THE PROGRESSIVE OCCULTATION OF THE BINARY CENTRAL STAR OF NGC 2346 BY A DENSE DUST CLOUD*

R.H. Méndez[1,5,6], B.F. Marino[2], J.J. Clariá[3,5,6]
and W. van Driel[4]

RESUMEN. La estrella central binaria de la nebulosa planetaria bipolar NGC 2346 está siendo progresivamente ocultada por una nube de polvo que presumiblemente es un subproducto del proceso de formación de la nebulosa planetaria. En este trabajo presentamos nuevas determinaciones fotoeléctricas y fotográficas del brillo de la estrella; aportamos evidencias de irregularidades en la evolución temporal de la curva de luz, atribuibles a inhomogeneidades en el borde de la nube; utilizamos la nube para mejorar estimaciones de algunos parámetros orbitales y características del sistema binario; obtenemos un límite inferior muy alto para la densidad total de material en el borde de la nube; y adelantamos una especulación sobre el origen de este objeto extremadamente denso.

ABSTRACT. The binary central star of the bipolar planetary nebula NGC 2346 is being progressively occulted by a dust cloud, presumably a by-product of the process that led to the formation of the planetary nebula. In this paper we present new photoelectric and photographic measurements of the stellar brightness; we show evidence of irregularities in the time evolution of the light curve, ascribable to inhomogeneities at the edge of the cloud; we use the cloud to improve our knowledge of some orbital parameters and characteristics of the binary system; we obtain a very high lower limit for the total density of material at the edge of the cloud; and we advance a speculation about the origin of this extremely dense object.

I. INTRODUCTION

The central star of the bipolar planetary nebula NGC 2346 has too late a spectral type (A5) to account for the ionization of the gas. This implies that a hot, visually undetected, star must be present. Radial velocity measurements on spectrograms taken from 1976 to 1981 have shown that the A-type star is a single-spectrum spectroscopic binary with a period of 16 days [Méndez and Niemela 1981 (Paper I), Méndez, Gathier and Niemela 1982 (Paper II)]. Since the γ-velocity of the binary system coincides with the nebular velocity, there is good reason to believe that the undetected companion is the true central star of NGC 2346. The interesting fact that the reddening determined from data of the nebula was larger than that derived from

[1] Instituto de Astronomía y Física del Espacio, Argentina.
[2] Auckland Astronomical Society, New Zealand.
[3] Observatorio Astronómico de Córdoba, Argentina.
[4] Kapteyn Laboratorium, The Netherlands.
[5] Visiting Astronomer, Cerro Tololo Inter-American Observatory, operated by the Association of Universities for Research in Astronomy, Inc., under contract with the U.S. National Science Foundation.
[6] Member of the Carrera del Investigador Científico, CONICET, Argentina.

* Based partly on observations made at the European Southern Observatory.

data of the central star led to the conclusion (see Paper I) that there must be a large amount of cold dust concentrated toward the outer parts of the nebula.

Shortly after Paper I was published, Kohoutek (1982a,b) announced surprisingly larg variations in the brightness of the central star. These variations did not exist before. A new spectrographic and photometric study, made immediately after Kohoutek's announcement, led us to ascribe this behaviour to the progressive occultation of the binary system by a dust cloud showing a large ratio of total to selective extinction, $R = A_V/E(B-V)$; we found R to lie betwee 5 and 7 (see Paper II).

More recently, several authors have published additional photographic and photoelectric photometry: Marino and Williams 1983, Schaefer 1983, Luthardt 1983, Kohoutek 1983.

In this paper we present further photoelectric and photographic photometry of the central star of NGC 2346; we rediscuss all the photometry collected since the beginning of the occultation; we take advantage of the occultation to obtain more information about the binary central star; we show that the cloud is extremely dense; and we advance an hypothesis about its origin.

II. NEW PHOTOELECTRIC OBSERVATIONS

Table 1 lists our new photoelectric measurements, obtained by JJC and RHM at the Cerro Tololo Inter-American Observatory (CTIO), and by WvD at the European Southern Observatory (ESO).

