

- Présentation papier Rigaut
- Point sur exercices 1,2,3...

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 ($0 < g < 1$), A the $(n \times m)$ command matrix.

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

$$A = D^+ = V \Sigma^+ U^*$$

where Σ is an $m \times n$ rectangular diagonal matrix with non-negative numbers on the diagonal (Σ_{ii} are the singular values of D), and U ($m \times m$) and V ($n \times n$) are orthonormal unitary matrices. (Note : $D^+ = (D^t D)^{-1} D^t$)

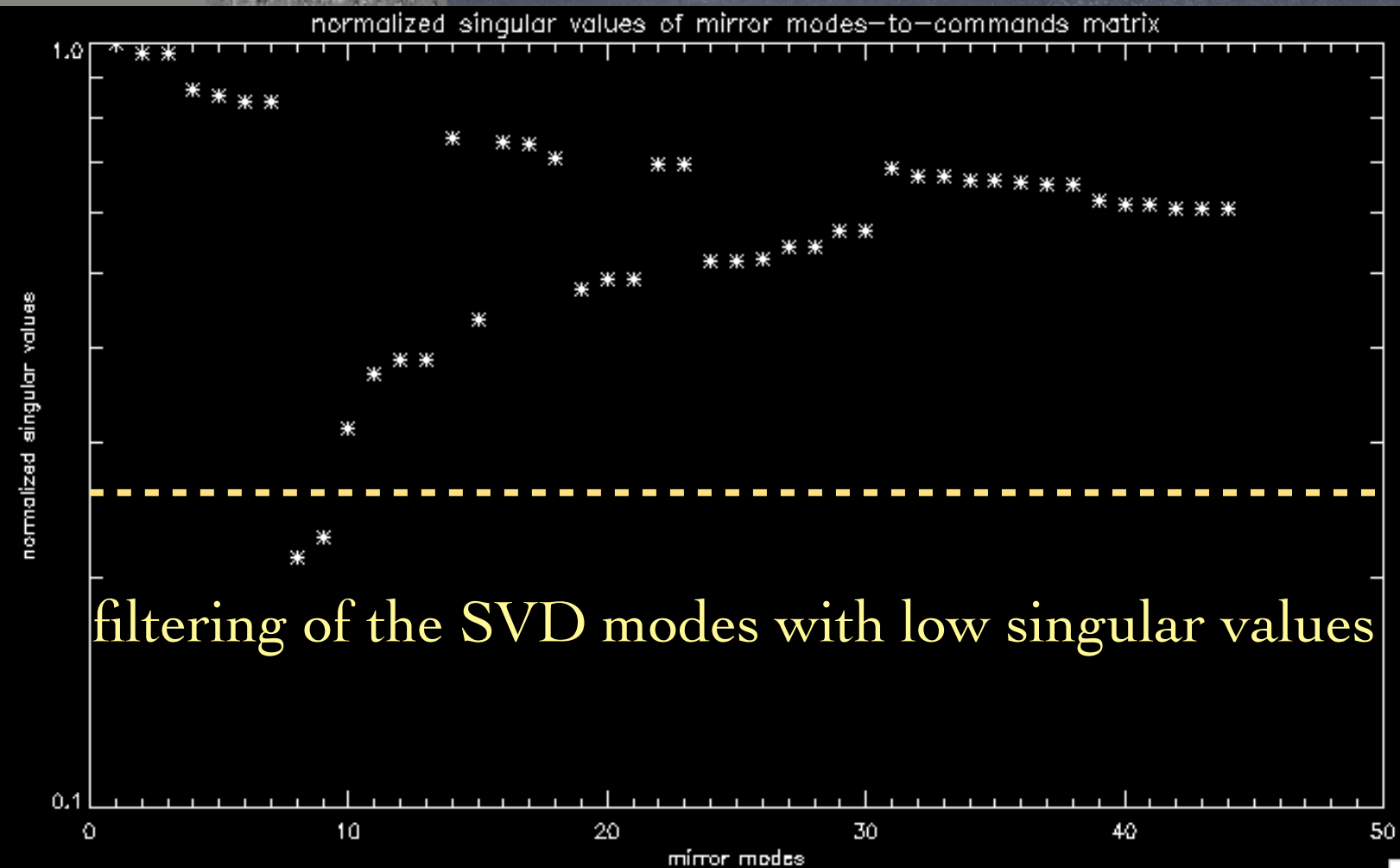
Filtering of SVD modes: Σ_{ii} 'too small' $\Rightarrow \Sigma^+_{ii}$ set to 0 (truncated SVD).

