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PC 11: SYMBIOTIC STAR OR PLANETARY NEBULA?

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RESUMEN. PC 11 es un objeto nebuloso que aparece en el Catálogo de Nebulosas Planetarias Galácticas de Perek y Kohoutek (1967) con el nombre PK 331 -5°1. Algunos autores sugieren que no es una nebulosa planetaria, sino que tiene algunas características (aunque no todas) de las estrellas simbióticas. Se han hecho observaciones fotográficas, espectrofotométricas y espectroscópicas de PC 11. El análisis de los resultados sugiere que se trata de una nebulosa planetaria joven.

ABSTRACT. PC 11 is an object listed in Perek and Kohoutek (1967) Catalogue of Galactic Planetary Nebulae as PK 331 -5°1. Some authors suggest that it is not a planetary nebula, but that it has some characteristics (though not all) of symbiotic stars. We have made photographic, spectrophotometric and spectroscopic observations of PC 11. The analysis of the results suggests that it is a young planetary nebula.

Key words : NEBULAE-PLANETARY -- SPECTROPHOTOMETRY -- STARS-SYMBIOTIC

I. INTRODUCTION

PC 11 (HD 149427, He2-172) is an object listed in the Catalogue of Galactic Planetary Nebulae (Perek and Kohoutek 1967) with the designation PK 331 -5°1. Its coordinates are $\alpha = 16^h\ 33.9^m$, $\delta = -55°\ 39'$ (1950.0). Peimbert and Costero (1961) were the first ones to realize its nebular character; they described it as being semi-stellar, without continuum, and with emission in Hα, Hβ, N_1 and N_2. Henize (1967) included it in his survey of southern planetary nebulae. Webster (1966) described it as having a strong continuum, showing absorption features in addition to the nebular lines; she suggested that the absorption spectrum and the observed colors implied the presence of an F-type star; thus, the object would not be a planetary nebula (PN), but would show some of the characteristics (but not all) of symbiotic stars (SS). We may remember here that for an object to be classified as SS it must have the following characteristics (Allen 1979): 1) it must appear stellar; 2a) emission from ions of ionization potential greater than 55 eV (i.e. He II emission) must at some time have been present; evidence for stellar spectral type G or later must also exist; 2b) in the absence of convincing evidence of a late-type star, the ionization potential represented must at some time have exceeded 100 eV (i.e. [Fe VII] emission). An additional criterium (Boyarchuk 1969) suggests that the object must have variable brightness, with amplitudes up to 3 magnitudes and periods of several years. Several classifications of SS have been attempted; Boyarchuk (1981) has made a summary of the classifications from different points of view; we wish to point out here his inclussion of Y SS (yellow symbiotic stars), with F, G or K-type absorption spectra, which would allow the inclusion of PC 11 according to Webster (1966) results. An important classification is made on the basis of infrared observations (Webster and Allen 1975); it divides the SS in two groups; those in which the 1-4 μm continuum shows only the presence of a cool star (S-type) and those in which the dust dominates the infrared radiation, with dust temperatures of the order of 800-1000 K (D-type); sometimes (Allen 1981) a sub-class D' is added, with dust temperatures half as great as in class D itself.

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Glass and Webster (1973), in an infrared study of some southern emission line objects, found for PC 11 the following values: J = 10.67, H = 10.59, K = 10.20 and L = 8.40, with a large infrared excess in K-L; but they state that the measurements of PC 11 have large errors and cannot be used reliably to identify the infrared emission mechanism, although there is a suggestion of a brightening at L which would indicate a dust contribution. Allen and Glass (1974) give values for this object in the infrared which do not differ from the previous values; the L magnitude is not included; they classify PC 11 as an S object with high density and high excitation, and indicate that S objects may be supposed to be mostly SS. Nevertheless, later on Allen (1979) included PC 11 in a list of objects previously classified as SS, but then rejected for different reasons; in the case of PC 11, due to its low excitation. But the same author (Allen 1981) includes it again in his list of SS with infrared observations, and classifies it as a D' object.

Radio observations have been made, among others, by Milne and Aller (1975) and Milne (1979). This last author gives the peak intensity and the integrated flux density at 5 GHz as < 0.010 Jy, which implies a faint continuum; he classifies it as "not PN: peculiar".

