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NEAR-INFRARED SURFACE BRIGHTNESS FLUCTUATIONS AS DIAGNOSTICS OF UNRESOLVED STELLAR POPULATIONS

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RESUMEN

Las medidas de fluctuaciones de brillo superficial (FBS) constituyen un método muy poderoso para la determinación de distancias cosmológicas. Sin embargo, la posibilidad de utilizarlas como diagnósticos de poblaciones estelares no resueltas no se ha materializado. Aquí presentamos un proyecto en curso para explotar los datos del mapa del cielo 2MASS justamente con este propósito. Este trabajo ayudará a 1) explicar la dispersión observada en las medidas de FBS en cúmulos de galaxias cercanas; 2) calibrar los modelos de síntesis de poblaciones estelares que son utilizados, en combinación con datos observacionales, para derivar distancias cosmológicas, y 3) expandir las capacidades de los telescopios más grandes, como el GTC, para estudiar poblaciones estelares muy distantes.

ABSTRACT

Surface brightness fluctuations (SBFs) are already a very powerful tool for deriving cosmological distances. However, their promise as diagnostics of unresolved stellar populations has not yet been fulfilled. Here, we present an ongoing project to mine the 2MASS database with exactly that purpose. This work should help 1) explain the observed dispersion of measured SBFs in nearby galaxy clusters; 2) calibrate the stellar population synthesis models that are used, in combination with observational data, to derive cosmological distances; and 3) expand the capabilities of the largest telescopes, like the GTC, to study very distant stellar populations.

Key Words: **GALAXIES: STAR CLUSTERS — GALAXIES: STELLAR CONTENT — INFRARED: STARS — MAGELLANIC CLOUDS — STARS: AGB AND POST-AGB**

1. INTRODUCTION

Surface brightness fluctuation (SBF; Tonry & Schneider 1988) measurements are a powerful method for determining cosmological distances to early-type galaxies, with a well-understood physical basis. SBFs arise from Poisson fluctuations in the number of stars within a resolution element. While the mean surface brightness of a galaxy is independent of distance, for a given resolution the variance about the mean decreases with distance—more distant galaxies appear smoother. The observed ratio of the variance to the mean surface brightness of a galaxy is the ratio (denoted $\bar{L}$) of the second to the first moment of its stellar luminosity function scaled by d^{-2}. SBF measurements are expressed in $\bar{m}$ and $\bar{M}$, which are, respectively, the apparent and absolute magnitudes of $\bar{L}$.

SBF magnitudes, however, depend not only on galaxy distances but also on stellar population variations (age and metallicity). Therefore, SBFs also offer a unique possibility to investigate unresolved stellar populations. For example, as a luminosity-weighted mean, $\bar{M}$ is much more sensitive than integrated colors to giant stars (Worthey 1993a; Ajhar & Tonry 1994).

We have started a campaign to calibrate, for the first time, SBFs in the near-IR for the study of unresolved stellar populations. This spectral band is very favorable for SBF measurements from the point of view of improved signal (the light of intermediate and old populations is dominated by the red giant branch) and reduced dust extinction. However, there are disadvantages as well. Infrared SBFs seem to be more sensitive than fluctuations in the optical to age and metallicity (Worthey 1993b; Pahre & Mould 1994; Liu et al. 2000). This is in principle good for their use in studying stellar populations, but for the time being it is problematic because stellar population synthesis models are particularly discrepant in the near IR (Charlot, Worthey, & Bressan 1996; Liu et al. 2000; Blakeslee, Vazdekis, & Ajhar 2001). The discrepancy is up to $\sim 20\%$ in $(V-K)$, compared to $\sim$5% in $(B-V)$; the models even predict opposite trends with metallicity (Liu et al. 2000; Blakeslee et al. 2001). The ill-determined contribution of AGB stars to the integrated light may be the most important source of this problem (Ferraro et al. 1995).

2. THEORY, REALITY, AND SOLUTION

A good starting point to assess the impact of stellar population variations on SBFs and to empirically calibrate $\bar{M}$ is to observe a number of simple stellar populations with known distances. Globular clusters, and particularly the Magellanic clusters, appear to be ideal laboratories for this experiment. The clusters in the Magellanic Clouds span a much wider range of ages than Galactic globular clusters, while sampling the same range of metallicities. They also offer the advantage of very well known distance.

In reality, for this approach to work, the sample should include as many clusters as possible because it is in such systems where the AGB problem manifests itself most dramatically. In each individual cluster, the stars populating the AGB and the upper RGB are so few that they do not properly represent the distribution of the brightest AGB/RGB stars on the isochrone. Often, the integrated near-IR light and, even worse, the SBFs will be dominated by a single luminous, cool star.

Clearly, the way around this problem is an appropriate treatment of a sufficiently rich database. Fortunately, J, H, and K_s data on most Magellanic clusters are now available through the Two Micron All Sky Survey (2MASS; Skrutskie et al. 1997).

Rather than analyzing each cluster separately, we have built "superclusters" by coadding clusters in the Elson & Fall (1985, 1988) sample that has similar SWB type (Searle, Wilkinson, & Bagnuolo 1980).

This coaddition, of course, takes into account differences in distance and reddening, and also variations in the sky brightness and atmospheric transmission when the data were taken.

3. GOALS

With this work, we will be able to derive an empirical calibration of $\bar{M}$ in the near IR. We will compare the derived SBFs with those predicted by stellar population synthesis models; this comparison will allow the calibration of the latter. As a next step, we will compare linear combinations of SBFs with existing IR data for elliptical galaxies and bulges. *These steps will help us understand quantitatively the scatter of SBFs in such early systems; open the window for the use of the SBF method as a probe of stellar populations in distant galaxies; and also significantly improve the distance estimates derived from SBFs.* The largest IR telescopes, like the GTC, will help push studies of unresolved populations to further distances and into the cosmological past.

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