

# LITpro

## Lyon's Interferometric Tool prototype a model fitting software

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The screenshot shows the LITpro website with an orange navigation bar containing: PÔLE / SNO, TOOLS, USER SUPPORT, PUBLICATIONS, TRAINING, NEWS. A left sidebar lists: TOOLS, Proposal Preparation, Data Processing, Data Analysis (highlighted), OIFits Validator, OIFits Explorer, LITpro (highlighted), OImaging, Data Bases, VO Tools, OpenDev Tools. The main content area includes:

- Home > TOOLS > Data Analysis > LITpro
- LITpro**
- LITpro is a **model fitting software**, developed and maintained by the JMMC.
- Subscribe to Modelfitting feed
- This software has been developed for the model fitting of data obtained from various stellar optical interferometers and written in the OI Exchange Format. It provides a set of elementary geometrical and center-to-limb darkening functions, all combinable together, which allow to fit Visibilities, Square Visibilities or Triple Products, or any combination of previous observables. It allows to visualize by various plots the data as well as the models and the results of the fits. Tools also have been developed to help users to find the global minimums.
- Scientific and technical background of LITpro are described in the paper
  - LITpro: a model fitting software for optical interferometry Tallon-Bosc, I., Tallon, M., Thiébaud, E., et al., 2008, SPIE 7013E 44
- run newest public version of LITpro LITpr or find other release packages
- One **optical interferometric data sharing area** is provided to test software. This area may be enriched by data of the user who wishes to share with the community his experience of model fitting with LITpro (success or problem). That will help us for improving the software, the GUI as well as LITpro.
- Most of the oifits files of this area, which is also available for image reconstruction, can be used by LITpro. But for the objects of the Interferometric Imaging Beauty contests for example, model fitting can only help for the measurement of parameters.
- No oifits data is stored on server side when running in client/server mode.
- Documentation**
  - LITpro, a model fitting software - PDF
  - LITpro GUI - User's Manual (Reference Guide) - PDF
  - Tutorial of LITpro and corresponding Java GUI - PDF
    - Example 1, Example 2, Example 3 - Xml Settings Files
  - FAQ will be completed by the **user support** according users requests
  - Public forum used to share LITpro experience
- Acknowledgement**





# Model fitting: an adventure with LITpro

Successive steps – in general -:

- observe your data
- build a model
- explore the "chi2 space"
- fit
- analyse the results carefully
- also with OIFitsExplorer
- create a setting = data +model
- to fix the initial guess of the fit
- **Levenberg-Marquardt algorithm (modified)**
  - Combined with a Trust Region method
  - Bounds on the parameters
  - Partial derivatives of the model by finite differences
- reduced chi2, **sig\_chi2**, correlation matrix, plots

run newest public version of LITpro

LITpro

or find other release packages

<https://releases.jmmc.fr/index.html>



# How to use LITpro

- some demos
  - a UD /LB disk *CL Lac*
    - basic functionalities
    - helpful plots: `chi2_slice`, `image`, `uvmap`
    - advices: fill a notebook, save setting regularly
  - a circumstellar disk *gam Cas*
    - data files loaded from OIFITsExplorer
- practice together on a binary



