

Lyngå 7: a new disk globular cluster? *

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Received September 22, accepted September 28, 1992

Abstract. We have observed Lyngå 7, previously catalogued as an open cluster, in B , V and I . The Colour-Magnitude Diagrams (CMDs) show that it is old like a globular cluster, or an extremely old thick/old disk cluster. It has a red horizontal branch and the CMD morphology indicates that it is metal rich, intermediate between 47 Tuc and NGC 6553. We derive a reddening of $E(B-V) = 0.72$ and a distance of ≈ 6.7 kpc from the Sun. Its position in the Galaxy shows that it should belong to the metal-rich disk system of globular clusters, being close to its edge.

Key words: globular clusters – metallicity – galactic structure

1. Introduction

Some star clusters previously catalogued as open clusters have been recently classified as globular clusters from Colour-Magnitude Diagram (CMD) analyses, e.g. Ruprecht 106 (Buonanno et al. 1990). They arise a major interest because they might present the age and metallicity values of a possible intermediate population between the disk and the old spheroidal subsystems of the Galaxy (Janes 1988).

Lyngå 7 (= OCL 949, BH 184, ESO 178 SC 11) is a rich loose star cluster located at $\alpha = 16^{\text{h}}07^{\text{m}}04^{\text{s}}$, $\delta = -55^{\circ}11'06''$ (1950) and $l = 328^{\circ}8$, $b = -2^{\circ}8$. It is projected on one of the richest stellar fields of the Galaxy, in the direction of the Norma region.

Not much information is available for this cluster, only measurements of angular diameter and richness classifications are reported [Alter et al. (1970) and references

therein]. More recently van den Bergh & Hagen (1975) derived a diameter of 2'.5 and classified it as rich in stars. The cluster called our attention in Sky Survey plates because of its globular appearance dominated by faint stars, where we have estimated a diameter of $\approx 3'$. The only attempt for a deeper study of the cluster was that by Lyngå (1964) who reports spectral types B3–A0. However we will show that it is heavily contaminated by a young field main sequence (MS).

In Sect. 2 we describe the observations. The CMD morphology is discussed in Sect. 3 together with that of an offset field. Reddening, distance and metallicity are derived in Sect. 4. As the cluster is metal-rich we discuss in Sect. 5 its relation to the metal-rich disk system of globular clusters. The conclusions are given in Sect. 6.

2. Observations and reductions

The observations were carried out in the B , V and I Johnson–Cousins bands at the 1.54 m Danish Telescope at the European Southern Observatory (ESO), La Silla, Chile in April 1991. We used the 512×320 pixel RCA CCD ESO No. 5. The pixel size is $30 \times 30 \mu\text{m}$ corresponding to $0''.47$ on the sky. The field projected on the sky is $4' \times 2'.5$. In addition to the cluster frames we have observed in the same bands an offset field $20'$ north of the cluster, and the globular cluster NGC 6171 for comparison. The logbook of observations is given in Table 1 and a V frame of the cluster is shown in Fig. 1.

The reductions and calibrations were made at ESO-Garching with the Midas package. The DAOPHOT code in the Midas environment was employed for the stellar photometry. Standard stars from Landolt (1983) were used for the calibrations. A detailed discussion of the observing procedures, reductions and photometric errors is given in Ortolani et al. (1990, 1992, 1993) respectively about the metal rich globular clusters NGC 6553, NGC 6528 and

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* Observations collected at the European Southern Observatory, La Silla, Chile

