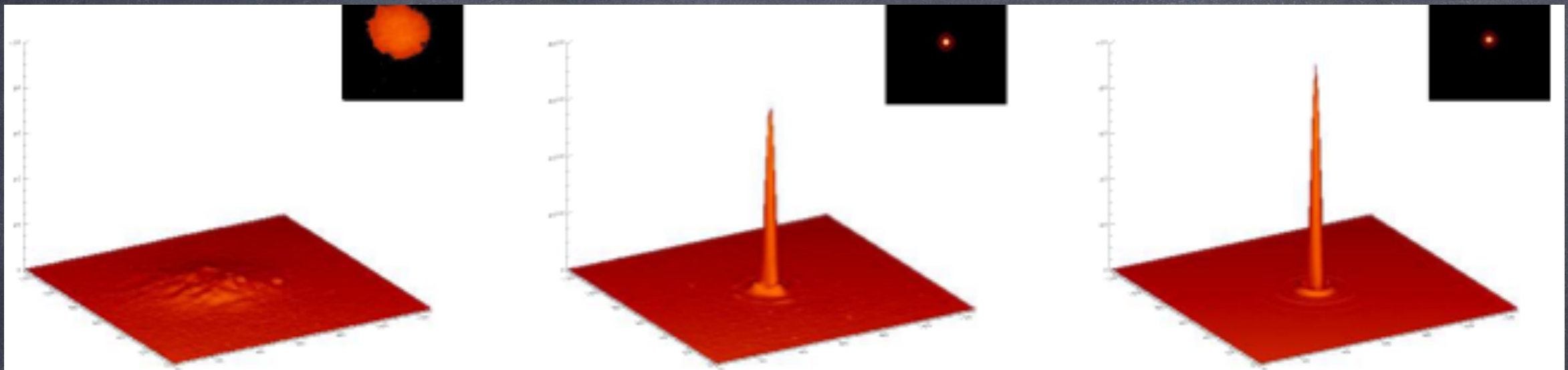


Morphologie de la PSF - 1



no correction

corrected ($SR = 64\%$)

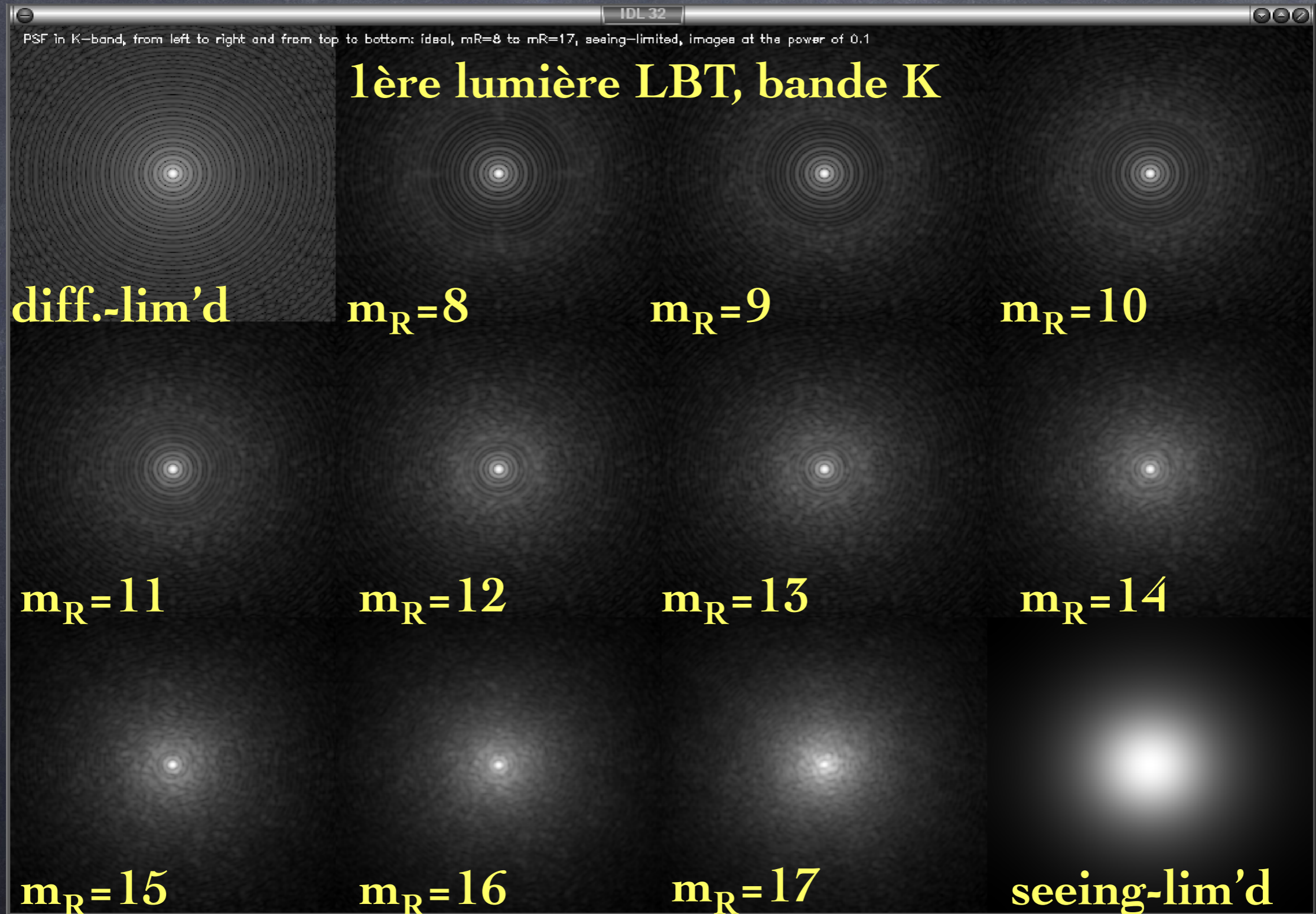
Airy pattern

Imaging wavelength : $2.2\mu m$

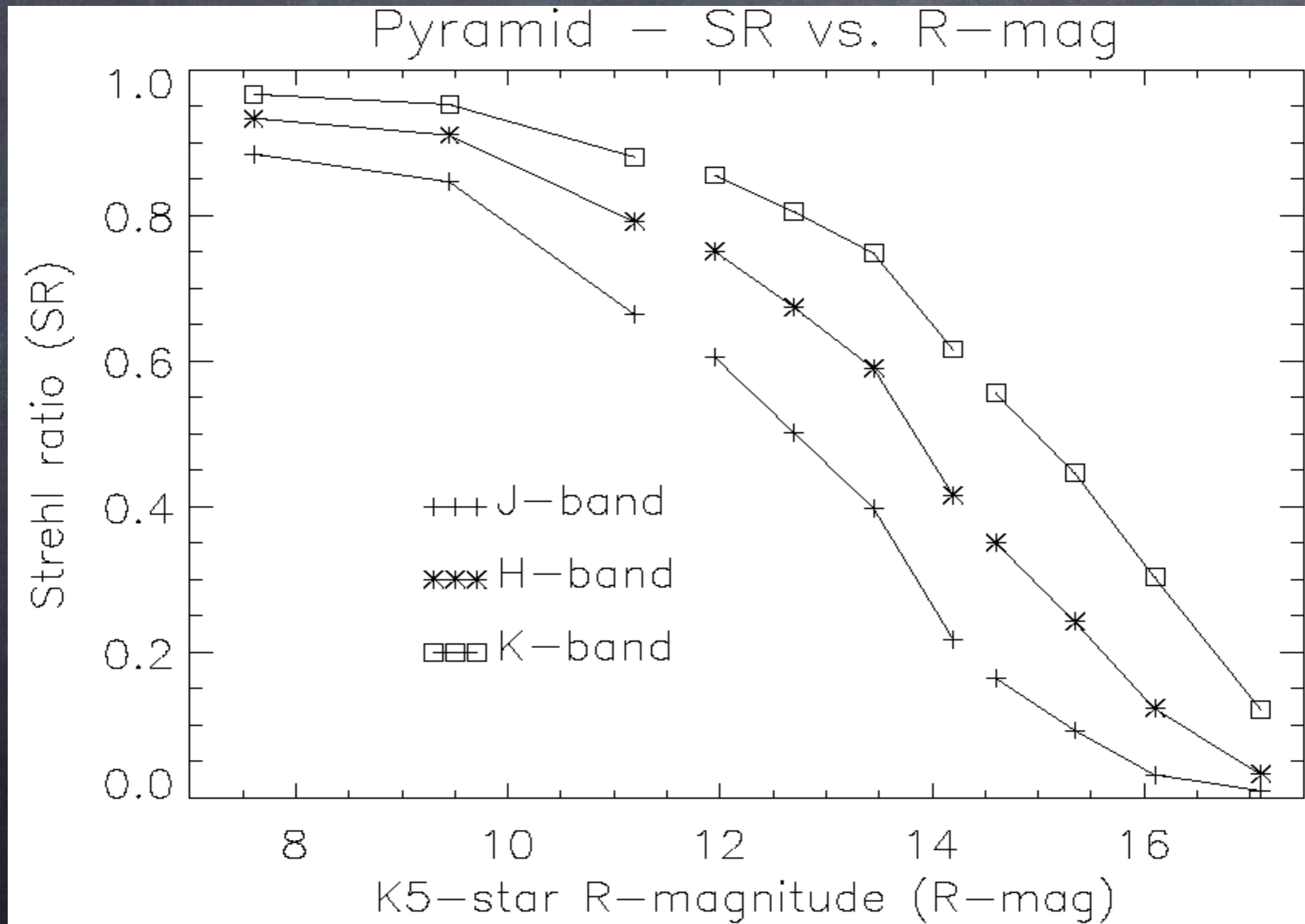
Turbulence : $r_o = 1m$ à $2.2\mu m$, wind speed = $10m/s$, telescope : $D = 8m$

System (NAOS) : 144 sub-aperture, 185 actuators, $500Hz$ temporal sampling frequency