Reconstruction & control of the commands - 2

interaction matrix

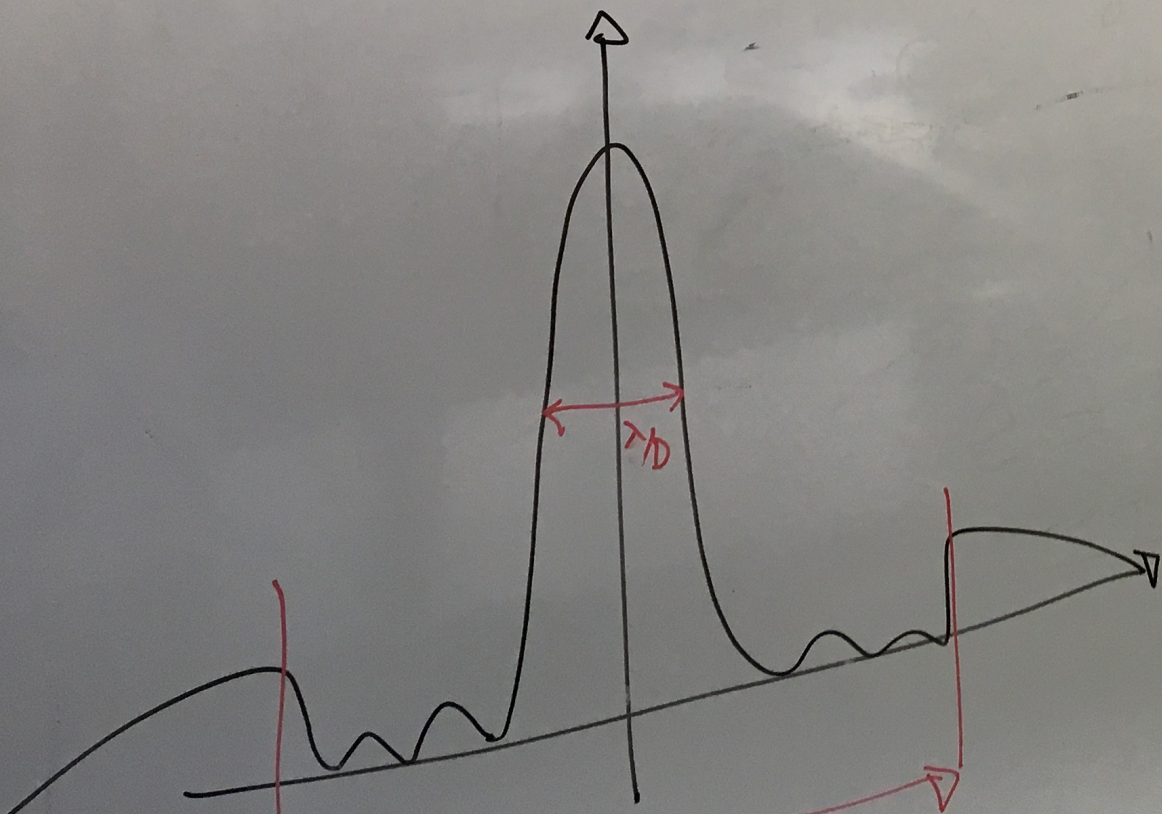
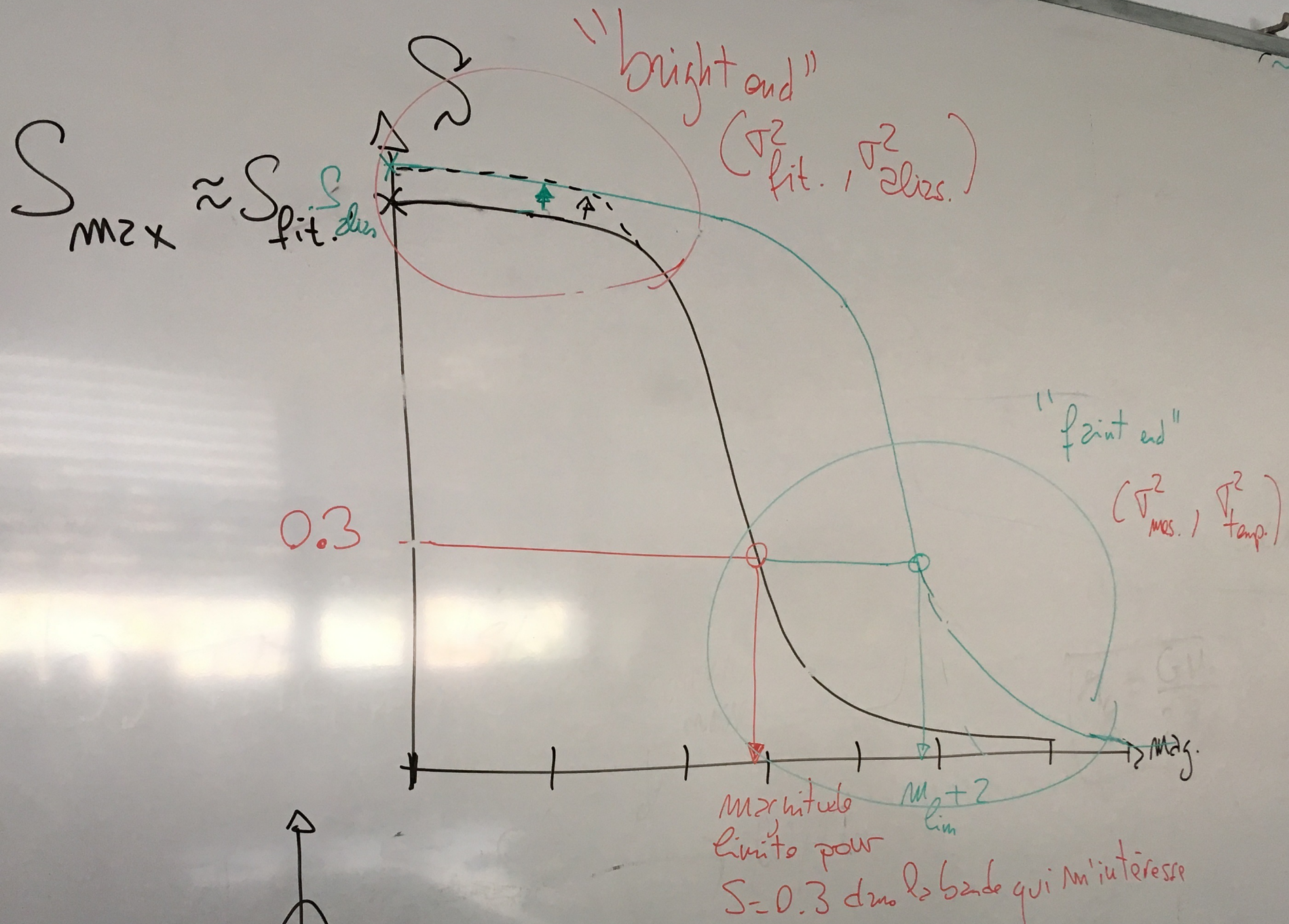
m mirror modes

