*Title : will be set by the publisher*
*Editors : will be set by the publisher*
*EAS Publications Series, Vol. ?, 2003*

# A STUDY OF 11 NEWLY DISCOVERED AND 11 POORLY KNOWN OPEN CLUSTERS IN THE SOLAR VICINITY

A. Moitinho[1,2], B. S. Alessi[3] and W. S. Dias[2]

**Abstract.** We present the first determination of fundamental parameters (positions, reddenings, distances, ages and kinematics) for a sample of 22 open clusters in the solar vicinity.
A systematic search for unknown open clusters using the astrometric and photometric data included in the Tycho2 catalogue has resulted in the identification of several candidates. In this work, we introduce 11 of the most promising open cluster candidates. The reality of the stellar aggregates is supported by the analysis of proper motions, colour-magnitude diagrams, stellar density distributions, and by the visual inspection of the Digitized Sky Survey (DSS) plates.
The proper motion data included in the Tycho2 catalogue has also allowed us to identify members in 11 open clusters for which no information, besides their positions and estimates of their apparent diameters, was previously available.
Reddenings, distances and ages were determined for most objects using colour-magnitude diagrams for cluster members, built using the photometry included in Tycho2, complemented by spectral types found in the literature. We find that the majority of the aggregates are nearby (closer than $\sim$ 500 pc) open clusters.

## 1 Introduction

The new generation of high precision astrometric catalogues, such as Tycho and Hipparcos (ESA, 1997) and Tycho2 (Høg et al., 2000), offers an important opportunity to study the kinematics of the nearby known open clusters and associations (Dias et al., 2001; Baumgardt et al., 2000; Robichon et al., 1999; de Zeeuw et al., 1999). Moreover, these catalogues also provide data for systematic searches for

[1] Observatorio Astronómico Nacional, UNAM, Apdo. Postal 877, C.P. 22800, Ensenada B.C., México
[2] CAAUL, Observatório Astronómico de Lisboa, Tapada da Ajuda, 1349-018 Lisboa, Portugal
[3] Universidade de São Paulo, Dept. de Astronomia, CP 3386, São Paulo 01060-970, Brazil


DOI: (will be inserted later)

new open cluster candidates based on proper motions and trigonometric parallaxes (Platais et al., 1998).

In this work, we present the first results from a study of open clusters in the solar vicinity, based on the analysis of observational data (proper motions, photometry and images) provided by the Tycho2 catalogue and by the Digitized Sky Survey (DSS) plates. This dataset has allowed us not only to obtain the first estimates of the fundamental parameters (reddening, distance, age, kinematics) of several nearby unstudied open clusters, but also to detect and study a number of clusters that were previously unknown, or at least unlisted according to the most up-to-date catalogue of open clusters presently available (Dias et al., 2002).

In the next section we describe the procedures adopted in the search for clusters and the tools used in their analysis. Sect. 3 is dedicated to the presentation of the results. Finally, in Sect. 4 we summarise the main results of this paper and give some concluding remarks.

## 2 Cluster search and analysis strategy

A stellar field in which an open cluster is present, exhibits a number of particular characteristics which reveal its existence. The cluster members are within a limited volume, resulting in an increased stellar density when compared to the surrounding field. Furthermore, they share similar radial velocities and proper motions, and have similar ages and chemical compositions. So, in theory, it is possible to distiguish cluster members from field stars in a certain region of the sky.

We started by searching the Tycho2 catalogue for groups of bright stars with small deviations in proper motions and a noticeable enhancement in the local star density. As a result, several fields were selected as potential open cluster candidates. These fields were then visually inspected in the DSS plates, and those seeming to host actual clusters were included in a final list of open cluster candidates.

For each selected field, individual membership probabilities were determined by applying the statistical method of Sanders (1971) to the Tycho2 proper motions. For further details on the method and its utilisation we refer the reader to recent papers such as Dias *et al.*(2001) and Sanner and Geffert (2001), among others.

Most fields yielded significant results for proper motions from statistical analysis, as well as a good separation between two populations in the proper motion vector-point diagrams (hereinafter VPD; as an example see the left panel of Fig. 1). The validity of the VPD analysis was tested by comparing to a number of nearby control fields (north, south, east and west of each cluster) with about the same diameter of the probable cluster. For most objects we found a good contrast between the candidate VPD and the control fields' VPDs, further assessing that the feature observed in the candidate VPD could be real.

As mentioned in the beginning of this section, another indicator of the presence of a stellar aggregate is an enhancement of the stellar density with respect to the surrounding field. We have plotted the Radial Density Profile Diagrams (hereafter

RDPs; see the middle panel of Fig. 1) to address this point. The RDPs contain all Tycho2 stars with proper motions within $2\sigma$ from the values given by the Sanders method. To avoid incompleteness effects, we included only stars brighter than $V_T$= 11.5 mag (Tycho2 is 90% complete in this range).

