IDL Binary Grid Search



NOIR Lab

Gail Schaefer

CHARA Array of Georgia State University

IDL Grid Search

















Binary Grid Search — Mozilla Firefox

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<u>File Edit View History Bookmarks Tools Help</u>

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



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Adaptive Grid Search for Binary Stars

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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 he 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

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• 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.

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

- Copy lota 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 Sig Ori data to local directory:
 - cp /dbstorage/workshop_data/MIRC_sigOri_Schaefer_2016/* .
 - 2011Sep29_01_MIRC_sigOri_Schaefer_2016.oifits













Examine lota 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 lota Peg
 - What signatures do you see in the data?
 - Binary?
 - Resolved diameter?
 - Background flux?













MIRC-X Data on lota 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='lota_Peg_Merged.fits', infiles=['2018Oct22_06_MIRCX_iotaPeg_Anugu_2020.fits', '2018Oct22_07_MIRCX_iotaPeg_Anugu_2020.fits']
- Merged output file: lota_Peg_Merged.fits







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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	h Parameters	5					×
pen Param File	Ĭ									
elect Data File	2011Sep29_01	L_MIRC_sigOri_	Schaefer_20:	16.oifits						-
nitial Binary Par	rameters									
sepRA (mas):	Þ.0	☐ Fix	Companion is	s located at	(sepRA, se	epDEC) in ⊓	mas.			
sepDEC (mas):	p.0	Fix								
f1:	Þ.5	🔲 Fix	Flux contrib	bution of sta	ar 1 (value	es from O t	to 1). H	°1 + f2 + f3	3 = 1.0	
f2:	Þ.5	🔲 Fix	Flux contrib	bution of sta	ar 2 (valu	es from O t	to 1).			
f3:	p.0	☐ Fi×	Incoherent f	flux (values	from O to	1). Fix t	to 0 if no	incoherent	flux.	
Diam1 (mas):	p.0	Fix	Diameters of	f star 1 and	star 2 (in	n mas)				
Diam2 (mas):	þ.0	Fix	For unresolv	ved diameters	s, fix to (0 or fix to	o estimate	d size.		
mu1:	Þ.0	Fix	Limb-darken:	ing coefficie	ents.					
mu2:	þ.o	🗖 Fix	For uniform	disk diamete	er, fix to	0.				
rid Search Parama	eters									
RA range (mas)): 20.0	RA st	ep (mas):	Þ.5]					
DEC range (ma:	s): 20.0	DEC s	tep (mas):	Ď.5]	\triangleright				
ır an adaptive gr	rid search, le	ave sepRA and	sepDEC as f	ree paramete	rs.					
r a grid search	at fixed inte	rvals, check t	the boxes to	∫fix sepRA a	nd sepIEC.					
∣Pseudo-adaptiv	ve grid At eau	ch grid point.	, optimize p	osition with	in a fixed	l box set b	by the step	size.		
⊒ Grid center at	t (0,0) Check	to center gr:	id search at	(0,0) rathe	r than (se	pRA,sepDEC	:).			
Include bandwi	idth smearing									
⊒ Fit V2 only	🗐 Fit T3 only	y If unclicke	ed then fit	to both V2 a	nd T3 data	•				
ave Param File	temp_param.tx	t								
Run Grid	Search									
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NOTE: lota Peg files are big and take a long time to fit. Sig Ori file will give faster results.

