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1. WHO5 SYSTEM OPERATION

Below, we overview how the WHO5 Secondary Parameter Determination System works. We will list the needed files and system setup, define the program parameters in header files, walk through a basic data run, and explain how the results are packaged.

This system was built on the openSUSE operating system, using tcsh scripts and the Portland Group Fortran 90 compiler (pgf90). The compiler can be changed by modifying the scripts below.

The input files are provided based on the CSP observations of the UBV colors and models, see https://doi.org/10.48550/arXiv.2311.03473 for the analysis.

Different filters and model eigenfunctions can be used by modifying list of files (see below) within this tool set.

2. SYSTEM CONTENTS

The working directory should have these components present:

ALPHA11 script which guides the primary-parameter conditioning (shifting and stretching) of the raw data.

alpha.h parameter file for ALPHA11 and its dependencies.

ATEST script which guides the primary-parameter determination based on V-band light curves.

ATEST1_tcsh script which calls ATEST and recalls ATEST using augmented data (from NARC) if LCs with large gaps around maximum light are found.

BANDER2v script which handles finding the times of maximum and maximum apparent magnitude of bands other than (V).

BANDER2u is same as BANDER2v, but special for (U) band.

CDAT folder containing temporary light curve photometry that has been "conditioned," i.e. been stretched and shifted by ALPHA11.

CODES folder containing all source code.

CONSOLID script which combines "in.dat.opt" files when augmented data is needed for some SNe (when NARC is called).

DATACHECK_NEW1 script that checks if there is LC data in region II for all SNe Ia, except for CSP-I. If an object does not have data in that region, then its name is written in a file named "BadSNeAuto". All other usable object names are written in the "in.dat" file, and their redshifts in the "redshifts25.dat" file. The numbers of the usable SNe are written in the "input.par" file.

DATACHECK_NEW2 script checks if the LC data covers up to +25 days. If not, then the name of the object is written in the "BadSNeAuto2" file. It also rewrites the "in.dat", "redshifts25.dat", and "input.par" files.

DIFL folder containing temporary differential light curves for all SNe pairs created by SADIE.

EPCSOLV3v solves the overdetermined system of principal component coefficients, for use when PCs of residuals are sought.

EPCSOLV3u same as EPCSOLV3, but for use with the (U) band.

EPCSOLV4v same as EPCSOLV3, but for use when PCs of differentials are sought.

EPCSOLV4u same as EPCSOLV4, but for use with the (U) band.

EPSILv script guiding the principal component finder.

EPSILu same as EPSIL but for the (U) band.

GRID folder for temporary storage of secondary-parameter χ^2 data produced by SADIE.

INCLUDE folder containing all the header files.

in.dat_all file contains a list of all filenames of SNe photometry data.

LCP3v_d1, LCP3v_d2, LCP3v_d3, LCP3v_d4 scripts generate overlay plots of stretched and shifted light curves.

LCP3u same as LCP3v but for use with (U)-band data.

LCP5 script which plots overlaid scaled PC signals. NARC script which handles LCs with large gaps by filling them with template LC data.

names_CSPI8.dat - this file lists the names of the eight messenger SNe Ia from CSPI. This file must be present in the folder named "Peter".

NEWCHECK removes the duplicate or same-day data points from LC data.

Peter - this folder contains the source codes for the projection of the generic parameters to the physical space, as well as the theoretical relationships to project them ("mrho.data" file). It also contains the names of the "messenger" SNe.

redshifts25.dat_all file containing redshift information. The format of each line is the six-character SN name followed by the floating-point redshift value.

RDAT folder containing all raw (unstretched, unshifted) data. This data should be in files with names 12 characters long; the nominal file format is:
"xxxxxx.x.fin", where the first six characters "xxxxxx" contain the SN identifier (i.e., "2004ef") while the second field "x" is the band of the data (valid options are u,v,b,g,r,i). The last three characters must be "fin". The data files need to have a three-line header and be in a three-column format:
(epoch) (apparent magnitude) (photometric uncertainty)

The data files can have any length necessary.

RSDL folder containing all temporary residuals created by SADIE.

RUNS folder into which all run tarballs are placed.

SADIE script which guides the secondary-parameter determination from the shifted and stretched light curves.

SADIE013 script which calculates the second-stage primary parameter modifications.

