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THE SYMBIOTIC STAR NEAR THE GLOBULAR CLUSTER NGC 6401

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RESUMEN

Se presentan observaciones espectrofotométricas del objeto con líneas de emisión cercano al cúmulo globular NGC 6401 descubierto por Peterson (1977), Pt-1. Se encuentra que Pt-1 es una estrella simbiótica y no una nebulosa planetaria. Sus espectros muestran: bandas de TiO en absorción, líneas de H y He muy intensas en emisión y ausencia de líneas prohibidas lo cual indica que $N_e \gtrsim 10^8$ cm^{-3} en la región donde se originan las líneas de emisión. Las líneas de He de la serie $2^1P - n^1D$ son un orden de magnitud más intensas que lo predicho bajo la hipótesis del caso B y $N_e \leqslant 10^7$ cm^{-3}. Se sugiere que esto se debe a redistribución colisional del momento angular en los niveles con $n > 2$.

ABSTRACT

Spectrophotometric observations of the emission line object near the globular cluster NGC 6401 discovered by Peterson (1977), Pt-1, are presented. It is found that Pt-1 is a symbiotic star and not a planetary nebula. Its spectra show: TiO bands in absorption, very strong H and He lines in emission; there are no forbidden lines present implying that $N_e \gtrsim 10^8$ cm^{-3} for the region where the emission lines originate. The observed He lines of the $2^1P - n^1D$ series are about one order of magnitude stronger than predicted under the assumption of case B and $N_e \leqslant 10^7$ cm^{-3}. It is suggested that this is partly due to collisional redistribution of the angular momentum for levels with $n > 2$.

Key words: CLUSTERS-GLOBULAR – ATOMIC PROCESSES – NEBULAE-PLANETARY – STARS-COMBINATION SPECTRA.

I. INTRODUCTION

Peterson (1977) reported an emission line object, Pt-1, located approximately 3′ east and 0.′5 north of the center of the globular cluster NGC 6401. Observations with interference filters taken on 1976 August 27/28 and 29/30 by Peterson showed Hα and [N II] lines in emission and very faint, if any, of the central star's continuum. Based on these data Peterson suggested that Pt-1 is a planetary nebula probably associated to NGC 6401.

We decided to make detailed observations of Pt-1 to continue our studies on the halo planetary nebulae. At present here are only three extreme halo planetary nebulae known in the Galaxy and these objects give very important clues for the study of the early stages of the galactic chemical evolution (i.e. Torres-Peimbert and Peimbert 1979).

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II. OBSERVATIONS

The observations were carried out during three observig seasons (1977 July 12-16, 1978 May 11-15, 1979 March 23-26) at KPNO with the 2.1 m telescope and the Image Intensifier Dissector Scanner, IIDS. The instrument and the observational procedure have been described elsewhere (Torres-Peimbert and Peimbert 1977, 1979). The dual entrance slits used were 0.30 × 0.98 mm where the first value is along and the second perpendicular to the dispersion; they correspond to 3.8 × 12.4 arc sec on the plane of the sky. For the observations reported here the slits were oriented east-west, the separation between the centers of both slits corresponds to 99 arc sec. Two gratings, at a dispersion of 86 Å/mm, were used to cover the wavelength range of interest, one for 3 400-5 200 Å and the other for 5 600-7 400 Å. The half-width resolution was 6–7Å for both settings.

The calibration was derived from standard star fluxes by Stone (1974) and Oke (1974) modified by means of the calibration by Hayes and Latham (1975).

Table 1 contains the emission line intensities, it includes the log F(λ)/F(Hβ) values where F(λ) is the observed line flux in erg cm^{-2} s^{-1} corrected for atmospheric extinction. The continuum contribution to each emission line was subtracted by interpolating the continuum at both sides of the emission line; the rms errors for the line intensity ratios have been estimated by comparing results of different nights and are smaller than 0.06 dex with the exception of the measurements marked with a colon; the values for the undetected lines are 2σ upper limits. In Table 2 we present the log f(λ)/f(6 620) values at selected wavelengths where f(λ) is the observed continuum flux in erg cm^{-2} s^{-1} $Å^{-1}$; our f(λ) values in the blue are averages over 16 Å and in the red over 32 Å to make our system comparable with that of Spinrad and Taylor (1969); the rms errors are smaller than 0.05 dex. We do not present the fluxes for $\lambda < 4\,500$

