

New and known planetary nebulae on plates taken with the UK 1.2-m Schmidt telescope

A. J. Longmore *UK Schmidt Telescope Unit, Siding Spring Observatory and Royal Observatory, Edinburgh*

Received 1976 July 19; in original form 1976 May 24

Summary. Positions, photographs and descriptions of 17 new planetary nebulae are presented. New descriptions are also given of 10 known planetary nebulae appearing on deep UK 48-in Schmidt Sky Survey Plates. Two of these are found to have incomplete outer rings. The significance of the appearance of the known nebulae is discussed.

1 Introduction

Six hundred and six field centres have been specified for the ESO–SRC Southern Sky Survey. At the UK Schmidt Telescope Unit, Siding Spring Observatory, hypersensitized Eastman Kodak IIIaJ emulsion, in combination with a Schott GG395 filter, is being used to produce the ‘blue’ section of the Survey. Astronomically useful plates of over half the 606 fields have been obtained with the Survey plate–filter combination, and over one-third of the region has been covered to acceptable Survey standards (1976 April). The fine grain, high contrast and low reciprocity failure which are characteristic of the IIIaJ emulsion are ideal for the detection of very faint nebulosity. This emulsion is usefully sensitive out to $\lambda 5500 \text{ \AA}$. The [O III] $\lambda\lambda 4959, 5007$ lines (usually strong in medium–high excitation nebulae), and the $H\beta \lambda 4861$ line, are therefore included in the passband of the combination. One would then expect to find many previously undiscovered faint planetary nebulae on the deep, sky-limited Survey plates. Abell (1955, 1966) discovered 86 planetary nebulae during the production of the Palomar Sky Survey.

The new plates are examined during ‘quality control’ for interesting new objects. These include interacting and peculiar galaxies, planetary nebulae and faint star and galaxy clusters. Because of the nature of the search (scanning by eye and with a hand lens) there is a bias towards the discovery of the more extended objects. From a search of approximately 200 plates (about 30 per cent with $|b^{\text{II}}| < 20^\circ$), 17 new planetary nebulae have been found. These are described in Section 2. Positions in equatorial coordinate designations according to the Perek & Kohoutek (1967) system (hereafter P&K) are given in Table 1. The Table includes the number of the SRC plate from which the picture was reproduced, the measured X, Y position on the plate (in millimetres from the south-east corner of the original glass plate), and the ESO/SRC field number.

Table 1. New nebulae: coordinates and plate details.

No.	Designation	RA (1950)			Dec. (1950)		ESO/SRC field	Plate	Measured position	
		h	m	s	°	'			x	y
1	255 - 59°1	02	55	02	-44	22.6	247	J1929	110.8	210.0
2	284 - 39°1	04	03	19	-70	23.0	55	J1942	255.3	155.2
3	258 - 15°1	07	13	22	-46	52.1	257	J1315	313.5	75.0
4	274 + 9°1	10	03	44	-44	04.2	263	J1447	297.5	226.0
5	286 + 11°1	11	11	32	-47	49.2	265	J1369	183	35.0
6	294 + 14°1	11	58	10	-47	16.5	266	J1529	15.0	51.5
7	302 + 0°1	12	45	28	-62	33.1	-	J1583	169.9	141.9
8	310 + 24°1	13	22	43	-37	29.6	382	J1530	65.5	51.0
9	330 + 5°1	15	38	40	-47	31.2	274	J1324	46.0	39.5
10	328 + 1°1	15	45	46	-52	21.4	225	J1713	296.0	48.8
11	340 + 12°1	16	00	04	-35	52.3	389	J1459	178.5	131.5
12	340 + 10° 1	16	05	10	-36	59.0	389	J1459	124.5	72.0
13	345 + 15°1	16	06	35	-30	46.2	451	J702	171.5	137.0
14	331 + 0°2	16	07	57	-51	10.1	225	J1713	112.5	114.5
16	349 - 4°1	17	32	10	-40	10.1	334	J1543	320.5	166.5
17	356 - 11°1	18	24	24	-37	17.9	395	J664	171.5	55.0
18	341 - 24°1	19	05	38	-55	39.5	184	J1767	249.9	140.5

Several attempts have been made to devise a consistent system for the morphological classification of planetary nebulae. Evans & Thackeray (1950) proposed a scheme based on properties of symmetry. Hromov & Kohoutek (1968) and Hromov (1962) devised a system classifying nebulae according to three frequently observed forms. Greig (1971) attempted to define morphologically similar groups, based on symmetry, which would also correlate with observed nebula and central star spectral properties. In an effort to intercompare the effectiveness of these systems, the new nebulae have been classified according to the author's understanding of each. Results appear in Table 2, along with the maximum extent of each nebula, the extent in a direction perpendicular to this (in angular measure) and the position angle of the maximum. Further numerical details are given in the individual descriptions.

