Developing a Model Pipeline for VERITAS Stellar Intensity Interferometry

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Context and Need

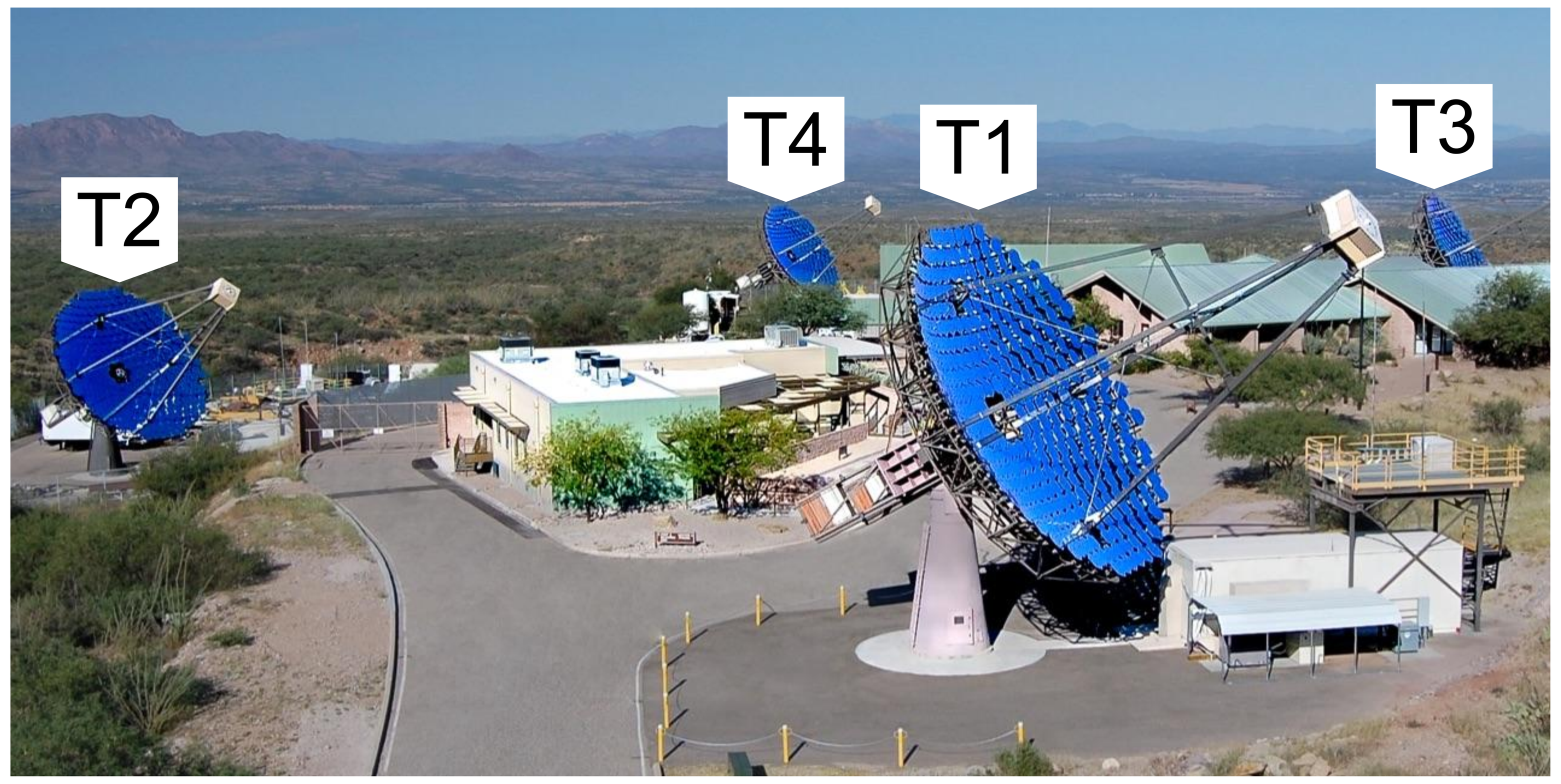

Figure 1: The Very Energetic Radiation Imaging Telescope Array System (VERITAS) is the first experiment to routinely perform stellar intensity interferometry in the last 50 years. Six unique telescope pairs, yielding six interferometric baselines, can be formed using telescopes T1, T2, T3 and T4. Observations are made at 400 nm, in the blue.

