The UV and Optical Reddening Law to the Galactic Bulge and CNO Abundances in Bulge Planetary Nebulae

N.A. WALTON and M.J. BARLOW
Department of Physics & Astronomy, University College London, Gower Street, London WC1E 6BT, UK

and

R.E.S. CLEGG
Royal Greenwich Observatory, Madingley Road, Cambridge CB3 0EZ, UK

Abstract. An analysis of the differential *ultraviolet* extinction towards four bulge planetary nebulae, based on the observed line ratio of He II 1640/4686Å, shows that the ultraviolet reddening law towards the bulge is much steeper than in the solar neighbourhood. An analysis of the *optical* reddening law for 42 bulge PN, based upon observed Balmer line ratios and Hβ to radio free-free flux ratios, is presented. The optical reddening law towards the bulge is steeper than in the local ISM, and thus the ratio of total to selective extinction, $R_V = 2.29(\pm 0.50)$, is lower than the standard solar neighbourhood value of $R_V = 3.10$.

We present abundance determinations, in particular C/H and C/O ratios, for 11 Galactic bulge PN, based on spectrophotometry in the UV from IUE and in the optical from the Anglo-Australian Telescope. The derived abundances are compared with values for PN in the Galactic disk. The mean C/O ratio for bulge PN is significantly lower than that found for Galactic disk PNs. Additionally we present an abundance analysis of the very metal-poor halo population PN M2-29, which is located in the bulge.

Background & Method: The standard Galactic reddening law is generally adopted in studies of objects towards the bulge. But it is known that the value of R_V, the ratio of the total to selective extinction, can vary in certain directions. Reddening laws are normally derived from differential measurements of reddened and unreddened luminous early-type stars. But such stars are absent in the Galactic Bulge, so the reddening law towards the bulge has never been previously determined. However, an analysis of the differential optical extinction towards bulge planetary nebulae (PN) (based on a comparison of the observed Balmer line ratios for Hα, Hβ and Hγ with Case B recombination theory) allows a direct determination of R_V towards the bulge to be made. The steepness of the ultraviolet reddening law in the bulge can be diagnosed from a comparison with Case B recombination theory of the observed flux ratios of He II λ1640 to λ4686 from high-excitation PN.

The optical reddening law was derived using data from the literature: reliable *total* Hβ fluxes were taken mainly from Webster (1983, PASP, 95, 610) and Shaw & Kaler (1989, ApJS, 69, 495). Balmer line flux ratios were taken from Acker et al (1991, A&AS, 89, 237) and Aller & Keyes (1987, ApJS, 65, 405). 5 GHz radio fluxes were taken mainly from Zijlstra (1989, Thesis, University of Groningen) and Gathier et al (1983, A&A, 128, 325).

The 11 PN predicted to be bright enough in the UV were observed with the IUE telescope in 1990 and 1992. Optical spectrophotometry was obtained for these objects at the 3.9m Anglo-Australian Telescope. The carbon abundances were determined by analysis of the UV C III] and C IV lines, using an ultraviolet reddening law that was interpolated from our mean measurements plotted in Fig. 1. The

H. Dejonghe and H. J. Habing (eds.), Galactic Bulges, 337–338.

abundances of the elements He, O, N, Ne, Ar and S were determined by analysis of the UV and optical emission lines.

	He	C $\times 10^4$	N $\times 10^4$	O $\times 10^4$	Ne $\times 10^4$	C/O	N/O
Bulge mean	0.118	3.49	2.01	4.62	1.10	0.603	0.487
±	0.029	4.10	1.14	1.83	0.590	0.532	0.435

Table 1. The mean abundances determined for the 11 bulge PNs.

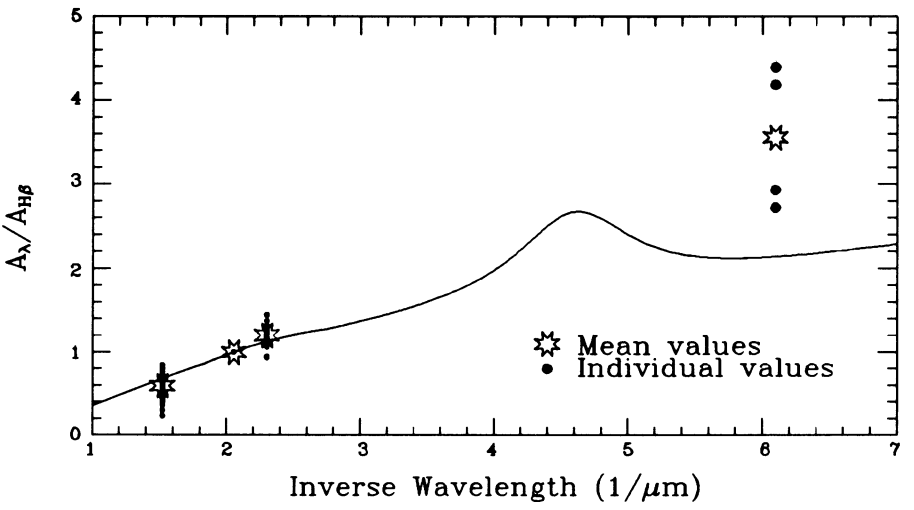

Fig. 1. The UV and optical reddening law. The standard reddening curve is that of Seaton (1979, MNRAS, 187, 79p) for R=3.10. The open circles show the $A_\lambda/A_{H\beta}$ values for the individual PNs at Hα, Hβ, Hγ and He II λ1640. The stars mark the mean values of $A_\lambda/A_{H\beta}$.

Conclusions: The optical and UV reddening law in the bulge is clearly steeper than the normal Galactic law (e.g. Seaton, 1979). The optical analysis of 42 galactic bulge PN, shows that R_V is 2.29 (±.50), significantly lower than the value of R_V=3.1 found for the Galactic diffuse interstellar medium in the solar neighbourhood. The optical data supports the conclusion, obtained from the UV data, that the reddening law is steeper towards the bulge.

Only 2 of the 11 PN have C/O>1, compared with 60% for Solar neighbourhood PN (Zuckerman & Aller, 1986, ApJ, 301, 772). The only bulge PN with C/O clearly in excess of unity (Cn 1-5) has a WC4 Wolf-Rayet central star. The mean O/H ratio for the bulge PN is similar to that found for local PN, a result in agreement with that of Ratag et al (1992, A&A, 255, 255). One of the bulge PN (M 1-42) is of Type I (i.e. it has high He/H and N/O ratios).

M 2-29, probably a halo population object currently passing through the bulge, has very low metallicity and in addition is extremely carbon-poor: we derive $O/H = 2.8\times10^{-5}$, $He/H = 0.093$ and $C/O = 0.04$.

https://doi.org/10.1017/S0074180900123496 Published online by Cambridge University Press