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A study of visual double stars with early type primaries.
IV. Astrophysical data (*)

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Summary. — Astrophysical parameters (MK class, colour excess, absolute magnitude, distance, effective temperature, mass and age) are derived from calibrations of the *uvbyβ* indices for the members of 253 double stars with O or B type primaries and faint secondaries. The photometric spectral classification is compared to the MK classes and the agreement is very good. The derived data together with spectroscopic and *JHKL* data are used for deciding which pairs are likely to be physical and which are optical and it is shown that 98 (34 %) of the secondaries are likely to be members of physical systems. For 90 % of the physical pairs the projected separations between the components is less than 25000 AU. A majority of the physical secondaries are late type stars and 50 % of them are contracting towards the zero-age main-sequence. Also presented are new *uvbyβ* data for 43 secondaries and a computer programme for determining astrophysical parameters from *uvbyβ* data.

Key words : visual double stars — early stellar evolution — photometry.

1. Introduction.

This is the fourth in a series of articles describing an investigation of young double stars with the main purpose of detecting a group of young stars in order to study characteristics of early stellar evolution. The first steps have been to survey spectroscopically and photometrically a large number of double or multiple systems with O or B type primaries selected from the catalogue by Jeffers *et al.* (1963) and the results have been presented in the previous three articles. Most of the data have been obtained by new observations but much is also collected from the literature. The scientific background of this investigation is laid out in more details in Paper I (Gahm *et al.*, 1983) and in a forthcoming article (Lindroos, 1985). In Paper I the spectroscopic results (MK classes, notes on spectroscopic peculiarities, etc.) and comments on the relation between the components (common proper motion, common radial velocity, etc.) are presented for the members of 254 double or multiple systems. In Paper II (Lindroos, 1983) *V* magnitudes and *uvbyβ* indices are given for the members of 248 systems and *JHKL* magnitudes for the members of 45 systems. Papers I and II also provide the separations between the components. A list of radial velocities was given in Paper III (Gahm, 1982). The overlap of the photometric and spectroscopic material is not complete, particularly for systems with separations less than 10″ where the secondary is difficult to measure photometrically.

In the present work the photometric data are used for deriving astrophysical parameters for the components and to decide which pairs are optical and which are likely to be physical. By comparing the ages of the physical systems and the contraction times to the zero-age main-sequence (ZAMS) for theoretical model stars, contracting secondaries are identified. The discussion of these stars is reserved for a coming article in the main journal. Also presented are new *uvbyβ* indices for some secondaries. A computer programme for deriving astrophysical parameters from *uvbyβ* indices is described in Appendix A. Definitions of some indices and relations between the *uvby* and *UBV* systems are given in Appendix B.

2. New photometric data.

The photometric data were basically collected between 1977 and 1981 using the ESO facilities in Chile and are presented in Paper II. However, in February and March of 1983 several of the secondaries were re-observed with the ESO 50 cm and 1 m telescopes. Stars of special interest were selected in addition to stars for which the previous results were uncertain because the stars are faint and/or the separation from the primary is small or because of possible light variability. The reductions were performed using the programmes described by Lindroos (1980) and the results are presented in table I. As a rule, the earlier observations are included in the new mean values which in most cases are not changed by much and the errors of a single observation as given in the table are not reduced compared to the earlier results. The question of variability will be discussed in a forthcoming article.

(*) Based on observations collected at the European Southern Observatory, La Silla, Chile.

Description of table I

Column 1 : HD number and component designation as in Paper II.
Column 2 : Number of observations in *uvby*.
Columns 3-10 : The indices and the errors of a single observation in units of 0.01 magnitudes.
Column 11 : The number of observations in Hβ.
Columns 12, 13 : The Hβ index and the error of a single observation in units of 0.01 magnitudes.
Column 14 : An asterisk (*) indicates that there is a comment to the star in the section with notes.

3. The primaries.

The double stars selected for this investigation have a primary component of spectral type earlier than A0 and in the $[m_1]$, $[c_1]$ diagram in figure 1 almost all of them fall in the region of early type stars, (see Strömgren, 1966) while only 7 fall outside. Of the latter the following four stars did not qualify as members of the early group : HD 44944 A, 83965 A, 152408 AB and 169337 AB and they are discussed in the section with notes to individual stars. The parameters described below were derived by the computer programme presented in Appendix A. Each star has been studied to ensure that the results are not affected by emission lines, duplicity and other peculiarities.

3.1 COLOUR EXCESS, INTRINSIC COLOURS, ABSOLUTE MAGNITUDE, DISTANCE. — For the primaries which belong to the early group the calibration by Crawford (1978) for B stars is used to derive the following parameters : colour excess $E(b\text{-}y)$, intrinsic colours $(b\text{-}y)_0$, m_0 and c_0, the absolute magnitude M_v, the height above the ZAMS in magnitudes ΔM_v and the MK class. The result is presented in table VI. It should be pointed out that the validity of the calibration is actually limited to luminosity classes V-III but here it was applied also to include a few more luminous stars. The method to determine the intrinsic colours is iterative and the iterations were stopped when the difference between two successive $(b\text{-}y)_0$ was less than 0.0005. From $(b\text{-}y)_0$ the colour excess $E(b\text{-}y)$ is obtained and then m_0, c_0 and V_0 are derived from the relations specified in Appendix B. Sometimes $E(b\text{-}y)$ turned out to be negative and in these cases it was assumed that the stars are unreddened. The negative values are printed in table VI, however.

For B stars c_0 serves as a good indicator of the temperature and β as a good indicator of the luminosity. In figure 2 the observed β index is plotted against c_0. It is seen that the distribution of the primaries over temperature is rather uniform and by comparing with figure 10 by Crawford (1978) that most of them are of luminosity classes V-III. Only a small number of stars fall below the ZAMS by more than 0.01 in β.

The absolute magnitude is determined from the β index and for stars with c_0 between 0.20 and 0.90 the correction of $-10\,\Delta\beta$ (where $\Delta\beta = \beta_{\text{ZAMS}} - \beta_{\text{observed}}$ for a given c_0) is applied in order to obtain the true magnitude. For a small number of stars β is less than 2.55 and here the $M_v(\beta)$ calibration by Fernie (1965) is applied. The height above the ZAMS is defined as $\Delta M_v = M_v(\beta_{\text{ZAMS}}) - M_v$ for a given c_0. For some stars later than B9 β_{ZAMS} is larger than 2.900, the upper limit in Crawford's calibration. In these cases $(b\text{-}y)_0$ is transformed to $(B\text{-}V)_0$ by the relations in Appendix B and M_v(ZAMS) is taken from Schmidt-Kaler (1982).

The distances are calculated after correction for interstellar extinction and for stars noted to be spectroscopic binaries in Paper I it is corrected for equally bright components. Such cases are indicated by « SB » in the last column of table VI. In figure 3 the colour excess $E(b\text{-}y)$ is plotted against the distances of the stars. Out to 100 pc the extinction is small but farther out it begins to build up. Yet, even at large distances many of the stars are only weakly reddened, $E(b\text{-}y) < 0.05$. However, interstellar reddening is important for most of the stars.

The error in the absolute magnitude is first of all dependent on the error in the β index but for stars with c_0 between 0.20 and 0.90 c_0 must also be considered. From Paper II a representative error in β of 0.005 was found for the primaries. Taking into account the error in transforming to the standard system the maximum error is 0.010. The upper limit for the error in $M_v(\beta)$ is then 0.7 at $\beta = 2.56$ (Crawford, 1978, table V) and decreases rapidly to a constant level of 0.1 at $\beta = 2.75$ and larger. Taking the average β values for luminosity class V from Crawford (1978) the errors in $M_v(\beta)$ are the following : 0.5 at B0, 0.3 at B2.5, 0.2 at B5 and 0.1 at B8. For luminosity class III the errors are 0.1 mag larger. The upper limit to the error in c_0 is 0.015. This propagates to an error in β_{ZAMS} of 0.005 so that the error in 10 $\Delta\beta$ is less than 0.12. The maximum error expected in M_v is shown in table II as a function of spectral type and luminosity class. The error in the height above the ZAMS is derived from the errors in M_v and M_v(ZAMS). The result for luminosity classes V and III is shown in table II. In addition to these errors the uncertainty in the calibration itself must be considered. This amounts to 0.2 magnitudes for late B stars but is larger for the early types.

3.2 PHOTOMETRIC MK CLASSES. — To derive photometric spectral types for the B stars the relations between *uvbyβ* indices and spectral type given by Crawford (1978) are used for luminosity classes V, IV and III. The relation for V is also used for IV. For main-sequence stars earlier than B0 and for giants of classes I and II the relations derived by Lindroos (1981) are used. The luminosity class is then derived from the spectral type and absolute magnitude using the calibration by Schmidt-Kaler (1982).

To check the reliability of the photometric classification the result was compared with the spectroscopic MK classes given in table VI. For this comparison the following spectral subtypes and luminosity classes were used : O6, O6.5, O7, ... B2.5, B3, B4, ... B9, B9.5, A0 and V, IV, III, II, I. The result is presented in figure 4 which shows the number of stars with different values of ΔS (= photometric spectral subtype − MK subtype) and ΔL (= photometric luminosity class − MK luminosity class). It is seen that the consistency of the two classifications is good. For 41 % of the stars the results match perfectly while for 82 % the agreement is within one luminosity class or spectral subtype. Conflicting cases are predominantly of the kind where the photometric spectral classification provides earlier spectral types than the MK classification.

The luminosity classification was studied by Lindroos (1981) and it was found that stars of spectral type B5 and later in comparison to earlier types are more often given a higher luminosity from the photometry than from the MK classification. It is interesting to note that the $-10\,\Delta\beta$ correction to M_v, which increases the luminosity, only is applied to the late B stars.

3.3 EFFECTIVE TEMPERATURE AND LUMINOSITY. — The effective temperature T_e is determined from c_0 or from the a index defined by Strömgren (1966). The calibration by Davis and Shobbrook (1977) is used for c_0 and their calibration for luminosity class I is also applied to luminosity class II. For the late B and early A type stars the a index is used with a method given by Grosbøl (1978). For temperatures derived from c_0 the maximum error in $\log(T_e)$ is expected to be 0.01.

To determine the bolometric correction the calibration by Davis and Shobbrook is used if c_0 is large enough, otherwise the calibration by Flower (1977) is used. The luminosity $\log(L) = \log(L/L_{\text{sun}})$ is calculated by taking $M_{\text{bol}}(\text{sun}) = 4.76$. For a B0 III star the error in $\log(L)$ is estimated to be less than 0.3 and for main-sequence stars later than B5 to be less than 0.15.

3.4 THE ZERO-AGE MAIN-SEQUENCE FOR B STARS. — The positions of the primaries in the HR diagram is shown in figure 5. Inserted in the figure are also the theoretical ZAMS by Iben (1965) extrapolated to the 30 solar mass model by Stothers (1966) and the more recent one by Hejlesen (1980) together with the observed ZAMS by Crawford (1978) which is used in this work. The zero-age line by Hejlesen practically coincides with the one calculated by Stothers (1976) using the Cox-Stewart opacities. Hejlesen's calculations are for a chemical composition of $X = 0.73$, $Z = 0.03$ while Stothers used $X=0.73$, $Z = 0.02$. Both these zero-age lines lie to the right of the one by Iben ($X = 0.708$, $Z = 0.02$). The shift is approximately 0.02 to 0.03 in $\log(T_e)$.

The most striking feature of figure 5 is that the stars and the observed ZAMS lie so far to the right of the theoretically predicted ZAMS. At the upper main-sequence the difference is 0.07 in $\log(T_e)$ but the agreement improves at lower temperatures. Seen as a problem of the luminosity the discrepancy is very large. At $\log(T_e) = 4.5$ Crawford's ZAMS is more than a magnitude brighter than that calculated by Iben. Although the agreement is somewhat improved in the later models it remains large, especially at the higher temperatures. The difference in $\log(T_e)$ between Hejlesen's and Crawford's ZAMS is about 0.05 at $\log(T_e) = 4.4$ and decreases to 0.02 at $\log(T_e) = 4.3$. For temperatures below $\log(T_e) = 4.2$ Hejlesen's ZAMS very closely coincides with Crawford's and they both lie to the right of Stothers' ZAMS. Part of the difference between Hejlesen's and Stothers' ZAMS is certainly due to the difference in chemical composition of the models. Concerning the lower part of the ZAMS for the B stars it can be noted that the discrepancy discussed by Underhill (1980), namely that her stars fall approximately 0.05 in $\log(T_e)$ to the right of Stothers' ZAMS is not evident for this sample.

Although it appears that the observed and theoretical zero-age lines agree rather well for $\log(T_e) < 4.3$ they still disagree at higher temperatures. However, this discrepancy is largely reduced if one adopts the ZAMS calculated by Stothers (1976) using Carson opacities. This ZAMS coincides with the one mentioned above at the lower temperatures but for $\log(T_e) > 4.3$ it is increasingly more luminous. At $\log(T_e) = 4.5$ it lies only 0.2 units in $\log(L)$ below Crawford's ZAMS. Observational support for these models is presented by Underhill (1980).

The major concern regarding the position of the zero-age line for this work is the effect it has on the age determination which is discussed in the next section.

3.5 AGE AND MASS. — The age and mass for the primaries are determined from the height above Crawford's ZAMS and the effective temperatures by comparison with the evolutionary tracks and isochrones calculated by Hejlesen (1980) for a chemical composition of $X=0.70$, $Z=0.03$ corresponding to population I. For stars with $\Delta M_v < 0.10$ no reliable age can be derived and in such cases as for cases with negative ΔM_v upper limits to the age are determined by adding to ΔM_v the expected error as given in table II. For a limited number of primaries the age and mass are estimated from the evolutionary tracks calculated by Iben (1967) or by Stothers (1966). The primaries for which the age and mass could be determined are plotted in the ΔM_v, $\log(T_e)$ diagram in figure 6 together with isochrones for log (age) = 6.0 to 8.0. Most of the primaries are in the phase of core hydrogen burning and their typical age is about 30 million years.

The errors in the age depend upon the errors in $\log(T_e)$ and ΔM_v. From figure 6 it is clear that with an error of only 0.01 in $\log(T_e)$ the uncertainty in the age is dominated by the error in ΔM_v. It is also evident that the age determination is much more uncertain close to the zero-age line than somewhat higher up where the isochrones are more vertical. From the distribution of stars in figure 6 one finds that a representative value for ΔM_v is 0.7 magnitude. From the errors in ΔM_v given in table II the maximum uncertainty in the age is the following :

B0 : $0 < \log(\text{age}) < 6.9$
B2 : $6.5 < \log(\text{age}) < 7.4$
B5 : $7.2 < \log(\text{age}) < 7.7$
B8 : $7.8 < \log(\text{age}) < 8.0$
A0 : $8.4 < \log(\text{age}) < 8.5$

From this result it is clear that the age for any particular star has a large uncertainty. For a B5 star the listed range corresponds to an age between 15 and 50 million years. Systematic errors in the ages cannot be excluded, particularly not because of the discrepancy between the observed and theoretical ZAMS. If indeed the observed ZAMS is too luminous it means that the height above the ZAMS as defined here is too small which leads to an underestimation of the age. Crawford's ZAMS coincides with the isochrone corresponding to an age of 5 to 10 million years. However, it is more likely that the theoretical models are too hot and in that case the effects on the age determination is very small. By shifting Hejlesen's ZAMS in $\log(T_e)$ so that it coincides with Crawford's ZAMS one finds that the ages would be a few million years smaller. The sensitivity of the ages to the chemical composition is not very high. By taking $X=0.70$, $Z=0.04$ the stars would typically be 3 million years younger.

3.6 COMPARISONS WITH OTHER INVESTIGATIONS. — Several of the primaries have been included in previous investigations. 21 of them are included by Grosbøl (1978) who derived the same parameters but from other data and with other calibrations. In that work the intrinsic colours were calculated from an unpublished relation by Strömgren between $(b\text{-}y)_0$ and $[u\text{-}b]$. The effective temperature was derived from $[u\text{-}b]$ with the calibration by Davis and Shobbrook (1977) or from the a index for stars with large $[u\text{-}b]$. β (ZAMS) was derived from $[u\text{-}b]$ with an unpublished relation by Strömgren and M_v(ZAMS) was derived from β(ZAMS) with the calibration by Fernie (1965). Depending on the value of $[u\text{-}b]$ the latter calibration or an unpublished one by Strömgren were used to derive M_v and ΔM_v. Age and mass were determined as in the present work. The result of the comparison is presented in table III. The number given for each parameter is the difference between the result of this work and that of Grosbøl. The agreement in colour is excellent. The overall agreement in M_v and ΔM_v is also good but for some stars the differences are large. The height above the ZAMS is generally smaller in Grosbøl's work and for stars of higher luminosity the absolute magnitude is larger. The former result indicates that the ZAMS used in this work (Crawford, 1978) lies lower than the ZAMS used by Grosbøl. The results for $\log(T_e)$ also agree except for one luminosity class II star. For the age, log (a), and the mass, log (m), the results agree despite the differences in ΔM_v.

Absolute magnitudes have been derived by Eggen (1975, 1982) using calibrations of the type $M_v = f([u\text{-}b], \beta)$. Some 40 of the primaries are included in his studies and it is possible to compare the derived values for 36 of them. The result is shown in table IV and it is seen that for 23 stars the agreement is satisfactory (often better than a few tenths of a magnitude) but for 13 the difference is larger than $0^m.5$. No systematic difference is evident except that giants generally are brighter in the present work. A few more primaries are included by Eggen (1983) as indicated in the section of notes. The agreement in absolute magnitude is quite good for these stars. The absolute magnitude of the primary is of great importance in this work since it is used for evaluating if a system is physical or optical (Sect. 4.1). As a support for selecting the calibration by Crawford (1978) it can be noted that the absolute magnitudes derived in the present work agree better to the MK class (taking the relations by Schmidt-Kaler, 1982) than those calculated by Eggen.

