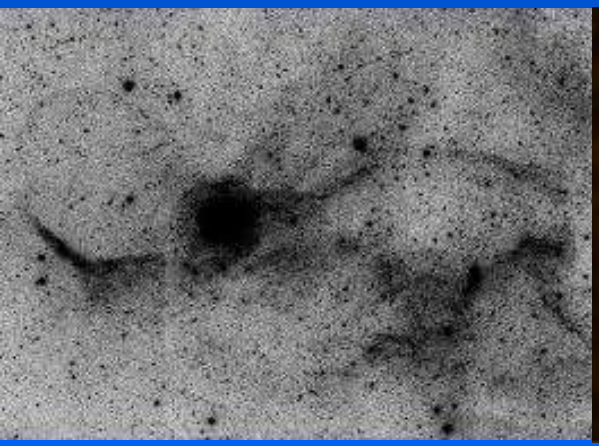
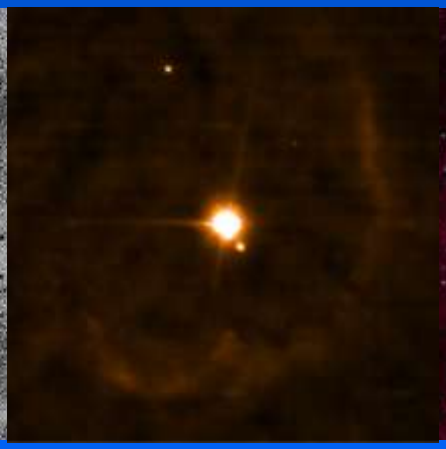
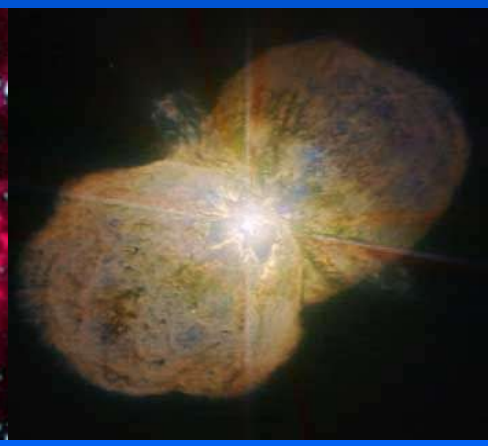
Modeling the Asymmetric Wind of the Luminous Blue Variable Binary MWC 314



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Motivation

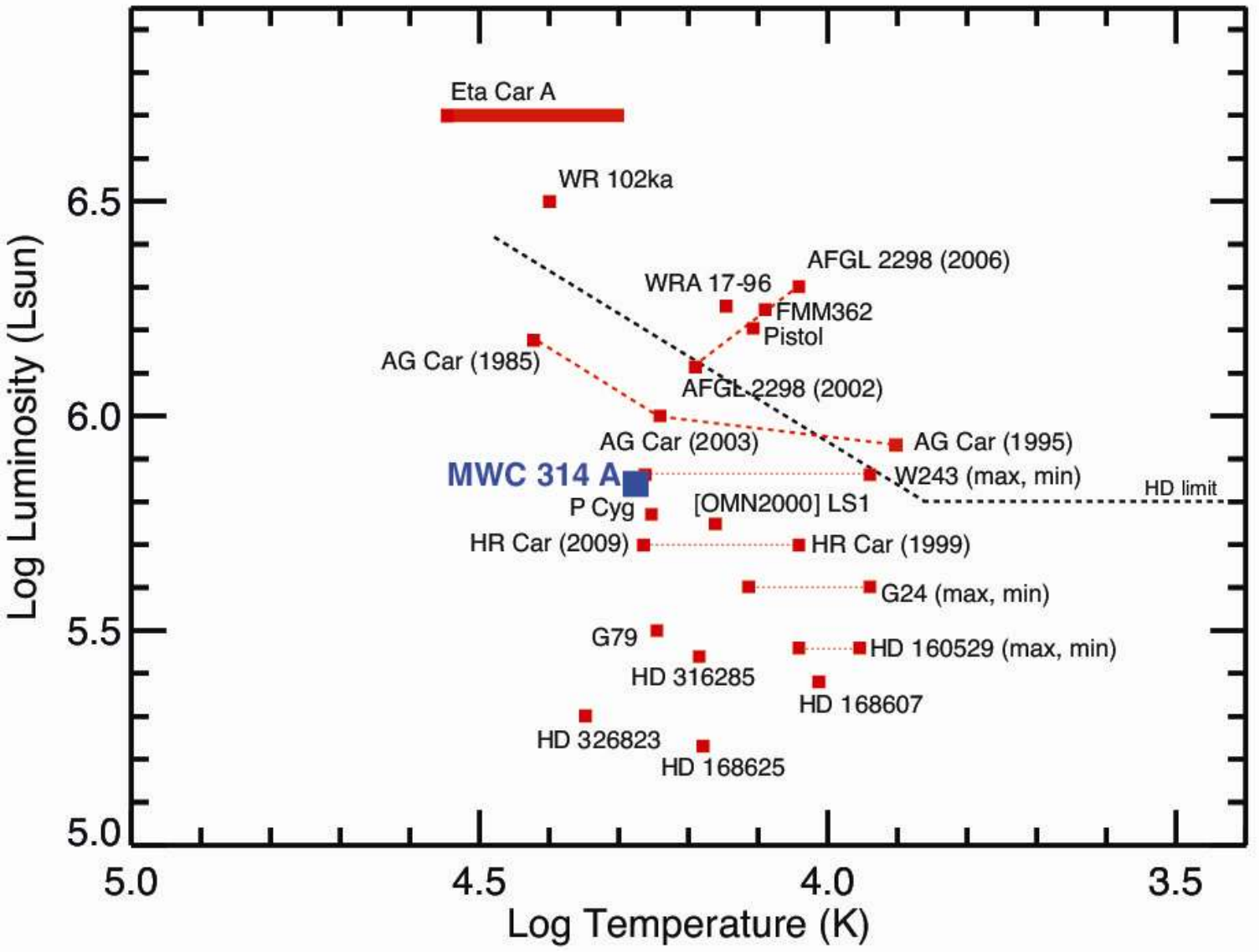
- Are there analogs of notorious LBV binary stars, i.e. like η Carinae? Long-term monitoring with HERMES of various (single) LBVs and candidate LBVs, searching for new LBV or cLBV binaries.

- 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 montioring in 2009-2014 reveals it is a semi-detached massive binary system with P_{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 contraints on wind-density and -velocity structure around primary LBV star.

MWC 314 in the upper H-R diagram



***T*eff = 18000 K**
log *g* = 2.26
$L_* / L_\odot = 5.8$

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

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

B[e] or LBV?

