1985RMxAA..10..203F

PHOTOMETRIC MEASUREMENTS OF THE PLANETARY NEBULA NGC 1535

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RESUMEN. Datos fotoeléctricos UBVRI de la nebulosa planetaria NGC 1535 sugieren un tipo espectral muy temprano para la estrella central: V = 12,6 , B-V = -0.31 , U-B = -1,2 , V-I = -0,30. El diámetro aparente fotométrico de la nebulosa resulta de 22 segundos de arco con una magnitud total de V = 10,1. Las estrellas alrededor de la nebulosa no indican la presencia de enrojecimiento hasta una distancia de 0,45 kpc.

ABSTRACT. Photoelectric UBVRI data of the planetary nebula NGC 1535 suggest a very early spectral type for the central star: V=12.6, B-V=-0.31, U-B=-1.2, V-I=-0.30. The derived apparent photometric diameter of the nebula is of 22 arc sec with a total magnitude of V=10.1. Stars on the sky in the neighborhood of the nebula do not give indication of reddening up to a distance of 0.45 kpc.

During one observing run on February 8-14, 1980, at the Cerro Tololo Inter-American Observatory (Chile), the planetary nebula NGC 1535 was observed photoelectrically in the UBVRI system. The measurements carried out with the 90- and 60-cm telescopes were obtained using the RCA 31034A photomultiplier in a pulse-counting mode, with a set of standard filters set available at the Observatory, and focal-plane apertures ranging between 4.3 and 42.8 arc sec.

The relevant data for the planetary nebula are listed in Table 1. The first column gives D, the diameter apertures in arc sec. The next five columns include the V magnitude, and the B-V, U-B, V-R and R-I color indices, where the RI data are in the Kron-Cousins system. Finally, in the last column the telescopes employed are indicated.

At the same time that the planetary nebula, 29 stars located in a circle of 15 arcmin around the nebula were measured in the UBVRI system, with visual apparent magnitudes ranging from 10 to 15 (see Table 2). The U-B vs B-V array for all of them is plotted in Figure 1, where the dashed line indicates the location of the intrinsic mean sequence. A coincidence of those stars with the position of the unreddened sequence implies that no absorption is present up to the distance of the earliest star. As its color index suggests a spectral type about F7, the absolute magnitude will be about M_V = 3.8 (Schmidt-Kaler 1982). The mean apparent magnitude V of the four earliest stars is V = 12.0, which gives a distance modulus for them of $V-M_V$ = 8.2, meaning a distance of 450 pc. The very small absorption in the direction of the planetary nebula NGC 1535 was already indicated in the literature (see Pottasch *et al.*, 1978).

In Figure 2 are displayed the observed magnitude V of the planetary nebula *vs.* D, the aperture in arc sec, and in Figure 3 the color indices *vs.* D. Small variations in the magnitude and color indices between 42 and 22 arc sec are noted. But, a clear modification of the photometric values starts for D<22", which may be due to a decrease of the flux from of the nebula as the diaphragms become smaller than the apparent diameter of the nebula. Therefore, we may conclude, that the angular diameter of the planetary nebula is about 22 ± 1 arc sec.

TABLE 1

PHOTOELECTRIC UBVRI MEASUREMENTS OF NGC 1535

D (")	V	B-V	U-B	V-R	R-I	Telesc. (cm)
42.8	9.69	1.12	-1.01	-0.94	-0.56	90
35.8	9.82	1.08	-1.00	-0.90	-0.60	90
35.8	9.83	1.09	-0.98	-0.91	-0.56	90
27.1	10.00	1.04	-1.04	-0.91	-0.52	90
26.1	10.00	1.06	-0.97	-0.89	-0.54	60
26.1	10.05	1.01	-1.06	-0.89	-0.50	60
21.8	10.16	1.00	-1.08	-0.85	-0.52	60
18.4	10.54	0.83	-1.05	-0.78	-0.47	90
18.4	10.48	0.80	-1.07	-0.80	-.047	90
18.4	10.54	0.77	-1.07	-0.78	-0.44	90
16.5	10.50	0.81	-1.09	-0.79	-0.42	60
12.5	11.20	0.41	-1.18	-0.57	-0.31	90
11.2	11.22	0.42	-1.14	-0.56	-0.32	60
11.2	11.21	0.33	-1.21	-0.51	-0.31	60
7.0	11.86	0.06	-1.05	-0.35	-0.13	90
7.0	12.03	0.19	-0.88	-0.49	-0.28	90
4.3	12.17	-0.14	-1.19	-0.40	-0.10	60

