Reconstruction & control of the commands - 1

Pure integrator case:

$$c_{t+1} = c_t + g\,A\,m_t$$

where ***c*** is the commands vector (*n* actuators), ***m*** the measurement vector (*m* elements), ***g*** a scalar loop gain (usually < 1), ***A*** the (*n*x*m*) control matrix.

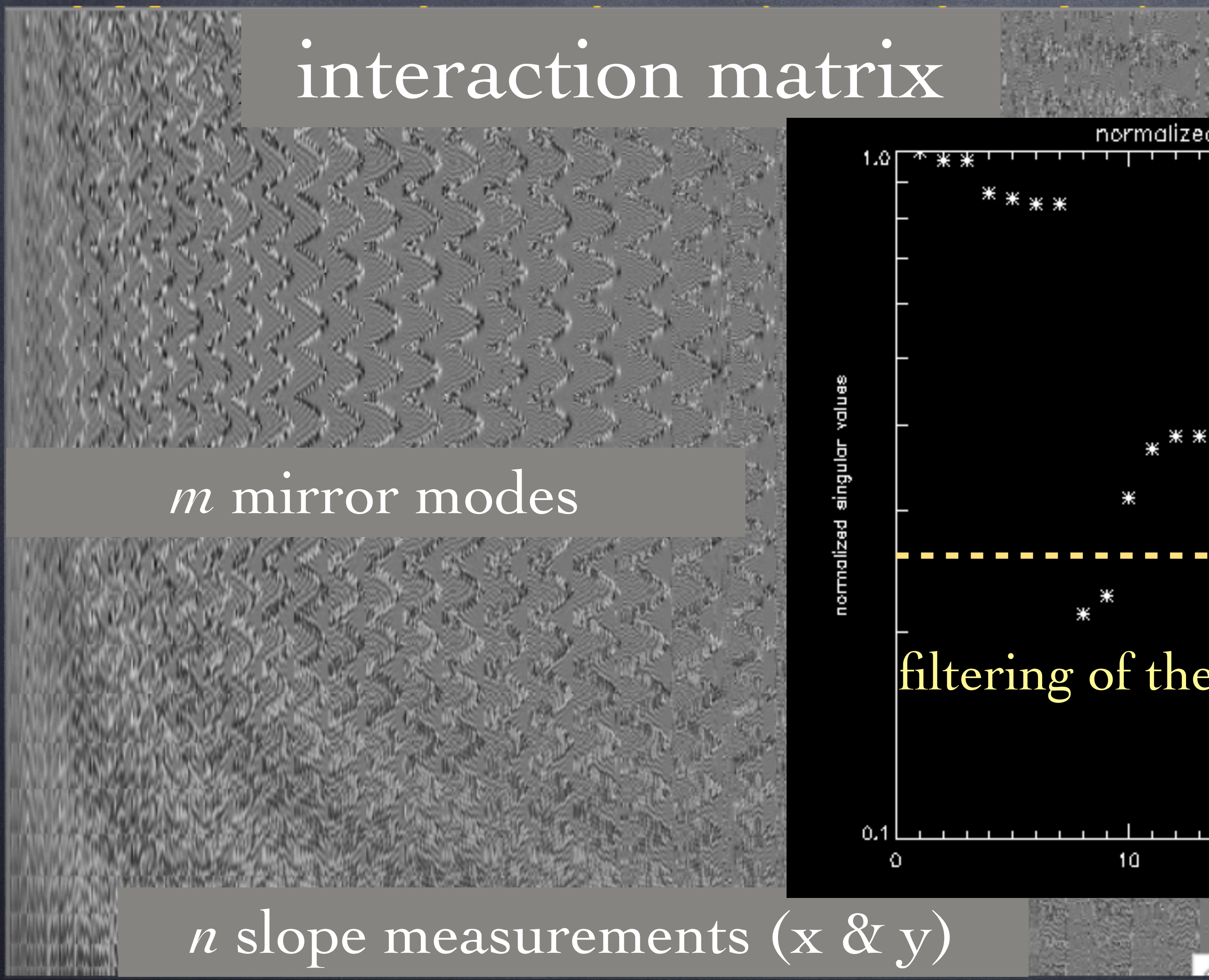
The commands matrix ***A*** is, in practice, the pseudo-inverse (SVD) of the measured (during calibration stage) interaction matrix ***D*** (*m*x*n*):

