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Atomic and molecular gas in the environs of the ring nebula RCW 78

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Abstract. We present a study of the neutral atomic and molecular gas associated with the ring nebula RCW 78 around the WR star HD 117688 (= WR 55) based on HI 21cm line data and CO(1-0) observations obtained with the SEST. The analysis of the neutral atomic gas distribution reveals an HI shell which is interpreted as the neutral gas counterpart of the optical ring nebula RCW 78, while CO observations show the presence of molecular material interacting with the nebula. The surface of the detected molecular cloud has probably been photodisociated and ionized by the UV photons of the WR star.

1. Introduction

Interstellar bubbles created by the stellar winds of massive stars are generally detected as thermal radio continuum shells, as cavities and expanding shells in the HI 21cm line emission distribution, and as infrared shells (see Cappa et al. 2003 for a summary). Molecular line observations allowed the detection of molecular gas related to these bubbles, although a few cases have been analyzed. These studies have shown that photodisociation regions and shock fronts are common phenomena linked to interstellar bubbles (Cappa et al. 2001; Rizzo et al. 2003).

Here we investigate the atomic neutral and molecular gas associated with the optical ring nebula RCW 78 around WR 55 based on CO observations of the brightest part of the nebula and HI 21cm line data of the whole ionized region. Our aims are to identify the neutral gas linked to the ionized interstellar bubble and to study the kinematics and energetics of the nebula.

2. RCW 78 around WR 55

RCW 78 is a ring nebula of about 35′ in diameter, roughly centered on the WR star WR 55. An Hα image of the whole nebula is shown in figure 5 by Chu, Treffers, & Kwitter (1983). The brightest part of RCW 78 is about 10′ in size and offset to the northwest of the star, while fainter regions are present to the northeast, east and south of the star. Chu & Treffers (1981) classified the nebula as R_a since no shell structure was apparent. Their Hα study shows that the velocity of the ionized nebular material varies from –44 km s^{-1} near the star to –53 km s^{-1} 7′ north of the star.

The nebula is related to HD 117688 (= WR 55 = MR 49), a WN7 star placed at *(l,b)* = (307$^\circ\!\!.$80,+0$^\circ\!\!.$16) or (α,δ(J2000)) = (13^{h}33^{m}30.1^s, –62°19′1.2″) at a spectrophotometric distance of about 6.0 kpc (Conti & Vacca 1990; van der Hucht 2001).

3. Data bases

CO(1-0) line data towards the brightest region of RCW 78 were acquired with the Swedish-ESO Submillimetre Telescope (SEST) located at La Silla, Chile, during 2002 January and 2003 March. The half-power beamwidth (HPBW) of the telescope at 115 GHz was 44″. The data were acquired in the position-switching mode on a grid spacing 45″. After smoothing in velocity, the data have a velocity resolution and rms noise of 0.43 km s^{-1} and 0.20 K, respectively. The observed line intensities were expresed as main-beam brightness temperatures by dividing the antenna temperatures by a main-beam efficiency of 0.70. The CO(1-0) profiles cover the velocity interval (–80 to 0 km s^{-1}).

The HI data belong to the Southern Galactic Plane Survey (SGPS) obtained with the Australia Telescope Compact Array (ATCA) and the Parkes Radiotelescope. The data have a synthesized beam of 2$'\!\!.$4×2$'\!\!.$1, a velocity resolution of 1.64 km s^{-1}, and a rms noise of 2.1 K.

4. CO results

Within the observed velocity range, the CO(1-0) profiles of this section of the Galaxy show molecular components within the velocity interval –65 to –8 km s^{-1}.

