The Optimization of a Model Pipeline for Rapidly Rotating Stars

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Results

After optimization, the pipeline is 3-5x more efficient. This efficiency depends on how close the star is to its critical rotation rate, the rate at which the star would break apart.

Our models at two wavelengths show that intensity gradients will be stronger at shorter wavelengths, as seen in Figure 4. We predict the effects of gravity-darkening to be subdued in stars that are viewed equator-on, because the bright poles are limb darkened.

Observations

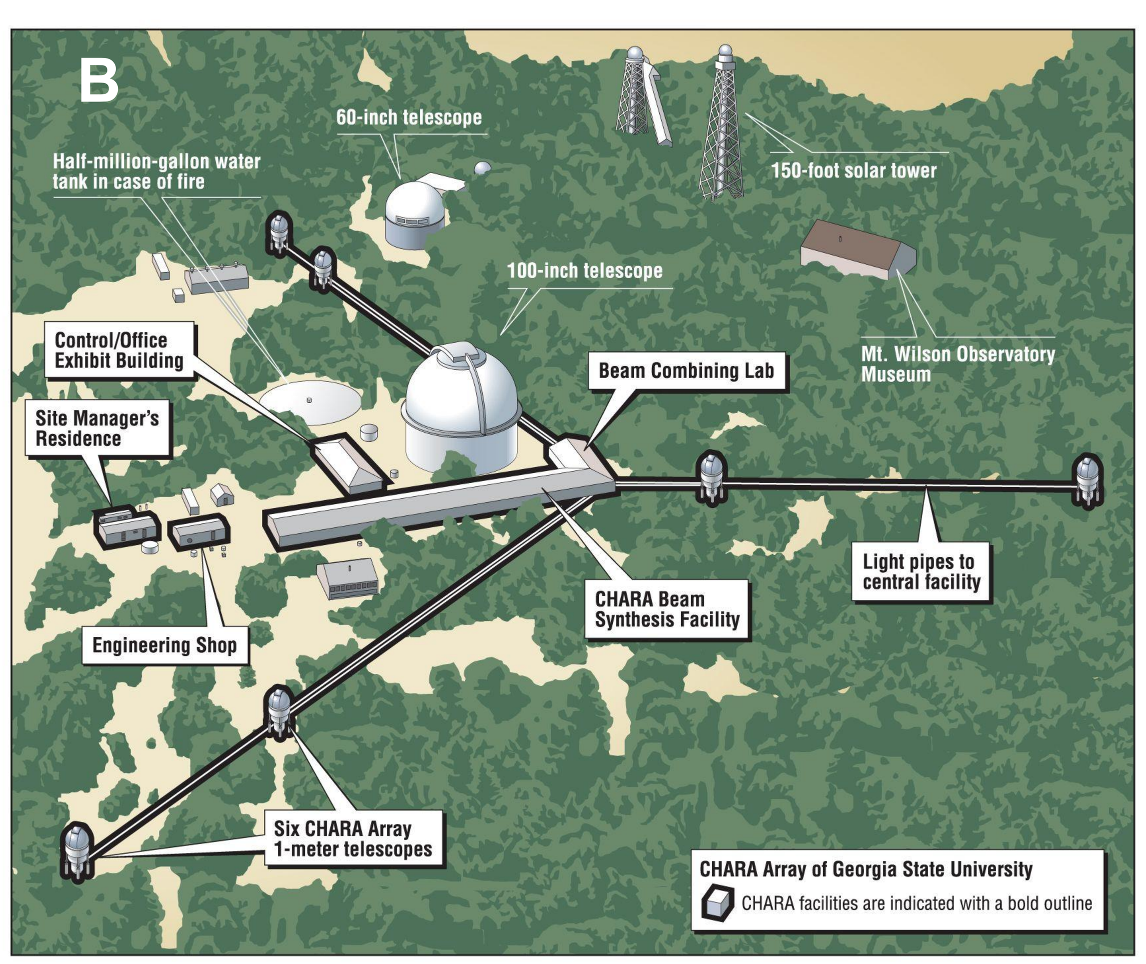

Figure 1: Our models can be compared with data from ground-based arrays of telescopes. (Top) A: The Very Energetic Radiation Imaging Telescope Array System (VERITAS), the first experiment to routinely perform Stellar Intensity Interferometry (SII) in the last 50 years, with six interferometric baselines, enables the observation of stars at 416 nm, in the blue. (Bottom) B: The Center for High Angular Resolution Astronomy (CHARA) Array, with 15 unique baselines, makes possible the imaging of stars at near-infrared wavelengths (~1746 nm).