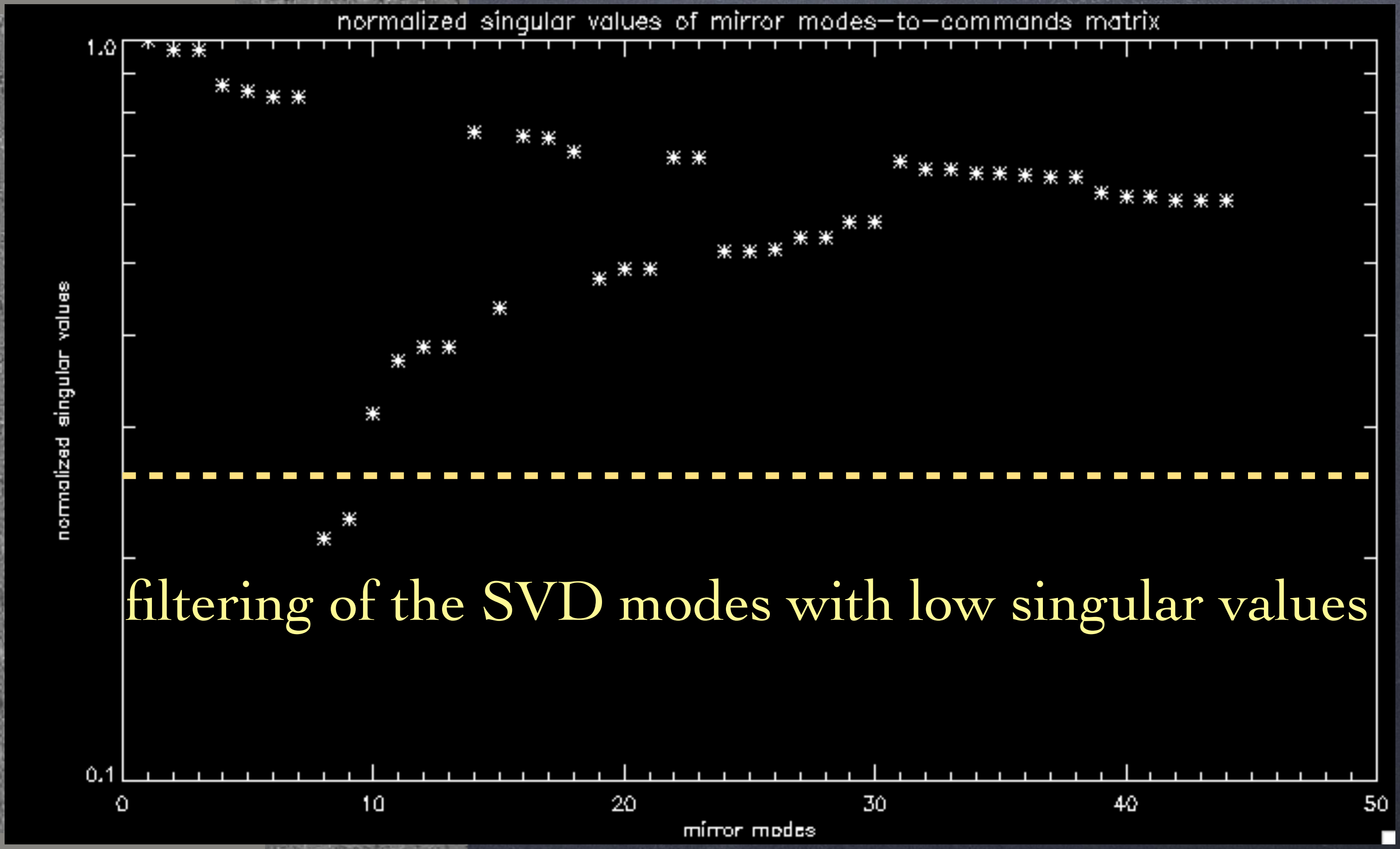
$$A = D^{+} = V\,\Sigma^{+}\,U^{*}$$

where Σ is an *m*x*n* rectangular diagonal matrix with non-negative numbers on the diagonal (Σ_{ii} are the singular values of ***D***), and ***U*** (*m*x*m*) and ***V*** (*n*x*n*) are orthonormal unitary matrices.

Filtering of SVD modes: Σ_{ii} 'too small' => Σ^{+}_{ii} set to ***0*** (truncated SVD).

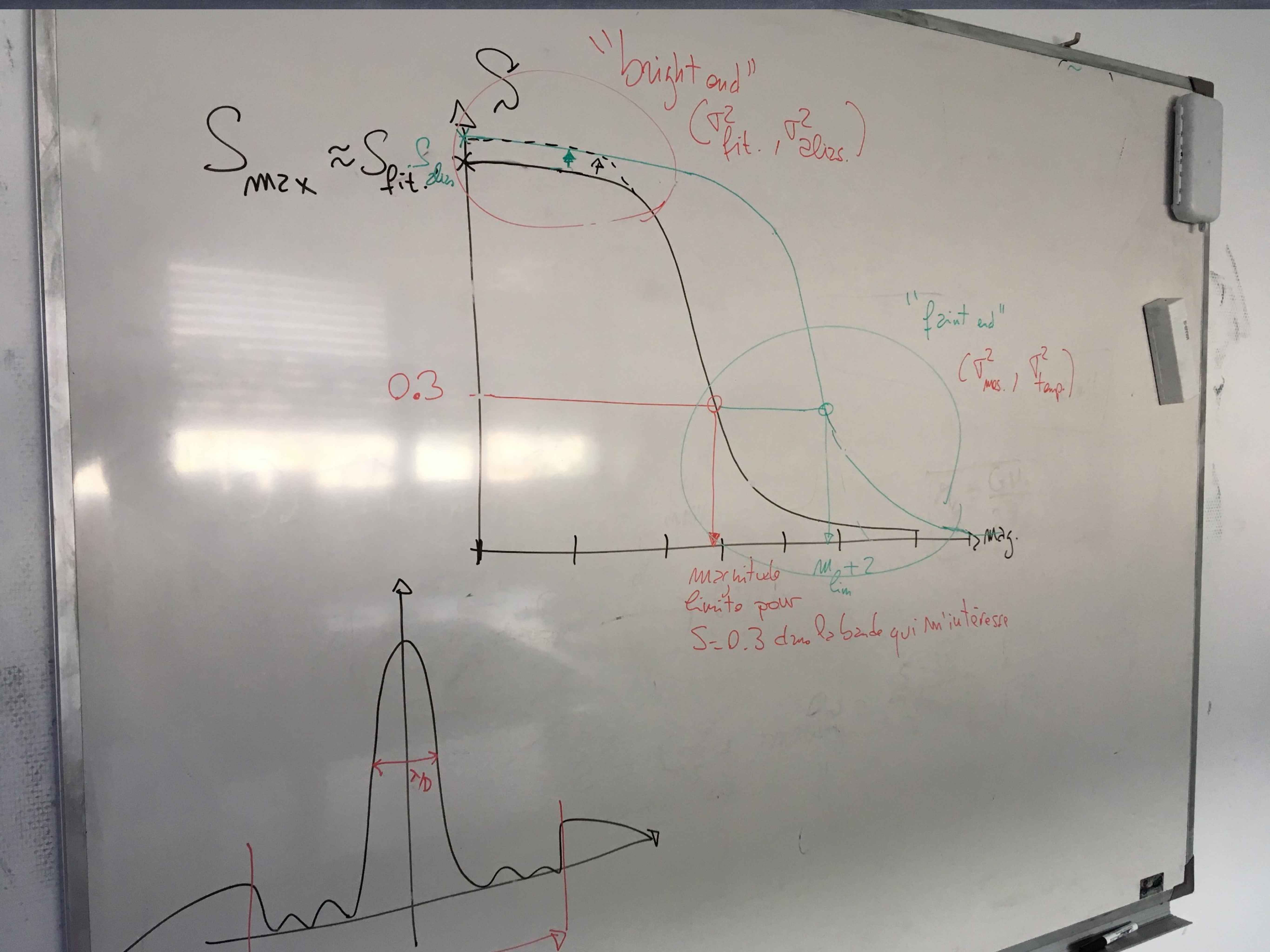
Reconstruction & control of the commands - 2





