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NEBULAR SPECTRUM OF CPD-56°8032 AND He2-113

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SUMMARY

The electron density, temperature and ion abundances in the nebulae surrounding the two WC 10 stars CPD−56°8032 and He2-113 have been estimated. In CPD−56°8032 sulphur, nitrogen and oxygen seem to have solar abundances, whereas carbon and neon are enhanced. The nebular properties of all the four WC 10 stars He2-113, CPD−56°8032, M4-18 and V348 Sgr are compared.

Webster & Glass (1974) identified a group of four stars consisting of CPD−56°8032, He2-113, M4-18 and V348 Sgr as belonging to the cooler extension of planetary nebulae with WC 10 nuclei and hoped that their evolutionary stage might perhaps be identified. All four have substantial infrared excesses and their central stars appear to be hydrogen deficient. V348 Sgr has an optical nebulosity extending to 9 arcsec from the star, and in CPD−56°8032 the nebular size is inferred by Roche, Allen & Bailey (1986) as 1·3 arcsec by mapping the 3·28 μm dust emission feature. In this note we try to study the physical conditions and abundances in the nebulae around the stars CPD−56°8032 and He2-113.

The spectroscopic observations used here were obtained with the ESO 1·5-m telescope using the Reticon system in the wavelength region λ5530–λ10300 at 228 Å mm^{-1} and 78 Å mm^{-1} dispersions for CPD-56°8032 and He2-113 respectively. The spectrum of CPD-56°8032 was discussed earlier by Thackeray (1977) and Houziaux & Heck (1982) in the wavelength region shortward of λ8200. Apart from the nebular lines identified by Thackeray, lines of [CI] λ8727, λ9859 and [SIII] λ9069, λ9534 are also present. We obtained the relative intensities of blended nebular lines using the line lists of Thackeray and assuming that the line profiles are Gaussian.

The reddening in CPD−56°8032 and He2-113 was estimated by Aitken *et al.* (1980) from both the Balmer decrement and the radio-Hβ flux relationship as $E(B-V)=0{\cdot}6$ and 1·05 mag, respectively. The line intensities are corrected using these reddening values.

The electron temperature and density are estimated in CPD−56°8032 using the line ratio of [NII] λ5755 to λ6548 and the radio flux. The [SIII] lines provided an upper limit to the electron temperature and the [CI] line ratio of λ8727 to λ9850 provided the measure of electron densities once the electron temperature is fixed. The adopted T_e and N_e are $1{\cdot}1\times10^4$ K and 2×10^4 cm^{-3}, respectively.

The radio flux distribution of He2-113 and the stellar planetary nebulae SwSt 1 are both very similar and have a high emission measure of 2×10^8 cm^{-6} (Jones 1985). By equating the emission measure obtained from the critical frequency and the optically thin emission, the angular size is estimated as 0·8 arcsec (Kwok, Purton & Keenan 1981). For planetary nebulae Pottasch

TABLE I

Ion abundances

Log $(X^+/H^+)+12{\cdot}0$

	λ	He2-113	CPD−56°8032	M4-18	V348 Sgr
T_e(K)	—	8800	11 000	5600	15000
N_e(cm^{-3})	—	10^5	2×10^4	$1{\cdot}1\times10^4$	10^3
C I	8727	—	7·15	—	—
	9850	—	7·17	—	—
C II*	2326	—	9·22	—	—
C III*	1908	—	8·91	—	—
N II	5755	—	7·72	—	—
	6548	—	7·14	8·4±0·3	7·4
O II	7319	—	8·35	9·7±0·6	7·3
	7330	—	—	—	—
O I	6300	—	7·50	7·9±0·4	6·1
S II	6716	—	6·8	7·1±0·3	6·1
S III	9069	6·3	5·84	—	—
	9534	—	5·81	—	—
Ne II†	12810	8·0	8·15	—	—

* From Houziaux & Heck (1982).
† From Aitken *et al.* (1980).

et al. (1984) derived a relation between the linear nebular radius and the blackbody dust temperature obtained from IRAS fluxes. We used this relation to obtain the distance of He2-113, and using the Hβ flux given by Aitken *et al.* we estimated the electron density as $7\text{–}10\times10^4$ cm^{-3}. Flower, Goharji & Cohen (1984) obtained $T_e \simeq 8800$ K and $N_e \simeq 1\times10^5$ cm^{-3} for SwSt 1. Since the nebular properties of He2-113 and SwSt 1 appear to be similar, we may adopt $T_e \simeq 8800$ K for He2-113 also and the [C I] line ratio of λ8727 to λ9850 again indicates $N_e \simeq 1\times10^5$ cm^{-3} for He2-113.

