KODAIKANAL OBSERVATORY

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Photoelectric and Spectrographic Studies of Nova Delphini (1967)

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Abstract

The measurement and analysis of the spectra of Nova Delphini (1967) obtained at Kodaikanal is presented. An estimate of the photospheric temperature of the nuclear star of the nova is also made.

Key words : Nova Delphini—Radial velocities and line profiles—Ionisation temperature

Introduction

Nova Delphini was discovered on July 8, 1967, by Alcock (1967) at a visual magnitude of 5.6. From the prediscovery magnitude records published in later IAU circulars, it appears that the star took nearly 35 days to attain this brightness from an initial value of $12^m.0$. The nova reached a maximum brightness of 3.7 magnitude on 14th December 1967. In this paper we present a detailed study of photoelectric and spectrographic observations of Nova Delphini obtained at Kodaikanal during the period September 12, 1967 to December 13, 1968. This bright slow type nova gave us an unique opportunity to record spectra at different stages of nova development viz. premaximum, principal and early nebular stages.

Photoelectric observations

The first Kodaikanal photoelectric observations on Nova Delphini were made on September 12, 1967, with the photometer on the 20 cm. Cooke refractor. The nova was observed through standard B, V filters. The comparison star was BD + 19°4484 with V = 6.29 and (B-V) = + 0.64. The V magnitudes and the colours obtained by us for the nova are given in Table I. The plotted light curve contains data obtained from the IAU circulars and Onderlicka and Vetesnick (1968) as well as Grygar *et al.* (1968). Figure 1 shows this plot which includes the Kodaikanal observations. During September 1967 the V and (B-V) values were around 4.6 and + 0.37 respectively with a fluctuation of only 0.1 magnitude. After the discovery there

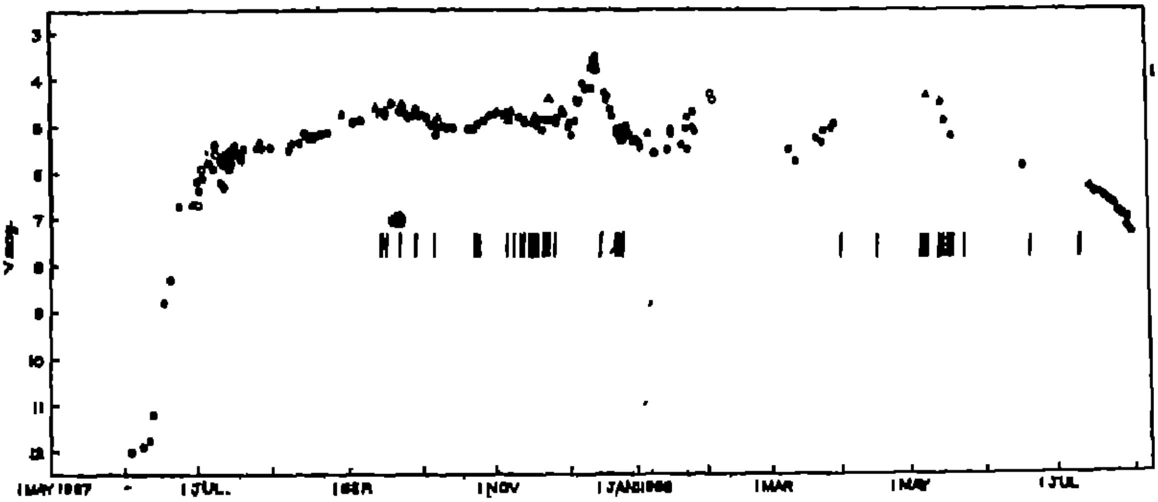

Figure 1 : Light curve of Nova Delphini (1967)
Published photoelectric values
Visual observations
Kodaikanal photoelectric values
Line to indicate the epoch of Kodaikanal spectrograms.

were many conspicuous bursts of $0^m.5$ to $0^m.9$ but the major outburst was reported on December 14, 1967, when the Nova reached the maximum brightness of 3.4 magnitude. The brightness variation of Nova Delphini resembles that of a typical very slow nova.

The Spectroscopic Observations

Our first spectrographic observations of the nova were made on September 15, 1967. The absorption spectrum with faint emission lines recorded on September 15, refer to the pre-maximum stage of the nova's spectral development. The spectra were obtained during the period September 15, 1967 to December 13, 1968.

TABLE I

Nova Delphini 1967—Photoelectric measurements

Date U.T.				V	(B-V)
1967	September	..	12.71	4.60	+0.27
			14.64	4.70	+0.36
			15.69	4.68	+0.38
			23.62	4.52	—
			29.76	4.62	—
	October	..	7.73	4.84	+0.42
	November	..	6.70	4.85	+0.46
			7.63	4.67	+0.34
			18.62	4.84	+0.37
			23.59	4.42	+0.34
	December	..	19.60	4.30	+0.33
1968	May	..	7.94	4.34	—

The spectrograms, discussed in this paper, were obtained with the Cassegrain spectrograph of the 50cm. telescope. The dispersion in the second order is 45 A/mm with the 5-inch camera. During the faint stages of the nova apparition, a 2-inch camera was utilized with the spectrograph for slitless spectroscopy. Details of the spectrograms obtained are given in Table II. The spectral region indicated as photographic, covers from 3800A-4600A. The visual range covers from 4860-6570A. The spectrograms were calibrated for spectro-photometry by a Hilger step wedge filter, attached to an auxiliary spectrograph. Radial velocity measures and line identifications have been carried out with the aid of an Abbe Comparator. Tables III and IV cover identifications made on spectra obtained on September 15 and October 7, 1967, respectively.