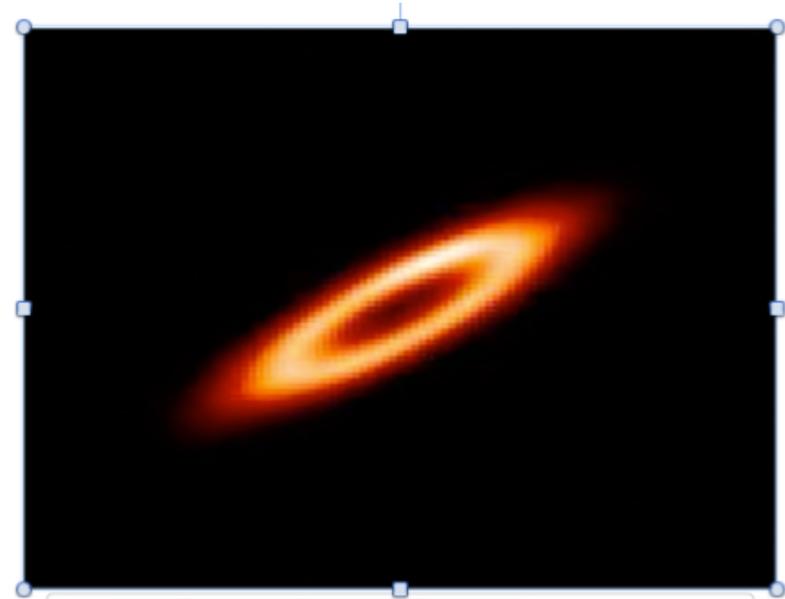
lpb_punct()	- Single point (Dirac function)		
lpb_background()	- Background		
lpb_disk()	- Uniform disk with normalized total flux		
lpb_disk_polar()	- Uniform disk with normalized total flux		
lpb_nonorm_disk()	- Not normalized uniform disk		
lpb_circle()	- Circle	lpb_stretched_gauss_bspline1_ring2()	- Stretched gaussian ring modulated by cubic B-splines
lpb_gaussian()	- Gaussian	lpb_stretched_gauss_bspline1_ring4()	- Stretched gaussian ring modulated by cubic B-splines
lpb_ring()	- Uniform ring	lpb_stretched_gauss_bspline1_ring8()	- Stretched gaussian ring modulated by cubic B-splines
lpb_gaussian_ring()	- Gaussian ring	lpb_stretched_gauss_bspline1_ring16()	- Stretched gaussian ring modulated by cubic B-splines
lpb_square()	- Uniform square	lpb_stretched_gauss_bspline1_ring32()	- Stretched gaussian ring modulated by cubic B-splines
lpb_modulated_circle()	- Circle modulated with 1+cos	lpb_stretched_gauss_bspline3_ring2()	- Stretched gaussian ring modulated by 8 cubic B-splines
lpb_elong_disk()	- Ellipse (elongated disk)	lpb_stretched_gauss_bspline3_ring4()	- Stretched gaussian ring modulated by 8 cubic B-splines
lpb_nonorm_elong_disk()	- Not normalized ellipse (elongated disk)	lpb_stretched_gauss_bspline3_ring8()	- Stretched gaussian ring modulated by 8 cubic B-splines
lpb_elong_gaussian()	- Elongated Gaussian	lpb_stretched_gauss_bspline3_ring16()	- Stretched gaussian ring modulated by 16 cubic B-splines
lpb_elong_ring()	- Elongated ring	lpb_stretched_gauss_bspline3_ring32()	- Stretched gaussian ring modulated by 32 cubic B-splines
lpb_elong_limb_power()	- Ellipse (elongated disk)	lpb_stretched_gaussian_ring()	- Stretched Gaussian Ring
lpb_flatten_disk()	- Ellipse (flattened disk)	lpb_stretched_modulated_circle()	- Stretched circle modulated by 1+cos
lpb_nonorm_flatten_disk()	- Not normalized Ellipse (flattened disk)	lpb_stretched_modulated_gaussian_ring()	- Stretched modulated gaussian ring
lpb_flatten_gaussian()	- Flattened Gaussian		
lpb_flatten_ring()	- Flattened ring		
lpb_stretched_disk()	- Stretched Gaussian		
lpb_stretched_gaussian()	- Stretched Gaussian		
lpb_limb_power()	- Limb-darkened disk with power law		
lpb_limb_linear()	- Limb-darkened disk with linear law		
lpb_limb_quadratic()	- Limb-darkened disk with quadratic law		
lpb_limb_sqrt()	- Limb-darkened disk with square root law		
lpb_limb_nonlinear_Claret()	- Limb-darkened disk with the new non-linear law of Claret (2000)		
lpb_blackbody()	- Weight with relative flux of black-body		
lpb_background_BB()	- Background with black-body emission		
lpb_punct_BB()	- Single point (Dirac function) with black body emission		
lpb_disk_BB()	- Uniform disk with black body emission		
lpb_elong_disk_BB()	- Elongated disk with black body emission		
lpb_stretched_disk_BB()	- Stretched disk with black body emission		
lpb_gaussian_BB()	- Uniform disk with black body emission		
lpb_stretched_gaussian_BB()	- Stretched Gaussian with blackbody		

disk functions

# A large library of models, built from requests

for ex.: stretched\_gauss\_bspline3\_ring32

- azimuthal variation of intensity
  - linear combination of 32 cubic B-splines
- + radial gaussian profil
- + anamorphosis (orientation & amplitudes variable)
- exact in the uv plane
  - the image is calculated from the expressions in the Fourier plane



