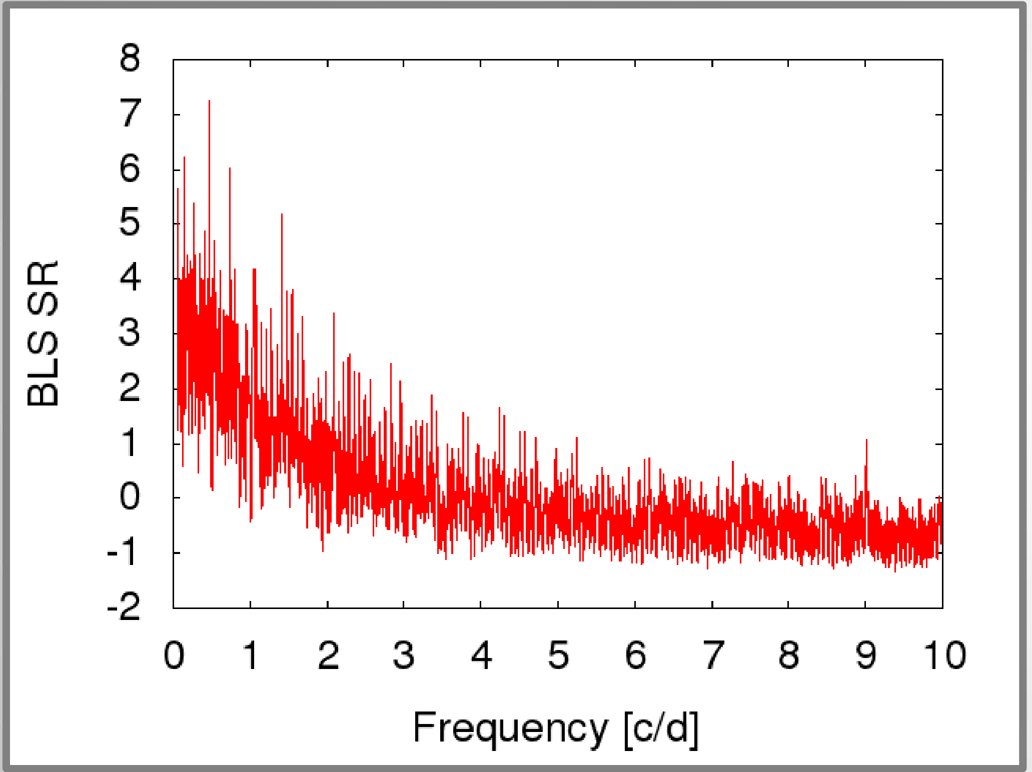
# Software for Analysis of Transit Data

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# Overview

- Summary of Available Packages
- Worked examples for 4 packages
  - VARTOOLS
  - FITSH
  - JKTEBOP
  - Phoebe

# Available Packages

- Many packages! Here we focus on the following selection:
  - Provides tools for analysis of TEP LC or RV data
    - Excludes:
      - Image or spectroscopic reduction tools
      - Stellar modelling tools
  - Tool is executable (not a function, or library of functions)
  - Publicly available
  - Free (though platform may not be free)
  - I'm aware of it

| Name | Uses | Platform | URL |
| --- | --- | --- | --- |
| EXOFAST, Time | MCMC fitting of transit LCs and/or RV data<br>Time conversion | Web, IDL | http://astroutils.astronomy.ohio-state.edu/ |
| FITSH | Fitting RVs+LCs (general nonlinear fitting), image reduction and photometry | C | http://fitsh.szofi.net |
| JKTEBOP | Fit detached EB LCs, approximate proximity effects | Fortran | http://www.astro.keele.ac.uk/jkt/codes/jktebop.html |
| Nightfall | Fit EB LCs and RVs (detailed proximity effects) | C + GTK | http://www.hs.uni-hamburg.de/DE/Ins/Per/Wichmann/Nightfall.html |
| PHOEBE | Fit EB LCs and RVs (detailed proximity effects) | C + GTK + Fortran | http://phoebe.fmf.uni-lj.si/ |
| PhoS-T | Image Reduction+photometry. Fitting transit LCs. | GTK + Python + Fortran + BASH | http://www.hs.uni-hamburg.de/grk/phost.html |
| Systemic | Fits RVs. Handles multi-planet systems, dynamical interactions (RVs and TTVs). Period search. | Java | http://www.ucolick.org/~smeschia/SystemicConsole/ |
| TAP<br>autoKep | MCMC fitting of transit LCs<br>Prepare Kepler LCs for TAP. | IDL | http://ifa.hawaii.edu/users/zgazak/IfA/TAP.html |
| VARTOOLS | General time series analysis (trend filtering, transit search, some fitting, transit recovery simulations). Batch processing LCs. | C | http://www.astro.princeton.edu/~jhartman/vartools |

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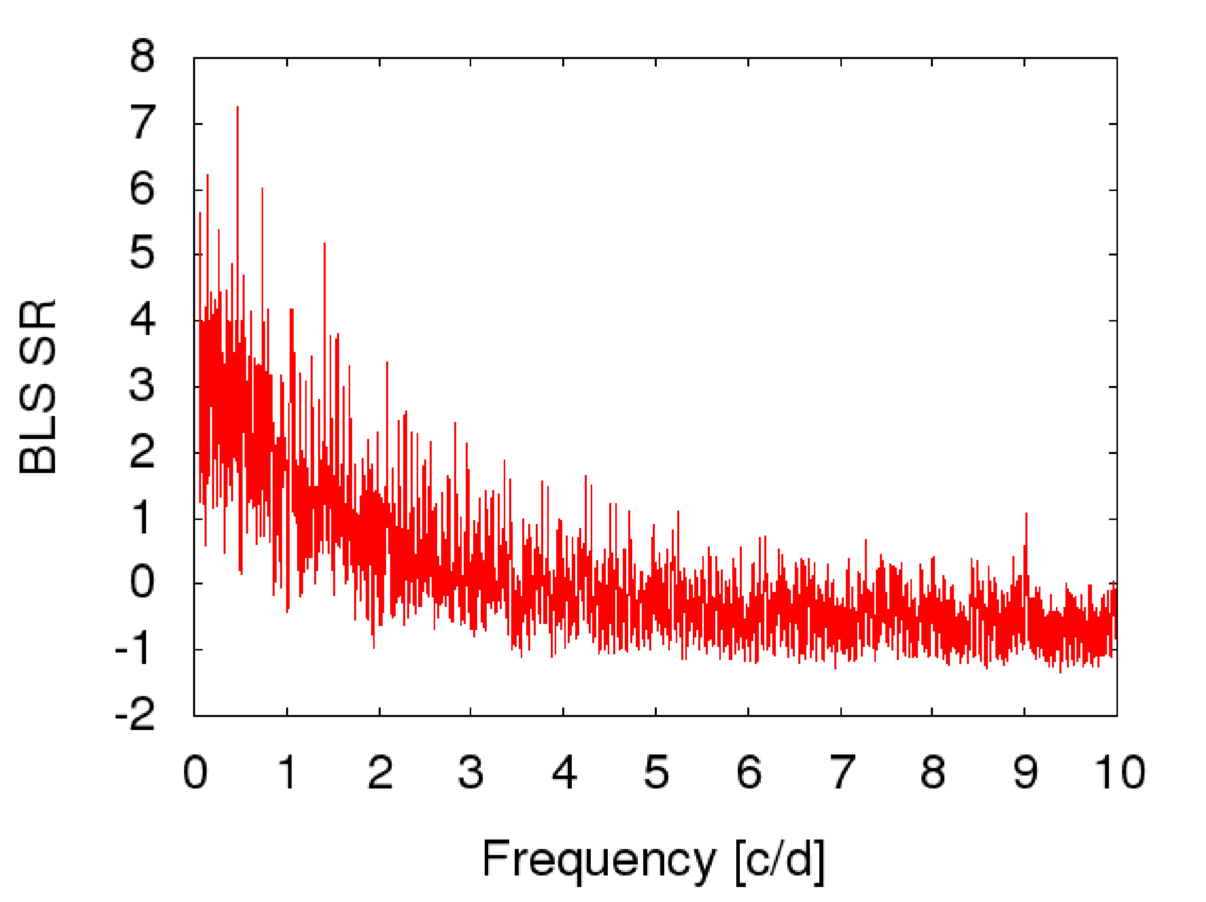
# VARTOOLS

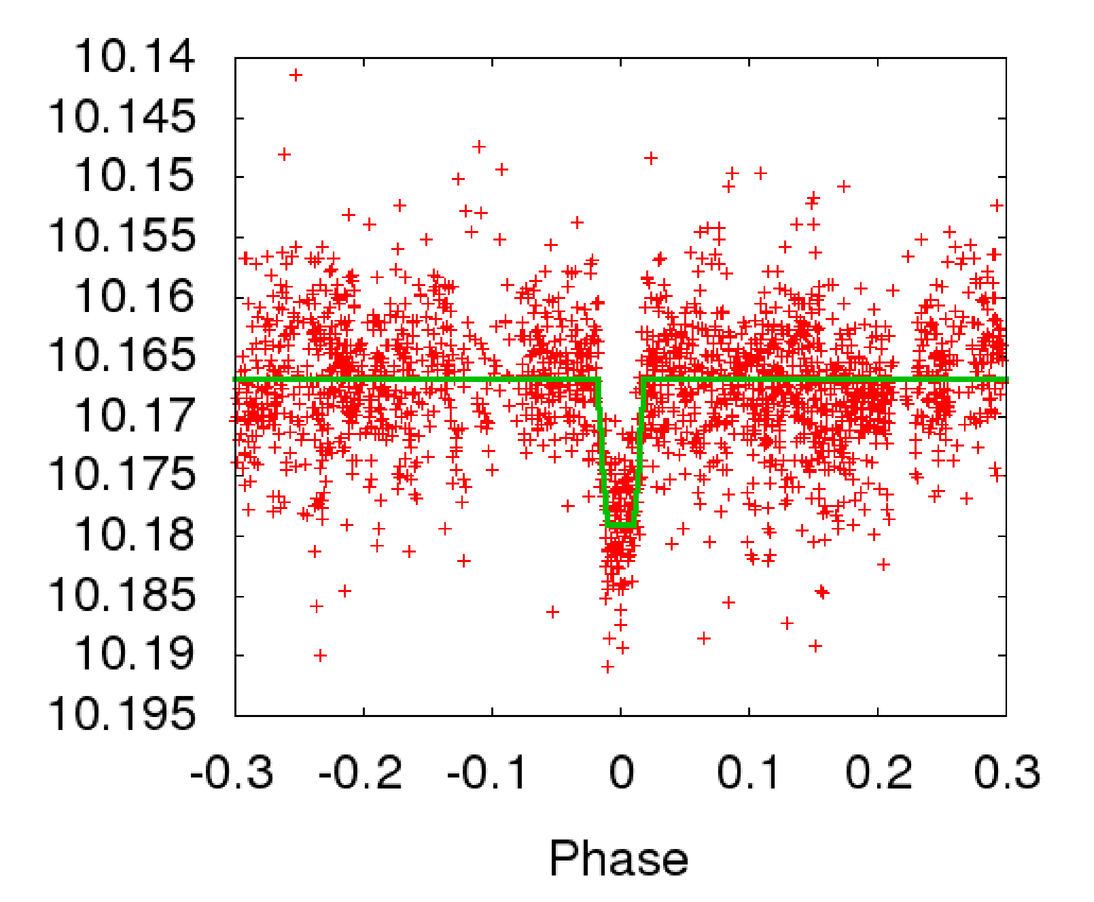
- Hartman et al., 2008, ApJ, 675, 1254
- General Time-Series Analysis
- written in C, run on command-line
- Read-in one or more light curve, process each light curve with one or more “command”.
- allows parallel processing.
- For this workshop, primary uses:
  - Transit search
    - LC statistics
    - Variability search
    - Trend filtering
      - Harmonic fitting/subtraction.
      - Decorrelation
      - Median Filtering
      - TFA or SYSREM
    - BLS
    - Transit model fitting
  - Transit yield simulations
    - Injecting transits, plus above

Example:
Running BLS on 1 LC

```
$./vartools -i EXAMPLES/3.transit -ascii -oneline \
>     -BLS q 0.01 0.1 0.1 20.0 100000 200 0 1 \
>         1 EXAMPLES/OUTDIR1/ 1 EXAMPLES/OUTDIR1/ 0 fittrap \
>         nobinnedrms ophcurve EXAMPLES/OUTDIR1/ -0.1 1.1 0.001
Name                            = EXAMPLES/3.transit
BLS_Period_1_0                  =     2.12334706
BLS_Tc_1_0                      = 53727.297293937358
BLS_SN_1_0                      =   7.26127
BLS_SR_1_0                      =   0.00238
BLS_SDE_1_0                     =   6.34195
BLS_Depth_1_0                   =   0.01220
BLS_Qtran_1_0                   =   0.03576
BLS_Qingress_1_0                =   0.19618
BLS_OOTmag_1_0                  =  10.16686
BLS_i1_1_0                      =   0.98213
BLS_i2_1_0                      =   1.01790
BLS_deltaChi2_1_0               = -24217.21939
BLS_fraconenight_1_0            =   0.43155
BLS_Npointsintransit_1_0        =   165
BLS_Ntransits_1_0               =     4
BLS_Npointsbeforetransit_1_0 =   127
BLS_Npointsaftertransit_1_0  =   143
BLS_Rednoise_1_0                =   0.00151
BLS_Whitenoise_1_0              =   0.00489
BLS_SignaltoPinknoise_1_0       =  14.38935
BLS_Period_invtransit_0         =     1.14594782
BLS_deltaChi2_invtransit_0      = -3301.69183
BLS_MeanMag_0                   =  10.16740
```




