A Massive Star Odyssey, from Main Sequence to Supernova
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Colliding winds in the WR+OB binary θ Muscae (WR 48, WC5+O6-7V)

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Abstract. Spectra, providing full phase coverage, of the 19 d WC6+OB binary θ Mus (WR 48, HD 113904), have been obtained and show dramatic variations of the C III λ5696 emission line profile. We have modeled these line profile variations assuming the winds from the WR star and its close OB companion are colliding and forming a shock region from which extra emission originates.

1. Introduction

Studying colliding winds.... Bang (for the buck). The physics of colliding winds is fascinating and much can be learned about massive stars and their descendants by studying them. Modeling their spectra can yield information about the strengths of the winds, orbital inclination, velocity and turbulence of post-collision plasma etc. Massive stars affect their environments both chemically and physically, so studying colliding wind systems can really pay off.
One star probing the other.... Shocking! Where the winds collide, a shock forms, wrapping around the star with the weaker wind. As material streams along the shock, it cools and excess line emission is created. In a WR+OB pair, one can think of the OB star as acting like a probe of the much stronger wind from the WR star.

2. Observations

Observing θ Mus with UTSO.... Pretty fly for a little guy. θ Mus is a 19 d binary containing a WC5 star with an unseen OB companion. A late O-type supergiant is a distant third (VB) star. High S/N spectra obtained with the 0.6-m UTSO telescope allowed uninterrupted coverage for almost three weeks.
Canary in the gold mine. One emission line in our spectra is remarkably variable. C III λ5696 appears to have an underlying flat-topped component like that seen in single WC stars and variable extra emission. It seems this line is a sensitive indicator of wind-wind collisions. If one thinks of WR+OB binaries as gold mines of information, then this line is like the proverbial canary.

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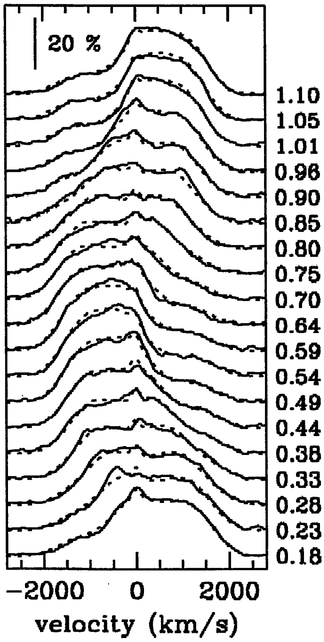

Fitting parameters for C III 5696 profiles.

Half opening angle of cone:	46 +- 4 deg
Thickness of cone:	6 +- 6 deg
Orbital inclination:	49 +- 6 deg
Coriolis deviation:	15 +- 6 deg
Streaming velocity (cone):	1320 +- 80 km/s
Turbulence (cone):	530 +- 80 km/s
Streaming velocity (shell):	1760 +- 80 km/s
Turbulence (shell):	480 +- 240 km/s

Figure 1. Fit of synthetic profiles (dashed lines) to the θ Mus C III λ5696 emission line profiles. Individual spectra are labelled by phase, with phase 0.0 corresponding to the WR star in front.

3. Modeling

Three is the number (of sources) ye shall count. Modeling the λ5696 emission assumes it arises from three sources. A weak, stationary spike of emission comes from the distant supergiant. The underlying profile originates from a spherical, optically thin shell. In the absense of wind-wind collisions, both of these would be seen. The cone shaped shock front, formed where the winds collide gives rise to the variable excess emission.

Its all downhill from here. Emission from the three sources is numerically integrated and convolved with the instrumental profile. The code is embedded in a downhill symplex routine that searches χ^2 space for a best fit. The parameters resulting in a best fit are listed next to in Figure 1.

Based on wind balance arguments, the companion is most likely an O6V or O7V star. We detect the radial velocity signature of the companion for the first time. The inclusion of turbulence in the modeling is essential. In previous studies of WR 42 and WR 79 we did not include it. Including it now for those stars, results in much better agreement with inclinations found via other methods. We do not yet include the effects of acceleration through the line forming regions. Some of what we are calling turbulence will be accounted for by this.

Details of this study can be found in Hill *et al.* (2002).

References

Hill, G.M., Moffat, A.F.J., St-Louis, N. 2002, MNRAS 335, 1069