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AGE CONSTRAINTS FOR AN M31 GLOBULAR CLUSTER FROM SEDs FIT

Jun Ma,[1] Yanbin Yang,[1] David Burstein,[2] Zhou Fan,[1,3] Zhenyu Wu,[1] Xu Zhou,[1]
Jianghua Wu,[1] Zhaoji Jiang,[1] and Jiansheng Chen[1]
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ABSTRACT

We have constrained the age of the globular cluster S312 in the Andromeda galaxy (M31) by comparing its multicolor photometry with theoretical stellar population synthesis models. This is both a check on the age of this globular cluster and a check on our methodology. Main-sequence photometry has been the most direct method for determining the age of a star cluster. S312 was observed as part of the Beijing-Arizona-Taiwan-Connecticut (BATC) Multicolor Sky Survey from 1995 February to 2003 December. The photometry of BATC images for S312 was taken with nine intermediate-band filters covering 5000–10000 Å. Combined with photometry in the near-ultraviolet (NUV) of *GALEX*, broadband *UBVR*, and infrared JHK_s of 2MASS, we obtained the accurate spectral energy distributions (SEDs) of S312 from 2267–20000 Å. A quantitative comparison to simple stellar population models yields an age of $9.5^{+1.15}_{-0.99}$ Gyr, which is in very good agreement with the previous determination by main-sequence photometry. S312 has a mass of $9.8 \pm 1.85 \times 10^5\ M_\odot$ and is a medium-mass globular cluster in M31. By analyzing the errors of ages determined based on the SED-fitting method of this paper, secure age constraints are derived with errors of <3 Gyr for ages younger than 9 Gyr. In fact, the theoretical SEDs are not sensitive to the variation of age for ages $> \sim 10$ Gyr. Therefore, our method does not accurately distinguish globular clusters (GCs) as old as the majority of the Galactic GCs. We emphasize that our results show that even with multiband photometry spanning from NUV to K_s, our age constraints from SED fitting are distressingly uncertain, which has implications for age derivations in extragalactic globular cluster systems.

Subject headings: galaxies: individual (M31) — galaxies: star clusters — galaxies: stellar content

1. INTRODUCTION

Galactic globular clusters (GCs), which are thought to be among the oldest stellar objects in the universe, provide vitally important information regarding the minimum age of the universe and the early formation history of our Galaxy. The most direct method for determining the age of a star cluster is main-sequence photometry, since the turnoff is mostly affected by age (see Puzia et al. 2002b, and references therein) . However, this method has only been applied to the Galactic GCs and globular clusters in the satellites of the Milky Way (e.g., Rich et al. 2001) before Brown et al. 2004) used this method to constrain the age of a M31 globular cluster. Generally, extragalactic globular cluster ages are inferred from composite colors and/or spectroscopy. S312, first detected by Sharov (1973; No. 19 in his Table 1), then by Sargent et al. (1977; No. 312 in their Table 2, =S312), and Battistini et al. (1987; No. 379 in their Table 4, =Bo379), is among the first extragalactic globular clusters whose age was accurately estimated by main-sequence photometry (Brown et al. 2004). Brown et al. (2004) obtained the color-magnitude diagram (CMD) below the main-sequence turnoff for S312 by using the extremely deep images of M31 from the Advanced Camera for Surveys (ACS) on the *Hubble Space Telescope* (*HST*). Brown et al. (2004) estimated an age of 10 Gyr for S312 by the quantitative comparison to the isochrones of VandenBerg et al. (2006).

This cluster was also observed as part of the galaxy calibration program of the Beijing-Arizona-Taiwan-Connecticut (BATC) Multicolor Sky Survey (e.g., Fan et al. 1996; Zheng et al. 1999) in nine intermediate-band filters. Combined with photometry in NUV of *GALEX*, broadband *UBVR*, and infrared JHK_s of the Two Micron All Sky Survey (2MASS), we obtained the accurate SEDs of S312 in 17 filter bands from 2267 to 20000 Å.

