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A SURVEY OF EXTREMELY RED STARS IN THE ORION REGION WITH 40/70/120 cm SHMIDT TELESCOPE

By

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ABSTRACT

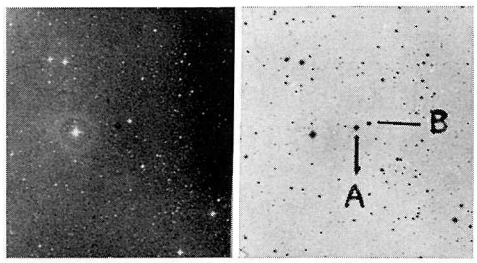
The Orion region was surveied in red and near infrared region with the 40/70/120 cm Schmidt telescope. By means of the composite photograph, fifty-five extremely red stars redder than $V-R=1.85$ were detected. One of them was identified to an infrared source IRC00085 whose optical counterpart had not been known precisely.

For a first step of a systematic survey of extremely red stars with the 40/70/120-cm Shmidt telescope (Imagawa, Kawai, Tsujimura, Ohtani, and Hirata 1976), we have examined a region around the Orion Neubla. The method of Chavira (1967), i.e., the comparison of stellar images on plates taken in red wavelength region and in infrared region, was employed. By this method, fainter stars can be sought than by means of objective prism spectra (Ackermenn 1970), and also the position of star can be determined more precisely.

Four plates were taken on 3 February in 1976 with exposures 30 and 60 minutes both for red and infrared regions. The adopted combinations of photographic emulsion and filter are Kodak $103a-E$ with Fuji-SC58 for red and IN with SC68 for infrared. This system yields effective wavelengths of 6300A and 7090A with the respective bandwidths of 800A and of 2000A. The IN plates were sensitized by bathing in cool water before exposures. In the development of the plates, some inhomogenieties appeared accidentally at small area of the plates.

For ease of detection of extremely red stars, we constructed a composite photograph from the IN plate of the shoter exposure and the $103a-E$ of the longer exposure. On this photograph, stars brighter in the infrared than in the red appear darker than the sky level, as seen in Figure 1. Apart from the region of the plate inhomogeniety, forty-two 'dark stars' were picked up as the candidates of 'extremely red stars' within the sky field illustrated in Figure 2.

The limit of the present survey in stellar magnitude and color can be estimated from comparison of our plates with Andrews' *UBVR* survey (1974), which overlpaps the central part of our field (Figure 2) and is deeper than the present observation. The limiting magnitude in R was found to be 15.2 for the red plate and 14.1 for the infrared. In Andrews' field, there are located ten 'dark stars', among which minimum of $V-R$ is 1.85 magnitude. Therefore, it can be safely concluded that all stars picked up are so extremely red as to be in the class of so-called infrared star.



(*a*) (*b*)

Fig. 1. The finding chart of an infrared star IRC00085. (*a*) is the composite photograph (103a-E minus IN), and (*b*) is the reproduction of the IN plate. The optical counterpart of IRC00085, found in the present work, is designated by letter A, and the star B is BD-04°1233 to which the infrared source was falsely identified in the IRC catalogue. Scale is 96″.1 per millimeter. North is top and east to the left.