In this paper we present further observations of PC 11 in the optical region. In addition to the usual treatment of the results in order to obtain, as far as possible, some of the physical parameters of the object, we also analyze them from the point of view of Baldwin, Phillips and Terlevich (BPT, 1981). These authors have made a study of different parameters of emission line objects, in order to separate them according to the type of excitation mechanism; in their diagram PN are clearly separated from other emission line objects, such as H II regions or emission line galaxies. Gutiérrez-Moreno et al. (1986) have already used these diagrams to study the behaviour of He2-106, a well established SS, and of He2-104, considered as a doubtful SS.

II. OBSERVATIONS AND RESULTS

PC 11 was observed photographically, spectrophotometrically and spectroscopically.

The photographic observations were made in July 1981, 1983 and 1984, using an image tube camera attached to the 1.0-m telescope of Cerro Tololo Interamerican Observatory (CTIO). Plates were taken using a V wide-band filter and two interference filters centered at [OIII] λ 5007 and Hα. These photographs were taken as a part of a larger program of observations of PN, and the observational procedure is described elsewhere (Moreno et al. 1987).

The visual image looks almost stellar. The images in Hα and [OIII] are somewhat more extended, with diameters of the order of 8" and 10" respectively. The images look very homogeneous, but this may be due to overexposure.

The spectrophotometric observations were made with the Harvard scanner attached to the 0.9-m telescope of CTIO, also as a part of a more extensive program of spectrophotometric observations of PN. The details of the observational procedure have been described elsewhere (Gutiérrez-Moreno et al. 1985). Two sets of observations were made, in May 1981 (6 scans) and August 1984 (4 scans).

The observed fluxes, corrected for atmospheric extinction by means of Gutiérrez-Moreno et al. (1984, 1986) extinction curves, and calibrated by means of Hayes (1970) standards as improved by Taylor (1984), are listed in the first part of Table 1, with the internal mean errors of the observations. The Table lists the logarithm of the flux, with F(Hβ) = 1. At the end of the Table, the values of the average reddening constant ⟨C⟩ and of the observed Hβ fluxes are given for both observing periods. ⟨C⟩ was determined by the Balmer decrement method, using both Hα/Hβ and Hγ/Hβ. Theoretical values of the Balmer decrement were obtained from Brocklehurst (1971) for T = 20 000 K and $N_e = 10^4$. The reddening curve used is derived from the normal extinction law (Whitford, 1958) normalized at Hβ.

A comparison of the values obtained in 1981 and in 1984 shows that the differences are of the order of what can be expected from the observational errors. The agreement between both values of F(Hβ) is remarkable but fortuitous; they agree well with the value given by

Webster in 1966: F(Hβ) = -11.52; though Webster does not give the internal errors of her measures, the difference seems to be well within the range of the observational errors. All this would suggest that PC 11 is not variable, thus not accomplishing one of the conditions imposed to SS by Boyarchuk (1969).

Considering this non variability, we have averaged the fluxes obtained in the two periods to obtain the dereddened intensities, given in the fifth column of Table 1.

The spectroscopic observations were made in July 1983, using a Reticon detector attached to the 2.5-m telescope of Cerro Las Campanas Observatory. A 2" diaphragm was used. Two spectra, ranging from 3200 to 7200 Å, were obtained, one of them in the center of the nebula and the other in the northern edge. These observations were made within the scope of a different program and the observational procedure will be described elsewhere (Campusano, in preparation). The corrected observed fluxes are listed in the second part of Table 1. [OIII] λλ 4959, 5007 are not included, since it was considered that they could be saturated.