The depth of the plates also makes it worthwhile to re-examine known planetaries. Millikan (1974) found that most of a small sample he studied with limiting photographs on the Kitt Peak National Observatory 4-m telescope exhibited large diameter haloes. Such haloes have also been found round NGC 7009 and NGC 7662 (Kaler 1974). Fifty-five southern planetaries were searched for evidence of faint extensions, and the results are presented in Section 3. They were chosen by selecting all the extended objects in the list of Westerlund & Henize (1967) and examining all those of which we had deep IIIaJ plates. The list is therefore not complete, and further studies will be done as more plates are taken.

Section 4 includes a brief discussion of the three classification systems used. The implications of the results from the further look at the known planetary nebulae are also discussed.

2 The new planetary nebulae

255 - 59°1. Very large angular size, with a faint outer rim extending from a broad, also faint, I-shaped bar. Vaguely tubular with a hint of the overlapping disk-type system. The bar has pa 108°, maximum elongation is perpendicular to this. The most obvious candidate for the central star has been observed using the Robinson-Wampler Image-Dissector Scanner on the Anglo-Australian 3.9-m telescope. It shows a very blue almost featureless continuum, confirming it as the planetary nucleus.

Table 2. New nebulae: dimensions and classification.

No.	Designation	Extent (arcsec)		Pa of max	Greig	Classification	
		Max	Min			E & T*	H & K†
1	255 – 59°1	(373)		‡	BIT?	d	?
2	284 – 39°1	29			C	b	1
3	258 – 15°1	100	67	135‡	BNat	?	2a
4	274 + 9°1	54	42	63‡	BT?	k?	?
5	286 + 11°1	216		‡	A	b	1
6	294 + 14°1	66	59	20	BN	h	2a
7	302 + 0°1	58	50	35‡	BN or 3N?	h?	2?
8	310 + 24°1	125	104	55	BT	k	1
9	330 + 5°1	(116)	(95)	90	BI?	d?	?
10	328 + 1°1	12			U	a	?
11	340 + 12°1	67	50	62	iSy1	e?	2a?
12	340 + 10°1	83	75	105	U or Bit	d	?
13	345 + 15°1	71			A	a–b	1
14	331 + 0°1	125	117	90	iSy1	a?	?
16	349 – 4°1	(83)		‡	i	?	?
17	356 – 11°1	104			A	b	1 (d)
18	341 – 24°1	44	41	115	BR or A	b?	1?

Notes:

* Evans & Thackeray (1950).

† Hromov & Kohoutek (1968).

‡ Indicates more information is given in text.

284 – 39°1. A small ring with prominent central star.

258 – 15°1. Consists of a thick non-uniform ring with two condensations pa 152° relative to each other. Weak extensions visible defining a major axis pa 135°. They could equally well be described as ansae, tubes or an incomplete outer ring. Obvious central star.

274 + 9°1. A complex structure with an overall tubular appearance. Asymmetrical in form and brightness, having two condensations at pa –137° and –172°. Obvious central star.

286 + 11°1. A fairly large ring with diffuse inner boundary and a sharp outer edge. The nebula is marginally brighter through pa 128°. Possible indication of diffuse tubular structure, especially near the north-west rim. Two contenders of unequal brightness for the nucleus, with the brighter the more probable.

294 + 14°1. Binebulous, but with a possible break in the south condensation. An almost uniform nebular background. Two candidates for the central star, one noticeably brighter than the other.

302 + 0°1. Asymmetrically binebulous, no obvious central star. The break in the north-west condensation could put it in the trinebulous (3N) class. Uniform weak nebular background. Pa of the brighter lobes is 135°, with 50-arcsec separation.

310 + 24°1. Tubular structure clearly seen in the form of two similar rings displaced with pa 55°. The brightest central star with diffraction spikes stands out as the most obvious candidate for the nucleus.

330 + 5°1. Extremely low surface brightness makes the morphology difficult to determine. On the original plate, two overlapping uniform disks are suggested, with relative pa 90° . In a crowded star field there are no outstanding candidates for the central star.

328 + 1°1. Very small nebula with uniform surface brightness. Faint central star.

340 + 12°1. Has a broken egg-shaped thin outer ring with a fainter filled-in centre possibly exhibiting structure. Good candidate for central star.

345 + 15°1. Very diffuse ring, not quite a uniform disk. The brighter of the two central star candidates is nearer the middle.

331 + 0°2. Structureless nebula with an indistinct boundary, brighter on the east side of the central star. This object could fall into the class of diffuse or reflection nebulae.

349 - 4°1. A comparatively bright, irregular nebula. Asymmetrical condensations near the centre are seen against a more uniform approximately circular background. A star is visible at exactly the position estimated for the centre of the nebula.

356 - 11°1. A broad ring with diffuse inner edge and a well-defined outer boundary. One star is situated at precisely the central point, very close to a brighter star slightly off-centre.

341 - 24°1. A diffuse ring of low surface brightness. One obvious but faint central star.