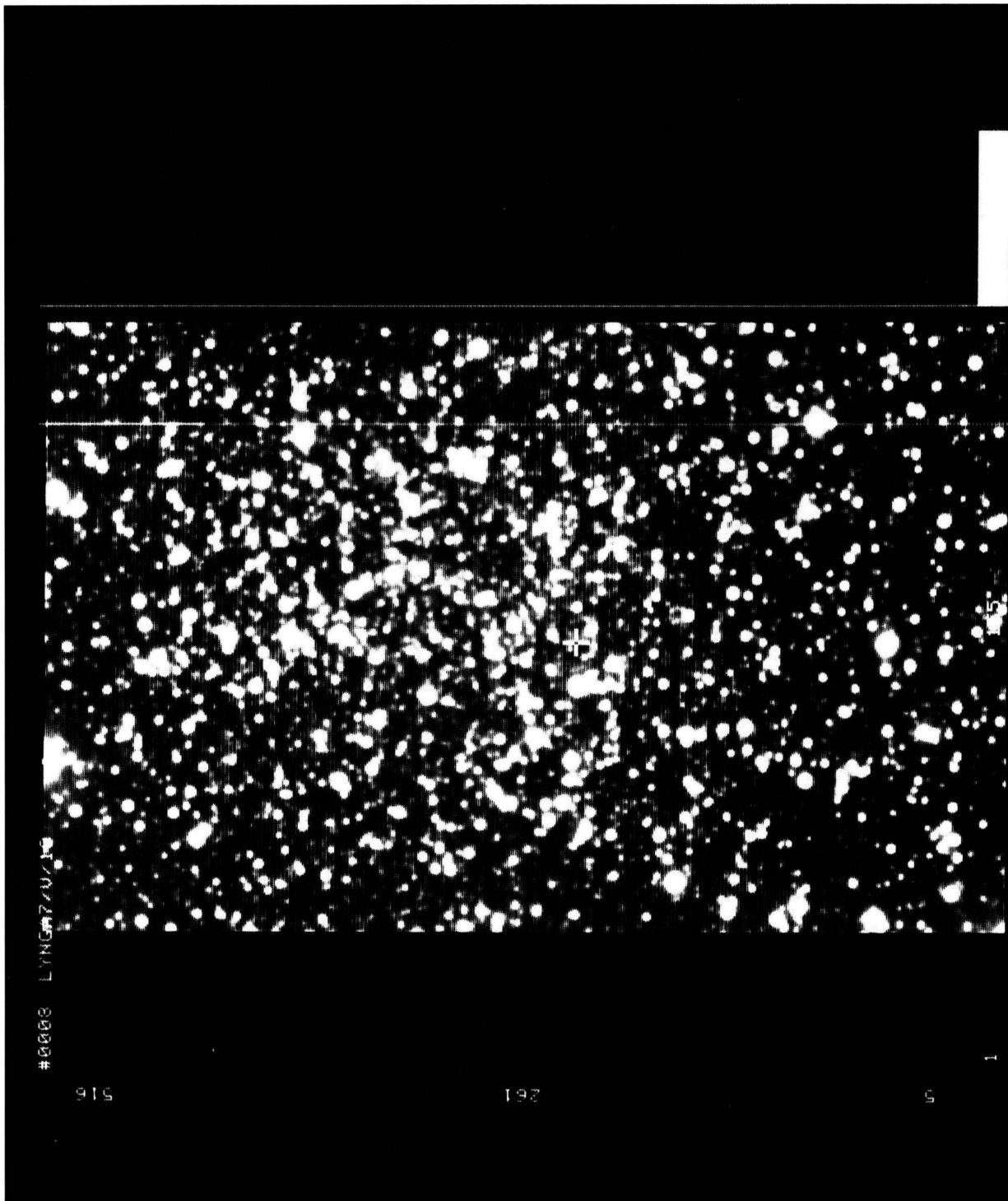


Fig. 1. V band frame of the cluster Lyngå 7. The field size is 2:5 vs. 4:0

Terzan 1, which are as well embedded in dense stellar fields. Lyngå 7's observations were taken with the same instrumentation at similar conditions. The typical transformation error equations are ± 0.015 , but our errors are dominated by the scatter of the aperture magnitudes compared to the instrumentally fitted ones which amount to 0.03 mag for all colours. The internal photometric errors

are dominated by crowding effects from $V = 15$ to 18 mag, whereby the errors are in the range 0.04 to 0.06 mag.

