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Two senile nearby planetary nebulae and the local PN population

K. Ishida [1] **and R. Weinberger** [2,⋆]

[1] Tokyo Astronomical Observatory, University of Tokyo, Mitaka, Tokyo, 181 Japan
[2] Institut für Astronomie der Universität Innsbruck, Technikerstrasse 25, A-6020 Innsbruck, Austria

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Summary. Two large ($\phi \geqq 13'$) nearby ($D \leqq 0.33$ kpc) planetary nebulae (PN) were discovered by use of Kiso plates and POSS prints. Both are nebulae of very late evolutionary state with Hα surface brightnesses of $\geqq 25.1$ mag/arcsec^2, linear radii $r \geqq 0.56$ pc and electron densities $n_e < 10$ cm^{-3}. The expansion velocities are small, $V_{\rm exp} \leqq 8$ km s^{-1} in [O III]. Also, the absolute magnitudes of the central stars are very small: one ($M_v = +10.0$) appears even to be of extremely low luminosity with $\log L/L_\odot \leqq 1.10$.

The detection of these nearby objects motivated us to investigate the local PN population including all close PN discovered after the editing of the PK-catalogue too. We chose $D = 500$ pc as limit, where we used the averages of data of up to five recent distance scales for the PK-nebulae, and Shklovsky distances for most of the PN detected later than 1966. Twenty of the 31 objects lie at $\delta > 0°$. Projected surface densities and space densities are high, amounting to $\gtrsim 80$ kpc^{-2} and $\gtrsim 330$ kpc^{-3}, respectively. The birthrate is $\sim 8\ 10^{-3}$ kpc^{-3} yr^{-1} and thus much larger than the white dwarf birthrate; multiplicity of the PN phenomenon and the observed decrease in $V_{\rm exp}$ of large PN would reduce this discrepancy. The total number of PN in the Galaxy is in excess of 10^5 – the overwhelming majority obviously are planetary nebulae in very late stages of evolution.

Key words: new planetary nebulae – late evolutionary state – local population – birthrates

1. Introduction

Local planetary nebulae (PN) are an important subset of the galactic PN, since

(i) the total number of PN in the Galaxy (and consequently the effects on it like mass return etc.) is based on them,

(ii) they have considerable influence on conceptions on late stellar evolution (e.g., via birthrates of PN and white dwarfs),

(iii) they allow to pursue planetary nebulae central stars (PNCS) as far as possible on their way towards white darfs, because local PN contain several nebulae in the latest observable stages of evolution, and

(iv) the true luminosity function of PN and PNCS will depend on them (especially with regard to the faint end).

The above problems have been treated in numerous papers – in the review article by Terzian (1980) they are emphasized to some extent.

For a long time it is understood that the number and space density of the local PN along with the various conclusions drawn from them are affected by two severe difficulties:

The *distance problem.* Despite considerable efforts, even the statistical distances, i.e., distance scales, are strongly at variance.

Selection effects. Even at small distances, an appreciable interstellar extinction can be present (Lucke, 1978), thus hiding low surface brightness nebulae. Smith (1976) thoroughly discussed this subject.

It is the basic aim of this paper to point to a third difficulty and its consequences: The *incompleteness of PN searches.* As we shall demonstrate in Sect. 5, during the last decade there were more nearby ($D \leqq 0.5$ kpc) PN at $\delta \geqq 0°$ discovered than in all the years before! Moreover, most of the new ones were detected on the POSS or are recognizable as faint, extended PN in this atlas; it now appears that about half of the low surface brightness PN on the POSS have escaped the original survey (Abell, 1966).

None of these new PN were up to now taken into account in investigations of the local population.

In this article, we present two newly found exceptionally large, nearby PN, one at 3^h45^m, $+49\overset{\circ}{.}9$, the other at 22^h12^m, $+65\overset{\circ}{.}7$, and give some information on the local PN sample, as it can be defined today. Both PN were found as part of a program on nearby PN which consists of (i) the search for new PN on the POSS, (ii) the determination of expansion velocities, and (iii) accurate distance determinations for a selection of the closest PN. (i) and (ii) are in good progress (Weinberger et al., 1983, and references therein; Gieseking et al., 1986; Hippelein and Weinberger, in preparation). The realization of (iii) depends on the allocation of observing time on the Hubble Space Telescope.

2. Observations

Photographic brightnesses in *UBGV* were determined for the stars suspected as nuclei of the two PN. The plates were taken by the

Send offprint requests to: R. Weinberger

⋆ Visiting Astronomer at the Centro Astronomico Hispano-Aleman, Calar Alto, operated by the Max-Planck-Institut für Astronomie, Heidelberg, jointly with the Spanish National Commission for Astronomy, and at the Kiso Observatory, a branch of the Tokyo Astronomical Observatory, University of Tokyo authors in 1984–1985 with the 105 cm Schmidt telescope at the Kiso Station of the Tokyo Astronomical Observatory and were supplemented by plates of the Kiso archive. The following emulsion-filter (Kodak-Schott) combinations were used: IIa-O + UG1 (U,1 plate); IIa–O + GG 385 (B, 5 plates); IIIa-J + GG455 (G,2 plates); IIa-D + GG495 (V, 4 plates). For the U plate (hypersensitized), the exposure time amounted to 90 min, for the residual plates (hypersensitized in part) 30 to 75 min.

Of the standard sequence in NGC 1444 (Hoag et al., 1961) all stars with $V \geqq 13^m.77$ were employed for the calibration of the PNCS at 3^h45^m. For the PNCS at 22^h12^m, stars in NGC 7142 served as standards (van den Bergh and Heeringa, 1970). The $G(\lambda_{\rm eff} \approx 5000$ Å) magnitudes were obtained by interpolation. All measurements were done with the irisphotometer at the Kiso station.

From the calibration curves we found for the former PN values of $s = [(\Sigma(\Delta {\rm mag})^2/n-1]^{1/2}$ of $\pm 0^m.04$, $0^m.09$, $0^m.11$ in B; $0^m.04$ in G; $0^m.12$, $0^m.07$, $0^m.08$ in V. For the latter PN, $s = \pm 0^m.13$ in U; $0^m.11$, $0^m.11$ in B; $0^m.08$ in G; $0^m.10$ in V.

The colour equations following from the standards and averaged over all plates of a respective colour (small letters denote the instrumental magnitudes) are:

$$U = u$$
$$B = b + 0.09\,(B-V) - 0.10$$
$$G = g + 0.12\,(B-G) - 0.08$$
$$V = v + 0.14\,(B-V) - 0.16.$$

Unfortunately, due to their extreme colour or faintness, the brightness errors of both central stars are considerable, as will be shown below.

With a scanning Pabry-Pérot spectrometer (Hippelein and Münch, 1981) attached to the 1.23 m telescope on Calar Alto, in October 1984 the central (ϕ 2′) parts of both PN were observed in the lines of Hα and [O III] λ5007 Å and, in addition, the nebula at 22^h12^m in [N II] λ6584 Å. The spectral resolution was chosen to be 10 km s^{-1}; an RCA C31034A photomultiplier served as detector. NGC 7027 was used as the main standard.

