CONTENTS

I. SUMMARY

Several programs used at University College London (UCL) for the analysis of $uvby\beta$ photometry are presented in this report. All are written in FORTRAN 77 and are currently used at the UCL node of the STARLINK network, running under VAX/VMS version 4.1. Listings and samples of output are given, together with discussions of the formulae used.

1. Programs UVBYBETA and UVBYLIST.

UVBYBETA is an interactive program which dereddens *uvby* colours, calculates M_V and $R/R_{\odot}$, and estimates T_{eff} from observed $uvby\beta$ photometry for an individual star. To process a number of stars at one time (e.g., a star cluster), program UVBYLIST should be used. Here, data are read from a file according to FORMAT statement 9999 which may be altered, along with the preceding READ statement, to suit the user's requirements. Similarly, the form of the output may be changed at FORMAT statement 20000 and the preceding WRITE statement. The version presented allows for input of a "cluster" number, an HD number, $(b-y)$, m_1, c_1 colours, β index, spectral type and the "group" in which the star is to be processed. However, UVBYLIST only allows for processing of spectral types B0-G2 within luminosity classes III-V. The four "processing groups" are: 1: B0-A0; 2: A0-A3; 3: A3-F0; 4: F1-G2

Sample output from programs UVBYBETA and UVBYLIST, given in Tables 1 and 3, provides a check on the operation of these programs and illustrate the form in which the output is presented. A detailed description of program UVBYBETA and the algorithms used within it is given in section IIIa. Program listings for UVBYBETA and UVBYLIST are given in sections IIIa and IVa.

2. Programs TEFFLOGG and TGLIST.

TEFFLOGG is an interactive program consisting of numerical approximations to the T_{eff}, $\log g$ grids of Moon & Dworetsky (1985, hereafter MD). Using dereddened colours and an initial estimate of T_{eff} obtained from program UVBYBETA, program TEFFLOGG calculates T_{eff} and $\log g$ consistent with the MD grids and the $uvby\beta$ photometry. For each result the standard error of the numerical approximation is given. Agreement between values obtained using this numerical simulation and those read from the MD grids is excellent, with the standard errors of the numerical fits substantially smaller than the errors in T_{eff} and $\log g$ quoted by MD. Values of T_{eff} and $\log g$, $(b-y)_0$, c_0 and β used to construct the MD grids are given in Table 2; m_0 colours for the (a_0, r^*) region were obtained from Relyea & Kurucz (1978). These data can be used to check the operation of program TEFFLOGG.

For processing a number of stars, TGLIST can be used. The version presented in this report accepts input data in the same format (see FORMAT statement 9999) as the output data from UVBYLIST (with heading removed). In addition to T_{eff} and $\log g$ calculated from the numerical fits to the MD grids, T_{eff} and $\log g$ calculated from numerical fits to the grids of Relyea & Kurucz (1978), using $(b-y)_0$, m_0, c_0, are given in sections IIIb and IVb, and sample output from TGLIST is given in Table 4.

II. PROGRAM UVBYBETA

a) DESCRIPTION OF PROGRAM

Introduction

Calibrations between colours and indices derived from *uvbyβ* photometry and various physical parameters of stars have been performed by several investigators (see Strömgren 1966; Crawford 1975, 1978, 1979). Program UVBYBETA attempts to assemble the various calibrations for specific ranges of spectral type into one place; hence, for many stars between spectral types B0 and M2, dereddened colours, absolute magnitudes, effective temperatures, radii and metallicities can be calculated using this program. The approach has been to use empirical calibrations; stellar atmosphere models (e.g. Relyea & Kurucz 1978) are not used.

uvbyβ Photometry

This system was developed by Strömgren (1966) and Crawford (1966); since its inception it has received widespread use with virtually all bright stars, and many fainter ones, having been measured on this system. Extensive catalogues of *uvbyβ* photometry have been published by Hauck & Mermilliod (1980), Olsen (1983) and Olsen & Perry (1984).

In *uvbyβ* photometry the *y*-band measurements can be directly related to a *V*-magnitude while the colours and indices formed are:

$(b-y) = (b) - (y)$: analogous to $(B-V)$ of the *UBV* system.

$m_1 = (v-b) - (b-y)$: a measure of the effects of blanketing.

$c_1 = (u-v) - (v-b)$: indicates the size of the Balmer discontinuity.

$\beta = \beta(narrow) - \beta(intermediate)$: measures the strength of the Balmer line (Hβ).

$(u-b) = (u) - (b)$: analogous to the $(U-B)$ colour index.

Observed and dereddened indices.

The observed colours and indices are denoted as $(b-y)$, m_1, c_1, β and $(u-b)$ while, following the scheme of Crawford (1975), dereddened colours are written as $(b-y)_0$, m_0, c_0 and $(u-b)_0$ where:

$(b-y)_0 = (b-y) - E(b-y)$

$m_0 = m_1 - E(m_1)$ {i.e. $(m_1)_0$}

$c_0 = c_1 - E(c_1)$ {i.e. $(c_1)_0$}

$(u-b)_0 = (u-b) - E(u-b)$

The β index is virtually unaffected by interstellar extinction. Strömgren (1966) also defined the following-reddening free parameters:

$[m_1] = m_1 + 0.3(b-y)$

$[c_1] = c_1 - 0.2(b-y)$

$[u-b] = (u-b) - 1.6(b-y)$

Where possible, use of these parameters has been avoided for the following reasons:

1. Corrections applied to m_1 and c_1 to calculate $[m_1]$ and $[c_1]$ are generally larger than corresponding corrections to obtain m_0 and c_0; consequently errors arising from imprecise knowledge of the reddening ratios

will propagate larger uncertainties in $[m_1]$ and $[c_1]$.

2. The scheme of Crawford is a more "natural" system in that m_0 and c_0 will be the same as m_1 and c_1 for unreddened stars.

3. Model calibrations of *uvby* photometry with T_{eff} and log g by Relyea & Kurucz (1978) are in terms of $(b-y)_0$, m_0, c_0 and $(u-b)_0$.

Division of the main sequence band from B0-G2 into four sections.

Closely following the scheme of Strömgren (1966), stars on or near the main sequence, in the spectral range B0-G2, are considered as belonging to one of the following four sections (see also Perry, Walter & Crawford 1978):

Early group, spectral types B0-A0; $2.59 < \beta < 2.88$

Intermediate group, types A0-A3; $2.87 < \beta < 2.93$

Late group, division I, types A3-F0; $2.72 < \beta < 2.88$

Late group, division II, types F1-G2; $2.60 < \beta < 2.72$

In addition Zhang (1983) has produced calibrations for B0-A0 supergiants and bright giants, while Olsen (1984) has extended *uvby* photometry into the spectral range G2-M2 for luminosity classes IV and V.

These boundaries are not rigidly defined, with one group blending into the next, consequently for some stars it will be difficult to decide on which group to process them in. Because of this, program UVBYBETA is interactive allowing the user to process data in more than one group where the assignment to a group is uncertain or ambiguous. In such borderline cases the other colours can be used to differentiate between groups, but care must be exercised as some of these colours can be substantially reddened, particularly $(b-y)$.

Group 1: Spectral types B0-A0, luminosity classes III-V

For dereddening the $(u-b)$ colour index, program UVBYBETA uses a revised version of the expression given by Crawford (1978), obtained by coupling a linear relation between the intrinsic $(b-y)$ and $(u-b)$ colours with the reddening ratios given by Crawford & Mandwewala (1976). If β is not available it is estimated using a cubic equation in c_0. This equation is a least-squares fit to data for luminosity class V given in Table II of Crawford (1978) with values for $c_0 > 0.8$ taken from Table I of the same reference (s.e. = ±0.007 mag.)

The absolute magnitude is calculated using the calibration of Balona & Shobbrook (1984), the radius is then determined by linking the calculated M_V with the F_V, $(b-y)$ relation given by Moon (1984).

Effective temperature is determined from a linear relation between c_0 and θ_{eff} {= $5040/T_{eff}$}. This equation is a least-squares fit to data for stars with fundamentally determined effective temperatures as given by Code et al. (1976) {see Davis & Shobbrook 1977}.

Metallicity is not as useful a parameter in the case of B stars as it is for later spectral types; it is calculated here for completeness. The ZAMS value of m_0 is calculated from a cubic equation in c_0 fitted to the data in Table I of Crawford (1978) revised at the red end of this calibration in accordance with Hilditch et al. (1983). The standard error of this fit is ±0.003 mag., and $\delta m_0 = m_0(\text{ZAMS}) - m_0(\text{star})$.

Groups 2,3 & 4: Spectral types B0-B9, supergiants and bright giants.

Dereddening equations for each luminosity class were derived by coupling linear relations between the c_0 and $(u-b)_0$ colours (determined from Table IV of Zhang (1983) with the reddening ratios given by Crawford & Mandwewala (1976). Where β is not available program UVBYBETA calculates it from the c_0 colour index using equations fitted to Table V of Zhang (1983) {s.e. = ±0.015 mag.}.

M_V is determined by using the Δβ, ΔM_V relation given in Table VIII of Zhang. A quadratic equation was fitted to these values to within a standard error of ±0.02 mag. In place of the ZAMS values of M_V given by Crawford (1978), M_V(ZAMS) is calculated from a cubic equation given by Balona & Shobbrook (1984). Here β(ZAMS) is calculated through a quadratic equation in c_0 fitted to Table I of Crawford (1978) with revisions at c_0 = 1.00 and 1.07 as outlined by Hilditch et al. (1983). A linear relation between θ_{eff} and $(u-b)_0$ was determined by coupling the T_{eff}, [spectral type] table of Böhm-Vitense (1981) with the *uvby*β, [spectral type] table of Zhang (1983).

Group 5: Spectral types A0-A3, luminosity classes III-V.

Reddening is determined through an iterative method outlined by Hilditch et al. (1983); in program UVBYBETA the $(b-y)_0$ colour index is expressed as quadratic equations in m_0 and $[m_1]$ (s.e. = 0.001 mag.). If β is not given it is evaluated from *uvby* colours using a relation which is the average of a relation for estimating β from m_0 and c_0 for earlier stars (least-squares fit to class V values in Table II of Crawford 1978), and that for estimating β from $(b-y)$ and c_1 in the case of later spectral types (Crawford 1966).

Between A0 and A3, the Hydrogen Balmer lines reach a maximum. Consequently β alone is no longer an adequate indicator of luminosity, so a linear combination of β (luminosity indicator for group 1) and c_1 (luminosity indicator for groups 6 & 7) is used to determine M_V. The method and relations given by Strömgren (1966) are used, with $[c_1]$ suitably transformed to c_0 and corrections as given by Moon & Dworetsky (1984).

A linear equation between θ_{eff} and the dereddened *a* parameter (defined by Strömgren 1966) was determined using data for stars with empirically determined effective temperatures (Code et al. 1976). The metallicity is given by $\delta m_0 = m_0$(ZAMS) - m_0(star) where m_0(ZAMS) is calculated using an equation in $(b-y)_0$ derived from the standard relations of Hilditch et al. (1983) {s.e. = ±0.0007}.

Group 6: Spectral types A3-F0, luminosity classes III-V.

If β has not been measured it is estimated from $(b-y)$ and c_1 using the relation given by Crawford (1966). Values of c_1(ZAMS) and M_V(ZAMS) given in Table I of Crawford (1979) are synthesized by dividing the β range of this group into three sections. Hence linear equations for c_1(ZAMS) as a function of β match tabulated values precisely as do M_V(ZAMS) values as a function of β for the ranges 2.72 ≤ β ≤ 2.74 and 2.74 ≤ β ≤ 2.82. For 2.82 ≤ β ≤ 2.88, M_V(ZAMS) is estimated through a quadratic equation in β which fits the tabulated values to within a standard error of ±0.003 mag. M_V is calculated from M_V(ZAMS) and δc_1 via the relation given by Crawford (1979).

m_1(ZAMS) is evaluated from a quadratic equation in β fitted to the data in Table I of Crawford (1979) and δm_1 is given by m_1(ZAMS) - m_1(-star); $(b-y)_0$ and hence reddening is calculated from equations given by Crawford (1979). T_{eff} is determined from a linear relation between θ_{eff} and $(b-y)_0$ derived by transposing the T_{eff}, $(B-V)$ calibration of Böhm-

Vitense (1981) into θ_{eff}, $(b-y)_0$ values using Table II of Crawford & Perry (1966). Giants may be up to 200 K cooler than this "main sequence" value of T_{eff}.

