

## JMMC Tools

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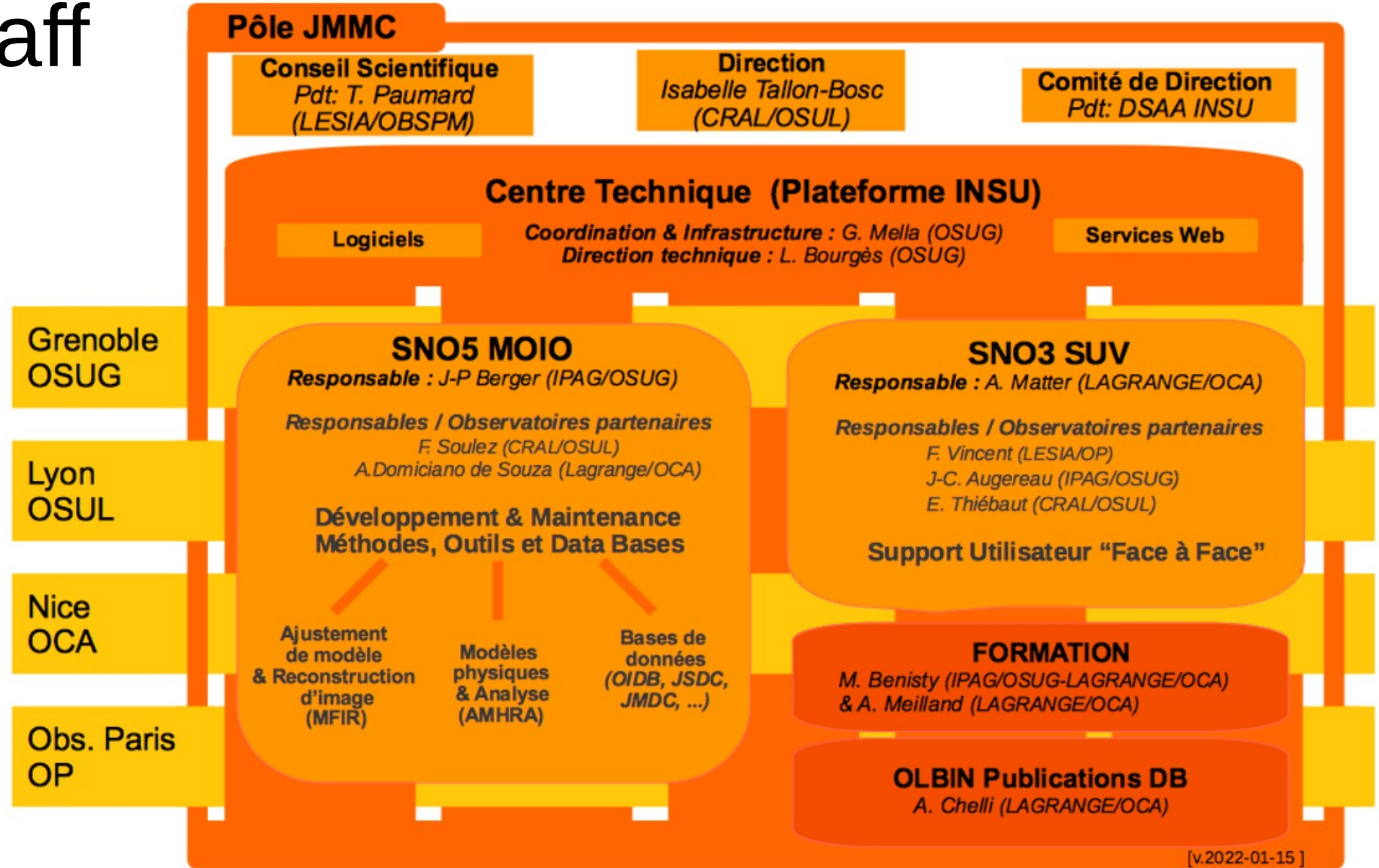


# Outline

- JMMC overview
- It's software and services suite
- Focus on
  - Observation preparation tools
  - Modelfitting tool
- Demo
- Conclusion

# JMMC staff

~20 researcher  
& 2 engineers  
part time  
< 3 or 4 FTE



[v.2022-01-15]

# JMMC overview

The **Jean-Marie Mariotti Center** coordinates the efforts of French Partner Laboratories with interferometric expertise to offer all the potential users of interferometric facilities the best operational environment.

The mission of JMMC is threefold and consists in:

- develop, produce, document and maintain the software necessary for the exploitation and the follow-up of new interferometric equipments, especially the VLTI,
- stimulate and coordinate the academic formation of non specialists,
- participate to the prospective around new interferometric instruments.



# Service overview



- + Expertise Center
- + User Support
- + Training
- + OLBIN publications

Real time astrophysical models

**AMHRA**

Asymmetric Model for High Resolution Astronomy

Evolved star (BSG, AGB)

Binary spiral model

Analytical Limb-darkening Elliptical or Spherical - ALDES

SearchCal

Query Parameters

1) Instrument Configuration 2) Science Object 3) SearchCal Parameters

Wavelength band: 0.15

Min. Magnitude: 2.0

Found Calibrators

Index	ID	RAD2000	DEC2000	mag	mag_err
1	0.0	03 47 29.08	+24 06 18.5	0.0010	-0.0020
2	0.386	03 49 39.74	+24 03 12.3	0.714	0.034
3	0.45	03 45 19.61	+24 22 31.9	0.936	0.036
4	0.595	03 44 52.54	+24 06 48.0	0.71	0.035

a2p2

Reduce data

- amdlib
- pndrs

Aspro2

Targets

Instrument mode

Map

Observability

UV coverage

Offaxis viewer

VLT I Periodic RR - AMBER - A1 G111

Day: 2011-10-15

Source: HRP1234

Prepare Observations

SearchFTT

GRAVITY+ filter: Find all off-axis fringe tracking targets

Underlying model

Search parameters

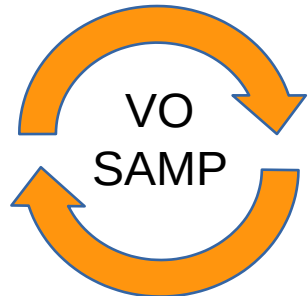
View Data

OIFits Explorer

VLT I - GRAVITY (L1900 nm - 2.450 μm) - A0-G1-J2-K0

Day: 2016-10-05T05:30:45 - Source: MYSTERYYY

Plot of flux vs spatial frequency



CDS Catalogs

Search Criteria

Search Results

Record number assigned by the VOdata team

Instrument: Any Instrument

Wavelength range: any value

Collection: Any Collection

DataPI name: Any DataPI

Data reduction level: L0, L1, L2, L3

Availability: Public, Restricted, All

Results

Meta-data will try to follow VOdata proposal and look for OI in the associated doc

19 observations from 19 offis files (10 private)

Search Data

JMIMC OI DB

Filters

Position: alpha, cm

Radius: 2

Date of observation: after YYYY-MM-DD before YYYY-MM-DD

Instrument: Any Instrument

Wavelength range: any value

Collection: Any Collection

DataPI name: Any DataPI

Data reduction level: L0, L1, L2, L3

Availability: Public, Restricted, All

Results

Meta-data will try to follow VOdata proposal and look for OI in the associated doc

19 observations from 19 offis files (10 private)

