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On the Structure of the Nebula M 2-9*

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Summary. The structure of planetary nebula M 2-9 has been investigated on direct plates taken with the ESO 3.6 m-telescope in 1977–78. Compared with the photographs from 1952, 1971, and 1973 the main condensations in the wings show a remarkable shift approximately in the W-E direction which can be explained as a rotating motion about the nebular axis of symmetry (N-S axis). The angular velocity seems to increase with the distance from the core. Two faint loops extending to about 1′ on each side of the core and lying on the nebular axis were discovered. The very elongated shape of the nebula indicates the presence of an anisotropic velocity field in it.

Key words: planetary nebulae – morphology – structural changes

1. Introduction

The object M 2-9 = MH$_\alpha$ 362–8 (PK 10+18°2), sometimes called the Butterfly nebula, was classified as a planetary nebula by Minkowski (1947). This "remarkable planetary possessing a unique symmetry" (Aller, Liller, 1968) comprises a bright core and two symmetrical wings containing some bright condensations or knots. It is considered to be a planetary nebula in a formative stage (Allen, Swings, 1972; Calvet, Cohen, 1978; Andrillat, Swings, 1978).

Allen and Swings (1972) found large structural changes of the nebula between 1952 and 1971. They considered changes in the ambient radiation field and suggested that the radiation from a central star is moderated by variation in the surrounding dust cloud. Van den Bergh (1974) observed in 1973 that the distribution of bright condensations was similar to that existing in 1971, but he found some real changes also during these two years. He agreed with the suggestion made by Allen and Swings and regarded "shifting beams of ultraviolet radiation that escape between dust clouds that are swirling around a hot central object" as being responsible.

In this paper we report new measurements of M 2-9 for 1977–78 which hardly support the above explanation of the observed structural changes. We expect that the very extended shape of this nebula has dynamical consequences which are expressed by a large internal motion within the wings.

2. Observations

In 1977 and 1978 we photographed M 2-9 using the 3.6 m-telescope (F/3 prime focus, scale = $19''.03$ mm^{-1}) of the European Southern Observatory at La Silla. The parameters of the plates are given in Table 1.

In order to make positional measurements of the nebula as well as of its bright condensations some comparison stars had to be chosen on the 3.6 m-telescope direct plates. We measured eight secondary standard stars in the field of M 2-9 (Fig. 1) using a plate taken with the 40/404 cm astrograph (IIaO, exp. 30 min) at La Silla on April 29, 1978. The positions of M 2-9 (core) and of the comparison stars are based on 12 SAO standard stars. The absolute accuracy of the coordinates given in Table 2 can be

Table 1. List of plates

Plate No.	Date	Plate + filter combination	Exp. (min)
874	1977 Mar. 2/3	098 − 02 + H$_\alpha$	40
784	1977 May 16/17	IIIaJ + GG 385	40
808	1977 May 19/20	IIaO + GG 385	1
1540	1978 Apr. 1/2	IIIaF + RG 630	10
1541	1978 Apr. 1/2	IIIaF + RG 630	3
1656	1978 Apr. 13/14	IIIaF + RG 630	25
1657	1978 Apr. 13/14	098 − 02 + H$_\alpha$	20
1676	1978 Apr. 15/16	098 − 02 + RG 630	100

Table 2. Position of M 2-9 (core) and of the standard stars

Star	α	δ
	(1950.0)	
M 2-9	$17^h02^m52^s.57$	$-10°04'30''.8$
Comp. 1	02 53.40	11 23.4
Comp. 2	02 45.45	05 37.6
Comp. 3	03 13.59	05 22.6
Comp. 4	02 31.97	01 23.3
Comp. 5	03 07.06	09 22.9
Comp. 6	02 49.58	04 11.6
Comp. 7	02 42.32	06 24.1
Comp. 8	02 52.03	04 27.6

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* Based on observations made at the European Southern Observatory, La Silla, Chile

