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Quenching or bursting?

Physical processes in green valley galaxies and the star formation acceleration

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Abstract. One of the main open questions in contemporary astrophysics is how galaxies quench star formation. The observed color bimodality is a strong indication that galaxies do not passively exhaust their gas reservoirs, instead requiring an active process that shuts down star formation over short timescales. In this work we show recent results by our group measuring quenching timescales of galaxies in different epochs and of different types, supporting the idea that some processes are more efficient for quenching star formation. We also present a new technique combining spectroscopic and photometric indices that allows for a measurement of the time derivative of the star-formation rate, i.e. the star formation acceleration. Finally we discuss the implications of this measurement, comparing for example the quenching timescales of galaxies with and without AGN activity.

Resumo. Uma das principais questões em aberto na astrofísica contemporânea é como galáxias param de formar estrelas. A bimodalidade em cores observada é um dos principais indícios de que galáxias não esgotam seus reservatórios de gás passivamente, mas requerem um processo ativo que acabe com a formação estelar em escalas de tempo curtas. Neste trabalho apresentamos resultados de nosso grupo medindo escalas de tempo de cessação de formação estelar em galáxias de diversos tipos e épocas, dando suporte à ideia de que alguns processos são mais eficientes para tal cessação. Também apresentamos uma nova técnica que combina índices espectroscópicos e fotométricos que nos permitem medir a derivada temporal da taxa de formação estelar, ou seja, a aceleração da formação estelar. Finalmente, discutimos aplicações práticas desta medida, usando como exemplo uma comparação entre galáxias com e sem núcleos ativos.

Keywords. galaxies: evolution – galaxies: stellar content – galaxies: structure

1. Introduction

A key problem in galaxy evolution is how galaxies stop forming stars. The bimodality in the color distribution of galaxies (e.g., Strateva et al. 2001; Baldry et al. 2004) indicates the process of star formation quenching – and the conversion of star-forming galaxies into passively evolving objects – happens relatively quickly. How fast is that transition, and what physical processes are associated with it? In order to understand such processes, one must study galaxies with intermediate colors, assumed to be undergoing quenching – the green valley.

2. Evolution with redshift

Using spectral indices (the break at 4000Å and the H_δ absorption) and stellar population synthesis models, Martin et al. (2007) have determined that galaxies in the green valley at low redshift ($z \sim 0.1$) stop forming stars typically in less than 1 Gyr. Following the same methodology, Gonçalves et al. (2012) have determined that when the universe was half its current age ($z \sim 0.8$), galaxies quenched faster – typically in less than 500 Myr – and the transition would occur for more massive objects. Therefore, the red sequence forms in a top-down manner: the massive end was created first (and quickly), and the low-mass end forms later and more slowly (Figure 1).

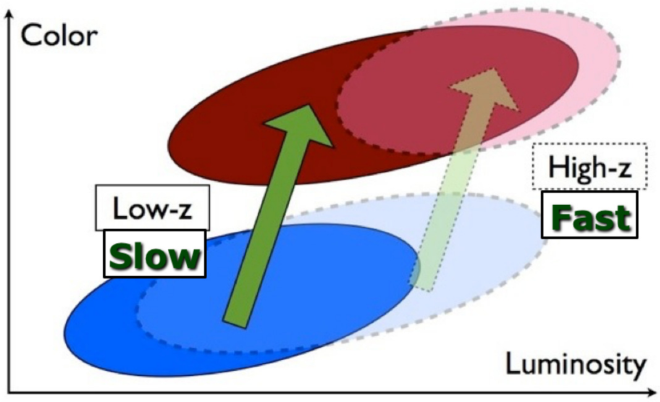

Figure 1. Summary of results in Gonçalves et al. (2012). Massive galaxies quench at earlier times, and at a faster pace.

3. Quenching timescales as a function of morphology

More recently, we have analyzed quenching timescales independently according to galaxy morphology. Our results indicate that spirals in the green valley are quenching more slowly than ellipticals (Nogueira-Cavalcante et al. 2018). In particular, barred spirals, which are clearly undergoing secular evolution without any strong external influences, are the slowest to quench their star formation. Major mergers, on the other hand, are the fastest to stop forming stars (Figure 2).