Rapidly rotating stars are being observed with VERITAS, a telescope array at the Fred Lawrence Whipple Observatory (see Figure 1), using a technique called stellar intensity interferometry. Rotation can significantly affect a star's evolution, thus constraints on this fundamental stellar parameter provide insight into the lives of stars.

The long-baseline interferometer CHARA, observing at near-infrared wavelengths, imaged six of these stars, beginning 13 years ago. One example is the bright star Alderamin (see Figure 2), which has its rotational axis tilted towards Earth. As predicted by theory, the star exhibits significant rotational distortion, and has higher polar temperatures and a cooler equator, relative to slowly-rotating stars.

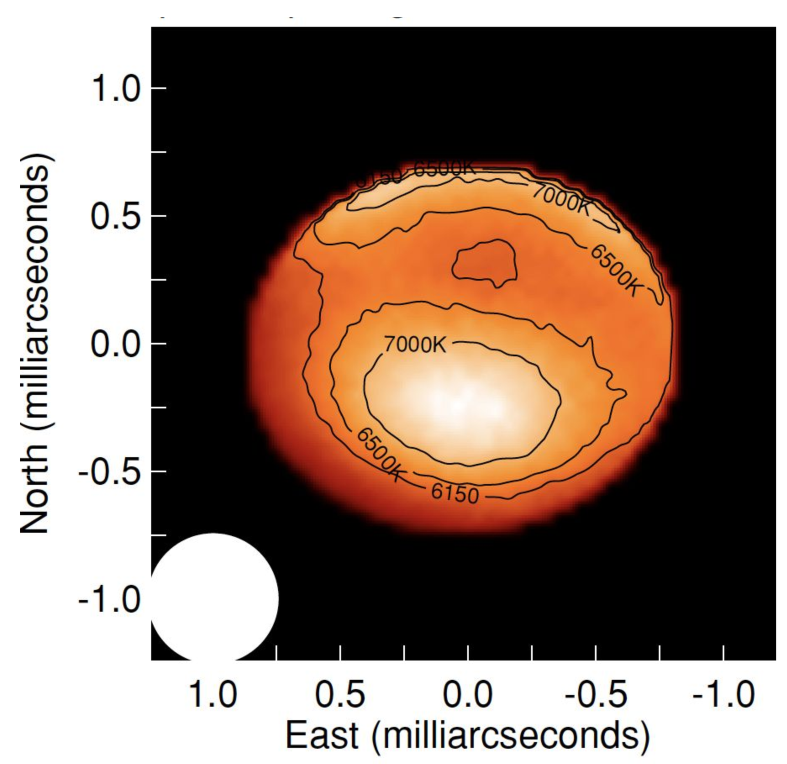

Figure 2: The first ultra-high resolution image of the rapidly-rotating star Alderamin, clearly showing a hot pole, taken by the Michigan Infra-Red Combiner (MIRC) at the Center for High Angular Resolution Astronomy (CHARA) array.

