A PHOTOMETRIC STUDY OF THE GALACTIC CLUSTER NGC 6124

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ICHTISAR

Magnitudo dan warna dalam sistim B, V daripada bintang² dalam gugus galaktik NGC 6124 telah ditentukan berdasarkan suatu deret photoelektrik jang diukur oleh Koelbloed dan perluasannja kepada bintang-bintang jang lemah tjahajanja. Djarak daripada gugus itu telah ditentukan kira² 580 pc. dan usianja kira² 10^8 tahun lebih sedikit.

ABSTRACT

Magnitudes and colours on the B, V system are determined for stars in the galactic cluster NGC 6124, based on a photoelectric sequence measured by Koelbloed and an extension of this towards fainter stars. The distance of the cluster is about 580 pcs. and the age somewhat more than 10^8 years.

INTRODUCTION

The galactic cluster NGC 6124 (R.A. = $16^h18.^m8$; Dec. = $-40°26'$; 1950) has been studied by Koelbloed (1959) photoelectrically. Lacking faint stars in his study Koelbloed only made a rough estimate of the distance and age of the cluster.

In order to make a more accurate determination of distance and age of the cluster the study by Koelbloed has been extended photoelectrically and photographically to fainter stars.

The extension of the photoelectric sequence will also be useful for the study of a nearby T association found by The (1962). It is important to mention that the cluster is seen projected on the edge of a dark cloud, obscuring away faint field stars in the northwestern part of the cluster area.

Older distance determinations of this cluster range from 180 to 2100 pcs. Estimates of the cluster diameter range from 22'.5 to 43'. In our photographic study we have measured all the stars down to a limiting apparent magnitude of about V = 14.0 magn. lying in a circular area of about 50' diameter.

PHOTOELECTRIC PHOTOMETRY

In addition to the forty-six stars which were measured photoelectrically by Koelbloed, a sequence of faint stars is currently being measured

by Lyngå with the 127 cm reflector at the Mt. Stromlo observatory. These faint stars are situated near Nos. 15 and 33 in Koelbloed's series. Nos. 15 and 33 are used as photoelectric standards. Preliminary data are given in Table I.

TABLE I

Preliminary data for stars measured photoelectrically.

No.	V	B-V	n
15a	14.48	1.87	1
b	15.77	2.25	1
c	14.90	1.26	1
d	13.92	1.19	1
33a	15.67	1.97	3
b	15.91	1.35	2
c	16.25	1.59	1
d	14.06	0.99	2
e	13.25	0.86	3
f	13.38	0.93	2
g	13.95	1.06	1

In Table I, the last column gives the number of observing nights for each star. From the internal scatter of the observations a probable error of $\pm$ 0.03 magn. is calculated for V as well as for B-V. The stars are identified according to their numbers in Figures 3 and 6.

PHOTOGRAPHIC PHOTOMETRY

For the photographic determination of the magnitudes of the stars in the cluster region photographic plates were obtained using the 20-28 inch Schmidt-type telescope at Lembang. The type of plates used is Kodak 103aD exposed behind a 2 mm Schott GG11 filter for the determination of the visual magnitudes, and for the blue magnitudes Kodak IIaO combined with a 2 mm Schott GG13 filter. Only plates of good quality were measured. A specification of the measured plates is given in Table II.

TABLE II.

List of photographic plates.