BLS Spectrum



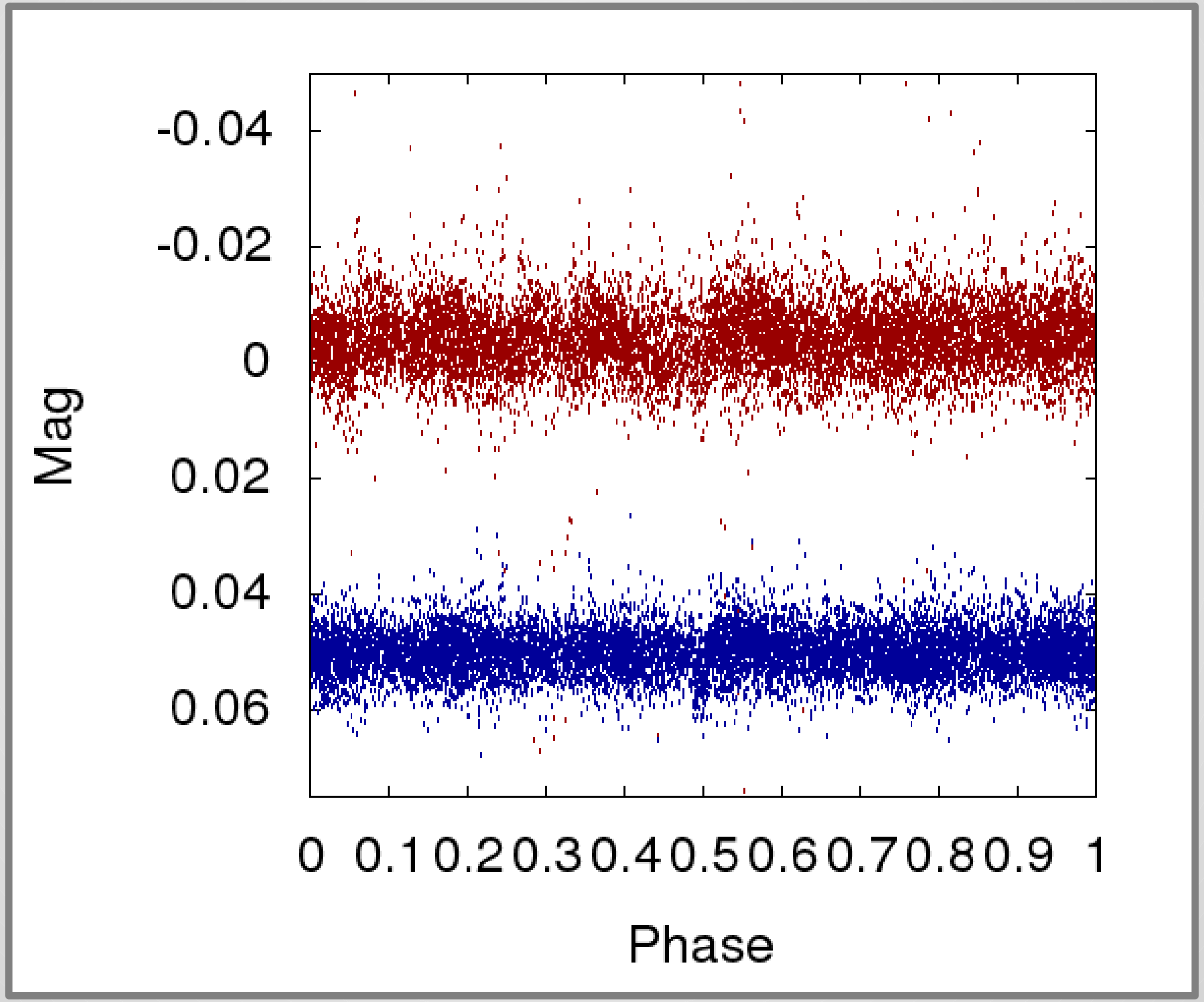

Best Box-transit Fit to LC

Example: A transit search pipeline

```
#! /bin/bash

# Before running this:
# 1. Prepare a list of light curves (format: filename, star_x_pos, star_y_pos)

# 2. Prepare a list of TFA template light curves and a dates file.

vartools -l input_lc_list \
         -rms \                         #  Get initial lc rms
         -LS 0.1 100.0 0.1 1 0 \        #  Search for periodic variations
         -Killharm ls 5 0 0 \           #  Remove them
         -decorr 1 1 1 0 4 4 2 5 2 6 1 7 1 \ # decorrelate the light curves
                                         \ # against x, y, airmass, and fwhm
         -TFA trend_list_tfa dates_file_tfa 5 xycol 2 3 0 0 0 \ # Apply the
                                         \ # trend-filtering algorithm
         -rms \                         # Get rms of cleaned light curve
         -medianfilter 1.5 \            # Apply a high-pass filter to the light curve
         -BLS q 0.01 0.1 0.1 20.0 100000 200 0 5 0 0 0 fittrap nobinnedrms \
                          \             # search for transits with BLS.
         -parallel 8 \                  # Process 8 LCs in parallel.
         -header \                      # Include a header in the output statistics
                 \                      # file
         -numbercolumns \               # Prepend column numbers to the column
                        \               # headings in the output stats file.
> vartools_transit_search.out
```

# Cleaning a light curve

HAT-P-11
Red = pre-cleaning
Blue = post-cleaning



# Available Commands

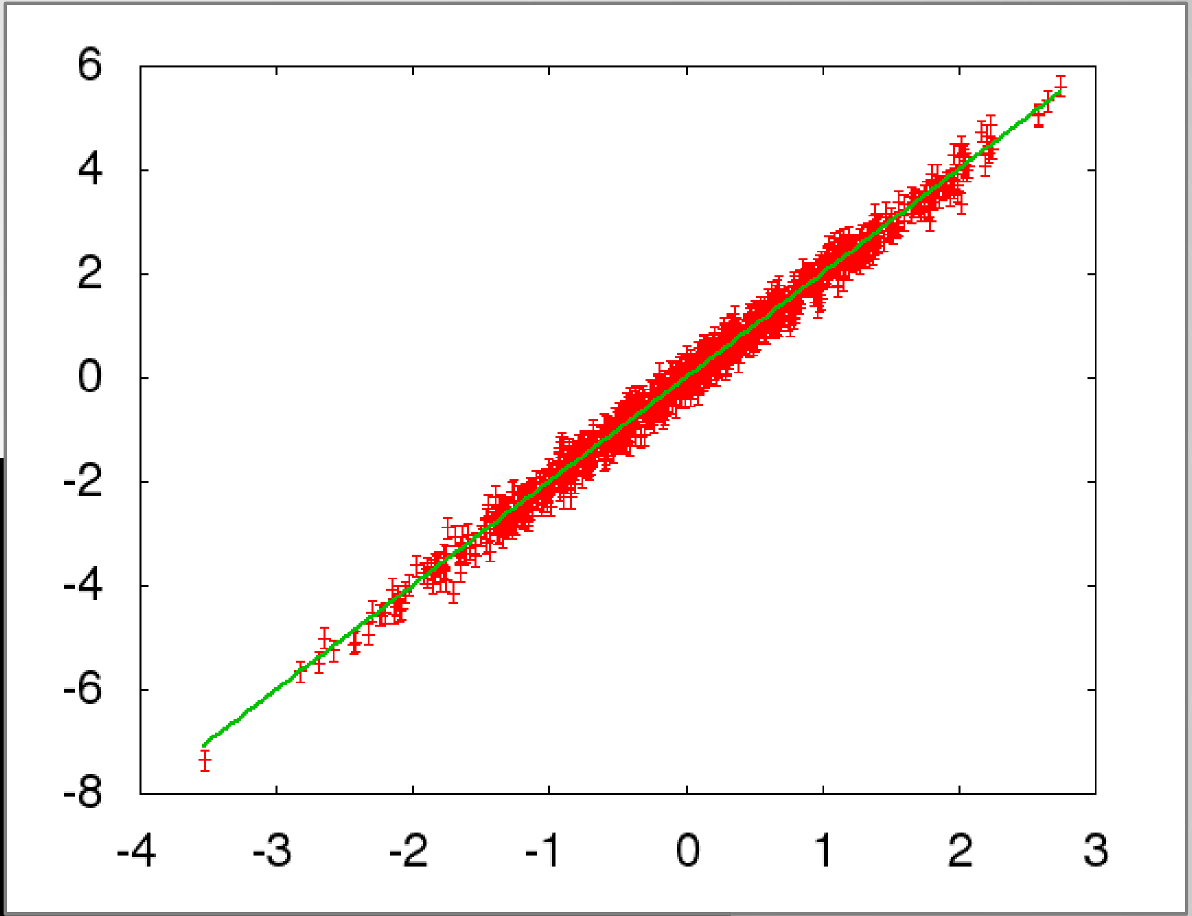
| | | | | |
|---|---|---|---|---|
| addnoise | changeerror | ensemblerescalesig | LS | rms |
| alarm | chi2 | findblends | MandelAgolTransit | rmsbin |
| aov | chi2bin | fluxtomag | medianfilter | savelc |
| aov_harm | clip | GetLSAmpThresh | microlens | SoftenedTransit |
| autocorrelation | converttime | Injectharm | o | Starspot |
| binlc | decorr | Injecttransit | Phase | SYSREM |
| BLS | dftclean | Jstet | rescalesig | TFA |
| BLSFixPer | difffluxtomag | Killharm | restorelc | TFA_SR |

# FITSH

- A. Pál (Pál, 2012, MNRAS, 421, 1825)
- Package used by HAT for image reduction, astrometry, photometry (aperture and image subtraction), and LC+RV modelling
- *lfit* - command-line program providing linear/non-linear fitting of analytic expressions to data
  - MCMC
    - optional marginalization over linear parameters (e.g. parameters for the instrumental model).
    - differentiable model --> optimize MCMC proposal distribution --> fast convergence.
  - Simultaneous fitting of multiple data blocks (e.g. LCs + RVs).
  - Includes transit (Mandel & Agol 2002) and Keplerian RV models
    - Mutual events by multiple transiting planets.
    - Partial derivatives for these models are known and stored in *lfit*

Example:
Linear Fit with lfit

```
$head foo.txt
-0.432493 -0.79826 0.2
0.359776 0.779453 0.2
0.695685 1.10855 0.2
-0.0415469 -0.0654869 0.2
-0.864329 -1.49341 0.2
-1.06888 -2.02902 0.2
-1.35093 -2.81154 0.2
-2.12531 -4.39771 0.2
0.0290041 0.193488 0.2
-0.276666 -0.536742 0.2
$
$lfit foo.txt -c x:1,y:2,e:3 -e e -y y -f 'a*x+b' -v a,b --error-line
    2.00124  0.00630464  -0.0112592  0.00627612
```



# Example: Fitting an LC+RV with lfit

```
#! /bin/bash

P=4.64034814; E=55426.923753; G=-0.11; K=35.28; # Set the initial values for the period, epoch, gamma velocity and K
p=0.09174; om=17.45; b2=0.1; mag0=0;            # rp/rstar, zeta/rstar, impact parameter^2, out-of-transit magnitude

LIMBDARK1=0.3464                                # quadratic limb darkening coefficients to use
LIMBDARK2=0.2857
n=$(echo $P | gawk '{printf("%.17g\n", 4*atan2(1,0)/$1);}') # 2*pi/period = parameter that we will vary

lfit -x "delta(t,e,p)=mod(t-e+p/2,p)-p/2" \      # the -x commands define macro functions, below are functions
     -x "absdelta(t,e,p)=abs(delta(t,e,p))" \    # useful for fitting transiting planet lcs and RVs
     -x "phase(t,e,p)=mod(t-e,p)/p" \
     -x "zcorr(ph)=1-ph^2" \
     -x "ycorr(ph)=1-ph^2/3" \
     -x "lcbase(p,b2,om,dt,n)=ntiq(p,sqrt(abs(b2)*zcorr(n*dt)+(1-abs(b2))*(om*dt)^2*ycorr(n*dt)),$LIMBDARK1,$LIMBDARK2)" \
     -x "magflux(f)=-2.5*log(f)/log(10.0)" \
     -x "fluxmag(m)=exp(-0.4*m*log(10.0))" \
     \
     -x "rvcirc(dt,K,G,n)=G-K*sin(n*dt)" \
     \
     -i1 hatp38_lc.dat \                          # The light curve is the first data block
     -c1 t1:1,mag1:2,err1:3 -y1 mag1 -e1 err1 \  # Use -c1 to specify which variables will be read from which columns
     \                                            # -y1 is the dependent variable for the first block, -e1 is the error
     -f1 "mag0+magflux(lcbase(p,b2,om,absdelta(t1,E,2*pi()/n),n))" \  # The function to fit to this block
     \
     -i2 hatp38_rv.dat \                          # The radial velocity data is the second data block
     -c2 t2:1,rv2:2,err2:3 -y2 rv2 -e2 err2 \
     -f2 "rvcirc(delta(t2,E,2*pi()/n),K,G,n)" \
     \
     -v mag0=$mag0:0.01,p=$p:0.0001,b2=$b2:0.01,om=$om:0.1,n=$n:0.00001,E=$E:0.001,K=$K:0.1,G=$G:1 \ # The variables, initial
     \                                                                                                  # values, and ranges
     -F mag0=%.5f,p=%.6f,b2=%.6f,om=%.5f,n=%.17g,E=%.17g,K=%.5f,G=%.5f \  # The format for the output data
     --xmmc --iterations 1000 \                   # Use the -xmmc fitting procedure (downhill simplex, followed by MCMC), stop
     \                                            # after 1000 accepted transitions.
     --output out.xmmc                            # File to dump the MCMC chain to
```