Group 7: Spectral types F1-G2, luminosity classes III-V.

Hilditch et al. (1983) suggested a revision to the F star calibration of Crawford (1975) so that the blue end of this calibration coincides with the red end of the calibration for A stars (Crawford 1979). Also, Olsen (1984) has revised Crawford's M_V(ZAMS) values at $\beta = 2.59$ and 2.60, and the m_1(ZAMS) value at $\beta = 2.59$. Formulae used in program UVBYBETA were derived from Table I of Crawford (1975) with these revisions applied.

Where β has not been measured it is estimated from a "corrected" value of $(b-y)$, determined through an iterative procedure involving the use of δm_1 to correct the observed $(b-y)$. Group 7 is divided into two ranges in order to synthesize Table I of Crawford (1975). For $\beta < 2.65$, calculated values are determined to within a standard error of ±0.002 mag. from a quadratic relation in β. A cubic equation in β suitably predicts values of M_V(ZAMS) over the whole range of β (s.e. = ±0.011 mag.). M_V is then calculated from M_V(ZAMS) using the relation of Crawford (1975). Note that the correction factor in this equation is a function of β; $(b-y)_0$ is calculated via the relation given by Crawford and reddening subsequently evaluated.

T_{eff} is calculated using the same equation used in group 6 while δm_1 is given by m_1(ZAMS) - m_1(star), where m_1(ZAMS) is calculated from a quadratic equation in β which fits tabulated values to within a s.e. = ±0.001 mag.

Group 8: Spectral types G2-M2, luminosity classes IV & V.

Preliminary calibrations for G2-M2 dwarfs and subgiants have been carried out by Olsen (1984). Dereddening relations were not explicitly given by Olsen but can be inferred from the standard relations given in his Table VI. To facilitate the calculation of reddening relations this group has been divided into three ranges, i.e. $0.39 < (b-y) \le 0.65$, $0.65 < (b-y) < 0.79$ and $0.79 \le (b-y) < 1.00$, where linear equations between intrinsic colours have been combined with reddening ratios given by Crawford & Mandwewala (1976) to determine the dereddening equations used in this program.

For the first range, $0.39 < (b-y) \le 0.65$, ZAMS values of c_1 are synthesized by a cubic equation in $(b-y)_0$ (s.e. = ±0.007 mag.) and M_V(ZAMS) values are calculated via a quadratic relation in $(b-y)_0$ which fits the tabulated values within a standard error of ±0.011 mag. In the range $0.65 < (b-y) < 0.79$, c_1(ZAMS) is calculated using a quadratic relation in $(b-y)_0$ (s.e. < ±0.001); M_V(ZAMS) is evaluated using a quadratic equation in $(b-y)_0$ (s.e. = ±0.002 mag.). For $0.79 \le (b-y) < 1.00$, c_1(ZAMS) is given by a quadratic equation in $(b-y)_0$ (s.e. < ±0.001 mag.) and M_V-(ZAMS) is determined using a quadratic relation in $(b-y)_0$ (s.e. = ±0.006 mag.).

Over the entire range of $(b-y)$ for this group, m_1(ZAMS) is given by a quartic equation in $(b-y)_0$ (s.e. = ±0.006). Colour differences δc_1 and δm_1 are formed in the usual way and equations (3) & (5) of Olsen (1984) are used to calculate M_V. T_{eff} is given by Olsen's equations (8) & (9). The radius is determined from a linear F_V, $(b-y)_0$ relation which has been defined for $0.39 < (b-y)_0 < 1.00$ using stars with measured *uvby* colours and known angular diameters.

Metallicity indicator.

For A0-G2 stars the metallicity indicator δm_1 (or δm_0) calculated in program UVBYBETA is not the same as that determined by Strömgren (1966) as β now forms the independent variable whereas, under Strömgren's original scheme, $(b-y)$ was the independent variable (see Crawford 1975). However the following categories probably suffice to classify population types approximately, according to this calculated metallicity and to isolate metallic-line or peculiar stars.

Range of δm_1	Category
$\delta m_1 < -.010$	*Am* and *Ap* stars
$-.010 < \delta m_1 < 0.025$	normal population I stars
$0.025 < \delta m_1 < 0.045$	Older population I and old disk stars
$0.045 < \delta m_1 < 0.090$	Intermediate population II stars
$0.090 < \delta m_1$	Extreme population II stars

N.B. The mean δm_1 for the Hyades is 0.000, while that for the Sun is 0.018 (Crawford 1975). See also McFadzean et al. (1983).

Output

The designation of the star processed, the group in which this processing has occurred, the observed colours and indices, dereddened colours, reddening, absolute magnitude, radius, metallicity and effective temperature are recorded in a file UVBYOUT.DAT, created by program UVBYBETA.

b) LISTING FOR PROGRAM UVBYBETA.

```
      PROGRAM UVBYBETA
C
C Measured (b-y), m1, c1 and Beta colours and indices are entered. The
C user chooses one of eight groups in which data are to be processed. From
C observed parameters the reddening, dereddened colours, absolute
C magnitude and metallicity are calculated using known empirical
C-calibrations.
C-Effective temperature is estimated using relations linking various
C-colours and indices with empirical data of Code et al. (1976), the
C-calibrations of Bohm-Vitense (1981) or Olsen (1984), while the radius
C-is determined by coupling the surface brightness parameter and absolute
C-magnitude where the surface brightness parameter is calculated from the
C-(b-y) colour index (see Moon, 1984).
C-The various multivariable and polynomial relations used are fits to
C-the tabular data to within the errors of such data and in all cases
C-suitably reconstruct the tables from which they were derived.
C-----------------------------------------------------------------------
      REAL m,m0,m1,m0zams,m1zams,m1by,m1init,MV,MVzams
      INTEGER Teff,flag1,flag2
      CHARACTER name*20,metal*12,reply*1
      PARAMETER(Rm1=-0.33,Rc1=0.19,Rub=1.53)
      PRINT'(1X,''Program UVBYBETA for determining physical parameters
     &'',/,1X,''of stars using uvby & Beta photometry.''/)'
      OPEN(99,FILE='UVBYOUT',STATUS='NEW')
10000 PRINT'(1X,''Enter designation of star (up to 20 characters)'')'
      READ(*,'(A20)')name
      flag1=0
      flag2=0
      PRINT'(1X,''Enter (b-y), m1, c1, Beta in that order'',/,
     &1X,''If Beta is not available, then enter 0'')'
C-Observed colours are : (b-y), m1 {=(v-b)-(b-y)}, c1 {=(u-v)-(v-b)},
C-while the dereddened colours are denoted as by0 = (b-y)o, m0 = (m1)o
C- = m1-E(m1), c0 = (c1)o = c1-E(c1), m = [m1] = m1-{E(m1)/E(b-y)}(b-y)
C- and [c1] = c1-{E(c1)/E(b-y)}(b-y)
      READ*,by,m1,c1,beta
      IF(beta.EQ.0)flag1=1
C- (u-b) is calculated from other indices.
      ub=c1+2*(m1+by)
20000 WRITE(*,1000)
 1000 FORMAT(1X,'Enter No. of group in which this star lies',//
     &,1X,'1:B0-A0, classes III-V; 2.59<Beta<2.88;-0.20<  co  < 1.00'/
     &,1X,'2:B0-A0, class Ia     ; 2.52<Beta<2.59;-0.15<  co  < 0.40'/
     &,1X,'3:B0-A0, class Ib     ; 2.56<Beta<2.61;-0.10<  co  < 0.50'/
     &,1X,'4:B0-A0, class II     ; 2.58<Beta<2.63;-0.10<  co  < 0.10'/
     &,1X,'5:A0-A3, classes III-V; 2.87<Beta<2.93;-0.01<(b-y)o< 0.06'/
     &,1X,'6:A3-F0, classes III-V; 2.72<Beta<2.88; 0.05<(b-y)o< 0.22'/
     &,1X,'7:F1-G2, classes III-V; 2.60<Beta<2.72; 0.22<(b-y)o< 0.39'/
     &,1X,'8:G2-M2, classes IV-V ; 0.20< mo <0.76; 0.39<(b-y)o< 1.00'/)
      READ*,n
      GOTO(1,2,3,4,5,6,7,8)n
      GOTO 20000
C-----------------------------------------------------------------------
    1 CONTINUE
C-For group 1, Beta is a luminosity indicator and c0 is a temperature
C-indicator {(u-b)o is also a suitable temperature indicator}.
      Eby=(13.608*by-ub+1.467)/(13.608-Rub)
      Ebycal=Eby
      CALL DEREDD(Eby,by,m1,c1,ub,by0,m0,c0,ub0)
      IF(flag1.EQ.1)beta=[illegible]
     &[illegible]
      g=ALOG10(beta-2.515)-1.6*ALOG10(c0+0.322)
      MV=3.4994+7.2026*ALOG10(beta-2.515)-2.3192*g+2.9375*g**3
      Te=5040/(0.2917*c0+0.2)
      m0zams=0.0957758*c0**3-0.139003*c0**2+0.109804*c0+0.07473
      delm0=m0zams-m0
C-Setting of flag2 for textual printing purposes only.
      flag2=1
      GOTO 30000
C-----------------------------------------------------------------------
    2 CONTINUE
      Eub=(1.5*c1-ub+0.035)/(1.5/(Rub/Rc1)-1)
      Eby=Eub/Rub
      Ebycal=Eby
      CALL DEREDD(Eby,by,m1,c1,ub,by0,m0,c0,ub0)
      IF(flag1.EQ.1)beta=0.037*c0+2.542
      GOTO 234
C-----------------------------------------------------------------------
    3 CONTINUE
      Eub=(1.36*c1-ub+0.004)/(1.36/(Rub/Rc1)-1)
      Eby=Eub/Rub
      Ebycal=Eby
      CALL DEREDD(Eby,by,m1,c1,ub,by0,m0,c0,ub0)
      IF(flag1.EQ.1)beta=0.047*c0+2.578
      GOTO 234
C-----------------------------------------------------------------------
    4 CONTINUE
      Eub=(1.32*c1-ub-0.056)/(1.32/(Rub/Rc1)-1)
      Eby=Eub/Rub
      Ebycal=Eby
      CALL DEREDD(Eby,by,m1,c1,ub,by0,m0,c0,ub0)
      IF(flag1.EQ.1)beta=0.066*c0+2.59
C-----------------------------------------------------------------------
  234 betaza=-0.160402*c0**4+0.277363*c0**3-0.099623*c0**2
     &+0.228638*c0+2.62745
      B=betaza-2.5
      MVzams=203.704*B**3-206.98*B**2+77.18*B-9.563
      dbeta=betaza-beta
      dMV=-121.6*dbeta**2+61.0*dbeta+0.08
      MV=MVzams-dMV
      Te=5040/(0.35866*ub0+0.27346)
C-Setting of flag2 for textual printing purposes only.
      flag2=2
      GOTO 30000
C-----------------------------------------------------------------------
    5 CONTINUE
C-For group 5, the Hydrogen Balmer lines are at maximum; hence two
C-parameters, a0 = f{(b-y),(u-b)} and r = f{Beta,[c1]}, are defined in
C-order to calibrate absolute magnitude and metallicity.
      m=m1-Rm1*by
      bycorr=4.2608*m**2-0.53921*m-0.0235
      DO I=1,10
        m0=m1-Rm1*(by-bycorr)
        by0=14.0881*m0**2-3.36225*m0+0.175709
        IF(ABS(bycorr-by0).LT.0.001)GOTO 51
        bycorr=by0
      ENDDO
```

