Bull. Astr. Soc. India (1994) **22**, 291-302

# CCD photometry of galactic open star clusters—III. NGC 1931

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Received 1993 August 27, accepted 1993 November 12

**Abstract.** CCD photometric observations of young open cluster NGC 1931 in *UBVRI* passbands have been made down to 20.5 mag. The reddening across the cluster is found to be variable. The reddening varies from $E(B-V)_{min} = 0.55$ mag to $E(B-V)_{max} = 1.00$ mag. A distance of 2.17 kpc, an age of ~ $10^7$ yr and luminosity function for the cluster have also been derived. The luminosity function has been compared with the luminosity function of other young clusters.

*Key words* : open cluster—photometry

## 1. Introduction

The young open cluster NGC 1931 (C0528 + 342) ($l = 173°.9$, $b = +0°.28$) is situated in the spiral arm which is an extension of the Perseus arm (Moffat *et al.* 1979; Pandey & Mahra 1986). Moffat *et al.* (1979) have obtained photometric magnitudes of four stars in the cluster field. Pandey & Mahra (1986) have obtained the photoelectric magnitudes for 27 stars in the cluster region and discussed reddening across the cluster, its distance and age. Trumpler class I 3 p has been assigned to the cluster in the catalogue of Lynga (1987). The faint members of this poor cluster have not been studied before, but with the advent of charge couple devices (CCD) it is now possible to study such faint cluster members even with a moderate sized (~1-metre class) telescope.

The aim of the present study is to describe the *UBVRI* CCD photometric observations of the stars in the field of NGC 1931 and to compare the results with those obtained by Pandey & Mahra (1986). Since the cluster is a young one, present observations give us an opportunity to study the luminosity function (LF) and subsequently we expect to gain insight into the star formation process itself by comparing the luminosity function of NGC 1931 with similar young clusters.

## 2. Observations

The observations of NGC 1931 were carried out in the *U, B, V, R* and *I* passbands using the Photometrics CCD system having a 384 × 576 pixels Thomson chip, at f/13 Cassegrain

focus of the 104-cm reflector of the Uttar Pradesh State Observatory (UPSO) during December 1991, November 1992 and January 1993. In this set up the entire CCD chip covers a field of 2.0 × 3.0 sq arc-min of the sky. In order to improve the *S/N* ratio the observations were taken at 2 × 2 binning mode. The details of the present CCD system have also been described by Bhatt (1993) and Mohan *et al.* (1991). From Palomer charts we find that there are two nebulus clouds in the cluster region. Therefore, the cluster region was observed in two fields covering both the clouds in the North and South regions (figures 1a and 1b). Multiple exposures were taken with exposure time ranging from 5 seconds to 1800 seconds depending upon the presence of bright stars and filter used and the frames were coadded in order to achieve a total integration time of 60 minutes in *U*, 40 minutes in *B*, 20 minutes in *V* and 5 minutes each in *R* and *I* filters. The observing details are given in the table 1. A number of flats were also taken in each passband by observing the twilight sky. Landolt (1983) standard stars were also observed for calibration purposes.

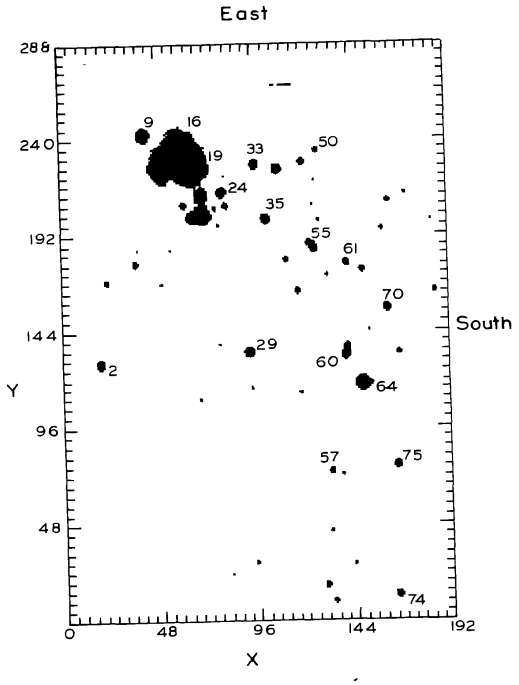


**Figure 1a.** Identification map for the North region of the cluster NGC 1931.

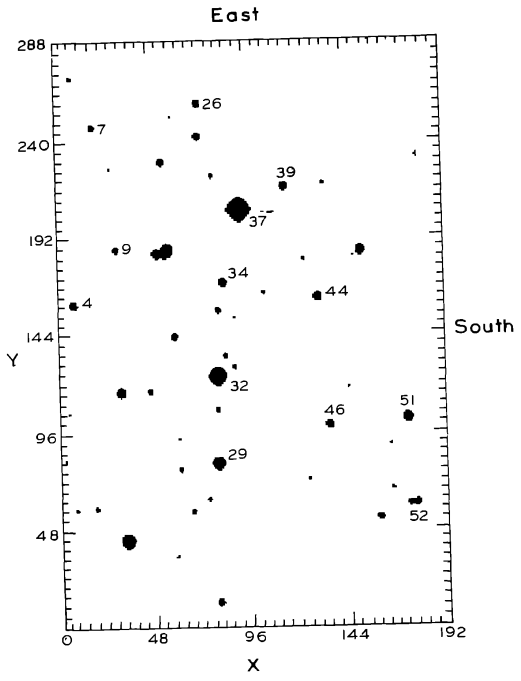


**Figure 1b.** Identification map for the South region of the cluster NGC 1931.

## 3. Data reduction

The observations have been reduced using the Micro Vax II system of UPSO. Clean images have been obtained using the ESO MIDAS software package. The cleaned frames in the same filters having similar exposure times were coadded. The photometry was carried out using the DAOPHOT profile-fitting software (Stetson 1987). The stellar point-spread-function (PSF) was evaluated from several uncontaminated stars present in each frame. For a few bright stars which were saturated in the long exposure frames, short exposure frames were used. The X and Y coordinates as well as photometric data of the stars measured in the North and South cluster fields are given in table 2.