Bi-polar Hα nebula of MWC 314

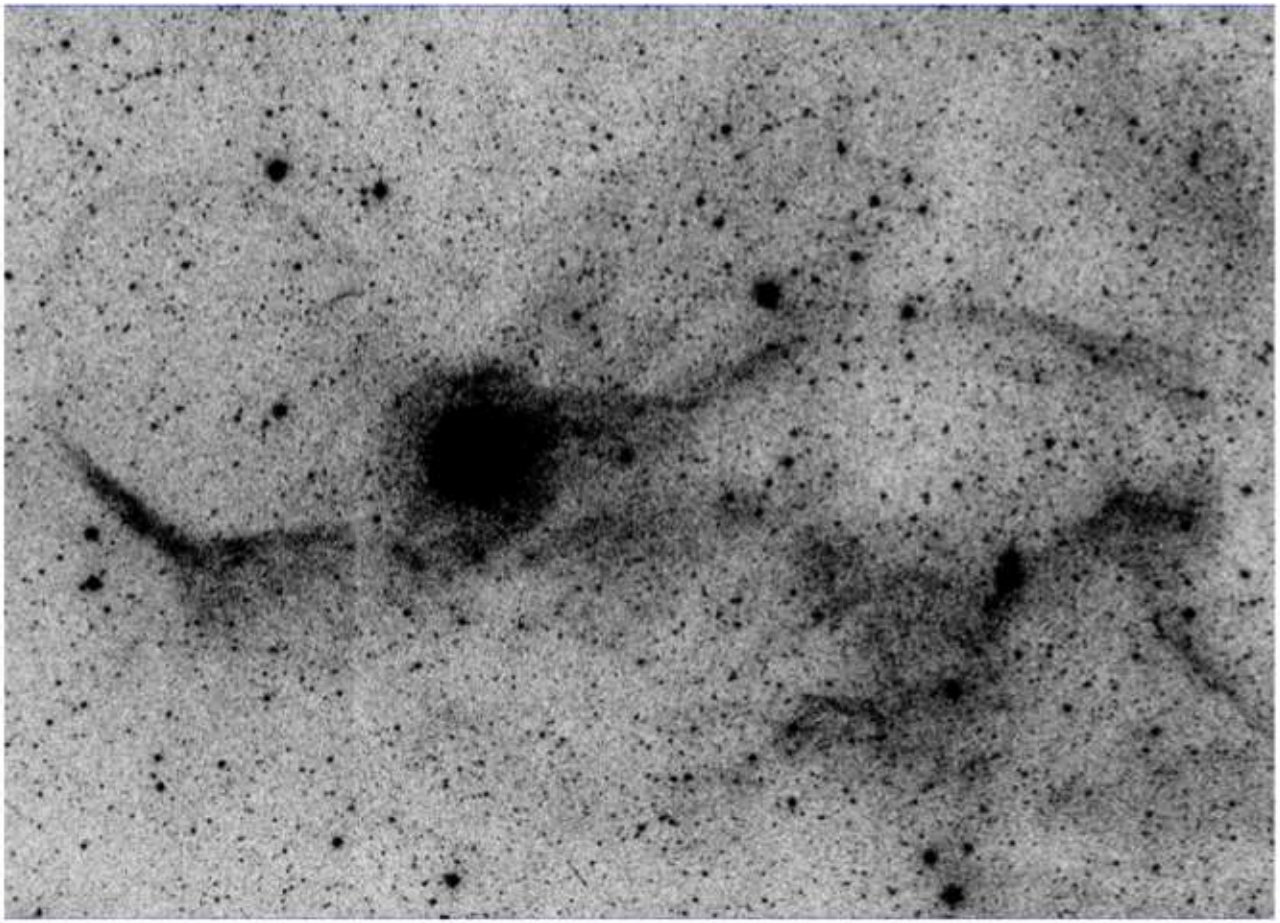


Fig. 1. Narrow band Hα image of the environments of MWC 314 showing the large east-west bipolar feature around the star. The figure is 12′.5 vertically. For all figures, north is up and east to the left.

(Marston & McCollum A&A, 2008)

Bi-polar Hα nebula of MWC 314

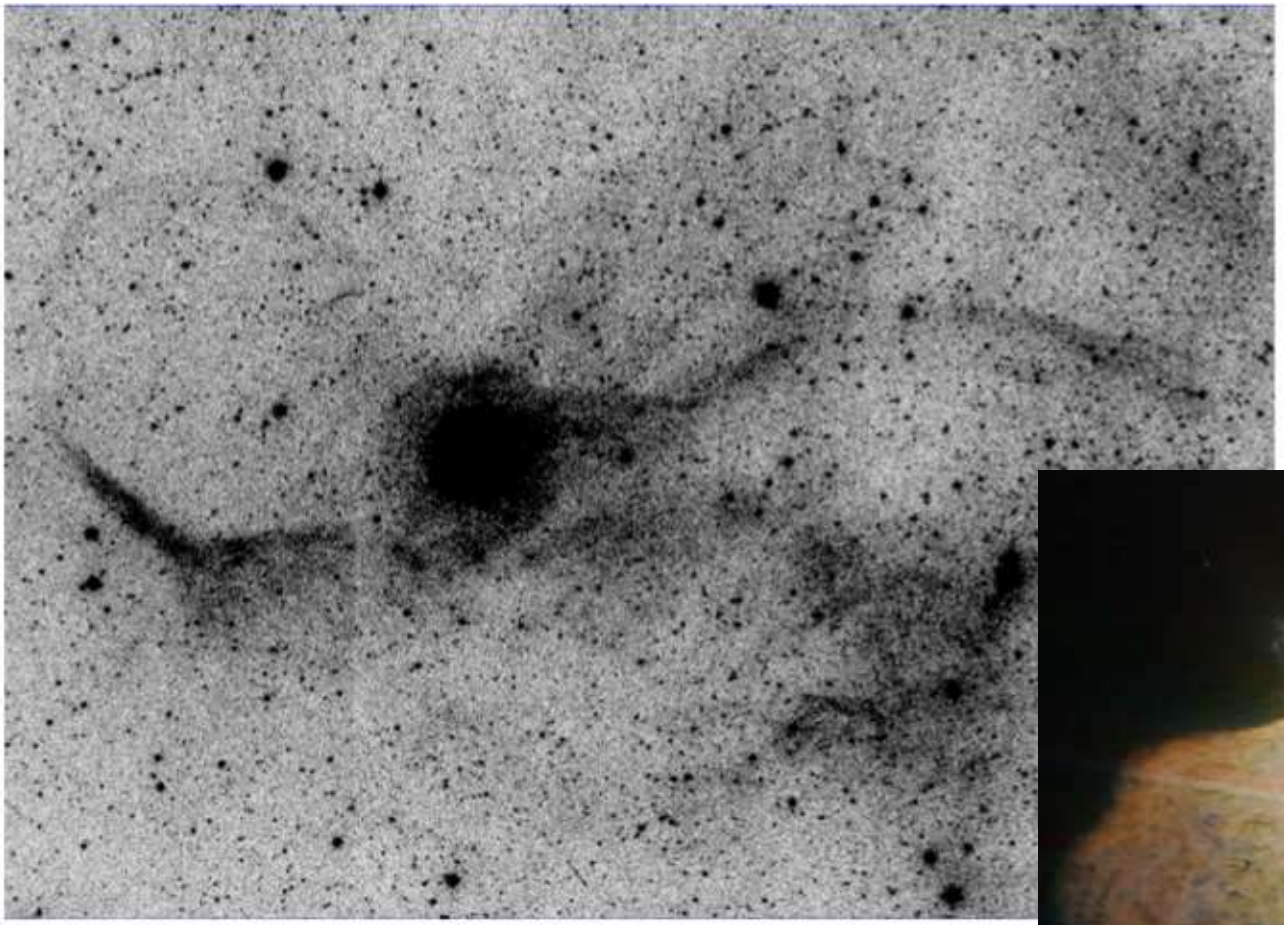
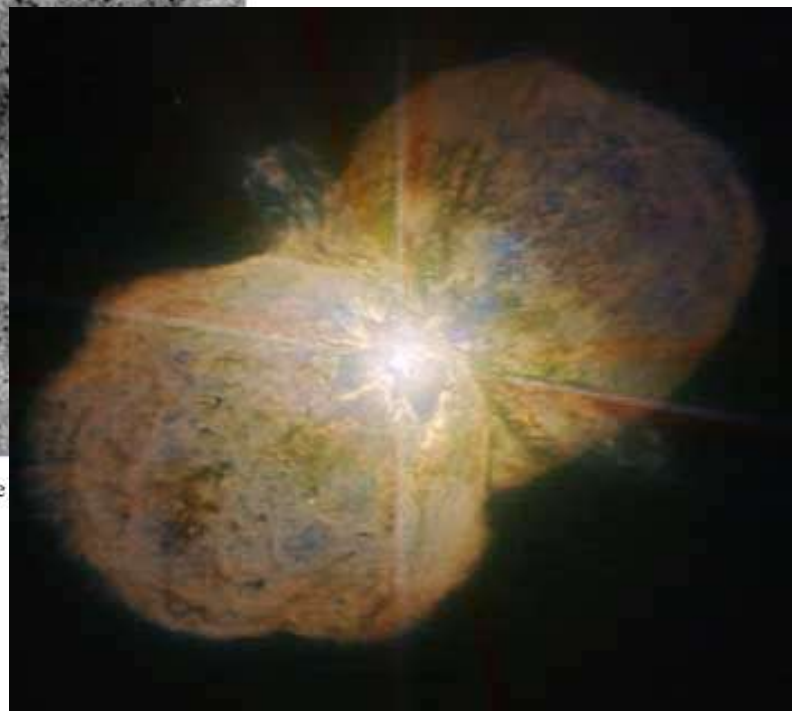


Fig. 1. Narrow band Hα image of the environments of MWC 314 showing the large east-west bipolar feature 12′.5 vertically. For all figures, north is up and east to the left.

