Massive Stars Near and Far
Proceedings IAU Symposium No. 361, 2024
J. Mackey, J. S. Vink, & N. St-Louis, eds.
doi:10.1017/S1743921322002927

M 1-67 and RCW 58: nebulae around WN8h stars formed through CE evolution

P. Jiménez-Hernández[1], S. J. Arthur[1], J. A. Toalá[1] and A. P. Marston[2]

[1]Instituto de Radioastronomía y Astrofísica, UNAM, Antigua Carretera a Pátzcuaro # 8701, Ex-Hda. San José de la Huerta, Morelia, Michoacán, México C.P. 58089
email: p.jimenez@irya.unam.mx

[2]European Space Astronomy Centre, ESA, PO Box 78, 28691 Villanueva de la Cañada, Madrid, Spain

Abstract. We present the analysis of the dust properties of the Wolf-Rayet nebulae M 1-67 and RCW 58 around the WN8h stars WR 124 and WR 40, respectively. Modeling with the photoionization code `Cloudy` shows that in both nebulae the IR spectral energy distributions and ionized gas properties can be reproduced by a dust shell consisting of two populations of dust grains. Furthermore, taking into account the initial mass, the morphology and the kinematics of the nebulae we propose M 1-67 and RCW 58, together with their progenitor stars, as the first observational evidences of post-common envelope evolution in nebulae around massive stars.

Keywords. stars: circumstellar matter, stars: evolution, stars: individual (WR 40, WR 124)

1. Introduction

Some late-type WNh Wolf-Rayet (WR) stars are surrounded by clumpy or irregular ejecta nebulae, suggesting a violent mass-loss episode as their origin. The study of WR nebulae properties can provide information of the mass-loss history of the progenitor massive stars in the late stages of their evolution. In this work we look at the dust properties in WR nebulae around WN8h stars in order to understand the post-main sequence evolution of these objects.

2. Methods

`Cloudy` (Ferland et al. 2017) allows us to treat the interaction between the UV flux from the central star and the nebular gas and dust simultaneously. For the spectrum of the central stars we used PoWR stellar atmosphere models (Hamann et al. 2006).

To constrain our models we used the shape and flux of the IR spectral energy distribution (SED) to fit dust emission. The IR SED was built from public data corresponding to *Spitzer*, *WISE* and *Herschel* (and ATCA to the RCW 58 case) observations. We estimated the quantity of ionized gas from the Hα and Hβ emission line fluxes and radio observations, when available.

Multi-layer models were required to reproduce the observed SEDs of M 1-67 and RCW 58. A global model of RCW 58 is hampered by the extended background emission and so representative regions RC and LC were modeled to infer the properties of the ring nebula. Fig. 1 shows color-composite images of these two nebulae. Schematic views of the model density distributions are shown in Fig. 2. From our models (see Jiménez-Hernández et al. 2020; 2021; for more detail): we need an inner layer of pure gas and

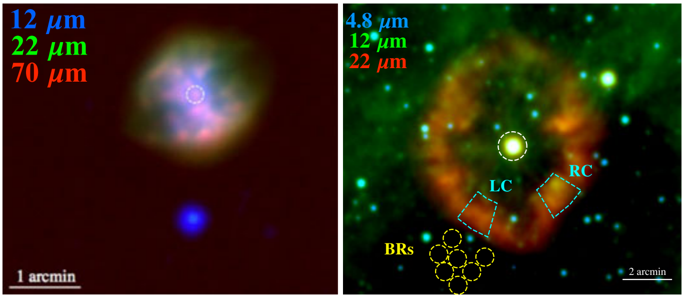

Figure 1. Left: Color-composite IR image of M 1-67. Right: Color-composite IR image of RCW 58. Cyan polygonal shapes indicate the selected regions for study. North is up, east is left.

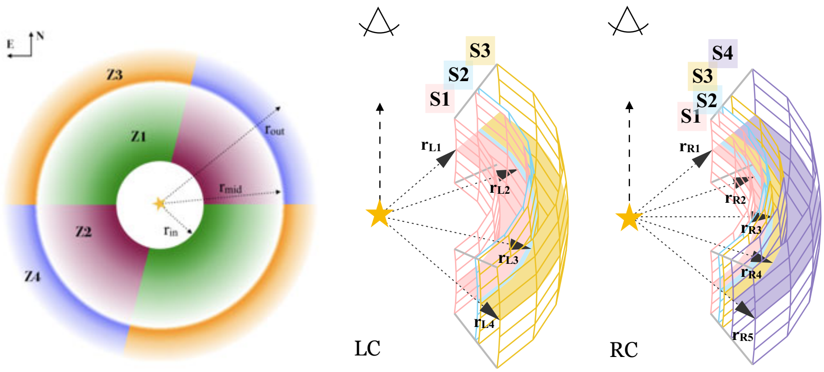

Figure 2. Left: Schematic view of the distribution of gas (Z1,Z2,Z4) and dust (Z3) in our model of M 1-67. Right: Schematic view of the gas and dust distribution in LC and RC clumps, on which our models of RCW 58 are based. See Jiménez-Hernández et al. (2020; 2021)

a dusty outer layer; and the dusty layer has two populations of dust, small (0.002 μm $\leq a \leq$ 0.05 μm) and big (0.6 μm $\leq a \leq$ 0.9 μm) grains. In our models we include only spherical silicate grains, in particular, olivine.

3. Single or binary origin?

The maximum grain size of 0.9 μm supports an eruptive formation for both M 1-67 and RCW 58. This is because mass-loss rates above $\dot{M} \geq 10^{-3}$ $M_\odot$ yr^{-1} are required to shield the dust-formation region from stellar UV photons (Kochanek 2011).

We estimated an initial massess for WR 124 and WR 40 (nebular mass calculated plus current mass) around 40 $M_\odot$, this rules out the possibility that the WR star had a LBV phase. In addition, the morphology (bipolar and torus pole-on) and the dynamics of each nebula allows us to suggest dust formation though a common envelope (CE) ejection.

CE evolution can lead to the ejection of the common envelope and tighter binary (Ivanova et al. 2013). Furthermore, the presence of a compact object of WR 124 and WR 40 can not be rule out because their dense stellar wind.

Acknowledgements

This research was supported by DGAPA-PAPIIT projects IA100720 and IN107019.

Supplementary material

To view supplementary material for this article, please visit http://dx.doi.org/10.1017/S1743921322002927.

References

Ferland, G. J., et al. 2017, RMxAA, 53, 385
Hamann, W. R., Gräfener, G., & Liermann, A. 2006, A&A, 457, 1015
Ivanova, N., et al. 2013, A&A Rev., 21, 59
Jiménez-Hernández, P., Arthur, S. J., & Toalá, J. A. 2020, MNRAS, 497, 4128
Jiménez-Hernández, P., Arthur, S. J., Toalá, J. A., & Marston, A. P. 2021, MNRAS, 507, 3030
Kochanek, C. S. 2011, ApJ, 743, 73