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The old open cluster Trumpler 5 and the chemical evolution of the galactic disc

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Abstract. We present CCD VI_{KC} and Washington CT_1 photometry in the field of Trumpler 5. From the comparison of the cluster CMDs with theoretical isochrones, the Standard Giant Branches method and measures of δV and δT_1, we derive reddening, distance, age and metallicity. We examined the overall properties of all clusters with ages of 3 Gyr or older. No evidence either for an abundance Z gradient or for an age-metallicity relation is found. We suggest that the Galactic disc might have been formed inside-out and that the relative lack of very old clusters with Z>0.5 kpc would be reflecting the transition between the formation of the globular and open cluster systems.

Resumen. Presentamos fotometría CCD VI_{KC} y Washington CT_1 en el campo de Trumpler 5. Comparando los diagramas CM con isócronas teóricas, usando el método de las Ramas Gigantes Standard y midiendo δV y δT_1, derivamos enrojecimiento, distancia, edad y metalicidad. Un análisis de las propiedades de los cúmulos más viejos que $\sim 3 \mathrm{x} 10^9$ años no aporta evidencia alguna sobre la existencia de una relación edad-metalicidad, ni tampoco de un gradiente de abundancia en la dirección Z. Sugerimos que el disco podría haberse formado de adentro hacia afuera y que la ausencia de cúmulos muy viejos con Z>0.5 kpc podría estar reflejando la transición entre la formación de los sistemas de cúmulos abiertos y globulares galácticos.

1. Cluster fundamental parameters

We report here the results obtained from high-quality CCD VI_{KC} and Washington CT_1 photometry in the field of Trumpler 5. The CCD images were obtained using the CTIO 0.9-m telescope. Details on the data reduction are given in Piatti et al. (2003). Fig. 1 (left) shows a schematic finding chart of the observed field, including three concentric circles of 300, 600 and 900 pixels wide around the cluster center. To remove the field contamination, we counted the number of stars in boxes of (Δ(V-I),ΔV) = (0.1,0.5) mag in the field CMD (r > 900 pixels) and subtracted per unit area the same number of stars per CM bin in the entire field. In Fig. 1 (right) we present the field star cleaned extracted CMDs. We accounted for field contamination in the (T_1,C-T_1) CMD following the same precepts applied to the VI data. To estimate the cluster parameters we used the cleaned innermost extracted (V,V-I) CMD. We measured δV = 2.05 $\pm$ 0.15, which implies an age of (4.6 $\pm$ 0.8) Gyr (Janes & Phelps 1994). The

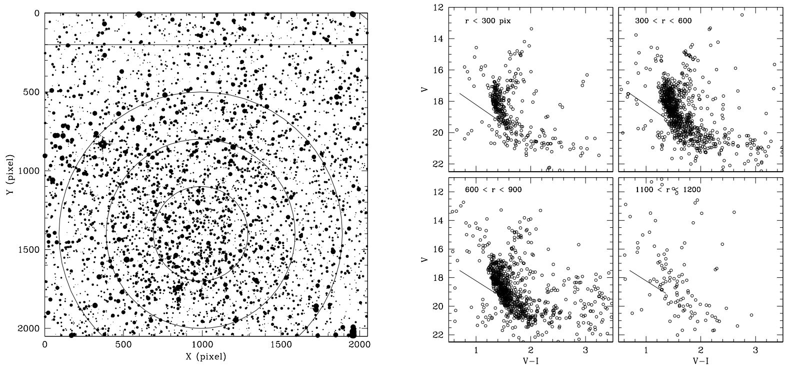

Figure 1. *Left:* Schematic finding chart of the stars observed in Tr 5. Three concentric circles around the cluster center and a horizontal line delimiting the southern border of the star field are drawn. *Right:* Field star cleaned (V,V-I) CMDs for stars in different extracted regions.

Geneva group's isochrone that best reproduces the cluster features corresponds to log t = 9.70 (t = 5.0 Gyr) and Z = 0.008 ([Fe/H] = -0.40). We derived E(V-I) = 0.80 and V-M_V = 13.80, these values implying E(B-V) = 0.60 ± 0.04 and d = (2.4 ± 0.5) kpc, respectively. Fig. 2 (left) shows three different isochrones shifted by Δ(V-I) = 0.80 and ΔV = 13.80, which illustrate the age-metallicity effect on the cluster CMD. We used the same precepts as described above for estimating the cluster properties from the cleaned r < 300 Washington CMD, using now δT_1 as age reference (Geisler et al. 1997). The best fit is now achieved when matching the isochrone of log t = 9.65 (t = 4.4 Gyr) and Z = 0.008 with E(C-T_1) = 1.17 and T_1-M_{T_1} = 13.65. By using E(C-T_1)/E(B-V) = 1.97 and A_{T_1}/E(B-V) = 2.62 (Geisler et al. 1996), we derive E(B-V) = 0.60 ± 0.08 and d = (2.6 ± 0.7) kpc. The cluster parameters estimated from both photometries resulted in excellent agreement. We made an independent metallicity determination using the [M_{T_1},(C-T_1)$_o$] plane with the Standard Giant Branches (SGBs) of Geisler & Sarajedini (1999). Fig. 2 (right) shows the cleaned innermost extracted Washington CMD with the SGBs superimposed. From this figure we derived and observed cluster metallicity of [Fe/H] = -0.50 ± 0.10 dex. However, in view of the well-known age-metallicity degeneracy, we followed the prescriptions described by Geisler et al. (2003) and applied a correction of +0.20 dex to the observed metallicity. Thus, we finally obtained [Fe/H] = -0.30 ± 0.15, in full accordance with the isochrones' matching.

