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Citation

Genderen, A. M. van, Bijleveld, W., & Groningen, E. van. (1984). VBLUW photometry of the association SCO OB1 (containing the open cluster NGC 6231) - A discussion on the evolutionary status of the hypergiant Zeta(1) SCO (B1Ia+). *Astronomy And Astrophysics Supplement Series*, 58, 537-548. Retrieved from <https://hdl.handle.net/1887/7027>

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Astron. Astrophys. Suppl. Ser. **58**, 537-548 (1984)

***VBLUW* photometry of the association Sco OB1 (containing the open cluster NGC 6231). A discussion on the evolutionary status of the hypergiant ζ^1 Sco (B1Ia⁺)**

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Received March 22, accepted June 26, 1984

Summary. — *VBLUW* photometry of nearly 190 stars in the very young association Sco OB1, including the cluster NGC 6231, is presented and discussed. Nearly 60 stars in this sample appear to be presumably foreground objects. Temperature and surface gravity are determined with the aid of theoretical colours. Individual reddenings are also obtained. The distance modulus $(m - M)_0 = 11.00 \pm 0.25$ is similar to the value found by Shobbrook (1983). It appears that the reddening is not uniformly distributed across the association ($\sim 2^\circ \times 1^\circ$), but that areas of low and high reddening, varying from $E(B-V)_r = 0.35$ up to 0.67, can be distinguished. Practically all reddening is caused by dust in the local spiral arm up to a distance of at most 700 pc from the Sun. The Sagittarius-Carina arm where Sco OB1 is situated is practically transparent over a distance of ~ 0.5 kpc. The kinematical age of $\sim 10^6$ yr determined by Braes (1967b) is considering the uncertainties in reasonable agreement with the average evolutionary age of $\sim (3.6 \pm 0.6) \cdot 10^6$ yr of the 12 brightest stars, using the evolutionary tracks of Maeder (1981a,b). The evolutionary status of the hypergiant ζ^1 Sco (B1Ia⁺) is discussed.

Key words : association — open cluster — photometry — supergiant.

1. Introduction.

The very young association Sco OB1 (which contains the open cluster NGC 6231 = C 1650-417) with a kinematical age of $\sim 10^6$ yr (Braes, 1967b), is situated in the Sagittarius-Carina spiral arm. (A part of the association is also called Trumpler 24.) Braes (1967a, b) studied the stellar complex astrometrically and photometrically (*VBLUW* system). Walraven and Walraven (1960) observed nearly 60 stars of the association in the same photometric system.

The association and its surrounding are shown on plate 1 of Braes' first paper and schematically sketched in our figure 3. The association is rich in high luminosity OB type stars, amongst others 12 supergiants including the hypergiants (= super-supergiants) ζ^1 Sco (Braes No. 139), one of the brightest stars in our galaxy, and HD 152424 (Braes No. 162), both with an early B type spectrum and with a luminosity class Ia⁺. The NE contains the HII region IC 4628 and a possible supernova remnant close to the star HDE 322417 (Braes No. 314) (Braes and Hovenier, 1966).

A large amount of literature has appeared on this star group, most of which deals with photometric problems of which the different aspects will be compared with the results discussed here. This paper describes new *VBLUW* photometry of in total 189 stars of which 102 are in common with Braes. The visual brightness ranges from 4.8 (= ζ^1 Sco) up to 11.8. Nearly 60 of them are probably non-members.

The aim was to find temperatures and gravities with the aid of a theoretical two-colour diagram, individual reddenings, the distribution of the reddening across the whole association and the distance modulus. The evolutionary status of ζ^1 Sco is discussed and the evolutionary age of the association is determined.

2. The observations and reductions.

The observations were made with the *VBLUW* photometer of Walraven, attached to the 90-cm lightcollector of the former Leiden Southern Station at the SAAO annex in South Africa in 1976 and 1977. A description of the photometer and the photometric system has been given by Walraven and Walraven (1960), Rijn *et al.* (1969) and Lub and Pel (1977).

Nearly 190 stars were measured relative to the substandard HD 151515 (Br. No. 92) and to a number of standard stars. More than 110 stars were measured twice. Integration times of 1-2 min and a diaphragm aperture of 23" were employed. Corrections for differential extinction were applied. The standard deviations of the brightness and colours of the substandard, which was measured frequently, amount to ± 0.004 in log intensity scale. Those for the other stars were determined with the aid of the stars measured twice and amount to on the average ± 0.004 in V , ± 0.002 in $V-B$, ± 0.004 in $B-U$, ± 0.010 in $U-W$ and ± 0.003 in $B-L$. For the brightest stars they will be smaller, for the fainter ones somewhat higher. As in the normal practice, brightness and colours in the *VBLUW* system are expressed in terms of the log of the

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intensity. The brightness V of the $VBLUW$ system can be transformed into the V of the UBV system (with subscript J) with the aid of the formula

$$V_J = 6.879 - 2.5[V + 0.068(V-B)]$$

(Pel, 1983). $V-B$ of the $VBLUW$ system can be transformed into $(B-V)_J$ with the relation given by Thé *et al.* (1980). This transformation is best applicable to unreddened stars.

The stability of the $VBLUW$ system was checked by plotting the photometric parameters of stars in common with Walraven and Walraven (1960) (hereafter called WW) and Braes (1967b) against each other. For that purpose those of WW (observations made between 1958-1960) and Braes (observations made in August 1963) were transformed into the 70/78 photometric system by using transformation formulae provided by Lub and Pel (1977). It appeared that for V and $V-B$ our results and those of WW showed only slight differences, in contrast with the differences with Braes. The reason is perhaps the fact that the observers of Braes' photometry used always two standard stars only and that they were not aware of the high extinction (twice as high as normal) caused by the volcanic eruptions of Mt. Agung on the island of Bali. Therefore we did not use them for the averages in our table I.

The colour indices $B-U$, $U-W$ and $B-L$ of Braes showed some systematic differences with ours. The spread around the mean relation amounts to at most ± 0.01 in $B-U$ and $B-L$, which is quite satisfactory. For $U-W$ the maximum scatter stays usually below 0.03, but for a number of individual cases the deviations amounts to 0.1 or more. The cause is that the stars are very faint in the passband W ($\lambda_{\text{eff}} \sim 3250 \text{ \AA}$). Transformation formulae were derived in order to transform these colour indices into the 70/78 system. The colour indices $B-L$, $B-U$ and $U-W$ of WW were not used, because they did not give them explicitly. Only the reddening independent indices are tabulated while the precise transformations are not known.

Table I lists all photometric parameters. A colon means that the accuracy cannot be guaranteed below ± 0.010 . The column « Remarks » gives spectral types if known. « NM » stands for « presumably a non-member », « SB » stand for spectroscopic binary. References or extra remarks are indicated by small numbers ranging from 1-17 and are listed at the end of the table.

The average difference between our values for V_J and $(B-V)_J$ and those of other authors giving photoelectric UBV photometry for stars in common (results of this work minus those of others), are listed in table II together with standard deviations. The last column lists stars not used for this comparison because they are less reliable (wrong identifications; photometric errors; variability) and identified with their Braes numbers. Our values for V_J agree very well with those of Bok *et al.* (27 stars in common), Garrison and Schild (15 stars in common) and Klare and Neckel (24 stars in common), while our values for $(B-V)_J$ are 0.02 mag too blue.

3. The determination of the reddening, T_{eff} and $\log g$.

Figure 1 shows the position of the members of Sco OB1 (including those of NGC 6231) in the $V-B/B-U$ diagram,

uncorrected for reddening. Thus all possible non-members (nearly 60) are omitted. The criteria for the membership are based on a proper motion study (Braes, 1967a) and on photometric and reddening considerations (Braes, 1967b; Crawford *et al.*, 1971 and this paper, see later). The main sequence (Lub, 1982) and the reddening line (long arrow) are indicated. Supergiants (Ia, b and II) and hypergiants (Ia⁺) are indicated by plus signs. Crawford *et al.* (1971) suggested that the stars Br. 314, 668 and 688 are non-members, but in our view this may still be questionable. Therefore we have plotted them also in figure 1. Br. 180, a B2 II-III star, is suspected to be also a non-member by them, because the distance is ~ 1 kpc (based on the β/M_V calibration). On the contrary the distance found by Klare and Neckel (1977) suggests membership ($r \sim 1.3$ kpc). The age, estimated with the aid of theoretical evolutionary tracks however, appears to be ~ 3 times as old as that for the association (see Sect. 5) even if Klare and Neckel's distance is employed, thus confirming the suspicion that it is no member of the association. Br. 314 (a possible member, see note no. 15 at the bottom of table I) is situated in a dusty area close to a possible supernova remnant (Braes and Hovenier, 1966). It has suffered a large amount of reddening ($E(B-V)_J = 1.23$) which may be of local origin.

