PLANETARY NEBULAE AND SYMBIOTIC STARS

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ABSTRACT A brief presentation of some characteristics of symbiotic stars is made. Some methods for discriminating between symbiotic stars and planetary nebulae on the basis of emission lines intensities in the visual region are presented. Finally, the possible evolutionary relations between symbiotic stars and planetary nebulae are discussed.

INTRODUCTION

Symbiotic stars are peculiar emission lines objects which have attracted the attention of the astronomers during the last decades, both from the theoretical and observational points of view. Two Colloquia of the International Astronomical Union, dealing with this subject, have been held since 1980: Colloquium N°70, "The Nature of Symbiotic Stars" (Friedjung and Viotti 1982), and Colloquium N°103, "The Symbiotic Phenomenon" (Kenyon and Friedjung 1988). Besides, in 1986 the book "The Symbiotic Stars" (Kenyon 1986) appeared. The author is a well known specialist in the field, who gives an excellent summary of our current knowledge about these objects. He includes theoretical and observational problems, in different regions of the spectrum, as well as a review of the known characteristics of some selected symbiotic stars, mostly binaries.

In this presentation I will give a brief introduction about the nature of symbiotic stars, and then I will speak only about two aspects which relate to planetary nebulae: the discrimination between both kinds of objects and their possible evolutionary relationship.

A BRIEF REVIEW OF SYMBIOTIC STARS

The study of the objects called now "symbiotic stars" was started in 1932, when Merrill and Humason wrote a note calling attention to the existence of a small group of stars characterized for their "combination spectra", showing late-type features, as TiO bands, together with high excitation emission lines, as He II λ4686, [O III] λ4363, and other lines typical of gaseous nebulae. The name "symbiotic star" was introduced by Merrill in 1941, when he presented a paper on BF Cygni, at a meeting of the American Astronomical Association (cf. Merrill 1958); with this name he pointed out the apparently impossible co-existence of two types of spectra, corresponding to very hot and very cool objects.

Soon it became evident that the initial characterization was not enough since when catalogues were prepared a non-homogeneous list of objects was obtained. Consequently, several attempts have been made more recently to add some quantitative conditions to Merrill and Humason's definition. For example we may quote:

i) the star must present irregular optical variability, with an amplitude up to 3 magnitudes and a period of several years (Boyarchuk 1969), and

ii) emission lines from ions of greater than 55 eV ionization potential must be observable (Allen 1979); he adds the condition that the object must have stellar aspect.

But these conditions have also some limitations. In fact, it may be said that every known symbiotic star has violated, at some time or another, all the classification criteria presented in the last 50 years (Kenyon 1986). Besides, Boyarchuk's condition of variability has the inconvenience that it leaves aside recurrent novae such as RS Ophiuchi and slow novae such as RR Telescopii, which are recognized as members of the class of symbiotic stars. For this reason, Kenyon proposes a less restrictive set of properties; he states that the object must show:

1) the absorption features of a late-type giant star (a G, K, or M star which is not obviously a main sequence or a supergiant star);

2) bright H I and He I emission lines and either

(a) additional bright lines of ions with an ionization potential of at least 20 eV (e.g., [O III]) and an equivalent width exceeding 1 Å, or

(b) an A or F-type continuum with additional absorption lines from H I, He I, and singly ionized metals (Kenyon 1986).

The last condition represents the outburst state of a typical symbiotic star.

The angular distribution of symbiotic stars in the sky shows a strong concentration towards the galactic plane, very similar to that of planetary nebulae and, in general, to old disk population (Boyarchuk 1975). On the other hand, there is very little kinematic information about these objects. It has not been possible to associate them with open or globular stellar clusters; there are no reliable parallaxes known, but some spectroscopic distances have been derived by Allen (1980) from infrared photometry; the proper motions are very small (see Table A.6 in Kenyon 1986); and radial velocities have been determined for some of them, but it is necessary to be careful with the interpretation of these measures, since they have been made mainly by using emission lines, which may reflect the streaming motion of the gas, and not the motion of the system as a whole. Wallerstein (1981) has presented a compilation of radial velocities which may be considered reliable, and they are consistent with what can be expected from an old disk population.

Symbiotic stars are also present in extragalactic systems. Five of them have been found in the Magellanic Clouds; it could be expected that they could be used to calibrate the distances of our galactic symbiotics; but this cannot be done, since the MC objects differ from those in our galaxy; in fact, 80% of the symbiotic stars in the MC contain carbon stars; and in our galaxy only 3 out of 125 accepted symbiotic stars have this characteristic; Kenyon (1986) mentions only 2, but recently the discovery of a new symbiotic star with a carbon star was communicated (Schulte-Ladbeck et al. 1988); this small percentage (2.4%) shows that the presence of carbon stars is not a general characteristic of the galactic symbiotic stars.

Boyarchuk (1982) made a classification of symbiotic stars from different points of view. We may point out the classification according to the infrared radiation, which comprises four classes:

S-stars, whose infrared spectrum corresponds to that of a cool star;

D-stars, whose infrared spectrum corresponds to dust emission;

N-stars, with constant infrared radiation; and

V-stars, with variable infrared radiation.

The classification according to the absorption spectrum is also interesting. It comprises two classes:

M-stars, with M-type absorption spectrum; and

Y-stars (yellow), with F-, G-, or K-type absorption spectrum.

Allen (1982) adds to class D a class D', with dust temperature about half as great as in class D (which has $T \approx 800$-1000 K). D' symbiotics are all yellow symbiotics.

SYMBIOTIC STARS MODELS

Two types of models have been developed to explain the spectral characteristics of symbiotic stars; the single star model and the double star model.

Double star models sought to explain some notorious features of these objects, like variability and radial velocity variations, while single star models were developed in response to the failure to find these periodic variations in a number of symbiotic objects.

These single star models consider two possibilities: a) a hot central star, like the condensed stellar core of an extremely evolved long period variable, surrounded by a cool envelope; for instance Sobolev (1960) proposes an envelope with a significant optical thickness in some subordinate continua as the Balmer continuum, which would produce the absorption spectrum; b) a cool central object, for example a normal red giant, surrounded by a hot envelope, like a very active chromosphere or corona (Aller 1954); Wood (1973) proposed the idea that the strong emission lines could be produced in a shock-heated chromosphere or corona. Oliversen et al. (1980) suggested that a large starspot (and the associated magnetic activity) on the surface of a K giant could explain the behaviour of some symbiotic objects, as AG Draconis.

