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PRESENTACIÓN ORAL

Molecular gas related to the ring nebula RCW 78 around HD 117688

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Abstract. We investigate the distribution of the interstellar gas related to RCW 78 based on ^{12}CO(1-0) observations carried out with the SEST telescope and on data belonging to the NANTEN survey. Complementary HI 21cm line data from the SGPS and radio data at 4.85 GHz were also used. We report the detection of molecular gas having velocities in the range [–56,–33] km s^{-1} associated with the western section of RCW 78. The CO emission distribution is compatible with the interpretation that the western section of the nebula originated in the photodissociation and ionization of the molecular gas by the UV photons of the WN7 star HD 117688, which, along with the action of the stellar winds, carved the molecular cloud.

Resumen. Investigamos la distribución del gas interestelar asociado a RCW 78 utilizando observaciones de ^{12}CO(1-0) obtenidas con el telescopio SEST y datos pertenecientes al relevamiento de NANTEN. Se utilizan también datos complementarios de la línea de 21 cm del HI extraídos del SGPS y del continuo de radio en 4.85 GHz. Reportamos la detección de gas molecular con velocidades en el intervalo [–56,–33] km s^{-1} asociado con el sector oeste de RCW 78. La distribución del CO es compatible con la interpretación de que la nebulosa se originó en la fotodisociación e ionización del gas molecular por los fotones ultravioletas de la estrella WN7 HD 117688, los cuales, junto con la acción de los vientos estelares, socavaron la nube molecular.

1. RCW 78 around HD 117688

RCW 78 is a ring nebula of about 35′ in diameter. Its brightest part is about 10′×6′ in size and offset to the northwest of the star, while fainter regions are present to the northeast, east and south (see Figure 5 by Chu et al. 1983). The nebula was classified as R$_a$ due to its low expansion velocity (Chu & Treffers 1981). The velocity of the ionized gas spans the interval [–53,–38] km s^{-1} (Chu & Treffers 1981, Georgelin et al. 1988). The study of the ionization structure by Esteban (1993) indicates that photoionization is the main source of excitation, compatible with its R$_a$-classification.

The nebula is related to HD 117688 (= WR 55), a WN7 star. Spectrophotometric distances are in the range 4.0-6.0 kpc (Georgelin et al. 1988, Conti & Vacca 1990, van der Hucht 2001). New NIR calibrations in the K band (Crowther et al. 2006) indicate a distance d = 4.5-5.0 kpc. Based on the available distance estimates, we adopt $d = 5.0 \pm 1.0$ kpc for the WR star and its surrounding ring nebula.
Here we investigate the distribution of the molecular, neutral atomic, and ionized gas associated with the nebula. Our aims are to identify and characterize the material linked to the ring nebula and to study its kinematics and energetics.

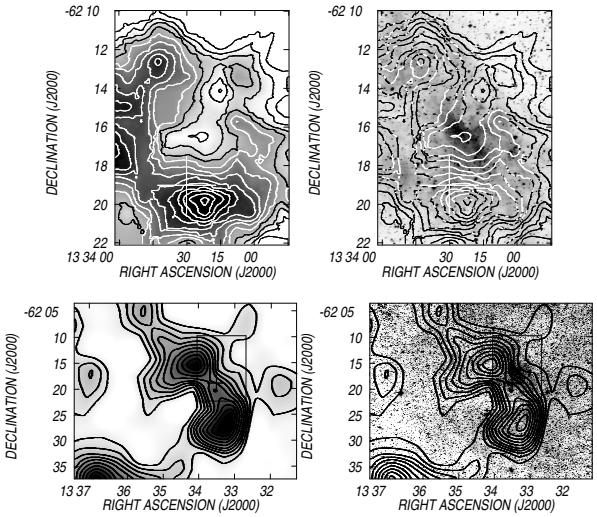

Figure 1. *Upper panels:* Left: CO(1-0) emission distribution for the range [–56,–33] km s^{-1} from the SEST observations (contours: 10 to 70 K km s^{-1}, in steps of 5 K km s^{-1}). The cross indicates the position of WR 55. Right: Overlay of the same contours and the SuperCOSMOS image.
Central panels: Left: NANTEN CO(1-0) emission distribution for the range [–52.5,–43.5] kms s^{-1} (contours: 8, 12, 16, 20, 24, 28, 32, and 36 K km s^{-1}), and [–43.5,–38.5] km s^{-1} (contours: 5, 8, 11, 14, 17, and 20 K km s^{-1}). The box and the star indicate the region observed with SEST and the position of WR 55. Right: SEST CO(1-0) emission distribution for the range [–52.9,–43.3] kms s^{-1} and [–43.0,–39.3] km s^{-1} (contours: 2, 4, 6, 8, 10, 12, and 14 K km s^{-1}).
Bottom panels: Left: HI emission in the range [–50,–40] km s^{-1} (contours: 80, 85, 90, 95, 100, 105, and 110 K). Right: Image at 4.85 GHz (contours: 30, 50, 100, 150, 200, and 250 mJy b^{-1}).

