JMMC-MAN-2300-0002

Revision 2.0

Date: 8 Jun 2010

JMMC

Tutorial of LITpro and corresponding JAVA GUI

Authors:
A. Domiciano de Souza et al. — FIZEAU

Author: A. Domiciano de Souza Institute: FIZEAU	Signature: SUBMITTED Date: 8 Jun 2010
Approved by: I. Tallon-Bosc Institute: CRAL	Signature: APPROVED Date: 2010
Released by: G. Duvert Institute: LAOG	Signature: RELEASED Date: 2010

Change record

Revision	**Date**	**Authors**	**Sections/Pages affected**
	Remarks		
0.1	22 oct 2008	Guillaume Mella	all
	First empty document		
0.2	30 mar 2009	Armando Domiciano	all
	Preliminary version		
0.3	16 jun 2009	Armando Domiciano	all
	Add comments from the modelfitting group members		
0.4	16 jun 2009	Guillaume Mella	all
	Perform modifications to follow jmmc latex style. File header changed , figure location srt in curren		
0.5	29 jun 2009	Armando Domiciano	all
	Update text and screenshots for first public version		
0.6	7 sep 2009	Guillaume Mella	all
	Add minor comments of Herve B.		
0.7	22 sep 2009	Guillaume Mella	figures
	Update figure layouts and add AD comments		
1.0	2 Oct 2009	DOCMGR	all
	Release with update of main software url		
1.1	8 Jun 2010	Armando Domiciano	
	Update Third example with use of T3phi		
2.0	8 Jun 2010	DOCMGR	
	Public Release		

Table of contents

List of Tables

List of Figures

1 Introduction

1.1 Object

This tutorial is intended to give some hints on the use of LITPro and the associated JAVA GUI via a few simple examples. We invite the reader to consult the User Manual of LITPro for a full description of the software.

LITPro itself and the corresponding documentation can be found at http://www.jmmc.fr/litpro.

1.2 Reference documents

[1] JMMC-MAN-0000-0003, Revision 2.0, LaTeXdocument style manual

1.3 Abbreviations and acronyms

JMMC	Jean-Marie Mariotti Center
LITpro	Lyon Interferometric Toolkit prototype

2 First example: Angular diameter of a single star

Let us start with a simple fit aiming to measure the angular diameter of a single star. We will use the real interferometric data obtained on the K giant star Arcturus (α Bootis; type spectral K1.5III; magnitude H of -2.8). The data, provided by Sylvestre Lacour, were recorded in the H band with the IOTA/IONIC interferometer. To download the data go to the web page http://apps.jmmc.fr/oidata and look for the data Set 1 (Arcturus). Download the file arcturus.1.79mu.oifits (oifits format) and save it in any suitable local directory in your computer.

2.1 Starting the GUI and begin creating new models

Start the JAVA GUI by clicking on the icon **LITpro** under the section **Run the Java Graphical User Interface**. After accepting the execution of the file LITpro.jnlp the first window of the JAVA GUI appears as in Fig. 1.

Choose *File* → *New settings...* in the menu bar to begin a new 'model' (in LITPro vocabulary). Alternatively, a new model can also be created by selecting CTRL+N in the keyboard or by clicking on the first icon (starting from the left) of the toolbar. This will open the panel showed in Fig. 2. In the left frame of the GUI there is a panel called *Settings tree* showing the tree structure of the model.

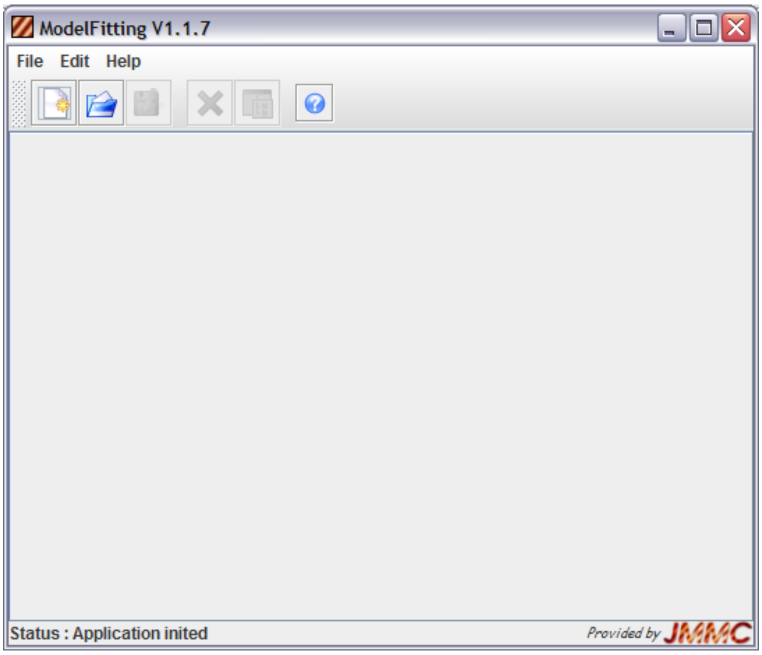

Figure 1: Initial page of the LITPro JAVA GUI.

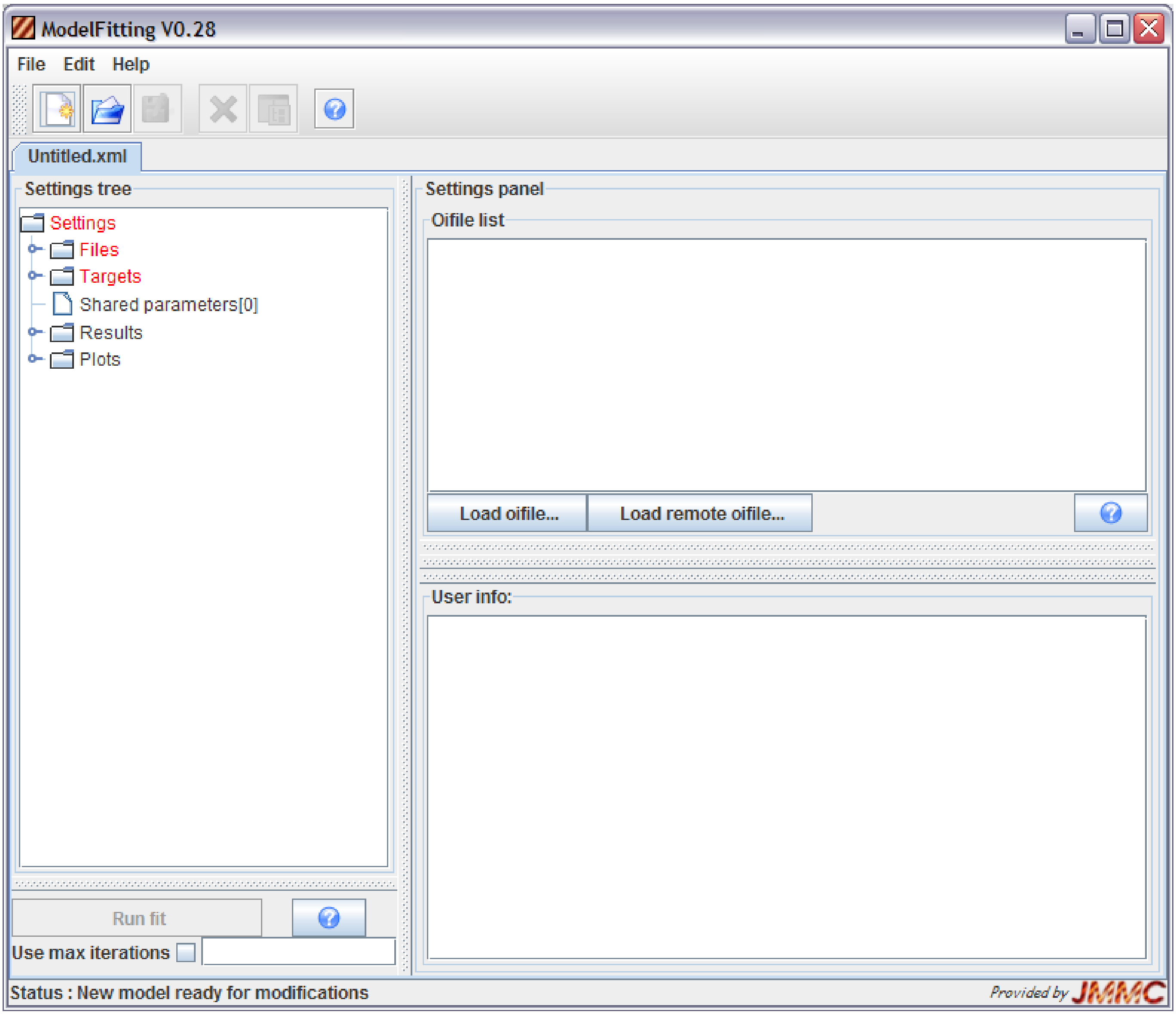

Figure 2: First panel to create a new model after choosing *File* → *New settings...* in the initial panel of the GUI (Fig. 1). Alternatively, a new model can also be created by selecting CTRL+N in the keyboard or by clicking on the first icon (starting from the left) of the toolbar.

2.2 Loading data files and choosing targets

To load the observational data of Arcturus (α Bootis) click on the $\boxed{\text{Load remote oifile...}}$ or $\boxed{\text{Load oifile...}}$ button in the upper right frame named *Settings panel* (many oidata files can be uploaded to the GUI, their filenames often have *fits* or *oifits* extensions). If you choose the $\boxed{\text{Load oifile...}}$ button, then you need to search and select the oifits file (arcturus.1.79mu.oifits) already downloaded into your computer. An automatic check of the validity of the oifits file is performed and a small window entitled *Test Status for PATH+FILENAME* is shown. If the file is valid then zero severe errors should be indicated (warnings can be accepted in most cases). After this file check is performed the GUI should look like in Fig. 3.

The name of the chosen oifits file appears in the *Settings tree* left panel (*Settings-Files*). To select the target to be treated (several targets could be present in principle) go to the *Target list* panel by following the tree *Settings-Targets*. Select the *alphaboo* target in this list (this is the only entry in our case) and click on the $\boxed{\text{Add new target}}$ button. The GUI should resemble such as in Fig. 4.

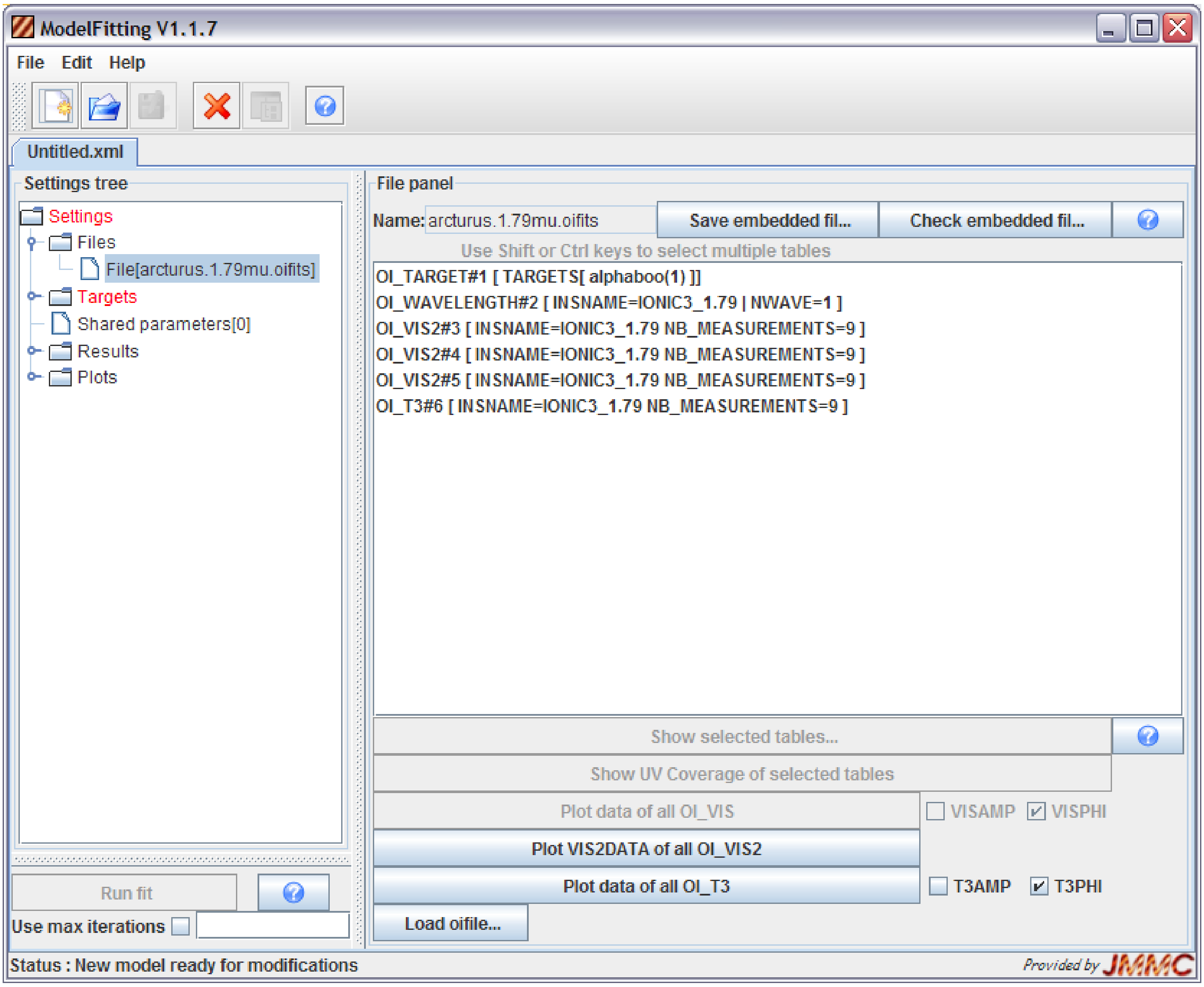

Figure 3: Appearance of the GUI after loading an oifits data file through the Load oifile... button or at any time we chose *Settings-Files-File[arcturus.1.79mu.oifits]* in the left frame .