From the Table, we can see that all the general characteristics of the spectrum, as observed with the Harvard scanner, are also observed with the Reticon detector. Some remarks concerning the intensities can be made:

a) [OIII] λλ5007 and 4363 are very intense, and their ratio suggests a high T_e;
b) [OII] λ3728 is very faint; it appears weakly in the center of the nebula, but it is not visible in the edge;
c) the more intense line, not considering Hα, Hβ and the [OIII] lines, is [NeIII] λ3869;
d) lines of [ArIII] and [ArIV] (these last very faint) are present;
e) HeII λ4686 is very faint in both regions of the nebula; HeII λ5411 is not detected;
f) [NeV] λ3425 is not detected;
g) [NII] lines are faint, and their ratio suggests that they are not good indicators of temperature, but rather of electron densities;
h) The spectrum of the center shows no [SII] or [CℓIII] lines, while it shows [SIII]; on the other hand, the nebular [SII] and [CℓIII] lines are faintly seen in the spectrum of the edge. They are barely distinguishable from the noise in the continuum, but their intensities were measured, even though they are very uncertain, just to give an idea of the behaviour of the nebular ratios, which are correct at least in their order of magnitude;
i) [OI] λ6300 is fainter at the center than at the edge;
j) The spectra show a faint continuum, slightly increasing towards the red; this is an effect of the interstellar reddening;
k) There seems to be no traces of a G band, or of a cool spectrum;
l) There is no observable Balmer discontinuity either in emission or in absorption;
m) The lines listed in the second part of Table 1 are all the lines observed in the spectra, except for the [OIII] lines; thus, higher excitation lines, which are supposed to be observable in SS, as [FeVI], [FeVII], [CaV], etc. (Allen 1984) are not detectable;
n) The line of CII λ4267 is not detectable.

Points a) to d) indicate a high degree of excitation, but this is contradicted by the weakness of λ4686, one of the best indicators of the excitation class, and by the absence of λ3425.

Besides, the comparison of the results for both regions of the nebula obtained with the Reticon detector shows that the excitation is higher in the center than in the edge, though HeII λ4686 is faint also in the center.

III. BPT DIAGRAMS

In a previous paper (Gutiérrez-Moreno et al., 1986), we have attempted to separate PN from SS by using BPT diagrams (Baldwin et al., 1981). There we analyzed the behaviour of He2-104 and He2-106, and we found that they occupied in BPT diagrams a position clearly different from the region occupied by PN.

With the measures for [OIII], [OII], [OI], [NII] and Hα obtained in Table 1, we may

TABLE 1. Line Intensities for PC 11

λ	Ion	Scanner log [Fλ/F(Hβ)] May 1981		Scanner log [Fλ/F(Hβ)] August 1984		Scanner Iλ	Reticon log [Fλ/F(Hβ)] Center	Reticon log [Fλ/F(Hβ)] Edge	Reticon Iλ Center	Reticon Iλ Edge
3728	[OII]	-1.35	±0.04	-1.34	±0.06	9.33	-1.34	-	9.65	-
3869	[NeIII]	-0.14	.02	-0.11	.00	138	-0.08	-0.18	158	128
3889	H8+HeI	-	-	-1.04	.12	16.7	-1.28	-1.29	9.84	9.79
3968	H7+[NeIII]	-0.48	.02	-0.47	.01	57.2	-0.43	-0.58	64.9	46.7
4072	[SII]	-1.12	.06	-1.18	.06	11.5	-	-1.54:	-	4.82:
4100	Hδ+NIII	-0.64	.09	-0.64	.02	36.1	-0.95	-1.02	18.0	15.6
4340	Hγ	-0.46	.01	-0.45	.01	47.7	-0.46	-0.46	47.8	48.2
4363	[OIII]	-0.30	.02	-0.33	.01	65.2	-0.25	-0.37	76.5	58.6
4472	HeI	-1.25	.03	-1.24	.01	7.24	-1.13	-1.31	9.51	6.33
4686	HeII	-1.78:	.06	-1.63:	.06	2.22:	-1.75:	-1.78:	1.98:	1.85:
4712	[ArIV]+HeI	-1.59:	.11	-1.61:	.05	2.72:	-1.22:	-1.34:	6.55	4.98
4740	[ArIV]	-1.08:	.06	-1.22:	.13	7.68:	-1.09:	-1.20:	8.73	6.79
4861	Hβ	0.00	-	0.00	-	100.0	0.00	0.00	100.0	100.0
4959	[OIII]	+0.74	.02	+0.69	.01	496	-	-	-	-
5007	[OIII]	+1.23	.02	+1.18	.01	1500	-	-	-	-
5518	[ClIII]	-	-	-	-	-	-	-1.82:	-	1.08:
5538	[ClIII]	-	-	-	-	-	-	-1.68:	-	1.47:
5755	[NII]	-1.42	.06	-1.53	.07	2.19	-1.26	-1.26	3.50	3.46
5876	HeI	-0.49	.01	-0.49	.01	20.0	-0.46	-0.46	21.1	20.8
6300	[OI]	-1.17	.06	-1.22	.06	3.33	-1.32	-1.16	2.43	3.33
6311	[SIII]	-1.12:	.17	-1.18	.06	3.66:	-1.53	-1.00	1.48	4.93
6363	[OI]	-1.60	.06	-1.57	.04	1.31	-1.70	-	1.01	-
6548	[NII]	-1.05	.01	-	-	4.20	-	-	-	-
6563	Hα	+0.76	.02	+0.78	.02	274	+0.78	+0.79	272	272
6584	[NII]	-0.57	.01	-0.58.	.01	12.3	-0.50	-0.63	14.1	10.2
6678	HeI	-1.02	.06	-1.08	.03	3.93	-1.00	-0.98	4.26	4.35
6717	[SII]	-1.28	.02	-	-	2.26	-	-1.51:	-	1.25:
6731	[SII]			-	-		-	-1.62:	-	0.97:
7065	HeI	-0.47	.03	-0.48	.01	13.5	-0.52	-0.41	11.7	14.7
7136	[ArIII]	-0.58	.06	-0.63	.01	9.77	-0.51	-0.51	11.7	11.4
7325	[OII]	-0.62	±0.04	-0.67	.05	8.42	-	-	-	-
⟨c⟩		0.99	±0.03	0.99	±0.03		1.03	1.06		
log F(Hβ)		-11.47	±0.02	-11.47	±0.03					

