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Manual for the program package BBK⋆

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ABSTRACT
The program package BBK is designed to execute the computational steps of determining the fundamental parameters mass, distance, metallicity, reddening, position in a Hertzsprung-Russel diagram, variation of angular radius of spherically pulsating stars. Theoretical background is given in the papers of Barcza & Benkő (2009), Barcza (2010), Barcza & Benkő (2011). A successful use of the program package may be expected only after studying these papers intensively.

1 THE CONTENT

The program package is composed of the FORTRAN77 programs KUM.F, GENKUM.F, THAV.F, FUNDPARS.F, FUNDPAR.F, HRDPOS.F which must be compiled. The programs can be found in the subdirectory /bbk/f77_programs. Before running the programs it is advised to read the comment lines in the programs.[1] The results can be plotted by SuperMongo (Lupton & Monger) routines written out for convenience by the FORTRAN77 programs.

The program KUM.F solves the photometric inverse problem described in (Barcza 2010; Barcza & Benkő 2011) (Papers I and II). THAV.F is a fitting program to the results from the photometric inverse problem. (It is given for convenience, it can be replaced by other program(s) written by the user.) The programs FUNDPARS.F, FUNDPARUJ.F solve the hydrodynamic problem along the lines described in points (ii)-(iv) of Paper II. HRDPOS.F computes the position of the target star in a theoretical HRD (i.e. $L_{\rm eq}$-$T_{\rm eq}$ diagram).

The data files (UBV*K2.REDCD, COUSINS*.REDCD). were extracted from the homepage of R. L. Kurucz
`http://cfaku5.cfa.harvard.edu` ((Kurucz 1997), hereafter KTs as an abbreviation for Kurucz-tables),
they belong to KUM.F. These are in the subdirectory /bbk/kurucz_tables in zipped format.

The input files of the FORTRAN programs are (KUMBE1.DAT, KUMBE2.DAT, GENKUMBE.DAT, THAVBE.DAT, FUNDPARSBE.DAT, FUNDPARBE.DAT, HRDPOSBE.DAT). The files in the subdirectories /bbk/step*/GSC4868-0831 were the input files in Paper II, these can be used as an exercise. The content of the files THAVBE.DAT, FUNDPARSBE.DAT, FUNDPARBE.DAT, HRDPOSBE.DAT can be derived subsequently from the results of Steps (I) and (II).

The program package is designed for free use. Comments on it are welcome and may serve as a basis for eventual revisions which will later be designated by version numbers.

2 THE PROGRAM KUM.F

The program KUM.F executes different tasks depending on the value of its general control parameter **ir**, see the comment lines 115- in kum.f.

If **ir**=9 only the functions

$$T_{\rm e} = T_{\rm e}(A;\ \text{at a fixed}\ \log {\rm g}), \quad (1)$$

$$\log g = \log g(A;\ \text{at a fixed}\ {\rm T_e}) \quad (2)$$

are extracted from KTs where A is a colour index ${\rm CI}_i, i = 1, 2, ...$ or magnitude U, B, V, R_C, I_C or the bolometric correction.

The functions (1), (2) are stored in the output files MOUBV*.DAT enabling to plot colour-colour diagrams which show e.g.

⋆ Auxiliary material for (Barcza & Benkő 2011, Paper II), accepted for publication in MNRAS
[1] Only the important comments are in English. If the comment is in Hungarian, the user might safely ignore it.

the variation of the [$(U-B)$ and $(B-V)$] etc. colour index pairs of the ATLAS models as a function of [$T_{\rm e}$ at a fixed $\log g$] or [$\log g$ at a fixed $T_{\rm e}$], respectively.

If **ir**=16,17 in addition to extracting and storing the functions (1), (2) the program KUM.F executes the inversions

$$T_{\rm e} = f_1({\rm CI}_1, {\rm CI}_2) \quad (3)$$

$$\log g_{\rm e} = f_2({\rm CI}_1, {\rm CI}_2) \quad (4)$$

where the pairs $[{\rm CI}_1, {\rm CI}_2]$ of the colour indices to be used are fixed in the input file KUMBE1.DAT. The observed colour indices ${\rm CI}_i, i = 1, 2, ...$ themselves must be given in the input file KUMBE2.DAT.