Reconstruction & control of the commands - 3

Reconstruction	Contrôle
Inverse généralisée (SVD tronquée) → matrice d'interaction	Intégrateur (ou autre filtrage temp.) → déf. du filtre, déf. des gains/mode
MAP (Fusco 2001) → + coeff. bruit, var./covar. spat.	Idem
OMGI (Gendron & Léna 1994) → matrice d'int., coeff. bruit/mode, DS de la phase/mode (débruitée)	
OMGI alternatif (Dessenes 1998) → matrice d'int., DS de la phase/mode (bruitée)… + ajustement de la DS !	
Kalman (éq. MAP en boucle fermée - Le Roux et al. 2004) → matrice d'interaction, coeff. bruit, var./covar. spatio-temp.	



S
S max ≈ S fit. S alias
"bright end"
(σ² fit. , σ² alias.)
0.3
"faint end"
(σ² mes. , σ² temp.)
mag.
magnitude limite pour S=0.3 dans la bande qui m'intéresse
m lim + 2
λ/D

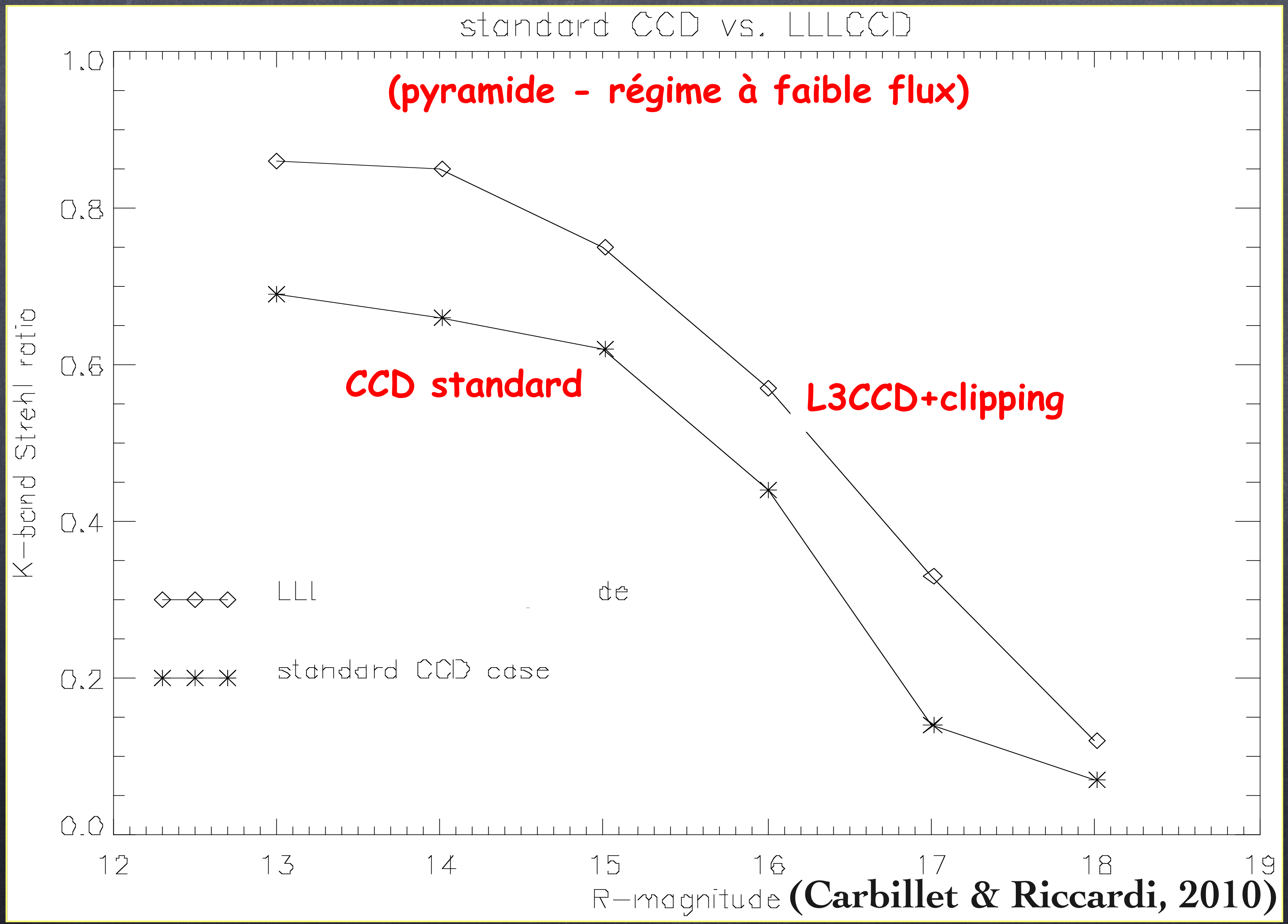
TT bad correction
=> agitation
=> image blurring

HO bad correction
=> coherence loss
=> coherent core reduced, more intense halo

Hence, for a given Strehl ratio:
- NGS AO => better resolution,
- LGS AO => better encircled energy.