SDAT folder containing temporary data secondary-parameter light curve signals.

SSIG folder containing temporary data used to construct residual plots.

ssptv script which creates plots of residuals and weighted signals.

ssptu is similar to ssptv, but for U-band analysis.

TDAT folder containing all templates, for both interpolation and s-correction normalization. This directory must contain the templates:
ntemp.ti
btemp.ti6
utemp.ti6

temp.dat data file listing the names and dm_15's of templates in TDAT/.

UDEV script which computes (U-V) color.

WHO5 master script.

wscrp script which creates the secondary-parameter covariance plots.

3. PROGRAM PARAMETERS

In this section, we will define the program parameters as they are found in the header files.

Header file	Variable Name	Variable Type	Description
alpha.h	inpath	CHARACTER*5	Path to raw data, default = "RDAT/".
	outpath	CHARACTER*5	Path to conditioned data, default = "CDAT/".
	mrec	INTEGER	Maximum number of records per raw photometry file, default = 200.
	msne	INTEGER	Maximum number of SNe, default = 275.

	fnlen	INTEGER	Character length of photometry file names plus path length, default = 19.
	tmax	REAL	Deprecated.
	tmin	REAL	Deprecated.
	nstep	REAL	Deprecated.
	nlen	INTEGER	Character length of photometry file names, default = 14.
	ierror	INTEGER	Deprecated.
	stand	REAL	Inverse theoretical characteristic signal stretch parameter, default = 1.087.
atest.h	ec	REAL	Deprecated.
	tmax	REAL	Deprecated
	tmin	REAL	Deprecated
	dsmin_p	REAL	Minimum grid stretch value, default = -0.05.
	dsmax_p	REAL	Minimum grid stretch value, default = 0.05.
	dsmin_p	REAL	Deprecated
	dtmin_p	REAL	Deprecated
	dtmax_p	REAL	Deprecated
	chi2min	REAL	Deprecated
	tfmin	REAL	Minimum of flat window interval, default = -4.0.
	tfmax	REAL	Maximum of flat window interval, default = 15.0.
	qcon	REAL	Deprecated
	slack	REAL	Value in days; if no photometry points are found within [tfmin:(tfmin+slack)] then 'tfmin' will be extended to 'tfmin-slack/2.0'. Similarly, if no photometry points are found within [(tfmax-slack):tfmax] then 'tfmax' will be extended to 'tfmax+slack'. Default = 3.0.
	snorm	REAL	Deprecated
	gaplim	REAL	Deprecated
	sf1	REAL	Signal factor 1. This prevents the "over-flattening" of the LC in the flat window. this factor is multiplied by characteristic signal 1, and its value is interpolated at the time of photometry points being fit in the flat window. The interpolated value is added to the photometry point's uncertainty. Default = 1.0.

sf2	REAL	Same as 'sf1' but for characteristic signal 2. Default = 1.0.
hlevel	REAL	Deprecated
qlevel	REAL	Deprecated
kw	REAL	Deprecated
eps	REAL	Deprecated
seglim	REAL	Deprecated
dmmin	REAL	Deprecated
dmmax	REAL	Deprecated
mwinmin	REAL	Deprecated
mwinmax	REAL	Deprecated
exten	REAL	Deprecated
malpha	INTEGER	Defined in parameter file as msne**2/2-msne/2.
ieo	INTEGER	Deprecated
mrec	INTEGER	Maximum number of photometry records per object. Default = 200.
nstep	INTEGER	Deprecated
msne	INTEGER	Maximum number of SNe. Default = 275.
fnlen	INTEGER	Number of characters of photometry file names plus path name. default = 19.
nlen	INTEGER	The number of characters in the photometry file names. Default = 14.
nlarge	INTEGER	Maximum number of differential photometry points. Default = 300.
nsstep	INTEGER	The number of discrete steps in stretch parameter used during stretch primary parameter scan. Default = 32.
ntstep	INTEGER	The number of discrete steps in the time parameter, used during the time primary parameter scan. Default = 32.
nsteptemp	INTEGER	Deprecated
ntemplate	INTEGER	Deprecated
nwinmin	INTEGER	Deprecated
nmstep	INTEGER	Number of discrete steps in magnitude parameter, used during magnitude primary parameter scan.
ntrace	INTEGER	Deprecated
itest1	INTEGER	Deprecated
itest2	INTEGER	Deprecated
itertest	INTEGER	Deprecated
iter_max	INTEGER	Deprecated
ndmstep	INTEGER	Deprecated