Colour	Plate No.	Date	Emulsion	Filter	Exposure
B	273	18 May '63	IIaO	GG 13	20 sec.
	278	17 June '63			
	286	17 June '63			
	176	30 May '62			1 min.
	271	18 May '63			
	282	15 June '63			
	291	17 June '63			3 min.
	295	17 June '63			10 min.
	326	13 July '63			
V	171	27 May '62	103aD	GG 11	1 min.
	175	30 May '62			
	265	17 May '63			
	267	17 May '63			
	308	22 June '63			2 min.
	275	18 May '63			3 min.
	94	15 July '61			10 min.
	335	14 July '63			

The measurements of the photographic plates were carried out using the modified Eichner iris-diaphragm astrophotometer of the Warner and Swasey Observatory, during my stay at this observatory. In order to correct the measurements for a drift of the zero point of the photometer, the standard stars were measured at least three times per plate, at the beginning of the session, at the middle and at the end. The procedure of the reduction of the measurements after correction for the drift of the photometer is as follows. All Koelbloed's V magnitudes and the newly obtained V measurements of the fainter stars given in Table I are used to obtain a calibration curve for V magnitudes. Photographic V magnitudes of these sequence stars are read back through the calibration curve and then intercompared with the photoelectric V measurements. This intercomparison shows that there is no magnitude and colour equation present between

the photoelectric and photographic V magnitudes. This fact is also illustrated in Figures 1 and 2, where the residuals are taken in the sense photoelectric minus photographic. For the final photographic V values the mean obtained from the different plates were used.

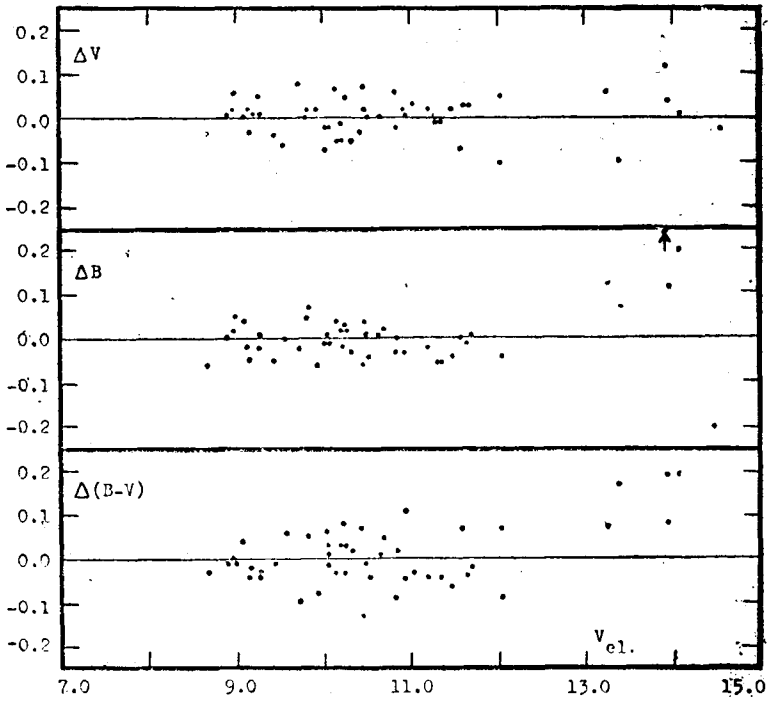

Fig. 1. The intercomparison between photoelectric and photographic measurements.

When the photoelectric B magnitudes of Koelbloed are plotted against the photometer readings of the blue plates it is evident that all the red giants (except Koelbloed's star No. 29) fall about 0.25 magn. above the points corresponding to the main sequence stars. It is thus obvious that there is a colour equation present for the B magnitudes. The photographic B magnitudes of all Koelbloed's stars were read off from the calibration curve and an inter-comparison was made of these magnitudes with the original photoelectric B magnitudes. This gave the colour equation for the plates. In order to apply the photoelectric B magnitudes of the fainter stars for the extension of Koelbloed's standard stars, these faint stars,

