Crystal Math: Modeling Continuous Distributions of Ellipsoids in Radiative Transfer Models

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Introduction

- A precise characterization of dust properties is essential
- Dust comes in many shapes and sizes and compositions and crystal structures, which affect how it interacts with light
- For simplicity we often assume dust is spherical (like cows)
- We use radiative transfer (RT) models to generate model spectra to compare with spectrographs.
- Many RT models only use spherical grains because they are simple to incorporate.
- Most work done of grain shapes has not included combinations of different materials.
- Here we present **a new code** that will allow incorporation of the **absorption and scattering cross-sections** for a **distribution of sizes and non-spherical grain shapes into RT modeling**

The Math

In order to model the differences in spectra due to different grain shapes and size distributions, we need to calculate the average absorption and scattering cross section. Here, k is our wavenumber (2pi/wavelength) and V is our sphere-equivalent volume.

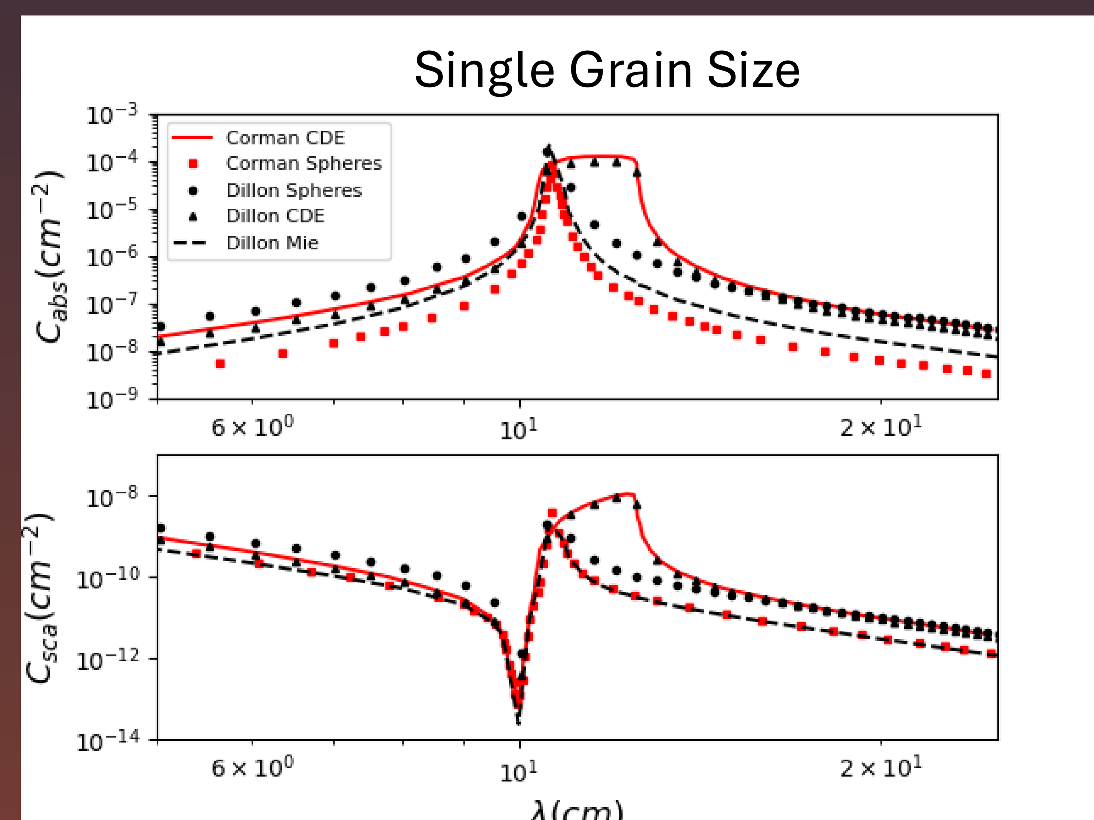
$$\langle C_{abs} \rangle = kV \Im \bar{\alpha}$$