Results

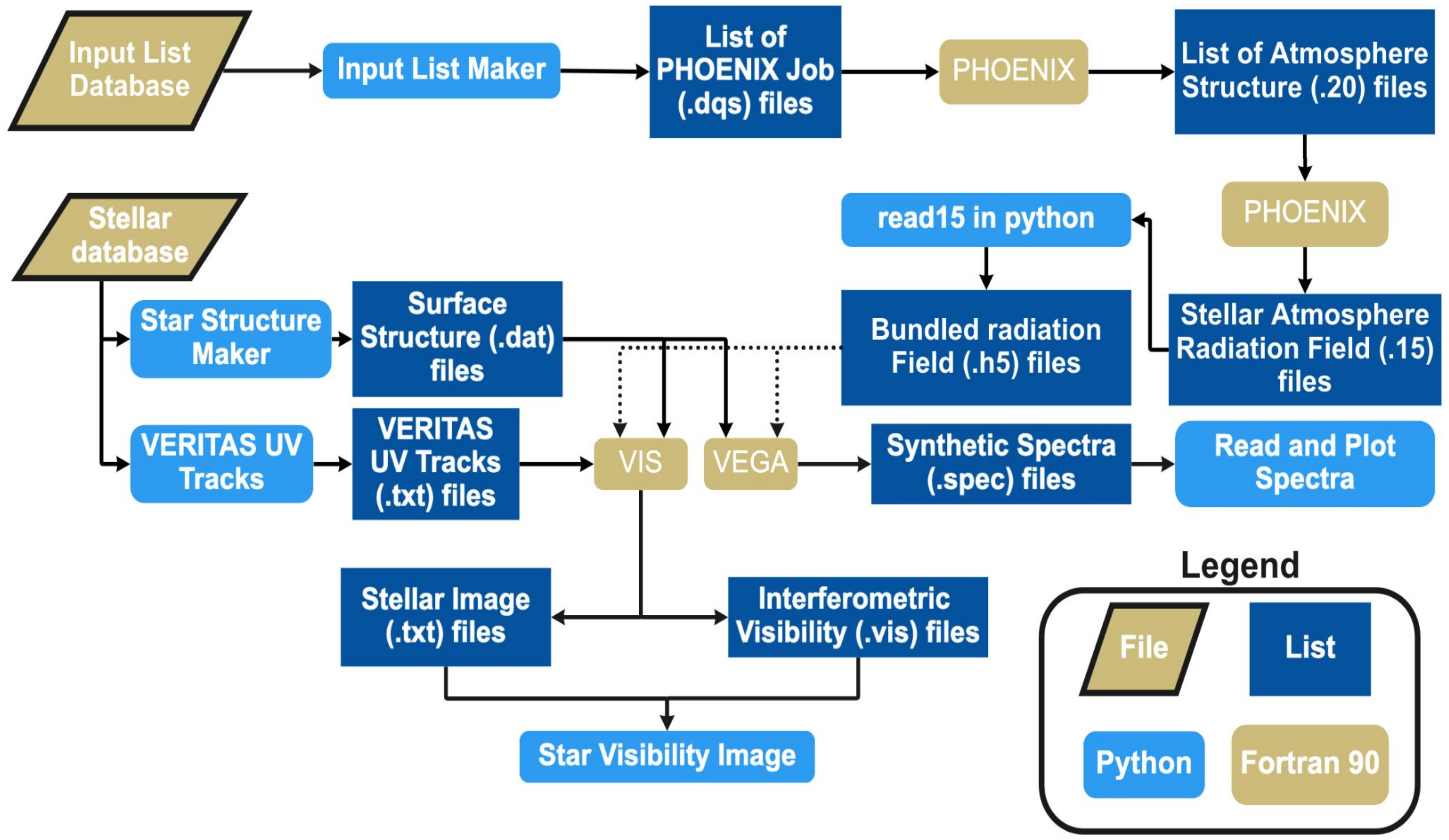

Figure 3: This flow chart details the software pipeline that takes the supercomputer output of the PHOENIX code to the programs VIS and VEGA, and then feeds synthetic VERITAS data to Python codes for data visualization.