# Image Reconstruction Contest, SPIE 2018

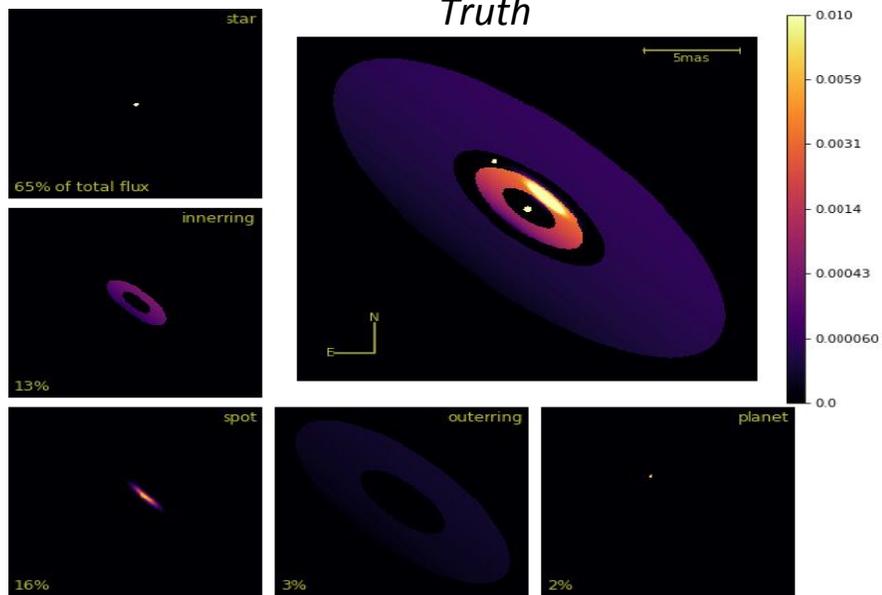
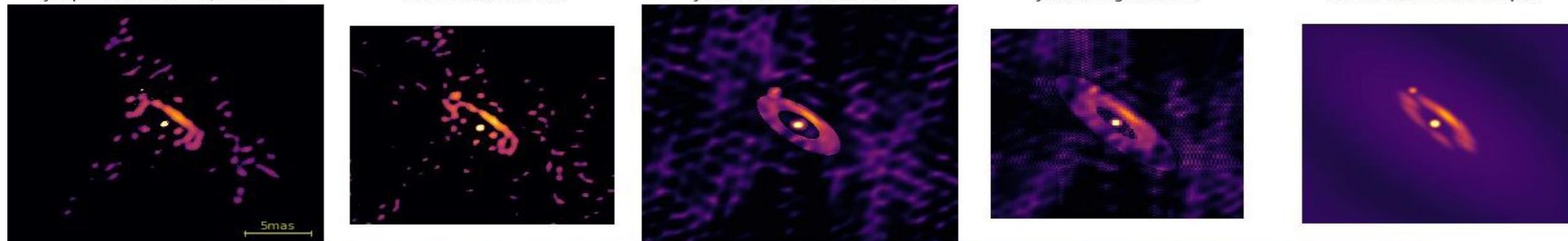
Jacques Kluska (MiRA/SPARCO)

Eric Thiebaut (MiRA)

Joel Sanchez et al. (BSMEM)

John Young (BSMEM)

Michel Tallon et al. (LITpro)



