

Distance estimates to five open clusters based on 2MASS data of red clump giants

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Abstract. Red clump (RC) giants are excellent standard candles in the Milky Way and the Large Magellanic Cloud. The near-infrared K -band intrinsic luminosity of RC giants exhibits only a small variance and a weak dependence on chemical composition and age. In addition, RCs are often easily recognizable in the color–magnitude diagrams of open clusters, which renders them extremely useful distance indicators for some intermediate-age or old open clusters. Here we determine the distance moduli of five Galactic open clusters covering a range of metallicities and ages, based on RC giants in the cluster regions using 2MASS photometric data. We compare our result with those from main-sequence fitting and also briefly discuss the advantages and disadvantages of RC-based cluster distance determination.

Keywords. open clusters and associations: individual (NGC 6791, NGC 2420, NGC 2682, NGC 2158, NGC 7789), distance scale

1. Cluster sample and red clump selection

The red clump (RC) is made up of core-helium-burning giant stars, just like a normal horizontal branch. RC stars occupy a very compact locus in the Hertzsprung–Russell diagram. Thus, its identification and its basis for accurate distance determination have been proven, and the RC turns out to be an excellent tool for large-scale Galactic structure and kinematic studies (see, e.g., Paczyński *et al.* 1999; Alves 2000; Van Helshoecht *et al.* 2007; Groenewegen 2008; and references therein).

In particular, the small variance of the RC's intrinsic K -band luminosity and the weak dependence on chemical composition and age make it an extremely useful distance indicator (Van Helshoecht 2007). In addition, the RC also has the advantage that it is easily recognizable in the color–magnitude diagrams (CMDs) of most open clusters.

We plan to undertake a systematic search of RC stars in Galactic open clusters based on 2MASS/Point Source Catalog data. As a preliminary performance test, we selected five open clusters covering a wide range in metallicity and age as a test sample. Table 1 lists the basic parameters of the five star clusters (Dias *et al.* 2002), including their central positions in both equatorial and Galactic coordinates, their average reddening values, distances to the sun, ages, and metallicities.

We used 2MASS infrared photometry (Cutri *et al.* 2003) to extract sample RC stars in the fields of the five Galactic open clusters. Radii from 3.75 to 12 arcmin were adopted for the different clusters, based on the values in Dias' catalog (Dias 2002). The K_s versus $(J-K_s)$ CMD was plotted for each cluster field, and median RC magnitudes were derived.

As an example, Fig. 1 shows the CMD of NGC 6791 for radii $r < 5'$ (top left) and the K_s -band luminosity function in the same region (top right). In addition, we present the

Table 1. Basic information about our sample of five open clusters

Cluster	R.A. (J2000.0) (hh:mm:ss)	Dec. (J2000.0) (dd:mm:ss)	l (deg)	b (deg)	$E(B - V)$ (mag)	Distance (pc)	Age (Gyr)	[Fe/H] (dex)
NGC 6791	19 20 53	+37 46 18	69.96	10.90	0.12	5853	4.4	0.15
NGC 2420	07 38 23	+21 34 24	198.11	19.63	0.04	2480	1.1	-0.26
NGC 2682	08 51 18	+11 48 00	215.70	31.92	0.06	908	2.6	0.0
NGC 2158	06 07 25	+24 05 48	186.63	1.78	0.36	5071	1.9	-0.25
NGC 7789	23 57 24	+56 42 30	115.51	-5.38	0.28	1795	1.7	-0.08

relation between magnitude and the corresponding uncertainties in the J band (bottom left) and the K_s band (bottom right). The rectangle superimposed on the CMD covers a color range of $0.7 \leq (J - K_s) \leq 0.8$ mag and a magnitude range of 0.4 mag, i.e., $11.3 \leq K_s \leq 11.7$ mag. A total of 19 RC stars fall in the region of interest and a median apparent K_s magnitude of 11.52 ± 0.07 was obtained.

We adopt $M_{K_s} = -1.54 \pm 0.04$ mag, based on Groenewegen's (2008) calibration using revised *Hipparcos* parallaxes. Thus, we derived the distance modulus of NGC 6791 as $(m - M)_{K_s}^0 = m_{K_s} - M_{K_s} - 0.11 \times 0.31 \times E(B - V) = 13.02 \pm 0.08$ mag. Here we adopt a reddening of $E(B - V) = 0.117$ mag (from the WEBDA database: <http://www.univie.ac.at/webda/>).

2. Results and Discussion

Based on 2MASS infrared photometry, we derived the distance moduli of our five test open clusters using the RC's K_s -band magnitude as a 'standard candle.'

Table 2. Distance estimates for the five open clusters based on their RCs compared with results from main-sequence fitting (MSF).

