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High resolution spectroscopy of the high latitude rapidly evolving post-AGB star SAO 85766 (= IRAS 18062+2410)*

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Abstract. SAO 85766 (b = +20^o) is an IRAS source with far-infrared colours similar to planetary nebulae. According to the HDE catalogue, its spectrum in 1940 was that of an A5 star. The UV fluxes and colours derived from data obtained by the TD1 satellite in 1972 also indicate that SAO 85766 was an A-type supergiant at that epoch. However, high resolution spectra of SAO 85766 obtained in 1993 in the wavelength interval 4350Å to 8820Å shows that now it is similar to that of an early B type post-AGB supergiant.

In addition to the absorptions lines typical of a B1I type star, the spectrum of SAO 85766 is found to show numerous permitted and forbidden emission lines of several elements, typically observed in the spectra of young high density low excitation planetary nebulae.

From an analysis of the absorption lines we have estimated T$_{eff}$=22000±500 K, log g=3.0±0.5, ξ_t=15±2km s^{-1} and [M/H]=−0.6. Carbon is found to be strongly underabundant ([C/Fe] = −1.0), similarly to what has been observed in other high galactic latitude hot post-AGB stars. The underabundance of carbon and metals, high galactic latitude, high radial velocity (46 km s^{-1}), the presence of planetary nebula type detached cold circumstellar dust shell and also the presence of low excitation nebular emission lines in the spectrum indicate that SAO 85766 is a low mass star in the post-AGB stage of evolution.

The above mentioned characteristics and the variations observed in the spectrum of SAO 85766 suggest that it has rapidly evolved during the past 50 years and it is now in the early stages of the planetary nebula phase. The central star may just have become hot enough to photoionize the circumstellar envelope ejected during the previous AGB phase. From an analysis of the nebular emission lines we find T$_e$=10000± 500K and N$_e$=2.5 10^4 cm^{-3}. The nebula also shows an abundance pattern similar to that of the central star. The rapid post-AGB evolution of SAO 85766 appears to be similar to that observed in the case of hot post-AGB star Hen 1357 (= SAO 244567).

Key words: stars: AGB and post-AGB – stars: evolution – stars: emission-line, Be – stars: circumstellar matter – stars: abundances – stars: individual: SAO 85766

1. Introduction

From an analysis of IRAS data several cool and hot post-Asymptotic Giant Branch (post-AGB, hereafter) supergiants have been found (Parthasarathy and Pottasch 1986; Pottasch and Parthasarathy 1988; Parthasarathy 1993a). They seem to form an evolutionary sequence evolving from cool post-AGB stars towards hot post-AGB stars and then into planetary nebulae (Parthasarathy 1993b; Parthasarathy et al. 1993, 1995). The evolution from B-type post-AGB stars into young planetary nebulae can sometimes be rather rapid. One such example is the post-AGB star SAO 244567 (Hen 3−1357 = Stingray Nebula) (Parthasarathy et al. 1993, 1995; Bobrowsky et al. 1998) which has turned into a planetary nebula within the past 20 years. SAO 85766 seems to be another case of rapid post-AGB evolution.

SAO 85766 (HDE 341617 = BD +24^o 3337 = IRAS 18062+2410) is an IRAS source with far-infrared colours similar to planetary nebulae. It is a high galactic latitude star (l=51^o; b=+20^o). Based on the IRAS colours and high galactic latitude it was first classified as a post-AGB star (Volk and Kwok 1989; Parthasarathy 1993a. More recently it has been found to be a transition object from the AGB to the PN phase (García-Lario et al. 1997a; Arkhipova et al. 1999) which has significantly evolved within the past 50 years. According to the HDE catalogue its spectral type in 1940 was A5 indicating an effective temperature of 8500 K. The spectral energy distribution obtained in 1985-1987 indicates, however, that it was a Be star less than 50 years later (Downes and Keyes, 1988). The red-sensitive objective prism spectra taken in 1978-1984 shows Hα emission (Stephenson, 1986) and its visual magnitude was estimated to be 11.4 while the BD and SAO catalogues give

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* Based on observations made with the Issac Newton Telescope (INT) operated on the island of La Palma (Spain) by the Instituto de Astrofísica de Canarias in the Spanish Observatorio del Roque de Los Muchachos

magnitudes of 8.8 and 9.6 respectively. In this paper we present an analysis of the high resolution spectrum of SAO 85766 and its low excitation nebula, as of 1993.

2. Observations

We have obtained high resolution (0.3 Å) spectra of SAO 85766 using the 2.5m Issac Newton Telescope (INT) at La Palma with a 1800 grooves/mm grating (H1800V) in July/August 1993 and a GEC CCD as detector. The spectra cover the wavelength regions 4350Å- 5200Å, 5260Å- 5520Å, 6500Å-6750Å, 7000Å- 7240Å, 7320Å- 7560Å and 8600Å- 8820Å. All spectra have reasonably high signal to noise ratio.

3. Analysis

The high dispersion spectra have been processed using the standard IRAF routines. The data reduction process includes bias and flat-field corrections, sky subtraction and wavelength calibration. After that, the continuum was normalised and the equivalent widths of the absorption and emission lines were measured using IRAF software. We have used Kurucz (1993) stellar model atmospheres and SYNSPEC (Hubeny 1988) radiative transfer code for calculating the theoretical spectrum. For the emission line analysis of the nebula, we used the NEBULAR package in STSDAS inside IRAF. The *gf* values and the atomic data for the forbidden lines were taken from Wiese and Martin (1980), Hibbert et al. (1991), Parthasarathy et al. (1992) and Sivarani et al. (1999 and references therein).

3.1. Description of the spectrum

The high resolution spectrum of SAO 85766 (Fig. 1) is found to show absorption lines due to He I, O II, N II, C III, C II, Fe III, Si III, Si II, etc. (Fig. 1). The presence of these lines indicate that the present spectral type of SAO 85766 is B1I. Arkhipova et al. (1999) also classified the recent spectrum of SAO 85766 and found it to be B1-1.5 II in 1996-1997.

The Balmer lines Hα and Hβ appear strongly in emission but superposed on the corresponding stellar absorption lines. The Paschen line P12 shows a complex absorption and emission profile. Several permitted and forbidden lines of Fe II are found in emission. Emission lines due to Mg I, Ca I, Ni I, Ni II, Co I, Ti I, Ti II, V II, Cr II, Si II, etc. are detected. Some of the N I, O I and He I lines are found to be in emission (Fig. 1). The nebular emission lines due to [O II], [N II], [S II], and [C I] are also present (Fig. 1), indicating the presence of a low excitation nebula. The [O III] 5007Å line is not detected. The He I 4388Å and 4471Å absorption lines do not show any indication of emission. Arkhipova et al. (1999) found the He I 5015 Å line to be in emission. In our spectra, it appears to be a weak and narrow absorption line although it might be affected by emission in the red wing. This could be due to blending by the nearby Fe II emission lines or may be due to a P-Cygni type profile. The 7065Å line is in emission. Our spectra do not cover the HeI 5876Å region. Arkhipova et al. (1999) found the He I 5876Å line also to be in emission. The full list of absorption and emission lines detected in our spectra are listed in Tables 1 and 2 respectively.

