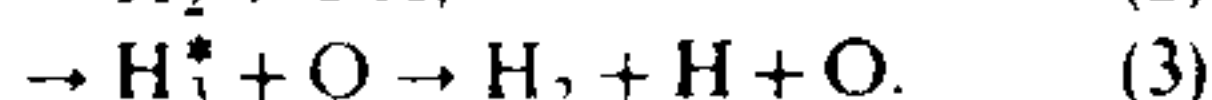
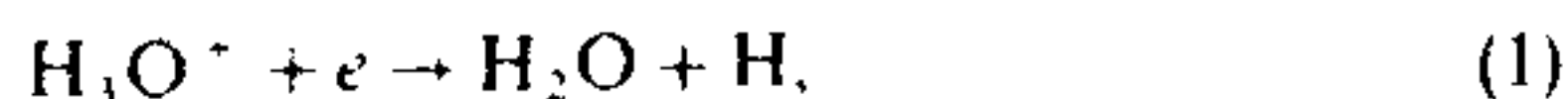


Figure 3. Spectra of P/Halley in the spectral region 6050–6450 Å and normalized at 6330 Å.

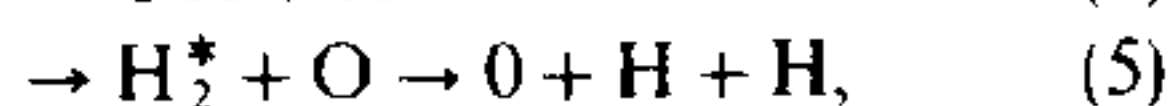
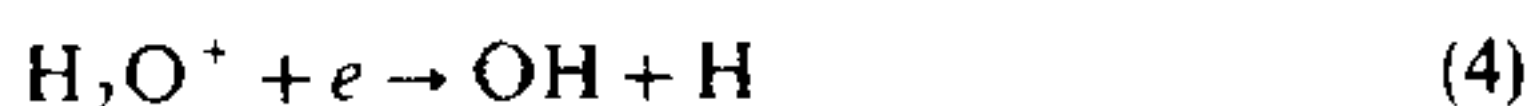
Table 1 Identified atoms, molecules and ions in the atmosphere of P/Halley

Observed wavelength (Å)	Laboratory identification	Observed wavelength (Å)	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 Σ - X ² Σ) (0-1) Head P (17), P (18)	5585	P ₂ (17), ...
4231	CO ⁺ (B ² Σ - X ² π) (0-1) Head		C ₂ (1-2) Head
4252	CO ⁺ (A ² π - X ² Σ) (2-0) Head	5623	P ₁ (18), P ₁ (17), ...
4304	CH (A ² Δ - X ² π) (0-0) R ₁ cd(1), R ₁ dc (1)	5635	H ₃ (λ _{Lab} = 5621.0)
4313	CH (A ² Δ - X ² π) (0-0) Q ₂ d(3), Q ₂ d(2), ...		C ₂ (0-1) Head
		5723	P ₃ (14), P ₃ (15), ...
		5751	H ₃ (λ _{Lab} = 5722.0)
			H ₃ (λ _{Lab} = 5750.3)
		5774	H ₃ (λ _{Lab} = 5773.4)
		5890	NaI D ₂
4545	CD ⁺ (A ² π - X ² Σ) (1-0) Head	5897	NaI D ₁
4685	C ₂ (4-3) Head	5922	H ₃ (λ _{Lab} = 5920.2)
4697	C ₂ (3-2) Head	5932	H ₃ (λ _{Lab} = 5931.5)
4715	C ₂ (2-1) Head	5953	H ₃ (λ _{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 P ₃ (18), P ₁ (19)		5 ₀₅ -5 ₁₅ , 1 ₀₁ -1 ₁₁
		5994	NH ₂ (0, 9, 0) 1 ₀₁ -2 ₁₁ ,
		6004	C ₂ (3-5) Head
5428	NH ₂ (0, 11, 0) 2 ₀₂ -2 ₁₂ , 4 ₀₄ -4 ₁₄ , 3 ₀₃ -3 ₁₃ , 1 ₀₁ -1 ₁₁ ,	6021	NH ₂ (0, 9, 0) 3 ₀₃ 4 ₁₃ ,
		6122	C ₂ (1-3) Head
5443	NH ₂ (1, 7, 0) 2 ₂₁ -1 ₁₁ ,	6200	H ₂ O ⁺ (8-0), P
			P ₂ , N 2 ⁽²⁾
5502	C ₂ (3-4) Head	6300	[O I]

P Halley⁻ may be the important constituent for the formation of H₃ molecule. The excitation mechanism of H₃ molecule may be as follows:



Reactions (1) and (2) may be the dominant channels for reaction between H₃O⁺ and *e*. However, reaction (3) may produce metastable H₃^{*} molecule (H₃) and it may emit radiation in different band systems of H₃. From the laboratory results of similar type of reactions between H₂O⁺ and *e*, which are as follows⁸



it can be expected that reaction (3) is also probable. Detected band systems of H₃ 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 H₃ molecule in the neutral atmosphere of P/Halley. It is, therefore, 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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ANNOUNCEMENT

SYMPOSIUM ON MAN, DEVELOPMENT, BIORESOURCES AND ENVIRONMENT

The 7th Annual Session of The Academy of Environmental Biology, India, will be held at Sagar (MP) from 26–28 December, 1986. On this occasion, a National Symposium on "Man, Development, Bioresources and Environment" is also held. The main objectives of the Session and Symposium comprise of review and analysis of the situations and taking stock of the outstanding problems of the Environment besides providing the scientists a forum for exchange of the informations and updating of the current knowledge of Environmental Pollution and Toxicology.

It is further stated that Dr C. Sreeramulu Chetty, Reader, Department of Zoology, S.V. University, Tirupati, has been selected by the committee for the first 'Journal of Environmental of Biology Prize' of 1985, to be awarded at Sagar.

Further particulars may be had from: Shri Gala Ramesh Reddy, or Shri G. R. Veera Babu, Department of Zoology, S.V. University, Tirupati 517 502.