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NEW PLANETARY NEBULAE OF LOW SURFACE BRIGHTNESS

R. WEINBERGER
Max-Planck-Institut für Astronomie, Heidelberg/Königstuhl,
Federal Republic of Germany
and
Institut für Astronomie der Universität Innsbruck, Austria

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Twelve new planetary nebulae of low surface brightness have been detected during a search for strongly reddened galaxies on the Palomar Observatory Sky Survey (POSS) prints. The maximum diameters range from 16 to 194″, the surface brightnesses in red from 20.0 to 23.3 mag/arcsec^2, in blue from 24.0 to >26.5 mag/arcsec^2, the integrated magnitudes in red from 11.4 to 16.7 mag, in blue from 15.1 to ≥ 20.6 mag and the estimated distances (uncorrected for extinction) from 700 to 8300 pc.
Obviously, a number of planetaries still waits for detection on the POSS.

Key words: new planetary nebulae – low surface brightness – probable further detections

INTRODUCTION

In an extensive work, Abell (1966) examined 86 planetary nebulae (PN) which were found on the POSS in surveys covering the whole region north of $\delta = -33°$. The Abell planetaries have since received much attention, mainly because many of them appear to be at an advanced stage in their evolution and are nearby objects. During the last decade, the detection of 13 new PN on the POSS was reported; seven of them were discovered in the $-36°$ and $-42°$ declination zones.

The new planetaries described in this paper exhibit somewhat different properties from the Abell planetaries: On the average, they are smaller in angular diameter, more distant, and suffer from higher extinction. The differences are probably conditional upon the searching method.

THE SEARCHING PROCEDURE

The 12 new PN were found as a by–product in the course of a survey for galaxies in the galactic plane. The search was performed on POSS E prints. The O prints were examined only for comparison. A binocular microscope was used and a 14-fold magnification chosen. 97 prints were surveyed fully or partly, the average searching time being about three hours per print. The area searched comprises ~ 3400 square degrees and extends from $l \approx 16°$ to $l \approx 230°$ along the galactic equator (figure 1a-c); its boundaries were chosen in order to meet the requirements of the search for heavily reddened galaxies. In particular, regions with obvious or suspected noticeable extinction near the galactic plane were included. Overlapping zones were generally (but not always) inspected on all relevant POSS prints.

RESULTS

Identification charts of the new PN are shown in figure 2, results are summarized in table 1.

The entries in the table are as follows:

The designation is according to the system of the CGPN (Perek and Kohoutek 1967). The equatorial coordinates α and δ were measured with an accuracy of $\pm 10''$ on enlargements of POSS prints by use of five SAO reference stars. In those six cases, where no possible central stars could be detected, the coordinates apply to the centres of the nebular images; fortunately, the latter are rather well-defined and little extended. l and b are the galactic coordinates. x and y are rectangular coordinates (in mm), measured from the lower left corner of the first POSS field given in the subsequent column. "Dimension" means the maximum and

minimum diameters of the nebular images as visible on the E prints. The class is defined according to Greig (1971). Magnitudes of central stars were determined on the POSS prints by use of the magnitude-diameter relation published by Dorschner *et al.* (1966). The errors in both colours are about $\pm 0^m.8$ for central stars of $\gtrsim 17^m$ and about $\pm 0^m.5$ for those of $< 17^m$. The red (m_r^s) and (m_b^s) surface brightnesses were estimated by comparison with surface brightnesses of Abell planetaries and are expected to be reliable to ± 1.0 mag/arcsec^2 at worst. The values listed correspond to the brightest section of each nebula. m_r^i and m_b^i are the integrated nebular magnitudes, computed from the surface brightnesses of the various sections of the respective nebula and their projected areas. Ranges of m_b^i are specified in cases when a section of the PN was undetectable on the O print; the brighter limits are based on the supposition that the invisible sections have surface brightnesses at the limit of detection (26.5 mag/arcsec^2), the fainter ones on the assumption that these sections give off no light at all. The distances were calculated using Abell's (1966) formula

$$\log r = 3.240 + 0.08\, m_r^i - 0.2 \log v \qquad (1)$$

the volume v expressed in arcsec^3; from the measured dimensions of the projected nebular images angular volumes have been calculated, based on three-dimensional models as outlined by Abell. Since m_r^i is not corrected for interstellar extinction, the distance values are upper limits.

