

# NGC 1883: a neglected intermediate-age open cluster located in the outskirts of the Galactic disc

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## ABSTRACT

We report on *BVI* CCD photometry of a field centred in the region of the open cluster NGC 1883, down to  $V = 21$ . This cluster has never been studied so far; we provide, for the first time, estimates of its fundamental parameters – namely radial extent, age, distance and reddening. We find that the cluster has a radius of about 2.5 arcmin, and shows signatures of dynamical relaxation. NGC 1883 is located in the anticentre direction, and exhibits a reddening in the range  $E(B - V) = 0.23\text{--}0.35$ , depending on the metal abundance. It turns out to be of intermediate age (1 Gyr old), and is quite distant for an open cluster. In fact, it is located 4.8 kpc from the Sun, and more than 13 kpc from the Galactic centre. This results makes NGC 1883 one of the most peripheral old open clusters, with important consequences for the trend of the metallicity with distance in the outer Galactic disc.

**Key words:** Hertzsprung–Russell (HR) diagram – open clusters and associations: general – open clusters and associations: individual: NGC 1883.

## 1 INTRODUCTION

NGC 1883 (C 0522+465, OCL 417) is a northern open cluster, located toward the anticentre direction ( $\alpha = 05^{\text{h}}25^{\text{m}}9$ ,  $\delta = +46^{\circ}29'$ ,  $l = 163^{\circ}08$ ,  $b = +06^{\circ}16$ , J2000.). This cluster has never been studied so far. The only information we have is from Trumpler (1930), who suggests that this cluster is fairly well-detached from the field, shows a clear central concentration with a radius of about 3 arcmin, and is moderately rich (I 2 m Trumpler class). The same kind of information can be found by consulting the work of Collinder (1931). This paper presents the first photometric study of the cluster, and it is part of a series dedicated to improving the photometry of northern open clusters at Asiago Observatory (see Carraro, Barbon & Boschetti 2002, and references therein). Section 2 of this paper illustrates the observation and reduction strategies. An analysis of the geometrical structure and star counts in the field of NGC 1883 are presented in Section 3, with a discussion of the colour–magnitude diagram (CMD) given in Section 4. Section 5 deals with the determination of cluster reddening, distance and age. Finally, Section 6 summarizes our findings.

## 2 OBSERVATIONS AND DATA REDUCTION

CCD *BVI* observations were carried out with the Asiago Faint Object Spectrograph and Camera at the 1.82-m Copernico tele-

scope at Cima Ekar (Asiago, Italy), in the photometric night of 2002 November 8. AFOSC, with a pixel size of 0.473 arcsec, samples a  $8.14 \times 8.14$  arcmin<sup>2</sup> field in a 1 K  $\times$  1 K nitrogen-cooled thinned CCD.

Details of the observations are listed in Table 1 where the observed field is reported together with the exposure times, the typical seeing values and the airmasses. Fig. 1 shows the finding chart for the NGC 1883 region taken from the DSS-2<sup>1</sup> archive. The data has been reduced with the IRAF<sup>2</sup> packages CCDRED, DAOPHOT and PHOTCAL using the point spread function (PSF) method (Stetson 1987). The calibration equations obtained by observing the PG 0231+051 and PG 2213–006 fields of Landolt (1992), observed throughout the night, are:

$$b = B + b_1 + b_2(B - V) + b_3X \quad (1)$$

$$v = V + v_{1bv} + v_{2bv}(B - V) + v_3X \quad (2)$$

$$v = V + v_{1vi} + v_{2vi}(V - I) + v_3X \quad (3)$$

$$i = I + i_1 + i_2(V - I) + i_3X \quad (4)$$

where  $B$ ,  $V$  and  $I$  are the standard magnitudes,  $b$ ,  $v$  and  $i$  are the instrumental ones,  $X$  is the airmass, and the derived coefficients are presented at the bottom of Table 1. When the  $B$  magnitude was