Fit Models

LITPro

Parameters

Filter setup

Plot model panel

Plot image

Plot residuals

Plot residuals with out angle

Reconstruct Images

Olmaging

LIT Unit

Color scale

Scale

Resolution

Scale

Scale

Scale



# Observation / Proposal preparation tools

Aspro2, AMHRA, SearchCal/JSDC, SearchFTT, a2p2

# ASPRO 2: Feature overview

Observation preparation = VLTI / CHARA / NPOI

Target & calibrator list with their models and groups

Target observability, UV coverage

Instrument modes + noise modeling => **OIFITS data**

Noise modeling & OIFits simulator: [see SPIE 2016](#)

Interoperability :

AMHRA

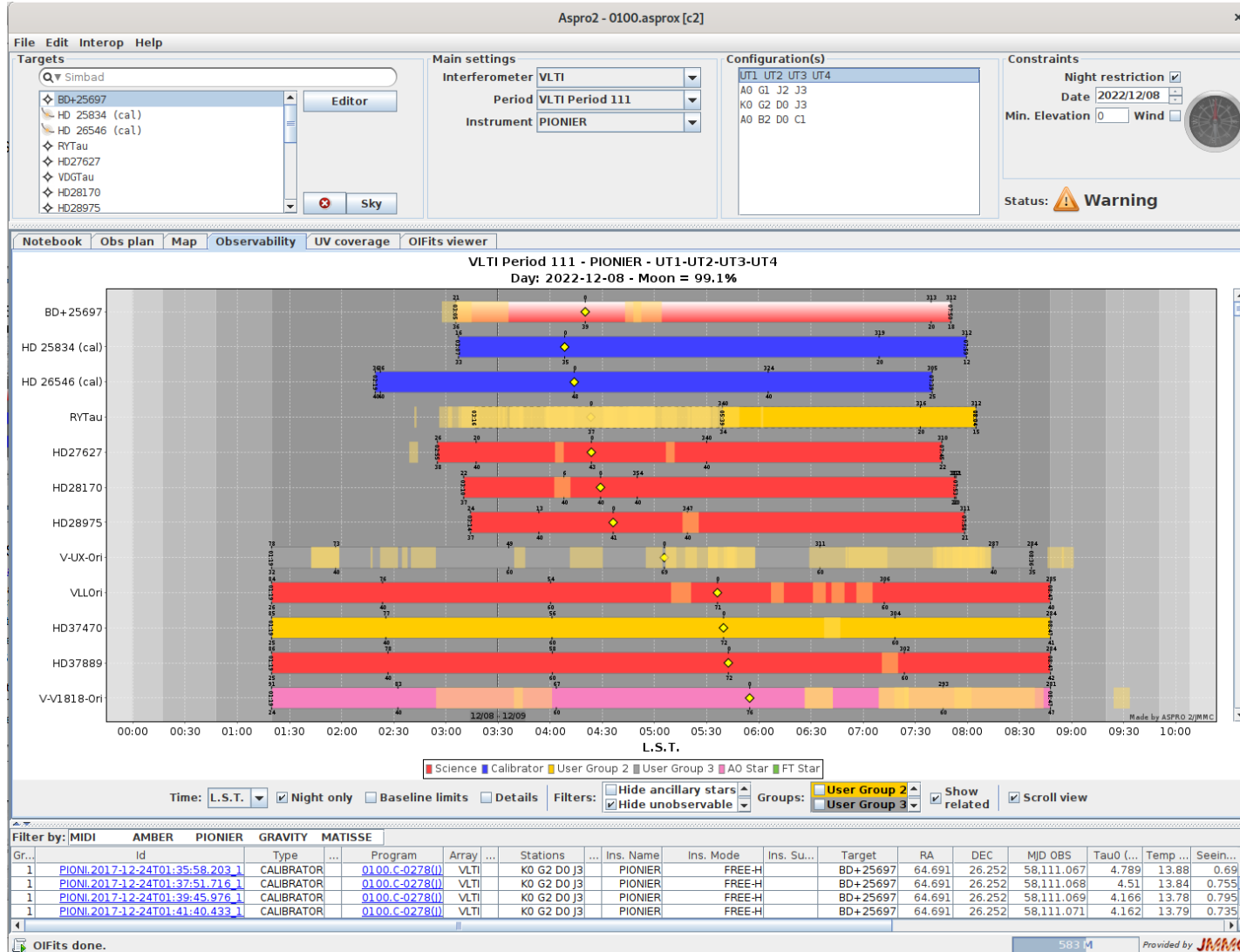
GetStar, SearchCal, Vizier / Simbad (flux)

OiDB, OIFits Explorer, LITpro or Olmaging ...

a2p2



# ASPRO 2: Observability



Observation = Targets, array & instrument setup, baselines...

SCI / CAL

Horizon / Delay Line constraints

Configuration comparison

Groups (AO, FT star + user)

Time markers (night mode)



# ASPRO 2: Target Editor

- Fluxes (mag) use GetStar

Target Editor

Targets Models Groups

Q Simbad ▲ ▼ ✕ Sort by: RA DEC Flag calibrator Remove calibrator

Targets

- BD+25697
- RYTau
- HD27627
- VDGTau
- HD28170
- HD28975
- V-UX-Ori
- VLLOri
- VCQTau
- HD37470
- HD37889
- VFUori
- V-V1818-Ori
- HD40003
- HD250289
- HD100546
- HD103924

Calibrators

- HD 25834 (cal)
- HD 26546 (cal)

Target

Name HD27627 Simbad SED **GetStar** SearchFTT

RA [HMS] 4.372002 DEC [DMS] 22.66223

PMRA PMDEC

Magnitudes: Mag calc.

B V

G R

I J

H K

L M

N flux unit:  mag  jy

Radial Velocity

Parallax Error

Spectral type

Object types

Identifiers

Name	Value	Unit
------	-------	------

Extra Information

Target notes [i]

Cancel OK

# ASPRO 2: Target Editor

- Fluxes (mag) use GetStar
- ( try with firefox
- if send VOTable does not work )

Target Editor

Targets Models Groups

Q Simbad ▲ ▼ ✕ Sort by: RA DEC Flag calibrator Remove calibrator

Targets

- BD+25697
- RYTau
- HD27627
- VDGTau
- HD28170
- HD28975
- V-UX-Ori
- VLLOri
- VCQTau
- HD37470
- HD37889
- VFUOri
- V-V1818-Ori
- HD40003
- HD250289
- HD100546
- HD103924

Calibrators

- HD 25834 (cal)
- HD 26546 (cal)

Target

Name HD27627 Simbad SED GetStar SearchFTT

RA [HMS] 4.372002 DEC [DMS] 22.66223

PMRA 5.84 PMDEC -36.61

Magnitudes: Mag calc.

B 9.836 V 8.79

G R 7.94714

I 7.43906 J 6.886

H 6.373 K 6.253

L 0.87411 M 0.59494

N 0.11863 flux unit:  mag  jy

Radial Velocity

Parallax 2.74 Error 1.6

Spectral type K0III

Object types ,Star,\*IR,

Identifiers HIP 20412,HD 27627,2MASS J04221920+2239445,DM 2200683,

Name	Value	Unit
SearchCalServerVersion	SearchCal Server v5.1.1	
baseMax	0.0	m
wlen	0.0	um

Extra Information

Target notes [i]

Cancel OK

# ASPRO 2: Target Editor

- Fluxes (mag) use GetStar Models
  - Analytical

**Target Editor**

Targets Models Groups

Models

- BD+25697
  - RYSau
  - HD27627
    - disk1
    - disk2
    - elong\_disk3

Model

Mode  Analytical  User Model

Name

model type

**Model description**

Returns the Fourier transform of a normalized ellipse centered at coordinates (X,Y) (milliarcsecond) with a ratio ELONG\_RATIO between the major diameter and the minor one MINOR\_AXIS\_DIAMETER, turned from the positive vertical semi-axis (i.e. North direction) with angle MAJOR\_AXIS\_POS\_ANGLE, in degrees, towards to the positive horizontal semi-axis (i.e. East direction). (the elongation is along the major\_axis)

For avoiding degenerescence, the domain of variation of MAJOR\_AXIS\_POS\_ANGLE is 180 degrees, for ex. from 0 to 180 degrees.