A few preliminary results are already included in Gieseking et al. (1986), who performed expansion velocity measurements of PN of large linear diameters. For the sake of brevity, we will not go into details of the measurements and data reductions, but instead refer to the explanations given in Gieseking et al. (1986).

3. The planetary nebula at R.A. = 3^h45^m

3.1. The photographical appearance

On direct photographs in at least two colours, PN of low surface brightness can be identified with remarkable certainty due to the more or less regular (symmetric) appearance of the nebula *and* the presence of a faint ($\gtrsim 14^m$) very blue central star (provided the interstellar extinction is small or zero).

By use of film copies of Kiso archive plates we could locate a faint, extremely blue star at $\alpha = 3^h45^m$, $\delta = +49°51'$ (later we found out that this star was already contained in a list of bluish stars – see below). Faint, extremely blue stars can at best be very hot subdwarfs (white dwarfs), which are interesting due to their rareness, or are PNCS; main sequence O stars would ordinarily be too distant or reddened. An inspection of the red-sensitive POSS print containing the region of interest indeed revealed a nebula at the very limit of visibility (note: according to Abell 1966, the limiting red surface brightness is 25.0 mag/arcsec^2). The "nebula" is such faint that one would almost certainly overlook this object even in a search dedicated to nebulae of low surface brightness; it appears to be the faintest PN ever discovered originally on the POSS.

High contrast photographs in the field 150°.5, −5° in Hα and [O III] λ5007 Å containing the region of interest were kindly sent to us by Dr. R. Parker on our request; they stem from the "Emission Line Survey" of Parker et al. (1979). In Hα a very faint round or slightly elliptical nebula, best visible in the NE (as on the POSS) appears to be present. The reality of the nebula eventually is demonstrated in the [O III] reproduction: there is a very faint diffuse nebula of smaller size than in Hα that is centrally located, thus obviously reflecting the ionization stratification characteristic for planetary nebulae.

From the Hα reproduction and the POSS print we deduce a diameter for the nebular image of 13′ ± 2′.

3.2. Data on the nebula

From Fabry-Pérot spectrometer observations in Hα and [O III] 5007 Å of the central region (ϕ 2′) of the nebula, radial and expansion velocities, fluxes, and subsequently distances etc. were derived. The line profiles in both lines show no splitting at our resolution and were considered to be the instrumental profiles broadened thermally and by the macroscopic Doppler effect due to expansion.

The nebula is nearly at rest with respect to the sun: we find $V_{\rm hel} = -1$ and -2 km s^{-1} for [O III] and Hα, respectively, with an uncertainty of ~5 km s^{-1}.

The expansion velocities amount to $V_{\rm exp} = 5$ km s^{-1} in [O III] and 12 km s^{-1} in Hα. These values are remarkably low and might reflect a deceleration by the interstellar medium. According to Sabbadin (1984), there is another explanation possible: on the average, B nebulae of large linear dimensions show smaller $V_{\rm exp}$ than C nebulae; indeed, from a morphological point of view and the line ratio described below our nebula might well represent a B type.

As anticipated from the photographs, the fluxes measured by us with the 2′ diaphragm were exeedingly low. For Hα we found 2.9 10^{-13} erg cm^{-2} s^{-1}, and 4.3 10^{-13} erg cm^{-2} s^{-1} for [O III]. The corresponding surface brightnesses are 25.6 and 25.2 mag/arcsec^2, respectively. PN are visible due to their Hα and [N II] λλ6548 + 6584 Å emission as far as we consider their visibility on the red-sensitive POSS exposures, which contain objects up to an average of 25.0 mag/arcsec^2 (Abell, 1966). Since our object is at the very brightness limit, we could roughly estimate its [N II] surface brightness and found [N II] ≈ Hα (probably [N II] is fainter by a few tenths). Moreover, for 5 of the 15 PN of large diameter discussed by Gieseking et al. (1986), both Hα and [N II] λ6584 Å brightnesses were measured, with [N II] fainter by 0.4 mag/arcsec^2 on the average, thus confirming the above estimate. In short, this nebula appears to be of type B.

With the realistic assumption that the nebula is optically thin and assuming an ionized mass, a distance can now be calculated by use of the Hα flux. A dereddened Hα flux, however, is necessary to get a distance corrected for extinction.

For the determination of interstellar extinction, we apply the extinction-distance method, but in reversed order. The basis is as follows: As can be seen from an examination of Kiso plates and POSS prints, there is a rather homogeneous distribution of stars in the angular vicinity (< 2°) of the PN. The PN, on the other hand,

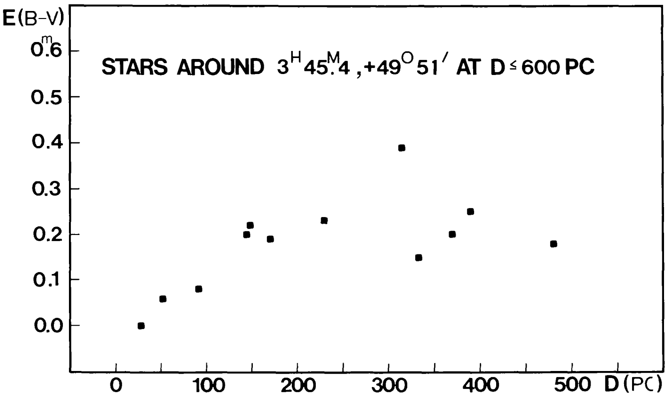

Fig. 1. Stars with data on spectral type, luminosity class and reliable colours taken from the literature were used for the construction of a distance versus reddening diagram within 1°5 of the planetary

cannot be farther away than several 100 pc and not nearer than 200 pc, unless it is an intrinsically very peculiar object: this distance range follows from a comparison with other faint, large-sized PN whose distances were determined (see, e.g., Kaler, 1983). – In the literature, we have searched for stars with data on spectral type, luminosity class, and reliable colours in the angular vicinity of the nebula: at distances $\leqq 600$ pc, there are 12 within 1°5. As can be seen from Fig. 1, an $E(B-V)=0^{m}2$ extends from 150 pc onwards and we take this value as foreground extinction for our nebula.

For our distance determination with the constant mass method, we adopt $T_e = 10^4$ K, $y = n(\mathrm{He})/n(\mathrm{H}) = 0.10$ and further assume that the free electrons are contributed by hydrogen and singly ionized helium, i.e., $n_e = 1.10\, n_1$. Transformations to convenient units eventually lead to

$$D = 160.83\, \frac{M^{2/5}}{F_c(\mathrm{H}\alpha)^{1/5}\,(r'')^{3/5}}, \tag{1}$$

where M = mass of emitting gas in units of $M_\odot$, $F_c(\mathrm{H}\alpha)$ = total observed flux in erg cm^{-2} s^{-1} corrected for extinction, r'' = radius of the nebula in arcsec, and D = distance in pc.

We chose $M = 0.2\, M_\odot$ as ionized mass, but are well aware that there is a marked spread in PN masses; fortunately, the derived distance is rather insensitive to the assumed mass.

Due to the homogeneity of the nebula's surface brightness, the determination of the total Hα flux was straightforward, amounting to $\log F(\mathrm{H}\alpha) = -10.91$; with $E(B-V)=0^{m}2$, the corrected flux is $\log F_c(\mathrm{H}\alpha) = -10.71$. By application of the above equation, a distance of 330 pc was found.

