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REVISITING THE SURFACE BRIGHTNESS-COLOUR RELATION IN THE CONTEXT OF THE ARAUCARIA PROJECT AND THE PLATO SPACE MISSION

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Abstract. The ease of use of Surface Brightness-Colour Relations (SBCRs) is a major advantage in the determination of stellar angular diameters. It currently plays a significant role for the distance determination of eclipsing binaries and also for the characterization of exoplanets host stars. Despite the large number of existing SBCRs, strong discrepancies occur on the outer edges of the surface brightness F_V versus $V - K$ colour diagram. Challouf et al. (2014) reached a precision of 7% on the estimate of the angular diameter for $V - K < 0$ mag, while 10% of accuracy only is expected on the other part of the diagram. To overcome these discrepancies, we apply the same methodology to all the angular diameter and photometric estimates available in the literature. We also observe new stars using the CHARA/VEGA and PAVO instruments. We show that the SBCR strongly depends on the spectral type and the luminosity class of stars. An unique SBCR can therefore not be used for any type of star.

Keywords: stars: fundamental parameters – cosmology: distance scale – techniques: interferometric

1 Introduction

Surface Brightness-Colour Relations (SBCRs) are very convenient tools to determine precisely stellar angular diameters. Assuming the star is a black body, the surface brightness (i.e. the flux density per unit angular area) is connected to the angular diameter. Also, the bolometric surface flux $f_{\rm bol}$ is proportional to the effective temperature T_{eff}^4 of the star, and therefore to its colour $m_{\lambda_1} - m_{\lambda_2}$. In this way, the surface brightness can be estimated by the linear relation

$$F_{\lambda_1} = a\,(m_{\lambda_1} - m_{\lambda_2}) + b. \tag{1.1}$$

Pietrzyński et al. (2019) have recently constrained the Large Magellanic Cloud distance to 1%, applying SBCRs to 20 eclipsing binaries. The PLATO (PLAnetary Transits and Oscillations of stars) space mission, planned for a launch in 2026, has the aim of characterizing exoplanetary systems, basing on the transit method (Catala & PLATO Team 2006). Knowing the angular diameter of the star very accurately allows to determine the distance of nearby galaxies or the radius of exoplanets. So far, 23 SBCRs have been established in the $V - K$ colour range, covering all spectral types and luminosity classes. We have represented these SBCRs on Fig. 1. Following Nardetto (2018) analysis, we find an agreement of 1-4% (resp. 2-6%) in the PLATO spectral range domain (F5-K7) for stars with classes of IV/V (resp. II/III). For M stars (V-K<5), SBCRs available are precise but inconsistent at the 10% level. For O, B stars (V-K<0), SBCR are unprecise at the 7% level. The major limitation of these SBCRs comes from their inhomogeneous datasets and methodologies.

2 Revisiting the calibration of the SBCRs

2.1 Early-type stars: the distance of bright eclipsing binaries in nearby galaxies (M31, M33)

Early-type eclipsing binaries are usually used to determine distances of M31 and M33 (Vilardell et al. 2010; Bonanos et al. 2006). In the course of the Araucaria project (Pietrzyński & Gieren 2002), an observing program with the VEGA instrument on the CHARA array is ongoing. This program, based on the observation of 20 early-type stars, aims at developing a new SBCR that could allow to estimate stellar angular diameters with a precision of about 2%.

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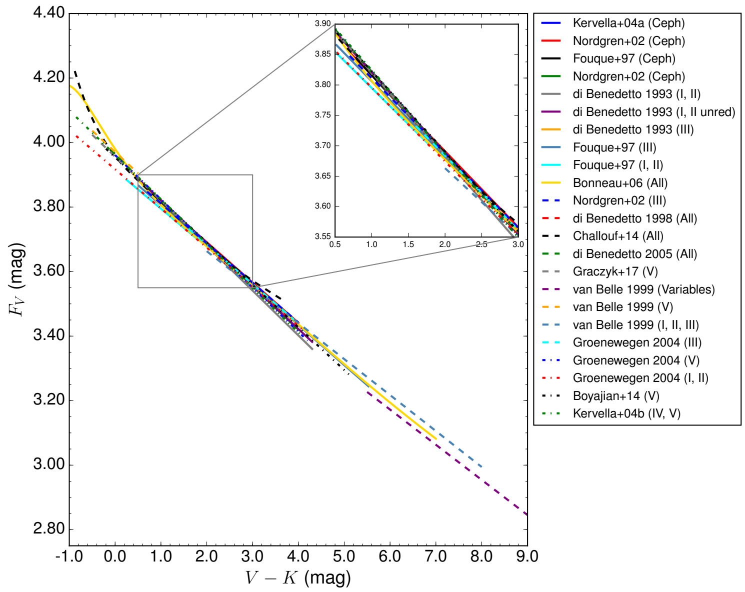

Fig. 1. Comparison of the 23 existing SBCRs in their respective $V - K$ colour domain of application. The square in the upper-right corner shows a zoom in the [0.5;3] mag colour region. See Nardetto (2018) for the references.

2.2 Late-type stars: characterization of exoplanets

On the other hand, late-type stars are stars with F5 to F9, K and M spectral types. Building SBCRs for these cool stars are of primary importance for the PLATO mission. Indeed, SBCRs give stellar angular diameters, that are essential to characterize exoplanetary systems with the transit method. An observation program is dedicated to implement a new SBCR for these types of star. The advantage here is the availability of data from both VEGA and PAVO instruments on the CHARA array. We want first to compare the angular diameters obtained with both instruments, and include them in SBCRs we have developed for late-type stars using existing interferometric data combined with selection criteria we have implemented (Salsi et al. 2019).

3 Conclusions and preliminary results

SBCRs are largely involved in many international projects. However, using one or another relation can lead to significant differences according to the $V - K$ colour of the star. Our works on early-type and late-type stars have therefore the aim to better understand the physics behind the SBCRs and also clarify the effect of stellar activity by revising with a homogeneous approach the whole F_V versus $V - K$ colour diagram. For the very first time, we have implemented criteria to properly select interferometric measurements from the JMMC Measured stellar Diameters Catalog (Chelli et al. 2016) to build strong and accurate SBCRs for late-type stars. This part of the work will be described in Salsi et al. (2019). In this work, we show that considering both the spectral type and the luminosity class of stars is of primary importance to develop accurate SBCRs, since relations for giants are totally inconsistent with those of subgiants and dwarfs.

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