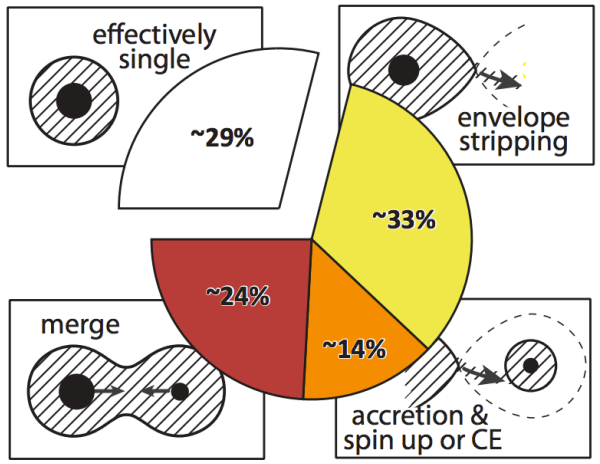
The First Dynamical Mass Determination of a Nitrogen-rich Wolf–Rayet Star Using a Combined Visual and Spectroscopic Orbit

Noel Richardson, Laura Lee, et al.

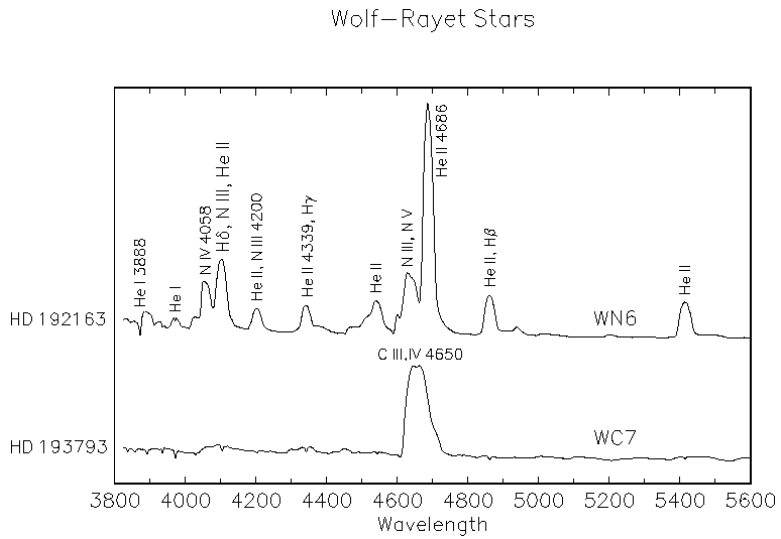
Embry-Riddle Aeronautical University

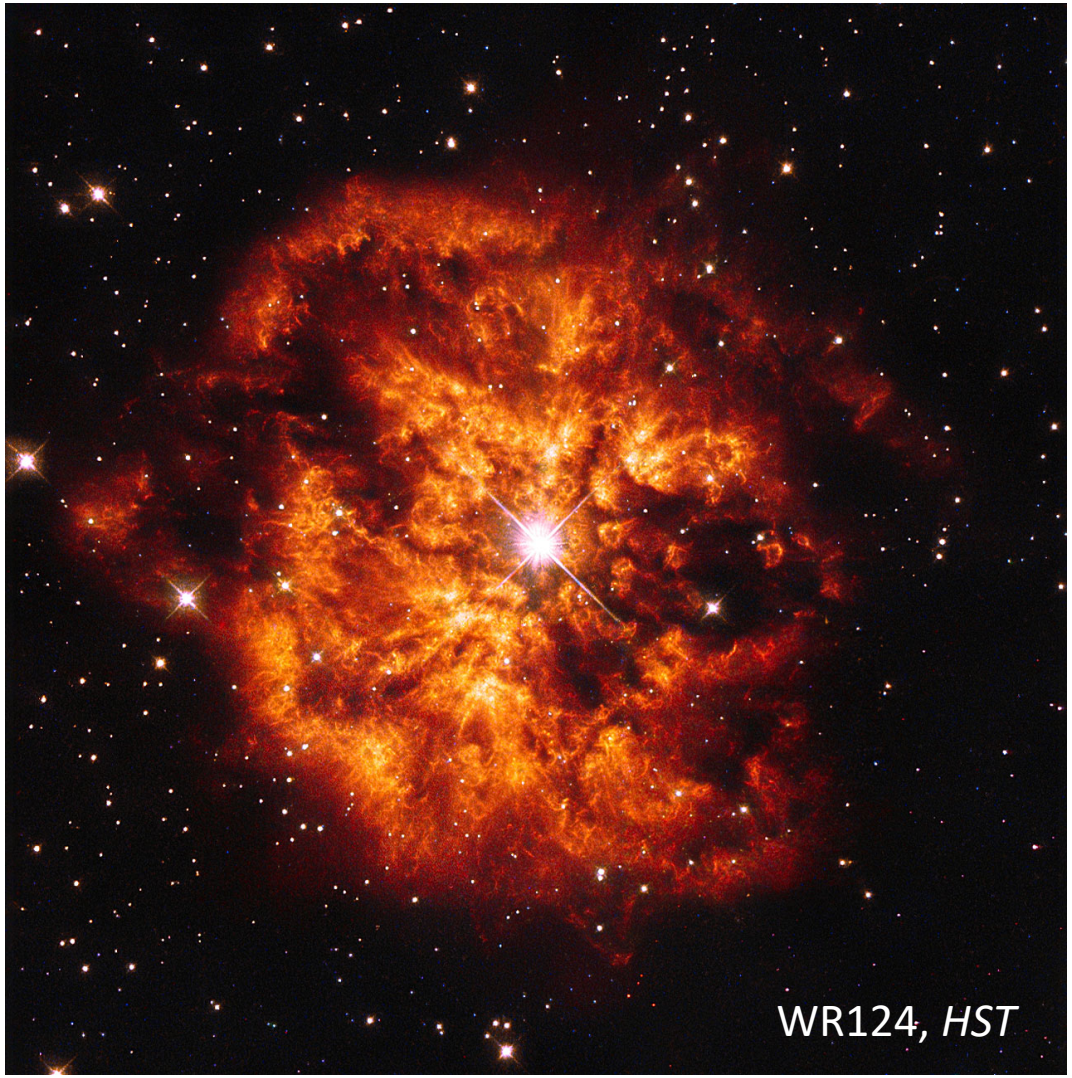
What is a Wolf-Rayet star?