3. CMD morphology

We show in Figs. 2a, 2b and 2c respectively the V vs. $(V-I)$ CMDs of the cluster, of NGC 6171 for comparison, and the

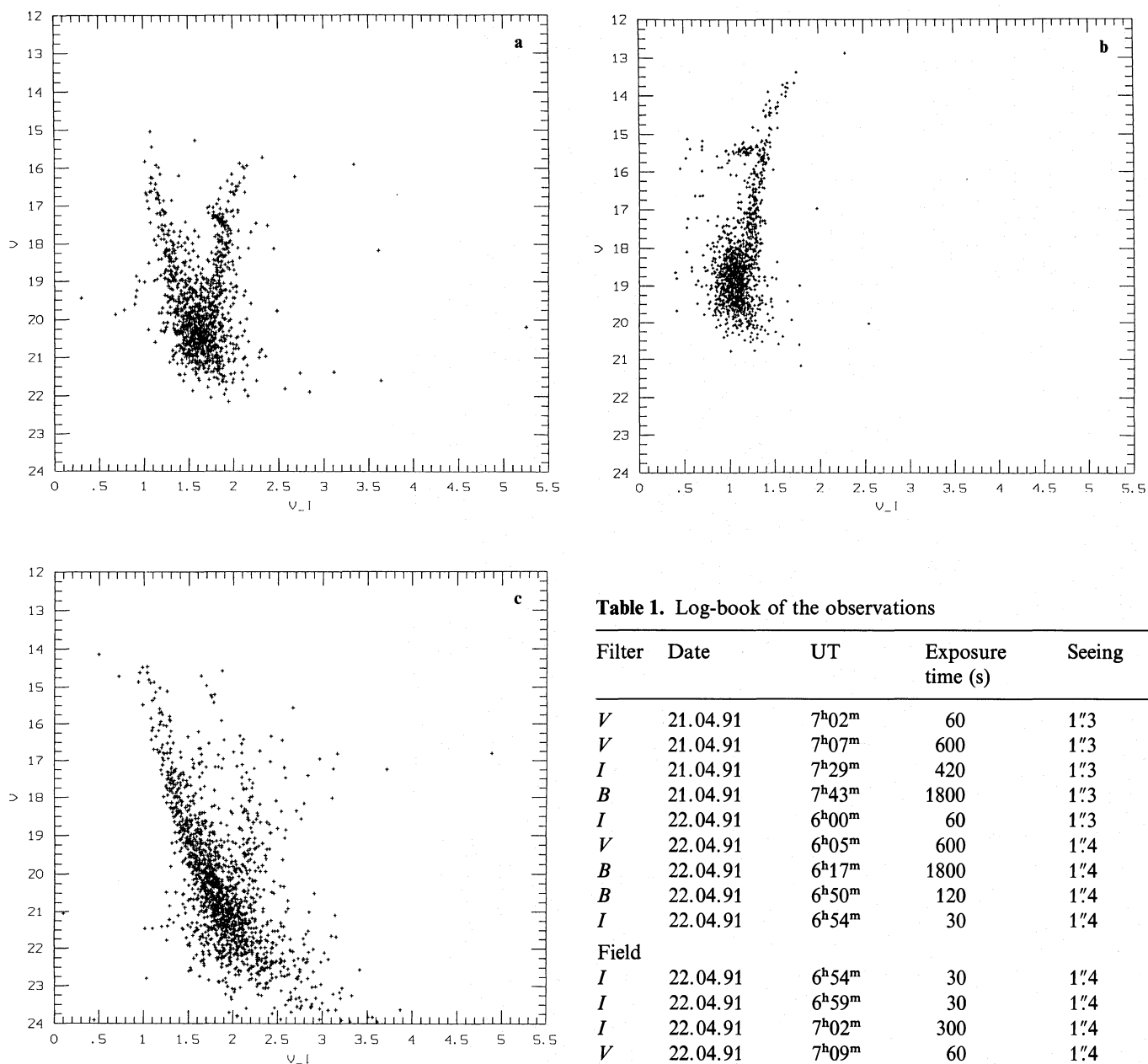


Fig. 2a–c. V vs. $(V-I)$ CMDs. **a** Lyngå 7 with circular extraction of radius $r = 180$ pixels; **b** NGC 6171 for comparison; **c** offset field 20' north