compute the parameters needed for BPT diagrams. The final result is presented in Fig. 1, which shows that PC 11 falls near the PN zone, far from He2-104 and He2-106. In fact, it falls to the left of the PN zone; this is a consequence of its higher temperature. We must point out that due to the faintness of λ3728 no attempt has been made to correct it by a possible contamination by the nearby H lines: thus, the value of λ3728 is an upper limit.

IV. TEMPERATURE, DENSITY AND CHEMICAL COMPOSITION

From the data listed in Table 1 we have obtained the plasma diagnostic diagram shown in Fig. 2. All the relevant atomic parameters have been taken from Mendoza (1983). As stated in a previous paragraph, the [NII] lines are not indicators of electron temperatures, but they are fairly good indicators of electron densities and as such will be used.

From the diagram we get:

a) from [OIII] and $[SII]_{tn}$: $\log N_e = 5.00$; (1)

b) from [OIII] and $[OII]_{an}$: $\log N_e = 4.56$; (2)

c) from [OIII] and [NII] : $\log N_e = 5.14$. (3)

From these values we get:

$\langle N_e \rangle = 9.14 \times 10^4$; $\log \langle N_e \rangle = 4.96$; $T_e = 20\ 400$ K

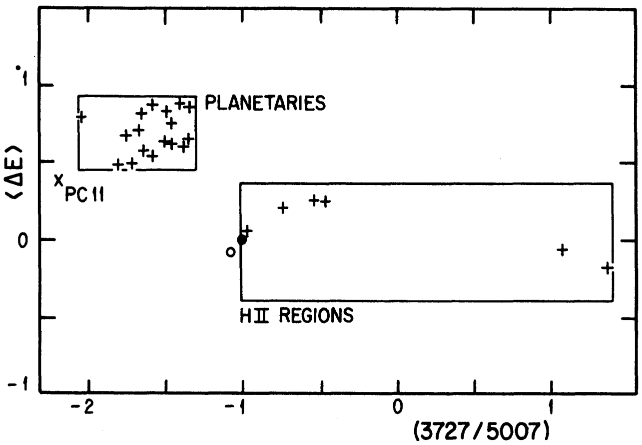

Fig. 1. Reproduction of Figure 8 from Baldwin et al. (1981), keeping only the zone of PN and the zone where He II regions are located. PN are represented by crosses. For the meaning of ⟨ΔE⟩ see BPT paper. There are some PN used by BPT in their study which are located within the zone of H II regions. They state that these objects may be misclassified H II regions or planetaries having unusually cool central stars. He2-106, an accepted SS, is represented by the open circle, while He2-104, a suspected SS, is represented by the black dot. The position of PC 11, close to the PN region, is shown.