*Mérand et al. 2018*

Model fitting & Image Reconstruction: complementarity

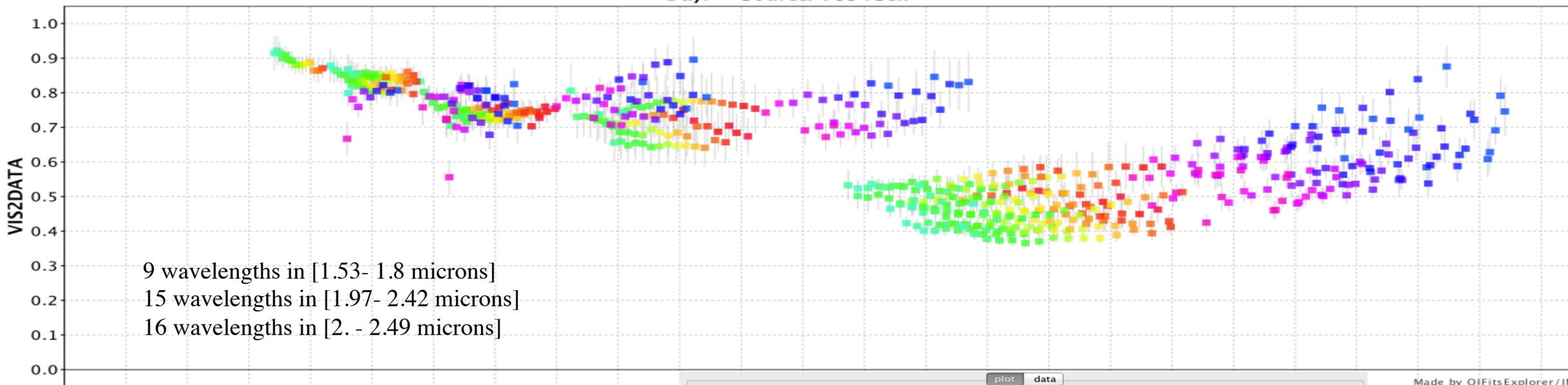


- |                                         |                                                                   |   |                                 |  |  |
|-----------------------------------------|-------------------------------------------------------------------|---|---------------------------------|--|--|
| lpb_punct()                             | - Single point (Dirac function)                                   |   |                                 |  |  |
| lpb_background()                        | - Background                                                      |   |                                 |  |  |
| lpb_disk()                              | - Uniform disk with normalized total flux                         |   |                                 |  |  |
| lpb_disk_polar()                        | - Uniform disk with normalized total flux                         |   |                                 |  |  |
| lpb_nonorm_disk()                       | - Not normalized uniform disk                                     |   |                                 |  |  |
| lpb_circle()                            | - Circle                                                          |   |                                 |  |  |
| lpb_gaussian()                          | - Gaussian                                                        |   |                                 |  |  |
| lpb_ring()                              | - Uniform ring                                                    |   |                                 |  |  |
| lpb_gaussian_ring()                     | - Gaussian ring                                                   |   |                                 |  |  |
| lpb_square()                            | - Uniform square                                                  |   |                                 |  |  |
| lpb_modulated_circle()                  | - Circle modulated with 1+cos                                     |   |                                 |  |  |
| lpb_elong_disk()                        | - Ellipse (elongated disk)                                        |   |                                 |  |  |
| lpb_nonorm_elong_disk()                 | - Not normalized ellipse (elongated disk)                         |   |                                 |  |  |
| lpb_elong_gaussian()                    | - Elongated Gaussian                                              |   |                                 |  |  |
| lpb_elong_ring()                        | - Elongated ring                                                  |   |                                 |  |  |
| lpb_elong_limb_power()                  | - Ellipse (elongated disk)                                        |   |                                 |  |  |
| lpb_flatten_disk()                      | - Ellipse (flattened disk)                                        |   |                                 |  |  |
| lpb_nonorm_flatten_disk()               | - Not normalized Ellipse (flattened disk)                         |   |                                 |  |  |
| lpb_flatten_gaussian()                  | - Flattened Gaussian                                              |   |                                 |  |  |
| lpb_flatten_ring()                      | - Flattened ring                                                  |   |                                 |  |  |
| lpb_stretched_disk()                    | - Stretched Gaussian                                              |   |                                 |  |  |
| lpb_stretched_gaussian()                | - Stretched Gaussian                                              |   |                                 |  |  |
| lpb_limb_power()                        | - Limb-darkened disk with power law                               | } | <b>limb-darkening functions</b> |  |  |
| lpb_limb_linear()                       | - Limb-darkened disk with linear law                              |   |                                 |  |  |
| lpb_limb_quadratic()                    | - Limb-darkened disk with quadratic law                           |   |                                 |  |  |
| lpb_limb_sqrt()                         | - Limb-darkened disk with square root law                         |   |                                 |  |  |
| lpb_limb_nonlinear_Claret()             | - Limb-darkened disk with the new non-linear law of Claret (2000) |   |                                 |  |  |
| lpb_blackbody()                         | - Weight with relative flux of black-body                         | } | <b>black-body functions</b>     |  |  |
| lpb_background_BB()                     | - Background with black-body emission                             |   |                                 |  |  |
| lpb_punct_BB()                          | - Single point (Dirac function) with black body emission          |   |                                 |  |  |
| lpb_disk_BB()                           | - Uniform disk with black body emission                           |   |                                 |  |  |
| lpb_elong_disk_BB()                     | - Elongated disk with black body emission                         |   |                                 |  |  |
| lpb_stretched_disk_BB()                 | - Stretched disk with black body emission                         |   |                                 |  |  |
| lpb_gaussian_BB()                       | - Uniform disk with black body emission                           |   |                                 |  |  |
| lpb_stretched_gaussian_BB()             | - Stretched Gaussian with blackbody                               |   |                                 |  |  |
| lpb_stretched_gauss_bspline1_ring2()    | - Stretched gaussian ring modulated by cubic B-splines            |   |                                 |  |  |
| lpb_stretched_gauss_bspline1_ring4()    | - Stretched gaussian ring modulated by cubic B-splines            |   |                                 |  |  |
| lpb_stretched_gauss_bspline1_ring8()    | - Stretched gaussian ring modulated by cubic B-splines            |   |                                 |  |  |
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| lpb_stretched_gaussian_ring()           | - Stretched Gaussian Ring                                         |   |                                 |  |  |
| lpb_stretched_modulated_circle()        | - Stretched circle modulated by 1+cos                             |   |                                 |  |  |
| lpb_stretched_modulated_gaussian_ring() | - Stretched modulated gaussian ring                               |   |                                 |  |  |