Since the pioneering work of Tinsley (1968, 1972) and Searle et al. (1973), evolutionary population synthesis modeling has become a powerful tool for interpreting integrated spectrophotometric observations of galaxies and their subcomponents, such as star clusters (Anders et al. 2004). The evolution of star clusters is usually modeled by means of a simple stellar population (SSP) approximation. An SSP is defined as a single generation of coeval stars formed from the same progenitor molecular cloud (thus implying a single metallicity) and governed by a given initial mass function (IMF). Globular clusters, which are bright and easily identifiable, are typically characterized by homogeneous abundance and age distributions. For example, Barmby & Huchra (2001) compared the predicted SSP colors of three stellar population synthesis models to the intrinsic broadband *UBVIRJHK* colors of Galactic and M31 GCs and found that the best-fitting models match the clusters' SEDs very well indeed.

In this paper, we constrain the age of S312 by comparing observational SEDs (§ 2) with population synthesis models (§ 3). Our independently constrained result is in very good agreement with the previous determination of Brown et al. (2004). We give discussions and summarize our results in § 4.

2. OPTICAL AND INFRARED OBSERVATIONS OF GC S312

2.1. *Historical Observations of GC S312*

S312 was first detected by Sharov (1973), who searched 25 M31 globular clusters and cluster candidates using plates taken with the 80/120/240 cm Schmidt telescope of the Radio Astrophysical Observatory of the Latvian Academy of Sciences. Since

[1] National Astronomical Observatories, Chinese Academy of Sciences, Beijing, 100012, China; majun@vega.bac.pku.edu.cn.
[2] Department of Physics and Astronomy, Arizona State University, Tempe, AZ 85287–1504.
[3] Graduate University of Chinese Academy of Sciences.

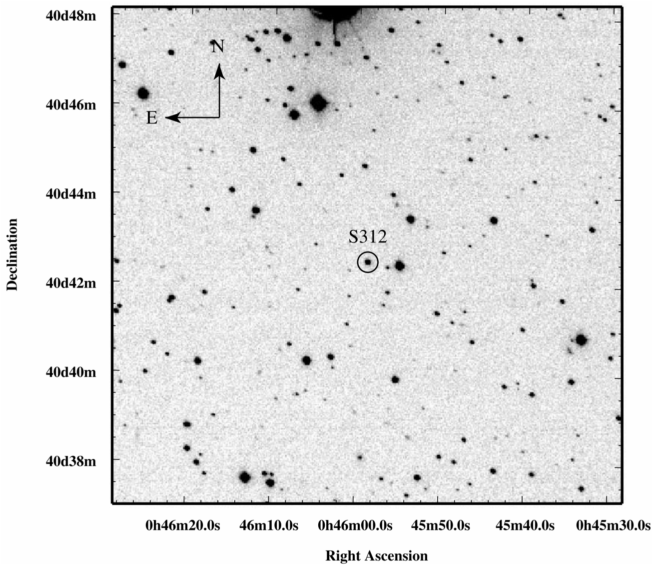

Fig. 1.—Image of S312 in the BATC g band of the NAOC 60/90 cm Schmidt telescope. S312 is circled. The field of view of the image is $11' \times 11'$.

that time, Sargent et al. (1977) and Battistini et al. (1987) have confirmed S312 to be an M31 globular cluster.

2.2. *Archival Images of the BATC Sky Survey*

Observations of S312 were obtained by the BATC 60/90 cm Schmidt telescope located at the XingLong station of the National Astronomical Observatory of China (NAOC). This telescope has 15 intermediate-band filters covering the optical wavelength range of 3000–10000 Å, and is specifically designed to avoid contaminations from the brightest and most variable night-sky emission lines. Descriptions of the BATC photometric system can be found in Fan et al. (1996). The finding chart of GC S312 in the g band (centered on 5795 Å) of the BATC system with the NAOC 60/90 cm Schmidt telescope is illustrated in Figure 1.

We extracted 86 images of M31, taken in nine BATC filters from the BATC survey archive during 1995 February–2003 December. Table 1 contains the log of observations. Multiple images of the same filter were combined to improve the image quality.

