



IDL Binary Grid Search



Gail Schaefer

CHARA Array of
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Binary Grid Search — Mozilla Firefox

File Edit View History Bookmarks Tools Help

<https://www.chara.gsu.edu/analysis-software/binary-grid-search>

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Adaptive Grid Search for Binary Stars

A set of IDL routines for performing an adaptive grid search for binary stars was written by Gail Schaefer. The program fits a binary model to interferometric data by searching through a grid of binary positions to find a global solution with the minimum chi squared. At each step in the grid, the code uses mpfit to minimize the binary solution. An "adaptive" grid search can be performed where the program adjusts the separation in RA and DEC, as well as the flux ratios at each step in the grid. This is useful for finding the global minimum in the chi2 surface over a wide range of separations. Alternatively, a fixed grid search can be performed to map out the chi2 surface at fixed separation intervals after the best fit solution is found.

The program extracts the squared visibilities, closure phases, and uv coordinates from an OIFITS file. The uv coordinates are used to calculate the visibilities and closure phases for a binary model based on the initial separation, position angle, and flux ratio. The code uses the mpfit package to minimize the binary solution at each step in the grid. The global minimum in the grid is retained as the best fit solution.

Download the IDL Binary Grid Search Software

[Download the IDL gridsearch_binary_oifits package here](#) (updated 2023Jan19). Unpack the tar file and include the gridsearch_binary_oifits directory in your IDL path.

Running the binary grid search routine also requires the IDL OIFITS library developed by John Monnier, the IDL mpfit package developed by Craig Markwardt, and the IDL astronomy library maintained by NASA Goddard Spaceflight Center. These packages can be downloaded through the following links:

- [Download the IDL OIFITS Library](#) (both OI_DATA and OI_FITTING)
- [IDL MPFIT Package](#)
- [IDL Astronomy Library](#) (including the Coyote Graphics Library)

Starting the IDL Program

Running the gridsearch_binary_oifits_gui routine will bring up a graphical user interface (GUI) where the user can enter the initial binary parameters and search ranges directly into the GUI. Alternatively, these values can be loaded from a formatted text file ([see sample parameter file](#)). If the values are entered into the GUI by hand, make sure to hit enter after typing in the values in each box so that they are registered by the GUI. Each parameter and option is discussed in more detail below. After entering all of the parameters, click the "Run Grid Search" button to begin the binary grid search.



MIRC-X Data on Iota Peg

MIRC Data on Sigma Ori

- Copy Iota Peg data to local directory:
 - `cp /dbstorage/workshop_data/MIRCX_iotaPeg_Anugu_2020/* .`
 - 2018Oct22_01_MIRCX_iotaPeg_Anugu_2020.fits
 - 2018Oct22_02_MIRCX_iotaPeg_Anugu_2020.fits
 - 2018Oct22_03_MIRCX_iotaPeg_Anugu_2020.fits
 - 2018Oct22_04_MIRCX_iotaPeg_Anugu_2020.fits
 - 2018Oct22_05_MIRCX_iotaPeg_Anugu_2020.fits
 - 2018Oct22_06_MIRCX_iotaPeg_Anugu_2020.fits
 - 2018Oct22_07_MIRCX_iotaPeg_Anugu_2020.fits
- Copy Sigma Ori data to local directory:
 - `cp /dbstorage/workshop_data/MIRC_sigOri_Schaefer_2016/* .`
 - 2011Sep29_01_MIRC_sigOri_Schaefer_2016.oifits



Examine Iota Peg and Sig Ori Data - OIFitsExplorer

- Activate virtual environment on vnc:
 - Type “source workshop” at vnc terminal prompt
- Examine Files Using OIFitsExplorer
 - Type “OIFitsExplorer”
 - Load OIFITS Files for Iota Peg
 - What signatures do you see in the data?
 - Binary?
 - Resolved diameter?
 - Background flux?