The first suggestions of binarity appeared very early, with the communications by Berman (1932) and Hogg (1934); they proposed an M-type giant with a faint O- or B-type companion, surrounded by nebulosity. Kuiper (1940) proposed a different binary model: a normal main sequence star, with a companion filling its Roche lobe; the strong emission lines would be produced in an emission region due to the matter lost by the giant, falling in the fainter companion.

The first attempts to compare models of symbiotic stars with actual data obtained from observations were made by Boyarchuk (1969, 1975). His model symbiotic stars considered three sources of radiation: a giant of late spectral type G-M, a small hot star with an effective temperature of 10^5 K, and an ionized nebula with an electron temperature of about 17.000 K and an electron density higher than 10^6 cm^{-3}. Later on, accretion became important for symbiotic stars physics. Friedjung (1982) states that the various phenomena of accretion, as Roche lobe overflow, bright spots, accretion disks, boundary layers, accretion columns, etc., are basic to the physics of cataclysmic variables, to which symbiotic stars are often related; but he considers that, although these phenomena are probably present in symbiotic stars, they possibly cannot explain all the characteristics of these objects. Kenyon and Webbink (1984) considered two types of hot components: a) a hot, compact star similar to the central stars of planetary nebulae, or b) an accretion disk surrounding a low mass white dwarf or main sequence star. Previously Plavec (1982) stated that it was necessary to consider the possibility that the companion to the red giant could be intrinsically hot and luminous enough so that no accretion is necessary; in this case the mass loss from the cool star would be needed only for maintaining the nebulosity; the model would require a subdwarf, similar to the nuclei of planetary nebulae. Thus, he calls this type of objects "natural symbiotics" or "PN symbiotics".

Duschl (1986a, b) considers in his models two types of accretion disks, stationary and time dependent, and arrives to the conclusion that the light curves of symbiotic stars can be explained as being due to the time dependent evolution of accretion disks around main sequence stars, by a process similar to dwarf novae outbursts. Nussbaumer (1986), on the other hand, using IUE observations of HBV 475, proposes a model in which the nebular emission does not need to originate around the hot compact component, but may be formed close to the cool star due to the radiative action of the hot component.

Today, the specialists in the field prefer the binary star models of symbiotic stars; nevertheless, single star models cannot be totally discarded, since the group is not completely homogeneous, and the behaviour of some symbiotics cannot be well explained by the double star model.

SPECTRA OF SYMBIOTIC STARS AND PLANETARY NEBULAE

If we look at a catalogue of symbiotic stars (e.g. Allen 1984) we find that many of them are well known variable stars, with spectra which satisfy the conditions imposed to be classified as symbiotic stars. Besides, there are many which are not known variables, but which show clearly in their spectra their symbiotic character. In addition, there are a few, in general classified initially as planetary nebulae, for which the symbiotic character is not so obvious; for some of these objects the distinction may be very difficult. On the other hand, there are objects classified as planetary nebulae which, after further study, may turn out to be symbiotic stars.

It may be added that these difficulties extend to other regions of the spectrum. A comment made by Michalitsianos to a paper presented by Boyarchuk (1982) at Colloquium N°70 may be mentioned here: "Symbiotics in the ultraviolet present a spectrum very similar to planetary nebulae. The only thing that tells a UV observer that he is in fact looking at a symbiotic star is that someone has found evidence for a cool component in the optical or infrared". To this, Whitelock added: "In the infrared the reverse is often the true: they are not different from M giants".

Figure 1 illustrates this fact. It shows the spectra, in the region λλ3900-7200 Å, for four objects: a) a typical simbiotic star (AS 270); b) a well recognized symbiotic with a spectrum which does not differ much in this region from that of a planetary nebula (He2-106); c) a low excitation planetary nebula (He2-131); and d) a high excitation planetary nebula (Me2-1). All these spectra were obtained by H. Moreno at CTIO, using the 1m telescope with Cassegrain Spectrograph and 2-

