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THE SPECTRAL EVOLUTION OF GALAXIES. I. AN OBSERVATIONAL APPROACH[1]

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ABSTRACT

We have conducted a major new spectrophotometric survey of giant elliptical galaxies in order to measure changes due to spectral evolution. The data set consists of good spectrophotometry on 33 galaxies to a redshift of $z = 0.8$. The look-back time for this redshift, $H_0 \approx 50$ km s^{-1} Mpc^{-1}, $q_0 \approx 0$, is 7–8 Gyr, which is about half the age of the universe.

Our objects were chosen from a new multicolor (*ugri*), multifield survey using the prime focus cameras of the KPNO and CTIO 4 m telescopes. All plates were scanned by a microdensitometer and reduced with the KPNO implementation of FOCAS. Our primary selection criterion was redness in color-color diagrams. The galaxies selected for the spectrophotometric program were not always the reddest giant elliptical galaxies, but an attempt was made to sample along the perceived color distribution of these galaxies. It is hoped that this procedure reduces any potential biases. This is the first survey to be conducted which selects program objects according to optical colors. We intentionally did not select galaxies which are members of the cores of rich clusters of galaxies; those observed are also known not be radio sources. No other survey has yet been conducted in this manner or spirit, with control over known selection effects.

The amplitude of the 4000 Å break was used as the indicator of spectral evolution. The data of the evolution diagram (redshift vs. break amplitude) indicate that a change of less than 7% in the break amplitude is evident at the high-redshift end, $z \approx 0.8$. These data also indicate that giant elliptical galaxies are much older than 8 Gyr, and within simple Friedmann models we suggest, therefore, H_0 is less than 70 km s^{-1} Mpc^{-1} for $q_0 \approx 0$. Only for $H_0 \lesssim 32$ km s^{-1} Mpc^{-1} is $q_0 > 0.5$ possible.

The observed width of the break amplitude distribution for all program galaxies indicates the validity of the assumption of coevality to within ± 2 Gyr to a redshift of $z \approx 0.8$.

Extension of the evolution diagram to higher redshifts ($0.8 < z < 1.0$) will provide valuable constraints on galaxy evolution and help enlighten our knowledge of any potential biases that the red-selection criteria may have introduced.

Subject headings: cosmology — galaxies: evolution — galaxies: photometry — spectrophotometry

I. MOTIVATION

It was realized very early on in the establishment of the cosmological problem that at sufficiently high redshifts (or large light-travel times) the character of the light from distant galaxies would be different from that of low-redshift objects of the same type (Hubble and Tolman 1935). The difference would arise from having different main-sequence turnoff points; the more distant galaxies would have a younger population of stars. The character of the light in the ultraviolet-blue region of the spectrum would, therefore, become systematically bluer with increasing redshift. This is illustrated in Figure 1, where the hydrogen-burning lifetime of some main-sequence stars is displayed along with the redshift and look-back time for various values of the deceleration parameter q_0. It is through this relation that the hydrogen-burning lifetime of stars determines the evolutionary rate of change to the intrinsic light of galaxies. The time scale for cosmology is set through the Hubble constant.

The gradient of this bluing effect with redshift is also depen-

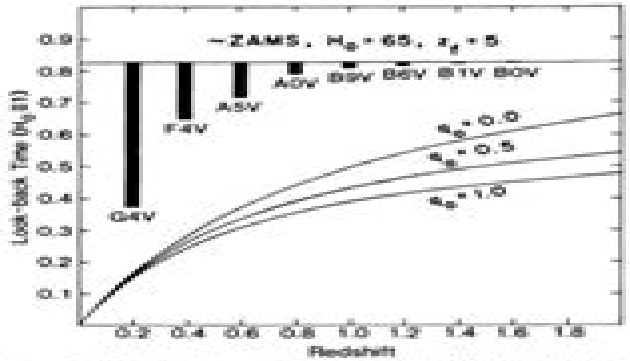

FIG. 1.—Look-back time as a function of redshift. In order to place the look-back time on an absolute basis we have assumed that $H_0 = 65$ km s^{-1} Mpc^{-1}. Length of black bar schematically represents lifetime of a star. Redshift of formation is $z = 5$, corresponding to a look-back time of 12.8 Gyr for $H_0 = 65$ km s^{-1} Mpc^{-1} and $q_0 = 0$. We have assumed spectral types for an approximate zero-age main sequence. Stellar ages from Iben (1967).

[1] Presented as a thesis to the Department of Physics, University of Chicago, in partial fulfillment of the requirements for the Ph.D. degree.

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Spectral Evolution Of Galaxies

B. Barbuy,Alvio Renzini

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