MIRC-X Data on Iota Peg MIRC Data on Sig Ori

- Iota Peg – Binary + primary with resolved diameter
 - Anugu et al. 2020, AJ, 160, 158
- Sig Ori – Binary with incoherent flux from wide companion
 - Schaefer et al. 2016, AJ, 152, 213



Merging Data Files

- IDL Grid Search read in only a single file
- Merge OIFITS files using `merge_oidata.pro`
 - IDL with Asto package and Gail Schaefer's Binary Grid Search scripts loaded.
 - IDL> `merge_oidata, outfile='Iota_Peg_Merged.fits',
infiles=['2018Oct22_06_MIRCX_iotaPeg_Anugu_2020.fits',
'2018Oct22_07_MIRCX_iotaPeg_Anugu_2020.fits']`
- Merged output file: `Iota_Peg_Merged.fits`



Starting IDL Grid Search Procedure

- Start IDL with grid search dependencies loaded:
 - Type “binarygs_idl” at vnc terminal prompt
- Start IDL grid search procedure:
 - IDL> gridsearch_binary_oifits_gui



NOTE: Hit enter after entering new values!

Grid Search Parameters

Open Param File:

Select Data File:

Initial Binary Parameters

sepRA (mas): Fix Companion is located at (sepRA, sepDEC) in mas.

sepDEC (mas): Fix

f1: Fix Flux contribution of star 1 (values from 0 to 1). $f1 + f2 + f3 = 1.0$

f2: Fix Flux contribution of star 2 (values from 0 to 1).

f3: Fix Incoherent flux (values from 0 to 1). Fix to 0 if no incoherent flux.

Diam1 (mas): Fix Diameters of star 1 and star 2 (in mas)

Diam2 (mas): Fix For unresolved diameters, fix to 0 or fix to estimated size.

mu1: Fix Limb-darkening coefficients.

mu2: Fix For uniform disk diameter, fix to 0.

Grid Search Parameters

RA range (mas): RA step (mas):

DEC range (mas): DEC step (mas):

For an adaptive grid search, leave sepRA and sepDEC as free parameters.
For a grid search at fixed intervals, check the boxes to fix sepRA and sepDEC.

Pseudo-adaptive grid At each grid point, optimize position within a fixed box set by the step size.

Grid center at (0,0) Check to center grid search at (0,0) rather than (sepRA, sepDEC).

Include bandwidth smearing

Fit V2 only Fit T3 only If unclicked then fit to both V2 and T3 data.

Save Param File:



Load OIFITS File



NOTE: Iota Peg files are big and take a long time to fit. Sig Ori file will give faster results.

Grid Search Parameters

Open Param File:

Select Data File:

Initial Binary Parameters

sepRA (mas): Fix Companion is located at (sepRA, sepDEC) in mas.

sepDEC (mas): Fix

f1: Fix Flux contribution of star 1 (values from 0 to 1). $f1 + f2 + f3 = 1.0$

f2: Fix Flux contribution of star 2 (values from 0 to 1).

f3: Fix Incoherent flux (values from 0 to 1). Fix to 0 if no incoherent flux.

Diam1 (mas): Fix Diameters of star 1 and star 2 (in mas)

Diam2 (mas): Fix For unresolved diameters, fix to 0 or fix to estimated size.

mu1: Fix Limb-darkening coefficients.

mu2: Fix For uniform disk diameter, fix to 0.

Grid Search Parameters

RA range (mas): RA step (mas):

DEC range (mas): DEC step (mas):

For an adaptive grid search, leave sepRA and sepDEC as free parameters.
For a grid search at fixed intervals, check the boxes to fix sepRA and sepDEC.

Pseudo-adaptive grid At each grid point, optimize position within a fixed box set by the step size.

Grid center at (0,0) Check to center grid search at (0,0) rather than (sepRA, sepDEC).

Include bandwidth smearing

Fit V2 only Fit T3 only If unclicked then fit to both V2 and T3 data.

Save Param File:



Initial Binary Separation
in RA and DEC



Grid Search Parameters

Open Param File:

Select Data File:

Initial Binary Parameters

sepRA (mas): Fix Companion is located at (sepRA, sepDEC) in mas.

sepDEC (mas): Fix

f1: Fix Flux contribution of star 1 (values from 0 to 1). $f1 + f2 + f3 = 1.0$

f2: Fix Flux contribution of star 2 (values from 0 to 1).

f3: Fix Incoherent flux (values from 0 to 1). Fix to 0 if no incoherent flux.

Diam1 (mas): Fix Diameters of star 1 and star 2 (in mas)

Diam2 (mas): Fix For unresolved diameters, fix to 0 or fix to estimated size.

mu1: Fix Limb-darkening coefficients.

mu2: Fix For uniform disk diameter, fix to 0.