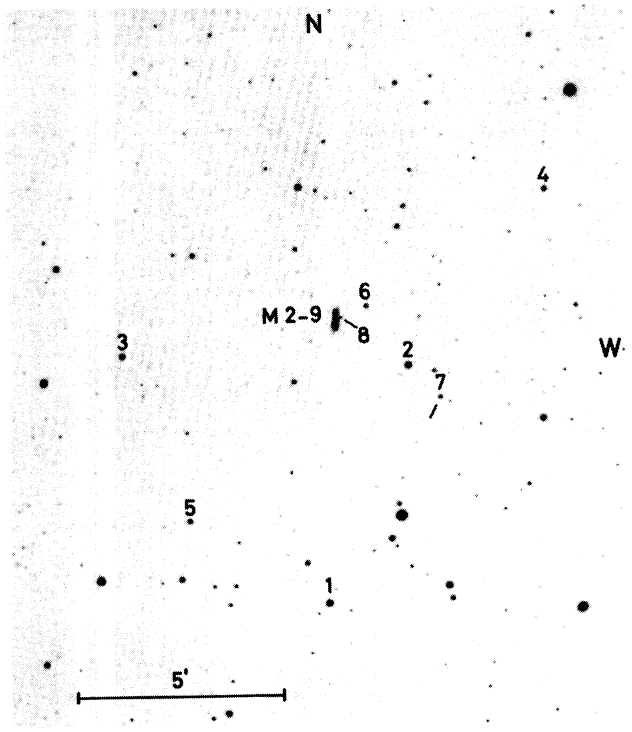

Fig. 1. Identification chart reproduced from a 30 min exposure of M 2-9 and standard stars (ESO 40 cm-astrograph, IIa-O); north at the top and east on the left

Fig. 2. M 2-9 in 1977. (ESO 3.6 m-telescope, Plate No. 784, scale $= 1\overset{\prime\prime}{.}1$/mm, north at the top)

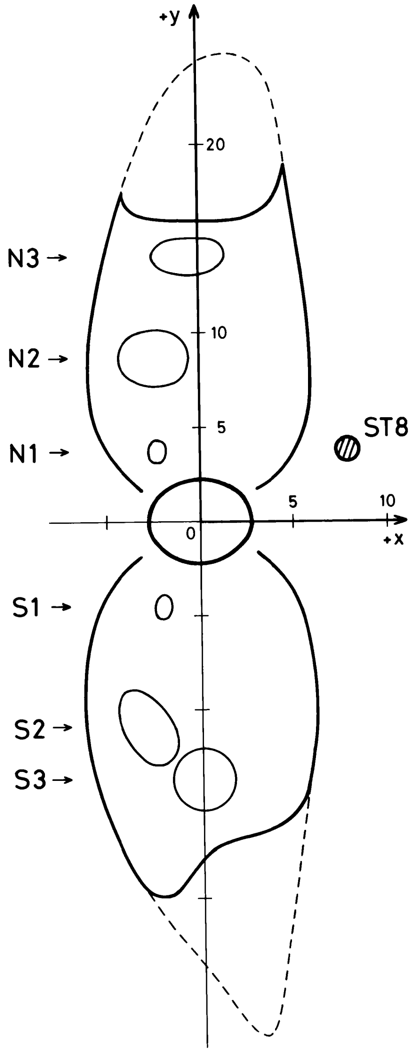

Fig. 3. Schematic drawing of M 2-9 showing the core, the nebular body including its faint structure (dashed line), the main condensations N 1, N 2, N 3, S 1, S 2, S 3 and star No. 8. The nebular axis was set identical with the *Oy*-axis having p.a. $= 358\overset{\circ}{.}1$. Scale in arc s

3. Structure of M 2-9 in 1977–78

The nebula M 2-9 consists of a bright central core and of two symmetrical but inhomogeneous wings containing some bright condensations (Fig. 2). The designation of the main condensations is given on the schematic drawing (Fig. 3). We introduced a rectangular x, y, z-coordinate system associated with the nebula having the zero point in the nebular centre, the y-axis identical with the axis of symmetry of the nebula and the z-axis lying in line of sight. The position angle of the y-axis was determined on the long-exposed plates Nos. 784, 1540, 1656, 1657, and 1676 and found to be very close to the north-south direction, p.a. (axis) $= 358\overset{\circ}{.}1 \pm 0\overset{\circ}{.}2$.

The dimensions of the core, of the wings, and of the six condensations are presented in Table 3. In the case of the core and of the condensations the seeing was taken into account and the observed values s_{obs} were corrected using a simple expression

$$s = (s_{\text{obs}}^2 - s_*^2)^{1/2},$$

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estimated to about $\pm 0\overset{\prime\prime}{.}3$, whereas their relative accuracy should be better. The position of M 2-9 can be compared with that published by Milne (1973): $52\overset{s}{.}5$, $31''$.