2.3. *Intermediate-Band Photometry of S312*

Since S312 is located in the M31 halo, it is easy to do the photometry. The intermediate-band magnitudes of S312 are determined on the combined images with the standard aperture photometry, i.e., the PHOT routine in DAOPHOT (Stetson 1987). The BATC photometric system calibrates the magnitude zero level similar to the spectrophotometric AB magnitude system. For the flux calibration, the Oke-Gunn primary flux standard stars HD 19445, HD 84937, BD +26° 2606, and BD +17° 4708 taken from Oke & Gunn (1983) were observed during photometric nights (Yan et al. 2000). The results of well-calibrated photometry of S312 in nine filters are summarized in the fifth column of Table 1.

2.4. *GALEX, Broadband, and 2MASS Photometry of S312*

In order to constrain the age of S312 accurately, we use as many photometric data points covering as large a wavelength range as possible. M31 field was observed as part of the Nearly Galaxy Survey (NGS) carried out by *Galaxy Evolution Explorer*

TABLE 1

BATC Photometry of the M31 Globular Cluster S312

Filter (1)	λ (Å) (2)	FWHM (Å) (3)	N^a (4)	Magnitude (5)
e	4925	390	11	17.81 ± 0.021
f	5270	340	12	17.23 ± 0.016
g	5795	310	7	16.40 ± 0.012
h	6075	310	5	16.14 ± 0.009
i	6656	480	3	15.54 ± 0.007
j	7057	300	12	15.25 ± 0.006
k	7546	330	6	14.89 ± 0.006
o	9182	260	18	13.95 ± 0.004
p	9739	270	12	13.78 ± 0.005

[a] N is the number of images taken by the BATC telescope.

(*GALEX*) in two UV bands: far-ultraviolet (FUV) and near-ultraviolet (NUV; see details from Rey et al. 2005, 2007). Rey et al. (2007) presented the photometric data for 485 and 273 M31 GCs in *GALEX* NUV and FUV, respectively. S312 was not detected in FUV from (S.-C. Rey 2006, private communication; Rey et al. 2007). Using the CCD imaging of 0.9 m telescope at the Kitt Peak National Observatory, Reed et al. (1994) presented CCD *BVR* integrated magnitudes and color indices for 41 globular clusters and cluster candidates in the outer halo of M31, including S312. Battistini et al. (1987) presented *UBVR* photometry from the photographic plates of their most sampled globular clusters and candidates, including S312; however, they did not give photometric uncertainties. In this paper, for S312, we adopted CCD *BVR* photometry of Reed et al. (1994) and photographic U photometry of Battistini et al. (1987), with a photometric uncertainty of 0.08 mag as suggested by Galleti et al. (2004).

As pointed out by Worthey (1994), the age-metallicity degeneracy in optical broadband colors is $\Delta\text{age}/\Delta Z \sim 3/2$; implying that the composite spectrum of an old stellar population is indistinguishable from that of a younger, but more metal-rich population (and vice versa) (also see MacArthur et al. 2004). De Jong (1996) showed that this degeneracy can be partially broken by adding 2MASS infrared photometry to the optical colors. Cardiel et al. (2003) found that inclusion of an infrared band can improve the predictive power of the stellar population diagnostics by ~30 times over using optical photometry alone. Wu et al. (2005) also showed that the use of near-infrared colors can break the age-metallicity degeneracy. At the same time, Kissler-Patig et al. (2002) and Puzia et al. (2002a) indicated that near-infrared photometry is less sensitive to interstellar extinction with respect to the classical optical bands, which provides useful complementary information that can help to disentangle the age-metallicity degeneracy (also see Galleti et al. 2004).

In this paper, we add JHK_s photometry from the 2MASS Point Source Catalogue (PSC) to broad- and intermediate-band optical, and ultraviolet photometry to constrain the age of S312 to the highest possible accuracy. 2MASS presents J, H, and K_s complete homogeneous photometry of 99.998% of the sky down to $K_s \sim 15.5$ (completeness >99% for $K_s \leq 14.3$). The near-ultraviolet, broadband, and 2MASS photometric data points of S312 are listed in Table 2.