Grid Search Parameters

RA range (mas): RA step (mas):

DEC range (mas): DEC step (mas):

For an adaptive grid search, leave sepRA and sepDEC as free parameters.
For a grid search at fixed intervals, check the boxes to fix sepRA and sepDEC.

Pseudo-adaptive grid At each grid point, optimize position within a fixed box set by the step size.

Grid center at (0,0) Check to center grid search at (0,0) rather than (sepRA, sepDEC).

Include bandwidth smearing

Fit V2 only Fit T3 only If unclicked then fit to both V2 and T3 data.

Save Param File:



Initial Flux Contributions

- Fraction of flux in each component (0 – 1)
- Total sums to 1
- Unclick the fix button for f3 to solve for incoherent background flux



Grid Search Parameters

Open Param File:

Select Data File:

Initial Binary Parameters

sepRA (mas): Fix Companion is located at (sepRA, sepDEC) in mas.

sepDEC (mas): Fix

f1: Fix Flux contribution of star 1 (values from 0 to 1). $f1 + f2 + f3 = 1.0$

f2: Fix Flux contribution of star 2 (values from 0 to 1).

f3: Fix Incoherent flux (values from 0 to 1). Fix to 0 if no incoherent flux.

Diam1 (mas): Fix Diameters of star 1 and star 2 (in mas)

Diam2 (mas): Fix For unresolved diameters, fix to 0 or fix to estimated size.

mu1: Fix Limb-darkening coefficients.

mu2: Fix For uniform disk diameter, fix to 0.

Grid Search Parameters

RA range (mas): RA step (mas):

DEC range (mas): DEC step (mas):

For an adaptive grid search, leave sepRA and sepDEC as free parameters.
For a grid search at fixed intervals, check the boxes to fix sepRA and sepDEC.

Pseudo-adaptive grid At each grid point, optimize position within a fixed box set by the step size.

Grid center at (0,0) Check to center grid search at (0,0) rather than (sepRA, sepDEC).

Include bandwidth smearing

Fit V2 only Fit T3 only If unclicked then fit to both V2 and T3 data.

Save Param File:



Initial Diameters:

- Unclick Fix button if you want to solve for the diameter
- Unresolved star = 0 mas



Grid Search Parameters

Open Param File:

Select Data File:

Initial Binary Parameters

sepRA (mas): Fix Companion is located at (sepRA, sepDEC) in mas.

sepDEC (mas): Fix

f1: Fix Flux contribution of star 1 (values from 0 to 1). $f1 + f2 + f3 = 1.0$

f2: Fix Flux contribution of star 2 (values from 0 to 1).

f3: Fix Incoherent flux (values from 0 to 1). Fix to 0 if no incoherent flux.

Diam1 (mas): Fix Diameters of star 1 and star 2 (in mas)

Diam2 (mas): Fix For unresolved diameters, fix to 0 or fix to estimated size.

mu1: Fix Limb-darkening coefficients.

mu2: Fix For uniform disk diameter, fix to 0.

Grid Search Parameters

RA range (mas): RA step (mas):

DEC range (mas): DEC step (mas):

For an adaptive grid search, leave sepRA and sepDEC as free parameters.
For a grid search at fixed intervals, check the boxes to fix sepRA and sepDEC.

Pseudo-adaptive grid At each grid point, optimize position within a fixed box set by the step size.

Grid center at (0,0) Check to center grid search at (0,0) rather than (sepRA, sepDEC).

Include bandwidth smearing

Fit V2 only Fit T3 only If unclicked then fit to both V2 and T3 data.

Save Param File:



Search Range and Step Size



Grid Search Parameters

Open Param File:

Select Data File:

Initial Binary Parameters

sepRA (mas): Fix Companion is located at (sepRA, sepDEC) in mas.

sepDEC (mas): Fix

f1: Fix Flux contribution of star 1 (values from 0 to 1). $f1 + f2 + f3 = 1.0$

f2: Fix Flux contribution of star 2 (values from 0 to 1).

f3: Fix Incoherent flux (values from 0 to 1). Fix to 0 if no incoherent flux.