Table 3. Dimensions of the nebular features in the x- and y-direction (in arc s)

Feature	Dimension			Colour	Plates used
	s_x	s_y			
Core	3″.4	3″.1		red	1541
	4.6	4.2		red	1540
	5.3	4.4		red	1657
	5.4	4.4		red	1656
	6.4:	5.1:	[a]	red	874
	4.0	3.8		blue	784
Northern wing	11.8	17.6	(24″.7)[b]	red	874, 1540, 1656, 1657
	11.2	16.6		blue	784
Southern wing	12.2	19.8	(27″.3)[b]	red	874, 1540, 1656, 1657
	12.0	19.5		blue	784
Condensation					
N 1	0.93	1.20		red + blue	784, 1656, 1657
N 2	3.72	2.98		red + blue	784, 1540
N 3	3.82	1.97		red + blue	784, 1540
S 1	0.95	1.31		red + blue	784, 1540, 1656, 1657
S 2	4.4	2.6	[c]	red + blue	784, 1541
S 3	3.3	3.4		red + blue	784

[a] Slightly overexposed

[b] Faint structure which still belongs to the main nebular body

[c] Not in the (x, y) system; main axis of this condensation in p.a. = 29°

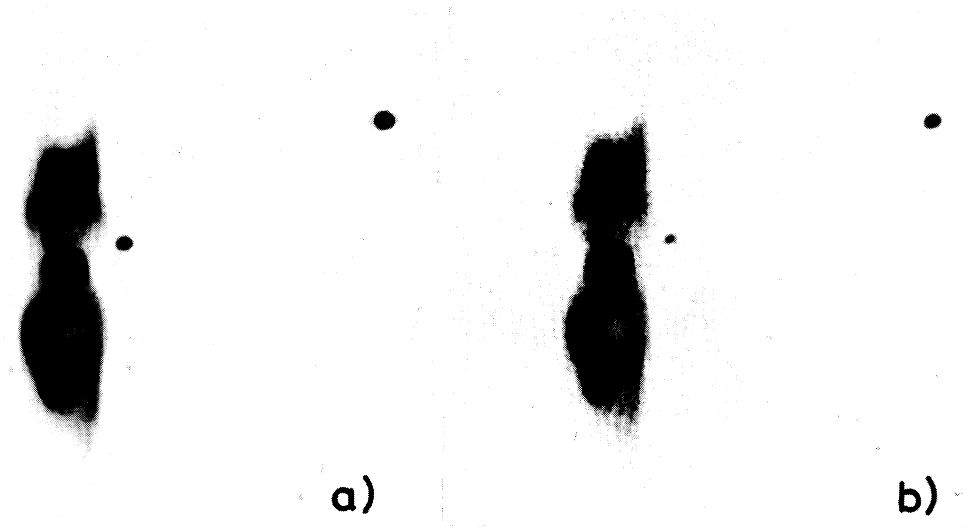

Fig. 4. M 2–9 in 1978. (ESO 3.6 m-telescope, scale = 1″.0/mm. **a** Plate No. 1656, IIIaF + RG 630, **b** Plate No. 1657, 098–02 + H_α)

where s_* is the diameter of the stellar seeing disc having a "surface" brightness similar to that of the measured feature. The seeing discs varied between 0″.85 and 1″.20.

The bright *central core* is nearly circular on the blue plate No. 784 but it is slightly elongated in the x-direction on the red plates. Its visible size grows with exposure time. This effect can be explained if we consider only a slow decrease of the nebular surface brightness from the centre. The diameter of the core as reported in Table 3 probably has a limit near 6″ × 5″; the 8″ core which was measured on the plate No. 1676 is obviously overexposed.

The northern and southern *wings* are similar in size and brightness and contain a bright inner region which extends into a fainter peripheral structure. The small difference in dimensions of the wings between the red and blue plates may be an effect of the exposure time.

