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THE RELATIONSHIP BETWEEN HD 87892 AND NGC 3132

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ABSTRACT

The observations suggest that the central star of NGC 3132 is a double system, the visually brighter component being HD 87892. The nebula is ionized by a very hot object whose characteristics are briefly discussed. The assumption that NGC 3132 lies at the same distance as HD 87892 leads to a very small ionized nebular mass.

Subject headings: nebulae, individual — planetary nebulae — stars, individual

I. INTRODUCTION

The A-type star HD 87892 lies at the center of the planetary nebula NGC 3132. Since such a star is not able to excite the nebula, there must be a hotter star responsible for the nebular spectrum, and the question immediately arises if there actually is a physical connection between these two stars or if we are dealing with just a chance configuration, which is rather improbable but cannot be neglected *a priori*. In fact, the only way to show conclusively that they are related would be to detect some contribution from the hot star in the spectrum of HD 87892, and demonstrate that both stars are revolving around each other. If we lacked these evidences, we could only take the physical connection between the A star and the nebula as highly probable, even if we found no observational argument against it.

The radial velocities of HD 87892 and NGC 3132 have been studied by Evans (1968). The nebular emission lines always appear superposed upon the stellar spectrum, thus making it possible (but also difficult) to determine both sets of radial velocities on the same plate. From the analysis of seven spectra, Evans found some indication of variations in the radial velocity of the star, and interpreted these possible variations as due to binary motion.

Webster (1969*a*) has stated that HD 87892 and NGC 3132 cannot be at similar distances because of the considerable difference between the interstellar extinctions independently determined for them; the photometric observations by Evans (1968) and Webster (1969*b*) suggest very little interstellar reddening for HD 87892, while the Hγ to Hβ ratio measured by Aller and Faulkner (1964) leads to a large value of the extinction for the nebula. On the other hand, recent determinations of the extinction coefficient for NGC 3132, from comparisons between radio and optical data, yield much lower values (Cahn and Kaler 1971; Aller and Milne 1972).

Carlson (1968) has reported the presence of the λ4471 absorption line of He I in the spectrum of HD 87892. Brown, Higginbotham, and Lee (1970) have reported both the λ4471 line and the λ4144 line of He I, and have suggested that they are due to the hot star which ionizes the nebula. This is in disagreement with the photometric data of Evans (1968) and Webster (1969*b*), which show no indication of the ultraviolet excess one should expect if there is a significant contribution from a hotter object to the continuum of the A star.

This paper presents new observations in an attempt to clarify some discrepancies described above and to reach more definite conclusions on the relationship between HD 87892 and NGC 3132.

II. THE OBSERVATIONAL MATERIAL[1]

Photoelectric *UBV* measurements of HD 87892 were made with one of the 16-inch (40 cm) telescopes at Cerro Tololo Inter-American Observatory (CTIO) on 1973 May 21 (JD 2441823.59), using an amplifier instead of an integrator. Suitable standard stars were measured to correct for atmospheric extinction and express the results in the *UBV* system. The observations were performed through a diaphragm 20″ in diameter, and the nebula was carefully scanned with it in order to estimate the contributions due to the emission lines when the diaphragm was centered on HD 87892. These contributions were allowed for to obtain the corrected *UBV* magnitudes of the star, which should not be in error by more than 0.04 mag, and are given in Table 1 together with the values of Evans (1968), for comparison.

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[1] The radial velocity measurements and microphotometer tracings were made at La Plata Observatory with a Grant comparator microphotometer funded through AFOSR grant 3114-66 to Dr. J. Sahade. The radial velocity and *UBV* measurements were reduced with the IBM/360 computer at the Mathematics Department of La Plata University.