	alph2	INTEGER	Deprecated
	natr	INTEGER	Number of records in template data. Default = 191.
	iflatness	INTEGER	Deprecated
	srec	INTEGER	Number of records in the characteristic signal data. Default = 245.
	inpath	CHARACTER*5	Path to raw data files. Default = 'RDAT/'.
	outpath	CHARACTER	Deprecated
	tpath	CHARACTER*5	Path to template files. Default = 'TDAT/'.
epcs.h	malpha	INTEGER	The largest number of differentials allowed. automatically set as ([msne]**2-[msne])/2.
	msne	INTEGER	Maximum number of SNe used; default = 275.
	mrec	INTEGER	Array initializer. Default = 200.
	nstep	INTEGER	Number of uniformly interpolated time bins. Default = 61.
	scalsigpath	CHARACTER*5	Path to the temporary directory holding scaled signals. Default = "ESCL/".
epsil.h	nlarge	INTEGER	Array initializer. Default = 300.
	nstep	INTEGER	Number of uniformly interpolated time bins for PC analysis. Default = 61.
	msne	INTEGER	Maximum number of SNe. Default = 50.
	malpha	INTEGER	Maximum number of pairs. Automatically = (msne**2-msne)/2.
narc.h	iflatness	INTEGER	Deprecated
	erradd	REAL	Uncertainty added to template-augmented photometry points. Default = 0.005.
	gap	REAL	Value in days; half the limit for photometry gaps in the flat window. larger gaps than (2*gap) will be filled with temporary template points. Default = 2.5.
	tfmax	REAL	Maximum day value of flat window. same as in 'atest.h'. Default = 15.0.
	tfmin	REAL	Minimum day value of flat window. same as in 'atest.h'. Default = -4.0.

	mrec	INTEGER	Maximum number of photometry records per SN. Default = 200.
	natr	INTEGER	Number of records in the template file. same as in 'atest.h'. Default = 191.
	nlarge	INTEGER	Array initializer. Default = 300.
	msne	INTEGER	Maximum number of SNe. Default = 275.
	one	INTEGER	Integer constant. Default = 1.
	inpath	CHARACTER*5	Path to raw photometry data. Default = 'RDAT/'.
	outpath	CHARACTER*5	Path to place temporary augmented data. Default = 'RDAT/'.
	echar	CHARACTER*10	Diagnostic character. Default = 'narcxxxxxx'.
sadie.h	header	INTEGER	Deprecated
	nsig	INTEGER	Number of characteristic signals to analyze. Default = 2.
	msne	INTEGER	Maximum number of SNe. Default = 275.
	malpha	INTEGER	Maximum number of pairs, automatically = (msne**2-msne)/2).
	nstep	INTEGER	Deprecated
	nlarge	INTEGER	Array initializer. Default = 300.
	ndmstep	INTEGER	Deprecated
	ngrid	INTEGER	Number of discrete grid elements in covariance analysis. Default = 100.
	inpath	CHARACTER*5	Path to conditioned data. Default = 'CDAT/'.
	spath	CHARACTER*5	Path to characteristic signals. Default = 'SDAT/'.
	rsidpath	CHARACTER*5	Path where residual data is placed. Default = 'RSDL/'.
	dpath	CHARACTER*5	Path where differentials are placed. Default = 'DIFL/'.
	scalsigpath	CHARACTER*5	Path to the temporary placement of scaled characteristic signals. Default = 'SSIG/'.
	tmin	REAL	Deprecated
	tmax	REAL	Deprecated
	ec	REAL	Exponential constant used to determine differential point interpolated uncertainty. default = 0.098.