The bright *condensations* clearly visible on the background of the wings possess a remarkable symmetry with respect to the x (east-west) axis: the southern condensations present more or less a mirror image of the northern ones. No substantial difference

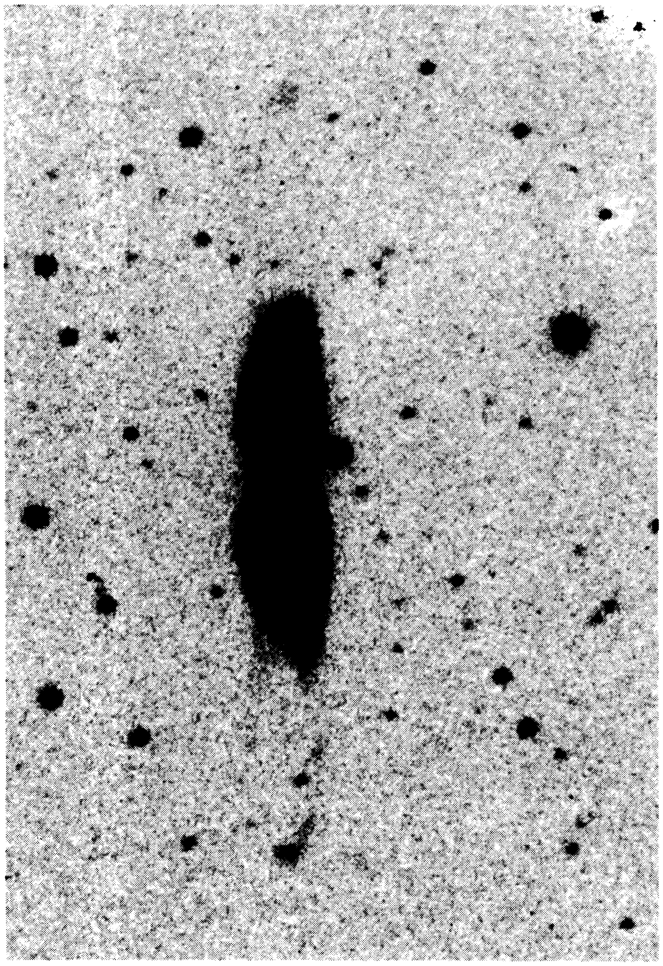

Fig. 5. M 2-9 in 1978. (ESO 3.6 m-telescope, plate No. 1676, scale = 1.″0/mm, north at the top.)

in size of the condensations has been found between the blue and red plates.

If we compare the structure of the nebula seen on the plate No. 1656 (red) and No. 1657 (H_α) (Fig. 4) we do not notice any substantial difference. This is to be expected because according to Allen and Swings (1972) H_α is much brighter than any other emission line in the red part of the spectrum of M 2-9. Moreover, H_α emission is substantially stronger than the continuum radiation in any part of the nebula as can be seen by comparing the stellar images on both plates.

Some new details in the structure of M 2-9 were discovered on the plate No. 1676 (Fig. 5). Two extremely faint loops protrude from the main nebular body along the north-south axis. At their ends two faint diffuse knots are visible having the following parameters:

Knot:		northern	southern
Position (1950.0)	α	$17^h02^m52.^s42$	$17^h02^m52.^s68$
	δ	$-10°03'33.''8$	$-10°05'27.''5$
Distance from the centre		$57.''0$	$56.''7$
Dimensions		$4.''4 \times 4.''8$	$3.''2 \times 1.''9$.

The position angle of the line connecting the two faint knots, $358.^\circ1$, is identical with that of the axis of symmetry of the main nebular body. The southern knot can be detected on the H_α plate No. 874 which leads to the conclusion that the gas of the knots also is ionized.

4. Morphological changes of M 2–9

The changes in the structure of this nebula discovered by Allen and Swings (1972) continued also in 1977–78. The present configuration of the main condensations is very similar to that in the year 1952 – except for one substantial difference: now the condensations lie at the *opposite* side of the nebula. A conspicuous shift of the condensations parallel to the x-axis can be observed. In order to investigate the morphological changes quantitatively we have measured the positions of N 1, N 2, N 3, S 1, S 2, S 3 on all suitable plates. The respective coordinates in the x, y-system (see Fig. 3) are summarized together with their mean errors in Table 4.

We succeeded in identifying all condensations in the years 1952, 1971, and 1973 also. We used the photographs which were reproduced from the following original plates taken at the $F/3.67$ prime focus of the Hale 508 cm telescope:

1952 – 103aE + OR 1, exp. 20 min, photo R. Minkowski, see Aller, Liller (1968),

1971 – 103aE + RG 2, exp. 5 min, photo H. C. Arp, see Allen, Swings (1972),

1973 – 098–04 + RG 2, exp. 10 min, photo S. van den Bergh, see van den Bergh (1974).

