Modeling the Asymmetric Wind of the Luminous Blue Variable Binary MWC 314

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Motivation

• Are there analogs of notorious LBV binary stars, i.e. like \( \eta \) Carinae? Long-term monitoring with HERMES of various (single) LBVs and candidate LBVs, searching for new LBV or cLBV binaries.

• MWC 314 is a very promising case because of its extended bipolar nebula and possible binarity.

• Determine accurate orbital elements of MWC 314. Provide first evidence it is a massive binary instead of low-mass B[e] star. HERMES monitoring in 2009-2014 reveals it is a semi-detached massive binary system with \( P_{\text{orb}} = 60.8 \) d.

• Investigate and model quantitatively the asymmetric wind structure in MWC 314. Use advanced 3-D radiative transfer calculations with Wind3D to fit orbitally modulated optical He I P Cyg line profiles. Put strong constraints on wind-density and -velocity structure around primary LBV star.
MWC 314 in the upper H-R diagram

$T_{\text{eff}} = 18000$ K

$\log g = 2.26$

$L^*/L_\odot = 5.8$

$\dot{M} = 3 \times 10^{-5} M_\odot/\text{yr}$

MWC 314 was known as a candidate LBV (Miroshnichenko et al., A&A 1998)

B[e] or LBV?
Fig. 1. Narrow band Hα image of the environments of MWC314 showing the large east-west bipolar feature around the star. The figure is 12.5 vertically. For all figures, north is up and east to the left.
Bi-polar Hα nebula of MWC 314

A. P. Marston and B. McCollum: Extended shells around B[e] stars

η Carinae
LBV binary $P_{\text{orb}} = 5.5$ yr


Fig. 1. Narrow band Hα image of the environments of MWC314 showing the large east-west bipolar feature 12.5 vertically. For all figures, north is up and east to the left.
Radial velocity monitoring 2009-2014

- 1 ESO-FEROS spectrum June 2009
- 20 Mercator-HERMES spectra Sep 2009 – May 2014

Orbital solution: $P_{\text{orb}} = 60.799 \text{ d}$

- $e = 0.235 \pm 0.003$
- $i = 72.79 \pm 13.05 \text{ deg.}$
- $a = 262.58 \pm 19.52 \text{ R}_\odot$
PHOEBE code combined best fit of RV and V

MWC 314 is massive binary system with primary filling its Roche volume

V-curve shows partial eclipses for $i = 72.79 \pm 13.05$ deg.

**Primary star:**

$M_1 = 39.66 \pm 4.3 \, M_\odot$

$R_1 = 86.80 \, R_\odot$

**Secondary star:**

$M_2 = 26.26 \pm 2.5 \, M_\odot$

$R_2 = 20.41 \, R_\odot$
$R_1 = 86.8 \ R_\odot$

$a = 262.6 \ R_\odot$
Primary star fills its Roche lobe

\[ \phi = 0.6 \]

\[ \phi = 0.3 \]

apastron

\[ \phi = 0.8 \]

\[ \phi = 0.96 \]

V brightness maximum periastron
• All He I lines show orbitally modulated wind absorption.
• Maximum wind absorption around $\phi = 0.65 - 0.85$, or max. RV blueshift.
primary at apastron

β-law wind model is asymmetric near gravity center becoming symmetric at large distances
- Parametrized 3-D wind velocity & density model around primary star.
- Wind density enhancement of $\rho / \rho_{sm} \sim 3.3$ in front of the primary’s orbit.
Parametrized 3-D model reproduces enhanced absorption at $\phi=0.65 - 0.85$.

- 3-D RT Wind3D includes convergence of 3-D line source function with $\phi$.
2014 results on MWC 314

• Approved XMM-Newton program for two MWC 314 observations in eclipse phase (May 2014) and quadrature phase (Oct 2014).

• May 6 2014: significantly detected with average X-ray rate of 0.015 cts/s.

MWC 314 is a new High Mass X-ray Binary
• HERMES observation of 6 May 2014 in eclipse phase reveals Discrete Absorption Components in violet wings of He I lines

• Are the DACs evidence of large-scale wind structures near L3 observed when primary LBV star is in front of the secondary? HERMES monitoring is needed for RT modeling of DAC evolution
• ESO VLT-NACO observes possible distant companion at 1.9” (~5700 AU)

• MWC 314 is possibly wide triple system (Martayan, Lobel, et al., in prep.)
Conclusions

- MWC 314 is a semi-detached massive LBV binary system (HMXB) with $T_{\text{eff}}_1 = 18$ kK, $M_1+M_2 > 65$ $M_\odot$ and $P_{\text{orb}} = 2$ m.

- Accurate orbital elements: $e=0.23$, $i = 73^{13}$, $a_1+a_2\approx 1.22$ AU. Accurate stellar parameters from combined RV- and $V$-curve: $R_1 = 86.80$ $R_\odot$ and $R_2 = 20.41$ $R_\odot$ ($T_{\text{eff}}_2 = 6200$ K).

- SED of MWC 314 identical to P Cygni, signaling radiatively accelerating wind with $r^{-2}$ smooth wind density structure.

- Optical emission lines and P Cyg line variability are orbitally modulated. He I P Cyg lines show wind outflow $> 1200$ km/s.

- We develop 3-D model of the asymmetric wind structure around the primary. Detailed fits to He I P Cyg absorption using Wind3D determine density increase of $\sim 3.3$ above smooth wind that leads the orbital path of the primary star.