b) LISTING FOR PROGRAM UVBYBETA. (continued)

```
   51 Eby=by-byO
      Ebycal=Eby
      CALL DEREDD(Eby,by,ml,cl,ub,byO,mO,cO,ubO)
      IF(flag1.EQ.1)beta=2.7905-0.6105*by+0.5*mO+0.0355*cO
      r=0.35*(cl-Rcl*by)-(beta-2.565)
      aO=byO+0.18*(ubO-1.36)
      MV=1.5+6.0*aO-17.0*r
      Te=5040/(0.8572*aO+0.5152)
      mOzams=-3.95105*byO**2+0.86888*byO+0.1598
      delmO=mOzams-mO
      GOTO 30000
C-----------------------------------------------------------------------
    6 CONTINUE
C-For group 6, cl is the luminosity indicator for a particular Beta,
C-while (b-y)o (or Beta) indicates temperature.
      IF(flag1.EQ.1)THEN
      PRINT'(1X,''Estimate of Beta only valid if star unreddened''/)'
        beta=3.06-1.221*by-0.104*cl
      ENDIF
      mlzams=-2.158*beta**2+12.26*beta-17.209
      IF(beta.LE.2.74)THEN
          clzams=3*beta-7.56
          MVzams=22.14-7*beta
        ELSEIF(beta.GT.2.74.AND.beta.LE.2.82)THEN
          clzams=2*beta-4.82
          MVzams=11.16-3*beta
        ELSEIF(beta.GT.2.82)THEN
          clzams=2*beta-4.83
          MVzams=-88.4*beta**2+497.2*beta-696.41
      ENDIF
      delml=mlzams-ml
      delcl=cl-clzams
      IF(delml.LT.0)THEN
          byO=2.946-beta-0.1*delcl-0.25*delml
        ELSE
          byO=2.946-beta-0.1*delcl
      ENDIF
      Eby=by-byO
      Ebycal=Eby
      CALL DEREDD(Eby,by,ml,cl,ub,byO,mO,cO,ubO)
      delmO=mlzams-mO
      delcO=cO-clzams
      MV=MVzams-9.0*delcO
C-Temperature calibration is valid for luminosity classes IV and V
C-with solar-type abundances, giants may be up to 200 K cooler.
      Te=5040/(0.771453*byO+0.546544)
      GOTO 30000
C-----------------------------------------------------------------------
    7 CONTINUE
C-For group 7, cl is a luminosity indicator for a particular Beta
C-(or (b-y)o), while (b-y)o (or Beta) indicates temperature.
C-Where Beta is not available iteration is necessary to evaluate
C-a corrected (b-y) from which Beta is then estimated.
      IF(flag1.EQ.1)THEN
        byinit=by
        mlinit=ml
        DO I=1,10
          mlby=[illegible]*byinit+0.345
          bycorr=byinit+(mlby-mlinit)/2.0
          IF(ABS(bycorr-byinit).LE.0.001)GOTO 71
          byinit=bycorr
          mlinit=mlby
        ENDDO
   71   beta=1.01425*bycorr**2-1.32861*bycorr+2.96618
      ENDIF
      mlzams=6.41701*beta**2-34.4538*beta+46.4167
      MVzams=5.48012*beta**3+11.0494*beta**2-188.748*beta+324.482
      IF(beta.LE.2.65)THEN
          clzams=2*beta-4.91
        ELSE
          clzams=11.1555*beta**2-56.9164*beta+72.879
      ENDIF
      delml=mlzams-ml
      delcl=cl-clzams
      dbeta=2.72-beta
      byO=0.222+1.11*dbeta+2.7*dbeta**2-0.05*delcl-(0.1+3.6*dbeta)*delml
      Eby=by-byO
      Ebycal=Eby
      CALL DEREDD(Eby,by,ml,cl,ub,byO,mO,cO,ubO)
      delmO=mlzams-mO
      delcO=cO-clzams
      f=9.0+20.0*dbeta
      MV=MVzams-f*delcO
C-Temperature calibration is valid for luminosity classes IV and V
C-with solar-type abundances, giants may be up to 200 K cooler.
      Te=5040/(0.771453*byO+0.546544)
      GOTO 30000
C-----------------------------------------------------------------------
    8 CONTINUE
C-For group 8, (b-y)o indicates temperature and cl measures luminosity.
      IF(flag1.EQ.1)flag1=2
      IF(by.LE.0.65)THEN
          Eby=(5.8651*by-ub-0.8975)/(5.8651-Rub)
        ELSEIF(by.GT.0.65.AND.by.LT.0.79)THEN
          Eby=(-0.7875*by-cl+0.6585)/(-0.7875-Rcl)
          byO=by-Eby
          IF(byO.LT.0.65)Eby=(5.8651*by-ub-0.8975)/(5.8651-Rub)
        ELSE
          Eby=(0.5126*by-cl-0.3645)/(0.5126-Rcl)
          byO=by-Eby
          IF(byO.LT.0.79)Eby=(-0.7875*by-cl+0.6585)/(-0.7875-Rcl)
          byO=by-Eby
          IF(byO.LT.0.65)Eby=(5.8651*by-ub-0.8975)/(5.8651-Rub)
      ENDIF
      Ebycal=Eby
      CALL DEREDD(Eby,by,ml,cl,ub,byO,mO,cO,ubO)
      mlzams=42.93678*byO**4-122.466*byO**3+122.1875*byO**2
     &-49.43695*byO+7.18436
      IF(byO.LT.0.65)THEN
          clzams=-28.7056*byO**3+42.7486*byO**2-21.278*byO+3.78514
          MVzams=-552.48*byO**4+1272.503*byO**3-1101.257*byO**2
     &    +432.156*byO-59.2095
        ELSEIF(byO.GE.0.65.AND.byO.LT.0.79)THEN
          clzams=-0.631821*byO**2+0.116031*byO+0.33657
          MVzams=1.37632*byO**2+4.97911*byO+3.4305
        ELSE
```

```
mlinit=ml
DO I=1,10
   mlby=2.5*byinit**2-1.32*byinit+0.345
```

```
MVzams=1.37632*by0**2+4.97911*by0+3.4305
ELSE
```

b) LISTING FOR PROGRAM UVBYBETA. (continued)

```
            clzams=-0.010028*by0**2+0.530426*by0-0.37237
            MVzams=1.18298*by0**2+3.92776*by0+4.37507
        ENDIF
        delm0=mlzams-m0
        delc0=c0-clzams
        IF(by0.LE.0.505)THEN
            f=10-80*(by0-0.38)
            Te=10**(-0.416*by0+3.924)
          ELSE
            f=0.0
            Te=10**(-0.341*by0+3.869)
        ENDIF
        MV=MVzams-f*delc0+3.2*delm0-0.07
C-----------------------------------------------------------------
30000 CONTINUE
        IF(flag2.EQ.1)THEN
            metal='no delta(mo)'
          ELSE
            metal='delta(m0) = '
        ENDIF
        IF(by0.LE.0.335)THEN
            FV=-6.759*by0**3+3.731*by0**2-1.092*by0+3.981
          ELSE
            FV=-0.534*by0+3.959
        ENDIF
        radius=10**(2.*(4.236-0.1*MV-FV))
        beta=ANINT(beta*1000.0)/1000.0
        by0=ANINT(by0*1000.0)/1000.0
        m0=ANINT(m0*1000.0)/1000.0
        c0=ANINT(c0*1000.0)/1000.0
        Eby=ANINT(Eby*1000.0)/1000.0
        MV=ANINT(MV*100.0)/100.0
        Teff=NINT(ANINT(Te/10.0)*10.0)
        delm0=ANINT(delm0*1000.0)/1000.0
        WRITE(99,2000)name,n
 2000 FORMAT(10X,'Star is : ',A20,10X,'Processed in group',I2,/)
        IF(flag1.EQ.2)THEN
            WRITE(99,2001)by,m1,c1
 2001 FORMAT(1X,' b-y   = ',F6.3,7X,'m1 = ',F5.3,10X,'c1 = ',F5.3,6X,
     &'Beta is not used')
          ELSEIF(flag1.EQ.1)THEN
            WRITE(99,2002)by,m1,c1,beta
 2002 FORMAT(1X,' b-y   = ',F6.3,7X,'m1 = ',F5.3,10X,'c1 = ',F5.3,2X,
     &'estimated Beta = ',F5.3)
          ELSE
            WRITE(99,2003)by,m1,c1,beta
 2003 FORMAT(1X,' b-y   = ',F6.3,7X,'m1 = ',F5.3,10X,'c1 = ',F5.3,8X,
     &'Beta    = ',F5.3)
        ENDIF
        WRITE(99,2004)by0,m0,c0,Ebycal
 2004 FORMAT(1X,'(b-y)o = ',F6.3,7X,'mo = ',F5.3,10X,'co = ',F5.3,8X,
     &'E(b-y) = ',F5.3,/)
        WRITE(99,2005)MV,radius
 2005 FORMAT(1X,'Absolute Magnitude (Mv) = ',F6.2,5X,
     &'Radius (R/R[solar]) = ',F7.2)
        IF(flag2.EQ.1)THEN
            WRITE(99,2006)metal,Teff
 2006 FORMAT(1X,A12,25X,'Effective Temperature (Teff) = ',I5,1X,'K'//)
          ELSE
            WRITE(99,2007)metal,delm0,Teff
 2007 FORMAT(1X,A12,F5.3,20X,'Effective Temperature',1X,
     &'(Teff) = ',I5,1X,'K',//)
        ENDIF
        PRINT'(1X,''Data has been recorded in file  UVBYOUT.DAT '',/)'
        PRINT'(1X,''Enter Q to quit program or (return) to continue ''$)'
        READ(*,'(A1)')reply
        IF(reply.EQ.'Q'.OR.reply.EQ.'q')THEN
            GOTO 40000
          ELSE
            GOTO 10000
        ENDIF
40000 CLOSE(100)
        STOP
        END
C**********************************************************************
        SUBROUTINE DEREDD(Eby,by,m1,c1,ub,by0,m0,c0,ub0)
        REAL m0,m1
        PARAMETER(Rm1=-0.33,Rc1=0.19,Rub=1.53)
        IF(Eby.LT.0)Eby=0
        by0=by-Eby
        m0=m1-Rm1*Eby
        c0=c1-Rc1*Eby
        ub0=ub-Rub*Eby
        RETURN
        END
C**********************************************************************
```