3. STELLAR POPULATION OF S312

3.1. *Stellar Populations and Synthetic Photometry*

As a check on the age of S312, and also on a check of our methodology, we compare its spectral energy distributions with

TABLE 2
NUV, Broadband, and 2MASS Photometry for S312

Filter	Magnitude	Reference
NUV	21.881 ± 0.123	Rey et al. (2007)
U	17.460 ± 0.08	Battistini et al. (1987)
B	17.032 ± 0.018	Reed et al. (1994)
V	16.130 ± 0.011	
R	15.560 ± 0.014	
J	14.195 ± 0.032	2MASS
H	13.495 ± 0.037	
K_s	13.390 ± 0.043	

theoretical stellar population synthesis models. We used the SSP models of Bruzual & Charlot (2003, hereafter BC03), which have been upgraded from the Bruzual & Charlot (1993, 1996, unpublished) version, and now provide the evolution of the spectra and photometric properties for a wider range of stellar metallicities. BC03 provide 26 SSP models (both of high and low resolution) using the 1994 Padova evolutionary tracks, 13 of which were computed using the Chabrier (2003) IMF assuming lower and upper mass cutoffs of $m_L = 0.1\,M_\odot$ and $m_U = 100\,M_\odot$, respectively. The other 13 were computed using the Salpeter (1955) IMF with the same mass cutoffs. In addition, BC03 provide 26 SSP models using the 2000 Padova evolutionary tracks. However, as BC03 pointed out, the 2000 Padova models, which include more recent input physics than the 1994 models, tend to produce worse agreement with observed galaxy colors. These SSP models contain 221 spectra describing the spectral evolution of SSPs from 1.0×10^5 yr to 20 Gyr. The evolving spectra include the contribution of the stellar component at wavelengths from 91 Å to 160 μm. In this paper, we adopt the high-resolution SSP models computed using the 1994 Padova evolutionary tracks and a Salpeter (1955) IMF.[4] We note that although the current best constraint of the age of the universe is of order 13.7 Gyr, the SSP models and the stellar evolutionary tracks that form their basis have been calculated for ages up to 20 Gyr. It is not straightforward to correct for this discrepancy; one would need to recalculate all stellar evolutionary tracks for all metallicities.

Since our observational data are integrated luminosities through our set of filters, we convolved the BC03 SSP SEDs with the BATC intermediate-band, *GALEX* NUV, broadband *UBVR*, and 2MASS filter response curves to obtain synthetic ultraviolet, optical, and near-infrared photometry for comparison. The synthetic *i*th filter magnitude can be computed as

$$m = -2.5 \log \frac{\int_\lambda F_\lambda \varphi_i(\lambda)\, d\lambda}{\int_\lambda \varphi_i(\lambda)\, d\lambda} - 48.60, \qquad (1)$$

where F_λ is the theoretical SED and φ_i the response curve of the *i*th filter of the BATC, *GALEX*, *UBVR*, and 2MASS photometric systems. Here, F_λ varies with age and metallicity.

3.2. *Reddening and Metallicity of S312*

To obtain the intrinsic SEDs of S312, the photometry must be dereddened. Barmby et al. (2000) determined the reddening for each individual cluster using correlations between optical and infrared colors and metallicity and by defining various "reddening-free" parameters using their large database of multicolor photometry. Barmby et al. (2000) found that the M31 and Galactic GC extinction laws, and the M31 and Galactic GC color-metallicity relations are similar to each other. They then estimated the reddening to M31 objects with spectroscopic data using the relation between intrinsic optical colors and metallicity for Galactic clusters. For objects without spectroscopic data, they used the relationships between the reddening-free parameters and certain intrinsic colors based on the Galactic GC data. Barmby et al. (2000) compared their results with those in the literature and confirmed that their estimated reddening values were reasonable and quantitatively consistent with previous determinations for GCs across the entire M31 disk. In particular, Barmby et al. (2000) showed that the distribution of reddening values as a function of position appears reasonable in that the objects with the smallest reddening are spread across the disk and halo, while the objects with the largest reddening are concentrated in the galactic disk. Therefore, we adopted the reddening values from P. Barmby (2002, private communication; Barmby et al. 2000) for S312 to be $E(B-V) = 0.10$, as Rey et al. (2007) did. The values of extinction coefficient R_λ are obtained by interpolating the interstellar extinction curve of Cardelli et al. (1989).