$E(b\text{-}y)$ has been compared with $E(B\text{-}V)$ given by Whittet and van Breda (1980) using $E(b\text{-}y)/E(B\text{-}V) = 0.73$ (Crawford, 1973). The results are consistent except for HD 124471 which otherwise also is peculiar.

11 of the primaries for which distances could be derived have positive parallaxes in the catalogue by Jenkins (1963). In table V the photometric and trigonometric parallaxes are compared. With two exceptions the distances match well. For HD 87901 (Regulus) the distances agree very well and at such a distance the absolute magnitude of the star corresponds to the photometric result B8 III rather than to the established MK class B7 V. If the luminosity class is V the spectral type must be B5/6 which is contradicted by c_0. Similar results are given by Eggen (1983).

3.7 COMPOSITE PRIMARIES. — In many cases the separation between the components is so small that one or more secondaries are included in the photometric measurement of the primary. Depending on the brightness and colour difference between the components the parameters derived for the primary will be more or less affected by this disturbance. This problem was investigated by Lindroos (1981) and it was concluded that if the magnitude difference ΔV is more than 4.0 the disturbance can be neglected. 19 of the composite primaries do have $\Delta V < 4.0$ and for them the dereddened colours and derived parameters are uncertain. These cases have been marked with an asterisk (*) following the component designation in table VI.

4. The secondary components.

The systems were selected to have secondaries brighter than $V = 12.0$ with separations less than 60″. The first requirement was demanded by observational constraints and the second was set to exclude secondaries which very likely are optical. While a limited number of pairs with larger separations were included (e.g. Regulus, $d = 177''$) the photoelectric observations proved that many of the secondaries were considerably fainter than listed by Jeffers *et al.* (1963). Systems with large magnitude differences were also favoured in order to detect late type secondaries. The distribution of the secondaries over separation and magnitude difference is shown in figure 7. The majority of the secondaries have separations between 5″ and 30″ and are 2 to 7 magnitudes fainter than the primaries. The distribution of the secondaries over spectral type was studied in Paper I and was found to be different from that of normal field stars, indicating that a significant number of the secondaries are likely to be physical. To find these is the main purpose of this investigation.

4.1 CRITERIA FOR OPTICAL SECONDARIES. — For many investigations the purpose of using double stars have been to study relationships between e.g. magnitudes and spectral types or to derive and test various methods for determining the absolute magnitude. In this work existing calibrations are applied to derive properties for the stars from which it can be decided if a system is likely to be physical or if it is optical. In this way the use of the photometric and spectroscopic data is twofold. First it is used to exclude optical components and secondly to derive basic physical parameters for the qualified physical secondaries.

Both of these goals could be achieved for the B, A and F type secondaries by applying the calibrations by Crawford (1975, 1978, 1979) to derive intrinsic colours and absolute magnitudes. The distance modulus and colour excess for the primary and secondary could then be compared to see if the system is optical. If not, the results could be used to determine the temperature and luminosity for the secondary. However, the errors in the indices are rather large because the secondaries are faint and furthermore many of them are later than G0 for which no calibrations exist. The former is particularly true for c_1 which is used as a luminosity parameter for A and F stars. Instead, another method was preferred which has the advantage to rely basically on the result for the primary for which the photometry is of high accuracy. In this method all the secondaries are « forced » to be physical companions to their respective primary by applying the colour excess and distance modulus as derived for the primary. Parameters derived in this way are denoted by a prime (′) below. A secondary is classified as an optical component if any of the following criteria is fulfilled.

1. The absolute magnitude, M_v', places the star more than 0.5 magnitudes below the ZAMS at $(b\text{-}y)'$, (or at the $(b\text{-}y)_0$ corresponding to the spectral type). Primaries noted to be spectroscopic binaries have been corrected for equally bright components.
2. M_v' inconsistent with the MK classification.
3. $(b\text{-}y)'$ (or c' for B stars) inconsistent with the MK classification.
4. For stars earlier than G0 the difference between M_v' and $M_v(\beta)$ or $M_v(c')$ is larger than 1.0 magnitudes.
5. The indices m', c' and β are inconsistent with the MK class corresponding to $(b\text{-}y)'$ and M_v'.
6. The components have different radial velocities in Paper III.
7. Astrometric data show that the system is optical.
8. Some secondaries which did qualify as physical companions by the criteria above were still considered as optical if their position in the HR diagram would be in serious conflict with the evolutionary tracks and the assumption of coeval formation of the primary and secondary.

The absolute magnitudes of the primaries enters directly in criteria 1 and 4 and as mentioned earlier their values are not always undisputed. In some difficult and unclear cases this has been taken into consideration but in most cases the uncertainties should not be greater than the limits chosen in these criteria. Criterion 4 must be used with care since many young stars (e.g. T Tauri stars) are suspected to have strong ultraviolet excess emission. The material includes 7 stars for which $M_v(c_0) - M_v' > 1.0$ and these were carefully checked. However, no ultraviolet excess is evident and they are classified as optical components.

An advantage of this method is that background main-sequence stars are detected since they will fall below the ZAMS. A disadvantage is that foreground stars will be given higher luminosity and will tend to be pushed into areas of the HR diagram where contracting stars are expected. From the spectra it was normally impossible to distinguish between luminosity classes V and IV and in such cases only criteria 6, 7 or 8 could be used to decide if the secondary is optical. Most of the stars that would have fallen high above the ZAMS were rejected by these criteria. Criterion 6 is especially important for secondaries with small separations for which no photometry is available. For the larger separations it can be noted that practically all the systems with discordant radial velocities also are classified as optical by the photometric criteria.

The result of the evaluation is presented in column 2 of table VI. Physical companions are noted by « PH » and optical by « OPT ». Cases where the result is uncertain are indicated by a « ? » after the most likely relation. For a few stars no evaluation of the relation was possible and these are indicated by only a « ? ». The combination of photometric and spectroscopic data proved to be a powerful tool for the detection of optical components. 63 % of the secondaries are classified as optical while for 3 % the relation is undecided. The remaining 34 % will in the following be regarded as physical, this includes the 5 % for which the physical relation is more uncertain (PH ?). Several of the systems have been included in other investigations in which the question of the relation between the components has been addressed. It is satisfying to find that in most of the cases the verdict is the same. Many pairs are listed as binaries in Paper I and in the Bright Star catalogue (Hoffleit and Jaschek, 1982) and most of them are also classified as physical here. The frequency of physical secondaries is also higher for pairs noted with common proper motion in Paper I : 40 % compared to 22 % for the rest.

4.2 PHOTOMETRIC MK CLASSES FOR THE SECONDARIES.

— For the secondaries with $(b\text{-}y)' < 0.000$, i.e. B type stars, the MK class is determined as for the primaries. For spectral types between A2 and G0 the spectral type is derived from $(b\text{-}y)'$ using the calibrations by Crawford (1975, 1979). The luminosity class is then derived from M_v' through the calibration by Schmidt-Kaler (1982). For stars later than G0 the latter calibration is used both for spectral and luminosity class. A secondary is regarded as optical if $(b\text{-}y)'$ differs from the value expected from the spectroscopic MK class by an amount corresponding to two subtypes. Taking into account the errors this normally means a difference of 0.1. For optical secondaries earlier than G0 the MK class is estimated by application of Crawford's calibrations if the errors in the indices are small enough. Otherwise the spectral type is estimated from the bracket indices using the results by Oblak (1976) or Olsen (1979).

4.3 THE HEIGHT ABOVE THE ZAMS, LUMINOSITY AND EFFECTIVE TEMPERATURE.

— The height above the ZAMS is determined as for the primaries for the B type secondaries. For later spectral types the ZAMS by Crawford (1975, 1979) or by Schmidt-Kaler (1982) is used.

For the B type stars $\log(L)$ and $\log(T_e)$ are derived as for the primaries. For A and F type stars the effective temperatures are determined from $(b\text{-}y)'$ using the calibration by Philip and Relyea (1979). For still later stars the compilation by Novotny (1973) is used. The bolometric corrections are taken from Flower (1977) or Novotny (1973). For luminosity class IV mean values for class V and III are used.

The error in $\log(T_e)$ is estimated to be less than 0.03. The luminosity is mainly dependent on the distance which is determined from the absolute magnitude of the primary. The error in the luminosity of the secondary is therefore depending on the primary. The error in $\log(L)$ is estimated to be less than 0.20 for a B2 V primary and less than 0.10 for a B9 V primary.

4.4 SYSTEMS WITH VERY REDDENED SECONDARIES.

— Many secondaries have $(b\text{-}y)'$ much larger than is expected from the spectroscopic MK class. The majority of these are obviously optical since according to the luminosity class they are more distant than the primary component. However, for the following secondaries HD 38426 B, 74531 B, 135240 B, 141468 B, 149249 C and 185507 B it was not obvious that the reddening is interstellar since the luminosity classification is uncertain. The spectrograms indicate luminosity classes V or IV but it is not excluded that they are giants. Several of these stars were observed in *JHKL* (Paper II) in order to detect possible infrared excess emission from circumstellar dust. However, no excess emission is apparent but the *uvbyJHKL* data indicate that these stars are distant and reddened giants and they are classified as optical components.

4.5 FRACTION OF PHYSICAL SECONDARIES IN DIFFERENT INTERVALS OF SEPARATION AND MAGNITUDE DIFFERENCE. — The distribution of optical and physical secondaries over separation and magnitude difference $\Delta V = V_B - V_A$ is shown in figure 7 and the percentage of physical secondaries in different intervals of separation and magnitude difference is shown in figures 8 and 9. It is seen that the probability of finding a physical secondary is small for large separations ($> 50''$) and for large values of ΔV (> 7). The fraction of physical secondaries increase, as expected, with decreasing separation and has a rather flat maximum around 38 % between 10″ and 40″. Below 10″ this fraction decreases rather than increases as is the case for double stars in general. Most likely this is due to selection effects. The sampling is not complete in either ΔV or separation, e.g. at the smaller separations the observed pairs tend to be those with smaller ΔV. This incompleteness also affects differently stars of different types. There are e.g. few G and K type stars below separations of 10″ and at the larger separations many of them are physical companions. Other possibilities have also been investigated. Straylight from the primary is a problem at smaller separations and could perhaps have introduced errors in the observations of secondaries. This is not likely, however. At such separations only secondaries with small ΔV were measured and the disturbance cannot have caused any large error in the photometry. Besides, for the closer pairs, separations less than 10″, photometry is lacking for many of the secondaries (see Fig. 1 in Paper II) which have been observed spectroscopically. For this group most of the optical classifications (70 %) are based on criteria 1 or 2, i.e. the absolute magnitude M'_V of the secondary disagrees with the MK class. Since photometry is lacking M'_V is calculated from the visual estimates of the brightness as given by Jeffers *et al.* (1963), which for secondaries with larger separations often are found to be wrong by up to one magnitude (to be discussed in Paper V). However, except for some stars, the difference required to make the systems physical is much larger than this and such errors are less likely. Thus, although better photometry of the secondary could possibly increase somewhat the fraction of physical pairs, it could not be dramatically changed. Another possible reason for errors in M'_V is that, due to the small separations, several observations of primaries include the light from the secondary which could affect the results, particularly the absolute magnitude. However, this is unlikely due to two reasons, firstly, the secondaries are generally a few magnitudes fainter than the primaries and no disturbance is expected from the results of section 3.7, secondly, errors of the required amount would cause a difference between the photometrically derived luminosity class and the MK class which is not evident. As the small number of physical systems with small separations appear to be correct, one can instead question if for the wider pairs the fraction of physical ones has been overestimated by the method employed. The overlap between the photometric and spectroscopic data is far from complete. In particular many secondaries have not been observed spectroscopically and therefore some of the criteria for detecting optical cases cannot be applied to all stars. However, by comparing the fractions of physical secondaries amongst those which have been observed both spectroscopically and photometrically and those which have not, it is found that they are equal. Except for criteria 1 and 2 as discussed above, none of the other ones are more frequently applied at any particular interval of separation than the rest. The conclusion from this discussion is that the decrease of the percentage of physical systems with small separations is unlikely to be caused by the method used for distinguishing the optical from the physical secondaries but more likely is the result of selection effects.

4.6 COMPARISON BETWEEN OPTICAL AND PHYSICAL SECONDARIES. — The optical and physical secondaries have been marked differently in the $[m_1]$, $[c_1]$ diagram in figure 1 and in the ΔV, separation diagram in figure 7. The distribution of the two categories of secondaries in these diagrams is not different. In the latter figure it is seen that physical secondaries are rare at large and small separations but otherwise it is not possible to distinguish them from optical secondaries. A common procedure to achieve this has been to define a maximum separation $d_{\max}$ for a given total brightness and to regard systems with smaller separations as physical, see e.g. Dommanget (1967). To test if such a criterion can be applied to this material the combined magnitude of the primary and secondary have been plotted against separation in figure 10. Again there is a complete mixture of optical and physical systems and it is not possible to decide whether a system is physical or optical only from the brightness and the separation.

Kubikowski *et al.* (1959) concluded on statistical grounds that the limit below eliminated practically all optical pairs from The New General Catalogue of Double Stars by Aitken (1932), which includes most stars in this study.

$\log(d_{\max}) < 2.8 - 0.2 \times m$ (m is the total magnitude). This relation is plotted in figure 10 and it is evident that the conclusion of Kubikowski *et al.* does not apply to this sample. However, it is true that systems which do not fulfil this relation almost always are optical.

Kubikowski *et al.* (1959) also calculated upper limits to the separations for given V and ΔV at which the probability of encountering an optical pair is $P = 0.05$. Applying their result to this material means that only a few percent of the secondaries should be optical contrary to the fact that at least 60 % are found to be optical. Part of this large discrepancy is that the stars in this sample are concentrated to the galactic plane (Paper II) while the statistical calculations were based on average star numbers per square degree.

A probably better statistical approach to the question of deciding whether a specific pair is physical or not is by counting the number of stars in the region. Formulae for such calculations are also given by Kubikowski *et al.* (1959).

Lindroos (1981) studied the relations between the distances of the primaries and the secondaries and found that most of the optical secondaries are background objects. The reason for this is that the late type physical secondaries on the main sequence are too faint to be seen at the distances of many of the primaries and since systems with large magnitude difference were favoured many intrinsically bright background objects were included. This can be seen from table VII which shows the distribution of secondaries over spectral type. Many are of spectral types B or A but of these only 36 % are physical. The remaining 64 % are mostly background objects. Surprisingly few (23 %) of the F type secondaries are physical while 46 % of the G and K secondaries are likely to be physical. The reason for this is probably that due to their higher intrinsic brightness the F stars are seen at larger distances and many of them are therefore background objects. The number of physical secondaries are quite evenly distributed over spectral type over the range B to K.

5. The physical secondaries.

Of the total of 290 secondaries included in the investigation 98 remain as likely physical components in 92 systems. For 14 of these secondaries the physical relation is more uncertain but they are included in the discussion below. The combinations of MK classes for the primaries and secondaries are summarized in table VIII. The primaries are normally main sequence stars. The number of physical systems with very early type primaries is small. This is partly a selection effect since few such primaries were included but from evolutionary effects it is also not likely to find many systems with O type primaries and late type secondaries. Furthermore, such primaries are generally so distant that late type main sequence companions would be too faint for this investigation. Primaries of spectral type B2 and later are often found to have a late type companion. There is also an indication that the main-sequence secondaries of very late type (G and K) only accompany the later B type primaries. The K type secondaries of primaries of type B3 and earlier all have luminosity class IV.

Spectroscopic peculiarities are given in the section with notes to individual stars and it is interesting to find that many of these young secondaries exhibit spectral features like emission lines (particularly Ca II H, K and Hα) and a strong absorption of Li at λ6707 Å, which in some cases are reminiscent of T Tauri stars. Another indication that these secondaries are physical is that the fraction of stars noted with such peculiarities in Paper I is substantially higher for the physical than for the optical ones. The spectroscopic properties will be discussed in more detail in Paper V.

5.1 THE DISTRIBUTION OF THE SECONDARIES OVER PROJECTED SEPARATION. — The distribution of the projected separation between primaries and secondaries is shown in figure 11. An upper limit of about 50000 AU can be found from table VI, but 91 % of all the secondaries have separations less than 25000 AU and 84 % less than 14000 AU. The number of systems increases as expected with decreasing separation but it is noteworthy that it does not continue to increase below about 1000 AU as is observed for the distribution of the semimajor axis of other binary stars, see e.g. Heintz (1978). This is most likely at least partly due to the deficiency of physical pairs at smaller separations, which was discussed earlier. The relative distribution of the number of physical secondaries over separation is shown in figure 8 (the thick line) and a drop is evident below 10″. At the typical distances of the primaries in this investigation 10″ corresponds to a projected separation of less than a few thousand astronomical units, i.e. approximately in agreement with the drop in the distribution over projected separation. Although it appears likely that at least part of the lack of close pairs is caused by selection effects one should not forget that the double stars studied here are special since the components differ so much in mass. The survey did include a large number of pairs which, if physical, should have projected separations of less than 1000 AU but 80 % of them turned out to be optical.

A deficiency of close pairs of this kind is not unconceivable if one considers how sensitive the rate of stellar evolution is to the mass. The formation of the primary is much more rapid than that of the secondary and it reaches the ZAMS while low mass secondaries have barely reached the Hayashi track. It is well known that massive stars disturb the surrounding gas and dust e.g. by the creation of ionization fronts. During the last years it has also become evident that outflows of gas are normal phenomena of early stellar evolution, see e.g. Bally and Lada (1983). These so called bipolar massflows reach out to several thousands astronomical units from the star and the force of the wind increase with the luminosity of the star while the wind speed is highest close to the star. It seems plausible that these disturbances of the medium surrounding massive stars will make it more difficult to form close low mass companions and even prevent their formation within a certain radius. Further studies of close visual double stars are obviously required before one can be certain that the result found here is real and not only a selection effect.