- Classical WR stars are H-free, evolved massive stars. They have extremely high effective temperatures and strong stellar winds.



Sana et al. (2012)



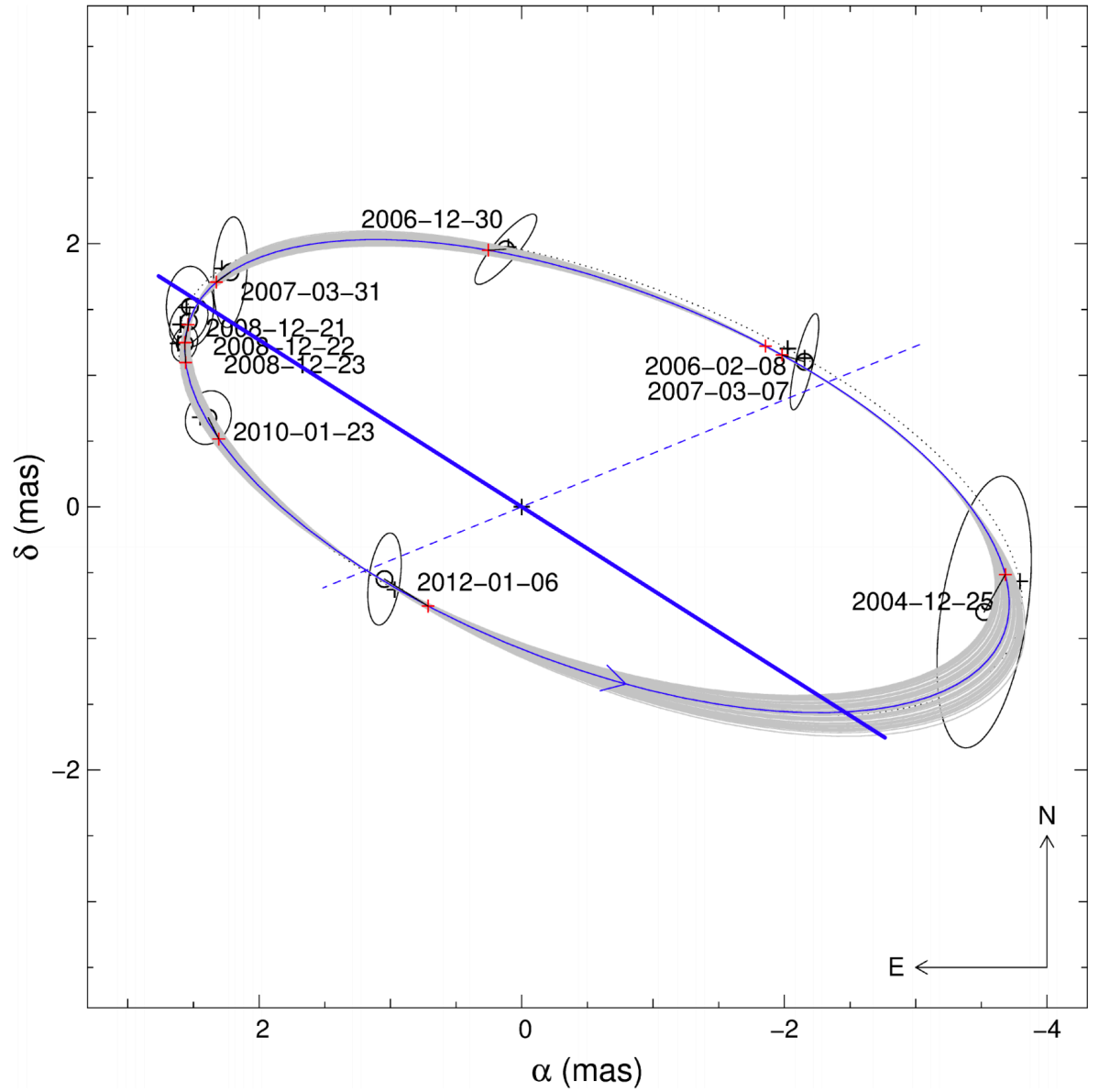


Previous Interferometry of WR stars

- Due to the rarity of these objects, only a few have been observed.