TABLE 1

HD 87892: *UBV* MAGNITUDES

Spectral Region	This Work	Evans
V..............	9.99	10.17
$B - V$..........	+0.05	+0.05
$U - B$..........	+0.14	+0.19

The spectral energy distribution of HD 87892 from 3500 to 8400 Å was measured relative to that of the B9 V star θ Crt, one of the standards calibrated by Hayes (1970). The spectrophotometric observations were carried out by Virpi Niemelä with the two-channel spectrum scanner of CTIO on 1972 June 23/24 and 1973 May 21/22. The 1972 observations were made with the 60-inch (150 cm) telescope, the exit slit bandpasses being 10 Å in the second order (3600–4600 Å) and 20 Å in the first order (5600–8400 Å); while the 1973 observations were made with the 36-inch (90 cm) telescope in the second order (3500–4600 Å), using an exit slit of 20 Å. The monochromatic extinction coefficients applied to correct the observed fluxes for atmospheric extinction were determined in each case from scanner observations and narrow-band photometry of standard stars. The difference of the monochromatic magnitudes of HD 87892 and θ Crt was calculated, and is plotted as a function of wavelength in Figure 1. The V-magnitude of HD 87892 was estimated from a monochromatic magnitude difference of 5.30 mag at $\lambda = 5480$ Å as taken from Figure 1, adopting $V = 4.70$ for θ Crt (Hayes 1970). The result is $V = 10.00$, in good agreement with the measured value of V given in Table 1.

The spectrograms of HD 87892 secured for the present investigation are listed in Table 2, and the heliocentric radial velocities obtained from them are given in Table 3. The A and C plates were taken with the Cassegrain spectrographs attached respectively to the 36-inch and 60-inch telescopes at CTIO. Each of the two C plates was

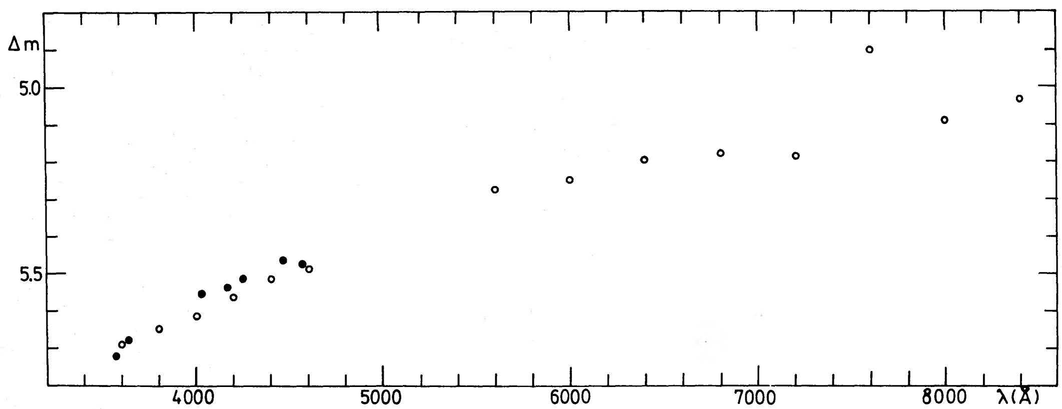

FIG. 1.—The monochromatic magnitude differences (HD 87892 − θ Crt). *Open circles*, 1972 observations; *filled circles*, 1973 observations.

TABLE 2

SPECTROGRAMS OF HD 87892

Plate*	Date	UT (mid-exp.)	Julian Day† (2,441,000+)	Dispersion (Å mm^{-1})
C2198............	1971 Dec. 6	6:44	291.780	79
C2202............	1971 Dec. 7	7:32	292.813	79
I8194............	1972 Jan. 28	7:04	344.797	42
I8199............	1972 Jan. 30	6:37	346.778	42
I8211............	1972 Feb. 4	4:00	351.670	42
A2294............	1972 June 21	23:52	490.494	125
A2321............	1972 June 25	23:20	494.471	125
A2612............	1973 May 21	0:36	823.527	125
A2619............	1973 May 25	1:57	827.583	121
A2632............	1973 May 27	1:10	829.550	121

* All the spectrograms were taken on Kodak IIa-O emulsion.

† The light-time correction has been applied.