From the separations and masses, orbital periods can be calculated. Due to the rather large orbits, even the shortest of these periods is more than one thousand years and generally they are counted in tens of thousands of years. Orbital motions can therefore not be detected and common proper motion is required for physical systems. The orbital velocity will be only 5 km s^{-1} at most and normally less than 1 km s^{-1} so that within the accuracy of the measurements a common radial velocity is also required for the components in most of the systems.

Data about radial velocities and common proper motion are provided in Papers I and III.

5.2 CONTRACTING SECONDARIES. — The contraction time to the ZAMS for the low mass secondaries is much longer than for the more massive primaries. For systems with sufficiently large differences in mass the contraction time of the secondary even exceeds the entire life time of the primary at the main sequence. In such cases both components cannot be at the main sequence at the same time. A relation between the masses of the primary and the secondary in such systems was derived from the main sequence life times calculated by Hejlesen (1980) and from the contraction times calculated by Iben (1965). The result is presented in table IX. By comparing tables VIII and IX some 7 or 8 secondaries must be in the phase of contraction. The luminosity classes for these stars are often III or IV which supports that they are contracting.

A more general criterion for a star to be contracting is that it is younger than the contraction time. To find such secondaries it was assumed that the primary and secondary had the same age (as derived from the primary) and this was compared with the contraction times calculated by Iben (1965). The result is shown in figure 12 where the age is plotted against log (T_e) together with the theoretical contraction time as a function of log (T_e) on the ZAMS. Stars lying above the curve are still contracting or have just reached the ZAMS while stars below the line are not contracting. While all the B type secondaries have reached the ZAMS, 37 (or 50 %) of the secondaries later than A0 are young enough to be in the phase of contraction. This number includes the stars which above were declared to be contracting so the results are consistent. It should be noted that the only criterion that has to be fulfilled here is that the star is younger than the theoretical contraction time, it is not required that it falls above the ZAMS. It is therefore interesting to find that the mean value of the height above the ZAMS is $0\overset{m}{.}8$ for the contracting stars but only $0\overset{m}{.}3$ for the other late type secondaries. The contracting secondaries are marked by a « C » in the last column of table VI. Their properties will be discussed further in Paper V.

5.3 SYSTEMS WITH B TYPE SECONDARIES. — Since the secondaries of early spectral type have reached the ZAMS it is possible to determine their ages in the same way as for the primaries. By comparing the result for both components a few cases were found to differ too much and they were classified as optical. For the remaining systems the ages of both components are tabulated in table X and they agree well. For the six best cases the dispersion is less than 0.12 in log(age) corresponding to a few million years which supports the assumption above of coeval formation.

6. The table of astrophysical data.

The results of the analysis for both primaries and secondaries is presented in table VI which is described below.

Description of table VI.

Column 1 : HD number and component designation as given in Paper II. An asterisk (*) following the component designation of composite primaries indicates that the magnitude difference is less than 4.0.
Column 2 : Relation between the secondary and the primary as evaluated in this work. Physical secondaries are indicated by « PH » and optical by « OPT » and a number which refer to which of the criteria in section 4.1 the classification is based on. Uncertain cases are indicated by a « ? » following the most likely relation and undecided cases by only a « ? ».
Column 3 : MK class adopted from the compilation in Paper I or from the literature. Occasionally the choice has been guided by the photometric result.
Column 4 : MK class estimated from the photometric indices. The prefixes d and g indicate dwarf and giant.
Column 5 : Colour excess $E(b\text{-}y)$. If negative it is assumed to be zero.
Column 6 : Absolute magnitude.
Column 7 : Height (in magnitudes) above the zero-age main-sequence.
Column 8 : Logarithm of the luminosity in solar units.
Column 9 : Logarithm of the effective temperature.
Column 10 : Age (in millions of years) of the primary. Upper limits are indicated by « < ».
Column 11 : Mass in solar units for primaries.
Column 12 : Distance in parsecs. For primaries indicated to be spectroscopic binaries in the last column it is calculated by assuming equally bright components.
Column 13 : Projected separation in AU between physical secondaries and the primary.
Column 14 : Notes. An asterisk (*) indicates that there is a comment in the section with notes. The letter C indicates that according to its age the star is still contracting to the ZAMS. SB indicates spectroscopic binaries.

7. Conclusions.

In this investigation 92 double or multiple star systems containing 98 secondaries have been found likely to be physical. Most of these secondaries are of late spectral type (F, G or K) and represent stars in early stages of their evolution and a large fraction are so young that they have not reached the ZAMS. Spectral peculiarities like emission lines and strong absorption of Li at λ6707 Å are frequent for these stars and appear to be related to their youth. In a forthcoming article (Paper V) the properties of the physical secondaries will be investigated in more detail.

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Notes to individual stars.

Stars noted with an asterisk in table I or VI are commented upon below. For more complete data about all the stars the reader is referred to the other articles in this series. The Bright Star catalogue by Hoffleit and Jaschek (1982) is abbreviated BS and common proper motion CPM. Radial velocities (RV) are from Paper III and given in km s^{-1}.

HD 560 B : Ca II H, K are in emission and the lithium line is strong. Hα is weak, probably filled in by emission.
HD 3369 B : An orbital period of 103000 y is indicated in the BS catalogue.
C : Also listed as optical in the BS catalogue.
HD 4180 A : Hβ missing.
HD 8803 B : Listed as binary in the BS catalogue.
HD 16047 B : Listed as binary in the BS catalogue but if physical it would fall $0\overset{m}{.}6$ below the ZAMS.
Oblak (1978) also found the distance modulus to be discordant.
HD 17543 B : Optical : RV(A) = 8, RV(B) = − 21.
HD 23793 B : Diffuse lines. Listed as binary in the BS catalogue.

HD 27638 B : Strong lithium line. Listed as optical ? by Abt and Cardona (1983).

HD 29227 B : The evaluation is PH ? since it falls below the ZAMS and the absolute magnitude calculated from c'_0 differs from M'_v but the difference is less than one magnitude if the error in c_1 is considered. CPM is also observed.

HD 32964 B : Eggen (1963) suggested that it is optical but CPM is observed. Optical ? in the BS catalogue.

HD 33224 B : Optical ? $RV(\mathrm{A}) = 27$, $RV(\mathrm{B}) = 72$. However, $RV(\mathrm{A})$ is variable.

HD 33802 B : Ca II H, K and Hα in emission. Strong lithium line.

HD 34503 D : The indices fit somewhat better an optical F9 V star but the errors are rather large.

HD 34797 B : Evaluated as physical ? by Olsen (1982).

HD 35148 B : Optical. $RV(\mathrm{A}) = 20$, $RV(\mathrm{B}) = -58$. Fixed, however. Gahm *et al.* (1983) classified it as B8nnp. Others have reported B3 V which agrees with the photometry. The BS catalogue gives B5 Vn and $v \sin i = 350$.

HD 35173/2 B : Oblak (1978) classified it as optical. CPM is observed.

HD 35708 A : MK from the BS catalogue. Occultation double with equally bright components.

B : Separation is $37''.8$.

C : Separation is $58''.8$.

HD 36013 B : Strong lithium line.

HD 36861 A : Age and mass are estimated from Iben (1967).

HD 36898 B : If physical it would fall $0^{\mathrm{m}}.7$ below the ZAMS.

The indices indicate an early A type star. The errors are rather large and a physical system is not excluded although unlikely.

HD 38426 B : The secondary is much more reddened than the primary. To place it beyond the latter luminosity class III is needed at G8.

HD 43112 B : Optical : $RV(\mathrm{A}) = 38$, $RV(\mathrm{B}) = -2$.

HD 44458 A : Hβ in emission.

C : Large errors in the indices.

HD 44944 A : The system was included because the HD classification is B9. The spectroscopic and photometric results both indicate A5 V, however.

HD 45995 A : Hβ in emission.

B : Listed as binary in the BS catalogue and Olsen (1982) evaluated it as physical ?

HD 46064 B : Also evaluated as optical by Olsen (1982).

HD 46547 B : The primary is possibly a spectroscopic binary. Correcting for equally bright components makes it even more unlikely that the system is physical, however. Oblak (1978) also classified it as optical and B8 V. Olsen (1982) evaluated it as physical ? The spectroscopic MK classification is uncertain.

HD 47116 B : Oblak (1978) also classified it as optical and F6 V. Olsen (1982) evaluated it as physical ?

HD 47247 B : Listed as binary in the BS catalogue.

HD 48917 A : Hβ in emission. MK from the BS catalogue. Variable.

HD 49606 A : MK from the BS catalogue. Photometry is taken from Crawford *et al.* (1973).

B : Separation is $27''.5$.

HD 52140 B : Evaluated as physical ? by Olsen (1982).

HD 55856 A : Eggen (1983) gives photometric data similar to the ones used here (Paper II). He derives $M_v = -3.15$ and $E(b\text{-}y) = 0.025$ which agree with the present results.

B : Discussed by Eggen (1983) who gives photometric data similar to the ones used here (Paper II).

If physical it would be a pre-main-sequence companion but $RV(\mathrm{A}) = 17$, $RV(\mathrm{B}) = -3$ indicate that it is optical. Evaluated as physical ? by Olsen (1982).

HD 56504 B : Evaluated as physical ? by Olsen (1982).

HD 60855 A, C : Optical ? The positions of the stars in the HR diagram require C to be much older than A. However, emission is present in the spectra of A and Hβ could be too small. This would bring the luminosity in agreement with the MK class and the ages could agree.

HD 60863 C : Strong lithium line. Also evaluated as optical by Olsen (1982).

HD 61556 B : Listed as binary in the BS catalogue.

HD 63425 A : The star has also been classified as B1/2 Ib/II.

B : Optical : $RV(\mathrm{A}) = 37$, $RV(\mathrm{B}) = 60$.

HD 63922 A : The β index has a large error (variable ?) and the MK classification lies within the error.

Eggen (1975) gives $\beta = 2.592$.

B : Optical : $RV(\mathrm{A}) = 24$, $RV(\mathrm{B}) = -72$. Listed as K0 in the BS catalogue.

HD 64755 AB : The photometric MK class is derived from M_v, $(B\text{-}V)_0$ and $(U\text{-}B)_0$.

HD 66230 A : The MK classification (Houk, 1982) is very different from the photometric result which agrees better with the HD classification B5.

B : Optical even if the primary is B7 II since the required luminosity is contradicted by c'_0.

HD 66539 B : Luminosity class III is required to make it physical.

HD 66546 B : Peculiar. Spectroscopically it is classified as B9 IIIp. Photometrically it appears as B3 V. Oblak and Chareton (1980) list B5 V.

HD 66624 B : Olsen (private communication) suggests that it is a Mira type variable. Landolt (1971) gives $V = 8.77$, $B\text{-}V = 1.30$ and

U-B = 0.07 which is different from the *uvby* data.

HD 69144 B : Optical : RV(A) = 24, RV(B) = 7.

HD 71304 A : Age and mass are estimated from Stothers (1966).

HD 71510 B : Also evaluated as optical by Olsen (1982).

HD 71833 B : Peculiar. The spectrum indicates an earlier type than the photometry. The low value of m_1 suggests population II.

HD 72798 B : The primary is possibly a spectroscopic binary. Correcting for equally bright components makes it even more unlikely that the system is physical, however.

HD 74067 B : Listed as binary in the BS catalogue.

HD 74531 B : The reddening is larger than for A. To place it beyond the primary the luminosity class must be III.

HD 77484 AB : Hβ corresponds to B9 Ia and a distance of 8 kpc which is improbable since $E(b$-$y)$ = 0.02. The *uvby* indices agree with B9.5 V which is adopted together with M_v = 0.8.

B : Strong lithium line ?

HD 82919 B : PH ? because the star falls below the ZAMS but allowing for the error in $(b$-$y)$ it could fall on the ZAMS.

HD 83953 A : The photometry gives B5 II but the MK class is B5 Ve. Since Hβ probably is affected by emission luminosity class V is adopted.

B : Optical : RV(A) = 26, RV(B) = 14.

HD 83965 A : The HD classification is B9 but the photometry gives A4 III. Forcing the star through the B star calibration gives A0 V but m_0 is quite high.

HD 86440 A : Whittet and van Breda (1980) give $E(B$-$V)$ = 0.05, in agreement with $E(b$-$y)$ = 0.06.

HD 86523 B : The primary is possibly a spectroscopic binary but correcting for equally bright components still places the secondary below the ZAMS.

HD 87901 A : Eggen (1983) gives M_v = − 1.05, $E(b$-$y)$ = 0.007 in agreement with this paper.

HD 87884 B : Also listed as binary and K1 V in the BS catalogue. Eggen (1983) gives M_v = 5.85 in agreement with this paper.

HD 90972 B : Ca II H, K in emission. Strong lithium line.

HD 92029 B : Evaluated as optical ? by Olsen (1982).

HD 93010 B : Optical ? The radial velocities differ : RV(A) = 4, RV(B) = − 19 but CPM is observed and photometrically it is a physical B6 V companion. The MK classification A0 III is uncertain and not reconcilable with the photometry.

HD 93632 A, B : Both components are highly reddened. The photometry of A corresponds to B1 I rather than the MK class O4 IIIf. The system is estimated as optical ? since the reddening of B appears to be less than that of A. However, the spectra are contaminated by nebular emission which also could have affected the colours.

HD 93873 B : The spectrum is peculiar and the indices are typical for peculiar stars (Oblak, 1976). b-y is 0.46 too large to make it physical. Adopting M_v = − 6.9 for the primary the secondary must be of luminosity class Ib if it is to be beyond the primary. This is not excluded by the spectra.

HD 94565 B : Optical ? The radial velocities differ : RV(A) = − 5, RV(B) = − 31 but CPM is observed and photometrically it is physical. No metal lines are visible in the spectrum.

HD 94909 A : Whittet and van Breda (1980) give $E(B$-$V)$ = 0.72 which agrees with $E(b$-$y)$ = 0.53.

HD 96264 B : Physical ? The positions of the stars in the HR diagram are somewhat contradictory to the pair being physical. The error in the luminosity of the primary is rather large, however. CPM is also observed.

HD 100600 AB : MK from the BS catalogue. The photometry is from Olsen (1975) and Grønbech and Olsen (1977).

C : Separation is 63″. The spectral type F5 from the BS catalogue is not reconcilable with the photometry.

HD 100841 A : c_1 is too large for the B star calibration. Taking $E(B$-$V)$ = 0.04 by Whittet and van Breda (1980) it is found that $(b$-$y)_0$ agrees with B9 III but c_0 is too large. Hβ gives luminosity class IV.

HD 101436 B : Optical : RV(A) = 11, RV(B) = − 39. If physical it must be B0 Ib which is contradicted by the MK class B0 V.

HD 104901 A : The photometric MK class is derived from M_v, $(B$-$V)_0$ and $(U$-$B)_0$. The age and mass are estimated from Iben (1967).

B : The low value for m_0 is normal for F0 II and the bracket indices also fit the values given by Oblak (1976). Hα is in strong emission with a violet displaced absorption component (P Cygni type line profile), indicating that the star is surrounded by an expanding shell. Variability is discussed in Paper V.

HD 107348 B : Also listed as optical in the BS catalogue.

HD 108767 B : Ca II H, K in emission. Strong lithium line.

HD 109867 B : Peculiar. Spectroscopically it is classified as B7 p but the photometry gives B2.5 V.

HD 110956 B : Listed as probably optical in the BS catalogue. The m_1 index is very large, indicating an Am type.

HD 112091 B : Hβ in emission. Common radial velocity.

HD 112244 A : Age and mass are estimated by interpolation between the 30 m_0 model by Stothers (1966) and the 15 m_0 model by Iben (1967). Whittet and van Breda (1980) give $E(B\text{-}V) = 0.32$ consistent with $E(b\text{-}y) = 0.21$.

HD 112412 B : Also listed as binary in the BS catalogue.

HD 113703 B : *B-V* by Catchpole (1971) gives K0 V. Ca II H, K and Hα are in emission. High lithium abundance.

HD 113791 B : PH ? because the c_0' index places it slightly below the ZAMS. The error in the index is rather large, however.

HD 114911 B : m_0 and c_0 indicate that this is an Am star.

HD 117460 B : The B star calibration gives B1 III but Hβ is filled in by emission. *B-V* and *U-B* also indicate a giant, however. Positions in the HR diagram contradicts that the pair is physical even if the secondary is a dwarf.

HD 119423 AB : The spectrum of A shows emission which could explain the small value for Hβ.

HD 120324 A : Hβ in emission.

HD 120642 B : The radial velocity is uncertain due to broad lines but common radial velocity is possible and CPM is observed.

HD 120991 A : Hβ gives $M_v = -7.23$ but since emission is present in the spectrum luminosity class II and $M_v = -4.8$ is adopted. The star is a variable.

HD 124367 A : Hβ is probably affected by emission.

HD 124471 A : The photometric luminosity class is different from the MK classification. Also, Whittet and van Breda (1980) give $E(B\text{-}V) = 0.11$ which is smaller than $E(b\text{-}y) = 0.13$.

HD 127304 B : *UBV* data by Eggen (1963) are used.

HD 128919 B : If the primary is a giant as indicated by the MK class, the secondary will fall on the main-sequence and can be a physical companion.

HD 129791 B : Ca II H, K and Hα in emission and strong lithium line.

HD 131168 A : Hβ in emission.

B : Optical : $RV(\text{A}) = 1$, $RV(\text{B}) = -32$.

HD 135160 C : Optical : $RV(\text{A}) = 4$, $RV(\text{B}) = -16$.

HD 135240 B : The reddening is much larger than for A and the *uvbyJHKL* data agree with G5 III. This is not excluded by the spectrogram. Also listed as optical in the BS catalogue.

HD 135591 AB : Whittet and van Breda (1980) give $E(B\text{-}V) = 0.19$ in agreement with $E(b\text{-}y) = 0.13$. The age and mass are derived from Stothers (1966).

HD 137387 A : Hβ in emission. B1.5 IV and $M_v = -3.6$ is adopted.