**Table 1.** Details of observations

| Filter | North region | | | | South region | | | |
|---|---|---|---|---|---|---|---|---|
| | 2/3 Nov 92 | | 12/13 Jan. 93 | | 30/31 Dec. 91 | | 1/2 Nov. 92 | |
| | a | b | a | b | a | b | a | b |
| *U* | 2 | 1800 | 2 | 300 | 3 | 600 | 2 | 1800 |
| | 1 | 90 | | | 1 | 300 | 1 | 100 |
| *B* | 2 | 1200 | 2 | 120 | 2 | 600 | 2 | 1200 |
| | | | | | 1 | 300 | 1 | 60 |
| | | | | | 1 | 60 | | |
| *V* | 2 | 600 | 2 | 50 | 2 | 600 | 2 | 600 |
| | 1 | 15 | | | 1 | 300 | 1 | 20 |
| | | | | | 1 | 60 | | |
| *R* | 1 | 300 | 1 | 10 | 1 | 300 | 1 | 300 |
| | 1 | 10 | 1 | 12 | 1 | 15 | 1 | 5 |
| *I* | 1 | 300 | 2 | 15 | 1 | 300 | 1 | 300 |
| | 1 | 15 | | | 1 | 20 | 1 | 10 |

Note: Column a and b for each night show the number of frames observed and exposure time in seconds respectively.

**Table 2.** Magnitudes and colours of the stars in the field of NGC 1931

| Star ID | *X* | *Y* | $(U-B)$ | $(B-V)$ | *V* | $(R-I)$ | $(V-I)$ | Remark |
|---|---|---|---|---|---|---|---|---|
| North Region | | | | | | | | |
| 1 | 6.87 | 92 95 | * | 1.150 | 20 837 | 1.003 | 2 199 | |
| 2 | 16.42 | 124.72 | 1.067 | 1 585 | 15.981 | 0 996 | 2.025 | |
| 3 | 20.06 | 166.92 | * | 1 364 | 17.524 | 0.825 | 1.822 | m |
| 4 | 32.11 | 230 40 | * | 0.525 | 17.762 | 0.183 | 0.881 | |
| 5 | 34.72 | 176.49 | 0.426 | 0.746 | 16.423 | 0.501 | 1.011 | m |
| 6 | 35.73 | 183 55 | * | 1.612 | 18.374 | 0.897 | 1.575 | |
| 7 | 38.60 | 26 79 | * | 1.125 | 18.958 | 0.755 | 1.538 | |
| 8 | 38.61 | 98.18 | * | 1.606 | 19.929 | 0.704 | 1.680 | m |
| 9 | 39.50 | 244.03 | –0.098 | 0.620 | 13.971 | 0.518 | 0.837 | M |
| 10 | 48.17 | 166.00 | * | 1.347 | 19.157 | 1.178 | 2.236 | m |
| 11 | 48.53 | 222.99 | –0 393 | 0.481 | 13.019 | 0.487 | 0.948 | m |
| 12 | 51.58 | 208.57 | –0.484 | 0.705 | 18.105 | * | 1.046 | |
| 13 | 52.87 | 183.98 | * | 1.221 | 18 771 | 1.829 | 1.804 | m |
| 14 | 53.27 | 151.87 | * | 1.508 | 19.763 | 1.151 | 2.459 | m |
| 15 | 59.73 | 206.90 | * | 1 270 | 18.243 | 1.255 | 2.098 | m |
| 16 | 60 53 | 236 31 | –0 459 | 0.526 | 11 447 | 0.471 | 0.679 | M |
| 17 | 63.73 | 200.63 | –0.098 | 0.702 | 15 645 | 0.783 | 1.396 | m |