Optimization of Pipeline

The pipeline, excluding Fortran, consists of 43.7% Perl, 34.4% Shell, and 21.9% Python scripts and is completely automated by two KornShell programs, as shown in Figure 2. Previously, creating model visibilities was a tedious and long process. The optimization both reduces the total number of models needing to be run and eliminates any hand-editing of scripts. For rapidly-rotating stars, the temperature and gravity gradients across their surface require many models to fully simulate. However, the number of models was nearly cut by two-thirds using a comparison algorithm to determine what models were essential to effectively model the gradients.

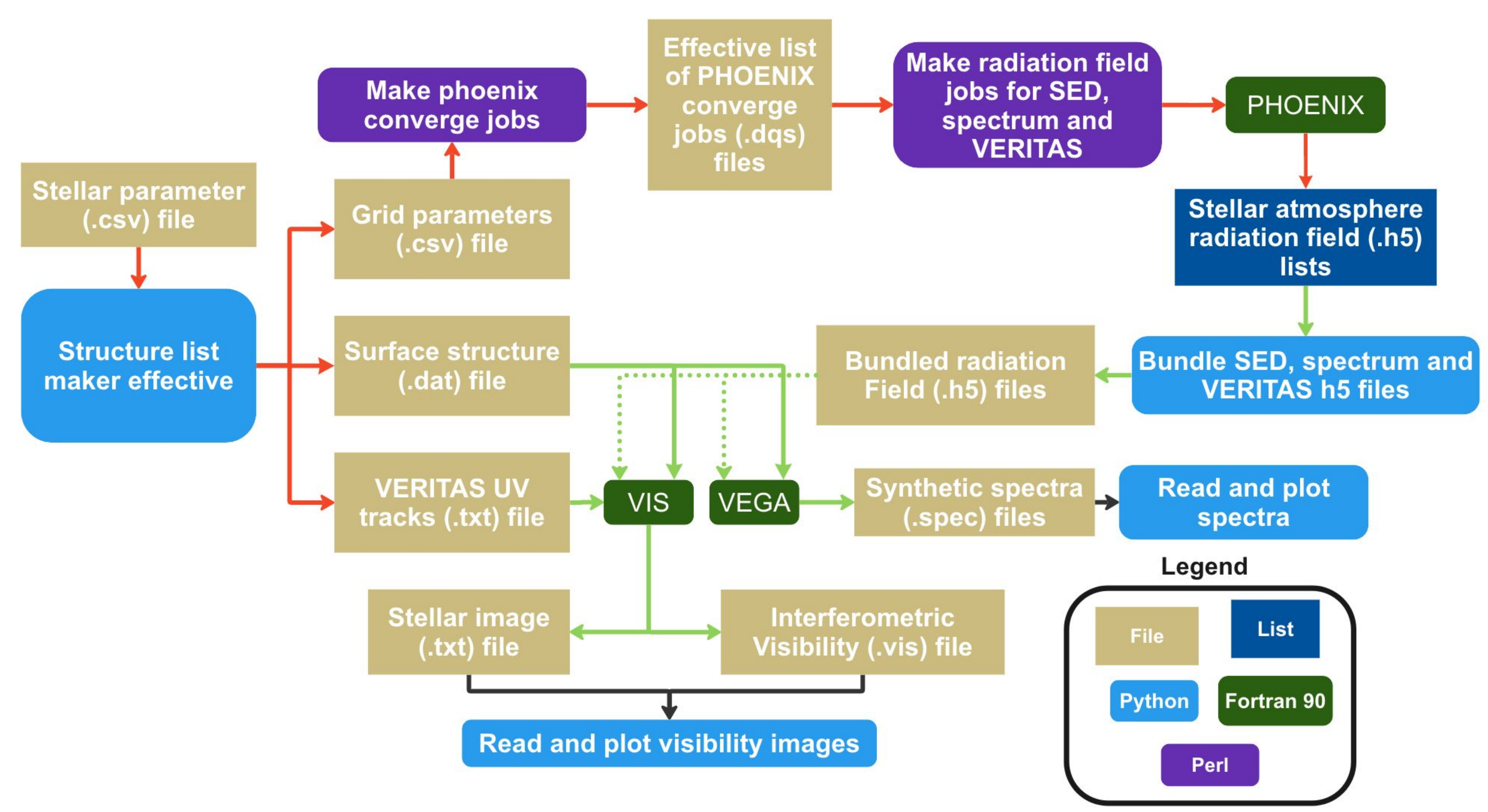

Figure 2: A visualization of the elements utilized by the pipeline. The red and green arrows indicate the functions of the first and second automation KornShell scripts, respectively.

