1968ApJ...152...83E

THE ASTROPHYSICAL JOURNAL, Vol. 152, April 1968

# THE INTERMEDIATE-AGE CLUSTER NGC 2360

O. J. EGGEN
Mount Stromlo and Siding Spring Observatories, Research School of Physical Sciences,
Australian National University

*Received September 25, 1967*

ABSTRACT

Three-color, photoelectric observations of NGC 2360 indicate that it has (*a*) a corrected distance modulus of 10 3 mag, $E(B-V) = +0.07$ mag, and $\delta(U-B) = 0.05$ mag; (*b*) an age intermediate between that of the Hyades and NGC 752; (*c*) a small Hertzsprung gap; (*d*) a 0.2-mag gap at $M_v = +2.9$ in the sequence of evolved stars near the breakaway from the main sequence; and (*e*) at least two blue stragglers. The ($M_v$,*C*) diagrams of M67, NGC 752, and NGC 2360 are compared.

Previous observations (Becker 1960, 1968) of NGC 2360 ($\alpha = 7^h13^m$, $\delta = -15°27'$, $l = 230°$, $b = -1°$: 1900) show a color-luminosity array of an intermediate-age cluster. The present (*UBV*) observations were made with the 200-inch reflector at Palomar Mountain, the 100-inch and 60-inch reflectors at Mount Wilson and the 40-inch reflector at Siding Spring Mountain. The observations are given in Table 1, where the numbering system is that used by Becker (1968); a few fainter stars are identified in Figure 1 (Plate 2). All stars to visual magnitude near 13.5 in the inclosed area of Figure 1 have been observed. A few stars outside this area are identified by asterisks in Table 1. Star No. 98 is variable; Becker (1960) gives $V = 12.47$ on December 14, 1958, and 13.33 on January 5, 1959. Twelve observations from 1963 to 1967 give a mean $V_E = 12.70$ with only three additional measures, listed in Table 1, showing deviations from this mean up to 0.5 mag. If the variation is regular the period may be near some multiple of $1^d$.

The brightest star, No. 1 (=HD 56847), is a distant supergiant also observed by Hiltner (1956); the reddening is $E = +0.4$ mag, and the corrected modulus is near 13.5 mag.

| | *V* | *B*−*V* | *U*−*B* | Sp |
|---|---|---|---|---|
| Eggen .. | 8 96 | +0 18 | −0.47 | . . . . . |
| Hiltner | 8 91 | +0 19 | −0.47 | B7Ib?, Shell? |

The reddening of the cluster is not well determined. An attempt to derive values of $E(B-V)$ and $\delta(U-B)$ from the displacement of the main-sequence stars from the $(U-B, B-V)$ relations for the Hyades, using a method discussed elsewhere (Eggen and Sandage 1964) gave the following, compared to results similarly derived for NGC

| | *E* | δ |
|---|---|---|
| NGC 752 | +0 04 | +0 06 |
| NGC 2360 | +0 07 | +0 05 |

752 (Eggen and Sandage 1964); the similarity of the two clusters is also shown in Figure 2, where the colors of the giant stars, cleared of reddening, are compared with the standard $(U-B, B-V)$ relation for Hyades giants.