2. Discussion

In order to investigate the chemical evolution of the Galactic disc during more than 2/3 of the disc lifetime, clockwise from its formation, we selected from the WEBDA data base 27 old open clusters (age ≥ 3 Gyr) with well known cluster parameters. Fig. 3 illustrates different relationships between the main cluster parameters. The upper left-hand panel reveals an overall tendency of clusters to be located at farther distances from the plane as their distances increase from the

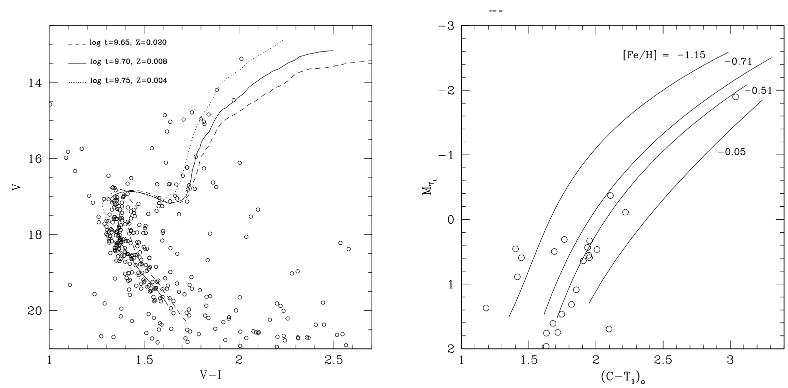

Figure 2. *Left:* (V,V-I) CMD for stars in Tr 5. Isochrones from the Geneva group are overplotted. *Right:* [M_{T_1}, $(C\text{-}T_1)_o$] diagram of cluster giants in the innermost extracted CMD with SGBs from Geisler & Sarajedini (1999) superimposed. An age-dependent correction to the indicated metallicities was applied for Tr 5.

galactic center. Thus, for example, clusters with $|Z| > 0.5$ kpc have in general $R_{GC} > 10$ kpc. Fig. 3 suggests that old open clusters are indistinctly observed with any metal content at low and high Z-values, a fact which tends to favour the inexistence of an abundance Z gradient. Indeed, Tr 5 is a relatively metal-poor cluster nearly placed onto the Galactic plane. The upper right-hand panel of Fig. 3 shows a remarkable characteristic consisting in the relative absence of clusters at large |Z| values during the first epoch of the disc formation. Clusters distributed near and far from the Galactic plane have been mostly observed with ages smaller than 6 Gyr. Precisely, within this group of objects, those located farther from the Galactic plane belong to the outer disc (open symbols), in agreement with the behaviour shown in the upper left-hand panel. In contrast, the inner disc clusters (filled circles) cover practically the total age range. All these trends suggest that the disc might have been formed inside-out (see, e.g., Burkert et al. 1992) and that the relative lack of clusters older than 6 Gyr and $Z > 0.5$ kpc would be reflecting the transition between the formation of the globular and open cluster systems, the latter beginning to develop towards the end of the formation stage of the former. The radial abundance gradient for the old open cluster system is depicted in the lower left-hand panel of Fig. 3. The formal value of this gradient is (0.05 ± 0.02) dex kpc^{-1}, in very good agreement with previous studies (e.g., Chen et al. 2003). Similar abundance gradients are derived when dividing the sample into clusters older and younger than 6 Gyr. On the other hand, the resulting metallicity-Galactocentric distance relationship can hardly be interpreted in terms of a discontinuity at $R_{GC} = 10$ kpc, as suggested by Twarog et al. (1997). We corrected the adopted cluster metallicities because of the radial gradient existence and determined the abundances the clusters would have if they were placed at a solar Galactocentric distance of $R_{GC} = 8.5$. The lower right-hand panel shows the resulting age-metallicity relation using the corrected [Fe/H] values. Note that there is no hint of a correlation between both parameters. The clusters at $Z < 0.5$ kpc appear to have been formed along

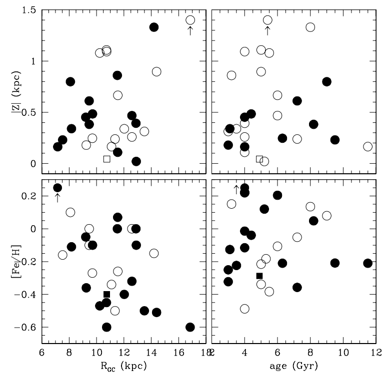

Figure 3. Relationships between the height, the Galactocentric distance, the age and the metallicity of old open clusters. Circles and the square represent the selected old clusters and Tr 5, respectively. Filled symbols correspond to clusters with: [Fe/H] > -0.2 dex (upper left-hand panel); R_{GC} < 10 kpc (upper right-hand panel); age < 6 Gyr (lower left-hand panel); and Z < 0.5 kpc (lower right-hand panel). Metallicities in the lower right-hand panel are corrected by the radial abundance gradient.

the whole disc lifetime with a growing range of their metallicities as their ages decrease. Despite the limited number of clusters with Z > 0.5 kpc (open circles), we did not find any trend either between their metal abundance and ages.

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