Table 1. Absorption lines in the spectrum of SAO 85766

λ obs	Eqw in Å	λ lab	Ident.	Log gf
4368.344	0.211	4366.896	OII(2)	-0.3195
4389.126	0.462	4387.929	HeI(51)	-0.8894
4416.202	0.2154	4414.909	OII(5)	0.2108
4417.907	0.2213	4416.975	OII(5)	-0.0411
4434.418	0.0738	4433.48	NII(7)	-0.0440
4438.743	.1443	4437.549	HeI(50)	-2.0114
4472.025	0.1314	4471.477	HeI(14)	0.0437
4472.917	0.3891	4471.688	HeI(14)	-0.900
4482.324	0.082	4481.129	MgII(4)	0.9730
4553.983	0.311	4552.654	SiIII(2)	-0.1500
4569.067	0.249	4567.872	SiIII(2)	0.0700
4576.006	0.1496	4574.777	SiIII(2)	-0.4060
4592.26	0.1253	4590.971	OII(15)	0.3463
4596.15			unid.	
4597.574	0.1126	4596.174	OII(15)	0.1962
4602.905	0.086	4601.478	NII(5)	-0.4096
4608.317	0.0643	4607.153	NII(5)	-0.4986
4631.937	0.1283	4630.537	NII(5)	0.1017
4640.07	0.095	4638.854	OII(1)	-0.3069
4643.3	0.273	4641.82	OII(1)	0.0842
4650.585	0.2499	4649.139	OII(1)	0.3430
4659.826	0.048		unid	
4662.894	0.1738	4661.635	OII(1)	-0.2491
4675.108	0.118	4673.75, 4673.91	OII(1), CIII(5)	-1.0804, -0.4680
4677.56	0.192	4676.234	OII(1)	-0.3590
4706.369	0.2305	4705.355	OII(25)	0.5181
4713.348	0.049	4712.13	NII(68)	-0.620
4714.523	0.2339	4713.143	HeI(12)	-1.0204
4923.35	0.7183	4921.929	HeI(48)	-0.4443
6578.526	0.2063	6578.052	C II	0.118

3.2. Atmospheric parameters and abundances

The number of absorption lines in the spectrum of SAO 85766 are not too many. Therefore, it is rather difficult to determine the atmospheric parameters with high accuracy. We have used the O II, C II, and C III absorption lines (Table 1) to derive the effective temperature T_{eff}, surface gravity log g and microturbulent velocity ξ. We have used the Kurucz (1993) stellar model atmospheres and SYNSPEC (Hubeny 1988) radiative transfer code for calculating the theoretical spectrum with LTE approximation.

The mean UBV magnitudes of SAO 85766 in 1995 were V= 11.47, B = 11.52, and U = 10.79 (Arkhipova et al. 1999). The spectral energy distribution of SAO 85766 obtained by Arkhipova et al. (1999) in 1995 (Fig. 2) is compared with the spectral energy distribution in 1986 which was obtained by Downes and Keyes (1988). In Fig. 2 we also show the theoretical flux distribution using the model atmosphere with T_{eff}

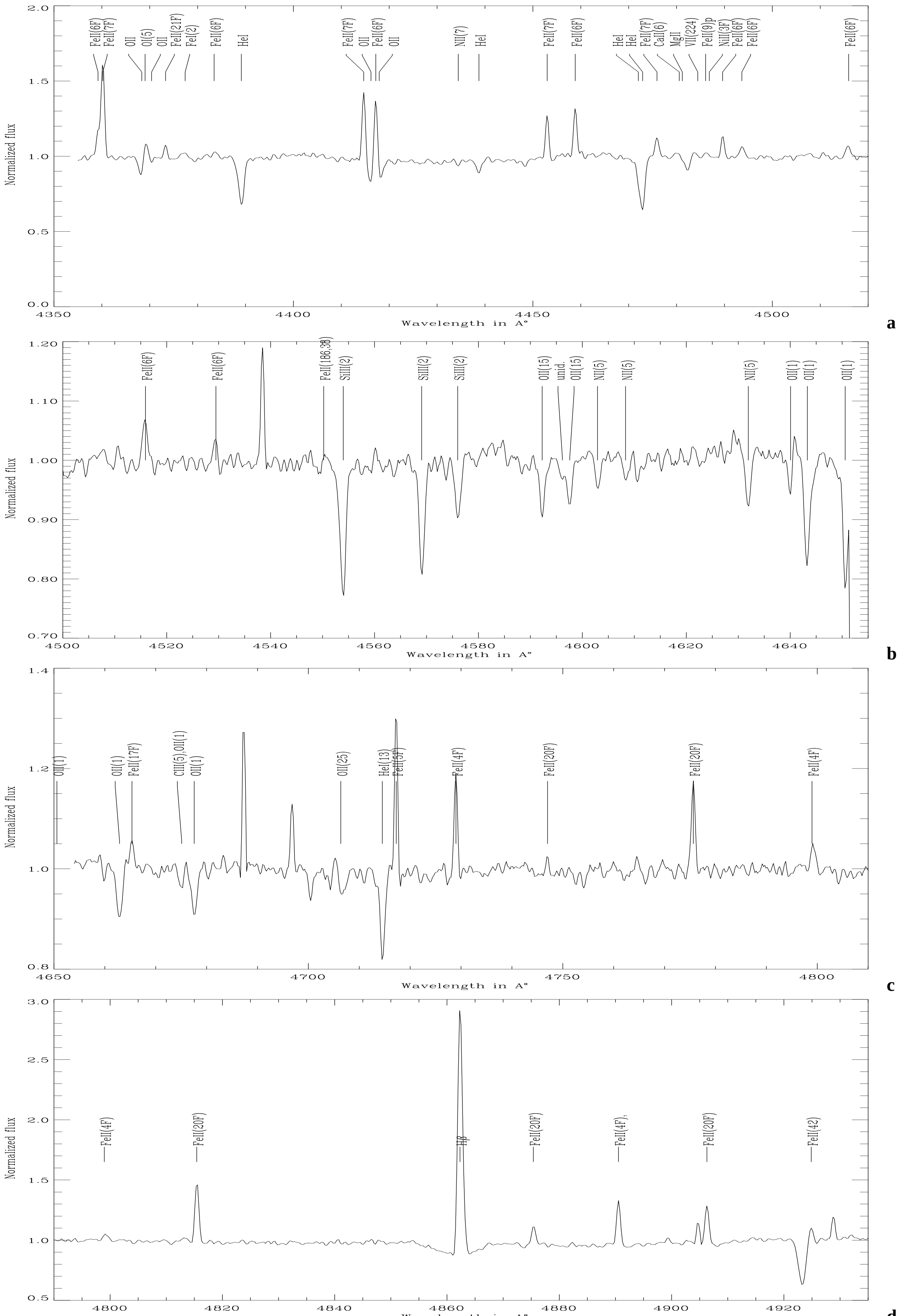

Fig. 1a–p. High resolution spectra of SAO 85766 obtained with the 2.5M Issac Newton Telescope (INT) at La Palma