The SEDs for clusters are significantly affected by the adopted metallicity, especially for old clusters. So, only if the metallicity is known, the age of a cluster can be constrained accurately. Huchra et al. (1991) derived metallicities for 150 M31 globular clusters including S312, using the strengths of six absorption features in the cluster integrated spectra. The metallicity of S312, obtained by Huchra et al. (1991) is [Fe/H] $= -0.7$. Holland et al. (1997) used *HST* WFPC2 photometry to construct deep color-magnitude diagrams for S312, and the shape of the red giant branch gave an iron abundance of [Fe/H] $= -0.53$. In this paper, we adopt for comparison [Fe/H] $= -0.53$ as Brown et al. (2004) did.

3.3. *Comparison of the Age Scale*

Before constraining the age of S312, we compare the age scale between the 1994 Padova evolutionary tracks (Bertelli et al. 1994) used by BC03 and the 2006 VandenBerg isochrones (VandenBerg et al. 2006) used in Brown et al. (2004). As an example, we only draw the isochrones with a 10 Gyr age and solar metallicity. Figure 2 shows the isochrones between effective temperature and bolometric magnitudes. It is clear that the matching is very good in the main sequence (MS) and the subgiant branch (SGB). As we know, the main-sequence photometry focuses on the upper end of the MS and SGB, since uncertainties in models of stars on the red giant branch (RGB) are large. So, if Brown et al. (2004) had fitted the color-magnitude diagram (CDM) of S312 with the 1994 Padova evolutionary tracks, its age would have been close to 10 Gyr.

3.4. *Fit Results*

We use a χ^2 minimization test to examine which BC03 SSP models are most compatible with the observed SEDs, following

$$\chi^2 = \sum_{i=1}^{17} \frac{\left[m_{\lambda_i}^{\rm intr} - m_{\lambda_i}^{\rm mod}(t)\right]^2}{\sigma_i^2}, \qquad (2)$$

[4] We note that because of the slow SED evolution of SSPs at ages in excess of a few Gyr, all of the most commonly used spectral synthesis models agree very well at these ages. Therefore, the choice of IMF is *only* important for estimating the photometric mass of the cluster, and does *not* affect the determination of the age of S312.

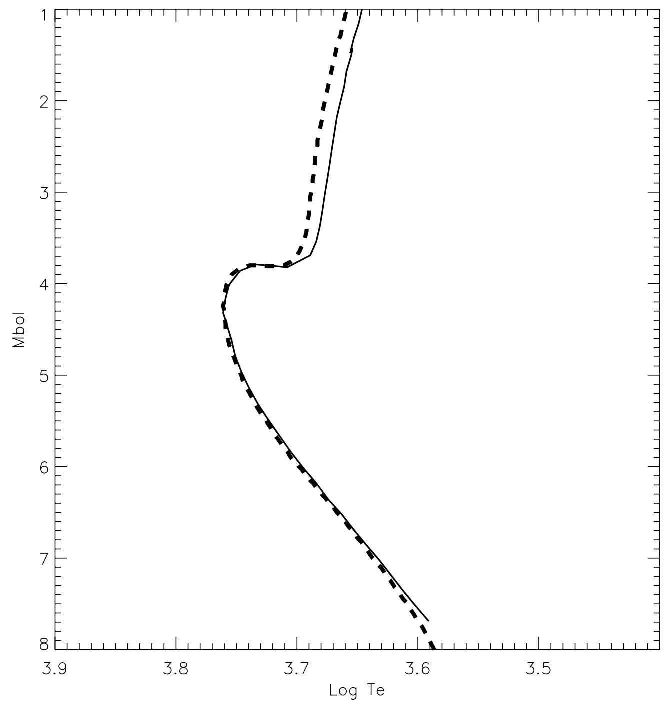

FIG. 2.—Comparison of the age scale between the 1994 Padova tracks and the 2006 VandenBerg isochrones used in Brown et al. (2004). Dashed and solid lines are the 1994 Padova tracks and 2006 VandenBerg isochrone, respectively, for a 10 Gyr age and the solar metallicity.