TABLE 1

EMISSION LINE INTENSITIES*

λ	Ident.	g(λ)	F(λ) May 78	I(λ) May 78	I(λ) May 78	F(λ) July 77	F (λ) March 79
3726+3729	[O II]	+0.315	<-1.88	<-1.14	<-1.41	<-1.26	<-1.42
3888+3889	HeI+H8	+0.265	-1.54:	-0.91:	-1.14:	....	....
3965+3970	HeI+H7	+0.235	-1.30:	-0.75:	-0.95:	....	....
4102	Hδ	+0.200	-1.05	-0.58	-0.75	-1.01	-1.08
4340	Hγ	+0.135	-0.67	-0.35	-0.47	-0.62	-0.74
4388	HeI	+0.125	-1.36	-1.06	-1.17	....	....
4472	HeI	+0.105	-1.64:	-1.39:	-1.48:	....	....
4686	HeII	+0.045	-0.39	-0.28	-0.32	-0.20	-0.24
4713	HeI	+0.035	-1.50	-1.42	-1.45	....	....
4861	Hβ	0.000	0.00	0.00	0.00	0.00	0.00
4922	HeI	-0.010	-0.78	-0.80	-0.80	-1.10	-0.90
4959	[O III]	-0.020	<-2.13	<-2.18	<-2.16	<-1.50	<-1.77
5007	[O III]	-0.030	<-1.73	<-1.80	<-1.78	<-1.15	<-1.29
5016	HeI	-0.030	-1.29	-1.36	-1.34	....	....
5876	HeI	-0.210	-0.32	-0.82	-0.64	....	-0.47
6563	Hα	-0.335	+1.28	+0.49	+0.78	....	+1.30
6583	[N II]	-0.340	<-0.90	<-1.70	<-1.41	....	<-0.43
6678	HeI	-0.360	+0.13	-0.72	-0.41	....	+0.07
7065	HeI	-0.400	-0.11	-1.05	-0.71	....	+0.01:
7281	HeI	-0.420	-0.54:	-1.53:	-1.17:	....	....
log F(Hβ)		....	-13.61	....	....	-13.98:	-13.72:
C(Hβ)		....	....	2.36	1.50	....	....

* Given in log F(λ)/F (Hβ). Flux in erg cm^{-2} s^{-1}.

TABLE 2

CONTINUUM FLUXES*

λ	f(λ) May 78	f(λ) March 79
4500	−1.30	−1.32
4715	−1.16	−1.11
4900	−1.01	−0.98
5000	−0.94	−0.90
5175	−0.98	−0.95
5840	−0.31	−0.33
5892	−0.36	−0.38
6110	−0.15	−0.14
6180	−0.25	−0.30
6386	−0.08	−0.06
6620	0.00	0.00
7000	+0.15	+0.18
7100	+0.03	+0.02
7400	+0.21	+0.26
log f(6620)	−14.30	−14.28

* Given in log f(λ)/f(6620). Flux in erg cm^{-2} s^{-1} Å^{-1}.

Å because of the low signal to noise ratio of our observations; the observations of July 1977 were only made in the blue region and due to the very short integration time the noise was about four times larger than in the May 1978 observations. In Table 3 we present the equivalent widths of three absorption features; the rms errors are smaller than 0.04 dex. The absolute fluxes in F(Hβ) and f(6 620) have rms errors smaller than 0.05 dex in May 78 and 0.10 in March 79; the F(Hα) f(6 620) ratios have rms errors smaller than 0.03 dex for both observing seasons, therefore the decrease in this ratio of 0.11 dex is real. In Figures 1 and 2 we present our May 78 spectra.

III. DISCUSSION

The TiO bands in absorption together with the H and He emission lines indicate that Pt-1 is a symbiotic star. To make a quantitative discussion of the spectrum of Pt-1 it is necessary to estimate the interstellar reddening to this object. The intrinsic emission line intensities are given by

$$\log I(\lambda)/I(H\beta) = \log F(\lambda)/F(H\beta) + C(H\beta)g(\lambda) \; , \quad (1)$$

where C(Hβ) is the logarithmic reddening correction at Hβ and g(λ) is the reddening function normalized at Hβ adopting the normal extinction law (Whitford 1958). In Table 1 we present g(λ) and I(λ) for two values of C(Hβ). A similar equation relates the intrinsic, i(λ), and the observed, f(λ), continuum fluxes.