Table 1. Sample output from program UVBYBETA.

```
            Star is : 16 Tau (B7 IV)                      Processed in group 1

b-y    = -0.001         m1 = 0.105            c1 = 0.647            Beta   = 2.750
(b-y)o = -0.051         mo = 0.121            co = 0.638            E(b-y) = 0.050

Absolute Magnitude (Mv) =  -0.27           Radius (R/R[solar]) =    2.71
delta(mo) = -.008                          Effective Temperature (Teff) = 13060 K

            Star is : 21 Tau (B8 V)                       Processed in group 1

b-y    = -0.002         m1 = 0.114            c1 = 0.765            Beta   = 2.793
(b-y)o = -0.039         mo = 0.126            co = 0.758            E(b-y) = 0.037

Absolute Magnitude (Mv) =   0.24           Radius (R/R[solar]) =    2.31
delta(mo) = -.007                          Effective Temperature (Teff) = 11970 K

            Star is : Gamma Ori (B2 III)                  Processed in group 1

b-y    = -0.091         m1 = 0.076            c1 = 0.111            Beta   = 2.614
(b-y)o = -0.103         mo = 0.080            co = 0.109            E(b-y) = 0.012

Absolute Magnitude (Mv) =  -2.98           Radius (R/R[solar]) =    6.11
delta(mo) = 0.005                          Effective Temperature (Teff) = 21750 K

            Star is : Alpha Gru (B7 IV)                   Processed in group 1

b-y    = -0.061         m1 = 0.105            c1 = 0.576            Beta   = 2.728
(b-y)o = -0.061         mo = 0.105            co = 0.576            E(b-y) = -.002

Absolute Magnitude (Mv) =  -0.58           Radius (R/R[solar]) =    2.89
delta(mo) = 0.005                          Effective Temperature (Teff) = 13690 K

            Star is : Alpha Gru (B7 IV)                   Processed in group 1

b-y    = -0.061         m1 = 0.105            c1 = 0.576   estimated Beta = 2.735
(b-y)o = -0.061         mo = 0.105            co = 0.576            E(b-y) = -.002

Absolute Magnitude (Mv) =  -0.47           Radius (R/R[solar]) =    2.75
delta(mo) = 0.005                          Effective Temperature (Teff) = 13690 K

            Star is : HD 14134 (B3 Ia)                    Processed in group 2

b-y    =  0.403         m1 = -.074            c1 = 0.215            Beta   = 2.552
(b-y)o = -0.011         mo = 0.063            co = 0.136            E(b-y) = 0.414

Absolute Magnitude (Mv) =  -6.91           Radius (R/R[solar]) =   73.51
no delta(mo)                               Effective Temperature (Teff) = 14030 K

            Star is : HD 14134 (B3 Ia)                    Processed in group 2

b-y    =  0.403         m1 = -.074            c1 = 0.215   estimated Beta = 2.547
(b-y)o = -0.011         mo = 0.063            co = 0.136            E(b-y) = 0.414

Absolute Magnitude (Mv) =  -7.08           Radius (R/R[solar]) =   79.58
no delta(mo)                               Effective Temperature (Teff) = 14030 K

            Star is : HD 13841 (B2 Ib)                    Processed in group 3

b-y    =  0.244         m1 = -.053            c1 = 0.051            Beta   = 2.568
(b-y)o = -0.039         mo = 0.040            co = -.003            E(b-y) = 0.283

Absolute Magnitude (Mv) =  -5.94           Radius (R/R[solar]) =   39.84
no delta(mo)                               Effective Temperature (Teff) = 18420 K

            Star is : HD 13841 (B2 Ib)                    Processed in group 3

b-y    =  0.244         m1 = -.053            c1 = 0.051   estimated Beta = 2.578
(b-y)o = -0.039         mo = 0.040            co = -.003            E(b-y) = 0.283

Absolute Magnitude (Mv) =  -5.46           Radius (R/R[solar]) =   32.05
no delta(mo)                               Effective Temperature (Teff) = 18420 K

            Star is : HD 14053 (B1 II)                    Processed in group 4

b-y    =  0.255         m1 = -.051            c1 = 0.070            Beta   = 2.589
(b-y)o = -0.090         mo = 0.063            co = 0.004            E(b-y) = 0.345

Absolute Magnitude (Mv) =  -4.93           Radius (R/R[solar]) =   16.92
no delta(mo)                               Effective Temperature (Teff) = 19730 K

            Star is : HD 14053 (B1 II)                    Processed in group 4

b-y    =  0.255         m1 = -.051            c1 = 0.070   estimated Beta = 2.590
(b-y)o = -0.090         mo = 0.063            co = 0.004            E(b-y) = 0.345

Absolute Magnitude (Mv) =  -4.86           Radius (R/R[solar]) =   16.40
no delta(mo)                               Effective Temperature (Teff) = 19730 K

            Star is : Alpha CMa (A1 Vm)                   Processed in group 5

b-y    = -0.004         m1 = 0.158            c1 = 0.982            Beta   = 2.906
(b-y)o = -0.004         mo = 0.158            co = 0.982            E(b-y) = 0.000

Absolute Magnitude (Mv) =   1.35           Radius (R/R[solar]) =    1.70
delta(mo) = -.002                          Effective Temperature (Teff) = 10060 K
```

no delta(mo)   Effective Temperature (Teff) = 14030 K

Table 1. Sample output from program UVBYBETA. (continued)

```
         Star is : Alpha Lyr (A0 V)                 Processed in group 5

b-y    =  0.004        m1 = 0.157          c1 = 1.089        Beta   = 2.903
(b-y)o = -0.003        mo = 0.159          co = 1.088        E(b-y) = 0.007

Absolute Magnitude (Mv) =    0.60          Radius (R/R[solar]) =    2.21
delta(mo) = -.002                          Effective Temperature (Teff) =  9710 K


         Star is : Beta Leo (A3 V)                  Processed in group 5

b-y    =  0.044        m1 = 0.210          c1 = 0.975        Beta   = 2.900
(b-y)o =  0.044        mo = 0.210          co = 0.975        E(b-y) = -.026

Absolute Magnitude (Mv) =    1.84          Radius (R/R[solar]) =    1.68
delta(mo) = -.020                          Effective Temperature (Teff) =  8810 K


         Star is : Alpha PsA (A3 V)                 Processed in group 5

b-y    =  0.036        m1 = 0.206          c1 = 0.991        Beta   = 2.906
(b-y)o =  0.036        mo = 0.206          co = 0.991        E(b-y) = -.026

Absolute Magnitude (Mv) =    1.78          Radius (R/R[solar]) =    1.67
delta(mo) = -.020                          Effective Temperature (Teff) =  8940 K


         Star is : Alpha PsA (A3 V)                 Processed in group 5

b-y    =  0.036        m1 = 0.206          c1 = 0.991  estimated Beta = 2.907
(b-y)o =  0.036        mo = 0.206          co = 0.991        E(b-y) = -.026

Absolute Magnitude (Mv) =    1.79          Radius (R/R[solar]) =    1.66
delta(mo) = -.020                          Effective Temperature (Teff) =  8940 K


         Star is : Alpha Oph (A5 III)               Processed in group 6

b-y    =  0.093        m1 = 0.168          c1 = 1.039        Beta   = 2.832
(b-y)o =  0.093        mo = 0.168          co = 1.039        E(b-y) = -.001

Absolute Magnitude (Mv) =    0.83          Radius (R/R[solar]) =    3.12
delta(m0) = 0.036                          Effective Temperature (Teff) =  8150 K


         Star is : Alpha Aql (A7 IV-V)              Processed in group 6

b-y    =  0.137        m1 = 0.178          c1 = 0.880        Beta   = 2.828
(b-y)o =  0.113        mo = 0.186          co = 0.875        E(b-y) = 0.024

Absolute Magnitude (Mv) =    2.24          Radius (R/R[solar]) =    1.71
delta(m0) = 0.017                          Effective Temperature (Teff) =  7960 K


         Star is : B Oct (A7 IV)                    Processed in group 6

b-y    =  0.181        m1 = 0.177          c1 = 0.844        Beta   = 2.751
(b-y)o =  0.179        mo = 0.178          co = 0.844        E(b-y) = 0.002

Absolute Magnitude (Mv) =    1.45          Radius (R/R[solar]) =    2.81
delta(m0) = 0.009                          Effective Temperature (Teff) =  7360 K


         Star is : B Oct (A7 IV)                    Processed in group 6

b-y    =  0.181        m1 = 0.177          c1 = 0.844  estimated Beta = 2.751
(b-y)o =  0.179        mo = 0.178          co = 0.844        E(b-y) = 0.002

Absolute Magnitude (Mv) =    1.46          Radius (R/R[solar]) =    2.80
delta(m0) = 0.009                          Effective Temperature (Teff) =  7360 K


         Star is : Delta Sct (F2 IIIp)              Processed in group 6

b-y    =  0.213        m1 = 0.202          c1 = 0.812        Beta   = 2.743
(b-y)o =  0.193        mo = 0.209          co = 0.808        E(b-y) = 0.020

Absolute Magnitude (Mv) =    1.65          Radius (R/R[solar]) =    2.63
delta(m0) = -.025                          Effective Temperature (Teff) =  7250 K


         Star is : Beta Cas (F2 III-IV)             Processed in group 7

b-y    =  0.216        m1 = 0.177          c1 = 0.785        Beta   = 2.709
(b-y)o =  0.216        mo = 0.177          co = 0.785        E(b-y) = -.008

Absolute Magnitude (Mv) =    1.12          Radius (R/R[solar]) =    3.52
delta(m0) = -.003                          Effective Temperature (Teff) =  7070 K


         Star is : Alpha CMi (F5 IV-V)              Processed in group 7

b-y    =  0.272        m1 = 0.167          c1 = 0.532        Beta   = 2.674
(b-y)o =  0.272        mo = 0.167          co = 0.532        E(b-y) = -.002

Absolute Magnitude (Mv) =    2.74          Radius (R/R[solar]) =    1.89
delta(m0) = 0.004                          Effective Temperature (Teff) =  6660 K


         Star is : Chi 1 Ori (G0 V)                 Processed in group 7

b-y    =  0.380        m1 = 0.193          c1 = 0.307        Beta   = 2.599
(b-y)o =  0.380        mo = 0.193          co = 0.307        E(b-y) = -.002

Absolute Magnitude (Mv) =    4.55          Radius (R/R[solar]) =    1.12
delta(m0) = 0.024                          Effective Temperature (Teff) =  6000 K
```

Table 1. Sample output from program UVBYBETA. (continued)

```
             Star is : Chi 1 Ori (G0 V)                    Processed in group 7

  b-y    =  0.380          m1 = 0.193           c1 = 0.307   estimated Beta = 2.603
  (b-y)o =  0.378          mo = 0.194           co = 0.307           E(b-y) = 0.002

  Absolute Magnitude (Mv) =    4.57          Radius (R/R[solar]) =     1.10
  delta(m0) = 0.018                          Effective Temperature (Teff) =  6020 K

             Star is : HD 2151 (G1 V)                      Processed in group 8

  b-y    =  0.394          m1 = 0.186           c1 = 0.362       Beta is not used
  (b-y)o =  0.394          mo = 0.186           co = 0.362         E(b-y) = -.025

  Absolute Magnitude (Mv) =    3.94          Radius (R/R[solar]) =     1.53
  delta(m0) = 0.032                          Effective Temperature (Teff) =  5760 K

             Star is : HD 20630A (G5 V)                    Processed in group 8

  b-y    =  0.420          m1 = 0.237           c1 = 0.313       Beta is not used
  (b-y)o =  0.420          mo = 0.237           co = 0.313         E(b-y) = -.014

  Absolute Magnitude (Mv) =    4.71          Radius (R/R[solar]) =     1.15
  delta(m0) = 0.001                          Effective Temperature (Teff) =  5610 K

             Star is : HD 10700A (G8 V)                    Processed in group 8

  b-y    =  0.449          m1 = 0.246           c1 = 0.247       Beta is not used
  (b-y)o =  0.426          mo = 0.254           co = 0.243         E(b-y) = 0.023

  Absolute Magnitude (Mv) =    5.23          Radius (R/R[solar]) =     0.92
  delta(m0) = -.009                          Effective Temperature (Teff) =  5580 K

             Star is : HD 26965A (K1 V)                    Processed in group 8

  b-y    =  0.487          m1 = 0.327           c1 = 0.306       Beta is not used
  (b-y)o =  0.481          mo = 0.329           co = 0.305         E(b-y) = 0.006

  Absolute Magnitude (Mv) =    5.78          Radius (R/R[solar]) =     0.82
  delta(m0) = 0.016                          Effective Temperature (Teff) =  5290 K

             Star is : HD 16160A (K3 V)                    Processed in group 8

  b-y    =  0.558          m1 = 0.519           c1 = 0.285       Beta is not used
  (b-y)o =  0.558          mo = 0.519           co = 0.285         E(b-y) = -.015

  Absolute Magnitude (Mv) =    6.53          Radius (R/R[solar]) =     0.70
  delta(m0) = 0.010                          Effective Temperature (Teff) =  4770 K

             Star is : HD 201091A (K5 V)                   Processed in group 8

  b-y    =  0.656          m1 = 0.677           c1 = 0.134       Beta is not used
  (b-y)o =  0.656          mo = 0.677           co = 0.134         E(b-y) = -.008

  Absolute Magnitude (Mv) =    7.34          Radius (R/R[solar]) =     0.61
  delta(m0) = 0.038                          Effective Temperature (Teff) =  4420 K

             Star is : HD 36395A (M1 V)                    Processed in group 8

  b-y    =  0.934          m1 = 0.532           c1 = 0.131       Beta is not used
  (b-y)o =  0.934          mo = 0.532           co = 0.131         E(b-y) = -.052

  Absolute Magnitude (Mv) =    8.88          Radius (R/R[solar]) =     0.60
  delta(m0) = -.039                          Effective Temperature (Teff) =  3550 K
```

III. PROGRAM TEFFLOGG

a) DESCRIPTION OF PROGRAM

Introduction.