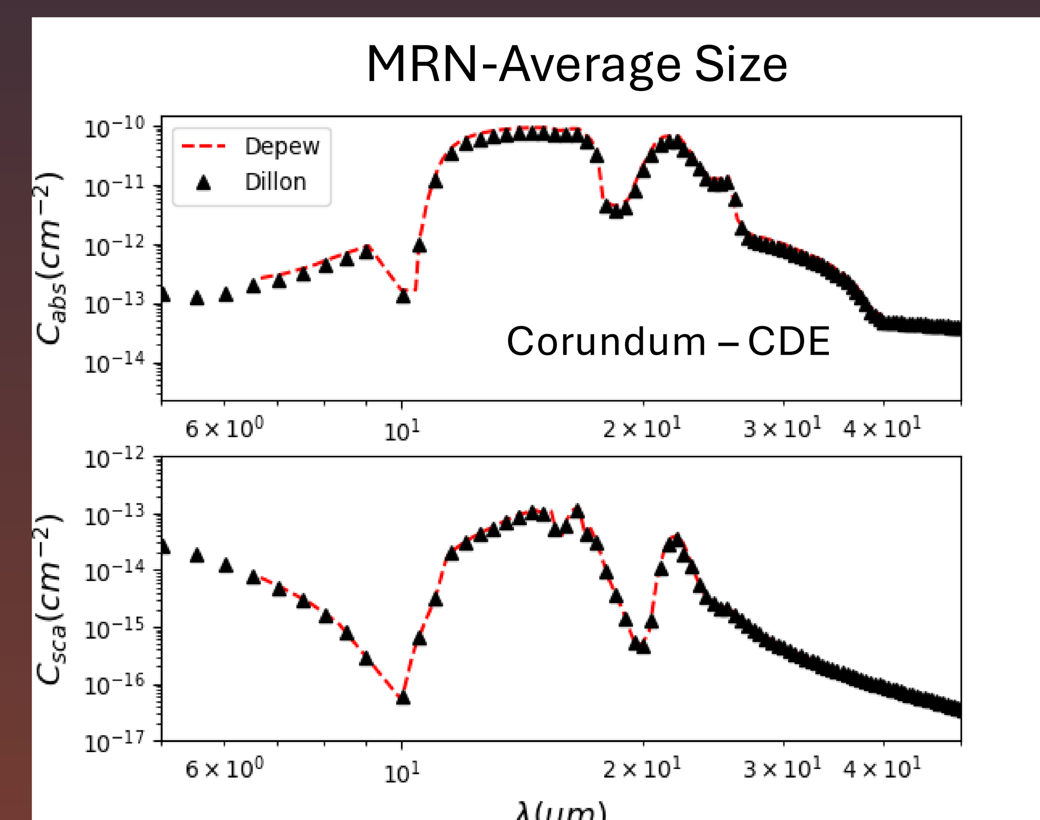
$$\langle C_{sca} \rangle = \frac{kV}{\sigma} \Im \bar{\alpha}$$