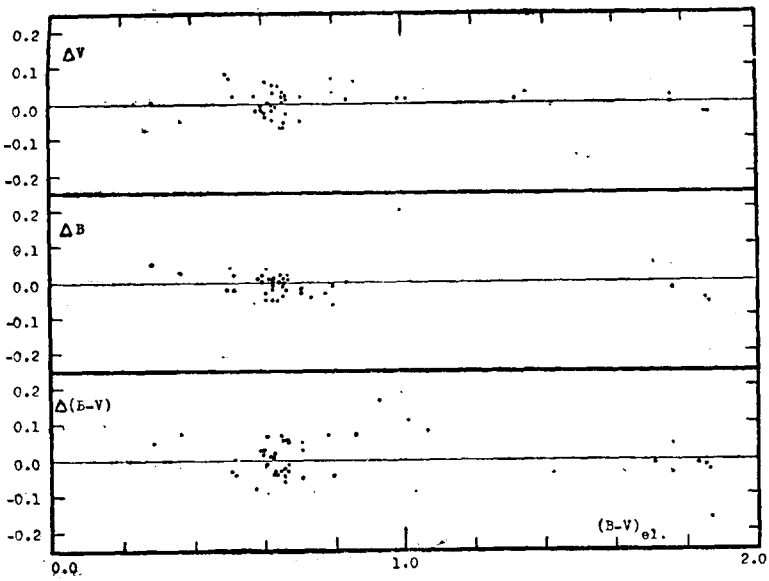

Fig. 2. The intercomparison between photoelectric and photographic measurements.

which are all of intermediate colour, were first corrected using the obtained colour equation. The calibration curve then plotted is on the system of the photographic plates.

After the photographic B-V colour indices of the standard and program stars were determined, their B magnitudes were corrected for colour equation using the same relation as above but with opposite sign. The final photographic B magnitudes and B-V colour indices of all the stars are thus on Koelbloed's B, V system, as is apparent from Figures 1 and 2, where intercomparisons of the photoelectric and mean photographic B magnitudes and B-V colour indices of the standard stars are illustrated.

From the intercomparisons it was also found that the dispersion of the V magnitudes and (B-V) colour indices of the photographic measurements with respect to the photoelectric ones are, respectively, $\pm$ 0.03 magn. and $\pm$ 0.03 magn. for stars brighter than apparent visual magnitude 12.5. For fainter stars the dispersions are estimated to be $\pm$ 0.06 magn. and $\pm$ 0.11 magn. respectively.

In order to facilitate the measurements of the photographic plates, the cluster area is divided into 4 quadrants. All stars, brighter than apparent visual magnitude V = 14.0, and situated within a radius of 50′ in the cluster area, were measured. The stars which are not well seperated on the plates were not measured. The four quadrants I, II, III and IV correspond, respectively, to the northwestern, southwestern, northeastern and southeastern parts of the cluster area.

Identifaction charts of the 4 regions are given in Figures 3, 4, 5 and 6. The result of the photographic measurements is given in Tables III, IV, V and VI, in which the stars are identified by their numbers in Figures 3, 4, 5 and 6.

The photographic determination of the V magnitudes and B-V colour indices of Koelbloed's standard stars is presented in Table VII.