	gaplim	REAL	Largest day gap between photometry points of pair SNe in which differential point will still be created. Default = 3.5.
	gapsig	REAL	The smallest day gap allowed between two differential data points. Default = 0.5.
	meiminp	REAL	Deprecated
	meimaxp	REAL	Deprecated
	gmax1	REAL	Maximum of coefficient covariance grid used in covariance analysis; dimension 1. Default = 5.0.
	gmax2	REAL	Maximum of coefficient covariance grid used in covariance analysis; dimension 2. Default = 5.0.
	gmin1	REAL	Minimum of coefficient covariance grid used in covariance analysis; dimension 1. Default = -5.0.
	gmin2	REAL	Minimum of coefficient covariance grid used in covariance analysis; dimension 2. Default = -5.0.
	ftol	REAL	Fractional tolerance of simplex minimizer. default = 1.E-30.
	cofsummax	REAL	Deprecated
	moffmin	REAL	Deprecated
	moffmax	REAL	Deprecated
	mzlim	REAL	Deprecated
	mzratio	REAL	Deprecated
	mpoints	INTEGER	Deprecated
	nrand	INTEGER	Deprecated
	iseed	INTEGER	Deprecated
	mgrid	INTEGER	Number of grid points for high-tolerance covariance analysis. Automatically = ngrid**nsig.
sadie0.h	elpoints	INTEGER	Deprecated
	iflatness	INTEGER	Deprecated
	rpath	CHARACTER*5	Path to raw photometry data. Default = 'RDAT/'.
	msne	INTEGER	Maximum number of SNe. Default = 275.
	malpha	INTEGER	Maximum number of pairs. Automatically = (msne**2-msne)/2.
	nlarge	INTEGER	Array initializer. Default = 300.

nmstep	INTEGER	Deprecated
nsig	INTEGER	Number of characteristic signals analyzed.
nsrec	INTEGER	Number of records in the characteristic signal files. Default = 245.
nsstep	INTEGER	The number of discrete steps of the stretch parameter in the grid scan. Default = 15.
ntstep	INTEGER	The number of discrete steps of time parameter in grid scan. Default = 15.
itermax	INTEGER	Maximum number of iterations. Default = 10.
ftol	INTEGER	Simplex minimization fractional tolerance. Default = 1.0E-5.
stand	REAL	Reciprocal of characteristic signals' stretch. Default = 1.087.
xmax	REAL	Maximum delta-stretch grid scan value. Default = 0.10.
xmin	REAL	Minimum delta-stretch grid scan value. Default = -0.10.
ymax	REAL	The maximum delta-time grid scan value. Default = 3.0.
ymin	REAL	The minimum delta-time grid scan value. Default = -3.0.
zmax	REAL	Deprecated
zmin	REAL	Deprecated

4. PLOTTING ROUTINES

Descriptions of the plotting routines in the system and instructions for using them are given below. All plotting routines are in the main folder SN-DATA-RUN unless otherwise mentioned.

1.
   - **LCP3v_d1:** Modified from LCP3v script of . Creates overlay plots of the stretched and shifted LCs - batch 1.
   - **LCP3v_d2:** Modified from LCP3v script of . Creates overlay plots of the stretched and shifted LCs - batch 2.
   - **LCP3v_d3:** Modified from LCP3v script of . Creates overlay plots of the stretched and shifted LCs - batch 3.
   - **LCP3v_d4:** Modified from LCP3v script of . Creates overlay plots of the stretched and shifted LCs - batch 4.

   These scripts are called from within WHO5.

2. **LCP3v_in:** Creates plots of the stretched and shifted LCs for each individual SN in V-band.

3. **LCP3v_pairOverlay:** Creates overlay plots of the stretched and shifted LCs for each individual pair of SNe in V-band. Commented out currently in WHO5, but can be used to investigate the LC pair further.

4. **LCP3u:** creates overlay plots of the stretched and shifted LCs for u-band.

5. **ssptv:** creates differential plots (residuals and weighted signals) for V-band LCs.

6. **ssptu:** creates differential plots (residuals and weighted signals) for u-band LCs.

7. **wscrp:** creates secondary parameter covariance plots.

8. **LCP5:** , plots overlaid scaled PC signals.

9. **comparemmscdnfitWOerrpl:** In folder "subsamples". Plots the comparison between the physical secondary parameter values of SNe between the full sample and the subsamples.

10. **reddeningfreqpl:** Plots the reddening distribution histogram. In folder "REDDENING".

11. **reddenningpl:** Plots the relationship between M_{MS} and ρ_c values and reddening of the SNe in the sample, marks the average M_{MS} and ρ_c values of the low, medium, and high reddening groups separately. In folder "REDDENING".