TABLE 1

NEW PHOTOELECTRIC MEASUREMENTS OF THE CENTRAL STAR OF NGC 2346

HELIOCENTRIC JULIAN DATE (2440000 +)	V	B–V	OBSERVER
5288.822	11.93	0.42	JJC
5290.793	12.08	0.50	JJC
5291.821	12.28	0.51	JJC
5292.825	13.19	0.59	JJC
5293.826	13.52	0.62	JJC
5294.824	14.01	0.69	JJC
5295.824	14.20	0.73	JJC
5308.806	13.67	0.62	WvD
5311.708	15.5:		WvD
5312.792	15.5:		WvD
5322.823	12.48	0.49	WvD
5323.778	12.96	0.53	WvD
5324.755	13.91	0.65	WvD
5325.792	15.0:		WvD
5339.854	13.3		RHM
5340.845	14.5		RHM
5341.843	14.7		RHM
5342.702	14.4		RHM

JJC made UBV measurements in 1982 November with the CTIO 1-m telescope, using cold box No. 54 with an S-20 photomultiplier. Several photometric standards were selected in the E-regions (Cousins 1973, 1974) and were measured every night. Stars a, b, c and d in Kohoutek's (1982b) finding chart were also measured several times and did not show any evidence of variations. Their average magnitudes and colors are listed in Table 2.

After some trials, the problem of the nebular background was handled in the following way: the central star was measured carefully using a diaphragm of 8.4 arc seconds (the seeing was always better than 2 arc seconds) the contribution from sky+nebula was measured witl the same diaphragm in several parts near the central star, and the average value was adopted. The uncertainty in the background level at the position of the star caused an estimated uncertainty of 0.1 mag at visual magnitude 14.

TABLE 2

COMPARISON STARS IN THE FIELD OF NGC 2346

STAR	V	U-B	n
a	10.26	0.20	16
b	11.04	0.12	4
c	12.02	0.12	3
d	12.83	0.23	3

WvD obtained VBLUW (Walraven) photometry in 1982 December with the ESO Dutch 90-cm telescope. The observational and reduction procedures were exactly the same as in Paper II.

RHM made observations in 1983 January with the CTIO 91-cm telescope, using the y filter of the Stromgren uvby system (CTIO set No. 4) and cold box No. 57 with an ITT FW 130 (S-20) photomultiplier.The diameter of the diaphragm used was 24 arc seconds. Since the y filter does not transmit strong nebular emissions, the contribution of nebular light was not so important as in the other cases. The measurements were made relative to the comparison star e in Kohoutek's (1982b) finding chart.

III. THE AUCKLAND PHOTOGRAPHIC MAGNITUDES

These magnitudes have been obtained by BFM from photographs taken with a 53-cm telescope on Kodak Tri-X film, using a yellow filter to approximate visual magnitudes. The data obtained in 1982 have already been published (Marino and Williams 1983). Some preliminary data obtained in 1983 January to April have been sent to the *IAU Information Bulletin on Variable Stars*. Meanwhile, new photoelectric V magnitudes for faint comparison stars, provided by Roel Gathier, have led to improvements at the faint end. Therefore, we have decided to publish, in Table 3, a revised list of all the Auckland *photovisual* magnitudes. A chart including the new comparison stars is being prepared, at the time of writing this paper, by the Variable Star Section of the Royal Astronomical Society of New Zealand.

TABLE 3

AUKLAND PHOTOGRAPHIC MAGS OF THE CENTRAL STAR OF NGC 2346

JULIAN DATE (2440000 +)	m_V	JULIAN DATE (2440000 +)	m_V
5090.8	14.1	5129.8	11.3
5091.8	14.0	5130.8	11.6
5092.8	12.5	5337.9	12.6
5093.8	11.8	5339.9	13.4
5094.8	11.6	5340.9	14.2
5095.8	11.4	5341.9	14.8
5099.8	11.5	5342.9	14.6
5100.8	11.7	5343.9	14.1
5101.8	11.9	5344.9	14.3
5105.8	14.6	5345.9	14.0
5106.8	14.5	5348.9	14.3
5111.8	11.5	5349.9	14.5
5113.8	11.5	5350.9	14.2
5114.8	11.6	5351.9	12.8
5115.8	11.4	5352.9	12.7
5116.8	11.4	5353.9	12.5
5117.8	11.9	5354.9	12.4
5118.8	12.7	5355.9	12.9
5119.8	14.0	5359.9	14.1
5120.8	14.6	5374.9	14.6
5127.8	11.4	5382.9	13.5
5128.8	11.4	5383.9	13.1