ELONG\_RATIO = major\_axis / minor\_axis  
FLUX\_WEIGHT is the intensity coefficient. FLUX\_WEIGHT=1 means total energy is 1.

The function returns an error if MINOR\_AXIS\_DIAMETER is negative or if ELONG\_RATIO is

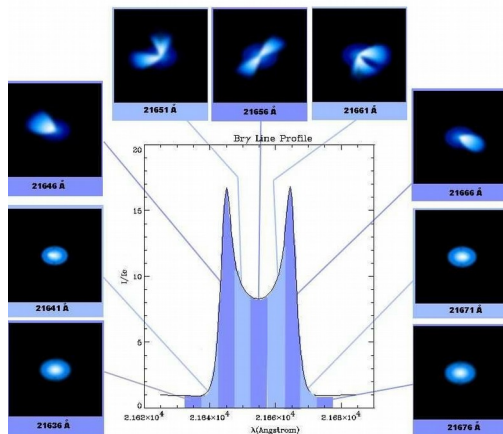
**Model Parameters**

Model	Name	Units	Value
disk1	flux weight1		1
	x1	mas	0
	y1	mas	0
disk2	diameter1	mas	0.269
	flux weight2		1
	sep2	mas	0
	pos_angle2	deg	0
elong disk3	diameter2	mas	0
	flux weight3		1
	sep3	mas	0

edit positions:  x / y (mas)  sep. (mas) / pos. angle [-180°; 180°]

# ASPRO 2: Target Editor

- Fluxes (mag) use GetStar Models
  - Analytical
  - User models (Fits cubes)



Target Editor

Targets Models Groups

Models

- BD+25697
- RYTau
- HD27627
  - disk1
- VDGTau
- HD28170
- HD28975
- V-UX-Ori
- VLLOri

Model

Mode  Analytical  User Model

State  enabled  disabled Info ?

File  Open

Scale   linked

Rotation  reset AMHRA

Fits Image

Color scale: 1.0E-5 to 1.1E-4

$\Delta RA$  (mas) - [North]

$\Delta DE$  (mas) - [East]

Coordinates:  
RA: 00:00:00  
DE: +00:00:00

Increments:  
RA: 1.6E-3 mas  
DE: 1.6E-3 mas

Image FOV:  
0.33 mas

Pixels:  
206 x 206

Image: 20/20

Model  $\lambda$ :  
2.45  $\mu m$

LUT table aspro Color scale LINEAR Display keywords Ruler Auto

Cancel OK autom



# AMHRA Service

AMHRA develops and provides online astrophysical models and data analysis tools dedicated to the scientific exploitation of high angular and high spectral facilities such as ESO-VLTI

- astrophysical models (parametric and grids) <https://amhra.oca.eu>

PI: Armando Domiciano de Souza

The image displays the AMHRA service interface, including a list of models, a detailed view of a 'Kinematic Be disk result', and a 'Target Editor' window showing a 'Fits Image' plot and a 'Send data to an application' dialog box.

**Real time astrophysical models:**

- Kinematic Be disk:** Model of the geometry (size and shape) and kinematics (rotation and expansion) of circumstellar, flat, rotating disks, relevant to Be stars. It is suited to interpret spectro-interferometric data obtained on emission lines formed in the disk.
- Disk and stellar continuum – DISCO:** Model of the continuum emission from a star surrounded by a gaseous circumstellar disk (free-free and bound-free), with partially ionized and geometrically thin disk with a physical structure given by the viscous Keplerian accretion disk model. DISCO is well suited to model Be stars.
- Evolved stars (RSG, AGB):** Stellar surface maps of evolved stars (RSG and AGB) computed from a 3d hydrodynamical simulation with COSBOLD-OPTIM3D. The available model corresponds to a star similar to the famous RSG Betelgeuse.
- Binary spiral model:** Phenomenological model mimicking the shock caused by the collision between the winds from massive stars (e.g. WR and OB stars) and that results in dusty spirals.
- Analytical Limb-darkening Elliptical or Spherical – ALDES:** ALDES provides intensity maps (images) or 1d intensity profiles for spherical or elliptical stars showing the limb darkening (LD) effect. Different LD laws are offered: uniform disk, linear, power law, quadratic, square root, logarithmic and four-parameter.

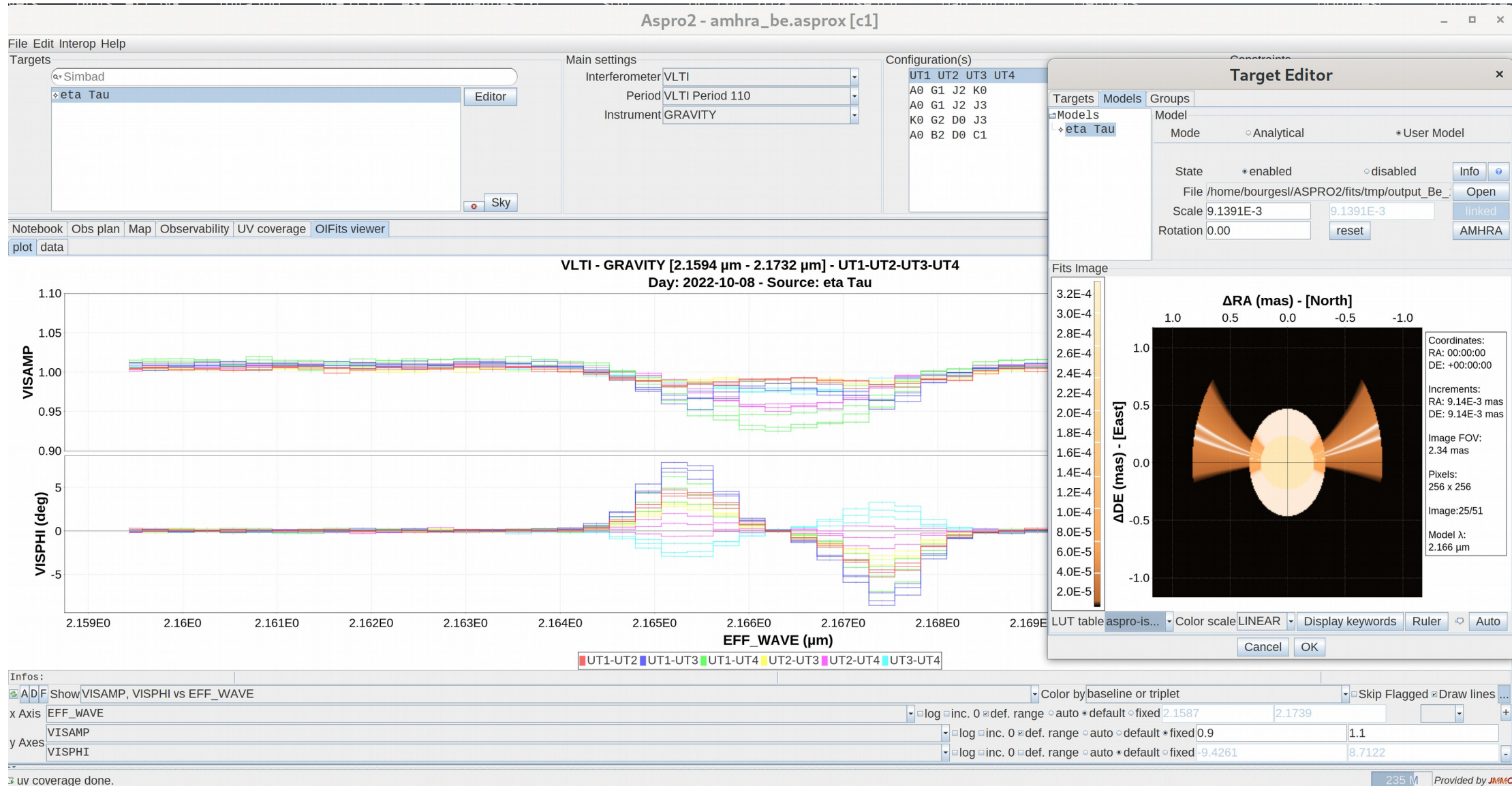
**Precalculated grids of astrophysical models:**

