PROPER MOTIONS AND PHOTOGRAPHIC PHOTOMETRY IN THE FIELD OF THE SOUTHERN OPEN CLUSTER NGC 2516

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ABSTRACT.
In this work we deal with the determination of membership probabilities for stars in the field of the southern open cluster NGC2516 via the determination of their relative proper motions, colours and magnitudes. To reach this goal we used plates taken with four different southern telescopes. A reliable membership determination is achieved for stars down to apparent magnitude B $\sim$ 16.5, which, at the distance of the cluster, corresponds approximately to the early KV spectral type.

1. Introduction

The study of open clusters is a helpful tool for investigating the various links between astrophysical stellar parameters (age, metal abundances, rotation, X-ray activities, mass) as they are star samples with essentially homogeneous properties.

However, to better understand these links it is necessary to investigate, on one hand, several different clusters to explore the widest possible range of key parameters like age, distance, location within the Galaxy, etc..; on other hand, it is highly important to use samples reaching the faint main sequence.

The first problem to be solved is the selection of real cluster members from background (and foreground) stars. The determination of accurate relative proper motions is a well known method independent, typically, of "a priori" criteria.

This work focuses on NGC 2516 (α = 07 57 30, δ = -60 44 (1950.0); $l = 274°$, $b =$ -16°), one of the most conspicuous clusters of the southern sky and indeed a remarkable subject for astronomical studies because it is an intermediate age cluster, between the Pleiades and the Hyades.

The age is estimated between 60×10^6 years (Feinstein et al. 1972) and 137×10^6 years (Snowden 1972). Dachs and Kabus (1989) found values of 110×10^6 for main sequence stars and a probable age of 25×10^6 for some blue and giants stars.

Distance is between 400 pc (Cox 1955, Feinstein et al. 1972) and 450 pc (Eggen 1983); the distance modulus lies between V-M_V=7.94 (Snowden 1972) and V-M_V=8.25 (Eggen 1983); the colour excess is evaluated at $E_{(B-V)} = +0.15$ by Eggen (1972) and $E_{(B-V)} = +0.12$ by Feinstein te al. (1972) and Snowden (1972), the latter via $uvby$ photometry.

Metal abundance estimates are [Fe/H] = -0.42 (Cameron 1985) and [Fe/H] = -0.23 (Lang 1992).

Other important elements for NGC 2516 were given by Eggen: 1) the radius of the cluster core is about 2 pc, but he found probable cluster members in a circle of 5 pc of radius (Eggen 1983); 2) it shows an ultraviolet excess for F stars (Eggen 1972), similar to what found for the Pleiades; 3) the V component of the space motion of NGC 2516 is nearly identical to that of the Pleiades (Eggen 1983), IC2602, and the α Persei clusters, and probably similar to the V velocity component of the clusters NGC 2287 and Cr 121.

Finally, chemically peculiar stars (Dachs 1972), variable stars (Antonello and Mantegazza 1986), and white dwarfs (Reimers and Koester 1982) are present in the cluster.

The cluster is interesting in other bands besides the optical one. Recently Jeffries et al. (1997) presented an analysis of a 60ksec X-ray exposure performed with the ROSAT satellite showing, among other interesting features, the *presence* of many F,G and K stars, with a peak of activity for G-type stars.

2. Astrometric and Photometric reductions

The plate material considered for this study is listed in table 1 with the relevant informations.

