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EXTINCTION DISTANCES TO THE PLANETARY NEBULAE NGC 6565 AND NGC 5979

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RESUMO. Excessos de cor e distâncias de estrelas de tipos espectrais conhecidos angularmente próximas às nebulosas planetárias NGC 6565 e NGC 5979 são obtidos a partir de fotometria fotoelétrica no sistema UBV. As relações excesso de cor x distância obtidas são utilizadas para a determinação das distâncias às nebulosas, que são comparadas a outras determinações existentes na literatura.

ABSTRACT. Colour excesses and distances of stars of known spectral types close to the planetary nebulae NGC 6565 and NGC 5979 in the plane of the sky are obtained from UBV photoelectric photometry. The colour excess x distance relations are used to determine the nebular distances, which are compared to other estimates available in the literature.

Key words: planetary nebulae - extinction - distances

I. INTRODUCTION

The determination of accurate distances remains one of the central problems in the study of planetary nebulae. Individual distances are available for a limited number of objects, and statistical distances can be affected by errors up to a factor of two, when individual objects are considered (Pottasch 1980, 1983). Recent work on distance estimates has stressed the importance of the so-called "extinction method", according to which the nebular distance can be obtained from the extinction x distance relation in the direction of the nebula (Pottasch 1980, 1983; Gathier and Pottasch 1983; Maciel 1984a). The application of the extinction method to the planetary nebulae is usually made

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through the use of general extinction curves (see for example Acker 1978; Pottasch 1980), which are obtained from the galactic distribution of the interstellar absorbing material (FitzGerald 1968; Lucke 1978). Alternatively, specific measurements of stars of known spectral types lying close to the nebula in the plane of the sky usually produce better estimates of the distances, a method which has been applied to several objects (Metik and Pronik 1963; Lutz 1973; Gathier 1983).

In this work, individual distances to the planetary nebulae NGC 6565 (PK 003-04 5, $\alpha(1950) = 18^h\ 08^m\ 43^s$, $\delta(1950) = -28^\circ\ 11'$) and NGC 5979 (PK 322-05 1, $\alpha(1950) = 15^h\ 43^m\ 31^s$, $\delta(1950) = -61^\circ\ 02'$) have been obtained from specific extinction determinations in the nebular directions.

II. THE OBSERVATIONS

The observations were made with the 60 cm OAB (Observatório Astrofísico Brasileiro) telescope at Brazópolis, in July, 1984, using a bialkali EMI 9789 B photomultiplier. Photoelectric measurements in the UBV system were obtained for a large number of stars within 2° of the nebulae in the plane of the sky. All program stars were observed at least twice, and the observations were reduced according to conventional techniques.

Tables 1 and 2 show the observational results and derived parameters for the stars in the direction of NGC 6565 and NGC 5979, respectively. The tables display: (a) the HD number, (b) the galactic coordinates, (c) spectral types and luminosity classes (Houk and Cowley, 1975), (d) observed V magnitude, (e) colour index B-V, (f) adopted visual absolute magnitude, (g) colour excesses E(B-V) and (h) derived distances. Spectral type-colour index and colour index-absolute magnitude calibrations were used (Allen 1973; Golay 1974; Acker 1976; Mihalas and Binney 1981). The absorption in magnitudes was taken as $A_V = 3.2\ E(B-V)$ (Pottasch et al. 1977).

III. RESULTS AND DISCUSSION

Figures 1 and 2 show the colour excess-distance diagrams for NGC 6565 and NGC 5979, respectively. Least-squares straight lines of the form

$$E(B-V) = a\ d(Kpc)$$

are shown in the figures, along with the slope a, the standard deviation σ, the correlation coefficient r, and the number of stars n. The dispersion is relatively low in both cases, considering the uncertainty involved in the

