Advancing the Physics of Cosmic Distances
Proceedings IAU Symposium No. 289, 2012
Richard de Grijs, ed.

doi:10.1017/S1743921312021734

Near-infrared surface brightness fluctuation measurements with the *Hubble Space Telescope*'s WFC3/IR channel

Hyejeon Cho,[1] Joseph B. Jensen,[2] John P. Blakeslee,[3] Brigham S. French,[2] Hyun-chul Lee,[4] and Young-Wook Lee[1]

[1]Department of Astronomy & Center for Galaxy Evolution Research, Yonsei University, Seoul 120-749, Republic of Korea
email: hyejeon@yonsei.ac.kr

[2]Department of Physics, Utah Valley University, Orem, UT 84058–5999, USA

[3]Dominion Astrophysical Observatory, Herzberg Institute of Astrophysics, National Research Council of Canada, Victoria, BC V9E 2E7, Canada

[4]Department of Physics and Geology, The University of Texas–Pan American, Edinburg, TX 78539–2999, USA

Abstract. The surface brightness fluctuation (SBF) method at near-infrared (NIR) wavelengths is a powerful tool for estimating distances to unresolved stellar systems with high precision. The IR channel of the Wide Field Camera 3 (WFC3), installed on board the *Hubble Space Telescope (HST)* in 2009, has a greater sensitivity and a wider field of view than the previous generation of *HST* IR instruments, making it much more efficient for measuring distances to early-type galaxies in the Local Volume. To take full advantage of its capabilities, we need to empirically calibrate the SBF distance method for WFC3's NIR passbands. We present the SBF measurements for the WFC3/IR F160W bandpass filter using observations of 16 early-type galaxies in the Fornax and Virgo Clusters. These have been combined with existing $(g_{475} - z_{850})$ color measurements from the Advanced Camera for Surveys Virgo and Fornax Cluster Surveys to derive a space-based H_{160}-band SBF relation as a function of color. We have also compared the absolute SBF magnitudes to those predicted by evolutionary population synthesis models in order to study stellar population properties in the target galaxies.

Keywords. galaxies: clusters: individual (Fornax, Virgo), galaxies: distances and redshifts, galaxies: dwarf, galaxies: elliptical and lenticular, cD

1. Introduction

The surface brightness fluctuation (SBF) method is one of the most precise tools for estimating distances to galaxies within 150 Mpc (e.g., Jensen *et al.* 2001, 2003; Tonry *et al.* 2001; Biscardi *et al.* 2008). Tonry & Schneider (1988) first described how to measure the quantity of surface brightness bumpiness in a galaxy image and determine a distance to the galaxy. The SBF signals at near-infrared (NIR) wavelengths are intrinsically much stronger than in the optical. This means that we can reach much more distant early-type galaxies and bulge-dominated spirals using NIR SBF measurements. The installation of the IR channel of the Wide Field Camera 3 (WFC3) on the *Hubble Space Telescope (HST)* in 2009 opened up a new chapter in SBF studies at NIR wavelengths with its wide field of view and high filter throughputs. For measuring accurate distances to galaxies from NIR imaging data obtained with this instrument, it is essential to calibrate the SBF method for WFC3/IR NIR passbands in a manner comparable to what has been done