B : The position in the HR diagram corresponds to an age of 3×10^4 years. This is consistent if the primary is still approaching the ZAMS.

HD 140022 B : PH ? because the radial velocities are $RV(\text{A}) = -26 \pm 5$ and $RV(\text{B}) = -51 \pm 11$.

HD 141318 B : Also evaluated as optical by Olsen (1982).

HD 141468 B : The reddening is much larger than for A and the *uvbyJHKL* data agree with K2 III. This is not contradicted by the spectrogram.

HD 143118 A : The Hβ by Oblak (1978) is used. The value by Lindroos (1983) gives luminosity class III. Eggen (1975) gives H$\beta = 2.615$.

B : Very diffuse lines. Also listed as binary in the BS catalogue.

HD 143939 B : Ca II H, K in emission.

HD 144217 ABC : For the distance calculation the *V* magnitude was corrected for the contribution from C, but *B* was neglected. Complex system, see note in the BS catalogue.

HD 145483 B : Also listed as binary in the BS catalogue.

HD 148066 B : Optical : $RV(\text{A}) = 0$, $RV(\text{B}) = -36$.

HD 148688 AB : $M_v = -6.6$ is adopted.

HD 149249 C : Reddening is much larger than for A. To place it beyond the primary it must be a giant. This is supported by the photometry and is not excluded by the spectrogram.

HD 151158 AB : Hβ is too small. Also classified B2 II/Ib.

HD 152408 AB : The star is peculiar (Paper I) and was forced through the B star calibration. However, Hβ is in emission and no absolute magnitude is obtained.

HD 152723 C : Optical : $RV(\text{A}) = 4$, $RV(\text{B}) = -50$.

HD 152901 B : Optical ? The MK class A7 III places it beyond the primary. The photometry, although uncertain, also supports that it is a giant.

HD 156325 B : m_0 is 0.10 too small for a normal population I F2 V, indicating population II membership. This would make the system optical.

HD 157042 A : Hβ in emission.

HD 157246 A : Whittet and van Breda (1980) give $E(B\text{-}V) = 0.13$ in agreement with $E(b\text{-}y) = 0.10$.

B : Luminosity class III is not excluded by the spectra.

HD 157736 B : The photometry indicates a G type star but the separation is only 5″ and contamination from the primary possible.

HD 158427 A : Hβ is affected by emission, Eggen (1975).

HD 159574 A : The photometric MK class is derived from M_v, $(B\text{-}V)$ and $(U\text{-}B)$. Age and mass are derived from Iben (1967).

HD 160281 A : Large errors in the indices (variable ?).

B : Only one observation. Taking into account the uncertainties involved it is possible that the system is physical.

HD 160974 B : If physical the luminosity class must be III and the star contracting. Emission is present in the spectrum but it is possibly due to contamination from the primary.

HD 163181 A : Hβ too small, $M_v = -6.2$ adopted.

HD 164492 B : The star is 6 magnitudes too faint to be a physical A2 Ia companion. A2 III is possible, however.

HD 166937 A : The B star calibration gives $E(b\text{-}y) = 0.33$ which makes $(b\text{-}y)_0$ incompatible with B8 Ia. This reddening also makes the secondaries optical. By selecting $E(b\text{-}y) = 0.24$ the indices agree with the MK class. $M_v = 7.0$ is adopted.

D : Listed as optical by Abt and Cardona (1983).

E : Also listed as physical in the BS catalogue.

HD 167263 AB : The age and mass are estimated from Stothers (1966).

HD 167647 A : Algol type spectroscopic binary. MK class is from the BS catalogue and the photometry from Grønbech and Olsen (1976, 1977). Eggen (1983) gives similar photometric data and B4 IV. He derives $M_v = -1.8$ which agrees with this paper.

B : Separation is 38″.9. Grønbech and Olsen (1976, 1977) and Eggen (1983) give similar photometric data. Eggen derives $M_v = 1.75$, in agreement with this paper.

HD 167771 B : Photometry uncertain. If physical the luminosity class must be III.

HD 169337 AB : The star was included because the HD classification is B8. However, the spectroscopic investigation shows that it is a spectroscopic doublet with very different components. The B star calibration gives B5 IV but with a very large m_0 and the result is uncertain.

B : Assuming equally bright components for the primary the magnitude difference between the A3 V secondary and the primary (B8 V) is 4.2. Since this is much more than the difference in absolute magnitude (2.5) for such stars the secondary is most likely optical.
The reddening also appears to be different but the errors are large.

HD 170580 B : The lines are broad indicating a high rotational velocity. m_0 is large.

HD 170740 B : The MK class B9 V has also been reported (Paper I).

HD 174152 A : Oblak (1978) gives B6 V.

B : The B star calibration gives B9 III but Oblak (1978) gives B9 V.

HD 174585 B : *UBV* data from Wallenquist (1981) have been used. Separation is 34″.8.

HD 174638 A : β Lyrae. Eggen (1975) gives $M_v = -3.9$, this makes the secondaries optical since they would fall below the ZAMS.

B : Spectroscopic binary. Physical in the BS catalogue.

E : Optical in the BS catalogue.

F : Physical in the BS catalogue.

HD 175876 A : Whittet and van Breda (1980) give $E(B\text{-}V) = 0.21$ which is larger than $E(b\text{-}y) = 0.12$. Also, M_v is too large for O6.5 III.

HD 179316 B : Evaluated as physical ? by Olsen (1982).

HD 181454 B : Also classified as optical by Oblak (1978).
Photometrically it is a physical F0 V companion but the MK class is A5 V.

HD 181558 B : Optical : $RV(\mathrm{A}) = -23$, $RV(\mathrm{B}) = -3$.

HD 185507 A : β Lyrae type variable. Both components are B3 V.

B : The reddening is much larger than for the primary. However, to be more distant than the primary the luminosity class must be IV which is not contradicted by the spectrogram and agrees with the photometry. Also listed as optical by Eggen (1963) and in the BS catalogue.

HD 199218 A : The indices correspond to B8 Ib and a distance of 3 kpc. However, $E(b\text{-}y)$ is rather small for such a distance and $(b\text{-}y)$ and $(u\text{-}b)$ better agree with the spectroscopic result B8 V. The lines are diffuse.

HD 224098 B : $M_v = 0.2$ is used for the primary.

Appendix A.

To derive astrophysical parameters from the *uvby*β indices for stars earlier than G0 a computer programme in FORTRAN 77 was developed. The programme uses current calibrations (described earlier in the article) of the indices to determine the following data :

The $(u\text{-}b)$, $(B\text{-}V)$ and $(U\text{-}B)$ indices.

The reddening free indices $[m_1]$, $[c_1]$ and $[u\text{-}b]$.

The colour excess $E(b\text{-}y)$ and extinction A_v.

The reddening corrected indices.

The parameters δm_0 and δc_0 for A and F stars.

The height above the zero-age main-sequence.

The absolute magnitude.

The distance.

The spectral type.

For B and early A stars also :

The bolometric correction BC.

The logarithm of the luminosity in solar units, $\log(L)$.

The logarithm of the effective temperature, $\log(T_e)$.

For stars earlier than A0 also :

The logarithm of the age in years.

The logarithm of the mass in solar units.

A complete description of the programme is given by Lindroos (1981).

Examples of the output is shown in figure 13. The programme is called ANALYS and is available on magnetic tape upon request.

Appendix B.

The following relations between *uvby* and *UBV* have been used to transform between the two systems. These relations have been derived from table 1 given by Crawford (1978) and from figures 4 and 5 given by Crawford and Barnes (1970). For normal unreddened stars the *UBV* indices calculated by these relations agree within 0.02 magnitude with the observed values.

If $(b\text{-}y) < 0.000$ then : $(b\text{-}y) = 0.49(B\text{-}V)$
$(u\text{-}b) = 1.56(U\text{-}B) + 1.38$.

If $(b\text{-}y) > 0.000$ then : $(b\text{-}y) = 0.62(B\text{-}V) + 0.01$
$(u\text{-}b) = 1.32(U\text{-}B) + 1.39$.

The following relations between $E(b\text{-}y)$ and $E(m_1)$, $E(c_1)$ and the extinction in V were used :

$$E(m_1) = -0.32\,E(b\text{-}y)$$
$$E(c_1) = 0.20\,E(b\text{-}y)$$
$$A_v = 4.3\,E(b\text{-}y)\,.$$

The reddening free bracket indices have been calculated as :

$$[m_1] = m_1 + 0.32(b\text{-}y)$$
$$[c_1] = c_1 - 0.20\,(b\text{-}y).$$

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TABLE I. — *uvbyβ indices and V magnitudes for double stars.*

HD	NN	V	err	b-y	err	m_1	err	c_1	err	NN	β	err	Notes
27638 B	2	8.40	2	.41	3	.22	3	.39	2	2	2.66	2	
29227 C	3	13.61	6	.45	1	.12	4	.48	5	3	2.61	9	
32964 B	5	10.83	1	.73	1	.59	4	.59	17	4	2.59	5	
33802 B	3	9.94	2	.50	2	.26	1	.31	5	3	2.58	2	
34503 D	4	10.94	5	.47	4	.13	5	.38	4	4	2.61	8	
35007 C	4	11.88	6	.45	5	.22	3	.36	4	4	2.61	2	
35708 A	3	4.87		-.058		.090		.151		3	2.642		*
35708 B	1	12.39		.39		.12		.78		1	2.81		*
35708 C	1	11.55		.55		.16		.42		1	2.62		*
36013 B	4	12.52	5	.38	1	.18	4	.36	3	4	2.62	2	
36779 B	7	11.20	4	.86	5	.46	6	.55	15	6	2.59	5	
38426 B	7	11.53	6	.64	7	.45	6	.22	3	4	2.57	8	
38622 B	3	12.14	9	.91	2	.27	3			2	2.61	1	
40494 B	3	12.66	2	.45	1	.23	4	.28	6	2	2.60	3	
47247 B	5	9.28	7	.06	1	.22	2	1.08	8	4	2.91	1	
48383 B	9	9.59	3	.12	2	.18	2	.92	3	7	2.84	3	
48917 B	7	12.44	14	.26	6	.18	7	.55	18	5	2.66	3	
49606 A	3	5.87		-.058		.116		.489		2	2.703		*
49606 B	1	13.31		.47		.12		.30					*
60575 C	7	12.67	18	1.34	6	-.18	9	1.60	7	5	2.67	7	
63465 B	4	11.09	7	.30	4	.16	8	.44	12	4	2.70	5	
70309 B	4	11.28	2	.70	2	.38	2	.46	8	4	2.61	5	
82919 B	4	11.37	9	.11	7	.15	10	.97	17	3	2.87	4	
87901 B	8	8.09	1	.54	2	.36	2	.30	2	8	2.56	1	
90972 B	7	9.59	3	.39	2	.12	7	.41	5	8	2.63	5	
100600 A		5.95		-.070		.104		.319			2.686		*
100600 C	3	9.64	5	.01	4	.17	4	1.04	2	3	2.90	2	*
104901 B	8	7.71	11	.39	1	.08	4	1.37	8	3	2.60	3	
108767 B	8	8.45	2	.54	3	.43	2	.31	3	8	2.56	2	
111123 B	1	11.96		.56									
113703 B	2	10.90	3	.61	6	.35	3	.09	3	3	2.55	5	
118716 B	2	13.70	20	1.51	20								
120991 B	3	11.54	1	.09	1	.20	3	1.05	3	3	2.97	5	
123445 B	3	12.54	7	.69	2	.54	4	.35	7				
123635 B	2	11.33	5	.33	7	.10	6	.54	14	2	2.67	4	
124471 B	1	12.98		.50		.08		.36		2	2.60	6	
127971 B	3	11.23	2	.64	3	.53	7	.39	5	4	2.63	8	
129791 B	4	12.91	3	.76	4	.67	5	.09	4	3	2.44	7	
135240 B	6	12.94	9	1.12	7	.50	5			6	2.55	17	
135591 C	4	11.70	1	.26	3	.19	4	.94	7	3	2.84	3	
137387 B	5	11.30	4	1.07	2	.88	16			5	2.53	9	
157246 B	3	10.18	7	.19	2	.12	1	.66	9	3	2.83	2	
159176 B	1	10.09		.16		.14		1.05		1	2.52		
159176 C	1	10.90		.16		.01		.44		1	2.71		
159176 X	2	10.77	2	.17	2	.02	2	.24	1	2	2.69	1	
162082 B	3	11.00	4	.38	2	.14	3	.66	6	3	2.76	3	
167647 A	3	6.238	37	-.025	2	.089	1	.344	6	3	2.672	1	*
167647 B	1	9.68		.06		.16		1.04		1	2.86		*

TABLE II. — *Errors in M_V and ΔM_V for different spectral types and luminosity classes.*

Sp	V		III	
	$\sigma(M_V)$	$\sigma(\Delta M_V)$	$\sigma(M_V)$	$\sigma(\Delta M_V)$
O8	$0\overset{m}{.}6$	$0\overset{m}{.}9$	$0\overset{m}{.}7$	$1\overset{m}{.}0$
B0	0.5	0.7	0.6	0.8
B2	0.4	0.6	0.5	0.7
B5	0.3	0.5	0.4	0.6
B8	0.2	0.3	0.3	0.4
A0	0.1	0.2	0.2	0.3

TABLE IV. — *Comparison with Eggen.*

HD	M_V This	M_V Eggen	Diff	MK
3369	-1.70	-1.95	0.25	B5 V
17543	-0.92	-1.35	0.43	B6 IV
23793	-0.58	-1.6	1.0	B3 V
34503	-1.99	-1.65	0.34	B7 III
35007	-1.35	-1.2	-0.15	B3 V
38622	-2.17	-2.15	-0.02	B2 V
40494	-3.03	-2.8	-0.2	B3 IV
43112	-3.53	-2.85	-0.68	B1 V
48383	-1.00	-1.95	0.95	B4 V
54764	-5.65	-4.15	-1.50	B1 II
63465	-3.39	-2.75	-0.64	B2.5 III
63922	-4.33	-4.3	-0.0	B0 III
67880	-2.19	-2.95	0.76	B2 V
69144	-2.48	-2.6	0.1	B3 III
70556	-2.71	-3.55	0.84	B2 V
71510	-1.77	-2.15	0.38	B3 V
74146	-0.41	-1.65	1.24	B5 V
76566	-1.64	-2.15	0.51	B3 V
86440	-5.36	-4.3	1.1	B5 Ib
87901	-0.95	-1.05	0.10	B8 V
109668	-2.19	-2.25	0.06	B2 IV
118716	-3.62	-3.2	-0.4	B1 IV
120955	-1.59	-2.4	0.8	B5 IV
135160	-3.82	-3.65	-0.17	B1 V
141318	-4.07	-3.9	-0.2	B2 III
143118	-2.56	-2.9	0.3	B2 V
150742	-1.09	-1.0	-0.1	B2.5 V
156247	-0.99	-1.0	0.0	B5 V + B5 N
157246	-6.51	-5.45	-1.06	B1 III
166182	-3.44	-3.55	0.11	B2 IV
170580	-2.35	-2.3	-0.1	B2 V
170740	-2.40	-2.45	-0.1	B2 V ·
174585	-1.91	-1.95	0.04	B2.5 V
179761	-1.59	-1.0	-0.6	B8 III
185507	-2.29	-2.35	-0.04	B2.5 V
211924	-2.09	-2.2	0.11	B5 IV
mean difference			0.10±0.59	

TABLE III. — *Comparison with Grosbøl.*

HD	MK	ΔE(b-y)	ΔM_V	$\Delta(\Delta M_V)$	Δlog T	Δlog a	Δlog m
23793	B3V	0.001	0.80	-0.53	0.010	-	-0.02
34503	B7III	0.006	-0.70	0.70	0.014	-0.13	0.06
38622	B2V	-0.007	-0.02	0.43	0.002	-0.05	0.03
40494	B3IV	-0.001	-0.74	1.09	0.001	-0.14	0.08
43112	B1V	0.016	-0.41	0.42	0.023	-	0.08
49028	B7IV	-0.006	0.34	-0.27	0.012	-0.20	0.00
54764	B1II	0.007	-0.93	1.02	0.101	0.26	-0.11
63465	B2.5III	-0.006	-0.88	1.34	0.000	-0.13	0.11
77002	B2.5IV	-0.011	0.00	0.39	0.011	0.22	0.06
86440	B5II	-0.001	-1.92	2.22	-	-	-
87901	B8V	-0.003	-0.28	0.27	-0.001	0.07	-0.01
97583	B9V	0.000	0.00	-0.11	0.006	-0.12	0.00
100841	B9II	0.000	-1.24	1.58	-0.035	-	-
106983	B2.5V	-0.006	0.41	-0.17	0.021	-	0.02
110956	B3V	-0.002	0.50	-0.21	-0.013	-	-
118716	B1IV	-0.003	-0.07	0.55	-0.012	0.24	0.02
158094	B8V	0.000	-0.13	0.13	-0.005	0.04	0.00
166182	B2IV	0.000	0.35	0.29	-0.010	0.05	-0.01
170580	B2V	-0.002	-0.25	0.27	0.035	-0.04	0.08
174585	B2.5V	-0.001	0.05	0.41	0.004	0.16	0.04
195556	B2.5IV	-0.002	-0.90	1.35	0.001	-	-
Mean difference		-0.001	-0.29	0.53	0.010	0.02	0.03
σ		±0.006	±0.66	±0.69	±0.026	±0.16	±0.05

TABLE V. — *Comparison of trigonometric and photometric parallaxes. Numbers are in units of 0″.001.*

HD	π(trig.)		π(this)	Δ
32964	21	± 6	10	11
33949AB	30	11	7	23
36861AB	6	11	2	2
87901	39	7	36	3
108767	18	5	43	-25
112413	23	6	34	-11
143018	5	10	4	1
144217	4	8	6	-2
179761	5	7	5	0
180555	19	7	12	7
222661	35	9	16	9

