A PHOTOGRAPHIC SURVEY
OF BRIGHT SOUTHERN PLANETARY NEBULAE

David S. Evans and A. D. Thackeray

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Summary

Twenty-six objects believed to be planetary nebulae with diameters greater than 8 seconds of arc, south of declination \(-40^\circ\), have been investigated. Descriptions, and photographs of those which definitely are planetary nebulae, are presented. Some comments on the classification of planetary nebulae are offered, and the proportions exhibiting various types of symmetrical form are tabulated.

The present project originated in a suggestion by Professor J. H. Oort, made during a visit to the Radcliffe Observatory in 1948. It was felt that, although the proper motions of planetary nebulae would probably be very small, it was nevertheless desirable that plates which might provide first-epoch positions should be obtained as soon as possible. The project was later extended, and much longer exposure plates were taken, in order to provide, in addition, a descriptive catalogue of bright southern planetaries. A list of objects believed to be planetary nebulae, having diameters of more than 8 seconds of arc, south of declination \(-40^\circ\), contained 26 objects. In the course of 1948–50, a total of 123 plates of these objects was obtained. This included 16 plates of IC 4406 (already described elsewhere by one of us, DSE)* and of the remainder, 89 plates are by DSE and 18 by ADT.

Table I lists the objects observed, with references to the literature, the numbers of the plates in the Radcliffe files which are recommended for possible proper motion studies, and the numbers of the accompanying illustrative photographs.

At first sight it appears that there is a large literature on the planetary nebulae described here, but, in actual fact, a great many of the works cited are compilations from earlier publications. In the NGC (1), based to a considerable extent on the work of the Herschels, the classification of southern planetaries as such is by appearance, and rests on Sir John Herschel's "Results of Astronomical Observations made in 1834–8 at the Cape of Good Hope" (London, 1847). Campbell and Moore's work (2), done with the spectroscope, represents the most reliable source. A number of identifications by Mrs Fleming, quoted in the Index Catalogue, also have a spectroscopic basis. For the southern nebulae the source of the magnitudes and diameters given by Vorontsov-Velyaminov and Parenago (3) is the examination of the Franklin-Adams plates. The results obtained are repeated by Vorontsov-Velyaminov in his compilation (4). In this work it is stated that all the images were stellar, and that the appearance of the stellar images was used to assign integrated magnitudes. In addition the image diameters were used to assign diameters to the nebulae. This seems to be a double use of the same material, and does not seem very reliable. Indeed,

* M.N., 110, 37, 1950.
Vorontsov-Velyaminov himself does not regard the results of any of these southern nebulae as meriting more than assignation to his class of third quality results. In addition all “stellar” nebular images were arbitrarily assigned a diameter of "2". Most of the other references are to particular individual nebulae. It follows, therefore, that in fact the observational basis for previous

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In the Remarks column: P denotes an accepted planetary.
NP denotes "not a planetary".
PNP denotes "probably not a planetary".
discussions of southern planetary nebulae has been very slight, and is by no means as extensive as might be inferred from our reference list.

We now proceed to a short discussion of each object in turn:

No. 1:
Innes (9), studying three plates taken with the 10-inch Franklin-Adams cameras, gives the three descriptions:

"Large but faint spiral with stars: a small cluster forms the nucleus."
"Fine circular spiral with stars."
"Very fine circular spiral with stellar nucleus."

In 1927 the same author (11) says: "The stars in this spiral nebula are shown as a letter S but the nebulosity is virtually invisible". Jenka Mohr (7) discusses plates taken with the 24-inch Bruce, the 10-inch Metcalf and the 3-inch Ross Fecker instruments at Bloemfontein. The diameter is given as 420 seconds of arc, and it is stated that the nucleus "appears to be a central star of magnitude 12-6, but it is possible that this star is merely superposed". It is pointed out that the nebula is almost certainly superposed on the Magellanic Cloud, since, at the distance of the cloud, it would have the very large diameter of 50 parsecs. Estimates based on statistical discussions of planetaries, assuming the selected star to be the central star, give distances of 1200 parsecs and 2000 parsecs.