- Supergiant B(e) with HDUST:** Grid of models for B(e) supergiant stars computed with the 3d Monte Carlo radiative transfer code HDUST. The non-spherical circumstellar envelope (CSE), composed of gas (hydrogen) and dust (silicate), is modelled considering a bimodal outflow description (two-component wind).
- Limb-darkening with SATLAS:** Grid of models providing intensity maps for spherically symmetric stars, showing the limb darkening effect. The models were computed with the SATLAS model stellar atmospheres for several spectral bands. Data is provided for FGK dwarfs and red giants.

**Target Editor:**

The Target Editor window shows the 'Kinematic Be disk result' and a 'Fits Image' plot. The 'Send data to an application' dialog box lists applications like Aladin, Aspro2, Olmaging, SAOImage DS9, and gaia. The 'Fits Image' plot shows a color scale from 2.0E-5 to 3.2E-4 and a plot of  $\Delta RA$  (mas) - [North] vs  $\Delta DE$  (mas) - [East].

# Simulated data – e.g. : GRAVITY HIGH



# ASPRO 2: Target Editor

- Fluxes (mag) use GetStar Models
  - Analytical
  - User models (Fits cubes)
- Groups
  - Guide Star
  - Adaptive Optic Star
  - Fringe Tracking Star
  - Custom...

**Target Editor**

Targets Models Groups

Remove association Add group Delete group

Target

Name Sirius A

AO Star

FT Star

Guide Star

Groups

Group

Name AO Star

Category [OB]

Desc. Group indicating star optics system

Color #F781BF edit

Cancel OK

**Create Custom Groups & use drag and drop to arrange your targets (backup, priority ...)**

Aspro2 - Aspro2\_sample\_AO\_on\_SiriusB.aspr...

File Edit Interop Help

Targets

Main settings

Interferometer VLT1

Period VLT1 Period 103

Instrument GRAVITY

Configuration(s)

UT1 UT2 UT3 UT4

AO G1 J2 J3

AO G1 J2 K0

AO G2 J3 K0

AO B2 C1 D0

Constraints

Night restriction

Date 2018/12/08

Min. Elevation 45

Wind

Status **Warning**

Notebook Obs plan Map Observability UV coverage OIFits viewer

UVLT Period 103 - GRAVITY - UT1 UT2 UT3 UT4

Day: 2018-12-08 - Moon = 0.0%

Sirius B

Sirius A

12/08 - 12/09

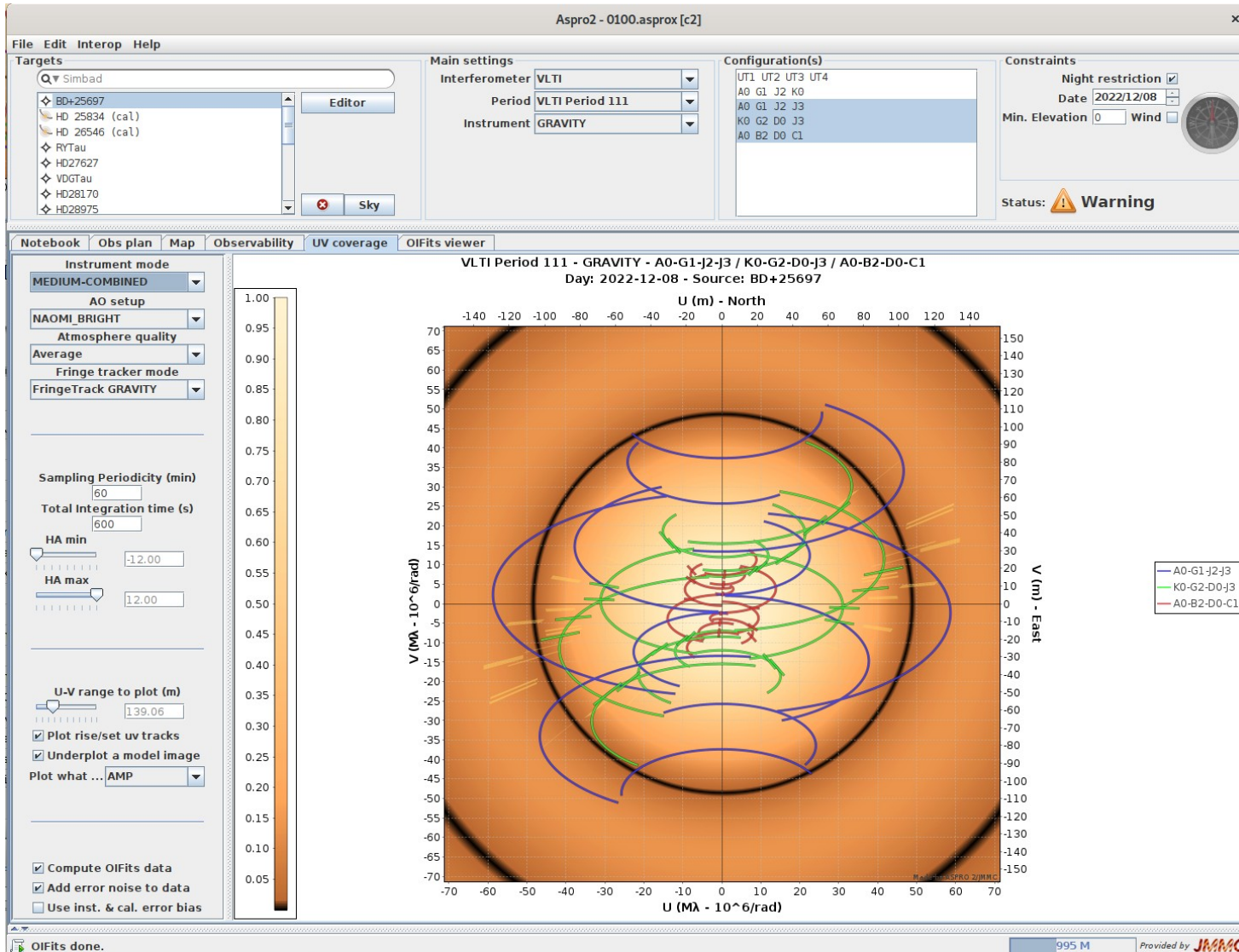
L.S.T.

