The Invisible Monster Returns
Further Investigations of the Epsilon Aurigae Disk

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Abstract

Epsilon Aurigae is a long-period eclipsing binary consisting of an F0Ia primary star and a secondary object - likely a main-sequence B star - enshrouded by a circumstellar, dusty disk. This circumstellar material gets heated from both the interior and exterior stars. Further information about the system has long been marred due to high uncertainty in its parallax. In response to this uncertainty, we constructed models corresponding to parallaxes observed by Gaia Data Release 2 and 3, which produced two predicted distances of 415 pc and 1033 pc, respectively. We also built a test model distance of 794 pc in which the distance corresponds to a stellar mass ratio of 1. Spectral energy distributions and temperature maps are used as analytic comparative tools to determine dust disk composition. Preliminary testing has indicated the composition of the secondary star disk does not match that of the interstellar medium - small silicates and carbon particles - and more work is underway to better constrain the disk composition. The models are built within the Hyperion package, a Fortran-based Monte Carlo radiative transfer code. From this investigation, we hope to better constrain the parameters of the F star, B star, and disk itself.

Methods

To analyze ε Aurigae's spectral energy density and how it's affected by dust extinction. To do this, we used a Fortran-based Monte-Carlo radiative transfer code called Hyperion. Due to conflicting distances estimates by GAIA, we decided to model the system at both GAIA estimates from GDR2 and GDR3, as well as a distance between the two which provided a mass ratio of 1 between the stars. We have decided to focus on the IR band, with a wavelength range of 0.1 - 1000 µm. To begin, we used a dust model with a composition similar to that of the interstellar medium - small silicates and carbon particles. We modeled ε Aurigae at 0°, 90°, and -90° inclination angles, maintaining a constant 0° azimuthal angle. Since 0° is considered a "face-on" view, 90° and -90° covers both possible eclipses. We then built spectral energy diagrams (SEDs) based off this data using Hyperion's `AnalyticalYSOModel` function. In these SEDs we analyzed the flux density [Jy] to determine how it changes between ε Aurigae's eclipses, using the face-on view as a baseline.

Results

The figures on the bottom-right of this poster display our results. Present in each figure is a bump at the 10 µm wavelength. This represents a poor fitting of the dust to the SED, so we have determined that the dust composition of the disk does not match the interstellar medium. However, the general shape of the figures matches our expectations and validates Hyperion as a strong codebase for continued work. Primary eclipse (row 1) has a very low energy density towards the UV, congruent with the central F star being occluded by the orbiting B star's dust disk. The secondary eclipse (row 2) has a slightly higher but still low energy density towards the UV, agreeing with the exposure of the F star and occlusion of the B star.

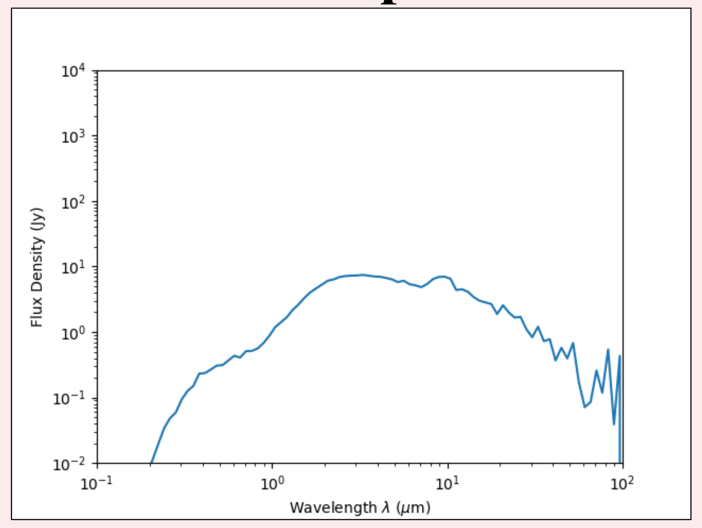
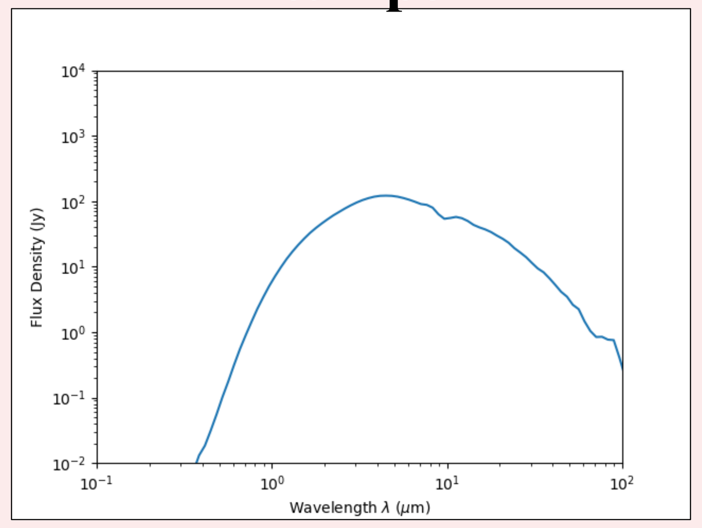
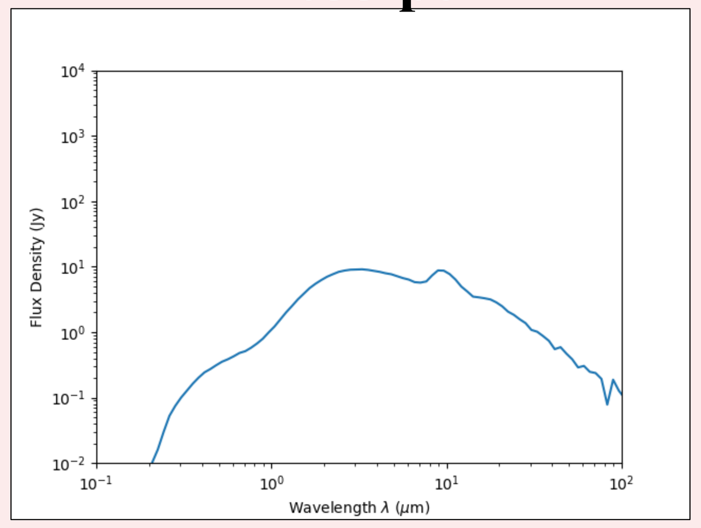
Next Steps

