LITpro: a model fitting software for optical interferometry

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Outline

- Short presentation of the main features of LITpro
- An example of a fit on real data :
  - chromatic model + heterogeneous data

What is LITpro ?

- Parametric model fitting software for interferometry
  - LITpro: Lyon Interferometric Tool prototype
  - Conceived and developed up-to-now at CRAL in Lyon
  - Graphical User Interface developed at JMMC (Jean-Marie Mariotti Center)
  - Now tested by a group within the JMMC research group (several labs in France)

- Aim: "exploit the scientific potential of existing interferometers", e.g. VLTI

- Complementary to image reconstruction
  - Sparse (u,v) coverage
  - Reconstructed images identify models
  - Model fitting extracts measured quantities

Leading requirements of LITpro

- Accessible to "general users" + flexible for "advanced users"
  - Opposite needs:
    - General users want simplicity (stepping stone)
    - Advanced users want a powerful tool (pioneering work)
  - Exchanges:
    - general users —(needs)—› advanced users
    - general users ‹—(training)— advanced users
  - Progress must benefit to everybody (share experiences)

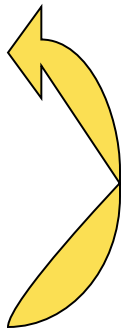
- Concentrate on the model of the object
  - Easy implementation of new models.
  - Only need to compute the Fourier transform of the object specific intensity on given coordinates (*u, v, wavelength, time*)

Leading requirements => implementation

- Accessible to astronomers + flexible for advanced users
  - flexible => high level language (*Yorick*)
    - easy modifications and adds in the software
    - "expert layer"
  - accessible => GUI
    - new abilities exposed once they are validated in the "expert" layer
- Concentrate on the model of the object
  - From Fourier transform of the object:
    - Simulated data (interferometric, spectroscopic, photometry, …)
    - Images
  - LITpro also provides
    - Modeling builder (with GUI or filling a form)
    - Fitter "engine"
    - Tools for analysis

