AGB Stars in Population Synthesis Models

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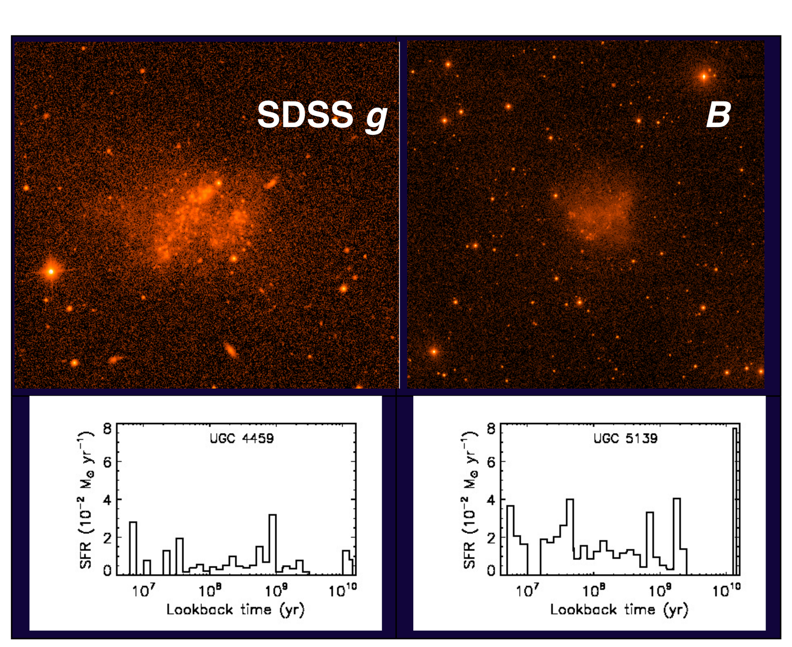
Abstract

We have used theoretical AGB spectra from the **G**rid of **R**ed supergiant (RSG) and **AGB** **M**odel**S** (GRAMS) in simple stellar populations (SSPs), combined with the star formation history (SFH) estimated from optical color-magnitude diagrams (CMDs) of stars, to predict the total integrated spectral energy distribution (SED) from the ultraviolet (UV) through the near-infrared (NIR) wavelengths of two galaxies. We compare these results to models using popular prescriptions for the thermally-pulsing (TP) AGB phase and find that we are in good agreement with their predictions. The GRAMS grid offers the convenience of pre-calculated radiative transfer models that incorporate the latest photosphere models, and it therefore spans the entire range of parameters expected for AGB stars.

Introduction

AGB stars are the site of dust formation and copious mass loss resulting in circumstellar shells which reprocess the stellar light, reemitting it in the infrared. This reprocessing makes them dominate the integrated infrared light of galaxies with ages ~100 Myr to a few Gyr. Therefore, they are necessary ingredients of stellar population synthesis (SPS) models. While most of the interstellar medium (ISM) dust mass is in the cold component, the warm component is necessary to constrain parameters such as the interstellar radiation field. Before this can be done, it is important to account for the contribution from circumstellar dust, especially AGB dust. However, it is difficult to incorporate the effects of dusty mass loss along the AGB into population models. Most contemporary studies use either semi-empirical spectra incorporating dust extinction through color-based relations (e.g., the Lançon & Mouhcine 2002), or sparse model grids that may not provide adequate resolution in the parameter space (e.g., luminosities, effective temperatures, colors, optical depths, mass-loss rates); some may not even span the entire parameter space. To remedy this, we have developed the **G**rid of **R**SG and **AGB** **M**odel**S** (GRAMS, Sargent et al. 2011, Srinivasan et al. 2011). In this study, we incorporate the GRAMS models into the Flexible Stellar Population Synthesis (FSPS, Conroy et al. 2009, Conroy & Gunn 2010) code. This code is then used to model the integrated SED of two galaxies for which integrated SEDs as well as star-formation histories (SFH) were available.