- Large distances – not much to resolve for most WR stars
- Binaries are main focus with current instrumentation

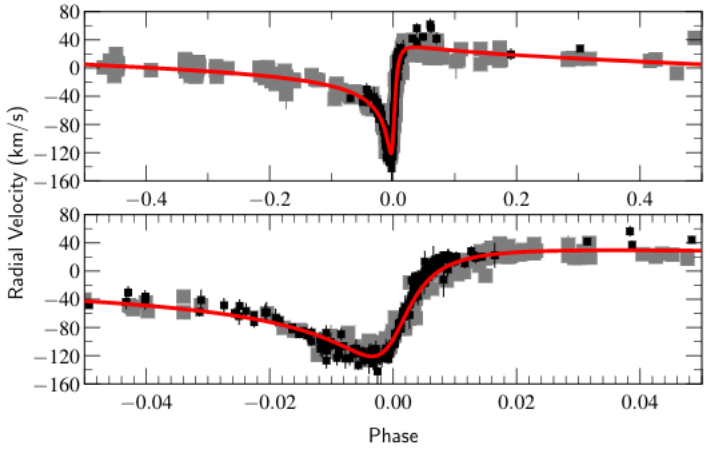
Gamma2 Vel

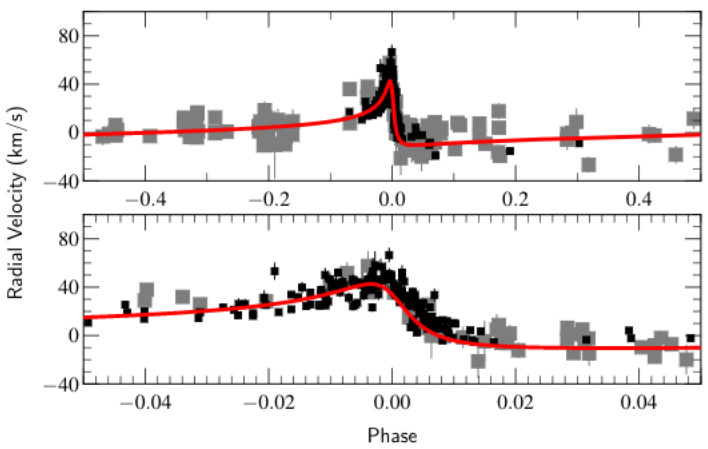
- WC8 + O7.5III
- P = 78.53 d
- e = 0.33
- Lamberts et al. 2017 + Richardson et al. 2017
- M_O = 28.4 Msun
- M_WR = 9 Msun