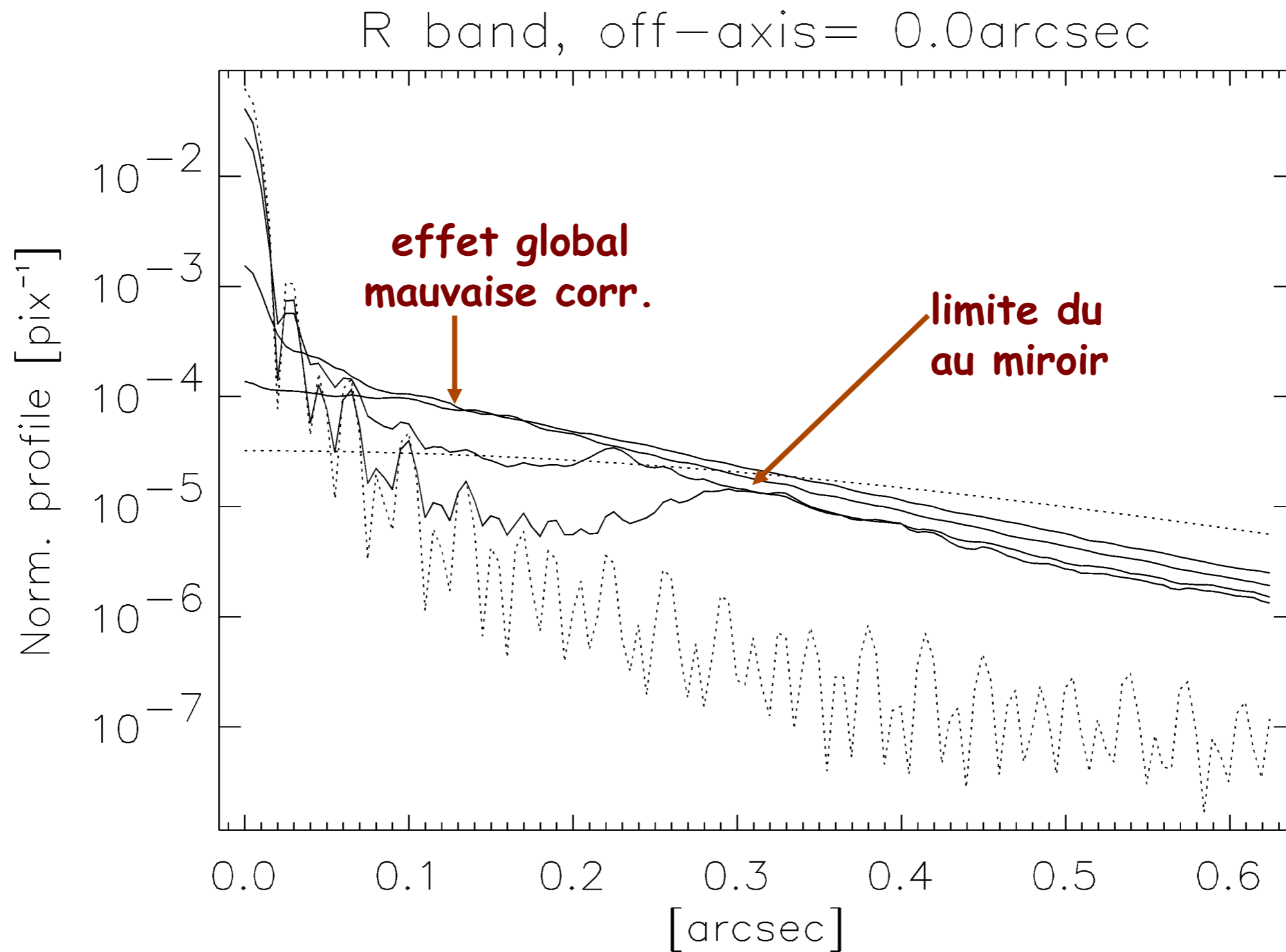
Morphologie de la PSF - 2



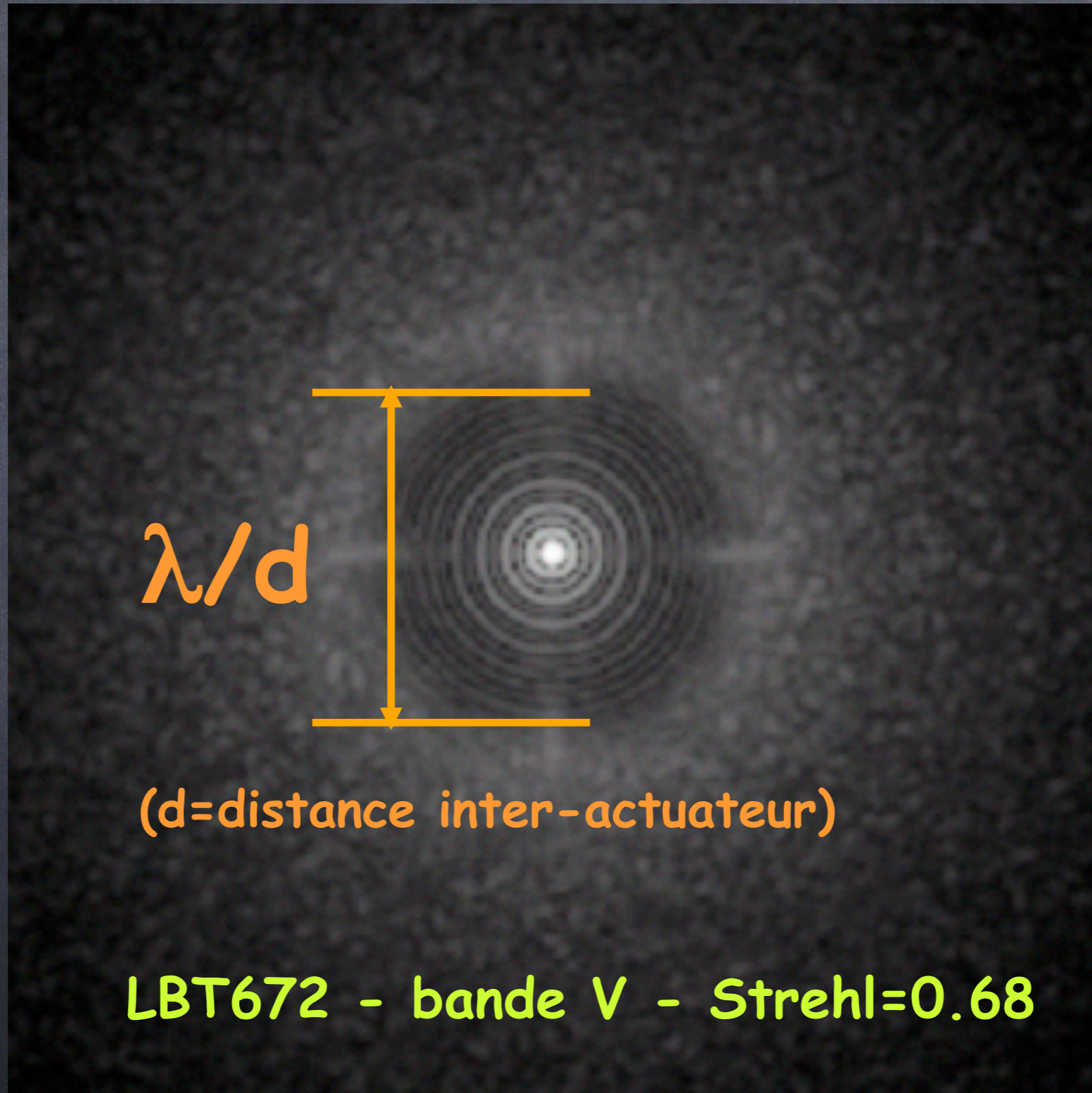
Morphologie de la PSF - 3



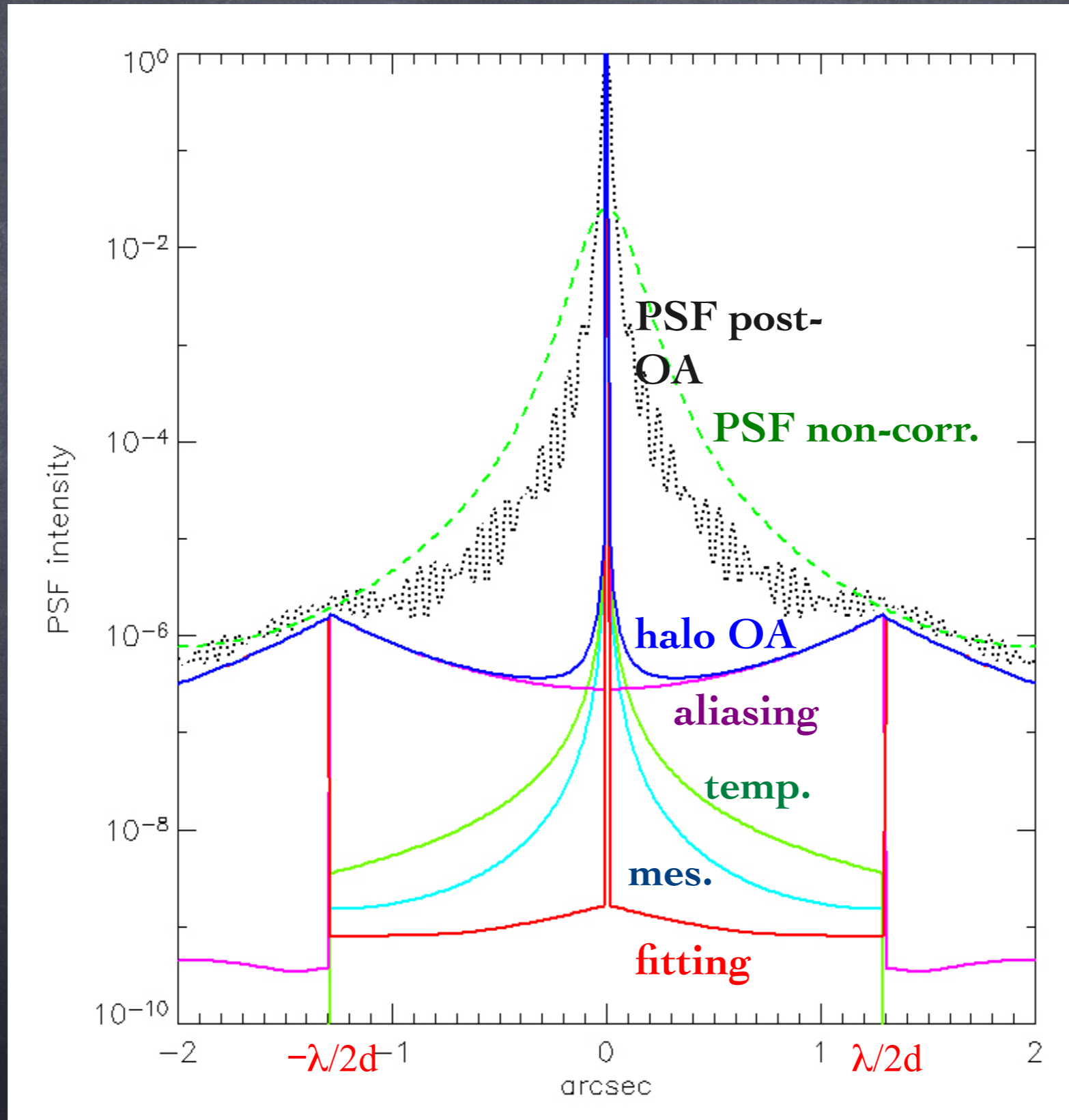
Morphologie de la PSF - 4



Morphologie de la PSF - 5



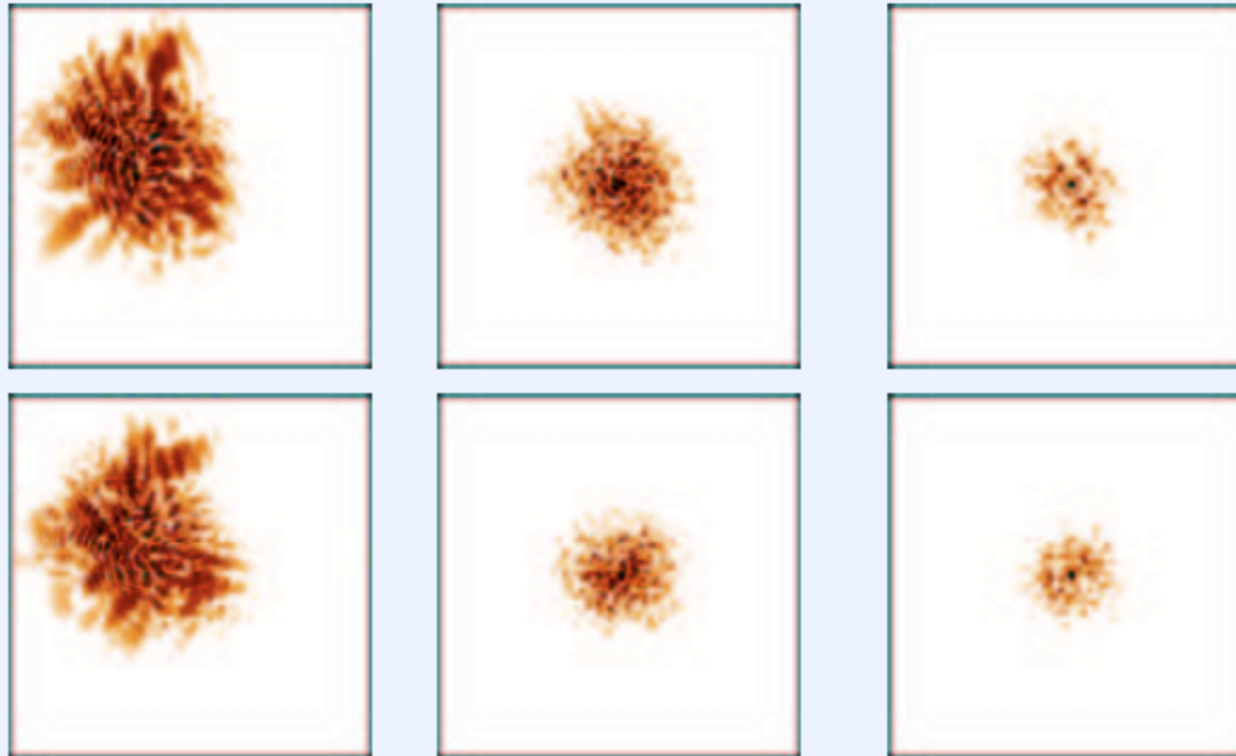
Morphologie de la PSF - 6



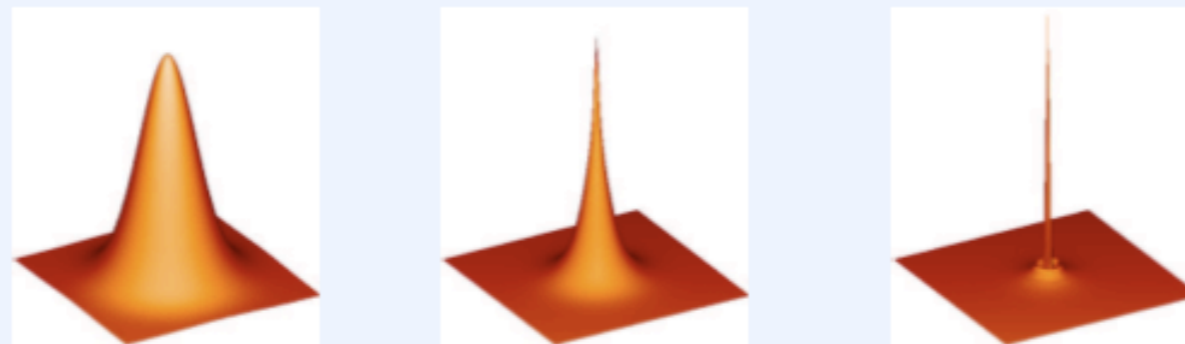
Morphologie de la PSF - 7