From Kaler (1983) and various other sources, we conclude that PN are visible on the POSS up to a mean linear diameter of 1.45 pc. With such a size, our PN would be at a distance of 380 pc. It therefore appears that the accuracy of the distance probably is better than the often cited factor 2.

At $D = 330$ pc, the height below the galactic plane is $z = 20$ pc and the linear radius is $r = 0.62$ pc. The kinematical age can now be evaluated by use of our Fabry-Pérot observations: assuming a constant expansion velocity for Hα (note that r is based on the object's size in Hα), an age of 50,000 years results, a remarkably high value. Clearly, both the linear radius and the kinematical age are an evidence for a very late evolutionary state of the nebula.

An estimate of n_e supports this outcome: the average electron density can be computed from the Hα emissivity, the received corrected flux, and the radius and distance of the nebula. According to Pengelly (1964; his tables IV and V), for an optically thin nebula at $T_e = 10^4$ K the energy emitted in Hα per unit volume and unit time is $E(\mathrm{H}\alpha) = 2.37 \times 10^{-25}\, n_i n_e$ erg cm^{-3} s^{-1}; by assumption of $n_e = 1.10\, n_i$ and $y = 0.10$ we derive $n_e = 6$ cm^{-3}. A similar, rough estimate is possible by means of the nebula's emission measure as judged from its brightness on photographs: since the POSS E prints are reported to have a detection limit of about 50 cm^{-6} pc, we consider as a somewhat realistic estimate about 30 cm^{-6} pc for the nebula in Hα. Taking the object as a full sphere (filling factor $\varepsilon = 1$), we get a path length of 1.06 pc halfway ($r/2$) between centre and rim and derive $n_e = 5$ cm^{-3}. Such low values are consistent with the one for, e.g., A35 ($n_e = 11$ cm^{-3}), which is a nebula similar in size, distance, and surface brightness (Jacoby, 1981).

No radio emission is reported from the direction of the nebula. However, an estimate of the radio flux that can be expected would be useful. For this purpose we refer to Milne and Aller (1975), who give the following expression for the distance to a PN:

$$D = \left(\frac{3.23\ 10^{19}\, M^2 \ln(9900\, t^{3/2})}{t^{1/2}\, \varepsilon\, (r'')^3\, S}\, \psi\right)^{1/5}, \tag{2}$$

where M, D, and r'' are expressed in $M_\odot$, pc and arcsec, S is the 5 GHz flux density in Jy, and $t = T_e/10^4$ K. The term ψ in our case is $[(1+y)/(1+4y)]^2$, since we neglected the contribution from doubly ionized helium. Whereas Milne and Aller (1975) used equation (2) for the determination of distances on the basis of *observed* fluxes, we want to *predict* the radio flux. With $y = 0.10$, $\varepsilon = 1$, $t = 1$, and $M = 0.2\, M_\odot$, eq. (2) reduces to

$$S(5\,\mathrm{GHz}) = 7.34\ 10^{18}\, (r'')^{-3}\, D^{-5}. \tag{3}$$

For our nebula, we find $S = 0.03$ Jy; its radio brightness therefore probably is exeedingly small, consistent with its absence from radio catalogues.

In Table 1, we have summarized the data on the nebula.

3.3. The central star

As described above, the star was detected by us in a comparison of Kiso Schmidt plates as an extremely blue object. By use of 25 AGK 3 stars, its 1950 position was evaluated as $\alpha = 3^h45^m25^s69$ ($\pm 0''33$), $\delta = +49°51'06''7$ ($\pm 0''35$); as far as can be judged from the nebula's position on the POSS, the star is located at the centre. After completion of measurements on the Kiso plates and POSS prints we recognized that this star was already contained (as no. 73) in a finding list of blue stars (Rubin et al., 1974). They gave approximate coordinates, finding charts, designated it as "very blue" and estimated $V \approx 18^m$. In a photoelectric investigation of many stars of Rubin et al., Chromey (1978) reported $V = 16^m57$, $B-V = 0^m18$, $U-B = -1^m04$, and $E(B-V) = 0^m14$, $D = 177$ kpc (assuming LC V and noting "reliable observations on one night only"); obviously, due to a typing error, the negative sign was omitted in $B-V$. In addition, the star was included in a proper motion program by Cudworth (1977), who computed $\lesssim 0''04$/yr. None of the above authors suspected the star as a nucleus of a planetary nebula.

We determined the brightness of the central star on 3B, 1G, and 3V Kiso plates and additionally estimated its brightness on 2E and 2O prints of the POSS (since it is contained in overlap regions) and 1 red and 1 infrared print of the Palomar Infrared Milky Way Atlas (Hoessel et al., 1979). Unfortunately, in the colour equations no blue stars could be taken into account and the

Table 1. The planetary nebula at $\alpha = 3^h45^m$, $\delta = +49°.9$

The nebula	
Diameter:	$d = 13'$
Total flux:	$\log F(H_\alpha) = -10.91\,\mathrm{erg\,cm^{-2}\,s^{-1}}$
5007 Å flux at central 2′:	$\log F([O\,\mathrm{III}]) = -12.37\,\mathrm{erg\,cm^{-2}\,s^{-1}}$
Expansion velocity:	$V_{exp}(H_\alpha) = 12\,\mathrm{km\,s^{-1}}$
:	$V_{exp}([O\,\mathrm{III}]) = 5\,\mathrm{km\,s^{-1}}$
Radial velocity:	$V_{hel}(H_\alpha) = -2\,\mathrm{km\,s^{-1}}$
:	$V_{hel}([O\,\mathrm{III}]) = -1\,\mathrm{km\,s^{-1}}$
Interstellar extinction:	$E(B-V) = 0^m.2$
Distance:	$D = 330\,\mathrm{pc}$
Linear diameter:	$2r = 1.25\,\mathrm{pc}$
Dist. from gal. plane:	$z = 19.6\,\mathrm{pc}$
Electron density:	$n_e = 6\,\mathrm{cm^{-3}}$
Kinematical age:	$t_{kin} = 50\,000\,\mathrm{yr}$
The central star	
Position 1950:	$\alpha = 03^h45^m25^s.69$ $\pm 0''.4$
:	$\delta = +49°51'06''.7$
U(Chromey 1978):	$15^m.71$
B_{POSS}(4100 Å):	$16^m.8 \pm 0^m.7$
B:	$16^m.45 \pm 0^m.10$
G(5000 Å):	$16^m.39 \pm 0^m.25$
V:	$16^m.56 \pm 0^m.10$
R_{POSS}(6450 Å):	$17^m.4 \pm 0^m.5$
I_{PIA}(8200 Å):	$18^m.5 \pm 0^m.8$
Abs. magnitude:	$M_V = +8^m.4$

assumption of linearity might not strictly be valid, thus increasing the brightness error. The total errors given subsequently are estimates. We found from the Kiso plates; $B = 16^m.51 \pm 0^m.20$, $G = 16^m.39 \pm 0^m.25$, $V = 16^m.55 \pm 0^m.20$. A comparison with Chromey's (1978) values shows that V practically agrees, but B differs by $0^m.12$. We assign the same weight to our mean values and those of Chromey and summarize their averages in Table 1, including Chromey's U brightness. From the mean of both $E(B-V)$ data and $(B-V)_0 = -0^m.33$ for a central star of a PN, $E(B-V) = 0^m.22$ results, in agreement with the interstellar extinction inferred from Fig. 1.