Densities were calculated by counting stars in a number of concentric rings and then dividing the counts by the ring area. For each RDP, we have also plotted a line indicating the average value of the densities of the four nearby control fields above mentioned. Although we are number of stars is small and the statistical fluctuations are high, we have used the proper motion criteria to isolate the potential cluster members from the field stars. Thus, we considered a high concentration of stars with similar motions around the candidate cluster centre as a strong indication of the reality of the candidate cluster. All the candidates display clear over-densities of Tycho2 stars. A further check on the first and second generation DSS images also reveals the majority of these objects as slight concentrations of bright stars, corroborating the results from the RDP analysis.

The next step was to perform a photometric analysis. Colour-magnitude diagrams (hereafter CMDs) of the cluster fields were plotted using the Tycho2 BV photometry transformed to the Johnson system using the relations given in the Hipparcos Catalogue. Membership probabilities were used to select only the probable cluster members, reducing the contamination by field stars and allowing the construction of clearer CMDs.

For each cluster field there were some stars with published spectral types. These were used to derive intrinsic colours by interpolating over the tables relating spectral types and colours given by Schmidt-Kaler (1982), taking care not to use stars with peculiar spectral features (Be, Ap, etc). Once the intrinsic colours were determined, individual colour excesses were computed. The colour excesses distributions were then used in deriving the mean reddenings for the candidate clusters. In a similar fashion, the spectral types were used to estimate the absolute magnitudes, and from there the apparent and absolute distance moduli distributions. However, contrary to the reddening determination, where stars were used regardless of their luminosity class, only stars of luminosity class V (dwarfs) were used in the distance determination. Although the reddening values obtained from spectral types are quite precise, the distances are much more uncertain. Using the distance to the cluster derived from spectral types as a rough estimate, we then refined the determination via ZAMS fitting in the CMD. The right panel of Fig. 1 shows the CMD for Alessi 09, one of the newly discovered clusters. We have superimposed the Schmidt-Kaler (1982) ZAMS and solar composition isochrones from Girardi *et al.*(2000) shifted to account for the effects of reddening and distance.

## 3 Results

Considering the results obtained from each point of view - astrometric, photometric and star counts -, the investigated fields show evidence for the existence of real open clusters.

Of the 22 fields presented in this study, 11 were previously unknown, and for

the other 11 no information was available besides approximate coordinates and a rough estimate of their diameters. The new clusters were named Alessi 1, 2, 3, etc, sorted by right ascension.

The main results are summarised in Tab. 1, where the clusters' positions, (core) diameters, reddenings, distances, ages, and mean proper motions are given. In some of the analysed fields we were able to identify a few likely Hipparcos members, which allowed us to estimate the clusters' distances in a different manner. Because of the small number of such stars, the mean cluster parallax was simply taken as the mean of the individual stellar parallaxes, and no special corrections were applied. The distances derived from these parallaxes are also presented in Tab. 1. Although their errors are quite high, it is interesting to see how they compare to the CMD derived distances. As one can see, both values are quite consistent.

Good CMDs were found for nearly all cluster candidates except for three of the fainter ones for which no reddening, distance, or age are listed in Tab. 1. However, although the Tycho2 magnitudes have reasonable precision for brighter stars ($V \leq 9$), for the fainter ones the errors in B and V become quite large yielding almost useless colours for $V$ greater than $\sim 10 - 11$. So our failure to identify a MS does not necessarily reflect the nonexistence of a cluster.