The nearby star No. 8 enabled us to determine the scale factor of the photographs and to transform the measured rectangular coordinates into our x, y-system. The resulting coordinates given also in Table 4 are obviously of lower accuracy than that we would have reached by measuring the original plates.

The mean errors of the rectangular coordinates in Table 4 represent only the inner accuracy of our measurements. In the case of the photographs from the years 1952, 1971, and 1973 the errors were determined using measurements on three different enlarged prints.

The observed shift of a given condensation along the x-axis can be imagined as a projection of the changing position in a plane perpendicular to the axis of symmetry and parallel to xz-plane. In this plane at a distance y from the centre of the nebula the position of a condensation can be described using polar coordinates (r, φ), where r is the distance from the axis of symmetry and φ the angle given by

$$\varphi = \pm \arccos (x/r).$$

The distance r is unknown but it can in principle be estimated from the photographs.

Indeed, we may assume that the plane $y = \text{const.}$ intersects the nebula in a circle having a radius r_n. If the condensation lies on the surface of the nebula the distance of its centre from the axis would be $r = r_n - s_r/2$, where s_r is the "thickness" of the condensation. The minimum value of r is identical with the maximum value of $|x|$ which we observe for the given condensation.

In Table 5 we present the polar coordinates of the condensations at five different epochs: $\bar{y}$ is the mean distance of the respective condensation from the xz-plane, s_x is its diameter in the x-direction (not corrected for the seeing).

Table 4. Rectangular coordinates of the main nebular condensations (in arc s)

t	1952.4[a]		1971.4[a]		1973.58		1977.32		1978.26	
	x	y	x	y	x	y	x	y	x	y
N 1	2″27	4″34	−0″83	3″70	−1″61	3″81	−2″25	3″87	−2″32	3″65
m.e.	± 5	5	6	2	4	4	7	1	3	6
N 2	3.58	8.64	−0.77	8.00	−1.03	7.70	−2.27	8.98	−2.58	8.40
m.e.	± 6	10	2	5	3	10	19	15	6	12
N 3	1.04	14.14	−0.03	14.11	−1.21	13.93	−0.84	14.13	−0.45	14.02
m.e.	± 11	12	18	7	8	14	9	6	10	9
S 1	2.32	− 4.16	−0.57	− 4.52	−1.48	− 4.22	−2.07	− 4.54	−1.97	− 4.44
m.e.	± 8	5	5	3	4	9	4	16	4	8
S 2	4.38	−11.08	−0.66	[b]	−1.96	[b]	−2.76	−11.15	−2.96	−10.63
m.e.	± 16	8	6		8		11	14	10	12
S 3	1.32	−13.88	[c]	[c]	[c]	[c]	−0.07	−13.98	0.31	−13.21
m.e.	± 16	7					17	15	7	9

[a] Fraction of the year estimated
[b] Overexposed, measurements uncertain
[c] Overexposed

Table 5. Parameters of the main nebular condensations (see the text)

Cond.	$\bar{y}$	r_n	$s_x/2$	r	φ					ω [°/yr]
					1952.4	1971.4	1973.6	1977.3	1978.3	
N 1	3″87	4″99	0″77	4″22 a	57°5	101°3	112°4	122°2	123°4	2.56 ± 0.13
	± 12			3.38 b	47.7	104.2	118.5	131.8	133.4	3.33 0.17
N 2	8.34	5.82	1.94	3.88 a	22.7	101.4	105.4	125.8	131.7	4.14 0.14
	± 23			4.85 c	42.4	99.1	102.3	117.9	122.1	3.02 0.12
N 3	14.07	4.98	1.99	1.4 d	−318.0	91.2	149.8	233.1	251.2	22.0 0.3
	± 04									
S 1	− 4.38	5.24	0.77	4.47 a	58.7	97.3	109.3	117.6	116.1	2.29 0.16
	± 08			3.58 b	49.6	99.2	114.4	125.4	123.4	2.94 0.20
S 2	−10.95	6.12	1.54	4.58 a	17.0	98.3	115.3	127.1	130.3	4.43 0.15
	± 16			5.35 c	35.0	97.1	111.5	121.1	123.6	3.46 0.13
S 3	−13.69	5.68	1.75	1.4 d	[a]	—	—	267.1	282.8	16.9: —
	± 24									