Are other improvements possible ? - Examples - 1

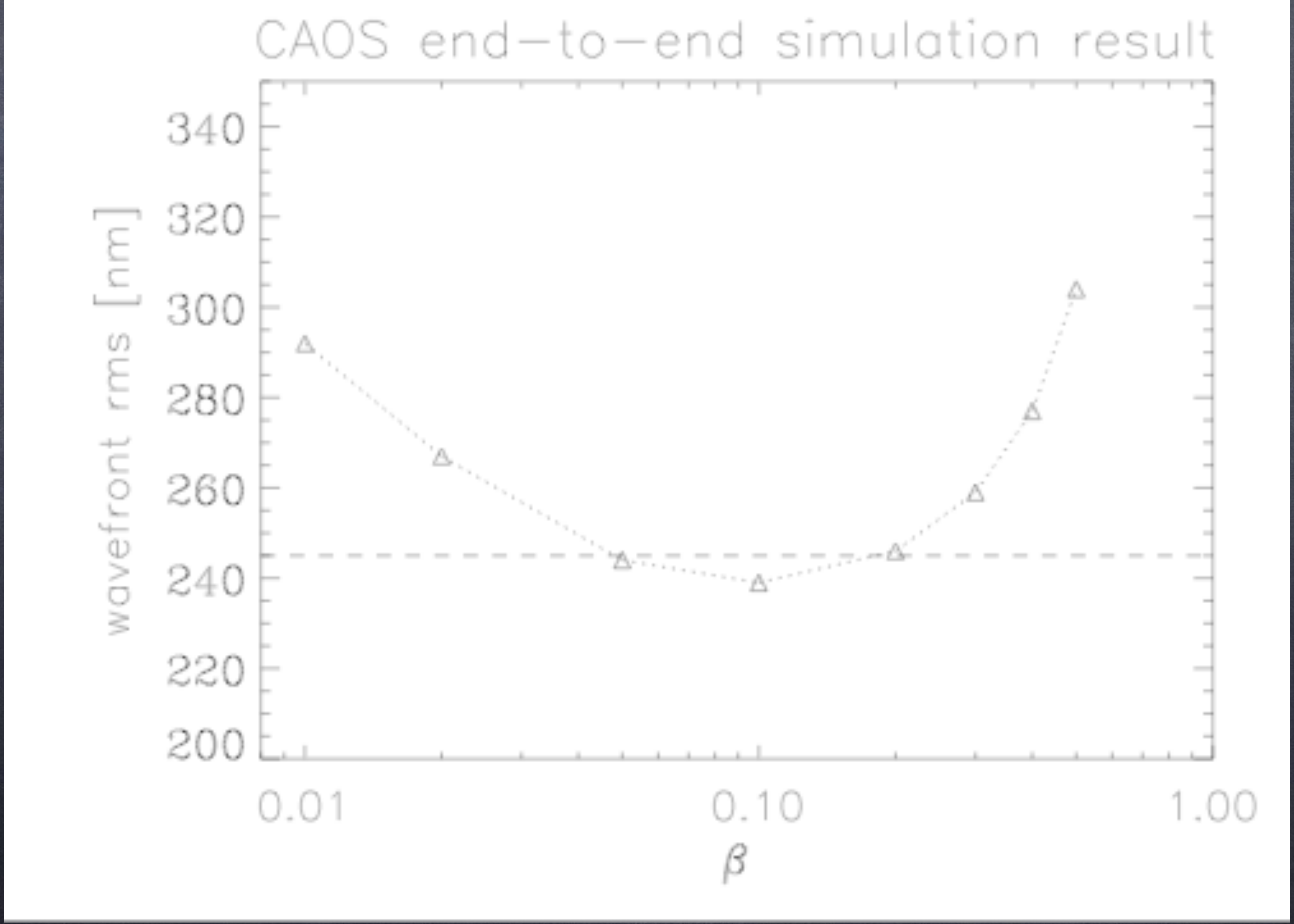
WFS: replace CCDs with EMCCDs ?...



(Carbillet & Riccardi, 2010)

Are other improvements possible ? - Examples - 2

WFS: add a TT sensor ?…



Are other improvements possible ? - Examples - 3

Image reconstruction : take into account the quality of correction within deconvolution process ?... (=> Strehl constraint)