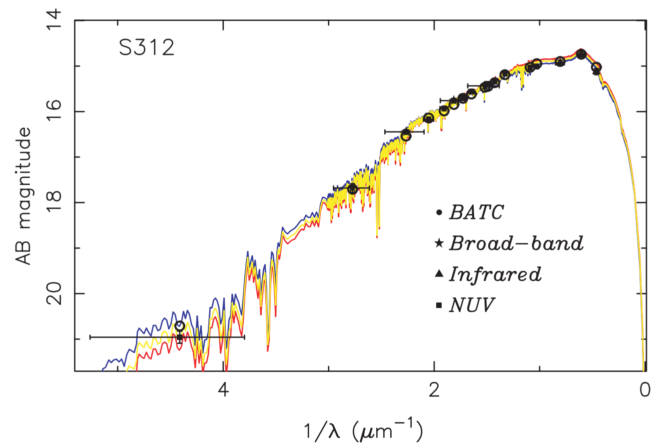

FIG. 3.—Plots of the best-fitting integrated SEDs of SSP models plotted on top of the intrinsic SEDs for S312. The photometry itself is shown by the symbols with error bars (vertical ones for uncertainties and horizontal ones for the approximate wavelength coverage of each filter). Open circles represent the calculated magnitude of the model SED for each filter. Yellow, red, and blue indicate the spectra of the best-fitting model, plus and minus the 3 σ spectra, respectively.

where $m_{\lambda_i}^{\rm mod}(t)$ is the integrated magnitude in the ith filter of a theoretical SSP at age t, $m_{\lambda_i}^{\rm intr}$ presents the intrinsic integrated magnitude in the same filter and

$$\sigma_i^2 = \sigma_{{\rm obs},i}^2 + \sigma_{{\rm mod},i}^2. \quad (3)$$

Here, $\sigma_{{\rm obs},i}^2$ is the observational uncertainty, and $\sigma_{{\rm mod},i}^2$ is the uncertainty associated with the model itself for the ith filter. Charlot et al. (1996) estimated the uncertainty associated with the term $\sigma_{{\rm mod},i}^2$ by comparing the colors obtained from different stellar evolutionary tracks and spectral libraries. Following Wu et al. (2005), we adopt $\sigma_{{\rm mod},i}^2 = 0.05$ in this paper.

The BC03 SSP models include six initial metallicities, [Fe/H] $= -2.2490, -1.6464, -0.6392, -0.3300, +0.0932$ (solar metallicity), and $+0.5595$. Spectra for other metallicities can be obtained by linear interpolation of the appropriate spectra for any of these metallicities. For S312, whose metallicity and reddening values have been published by other authors, the cluster age is the sole parameter to be estimated (for a given IMF and extinction law, which we assume to be universal). In Figure 3, we show the intrinsic SEDs of S312, the integrated SEDs of the best-fitting model, and the spectra of the best-fitting model superimposed with the 3 σ spectra. The best reduced χ^2 of 18.23 is achieved with an age of $9.5_{-0.99}^{+1.15}$ Gyr, which is in very good agreement with the previous determination (10 Gyr) of Brown et al. (2004) by main-sequence photometry. From Figure 3, we can see that the 3 σ spectra deviate clearly from best-fitting ones, i.e., these three spectra clearly separate. This indicates that we can constrain the age of S312 with errors of about 3 Gyr.

3.5. *Mass of S312*

Star cluster masses can be estimated by comparing the measured luminosity in V band with the theoretical mass-to-light ratios (M/L). These ratios are a function of the cluster age and metallicity. BC03 calculated these ratios for a range of metallicities. Mass-to-light ratios for other metallicities can be obtained by linear interpolation of the appropriate ratios for any of these metallicities. For [Fe/H] $= -0.53$ and 9.5 Gyr, we derived the M/L in broadband V to be 3.69 $M_\odot/L_\odot$. Based on its present luminosity, $V = 16.13 \pm 0.01$ mag, and the extinction, $E(B-V) = 0.10$, its intrinsic luminosity is $V_0 = 15.82 \pm 0.01$ mag (assuming the Cardelli et al. [1989] Galactic reddening law, $A_V = 0.31$ mag). From this we determine the mass of S312 to be $9.8 \pm 1.85 \times 10^5$ $M_\odot$. Comparing with 037-B327 [$M_{\rm 037\text{-}B327} \sim 8.5 \times 10^6$ $M_\odot$ (Barmby et al. 2002) or $M_{\rm 037\text{-}B327} \sim 3.0 \pm 0.5 \times 10^7$ $M_\odot$ (Ma et al. 2006)] and G1 [$M_{\rm G1} \sim (7\text{–}17) \times 10^6$ $M_\odot$ (Meylan et al. 2001)] in M31 and ω Cen [$M_{\omega\,{\rm Cen}} \sim (2.9\text{–}5.1) \times 10^6$ $M_\odot$ (Meylan 2002)] in the Milky Way, the most massive clusters in the Local Group, S312, is only a medium-mass globular cluster.