TABLE 3 (continued)

JULIAN DATE	m_V	JULIAN DATE	m_V
5384.9	13.0	5414.8	14.4
5387.9	13.8	5422.9	14.5
5398.9	14.3	5423.8	14.5
5400.9	12.9	5433.9	13.4
5403.8	13.7	5434.8	14.0
5408.9	14.2		

At magnitudes brighter than 14, the Auckland magnitudes are in good agreement with the photoelectric V magnitudes measured on the same dates by RHM (see Table 1) and by Kohoutek (1983). Some problems arise at fainter levels: the photographic V magnitudes become systematically brighter than the photoelectric ones, presumably because the nebular light produces an enhancement of the photographic image of the central star. We should add that the photographic *blue* magnitudes published by Schaefer (1983) and Luthardt (1983) appear to show a similar enhancement effect at brighter levels. In particular, Luthardt's magnitudes are systematically brighter than Gathier's B magnitudes measured on the same dates (compare with Table 2 of Paper II).

IV. THE EVOLUTION OF THE V LIGHT CURVE

In view of the problems mentioned at the end of Section 3, we have decided to avoid in our discussion all the blue magnitudes, and also the photographic V magnitudes fainter than 14. In Figure 1 we have plotted all the remaining V magnitudes, as a function of the orbital phase. The sources are: Kohoutek (1982b), Paper II, Tables 1 and 3 of this paper, and Kohoutek (1983). All phases were computed using a period P=15.991 days and a t_0=2443126.0, as determined from the radial velocities measured before the beginning of the occultation (see Paper II). The uncertainty in the period is 0.02 days. The *photometric period* determined by Kohoutek (1983) is somewhat misleading, because the phase of minimum light does not necessarily remain constant as the A-type star moves relative to the dust cloud. In fact, at the beginning of the occultation (1982 Jan.-Feb.) the phase of minimum light was 0.85; one month later it had decreased somewhat, and afterwards it has remained more or less constant at 0.80.

Fig. 1 shows that the variation of the light curve has not been monotonous; for example, between 1982, March and June (JD 2445050-5130) the maximum magnitude became brighter. The fluctuations can be seen more easily in Fig. 2, where we have plotted the amount of visual absorption, in magnitudes, as a function of time, for orbital phases 0.3 and 0.6. To measure the absorptions, we have adopted 11.2 as the normal V magnitude of the A-type star (Méndez 1978). We ascribe the fluctuations shown in Fig. 2 to inhomogeneities at the edge of the cloud.

In the plot for phase 0.6 we have added two important points derived from Schaefer (1983): a Harvard B plate taken on JD 2444911.887 shows no evidence of occultation, and another one taken on JD 2444958.793 shows more absorption than measured by Kohoutek 40 days later. This confirms that the cloud has a somewhat irregular edge. The remarkable sharpness of the cloud's edge will be discussed in Section VI.

V. ANALYSIS OF THE V LIGHT CURVE: THE BINARY ORBIT AND THE UNSEEN COMPANION

From Paper I we know that the eccentricity of the orbit of the A-type star is small; our conclusions will not be affected significantly if we assume for a moment that the orbit is circular.

Let us define a coordinate system in the plane of the sky, fixed to the dust cloud, such that the y-axis coincides, at some arbitrary time t=0, with the line of nodes of the star's orbit. The helical motion of the star relative to the cloud, as it performs its orbit, can be expressed as follows:

$$X(t) = a_1 \cos i \cos (2\pi t) + V_x t \qquad (1)$$

$$Y(t) = a_1 \sin (2\pi t) + V_y t \qquad (2)$$

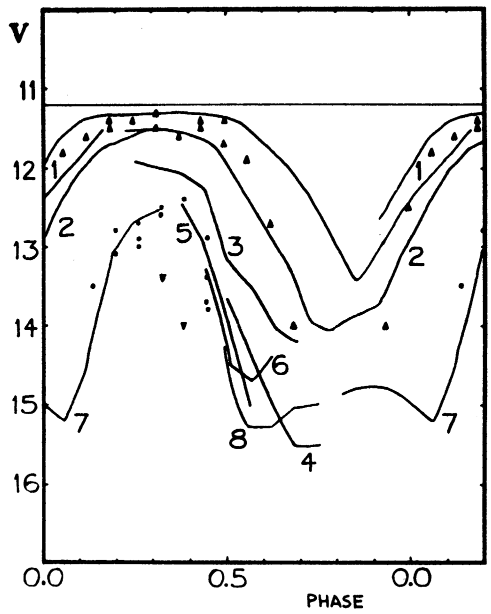

Fig. 1. The evolution of the V light curve. We have presented the photoelectric measurements as solid lines, labeled in chronological order as follows: 1: Kohoutek, 1982 Jan-Feb. 2: Gathier, 1982 Mar-Apr. 3: Clariá, 1982 Nov. 4,5: van Driel, 1982 Dec. 6: Méndez, 1983 Jan. 7,8: Kohoutek, 1983 Jan. The Auckland photographic V magnitudes are presented as isolated symbols, defined as follows: Triangles pointing up: 1982 May-Jun. Filled squares: 1983 Jan-Mar. Triangles pointing down: 1983 Apr. All phases have been computed with P = 15.991 days and t_o = 2443126.0 (see text).

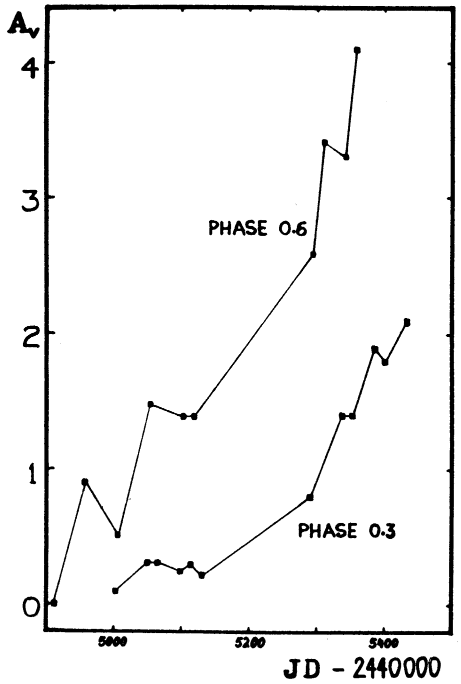

Fig. 2. The visual absorption, in magnitudes, as a function of time, for orbital phases 0.3 and 0.6. The observed fluctuations are ascribed to irregularities at the border of the cloud.

where t is time, measured in units of the orbital period, a_1 is the major semiaxis (radius) of the star's orbit, i is the orbital inclination, and V_x, V_y give the motion of the binary's center of mass relative to the cloud.

An inspection of Fig. 1 shows that, for each orbital phase t_1, there is another phase t_2 for which the amount of absorption remains more or less the same as for t_1; for example, phases 0.10 and 0.51, or 0.00 and 0.61. This implies that the behaviour of the light curve as a function of time is consistent, to a first approximation, with a cloud having straight, parallel lines of equal absorption. These lines of equal absorption have been schematically represented in Fig. 3 as horizontal lines. In Fig. 3 we have also defined an angle α between the y-axis (the line of nodes) and the lines of equal absorption.

