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The IMF-SFH connection in massive early-type galaxies

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The stellar initial mass function (IMF) is one of the fundamental pillars in studies of stellar populations. It is the mass distribution of stars at birth, and it is traditionally assumed to be universal, adopting generic functions constrained by resolved (i.e. nearby) stellar populations (e.g., Salpeter 1955; Kroupa 2001; Chabrier 2003). However, for the vast majority of cases, stars are not resolved in galaxies. Therefore, the interpretation of the photo-spectroscopic observables is complicated by the many degeneracies present between the properties of the unresolved stellar populations, including IMF, age distribution, and chemical composition. The overall good match of the photometric and spectroscopic observations of galaxies with population synthesis models, adopting standard IMF choices, made this issue a relatively unimportant one for a number of years. However, improved models and observations have opened the door to constraints on the IMF in unresolved stellar populations via gravity-sensitive spectral features. At present, there is significant evidence of a non-universal IMF in early-type galaxies (ETGs), with a trend towards a dwarf-enriched distribution in the most massive systems (see, e.g., van Dokkum & Conroy 2010; Ferreras et al. 2013; La Barbera et al. 2013). Dynamical and strong-lensing constraints of the stellar M/L in similar systems give similar results, with heavier M/L in the most massive ETGs (see, e.g., Cappellari *et al.*2012; Posacki *et al.*2015). Although the interpretation of the results is still open to discussion (e.g., Smith 2014; La Barbera 2015), one should consider the consequences of such a bottom-heavy IMF in massive galaxies.

The physical properties of the interstellar medium during the formation of a massive ETG must be very different from the typical star forming regions observed in the local Universe. Given the old, metal rich and mostly co-eval stellar populations found in these galaxies (e.g. de la Rosa *et al.*2011), one should expect turbulence to play a major role during the fragmentation of the gas clouds into pre-stellar cores. Simulations and analytic models have suggested a transition towards an excess of low-mass clumps in highly supersonic, turbulent environments (see, e.g., Padoan & Nordlund 2002; Hopkins 2013; Chabrier et al. 2014). Weidner *et al.*(2013) applied a simple model of galactic chemical enrichment to show that a *time invariant*, bottom-heavy IMF was not capable of producing the most fundamental constraints of the stellar populations of massive ETGs. An excess of low-mass stars locks too much long-lived stellar mass at low metallicity, as the enrichment process is highly suppressed. Moreover, other functional forms of the IMF, such as an enhancement *both* at the low- and the high-mass end (i.e. a "V-shaped function") give similar results (Ferreras *et al.*2015). Fig. 1 shows the simplest alternative option to reconcile a bottom-heavy IMF, from the observations of the passive populations at present time, with galactic chemical enrichment. Such a scenario (from Weidner et al. 2013; see also Vazdekis *et al.*1996) involves an initial stage, where the IMF is either the standard Milky-Way type, or even top-heavy. During this phase, the bulk of metal enrichment takes place. This phase is followed by a change in the IMF – motivated by the intense stellar feedback – towards an increased fragmentation, producing an excess of low-mass stars. During this phase, the bulk of the stellar mass is formed, locking the elements produced during the first stage. Such a scenario would produce old, metal-rich, α-enhanced populations, with an excess of low-mass stars.

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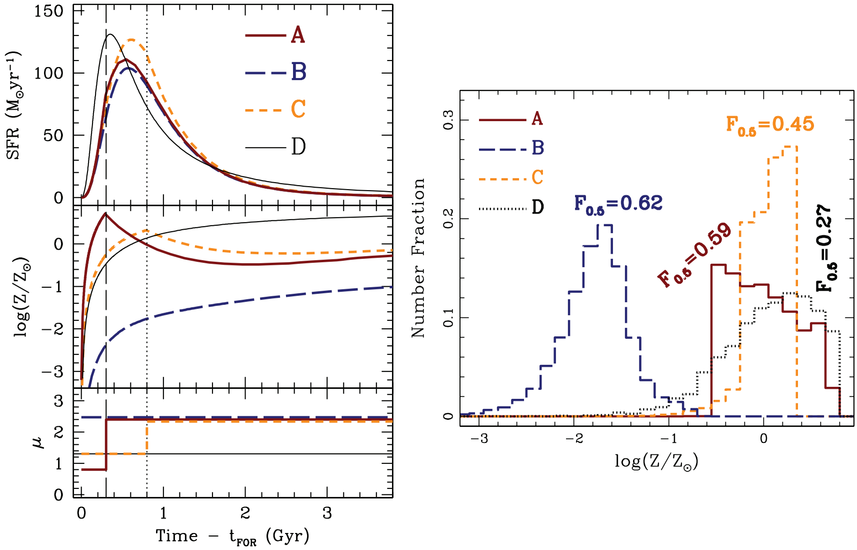

Figure 1. *Left:* Typical star formation history of a massive early-type galaxy, dominated by an early, strong, and short-lived burst of star formation (top). The middle panel shows the evolution of the metallicity in the newly formed stellar populations. The bottom panel gives the adopted evolution of the IMF slope of the four models (A,B,C,D, with $\mu >1.3$ giving an IMF more bottom-heavy than the Milky Way standard). *Right:* Distribution of stellar metallicities in the models at zero redshift. The labels denoted $F_{0.5}$ give the mass fraction in young stars, at birth, with masses below $0.5 M_\odot$. Note the spectroscopic constraints from gravity-sensitive features suggest $F_{0.5} \gtrsim 0.6$. Figures from Weidner et al. (2013)

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