The tables present in the oifits file can be viewed and plotted from the *File panel*, which can be reached by following the tree structure *Settings-Files-File[arcturus.1.79mu.oifits]* in the left frame (Fig. 3). As an example let us check the H band squared visibilities (V^2) of Arcturus versus the spatial frequency by clicking on the Plot VIS2DATA of all OI_VIS2 button. A plot like in Fig. 5 will appear, where one can also notice that the GUI changed automatically to the tree position *Settings-Plots-arcturus.1.79mu.oifits(VIS2DATA)* in the *Settings tree* left panel.

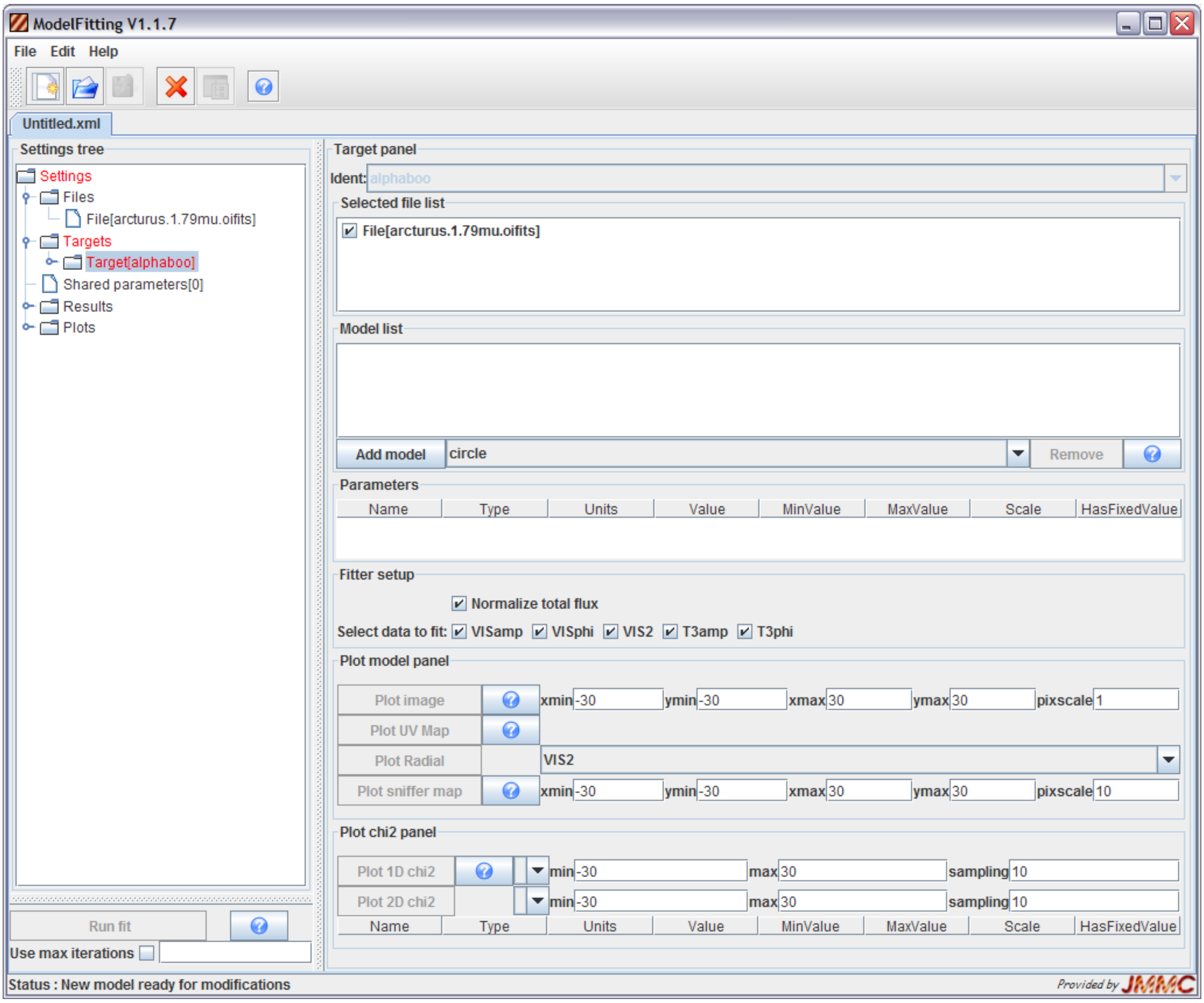

Figure 4: Appearance of the GUI after loading a target (*alphaboo* in this case) through the Add new target button in the *Target list* panel, which is found by following the tree *Settings-Targets* in the *Settings tree* left panel.

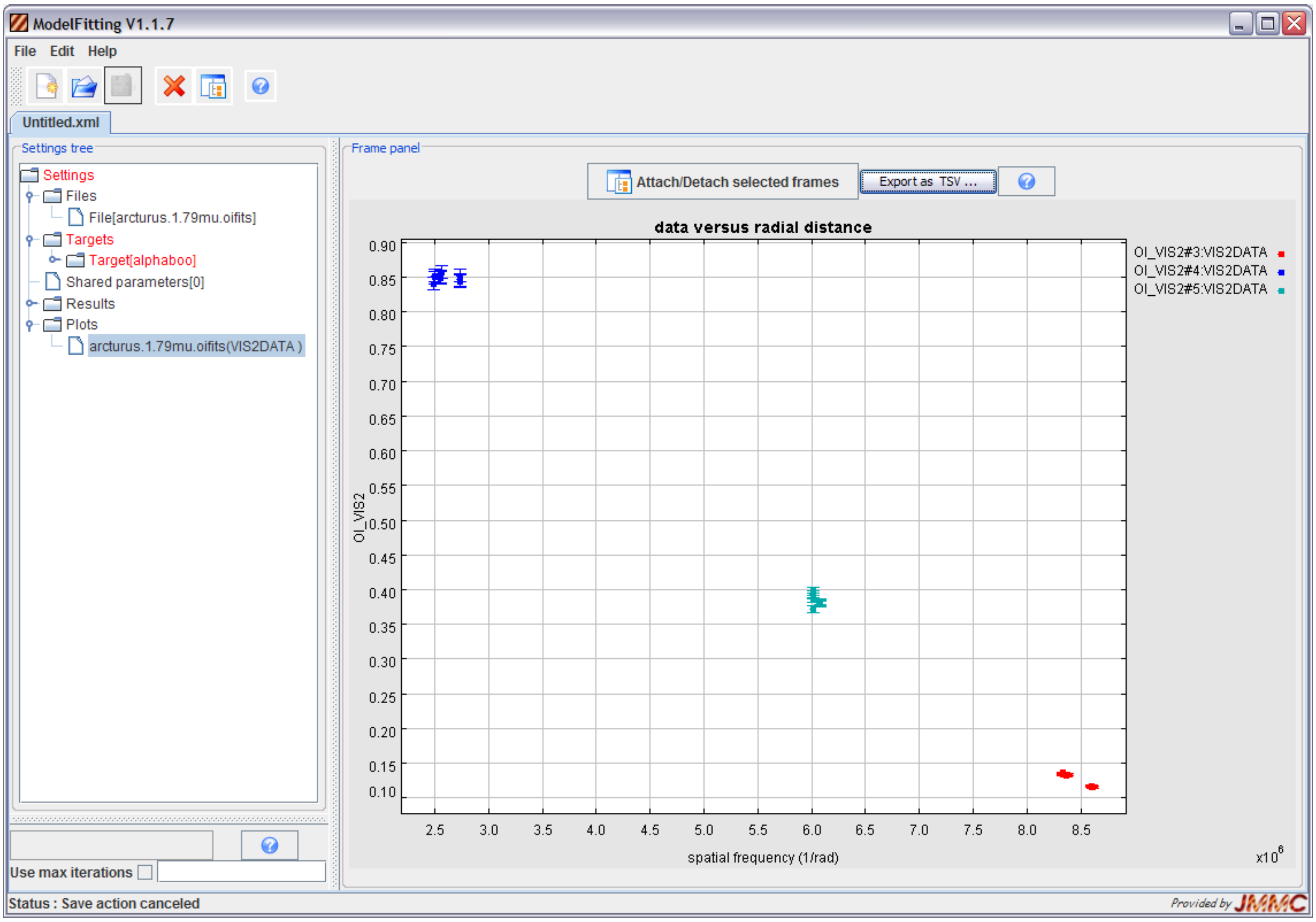

Figure 5: Data in the oifits files can be viewed and plotted from the *File panel* (follow the tree structure *Settings-Files-File[arcturus.1.79mu.oifits]* in this example). This plot showing the squared visibilities measured on Arcturus (V^2) was obtained by clicking on the $\boxed{\text{Plot VIS2DATA of all OI\_VIS2}}$ button. The V^2 (and corresponding uncertainties) are shown as a function of the spatial frequency (baseline length projected on the sky divided by the wavelength). One can zoom in and out this plot using the cursor (further details are given in the GUI user guide.)

2.3 Fit of a uniform disk model

Let us initially perform a fit of the Arcturus squared visibilities using a uniform disk model. By following the *Settings-Targets-Target[alphaboo]* tree structure we choose the model *disk*[1] in the *Model list* panel as shown in Fig. 6. Click on the Add model button to include it in the *Model list* panel (we remind the reader that several models can be included simultaneously if necessary).