TABLE 3

HD 87892 AND NGC 3132: HELIOCENTRIC RADIAL VELOCITIES (km s^{-1})

Feature	C2198	C2202	I8194	I8199	I8211	A2294	A2321	A2612	A2619	A2632	Unweighted Mean of All Plates
Weighted mean of Balmer absorptions (see text)	+8(7)	+23(8)	−15(5)	+9(6)	+11(4)	+13(7)	+14(7)	+8(5)	−14(2)	+5(2)	+6.2
Ca II K	−6	−8	−7	−14	−7	+6	−4	−10	...	−7	−6.3
Mg II λ4481	−32	−8	−15	+4	−16	+13	+57	−10	−27	−3	−3.7
Other metallic lines (see text), unweighted mean	...	...	−17(3)	−19(2)	−8(3)	...	...	...	...	...	...
HD 87892, weighted mean (see text)	−2	+10	−12	+1	−2	+11	+15	−2	−21	−3	−0.5
[Ne III] λ3868	−4	−2	−6	−16	−8	−7	+21	−19	−8	−14	−6.3
NGC 3132, unweighted mean	−2(5)	−1(5)	+3(5)	−12(4)	−9(4)	+2(5)	+18(2)	−24(2)	−8(2)	−13(2)	−4.6
V star − V nebula	0	+11	−15	+13	+7	+9	−3	+22	−13	+10	...
Internal probable errors, stellar velocities	6	8	5	5	6	4	9	4	14	3	...
Internal probable errors, nebular velocities	1	3	2	1	5	4	2	3	...	...	...

NOTE.—The numbers in parentheses indicate how many lines enter in each mean value.

developed together with intensity calibrations obtained employing a spot sensitometer illuminated through colored filters centered at 3650 and 4350 Å; these calibrated spectra were used to measure the intensity ratio of the [O II] doublet at λ3727 and the equivalent width of the Hγ stellar absorption. The I plates were secured with the Cassegrain spectrograph attached to the 154-cm telescope at the Bosque Alegre station of Córdoba Observatory.

Also, a calibrated slit spectrogram of NGC 3132 from 3300 to 4800 Å (second order, 75 Å mm^{-1}) and from 4600 to 7200 Å (first order, 150 Å mm^{-1}) was obtained on 1970 February 27 with a Carnegie image tube attached to a nebular spectrograph at the Newtonian focus of the 154-cm telescope at Bosque Alegre. The slit was placed in the east–west direction, through the central star. The reduction procedure was similar to that described by Ringuelet and Méndez (1973). The emission lines appearing in the first-order spectrum are: Hβ, Hα; He I λ5875; He II λ4685; [N II] λλ5754, 6548, 6583; [O I] λλ6300, 6363; [O III] λλ4958, 5006; [S II] λλ6716, 6730. The following intensity ratios were determined: $I(H\alpha)/I(H\beta) = 2.8$ and $I(\lambda 6716)/I(\lambda 6730) = 1.13$. These values are not corrected for wavelength dependence of instrument transmission, cathode sensitivity, and atmospheric extinction; but this should not affect the ratio of the [S II] lines, and the value of the Hα/Hβ ratio will be found to be useful in the discussion.

III. DISCUSSION OF THE OBSERVATIONS

a) *Spectral Classification and Helium Lines*

The spectral type and luminosity class of HD 87892 were determined by comparison of the 125 Å mm^{-1} plates (see Table 2) with spectrograms of standard stars taken by O. H. Levato with the same spectrograph and dispersion. The adopted classification is A2 (±1) V; previous classifications were in the range from AO V (Carlson 1968) to A3 V (Evans 1968).