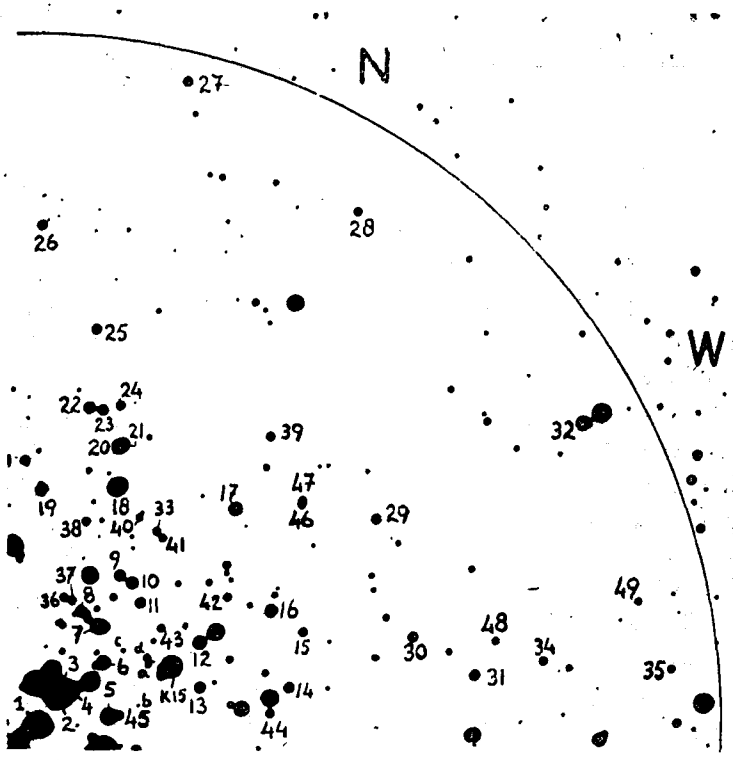

Fig. 3. Finding chart of stars in quadrant I of NGC 6124, reproduced from a visual plate. The radius of the circle is about 25 min. of arc. K 15 is Koelbloed's star No. 15 ; a, b, c, and d represent stars measured photoelectrically by Lynga.

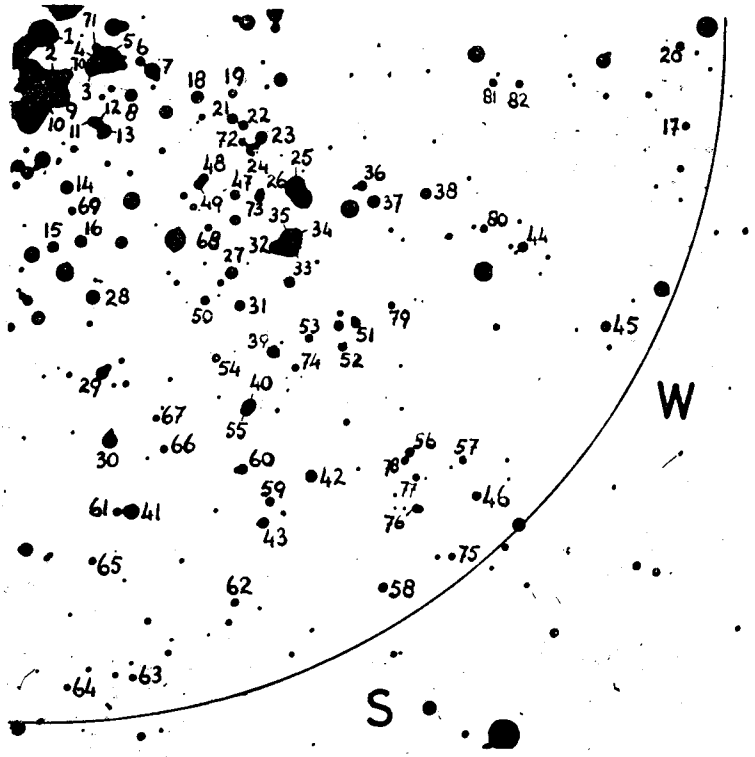

Fig. 4. Finding chart of stars in quadrant II of NGC 6124, reproduced from a visual plate. The radius of the circle is about 25 min. of arc.