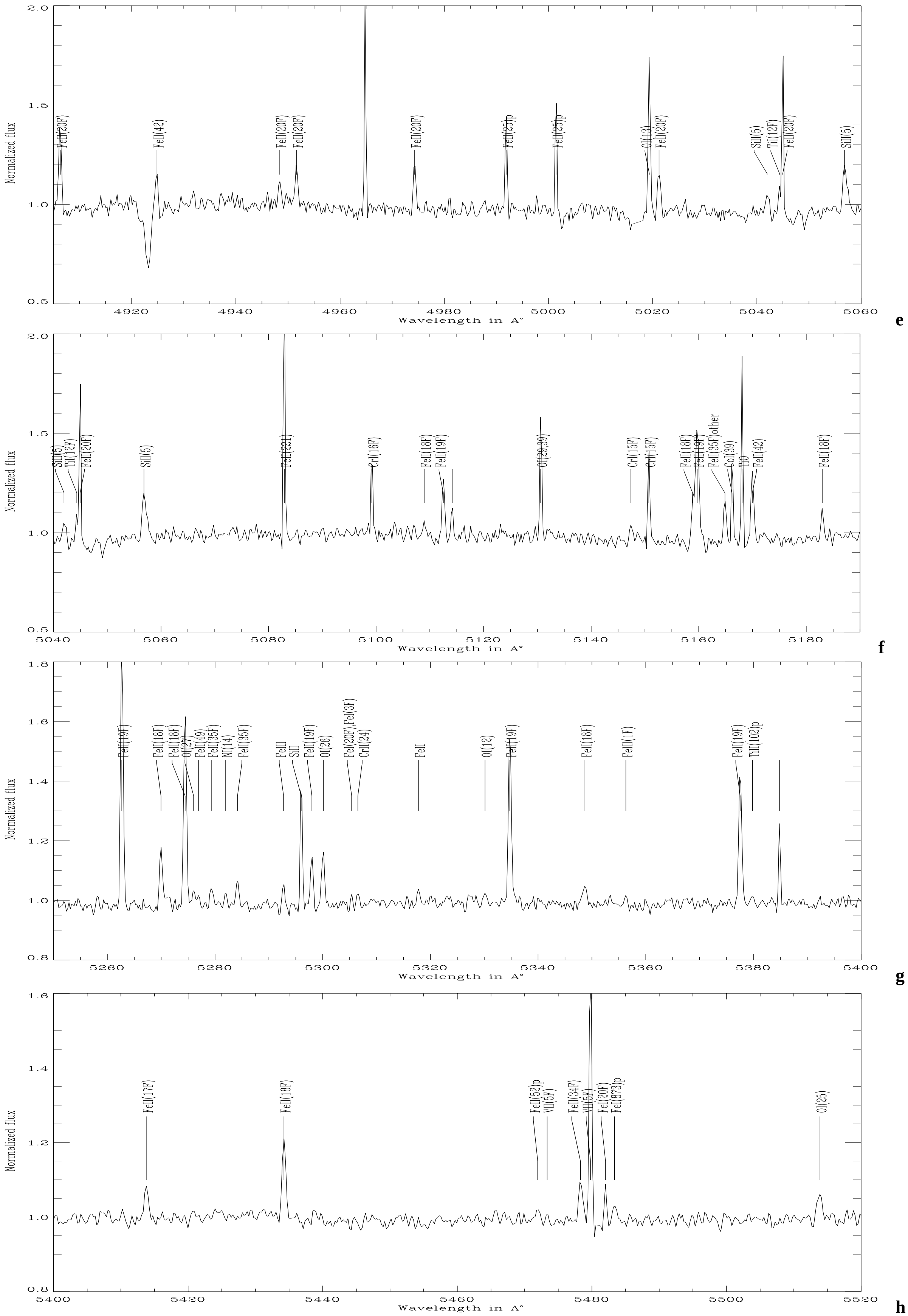

Fig. 1a–p. (continued)

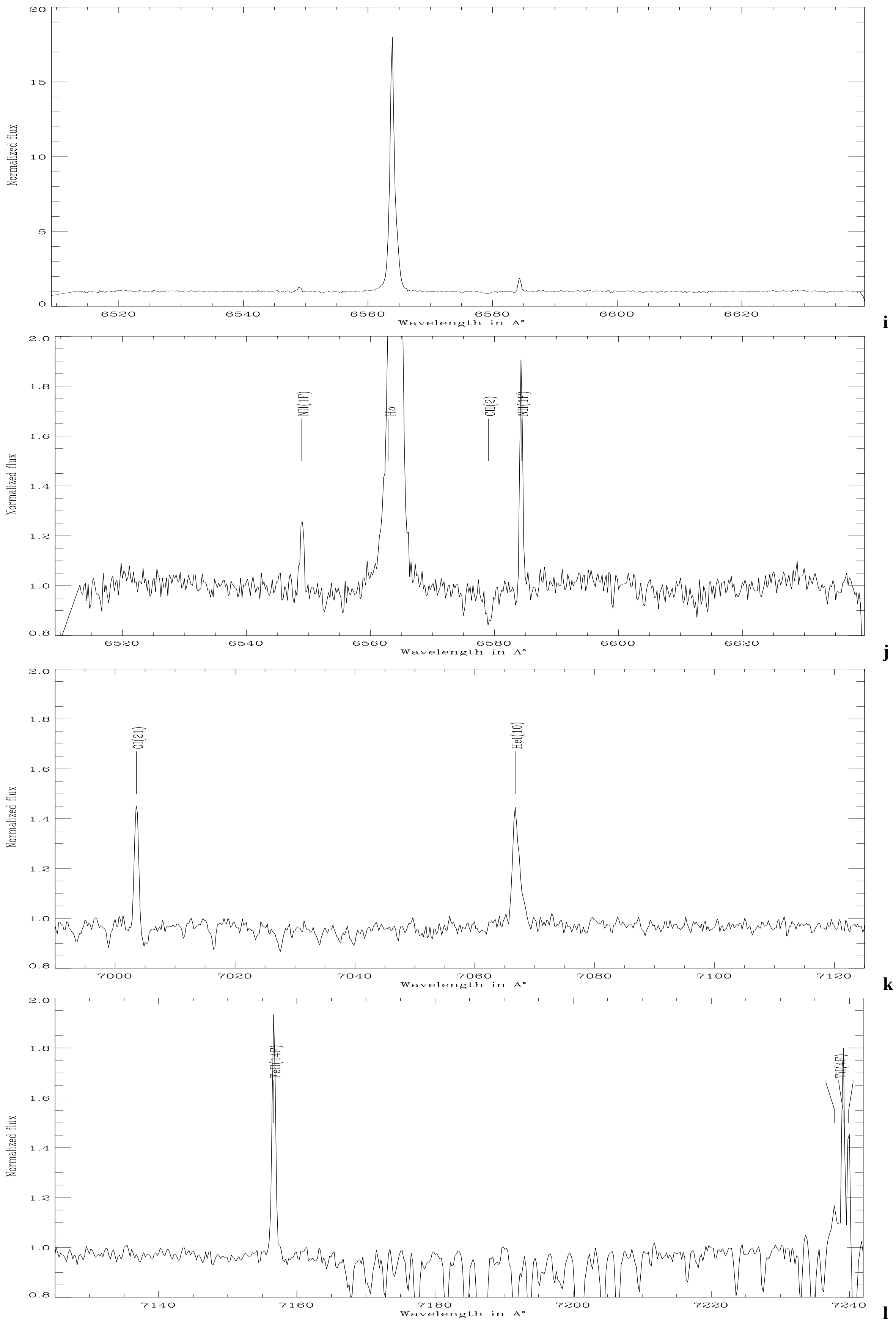

Fig. 1a–p. (continued)