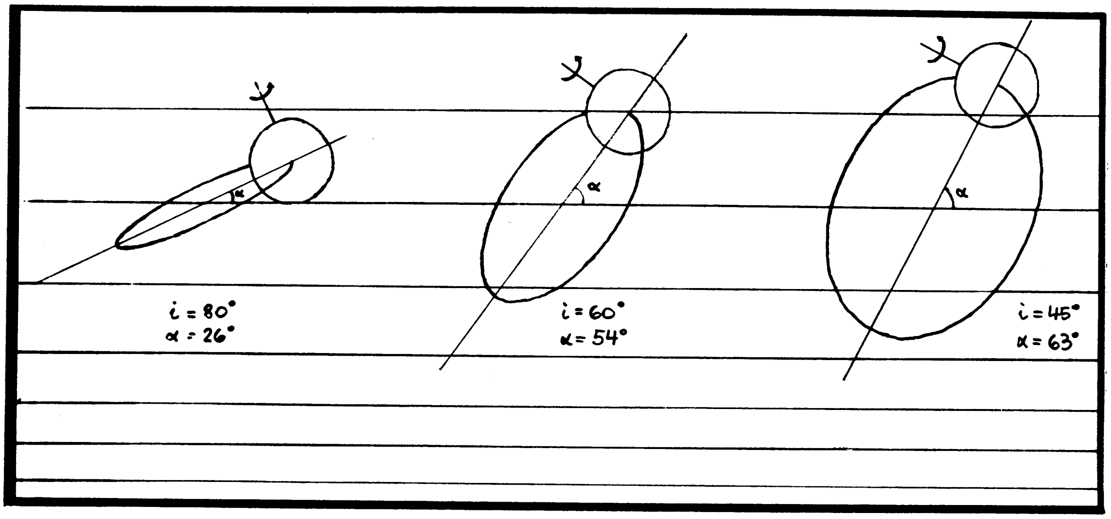

Fig. 3. The A-type star and its orbit, drawn to scale for three different values of the angle α between the line of nodes and the lines of equal absorption in the cloud (the amount of absorption increases downward). The radius of the A-type star is 2.2 solar radii (see Table 4). The position of the star on its orbit corresponds to orbital phase 0.25, and the drawings are made, for simplicity, for the case $V_x=V_y=0$ (see equations 1 and 2). Actually, of course, the motion of the A-type star relative to the cloud is helical. The star's projected axis of rotation is also indicated in each drawing.

There is a relation between the angle α and the orbital inclination, given by the equation of the line of equal absorption that goes through the points $(X(t_1), Y(t_1))$ and $(X(t_2), Y(t_2))$. For $V_x = V_y = 0$, the following relation holds:

$$\mathrm{tg}\,\alpha = \frac{X(t_1) - X(t_2)}{Y(t_1) - Y(t_2)} = \left[\frac{\cos(2\pi t_1) - \cos(2\pi t_2)}{\sin(2\pi t_1) - \sin(2\pi t_2)}\right] \cos i$$

Replacing t_1 and t_2 by their observed values (e.g. 0.10 and 0.51), we find:

$$\mathrm{tg}\,\alpha = 2.77 \cos i$$

In Fig. 3 we have plotted three possible solutions. For large orbital inclinations, near 90 degrees, α becomes very small. In this case it is very difficult to explain the large rotation effect on the radial velocity curve, observed in 1982, March-April (see Paper II), because the rotation axis of the A-type star becomes almost perpendicular to the lines of equal absorption. Using this argument, we can reject very large inclinations. On the other hand, orbital inclinations smaller than about 45 degrees would not be consistent with the bipolar structure of the nebula, as already discussed in Paper I. Summarizing, the analysis of the light curve permits a rough estimate of the orbital inclination:

$$i = 60 \pm 15 \text{ degrees.}$$

From Paper I we know that $a_1 \sin i = 3.6 \times 10^6$ km, then $a_1 = 4.2 \times 10^6$ km; moreover if we assume that the mass of the A-type star is 1.8 solar masses, then the mass of the unseen companion is slightly less than 0.4 solar masses. An exploration of the possible significance of this rather low value is beyond the scope of the present paper.

Now let us consider if the hot exciting star can be detected. Table 4 lists some useful parameters. The luminosity of the hot star was computed using the Harman-Seaton method, which assumes a blackbody spectral energy distribution (see Méndez 1978), and adopting a distance of 700 ± 100 pc (see Paper I). Assuming a blackbody energy distribution, we can estimate m_{V_0}, the (dereddened) apparent visual magnitude of the hot star; the dereddened flux received at the earth at $\lambda_V = 5480$ Å is

$$\frac{4\pi R_*^2}{4\pi d^2} \pi B_{\lambda_V} = 10^{-0.4\, m_{V_0}} \times 0.365 \frac{\text{erg}}{\text{cm}^2 \text{ s cm}} ,$$

where R_* is the stellar radius, d is the distance, πB_{λ_V} is the monochromatic flux emerging from the stellar surface, and 0.365 is the flux, in erg cm^{-2} s^{-1} cm^{-1}, received from a star with m_V=0. In this way we find, for the hot star, m_{V_0} = 16.5. This is so faint that the nebular light will make it very difficult to detect the hot star in the optical region.