The systematic effect of the foreground reddening on the main sequence stars as well as the effect of the differential reddening is obvious. A small part of the spread is caused by gravity effects. Because the knowledge of individual gravities can improve the individual reddenings, they will be determined at first, together with the temperatures.

These physical parameters were determined with the aid of a theoretical extinction independent two-colour diagram $[B-L]/[B-U]$. For the 70/78 photometric system $[B-L] = (B-L) - 0.43(V-B)$ and $[B-U] = (B-U) - 0.67(V-B)$. (These indices were for the first time defined and used by Walraven and Walraven, 1960). This diagram is constructed with the aid of theoretical colours computed by Pel and Lub (1983) and based on model atmospheres of Kurucz (1979) for solar abundances. For most of the stars values for T_{eff} and $\log g$ could be read off. The estimated errors in T_{eff} are ± 2000 K for $T_{\text{eff}} > 25000$ K and decrease to ± 200 K near $T_{\text{eff}} \sim 10000$ K. The temperatures appear to be in good accordance with the spectral types, if known. The estimated errors in $\log g$ amount to ± 0.5 for $T_{\text{eff}} > 25000$ K (in table I these $\log g$ values are followed by a colon) and decrease to ± 0.1 near $T_{\text{eff}} \sim 10000$ K. All estimated errors include systematic errors in the grid of theoretical colours. If the lines of constant T_{eff} and $\log g$ come too close to each other, or if the models appear to be not yet perfect, no meaningful values for T_{eff} and $\log g$ could be derived. These effects become particular relevant in the region of low gravities ($\log g < 3$). The problem with the normalization of these models was also noticed in the $VBLUW$ photometric studies of the open clusters NGC 2516 and NGC 4755 (Verschoor and van Genderen, 1983 and de Waard *et al.*, 1984, respectively). Therefore we adopted for the supergiants $\log g = 3$ or 3.5, in order to get yet reliable reddening determinations. These adopted values for $\log g$ as well as those for the temperatures are in table I followed by a question mark. For Br. 139 = ζ^1 Sco

we adopted $\log g = 2.1$, which was derived from the radius and mass given by Burki *et al.* (1982). The T_{eff} is taken from Humphreys (1978).

If stars fall outside the grid of theoretical colours, because of peculiar colours or because of the incompleteness of the grid, especially at $T_{\text{eff}} < 9000$ K, no values for T_{eff} and $\log g$ could be determined as well.

In order to find individual reddenings, all stars were shifted along the reddening path onto the appropriate $\log g$ line in the theoretical $V-B/B-U$ and $V-B/B-L$ diagrams. In the former diagram the gravity lines for $\log g > 3.5$ practically coincide with the empirical main sequence (shown in Fig. 1) even up to very high temperatures. Therefore stars of which no $\log g$ value could be determined, were shifted onto the main sequence. Consequently in case of peculiar colours the reddenings so derived are less reliable.

The reddenings $E(V-B)$ found with the aid of the two two-colour diagrams generally agree very well with each other. Usually the differences are smaller than 0.005. The averages are given in table I. To transform these reddenings into $E(B-V)_J$ (also listed in table I), we multiplied $E(V-B)$ by a factor 2.57, which is valid for OB type stars and by a factor 2.50 for stars with temperatures near 9000 K (Lub, 1980; Pel, 1981). The estimated errors in $E(B-V)_J$ are ± 0.02 mag. The average difference in the reddenings for stars in common with other authors (those of this paper minus those of others) are given in table II with the standard deviations. The reddenings $E(b-y)$ of Crawford *et al.* and Shobbrook were transformed into $E(B-V)_J$ by means of the relation $E(b-y) = 0.74 E(B-V)_J$ (Maitzen and Hensberge, 1981). The agreement is excellent, only Garrison and Schild (15 stars in common) appear to have lower reddenings by 0.03 mag.

4. The distance modulus and the HR diagram.

The distance modulus of Sco OB1 and NGC 6231 can now be determined by correcting each star in the $V/V-B$ diagram for the reddening. V is corrected into V_0 with the aid of the expression $A_V = 3.43 E(V-B)$ (Pel, 1981).

Fitting the main sequence of Thé *et al.* (1980) to the observations, especially those in the lower part of the diagram $V_0/(V-B)_0$ (Fig. 2) revealed the distance modulus :

$$(m-M)_0 = \begin{cases} -4.40 \pm 0.10 & (\text{log intensity scale}) \\ 11.00 \pm 0.25 & (\text{mag scale}) \end{cases}$$

This corresponds with a distance of 1585 ± 200 pc. NGC 6231 has the same distance as the rest of Sco OB1. Our modulus is low compared to the following ones : Seggewiss (1968) : 11.24, Bok *et al.* (1966) : 11.3, Feinstein and Ferrer (1968) : 11.4, Crawford *et al.* (1971) : 11.5 (based on an old β/M_{V_J} calibration) and Garrison and Schild (1979) : 11.6, but is equal to the most recent one of Shobbrook (1983) : 11.0 (based on a revised β/M_{V_J} calibration and applying 26 previously unobserved faint members of NGC 6231). An even lower value has been obtained by Mermilliod (1981a) *viz.* 10.7. One can see in his figure 24 that the empirical isochronous curve forms the lower boundary of the main sequence band, instead of a mean curve like in our figure 2. According to Mermilliod (1981b) it cannot yet be proven that the ZAMS

is strictly unevolved at $M_{V_J} = -2$ (that is near $V_0 \sim -0.9$). Thus we may conclude that the distance may be perhaps even slightly smaller than the one found by us and Shobbrook.

The evolutionary effect of the stars in the upper part of figure 2 is obvious. Super- and hypergiants are indicated with plus signs.

5. The age of Sco OB1 and the evolutionary status of the hypergiant ζ^1 Sco.

The evolutionary age of Sco OB1 is determined with the aid of the brightest stars. Three supergiants (I, II) with known temperatures, 9 O and Of stars and one WN 7 star were plotted in the theoretical HR diagram and ages were determined with the aid of the evolutionary tracks for stars with 60, 30 and 15 M_\odot with mass loss case B (Maeder, 1981a, b). The 9 other supergiants were not used because it is difficult to obtain reliable temperatures for reasons explained in section 3. The temperatures for these stars are listed in table I (with a question mark) and are only rough values based on their spectral types. Since the ages are very sensitive to the temperatures, we could not use them. Table IV summarizes some physical parameters like luminosities, masses and ages. We included also Br. 180 a B2 II-III star, which is likely a non-member according to its much higher evolutionary age. This is in accordance with the shorter distance based on the β/M_{V_J} calibration by Crawford *et al.* ($r \sim 1$ kpc).

The average age turns out to be $3.6 \pm 0.6 \times 10^6$ yr, which is considering the uncertainties consistent with the kinematical age of $\sim 10^6$ yr determined by Braes. A part of the standard deviation must be caused by errors in the temperatures. It appears that the three stars belonging to NGC 6231 have the same ages as the other ones of the association. According to Mermilliod (1981a, b) NGC 6231 belongs together with NGC 2264 and the Orion cluster to the youngest clusters known.

The only Wolf-Rayet star listed in table IV, Br. 114 (= HR 6249 = HD 151932 = WR 78 in the catalogue of van der Hucht *et al.* (1981)), a WN 7 star, fits the evolutionary track of a star with an initial mass of $\sim 60 M_\odot$ of Maeder (1981a, 1983). Its age should then be $\sim 4.5 \times 10^6$ yr if mass loss case B is adopted. The star has then already been in the yellow supergiant stage. This age may be too high in view of the other ages. If the mass loss rate is 2.5 times higher (Maeder, 1983) then, by the time the star becomes a WN star, the age is $\sim 3.9 \times 10^6$ yr. There are however more scenarios possible, which can lead a massive star into the Wolf-Rayet stage (Maeder, 1982). For example, according to the computations of Noels *et al.* (1980) and Noels and Gabriel (1981) stars with initial masses of 40-60 M_\odot and mass loss rates of $\sim 7 \times 10^{-6} M_\odot/\text{yr}$ can expose CN processed material at the surface at the end of the main sequence lifetime within $\sim 4 \times 10^6$ yr. This is thus also compatible with the mean age of the association.

For the hypergiant ζ^1 Sco (= Br. 139) we assumed that it is in the core He burning stage also and on its way to become a Wolf-Rayet star. The ages for the two possible directions of evolution (to the red-supergiant stage or to the Wolf-Rayet stage) are : 4.2 and 4.3×10^6 yr, respectively (Maeder, 1981a). The chance to observe a

star in the second stage is 10 times larger in view of the much slower evolution. Thus from a statistical point of view it is more likely that the star is now for the second time a blue supergiant. The present mass of ζ^1 Sco should then be $\sim 30 M_{\odot}$ and the initial mass $\sim 60 M_{\odot}$.