Our plates show very faint nebulosity (invisible to the eye in the telescope) with a diameter of 420 seconds of arc. The nebulosity is much brighter on the preceding side. There is a wispy structure with some suggestion of a spiral or helical form. The nebula does not seem to be a typical planetary, and it is quite impossible to designate any particular star as the nucleus. Our photographs show the central area to be occupied by two distinct and compact groups of stars, some of which appear to be directly mingled with nebulous wisps. The galactic latitude is greater than that of any accepted planetary in our list, and in view of the great variety of nebulosities with complex forms appearing throughout the Magellanic Cloud, the explanation in terms of a galactic planetary superposed on the Cloud is not clearly demanded. Evidence in favour of its belonging to the Cloud is strengthened by the presence of the double cluster in the central region, which is unlikely to be galactic. If it belongs to the Cloud it must be rejected as a true planetary, and the problem arises of how such regularity can be exhibited by nebulosity 50 parsecs in diameter. Purely on appearance the nebula might be thought to resemble the final stage of a supernova outburst. The photograph, Plate 8, Fig. 1, has been intensified to bring up the faint nebulosity.

No. 2: IC 2448.

This planetary (x) was found on the basis of its spectrum by Mrs Fleming, who designated it as "Planetary, stellar". Campbell and Moore (2) give a diameter of 8", magnitude 9, spectrum $N_1$, $N_2$, $H\beta$ (10:4:1), velocity = $-24$ km./sec. Vorontsov-Velyaminov (3), (4) gives diameter 8", integrated magnitude 11.5. Our plates, Fig. 2, show a bright central star, with a small oval patch of luminosity placed slightly eccentrically; dimensions 9" $\times$ 7".

No. 3: NGC 2792.

Dreyer (x) says: "Remarkable planetary, pretty bright, equivalent to 9th magnitude star, very small, round, among stars". Campbell and Moore (2) give a diameter of 10", 10th magnitude, spectrum $N_1$, $N_2$, velocity = $+14$. 31
Innes (8) says: "An 11th magnitude planetary about 20" in diameter. Is Np a pair of 10.5 mag. stars. No stars within 3"." Gregory (14) has: "Planetary, pretty bright, small, very little extended in P.A. 165° ±. Appears as a nearly uniform disc without a central star". Vorontsov-Vel’yanov (3), (4) assigns diameter 10", magnitude 13.5. We find a typical, almost symmetrical, ring nebula, with central star. The ring is slightly brighter to the south. Diameter 13". (Plate 8, Fig. 3.)

No. 4: NGC 2867.

Dreyer (1) says: "Very remarkable planetary, equals 8th mag. star, very small, round. 15th mag. star at P.A. 59°, distant 13". Delisle Stewart (18) gives a diameter of 18". Campbell and Moore (2) have: "Diameter 8", round, edges sharply defined. Centre appears fainter. May be very small ring nebula. Mag. 8.5. Velocity = +18 km/sec. Vorontsov-Vel’yanov (3), (4) has diameter 8", magnitude 9.7. The object is a bean-shaped ring nebula, the ring being broken up into spots of brightness, brightest in the Sp sector. The central star is faint. About 13"×11". (Plate 8, Fig. 4.)

No. 5: NGC 3132.

Dreyer (1) says: "Very remarkable planetary; very bright, very large; little extended; star of 9th magnitude in the middle, 4½ diameter". Campbell and Moore say: "Ring nebula with 8.8 magnitude star in centre. Diameter of ring about 30". Spectrum: N1, N2, Hβ, N3(10:4; 1:1); V = -8 km/sec." There is a drawing by Wilson. Vorontsov-Vel’yanov (3), (4) gives diameter 30", integrated magnitude 8, central star, magnitude 10.6. Knox Shaw (13) has: "Very bright, pretty small, little elongated in P.A. 150° ±: annular ring, fainter on preceding side. B star not quite central and thus probably unconnected." A note says that the spectrum of the bright central star is continuous. Shapley and Paraskevopoulos (12) say: "A series of photographs of varying exposures would be necessary to bring out the intricate details... It could well be named the "8-burst" planetary from the number of distinct arcs on the boundary of the main disc or shell. The class A star, HD 87892, mag. 9.5 is centrally superposed". A photograph is given.

The object has a complex structure, including a bean-shaped ring, very bright, with fainter, helical, extensions. Dimensions about 84"×53". The object is illustrated in Plate 8, Fig. 5. Photographic manipulation has been employed to bring up the centre on the print, but the structure has not been falsified. There is a nucleus or foreground star on the ring in the Sp sector.