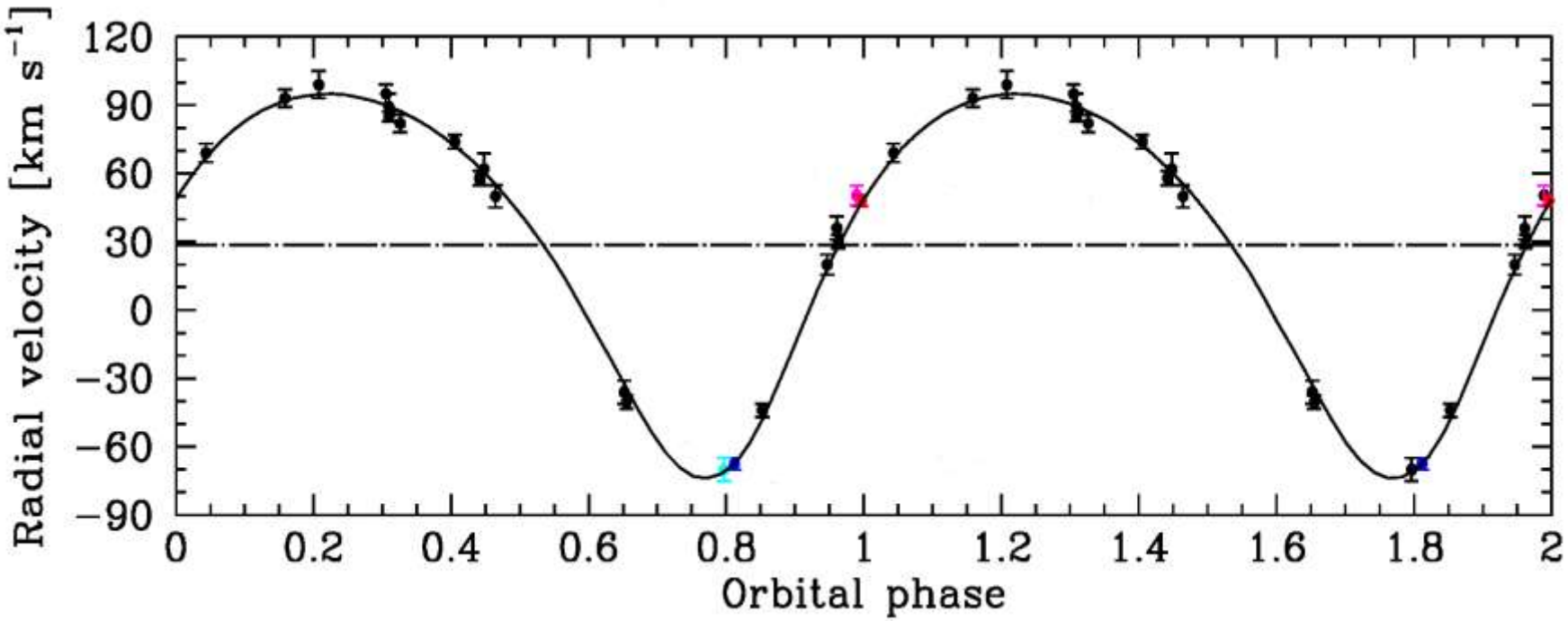
(Marston & McCollum A&A, 2008)

η Carinae
LBV binary P_{orb}= 5.5 yr



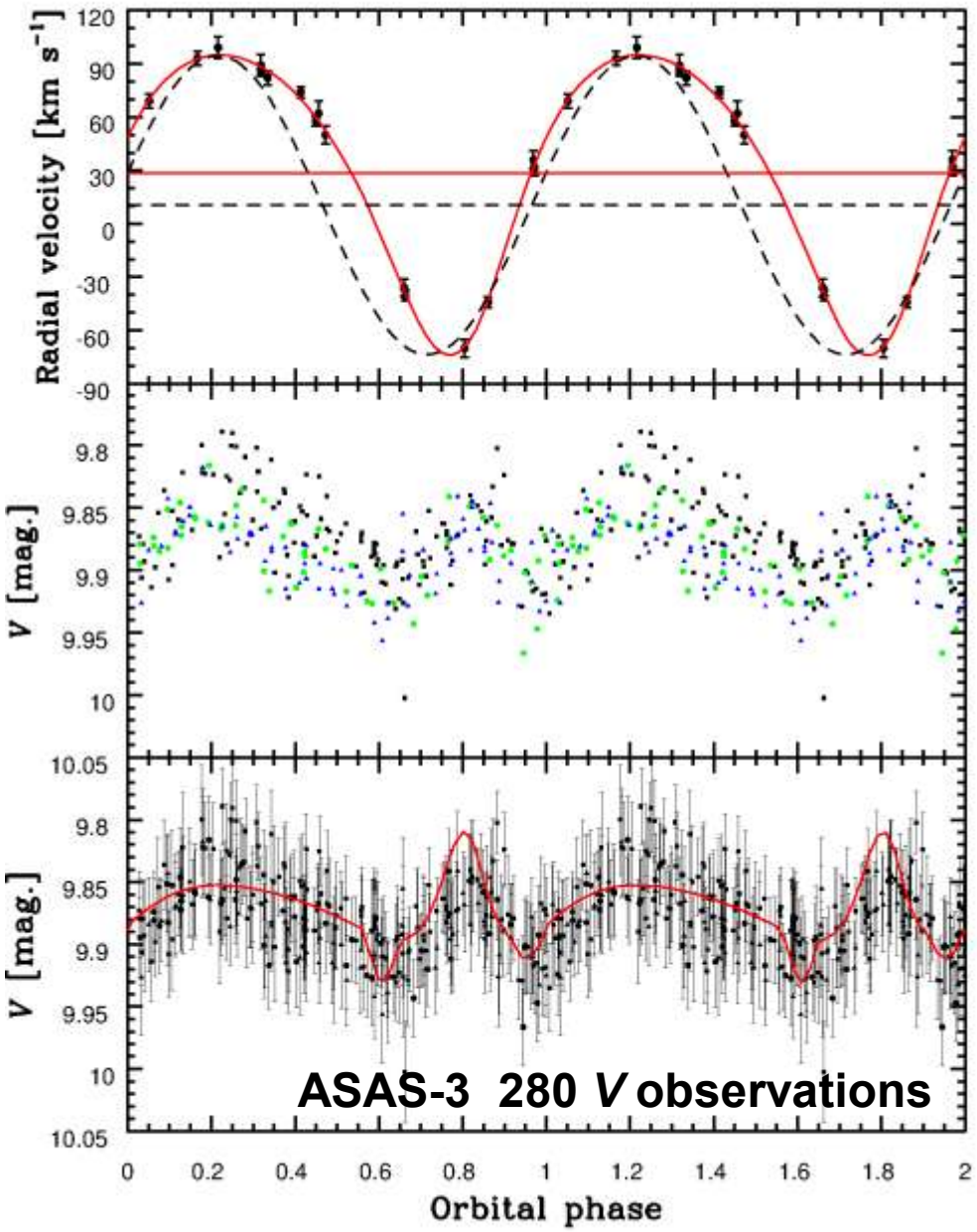
Radial velocity monitoring 2009-2014

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



- Orbital solution: P_{orb} = 60.799 d
  e = 0.235 0.003
  i = 72.79 13.05 deg.
  a = 262.58 19.52 $R_\odot$