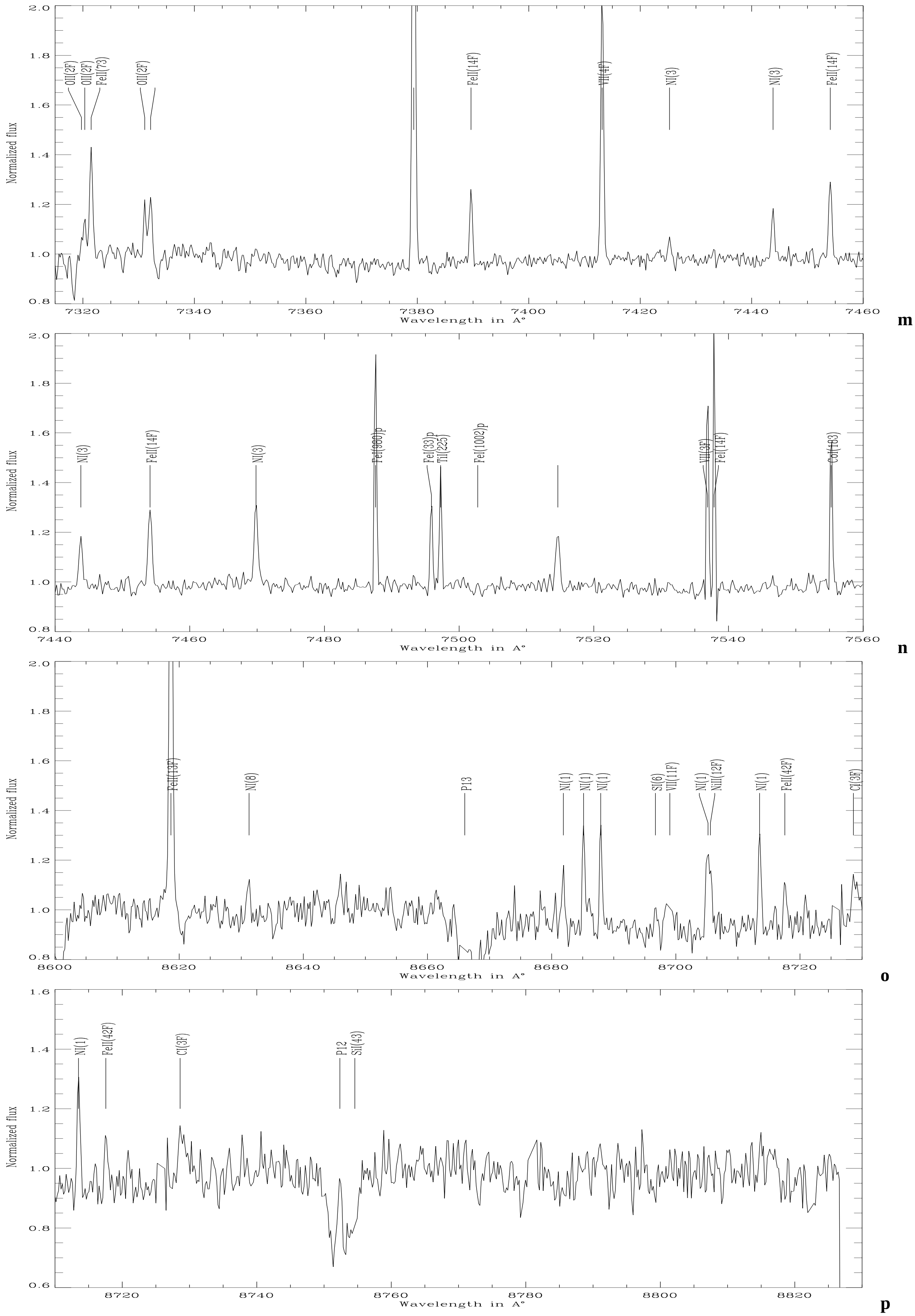

Fig. 1a–p. (continued)

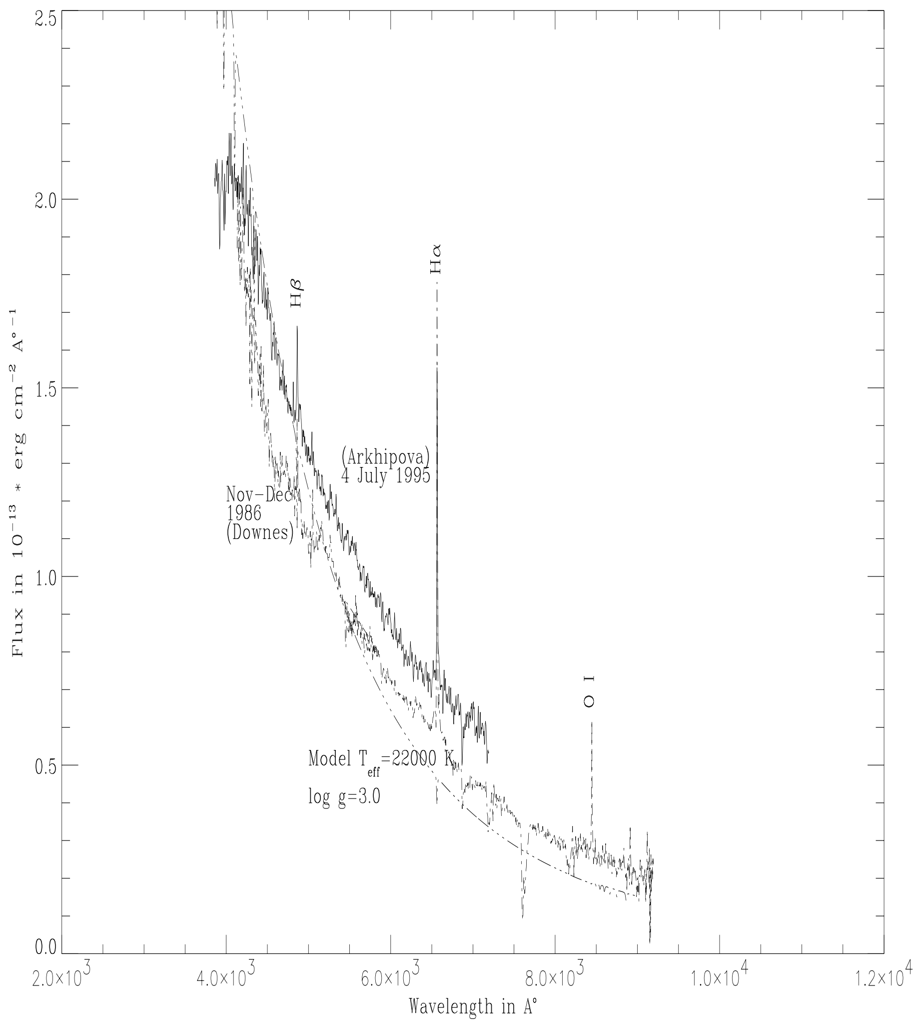

Fig. 2. The flux calibrated spectra at different epochs by (Downes and Keyes (1988) and Arkhipova et al. (1999)) compared with the theoretical continuum for T_{eff}=22000K, log g=3.0, V_t=15km s^{-1}. The observed spectrum shows higher flux in the red.

= 22000K and log g = 3.0. As SAO 85766 is a high galactic latitude star (b = + 19.8), we can estimate an upper limit for the interstellar extinction of E(B-V) = 0.14. However, from the observed B-V and spectral type (B1I as derived from our high resolution spectra), we infer an E(B-V) of 0.2. This indicates that SAO 85766 has significant amount of circumstellar reddening due to the presence of circumstellar dust with far-IR colours similar to planetary nebulae (Manchado et al. 1989). Therefore we have not used the B-V colour to estimate the temperature of the star. The T_{eff} obtained from the present assigned spectral type was adopted for further analysis of the spectrum.

We have used 10 O II absorption lines in the spectrum of SAO 85766 (Table 1) and derived the microturbulent velocity ξ=15±2 km s^{-1} and T_{eff} of 22000± 500K. From the C II and C III lines we derived log g=3.0±0.5. The references for the atomic data and *gf* values used here can be found in the papers of Brown et al. (1986), McCausland et al. (1992), Conlon et al. (1993) and Hambly et al. (1996) who have analysed the spectra of other high latitude hot post-AGB stars with atmospheric parameters similar to those of SAO 85766.

We could not use the helium lines and Balmer lines of hydrogen to determine the atmospheric parameters because of the filled-in emission. The He I 4388Å and He I 4471Å absorption lines in the spectrum of SAO 85766 appear to be not affected by emission and the analysis of these lines indicates that the He abundance is normal.