Time: L.S.T.  Night only  Baseline limits  Details  Filters:  Show groups  Hide calibrators  Show related  Scroll view

uv coverage done. 471 M Provided by JMNC



# ASPRO 2: UV Coverage



UV Plot for GRAVITY MEDIUM-COMBINED mode with a disk model

Instrument mode:

Wavelength range / spectral channels

Transmission, camera parameters

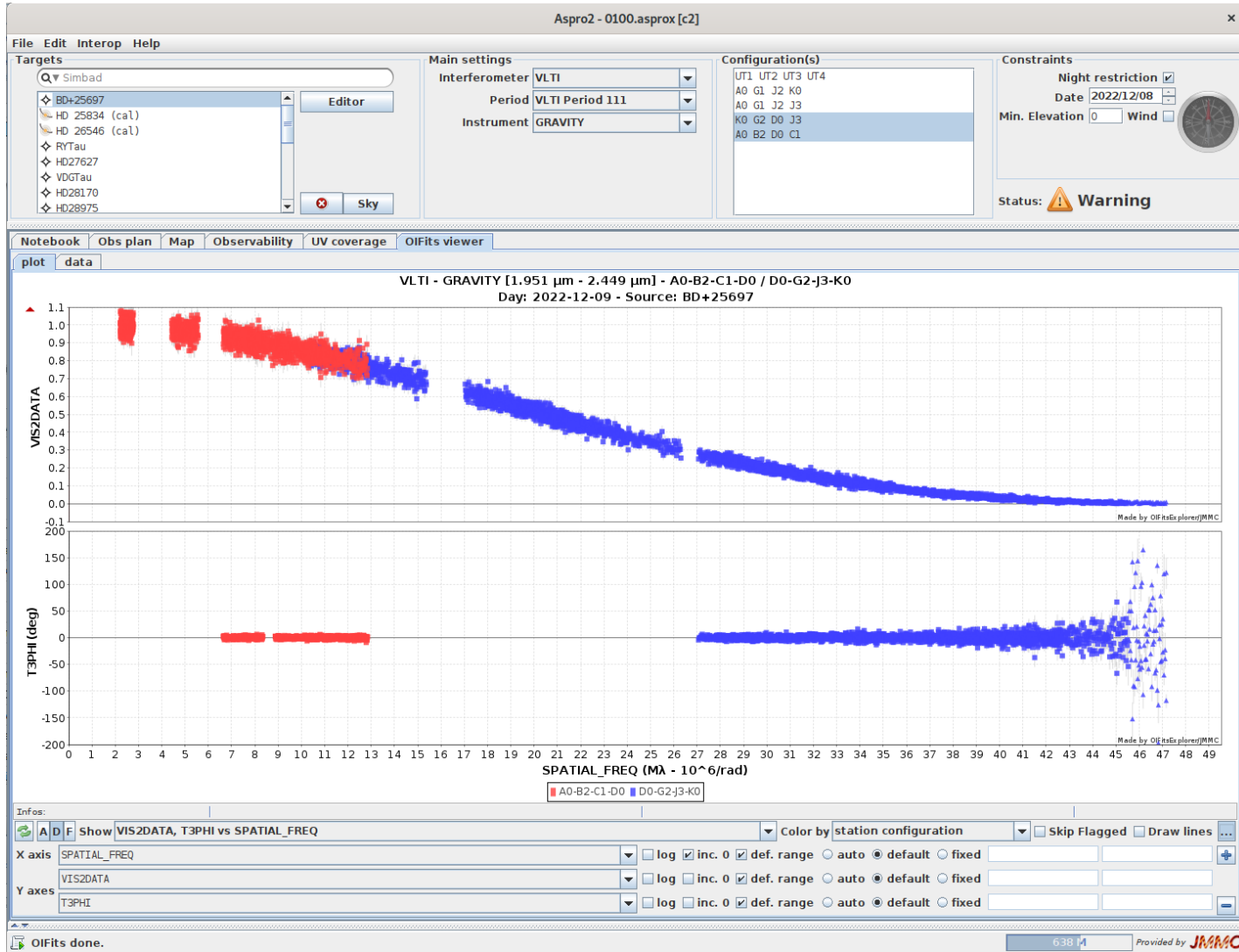
Seeing (atm quality)

Total integration time (s) on SCI

*Select baselines adapted to your model (scaling)*



# ASPRO 2: OIFits simulator



Exact Fourier Transform  
from user model images

*Click 'Skip flagged data' to hide data  
with low SNR*

Noise modelling:

Target photometry

Atm. transmission

Instrument parameters

# SearchCal / JSDC 2

Search Calibrators close to your target object and phot.

Filter results (SP type, luminosity, V2 ...)

Interoperability with ASPRO2, Aladin

Query JSDC 2: [Vizier II/346](https://vizier.cesr.edu/vizier/votable?source=JSDC2)

~400 000 stellar diameters

The screenshot shows the SearchCal [c2] application window. It is divided into several sections:

- Query Parameters:**
  - 1) Instrumental Configuration:** Magnitude Band: H, Wavelength (H) [μm]: 1.65, Max. Baseline [m]: 130.0
  - 2) Science Object:** Name: QV BD+25 697, RA 2000 [hh:mm:ss]: 04 18 45.7812725184, DEC 2000 [+-dd:mm:ss]: +26 15 06.644022732, Magnitude (H): 7.428
  - 3) SearchCal Parameters:** Min. Magnitude (H): 2.0, Max. Magnitude (H): 4.0, Scenario: Bright, RA Range [mn]: 240.0, DEC Range [deg]: 20.0
- Found Calibrators (960 sources, 913 filtered):** A table with columns: Index, dist, HD, RAJ2000, DEJ2000, vis2, vis2Err, diam\_chi2, LDD, e\_LDD\_rel, UD\_V, UD\_J, UD\_H, UD\_K. Row 6 is highlighted in yellow.
- Filters:** A list of checkboxes for filtering results, including:
  - Reject stars farther than: Maximum RA Separation (mn): 10.0, Maximum DEC Separation (degree): 10.0
  - Reject stars with magnitude: below: 0.0, and above: 10.0
  - Reject Spectral Types (and unknowns): [X] O [X] B [X] A [X] F [X] G [X] K [X] M
  - Reject Luminosity Classes (and unknowns): [ ] I [ ] II [ ] III [ ] IV [ ] V [ ] VI
  - Reject Visibility below: vis2: 0.5
  - Reject Visibility Accuracy above (or unknown): vis2Err/vis2 (%): 2.0
  - Reject Variability
  - Reject Multiplicity
  - Reject Invalid Object Types
  - Diameter quality: Maximum chi square: 2.0, Maximum relative error (%): 10.0
- Bottom:** A progress bar shows "searching calibrators... done." and a status "177 M" with the JMIMC logo.

# SearchFTT

Search Fringe Tracker Targets within 30'' for VLT/GRAVITY wide Dynamic queries to get candidates:

- Simbad
- GAIA : GAVO & ESAC
- GSC2 : VizieR
- Display table results & FOV image (AladinLite)

GRAVITY-wide: finding off-axis fringe tracking targets.  
This newborn tool is in its first version and is subject to various changes in its early development phase.

