ON THE METHODS OF CORRECTION FOR THE INTERSTELLAR REDDENING OF PLANETARY NEBULAE

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Knowledge of the interstellar extinction is of great importance for the study of the properties of planetary nebulae. An estimate of the interstellar reddening for an individual nebula may be obtained by means of three independent methods. In the first method the observed Balmer decrement is compared with the theoretical decrement (case B of Baker and Menzel). The second method consists of a comparison of the observed ratio of Balmer and Paschen intensities of lines, arising from a common upper level, with the theoretically predicted ratio. Finally, for thermal planetary nebulae with well-determined radio spectra, the optically thin part of their spectra can be used for a determination of interstellar reddening. Comparison of the radio flux from an optically thin nebula with the observed $H\beta$ flux (in absolute units) allows us to evaluate the amount of extinction. Radio observations may thus give the interstellar extinction with high accuracy. It may especially be noted that the Balmer-decrement method, which is widely applied, gives satisfactory accuracy only if highly accurate H-line intensities are used. In all other cases it gives the most uncertain results, since its wavelength base-line is small. One must also take into account the fact that the $H\alpha$-line intensity is often not measured.

In the present work a comparison has been made among the values of the interstellar extinction at the $H\beta$-line derived for 28 planetary nebulae by the above-mentioned methods. For each nebula the observed Balmer decrement was deduced using intensities of the hydrogen lines taken from the literature. The relative intensities of the $H\alpha$, $H\beta$, $H\gamma$, and $H\delta$ lines were used for the determination of the interstellar extinction. The theoretical Balmer decrement was taken from Burgess, and the reddening law of Whitford was used. Published radio flux densities of planetary nebulae at frequencies 430–3000 MHz taken from the works of Terzian and Menon, Lynds, Slee and Orchiston, Davies *et al.*, and absolute $H\beta$ fluxes from O'Dell and Vorontsov-Velyaminov, Kostjakova, Dokuchaeva and Arhipova, were used for the determination of the extinction by the third method.

The results are given in Table 1. The table includes all nebulae for which the interstellar extinction may be computed by at least two of the three methods mentioned. The first column of the table gives the nebula, and the following three columns show its interstellar extinction at $H\beta$, in stellar magnitudes, obtained by the three methods.

Osterbrock and O'Dell (eds.), Planetary Nebulae, 159–161. © *I.A.U.*

Table 1

Interstellar extinction Aβ

Nebula	From Balmer decrement	From Paschen/Balmer	From radio method	Average
NGC 1535	0·25		0·48	0·36
2022	1·3		1·3	1·3
2392	0·6	0·5	0·91	0·66
3242	0·65		0·70	0·67
6210	0·4		0·44	0·42
6543	0·57	0·75	0·35	0·56
6572	0·6	0·85	0·87	0·77
6741	1·4		1·01	1·1
6818	0·0		0·41	0·2
6826	0·70	0·72	–	0·71
7009	0·06		0·30	0·18
7027	3·0	3·10	3·6	3·25
7662	0·8	0·9	0·83	0·84
IC 418	1·2	0·96	1·12	1·1
2149	1·6	1·6	1·5	1·57
4593	0·35		0·46	0·40
4634	1·7		1·7	1·7
4997	1·3	1·53	–	1·41
BD + 30°3639	1·7	1·6	–	1·65
NGC 246	2·2		0·0	0·0
1514	2·8		1·2	1·2
3587	1·4		0·30	0·30
4361	1·9		0·73	0·73
6720	1·0		0·58	0·6:
6853	0·9		0·23	0·23
7293	1·55		0·12	0·1

The values of the interstellar extinction derived from the Paschen/Balmer ratio method were taken from the work of O'Dell. The last column gives the average interstellar extinction for each nebula. As the table shows, the agreement of results is generally good within the random errors in line intensities and those in the radio fluxes. One can also see that the extended nebulae with lower surface brightness show a noticeable discrepancy between the interstellar reddening values obtained by the optical method and by the radio method. These seven nebulae are listed at the foot of the table. The discordance is too large, being beyond the error limits.

The relative intensities of the Hβ, Hγ and Hδ lines used for the determination of extinction of these nebulae were measured chiefly by Minkowski. The extinction derived from the radio-observation method is considerably smaller than the extinction derived from the Balmer-decrement method. There are several independent reasons for adopting the smaller values of interstellar extinction for these particular planetaries: their high galactic latitudes, their relatively small distances from the Sun, etc.

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One can show that the Balmer decrements of the nebulae with low surface brightness observed by Minkowski have a systematic error; his relative intensities of the Hγ and Hδ lines are too low. Therefore the interstellar extinction for these nebulae should be determined from the radio data. Furthermore, it is very desirable that the line-intensity measurements for these nebulae be repeated.

The good numerical agreement of interstellar extinction values derived by the Balmer-decrement method and by the radio method means that the theoretical Balmer decrement seems to be true (at least for the first four lines).

DISCUSSION

Minkowski: My observations, reported in 1942, were based on a few slit spectrograms per object. They therefore cover a negligibly small part of the area of any of these large, low-surface brightness nebulae, and the decrements derived from them may not necessarily be representative of the nebulae as a whole.

Osterbrock: Was the extinction determined from the radio/Hβ fluxes calculated under the assumption $T_e = 10^4$?

Arhipova: Yes.

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