Mid-Ultraviolet Spectral Diagnostics of Galaxy Evolution

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Abstract. We describe how optical spectra of $z = 1 - 2$ galaxies can help test the hypothesis of hierarchical galaxy formation.

1 Introduction

The Redshift Desert of galaxies ($z \cong 1 - 2.5$) is rapidly being converted into the Redshift Riviera thanks to new, deep galaxy surveys at Keck, Gemini, VLT, and other large, ground-based telescopes. As we have seen (Steidel, this conference; Crampton, this conference), this redshift region is rich in star-forming galaxies, which can be used to track the progress of galaxy assembly. The Redshift Riviera is also rich in somewhat older galaxies, whose restframe mid-UV spectrum gives clues to the formation and evolution of galaxies. It is these intermediate-age galaxies that we wish to discuss today. As shown in Figure 1, intermediate-age galaxies can be at any age up to 3 Gyr old at $z \sim 2.5$, and up to 6 Gyr old at $z \sim 1$, depending on the redshift of formation. By our definition, intermediate-age galaxies are older than about 0.5 Gyr.

Figure 2 shows the isochrone of a typical intermediate-age stellar population. As happens for all populations younger than 6 Gyr, the hottest stars are those at the Main-Sequence Turn-off (MSTO). (Stellar populations older than 6 Gyr have horizontal-branch stars, which could be hotter than the MSTO stars.) Since the wavelength of peak flux decreases with increasing temperature, there will be a spectral region where MSTO stars – and only MSTO stars – are bright. For intermediate-age galaxies, that region is the mid-UV (2000-3000 Å), which at $z > 1$ is conveniently redshifted into the domain where large, groundbased telescopes are sensitive. By viewing galaxies in the restframe mid-UV, we can cleanly isolate the MSTO stars, which are the timekeepers of stellar evolution. The restframe mid-UV spectrum of such a stellar population looks like the spectrum of a single F-type star, so estimating the age of that population should be no harder than analyzing the spectrum of a single star.

Of course, galaxies are not single stellar populations. Particularly under the hypothesis of hierarchical galaxy formation, massive galaxies are composite: they consist of many generations of stars with the oldest ones generally being the most metal-poor. In this more complex scenario, the MSTO stars producing the mid-UV spectrum belong to the youngest stellar population of the galaxy. In other words, the mid-UV spectrum gives the age since the most recent episode of star-formation, not the age of the galaxy.

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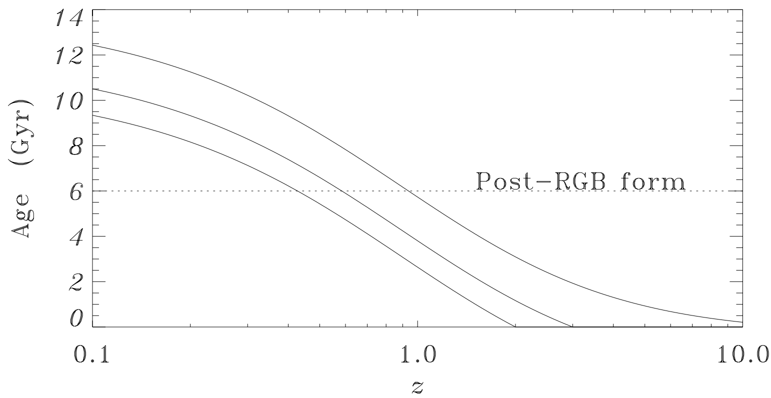

Fig. 1. Galaxy ages as a function of redshift for three different formation redshifts: $z_f =$ 2, 3, and 15. The concordance cosmology is assumed: $\Omega_M = 0.3,\ \Omega_\Lambda = 0.7,\quad H_0 = 67$. The dotted line shows the age at which post-RGB stars form.

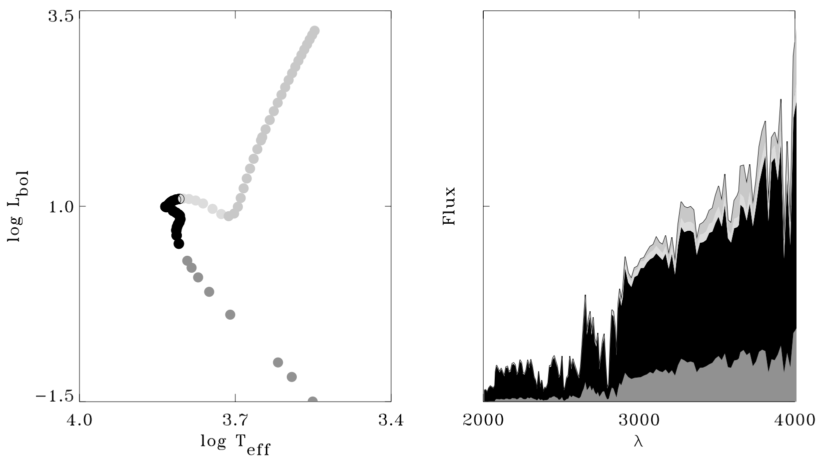

Fig. 2. Production of the mid-UV flux by MSTO stars. Left: isochrone of a 2 Gyr-old stellar population with a solar metallicity. Main sequence stars, stars on the MSTO (black), subgiants, and red-giants are shown in different shades of gray. Right: contributions to the SED by the four stellar components. Below 3000 Å, MSTO stars contribute nearly all the flux.

This more restricted meaning of age does not put us at a disadvantage. In fact, it helps provide a direct observational test of hierarchical galaxy formation. Please refer back to Figure 1. If we find giant ellipticals at $z \sim 1$ with mid-UV ages of 5-6 Gyr, then we will have proof that at least some massive galaxies were fully formed at a very early epoch. If instead we find that $z \sim 1$ galaxies have ages