Continued

**Table 2.** Continued

| Star ID | X | Y | (U − B) | (B − V) | V | (R − I) | (V − I) | Remark |
|---|---|---|---|---|---|---|---|---|
| 18 | 66 00 | 79.09 | −0.837 | 1.349 | 19.049 | 0.784 | 1.607 | |
| 19 | 66 79 | 226.54 | −0.455 | 0.496 | 12.297 | 0 669 | 1 003 | M |
| 20 | 67.29 | 106.60 | * | 1.606 | 18 638 | 0.983 | 2 091 | m |
| 21 | 69.25 | 212 39 | 0 027 | 0.670 | 15.332 | 0.720 | 1 358 | m |
| 22 | 69 76 | 200 96 | −0.376 | 0 541 | 14.119 | 0.672 | 1 289 | m |
| 23 | 79.45 | 95.86 | * | 1.266 | 19.707 | 0.767 | 1 611 | |
| 24 | 79.68 | 213.62 | −0 074 | 0.569 | 15.631 | 0.543 | 1.070 | |
| 25 | 81.48 | 206.71 | −0.360 | 0.795 | 17.400 | 0.722 | 1 395 | |
| 26 | 82.49 | 15.76 | * | 1 435 | 18.445 | 0 751 | 1.628 | m |
| 27 | 85.39 | 89.11 | * | 1.306 | 20.706 | 0 940 | 1 966 | |
| 28 | 90 93 | 126.06 | * | 1.240 | 19.698 | 1 296 | 2.578 | |
| 29 | 92.75 | 131.11 | 0 479 | 1.118 | 14.971 | 0 736 | 1.476 | |
| 30 | 94.04 | 112.21 | * | 1 488 | 18.674 | 1 059 | 2.111 | m |
| 31 | 95 17 | 21.98 | * | 1.481 | 18 099 | 0.819 | 1.742 | m |
| 32 | 96 20 | 34 76 | * | 1.885 | 19.298 | 1.045 | 2.110 | |
| 33 | 96 34 | 228.30 | −0.049 | 0.457 | 14.984 | 0.476 | 0.919 | |
| 34 | 98.94 | 25.28 | * | 1.396 | 19 562 | 0.878 | 1 615 | m |
| 35 | 101.70 | 200 00 | −0.205 | 0.287 | 14.499 | 0.339 | 0.775 | |
| 36 | 101 88 | 165.54 | * | 1.217 | 19.300 | 1.009 | 2.065 | m |
| 37 | 102.99 | 113.13 | * | 1.585 | 19.276 | 1 006 | 2 077 | m |
| 38 | 103 93 | 139 21 | * | 0.977 | 19.527 | 0.743 | 1 601 | |
| 39 | 107.79 | 226.00 | * | 1.970 | 16.407 | 1.282 | 2 583 | |
| 40 | 112.13 | 178.69 | 0 430 | 1.228 | 17.428 | 0.800 | 1 721 | m |
| 41 | 117.76 | 162.58 | 0.223 | 0 843 | 16.811 | 0.605 | 1 278 | m |
| 42 | 118.63 | 148.84 | * | 0 850 | 19 415 | 0.890 | 1.710 | |
| 43 | 120.13 | 207.55 | * | 1.069 | 19.551 | 0.789 | 1 776 | |
| 44 | 120.60 | 229.63 | 0 618 | 1 207 | 17.006 | 0.921 | 1.714 | m |
| 45 | 123.45 | 22 40 | * | 1.741 | 19 216 | 0.988 | 2 007 | |
| 46 | 123 87 | 187.46 | 0.837 | 1.454 | 17.160 | 0.890 | 1.834 | M |
| 47 | 125.91 | 207.55 | * | 1.183 | 18.495 | 0.800 | 1 733 | m |
| 48 | 126 37 | 184.48 | 0.345 | 0.535 | 15.902 | 0 526 | 1.104 | M |
| 49 | 126 95 | 220.23 | 0.240 | 0.812 | 18.325 | 1.399 | 1 500 | |
| 50 | 128.14 | 235.68 | 0 155 | 0 760 | 16.905 | 0.594 | 1.055 | |
| 51 | 128.69 | 199.35 | * | 1.684 | 19.178 | 1.139 | 2.546 | m |
| 52 | 130.33 | 189.96 | * | 1.934 | 19.875 | 1.232 | 2.517 | |
| 53 | 130.75 | 10.60 | 0.032 | 0.828 | 16 250 | 0 432 | 0 949 | m |
| 54 | 132.96 | 171.04 | * | 1.444 | 18.633 | 1.039 | 2 093 | m |
| 55 | 133.16 | 175.16 | * | 1.162 | 19.094 | 0.845 | 1 583 | |
| 56 | 133.34 | 38.36 | * | 1.487 | 18.202 | 0 870 | 1.811 | m |