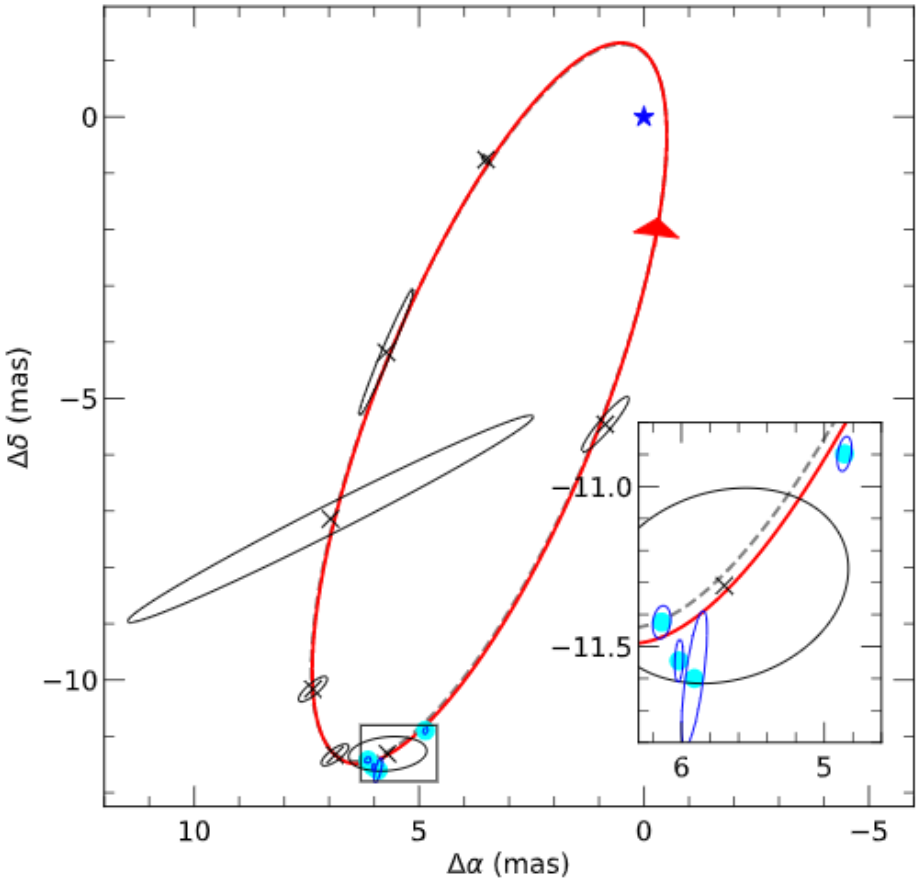


WR140 – Monnier et al. (2011); Thomas, Richardson et al. (submitted)

- WC7pd + O5.5fc
- P = 7.93 years
- e = 0.8993
- M_O = 29.3 Msun
- M_WR = 10.3 Msun

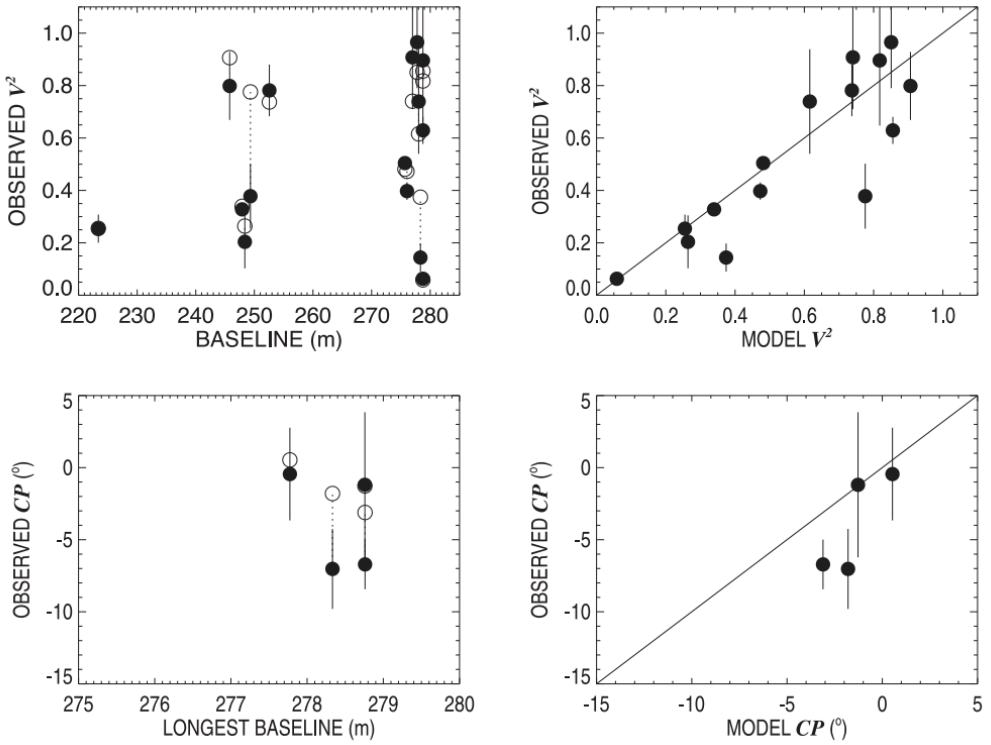






WR137, WR138 – resolved with CHARA (Richardson et al. 2016)

- WR 137
  - WC7 + O
  - P = 13 yr
  - Dust formation at periastron
- WR 138
  - WN + O
  - P – unknown, possibly ~4 yr?
- CLIMB observations resolved the binaries – began a long-term ~~NOAO~~ NOIR Lab program for orbits.
  - Upgraded MIRC-X made the program finally take off!