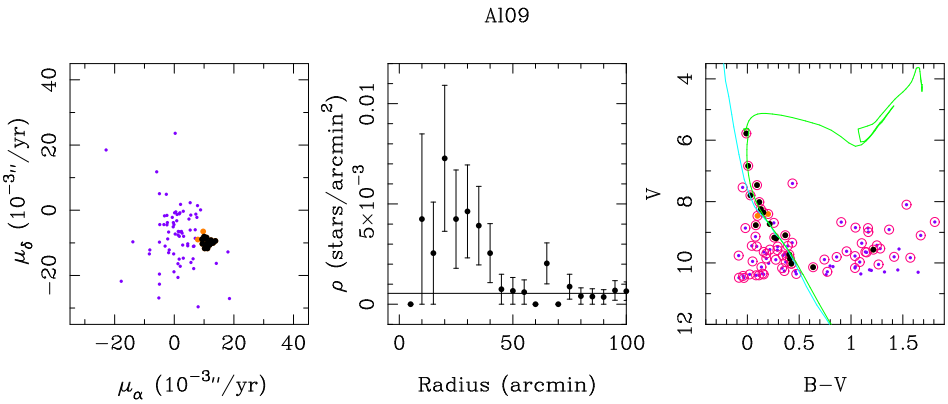


**Fig. 1.** Diagrams for the newly discovered cluster Alessi 09. **Left panel:** Vector-point diagram (VPD). The big dots are stars considered members (dark dots) and probable members (light dots); non members are represented by smaller dots. We included only Tyc2 stars at the 90% completeness level. **Middle panel:** Radial density profile (RDP). The horizontal line gives the mean stellar density of the surrounding control fields. The profile and horizontal line are based on stars with proper motions within 2 $\sigma$ from the mean cluster motion. **Right Panel:** Colour-magnitude diagram (CMD). As in the VPDs, big dots are stars considered members (dark dots) and probable members (light dots); non members are represented by smaller dots. Stars with available spectral types are marked with circles. The best fit ZAMS and isochrone have also been plotted.

To test the validity our analysis, we also applied the same procedures to five well studied open clusters. The left side of Tab. 2 lists the reddening, distance

**Table 1.** Fundamental parameters of the studied clusters. $D$ is the cluster angular diameter; $d$ is the distance to the cluster determined from the HR diagram, dHIP is the distance determined from the parallaxes of Hipparcos member stars; $\log t$ is the logarithm of the age (in years); $\mu_\alpha$ and $\mu_\delta$ are the mean cluster proper motion in miliarcsec/year

| Cluster | $\alpha_{2000}$ | $\delta_{2000}$ | D | E(B-V) | $(m\text{-}M)_o$ | d | dHIP | logt | $\mu_\alpha$ | $\mu_\delta$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | (') | (mag) | (mag) | (pc) | (pc) | | $(10^{-3''}/yr)$ | |
| Al 01 | $00^h53^m27^s$ | $+49°34'.0$ | 48 | 0.09 | 7.40 | 300 | | 8.20 | 6.7 | -7.8 |
| Al 02 | $04^h46^m02^s$ | $+55°12'.4$ | 30 | 0.18 | 8.50 | 500 | | 8.50 | 0.2 | -1.1 |
| Al 03 | $07^h16^m29^s$ | $-46°41'.1$ | 72 | 0.11 | 7.30 | 290 | 330 | 8.70 | -11.5 | 12.4 |
| Al 05 | $10^h43^m08^s$ | $-61°10'.0$ | 33 | 0.15 | 8.00 | 400 | 230 | 7.60 | -14.3 | 4.4 |
| Al 06 | $14^h40^m07^s$ | $-66°07'.0$ | 48 | 0.19 | 8.20 | 440 | | 8.20 | -7.3 | -4.3 |
| Al 08 | $15^h29^m33^s$ | $-51°14'.0$ | 24 | 0.09 | 8.80 | 580 | | 8.15 | -6.1 | -5.8 |
| Al 09 | $17^h42^m25^s$ | $-47°00'.3$ | 110 | 0.07 | 6.45 | 190 | 250 | 8.40 | 10.9 | -9.7 |
| Al 10 | $20^h04^m46^s$ | $-10°28'.7$ | 18 | 0.18 | 7.90 | 380 | 360 | | 2.3 | -8.6 |
| Al 11 | $20^h21^m24^s$ | $+18°21'.6$ | 24 | | | | | | -0.3 | -9.6 |
| Al 12 | $20^h43^m48^s$ | $+23°47'.5$ | 40 | 0.08 | 8.65 | 540 | 860 | 8.10 | 4.3 | -5.3 |
| Al 19 | $18^h18^m28^s$ | $+12°10'.0$ | 88 | 0.03 | 8.70 | 550 | 310 | 8.20 | 0.4 | -6.6 |
| BH 23 | $08^h14^m24^s$ | $-36°23'.0$ | 39 | 0.06 | 8.40 | 480 | 380 | 7.20 | -7.4 | 5.2 |
| BH 34 | $08^h31^m15^s$ | $-44°30'.0$ | 25 | | | | 670 | | -6.0 | 5.1 |
| BH 164 | $14^h48^m14^s$ | $-66°20'.2$ | 64 | 0.13 | 8.20 | 440 | 310 | 7.20 | -7.4 | -10.9 |
| Cr 106 | $06^h37^m06^s$ | $+05°57'.0$ | 35 | 0.12 | 9.90 | 1000 | | | -2.3 | 1.9 |
| Cr 65 | $05^h25^m54^s$ | $+16°06'.0$ | 220 | 0.27 | 8.80 | 580 | 270 | | 0.8 | -5.6 |
| Ros 6 | $20^h28^m48^s$ | $+39°23'.0$ | 50 | | | | | | 0.8 | -2.5 |
| Ru 145 | $18^h50^m36^s$ | $-18°15'.0$ | 35 | 0.18 | 7.50 | 320 | 280 | | 7.3 | -4.4 |
| Ru 147 | $19^h16^m42^s$ | $-16°17'.0$ | 25 | 0.20 | 6.50 | 200 | 250 | | -0.8 | -28.4 |
| St 10 | $05^h39^m00^s$ | $+37°56'.0$ | 25 | 0.07 | 7.90 | 380 | 330 | 8.35 | -2.8 | -2.6 |
| St 12 | $23^h35^m36^s$ | $+52°41'.2$ | 25 | 0.06 | 8.40 | 480 | | 8.55 | 7.9 | -1.4 |
| Tr 03 | $03^h11^m48^s$ | $+63°15'.0$ | 14 | 0.19 | 8.30 | 460 | 400 | | -2.1 | 1.6 |