Continued

**Table 2.** Continued

| Star ID | $X$ | $Y$ | $(U-B)$ | $(B-V)$ | $V$ | $(R-I)$ | $(V-I)$ | Remark |
|---|---|---|---|---|---|---|---|---|
| 57 | 134.00 | 69.37 | 0.458 | 1.086 | 16.626 | 0.708 | 1.456 | m |
| 58 | 136.72 | 149.82 | * | 1.326 | 20.323 | 0.917 | 1 784 | |
| 59 | 139.64 | 67 79 | * | 1.727 | 18.509 | 0.986 | 1.947 | |
| 60 | 141.66 | 129.53 | 0 215 | 0 702 | 14.746 | 0.416 | 0.919 | M |
| 61 | 142.67 | 177 35 | 0.783 | 0.945 | 16.711 | 0.848 | 1 667 | M |
| 62 | 142.83 | 133 99 | 0.821 | 0.889 | 16.139 | 0.608 | 1 143 | M |
| 63 | 145.23 | 21.52 | * | 1.529 | 18.514 | 0.970 | 1.973 | m |
| 64 | 150.24 | 114 81 | –0.341 | 0.422 | 12.374 | 0 313 | 0 506 | M |
| 65 | 150.66 | 173 68 | 0.824 | 1 200 | 17 167 | 0.805 | 1 659 | M |
| 66 | 152.32 | 248 50 | * | 0.910 | 19.543 | 0 746 | 1 873 | |
| 67 | 153.75 | 142.38 | * | 1.289 | 18.414 | 0.792 | 1.583 | m |
| 68 | 159.25 | 173.99 | * | 1.718 | 19 566 | 1.313 | 2.397 | m |
| 69 | 160.99 | 195.08 | * | 1.655 | 18 905 | 1 195 | 2.523 | m |
| 70 | 163.43 | 154.01 | 0.441 | 0.939 | 15.840 | 0.617 | 1 340 | M |
| 71 | 164 21 | 209.57 | 0 585 | 1.038 | 17.477 | 0.712 | 1.541 | m |
| 72 | 165.04 | 199 77 | * | 1.414 | 20.317 | 1.325 | 2 424 | m |
| 73 | 165.27 | 54.98 | * | 0.936 | 18 871 | 0.448 | 1 457 | |
| 74 | 167.13 | 5 57 | 0 203 | 0.668 | 15 421 | 0.381 | 0 816 | m |
| 75 | 167.54 | 72.79 | 0 301 | 0 669 | 15.086 | 0 420 | 0.693 | M |
| 76 | 168 92 | 130 97 | 0 612 | 1.007 | 17 040 | 0.515 | 1.144 | m |
| 77 | 169.18 | 172.09 | * | 1.156 | 19.698 | 0.911 | 1.663 | |
| 78 | 172.93 | 213.71 | * | 1.044 | 18 117 | 0.860 | 1 695 | m |
| 79 | 177.78 | 194.28 | * | 1.285 | 19.587 | 0.834 | 1.758 | |
| 80 | 182.67 | 121.36 | * | 1.825 | 19.966 | 1.073 | 2.087 | m |
| 81 | 185.83 | 199 52 | * | 0 931 | 18 443 | 0.703 | 1 527 | |
| 82 | 187.60 | 163 09 | * | 1.168 | 17 608 | 0.806 | 1 747 | m |
| 83 | 187.65 | 169 41 | * | 1.251 | 19.725 | 1.285 | 2.575 | m |
| 84 | 188.34 | 179.93 | * | 1 348 | 20 077 | 1 305 | 2.660 | m |
| South region | | | | | | | | |
| 1 | 2 31 | 85.38 | 0 268 | 0.759 | 18.023 | 0.465 | 0 845 | |
| 2 | 4 51 | 109.94 | 0.162 | 0.477 | 18.243 | 0.646 | 0 938 | |
| 3 | 7.24 | 60.16 | –1.361 | 1.434 | 18.547 | 0.823 | 1.605 | |
| 4 | 7.92 | 166.33 | 0 376 | 0.725 | 15.807 | 0 511 | 0.854 | m |
| 5 | 9 13 | 283.56 | * | 2.005 | 18.650 | 0.971 | 1.825 | m |
| 6 | 17 17 | 60.78 | * | 1 255 | 18.252 | 0.857 | 1.586 | m |
| 7 | 19.84 | 257 88 | * | 1.622 | 17.698 | 0.962 | 1 768 | |
| 8 | 27.86 | 236 62 | * | 1.449 | 19.397 | 1 215 | 2.217 | m |
| 9 | 30.28 | 194.79 | * | 2.094 | 18.140 | 1 259 | 2.345 | m |
| 10 | 31 11 | 120.75 | 0.369 | 0.991 | 15.225 | 0.642 | 1 139 | M |
| 11 | 32.23 | 191.58 | * | 1.602 | 19.466 | 0.953 | 1.710 | m |

Continued

**Table 2.** Continued

| Star ID | $X$ | $Y$ | $(U-B)$ | $(B-V)$ | $V$ | $(R-I)$ | $(V-I)$ | Remark |
|---|---|---|---|---|---|---|---|---|
| 12 | 32.49 | 43.91 | 0.229 | 0.498 | 13.056 | 0.407 | 0 660 | m |
| 13 | 42.05 | 64.30 | * | 1.728 | 20.233 | 0.799 | 1.447 | m |
| 14 | 44.09 | 191.24 | * | 1.349 | 19.582 | 0.860 | 1 672 | m |
| 15 | 46.20 | 121.13 | 0.352 | 1.087 | 17.364 | 0.662 | 1 227 | m |
| 16 | 46 21 | 55.23 | * | 0.849 | 19 305 | 0.924 | 1.533 | |
| 17 | 51.05 | 192.36 | 0 354 | 0.932 | 15.428 | 0.649 | 1.144 | M |
| 18 | 54.54 | 239 79 | * | 1.648 | 17.422 | 1 001 | 1 908 | |
| 19 | 56.48 | 194.33 | –0.318 | 0.427 | 13.477 | 0.305 | 0 531 | m |
| 20 | 57.67 | 35.21 | * | 1.219 | 18 323 | 0.698 | 1.289 | m |
| 21 | 59.18 | 149.31 | 0.656 | 1.115 | 16.527 | 0.606 | 1.162 | M |
| 22 | 60.61 | 80.33 | * | 1.522 | 18.303 | 0.974 | 1.856 | m |
| 23 | 60.76 | 96.08 | * | 1.436 | 18.850 | 0.923 | 1.708 | m |
| 24 | 66.70 | 58.60 | * | 1.647 | 18.276 | 1.029 | 1.951 | m |
| 25 | 73.65 | 252.37 | 0.711 | 0.947 | 16.613 | 0.728 | 1.277 | m |
| 26 | 73.92 | 269.73 | * | 1 251 | 16.444 | 0.644 | 1.348 | m |
| 27 | 75 00 | 64.99 | * | 0.972 | 19.467 | 1.430 | 2.614 | |
| 28 | 79.07 | 11.39 | * | 2.085 | 17.332 | 1.203 | 2.268 | m |
| 29 | 79.96 | 83.54 | 0.464 | 0.694 | 13.779 | 0.551 | 0.926 | m |
| 30 | 80 28 | 232.08 | * | 1.238 | 18.664 | 1.042 | 1.880 | m |
| 31 | 80.36 | 111 11 | 0.233 | 0.883 | 17.680 | 0.701 | 1.226 | |
| 32 | 80.81 | 128.82 | –0.378 | 0.359 | 11.937 | 0.263 | 0.480 | M |
| 33 | 81.75 | 162.65 | * | 1 540 | 17.931 | 0.970 | 1.809 | |
| 34 | 84.65 | 176 80 | 0.325 | 0 895 | 15.528 | 0 543 | 1.003 | M |
| 35 | 85.09 | 139.10 | * | 1.239 | 18.560 | 1 069 | 2.010 | m |
| 36 | 89.67 | 133.27 | * | 0.872 | 17.847 | 0.742 | 1.257 | |
| 37 | 93.65 | 214.25 | –0.486 | 0.300 | 11.116 | 0.286 | 0.529 | M |
| 38 | 105.55 | 171.51 | * | 1.512 | 19.872 | 1.490 | 2.835 | m |
| 39 | 117.21 | 226.25 | 0.353 | 0.934 | 15.940 | 0.575 | 1.139 | M |
| 40 | 118 35 | 108 50 | * | 1.405 | 19.603 | 1.038 | 1 714 | m |
| 41 | 126 60 | 188.54 | * | 0.955 | 18.882 | 0.990 | 1 737 | |
| 42 | 126.73 | 74.36 | * | 1.392 | 18.582 | 0.867 | 1.570 | m |
| 43 | 131 29 | 116 60 | * | 1.523 | 19 610 | 1 104 | 1.941 | m |
| 44 | 133.19 | 168.59 | 0.299 | 0.446 | 15.017 | 0 402 | 0.663 | |
| 45 | 137.19 | 227.47 | * | 1.172 | 18.416 | 0 735 | 1.504 | m |
| 46 | 137.70 | 102.37 | 1.124 | 1.503 | 16.784 | 0 902 | 1.689 | |
| 47 | 155.44 | 192.36 | 0.121 | 0.425 | 14.891 | 0.413 | 0.748 | |
| 48 | 162.07 | 63.64 | * | 1.622 | 19.716 | 1.168 | 2.178 | m |
| 49 | 162.56 | 54.06 | 0.669 | 1.145 | 16.533 | 0.605 | 1.162 | M |
| 50 | 169.17 | 69.29 | * | 1.749 | 19.115 | 1 241 | 2.276 | |
| 51 | 177.64 | 105.25 | 0.377 | 0.510 | 14.414 | 0.399 | 0.657 | M |
| 52 | 181.42 | 61.15 | –0.214 | 1.926 | 16.674 | 0.685 | 1.273 | |