WR 133 - background

- WN5o + O9I
- Known SB2 orbit with P=133 d, but relatively understudied.
- member of NGC 6871
- Inclination at least 115deg from polarimetric analysis

CHARA observations and the new paper

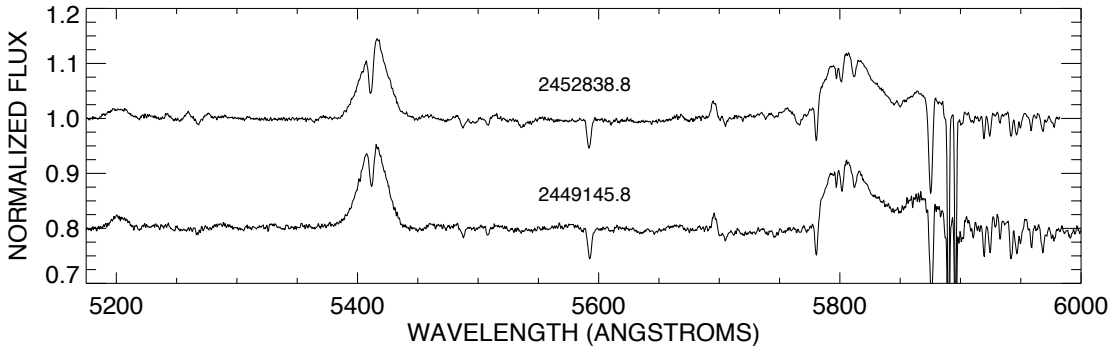
The Astrophysical Journal Letters, 908:L3 (10pp), 2021 February 10 https://doi.org/10.3847/2041-8213/abd722

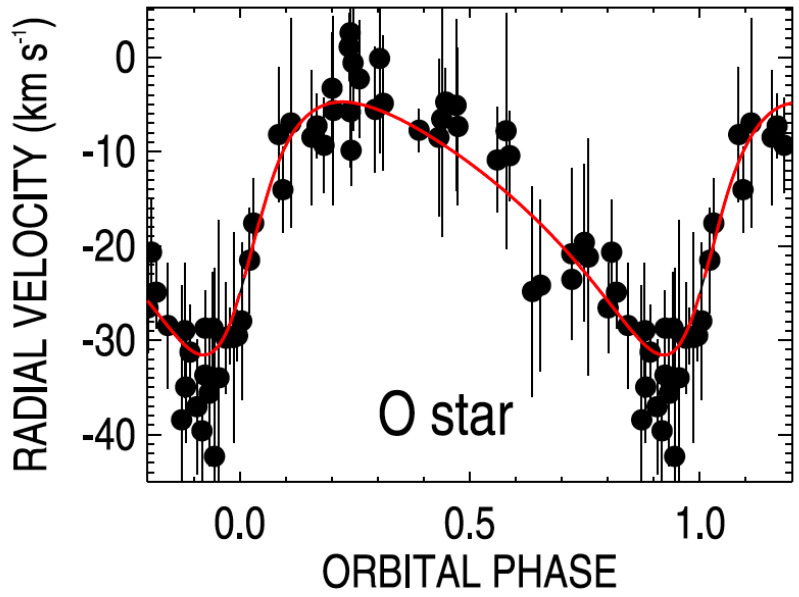
The First Dynamical Mass Determination of a Nitrogen-rich Wolf–Rayet Star Using a Combined Visual and Spectroscopic Orbit