© American Astronomical Society • Provided by the NASA Astrophysics Data System

1968ApJ...152...83E

PLATE 2

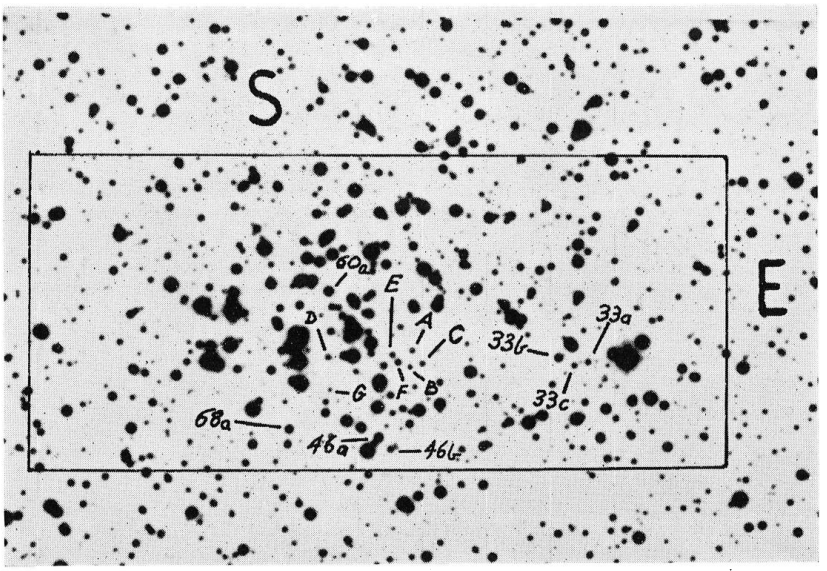


FIG. 1.—The region of NGC 2360. The numbered stars are additional objects not numbered by Becker (1958). All stars to visual magnitude 13.5 have been observed in the inclosed area.

EGGEN (*see* page 83)