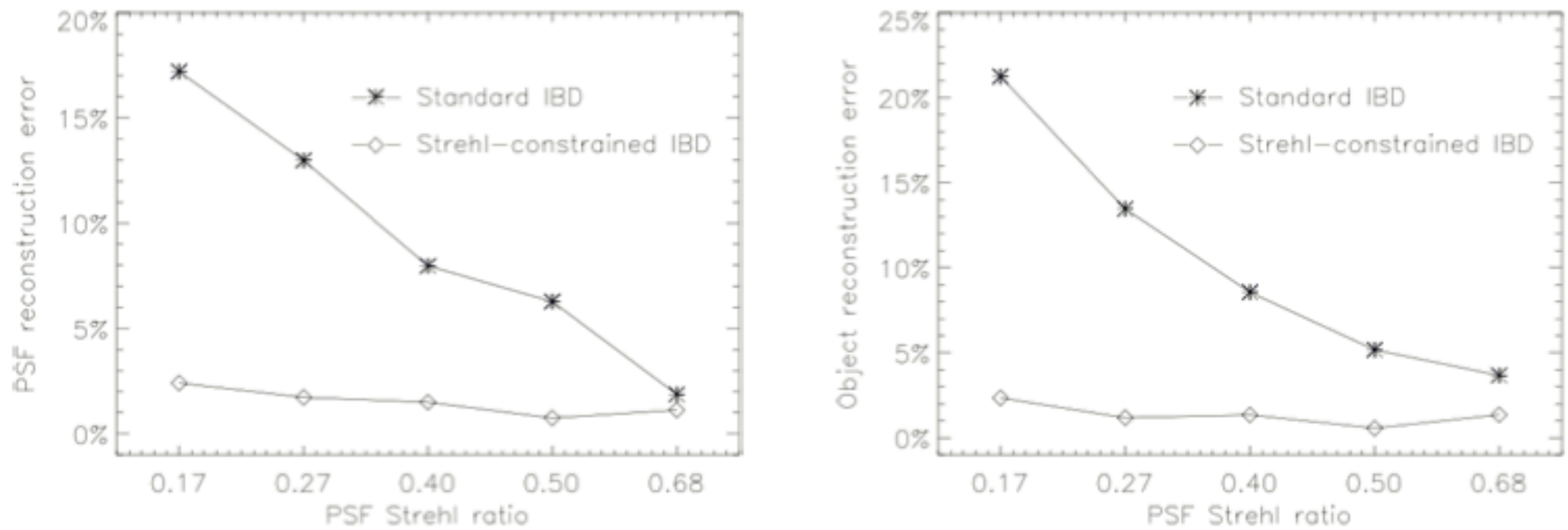
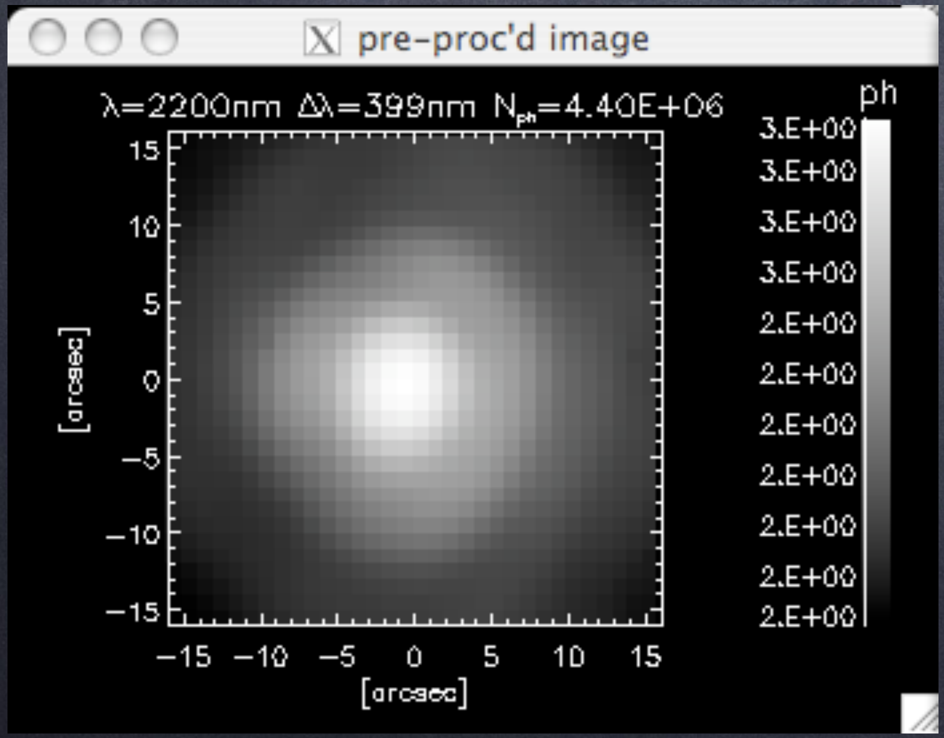
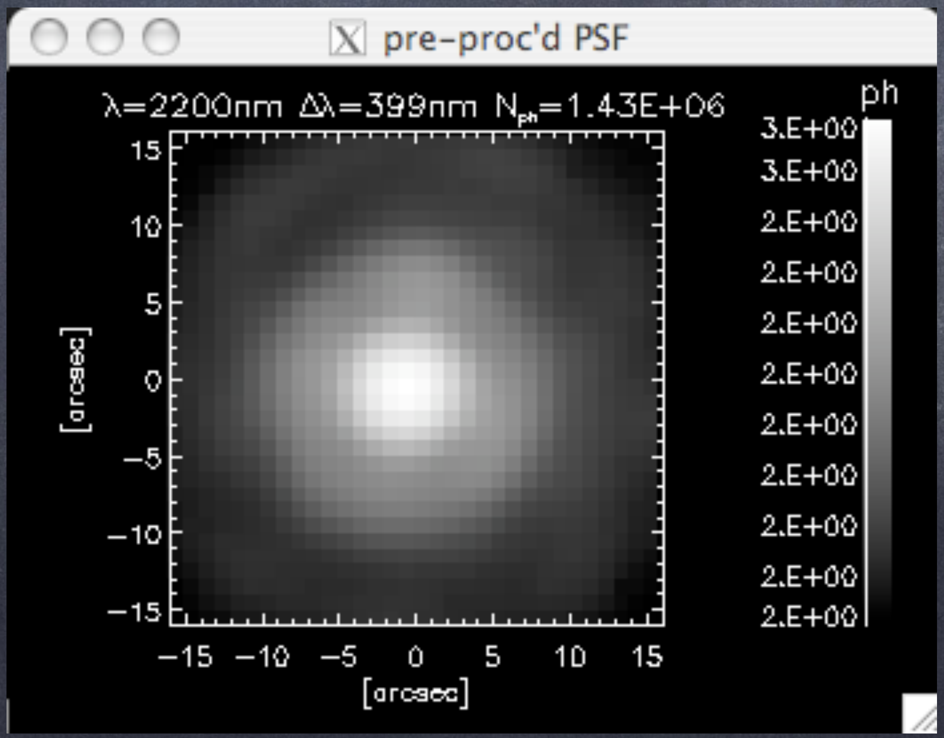


Fig. 2. *Left*: final error on the reconstruction of the PSF. *Right*: final error on the reconstruction of the object. Both plots are made as a function of the SR of the image data and comparing the simple IBD (rhombuses) to the Strehl-constrained IBD (asterisks). A gain of up to a factor ~10 is achieved for the poorer SR.

