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Further VLA* Observations of Hydrogen Deficient Stars

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Abstract. VLA observations at 6 cm have been obtained for three hydrogen-deficient objects υ Sgr, V 348 Sgr, and Abell 58. Abell 58 was also observed at 2 cm. Only upper limits to the flux density could be set for these sources. A new radio source at 6 cm was found in the field of υ Sgr.

The upper limit for 6 cm flux density of V 348 Sgr sets an upper limit to its reddening as $E(B-V) \leqslant 0.65$. The hydrogen deficient planetary nebula A 58 shows much lower radio flux than expected from the infrared-radio flux density relationship of planetary nebulae.

Key words: stars, hydrogen-deficient—stars, radio observations—stars, individual—planetary nebulae

1. Introduction

In order to study the mass-loss rates and the nebular properties around hydrogen-deficient stars we surveyed six extreme hydrogen-deficient stars with VLA at 2 cm and 6 cm and could place upper limits to the flux density (Rao, Venugopal & Patnaik 1985). Because of the suspicion of variablity of the flux in some of the objects and to include few other hydrogen-deficient nebulae in the sample we have obtained additional observations of three objects V 348 Sgr, υ Sgr and the planetary nebula A 58.

2. Observations

The observations were obtained with VLA (Napier, Thompson & Ekers 1983) in the B/C hybrid configuration on 1985 July 5. V 348 Sgr and υ Sgr were observed only at 6 cm (C-band) whereas A 58 was observed both at 6 and 2 cm (U-band) with a bandwidth of 50 MHz. The data were acquired in both AC and BD IFs (4835 MHz and 4885 MHz in C band and 14915 and 14965 MHz in U band). The data from the two IFs were combined to make maps. Regions of about 256 arcsec × 256 arcsec at 6 cm and 102 arcsec × 102 arcsec at 2 cm were mapped around these objects. The maps were cleaned and restored using the software package AIPS. We could not detect any source

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Table 1. Upper limits to the radio flux densities.

Object	6 cm			2 cm		
	Beam size arcsec	PA	Upper limit (3σ) flux density mJy/beam	Beam size arcsec	PA	Upper limit (3σ) flux density mJy/beam
V 348 Sgr	4.09×2.30	$-65°$	0.15			
υ Sgr	7.03×2.01	$-62°$	0.21			
A 58	4.02×1.16	76°	0.15	1.43×0.45	75°	0.37

near the position of these objects; however the upper limits to the flux densities are given in Table 1.

3. Discussion of the programme stars

υ Sgr: This is one of the four known hydrogen-deficient binaries. The properties and the earlier VLA measurements have been discussed by Rao & Venugopal (1985) and Rao, Venugopal & Patnaik (1985). The present upper limit is a further refinement on the earlier measurements and changes the mass-loss rate to $\lesssim 4.8 \times 10^{-7} \lesssim M_{\odot}\,\mathrm{yr}^{-1}$ for the system. We used the value of the terminal velocity $V_{\infty} = 813\ \mathrm{km\,s}^{-1}$ as suggested by Parthasarathy, Cornachin & Hack (1986).

There is a source roughly 4 arcmin north of υ Sgr whose 1950 coordinates are:

$$\alpha = 19^{\mathrm{h}}\ 18^{\mathrm{m}}\ 54^{\mathrm{s}}.85 \pm 0^{\mathrm{s}}.02, \qquad \delta = -15°\ 59'\ 13''.93 \pm 0''.16.$$

After fitting a single-point gaussian for this source the 6 cm peak flux is 0.89 ± 0.08 mJy/beam and the total flux is 1.135 ± 0.225 mJy. There is no obvious optical candidate to be identified with this source on Palomar Observatory Sky Survey (POSS) prints.

V 348 Sgr: This is one of the hot hydrogen-deficient stars associated with an optical nebulosity. The present upper limit at 6 cm improves the one given in Rao, Venugopal & Patnaik (1985). Purton *et al.* (1982) had earlier observed this object with the Parkes radio telescope in the period 1977–78. Only the 14.5 GHz flux measurement has a smaller probable error and is given as 6 ± 3 mJy. The half-power beam width was however 2.3 arcmin. Our earlier measurements with the VLA at 2 and 6 cm and the present measurement at 6 cm do not show any detectable flux. There is a possibility that the Parkes measurement might have included the galaxy which is 4 arcmin west of V 348 Sgr.