© American Astronomical Society • Provided by the NASA Astrophysics Data System

© American Astronomical Society • Provided by the NASA Astrophysics Data System

TABLE 1

STARS NEAR NGC 2360

| No | $V_E$ | $B-V$ | $U-B$ | $\eta$ | No. | $V_E$ | $B-V$ | $U-B$ | $\eta$ |
|---|---|---|---|---|---|---|---|---|---|
| 1* | 8 96 | +0 18 | −0 47 | Std | 85† | 11 27 | +0 93 | +0.54 | 1 |
| 2 | 12 94 | +0 35 | +0 12 | 3 | 98 | 12 57 | +0 42 | +0.11 | 12 |
| 3. | 11 62 | +0 44 | +0 28 | 2 | 98 | 12 70 | +0.38 | +0.07 | 18‡ |
| 4. | 11 62 | +0 34 | +0 21 | 2 | 98. | 12 84 | +0.37 | +0 11 | 23§ |
| 8† | 11 06 | +0 99 | +0.68 | 2 | 98 | 12.98 | +0.45 | +0 04 | 3‖ |
| 9† | 12 16 | +0 39 | +0 15 | 2 | 99 | 12 53 | +0.34 | +0 19 | 6 |
| 12† | 11 43 | +1 04 | +0 66 | 2 | 100 | 11 16 | +0 05 | +0 06 | 1 |
| 27 | 11 59 | +0.47 | +0.27 | 2 | 101 | 11.29 | +1.02 | +0.68 | 2 |
| 28. | 13 04 | +0 37 | +0.21 | 2 | 108 | 11 53 | +0.43 | +0.245 | 2 |
| 29. | 11.83 | +0.34 | +0.145 | 2 | 109. | 11.48 | +0.97 | +0 665 | 2 |
| 30 | 13 54 | +0.53 | +0 08 | 2 | 110* | 11.84 | +0 995 | +0.705 | 2 |
| 31. | 12 96 | +0.395 | +0 175 | 2 | 111 | 13 40 | +0.41 | +0.115 | 2 |
| 32* | 13.32 | +0 31 | +0.07 | 2 | 112. | 13.78 | +0.51 | +0.24 | 3 |
| 33a | 14 22 | +0 67 | +0.10 | 1 | 113. | 12.83 | +0.34 | +0 13 | 2 |
| 33b | 16.11 | +0 90 | +0.40 | 1 | 114 | 11.08 | +0.98 | +0 68 | 2 |
| 33c | 16 09 | +0 87 | +0 40 | 1 | 115 | 11.46 | +0.30 | +0 20 | 3 |
| 35 | 13 20 | +0 50 | +0.10 | 3 | 116. | 12.90 | +0.38 | +0 105 | 3 |
| 36. | 12 20 | +0 345 | +0.17 | 2 | 117. | 11.30 | +0.86 | +0 505 | 2 |
| 37. | 13 56 | +0 53 | +0 09 | 3 | 118 | 10.36 | +1.16 | +1.01 | 2 |
| 38 | 12 18 | +0 345 | +0.20 | 4 | 119 | 13.33 | +0.50 | +0.055 | 3 |
| 39. | 12 14 | +0.38 | +0 165 | 2 | 121 | 11.31 | +0.765 | +0 425 | 2 |
| 40. | 12 20 | +0.42 | +0 15 | 2 | 122 | 13 46 | +0.42 | +0 14 | 1 |
| 41. | 11 52 | +0 485 | +0 25 | 2 | 123 | 12.61 | +0.405 | +0 165 | 2 |
| 43* | 12 80 | +1 11 | +0.78 | 2 | 124 | 12 52 | +0.40 | +0.12 | 1 |
| 44 | 12 44 | +0 425 | +0 10 | 2 | 142 | 11.74 | +0.36 | +0 20 | 3 |
| 45 | 12 03 | +0.37 | +0 195 | 2 | 143 | 11.64 | +0.43 | +0 22 | 3 |
| 46 | 11 32 | +1 02 | +0 675 | 2 | 146a | 13.91 | +0 59 | +0 06 | 1 |
| 46a | 13 80 | +0 67 | +0 13 | 1 | 147 | 12 23 | +0.355 | +0 21 | 2 |
| 46b | 15 54 | +0 80 | +0 33 | 1 | 148. | 13.12 | +0 38 | +0 125 | 2 |
| 48 | 13 31 | +0 395 | +0 115 | 2 | 149. | 12.62 | +0.35 | +0 17 | 1 |
| 49 | 12 22 | +0 39 | +0.155 | 2 | 150. | 11.05 | +1 03 | +0 745 | 3 |
| 50 | 12 02 | +0 39 | +0 14 | 2 | 151 | 12.73 | +0.49 | +0 085 | 2 |
| 51 | 11 12 | +0 21 | +0 12 | 2 | 153. | 11 74 | +0.375 | +0 21 | 2 |
| 52 | 12 00 | +0.425 | +0 16 | 3 | 154* | 12 36 | +1.02 | +0 61 | 2 |
| 53. | 11 39 | +0 32 | +0 195 | 2 | 155. | 13.58 | +0.565 | +0 11 | 2 |
| 54 | 10 73 | +0 98 | +0 72 | 3 | 156 | 12 86 | +0 43 | +0.11 | 2 |
| 55 | 13 68 | +0 525 | +0.12 | 2 | 156a | 14 30 | +0 605 | +0 065 | 2 |
| 58. | 13 30 | +0 395 | +0 09 | 2 | 157 | 12.74 | +0 375 | +0 12 | 2 |
| 59* | 13 02 | +1 24 | +1 12 | 1 | 158. | 12 30 | +0 455 | +0 055 | 2 |
| 60 | 11 90 | +0 33 | +0 16 | 1 | 159* | 13.08 | +1 20 | +0 68 | 1 |
| 60a | 14 37 | +0 57 | +0 10 | 2 | A | 16.07 | +0 80 | +0 30 | 1 |
| 61 | 12 76 | +0 33 | +0 12 | 1 | B | 16 52 | +0 87 | | 1 |
| 67 | 11 06 | +1 03 | +0 72 | 3 | C | 16.38 | +0.97 | +0 49 | 1 |
| 68 | 11 18 | +1 10 | +0 84 | 3 | D | 15.96 | +0 66 | | 1 |
| 68a | 14 12 | +0 59 | +0 055 | 2 | E | 16 14 | +0.90 | | 1 |
| 69 | 11 21 | +0 99 | +0 705 | 2 | F | 15 53 | +0.72 | +0 18 | 1 |
| 70. | 13 57 | +0 43 | +0 05 | 2 | G | 17.24 | +1 08 | | 1 |
| 81† | 11 29 | +0 94 | +0.58 | 1 | | | | | |

* Probable field stars.
† Stars in inclosed region of Fig. 1.
‡ December, 1966.
§ February, 1963.
‖ March, 1967.