3.6. *Comparison with SSP Models Based on the 2000 Padova Evolutionary Tracks*

As discussed in § 3.1, BC03 provide two sets of SSP models based on the 1994 and 2000 Padova evolutionary tracks. In § 3.4, we adopted the SSP models based on the 1994 Padova evolutionary tracks to constrain the age of S312. However, it is interesting to note what the best fit is based on the 2000 Padova models. Using the 2000 Padova models, we fitted the intrinsic SEDs of S312 again; it is surprising that the fitting is very good with the best reduced χ^2 of 9.71, but the age of $11.75_{-0.62}^{+1.17}$ Gyr is older than the 10 Gyr age of Brown et al. (2004) by main-sequence photometry. In Figure 4, we plot the intrinsic SEDs of S312, the integrated SEDs of the best-fitting model, and the spectra of the best-fitting model superimposed with the 3 σ spectra based on the 2000 Padova evolutionary tracks. Figure 4 also shows that the 3 σ spectra greatly deviate from the best-fitting ones. As things stand now, without having other clusters to compare to, there is a problem that an SED fitting based on the older isochrones (the 1994 Padova) constrains the age of S312 in agreement with the main-sequence turnoff fit, while the fitting with newer isochrones (the 2000 Padova) gives an older age constraint for S312. These are therefore issues that one needs to keep in mind in the context of more recent input physical parameters of the 2000 Padova evolutionary tracks as indicated

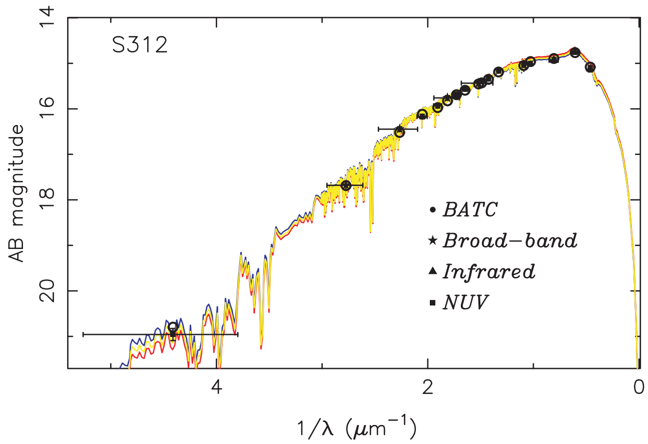

FIG. 4.—Graphs of the best-fit integrated SEDs of SSP models based on 2000 Padova models plotted on top of the intrinsic SEDs for S312. The symbols are the same as in Fig. 3.

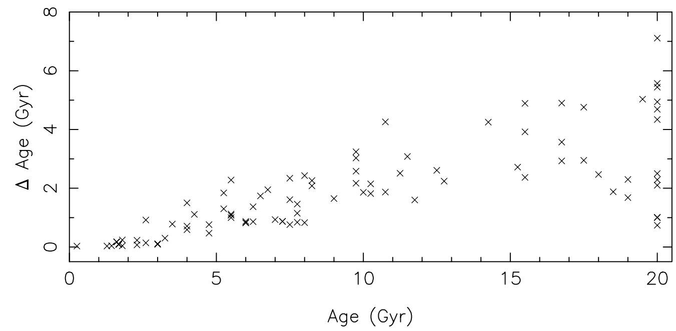

FIG. 5.—Age uncertainty (1 σ spread) plotted as a function of derived age. The data are from Fan et al. (2006). Notice that ages in excess of 3–4 Gyr are very uncertain at best.

