

An Interferometric Imaging Survey of Red Supergiant Stars

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Abstract

Red supergiant stars (RSGs) are an end stage of massive star evolution. Among the notable behaviors of stars during this stage are their irregular and semi-regular variability and mass-loss. In order to better understand the sources of these phenomena, we collected high resolution optical interferometric observations of 17 RSGs using the Center for High Angular Resolution Astronomy (CHARA) Array at Mount Wilson between 2015 and 2016. Here, we present stellar diameters derived from these data. We comment on evidence of surface asymmetries on those stars for which we were able to obtain closure phases and present an example image for one of these objects. In addition, we have obtained near-contemporaneous spectroscopy of these stars using SpeX on the NASA InfraRed Telescope Facility (IRTF). We have developed libraries of synthetic spectra derived from spherical MARCS, PHOENIX, and SATLAS stellar atmospheres, and are currently working to derive fundamental stellar parameters with these data.

Diameters

Star	Sp Type	θ (mas)	α^1	χ^2	Diameter (R_{\odot}^N) ²
NR Vul	K3 I (L05)	3.04	0.1	4.12	555^{+55}_{-46}
BD+354077	M2.5 I (L05)	3.18	0.13	5.45	542^{+67}_{-54}
BI Cyg	M3-M4 I (L05)	5.16	0.34	9.21	740^{+93}_{-75}
RW Cyg	M3 I (L05)	5.09	0.36	11.8	1103^{+251}_{-177}
AZ Cyg	M3 Iab (M19)	3.74	0.18	8.41	814^{+175}_{-124}
V424 Lac	M0 I (L05)	3.77	0.08	12.6	257^{+37}_{-29}
V 336 And	M2Ib (KM89)	2.46	0.05	3.08	567^{+215}_{-135}
AD Per	M2.5 Iab (M19)	2.39	0.15	8.39	528^{+70}_{-56}
BU Per	M3 I (L05)	2.27	0.29	21.0	354^{+54}_{-42}
FZ Per	M1.5 (M19)	1.8	0.24	13.7	413^{+40}_{-34}
KK Per	M2 Iab-Ib (M19)	2.27	0.10	2.17	394^{+37}_{-31}
SU Per	M3-M4 I (L 05)	3.20	0.21	10.9	952^{+263}_{-176}
RS Per	M4 I (L 05)	2.96	0.13	5.13	476^{+70}_{-55}
S Per	M4.5 I (L 05)	4.08	0.36	6.91	1428^{+627}_{-379}
W Per	M4.5 I (L05)	2.93	0.12	6.14	385^{+45}_{-36}
XX Per	M4 Ib (M19)	2.77	0.16	5.90	604^{+97}_{-74}
6 Gem	M1-M2 Ia-Iab (KM89)	4.11	0.48	49.3	649^{+438}_{-198}
TV Gem	M1 I (L 05)	3.41	0.53	37.5	992^{+473}_{-266}
WY Gem	M2 Iabep+ (M19)	2.68	0.03	3.96	444^{+83}_{-61}

1: Linear limb-darkening coefficient.

2: Using *Gaia* parallaxes as reported in Bailer-Jones et al. 2018

Diameter Fitting

We used the OITools.jl¹ package to run a grid search for fitting model limb-darkened disks to the squared visibilities. Future efforts will restrict the fit to the first two lobes of the visibility curve in order to avoid effects from large surface features.