The largest known PN have a linear diameter of ~ 1.2 pc. Maximum distances for the 12 PN derived from this linear diameter and the observed apparent diameters turned out to be 1.4–2.6 times larger than the distances quoted in table 1 and are therefore not individually mentioned.

The PN nos. 1, 8, 9 and 11 fulfil the selection criteria of Melnick and Harwit (1975). Their position angles are, respectively, 122°, 44°, 70° and 46°. The corresponding angles between the major axes and the galactic equator are 35°, 12°, 37° and 1°. These numbers are accurate to about $\pm 10°$.

DISCUSSION

First of all, it is illuminating to compare our results with those of Abell (1966) for his 86 PN. The following discussion applies to average values only:

The apparent maximum diameters of our PN are ~ 2.5 times smaller than those of Abell. The reason lies probably in our search method: a) During the whole survey, our attention was focused on small, compact objects, *viz.* the cores of galaxies, and b) the large magnification used causes very extended PN to be seen only in part. It would be difficult to recognize them.

Our brightnesses are (number of objects in parentheses): $m_r^i = 14.4(12)$, $m_r^s = 21.6(12)$, $m_b^i = 18.3(8)$, $m_b^s = 25.7(8)$. The corresponding numbers of Abell are 12.8(85), 21.7(85), 15.6(67), and 24.5(66). Our planetaries are therefore redder than those of Abell and are farther away (uncorrected distance 4000 pc as compared to 2000 pc). Accordingly, a larger extinction can be expected. The true distance ratio will consequently be smaller than 2. Then the apparent diameter ratio of 2.5 implies that our PN are intrinsically smaller and brighter.

Our data are consistent with the assumption that there are no systematic differences between our PN and those of Abell, except that they have an additional extinction of $\Delta A_r = 1.8$ mag ($\Delta A_b = 3.1$ mag), a distance 1.7 times larger (which increases m^i by 1.1 mag but leaves m^s unchanged), and an intrinsic diameter of 1.5 times smaller. The latter implies, by equation (1), an increase in the intrinsic integrated brightness by 1.3 mag, or a corresponding increase in the surface brightness by 2.2 mag/arcsec^2. If we accordingly reduce our measurements to the mean conditions of Abell we find $m_r^i = 12.8$, $m_r^s = 22.0$, $m_b^i = 15.4$, $m_b^s = 24.8$, in good agreement with the numbers of Abell. It therefore seems reasonable to multiply our uncorrected distances by $1.7/2 = 0.85$, if they are to be compared with the uncorrected distances of Abell.

Out of the observable central stars, three can be found on overlapping zones of POSS prints: time differences of their exposure dates are ~ 1 month (for no. 2), ~ 61 months (no. 6), and ~ 9 months (no. 12); no variability of these stars is noticeable. The possible central star of the planetary no. 12 deserves special attention. If it is in fact the central star, it would be one of the brightest representatives of this class of

objects. Although it is so bright, the star could not be found listed in various catalogues; moreover, it has not been reported to be a variable by Rosino *et al.* (1976), who examined a field of 30 square degrees centered on NGC 7635 ($\ell = 112°$, $b = 0°$). In any case, the star must be appreciably reddened to be a true central star.

Melnick and Harwit (1975) found a tendency for an alignment of the major axes of PN parallel to the galactic equator. It is interesting to note that the four planetaries of our sample that correspond to the selection criteria of these authors show the same tendency, the average angle between axis and equator being 21°.

In our opinion, a considerable number of PN has still not been discovered on the POSS. This conclusion is based on the following facts:

1) Besides the twelve objects in this paper which obviously appear to be PN, we found six other new possible planetaries in the area investigated (these will be included in a finding list–in preparation by the author–of presumably all possible, probable and true planetaries discovered since the finishing of the CGPN). We estimate about half of these additional objects to be true PN.