# Fitting an LC+RV with lfit

A portion of the MCMC chain stored in out.xmmc:

```
0.00005 0.090738 0.017484 17.42700 1.3540900820185131 55426.945585219109 36.19271 -1.07278    358.44582
0.00005 0.090738 0.017484 17.42700 1.3540900820185131 55426.945585219109 36.19271 -1.07278    358.44582
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-0.00001 0.090745 0.043527 17.47576 1.3539400856114499 55426.896483891564 37.98037 1.29746    360.04094
0.00003 0.090623 0.064280 17.46916 1.3539678709103022 55426.905527551397 36.16468 -0.41661    358.55435
0.00003 0.090623 0.064280 17.46916 1.3539678709103022 55426.905527551397 36.16468 -0.41661    358.55435
-0.00003 0.090353 0.069983 17.41757 1.354115051542313 55426.953398487451 34.04267 -0.08502    363.30628
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-0.00003 0.090353 0.069983 17.41757 1.354115051542313 55426.953398487451 34.04267 -0.08502    363.30628
-0.00003 0.090353 0.069983 17.41757 1.354115051542313 55426.953398487451 34.04267 -0.08502    363.30628
-0.00004 0.091172 0.065757 17.44749 1.3540312350231503 55426.926075875017 35.69222 -0.64668    357.89861
-0.00004 0.091172 0.065757 17.44749 1.3540312350231503 55426.926075875017 35.69222 -0.64668    357.89861
```

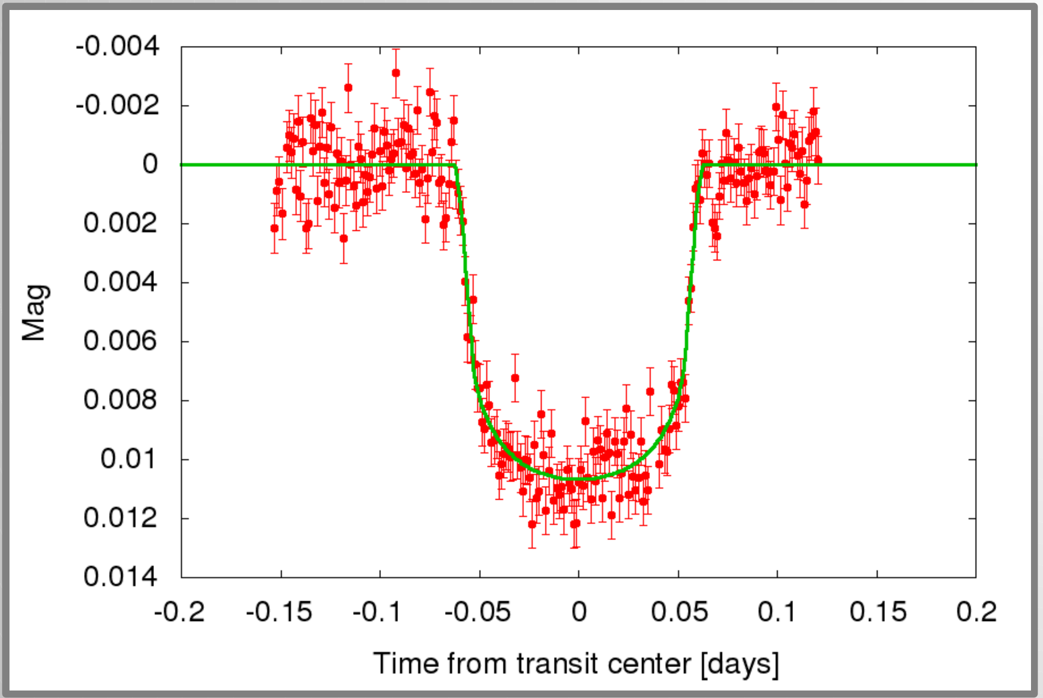
# Example: Generate model curves for plotting

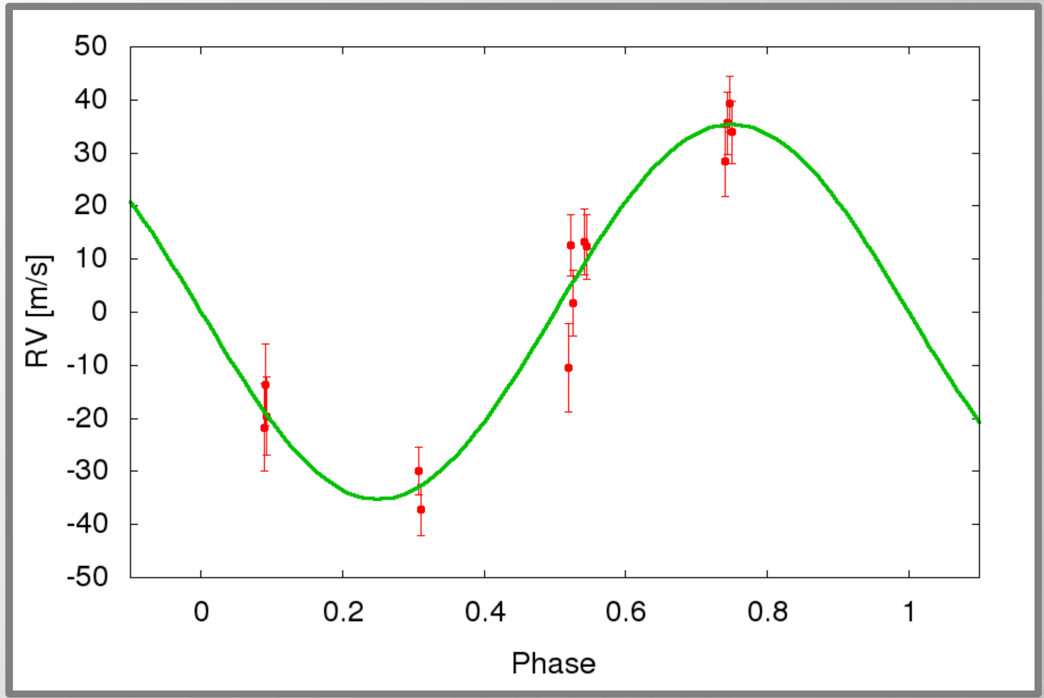
```
A=( $(grep -v '^#' out.xmmc | sort -g -k 9,9 | head -1) ) # store the best-fit parameters in the array A

lfit -x "delta(t,e,p)=mod(t-e+p/2,p)-p/2" \       # Make a separate call to lfit to evaluate the best-fit model
     -x "absdelta(t,e,p)=abs(delta(t,e,p))" \
     -x "phase(t,e,p)=mod(t-e,p)/p" \
     -x "zcorr(ph)=1-ph^2" \
     -x "ycorr(ph)=1-ph^2/3" \
     -x "lcbase(p,b2,om,dt,n)=ntiq(p,sqrt(abs(b2)*zcorr(n*dt)+(1-abs(b2))*(om*dt)^2*ycorr(n*dt)),$LIMBDARK1,$LIMBDARK2)" \
     -x "magflux(f)=-2.5*log(f)/log(10.0)" \
     -x "fluxmag(m)=exp(-0.4*m*log(10.0))" \
     -x "rvcirc(dt,K,G,n)=G-K*sin(n*dt)" \
     hatp38_lc.dat \                              # Use one data-block in this case
     -c t1:1,mag1:2,err1:3 \                      # skipping -y and -e options leads to evaluation mode
     -f "delta(t1,E,2*pi()/n),mag1,err1,mag0+magflux(lcbase(p,b2,om,absdelta(t1,E,2*pi()/n),n))" \
     \                                            # The above line outputs the above comma-separated list of quantities for
     \                                            # each row in the input file.
     -v mag0=${A[0]},p=${A[1]},b2=${A[2]},om=${A[3]},n=${A[4]},E=${A[5]},K=${A[6]},G=${A[7]} \ # Set the parameters to thei
     \                                                                                        # best-fit values
     -F %12.7f,%10.6f,%10.6f,%10.6f \             # The format of the output data
     -o - > hatp38_lc.model                       # output the evaluation to the file hatp38_lc.model

seq -0.5 0.001 0.5 | \
lfit -x "delta(t,e,p)=mod(t-e+p/2,p)-p/2" \       # This call to lfit generates a smooth model curve. Here the input is read
     -x "absdelta(t,e,p)=abs(delta(t,e,p))" \     # from stdin, which is a vector of evenly spaced numbers generated by the
     -x "phase(t,e,p)=mod(t-e,p)/p" \             # "seq" shell command.
     -x "zcorr(ph)=1-ph^2" \
     -x "ycorr(ph)=1-ph^2/3" \
     -x "lcbase(p,b2,om,dt,n)=ntiq(p,sqrt(abs(b2)*zcorr(n*dt)+(1-abs(b2))*(om*dt)^2*ycorr(n*dt)),$LIMBDARK1,$LIMBDARK2)" \
     -x "magflux(f)=-2.5*log(f)/log(10.0)" \
     -x "fluxmag(m)=exp(-0.4*m*log(10.0))" \
     -x "rvcirc(dt,K,G,n)=G-K*sin(n*dt)" \
     -c dt1:1 \
     -f "dt1,mag0+magflux(lcbase(p,b2,om,abs(dt1),n))" \
     -v mag0=${A[0]},p=${A[1]},b2=${A[2]},om=${A[3]},n=${A[4]},E=${A[5]},K=${A[6]},G=${A[7]} \
     -F %12.7f,%10.6f,%10.6f,%10.6f \
     -o - > hatp38_lc.curve
```

```
gnuplot> set terminal png font "Helvetica,20" size 900,600
Terminal type set to 'png'
Options are 'nocrop font Helvetica 20 size 900,600 '
gnuplot> set output "hat38_lcmodel.png"
gnuplot> unset key
gnuplot> set xlabel "Time from transit center [days]"
gnuplot> set ylabel "Mag" offset 1,0
gnuplot> set xrange [-0.2:0.2]
gnuplot> set yrange [*:*] reverse
gnuplot> plot "hatp38_lc.model" u 1:2:3 w yerrorbars pt 7 ps 1.2 lw 1.5, "hatp38_lc.curve" u 1:2 w l lw 3
gnuplot> exit
```



# JKTEBOP

- J. Southworth (Southworth et al. 2004, MNRAS, 351, 1277)
- Based on the Ecliping Binary Orbit Program (EBOP) by P. Etzel (Popper & Etzel, 1981, AJ, 86, 102; Etzel 1981; Nelson & Davis, 1972, ApJ, 174, 617).
- Popular program for modelling detached eclipsing binary light curves.
  - Includes nonlinear limb darkening
  - treatment of proximity effects (ellipsoidal objects)
  - numerical integration over exposure times
  - bootstrap + Monte Carlo for parameter error analysis.
- Used by John Southworth for conducting a homogenous analysis of transiting planet systems (e.g. Southworth et al. 2011, MNRAS, 417, 2166).
- Written in FORTRAN 77.
- Non-standard parametrization (for planets):
  - (R1+R2)/a; R2/R1; inclination; ecos(omega); esin(omega); J2/J1;

# JKTEBOP Example - WASP4

```
3     1          Task to do (from 1 to 9)   Integ. ring size (deg)
0.21  0.15       Sum of the radii           Ratio of the radii
88.5  0.0013     Orbital inclination (deg)  Mass ratio of system
0.0   0.0        Orbital eccentricity       Periastron longitude deg
1.0   1.0        Gravity darkening (star A) Grav darkening (star B)
0.0   0.0        Surface brightness ratio   Amount of third light
quad  lin        LD law type for star A     LD law type for star B
0.3   0.0        LD star A (linear coeff)   LD star B (linear coeff)
0.3   0.0        LD star A (nonlin coeff)   LD star B (nonlin coeff)
0.0   0.0        Reflection effect star A   Reflection effect star B
0.0   0.6        Phase shift of primary min Light scale factor (mag)
1.3382320363     Orbital period of eclipsing binary system (days)
54740.62         Reference time of primary minimum (HJD)
 1  1            Adjust RADII SUM  or  RADII RATIO     (0 or 1 or 2)
 1  0            Adjust INCLINATION  or  MASSRATIO     (0 or 1 or 2)
 0  0            Adjust ECCENTRICITY  or  OMEGA        (0 or 1 or 2)
 0  0            Adjust GRAVDARK1  or  GRAVDARK2       (0 or 1 or 2)
 0  0            Adjust SURFACEBRIGHT2  or  THIRDLIGHT (0 or 1 or 2)
 1  0            Adjust LD-lin1  or  LD-lin2           (0 or 1 or 2)
 1  0            Adjust LD-nonlin1  or  LD-nonlin2     (0 or 1 or 2)
 0  0            Adjust REFLECTION COEFFS 1 and 2      (-1, 0, 1 ,2)
 0  1            Adjust PHASESHIFT  or  SCALE FACTOR   (0 or 1 or 2)
 0  1            Adjust PERIOD  or  TZERO (min light)  (0 or 1)
wasp4.dat        Name of file containing light curve
wasp4.par        Name of output parameter file
wasp4.out        Name of output light curve file
wasp4.fit        Name of output model light curve fit file


# Enter the appropriate numbers on the left-hand side of each line of this file.
# Most of the lines require two numeric parameters separated by spaces.
```