There is no evidence of He I absorption lines in any of the available spectrograms. In some plates a very weak feature near 4469 Å is visible, but it can be easily explained as due to Ti II (see, e.g., Wright *et al.* 1963). We may add that He I lines arising from a hotter star are not expected, because the *UBV* and scanner observations show no indication of an ultraviolet excess. Thus the findings reported by Carlson (1968) and Brown *et al.* (1970) are not confirmed by the present investigation.

b) *The Absolute Magnitude of HD 87892*

The plate C 2198 was used to measure the equivalent width of the Hγ absorption. The intensities relative to the continuum were obtained from a microphotometer density tracing by means of a (density, log *I*)-curve constructed from a tracing of the corresponding calibration plate. It was necessary to extrapolate the central part of the profile because of the presence of the Hγ emission from the nebula; but this should not significantly affect the result, since the main contribution to the equivalent width comes from the wings. The Hγ equivalent width turned out to be 18 Å, with an estimated uncertainty of about 0.5 Å. It corresponds to an absolute visual magnitude of about +1.8 mag if we use the calibration of Petrie (1965), or +1.4 mag if the new calibration of Balona and Crampton (1974) is employed. Schmidt-Kaler (1965) lists the absolute visual magnitude of an A2 V star as +1.6 mag.

c) *The Radial Velocities*

The radial velocities originating from different lines are shown in Table 3. The Balmer absorptions proved to be very difficult to measure because of their broad profiles and the presence of central emissions from the nebula. A few lines were given half-weight for the evaluation of the means of the Balmer absorption values, because their measurements had been particularly uncertain.

In contrast, the Ca II K-line is sharp and much more reliable. The Mg II λ4481 line is also sharp but is rather weak on some plates. Other metallic absorption lines due to Fe I, Fe II, and Ti II were measurable on the Córdoba plates but were very weak or undetectable on the lower dispersion plates. Their radial velocities are given in Table 3, but were not included in the calculations of the mean velocities of the star in order to use a homogeneous set of values in the discussion; in any case, they do not alter the conclusions arrived at below.

Since the strength of the Ca II K-line is normal for the spectral type of HD 87892 and the interstellar extinction is negligible (see below), we must conclude that all the absorption line velocities are representative of the stellar motion.

The weighted means of the radial velocity of HD 87892 were calculated by assigning unit weight to each Balmer absorption line, weight 2 to the Mg II λ4481 line, and weight 4 to the Ca II K-line. This last weight may seem to be excessive, but it reflects a real difference in the qualities of the lines; it was determined from the comparison of the differences between individual bisections of the profiles at the Grant comparator, and is supported by the fact that the internal agreement between the Balmer lines on each plate is very poor, showing in some cases differences of up to 60 km s^{-1}.

The emission lines measured for radial velocity were [O II] λ3726 and 3728 (only when clearly separated), [Ne III] λ3868, Hδ and Hγ; the [Ne III] line and Hγ were measured on all the plates.

The values of the difference ($V_{\mathrm{Star}} - V_{\mathrm{Nebula}}$) suggest that there may be real variations in the stellar radial velocity; but more material is needed to be sure.

Turning now to the last column of Table 3, we find an almost perfect agreement between the calcium and Mg II mean velocities and the nebular one; but there appears a difference of about 10 km s^{-1} with that of the Balmer absorptions, in the sense that the hydrogen mean value is more positive.

A similar behavior is also found in the results of Evans (1968) and Carlson (1968). D. S. Evans has kindly allowed me to go through his measurements, which combined with the values published in Carlson's work yield (from six plates) a mean calcium velocity similar to that of the nebula, -14 km s^{-1}, while Balmer absorption velocities measured on three plates are more positive.

The reality of this discrepancy remains to be confirmed from higher-dispersion measurements; but anyway it is not likely to affect the conclusion that the mean radial velocity of HD 87892 is not significantly different from that of NGC 3132.

d) T_e, N_e, *and Helium Abundance in NGC 3132*

The statistical equilibrium expressions for the relative level populations of three-level ions were used to calculate the [O III] nebular to auroral line ratio as a function of N_e and T_e, using collision strengths from Czyzak *et al.* (1968) and transition probabilities from Garstang (1968). Taking $N_e = 10^3$ cm^{-3}, the ratio was made to coincide with that measured by Aller and Faulkner (1964) by adopting $T_e = 9100$ K.

