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The Temperature Scale of Globular Cluster Stars

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Abstract. The empirical temperature scale for Pop I A-K stars has been well established for over 20 years from application of stellar intensity interferometry, lunar occultation, infrared flux method and Michelson interferometry. Line-blanketed model atmospheres and a better understanding of the handling of convection now produce synthetic colours that are in excellent agreement with this empirical temperature scale. Model atmosphere colours and fluxes for higher and lower abundances than solar can be used confidently to derive temperatures for the globular cluster stars.

Key words. temperature scale – convection – stellar atmosphere

1. Temperature scales from interferometry

The empirical temperature scale for Pop I A-K stars has been well established for over 20 years from fundamental temperature derivations using stellar intensity interferometry and lunar occultations and more recently Michelson interferometry and the infrared flux method. We show in Fig. 1 the well defined temperature calibrations based on V-I or V-K colours. These colors being less affected by line blanketing and convection are well suited for deriving temperatures for stars with different metallicities and gravities. Although not shown here, the empirical relation between b-y and V-I is remarkably tight and indicates that b-y temperature calibrations like those for V-I are not very sensitive to metallicity.

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2. Temperature scale from the Infrared-Flux Method

The Code et al (1976) calibration extended from O stars to early mid F stars while the lunar occultation and Michelson interferometry detailed the K to M giants. The Infrared-Flux Method has very successfully been used to bridge the F-K gap that initially only had the sun as a fundamental calibrator (and the sun has notoriously been difficult to derive accurate colors for). Blackwell has been the major proponent of this technique and his latest paper with Lynas Gray summarises the results well. In Fig. 2 are shown this calibration compared with the theoretical calibration from Bessell, Castelli & Plez (1998). BCP98 discuss the no-overshoot versus overshoot question and show that the 1-dimensional models computed with no-overshoot best match the empirical temperature scale.

For a given color the models give a slightly hotter temperature scale for main sequence stars than the empirical IRFM temperature scale. Alonso et al. (1995, 1996) have also

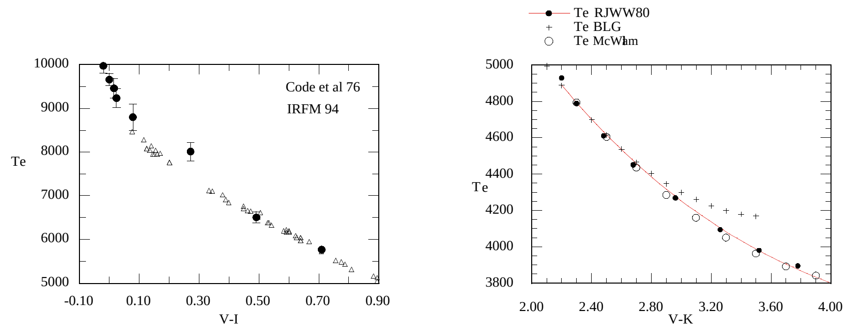

Fig. 1. Left panel: V-I temperature scale from Stellar Intensity interferometry (Code et al (1976); IRFM Blackwell & Lynas Gray (1994). Right panel: V-K temperature scale for K giants from lunar occultation Ridgway et al (1980); IRFM Blackwell & Lynas Gray (1994); McWilliam (1990)

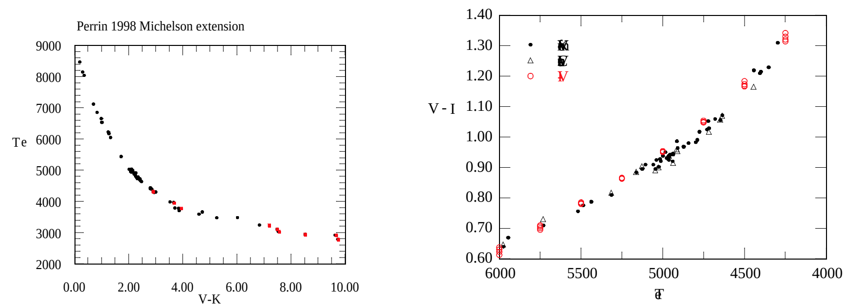

Fig. 2. Left panel: V-K temperature scale for M stars from Perrin et al (1998). Right panel: V-I temperature scale for F-K stars from the IRFM Blackwell & Lynas Gray (1994) compared with model atmosphere calibrations based on no-overshoot models.The observed V-K colors have been transformed into V-I using an empirical relation.

presented IRFM temperature for subdwarfs with a range of metallicities. In Fig 2b are shown a comparison between the model Te and the IRFM temperatures of Blackwell & Lynas Gray and those of Alonso et al (1995) (Ta) for stars with metallicities between -0.5 and +0.2 dex compared to the sun.

3. Theoretical halo isochrones

Theoretical isochrones are available for a range of metallicities and ages from the work of Bergbusch & Vandenberg (2001) or Girardi et al (2000) and Salasnich et al (2000). The Padova and Vandenberg isochrones are not identical. Fig 3b shows a comparison between them. The Bergbusch & Vandenberg tracks are slightly cooler. Using the Bergbusch & Vandenberg (2001) log g versus Te isochrones we have derived halo giant branch colour versus temperature relations for different metallicities shown in Figs 4, 5a. It is seen that the V-I versus V-K relations show little metallicity sensitivity down to 5000K (V-I) and 4500K (V-K) which makes for robust abundance determinations.