sans correction faible correction correction partielle

images courte pose [échelle log]



images longue pose (normalisées)

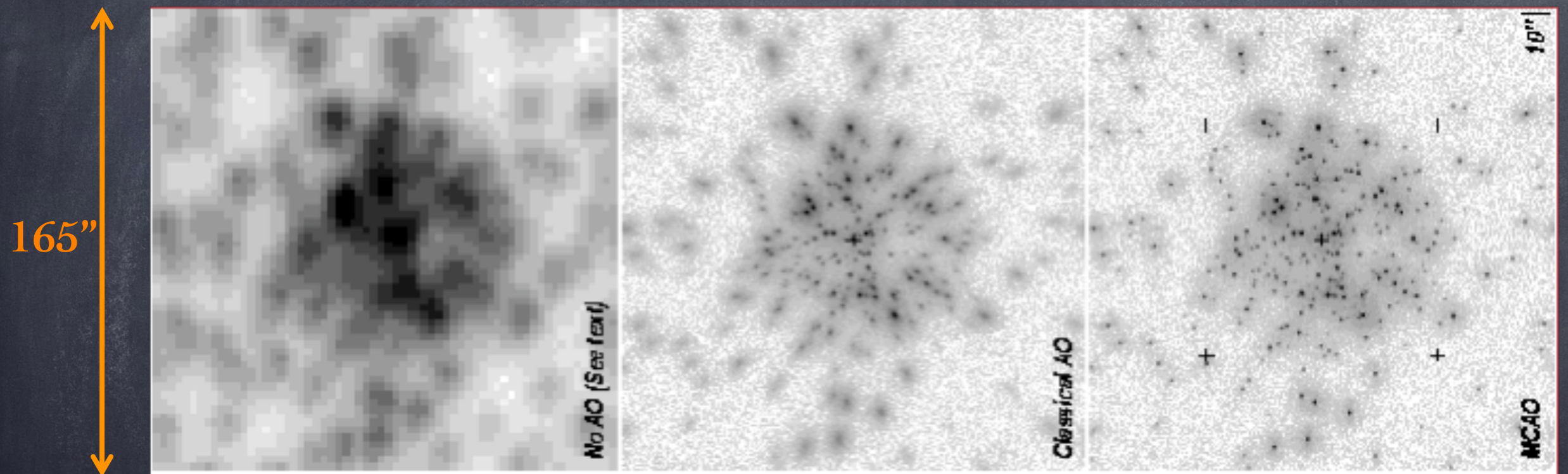


Réduction du nombre de speckle

Concentration des photons dans le coeur cohérent

Anisoplanétisme - 1

Cas de l'AO grand-champ : anisoplanétisme...

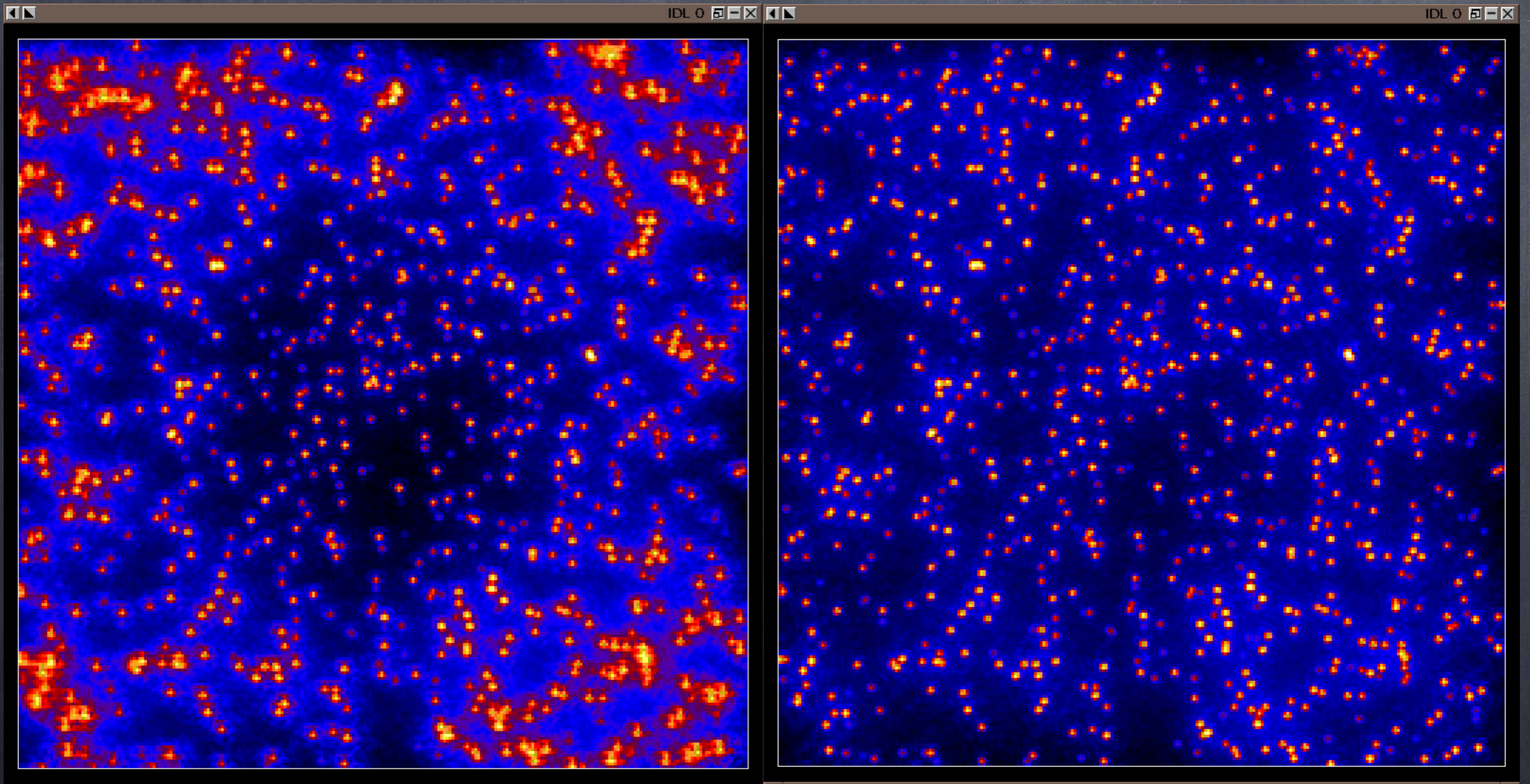


Sans OA

OA classique
(1 DM, 1 NGS)