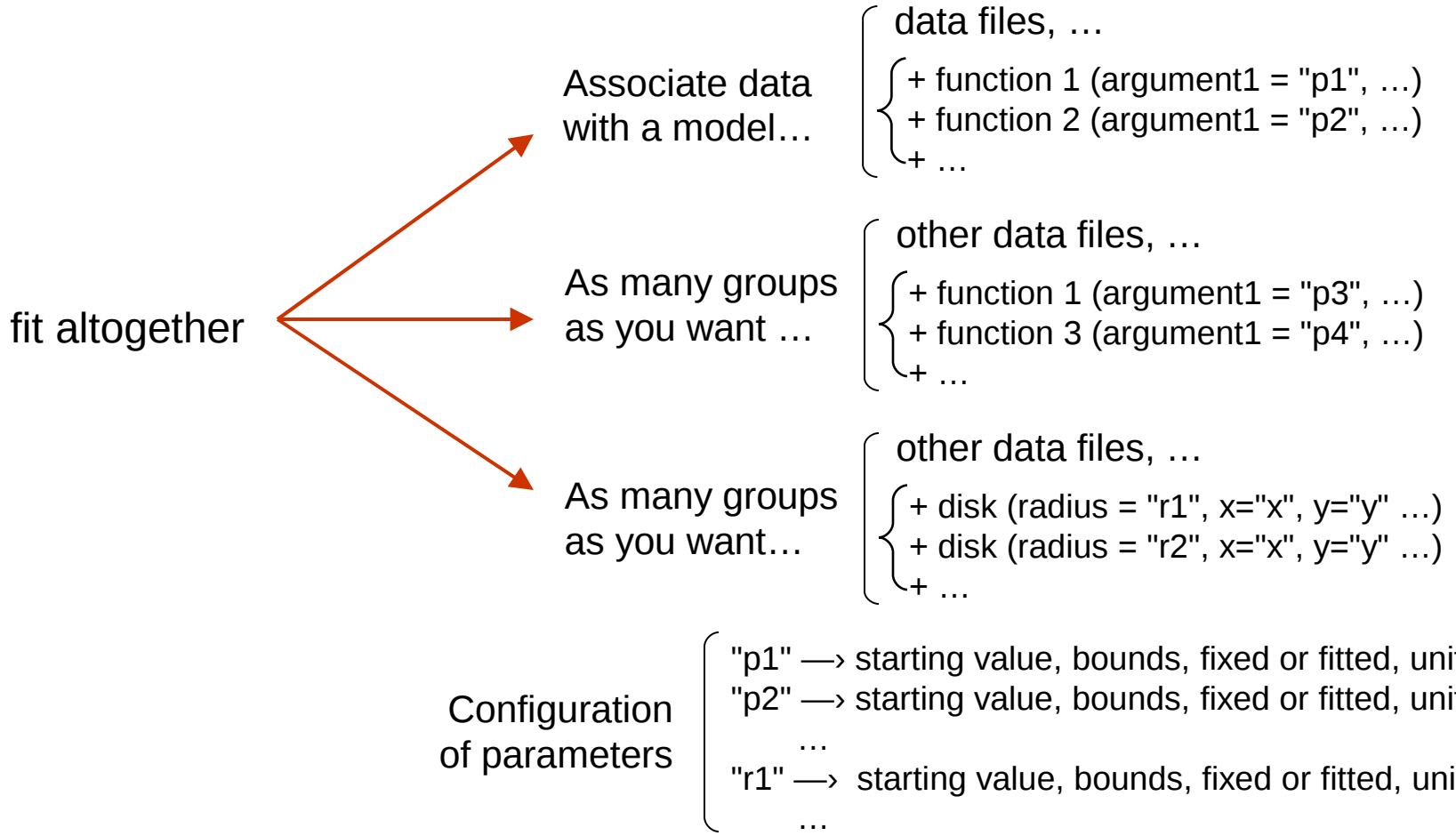
Types of data

- OIFITS
  - Squared visibilities (VIS2)
  - Complex visibilities (VISAMP, VISPHI)
  - Bispectrum (T3AMP, T3PHI)



- Others
  - Spectral Energy Distribution (dispersed fringes mode)
  - Photometry (see example)
  - …

Setting up the fitting process / principle



- Through the GUI
  or through a form (file editor)

Fitting process

- No correlations on measurements in OIFITS:

$$\chi^2(\boldsymbol{p}) = \sum_{i=1}^{N_d} \left(\frac{r_i(\boldsymbol{p})}{\sigma_i} \right)^2$$

- If total energy is degenerated:

$$\chi^{2'}(\boldsymbol{p}) = \chi^2(\boldsymbol{p}) + N_d \left(\frac{\sum_j \Delta\lambda_j \; m_j(0)}{\sum_j \Delta\lambda_j} - 1 \right)^2$$

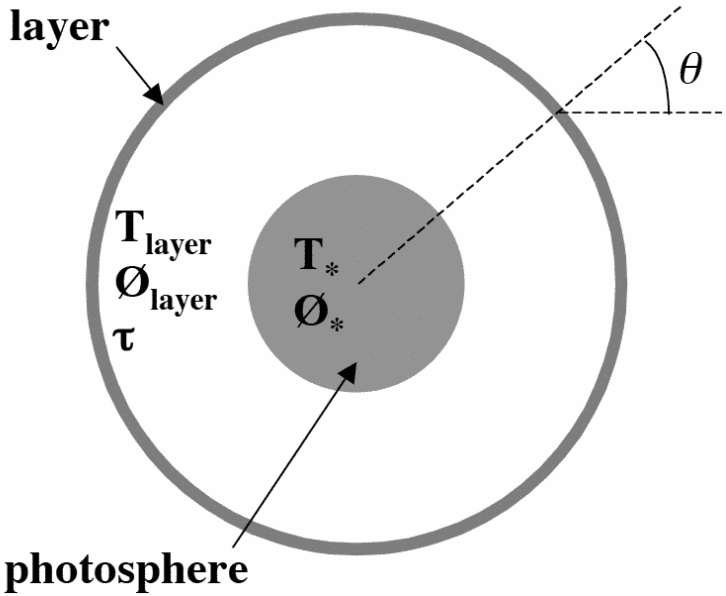
- Levenberg-Marquardt algorithm (modified)
  - Combined with a Trust Region method
  - Bounds on the parameters
  - Partial derivatives of the model by finite differences
- More latter…
  - Search of global minimum

Implementation of the GUI

QuickTimeÊ et un
d· compresseur
sont requis pour visionner cette image.

