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UV VISIBILITY OF MODERATE-REDSHIFT GIANT ELLIPTICAL GALAXIES

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ABSTRACT

We show quantitatively whether giant elliptical galaxies would be visible at far UV wavelengths if they were placed at moderate redshift of 0.4-0.5. On the basis of simple cosmological tests, we conclude that giant elliptical galaxies can be detectable upto the redshift of 0.4-0.5 in the proposed GALEX (Galaxy Evolution Explorer) Deep Imaging Survey. We also show that obtaining UV color index such as $m_{1550} - V$ from upcoming GALEX and SDSS (Sloan Digital Sky Survey) observations should be feasible.

1. INTRODUCTION

Although the UV-upturn in giant elliptical galaxies is a well known observational phenomenon, its physical origin is not yet fully understood. Metal poor horizontal branch (HB) stars (*e.g.* Park & Lee 1997, Lee 1994) as well as metal rich HB stars (*e.g.* Bressan *et al.* 1994, Yi *et al.* 1998) have been suggested as the most likely dominant UV sources. Both evolutionary models either with metal poor or with metal rich HB stars successfully reproduce the present-day UV-upturn phenomenon in giant elliptical galaxies.

Two models, however, predict considerably different ages for nearby giant elliptical galaxies. In addition, the behaviors of the UV color (*e.g.* $m_{1550} - V$) variation as a function of redshift (*i.e.* look-back time) show significant differences even in the moderate redshift ($z = 0.4 - 0.5$) for two models (Yi *et al.* 1998). It is, therefore, of great interest to examine whether any one of them can be ruled out by new systematic observations of giant elliptical galaxies with upcoming space UV telescope such as GALEX (Galaxy Evolution Explorer, Martin *et al.* 1998) and with ground-based all-sky surveys such as SDSS (Sloan Digital Sky Survey; Gunn & Knapp 1993).

In this paper, we have performed a series of tests to see whether moderate-redshift giant elliptical galaxies could be detectable in the UV wavelengths with GALEX. In doing this, we only considered Park & Lee's metal-poor HB model with a particular set of plausible cosmological parameters. Detailed and complete examination of the detectability of moderate-redshift giant elliptical galaxies with GALEX and SDSS based on various possible evolution scenarios will be presented in a separate paper.

2. VISIBILITY OF GIANT ELLIPTICAL GALAXIES IN THE UV

We first discuss below our choice of cosmological parameters, template galaxy, and evolutionary model for giant elliptical galaxies. We then describe how we have calculated the observed apparent magnitudes of a template giant elliptical galaxy if it were seen at various redshifts in the UV wavelengths.

2.1 Cosmological Parameters

Currently the preferred ranges for cosmological parameters are $\Omega_M = 0.2-0.4, \Omega_\Lambda = 0.6-0.8$, $H_0 = 67 - 73$ km/sec/Mpc, and the flat geometry ($\Omega_M + \Omega_\Lambda = 1$) (Freedman 1997, Roos & Harun-or-Rashid 1998). Taking into account the recent Hipparcos results (Feast & Catchpole 1997) implying further decrease of H_0 by 10%, we have adopted a Ω_Λ dominated flat universe, *i.e.* $\Omega_M = 0.3$ and $\Omega_\Lambda = 0.7$, with $H_0 = 65$ km/sec/Mpc. The look-back time and luminosity distance have been calculated using the formulae given by Carroll *et al.* (1992) and by Kayser *et al.* (1997) with the adopted cosmological parameters.

2.2. Template Galaxy: NGC 4649

NGC 4649 is one of the brightest giant elliptical galaxies in the UV wavelengths, showing strong UV-upturn (Burstein *et al.* 1988). The distance to NGC 4649 is 19.3 Mpc (with $H_0 = 65$ km/sec/Mpc). UV magnitude of NGC 4649 from recent HUT (Hopkins Ultraviolet Telescope) observations shows $m_{1550}(HUT) = 13.89$ (Brown *et al.* 1997). Note that this magnitude is the lower limit of the true m_{1550} in the sense that it was observed through $10'' \times 56''$ slit covering only the central part of the galaxy.

We have also calculated total (extrapolated) UV magnitude within optical region, $m_{1550}(tot)$, using V magnitude given by LEDA (Lyon-Meudon Extragalactic Database) and $m_{1550} - V$ from HUT observations (Brown *et al.* 1997). In doing this, we explicitly assumed that there is no color gradient in NGC 4649. As UV light is in general more concentrated than optical one, it may be safe to consider $m_{1550}(tot)$ as the upper limit. The resulting $m_{1550}(tot)$ is 11.17 mag.

Series of model Spectral Energy Distribution (SED) as a function of look-back time have been constructed based on the results of an existing metal poor HB model for the average luminosity weighted metallicity of $Z = 0.027$ (Park & Lee 1997, see their Figure 6; see also Woo 1998). We assumed the SED of NGC 4649 has evolved in the manner that is predicted by this model.

2.3. Visibility of Giant Ellipitical Galaxies in the UV Wavelenths

We describe below how we have calculated the observed apparent magnitudes of the giant elliptical galaxy NGC 4649 if it were seen at various redshifts in the UV wavelengths.

