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ABSORPTION LINE GRADIENTS IN THE SPECTRUM OF AN ELLIPTICAL GALAXY NGC 5846A

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ABSTRACT

The archival long-slit spectra, covering the wavelength range 4050 ~ 5150 Å, have been used to investigate the radial behavior of absorption line features (G4300, Fe4383, Ca4455, Fe4531, and Hβ) of an elliptical galaxy NGC 5846A. The heliocentric recession velocity of NGC 5846A has been derived as $1949 \pm 87\ kms^{-1}$. Fe absorption lines of NGC 5846A show significant radial gradients with the mean slope of Δ<Fe>/$\Delta(r'')=-0.863\pm0.202$. There is also a significant radial gradient of G band with a slope of -1.109 ± 0.098. On the other hand, no radial gradients has been detected on the Ca4455 and Hβ absorptions of NGC 5846A. A metallicity gradient, which is derived from the Fe line gradients, is similar to the abundance gradient predicted by Larson's (1975) dissipative models for the formation of elliptical galaxies. We also note that a galaxy-galaxy interaction could affect the line gradients of NGC 5846A.

1. INTRODUCTION

The study of absorption line-strength gradients in early type galaxies provides fundamental information for testing models of galaxy formation and evolution. Early photoelectric (e.g., Sandage & Visvanathan 1978) and photographic (e.g., Strom & Strom 1978) surveys and the compiled CCD aperture photometry data (Prugniel & Heraudeau 1998) of elliptical galaxies revealed that the majority of these systems contain color gradients, in the sense that the nuclear regions are redder than the surrounding spheroid. Metallicity gradients, which are predicted to occur as a consequence of dissipation during the initial collapse of galaxies (e.g., Larson 1975, Carlberg 1984), seem to be the most reasonable explanation for the observed radial color variations. Moreover, it is now well established that radial stellar popualation gradients exist in many elliptical galaxies which can be seen in broad band photometry (e.g., Peletier et al. 1990 and refernces therein) and abosorption line strength measurements (e.g., Davies et al. 1993, Gorgas et al. 1990). However, there are evidences that dissipation may not be the only physical processes responsible for producing metallicity gradients, and color gradients may also be influenced by the dynamical interactions, which are relatively common occurrences during the evolution of most galaxies (e.g., Kormendy & Djorgovski 1989). There are also indications that radial abundance gradients would be weak if ellipticals are formed by dissipationless hierachical merging (White 1980, Gott 1975). Local environments would also affect the collapse history of elliptical galaxies (e.g., Davidge & Clark 1994).

To date, a few measurements of line strength gradients in elliptical galaxies have been published, from which no strong correlations between the size of the gradient and any other global parameter of the galaxies, such as luminostity or flattening, have been detected (see Sohn et al. 1999). Note the conclusion that line gradients are primarily driven by radial metallicity gradients is by no means certain. Line indices in galaxies may reflect some complex combination of age and metallicity effects (Burstein et al. 1984, Burstein 1985, Faber et al. 1992, Worthey et al. 1992). Moreover, a calibration between line strength and metallicity is extremly complicated for an unresolved composite stellar population because variations in age and the initial mass function can also produce gradients in the strengths of spectral features (Lee et al. 1999).

In this paper, we report radial absorption line indices (G4300, Fe4383, Ca4455, Fe4531, and Hβ) distributions of NGC 5846A (UGC 9706) derived from the archival long-slit spectroscopic data, which was obtained from the 3.6m Canada-France-Hawaii Telescope (CFHT). NGC 5846A is an cE2-3 elliptical galaxy (de Vaucouleurs et al. 1991), which is located immediately south of a giant elliptical galaxy NGC 5846. Davidge (1991) did not find clear radial trends on the Mg_1 and Mg_2 line indices of NGC 5846A from the long-slit spectroscopy.

2. DATA AND DATA REDUCTIONS

The archival long-slit spectral data of NGC 5846A, which were obtained during the night of July 21 1991 using the Herzberg spectrograph mounted at the $f/8$ focus of the 3.6m Canada-France-Hawaii Telescope (CFHT) by T.J. Davidge and J.L. Nieto, were retrieved from the CADC (Canadian Astronomy Data Center). The detector was LICK2, a three phase thick Ford Aerospace designed CCD with 15 μm square pixels in a 2048 × 2048 format. Each pixel subtended 0.63 Å along the dispersion axis and 0.43 arcsec along the slit, which has a projected length of 131 arcsec. The slit was opened to a width of 3 arcsec, and two 1200 seconds exposures were recorded. The resolution of the data, as measured from the FWHM of arc lines, is $\sim$ 3.5 Å.