Notes. *—Observations not available.; m and M—Cluster members (see text)

The cluster fields are observed on different nights. The photometric errors ($\pm\sigma$) of observations are found to be 0.025, 0.030, 0.033, 0.030, 0.019 and 0.023 mag in $V$, $(B-V)$, $(U-B)$, $(V-R)$, $(R-I)$ and $(V-I)$ respectively. The data have also been compared with the UBV photoelectric photometry of stars by Pandey & Mahra (1986). The mean difference between the two observations and standard deviations ($\sigma$) are found to be $-0.015 \pm 0.030$, $-0.007 \pm 0.023$ and $0.025 \pm 0.024$ mag in $V$, $(B-V)$ and $(U-B)$ respectively for the stars having $V < 15.0$ mag.

## 4. Interstellar extinction

To estimate the interstellar extinction in the cluster region, we have used the $(U-B, B-V)$ diagram shown in figure 2. The intrinsic zero-age-main-sequence (ZAMS) given by Schmidt-Kaler (1982) was fitted to the main-sequence stars of spectral type earlier than A0 in the cluster field. The minimum and maximum reddening values estimated by sliding fit method comes out to be $E(B-V)_{min} = 0.55$ mag and $E(B-V)_{max} = 1.00$ mag. The slope $E(U-B)/E(B-V)$ has been taken to be equal to 0.72 (Johnson & Morgan 1953). The observed dispersion in the $E(B-V)$ values cannot be explained due to errors in the data and other parameters such as rotation, duplicity etc. which can produce a maximum variation of 0.11 mag in $E(B-V)$ for MS stars (cf. Burki 1975). Therefore, we conclude that the reddening is non-uniform across the cluster field. The interstellar extinction for individual MS stars has

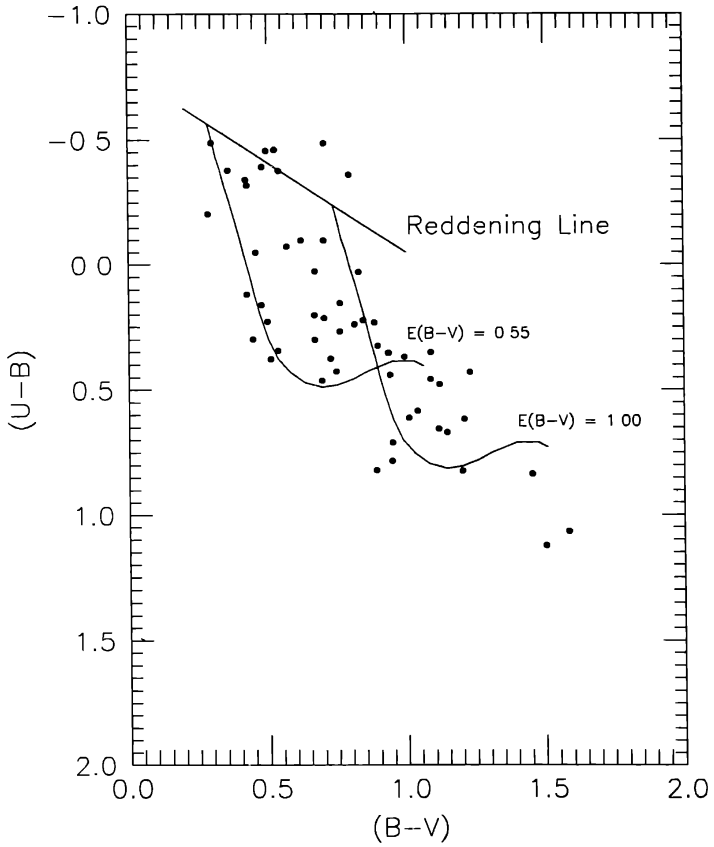


**Figure 2.** The colour-colour diagram for the stars in the cluster region.

also been derived using the Q-method (Johnson & Morgan 1953). The maximum and minimum values obtained by Pandey & Mahra (1986) are 1.00 and 0.47 mag respectively and which are in close agreement with those obtained in the present study.