- Implemented in JAVA
  - Web service
  - Links with other services (JMMC)
    - Virtual Observatory
    - Data explorer
    - User feedback
    - …
- GUI only tell "expert layer" (*Yorick*) what to do
- Currently beta testing
- First release expected ~ end of 2008

Example: chromatic model + heterogeneous data / 1



Perrin et al, A&A 426, 279, 2004

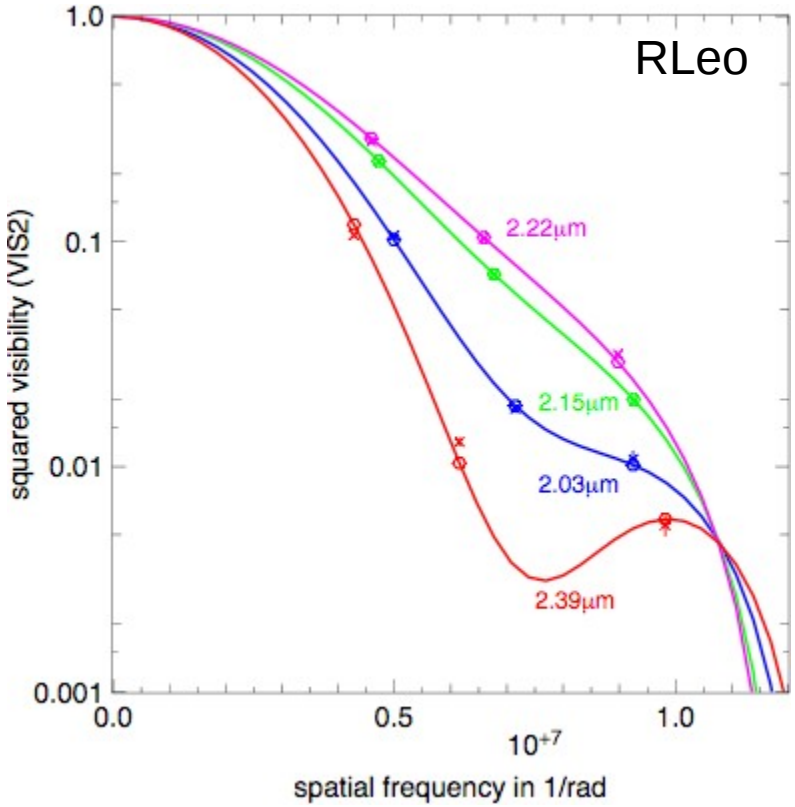
$$I(\lambda,\theta) = B(\lambda,T_\star)\exp(-\tau(\lambda)/\cos(\theta)) + B(\lambda,T_{\text{layer}})\left[1-\exp(-\tau(\lambda)/\cos(\theta))\right]$$

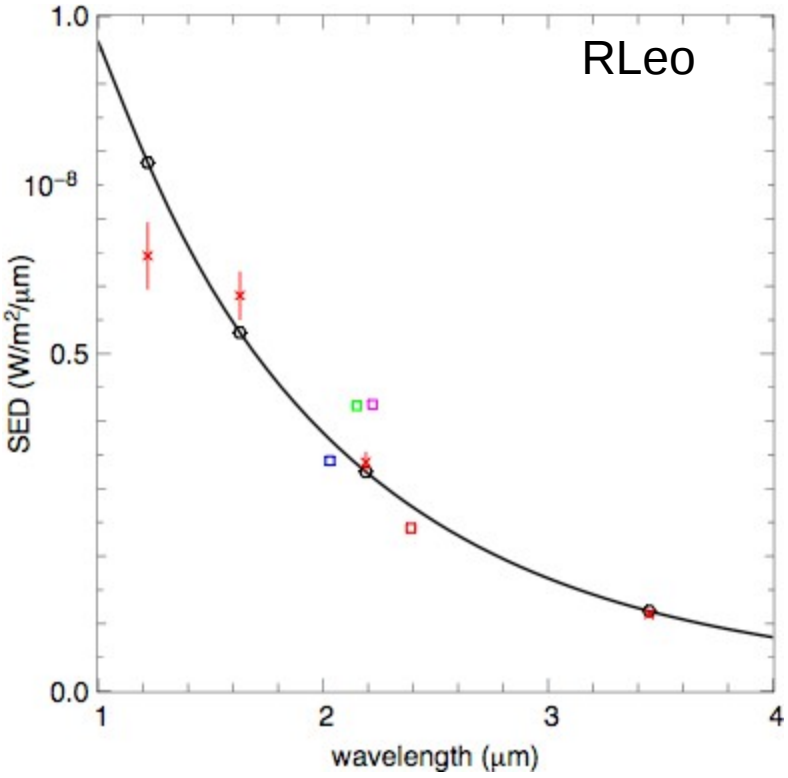
for $\sin(\theta) \le \text{Ø}_\star/\text{Ø}_{\text{layer}}$ and:

$$I(\lambda,\theta) = B(\lambda,T_{\text{layer}})\left[1-\exp(-2\tau(\lambda)/\cos(\theta))\right]$$

- Why this example in particular ?
  - Fitting procedure is difficult
    - Need to improve procedures for "general users" (accessible ?)
    - How LITpro performs ?
  - Fitting interferometric + photometric data
    - Assess how it can help the fitting process

Example: chromatic model + heterogeneous data / 2

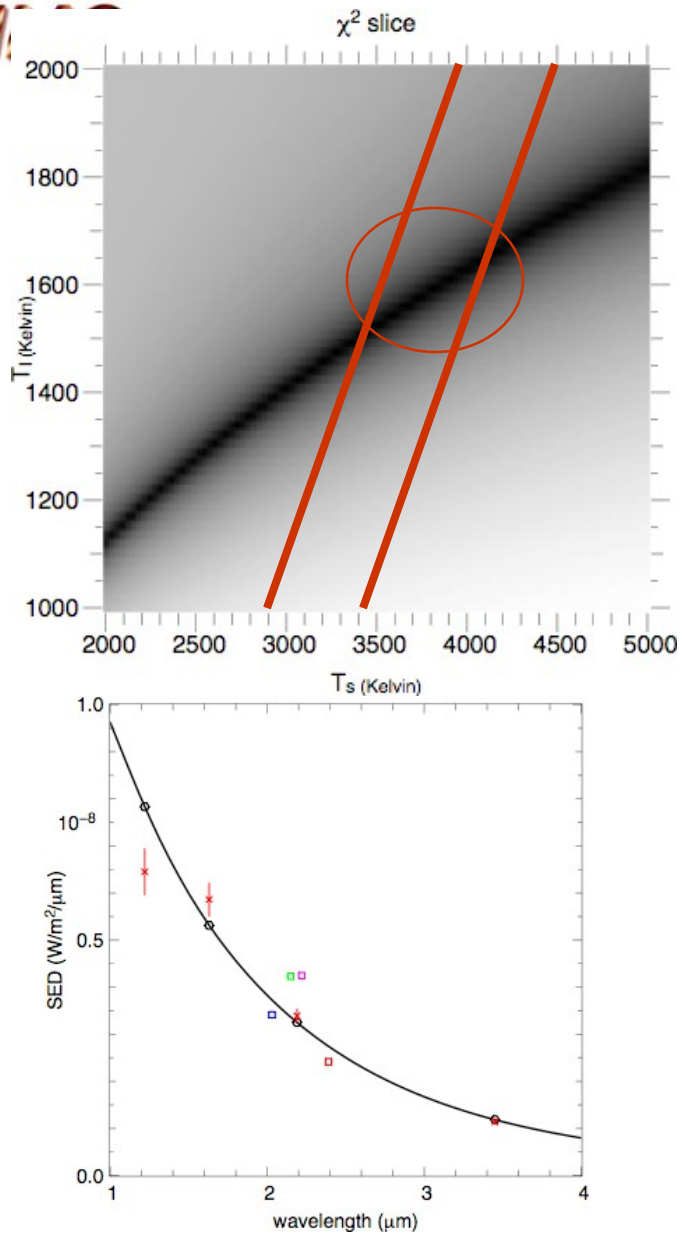




Perrin et al, A&A 426, 279, 2004

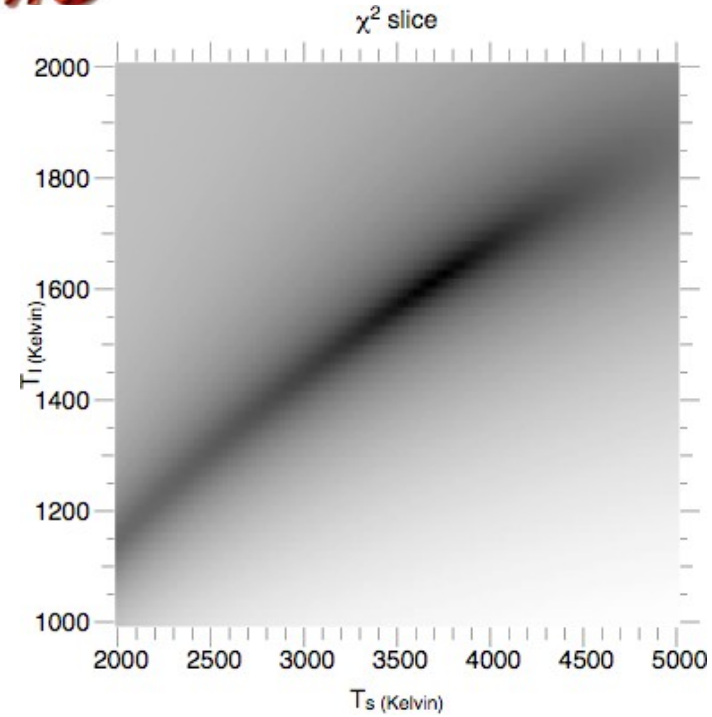
- squared visibilities : 4 sub-bands in K band
- magnitudes : J, H, K, L bands (Whitelock et al 2000)

Perrin et al. fitting procedure



- (R_*,R_L) from gridding
  - fit all other parameters from fixed sampled values (R_*,R_L)
  - arbitrary initial values of other parameters
- (T_*, T_L) from gridding + intersection with K photometry
  - Difficult to use the other bandwidths
- Fit 4 optical depths from fixed other parameters
- Compare photometry with other bandwidths: J, H, L.

Simulatenous fitting of all the data



١) Overall size of the object ?
- Radius of uniform disk: 18 mas

٢) Overall temperature ?
- For an uniform disk: 1540K

٣) Fit from this initial values
- Initial values of optical depths set to zero => uniform disk