TABLE 4

PARAMETER	A-TYPE STAR	HOT STAR	REFERENCES
T_{eff}	8000 K	100000 K	3, 1, 2
Luminosity	18 $L_\odot$	33 $L_\odot$	3, 1
Radius	2.2 $R_\odot$	0.019 $R_\odot$	

LIST OF REFERENCES:

1. Méndez 1978.
2. Calvet and Cohen 1978.
3. Méndez and Niemela 1981 (Paper I).

The situation is different in the ultraviolet. From the data listed in Table 4 we find that the hot star should provide about 85% of the observed flux at 1500 Å. Perhaps we should point out here that the conclusion in a previous paper (Méndez 1978), that we should not expect a contribution of more than 10% at 1550 Å, was based on the assumption that the interstellar reddenings of the hot star and of the nebula were the same; while we are now assuming the same reddening for both the hot star and the A-type star, which are much less reddened than the nebula (see a detailed discussion in Paper I).

Indeed, in Paper I we showed that the ANS ultraviolet data (Pottasch *et al.* 1978) appear to be consistent with the existence of a strong ultraviolet excess in the spectral energy distribution of the A-type star.

This opens the possibility of an interesting test: if the hot star is the companion to the A-type star, its brightness should be maximum, that is to say near orbital phase 0.8, and viceversa near phase 0.3. Therefore, we would expect the dust cloud to produce a measurable enhancement of the ultraviolet excess near phase 0.8, and a decrease near phase 0.3. Unfortunately, in all the IUE spectra obtained after the beginning of the occultation the continuum is so faint and noisy that probably it is not possible to obtain a reliable slope (W.A. Feibelman, private communication). Better ultraviolet observations through the dust cloud (if possible) would help to obtain useful information about the motion and spectral energy distribution of the hot exciting star of NGC 2346.

VI. ANALYSIS OF THE V LIGHT CURVE: CHARACTERISTICS OF THE CLOUD

It is possible to establish a lower limit for the motion of the cloud relative to the binary's center of mass. In Fig. 1 we see that the magnitude at maximum in 1983 April orbital phase 0.3) was the same as the magnitude at minimum in 1982, February (orbital phase 0.85). Therefore, the cloud has moved at least 7 x 10^6 km relative to the binary in 423 days, which implies a lower limit of about 0.2 km/s for the relative velocity.

Moreover, there are reasons to increase this lower limit. In 1982, March-April the rotation effect on the radial velocity curve was very strong (see Paper II), implying a strong absorption gradient. However, at that time the light curve was almost stationary (see Figs. 1 and 2). From these two facts we infer that the motion of the binary, relative to the cloud, has been almost parallel to the lines of equal absorption; that is to say, in Fig. 3 the horizontal component of the orbital motion must be substantially larger than the vertical component, for which we have just derived a limit of 0.2 km/s. So we conclude that the lower limit for the relative velocity must be 0.6 km/s. More detailed studies of the changes in the light curve may provide a more precise determination of the relative motion, which is important in a discussion of the origin of the dust cloud.

Finally, we consider the most remarkable observational fact in this unexpected occultation: the very sharp edge of the dust cloud. In 1982, March-April (see Fig. 1) the maximum visual absorption was 2.8 mag (phase 0.8) and the minimum was 0.4 mag (phase 0.3). From the analysis in Section 5 we know that the corresponding distance an the plane of the sky was not more than 10 km. We shall call this distance X (see Fig. 4, which is explained below).

We can obtain the corresponding column densities N_d (dust particles/cm) from

$$A_v = 1.086\, Q_v\, \pi\, a^2\, N_d \quad ,$$

where A_V is the visual absorption in magnitudes, Q_V is the extinction efficiency and πa^2 is the geometrical cross section of a dust grain. Using $a = 10^{-5}$ cm and $Q_V = 2.1$, we find the column density to be 5.6×10^8 particles/cm^2 at maximum light, and 7 times larger at minimum light.

In order to derive the density at the border, in dust particles/cm^3 , we need the length of the column through the cloud.