The microturbulent velocity of 15 km s^{-1} found from the analysis of absorption lines in the spectrum of SAO 85766 is similar to that found in other hot post-AGB stars (McCausland et al. 1992; García-Lario et al. 1997b). It is also consistent with that found in other low gravity early B stars (Underhill and Fahey 1973). However, for SAO 85766 the abundance estimates of metals are insensitive to the value chosen for the microturbulence since the corresponding line strengths are small. We have carried out spectrum synthesis calculations using the above mentioned atmospheric parameters and derived the abundances. The observed and synthetic spectra are shown in Fig. 3. The abundances are given in Table 3. The number of absorption lines used in deriving the abundances are also given in Table 3. The uncertainties in abundances due to uncertainties in T_{eff} of

Table 2. Emission lines in the spectrum of SAO 85766

λ obs	Eqw in Å	λ lab	Ident.
4359.195	0.1452	4358.10	FeII(6F) 4358.37 FeII(21F)
4360.199	0.5542	4359.34	FeII(7F)
4369.029	0.1772	4368.30	OI(5)
4373.302	0.09853	4372.43	FeII(21F)
4377.392	0.05241	4375.932	FeI(2)
4381.867	0.0893	4380.38	MgI(12)
4383.444	0.09488	4382.75	FeII(6F)
4414.682	0.4398	4413.78	FeII(7F)
4417.2	0.5124	4416.27	FeII(6F)
4452.986	0.269	4451.11	FeII(7F)
4458.841	0.3057	4457.95	FeII(6F)
4475.909	0.1341	4474.91	FeII(7F)
4480.572	0.01704	4479.29	CaII(6)
4483.632	0.0584	4482.40	TiII(30)p
4484.422	0.01016	4483.50	VII(224)
4486.076	0.05248	4484.93	FeII(9)p
4486.833	0.0081	4485.87	NiII(3F)
4489.612	0.1299	4488.75	FeII(6F)
4493.636	0.1114	4492.64	FeII(6F)
4515.926	0.129	4514.90	FeII(6F)
4529.471	0.0441	4528.39	FeII(6F)
4550.22	0.06751	4549.214,4549.467	FeII(186,38)
4665.331	0.06971	4664.97	FeII(17F)
4717.264	0.2669	4716.36	FeII(5F)
4729.004	0.2077	4728.07	FeII(4F)
4746.996	0.05725	4745.49	FeII(20F)
4775.648	0.1883	4774.74	FeII(20F)
4798.973	0.04243	4798.29	FeII(4F)
4815.427	0.5053	4814.55	FeII(20F)
4862.311	2.53	4861.332	Hβ
4875.373	0.2239	4874.49	FeII(20F)
4890.532	0.3656	4889.63	FeII(4F), 4889.70 FeII(3F)
4906.291	0.368	4905.35	FeII(20F)

* Flux above the normalised local continuum

Table 2. (continued)

λ obs	Eqw in Å	λ lab	Ident.
4924.927	0.2921	4924.5	FeIII(2F)
4906.255	0.3253	4905.35	FeII(20F)
4924.866	0.1195	4923.921	FeII(42)
4948.419	0.1047	4947.38	FeII(20F)
4951.622	0.1489	4950.74	FeII(20F)
4974.308	0.1866	4973.39	FeII(20F)
4991.874	0.2435	4991.11	FeII(25)p
5001.445	0.2545	5000.73	FeII(25)p
5019.348	0.4743	5018.78	OI(13)
5021.224	0.2281	5020.24	FeII(20F)
5041.965	0.1592	5041.063	SiII(5)
5044.342	0.07459	5343.30	TiI(12F)
5044.957	0.3166	5043.53	FeII(20F)
5056.824	0.2334	5056.020	SiII(5)
5082.938	0.6034	5081.920	FeII(221)
5099.208	0.2118	5098.44	CrI(16F)
5108.947	0.08352	5107.95	FeII(18F)
5112.513	0.2287	5111.63	FeII(19F)
5114.152	0.09261		
5130.615	0.3625	5130.53	OI(29,39)
5147.392	0.09939	5146.55	CrI(15F)
5150.724	0.2607	5150.07	CrI(15F)
5158.867	0.1246	5158.00	FeII(18F)
5159.712	0.54	5158.81	FeII(19F)
5164.874	0.1652	5163.94	FeII(35F)
5166.2	0.1883	5165.156	CoI(39)
5168.06	0.3638	5167.0	TiO(?)
5169.963	0.3076	5169.030	FeII(42)
5182.967	0.1619	5181.97	FeII(18F)
5262.683	0.5947	5261.61	FeII(19F)
5269.958	0.1529	5268.88	FeII(18F)
5274.447	0.4818	5273.38	FeII(18F)
5276.027	0.08072	5275.08	OI(27)

* Flux above the normalised local continuum

$\pm$ 1000K, in log g of $\pm$ 0.5 dex and $\pm$ 5 km/sec in microturbulence are estimated to be of the order of $\pm$ 0.2 dex. We could estimate the abundances of C, N, O, Mg, Al, Si, S and Fe, based on the absorption lines.

The abundance pattern in the atmosphere of SAO 85766 (Table 3) indicates that it is metal poor ([Fe/H] = -0.6). The significant underabundance of carbon ([C/Fe] = -1.0) is similar to that observed in other high galactic latitude hot post-AGB stars (McCausland et al. 1992). The C/N and O/N ratios suggest that products of CNO equilibrium reactions are visible at the photosphere. The abundances of S and Fe indicate that under abundance of Fe is intrinsic and there is no depletion of refractory elements. The underabundance of metals and high galactic latitude indicates that SAO 85766 is a low mass old disk population II star. It is not a population I B supergiant and also it is not a Luminous Blue Variable (LBV).

The underabundance of carbon and metals, high galactic latitude, detached cold circumstellar dust shell and the coincidence of the atmospheric parameters with the post-AGB tracks of Schönberner (1983, 1993) suggest that SAO 85766 is a low mass star in the post-AGB stage of evolution. The post-AGB mass loss appears to have speeded up the evolution of SAO 85766 into the early stages of a low excitation planetary nebula.

3.3. Analysis of emission lines

SAO 85766 shows numerous emission lines of Fe II and [Fe II]. The method used for the analysis of the emission lines is described in our previous paper on the post-AGB star HD 101584 (Sivarani et al. 1999). From the forbidden lines of [Fe II] we derived T_e=10000K$\pm$ 500K. For T_e=10000K we estmated N_e=2.50 $10^4 \pm 100$ cm^{-3} from the [S II] lines and for these values of N_e and T_e the nebular abundances of C, N, O, S and Fe were derived (Table 4).

The elemental abundance pattern of the nebula is quite similar to the photospheric abundances. Carbon and sulfur abundances in the nebula also indicate that it is metal-poor and

Table 2. (continued)

λ obs	Eqw in Å	λ lab	Ident.
5276.922	0.03084	5275.994	FeII(49)
5279.305	0.05391	5278.39	FeII(35F)
5281.977	0.03863	5181.18	NI(14)
5284.171	0.06854	5283.11	FeII(35F)
5292.737	0.06025	5291.78	
5296.004	0.2227	5294.97	SiII
5297.995	0.1348	5286.84	FeII(19F)
5300.114	0.1195	5399.00	OI(26)
5305.379	0.03855	5304.06,	FeI(20F),
		5303.99	FeI(3F)
5306.522	0.06357	5305.85	CrII(24)
5317.772	0.05139	5316.777	FeII
5330.151	0.07955	5329.59	OI(12)
5334.743	0.4354	5333.65	FeII(19F)
5348.704	0.05918	5347.67	FeII(18F)
5356.301	0.04503	5355.9	FeIII(1F)
5377.532	0.3745	5376.47	FeII(19F)
5413.779	0.08574	5412.64	FeII(17F)
5434.243	0.1781	5433.15	FeII(18F)
5478.298	0.08474	5477.25	FeII(34F)
5479.798	0.3986	5478.76	VII(5F)
5482.021	0.05665	5481.17	FeI(20F)
5483.358	0.05555	5482.26	FeI(873)p
5513.891	0.06537	5512.71	OI(25)
7003.572	0.4409	7002.22,7001.93	OI(21)
7066.725	0.8383	7065.188,7065.719	HeI(10)
7156.663	0.692	7155.14	FeII(14F)
7237.869	0.1062		
7239.09	0.3659	7238.29	TiI(4F)
7239.892	0.1797		
7319.74	0.026	7318.6	OII(2F)
7320.33	0.096	7319.4	OII(2F)
7321.471	0.2997	7320.70	FeII(73)
7331.087	0.1311	7330.7	OII(2F)