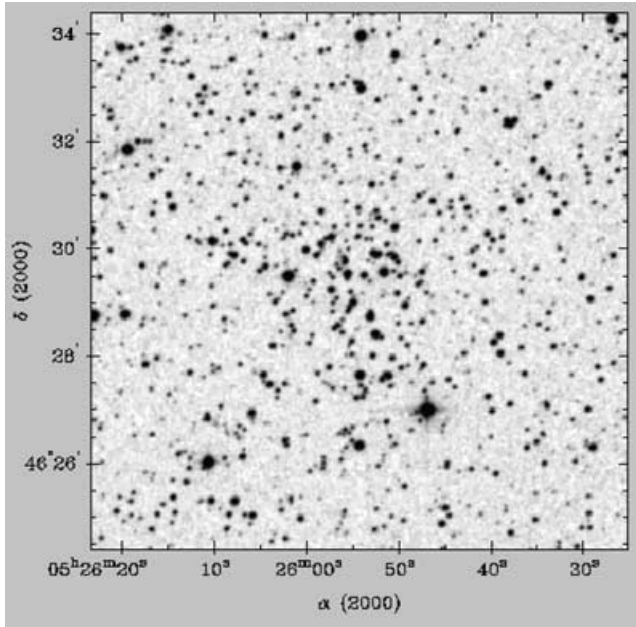
<sup>1</sup>Second Generation Digitized Sky Survey, <http://cadwww.dao.nrc.ca/cadcbn/getdss>

<sup>2</sup>IRAF is distributed by NOAO, which are operated by AURA under cooperative agreement with the NSF.

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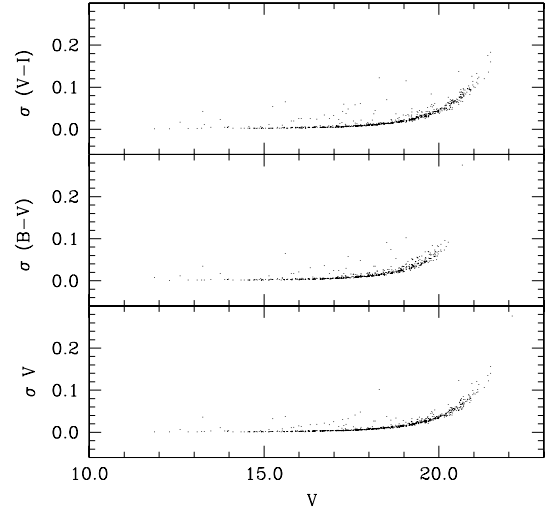
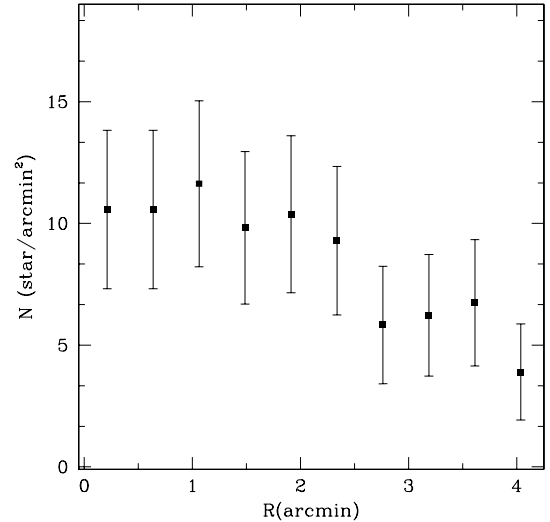
**Table 1.** Journal of observations of NGC 1883 and standard star fields together with calibration coefficients (2002 November 8).

Field	Filter	Exposure time		Seeing	Airmass	
		[s]	[s]	[arcsec]		
NGC 1883	<i>B</i>	600	60	5	2.1	1.015
	<i>V</i>	300	30	3	2.0	1.018
PG 0231+051	<i>I</i>	300	30	3	2.0	1.020
	<i>B</i>	300			2.4	1.324
	<i>V</i>	60			2.2	1.316
PG 2213-006	<i>I</i>	90			2.2	1.315
	<i>B</i>	150			2.3	1.291
	<i>V</i>	30			2.3	1.298
Calibration coefficients	<i>I</i>	30			2.5	1.295
	$b_1 = +1.602 \pm 0.004$					
	$b_2 = +0.038 \pm 0.006$					
$b_3 = +0.29$						
$v_{1bv} = +1.003 \pm 0.014$				$i_1 = +1.691 \pm 0.044$		
$v_{2bv} = -0.016 \pm 0.018$				$i_2 = +0.057 \pm 0.043$		
$v_3 = +0.16$				$i_3 = +0.08$		
$v_{1vi} = +1.002 \pm 0.016$						
$v_{2vi} = -0.013 \pm 0.016$						

**Figure 1.** A Digitized Sky Survey image of a region around NGC 1883 covered by the present study. North is up; east is to the left.

available, we used expression (2) to compute the *V* magnitudes; elsewhere, expression (3) was used. The standard stars in these fields provide a very good colour coverage. For the extinction coefficients, we assumed the typical values for the Asiago Observatory (Desidera, Fantinel & Giro 2002).