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**Legends to Plate 8.**

**Fig. 1.**
Object: 5h 43m 4s, -67° 53' 22".
Kodak 103-a O, 30 mins.

**Fig. 2.**
IC 2448, ×7.9.
Ilford Astronomical Zenith, 90 secs.

**Fig. 3.**
NGC 2792, ×7.9.
Ilford Astronomical Zenith, 5 mins.

**Fig. 4.**
NGC 2867, ×7.9.
Ilford Astronomical Zenith, 60 secs.

**Fig. 5.**
NGC 3132, ×5.8.
Kodak 105-a O, 16 mins.

**Fig. 6.**
NGC 3195, ×6.3.
Kodak 105-a O, 15 mins.

**Fig. 7.**
NGC 3211, ×6.3.
Ilford Astronomical Zenith, 10 mins.

Note.—The magnifications are relative to the original plate scale of 22"/5/mm.
**Fig. 8.**
*Object: 11h 26m 2, -52° 39' × 9°.*
*Kodak 103-a O, 30 mins.*

**Fig. 9.**
*NGC 3918, × 5.*
*Ilford Astronomical Zenith, 20 secs.*

**Fig. 10.**
*NGC 5180, × 7°.*
*Kodak 103-a O, 30 mins.*

**Fig. 11.**
*NGC 5307, × 7°.*
*Ilford Astronomical Zenith, 5 mins.*

FIG. 12.
Object: $15^{h} 47^{m} 4, -51^\circ 21'$
$\times 8.8$.
Kodak 103-a E, 20 mins.

FIG. 13.
Object: $15^{h} 30^{m} 2, -58^\circ 59'$
$\times 6.3$.
Kodak 103-a E, 20 mins.

FIG. 14 a.
Object: $16^{h} 10^{m} 5, -54^\circ 50'$
$\times 10$.
Kodak 103-a O, 40 mins.

FIG. 14 b.
Object: $16^{h} 10^{m} 5, -54^\circ 50'$
$\times 23$.
Kodak 103-a O, 40 mins.

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No. 6: NGC 3195.

Dreyer (1) says: "Remarkable planetary, pretty bright, small, little extended; 13" diameter; three small stars near". We find (Plate 8, Fig. 6) an oval nebula with central star. There are two sectors of great brightness on the oval to east and west, and faint extensions in the form of the ring to north and south. Dimensions about 44" × 33".

No. 7: NGC 3211.

Dreyer (1) says: "Planetary, equals 10th magnitude star, round, among 150 stars". Campbell and Moore (2) give: "Planetary, round, diameter 8", 10th magnitude. Spectrum $N_1$, $N_2$, $H\beta$, $N_3$ (10:4:1:2). $V = -16$ km/sec." Vorontsov-Velyaminov (3), (4) has diameter 8", integrated magnitude 11.8. The object (Plate 8, Fig. 7) is a bright disk 14" in diameter, with a slight bump on the northern edge. The central star is barely visible.

No. 8:

Campbell and Moore (2) give the description: "Faint patch of nebulosity slightly elongated: trace of nucleus: diameter about 15", but limits are quite indefinite. Spectrum; $N_1$, $V = +2.8$ km/sec. All the plates are much underexposed." Vorontsov-Velyaminov (4) merely repeats these details.

Positive prints show an image precisely like the face of a circus clown, but a negative is more revealing. The central star is surrounded by an oval extended roughly east and west, and having dimensions about 45" × 30". There is a faint dark lane concentric with the main oval, so that in fact we have an oval outer ring. On the following side is a dark indentation (the clown's mouth), while the "eyes" are dark areas extending almost north and south from the central star. The ring is brighter on the north preceding side, while on the preceding end is a bright nucleus (?) star. There is a very faint equatorial hoop extending north and south (the clown's "ears"), having a total extent of about 60". The contrast of the negative print (Plate 9, Fig. 8) has been increased.

No. 9: NGC 3918.

