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Physically Motivated Dust SED Models from the BPASS Population Synthesis Models

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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the assumptions underlying these models, and widely used model sets such as Bruzual & Charlot (2003, BC03) are becoming outdated.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. We report the parameter space BPASS identifies for example galaxies drawn from the COSMOS2015 catalogue (Laigle et al. 2016). Adaptations to the dust parameter space in the distant Universe will be explored in future work.

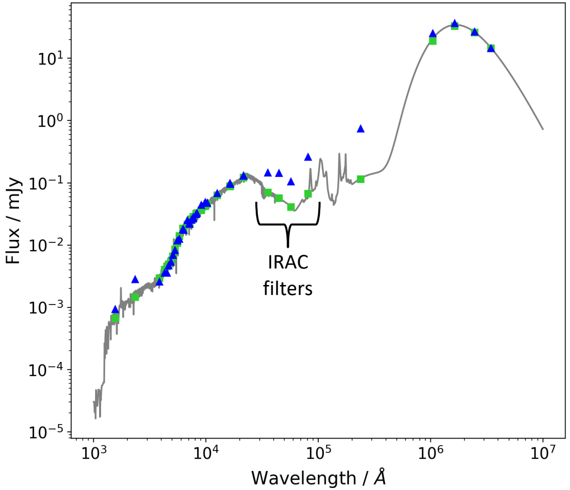

Figure 1. Fit to a composite of galaxies with $10.5<\log(M_{\odot})<11.0$ and $0.35<z<0.40$ in the COSMOS2015 catalogue. Icons same as in Figure 2. The model fits the far-infrared dust emission and the stellar spectrum. The IRAC filters are not included when fitting as a further model component is required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

Dust SED Models from the BPASS Models

Dust Model

We have generated 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). 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.

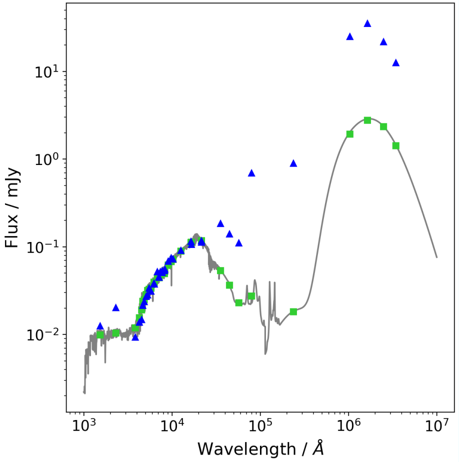

Figure 2. Example of a poor fit to a composite spectrum of galaxies with $9.5<\log(M_\odot)<10.0$ and $0.1<z<0.2$ in the COSMOS2015 catalogue. The blue triangles are the COSMOS2015 flux values in each filter while the green squares are our model flux values in each filter. The grey curve shows the best 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).

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Stellar Parameter Estimation

The parameters of our best fit model to each galaxy group are compared to the BC03 best fits within the COSMOS2015 catalogue in Figure 3. While a few models agree, most of the BPASS predictions for the galaxies tend to be older, and more extincted, which causes the mass prediction to be higher to achieve the same flux levels. This emphasises the systematic uncertainties that arise when relying on a single model prescription and its implicit assumptions.

Conclusions & Future Work

The current model can fit some galaxy's dust emission but work is needed to include further components in the model and better fit the whole spectrum for all galaxies. Systematic offsets between BPASS and other parameterisations for galaxies will be explored, and whether this can be explained by the inclusion of binary evolution or varying the star formation history. We aim to explore alternate dust reemission prescriptions. Work will then be done into adapting the dust parameter space for the distant Universe, including finding potential samples for calibration.

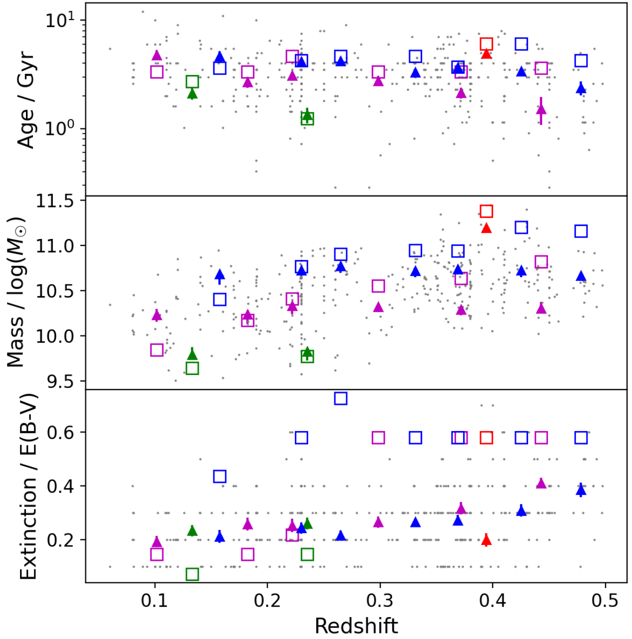

Figure 3. Parameter estimation from the COSMOS2015 catalogue using BC03 models (triangles), and from our model (open squares). Grey dots represent individual galaxy parameters, while large symbols represent the stacked galaxy groups, with bins in $\log(M/M_\odot)$ of 9.5-10, 10-10.5, 10.5-11, and 11-11.5, plotted in green, magenta, blue, and red.

References

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