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NEUTRAL GAS BUBBLES SURROUNDING SOUTHERN OPTICAL RING NEBULAE: ANON(WR 23) AND RCW 52

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RESUMEN

Utilizando datos interferométricos de la línea de 21 cm del H I analizamos la distribución del hidrógeno neutro en la vecindad de las nebulosas anillo ópticas alrededor de las estrellas WR 23 (WC6) y LS 1887 (O8V). Identificamos sendas burbujas de gas neutro interestelar asociadas a las nebulosas anillo Anon(WR 23) y RCW 52.

ABSTRACT

Based on interferometric H I 21 cm line data we analyze the distribution of the neutral hydrogen in the environs of the optical ring nebulae around WR 23 (WC6) and LS 1887 (O8V). We identify the interstellar atomic gas bubbles associated with the optical ring nebulae Anon(WR 23) and RCW 52.

Key Words: **ISM: RING NEBULAE — STARS: EARLY-TYPE — STARS: INDIVIDUAL (HD 92809, LS 1887) — STARS: WOLF-RAYET**

1. INTRODUCTION

The strong stellar winds of massive stars strongly perturb their surrounding interstellar medium creating interstellar bubbles, which have been modeled by several authors (e.g., Dyson 1989).

These bubbles can be detected in several ways: as optical ring shaped nebulae (e.g., Marston, Chu, & García-Segura 1994), as shell shaped thermal radio continuum sources (e.g., Goss & Lozinskaya 1995), as neutral gas voids and expanding shells in the H I 21 cm line emission distribution (e.g., Cappa et al. 2003) and as infrared shells (e.g., Mathis et al. 1992).

Here we report the detection of two new H I bubbles surrounding the optical ring nebulae Anon(WR 23) around HD 92809 (WC6) and RCW 52 around LS 1887 (O8V).

2. H I DATA

To investigate the neutral gas distribution we analyzed the H I 21 cm line emission in an area of $2^\circ \times 2^\circ$ centered approximately at the position of the WR star HD 92809 (WR 23). The H I data are part of the Southern Galactic Plane Survey (SGPS) and were obtained using the Australia Telescope Compact Array (ATCA) and the Parkes Radiotelescope. The synthesized beam in this region is $2'.4 \times 2'.1$. The H I data have a velocity resolution of $0.82\,\mathrm{km\,s^{-1}}$ and an rms noise of 2.3 K.

3. ANON(WR 23) AROUND HD 92809

WR 23 is a WC6 type star located towards $(l, b) = (286^\circ.78, -0^\circ.03)$ at 2.5 kpc, related to Car OB1 (Feinstein, Marraco, & Muzzio 1973; Walborn 1995). Its optical ring nebula, Anon(WR 23), was first identified by Lortet, Niemela, & Tarsia (1980) as a filamentary shell of about $30'$ in diameter. WR 23 appears projected close to the center of the W-type nebula (Chu 1982). The optical emission is brighter toward lower Galactic longitudes and negative Galactic latitudes, where it displays a complex net of thin filaments, while the presence of diffuse emission is clear toward positive Galactic latitudes as depicted in Figure 1.

The kinematics of the region are quite complex. Chu (1982) and Georgelin, Lortet, & Testor (1986) found that the ionized gas has Hα velocities in the range -30 to $-1\,\mathrm{km\,s^{-1}}$. The expansion velocity and the dynamical age of the nebula were estimated as 15 to $30\,\mathrm{km\,s^{-1}}$ and (2 to 4) $\times\ 10^5$ yr, respectively, by Georgelin et al. (1986).

The analysis of the H I gas emission distribution in the environs of Anon(WR 23) has enabled us to identify an H I cavity and shell positionally coincident with the ring nebula. The cavity and the surrounding envelope are clearly identified in the upper panel of Figure 2, which shows the H I column density distribution within the velocity interval -21.4 to $-12.0\,\mathrm{km\,s^{-1}}$. As in Fig. 1, the cross near the center of the image indicates the position of the WR

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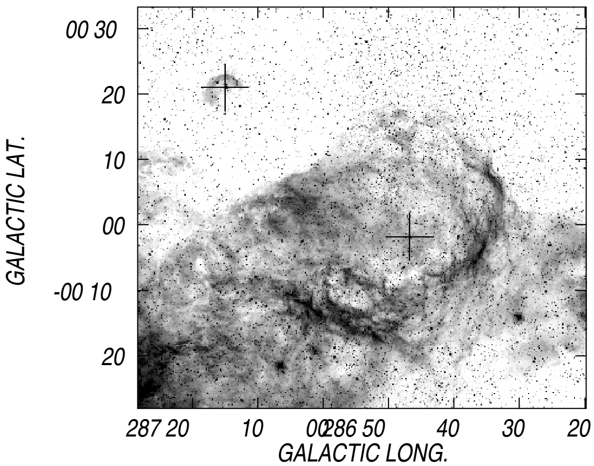

Fig. 1. DSS image showing the ring nebulae Anon(WR 23) around HD 92809, $(l, b) = (286.^\circ78, -0.^\circ03)$, and RCW 52 around LS 1887, $(l, b) = (287.^\circ25, +0.^\circ35)$. The crosses mark the position of the stars.

star. The mean diameter of the H I shell is $36'$. The H I structure has a systemic velocity of about $-17\,\mathrm{km\,s^{-1}}$. The lower panel of Fig. 2 shows an overlay of the H I and the Hα line emissions. There is a striking correlation between the optical ring nebula and the H I structure, with most of the thin optical filaments projected onto the inner border of the surrounding H I shell.

The clear morphological correspondence between Anon(WR 23) and the H I structure, and the agreement of the H I and Hα velocities indicate that the H I shell is the atomic gas counterpart of the optical nebula.