Best fit of radial velocity- and *V*-curve



PHOEBE code
<u>combined best fit</u> 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 13.05 deg.**

<u>Primary star:</u>

$M_1 = 39.66 \quad 4.3\ M_\odot$
$R_1 = 86.80\ R_\odot$

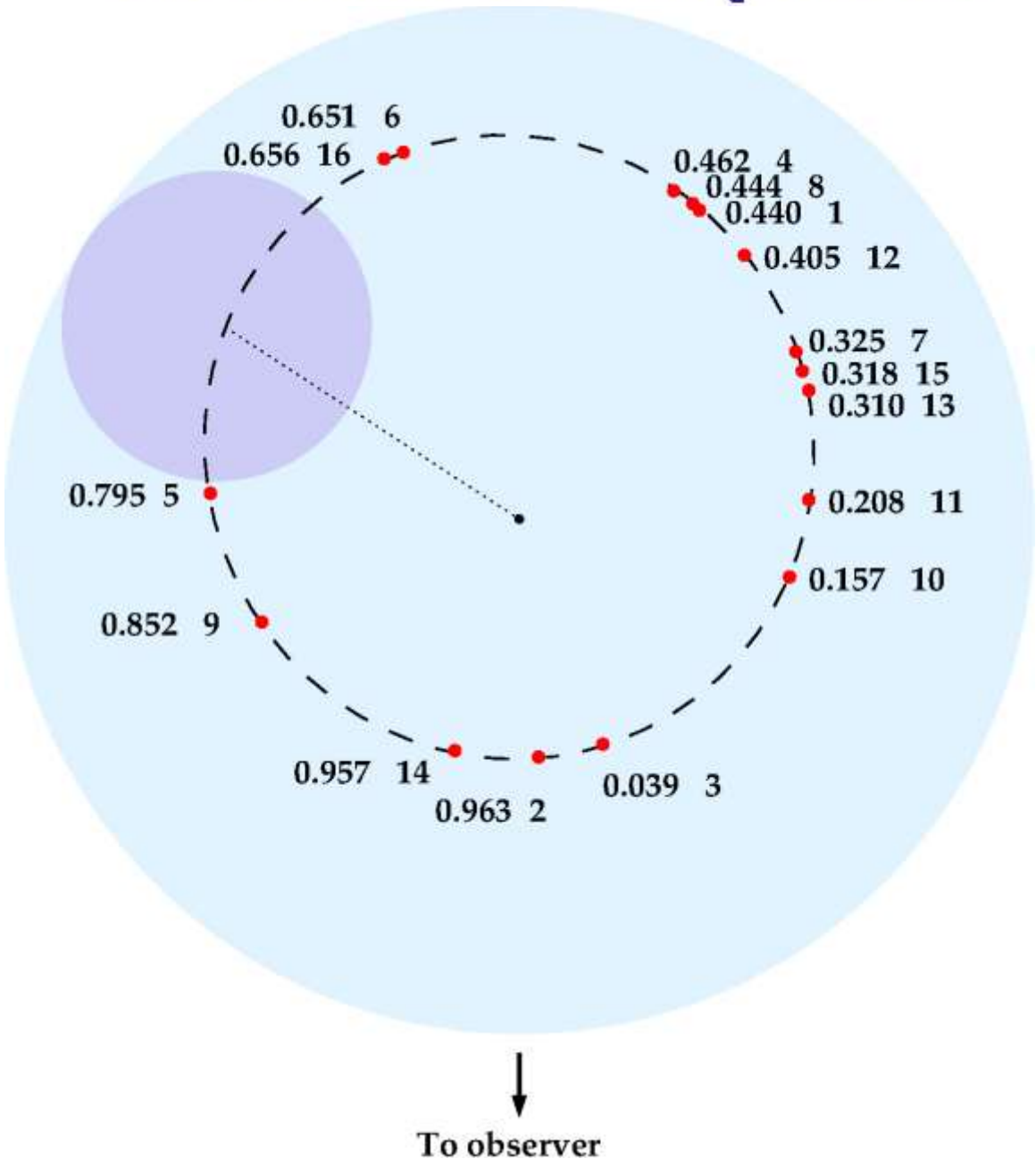
<u>Secondary star:</u>

$M_2 = 26.26 \quad 2.5\ M_\odot$
$R_2 = 20.41\ R_\odot$

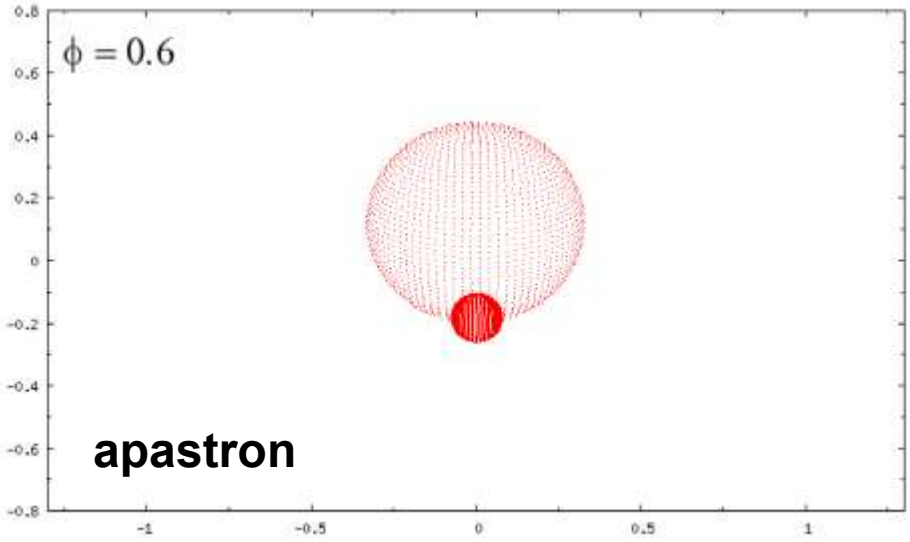