3 Some known planetary nebulae re-examined

The appearance of 55 known planetary nebulae in P&K was compared with their appearance on the Schmidt plates. The comparisons elicited three possible results:

- (i) the form was the same on both photographs,
- (ii) the Schmidt plates showed the same angular size and major axis orientation as the Catalogue pictures, but were much blacker or even filled in completely where the Catalogue showed structural detail,
- (iii) the Schmidt plates showed marked changes in major axis orientation and/or visible structure and extent.

Only the third category was examined further. Descriptions highlighting the fundamental differences are given below.

243 - 1°1 (NGC 2452). The P&K north-south binebulous structure is filled in, and becomes much more extended in an east-west direction. This results in an almost 90° change in the direction of the major axis.

317 - 5°1 (He 2-119). East-west structure in P&K is saturated, and faint fuzzy extensions to the north and south of the planetary change the position angle from 90° to 0° . The total north-south extent is 120 arcsec, the overall shape becoming elliptical.

322 – 2°1 (He 2-130). The direction of the thin wisps projecting from the ring in P&K indicates the major axis on the Schmidt plates. The ring is filled in. The new appearance is that of an ellipse with major/minor axis ratio of 2:1, with a centric brightness increase. Greatest extent is 165 arcsec.

331 – 1°1 (Mz3, VV80, He 2-154). The binebulous structure is filled in and the nebula assumes a butterfly shape with the same north–south major axis orientation. Extending just over 40 arcsec, the boundary is indistinct.

336 – 0°1 (NGC 6164-5). More structure is seen in the central region. The most important new feature is the very faint but sharp halo, with lobes, surrounding almost the entire nebula (Plate 19). The greatest extent, at the same position as the main nebulosity, covers 20.5 arcmin. Perpendicular to this, the sidelobes extend about 15 arcmin, although the south-western limit of the halo is poorly defined. This halo is marginally visible in the H α photograph by Westerlund reproduced in *Nebulae and interstellar matter* (Middlehurst & Aller 1968). It is one of a series of shells round HD 148937. The halo radius is four to five times that of the next innermost shell, which places it with NGC 6543, 6826, 6891 and IC 4593 in Kaler's (1974) list of giant halo nebulae. There is some dispute as to whether the object is really a planetary. It has been suggested that it may be a Population I Of star undergoing mass loss.

336 – 6°1. On the Schmidt plates the object appears as a small black rectangle, 12 arcsec by 7 arcsec, elongated east–west. It is nearly stellar in P&K.

338 + 5°1 (He 2-155). This nebula has a pa of 110° in P&K, and is described as being 25 arcsec in diameter. The Schmidt plate shows a filled rectangle, pa 60° and 40 arcsec extent.

342 + 10°1 (NGC 6072). The north–south orientation in the Catalogue is hidden by a structure exhibiting two joined filled-in lobes with pa 70°. Broad, faint diffuse 'jets' extend from the west and south edges of the west lobe. Maximum extent is 40 arcsec.

342 – 4°1 (He 2-207). Binebulous structure is still evident in the same form as the Catalogue reproduction, but this is now capped by ansae at the east and west extremities of the nebula.

17 – 21°1 (A65). The main nebula structure is identical to that in the P&K photograph, but the Schmidt plate also shows evidence for a very faint incomplete outer ring, seen only along the north-eastern edge of the brighter nebulosity (Plate 20). It is at twice the inner nebula radius, and therefore fits into Greig's C class of nebulae.

4 Discussion

Seventy-six per cent (13) of the new nebulae have galactic latitude $|b^{\text{II}}| < 15^\circ$, and 50 per cent of these lie in the region $10 < |b^{\text{II}}| < 15^\circ$. This distribution is almost certainly due to selection effects in discovering the nebulae. Very close to the galactic plane the background star density is extremely high, making it very difficult to detect faint nebulosity. Obscuration by gas and dust in the plane is also a contributing factor.

Several of the new nebulae are difficult to classify unambiguously (see Table 2). In all three systems about 50 per cent of the nebulae had some query remaining as to their classification. This may have been due to the author's inexperience with each of the systems, but despite this it was felt that none was particularly satisfactory. It should be noted that the visible structure and extent of planetary nebulae usually changes considerably between low- and high-energy lines, and this probably affects some of the classifications given in this paper.

It is interesting to note that of the ten nebulae listed in Section 3, five showed significant changes in the major axis orientation, either of the brightest region of the nebula or of the axis of greatest extent. Melnick & Harwit (1975) selected 73 nebulae which they considered had a well-defined measurable orientation. These were then shown statistically to lie in a preferred direction parallel to the galactic plane, with binebulous, or polar cap, structures aligning themselves perpendicular to the plane. From the small sample studied here it seems that on deep photographs the binebulous appearance can be lost and a new major axis defined. In the current sample, 243 - 1° became more extended perpendicular to the binebulous structure and 331 - 1° extended along the binebulous structure. Although obviously not statistically significant, this must make one wary of defining major axes as perpendicular to bipolar axes.