1: <https://github.com/fabienbaron/OITools.jl>

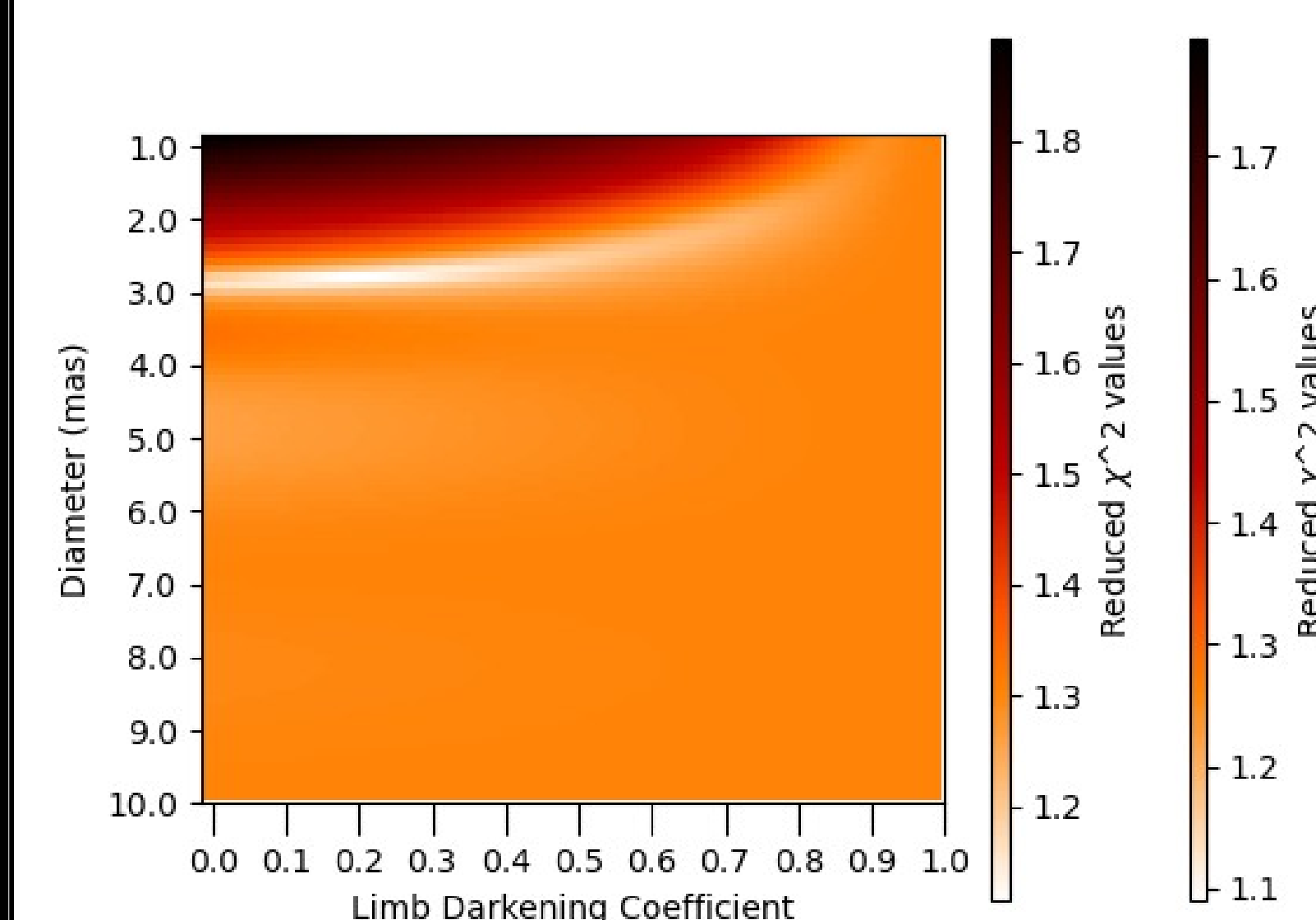


Figure 1: Example χ^2 surface for the linearly limb-darkened disk of RS Per.

Image Reconstruction

Of the 17 stars observed 10 have enough (u, v) coverage for image reconstruction and have closure phases suggesting surface asymmetries. In Figure 2, we present an example image for RS Per. Details of the reconstruction process can be found in Norris et al. 2021. We used SQUEEZE¹ and the OITools.jl package to reconstruct images.