Observed orbital phases

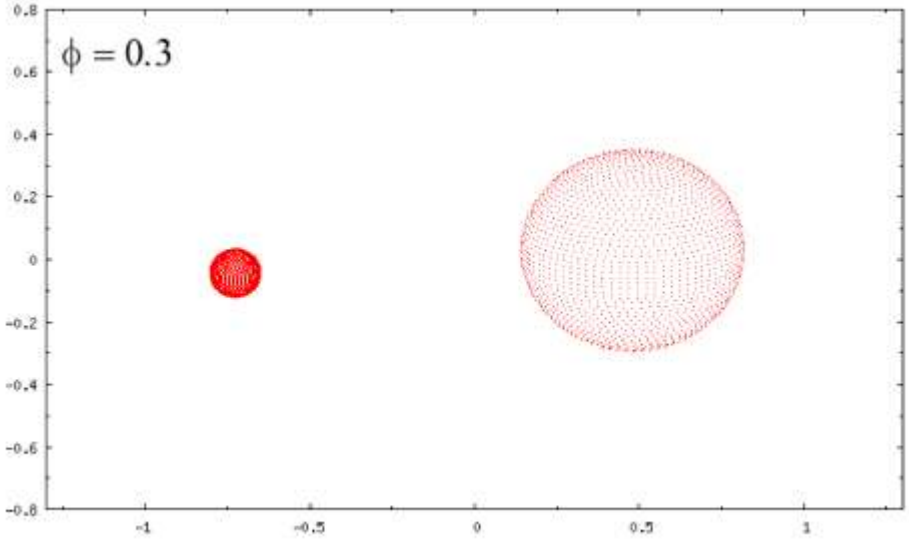
$R_1 = 86.8\ R_\odot$

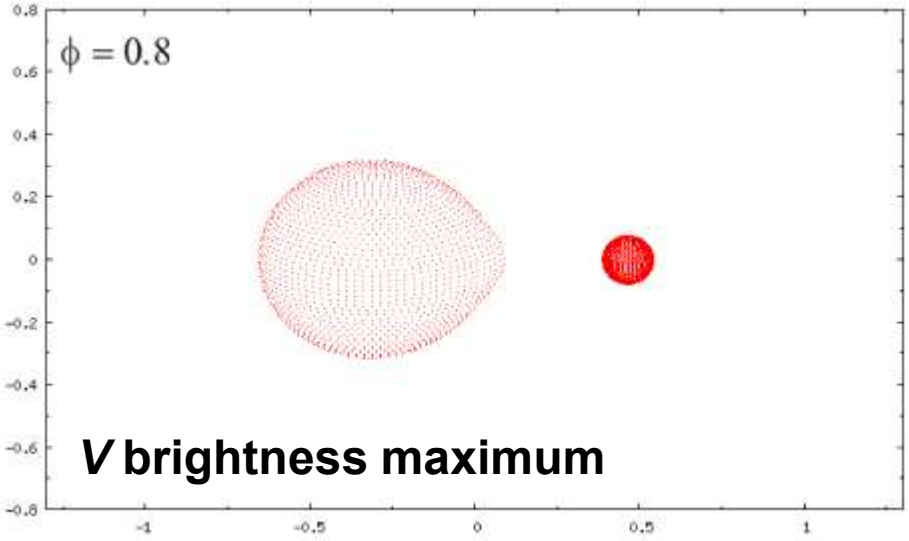
$a = 262.6\ R_\odot$

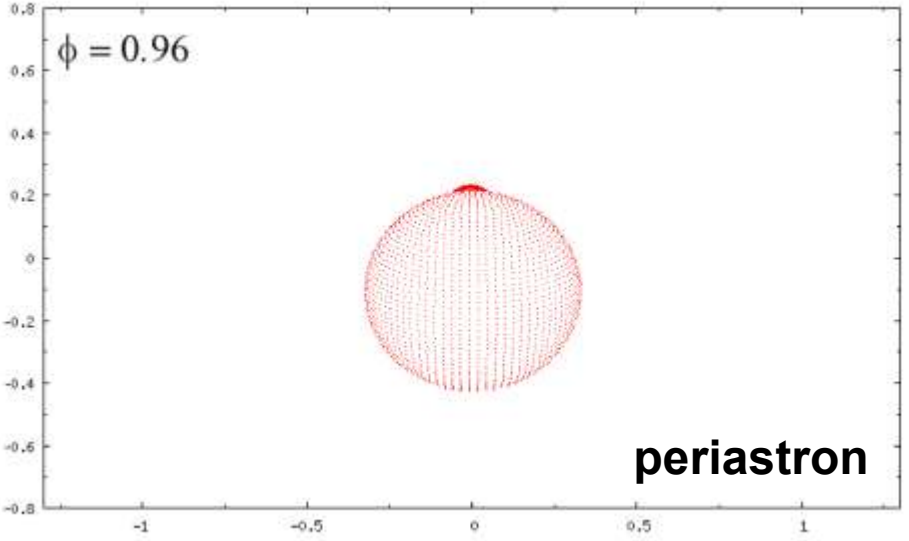


Primary star fills it Roche lobe

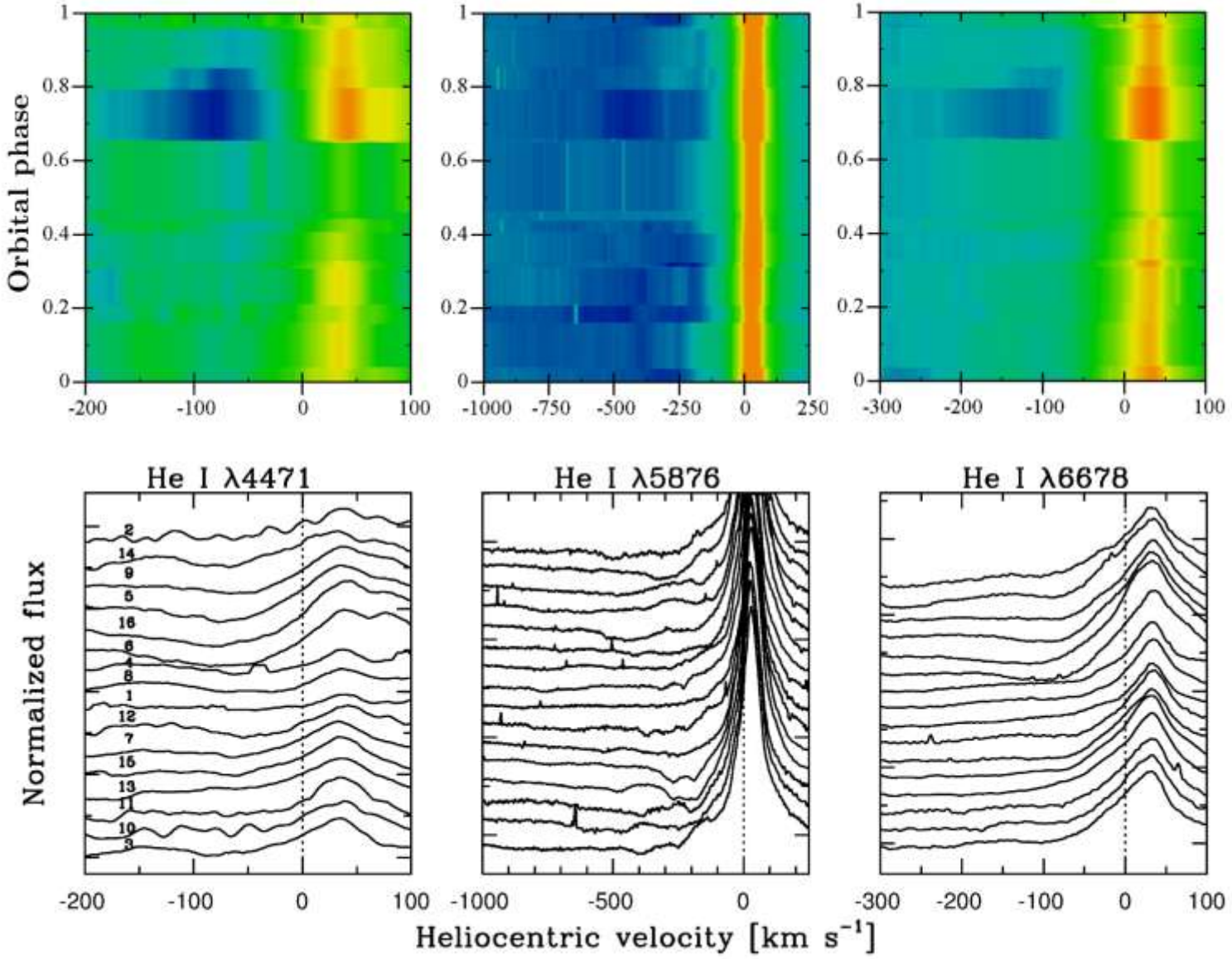








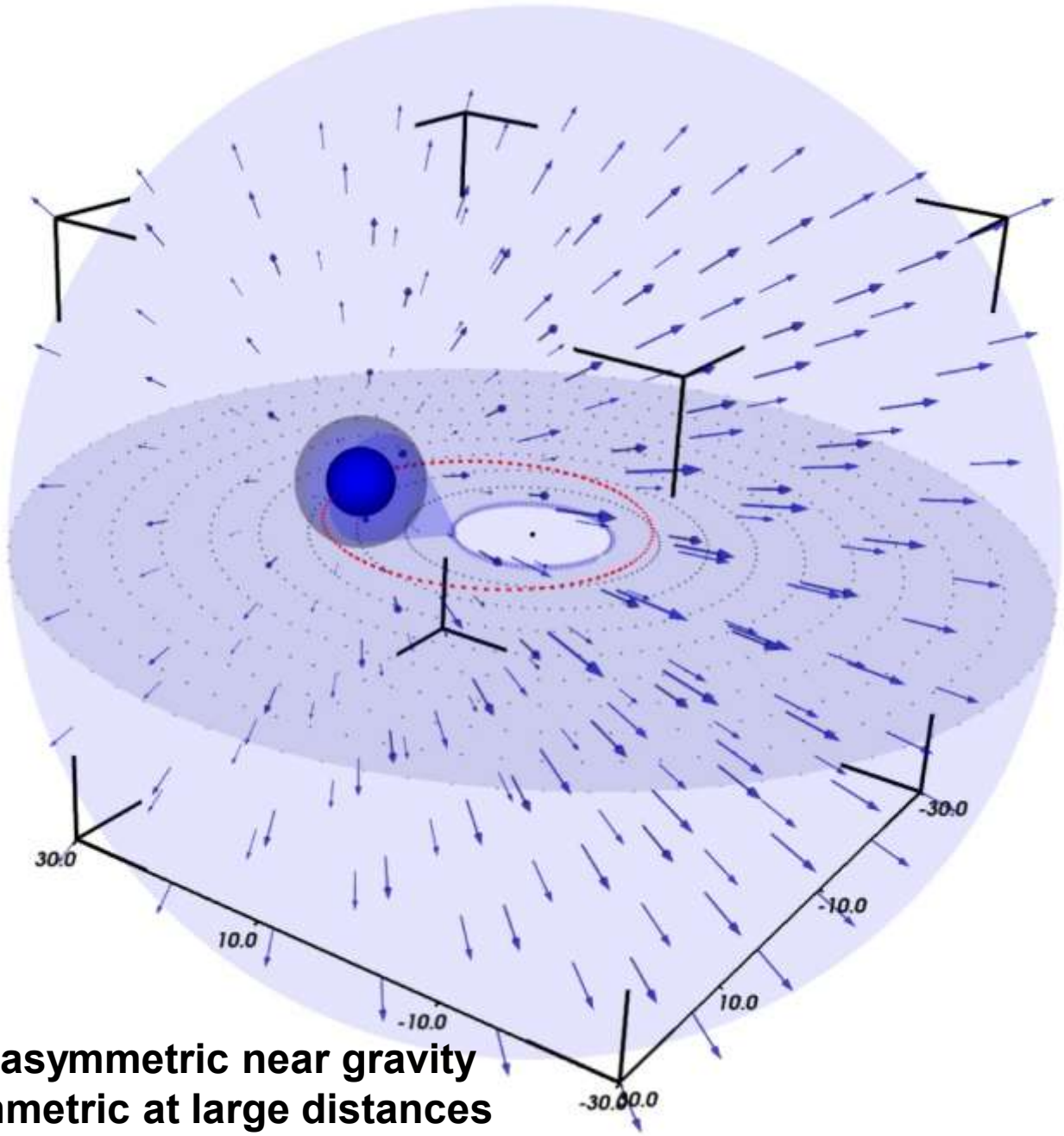
Orbital variability of He I lines in MWC 314



