APPENDIX D

WHO4 SYSTEM OPERATION

Below, we overview how the WHO4 Secondary Parameter Determination System works. We will list the needed files and system setup, define 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.

D.1 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	script which calls ATEST and recalls ATEST using augmented data (from NARC) if LCs with large gaps around maximum light are found.
atest.h	parameter file for ATEST and its dependencies.
BANDER2	script which handles finding the times-of-maximum and maximum apparent magnitude of bands other than (V).
BANDER2u	same as BANDER2, 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).
DIFL	folder containing temporary differential light curves for all SNe pairs created by SADIE.
epcs.h	parameter file for the PC overdetermined system solver.
EPCSOLV3	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.
EPCSOLV4	same as EPCSOLV3, but for use when PCs of differentials are sought.
EPCSOLV4u	same as EPCSOLV4, but for use with the (U) band.
EPSIL	script guiding the prinicipal component finder.
EPSILu	same as EPSIL but for (U) band.
epsil.h	parameter file for principal component finder and its dependencies.
GRID	folder for temporary storage of secondary-parameter chi^2 data produced by SADIE.
in.dat	this file contains a list of all filenames of SNe photometry data.
input.par	user-defined input file, currently responsible for stating number of supernovae analyzed.
LCP3	script to generate overlay plot of stretched and

	shifted light curves.
LCP3u	same as LCP3 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.
narc.h	parameter file for NARC and its dependencies.
redshifts25.dat	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., "2005ag") 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.
sadie.h	parameter file for SADIE and its dependencies.

SADIE013	script which calculates second-stage primary parameter modifications.
sadie0.h	parameter file for SADIE013 and dependencies.
SDAT	folder containing temporary data secondary-parameter light curve signals.
SSIG	folder containing temporary data used to construct residual plots.
sspt	script which create plots of residuals and weighted signals.
ssptu	similar to sspt, 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.
WHO4	master script.
wscrp	script which creates the secondary-parameter covariance plots.

D.2 Program Parameters

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

Header File height	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 = 300
	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 = -0.5
dsmax_p	REAL	deprecated
dsmin_p	REAL	deprecated
dtmin_p	REAL	deprecated
dtmax_p	REAL	deprecated
chi2min	REAL	deprecated
tfmin	REAL	minimum of flat window interval default = -3.0
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 "over- flattening" of the LC in the flat window. this factor is multiplied to characteristic signal 1, and its value 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 = 100
nstep	INTEGER	deprecated
msne	INTEGER	maximum number of SNe.
		default = 50
fnlen	INTEGER	number of characters of photometry file names plus path name.
		default = 19
nlen	INTEGER	number of characters of photometry file

		names.
		default = 14
nlarge	INTEGER	maximum number of differential photometry points.
		default = 300
nsstep	INTEGER	number of discrete steps in stretch parameter parameter used during stretch primary parameter scan.
		default = 32
ntstep	INTEGER	number of discrete steps in time parameter used during time primary parameter scan.
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 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	largest number of differentials allowed.
			automatically set as ([msne]**2-[msne])/2
	msne	INTEGER	maximum number of SNe used;
			default = 50
	mrec	INTEGER	array initializer.
			default = 100
	nstep	INTEGER	number of uniformly-interpolated time bins.
			default = 61
	scalsigpath	CHARACTER*5	path to temporary directory holding
			scaled signals.
			default = "ESCL/"
epsil.h	nlarge	INTEGER	array initializer.
			default = 400
	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
	iflatness	INTEGER	deprecated
narc.h	erradd	REAL	uncertainty added to template-augmented photometry points. default = 0.005
	gap	REAL	value in days; half the limit for photometry gaps in 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 = -3.0
	mrec	INTEGER	maximum number of photometry records per SN. default = 200
	natr	INTEGER	number of records in template file. same as in 'atest.h'. default = 191
	nlarge	INTEGER	array initializer. default = 300
	msne	INTEGER	maximum number of SNe. default = 50
	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 = 50
	malpha	INTEGER	maximum number of pairs.
			automatically = (msne**2-msne)/2)
	nstep	INTEGER	deprecated
	nlarge	INTEGER	array initializer.
			default = 1000
	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 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 = 0.09531
gaplim	REAL	largest day gap between photometry points of pair SNe in which differential point will still be created. default = 3.5
gapsig	REAL	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
	elpoints	INTEGER	deprecated
	iflatness	INTEGER	deprecated
sadie0.h	rpath	CHARACTER*5	path to raw photometry data.
			default = 'RDAT/'
	msne	INTEGER	maximum number of SNe.
			default = 50
	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 characteristic signal

		files.
		default = 245
nsstep	INTEGER	number of discrete steps of stretch parameter in grid scan.
		default = 15
ntstep	INTEGER	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	maximum delta-time grid scan value
		default = 3.0
ymin	REAL	minimum delta-time grid scan value
		default = -3.0
zmax	REAL	deprecated
zmin	REAL	deprecated