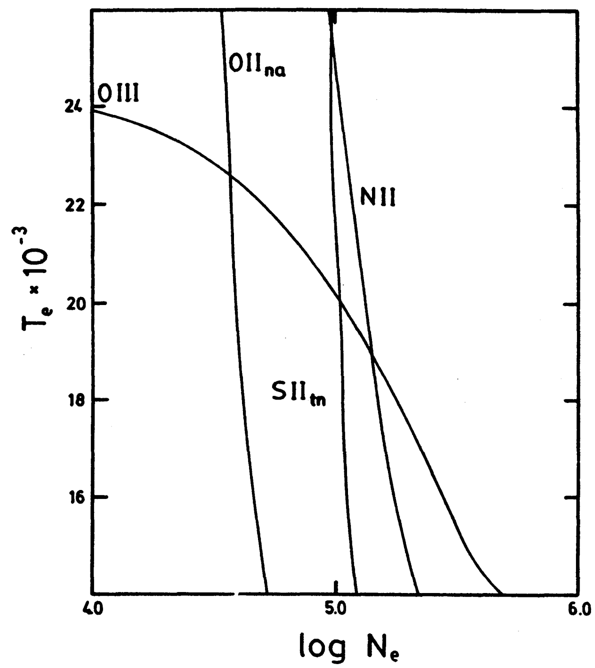

Fig. 2. Plasma diagnostic diagram for PC 11. The line labelled O II$_{na}$ corresponds to the ratio [O II]I(λ3727)I(λ7325), and the line labelled S II$_{tn}$ corresponds to the ratio [S II] I(λ4072/ I(λ6724). Notice that the O III locus for high densities is dependent both on T_e and N_e: this fact introduces an uncertainty in the determination of T_e, which is strongly dependent on the values and the errors of N_e. For the density here represented, the range of possible values of T_e runs from 19 000 K to 22 600 K. Notice also that lower N_e values would imply still larger values of T_e.

These results correpond to the OIII region. We have no means for obtaining T(NII).

The nebular lines of [CℓIII] and [SII] are, in general, good density indicators; but, as stated in the preceding paragraph, in PC 11 they are faint and cannot be measured accurately. Nevertheless, the measured values for [CℓIII] in the edge give a logarithmic density of approximately 3.8 for T_e = 21 000 K. Special mention deserves the ratio of the nebular lines of [SII]. In spite of their faintness, the Reticon spectrum shows clearly that I(λ6717) > I(λ6731); and this implies a very low density. With the values listed in Table 1, we get log $N_e \approx 2.2$ for T_e = 21 000 K. But it must be kept in mind that the values just quoted are not directly comparable with those given in (1), (2) and (3), since the previous values refer to the whole nebula, and the last ones to one of the edges.

The chemical composition was obtained by assuming temperature fluctuations, following the method by Peimbert and Torres-Peimbert (1971), with mean temperature fluctuations t^2 = 0.035 and t^2 = 0.000. For [NeIII], [OIII], [ArIII] and [ArIV] the temperature of the [OIII] zone was used. For the remaining ions, the calculations were made twice, first using T(OIII) and then a slightly lower temperature, taken arbitrarily as T(NII) = 19 000 K (corresponding to the intersection of the NII and OIII locus in Fig. 2). The He abundance was obtained using T = T(OIII), and the same temperature fluctuations. For HeII, λλ4472, 5876 and 6678 were used, with double weight for λ5876. The abundance of HeIII was determined from λ4686. The intensities of λλ4472 and 5876 were corrected by self-absorption, by comparing the observed values of I(7065)/I(4472) with the computations by Robbins (1968), normalized to the maximum values for total self-absorption presented by Cox and Daltabuit (1971). Besides, due to the high temperature, it was considered necessary to correct the observed intensities for the effects of collisional excitations from level 2^3S. Since the corrections given by Cox and Daltabuit (1971) are probably too large, we adopted for γ_{CE} a value equal to one third of their value, following Peimbert and Torres-Peimbert (1971). If this correction is not applied, the He abundance rises to 0.152.