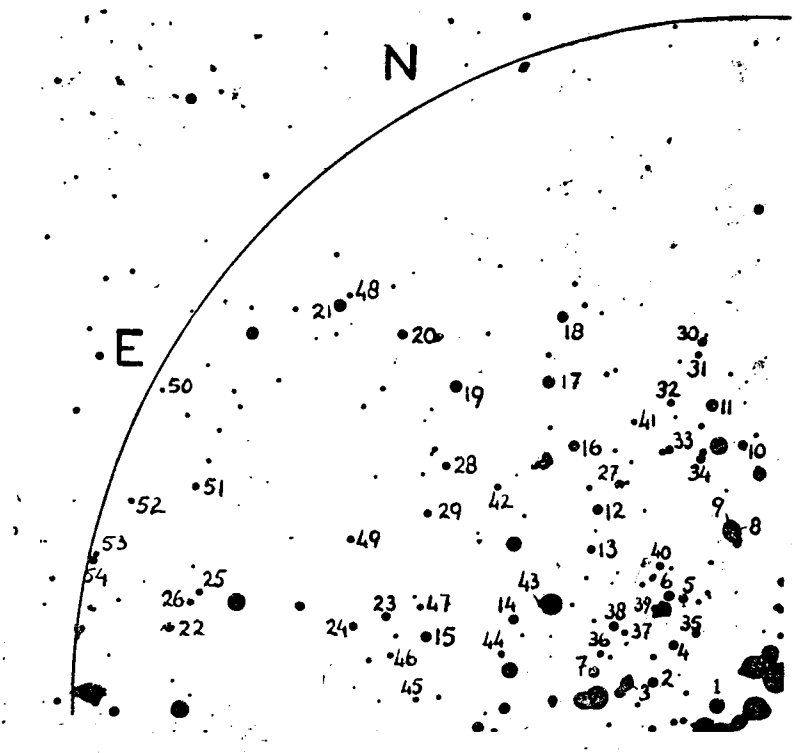

Fig. 5. Finding chart of stars in quadrant III of NGC 6124, reproduced from a visual plate. The radius of the circle is about 25 min. of arc.

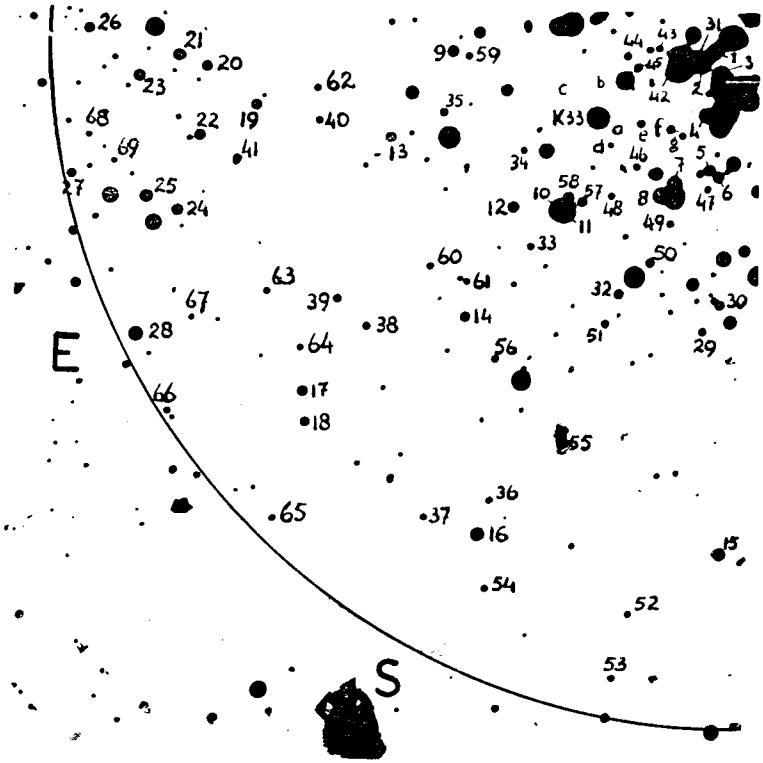

Fig. 6. Finding chart of stars in quadrant IV of NGC 6124, reproduced from a visual plate. The radius of the circle is about 25 min. of arc. K 33 is Koelbloed's star No. 33 ; a, b, c, d, e, f, g, represent stars measured photoelectrically by Lynga.