TABLE VII. — *Distribution of secondaries over spectral type.*

Spectral type	Total number	Number of physical	% physical	% of all physical
O	0			
B	58	24	41	24
A	68	21	31	21
F	80	18	23	18
G	40	19	48	19
K	36	16	44	16
M	4	0		

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TABLE VI. — *Astrophysical data for double stars.*

HD	Relation	MK	(MK)	E(b-y)	M_V	ΔM_V	Log L	Log T_e	Age (10^6y)	Mass	Dist (pc)	Sep (au)	Notes
480 A		B5 V	(B7 V)	-.01	-0.82	1.16	2.64	4.129	83	4.2	377		
B	OPT 8	K0	(K2 V)										
560 A		B9 V	(B9 V)	-.00	0.98	-0.05	1.75	4.064	<50	2.8	81		
B	PH	G5 V E	(G9 V)	.00	5.82	-0.08	-0.28	3.73			81	624	C *
1438 A		B8 V	(B8 V)	.01	-0.15	0.71	2.30	4.104	93	3.5	171		
B	PH	F3 V	( )		4.0	-0.5	0.32	3.84			171	1060	
3369 A		B5 V	(B5 IV)	-.00	-1.70	1.54	3.14	4.183	68	5.1	231		SB
B	PH	A6 V	(A7 IV)	.00	1.79	0.85	1.19	3.91			231	8300	*
C	OPT 1	F3	( )										*
4180 A		B5 III	(B5)	.07				4.171					*
B	?	F8	( )										
8803 A		B9 V	(B9 V)	.03	0.44	0.67	1.94	4.049	141	3.0	164		
B	PH	F6 V P	(F6 V)	.03	3.47	0.09	0.53	3.82			164	984	*
10161 A		B9 V	(B9 IV)	.00	-0.03	1.10	2.13	4.052	166	3.2	309		SB
B	PH?		(G4 V)	.00	4.85	-0.01	0.00	3.74			309	6573	
10293 A		B7 V	(B5 III)	.09	-2.05	1.98	3.26	4.174	60	5.5	403		
B	OPT 6	K2 V	( )										
16046 A		B9 V	(B9.5 V)	-.00	0.99	0.38	1.66	4.038	120	2.7	88		SB
16047 B	OPT? 1	A3 V m	(A5 V)										*
17543 AB*		B6 IV	(B5 V)	.05	-0.92	0.91	2.79	4.168	59	4.7	222		SB
B	OPT 6	A0 V P	( )										*
C	PH	F8 V	(F8 V)	.05	3.78	0.42	0.41	3.78			222	5602	
23793 A		B3 V	(B4 V)	.02	-0.58	0.08	2.77	4.218	<28	4.8	131		
B	PH	F3 V P	(F3 V)	.02	3.73	-0.25	0.41	3.83			131	1179	C *
23990 A		B9	(B9.5 V)	.03	0.89	0.31	1.73	4.049	8	2.8	142		
B	OPT 1		(K3 V)										
24388 A		B8 V	(B8 V)	.01	-0.14	0.50	2.36	4.127	63	3.7	130		
B	OPT 1	F4 V	(F5 V)										
25330 A		B5 V	(B5 V)	.10	-0.48	0.42	2.63	4.173	42	4.3	140		
B	OPT 3	F8 V	(F8 V)										
27638 A		B9 V	(B9.5 V)	-.00	0.91	0.42	1.69	4.036	123	2.7	79		
B	PH	G2 V	(G3 V)	.00	3.91	1.00	0.37	3.75			79	1533	*
28107 A		B6 V	(B6 V)	.02	0.02	0.12	2.37	4.152	13	3.2	285		
29227 A		B7 III	(B8 III)	.01	-0.91	1.33	2.65	4.121	93	4.1	278		
B	PH?		(F1 V)	.01	3.44	-0.48	0.53	3.86			278	4865	*
C	OPT 1		(F/G)										
31065 AB		A0 V	(A0 V)	.01	1.16	0.15	1.54	4.007	79	2.3	206		
32202 A		B9 V	(B9 III)	.10	-0.95	1.98	2.51	4.056	174	3.5	359		
B	OPT 3	A2 V	(A2 V)										
32964 A		B9 V	(B9 V)	.00	0.92	0.14	1.75	4.054	42	2.7	96		SB
B	PH?		(K5 V)	.00	5.90	1.56	-0.18	3.63			96	5072	C *
33224 A		B9 V	(B8 V)	.01	-0.09	0.58	2.30	4.112	79	3.6	148		
B	OPT? 6	K0 IV	( )										*
33802 A		B8 V	(B8 V)	.00	0.06	0.30	2.27	4.126	40	3.6	75		
B	PH	G8 V E	(G9 V)	.00	5.49	0.43	-0.22	3.72			75	952	C *
33949 AB*		B8 III	(B8 III)	.00	-1.35	1.98	2.75	4.095	112	4.3	137		
B	OPT? 1	B9 V	( )										
34503 A		B7 III	(B7 III)	.02	-1.99	2.25	3.14	4.139	68	5.1	127		
D	PH?		(G6 V)	.02	5.26	0.00	-0.39	3.74			127	4527	*
34527 A		B9.5 V	(B9 V)	.02	0.34	0.72	1.99	4.053	151	3.0	205		
B	OPT 6	A0.5 V	(B9.5 V)										
34798 A		B4 V	(B4 V)	.00	-0.32	-0.17	2.67	4.216	<18	4.5	216		
34797 B	PH	B6 V	(B6 V)	.00	-0.16	0.31	2.46	4.15			216	8510	*

TABLE VI *(continued)*.

HD	Relation	MK	(MK)	E(b-y)	M_V	ΔM_V	Log L	Log T_e	Age (10^6y)	Mass	Dist (pc)	Sep (au)	Notes
35007 A		B3 V	(B3 V)	.04	-1.35	0.52	3.15	4.248	22	5.8	236		
B	OPT 1		(G1 V)										
C	PH		(G3 V)	.04	4.85	0.03	-0.01	3.74			236	8873	C
35149 A		B1 V	(B1 V)	.06	-2.59	0.12	3.88	4.366	2	8.5	293		
35148 B	OPT 1,6	B3 V	(B3 V)										*
35173 A		B8	(B5 V)	.13	-0.91	0.68	2.84	4.190	44	4.8	331		
35172 B	PH	A	(B7 V)	.13	0.11	0.06	2.31	4.15			331	8606	*
35708 A		B2.5 IV	(B2 V)	.04	-2.29	0.54	3.66	4.316	13	7.4	350		*
B	OPT 4,5		(A7 V)										*
C	OPT 5		(F9 V)										*
35715 AB		B1 IV	(B1 V)	.02	-3.44	0.73	4.25	4.383	10	10.2	541		SB
C	OPT 1		(F)										
36013 A		B2 V	(B3 V)	.01	-1.80	1.21	3.28	4.227	39	6.6	535		
B	PH	F3	(F9 V)	.01	3.84	0.61	0.39	3.77			535	13375	C *
36151 A		B5 V	(B4 V)	.02	-0.18	-0.22	2.59	4.206	<18	4.3	227		
B	PH		(G1 V)	.02	3.73	0.95	0.44	3.76			227	11032	C
X	PH		(G7 V)	.02	5.12	0.26	-0.09	3.74			227	10200	C
36408 A		B8 III	(B9 III)	.08	-1.02	1.71	2.61	4.089	135	3.9	318		SB
B	OPT 4	B7 IV	(B9 III)										
36779 A		B2.5 V	(B1.5 V)	.02	-1.95	0.26	3.51	4.311	9	7.1	413		
B	PH	K	(K5 IV)	.02	3.01	5.31	1.11	3.59			413	11357	C
36861 AB*		O8 III	(B0 III)	.08	-5.05	1.34	5.05	4.458	8	20	430		*
B	PH?	B0 V	( )		-3.5	0.3	4.46	4.46			430	1892	
C	OPT 5		(F8 V)										
36898 A		B7 V	(B7 V)	.00	0.29	-0.05	2.23	4.141	<35	3.5	234		
B	OPT? 1		(A1 V)										*
36960 A		B0.5 V	(B0.5 V)	-.01	-3.72	0.37	4.46	4.431	4	12.0	528		
36959 B	PH	B1 V	(B1 V)	.00	-2.89	0.29	4.03	4.38			528	18849	
38426 A		B2 V	(B2 V)	.00	-1.13	-0.06	3.12	4.277	<18	5.9	380		
B	OPT 3	G8 V	(gG/K)										*
38622 A		B2 V	(B3 IV)	.01	-2.17	1.52	3.44	4.232	35	6.3	302		
B	OPT 5		( )										
C	PH		(G2 V)	.01	4.57	0.15	0.12	3.75			302	7519	C
38672 A		B5	(B8 V)	.01	-0.23	0.68	2.36	4.116	81	3.7	237		
B	OPT 8		( )										
40494 A		B3 IV	(B4 III)	-.00	-3.03	2.60	3.74	4.210	33	7.2	300		
B	PH		(G8 V)	.00	5.27	0.17	-0.15	3.73			300	10139	C
43112 A		B1 V	(B1 V)	.02	-3.53	0.46	4.34	4.410	6	11.0	759		
B	OPT 4,6		(G0 V)										*
43286 A		B5	(B5 IV)	.01	-1.55	1.34	3.10	4.189	62	5.4	498		
B	PH		(G3 V)	.01	3.84	1.21	0.42	3.74			498	9113	
C	OPT 5		(A8 V)										
43983 A		B8	(B8 IV)	-.00	-0.78	1.16	2.60	4.124	107	4.3	489		
B	OPT 5		(F9 V)										
44458 AB		B1 V E	(B0 V)	.20				4.459					*
C	OPT? 5		(A0 IV)										*
44944 A		A5 V	(A5 V)	.01	2.58	0.06					110		*
B	OPT 1		(B9 IV)										
44996 A		B5 IV	(B3 IV)	.06	-2.48	1.85	3.56	4.230	44	6.3	459		
B	OPT 8	F0 V	(F0 V)										
45995 A		B1.5 IV E	(B1)	.13				4.410					*
B	OPT 3	B9 IV E	(B9 IV)										*
46035 A		B8	(B8 V)	.06	0.16	0.37	2.18	4.107	60	3.4	186		
B	OPT 1		(A4 V)										
46064 A		B2 V	(B2 V)	.05	-2.29	0.53	3.66	4.317	13	7.4	446		
B	OPT 4	F5 V	(F5 V)										*

TABLE VI *(continued)*.

HD	Relation	MK	(MK)	E(b-y)	M_V	ΔM_V	Log L	Log T_e	Age (10^6y)	Mass	Dist (pc)	Sep (au)	Notes
46547 A		B2 IV	(B2 III)	.01	-3.87	2.07	4.30	4.319	19	9.5	814		
B	OPT 4	A0 V	(B7 V)										*
47116 A		B9 V	(B8 V)	.04	0.11	0.41	2.21	4.108	63	3.4	308		
B	OPT 4	F6 V	(F6 V)										*
47247 A		B5 V	(B5 V)	.00	-0.42	0.20	2.64	4.190	15	4.5	230		
B	PH	A2 V	(A3 V)	.00	2.46	-0.35	0.93	3.93			230	2091	C *
47732 A		B3 V	(B3 V)	.02	-0.03	-0.64	2.59	4.235		5.0	477		
B	OPT 5		(B0.5 V)										
C	OPT 5		(B2 V)										
47851 A		B2 V	(B2 V)	.00	-2.40	1.02	3.65	4.291	23	7.4	1027		
B	OPT 4	F2	(F2 V)										
47887 A		B2 III	(B0.5 V)	.02	-2.71	-0.41	4.02	4.414	<4	10.2	919		
B	OPT 3,6	B9 V	(B8 V)										
48383 A		B4 V	(B4 V)	-.00	-1.00	0.60	2.92	4.207	35	5.0	270		
B	PH	A	(A8 V)	.00	2.43	0.25	0.94	3.91			270	4157	
48425 A		B5	(B3 V)	.00	-0.62	-0.04	2.82	4.233	<25	4.9	355		
C	PH		(G5 V)	.00	5.07	0.25	-0.08	3.74			355	12389	C
48857 A		B4 V	(B3 V)	.02	-1.68	1.09	3.23	4.227	32	6.5	531		
B	PH		(B9 V)	.02	0.45	0.45	1.96	4.07			531	22461	
48917 A		B2 III E	(B0.5)	.10				4.436					*
B	?		(F)										
49606 A		B7 III	(B6 V)	.00	-0.95	0.98	2.79	4.164	65	4.6	230		*
B	OPT 1		(F/G)										
52140 A		B5 III	(B4 V)	-.00	-0.50	0.09	2.72	4.209	<32	4.6	229		
B	OPT? 3	M5 III	( )										*
C	OPT 1	F6 V	(F6 V)										
52437 AP		B2 V	(B1.5 V)	.02	-3.49	1.52	4.16	4.330	19	9.8	972		
X	OPT 3	K	(gK)										
53191 A		A0 V	(B9 V)	.01	0.79	0.30	1.80	4.051	89	2.8	240		
B	PH		(G5 V)	.01	4.80	0.10	0.03	3.74			240	4080	
53755 AB*		B0.5 IV	(B0.5 III)	.15	-4.82	1.54	4.89	4.426	<10	14.1	1371		
B	PH	F5 III	( )		-0.92	4.6	1.52	3.83			1371	8500	C
54764 A		B1 II	(B1 Ib)	.22	-5.65	2.39	4.99	4.311	18	10.0	1420		
B	OPT 3,4	F3 V	(F3 V)										
55856 A		B2 V	(B1.5 V)	.01	-3.31	1.36	4.09	4.329	19	9.8	839		*
B	OPT 6	G5 III	(gG)										*
56456 A		B9 V	(B9 V)	.00	0.15	0.68	2.10	4.073	123	3.2	83		
B	OPT 1		(gF)										
56504 A		B9 IV	(B8 IV)	.02	-0.84	1.49	2.55	4.094	138	3.8	932		
B	PH	G5	(G6 III)	.02	0.00	6.25	2.00	3.70			932	28985	*
58420 A		B5 V	(B5 V)	.00	-0.36	0.20	2.61	4.183	16	4.3	217		
B	OPT 1	F5 V	(F5 V)										
60102 A		B9.5 V	(B9.5 V)	.05	0.82	0.36	1.77	4.043	102	2.7	198		
B	PH		(G8 V)	.05	5.15	0.50	-0.10	3.73			198	3247	
60575 A		B4 V	(B4 V)	.10	-1.25	0.80	3.03	4.212	41	5.2	806		
B	PH		(B8 V)	.10	0.10	0.39	2.30	4.11			806	12412	
C	OPT 3	M4	(M4 III)										
60624 AB		B9	(B7 IV)	.09	-0.89	1.09	2.72	4.146	74	4.4	416		
B	OPT 1	A3 V	( )										
60855 AB		B2 IV	(B2.5 III)	.07	-3.95	2.71	4.25	4.281	19	9.8	751		*
C	OPT? 8	B9.5 V	(B9.5 V)										*
60863 A		B8 V	(B8 V)	-.01	0.26	0.08	2.20	4.129	<50	3.5	75		
B	OPT 1		(F1 V)										
C	OPT 3	G	(gG)										*

TABLE VI *(continued)*.

HD	Relation	MK	(MK)	E(b-y)	M_V	ΔM_V	Log L	Log T_e	Age (10^6y)	Mass	Dist (pc)	Sep (au)	Notes
61555 A		B3 V	(B3 V)	-.02	-0.99	0.24	2.99	4.241	12	5.4	127		
61556 B	PH	B7 V	(B7 V)	.00	-0.74	0.10	2.67	4.14			127	1257	*
63065 A		B9	(B9.5 V)	.03	0.91	0.36	1.70	4.040	107	2.7	293		
B	PH		(A2 V)	.03	1.83	-0.13	1.21	3.95			293	5128	
C	OPT 1		(F5 IV)										
63425 A		B0 V	(B0 V)	.06	-3.82	0.38	4.51	4.438	4	12.6	1245		*
B	OPT 6	K7 III	( )										*
63465 A		B2.5 III	(B3 III)	.06	-3.39	2.61	3.95	4.243	26	8.3	441		
B	PH		(F2 V)	.06	2.62	0.64	0.87	3.84			441	4806	C
63922 A		B0 III	(B0 V)	.07	-4.33	0.51	4.78	4.466	4	14.1	425		*
B	OPT 6	B9 V	(B9 IV)										*
64755 AB*		B9 Ib	(B9 II)	.39	-3.66	4.08	3.75	4.121			1365		*
B	OPT 2	G6 V	( )										
65162 AB		B3 V	(B4 V)	.08	-1.19	0.71	3.01	4.216	36	5.2	620		
C	OPT 1		(B7 V)										
66005 A		B2 V	(B1.5 V)	.04	-1.95	0.03	3.54	4.327	<14	7.2	424		
66006 B	PH	B2 V	(B1.5 V)	.04	-1.94	0.31	3.49	4.31			424	6953	
66230 A		B7 II	(B6 V)	.05	-0.32	0.48	2.50	4.149	50	4.0	453		*
B	OPT 1	A5	(A8 V)										*
66539 A		B2.5 V	(B2.5 IV)	.09	-2.85	1.95	3.76	4.254	32	7.2	1070		
B	OPT? 2	F5 V											*
66546 A		B3 IV	(B2 V)	.12	-2.40	1.05	3.65	4.289	23	7.4	565		SB
B	?	B9 III P	(PEC)										*
66624 A		B9 P	(B7 V)	-.03	-0.41	0.63	2.52	4.143	63	4.0	153		
B	OPT 6	M6 III	( )										*
67059 AB		B3 III	(B4 II)	.08	-4.26	3.12	4.36	4.274	17	10.7	1863		
B	OPT 2	G2 V	( )										
67880 AB		B2 V	(B2 V)	.03	-2.19	0.81	3.56	4.291	21	7.1	348		
B	OPT 1	A5 III	( )										
69144 A		B3 III	(B4 IV)	.02	-2.48	2.09	3.51	4.206	43	6.3	456		SB
B	OPT 6	K5 V	( )										*
70309 A		B3 IV	(B3 V)	.03	-1.08	0.37	3.02	4.238	19	5.4	304		
B	PH		(K2 IV)	.03	3.75	3.23	0.59	3.66			304	12920	C
70556 AB		B2 V	(B2 V)	.01	-2.71	1.03	3.82	4.311	20	7.9	369		
B	OPT 1	A2 V	( )										
71304 A		O9 II	(O9 I)	.60	-6.44	2.06	5.69	4.498	5	31.6	2670		*
B	OPT 4,5		(F7 V)										
C	OPT? 8		(B2 V)										
71510 A		B3 V	(B3 V)	.00	-1.77	0.95	3.31	4.247	32	6.2	244		
B	OPT 1,3	B8 V	(B9 III)										*
C	PH	G3 V	(G5 V)	.00	3.81	1.34	0.42	3.75			244	8515	C
71833 A		B8 III	(B8 III)	.04	-1.55	1.96	2.90	4.120	95	4.5	414		
B	OPT? 3,4	F2 V	(F6 V)										*
72798 A		B5 III	(B5 III)	.03	-2.60	2.42	3.50	4.185	44	6.3	614		
B	OPT 3	A0 V	(B9 V)										*
74067 AB*		B9 V	(B9.5 V)	-.02	1.01	0.21	1.67	4.046	63	2.7	69		
B	PH	A2 V	( )		2.3	-0.5	1.0	3.96			69	269	*
74115 A		B9 V	(B9.5 V)	.02	0.98	0.28	1.64	4.023	100	2.5	270		
B	OPT 1,3	F3 V	(F1 V)										
74146 A		B5 V	(B4 V)	.01	-0.41	0.14	2.65	4.195	10	4.5	184		SB
B	PH	F0 IV	(F0 IV)	.01	2.31	0.48	0.98	3.86			184	3054	C
74531 A		B2 IV	(B1 V)	.04	-2.56	-0.24	3.91	4.390	<6	9.5	843		
B	OPT 3	A7 V	(gA/F)										*
76323 A		B5 V	(B5 IV)	.01	-1.71	1.50	3.15	4.188	62	5.4	634		
B	PH	A1 V	(B9.5 V)	.01	1.14	-0.25	1.56	4.01			634	11095	

TABLE VI *(continued)*.