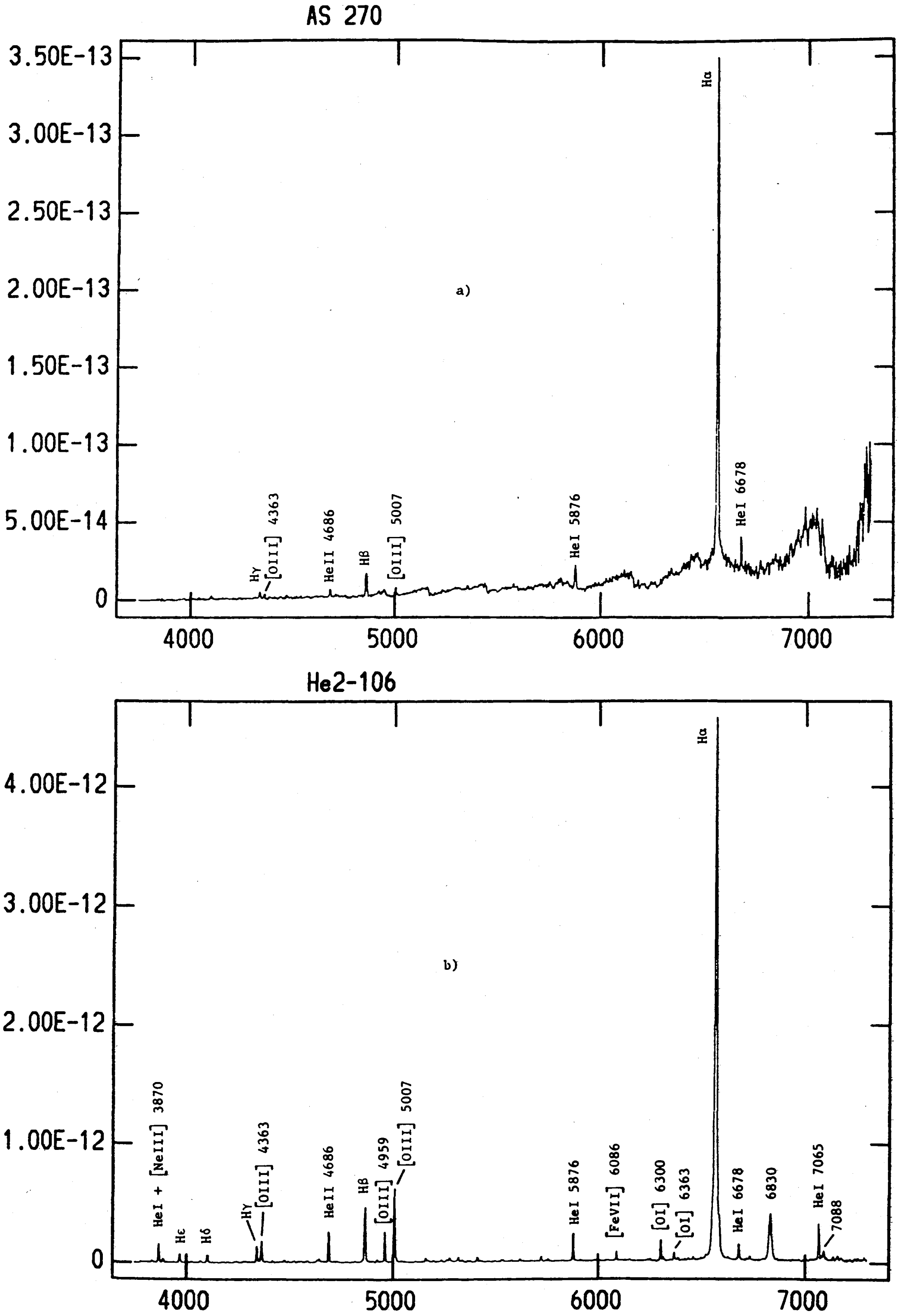

Fig. 1 Spectra of four emission lines objects: a) symbiotic star AS 270; b) symbiotic star He2-106.

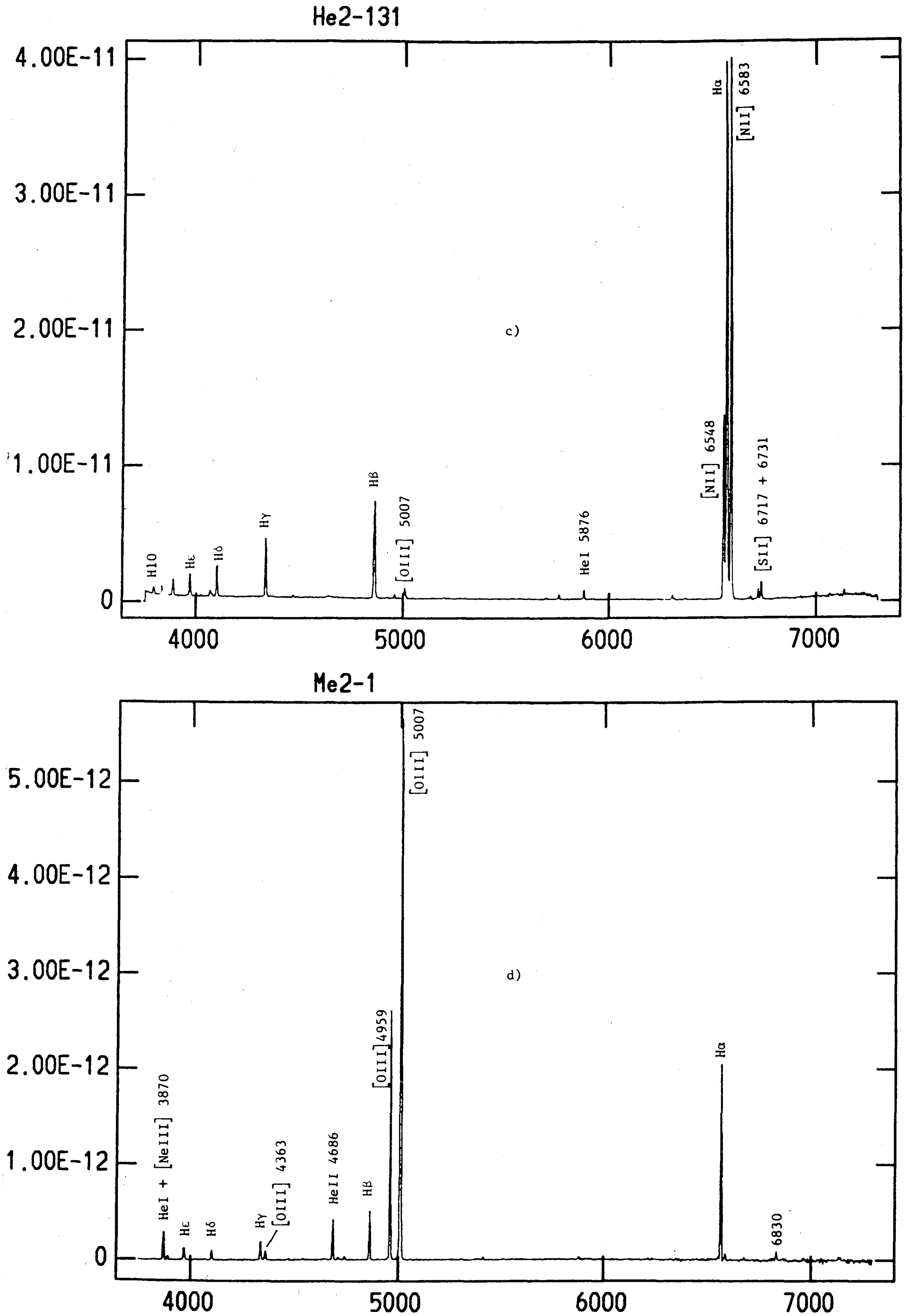

Fig. 1 c) low excitation planetary He2-131; d) high excitation planetary Me2-1.

Dimensional Photon Counter. The difference between a) and the other spectra is obvious, but the differences between b) and c) or d) are not very clear; if we had only this information, our choice between a classification of He2-106 as planetary nebula or symbiotic star would be rather difficult.