Model a: Condensation on the nebular surface; $s_r = s_x$ (nearly spherical)
Model b: Condensation located closer to the axis, a distance of $0.8r$ chosen; $s_r = s_x$
Model c: Condensation on the nebular surface; $s_r = s_x/2$ (like flattened disc or ellipsoid)
Model d: Condensation at distance r derived as the best linear fit of $\varphi(t)$
[a] φ ambiguous

Because of an uncertainty in r and in the shape of the given condensation only some representative models were calculated for $\varphi(t)$. At first we simply assumed (model "a") that the condensations N 1, N 2, S 1, and S 2 lay on the nebular surface and that $s_x = s_r$. We found φ to be in the range $\pm(17°, 131°)$; only φ increasing with time was taken into consideration.

Condensations N 1 and S 1 appear nearly spherical so that $s_x = s_r$ is valid, but they might also be located closer to the axis. As an alternative model ("b") we used $0.8r$. On the other hand N 2 and S 2 look like flattened discs or ellipsoids and we used $s_r = s_x/2$ for them (model "c").

The main result of all solutions is the *linear change of* φ *with time*. The slopes of the relation $\varphi = \omega \cdot t + \varphi_0$ are also given in Table 5.

As to condensation N 3, large differences in φ were observed during the interval 1971–1978. The best linear fit of these four values of φ was found for $r = 1''5$, the slope being $\omega = 23.9 \pm 0.5$. By extrapolating this solution to 1952 we derived $\varphi'(1952.4) = -362°$. The two observed values of φ closest to φ' were $\pm\varphi - 360°$; we then solved the linear dependence $\varphi(t)$ once more in the whole interval 1952–1978 and found the best fit to be for $r = 1''4$ as given in Table 5 (solution "d").

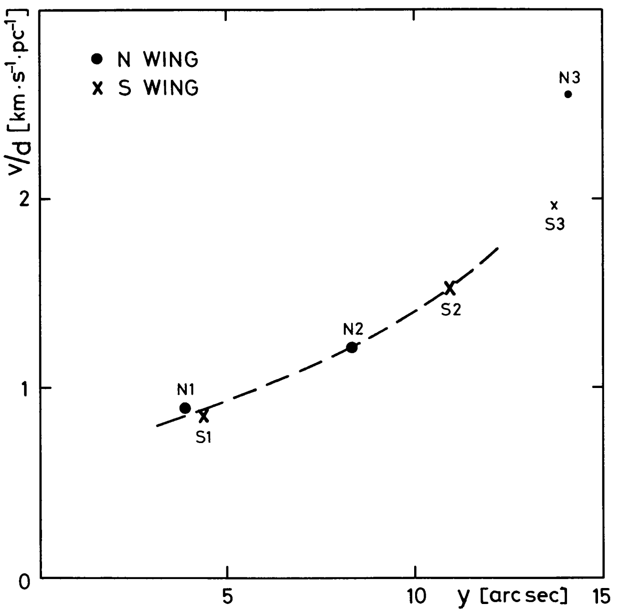

Fig. 6. Ratio v/d of the expected rotational velocity of the condensations v [km s^{-1}] (at the nebular distance d[pc]) as a function of the angular distance y'' from the core. Model a) has been used for N 1 and S 1, model c) for N 2 and S 2; N 3 and S 3 uncertain

In the case of condensation S 3 only a rough estimate of ω can be made. Assuming $r = 1''.4$ (like N 3) we got $\omega = 16.9$ from the measurements of φ in 1977 and 1978. It is difficult to link these two measurements with $\varphi(1952.4)$ because the latter can reach the values 19.5, -19.5, -340.5, and -379.5. The resulting ω could then lie between 10 and 26.

5. Discussion

Before coming to the interpretation of our measurements of the structural changes in M 2-9 we summarize the most important observational data:

1. The main condensations visible in the wings of M 2-9 in 1977–78 were identified also on the photographs taken in 1952, 1971, and 1973. Their corrected angular diameters lay between $0''.9$ and $4''.4$.
2. A shift of the main condensations in the x-direction occurred between 1952 and 1978; the y coordinates remained approximately constant.
3. The shift along the x-axis resulted from the changing position of the condensation in a plane approximately perpendicular to the axis of symmetry. Adopting polar coordinates in that plane we found a linear change of φ with time (assuming $r = \text{const.}$).
4. The "angular velocity" ω is not constant over the whole nebula, being greater near the nebular poles.
5. The configuration of the condensations is nearly symmetrical with respect to the x-axis (xz-plane). The northern condensations have counterparts in the southern wing.