TABLE 1. Stars near the direction of NGC 6565

HD	l	b	type	V	B-V	M_v	E(B-V)	d(pc)
164867	3.4	-2.8	B9 II/III	7.75	0.04	-1.38	0.10	578
164909	3.9	-2.6	F5 Ib	7.44	0.74	-4.70	0.34	1623
165118	1.9	-4.0	A2 IV	7.24	0.21	0.60	0.15	171
165207	1.8	-4.1	B2 III	8.20	0.01	-4.14	0.25	2032
165225	4.0	-2.9	B2 II/III	8.53	0.08	-4.14	0.32	2134
165269	3.5	-3.2	G1 V	7.23	0.59	4.45	0.00	36
165365	2.8	-3.7	B7/8 III	7.04	0.13	-1.77	0.22	418
165708	3.6	-3.7	K1 III	7.92	1.20	0.38	0.09	282
165766	2.7	-4.3	F5 V	7.52	0.50	3.44	0.08	58
165767	1.6	-4.9	K2/3 III	7.00	1.20	0.20	0.00	229
165787	3.6	-3.9	K0 III	7.52	1.06	0.54	0.03	238
166080	2.4	-4.8	A6 IV/V	7.68	0.33	1.35	0.18	142
166264	3.3	-4.5	A1 IV	8.72	0.16	0.00	0.16	438
166265	2.0	-5.2	A9 V	7.76	0.34	2.56	0.08	97
166470	2.3	-5.3	B9 V	7.76	0.18	0.16	0.24	232
166789	4.5	-4.4	B6 III	8.02	-0.01	-2.54	0.13	1069
166968	4.4	-4.7	B8 II/III	7.11	-0.03	-1.77	0.06	547
167121	2.4	-6.0	M1 III	6.76	1.58	-0.28	0.00	256
167439	4.7	-5.1	B9 Ib/II	7.77	0.30	-4.30	0.30	1667
167576	4.5	-5.4	K1 III	6.58	1.21	0.38	0.10	150

TABLE 2. Stars near the direction of NGC 5979

HD	l	b	type	V	B-V	M_v	E(B-V)	d(pc)
139188	322.33	-4.02	A7 V	10.16	0.23	2.13	0.04	381
139189	321.86	-4.66	K0 V	9.50	0.93	6.05	0.08	44
139211	322.63	-3.63	F6 V	6.00	0.54	3.79	0.07	25
139238	321.73	-4.92	G8 III	10.57	1.23	0.70	0.28	623
139700	321.81	-5.33	F6 V	9.29	0.63	3.79	0.16	99
139832	323.14	-3.68	M1 III	7.88	1.79	-0.26	0.23	303
139833	322.19	-4.96	G3 V	9.87	0.75	4.80	0.10	89
139915	322.80	-4.25	G0 Ib	6.52	1.10	-4.70	0.40	973
140044	322.90	-4.26	F2 V	8.14	0.52	3.10	0.16	80
140060	323.07	-4.06	G5 IV	9.10	0.77	3.10	0.07	143
140111	323.61	-3.40	A2/3 III	7.54	0.29	-0.18	0.23	249
140248	321.67	-6.09	G8 III	8.57	1.01	0.70	0.06	343
140380	323.04	-4.43	G3/5 V	9.31	0.64	4.92	0.00	76
140426	322.70	-4.93	F2 IV/V	9.47	0.56	3.10	0.20	140
140450	322.17	-5.66	G6/8 IV	9.08	0.67	3.10	0.00	157
140506	323.62	-3.82	A2 III/IV	9.83	0.33	-0.18	0.27	675
140507	321.97	-5.97	K3 III	7.69	1.51	0.10	0.21	242
140569	322.14	-5.83	B8/9 V	10.03	0.09	-0.11	0.18	818
140709	322.97	-4.91	K1 III	8.53	1.14	0.40	0.04	398
140807	324.14	-3.49	B6 III/IV	8.01	0.11	-2.54	0.25	891
140826	323.23	-4.70	F5 V	6.69	0.48	3.44	0.06	41
140885	322.20	-6.08	F6/7 V	8.97	0.51	3.79	0.04	102
140947	322.21	-6.13	B9 V	10.38	0.16	0.16	0.22	800
141137	323.16	-5.13	A0 V	9.85	0.24	0.70	0.24	475
141201	323.00	-5.41	G6/8 III	10.68	1.10	0.84	0.22	672
141321	322.91	-5.64	F2 IV/V	9.93	0.50	2.32	0.14	271
141583	324.44	-4.00	F7 V	7.10	0.57	4.05	0.06	37
141584	323.10	-5.68	B9 IV/V	10.38	0.17	0.16	0.23	788
141624	323.02	-5.81	F8/G0 V	8.18	0.60	4.20	0.06	57
141913	323.55	-5.45	B9 II	6.21	0.17	-3.32	0.18	618

calibration process and the intrinsic scatter due to the inhomogeneity of the Interstellar absorbing material.

