Science and
Technology
Facilities Council

Physically Motivated Dust SED Models from the BPASS Population Synthesis Models

Gareth T. Jones, Elizabeth R. Stanway
Department of Physics, University of Warwick, Gibbet Hill Road, Coventry, CV4 7AL, UK
Contact: G.Jones.6@warwick.ac.uk

Motivation

Measuring the physical properties of galaxies is central to our understanding of their evolution, but this is challenging, particularly in the distant Universe where both measurement and modelling uncertainties are large. Galaxy parameters are encoded within their SEDs and extracted by comparison with population synthesis models for the stellar component. However, the resulting estimations are highly dependent on the assumptions underlying these models, and widely used model sets such as Bruzual & Charlot (2003, BC03) are becoming outdated. Recent models utilize our improving knowledge of stellar evolution, and some, such as BPASS (Stanway & Eldridge 2018), are now including binary evolution; a phenomenon that is near-ubiquitous in massive stars. However a great deal of information can come from components of an SED beyond the star light. These are increasingly well constrained by infrared and submillimeter measurements. This poster describes ongoing work exploring prescriptions for dust reemission models which are self-consistent with the stellar population, initially using the da Cunha et al. (2008) energy balance formalism for dust emission. BAGPIPES (Carnall et al. 2018) fitting is also tested, which implements Draine & Li (2007) dust models. We report the parameter space BPASS identifies for example galaxies drawn from the COSMOS2015 catalogue (Laigle et al. 2016).

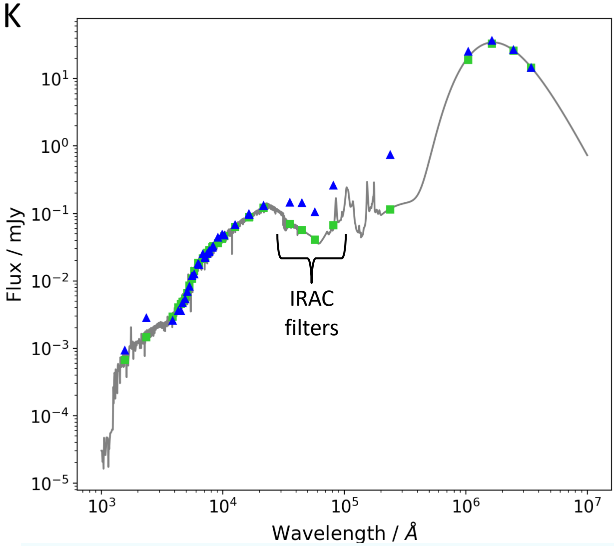

Figure 1. Fit to a composite of galaxies with $10.5<\log(M_\odot)<11.0$ and $0.35<z<0.40$ in the COSMOS2015 catalogue. Icons same as in Figure 2. The model fits the far-infrared dust emission and the stellar spectrum. The IRAC filters are not included when fitting as a further model component is required in this region.

Dust SED Models from the BPASS Models

Dust Model

Preliminarily, a grid of models which define the dust emission for a given stellar population using the energy balance prescription described by da Cunha et al. (2008) were generated. This involves the following steps:

- The UV and optical energy absorbed by dust is balanced by energy reradiated in the infrared, through birth cloud and interstellar medium (ISM) components.
- An old stellar population with a parameterized star formation history and young starburst are modelled.
- Energy is radiated in several dust components:
  - PAH emission, for which galaxy templates by Smith et al. (2007) and Bernhard et al. (2021) are tested.
  - Mid-infrared emission, modelled using multiple greybodies.
  - Dust grains in thermal equilibrium, modelled using greybodies for a hot (~30-60 K) and a cold (~15-30 K) grain component.
- Each component's effective contribution is calculated to yield the overall dust SED model.