Figure 1 displays an overlay of a series of CO images corresponding to selected velocity intervals (*contour lines*) and the DSS R image of the brightest part of RCW 78 (*grayscale*). The velocity intervals, indicated in the upper part of each image, were selected to emphasize the correlation between the molecular and the nebular gas. The CO emission distribution reveals that molecular gas with velocities in the range –66.4 to -53.1 km s^{-1} (shown in the top panel of Fig. 1), surrounds the northern border of the nebula, while molecular material having velocities in the range –53.1 to –39.4 km s^{-1} (top and central panels of Fig. 2) borders the eastern, southern and western sections. Gas with velocities in the ranges –38.5 to –36.7 km s^{-1} and –35.8 to –32.7 km s^{-1} (central and bottom panels) encircle the western and northwestern borders, respectively. The last two images of Fig. 1 depict the CO emission integrated within the velocity interval –66.4 to –32.7 km s^{-1} in grayscale and contour lines. Clearly, the bright molecular clumps encircle the brightest region of RCW 78.

The velocities of the molecular gas are similar to the velocities of the ionized gas: larger negative CO and Hα velocities are present bordering the northwestern region, while lower negative CO and Hα velocities were detected close to the star.

The molecular mass in the area was estimated as 3×10^4 M$_\odot$.

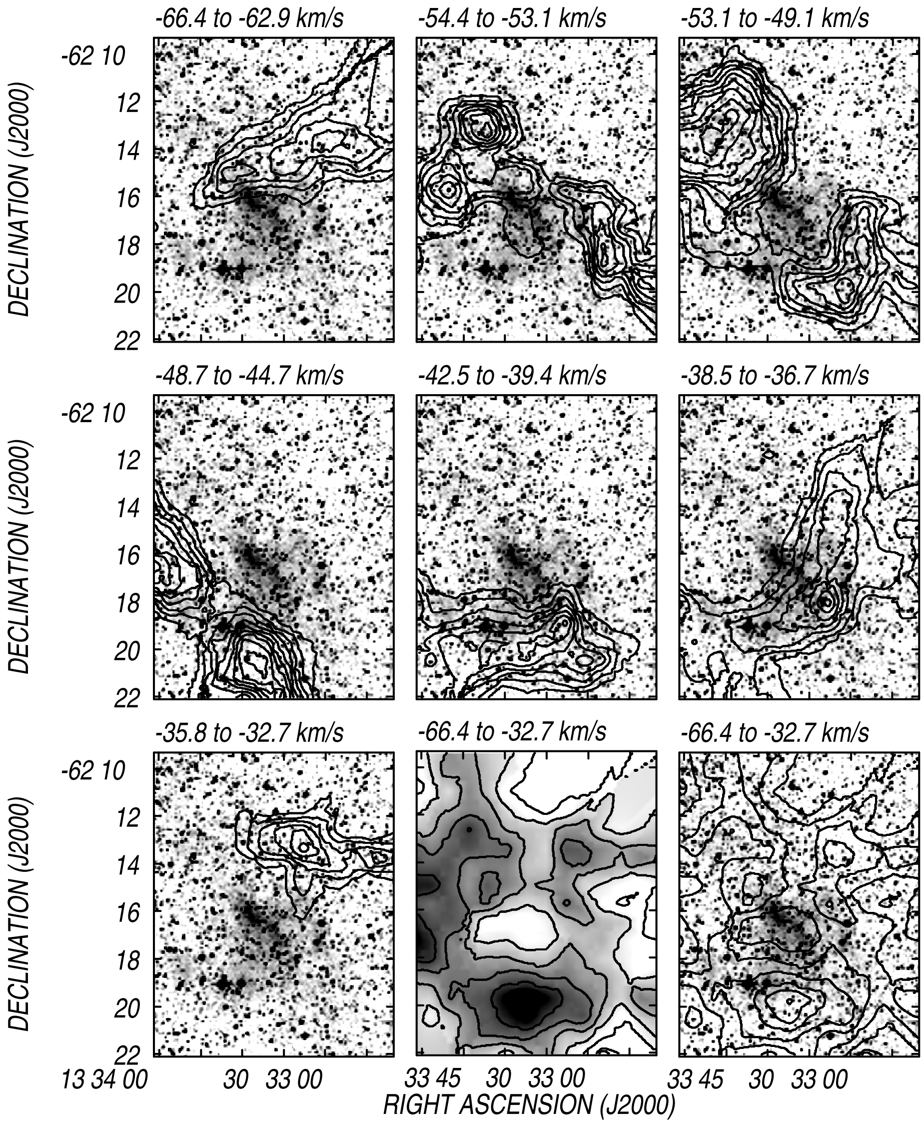

Figure 1. Overlay of the CO gas emission distribution for selected velocity ranges (*contour lines*) and the DSS R image of the brightest region of RCW 78. The images show the main-beam brightness temperature averaged within the corresponding velocity intervals. Contour lines corresponding to the first seven images are from 1.44 to 10.0 K in steps of 0.72 K. Contour lines corresponding to the last two images are 0.72 to 1.86 K in steps of 0.72 K.