TABLE II

Details of Spectrograms of Nova Delphini (1967)

Plate No.	Date of mid-exposure U.T.		Exposure time Minutes	Spectral region (*)	Type of emulsion
1	2		3	4	5
492	1967 September	15.74	120	P	IIa-O
495		17.77	70	P	103a-F
496		23.72	104	P	IIa-O
499		29.71	90	P	IIa-O
500		30.73	90	V	103a-F
503	October	7.74	110	V	103a-F
508		24.63	125	P	IIa-O
514		25.65	120	V	103a-F
518		26.69	130	P	IIa-O
522	November	6.71	68	V	103a-F
524		9.65	135	P	IIa-O
530		12.68	145	V	103a-F
533		14.67	110	P	IIa-O
536		15.64	90	V	103a-F
537		16.65	145	P	IIa-O
538		17.68	93	V	103a-F
539		18.65	140	P	IIa-O
540		19.64	90	V	103a-F
541		22.64	141	P	IIa-O
542		23.64	75	V	103a-F
544		24.64	150	P	IIa-O
545		26.62	85	V	103a-F
548		27.64	90	P	IIa-O
551	December	16.60	75	V	103a-F
552		23.62	38	P	IIa-O
553		24.58	65	V	103a-F
555		26.58	88	V	103a-F
731	1968 April	1.99	55	V	103a-F
743		17.94	80	P	IIa-O
746	May	6.00	10	V	103a-F
750		7.00	5	V	103a-F
751		7.00	15	P	IIa-O
753		7.94	14	P	IIa-O
754		7.96	15	P	IIa-O
756		8.98	6	V	103a-F
764		13.96	6	V	103a-F
769		15.00	7	P	IIa-O
770		15.83	46	I	I-N+H_2O
772		15.95	7	V	103a-F
774		15.98	7	P	IIa-O

* P = Photographic, V = Visual, I = Infrared.

TABLE II—(*Contd.*)

Details of Spectrograms of Nova Delphini (1967)

Plate No.	Date of mid-exposure U.T.		Exposure time Minutes	Spectral region (*)	Type of emulsion
1	2		3	4	5
777		17.93	8	V	103a-F
778		17.96	10	P	IIa-O
780		18.98	20	P	IIa-O
782		19.97	10	P	IIa-O
784		20.93	9	V	103a-F
785		23.86	20	P	IIa-O
788		28.95	12	V	103a-F
789		29.86	20	P	IIa-O
797	June	19.82	18	V	103a-F
799		19.97	60	V	103a-F
802	July	10.75	15	V	103a-F
812	September	25.00	5	V	103a-F
813	October	4.75	100	V	103a-F
814		4.81	10	P	103a-F
815		14.68	10	V	103a-F
817		21.69	20	V	103a-F
823	November	15.60	30	V	103a-F
831	December	13.62	20	V	103a-F

* P = Photographic, V = Visual, I = Infrared

TABLE III

Identification of absorption lines in photographic region on September 15, 1967

Measured λ A	Reduced with factor 0.00075 A	λ lab. A	Element and Multiplet No.	λ lab.— λ red A
3886.1	3889.0	3889.1	He (1)	+0.1
3897.9	3900.8	3900.6	Ti II (34)	—0.2
3911.3	3914.2	3913.5	Ti II (34)	—0.7
3929.9	3932.8	3933.7	Ca II (1)	+0.9
3964.5	3967.4	3968.5	Ca II (1)	+1.1
4009.2	4012.2	4012.4	Ti II (11)	+0.2
4021.3	4024.3	4025.1	Ti II (11)	+0.8
4026.1	4028.0	4028.3	Ti II (87)	+0.3
		4029.6	Ti II (87)	+1.6
4042.8	4045.8	4046.8	Fe II (126)	+1.0
4050.9	4053.9	4053.8	Ti II (87)	—0.1
4074.9	4077.9	4077.7	Sr II (1)	—0.2
4098.9	4102.0	4101.7	Hδ (1)	—0.3
4160.8	4163.9	4163.6	Ti II (105)	—0.3
4169.7	4172.8	4173.5	Fe II (27)	+0.7
4176.6	4179.7	4178.8	Fe II (28)	—0.9
4212.6	4215.8	4215.5	Sr II (1)	—0.3
4223.4	4226.6	4226.7	Ca I (2)	+0.1
4230.2	4233.3	4233.2	Fe II (27)	—0.1
4243.8	4246.9	4246.8	Sc II (7)	—0.1
4286.6	4289.8	4290.2	Ti II (41)	+0.4
4292.0	4295.3	4296.6	Fe II (28)	+1.3
		4294.8	Sc II (15)	—0.5
4298.0	4301.2	4300.0	Ti II (41)	—1.2
		4300.2	Mn II (6)	—1.0
		4301.9	Ti II (41)	+0.7
4305.1	4308.4	4307.9	Ti II (41)	—0.5
4311.1	4314.3	4314.1	Sc II (15)	—0.2
		4315.0	Ti II (41)	+0.7

TABLE III—(*Contd.*)

Identification of absorption lines in photographic region on September 15, 1967

Measured λ A	Reduced with factor 0.00075 A	λ lab. A	Element and Multiplet No.	λ lab.— λ red A
4318.0	4321.3	4320.9	Ti II (41)	—0.4
		4320.7	Sc II (14)	—0.4
4322.6	4325.8	4325.0	Sc II (15)	—0.8
		4325.1	Mn II (6)	—0.7
4336.5	4339.8	4340.5	Hδ I (1)	+0.7
4348.7	4351.9	4351.8	Fe II (27)	—0.1
4365.0	4368.2	4369.4	Fe II (28)	+1.2
4372.0	4375.3	4374.5	Sc II (14)	—0.8
		4374.8	Ti II (93)	—0.5
4382.1	4385.4	4385.4	Fe II (27)	0.0
		4384.8	Sc II (14)	—0.6
4391.9	4395.2	4395.0	Ti II (19)	—0.2
4397.7	4400.9	4400.4	Sc II (14)	—0.5
		4400.6	Ti II (93)	—0.3
4413.8	4417.1	4416.8	Fe II (27)	—0.3
		4415.6	Sc II (14)	—1.5
		4417.7	Ti II (40)	+0.6
4440.7	4444.0	4443.8	Ti II (19)	—0.2
		4444.6	Ti II (31)	+0.6
4447.4	4450.7	4450.5	Ti II (19)	—0.2
4465.9	4469.2	4468.5	Ti II (31)	—0.7
		4469.2	Ti II (18)	0.0
		4470.8	Ti II (40)	+1.6
4477.8	4481.2	4481.3	Mg II (4)	+0.1
		4481.1	Mg II (4)	—0.1
4485.9	4489.3	4489.2	Fe II (37)	—0.1
4498.2	4501.5	4500.3	Ti II (18)	—1.2
		4501.3	Ti II (31)	—0.2
4505.5	4508.9	4508.3	Fe II (38)	—0.6
4511.9	4515.3	4515.3	Fe II (37)	0.0
4518.6	4522.0	4520.2	Fe II (37)	—1.8
		4522.6	Fe II (38)	+0.6
4531.0	4534.4	4534.0	Ti II (50)	—0.4
		4534.2	Fe II (37)	—0.2
4546.6	4550.0	4549.6	Ti II (82)	—0.4
		4549.5	Fe II (38)	—0.5
4553.2	4556.6	4555.9	Fe II (37)	—0.7
4561.0	4564.5	4563.8	Ti II (50)	—0.7
4569.0	4572.4	4572.0	Ti II (82)	—0.4
4580.0	4583.5	4582.8	Fe II (37)	—0.7
		4583.8	Fe II (38)	+0.3
4586.3	4589.8	4590.0	Ti II (50)	+0.2

