Origin of the Galaxy Mass-Metallicity-Star-Formation Relation

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Abstract

We describe an equilibrium model that links the metallicity of low-redshift galaxies to stellar evolution models. It enables the testing of different stellar initial mass functions and metal yields against observed galaxy metallicities. We show that the metallicities of more than 10^5 Sloan Digital Sky Survey (SDSS) galaxies in the low-redshift range $0.07 \leq z \leq 0.3$ considerably constrain stellar evolution models that simultaneously relate galaxy stellar mass, metallicity, and star formation rates (SFRs) to the infall rate of low-metallicity extragalactic gas and outflow of enriched matter. A feature of our model is that it encompasses both the active star forming phases of a galaxy and epochs during which the same galaxy may lie fallow. We: (i) determine the fraction of their lives that the selected SDSS galaxies in different mass ranges spend in star-forming phases; (ii) make use of data on extragalactic metallicities in estimating the metallicity of matter falling into these galaxies; (iii) find no significant change in metallicity at an approximately 1% level in more than 8000 of the most reliably documented low-mass galaxies over a 0.5 Gyr epoch; (iv) find no significant increase or decrease in infall rate over this time span; (v) but, at a level of a few percent, do find a significantly reduced metallicity in galaxies of increasing radius as would be expected from their lower gravitational potential at large radii and a correspondingly increased loss of high-metallicity supernova ejecta. Finally, we derive quantitative expressions relating infall, star-formation, and outflow to the mass-metallicity-star-formation data.