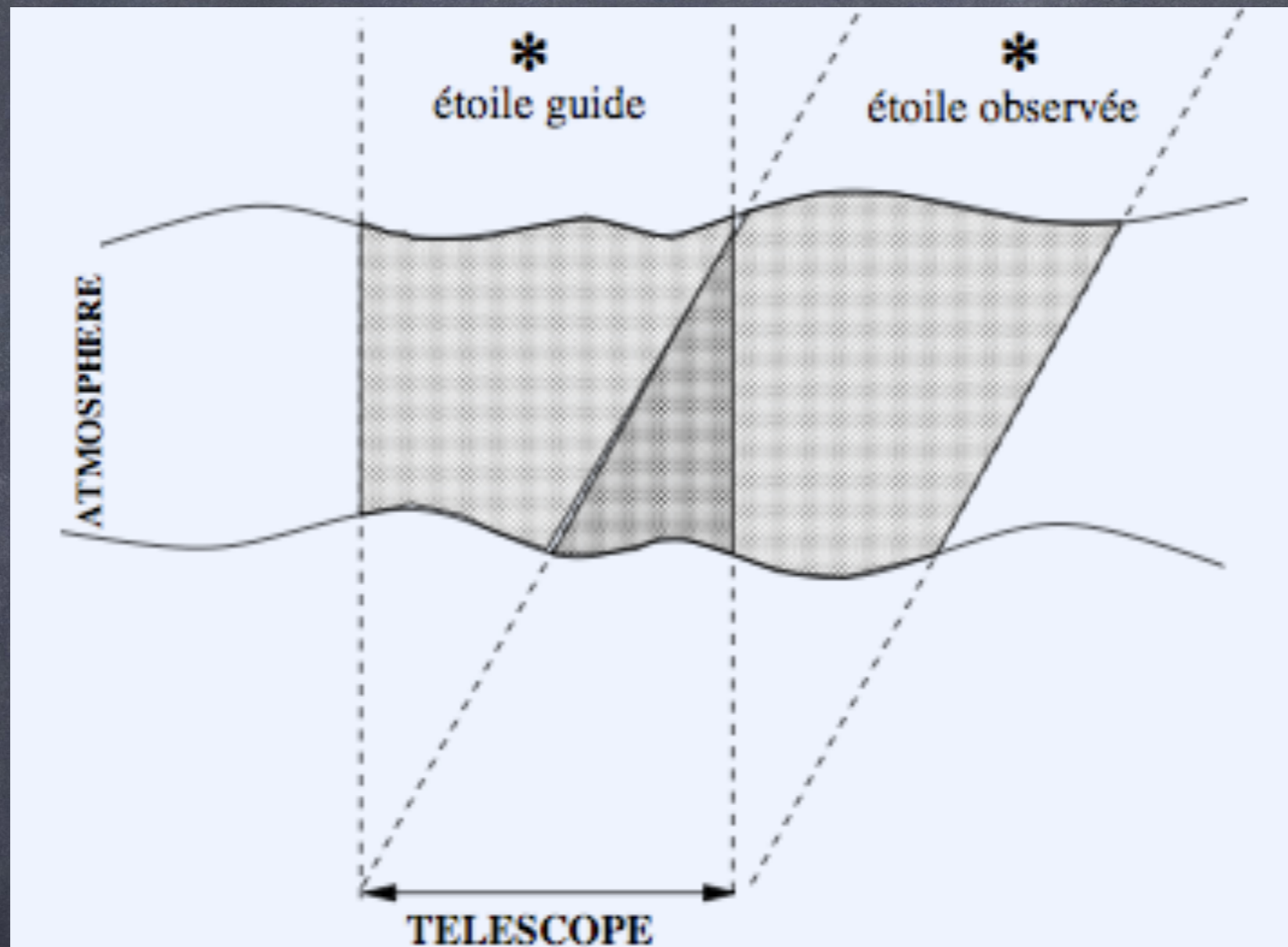
OA multi-conjuguée
(2 DMs, 5 NGS')

Anisoplanétisme - 2



(bande J, champ de 1', simu. B.Ellerbroek, Gemini Obs.)

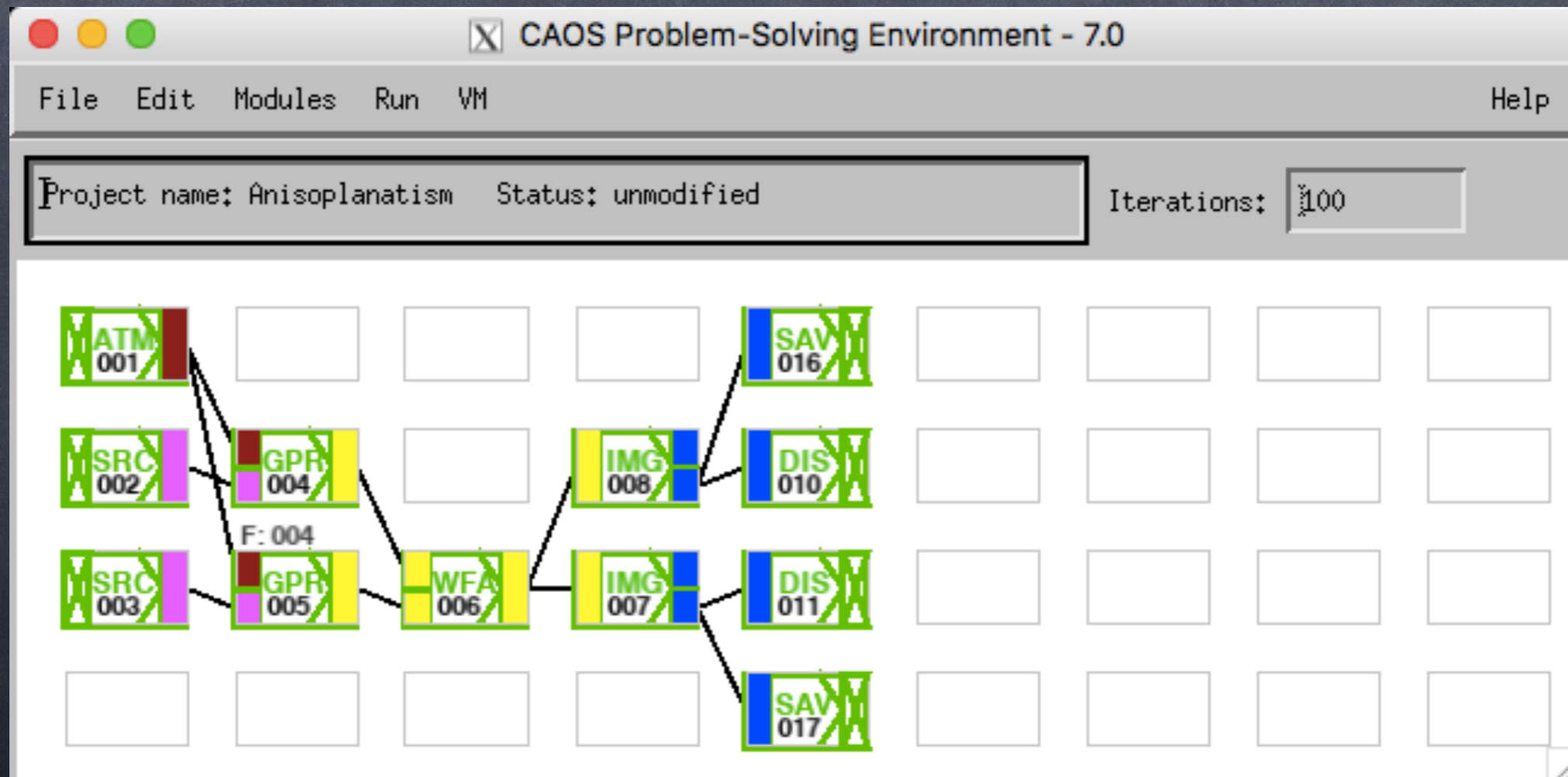
Anisoplanétisme - 3



Anisoplanétisme - 4

Outil numérique utilisé pour cette étude : CAOS

(CAOS Problem-Solving Environment + Software Package CAOS + Example project "Anisoplanatism"...)



The CAOS “PSE”...

- CAOS means **Code for Adaptive Optics Systems**.
- “PSE” means **Problem-Solving Environment**.
- It is written in IDL, and based on a **modular** structure.
- It is composed of a global interface (the **CAOS Application Builder**), a library of utility routines (the **CAOS Library**), and some scientific packages (the **Software Packages**).
- a **Software Package** is a set of modules dedicated to a given scientific subject (AO, imaging, whatever).