The intensity ratio $I(3728)/I(3726)$ of the [O II] doublet was measured on the calibrated plates C2198 and C2202, the mean of the two determinations being 0.96. If we use the formula given by Seaton and Osterbrock (1957) with $T_e = 9100$ K, we find $N_e = 7.9 \times 10^2$ cm^{-3}. Using the ratio $I(6716)/I(6730)$ of [S II] obtained before and the table given by Krueger, Aller, and Czyzak (1970), we get $N_e = 1.3 \times 10^3$ cm^{-3}.

The abundance of He^{++} ions relative to that of ionized hydrogen was calculated with a formula given by Miller and Mathews (1972). Adopting $I(\lambda 4685)/I(H\beta) = 0.27$ as measured by Aller and Faulkner (1964) and $T_e = 9100$ K, we find $N(He^{++})/N(H^+) = 0.022$. Unfortunately a reliable calculation of the He^+ abundance is not possible. We shall assume a He/H ratio of 0.15, yielding $N(He^+)/N(H^+) = 0.128$.

e) *The Interstellar Extinction*

The measured $(U - B)$ and $(B - V)$ values indicate that HD 87892 falls slightly below the point corresponding to its spectral type on the mean curve for main-sequence stars in the two-color diagram, confirming that its interstellar reddening, if existing, is small. The fact that the star lies below the curve is not necessarily peculiar, since the mean relation shows a certain dispersion; see, e.g., Jaschek and Jaschek 1973.

Now let us turn to the determinations of the interstellar extinction for the nebula. If we assume the case B theoretical Balmer decrement calculated by Brocklehurst (1971) to be correct for NGC 3132, the $H\gamma/H\beta$ ratio of 0.33 measured by Aller and Faulkner (1964) suggests a large value of the interstellar extinction, which in turn implies an $H\alpha/H\beta$ ratio of about 6 if we use the Whitford (1958) reddening curve (see, e.g., Miller and Mathews 1972); yet the ratio measured on the available spectrogram is 2.8. An inspection of the $H\alpha/H\beta$ ratios obtained for other planetary nebulae with the same equipment (Ringuelet and Méndez 1973) suggests that the discrepancy cannot be attributed to instrumental effects, leading thus to the conclusion that the observed $H\alpha/H\beta$ ratio indicates a much lower reddening than the $H\gamma/H\beta$ ratio. Obviously, a new determination of the observed Balmer decrement of NGC 3132 is desirable.

Another evidence pointing to a low value for the extinction comes from the analysis of the radio observations. If we know the electron temperature and the helium abundance, it is possible to calculate the expected ratio of the nebular flux in $H\beta$ to the free-free emission at radio wavelengths for which the nebula is optically thin. The logarithmic extinction at $H\beta$ then follows from

$$c = \log\left(\frac{F_{\rm radio}}{F(H\beta)}\right)_{\rm obs} - \log\left(\frac{F_{\rm radio}}{F(H\beta)}\right)_{\rm calc} .$$

In this way Cahn and Kaler (1971) obtained $c = 0.37$ for NGC 3132, and Aller and Milne (1972) found $c = 0.00$. In view of the discrepancy a recalculation of c using this method was indicated. The values of T_e and the helium abundance found in § III*d* were used to evaluate the ratio of the radio flux at $\nu = 2.7$ GHz to the flux in $H\beta$ by means of

$$\left(\frac{F_{\rm radio}}{F(H\beta)}\right)_{\rm calc} = \frac{9.2332 \times 10^{-27}}{\alpha(H\beta)T_e^{1/2}}\left[1 + \frac{N(He^+)}{N(H^+)} + \frac{4N(He^{++})}{N(H^+)}\frac{\ln(CT_e^{3/2}/2\nu)}{\ln(CT_e^{3/2}/\nu)}\right]\ln\left(\frac{CT_e^{3/2}}{\nu}\right) ,$$

where $C = 4.9545 \times 10^7$, and $\alpha(H\beta)$ is the effective recombination coefficient as interpolated from Table 5 of Brocklehurst (1971), with $N_e = 10^3$ cm^{-3}. The logarithm of the calculated ratio of fluxes turned out to be -13.47.