Table 1. Log-book of the observations

Filter	Date	UT	Exposure time (s)	Seeing
V	21.04.91	7 ^h 02 ^m	60	1".3
V	21.04.91	7 ^h 07 ^m	600	1".3
I	21.04.91	7 ^h 29 ^m	420	1".3
B	21.04.91	7 ^h 43 ^m	1800	1".3
I	22.04.91	6 ^h 00 ^m	60	1".3
V	22.04.91	6 ^h 05 ^m	600	1".4
B	22.04.91	6 ^h 17 ^m	1800	1".4
B	22.04.91	6 ^h 50 ^m	120	1".4
I	22.04.91	6 ^h 54 ^m	30	1".4
Field				
I	22.04.91	6 ^h 54 ^m	30	1".4
I	22.04.91	6 ^h 59 ^m	30	1".4
I	22.04.91	7 ^h 02 ^m	300	1".4
V	22.04.91	7 ^h 09 ^m	60	1".4
V	22.04.91	7 ^h 12 ^m	420	1".4
B	22.04.91	7 ^h 22 ^m	120	1".4
B	22.04.91	7 ^h 26 ^m	1200	1".4

offset field. A blue disk MS is clearly contaminating the cluster CMD. The global morphology of the red stellar sequences in Fig. 2a suggests that Lyngå 7 is old like a globular cluster: (i) the vertical subgiant branch (SGB) is typical of globular clusters; (ii) a turn-off region is suspected, although severely blended to the field MS; (iii) the cluster presents a red horizontal branch (HB) typical of metal rich globular clusters like 47 Tuc, although this occurs also at intermediate ages (e.g. Hesser et al. 1987; Aurière & Ortolani 1988); (iv) the red giant branch (RGB) is poorly populated, but the few cool giants might suggest a flat or

curved RGB which is also a metal rich globular cluster indication (Ortolani et al. 1991). Figure 2b gives the CMD of NGC 6171, a metal-rich globular cluster. Da Costa et al. (1984) estimated a metallicity of $[M/H] = -0.9$ and an age of 16 ± 3 Gyr for this cluster. The comparison of Figs. 2a and 2b shows that (a) Lyngå 7 is younger than NGC 6171, which can be derived from their relative positions of turn-off (TO) and HB and (b) that Lyngå 7 is more metal-rich than NGC 6171 as can be seen from the curvature of the RGB.

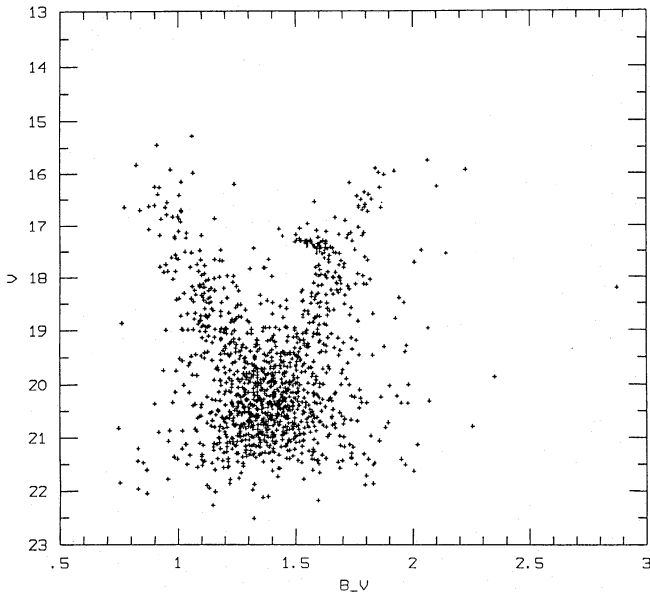


Fig. 3. V vs. $(B-V)$ CMD of Lyngå 7 for a circular extraction of $r = 180$ pixels