*elementary functions affected by a Planck function*

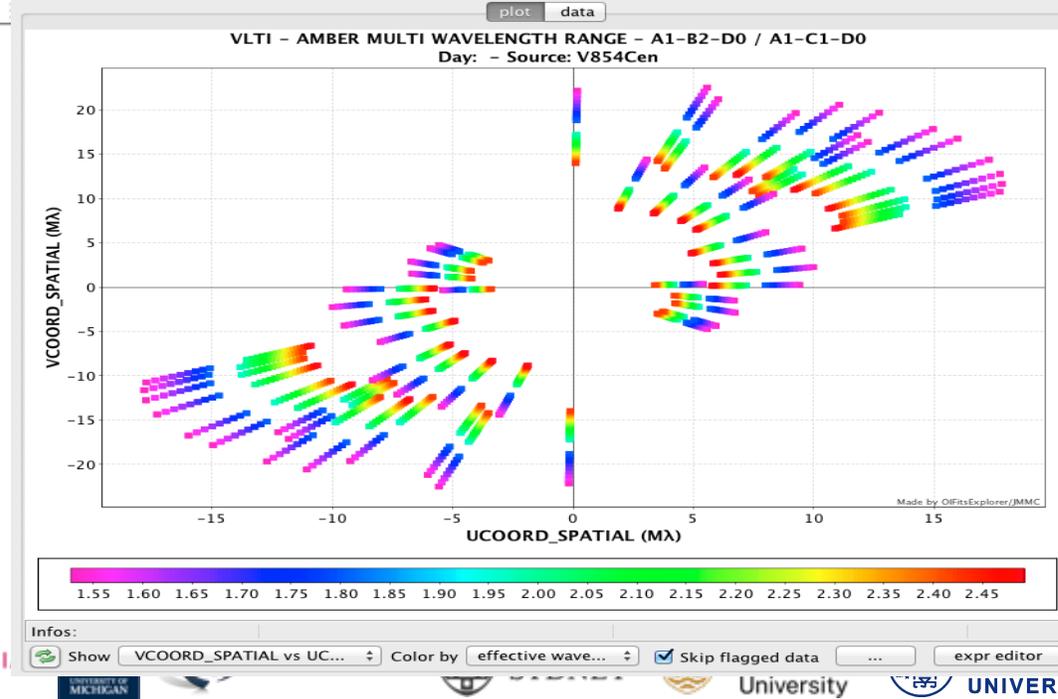
VLTI - AMBER MULTI WAVELENGTH RANGE - A1 B2 D0 / A1 C1 D0

Day: - Source: V854Cen



Made by OIFitsExplorer/JM

"Commas" in VIS2 are a chromatic artifact



Made by OIFitsExplorer/JMM

## V853 Cen: a star with circumstellar environment

VIS2 & T3phi with central punct\_BB (T<sub>1</sub>=6750 fixed) & stretched\_gaussian\_BB

reduced Chi2 final= 2.128  
 fwhm2 = 10.814 +/- 0.192 mas  
 flux\_weight1 = 325.89 +/- 16.4 punct  
 flux\_weight2 = 31.273 +/- 1.86 shell  
 stretch\_pos\_angle2 = **35.785** +/- 1.16 degree  
 stretch\_ratio2 = **0.72009** +/- 0.0119  
 temperature2 = 1606.2 +/- 35.6 Kelvin