Load OIFITS File

			Grid Search Parameters – D
Open Param File	Ĭ		
Select Data File	2011Sep29_0)1_MIRC_sigO	ri_Schaefer_2016.oifits
nitial Binary Par	ameters		
sepRA (mas):	Ď.0	☐ Fix	Companion is located at (sepRA, sepDEC) in mas.
sepDEC (mas):	þ.0	☐ Fix	
f1:	Þ.5	☐ Fix	Flux contribution of star 1 (values from 0 to 1). $f1 + f2 + f3 = 1.0$
f2 :	þ.5	☐ Fix	Flux contribution of star 2 (values from 0 to 1).
f3:	þ.0	☐ Fix	Incoherent flux (values from 0 to 1). Fix to 0 if no incoherent flux.
Diam1 (mas):	þ.0	Fix	Diameters of star 1 and star 2 (in mas)
Diam2 (mas):	Þ.0	Fix	For unresolved diameters, fix to 0 or fix to estimated size.
mu1:	þ.0	Fix	Limb-darkening coefficients.
mu2:	.0	Fix	For uniform disk diameter, fix to 0.
Grid Search Parame	ters		
RA range (mas)	20.0	RÂ	step (mas): 0.5
DEC range (mas): 20.0	DE	C step (mas): 0.5
or an adaptive gr	id search, l	eave sepRA a	and sepIEC as free parameters.
or a grid search	at fixed int	ervals, chec	sk the boxes to fix sepRA and sepDEC.
🔲 Pseudo-adaptiv	e grid At e	ach grid poi	nt, optimize position within a fixed box set by the step size.
□ Grid center at	(0,0) Check	k to center	grid search at (0,0) rather than (sepRA,sepJEC).
🗖 Include bandwi	dth smearing		
□ Fit V2 only	□ Fit T3 on	ly If uncli	cked then fit to both V2 and T3 data.
Save Param File	temp_param.t	xt	
Run Grid	Search		
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Initial Binary Separation in RA and DEC

		Grid Search Parameters – 🗆 🗙
Open Param File	Ĭ	
Select Data File	2011Sep29_01_M	IRC_sigOri_Schaefer_2016.oifits
Initial Binary Par	ameters	
sepRA (mas):	.0	□ Fix Companion is located at (sepRA, sepDEC) in mas.
sepDEC (mas):	.0	II Fix
f1:	.5	\Box Fix Flux contribution of star 1 (values from 0 to 1). f1 + f2 + f3 = 1.0
f2:	Ď.5	□ Fix Flux contribution of star 2 (values from 0 to 1).
f3:	0.0	□ Fix Incoherent flux (values from 0 to 1). Fix to 0 if no incoherent flux.
Diam1 (mas):	٥.0 <u>ۆ</u>	F Fix Diameters of star 1 and star 2 (in mas)
Diam2 (mas):	0.0	\blacksquare Fix \blacksquare For unresolved diameters, fix to 0 or fix to estimated size.
mu1:	0.0	Fix Limb-darkening coefficients.
mu2:	0.0	Fix For uniform disk diameter, fix to 0.
Grid Search Parame	eters	
RA range (mas)	20.0	RA step (mas): 0.5
DEC range (mas	e): 20.0	DEC step (mas): [0.5
For an adaptive gr	rid search, leave	sepRA and sepDEC as free parameters.
For a grid search	at fixed interva	ls, check the boxes to fix sepRA and sepDEC.
🔲 Pseudo-adaptiv	e 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,sepIEC).
🗖 Include bandwi	dth smearing	
□ Fit V2 only	⊒ Fit T3 only	If unclicked then fit to both V2 and T3 data.
Save Param File	temp_param.txt	
Run Grid	Search	





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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