Dreyer (1) says: "Planetary, remarkable, small, round, blue, equals 7th magnitude star. Diameter 18.5". Campbell and Moore (2) say: "Very bright planetary, magnitude 8.5, diameter 10", spectrum: $N_1$, $N_2$, $H\beta$, $N_3$, $\lambda 4363$, $H\gamma$, $H\delta$, $\lambda 3768$; $V = -16.4$ km/sec. Intensities, $N_1$, $N_3$, $H\beta$, $N_3$ (10:3:1:1)." Vorontsov-Velyaminov (3), (4) gives a diameter of 10" and integrated magnitude 8.4. We find a simple disk with very slight equatorial structure. No central star is visible.

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**Fig. 15.**

**Object:** 16h 13m 5s, −51° 52' x 6.5.

Kodak O-E, 20 mins.

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**Fig. 16.**

NGC 6153, × 9.0.

Ilford Astronomical Zenith, 10 mins.

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**Fig. 17.**

IC 4642, × 6.5.

Ilford Astronomical Zenith, 10 mins.

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**Fig. 18.**

NGC 6326, × 6.6.

Kodak O-O, 3 mins.

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**Fig. 19.**

NGC 6630, × 6.6.

Kodak 103-a E, 15 mins.

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**Fig. 20.**

IC 4723, × 6.6.

Kodak 103-a E, 15 mins.

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**Fig. 21.**

Types of symmetrical planetary nebulae.

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**Note.**—The magnifications are relative to the original plate scale of 22"/5/mm.
Efforts by one of us (ADT) to reveal it, using green filters and F-type plates to cut out the nebulium lines, have met with no success. Diameter 13". (Plate 9, Fig. 9.)

No. 10: NGC 5189.

The NGC says: "Remarkable, blue, pretty large: considerably extended: brighter towards the middle: curved axis: 4 stars involved". There is a drawing by Sir John Herschel (loc. cit.). Campbell and Moore (2) say: "Nebulous field about 1'-3 in length. Composed of three nebulae. NGC 5189, the following one of the three is about 20" in diameter, and slightly fainter than the spindle shaped nebula in the centre. Spectrum, $N_1, N_2$ (10:3). $V = -6$ km./sec.". There is a drawing by Wilson. It is evident from this that Campbell and Moore regard NGC 5189 as being one of a group of nebulae, whereas in fact the whole mass is a single complex nebulus which is not a typical planetary. Vorontsov-Velyaminov (4) simply quotes Campbell and Moore (2). Shapley and Paraskevopoulos (12) give a drawing and say: "NGC 5189, near the galactic equator is a gaseous nebulus of such remarkable knotted structure that it is here best represented by a drawing. No bright star is involved in the nebulosity, but 6' to the south is the 7th magnitude star HD 117694, B9. In the HD catalogue there is no star with a spectrum earlier than B5 within a degree of the nebulosity. Overall dimensions 3'0 x 2'0". Our photograph, Plate 9, Fig. 10, shows no central star; the object is clearly not an ordinary planetary. Dimension, east–west 185"; north–south 130". The structure is helical or S-shaped.

No. 11: NGC 5307.

Dreyer (1) says: "Planetary, or very faint extended small double nebulus". Campbell and Moore (2) say: "Planetary, elongated in north and south direction, 8" x 10". Magnitude III. Spectrum: $N_1, N_2, H\beta$ (10:3:?). $V = +42$ km./sec.". Vorontsov-Velyaminov (3), (4) gives the same dimensions, but integrated magnitude 12:1. We find (Plate 9, Fig. 11) a small gaseous parallelogram elongated roughly north and south with a central star. Dimensions about 15" x 10".

No. 12: IC 4406.

This nebula has been discussed at length by one of us (DSE).†

No. 13:

Found by Menzel (5) on a Bruce plate taken at Arequipa and classified as planetary on the basis of its appearance. Menzel states that it is bi-nuclear and gives an angular diameter of 24". Vorontsov-Velyaminov (3), (4) gives a diameter of 24", integrated magnitude 12:5. Our photograph, Plate 10, Fig. 13, shows a very complex structure. A bright ring 34" in diameter and of oval shape, shows two stars within it. The appearance is as if this bright ring formed the base of a cylinder with generators extending roughly northward, with the exception of one line, which also extends slightly south. The nebula terminates in the north with a second, fainter and slightly smaller ring, seeming to form the top of the cylinder. This ring has three bright spots on it, and also has a bright nucleus (? faint star). Total length about 55".

*NGC 5189 is referred to by Radlova, Katz and Dokychaeva, Russian Astronomical Journal, 26, 160, 1949 (in Russian). The data are however merely derived from Franklin-Adams and Wolf Palisa charts.

