X-ray Emission from Wolf-Rayet Nebulae

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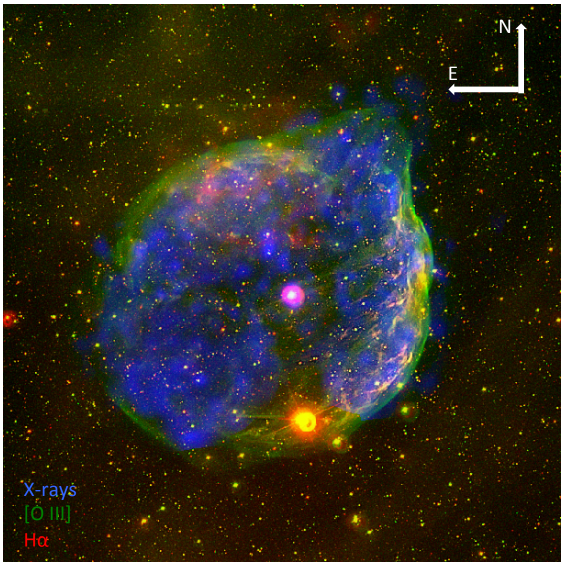
1. Introduction

Wolf-Rayet (WR) bubbles are the most advance evolutionary stage of the circumstellar medium around massive stars with initial masses $M_i \geq 30\ M_\odot$. These nebulae are formed due to the interaction of the current fast wind (1000–3000 km s^{-1}) against the slow (10–100 km s^{-1}) and dense wind ejected by a previous stage of evolution (Red Supergiant or Luminous Blue Variable). This dense and slow shell is photoionized by the central star up to temperatures of ~ 10^4 K, making the nebula detectable in optical wavelengths (e.g., Gruendl et al. 2000; Stock & Barlow 2010). Theoretically, the shocked stellar wind inside the WR nebula reaches temperatures of 10^7–10^8 K, but the density is too low ($n \leq 10^{-2}$ cm^{-3}). Heat conduction and mass-evaporation at the interface will lower the temperature and increase the density to produce soft X-ray emission with luminosities of $L_X \geq 10^{35}$ erg s^{-1} (Weaver et al., 1977).

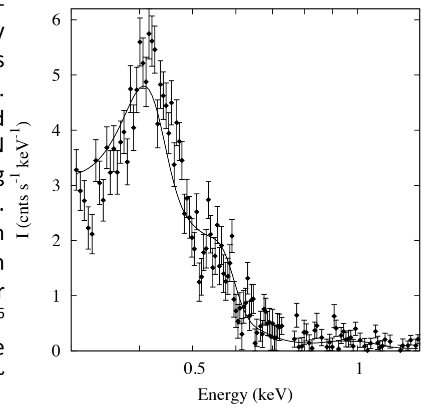
Here we present the properties of the hot plasma of the only two WR bubbles detected in X-rays: S 308 and NGC 6888 around WR 6 and WR 136, respectively.

2. *XMM-Newton* observations of S 308

S 308 is the biggest WR bubble with an angular size of ~40′ in diameter. We obtained 4 observations that map 90% of the nebula (Toalá et al. 2012). With this, we are able to study the hot gas distribution and to compare it to the nebular material.

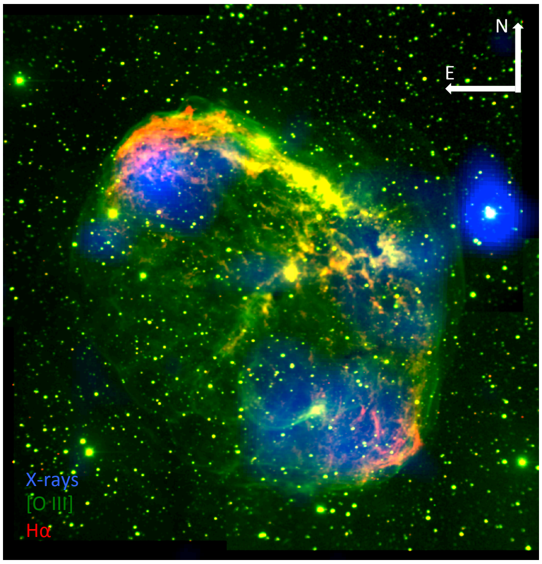


S 308 displays a limb-brightened morphology with the X-ray-emitting gas inside the ionized material. The spectrum is dominated by the He-like triplets of N VI at 0.43 keV declining toward higher energies. The spectrum was fit with a 2T plasma emission model with nebular abundances, T_1 = 1.1 x10^6 K and T_2 = 13x10^6 K. The total X-ray luminosity is L_X~ 2x10^{33} erg s^{-1}.

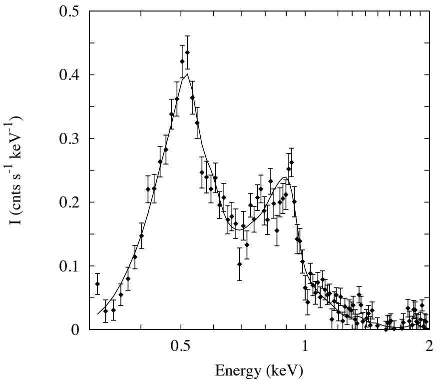


3. *Chandra* observations of NGC 6888

We obtained *Chandra* ACIS-S observations of the WR bubble NGC 6888, which maps ~60% of the nebula (Toalá et al. In prep.). The X-ray emission from this WR bubble is detected in three maxima: two maxima spatially coherent with the caps of the optical nebula and an another one extending toward the Northwest, beyond the Hα line emission but interior to the [OIII] blowout.



The X-ray spectrum is dominated by the N VII Lyα line at 0.5 keV and by the Fe complex and Ne lines around ~0.8 -0.9 keV. This can be fit by a 2T plasma emission model with nebular abundances: T_1=1x10^6 K and T_2=7.5x10^6 K. The toal estimated luminosity is L_X~ 1x10^{34} erg s^{-1}.



4. Discussion

As the X-ray emission from WR bubbles is expected to peak at temperatures in the range of 10^7 – 10^8 K due to the adiabatically shocked stellar material inside the bubble ($kT = 3/16 \times \mu m_H V_\infty^2$; Dyson & Williams 1997), it has been always argued that some extra physics have to be take into account to diminish the temperature to observable values. Clasical and Saturated thermal conduction has been used by Toalá & Arthur (2011) to study the distribution of the hot gas inside the WR bubble, the soft X-ray temperatures, and resultant luminosity, but non-equilibrium ionization conditions could also play an important rôle.

References

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