A few comments with respect to these spectra may be added.

a) There are symbiotic stars whose late components are not easy to detect, since their absorption characteristics are not clearly distinguished from the noise. In these cases the separation from planetary nebulae may become very difficult.

b) Two lines which are characteristic of many symbiotic stars are the two unidentified lines (or bands) at λλ6830 and 7088; but there are some of these objects for which these lines are very faint or not detected; examples of this behaviour, taken from our spectra, are AS 296 and AS 304; thus, the absence of these lines, although a strong indication against the symbiotic nature of an object, is not always conclusive.

c) The [O III] λ5007 line is in general very faint in symbiotic stars; in some spectra it may even be undetectable; in this aspect, the spectrum resembles that of a low excitation planetary nebula. Nevertheless, there are some objects for which this line may be fairly strong, with R=I(5007)/I(Hβ) >1; examples of this type of spectrum are He2-106, with R≈ 1.5-5, and PC 18, with R ≈ 2 (He2-106 is V835 Cen).

d) A similar behaviour is presented by the [N II] lines λλ6548 and 6583. In most symbiotic stars they are very faint, almost undetectable, or completely lost in the wings of Hα; in this aspect the spectrum resembles that of a high excitation planetary nebula. But there are some cases in which the intensity of λ6583 is comparable to that of Hα; an example is He2-171.

e) A special remark concerns Me2-1: its [O III] lines have intensities adequate for planetary nebulae, and in general, all the spectral characteristics correspond to a high excitation planetary; nevertheless, it shows a line at λ6830, which corresponds to the typical feature of symbiotic stars mentioned in point b). This object may deserve further study.

OBSERVATIONAL DIAGNOSTIC DIAGRAMS FOR PLANETARY NEBULAE AND SYMBIOTIC STARS

These differences in the spectra of symbiotic stars imply that for many objects the distinction from planetary nebulae is not easy. An evidence of the difficulties involved is given by the lists of misclassified planetaries presented every five years by Kohoutek (1978, 1983, 1988), in the IAU Symposia on planetary nebulae. Several of the objects included in his lists are designated as symbiotic stars. It is worth mentioning that in the list of 1978 the name "symbiotic star" is not used, but the characteristics attributed to many of the objects there included are clearly symbiotic spectral characteristics. Further evidence may be found in recent papers by Acker et al. (1987, 1988), which present lists of misclassified planetary nebulae, many of which are now listed as symbiotic or possible symbiotic stars. Besides, there are some objects which keep going in and out of the list of symbiotic stars. A typical object of this class is PC 11 (He2-172), recently studied by Gutiérrez-Moreno et al. (1987). Another study of this type, made by Kohoutek (1987) corresponds to AS 201, considered by Allen (1984) as a symbiotic star, and by Kohoutek as a dense planetary nebula of moderate excitation class.

Considering all the difficulties mentioned before, we have made some attempts to find diagnostic diagrams for separating planetary nebulae from symbiotic stars on the basis of observations in the visual region of the spectrum alone.

Since the high density is one of the important characteristics of symbiotic stars, it seemed tempting to use the density - or the ratio of a pair of lines which allow the determination of the density - as one of our diagnostic criteria. Nevertheless, this is not very easy to do; in fact, in the visual region, the main criteria for determining densities of planetary nebulae are the [S II] lines λλ6717, 6731, the [Cl III] lines λλ5518, 5538, and the [O II] lines λλ3727, 3729; but these lines are not adequate in the case of the high densities present in symbiotic stars.

In 1981 Baldwin, Phillips and Terlevich (BPT) presented some diagrams which allowed the separation of extragalactic objects according to their excitation mechanisms, on the basis of the ratios of the intensities of various emission lines. They separate four categories of objects: normal H II regions, planetary nebulae, objects photoionized by a power-law continuum, and objects excited by shock-heating. Considering that such a diagram, which appeared to separate well the planetary nebulae from other emission lines objects, could also be useful to distinguish symbiotic stars, Gutiérrez-Moreno et al. (1986a) tried to use it as a diagnostic tool; in that moment, we had only one symbiotic star (He2-106) and one suspected symbiotic (He2-104) with measures of the fluxes of all the relevant emission lines, λλ3727, 4861, 5007, 6300, 6563, and 6584; these measures were obtained from spectrophotometric observations made by the authors. No other symbiotic stars were found with measured fluxes of all these lines. Applied to the two objects available, the method seemed to work well, showing He2-106 separated from the planetary nebulae, and the suspected symbiotic He2-104 very close to it, suggesting that it is also symbiotic.

Later on, H. Moreno obtained spectra for a few more symbiotic objects in the spectral range involved; the observations

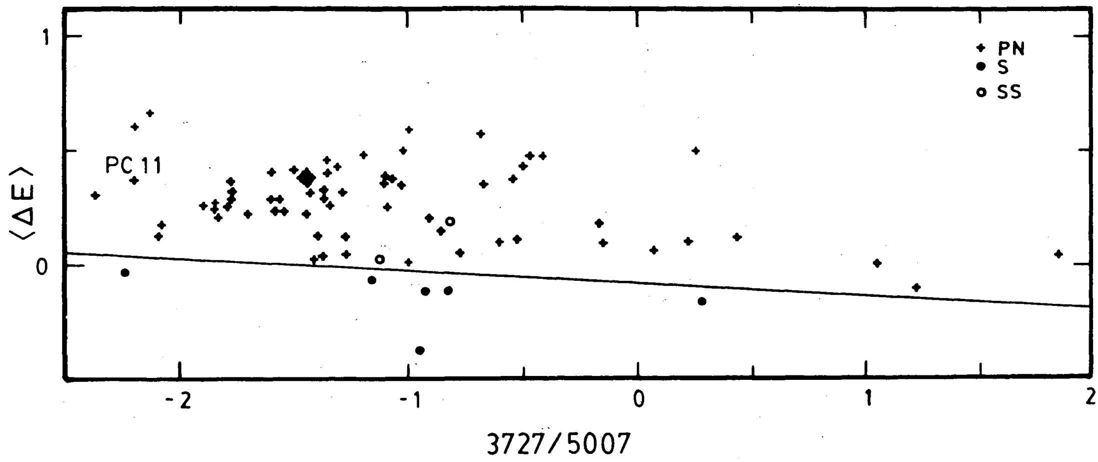

Fig. 2 BPT diagnostic diagram, showing the position of planetary nebulae and symbiotic stars. The line which separates both types of objects is a free hand line, traced so as to separate them as well as possible. Notice that two suspected symbiotic stars, He2-104 and Cn1-1, fall in the region of planetary nebulae. PN = planetary nebulae; S = symbiotic stars; SS = suspected symbiotics.

were made at CTIO, using the 1.5 m telescope with a Cassegrain spectrograph and a SIT Vidicon. These new observations permitted an extension of the diagram, shown in Fig. 2, including all the planetary nebulae and symbiotic stars for which measures of the relevant lines were available. The data for planetary nebulae line intensities have been taken from Peimbert and Torres-Peimbert (1971), Torres-Peimbert and Peimbert (1977), Barker (1978) and Gutiérrez-Moreno et al. (1985); some additional data were taken from the catalogue by Kaler (1976). The data for the symbiotic stars correspond to the Vidicon observations. Fig. 2 shows that planetary nebulae are not constrained to a limited region of the diagram; in fact, they occupy a zone which covers from the shock-heated region to the power-law ionization region. All the nebulae included are located above a straight line, traced free hand through the lowest points corresponding to planetary nebulae.

