Draft version November 2, 2023
Typeset using LaTeX **twocolumn** style in AASTeX631

PhotoD: LSST photometric distances out to 100 kpc.

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ABSTRACT

This example manuscript is intended to serve as a tutorial and template for authors to use when writing their own AAS Journal articles. The manuscript includes a history of AASTeX and documents the new features in the previous versions as well as the bug fixes in version 6.31. This manuscript includes many figure and table examples to illustrate these new features. Information on features not explicitly mentioned in the article can be viewed in the manuscript comments or more extensive online documentation. Authors are welcome replace the text, tables, figures, and bibliography with their own and submit the resulting manuscript to the AAS Journals peer review system. The first lesson in the tutorial is to remind authors that the AAS Journals, the Astrophysical Journal (ApJ), the Astrophysical Journal Letters (ApJL), the Astronomical Journal (AJ), and the Planetary Science Journal (PSJ) all have a 250 word limit for the abstract[a]. If you exceed this length the Editorial office will ask you to shorten it. This abstract has 182 words.

Keywords: Distance measure (395) — Interstellar extinction (841) — Photometry (1234) — Stellar distance (1595) — Two-color diagrams (1724)

1. INTRODUCTION

Thanks to the *Vera C. Rubin* observatory's *Legacy Survey of Space and Time* (LSST), for the first time in history, an astronomical catalog will contain more Milky Way stars than there are living people on Earth – of the order 10-20 billion, depending on model assumptions. In order to map the Milky Way in three dimensions, distances to these stars must be accurately estimated. In this paper we describe a method that will deliver LSST-based stellar distance estimations complementary to *Gaia's* state-of-the-art trigonometric parallaxes and reach about 10 times further, to approximately 100 kpc. These results will be transformative for the studies of the Milky Way in general, and the stellar and the dark matter halo in particular as never before was there a survey that simultaneously observed roughly two thirds of the sky, to the co-added depth of $r \approx 26$ mag.

A bit about the importance of the distance estimation in the MW, dust implications (for extragalactic science too).

There are a variety of astronomical methods to estimate distances to stars, ranging from direct geometric (trigonometric) methods for nearby stars to indirect methods based on astrophysics for more distant stars.

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[a] Abstracts for Research Notes of the American Astronomical Society (RNAAS) are limited to 150 words

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Mention Bailer-Jones et al. (2021), Green et al. (2014, 2015, 2019), Jurić et al. (2008) and Lallement et al. (2014), Queiroz et al. (2018).

Layout of the paper is...

2. METHOD

The photometric distance estimation method (hereafter `photoD`) is conceptually quite simple and relies on the strong correlations between the stellar colors and spectral energy distributions (SED) for dominant stellar populations. The stellar spectral energy distributions, and consequently colors, are determined by the effective temperature (T_{eff}), the surface gravity (g), and the metallicity ([M/H]), or alternatively, by the absolute magnitude in band b (M_b), [M/H] and age.

The distributions that describe these correlations are obtained either from models or from observations. For example, the distribution of stellar SEDs in the color-color diagram in Figure 1 provides key insights in stellar evolution and classification of different stellar populations such as main-sequence stars, giant stars, white dwarf stars, a majority of unresolved binary stars and even extragalactic objects. Analogous distributions are responsible for the abundant structure seen in the Hertzsprung-Russell diagram (HRD).

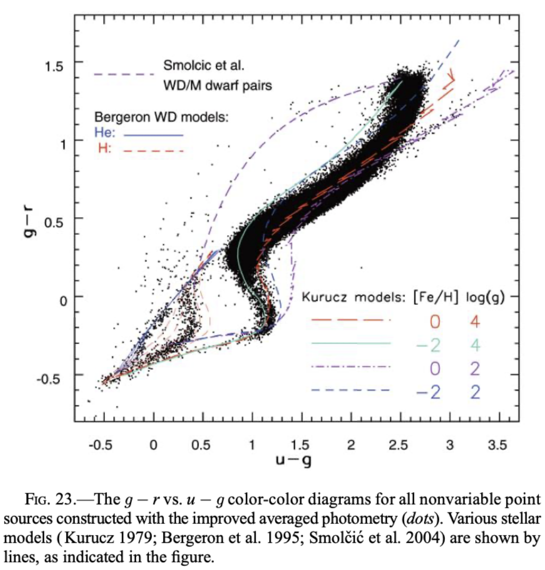

Figure 1. Color-color diagram. Add a version with overlaid evolutionary tracks in order to emphasize the required precision of the photometry required to disentangle the dwarfs and giants and different metallicities. **Are ev. tracks with different metallicities overlapping**? Can there be a situation where there is confusion between giants and dwarfs with different metallicities?