Finally, Fig. 2 presents the run of photometric errors as a function of magnitude. These errors take into account calibration errors, and fitting errors from DAOPHOT, and have been computed following the methods of Patat & Carraro (2001). It can be noted that stars brighter than  $V \approx 21$  mag have photometric errors lower than 0.10 mag in magnitude and lower than 0.15 mag in colour. The final

**Figure 2.** Photometric errors, as a function of magnitude, for our NGC 1883 observations.**Figure 3.** Star counts in the field of NGC 1883, as a function of the radius.

photometric data are available in electronic form at the WEBDA site.<sup>3</sup>

### 3 STAR COUNTS AND CLUSTER SIZE

Lyngå (1987) and Dias et al. (2002) report a preliminary estimate of the radius of NGC 1883, amounting to 2.5–3.0 arcmin. This is basically confirmed by the appearance of the cluster in the finding chart (Fig. 1), from which one can readily see that we were able to cover all the cluster region. We perform star counts by using our CCD data to obtain a new estimate of the cluster size. We derive the surface stellar density by performing star counts in concentric rings around star #12 (the present numbering), selected as the approximate cluster centre, and then dividing by their respective areas. The final density profile and the corresponding Poisson error bars are shown in Fig. 3, where we take into account all the measured stars brighter than  $V \approx 19.5$  mag.

<sup>3</sup> <http://obswww.unige.ch/webda/navigation.html>

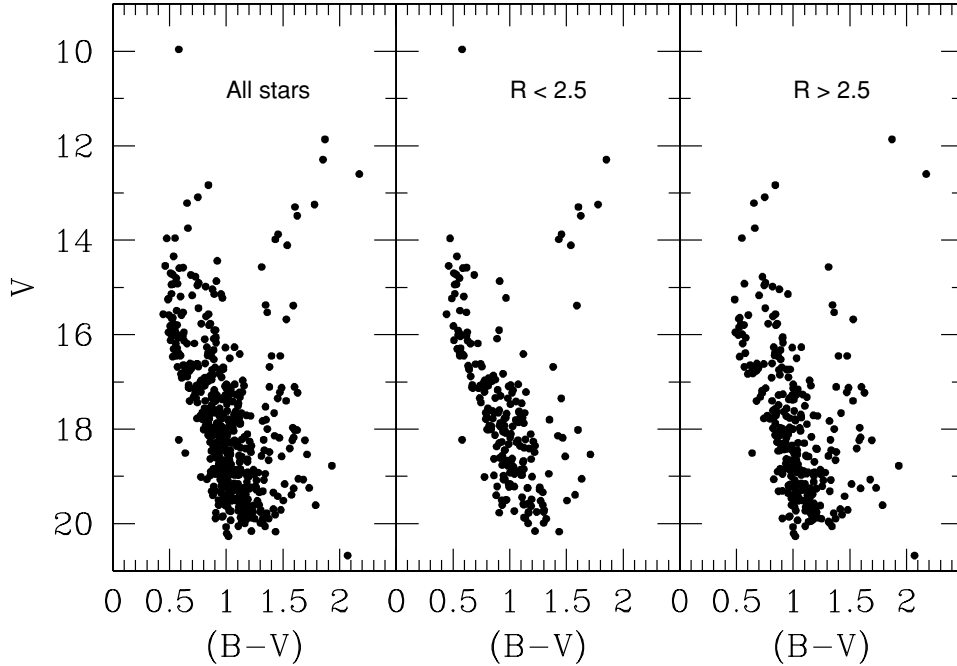


Figure 4. CMDs of NGC 1883, as a function of the radius.

The surface density has a value of  $10\text{--}12$  star  $\text{arcmin}^{-2}$  within a radius of 2.5 arcmin, and a value of  $4\text{--}6$  star  $\text{arcmin}^{-2}$  outside this. From this sharp density variation, we argue that the cluster population is dominant within a radius of 2.5 arcmin; outside this, the general Galactic disc field dominates the star counts (see also Fig. 1).

The precise value of the cluster radius is, however, difficult to obtain, and we consider 2.5 arcmin as a lower limit. Obviously, we expect that some cluster stars are located out of this radius, which we simply consider as the distance from the cluster centre inside which the cluster dominates over the field.