TABLE IV

Identification of Absorption lines on Plate No. 503 taken on October 7, 1967

Measured λ	Reduced with a factor 0.00076	λ Lab.	Element and Multiplet No.	λ lab.— λ red.
6557.5	6562.5	6562.8	Hα (1)	+0.3
6513.1	6518.1	6516.1	Fe II (40)	−2.0
		6519.4	Mn I (39)	+1.3
6450.4	6455.3	6456.4	Fe II (74)	+1.1
6377.9	6382.7	6383.7	Fe II ( )	+1.0
		6382.2	Mn I (39)	−0.5
		6384.7	Mn I (39)	+2.0
6341.4	6346.2	6347.1	Si II (2)	+0.9
6243.5	6248.2	6247.6	Fe II (74)	−0.6
6154.4	6159.1	6158.2	OI (10)	−0.9
		6156.8	OI (10)	−2.3
		6156.0	OI (10)	−3.1
5892.0	5896.5	5895.9	Na I (1)	−0.6
5886.3	5890.8	5889.9	Na I (1)	−0.9
5532.1	5536.3	5534.9	Fe II (55)	−1.4
5312.2	5316.2	5316.6	Fe II (49)	−0.4
		5316.8	Fe II (48)	−0.6
5279.9	5283.9	5284.1	Fe II (41)	+0.2
5271.1	5275.1	5276.0	Fe II (49)	+0.9
5231.1	5235.1	5234.6	Fe II (49)	−0.5
5193.4	5197.4	5197.6	Fe II (49)	+0.2
5165.0	5168.9	5169.0	Fe II (42)	+0.1
5012.4	5016.2	5018.4	Fe II (42)	+2.2
4916.5	4920.2	4923.9	Fe II (42)	+3.7
4853.7	4857.4	4861.3	Hβ (1)	+3.9

General discussion of the development of the nova spectrum

The main features of the spectra in September, October and November 1967 were the strong violet displaced absorption lines of H, CaII, FeII, TiII, SrII, ScII, CaI, OI and NaI. Almost all absorption lines are accompanied by faint emission features on the longward side. These absorption lines did not show any companion absorption system.

The radial velocity measures show that all absorption lines were systematically displaced towards the shortward side indicating velocity of approach. The hydrogen absorption lines did not show the same velocity. This may be explained as due to the interaction of absorption profile with emission line on the longer wavelength side and as the emission associated with the hydrogen lines increases with decreasing member of the Balmer series, a spurious violet shift may be introduced in the velocity measurements from the hydrogen lines. Tables V and VI give the radial velocity measures made on the blue and red spectra respectively.

The expanding envelopes showed uniform constant velocity of ejection around 250 km/sec. from September 1967 until the burst that enabled peak brightness to be attained on December 14, 1967. The premaximum spectra during September, October and November 1967 showed very few changes other than a gradual increase in the intensity of the emission lines. This stage was characterised by strong absorption lines due to hydrogen and ionized calcium and also those of TiII and FeII. All the strong absorption lines were associated with faint emission on the longward side.

The spectrum in the visual region obtained on December 16, 1967, two days after the major outburst, is of particular interest. This showed tremendous changes as compared to the earlier spectra which were rather steady for nearly three months. Remarkable changes had taken

TABLE V

Velocities in km/sec of absorption lines (Photographic region)

A	Plate No. Date Identi- fication	492 1967 Sept. 15	496 1967 Sept. 23	499 1967 Sept. 29	539 1967 Nov. 18	548 1967 Nov. 27	743 1968 Apr. 18	753 1968 May 7	769 1968 May 15	785 1968 May 23
1	2	3	4	5	6	7	8	9	10	11
3889.1	Mg	232			239		1128			
3900.6	Ti II	203		230						
3913.5	Ti II	167		185	219					
3933.7	Ca II (K)	288		308	358		383 1100		494 1220	
3968.5 3970.1	Ca II (H) Hε }	303		277	280				529 1246	
4012.4	Ti II	237		188	241					
4025.1	Ti II	230		241						
4029.0	Ti II	164	241							
4046.8	Fe II	298	208	293	283					
4053.8	Ti II	216			164					
4077.7	Sr II	164		159	212					
4101.7	Hδ	203	174	150	159	139	332	998	426 1256	1118 1518
4163.6	Ti II	204		237	218					
4173.5	Fe II	271		227						
4178.8	Fe II	164	290							
4215.5	Sr II	205		181	202					
4226.7	Ca I	236	199	212	183					
4233.2	Fe II	213	184	198	271					
4246.8	Sc I	215	165	166	179					
4290.2	Ti II	258	207	207	201					
4294.8 4296.6	Sc II Fe II }	191	244	292	165					
4300.0 4300.2 4301.9	Ti II Mn II Ti II }	145	135	107						
4307.9	Ti II	192	155	152	125					
4314.1 4315.0	Sc II Ti II }	210	195	191	216					
4320.7 4320.9 }	Sc II	204	212	171	188					
4325.0 4325.1	Sc II Mn II }	167	132	128	120					
4340.5	Hγ	272		288	269	216	237 1116	1006	426 1221	1116 1534
4351.8	Fe II	213		177	154					
4374.5 4374.8	Sc II Ti II }	169	150	169						
4384.8 4385.8	Sc II Fe II }	225	217	203	219		397 983			
4395.0	Ti II	210	180	204	209					
4400.4 4400.6	Sc II Ti II }	184	196	198	193					
4415.6 4416.8 4417.7	Sc II Fe II Ti II }	204	168	161	162					
4443.8 4444.6	Ti II Ti II }	212	198		197					

TABLE V—(*Contd.*)

Velocities in km/sec of absorption lines (Photographic region)