The observed apparent magnitude of a galaxy at a redshift z, observed at the present epoch, can be expressed in general as follow:

$$m_{\lambda_0} = M_{\lambda_0}(t_0) + 5\log D_L + C + K + EC + A_{ext}, \quad (1)$$

where $M_{\lambda_0}(t_0)$ is the absolute magnitude of a galaxy in the rest frame, D_L the luminosity distance, C a constant term depending on the passband used, K the K correction term due to the effect of redshift, EC the evolutionary correction term due to the intrinsic evolution of the SED, and A_{ext} dust extinction correction term. We now calculate the observed apparent UV magnitudes of NGC 4649 as a function of redshift.

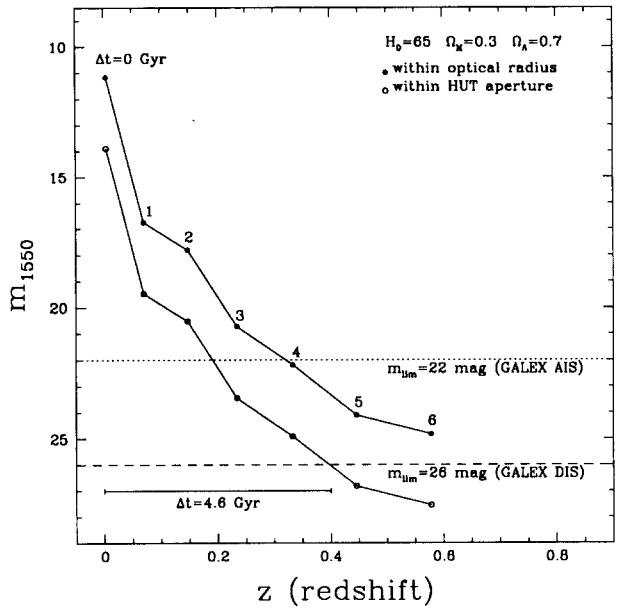

Figure 1. Figure 1. The observed apparent magnitude, m_{1550}, as a function of redshift. The filled circles represent m_{1550} within optical region (upper limit) and open circles m_{1550} within HUT aperture (lower limit). The true values of m_{1550} should be located somewhere between filled and open circles at the corresponding redshift. Numbers right above the filled circles represent look-back time in Gyr. The dotted line indicate the limiting magnitude for GALEX All-Sky Imaging (Martin 1997) in AB magnitude system (Oke & Gunn 1983). The dashed line indicates the limiting magnitude for GALEX Deep Imaging Survey in AB system.

With distance to NGC 4649 of 19.3 Mpc, the absolute magnitudes $M_{1550}(HUT)$ and $M_{1550}(tot)$ have been calculated using observed apparent magnitudes $m_{1550}(HUT)$ and $m_{1550}(tot)$, respectively. The look-back time, conversion of look-back time to redshift, and luminosity distance have been calculated using formulae given by Carroll *et al.* (1992) and by Kayser *et al.* (1997) with the adopted cosmological parameters, *i.e.* $\Omega_M = 0.3$ and $\Omega_\Lambda = 0.7$, with $H_0 = 65$ km/sec/Mpc. K correction and EC correction terms have been estimated directly from the *redshifted* model SEDs (see section 2.2). The extinction correction term, A_{ext} is not explicitly considered as $m_{1550}(HUT)$ and $m_{1550}(tot)$ are already suffered from extinction by dust. Dust evolutionary effects on extinction are not considered.

Putting all parameters to equation (1) gives the observed apparent magnitudes as a function of redshift as seen in Figure 1. In Figure 1, the apparent UV magnitudes m_{1550}, calculated from equation (1) with the aboved-mentioned considerations and parameters, are plotted as a function of redshift. The filled circles represent m_{1550} within optical region (upper limit) and open circles m_{1550} within HUT aperture (lower limit). We expect that the true values of m_{1550} should be located

somewhere between filled and open circles at the corresponding redshift. The number annotated to each filled circle represents look-back time in Gyr. The dotted and dashed lines indicate the limiting magnitudes for GALEX All-Sky Imaging (AIS) and Deep Imaging Survey(DIS; Martin *et al.* 1997), respectively, in the AB magnitude system (Oke & Gunn 1983).

Figure 1 shows that giant elliptical galaxies such as NGC 4649 can be detectable upto the redshift of 0.4-0.5 in GALEX DIS mode. As the limiting magnitude for SDSS is similar to that of GALEX DIS and giant elliptical galaxies are much brighter in optical than in UV, extracting the UV color index, $m_{1550} - V$, from GALEX and SDSS observations should be feasible.

On the other hand, metal rich HB models predict 1-2 mag less luminosity in m_{1550} compared to metal poor HB models at redshift around 0.4 (Yi *et al.* 1998). Consequently, in case of metal rich HB models, it is necessary to add extra exposure time for giant elliptical galaxies to be detectable at $z = 0.4 - 0.5$.

3. CONCLUDING REMARKS

In summary, giant elliptical galaxies can be detectable upto redshift of 0.4-0.5 in GALEX DIS mode and obtaining UV color index, $m_{1550} - V$, from GALEX and SDSS observations should be feasible. Detailed and expanded simulations of the detectability of moderate-redshift giant elliptical galaxies with UIT (Ultraviolet Imaging Telescope) images as well as SDSS & GALEX filters will be presented in a separate paper. We will consider in a future paper serveral different combinations of cosmological parameters and different evolutionary models.

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