Altogether 12 nebulae examined on the Schmidt plates were also used in Melnick & Harwit's compilation. Of these, five remained aligned with the galactic plane, five remained perpendicular to the plane, and two (317 - 5°, 322 - 2°) had major axes redefined from parallel to perpendicular to the plane. None became aligned along the plane which had not been so previously. Again this is not statistically significant, but it does emphasize the difficulty of using plates with such an inhomogeneous a depth as found in P&K, as a basis for statistical discussion.

Melnick & Harwit tentatively suggested that a mean motion of planetary nebulae perpendicular to the galactic plane, resulting in a flattening of the nebulae (due to interaction with the interstellar medium), may explain their results. This has been disputed by Cudworth (1975) on kinematical grounds. Also it is not clear that such motion would produce the desired compression. Dividing a nebula arbitrarily into 'high' and 'low' density regions, it appears likely that the interstellar medium will affect the two regions differently. Short exposures will preferentially detect density concentrations. If the less dense regions of the nebula are more affected by passage through interstellar material, any effects will be shown on deep exposures.

The spectral sensitivity range of the SRC Survey plates includes the [O III] N₁ and N₂ lines and H β . Examining the radial ionization distribution in model planetary nebulae (e.g. Osterbrock 1974) H α would seem to be a better spectral region in which to look for their outer extensions. As the [N II] $\lambda\lambda$ 6548, 6584 lines are associated with low excitation conditions, their presence in the same passband as H α should not be misleading with regard to this study. An alternative approach may be to use narrow band filters centred on the low excitation [O I] or [N I] lines. There is evidence that [O I] photographs, for example, are suitable for detecting neutral shells around planetary nebulae. Thus a reworking of the results of Melnick & Harwit based on a series of limiting exposure photographs in H α light, combined with a homogeneous selection of short exposures, offers the best attempt at a solution to the problem. This assumes spherically symmetric ejection, and that other restraining effects (such as magnetic fields) are secondary, which is by no means well established. Confirmation of alignment with the galactic plane would then demand a close examination of the kinematics of planetary nebulae and of possible effects of stellar and/or galactic magnetic fields.

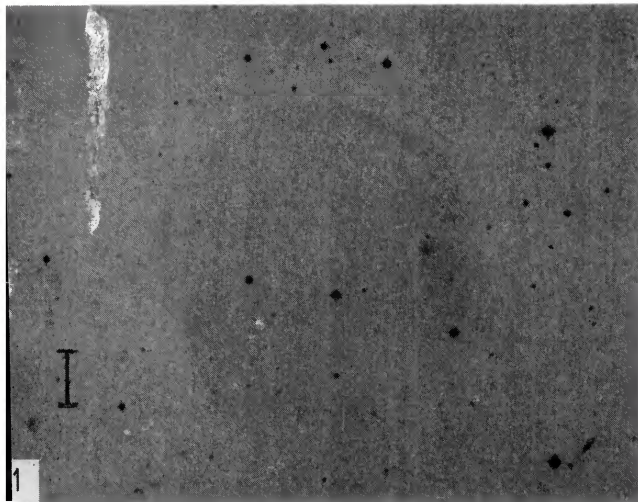


Plate 1. 255-59°1.

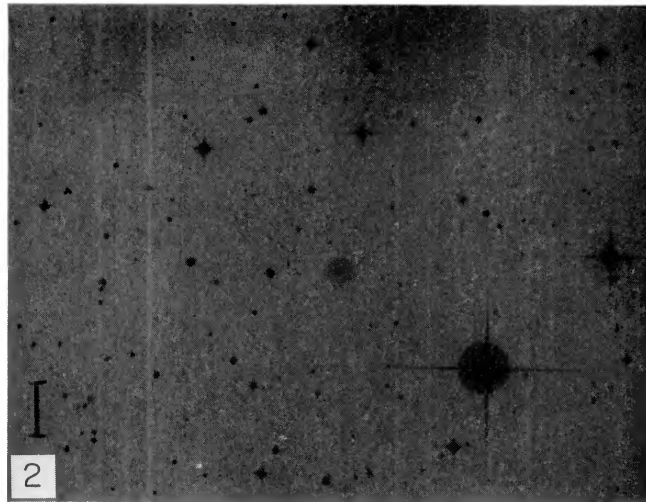


Plate 2. 284-39°1.



Plate 3. 258-15°1.

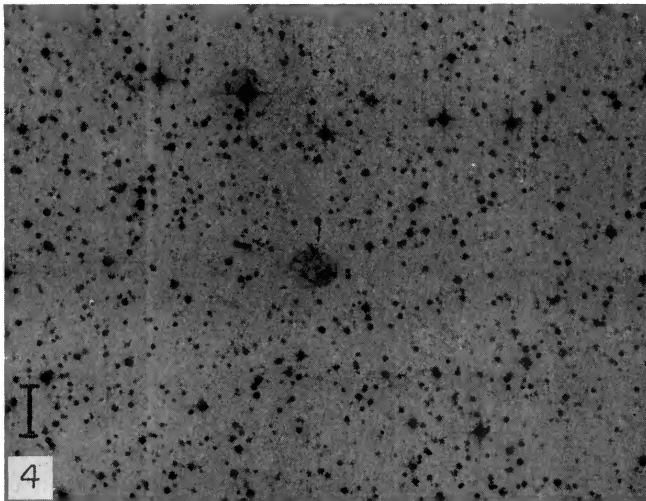


Plate 4. 274+9°1.