λ	Plate No. Date Identification	492 1967 Sept. 15	496 1967 Sept. 23	499 1967 Sept. 29	539 1967 Nov. 18	548 1967 Nov. 27	743 1968 Apr. 18	753 1968 May 7	769 1968 May 15	785 1968 May 23
1	2	3	4	5	6	7	8	9	10	11
4450.5	Ti I	208	187	202	152					
4468.5 4469.2 4470.8	Ti II Ti II Ti II	175	140	144	152					
4481.1 4481.3	Mg II Mg II	234		145	182					
4489.2	Fe II	218	169	233						
4500.3 4501.3	Ti II Ti II	144	169		104					
4508.3	Fe II	186	123	197	182					
4515.3	Fe II	215	209	177	182					
4520.2 4522.6	Fe II Fe II	190	142	126						
4534.0 4534.2	Ti II Fe II	198	125	177	154					
4549.5 4549.6	Fe II Ti II	196	185	200	188					
4555.9	Fe II	176		129	157					
4563.8	Ti II	179	188	157	159					
4572.0	Ti II	195	200	198	186					
4582.8 4583.8	Fe II Fe II	183	155	136	116					
4590.0	Ti II	237		240	221					

place in the continuum as well as absorption and emission lines. Continuum and emission were considerably increased in intensity whereas absorption lines had become narrower with secondary absorption system appearing on violet side. Emission was found spilled over the first absorption system on to its violet side. The new absorption system was identified as the principal absorption spectrum with associated strong and wide emission bands.

All these and the foregoing features can be noticed from the mosaic of nova spectra presented in Plates 1 and II. It can be clearly seen how the intensity of the emission lines have increased and reached maximum after the December outburst. The premaximum absorption lines could be traced even after a few days of this major outburst, but with narrowed lines. Most of the metallic lines especially in the photographic region had disappeared. The gradual decrease in the earlier absorption system would mean that the premaximum shell responsible for this absorption was being dissipated slowly. The new shell ejected due to 14th December outburst could be identified on 16th December itself by the doubling of FeII lines in the green region. A faint suggestion of this secondary absorption for H-alpha could be seen on 24th December. This became a conspicuous shallow broad absorption on 26th December 1967. The measured velocity of −1350 km/sec is the highest velocity recorded at Kodaikanal for this Nova.

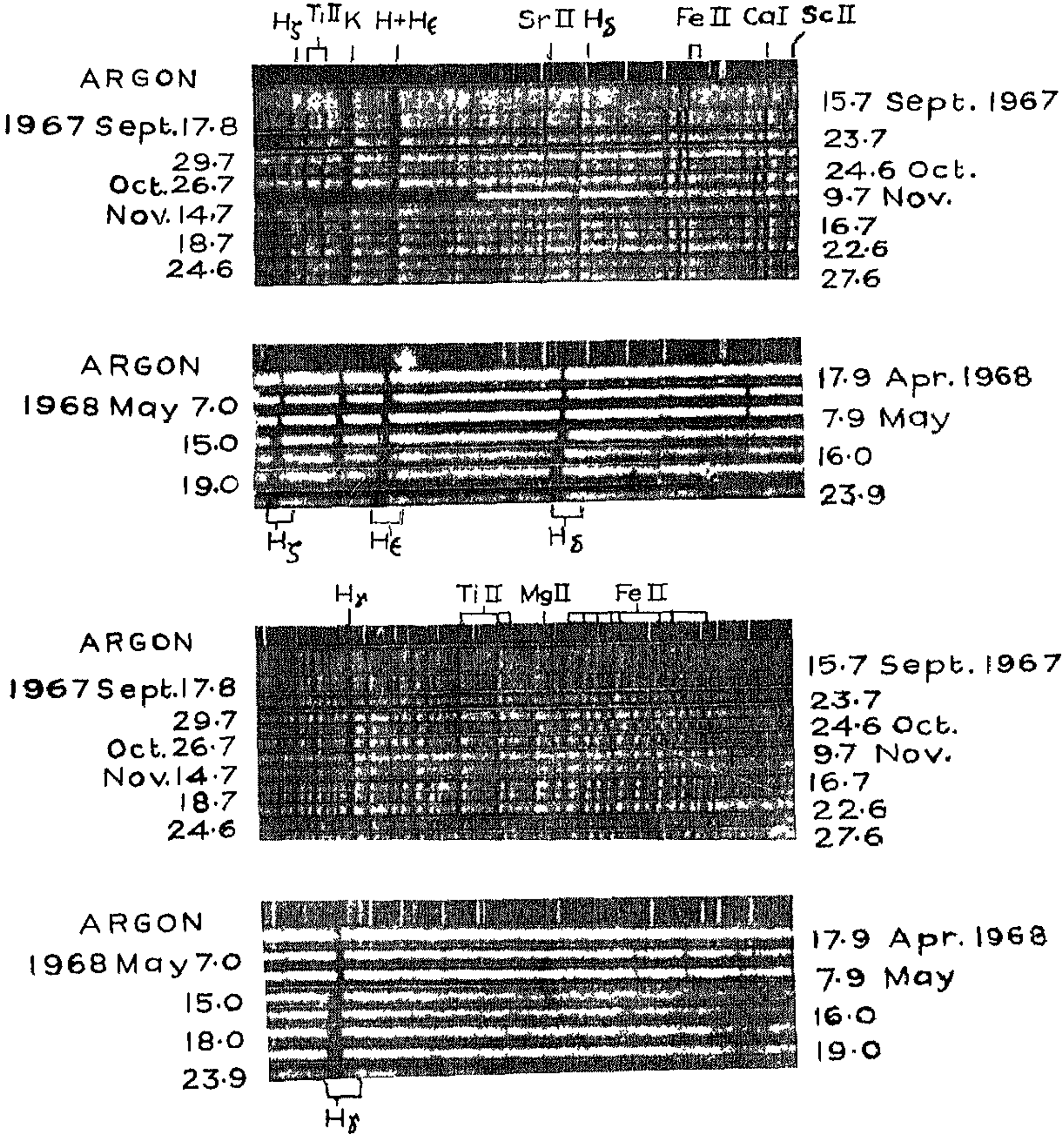

Plate I · Mosaic of blue spectrograms of Nova-Delphini (1967)—Dates are in U.T.