CAOS Problem Solving Environment -1

CAOS
Application Builder

global interface

CAOS
Library

ASTROLIB
Library

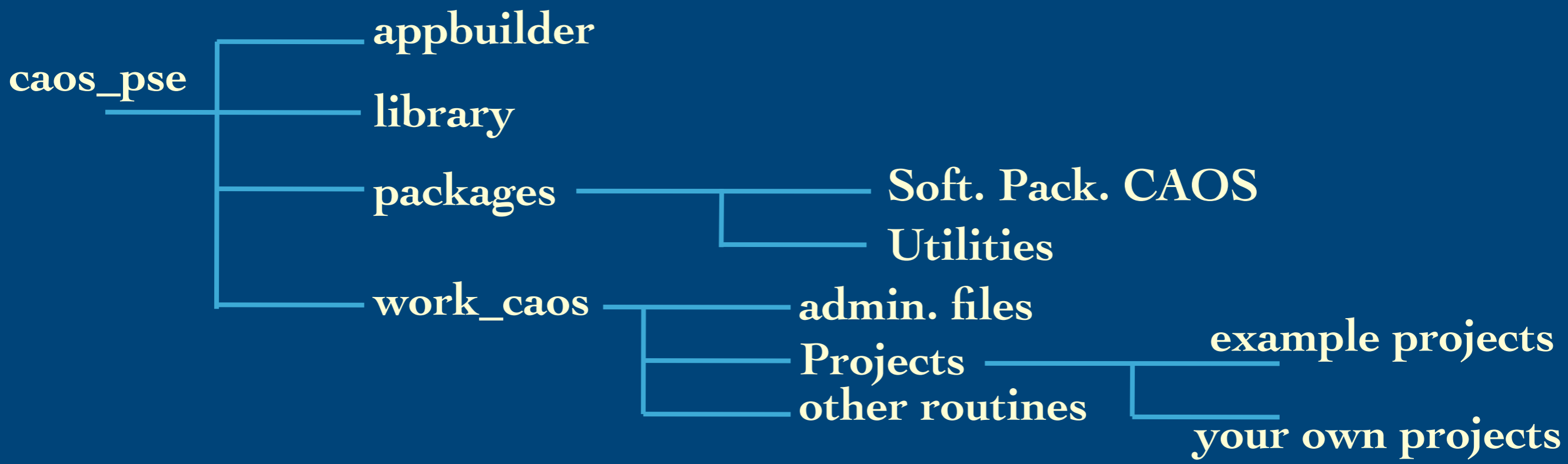
libraries

Software Package
CAOS

Software Package
AIRY

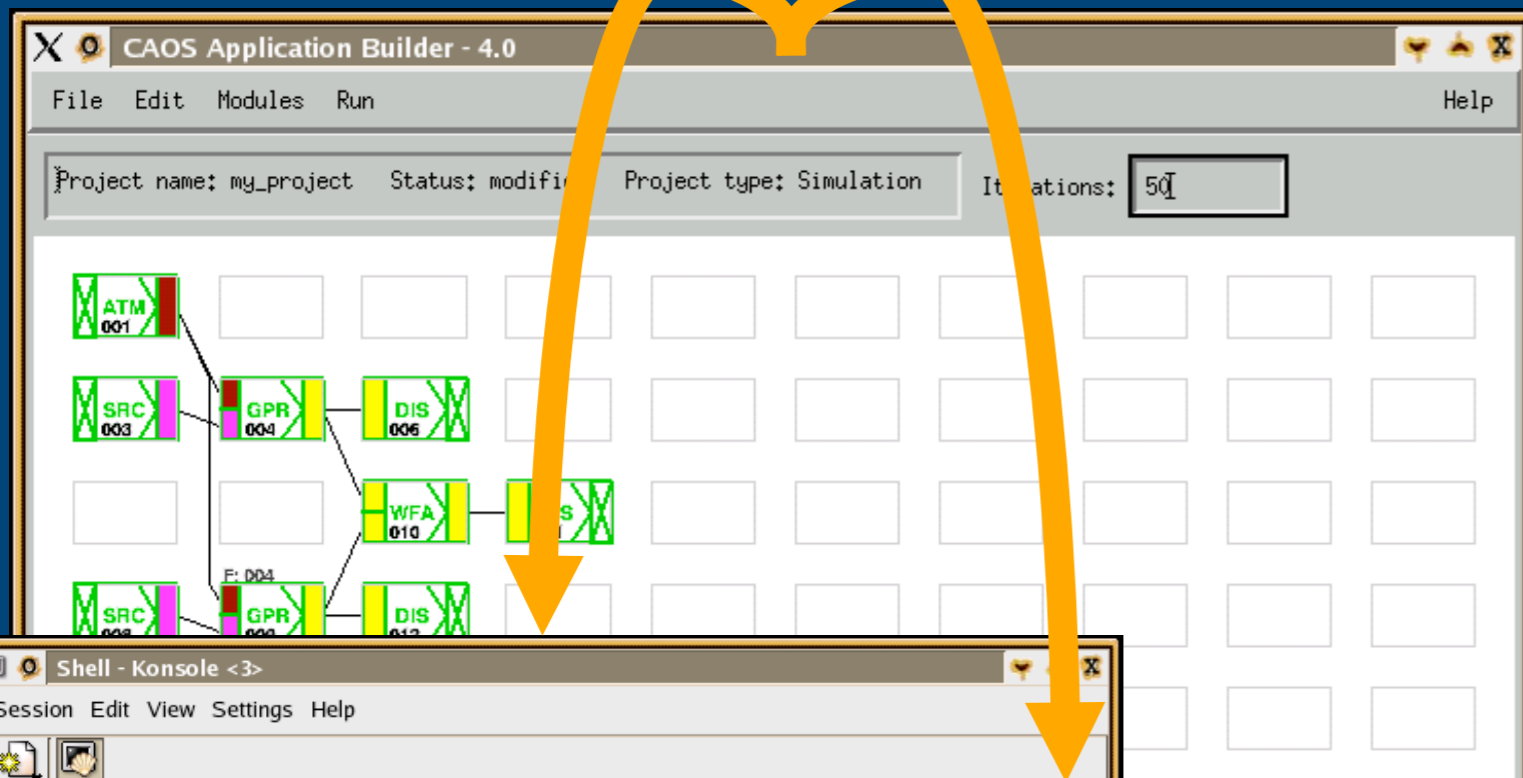
packages

CAOS Problem Solving Environment -2



somewhere else: astrolib, possibly some other library

CAOS Application Builder



It is the global user interface of the CAOS PSE: essentially a worksheet where the user can place small blocks, the modules, and connect them with data paths to form a project.

When the project is designed, it can be saved on disk, generating the IDL code which implements the simulation program.

The “virtual machine” feature of IDL permits in addition to have an IDL-licence-free version of a given project...

```
COMMON caos_block, tot_iter, this_iter
ret = mds(0_001_00,
          mds_00001_p,
          INIT=mds_00001_c)
IF ret NE 0 THEN ProjectMsg, "mds"

ret = src(0_002_00,
          src_00002_p,
          INIT=src_00002_c)
IF ret NE 0 THEN ProjectMsg, "src"

ret = gpr(0_002_00,
          0_001_00,
          0_003_00,
          gpr_00003_p,
          INIT=gpr_00003_c)
IF ret NE 0 THEN ProjectMsg, "gpr"

ret = dis(0_003_00,
          dis_00010_p,
          INIT=dis_00010_c)
IF ret NE 0 THEN ProjectMsg, "dis"
```

```
Shell - Konsole <3>
Session Edit View Settings Help

; Initialization;
; Loop Control ;

print, "=== INITIALIZATION... ==="
@Projects/pyr_calib/mod_calls.pro

; Begin Main Loop
FOR this_iter=1, tot_iter DO BEGIN
    print, "=== ITER. #" + strtrim(this_iter) + "/" + strtrim(tot_iter) + "..."
    @Projects/pyr_calib/mod_calls.pro
ENDFOR
; End Main Loop

; End Main ;

END

200,3 Bot
```

CAOS PSE: availability

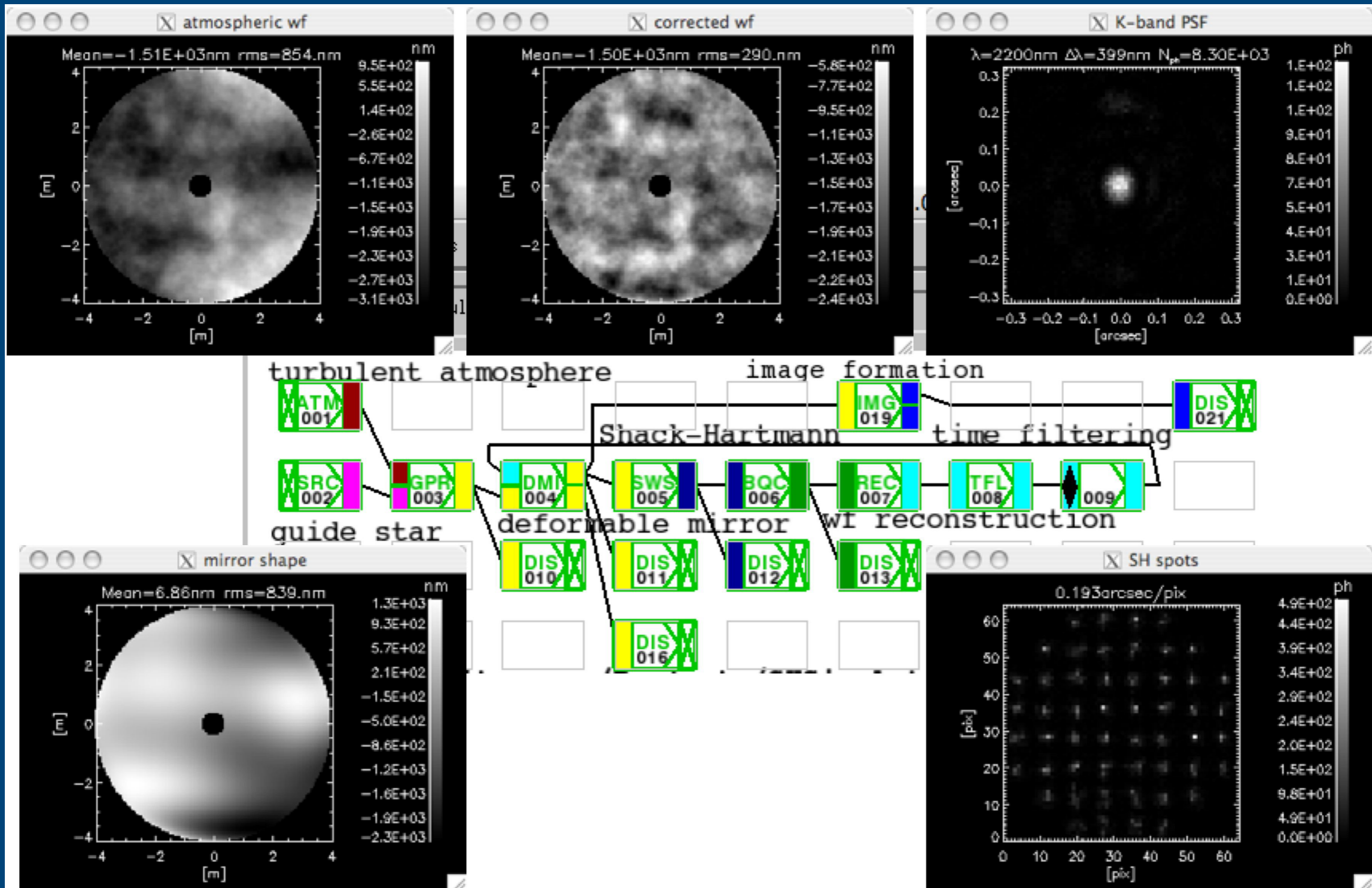
All (*public!*) parts of the CAOS PSE are available for download:

<http://lagrange.oica.eu/caos/>

Current status of the dedicated mailing-lists
(as on February 2017):

- Soft. Pack. CAOS: 101 subscribers,
- Soft. Pack. AIRY: 25 subscribers.

End-to-end AO modeling with the Software Package CAOS - 1



End-to-end AO modeling with the Software Package CAOS - 2

Table 1. The 31 modules of the Software Package CAOS, version 7.0.