D.3 Running the System

The only things the user needs to define prior to a run are the number of SNe in the "input.par" file. The first line of this file should appear:

nsne x where x is the number of SNe analyzed.

Also, the file 'in.dat' 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
2005ag.v.fin
...

Afterwards, the system is run by the following single command:

WHO4 [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:

"WHO4 Y35 v PCr"	will create a run named "Y35" analyzing all V-band data and will perform a PC analysis on the residuals.
"WHO4 D40 b PCd"	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) WHO4 looks for the presence of a pre-existing primary paramter file, "in.dat.opt."

(2) if the file is not found, ATEST1 is called, which uses V-band data to produce the primary paramters 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 will run ATEST again to get primary parameters from the augmented LC photometry and store them in "in.dat.opt".

(3) 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".

(4) 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/.

(5) the file "in.dat.opt" is renamed "in.dat.name" where name is the run name.

(6) the LCP3 script is called, which creates a light-curve overlay plot named "nameLC.jpg". If the band analyzed is (U), the LCP3u script is called.

(7) the WHO4 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.

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

(9) the script sspt 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.

(10) the script wscrp is run, which creates signal coefficient covariance plots.

(11) the UDEV script is run if the analysis color is (U). This script calculates the average (U-V) color around 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'.

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

(12) the script EPSIL (or EPSILu, if the (U) band is being analyzed) is run, which initiates the PC analyzer.

(13) the EPCSOLV3, EPCSOLV4, EPCSOLV3u, 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.

(14) the LCP5 script is run, which plots all scaled PCs overlaid upon each other.

(15) temporary data is deleted from the working directory, 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.

(16) the run tarball is placed into the directory RUNS/ and the script exits, leaving the working directory unchanged.

D.4 Reading Results

The results are packaged in the run tarball, which is placed in the RUNS/ directory at the end of the run. Unpacking the tarball produces a directory named

RUN[name]/

in the RUNS/ directory, and this new run directory contains several subdirectories:

DATA/	containing copies of RDAT/, the stretched and shifted photometry in CDAT/, and all signals and templates in SDAT/ and TDAT/.
DPAR/	contains data parameters. Inside are the "cof.dat" signal coefficients file, along with parameter variances and covariances; the "in.dat.[run name]" file of primary parameters; the PC coefficients file "epccof.dat"; the pre-flatness primary parameters "primary.dat"; "epc.dat"; "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).
EPJPG/	a folder filled with the differentials (if the PCd option was used) or residuals (if the PCr option was used) overlaid with the optimally scaled PC signal.

[name]RES/	a folder filled with residual plots and scaled signals.
[name]TST/	a folder with signal coefficient covariance plots.
PPAR/	contains program parameters. Inside are the parameter files for ATEST "atest.h"; for ALPHA11 "alpha.h"; for EPSIL "epsil.h"; for SADIE "sadie.h"; for NARC "narc.h"; for SADIE013 "sadie0.h"; along with copies of data files describing templates used "temp.dat" and signals "sig.dat".
SRC/	contains a copy of the source code directory CODES/ along with all the scripts used: ATEST, ATEST1, EPSIL, the EPCSOLV scripts, LCP3, LCP5, SADIE, SADIE013, sspt, WHO4, and wscrp.

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

avg.jpeg	a plot of the average differential (if the PCd option was used) or average residual (if the PCr option was used).
cdn.jpg	a histogram of central density signal coefficients.
chi2.jpg	a histogram of chi2 fit residuals.
epc.jpeg	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.jpg	a histogram of optimal PC coefficients.
[name]LC.jpg	the stretched and shifted light-curve overlay plot.
[name]EPCscaled.jpg	a plot of all optimally-scaled PCs overlaid
runlog.[name]	a log containing each stages' status output, along with the start and end times of the run.
mms.jpg	a histogram of main-sequence mass signal coefficients.