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dust_extinction: Interstellar Dust Extinction Models

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Software

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Summary

Extinction describes the effects of dust on observations of a single star due to the dust along the line-of-sight to the star removing flux by absorbing photons and scattering photons out of the line-of-sight. The wavelength dependence of dust extinction (also known as extinction curves) provides fundamental information about the size, composition, and shape of interstellar dust grains. In general, models giving the wavelength dependence of extinction are used to model or correct the effects of dust on observations. This Python Astropy-affiliated package (Astropy Collaboration et al., 2022) provides many of the published extinction models in one place with a consistent interface.

Statement of need

Many observation- and theory-based extinction curves have been presented in the literature. Having one Python package providing these models ensures that they are straightforward to use and used within their valid wavelength and parameter (where appropriate) ranges. Other packages provide extinction curves, but they generally provide one or a small number of curves for specialized purposes (e.g., Barbary, 2016).

The types of extinction models supported are Averages, Parameter Averages, Grain odels, and Shapes. The Averages are averages of a set of measured extinction curves and examples are shown in Figure 1. The Parameter Averages are extinction curve averages that depend on a parameter, often $R(V) = A(V)/E(B-V)$ which is the ratio of total to selective extinction. Figure 2 shows examples of such models. The Grain odels are those extinction curves computed using dust grain models (**??**. Note that only these models provide dust extinction predictions from X-ray through submm wavelengths. The final type of models are Shapes that provide flexible functional forms that fit selected wavelength ranges (see Figure 4 for examples).

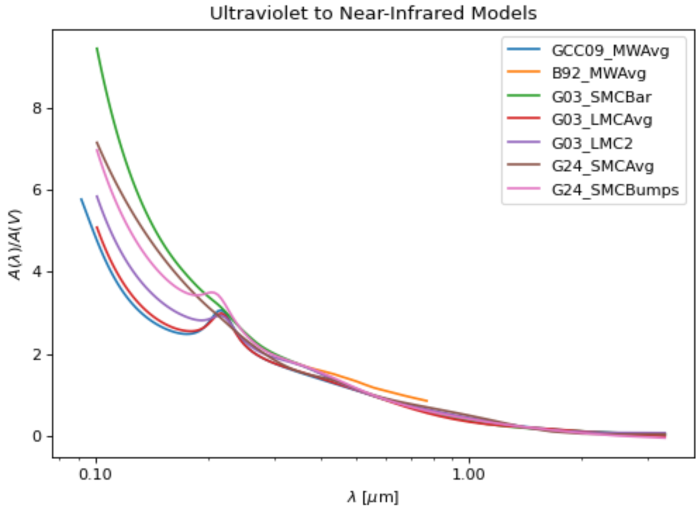

Figure 1: Examples of Average models based on observations in the Milky Way, Large Magellanic Cloud (LMC), and Small Magellanic Cloud (SMC) (Bastiaansen, 1992; Gordon et al., 2003, 2009, 2021, 2024).

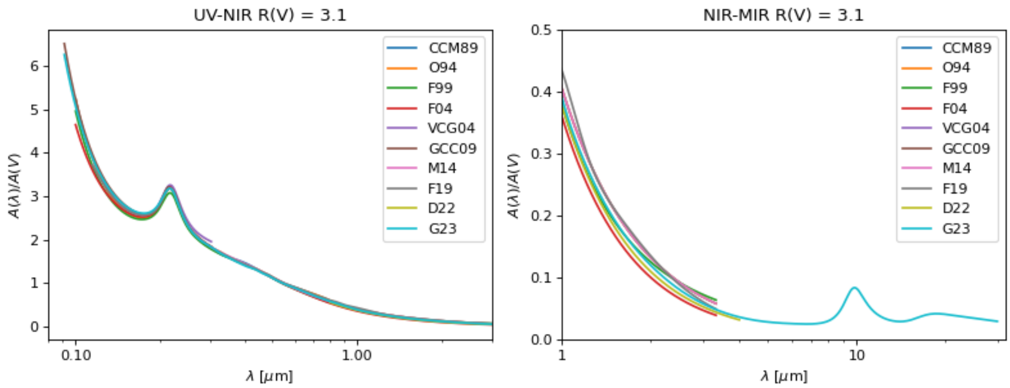

Figure 2: Examples of Parameter Average models (Cardelli et al., 1989; Decleir et al., 2022; Fitzpatrick, 2004, 1999; Fitzpatrick et al., 2019; Gordon et al., 2009, 2023; Maíz Apellániz et al., 2014; O'Donnell, 1994; Valencic et al., 2004).