In the same run, the

$$\vartheta = f_3(T_{\rm e}, \log g_{\rm e}) \quad (5)$$

conversion is performed to the pairs $[T_{\rm e}, \log g_{\rm e}]$ which were determined from the colour indices listed in the input file KUMBE2.DAT.

The functions (1), (2), f_1, f_2, f_3 are based on linear interpolations for metallicity [M] and reddening $E(B-V)$ in the KTs.

The inversion is performed for all lines in KUMBE2.DAT if **ir**=17, for the line 4 only if **ir**=16. Of course, the output files are different for the values of the control parameter **ir**.

2.1 The input files

2.1.1 KUMBE1.DAT

is an input file, it contains the control parameters of the program KUM.F. Lines beginning with # indicate the role of the control parameters which are listed below. Examples are given in steps (I), (II) on how to give the control parameters. The main parameter is **ir** in the second line, the following functions belong to its different values.

- **ir**=9: the program stops after extracting the moubv*.dat files from the KTs. For orientation it can be useful to plot these files in the suspected range of T_e and $\log g$ of the target star because unique solution to the inverse problem (3), (4) can sometimes be provided by the program if the search interval of $T_e, \log g$ is constrained by giving the upper and lower limits $T_{\rm u}$, $T_{\rm l}$, $(\log g)_{\rm u}$, $(\log g)_{\rm l}$.
- **ir**=16: the functions (1) are given as output files LGGTE*.DAT which belong to the different colour index pairs ($i = 1, 2;\ 1, 3$ etc. in line 4 of KUMBE2.DAT. The files LGGTE*.DAT can be plotted by the SUPERMONGO routine MONTEG000.
- **ir**=17: files LGGTE*.DAT are not stored, lines from KUMBE2.DAT are elaborated from line 4 until the first line with 'phase' < -1.
- Other values of **ir** were used to find bugs.

The upper and lower limits of the inversions in (1)-(5) i.e. $T_{\rm l} \le T_{\rm e} \le T_{\rm u}$ and $(\log g)_{\rm l} \le \log g_{\rm e} \le \log g_{\rm u}$ must be fixed in the second line of KUMBE1.DAT because the limits of the KTs are $T_{\rm l} = 3500$ K,, $T_{\rm u} = 50000$ K, $(\log g)_{\rm l} = 0.5$, $(\log g)_{\rm u} = 5.0$, these are usually too wide. The KTs are extrapolated by KUM.F to $(\log g)_{\rm u} = 5.50$. (Do not forget that the units of $\log g$ are ${\rm cms}^{-2}$.)

[M] and $E(B-V)$ must be specified in line 4.

The colour indices to be used in the inversions (3), (4), (5) must be specified it the lines 5-65 by 0 or 1 for no or yes, respectively. E.g. if the pairs ${\rm CI}_1 = U - 2B + V$ and ${\rm CI}_2 = U - V, U - R, ...$ are to be used and ${\rm CI}_2 = U - B$ is to be omitted, and if the pairs ${\rm CI}_1 = U - B$ and ${\rm CI}_2 = U - V, U - R, ...$ are not to be used etc. the lines 6-11, 12-17 etc. must look like as they are in Table 1. (The use of the hybrid colour index $U - 2B + V$ is substantiated in (Barcza & Benkő 2009): the form of (1)-(5) is better for an inversion because these are single-valued functions in the colour interval showing up by an RR Lyrae star.)

2.1.2 KUMBE2.DAT

is the input file containing the photometric data. The lines 1-3 can contain any text which is reproduced in the output files. From line 4 the format must be one phase point/line as follows.

Phase V $B-V$ $U-B$ $V-R_C$ $V-I_C$,

the data are read until the line beginning with

phase < -1.

The allowed number of phase points is 999.

Table 1. Example for the lines 6-11, 12-17 etc. of KUMBE1.DAT

# U-2B+V									
1									
# and									
# U-B	U-V	U-R	U-I	B-V	B-R	B-I	V-R	V-I	R-I
0	1	1	1	1	1	1	1	1	1
#- -									
# U-B									
0									
# and									
# U-V	U-R	U-I	B-V	B-R	B-I	V-R	V-I	R-I	
1	1	1	1	1	1	1	1	1	
#- -									

2.2 The output files

2.2.1

KUMOKI.DAT: this is a dump file, it may help to find errors like wrong $T_{\rm l}, T_{\rm u}$, $(\log g)_{\rm l}, (\log g)_{\rm u}$ in KUMBE1.DAT or problems arising from more than one pair $[T_{\rm e}, \log g]$ from the inversions (3, 4).

