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THE ISM AROUND WR 152 AND WR 153AB

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RESUMEN

Analizamos la distribución del material interestelar en la vecindad de las estrellas WR 152 y WR 153ab, asociadas a nebulosas anillo en la región HII Sh2-132. Nuestro estudio se basa en datos en la banda de radio (observaciones del continuo, HI y CO(1-0)) e imágenes en el IR lejano y mediano. Hemos detectado las contrapartes de las cáscaras ionizadas asociadas a WR 152 en el continuo de radio y en el lejano IR, al igual que HI delineando la cáscara ionizada externa. En la vecindad de WR 153ab, la distribución del gas ionizado y molecular, y la de los hidrocarburos aromáticos policíclicos (PAHs) sugiere la presencia de regiones de fotodisociación en la interfase entre el material ionizado y el molecular. Derivamos parámetros físicos del gas asociado.

ABSTRACT

We analyzed the distribution of the interstellar matter in the environs of the WR stars WR 152 and WR 153ab, associated with ring nebulae in the Sh2-132 HII region. Our study is based on radio data (continuum, HI, and CO(1-0) observations) and images in the far and mid IR. We have detected the radio continuum and far IR counterparts of the ionized shells related to WR 152, as well as HI gas linked to the outer ionized shell. The distributions of the ionized and molecular gas related to WR 153ab and that of the PAHs suggest the presence of photodissociation regions at the interface between the ionized and molecular material. We estimate the main physical parameters of the gas components.

Key Words: ISM: ring nebulae — stars: individual (WR 152, WR 153ab) — stars: Wolf-Rayet

1. THE STARS AND THEIR RING NEBULAE

WR 152 (= HD 211564, WN3[h]) and WR 153ab (= HD 211853, WN6/WCE+O6I) are probable members of the Cep OB1 association. WR 153ab is a multiple system formed by two spectroscopic binary systems. Distance determinations locate WR 152 at 2.75 kpc and WR 153ab at 2.75–3.5 kpc (van der Hucht 2001; Nugis & Lamers 2000). We adopt a distance d=3.0 kpc for both stars.

The Wolf-Rayet stars are related to Sh2-132.

WR 152 is associated with a double shell structure detected in Hα and [OIII] lines (Heckathorn et al. 1982). The inner structure is a filamentary shell of about 17$'$ in diameter (15 pc at 3.0 kpc).

The outer shell, of 36$'$ in diameter (31 pc), is more diffuse. The WR star is projected close to the center of the inner shell.

WR 153ab is buried in the brightest section of Sh2-132. The velocity of the ionized gas is about −48 km/s (Esteban & Rosado 1995). The WR star is the main ionizing source of the nebula, which is classified as Rs-type.

The star appears related to a semicircular radio shell of 4$'$×9$'$ in diameter (3.5×7.9 pc at 3.0 kpc), first identified by Harten et al. (1978, their Shell B).

With the aim of investigating the interaction of the massive stars with the surrounding ISM, we analyzed the distribution of the ionized, neutral atomic and molecular gas and that of the interstellar dust in the environs of the WR stars based on radio continuum data at 408 and 1420 MHz, and HI 21 cm line data extracted from the Canadian Galactic Plane Survey (CGPS) (Taylor et al. 2003); CO(1-0) line data obtained with the Five College Radio Astronomy Observatory (FCRAO), and IR images in the IRAS and MSX bands.

2. THE RING NEBULA RELATED TO WR 152

The inner and outer optical shells detected around this star are clearly identified at 1420 MHz (Figure 1). The emission is thermal in origin.

From the image at 1420 MHz and adopting a filling factor f=0.2, we estimated that the electron density and ionized mass of the inner shell are 16 cm^{-3} and 290 $M_\odot$. The corresponding values for the outer nebula are 15 cm^{-3} and 400 $M_\odot$. The large amount

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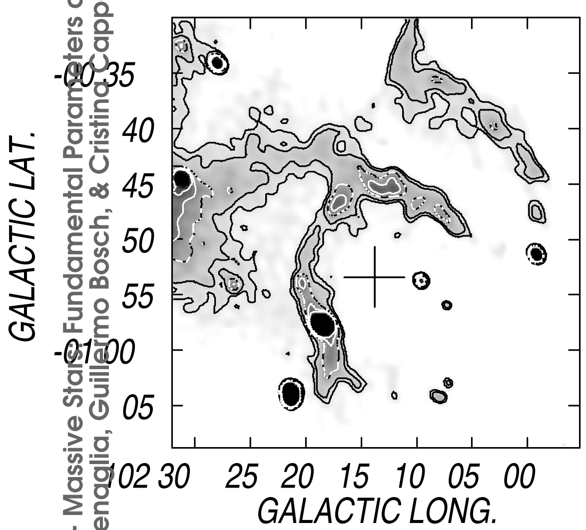

Fig. 1. Radio continuum emission of the ring nebula around WR 152. The grayscale is from 7 to 10 K. Contour lines are 7.3, 7.5, 8.0, 8.5, and 9.0 K. The cross marks the position of WR 152.

of ionized material indicates that the nebula mainly consists of interstellar gas.