1968ApJ...152...83E

1968ApJ...152...83E

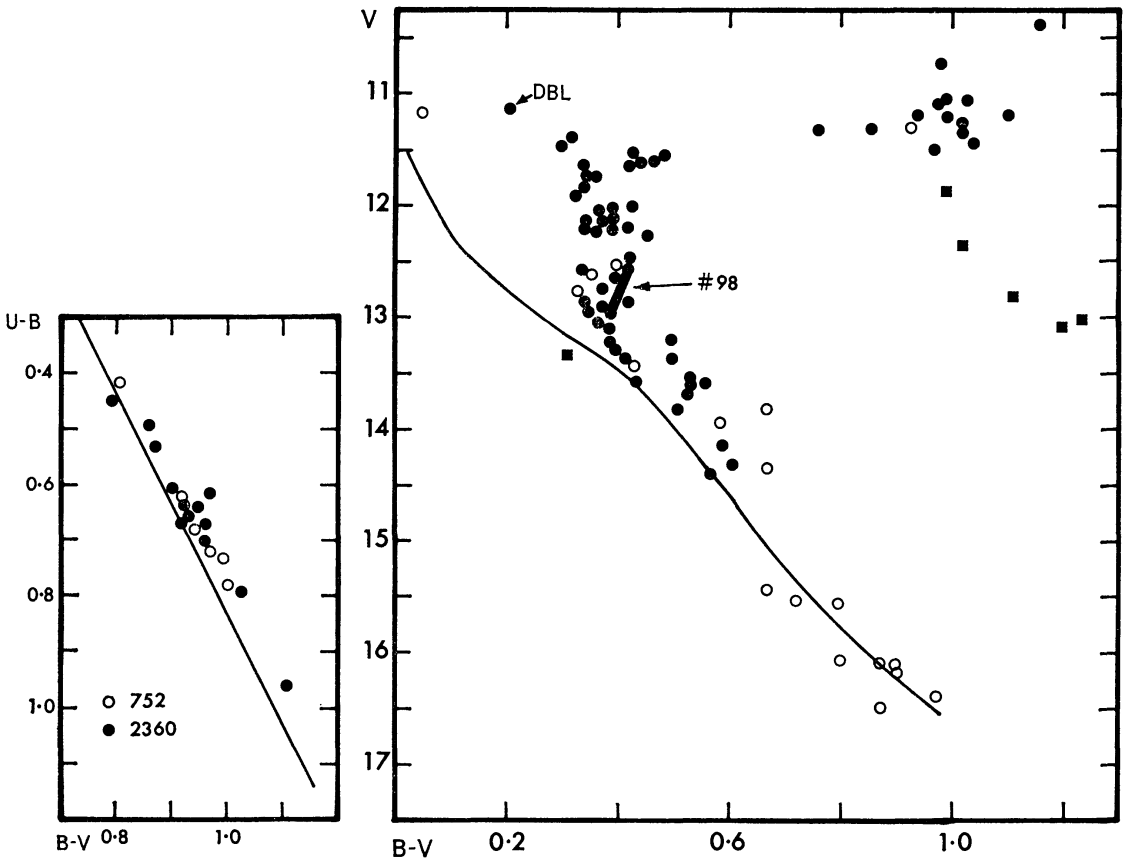


FIG. 2 (*left*).—The $(U - B, B - V)$ relation for the giants in NGC 752 and 2360, cleared of reddening. The straight line represents the giants in the Hyades group.

FIG. 3 (*right*).—The observed color-magnitude diagram for NGC 2360. Open circles represent single observations; squares, probable field stars. The continuous curve represents the zero-age main sequence corrected for $E(B - V) = +0.07$, $\delta(U - B) = +0.05$, and $(m - M)_0 = 10.3$. The path of the variable star, No. 98, is indicated by a bar.