We think that our observations are not compatible with the hypothesis of van den Bergh (1974) based on the suggestion of Allen and Swings (1972) that "the observed brightness changes in the nebula are due to modulation of the ultraviolet emission of the central object by dust clouds".

In our opinion it is difficult to imagine that only the "holes" in the dust clouds swirling around the exciting star are responsible for the changes in the structure described above. Even small changes in the configuration and in the size of such holes would be reflected as substantially larger changes in the illuminated areas of the nebula – but this was not observed (compare the condensations N 1 and S 1 in 1952 and 1977–78). If the dust envelope rotating around the star were to retain a stable form, how could the observed different angular velocities of the nebular condensations be explained? Moreover, the observed north-south symmetry of the condensations would require the same symmetry in the configuration of the holes in the dust envelope which seems to be very unlikely.

We suppose that the observed nebular condensations are actual gas clouds moving approximately in the planes parallel to the nebular equator (xz-plane). The observed change of φ is then interpreted as a result of the rotational motion having an angular velocity ω. This hypothesis is supported by radio observations of Purton, Feldman and Marsh (1975) who found evidence for small condensations of high density in the wings.

The main objection against large gas motions within the nebula may be found in the resulting high velocity of the condensations. At a distance of 1 kpc the velocity would be of the order of 10^3 km s^{-1}! Allen and Swings (1972) measured the internal motion in M 2-9 and found the radial velocities of the core, of the N and of the S condensation to be $+75$ km s^{-1}, $+47$ km s^{-1}, and $+83$ km s^{-1}, respectively. The relative velocities in the wings seemed to increase with distance from the core. Allen and Swings explained them "either by expansion in a direction inclined to the line of sight or by rotation about an E-W axis".

Allen and Swing's results do not contradict our hypothesis. The slit of their spectra was set approximately along the y-axis, in which the radial velocity corresponding to the rotation motion must be near zero. With regard to the radial velocities of ± 18 km s^{-1} relative to the core, we do interpret them as an expansion along the nebular N-S axis. The inclination of this axis to the line of sight seems to be close to 90°. For $i \approx 80°$ or 70° we would obtain $v_{\text{exp}} \approx \pm 100$ km s^{-1} or ± 50 km s^{-1}, respectively, at a distance of 12″ from the core.

The value of the rotational velocity depends strongly on the adopted distance of the nebula. This important parameter is actually unknown. Statistical methods which consider M 2-9 to be a common planetary nebula optically thin in the Lyman continuum locate it at very large distances: Perek (1963): 2.7 kpc; Cahn, Kaler (1971): 3.45 kpc; Cahn (1976): 3.25 kpc. Milne and Aller (1975) found combining radio and H_β measurements a distance of 3.33 kpc; however they derived the "effective absorbing distance" of M 2-9 to be only 0.48 kpc. Calvet and Cohen (1978) estimated the total nebular mass of M 2-9 to be $\approx 0.2\, d^3 M_\odot$ (d in kpc). The distance would then be about 0.9 kpc "to produce the conventional shell mass of a planetary nebula". The large uncertainty in the total nebular mass, in the filling factor, and the effect of the local absorption associated with M 2-9 are probably responsible for the very different values of its distance.

In our opinion the distance of M 2-9 has been *strongly* overestimated. If we were to admit a distance of 0.9 kpc, the respective diameter of the core (0.026 pc), the total extension of the wings (0.23 pc) and that of the outer peripheral structure (0.50 pc) would be unbelievably large for a planetary nebula in a formative stage. Only a fraction of a "conventional" shell mass of 0.1–0.2 solar mass can be expected for such a nebula. Assuming 1/10 of that value, which is for instance the total nebular mass of V 1016 Cyg according to Ahern et al. (1977), the distance estimated by

Calvet and Cohen would be reduced to about 0.4 kpc. Even a smaller value of the total mass can be imagined for proto-planetary nebulae.