Are other improvements possible ? - Examples - 4

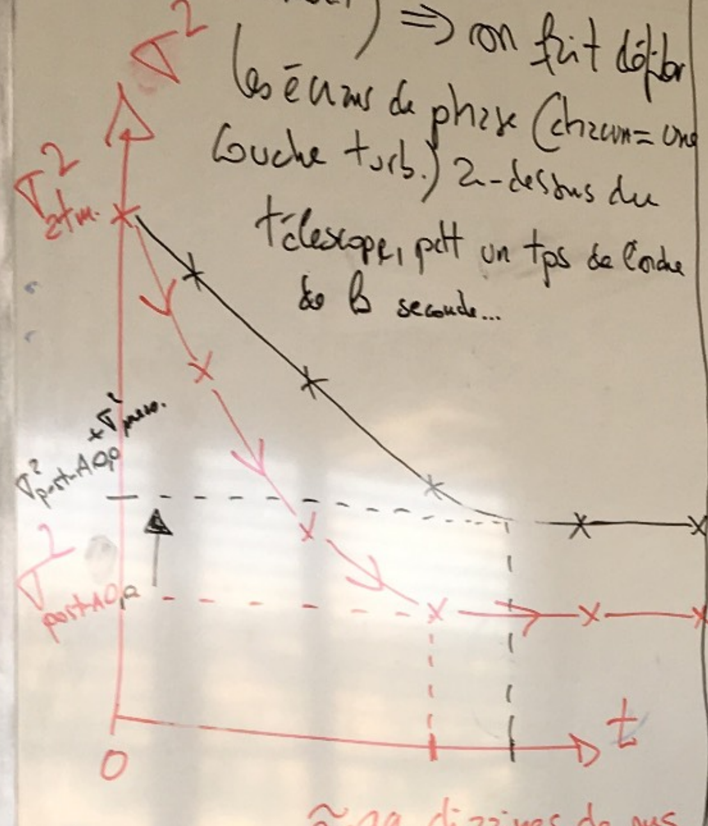
Image reconstruction : improve again resolution ?…
(=> Computational Super-Resolution)





(HD 87643 observed with NACO/VLT, super-resolution algorithm of Anconelli et al. (A&A 2005))

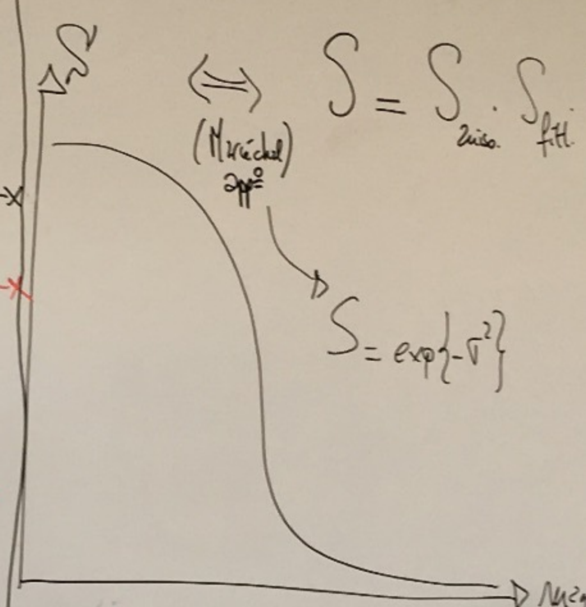
[...] de Taylor (pas de bouillonnement) ⇒ on fait défiler les écrans de phase (chacun = une couche turb.) au-dessus du télescope, pdt un tps de l'ordre de 10 secondes...



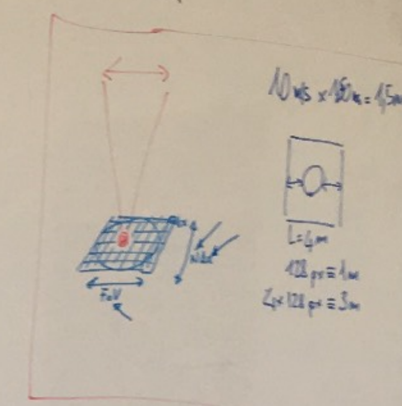
$$\sigma^2_{post-AO} = \sigma^2_{aniso.} + \sigma^2_{fitt.} + \sigma^2_{meas.} + \sigma^2_{alias.} + \sigma^2_{temp.} + \sigma^2_{NCPA} + \ldots$$

⟺ (Maréchal approx)

$$S = S_{aniso.} \cdot S_{fitt.} \cdot S_{meas.} \cdot S_{alias.} \cdot S_{temp.} \cdot S_{NCPA}$$



$$S = \exp\{-\sigma^2\}$$



mag ↗ ⇒ $\left\{ \frac{1}{N} \nearrow, \ \frac{\sigma^2}{N^2} \nearrow \right\}$ ⇒ $\sigma^2_{meas.} \nearrow$ ⇒ $S_{meas.} \searrow$

Ici :
- objet = étoile guide ⇒ $\sigma^2_{aniso} = 0$ ($\Rightarrow S_{aniso.} = 1$)
- pas d'aberrations non-vues ⇒ $\sigma^2_{NCPA} = 0$ ($\Rightarrow S_{NCPA} = 1$)
- $\sigma^2_{fitt.}$, $\sigma^2_{alias.}$ restent constants (r_0 et $d_{WFS} = d_{DM}$ fixes)
- $\Delta t_{intégration}$ fixé ⇒ $\sigma^2_{temp.}$ constant
- Seul $\sigma^2_{meas.}$ varie, en fonction de N. Et, dans un 1er temps, on ne considère que le bruit de photons.

$$\sigma^2_{meas.} = \sigma^2_{phot} \propto \frac{1}{N}$$

[...] σ^2 + $\sigma^2_{temp.}$ + $\sigma^2_{meas.}$

(Introduction to)
The CAOS Problem-Solving Environment
&
The Software Package CAOS
+
AO Simulations...