With the above adopted values of T_e and N_e the ion abundances have been obtained for CPD−56°8032 and He2-113 and are given in Table I along with the abundances for M4-18 and V348 Sgr taken from Goodrich & Dahari (1985) and Dahari & Osterbrock (1984). Unlike M4–18 the oxygen abundances do not seem to be enhanced in CPD−56°8032, although carbon is quite abundant in the nebula. However, nitrogen, which probably is mostly in the form of N^+, appears to be roughly solar in all the three objects CPD−56°8032, M4-18 and V348 Sgr. Sulphur, which is mostly in the form of S^+ in CPD−56°8032, is roughly solar, and this probably is the case for the other objects also.

There appears to be a systematic behaviour in the nebular properties of these four objects. He2-113, which has a hotter central star at 30000 K (Aitken *et al.* 1980), has compact nebulosity (~0·8 arcsec) and a high electron density of 10^5 cm^{-3}. CPD−56°8032, with a central star temperature of 26000–23000 K (Houziaux & Heck 1982), has a nebula of 1·3 arcsec extent and an electron density of 2×10^4 cm^{-3}, and V348 Sgr, with a central star at 20000 K (Schönberner & Heber 1986) and optical nebulosity of 18 arcsec extent, has an electron density of 10^3 cm^{-3}. M4-18 is similar to CPD−56°8032, with a central star at 22000 K and $N_e \simeq 1{\cdot}1\times10^4$ cm^{-3}. If we adopt the distances from the relationship obtained by Pottasch *et al.* (1984)

for the linear nebular radius and blackbody dust temperature, then the luminosities obtained for these four central stars are roughly the same, log $L_*/L_\odot$ ranging from 3·66 to 3·33. In the *H-R* diagram they scatter around the theoretical evolutionary track for a post-asymptotic-giant-branch star of mass 0·56 $M_\odot$ as computed by Schönberner. The fact that the hotter star is surrounded by a compact, high-density nebula whereas the cooler star has an extended nebula with low electron-density might indicate that the evolution is proceeding from left to right towards the asymptotic giant branch for a second time (Iben 1984), and the central stars might form a link with RCrB stars (Rao & Nandy 1986).

REFERENCES

Aitken, D.K., Barlow, M.J., Roche, P.F. & Spencer, P.M., 1980. *Mon. Not. R. astr. Soc.*, **192**, 679.

Dahari, O. & Osterbrock, D.E., 1984. *Astrophys. J.*, **277**, 648.

Flower, D.R., Goharji, A. & Cohen, M., 1984. *Mon. Not. R. astr. Soc.*, **206**, 293.

Goodrich, R.W. & Dahari, O., 1985. *Astrophys. J.*, **289**, 342.

Houziaux, L. & Heck, A., 1982. In *Wolf–Rayet Stars: Observations, Physics, Evolution*, IAU Symp. No. 99, p. 139, eds de Loore, C.W.H. & Willis, A.J., Reidel, Dordrecht, Holland.

Iben, I. Jr., 1984. *Astrophys. J.*, **277**, 333.

Jones, P.A., 1985. *Mon. Not. R. astr. Soc.*, **216**, 613.

Kwok, S., Purton, C.R. & Keenan, D. W., 1981. *Astrophys. J.*, **250**, 232.

Pottasch, S.R., Baud, B., Beinteman, D., Emerson, J., Habing, H.J., Harris, S., Houck, J., Jennings, R. & Marsden, P., 1984. *Astr. Astrophys.*, **138**, 10.

Rao, N.K. & Nandy, K., 1986. *Mon. Not. R. astr. Soc.*, **222**, 357.

Roche, P.F., Allen, D.A. & Bailey, J.A., 1986. *Mon. Not. R. astr. Soc.*, **220**, 7P.

Schönberner, D. & Heber, U., 1986. In *Hydrogen Deficient Stars and Related Objects*, p. 217, eds Hunger, K., Schönberner, D. & Kameswara Rao, N., Reidel, Dordrecht, Holland.

Thackeray, A.D., 1977., *Observatory*, **97**, 165.

Webster, B.L. & Glass, I.S., 1974. *Mon. Not. R. astr. Soc.*, **166**, 491.