North is to the top and East to the left on all photographs. The bars on all photographs indicate 1 arcmin.

[facing page 256

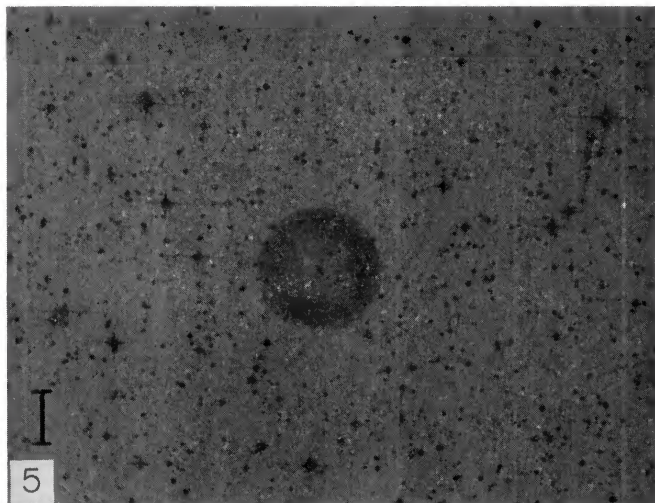


Plate 5. $286+11^{\circ}1$.

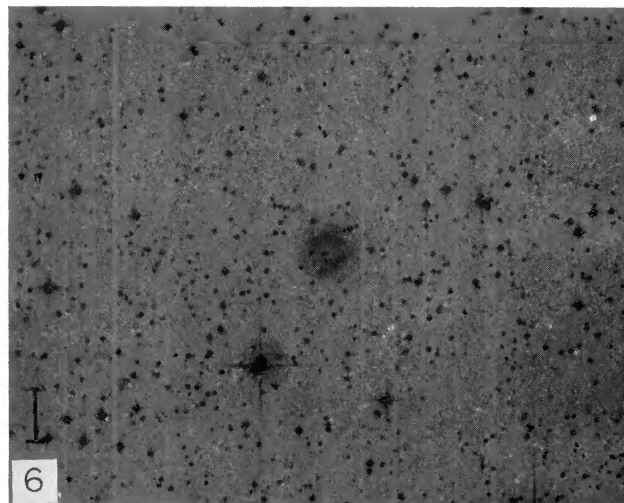


Plate 6. $294+14^{\circ}1$.

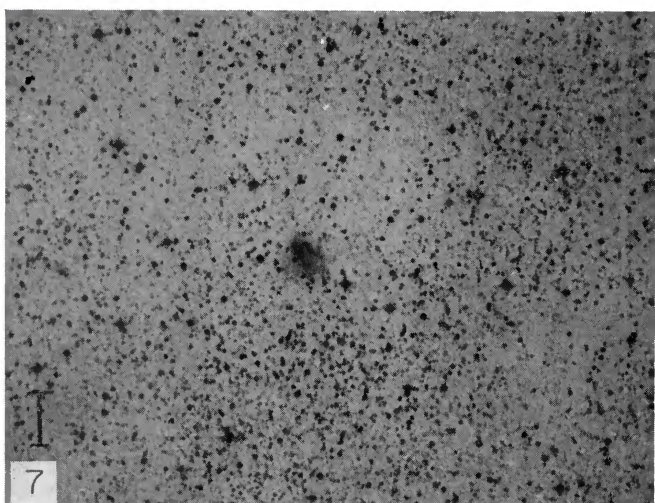


Plate 7. $302+0^{\circ}1$.

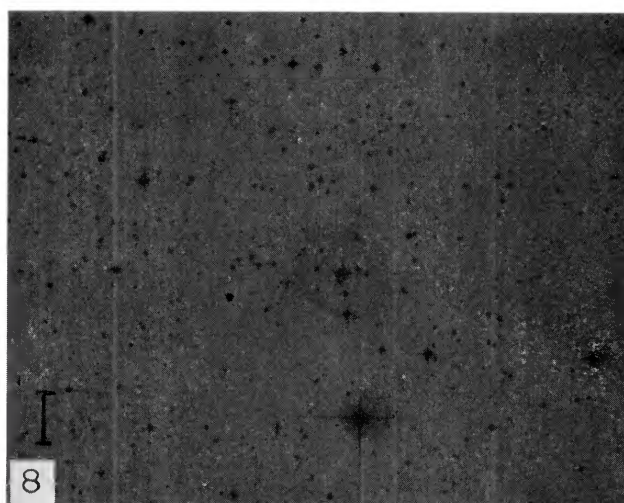


Plate 8. $310+24^{\circ}1$.