There is considerable uncertainty about the estimate of reddening in the nebulosity. Dahari & Osterbrock (1984) obtained $E(B-V)$ of 1.4 from the Balmer decrement when the star was at minimum light, whereas Houziaux (1986, personal communication) obtained $E(B-V)$ of 0.45 from the Hα/Hβ measurements when the star was at maximum light. Schönberner & Heber (1986) estimates $E(B-V) = 0.60$ with 0.15 of this caused by amorphous carbon dust in the circumstellar environment. The Hβ flux measured by Dahari & Osterbrock (1984) is 4.07×10^{15} erg cm^{-1} s^{-1}. If the 3σ upper limit to the flux density at 6 cm is taken as the upper limit to the free-free flux from the nebula then the flux density S_ν is related to Hβ flux, $F_{\mathrm{H}\beta}$ as (The VLA beam size used is about same as the slit size used by Dahari & Osterbrock.)

$$\frac{S_\nu}{F_{\mathrm{H}\beta}} = 2.51 \times 10^7 \; T_e^{0.53} \nu^{-0.1} \; Y \; \mathrm{Jy/(erg\,cm^{-2}\,s^{-1})}$$

(Pottasch 1984) where

$$Y = \left(1 + \frac{n(H_e^+)}{n(H^+)} + \ldots\right).$$

Using $T_e = 1.5 \times 10^4$ K and $Y = 1.13$ (Dahari & Osterbrock 1984) the resulting $F_{\mathrm{H}\beta}$(cal) is 3.79×10^{-14} erg cm^{-2} s^{-1} and the value of $E(B-V)$ is obtained as $\leqslant 0.65$ using the relation $E(B-V) = (1/1.46)\log\,[F_{\mathrm{H}\beta}\,(\mathrm{cal})/F_{\mathrm{H}\beta}\,(\mathrm{obs})]$ (Pottasch 1984). This value of $E(B-V)$ is in agreement with the reddening estimated by Houziaux (1986, personal communication) and Schönberner & Heber (1986) indicating that most of the reddening is attributable to the interstellar medium.

Abell 58: This is a low-surface-brightness planetary nebula showing an extension of 44×36 arcsec on red plates (van den Bergh 1971). However it does not appear on blue POSS prints. On the UK Schmidt *J* plates the nebular filaments near the centre are faintly seen, the nebula is of low-excitation class with [N II] λ 6584 > Hα and λ 5007, λ 4959 of [O III] being very weak (Ford 1971; Pottasch *et al.* 1986). This is also a strong IRAS source with T_{BB} of the dust $\sim$122 K. The central object of this nebula was first known as V 605 Aql and became visible in 1917; it reached a magnitude of about 10 in 1919 (Lundmark 1921), faded thereafter and was last observed in 1923. The spectrum of the star observed in 1921 showed the characteristics of a hydrogen-deficient star and a very good match to HD 182040 (Bidelman 1973). At present there is a hydrogen deficient nebulous knot near the centre (Pottasch *et al.* 1986; Seitter 1985). There is a very faint star (20 mag) 1 arcsec north of the central nebula which may be what remains of V 605 Aql. The nebular expansion velocity as measured from the line widths of [N II] $\lambda\lambda$ 6548, 6584 and Hα on a CCD spectrum obtained with 3-m Shane telescope is less than 40 km s^{-1}. Thus the nebula has existed much before the 1919 outburst. We planned to look for the remnant of the 1917 outburst if it exists in the radio with the VLA. Secondly, Pottasch *et al.* (1984) showed that for planetary nebulae there is a strong correlation between the total infrared flux as obtained by IRAS measurements and 6 cm radio flux density. With measured infrared flux density (6.0×10^{-2} W m^{-2}) for A 58 (Pottasch *et al.* 1984) we expected to see about 300 mJy at 6 cm. Surprisingly we could not detect any flux density either at 2 cm or 6 cm and the upper limits for the flux density are given in Table 1. Similar result has also been reported for A 30 and A 78 by Zijlstra (Pottasch *et al.* 1986). The infrared radiation seems to be much higher than expected from the free-free radio emission from hydrogen-deficient nebulae. The present results seem to support the suggestion of Pottasch *et al.* (1986) that this property could probably be used to identify other hydrogen-deficient nebulae.

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