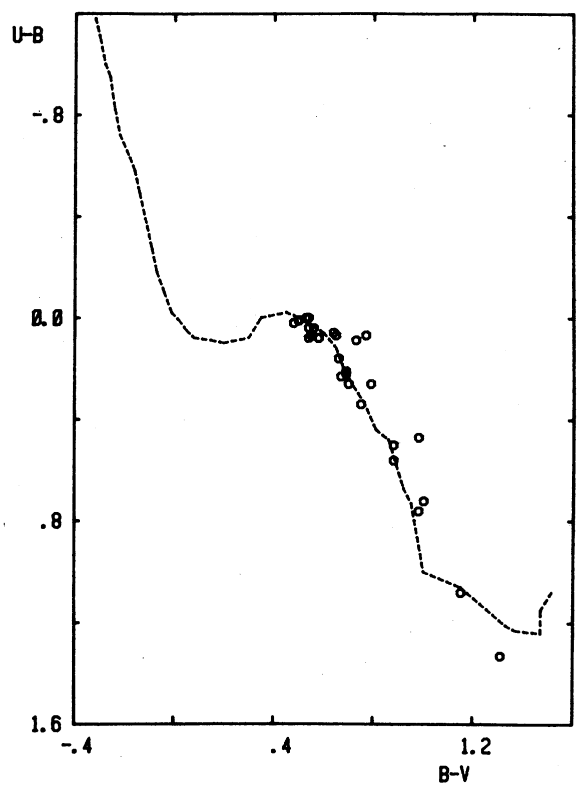

Fig. 1. The two-color diagram for stars on the sky close to the planetary nebula NGC 1535.

TABLE 2

STARS AROUND NGC 1535

No.	V	B-V	U-B	V-R	R-I	V-I
1	12.91	0.64	0.06			
2	13.84	0.73	0.09			
4	14.20	0.88	0.56	0.58	0.57	1.09
6	13.37	0.88	0.50	0.50	0.47	0.97
7	13.58	0.50	0.01	0.34	0.32	0.66
8	13.87	0.55	0.07	0.34	0.34	0.68
9	11.26	0.54	0.04	0.35	0.33	0.68
10	11.09	0.58	0.08	0.36	0.32	0.68
11	12.11	0.54	0.08	0.36	0.34	0.70
12	10.12	1.15	1.08	0.57	0.51	1.08
13	11.90	0.48	0.02	0.28	0.30	0.58
14	10.51	0.98	0.76	0.54	0.48	1.02
15	14.05	0.67	0.23			
16	12.73	0.56	0.04			
17	11.19	0.79	0.26	0.44	0.44	0.88
18	13.58	0.75	0.34	0.38	0.40	0.78
19	14.64	0.69	0.22			
20	13.27	0.65	0.07	0.30	0.34	0.64
21	12.27	0.98	0.47	0.51	0.50	1.01
22	11.49	0.69	0.21	0.38	0.34	0.72
23	11.54	0.54	0.00	0.30	0.30	0.60
24	13.60	0.66	0.16	0.37	0.65	1.02
25	12.60	0.50	0.01	0.30	0.33	0.63
26	11.49	0.58	0.08	0.35	0.33	0.68
27	11.04	0.70	0.26	0.39	0.36	0.75
28	14.61	0.77	0.07	0.38	0.41	0.79
29	11.36	1.00	0.72	0.54	0.48	1.02
30	11.86	0.53	0.00	0.31	0.30	0.61
31	11.77	1.31	1.33	0.67	0.60	1.27

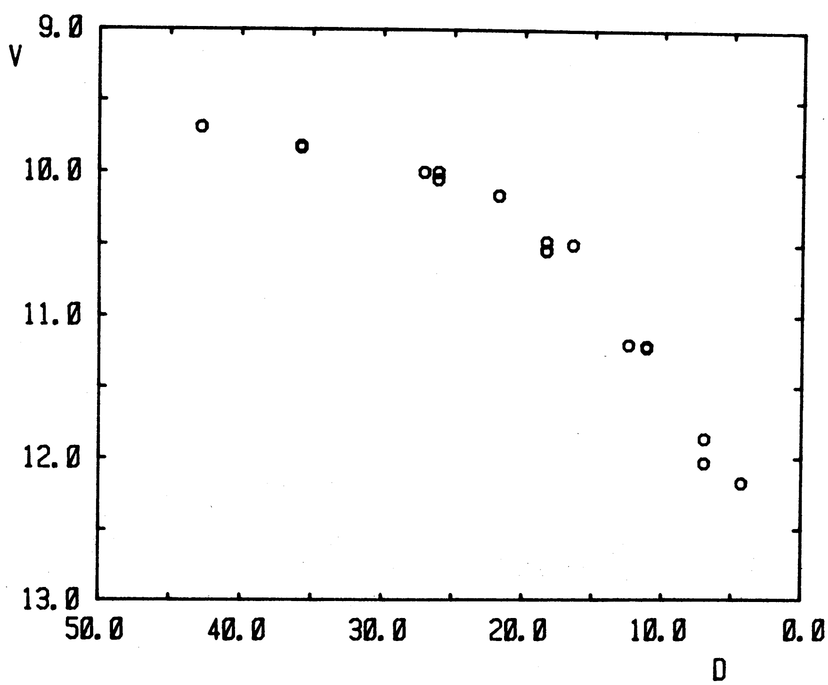

Fig. 2. The V magnitude vs the aperture of the diaphragm D in arc sec.

