K-LUMINOUS GALAXIES AT Z ∼ 2

Metallicity and B Stars

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Abstract We present the results from the analysis of the composite spectrum of five near-IR luminous (K < 20) galaxies at z ∼ 2. Several of the strongest absorption lines are present in the UV spectrum of the merging galaxy NGC 6090 and not in the spectra of Lyman Break Galaxies at z ∼ 3. They were identified as Si\textsc{ii} λ1296, C\textsc{iii} λ1428, Si\textsc{ii} λ1485, and Fe ∼ λ1380 Å, which are photospheric lines typical of B stars. A metallicity higher than solar is suggested by comparing the pure photospheric lines known as the 1425 Å index (Si\textsc{ii}, C\textsc{iii}, Fe\textsc{v}) with \textsc{Starburst99} models. The evidence of high metallicity, together with the high masses, high star-formation rates, and possibly strong clustering, suggest that these galaxies are candidates to become massive spheroids.

1. Introduction – The K20 Survey

A key open question in galaxy evolution is the epoch of formation of massive spheroidal galaxies. As the rest-frame optical–near-infrared traces the galaxy mass, the K\textsubscript{s} band allows a fair selection of galaxies based on their masses up to z ∼ 2. Based on this, a VLT spectroscopic survey of about 500 galaxies with K<sub>s</sub> < 20 in the GOODS southern field was conducted (Cimatti et al. 2002). In this contribution (see also de Mello et al. 2004), we analyze the average spectrum of five K20 galaxies at 1.7 < z < 2.3 with the highest S/N ratios among the ones presented in Daddi et al. (2004). These K < 20 galaxies at z ∼ 2 appear to be massive (≥ 10\textsuperscript{11} M\odot) and have high star-formation rates (SFR 100–500 M\odot yr\textsuperscript{-1}; Daddi et al. 2004), thus qualifying as good candidates for assembling/forming massive early-type galaxies.

2. Local starbursts and B stars

We have compared the K20 average spectrum with the local starburst galaxies NGC 1705, NGC 1741, NGC 4214, and NGC 6090. The best match is ob-
tained with NGC 6090 which is an interacting system at \( v \sim 9062 \text{ km s}^{-1} \), and in the process of merging. It is a luminous infrared galaxy \( \log L_{\text{IR}} = 11.51 \) \((L_{\odot}; \text{Scoville et al. 2000})\), containing a number of luminous clusters triggered by the galaxy-galaxy interaction. The Sloan Digital Sky Survey \( r \)-band image (Fig. 1) \(^1\) shows tidal tails that extend several arcminutes from the two merging objects. \( HST/NICMOS \) images of NGC 6090 (Scoville et al. 2000) show the inner site of the interaction in more detail, where a less massive galaxy seems to be merging with a disk. The spectrum of NGC 6090 taken by the HUT during the Astro-2 mission (González Delgado et al. 1998) is shown in Fig. 2. It has several absorption lines which are similar in strength to the K20 composite spectrum, such as the photospheric lines \( \text{Si} \text{ii} \lambda 1295 \text{ Å}, \text{C} \text{ii} \lambda 1430 \text{ Å} \) and \( \text{Si} \text{ii} \lambda 1465 \text{ Å} \), and a marginally weaker \( \text{Fe} \text{v} \lambda 1380 \text{ Å} \) line.

In order to search for the stellar population from which these photospheric lines originate, we examined a far-UV (IUE) library of Milky Way OB stars (de Mello et al. 2000). The similarity between the spectra of B stars and the K20 composite spectrum is remarkable. In Figs. 3 and 4, we show the average spectrum of two main sequence stars (B0V and B8V) and a supergiant (B3I), where the main photospheric lines are identified. B stars live longer than the more luminous short-lived O stars and become a major source of the UV flux in the integrated spectrum of starbursts. The photospheric lines found in the spectrum of K20 galaxies, and in NGC 6090, are stellar features of B stars.