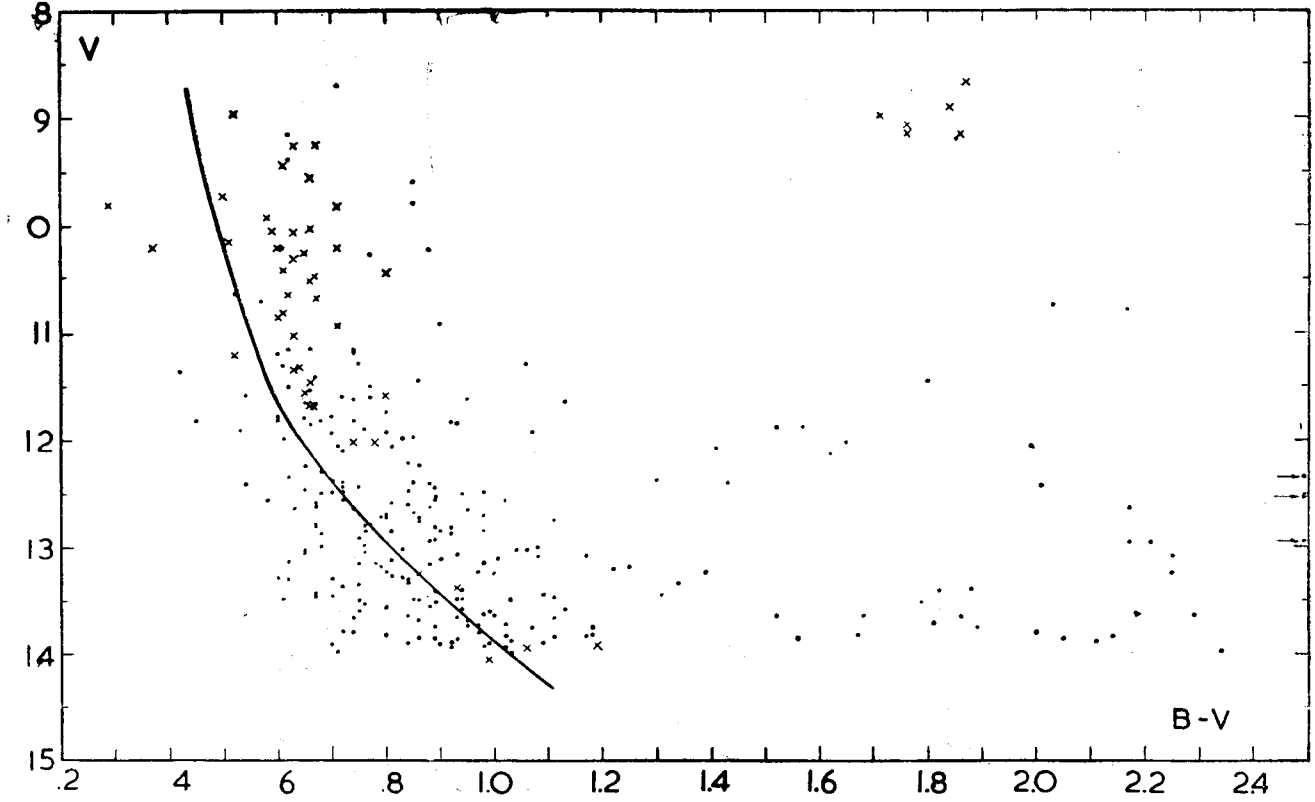

Fig. 7. The colour magnitude diagram of NGC 6124. Crosses and dots represent, respectively, stars measured photoelectrically and photographically. The line represent the zero age main sequence, fitted to the colour magnitude diagram of the cluster.

DISCUSSION OF THE PHOTOMETRY

In Figure 7 the colour-magnitude diagram of all the measured stars is given. In this figure the photoelectric measurements are indicated by crosses. The lower part of the diagram shows a strong intermixing by field stars, which begin to appear around $V = 12.0$ magn.

For the plot of Koelbloed's stars No. 9, 10 and 29 the photographic measurements are used because the photoelectric measurements seem to be influenced by some error or by the variability of the stars.