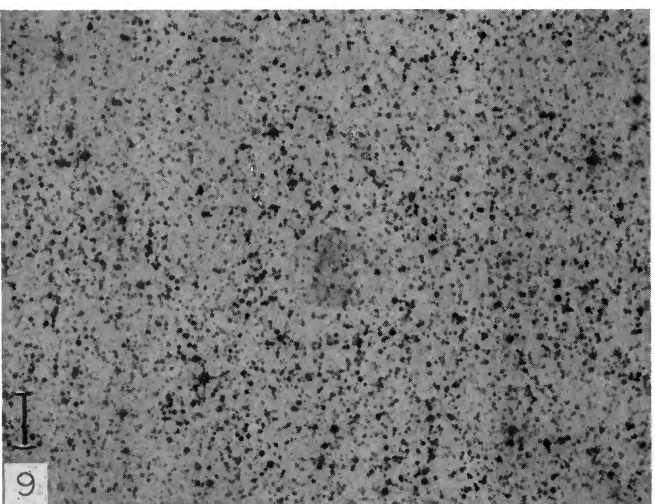


Plate 9. $330+5^{\circ}1$.

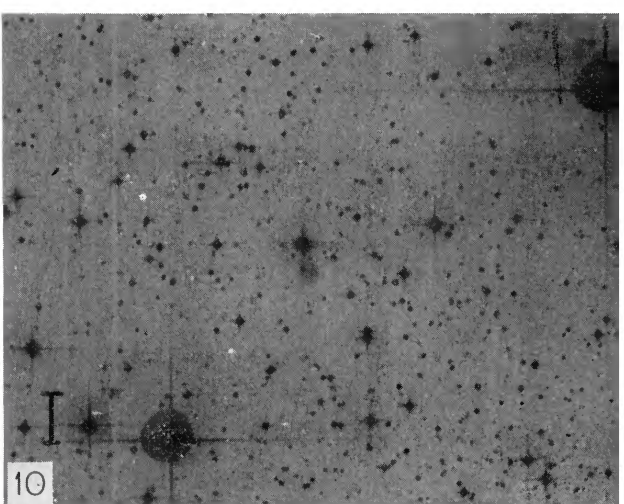


Plate 10. $328+1^{\circ}1$.

North is to the top and East to the left on all photographs. The bars on all photographs indicate 1 arcmin.

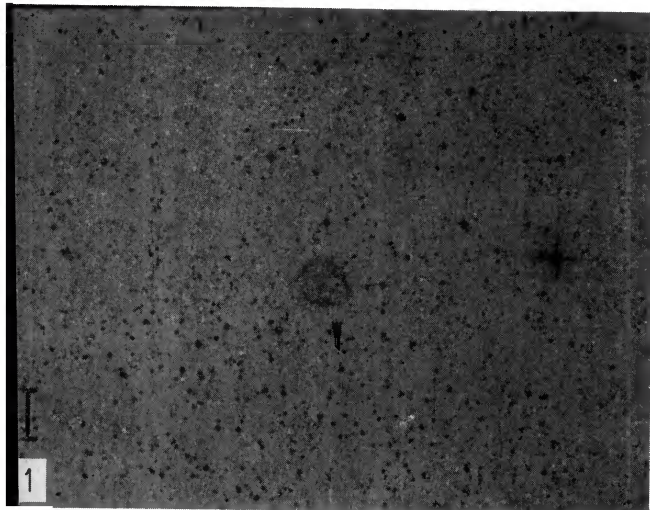


Plate 11. $340+12^{\circ}1$.

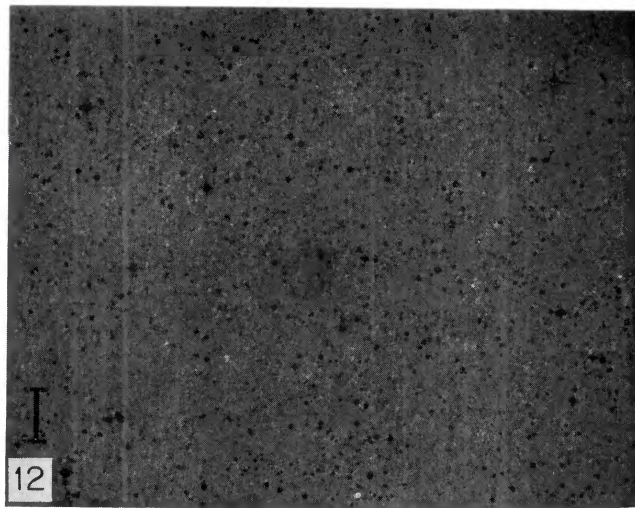


Plate 12. $340+10^{\circ}1$.