## 5. Distance to the cluster

The colour-magnitude diagrams ($V$, $B - V$) and ($V$, $V - I$) are plotted in figures 3 and 4 respectively. A broad but well defined cluster MS is clearly visible up to 20.0 mag. To estimate the distance to the cluster we have fitted the ZAMS given by Schmidt-Kaler (1982) in the ($V$, $B - V$) colour-magnitude diagram (CMD) and the ZAMS given by Walker (1985) in the ($V$, $V - I$) CMD) on the bluest envelope of data points in figures 3 and 4 respectively and a distance modulus $(m - M)_v = 14.1$ mag has been obtained for the cluster. We have adopted the relation $E(V - I) = 1.25 \times E(B - V)$ (Walker 1985) to estimate distance modulus from figure 4 and it seems that the slope of 1.25 is valid for this cluster. However, different slopes have been obtained for other clusters, e.g. Bhatt *et al.* (1993) have found a slope of 1.36 for the open cluster NGC 7419 and Alcala & Ferro (1988) have obtained a value of 1.68 for NGC 7790.

Using the mean $E(B - V) = 0.78$ mag for the cluster, the most acceptable value of $R = 3.1$, $A_v = 3.1 \times 0.78$, the true distance modulus $(m - M)_0$ comes out to be 11.68 mag, which corresponds to a distance of 2.17 kpc. The same value for the distance was obtained by Pandey & Mahra (1986), but in the present work we have confirmed this distance from ($V$, $V - I$) CMD also.

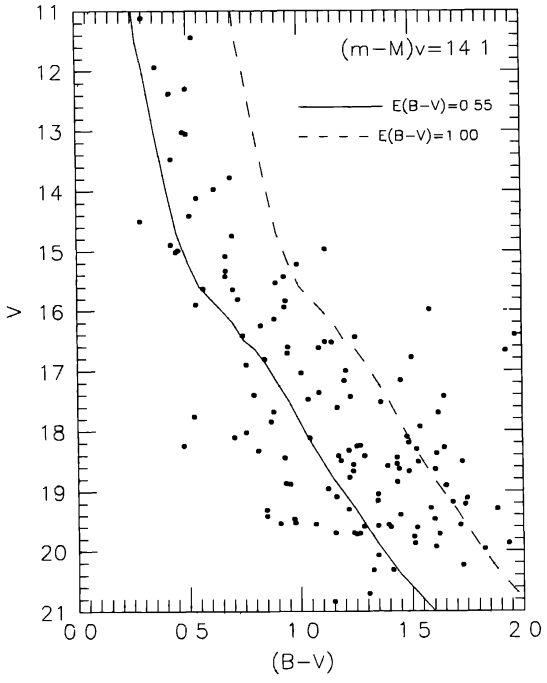


**Figure 3.** The colour-magnitude diagram ($V$, $B - V$) for all stars measured in the North and South regions of NGC 1931. The full line and dashed line represent the ZAMS given by Schmidt-Kaler (1982) for minimum and maximum reddening values respetively.

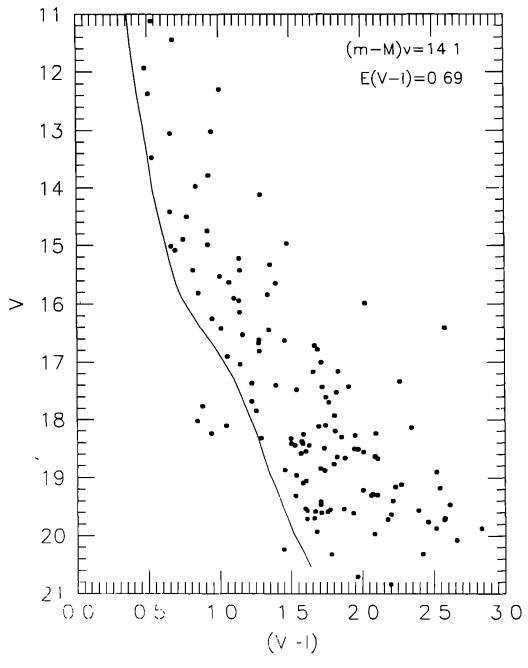


**Figure 4.** The colour-magnitude diagram ($V$, $V - I$) for all stars measured in the north and South regions of NGC 1931. The full line represents the ZAMS given by Walker (1985).

## 6. Membership

Since the proper motion and spectroscopic studies are not available for the stars in the cluster region, the discrimination of non-members from the observed sample has been carried out using the photometric and statistical criteria. We have considered only those stars as members which lie in between blue and the red envelopes of the MS, obtained by shifting the MS for the maximum value of $E(B-V)$ in the $(V, B-V)$ CMD. The stars found inside this belt are designated as 'm' in table 2. The unreddened colour-magnitude diagrams, $(V_0, (B-V)_0)$ and $(V_0, (U-B)_0)$ are plotted in figures 5 and 6 respectively. The main-sequence is drawn and also shifted to 0.75 mag in $V_0$ with dashed lines in both the CMDs to account for the possible widening of the MS due to binary stars etc. The stars found in this belt are cluster members with a greater probability. These stars are designated as 'M' in table 2.