References

VERITAS photo in Figure 1 is from Abeysekara et al. (2020) in *Nature Astronomy*, 4, 1164 and VERITAS baselines are from Davis, Matthews and Kieda (2020) in *Journal of Astronomical Telescopes and Systems,* 6 , 3.

CHARA are graphic courtesy of Georgia State University.

Model atmospheres were computed using the PHOENIX code, see Hauschildt and Baron (1999) in *Journal of Computational and Applied Mathematics,* 109, 41.

Archival spectra retrieved from Elodie Archive, http://atlas.obs-hp.fr/elodie.

Higher level details of the pipeline can be found from Sackrider, J. L. and Aufdenberg, J. P., 2023, RNAAS, 7, 216. doi:10.3847/2515-5172/ad023b.

Equations utilized by the pipeline are from Sackrider J. L., Aufdenberg J. P. and Sonnen K. 2022, *Beyond*: Undergraduate Research Journal, 6, 6.

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Model Output

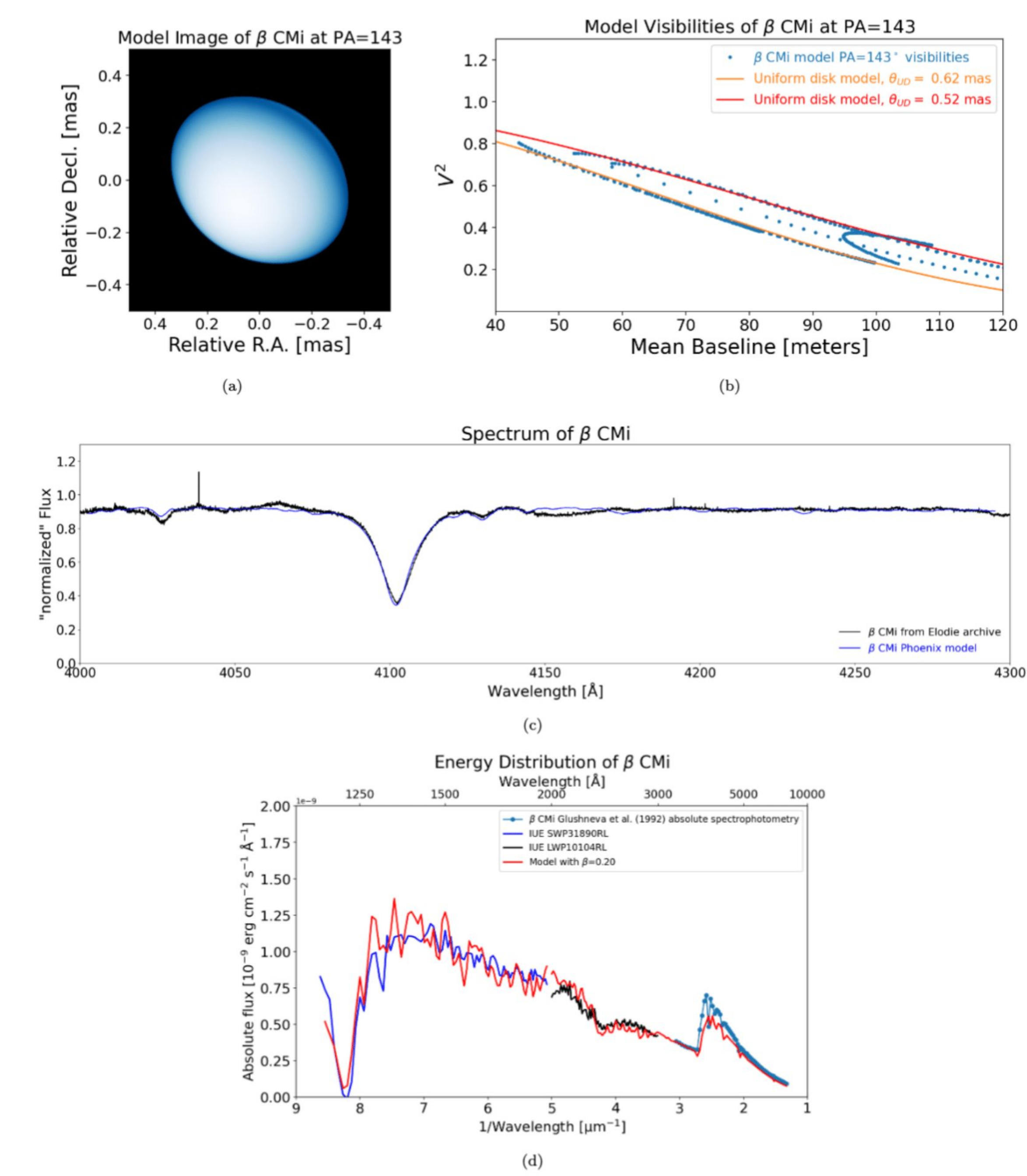

Figure 3: (a) A synthetic image for β CMi at a position angle of 143°, (b) corresponding synthetic visibilities for VERITAS baselines, (c) a synthetic spectrum compared to an archival spectrum (elodie:20020328/0018), (d) a model spectral energy distribution compared to archival absolute spectrophotometry.