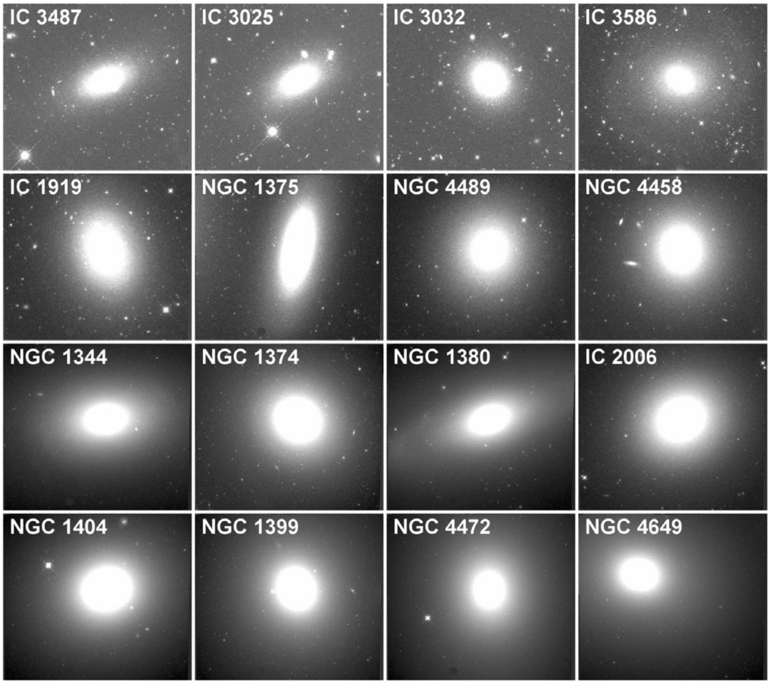

Figure 1. 136×123 arcsec^2 WFC3/IR F160W-band images of 16 target galaxies in the Fornax and Virgo Clusters of galaxies. The $(g_{475} - z_{850})$ color of each galaxy increases from top left to bottom right.

for the Advanced Camera for Surveys (ACS) optical passbands (e.g., Mei *et al.* 2005, 2007, hereafter ACSVCS-XIII; Blakeslee *et al.* 2009, hereafter ACSFCS-V, 2010).

Here we present a preliminary empirical NIR SBF calibration for the WFC3/IR F160W filter. NIR images in the F110W (J_{110}) and F160W (H_{160}) bands for each program galaxy were acquired with *HST* WFC3/IR within a single orbit during *HST* Cycle 17. Fig. 1 shows the F160W images of 16 Fornax and Virgo Cluster galaxies. A total of 1021 s of integration was acquired for every galaxy except for three Fornax galaxies, NGC 1375, NGC 1380, and NGC 1399, which have each 1197 s of total integration time.

2. WFC3/IR NIR SBF Calibration

As part of *HST* program 11712 to achieve the first WFC3/IR NIR SBF calibration, we measured fluctuation signals in the F160W imaging data of 16 early-type galaxies in the Fornax and Virgo Clusters. We computed the power spectrum using galaxy-subtracted images to obtain the apparent F160W SBF magnitudes, $\overline{m}_{\mathrm{F160W}}$, for the target galaxies. The absolute F160W SBF magnitudes, $\overline{M}_{\mathrm{F160W}}$, have been derived using $\overline{m}_{\mathrm{F160W}}$ measured from this study and the individual optical SBF distance moduli from ACSFCS-V.

The dependence of $\overline{M}_{\mathrm{F160W}}$ on $(g_{475} - z_{850})$ color from optical SBF studies with *HST* ACS is shown in Fig. 2. The preliminary fitting equation of the calibration, the solid black line in Fig. 2, has coefficients which are given by

$$\overline{M}_{\mathrm{F160W}} = -5.17 + 0.70x + 2.90x^2, \tag{2.1}$$

where $x \equiv (g_{475} - z_{850}) - 1.3$.

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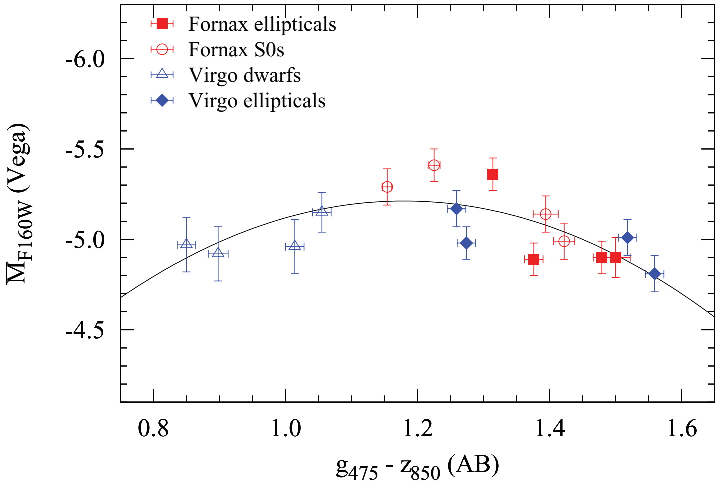

Figure 2. Empirical calibration of absolute F160W SBF magnitudes as a function of optical colors from ACS SBF studies (ACSVCS-XIII and ACSFCS-V). The colors are in the AB magnitude system as published in ACSFCS-V and ACSVCS-XIII. We follow the convention of Jensen *et al.* (2003) for the *HST* Near Infrared Camera and Multi-Object Spectrometer IR SBF calibration and use Vega-based F160W SBF magnitudes.