An observed flux of 0.23 flux units (2.3×10^{-24} ergs cm^{-2} s^{-1} Hz^{-1}) at 2.7 GHz was adopted from the values published in Higgs's (1971) catalog of radio observations and related data, and seems to be relatively well determined. The main source of uncertainty is the value of the flux in $H\beta$, because the only determinations found in the literature (Aller and Faulkner 1964; Webster 1969*a*) are, respectively, -9.87 and -10.37 for the logarithm of the flux. If we use the unweighted mean of the two Hβ measurements, we obtain $c = -0.12$; and if we choose the mean logarithm adopted by Higgs in his catalog, we get $c = +0.04$. A new determination of the flux in Hβ would be useful; meanwhile, there seems to be no reason to suppose that the interstellar extinction is larger for NGC 3132 than for HD 87892, and therefore it will be neglected in what follows.

f) Some Characteristics of the Exciting Star

The method of Harman and Seaton (1966) was used to estimate the surface temperature of the star that excites NGC 3132. The value of the logarithm of the nebular Hβ flux adopted by Higgs (1971) yields $F(\mathrm{H}\beta) = 6.266 \times 10^{-11}$ ergs cm^{-2} s^{-1}; we also have $F(\lambda 4685) = 0.27\, F(\mathrm{H}\beta)$ (Aller and Faulkner 1964).

The following relations, involving the observed nebular fluxes F, the luminosity parameter Λ, and the stellar temperature T, were plotted on the (log Λ, log T)-plane:

$$\Lambda = \frac{L}{d^2 L_\odot} = \frac{4.151 \times 10^{21}}{\nu_\beta} \frac{\alpha_B(\mathrm{H}^0)}{\alpha(\mathrm{H}\beta)} \frac{F(\mathrm{H}\beta)}{\xi\eta} \frac{T}{F_1(T)}\,, \tag{1}$$

$$\Lambda = \frac{4.151 \times 10^{21}}{\nu_{4685}} \frac{\alpha_B(\mathrm{He}^+)}{\alpha(\lambda 4685)} \frac{F(\lambda 4685)}{\xi} \frac{T}{F_4(T)}\,. \tag{2}$$

Here L is the luminosity of the exciting star, which is assumed to radiate as a blackbody, d is the distance in kpc, the α's are recombination coefficients, ξ is the solid angle subtended by the nebula at its central star divided by 4π, $\eta = 1$ if the nebula is optically thick in the Lyman continuum, and $\eta < 1$ otherwise.

Equation (2) is valid if the nebula is optically thick in the He II continuum, which seems to be the case for NGC 3132 in view of the abundances obtained in § III*d*.

The functions $F_1(T)$ and $F_4(T)$ can be found in Table 6 of Harman and Seaton's paper; the ratios of recombination coefficients were extrapolated for $T_e = 9100$ K from Table 4 of the same paper.

The curves defined by equations (1) and (2) were calculated for the case $\xi = \eta = 1$; thus their intersection gives an upper limit for T, $T \leqslant 1.35 \times 10^5$ K, and a lower limit for Λ, $\Lambda \geqslant 247$. This can be transformed into a lower limit for the stellar flux at Hβ by means of the relation

$$\Lambda = 1.600 \times 10^{24}\, F_{\nu_\beta}(^*) t^4 (e^{2.9588/t} - 1)\,,$$

where $t = 10^{-4} T$. In this way we obtain

$$F_{\nu_\beta}(^*) \geqslant 1.89 \times 10^{-26} \text{ ergs cm}^{-2}\text{ s}^{-1}\text{ Hz}^{-1}\,. \tag{3}$$

The model atmosphere calculations of Hummer and Mihalas (1970) suggest that any attempt to allow the exciting star to deviate from a blackbody distribution is not certain to improve the present results.