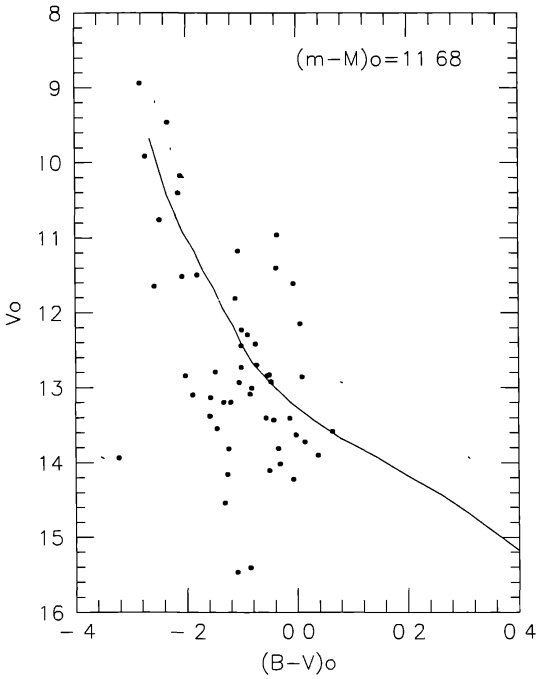


**Figure 5.** The $(V_0, (B-V)_0)$ diagram of NGC 1931.

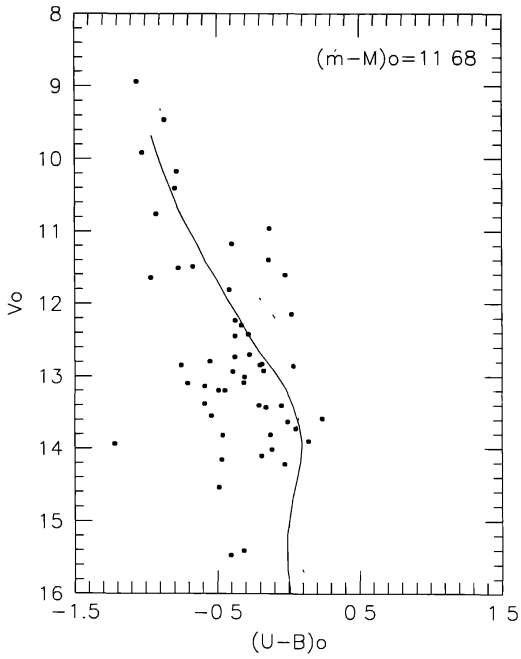


**Figure 6.** The $(V_0, (U-B)_0)$ diagram of NGC 1931

## 7. Age of the cluster

To estimate the age of the cluster we have used the observations of those stars for which individual reddening could be obtained. The $(M_v, (B-V)_0)$ and $(M_v, (U-B)_0)$ diagrams for cluster member stars are shown in figures 7 and 8 respectively. The age of the post-main-sequence stars has been estimated using the empirical isochrones given by Mermilliod (1981). From the $(M_v, (B-V)_0)$ and $(M_v, (U-B)_0)$ diagrams it is inferred that the cluster lies between the ages of NGC 6231 and NGC 884 groups. The age of the cluster NGC 6231 and NGC 884 arc $0.60 \times 10^7$ yr and $1.4 \times 10^7$ yr respectively (cf. Maeder & Maynet 1991). The colours of stars at blue turn-off point (in the CMD of NGC 1931) suggest an age ~ $10^7$ yr (cf. Maeder & Maynet 1991).