† M.N., 110, 37, 1950.
No. 14:
Shapley (6), who found this fine ring nebula on plates of Milky Way field 233, gives a magnitude of 3.16 and a diameter of 72". He says: "The width of the ring, which is circular, and nearly uniform all the way round, is 15 seconds of arc". Plate 10, Fig. 12, in which the contrast of the faint ring has been increased, shows these data to be correct. The ring is brighter on the preceding side.

No. 15:
Found by Menzel (5) and classified on appearance. Diameter 30", quoted by Vorontsov-Velyaminov (4). Menzel says that it appears to be annular. The object consists of a ring of diameter 28", breached to north and south, so that in effect, it is composed of two comma-shaped masses of gas. From the tails of the commas extend curved wisps of faintly illuminated gas with small radii of curvature. The northern one has a bright knot on it, almost in line with the breach in the main ring. Total extent, north to south, about 45". Plate 10, Fig. 14a is a normal print: the contrast of Plate 10, Fig. 14b has been increased, the better to show the fainter parts of the nebula.

No. 16:
Found by Menzel (5), who gives a diameter of 12" and says that it appears to be annular. Vorontsov-Velyaminov (4) quotes this diameter. This peculiar object consists of a central star with luminous masses to north and south (Plate 11, Fig. 15). That to the north is almost globular and appears slightly to overlap the central star. The mass to the south is concave towards the star, and shows some trace of an absorption shell. Extending southward from this second mass is a faintly luminous pointed "beard". Dimensions: north–south, 35"; east–west about 16".

No. 17: NGC 6153.
Dreyer (1) describes this planetary, discovered by Copeland, as "planetary, stellar". Campbell and Moore (2) observed the $N_2$ line, and assigned $V = +39$. Van den Bos (11), observing with the 26-inch refractor of the Union Observatory, described it as a planetary, with major axis 28" in P.A. 7°–187°, minor axis 22". Finsen (10) describes it as a ring nebula. Vorontsov-Velyaminov (3), (4) assigns his conventional diameter ?2", and magnitude II-5.

We find (Plate 11, Fig. 16) an object with a central star surrounded by a circular area of luminosity of diameter 20". On this is superposed a curious arched structure resembling a geometrical diagram. It is a line of gas in the form of part of an elongated ellipse terminated by an asymmetrical chord. The curved part, which extends beyond the circular area, is faint. The sharper (preceding side) join of the chord and the ellipse is slightly extended in the form of a faint point projecting a little beyond the circular patch of luminosity. Dimensions: east–west, 21"; north–south, 28".

No. 18: IC 4642.
Dreyer (1) takes this from the list of planetaries discovered by Mrs Fleming from their spectra. It is "planetary, stellar". Campbell and Moore (2) say: "This nebula is remarkable for the strength of the $N_2$ radiations. The exposures are too short. $V = +44$ km./sec.".

Vorontsov-Velyaminov (3), (4) assigns the conventional diameter ?2", and integrated magnitude 12.4. Shapley (6) gives magnitude 14.4 and diameter 30".

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We find (Plate II, Fig. 17) an oval ring nebula with central star. The principal axis is in the direction Ne–Sp. The illumination of the ring is not uniform, and dark areas form a cross on the major and minor axes of the oval. Dimensions 18″ × 15″.

No. 19: NGC 6326.

Dreyer (1) says: “Very, very remarkable: pretty bright: very small, round.” Herschel (loc. cit.) has a drawing. Campbell and Moore found the lines Nᵢ, N₂, Hβ (10:3:1 ±) (Hβ very very faint), and give V = +11 km/sec. Vorontsov-Velyaminov (3), (4) assigns a magnitude 12:2 but no diameter. The object (Plate II, Fig. 18) consists of a roughly rectangular area of luminosity about 12″ × 10″ with a central star. This forms the main “ring” of the nebula and in the south following corner it has a bright spot. There is a smaller, fainter, rectangular extension from the southern half of the preceding side. Dimensions about 16″ × 11″.

No. 20:

Shapley (6) reports a nebula, magnitude 11:9, diameter 36″ at position (1900) 17° 58′ 53″, −50° 37′ 1″. We find nothing at the corresponding 1950 position.