The absence of the typical forbidden lines in planetary

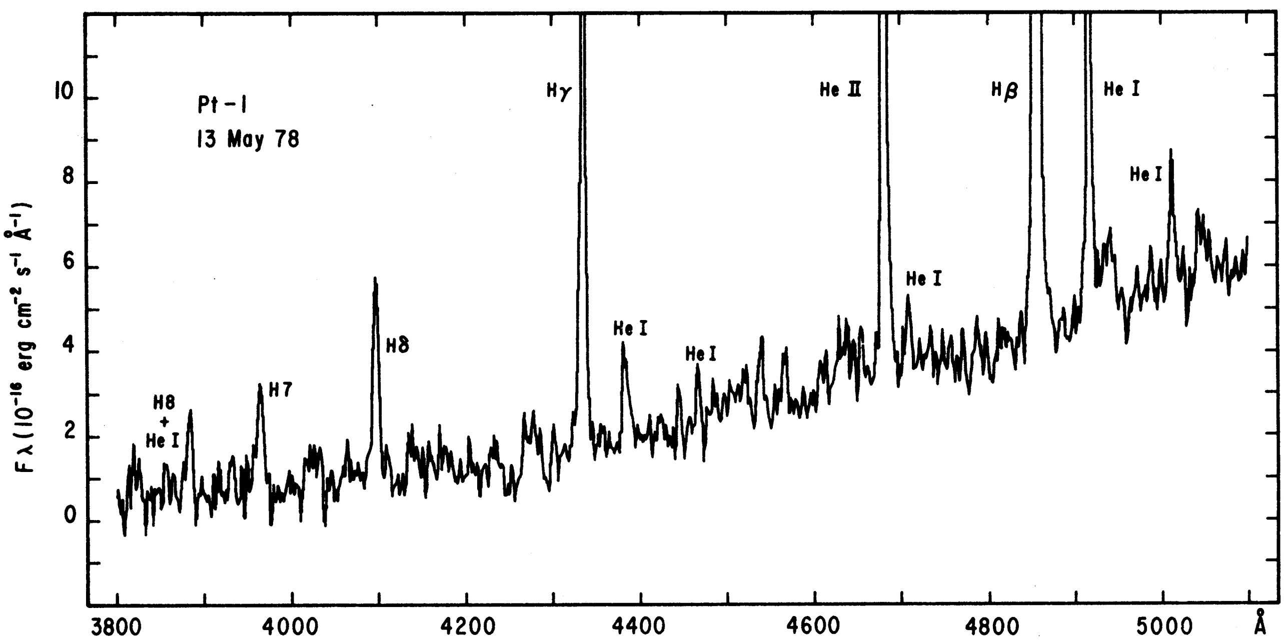

Fig. 1. Scanner observations of Pt-1. Blue region of the spectrum.