We note that the intercomparison of the 3 V plates and another 2V plates from the Kiso archive, the 2 O and 2 E POSS prints, and 2 blue plates (taken at the beginning of the century) from the archive of the Landessternwarte Heidelberg/Königstuhl shows no variability of the central star.

At a distance of 330 pc and with $A_v = 0^m.6$, $M_v = +8.4$. This value is of interest if inserted in Figs. 2a and 7 of Schönberner (1981): only 5 objects are fainter and its position fits well to the general trend in M_v vs. linear nebular radius. One can further infer a high mass of about 1 $M_\odot$.

In summary, the nebula and its central star obviously are highly evolved, the nearly dissolved nebula representing an object near the borders of invisibility even for sophisticated instrumentation.

4. The planetary nebula at R.A. = 22^h12^m

With the exception of the unusual central star, the discussion on this object is kept more concise compared to the previous PN, since both share similar properties.

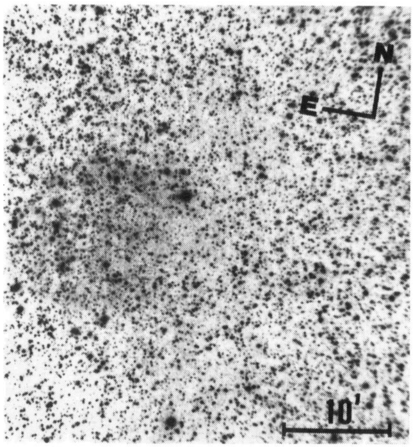

Fig. 2. The planetary nebula at $\alpha = 22^h12^m$, $\delta = +65°.7$. The figure is a high-contrast reproduction from the POSS print E1165, where the nebula lies at the left border of the field. Copyright by the National Geographic Society – Palomar Observatory Sky Survey

4.1. Data on the nebula

During a photometric investigation of a number of stars around or near to the PN NGC 7139 on Kiso and Tautenburg Schmidt plates (Weinberger and Ziener, 1986), a hitherto unregistered large roundish nebula of extremely low surface brightness, best visible on POSS print E 1165, attracted our attention. The nebula is also contained on the POSS field 553, where it is much more favourably located with respect to the edge, but is almost imperceptible. Nothing can be seen on the blue-sensitive POSS prints. The region of interest is unfortunately not included in the "Emission Line Survey" of Parker et al. (1979).

In Fig. 2, the nebula is shown in a high-contrast reproduction from E1165. Consequently, its visibility is artificially enhanced as compared to the POSS, as are brightness irregularities and – especially in the eastern part – the decreasing sensitivity near to the edge of the field appears exaggerated.

The rectangular coordinates of the nebula on POSS E1165 are $x \approx 7$ mm, $y \approx 142$ mm from the lower left corner of the field. Taken as a whole, the object is of rather homogeneous surface brightness and has angular dimensions of $16'.0 (\pm 2') \times 14'.0 (\pm 1')$, with its long axis in the NW-SE direction. This nebula, whose nature as PN will be proven subsequently, belongs to the largest planetaries found to date.

Fabry-Pérot observations of the central region (ϕ 2′) were carried out in [O III] λ5007 Å, Hα, and [N II] λ6584 Å. As with the PN at 3^h45^m, there is no splitting in any of these lines evident. The radial velocities V_{hel} are low and amount to −8, −10, and $-5\,\mathrm{km\,s^{-1}}$ in [O III], Hα, and [N II], respectively. The expansion velocities V_{exp} are 8, 16, and 12 km s^{-1} for the three lines, thus demonstrating that the nebula expands at a distinctly slower rate than an "average" PN.

Within the diaphragm of ϕ 2′ the observed fluxes are low, but higher than those of the previous PN in Hα and [N II], as anticipated from the brightness of the red-sensitive POSS prints. For Hα we evaluated $4.8\ 10^{-13}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$, and $5.1\ 10^{-13}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$ for [N II] λ6584 Å. Also in the case of this nebula the [N II]/Hα ratio is an argument for a B type PN. Noteworthy is the flux in [O III] λ5007 Å ($1.1\ 10^{-13}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$), which is a factor of 4 lower than that of the PN discussed above.

For the determination of the distance to the nebula, we follow the same procedure as described above. Unfortunately, the estimation of the interstellar extinction in front of the object is less certain than for the other PN: first, an inspection of the Kiso *U* plate shows that several dust clouds are scattered across the region around the nebula (which are, very probably, located farther away); second, for the extinction-distance method there are only 4 stars (within 1°.7 around the PN) with reliable data – two are nearer than 500 pc, one at $D=130$ pc with $E(B-V)=0^{m}.22$, the other at $D=460$ pc with $E(B-V)=0^{m}.20$. We thus chose $E(B-V)=0^{m}.2$ as the foreground extinction, since the PN can be expected to lie in that distance range on the basis of the same arguments as outlined for the former PN.

By application of Eq. (1), a distance of 260 pc was found for the planetary. This value corresponds to a mean harmonic linear diameter of 1.13 pc. With a maximum observable diameter on the POSS of 1.45 pc, the PN would be at a distance of 330 pc distant. Again, we therefore conclude that our distance is probably better than a factor 2, except the object is of quite uncommon size. Unfortunately, due to the extreme faintness of the central star (see below), even the use of the Hubble Space Telescope might not lead to a reliable distance.

To estimate the electron density we proceeded as above and used $r''=449''$ and a total corrected flux $F_c(\mathrm{H}\alpha)=4.26\ 10^{-11}$ erg cm^{-2} s^{-1}. The result was $n_e=8$ cm^{-3}. Since the total surface brightness of the nebula in Hα corresponds to 25.1 mag/arcsec^2, that is practically equal to the average limiting POSS surface brightness of 25.0 as determined by Abell (1966), we can estimate n_e using the limiting Hα emission measure on the POSS of 50 cm^{-6} pc. Provided the object is a full sphere ($r=0.57$ pc), we get a path length of 0.98 pc halfway ($r/2$) between centre and rim and derive $n_e=7$ cm^{-3}. The electron density thus perhaps is slightly higher than for the other PN, as expected from the higher surface brightness and the smaller linear radius.

The kinematical age based on an assumed constant expansion velocity in Hα and [N II] amount to the large value of about 40,000 yr (35,000 and 46,000 yr, respectively) and demonstrate the advanced evolutionary state of the nebula.

No radio source is reported for the direction of the nebula, which is easily comprehensible, since Eq. (3) would lead to a 5 GHz flux of only 0.07 Jy.

In Table 2, the data on the nebula are summarized.

4.2. *The central star*

Within the boundaries of the nebula, there is only one obvious candidate for the central star. The star is located slightly off-centre, 1′–2′ towards NE; it is very faint and of very blue colour as can be seen from a comparison of reproductions from Kiso plates in 4 colours (Fig. 3). Its position as derived with the help of 5 SAO stars is $\alpha=22^{h}11^{m}55^{s}.66$, $\delta=+65°39'01''.2$; $\pm 0''.5$ (1950). Nothing can be found in the literature on this object.