* Flux above the normalised local continuum

Table 2. (continued)

λ obs	Eqw in Å	λ lab	Ident.
7332.146	0.1931		
7379.362	1.814		
7389.636	0.2132	7388.16	FeII(14F)
7413.166	0.7228	7411.90	VII(4F)
7425.256	0.08306	7423.63	NI(3)
7443.829	0.152	7442.28	NI(3)
7454.101	0.272	7452.50	FeII(14F)
7469.837	0.2485	7468.29	NI(3)
7487.587	0.4295		
7495.89	0.1697		
7497.253	0.2242	7426.12	TiI(225)
7514.663	0.1684		
7536.891	0.399	7533.84	VII(3F)
7537.863	0.4752	7536.93	FeI(14F)
7555.251	0.3281	7553.970	CoI(183)
8618.675	1.67	8616.96	FeII(13F)
8631.259	0.3081	8629.24	NI(8)
8666.0		8660.0	P12 narrow emission from the absorption core
8681.889	0.1565	8680.24	NI(1)
8685.133	0.2976	8683.38	NI(1)
8687.898	0.307	8686.13	NI(1)
8696.707	0.1419	8694.70	SI(6)
8699.034	0.7202	8698.18,8698.69	VII(11F)
8705.182	0.4089	8703.24	NI(1)
8705.572	0.2601	8704.24	NiII(12F)
8713.493	0.3372	8711.69	NI(1)
8717.557	0.1405	8715.84	FeII(42F)
8728.606	0.1762	8727.4	CI(3F)
8717.557	0.2341	8715.84	FeII(42F)
8752.357	0.516	8750.475	P12 narrow emission from the absorption core
8754.583	1.135	8752.17	SiI(43)

* Flux above the normalised local continuum

strongly underabundant in carbon. The oxygen abundance estimated by Arkhipova et al. from the 5577Å line is very high compared to the value derived from the analysis of the 6300Å and 6363Å [O I] and other [O II] lines. There is quite a large uncertainty in the derived N_e and T_e values. The N_e, T_e contours calculated from the [S II] lines and from the [O I] lines do not overlap (see Fig. 4).

3.4. Radial velocities

The absorption lines give an average radial velocity of 46±5 km s^{-1}. The emission lines also show almost the same radial velocity. The radial velocities derived from the emission lines show large scatter, however. There appears to be a weak correlation for emission lines between the optical depth and the radial velocities (Fig. 5). The radial velocity reduces as the optical depth becomes high. That is to say that the velocity increases in the outward direction. But the scatter in the radial velocities from emission lines could be due to pulsation, shock waves or mass motions. Arkhipova et al. (1999) have found SAO 85766 to show irregular rapid light variations with an amplitude up to 0.3 magnitudes in the V filter. The cause for such variations may be due to pulsation of the central star. The present high resolution spectra of SAO 85766 do not show any signature for binarity or symbiotic type. It is most likely a single star. It is not a binary star and it is not a symbiotic star.

4. Discussion and conclusions

Our high resolution spectra of SAO 85766 show that it corresponds, as of 1993, to an early B-type star (B1I) with numerous emission lines. The presence of nebular emission lines indicates the recent development of a low excitation nebula around the star.

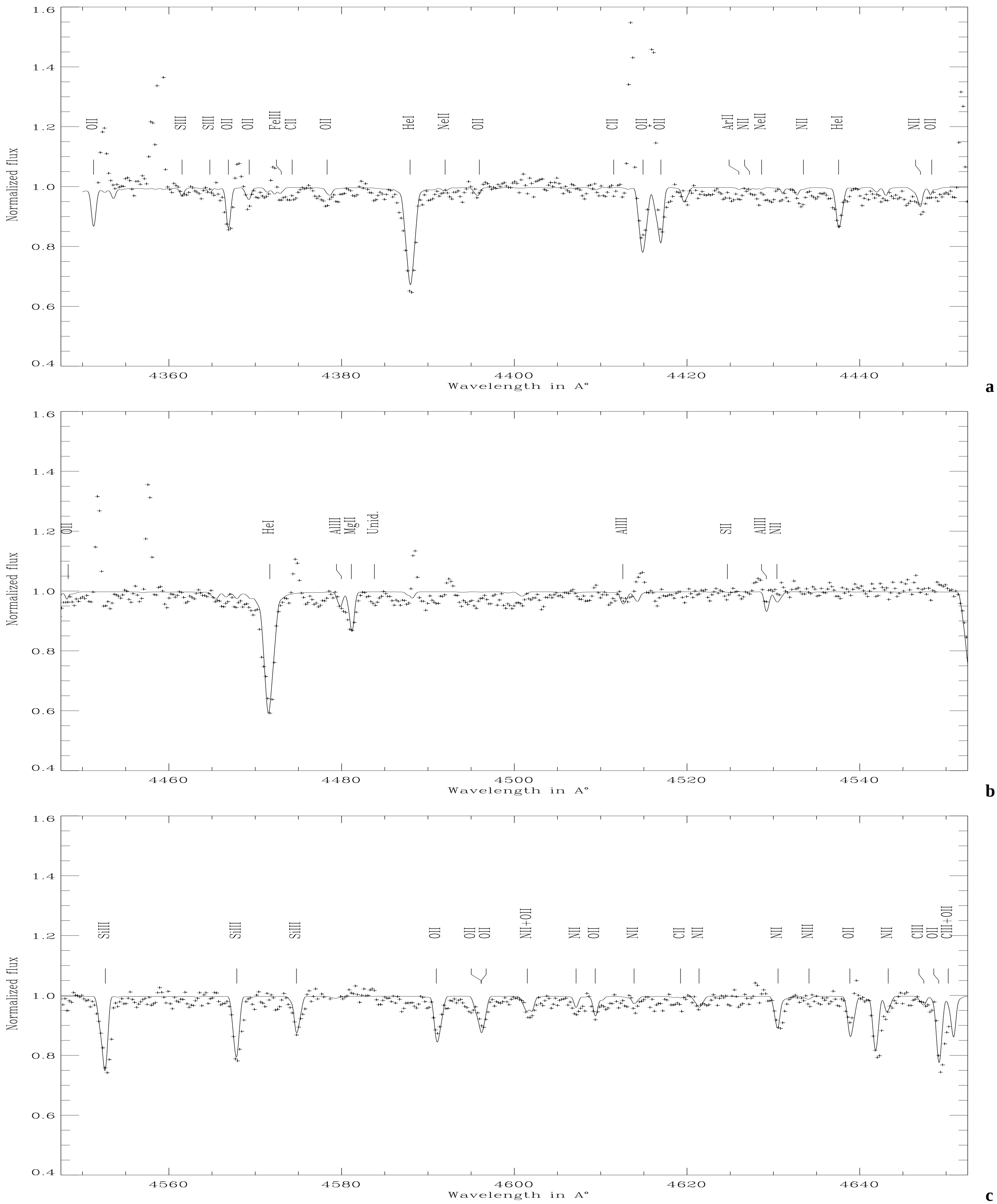

Fig. 3a–f. The dotted line corresponds to the observed and the solid line is the theoritical synthetic spectrum for the model T_{eff}=22000K log g=3.0 and V_t=15km s^{-1}