5. HI results

The analysis of the HI emission distribution reveals that RCW 78 as a whole is projected onto an HI cavity detected within the velocity range –54 to –36 km s^{-1} (Figure 2). Regions of enhanced HI emission encircle the section of the nebula at $l < 307^{\circ}.85$ (corresponding approximately to the northwest, west and southeast regions of the nebula). The correlation between the ionized and neutral atomic gas is not so clear for $l > 307^\circ\!.90$.

The HI structure has a systemic velocity of –47 km s^{-1}. Circular galactic rotation models (e.g. Brand & Blitz 1993) predict that gas at this velocity should be located at a kinematical distance $d_k = 5\pm1$ kpc, in agreement with the spectrophotometric distance of WR 55.

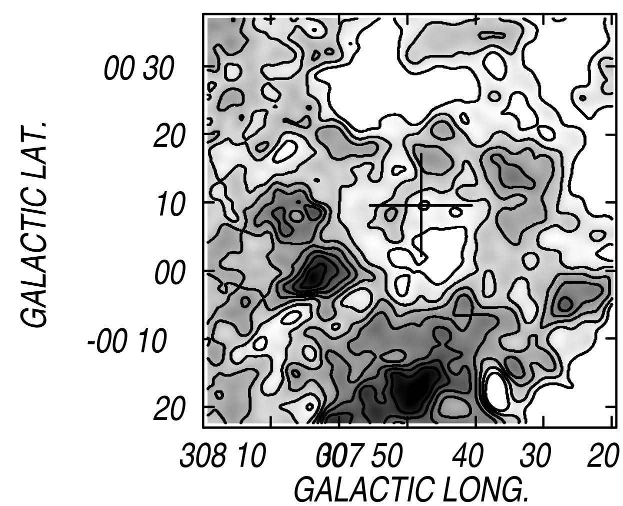

Figure 2. HI column density distribution within the velocity interval –54 to –36 km s^{-1}. The cross marks the position of WR 55. The grey scale corresponds to 80 to 120 K. Contour lines are from 80 to 115 K in steps of 5 K.

The neutral gas structure is expanding at $\simeq$10 km s^{-1} and has a mean radius is $15'\!.5$, corresponding to 26 pc at a distance $d = 6.0$ kpc.

The morphological correlation between the outer border of RCW 78 and the inner border of the neutral gas structure, along with the agreement between the velocities of the neutral and ionized material strongly suggest that the HI shell is an HI interstellar bubble associated with RCW 78 and WR 55.

The neutral atomic mass in the HI structure turns out to be about 1800 $M_\odot$. According to evolutionary models of interstellar bubbles (e.g. Koo et al. 1993), the dynamical age of the structure is $t_d = 1.4\times10^6$ yr. This value is larger than the duration of the WR phase of the star, suggesting that the massive O-type progenitor of the WR star has contributed in shaping the interstellar bubble.

6. Conclusions

The analysis of the HI gas emission distribution allowed the identification of an HI void and shell linked to RCW 78 and WR 55. This structure was interpreted as the neutral gas counterpart of the optical ring nebula RCW 78 and WR 55.

The comparison between the wind mechanical energy released by the WR 55 and its massive progenitor and the kinetic energy of the interstellar bubble indicates that the stellar wind of this star is capable of blowing the interstellar bubble. Thus, WR 55 is not only responsible for the ionization of the gas in the nebula but for the creation of the interstellar bubble.

The molecular gas data suggest that RCW 78 has probably developped at the surface of the molecular cloud, where the UV stellar photons have photodissociated and ionized the dense gas.

7. References

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