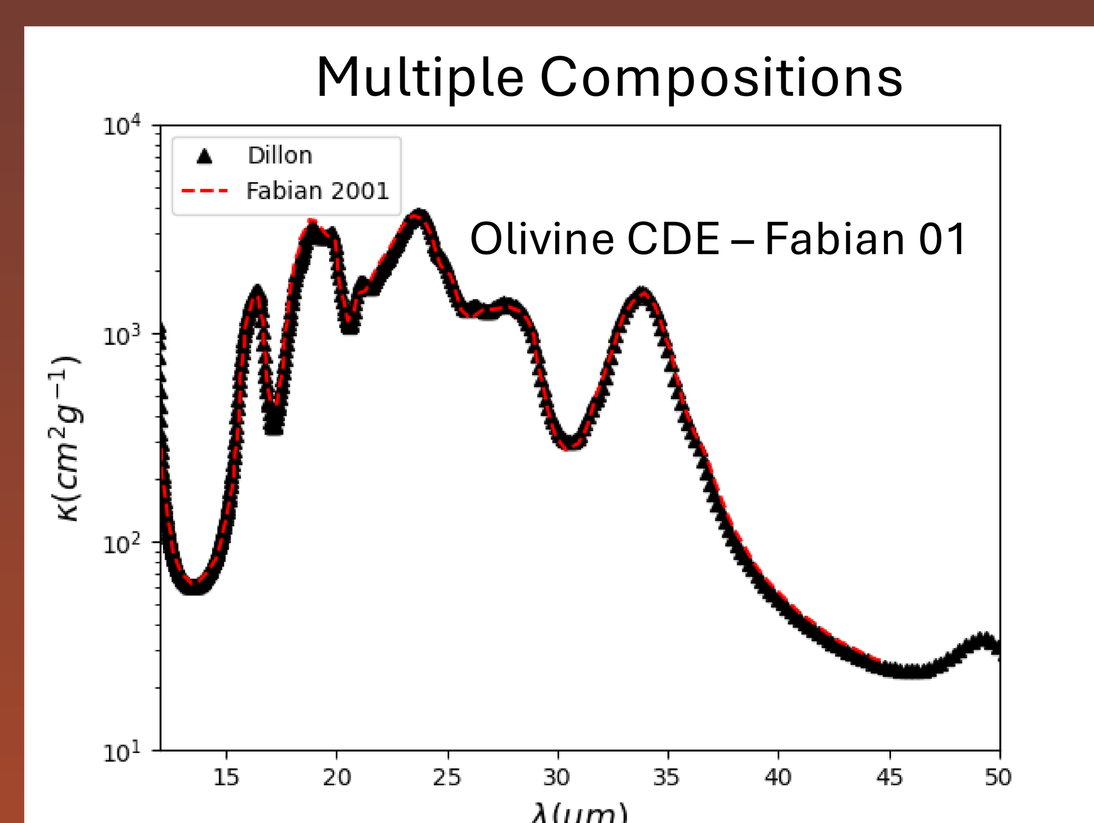
The squiggly character next to α denotes taking the imaginary value of α, which is the average polarizability per unit volume of our dust grain. This is calculated for each shape probability function, P(L1,L2). For each grain shape distribution, we use a different shape probability function. The average polarizability is shape dependent with geometric factors L1, L2, L3.

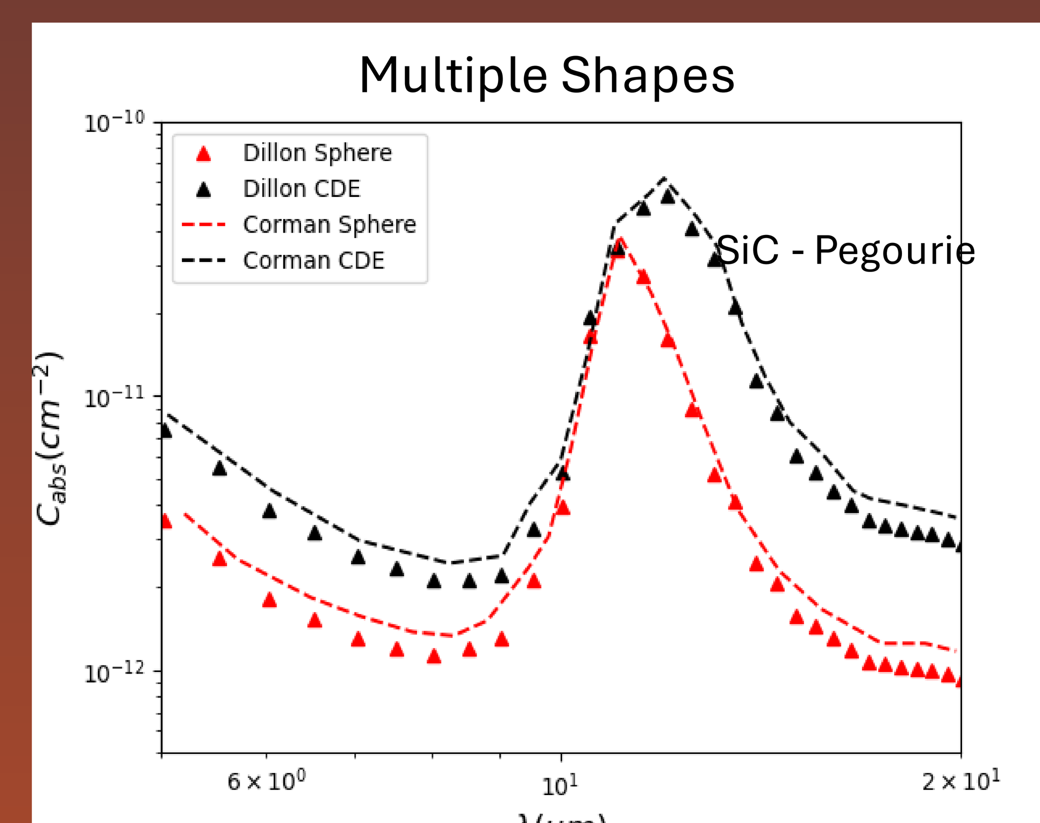
$$\bar{\alpha} = \int_0^1 dL_1 \int_0^{1-L_1} dL_2 (\alpha_1 + \alpha_2 + \alpha_3) \mathcal{P}(L_1, L_2)$$