We intend to test different compositions of dust and build temperature maps to help further understand the disk composition. In addition, we also will build out models to better understand the shape of the disk using Hyperion.

415 pc | **794 pc** | **1033 pc**

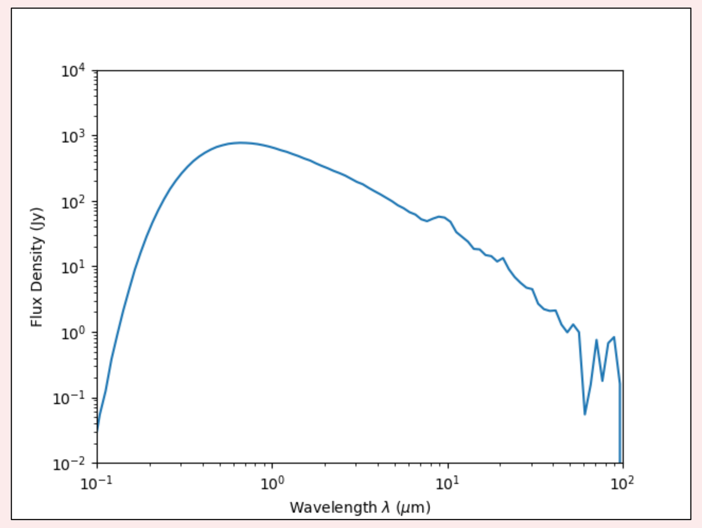
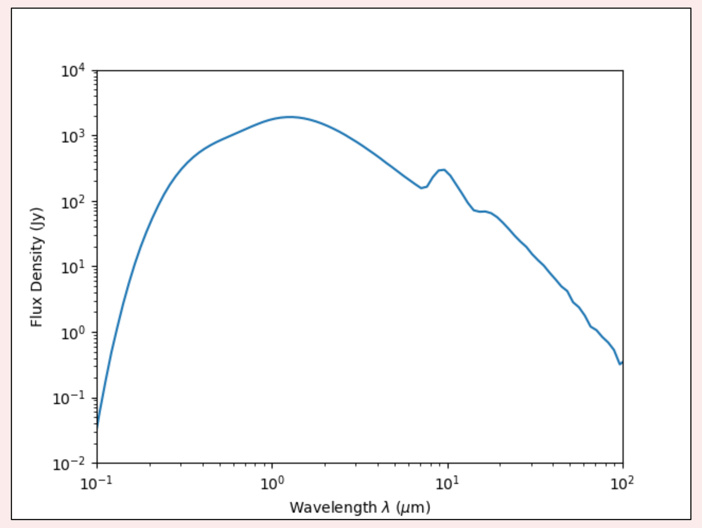
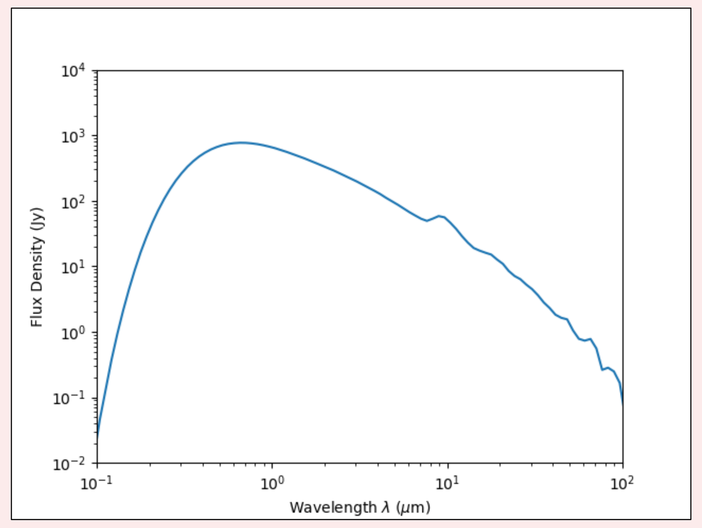
Primary Eclipse

The central F star is occluded by the B star and dust disk, reducing light in the UV.

