DISTANT GALACTIC OPEN CLUSTERS

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The motivation for studying distant open clusters primarily arose out of a desire to gain some understanding of star formation processes in the general context of galactic structure. Of specific interest are faint open clusters (c.f. Alter, Balázs and Ruprecht 1970) near the galactic anticenter which are part of a larger survey of objects which may be located in the "periphery" of the Galaxy. Table I contains a sample of results from broad-band photometric studies for clusters near $l^{II}=180^{o}$, $b^{II}=0^{o}$. The characteristics of these clusters are consistent with other investigations, which suggest that the disk of the galaxy extends to large galactocentric distances; for example, deep surveys of blue stars (Chromey 1979; McCarthy and Miller 1974) and investigations of the rotation curve of the galaxy (Blitz 1979; Knapp, Tremaine and Gunn 1978), to mention a few. There is also a considerable amount of evidence that the distributions of distant objects basically reflect the locations of local absorbing clouds and low absorption "windows" (Westpfahl and Christian 1979), rather than distant galactic structure. Therefore, in this study, emphasis is being placed on the determination of ages, abundances and luminosity functions of clusters, rather than considering them as "spiral tracers".

James E. Hesser (ed.), Star Clusters, 223–226.

Table 1

Distant Anticenter Clusters

Cluster	l^{II}	b^{II}	d (from Sun)	R (from G.C.)	$E(B-V)$ ± 0.1mag	Age estimate	Reference, Comment
Be 21	186°	$-2\overset{\circ}{.}5$	10-15 kpc	20-25 kpc	1.0mag	3×10^{7} y	1, $\delta(U-B)\sim$ 0.3 mag
Be 19*	177	-3.6	3-5	13-15	0.4	$>10^{9}$	2
King 8*	177	+3.1	3-6	13-16	0.5	$8-20\times10^{8}$	this paper, possibly metal poor
Ba 4	180	+1.4	∿5.9	∿15.9	0.74		3, earliest spectral type=B2
NGC 2141	198	-6.0	∿4.4	∿14.3	0.30	$\sim4\times10^{9}$	4
Bo 1	192	+3.4	∿4.1	∿14	0.55	OB assoc	5 (8 stars)

* from preliminary *BV* photometry
1 Christian, C.A. and Janes, K.A.: 1979, *Astron. J.* 84, 204.
2 Christian, C.A.: 1979, *ibid.* (Submitted).
3 Becker, W. and Fenkart, R.: 1971, *Astron. Astrophys. Suppl.* 4, 241.
4 Burkhead, M.S., Burgess, R.D., and Haish, B.M.: 1972, *Astron. J.* 77, 661.
5 Moffat, M.P., and Vogt, N.: 1975, *Astron. Astrophys. Suppl.* 20, 85.

REFERENCES

Alter, G., Balazs, B., and Ruprecht, J.: 1979, *Catalogue of Star Clusters and Association,* Akademiai Kiado, Budapest.
Blitz, L.: 1979, *Astrophys. J. Letters* 231, L115.
Chromey, F.R.: 1979, *Astron. J.* 84, 534.
Knapp, G.R., Tremaine, S.D., and Gunn, J.E.: 1978, *ibid.* 83, 1585.
McCarthy, C.C., and Miller, E.W.: 1974, *ibid.* 79, 1396.
Westpfahl, D.J., and Christian, C.A.: 1979, *Bull. Am. Astron. Soc.* 11, 415.

DISCUSSION

HARWARDEN: On what grounds did you say that there was a hint that King 8 was heavy element deficient?

CHRISTIAN: Because the giant stars are ever so slightly brighter than the main sequence stars, when compared to galactic clusters which have approximately a solar abundance. This effect, for clusters of similar age, has been attributed to metal deficiency, but it's just a hint and, you know, I'm not placing much weight on that result.

HARWARDEN: How did you establish the age?

CHRISTIAN: By a comparison with the galactic clusters - by just matching up the color-magnitude diagrams.

HARDY: May I mention that there is another anticenter cluster, NGC 2158, which is around 17 kpc, which has similar properties in the sense that the giant branch is extremely bright, like a globular cluster giant branch. Janes measured the metallicity from *DDO* to be -0.6 and I get -0.7 from the Washington system, and that matches exactly what you're saying.

CHRISTIAN: Yes. I forget what the galactic latitude of that cluster is.

CANNON: Turning quickly to Berkeley 21, could you tell us just how you got the faint photometry at 19th magnitude, and what sort of errors you would put on your colors at that limit? And, similarly, how did you estimate the reddenings, and what errors would you put on the reddening?

CHRISTIAN: The errors at 19th magnitude are almost getting up around 0.07 mag, so it's pretty bad. The photometry came from the 2-m computer photometer, and I took 0.9-m direct plates, so one of the things that I intend to do this fall is to use the video camera to get down there and find out just exactly where the main sequence of this cluster is. The color errors are slightly less than that, maybe by 0.05 mag, but it really rapidly gets very bad below 19th.

CANNON: And what about the reddening?

CHRISTIAN: The reddening came from comparison to the Magellanic Cloud clusters and also from the two-colour diagram; for that particular cluster, I have *U* photometry and the two-colour diagram also indicates that the reddening is about 1.0 ± 0.1 mag. The giants, which heavily influence that value, appear to have a large $\delta(U-B)$, which is consistent with the idea that it's metal poor.

BOK: I'm looking through my notebook and find that Blitz at the symposium at Mont Tremblant has clusters out to 18 kpc with the total mass of the Galaxy to that distance > 3.5×10^{11} $M_\odot$. The rotation curve is stuck at 300 km s^{-1} and shows no indication of going down and that Martin Schmidt's rotation curve is out!

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CHRISTIAN: That's right and part of that has appeared in the *Astrophys. J. Letters*.

BOK: Yes, but it's getting stronger, much stronger.

MOFFAT: I should perhaps point out after Dr. Bok that the distances to those CO regions that were studied are based on our photometry of clusters in this region; in fact, there are I'd say, $\sim$ 6-8 clusters out to 8 kpc in the regions he mentioned.

CHRISTIAN: This was not meant to be representative; it was just to show that there are some clusters out there, and people shouldn't believe any more that the Galaxy ends at 15 kpc.

BOK: Oh, no.

MOFFAT: May I ask how you got colors out to $(B-V)_o$=-0.7 in Berkeley 21?

CHRISTIAN: Oh that's just, I think, a lot of effects combined. First of all, the whole color-magnitude diagram was dereddened, ok, so there are field stars in there which have not been subtracted out. So that's a part of the problem. And some of the other problems are that the photometry is not terriby good for those 20th magnitude and 19th magnitude stars.

KING: I might just remind you that when dealing with broadband photoelectric systems, when you deredden colors, you also change your color base line, and that may affect your interpretation of diagrams.

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