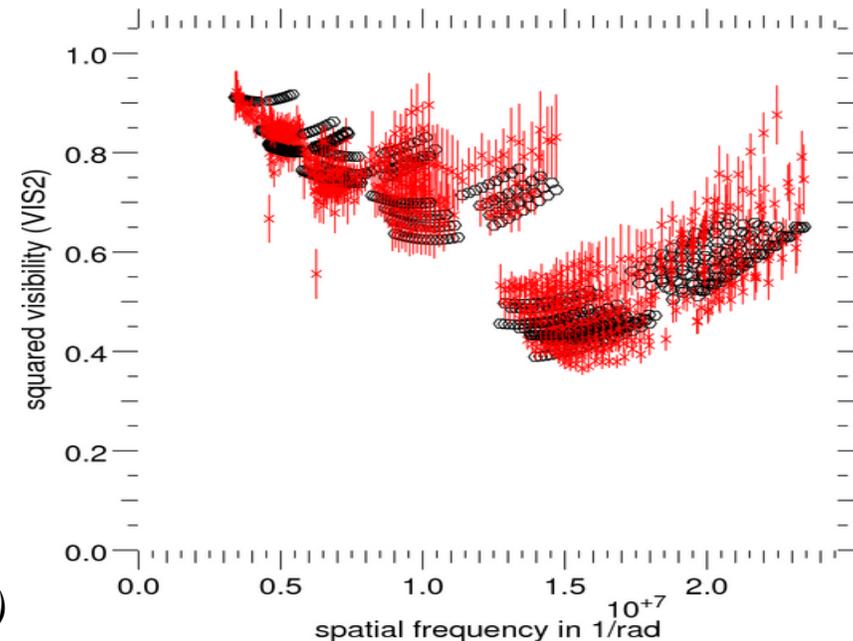
## Compatibility with the published results

*Chesneau O., Millour F. et al., A&A 569, L4 (2014)*

Extracted from the paper : "Our best-match model for the compact array is a two-component model, consisting of an unresolved uniform disk ( $\Theta \leq 2.5$  mas, star component), and a flattened Gaussian (shell component) with a FWHM of the minor axis of  $8 \pm 1$  mas, and a major axis of  $11 \pm 3$  mas.

The orientation of the major axis is  $126 \pm 29^\circ$ . The quality of the fit is relatively good with a reduced  $\chi^2$  of 1.5."

→ stretch\_ratio = **0.72** & orientation of the major axis =  $126 - 90 = 36$  deg.





## To compare with the published results

*Chesneau O., Millour F. et al., A&A 569, L4 (2014)*

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*The orientation of the major axis is  $126 \pm 29^\circ$ . The quality of the fit is relatively good with a reduced  $\chi^2$  of 1.5."*

**→ stretch\_ratio = 0.72 & orientation of the major axis =  $126 - 90 = 36$  deg.**

## Fit VIS2 & T3phi with central punct\_BB ( $T_1=6750$ fixed) & stretched\_gaussian\_BB

reduced Chi2 final= 2.128

fwhm2 = 10.814 +/- 0.192 mas

flux\_weight1 = 325.89 +/- 16.4 punct

flux\_weight2 = 31.273 +/- 1.86 shell

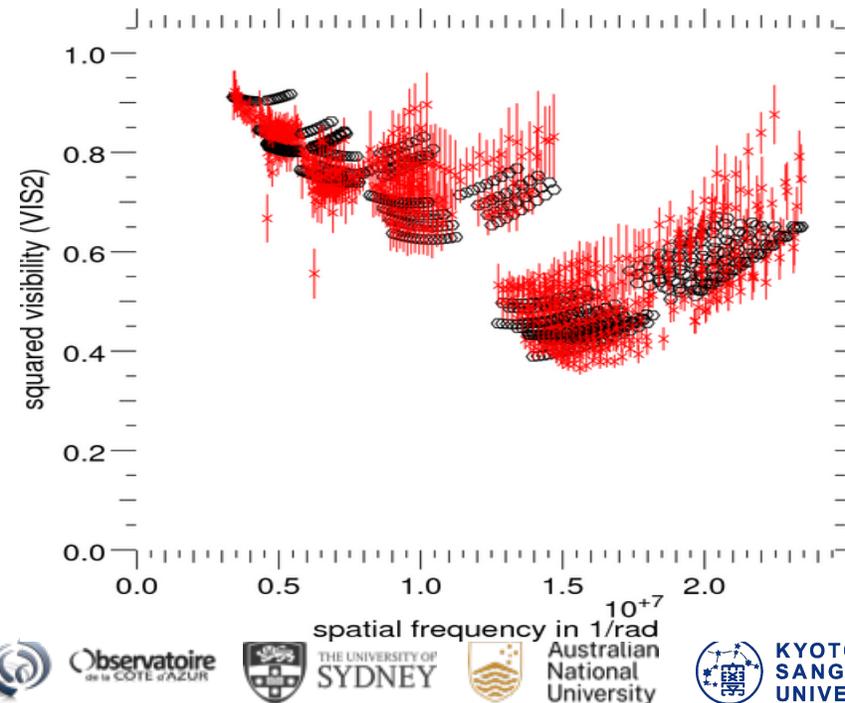
stretch\_pos\_angle2 = **35.785** +/- 1.16 degree

stretch\_ratio2 = **0.72009** +/- 0.0119

temperature2 = 1606.2 +/- 35.6 Kelvin

*see the help of the function stretched\_gaussian\_BB  
for a better knowledge of the parameters*