- All He I lines show orbitally modulated wind absorption.
- Maximum wind absorption around ϕ = 0.65 – 0.85, or max. RV blueshift.

Asymmetric 3-D wind model of MWC 314

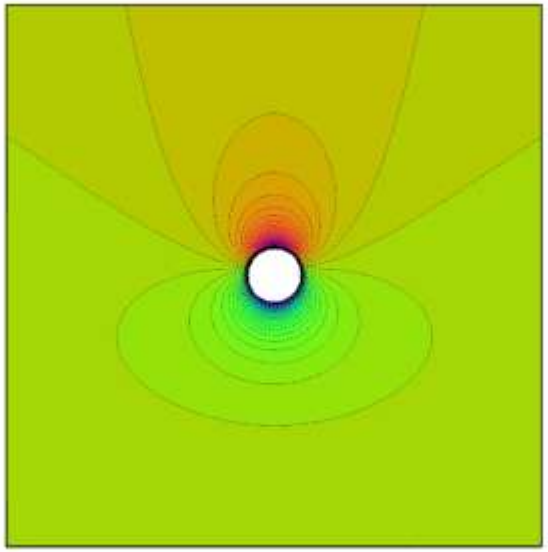
primary at apastron



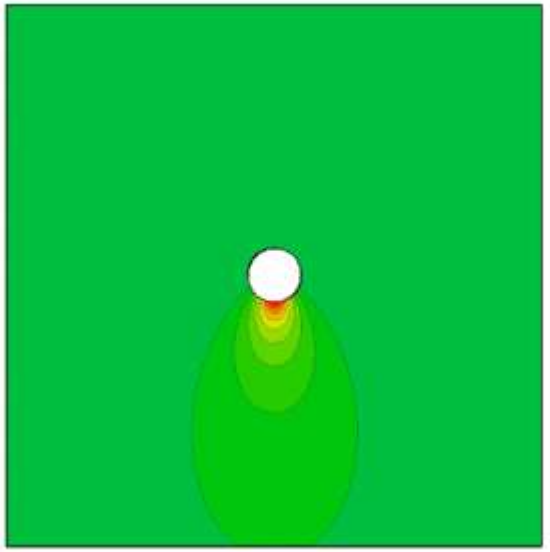
β-law wind model is asymmetric near gravity center becoming symmetric at large distances