HD	Relation	MK	(MK)	E(b-y)	M_V	ΔM_V	Log L	Log T_e	Age (10^6y)	Mass	Dist (pc)	Sep (au)	Notes
76566 A		B3 V	(B3 V)	.00	-1.64	1.05	3.22	4.227	38	5.9	383		
B	PH		(G4 V)	.00	4.72	0.43	0.06	3.74			383	13405	C
77002 A		B2.5 IV	(B2.5 V)	.01	-1.90	0.70	3.43	4.278	22	6.8	228		
B	PH	B9.5 V	(B6 V)	.01	0.01	0.06	2.36	4.16			228	9211	
77484 AB*		B9	(B9.5 V)	.02	0.8		1.5	4.023			555		*
B	PH	G5 V	( )		4.8	0.5	0.00	3.75			555	2440	*
82906 A		B9	(B7 V)	.01	-0.54	0.82	2.55	4.137	72	4.1	476		
B	OPT 4,7		(F8 V)										
82919 A		B5 V	(B5 IV)	.08	-1.75	1.57	3.17	4.186	63	5.4	506		
B	PH?	A2 V	(A2 V)	.08	2.49	-0.61	0.95	3.96			506	5465	*
83953 A		B5 V E	(B5)	.01	-1.0			4.181			138		*
B	OPT 6	G8 V	(gG)										*
83965 A		B9	(A4 III)	.00	0.66	1.83	1.65	3.92	490	2.4	346		*
B	OPT 7,8		(F/G)										
86388 A		B9 V	(B9 V)	.00	0.70	0.25	1.86	4.063	65	2.8	170		
B	PH	F5 V	(F5 V)	.00	3.81	-0.11	0.40	3.81			170	1563	
86440 A		B5 Ib	(B8 Ib)	.06	-5.36	4.82	4.69				535		*
B	OPT 3	K0 III	(gG/K)										
86523 A		B2.5 V	(B2.5 V)	.03	-1.74	0.63	3.35	4.271	21	6.5	345		
B	OPT 1	A1 III	(A1 V)										*
87901 A		B8 V	(B8 III)	.00	-0.95	1.60	2.59	4.093	135	3.8	28		*
87884 B	PH	K0 V	(K1 V)	.00	5.79	0.41	-0.39	3.70			28	4956	*
90972 A		B9.5 V	(B9 V)	.01	0.55	0.51	1.90	4.053	123	2.9	140		SB
B	PH	F9 V E	(F9 V)	.01	3.81	0.79	0.40	3.78			140	1538	*
91355 A		B6 II	(B2.5 V)	-.01	-1.56	0.62	3.25	4.257	25	6.0	294		
91356 B	OPT 8	B8 II	(B7 III)										
91590 A		AP	(B7 V)	.00	0.02	0.29	2.31	4.132	39	3.5	259		
B	PH	AP	(A7 V)	.00	2.91	-0.24	0.74	3.88			259	7355	
91645 AB*		A0 IV	(A0 V)	.03	1.07	0.19	1.57	4.000	126	2.3	139		
B	OPT 1	F4 V	( )										
92029 A		B5 IV	(B5 V)	.07	-0.58	0.41	2.70	4.184	34	4.4	295		
B	OPT 4	A8 III	(A8 III)										
93010 A		B4 IV	(B3 V)	.11	-1.66	0.94	3.25	4.238	35	5.9	366		
B	OPT? 6	A0 III:	(B6 V)										*
93632 A		O4 III	(B1.5 I)	.39	-6.9	4.7	5.36	4.175			5200		*
B	OPT? 3	B2 V E	(B0.5 V)										*
93873 A		B1 Ia	(B0 Ia)	.54	-6.9	2.7	5.61	4.458			2900		
B	OPT 3	A2 III P	(PEC)										*
94565 A		B8 III P	(B8 V)	.04	0.01	0.59	2.22	4.098	89	3.4	237		
B	OPT 6	A8 P	(A8 IV)										*
94909 A		B0 I	(B0 I)	.53	-7.0	2.8	5.65	4.448			2500		*
B	OPT 3	G5 V	(G)										
95198 A		B9 P	(B9 III)	.00	-0.41	1.44	2.29	4.056	200	3.3	449		
B	OPT 8		(gK)										
96261 A		B0.5 II	(B0.5 IV)	.36	-4.39	1.03	4.72	4.431	8	13.5	1278		
B	OPT 1,6	B/A E	(B E)										
96264 A		O9.5 V	(O9 III)	.17	-5.84	1.62	5.46	4.503	<8		3522		
B	PH?	B4 V	(B1.5 E)	.17	-3.28	1.27	4.10	4.34			3522	84528	*
97583 A		B9 V	(B9 V)	-.00	0.54	0.33	1.94	4.069	79	3.0	86		
B	OPT 1	A0	(B9.5 V)										
99803 A		B9 V P	(B9.5 V)	.01	0.86	0.42	1.72	4.042	126	2.7	100		SB
B	PH	A3 V	(A4 V)	.01	2.74	-0.34	0.82	3.93			100	1310	
100359 A		B7 IV	(B7 III)	.29	-1.79	2.01	3.06	4.143	44	5.0	301		
B	PH	A1 V	(A0 V)	.29	-2.23	-0.38	2.87	3.97			301	6321	

TABLE VI *(continued)*.

HD	Relation	MK	(MK)	E(b-y)	M_V	ΔM_V	Log L	Log T_e	Age (10^6y)	Mass	Dist (pc)	Sep (au)	Notes
100600 AB*		B4 V	(B3 V)	.01	-1.10	0.43	3.02	4.234	22	5.4	251		*
C	OPT 1	F5	(A1 V)										*
100841 A		B9 III	(PEC)										*
B	OPT 1	B9 V	( )										
101436 A		B0 V	(09.5 I)	.24	-6.65	2.40	5.70	4.465			4401		
B	OPT 2,6	B0 V E	(B0)										*
102340 AB		B5 V	(B6 V)	.04	-0.68	0.79	2.66	4.156	63	4.4	447		
C	OPT 1	A2 V	( )										
104901 A		B9 II	(B9 II)	.26	-3.86	4.56	3.74	4.087	46	7.1	1052		*
B	PH	F0 II E	(A8 II)	.26	-3.51	6.23	3.31	3.86			1052	24196	*
106983 A		B2.5 V	(B2.5 V)	.00	-0.96	-0.03	3.02	4.261	<22	5.5	99		
B	OPT 3	G8 III	(gG/K)										
107348 A		B8 V	(B8 IV)	.00	-0.56	1.20	2.44	4.094	141	3.7	201		SB
B	OPT 1,7	F6 III	( )										*
108610 A		B3 V	(B3 V)	.09	-1.27	0.74	3.06	4.221	36	5.4	367		
B	OPT 1,3	A5 V	(A V)										
108767 A		B9.5 V	(B9.5 V)	-.00	1.07	0.03	1.61	4.029	<112	2.4	23		
B	PH	K2 V E	(K1 V)	.00	6.58	-0.38	-0.62	3.70			23	556	C? *
109668 A		B2 IV	(B1.5 V)	.00	-2.19	0.20	3.65	4.331	5	7.4	94		
B	OPT 1	B4 V	( )										
109867 A		B0.5 Iab	(B0 Ia)	.24	-7.2	3.3	5.73	4.394	<10		3100		
B	PH?	B7 P	(B2.5 V)	.24	-1.0	0.0	3.06	4.27			3100	52700	*
110956 A		B3 V	(B3 V)	.01	-0.51	-0.25	2.80	4.242	<18	5.0	104		
B	OPT 1,3,6	A3 P	(A7 P)										*
111123 A		B0.5 IV	(B0.5 IV)	.02	-4.28	0.94	4.68	4.431	8	12.6	123		
B	OPT 1,3	F8 V	( )										
112092 A		B2 V	(B2 V)	.02	-1.85	0.46	3.43	4.291	15	6.6	143		
112091 B	PH	B5 V E	(B4 V)	.02	-0.72	0.32	2.78	4.21			143	4990	*
112244 A		09 Iab	(09 I)	.21	-7.50		6.16	4.526	<5		2489		*
B	PH	K0 III	(G8 III)	.21	-1.12	7.50	2.45	3.68			2489	72430	C
112413 A		A0 III P	(B8 V)	-.01	0.52	-0.08	2.07	4.117	<28	3.2	29		
112412 B	1 PH	F0 V	(F1 V)	.00	3.23	-0.04	0.61	3.85			29	568	C? *
113703 A		B4 V	(B4 V)	-.00	-0.07	-0.32	2.54	4.206	<35	3.5	90		
B	PH	K0 V E	(K2 V)	.00	6.11	0.59	-0.38	3.68			90	1026	C *
113791 A		B2 V	(B2 V)	.02	-1.63	-0.15	3.40	4.318	<11	6.9	205		SB
B	PH?	F7 V	(F6 V)	.02	2.75	1.19	0.82	3.76			205	4763	C *
114911 A		B8 V	(B8 V)	.01	0.70	-0.25	1.99	4.116	<20	3.2	90		SB
B	PH	AP	(A3 V)	.01	2.50	-0.25	0.92	3.93			90	5400	*
117460 A		B2 III	(B2 III)	.23	-3.49	1.60	4.15	4.325	19	9.5	996		
B	OPT 4,8	B2 E	(B1)										*
118716 A		B1 IV	(B1 V)	.02	-3.62	1.03	4.30	4.375	13	10.5	147		
B	OPT 1,3	B1 P	( )										
119423 AB		B4 V E	(B2.5)	.11									*
B	OPT 1	B7 V	( )										
120324 A		B2.5 V E	(B0.5 V)	.07				4.430					SB *
B	OPT 1	F2 V	(F)										
120642 A		B8 V	(B8 V)	-.01	0.56	0.08	1.99	4.094	<71	3.0	87		
120641 B	PH	F0 V P	(F0 V)	.00	2.82	0.01	0.78	3.89			87	1566	*
120955 A		B5 IV	(B5 IV)	.00	-1.59	1.50	3.08	4.176	71	5.0	265		SB
B	OPT 3,6	A3 V M	(A8 V)										
120991 A		B2 II E	(B0.5 II)	.12	-4.8	1.3	4.74	4.355	13	10.0	1219		*
B	PH	B8 V	(B9 V)	.12	0.6	0.5	1.94	4.06			1219	18163	
123445 A		B9 V	(B9 V)	.03	0.91	-0.20	1.83	4.087	<20	3.0	107		
B	PH	K2 V	(K4 V)	.03	7.26	-0.36	-0.81	3.66			107	3060	C

TABLE VI *(continued)*.

HD	Relation	MK	(MK)	E(b-y)	M_V	ΔM_V	Log L	Log T_e	Age (10^6y)	Mass	Dist (pc)	Sep (au)	Notes
123635 A		B9 II	(B8 IV)	.05	-0.75	1.16	2.58	4.121	87	4.2	457		
B	OPT? 3	F0 V	(F0 V)										
124367 A		B4 V E	(B2 V)	.10				4.30					*
B	OPT 3	M3 IV	( )										
C	OPT 1,3	F4 V	(F4)										
124471 A		B2 III	(B0.5 V)	.13	-3.62	0.32	4.41	4.428	3	11.7	584		*
B	OPT? 3	F5 V	(F)										
126981 A		B8 V	(B9 IV)	-.00	-0.04	0.98	2.16	4.064	145	3.3	129		
B	OPT 1,3	G6 V E	( )										
127304 A		A0 V	(A0 V)	.01	1.23	-0.05	1.53	4.017	<79	2.3	91		
B	PH	K1 V	(K1 V)	.01	6.53	-0.18	-0.61	3.71			91	2349	C? *
127971 A		B7 V	(B7 V)	.02	0.54	-0.26	2.11	4.136	<18	3.5	112		
B	PH	K0 V	(K3 V)	.02	5.89	0.73	-0.30	3.68			112	3012	C
128819 A		B9 V	(B9 V)	.00	0.62	0.15	1.93	4.080	35	3.0	161		
B	OPT 1,3	A0 V E	( )										
128919 AB*		B9 II	(B6 V)	.25	-0.69	0.76	2.67	4.159	62	4.4	566		
B	OPT? 1	A1 V	( )										*
129791 A		B9.5 V	(B9.5 V)	.06	1.22	0.11	1.56	4.029	45	2.5	123		
B	PH	K5 V E	(K5 V)	.06	7.19	-0.05	-0.75	3.65			123	4341	C *
130081 A		B9 V P	(B9 V)	.07	0.58	0.20	1.94	4.079	42	3.0	154		
B	OPT 1	F4 V	( )										
131168 A		B2 V E	(B1.5)	.13				4.332					*
B	OPT 6	G5 IV	(gG)										*
135160 ABC*		B1 V	(B0 V)	.14	-3.82	0.15	4.55	4.455	1	12.6	622		
C	OPT 6	A5 V	( )										*
135240 A		O8 V	(O8 V)	.14	-4.94	0.66	5.11	4.508	8	20.0	752		
B	OPT 3	G5 V	(G5 III)										*
135591 AB		O8 V	(O8 V)	.14	-5.22	0.86	5.25	4.521	5	27.5	1036		*
B	?	B9 V	( )										
C	PH	A	(A8 III)	.14	1.03	1.64	1.49	3.90			1036	46102	C
136454 AB*		B9 III	(B8 V)	.09	0.68	-0.04	1.94	4.094	<50	3.0	484		
B	OPT? 1	F0	( )										
137387 A		B3 IV E	(B1.5 IV)	.11	-3.6		4.0	4.344	<20		524		*
B	PH	K5 IV	(K7 IV)	.11	2.2	8.6	1.6	3.57			524	1470	C *
138800 A		B8 IV	(B8 IV)	.05	-0.71	1.25	2.53	4.106	126	4.0	168		
X	PH	K0 V	(K1 V)	.05	6.50	-0.35	-0.60	3.71			168	2520	
Y	OPT 1		(gG/K)										
139619 A		B7 V	(B6 V)	.08	-0.99	1.07	2.79	4.158	69	4.6	842		
140022 A		B8 V	(B8 V)	.04	0.52	-0.10	2.07	4.120	<28	3.2	472		
B	PH?	A0 V	(A2 V)	.04	2.02	0.03	1.14	3.96			472	3634	*
141318 A		B2 III	(B1.5 III)	.19	-4.07	1.67	4.46	4.361	15	11.5	907		SB
B	OPT 2,7,8	K0 V	(G/K)										*
X	OPT 5		(F/G)										
141468 A		B8 V	(B8 V)	.10	0.25	0.15	2.19	4.122	25	3.4	383		
B	OPT 3	K2 V	(K2 III)										*
141569 A		A0 V	(A0 V)	.07	1.59	-0.20	1.37	4.004		2.2	111		
BC	OPT 1	G0 V E P	( )										
142448 A		B9 V	(B9 IV)	.18	-0.23	1.29	2.21	4.053	200	3.3	125		
B	OPT 1	G8 V	( )										
142514 AB		B7 IV	(B8 V)	.03	-0.30	0.65	2.42	4.128	69	3.9	152		
B	OPT 1	F5 V	(F)										
143018 A		B1 V	(B1 V)	.05	-3.44	0.66	4.26	4.388	9	10.2	239		SB
B	OPT 1	F4 V	(F)										
143118 A		B2 V	(B1.5 V)	.00	-2.56	0.15	3.81	4.339	3	7.6	157		*
B	PH	A5 V P	(A6 IV)	.00	1.86	0.70	1.17	3.92			157	2351	C *

TABLE VI *(continued)*.