This program determines T_{eff} and log g from dereddened $uvby\beta$ photometry through relations fitted to the three grids of Moon & Dworetsky (1985).

The user inputs $(b-y)_0$, m_0, c_0 and β for a particular star, then enters an estimate for T_{eff}. The program returns values of T_{eff} and log g consistent with the photometry and the least-squares fits to the relevant section of the grids. Dereddened colours and a reliable first determination of T_{eff} can be obtained using program UVBYBETA. T_{eff} and log g are recorded in a file called TGOUT.DAT in addition to being displayed on the terminal.

Relations linking T_{eff} and log g with $uvby\beta$ photometry.

Iterative relations:

$$\log g = p_{1,k} + p_{2,k}X + p_{3,k}c_0 + p_{4,k}\beta + p_{5,k}c_0^2 + p_{6,k}\beta^2 + p_{7,k}c_0^3 + p_{8,k}\beta^3 + p_{9,k}c_0^4 + p_{10,k}\beta^4 \quad (1)$$

$X = T_{eff}$ for 6000 K < T_{eff} < 8500 K and 2.0 < log g < 4.5 (k=1)

$X = \log T_{eff}$ for 8500 K < T_{eff} < 11000 K and 2.0 < log g < 3.5 (k=2)

$X = \log T_{eff}$ for 10000 K < T_{eff} < 20000 K and 2.0 < log g < 4.5 (k=3 & 4)

$$\log T_{eff} = q_{1,k} + q_{2,k}\log g + q_{3,k}c_0 + q_{4,k}\beta + q_{5,k}\log^2 g + q_{6,k}c_0^2 + q_{7,k}\beta^2 \quad (2)$$

where 6000 K < T_{eff} < 8500 K and 2.0 < log g < 4.5 (k=1)

or 8500 K < T_{eff} <11000 K and 2.0 < log g < 3.5 (k=2)

or 10000 K < T_{eff} <20000 K and 2.5 < log g < 4.5 (k=3 & 4)

$$\log g = s_1 + s_2\log T_{eff} + s_3(b-y)_0 + s_4c_0 + s_5\beta \quad (3)$$

$$\log T_{eff} = t_1 + t_2\log g + t_3(b-y)_0 + t_4c_0 + t_5\beta \quad (4)$$

where 7500 K < T_{eff} < 8500 K and 2.0 < log g < 3.0 (k=1)

Non-iterative relations in the (a, r) region:

$$\log g = v_1 + v_2a_0 + v_3r^* + v_4r^{*2} + v_5r^{*3} \quad (5)$$

$$\theta_{eff} = w_1 + w_2a_0 + w_3r^* + w_4a_0^2 + w_5r^{*2} \quad (6)$$

where 8500 K < T_{eff} < 11000 K and 3.5 < log g < 4.5 (k=2)

T_{eff} = 5040/θ_{eff}

N.B. For T_{eff} > 20000 K (i.e k=5), the equations of Balona (1984) are used.

b) LISTING FOR PROGRAM TEFFLOGG.

```
      PROGRAM TEFFLOGG
C-----------------------------------------------------------------------
C-This program determines Teff and log g from dereddened (b-y), m1 & c1
C-colours, and Beta, by iterating initial estimates through relations
C-fitted to the theoretical values of these indices calculated by Relyea
C-& Kurucz (1978), Philip & Relyea (1979) and Schmidt (1979), and
C-corrected by Moon & Dworetsky (1985). For effective temperatures
C-above 20000 K, the formulae of Balona (1984) are used.
C-----------------------------------------------------------------------
      CHARACTER name*20
      INTEGER Teff,errT(5)
      REAL lg,errlg(5),m
      REAL p(10,4),q(7,4)
      REAL s(5),t(5),v(5),w(5)
C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
      DATA (p(i,1),i=1,10)/-283.495,-0.681088E-3,-14.4427,
     &226.072,10.0732,-51.9441,-2.82768,3.35794,0.0,0.0/
      DATA (q(i,1),i=1,7)/0.412702,0.10384E-1,0.202807E-1,
     &1.9946,0.127534E-3,0.303475E-2,-0.277311/
      DATA (p(i,2),i=1,10)/-72.8552,6.42625,2.24602,
     &26.9562,-1.32693,-3.29916,0.0,0.0,0.0,0.0/
      DATA (q(i,2),i=1,7)/3.37447,0.121598,-0.267488,
     &1.13197,-0.653663E-2,0.109494,-0.346268/
      DATA (p(i,3),i=1,10)/-87.0415,-2.76608,6.35322,28.0121,
     &-23.6281,6.42367,24.7614,2.6226,-9.04172,-1.34873/
      DATA (q(i,3),i=1,7)/3.15269,0.107653,-0.404474,1.00184,
     &-0.110018E-1,0.143814,-0.244699/
      DATA (p(i,4),i=1,10)/-127.038,1.30855,-1.9978,27.7581,
     &-6.99284,11.84,25.2917,3.77239,-27.529,-2.05058/
      DATA (q(i,4),i=1,7)/-4.89169,0.157642,-0.241133,
     &7.69283,-0.10704E-1,0.114035E-1,-1.65242/
C-----------------------------------------------------------------------
      DATA (s(i),i=1,5)/30.2492,-9.99635,-6.75889,-3.15249,5.80135/
      DATA (t(i),i=1,5)/4.03945,-0.0277304,-0.646848,-0.153423,
     &0.0703712/
      DATA (v(i),i=1,5)/4.390277,-0.452433,-6.38776,-41.37727,
     &281.9522/
      DATA (w(i),i=1,5)/0.525018,0.849042,-0.0276477,0.1877788,
     &0.07080026/
C-----------------------------------------------------------------------
      DATA (errT(i),i=1,5)/30,130,40,50,800/
      DATA (errlg(i),i=1,5)/0.06,0.05,0.02,0.04,0.07/
C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
      OPEN(100,FILE='TGOUT',STATUS='NEW',IOSTAT=io)
      IF(io.NE.0)THEN
        WRITE(*,1000)io
 1000   FORMAT(1X,'Error on opening output file, IOSTAT = ',I3)
        GOTO 60
      ENDIF
C-----------------------------------------------------------------------
   10 PRINT'(1X,''Enter designation of star (up to 20 characters)'')'
      READ(*,'(A20)')name
      PRINT'(1X,''Enter (b-y)o, (m1)o, (c1)o, Beta  (in that order)'')'
      READ*,by,m,c,beta
      a0=1.36*by+0.36*m+0.18*c-0.2448
      r=0.35*c-0.07*by-beta+2.565
   20 PRINT'(1X,''Enter guess at effective temperature in'')'
      READ*,Te
   30 IF(Te.GE.5500.AND.Te.LT.8500)THEN
        k=1
       ELSEIF(Te.GE.8500.AND.Te.LE.11000)THEN
        k=2
       ELSEIF(Te.GT.11000.AND.Te.LT.15000)THEN
        k=3
       ELSEIF(Te.GE.15000.AND.Te.LE.20000)THEN
        k=4
       ELSEIF(Te.GT.20000.AND.Te.LE.35000)THEN
        k=5
       ELSE
        GOTO 20
      ENDIF
      IF(k.EQ.5)THEN
        c=ALOG10(c+0.2)
        beta=ALOG10(beta-2.5)
        TO=3.9036-0.4816*c-0.529*beta-0.126*c**2+0.0924*beta*c
     &  -0.4013*beta**2
        lg=5.9046-3.2262*c+4.0883*beta-0.5383*c**2-0.2774*beta*c
     &  -0.0007*beta**2
        GOTO 40
       ELSEIF(k.EQ.2.AND.a0.GE.-0.09.AND.a0.LE.0.09.AND.
     & r.GE.-0.03.AND.r.LE.0.14)THEN
        lg=v(1)+v(2)*a0+v(3)*r+v(4)*r**2+v(5)*r**3
        theta=w(1)+w(2)*a0+w(3)*r+w(4)*a0**2+w(5)*r**2
        TO=ALOG10(5040.0/theta)
        errT(2)=20
        errlg(2)=0.03
        GOTO 40
       ELSEIF(k.EQ.1.AND.c.GE.1.3.AND.c.LT.1.65.AND.beta.GE.2.74
     & .AND.beta.LE.2.86)THEN
        TO=ALOG10(Te)
        errT(1)=20
        errlg(1)=0.02
        DO JJ=1,50
          lg=s(1)+s(2)*TO+s(3)*by+s(4)*c+s(5)*beta
          Titer=t(1)+t(2)*lg+t(3)*by+t(4)*c+t(5)*beta
          IF(ABS(Titer-TO).LT.0.0001)THEN
            TO=Titer
            GOTO 40
          ENDIF
          TO=Titer
        ENDDO
        GOTO 40
       ELSEIF(k.EQ.1)THEN
        TO=Te
        DO JJ=1,50
          lg=p(1,k)+p(2,k)*TO+p(3,k)*c+p(4,k)*beta+p(5,k)*c**2
     &    +p(6,k)*beta**2+p(7,k)*c**3+p(8,k)*beta**3
          Titer=q(1,k)+q(2,k)*lg+q(3,k)*c+q(4,k)*beta
     &    +q(5,k)*lg**2+q(6,k)*c**2+q(7,k)*beta**2
          IF(ABS(Titer-ALOG10(TO)).LT.0.0001)THEN
            TO=Titer
            GOTO 40
          ENDIF
          TO=10**Titer
        ENDDO
```

```
      READ*,by,m,c,beta
      a0=1.36*by+0.36*m+0.18*c-0.2448
      r=0.35*c-0.07*by-beta+2.565
   20 PRINT'(1X,''Enter guess at effective temperature in'')'
      PRINT'(1X,''range: 5500 K < Teff < 35000 K      ''$)'
```

```
            TO=Titer
            GOTO 40
          ENDIF
            TO=10**Titer
        ENDDO
```

b) LISTING FOR PROGRAM TEFFLOGG, (continued)

```
        TO=Titer
      GOTO 40
      ELSE
        TO=ALOG10(Te)
        DO JJ=1,50
           lg=p(1,k)+p(2,k)*TO+p(3,k)*c+p(4,k)*beta+p(5,k)*c**2
     &     +p(6,k)*beta**2+p(7,k)*c**3+p(8,k)*beta**3
     &     +p(9,k)*c**4+p(10,k)*beta**4
           Titer=q(1,k)+q(2,k)*lg+q(3,k)*c+q(4,k)*beta
     &     +q(5,k)*lg**2+q(6,k)*c**2+q(7,k)*beta**2
           IF(ABS(Titer-TO).LT.0.0001)THEN
             TO=Titer
             GOTO 40
           ENDIF
           TO=Titer
        ENDDO
      ENDIF
C-----------------------------------------------------------------------
   40 TO=10**TO
      Teff=NINT(ANINT(TO/10.0)*10.0)
      lg=ANINT(lg*100.0)/100.0
      WRITE(*,1003)name,Teff,errT(k),lg,errlg(k)
 1003 FORMAT(1X,'Star is : ',A20,3X,'Teff = ',I5,1X,'+/- ',I3,1X,'K',5X,
     &'log g = ',F4.2,1X,'+/- ',F4.2)
      WRITE(100,1004)name,Teff,errT(k),lg,errlg(k)
 1004 FORMAT(1X,'Star is : ',A20,3X,'Teff = ',I5,1X,'+/- ',I3,1X,'K',5X,
     &'log g = ',F4.2,1X,'+/- ',F4.2/)
C-----------------------------------------------------------------------
      PRINT'(1X,''Enter Q to quit program or {return} to continue ''$)'
      READ(*,'(A1)')reply
      IF(reply.EQ.'Q'.OR.reply.EQ.'q')THEN
          GOTO 50
        ELSE
          errT(1)=30
          errlg(1)=0.06
          errT(2)=130
          errlg(2)=0.05
          GOTO 10
      ENDIF
C=======================================================================
   50 PRINT'(1X,''Data has been recorded in file TGOUT.DAT'')'
      CLOSE(100)
   60 STOP
      END
```

Table 2. Grid points for Moon & Dworetsky (1985).