# JKTEBOP Example - WASP4

```
3       1             Task to do (from 1 to 9)   Integ. ring size (deg)
0.21    0.15          Sum of the radii           Ratio of the radii
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quad    lin           LD law type for star A     LD law type for star B
0.3     0.0           LD star A (linear coeff)   LD star B (linear coeff)
0.3     0.0           LD star A (nonlin coeff)   LD star B (nonlin coeff)
```

```
$./jktebop wasp4.in

JKTEBOP  v28      John Southworth  (Keele University, UK, jkt~astro.keele.ac.uk)
Task 3  finds the best fit of the model to observations (internal errors quoted)
>> Opened new parameter  file:  wasp4.par
>> Opened new lightcurve file:  wasp4.out
>> Opened new model fit  file:  wasp4.fit
>> Read    104 datapoints (with errors) from file wasp4.dat
>> Best fit has been found after 42 iterations.

$
```

```
wasp4.dat             Name of file containing light curve
wasp4.par             Name of output parameter file
wasp4.out             Name of output light curve file
wasp4.fit             Name of output model light curve fit file


# Enter the appropriate numbers on the left-hand side of each line of this file.
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```
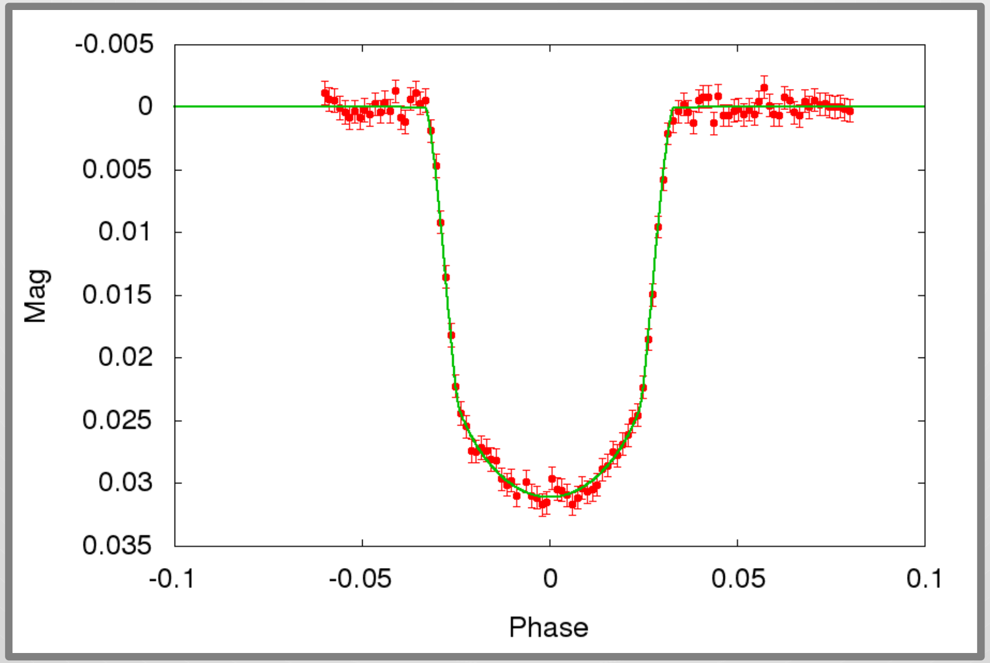
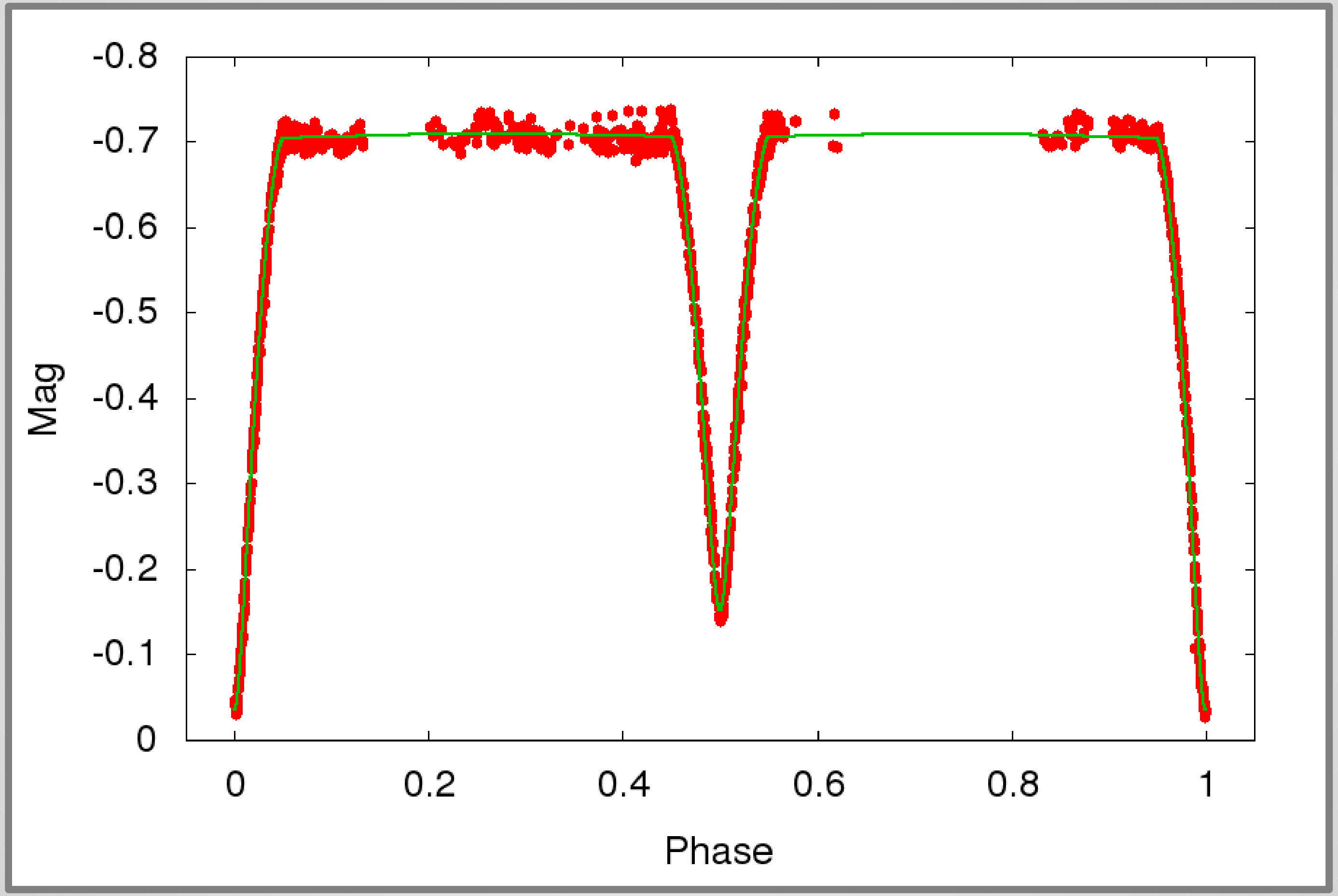

```
gnuplot> set terminal png font "Helvetica,20" size 900,600
Terminal type set to 'png'
Options are 'nocrop font Helvetica 20 size 900,600 '
gnuplot> set output "wasp4_lcmodel.png"
gnuplot> unset key
gnuplot> set xlabel "Phase"
gnuplot> set ylabel "Mag" offset 1,0
gnuplot> set xrange [-0.1:0.1]
gnuplot> set yrange [*:*] reverse
gnuplot> plot "wasp4.out" u ($4 > 0.5 ? $4 - 1 : $4):2:3 w yerrorbars pt 7 ps 1.2 lw 1, \
>             "wasp4.fit" u ($1 > 0.5 ? $1 - 1 : 1/0):2 w l lw 2 lt 2, \
>             "wasp4.fit" u ($1 < 0.5 ? $1 : 1/0):2 w l lw 2 lt 2
gnuplot> exit
```



# JKTEBOP Example – WW Aur

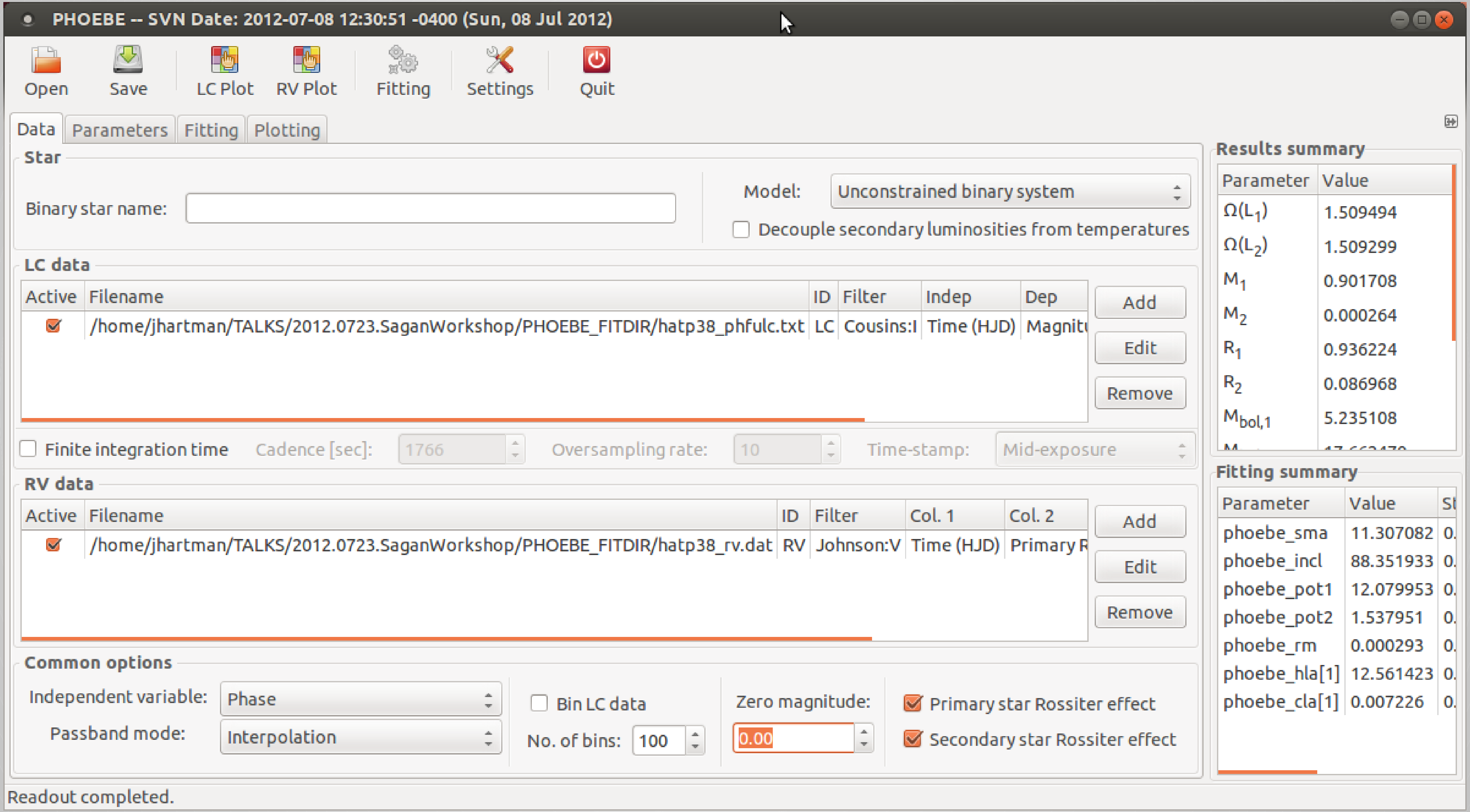
```
3     5          Task to do (from 1 to 9)   Integ. ring size (deg)
0.31  0.95       Sum of the radii           Ratio of the radii
87.5  0.92       Orbital inclination (deg)  Mass ratio of system
0.0   0.0        Orbital eccentricity       Periastron longitude deg
1.0   1.0        Gravity darkening (star A) Grav darkening (star B)
0.85  0.0        Surface brightness ratio   Amount of third light
lin   lin        LD law type for star A     LD law type for star B
0.51  0.53       LD star A (linear coeff)   LD star B (linear coeff)
0.0   0.0        LD star A (nonlin coeff)   LD star B (nonlin coeff)
0.0   0.0        Reflection effect star A   Reflection effect star B
0.0  -0.7        Phase of primary eclipse   Light scale factor (mag)
2.52501941       Orbital period of eclipsing binary system (days)
41969.95837      Reference time of primary minimum (HJD)
 1  1            Adjust RADII SUM  or  RADII RATIO      (0, 1, 2, 3)
 1  0            Adjust INCLINATION  or  MASSRATIO      (0, 1, 2, 3)
 0  0            Adjust ECCENTRICITY  or  OMEGA         (0, 1, 2, 3)
 0  0            Adjust GRAVDARK1  or  GRAVDARK2        (0, 1, 2, 3)
 1  0            Adjust SURFACEBRIGHT2  or  THIRDLIGHT  (0, 1, 2, 3)
 0  0            Adjust LD-lin1  or  LD-lin2            (0, 1, 2, 3)
 0  0            Adjust LD-nonlin1  or  LD-nonlin2      (0, 1, 2, 3)
 1  1            Adjust REFLECTION COEFFS 1 and 2       (-1,0,1,2,3)
 1  1            Adjust PHASESHIFT  or  SCALE FACTOR    (0, 1, 2, 3)
 0  0            Adjust PERIOD  or  TZERO (min light)   (0, 1, 2, 3)
wwaur-V.dat      Name of file containing light curve
wwaur-V.par      Name of output parameter file
wwaur-V.out      Name of output light curve file
wwaur-V.fit      Name of output model light curve fit file