by BC03. In fact, BC03 have illustrated the influence of the stellar evolution prescription on the predicted photometric evolution of an SSP for solar metallicity in their Figure 2, which showed models computed using the 1994 Padova, the Geneva, and the 2000 Padova evolutionary tracks. From Figure 2 of BC03 we can see that, at late ages, the $V - K$ color is significantly bluer in the 2000 Padova model than in the 1994 Padova model. The reason for this is that the giant-branch temperature in the 2000 Padova tracks has not been tested against observational calibrations (see BC03, and references therein). So, it is certain that an SED fitting based on the 2000 Padova model gives an older age for S312 than the age we obtained from the 1994 BC03 models.

3.7. *Overview of Age Constraint by Photometry in Different Bands*

In § 3.4, we constrain the age of S312 based on the integrated photometric measurements in *GALEX* NUV, broadband *UBVR*, nine intermediate-band filters of BATC, and infrared JHK_s of 2MASS. These photometries constitute the accurate SEDs of S312 from 2267 to 20000 Å. In order to constrain the age of S312 accurately, we use as many photometric data points covering as large a wavelength range as possible. In this section, we investigate which passbands actually constrain the age. The results show that, except for NUV, a lack of any band does not result in great problems in constraining the age of S312, the dispersions in the recovered age are smaller than 0.5 Gyr. The reason may be that for S312, whose metallicity and reddening values were published by other authors, the cluster age is the sole parameter to be constrained. If we constrain the age and metallicity of S312 simultaneously, the importance of the *U* or *B* will appear. As Anders et al. (2004) pointed out, the age deviations from the input values for the combinations without the *U* or *B* bands are caused by an insufficiently accurate determination of the cluster metallicity, i.e., the *U* or *B* bands play a major role in determining the metallicity. Missing *U*- or *B*-band information leads to the underestimation of metallicity, thereby causing ages to be adjusted improperly. The results also show that a lack of the NUV band results in problems in constraining the age of S312; the dispersion in the recovered age is 2.5 Gyr, which reflects that the NUV flux point shows promise for being a useful determination of age. A lack of all bands bluer than *V* or of all bands redder than *I* results in great problems in constraining the age of S312, the dispersions in the recovered age are 4.25 or 7.25 Gyr, respectively.

4. SUMMARY AND DISCUSSION

In this paper, we constrain the age of the M31 globular cluster S312 by comparing its multicolor photometry with theoretical stellar population synthesis models. This is both a check on previous results, and a check on our methodology of applying age constraints via our SEDs of stellar systems. Multicolor photometric data are from *GALEX* NUV, broadband *UBVR*, nine intermediate-band filters, and 2MASS JHK_s, which constitute the SEDs covering 2267–20000 Å. Our result is in very good agreement with the previous determination (10 Gyr) of Brown et al. (2004) using main-sequence photometry. We also estimate the mass of S312, which shows it to be a medium-mass globular cluster in M31. Since there are no other clusters available to confirm our SEDs-fitting method for constraining ages of globular clusters, a large sample of globular clusters, whose ages are derived based on our SEDs-fitting method, may boost confidence in the data set and in our SEDs-fitting method. Fan et al. (2006) obtain age constraints for 91 M31 globular clusters based on the same sources of photometric data (not including *GALEX* NUV), the same theoretical stellar synthesis models, and the same fitting methods. Figure 5 shows a plot of age errors (1 σ spread) as a function of age based on the data of Fan et al. (2006). It is clear that the absolute age errors increase significantly with increasing age, and derived ages with errors of <3 Gyr are available for ages younger than 9 Gyr.

Fan et al. (2006) argue for peaks in the age distribution at ∼3 and 8 Gyr, in addition to the expected complement of Milky Way-like "old" globular clusters. While their results have considerable scatter, they show a noticeable lack of young, metal-poor globular clusters, or old and very metal-rich globular clusters, which might be consistent with an age metallicity relationship.

At the same time, the results of this paper also indicate that despite having such good multicolor photometry, we still cannot get solid age constraints from SEDs fitting even with NUV to K_s photometry. This has implications for attempting to learn the ages of distant cluster systems.

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