Using the data given in Table 5 we derived the rotational velocity of the condensations in the wings: $v\,[\mathrm{km\,s^{-1}}] = 0.0827 \cdot \omega \cdot r \cdot d\,[\mathrm{pc}]$; ω is given in [°/yr] and r in arc s. The expression v/d shows an increase with distance from the core (see Fig. 6).

6. Preliminary Spectroscopic Results

M 2-9, classified sometimes as a bipolar nebula, has a very elongated shape. According to Mathews (1978) bipolar nebulae "appear to be prolate sheroids that have blown their bubbles out at each end". Accepting that the morphological picture of a nebula reflects the dynamical one (see Khromov, Kohoutek, 1968) we may expect an outstandingly anisotropic velocity field in M 2-9.

An attempt has been made to determine the radial velocity within the wings in the direction perpendicular to the N-S axis. In April 1978 only one useful spectrogram could be taken by one of us (J.S.) using the Boller and Chivens spectrograph of the ESO 3.6 m-telescope at La Silla (Carnegie image tube, IIIaJ baked, 80 Å/mm). The slit was set about 8″ from the core in the northern wing. The spectrum was taken through clouds with bad seeing and is underexposed except for H_α. The radial velocities of [O III] 5007 and H_β give the mean (heliocentric) value of (79 ± 16) km s^{-1}. The H_α and [O I] 6302 emission lines have been found to be very broadened which could be explained by Doppler shift but also by the instrumental effects.

The same telescope and equipment (dispersion 40 Å/mm) were used again in January 1979. Four spectrograms of the nebular wings in the range 4620–5620 Å were taken. The slit was set between 4 and 10″ to the north and south of the core, respectively. Unfortunately, the optical quality of the spectrograms is not very good, so that the following results are still preliminary:

1. The most prominent emission lines of [O III] 5007, 4959, and H_β have been found to be broadened. The lines are however partly overexposed.
2. Some lines, for instance Fe II 5198, Fe I 5587, and Fe II 5591, are slightly *inclined* (a redshift can be seen on the east side, a blueshift on the west side of both the northern and southern wing). The differential radial velocity was estimated to be $\Delta v_{\mathrm{rad}} = v_{\mathrm{rad,\,E}} - v_{\mathrm{rad,\,W}} \lesssim 50$ km s^{-1}.
3. The line inclination can be interpreted as rotation of the nebula about the N-S axis. The rotational velocity would then be $\Delta v_{\mathrm{rad}}/2$ or larger because the observed lines belong only to the brighter central part of the wings. This effect might increase the actual rotational velocity by a factor of two, so that we estimate $v \approx 50$ km s^{-1}.
4. If we link this slow rotation to the large changes of the structure of the nebular wings described above, we obtain the distance of M 2-9 to be near 50 pc (!).

We are aware of the large consequences which would follow from the spectroscopic results given (for instance unusual physical parameters of the exciting star, or high space density of such kind of objects). But it would be too simple to declare the extremely small distance of M 2-9 as highly improbable and to reject only merely for this reason the rotational hypothesis. We are not doing this because, firstly, the location of M 2-9 among local objects cannot in principle be excluded, and secondly, we do not know a better explanation for the observed structural changes within the wings than the rotation. Because the spectroscopic results given here are only very preliminary and insufficient, we think that it is too early to discuss the consequences mentioned as well as to calculate a theoretical model which could describe and explain the nature of this nebula. Better quality spectroscopic observations of M 2-9 are needed in order to confirm and supplement the above results.

7. Conclusions

The changes of position of the main condensations in the wings of M 2-9 discovered by Allen and Swings (1972) also continued in 1977–78. Compared with 1952 the condensations were shifted perpendicular to the axis of symmetry of the nebula (approximately in the W-E direction). In our opinion these observations are not compatible with the hypothesis of van den Bergh (1974) that the modulation of the ultraviolet radiation of the exciting star by dust clouds is responsible for the observed morphological changes. We believe that the condensations are actual gas clouds rotating about the nebular axis of symmetry (N-S axis) with an angular velocity probably increasing with the distance from the core. Our preliminary spectroscopic results support the proposed hypothesis of rotation and place M 2-9 among local objects.

Two very faint loops extending to about 1′ on each side of the core and lying on the nebular axis of symmetry were discovered. The very elongated shape of the nebula indicates the presence of an anisotropic velocity field in it.

More spectroscopic and photometric observations are planned in order to check the hypothesis of rotation and to investigate this remarkable nebula in all details.

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