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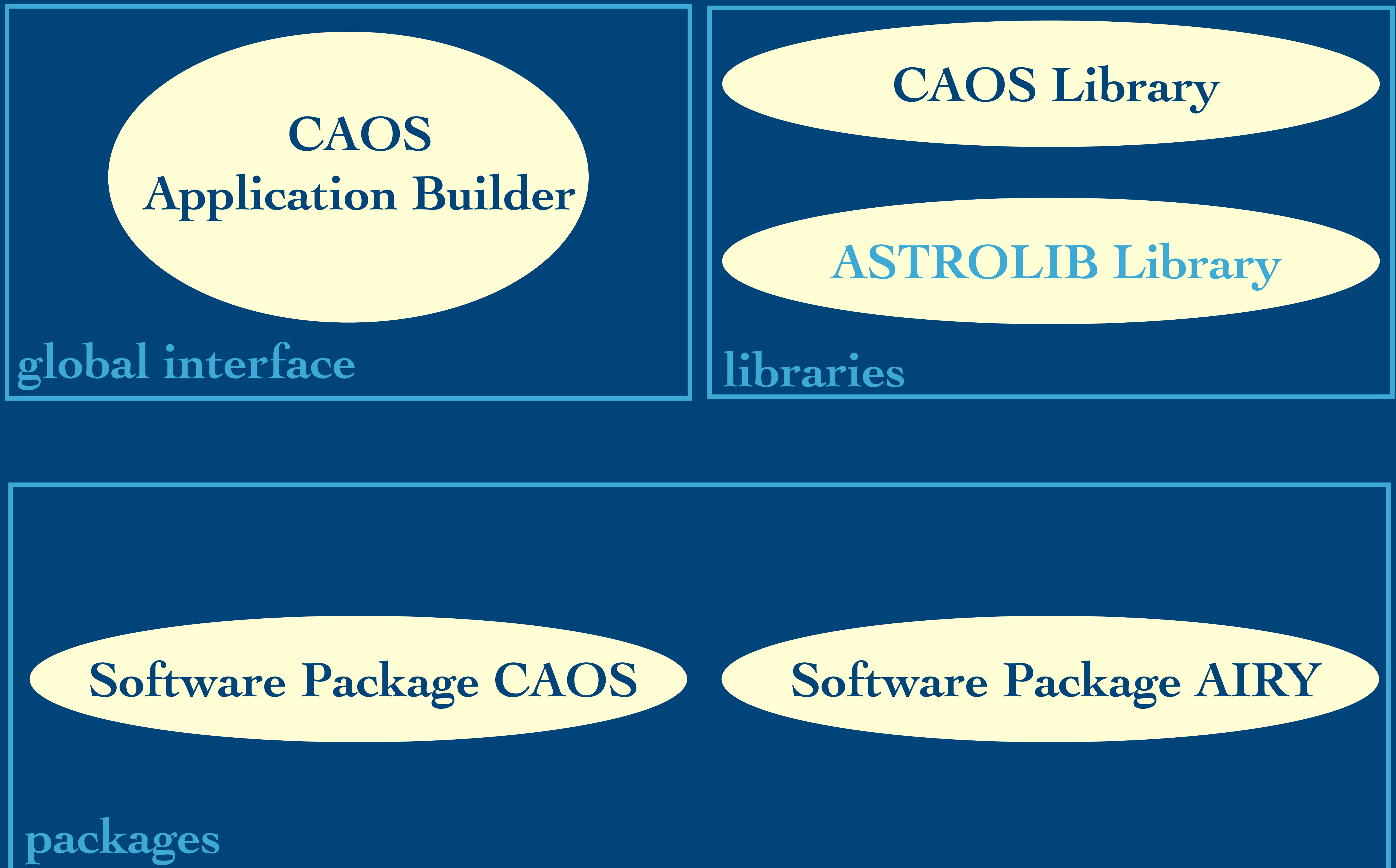
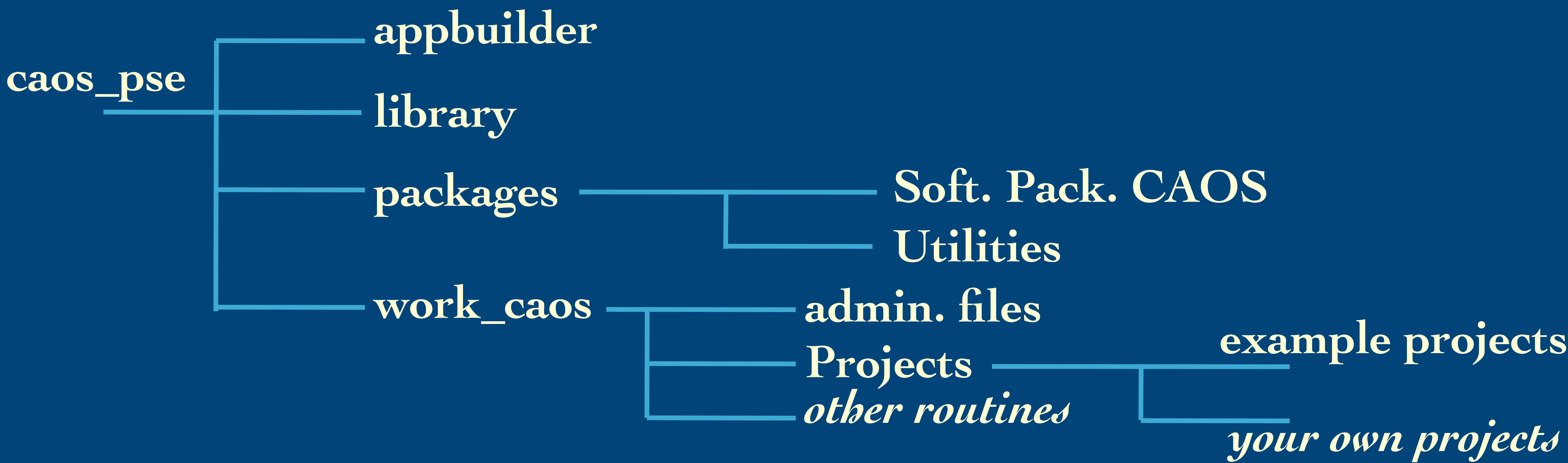
The CAOS "PSE"...