**Compatibility** (except for chi2 value)





# How to use LITpro

- some demos
  - a UD /LB disk *CL Lac*
    - basic functionalities
    - helpful plots: `chi2_slice`, `image`, `uvmap`
    - advices: fill a notebook, save setting regularly
  - a circumstellar disk *gam Cas*
    - open a new setting
    - data files loaded from OIFITsExplorer
  
- practice together on a binary



# How to use LITpro

a circumstellar disk (H band)  $\gamma$  Cas

reduced Chi2: final= 6.803 - sigma= 0.0454311  
 Number of degrees of freedom = 969  
 Number of iterations: 15 (max number= 200)  
 Number of evaluations of the model: 164  
 Final values and standard deviation for fitted parameters:

flatten\_ratio3 = 1.4076 +/- 0.0322

flux\_weight1 = 0.46723 +/- 0.133

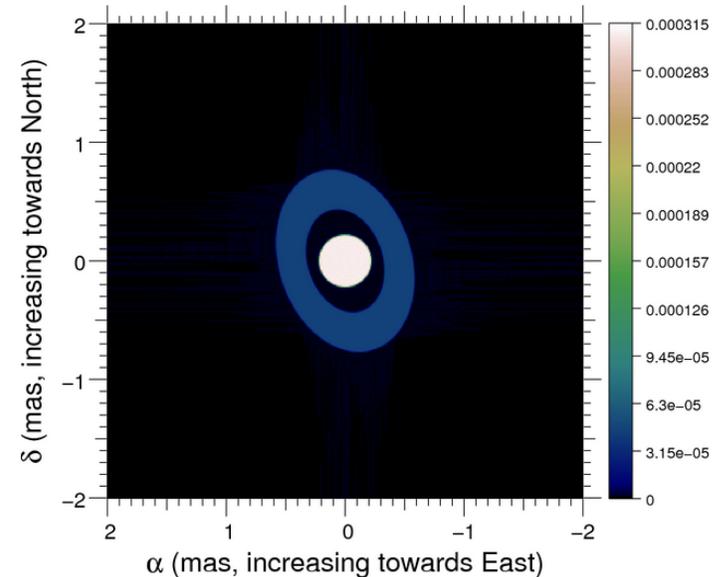
flux\_weight2 = 0.12415 +/- 0.0137

flux\_weight3 = 0.40861 +/- 0.138

major\_internal\_diameter3 = 0.89034 +/- 1.18 mas

minor\_axis\_pos\_angle3 = 107.57 +/- 1.01 degrees

width3 = 0.3409 +/- 0.792 mas



comparable to the paper but...

*Stee et al. (2012)*

reduced chi2 ~ 4

flatten\_ratio3 =  $1.39 \pm 0.08$

minor\_axis\_pos\_angle3 =  $102 \pm 9$  (adding  $90^\circ$ )

width3 =  $0.25 \pm 0.26$

flux\_weight1 = ?

flux\_weight2 =  $0.14 \pm 0.01$

flux\_weight3 =  $0.41 \pm 0.06$



# How to use LITpro

- some demos

- a UD /LB disk *CL Lac*

- basic functionalities
    - helpful plots: chi2\_slice, image, uvmap
    - advices: fill a notebook, save setting regularly

- a circumstellar disk *gam Cas*

- open a new setting
    - data files loaded from OIFITsExplorer
    - model to improve