TABLE 3

ESTIMATED DATA FOR THE CENTRAL STAR

	D(")			
	0.5	1	2	3
V	$12^m.62$	$12^m.56$	$12^m.44$	$12^m.32$
B-V	-0.31	-0.28	-0.22	-0.16
U-B	-1.26	-1.25	-1.24	-1.23
V-R	-0.24	-0.25	-0.28	-0.31
R-I	-0.05	-0.06	-0.08	-0.10

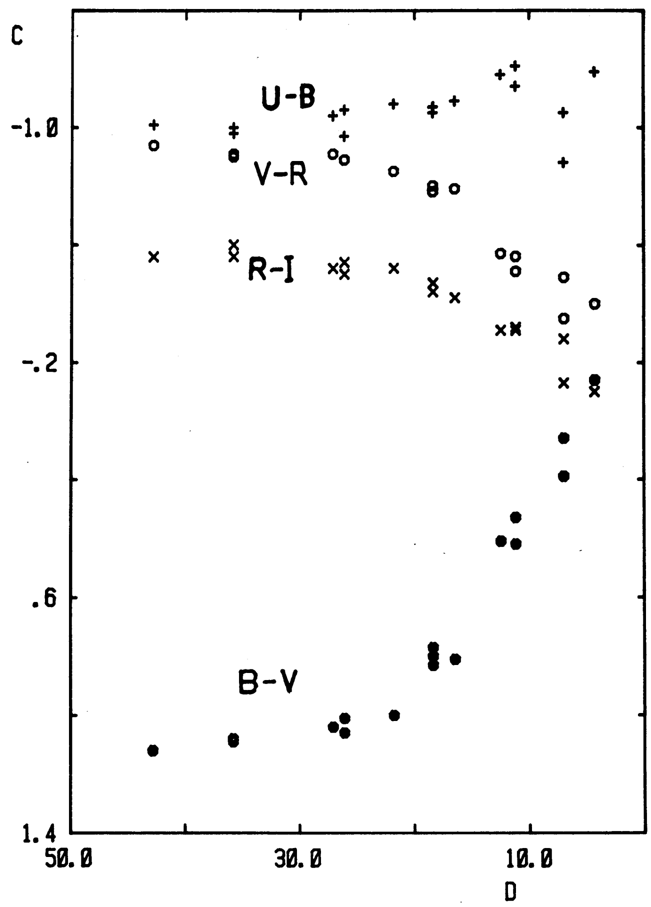

Fig. 3. The U-B, V-R, R-I and B-V color indices vs the aperture of the diaphragm D in arc sec.

If we want to know something about the central star we need to extrapolate our measures to smaller apertures than those actually employed. A straight line for the magnitude and for each color index was computed for the points from 21 to 4 arc sec in D. In Table 3 the final values for apertures in the range 2 to 0.5 arc sec are listed. But, at which D stands the photometric data for the central star? In the sky at Cerro Tololo, it seems that the data for D = 1 or 0.5 arc sec could be the most reliable ones. On the other hand the values corresponding to other diaphragms appear to be outside the range for standard-type stars. The photometric values for different diaphragms vary mainly in the V magnitude and in the B-V color index, while the other two color indices: U-B and V-I, display very little change. In this respect we did not take into account, in our computation, the two U-B values for D = 7", which are discordant in comparison with the rest, and therefore the extrapolated U-B color index is of lower weight. Finally, the assumed photometry of the central star would be V = 12.6, B-V = -0.31, U-B = -1.25, V-R = -0.24, V-I = -0.29, which suggests a normal star of early spectral type, about 07-9 with a slight ultraviolet excess. Large differences result in comparing these values with the photometric UBV data presented by Kostjakova *et al.* (1968), V = 11.59, B-V = 0.00, U-B = -0.94.

Combining our photometric data with the distance of d = 2.3 kpc, from the analysis of Cahn and Kaler (1971), the absolute magnitude of the central star of NGC 1535 becomes M_V=0.9. On the other hand, the absolute magnitude M_V = -2.2, as given by Minello and Sabbadin (1977), yields a distance modulus of 14.8, which corresponds to a distance of 9.8 kpc. This result implies a radius of 0.65 pc for the nebula in discrepancy with Minello and Sabbadin who listed a radius of 0.17 pc. The large difference between the two M_V values indicates how deficient is our knowledge of these objects.

The only possibility for clarifying this problem is by some safe method of obtaining an unambiguous estimate of the luminosity.

In conclusion, in Table 4 are summarized the derived data for the planetary nebula NGC 1535 and its central star. It should be taken into account that many uncertainties still remain to be settled.

TABLE 4

SUMMARY OF THE PHOTOMETRIC DATA FOR NGC 1535 AND THE CENTRAL STAR

NGC 1535	Central star
D = 22" + 1"	D = $0\overset{''}{.}5$
V = $10\overset{m}{.}1$	V = $12\overset{m}{.}6$
B-V = 1.0	B-V = -0.31
U-B = -1.0	U-B = -1.2
V-I = -1.37	V-I = -0.29

I wish to thank Dr. R.S. Pottasch for suggesting this problem and to the Cerro Tololo Inter-American Observatory for the allocation of observing time. The collaboration of Maria C.F. de Correbo in the preparation of the paper is acknowledged. This work was partially supported by CIC and CONICET.

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