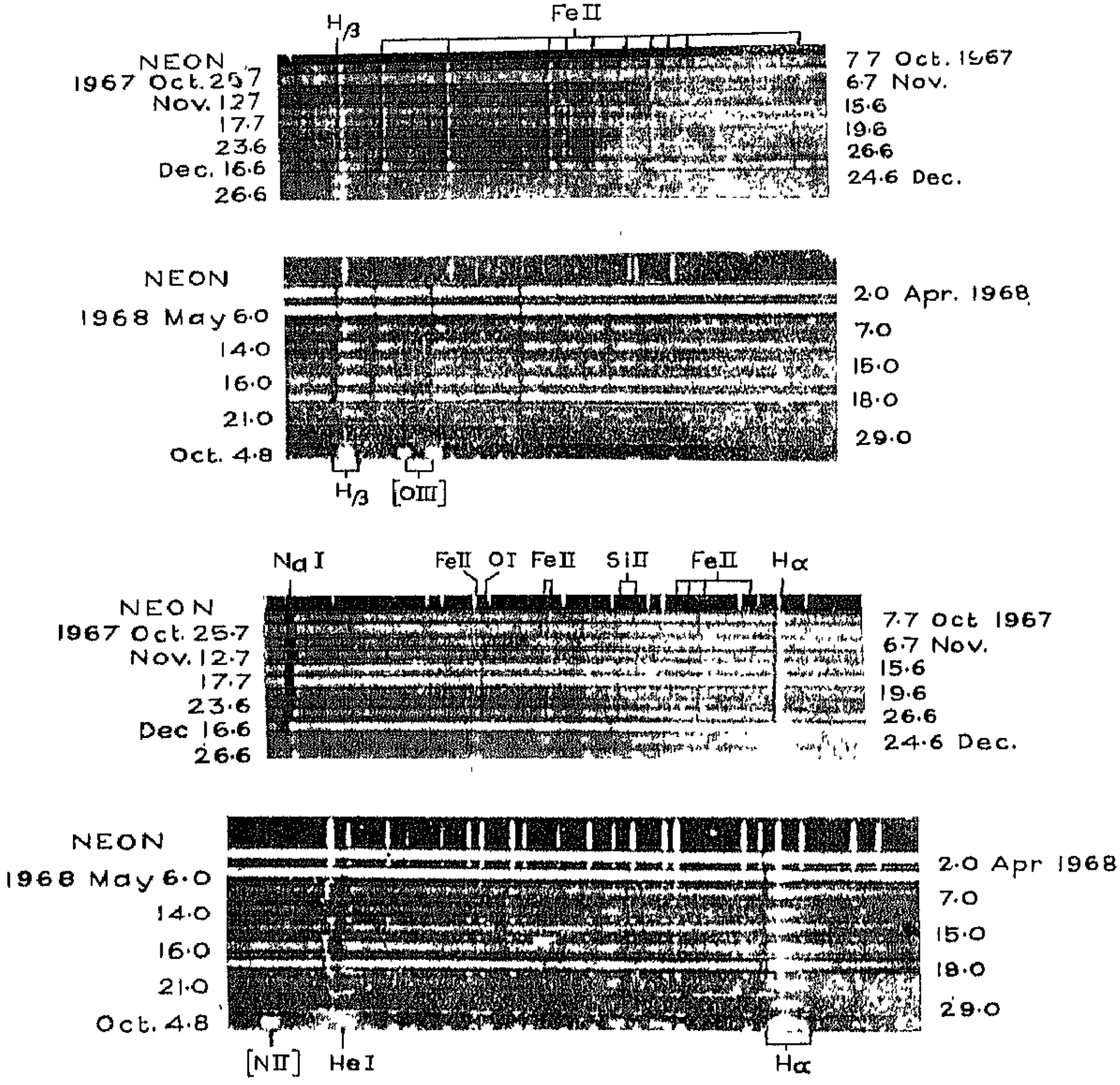

Plate II : Mosaic of red spectrograms of Nova-Delphini (1967). Dates are in U.T.

TABLE VI

Velocities in km/sec of absorption lines (Visual region)

λ	Plate No. Date Identification	503 1967 Oct. 7	514 1967 Oct. 25	522 1967 Nov. 6	530 1967 Nov. 12	536 1967 Nov. 15	538 1967 Nov. 17	542 1967 Nov. 23	551 1967 Dec. 16	553 1967 Dec. 24	555 1967 Dec. 26	731 1968 Apr. 1	746 1968 May 6	750 1968 May 7	772 1968 May 15	777 1968 May 17
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
6562.8	Hα	240	270	264	225	234	225	220	191	181	207 1350	848 1115	401 946	420 968	414 1227	411 977 1382
6516.1	Fe II Mn I }	137														
6456.4	Fe II	279	249	105	108	219	186						957			
6383.8	Fe II Mn I }	275														
6437.1	Si II	247					129									
6247.6	Fe II	194	177	138	63	153	153									
6157.0	O I	185		609								846 1199	964			
5895.9	Na I	202		258	249	255	228	231	225				435			
5890.0	Na I	188	144	225	240	225	225		215			1078	489 1026	1062	450 1262	
5534.9	Fe II	148														
5316.8	Fe II	261							283				1017			
5276.0	Fe II	233			381								1021			
5234.6	Fe II	203			333				212				939			
5197.6	Fe II	333			345											
5169.0	Fe II	232						232	293 667			646 1060			1282	1259
5018.4	Fe II				339			223	356 766			587 1131	877	1064	445 1258	420
4923.9	Fe II		314	321	267	354	342	222	362 774			627 1170	910	1074	387 1227	445 1188
4861.3	Hβ		371	345	258	297	351	286	326	302	315	648 1180	605 1045	462 1008	434 1213	569 1351

No spectrographic observations were possible between January 1968 to March 1968 because of the proximity of the nova to the Sun. Spectra obtained during April 1968 showed two distinct absorption systems one narrow and the other broad. On May 17, 1968, the broad absorption line of H-alpha appeared to have split into two, conveying the emergence of another shell. The velocities of these 3 shells as on 17th May, 1968, were 1382 km/sec, 977 km/sec, and 411 km/sec.

In the development of the principal spectrum, the OI flash at 6300A was recorded earlier than OI at 6364A. Both these lines could be seen conspicuously on the spectrum of 17th May 1968. The NII flash at 5755A was first recorded on 10th July 1968 on a slitless spectrum. The next slitless spectrum obtained on 25th September, 1968, showed the emergence of the nebular stage with the characteristic emission blobs of OIII at 4959A and 5007A. The line OIII 5007A was more intense than Hβ. Also the 4640A band of NIII appeared on a slitless spectrum taken on 4th October 1968 along with the emission band 4363A OIII. An infra-red spectrum obtained on 15th May 1968 on hypersensitized I-N film showed apart from intense 6563A, emission lines of OI at 7774A and 8446A.