HD	Relation	MK	(MK)	E(b-y)	M_V	ΔM_V	Log L	Log T_e	Age (10^6y)	Mass	Dist (pc)	Sep (au)	Notes
143939 A		B9 III	(B9 V)	-.05	1.05	-0.14	1.73	4.066	<32	2.8	153		
B	PH	K3 V E	(K3 V)	.00	5.87	0.89	-0.28	3.67			153	1316	C *
144217 ABC*		B0.5 V	(B1 V)	.12	-4.02	0.96	4.53	4.409	9	12.0	174		*
144218 C	PH	B2 V	(B2 V)	.12	-1.81	0.21	3.44	4.30			174	2366	
145483 AB*		B9 V	(B9 V)	.06	0.86	0.05	1.80	4.066	<71	2.8	81		
B	PH	F3 V	( )		2.9	0.5	0.78	3.84			81	373	*
147049 A		B1 Ia	(B1 I)	.44	-7.5	3.7	5.66	4.374			4600		
B	OPT 2,3	A0 V	(A)										
148066 A		B5 III	(B5 V)	.03	-0.77	0.67	2.75	4.177	49	4.6	600		*
B	OPT 6	F2 V P	(A)										
148688 AB		B1 Ia	(B0 I)	.48	-6.6		5.62	4.455			925		*
B	OPT 2	F5 V	( )										
C	OPT 5		(F9 V)										
149249 AB*		B4 III	(B3 III)	.11	-3.40	2.85	3.91	4.223	26	8.1	1153		
C	OPT 3	A5 V	(gA1)										
150742 AB		B2.5 V	(B2.5 V)	.06	-1.09	0.23	3.05	4.250	11	5.6	197		
B	OPT 1,3	A5 V	( )										
151158 AB*		B2 V	(B3)	.35	-2.5		3.5	4.219			700		*
B	PH?	B7 V	( )		0.5		2.1	4.13			700	1900	
152408 AB		O7 I	(O7 I E)	.23									*
B	?	F4 P	( )										
152723 A		O6.5 III	(<O8)	.31	-5.59	1.17					2011		
B	?	A4 V	( )										
C	OPT 2,6	B5 V	( )										*
D	OPT? 1	B6 V	(B0.5 V)										
152901 A		B2 V	(B2 V)	.24	-2.19	0.71	3.58	4.297	19	7.2	536		
B	OPT? 1,2	A7 III	(gA)										*
153519 AB*		B9 V	(B6 V)	.20	-0.98	1.05	2.79	4.160	65	4.7	473		
153613 A		B8 V	(B8 V)	-.00	0.25	0.27	2.15	4.109	42	3.4	90		
B	OPT 3,7	A8 V	(A)										
C	OPT 1,3	F5 V	( )										
D	OPT 5		(gK)										
156247 A		B5 V+B5 N	(B4 V)	.15	-0.99	0.57	2.92	4.210	33	5.0	249		SB
B	OPT 3	G0 V	( )										
156325 A		B5 IV E	(B5 III)	.23	-3.16	3.10	3.70	4.172	33	7.2	513		
B	PH?	F2 V	(F2 IV)	.23	2.37	0.92	0.95	3.84			513	10003	*
157042 A		B2 III E	(B1 III)	.10				4.389					*
B	OPT 3	G5 III	(gG/K)										
157246 A		B1 III	(B1 Ia)	.10	-6.51	3.03	5.40	4.342	12	13.5	760		*
B	PH	A7 V	(A7 III)	.10	0.36	2.17	1.77	3.89			760	13604	C *
C	OPT 4		(F2 III)										
157736 AB		B9 V	(B9 V)	.10	1.35	-0.07	1.52	4.040	<63	2.5	137		
B	OPT 1,3	A1 V	( )										*
157741 AB		B9.5 V	(B9.5 V)	.04	0.20	0.94	2.03	4.046	166	3.1	157		
B	OPT 1	A6 V	( )										
158094 A		B8 V	(B9 IV)	-.00	-0.04	0.87	2.18	4.074	132	3.3	57		
B	OPT 3	K0 III	(gK)										
158427 A		B2.5 V E	(B2.5)	.03				4.26					SB *
B	OPT 3	K0 IV	(G/K)										
159091 A		B9 III	(B7 V)	.20	-0.77	1.10	2.62	4.131	83	4.2	319		
B	OPT 3	F4 V	(dF)										
159176 AB		O7 V+O7 V	(<O8)	.23	-5.84	1.41					1832		SB
B	PH	B9 V	(B7 III)	.23	-2.22	1.95	3.26	4.15			1832	9893	
C	PH	B8 V	(B7 IV)	.23	-1.41	1.14	2.94	4.15			1832	24365	
X	PH		(B5 IV)	.23	-1.54	0.61	3.05	4.18			1832	45800	

TABLE VI *(continued)*.

HD	Relation	MK	(MK)	E(b-y)	M_V	ΔM_V	Log L	Log T_e	Age (10^6y)	Mass	Dist (pc)	Sep (au)	Notes
159574 A		B8 Ib	(B8 II)	.25	-3.15	3.58	3.54	4.118	46	6.3	938		*
B	PH	B7 V	(B6 V)	.25	0.10	-0.06	2.37	4.16			938	11912	
160281 A		B5 V	(B2 III)	.16	-3.59	2.27	4.12	4.287	22	9.1	1737		*
B	?	A0 V	(A)										*
160974 AB		B1 II	(B1 V)	.46	-3.04	0.05	4.13	4.404	<9	10.0	910		
B	?	F2 P	( )										*
161004 A		B8 V	(B9 II)	.28	-3.42	3.76	3.67	4.129			1542		
B	OPT 2,7	G8 IV P	(G/K)										
162082 A		B7 V	(B5 V)	.15	0.04	-0.07	2.41	4.169	<14	4.0	314		
B	PH	F2 V	(F2 V)	.15	2.88	0.33	0.76	3.85			314	3359	C
D	OPT 2,3	A4 V	(A1 V)										
163181 A		B0 I	(B0 I)	.57				4.444					SB *
B	OPT 2,3	F7 V	(gF)										
164492 A		O7.5 III	(O7 V)	.21	-4.02	-0.38					1375		
B	OPT 2	A2 Ia	( )										*
CD	OPT 2	B0 II	(B1 II)										
E	OPT 2	F3 V	( )										
165493 AB*		B8 III	(B6 V)	.04	-0.91	0.91	2.78	4.166	74	4.7	237		
B	OPT? 1	B9 V	( )										
165530 A		B7 V	(B4 IV)	.11	-2.28	1.83	3.44	4.212	47	6.0	480		
B	PH	B9 III P	(B8 V)	.11	0.02	0.39	2.36	4.12			480	6384	
166182 A		B2 IV	(B2 III)	.04	-3.44	1.88	4.09	4.302	23	8.7	331		
B	OPT 1,3	A6 V	( )										
166563 A		A0 V	(A0 V)	.05	1.06	0.20	1.59	4.009	126	2.3	124		
B	OPT 2,3,7	F3 V	(F2 V)										
166566 AB*		B0.5 III	(B0.5 I)	.36	-7.1	3.2	5.78	4.390			5000		
B	OPT 2	F2 V	( )										
166937 A		B8 Ia E	( )	.24	7.0		4.98	4.00			1300		SB *
B	PH	B9 III	(B3 V)	.24	-1.2	0.2	3.08	4.26			1300	21970	
D	PH	B3	(B2 V)	.24	-2.0	0.5	3.52	4.31			1300	63050	*
E	PH	B2 V	(B1.5 V)	.24	-2.4	0.4	3.69	4.32			1300	65000	*
167263 AB		O9 III	(O9 IV)	.21	-5.41	1.08	5.31	4.513	5	27.5	1227		*
B	PH	A3 V	( )		1.92	0.38	1.18	3.94			1227	7362	C
167647 A		B3 V+A	(B3 V)	.05	-1.65	1.06	3.22	4.227	39	5.9	339		*
B	PH		(A1 V)	.05	1.79	0.01	1.26	3.98			339	13187	*
167771 A		O8 If	(O8)	.26	-6.11	1.74	5.61	4.523			1996		
B	OPT? 2,3	A3 V	( )										*
169337 AB		B8 V+G8	(B5 IV)	.66	-1.99	1.89	3.24	4.176	62	5.5	210		*
B	OPT? 2,3	A7 V	(dA)										
170385 AB		B3 V	(B3 V)	.01	-0.87	0.15	2.94	4.239	8	5.2	553		
B	OPT? 1	A8 V	( )										
170580 A		B2 V	(B2.5 V)	.20	-2.35	1.34	3.58	4.263	35	7.1	431		
B	PH	A7 V P	(A8 V)	.20	2.27	0.46	1.00	3.90			431	8663	*
C	OPT 1	F5 V	(F)										
D	?	F8 V	( )										
170740 A		B2 V	(B2 V)	.32	-2.40	0.81	3.68	4.304	19	7.4	225		
B	PH	A0 V	(B9 V)	.32	1.13	-0.30	1.71	4.08			225	2767	*
171247 A		B8 III	(B9 III)	.05	-1.12	1.81	2.64	4.088	126	4.0	291		
B	OPT 8		(K)										
173360 A		B9 V	(B9 V)	.01	0.37	0.68	1.97	4.054	141	3.0	202		
B	OPT 1	F3 V	(F2 V)										
C	OPT 8		(K)										
174152 A		B5 III	(B5 V)	.05	-0.63	0.57	2.68	4.172	46	4.4	240		*
B	OPT 1	B9 III	(B9 III)										*

TABLE VI *(continued)*.

HD	Relation	MK	(MK)	E(b-y)	M_V	ΔM_V	Log L	Log T_e	Age (10^6y)	Mass	Dist (pc)	Sep (au)	Notes
174585 A		B2.5 V	(B2.5 V)	.04	-1.91	0.85	3.41	4.267	26	6.6	338		
B	PH		(K2 IV)	.04	3.08	3.53	0.83	3.68			338	11762	C *
C	PH	G0 V	( )		2.8	1.9	0.81	3.78			338	19841	C
174638 A		B8 II+A8	(B7 I)										*
B	OPT? 1	B8 V	( )										*
E	OPT? 1	B9 V	( )										*
F	OPT? 1	B9 V	( )										*
175876 A		O6.5 III	(<O8)	.12	-4.94	0.53					1868		*
B	OPT 3	G6 III	( )										
176873 A		B9 V	(B8 III)	.14	-1.05	1.42	2.72	4.125	107	4.3	281		
B	OPT 1,7	A2 V	(A2 V)										
C	OPT 1	F6 V	( )										
177817 A		B8 IV	(B8 III)	.05	-0.87	1.40	2.59	4.107	126	4.0	224		
B	PH	A0 V	(A0 V)	.05	1.81	-0.42	1.28	3.99			224	1434	
177880 A		B5 V	(B4 V)	.18	-1.37	1.07	3.04	4.197	49	5.2	303		
B	OPT 1	A0 V	(A0 V)										
179316 A		B3 V	(B2 V)	.42	-2.59	1.20	3.73	4.292	23	7.8	748		
B	OPT 3	F6 IV	(F8 V)										*
179761 A		B8 III	(B8 III)	.03	-1.59	2.04	2.90	4.115	85	4.7	208		
B	OPT 8		( )										
180183 A		B3 V	(B2 V)	.02	-1.88	0.45	3.45	4.294	14	6.8	523		
B	PH	K0 V	(K1 IV)	.02	2.75	3.61	0.94	3.69			523	10146	C
180555 A		B9.5 V	(B9.5 V)	.02	0.94	0.38	1.68	4.036	115	2.7	85		
B	OPT? 4	G0 IV	(F2 V)										
181454 A		B8 V	(B9 IV)	-.00	0.03	0.75	2.16	4.079	120	3.3	61		
B	OPT? 3	A5 V	(F0 V)										*
181558 A		B5 V	(B5 V)	.03	-0.21	0.11	2.53	4.177	10	4.2	184		
B	OPT 6	K2 IV	(K)										*
182110 AB		B9	(B9.5 V)	.02	1.28	0.01	1.51	4.018	<100	2.4	136		
B	OPT 3		( )										
185507 A		B2.5 V	(B2.5 V)	.17	-2.29	1.12	3.58	4.276	26	7.1	456		SB *
B	OPT 3	K0 V E	(gK)										*
185514 A		B9 V	(B5 V)	.08	-1.27	1.26	2.93	4.168	74	4.9	508		
B	OPT 1,3	B7 V	(B)										
193924 A		B2.5 V	(B2.5 V)	-.01	-1.89	0.98	3.38	4.255	30	6.5	82		SB
B	OPT? 5		(K)										
C	OPT? 5		(K)										
X	OPT 1	F5 V	(F)										
194262 A		B8 V	(B8 IV)	.01	-0.59	1.25	2.44	4.092	148	3.7	357		
B	OPT 1,3	F8 V	(G)										
195556 A		B2.5 IV	(B3 III)	.08	-3.93	3.19	4.16	4.240			503		
B	OPT 1	A5 V	( )										
199218 A		B8 V	(B8)	.04									*
201819 A		B0.5 IV	(B0.5 III)	.11	-4.94	1.68	4.93	4.424	10	14.1	1578		
B	PH?	B8 V	( )		0.9	-0.3	1.7	4.09			1578	34400	
211924 AB		B5 IV	(B5 III)	.09	-2.09	2.08	3.26	4.168	58	5.5	258		
B	PH?	A7 V	( )		3.2	-0.5	0.6	3.90			258	1600	
C	OPT 3,7	F6 IV	(F2 IV)										
212581 A		B9 V	(B9.5 V)	.01	1.07	0.11	1.61	4.023	63	2.4	48		
B	OPT 1	F5 III	(F)										
222661 AB		B9.5 V	(B9.5 V)	.01	1.22	0.01	1.58	4.043	<79	2.6	63		SB
B	OPT 1	A5 V E P	( )										
224098 A		B8 V	( )										
B	OPT 1	F0 V	( )										*

TABLE VIII. — *Combinations of MK classes for physical systems.*

	primary's spectral type																
	O7	O8	O9	O9.5	B0.5	B1	B2	B2.5	B3	B4	B5	B6	B7	B8	B9	B9.5	A0
secondary's MK class	B5 IV	B0 V	A3 V	B4 V	B1 V	A7 V	B2 V	B9.5 V	B7 V	B6 V	B7 V	F8 V	B9 IIIp	B2 V	A2 V	A2 V	F0 V
	B8 V	A8 III	K0 III		B2 V		B7 V	F2 V	A1 V	B8 V	A1 V		A1 V	B2 V	A3 V	F9 Ve	G5 V
	B9 V				B7 p		B5 Ve	G0 V	F3 Vp	B9 V	A2 V		A7 V	B7 V	F0 II	G5 V	K1 V
					B8 V		B8 V	K2 IV	G3 V	A8 V	A2 V		F1 V	B9 III	F3 V	G8 V	
					F5 III		A0 V	K5 IV	G3 V	K0 Ve	A6 V		F2 V	A0 V	F5 V	K2 Ve	
							A5 Vp		G4 V		A7 V		G6 V	A0 V	F6 Vp	K5 Ve	
							A7 Vp		G5 V		F0 IV		K0 V	Ap	G2 V		
							F7 V		G8 V		F2 V			F0 Vp	G4 V		
							F9 V		K0 V		G1 V			F3 V	G5 Ve		
							G2 V		K2 IV		G3 V			G8 Ve	G6 III		
									K5 IV		G7 V			K0 V	K2 V		
														K0 V	K3 Ve		
															K5 V		

TABLE IX. — *Double stars for which the main-sequence lifetime of the primary (t_{ms}) equals the contraction time to the ZAMS of the secondary.*

Primary			Secondary	
Sp	Mass	t_{ms}	Mass	Sp
O7	30	4.90×10^6	2.5	B7
O9	15	$1.04\ 10^7$	2.0	A0
B0.5	9	$2.21\ 10^7$	1.3	F0
B2	5	$6.68\ 10^7$	0.9	G5
B5	3	$2.42\ 10^8$	0.4	M0

TABLE X. — *Systems with B type components.*

System	log(age)	
HD	primary	secondary
34798/7	<7.25	7.52
35173/2	7.64	<7.70
36960/59	6.61	6.67
48857	7.50	7.98
60575	7.61	7.78
61555/6	7.09	7.10
66005/6	<7.15	6.93
76323	7.79	-
77002	7.35	<7.65
112092/1	7.18	7.32
120991	7.1	7.6
144217/8	6.95	6.80
159574	7.66	<7.60
165530	7.67	7.75
170740	7.28	<7.80

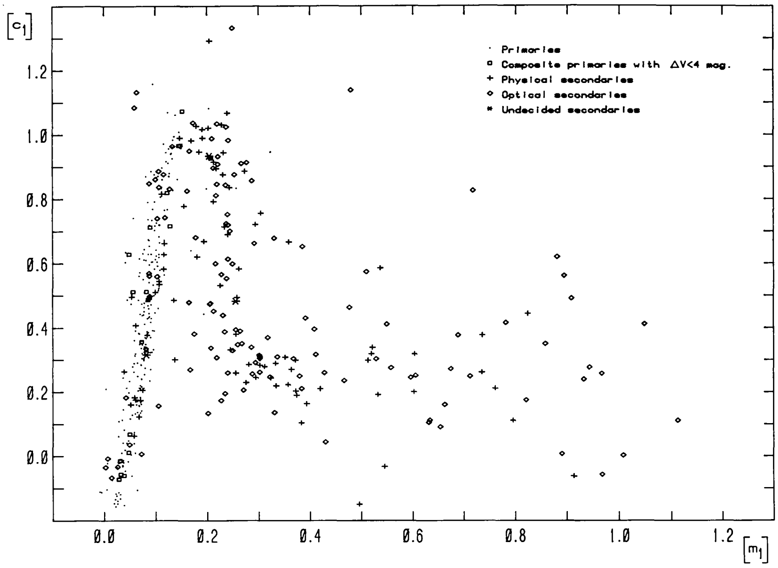


FIGURE 1. — $[m_1]$, $[c_1]$ diagram for the programme stars. The early type for the primaries and the late type of most secondaries is evident.