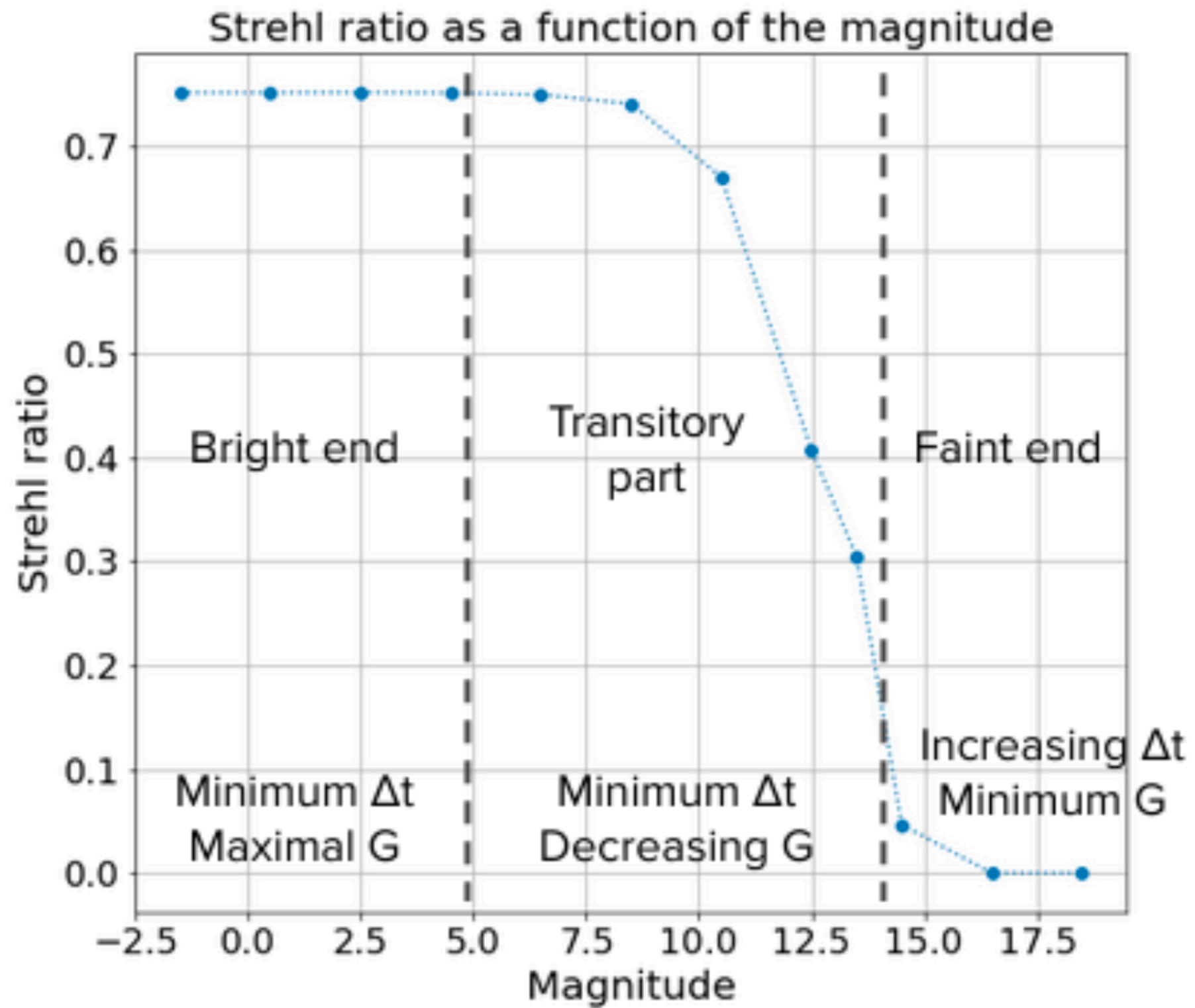
n slope measurements (x & y)



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.	