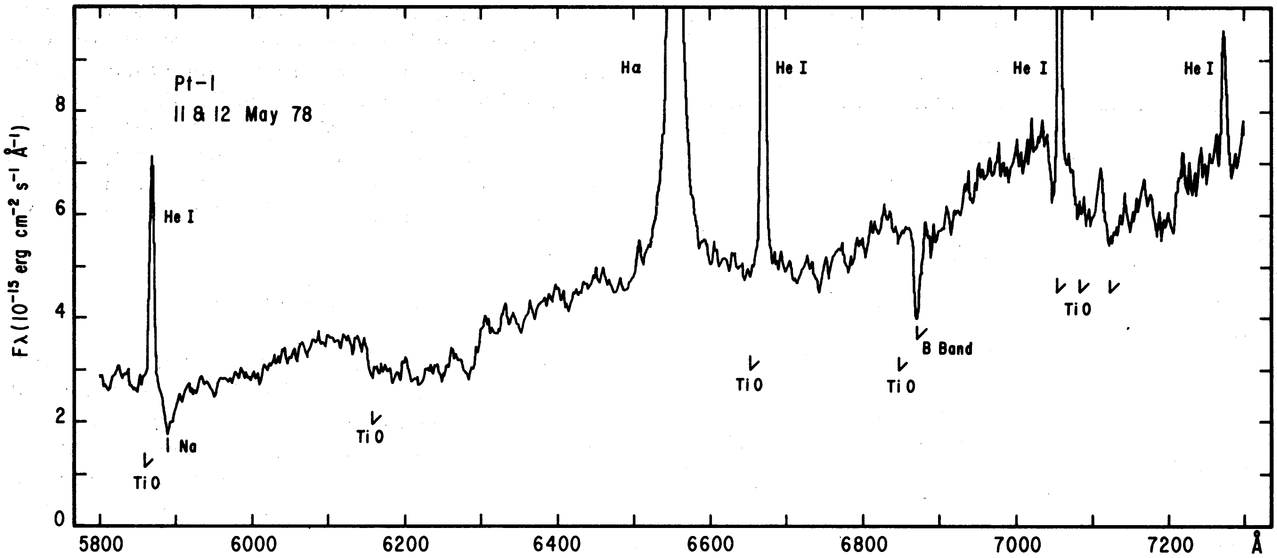

Fig. 2. Scanner observations of Pt-1. Red region of the spectrum. The spectrum is the average of the observations of 11 and 12 May 1978.

TABLE 3

ABSORPTION FEATURES

λ	Ident.	E.W. (Å) May 78	E.W. (Å) March 79
5892	Na	4.1	
6150-6320	TiO	27.0	32.5:
7050-7250	TiO	21.5	25.3:

nebulae of low, medium and high degree of ionization indicates that $N_e \gtrsim 10^8$ in the region where the H and He lines originate. For this object the effects of self-absorption (Capriotti 1964 *a, b;* Netzer 1975) and collisional redistribution (Adams and Petrosian 1974) on the Balmer line intensities with n < 7 might be significant and therefore it might not be possible to derive the reddening by assuming a pure recombination spectrum with $N_e < 10^6$ cm^{-3}.

There is an alternate method to estimate the interstellar reddening. By comparing the strength of the TiO bands in the red (see Figure 2 and Table 3) with the observations of late type stars (Spinrad and Taylor 1969), it is found that the continuum corresponds to a star of spectral type M1. Symbiotic stars show emission lines corresponding to a high degree of ionization superposed on a low temperature stellar spectrum, usually of type M (*i.e.* Swings 1970). Therefore by fitting the observed continuum fluxes to an M1 spectrum the interstellar reddening can be obtained; if there is a significant contribution of a hotter companion to the observed continuum, only a lower limit to the reddening can be derived.

In Figure 3 we show the continuum fluxes of χ Peg, an unreddened M1 III star observed by Spinrad and Taylor (1969) calibrated to m_λ by means of 58 Aql that Spinrad and Taylor have in common with Hayes (1970). In this figure we also show the May 78 fluxes of Pt-1 without correction for reddening. By fitting λ 6 620 and the blue fluxes of Pt-1 to those of χ Peg by means of Whitford's (1958) reddening curve a value of $A_V = 5.0$ mag is obtained (see also Figure 3) which corresponds to C(Hβ) = 2.36. A similar value is obtained from the March 79 observations. The fit is reasonable in the blue and red but Pt-1 shows a yellow excess of about 0.2 mag that might be significant.

In Table 1 we present the intrinsic line intensities corrected by C(Hβ) = 2.36. The Balmer decrement is very close to that obtained under case B for $N_e < 10^{11}$ cm^{-3}; (Brocklehurst 1971; Adams and Petrosian 1974), although Hα/Hβ is slightly higher perhaps due to Balmer self-absorption. Tables 1 and 4 include line intensity ratios corrected with a considerably smaller value of the reddening, C(Hβ) = 1.50, this value will be discussed later on.

In Table 4 we compare the He I intrinsic line intensity ratios of Pt-1 of May 78 with the theoretical ones com-

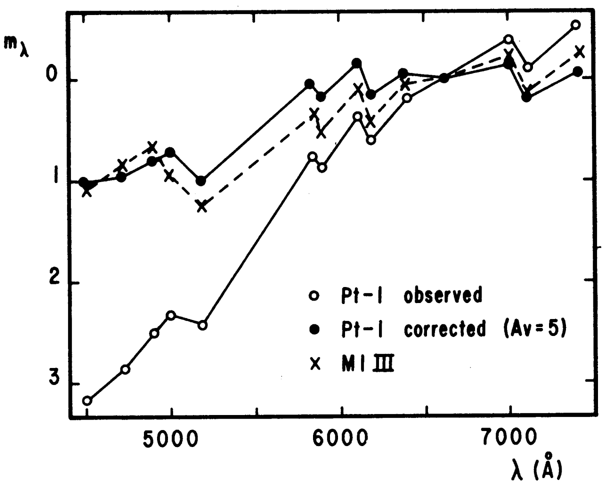

Fig. 3. Comparison of continuum fluxes of the symbiotic star Pt-1 to the M1 III unreddened star χ Peg, normalized at λ6 620. Open circles correspond to the observed fluxes of Pt-1. Filled circles correspond to the best fit of the observations of the blue continuum of Pt-1 to χ Peg assuming the normal reddening law; this fit yields $A_V = 5$ mag, or C(Hβ) = 2.36.