12. **reddenning99aa91Tpl:** Same as "reddenningpl", but only for 99aa-likes and 91T-likes. In folder "REDDENING".

13. **mmscdncorrplSpiralNOerror:** Plots M_{MS} and ρ_c correlation for all SNe, marks normal-bright, underluminous, 91T-like, and 99aa-like objects separately. In folder "MMSCDNcorr".

14. **plHostdm15corrAll:** Plots the correlation between $\Delta m_{15}(B)$, s, and host-types for all SNe used in our sample, and the outliers. Normal-bright, 91bg-like, and outliers are marked separately. In folder "HostDm15SNtypeRelation_all".

15. **mmsfreqLpl:** Plots M_{MS} distribution with normal-bright, transitional, and subluminous SNe marked with patterns. In folder "NEWerrplots".

16. **cdnfreqLpl:** Same as "mmsfreqLpl", but for ρ_c. In folder "NEWerrplots".

17. **mmsfreqYoungplot:** In folders "PlusMinusDwarfE", "PlusMinusDwarfEbulge", and "PlusMinusDwarfEbulgeS0". Plots the M_{MS} distribution for SNe in the spiral, S0, irregular, and small E hosts in folder "PlusMinusDwarfE". In folder "PlusMinusDwarfEbulge", this script excludes the SNe in spiral bulges, and in folder "PlusMinusDwarfEbulgeS0", it excludes SNe in S0 galaxies. Run FORTRAN code "plotml.f" (placed in folder "CODES") to prepare the data file required for the plotting routine to work. The make file for this code is "Makefile.plotml", placed in "SN-DATA-RUN" (the main directory containing WHO5). Run "make -f Makefile.plotml" and then "xplotml" to run the code. Input files for the code that must be present in the main directory are "hostmass130.dat", "in.dat.opt", and "plotdataPrimary". The "hostmass130.dat" file contains the host type information for all SNe. "plotml.f" prepares "cdnfreqhistEllipticalBatchX.dat" or "cdnfreqhistEllipticalBatchX.dat" files, on which the distribution scripts can run.For example, a part of the "hostmass130.dat" file is shown below:

    AS15db 12.8824955 3 bulge
    AS15dd 25.7039578 1 large E
    AS15eb 91.2010839 2 S0
    AS15ga 23.9883292 2 S0
    AS15gr 0.87096359 4 spirals

    Only the names of the SNe with six letters have been used in the first column. In the second column, the host type codes 1, 2, 3, and 4 have been used for large ellipticals, S0, spiral bulge, and spiral hosts, respectively. Host type code 5 is used when no host mass information is available.

18. **cdnfreqYoungplot:** In folders "PlusMinusDwarfE", "PlusMinusDwarfEbulge", and "PlusMinusDwarfEbulgeS0". Same as "mmsfreqYoungplot", but for ρ_c. Running instructions are the same as "mmsfreqYoungplot".

19. **mmsfreqOldplot:** In folders "PlusMinusDwarfE", "PlusMinusDwarfEbulge", and "PlusMinusDwarfEbulgeS0". Same as "mmsfreqYoungplot", but for SNe in large E hosts in folder "PlusMinusDwarfE". In folder "PlusMinusDwarfEbulge", this script includes the SNe in spiral bulges, and in folder "PlusMinusDwarfEbulgeS0", it includes SNe in S0 galaxies. Running instructions are the same as "mmsfreqYoungplot".

20. **cdnfreqOldplot:** In folders "PlusMinusDwarfE", "PlusMinusDwarfEbulge", and "PlusMinusDwarfEbulgeS0". Same as "mmsfreqOldplot", but for ρ_c. Running instructions are the same as "mmsfreqYoungplot".

5. RUNNING THE SYSTEM

1. Before the run, the file 'in.dat_all' should be created which lists the names of the photometry files. This file should have x entries, with each SN on a new line:

   2004ef.v.fin
   2004eo.v.fin
   2004gu.v.fin
   ... The first few names (presently eight, can be modified by the future user) of the "in.dat_all" file must be the "messenger" SNe Ia, these eight SNe must be present in all runs.