No. 21: NGC 6630.

Dreyer (1) says: “Planetary, faint, small, round, gradually brighter in the middle.” Shapley (6) gives magnitude 15:3, diameter 30″. The classification is by appearance. We find an object with a quadrilateral of four stars or nuclei surrounded by a nebulous envelope. The object is difficult, and it seems open to doubt whether the object is correctly classified as a planetary nebula. Dimensions about 19″ × 15″. (Plate II, Fig. 19.)

No. 22: IC 4723.

The object enters the Index Catalogue (1) as one classified as a planetary on appearance by Dudley Stewart. His description is: “very faint, very small, round.” Shapley (6) gives magnitude 15:4, diameter 27″.

We find (Plate II, Fig. 20) a curious round object of diameter about 19″ with three distinct nuclei running along a north–south line across it. The designation as a planetary again seems doubtful.

No. 23: NGC 6707, 6708.

For the former, Dreyer (1) has: “Faint, small, very little elongated, gradually brighter in the middle.” For the second: “Pretty faint, small, round, gradually pretty much brighter in the middle, last of group.” Reynolds (17) has NGC 6707 as “Faint spiral, 3′ × 1′”. The classification as planetaries is by Frost (19): “very faint planetary elongated about 2′”, and “Round planetary, magnitude 14′”. The objects prove to be definitely extragalactic.

No. 24: NGC 6902.

Dreyer (1) says: “Faint, considerably small, round, brighter in middle.” Shapley and Ames (16) make it extragalactic: they give no description. Reynolds (17) also calls it a spiral, without description. The classification as a planetary nebula is by Madwar (18), who says: “Faint, round, 30″ diameter; planetary with a bright, almost stellar, nucleus”.

Short exposures do show a structure closely resembling a planetary nebula, but longer ones reveal spiral arms. These are very faint, but the object is extragalactic, presumably a late-type spiral.
No. 25:
Discovered by Menzel (5), who gives a diameter of 30". Vorontsov-Velyaminov (3), (4) makes it a planetary fainter than the 15th magnitude with diameter 30". Our plates show a faint ring structure broken up into bright spots surrounding a blurred nucleus. The field is full of extragalactic nebulae, and we regard the classification as a planetary as incorrect.

No. 26: NGC 7408.
The NGC says: "Pretty bright, pretty small, round, very gradually a little brighter in middle". Vorontsov-Velyaminov gives a diameter of 72" and a magnitude of 12.8. Menzel (5) assigns it to the planetary nebulae on the basis of appearance and assigns a diameter of 72". The object is a barred spiral with a line of condensations or giant stars crossing it.

It is not the purpose of the present paper to offer a theoretical analysis of the forms of these planetary nebulae, but we are undoubtedly in a somewhat favoured position in having the original material to hand, and there would seem to be no harm in mentioning some of the theoretical points—avowedly speculative—which we have discussed between ourselves. It is possible that these may suggest sound lines of investigation to theoretical workers.

A first problem is the question of the stability of ring structures: the classical form of the planetary nebula is a star surrounded by a uniform shell such as No. 14. Is this form stable, or if not, will the ring later be breached at roughly opposite points as in No. 15?

A second problem is provided by the frequency of axially symmetrical forms such as Nos. 6, 8, 16 and 18. This type of form would seem to link up with the fairly common helical form such as Nos. 5 and 13, where the impression is, for all the world, as if matter had been squirted out from two opposite poles of a rotating star and left behind as it went along. This crude picture is palpably ridiculous: the ejected matter must have the momentum of the parent star. Can it then be that this type of form results from the interaction of two bodies or of the star with an interstellar medium? No. 13 is designated in the literature by "? two nuclei", while No. 5 has a second star or nucleus superposed on the nebula or involved in it. We can say nothing more here on this point.