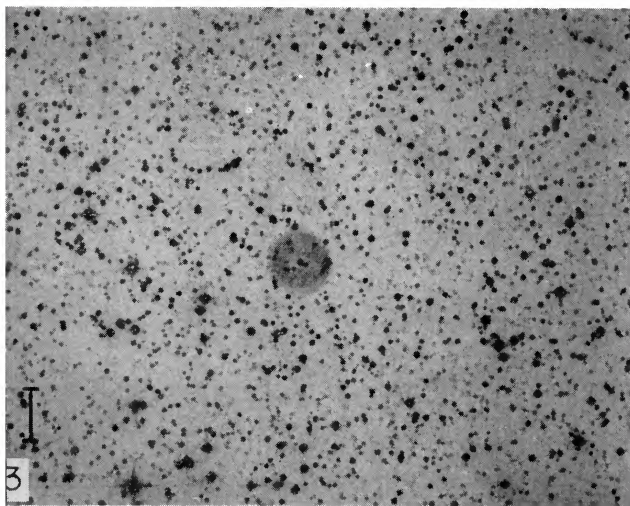


Plate 13. $345+15^{\circ}1$.

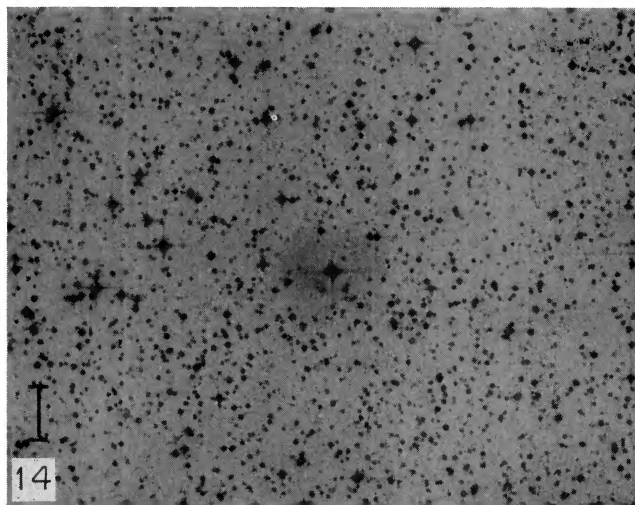


Plate 14. $331+0^{\circ}2$.

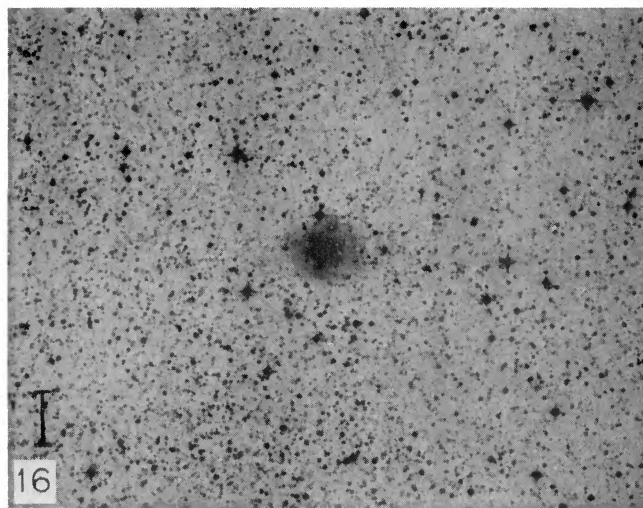


Plate 16.* $349+4^{\circ}1$.

North is to the top and East to the left on all photographs. The bars on all photographs indicate 1 arcmin.

* Plate 15 deleted in proof.

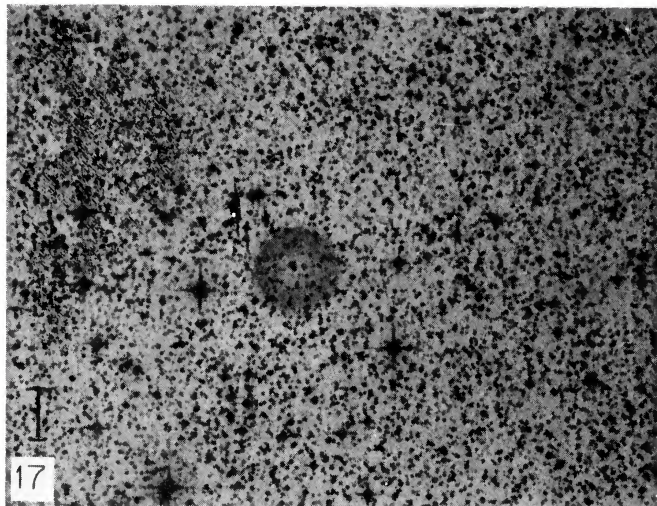


Plate 17. 356–11°1.

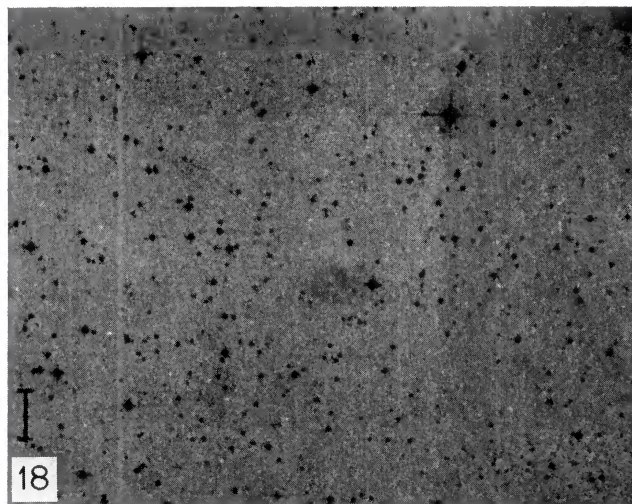


Plate 18. 341–24°1.

