EXTINCTION DISTANCE TO THE PLANETARY NEBULA He2-131

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RESUMO. A distancia de extincao da nebulosa planetaria He2-131 (315-13°1) e obtida, usando curvas publicadas de extincao geral e novas medidas de estrelas proximas a nebulosa no plano do ceu. Os resultados sao discutidos, e uma comparacao e feita com outras distancias encontradas na literatura.

ABSTRACT. The extinction distance to the planetary nebula He2-131 (315-13°1) is obtained, using both published general extinction curves and new measurements of stars close to the nebula in the plane of the sky. The results are discussed and a comparison is made with other distances given in the literature.

I. INTRODUCTION

Extinction distances to planetary nebulae are among the most accurate methods available for determining the distance to these objects (Pottasch 1980). According to this method, a diagram must be obtained relating the colour excesses and distances of stars in the neighbourhood of the nebula in the plane of the sky. It can be applied to the nebulae which are relatively close to the galactic plane, and for which the extinction is independently known.

The method has been used by Metik and Pronik (1963), Kohoutek (1968), Lutz (1973), Milne and Aller (1975), Acker (1976, 1978), and Pottasch (1980). More recently, Gathier and Pottasch (1983) presented preliminary results obtained through the use of VBLUW photometry of stars within 0°.5 of the nebulae in the plane of the sky (see also Gathier 1983).

The accuracy of the method is estimated as better than 50% (Pottasch 1980), if a reasonably large number of stars is included. The main source of error results from the inhomogeneity of the interstellar absorbing material, which can introduce a large scatter in the E(B-V) x distance diagrams.

In the present work, the extinction method will be applied to the planetary nebula He2-131 (PK 315-13°1), using both published general extinction curves and new measurements of stars lying in the direction of the nebula.

II. GENERAL INTERSTELLAR EXTINCTION

General extinction curves have been published by FitzGerald (1968) as colour-excess x distance diagrams for 74 zones of galactic longitude. The corresponding diagram for the direction of He2-131 is shown in Figure 1 (dots). The diagram corresponds to zone 65, comprising galactic longitudes between 310° and 320° (see also Milne and Aller 1975).

More recently, Lucke (1978) presented new results on the distribution of absorbing matter in the Galaxy, also shown in Figure 1 for the direction of He2-131 (crosses).

III. NEW MEASUREMENTS

Photoelectric measurements in the UBV system of stars within 2° of He2-131 in the plane of the sky were secured with the 60 cm USP (Universidade de Sao Paulo) telescope at Valinhos and the 1.6 m OAB (Observatorio Astrofisico Brasileiro) telescope at Brazopolis. Every star

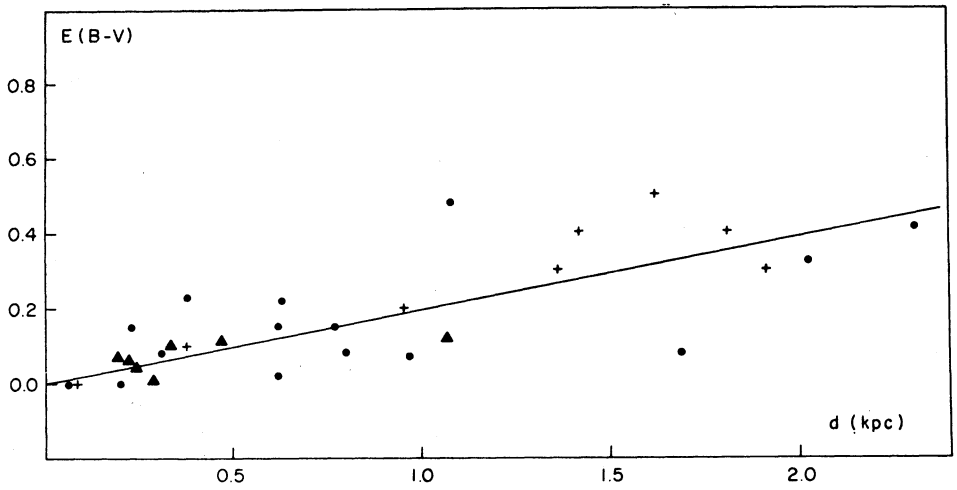

Fig. 1. Colour excess-distancediagram in the direction of He2-131. Dots: general extinction (FitzGerald 1968); crosses: general extinction (Lucke 1978); triangles: new measurements of field stars within 2° of the nebula in the plane of the sky.

in the program was observed two or three times and conventional reduction techniques have been used. Table 1 shows (a) the HD number, (b,c) the galactic coordinates, (d) spectral types and (e) luminosity classes (Houk and Cowley 1975), (f) measured V magnitude, (g) colour index B-V, (h) visual absolute magnitude, (i) colour excess E(B-V) and (j) distance d in pc. Colour-luminosity calibrations are from Allen (1973), Golay (1974) and Acker (1976). We have adopted the value R = 3.2 for the ratio between general and selective extinction (Pottasch *et al.* 1977). The results are also shown in Figure 1 (triangles).