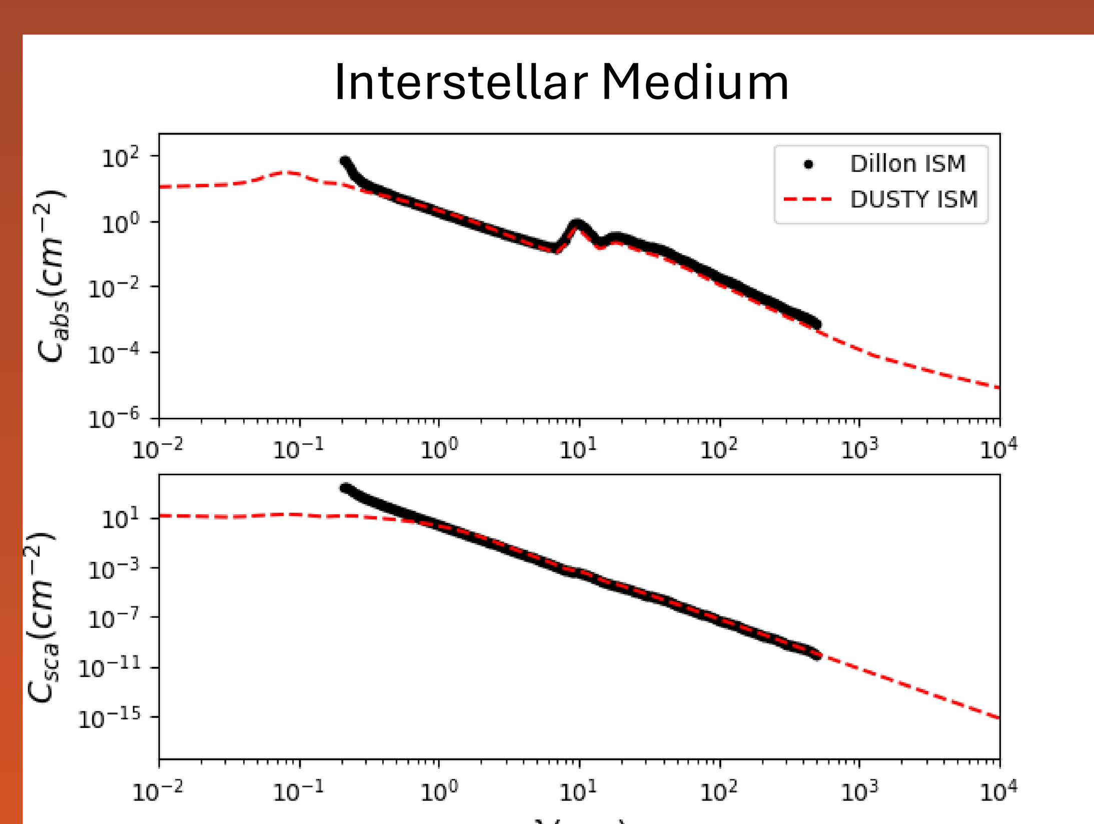
$$\alpha_i = \frac{m^2 - 1}{3 + 3L_i(m^2 - 1)}$$