Tab. 1 - Plate material

Telescope	Plate	Emulsion	Filter	Colour	Epoch	Exposure time
McLean refr.	13/3/1937	?	-	Mpg	1937.20	5 min.
Cape Astr.	3/2/1937	?	-	Mpg	1937.17	60 min.
McLean refr.	46224B	O	GG385	B	1971.12	4 min.
McLean refr.	46310B	O	GG385	B	1971.18	4 min.
McLean refr.	5/12/1989	IIa-O	-	Mpg	1989.93	15 min.
McLean refr.	5/12/1989	IIa-O	-	Mpg	1989.93	7.5 min.
ESO-GPO	14004	IIa-O	-	Mpg	1990.21	20 min.
ESO-GPO	14014	IIa-O	GG385	B	1990.22	2 min.
ESO-GPO	14015	IIa-O	GG385	B	1990.22	6 min.
ESO-GPO	14016	IIa-O	GG385	B	1990.22	20 min.
ESO-GPO	14033	103a-O	GG495	V	1990.22	2 min.
ESO-GPO	14034	103a-O	GG495	V	1990.22	6 min.
ESO-GPO	14035	103a-O	GG495	V	1990.22	20 min.
Plate scale						
30"/mm for the McLean refractor 60"/mm for the Cape Astrograph 51".3/mm for the ESO GPO Astrograph						

The plates were digitized in raster mode with PDS N.2 of the Space Telescope Science Institute in Baltimore (USA). Pixel size was 20μm $\times$ 20μm for all plates with the only exception of the Cape astrograph plate which was scanned with 15μm pixels.

This procedure was carefully investigated and its suitability for astrometric membership determination demonstrated by Lattanzi et al. (1991).

The digitized images were processed using PC-based software developed at Torino Observatory (Lanteri 1990, Lanteri 1996). After selection of reasonable general input parameters, an object finder looks for stellar objects and then, in a second step, stellar point spread function and sky background are modeled via a bi-dimensional Gaussian function plus a background plane. An instrumental photometric index, fitted stellar position, and other fit parameters are all provided as part of the program output.

Our photographic photometry is based only on reduction of ESO-GPO plates using Dachs' photoelectric photometry (Dachs and Kabus 1989, Table 1) and a new photometric sample (Jeffries, private communication) with many late spectral type stars down to 16^m in Johnson V.

After proving the absence of significant systematic differences between the two photometric lists, we merged them into one, relatively faint, standard sequence. We then used this sequence to reduce the six ESO-GPO plates. As expected, only simple polynomial functions were needed to convert the photographic indices to the Johnoson B and V bands. The average errors (rms) of the photographic photometry (as estimated from the residuals of the standard stars used for the fits) are 0.075^m in B and 0.069^m in V.

The astrometric treatment followed our standard scheme; all astrometric plates were reduced to a common reference frame using the cluster members themselves as reference stars (internal cluster velocities are beyond detectability with our material); the choice of these reference cluster members was iterated a few times after the initial guess. Modeling of some of the older plates required inclusion of higher order terms in the coordinates and magnitude, possibly due to optical distortions and sensible guiding errors. The relative proper motions (separately in X and Y) of each star are then derived by linear regression of all available positions as function of time; reliable estimates of the proper motion errors are also derived.

Finally, segregation of cluster members was done by fitting data in the velocity space (Vector Point Diagram) to a function given by the sum of two bi-dimensional gaussians, one for field stars and the other for the cluster stars (Lattanzi et al. 1991).

3. Results

We obtained relative proper motions and B and V photographic photometry for a sample of 2500 stars in a square field of 1 degree on a side centered on the southern open cluster NGC 2516. However, due to the lack of deep first epoch plates, the number of stars for which we have accurate proper motions (σ_X and $\sigma_Y \leq 0".006$/year) is ~ 1700, reaching down to B = 16.5 mag.

The proper motion distribution (the Vector Point Diagram) for this reduced sample of stars is reported in Fig. 1, showing that NGC 2516 is a difficult object to analyse from the proper motion point of view, as the cluster velocity is within the distribution of that of the field stars. Applying our software for the calculation of membership probabilities we were able to detect ~ 220 probable cluster members with p ≥ 0.50.

