I. THE OBSERVATIONAL PN DATABASE

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Introductory review

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CLASSIFICATION CRITERIA AND DATABASES

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Abstract

In this review lecture the increase of fundamental data for planetary nebulae is shortly reflected. Special attention is given to the new general catalogue of galactic planetary nebulae, and selection criteria for the entries are summarised. Some information on planetary nebula data in the Magellanic Clouds is also given.

1 Introduction

According to modern language, the term 'planetary nebula' is misleading, the objects of this kind have nothing to do with planets at all. But the view through the telescope by Antoine Darquier at the end of the 18th century, 'the fading disc of a planet' (for the Ring Nebula), was a hint that at least this object had a distinct morphology. Almost a century later, William Huggins spotted his spectroscope towards the heavenly bodies, noting that 'planetary nebulae' had an emission line spectrum of certain character. Since then, morphology and spectroscopy have gone hand in hand in the exploration of the ever-increasing number of planetary nebulae, combined with more modern observational approaches. Among them there is a wild variety of forms, and even the spectral appearance varies. The designation 'planetary nebula', however, still remains.

Although numerous listings and catalogues have appeared during the years, e.g. the most famouos of them all, the *Catalogue of Galactic Planetary Nebulae*, Perek and Kohoutek (1967)[2] , there is still reason to ask what a PN really is and what it looks like.

The ideal planetary nebula consists of two parts: 1) a spherical cloud or shell of gas (and dust) centred around and originating in 2) the central star, which once has expelled the gas shell during the late stages of its evolution. The central star, now a hot star of small diameter, is radiating mainly in the ultraviolet, exciting the gas which reradiates most of the energy through a number of emission lines. An ideal PN has thus a well-defined form or morphology, and the nebular component has a well-defined set of spectral lines.

In reality, morphology and radiation pattern can vary widely between individual objects. The morphology is affected by different processes where only little is known: the ejection mechanism, the rotation of the ejecting star, the nebular mass and the interaction between the ejected gas and the interstellar medium. Moreover, the morphology is practically unknown for a large fraction of the population, i.e. those PN which have just a "stellar" appearance because of large distance or compactness. On the other hand, the nebular spectrum is affected by the radiation properties of the central star as well as by the physical properties of the gas shell itself and its composition.

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[2]A fourth supplement to this catalogue is given as a poster at this symposium by L. Kohoutek.

R. Weinberger and A. Acker (eds.), Planetary Nebulae, 11–17.

This was the problem for the authors of the new *Strasbourg-ESO Catalogue of Planetary Nebulae*, Acker *et al.* (1992), SESO Cat, which is just released. Their selection criteria is given below in some detail.

2 How to tell a cat from a meat loaf

The problem may seem inappropriate, but at least in some applications it is important to know whether a population is homogenouos or not, i.e. if the objects in the sample represent for example the same evolutionary status or just happen to have important features in common. Therefore, along with the compilation of the new catalogue, the authors decided to perform spectroscopic observations of all possible PN candidates. This was also done. Optical spectroscopy in the region of approximately 400 – 740 nm was gathered for about 1 450 objects during the years 1985 – 1991. Armed with this information, along with other relevant data and a good portion of courage, the authors divided the PN candidate population in three parts: 1) true PN, 2) possible PN and 3) objects which clearly are something else than PN. The main criteria for selection into the three groups were in short:

1. True planetary nebulae *(1 143 objects)*

1. Objects with properties close to the ideal PN mentioned above, preferably with an identified central star.
2. Objects with stellar or nearly stellar appearance showing a spectrum close to the ideal one. If an IRAS observation exists, the object should be in the appropriate region of the IRAS two-colour diagramme.
3. Objects with non-ideal spectra, showing low excitation, sometimes with an infrared excess and molecular emission, being young PN.

2. Possible planetary nebulae *(347 objects)*

1. Objects without indentification, which therefore cannot be observed correctly.
2. Objects proposed as planetary nebulae but for which no informative spectrum could be obtained because of faintness or high reddening.
3. Objects of general unclear status with well-known spectra but possibly related to PN or objects which could evolve into PN.

3. Objects not being planetary nebulae *(330 objects)*

1. Stellar objects showing a continuous spectrum, or showing a stellar continuum with emission lines not typical for PN.
2. Objects showing a considerable redshift.
3. Objects showing low-excited PN spectra but being in the wrong place in the IRAS two-colour diagramme.
4. Non-existing objects.

The objects in the first category can be regarded as a very homogenous sample of PN in the Galaxy. The items here are really PN up to the highest degree of probability. A rough analysis of this population is given in the SESO Cat, such as galactic distribution, distributions of angular diameters, radial and expansion velocities etc.

Regarding the second category it was the ambition of the authors to keep the number as close to zero as possible. However, there is still a considerable amount of objects present. It is obviuos, that the above cited selection criteria is not sufficiently covering, and that there are a number of objects for which observational information is difficult to obtain. It is, in other words, still difficult to tell cats from meat loaves, at least when they are too distant!