The ionization correction formulae used to obtain the total abundance of the elements observed were taken from Aller (1984). For He we applied the relation given by Peimbert and Costero (1969) though, in fact, it applies only to the Orion Nebula; but, even so, it suggests that the abundance of neutral He is very low, and that practically all the He is in the form of He^+.

The final results are listed in Table 2, which gives, for both values of t^2 and for each element, the logarithmic abundance of the different ions observed determined from the best measured lines. Under the heading Σ we list the sum of the ionic abundances thus obtained, and the column log N(X) gives the total elemental abundances determined using the corresponding ionization correction factors.

TABLE 2. Chemical Abundances [log N(H) = 12]

	t^2 = 0.035						t^2 = 0.000					
X \ Ion	I	II	III	IV	Σ	log N(X)	I	II	III	IV	Σ	log N(X)
N	-	6.15	-	-	6.15	7.90	-	6.13	-	-	6.13	7.87
O	6.28	6.30	8.03	-	8.05	8.05	6.26	6.27	7.99	-	8.01	8.01
Ne	-	-	7.24	-	7.24	7.26	-	-	7.20	-	7.20	7.22
S	-	5.21	5.95	-	6.02	6.45	-	5.19	5.93	-	6.00	6.43
Ar	-	-	5.42	5.62	5.83	5.91	-	-	5.38	5.58	5.79	5.87
N(He)/N(H)		0.112	0.002		0.114	(0.116)		0.114	0.002		0.116	(0.118)

VI. DISCUSSION

From the above data, PC 11 does not seem to be a SS. It has almost stellar appearance, which is a characteristic of SS; but our observations show no traces of an F or later-type spectrum, and no traces, either, of high excitation lines. Besides, the object does not seem to be variable. In the BPT diagrams, it is located near the zone occupied by PN, though its position shows the high temperature effects. In all, our observations seem to suggest that PC 11 is a PN which distinguishes itself from other PN in several aspects:

a) Temperature and density: T(OIII) is very high, much higher than the average for planetary nebulae. We have not been able to determine T(NII), but we have adopted T = 19 000 K. The average density, taken over all the object, is high: the [NII] lines suggest $N_e = 1.38 \times 10^5$ cm^{-3}, and the [SII] lines give $N_e = 10^5$ cm^{-3}. Nevertheless, the density in the edges seems to be much lower. This fact implies that the density at the center must be higher than 10^5. Using the data for the center in Table 1, we find that the [NII] lines, the only ones that are available for density determinations, give an electron density which is about 1.5 times that obtained over the whole nebula. This gives $N_e \gtrsim 2 \times 10^5$, much higher than the normal densities of PN. We must point out that a comparison of our observations with those by Webster (1969) as listed by Kaler (1976) shows that the ratio I(λ4363)/I(λ5007) has decreased since 1969. This change may imply that the nebular electron density is diminishing with time, in agreement with the expansion of the nebular shell. At the same time, this decrease of N_e would imply that T_e is also diminishing.

b) Excitation class: The intensity of the [OIII] lines, I(λ4959)+I(λ5007), seems to indicate an excitation class between 7 and 8, since after these classes the intensity of these lines begins to diminish. The ratio of intensities [OII] I(λ3727)/[OIII] I(λ4959) also suggests and excitation class over 7. But this excitation class would imply an intensity for HeII λ4686 equal to about 30 times the intensity we have observed for this line. Besides, [NeV] λ3425 should have to be observed. Thus, the electron temperature T_e does not seem to correspond to an excitation temperature.

c) Abundances: The abundances are also peculiar. There is a clear depletion of O with respect to solar abundances and to normal planetaries. Also the absence of CII lines allowsus to assume that there may be a depletion of C. All the heavy elements for which we have determined abundances are underabundant; this effect is more noticeable when neglecting temperature fluctuations ($t^2 = 0$). The ratio N(N)/N(O) is larger than the corresponding value for the Sun and than the average for PN, while N(Ne)/N(O) is similar to the solar ratio, and N(S)/N(O) and N(Ar)/N(O) are closer to the average values for PN.