puted by Brocklehurst (1972) under the assumption of cases A and B for $N_e = 10^7$ cm^{-3} and $T_e = 10\,000$°K. The predicted ratios are not sensitive to the adopted values of T_e and N_e for $N_e < 10^7$ cm^{-3}. The observed singlet to $2^3P - n^3D$ line intensity ratios are from one to two orders of magnitude larger than those predicted under case A. It has been known for a long time that the singlet lines in symbiotic stars are enhanced with respect to the $2^3P - n^3D$ lines. Since transitions from singlet to triplet levels are forbidden and 1^1S is the ground level of the He I atom, absorption of Lyman line photons would increase the intensity of the singlet series without affecting the triplet series; therefore it has been suggested that the excess intensities in the $2^1P - n^1D$ series are due to fluorescense mechanisms involving the absorption of stellar continuum at the He I Lyman lines (e.g. Swings and Struve 1942, 1943; Swings 1970). In what follows we will consider this suggestion further.

In a gaseous nebula there are two sources of Lyman line photons, those produced by the nebula and those present in the stellar radiation field. Under case A it is assumed that there is no reabsorption of Lyman line radiation. Under case B it is assumed that there is no escape of Lyman line radiation produced by the nebula and that there is no stellar radiation field in Lyman lines. The absorption of Lyman photons excites the n^1P levels that decay spontaneously preferentially to the ^1S levels over the ^1D levels; therefore the absorption of Lyman line photons leaves the $2^1P - n^1D$ series almost unaffected, the $2^1P - n^1S$ series moderately enhanced and the $2^1S - n^1P$ series strongly enhanced. This effect can be seen from Table 4 where the excess in the singlet line intensities of case B relative to case A for the $2^1P - 3^1D$, $2^1P - 3^1S$ and $2^1S - 3^1P$ lines is of 0.02, 0.27 and 1.66 dex respectively.

The observed intensity of the λ5 016 line can be explained by case B at $N_e = 10^7$ cm^{-3} but not the very large intensities of the $2^1P - n^1D$ lines and of the $2^1P - 3^1S$ line. At $N_e = 10^7$ cm^{-3} by including the Lyman line photons of the stellar radiation field the increase in the singlet line intensities will be larger than in case B, but again most of the increase will be on the $2^1S - n^1P$ series and the $2^1P - n^1D$ series will remain almost unaffected, contrary to observations.

Another mechanism is needed to explain the large population of the ^1D levels and we suggest that it is due to inelastic electron-atom collisions producing a redistribution of the angular momentum within a given n. Since this effect depends on the time that the atoms remain in the excited levels, and the spontaneous transition probability decreases with increasing n, the effect is higher for higher levels. This is indeed what is observed; from Table 4 for C(Hβ) = 2.36 it is obtained that the excess of the $2^1P - n^1D$ series relative to $2^3P - 3^3D$ is of 0.65, 1.02, and 1.08 dex for n equal 3, 4, and 5 respectively.

From the computations by Brocklehurst (1971) it is found that for case B and $T_e = 10\,000$°K the line intensities of $2^1P - n^1D$ for n equal 13, 14 and 15 are 0.15, 0.18 and 0.21 dex brighter in the $N_e = 10^7$ cm^{-3} case than in the $N_e = 10^4$ cm^{-3} case while the $2^1S - n^1P$ for n equal 13, 14 and 15 lines are 0.09, 0.11 and 0.12 dex fainter; the trend of these results is in the right direction but to explain the line intensities in Pt-1, N_e has to be considerably higher than 10^7 cm^{-3}