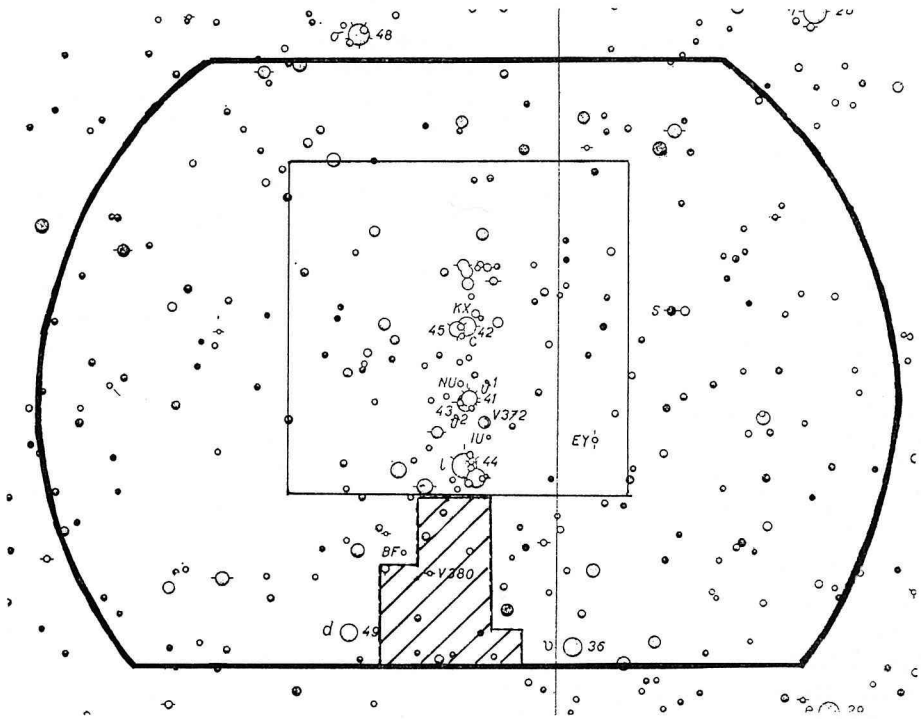


Fig. 2. The sky field of the present survey drawn on the Atlas Eclipticalis (Bečvař 1958). The cutouts of north and south parts from the circular fied are due to lack of filters with the larger aperture. Central square is the field surveied by Andrews (1974). The hatched area is affected by inhomogeniety in the photographic processing.

The positions of these stars were determined within accuracies of 0^{s}.07 in right ascension and 0″.5 in declination by Stephenson's method (1974) which was developed specially for classical Schmidt plates. The reference stars were selected from the Smithonian Astrophysical Observatory Star Catalogue.

For the 'extremely red stars' outside the field surveied by Andrews, magnitudes

Table 1. Catalogue of extremely red stars

Stars with asterisk in the first column are located in the region of the photographic inhomogeniety (the hatched area in Figure 2) and are selected only with the criterion that $B-V$ is larger than 1.5 on the Palomar Sky Survey Prints (PSSP). Magnitudes B and colors $B-V$ with parenthesis in the fourth and fifth columns are from Andrews (1974). The notanions for the identification are following; A: Andrews (1974), D: Lee et al. (1947), IRC: Neugebauer and Leighton (1969), P: Prenago (1954).

The stars Nos. 37 and 39 are detected only on the red print of the PSSP, and No. 49 can not find both on the blue and red prints. The star No. 50 seems to have a large proper motion from the comparison between positions of our plates and of the PSSP.

Nos.	α_{1950}	δ_{1950}	B	$B-V$	Identification
	h m s	° ′ ″	m	m	
1	5 20 24.1	−6 28 29	11.0	2.2	
2	20 36.6	−6 33 33	14.0	1.9	
3	20 52.2	−4 37 00	11.6	2.9	IRC 00071
4	22 2.1	−6 11 30	11.4	3.3	IRC-10091
5	24 3.5	−6 26 40	12.0	2.2	
6	24 7.2	−3 12 57	12.8	2.1	
7	24 40.0	−6 58 18	13.0	1.6	
8	24 47.8	−6 56 25	12.8	1.7	
9	25 59.3	−3 4 6	14.4	2.3	
10	26 27.4	−6 8 28	19.0	2.8	P 5 (var)
11	26 32.4	−4 43 52	10.8	5.0	IRC 00074, P 18 (var)
12	26 38.4	−7 2 40	12.6	2.2	
13	28 31.5	−3 25 37	15.0	2.6	
14	28 51.2	−5 3 27	(16.4)	(2.4)	A 313
15	29 27.5	−3 55 24	(13.3)	(2.2)	A 671
16	30 1.6	−7 16 19	12.4	1.5	
17	30 15.0	−3 52 34	(15.8)	(3.0)	A 935
18	30 33.2	−6 9 5	14.4	2.4	A 976, P 1072 (var)
19	30 34.0	−6 51 50	12.4	1.7	P 1081
20	31 35.2	−4 40 32	19.0	3.9	A 1332
21	31 46.9	−6 44 58	14.0	2.6	P 1398
22	31 47.6	−5 48 44	16.8	3.2	P 1397
23*	32 9.0	−7 21 53	13.0	2.0	
24	32 14.3	−3 10 34	14.6	1.8	
25	32 34.7	−3 58 20	(15.9)	(2.0)	A 1803
26*	32 34.9	−7 11 45	15.4	2.0	
27*	32 35.3	−6 33 28	16.2	2.0	
28*	32 39.0	−7 12 56	13.2	2.4	
29*	32 53.0	−7 10 36	12.6	2.4	
30*	33 7.4	−6 53 19	14.6	2.2	P 2126
31*	33 20.3	−6 54 29	14.4	1.9	P 2239
32	33 23.0	−5 11 20	18.2	3.6	
33*	33 37.4	−7 7 36	15.6	2.3	
34*	34 16.8	−7 22 22	16.2	3.2	
35	34 46.0	−6 53 42	16.8	2.7	
36*	34 50.4	−7 16 47	18.6	3.1	
37*	35 2.0	−6 48 25	≧20.2	V≧16.6	
38	35 3.0	−6 16 31	13.8	2.8	P 2556
39*	35 5.0	−7 17 44	≧20.2	V≧16.6	
40	35 18.6	−3 9 31	12.8	2.6	D 1214 (M4)
41	35 51.6	−5 59 13	18.0	3.0	A 2885
42	37 13.9	−6 8 58	16.6	2.6	A 3658