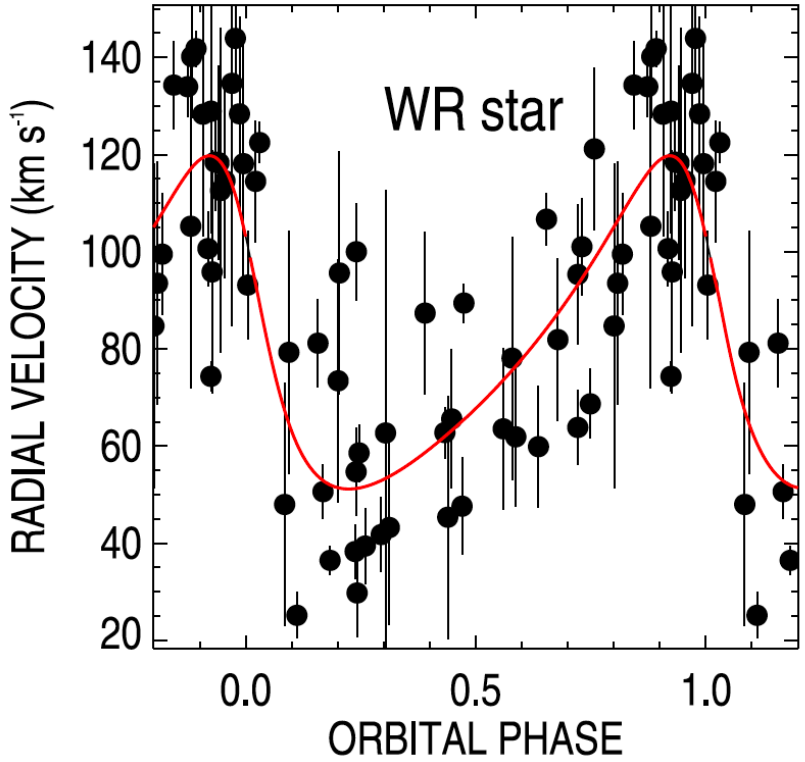
Noel D. Richardson[1], Laura Lee[1], Gail Schaefer[2], Tomer Shenar[3], Andreas A. C. Sander[4], Grant M. Hill[5], Andrew G. Fullard[6,7], John D. Monnier[8], Narsireddy Anugu[9,10], Claire L Davies[10], Tyler Gardner[8], Cyprien Lanthermann[11,12], Stefan Kraus[10], and Benjamin R. Setterholm[8]

[1] Department of Physics and Astronomy, Embry-Riddle Aeronautical University, 3700 Willow Creek Road, Prescott, AZ 86301, USA; noel.richardson@erau.edu
[2] The CHARA Array of Georgia State University, Mount Wilson Observatory, Mount Wilson, CA 91023, USA
[3] Institute of Astronomy, KU Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium
[4] Armagh Observatory, College Hill, Armagh BT61 9DG, UK
[5] W.M. Keck Observatory, 65-1120 Mamalahoa Highway, Kamuela, HI 96743, USA
[6] Department of Physics and Astronomy, Michigan State University, 567 Wilson Road, East Lansing, MI 48824, USA
[7] Department of Physics and Astronomy, University of Denver, 2112 E. Wesley Avenue, Denver, CO 80210, USA
[8] Department of Astronomy, University of Michigan, Ann Arbor, MI 48109, USA
[9] Steward Observatory, Department of Astronomy, University of Arizona, Tucson, AZ, USA
[10] School of Physics and Astronomy, University of Exeter, Stocker Road, Exeter EX4 4QL, UK
[11] Instituut voor Sterrenkunde, KU Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium
[12] Institut de Planetologie et d'Astrophysique de Grenoble, F-38058 Grenoble, France
Received 2020 October 16; revised 2020 December 16; accepted 2020 December 23; published 2021 February 9