AO partial correction...

TT bad correction

=> agitation

=> image blurring

H0 bad correction

=> coherence loss

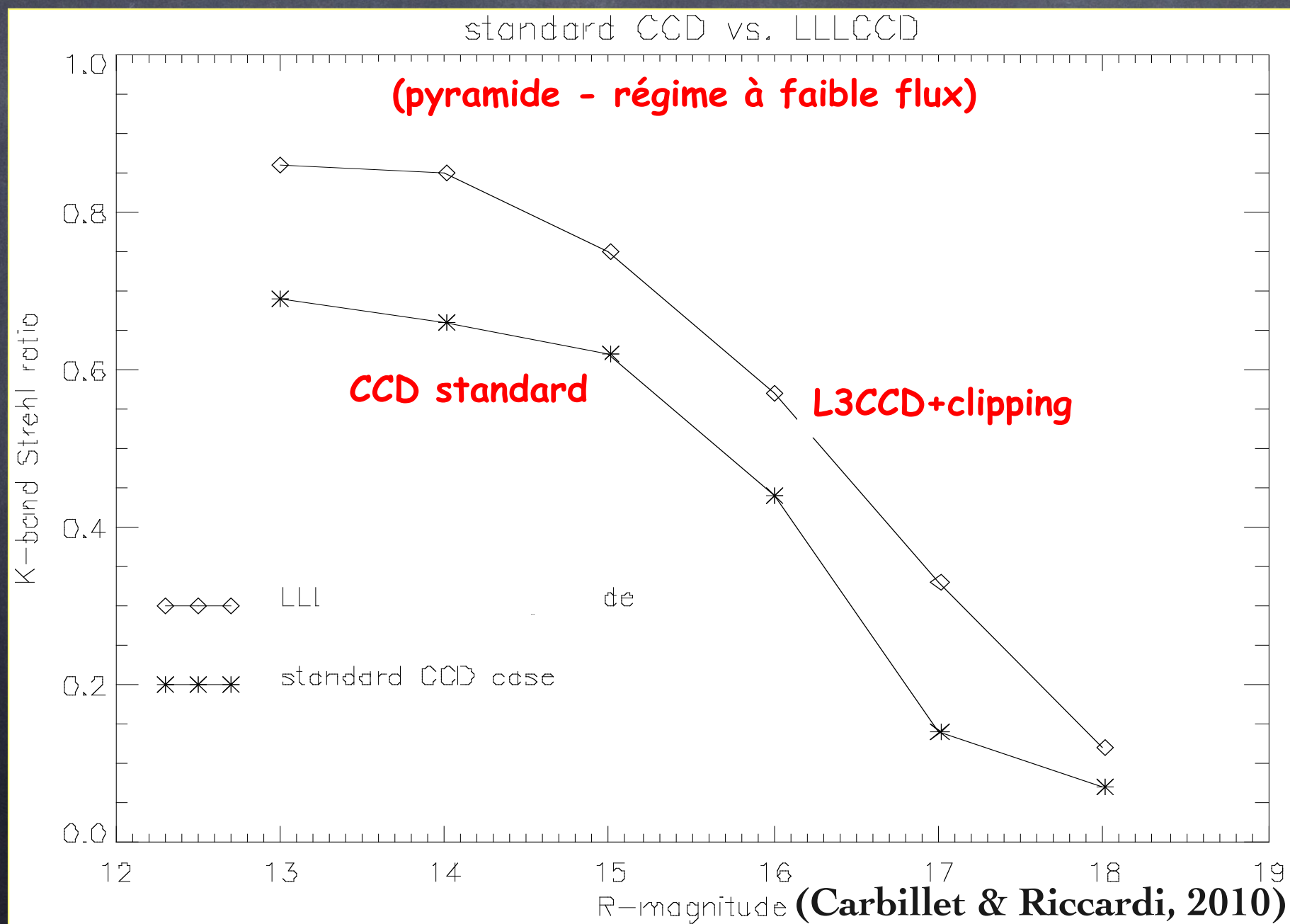
=> coherent core reduced, more intense halo

Hence, for a given Strehl ratio, one should have:

- NGS AO => better resolution,
- LGS AO => better encircled energy...