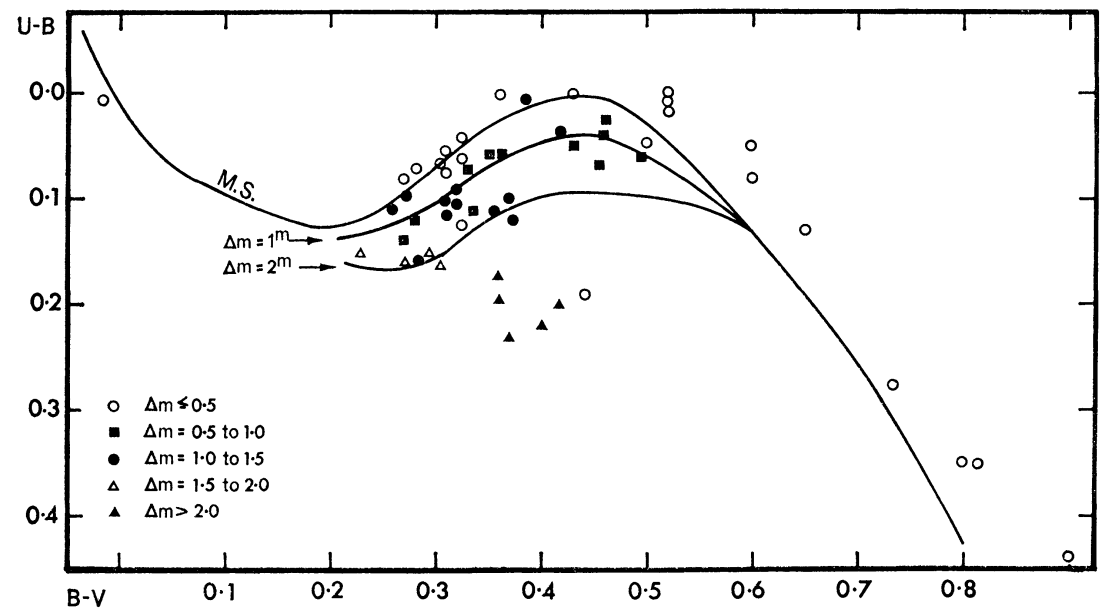


FIG. 4.—The $(U - B, B - V)$ relation for members of NGC 2360; the red giants have been omitted. The continuous curves represent the Hyades main sequence (M.S.) and stars lying 1 and 2 mag above that sequence. The coding represents various displacements from the Hyades main sequence for stars in NGC 2360.