Finally, the form of No. 15 is especially intriguing. One is almost compelled to see the structure as one in which matter is being driven away through the two breaches by radiation pressure. Then when it gets clear of the inner ring it becomes less luminous, since it is now partly screened by the central ring. Possibly the bright knot to the north represents a region crossing back across the full stream of stellar radiation escaping through the northern breach. But why, we may ask ourselves, does this wispy material show so marked a curvature? The track is impossible for matter moving under a purely gravitational force, and radiation pressure would reduce the curvature, not increase it. Is it merely fanciful to see a resemblance to solar prominences in these arched structures? Qualitatively one might see the central star, plus the inner ring, as a region from which energetic electrons might readily escape to form a space charge around the structure, while the wisps of gas themselves must be regions in which, outside the main radiation blast of the central star, recombination is the dominant process: that is to say, the wisp must be rich in ions. Have we here a situation somewhat
similar to that proposed by one of us (DSE) in connection with prominences, where, it was suggested, ions move in electric or magnetic fields. If this were so it might account for the opposite senses of the curvatures of the northern and southern wisps.

Now that we have good photographs of planetary nebulae available all round the Milky Way, it may be useful to offer some comments on the subject of the classification of planetary nebulae. Curtis proposed a classification on the basis of form, but, as has been pointed out by Stoy, this classification is not very satisfactory. It does not satisfy the essential conditions that the system must be so devised that each planetary goes into one and only one class, and that independent workers, classifying the same material, must arrive at substantially the same results. A classification on the basis of the observed spectrum is also possible, and has been proposed by Wright. However, it seems desirable that both types of classification should be attempted, since the relations between the two may throw light eventually on the origin and evolution of planetary nebulae.

One of the most striking things about planetary nebulae is that a high proportion of them possess symmetry of various types. Any system which has symmetry properties immediately becomes much more amenable to the mathematics of theoretical discussion, and it therefore seems desirable in order to assist theoretical development to concentrate on the symmetrical forms which occur. This may be only a temporary expedient, but, as the result of trial and error, the authors have found that the use of symmetry properties as a basis for classification is one (and indeed the only one) which enables a substantial measure of agreement to be secured between independent workers attempting to classify the same material.

In Plate 11, Fig. 21 we illustrate some of the symmetrical forms which are of common occurrence. Plate 11, Fig. 21 a and b illustrate what we call the spherically symmetrical forms, the simple disk and the simple ring respectively. Fig. 21 c, d, e, f, g, h and j are forms having biaxial symmetry about two axes at right angles. The first two we call the simple disk and the doubly indented disk. The next two are the simple ring and the doubly indented ring. The last three represent three examples of what we call complex biaxial forms. Plate 11, Fig. 21k is the helical form. Finally l and m represent centrally symmetric forms in which the structure is unchanged by reflection of each point of itself in the central star. We have proceeded on the system that no nebula which does not strictly fall into one of these classes should be classified as regular. The results of this classification for the 81 nebulae in our list and in Curtis’s list having dimensions over 8 seconds of arc are as follows:

- Spherical symmetry: 10 per cent,
- Biaxial symmetry: 45 per cent,
- Helical: 5 per cent,
- Central symmetry: 10 per cent,
- Irregular: 30 per cent.

That is to say, 70 per cent of planetary nebulae exhibit a high degree of symmetry. Further, we find that classification on this basis is unambiguous. If desired, it

† H. D. Curtis, Lick Obs. Publ., 13, 57, 1918.
‡ R. H. Stoy, The Observatory, 56, 269, 1933.
§ W. H. Wright, Lick Obs. Publ., 13, 193, 1918.
is possible to split the first two classes into the sub-classes already enumerated, e.g. simple disk, simple ring and so forth, but then the classification by independent workers becomes more ambiguous.

One final point of interest is provided by the question of projection. The maximum axis ratio exhibited by symmetrical nebulae is about $2:1$. If this is the true form of planetaries of this type, i.e. if they are prolate spheroids with axes in the ratios $2:1:1$, what proportion will appear circular as the result of projection? It can readily be shown that the proportion of nebulae with observed axis ratios in the range $R$ to $R+dR$ is

$$\frac{RdR}{\sqrt{3(4-R^2)}},$$

where $R$ runs from 1 to 2. The integral of this, giving the proportion with axis ratios between 1 and $1+x$, is

$$1 - \sqrt{(1 - 2x^2 + x^4/3)}.$$

This gives 3.5 per cent of cases with axes differing by less than 10 per cent and 7.6 per cent of cases with axes differing by less than 20 per cent. That is to say that the observed percentage of spherically symmetric cases is much too high to be accounted for by projection alone.

We hope that the material and comments presented here will be found to be in a form particularly adapted to the needs of theoretical workers.

Radcliffe Observatory,
Pretoria:
1950 May 11.

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