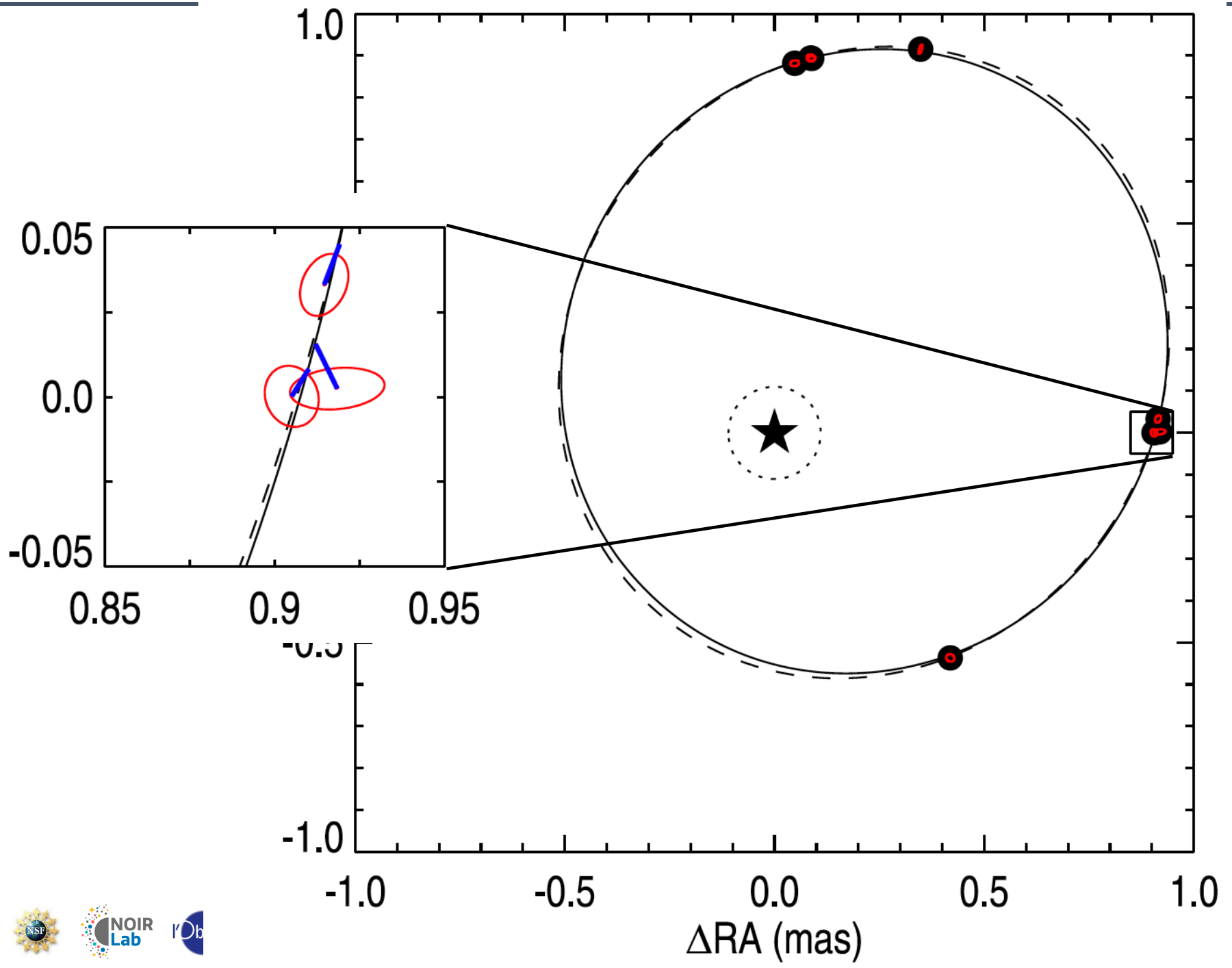
Archive of DAO Spectra







CHARA

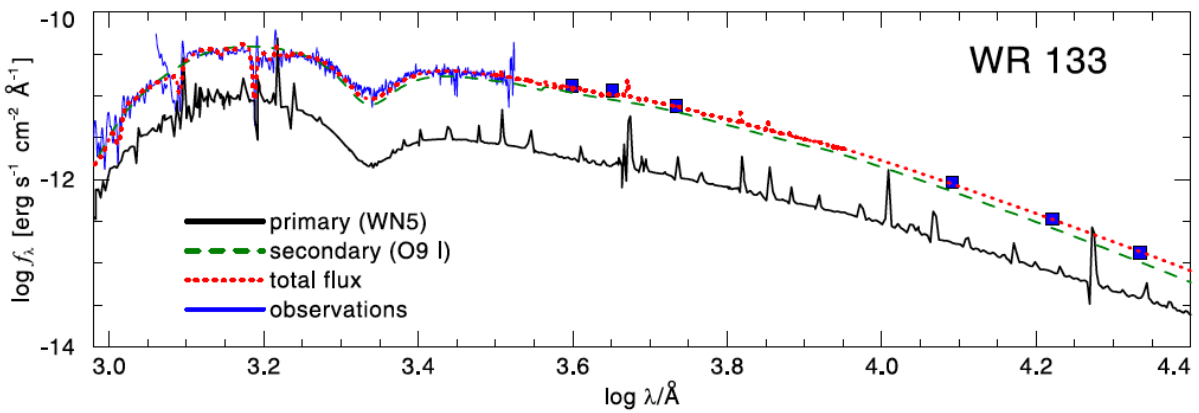


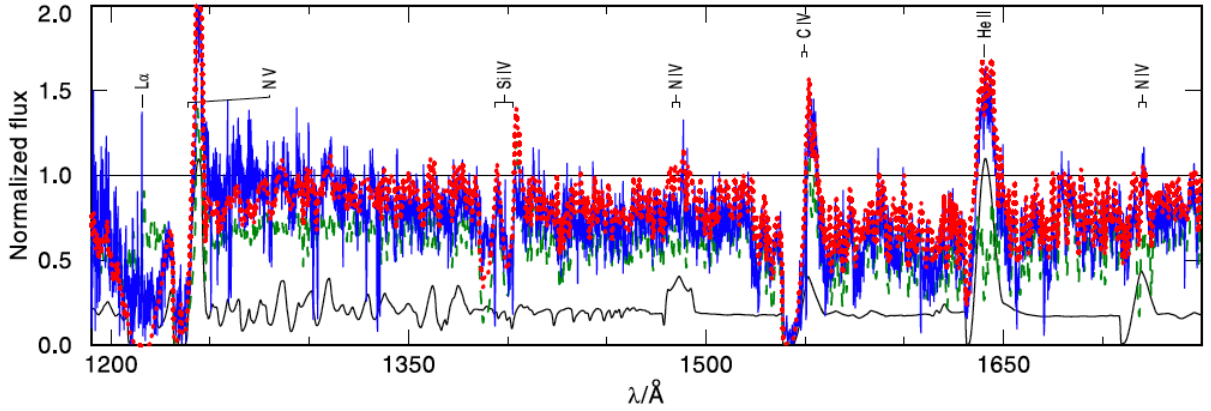
Orbital Elements/Masses

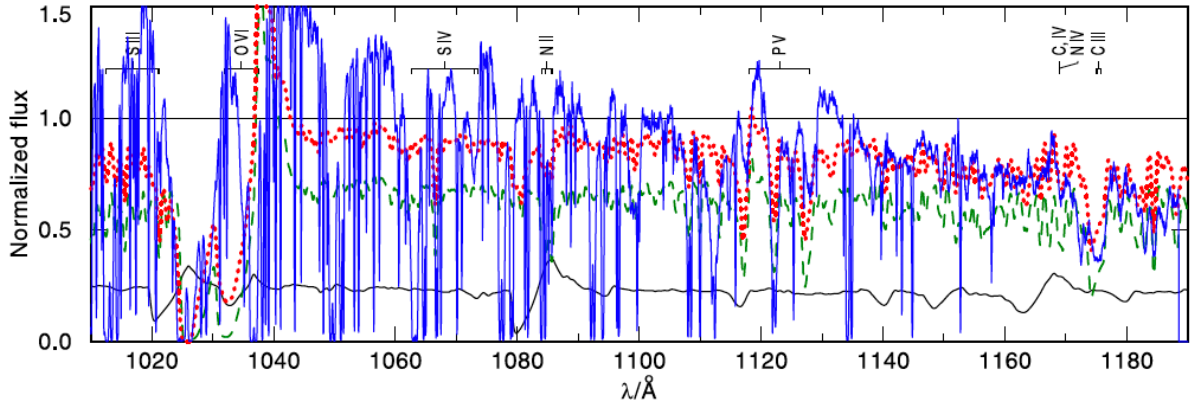
- P = 112.78 d
- e = 0.36
- d = 1.73 kpc
- a = 0.79 mas = 292 Rsun
- M_O = 18.1 Msun
- M_WR = 8.2 Msun

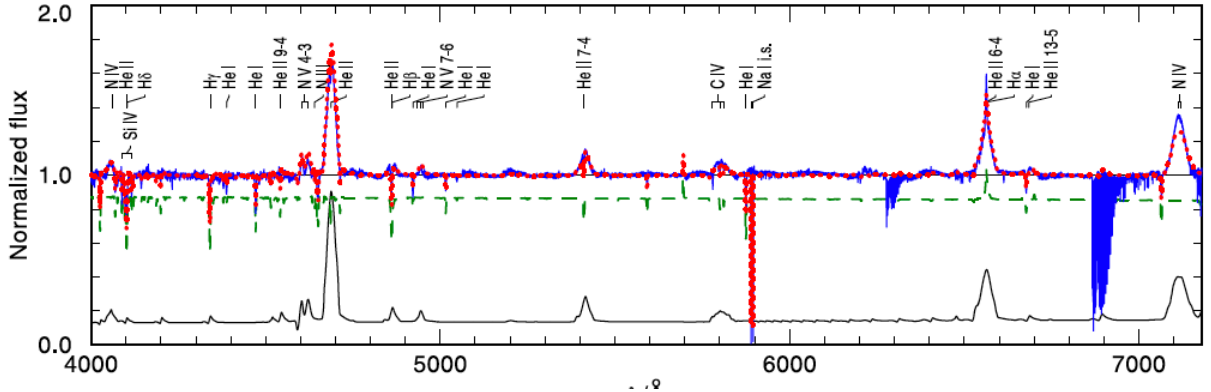
Comparisons with Theoretical models

Best models indicate a spectroscopic mass of 14 Msun,
~2-3 sigma from measured mass!









If you need supporting spectroscopy for CHARA observations…

We have a small telescope and an eshel (R~10,000) spectrograph that covers the ~4500-6800A range. We have up to 300 clear nights per year, and my students and I will gladly help with coverage.

Early results show that we can accurately measure an SB2 with a half hour exposure and a stellar contrast of