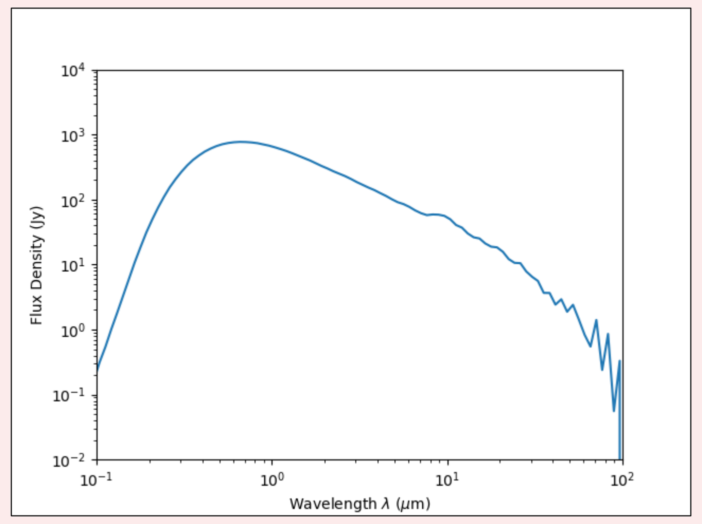
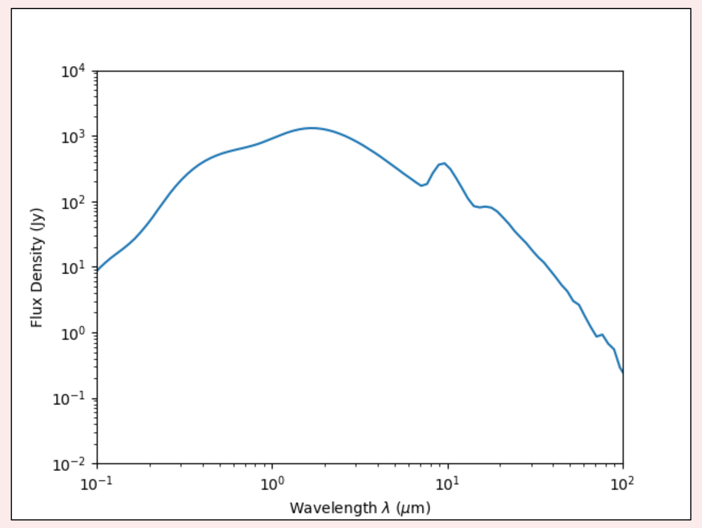
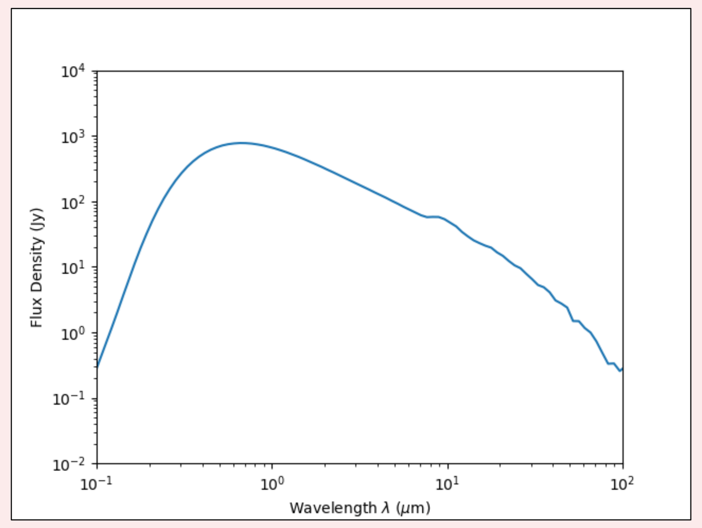
Secondary Eclipse

The central F star is exposed, allowing more light towards the UV.

Face-on View

Both stars are visible, allowing full exposure.

Stellar and Disk Parameters

Distance [pc]	415	794	1033
F Mass [$M_{\odot}$]	0.13	10.04	27.54
B Mass [$M_{\odot}$]	2.75	10.04	17.12
Mass Ratio (F:B)	0.05	1.00	1.61
F Radius [$R_{\odot}$]	99.05	189.43	246.59
B Radius [$R_{\odot}$]	2.42	5.37	6.72
Inner Disk Radius [$R_{\odot}$]	3.63	8.06	10.09
Outer Disk Radius [AU]	3.08	5.89	7.66
Disk Scale Height [AU]	0.43	0.82	1.07
Disk Mass [M_E]	1.00	3.65	6.22
F Temperature [K]	7625	7750	7625
B Temperature [K]	15300	24551	15300

Acknowledgements

We would like to thank Dr. Richard L. Pearson III for his guidance throughout this project. We also wish to thank the creators of Hyperion for their powerful and versatile codebase.