Comparison of results

Parameter	Perrin et al.	Simultaneous fit	Fit with relative photometry
$R_\star$ (mas)	10.94 ± 0.85	11 ± 0.13	11 ± 0.19
R_L (mas)	25.00 ± 0.17	25.4 ± 0.16	25.4 ± 0.18
$T_\star$ (K)	3856 ± 119	3694 ± 113	3778 ± 163
T_L (K)	1598 ± 24	1613 ± 35	1681 ± 174
$\tau_{2.03}$	1.19 ± 0.01	1 ± 0.14	0.9 ± 0.35
$\tau_{2.15}$	0.51 ± 0.01	0.42 ± 0.08	0.36 ± 0.17
$\tau_{2.22}$	0.33 ± 0.01	0.27 ± 0.05	0.23 ± 0.11
$\tau_{2.39}$	1.37 ± 0.01	1.2 ± 0.13	1.08 ± 0.32
γ	–	–	0.9 ± 0.2

Fit with only relative photometry, like the SED given by an optical interferometer

Correlation matrix

	R_l	Rs_ratio	T_l	T_s	tau1	tau2	tau3	tau4
R_l	1	-0.66	-0.36	0.14	0.21	0.17	0.16	0.13
Rs_ratio	-0.66	1	0.71	-0.6	-0.67	-0.67	-0.66	-0.62
T_l	-0.36	0.71	1	-0.74	-0.94	-0.93	-0.93	-0.92
T_s	0.14	-0.6	-0.74	1	0.91	0.91	0.92	0.92
tau1	0.21	-0.67	-0.94	0.91	1	0.99	0.99	0.99
tau2	0.17	-0.67	-0.93	0.91	0.99	1	0.99	0.99
tau3	0.16	-0.66	-0.93	0.92	0.99	0.99	1	0.99
tau4	0.13	-0.62	-0.92	0.92	0.99	0.99	0.99	1

Conclusions

- LITpro
  - First public release forseen ~ end of 2008
- High in the list
  - Search for global minimum of χ^2
  - Associate Image reconstruction and Model fitting
- Fitting simultaneously heterogeneous data is better
  - Needs for SED in OIFITS standard (dispersed fringes)