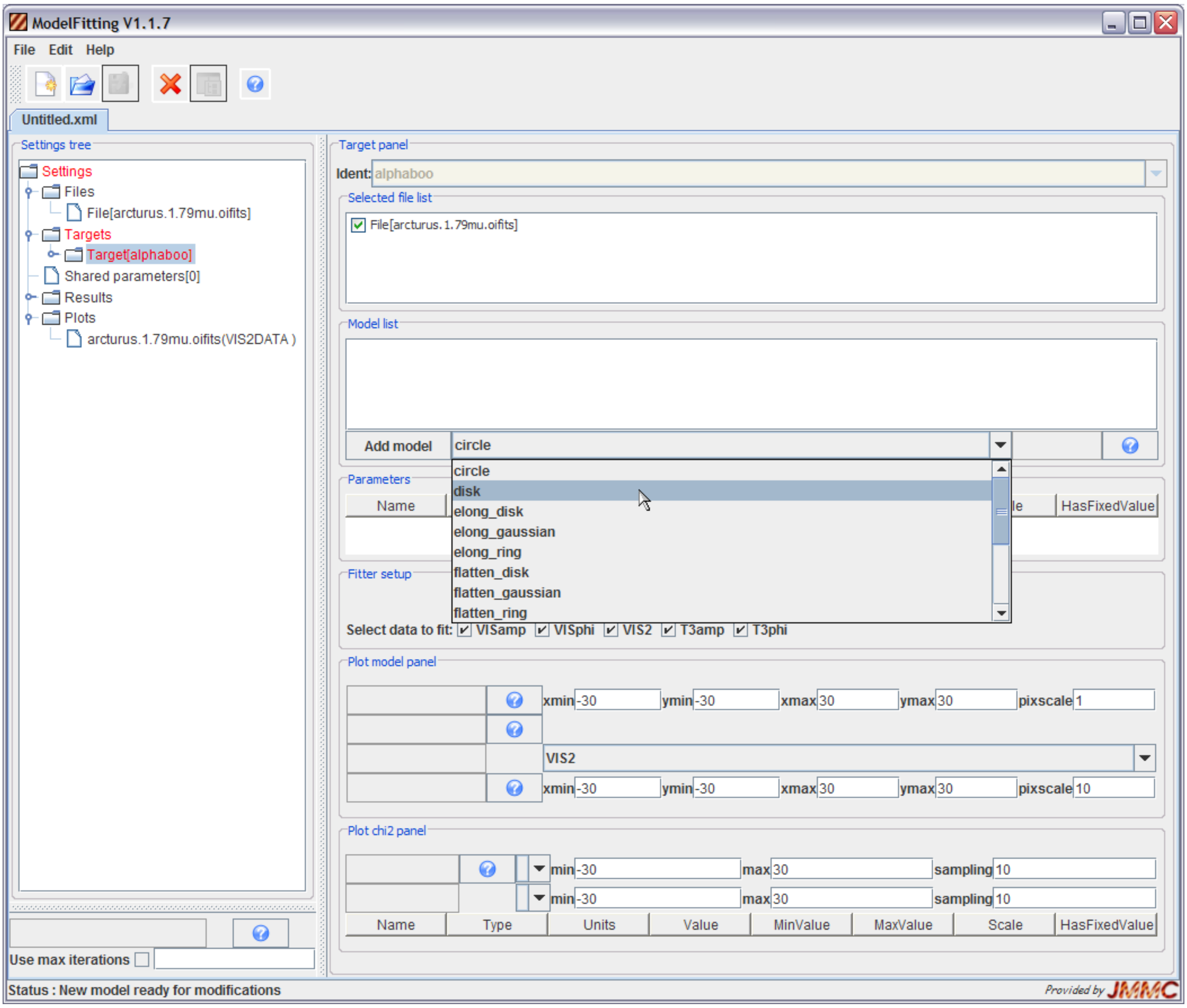

Figure 6: To fit a uniform disk to the Arcturus data choose the model *disk* in the scrolling list and click on the Add model button to include this model in the *Model list* panel.

Once the model is chosen it is necessary to set the initial and boundary parameter values of the model. This parameter setting is performed in the panel *Parameters*. An alternative way to reach this panel is to follow the tree structure *Settings-Targets-Target[alphaboo]-disk1*, where one can also find a brief description of the model is given in the panel *Description*. This panel can also be used to change the name and type of a chosen model. Fig. 7 shows the panel reached by following the tree structure *Settings-Targets-Target[alphaboo]*. Each line in the table shown in the panel *Parameters* corresponds to a parameter defining the uniform disk model (*disk1* in our case): *flux_weight1* (total stellar flux in arbitrary dimensions), *x1* (x

[1]The explanation of the models can be accessed from the ? button

position of the origin in mas), *y1* (y position of the origin in mas), and *diameter1* (stellar angular diameter in mas).

From the available data (squared visibilities V^2) and from the chosen model (uniform disk) the only parameter of the model that can be really constrained by the observations is the angular diameter (parameter *diameter1*). The stellar flux (*flux_weight1* parameter) and the absolute position of the star in the sky (*x1* and *y1* parameters) cannot be constrained by the present data set of interferometric observables. The user should always try to avoid fitting parameters that cannot be well constrained by the available data to prevent problems of unicity of solutions. Thus, in this example the values of the parameters *flux_weight1*, *x1* and *y1* are fixed by checking on the boxes in the column *HasFixedValue* (last column) and by setting their values to 1, 0 mas, and 0 mas, respectively, as indicated in Fig. 7.

As a first try for the fit let us set the parameter *diameter1* such that the initial guess for the angular diameter is *Value=10* mas. Moreover we set the lower and upper bounds for the fit to *MinValue*= 5 mas and *MaxValue*= 15 mas (Fig. 7).

Before starting the fit we need to define what data will be effectively used for the fit and if the total flux will be normalized or not. This is done with the check boxes in the panel *Fitter setup*. In this example we will normalize the total flux and perform the fit over the V^2 data alone, so that only the $VIS2$ box is checked on.

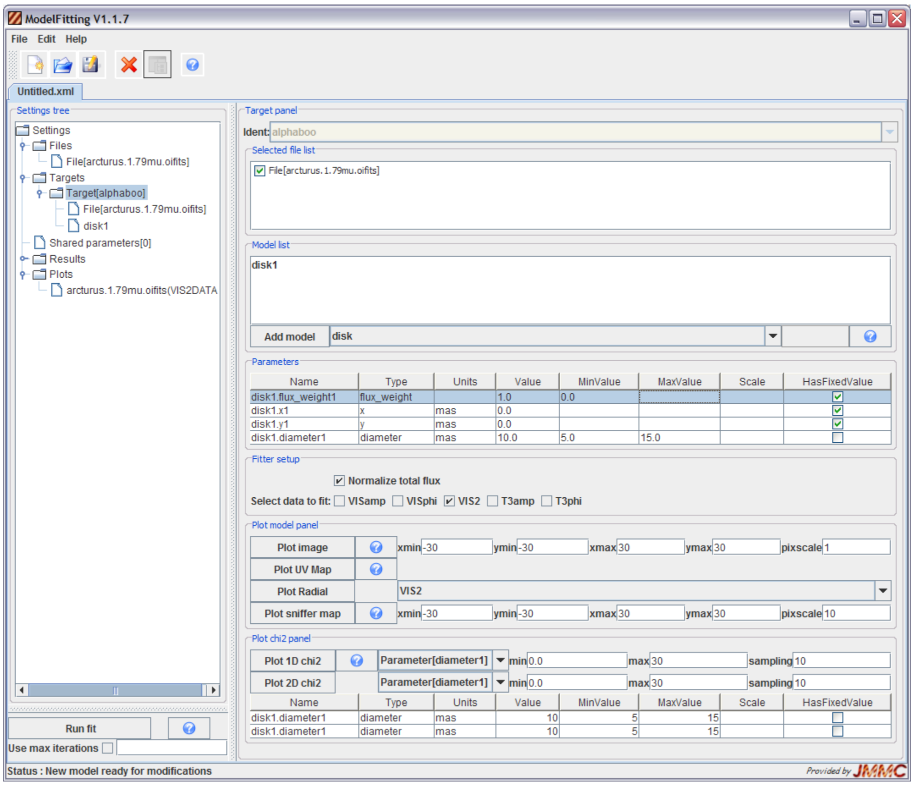

Figure 7: Setting the initial and boundary fitting values of the parameters of the uniform disk model.

The fit of the chosen model (uniform disk) can now be started simply by pushing the $\boxed{\text{Run fit}}$ button in the lower left frame. After a short time delay the GUI creates an entry in the tree structure *Settings-Results* called *Fit Result 0* (where 0 means that this is the fit try number 0). All values and plots resulting from the fit are gathered together in this structure. A general summary of the fit results is found at *Settings-Results-Fit Result 0*, as shown in Fig. 8 (top). This window shows several useful values from the fitting procedure such as Number of iterations, final parameter values and uncertainties, χ^2 of the fit, covariance and correlation matrices. Both, the extremely high value of the *Final reduced Chi2* ($\chi^2_{\rm red} \gg 1$) and the fact that the final value determined for the angular diameter is equal to the initial value indicate that there was a problem with the fit.

The quality of the fit can also be judged from the several plots available at *Settings-Results-Fit Result 0* (*plotBaselines, plotUVCoverage, vis2, vis2 residuals*). As an example let us check the plot called *vis2*, which shows the fitted squared visibilities V^2 together with the observed ones (Fig. 8 bottom). Clearly the model V^2 are too high compared to the observed values. The high $\chi^2_{\rm red}$ and the systematic high values of the model V^2 compared to the observations indicate that the angular diameter of the model is probably too high (the boundaries chosen for the parameter *diameter1* seem to be too restrictive).

Let us perform a new fit after re-defining the boundaries of *diameter1* to *MinValue=1* mas and *MaxValue=30* mas (follow the tree structure *Settings-Targets-Target[alphaboo]*). By clicking once more on the $\boxed{\text{Run fit}}$ button a new fit is performed and a new tree structure named *Settings-Results-Fit Result 1* then is created (Fig. 9). A *Final reduced Chi2* $\chi^2_{\rm red} \simeq 1$ is now much lower than before, indicating a much more satisfactory fit. The angular diameter derived (20.198 ± 0.022 mas) has a small relative uncertainty. One can see now that the value adopted for the upper boundary of the angular diameter was too low in the first try. The *vis2* plot now shows a very good agreement between the observed and measured V^2. In this case of a good fit the plot of the V^2 residuals normalized by σV^2 (*vis2 residuals*) is quite useful to check if there is a systematic trend between the model and the data. Fig. 9 (bottom) shows this V^2 residual plot for our uniform disk model fit. No clear trend is seen and the residual points are well distributed around zero with a small dispersion (roughly between $-1.2\sigma_{V^2}$ and $+1.2\sigma_{V^2}$). This is an additional indication of a good quality of the fit.

This is the end of our first example. If necessary, it is possible to save the fitting work for future use, with or without the results of the fit. To do so use the *File* menu and choose *Save settings...* (or click on the save icon) to save the present setting as a .xml file.

3 Second example: sharing parameters

This example explains how to share parameters between different models. To show this we will use visibility data from the K giant star Arcturus (α Bootis) taken at two distinct wavelengths (1.52 and 1.79 microns). The model to be fitted to these data is a wavelength-independent angular diameter with chromatic limb darkening coefficients.

Create a new setting as shown in Fig. 2 (further details in Sect. 2). Load both files (oifits files arcturus.1.52mu.oifits and arcturus.1.79mu.oifits) using the $\boxed{\text{Load remote oifile...}}$ or $\boxed{\text{Load oifile...}}$ button. To download manually the data go to the web page http://apps.jmmc.fr/oidata and look for the data Set 1 (Arcturus); download the oifits files
arcturus.1.52mu.oifits and arcturus.1.79mu.oifits (this one was already downloaded in example 1). Save them in any suitable local directory in your computer.

Go to the *Target list* panel by following the tree *Settings-Targets*. Choose the *alphaboo* target in this list (this is the only entry in our case) and click on the $\boxed{\text{Add new target}}$ button. Repeat this procedure once more in order to have two *alphaboo* entries in the *Target list* panel. Each entry will be correspond to a different data file. Follow the tree structure into each of the two *Settings-Targets-Target[alphaboo]*. In the *Selected file list* panel check/uncheck the boxes to select *File[arcturus.1.52mu.oifits]* in the first target structure and *File[arcturus.1.79mu.oifits]* in the second one. The GUI should look like Fig. 10.

Let us now choose the power-law limb darkening model to be fitted to the data. For each target (*Settings-Targets-Target[alphaboo]*) choose the *limb_power*[2] model in the *Model list* panel and click on the $\boxed{\text{Add model}}$ button to include it in the list. This procedure will create two new entries in the tree structure *Settings-Targets-Target[alphaboo]*: *limb_power1* and *limb_power2*. The two parameters panels show a table containing 5 lines corresponding to the parameters of each power-law limb darkening model (*limb_powerN*, where N is equal to 1 or 2): *flux_weightN* (arbitrary dimensions), *xN* (x position in mas), *yN* (y position in mas), *diameterN* (angular diameter in mas), and *powerN* (power of the limb darkening power law).