MWC 314 asymmetric expanding wind model

$v_{wind} - v_{sm}$



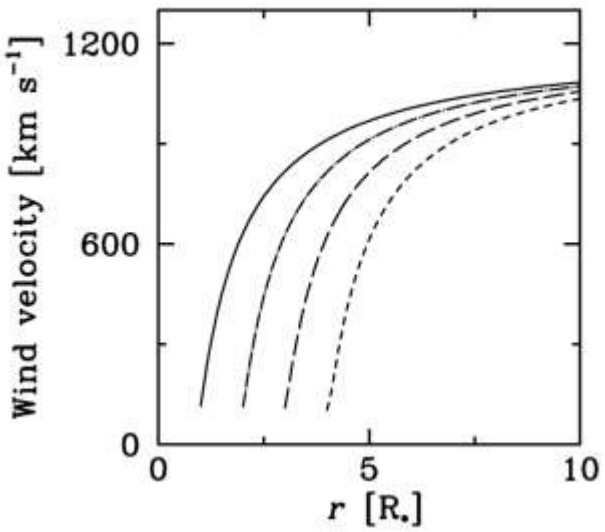
ρ / ρ_{sm}

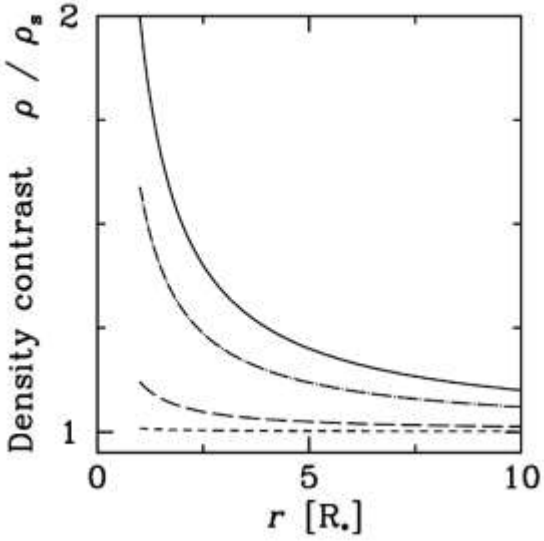


equatiorial cross-section

opening angle = π /4

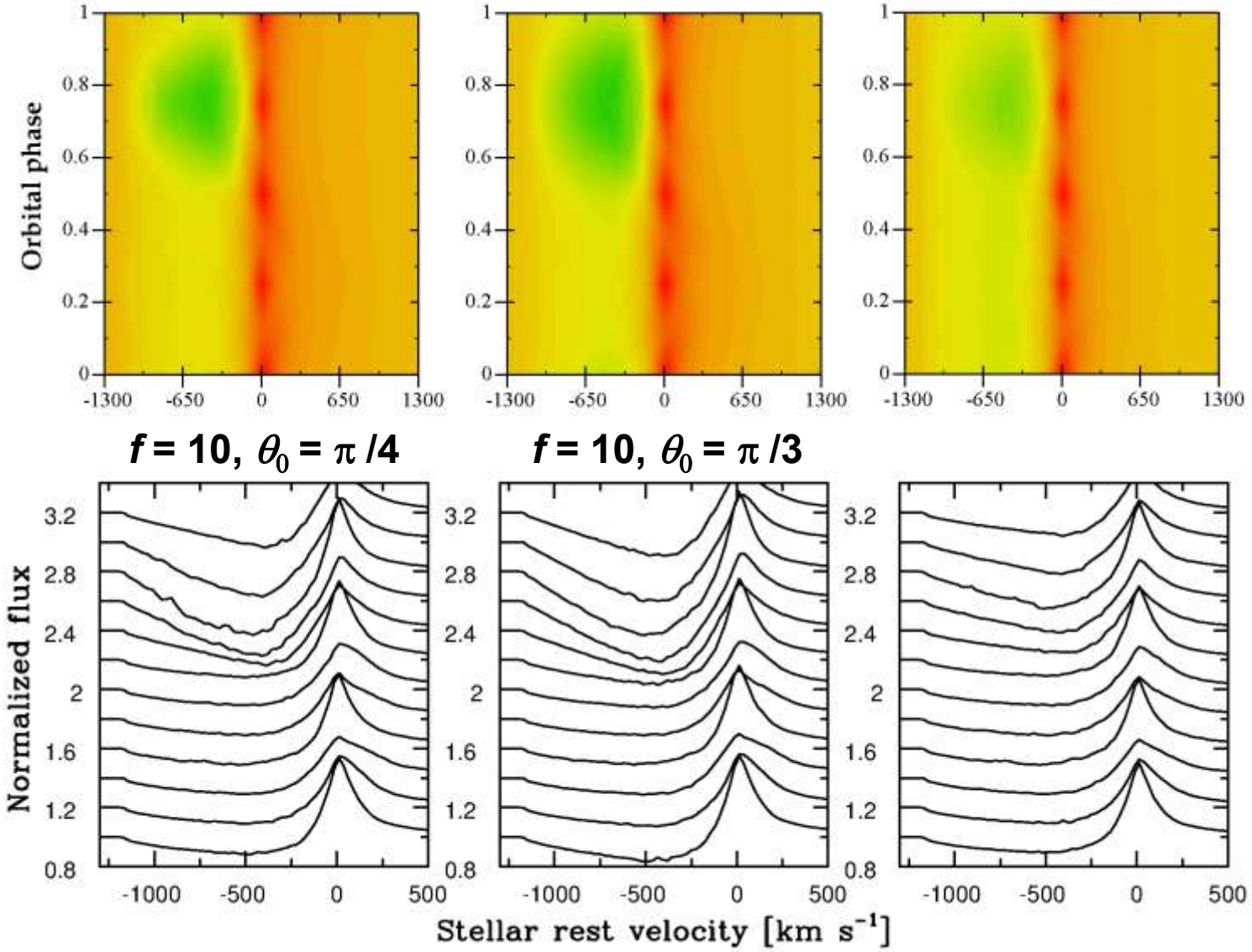
v_{wind}





- Parametrized 3-D wind velocity & density model around primary star.
- Wind density enhancement of ρ / ρ_{sm}~3.3 in front of the primary's orbit.

Wind3D RT fit to He I λ5876 orbital variability



Best fit:
f **= 3.3**

opening angle $\theta_0 = \pi/4$

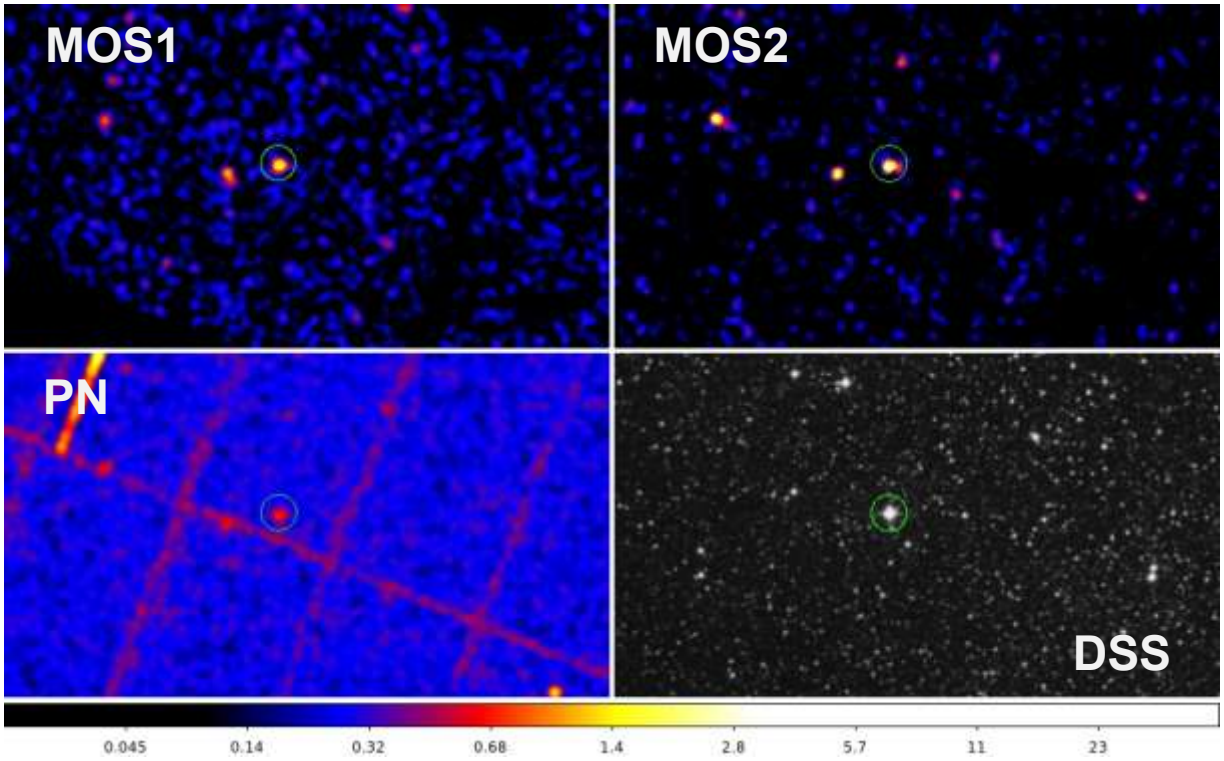
K_1 **= 84.5 km/s (obs. Vrad)**

Lobel et al. 2013 A&A 559, A16

- **Parametrized 3-D model reproduces enhanced absorption at ϕ=0.65 - 0.85.**
- **3-D RT Wind3D includes convergence of 3-D line source function with ϕ.**