Both shells are detected at 60 and 100μ, showing the presence of interstellar dust related to the nebula.

Neutral hydrogen with LSR velocities in the range -65 to -45 km s^{-1} partially encircles the outer shell. Including a 10% He abundance, the associated neutral atomic gas amounts to 310 $M_\odot$.

3. THE RING NEBULA RELATED TO WR 153AB

The ring nebula associated with this star is easily identified at 1.4 GHz. The rms electron density of the brightest radio continuum region is 30 cm^{-3}. Adopting a filling factor f=0.2, we derive an electron density of 65 cm^{-3} and an ionized mass of 100 $M_\odot$.

These values are compatible with previous findings by Harten et al. (1978). The small nebula is also identified in the far IR.

CO emission spanning the velocity range -45 to -39 km s^{-1} borders the brightest section of Sh2-132. The molecular mass amounts to 1800 $M_\odot$. The emission in the MSX-band A (Figure 2), which has a strong contribution from PAHs, strikingly delineates the bright optical and radio continuum emission region. The comparison of the ionized and molecular gas distributions with that of the PAHs indicates that photodissociation regions are present at the interface between the ionized and molecular material.

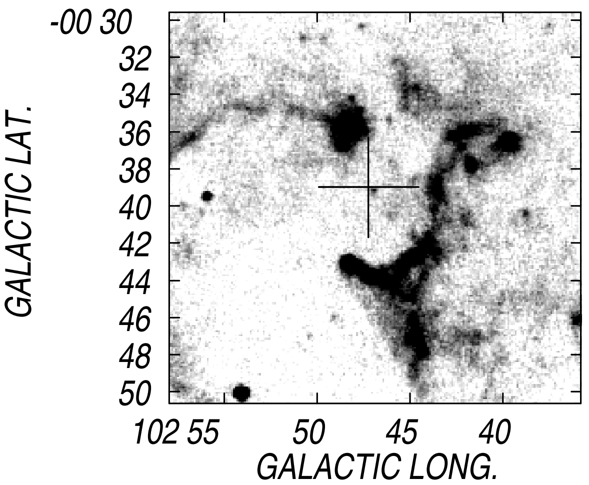

Fig. 2. MSX-band A image of the nebula around WR 153ab. The grayscale is from (0.7–3.0)$\times 10^{-6}$ W m^{-2} ster^{-1}. The cross marks the position of WR 152.

4. SUMMARY

The analysis of the radio continuum images at 408 and 1420 MHz, H I and CO(1-0) images, and IR data in the mid and far IR towards WR 152 and WR 153ab allowed identification of interstellar gas and dust linked to the ring nebulae.

We have detected the radio continuum and infrared counterparts of the inner and outer ionized shells related to WR 152, as well as an H I bubble surrounding the outer ionized shell, allowing us to estimate the parameters of the ionized and neutral atomic gas.

As regards WR153ab, we have identified dust and molecular gas related to the ring nebula. The emission in the MSX band A suggests the presence of a PDR at the interface between the ionized and molecular material.

The stellar wind mechanical energy supplied by the stellar winds of WR 152 and WR 153ab is enough to drive the expansion of the ionized and neutral structures.

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DISCUSSION

N. Smith - I am a bit puzzled by the WC/WN star so close to massive molecular clouds. This is a post-MS core-He burning object, what means that it is at less $\approx$4 Myr old. I thought natal molecular material around massive stars is usually cleared away by that time.

C. Cappa - Indeed, there is a lot of molecular gas in the environs of these stars. Some of this material can be originated in the action of the front shock, that comprises the gas in a dense shell. But most of the cases, most of it is natal molecular material.

R. Barbá - The MSX-A image shows some pillar structures pointing to the center of the cavity. Are there other additional ionizing sources? Also, could WR153ab be a runaway star crossing the area?

C. Cappa - An O9 star and some B stars have been found in the region. Additional sources might be hidden within regions with interstellar dust. The WR star is not catalogued as a runaway star. Indeed, its distance precludes from deriving confident proper motions.

Andy seems skeptical about Stan's physical explanation of wind collisions.