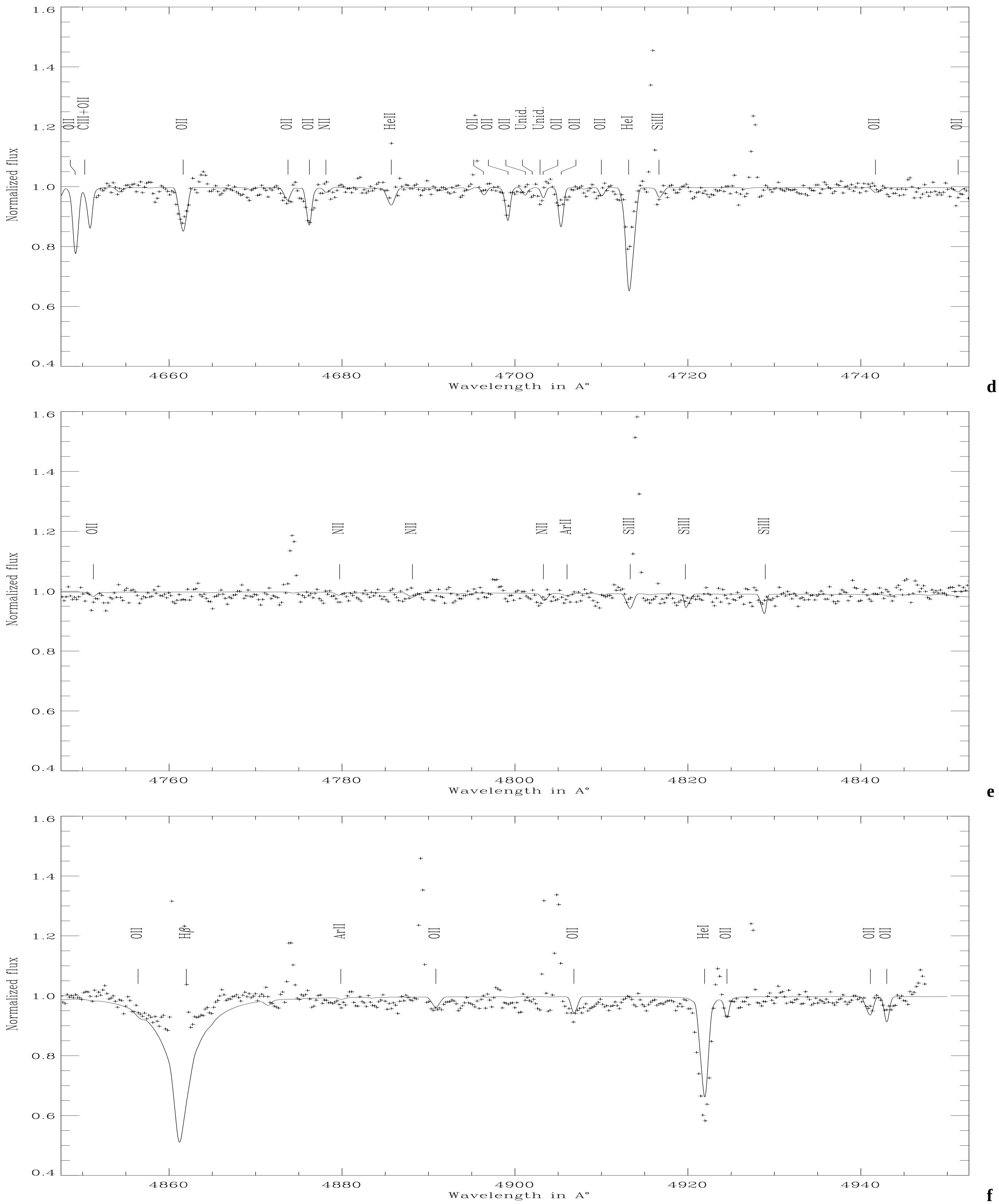

Fig. 3a–f. (continued)

Table 3. Chemical composition of SAO85766 for T_{eff} = 22000, log*g* = 3.0 and V_t = 15km s^{-1}

Element	[el/H]	no. of lines used
C	-1.6±0.2	3
N	-0.7±0.1	6
O	-0.6±0.1	20
Mg	-0.5±0.1	1
Al	-0.6±0.1	2
Si	-0.8±0.1	6
S	-1.0±0.3	3
Fe	-0.6±0.3	3

Table 4. Elemental abundance of the nebula around SAO 85766

Element	[el/H]
C	-1.6±0.4
N	-1.2±0.4
O	-0.7±0.3
S	-1.6±0.3

The elemental abundance pattern of SAO 85766 is similar to that of other recently found hot post-AGB stars at high galactic latitudes (McCausland et al. 1992, Napiwotzki et al. 1994). The high galactic latitude, underabundance of metals, high radial velocity, detached cold circumstellar dust shell and the presence of low excitation nebula indicate that SAO 85766 is a old disk star in the post-AGB stage of evolution. The nebular abundances derived from the forbidden emission lines also lead to the same conclusions. The A5 spectral type assigned to SAO 85766 in 1940 in the HDE catalogue indicates that strong variations in the spectrum have taken place within the last 50 years as a result of rapid post-AGB evolution of the central star towards higher temperatures. Significant post-AGB mass loss may be the cause for this rapid evolution.

From the combination of the derived atmospheric parameters with the theoretical post-AGB evolutionary tracks we can estimate the mass and evolutionary status of SAO 85766. From the post-AGB evolutionary tracks in the log g - log T_{eff} plane (Schönberner 1983, 1993) SAO 85766 should be a hot post-AGB star with a core mass of the order of 0.6 $M_\odot$. The observed abundance pattern of SAO 85766 is similar to that of Barnard 29 (Conlon et al., 1994, Moehler et al. 1998) which is a hot post-AGB star in the globular cluster M13. The underabundance of carbon in SAO 85766 and in other high latitude hot post-AGB stars is in agreement with the hypothesis pointed out by Iben (1991) that low mass stars may lose their envelopes and evolve blueward before thermal pulsing begins. However, in order for the star to have evolved so rapidly, it has to be a post-AGB star with a core mass of the order of 0.7 $M_\odot$ (Blöcker 1995, Blöcker and Schönberner 1997). Arkhipova et al. (1999) also estimate the core mass to be about 0.7 $M_\odot$, which translates to an initial mass of 5 $M_\odot$. Even if the core mass is 0.6 $M_\odot$ (which seems to be too low in view of the rapid evolution) the initial mass would be about 2 $M_\odot$. The rapid post-AGB evolution of SAO 85766 indicates that its initial mass may be more than 2 $M_\odot$ and the AGB phase of evolution was terminated only recently. According to Blöcker (1995) a post-AGB star of 0.7 $M_\odot$ traverses the spectral interval F0 to B1 in about 100 years.

SAO 85766 was observed during 1972-73 by the Ultraviolet Sky Survey Telescope (S2/68) onboard the ESRO satellite TD-1. The UV fluxes of this star in 1973 are given in the Catalogue of Stellar Ultraviolet Fluxes (Thompson et al. 1978). The UV colours (m_{1565} - m_{2740}) and (m_{1565}-m_{2365}) listed in this Catalogue indicate that in 1973 its spectral type was still A5I. The UV fluxes and colours clearly indicate that in 1973 it was not a B star. This implies that the changes observed in SAO 85766 from an A type spectrum to an early B type spectrum have occurred within the last 25 years as a result of the evolution of the central star towards higher temperatures.

Very rapid evolution has also been observed in the post-AGB star SAO 244567 (Hen 3−1357 = Stingray Nebula) (Parthasarathy et al. 1993, 1995; Bobrowsky et al. 1998). Hen 3−1357 has turned into a young planetary nebula within the last 20 years and the central star appears to be evolving rapidly into a DA white dwarf (Parthasarathy et al. 1993, 1995). SAO 85766 appears to be the second known case of rapid evolution of a hot post-AGB star. The high galactic latitude hot post-AGB stars LS II + 34 26 (Parthasarathy 1993b, 1994; García-Lario et al. 1997b) and LS IV −12 111 (Parthasarathy 1994; Conlon et al. 1993) are also IRAS sources with far-infrared colours similar to planetary nebulae and show nebular emission lines. They also show underabundance of carbon (Conlon et al. 1993; García-Lario et al. 1997b). The chemical composition SAO 85766 is very similar to that of LS IV −12 111 (Conlon et al. 1993). However, in the spectra of these two stars we do not see the permitted and forbidden emission lines due to Fe and other metals. As these stars evolve further towards higher temperatures it is possible that their spectra may show characteristics similar to those now observed in SAO 85766.