In the third category we find objects which clearly are something else than planetary nebulae, namely:

Galaxies	50
H II regions	35
Symbiotic stars	70
M stars	35
Other emission line stars	45
Objects without detectable emission	95

Among the galaxies, one fourth of them shows highly red-shifted emission lines. The symbiotic stars are classified following the characteristic emission at 683 nm in most cases. A number of objects seem to be just ordinary M stars. The reason for this is obviously that the continuum between the TiO bands has been confused with emission lines on objective prism plates. There are also other kinds of emission line stars, such as Wolf-Rayet stars and Be stars, in the group. There are also many candidates which did not show any detectable (line) emission. They are called "non-existing objects" above. A number of them are known as plate faults, the remaining are thought to be artifacts of similar character.

3 The planetary nebula database

3.1 Planetary nebulae in the Galaxy

Although the number of PN in the Galaxy may be estimated to several thousand, maybe ten thousand or more, only a fraction of these can actually be observed. If we believe that the new catalogue is representative for our present knowledge of the galactic population, which contains about 1 500 true or possible PN, it is therefore completely clear that the majority of PN is unobservable, at least in the visual domain. Further observations of the 'possible' PN in the catalogue will clarify the situation for them. Still more objects will be found, following classical methods of discovery, but analyses of the IRAS observations seem to be more promising. Preite-Martinez (1988) studied the IRAS Point Source Catalogue finding 340 objects as possible PN, mainly due to their infrared colours. Some of these objects have later been confirmed in radio and optical searches. A method of discovery combining infrared (IRAS) and radio observations is outlined in Pottasch *et al.* (1988) presenting also 36 new PN around the direction of the galactic centre. Additional 48 PN were presented in a subsequent paper, Ratag *et al.* (1991), and a third paper dealt with radio continuum observations of IRAS PN sources, Ratag and Pottasch (1991). Their work is summarised in Pottasch *et al.* (1990), which also gives an interesting comparison of the distributions of 3 000 unidentified IRAS sources with PN colours and the SESO Cat sample of (optically) known PN.

Fundamental radio data from the VLA are given in Zijlstra *et al.* (1989) and Aaquist and Kwok (1990). The first paper presents radio fluxes, diameters and positions for about 300 PN. The second paper gives radio data at 6 cm for 174 objects, most of them being optically unresolved. Combined with IRAS data this gives the total infrared flux, dust temperature and infrared excess.

Spectroscopic line intensity data are also given in some of the above mentioned papers. The SESO Cat contains line data for lines of major importance as obtained in the spectroscopic survey, on which the selection of cat objects rests. Line data from this survey are also given in Acker *et al.* (1989b and 1991). Data from the survey have been used in a number of papers to derive nebular and stellar parameters, e.g.:

- Central star B and V magnitudes, Tylenda *et al.* (1991b), $\approx$ 350 objects.
- Absolute Hβ fluxes, Acker *et al.* (1991), 880 objects.
- Extinction constants, Tylenda *et al.* (1992), $\approx$ 900 objects.
- Zanstra temperatures of central stars, Gleizes *et al.* (1989), 94 objects.
- Energy-balance (Stoy) temperatures of central stars, Preite-Martinez *et al,* (1989), 388 objects, (1991), 184 objects.
- Chemical compositions and galactic gradients, Köppen *et al.* (1991), 86 objects.
- Masses for PN nuclei in the galactic bulge, Tylenda *et al.* (1991a), 100 objects.

Shaw and Kaler (1989) studied a sample of 145 PN in the southern sky, measuring continuum and line fluxes, determining stellar and nebular parameters. Stanghellini and Kaler (1989) calculated electron densities for 146 objects using a large sample of forbidden lines. Another work concerning fundamental data is an up-dating of Kaler's (1976) catalogue of relative line intensities by Kaler and Browning (1992). Cahn *et al.* are publishing a catalogue of Hβ fluxes, 468.6 nm intensities, extinctions and radio fluxes.

In the ultraviolet spectral region, we note the appearance of an IUE catalogue of PN compiled by Feibelman *et al.* (1988). In two subsequent papers, Feibelman and Bruhweiler (1990) and Feibelman *et al.* (1991), altogether 26 central stars are studied based on IUE observations.

Zhang and Kwok (1991) make use of observations in a wide spectral range, between 0.1 and 100 μm, to map the spectral distribution for 66 compact PN. They fit model curves to the observed data and derive stellar temperature, gas and dust temperature and interstellar extinction.