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Open Param File	Ĭ	
Select Data File	2011Sep29_01_MIRC_sig	Ori_Schaefer_2016.oifits
Initial Binary Par	ameters	
sepRA (mas):	Ď.0 □ Fix	Companion is located at (sepRA, sepDEC) in mas.
sepDEC (mas):	0.0 □ Fix	
f1:	0.5 □ Fix	Flux contribution of star 1 (values from 0 to 1), f1 + f2 + f3 = 1.0
f2:	0.5 □ Fix	Flux contribution of star 2 (values from 0 to 1).
f3:	j0₊0 II Fix	Incoherent flux (values from 0 to 1). Fix to 0 if no incoherent flux.
Diam1 (mas):	Ď₊0	Diameters of star 1 and star 2 (in mas)
Diam2 (mas):	Ď₊0	For unresolved diameters, fix to 0 or fix to estimated size,
mu1:	Ď.0	Limb-darkening coefficients.
mu2:	Ď.0	For uniform disk diameter, fix to 0.
Grid Search Parame	ters	
RA range (mas)	: 20.0 R	A step (mas): 0.5
DEC range (mas): 20.0 D	EC step (mas): 0.5
For an adaptive gr	id search, leave sepRA	and sepDEC as free parameters.
For a grid search	at fixed intervals, che 	eck the boxes to fix sepRA and sepDEC.
🖵 Pseudo-adaptiv	e grid At each grid po	pint, 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 bandwig	dth smearing	
□ Fit V2 only	⊒ Fit T3 only If uncl	licked then fit to both V2 and T3 data.
Save Param File	temp_param.txt	
Run Grid S	Search	







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Initia	Diameters.
IIIIIIa	Diameters.

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

	Grid Search Parameters – 🗆 🗙
Open Param File	Y.
Gelect Data File	2011Sep29_01_MIRC_sigOri_Schaefer_2016.oifits
nitial Binary Par	ameters
sepRA (mas):	0.0 Fix Companion is located at (sepRA, sepDEC) in mas.
sepDEC (mas):	0.0 IFix
f1:	D.5 Fix Flux contribution of star 1 (values from 0 to 1). f1 + f2 + f3 = 1.0
£2+	10.5 Elux contribution of star 2 (values from 0 to 1)
12.	
f3:	0.0 Incoherent flux (values from 0 to 1). Fix to 0 if no incoherent flux.
Diam1 (mas):	▶.0 Fix Diameters of star 1 and star 2 (in mas)
Diam2 (mas):	▶ 0 Fix For unresolved diameters, fix to 0 or fix to estimated size.
mu1:	0.0 Fix Limb-darkening coefficients.
mu2:	0.0 Fix For uniform disk diameter, fix to 0.
Grid Search Parame	ters
RA range (mas)	: 20.0 RA step (mas): 2.5
DEC range (mas): 10.0 DEC step (mas): 10.5
or an adaptive gr	id search, leave sepRA and sepIEC as free parameters.
or a grid search	at fixed intervals, check the boxes to fix sepRA and sepDEC.
🔲 Pseudo-adaptiv	e 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 bandwi	th smearing
□ Fit V2 only	□ Fit T3 only If unclicked then fit to both V2 and T3 data.
Save Param File	temp_param.txt
Run Grid	Search

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	Open Param File
	Select Data File 2011Sep29_01_MIRC_sig0ri_Schaefer_2016.oifits
	Initial Binary Parameters
	sepRA (mas): D.O Fix Companion is located at (sepRA, sepDEC) in mas.
	sepDEC (mas): 0.0
	f1: [0.5] Flux contribution of star 1 (values from 0 to 1). f1 + f2 + f3 = 1.0
	f2: [0.5] Fix Flux contribution of star 2 (values from 0 to 1).
	f3: [0.0 Incoherent flux (values from 0 to 1). Fix to 0 if no incoherent flux.
	Diam1 (mas): D.O Fix Diameters of star 1 and star 2 (in mas)
	Diam2 (mas): D.O Fix For unresolved diameters, fix to 0 or fix to estimated size.
	mu1: D.O Fix Limb-darkening coefficients.
	mu2: 0.0 Fix For uniform disk diameter, fix to 0.
	Grid Search Parameters
arch Range and 📃 💦 📐	RA range (mas): 20.0 RA step (mas): 0.5
on Sizo	DEC range (mas): 20.0 DEC step (mas): 5
ep size	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 sepIEC.
	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).
	F Include bandwidth smearing
	Fit V2 only Fit T3 only If unclicked then fit to both V2 and T3 data.
	Save Param File temp_param.txt
	Run Grid Search

