

THE SPECTRAL EVOLUTION OF GALAXIES. I. AN OBSERVATIONAL APPROACH¹

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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, $H_0 \approx 50 \text{ km s}^{-1} \text{ Mpc}^{-1}$, $q_0 \approx 0$, 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 to 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 $70 \text{ km s}^{-1} \text{ Mpc}^{-1}$ for $q_0 \approx 0$. Only for $H_0 \leq 32 \text{ km s}^{-1} \text{ Mpc}^{-1}$ 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

1. 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-

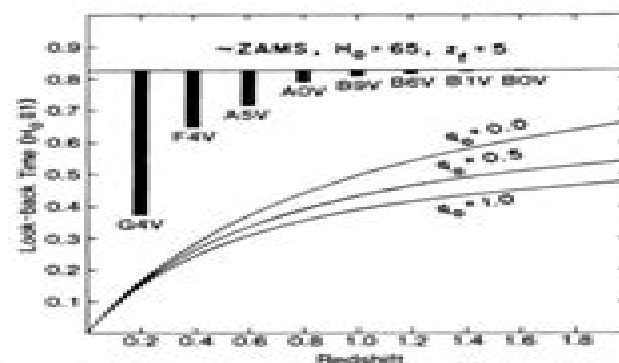


FIG. 1.—Look-back time as a function of redshift. In order to place the look-back time on an absolute basis we have assumed that $H_0 = 65 \text{ km s}^{-1} \text{ Mpc}^{-1}$. Length of black bar schematically represents lifetime of a star. Redshift of formation is $z = 5$, corresponding to a look-back time of 12.8 Gyr for $H_0 = 65 \text{ km s}^{-1} \text{ Mpc}^{-1}$ 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

Jacqueline Bergeron



Spectral Evolution Of Galaxies:

Spectral Evolution of Galaxies C. Chiosi, Alvio Renzini, 2012-12-06 As it was said by one of the participants to this workshop In our attempts to understand the spectral evolution of galaxies we are fortunate indeed to have the ability to look back in time and observe galaxies as they were billions of years ago Perhaps in no other discipline is it possible to gain such a direct view to history The galaxies we seek to study are remote their light faint and thus only recently has it become technically feasible to sample the spectra of normal luminosity galaxies at lookback times of five billion years or more or perhaps even to see galaxies in the process of their formation or shortly afterwards This fourth workshop organized by the Advanced School of Astronomy was indeed centered on the Spectral Evolution of Galaxies on reviewing and discussing the relevant astrophysical processes and on assessing our current ability to model and understand the evolution of stellar populations Following an opening session dealing with some outstanding questions of galaxy evolution Session I addressed the specific problems of galaxy and star formation processes topics of uncertainty and controversy to which IRAS observations may give novel perspectives The properties of stellar populations in the local group of galaxies formed the basis of Session II Session III dealt with the fundamentals of the theory of spectral and photometrical evolution of stellar populations and with recent developments in the theory of stellar structure a necessary step to model and understand galactic evolution

SPECTRAL EVOLUTION OF GALAXIES Gustavo Ramon Bruzual-Alfonzo, 1981 Spectral evolution of galaxies, 1984

The Spectral Evolution of Galaxies Donald Hamilton, 1986 **Spectral Evolution of Galaxies** Rutherford Appleton Laboratory, **Spectral Evolution of Galaxies** Cesare Chiosi, Alvio Renzini, 1986 **Spectral Evolution of Galaxies** Cesare Chiosi, Alvio Renzini, 1986 **Spectral Evolution of Galaxies** Rutherford Appleton Laboratory. Workshop on Astronomy and Astrophysics, 1984 Nearly Normal Galaxies Sandra M. Faber, 2012-12-06 It is sometimes said that astronomy is the crossroads of physics In the same spirit it can forcefully be argued that galaxies are the crossroads of astronomy Internal processes within galaxies involve all of the fundamental components of astrophysics stellar evolution star formation low density astrophysics dynamics hydrodynamics and high energy astrophysics Indeed one can hardly name an observational datum in any wavelength range on any kind of celestial object that does not provide a useful clue to galaxy formation and evolution Although internal processes in galaxies until recently occupied most of our attention we now know that it is also vital to relate galaxies to their environment How galaxies conglomerate in larger structures and are in turn influenced by them are crucial questions for galactic evolution On a grander level we have also come to regard galaxies as the basic building blocks of the universe the basic units whereby the large scale structure of the universe is apprehended and quantified On a grander level still we also believe strongly that galaxies are the direct descendants of early density irregularities in the Big Bang Galaxy properties are now viewed as providing a crucial constraint on the physics of the Big Bang and a vital link between the macroscopic and microscopic structure of the universe Spectral Evolution of Galaxies