The flux at Hβ from HD 87892 can be found from Figure 1 and the calibrations by Hayes (1970) and Oke and Schild (1970). A monochromatic magnitude difference of 5.41 mag leads to a flux

$$F_{\nu_\beta}(\text{HD } 87892) = 3.80 \times 10^{-24} \text{ ergs cm}^{-2}\text{ s}^{-1}\text{ Hz}^{-1}\,. \tag{4}$$

From equations (3) and (4) we then arrive at the following lower limit for the ratio of the Hβ fluxes of the exciting star and HD 87892:

$$\frac{F_{\nu_\beta}(*)}{F_{\nu_\beta}(\text{HD } 87892)} \geqslant 0.005\,. \tag{5}$$

If the hotter star radiates as a blackbody at about 1.3×10^5 K, relation (5) implies that the ratio of the fluxes at $\lambda = 3500$ Å must be at least 0.03. But since the *UBV* and scanner observations show no indication of an ultraviolet excess, we do not expect that ratio of fluxes to be much larger than 0.03; this implies that the actual values of T and Λ must be near the respective limits found above.

IV. SUMMARY OF RESULTS AND FINAL CONSIDERATIONS

In addition to the fact that it lies at the center of NGC 3132, the star HD 87892 has been shown to have the same radial velocity and interstellar extinction as the nebula. So we are justified in assuming that it is a member of a binary system, its companion being responsible for the ionization of NGC 3132.

From the apparent and absolute visual magnitudes of HD 87892 we obtain a distance of 479 pc; the assumption that NGC 3132 lies at the same distance (strongly supported by the lack of any observational evidence to the contrary) can be shown to have interesting consequences. Let us first compute the luminosity and radius of the exciting star. If we adopt $\Lambda = 250$, $T = 1.35 \times 10^5$ K, $T_\odot = 5800$ K, and $d = 0.479$ kpc, we find

$$L/L_\odot = \Lambda d^2 = 57\,, \qquad R^2/R_\odot{}^2 = \Lambda d^2 (T_\odot{}^4/T^4) = 1.95 \times 10^{-4}\,.$$

TABLE 4

NGC 3132: MEAN ELECTRON DENSITY AND IONIZED MASS

ϵ	N_e (cm^{-3})	$\mathfrak{M}_i/\mathfrak{M}_\odot$
0.5..........	660	0.025
0.3..........	852	0.020
0.1..........	1475	0.011

These values are somewhat small, but not unexpected if the star is fairly advanced in its evolutionary track towards the white dwarf stage.

It is also possible to evaluate the mean electron density and the ionized nebular mass as functions of the filling factor ϵ. If the ratio of helium to hydrogen is 0.15, we can write

$$N_i N_e = \frac{3F(\mathrm{H}\beta)}{\epsilon d r^3 \alpha(\mathrm{H}\beta) h\nu_\beta}\,,$$

$$N_e = 1.15 N_i\,,$$

$$\mathfrak{M}_i = 1.60 N_i m_{\mathrm{H}} \frac{4\pi}{3} r^3 d^3 \epsilon\,,$$

where N_i and N_e are the mean proton and electron densities, d is the distance, r is the angular radius of the nebula, and m_{H} is the mass of a hydrogen atom.

Table 4 gives N_e and $\mathfrak{M}_i$ for an angular radius of 35″ and three different values of ϵ. In order to obtain a mean electron density consistent with the values found from the forbidden line intensities, the filling factor must be between 0.5 and 0.1, giving an ionized mass of the order of 0.02 $\mathfrak{M}_\odot$.

Since the nebula is almost certainly optically thick in the Lyman continuum, its total mass may be larger; but even so it probably remains much smaller than the masses usually estimated for planetary nebulae. This is not the only case where a small nebular mass has been found; Peimbert (1973) has recently given an upper limit of 0.018 $\mathfrak{M}_\odot$ for the ionized mass of K648, the planetary nebula in the globular cluster M15. NGC 3132 may provide further evidence that there actually is a large range in the masses of planetaries.

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