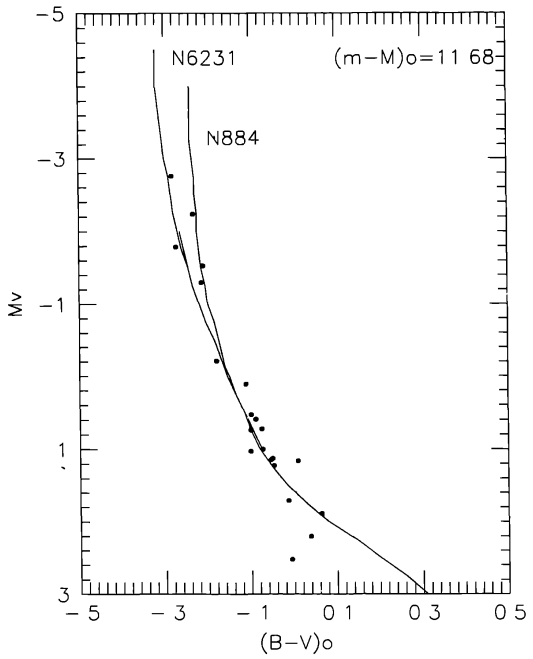


**Figure 7.** The $(M_v, (B - V)_0)$ diagram of the member stars in NGC 1931.

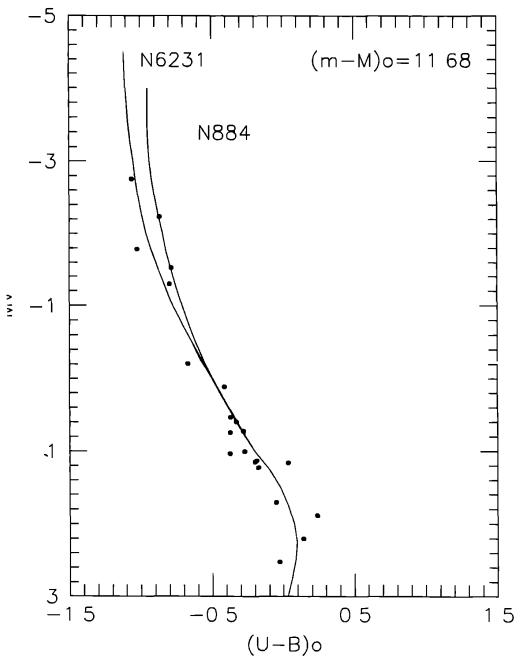


**Figure 8.** The $(M_v, (U - B)_0)$ diagram of the member stars in NGC 1931.

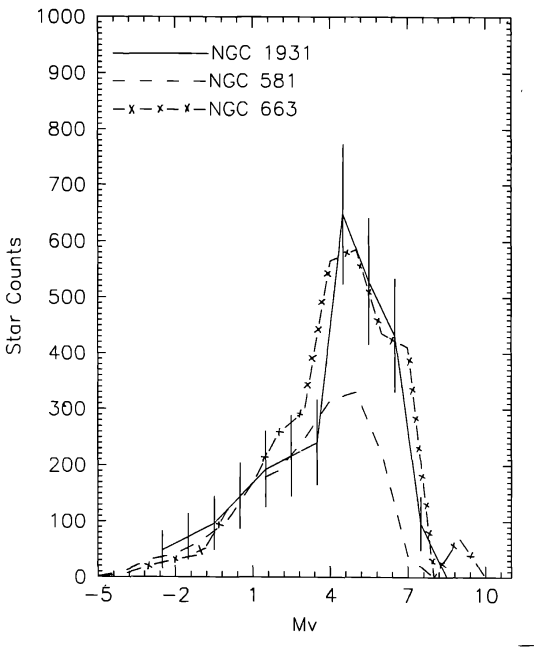


**Figure 9.** The luminosity function of the cluster stars in NGC 1931. The error bars corresponding to $\sqrt{N}$ are also shown in the figure.

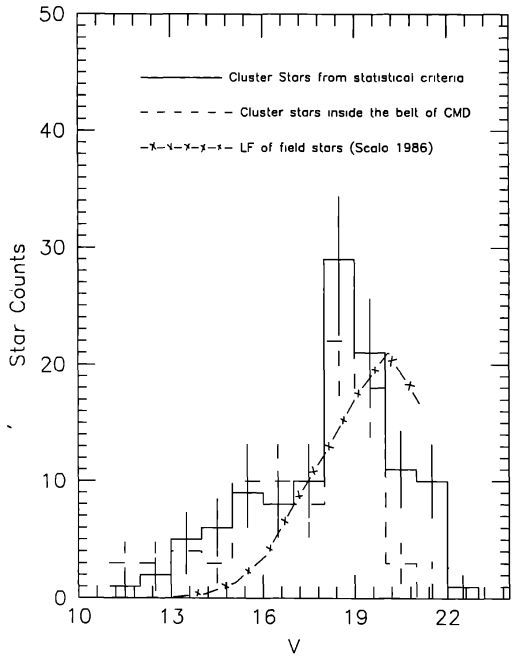


**Figure 10.** The luminosity distribution of the stars in NGC 1931. The error bars corresponding to $\sqrt{N}$ are also shown in the figure.

## 8. Luminosity function

We have also observed two field regions located at ~ 30 arc-minute towards East and South directions from the cluster region to estimate the approximate number of field stars present in the cluster region. It is assumed that the distribution of the field stars in the nearby field regions is same as the distribution of field stars in the cluster field. The cluster luminisity function (LF) is then obtained by subtracting the contribution of field stars in each magnitude bin. The luminosity function is shown in figure 9 and a comparison has been made with the LFs of the other young clusters. The data for the clusters NGC 581 and NGC 663 have been taken from Phelps & Janes (1991a, 1991b) and the number of stars were normalized at $M_v$ = 1.0 mag. The cluster luminosity functions agree very well towards the higher mass end ($M_v$ < 4.0 mag). We believe that $V$ = 18.0 mag represents a limit where our photometry is reasonably complete as in the case of NGC 581 and NGC 663. Towards the fainter end the LF of NGC 1931 agrees with that of NGC 581. The distance modulus of NGC 581 is 0.5 mag less than that of NGC 1931. The LF of NGC 1931 is quite different from that of field stars given by Scalo (1986). The LF has also been obtained for the stars which lie in between the blue and red envelopes of MS in the ($V$, $B - V$) CMD and a comparison has been made with the LF obtained using the statistical criterion and it is found that both the LFs agree fairly well (figure 10). Thus, it seems that the stars which lie between the two envelopes can be taken as possible members with less uncertainty.

## 9. Conclusions

The CCD photometry of the cluster NGC 1931 in *UBVRI* photometric passbands down to 20.5 mag indicates a well defined MS of the cluster and a true distance modulus of 11.68 mag corresponding to a distnace of 2.17 kpc has been obtained for the cluster. The age of the cluster is estimated to be ~ 10 Myr. The reddening in the cluster region is found to be variable having $\Delta E(B - V)$ = 0.45 mag. The LF of NGC 1931 has been compared with the LFs of the two young open clusters NGC 581 and NGC 663 and it is found that LF of NGC 1931 agrees fairly well with the LFs of NGC 581 and NGC 663 towards the higher mass end, however, the LF of field stars given by Scalo (1986) is significantly different.

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