#### 4 THE COLOUR-MAGNITUDE DIAGRAMS

The CMDs of NGC 1883 are shown in Fig. 4. To facilitate the interpretation, we consider the distribution of the stars in the CMD as a function of the distance from the cluster centre. In the left-hand panel of Fig. 4, we plot all the detected stars. Here, the cluster exhibits a well defined main sequence (MS), extending from  $V = 20$  to 14.5. Interestingly, there are a few stars in the red part of the CMD, which resemble a red giant branch (RGB). The MS is significantly wide, and some hints for a substantial population of unresolved binary stars is visible – particularly in the upper MS – in the form of a parallel redder sequence. The turn-off point (TO) is roughly located at  $V = 16$ ,  $(B - V) = 0.60$ . The group of stars above the TO (between  $V = 12.5$  and  $V = 13.5$ ) can be either blue stragglers belonging to the cluster or field stars. Finally, the brightest star (see also Fig. 1), located south-west of the cluster centre, and recorded as GSC 03358 – 01188 and TYC 3358 – 1188 – 1, is probably an interloper.

Much better information can be obtained by looking at the middle and right-hand panels in Fig. 4. The middle panel contains only the stars located inside the estimated cluster radius (2.5 arcmin), whereas the right-hand panel contains all the stars located outside

the cluster radius. The following considerations can be taken into account:

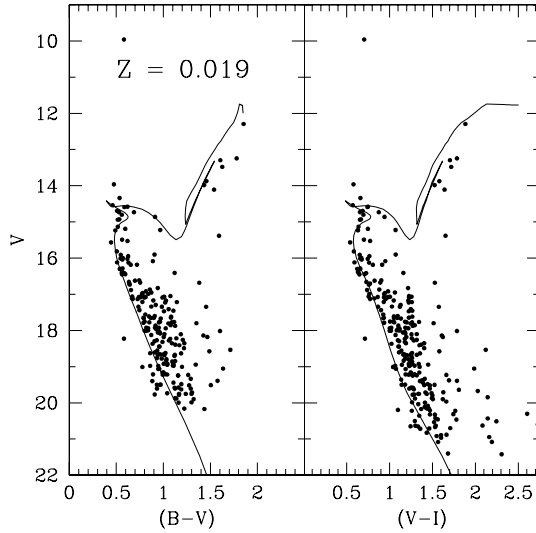
- (i) the MS and the TO region in the middle panel are much better defined;
- (ii) almost all the probable RGB stars are inside the inner region, which implies that the cluster underwent some dynamical relaxation; and
- (iii) the stars above the TO are probably field stars, because they all lie out of the cluster radius (see right-hand panel).

In particular, the fine shape of the TO deserves some attention. In fact, the shape of the TO is typical of intermediate-age open clusters, with a blue and red hook that is clearly visible, notwithstanding the contamination of the field stars. This is a clear indication of an age in the range of 1–1.5 Gyr, depending on the precise metal content of the cluster (Carraro & Chiosi 1994; Carraro, Girardi & Chiosi 1999).

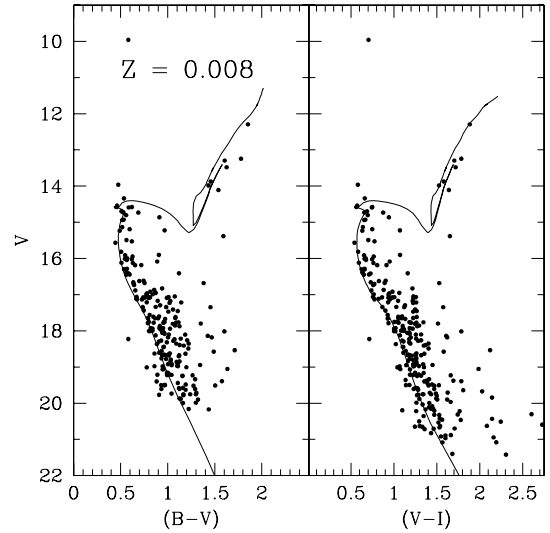
#### 5 CLUSTER FUNDAMENTAL PARAMETERS

In this section, we try to provide some estimates of the basic parameters of the cluster. To achieve this aim, we make use of the comparison between the distribution of the stars in the CMDs and a set of theoretical isochrones from the Padova group (Girardi et al. 2000). We already have an indication of the cluster age, but we do not know anything about the reddening, the distance and the metallicity. The results of the fitting are shown in Figs 5 and 6.

