A Massive Star Odyssey, from Main Sequence to Supernova
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A critical comparison of spectroscopic and evolutionary masses for O-type binary systems

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Abstract. We have embarked on a program to directly compare spectroscopic and evolutionary masses with those obtained from a combination of spectroscopic and photometric orbital solutions for O-type binary systems. The ability to directly determine the spectroscopic masses of the individual components of O-type binary systems has been difficult, because of the severe line blending that is present in these systems. Doppler tomography is an iterative scheme, that uses an ensemble of spectra to reconstruct the individual component spectra. These individual spectra can then be analyzed.

1. Introduction — dynamical masses

The one high-resolution UV spectrum of HD 115071 (V961 Cen, O9.5V+B0.2III) from *IUE* shows a double-peaked cross-correlation function (Penny 1996). The observed *Hipparcos* light curve shows ellipsoidal variations (probably due to distortion of stars within their Roche surfaces) of ~ 0.07 mag. Stickland & Lloyd (2001) and Lloyd & Stickland (2001) combined the *Hipparcos* light curve with the *IUE* spectrum to determine a $P = 2.73126$ d. They also argued that this system is a post Case A mass transfer one. Details of the analysis presented here (not including the atmospheric modeling) are given in Penny *et al.* (2002). Our spectra were obtained during two observing runs at: (*i*) the 2.15m telescope of the Complejo Astronomico El Leoncito (CASLEO, 3575 - 5700 Å, $\lambda/\Delta\lambda = 13\,000$); and (*ii*) the 74-inch telescope at Mount Stromlo Observatory (3804 - 4220 Å, $\lambda/\Delta\lambda = 13\,400$). Our methodology for radial velocity measurements and determination of orbital parameters are presented in Penny *et al.* (2002). The individual primary and secondary spectra were reconstructed using the tomography algorithm described in Bagnuolo *et al.* (1994). We compared the reconstructed spectra with the spectrum standards in the atlas of Walborn & Fitzpatrick (1990) to determine the spectral classifications of the components: primary O9.5 V and secondary B0.2 III. These correspond to $T_{\rm eff,1} = 32\,000$ K, $\log g_1 = 3.9$ and $T_{\rm eff,2} = 29\,000$ K, $\log g_2 = 3.6$, respectively. We determined the flux ratio from matching line depths of spectral standards

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Table 1. Atmospheric properties of HD 115071 (O9.5V+B0.2III).

parameter	primary	secondary
$T_{\rm eff}$ (K)	32 500	30 000
$\log g$	3.80	3.50
$R/{\rm R}_\odot$	6.70	7.10
$\log L/{\rm L}_\odot$	4.65	4.57

Table 2. Comparison of mass estimates ($M/{\rm M}_\odot$) of HD 115071.

component	dynamical	spectroscopic	evolutionary
primary	11.6	10.6	18.3
secondary	6.7	6.4	16.0

(HD 93027, HD 108639) to those of the reconstructed spectra: $r = 1.04 \pm 0.06$ (CASLEO data); $r = 1.08 \pm 0.08$ (MSO data). The projected rotational velocities for the stars are: primary $101 \pm 10\,{\rm km\,s^{-}1}$; secondary $132 \pm 15\,{\rm km\,s^{-}1}$. The observed *Hipparcos* light curve was modelled with the GENSYN code (Mochnacki & Doughty 1972), with constraints from the tomographic and spectrscopic analysis. Our best fit light curve was at an inclination of $48^\circ\!.7 \pm 2^\circ\!.1$ with a Roche filling secondary. At this inclination the radii of the two stars are $6.5 \pm 0.2\,{\rm R}_\odot$ and $7.2 \pm 0.2\,{\rm R}_\odot$, respectively.

2. Atmospheric modeling — discussion

The individual reconstructed spectra were fit with synthetic spectra from the atmospheric model FASTWIND (Herrero, Puls & Najarro 2002). The best fit model has the following parameters (see Table 1).

We present dynamical, spectroscopic, and evolutionary masses (derived from models of Schaller *et al.* 1992) in Table 2. Since we believe this system is post-mass-transfer, the comparison to evolutionary models (for single stars) is actually unfair. However, the agreement between the dynamical masses and those from atmospheric models is excellent. In the future we plan to implement this methodology to non-interacting binaries.

References

Bagnuolo, W.G., Gies, D.R., Hahula, M.E., *et al.* 1994, ApJ 423, 446

Herrero, A., Puls, J., Najarro, P. 2002, A&A 396, 949

Lloyd, C., Stickland, D.J. 2001, A&A 370, 1026

Mochnacki, S.W., Doughty, N.A. 1972, MNRAS 156, 51

Penny, L.R. 1996, ApJ 463, 737

Penny, L.R., Gies, D.R., Wise, J.H., Stickland, D.J., Lloyd, C. 2002, ApJ 575, 1050

Schaller, G. Schaerer, D., Meynet, G., Maeder, A. 1992, A&AS 96, 269

Stickland, D.J., Lloyd, C. 2001, The Observatory 121, 1

Walborn, N.R., Fitzpatrick, E.L. 1990, PASP 102, 379