Underlying method:  
You can query one or several Science Targets. For each of them, Fringe Tracker Targets will be given using following research methods:

- Simbad for sources that are suitable for fringe tracking.
- Main catalogs
  - GSC2 [The Guide Star Catalogue, Version 2.4.2 \(2020\)](#)
  - Gaia DR3 Gaia DR3 catalogues and cross-matched catalogues through [ESA archive center](#).
- Additional catalogs (use toggle button in the menu to get result tables)
  - GDR2AP [The Astrophysical Parameters from Gaia DR2, 2MASS & AllWISE](#) catalog through the GAVO DC.
  - Gaia DR2 Gaia DR2 catalogues [with its external catalogues cross-match](#) through [ESA archive center](#).

Each query is performed within 30' of the Science Target. A magnitude filter is applied on every Fringe Tracker Targets according to the best limits offered in P110 for UT (MACAO) OR AT (NAOMI) respectively ( $K < 11$  AND  $V < 15$ ) OR ( $K < 10$  AND  $R < 12.5$ ). When missing, the V and R magnitudes are computed from the Gaia G, Grb and Grp magnitudes. The user must [refine its target selection](#) to take into account [VLT Adaptive Optics specifications](#) before we offer a configuration selector in a future release.

- Enter comma separated names ( resolved by [Simbad](#)) or coordinates (RA +/-DEC in degrees J2000), in the TextBox below.
- Move your pointer to the column titles of the result tables to get the column descriptions.
- To send a target to [Aspro2](#) (already open), click on the icon in the [GetStar](#) column, then press "Send Votable".
- Please [fill a report](#) for any question or remark.

HD224803, 0.1 -0.1, DH38

**HD224803**  
ICRS coord. [deg] (ep=J2000) : 0.20702433180999996 36.78009900429  
Proper motions [mas/yr] : -24.63 -22.343

2 Simbad 2 GSC2 2 Gaia DR3 2 GDR2AP 2 Gaia DR2

Simbad Name	dist [arcsec]	ra [deg]	dec [deg]	G	K	V	R	otype_txt	GetStar
<a href="#">HD 224803</a>	0	0.207	36.78	8.053	6.181	8.26	-	-	
<a href="#">HIP 70</a>	15.38	0.203	36.778	10.379	8.82	10.22	-	-	

Simbad link for GSC2	j2000_dist [arcsec]	ra [deg]	dec [deg]	mag_ks [mag]	mag_v [mag]	mag_r [mag]	GetStar
<a href="#">GSC2 NBH5000476</a>	0.077	0.207	36.78	6.181	8.283	-	-
<a href="#">GSC2 NBH5000478</a>	15.447	0.203	36.777	8.82	10.308	13.672	-

Simbad link for Gaia DR3	j2000_dist [arcsec]	ra [deg]	dec [deg]	mag_ks [mag]	mag_g [mag]	mag_v [computed]	mag_r [computed]	GetStar
<a href="#">HD 224803</a>	0.078	0.207	36.78	6.181	8.053	8.27	7.795	
<a href="#">HIP 70</a>	15.445	0.203	36.777	8.82	10.379	10.526	10.148	

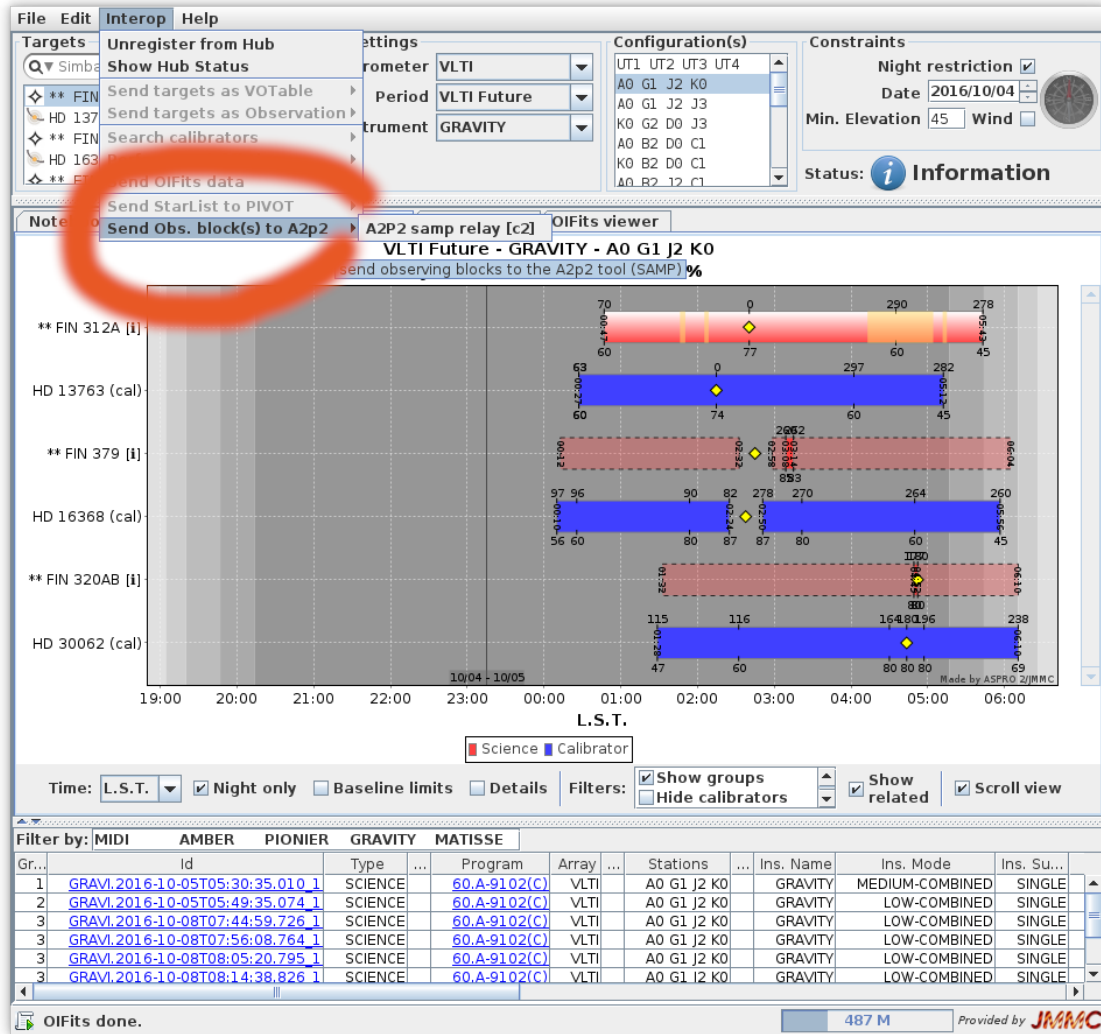
**0.1-0.1**  
ICRS coord. [deg] (ep=J2000) : 0.1 -0.1  
Proper motions [mas/yr] : 0.0 0.0

Sorry, no fringe tracking star found for 0.1-0.1 in Simbad.  
Sorry, no fringe tracking star found for 0.1-0.1 in GSC2.  
Sorry, no fringe tracking star found for 0.1-0.1 in Gaia DR3.

**DH38**  
ICRS coord. [deg] (ep=J2000) :

# A2P2, the ASPRO2 companion tool in Python

Send your VLT/ OB (SCI & ancillary stars) from ASPRO2 to ESO p2: PIONIER, GRAVITY & MATISSE



The screenshot shows the ESO p2 interface with a list of observing runs. A blue arrow points from the A2P2 interface to this list.