In detail, we present the CMDs for the stars within 2.5 arcmin of the cluster centre in Fig. 5, superimposed with an isochrone of 1.2 Gyr for a solar ( $Z = 0.019$ ) metallicity. The fit is quite good in the  $V$  versus  $(B - V)$  plane (left-hand panel), but the shape of the MS is not very well reproduced in the  $V$  versus  $(V - I)$  plane (right-hand panel). Moreover, the precise location of the RGB is not well matched. We achieved this aim by shifting the isochrone,



**Figure 5.** Left-hand panel: NGC 1883 data in the  $V$  versus  $B - V$  diagram, compared to a Girardi et al. (2000) isochrone of age  $1.2 \times 10^9$  yr (solid line), for the metallicity  $Z = 0.019$ . A distance modulus of  $(m - M)_0 = 13.25$  mag and a colour excess of  $E(B - V) = 0.23$  mag have been derived. Right-hand panel: NGC 1883 data in the  $V$  versus  $V - I$  diagram, compared to a Girardi et al. (2000) isochrone of age  $1.2 \times 10^9$  yr (solid line), for the metallicity  $Z = 0.019$ . A distance modulus of  $(m - M)_0 = 13.15$  mag and a colour excess of  $E(V - I) = 0.30$  mag have been derived.



**Figure 6.** Left-hand panel: NGC 1883 data in the  $V$  versus  $B - V$  diagram, compared to a Girardi et al. (2000) isochrone of age  $1.0 \times 10^9$  yr (solid line), for the metallicity  $Z = 0.008$ . A distance modulus of  $(m - M)_0 = 13.40$  mag and a colour excess of  $E(B - V) = 0.35$  mag have been derived. Right-hand panel: NGC 1883 data in the  $V$  versus  $V - I$  diagram, compared to a Girardi et al. (2000) isochrone of age  $1.0 \times 10^9$  yr (solid line), for the metallicity  $Z = 0.008$ . A distance modulus of  $(m - M)_0 = 13.20$  mag and a colour excess of  $E(V - I) = 0.50$  mag have been derived.

with  $E(B - V) = 0.23$ ,  $E(V - I) = 0.30$  and  $(m - M) = 14.00$ , and by adopting  $R_V = 3.1$ . We tried to improve the fit by lowering the metal abundance, based on the fact that a cluster located toward the anticentre might have a metal abundance lower than solar (Friel 1995). The result is shown in Fig. 6. Here, the isochrone has an age of 1.0 Gyr for the  $Z = 0.008$  metal content. The global fit is quite good, and has been obtained by shifting the isochrone, with  $E(B - V) = 0.35$ ,  $E(V - I) = 0.50$ , and  $(m - M) = 14.50$  ( $R_V = 3.1$ ).

In conclusion, a lower than solar metal abundance seems to be favored. If this is the case, NGC 1883 turns out to be located 4.8 kpc from the Sun towards the anticentre direction. This implies a distance from the Galactic centre somewhat larger than 13 kpc, assuming  $R_\odot = 8.5$  kpc, and a height above the Galactic plane of about 500 pc. According to Friel (1995, table 1), NGC 1883 turns out to be one of the few intermediate-age or old open clusters located in the outskirts of the Galactic disc. In fact we know only three other clusters (Tombaugh 2, Berkeley 20 and Berkeley 29) located more distant than NGC 1883. Therefore, NGC 1883 might play an important role in defining the precise shape of the radial abundance gradient in the external regions of the Galactic disc, which is one of the fundamental constraints of models of chemical evolution (Chiappini, Matteucci & Romano 2001). Moreover, NGC 1883 lies significantly above the Galactic plane. The position, together with its compactness, are probably the main reasons why the cluster survived until the present time.

## 6 CONCLUSIONS

We have presented the first CCD  $BVI$  photometric study of the open cluster NGC 1883. The CMDs we derive allow us to infer estimates of the cluster basic parameters. In detail:

- (i) we find that the age of NGC 1883 is around 1.0 Gyr;

- (ii) the reddening  $E_{B-V}$  turns out to be  $0.23 \pm 0.10$  mag if one assumes a metal abundance of  $Z = 0.019$ , or  $0.35 \pm 0.10$  mag if one assumes that  $Z = 0.008$ ;

- (iii) we place the cluster at about 4.8 kpc from the Sun, towards the anticentre direction; and

- (iv) in this way, NGC 1883 turns out to be one of the most distant intermediate-age open clusters.

Future work should concentrate on obtaining an estimate of the cluster metal abundance through spectra of the RGB stars. The knowledge of the cluster metallicity, which we could not constrain very well, is of paramount importance to better probe the trend of the metallicity in the outer parts of the Galactic disc (Friel & Janes 1993).

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