TABLE 1

PROGRAM STARS WITHIN 2° OF He2-131

HD	ℓ	b	tipo	V	B-V	M_V	E(B-V)	d(pc)
133385	313,1	-12,2	B2 III/IV	6,80	-0,13	-3,73	0,12	1070
136272	314,2	-12,6	A1 III/IV	6,91	0,07	0,23	0,07	196
138682	315,0	-13,5	A0 IV	7,37	0,01	0,10	0,01	280
138698	316,3	-11,7	A1/2 IV/V	9,48	0,14	0,75	0,11	474
138775	315,8	-12,5	F6/7 IV	9,58	0,50	2,50	0,04	246
138800	314,3	-14,4	B7 III/IV	5,65	-0,05	-1,30	0,06	225
138880	314,8	-13,9	G6 III	8,65	0,97	0,70	0,10	336

IV. RESULTS AND DISCUSSION

The colour excess-distance diagram for distances within 2 kpc can be well represented by the least-squares straight line shown in Figure 1:

$$E(B-V) = 0.19\ d\ (kpc)$$

This result is supported by recent VBLUW measurements of stars close to the nebula in the plane of the sky by Gathier (private communication).

The extinction to He2-131 has been given as E(B-V) = 0.13 (Pottasch *et al.* 1977) from measurements of the UV dip at 2200 A. Such method is one of the best available, and usually correlates well with the traditional determination of extinction from radio and Hβ fluxes (see for example Pottasch *et al.* 1977). An average value of E(B-V) = 0.15 has been advanced by Pottasch (1980), taking into account the results by Cahn (1976) based on radio and Hβ fluxes.

Using the values given above, Figure 1 implies distances of 700 and 800 pc, respectively. If the uncertainty in E(B-V) is ≃ 0.05 (Pottasch *et al.* 1977), the estimated error in the distance is ≃ 270 pc, or about 35%.

The obtained distances are not very different from the values given by Pottasch (1980), on the basis of Lucke's (1978) general extinction curves only. On the other hand, they can significantly differ from other values given in the literature (Table 2).

TABLE 2

DISTANCE OF He2-131 DERIVED IN DIFFERENT INVESTIGATIONS

Reference	Method	d (pc)
Cahn and Kaler (1971)	Shklovsky (Hβ)	3330
Cahn and Kaler (1971)	Shklovsky (Hβ)	2590
Cahn and Kaler (1971)	Shklovsky (red)	4470
Milne and Aller (1975)	Shklovsky (radio)	4009
Milne and Aller (1975)	effective absorption	660
Cahn (1976)	Shklovsky (Hβ)	3920
Pottasch (1980)	general extinction	700
Daub (1982)	mass-radius relation	909
Maciel and Pottasch (1980)	mass-radius relation	1615

In view of its small radius (0.02 pc at a distance of 1200 pc, see below), the nebula is probably optically thick for radiation in the Lyman continuum (Cahn 1976, Maciel and Pottasch 1980, Pottasch 1980). Furthermore, low ionization ions have been detected in the optical range, such as [OI] 6300 A and [SII] 6717 A, 6731 A (Torres-Peimbert and Peimbert 1977). The nebular [OIII] lines are usually much weaker than [OII] 3726 A, 3729 A (Torres-Peimbert and Peimbert 1977) in this low excitation nebula, consistently with the detection of [OII] 2470 A, [CII] 2326 A and the absence of [CIII] 1908 A (Adams and Seaton 1982). The relatively high value of the electron density derived from UV lines is 1.3×10^4 cm^{-3} (Adams and Seaton 1982), in agreement with the Hβ rms value given by Torres-Peimbert and Peimbert (1977).

Therefore, the distances obtained by the Shklovsky method are upper limits, and the mass-radius relationship used by Maciel and Pottasch (1980) can be considered as a correction to this fact. On the other hand, the distances based on the interstellar extinction are shorter and similar to each other. However, at a distance of about 800 pc and 13° from the galactic plane, the nebula would be ≃ 180 pc below the galactic plane, which is not very different from the half-thickness of the galactic absorbing layer (cf. Jackson and Kellman 1977). In other words, the obtained distance can be viewed as a lower limit, which is further strengthened by the small slope shown in Figure 1. If we take into account the distance derived by Maciel and Pottasch (1980) (see also Maciel 1984) on the basis of a mass-radius relationship, we would obtain for He2-131

$$1600 > d\ (pc) > 800$$

It is difficult to make this result more accurate, although the real distance may be closer to the lower limit, which was determined by a more accurate method. It should be noted that a simple average of the limits given above would imply a distance d ≃ 1200 pc, with an uncertainty of about 33%, which is comparable with the best methods available.

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DISCUSSION

Peimbert: ¿Se ha determinado la posición de este objeto en el diagrama HR?

Maciel: Todavía no, pero estamos tratando de hacerlo.

Ruiz: En varias presentaciones hechas esta mañana hemos visto que hay evidencia de la existencia de polvo en las nebulosas planetarias. ¿De qué manera puede afectar ésto tus estimaciones de distancia?

Maciel: En acuerdo con la discusión de Pottasch, la contribución de la nebulosa a la extinción en su dirección es probablemente pequeña.

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