We determined the brightness of the central star on 1 U, 2 B, 1 G, and 1 V Kiso plates and additionally estimated its brightness on 2 E and 2 O prints of the POSS (because it is contained in overlap regions) and on 1 red and 1 infrared print of the Palomar Infrared Milky Way Atlas (Hoessel et al., 1979). Mainly due to the faintness and colour of the star, which required large extra-polations of the standard sequence in *G* and *V* ($0^{m}.7$ in *V*, for example), the resulting uncertainties could only be estimated. We found the following values: $U=17^{m}.02\pm 0^{m}.15$, $B=18^{m}.06\pm 0^{m}.20$, $G=17^{m}.60\pm 0^{m}.50$, $V=17^{m}.71\pm 0^{m}.40$. From the POSS or the Palomar Infrared Atlas we estimated $B_{\mathrm{POSS}}=18^{m}.3\pm 0^{m}.6$, $R_{\mathrm{POSS}}=19^{m}.2\pm 0^{m}.8$ (including R_{PIA}), and $I_{\mathrm{PIA}}=19^{m}.5\pm 0^{m}.5$.

Irrespective of the uncertainties in brightness, the central star appears to be quite an unusual object. At a distance of 260 pc and behind an obscuration of $E(B-V)=0^{m}.2$ as estimated above, the absolute magnitude is $M_v=+10^{m}.04\pm 0^{m}.4$. To our knowledge,

Table 2. The planetary nebula at $\alpha=22^{h}12^{m}$, $\delta=+65°.7$

The nebula	
Diameter:	$d=16'\times 14'$
Total flux:	$\log F(\mathrm{H}_\alpha)=-10.57$ erg cm^{-2} s^{-1}
5007 Å flux at central 2′:	$\log F([\mathrm{O\,III}])=-12.96$ erg cm^{-2} s^{-1}
6584 Å flux at central 2′:	$\log F([\mathrm{N\,II}])=-12.29$ erg cm^{-2} s^{-1}
Expansion velocity:	$V_{\mathrm{exp}}(\mathrm{H}_\alpha)=16$ km s^{-1}
:	$V_{\mathrm{exp}}([\mathrm{O\,III}])=8$ km s^{-1}
:	$V_{\mathrm{exp}}([\mathrm{N\,II}])=12$ km s^{-1}
Radial velocity:	$V_{\mathrm{hel}}(\mathrm{H}_\alpha)=-10$ km s^{-1}
:	$V_{\mathrm{hel}}([\mathrm{O\,III}])=-8$ km s^{-1}
:	$V_{\mathrm{hel}}([\mathrm{N\,II}])=-5$ km s^{-1}
Interstellar extinction:	$E(B-V)=0^{m}.2$
Distance:	$D=260$ pc
Linear diameter:	$2r=1.13$ pc
Dist. from gal. plane:	$z=35.7$ pc
Electron density:	$n_e=8$ cm^{-3}
Kinematical age:	$t_{\mathrm{kin}}=40000$ yr
The central star	
Position 1950:	$\alpha=22^{h}11^{m}55^{s}.66$ $\pm 0''.5$
:	$\delta=+65°39'01''.2$
U:	$17^{m}.02\pm 0^{m}.15$
B_{POSS} (4100 Å):	$18^{m}.3\pm 0^{m}.5$
B:	$18^{m}.06\pm 0^{m}.20$
G (5000 Å):	$17^{m}.60\pm 0^{m}.50$
V:	$17^{m}.71\pm 0^{m}.40$
R_{POSS} (6450 Å):	$19^{m}.2\pm 0^{m}.8$
I_{PIA} (8200 Å):	$19^{m}.5\pm 0^{m}.5$
Abs. magnitude:	$M_V=+10^{m}.0$
Linear radius:	$R_{\mathrm{max}}=0.008\ R_\odot$

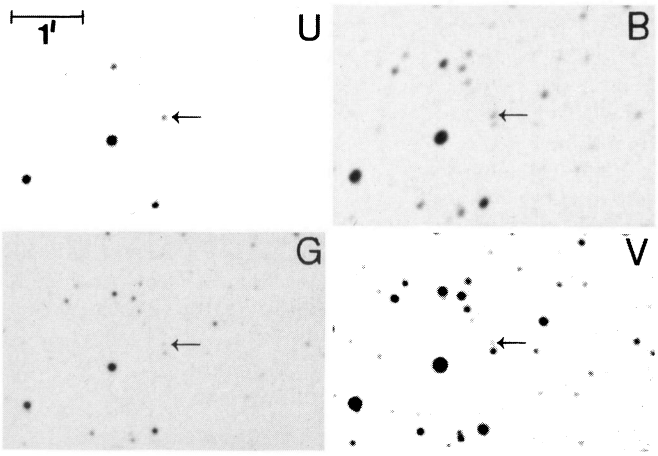

Fig. 3. The central star of the planetary nebula at $\alpha=22^{h}12^{m}$, $\delta=+65°.7$, reproduced from Kiso Schmidt plates in four colours

there is no fainter central star known (a promising competitor, however, is the nucleus of S176, see Weinberger et al., 1983).

As a result of their examinations of UV spectra of 32 nuclei of large planetary nebulae, Kaler and Feibelman (1985) evaluated Zanstra temperatures of ≧70,000 K in all cases. Consequently, we assume that the nucleus under discussion has such a minimum effective temperature $T_{\rm eff}$. Since the bolometric correction amounts to an interpolated value of -5.70 (Schmidt-Kaler, 1982), and $M_{\rm bol,\odot}=4.69$, we derive $L_{\rm min}=1.38\,L_\odot$. Eventually, a computation of the maximum radius (valid for a bb radiator, where $T_{\rm eff,\odot}=5784$ K has been assumed) via

$$\log(R/R_\odot)=(42.31-10\log T_{\rm eff}-M_{\rm bol})/5 \tag{4}$$

leads to $R_{\rm max}=0.008\,R_\odot$. At the minimum temperature as assumed above, our central star therefore clearly has the dimensions of a white dwarf. The same maximum value was, by the way, evaluated for the giant PN described by Weinberger et al. (1983).

If the central star would be as hot as 70,000 K, then its position in the $\log L-\log T$ diagram even for large (= old) PN (Fig. 6 in Kaler, 1983), would be far below (in $\log L$) other objects. If we assume a rather unreasonably high temperature of, say, 180,000 K ($\log L/L_\odot=1.10$), the star would still be located at the low luminosity end in Kaler's Fig. 6. We are therefore confident that the central star of this planetary is an extreme object even among the most evolved planetary nuclei and clearly deserves further detailed study. – For a summary of the various quantities derived for the central star see Table 2.

5. The local population of planetary nebulae

The local population of PN (LPPN) is a quantity of considerable interest and was subject to a number of investigations (e.g., Cahn and Wyatt, 1976; Daub, 1982; Amnuel et al., 1984). Motivated by the discovery of the two nearby PN discussed above and by the fact that PN found since the publication of the PK-catalogue (Perek and Kohoutek, 1967) were not included in these studies we decided to analyse the subject anew, confining the discussion to PN within 500 pc.