TABLE 4

HELIUM LINE INTENSITIES*

λ	Transition	Obs.	Obs.	Case A	Case B
4388	$2^1P - 5^1D$	−0.24	−0.53	−1.34	−1.32
4472	$2^3P - 4^3D$	−0.57:	−0.84:	−0.43	....
4713	$2^3P - 4^3S$	−0.60	−0.81	−1.30	....
4922	$2^1P - 4^1D$	+0.02	−0.16	−1.01	−1.00
5016	$2^1S - 3^1P$	−0.54	−0.70	−2.32	−0.66
5876	$2^3P - 3^3D$	0.00	0.00	0.00	....
6678	$2^1P - 3^1D$	+0.10	+0.23	−0.57	−0.55
7065	$2^3P - 3^3S$	−0.23	−0.07	−0.92	....
7281	$2^1P - 3^1S$	−0.71	−0.53	−1.56	−1.29
C(Hβ)		2.36	1.50		

* Given in log I(λ)/I(5876).

to significantly populate the ^{1}D states for n > 2, and additional absorption of Lyman line photons is needed to increase the population of the ^{1}P states. At these high densities also the triplet line system is affected by collisional redistribution.

In Table 5 we present the He^+/H^+ abundance ratios derived from the observed He II λ4 686 lines and the He I triplet lines λλ5 876, 4 472 relative to He together with the computations by Brocklehurst (1971, 1972) for T_e = 10 000°K, N_e = 10^6 or 10^7 cm^{-3} (the maximum density of Brocklehurst's computations) and case B for the hydrogenic line intensities. We have not considered the effect of self-absorption in the λλ4 472 and 5 876 line intensities which is expected to be smaller than 5% and 9% respectively (Robbins 1968; Cox and Daltabuit 1971), nor collisional excitation from the metastable 2^3S level which is expected to be small (Peimbert and Torres-Peimbert 1971; Brocklehurst 1972). It can be seen that the He/H abundance ratios are about the same as those of planetary nebulae in the direction of the galactic center (Torres-Peimbert and Peimbert 1977) and that the abundances derived from the May 78 and March 79 observations are similar. This result implies that λλ5 876 and 4 472 do not deviate considerably from the pure recombination case. If alternatively we assume that the 2^1P – n^1D lines are produced under case B and N_e = 10^7 cm^{-3} we would derive a He/H value about one order of magnitude higher than those encountered in galactic and extragalactic gaseous nebulae, this is a very unlikely situation; and even if we were to accept it, we would still need to explain the relative faintness of the triplet lines.

We have compared the high 7 065/5 876 and 4 713/5 876 ratios with the computations by Robbins (1968) that include the effect of self-absorption of the 2^3S – n^3P series. According to these computations the observed 7 065/5 876 line intensity ratio corresponds to a nebula of high optical thickness of τ_0(3 889) ~ 50, this value is compatible with the observed intensity of λ3 889 (He I + H I). Alternatively, the 4 713/5 876 line intensity ratio is stronger than predicted indicating that other processes, like collisional redistribution with the triplet series, are at play.

TABLE 5

HELIUM ABUNDANCE BY NUMBER FOR C(Hβ) = 2.36 UNDER THE ASSUMPTION OF CASE B FOR THE HYDROGENIC ATOMS

λ		May 78	Mar 79
4472	He^+/H^+	0.082	....
5876	He^+/H^+	0.114	0.081
4686	He^{++}/H^+	0.036	0.050
	He/H	0.12–0.15	0.13

NGC 6401 is a globular cluster located close to the galactic center (ℓ = 3.45°, b = +3.97°) in a very crowded region and therefore difficult to observe. Kron and Mayall (1960) obtained photoelectric photometry for this cluster; under the adoption of their case II and assuming that the integrated spectrum of the cluster is G5 (no observations of the spectrum are available) values of $E(B-V) = 0.56$ and $A_V = 1.7$ mag are derived. From the same observational data other authors have derived the following values of $E(B-V)$: 0.74, 0.69 and 0.5 (Knapp and Kerr 1974; Peterson and King 1975; Woltjer 1975), and the following values of the distance to the cluster: 7 kpc and 8.5 kpc (Kukarkin 1974; Alcaino 1977). At a distance of 7.8 kpc the projected separation on the plane of the sky from Pt-1 to the center of NGC 6401 is of 6.9 pc; at this distance, a physical relationship between both objects is unlikely, but it is not ruled out. Inspection of the Palomar Sky Survey Plates of the region around NGC 6401 shows that there is variable extinction on small angular scale indicating that even if Pt-1 were associated to NGC 6401 its reddening could be different.