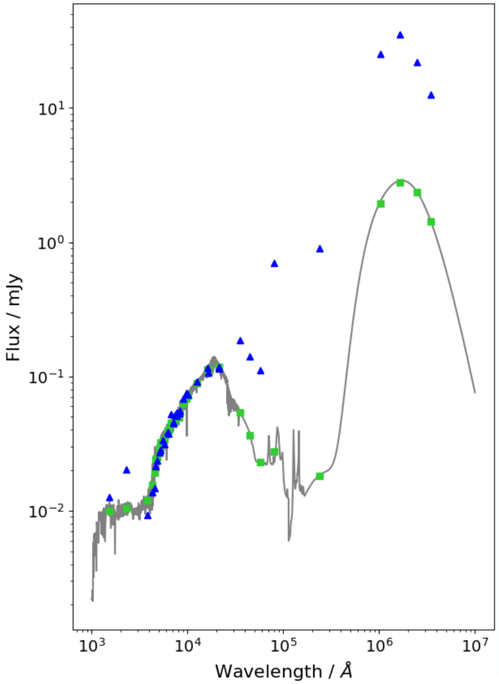

Figure 2. Example of a poor fit to a composite spectrum of galaxies with $9.5<\log(M_{\odot})<10.0$ and $0.1<z<0.2$ in the COSMOS2015 catalogue. The blue triangles are the COSMOS2015 flux values in each filter while the green squares are our model flux values in each filter. The grey curve shows the best model fit to the COSMOS2015 data. Optical observations are well constrained, the infrared is not, meaning some component (for example, a very high extinction population) is still missing from the model, and further investigation is needed.

Model Fits

The model has been fit to stacked galaxy samples in the local Universe (z<0.5) drawn from the COSMOS catalog. We select galaxies that have detections in the PACS 100 and 160 μm, SPIRE 250 and 350 μm, and GALEX filters. Example fits are shown, where some dust observations are well constrained (Figure 1) while others are not (Figure 2). This suggests that the model may still require additional components, for example a high extinction population (Av~20-30).

Dust SED Models from the BPASS Models

BAGPIPES Fitting

Fitting to the COSMOS stacked galaxy samples has also been trialled through the BAGPIPES fitting code. This allows for fitting both the stellar and dust components simultaneously compared to our previous model, which fit for the stellar and then dust parameters independently. BAGPIPES currently implements the Draine & Li (2007) dust emission model, which is defined by three parameters: the fraction of dust mass within PAHs (qpah), the lower limit of the starlight intensity distribution (U_{min}), and the fraction of stars at U_{min} (gamma).

An example best fit from BAGPIPES to the same stacked galaxy data in Figure 2 is shown within Figure 3. Fitting for both stellar and dust parameters simultaneously has helped to fit the whole spectrum, but further analysis into model components and prescriptions is still required to improve the shape of the spectrum fit. In Figure 4, the variation in flux at different infrared wavelengths is shown as the Draine & Li (2007) dust model parameters are varied, allowing for all the observational data points to be constrained by at least one model.

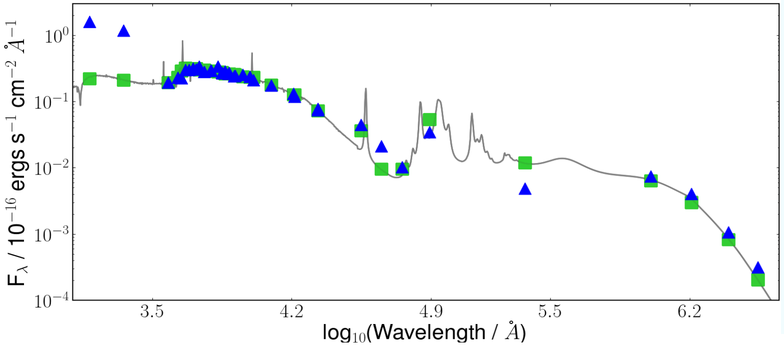

Figure 3. Example fit using BAGPIPES for the same stacked galaxies as in Figure 2, with identical icons. The infrared data is now better constrained.