Diam1 (mas): Fix Diameters of star 1 and star 2 (in mas)

Diam2 (mas): Fix For unresolved diameters, fix to 0 or fix to estimated size.

mu1: Fix Limb-darkening coefficients.

mu2: Fix For uniform disk diameter, fix to 0.

Grid Search Parameters

RA range (mas): RA step (mas):

DEC range (mas): DEC step (mas):

For an adaptive grid search, leave sepRA and sepDEC as free parameters.
 For a grid search at fixed intervals, check the boxes to fix sepRA and sepDEC.

Pseudo-adaptive grid At each grid point, optimize position within a fixed box set by the step size.

Grid center at (0,0) Check to center grid search at (0,0) rather than (sepRA, sepDEC).

Include bandwidth smearing

Fit V2 only Fit T3 only If unclicked then fit to both V2 and T3 data.

Save Param File:



Grid Search Parameters

Open Param File:

Select Data File:

Initial Binary Parameters

sepRA (mas): Fix Companion is located at (sepRA, sepDEC) in mas.

sepDEC (mas): Fix

f1: Fix Flux contribution of star 1 (values from 0 to 1). f1 + f2 + f3 = 1.0

f2: Fix Flux contribution of star 2 (values from 0 to 1).

f3: Fix Incoherent flux (values from 0 to 1). Fix to 0 if no incoherent flux.

Diam1 (mas): Fix Diameters of star 1 and star 2 (in mas)

Diam2 (mas): Fix For unresolved diameters, fix to 0 or fix to estimated size.

mu1: Fix Limb-darkening coefficients.

mu2: Fix For uniform disk diameter, fix to 0.

Grid Search Parameters

RA range (mas): RA step (mas):

DEC range (mas): DEC step (mas):

For an adaptive grid search, leave sepRA and sepDEC as free parameters.
 For a grid search at fixed intervals, check the boxes to fix sepRA and sepDEC.

Pseudo-adaptive grid At each grid point, optimize position within a fixed box set by the step size.

Grid center at (0,0) Check to center grid search at (0,0) rather than (sepRA, sepDEC).

Include bandwidth smearing

Fit V2 only Fit T3 only If unclicked then fit to both V2 and T3 data.

Save Param File:

Click "Run Grid Search"



Hit Enter to start grid search.... then wait...

```

Terminal - schaefer@Chara-Reduction: ~/chara/mircx/lot_Peg
File Edit View Terminal Tabs Help
IDL with Asto package and Gail Schaefer's Binary Grid Search scripts loaded.
IDL> gridsearch_binary_oifits_gui
% Compiled module: GRIDSEARCH_BINARY_OIFITS_GUI.
Datafile: /disk1/schaefer/chara/mircx/Iot_Peg/2011Sep29_01_MIRC_sigOri_Schaefer_2016.oifits
Initial Parameters:
sepRA      0.0
sepDEC     0.0
f1         0.5
f2         0.5
f3         0.0
diam1      0.0 F
diam2      0.0 F
mu1        0.0 F
mu2        0.0 F
Search ranges:
RA range   20.0
RA step    0.5
DEC range  20.0
DEC step   0.5
Centering grid search at (sepRA,sepDEC)
Include bandwidth smearing.
Fitting V2 and T3 data.
Hit enter to continue.
:

```

Final Results are printed to the screen

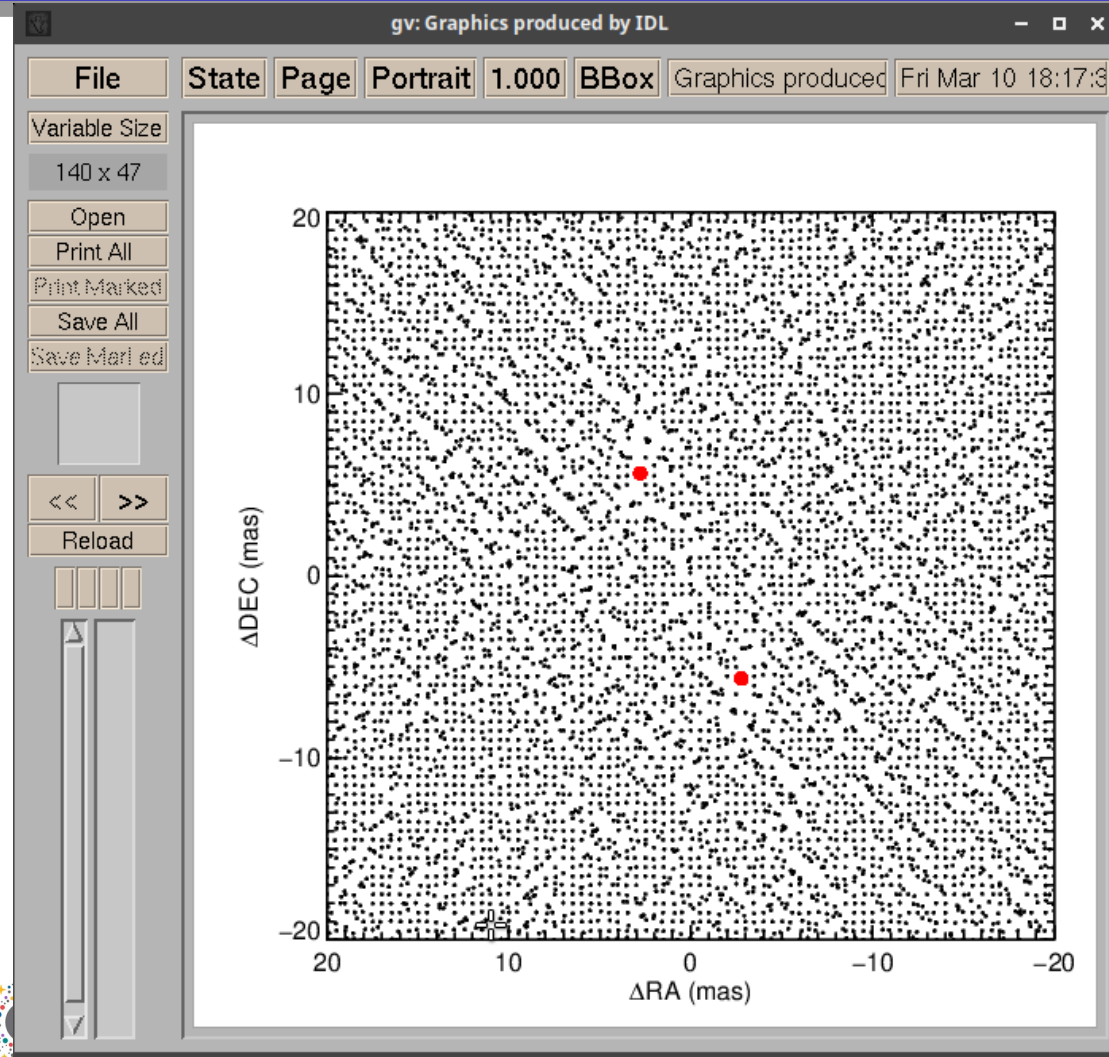
```

Terminal - schaefer@Chara-Reduction: ~/chara/mircx/Iot_Peg
File Edit View Terminal Tabs Help
-----
Data file: /disk1/schaefer/chara/mircx/Iot_Peg/2011Sep29_01_MIRC_sig0ri_Schaefer_2016.oifits
Best fit total(resid^2) from mpfit:      1848.9745
All chi2:      1848.9745      440      4.2505161
V2 chi2:      916.45145      200      4.6997510
T3 chi2:      932.52305      240      3.9681832
Number of free parameters:      5
Parameter Error
sepRA      -2.7699620      0.0019796831
sepDEC     -5.6180827      0.0025241986
f1         0.41709432      0.0035853982
f2         0.25053392      0.0025564735
f3         0.33237176      -0.00000000
diam1      0.0000000      -0.00000000
diam2      0.0000000      -0.00000000
mu1        0.0000000      -0.00000000
mu2        0.0000000      -0.00000000
Close pair separation:      6.2638281 +/-      0.0024273430
Close pair position angle:      206.24533 +/-      0.019184321
Close pair fratio (f2/f1):      0.60066491 +/-      0.0080142562
Flux ratio of wide component relative to primary:      0.79687433
Error ellipse - major, minor, PA:      0.0026494696      0.0018086002      155.43016
-----
Add systematic calibration uncertainties in quadrature with formal errors:
- MIRC: 0.25% uncertainty in wavelength scale (Monnier et al. 2012)
- MIRC: 5% uncertainty in visibility calibration
Total error ellipse - major, minor, PA:      0.015883143      0.010842266      155.43016
Total errors in f1, f2, f3:      0.011087303      0.0067382514      0.016726036
Total errors in diam1, diam2:      0.00000000      0.00000000
-----
Wavelength correction factor: 1.0000      -- No wavelength correction
Fit includes bandwidth smearing.
Fitting V2 and T3 data.