Nevertheless, the diagram turned out to be inadequate in many cases. The points corresponding to symbiotic stars with rather strong [N II] lines are located above the line, and thus cannot be distinguished from planetary nebulae. Besides, as was said before, for many symbiotic stars some of the lines used in the computation of <ΔE> are not measurable.

During 1987, new observations of symbiotic and suspected symbiotic stars were made using the 2 Dimensional Photon Counter attached to the 1m telescope of Cerro Tololo Inter-American Observatory. These observations included only the spectral region λλ3700 to 7000 Å, and thus could not be used in our previous study.

A new approach was then attempted. Symbiotic stars are objects characterized by their high excitation and density, and a good measure of these physical parameters is the relation between the intensities of the [O III] lines λλ5007 and 4363. In planetary nebulae the ratio of these two lines is of the order of 200 or somewhat higher for low excitations - for example IC 418 - to 60 or somewhat lower for high excitations - for example NGC 5882 - (Gutiérrez-Moreno et al. 1985, 1986b) while it is much lower for symbiotic stars. The use of these lines seemed obvious; thus, in a first approximation we decided to use directly a plot of the ratio R_1 = I(4363)/I(Hγ) versus R_2 = I(5007)/I(Hβ). The use of Hγ in R_1 has the advantage of minimizing the effects of an error in the reddening corrections; besides, it gives values larger than those that would be obtained by the use of Hβ; this is convenient since in general the values of R_1 are small.

Figure 3 shows the results of this diagnostic diagram:

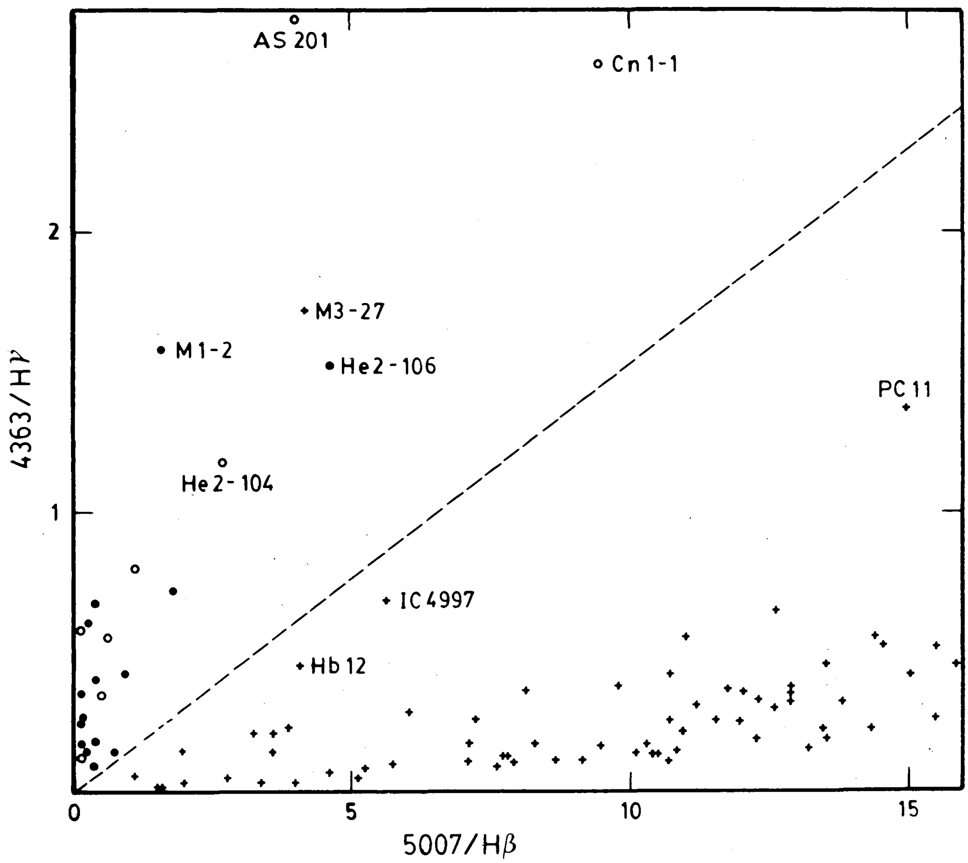

Fig. 3 Position of planetary nebulae and symbiotic stars in the I(4363)/I(Hγ) - I(5007)/I(Hβ) plane. The dashed line has been traced free hand. Both types of objects get rather confused near the origin, where the separation becomes uncertain. The objects labelled in this figure and in Fig. 5 are discussed in the text.

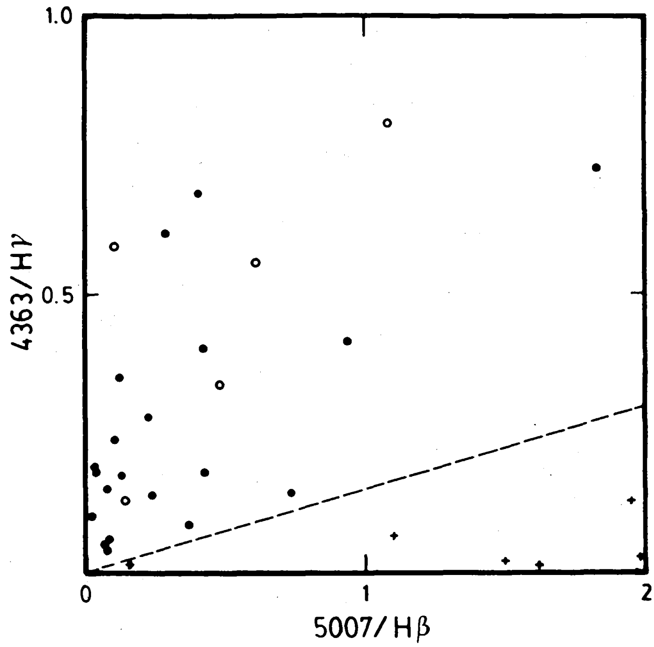

Fig. 4 An expansion of the region near the origin in Fig. 3. The behaviour of both types of objects in this region is consistent with that in Fig. 3. The dashed line is the same as in the preceding figure.

planetary nebulae are well separated from symbiotic stars, occupying two different regions in the plane R_1, R_2. There is a zone of confusion near the origin, where the separation between both classes of objects becomes more difficult. In fact, it was not possible to represent here all the objects for which we have observations. An expanded plot of this zone is presented in Fig. 4; it can be seen that the general behaviour of the points in this region is concordant with that of Fig. 3.