3. Comparison with Stellar Population Models

The SBF method can also reveal useful information about the underlying stellar populations, such as ages and chemical compositions, in unresolved early-type galaxies and bulge-dominated spirals (e.g., Worthey 1993a,b; Jensen *et al.* 2003; Cantiello *et al.* 2011). This is because the SBF quantity is weighted towards bright stellar components in a given passband. We have compared empirically determined $\overline{M}_{\mathrm{F160W}}$ magnitudes to theoretical SBF magnitudes computed from stellar population synthesis models (see Fig. 3) to constrain the properties of stellar populations in galaxies with accurate distances determined from the ACS Virgo and Fornax Cluster Surveys (Côté *et al.* 2004; Jordán *et al.* 2007).

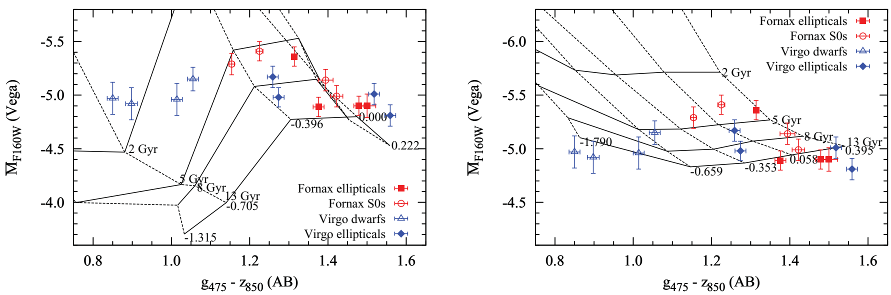

Figure 3. Comparison between empirical SBF magnitudes in the WFC3/IR F160W filter and predicted fluctuations using the Padova (left) and the Teramo/BaSTI (right) stellar population models, adopted from Lee *et al.* (2010; 2012, priv. commun.). Both are scaled-solar models with thermally pulsing asymptotic-giant-branch stages. The solid and dashed lines indicate the model grid of constant age and [Fe/H], respectively.

As shown in Fig. 3, the bluest (dwarf) galaxies have similar F160W SBF magnitudes as the reddest (giant) ellipticals, whereas the fluctuations are brightest for the intermediate-color galaxies. The F160W SBF magnitudes of the red and blue galaxies are consistent with the predictions for metal-rich and metal-poor stellar population models, respectively,

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although the different models disagree as regards the galaxy ages. We plan to undertake a detailed study of the theoretical uncertainties that underlie the considerable disagreement between the two sets of model predictions. We will also compare our SBF and color measurements to predictions of α-element-enhanced models to gain further insights into the stellar population properties of the sample.

4. Summary and Future Work

We have measured space-based NIR SBF magnitudes for 16 early-type galaxies in the Fornax and Virgo Clusters using F160W imaging data obtained from the WFC3/IR channel. Since calibrating the zero point and the dependence of the SBF magnitude on the stellar population is necessary to derive accurate distances to early-type galaxies and spiral bulges observed with the WFC3/IR, the empirical calibration of the absolute H_{160}-band SBF magnitudes has been derived as a function of ACS $(g_{475} - z_{850})$ colors.

We will also characterize J_{110}-band SBFs and measure $(J_{110} - H_{160})$ colors for 16 early-type galaxies from our *HST* WFC3/IR project and then derive a calibration of the absolute SBF magnitudes as a function of both NIR galaxy colors from this study and existing optical colors from the ACS Virgo and Fornax Cluster Surveys. When this NIR SBF calibration project is completed, it will be possible to obtain relatively precise SBF distances to early-type galaxies and bulge-dominated spirals beyond 150 Mpc from ongoing and future WFC3/IR programs, even for single-orbit observations. As a by-product, we are analyzing the optical–NIR color distributions of the globular cluster systems for this sample of galaxies (Blakeslee *et al.* 2012; H. Cho *et al.*, in prep.).

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