The next step is to define what are the fixed and free parameters of the models as well as their values and bounds. Since there is no available constraint to the flux intensity we fix *limb_power1.flux_weight1*

[2]The explanation of the models can be accessed from the $\boxed{?}$ button

and *limb_power2.flux_weight2* to 1 (check the boxes in the column *HasFixedValue*). The x and y positions are already fixed to 0 (star centered at the origin). Since we want to have the same angular diameter at both wavelengths we need to link *limb_power1.diameter1* and *limb_power2.diameter2*. To do so right-click on *diameter1* and choose *Share this parameter* in the menu as in Fig. 11. The name of this parameter is now changed to *diameter1* and this parameter appears in the *Shared parameters* list (see *Settings-Shared parameters* tree structure).

Based on the results in Sect. 2 set *Value*, *MinValue*, and *MaxValue* of *diameter1* to, 10, 1, and 30 mas, respectively. To define *limb_power2.diameter2* right-click on it and choose *Link to* → *diameter1* in the menu as in Fig. 12. We wish to allow the limb darkening parameter *power* to be distinct between the two wavelengths so that we set *Value* to 0.5, *MinValue* to 0.0, and *MaxValue* to 1.0 for both *limb_power1.power1* and *limb_power2.power2*.

Let us now define what data will be effectively used for the fit and if the total flux will be normalized or not. This is done with the check boxes in the panels *Fitter setup* of both files. We will not normalize the total flux since we already fixed it to 1 (then the normalize check box must not be checked). Choose the squared visibilities ($VIS2$) only to perform the fit.

All parameters are now defined and we can start the fitting engine. To avoid redefining all parameters again in the future the user may wish to save the present setting in a .xml file (*File* menu and *Save settings...*). In this example the present setting was saved as arcturus_1.52-1.79mu_tutorial.xml.

Start the fit by pushing the Run fit button in the lower left frame. After a few seconds the entry *Fit Result 0* containing the results appears in the tree structure *Settings-Results* (Fig. 13). To evaluate the fit quality one can check the parameter values and uncertainties, χ^2 of the fit, covariance and correlation matrices. The plot of the observed and modeled V^2 show a good agreement. The results of this example clearly indicate a good fit quality.

4 Third example: fit with degenerated parameters

This example explains how to:

- build a model from the combination of pre-defined simple models.
- perform a fit under unicity problems (degeneracy of parameters)

For this example we will use VLTI/AMBER data from the high-mass binary system θ^1 Ori C. To download the data go to the web page http://apps.jmmc.fr/oidata and look for the data Set 2 (theta Ori C); download the oifits files Theta1Ori2007Dec03_2.fits and Theta1Ori2007Dec05_2.fits. Save them in any suitable local directory in your computer.

Following the steps described in the previous sections, create a new setting, include the file Theta1Ori2007-Dec03_2.fits, and add the target T1ORIC. We wish to use a binary model to fit our data. However, there is not a binary model in the list of models (*Model list* panel). The idea is to combine two simple models (two Dirac delta functions) to build a more complex model (a binary in this case). To do so simply choose and add two *punct* models (Dirac delta) in the list. They will appear as *punct1* and *punct2* in the *Model list* panel[3].

To perform the fit we will fix the position of one binary component to the center, and allow the other component to be located between −30 mas and 30 mas both in x and y, starting from the origin. The flux ratio will be let free to vary and we will choose to normalize the total flux. As a first step the fit will be performed over $VIS2$ alone (squared visibilities). Before the starting the fit the *Target panel* window should look like in Fig. 14.

Start the fit by pushing the Run fit button in the lower left frame. The entry *Fit Result 0* containing the results appears in the tree structure *Settings-Results* (Fig. 15 top). By checking the χ^2 value and the uncertainties in the measured parameters it is clear that the fit did not work. This can be seen even more

[3]We note that, if necessary, the names and types of the individual models can be changed by double-clicking on them.

directly by checking the *vis2* plot, which shows a very poor agreement between the observed and measured V^2 (Fig. 15 bottom).

What is the origin of this bad fit quality? By checking the uncertainties in the fitted parameters we note that the position of the secondary star (*x2* and *y2*) is very poorly determined. This indicates that this parameters are probably not constrained by the data. Moreover, the high χ^2 value suggests that the parameter values are probably very far from the values leading to the best solution.

To investigate this idea let us create a χ^2 map as a function of *x2* and *y2*. This can be done in the bottom of the *Target panel* window (*Plot chi2 panel*). To create the χ^2 map choose the parameters *x2* and *y2* in the list and set their bounds (*min* and *max*) to -30 mas and 30 mas. In order to have enough resolution in the map choose *sampling* $= 100$. After pushing the Plot 2D chi2 button the χ^2 map is created in the tree structure *Settings-Plots-2D Chi2 Slice on x2 and y2* (Fig. 16). This map shows that the χ^2 presents several local minima as a function of *x2* and *y2*. In particular, there are two symmetrical and inclined bands presenting a low χ^2 values. From this map it is clear that the solution shown in Fig. 15 does not correspond to a region of minimum χ^2. Even if the χ^2 does not show a very clear minimum as a function of *x2* and *y2*, one can let the fitting engine search for a global minimum by setting starting values closer to the regions of lowest χ^2. The values of *x2* and *y2* corresponding to minimum χ^2 in the map are indicated in the map itself (Fig. 16).

Thus, one good choice for another fit with better starting values is simply to select the *x2* and *y2* indicated in the map and corresponding to the χ^2 minimum. Let us perform a new fit by setting $x2 = -17.88$ mas and $y2 = -2.12$ mas as initial values. The results of this new fit are shown in Fig. 17. The χ^2 value is now much lower than in the first try (Fig. 15). This is confirmed by the much better agreement between the modeled and observed V^2. Note that the fitting engine changed the position of the companion with regard to the initial values. But both the initial and final values of *x2* and *y2* lie on the linear band region of very low χ^2 (Fig. 16). This explains why the fit quality is much better now than in the first try where the fit converged to a local minimum.

However, even if we could find parameter values leading lower χ^2 values, it is clear from the χ^2 map that the present problem does not have a unique solution: it is a degenerated problem. This degeneracy translates also as large uncertainties on *x2* and *y2*. Different combinations of *x2* and *y2* lead to low χ^2 values if they correspond to values lying on the two dark and linear band regions in the χ^2 map (Fig. 16).

Degeneracy problems can arise from the fact that the available data is not able to constrain all the parameters of the model. Solutions to this problem could be to obtain additional data and/or use simpler models. Let us search for the origin of the degeneracy in our example. By checking the baselines used in the observations, or equivalently, the uv coverage of the data we can see that they are aligned (Fig. 18). This uv coverage spanning a line is the origin of the degeneracy problems found in during the fit. All binary separations leading to the same projection of visibilities along the line covered by the data in the uv plane will lead to a satisfactory fit. This is the origin of the dark linear band regions in the χ^2 map.

To attempt to remove at least part of this degeneracy we will include additional data before performing a new fit. Include the file Theta1Ori2007Dec05_2.fits in the *Settings-Files* tree structure. In the *Target panel* click on the corresponding check box to effectively include this file in the new fit.

As before, the χ^2 map will be used to determine the initial parameters of the fit. After setting the parameters in *Plot chi2 panel* as previously click on the Plot 2D chi2 button to create the map. Figure 19 shows the new χ^2 map, which can be compared with Fig. 16. The inclusion of new data removed the degeneracy. However, several local minima still exist so that it is important to consider the χ^2 map in order to start the fit from a set of parameters corresponding to a χ^2 close to the global minimum. Based on the χ^2 map, let us perform a fit over the new data by choosing the χ^2 minimum in the map as initial values: $x2 = 16.67$ mas and $y2 = 8.79$ mas.

The results of this new fit are shown in Fig. 20. This figure shows that the quality of the fit is good, even if the reduced χ^2 min is relatively high (81.5). Part of this high value is due to a relatively bad quality of the second data set. Another indication of a good quality of the fit is given by the much lower uncertainties on *x2* and *y2* in comparison with the previous tries. Note that the values of *x2* and *y2* determined are close to the initial values obtained from the χ^2 map. The degeneracy was thus removed by the new data set.

However, since we did not use any closure phase information for the fit there is still an ambiguity of 180° in the position of the companion. This can be clearly seen as the two lowest χ^2 regions in Fig. 19. These regions correspond to two possible solutions for *x2* and *y2*, which are symmetrical relative to the origin, i.e., $x2 \simeq \pm 16.4$ mas and $y2 \simeq \pm 9.1$ mas.

In order to remove this last degeneracy (ambiguity of 180°) we need to introduce an observable sensitive to the exact orientation of the binary on the sky. The closure phase presents a non zero signal in the case of non centrally symmetric intensity distributions (for example a binary with a flux ratio different from 1). We will thus simultaneously fit the squared visibilities ($VIS2$) and the closure phases ($T3phi$) for θ^1 Ori C (check the $T3phi$ box in the *Fitter setup* panel). Let us perform two fits with the following initial parameters corresponding to the two symmetrical positions of one binary component:

1. $punct1.flux_weight1 = 0.7$, $punct2.flux_weight2 = 0.3$, $punct2.x2 = 16.67$ mas, and $punct2.y2 = 8.79$ mas (this position corresponds to a position angle PA of 60°): reduced χ^2 min of 71.

2. $punct1.flux_weight1 = 0.7$, $punct2.flux_weight2 = 0.3$, $punct2.x2 = -16.67$ mas, and $punct2.y2 = -8.79$ mas (PA of 240°): reduced χ^2 min of 62.

Fig. 21 shows the fit of the closure phases for these two sets of parameters. By introducing the closure phases it was thus possible to determine a unique solution corresponding to a global minimum reduced χ^2 of 62. The positions and the fluxes of the binary were thus completely and unambiguously determined.

Fig. 22 shows the image of the binary (intensity and relative position) in the sky and the Fourier transform of this image together with the uv plane coverage of the data. To create these images click on the buttons *Plot image* and *Plot UV Map* in the *Plot model panel* in the *Settings-Targets-Target[T1ORIC]* tree structure.

Before finishing this example we note that the values derived for the relative positions of the binary components are in agreement with the expected values obtained from a work dedicated to θ^1 Ori C (see Kraus et al. 2009, A&A, 497, 195).

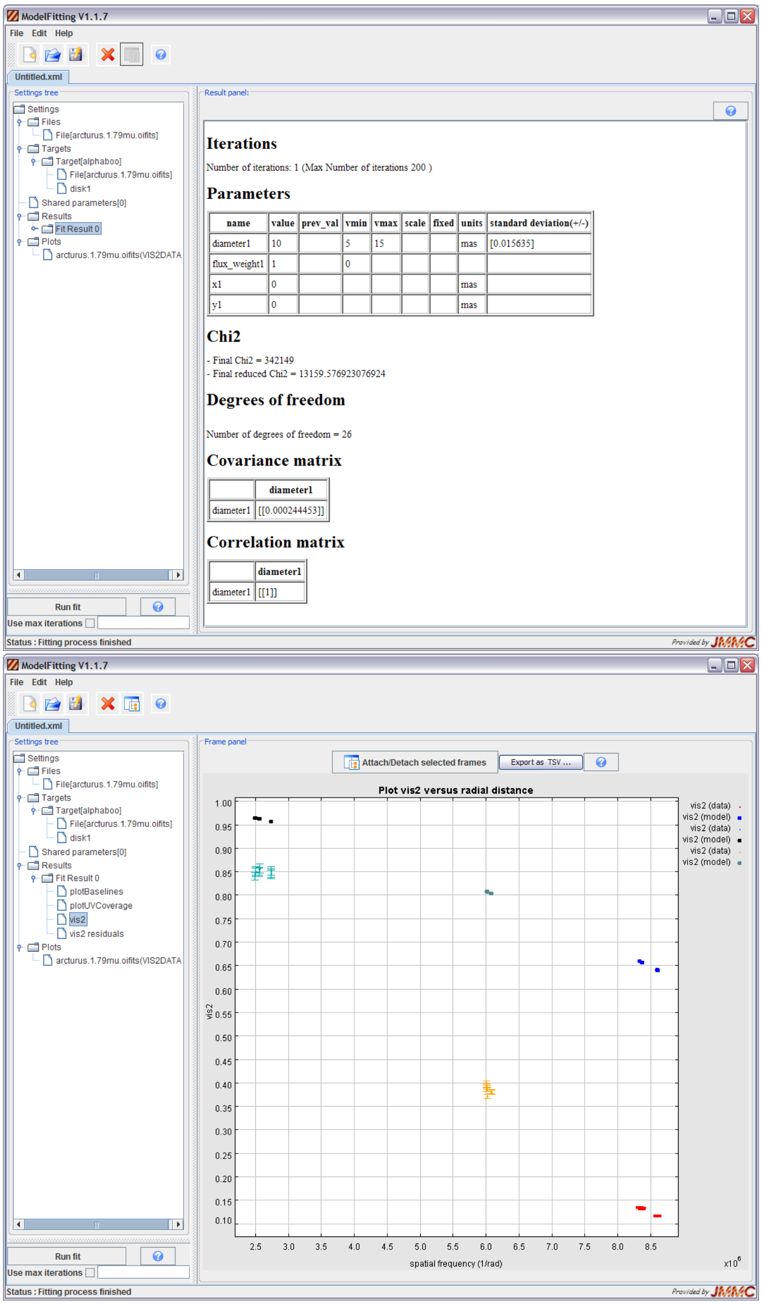

Figure 8: *Top:* Summary of the results obtained for the fit of the uniform disk model. *Bottom:* Plot of the fitted model squared visibilities V^2 together with the observed ones. This plot is accessed by choosing *vis2* in the tree structure *Settings-Results* at the left frame of the GUI. In this example the fit did not work well because the boundary limits for the angular diameter were too restrictive.