Some compact and young planetary nebulae have also been found to show permitted and forbidden emission lines of Fe. The spectrum of the compact planetary nebula HD 51585 (OY Gem) shows the so-called B[e] phenomenon. The spectrum of HD 51585 was described in detail by Jaschek et al. (1996), Arkhipova (1962) and Klutz and Swings (1977). Parthasarathy and Pottasch (1989) found it to be an IRAS source with far-IR colours similar to planetary nebulae. The spectrum of SAO 85766 appears to be very similar to that of HD 51585. Recently, Lamers et al. (1998) discussed the group of young planetary nebulae that show the B[e] phenomenon. Ciatti et al. (1974) suggested that some BQ[ ] stars must be evolving into planetary nebulae. Parthasarathy and Pottasch (1989) found several BQ[ ] and B[e] stars to show far-infrared IRAS colours similar to those of planetary nebulae. Their list included Hen 3−1357, and Hen 3−1475. Later, detailed observations of these objects confirmed that they are indeed in the young planetary nebula stage (Parthasarathy et al. 1993, 1995; Riera et al. 1995).

In the case of some BQ[ ] stars there is confusion on status between symbiotic stars and low excitation planetary nebulae (Lamers et al. 1998 and references there in). Symbiotic B[e]

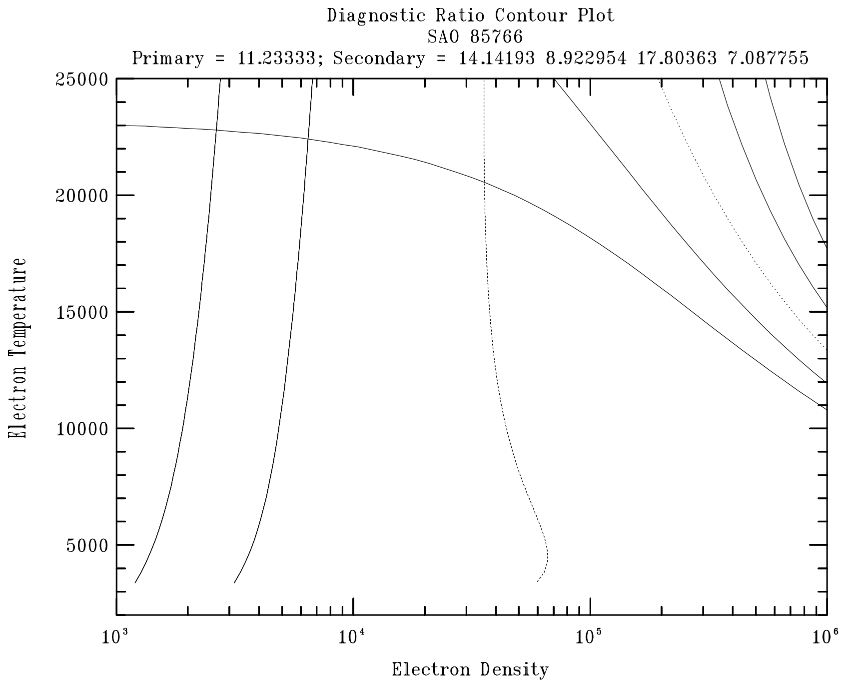

Fig. 4. Contour plot of electron temperature and electron density. Each line corresponds to a particular line ratio. The dotted line is for the observed line ratio. The vertical lines are for line ratio are for [S II] 6716/6731. The horizontal lines are for [O I] 6300+6363/5577.

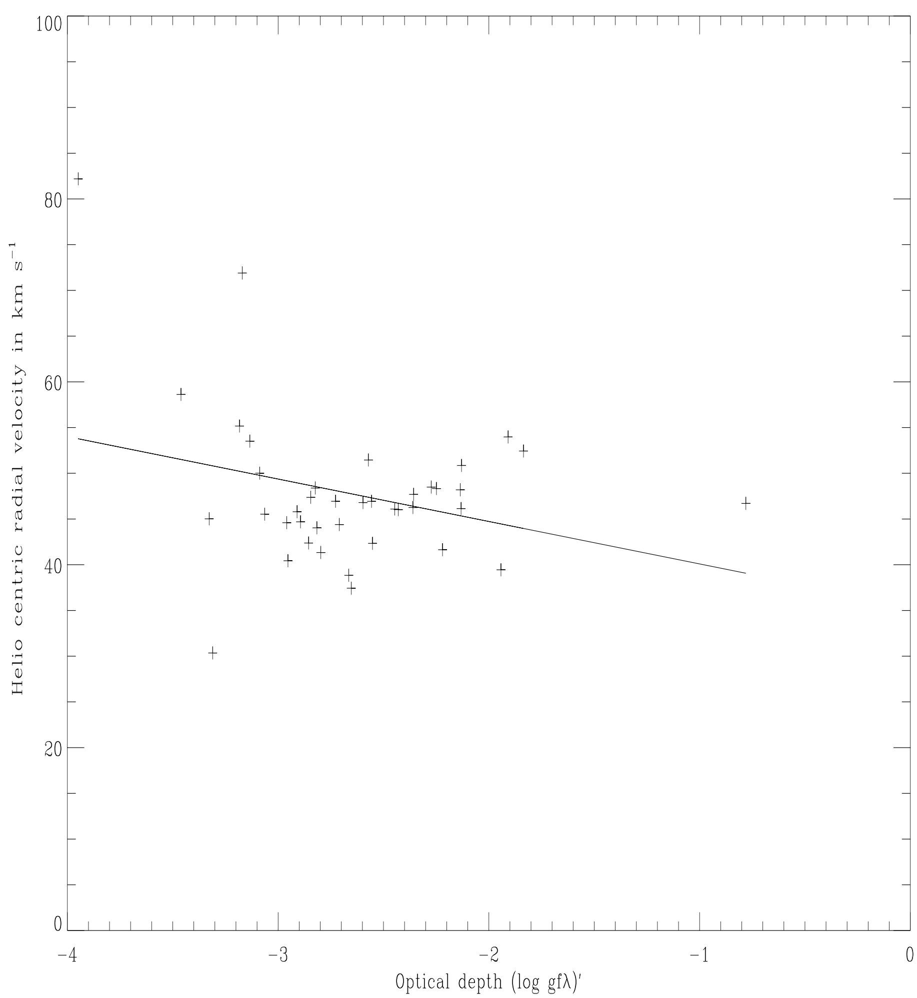

Fig. 5. The plot shows a correlation between the heliocentric radial velocities and the optical depth for the [FeII] emission lines.

stars are interacting binaries with a cool giant and a hot compact object. They often show the TiO absorption bands in their spectra. There are no Tio bands in our high resolution spectra of SAO 85766. There is no observational evidence for any late-type companion and we conclude that SAO 85766 is not a symbiotic star. The far infrared (IRAS) colours of symbiotic stars are very different from that of planetary nebulae. The far infrared (IRAS) colours of SAO 85766 are similar to that of planetary nebulae and proto-planetary nebulae. The observed changes in the spectrum are the result of rapid post-AGB evolution of SAO 85766.

Imaging SAO 85766 in Hα, Hβ and in the forbidden emission lines displayed by this star with the HST WFPC2 may reveal the shape and physical properties of the incipient nebula and enable us to further understand the birth and early evolution of planetary nebulae.

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