Spectrophotometric measurements and study of line profiles

As mentioned earlier, all spectrograms were calibrated using a step wedge filter attached to an auxiliary spectrograph. The density traces of the spectra were obtained with the recording microphotometer with a magnification of 108. The intensity measurements are in terms of the intensity of the continuum.

TABLE VII

Measured intensity of emission and absorption lines in terms of equivalent km/sec. (Photographic region)

Plate No.	Date		Emission						Absorption					
			Hγ	Hδ	H+Hε	K	Hζ	Hη	Hγ	Hδ	H+Hε	K	Hζ	Hη
	1967													
492	September	15.74	750	100	140	80			200	190			130	50
548	November	27.64	440	400	500	480	230						170	
	1968													
753	May	7.94	2680	1810	1850	680		440	410	390				330
769	May	15.00	1840	1150	700	210	320	190	510					410
785	May	23.86	620	810	330		300	200	610	400	310			

TABLE VIII

Measured intensity of emission and absorption lines in terms of equivalent km/sec. (Visual region)

Plate No.	Date U.T.		Emission			Absorption		
			Hα	Hβ	D_1 & D_2	Hα	Hβ	D_1 & D_2
	1967							
503	October	7.74		960	180		120	460
514	October	25.63	1990	900	60	80	230	
522	November	6.71	960	410	370	110	270	
530	November	12.68	1280	570	130	100	250	
536	November	15.64	1150	380	400	150	190	170
538	November	17.68	1430	720	210	230	230	
542	November	23.64	1300	980	180	250	250	290
551	December	16.60	1680	1320	1250	260	260	
553	December	24.58	14500		760			190
	1968							
750	May	7.0	3330	1550	350	250	260	340
772	May	15.95	12790	2380	360	450	380	430
777	May	17.93	33740	6740	480	340		440

Intensity profiles of 6563A and 4861A of hydrogen and 5890A, 5896A of neutral sodium are given in Figure 2. The profiles of Hγ, Hδ and the region between 3820A and 3970A are shown in Figure 4. In Tables VII and VIII, we give the total observed intensity of the hydrogen lines Hα to Hε, H and K, D_1 and D_2, all expressed in terms of equivalent Kms/sec for both absorption and emission. The striking increase in intensity and width of the hydrogen lines after the maximum phase can be seen clearly. The earlier absorption system is present like a sharp central absorption in the Hα and Hβ emission bands nearly at its normal position. This gives a saddle type structure to the line profiles. Such structures were recorded for earlier novae by Larson Leander (1954). Figures 2 and 3 bring out structural changes experienced by the emission and absorption bands of different lines with time. The emission lines are asymmetrical due to absorptions on the violet side. Hence a good approximation to the true total emission intensity of any line can be obtained by computing twice the area of emission on the longward half of the profile. Similarly the true total absorption band intensity can be computed by adding the difference between the longward half and the shortward half of the emission band to the intensity of the observed absorption band. In Tables VII and VIII are given the intensity of some of the emission and absorption bands. If E_L and E_S are the intensity of the longward and shortward half of the emission band and A is the intensity of the absorption band, we take the true emission band intensity as equal to 2 E_L and true absorption band intensity to be $A + (E_L - E_S)$. These are given in in Table IX.

TABLE IX

Computation of corrected intensity of emission and absorption lines in terms of equivalent Km/sec.

Date		Line	E_L	E_S	A	$E_L + E_S$	$2E_L$	$A + E_L - E_S$	E_β
1967									
November	23.6	Hα	700	600	250	1300	1400	350	0047
		Hβ	590	390	250	980	1180	450	0039
November	27.6	Hγ	270	170		440	540		0018
		Hδ	265	135		400	530		0018
1968									
May	7.0	Hα	1870	1460	250	3330	3740	660	0125
		Hβ	990	560	260	1550	1980	690	0066
May	7.9	Hγ	1860	820	410	2680	3720	1450	0124
		Hδ	1200	610	390	1810	2400	980	0080
May	15.0	Hγ	1300	540	510	1840	2600	1270	0087
		Hδ	670	480		1340	1150		0045
May	16.0	Hα	7540	5250	450	12790	15080	2740	0503
		Hβ	1370	1010	380	2380	2740	740	0091

Zanstra Ionisation temperature

It will be of interest to determine the photospheric temperature of the nuclear star at different phases of the nova development. An attempt has been made here to derive Zanstra ionisation temperatures using the intensities of hydrogen emission lines. The theory is based on the assumption that the radiation of the emission lines of expanding envelope are due to the photoionisation of atoms by the ultra-violet radiation of the central star followed by recombination. In the case of hydrogen the number of ultraviolet quanta emitted by the central star