Assuming after all these considerations that, in spite of some peculiarities, PC 11 is a PN, we may compute its distance to the Sun, d; to the center of the Galaxy, R, and to the galactic plane, z; and also its radius, r. Using an optically thin scale, and the radius of the image in Hα, we get r < 0.12 pc; so, as could be expected, we have to use an optically thick scale. Using the scale calibrated by Cudworth (1974) for optically thick PN we get:

$$d = 3.09 \text{ kpc}, \qquad r = 0.06 \text{ pc}, \qquad R = 5.98 \text{ kpc}, \qquad z = 0.6 \text{ kpc}.$$

We may summarize our results saying that PC 11 is a PN with high electron density and temperature, much higher than the typical values for PN. Besides, it has a small angular size, with almost stellar aspect, and a small linear radius. The [OIII] line ratio λ5007/λ4363 has increased since 1969, implying a decrease in N_e and T_e. All these facts suggest that PC 11 is a very young PN. It has an infrared excess which, according to Glass and Webster (1973), may indicate the presence of dust in the ionized gas. If this is the case, depletion of O and C could be accounted for by grain formation.

This object is very similar to IC 4997, which has been widely studied by several authors (see, for example, Flower 1980), and has been recognized as a very young PN. An analysis of the line intensities in the visual region listed by O'Dell (1963) shows many resemblances with the spectrum of PC 11, since IC 4997 shows no HeII λλ4686 and very faint [NII] lines. It also shows a strong depletion of O, with log N(O) = 8.04 (Flower 1980). These similarities seem to support the conclusion that PC 11 is a very young planetary nebula.

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REFERENCES

Allen, D.A. 1979, in *IAU Colloquium N°46, Changing Trends in Variable Star Research*, eds. F.M. Bateson, J. Small and I.H. Urch (Hamilton, New Zealand: U. of Waikoto), p. 125.
Allen, D.A. 1981, in *IAU Colloquium N°70, The Nature of Symbiotic Stars*, eds. M. Friedjung and R. Viotti (Dordrecht: D. Reidel), p. 225.
Allen, D.A. 1984, *Proc. Astr. Soc. Australia*, 5, 367.
Allen, D.A., and Glass, I.S. 1974, *M.N.R.A.S.*, 167, 337.
Aller, L.H. 1984, *Physics of Thermal Gaseous Nebulae* (Dordrecht: D. Reidel), pgs. 258, 280.

Baldwin, J.A., Phillips, M.M., and Terlevich, R. 1981, *Publ. A.S.P.*, 93, 5.

Boyarchuk, A.A. 1969, in *Non-Periodic Phenomena in Variable Stars*, ed. L. Detre (Budapest: Academic Press), p. 395.

Boyarchuk, A.A. 1981, in *IAU Colloquium N°70, The Nature of Symbiotic Stars*, eds. M. Friedjung and R. Viotti (Dordrecht: D. Reidel), p. 225.

Brocklehurst, M. 1971, *M.N.R.A.S.*, 153, 451.

Campusano, L. In preparation.

Cox, D.P., and Daltabuit, E. 1971, *Ap. J.*, 167, 257.

Cudworth, K.M. 1974, *A.J.*, 79, 1384.

Flower, D.R. 1980, *M.N.R.A.S.*, 193, 511.

Glass, I.S., and Webster, B.L. 1973, *M.N.R.A.S.*, 165, 77.

Gutiérrez-Moreno, A., Moreno, H., and Cortés, G. 1984, *Publ. A.S.P.*, 94, 722.

Gutiérrez-Moreno, A., Moreno, H., and Cortés, G. 1985, *Publ. A.S.P.*, 97, 397.

Gutiérrez-Moreno, A., Moreno, H., and Cortés, G. 1986, *Astron. Astrophys.*, 166, 143.

Gutiérrez-Moreno, A., Moreno, H., and Cortés, G. 1986, *Publ. A.S.P.*, in press.

Hayes, D.S. 1970, *Ap. J.*, 159, 165.

Henize, K.G., 1967, *Ap. J. Suppl.* 14, 125.