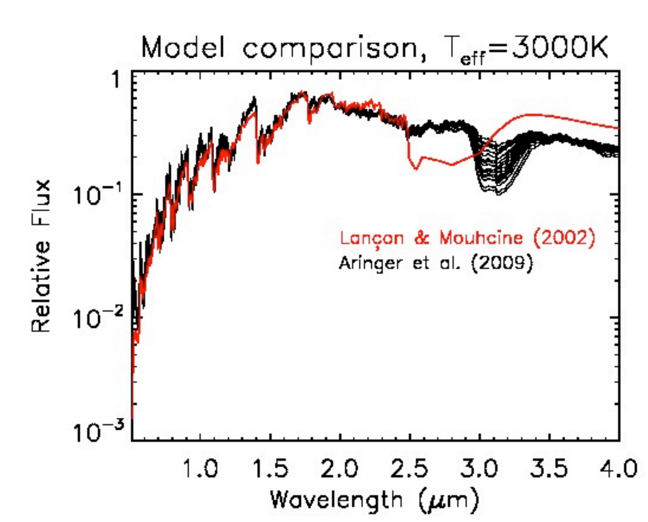
Data



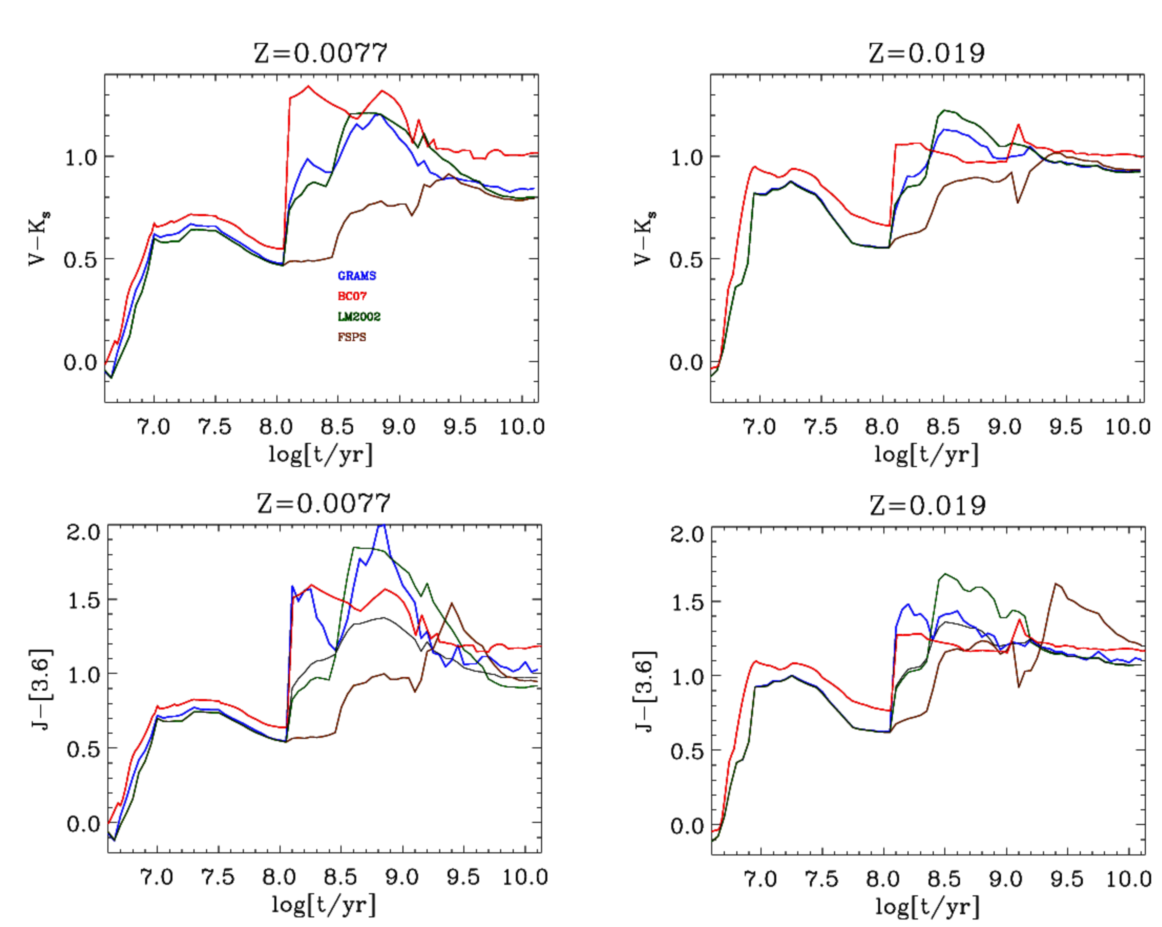
Spitzer data for UGC 4459 and UGC 5139 is available as part of the Local Volume Legacy survey (Dale et al. 2009). The Key Insights on Nearby Galaxies: a Far Infrared Survey with Herschel (KINGFISH, PI: Kennicutt) has also imaged these galaxies in the far-IR. The SFH for each galaxy was estimated by matching optical CMDs determined from HST ACS observations to synthetic CMDs (Weisz et al. 2011, Dolphin et al. 2002). The optical images as well as SFH plots are shown in the figure.

