The Bimodality of Galaxy Populations

Revisited through Spectral Synthesis

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ABSTRACT

We investigate the bimodality observed in galaxy properties in terms of spectral synthesis products, such as mean stellar ages and stellar masses, derived from the application of this method to a sample containing about 50 thousand galaxies from the SDSS. Galaxies are classified according to their emission-line properties in three spectral classes: star-forming galaxies, with young stellar populations; passive galaxies, dominated by old stars; and hosts of active nuclei. We show that the extremes of the distribution of some galaxy properties are associated to star-forming galaxies at one side and passive galaxies at another, with AGN hosts being an intermediate population. We find that the mean light-weighted stellar age of galaxies is directly responsible for the bimodality seen in the galaxy population. The stellar mass, in this view, has an additional role since most of the star-forming galaxies present in the local universe are low-mass galaxies. Our results give support to the existence of a 'downsizing' in galaxy formation, where most of star formation nowadays is occurring in low-mass galaxies.

Why spectral synthesis?

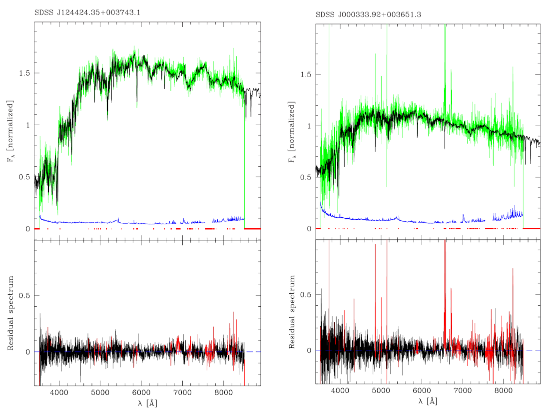
- **Galaxy spectra encode information on the age and metallicity distributions of the constituent stars;**
- **Then, they are an expression of the star-formation and chemical histories of the galaxies;**
- **Spectral Synthesis is a way to retrieve physical properties of galaxies. See Cid Fernandes et al. (2005) for details.**

Our approach

- **We mix techniques originally developed for empirical population synthesis with ingredients from evolutionary synthesis models;**
- **We fit an observed spectrum with 150 Simple Stellar Populations from the evolutionary synthesis models of Bruzual & Charlot (2003);**
- **Extinction is modeled as due to foreground dust, parametrized by A_V;**
- **Line-of-sight stellar motions are modeled by a Gaussian centered at velocity v_* and with dispersion σ_*.**

Main outputs

- **M_*: stellar mass;**
- **$<t_*>$: Mean stellar age, light and mass-weighted:**
- **A_V: stellar extinction at λ_V;**
- **σ_*: velocity dispersion of the stars;**
- **Residual spectrum (for emission line analysis), see examples below.**



Observed spectrum, model spectrum, **error spectrum**, **masked pixels**

Application to SDSS data

The sample

- **SDSS: enormous amount of good quality, homogeneously obtained spectra;**
- **Data extracted from Data Release 2 (Abazajian et al. 2004);**
- **Volume limited sample: 0.05 < z < 0.1; M(r) < -20.5; S/N > 5 in g, r, and i-bands;**
- **Sample: 49917 galaxies - completeness ~98.5%.**

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- Mateus A., Sodré L., Cid Fernandes R., Stasinska G., Schoenell W., Gomes J.M., 2006, MNRAS, 370, 721
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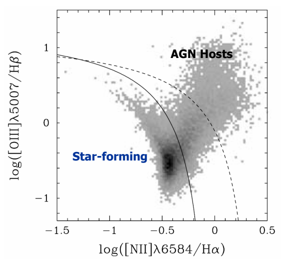
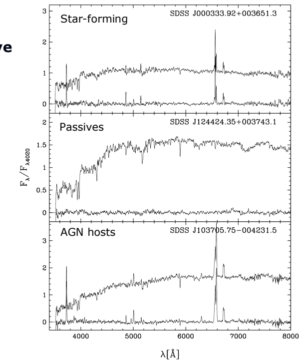
Galaxy classification

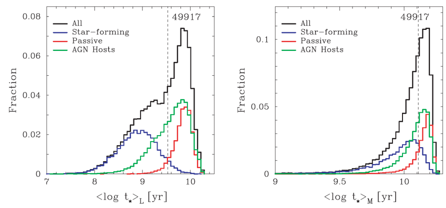
- **We use the [NII]/Hα x [OIII]/Hβ diagram to classify galaxies in three spectral classes: star-forming, passive (non-emission line) and AGN hosts.**



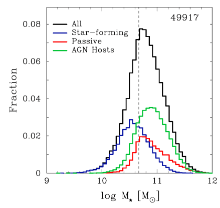


Physical properties of spectral classes:
Origin of the bimodal distribution

Mean stellar ages

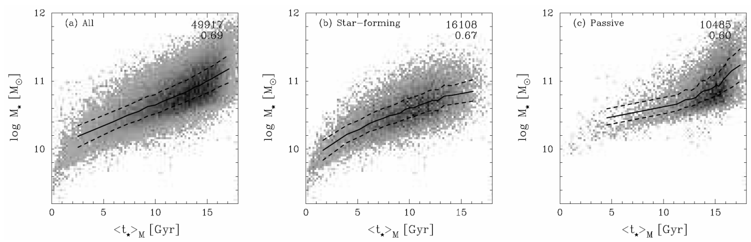


Stellar Mass



- **We clearly note two extreme galaxy populations: star-forming galaxies at one side; passives at another.**
- **The bimodality is not so apparent!**

The downsizing appears here!



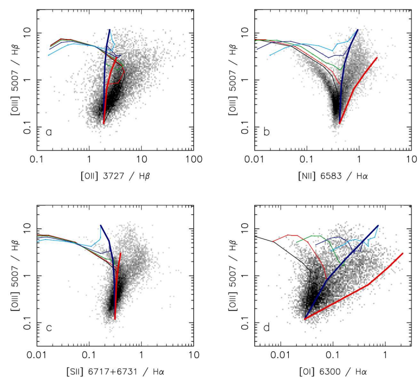
The mean light-weighted stellar age of galaxies is directly responsible for the bimodality observed in the galaxy population.

The stellar mass, in this view, has an additional role since most of the star-forming galaxies present in the local universe are low-mass galaxies.

See Mateus et al. (2006) for details.

More on galaxy classification:
How to distinguish AGN hosts?

- **Based on photoionization models computed using the stellar ionizing radiation predicted by population synthesis codes (essentially STARBURST99) and, for the AGNs, a broken power-law spectrum,**
- **We explain why, among the four classical emission-line diagnostic diagrams shown on the right, the [OIII]/Hβ versus [N II]/Hα diagram works best.**
- **Here we plot composite model sequences corresponding to an ionization parameter U equal 0.01 for the AGN and different values of the ratio η between the Hβ luminosity produced by the AGN and the Hβ luminosity produced by the HII regions.**
- **From these models, we propose a new divisory line between 'pure' NSF galaxies and AGN hosts.**



$$y = (-30.787 + 1.1358x + 0.27297x^2)\tanh(5.7409x) - 31.093$$

where: $y = \log([\mathrm{O\,III}]/H\beta)$, **and** $x = \log([\mathrm{N\,II}]/H\alpha)$

See Stasinska et al. (2006) for details.