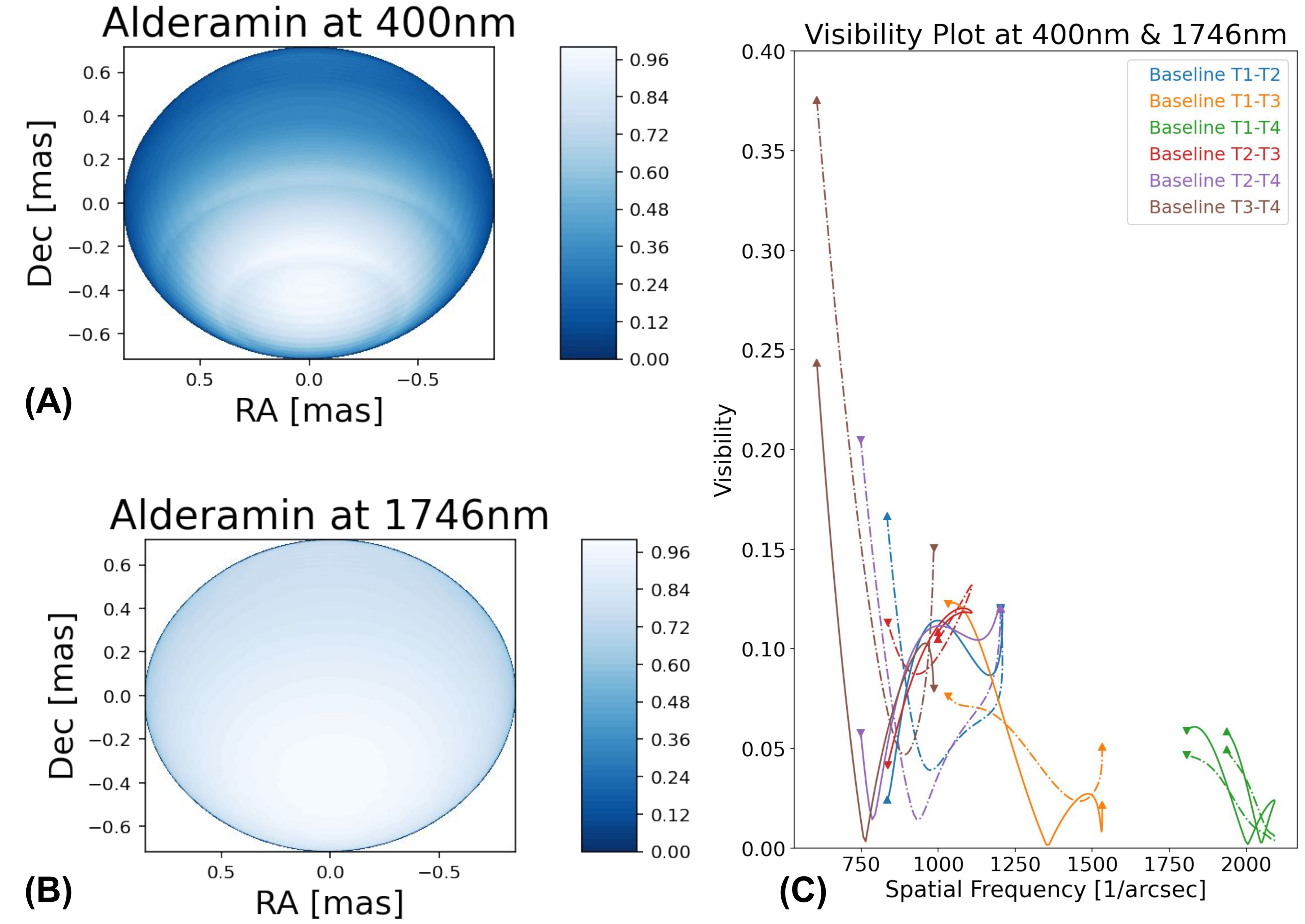

Figure 4: VERITAS will observe stars at high contrast (A), relative to longer wavelengths (B). Model visibilities at 400 nm (dashed) differ significantly from those at 1746 nm (solid) (C).