# Enter the appropriate numbers on the left-hand side of each line of this file.
# Most of the lines require two numeric parameters separated by spaces.
```

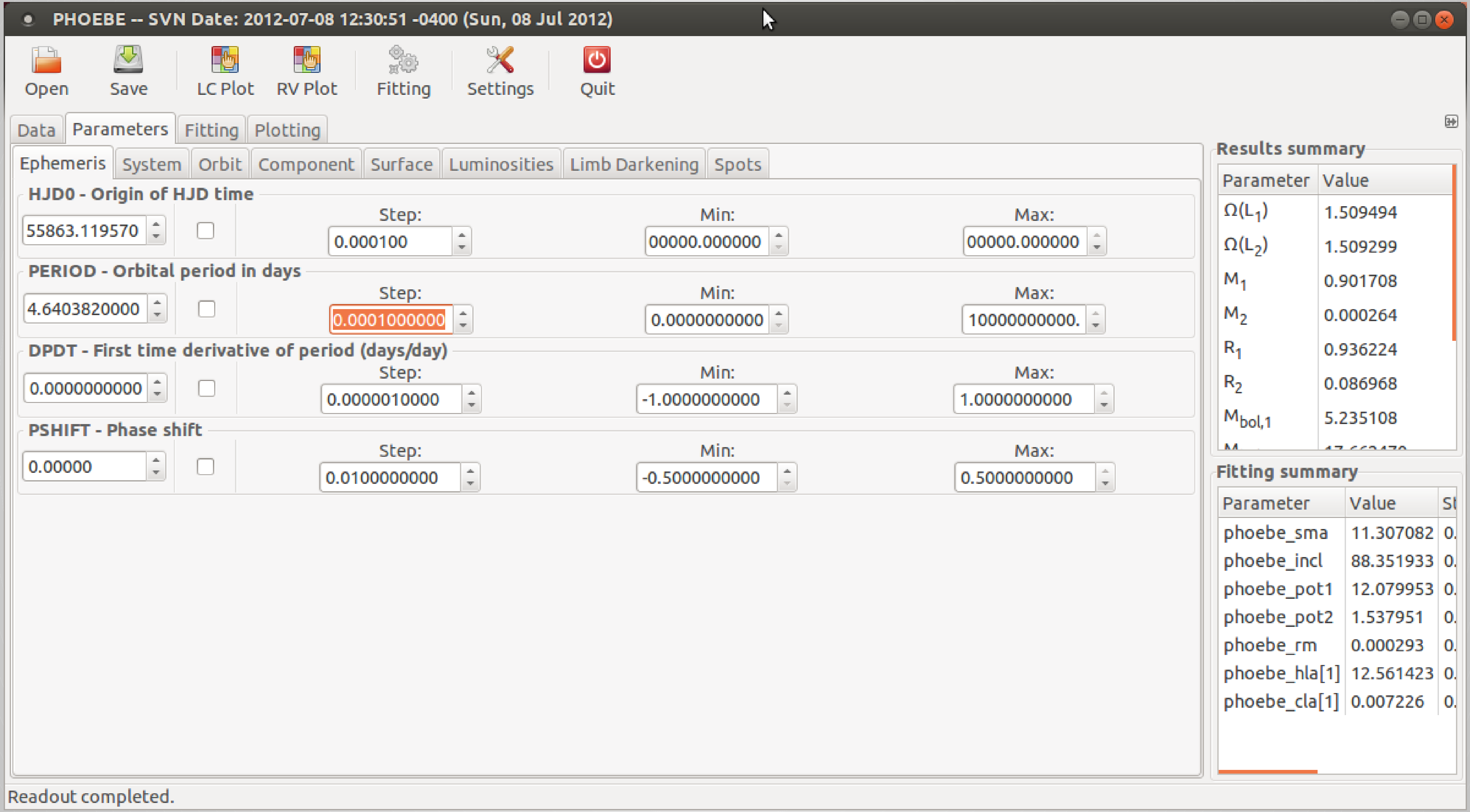
# JKTEBOP Example – WW Aur

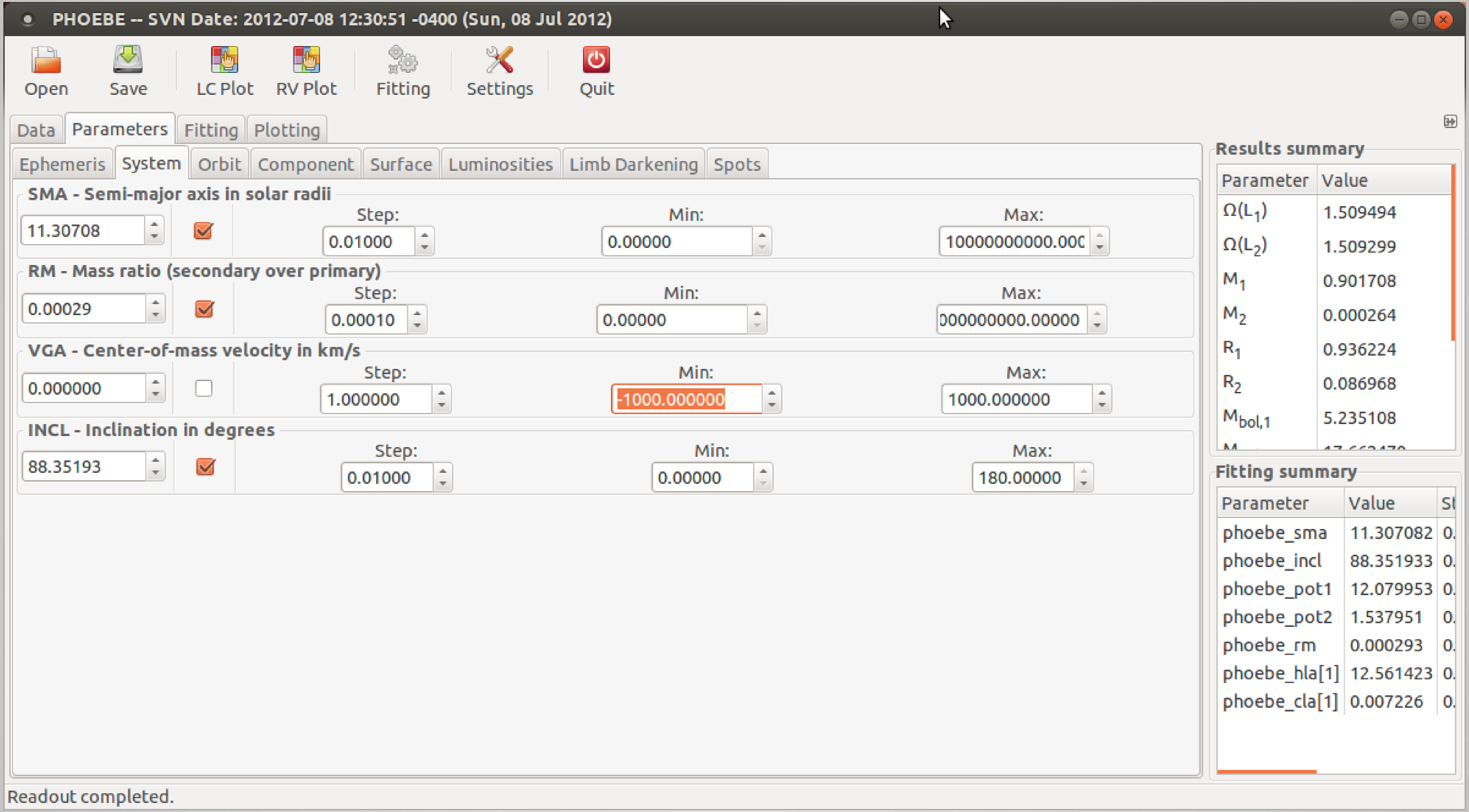


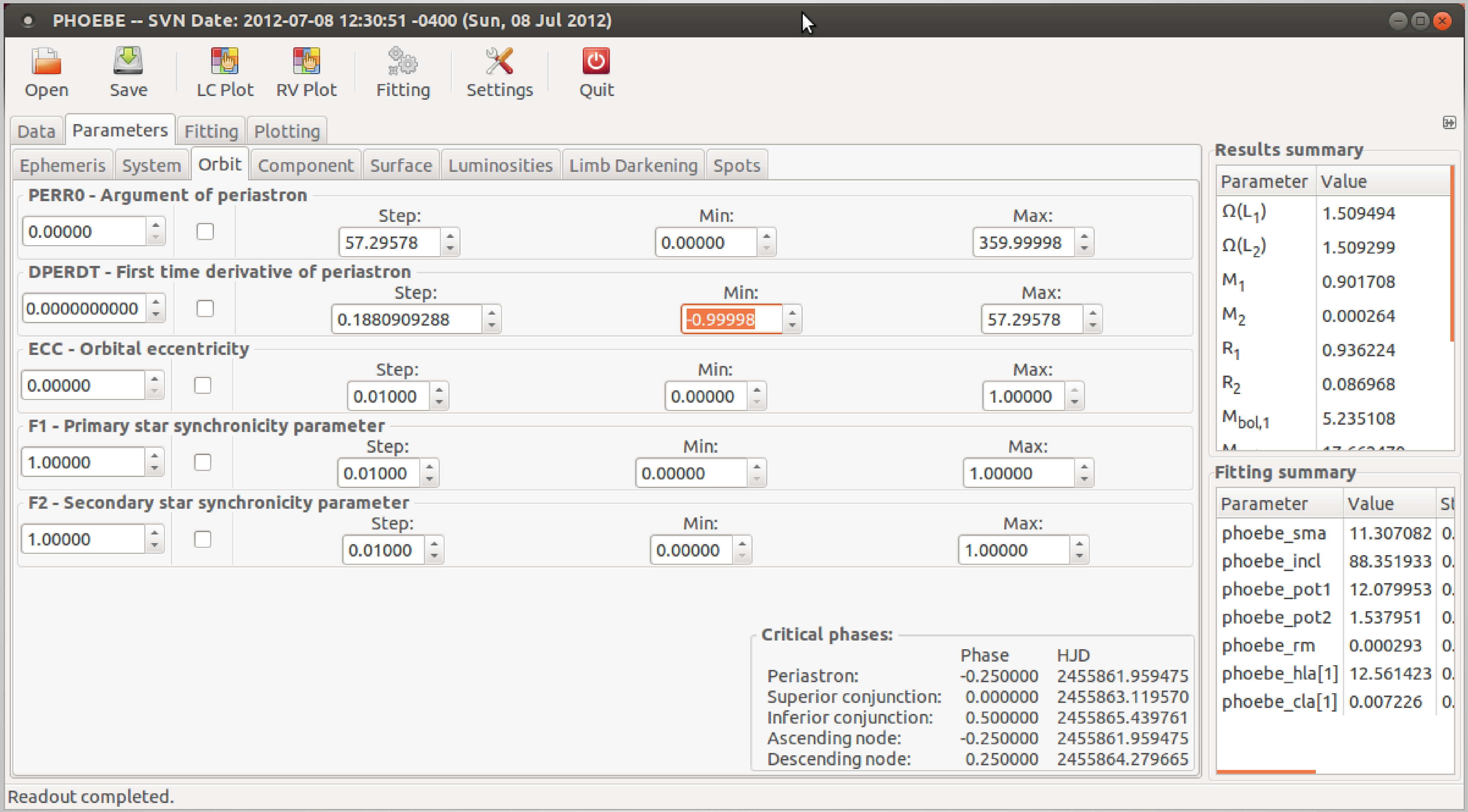
# PHOEBE

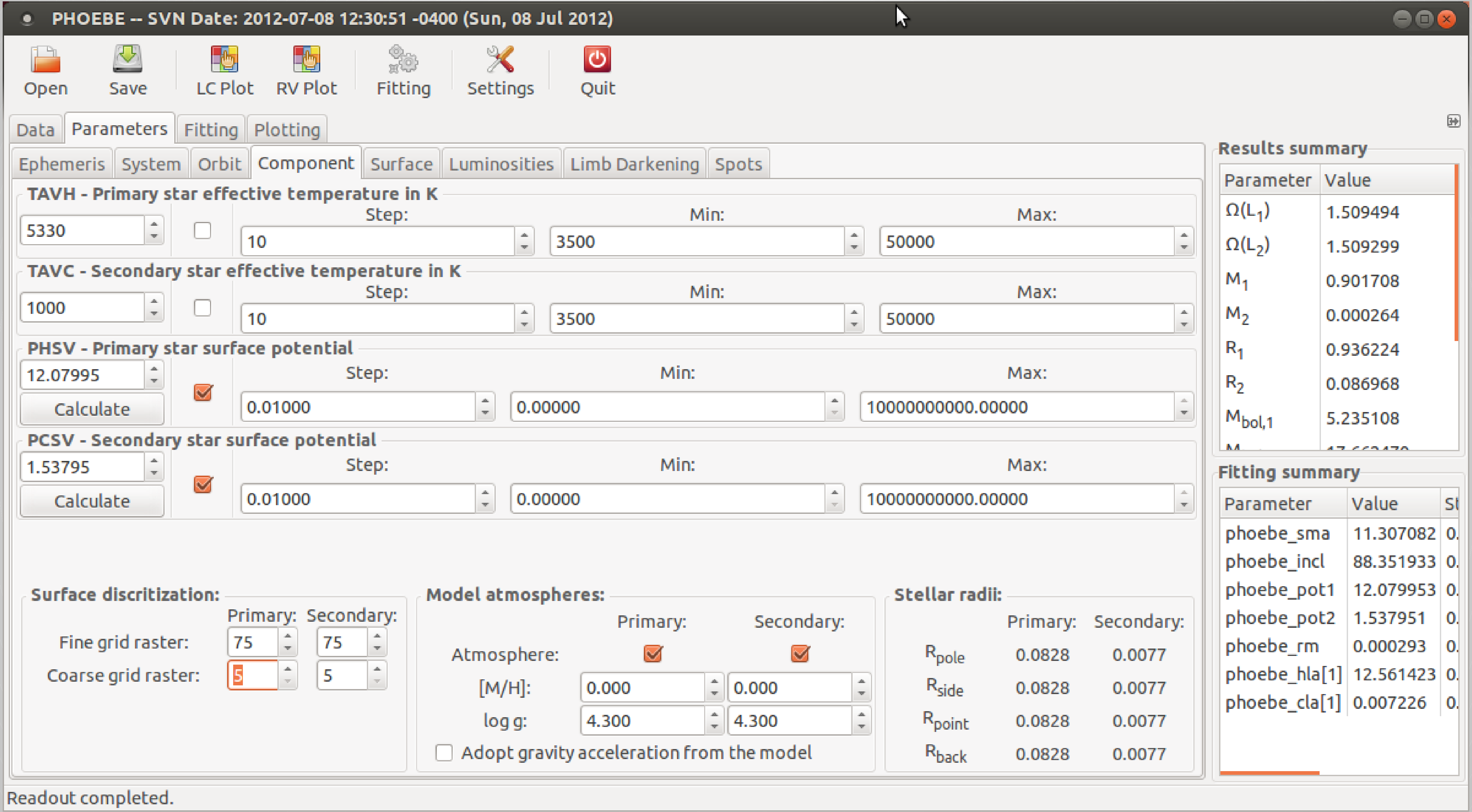
- A. Prša (Prša A & Zwitter T. 2005, ApJ, 628, 426)
- Front-end for the Wilson & Devinney (1971, ApJ, 166, 605) eclipsing binary LC+RV model
  - Roche model (stars are equipotential surfaces)
  - full calculation of proximity effects for close binaries
  - Performs numerical integration over visible primary and secondary surfaces.
- Handles multiple LCs and RVs
- GUI and command-line interpreter (scripter)
- Fitting by differential corrections or Downhill simplex.

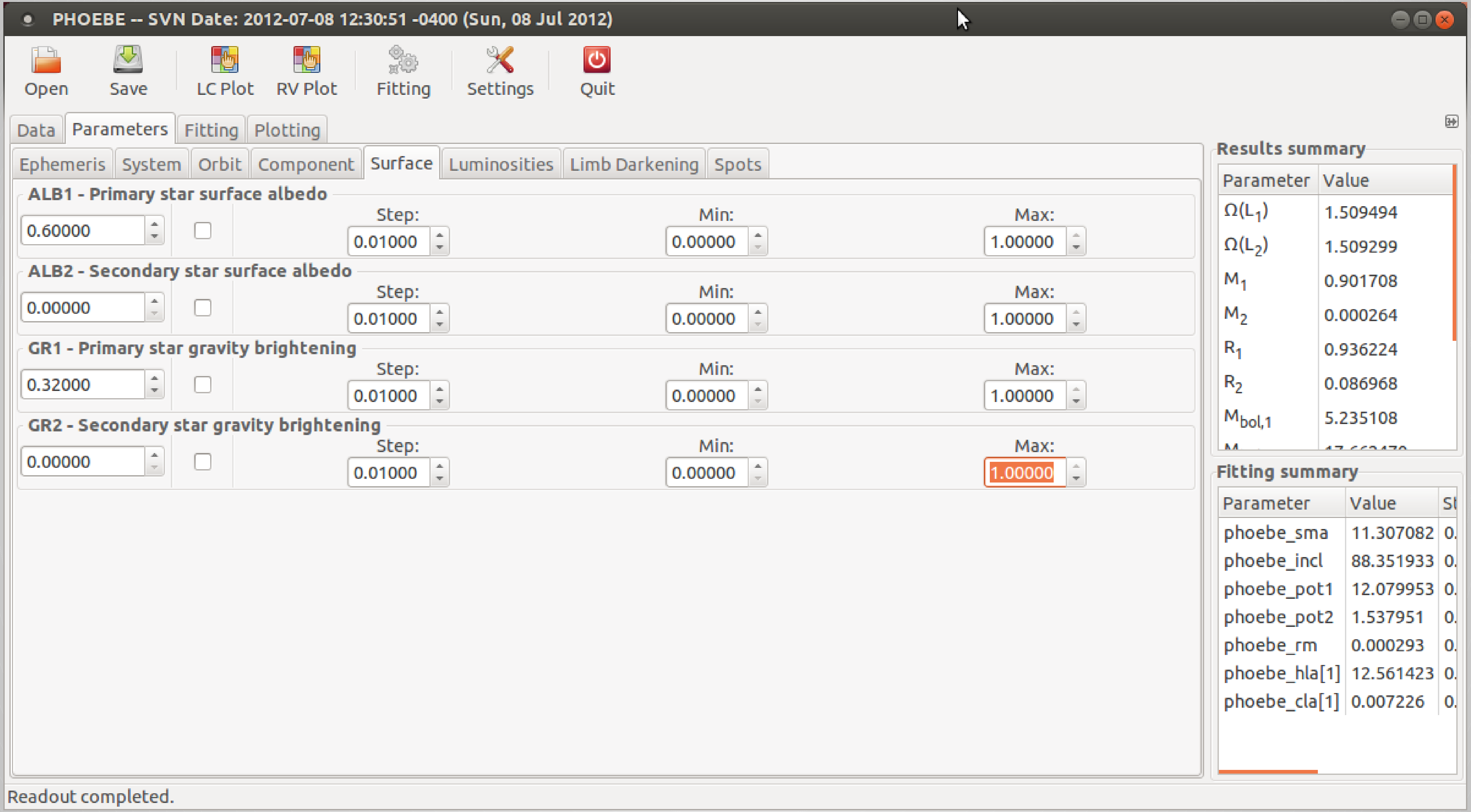

PHOEBE -- SVN Date: 2012-07-08 12:30:51 -0400 (Sun, 08 Jul 2012)
Open
Save
LC Plot
RV Plot
Fitting
Settings
Quit
Data
Parameters
Fitting
Plotting
Star
Binary star name:
Model:
Unconstrained binary system
Decouple secondary luminosities from temperatures
LC data
Active
Filename
ID
Filter
Indep
Dep
/home/jhartman/TALKS/2012.0723.SaganWorkshop/PHOEBE_FITDIR/hatp38_phfulc.txt
LC
Cousins:I
Time (HJD)
Add
Edit
Remove
Finite integration time
Cadence [sec]:
1766
Oversampling rate:
10
Time-stamp:
Mid-exposure
RV data
Active
Filename
ID
Filter
Col. 1
Col. 2
/home/jhartman/TALKS/2012.0723.SaganWorkshop/PHOEBE_FITDIR/hatp38_rv.dat
RV
Johnson:V
Time (HJD)
Add
Edit
Remove
Common options
Independent variable:
Phase
Passband mode:
Interpolation
Bin LC data
No. of bins:
100
Zero magnitude:
0.00
Primary star Rossiter effect
Secondary star Rossiter effect
Readout completed.
Results summary
Parameter
Value
Ω(L1) 1.509494
Ω(L2) 1.509299
M1 0.901708
M2 0.000264
R1 0.936224
R2 0.086968
Mbol,1 5.235108
Fitting summary
Parameter
Value
phoebe_sma 11.307082
phoebe_incl 88.351933
phoebe_pot1 12.079953
phoebe_pot2 1.537951
phoebe_rm 0.000293
phoebe_hla[1] 12.561423
phoebe_cla[1] 0.007226

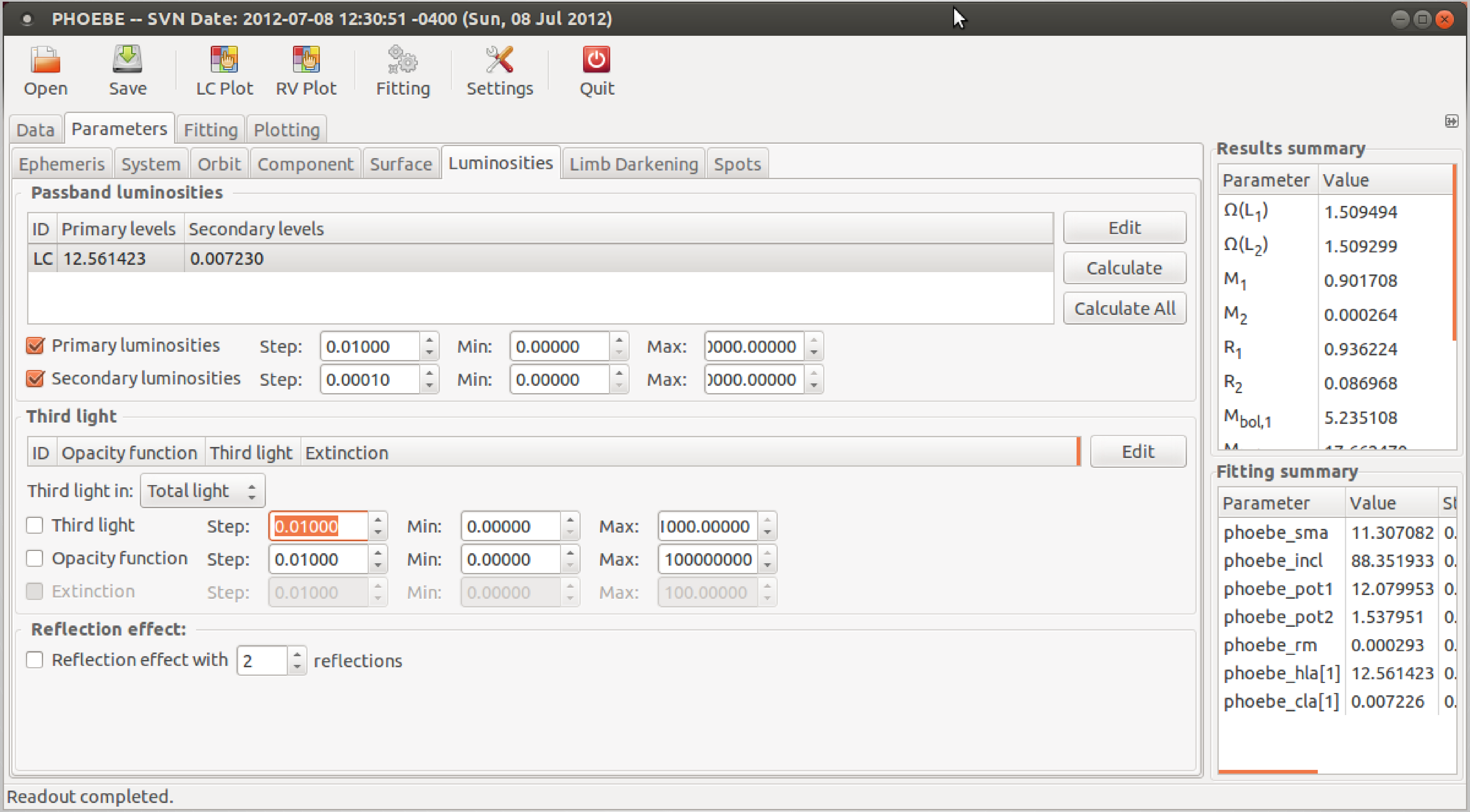

PHOEBE -- SVN Date: 2012-07-08 12:30:51 -0400 (Sun, 08 Jul 2012)
Open
Save
LC Plot
RV Plot
Fitting
Settings
Quit
Data
Parameters
Fitting
Plotting
Ephemeris
System
Orbit
Component
Surface
Luminosities
Limb Darkening
Spots
HJD0 - Origin of HJD time
55863.119570
Step: 0.000100
Min: 00000.000000
Max: 00000.000000
PERIOD - Orbital period in days
4.6403820000
Step: 0.0001000000
Min: 0.0000000000
Max: 10000000000.
DPDT - First time derivative of period (days/day)
0.0000000000
Step: 0.0000010000
Min: -1.0000000000
Max: 1.0000000000
PSHIFT - Phase shift
0.00000
Step: 0.0100000000
Min: -0.5000000000
Max: 0.5000000000
Results summary
Parameter Value
Ω(L1) 1.509494
Ω(L2) 1.509299
M1 0.901708
M2 0.000264
R1 0.936224
R2 0.086968
Mbol,1 5.235108
Fitting summary
Parameter Value
phoebe_sma 11.307082
phoebe_incl 88.351933
phoebe_pot1 12.079953
phoebe_pot2 1.537951
phoebe_rm 0.000293
phoebe_hla[1] 12.561423
phoebe_cla[1] 0.007226