© American Astronomical Society • Provided by the NASA Astrophysics Data System

1968ApJ...152...83E

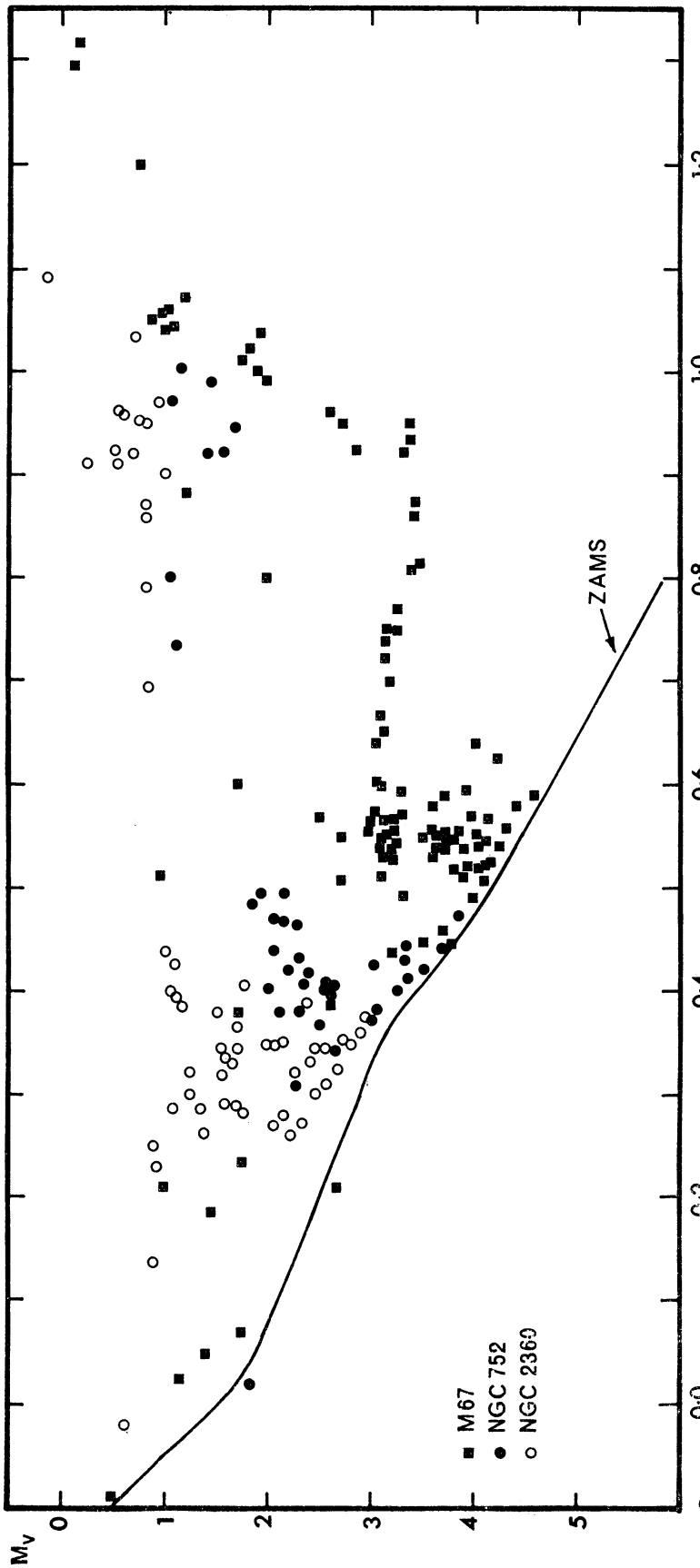


FIG. 5.—Composite ($M_v$,$C$) diagrams for NGC 2360, NGC 752, and M67. The color, $C$, represents $B - V$ corrected for reddening and blanketing effects. The zero-age main sequence is also shown.



© American Astronomical Society • Provided by the NASA Astrophysics Data System

1968ApJ...152...83E



The observed color-magnitude diagram for NGC 2360 is shown in Figure 3 where the continuous curve represents the zero-age main sequence (Eggen 1965) reddened by $E(B - V) = +0.07$ and corrected for $\delta(U - B) = +0.05$ and a distance modulus of $(m - M)_0$ of 10.3 mag for NGC 2360. Open circles represent single observations and squares, probable field stars. The color and magnitude of star No. 51 ($B - V = +0.21$) are slightly contaminated by a close companion some 2 mag fainter. The path traced in Figure 3 by the variation of star No. 98 is shown by a bar.

The ($U - B$, $B - V$) diagram for the cluster members in Figure 3 is shown in Figure 4. The relation for Hyades main-sequence stars (M.S.) and those for stars one and two magnitudes above the Hyades main sequence (Eggen 1966) are shown as continuous curves. The ultraviolet excess of the main-sequence stars redder than $B - V$ near 0.5 mag in NGC 2360 is clearly shown and the displacements of the bluer stars from the main sequence are, in general, consistent with their apparently lower gravities.

The main features of the color-luminosity array for NGC 2360 are (*a*) the small Hertzsprung gap; (*b*) the presence of one (star No. 100) and possibly two (star No. 51) "blue stragglers"; (*c*) a break-away from the main sequence near a color, $C$, corrected for reddening and blanketing, of +0.3 mag; and (*d*) a 0.2 mag break in the sequence of evolved stars near $M = +1.9$ mag. This last feature was previously noted in NGC 2477 at $M_v = +2.8$ mag (Eggen and Stoy 1961), NGC 752 at $M_v = +2.9$ mag (Eggen 1963), and M67 at $M_v = +3.4$ mag (Eggen and Sandage 1964). The correlation of this feature with other characteristics of the clusters will be discussed in detail in connection with NGC 188 (Eggen and Sandage 1968).

A composite ($M_v$,$C$) diagram for the members of M67 (*squares*), NGC 752 (*filled circles*), and NGC 2360 (*open circles*) is shown in Figure 5. The diagram is of interest in connection with the question of whether the blue stragglers in all three clusters and the "horizontal-branch" stars in M67 represent (*a*) objects in a post-giant evolutionary state or (*b*) late, pre-giant evolution. The fact that the bluest stragglers are represented by the zero-age main sequence would appear to favor alternative (*b*).

## REFERENCES

Becker, W. 1960, *Zs. f. Ap.*, **51**, 49.
———. 1968, *Pub. Univ. Basel* (in press).
Eggen, O. J. 1963, *Ap. J.*, **138**, 356.
———. 1965, *Ann. Rev. Astr. and Ap.*, **3**, 235.
———. 1966, *Roy. Obs. Bull.*, No. 120.
Eggen, O. J., and Sandage, A. R. 1964, *Ap. J.*, **140**, 130.
———. 1968, *ibid.* (in press).
Eggen, O. J., and Stoy, R. H. 1961, *Roy. Obs. Bull.*, No. 24.
Hiltner, W. A., 1959, *Ap. J. Suppl.*, No. 24.

Copyright 1968 The University of Chicago Printed in U S A.

© American Astronomical Society • Provided by the NASA Astrophysics Data System

1968ApJ...152...83E

© American Astronomical Society • Provided by the NASA Astrophysics Data System