The high value of the reddening for Pt-1 determined from the continuum relative to that of NGC 6401 led us to look for alternate methods to determine it.

Lutz *et al.* (1976) have observed He2–467. This object has H and He in emission superposed on the absorption spectrum of a G type star; it shows no forbidden emission lines and an excess in the 2^1P – n^1D line intensities. The 4 922/6 678 and 4 009/6 678 line intensity ratios for He2–467 are very close to those computed by Brocklehurst (1972) for N_e = 10^7 cm^{-3}. The 4 388/6 678 line ratio deviates from such computations; but the determination of the λ4 388 line intensity is strongly affected by the underlying stellar spectrum, particularly the absorption line λ4 383 of Fe I. The Balmer decrement for He2–467 shows a very mild deviation, if any, with respect to a normal Balmer decrement with no self-absorption.

By assuming that in Pt-1, as in He2–467, the line intensity ratios within the 2^1P – n^1D series correspond to those computed by Brocklehurst (1972) for $N_e = 10^7$ cm^{-3}, reddening values of $A_V = 3.18$ mag and C(Hβ) = 1.50 are derived.

In Tables 1 and 4 we also present the line intensities of Pt-1 derived under the assumption of C(Hβ) = 1.50. With this correction for reddening the Balmer decrement is very steep and can be explained by the models computed by Netzer (1975) with τ(Lyα) = 10^5, τ(Hα) = 128 and N_e = 10^8 or 10^9 cm^{-3}.

There is at least one symbiotic star that apparently shows a steep Balmer decrement; the optical counterpart of the hard X-ray source GX1 + 4 which exhibits an emission line spectrum superposed to an M6 type star. By correcting the observations for reddening Davidsen *et al.* (1977) obtain a very steep Balmer decrement which they explain with Netzer's (1975) models for $N_e = 10^9$, $\tau_0(Ly\alpha) = 10^6$ and $\tau_0(H\alpha) = 100$.

For Pt-1 the low reddening solution, $C(H\beta) = 1.50$ is possible, although with it the stellar continuum relative to that of an M1 star yields an excess of more than 1.5 mag between 6 620 and 4 500 Å which is not easy to explain. In what follows we will adopt $A_V = 5.0$ for Pt-1.

From the May 78 observations we obtain $m_V = 15.5$ which together with $A_V = 5.0$ mag and d = 7.8 kpc, yields $M_V = -4.0$ mag. This intrinsic luminosity is considerably higher than $M_V = -0.5$, the absolute magnitude of M giant stars of the solar neighborhood (Lee 1970), but it is similar to those of symbiotic stars of the nuclear bulge. Herbig (1969) has studied the symbiotic stars in the direction of the galactic center, that probably belong to the bulge, and has found that they have absolute magnitudes of –3 to –4 mag; he has proposed that these objects are Population II giant stars. Pt-1 seems to belong to the same class of symbiotic stars studied by Herbig. On the other hand, if we assume that Pt-1 is a Population I giant of $M_V = -0.5$ then it is located at d = 1.6 kpc which is far too close considering that A_V for Pt-1 is larger than for NGC 6401.

Under the assumption that the shell of ionized hydrogen is in case B, and that the rate of emission of hydrogen ionizing photons is equal to the rate of recombination to all levels but the first, the radius of the hot companion is given by

$$R_* = \left[\frac{I(H\beta)}{\mathcal{N}_H h\nu_{4\to2}} \frac{\alpha_B}{\alpha_{4\to2}} 4\pi d^2\right]^{1/2} , \quad (2)$$

where $\mathcal{N}_H$ is the rate of emission of hydrogen ionizing photons per unit area, α_B is the recombination coefficient to all levels but the first (Seaton 1960), $\alpha_{4\to2}$ is the $H\beta$ effective recombination coefficient (Brocklehurst 1971), and d is the distance to the object. By using the model atmospheres computed by Hummer and Mihalas (1970*a*) for stars of log g = 6.0 and assuming that only the photons between ν_0 and $1.807\nu_0$ ionize hydrogen we obtain

$$R_* = 0.15\, R_\odot \left(\frac{T_*}{125000^\circ K}\right)^{1.1} \left(\frac{d}{7.8\ \mathrm{kpc}}\right) . \quad (3)$$

From the high degree of ionization of helium (Table 4) it is expected that $T_* \sim 125\,000^\circ$K, which would yield a radius comparable to those of the nuclei of planetary nebulae.