T_{eff}	log g	$(b-y)_0$	c_0	β	T_{eff}	log g	$(b-y)_0$	c_0	β
6000	2.00	0.339	0.818	2.626	10000	4.50	−0.008	0.930	2.912
6000	2.50	0.342	0.689	2.622	11000	2.00	−0.001	0.765	2.622
6000	3.00	0.343	0.573	2.619	11000	2.50	−0.017	0.878	2.669
6000	3.50	0.345	0.475	2.613	11000	3.00	−0.025	0.925	2.718
6000	4.00	0.345	0.394	2.608	11000	3.50	−0.030	0.930	2.770
6000	4.50	0.345	0.329	2.605	11000	4.00	−0.031	0.899	2.824
6500	2.00	0.259	1.072	2.679	11000	4.50	−0.031	0.839	2.872
6500	2.50	0.267	0.926	2.677	12000	2.00	−0.010	0.573	2.604
6500	3.00	0.274	0.775	2.671	12000	2.50	−0.026	0.690	2.645
6500	3.50	0.281	0.632	2.665	12000	3.00	−0.034	0.743	2.689
6500	4.00	0.287	0.509	2.657	12000	3.50	−0.039	0.759	2.735
6500	4.50	0.292	0.399	2.651	12000	4.00	−0.041	0.746	2.782
7000	2.00	0.184	1.312	2.730	12000	4.50	−0.042	0.710	2.828
7000	2.50	0.198	1.144	2.731	13000	2.00	−0.019	0.429	2.590
7000	3.00	0.210	0.979	2.730	13000	2.50	−0.036	0.554	2.629
7000	3.50	0.221	0.813	2.724	13000	3.00	−0.044	0.607	2.668
7000	4.00	0.231	0.654	2.718	13000	3.50	−0.048	0.625	2.709
7000	4.50	0.239	0.511	2.710	13000	4.00	−0.050	0.618	2.751
7500	2.00	0.095	1.585	2.779	13000	4.50	−0.051	0.590	2.793
7500	2.50	0.128	1.358	2.782	14000	2.00	−0.026	0.308	2.578
7500	3.00	0.150	1.167	2.785	14000	2.50	−0.044	0.447	2.617
7500	3.50	0.165	0.985	2.785	14000	3.00	−0.052	0.503	2.653
7500	4.00	0.178	0.808	2.780	14000	3.50	−0.057	0.522	2.690
7500	4.50	0.190	0.641	2.773	14000	4.00	−0.058	0.517	2.729
8000	2.00	0.044	1.620	2.788	14000	4.50	−0.059	0.493	2.767
8000	2.50	0.051	1.516	2.826	15000	2.00	−0.031	0.193	2.567
8000	3.00	0.075	1.327	2.835	15000	2.50	−0.052	0.357	2.606
8000	3.50	0.107	1.100	2.836	15000	3.00	−0.061	0.419	2.641
8000	4.00	0.128	0.908	2.836	15000	3.50	−0.065	0.440	2.676
8000	4.50	0.144	0.725	2.830	15000	4.00	−0.066	0.436	2.713
8500	2.00	0.024	1.513	2.752	15000	4.50	−0.067	0.414	2.747
8500	2.50	0.022	1.468	2.809	16000	2.00	−0.032	0.074	2.555
8500	3.00	0.027	1.369	2.851	16000	2.50	−0.059	0.277	2.596
8500	3.50	0.036	1.236	2.880	16000	3.00	−0.068	0.348	2.630
8500	4.00	0.048	1.072	2.893	16000	3.50	−0.072	0.372	2.664
8500	4.50	0.063	0.895	2.895	16000	4.00	−0.074	0.369	2.698
9000	2.00	0.016	1.370	2.710	16000	4.50	−0.074	0.349	2.732
9000	2.50	0.007	1.381	2.773	17000	2.00	−0.027	−0.058	2.543
9000	3.00	0.008	1.323	2.829	17000	2.50	−0.064	0.201	2.586
9000	3.50	0.013	1.225	2.872	17000	3.00	−0.075	0.285	2.620
9000	4.00	0.021	1.095	2.902	17000	3.50	−0.079	0.314	2.653
9000	4.50	0.032	0.939	2.916	17000	4.00	−0.080	0.312	2.685
9500	2.00	0.012	1.197	2.674	17000	4.50	−0.081	0.295	2.718
9500	2.50	−0.001	1.259	2.737	18000	2.50	−0.068	0.125	2.578
9500	3.00	−0.006	1.245	2.798	18000	3.00	−0.081	0.226	2.612
9500	3.50	−0.004	1.181	2.852	18000	3.50	−0.085	0.261	2.642
9500	4.00	0.001	1.080	2.894	18000	4.00	−0.087	0.264	2.675
9500	4.50	0.009	0.947	2.921	18000	4.50	−0.087	0.248	2.706
10000	2.00	0.008	1.034	2.651	20000	2.50	−0.069	−0.019	2.558
10000	2.50	−0.007	1.124	2.707	20000	3.00	−0.089	0.117	2.596
10000	3.00	−0.014	1.140	2.765	20000	3.50	−0.096	0.168	2.626
10000	3.50	−0.015	1.106	2.823	20000	4.00	−0.098	0.179	2.656
10000	4.00	−0.013	1.036	2.875	20000	4.50	−0.098	0.170	2.685

IV. PROGRAMS UVBYLIST AND TGLIST.

```
      PROGRAM UVBYLIST
C-----------------------------------------------------------------------
C-Measured (b-y), m1, c1 colours and Beta indices are entered. The group
C-in which data for a star are to be processed must be given in the input
C-data. From photometry the reddening, dereddened indices, absolute
C-magnitude and metallicity are calculated using known empirical
C-calibrations. Effective temperature is estimated using relations linking
C-colours with the empirical data of Code et al. (1976) or the
C-calibrations of Bohm-Vitense (1981), while the radius is determined by
C-coupling the surface brightness parameter and absolute magnitude where
C-the surface brightness parameter is calculated from the (b-y) colour
C-index (see Moon, 1984 & 1985).
C-The various multivariable and polynomial relations used are fits to
C-the tabular data to within the errors of such data and in all cases
C-suitably reconstruct the tables from which they were derived.
C-----------------------------------------------------------------------
      REAL m,m0,m1,m0zams,m1zams,MV,MVzams
      INTEGER Teff
      CHARACTER cname*20,name1*9,name2*9
      CHARACTER CN*4,HD*6,type*10
      PARAMETER(Rm1=-0.33,Rc1=0.19,Rub=1.53)
      PRINT'(1X,''Program UVBYLIST for determining physical parameters
     &'',/,1X,''of stars using uvby & Beta photometry.''/)'
C-Observed colours are : (b-y), m1 {=(v-b)-(b-y)}, c1 {=(u-v)-(v-b)},
C-while the dereddened colours are denoted as by0 = (b-y)o, m0 = (m1)o
C- = m1-E(m1), c0 = (c1)o = c1-E(c1).
      PRINT'(1X,''What file is to be read?  ''$)'
      READ(*,'(A9)')name1
      OPEN(100,FILE=name1,STATUS='OLD',IOSTAT=io)
      IF(io.NE.0) THEN
        PRINT'(1X,''Error on opening input file, status = '',I3)',io
        GOTO 40
      ENDIF
      PRINT'(1X,''Assign name to output file  ''$)'
      READ(*,'(A9)')name2
      OPEN(101,FILE=name2,STATUS='NEW',IOSTAT=is)
      IF(is.NE.0) THEN
        PRINT'(1X,''Error on opening output file, status = '',I3)',is
        GOTO 40
      ENDIF
      PRINT'(1X,''Enter cluster designation (up to 20 characters)'')'
      READ(*,'(A20)')cname
      WRITE(101,9997)cname
 9997 FORMAT(37X,'Cluster : ',A20//)
      WRITE(101,9998)
 9998 FORMAT(3X,'No.',3X,'HD',4X,'(b-y)o',4X,'mo',6X,'co',5X,
     &'Beta',3X,'E(b-y)',4X,'dm',7X,'Mv',4X,'Teff',3X,'Radius',
     &2X,'Sp. type'/)
C=======================================================================
      DO 100I=1,200
C-----------------------------------------------------------------------
    5 READ(100,9999,END=20,ERR=30)CN,HD,by,m1,c1,beta,type,n
 9999 FORMAT(1X,A4,1X,A6,4(1X,F5.3),1X,A10,1X,I1)
C- (u-b) is calculated from other indices.
      ub=c1+2*(m1+by)
      GOTO(1,2,3,4)n
C-----------------------------------------------------------------------
    1 CONTINUE
```

a) PROGRAM LISTING FOR UVBYLIST.

```
C-For group 1, Beta is a luminosity indicator and c0 is a temperature
C-indicator ((u-b)o is also a suitable temperature indicator).
      Eby=(13.608*by-ub+1.467)/(13.608-Rub)
      Ebycal=Eby
      CALL DEREDD(Eby,by,m1,c1,ub,by0,m0,c0,ub0)
      g=ALOG10(beta-2.515)-1.6*ALOG10(c0+0.322)
      MV=3.4994+7.2026*ALOG10(beta-2.515)-2.3192*g+2.9375*g**3
      Te=5040/(0.2917*c0+0.2)
      m0zams=0.0957758*c0**3-0.139003*c0**2+0.109804*c0+0.07473
      delm0=m0zams-m0
      GOTO 6
C-----------------------------------------------------------------------
    2 CONTINUE
C-For group 2, the Hydrogen Balmer lines are at maximum; hence two
C-parameters, a0 = f{(b-y), (u-b)} and r = f{Beta,[c1]}, are defined in
C-order to calibrate absolute magnitude and metallicity.
      m=m1-Rm1*by
      bycorr=4.2608*m**2-0.53921*m-0.0235
      DO II=1,10
         m0=m1-Rm1*(by-bycorr)
         by0=14.0881*m0**2-3.36225*m0+0.175709
         IF(ABS(bycorr-by0).LT.0.001)GOTO 51
         bycorr=by0
      ENDDO
   51 Eby=by-by0
      Ebycal=Eby
      CALL DEREDD(Eby,by,m1,c1,ub,by0,m0,c0,ub0)
      r=0.35*(c1-Rc1*by)-(beta-2.565)
      a0=by0+0.18*(ub0-1.36)
      MV=1.5+6.0*a0-17.0*r
      Te=5040/(0.8572*a0+0.5152)
      m0zams=-3.95105*by0**2+0.86888*by0+0.1598
      delm0=m0zams-m0
      GOTO 6
C-----------------------------------------------------------------------
    3 CONTINUE
C-For group 3, c1 is the luminosity indicator for a particular Beta,
C-while (b-y)o (or Beta) indicates temperature.
      m1zams=-2.158*beta**2+12.26*beta-17.209
      IF(beta.LE.2.74)THEN
          c1zams=3*beta-7.56
          MVzams=22.14-7*beta
        ELSEIF(beta.GT.2.74.AND.beta.LE.2.82)THEN
          c1zams=2*beta-4.82
          MVzams=11.16-3*beta
        ELSEIF(beta.GT.2.82)THEN
          c1zams=2*beta-4.83
          MVzams=-88.4*beta**2+497.2*beta-696.41
      ENDIF
      delm1=m1zams-m1
      delc1=c1-c1zams
      IF(delm1.LT.0)THEN
          by0=2.946-beta-0.1*delc1-0.25*delm1
        ELSE
          by0=2.946-beta-0.1*delc1
      ENDIF
      Eby=by-by0
      Ebycal=Eby
```