Project ID	Instrument	Container type
60.A-9003(L)	GRAVITY	VM Run (IP 107.01)
New Folder	GRAVITY	Folder
GRAVITY Test Tristra	GRAVITY	Folder
New Folder	GRAVITY	Folder
WDS_J00003_441	GRAVITY	Folder
New Folder	GRAVITY	Folder
New Folder	GRAVITY	Folder
New Folder	GRAVITY	Folder
GRAVITY tests Julien	GRAVITY	Folder
Christian	GRAVITY	Folder
60.A-9003(M)	MATISSE	VM Run (IP 107.01)
60.A-9003(N)	PIONIER	VM Run (IP 107.01)
60.A-9252(M)	GRAVITY	SM Run (IP 107.01)
60.A-9252(N)	MATISSE	SM Run (IP 107.01)
60.A-9253(T)	PIONIER	SM Run (IP 107.01)

<https://www.eso.org/p2>

**Try A2P2:**  
**pip install -U a2p2**





# Model fitting with LITpro

# Model fitting principle

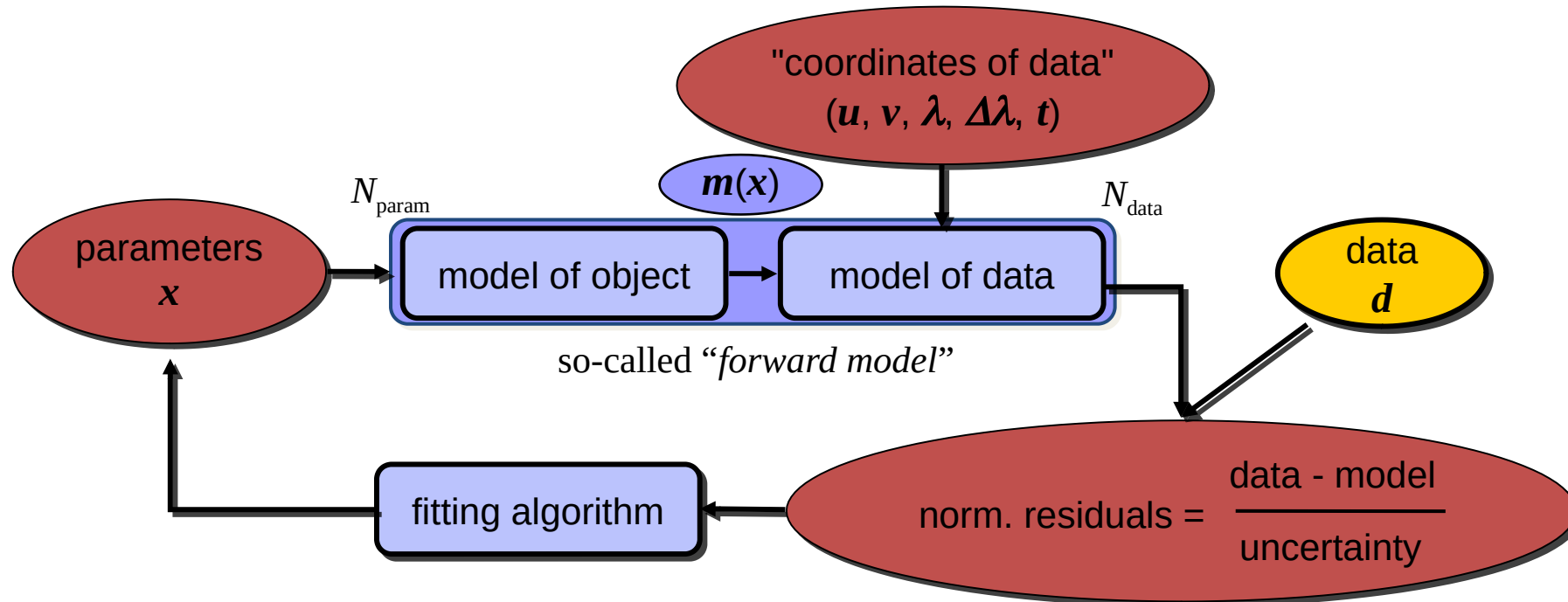
data  
 $d$

- What we have in hand
  - interferometric data (here OIFITS) **and uncertainties on data**
    - OI\_VIS2 squared visibility amplitude
    - OI\_T3 triple product (amplitude and phase)
    - OI\_VIS complex visibility (amplitude and phase)
  - other data :
    - OI\_FLUX calibrated or uncalibrated spectrum (OIFITS2)
    - absolute photometry, etc.
  - priors: all possible models of object

$m(x)$   
parameters  
 $x$

- What we want
  - identify the observed object seen by the instrument with a (forward) model  $m(x)$
  - estimate parameters  $x$ , **and uncertainties on the parameters**

# Model fitting principle



## Model fitting principle

- The **best parameters** maximize the probability of the data (*knowing the model*)

$$\mathbf{x}_{\text{best}} = \arg \max_{\mathbf{x}} \text{Pdf}(\mathbf{d} \mid \mathbf{m}(\mathbf{x}))$$

where  $\mathbf{d}$  data (**random quantities, known statistics**)

$\mathbf{x}$  parameters

$\mathbf{m}(\mathbf{x})$  model (of data):  $\sim$  *expected values of data*

**Assumptions:** data have **Gaussian statistics** and are **statistically independent**

$$\mathbf{x}_{\text{best}} = \arg \min_{\mathbf{x}} \sum_{i=1}^{N_{\text{data}}} \left( \frac{d_i - m_i(\mathbf{x})}{\sigma_i} \right)^2$$

$\sigma_i$  error on  $d_i$

$$= \arg \min_{\mathbf{x}} [ \chi^2(\mathbf{x}) ]$$



# Model fitting principle

data  
 $d$

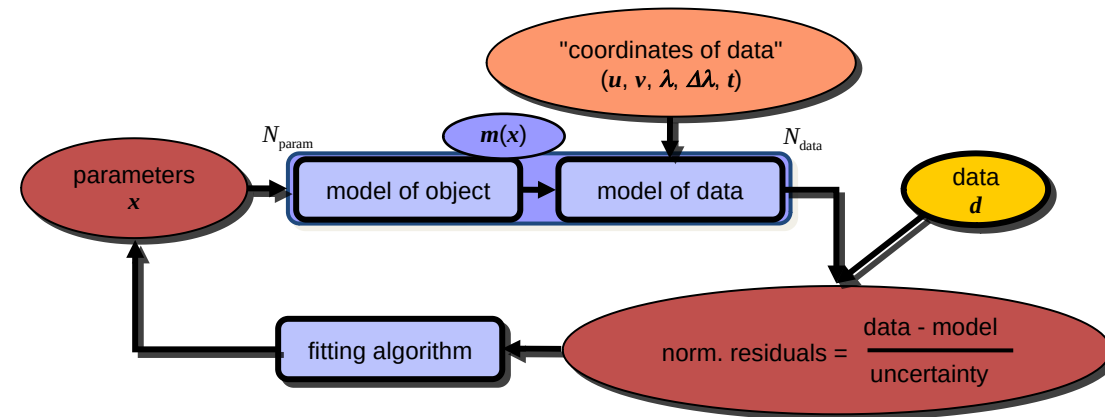
- What we have in hand
  - interferometric data (here OIFITS) **and uncertainties on data**
    - OI\_VIS2 squared visibility amplitude
    - OI\_T3 triple product (amplitude and phase)
    - OI\_VIS complex visibility (amplitude and phase)
  - other data :
    - OI\_FLUX calibrated or uncalibrated spectrum (OIFITS2)
    - absolute photometry, etc.
  - priors: all possible models of object  $\rightarrow m(x)$

$m(x)$   
parameters  
 $x$

- What we want
  - identity the observed object with a model  $m(x)$
  - estimate object parameters  $x$ , **and uncertainties on the parameters**

fitting algorithm

- What we need
  - tools for minimizing  $\chi^2(x) \rightarrow$  **fitting algorithm**
  - there are several methods on the "market"  $\rightarrow$  different softwares accessible
  - PMoired, OITools, ... and **LITpro**.