The predicted stellar continuum flux, at λ4 861, for an exciting star of $T_* = 125\,000^\circ$K is given by (Hummer and Mihalas 1970*a*).

$$f(4861) = 1.27 \times 10^{-4} F(H\beta) = 3.12 \times 10^{-18}\ \mathrm{erg\ cm^{-2}\ s^{-1}\ Å^{-1}} ,$$

which is independent of reddening and distance. This flux is only about 1% of the observed continuum at this wavelength and does not affect the determination of the reddening based on the stellar continuum. The predicted continuum at 3 700 Å (Hummer and Mihalas 1970*b*) is 3×10^{-18} erg cm^{-2} s^{-1} Å^{-1}, too faint to be discriminated by our observations.

The radius of the ionized nebula is

$$r = \left[\frac{3I(H\beta)}{h\nu_{4\to2}} \frac{d^2}{N_e N(H^+)}\right]^{1/3} = 140\, R_\odot \left(\frac{N_e}{10^{10}}\right)^{-2/3} \left(\frac{d}{7.8\ \mathrm{kpc}}\right)^{2/3} , \quad (4)$$

and the mass of ionized hydrogen in the nebula is given by

$$M = 4\pi r^3 m_H N(H^+) = 9.1 \times 10^{-8} M_\odot \left(\frac{d}{7.8\ \mathrm{kpc}}\right)^2 \left(\frac{N_e}{10^{10}}\right)^{-1} . \quad (5)$$

IV. CONCLUSIONS

We have detected variations in the spectra of Pt-1, from the observations of March 79 relative to those of May 78: a) the TiO bands became deeper, b) the line to continuum ratio, $F(H\alpha)/f(6\,620)$, decreased; and c) the ratio He II (4 686)/$H\beta$ increased (it had decreased from July 77 to May 78). The variability, the presence of emission lines and of TiO bands in absorption establish that this object is a symbiotic star. In an independent study, Allen (1979) has classified this object as a symbiotic star.

From m_V, A_V and the spectral type it follows that Pt-1 is probably associated with the bulge population and has a similar absolute magnitude to the symbiotic stars in the direction of the center of the galaxy studied by Herbig (1969).

Our spectra do not show forbidden lines, thus the H and He ionized envelope is of $N_e \geqslant 10^8$ cm^{-3}. The presence of the [N II] lines marginally detected on Aug 76 by Peterson (1977) would require drastic variations in the density (at least from ~ 10^4 to ~ 10^6 cm^{-3}) and/or degree of ionization in a short time scale.

Our data are compatible with a binary object, composed of a luminous M star and a hot star similar to the central stars of planetary nebulae, surrounded by an envelope of ionized H and He. Typical values that fit the observations are $A_V = 5$ mag, d = 7.8 kpc, an M1 star of $M_V = -4$ mag with a companion of $T_* \sim 125\,000$°K and $R_* \sim 0.15\ R_\odot$ surrounded by a nebular shell of $N_e \sim 10^{10}$ cm^{-3} $r \sim 140\ R_\odot$ and N(He)/N(H) ~ 0.13.

There are several anomalies in the He I line ratios: a) the observed singlet to $2^3P - n^3D$ ratios are from 1 to 2 orders of magnitude larger than predicted in case A. The excess in the $2^1S - n^1P$ series can be explained directly by the absorption of Lyman photons from the nebular or the stellar radiation field, but the excess in the $2^1P - n^1D$ and $2^1P - n^1S$ series cannot; b) the high intensity of the $2^1P - n^1D$ and $2^1P - n^1S$ transitions might be explained by overpopulation of the ^1P levels and subsequent collisional redistribution of the angular momentum within a given n, which is possible only at very high densities, $N_e > 10^9$ cm^{-3}, for the low values of n under consideration, and c) although the high ratio of 7 065/5 876 can be explained by self-absorption from the 2^3S level, 4 713/5 876 is higher than predicted, and other processes should be considered, like collisional redistribution of angular momentum within the triplet series.

To improve our understanding of the physical conditions of the emitting regions in this type of objects it is necessary to compute He I emission line intensities for densities from 10^8 to 10^{13} cm^{-3} for case B and for the additional case of the presence of a Lyman line radiation field (stellar). We would then be able to obtain better values for He/H, N_e, reddening, $\tau(H\alpha)$ and $\tau(Ly\alpha)$.

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