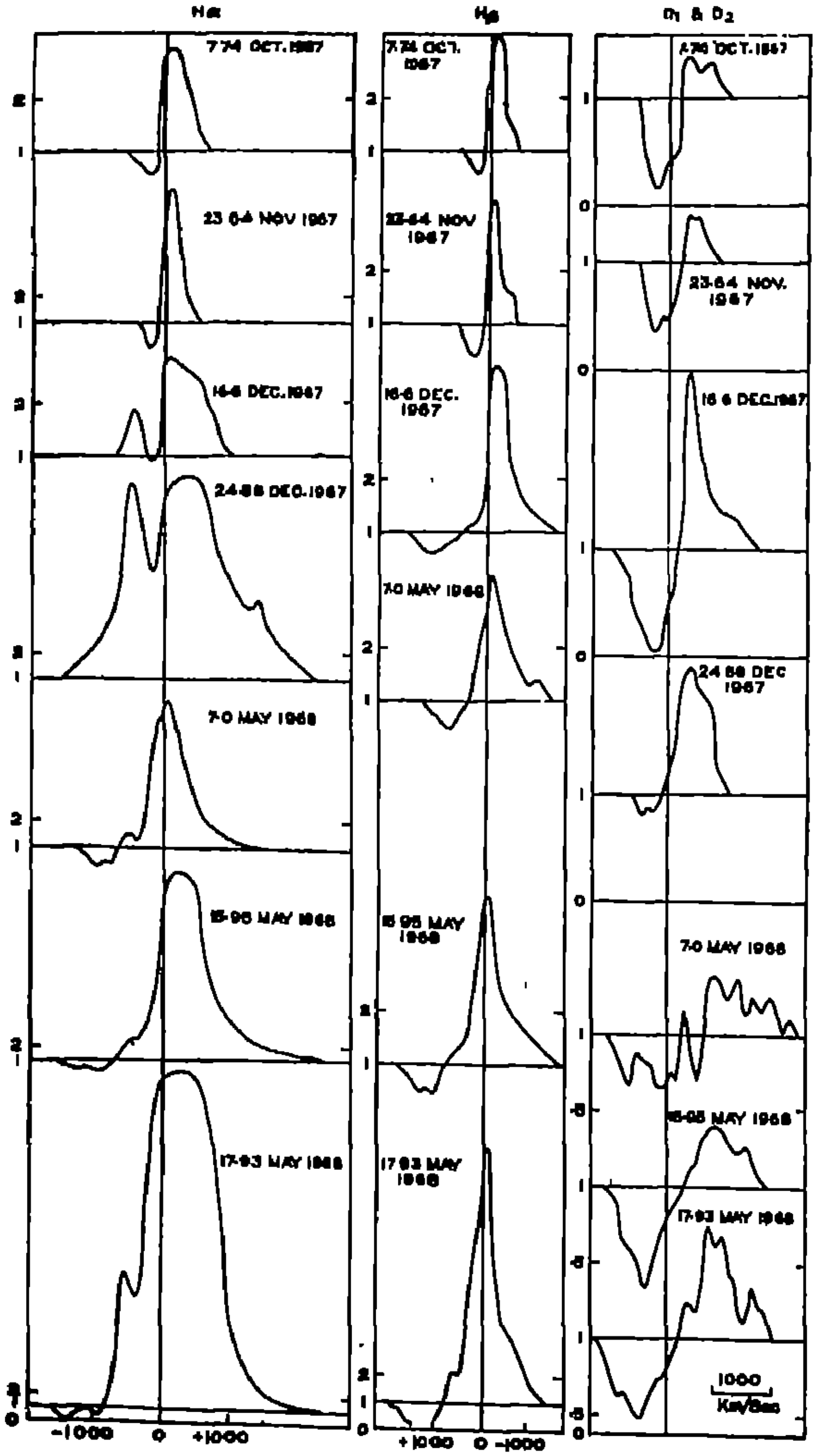

Figure 2 : Intensity profiles of Hα ; Hβ ; D1 & D2
Abscissa is in km/sec.

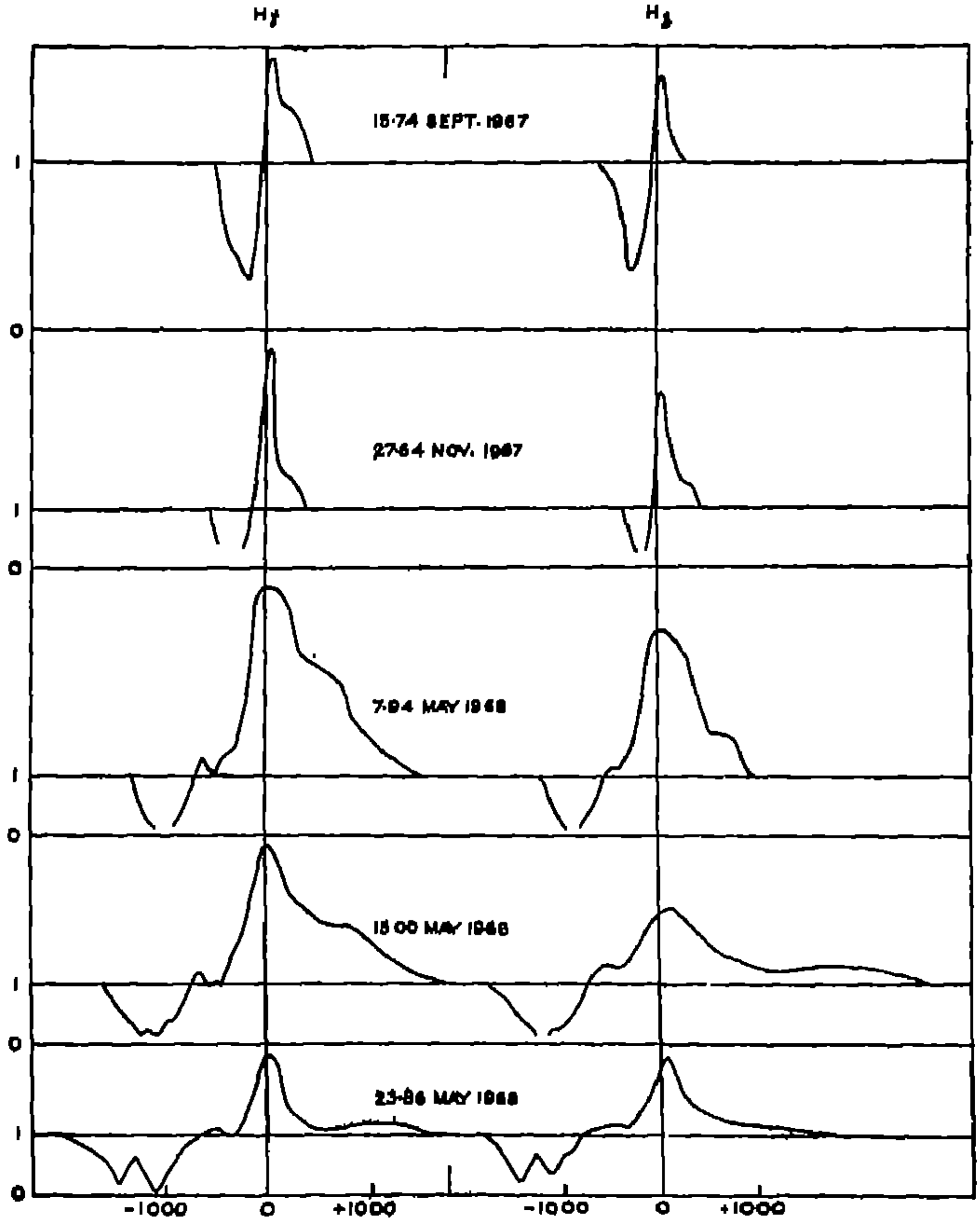

Figure 3 : Intensity profiles of Hγ and Hδ
Abscissa is in km/sec.