2.2.2

MOUBVTE=*.DAT (*$= T_{\rm e}$, $T_{\rm l} < T_{\rm e} < T_{\rm u}$),
MOUBVLGG=*.DAT (*$= \log g$, $(\log g)_{\rm l} < \log g < (\log g)_{\rm u}$):

these files contain the colour indices $U-B$, $B-V$, $V-R_C$, $V-I_C$, $U-V$, $U-2B+V$, R_C-I_C, the magnitudes U, B, V, R_C, I_C, and the bolometric correction which were interpolated from the KTs to the pairs of $\log g$ and $T_{\rm e}$ at the fixed [M] and $E(B-V)$ in the line 4 of KUMBE1.DAT.

The iso-$T_{\rm e}$, iso-$\log g$ functions, i.e.

$$T_{\rm e} = T_{\rm e}({\rm CI}_1, {\rm CI}_2; \log g) \quad (6)$$

$$\log g = \log g({\rm CI}_1, {\rm CI}_2; T_{\rm e}) \quad (7)$$

can be extracted from the files MOUBVTE=*.DAT, MOUBVLGG=*.DAT. It can be informative to plot (6), (7) in the different colour-colour diagrams, e.g. like in $(U-2B+V)$-$(B-V)$, $(U-B)$-$(B-V)$ etc.

2.2.3

MOKUMOKI.DAT contains the averaged results from the colour-colour index pairs fixed in KUMBE1.DAT, the header is in line 55. The columns are:

1: phase

2: the number of pairs of the colour indices giving $\log g$ and $T_{\rm e}$. If 'no' (=number) is less than the requested pairs to determine $\log g$ and $T_{\rm e}$ it indicates that either there were more than one solution to the inversion (3), (4) or there was no solution at all. The failed pair(s) of colour index (or indices) can be seen in MOKUMOKI1.DAT. If there were more than one solution narrowing the upper, lower limits of the search can help, physical insight, continuity considerations can help to determine which is the true solution.

3, 5, 7: the averaged $\log g$, $T_{\rm e}$, ϑ from the 'no' number of colour index pairs, their standard errors at 1σ level are in columns 4, 6, 8.

9: reciprocal barometric scaleheight $h_0^{-1} = g_{\rm e}/\mathcal{R}T_e$ for unit averaged molecular mass.

10: The input parameter metallicity [M] of KUMBE1.DAT. (It is on dex scale provided by the ATLAS models, for explanation see (Kurucz 1997) and Paper II, [M]=0 for solar composition).

11: The input parameter $E(B-V)$ of KUMBE1.DAT, for explanation see (Barcza & Benkő 2011).

2.2.4

MOKUMOKI1.DAT contains some details from the inversion, the columns are:

1: phase,

2,3: index pairs belonging to the different colour indices, their verbal equivalent can be found in column 10

4,5: $\log g$ and $T_{\rm e}$ from the index pair

6,7,8: ϑ derived from V, R_C and $V+$ bolometric correction compared with Stefan-Boltzmann law.

2.2.5

The files LGGTE*.DAT (*=UB, UBV, UV, UR, UI, BV, BR, BI, VR, VI, RI) contain the $T_{\rm e}$-$\log g$ relations for the colour indices (derived) from line 4 of KUMBE2.DAT. These files are preserved only if **ir**=16.

3 THE AUXILIARY PROGRAM GENKUM.F

This program generates the files KUMBE1_I.DAT, I $= 1, ...,$ I ≤ 99 and the shell script[2] KUMI.ZSH to the input values of [M] and $E(B-V)$ given in GENKUMBE.DAT to facilitate the execution of step (I) easily.

4 STEP (I): DETERMINATION OF THE ATMOSPHERIC METALLICITY [M] AND REDDENING $E(B-V)$ TOWARD A TARGET STAR

Reliable results can be expected if an average of $N^{(I)} > 20$ phase points are used in Eqs. (2), (3) of Paper II to map $\langle\Delta \log g_{\rm e}\rangle_{N^{(I)}}$, $\langle\Delta T_{\rm e}\rangle_{N^{(I)}}$ as a function of $E(B-V)$ and [M]. Visual inspection or parabolic fits can be useful to find $E(B-V)$ and [M].

