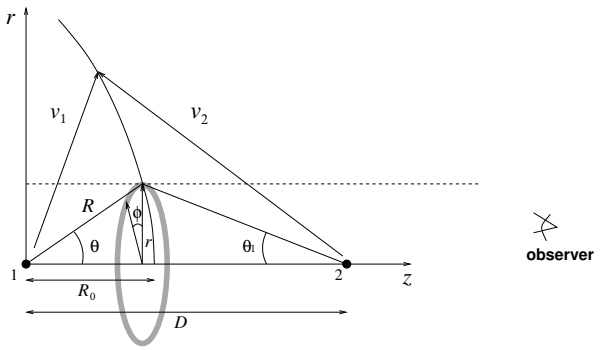

Fig. 1. Schematic diagram showing the interaction of two symmetric winds with velocities v_1 and v_2, and mass loss rates $\dot{m}_1$ and $\dot{m}_2$. The dotted line represent the line of sight from the observer through the stellar winds, which intersects the thin shell at the impact parameter r.

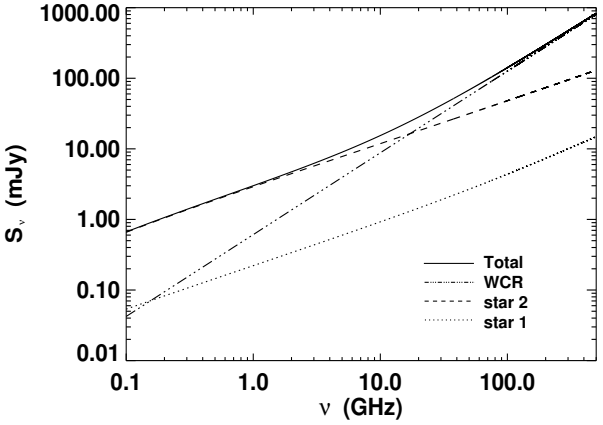

Fig. 2. Predicted thermal radio spectrum from a binary system with $\beta = 0.25$, $D = 4$ AU, $v_1 = v_2 = 10^3$ km s^{-1}, $\dot{M}_1 = 1.25\times10^{-5}\ M_\odot$ yr^{-1}, and $\dot{M}_2 = 5\times10^{-5}\ M_\odot$ yr^{-1}.

point radius is $R_0 = \beta^{1/2}D/(1+\beta^{1/2})$, where $\beta = (\dot{m}_1\, v_1)/(\dot{m}_2\, v_2)$.

These assumptions allow us to find an expression for the radio continuum flux from a system located at a distance L from the observer,

$$S_\nu = 2\pi B_\nu \left(\frac{R_0}{L}\right)^2 \int_0^{\tilde{r}(\theta_\infty)} [1 - \mathrm{e}^{-\tau(\theta,\theta_1)}]\, \tilde{r}\, d\tilde{r}, \quad (1)$$

where $\tau(\theta,\theta_1) = \tau_{\rm WCR}(\theta,\theta_1) + \tau_{w,1}(\theta) + \tau_{w,2}(\theta)$ is the total optical depth along the line of sight, $B_\nu = 2kT\nu^2/c^2$ (being k the Boltzmann's constant, and c the light speed) is the Planck function in the Rayleigh-Jeans approximation, and $\tilde{r}(\theta_\infty)$ is the impact parameter at the asymptotic angle θ_∞ of the thin shell, which corresponds to $R \to \infty$.

In Figure 2 we show the total thermal spectrum from a binary system with typical WR+O type star parameters. The shock emission remains optically thick with $\alpha_{\rm WCR} \sim 1.1$, and the stellar wind components shows the expected $\alpha \sim 0.6$ behavior. At low frequencies, the total spectrum approaches the emission from the strongest wind, and, at higher frequencies, the flux density is dominated by the shocked layer. Therefore, the impact of the WCR over the total spectrum is seen as an excess of emission at high frequencies (with respect to that expected for a single stellar wind spectrum). Furthermore, it can be shown that the flux density from the WCR increase with the binary separation D (Montes et al. 2011), which is in contrast with the D^{-1} dependence for adiabatic shocks (Pittard et al. 2006).

3. CONCLUSIONS

For close systems where the non-thermal emission is expected to be absorbed, this model shows that the thermal contribution from a radiative WCR may also impact the total radio spectrum. Such impact is expected to be detected as an excess of emission at high frequencies (>50 GHz). Thus, our model predicts steep spectral indices, similar to those observed for some WR and O type stars. This extra contribution must be taking into account in order to avoid a possible overestimation for mass loss rates determined from radio observations. Furthermore, the contribution from the WCR is expected to be modulated by the orbital motion, resulting in a variable thermal contribution. Therefore, observational studies to identify a modulated thermal excess of emission, might represent a new method to unveil close binary systems from high frequency radio observations.

REFERENCES

Cantó, J., Raga, A. C., & González, R. 2005, RevMexAA, 41, 101
Cantó, J., Raga, A. C., & Wilkin, F. P. 1996, ApJ, 469, 729
Contreras, M. E., & Rodríguez, L. F. 1999, ApJ, 515, 762
Eichler, D., & Usov, V. 1993, ApJ, 402, 271
González, R. F., & Cantó, J. 2008, A&A, 477, 373
Leitherer, C., & Robert, C. 1991, ApJ, 377, 629
Montes, G., González, R. F., Cantó, J., Pérez-Torres, M. A., & Alberdi, A. 2011, A&A, 531, A52
Montes, G., Pérez-Torres, M. A., Alberdi, A., & González, R. F. 2009, ApJ, 705, 899
Pittard, J. M. 2010, MNRAS, 403, 1633
Pittard, J. M., Dougherty, S. M., Coker, R. F., O'Connor, E., & Bolingbroke, N. J. 2006, A&A, 446, 1001
Stevens, I. R. 1995, MNRAS, 277, 163
Wright, A. E., & Barlow, M. J. 1975, MNRAS, 170, 41