The position of ζ^1 Sco in the HR diagram is right on the spot of P Cygni for which the same scenario is proposed (Lamers *et al.*, 1983). Burki *et al.* (1982) have suggested a different scenario in which ζ^1 Sco is still on the main sequence and vibrationally unstable in view of the variations of the radial velocity and the brightness. At present the mass should be $\sim 65 M_{\odot}$. This differs appreciably from the mass based on our photometry. The main reason is the revised distance of section 4 making the $M_{\text{bol}} \sim 0.8$ mag fainter. With Burki *et al.*'s M_{bol} and mass, the age of ζ^1 Sco should be $\sim 3 \times 10^6$ yr, which is still within the standard deviation of the average age found above. One could argue that the second possible reason to choose for the scenario proposed by us is the fact that the position of ζ^1 Sco in the HR diagram is far out of the main sequence band (for all mass loss cases) by ~ 0.14 in $\log T_{\text{eff}}$. Thus to lie just within the main sequence band, the temperature should be ~ 26000 K (instead of 19000 K), which is impossible for a star with a B1Ia⁺ spectral type. However, there is an increasing number of observational and theoretical arguments supporting the idea that the top of the main sequence is in fact much wider than predicted by current models. Various causes of main sequence widening exists (overshooting of the convective core, mass loss etc.) see for example Stothers and Chin (1977), Bressan *et al.* (1981). Bertelli *et al.*'s (1984) analysis even support the view that main sequence stars should comprise spectral types up to A0. It is therefore difficult to decide which of the two scenarios is correct.

6. The new non-members.

V_0 is transformed into V_{j_0} and with the aid of the distance modulus into M_{V_j} , which is listed in table I. $(V-B)_0$ is transformed into $(B-V)_{j_0}$ with the aid of the relation given by Thé *et al.* (1980) and with $E(B-V)_j$, $(B-V)_j$ is found and also listed in table I.

Figure 2 was used to identify new possible non-members, which were still present in our sample. Fifteen stars more are suspected to be non-members, bringing the total number in our sample close to 60. Their distance moduli (bracketed in table I in the column « Remarks ») could be derived by measuring in figure 2 their vertical distance to the main sequence. It must be emphasized that with this method some evolved background stars could be also present among these new possible non-members. Their distances will then be underestimated and should then be $\gg 1.6$ kpc. However we suppose that their number will be small. All the other non-members are largely identified by means of the H β photometry of Crawford *et al.* (1971) and the proper motion study of Braes (1967a). They will be used in the next section for the study of the dust distribution in the direction of Sco OB1.

7. The average reddening and the distribution of the reddening.

In figure 3 we outlined the distribution of the reddening across the whole area of Sco OB1. The figure is actually a part of Braes' figure 4, in which the proper motion of O-B5 stars (identified by his numbers) outside the main

body of Sco OB1 are indicated by vectors. (Thus not all stars are present on this map such like the non-members). The position of the galactic equator is sketched (at the left). It appears that one can clearly distinguish areas of different average reddening, in which the absorbing material is generally rather homogeneously distributed. These areas are in figure 3 outlined by curves and numbered I to V, while area IV (outside the main body of Sco OB1) is differentiated in a western and an eastern part (IVW and IVE, respectively). In table I each $E(B-V)_j$ value is followed by one of these numbers indicating in which area the star is situated. Area II covers largely NGC 6231 : the southern part contains three stars with high reddenings and are therefore included in area V, where the highest reddenings occur. Table III tabulates the average reddenings and the standard deviation for the members lying in the six areas. The total number of stars used range from 13 to 32. A few stars are excluded because they appeared to have much higher reddenings than the averages (last column in table III), perhaps caused by local concentrations of dust. They are marked by open squares in figure 3.

Area I shows the lowest average reddening of 0.35 mag and area V the highest one, with individual values ranging from 0.55 up to 0.80. The average of all reddenings listed in table III is of the same order as found by other authors.

With the aid of the non-members it can be easily demonstrated that the reddening in those six areas is mainly caused by foreground dust complexes in the local spiral arm. That the overall reddening is mainly a foreground effect has already been shown by Seggewiss (1968) and Schild *et al.* (1971). From the nearly 60 non-members in our sample, distances were derived by means of the distance moduli as listed in table I. Four non-members were added, which were not present in our sample *viz.* one of Bok *et al.* (Br. 793) and three of Braes (Br. 128, 279 and 731). Figure 4 shows for five areas a plot of $E(B-V)_j$ against the distance r (in kpc). No non-members in area II are known. The average reddening for the members are indicated with a black square, while the error bar represents the standard deviation. It is evident that presumably all reddening originates in the local dust arm, which extends in the direction of Sco OB1 up to a distance of at most 700 pc from the Sun. The average extinction A_V varies from 1.4 mag kpc⁻¹ for area I up to 2.8 mag kpc⁻¹ for area V, which agrees roughly with Neckel and Klare's (1980) dust distribution close around the Sun in the direction $l \sim 343^\circ$.

Figure 5 shows the spiral arms in the solar neighbourhood traced by a large number of young star clusters (Fenkart and Binggeli, 1979; see also Seggewiss, 1968 and Lyngå, 1980). Sco OB1 (including NGC 6231) is marked by a cross. The young clusters NGC 6242 and 6268 close to Sco OB1 (see plate 1 of Braes, 1967a) have suffered roughly the same reddening (see table 2 of Becker and Fenkart, 1971). Since Sco OB1 is situated at the other side of the Sagittarius-Carina spiral arm, we must conclude that in this particular direction this arm is virtually transparent over a distance of ~ 0.5 kpc. Thus apparently the hole in the Sagittarius-Carina arm is at least 3° wide in galactic longitude. Neckel and Klare (1980) studied the reddening distribution in the galactic plane up to 3 kpc around the Sun. According to their figure 9, the light way should pass through the dense dust cloud « G » (situated in the Sagittarius-Carina arm). Either the resolution of their study is

in that particular direction ($l = 343^\circ\text{--}346^\circ$, $b = 1^\circ\text{--}2^\circ$) not small enough to detect this dust free pass way, or the dust cloud extends only for at most 1° above the galactic plane.

Acknowledgements.

We are grateful to Prof. Dr. A. Blaauw and Dr. J. Lub

for suggesting the program and Dr. J. Lub for providing us with several particulars of the VBLUW system before publication. A part of the reduction has been done automatically by a computer program written by Dr. J. Tinbergen and Mr. J. J. Schafgans. We should also like to thank the referee Dr. Th. Neckel and Dr. J. Lub for their valuable comments.

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TABLE I. — Observations of the stars in Sco OBI (including NGC 6231) in the VBLUW system (log int. scale) and in the UBV system (mag scale with subscript J), their reddenings and some physical parameters.

