Extinction by dust hampers and possibly biases our understanding of galaxies at all redshifts. Moreover, extinction is not constant within or across the face of a galaxy, nor from galaxy to galaxy. We are testing an approximate spatially-resolved correction method for use with future JWST and existing HST imagery.

Project Overview

In Tamura et al. (2009), we presented an empirical method to correct galaxy images for extinction due to interstellar dust embedded within those galaxies (interposed with their stellar populations) on a pixel by pixel basis, using only rest-frame 3.6 and 0.55μm (V-band) images. While this “βV” method is approximate in nature, in its first application to a nearby late-type spiral galaxy we produced extinction maps and revealed hidden coherent galaxy structures like a stellar bar, and ridges of dust (Tamura et al. 2010), while anomalous infrared central extensions in several early-type disk galaxies proved powerful tracers of hidden AGN, independent of radio, optical spectroscopic, or X-ray observations (Tamura 2009). This method is particularly promising for deep mid-IR imaging surveys with the James Webb Space Telescope (JWST) in fields already covered (or soon to be covered) by the Hubble Space Telescope (HST) in visible and near-IR light, since their resolutions will be well-matched. Here we report on our follow-up investigation to explore the applicability, robustness, and fidelity of the βV method on linear size scales from pc to kpc and in regions of varying star formation histories, metallicities, and dust content/distribution. We can do so by combining WISE 3.4μm (or Spitzer/IRAC 3.6μm) images of both Magellanic Clouds—the nearest astrophysical laboratories with a range of sub-solar metallicities— with ground-based 2MASS (Skrutskie et al. 2006) JHK, and OGLE-III (Udalski et al. 2008) multi-year V and I reference images and catalogs. The proximity of the LMC and SMC and wealth of archival space- and ground-based data provide for the overconstrained boundary conditions needed to perform such analysis. We assess at ~1" (~0.25×0.35 pc) resolution the properties of the stellar populations that contribute to the flux in each WISE (or IRAC) resolution element using the 2MASS and OGLE-III data. That allows us to measure the observed, and derive through modelling the inherent, V- to 3.4(3.6)μm flux ratio per WISE (IRAC) resolution element. Subsequent resampling and PSF-matching at geometrically increasing scales from pc to kpc resolution elements allows us to assess the accuracy and fidelity of the method as a multi-variant function of the resolution, underlying stellar population mixture, physical environments, and projected distribution of dust. The resulting graphs and tables of biases, corrections, and predicted βV, will serve as calibrations in the application of the spatially-resolved extinction correction method to galaxies at all redshifts, or those redshifts or conditions where the method is proved reliable.

Modeling βV,0

The “βV” method

If we have knowledge of the intrinsic SED of a simple or composite stellar population, then we know the intrinsic flux ratio

$$\beta_V = \frac{f_V}{f_{2MASS}}$$

where V is an arbitrary filter at visible wavelengths ≥0.4μm, and both dust extinction and emission by PAHs and silicates account for the difference. This ratio has an intrinsic form that can be rewritten as:

$$A_V = m_V - m_{2MASS}$$

where V is the zeropoint magnitude for the V filter. The above equation, applicable on a pixel-by-pixel basis, is referred to by Tamura et al. (2009) as the “βV” method.

Fig. 1 — Modeled intrinsic values of βV, (i.e., extinction-free βV,0) for [top 3 panels] the V filter (λV ≳ 5740Å) and [bottom 3 panels] the J filter (λJ ≳ 7090Å), both with respect to the WISE 3.4μm passband. Shown are βV,0 as a function of metallicity (Z) and age (t) for 1 Gyr old, single stellar population representatives of an exponentially declining star formation rate (SFR) with an e-folding time τ = 1 Gyr; and [right] a composite stellar population representative of continuous star formation (τ = 10 Gyr).

For more prolonged star formation episodes and, hence, mixed stellar populations, as would be observed in actual galaxy regions, sharp features visible in the SSP graphs— associated with the rapid evolution of massive stars— tend to be smoothed out toward older ages, and the total range in βV,0 is significantly reduced (e.g., from βV,0≈0.32−1.09) for SSPs to [0.38−0.63] and [0.62−0.82] for declining SFRs with τ = 10 Gyr and 1 Gyr.

We adopt the stellar population models of Bruzual & Charlot (2003) for older ages and starburst39 (Leitherer et al. 1999; Vazquez, & Leitherer 2005) for young ages, and assume that the ratio of the intrinsic to total (J + V) magnitudes is a step function of the time between the 25-95 Myr range. The contours in the left panel show a direct comparison with Fig. 2 of Tamura et al. (2009), who used the GALEX survey of starburst galaxies. That code is maintained by the NASA/IPAC Infrared Science Archive.

We similarly model βV,0 for other common passbands in the visible range, and with respect to the Spitzer IRAC 3.6μm and ground-based 1.35μm bands, and for more complex star formation histories (Jansen et al. 2014). For display purposes, the renditions here oversample our coarser native grid of metallicities and ages.

Observed βV in the LMC & SMC


References


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$$A_V = m_V - m_{2MASS}$$

where V is the zeropoint magnitude for the V filter. The above equation, applicable on a pixel-by-pixel basis, is referred to by Tamura et al. (2009) as the “βV” method.