Surface Brightness Fluctuations with 8–m class telescopes

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We have studied I and K–band Surface Brightness Fluctuations as distance indicators when applied on 8-m class telescopes, such as the Very Large Telescope (VLT). With 8–m class telescopes one can extend I–band SBF measurements out to $\approx$ 7000 km / s. In the K–band, exposure times are very expensive from the ground, due to the high infrared background. K–band measurements from the ground are nevertheless necessary to understand the role of stellar population effects on SBF calibration, as a basis for future measurements in space. In the context of K–band SBF calibration, we re–measured K–band SBF in NGC 4489 and we confirm the detection of an anomalous stellar population in this galaxy.

1 Introduction

The use of Surface Brightness Fluctuations (SBF) as a distance indicator was introduced by Tonry and Scheineder 1988[21] and is based on a simple concept. The Poisson distribution of unresolved stars in a galaxy produces fluctuations in each pixel of the galaxy image. The variance of these fluctuations is proportional to the square of the flux of each star (f $\propto 1/d^2$) times the number of stars per pixel (n $\propto d^2$). While the mean flux per pixel does not depend on distance, the variance is inversely proportional to the square of the galaxy distance. The SBF amplitude is defined as the variance normalized to the mean flux of the galaxy[21], which then indicates the flux-weighted average stellar flux. This implies that the brightest stars (in evolved populations, the red giant branch) contribute most to the signal. I–band SBF have been successfully used to measure elliptical and S0 distances up to 4000 km / s from ground-based telescopes and 7000 km / s with the Hubble Space Telescope[23,1]. This sample of galaxies has also been used to measure galaxy bulk flows by Tonry and his collaborators[24]. Over the last few years, SBF measurements have been extended to the K–band[13,17,10,9,8]. In principle, the amplitude of SBF in this band is 30 times higher than in the I–band, but in practice the high background level in K hinders observational accuracy. We studied I and K–band SBF applications on 8–m class

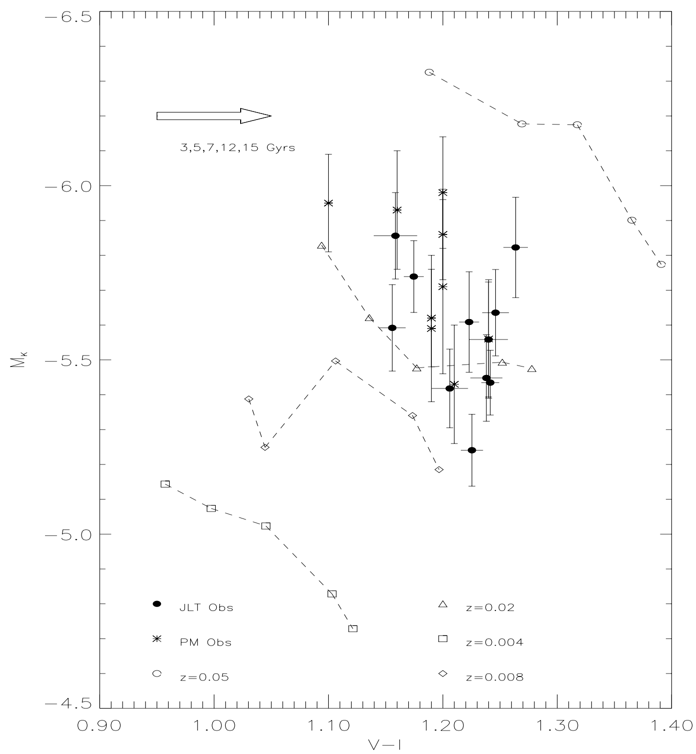

Figure 1: We plot K-band SBF from recent observations versus Bruzual and Charlot (2000) single burst stellar population models predictions. The filled circles are data from Jensen et al. 1998 (JLT), the asterisks are the data from Pahre & Mould 1994 (PM). Ages grow from left to right and have values 3, 5, 7,12 and 15 Gyrs. Twice solar metallicity are plotted by empty circles, solar metallicity models are plotted by triangles, 40% solar metallicity are plotted by diamonds, 20% solar metallicity are plotted by squares.

telescopes from a theoretical point of view and re–observed anomalous K–band SBF in NGC 4489 in the Virgo cluster.