There is at present no good method to compute individual distances for most PN. However, distance estimations are necessary for derivation of certain stellar and nebular physical parameters. To avoid this difficulty with the whole sample of galactic PN, one has instead selected PN close to the direction of the galactic centre, assuming then that that sample really is situated in the galactic bulge, i.e. at the common distance of $\approx$ 8 kpc. Such a sample was the subject for the thesis by Ratag (1991), which discusses several aspects of PN situated within about 20 degrees of the galactic centre. In total, 110 PN are studied. Abundances for the most important elements are derived. The results are discussed in relation to stellar and galactic evolution.

Acker *et al.* (1991a), Stasińska *et al.* (1991) and Tylenda *et al.* (1991a) also treat a sample of galactic bulge PN. In their case the number of objects is 275 PN. In the first paper the scene is set, presenting the data together with derived basic parameters. In the second paper some statistical properties of the nebular shells are given, including a distribution of the derived Shklovsky distances. The third paper is devoted to the central stars and its mass distribution. In a recent paper, Pottasch and Zijlstra (1992) attack the previous investigators because their calculation of Shklovsky distances was based on optical diameters. However, Tylenda *et al.* (1991a) discuss already consequences of errors in their adopted nebular model.

Also Webster (1988) treats a sample of 65 luminous PN towards the galactic centre with spectroscopic observations of her own. She derives abundances for most of them and discusses the mass distribution and its history in the galactic bulge. Pottasch and Acker (1989) investigate a similar sample with respect to the central stars and their evolution.

3.2 Planetary nebulae in the Magellanic Clouds

The problem of distances is also solved for populations of PN in other galaxies than our own. In this case, it is correct to say that the PN sample is situated at the same distance as seen from us. Moreover, the reddening caused by galactic extinction is small. This makes it possible, following Peimbert (1990), to study properties of the PN themselves, e.g. luminosity functions, envelope masses and progenitor masses, as well as properties of the galaxies as systems such as stellar death rate, production rate of the interstellar medium and chemical evolution. However, due to the general large distances to other galaxies, selection effects are introduced as only the brightest part of the complete population can be reached. Information on morphology is also scarce or non-existent.

The method can be applied to the galaxies nearest to us, the Magellanic Clouds, situated at a well-known distance. The PN populations in these galaxies have been surveyed spectroscopically by Boroson and Liebert (1989) who studied the Jacoby sample (68 objects) at Las Campanas Observatory, by Meatheringham and Dopita (1991a, 1991b) and by Vassiliadis *et al,* (1992), who studied mainly the Sanduleak-MacConnell-Philip sample (130 objects) at Siding Spring Observatory. Some of these objects turned out to be other kinds of objects than PN, but the majority is now regarded as true PN. In a poster at this symposium, Dopita and Vassiliadis present additional spectrophotometric results from the Clouds , as well as an analysis of the whole samples of PN in these galaxies.

The Siding Spring group compared their line intensities with earlier determinations finding excellent or very good agreement in most cases. In their last paper, Vassiliadis *et al.* (1992), aimed at the faintest objects in their sample, the agreement is less good, giving slightly lower intensities than the comparison values. The Las Campanas group do not make any comparison with previous observations, but a comparison with some objects which also have been observed by the Siding Spring group, gives a good agreement too, at least for brighter lines.

From the line intensities calculated from the Las Campanas observations, several physical parameters were derived and presented in the original paper, Boroson and Liebert (1989), as well as in Henry *et al.* (1989).

In a paper by Morgan and Good (1992), 86 new PN candidates in the Large Magellanic Cloud are presented, discovered on objective prism plates from the UK 1.2 m Schmidt

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telescope. This fruitful search, which almost doubles the number of known PN in this galaxy, continues. Dopita and Vassiliadis present in a poster at this symposium new PN from a recent objective prism survey.

In another poster, Walton, Barlow and Clegg present results from spectroscopic investigations of more than 50 central stars of PN in the Clouds. They derive a number of stellar parameters, using the known distance to the sample.

4 Final words and future prospects

When I was at the beginning of my career in astronomy, I was told by a senior astronomer, that there was once some kind of belief that some day it would be possible to stop observing. The time which was referred to was the beginning of this century, when a number of large telescopes were being constructed. When these big machines had been in action for some years, the whole sky would have been surveyed, the telescopes could be dismantled or turned into museum pieces, and the astronomers could be kept busy by analysing the observations only.

Almost a century later we know that this scenario never occurred and never will occur. The situation today is the opposite. Almost any observation in any wavelength region promotes further observations with higher resolution or higher photon rate. The period we now have in the rear mirror is a period when we have experienced big efforts to increase the number of objects of interest and to increase the quality of information about the objects. The period we have in front of us contains a number of important points. New optical telescopes with a light-collecting area bigger than ever are being constructed, and telescopes with mirror diameter up to 25 m are planned. New astronomical satellites will soon orbit the earth. As one of the authors of the new PN catalogue, I also hope that that work will inspire and spur observers for years to come. However, when data quality and quantity increase, even this new catalogue will be obsolete. Let us therefore try to make it obsolete as soon as possible! This can, however, only be done with *more and better observations.*

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