The selected $N^{(I)} > 20$ phase points of the target star (or the id., $V, B-V, ...$ values from tie-in observations of the comparison stars) must be written into the input file KUMBE2.DAT. The m trial values $E(B-V)$ and [M] must be written into the input files KUMBE1_I.DAT, I$= 1, ..., m$. The step is automatically performed by the shell script KUMI.ZSH generated by the auxiliary program GENKUM.F if the trial values $E(B-V)$ and [M] are written in the file GENKUMBE.DAT and the shell GENKUM.ZSH is executed.

After having $E(B-V)$ and [M] of the target star from the variation check the results by plotting $\Delta \log g_{\rm e}$, $\Delta T_{\rm e}$ in all available phase points, outlier points can indicate an observational error of the colour indices. If considerable number of outlier points was included in $N^{(I)}$ it can be useful to repeat the procedure with a reduced $N^{(I)}$.

It can be very informative to determine [M] and $E(B-V)$ of the comparison stars if $N^{(I)} = N$ tie-in observations are available. (The N V magnitudes and the colour indices must be written in KUMBE2.DAT, the trial values $E(B-V)$ and [M] for the comparison stars must be written in the file GENKUMBE.DAT and the shell GENKUM.ZSH must be executed.) The scatters $\langle\Delta \log g_{\rm e}\rangle_N$ $\langle\Delta T_{\rm e}\rangle_N$ of the comparison stars indicate the quality of the photometry if these are of similar colours as the target star.

4.1 An example

Copy KUMBE1.DAT, KUMBE2.DAT from the directory /stepI/GSC4868-0831.

Executing KUM.F with this KUMBE1.DAT uses each combination of the colour index pairs $U-2B+V$, $U-V$, $U-R_C$, $U-I_C$, $B-V$, $B-R_C$, $B-I_C$, $V-R_C$, $V-I_C$, R_C-I_C, containing one colour index at least with U, i.e. 30 pairs to determine the 30 pairs $[T_{\rm e}, \log g_{\rm e}]$ belonging to a phase point.

All lines were deleted from the complete photometric material (KUMBE2.DAT of /bbk/stepII/GSC4868-0831) except for phase intervals = 71.6077-71.6220, 73.5203-73.5919, 76.4228-76.5088, i.e. the $N^{(I)} = 35$ phase points remained in KUMBE2.DAT. These are the shock free intervals in the observational material of Paper II. (The observations in these time intervals were of the best photometric sky conditions.)

Now, fix the trial values of [M] and $E(B-V)$ in the input file GENKUMBE.DAT and execute the program GENKUM.F to generate the input files KUMBE1_I.DAT, I$= 1, 2, ...,$ $i \leq 99$ and the shell script KUMI.ZSH.

The shell script GENKUM.ZSH executes GENKUM.F and KUMI.ZSH with KUMBE1_I.DAT, I$= 1, 2, ..., m$, the result MEBMVKI.DAT will contain $\langle\Delta \log g_{\rm e}\rangle_{N^{(I)}}$, $\langle\Delta T_{\rm e}\rangle_{N^{(I)}}$ and their standard deviations at 1 σ level in columns 3-6 as a function of $E(B-V)$ and [M] (columns 1, 2). Furthermore, the average, minimum and maximum of $\log g_{\rm e}$, $T_{\rm e}$ are in columns 7-12. Columns 13-15 contain the average, minimum and maximum number of pairs of $[T_{\rm e}, \log g_{\rm e}]$ which could be determined from the phase points in KUMBE2.DAT. (This is ≤ 30 in our example.)

Plot the results or fit parabolas to find the simultaneous minima of $\langle\Delta \log g_{\rm e}\rangle_{N^{(I)}}$, $\langle\Delta T_{\rm e}\rangle_{N^{(I)}}$ which provides $E(B-V)$ and [M] of the target star in the sense described in Paper II.

[2] The shell scripts mentioned in this manual do not contain shell-specific commands, the shells scripts can be executed with z-shell, C-shell, Bourne shell, etc.