## LITpro model fitting software

M.Tallon, I. Tallon-Bosc, *conception, "expert layer"* CRAL / Lyon Observatory

G. Mella, *Graphical User Interface* Grenoble Observatory

*Maintenance and improvement inside a working group*

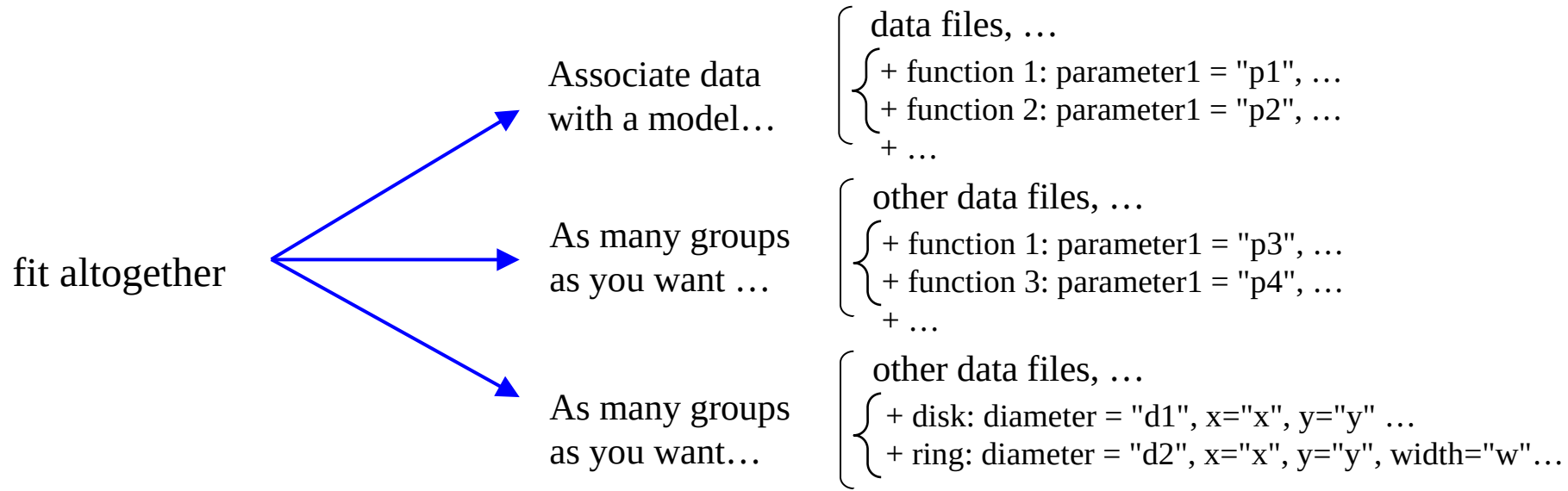
with F. Soulez, H. Beust, L. Bourgès, J.P. Berger

First public release Octobre 2009

## LITpro main features

- a user-friendly accessibility via a GUI
  - implemented in JAVA
  - interoperability with other tools
  - (OIFitsExplorer, OiDB, Aspro2, OImaging, SAOimageds9)
- an easy Modeling builder
  - rich library of elementary functions combinable between them
- a fast Fitter "engine": (modified) *Levenberg-Marquardt algorithm*
  - Combined with a Trust Region method
  - Bounds on the parameters
  - Partial derivatives of the model by finite differences
- some tools for analysis and help to conduct the fit
  - exploration of the  $\chi^2$  space

# Setting up the fitting process / principle

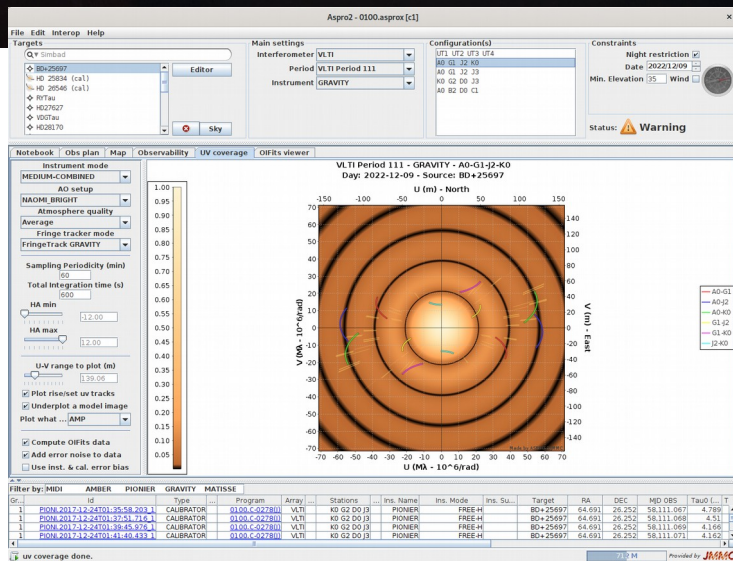


Configuration of parameters

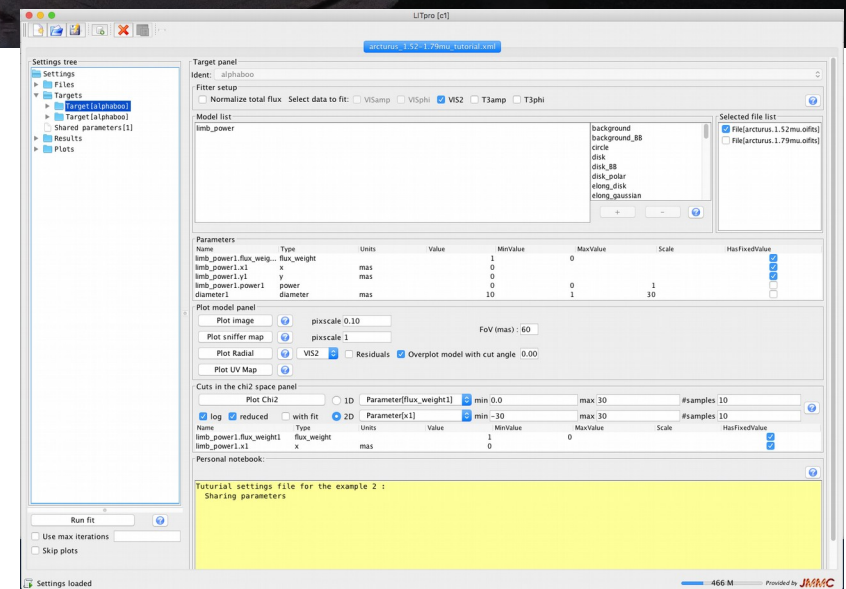
- "p1" → starting value, bounds, fixed or fitted, units
- "p2" → starting value, bounds, fixed or fitted, units
- ...
- "r1" → starting value, bounds, fixed or fitted, units
- ...

- Through the GUI





# Demo





# Final words

Get tools & documentation : [www.jmmc.fr](http://www.jmmc.fr)

Find courses and practice sessions  
of last VLTISchools...

Please report any problem, question or enhancement request to the JMMC  
User Support  
at

[www.jmmc.fr/support](http://www.jmmc.fr/support)

**Feedback always appreciated and useful !**

