Parametrising Star Formation Histories

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Introduction

• Increasingly rich data sets consisting of large samples of galaxies with multi-wavelength photometry open up several avenues:

• Evolutionary studies shift from luminosity and colour to more physical $M_\star$ (stellar mass) and $M'_\star$ (SFR).

• Median ages of stellar populations.

• Other aspects of galaxy evolution - e.g. importance of bursts, correlations with gas phase metallicity, dust extinction etc.

• Photo-z estimation requires model of intrinsic galaxy colour.
Parametrising Star Formation Histories

- **KEY STEP** - fitting parametrised SFH to observed SEDs.

  - Tau Model ($\text{SFR} = C e^{-t/\tau}$) most commonly used
  - Extended Tau Model ($\text{SFR} = C t e^{-t/\tau}$) has also been advocated

- We examine SFHs of galaxies in SPH simulation

  - What functional forms are necessary?
  - Are these models adequate?
  - What level of complexity is required?
• Smoothed Particle Hydrodynamics (SPH) simulation using GADGET.

• 50 $h^{-1}$Mpc box with $288^3$ ($\sim 24$ million) particles.

• Wind feedback.

• No AGN feedback.

• Post-processing prescription to quench star formation in massive galaxies and produce more realistic stellar mass function (match Bell et al., 2003).

• Use FSPS (Conroy, Gunn & White 2009) to compute luminosity and colour.
• Simple tau models ($e^{-t/\tau}$) do not describe SFHs adequately.

• $te^{-t/\tau}$ does better but fails to capture late time behavior - “too red” for blue galaxies and “too blue” for red galaxies.

• Need delayed start time.

• Need additional linear component to describe late time behavior.
Testing SFH Models - Part 1

Consider Tau model \((e^{-t/\tau})\), Extended tau model \((te^{-t/\tau})\) and our 4 parameter model:

\[
\text{SFR}(t) = A(t - t_0)e^{-(t-t_0)/\tau} \quad (t < t_{\text{trans}})
\]

\[
\text{SFR}(t) = \text{SFR}(t_{\text{trans}}) + \tan(\theta)(t - t_{\text{trans}}) \quad (t > t_{\text{trans}})
\]

• Fit each model to SFH of an SPH galaxy.

• Compute colours, M/L, median age of best-fit model of each type.

• Compare these to colour, M/L, median age of SPH galaxy whose SFH has been fit.
Testing SFH Models - Part I

Fig. 4.7.— Histogram of difference between parametric model colour and SPH galaxy colour in the winds simulation. Each curve stands for a different parametric model and the curves are normalised so that the area under each curve is the same.

Fig. 4.8.— Histogram of difference between parametric model colour and SPH galaxy colour in the doctored winds simulation. Each curve stands for a different parametric model and the curves are normalised so that the area under each curve is the same.

This figure is analogous to Figure 4.7 but using the doctored winds simulation.

Only Wind Feedback
Winds + Quenching (Doctored Winds)
Testing SFH Models - Part I

Fig. 4.10.— Histogram of difference between age of the galaxy stellar population predicted by the parametric models and their age in the doctored winds simulation. Each curve stands for a different parametric model and the curves are normalised so that the area under each curve is the same.

$t_{10}$, $t_{25}$, $t_{50}$ and $t_{90}$ stand for the time at which 10%, 25%, 50% and 90% of the stars were formed respectively.

Fig. 4.11.— Histogram of logarithmic ratio of the parametric model mass-to-light ratio and SPH galaxy mass-to-light ratio. Each curve stands for a different parametric model and the curves are normalised so that the area under each curve is the same.
Testing SFH Models - Part II

• In reality we do not know SFH and must fit SFH models to colours!

• Construct mock “observations” of galaxies in our simulation
  • Compute colours using SPS code in SDSS bands.
  • Assume errors of 0.02 magnitudes.

• Fit each type of model to these colours.

• Extract model M/L, median age, SFR and compare to M/L, median age, SFR of galaxy in simulation.

• How well can each type of model recover the M/L, SFR and median age of a galaxy given multi-wavelength photometry?
Mass to Light Ratio

- Tau model overestimates M/L by factor of ~1.5
- 4 parameter model gets M/L within 10% for 68% of galaxies
Stellar Population Age

- Tau model overestimates stellar population age by ~2-3 Gyr
- 4 parameter model gets M/L within 1 Gyr for 68% of galaxies
**Effect of UV and IR Colours**

- Compute GALEX NUV & FUV and 2MASS J,H & K colours and fit to those too

- Adding UV and IR does not seem to improve things

- BUT very likely to help break degeneracies with dust, metallicity and determination of photo-z
Conclusions

- We examine SFHs of galaxies in SPH simulation.
- **What model SFHs should be fit to observed SEDs?**
- Commonly Used Tau Model \((e^{-t/\tau})\) does not adequately describe the SFHs of galaxies in SPH simulation.
- It introduces significant biases in estimates of physical parameters such as M/L, median age, SFR.
- Extended tau model \((t e^{-t/\tau})\) is a substantial improvement.
- We advocate extended tau up to a transition time followed by linear with variable slope - 4 parameter model (start time, tau, transition time, slope of linear component) of which start time and transition time can be fixed for relatively small cost.