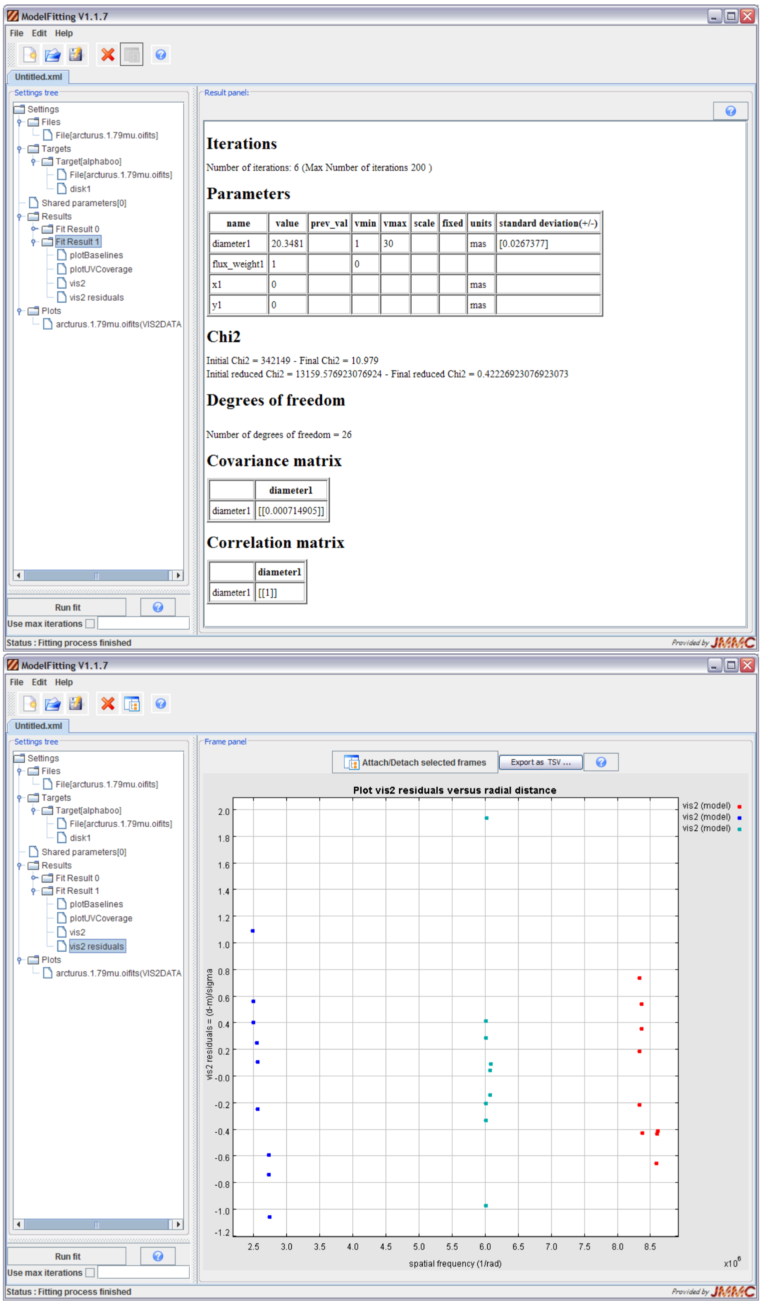

Figure 9: *Top:* Summary of the results obtained for the fit of the uniform disk model. In this example the fit much better than before, as indicated for example by the small value of the *Final reduced Chi2* $\chi^2_{\rm red} \simeq 1$. *Bottom:* Plot of the V^2 residuals of the fit, also indicating a good fit quality.

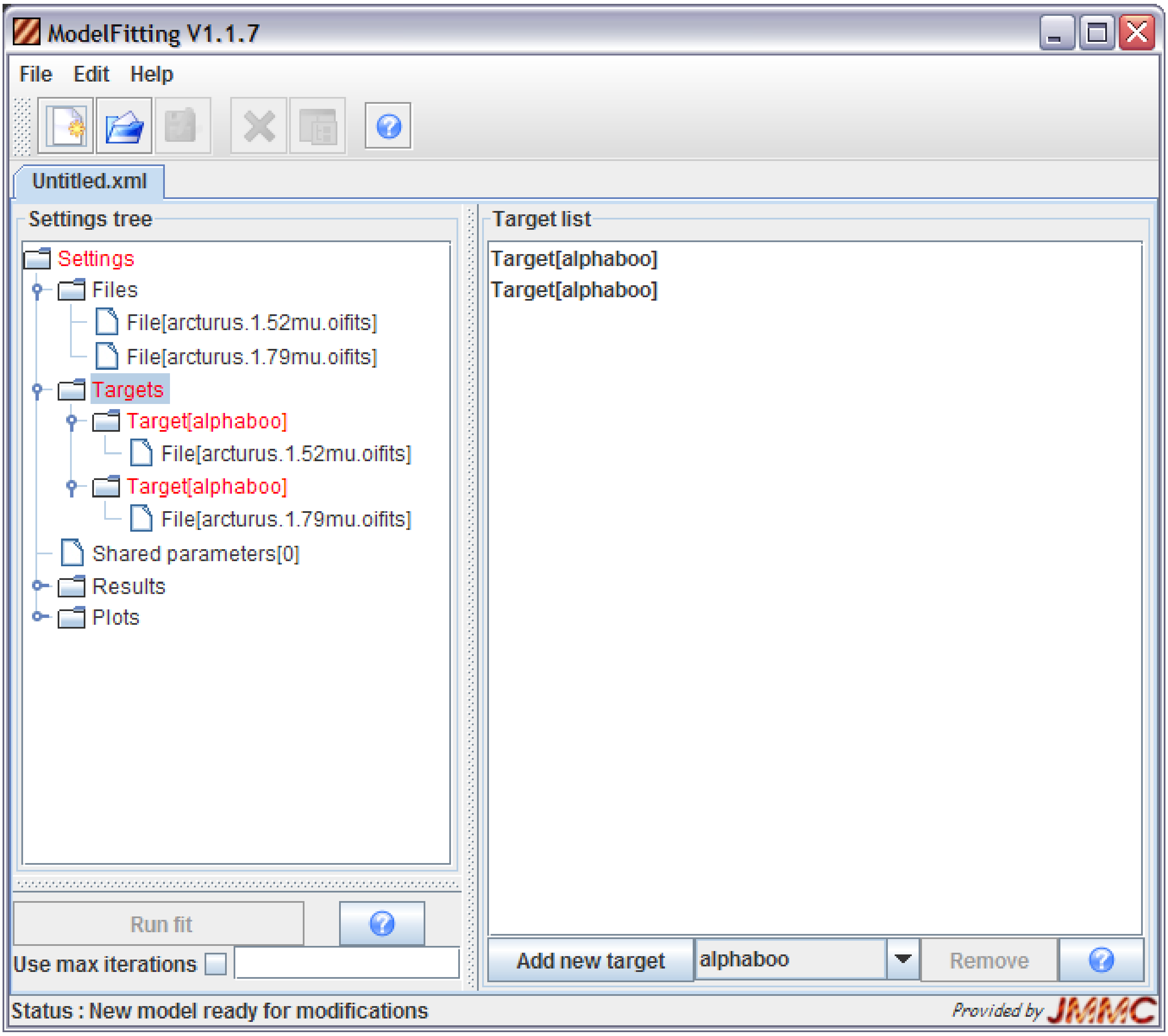

Figure 10: GUI after loading two oifits files and setting the corresponding *alphaboo* targets.

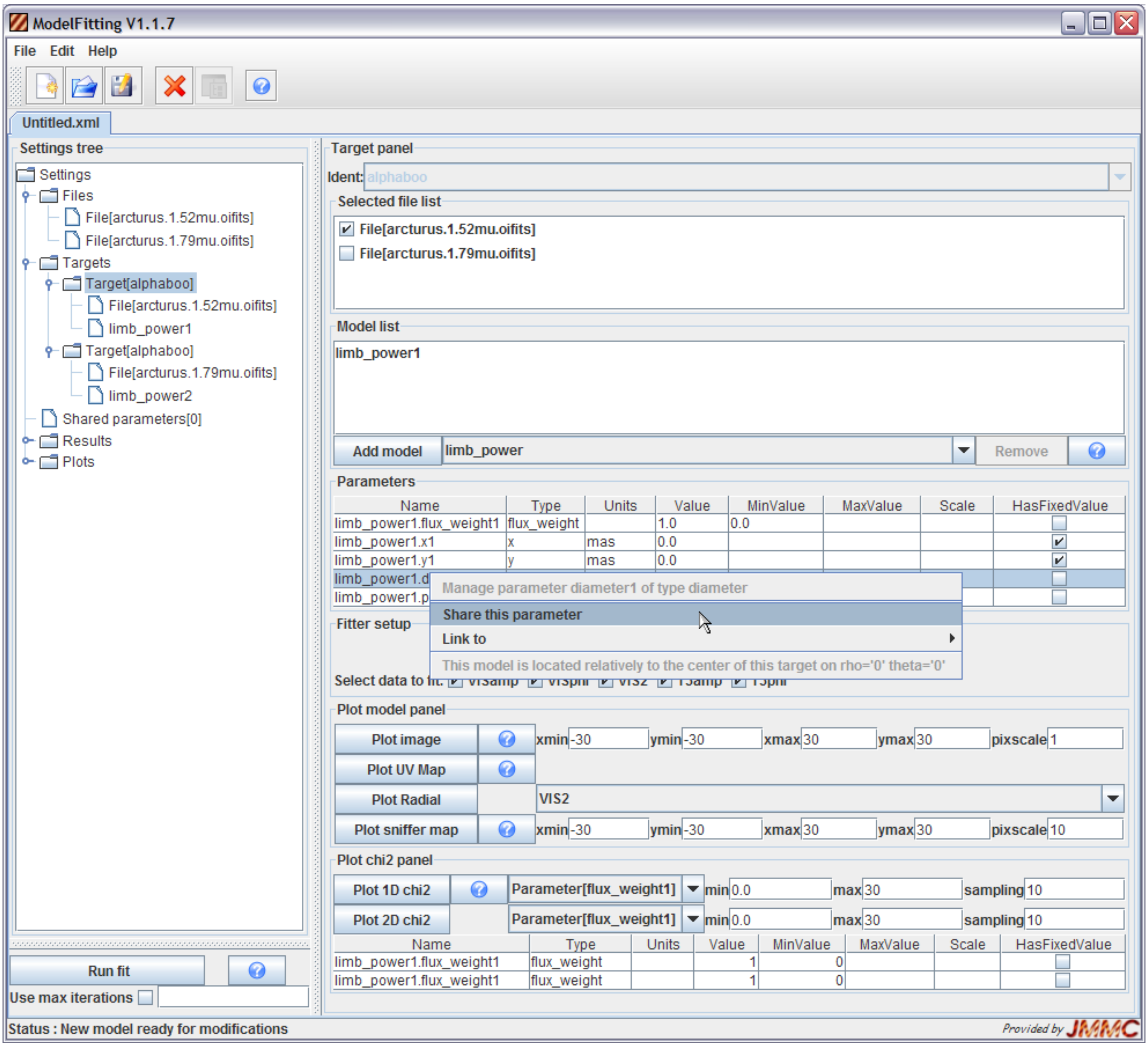

Figure 11: Share angular diameter parameter in order to have a wavelength-independent angular diameter.

