A bowshock model for the wind-ISM interaction of the run-away Wolf-Rayet star WR 124

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Introduction

WR 124 is a galactic Wolf-Rayet star of spectral type WN8, with a mass of about 20 $M_\odot$ and a luminosity of 6×10^5 $L_\odot$ [1]. The star is at a distance of about 6.5 kpc and moves away from us with 200 km s^{-1}. Around the star, the clumpy nebula M1-67 is seen (see Figure 1), believed to be ejected from the star. We received Fabry-Pérot observations to study the dynamics of M1-67 [2]. These data are displayed in Figure 2. The 'ears' at the left and right seem to correspond to arcs in Figure 1.

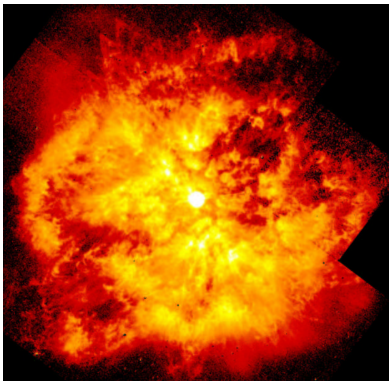

Figure 1. HST image of M1-67

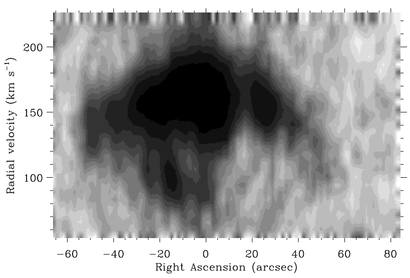

Figure 2. Emission distribution of M1-67

Evidence for a bowshock

From the observational data in Figure 2, we find evidence for a paraboloid-like bowshock around WR 124. Since the star has a high velocity with respects to the ISM, its wind causes a bowshock instead of a spherical bubble. The following points provide evidence for this bowshock and the fact that it is pointed almost exactly away from us:

- Hardly any emission is found at radial velocities higher than that of WR 124 (+200 km s^{-1})
- The bulk of the emission comes from the far hemisphere
- The far side looks like a paraboloid, the near side is rather 'flat' (though irregular)
- As seen from Earth, the star sits in the middle of the nebula

The model

We used 2D models based on momentum equilibrium [3], to create 3D models. The geometry is scaled by r_0, the distance from the star to the front of the bowshock:

$$r_0 = \frac{\dot{M}_* v_{\infty,*}}{4\pi \rho_{\rm ism} v_{\rm ism}^2}$$

The models give the geometry of the shock surface and the velocity of the gas along this surface. An example of the geometry and velocity for one case is shown in Figure 3.

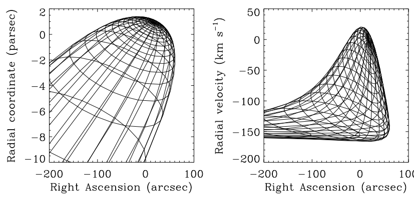

Figure 3. 3D bowshock model; *left:* geometry, *right:* velocity

Orientation of the bowshock

We used a range of possible values for the proper motion of WR 124, its distance and the ISM density ($\rho_{\rm ism}$) together with a model for galactic rotation to calculate a range of possible orientations and star-ISM velocities for the bowshock around M1-67 and are currently comparing these to the observations. An example is shown in Figure 4. The thick line is the model output, a contour of the output like in Figure 3. The thin lines are contours of the observational data. The two straight lines display the position and radial velocity of WR 124. This model has the lower limit values for the proper motion and a distance of 7.5 kpc, which results in $v_{\rm ism} \approx 180$ km s^{-1} and an inclination of about $20°$.

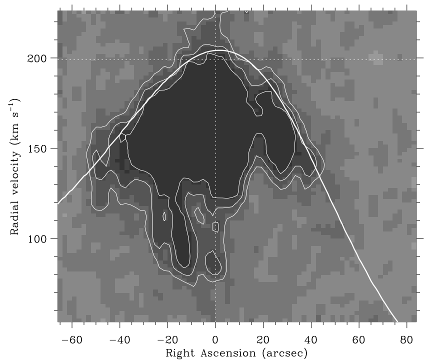

Figure 4. Comparison with observations

Future work

We will need to look a little closer to what combinations of the four parameters proper motion (two components), distance and $\rho_{\rm ism}$ lead to 'nice agreements' between model and observations. We will also look at what happens inside the bowshock. If an outburst occurs, it will interact with the shock at the far side, but expand freely at the near side. From the freely expanding part, we can derive dynamical timescale(s) for the outburst(s) or lower limits for them. The emission in Figure 2 around -10" and below v $\approx$ 110 km s^{-1}, for instance, fits to an outburst that occurred 13 000 years ago.

References

[1] Nugis, T. & Lamers, H.J.G.L.M., 2000, A&A 360, 227.

[2] Grosdidier, Y., Moffat, A.F.J. & Blais-Ouelette, S., 1999, Proc. IAU Symp. 193, 356.

[3] Canto, J., Raga, A.C. & Wilkin, F.P., 1996, ApJ 469, 729.