Kaler, J.B. 1976, *Ap. J. Suppl.* 31, 517.

Mendoza, C. 1983, in *IAU Symposium N°103, Planetary Nebulae*, ed. D.R. Flower (Dordrecht: D. Reidel), p. 143.

Milne, D.K. 1979, *Astron. Astrophys. Suppl.*, 36, 227.

Milne, D.K. and Aller, L.H. 1975, *Astron. Astrophys.*, 38, 183.

Moreno, H., Gutiérrez-Moreno, A., Torres, C., and Wenderoth, E. 1987.

O'Dell, C.R. 1963, *Ap. J.*, 138, 1018.

Peimbert, M., and Costero, R. 1961, *Bol. Obs. Tonanzintla y Tacubaya*, 3, 33.

Peimbert, M., and Costero, R. 1969, *Bol. Obs. Tonanzintla y Tacubaya*, 5, 3.

Peimbert, M., and Torres-Peimbert, S. 1971, *Ap. J.*, 168, 413.

Perek, L., and Kohoutek, L. 1967, *Catalogue of Galactic Planetary Nebulae* (Prague: Academia Publishing House of the Czechoslovak Academy of Sciences).

Robbins, R.R. 1968, *Ap. J.*, 151, 511.

Torres-Peimbert, S., and Peimbert, M. 1977, *Rev. Mexicana Astron. Astrofis.*, 2, 181.

Taylor, B.J. 1984, *Ap. J. Suppl.*, 54, 259.

Webster, B.L. 1966, *Publ. A.S.P.*, 68, 136.

Webster, B.L. 1969, *M.N.R.A.S.*, 143, 79.

Webster, B.L., and Allen, D.A. 1975, *M.N.R.A.S.*, 171, 171.

Whitford, A.E. 1958, *A.J.* 63, 201.

DISCUSSION

M. PEÑA: Este objeto debería tener un fuerte exceso IR tanto si es protonebulosa planetaria o estrella simbiótica. ¿Está en las listas de IRAS? ¿Se ha observado con el IUE?

GUTIERREZ-MORENO: Como se dijo al principio, Glass y Webster han encontrado un fuerte exceso en (K-L), pero no consideran que sus resultados sean muy preciso. Por otra parte, no hemos buscado este objeto en las listas de IRAS, y tampoco sabemos si tiene observaciones hechas on el IUE. En la literatura no hemos encontrado observaciones UV.

PEIMBERT: El objeto tal vez está acotado por densidad. Entonces se puede calcular la masa ionizada. Un cálculo rápido da $\cong 3\ M_\odot$. Una explicación sería que la estrella central no sea tan luminosa como lo asume Cudworth en su escala de distancias ($M_V \cong -2.0$). Con una estrella 2 o 3 veces más débil se tendría una distancia 2 o 3 veces menor y una masa más razonable. Otra solución es que la distancia sea correcta pero que el objeto tenga un factor de llenado $\epsilon \cong 1/10$ ($M \cong 0.3\ M_\odot$) o 1/30 ($M \cong 0.1\ M_\odot$).

GUTIERREZ-MORENO: Desgraciadamente no tenemos idea de cual debe ser el factor de llenado. Por otra parte, reducir la distancia a 1/2 o 1/3 reduciría el radio lineal también a 1/2 o 1/3, lo que reforzaría las conclusiones que se presentaron. Vale la pena mencionar que la distancia que aquí se presenta es ya la mitad de la que determinaron Milne y Aller (1975) en base a observaciones en radio (d > 6.7 kpc).

DOTTORI: ¿Colocaron el objeto en el gráfico O II+O III /Hβ vs. metalicidad de Pagel y Edmunds?

GUTIERREZ-MORENO: No hemos hecho este estudio por el momento.

PEIMBERT: Si la densidad es más alta que 9×10^4 en la región donde se forman las líneas del O III, T(O III) sería menor y se obtendría un valor mayor de O/H.

GUTIERREZ-MORENO: Si se toma $N_e = 2 \times 10^5$ como se menciona en el texto se obtendría T(O III) = 17500 K, lo cual daría N(O)/N(H)≅ 8.26, que siempre es menor que la abundancia promedio de O en las NP, por un factor del orden de 4.

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