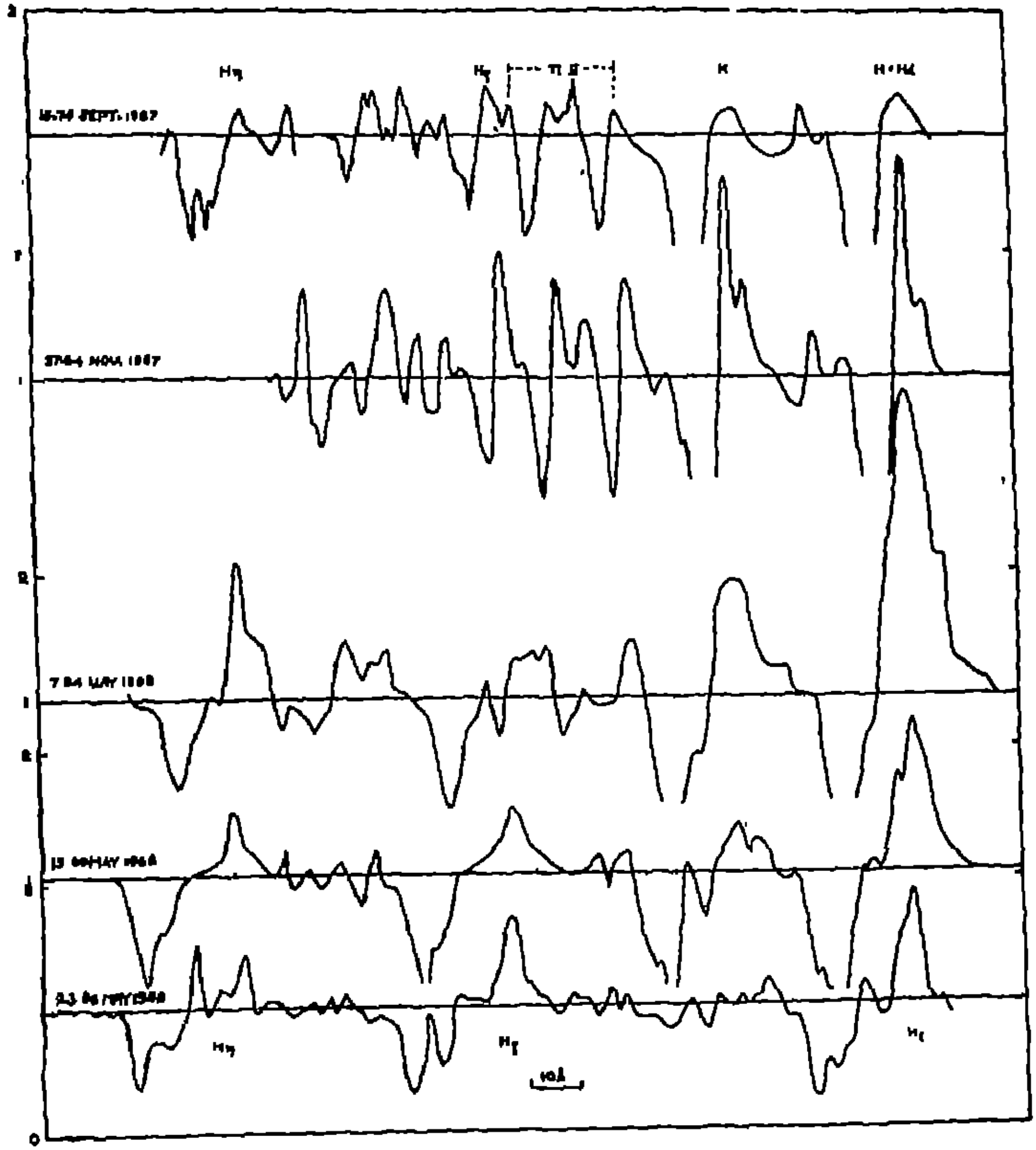

Figure 4 : Intensity profiles of the region 3820A—3970A
Abscissa is in Angstroms.

shortward of Lyman limit is equal to the number of quanta emitted by the expanding envelope in the Balmer lines and the adjoining continuum. Then the equation will be of the form

$$\int_{x_0}^{\infty} \frac{x^2}{e^x - 1}\, dx = \Sigma \frac{x^3}{e^x - 1} E_\nu \qquad (1)$$

where $x = \frac{h\nu}{kT}$, $x_0 = \frac{h\nu_0}{kT}$

ν_0 = minimum ionising frequency i.e., the Lyman limit = 912A
T = temperature of the nuclear star
h = Planck's constant
k = Boltzmann constant

E_ν is a quantity such that νE_ν is the total intensity of the emission band expressed in frequency units of the continuous spectrum.

Following Larson-Leander (1950) E_ν was obtained from the equation

$$E_\nu = \frac{2E_L}{c}$$

where 'c' is the velocity of light. The value of 2 E_L was obtained from Table IX which we consider to be the total intensity in equivalent km/sec of the emission band. The values of E_ν of Hα, Hβ, Hγ and Hδ on different dates are also listed in Table IX. The higher members of the Balmer lines and the adjoining continuum are not taken into account as they are relatively insignificant. But in practice extrapolations may be made from a limited number of observed bands.

In equation (1) let J represent the integral term and S the summation term. Then the equation can be written as

$$J - S = \Delta = O$$

In practice the difference is computed for various assumed values of temperature T, using Zanstra's (1931) tabulated values for the integral. The temperature T for which $\Delta = O$ is obtained by interpolating between two temperatures giving Δ values of positive and negative signs. The computed results are given in Table VI. We should point out that the intensities of the emission lines have been measured on plates obtained in a short interval of time within three to four days. Since Nova Delphini (1967) happens to be a very slow nova, the assumption that there are no large spectral variations on these spectrograms is, therefore, reasonable.

The summation term as obtained directly from the observed bands Hα, Hβ, Hγ and Hδ are given in the columns headed (S). The final value of this term including the extrapolated values for the higher members of the Balmer series is in the column headed S_{corr}.

The ionisation temperature values are in the last column of Table X.

TABLE X

Ionisation temperatures

Date		T	x_0	J	S	S_{corr}	$\Delta = J - S_{corr}$	Ionisation temperature
1967		°K						°K
November	25.6	17400	9.0	0.012	0.012	0.015	− 0.003	
		19600	8.0	0.028	0.011	0.013	+ 0.015	17800
1968 May	7.5	19600	8.0	0.028	0.037	0.047	− 0.019	
		22400	7.0	0.059	0.033	0.041	+ 0.018	21000
1968 May	15.5	19600	8.0	0.028	0.057	0.063	− 0.035	
		22400	7.0	0.059	0.048	0.054	+ 0.005	22100

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