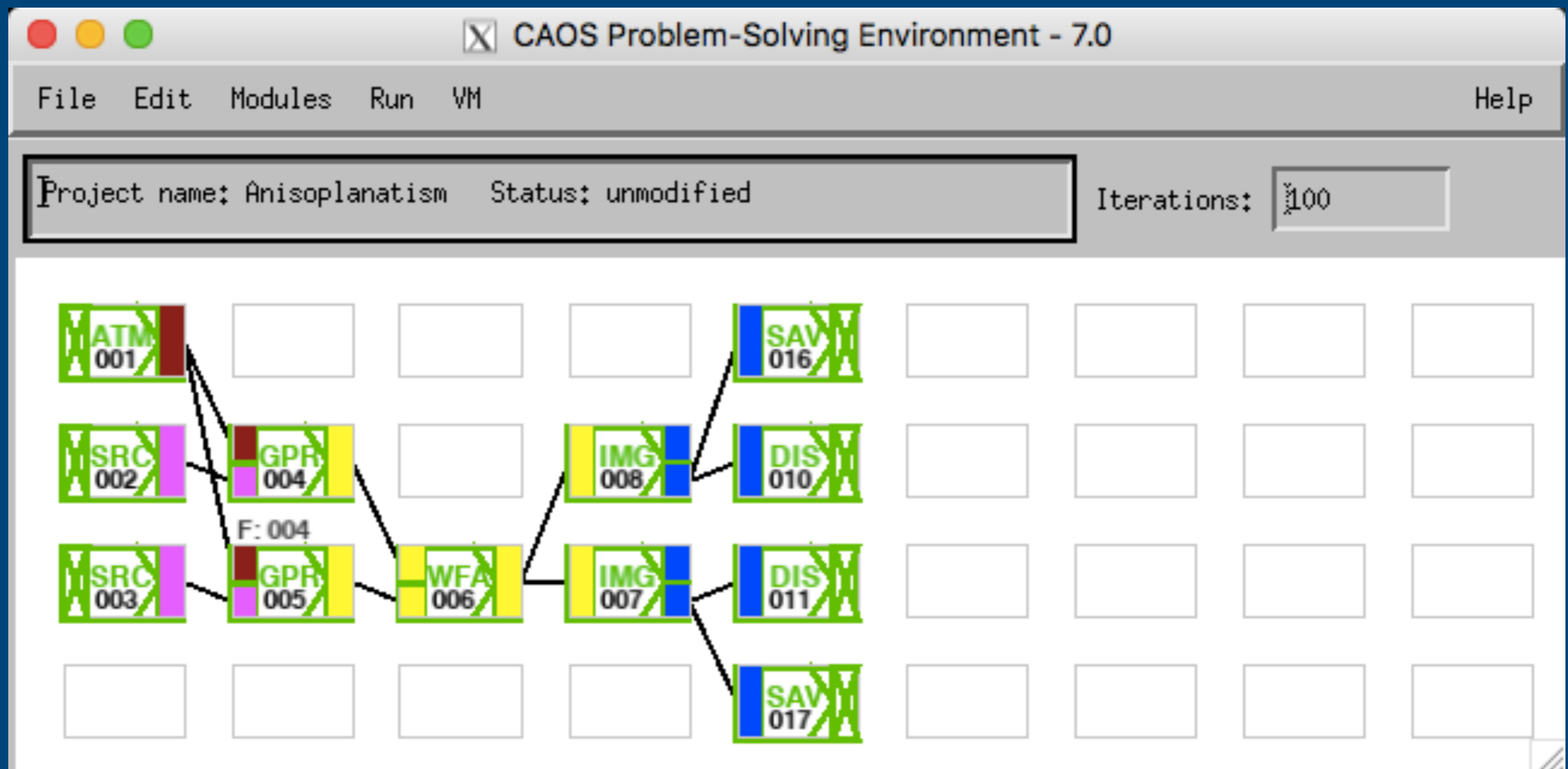
Module	Purpose
Optical turbulence & image formation	
ATM - ATMosphere building	-builds the turbulent atmosphere (FFT+subharmonics, Zernike) (see also utility PSG - Phase Screen Generation)
SRC - SouRCe definition	-characterizes the guide star/observed object
GPR - Geometrical PRopagator	-propagates light from source to telescope through atmosphere
IMG - IMAging device	-forms an image of the observed object (+detector noises)
Wavefront sensing	
PYR - PYRamid wavefront sensor	-simulates the pyramid wavefront sensor
SLO - SLOpe computation	-computes the slopes from the pyramid signals
SWS - Shack-Hartman Wavefront Sensor	-simulates the Shack-Hartmann (SH) wavefront sensor
BQC - Barycentre/Quad-cell Centroiding	-compute the signals from the SH spots centroiding calculus
IWS - Ideal Wavefront Sensing	-applies "ideal" wavefront sensing (see text)
TCE - Tip-tilt CEntroiding	-computes and reconstructs tip-tilt
Wavefront reconstruction, control & correction	
REC - wavefront REConstruction	-reconstructs the wavefront
TFL - Time-FILtering	-applies time-filtering after wavefront reconstruction
SSC - State-Space Control	-applies state-space control
DMI - Deformable MIRROR	-simulates the behavior of a deformable mirror (DM)
TTM - Tip-Tilt MIRROR	-simulates the behavior of a tip-tilt mirror
Calibration	
CFB - Calibration FiBER characterization	-defines a fiber to be used for calibration purpose
MDS - Mirror Deformation Sequencer	-generates a sequence of DM modes or influence functions
SCD - Save Calibration Data	-saves the calibration data (interaction matrix+set of deformates)
Wide-field AO	
AVE - signals AVEraging	-averages measurements from various wavefront sensors
COM - COMbine measurements	-combines measurements from various wavefront sensors
DMC - Deformable Mirror Conjugated	-corrects at different conjugated altitudes
Other modelling modules	
LAS - LASer characterization	-defines laser projector characteristics
NLS - Na-Layer Spot definition	-characterizes the Sodium-layer behavior
IBC - Interferometric Beam Combiner	-combines the light from two apertures
COR - CORonagraphic module	-simulates various coronagraphs (Lyot, Roddier&Roddier, FQPM)
AIC - Achromatic Interfero-Coronagraph	-simulates the Achromatic Interfero-Coronagraph
BSP - Beam SPlitter	-splits the light beam
Other utility modules	
WFA - WaveFront Adding	-adds or combines together wavefronts
ATA - ATmosphere Adding	-adds or combines together atmospheres
IMA - IMAge Adding	-adds or combines together images
STF - STructure Function	-calculates the structure function and compares to theory

Imaging through the turbulent atmosphere: anisoplanatism ! - 1

Table 1. The 31 modules of the Software Package CAOS, version 7.0.

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Imaging through the turbulent atmosphere: anisoplanatism ! - 2



Install CAOS PSE + Soft. Pack. CAOS + Example project... - 1

<http://lagrange.oca.eu/caos/>

DOWNLOADS:

- Last version of the **CAOS PSE** (version 7.1): [here](#).
- Last version of the **Software Package CAOS** (version 7.0): [here](#).
- Last version of the **Software Package AIRY** (version 7.2): [here](#).

**CAOS Problem-Solving Environment
(CAOS PSE) # version 7.1 #**

- [Installation instructions](#)
- [CAOS PSE 7.1 archive file](#)

Install CAOS PSE + Soft. Pack. CAOS + Example project... - 2

01-Click on "CAOS PSE 7.1 archive file" and unpack then the downloaded file `caos_pse_7.1.tgz` (with, e.g., `"tar xvfz"`). A directory called `"caos_pse_7.1"` will be created.

Note that no Software Package is included, but the template one. The Software Packages (`Soft.Pack.CAOS`, `Soft.Pack.AIRY`) are obtainable from:
<http://lagrange.oca.eu/caos/>

2a-UNIX/LINUX/MACOSX cases:

Change directory to `.../caos_pse/work_caos` and:

2a.1- Fix the paths in `caos_env.sh` (or `.csh`, depending on your shell).

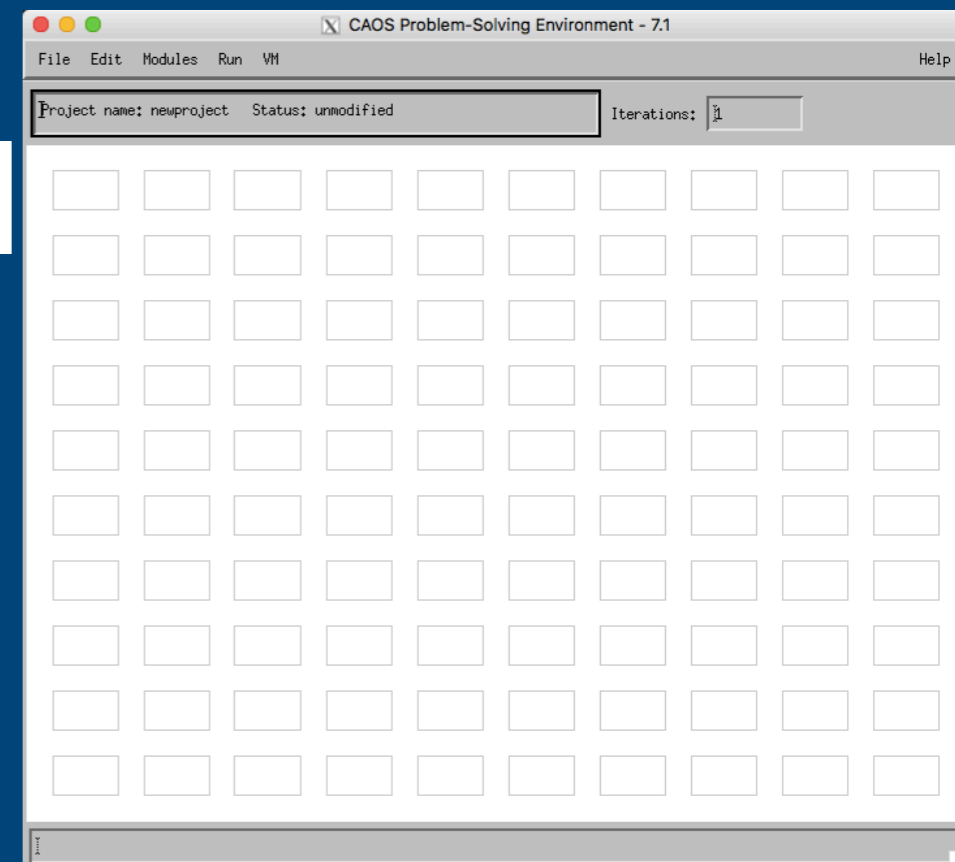
2a.2- Idem in `caos_startup.pro`.

03-UNIX/LINUX/MACOSX cases:

Type `"source caos_env.csh"` (or `.sh`).

04-Launch IDL.

05-Type `"worksheet"` at the CAOS prompt in order to use the CAOS Application Builder.



Install CAOS PSE + Soft. Pack. CAOS + Example project... - 3

DOWNLOADS:

- Last version of the CAOS PSE (version 7.1): [here](#).
- Last version of the Software Package CAOS (version 7.0): [here](#).
- Last version of the Software Package AIRY (version 7.2): [here](#).