Metallicity is an important factor in these correlations, as it has a strong effect on the luminosity of the stars. This is reflected in the width of the main stellar loci of the color-magnitude diagrams (CMD) of the stellar populations observed at the same distance and the two-color diagrams (quantify), as seen in Figure 2. The best photometric estimators of metallicity are colors whose shorter-wavelength component includes the metal absorbtion bands at near-UV wavelengths, short of Balmer break. Therefore, the LSST has a comparative advantage over the surveys lacking u-band measurements, and could provide accurate distances within the range of 5-10%. A plot of model spectra, fixed, *log(g)* and T_{eff}, several different metallicities?

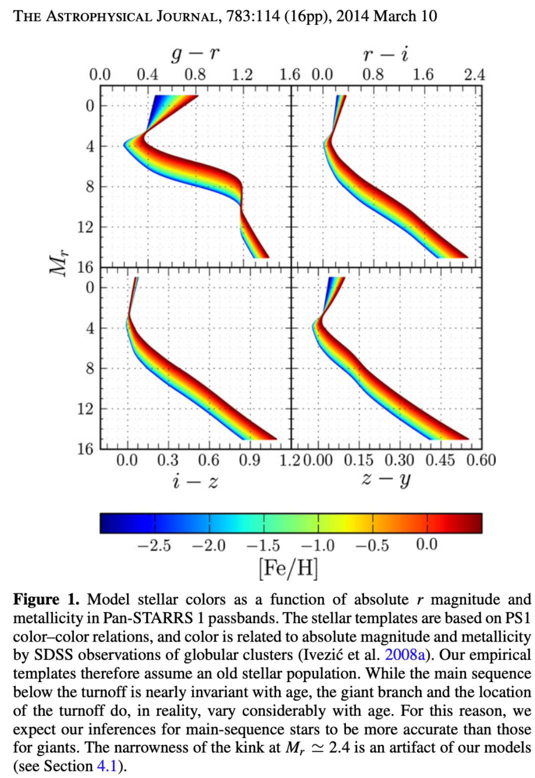

Figure 2. Yadayada.

Extinction is a major source of systematic errors in the process of luminosity and distance determination. The fact that the extinction vector is nearly parallel to the main stellar locus in the two-color diagrams gives rise to degeneracies that complicate the determination of the stellar type. An example is displayed in Fig. 3, where in the left panel any of the different star types designated as 1,2 and 3 can have the same observed colors as the star marked as "Obs". This degeneracy is a result of the combination of colors chosen for the two-color diagram and depends on the adopted extinction curve R_V and the position on the stellar locus. The degeneracy can be broken if several different colors are used, particularly those towards the infrared, where the stellar locus is not kinked and the extinction vector is not parallel to it (as shown in the right panel of the Figure 3).

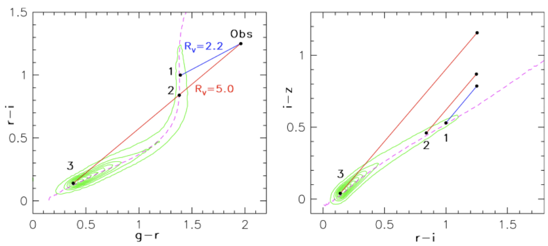

Figure 3. Extinction & degeneracies.

$$L = 4\pi\sigma R^2 T^4$$
$$g = \frac{GM}{R^2}$$
$$L = 4\pi\sigma \frac{GM}{g} T^4$$
$$\mu = m_b - M_b \; (-A_b)$$
$$log(d) = 1 + \frac{\mu}{5}$$

Given the observed colors, and assuming small errors, the estimation of stellar parameters is relatively straight forward and follows one of the two possible approaches: empirical or model-based. In the former case, the case the underlying distribution to which the observations are matched is obtained from (ideally) spectroscopic and photometric observations, while in the latter case the distributions are generated from population synthesis models.

Advantages & disadvantages of the model-based and empirical approaches, how model based approaches can be improved by adding empirical information for specific cases.

APPENDIX

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