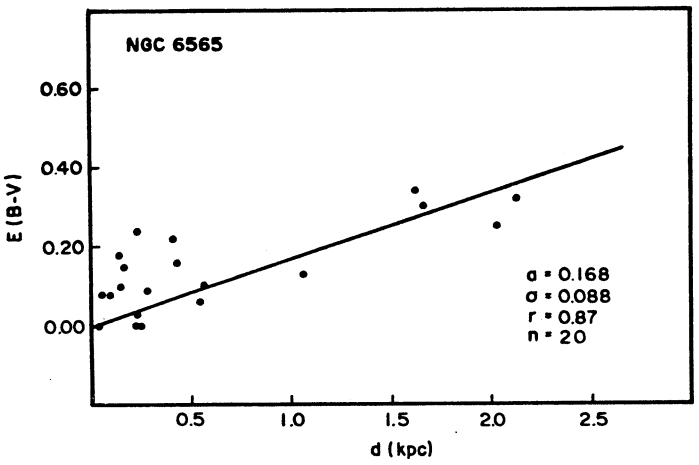

FIGURE 1. Colour excess x distance diagram in the direction of NGC 6565.

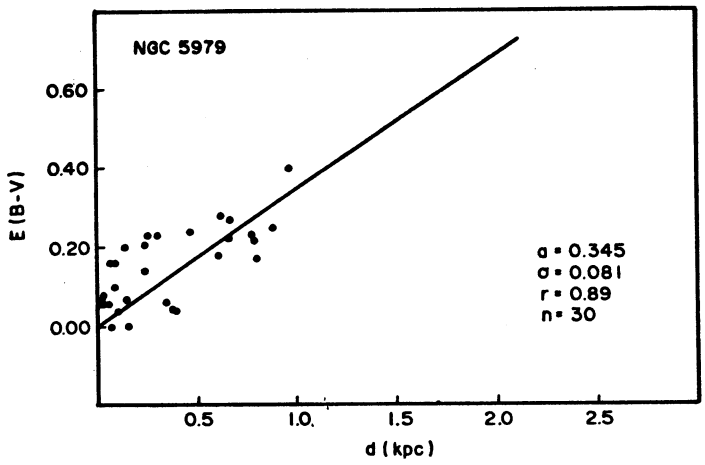

FIGURE 2. Colour excess x distance diagram in the direction of NGC 5979.

The colour excess of NGC 6565 has been determined by several methods, such as the Balmer decrement, radio/H beta fluxes and He II lines. The results are in the range 0.30-0.20 (Pottasch 1983; Feibelman 1982; Milne and Aller 1975), which from Figure 1 corresponds to a distance in the range 1780 - 1190 pc. Adopting the recent IUE measurement E(B-V)= 0.26 (Feibelman 1982), a distance d= 1540 pc is obtained, corresponding to z= -120 pc, and placing the nebula within the interstellar absorbing layer. In Table 3 the obtained dis-

tance is compared with recent determinations available in the literature.

TABLE 3. Distance to NGC 6565

reference	method	d(pc)
Cahn and Kaler (1971)	Shklovsky (Hß)	2490
Cahn and Kaler (1971)	Shklovsky (red)	2560
Milne and Aller (1975)	Shklovsky (radio)	4567
Milne and Aller (1975)	effective absorption	2860
Acker (1978)	syntetic	3000
Maciel and Pottasch (1980)		
Maciel (1984b)	mass-radius relation	3468
Daub (1982)	mass-radius relation	3540
Pottasch (1983)	general extinction	1300
This work	individual extinction	1540

At a distance of 1540 pc, NGC 6565 would have an intrinsic radius of 0.03 pc, being probably optically thick to radiation in the Lyman continuum (see for example Cahn and Kaler 1971; Acker 1978). Therefore, the Shklovsky distances would be upper limits. Distances obtained from mass-radius relations are not affected by the nebular mass as strongly as the Shklovsky distances. On the other hand, the good agreement between general and individual extinction and the good correlation shown in Figure 1 seem to indicate that the present extinction is to be favoured.