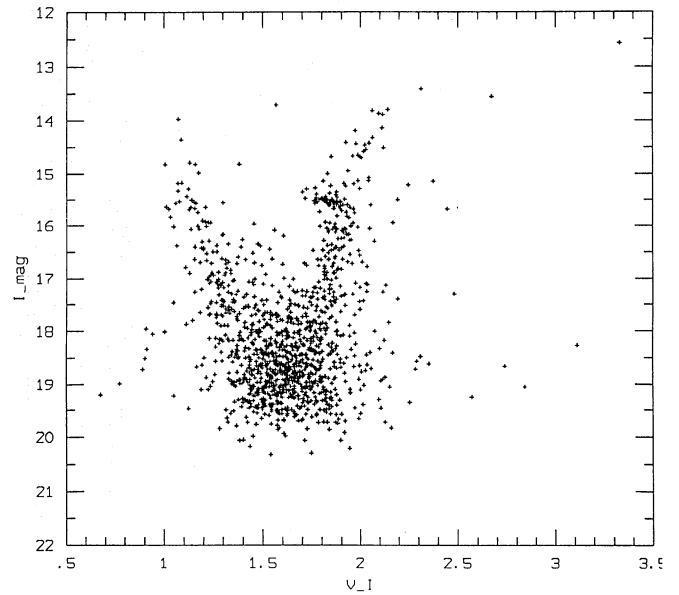


Fig. 4. I vs. $(V-I)$ CMD of Lyngå 7 for a circular extraction of $r = 180$ pixels

The field presents a sequence of giants parallel to the upper MS, which can be identified with massive red giants of ages in the range 100 to 600 Myr (Mermilliod 1981). Some fainter giants are also present which could be identified with a halo component.

The V vs. $(B-V)$ diagram of Lyngå 7 is presented in Fig. 3. In order to minimize field contamination, all the cluster diagrams are circular extractions of radius 180 pixels ($1'5$) centered on the frames at pixels (160, 270). The CMD is shifted to red colors which reveal an important interstellar reddening. The scatter is slightly larger than that observed in Fig. 2a, certainly due to the fact that the B filter is more affected by differential reddening. The possible member giants at the tip of the RGB are as faint as hotter giants, which denotes some blanketing typical of a metal-rich globular cluster.

The cluster I vs. $(V-I)$ diagram is presented in Fig. 4. The few cool giants mentioned above are ascending, which is expected owing to the weaker blanketing in the I band (Ortolani et al. 1991). The behaviour of the cooler giants in the different CMDs suggests that they are indeed metal-rich probable cluster members.

We show in Fig. 5 a deep V vs. $(V-I)$ diagram corresponding to a central extraction in Lyngå 7. It can be seen that the TO appears to be the concentration in the lower MS. We derive a magnitude difference between TO and HB, $\Delta V(\text{TO}-\text{HB})$ around 3.1 mag. The photometric error at the level of the turnoff is 0.1 mag., as derived from frame to frame comparison, but the error on the turnoff position can be larger due to differential reddening and crowding effects. As discussed in Ortolani et al. (1990) and in Buonanno et al. (1990), similar values were detected in

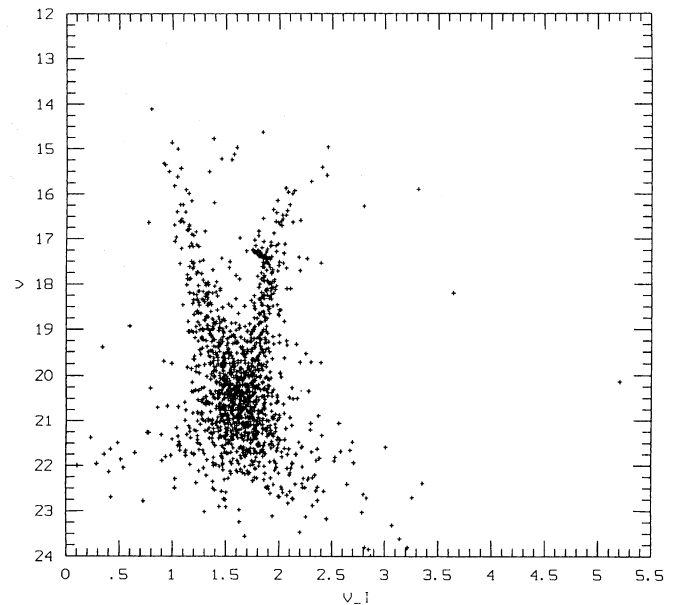


Fig. 5. Deep V vs. $(V-I)$ CMD of central extraction in Lyngå 7. Some bright stars are missing relative to Fig. 2a because of saturation effects and extraction differences

Pal 12 and Rup 106 ($\Delta(\text{TO}-\text{HB}) = 3.1$ and 3.15 respectively); such values indicate the possibility of an age younger than the classical halo globular clusters.