Software Package CAOS # version 7.0 #

- [Installation instructions](#)
- [Soft.Pack.CAOS 7.0 archive file](#)
- [Example projects using the Soft.Pack.CAOS 7.0](#)

Install CAOS PSE + Soft. Pack. CAOS + Example project... - 4

02-Change directory to `.../caos_pse/packages/`, then click on the link "Soft.Pack.CAOS 7.0 archive file" and unpack the downloaded file `CAOS_Software_Package_7.0.tgz` (with, e.g., `"tar xvfz"`).
A directory called "CAOS_Software_Package_7.0" will then be created.
Note that you will need to eliminate the `.tar` file when unpacking is concluded - in fact NO OTHER FILES than the set of modules (packages) have to be present in the "packages" directory.

03-Please note that some modules of this distribution also need the IDL Astronomy User's Library, commonly called "astrolib". This library is available from <http://idlastro.gsfc.nasa.gov>.

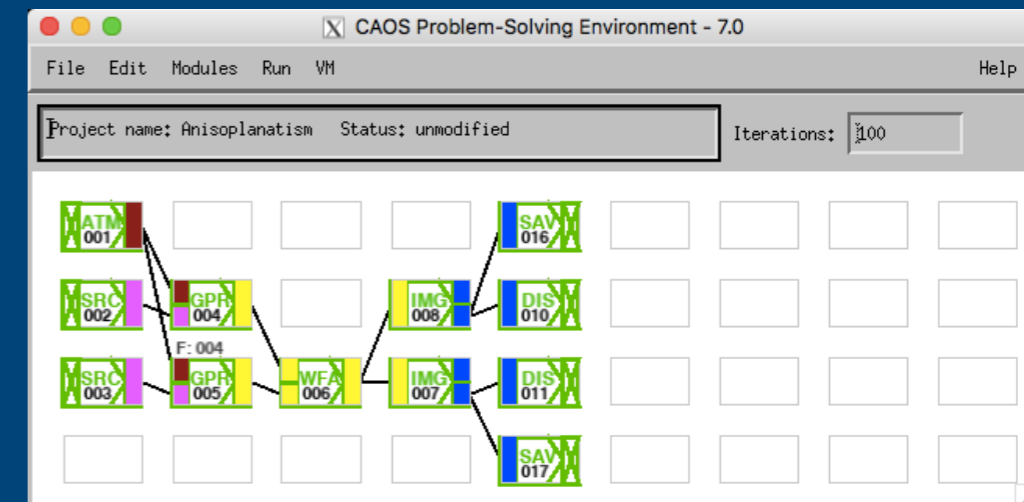
04-Change directory to `.../work_caos/`, then click on the link "Example projects using the Soft.Pack.CAOS 7.0" and unpack the downloaded file `Projects.tgz`, containing the directory "Projects" where some example projects can be found.

05-UNIX/LINUX/MACOSX cases:
Type `"source caos_env.csh"` (or `.sh`).

07-Type "worksheet" at the CAOS prompt in order to use the CAOS Application Builder.

08-Type `"@compile_all_CAOS_modules"` in order to re-generate the default parameter files of the whole set of modules (upgrading so any possible pre-defined path).

09-You can find some examples in `work_caos/Projects` to play around with.
Let open one example project from the worksheet ("File" -> "Open Project").



Alternative to regular installation: copy CAOS PSE + Soft. Pack. CAOS + project "Anisoplanatism"

02-Change directory to `../caos_pse/packages/`, then click on the link "[Soft.Pack.CAOS-7.0.archiver.file](#)" and unpack the downloaded file `CAOS_Software_Package_7.0.tgz` (with, e.g., "tar xzfa"). A directory called "CAOS_Software_Package_7.0" will then be created. Note that you will need to eliminate the tar file when unpacking is concluded, in fact NO OTHER FILES than the set of modules (packages) have to be present in the "packages" directory.

`>> cp -r ../marcel/caos_pse .`

03-Please note that some modules of this distribution also need the IDL Astronomy User's Library, commonly called "astrolib". This library is available from <http://idl.stroscop.fornasiv.org/>.

`>> cp -r ../marcel/astrolib .`

04-Change directory to `../work_caos/`, then click on the link "[Example projects using the Soft.Pack.CAOS-7.0](#)" and unpack the downloaded file `Projects.tgz`, containing the directory "Projects" where some example projects can be found.

... and adapt `caos_env.sh` & `caos_startup.pro`

05-UNIX/LINUX/MACOSX cases:

Type `"source caos_env.csh"` (or `.sh`).

then type 'IDL'...

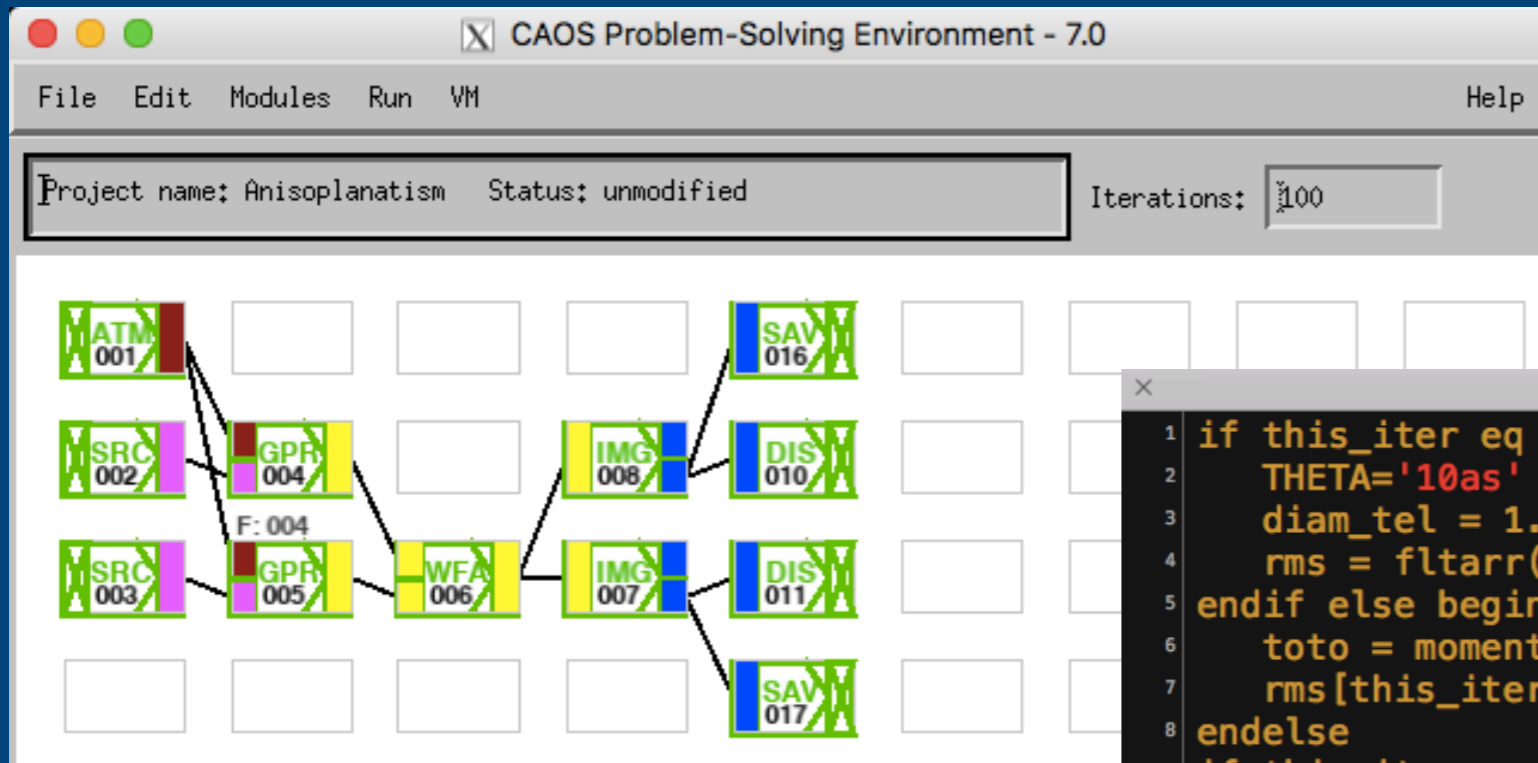
07-Type "worksheet" at the CAOS prompt in order to use the CAOS Application Builder.

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09-You can find some examples in `work_caos/Projects` to play around with. Let open one example project from the worksheet ("File" => "Open Project").

open project
"Anisoplanatism" ...

Modify project "Anisoplanatism"



```
modif_mod_calls.pro
1 if this_iter eq 0 then begin
2   THETA='10as'
3   diam_tel = 1.
4   rms = fltarr(tot_iter)
5 endif else begin
6   toto = moment(o_006_00.screen, SDEV=dummy)
7   rms[this_iter-1] = dummy
8 endif
9 if this_iter eq tot_iter then begin
10  save, rms, FILE='Projects/Anisoplanatism/rms_'+THETA+'.sav'
11  print, "rms moyen en sortie = ", mean(rms)*1E9, " [nm]"
12
13  PSF_H = o_007_00.image
14  LAMBDA = o_007_00.lambda
15  RES = o_007_00.resolution
16  toto = gauss2dfit(PSF_H,a) & sig = (a[3]+a[2])/2.
17  fwhm = 2*sig*sqrt(2*log(2))*RES
18  print, "FWHM en H = ", fwhm, ' ["] = ', $
19        fwhm/(LAMBDA/diam_tel*!RADEG*3600), " [lambda/D]"
20
21  PSF_500 = o_008_00.image
22  LAMBDA = o_008_00.lambda
23  RES = o_008_00.resolution
24  toto = gauss2dfit(PSF_500,a) & sig = (a[3]+a[2])/2.
25  fwhm = 2*sig*sqrt(2*log(2))*RES
26  print, "FWHM à 500nm = ", fwhm, ' ["] = ', $
27        fwhm/(LAMBDA/diam_tel*!RADEG*3600), " [lambda/D]"
28 endif
```

add the following code "by hand" at the end of the file "mod_calls.pro" ...
(copy it from file "modif_mod_calls.pro")

