1 Galactic Spectral Energy Distributions

- From observations of galaxies, a sort of "colour spectrum" can be obtained: A Distribution of Energy measured at the various wavelengths
- This *Spectral Energy Distribution* can be displayed as a graph of contributions of the wavelengths to the total energy received from the galaxy (compare with a probability density)
- Physically, the complete distribution is composed of the emission of all the individual stars as well as emission from dust, gas or molecular clouds

2 Stellar Population Synthesis

- Primary goal: determine physical properties of (unresolved) galaxies from their spectral energy distributions by fitting models [Conroy, 2013]
- Possible properties of interest are:
  - Star formation rate (SFR) / star formation history (SFH)
  - Metallicity (Z) / elemental abundance patterns
  - Mass to light ratios
  - Dust attenuation (possibly more details about dust such as galactic dust content and geometry of dust distribution)
- While the reconstruction of a galaxies' SFH via SPS can be seen as a "holy grail" of the technique [Conroy, 2013], results are met with scepticism as well [Walcher et al., 2011]
- How does SPS work?
  - Idea: build a model of the SED by adding up the effects of the constituents: considered are the stars and the dust, mostly
  - Basic building blocks are *simple stellar populations* (SSPs), which summarise the effects of a group of stars formed at the same time (termed *coeval*) with the same metallicity
  - To construct the SSPs, models of stellar evolution are necessary as well as initial mass functions (IMFs) for the simple population in question, and *isochrones*, i.e. the positions of the various coeval stars in the CM diagram at a given time

  - SSPs for all relevant stellar population ages and metallicities are then combined and supplemented by terms that take dust attenuation and emission into account, ultimately yielding a *composite stellar population* (CSP) and the spectral energy distribution derived from it
  - Models for stellar evolution, IMFs, and isochrones stem from works that explicitly treat these topics and provide reasonable results
  - The full SPS model contains the physical properties that are to be determined as parameters – it is then fit do data with a χ^2-minimising approach
  - The best fit parameters deliver the values of the physical quantities "measured" from the data

- A component that is often neglected in SPS models is nebular emission
- SFH is often implemented by assuming the SFR just drops exponentially with time (SFR $\propto e^{-\frac{t}{\tau}}$), another possibility is a two parameter model assuming an increasing SFR for some time early in the galaxy's evolution (SFR $\propto t^{\beta} e^{-\frac{t}{\tau}}$)
- Estimated parameters can end up model dependent, in that case the results have to be interpreted especially carefully → Uncertainties are explored in 3 papers starting with [Conroy et al., 2009] (to be elaborated?)

3 Results on Star Formation

[Salim et al., 2007]

- Utilised SDSS and GALEX data (≈50 000 galaxies)
- Compared the results with SFR results from methods using Hα emission – they compare "remarkably well"
- The differences in estimated SFRs between the methods are explained by different treatments of dust attenuation
- Here, SPS provides an alternative to the Hα method, especially when Hα emission is weak or obscured by an AGN

[da Cunha et al., 2010]

- 3258 low redshift galaxies analysed (data from SDSS, GALEX, 2MASS, IRAS)
- Measured the SFRs via SPS
- For a high SNR subsample, examining correlations was possible, in particular SFR is strongly correlated with galactic dust mass

4 Results on Metallicity

[Worthey, 1994]

- Examined data published from various earlier sources with SPS models, fitting for SED and absorption features
- *age-metallicity degeneracy*: If two stellar populations differ in age and metallicity such that $\Delta\text{age}/\Delta Z = 2/3$, most absorption features are indistinguishable

[Thomas et al., 2003]

- Calcium abundance in early-type galaxies
- Calcium turns out to be underabundant in these galaxies
- SPS used with absorption line data (Ca4227) rather than extended parts of the SED

[Gallazzi et al., 2005]

- SDSS data (44 254 galaxies), SPS models, trying to fit 5 absorption features
- Distribution of metallicity peaks at about $\log \frac{Z}{Z_\odot} = 0.1$, so at about $1.1 Z_\odot$
- Metallicity increases with a galaxy's stellar mass

5 Discussion

"Typical" criticism of simulation / fitting techniques:

- Results might be model dependent – correct, but often treatable by comparing with other techniques, e.g. spectral lines for elemental abundances
  - If certain models can be ruled out and others approved by these checks, additional insight into physical processes might be gained, e.g. singel vs. 2-parameter SFH
- "It is possible to fit anything using a sufficient number of parameters" – very much valid here

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