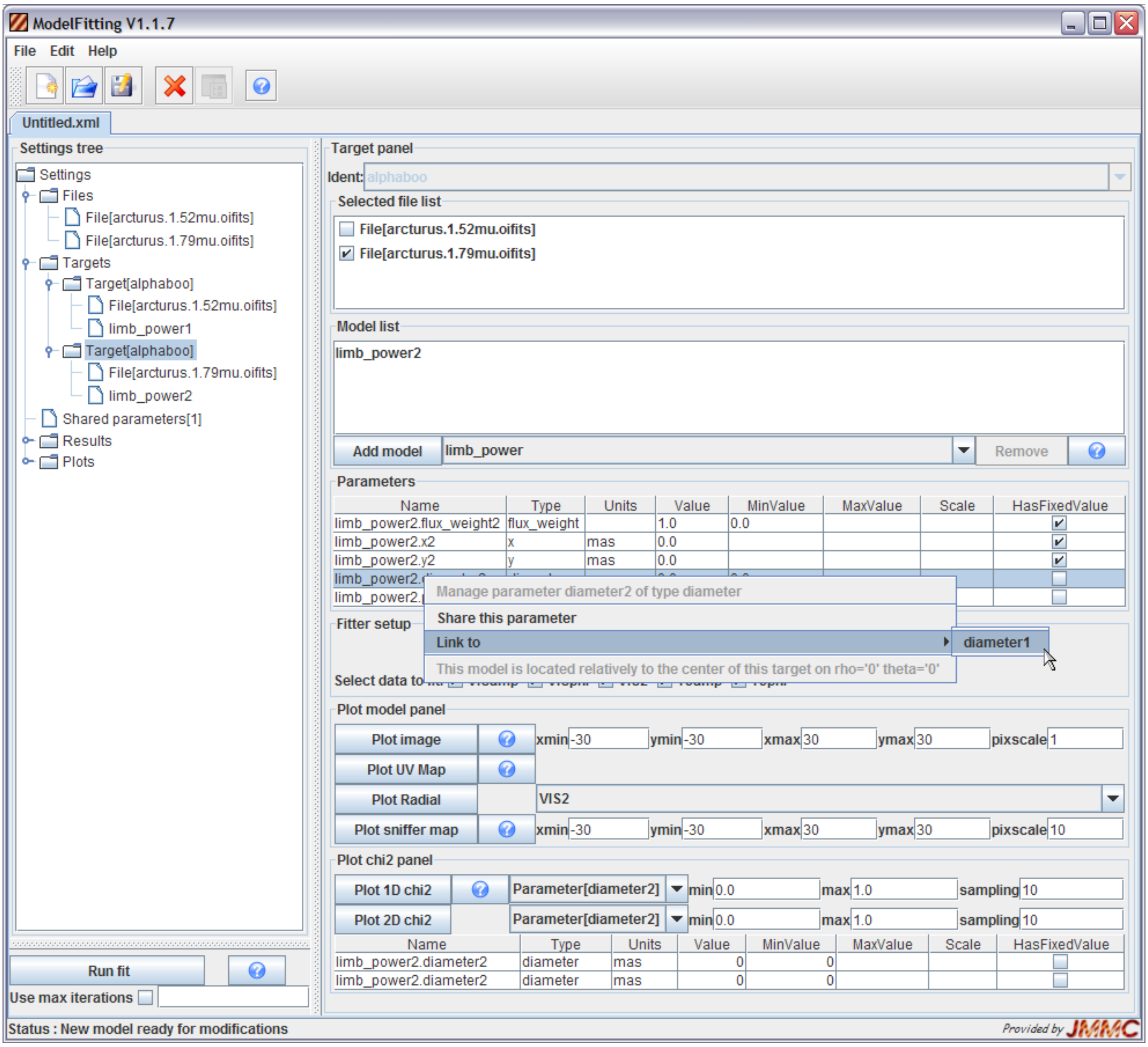

Figure 12: Link *limb_power2.diameter2* parameter to *diameter1* in order to have a wavelength-independent angular diameter.

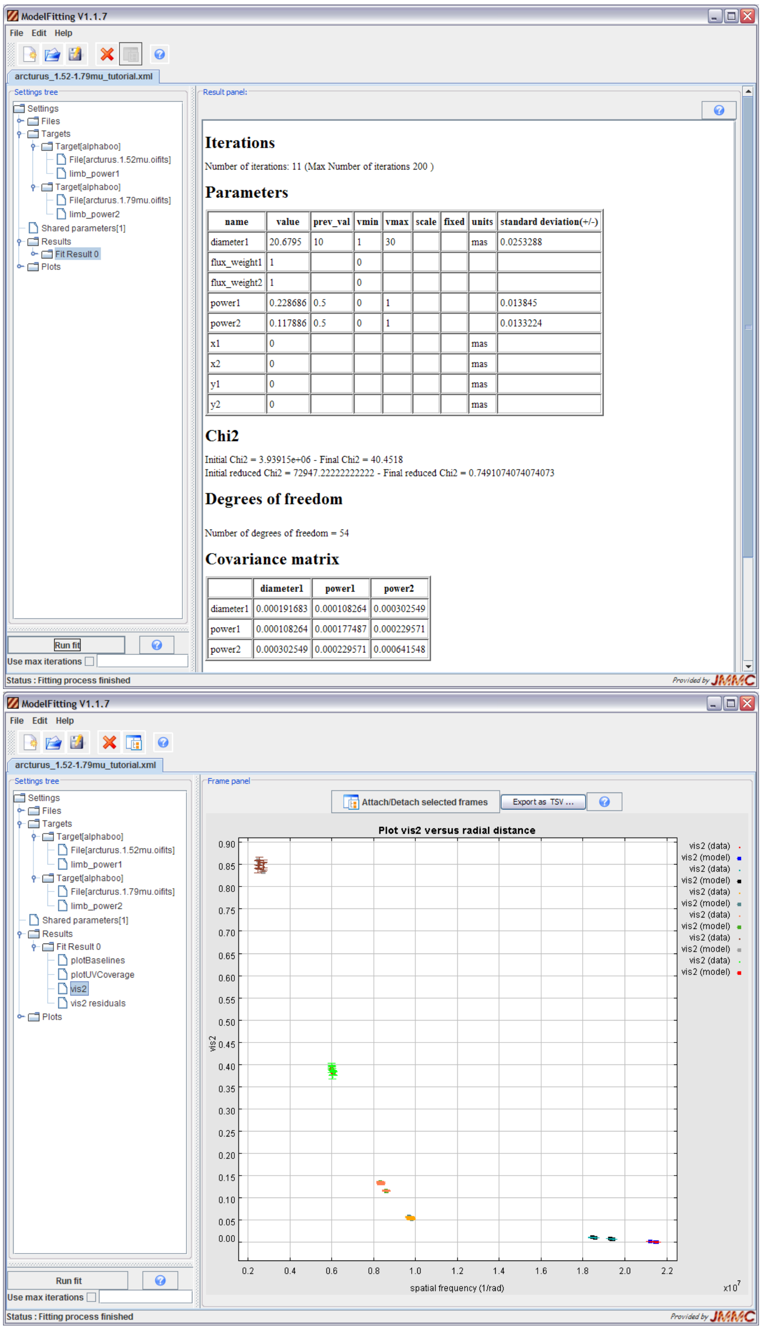

Figure 13: *Top:*Parameters derived from a fit of a limb-darkened disk over the Arcturus data. The low value of the *Final reduced Chi2*($\chi^2_{\mathrm{red}} \simeq 1$) and the relatively small uncertainties on the fitted parameters indicate a good quality for this fit. *Bottom:* Plot showing the nice agreement between the fitted squared visibilities V^2 and the observed ones. This plot is accessed by choosing *vis2* in the tree structure *Settings-Results* at the left frame of the GUI.

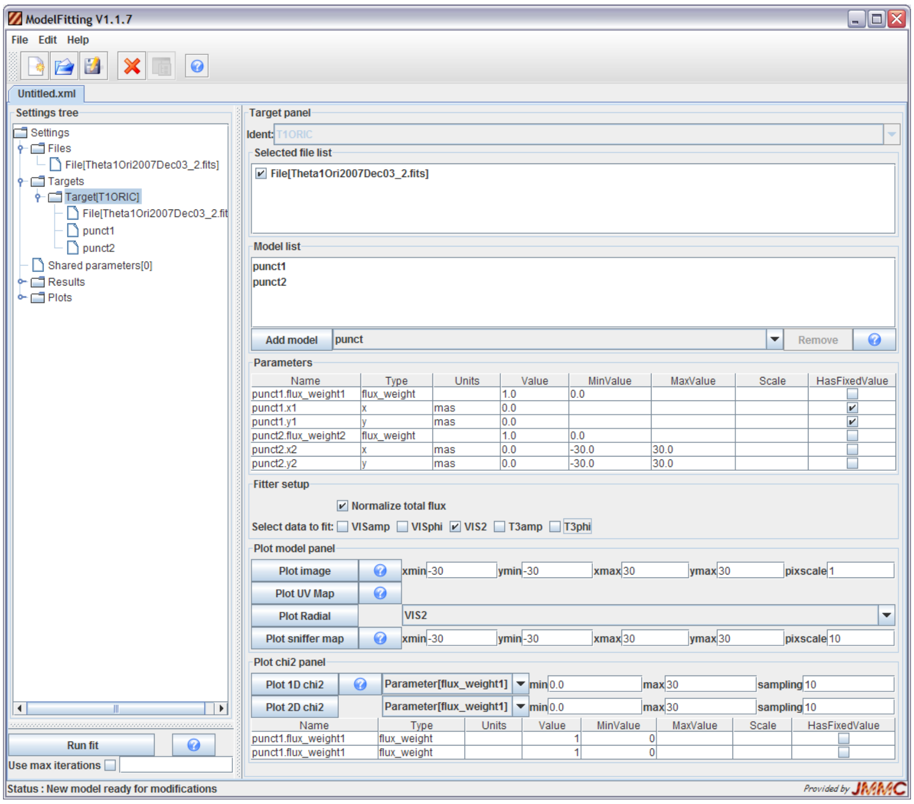

Figure 14: Setting the initial and boundary values parameters of the binary model for the fit.

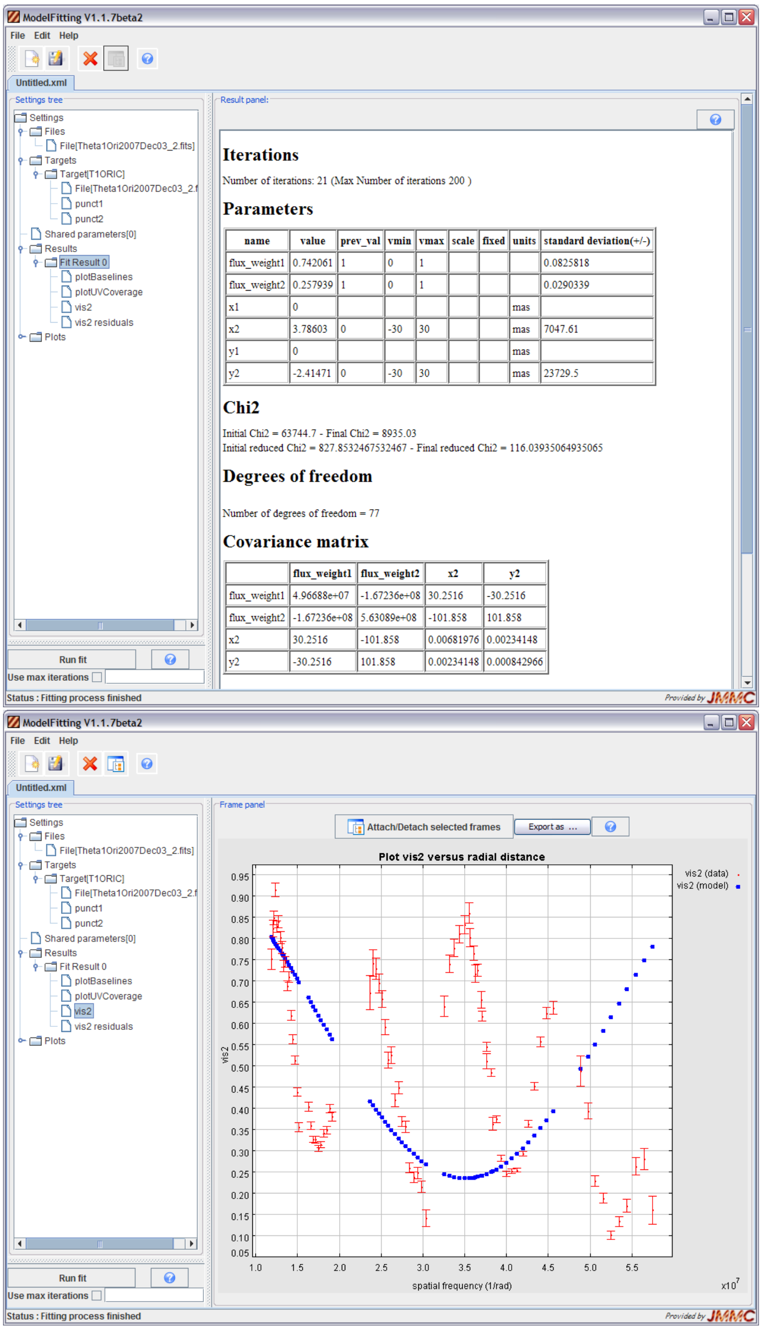

Figure 15: *Top:* Summary of the results obtained for the fit of the binary model. The high χ^2 value and the huge uncertainties in the fitted parameters *x2* and *y2* are indications that the fit did not work well. *Bottom:* Plot of the fitted model squared visibilities V^2 together with the observed ones. From this plot it is even more clear that the fit is highly unsatisfactory. This plot is accessed by choosing *vis2* in the tree structure *Settings-Results* at the left frame of the GUI.