run the simulation project:

```
.r ./Projects/Anisoplanatism/project.pro
```

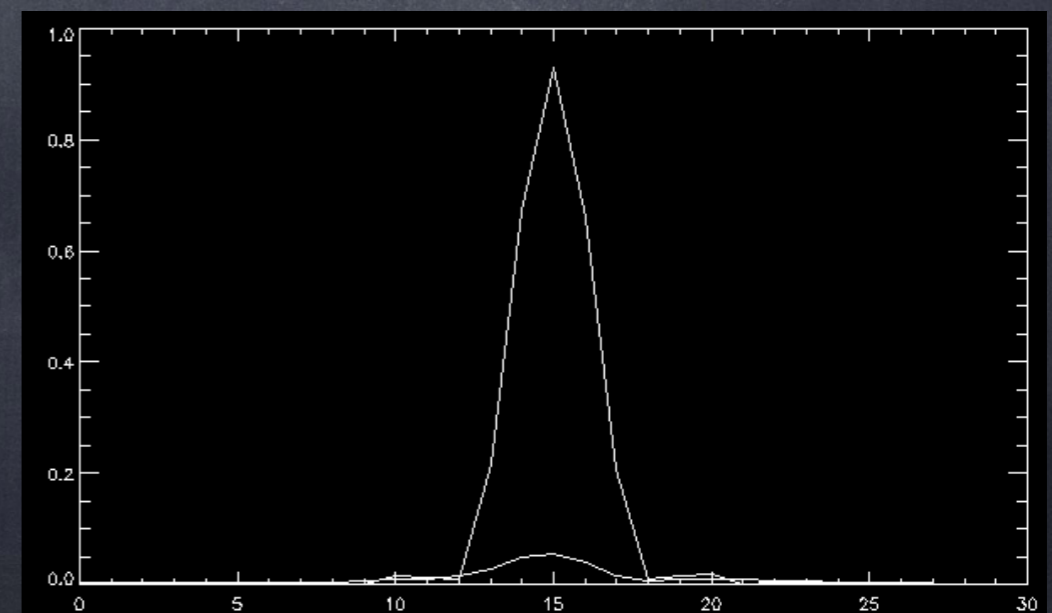
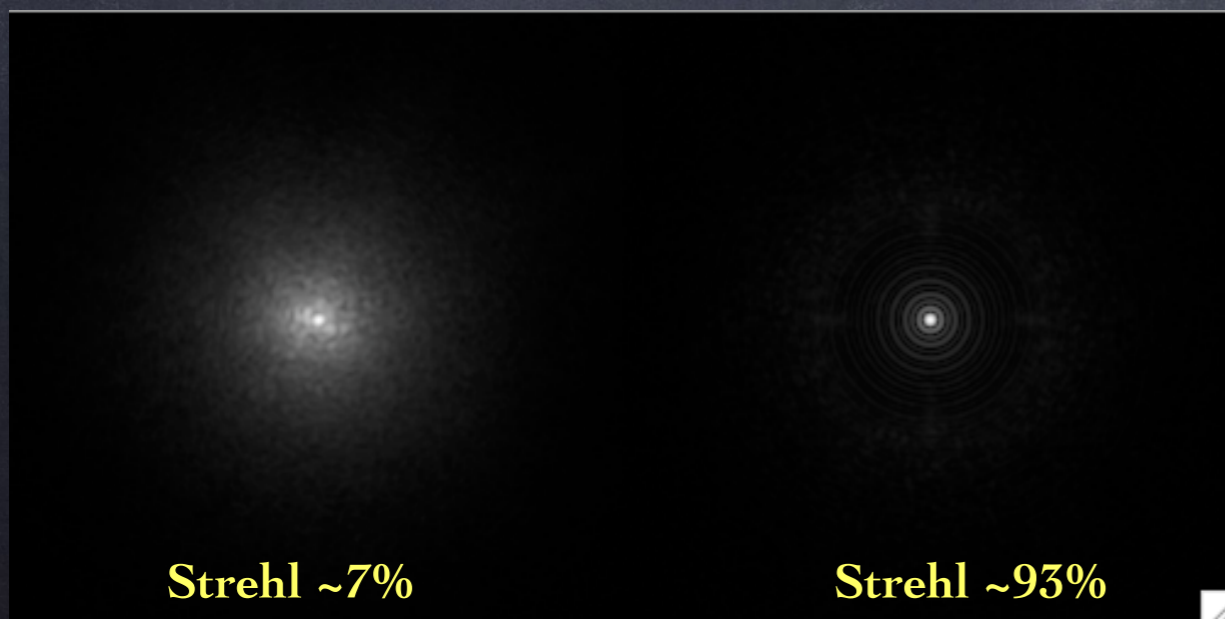
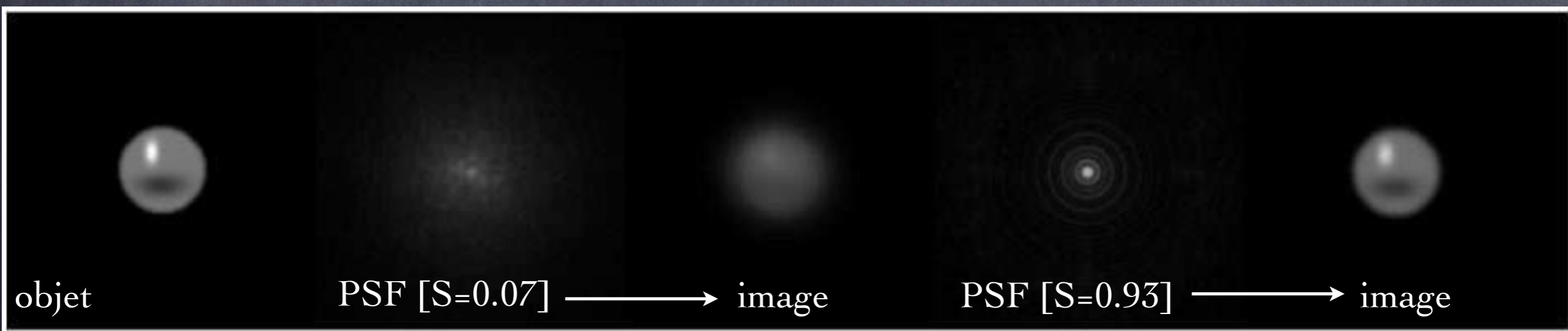
(Rappel : le rapport de Strehl)

$$S = \frac{I_{\text{post AO}}[0,0]}{I_{\text{perfect}}[0,0]}$$

$$S \simeq \exp\{-\sigma_{\text{post AO}}^2\}$$

où $I[0,0]$ est l'intensité de la réponse impulsionnelle sur l'axe optique (K. Strehl, Zeit. Instrumente 22, 213 (1902)).

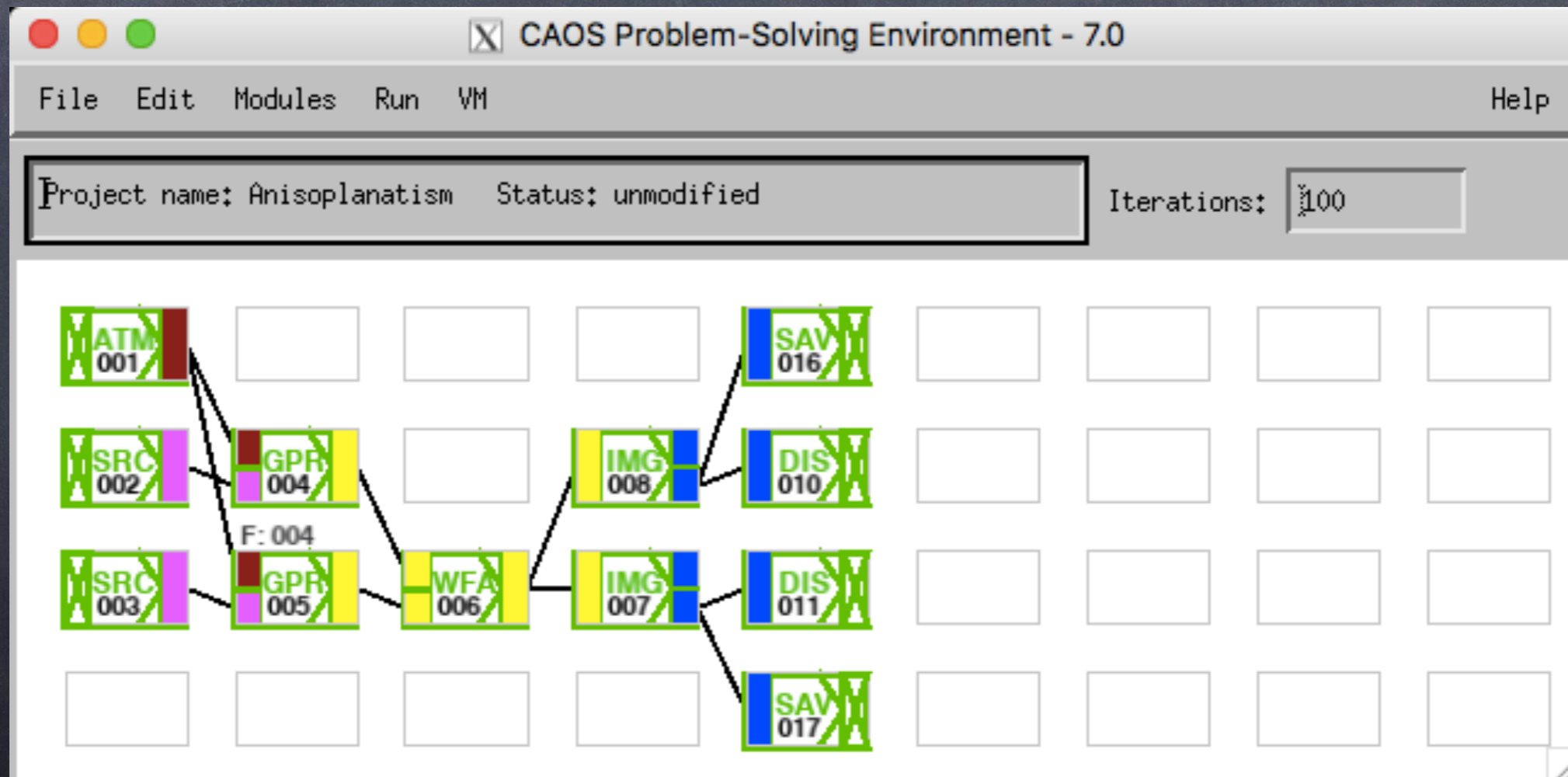
dans le cadre de l'approximation de Maréchal, où la variance (en radians²) est supposée être suffisamment petite...



Anisoplanétisme - 4

Outil numérique utilisé pour cette étude : CAOS

(CAOS Problem-Solving Environment + Software Package CAOS + Example project "Anisoplanatism"...)



Anisoplanétisme - 5

- Étude sur l'erreur d'anisoplanétisme
- détail :
- + mise en contexte anisoplanétisme (schéma+explications)
- + description outil CAOS/modélisation (CAOS+schéma+procédure)
- + mesures sur wf : rms(theta)
- + => retrouver que $\text{var_aniso} \propto \theta^{5/3}$
- + => Strehl(theta, lambda)
- + => ccl sur l'influence de theta et lambda sur Strehl
- + mesures sur img : FWHM(theta, lambda)
- + => ccl sur l'influence de theta et lambda sur FWHM