Task and Findings

Stellar surfaces are predicted to have much higher surface-brightness contrast at the visible wavelengths observed by VERITAS. To accurately predict such observations, we developed a pipeline (see Figure 3) for generating simulated data for detailed planning and analysis of VERITAS data. Models for Alderamin (see Figure 4) show the expected enhancement in surface-brightness contrast and also significant differences for visibilities in the visible relative to the near-infrared. Alderamin has a distinctly asymmetric intensity distribution relative to Vega, a pole-on rapid rotator (see Figure 5).

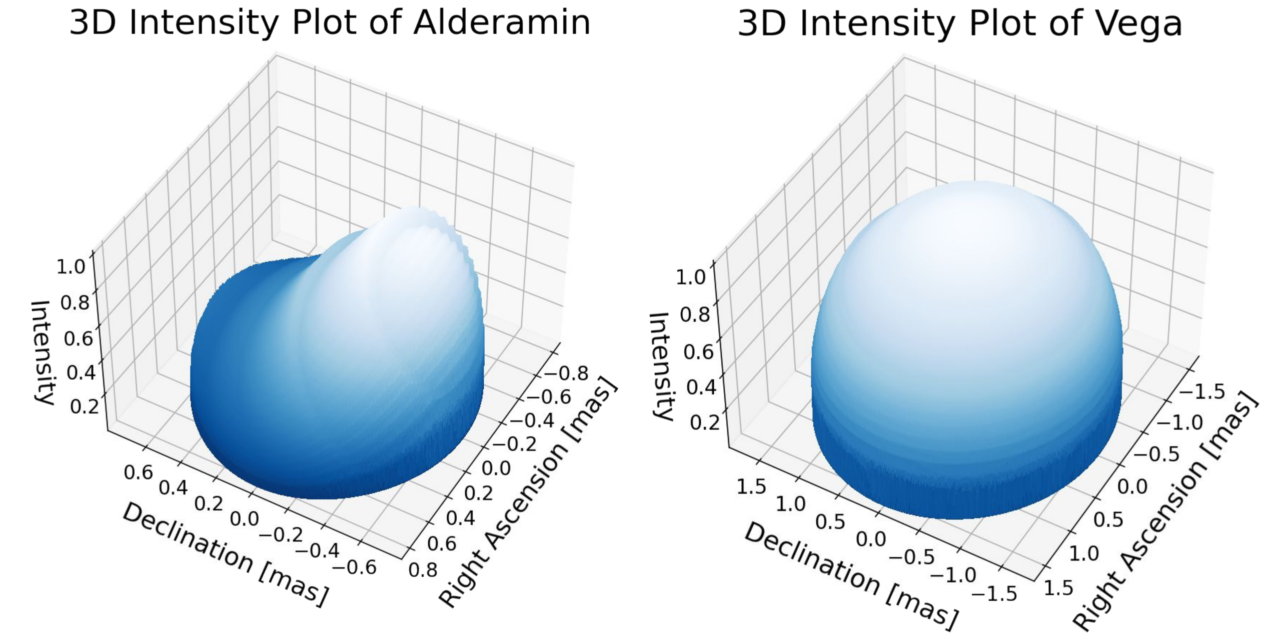

Figure 5: Alderamin's intensities are skewed due to its pole tilting 56° away from Earth. Vega, nearly pole-on, is shown for comparison.

References

VERITAS photo in Figure 1 is from Abeysekara et al. (2020) in *Nature Astronomy*, 4, 1164.

The image of Alderamin in Figure 2 is from Zhao et al. (2009) in *The Astrophysical Journal*, 701, 209.

VERITAS baselines are from Davis, Matthews and Kieda (2020) in *Journal of Astronomical Telescopes and Systems*, 6 , 3.

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

Python code development was aided using notebooks at **cocalc.com**, and the flow chart was made at **miro.com**