a) PROGRAM LISTING FOR UVBYLIST. (continued)

```
      CALL DEREDD(Eby,by,m1,c1,ub,by0,m0,c0,ub0)
      delm0=m1zams-m0
      delc0=c0-c1zams
      IF(delc0.GT.0.28)GOTO 5
      MV=MVzams-9.0*delc0
C-Temperature calibration is valid for luminosity classes IV and V
C-with solar-type abundances, giants may be up to 200 K cooler.
      Te=5040/(0.771453*by0+0.546544)
      GOTO 6
C-----------------------------------------------------------------------
    4 CONTINUE
C-For group 4, c1 is a luminosity indicator for a particular Beta
C-{or (b-y)}, while Beta {or (b-y)o} indicates temperature.
      m1zams=6.41701*beta**2-34.4538*beta+46.4167
      MVzams=5.48012*beta**3+11.0494*beta**2-188.748*beta+324.482
      IF(beta.LE.2.65)THEN
          c1zams=2*beta-4.91
        ELSE
          c1zams=11.1555*beta**2-56.9164*beta+72.879
      ENDIF
      delm1=m1zams-m1
      delc1=c1-c1zams
      dbeta=2.72-beta
      by0=0.222+1.11*dbeta+2.7*dbeta**2-0.05*delc1-(0.1+3.6*dbeta)*delm1
      Eby=by-by0
      Ebycal=Eby
      CALL DEREDD(Eby,by,m1,c1,ub,by0,m0,c0,ub0)
      delm0=m1zams-m0
      delc0=c0-c1zams
      IF(beta.GE.2.63.AND.delc0.GT.0.28)THEN
          GOTO 5
        ELSEIF(beta.LT.2.63.AND.delc0.GT.0.20)THEN
          GOTO 5
      ENDIF
      f=9.0+20.0*dbeta
      MV=MVzams-f*delc0
C-Temperature calibration is valid for luminosity classes IV and V
C-with solar-type abundances, giants may be up to 200 K cooler.
      Te=5040/(0.771453*by0+0.546544)
      GOTO 6
C-----------------------------------------------------------------------
    6 CONTINUE
      IF(by0.LE.0.335)THEN
          FV=-6.759*by0**3+3.731*by0**2-1.092*by0+3.981
        ELSE
          FV=-0.534*by0+3.959
      ENDIF
      radius=10**(2.*(4.236-0.1*MV-FV))
      beta=ANINT(beta*1000.0)/1000.0
      by0=ANINT(by0*1000.0)/1000.0
      m0=ANINT(m0*1000.0)/1000.0
      c0=ANINT(c0*1000.0)/1000.0
      Eby=ANINT(Eby*1000.0)/1000.0
      MV=ANINT(MV*100.0)/100.0
      Teff=NINT(ANINT(Te/10.0)*10.0)
      delm0=ANINT(delm0*1000.0)/1000.0
      WRITE(101,20000)CN,HD,by0,m0,c0,beta,Ebycal,delm0,MV,Teff,radius,
     &type
20000 FORMAT(1X,A4,2X,A6,6(2X,F6.3),2X,F6.2,2X,I5,2X,F6.2,3X,A10)
C-----------------------------------------------------------------------
  100 CONTINUE
C=======================================================================
      GOTO 40
   20 PRINT'(1X,''End of file reached''/)'
      GO TO 40
   30 PRINT'(1X,''Error in reading file''/)'
   40 CLOSE(100)
      CLOSE(101)
      STOP
      END
C***********************************************************************
      SUBROUTINE DEREDD(Eby,by,m1,c1,ub,by0,m0,c0,ub0)
      REAL m0,m1
      PARAMETER(Rm1=-0.33,Rc1=0.19,Rub=1.53)
      IF(Eby.LT.0)Eby=0
      by0=by-Eby
      m0=m1-Rm1*Eby
      c0=c1-Rc1*Eby
      ub0=ub-Rub*Eby
      RETURN
      END
C***********************************************************************
```

Table 3. Sample output from UVBYLIST.

Cluster : IC 2391

No.	HD	(b-y)o	mo	co	Beta	E(b-y)	dm	Mv	Teff	Radius	Sp. type
3	73681	0.024	0.219	0.960	2.918	-0.049	-0.041	2.05	9180	1.41	A2V
4	73722	0.284	0.150	0.476	2.663	0.004	0.023	3.13	6580	1.63	F5V
7	73951	0.012	0.180	1.000	2.879	-0.010	-0.010	1.00	9520	2.16	A2V n
8	73952	-0.044	0.124	0.703	2.782	0.004	-0.008	0.13	12440	2.35	B8V n
9	73967	0.157	0.215	0.857	2.780	0.021	-0.019	1.77	7550	2.33	F0V
10	74009	0.272	0.183	0.525	2.664	-0.019	-0.010	2.65	6660	1.97	F2V
11	74044	0.110	0.216	0.838	2.838	-0.002	-0.012	2.72	7980	1.36	A7V
12	74056	0.052	0.184	1.018	2.864	-0.018	0.019	1.39	8590	2.12	A2V
13	74071	-0.071	0.112	0.426	2.710	-0.001	-0.008	-0.82	15540	3.00	B6V
14	74117	0.239	0.165	0.560	2.703	0.003	0.007	3.04	6890	1.52	F2V
15	74145	0.140	0.208	0.772	2.801	-0.008	-0.008	2.85	7700	1.37	A7V
16	74146	-0.076	0.122	0.401	2.709	-0.005	-0.019	-0.84	15900	2.90	B4IV
17	74168	-0.059	0.145	0.496	2.755	0.004	-0.038	-0.18	14620	2.45	B9 p
18	74169	-0.043	0.213	0.835	2.855	-0.024	-0.088	0.90	11360	1.66	A0IV p
19	74182	0.151	0.185	0.820	2.788	0.012	0.013	2.22	7600	1.87	A5IV
20	74195	-0.080	0.095	0.343	2.666	0.005	0.005	-1.62	16800	4.01	B3IV
21	74196	-0.064	0.107	0.514	2.707	0.010	0.000	-0.90	14400	3.29	B7V n
23	74275	-0.010	0.166	0.931	2.896	-0.011	-0.015	1.39	10320	1.62	A0V
24	74340	0.318	0.144	0.379	2.635	0.002	0.042	3.91	6370	1.26	F6V
27	74438	0.126	0.223	0.765	2.831	0.008	-0.019	3.28	7830	1.09	A3V
29	74516	-0.005	0.184	0.986	2.911	-0.025	-0.029	1.46	9910	1.61	A0V
30	74517	0.072	0.197	1.026	2.860	0.002	0.006	1.28	8370	2.38	A3V
31	74535	-0.081	0.138	0.433	2.725	-0.015	-0.034	-0.59	15450	2.49	B9.5III
32	74536	-0.064	0.132	0.461	2.705	0.093	-0.026	-0.91	15060	3.30	B5V p
34	74560	-0.081	0.100	0.331	2.680	0.006	-0.001	-1.35	17000	3.53	B3IV
36	74582	0.225	0.198	0.749	2.708	0.072	-0.024	1.42	7000	3.12	F3III
37	74664	0.079	0.205	0.925	2.940	0.005	-0.001	3.07	8360	1.06	A3V
38	74665	0.103	0.191	0.920	2.834	0.020	0.012	1.92	8050	1.93	A3 m
39	74678	0.028	0.196	0.984	2.887	-0.018	-0.015	1.40	9160	1.93	A1V
40	74762	0.086	0.217	0.935	2.857	0.013	-0.014	2.07	8220	1.72	A5V
41	74955	0.029	0.211	0.958	2.900	-0.036	-0.029	1.79	9130	1.62	A1V
42	74999	0.067	0.175	1.055	2.861	-0.002	0.028	1.03	8420	2.64	A2V
43	75029	0.129	0.220	0.783	2.820	0.045	-0.017	3.04	7800	1.23	A7V
44	75066	0.237	0.207	0.723	2.704	0.002	-0.034	1.56	6910	3.00	F2III
45	75067	-0.047	0.121	0.684	2.736	0.087	-0.005	-0.54	12620	3.14	B9V
46	75105	-0.062	0.139	0.472	2.732	0.025	-0.033	-0.49	14920	2.76	B8V p
48	75185	0.068	0.154	1.105	2.855	0.029	0.050	0.52	8420	3.35	A3V
50	75466	-0.049	0.128	0.727	2.778	-0.007	-0.010	0.07	12230	2.35	B8V
76		0.164	0.188	0.724	2.760	-0.020	0.002	2.66	7490	1.56	A8V