In comparison with tackling the problem, say, one decade ago, there are three major differences: (i) PN of large linear size are optically thin (see, e.g., Schönberner, 1981), in contrast to earlier belief (ii) a wealth of distance scales have been determined (this does, however, not mean that distances have become much more reliable), and (iii) a number of new nearby PN have been discovered.

5.1. The distance problem

Although the number of reliable individual distance data steadily increases, the distance problem is still unsolved: Phillips and Pottasch (1984), e.g., evaluated a distance scale that is shorter by about a factor two than determined by the widely used Shklovsky method. For the determination of the LPPN we had chiefly to rely on published distances, but see no reason to prefer any of the distance scales. We decided to use five recent distance sets, assign equal weights to them, and derive the distance of a PN by computing the mean value. This procedure has the advantage that PN with very diverging values can be easily picked out and critically examined. By the way, only few objects turned out to be common to all five lists.

The distance sets employed are those of Maciel (1984) (663 objects), Amnuel et al. (1984) (335), Daub (1982) (299), Kaler (1983) (82), and Sabbadin (1986) (81). In the case of spectroscopic distances, these (and not the statistical ones) were taken.

Those nearby PN that are not contained in at least one of the five sets or where only a distance limit is given can be divided into two groups: One group includes objects already listed in the PK-catalogue. Examples are A 74, A 29, and Cn 1-1; in the case of the two Abell nebulae, the mean of the distances derived by Abell (1966) and Cahn and Kaler (1971) was chosen, and from the paper of Lutz (1984) the distance for Cn1-1 was taken. – The second group comprises most of the PN found since the editing of the PK-catalogue; the distances are more heterogenous and were usually, but not always, derived with the Shklovsky method. In several cases, no distances were given in the discovery papers and had to be estimated by us or Weinberger et al. (1983) according to Abell's (1966) suggestions. Sometimes, we felt that distances estimated with the latter method are preferable to those published: For the huge S216, e.g., with the Shklovsky method and the Hα flux measured by Reynolds (1985) we evaluated $D=0.04$ kpc instead of using Reynolds' limit of $D\lesssim0.08$ kpc. In a further few cases, there were reasons to prefer a certain distance estimate to others in other papers – S 188 (with $D=0.22$ kpc according to Salter et al., 1984) is an example.

Two objects (A69 and NGC6302) were omitted due to enormous distance divergences, although they would be closer than 500 pc according to one or more of the above five sets: A 69 is reported to be at $D=0.3$ kpc by Maciel (1984), but Abell (1966) gives 4.5 kpc for this rather small and faint PN. NGC6302 would be at $D\leqq0.4$ kpc (Maciel, 1984), 0.4 kpc (Daub, 1982), and 0.28 kpc (Amnuel et al., 1984), but in a recent thorough investigation Rodriguez et al. (1985) favoured $D=2$ kpc.

We tried to be careful not to include doubtful candidates into our compilation of nearby PN: the 20′ × 11′ large nebula of Ellis et al. (1984) is of this type. The lists of misclassified PN were also taken into consideration (Kohoutek, 1978; Lutz and Kaler, 1983; Kohoutek, 1983; Kohoutek and Pauls, 1985; West and Kohoutek, 1985). It should be noted that several of Cahn and Wyatt's (1976) "local optically thin PN" (then defined as having lateral distances $q\leqq1.1$ kpc and $0.08\,{\rm pc}\leqq r\leqq0.40$ pc) meanwhile turned out to be misclassified.

A "local" sample of PN is the more characteristic of the real distribution in number, size, luminosity etc. of galactic planetaries, the closer its members are to the sun – provided the number is sufficiently large for meaningful statistics; in this connection one should bear in mind that observational selection due to interstellar extinction can be significant even within a few hundred pc.

The increase in number of nearby PN and the knowledge nowadays as to optical thinness allows us to define a limit of $D=500$ pc for the LPPN. In Table 3, the 31 systems lying within this range are compiled together with another five that have $D>500$ pc, but whose lateral distances (projected on the galactic plane) are $q\leqq500$ pc.

Column (1) gives the designations, which must be considered as preliminary for the objects not included in the PK-catalogue. Columns (2) and (3) give 1950 equatorial coordinates (note: a list of all PN published since 1977 including references to the respective discovery papers can be sent on request; the list is a direct continuation of Weinberger, 1977). Columns (4) and (5) give galactic coordinates; column (6) gives the distances (spectroscopic ones are written in bold), (7) the lateral distances, (8) the distances z from the galactic plane. In columns (9) and (10) the

Table 3. Planetary nebulae with distances $\leqq 0.50$ kpc

Name	R.A. Decl. (1950)	l b	D (kpc)	q (kpc)	z (kpc)	$d/2$	r (pc)
S176	$00^{h}29^{m}.1+57^{\circ}06'$	$120^{\circ}.29-05^{\circ}.39$	0.27	0.27	− 0.03	359″	0.47
NGC246	00 44.5−12 09	118.87−74.71	**0.47**	0.12	− 0.45	125	0.28
S188	01 27.4+58 07	128.07−04.11	0.22	0.22	− 0.02	270	0.29
HFG1	02 59.4+64 44	136.36+05.56	0.37	0.37	+ 0.04	450	0.81
HW4	03 23.8+45 14	149.50−09.28	0.41	0.40	− 0.07	240	0.48
NGC1360	03 31.1−26 02	220.36−53.93	0.30	0.18	− 0.24	198	0.29
IW1	03 45.4+49 51	149.71−03.40	0.33	0.33	− 0.02	390	0.62
NGC1514	04 06.1+30 39	165.53−15.29	**0.40**	0.39	− 0.11	64	0.12
S216	04 37.3+46 35	158.23+00.15	0.04	0.04	+ 0.00	3000	0.58
A7	05 00.9−15 40	215.56−30.84	0.22	0.19	− 0.11	382	0.41
I418	05 25.2−12 44	215.21−24.28	0.48	0.44	− 0.20	6	0.01
WDHS1	05 56.6+10 42	197.41−06.44	0.32	0.32	− 0.04	463	0.72
PW1	06 15.4+55 38	158.92+17.86	0.24	0.23	+ 0.07	600	0.70
K2-2	06 49.8+10 02	204.16+04.76	0.48	0.48	+ 0.04	207	0.48
A21	07 26.2+13 21	205.14+14.24	0.27	0.26	+ 0.07	319	0.42
A29	08 38.1−20 44	244.60+12.57	0.41	0.40	+ 0.09	201	0.40
A31	08 51.5+09 05	219.13+31.29	0.24	0.21	+ 0.12	485	0.56
EGB6	09 50.3+13 59	221.59+46.37	0.35	0.24	+ 0.25	359	0.61
He2-77	12 06.4−62 59	298.18−00.78	0.33	0.33	− 0.00	11	0.02
A35	12 50.9−22 36	303.57+40.00	**0.36**	0.28	+ 0.23	400	0.70
LT5	12 53.1+26 10	339.92+88.46	**0.40**	0.01	+ 0.40	263	0.51
A36	13 38.0−19 38	318.46+41.50	0.38	0.28	+ 0.25	196	0.36
Cn1−1	15 47.7−48 36	330.79+04.14	0.45	0.45	+ 0.03	< 0.5	< 0.001
NGC6369	17 26.3−23 43	002.43+05.85	0.45	0.45	+ 0.05	15	0.03
S68	18 22.4+00 50	030.67+06.28	0.31	0.31	+ 0.03	199	0.30
A62	19 30.9+10 30	047.18−04.30	0.50	0.50	− 0.04	81	0.20
NGC6853	19 57.5+22 35	060.84−03.71	0.27	0.27	− 0.02	208	0.27
A74	21 14.7+24 00	072.71−17.12	0.23	0.22	− 0.07	415	0.46
IW2	22 12.0+65 40	107.74+07.81	0.26	0.26	+ 0.04	449	0.57
DHW5	22 18.4+70 41	111.09+11.64	0.40	0.39	+ 0.08	264	0.51
NGC7293	22 26.9−21 06	036.16−57.12	0.16	0.09	− 0.13	402	0.31
PHL932	00 57.3+15 28	125.94−47.09	0.59	0.40	− 0.43	138	0.40
Lo1	02 55.0−44 23	255.35−59.64	0.80	0.40	− 0.69	187	0.72
NGC2474-5	07 54.0+53 33	164.81+31.18	0.58	0.50	+ 0.30	194	0.54
NGC3587	11 11.9+55 17	148.50+57.06	0.59	0.32	+ 0.50	100	0.29
H4−1	12 57.1+27 54	049.24+88.16	11.87	0.38	+11.86	3	0.17