4. Cluster parameters

Concerning the metallicity, the main indicators we have are the RGB and HB morphologies. The former, according to

the sequences of Figs. 2 to 4, are very similar to those of 47 Tuc; the RGB of Lyngå 7 is flatter than that of NGC 6171 indicating that Lyngå 7 is more metal-rich. The red HB, moreover, partially superimposes on the RGB as for more metal-rich clusters like NGC 6553 and NGC 6528 (Ortolani et al. 1990, 1992). It also resembles these clusters in the sense that the red HB is tilted, although this might be caused by some differential reddening. We conclude that Lyngå 7 is intermediate in metallicity between 47 Tuc and NGC 6553/NGC 6528. Assuming the Zinn & West (1984) metallicity values for these clusters, we derive $[M/H] \approx -0.40$ for Lyngå 7.

From Fig. 3 we measure the magnitude and colour at the center of the HB: $V_{\text{HB}} = 17.35$, $(B - V)_{\text{HB}} = 1.59$. Taking 47 Tuc as the reference $[(B - V)_0]$, we derive a reddening $E(B - V) = 0.84$; when taking NGC 6553, with no blanketing correction (Paper I), as the reference, $E(B - V) = 0.59$ is found for Lyngå 7. We adopt $E(B - V) = 0.72 \pm 0.12$ for the cluster.

Using the HB absolute magnitude for solar metallicity $M_V = 1.06$ (Buonnano et al. 1989), a true distance modulus $(m - M)_0 = 14.13$ is obtained, which implies a distance of $d \approx 6.7$ kpc.

5. Lyngå 7 as a disk globular cluster

The metal-rich globular clusters appear to be distributed in a disk-like subsystem (Zinn 1985). Lyngå 7 is metal-rich (Sect. 4), in l, b coordinates it fits well the flattened apparent distribution of the suggested disk system. Owing to its very low Galactic latitude, the cluster is very close to the Galactic plane ($z \approx -300$ pc). Assuming a distance to the Galactic Center of 8.8 kpc we derive Galactocentric coordinates $x \approx -3.1$, $y \approx -3.5$ and $R_{\text{GC}} \approx 4.7$ kpc. We note that if the distance to the Galactic Center is 8 kpc (Feast 1987), then $x \approx -2.6$, $y \approx -2.9$ and $R_{\text{GC}} \approx 4$ kpc. Consequently it should belong to the edge of the globular cluster disk system. Another interpretation would be that Lyngå 7 is the oldest disk open cluster so far detected, possibly a thick disk cluster. In any case the peculiar actual galactic position of Lyngå 7 rises the question how the cluster could resist to the tidal forces for such a long time.

Armandroff (1989) has refined the analysis of the disk system of globular clusters with a selected sample of clusters with well determined distances. Three metallicity subgroups were proposed, and the most metal-rich one is contained in a scale height of about 1 kpc and within a