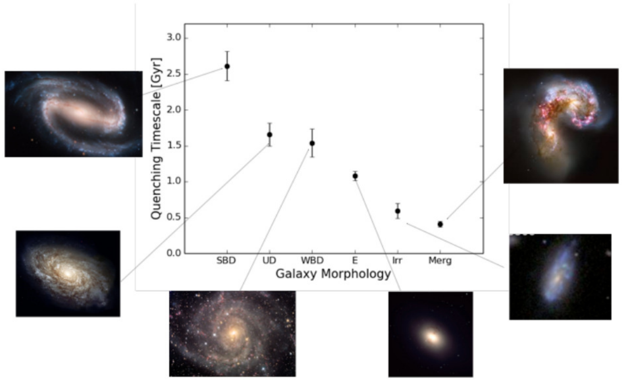

Figure 2. Quenching timescales as a function of galaxy morphology. Disk galaxies quench slowly, and barred galaxies are the slowest to quench, indicating the inefficiency of secular processes in stopping star formation. From Nogueira-Cavalcante et al. (2018).

4. Star formation acceleration

We have now improved our methodology in order to measure not only quenching timescales, but also the rate at which star formation rates are increasing or decreasing – the star formation acceleration (SFA, Martin et al. 2017). A combined analysis of stellar population synthesis models and cosmological simulations can yield a number of photometric (UV and optical) and spectral measurements (again, the 4000Å break and H_δ absorption) capable of recovering the instantaneous SFA of individual galaxies with remarkable accuracy (Figure 3). Our results show that the most massive galaxies in the green valley are bursting instead of quenching, through mergers with gas-rich satellites. Another result is that AGN hosts are quenching faster – a result that would be expected assuming AGN are capable of heating and/or expelling the gas from the galaxy (Figure 4).

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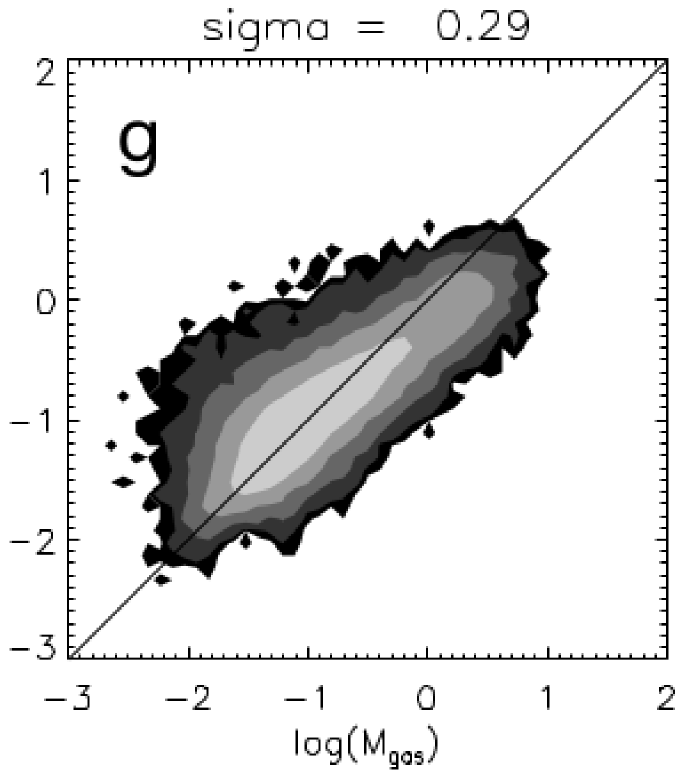

Figure 3. Results for SFA from linear regression as a function of simulation input. SFA of simulated galaxies is recovered with great accuracy. From Martin et al. (2017).

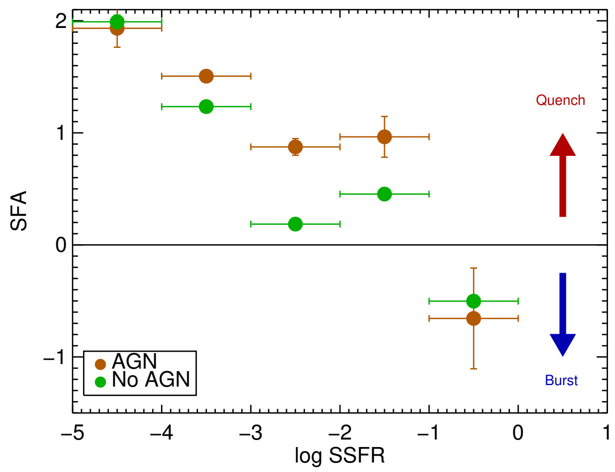

Figure 4. SFA of galaxies with (brown) and without (green) AGN. AGN hosts are quenching more strongly. From Martin et al. (2017).