HD/HDE BD	Br No	V	V-B	B-U	U-W	B-L	E(V-B)	V _J	(B-V) _J	E(B-V) _J	Area	T _{eff}	logg	M _{VJ}	Remarks
151515	92	- .126	.069	.003	.029	.018	.175	7.18	0.14	0.45	IV W			-5.30	O7IIIF ¹²
151564	95	- .462	.053	.028	.025	.022	.156	8.02	0.10	0.40	IV W	28000	4.2	-4.30	B0.5V ¹²
151804	103	.638	.032	-.023	.020	.006	.136	5.28	0.04	0.35	I	37000		-6.88	O8F(P) ¹ , EM ⁶
151805	104	- .812	.065	.033	.038	.028	.165	8.90	0.13	0.42	IV W	30000	4.5	-3.49	
151909	108	- .915	.210	.340	.205	.201	.030	9.13	0.52	0.00	IV W				NM ³ (4.68)
151910	109	-1.055	.062	.174	.067	.074	.130	9.51	0.13	0.33	I	17300	4.0	-2.58	
151911	110	- .877	.076	.121	.044	.064	.156	9.06	0.16	0.40	I	21300	4.3		NM ⁴ (9.50) ¹
151912	111	-1.044	.098	.493	.167	.166	.099	9.47	0.24	0.25	IV W	9600	3.6		NM ⁴ (6.70)
151930	112	-1.343	.052	.268	.106	.097	.099	10.23	0.11	0.25	I	13400	4.0	-1.60	
151931	113	-1.102	.029	.358	.105	.132	.053	9.03	0.06	0.14	I	11200	4.3		NM ³ (7.93)
151932	114	.146	.129	.033	.043	.044	.234	6.49	0.29	0.60	V	40000		-6.49	WN7 ⁰ , EM ⁶
151946	115	- .631	.035	.439	.116	.196	.000	8.45	0.09	0.00	IV W	9000	4.5		NM ³ (6.05)
151965	117	.197	-.047	.120	.033	.043	.000	6.40	-0.19	0.00	IV W	16100	4.3		NM ³ (5.93)
151986	119	-1.008	.033	.132	.037	.057	.104	9.59	0.06	0.27	I	18700	4.2	-2.30	
152003	120	- .073	.163	.059	.078	.048	.253	7.03	0.39	0.65	V	26000?	3.0?	-6.12	B0IA ¹
152042	121	- .532	.055	.022	.026	.019	.155	8.20	0.11	0.40	I	29000	4.0	-4.12	B0.5III ¹ , B0.5IV ¹²
152060	122	-1.094	.031	.046	.024	.023	.122	9.61	0.04	0.31	I	25000	4.1	-2.41	B2IV ¹ , EM ⁶
152076	123	- .655	.096	.041	.038	.033	.198	8.50	0.21	0.51	III	30000	4.0	-4.18	B0III ¹
152096	124	-1.018	.031	.064	.022	.037	.117	9.42	0.05	0.30	I	23000	4.4	-2.57	
152147	125	- .176	.173	.067	.073	.052	.263	7.29	0.42	0.60	V	26000?	3.0?	-5.95	B0IA ¹ , O9.5IB ¹²
152182	127	- .904	.036	.026	.014	.019	.141	9.13	0.05	0.36	I	27500	4.3	-3.06	B1III ¹²
152198	129	- .503	.065	.020	.011	.021	.166	8.32	0.13	0.43	IV E	32000	4.3	-4.10	
152199	130	- .705	.100	.038	.047	.034	.204	8.63	0.22	0.52	III	32000	4.2	-4.09	
152200	131	- .622	.050	.019	.031	.018	.160	8.42	0.11	0.41	II	30000	4.0	-3.93	O9.5V(N) ² , SB ¹¹
152217	133	- .645	.060	.033	.055	.026	.160	8.48	0.14	0.43	IV E	29000	4.2	-3.94	B0III ¹ , B0IV ¹²
152218	134	- .304	.078	.020	.045	.024	.103	7.63	0.16	0.47	III	34000	4.4	-4.92	O9.5IV ¹ , O9IV ² , SB ¹¹
152219	135	- .315	.071	.020	.035	.023	.173	7.65	0.14	0.44	II	32000	4.2	-4.80	O9.5IV ¹ , O9.5III ² , SB ¹¹
152233	136	.084	.056	.006	.029	.020	.150	6.66	0.11	0.41	II	34000	4.7	-5.69	O6F ¹ , O6III(F) ²
152234	137	.546	.091	.026	.051	.026	.100	5.50	0.19	0.46	II		3.0?	-7.03	B0.5IA ¹ , B0IAB ² , SB ¹¹
152235	138	.193	.224	.114	.107	.076	.309	6.36	0.54	0.79	V	24000?	3.0?	-7.25	B0.5IA ¹ , EM ⁶
152236	139	.034	.215	.003	.100	.064	.270	4.76	0.52	0.69	V	19000 ¹⁵	2.1 ⁷	-8.52	J ¹ SC0, B1IA ¹ , EM ⁶
152245	140	- .615	.040	.005	.019	.009	.142	8.41	0.06	0.36	IV W	30000	4.0	-3.78	B0III ¹ , O9.5V ¹²
152246	141	- .108	.069	.005	.033	.016	.174	7.34	0.14	0.45	IV E	35000	4.5	-5.15	O9.5III ¹ , O9III ¹²
152247	142	- .132	.007	.021	.042	.026	.192	7.19	0.18	0.49	III	34000	4.5	-5.43	O9.5II ¹
152248	143	.296	.067	-.001	.029	.019	.172	6.13	0.13	0.44	II	37000		-6.32	O8F ¹ , O7IB(F ₂ +O6AF) ² , O7F ⁵ , EM ⁶ , SB ¹¹
152249	144	.150	.007	.018	.038	.025	.186	6.49	0.19	0.48	II	27000?	3.5?	-6.09	O9.5IA ¹ , O9IAB ² , O9IB ⁰
152268	146	- .508	.056	.025	.034	.020	.156	8.14	0.11	0.40	I	29000	4.0	-4.18	B0III ¹ , B0.5III ¹²
152269	147	- .663	.052	.165	.061	.071	.119	8.53	0.11	0.31	III	17500	4.2		NM ⁶ (8.40)
152270	148	.062	.103	.055	.026	.066	.185	6.71	0.24	0.48	II	21000?	3.5?	-5.87	WC7 ² , B1I+W ¹ , WC7+O8 ⁰ , EM ⁶ , SB ¹¹
152291	149	- .741	.076	-.007	.020	.015	.105	8.72	0.16	0.48	IV W			-3.86	B0III:PN(E) ¹ , EM ⁶
152292	150	- .677	.054	.047	.019	.030	.148	8.56	0.10	0.38	I	26000	4.1	-3.69	B1IVN ¹²
152314	152	- .402	.007	.028	.043	.028	.190	7.07	0.19	0.49	II	33000	4.4	-4.75	O9.5III ¹ , O8.5III ²
152333	153	- .521	.098	.043	.054	.035	.201	8.16	0.22	0.52	III	31000	4.1	-4.56	B0IVN ¹²
152305	156	- .094	.069	.077	.016	.046	.150	9.10	0.15	0.41	IV E	24000	4.3	-3.25	
152405	157	- .153	.062	.000	.032	.014	.162	7.25	0.13	0.42	IV W	32000	4.0	-5.14	B0IB ¹ , O9.5IB ¹²
152407	159	- .790	.109	.436	.156	.214	.025	8.84	0.27	0.06	IV E	0300	4.3		NM ³ (5.73)
152408	160	.411	.079	.000	.024	.023	.184	5.84	0.16	0.47	IV E	37500	5.0	-6.71	O7F ¹ , EM ⁶
152424	162	.199	.177	.077	.059	.058	.267	6.35	0.43	0.69	V	26000?	3.0?	-6.93	B0IA ¹ , B0IAP ¹²
152436	163	- .904	.090	.198	.073	.078	.160	9.12	0.20	0.41	IV W	16000	3.7		NM ⁶ (8.00)
152437	164	- .918	.047	.442	.134	.157	.054	9.17	0.11	0.14	V	9000	4.0		NM ³ (6.93)
152457	165	-1.001	.067	.131	.042	.057	.147	9.57	0.14	0.38	IV E	20000	4.0	-2.68	
152458	166	-1.253	.068	.074	.045	.042	.158	10.00	0.15	0.41	IV E	24500	4.3	-2.35	
152459	167	- .691	.002	.254	.096	.130	8.59	0.18	0.33	V	13500	2.9		NM ⁴ (7.20)	
152490	168	- .365	.003	.467	.161	.216	.035	7.78	0.21	0.09	IV E	9000	4.4		NM ³ (4.90)
152553	170	- .744	.038	.046	.023	.028	.129	8.73	0.05	0.33	I	25000	4.2	-3.36	
152559	171	- .645	.054	.017	.047	.023	.154	8.48	0.11	0.40	I	31000	4.7	-3.84	B0.5V ¹²
152560	172	- .505	.051	.030	.027	.022	.150	8.33	0.10	0.39	IV E	27500	4.1	-3.96	B1IVN ¹²

TABLE I (continued).