Koelbloed's A0 type stars Nos. 44 and 45, which according to him may be members of the cluster, both are lying at the border of the investigated cluster area. These two stars also have smaller reddening than the other A type main sequence stars. Thus we assume that they are foreground stars rather than cluster members.

The spectral types of the photographically measured stars, which are given in the Henry Draper Extension, are listed in column 4 of Tables III, IV, V and VI.

Star No. 1-32 of spectral type G5 which lies in the outskirts of the cluster area, does not belong to the cluster; since its B-V value is 0.67 magn. It is a foreground star with little reddening, and thus similar to some F and G type stars assumed by Koelbloed to be foreground stars.

On an infrared objective prism plate (Eastman Kodak 1N + Schott RG2) some M stars has been found inside the cluster area. They are identified as such in column 4 of Table III, IV, V and VI. They are probably distant giant M stars not belonging to the cluster.

In the colour magnitude diagram, Johnson and Sandage's "zero age main sequence", as employed by Koelbloed (1959), has been drawn to fit the cluster main sequence, after allowing for reddening in the cluster area. The colour excess of $E_{B-V} = 0.68$ magn. determined by Koelbloed was used. By employing the curve-fitting method the uncorrected distance modulus 10.71 magn. was found. With an absorption of 2.04 magn. a distance of 550 pas. for NGC 6124 is obtained.

The distance of the cluster is also determined by using the evolutionary deviation curve method proposed by Johnson (1960). It is felt necessary to supplemenet the photoelectric data of Koelbloed with photographic ones, because Koelbloed's data do not go faint enough. In Figure 8 the distance moduli V_o-M° for main sequence stars are plotted against

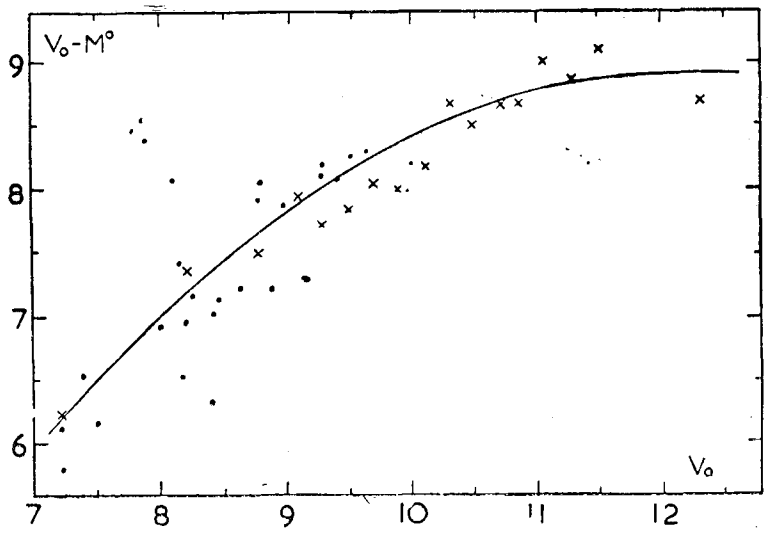

Fig. 8. The evolutionary deviation curve of NGC 6124. Dots represent stars measured photoelectrically. Crosses represent mean photographic values.

the visual mangitudes V_0. The dost represent the observations obtainced photoelectrically and the crosses mean values of the photographic points. As can be seen from Figure 8 the horizontal right end of the evolutionary deviation curve indicates a distance modulus of 8.95 magn. for NGC 6124. This is equivalent to a distance of 615 pcs.

By giving equal weight to both determinations a mean value of about 580 pcs. is obtainded for the galactic cluster NGC 6124. This is in good agreement with the distance of 570 pcs. determined by Barkhatova (1950).

The termination point in Figure 7 is near $M_V = -0.3$ magn. According to Sandage (1957) this corresponds to an age of somewhat larger than 10^8 years for NGC 6124.

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