5 STEP (II): THE CONVERSIONS (3)-(5)

[M], $E(B-V)$ from Step (I) and **ir**=17, must now be written in KUMBE1.DAT. The colour index pairs to be used must be fixed, see Table 1. V and the colour indices of all phase points must be written in KUMBE2.DAT from line 4 and a run of the program KUM.F executes the inversions (3)-(5). To automatize the step the shell script KUMII.ZSH executes the necessary delete operations and executes KUM.F. The result MOKUMOKI.DAT contains the variable parameters $T_{\rm e}$, $\log g_{\rm e}$, ϑ as a function of phase, MOKUMOKI1.DAT contains somewhat more detailed information of the inversion process. The output files MOUBV*.DAT render possible to draw colour-colour diagrams, similar to Fig. 2 of Paper II.

5.1 The $T_{\rm e}$-$\log g_{\rm e}$ functions of a phase point

It can be useful to plot the functions $T_{\rm e}$-$\log g_{\rm e}$ belonging to characteristic parts of the light curve to see how these do or dot not intersect from the different pairs of colour indices. Writing **ir**= 16 in line 2 of KUMBE1.DAT, the phase points 71.6124 etc. in line 4 of KUMBE2.DAT, executing the script KUMII.ZSH will produce the functions. They can be plotted by the SUPERMONGO routine MONTEG000. Comparing the result with other phase points, e.g. with 71.6077... etc., or with erroneous values of colour indices etc. will be informative. (The data files JELM*.DAT belong to MONTEG000 to denote the symbols in the figure.)

6 STEP (III): FITTING POLYNOMIALS TO THE VARIABLE PHYSICAL QUANTITIES

Execute (again) KUMII.ZSH with [M], $E(B-V)$ of the target star and **ir**=17 in KUMBE1.DAT and with all phase points in KUMBE2.DAT to produce the input data file MOKUMOKI.DAT for the program THAV.F that produces polynomial fits of degree 2-10 to ϑ, $\log g_{\rm e}$, h_0 and SUPERMONGO tasks to plot them. The shell script THAV.ZSH executes the delete operations and the program.

6.1 The input file THAVBE.DAT

Line 1: the input file (MOKUMOKI.DAT from step (II)).

Line 2, Col. 1 must contain the period in units sec or 86400 if the column phase is in format nn.frac(HJD). Col. 2: the integer part of HJD-nn.

Line 3: id. number of the phase segment to which the fitting must be done.

Lines 4-: id. number, start and end of the phase interval to which the fitting will be done.

6.2 The output files

6.2.1 THETA_S.DAT

The standard deviations of the polynomial fits of degree 2-10 are summarized in THETA_S.DAT.

6.2.2 THETA_0.DAT

THETA_0.DAT: the input values of THAV.F which were read from the input file given in line 1 of THAVBE.DAT.

6.2.3 THETA_I.DAT, I= 1, ..., 9

THETA_I.DAT I= 1, ..., 9: polynomial fits of degree I+1.

The content of a THETA_I.DAT from line 7:
column 1: phase (x), column 2: the input ϑ from MOKUMOKI.DAT, columns 3-5: fitted value of y, and $\dot{y}, \ddot{y}$, column 6,7: the input $\log g_{\rm e}$ and the fitted value, column 8,9: the input $T_{\rm e}, h_0$, columns 10-12: the fitted value of $h_0, \dot{h}_0, \ddot{h}_0$.

Attention! It is an artifact if the fitted $h_0(x) \leq 0$, this part must either be deleted from the analysis or the phase interval of the fitting must be modified for a repeated execution in order to find a fit with $h_0(x) > 0$ in the whole interval.

6.2.4 The SUPERMONGO *files*

The SUPERMONGO files MONGS_I, MONHS_I, MONLS_I, MONTS_I, I = 1, ..., 9 generated by THAV.F render possible to plot the input values of $\log g_{\rm e}, h_0, \vartheta$ and the polynomial fits of order I + 1.

7 STEP (IV): DETERMINATION OF THE ANGULAR VELOCITY AND ACCELERATION

7.1 The program FUNDPS.F

The program FUNDPS.F determines $\ddot{\vartheta}, \dot{\vartheta}$ and the angular acceleration and velocity $a/d, v/d$, for explanation see Paper II, paragraph 4 of Sec. 4. The maximal value(s) of $\ddot{\vartheta}$ must be found manually to estimate the upper limit of the search for the distance $d_{\max}$. (For explanation see the paragraph before Subsection 4.1 of Paper II.)