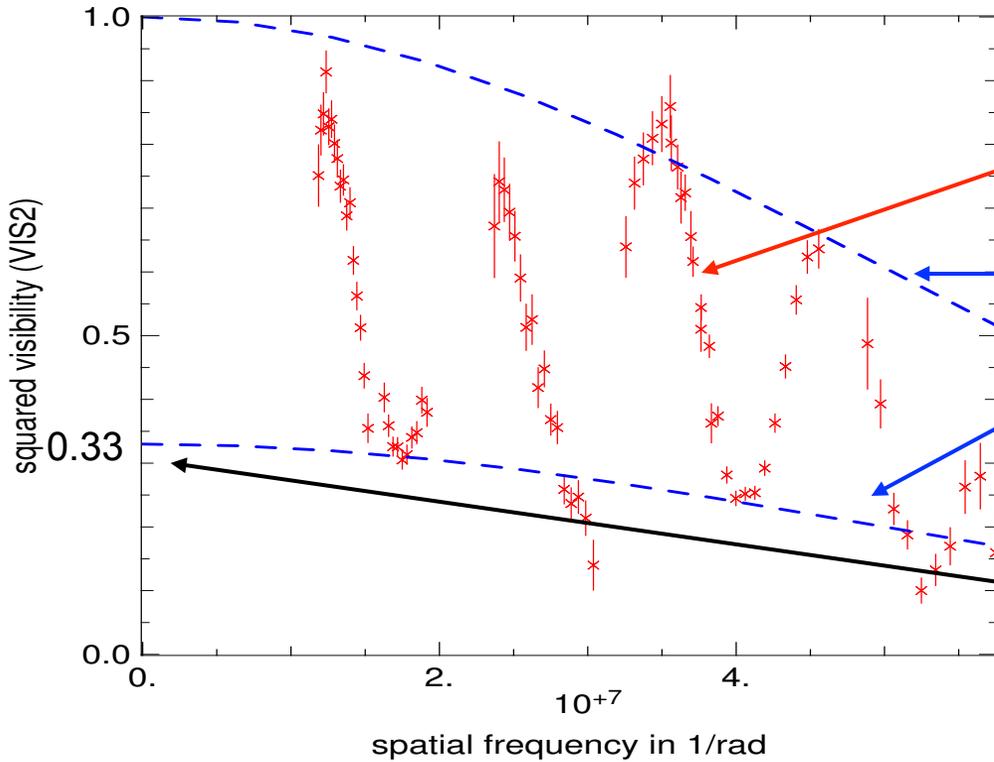
- practice together on a binary

- binary: V1334 cepheid and its companion  
v1334\_Cyg\_2012Jul27.oifits

*Galenne et al. 2013*

- disk
- then disk+punct
- flux ratio estimable without any fit
- Plot Chi2 "**with fit**"  
warning / time calculation

extract from VLTI School 2021



Modulation = binary (or >2 components)

Attenuation = components resolved

binary convolved by an extended function



Fourier transform multiplied by a window

Minimum of modulation gives intensity ratio of the components:

$$V_{\min}^2 = 0.33 \Rightarrow r = 0.27$$

$$r = \frac{1 - \sqrt{V_{\min}^2}}{1 + \sqrt{V_{\min}^2}}$$

here  $V_{\min}^2 \sim 0.9 \rightarrow r \sim 0.026$



reduced Chi2: initial= 0.5026 - final= 0.4203 - sigma= 0.0922531  
 Number of degrees of freedom = 235

Number of iterations: 6 (max number= 200)  
 Number of evaluations of the model: 77

Final values and standard deviation for fitted parameters:

diameter1 = 0.51481 +/- 0.0167 mas  
 flux\_weight1 = 0.96973 +/- 0.0626  
 flux\_weight2 = 0.030268 +/- 0.00243  
 x2 = -1.1525 +/- 0.0299 mas  
 y2 = -8.8381 +/- 0.0168 mas

comparable

*Galenne et al. 2013*

**Table 4.** Summary of the parameters estimated from the model fit.

	2012-07-27	2012-10-01
Single star model		
$\theta_{UD}$ (mas)	$0.565 \pm 0.052$	$0.487 \pm 0.045$
$\theta_{LD}$ (mas)	$0.575 \pm 0.052$	$0.496 \pm 0.045$
$\chi_r^2$	1.63	2.08
Binary model		
$\theta_{UD}$ (mas)	$0.494 \pm 0.053$	$0.436 \pm 0.045$
$\theta_{LD}$ (mas)	$0.503 \pm 0.053$	$0.444 \pm 0.045$
$f$ (%)	$3.15 \pm 0.15$	$3.08 \pm 0.09$
$\Delta\alpha$ (mas)	$-1.153 \pm 0.030$	$-0.113 \pm 0.014$
$\Delta\delta$ (mas)	$-8.836 \pm 0.017$	$-8.359 \pm 0.009$
$\chi_r^2$	0.34	1.24

# How to use LITpro

- practice yourself

and enjoy!

we are not far

## Welcome onto the JMMC User Feedback Form !

(\* : required field )

Application:	LITpro
Type:	Evolution Request
Your Email * :	your@email
Summary * :	
Comments * :	
Version:	Optional V.