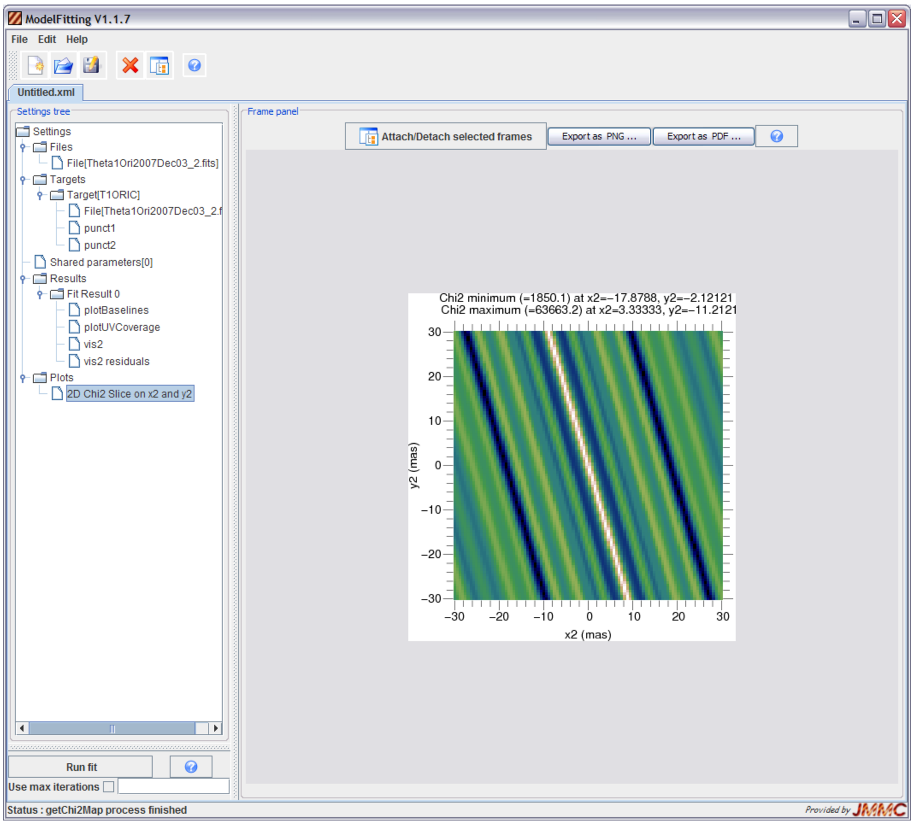

Figure 16: χ^2 map spanning the secondary position ($x2$ and $y2$) for the binary model. The minimum and maximum χ^2 values in the map are also indicated with the corresponding values of $x2$ and $y2$.

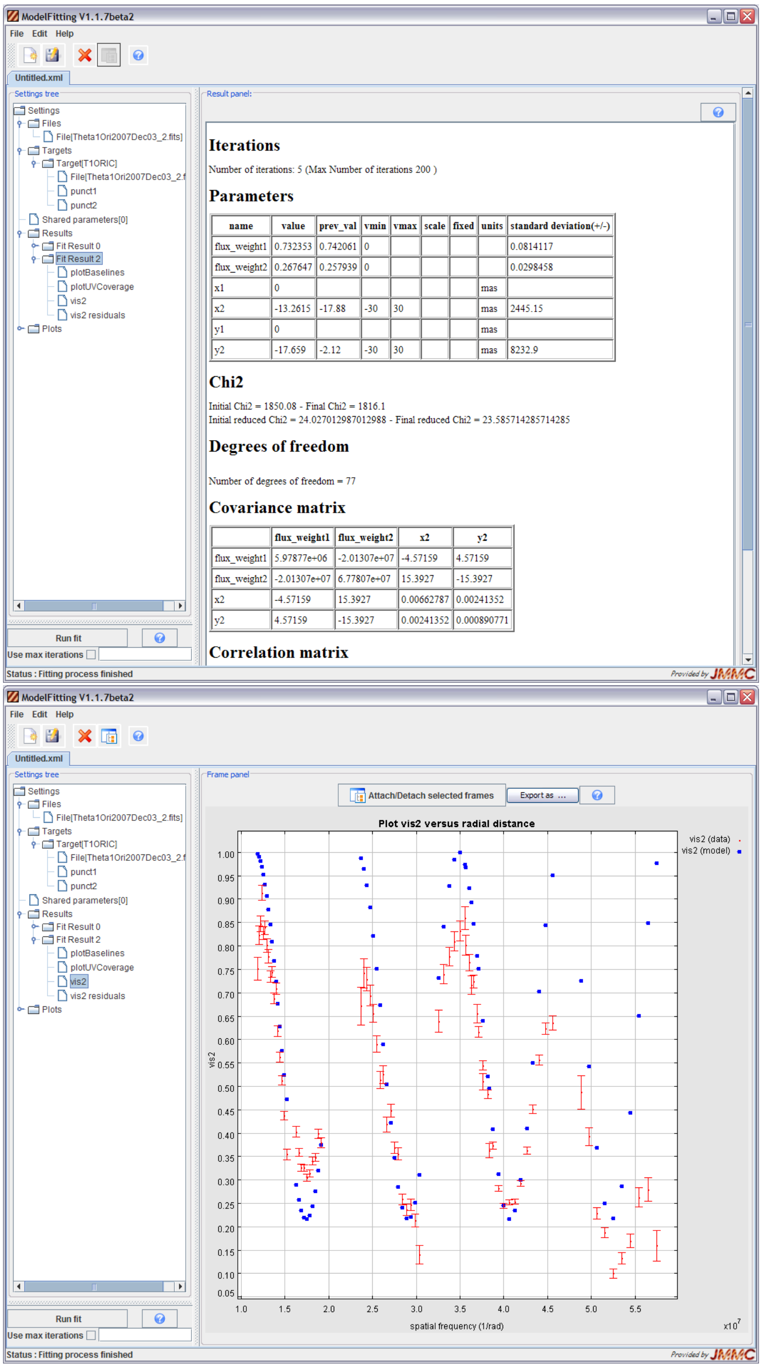

Figure 17: *Top:* Summary of the results obtained for the fit of the binary model with initial position of the secondary closer to a region of minimum χ^2. *Bottom:* Plot of the fitted model squared visibilities V^2 together with the observed ones. From this plot it is clear that this fit is much better than before. This plot is accessed by choosing *vis2* in the tree structure *Settings-Results-Fit Result 1* at the left frame of the GUI.

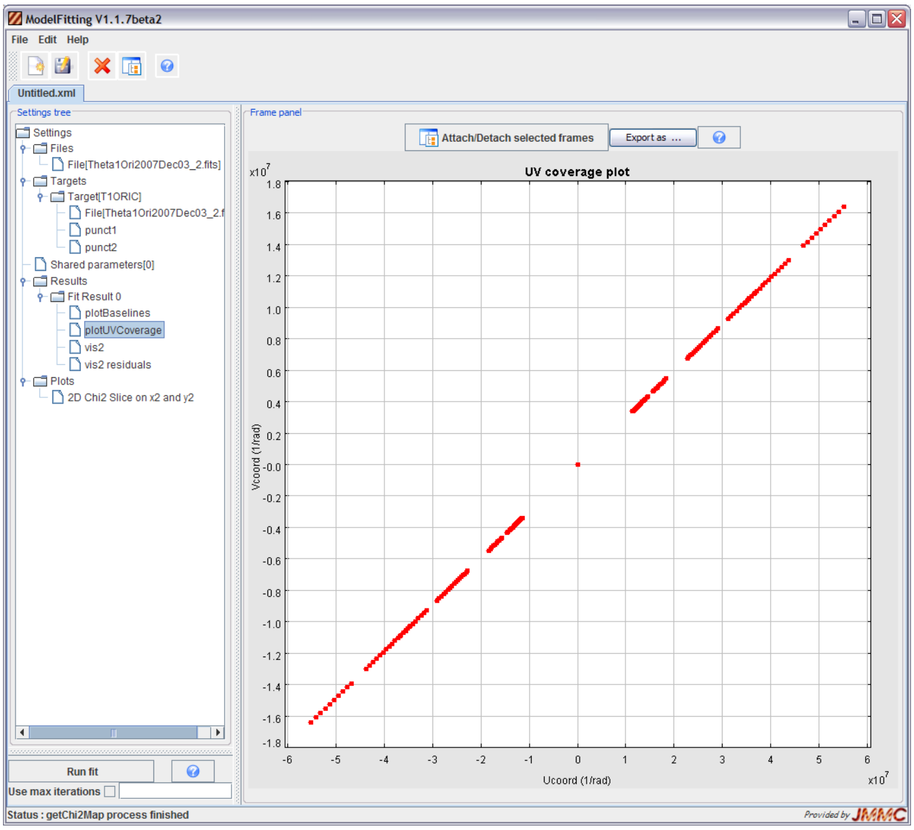

Figure 18: uv plane covered by the data of the binary θ^1 Ori C (file Theta1Ori2007Dec03_2.fits).

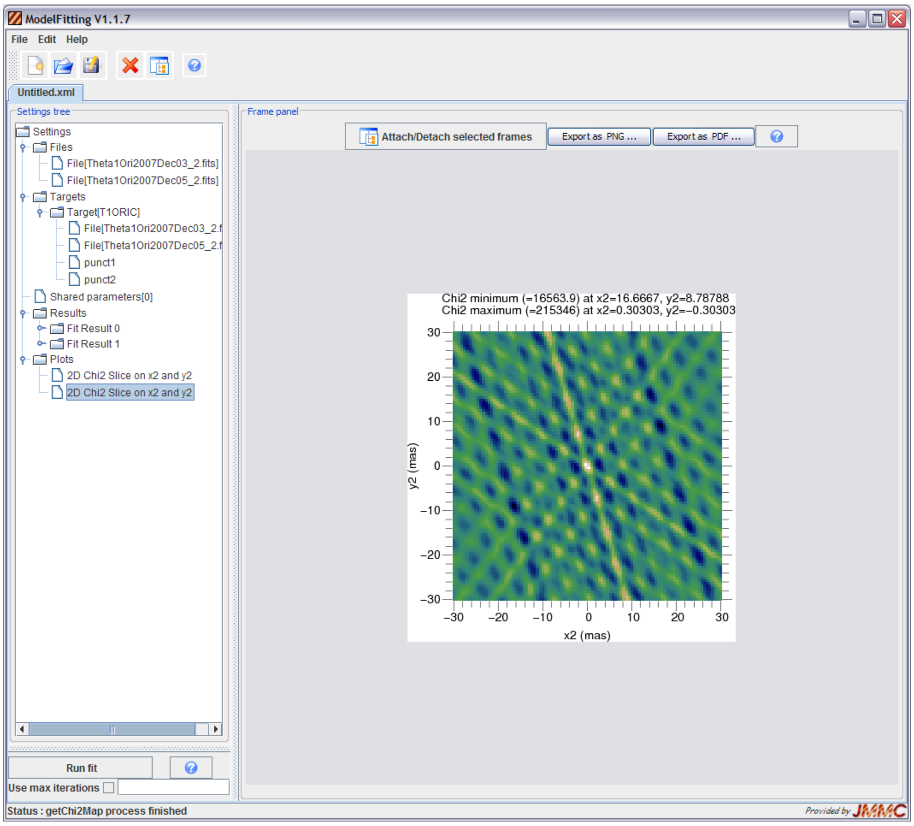

Figure 19: χ^2 map spanning the secondary position ($x2$ and $y2$) for the binary model including additional data (Theta1Ori2007Dec03_2.fits and Theta1Ori2007Dec05_2.fits).