Readout completed.

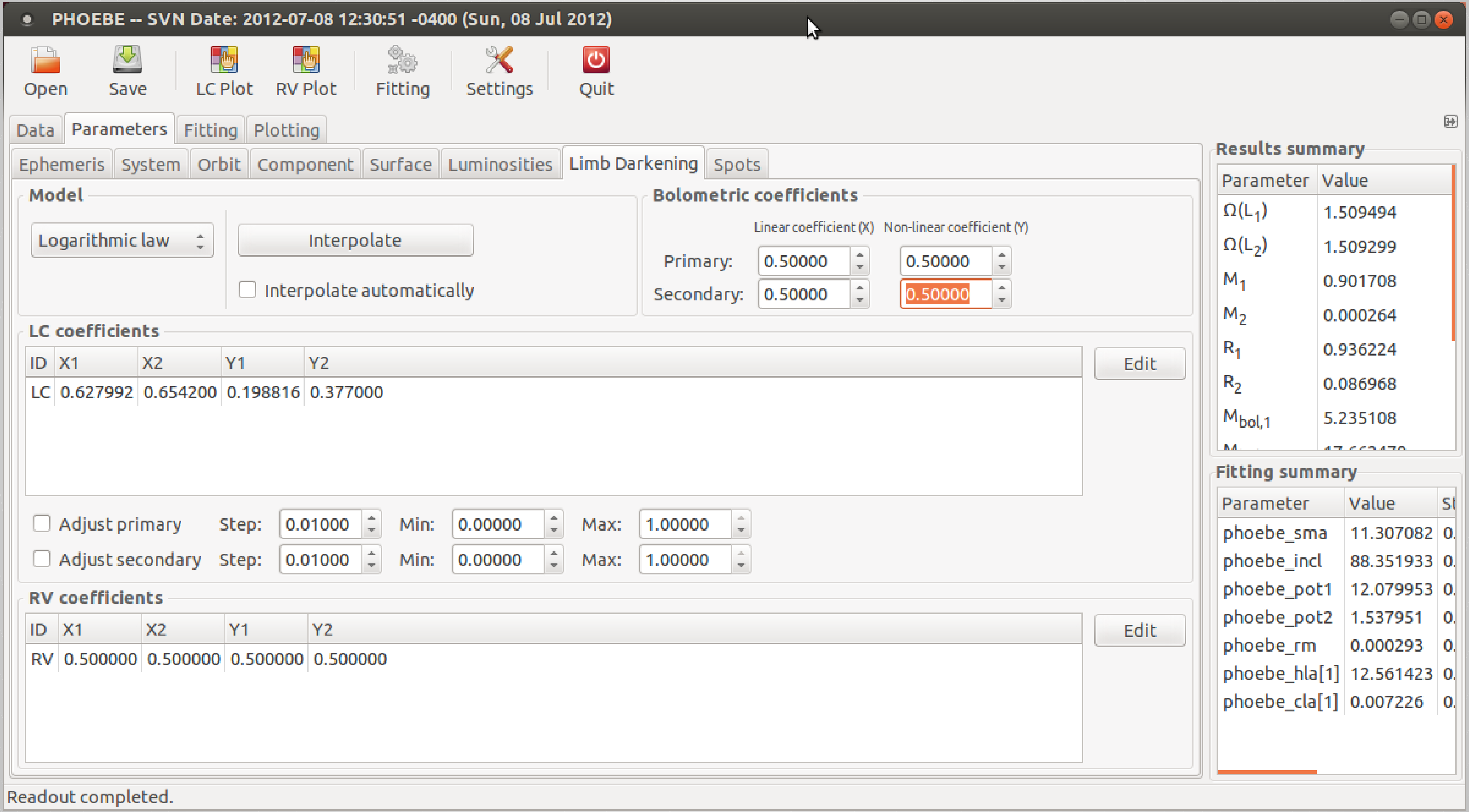

PHOEBE -- SVN Date: 2012-07-08 12:30:51 -0400 (Sun, 08 Jul 2012)
Open
Save
LC Plot
RV Plot
Fitting
Settings
Quit
Data
Parameters
Fitting
Plotting
Ephemeris
System
Orbit
Component
Surface
Luminosities
Limb Darkening
Spots
SMA - Semi-major axis in solar radii
11.30708
Step: 0.01000
Min: 0.00000
Max: 10000000000.000
RM - Mass ratio (secondary over primary)
0.00029
Step: 0.00010
Min: 0.00000
Max: 000000000.00000
VGA - Center-of-mass velocity in km/s
0.000000
Step: 1.000000
Min: -1000.000000
Max: 1000.000000
INCL - Inclination in degrees
88.35193
Step: 0.01000
Min: 0.00000
Max: 180.00000
Results summary
Parameter Value
Ω(L1) 1.509494
Ω(L2) 1.509299
M1 0.901708
M2 0.000264
R1 0.936224
R2 0.086968
Mbol,1 5.235108
Fitting summary
Parameter Value
phoebe_sma 11.307082
phoebe_incl 88.351933
phoebe_pot1 12.079953
phoebe_pot2 1.537951
phoebe_rm 0.000293
phoebe_hla[1] 12.561423
phoebe_cla[1] 0.007226
Readout completed.

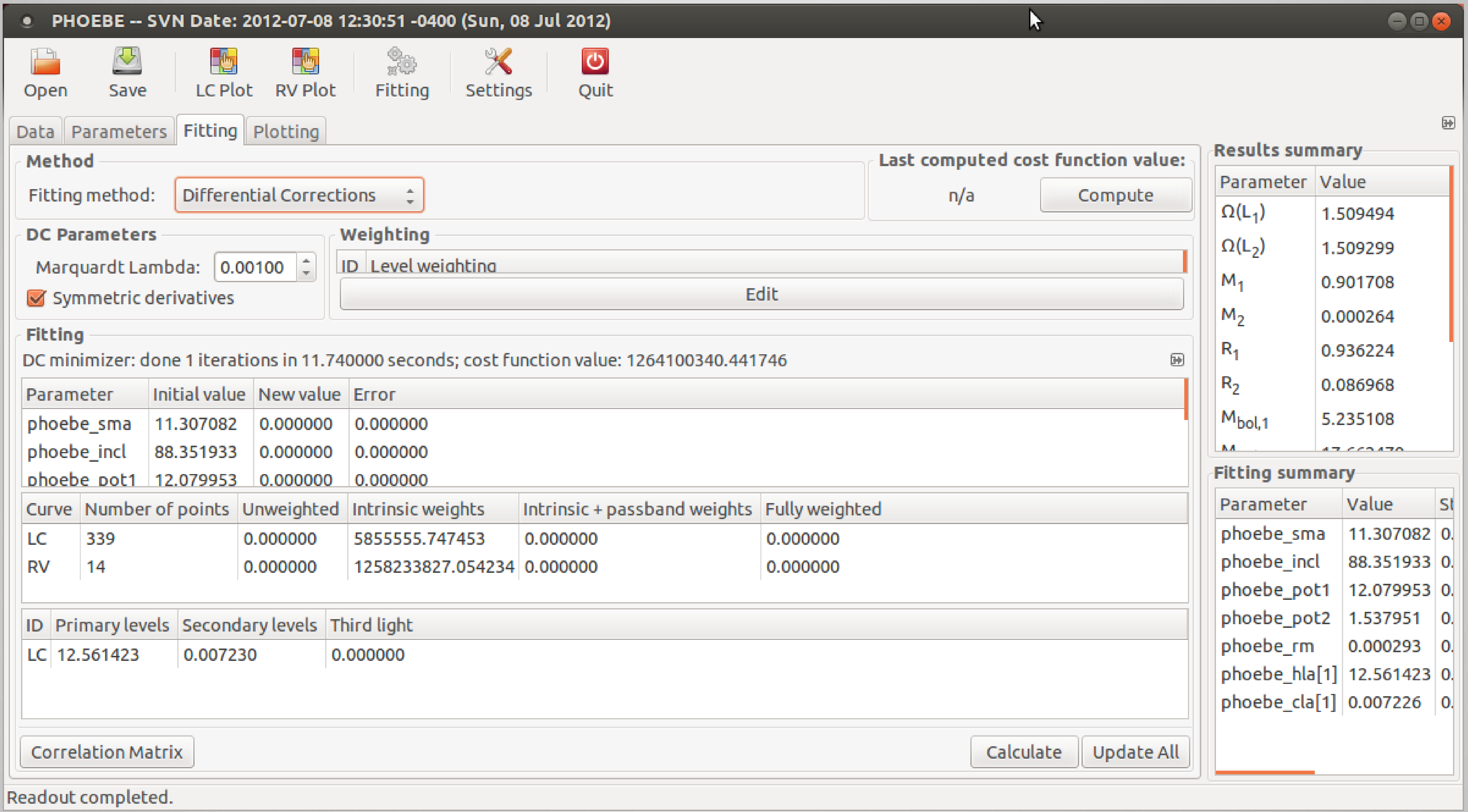

PHOEBE -- SVN Date: 2012-07-08 12:30:51 -0400 (Sun, 08 Jul 2012)
Open
Save
LC Plot
RV Plot
Fitting
Settings
Quit
Data
Parameters
Fitting
Plotting
Ephemeris
System
Orbit
Component
Surface
Luminosities
Limb Darkening
Spots
PERR0 - Argument of periastron
0.00000
Step: 57.29578
Min: 0.00000
Max: 359.99998
DPERDT - First time derivative of periastron
0.0000000000
Step: 0.1880909288
Min: -0.99998
Max: 57.29578
ECC - Orbital eccentricity
0.00000
Step: 0.01000
Min: 0.00000
Max: 1.00000
F1 - Primary star synchronicity parameter
1.00000
Step: 0.01000
Min: 0.00000
Max: 1.00000
F2 - Secondary star synchronicity parameter
1.00000
Step: 0.01000
Min: 0.00000
Max: 1.00000
Critical phases:
Phase HJD
Periastron: -0.250000 2455861.959475
Superior conjunction: 0.000000 2455863.119570
Inferior conjunction: 0.500000 2455865.439761
Ascending node: -0.250000 2455861.959475
Descending node: 0.250000 2455864.279665
Results summary
Parameter Value
Ω(L1) 1.509494
Ω(L2) 1.509299
M1 0.901708
M2 0.000264
R1 0.936224
R2 0.086968
Mbol,1 5.235108
Fitting summary
Parameter Value
phoebe_sma 11.307082
phoebe_incl 88.351933
phoebe_pot1 12.079953
phoebe_pot2 1.537951
phoebe_rm 0.000293
phoebe_hla[1] 12.561423
phoebe_cla[1] 0.007226
Readout completed.

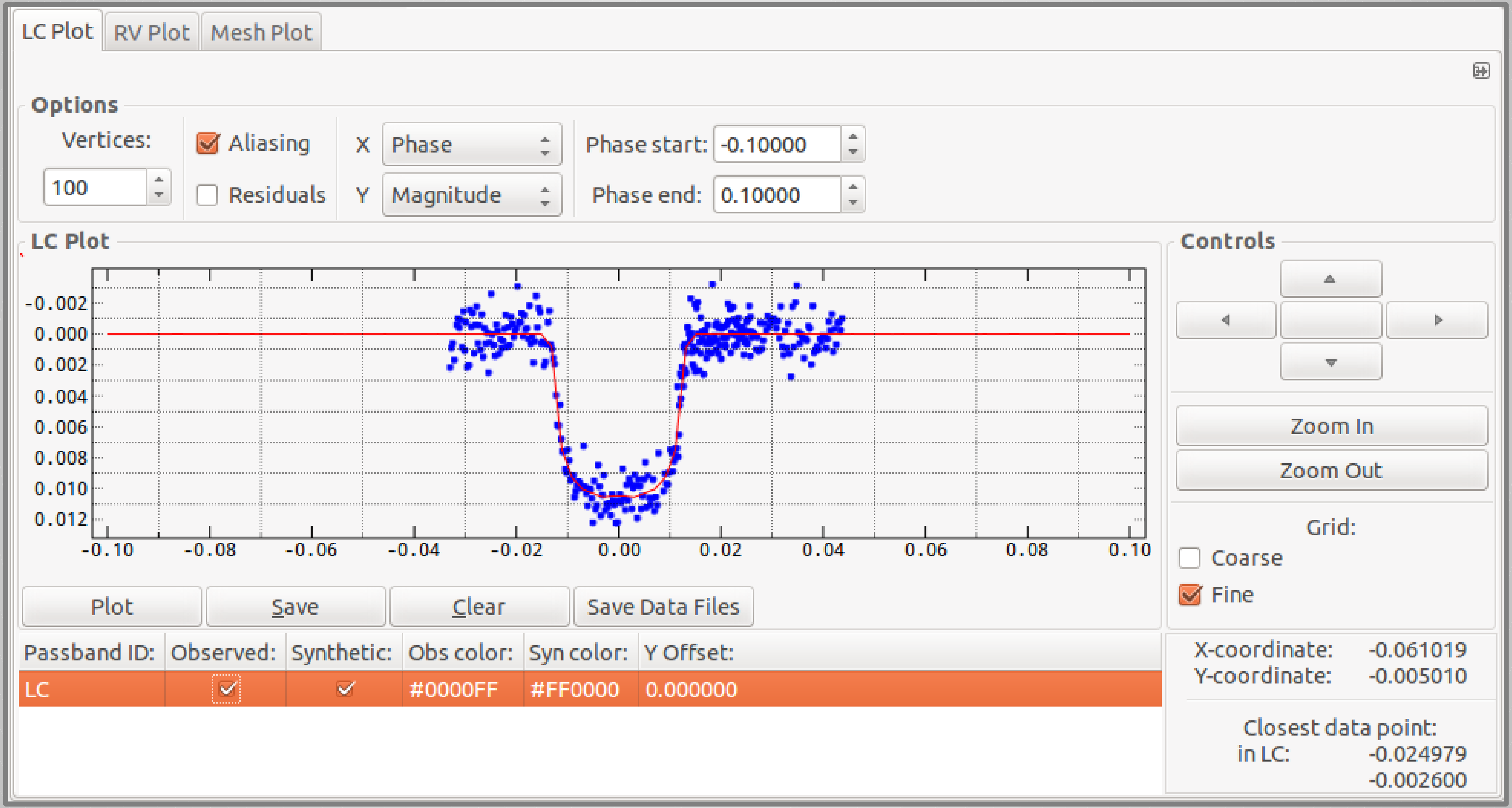

PHOEBE -- SVN Date: 2012-07-08 12:30:51 -0400 (Sun, 08 Jul 2012)
Open
Save
LC Plot
RV Plot
Fitting
Settings
Quit
Data
Parameters
Fitting
Plotting
Ephemeris
System
Orbit
Component
Surface
Luminosities
Limb Darkening
Spots
TAVH - Primary star effective temperature in K
5330
Step: 10
Min: 3500
Max: 50000
TAVC - Secondary star effective temperature in K
1000
Step: 10
Min: 3500
Max: 50000
PHSV - Primary star surface potential
12.07995
Calculate
Step: 0.01000
Min: 0.00000
Max: 10000000000.00000
PCSV - Secondary star surface potential
1.53795
Calculate
Step: 0.01000
Min: 0.00000
Max: 10000000000.00000
Surface discritization:
Primary: Secondary:
Fine grid raster: 75 75
Coarse grid raster: 5 5
Model atmospheres:
Primary: Secondary:
Atmosphere:
[M/H]: 0.000 0.000
log g: 4.300 4.300
Adopt gravity acceleration from the model
Stellar radii:
Primary: Secondary:
R_pole 0.0828 0.0077
R_side 0.0828 0.0077
R_point 0.0828 0.0077
R_back 0.0828 0.0077
Results summary
Parameter Value
Ω(L_1) 1.509494
Ω(L_2) 1.509299
M_1 0.901708
M_2 0.000264
R_1 0.936224
R_2 0.086968
M_bol,1 5.235108
Fitting summary
Parameter Value
phoebe_sma 11.307082
phoebe_incl 88.351933
phoebe_pot1 12.079953
phoebe_pot2 1.537951
phoebe_rm 0.000293
phoebe_hla[1] 12.561423
phoebe_cla[1] 0.007226
Readout completed.

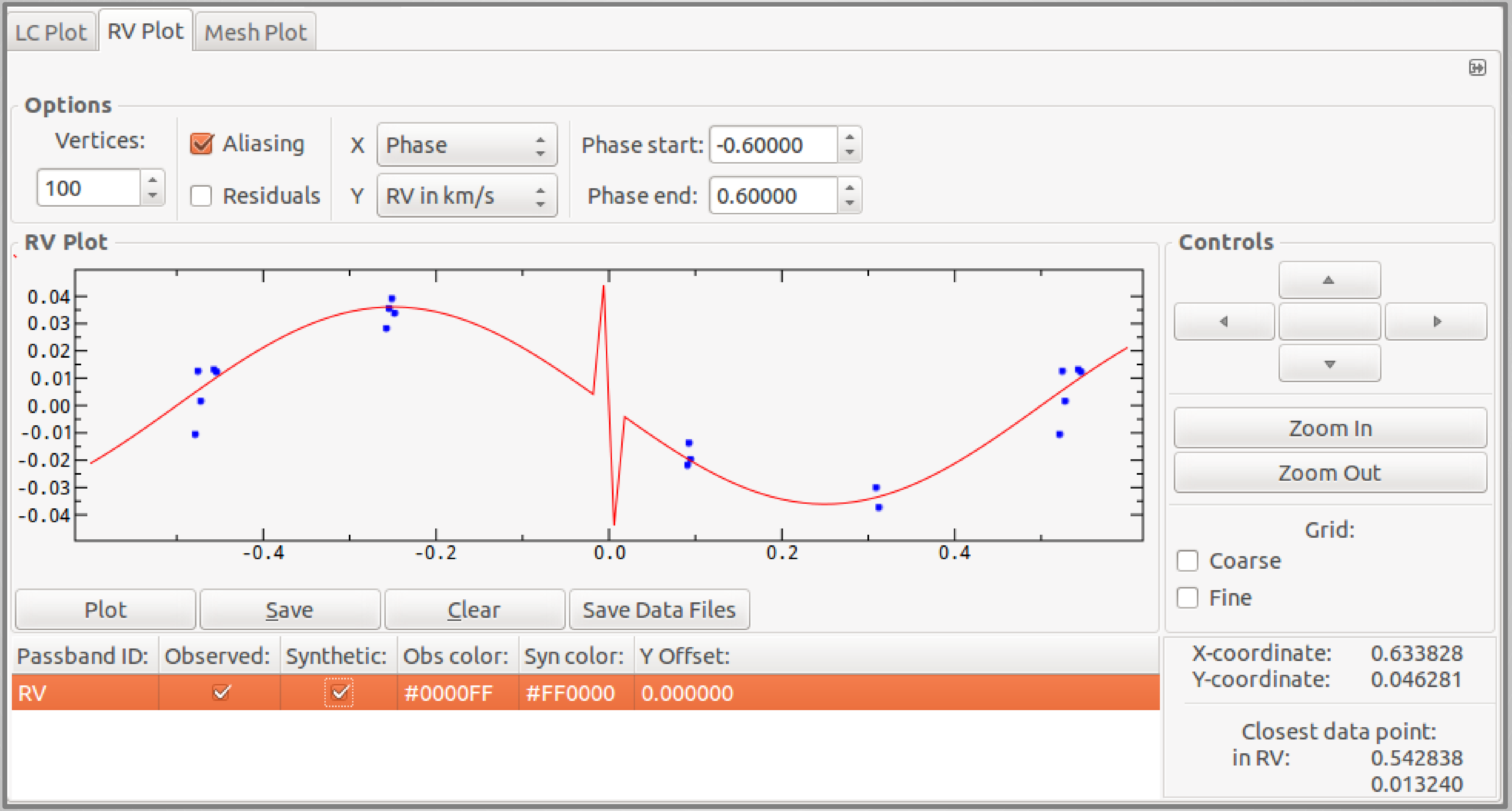

PHOEBE -- SVN Date: 2012-07-08 12:30:51 -0400 (Sun, 08 Jul 2012)
Open
Save
LC Plot
RV Plot
Fitting
Settings
Quit
Data
Parameters
Fitting
Plotting
Ephemeris
System
Orbit
Component
Surface
Luminosities
Limb Darkening
Spots
ALB1 - Primary star surface albedo
0.60000
Step: 0.01000
Min: 0.00000
Max: 1.00000
ALB2 - Secondary star surface albedo
0.00000
Step: 0.01000
Min: 0.00000
Max: 1.00000
GR1 - Primary star gravity brightening
0.32000
Step: 0.01000
Min: 0.00000
Max: 1.00000
GR2 - Secondary star gravity brightening
0.00000
Step: 0.01000
Min: 0.00000
Max: 1.00000
Results summary
Parameter Value
Ω(L1) 1.509494
Ω(L2) 1.509299
M1 0.901708
M2 0.000264
R1 0.936224
R2 0.086968
Mbol,1 5.235108
Fitting summary
Parameter Value
phoebe_sma 11.307082
phoebe_incl 88.351933
phoebe_pot1 12.079953
phoebe_pot2 1.537951
phoebe_rm 0.000293
phoebe_hla[1] 12.561423
phoebe_cla[1] 0.007226
Readout completed.


PHOEBE -- SVN Date: 2012-07-08 12:30:51 -0400 (Sun, 08 Jul 2012)
Open
Save
LC Plot
RV Plot
Fitting
Settings
Quit
Data
Parameters
Fitting
Plotting
Ephemeris
System
Orbit
Component
Surface
Luminosities
Limb Darkening
Spots
Passband luminosities
ID
Primary levels
Secondary levels
LC
12.561423
0.007230
Edit
Calculate
Calculate All
Primary luminosities
Step: 0.01000
Min: 0.00000
Max: )000.00000
Secondary luminosities
Step: 0.00010
Min: 0.00000
Max: )000.00000
Third light
ID
Opacity function
Third light
Extinction
Edit
Third light in: Total light
Third light
Step: 0.01000
Min: 0.00000
Max: 1000.00000
Opacity function
Step: 0.01000
Min: 0.00000
Max: 100000000
Extinction
Step: 0.01000
Min: 0.00000
Max: 100.00000
Reflection effect:
Reflection effect with 2 reflections
Readout completed.
Results summary
Parameter
Value
Ω(L1) 1.509494
Ω(L2) 1.509299
M1 0.901708
M2 0.000264
R1 0.936224
R2 0.086968
Mbol,1 5.235108
Fitting summary
Parameter
Value
phoebe_sma 11.307082
phoebe_incl 88.351933
phoebe_pot1 12.079953
phoebe_pot2 1.537951
phoebe_rm 0.000293
phoebe_hla[1] 12.561423
phoebe_cla[1] 0.007226

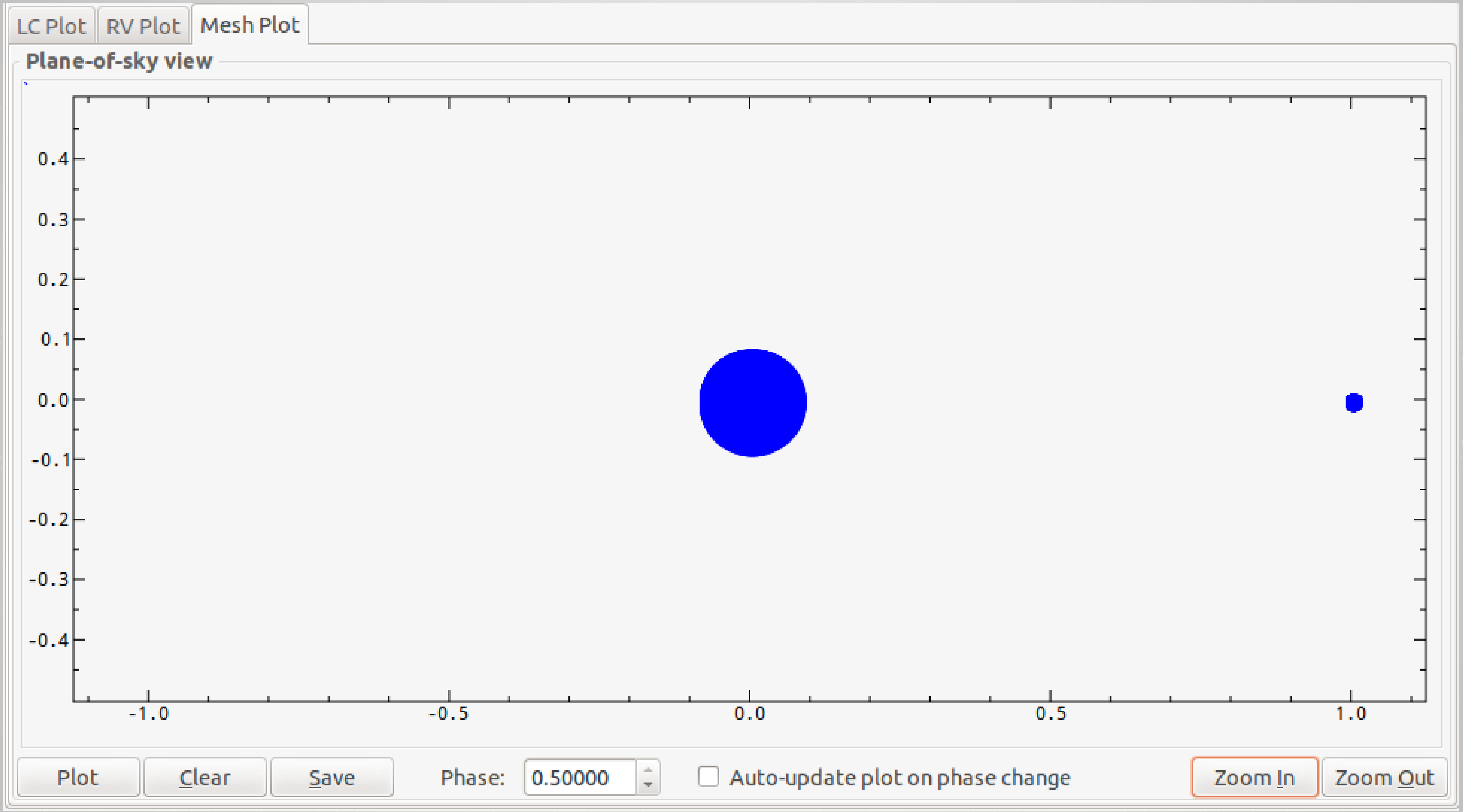

PHOEBE -- SVN Date: 2012-07-08 12:30:51 -0400 (Sun, 08 Jul 2012)
Open
Save
LC Plot
RV Plot
Fitting
Settings
Quit
Data
Parameters
Fitting
Plotting
Ephemeris
System
Orbit
Component
Surface
Luminosities
Limb Darkening
Spots
Model
Logarithmic law
Interpolate
Interpolate automatically
Bolometric coefficients
Linear coefficient (X)
Non-linear coefficient (Y)
Primary: 0.50000 0.50000
Secondary: 0.50000 0.50000