Anon(WR 23) is also detected as an ionized shell in the radio continuum emission at 4.9 GHz (PMN survey, Griffith & Wright 1993). We have estimated the ionized mass and the electron density of the nebula assuming a filling factor $f = 0.03$ to 0.15 using the 4.9 GHz image.

The main parameters of the neutral and ionized structures are listed in Table 1. The velocity interval corresponds to the velocity range in which the H I bubble is detected. The stellar wind mechanical energy E_{W} was estimated assuming a mass-loss rate $\dot{M} \approx 1.3\times10^{-5}\,M_\odot\,\mathrm{yr^{-1}}$ (Nugis & Lamers 2000) and a terminal wind velocity $V_{\mathrm{w}} = 2250\,\mathrm{km\,s^{-1}}$ (Eenens & Williams 1994).

4. RCW 52 AROUND LS 1887

RCW 52 is the optical ring nebula surrounding the O-type star LS 1887, $(l, b) = (287.^\circ25, +0.^\circ35)$ (Fig. 1). The velocity of the ionized gas in this arc-shaped nebula is $\simeq -17\,\mathrm{km\,s^{-1}}$ (Georgelin et al. 1986). The neutral gas emission distribution in the environs of RCW 52 shows an H I shell of $17.'8$ in diameter (Fig. 2).

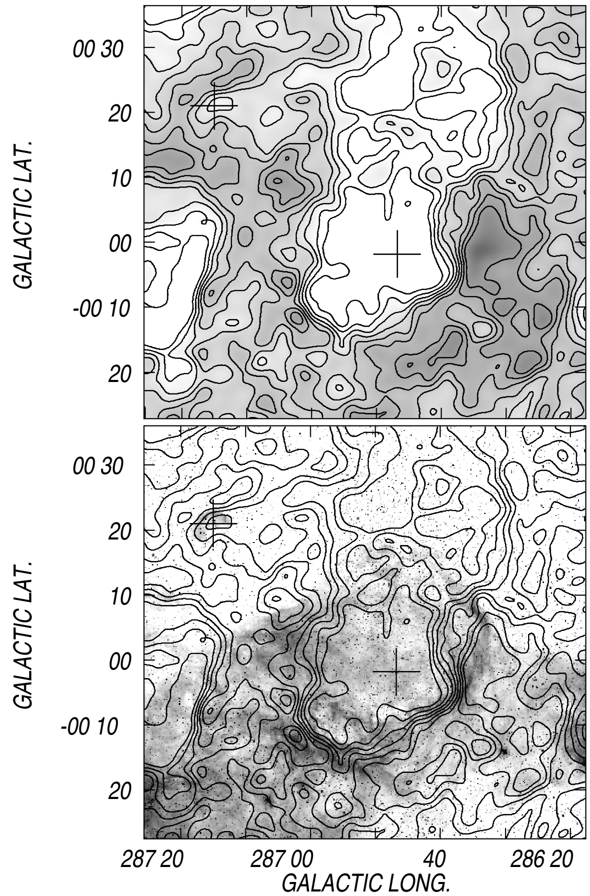

Fig. 2. Upper panel: H I column density distribution within the velocity interval -21.4 to $-12.0\,\mathrm{km\,s^{-1}}$. The grayscale corresponds to 13.0×10^{20} to $25.0\times10^{20}\,\mathrm{cm^{-2}}$. The contour lines correspond to 12.4×10^{20} to $18.0\times10^{20}\,\mathrm{cm^{-2}}$ in steps of $0.8\times10^{20}\,\mathrm{cm^{-2}}$. As in Fig. 1, the crosses indicate the position of the massive stars. Lower panel: Overlay of the Hα (*grayscale*) and H I (*contours*) emission.

The physical parameters of the ionized gas were derived from the radio continuum emission at 4.9 GHz. They are summarized in Table 1, along with the main data of the H I bubble. To estimate E_{W} we adopted $\dot{M} \approx 10^{-6}\,M_\odot\,\mathrm{yr^{-1}}$ and $V_{\mathrm{w}} = 1500\,\mathrm{km\,s^{-1}}$ (Prinja, Barlow, & Howarth 1990; Lamers & Leitherer 1993).

5. CONCLUSIONS

We have detected the neutral gas counterparts of the optical ring nebulae blown by the strong stellar winds of the massive stars HD 92809 (WC6) and

TABLE 1

MAIN PARAMETERS OF THE BUBBLES ASSOCIATED WITH WR 23 AND LS 1887

	Anon(WR 23)	RCW 52
(l, b) center	(286.°8, 0.°0)	(287.°1, +0.°4)
Velocity interval (km s^{-1})	-26 to -10	-22 to -12
H I systemic velocity (km s^{-1})	-17	-17
Expansion velocity (km s^{-1})	$\geq$10	$\approx$5
Radius of the H I shell (pc)	13.3	6.5
Dynamical age (10^5 yr)	7.3	
Swept-up atomic mass ($M_\odot$)	830	110
Ionized mass ($M_\odot$)	300–700	70
Electron density (cm^{-3})	40–70	65
Kinetic energy of the bubble E_k (10^{47} erg)	28	0.3
Stellar wind mechanical energy E_W (10^{49} erg)	25	7

LS 1887 (O8V). In both cases, the H I bubbles appear external to the ionized gas ring nebulae.

A comparison between the values of the kinetic energy (E_k) of the bubbles and the energy of the stellar winds (E_W) in Table 1 shows that, in both cases, the stellar wind power is enough to create the observed bubbles. The dynamical age derived for the neutral gas bubble surrounding HD 92809 suggests that the bubble was blown during the WR stage of the massive central star.

These new H I bubbles have similar parameters to those found around other WR and O-type stars (cf. Cappa et al. 2003).

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