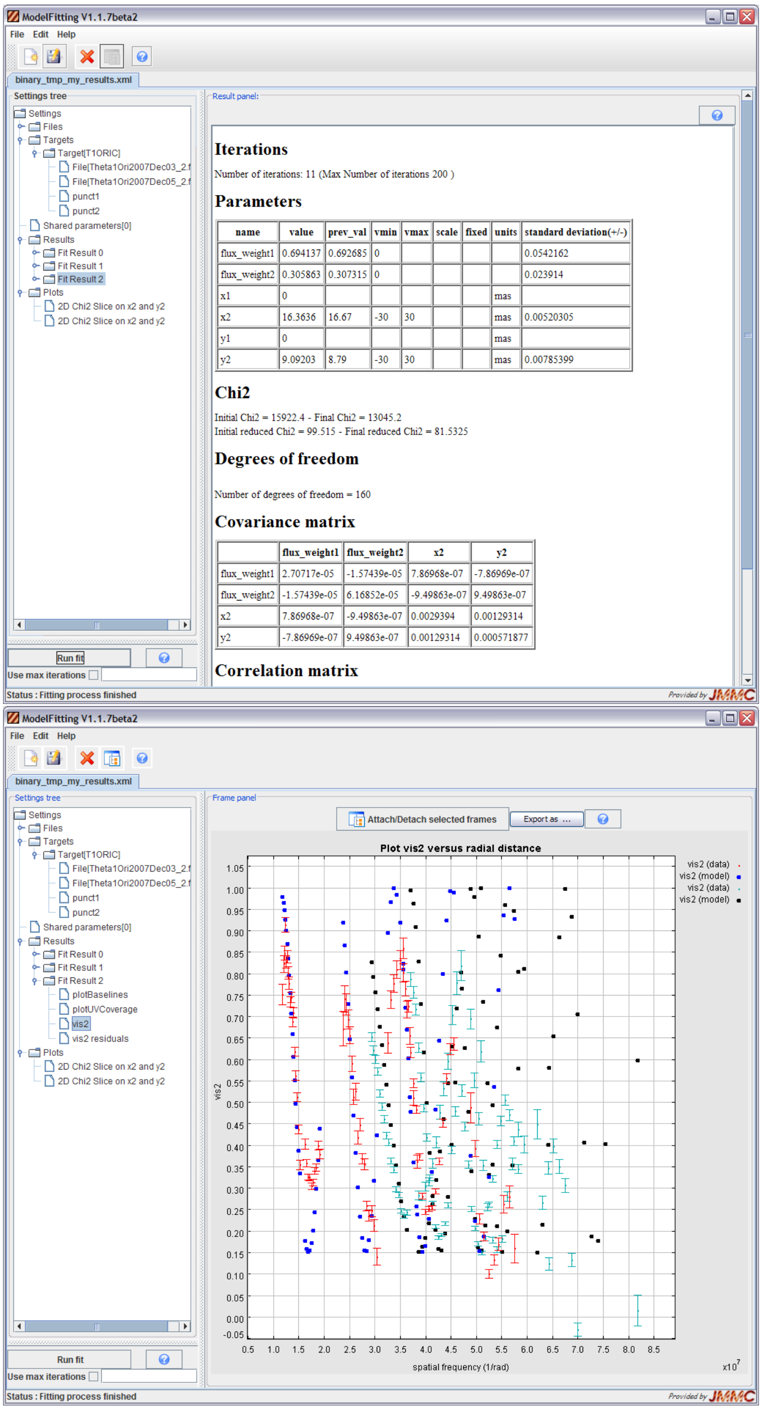

Figure 20: *Top:* Summary of the results obtained for the fit of the binary model including additional data and with initial position of the secondary closer to a region of the global minimum of the χ^2. *Bottom:* Plot of the fitted model squared visibilities V^2 together with the observed ones.

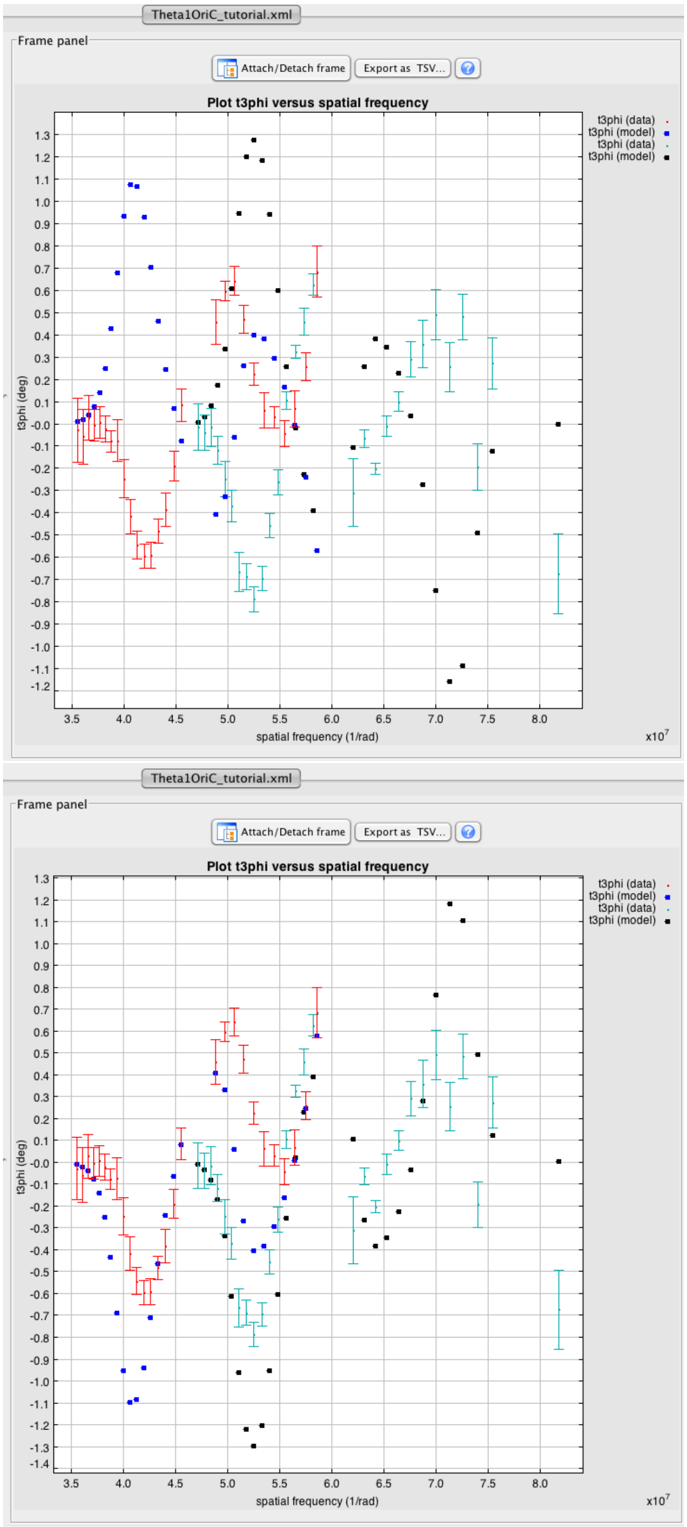

Figure 21: *Top:* Plot of the fitted binary model closure phases together with the observed ones. This fit corresponds to a companion position $x2 = +16.4$ mas, and $y2 = +9.1$ mas, leading to a reduced χ^2 min of 62. Note that there is a π rad shift between the model and observed closure phases for these parameters. *Bottom:* Same as the top panel but for a companion position $x2 = -16.4$ mas, and $y2 = -9.1$ mas, leading to a lower reduced χ^2 min of 62. For these parameters the observed closure phases are well reproduced by the model. This is thus the best solution allowing to reproduce all the observations of θ^1 Ori C.

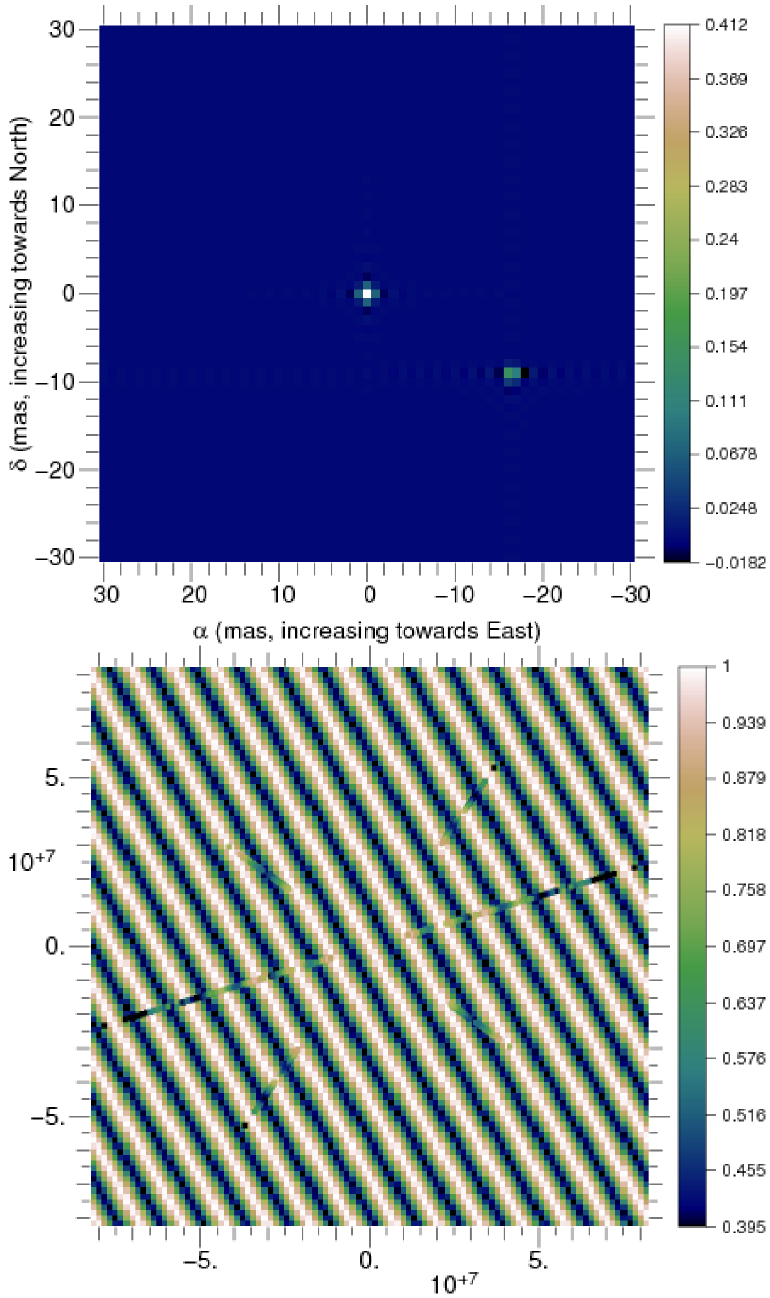

Figure 22: Intensity distribution (top) and Fourier transform (bottom) of the best fit binary model including squared visibilities and closure phases from two data sets: Theta1Ori2007Dec03_2.fits and Theta1Ori2007-Dec05_2.fits. The uv plane coverage of the data is also shown.