LC coefficients
ID X1 X2 Y1 Y2
LC 0.627992 0.654200 0.198816 0.377000
Edit
Adjust primary Step: 0.01000 Min: 0.00000 Max: 1.00000
Adjust secondary Step: 0.01000 Min: 0.00000 Max: 1.00000
RV coefficients
ID X1 X2 Y1 Y2
RV 0.500000 0.500000 0.500000 0.500000
Edit
Results summary
Parameter Value
Ω(L1) 1.509494
Ω(L2) 1.509299
M1 0.901708
M2 0.000264
R1 0.936224
R2 0.086968
Mbol,1 5.235108
Fitting summary
Parameter Value
phoebe_sma 11.307082
phoebe_incl 88.351933
phoebe_pot1 12.079953
phoebe_pot2 1.537951
phoebe_rm 0.000293
phoebe_hla[1] 12.561423
phoebe_cla[1] 0.007226
Readout completed.


PHOEBE -- SVN Date: 2012-07-08 12:30:51 -0400 (Sun, 08 Jul 2012)
Open
Save
LC Plot
RV Plot
Fitting
Settings
Quit
Data
Parameters
Fitting
Plotting
Method
Fitting method: Differential Corrections
Last computed cost function value:
n/a
Compute
DC Parameters
Marquardt Lambda: 0.00100
Symmetric derivatives
Weighting
ID Level weighting
Edit
Fitting
DC minimizer: done 1 iterations in 11.740000 seconds; cost function value: 1264100340.441746
Parameter Initial value New value Error
phoebe_sma 11.307082 0.000000 0.000000
phoebe_incl 88.351933 0.000000 0.000000
phoebe_pot1 12.079953 0.000000 0.000000
Curve Number of points Unweighted Intrinsic weights Intrinsic + passband weights Fully weighted
LC 339 0.000000 5855555.747453 0.000000 0.000000
RV 14 0.000000 1258233827.054234 0.000000 0.000000
ID Primary levels Secondary levels Third light
LC 12.561423 0.007230 0.000000
Correlation Matrix
Calculate
Update All
Results summary
Parameter Value
Ω(L1) 1.509494
Ω(L2) 1.509299
M1 0.901708
M2 0.000264
R1 0.936224
R2 0.086968
Mbol,1 5.235108
Fitting summary
Parameter Value
phoebe_sma 11.307082
phoebe_incl 88.351933
phoebe_pot1 12.079953
phoebe_pot2 1.537951
phoebe_rm 0.000293
phoebe_hla[1] 12.561423
phoebe_cla[1] 0.007226
Readout completed.


LC Plot
RV Plot
Mesh Plot
Options
Vertices:
100
Aliasing
Residuals
X
Phase
Y
Magnitude
Phase start:
-0.10000
Phase end:
0.10000
LC Plot
-0.002
0.000
0.002
0.004
0.006
0.008
0.010
0.012
-0.10
-0.08
-0.06
-0.04
-0.02
0.00
0.02
0.04
0.06
0.08
0.10
Controls
Zoom In
Zoom Out
Grid:
Coarse
Fine
Plot
Save
Clear
Save Data Files
Passband ID:
Observed:
Synthetic:
Obs color:
Syn color:
Y Offset:
LC
#0000FF
#FF0000
0.000000
X-coordinate: -0.061019
Y-coordinate: -0.005010
Closest data point:
in LC: -0.024979
-0.002600



LC Plot
RV Plot
Mesh Plot
Options
Vertices:
100
Aliasing
Residuals
X
Phase
Y
RV in km/s
Phase start:
-0.60000
Phase end:
0.60000
RV Plot
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.4
-0.2
0.0
0.2
0.4
Plot
Save
Clear
Save Data Files
Controls
Zoom In
Zoom Out
Grid:
Coarse
Fine
Passband ID:
Observed:
Synthetic:
Obs color:
Syn color:
Y Offset:
RV
#0000FF
#FF0000
0.000000
X-coordinate: 0.633828
Y-coordinate: 0.046281
Closest data point:
in RV: 0.542838
0.013240



LC Plot
RV Plot
Mesh Plot
Plane-of-sky view
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-1.0
-0.5
0.0
0.5
1.0
Plot
Clear
Save
Phase:
0.50000
Auto-update plot on phase change
Zoom In
Zoom Out