and age derived by us. The right side shows the typical values found throughout the literature. It is easily seen that both sets agree well, specially if one takes into account the modest quality of the Tycho2 photometry (transformed to the Johnson system).

## 4 Summary

The Sanders technique applied to the Tycho2 proper motions has proved to be a powerful tool to search for new bright and nearby open cluster candidates. Using radial density profiles, Tycho2 photometric data, and published spectral types, we have been able to analyse the target fields well beyond a simple "discovery". Indeed, cluster members have been identified and, except for 3 clusters, we have been able to obtain an estimate of their reddenings, distances, ages and kinematic parameters. We found that except for one, all the studied objects are closer than

**Table 2.** Comparison between the values determined using the procedure adopted in this work and the typical values found in the literature for 5 well studied clusters.

| | This study | | | Literature | | |
|---|---|---|---|---|---|---|
| Cluster | E(B-V) | d | logt | E(B-V) | d | logt |
| Bl 01 | 0.04 | 240 | | 0.02 | 220 | 7.70 |
| IC 2391 | 0.04 | 160 | 7.20 | 0.03 | 145 | 7.70 |
| Mel 022 | 0.05 | 140 | 8.00 | 0.04 | 140 | 7.90 |
| NGC 1662 | 0.34 | 360 | 8.55 | 0.30 | 340 | 8.50 |
| NGC 7092 | 0.03 | 330 | 8.55 | 0.05 | 285 | 8.45 |

0.6 kpc, which puts them in the solar vicinity. They are also all young or of intermediate age.

Using only archival data, this work has resulted in the finding of 11 new clusters, and in the first study of 11 poorly known stellar aggregates.

Extensive use has been made of the SIMBAD, WEBDA and DSS databases and of the *Sky Charts (http://astrosurf.com/astropc/)* facility. AM acknowledges financial support by CONACyT (Mexico; project I33940-E), DGAPA (Mexico; project IN111500), and FCT (Portugal; grant BPD/20193/99). WSD is supported by FAPESP (grant number 99/11781-4).

## References

Baumgardt, H., Dettbarn, C., and Wielen, R.: 2000, *A&AS* **146**, 251

de Zeeuw, P. T., Hoogerwerf, R., de Bruijne, J. H. J., Brown, A. G. A., and Blaauw, A.: 1999, *AJ* **117**, 354

Dias, W. S., Alessi, B. S., Moitinho, A., and Lépine, J. R. D.: 2002, *A&A* **389**, 871

Dias, W. S., Lépine, J. R. D., and Alessi, B. S.: 2001, *A&A* **376**, 441

ESA: 1997, *The Hipparcos and Tycho Catalogues*, European Space Agency (ESA)

Girardi, L., Bressan, A., Bertelli, G., and Chiosi, C.: 2000, *A&AS* **141**, 371

Høg, E., Fabricius, C., Makarov, V. V., Urban, S., Corbin, T., Wycoff, G., Bastian, U., Schwekendiek, P., and Wicenec, A.: 2000, *A&A* **355**, L27

Platais, I., Kozhurina-Platais, V., and van Leuwen, F.: 1998, *AJ* **116**, 2423

Robichon, N., Arenou, F., Mermilliod, J.-C., and Turon, C.: 1999, *A&A* **345**, 471

Sanders, W. L.: 1971, *A&A* **14**, 226

Sanner, J. and Geffert, M.: 2001, *A&A* **370**, 87

Schmidt-Kaler, T.: 1982, *Landolt-Börnstein, Group VI, Vol. 2b, Stars and Star Clusters*, p. 15, Springer, Berlin