2) As indicated in the beginning of this section, our search does not seem to be complete. Furthermore, six out of our twelve objects have been traced on overlapping zones which on the average comprise only one third of the area of a certain POSS field. Finally, whilst searching the first ~ 500 square degrees, we paid attention exclusively to galaxy-like objects, and correspondingly did not find a planetary there.

3) The present Palomar Sky Survey covers a galactic longitude range of $\sim 286°$. Our search area covered only three quarters of it. Moreover, its average latitude range is $-8°$ to $+8°$. Only half of the Abell planetaries are located within the same galactic latitude range.

Therefore, it may be expected that many more planetaries could be found on the POSS. Several will probably turn out to be nearby objects and may, consequently, have implications on the calculation of the local space density of planetary nebulae, which is a quantity of interest in the study of stellar evolution (see *e.g.* Smith 1976, Cahn and Wyatt 1976).

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R. Weinberger

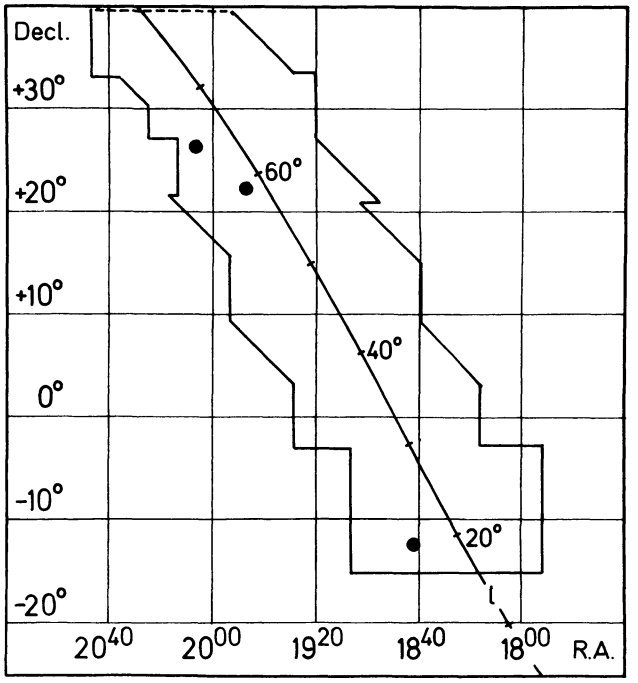
Institut für Astronomie der
Universität Innsbruck
Universitäts-Strasse 4
A–6020 Innsbruck (Austria)

Table 1 New planetary nebulae on the POSS

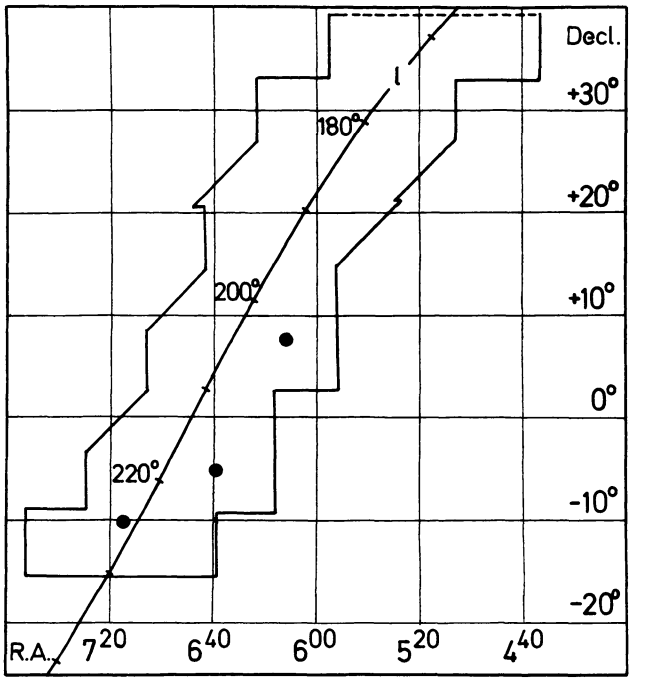
no.	Design.	R.A.$_{1950}$	Decl.$_{1950}$	ℓ	b	x	y	POSS no.	Dimension	Class
1	121 +3°1	$00^h35^m55^s2$	+66°07′12″	121°67	+3°55	292	160	1234,555	22″ × 16″	B
2	160 −0°1	04 43 07.0	+44 22 38	160.56	−0.54	109	292	644	92 × 92	A
3	163 −0°1	04 50 59.7	+42 11 47	163.16	−0.85	28	177	644,668	123 × 108	B
4	201 −4°1	06 11 51.0	+07 35 30	201.96	−4.66	84	260	229	40 × 40	B
5	216 −4°1	06 39 06.5	−04 59 44	216.31	−4.49	36	229	943	16 × 14	B
6	224 +1°1	07 15 03.6	−10 05 13	224.94	+1.06	193	288	1619,895	62 × 62	A
7	21 −3°1	18 41 19.4	−12 16 04	21.22	−3.94	15	158	296,308	17 × 17	C
8	59 −1°2	19 46 43.2	+22 17 41	59.30	−1.73	15	75	185,289	25 × 18	B
9	65 −3°1	20 06 58.8	+26 18 02	65.15	−3.54	89	280	289	26 × 23	B
10	86 +5°1	20 30 19.2	+48 42 27	86.19	+5.46	142	194	1099	194 × 187	B
11	91 +1°1	21 09 13.8	+50 34 48	91.66	+1.82	98	291	533	28 × 22	B
12	110 −0°1	23 10 02.7	+59 19 45	110.67	−0.89	323	114	1173,874	162 × 78	B