2. Databases

High resolution ^{12}CO(1-0) (115 GHz) observations of the brightest region of the nebula were carried out during two observing runs in February 2002 and March 2003, with the 15-m Swedish-European Submillimeter Telescope (SEST) at La Silla, Chile. The half-power beam width of the telescope is 44″.
Intermediate angular resolution CO(1-0) data obtained with the 4-m NANTEN millimeter-wave telescope of Nagoya University were used to investigate the large

scale distribution of the molecular gas in the environs of the whole RCW 78 nebula. The half-power beamwidth is 2′.6.
Radio continuum data at 4.85 GHz from the Parkes-MIT-NRAO (PMN) Southern Radio Survey (Condon et al. 1993) and HI data from the Southern Galactic Plane Survey (SGPS) allow to investigate the distribution of the ionized and neutral atomic gas.

3. The distribution of the interstellar gas

The upper and two central panels of Fig. 1 shows the CO(1-0) emission distribution as derived from the SEST and NANTEN data in grayscale and contours. The figure includes overlays with optical images.
The SEST observations allow to detect CO emission having velocities in the range [–56,–33] km s^{-1} encircling the brightest section of the nebula (Fig.1, upper left panel). The comparison with the optical emission distribution (upper right panel) suggests that part of the molecular gas has been photodissociated and ionized by the WR star, and partially swept-up by the stellar winds. The velocities of the CO gas are similar to those of the ionized gas, thus reinforcing the association of the ionized and molecular gas phases.
The NANTEN data allow to investigate the large scale CO emission distribution. The bulk of the molecular emission reveals two structures with velocities in the ranges [–52.5,–43.5] km s^{-1} and [–43.5,–38.5] km s^{-1}, respectively (central left panels). The central right panels display the SEST data corresponding to the same velocity intervals for comparison. The molecular velocities coincide with the Hα line velocities (Chu & Treffers 1981). Molecular gas present in the range [–52.5,–43.5] km s^{-1} is concentrated in an arc-like feature coincident with the western section of RCW 78, while the feature detected in the range [–43.5,–38.5] km s^{-1} appears partially projected onto a dust lane present at δ(J2000) = –62° 22′ in the optical image (see Georgelin et al. 1988). The two central right panels display the SEST data corresponding to almost the same velocity intervals. The molecular gas distribution observed with SEST is consistent with that of NANTEN data.
Based on both morphological and kinematics evidences, we conclude that the structure with velocities in the interval [–52.5,–43.5] km s^{-1} is clearly associated with the nebula. Kinematical evidences give support to the relation of the second feature to RCW 78. On the contrary, we were unable to identify molecular gas linked to the eastern weak sections of the nebula. At a distance of 5.0±1.0 kpc, the amount of molecular mass is $(3.7\pm1.4)\times10^4$ $M_\odot$.
The CO emission distribution towards RCW 78 is consistent with a scenario in which the joined action of the UV photons and stellar winds of the WR star dissociated, ionized, and swept-up part of the parental molecular cloud. Outside this dense cloud, the interstellar gas was also perturbed by the action of the WR star, creating lower density ionized regions which expanded more freely. The proposed scenario explains the off center location of WR 55.
For a radial velocity of –45 km s^{-1}, circular galactic rotation models (e.g. Brand & Blitz 1993) predict near and far kinematical distances of 4.2 and 6.4 kpc, respectively, in agreement with the stellar distance.

The HI gas emission distribution towards RCW 78 in the range [–55,–25] km s^{-1} is complex and clumpy, with few clear structures. The HI distribution in the range [–50,–40] km s^{-1} displays a low emission region encircled by enhanced HI emission (bottom left panel). The spatial coincidence of the low emission region with the bulk of the molecular gas suggests that most of the neutral gas is H_2. In this scenario, the HI gas encircling the depression may correspond to the envelope of the molecular cloud.
The image at 4.85 GHz (bottom right panel) shows the radio counterpart of both the eastern and western sections of the nebula, with a ring-like appearance. The strongest radio emission region coincides with the brightest section of RCW 78, compatible with the proposed scenario. The ionized mass is (3-5)$\times 10^3$ $M_\odot$.

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References

Brand, J., & Blitz, L. 1993, A&A, 275, 67

Chu, Y.-H., & Treffers, R. R. 1981, ApJ, 250, 615

Chu, Y.-H., Treffers, R. R., & Kwitter, K. B. 1983, ApJS, 53, 937

Condon, J.J., Griffith, M.R., Wright, A.E., 1993, AJ, 106, 1095

Conti, P. S., & Vacca, W. D. 1990, AJ, 100, 431

Crowther et al. 2006, MNRAS, 372, 1407

Esteban, C., 1993, PASP, 105, 320

Georgelin, Y.M., Boulesteix, J., Georgelin, Y.P., Le Coarer, E. & Marcelin, M., 1988, A&A, 205, 95

van der Hucht, K. A. 2001, New Astronomy Reviews, 45, 135