```



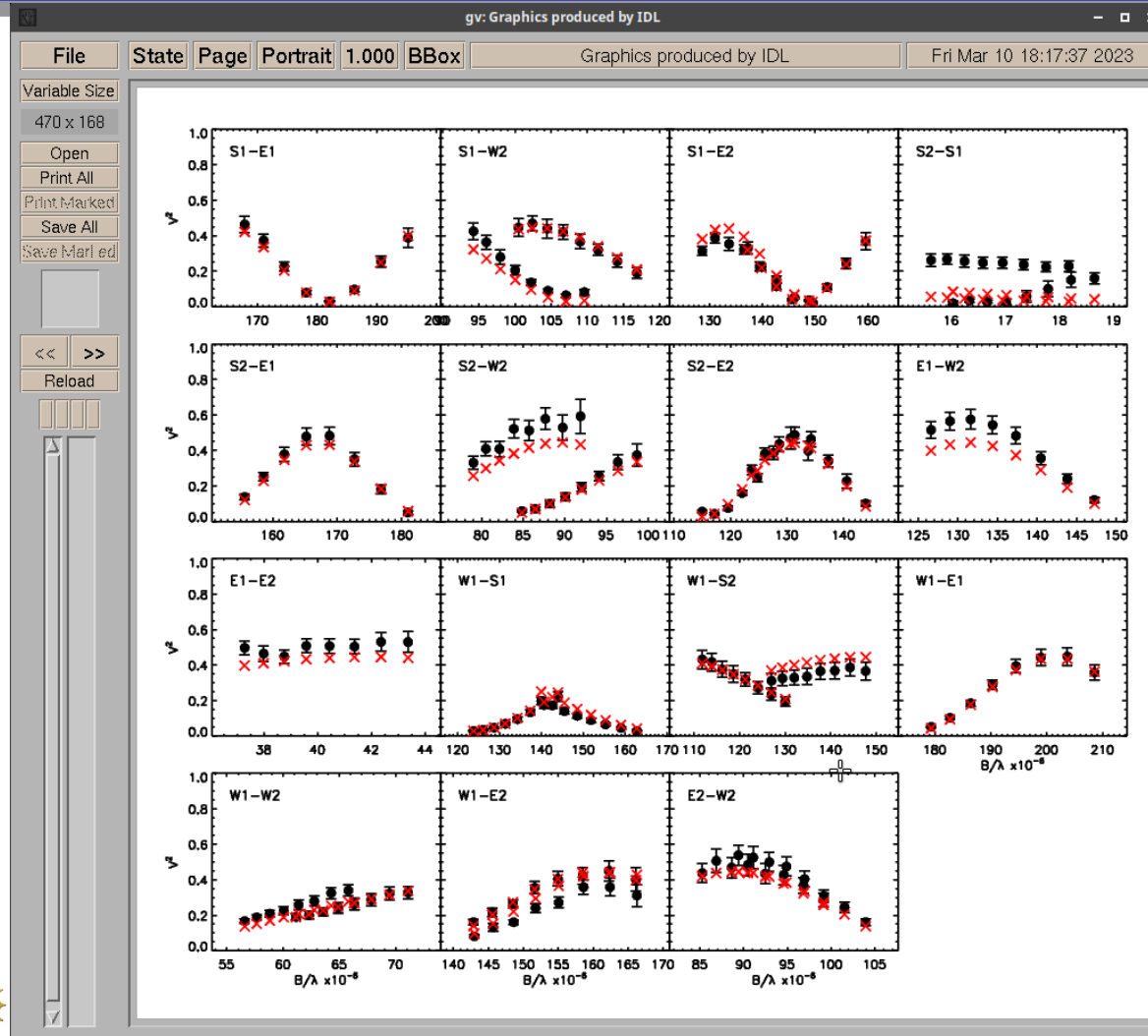

Look at chi2 map: gv temp.eps