Data reduction consisted of the following steps: (1) bias subtraction; (2) division by a flat field frame, to correct for pixel-to-pixel variations in detector sensitivity, as well as vignetting along the slit; (3) wavelength calibration, based on observations of a Fe/Ar arc which were recorded following each set of observations; (4) alignment and coaddition of the spectra; and (5) background subtraction. To correct for the additional background component from the companion galaxy NGC 5846, a template spectrum was constructed from data on the opposite side of NGC 5846 in an interval spanning the same range of galactocentric radii as NGC 5846A, and the result was subtracted from NGC 5846A spectrum. The final wavelength range of the spectra is 4050 $\sim$ 5150 Å.

One dimensional spectra were then constructed by summing the sky subtracted two dimensional spectra in the spatial direction. Five radial intervals, defined according to distance from the center of the galaxy, were used to bin the data of the major axis: (1) 0 - 0.64 arcsec; (2) 0.64 - 1.50 arcsec; (3) 1.50 - 3.21 arcsec; (4) 3.21 - 6.63 arcsec; (5) 6.63 - 17.31 arcsec. One dimensional spectra were corrected for atmospheric extinction using the extinction curve published by Beland et al. (1988), derived from previous CFHT observing runs. The summed spectra were then flattened by a continuum function, which was empirically determined by a polynomial fit. A 6th order function was fitted to the one dimensional spectra of the galaxy.

3. MEASUREMENT OF SPECTRAL FEATURES

Portions of the final binned spectra are shown in Figure 1. The strengths of various

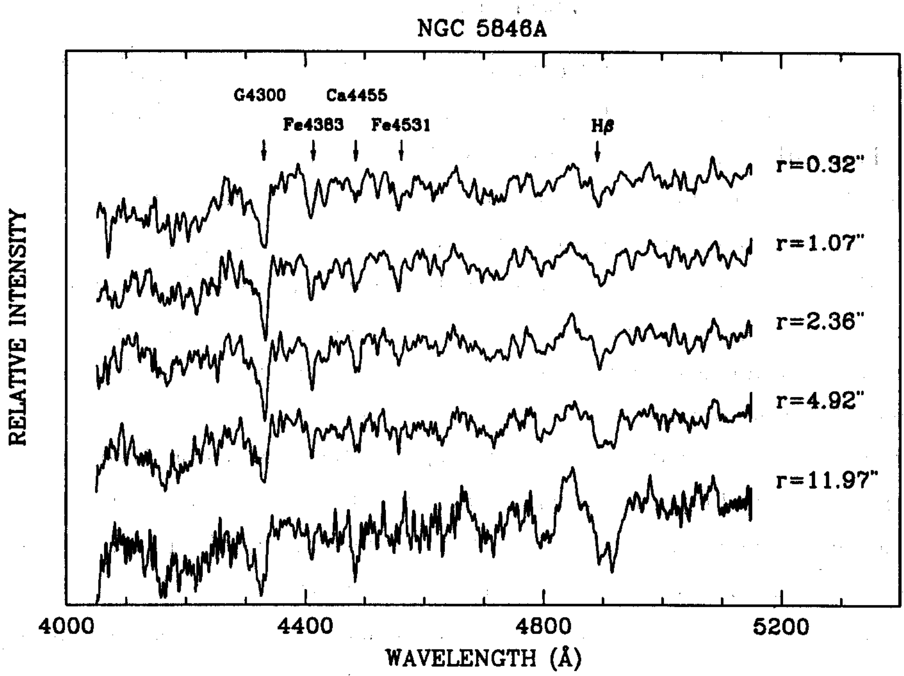

Figure 1. Spectra of NGC 5846A in the wavelength interval 4050 ~ 5150 Å ordered according to distance from the nucleus. The location of various features considered in this study are indicated.

absorption features in the spectra of NGC 5846A were measured using the line and continuum positions defined by Worthey et al. (1994). The resulting spectral indices are specified as equivalent widths of G 4300, Fe 4383, Ca 4455, Fe 4531, and Hβ in Å. An interactive multi-Gaussian fitting task SPLOT in IRAF has been applied to measure equivalent widths and central wavelengths of each line.