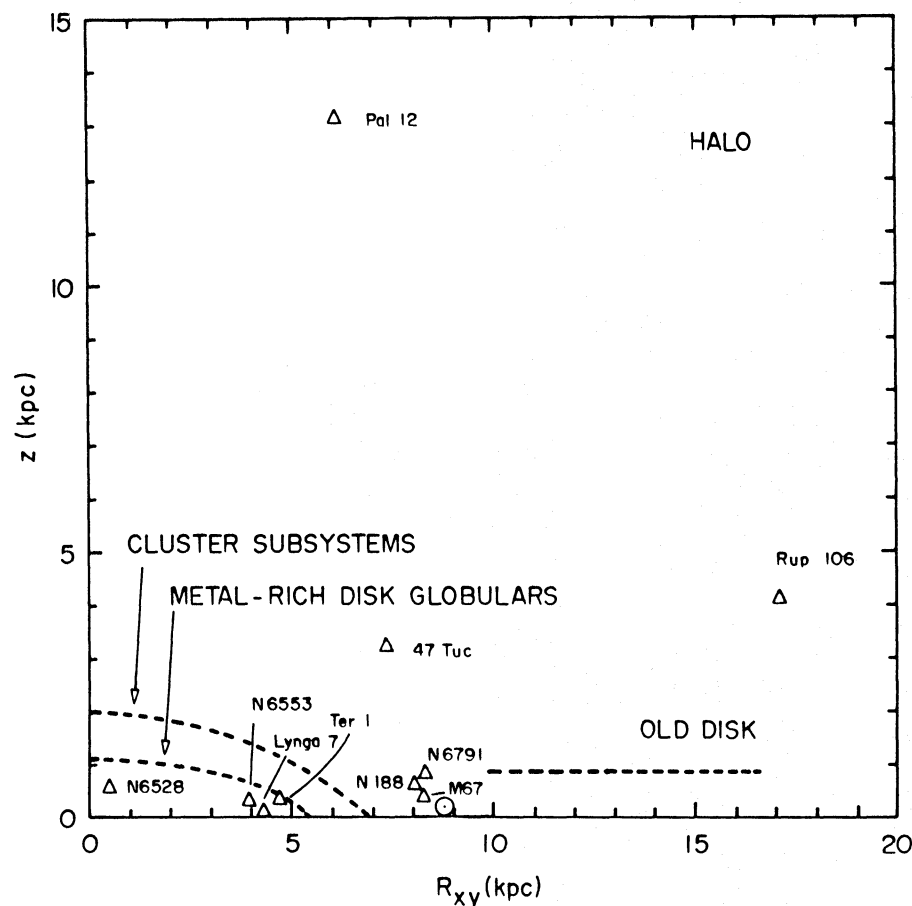


Fig. 6. Scale height z (kpc) vs. distance from the Galactic Center in the plane R_{xy} (kpc). The lines correspond to disk subsystems of metal-rich globular clusters cf. Armandroff (1989). Labeled clusters are discussed in Sect. 5

projected distance from the Galactic center on the plane $R_{xy} < 5$ kpc. The second and third less metallic groups were essentially contained in a scale height of 2 kpc and $R_{xy} < 7$ kpc, plus a few exceptions like 47 Tuc located farther away. We have recently studied a series of CCD CMDs of metal-rich clusters which have improved the distance determination for NGC 6528 and NGC 6553, besides Terzan 1 as a new entry in the sample (Ortolani et al. 1990, 1992, 1993). In Fig. 6 we gather all this information together with Lyngå 7 and the younger halo clusters Pal 12 and Rup 106, as well as the oldest disk clusters NGC 6791 (6–8 or 7–9 Gyr for above solar and solar metallicities), NGC 188 (6.5 Gyr) and M 67 (4 Gyr) (Demarque et al. 1992). We have measured in Demarque et al.'s CMDs the $\Delta(\text{TO} - \text{HB})$, resulting respectively 3.00, 2.75 and 2.20 mag (see also Janes 1988 for NGC 6791). These clusters clearly belong to the old disk which has a scale height of $z \approx 0.8$ kpc at the solar neighbourhood. From this age estimation method, one can conclude that while the halo was still forming clusters at moderate metallicities like Pal 12 and Rup 106, the metal-rich subsystem of disk globular clusters with scale height $z \approx 1$ kpc was probably forming Lyngå 7. This epoch almost overlaps with the formation of old disk clusters of about solar metallicity, like NGC 6791. Only radial velocity and proper motion studies can definitely clarify the origin of Lyngå 7.

6. Conclusions

The analysis of the CMD of Lyngå 7 shows that this cluster, previously classified as an open cluster, might be a metal rich globular cluster or, in alternative, the oldest open cluster so far detected.

The RGB and HB morphologies indicate that it is metal-rich, possibly intermediate between 47 Tuc and NGC 6553/NGC 6528. The turn-off is detected and its comparison with the horizontal branch level indicates that Lyngå 7 is a cluster significantly younger than classical halo

globular clusters, but older than the old open clusters NGC 188 and NGC 6791.

We derive a reddening of $E(B - V) = 0.72$ and a distance from the Sun of 6.7 kpc. The derived Galactocentric coordinates indicate that Lyngå 7 is at the edge of the disk subsystem of metal-rich globular clusters in the Galaxy, very close to the plane.

Acknowledgements. We are grateful to Mike Rich for helpful comments.

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