2 I–band versus K–band SBF

The current SBF sample can be extended to larger distances by the introduction of 8–m class telescopes, such as the VLT. Our aim is to understand how far we can reach with SBF observations with 8–m class telescopes and which band is more efficient in terms of telescope time versus distance[15]. We have studied the SBF error budget from a theoretical point of view in the I and in K–band. The critical sources of error in SBF measurements are: dust patches, data signal-to-noise, seeing, external source removal and variations in stellar populations. To avoid dust patches the observations are usually made in ellipticals, S0 and spiral bulges. With respect to signal-to-noise, seeing, and external sources removal, we have simulated I–band and K–band SBF observations with the VLT (FORS1 and ISAAC instruments). The results of our simulations showed that in the I–band it is possible to extend observations till $\approx$ 7000 km/s with the VLT, while the K–band is limited by the high background. This high background makes much more difficult to detect and correct for globular cluster and background galaxy contamination as well as increasing the background shot noise.
With respect to stellar population effects, I–band observations can be calibrated empirically by a direct dependence of the I–band absolute magnitude $\overline{M_I}$ as a function of the color (V–I) of the galaxy[23]. In the K–band at present about twenty galaxies have been observed in the Virgo, Fornax and Coma clusters. These measurements show a constant behavior as a function of

Table 1: K–band SBF for NGC 4489

Obs	Tel	Exp Time	$\overline{M}_K$
		sec	mag
This work	NTT	3780	-6.13 ± 0.16
	KPNO 2.1m	1700	-6.11 ± 0.24
Jen98	Hawaii 2.2m	1890	-6.09 ± 0.36

the galaxy color (V–I). This is consistent with theoretical predictions from Worthey[26,27,9]. This result remains to be confirmed, however, because most of the available data do not have a high signal-to-noise ratio.

3 Stellar population effects in the K–band

Some of the galaxies observed in the K–band show SBF higher than average fluctuation magnitudes[17,10,9]. We have studied K–band SBF absolute magnitude predictions from stellar population models by Bruzual & Charlot 2000[3,12,15] and have re–observed K–band SBF in one of these anomalous high fluctuation galaxies, NGC 4489. We plot K-band SBF from recent observations versus Bruzual and Charlot[3] single burst stellar population models predictions in Figure 1. We have considered Salpeter single burst models with ages ranging from 3 to 15 Gyr and metallicity Z= 0.004 (20 % solar), 0.008 (40% solar), 0.02 (solar) and 0.05 (almost twice solar). Theoretical predictions from these models show that solar metallicity old populations are consistent with the current observations. These models predict that high metallicities and young ages increase the amplitude of the fluctuations, while low metallicities decrease the amplitude[14,11,15,12].

4 Anomalous K–band SBF in NGC 4489

We have re–observed K–band SBF in one of the Virgo galaxies that showed anomalous higher K–band SBF, NGC 4489[17,10,8]. Our high signal–to–noise data were obtained at the 2.1m KPNO and at the 3.5m ESO / NTT telescopes [16]. We show our results, together with Jensen et. al 1998 result, in Table 1. Our average $\overline{M}_K = -6.12 \pm 0.19$ for NGC 4489 is distinguishable at the two sigma level from the current average K–band absolute magnitude from Jensen et al. 1998 [9] $\overline{M}_K = -5.61 \pm 0.20$. It suggests the presence of brighter giant stars than in the mean elliptical galaxy and might be the signature of an extended Giant Branch (GB) population, as predicted by Pahre and Mould[17], and Mei et al. [16]. We have studied the effects of adding an extended giant branch to a normal giant branch. An extended giant branch luminosity function, similar to the M32 LF reported by Elston & Silva[5] and Freedman[6], was mixed with normal GB luminosity functions from Bruzual & Charlot[3,15,12]. This high $\overline{M}_K$ value derived for NGC 4489 is consistent with an extended GB[17,10,9,15,16]. Such a feature could be produced by an intermediate-age AGB[5,6] or from high-metallicity giant stars[7]. From stellar population models a high K–band SBF absolute amplitude can be due to metallicities higher than solar or young ages.

5 Summary

We have studied optical and infrared SBF as distance indicators and stellar population discriminator, in their applications on 8–m telescopes. We have shown that:

- I–band measurements can be extended out to ≈ 7000 km / s from the ground with 8– class telescopes, such as the VLT.
- K–band measurements from the ground are less efficient than I–band. They are nevertheless important to understand the role of stellar populations effects on their calibration, in view of K–band observations from space.
- We have confirmed the measurement by Jensen et al. (1998) and Pahre & Mould (1994) of anomalously high K–band SBF in NGC 4489. These anomalous fluctuation are most likely the signature of an extended giant branch. They could be caused by either intermediate age asymptotic giant branch stars above the tip of the first-ascent giant branch or high-metallicity first-ascent giants.

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