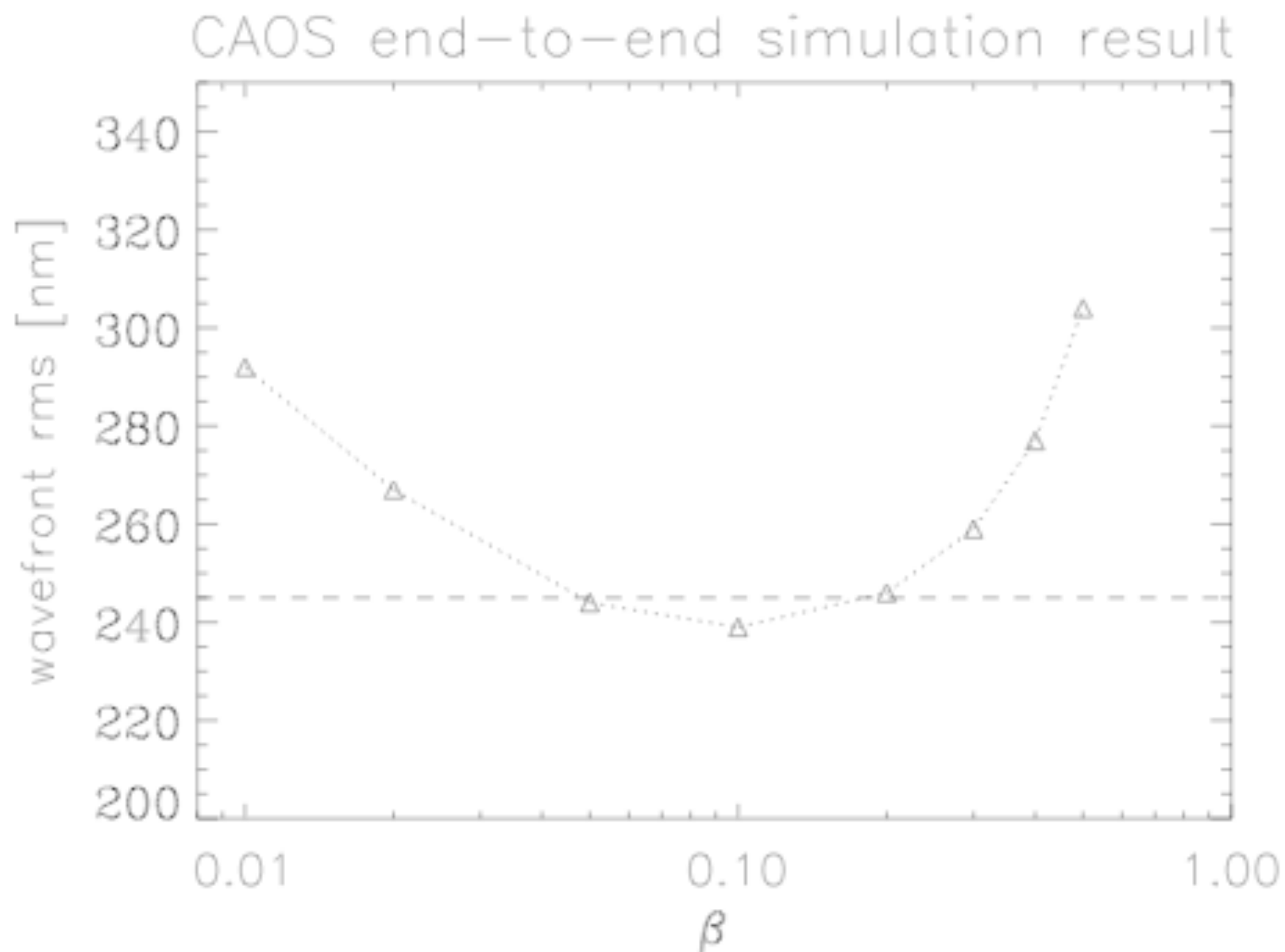
Are other improvements possible ? - Example #1

WFS: replace CCDs with EMCCDs ?...



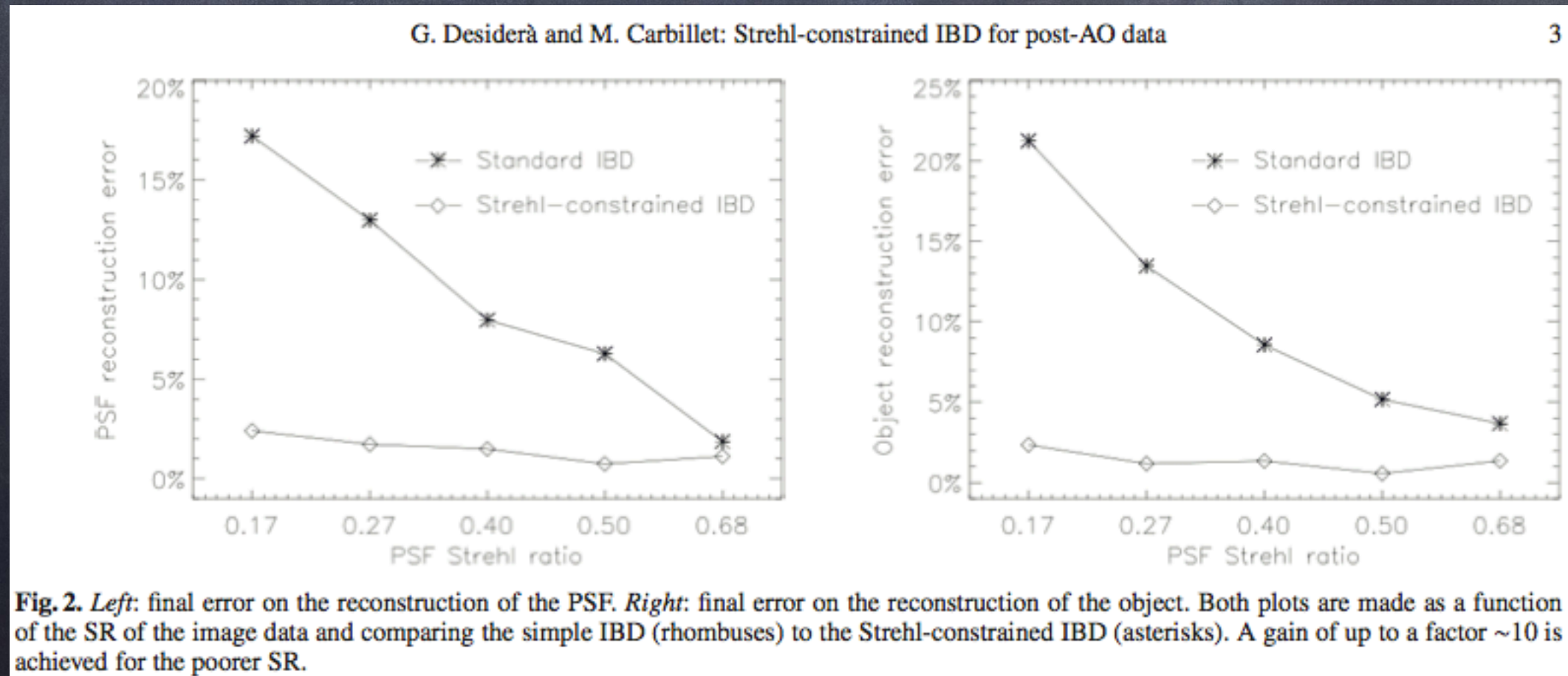
Are other improvements possible ? - Example #2