Cluster	RCs $(m - M)_0$	MSF $(m - M)_0$	MSF ref.
NGC 6791	13.02 ± 0.08	13.11	Chaboyer <i>et al.</i> (1999)
		13.0	King <i>et al.</i> (2005)
		13.07 ± 0.05	Carraro <i>et al.</i> (2006)
NGC 2420	11.76 ± 0.12	11.4 ± 0.2	McClure <i>et al.</i> (1974)
		11.80	Anthony-Twarog <i>et al.</i> (1990)
		11.9 ± 0.1	Lee <i>et al.</i> (1999)
NGC 2682	9.49 ± 0.09	9.38	Boyle <i>et al.</i> (1998)
		9.58	VandenBerg <i>et al.</i> (2007)
		9.70 ± 0.05	Sarajedini <i>et al.</i> (2009)
NGC 2158	12.91 ± 0.09	12.70	Christian <i>et al.</i> (1985)
		12.8	Carraro <i>et al.</i> (2002)
		12.98	Bedin <i>et al.</i> (2010)
NGC 7789	11.44 ± 0.18	11.25	Vallenari <i>et al.</i> (2000)
		11.56 ± 0.12	Bartasiute <i>et al.</i> (2004)
		11.27 ± 0.04	Wu <i>et al.</i> (2007)

In Table 2 we compare our distance modulus results based on the RC magnitudes with those derived from main-sequence-fitting (MSF). The comparison shows that our results agree well with most MSF results. However, using the RC's intrinsic K -band luminosity as

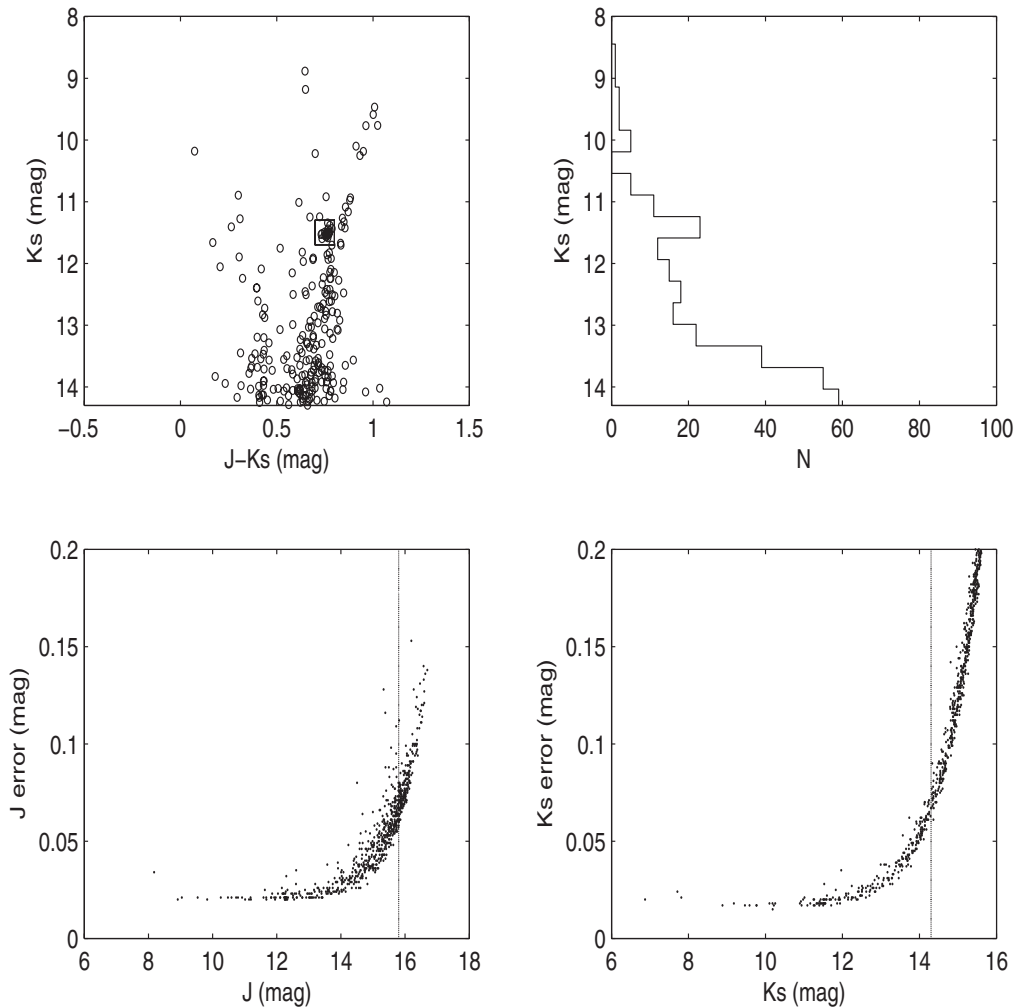


Figure 1. (top left) $(J - K_s)$ versus K_s CMD of NGC6791, within a radius $r < 5'$; (top right) K_s -band luminosity function in the same region; (bottom left) J versus uncertainty in J magnitude; (bottom right) K_s versus uncertainty in K_s magnitude.

a distance indicator has the advantage of a weaker dependence on chemical composition and age (for wide ranges), and also of being less affected by reddening. In particular, the RC's infrared-calibrated nature as a standard candle may play an important role in cluster distance determination. Among our five sample clusters, NGC 6791, NGC 2158, and NGC 7789 all have around 20 RC stars detected in their CMD, while the other two clusters have only approximately 10 RC stars each. The RC's number density in the cluster CMD would be one of the main limitations to the accuracy of the resulting distance modulus.

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