The radial velocity of NGC 5846A was estimated from central wavelengths of each line as 1949 ± 87 kms^{-1}, where the uncertainty is the standard error of central wavelength measurements of each line. This value is comparable to the recession velocity of NGC 5846A, $v_r = 2201 \pm 14$ kms^{-1}, quoted from RC3 (de Vaucouleurs et al. 1991). The indices measured from the spectra of NGC 5846A are listed in Table 1. The uncertainties listed in

Table 1. Spectral indices for NGC 5846A

Index	$0''.32$	$1''.07$	$2''.36$	$4''.92$	$11''.97$
G4300	6.34 ± 0.07	5.78 ± 0.10	5.61 ± 0.11	5.07 ± 0.15	4.57 ± 0.25
Fe4383	3.27 ± 0.12	3.14 ± 0.12	2.92 ± 0.18	2.62 ± 0.19	1.74 ± 0.25
Ca4455	1.36 ± 0.13	1.36 ± 0.13	1.50 ± 0.15	1.52 ± 0.14	
Fe4531	2.43 ± 0.15	2.26 ± 0.16	1.77 ± 0.16	1.51 ± 0.19	
Hβ	2.62 ± 0.10	2.46 ± 0.14	2.25 ± 0.13	2.51 ± 0.17	

these tables are standard errors of the mean.

4. ABSORPTION LINE GRADIENTS

The strengths of various absorption features of NGC 5846A are plotted as a function of log (radius) in Figure 2. The unweighted least square fits between the various spectral indices and $\log(r'')$ were applied to the data in Table 1 in an effort to determine the amplitude of radial apsorption line gradients in NGC 5846A. The resulting slopes, $\Delta index/\Delta \log(r)$, are summarized in Table 2.

It is apparent that the strengths of the Fe lines of NGC 5846A change with radius in the sense that they become weaker in the outer regions. There is still a significant G band line gradient. The mean slope of Fe line gradients of our measurements (Fe4383, Fe4531) is estimated as -0.863 ± 0.202. Line gradient of G band (-1.109 ± 0.098) is much steeper than those of Fe lines.

Table 2. Line gradients, $\Delta index/\Delta \log(r)$, for NGC 5846A

Index	major axis
G4300	-1.109 ± 0.098
Fe4383	-0.917 ± 0.243
Ca4455	0.152 ± 0.055
Fe4531	-0.808 ± 0.160
Hβ	-0.159 ± 0.184

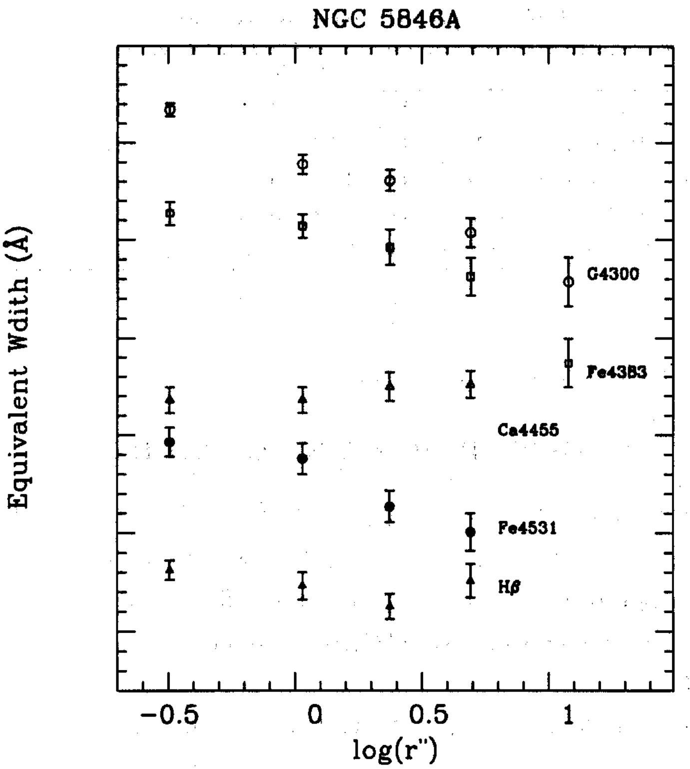

Figure 2. The behavior of various line indices in NGC 5846A as a function of the logarithm of the distance from the center of the galaxy, measured in arcsec.

The mean Fe lines gradient of NGC 5846A in this paper is pretty larger than the mean <Fe> of -0.38 ± 0.26 derived by Davies et al. (1993) for 13 elliptical galaxies and -0.58 ± 035 quoted by Gorgas et al. (1990) for a combined sample of elliptical, cD and SO galaxies. But, it is very similar to the mean of -0.87 ± 0.31 found by Davidge (1992) from long-slit spectra of eleven bright elliptical galaxies. The line gradient of G band is comparable to the previously determined mean value of elliptical galaxies (Davidge & Clark 1994), i.e., ΔCH/Δ log $(r)= -0.82$. It is apparent that the absorption line gradient of Ca4455 shows a remarkable discrepancy to the mean value ΔCaH&K/Δ log $(r)= -0.80$ of elliptical galaxies derived by Davidge & Clark (1994). We note, however, total six sample galaxies of Davidge & Clark (1994) show an unusually wide range of ΔCaH&K/Δ log (r), i.e., $-4.42 \sim 6.30$.