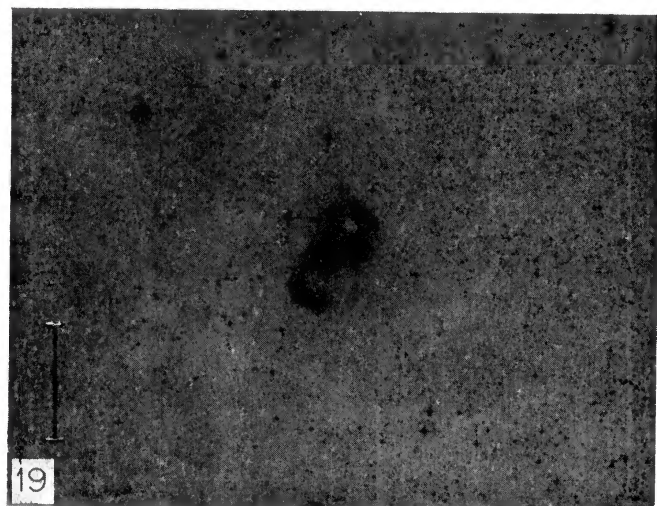


Plate 19. 336–0°1 (NGC 6164–5).

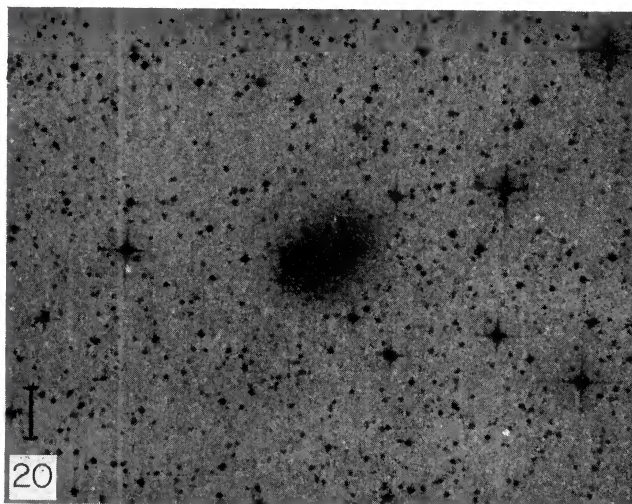


Plate 20. 17–21°1 (A65).

North is to the top and East to the left on all photographs. The bars on all photographs indicate 1 arcmin, except for 336–0°1—Plate 19—where the bar indicates 5 arcmin.

Acknowledgments

Several of the new planetary nebulae were found by colleagues at the UKSTU during their own work on the plates. I would therefore like to thank Russell Cannon, Tim Hawarden, Liz Sim and Peter Standen for bringing these to my attention.

References

- Abell, G. O., 1955. *Publ. astr. Soc. Pacific*, **67**, 258.
 Abell, G. O., 1966. *Astrophys. J.*, **144**, 259.
 Cudworth, K. M., 1975. *Mon. Not. R. astr. Soc.*, **172**, 57P.
 Evans, D. S. & Thackeray, A. D., 1950. *Mon. Not. R. astr. Soc.*, **110**, 429.
 Greig, W. E., 1971. *Astr. Astrophys.*, **10**, 161.
 Hromov, G. S., 1962. *Sov. Astr. AJ.*, **6**, 370.
 Hromov, G. S. & Kohoutek, L., 1968. *IAU Symp. 34*, Planetary nebulae, eds Osterbrock & O'Dell, University of Chicago Press.
 Kaler, J. B., 1974. *Astr. J.*, **79**, 594.
 Melnick, G. & Harwit, M., 1975. *Mon. Not. R. astr. Soc.*, **171**, 441.
 Middlehurst, E. M. & Aller, L. H. (eds), 1968. *Nebulae and interstellar matter*, University of Chicago Press.
 Millikan, A. G., 1974. *Astr. J.*, **79**, 1259.
 Osterbrock, D. E., 1974. *Astrophysics of gaseous nebulae*, W. H. Freeman and Co.
 Perek, L. & Kohoutek, L., 1967. *Catalogue of galactic planetary nebulae*, Czechoslovak Academy of Sciences, Prague.
 Westerlund, B. E. & Henize, K. G., 1967. *Astrophys. J. Suppl.*, **14**, 154.

Note added in proof

Dr N. Sanduleak has kindly pointed out that No. 3 on this list has appeared in the lists of Wray (1966, *Thesis*, Northwestern University) and Stock & Wroblewski (1972, *Publ. dep. astr. Universidad de Chile*, **2**, 59).