Considering a typical uncertainty of 0.05 in the colour excess, (see for example Pottasch et al. 1977), the estimated error in the distance is about 300 pc, or 20%. The colour excess in the direction of NGC 5979 has been determined as E(B-V)= 0.58 by the radio/H beta method (Milne and Aller 1975). The relation shown in the Figure 2 suggests by extrapolation a distance of 1680 pc, corresponding to z= -150 pc, with a typical error of 145 pc or 9%. The real uncertainty is probably larger, since no stars have been observed further away than about 1 Kpc. As shown in Table 4, the derived distance is in good agreement with the value given by Daub (1982). Analogously to the previous object, NGC 5979 has an intrinsic radius of 0.03 pc, so that the Shklovsky distances are probably upper limits.

Considering the results derived from the mass-radius relations, it is probably safe to place this nebula in the range 2.6 - 1.6 Kpc. Considering further the agreement between the value given by Daub (1982) and the extinction distance derived in the paper, the distance to NGC 5979 is of the order of 1.7 Kpc.

TABLE 4. Distances to NGC 5979

reference	method	d(pc)
Cahn and Kaler (1971)	Shklovsky (Hß)	3810
Milne and Aller (1975)	Shklovsky (radio)	4138
Milne and Aller (1975)	effective absorption	1640
Acker (1978)	syntetic	3300
Maciel and Pottasch (1980) Maciel (1984b)	mass-radius relation	2575
Daub (1982)	mass-radius relation	1780
This work	individual extinction	1680

Based on the recent work of Pottasch (1980, 1983), Gathier (1983), Maciel (1984a) and this work, and in view of the errors involved in the extinction distances, one may conclude that a systematical application of this method will give more reliable distances than most statistical methods. This would thus provide us with more accurate distance data to study other nebular parameters related to their galactic distribution and evolution.

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REFERENCES

Acker, A. 1976, Thesis, University of Strasbourg.
Acker, A. 1978, Astr. and Ap. Suppl. Ser. 33, 367.
Allen, C.W. 1973, Astrophysical quantities, Athlone.
Cahn, J.H., Kaler, J.B. 1971, Ap. J. Suppl. 22, 319.
Daub, C.T. 1982, Ap. J. 260, 612.
Feibelman, W.A. 1982, Astr. J. 87, 555.
FitzGerald, M.P. 1968, Astr. J. 73, 983.
Gathier, R. 1983, The Messenger nº 32, 20.
Gathier, R., Pottasch, S.R. 1983, IAU Symposium No. 103, ed. D.R. Flower,Reidel
Golay, M. 1974, Introduction to astronomical photometry, Reidel.
Houk, N., Cowley, A.P. 1975, University of Michigan Catalogue of two-dimensional spectral types for the HD stars.
Lucke, P.B. 1978, Astr. and Ap. 64, 367.
Lutz, J.H. 1973, Ap. J. 181, 135.

Maciel, W.J. 1984a, III Reunion Latinoamericana de Astronomia (in press).
Maciel, W.J. 1984b, Astr. and Ap. Suppl. Ser. 55, 253.
Maciel, W.J., Pottasch, S.R. 1980, Astr. and Ap. 88, 1.
Metik, L.P., Pronik, V.I. 1963, Izvestya Krimskoi Astrofiz. Obs. 30, 113.
Mihalas, D., Binney, J. 1981, Galactic astronomy 2nd. ed., Freeman.
Milne, D.K., Aller, L.H. 1975, Astr. and Ap. 38, 183.
Pottasch, S.R. 1980, Astr. and Ap. 89, 336.
Pottasch, S.R. 1983, IAU Symposium No. 103, ed. D.R. Flower, Reidel.
Pottasch , S.R., Wesselius, P.R., Wu, C.C., van Duinen, R.J. 1977, Astr. and Ap. 54, 435.

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