HD/HDE BD	Br No	V	V-B	B-U	U-W	B-L	E(V-B)	V _J	(B-V) _J	E(B-V) _J	Area	T _{eff}	logg	M _{VJ}	Remarks
152598	173	- .627	.868	-.883	.835	.811	.166	8.44	.812	.843	IV E	35888	4.8	-3.98	O7V ¹²
152591	174	- .615	.853	.836	.832	.824	.158	8.41	.811	.839	I	27588	4.1	-3.88	B8.5IV ¹²
152622	177	- .518	.877	.821	.848	.824	.188	8.14	.816	.846	IV E	33888	3.9	-4.38	B8III:N ¹ ,O9.5V ¹²
152623	178	.854	.844	-.887	.826	.813	.148	6.74	.808	.838	I	35888	4.7	-5.51	O8V ¹
152667	179	.254	.128	.827	.857	.838	.217	6.22	.828	.856	IV E	26888?	3.5?	-6.63	B8IA?P ¹ ,EM ⁶ ,B8.5IA ¹²
152685	188	- .249	.888	.898	.856	.844	.178	7.49	.818	.844	IV E	23888	3.8	-3.96	NM ¹⁴ (18.8),B2II-III ¹⁴
152755	184	- .476	.812	.176	.841	.878	.878	8.87	.801	.818	IV E	15688	4.3		NM ³ (7.88)
153677	213	- .523	.843	.166	.865	.868	.188	8.18	.809	.828	IV E	17888	3.8		NM ⁵ (7.93)
322247	257	-1.368	.888	.482	.135	.136	.128	18.26	.821	.831	IV W	11888	3.8		NM ⁴ (8.85)
322252	258	-1.786	.185	.481	.112	.198	.112	11.13	.826	.829	IV W	9788	4.2		NM ³ (8.38)
322256	261	-1.368	.119	.428	.148	.227	.142	18.28	.829	.836	IV W	9488	4.4		NM ⁴ (7.55)
322257	262	-1.458	.118	.494	.158	.219	.119	18.48	.829	.838	IV W	9488	4.3		NM ³ (7.55)
322258	263	-1.468	.218	.487	.283	.243	.117	18.51	.854	.829	IV W	7588	4.8		NM ⁴ (6.43)
322266	268	-1.434	.871	.274	.879	.188	.128	18.45	.816	.831	IV W	13688	4.1	-1.57	
322267	269	-1.498	.899	.187	.858	.893	.167	18.61	.823	.843	IV W	18888	4.3		NM ⁶ (18.85)
322268	278	-1.669	.155	.429	.117	.182	.183	11.82	.838	.847	IV W	11488	4.3		NM ⁴ (8.18)
322269	271	-1.535	.888	.166	.847	.877	.161	18.78	.819	.841	IV W	18888	4.1	-1.65	
322278	272	-1.394	.886	.168	.853	.879	.159	18.35	.819	.841	IV W	19888	4.2	-2.88	
322272	274	-1.448	.232	.315	.196	.223	.828	18.46	.858	.885	I				NM ³ (5.63)
322273	275	-1.878	.187	.466	.165	.214	.115	9.54	.826	.829	I	9888	4.5		NM ³ (6.73)
322274	276	-1.852	.868	.168	.853	.864	.132	9.58	.813	.834	I	17888	3.8	-2.62	
322275	277	-1.158	.824	.839	.824	.824	.114	9.77	.803	.829	I	25888	4.3	-2.19	
322276	278	-1.426	.871	.883	.814	.858	.159	18.43	.815	.841	I	24888	4.3	-1.92	
322278	288	-1.878	.821	.819	-.885	.813	.116	9.55	.882	.838	I	27588	4.2	-2.44	
322288	282	-1.126	.845	.429	.183	.148	.868	9.69	.818	.815	I	18188	3.8		NM ³ (7.55)
322282	284	- .854	.893	.817	.836	.832	.197	9.88	.821	.851	IV W	37888		-3.68	EM ⁶
322283	285	-1.386	.237	.316	.173	.256	.888	18.18	.859	.888	IV W				NM ³ (5.85)
322294	296	-1.255	.846	.139	.828	.868	.116	18.81	.889	.838	I	18988	4.4		NM ⁶ (18.85)
322295	297	-1.548	.879	.245	.874	.896	.135	18.72	.818	.835	I	14688	3.9	-1.44	
322299	388	-1.699	.186	.485	.119	.182	.113	11.11	.825	.828	I	9888	3.9		NM ³ (8.35)
322382	383	-1.437	.166	.513	.895	.238	.165	18.44	.848	.841	I	9888	4.3		NM ⁴ (7.13)
322386	387	-1.382	.388	.467	.219	.427	.888	18.27	.892	.888	I				NM ³ (2.88)
322389	318	-1.437	.878	.883	.833	.848	.166	18.46	.817	.843	IV W	24888	4.2	-1.96	
322488	311	-1.624	.876	.168	.856	.872	.149	18.93	.816	.838	IV W	18588	4.8	-1.32	
322417	314	-1.311	.366	.188	.159	.116	.488	18.89	.898	1.23	IV E			-4.97	O5.5 ¹⁶ ,NM ¹⁸ ,NEAR SNR ^{1c}
322422	317	-1.155	.885	.196	.898	.842	.165	9.75	.819	.842	IV E				B8.5III:EM ¹⁶ ,NM ¹⁸
322431	321	-1.246	.855	.861	.845	.835	.146	9.98	.811	.838	I	25888	4.2	-2.27	
322433	323	-1.879	.852	.845	.836	.824	.148	9.57	.818	.838	I	25888	3.8	-2.68	
322447	338	- .813	.854	.866	.848	.829	.146	8.98	.811	.838	I	23888	3.6	-3.35	B8III:PNE ¹ ,EM ⁶
322458	333	-1.258	.855	.874	.818	.841	.143	18.88	.811	.837	I	23588	4.2	-2.22	
322452	335	-1.133	.871	.123	.855	.856	.152	9.78	.815	.839	I	28588	3.9		NM ⁶ (18.38)
322453	336	-1.356	.858	.389	.886	.186	.893	18.26	.811	.824	I	12488	3.9		NM ³ (8.88)
322454	337	- .966	.869	.878	.849	.837	.161	9.28	.814	.841	IV E	24888	3.8	-3.87	
322456	339	-1.384	.165	.496	.235	.228	.174	18.31	.841	.845	IV E	18288	4.3		NM ³ (7.85)
326145	548	-1.685	.838	.368	.182	.138	.855	18.89	.886	.814	I	11888	4.2		NM ² (8.93)
326146	541	-1.634	.221	.424	.222	.223	.892	18.93	.857	.824	I				NM ³ (6.73)
326167	562	-1.387	.883	.118	.875	.855	.168	18.13	.818	.843	IV W	22288	4.8	-2.29	
326172	567	-1.488	.185	.488	.135	.186	.189	18.58	.825	.827	IV W	9788	3.9		NM ³ (7.88)
326176	571	- .917	.291	.152	.153	.899	.488	9.12	.871	1.83	IV W			-5.28	B1IV ¹
326285	628	-1.272	.818	.876	.833	.839	.899	18.86	.881	.825	I	22888	4.3	-1.77	
326286	629	-1.347	.878	.888	.856	.847	.168	18.23	.817	.843	IV E	24588	4.2	-2.19	
326288	631	-1.286	.877	.456	.137	.163	.886	9.88	.819	.822	IV E	18888	3.9		NM ⁴ (7.35)
326289	632	-1.481	.868	.887	.864	.843	.157	18.57	.814	.848	IV E	22888	3.9	-1.75	
326294	637	-1.389	.138	.394	.188	.125	.163	18.33	.834	.842	IV E	11588	3.2		NM ⁴ (7.55)
326295	638	-1.448	.184	.164	.896	.889	.274	18.45	.844	.878	V	22588	3.7	-2.86	
326296	639	-1.162	.883	.869	.846	.842	.177	9.77	.818	.845	IV E	25588	4.8	-2.72	B2V ¹
326297	648	-1.443	.877	.892	.849	.851	.164	18.47	.817	.842	IV E	23288	4.2	-1.92	

TABLE I (continued).