WFS: add a TT sensor ?...



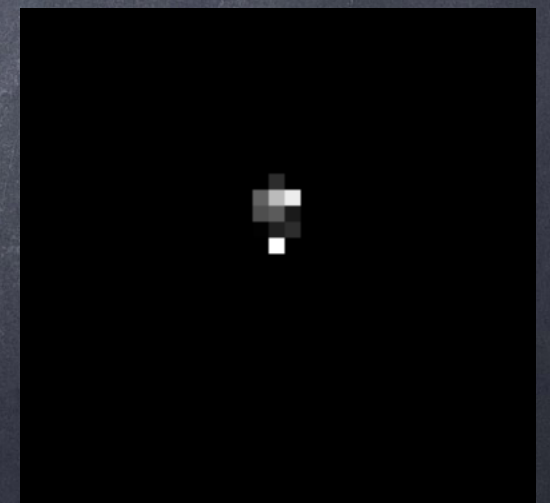
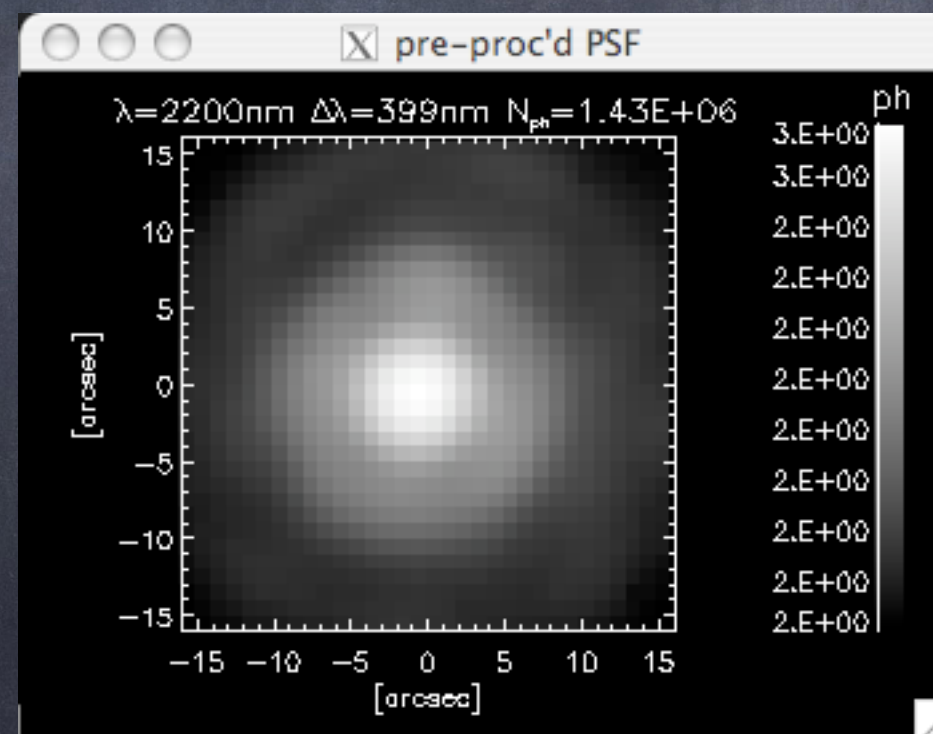
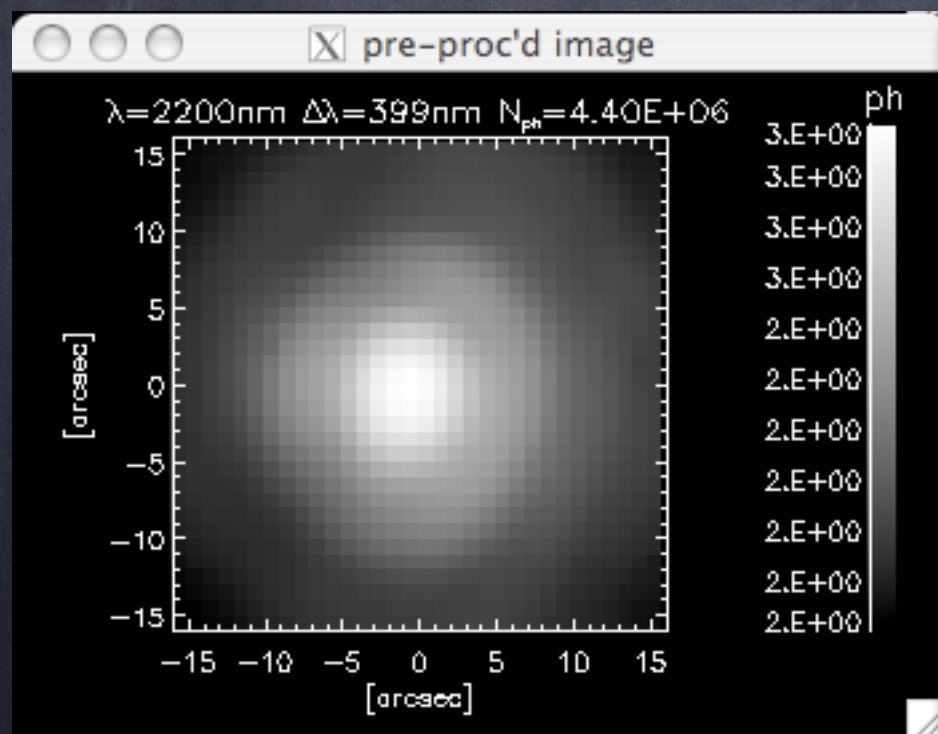
Are other improvements possible ? - Example #3