no.	Central star		Surface br. (mag/arcsec^2)		Integrated neb. magnitude		Dist. (pc)
	m_r^c	m_b^c	m_r^s	m_b^s	m_r^i	m_b^i	
1	>20.0	>21.1	21.1	>26.5	15.3	>20.4	6240
2 a)	>20.0	20.5	22.2	>26.5	13.3	>16.9	1623
3 a)	>20.0	20.5	23.3	>26.5	14.2	>16.5	1547
4	>20.0	>21.1	20.6	26.2	14.0	18.7−19.8	3406
5	18.2	18.9	21.5	25.8	16.7	20.3−20.5	8344
6	16.4	16.8	22.0	25.8	14.2	17.5−17.9	2342
7	>20.0	>21.1	22.1	26.0	16.5	20.1	7551
8	>20.0	>21.1	22.0	>26.5	16.5	>20.1	7102
9 b)	>20.0	>21.1	20.0	24.0	13.6	17.7−17.8	3639
10	18.7	18.1	22.1	25.8	11.4	15.1	690
11	>20.0	>21.1	20.7	26.3	14.9	19.7−20.6	4712
12 a)	9.8	10.7	21.7	25.7	12.1	16.0	1005

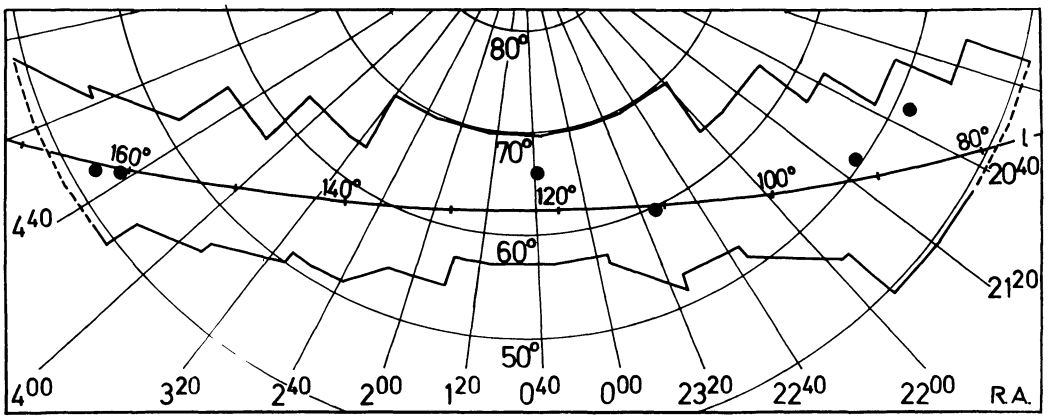
a) Possible central stars.
b) Roundish, probably nebular object somewhat displaced from the centre of the planetary, visible on E print only.



a



c



b

Figure 1a-c Location and boundaries of the survey. The black dots represent the new planetary nebulae.