HD/HDE BD	Br No	V	V-B	B-U	U-W	B-L	E(V-B)	V _J	(B-V) _J	E(B-V) _J	Area	T _{eff}	logg	M _{VJ}	Remarks
326299	641	-1.576	.074	.293	.100	.099	.125	10.81	0.17	0.32	I	13000	3.7	-1.25	
326303	644	-1.558	.064	.177	.070	.082	.130	10.76	0.13	0.33	I	17300	4.3	-1.33	
326305	646	-1.245	.078	.066	.039	.043	.171	9.98	0.17	0.44	III	26000	4.2	-2.47	
326306	647	-1.179	.039	.069	.044	.038	.125	9.02	0.07	0.32	I	23000	4.3	-2.24	B1V ¹
326307	648	-1.460	.103	.155	.089	.083	.178	10.51	0.24	0.46	III	20300	4.4	-2.01	
326308	649	-1.373	.076	.200	.091	.116	.123	10.30	0.18	0.32	III	13500	4.2		NM ⁶ (8.80)
326309	650	-1.264	.112	.087	.051	.057	.125	10.02	0.27	0.32	III	27000	4.3		NM ⁴ (7.10)
326310	651	-1.225	.105	.100	.049	.068	.192	9.92	0.24	0.49	III	24000	4.5	-2.70	B2V ¹
326311	652	-1.474	.107	.109	.061	.064	.194	10.55	0.25	0.50	III	24000	4.3	-2.10	
326313	654	-1.715	.224	.490		.240	.125	11.13	0.56	0.31	V	7000	4.2		NM ⁴ (7.00)
326317	658	-1.311	.084	.080	.042	.051	.103	10.14	0.18	0.47	III	25000	4.4	-2.41	
326319	660	-1.502	.136	.501	.206	.186	.147	10.61	0.33	0.37	III	9900	3.8		NM ⁴ (7.63)
326320	661	-1.221	.079	.084	.040	.048	.168	9.92	0.17	0.43	III	24000	4.1	-2.50	
326323	665	-1.304	.173	.557	.235	.206	.173	10.31	0.44	0.43	III	9300	3.6		NM ⁴ (6.93)
326326	668	-1.635	.120	.166	.062	.091	.194	10.95	0.28	0.50	V	20300	4.4	-1.70	NM ⁶ (10.80)
326327	669	-1.113	.116	.060	.067	.048	.216	9.64	0.27	0.56	V				-3.21; B2IV ¹ , B1.5IVE+SH ¹ , VAR ⁹
326328	670	-1.355	.085	.087	.056	.050	.175	10.25	0.19	0.45	II	24000	4.2	-2.24	
326329	671	- .749	.067	.026	.032	.033	.166	8.74	0.14	0.43	II	31000	5.0	-3.68	B0IV ¹ , O9V ⁺ , O9.5V ²
326330	672	-1.125	.085	.050	.034	.040	.181	9.68	0.20	0.47	II	27500	4.1	-2.07	B0.5V ⁺ , B1V(N) ³
326331	673	- .230	.080	.021	.034	.030	.102	7.44	0.17	0.47	II	34000	5.0	-5.11	O7 ⁺ , O7IIIF ⁺ , SB ¹¹
326332	674	-1.125	.109	.070	.032	.052	.204	9.67	0.24	0.52	II	20000	4.5	-3.05	B1III ²
326333	675	-1.109	.085	.067	.047	.052	.170	9.64	0.19	0.46	II	27000	4.9	-2.00	B1V(N) ² , CEPH ⁹
326340	681	-1.233	.114	.080	.052	.054	.210	9.94	0.27	0.54	V	27500	4.3	-2.04	
326341	682	-1.635	.105	.452	.166	.177	.110	10.95	0.25	0.30	V	10300	4.2		NM ⁴ (8.25)
326343	684	-1.505	.175	.157	.082	.095	.262	10.61	0.42	0.67	V	23500	4.3	-2.60	
326348	688	-1.225	.147	.092	.075	.061	.244	9.92	0.35	0.63	V	27500	4.0	-3.16	NM ⁶ (10.80), B1IV ¹
326351	691	- .945	.136	.062	.056	.050	.239	9.22	0.31	0.61	V	33000	4.4	-3.79	B0V ¹
326364	703	-1.107	.144	.066	.050	.055	.247	9.62	0.33	0.63	V	33000	4.5	-3.46	B0IV ¹
326454	732	-1.291	.307	.393	.201	.250	.120	10.05	0.70	0.31	IV E				NM ⁴ (4.75)
326466	743	-1.534	.111	.177	.085	.090	.184	10.70	0.25	0.47	IV E	19000	4.2	-1.05	
326467	744	-1.276	.141	.563	.223	.217	.119	10.04	0.35	0.30	IV E	8500	3.5		NM ³ (6.00)
326469	746	-1.500	.274	.393	.270	.232	.100	10.70	0.44	0.26	IV E				NM ³ (4.50)
326471	747	-1.507	.212	.456	.181	.237	.110	10.61	0.54	0.28	IV E	7500	4.2		NM ³ (6.50)
326473	749	-1.350	.172	.107	.073	.070	.272	10.22	0.41	0.70	V	27500	4.0	-3.09	
326476	752	-1.421	.126	.416	.100	.140	.160	10.41	0.30	0.41	III	11200	3.8		NM ⁴ (7.90)
326480	760	-1.409	.055	.372	.110	.131	.004	10.39	0.13	0.22	IV E	11200	4.0		NM ³ (8.43)
326490	762	-1.567	.071	.460	.175	.180	.065	10.70	0.17	0.16	IV E	9600	4.0		NM ¹ (8.10)
326492	764	-1.198	.101	.514	.190	.213	.075	9.06	0.25	0.19	IV E	8500	3.9		NM ³ (6.93)
326500	770	-1.563	.270	.373	.139	.235	.100	10.74	0.71	0.26	V				NM ³ (5.75)
-407579	898	-1.603	.062	.119	.016	.050	.140	10.00	0.13	0.36	I	20000	4.2	-1.31	
-407584	899	-1.176	.230	.240	.140	.124	.313	9.70	0.56	0.00	IV W	19000	3.6	-3.06	
-407585	900	-1.420	.074	.129	.053	.069	.152	10.42	0.16	0.39	I	20600	4.4	-1.07	
-407586	901	-1.371	.068	.107	.059	.059	.149	10.30	0.11	0.30	I	22000	4.4	-1.95	
-407606	902	-1.692	.109	.353	.147	.130	.152	11.09	0.26	0.39	I	12200	3.9	-1.20	
-407610	903	-1.691	.072	.103	.070	.082	.130	11.09	0.15	0.35	I	17000	4.2	-1.07	
-407627	906	-1.503	.147	.296	.106	.100	.195	10.01	0.35	0.50	IV E	14000	3.3	-1.04	
-407643	908	-1.321	.079	.070	.056	.040	.170	10.17	0.17	0.44	IV E	25000	4.3	-2.20	
-407647	909	-1.509	.075	.103	.063	.060	.150	10.04	0.17	0.41	IV E	22700	4.5	-1.51	
-407651	910	-1.492	.083	.095	.046	.052	.173	10.60	0.18	0.44	IV E	23000	4.1	-1.05	
-417696	928	-1.602	.143	.170	.093	.095	.222	10.06	0.34	0.57	III	20400	4.2	-2.02	
-417712	931	- .934	.074	.056	.012	.045	.167	9.20	0.16	0.43	II	27500	4.7	-3.22	B1V ²
-417717	933	-1.341	.082	.080	.054	.050	.172	10.22	0.18	0.44	III	24000	4.2	-2.23	
-417719	934	-1.043	.057	.062	.036	.037	.150	9.40	0.12	0.39	II	25000	4.2	-2.01	B1V ^{2,5}
-417723	936	-1.022	.064	.077	.030	.049	.152	9.42	0.13	0.39	II	24000	4.5	-2.07	B1V ^{2,5} , SB ¹¹
-417724	937	-1.068	.060	.047	.049	.045	.151	9.54	0.12	0.39	II	27500	5.1	-2.75	B0.5V ^{2,5} , SB ¹¹
-417727	939	-1.034	.066	.082	.050	.040	.154	9.45	0.14	0.40	II	24000	4.4	-2.07	B0.5V ² , B1V ^{2,5}
-417730	940	- .960	.080	.089	.046	.050	.166	9.20	0.18	0.43	II	24200	4.6	-3.14	B1V ^{2,5}

TABLE I (continued).

HD/HDE BD	Br No	V	V-B	B-U	U-W	B-L	E(V-B) _J	V _J	(B-V) _J	E(B-V) _J	Area	T _{eff}	logg	M _{VJ}	Remarks
-417733	941	- .418	.075	.016	.032	.024	.178	7.91	0.16	0.46	II	34000	4.5	-4.61	O9III ² ,SB ¹⁴
-417736	943	-1.328	.094	.114	.028	.058	.181	10.18	0.22	0.47	II	22400	4.0	-2.37	
-417737	944	-1.426	.083	.143	.050	.073	.160	10.43	0.18	0.41	II	20000	4.3	-1.92	B1.5V ⁵
-417742	945	- .643	.099	.043	.034	.031	.180	8.47	0.22	0.46	II			-4.05	B0IV ¹ ,O9IV ^{2,5} ,SB ¹⁴
-417743	946	-1.119	.104	.084	.043	.049	.199	9.66	0.23	0.51	II	25000	3.9	-3.02	B0.5V ^{2,5} ,SB ¹⁴
-417746	947	- .936	.093	.056	.038	.036	.180	9.20	0.21	0.46	III	27500	3.8	-3.32	
-417753	948	-1.183	.108	.074	.027	.042	.186	9.82	0.25	0.48	II	25000	3.6	-2.76	A ⁹ CEPH ⁹
-417755	949	-1.298	.095	.080	.033	.040	.189	10.11	0.22	0.49	II	25000	4.0	-2.51	
-417758	950	-1.551	.108	.257	.122	.089	.161	10.74	0.25	0.41	IV E	14500	3.3	-1.61	
-417760	951	-1.067	.172	.109	.069	.068	.265	9.52	0.41	0.68	V	27500	3.8	-3.72	
1013	-1.624	.097	.147	.089	.074	.176	10.92	0.22	0.45	II	20300	4.2	-1.57	B3 ⁵	
1017	-1.495	.084	.131	.027	.060	.166	10.60	0.19	0.43	II	20500	3.8	-1.82	B2IV-V ⁵	
1021	-1.793	.086	.167	.156	.062	.157	11.35	0.19	0.40	II	18000	3.4	-0.97	B2.5V ⁵	
1028	-1.597	.090	.153	.047	.082	.162	10.86	0.21	0.42	II	19900	4.5	-1.53		
1037	-1.012	.132	.149	.129	.079	.217	11.39	0.31	0.56	V	21800	4.0	-1.46	B2V ⁵	
1043	-1.697	.144	.231	.124	.103	.214	11.10	0.34	0.55	V	17000	3.7	-1.72		
1057	-1.658	.104	.156		.075	.183	11.01	0.23	0.47	II	20000	4.0	-1.54		
1062	-1.968	.131	.297		.094	.176	11.78	0.31	0.45	II	13300	3.0	-0.71		

References and notes to table I.