If the cloud is a foreground object, not related to the planetary nebula, then we do not expect its angular size to be larger than 2 arc seconds; otherwise, at light minimum we would see a dark spot superimposed upon the nebula. If the object is within the nebula, then we expect many similar objects to be present, with angular sizes much smaller than the nebular size. Again, 2 arc seconds appears to be a reasonable upper limit. One could argue that perhaps we are dealing with a large dust disk, as in other bipolar nebulae; however, these disks always produce a strong reddening, even when they are tilted; and, in Paper I, we have shown that the A-type star was not substantially reddened before the beginning of the occultation. If we try to overcome this objection by suggesting a fragmented, almost completely disrupted disk, then again the fragments are not expected to be very large. In summary, it seems reasonable to suggest that, whatever its origin, the dust cloud has a roughly spherical symmetry, with an angular size smaller than 2 arc seconds. At a distance of 700 pc (see Paper I), this implies that the radius of the proposed spherical cloud should be smaller than 10^{16} cm.

In Fig. 4 we have illustrated the geometry of the situation, assuming a perfectly spherical cloud. Let us call K the ratio of maximum to minimum absorption, which is also the ratio of maximum to minimum column density. For constant density in the outskirts of the cloud, $L_2 = KL_1$. Knowing $\Delta X = 10^{12}$ cm and K = 7, we can solve for the length L_1 as a function of R, the cloud radius. Expressing the solution in units of ΔX,

$$L_1^2 = \frac{\left[(K^2+1)^2 + (K^2-1)^2(4R^2-1)\right]^{0.5} - (K^2+1)}{(K^2-1)^2}$$

Table 5 gives the length L_1 for several possible values of R: we notice that an upper limit for L_1 is 20 ΔX = 2×10^{13} cm. Therefore, a lower limit for the dust grain density is:

$$n_d = \frac{N_d}{2L_1} \geq 10^{-5}\ cm^{-3}$$

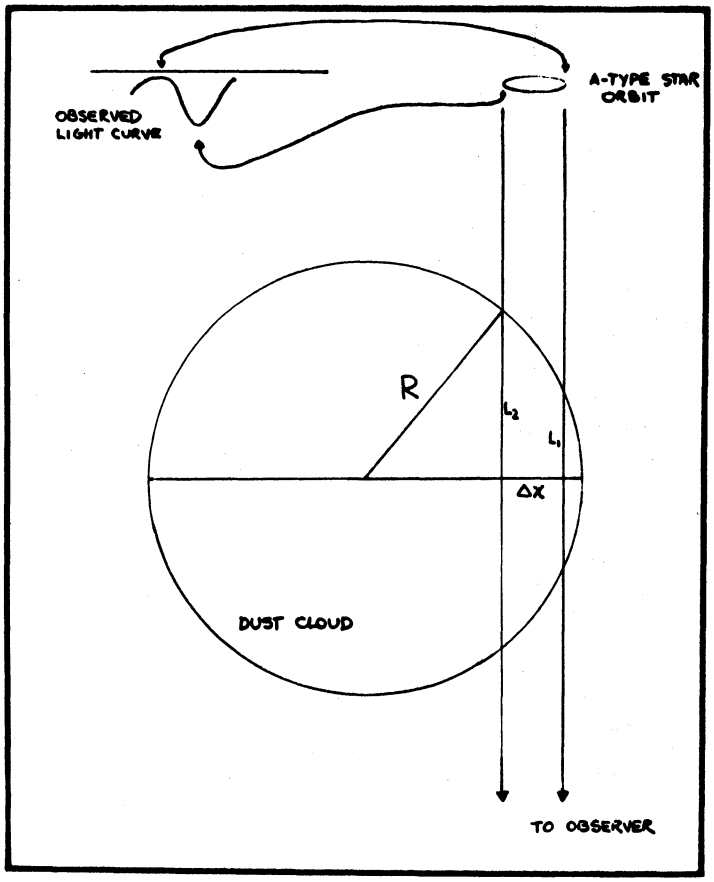

Fig. 4. A schematic model of the dust cloud (spherical, constant density), used to derive the length of the column through the cloud as a function of ΔX, the displacement of the A-type star on the plane of the sky; R, the cloud's radius; and K, the ratio of maximum to minimum visual absorption produced by the cloud (see text and Table 3).