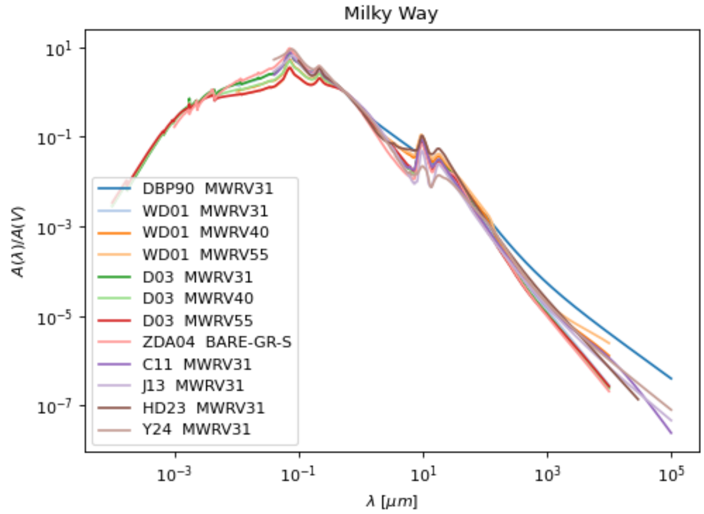

Figure 3: Examples of Grain models that are based on fitting observed extinction curves as well as other dust observables (e.g., emission and polarization) (Compiègne et al., 2011; Desert et al., 1990; Draine, 2003; Hensley & Draine, 2023; Jones et al., 2013; Weingartner & Draine, 2001; Ysard et al., 2024; Zubko et al., 2004).

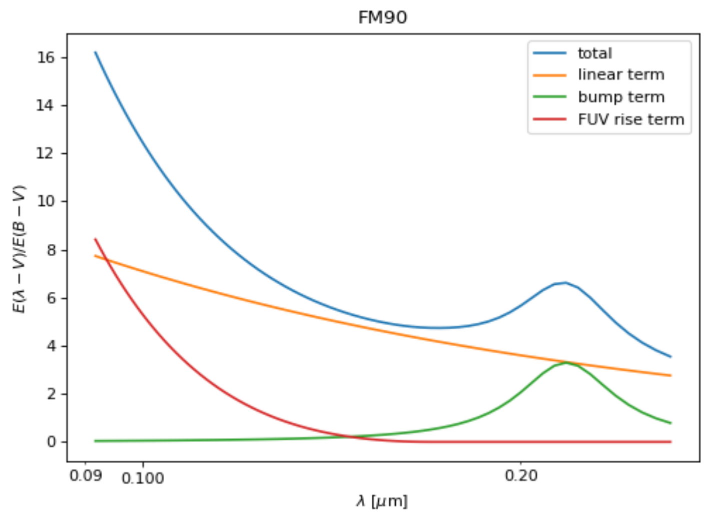

Figure 4: Example of a Shape model that is focused on decomposing the UV extinction curve (Fitzpatrick & Massa, 1990).

The wavelength dependence of extinction for a model is computed by passing a wavelength or frequency vector with units. Each model has a valid wavelength range which is enforced, as extrapolation is not supported. The model output is in the standard $A(\lambda)/A(V)$ units where $A(\lambda)$ is the extinction in magnitudes at wavelength λ and $A(V)$ is the extinction in magnitudes in the V band. Every model has a helper `extinguish` function that alternatively provides the fractional effects of extinction for a specific dust column (e.g., $A(V)$ value). This allows for the effects of dust to be modeled for or removed from an observation.

This package does not implement dust attenuation models[1]. Dust attenuation results when

[1] See karllark/dust_attenuation.

observing more complex systems such as a star with nearby, circumstellar dust or a galaxy with many stars extinguished by different amounts of dust. In both cases, the wavelength dependence of effects of dust are dependent not just on the dust grain properties, but also the effects of the dust radiative transfer (Steinacker et al., 2013). Specifically, these effects are the averaging of sources extinguished by differing amount of dust and the inclusion of a significant number of photons scattered into the observing beam.

Any published dust extinction model is welcome for inclusion in this package. I thank Kristen Larson and Aidan McBride for model contributions and P. L. Lim, Brigitta Sipocz, Soham Gaikwad, Clement Robert, and Adam Ginsburg for smaller much appreciated contributions.

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