2. File "redshifts25.dat_all". This must have the names and the redshifts (in floating point) of the same SNe names mentioned in "in.dat_all". The names may or may not be in the same order as "in.dat_all". Example of "redshifts25.dat_all" file:

   2004ef.v.raw 0.029771
   2004gu.v.raw 0.046897
   2005iq.v.raw 0.032929

   The names of the SNe are in the first column and the corresponding redshifts are in the second column. The redshift values all have six digits after the decimal.

Afterward, the system is run by the following single command:
WHO5 [name] [color] [PC choice]
where
[name] is the name given to the run.
[color] is the color to be analyzed; valid choices are [u,b,v].
[PC choice] determines which type of PC analysis to run; valid choices are:
PCd for differential analysis.
PCr for residual analysis.
Examples:
"WHO5 Y35 v PCr"
"WHO5 D40 b PCd"
will create a run named "Y35" analyzing all V-band data and will perform a PC analysis on the residuals.
will create a run named "D40" analyzing all B-band data and will perform a PC analysis on the differentials.
The rough anatomy of a run is:

1. WHO5 runs "DATACHECK_NEW1", which checks if there is LC data in region II, and writes "in.dat" and "redshifts25.dat" files.

2. "NEWCHECK" removes duplicate LC data points.

3. WHO5 looks for the presence of a pre-existing primary parameter file, "in.dat.opt.".

4. if the file is not found, ATEST1_tcsh is called, which uses V-band data to produce the primary parameters and store them in a new file called "in.dat.opt" by running a subscript ATEST. It then calls the NARC script which searches for large gaps in LC data and fills them with template points if necessary. If additional points are indeed needed, ATEST1_tcsh will run ATEST again to get primary parameters from the augmented LC photometry and store them in "in.dat.opt".

5. "DATACHECK_NEW2" checks if LC data covers up to at least +25 days, if not, then discards the SNe, and rewrites "in.dat" and "redshifts25.dat" files.

6. The second-stage primary parameter calculator SADIE013 is called. It modifies the primary parameters in "in.dat.opt". The old "in.dat.opt" of first-stage parameters is saved as "in.dat.opt.1".

7. The old or newly-created "in.dat.opt" file is read by the ALPHA11 script which takes the photometry data in RDAT/ and stretches and shifts the data and places the results in the temporary folder CDAT/.

8. The file "in.dat.opt" is renamed "in.dat.name" where name is the run name.

9. For B or V bands, "LCP3v_d1", "LCP3v_d2", "LCP3v_d3", "LCP3v_d4" plotting scripts are called. They create LC overlay plots by breaking the sample into four groups (for a large number of SNe, the overlay is hard to see if all LCs are overlaid together in one single plot). "LCP3v_in" is called next. This script plots the individual stretched and shifted LCs separately. In the case of u-band, these are replaced with "LCP3u".

10. The WHO5 script searches for all data in CDAT/ to create an input file, called "sadie.dat," for the secondary-parameter determination program SADIE.

    Also, the SDAT/ folder is searched for all signals of the user-chosen color.

11. The SADIE script is run, which determines the secondary signal presence, creates differentials and puts them into DIFL/, creates residuals and puts them in RSDL/, creates parameter covariance data, and places them in GRID/.

12. The script ssptv is run, which takes data from DIFL/, RSDL/, and SSIG/ to create residual plots. If the band analyzed is (U), then the variant ssptu is run. Later these plots are placed in the folder "nameRES" where "name" is the user-defined run name.

13. The script wscrp is run, which creates the signal coefficient covariance plots. Later these plots are placed in the folder named "nameTST" where "name" is the run name.

14. The UDEV script is run if the analysis color is (U). This script calculates the average (U-V) color around the maximum, and outputs several files of (U-V) data:

    udev0.dat: the average differential magnitude in the [0:5] day interval.

    udev1.dat: the individual magnitude of (U-V) color for each SN, the solution of the overdetermined system of the data in 'udev0.dat'.

    the average (V-U) color taken directly from the data in the udev2.dat: [-3:5] day interval.