- Houck (1965) or Jaschek *et al.* (1964).
- Levato and Malaroda (1980).
- Braes (1967b).
- This paper.
- Garrison and Schild (1979).
- Crawford *et al.* (1971).
- Derived from the mass and radius given by Burki *et al.* (1982).
- Graham (1965).
- Shobbrook (1983).
- Braes and Hovenier (1966).
- Levato and Morrell (1983).
- Garrison *et al.* (1977).
- Humphreys (1978).
- Spectral type according to Klare and Neckel (1977). That of Houck (1965) may be in error *viz.* B2I. According to the age (Sect. 3, 5) and to the distance of Crawford *et al.* (1971) (~ 1 kpc), it could be a non-member. According to Klare and Neckel's (1977) distance (1.3 kpc) a possible member.
- NM (foreground star) according to Crawford *et al.* (1971), member according to the distance derived in this paper, adopting that it is a main sequence star (spectral type O5.5).
- Crawford (1971).
- NM according to Crawford *et al.* (1971) and this paper. It is probably a background star.

TABLE II. — The differences of magnitudes V_J , colours $(B-V)_J$ and reddenings $E(B-V)_J$ between those based on this work and on other references.

	V_J	n	$\Delta(B-V)_J$	n	$\Delta E(B-V)_J$	n	Excluding (Br. No.)
Bok <i>et al.</i>	0.01	27	-0.02	28	0.00	27	for V: 122,672,673, 674,675,945,946
(1966)	±0.04		±0.02		±0.03		for B-V: 684
Braes (1967b)					0.00	172	650
					±0.06		
Crawford <i>et al.</i>					0.00	39	139,149,160,314,650,744
(1971)					±0.02		
Klare and Neckel	0.01	23	-0.02	24	-0.01	24	for V: 153
(1977)	±0.02		±0.01		±0.03		
Garrison and Schild	-0.01	15	-0.02	14	-0.03	15	
(1979)	±0.03		±0.02		±0.03		
Shobbrook (1983)					0.01	34	
					±0.02		

TABLE III. — The average reddenings in the six areas for members only.

Area	n	$\overline{E(B-V)_J}$	s.d.	Excluding (Br.No.)
I	32	0.35	+0.04	
II	32	0.45	+0.03	
III	14	0.48	+0.04	
IV W	13	0.42	+0.05	571 (1 ^m 03), 899 (0 ^m 80)
IV E	21	0.44	+0.04	314 (1 ^m 23), 317 (background star)
V	17	0.64	+0.07	

TABLE IV. — *Some physical parameters and ages for the brightest stars in the Sco OBI association.*

No HD	Br	Remarks	Sp	M_V	$\log T_{\text{eff}}$	B.C.	M_{bol}	$\log L/L_{\odot}$	M/M_{\odot}	$\tau(10^6 \text{ yr})$
152236	139	$\zeta^1 \text{ Sco}$	B1 Ia ⁺	-8.52	4.279	-1.5	-10.02	5.92	30	4.3
152247	142		O9.5 II:	-5.43	4.531	-3.2	- 8.63	5.36	30	3.5
152405	157		B0 Ib	-5.14	4.505	-3.0	- 8.14	5.16	25	4.5
152685	180	NM	B2 II-III	-3.96	4.362	-2.0	- 5.96	4.29	15	13.0
151804	103		O8 f(p)	-6.88	4.568	-3.4	-10.28	6.02	75	3.0
151932	114		WN 7	-6.49	4.602	-3.6	-10.09	5.94	25	3.9
152218	134		O9 IV SB	-4.92	4.531	-3.2	- 8.12	5.16	25	4.0
152223	136	NGC 6231	O6 III f	-5.69	4.531	-3.2	- 8.89	5.46	35	3.5
152246	141		O9:III:	-5.15	4.544	-3.3	- 8.45	5.29	30	3.5
152248	143	NGC 6231	O8f SB	-6.32	4.568	-3.4	- 9.72	5.80	30	2.9
152408	160		O7f	-6.71	4.574	-3.5	-10.21	5.99	60	2.7
152623	178		O8 V	-5.51	4.544	-3.3	- 8.81	5.43	35	3.5
326331	673	NGC 6231	O7 III f	-5.11	4.531	-3.2	- 8.31	5.23	27	4.0

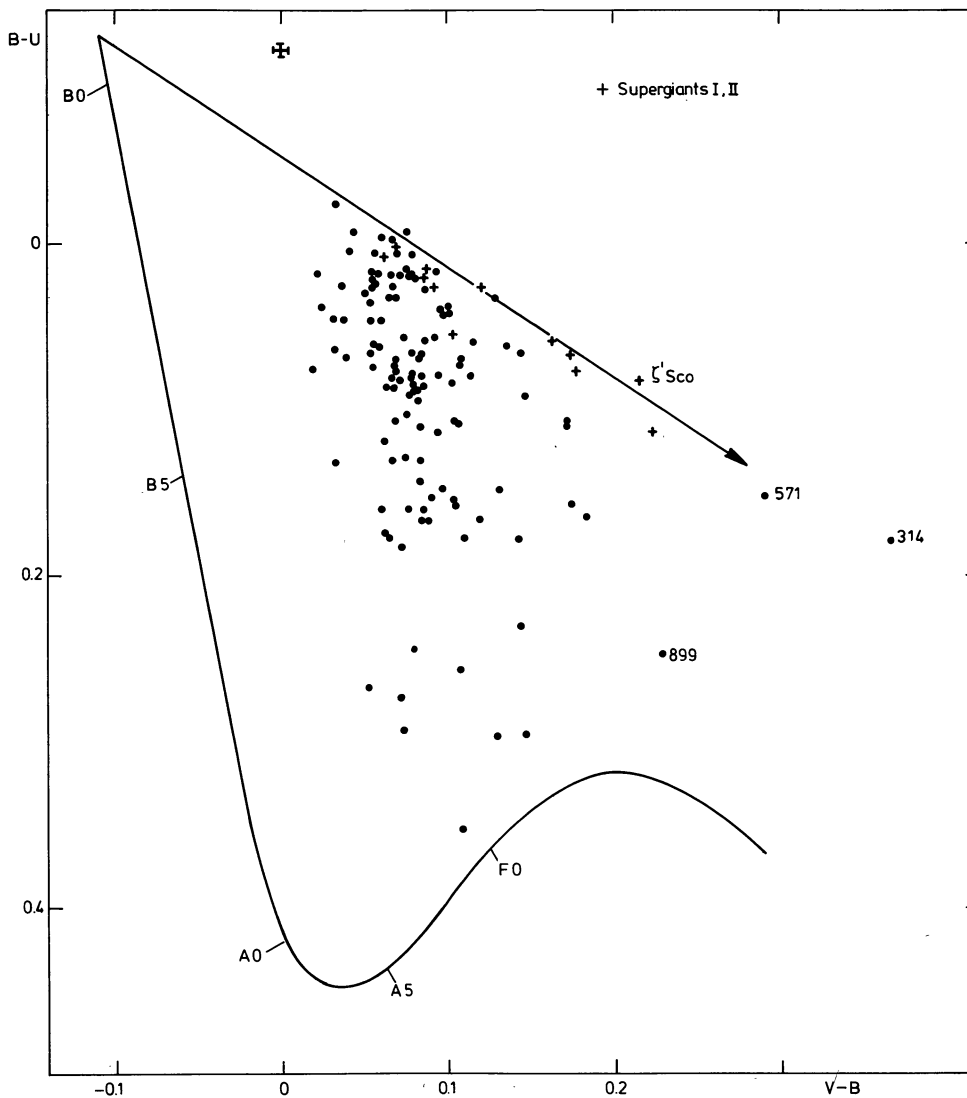


FIGURE 1. — The $V-B/B-U$ diagram (in log intensity scale) with the observed position of the members of Sco OBI including those of NGC 6231. The main sequence and the reddening trajectory (long arrow) are shown. The hypergiant $\zeta^1 \text{ Sco}$ is indicated and a few ordinary stars with high reddenings are identified with their Braes numbers. The error bars at the left top indicates the average error in the colours.