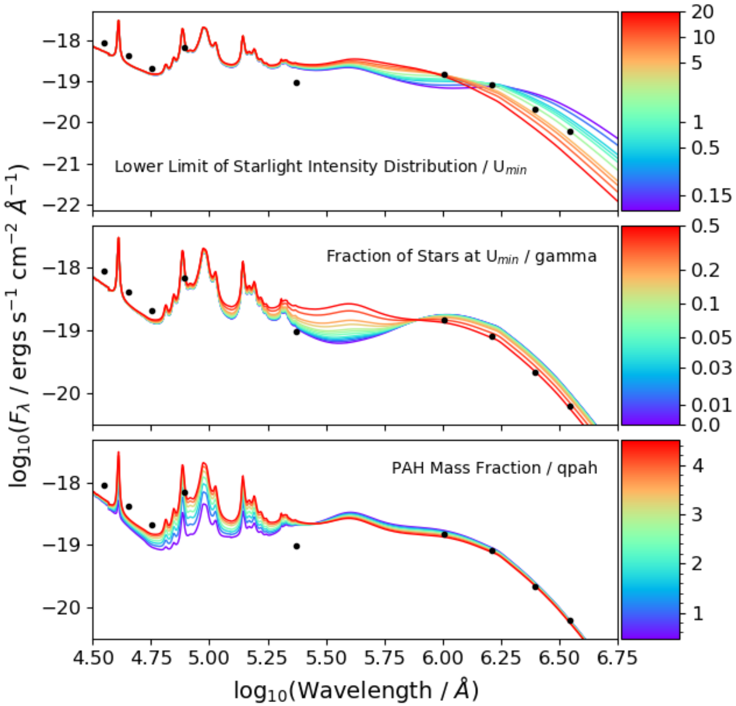

Figure 4. Dust models produced from variations in the U_{min} (top panel), gamma (middle) and qpah (bottom) Draine & Li (2007) dust parameters. The coloured lines represent different values for the dust parameters, with the value shown in the colourbar on the right. The black dots are observed data from the COSMOS2015 catalogue for the stacked galaxies shown in Figure 2.

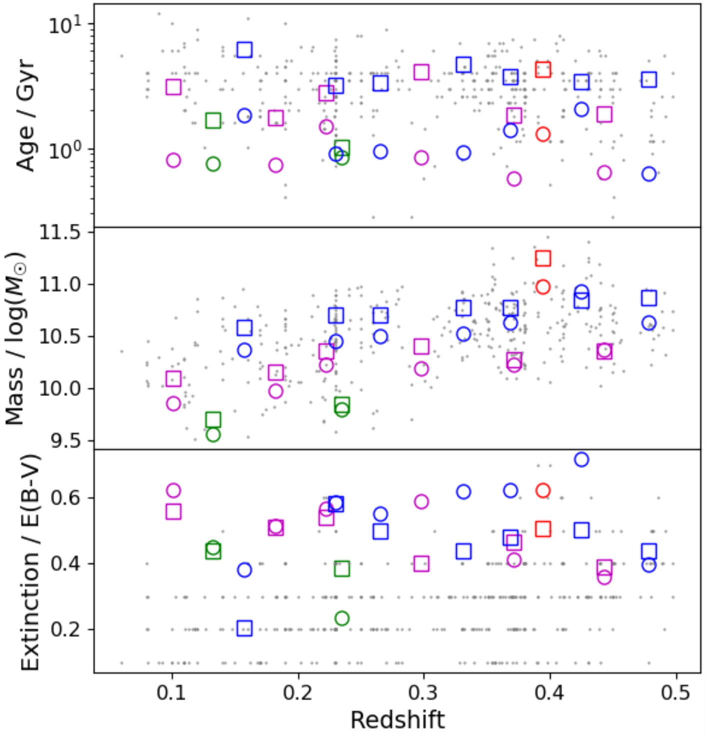

Figure 5. Parameter estimation from the BAGPIPES fitting code when using BC03 (circles) and BPASS (squares) models. Grey dots represent individual galaxy parameters as given from the COSMOS2015 catalogue, while the large symbols represent them stacked in groups, with bins in $\log(M/M_\odot)$ of 9.5-10, 10-10.5, 10.5-11, and 11-11.5, plotted in green, magenta, blue and red.

Stellar Parameter Estimation

The stellar parameters of the best fit model to each galaxy group from the BAGPIPES fitting code when using BC03 and BPASS models are shown within Figure 5. While some models agree on the stellar parameters, most BPASS models tend to be much older than the BC03 models, and slightly more massive. The comes down to the underlying assumptions of each model, most notably the inclusion of binary evolution within BPASS. This emphasises the systematic uncertainties that arise when relying on a single model prescription and its implicit assumptions.

Conclusions & Future Work

Current models can reach observed flux levels but require improvement to better fit the spectrum shape. We aim to explore alternate dust reemission prescriptions to determine models which best match the observed dust properties, and whether a connection between stellar and dust parameters can be made. Work will then be done into adapting the dust parameter space for the distant Universe, including finding potential samples for calibration.

References

da Cunha, Charlot & Elbaz, 2008, MNRAS, 388, 1595; Bernhard et al., 2021, MNRAS, 503, 2598; Bruzual & Charlot, 2003, MNRAS, 344, 1000; Carnall et al., 2018, MNRAS, 480, 4379; Draine & Li, 2007, ApJ, 657, 810; Laigle et al., 2016, ApJS, 224, 24; Smith et al., 2007, ApJ, 656, 770; Stanway & Eldridge, 2018, MNRAS, 479, 75