We must point out that these are preliminary results, since the spectra obtained with the 2 Dimensional Photon Counter have not been measured yet, and the values used here for these objects correspond to peak intensities, corrected by interstellar extinction in a first approximation. Definitive results will be published later.

An attempt was made to eliminate the zone of confusion in the preceding figure by plotting the ratio I(5007)/I(4363) versus I(4363)/I(4340). The results are shown in Figure 5, which plots the ratio R_3 = I(5007)/I(4363) versus the ratio R_4 = I(4363)/I(Hγ). In this case we obtain much better separation; planetary nebulae are located in the zone $R_3 > 16$ (some nebulae with $R_3 > 220$ have not been plotted) and $R_4 < 0.7$; an exception is PC 11, with $R_4 = 1.37$. Symbiotic stars occupy a much restricted zone, with $R_3 < 10$; most of them, on the other hand, have $R_4 < 0.9$.

Some objects deserve further comments:

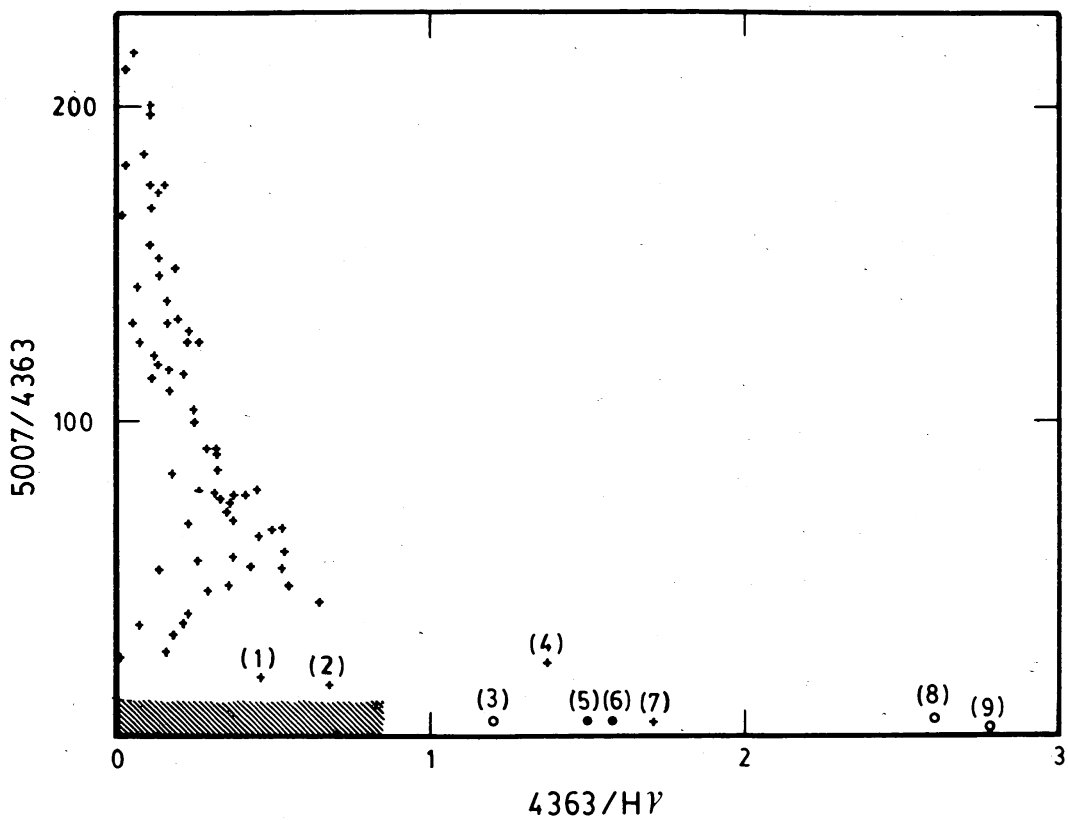

Fig. 5 Position of planetary nebulae and symbiotic stars in the I(5007)/I(4363)-I(4363)/I(Hγ) plane. The shadded are includes most of symbiotic and suspected symbiotic stars observed (20 and 6 respectively). The numbers in parenthesis indicate the objects which are commented in the text, as follows: 1) Hb 12; 2) IC 4997; 3) He2-104; 4) PC 11; 5) He2-106; 6) M1-2; 7) M3-27; 8)Cn1-1; 9) AS 201.

a) M1-2 (VV8, PK 133 -8°1, N°6 in Fig. 5).- It is described by Barker (1978) as a nebula undergoing strong Balmer line self-absorption from the metastable 2 ^{2}S level, an effect which is expected to be important in very dense planetaries. He mentions that this object has been studied previously by several authors, among them O'Dell (1966) who concluded that it is either a symbiotic star or a star which is currently ejecting a planetary nebula. Allen (1982, 1984) includes it in his catalogue of symbiotic stars, classified as D'-type with late-type companion of spectral type G2. Feibelman (1983) analyzed the ultraviolet spectrum and arrived to the conclusion that it is a young, high-density planetary nebula. The position of this object in Figs. 3 and 5 suggest that it may be a symbiotic star.

b) AS 201 (Hen 172, N°9 in Fig. 5).- This object has been classified by Allen (1982, 1984) as a D' symbiotic star with a G-type late component. Kohoutek (1987) has analyzed its spectrum and arrives to the conclusion that it is a dense planetary nebula of moderate excitation (similar to IC 4997), having a binary central star with a G2 III late component. The position of IC 4997 has also been indicated in Figs. 3 and 5, and it can be seen that in both diagrams it is located far from AS 201, in the region of rather high excitation planetaries. The position of AS 201, obtained from direct measures of the relevant line intensities in the spectrum published by Kohoutek (1987), uncorrected by reddening, seems to confirm its symbiotic character.