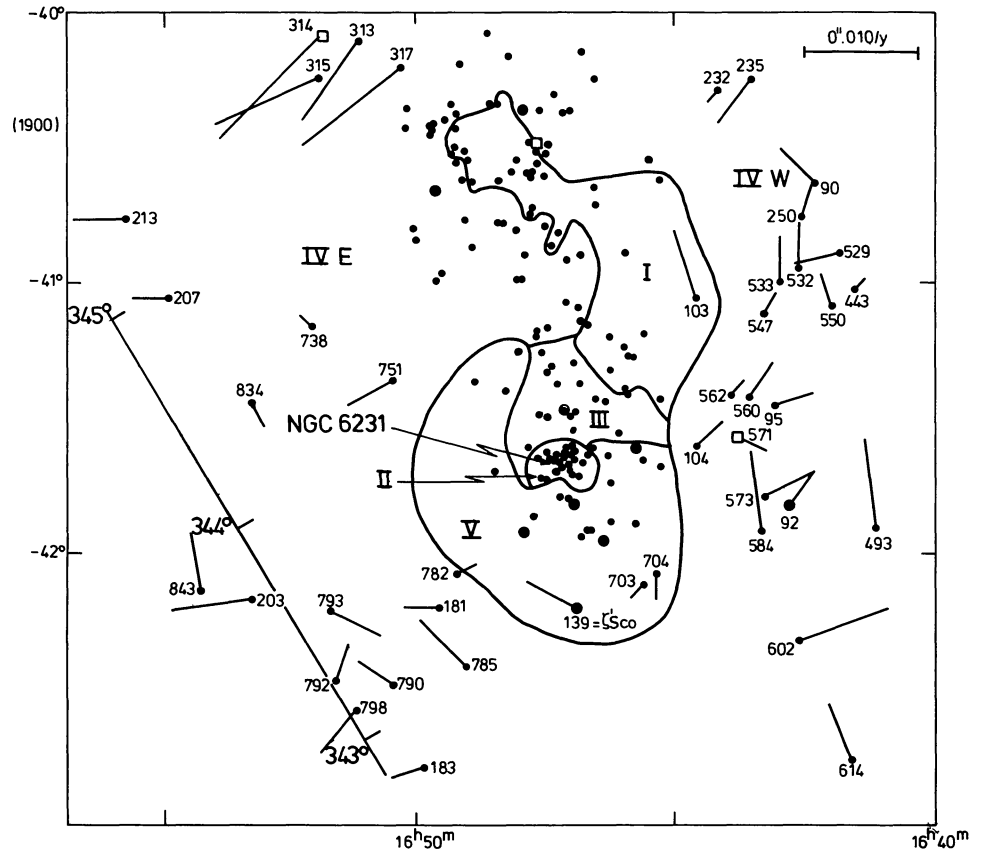
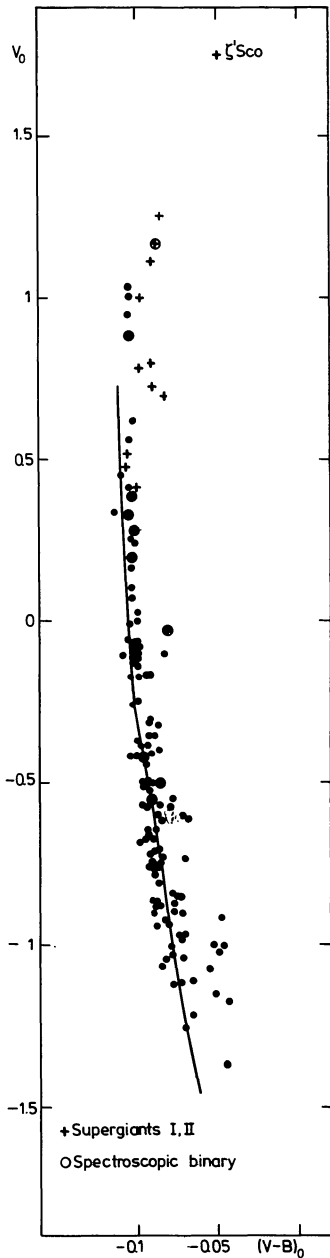


FIGURE 3. — A schematic chart of the association Sco OB1 and its environment, partly copied from Braes' (1967b) figure 4. Proper motions for the O-B5 stars in the outskirts are represented by vectors. The galactic equator is sketched ($l \sim 344^\circ$, $b \sim 1^\circ 5'$). The areas with a relative homogeneous reddening are outlined by curves and numbered I to V. Super- and hypergiants are encircled, except three stars which lie in the crowded part of NGC 6231. Members with exceptional high reddenings (last column of table III) are marked by open squares.

◀ FIGURE 2. — The $V_0/(V-B)_0$ diagram (in log intensity scale) for the members of Sco OB1 and NGC 6231. The ZAMS of the Thé *et al.* (1980) is shown. Encircled symbols are spectroscopic binaries according to Levato and Morrell (1983).

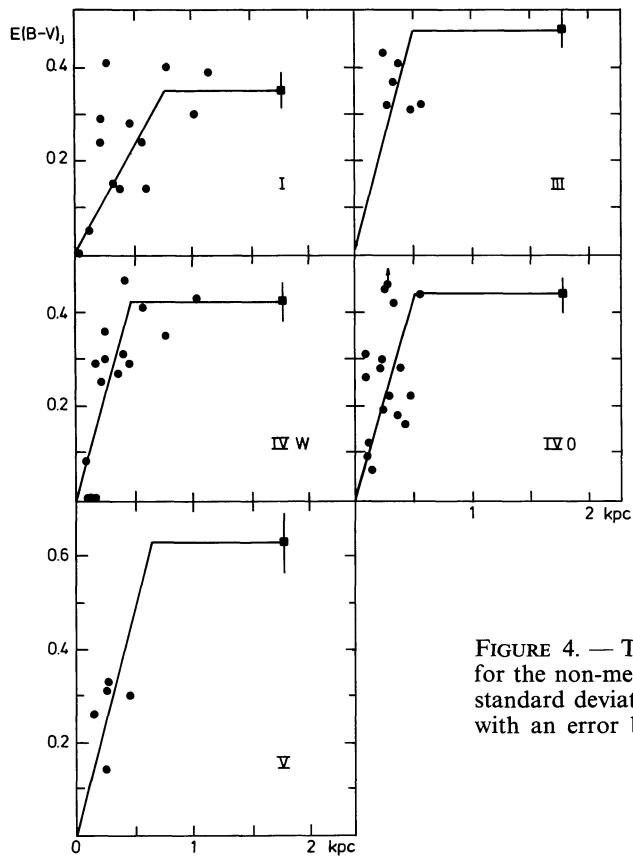


FIGURE 4. — The $E(B-V)_J$ plotted as a function of the distance r for the non-members in five areas. The average reddening and the standard deviation for the *members* is indicated by a black square with an error bar.

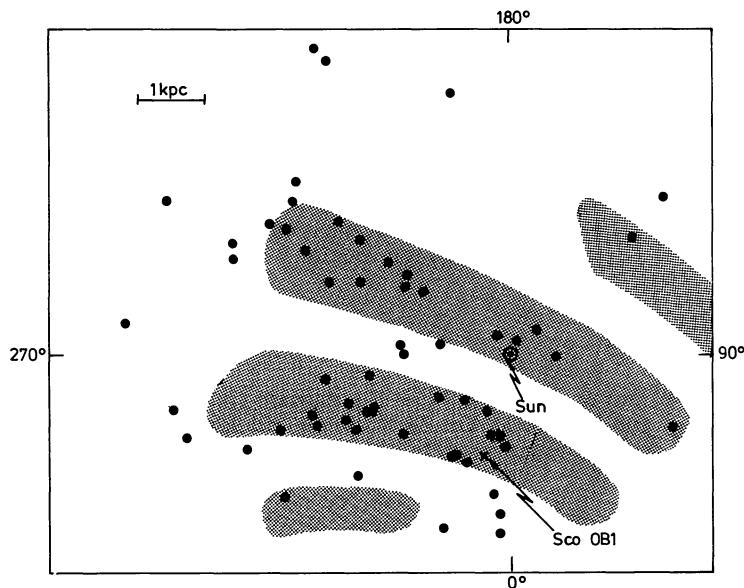


FIGURE 5. — The region around the Sun with the spiral arms traced by young clusters according to Fenkart and Bingeli (1979). The association Sco OB1 (including NGC 6231) is represented by a cross. Two clusters NGC 6242 and 6268, which lie in the sky close nearby are indicated by star-like symbols.