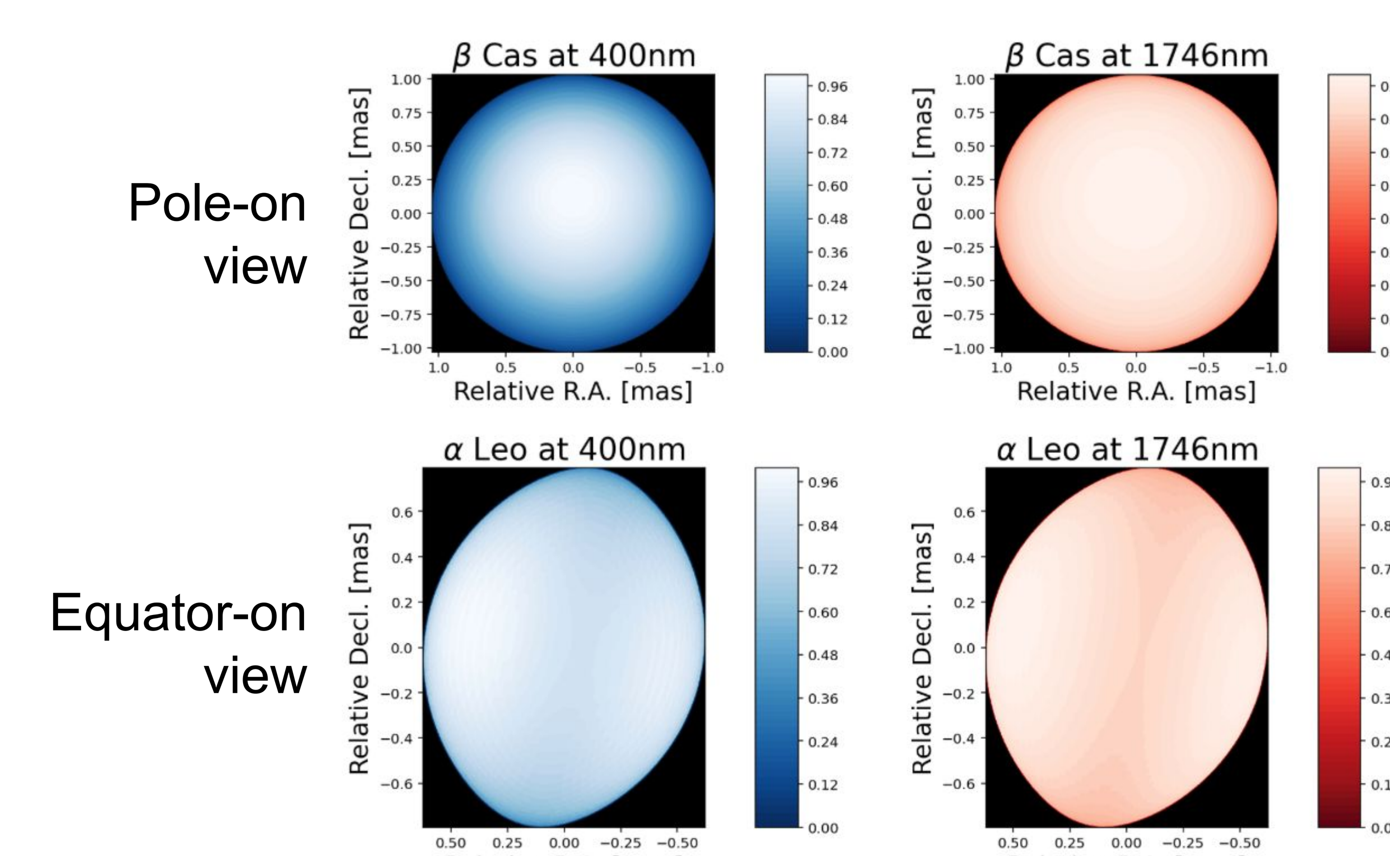

Figure 4: Synthetic images for β Cas and α Leo at 400 nm and 1746 nm, highlighting the intensity contrast between both wavelengths due to the Rayleigh-Jeans λ^{-4} approximation.