apparent and linear radii can be found: only the radii of the main nebulae were considered, if halos are present.

We note a distinct bias in the declination column for northern PN (20 entries) as opposed to southern PN (11 entries); 4 of the 5 PN at the end of Table 3 are northern objects, too. In galactic coordinates there is no such effect. Since we have selected only local PN and are therefore not concerned with the strong concentration towards the galactic nucleus, we expect no real north-south asymmetry in equatorial coordinates. The solution of this apparent puzzle is simple: More than half of the 31 systems were originally discovered as PN on the POSS, and 3/4 of these are at $\delta > 0°$. The remaining PN divide about equally between the two hemispheres. We shall correct for this incompleteness below.

5.2. The local space density

Before this important quantity is estimated, some remarks on other parameters are necessary.

From Table 3 it is evident that half of the planetaries lie within $|z| \leqq 0.07$ kpc, leading to a scale height of 100 pc. Very similar scale heights have been derived by most other authors; Cahn and Kaler (1971) found 90 pc, Cahn and Wyatt (1976) 115 pc, Daub (1982) 125 pc, and Amnuel et al. (1984) 130 pc.

Besides the north-sourth asymmetry, the PN listed in Table 3 undoubtedly are only a certain (but unknown) fraction of the actual population within D (or q) $\leqq 0.50$ kpc:

First, according to Smith (1976) and Khromov (1979), a distinct lack of PN even within this distance range seems unavoidable. – Second, for several of the PN with D (or q) > 0.50 kpc, it was not possible to determine the interstellar extinction and only upper limits on the distances were derived; a few of them might therefore be at $D \leqq 0.50$ kpc. – Third, the number distribution as a function of linear nebular radius (in the 9 radius intervals of 0.00–0.09 pc, 0.10–0.19 pc . . . , from Table 3 we find 4, 1, 5, 3, 7, 5, 2, 3, and 1 PN, respectively) might reflect the influence of interstellar obscuration. – Fourth, as is demonstrated

Table 4. Summary of raw data on local planetary nebulae

Parameter	Range of q (kpc)					
	0.0–0.25	0.0–0.30	0.0–0.35	0.0–0.40	0.0–0.45	0.0–0.50
Number of planetaries	11	17	22	30	33	36
Projected density (kpc^{-2})	56	60	57	60	52	46
Number with $\|z\| \leqq 0.05$ kpc	2	5	10	10	12	14
Number with $\|z\| \leqq 0.10$ kpc	4	8	12	16	18	20
Planar number density (kpc^{-3}) for $\|z\| \leqq 0.05$ kpc	102	177	260	199	189	191
Planar number density (kpc^{-3}) for $\|z\| \leqq 0.10$ kpc	102	141	156	159	141	127
Planar number density (kpc^{-3}) (Daub's (1982) equation 14)	280	300	285	300	260	230
Weighted planar number density (kpc^{-3}); preliminary	**173**	**219**	**249**	**231**	**208**	**194**

by our discovery of two nearby PN in this paper, large, nearby PN are still detectable on the POSS. – Last not least, the surface densities (as given in Table 4, row 2) indicate that above $q = 0.40$ kpc there is a distinct decrease which we ascribe to the influence of interstellar dust. – For some computations later on we will, however, assume that the PN with $D \leqq 0.40$ kpc and $\delta > 0°$ are completely known and are contained in Table 3.

Returning to Table 4 we want to point out that there are several methods in use to estimate the space density of the LPPN. Cahn and Wyatt (1976) give two estimates; one is based on the total numbers within 0.05 kpc of the plane, the second on the assumption that the number density is uniform in the galactic plane and its dependence on $|z|$ can be expressed by an exponential law (see Eqs. (13) and (14) in Daub, 1982). The latter method is the most widely used in the PN literature.

We applied both methods and additionally determined the number density for $|z| \leqq 0.10$ kpc, but assigned to it only weight 1 compared to weight 2 for the other two methods. The weighted planar number density ("preliminary", because uncorrected for the asymmetrical distribution in δ) is given in the last row of Table 4. Since we assume completeness within $q \leqq 0.40$ kpc, and the numbers for $|z| \leqq 0.05$ kpc and $|z| \leqq 0.10$ kpc in the range $0.0 \leqq q \leqq 0.25$ kpc are uncomfortably small, we use the residual three weighted number densities for a preliminary mean value of $n_v = 233$ PN kpc^{-3}.

It remains to correct for the southern-hemisphere incompleteness. From Table 3 we find the following total numbers, by doubling the numbers north of $\delta = 0°$: for $D \leqq 0.50$ kpc there should be 40, for $q \leqq 0.50$ kpc 48, for $D \leqq 0.40$ kpc 34, for $q \leqq 0.40$ kpc 42 PN. Therefore, the amplification factor is $48/36 = 1.33$ for $q \leqq 0.50$ kpc and $42/30 = 1.40$ for $q \leqq 0.40$ kpc. Assuming no interactions of these factors with the analysis shown in Table 4 and using the latter factor, we adopt as our best estimate of the projected surface density $58\ 1.40 = 81\ kpc^{-2}$ and as our best estimate of the space density of local PN $n_v = 233\ 1.40 = 326\ kpc^{-3}$. It is difficult to judge the total errors of these data, but from the above discussion it is clear that they must definitely be considered as lower limits, provided the distances are not larger on average.

A comparison with the results of similar investigations is eased by studying Table 1 of Maciel (1981), where a compilation of such data is given: according to this table, the largest projected and space densities are those by Cahn and Wyatt (1976), namely 19 kpc^{-2} and 80 kpc^{-3} (for PN with $0.08\ pc \leqq r \leqq 0.40$ pc). Not included in Maciel's table are, however, two papers which included also PN of the PK catalogue, but with larger linear radii, and where selection effects were thoroughly taken into account (Smith, 1976; Khromov, 1979). Smith estimated a space density of 150 kpc^{-3} and Khromov 170 kpc^{-2} as projected surface density and 430 kpc^{-3} as space density. Especially the estimates of Khromov (1979) therefore are in rough agreement with our data, although the initial values and the procedures are quite different and the application of Khromov's analysis to our objects would lead to an enormous space density. Moreover, a value of 117 kpc^{-3} was obtained by Amnuel et al. (1984).