c) He2-104 (PK 315 +9°1, N°3 in Fig. 5).- It has been classified both as a planetary nebula and is a symbiotic star. Allen (1982, 1984) includes it among the suspected symbiotics, classified as D-type, without indication of spectral type for the late companion. Lutz (1988) has studied its spectrum and has taken CCD images with [O III] and Hα narrow band filters. She finds that it shows a bright nebula with a radius of about 4", and a faint bipolar structure. This nebulosity would suggest that it is a planetary nebula. However, our Vidicon spectrum shows the presence of TiO bands, and Whiteoak (private communication to Lutz) states that a 400 days Mira pulsation has been observed in the infrared. Lutz concludes that this means that He2-104 could be one of the rare symbiotics which show nebulosity (as R Aqr), or it could be a planetary nebula with a binary nucleus in which the cooler component is a Mira star. It is worth mentioning here that Viotti (1987) has found that high spatial resolution radio observations have recently given evidence of the presence of small nebulae around symbiotic stars, with a variety of structures, such as shells, jets, bipolar nebulae and extended halos. The position of this object in our diagrams is consistent with a symbiotic character.

d) Cn1-1 (HD 330036, PK 330 +4°1, N°8 in Fig. 5).- This object has been listed by Allen (1982, 1984) as a suspected symbiotic star of D'-type with a late component of F- or G-spectral type. Previously he (Allen 1981) had found that this object is unique among those classified as symbiotic stars in showing emission features around 3.3 μm. Lutz (1984) has classified it as a dense planetary nebula. Bhatt and Mallik (1986) also find that it is a high density planetary nebula, probably a proto-planetary nebula with a massive nucleus. Kohoutek (1987) has pointed out a possible similitude between AS 201 and Cn1-1 and, in fact, they occupy rather similar positions in Figs. 3 and 5.

e) PC 11 (He2-172, HD 149427, PK 331 -5°1, N°4 in Fig. 5).- Listed by Allen (1982) as a symbiotic star of D'-type, with a late component of A-F spectral type. It is not included in his catalogue of 1984. Gutiérrez-Moreno et al. (1987) have studied it and arrived to the conclusion that it is a high density and high excitation (class 7 to 8) young planetary, very similar to IC 4997. Both objects occupy rather similar positions in Figs. 3 and 5, with PC 11 having much stronger flux at λ5007. Its position, far from symbiotic stars, would confirm its planetary nebula character.

f) M3-27 (PK 43 +11°1, N°7 in Fig. 5).- The data on the line intensities were taken from Barker (1978). Capriotti (1964) has studied this object in detail; he classifies it as a dense planetary nebula of high excitation. Barker (1978) states that this planetary nebula has a behaviour similar to M1-2, since it also shows important Balmer line self-absorption. Feibelman (1985) also infers a high density from the intensity of the [O III] lines, but states that it has zones of lower density; the UV characteristics are similar to those of M1-2, though indicating a slightly lower excitation class. The position of M3-27 in the diagrams is close to M1-2, already discussed, and to He2-106; this suggests that it could be also symbiotic.

g) Hb 12 (PK 111 -2°1, N°1 in Fig. 5).- It is mentioned by Barker (1978) as a nebula with possible self absorption, though less important than M1-2 and M3-27. Different authors classify it as a young planetary (see, for example, Pottasch 1984). Its position in Figs. 4 and 5 shows that it is more similar to IC 4997 than to M1-2 or M3-27; this is consistent with its being a young planetary nebula of high excitation.

Two additional remarks can be made concerning Figs. 3 and 5:

a) In Fig. 3, three objects, classified as dense, young planetary nebulae, occupy a position clearly different from both symbiotic stars and other planetary nebulae; they are Hb 12, IC 4997 and PC 11; we will come back to these objects in the next section.

b) In Fig. 5 most of the symbiotic and suspected symbiotic stars are located in the shaded area; nevertheless, there is a group of objects outside this zone; according to Allen (1982, 1984), three of them are symbiotic stars, two are suspected symbiotics and one is a dense planetary nebula; nevertheless, other analysis of these same objects classify them (except for He2-106 and probably He2-104) as high density planetary nebulae of medium to high excitation. The possible peculiar character of these objects has already been commented by other authors; for example Lutz (1984), in her study of Cn1-1, states that this planetary nebula (or symbiotic star) appears to have much in common with the peculiar objects M1-2, M3-27 and with the dense nebula IC 4997; she adds that it is apparent that there is considerable overlap between the characteristics of planetary nebulae and symbiotic stars, particularly among "fringe" objects in each of these groups.

Finally, I must mention a recent study made by Feibelman and Aller (1987) in which they use ultraviolet observations to discriminate between planetary nebulae and symbiotic stars;

they make a graph of log [F(C III 1909)/F(Si III 1982)] = log R versus the electron density. The discrimination between symbiotic stars and planetary nebulae appears very clear; but it is interesting to note that here again the objects Cn1-1, M1-2, and M3-27, occupy a peculiar position, with densities comparable to that of symbiotic stars but higher values of R, similar to those of planetary nebulae; at the same time, the planetary nebulae IC 4997 and Hb 12 are located in a different region, intermediate between that of planetary nebulae and symbiotic stars, with densities between both types of objects. Thus, IC 4997 does not seem to share the peculiar characteristics of Cn1-1, M1-2 and M3-27, but rather appears to belong to a different group of objects.

SYMBIOTIC STARS AND PLANETARY NEBULAE

We have seen that planetary nebulae and symbiotic stars have many characteristics in common, being in many cases difficult to separate. In fact, when the late-type spectrum is not clearly distinguished, the separation of both kinds of objects may be very difficult: symbiotic stars look in this case as planetary nebulae of high excitation. Besides, they share the distribution in space, they have comparable expansion velocities, similar location in the HR diagram, and similar kinematical behaviour. Then, the natural question is: are they related in any way? The subject is still open to discussion, since no definitive conclusions have been reached.