Results

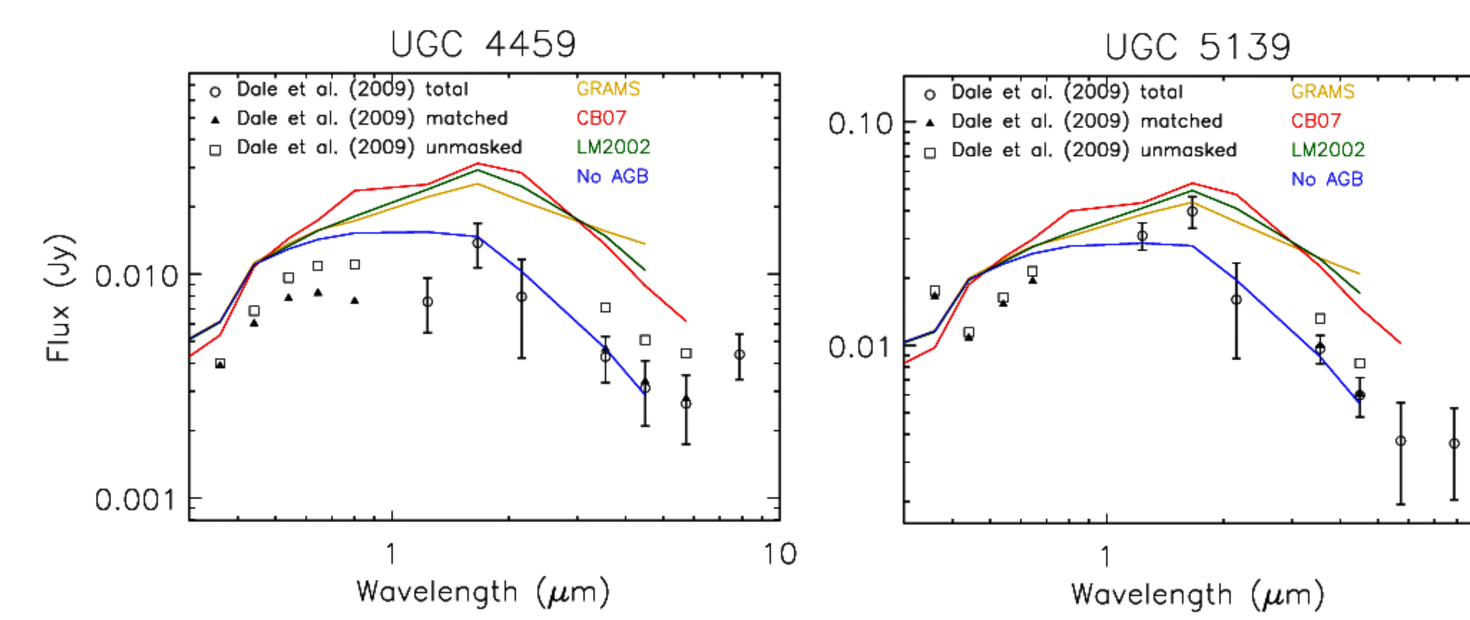
1. AGB spectra: The first step was to compare the photosphere models, which form the basis for the GRAMS grid, to other spectral libraries typically used in SPS studies. As the GRAMS grid is computed separately for oxygen-rich and carbon-rich AGB stars, it incorporates photosphere models of both types. Not only is it necessary to pay attention to the chemical nature of the TP-AGB star, it is also important to incorporate the most accurate atomic and molecular opacities available. For example, the Aringer et al. (2009) models are the state of the art in computations of carbon star photospheric spectra. The figure here compares 3000 K Aringer et al. carbon-star models to a carbon star spectrum for the same effective temperature from Lançon & Mouhcine (2002, hereafter LM2002) as used in the FSPS library. By default, the FSPS library stitches an M-star spectrum to the LM2002 spectra beyond 2.5 micron. The disagreement between the spectra results in significantly different colors for the two sets of models. The GRAMS grid avoids such stitching by extending redward of the MIPS 24 micron band.



2. Integrated SED of a simple stellar population (SSP): The figure below shows the broadband color evolution at two different metallicities (~LMC and solar) for SSP calculations using different TP-AGB prescriptions. The GRAMS integrated SED is in good agreement with other models that include a treatment of the TP-AGB phase (Bruzual 2007, hereafter CB07, and LM2002).



3. Finally, we compute SPS models for UGC 4459 and UGC 5319 using three different prescriptions for AGB dust (GRAMS, CB07, LM2002), and one without dusty AGB stars. The plot below compares the various models for both galaxies. The models agree extremely well in the UV and optical, which is expected since there is very little contribution at these wavelengths from cool stars. In the IR, however, emission from dusty AGB envelopes becomes important; while the GRAMS predictions are similar to those of CB07 and LM2002, they predict significantly higher fluxes than models incorporating no AGB dust. While there is good agreement between models, they do not reproduce the observed SEDs well. Complications in these comparisons include the need to use apertures matched to those used to derive the SFH, the faint integrated flux in the NIR bands, and the possibility that AGB stars are erroneously masked in the NIR photometry as foreground stars.



Conclusion

We have used the GRAMS model grid to incorporated an improved treatment of AGB mass loss in stellar population synthesis. SSP calculations with GRAMS agree well with computations performed using standard spectral libraries. Using optical through NIR photometry as well as SFH information estimated from the optical CMD of stars, we model the total integrated SED of UGC 4459 and UGC 5319. We find good agreement with other models that include AGB dust in some fashion. The advantage offered by the GRAMS grid over these models is that it is a pre-computed radiative transfer grid that (a) finely samples and (b) spans the entire range of stellar and dust shell parameters expected for both O-- and C--rich AGB stars.

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