1985A&AS...60..183L

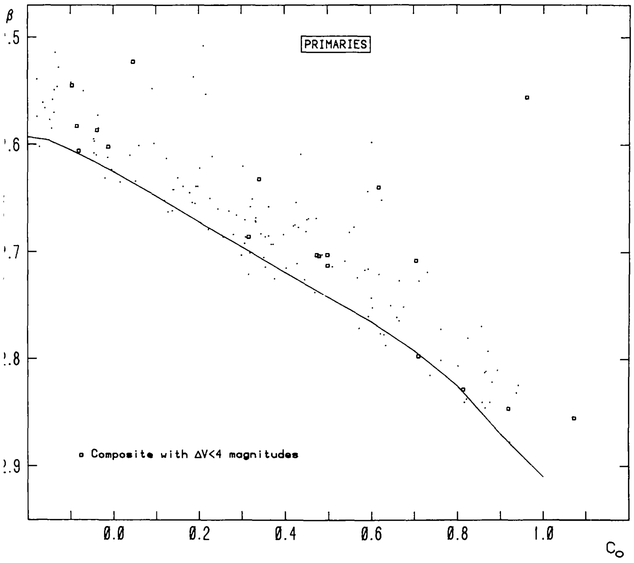


FIGURE 2. — The primaries in the β, c_0 diagram. The line is the ZAMS by Crawford (1978).

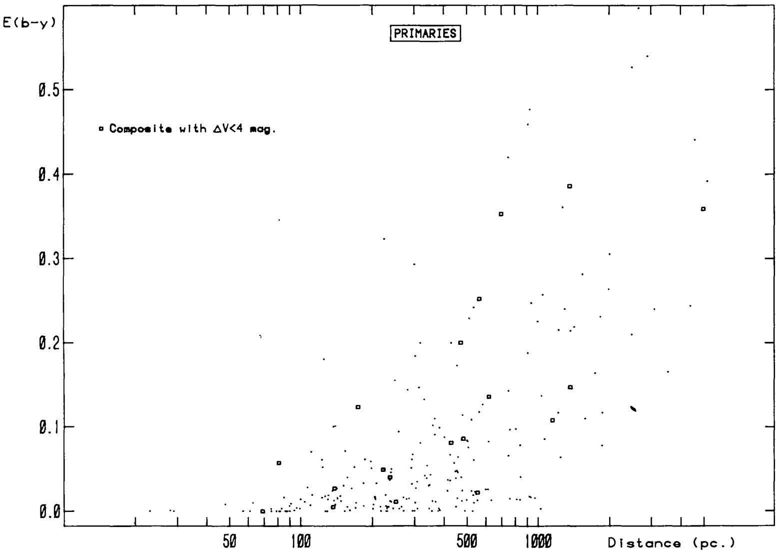


FIGURE 3. — The colour excess $E(b\text{-}y)$ for the primaries plotted against the distance. Most of the stars are affected by interstellar reddening.

ΔL \ ΔS	−4	−3	−2	−1	0	1	2	3
4				1E				
3						1L		
2		1L	1L	3L	1E 2L			
1		1L		1E 1L	7E 11L	4E 3L	1L	
0	1L	1E 1L	5E 1L	15E 10L	38E 47L	5E 10L		1L
−1				4E	6E 6L	1E 1L		
−2		2E 1L	2L	1E 2L	1E 3L			
−3	1L	1L		1L	1E			

◀ FIGURE 4. — Comparison of photometrically and spectroscopically determined MK classes for the primaries. The figure shows the number of stars with different ΔS and ΔL where ΔS = photometric spectral subtype – spectroscopic subtype. ΔL = photometric luminosity class – spectroscopic luminosity class. Stars of spectral type B4 and earlier are denoted by the letter E and later stars by L. The agreement is good — for 82 % of the stars the differences are within one subgroup. The photometric classification tend to give an earlier spectral type than the MK classification.

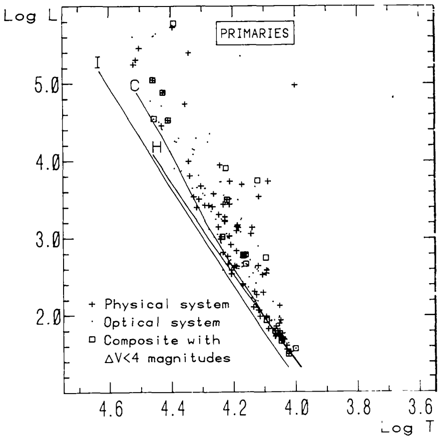


FIGURE 5. — The primaries in the HR diagram. The lines are the theoretical ZAMS by Iben (I) and by Hejlesen (H) and the observed one by Crawford (C). Systems for which the relation between the components is undecided have been marked as optical.

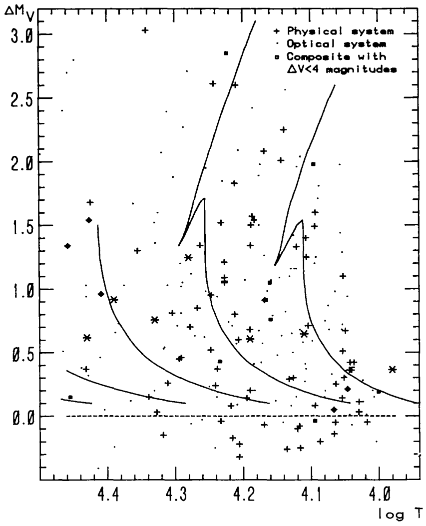


FIGURE 6. — ΔM_v, log T_e diagram for the primaries. Isochrones from Hejlesen (1980) are inserted for log(age) = 6.0, 6.5, 7.0, 7.5 and 8.0. The main sequence by Crawford (1978) is marked by the asterisks. Systems for which the relation between the components is undecided have been marked as optical.

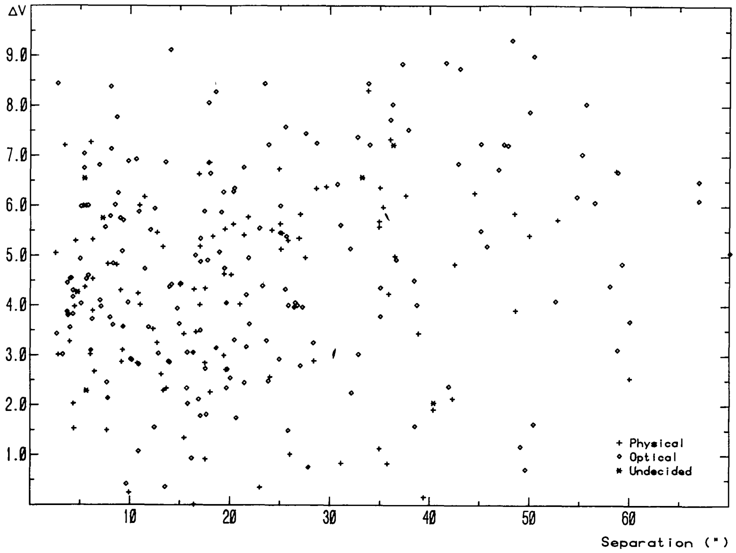


FIGURE 7. — Distribution of the secondaries over $\Delta V = V_B - V_A$ and separation. No obvious difference between physical and optical ones is evident.

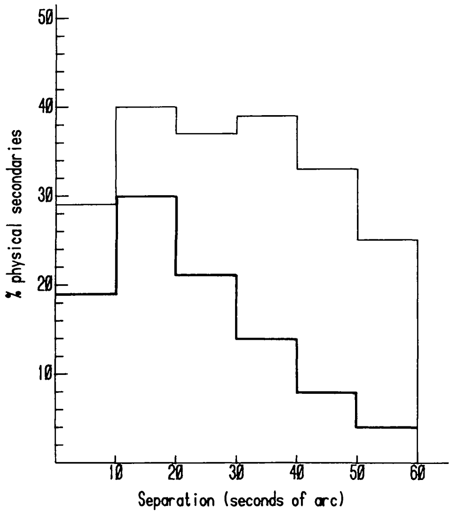


FIGURE 8. — Distribution of physical secondaries over separation. The thin line shows the fraction of physical secondaries in each 10″ interval of separation. The thick line shows the relative distribution of the physical secondaries over separation in intervals of 10″.

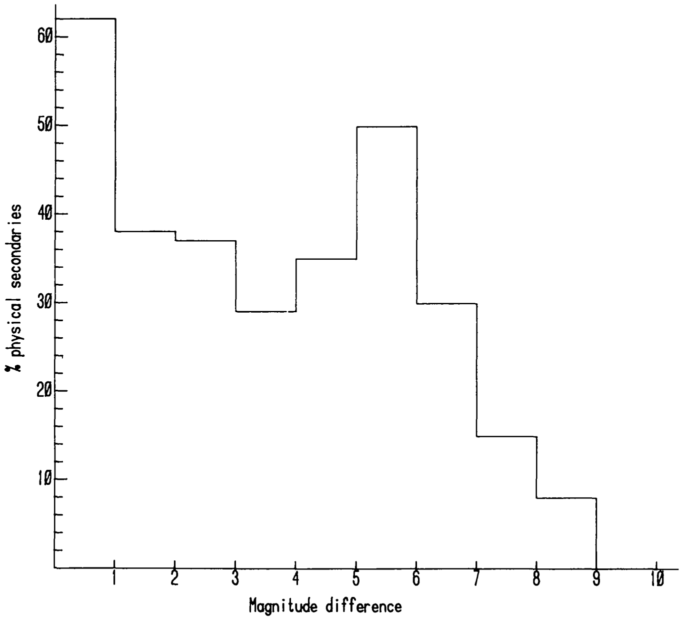
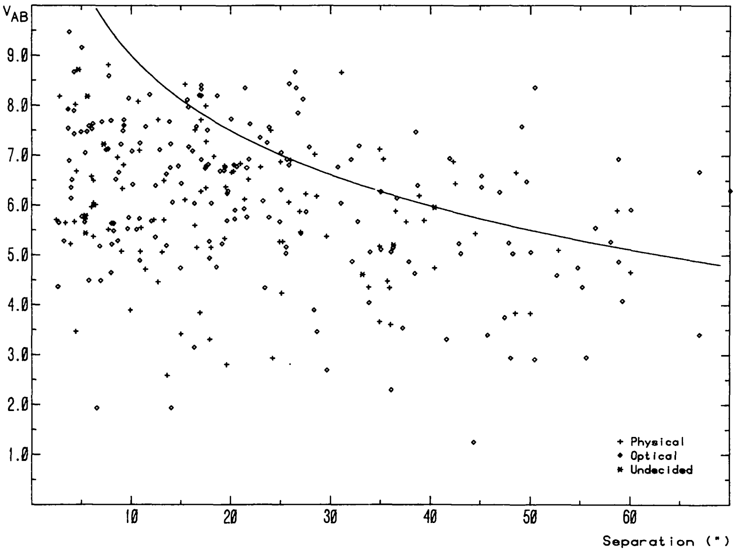


FIGURE 9. — Fraction of physical secondaries in different intervals of $\Delta V = V_B - V_A$.



◀ FIGURE 10. — Distribution of the combined visual magnitude and the separation between the components. It is expected that systems to the left of the curve to large extent should be physical. Clearly this is not the case for this sample.

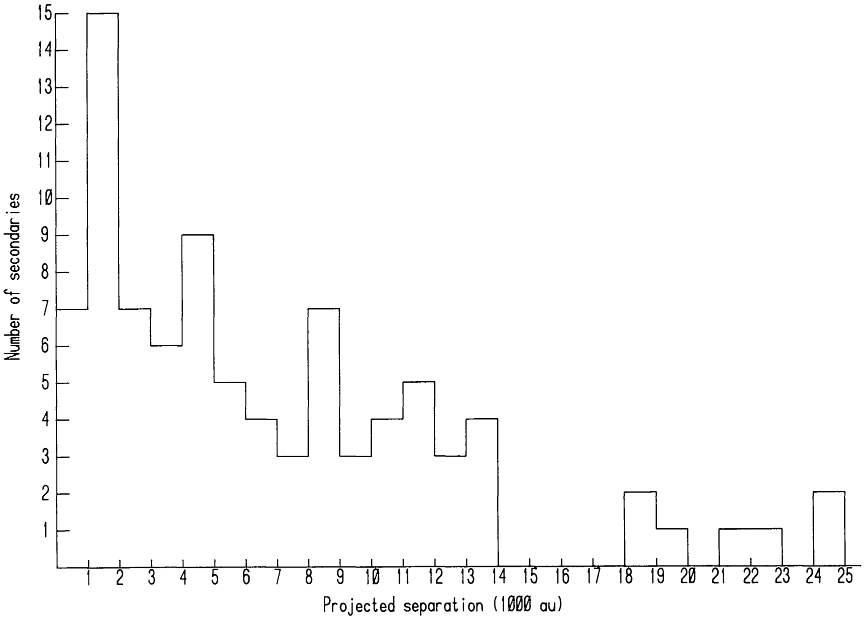


FIG. 11. — Projected separations between primaries and physical secondaries in units of 1000 AU. 9 secondaries fall outside the figure.

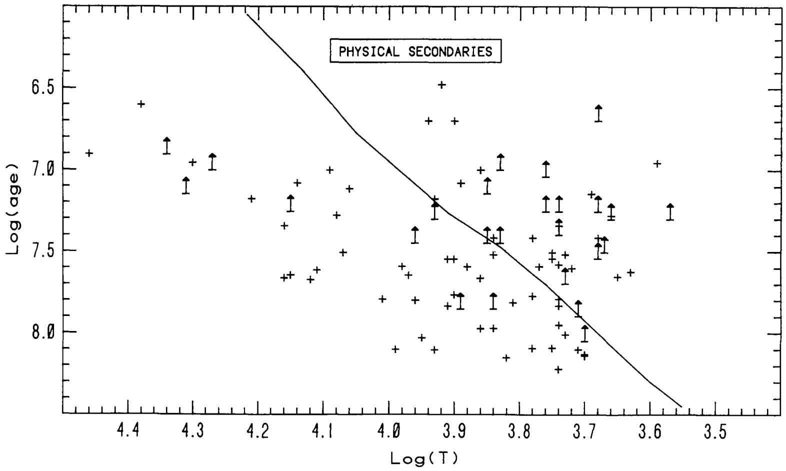
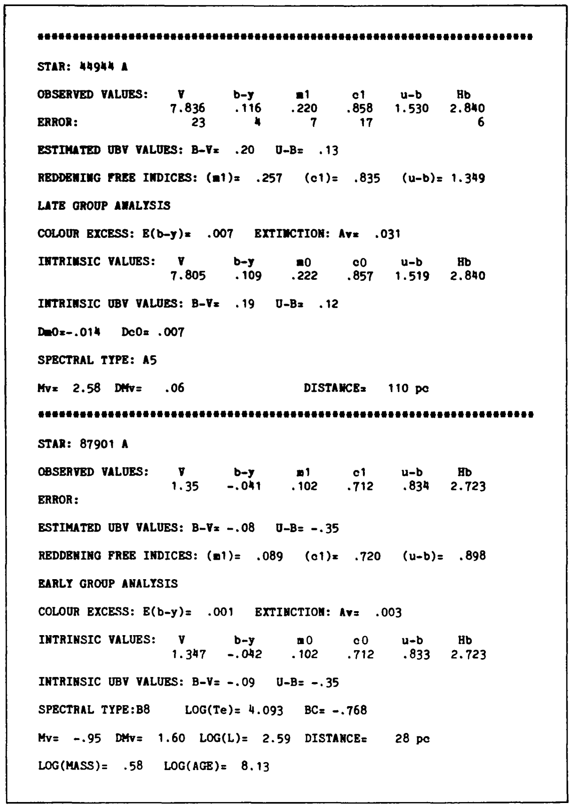


FIGURE 12. — Age and log (T_e) for physical secondaries. The curve is the contraction time to a given log (T_e) on the ZAMS. Secondaries above the curve are still contracting. Upper limits to the age are marked by arrows.



```
***********************************************************************

STAR: 44944 A

OBSERVED VALUES:    V       b-y      m1       c1      u-b      Hb
                 7.836    .116     .220     .858    1.530    2.840
ERROR:              23       4        7       17                 6

ESTIMATED UBV VALUES: B-V=  .20   U-B=  .13

REDDENING FREE INDICES: (m1)=  .257   (c1)=  .835   (u-b)= 1.349

LATE GROUP ANALYSIS

COLOUR EXCESS: E(b-y)=  .007   EXTINCTION: Av=  .031

INTRINSIC VALUES:   V       b-y      m0       c0      u-b      Hb
                 7.805    .109     .222     .857    1.519    2.840

INTRINSIC UBV VALUES: B-V=  .19   U-B=  .12

Dm0=-.014   Dc0= .007

SPECTRAL TYPE: A5

Mv=  2.58  DMv=   .06                   DISTANCE=   110 pc

***********************************************************************

STAR: 87901 A

OBSERVED VALUES:    V       b-y      m1       c1      u-b      Hb
                 1.35    -.041     .102     .712     .834    2.723
ERROR:

ESTIMATED UBV VALUES: B-V= -.08   U-B= -.35

REDDENING FREE INDICES: (m1)=  .089   (c1)=  .720   (u-b)=  .898

EARLY GROUP ANALYSIS

COLOUR EXCESS: E(b-y)=  .001   EXTINCTION: Av=  .003

INTRINSIC VALUES:   V       b-y      m0       c0      u-b      Hb
                 1.347   -.042     .102     .712     .833    2.723

INTRINSIC UBV VALUES: B-V= -.09   U-B= -.35

SPECTRAL TYPE:B8     LOG(Te)= 4.093   BC= -.768

Mv=  -.95  DMv=  1.60  LOG(L)=  2.59  DISTANCE=    28 pc

LOG(MASS)=  .58   LOG(AGE)=  8.13
```

FIGURE 13. — Examples of the output from the computer ▶ programme ANALYS.