b) PROGRAM LISTNG FOR TGLIST.

```
      PROGRAM TGLIST
C-----------------------------------------------------------------------
C-This program determines Teff and log g from dereddened (b-y), ml & cl
C-colours, and Beta, by iterating initial estimates through relations
C-fitted to the theoretical values of these indices calculated by Relyea
C-& Kurucz (1978), Philip & Relyea (1979) and Schmidt (1979), and
C-corrected by Moon & Dworetsky (1985). For effective temperatures
C-above 20000 K, the formulae of Balona (1984) are used.
C-----------------------------------------------------------------------
      CHARACTER CN*4,HD*6
      CHARACTER cname*20,name1*9,name2*9
      INTEGER Te,Teff1,Teff2
      REAL lg1,lg2,m
      REAL a(8,6),b(8,6)
      REAL p(10,4),q(7,4)
      REAL s(5),t(5),v(5),w(5)
C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
      DATA (a(i,1),i=1,8)/24.5862115,-1.68710534E-3,-30.9191161,
     &0.816327854,8.13402088,11.2199418,-5.4630658,0.334190849/
      DATA (b(i,1),i=1,8)/13048.2289,-397.416343,-17797.8975,
     &4546.58811,4823.35571,-1184.28554,-2105.76781,-75.125332/
      DATA (a(i,2),i=1,8)/8.99477705,-8.7349499E-5,-6.48645755,
     &-14.5885536,5.33113397,-16.1630551,-4.61473508,0.499591268/
      DATA (b(i,2),i=1,8)/5448.91694,-102.659912,-7289.69268,
     &-11639.2581,55742.4133,-156518.14,-851.107784,-94.5162057/
      DATA (a(i,3),i=1,8)/27.6320741,-1.70197601E-3,-37.7380876,
     &48.9341927,35.3107709,-115.099733,-12.1892981,2.57010599/
      DATA (b(i,3),i=1,8)/16557.9857,-346.439677,-18414.5379,
     &6711.21339,14915.0593,-64783.0278,-7997.1154,1900.98502/
      DATA (a(i,4),i=1,8)/7.55944013,-5.54081554E-4,31.6041895,
     &651.974261,72.922305,-222.047166,-2.71607554,-0.475019429/
      DATA (b(i,4),i=1,8)/15966.704,-541.024938,8919.50121,
     &591338.15,32742.8725,-114081.79,-8025.28359,2186.8098/
      DATA (a(i,5),i=1,8)/-2.3772603,3.80636413E-7,6.09117084,
     &109.730269,84.1836036,-239.978782,0.592105149,-1.15699607/
      DATA (b(i,5),i=1,8)/17959.5039,0.967370369,10161.0021,
     &595721.455,-7770.27437,-14176.1842,-12217.9616,7126.72263/
      DATA (a(i,6),i=1,8)/1.99376957,-1.17084159E-4,20.5515955,
     &269.279338,52.9593513,-83.272196,-4.81773676,11.0071897/
      DATA (b(i,6),i=1,8)/28628.7691,-2134.92776,162002.063,
     &1759274.69,-43371.8339,585665.92,-20351.3586,40859.0603/
C-----------------------------------------------------------------------
      DATA (p(i,1),i=1,10)/-283.495,-0.681088E-3,-14.4427,
     &226.072,10.0732,-51.9441,-2.82768,3.35794,0.0,0.0/
      DATA (q(i,1),i=1,7)/0.412702,0.10384E-1,0.202807E-1,
     &1.9946,0.127534E-3,0.303475E-2,-0.277311/
      DATA (p(i,2),i=1,10)/-72.8552,6.42625,2.24602,
     &26.9562,-1.32693,-3.29916,0.0,0.0,0.0,0.0/
      DATA (q(i,2),i=1,7)/3.37447,0.121598,-0.267488,
     &1.13197,-0.653663E-2,0.109494,-0.346268/
      DATA (p(i,3),i=1,10)/-87.0415,-2.76608,6.35322,28.0121,
     &-23.6281,6.42367,24.7614,2.6226,-9.04172,-1.34873/
      DATA (q(i,3),i=1,7)/3.15269,0.107653,-0.404474,1.00184,
     &-0.110018E-1,0.143814,-0.244699/
      DATA (p(i,4),i=1,10)/-127.038,1.30855,-1.9978,27.7581,
     &-6.99284,11.84,25.2917,3.77239,-27.529,-2.05058/
      DATA (q(i,4),i=1,7)/-4.89169,0.157642,-0.241133,
     &7.69283,-0.10704E-1,0.114035E-1,-1.65242/
C-----------------------------------------------------------------------
      DATA (s(i),i=1,5)/30.2492,-9.99635,-6.75889,-3.15249,5.80135/
      DATA (t(i),i=1,5)/4.03945,-0.0277304,-0.646848,-0.153423,
     &0.0703712/
      DATA (v(i),i=1,5)/4.390277,-0.452433,-6.38776,-41.37727,281.9522/
      DATA (w(i),i=1,5)/0.525018,0.849042,-0.0276477,0.1877788,
     &0.07080026/
C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
      PRINT'(1X,''What file is to be read?  ''$)'
      READ(*,'(A9)')name1
      OPEN(100,FILE=name1,STATUS='OLD',IOSTAT=io)
      IF(io.NE.0)THEN
        PRINT'(1X,''Error on opening input file, status = '',I3)'
        GOTO 400
      ENDIF
      PRINT'(1X,''Assign name to output file  ''$)'
      READ(*,'(A9)')name2
      OPEN(101,FILE=name2,STATUS='NEW',IOSTAT=is)
      IF(is.NE.0) THEN
        PRINT'(1X,''Error on opening output file, status  = '',I3)'
        GOTO 400
      ENDIF
      PRINT'(1X,''Enter cluster designation (up to 20 characters)'')'
      READ(*,'(A20)')cname
      WRITE(101,9997)cname
 9997 FORMAT(21X,'Cluster : ',A20//)
      WRITE(101,9998)
 9998 FORMAT(2X,'No.',5X,'HD',13X,'Teff',5X,'log g ',
     +9X,'Teff',5X,'log g '/,21X,'(from (b-y)o, mo, co)'
     +,6X,'(from co, Beta)'/)
C=======================================================================
      DO 1000I=1,200
C=======================================================================
      READ(100,9999,END=200,ERR=300)CN,HD,by,m,c,beta,Te
 9999 FORMAT(1X,A4,2X,A6,4(2X,F6.3),26X,I5)
      a0=1.36*by+0.36*m+0.18*c-0.2448
      r=0.35*c-0.07*by-beta+2.565
      IF(Te.GE.5500.AND.Te.LE.7000)THEN
        n=1
      ELSEIF(Te.GT.7000.AND.Te.LT.8500)THEN
        n=2
      ELSEIF(Te.GE.8500.AND.Te.LT.10500)THEN
        n=3
      ELSEIF(Te.GE.10500.AND.Te.LT.14500)THEN
        n=4
      ELSEIF(Te.GE.14500.AND.Te.LE.19000)THEN
        n=5
      ELSEIF(Te.GT.19000.AND.Te.LE.35000)THEN
        n=6
      ENDIF
      T1=REAL(Te)
      DO II=1,100
        lg1=a(1,n)+a(2,n)*T1+a(3,n)*by+a(4,n)*by**2+a(5,n)*m
     &  +a(6,n)*m**2+a(7,n)*c+a(8,n)*c**2
        Titer1=b(1,n)+b(2,n)*lg1+b(3,n)*by+b(4,n)*by**2+b(5,n)*m
     &  +b(6,n)*m**2+b(7,n)*c+b(8,n)*c**2
        IF(ABS(Titer1-T1).LT.5)THEN
          T1=Titer1
```

b) PROGRAM LISTING FOR TGLIST. (continued)

```
            GOTO 30
          ENDIF
          T1=Titer1
       ENDDO
C------------------------------------------------------------------------
   30 IF(Te.GE.5500.AND.Te.LT.8500)THEN
          k=1
        ELSEIF(Te.GE.8500.AND.Te.LE.11000)THEN
          k=2
        ELSEIF(Te.GT.11000.AND.Te.LT.15000)THEN
          k=3
        ELSEIF(Te.GE.15000.AND.Te.LE.20000)THEN
          k=4
        ELSEIF(Te.GT.20000.AND.Te.LE.35000)THEN
          k=5
      ENDIF
      T2=REAL(Te)
      IF(k.EQ.5)THEN
          c=ALOG10(c+0.2)
          beta=ALOG10(beta-2.5)
          TO=3.9036-0.4816*c-0.529*beta-0.126*c**2+0.0924*beta*c
     &    -0.4013*beta**2
          lg2=5.9046-3.2262*c+4.0883*beta-0.5383*c**2-0.2774*beta*c
     &    -0.0007*beta**2
          GOTO 40
        ELSEIF(k.EQ.2.AND.a0.GE.-0.09.AND.a0.LE.0.09.AND.
     &  r.GE.-0.03.AND.r.LE.0.14)THEN
          lg2=v(1)+v(2)*a0+v(3)*r+v(4)*r**2+v(5)*r**3
          theta=w(1)+w(2)*a0+w(3)*r+w(4)*a0**2+w(5)*r**2
          TO=ALOG10(5040.0/theta)
          GOTO 40
        ELSEIF(k.EQ.1.AND.c.GE.1.3.AND.c.LT.1.65.AND.beta.GE.2.74
     &  .AND.beta.LE.2.86)THEN
          TO=ALOG10(T2)
          DO JJ=1,50
             lg2=s(1)+s(2)*TO+s(3)*by+s(4)*c+s(5)*beta
             Titer2=t(1)+t(2)*lg+t(3)*by+t(4)*c+t(5)*beta
             IF(ABS(Titer2-TO).LT.0.0001)THEN
               TO=Titer2
               GOTO 40
             ENDIF
             TO=Titer2
          ENDDO
          GOTO 40
        ELSEIF(k.EQ.1)THEN
          TO=T2
          DO JJ=1,50
             lg2=p(1,k)+p(2,k)*TO+p(3,k)*c+p(4,k)*beta+p(5,k)*c**2
     &       +p(6,k)*beta**2+p(7,k)*c**3+p(8,k)*beta**3
             Titer2=q(1,k)+q(2,k)*lg2+q(3,k)*c+q(4,k)*beta
     &       +q(5,k)*lg2**2+q(6,k)*c**2+q(7,k)*beta**2
             IF(ABS(Titer2-ALOG10(TO)).LT.0.0001)THEN
               TO=Titer2
               GOTO 40
             ENDIF
               TO=10**Titer2
          ENDDO
          TO=Titer2
          GOTO 40
        ELSE
          TO=ALOG10(T2)
          DO JJ=1,50
             lg2=p(1,k)+p(2,k)*TO+p(3,k)*c+p(4,k)*beta+p(5,k)*c**2
     &       +p(6,k)*beta**2+p(7,k)*c**3+p(8,k)*beta**3
     &       +p(9,k)*c**4+p(10,k)*beta**4
             Titer2=q(1,k)+q(2,k)*lg2+q(3,k)*c+q(4,k)*beta
     &       +q(5,k)*lg2**2+q(6,k)*c**2+q(7,k)*beta**2
             IF(ABS(Titer2-TO).LT.0.0001)THEN
               TO=Titer2
               GOTO 40
             ENDIF
             TO=Titer2
          ENDDO
      ENDIF
C------------------------------------------------------------------------
   40 TO=10**TO
      Teff1=NINT(ANINT(T1/10.0)*10.0)
      lg1=ANINT(lg1*100.0)/100.0
      Teff2=NINT(ANINT(TO/10.0)*10.0)
      lg2=ANINT(lg2*100.0)/100.0
      WRITE(101,20000)CN,HD,Teff1,lg1,Teff2,lg2
20000 FORMAT(1X,A4,3X,A6,10X,I5,5X,F4.2,10X,I5,5X,F4.2)
C========================================================================
 1000 CONTINUE
C========================================================================
      GOTO 400
  200 PRINT'(1X,''End of file reached''/)'
      GOTO 400
  300 PRINT'(1X,''Error in reading input file''/)'
  400 CLOSE(100)
      CLOSE(101)
      STOP
      END
```

Table 4. Sample output from TGLIST.

Cluster : IC 2391

No.	HD	Teff (from (b-y)o, mo, co)	log g (from (b-y)o, mo, co)	Teff (from co, Beta)	log g (from co, Beta)
3	73681	8660	4.89	9010	4.48
4	73722	6530	3.80	6520	4.24
7	73951	9340	4.29	9370	4.12
8	73952	12220	4.14	12300	4.15
9	73967	7580	3.77	7510	3.81
10	74009	6600	4.19	6500	3.96
11	74044	8020	4.28	8050	4.30
12	74056	8610	4.01	8560	3.94
13	74071	15290	4.21	15150	4.02
14	74117	6920	4.27	6870	4.27
15	74145	7870	4.26	7730	4.28
16	74146	15720	4.55	15570	4.09
17	74168	13710	4.82	14140	4.36
18	74169	11060	4.14	11000	4.39
19	74182	7870	3.98	7590	4.01
20	74195	16740	3.74	16820	3.67
21	74196	14290	4.03	14130	3.73
23	74275	10140	4.32	10100	4.43
24	74340	6260	3.66	6320	4.50
27	74438	7830	4.41	8010	4.52
29	74516	9560	4.62	9720	4.40
30	74517	8390	3.93	8220	3.87
31	74535	15750	4.94	14750	4.15
32	74536	14360	4.65	14630	3.84
34	74560	16870	3.94	17050	3.92
36	74582	6920	4.14	6840	3.46
37	74664	8350	4.23	8910	4.46
38	74665	8230	4.06	8000	4.02
39	74678	8930	4.41	9010	4.23
40	74762	8160	4.13	8210	4.11
41	74955	8750	4.68	8970	4.38
42	74999	8470	3.88	8230	3.80
43	75029	7840	4.31	7900	4.38
44	75066	6790	4.23	6810	3.52
45	75067	12460	4.10	12610	3.71
46	75105	14090	4.76	14510	4.15
48	75185	8340	3.71	8180	3.64
50	75466	12300	4.23	12170	4.07
76		7790	4.21	7350	4.12

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