

# The Dusty Evolved Star Kit (DESK): A Python package for fitting the Spectral Energy Distribution of Evolved Stars

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## Software

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## Summary

One of the few ways that we can understand the environment around dusty stars and how much material they contribute back to the Universe, is by fitting their brightness at different wavelengths with models that account for how the energy transfers through the dust. Codes for creating models have been developed and refined (Elitzur & Ivezić, 2001; Ueta & Meixner, 2003), but a code for easily fitting data to grids of realistic models has been up-to-this-point unavailable.

The DESK is a python package designed to compare the best fits of different stellar samples and model grids for a better understanding of the results and their uncertainties. The package fits the Spectral Energy Distribution (SED) of evolved stars, using photometry or spectra, to grids of radiative transfer models using a least-squares method. The package includes newly created grids using a variety of different dust species, and state-of-the-art dust growth grids (Nanni et al., 2019). Early versions of the code have been used in (Goldman et al., 2019; Goldman et al., 2018, 2017; Orosz et al., 2017)

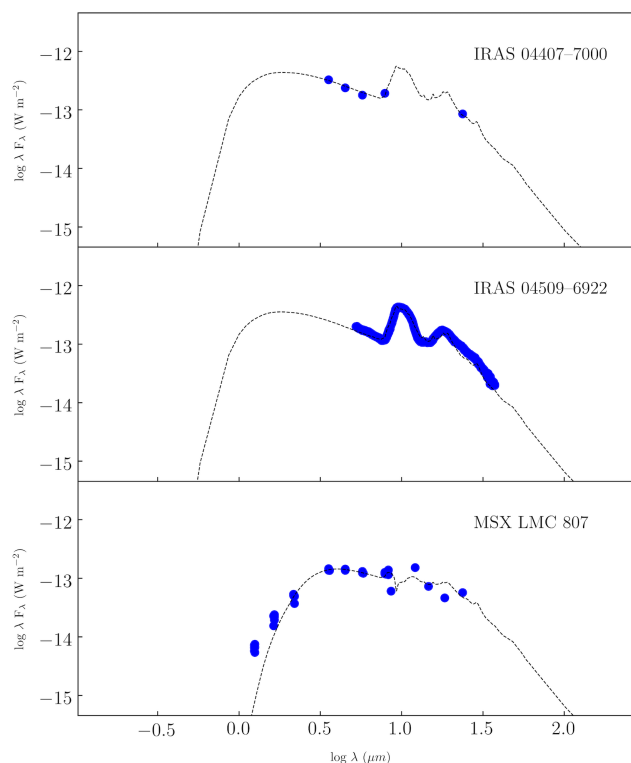
## Statement of need

To understand the ranges and estimated errors of fitted results, they must be compared to results from different model grids. Results from these grids (e.g. luminosity, mass-loss rate) can vary dramatically as a result of the unknown dust properties and geometry of evolved stars (Sargent et al., 2010; Srinivasan, Sargent, & Meixner, 2011; Wiegert, Groenewegen, Jorissen, Decin, & Danilovich, 2020). This is especially true of the oxygen-rich Asymptotic Giant Branch (AGB) stars. Adding to this challenge is the fact that models are calculated based on measured values of the dust (optical constants) which can not be interpolated over. A robust method for testing different model grids will be particularly important given the wealth of infrared data to come from the James Webb Space Telescope (JWST).

## User interface

The package can be installed using `pip` and imported within python. Using “entrypoints”, the package can also be accessed from any terminal prompt once installed. The fitting method uses a brute-force technique to ensure a true best fit. New grids of multi-dimensional radiative transfer models will be added to the model grid library as they are developed. The available model grids for this version are listed in Table 1.

## Figures



**Figure 1:** An example of three massive oxygen-rich AGB stars in the Large Magellanic Cloud (LMC) galaxy fit with the default oxygen-rich model grid (Oss-Orich-bb). These three example sources can be fit, and this figure can be created, using the command desk fit and then the command desk sed.

**Table 1:** The model grids available with this version. Shown is the name, size, atmospheric model chemical type of either oxygen (O) or carbon (C), the atmospheric model, and a brief description.

Grid name	Size	Type	Atmospheric model	Optical constants	References
Oss-Orich-aringer	2,000	O	COMARCS	Warm silicates	1, 6
Oss-Orich-bb	2,000	O	Black body (BB)	Warm silicates	6
Crystalline-20-bb	2,000	O	BB	80% warm silicates, 20% crystalline silicates	4, 6
corundum-20-bb	2,000	O	BB	80% warm silicates, 20% corundum silicates	2, 6
big-grain	2,000	O	BB	Warm silicates with higher maximum dust grain size of 0.35	6
fifth-iron	500	O	BB	80% warm silicates, 20% iron grains	3, 6
half-iron	500	O	BB	50% warm silicates, 50% iron grains	3, 6
one-fifth-carbon	500	O	BB	80% warm silicates, 20% carbonaceous grains	6, 7
arnold-palmer	500	O	BB	50% warm silicates, 50% carbonaceous grains	6, 7
Zubko-Crich-aringer	2,000	C	COMARCS	Amorphous carbon grains	1, 7
Zubko-Crich-bb	2,000	C	BB	Amorphous carbon grains	7
H11-LMC	90,899	C	COMARCS	Dust-growth grid with 1/2 solar metallicity	5
H11-SMC	91,058	C	COMARCS	Dust-growth grid with 1/5 solar metallicity	5
J1000-LMC	85,392	C	COMARCS	Dust-growth grid with 1/2 solar metallicity	5
J1000-SMC	85,546	C	COMARCS	Dust-growth grid with 1/5 solar metallicity	5

References: 1: Aringer et al. (2016), 2: Begemann et al. (1997), 3: Henning et al. (1995), 4: Jaeger et al. (1998), 5: Nanni et al. (2019), 6: Ossenkopf et al. (1992), 7: Zubko et al. (1996)

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