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



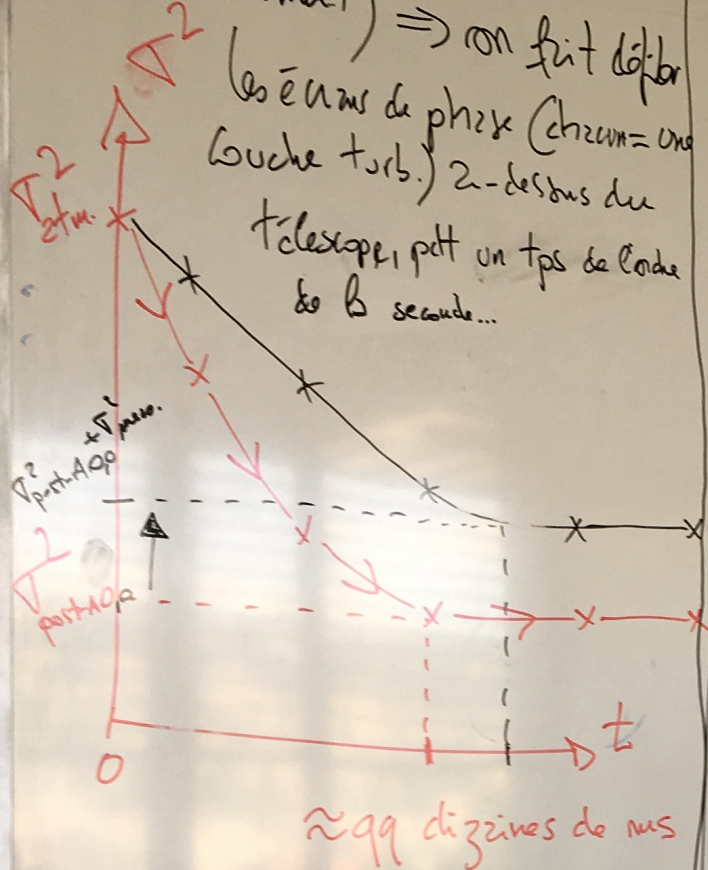
Are other improvements possible ? - Examples - 4

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



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

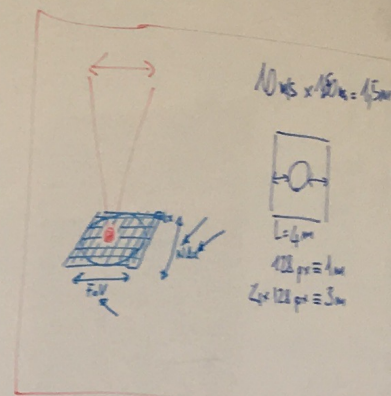
approximation de Taylor (pas le bouillonnement) $\Rightarrow$ on fait défiler les échos de phase (chaque = une couche turb.) 2-dessous du télescope, petit un tps de l'ordre de 6 seconde...



$$\sigma^2_{\text{post-A0}} = \sigma^2_{\text{ziso.}} + \sigma^2_{\text{fitt.}} + \sigma^2_{\text{meso.}} + \sigma^2_{\text{diss.}} + \sigma^2_{\text{temp.}} + \sigma^2_{\text{NRA}}$$

$$\Leftrightarrow S = S_{\text{ziso.}} \cdot S_{\text{fitt.}} \cdot S_{\text{meso.}} \cdot S_{\text{diss.}} \cdot S_{\text{temp.}} \cdot S_{\text{NRA}}$$