The n shock-free intervals of the atmosphere, i.e. $(a/d)_i \approx 0, (v/d)_i \approx$ constant must be selected manually from the output file FUNDPSKI.DAT to find $(\mathcal{M}_{\rm a} d^{-2})_i, i = 1, ..., n$ (see Eq. (6) of Paper II) and its standard error must be calculated $(\mathcal{M}_{\rm a} d^{-2})$ (see Eq. (7) of Paper II).

7.2 The input files

7.2.1 THSTB.DAT

The file THSTB.DAT must be composed manually by unifying the output files THETA_I.DAT from Step (III), this will be the input of the programs FUNDPARS.F, FUNDPUJ.F, HRDPOS.F. This must be done as follows. One of THETA_I.DAT I $= 1, ..., 9$ must be selected from each phase segment (of THAVBE.DAT) which contains the best fits of ϑ, $\log g_{\rm e}$, h_0 and it must be written in THSTB.DAT. Lines beginning with # must be deleted except for lines 1-3 an 8 of the first THETA_I.DAT.

Finally the period or 86400. must be written in the first line of THSTB.DAT.

7.2.2 FUNDPSBE.DAT

Line 1: the input file from Step (III) to be elaborated (THSTB.DAT).

Line 2: an output file which will contain of the data of the phases where a/d has a sign change. (See point (ii) in Sec. 4 of Paper II.)

Line 3: description of the input variables which must be given in Line 4.

Line 4, column 1: k is to give the boundary temperature of the atmosphere $T(0) = k * T_{\rm e}$, $k = 0.84$ for a grey model atmosphere, see Paper I, paragraph before Sec. 3.

Line 4, column 2: average molecular mass μ, $\mu = 1.3$ for a normal composition, see Paper I, paragraph before Sec. 3.

Line 4, column 3: 0 if UAA is wanted, 1 if the atmosphere is taken into account as a compressible system, see Paper I, first paragraph of Sec. 2.2.

Line 5: start and end of the phase interval to be elaborated from the input file.

Line 6: an arbitrary reference distance (in units pc) and mass (in units solar mass) to convert the quantities of THSTB.DAT in absolute units.

7.3 The output files

7.3.1 FUNDPSKI.DAT

The angular quantities to compute $(\mathcal{M}_{\rm a} d^{-2})_i$ are collected in this output file.

The columns are: phase, $\ddot{\vartheta}$, a/d, $\dot{\vartheta}$, v/d, $\vartheta^2 g_{\rm e}/G$ in cgs units and $\mathcal{M}_\odot/{\rm pc}^2$. The columns 8-10 are reproduced from the input THSTB.DAT: ϑ, $\log g_{\rm e}$, $T_{\rm e}$. For explanation see point (ii) in Sec. 4 of Paper II.

The phases $i = 1, ..., n$ with $a/d \approx 0$, $v/d \approx$ const must be selected manually from this file and $\mathcal{M}_{\rm a} d^{-2}$ must be computed using Eq. (7) of Paper II.

The maximal $\ddot{\vartheta}$ (or a/d) must be selected from this file for Eq. (10) of Paper II to find $d_{\max}$.

7.3.2 FUNDPSKI1.DAT, FUNDPSKI2.DAT

These files contain variable parameters given in the headlines computed for the reference mass and distance in line 6 of FUNDPSBE.DAT.

7.3.3 The output file specified in Line 2 of FUNDPSBE.DAT

The file given in Line 2 of FUNDPSBE.DAT contains the phases where the sign of a/d changes (see columns 13, 14).

8 STEP (V): THE SOLUTION OF EQ. (4) OF PAPER II, $L_{\rm EQ}$, $T_{\rm EQ}$, OF THE TARGET STAR

The program FUNDPUJ.F solves Eq. (4) of Paper II, the roots d_j (see Eq. (8) of Paper II) are searched in the interval $d_{\rm min} \le d \le d_{\rm max}$ with stepsize $d_{\rm l}$ fixed in the input file FUNDPUJBE.DAT.