- 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



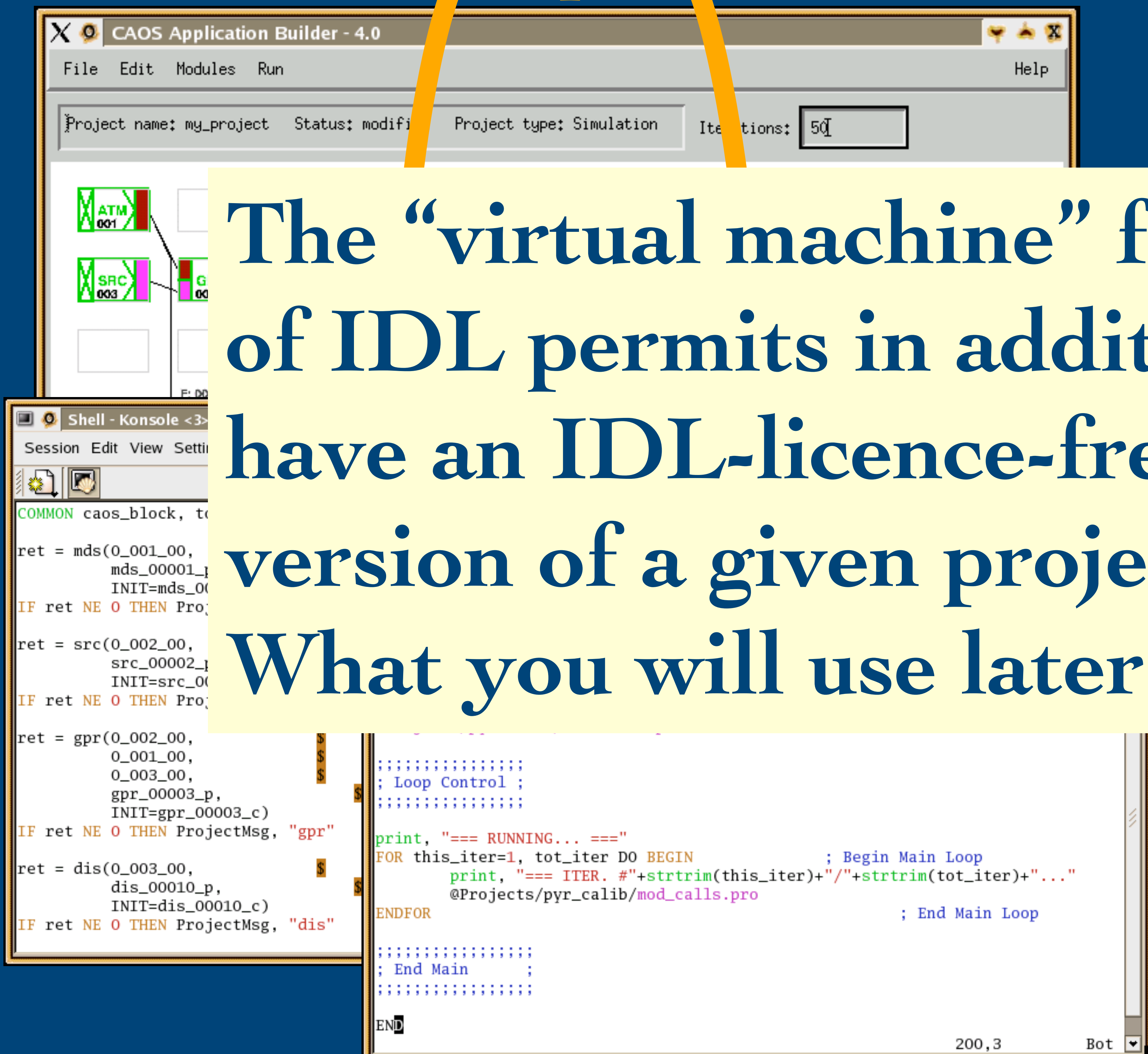
CAOS Problem Solving Environment -2



somewhere else: astrolib, *some other library*

CAOS Application Builder

It is essentially a **worksheet** where the user can place small ... modules, ... them with ... to form a



The "virtual machine" feature of IDL permits in addition to have an IDL-licence-free version of a given project... What you will use later on.

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

CAOS PSE: availability

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

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

Current status of the dedicated mailing-lists (as on May 2022):

- Soft. Pack. CAOS: 105 subscribers,
- Soft. Pack. AIRY: 24 subscribers,
- *Soft. Pack. SPHERE: 23 subscribers,* (as on 2016)
- *Soft. Pack. PAOLAC: 3 subscribers.* (as on 2016)