2014 results on MWC 314

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

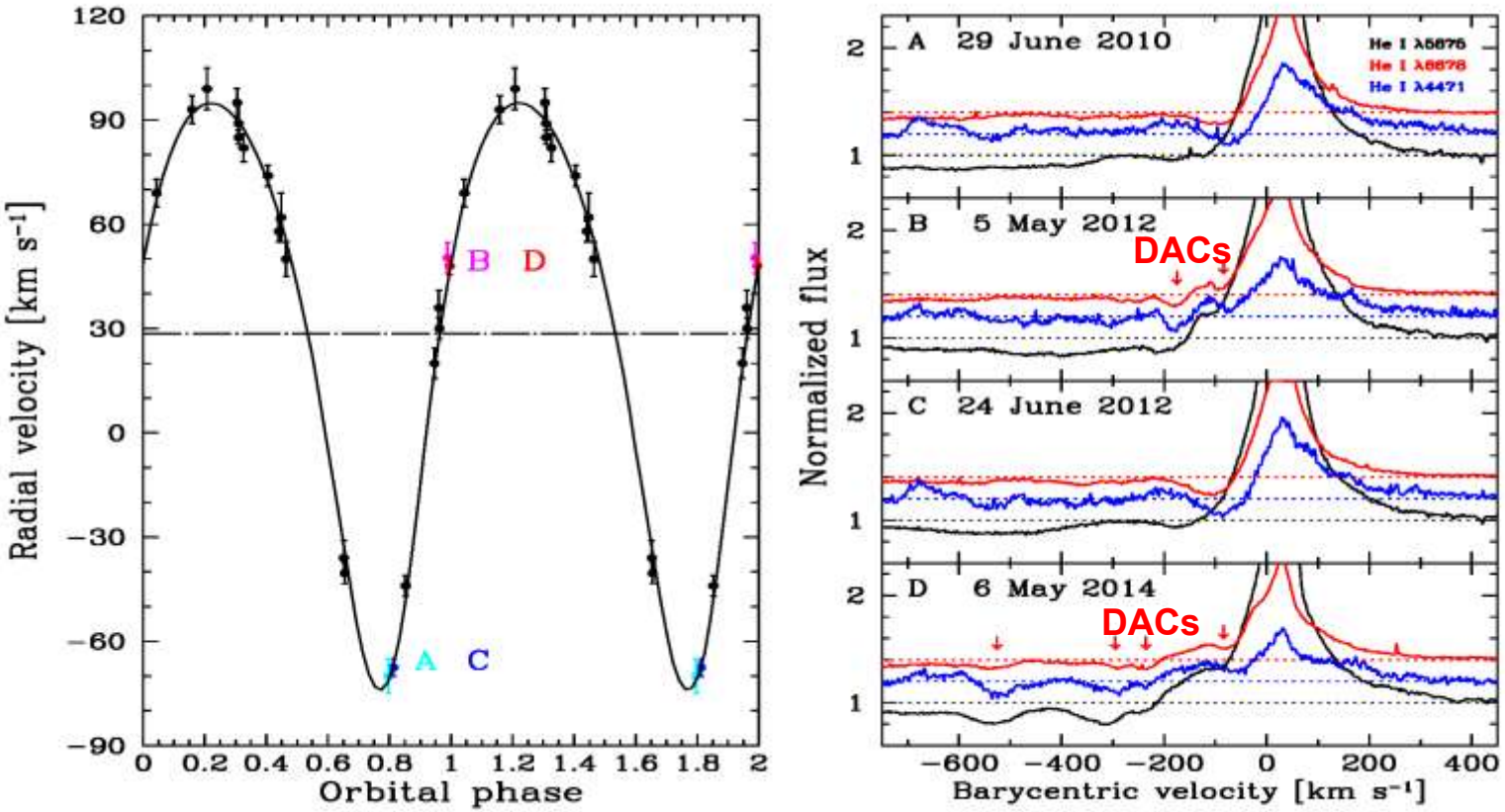


- May 6 2014: significantly detected with average X-ray rate of 0.015 cts/s.

MWC 314 is a new High Mass X-ray Binary

2014 results on MWC 314

- **HERMES observation of 6 May 2014 in eclipse phase reveals Discrete Absorption Components in violet wings of He I lines**

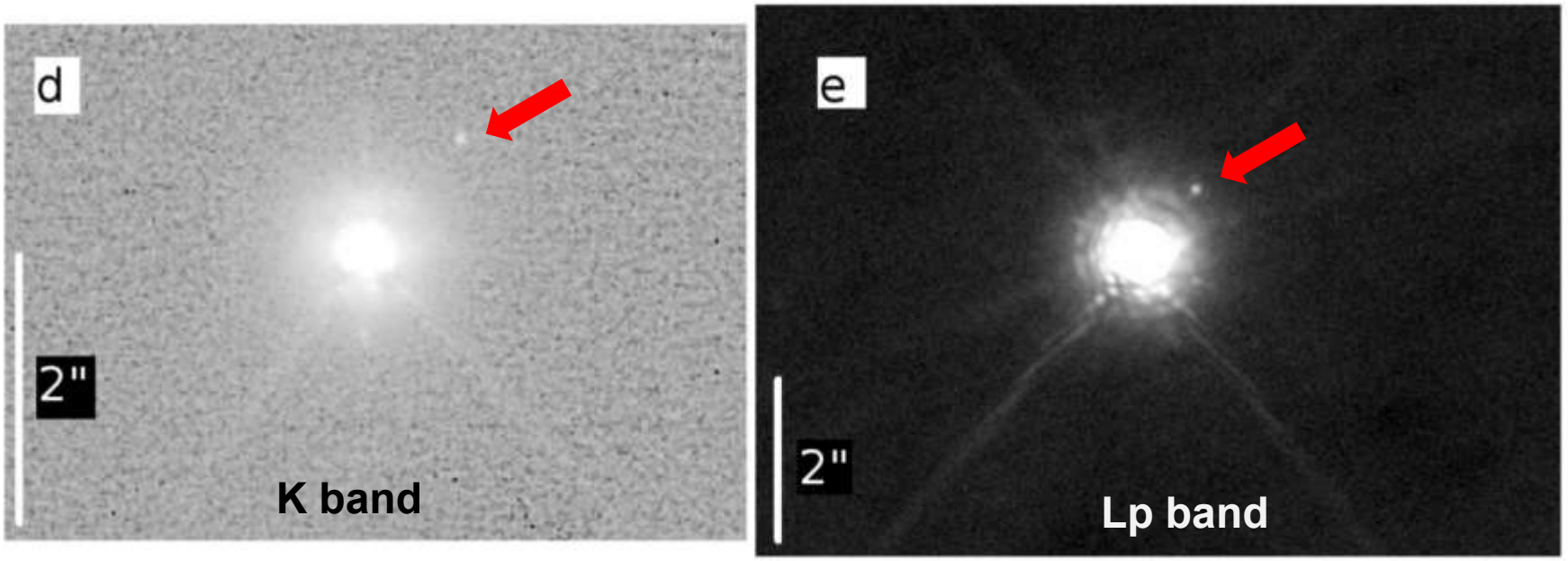


- **Are the DACs evidence of large-scale wind structures near L3 observed when primary LBV star is in front of the secondary?**

HERMES monitoring is needed for RT modeling of DAC evolution

2014 results on MWC 314

- 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 $T\mathrm{eff}_1$ = 18 kK, M_1+M_2 > 65 $M_\odot$ and P_{orb} = 2 m.
- Accurate orbital elements: e=0.23, i = 73 13 , $a_1+a_2\cong$1.22 AU. Accurate stellar parameters from combined RV- and V-curve: R_1 = 86.80 $R_\odot$ and R_2 = 20.41 $R_\odot$ ($T\mathrm{eff}_2$ = 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 ~3.3 above smooth wind that leads the orbital path of the primary star.