Radial profiles of metal lines would be interpreted in terms of radial variations in metallicity of stellar populations. If elliptical galaxies form purely by dissipational collapse, then they should have steep abundance gradients (Larson 1976, Carlberg 1984). In theoretical models (e.g. Larson 1976), the shape of the metallicity gradient is fixed by the star formation rate; steep metallicity gradients are produced if the star formation rate is slower than the time scale for gas to sink in the central region, a factor of 10 reduction for a factor of 10 increase of radius. Conversely, a purely stellar merger origin for elliptical galaxies produces no metallicity gradients. Using the calibration by Faber et al. (1985), and assuming that radial change of Fe lines in NGC 5846A is due to metallicity changes alone, we derive an abundance gradient of -0.45 ± 0.20 in [Fe/H]. This value is much larger than the value Δ[Fe/H]/Δlog(r) for ellipfical galaxies of -0.21 ± 0.10 derived by Davies et al. (1993), -0.22 ± 0.10 derived from the Mg_2 index by Gorgas et al. (1990), and -0.25 derived by Couture & Hardy (1988). But, it is similar to the abundance gradient of $d\log Z/d\log r \sim -0.35$ predicted by Larson's (1975) dissipative models for the formation of ellipticals.

No significant radial gradients has been detected on the Hβ absorptions of NGC 5846A. This result is in good agreement with Davies et al. (1993) who showed that Hβ absorption is constant or increase with increasing radius of elliptical galaxies, suggesting that profiles arise at the central region because of the weak emission in the galaxy nuclei. There are evidences that a number of elliptical galaxies have weak emissions in their nuclei and sometimes further out (Phillips et al. 1986, Caldwell 1984).

Considering simply to the dissipative and dissipationless collapse models, the values of radial gradients for metal and Hβ absorption lines of NGC 5846A imply that this galaxy could be formed through the dissipative collapse during the initial stage of the galaxy formation rather than hierarchical merging and dissipationless collapse. We note, however, a present galaxy-galaxy interaction with its companion galaxy NGC 5846 could also affect the line gradients of NGC 5846A. Davidge (1991) pointed out that the stellar content of NGC 5846A may not be distributed symmetrically about the nucleus, indicating a galactic interaction due to the close proximity to NGC 5846. We caution here that the conversion from line strength gradients to the abundance gradient is not straightforward. The population components sampled along the line of sight may be neither coeval nor of uniform metallicity (Davies et al. 1993, Tinsley & Gunn 1976). Therefore, to gain a better understanding of the abundance and age variation and, thus the formation history of NGC 5846A, it is necessary to compare the composite spectral synthesis models with high quality spectroscopy over a wide wavelength range. We expect that our measurements of line indices in this particular galaxy NGC 5946A will be able to give observational constraints to the theoretical models of elliptical galaxy formation. As pointed out by many authors (e.g., Ferguson 1995, Faber et al. 1995) in this field, the effects of warm stellar populations such as horizontal-brach stars and blue stragglers, and of sizable metallicity spreads expected in elliptical galaxies are not studied fully yet, and thus it is obviously needed to construct new population synthesis models.

5. SUMMARY

The archival long-slit spectral data of an elliptical galaxy NGC 5846A, covering the wavelength range 4050 $\sim$ 5150 Å, have been retrieved from CFHT archives of CADC. The data have been used to investigate the radial behavior of absorption features of this system. The heliocentric recession velocity of NGC 5846A was derived to be 1949 ± 87 kms^{-1}. Fe absorption lines of NGC 5846A show a significant radial gradient. There is also a significant radial gradient of G band absorption. On the other hand, no radial gradients has been detected on the Ca4455 and Hβ absorptions of NGC 5846A. A metallicity gradient which is derived from Fe line absorption gradients implies that NGC 5846A could be formed through the dissipative collapse during the initial stage of the galaxy formation. Note that, however, a galaxy-galaxy interaction could also affect the line gradients of NGC 5846A. Because the stellar population distribution in a galaxy may indicate radial variations in the mean age of the stellar population as well as variations in metallicity, it would be worthwhile to construct composite stellar population and spectral synthesis models to interpret the radial absorption line gradients in NGC 5846A.

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