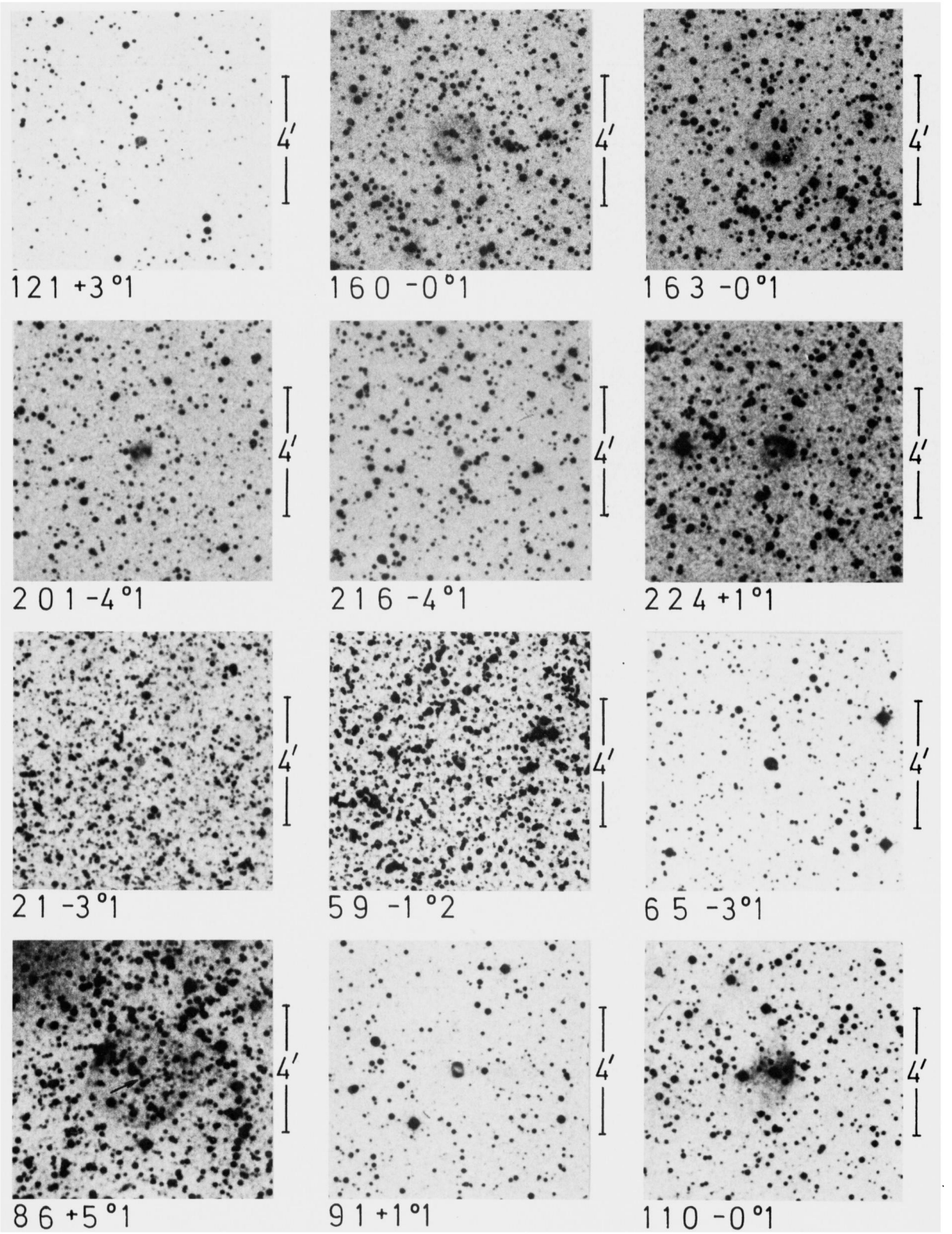


Figure 2 Identification charts for the planetary nebulae reproduced from the Palomar Observatory Sky Survey (E prints). The arrow in 86+5°1 marks the central star.