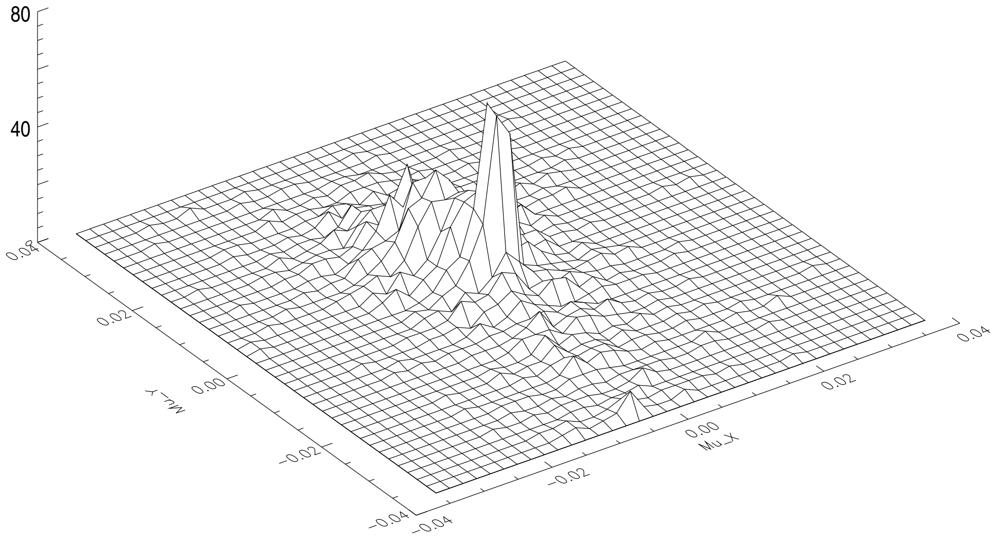

Fig. 1. 3D plot of Vector Point Diagram for NGC 2516

Fig. 2 shows the observed colour-magnitude diagram for the selected members only (no correction for reddening or absorption was applied): the main sequence is well defined, and the two giant stars measurable on our material (HD 3120 and HD 3153) are confirmed to be cluster members. We have not yet made any attempts to compare our data with previously published ones, so we do not have at present a good explanation for the discrepancy between the 362 cluster members reported in Dachs and Kabus (1989) and our finding of 220 members, in spite of comparable limiting magnitude and extension of surveyed area. We will be in a position to address this problem, and other outstanding issues concerning NGC2516, as soon as the extra plates not yet reduced will be included in the final solution.

Acknowledgements

We wish to thank Barry Lasker for digitizing the plates with STScI PDS and R.D. Jeffries for communication of photometric sequences in advance of publication

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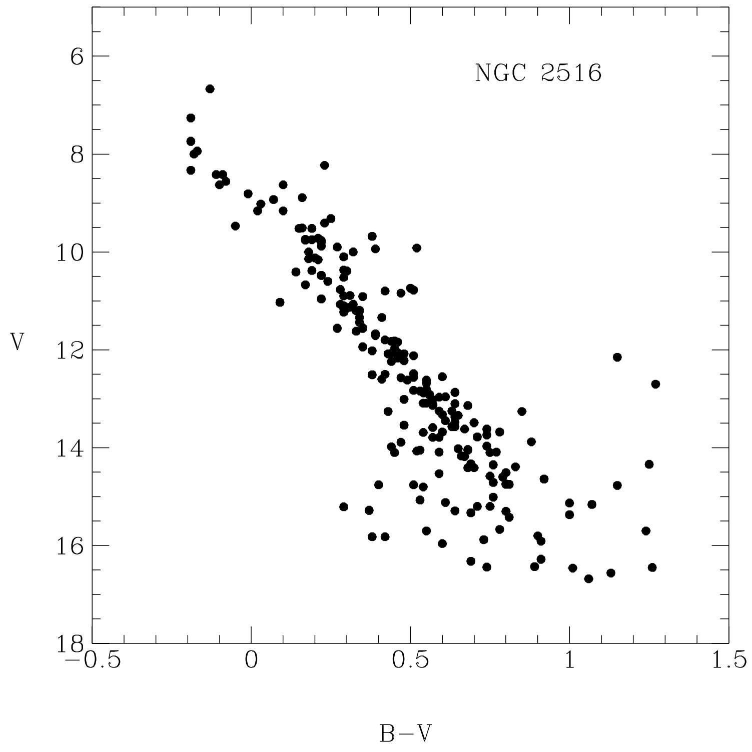

Fig. 2. Magnitude versus colour plot for NGC 2516

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