The value of $(\mathcal{M}_{\rm a} d^{-2})$ from Step (IV) must be given in FUNDPUJBE.DAT in cgs units. The program computes

$$\frac{\vartheta^2(t)}{G}\Big[g_{\rm e}(t) - a(r,t) - a^{(\rm dyn)}(r,t)\Big] - \frac{\mathcal{M}_{\rm a}}{d^2} = g(t,d) \tag{8}$$

for $r = R$ and each phase point t with $a^{(\rm dyn)}(r,t) \equiv 0$. If a root (i.e. $g(t_j, d_j) = 0$) is found d_j is stored for Eq. (8) of Paper II. Finally $d(N)$ is calculated and the dynamical correction $a^{(\rm dyn)}(r,t)$ is calculated for each phase point to this $d(N)$. The phase points with $|a^{(\rm dyn)}(r,t)| < a^{(\rm dyn)}_{\rm limit}$ are written in the output file given in line 6 of FUNDPUJBE.DAT. This output file is of the same format as the input file THSTB.DAT and it can be used iteratively to find the number $N^{(II)}$ of the phase points satisfying now $|a^{(\rm dyn)}(r,t)| < a^{(\rm dyn)}_{\rm limit}$. (See points (iii) and (iv) in Paper II.)

The obtained $d(N^{(II)})$ will be the final distance from the procedure and it will serve as a basis to compute the mass from the value of $(\mathcal{M}_{\rm a} d^{-2})$ determined in Step (IV). The other distance dependent parameters $L_{\rm eq}$ and $R(t)$ can be computed from Eq. (12) of Paper II and $R(t) = \vartheta(t) d$, respectively.

Of course, the input $\vartheta(t)$, $T_{\rm e}(t)$ for $T_{\rm eq}$ (Eq. (11) of Paper II) are stored in the input file THSTB.DAT. The magnitude or intensity averaged M_V can be computed by $d(N^{(II)})$ from the observed V magnitudes.

8.1 The input file FUNDPUJBE.DAT

The input file of FUNDPUJ.F must be specified in line 1, e.g. THSTB.DAT.

Line 2 is an explanation for the values to be introduced in line 3.

Line 3, col. 1-3: k, μ, and 0 or 1 as in FUNDPSBE.DAT.

Line 4, columns 1-3: $d_{\rm min}$, stepsize $d_{\rm l}$ of d when the roots of (8) are searched, $d_{\rm max}$. Column 4: stepsize $d_{\rm hist}$ for the histogram of the number of the roots d_j in the intervals $[d_{\rm min}, d_{\rm min} + d_{\rm hist}], [d_{\rm min} + d_{\rm hist}, d_{\rm min} + 2d_{\rm hist}], ...$

Line 5: start and end of the phase points to include, i.e. the start and end of t in (8).

Line 6: the name of the output file with the extracted phase points from the input THSTB.DAT satisfying $|a^{(\rm dyn)}(r,t)| < a^{(\rm dyn)}_{\rm limit}$, e.g. THSTB1.DAT. This file is of the same format as the input THSTB.DAT.

Line 7: the value of $a^{(\rm dyn)}_{\rm limit}$ in cgs units.

8.2 The output files of FUNDPUJ.F

8.2.1 FUNDPUJKI.DAT

This is the main output file. The angular quantities were converted in absolute units using the mass and distance from $d(N^{(II)})$. Line 12 is the headline indicating the absolute quantities.

The last 3 lines beginning with # are a statistical summary of the physical parameters. 1: the elaborated phase interval, 2: headline, 3-6: $\mathcal{M}_{\rm a}$, d and their standard error (1σ confidence interval) 7: number of the elaborated phases, from the second iterative step the number of the phases satisfying $|a^{(\rm dyn)}(r,t)| < a^{(\rm dyn)}_{\rm limit}$. 8: number of the roots $g(t,d) = 0$. 9-13: averaged $\overline{a^{(\rm dyn)}}$, see Eq. (9) of Paper II, its standard deviation, standard error, minimum and maximum.

8.2.2 MONDA, FUNDPUJKI1.DAT, FUNDPUJKI3.DAT

MONDA is a SUPERMONGO task to plot (8) and the histogram of the number of the roots as a function of d. The data are in FUNDPUJKI1.DAT and FUNDPUJKI3.DAT.

8.2.3 FUNDPUJKI2.DAT

This is a dump file.

8.3 The program HRDPOS.F

The program HRDPOS.F computes the position of the target star in a theoretical HRD from Eqs. (11), (12) of Paper II. Its input file is

HRDPOSBE.DAT containing the input file (e.g. THSTB.DAT) in Line 1.

Line 2: d [pc].

The output is HRDPOSKI.DAT, it contains the number of the included phases, $L_{\rm eq}$, $T_{\rm eq}$ computed from Eqs. (11), (12) of Paper II.

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