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	Grid Search Parameters – 🗆 🗙
Open Param File	Y MA
Select Data File	2011Sep29_01_MIRC_sigOri_Schaefer_2016.oifits
Initial Binary Par	ameters
sepRA (mas):	0.0 Fix Companion is located at (sepRA, sepDEC) in mas.
sepDEC (mas):	0.0 🖬 Fix
f1:	Ď.5 □ Fix Flux contribution of star 1 (values from 0 to 1). f1 + f2 + f3 = 1.0
f2:	.5 Flux contribution of star 2 (values from 0 to 1).
f3:	0.0 Incoherent flux (values from 0 to 1). Fix to 0 if no incoherent flux.
Diam1 (mas):	0.0 Fix Diameters of star 1 and star 2 (in mas)
Diam2 (mas):	0.0 Fix For unresolved diameters, fix to 0 or fix to estimated size.
mu1:	0.0 Fix Limb-darkening coefficients.
mu2:	0.0 Fix For uniform disk diameter, fix to 0.
Grid Search Parame	iters
RA range (mas)	: 20.0 RA step (mas): 0.5
DEC range (mas): 20.0 DEC step (mas): 0.5
For an adaptive gr	id search, leave sepRA and sepDEC as free parameters.
For a grid search	at fixed intervals, check the boxes to fix sepRA and sepJEC.
🔲 Pseudo-adaptiv	e 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,sepJEC).
🗖 Include bandwi	dth smearing
Fit V2 only	☐ Fit T3 only If unclicked then fit to both V2 and T3 data.
Save Param File	temp_param.txt
Run Grid	Search

IDL Grid Search



Click "Run Grid Search"













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

Terminal - schaefer@Chara-Reduction: ~/chara/mircx/lot_Peg

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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_sig0ri_Schaefer_2016.oifits
Initial Parameters:
sepRA 0.0
sepDEC 0.0
f1 0.5
f2 0.5
f3 0.0
diaml 0.0 F
diam2 0.0 F
mul 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.

IDL Grid Search

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Final Results are printed to the screen

Terminal - schaefer@Chara-Reduction: ~/chara/mircx/lot Peg ^ _ O X 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 1848.9745 All chi2: 440 4.2505161 V2 chi2: 916.45145 200 4.6997510 T3 chi2: 932.52305 3.9681832 240 Number of free parameters: 5 Parameter Error sepRA -2.7699620 0.0019796831 sepDEC -5.6180827 0.0025241986 0.41709432 0.0035853982 f1 f2 0.25053392 0.0025564735 f3 0.33237176 -0.0000000 0.0000000 -0.0000000 diam1 -0.0000000 diam2 0.0000000 0.0000000 mu1 -0.0000000 mu2 0.0000000 -0.0000000 Close pair separation: 0.0024273430 6.2638281 +/-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% uncertaintiy 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: 0.0000000 0.0000000 Wavelength correction factor: 1.0000 -- No wavelength correction Fit includes bandwidth smearing. Fitting V2 and T3 data. Australian NOIR THE UNIVERSITY OF Dbservatoire LESIA Observatoire

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Look at chi2 map: gv temp.eps



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Look at fit to visibilities: gv 2011Sep29_01_MIRC_sigOri_Schaefer_2016_vis2.eps





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







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Look at uv coverage: gv 2011Sep29_01_MIRC_sigOri_Schaefer_2016_uv_lam.eps



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Additional Questions/Tasks

- Why are there two solutions in the chi2 map?
 - Hint: Run a smaller fit centered on each solution.
 - Compare flux ratios for each solution.
- Map out detail of the chi2 map near the solution
 - Set sepRA and sepDEC to the best fit value

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Click fixed box sepRA and sepDEC to hold values fixed at each step in the grid

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• Use small search range (few times error bars) and small step size