5.3. The birthrates and total number in the Galaxy

The local birthrate of PN is

$$\chi_{PN} = \frac{n_v V_{exp}}{\Delta r} \quad (5)$$

where V_{exp} is the expansion velocity and Δr the observed linear radius (constant V_{exp} is assumed).

A wealth of new data on expansion velocities has become available in recent years, especially on highly evolved nebulae. For the purpose here, we used the compilations of Robinson et al. (1982), Sabbadin (1984), and the measurements of old nebulae by Gieseking et al. (1986) and Hippelein and Weinberger (in preparation). It turns out that of the 31 PN with $D \leqq 0.50$ kpc in Table 3, there are 22 with [O III] expansion velocities, 11 were measured in Hα, and 12 in [N II]. They have very similar mean V_{exp}, namely 17.2 km s^{-1} in [O III], 20.3 km s^{-1} in Hα, and again 20.3 km s^{-1} in [N II]. We adopt $V_{exp} = 20$ km s^{-1}.

Since the smallest nebula in Table 3 has a linear radius of <0.001 pc and the largest one ~ 0.80 pc, we adopt $\Delta r = 0.80$ pc, and with $n_v = 326\ kpc^{-3}$ we compute a local birthrate of

$$\chi_{PN} = 8.3\ 10^{-3}\ kpc^{-3}\ yr^{-1}.$$

Again, one should remember that this number in all probability is a lower limit due to selection effects (interstellar extinction), provided the distances are not larger on average than those presented in Table 3.

In this connection we want to demonstrate how sensitive χ_{PN} is to the distance scale: if the distance of each of the PN in Table 3 is 1.50 times larger and exactly the same procedures are applied as above, then the scale height is 160 pc, the preliminary space density is 65 kpc^{-3}, the corrected space density 95 kpc^{-3}, and (with $\Delta r = 1.2$ pc) the local birthrate would be 1.6 10^{-3} kpc^{-3} yr^{-1}. On the other hand, considering all the recent distance scales, also smaller distances than ours could be used, if the very short scale by Phillips and Pottasch (1984) is taken into account. We therefore proceed with our above derived χ_{PN}.

A birthrate of 8.3 10^{-3} kpc^{-3} yr^{-1} is astonishingly high considering the birth rate of white dwarfs of 1.4 10^{-3} kpc^{-3} yr^{-1} (Green, 1977) or 2 10^{-3} kpc^{-3} yr^{-1} (Weidemann, 1977). We are reluctant, however, to follow Smith (1976) in suggesting that a large fraction of PN central stars do not end as white dwarfs but as neutron stars and/or black holes or that the white dwarf formation rate has been grossly underestimated, although the latter possibility should perhaps again be examined in the light of the new results here. Besides, there are other effects which could lower χ_{PN}:

First, a larger space density of PN would result, if a second (or third ...) nebula is produced by a star after the first nebula is dispersed or recombined – the helium shell flashes might play a role here.

Second, Gieseking et al. (1986) found that – in contrast to the assumptions by most authors – the expansion velocities of large PN decrease; they suggested a decelerating influence of the interstellar medium. Consequently, these old PN would survive longer and thus "artificially" enhance the number density.

In addition, the outcome of the deceleration is to reduce the discrepancy between the scale heights of PN and white dwarfs: 100 pc has to be compared to 245–270 pc (Green, 1977) or ~300 pc (Ishida et al., 1982) for white dwarfs. Interestingly, Eggen and Bessell (1978) suggested that the hottest white dwarfs are highly concentrated near the galactic plane (~75 pc). Anyway, a deceleration due to the interstellar medium would involve mainly PN near the galactic plane, increasing their number there and lowering the PN scale height. A quantitative evaluation of all these effects is clearly premature at the moment.

For the determination of the total number of PN in the Galaxy, several methods can be found applied in the literature. It should be emphasized, however, that with regard to the considerable uncertainties inherent in both the surface and the space densities (stemming from the unreliable distances) as in the methods themselves, all results have to be viewed with caution. We chose the most widely used method.

The specific number of PN in the Galaxy be $n_s/m = 1.08\ 10^{-6}\ M_\odot^{-1}$, where $m = 75\ M_\odot\ \mathrm{pc}^{-2}$ is the local mass density according to Schmidt (1963) and n_s our projected density of 81 kpc^{-2}; if we take as galactic mass 1.3 $10^{11}\ M_\odot$ (ignoring the possible presence of a massive halo) from Innanen (1966), we obtain a total number of 140,000.

Total numbers of $>10^5$ PN in the Galaxy have previously been suggested by Cahn and Kaler (1971) and Khromov (1979). The ~1,500 galactic planetaries known to date therefore represent only a very small fraction of the PN of our Galaxy.

6. Conclusions

Two planetary nebulae were presented. They were observed in several lines with a Fabry Pérot-interferometer, where expansion velocities, radial velocities and surface brightnesses could be determined. Additional information was derived from POSS prints and – mainly with regard to the central stars – from Kiso Schmidt plates. – Both objects share similar properties: they are highly advanced in their evolution and are near or at the very limit of visibility on the POSS, although being close to the solar system ($D \approx 0.3$ kpc). Their central stars are very faint – one might even represent the nucleus with the lowest luminosity ever found.

Motivated by these discoveries, we investigated the local population of PN by taking into account also all nearby PN detected since the appearance of the Perek-Kohoutek (1967) catalogue. The relatively large number of PN allowed to define the local population as those objects located within 500 pc. By employing distance data from five recent scales for the PK-nebulae and Shklovsky distances for most of the remaining objects, several parameters were derived. We tentatively concluded that up to 400 pc (and without considering selection effects due to interstellar obscuration) northern PN are completely known. We had to correct, however, for a north-south inequality in equatorial coordinates. It finally turned out that the projected surface and space densities (~80 kpc^{-2} and ~330 kpc^{-3}) are much higher than estimates by other authors – with the exception of Smith (1976) and Khromov (1979), who considered solely PK-nebulae, but attempted to estimate the effect of interstellar dust on the number of local PN.

With the help of expansion velocity data that are new and/or more appropriate than previous ones we calculated a birthrate for planetaries of ~8 10^{-3} kpc^{-3} yr^{-1}, i.e., four to five times the generally accepted birthrate of white dwarfs. Distances for all local PN would have to be increased by a factor of 1.5 in order to bring both birthrates into agreement. Although such an increase cannot entirely be excluded, it appears improbable in the light of recent investigations. The observed decrease in expansion velocities for large PN (probably resulting in an "excess" of PN in the galactic plane) and possible multiplicity of the PN phenomenon might offer an explanation for the discrepancy.

The distribution of the linear diameters of the local planetaries within 500 pc plainly shows that, taken as a whole, the ~1,500 known galactic PN are quite unrepresentative; the vast majority of the $>10^5$ planetary nebulae in the Galaxy are objects of very low intrinsic surface brightness, i.e., PN of old age.

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