P. M. Gondhalekar,1983 **Spectral Evolution of Galaxies** P. M. Gondhalekar,1984 Literature 1986, Part 1 Prof. Dr. Roland Wielen,S. Böhme,U. Esser,H. Hefele,Inge Heinrich,W. Hofmann,D. Krahn,V. R. Matas,Dr. Lutz D. Schmalde,G. Zech,2013-04-17 *Galaxies at High Redshift* I. Pérez-Fournon,2003-03-20 This volume presents lectures of the XI Canary Islands Winter School of Astrophysics written by experts in the field **The Mass of Galaxies at Low and High Redshift** Ralf Bender,2003-01-23 Measuring the masses of galaxies as a function of redshift is perhaps one of the most challenging open issues in current astronomical research The evolution of the baryonic and dark matter components of galaxies is not only a critical test of the hierarchical formation paradigm but ultimately also provides new clues on the complex interplay between star formation the cooling and heating of gas and galaxy merging processes This book reviews current techniques to measure the baryonic stellar and dark masses of nearby galaxies and focusses on ongoing attempts to measure these same quantities in galaxies at higher and higher redshifts It also gives room to future perspectives with special emphasis on new survey projects and satellite missions **Towards Understanding Galaxies at Large Redshift** Richard G. Kron,Alvio Renzini,2012-12-06 This workshop was intended as an update and an extension of the workshop 011 the Spectral Evolution of Galaxies that was held in Erice two years ago It concentrates 011 the developments concerning galaxies seen at large look back times This seemed also a good opportunity to look ahead to the next generation of ground and space based instrumentation and to consider various future strategies for collecting information concerning the edge of the observable universe The main idea was to bring together people with specialities in modelling galaxy components such as stars clusters gas and dust as well as whole stellar systems stellar populations star formation rates chemical enrichment and people specialized in making direct measurements of galaxies and clusters at large look back times The confrontation of expectations and observations was planned to be the central theme of the conference which explains the title Towards Understanding Galaxies at Large Redshift The first part of the workshop focussed on the physical processes that operate in galaxies and that would likely have some observable manifestation at large redshifts In the second part the most recent observational work was reported and we were pleased to have the participation of most of the groups active in this field The last part was directed towards new approaches to be made possible by the next generation of instrumentation although in general all the contributions were indeed in this spirit of setting more ambitious goals High Redshift and Primeval Galaxies Jacqueline Bergeron,1987 **The Stellar Populations of Galaxies** B. Barbuy,Alvio Renzini,2012-12-06 One approach to learning about stellar populations is to study them at three different levels of resolution First in our own Galaxy secondly from nearby galaxies where stars can still be resolved and thirdly in remote galaxies in which the stellar population can only be studied in integrated light This IAU Symposium covered the entire range of galaxies in its study of their stellar populations Interspersed with theoretical papers the wealth of observational results provides an important state of the art presentation of the progress that has been made in this field *Extragalactic Astronomy and Cosmology* Peter

Schneider,2014-10-08 This second edition has been updated and substantially expanded Starting with the description of our home galaxy the Milky Way this cogently written textbook introduces the reader to the astronomy of galaxies their structure active galactic nuclei evolution and large scale distribution in the Universe After an extensive and thorough introduction to modern observational and theoretical cosmology the focus turns to the formation of structures and astronomical objects in the early Universe The basics of classical astronomy and stellar astrophysics needed for extragalactic astronomy are provided in the appendix While this book has grown out of introductory university courses on astronomy and astrophysics and includes a set of problems and solutions it will not only benefit undergraduate students and lecturers thanks to the comprehensive coverage of the field even graduate students and researchers specializing in related fields will appreciate it as a valuable reference work **New Aspects of Galaxy Photometry** Jean-Luc Nieto,2005-12-01 Star-Formation Rates of Galaxies Andreas Zezas,Véronique Buat,2021-04-29 Star formation is one of the key processes that shape the current state and evolution of galaxies This volume provides a comprehensive presentation of the different methods used to measure the intensity of recent or on going star forming activity in galaxies discussing their advantages and complications in detail It includes a thorough overview of the theoretical underpinnings of star formation rate indicators including topics such as stellar evolution and stellar spectra the stellar initial mass function and the physical conditions in the interstellar medium The authors bring together in one place detailed and comparative discussions of traditional and new star formation rate indicators star formation rate measurements in different spatial scales and comparisons of star formation rate indicators probing different stellar populations along with the corresponding theoretical background This is a useful reference for students and researchers working in the field of extragalactic astrophysics and studying star formation in local and higher redshift galaxies

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