Table 1. (Continued)

Nos.	α_{1950}	δ_{1950}	B	$B-V$	Identification
	h m s	° ′ ″	m	m	
43	5 37 29.6	−7 9 44	15.0	1.7	
44	37 35.8	−6 58 44	17.4	3.1	IRC 00074
45	38 0.9	−5 50 45	17.0	2.0	A 3918
46	38 24.1	−5 32 0	(16.4)	(2.6)	A 3938, P 2975
47	38 46.2	−3 18 18	14.6	2.7	
48	39 4.7	−4 9 21	16.0	2.9	IRC 00082
49	39 33.1	−6 5 12	≥20.2	—	
50	39 45.5	−5 29 42	17.8	2.9	large proper motion ~3″/year
51	40 30.6	−7 19 58	15.4	1.6	
52	42 22.7	−6 2 50	13.8	2.6	
53	42 57.5	−4 15 43	13.6	3.1	IRC 00085
54	43 0.7	−7 22 35	15.4	2.4	
55	43 48.4	−6 4 20	14.6	2.9	

B and V were estimated from the diameters measured on the Palomar Sky Survey Prints following the method of Takahashi and Huruhata (1961) or Dorschner, Gürtler, Schielicke, and Schmidt (1966). For the photometric standards, suitable stars were selected from the star catalogue of Andrews. The B magnitudes thus determined are accurate with 0.5 magnitude, while the V magnitudes are somewhat less accurate than B's. Table 1 gives the star position toegther with B and $B-V$.

As to the field affected by the plate inhomogeniety mentioned above, there can be seen about forty 'dark stars' on the composite photograph. The astrometries and photometries were performed also for these stars. Among them, thirteen were found to be redder than the bluest stars ($B-V=1.5$) among forty-two stars previously picked up. In Table 1, those thirteen stars are also listed with asterisks in the first column.

In order to identify the all fifty-five stars to known infrared sources, the star positions were compared with those of IRC sources (Neugebauer and Leighton 1969) and of CRL sources (Walker and Price 1975). As the result, four of five IRC sources in our field were identified. The residual one is the Orion Nebula, which is bright in two micron region but not 'extremely red'. Regarding to the CRL sources, whthin the field there exist four more sources other than the IRC sources stated above. However, none of them could be idnetified, since they are embedded in bright nebulosities. We also tried identifications to the Dearborn faint red stars (Lee, Baldwin, Bartlett, and Gore 1947) and to the stars in Parenago's catalogue (1954). The results are given in the last column of Table 1.

Finally, it should be mentioned to the identification of IRC00085. This source is identified to BD-04°1233 ($V=9.00$, F5) in the IRC catalogue. However, the deviation of the position of the IRC source from that of the star is large (9^s in right ascension and 0′.8 in declination), and is near the limit of the criterion of the IRC identification. Later, in the work of the identification of IRC sources to the Dearborn stars, Grasdalen and Gaustad (1971) rejected the IRC identification of IRC 00085, and listed it as one of unidentified sources. Further, this source was found to show the spectral type of M4 or M8 in two spectral surveys of IRC sources (Vogt 1973; Hansen and Blanco 1975). These circumstances strongly suggest the mis-

identification of the IRC catalogue. In the present work, a bright extremely red star (No. 53 in Table 1) was found to the southeast of BD-4°1233, and a very good agreement was obtained between the positions of the extremely red star and of IRC00085. Also, one can see the identification to be unique from the inspection of Figure 1.

In the next winter, a spectral study of these extremely red stars by means of objective prism spectra will be performed, and the nature of the individual object may be disclosed.

The computation of the star positions was carried out by Facom 230–75 of the Data Processing Center of the Kyoto University.

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