Ciatti (1982) points out that from the spectral characteristics of symbiotic stars it is possible to infer that these objects have higher densities (of the order of 10^{6-7} versus 10^{3-4} cm^{-3}) than planetary nebulae. In this aspect, they are more similar to some compact planetaries (as IC 4997) than to planetary nebulae in general. Thus, it is possible to think of an evolutionary connection among both types of objects, with symbiotic stars possible progenitors of planetary nebulae, having smaller and more compact ejected envelopes. Compact planetaries as IC 4997 could be intermediate objects between planetary nebulae and symbiotic stars. Notice that the position of this object in Figs. 3 and 5, as well as that of Hb 12 and PC 11 (already commented), would be consistent with this approach. Ciatti also points out that the binary star hypothesis of symbiotic stars would be consistent with the increasing number of binaries found in the nuclei of planetary nebulae. Nevertheless, he states that the picture of the correlation symbiotic star - planetary nebula is not yet clear.

Kenyon (1986) gives a summary of the evolutionary behaviour of symbiotic stars, considering two main cases: a) symbiotics with accreting main sequence stars, including: i) long period systems (P $\gtrsim$ 10 years) and ii) short period systems, (P $\gtrsim$ 1 - 3 years); and b) symbiotics with accreting white dwarfs; this last type is divided in two: i) short period systems (P $\lesssim$ 1000 days) and ii) long period systems (P $\gtrsim$ 10 000 days). In case a) a common enveloped binary would be produced, with an essentially unevolved main sequence star and a hot white dwarf orbiting inside a dense nebula (Paczynski 1976). Once the common envelope is ejected, the long period systems would appear as normal planetary nebulae with perhaps some bipolar structure; the relatively unevolved main sequence star may eventually become a red giant, and could initiate a second symbiotic phase; the short period systems, on the other hand, are considered the most promising mechanism for producing short period cataclysmic binaries. In case b), Kenyon states that the short period objects will again form a common envelope, with a core containing a white dwarf pair; most objects with short periods will eject a massive envelope, thus suffering drastic reductions in the orbital period; the final result would be a close binary consisting of two white dwarfs surrounded by an expanding planetary nebula; long period systems, on the other hand, do not evolve into contact systems; in this case, the red giant component will eventually eject a planetary nebula, which will be excited by a binary nucleus composed of two white dwarfs separated by more than 10 AU.

Kohoutek (1987), in his paper about AS 201, also refers to the connection between planetary nebulae and symbiotic stars. He states that the main problem for considering symbiotic stars as proto-planetary nebulae is the high excitation spectrum of most symbiotic stars, whereas the proto-planetary nebulae should be of low excitation. He analyzes two objects in addition to AS 201: Cn1-1 and M1-2; he states that the hot components of these objects are located in the region of the evolved central stars of planetary nebulae, and after some speculation suggests that the hot component of some symbiotic stars (perhaps for example those belonging to PN symbiotics (Plavec 1982)), are evolved central stars of planetary nebulae. Notice that this point of view of Kohoutek is completely contradictory with that presented above.

CONCLUSIONS

It is evident that, even in such a restricted topic as the relations between planetary nebulae and symbiotic stars, there is an ample field open for research. Symbiotic stars are found mostly in the southern hemisphere (just take a look at Allen's (1984) catalogue). On the other hand, about two thirds of the planetary nebulae listed in Perek and Kohoutek (1967) are also in the southern hemisphere; thus, we are in a position of privilege to observe these objects.

Several methods and techniques of observations can be mentioned:

a) CCD or 2 Dimensional Photon Counter spectroscopy, to obtain fluxes for more objects, to obtain new diagnostic diagrams or to fill the gaps in those presented here, to arrive at a good set of quantitative diagnostic criteria and also to obtain physical parameters which would allow discrimination between anomalous reddening produced by self absorption or by dust;

b) CCD photography with narrow band filters in the wavelengths of the most important lines, to obtain better details of the morphology of both kinds of objects, especially of symbiotic stars, to see if they differ in some way from planetary nebulae; or, following Lutz's(1988) procedure, to see if many symbiotic stars present a detectable nebula around them as reported by Viotti (1987) according to his radio observations, or they really have stellar aspect;

c) High dispersion spectroscopy, to obtain line profiles which could give information about velocity fields of the gas motion, and to study the possible differences in this aspect between planetary nebulae and symbiotic stars.

These new observations could be used, besides, to:

a) Review the classification of planetary nebulae in search of possible until now undetected misclassified objects, which may turn out to be symbiotic stars;

b) Combine visual observations with others made in the ultraviolet and the infrared, and use them to formulate new models which allow a better understanding of symbiotic stars and their evolutionary relation (if any) with planetary nebulae.

I feel sure that all this new information may add much to our knowledge about symbiotic stars (though evidently it may also add much to our confusion).

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DISCUSSION

N. VOGT: If symbiotic stars develop towards planetary nebulae, and if they are binaries, we should find many binaries among the nuclei of planetary nebulae. Is this true?

A. GUTIERREZ: I wish to point our first that, even if we accept that all symbiotic stars are binaries and that they evolve into planetary nebulae, this does not mean that all planetary nebulae originate in symbiotic stars, and thus there is no need for all planetary nebulae to have binary nuclei. Concerning the number of planetary nebulae with binary nuclei, according to Acker'scatalogue of central stars of planetary nebulae, about 8% of them are binaries or suspected binaries. This number may appear rather small, but it cannot be considered so small if we take into account that the number of known symbiotic stars is about 8% of the number of planetary nebulae contained, for example, in the Perek and Kohoutek catalogue. If we consider all the additions to this catalogue, the portion of symbiotic stars is still smaller.

J. GRAHAM: Some binary symbiotic stars are probably seen far from their orbital plane and may well appear single from radial velocity considerations.

A. GUTIERREZ: I agree, but I would like to insist on my point of view that not all symbiotics are necessarily binaries. We know that in our galaxy about 50% of the stars are binaries. It is not surprising, then, that a large percentage of symbiotic stars are also binaries.

H.E. SCHWARZ: When discussing evolution of symbiotic stars in planetary nebulae, the fact that symbiotics evolve into planetary nebulae will not much influence the number of binary planetary nebulae due to the scarcity of symbiotics. When talking about single/binary status symbiotics, the single-star people are not impressed by arguments about statistics of binaries among symbiotics. They say that a large proportion of all stars are binaries anyway and binarity does not necessarily influence "symbioticness"

J. SAHADE: Roberto Méndez, who has been working for a number of years on the question of binarity of central stars in planetary nebulae, has stated in a paper at the last planetary nebulae symposium in Mexico, that at present it is too early to state how large is the percentage of binaries among planetary nebulae to progress in this problem.