1: <https://github.com/fabienbaron/squeeze>

Example Imaging

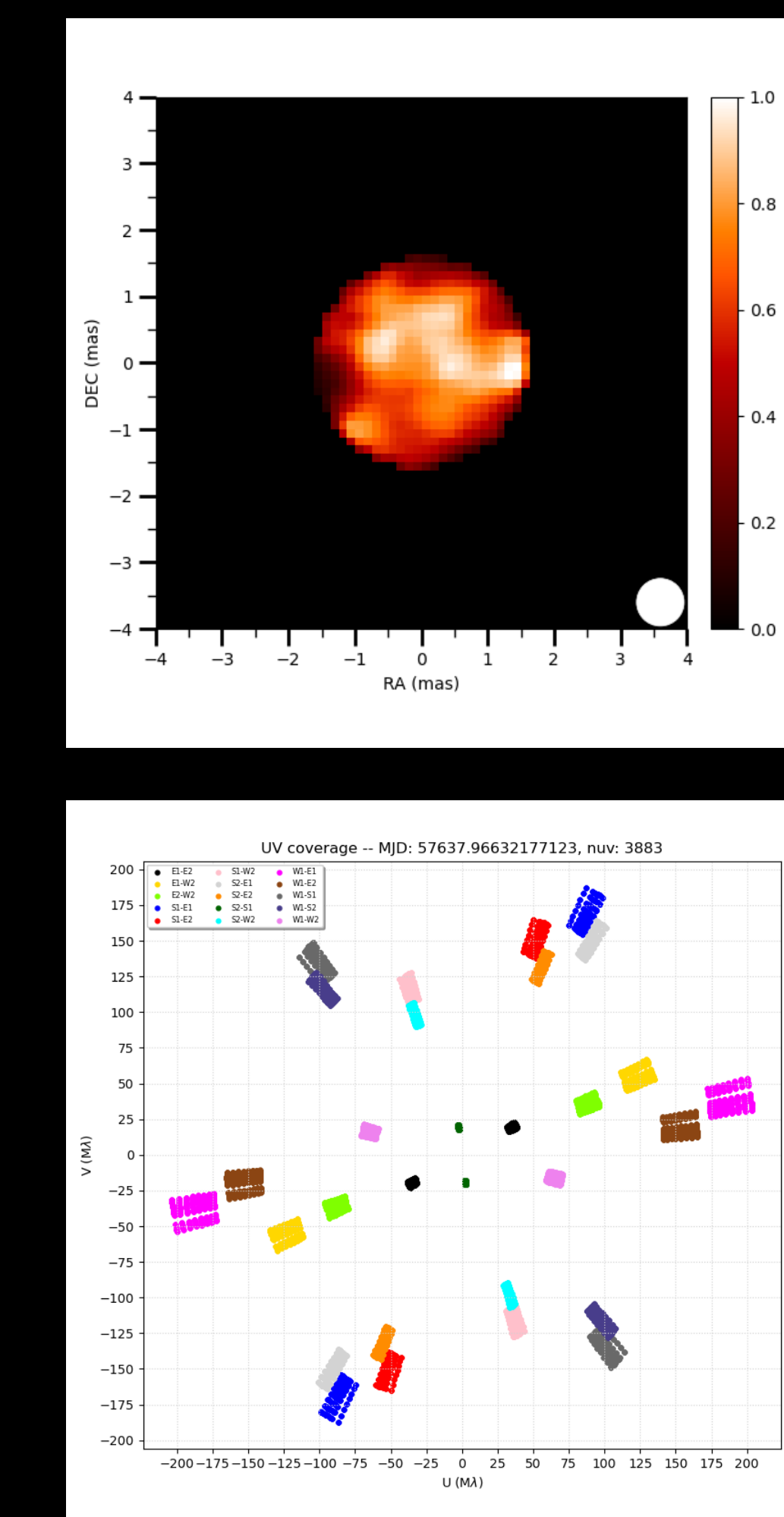


Figure 2: Image reconstruction of RS Per (top) and corresponding uv coverage (bottom). Beam size is depicted in the lower right corner of the image. Image was reconstructed using SQUEEZE and total variation and Laplacian regularizers.

References

- 1) Bailer-Jones, C. A. L., Rybizki, J., Fouesneau, M., Mantelet, G., & Andrae, R. 2018, AJ, 156, 58
- 2) Keenan P. C., McNeil R. C., 1989, ApJS, 71, 245 (KM89)
- 3) Levesque, E. M., Massey, P., Olsen, K. A. G., et al. 2005, ApJ, 628, 973 (L05)
- 4) Norris et al. 2021. Submitted.
- 5) Messineo, M., & Brown, A. G. A. 2019, AJ, 158, 20 (M19)