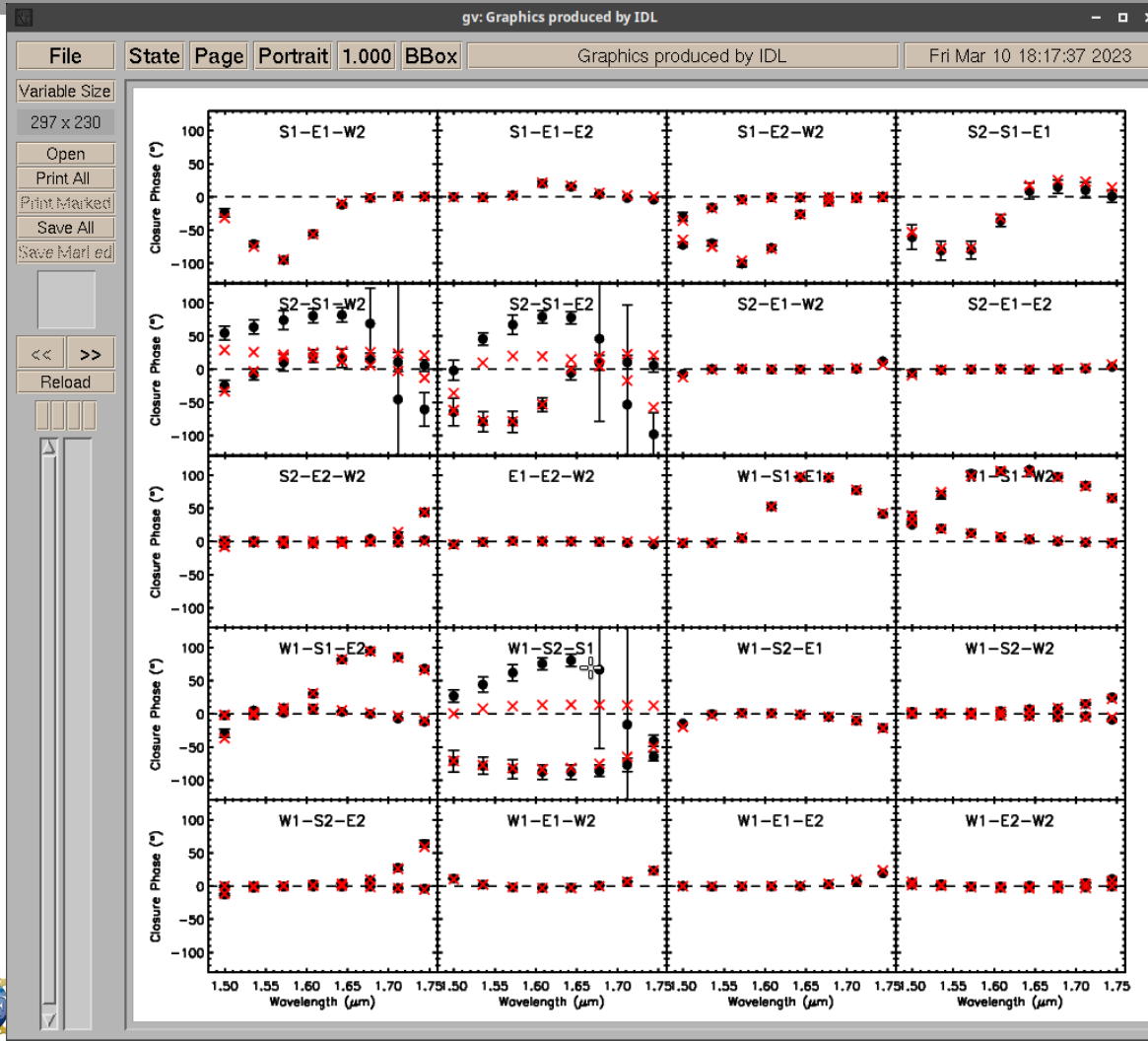
Look at fit to visibilities:

gv 2011Sep29_01_MIRC_sigOri_Schaefer_2016_vis2.eps





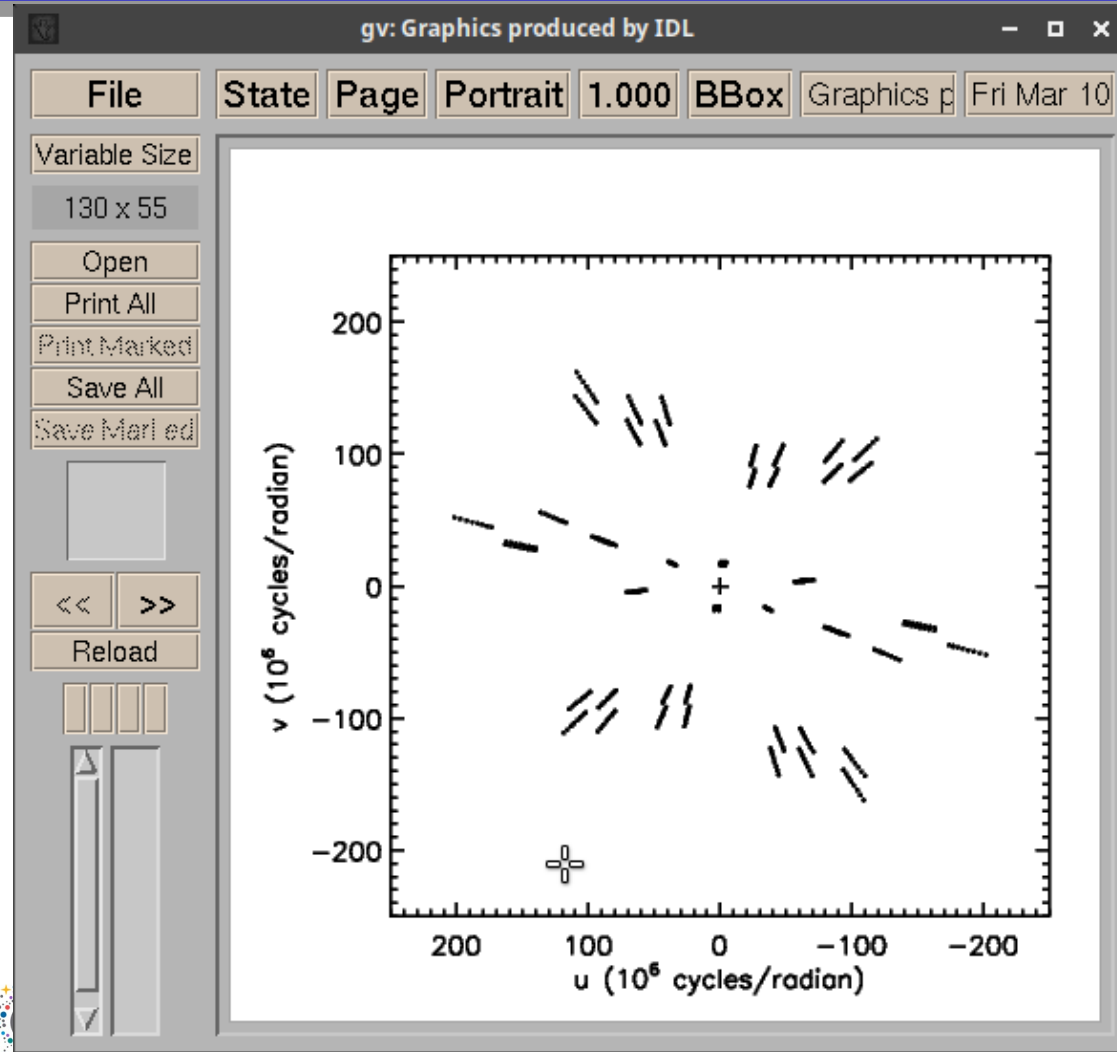
Look at fit to closure phases: gv 2011Sep29_01_MIRC_sigOri_Schaefer_2016_t3.eps





Look at uv coverage:

gv 2011Sep29_01_MIRC_sigOri_Schaefer_2016_uv_lam.eps





Additional Questions/Tasks

- Why are there two solutions in the χ^2 map?
 - Hint: Run a smaller fit centered on each solution.
 - Compare flux ratios for each solution.
- Map out detail of the χ^2 map near the solution
 - Set sepRA and sepDEC to the best fit value
 - Click fixed box sepRA and sepDEC to hold values fixed at each step in the grid
 - Use small search range (few times error bars) and small step size