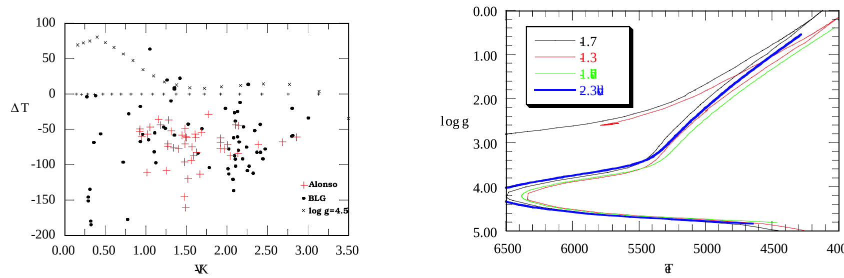

Fig. 3. Left panel: Temperature differences for a given V-K colour between the empirical IRFM temperature scale of Blackwell & Lynas Gray (filled boxes), Alonso et al. (+) Right panel: Comparison between theoretical isochrones of the Padova and Vandenberg groups. Metallicities are indicated.

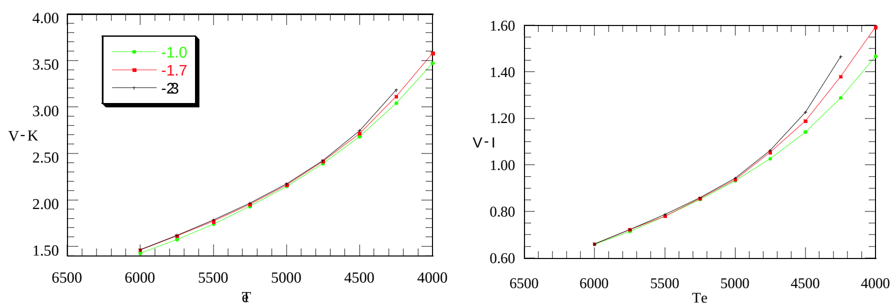

Fig. 4. Left panel: Theoretical V-K -Te relation for globular cluster giant branch; colours from BCP98. Right panel: Same, but for V-I.

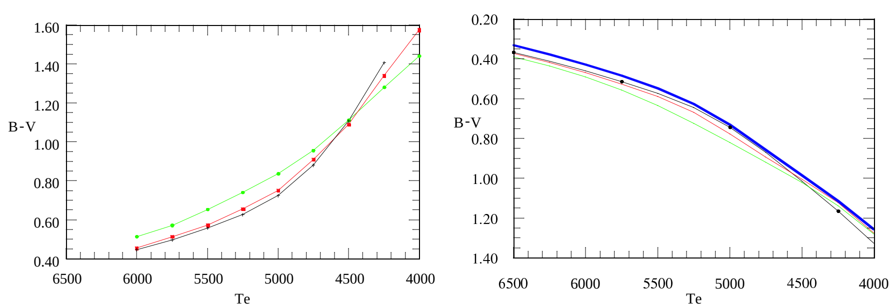

Fig. 5. left panel: Theoretical B-V -Te relation for globular cluster giant branch; colours from BCP98. Right panel: B-V -Te relations of Houdashelt et al. (2000) compared with colours for -2.5 dex models of BCP98. Symbols and lines as in Fig 6.

4. Houdashelt et al temperature calibrations

Houdashelt et al (2000a, 2000b) have provided model atmosphere temperature colour relations with empirical corrections. These provide similar V-K and V-I versus temperature calibrations to those of Bessell, Castelli & Plez (1998) while for a given T_{eff} Houdashelt's B-V is somewhat redder. These relations are shown in Figs. 5 and 6.

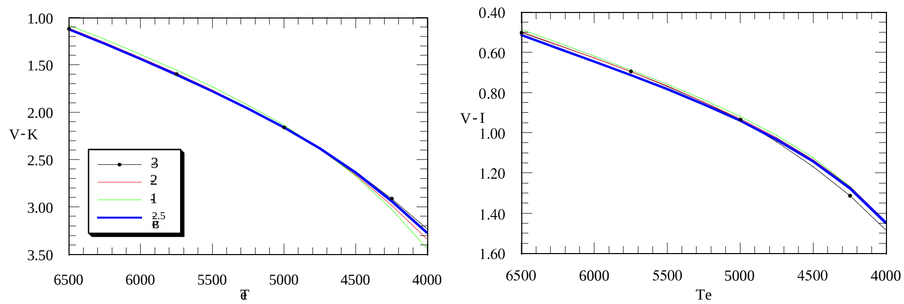

Fig. 6. left panel: V-K -Te relations of Houdashelt et al. (2000) and BCP98 (-2.5 dex). Right panel: V-I -Te relations of Houdashelt et al. (2000) and BCP98 (-2.5 dex).

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