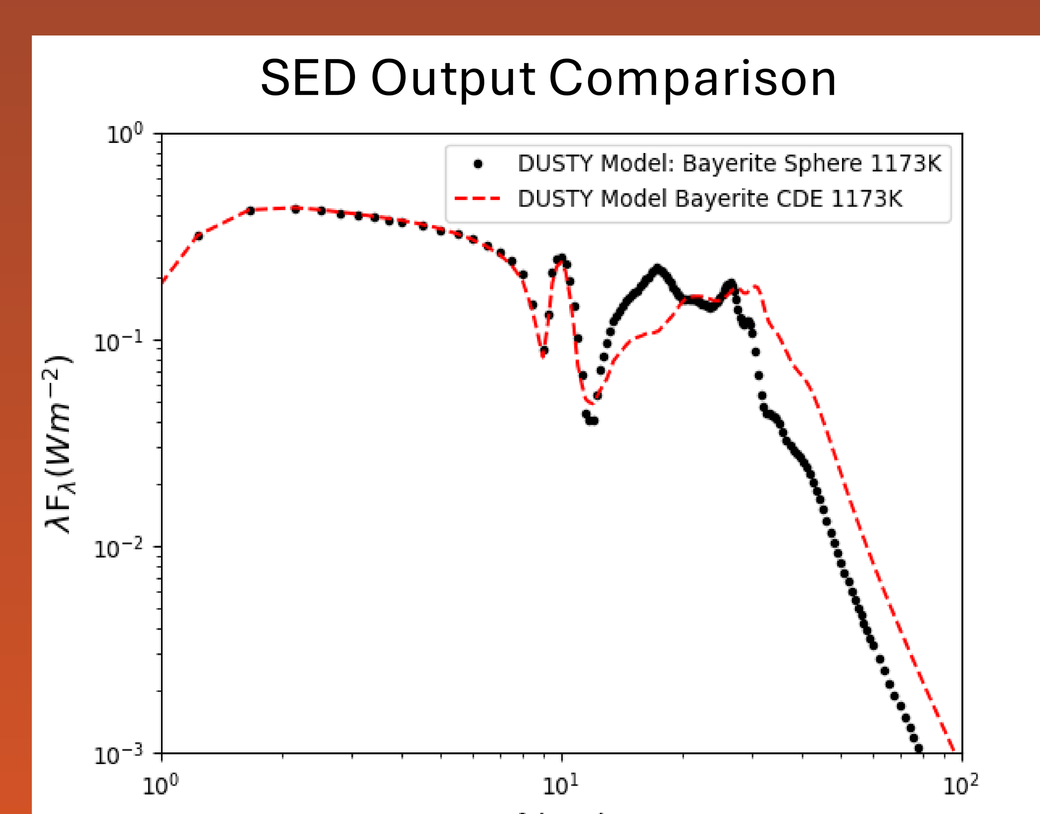




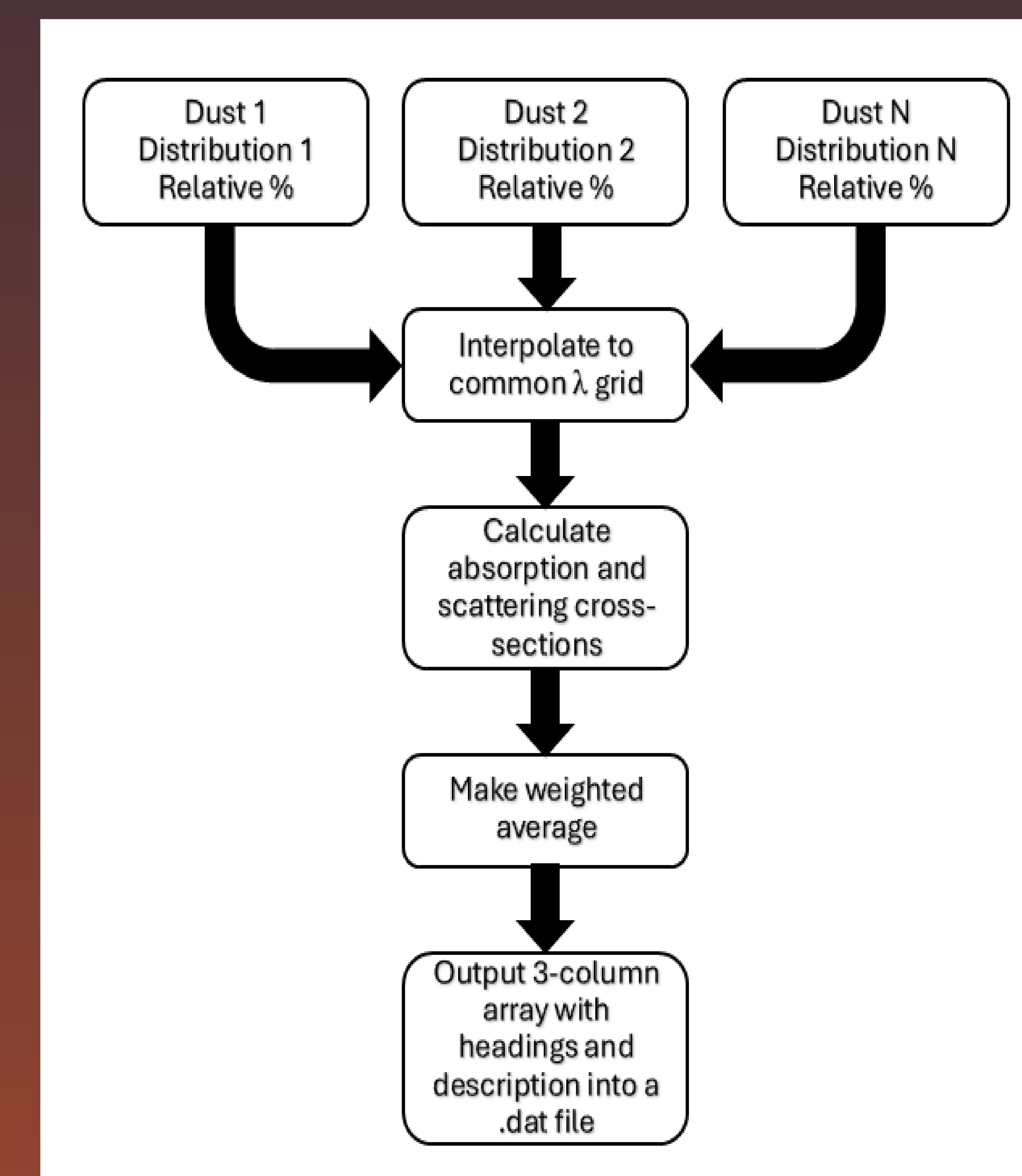


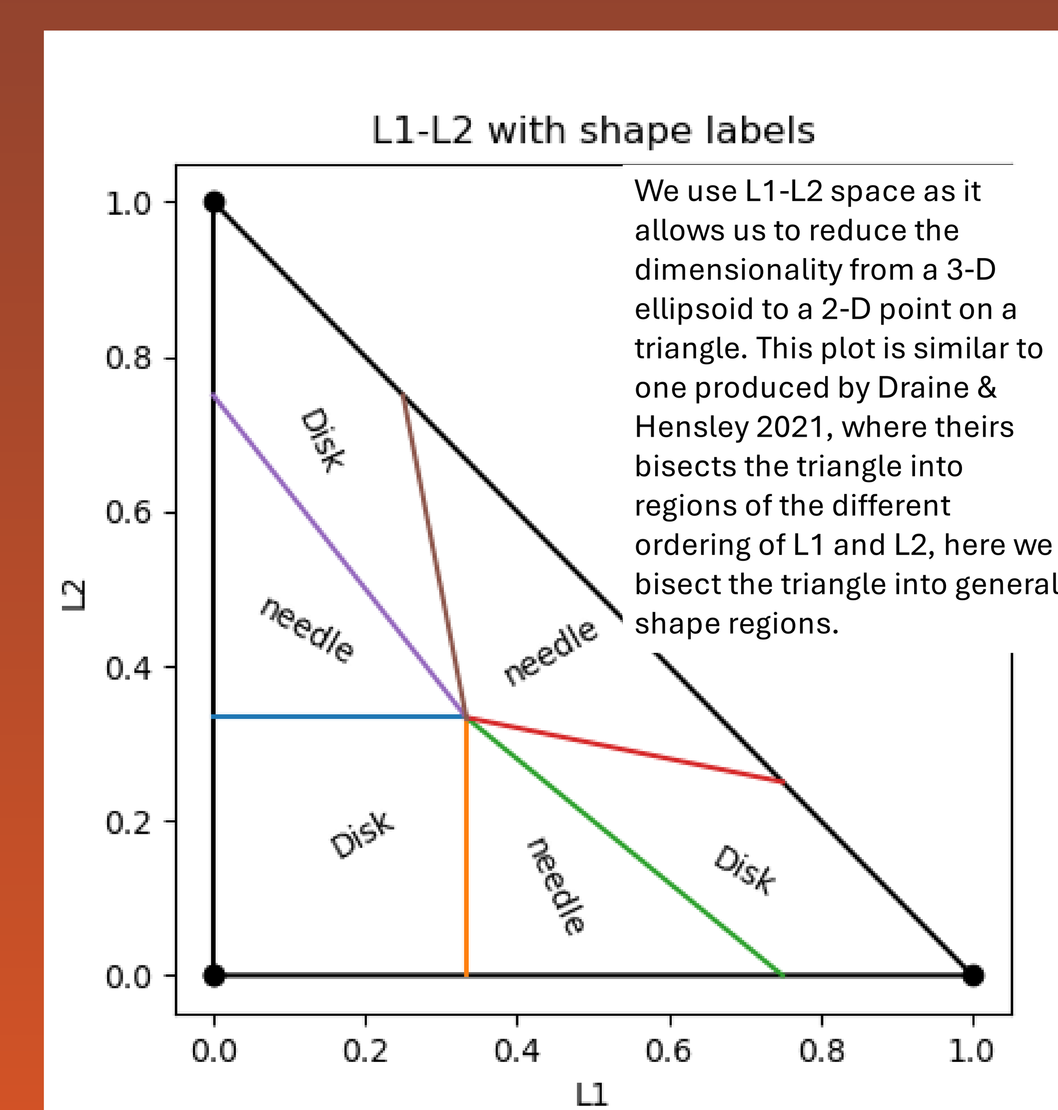






How It Works





Single Grain Size: This graph shows a comparison of our CDE and Spherical models of the absorption and scattering cross sections of beta-SiC. We compare our output with the thesis of Adrian Corman. We also added the spherical calculations derived from Mie Theory. We assume a singular grain size of 0.1 microns. **MRN-Average Size:** Here we compare our model with the work done by Depew et al 2006. For the size of our particles, we take the sphere-equivalent average of an MRN distribution with a minimum radius of 0.25 micron and a maximum radius of 500 microns. **Multiple Compositions:** Olivine is using the three axes of olivine with each axis given equal weight (1/3, 1/3, 1/3) but is input as if each dust axis were its own dust grain. We converted our units into the shape-averaged mass absorption coefficient (kappa). **Multiple Shapes:** This graph shows a comparison of our CDE and Spherical models of the absorption cross sections of SiC as described by Pegourie 1998. We compare our output with the thesis of Adrian Corman. **Interstellar Medium:** We model the interstellar medium using a mix of 53% astronomical silicate, 31.32% perpendicular graphite, and 15.66% parallel graphite, as defined by Draine & Lee 1984. This allows us to directly compare our results with the interstellar medium that comes with DUSTY. **SED Output Comparison:** This shows that the output from our code works with our radiative transfer code DUSTY. Here we show two identical RT models, both using Bayerite formed at 1173 K, one using spherical particles, another using a CDE.

BUGS: We are still correcting our unit analysis, and all models have been scaled by a constant. This is to show that while our units may be off, the shape still matches.