Since we assume grains with masses of about 10^{-14} g, we find that the dust mass density must be larger than 10^{-19} g cm^{-3}. Finally, assuming a dust-to-gas ratio of 1/100, we arrive at a total mass density, at the edge of the cloud, larger than:

$$10^{-17} \text{ g cm}^{-3}.$$

This lower limit we have found for the density *at the edge* is at least 2 orders of magnitude larger than the *average* densities usually determined for dense Bok globules (see e.g. Table 22 in Martin and Barrett 1978). Besides, the sharpness of the edge presumably indicates that this extremely dense dust cloud is gravitationally bound, and this leads us to expect a central density substantially larger than the density at the edge. Unfortunately, we do not have enough information to attempt to make a reliable estimate of the mass of this remarkable object.

TABLE 5

LENGTHS OF COLUMN THROUGH THE CLOUD

R (10^{12} cm)	L_1 (10^{12} cm)
10	0.63
100	2.04
1000	6.45
10000	20.4

VII. DISCUSSION

Although it is not yet possible to reach a firm conclusion about the origin of this dense cloud, perhaps it is useful to advance some ideas. We assume that the cloud is a by-product of the process which led to the formation of the planetary nebula, because the alternative of a foreground object, passing by chance in front of NGC 2346, would appear to be extremely unlikely. A prerequisite for the formation of a very dense cloud is a large amount of circumstellar material, presumably expelled from the more evolved component of the binary system. We assume that the material was ejected preferentially in the equatorial plane, forming a thick disk around the binary system.

The interesting point is that, while other bipolar nebulae show clear evidence of equatorial disks, NGC 2346 does not. These disks always produce a strong reddening, while we know that the A-type star of NGC 2346 was essentially unreddened before the beginning of the occultation. Moreover, the information collected by Schaefer (1983) and Luthardt (1983) shows no evidence of light variations from 1899 to 1981. From this we have to conclude that the sky is very *clean* near the A-type star.

To overcome this problem, Calvet and Peimbert (1983) have suggested that the disk is in a state of disruption. If this idea is correct, the dust cloud could be a fragment of a disrupting disk. However, as mentioned at the end of Section VI, the sharp edge of the cloud suggests that it is not being disrupted. Based on this argument, and on the previous absence of reddening in front of the A-type star, we would suggest that the disk has already been disrupted, and that most of the material has been dispersed towards the outer parts of the nebula (a necessary assumption in Paper I, to explain the nebular reddening, leaving the A-type star unreddened).

From these arguments we are led to the speculative conclusion that some remnants of the disk have collapsed or are collapsing, perhaps in the same way planets formed when the Sun was a protostar. This process of collapse might be a good explanation for the extremely high density we have found in Section VI. We have no way to decide if these proposed collapsed or collapsing clumps should remain bound to the binary system, or if they should instead become an inconspicuous component of the interstellar medium.

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DISCUSSION

Ibáñez: Uds. pueden dar un número para la razón: densidad de polvo/densidad de gas o están suponiendo una razón normal?

Méndez: No estamos suponiendo nada; nuestro análisis de la nube es independiente de la relación gas/polvo en la nebulosa, que por otra parte parece ser normal (IRAS, no publicado).

Rodríguez: Mencionaste que la magnitud visual de la estrella A5 disminuyó primero y luego volvió a aumentar antes de disminuír de nuevo. ¿Implica ésto que la nube que la está ocultando es inhomogénea?

Méndez: En efecto, suponemos que las fluctuaciones en la variación de la curva de luz se explican como resultado de las irregularidades en el borde de la nube.

Roberto H. Méndez: Instituto de Astronomía y Física del Espacio, C.C. 67, Suc. 28, 1428 Buenos Aires, Argentina.
B.F. Marino: Auckland Astronomical Society, P.O. Box 2858, Auckland 1, New Zealand.
Juan J. Clariá: Observatorio Astronómico de Córdoba, Laprida 854, 5000 Córdoba, Argentina.
W. van Driel: Kapteyn Laboratorium, Postbus 800, 9700 AV Groningen, The Netherlands.