15. Next, the codes in the folder named "Peter" are run. They translate the generic progenitor parameters into physical secondary parameters by using theoretical relationships. Also, Monte Carlo is done to determine the possible physical range covered by the limited number of SNe in the sample. Important things to note:

    - If using only the CSP-I SNe, then it should be a "reference" run.
    - A file called "switch.dat" must be present in the folder Peter, this must have two integers, "switch" and "jump". The only accepted values for these parameters are 0 or 1. "switch" should be 1 for a reference run (CSP-I), and 1 for all non-reference runs (mix of CSP-I and II, only CSP-II, or any other data, except for just CSP-I). The parameter jump should always be 1 unless the Monte-Carlo method is wished to be avoided.
    - A file named "plotdataPrimaryBen" should be present, this is for use in the reference run only. This file should not be modified, it contains the generic and physical secondary parameter values.
    - If it is a reference run, then the generic and physical secondary parameter values from the run are stored in a file called "plotdataPrimaryBig", used as a standard in all non-reference runs.
    - The "messenger" SNe names are stored in a file called "names_CSPI8.dat". This file is used for all runs.

- The results of this part of WHO5 are stored in files named "order.dat" and "plotdataPrimary". This "plotdataPrimary" file would be required for plotting all the secondary parameter distributions later.

16. The script EPSILv (or EPSILu, if the (U) band is being analyzed) is run, which initiates the PC analyzer.

17. The EPCSOLV3v, EPCSOLV4v, EPCSOLV3u, and EPCSOLV4u scripts are run, depending on the desired results and band analyzed. This script solves the overdetermined PC coefficient system and plots all residuals or differentials with their optimal scaled PCs overlaid.

18. The LCP5 script is run, which plots all scaled PCs overlaid upon each other.

19. Temporary data is deleted (or stored if necessary, examples are ".sm1", and ".sm2" files, which can be used for re-plotting the χ^2 maps later if any changes are needed. This can be easily switched off in WHO5) from the working directory, and the results are packaged into a tarball called "RUNname.tar," and all raw data, stretched and shifted data, templates, signals, differentials, residuals, parameter files, scripts, and source code are saved and bundled into the tarball.

20. The run tarball is placed into the directory RUNS/ and the script exits, leaving the working directory unchanged.

21. "epstojpg_all" command, where used, converts the ".eps" files to ".png". This command is switched off inside WHO5 currently and can be switched on whenever needed.

22. The run folder is placed in the main directory. WHO5 is complete.

6. READING RESULTS

The run results are stored in a directory called "RUNname", produced by the run, where "name" is the user-given run name. In the "RUNname" directory, there are several subdirectories:

- The "DATA" folder contains copies of raw data in "RDAT", stretched data in "CDAT", templates in "TDAT", and signals in "SDAT". Modification in this work: the run directory also contains a sub-folder named "DATA_TST" which has the necessary files for plotting the signal coefficient covariance plots (just in case any modifications are needed).

- Folder "nameRES" contains all differential plots and scaled signals. "name" is the run name.

- Folder "nameTST" contains signal coefficient covariance plots. "name" is the run name.

- The folder "LC" contains all individual and overlaid stretched LC plots.

- File "runlog.name" contains a detailed log of the run.

- Folder "UNCERTAINTY" contains files containing information to determine t_{cor} and f_{cor} if needed, which is in the case of a new data set being used.

- Folder "DPAR" contains "cof.dat" signal coefficients file, "epccof.dat" PC coefficients file, "primary.dat" pre-flatness primary parameter file, "epc.dat", and "avg.dat" which is the error-weighted average of the differentials (if the PCd option was used) or the residuals (if the PCr option was used).

- Folder "EPJPG" contains differentials or residuals with the optimally scaled PC signal overlaid.

- Folder "PPAR" contains all header files along with copies of data files describing templates used "temp.dat" and signals "sig.dat".

- Folder "SRC" contains copies of all source codes and scripts, along with WHO5.

- Along with the subdirectories, the run directory will also contain:

  avg.eps a plot of the average differential (if the PCd option was used) or average residual (if the PCr option was used).

  cdn.eps a histogram of central density signal coefficients.

  chi2.eps a histogram of chi2 fit residuals.

  epc.eps a plot of the principal component; this is the most prominent factor in the differentials (if the PCd option was set) or the residuals (if the PCr option was used).

  epchist.eps a histogram of optimal PC coefficients.

  [name]LC.eps the stretched and shifted light-curve overlay plot.

  [name]EPCscaled.eps

  a plot of all optimally scaled PCs overlaid.

  runlog.[name]

  a log containing each stage's status output, along with the start and end times of the run.

  mms.eps

  a histogram of main-sequence mass signal coefficients.