(Müschel) $\Rightarrow S = \exp\{-\sigma^2\}$



$$N_{\text{ph}} \propto \frac{1}{N} \Rightarrow \sigma^2_{\text{mes.}} \propto \frac{1}{N} \Rightarrow S \propto \frac{1}{N}$$

ici: - objet = étoile guide $\Rightarrow \sigma^2_{\text{ziso.}} = 0 \Rightarrow S_{\text{ziso.}} = 1$

- pas d'absorptions non-vues $\Rightarrow \sigma^2_{\text{NRA}} = 0 \Rightarrow S_{\text{NRA}} = 1$

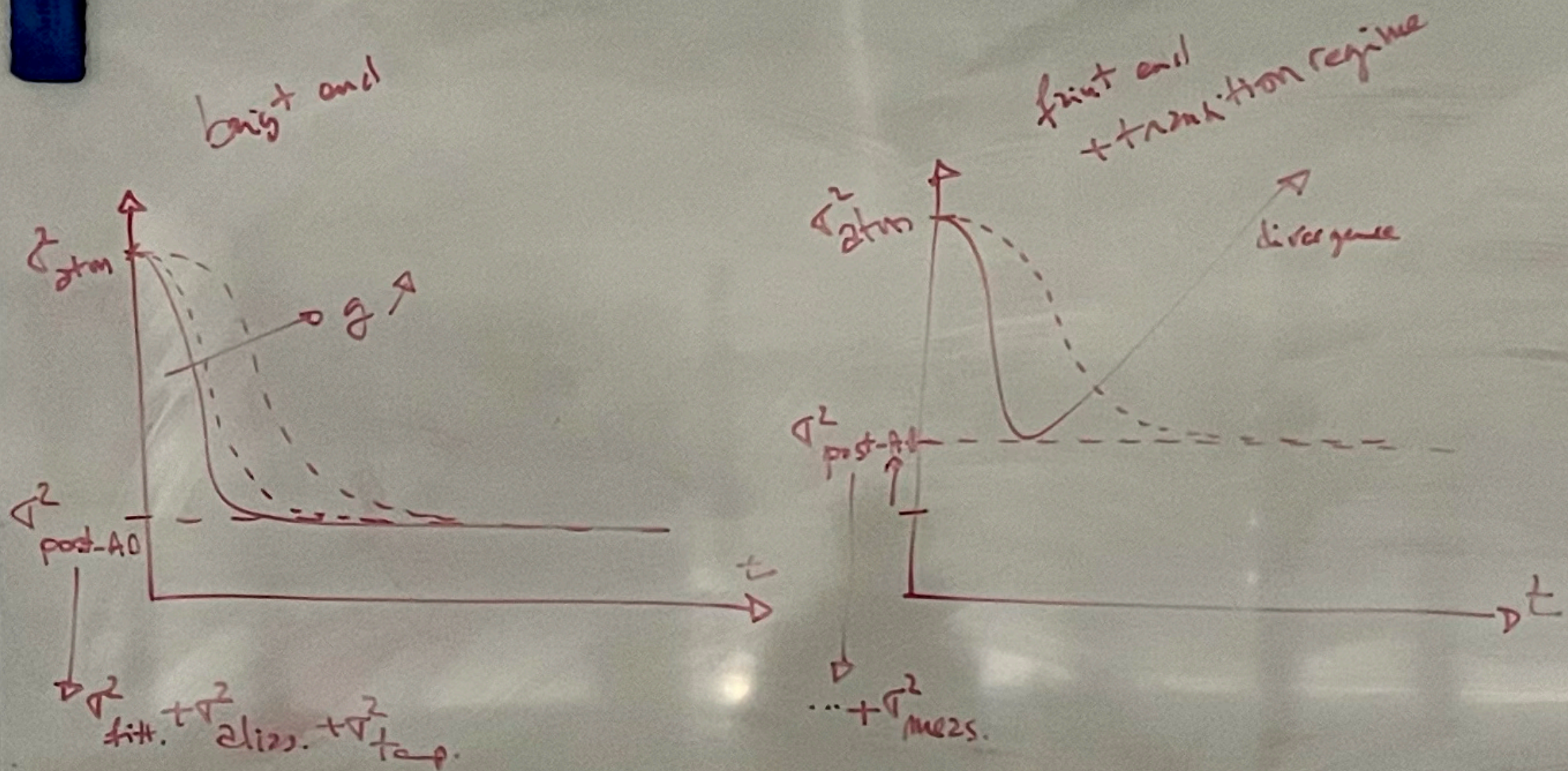
- $\sigma^2_{\text{fitt.}}$, $\sigma^2_{\text{diss.}}$ restent constants (r_0 et $d = d_{\text{fixe}}$)

- Δt intégration fixe $\Rightarrow \sigma^2_{\text{temp.}}$ constant.

- Seul $\sigma^2_{\text{meso.}}$ varie, en fonction de N . Et, dans un pet tps, on considère que le bruit de photons.

$$\sigma^2_{\text{meso.}} = \sigma^2_{\text{ph}} \propto \frac{1}{N}$$

about the gain of the pure integrator command law...



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

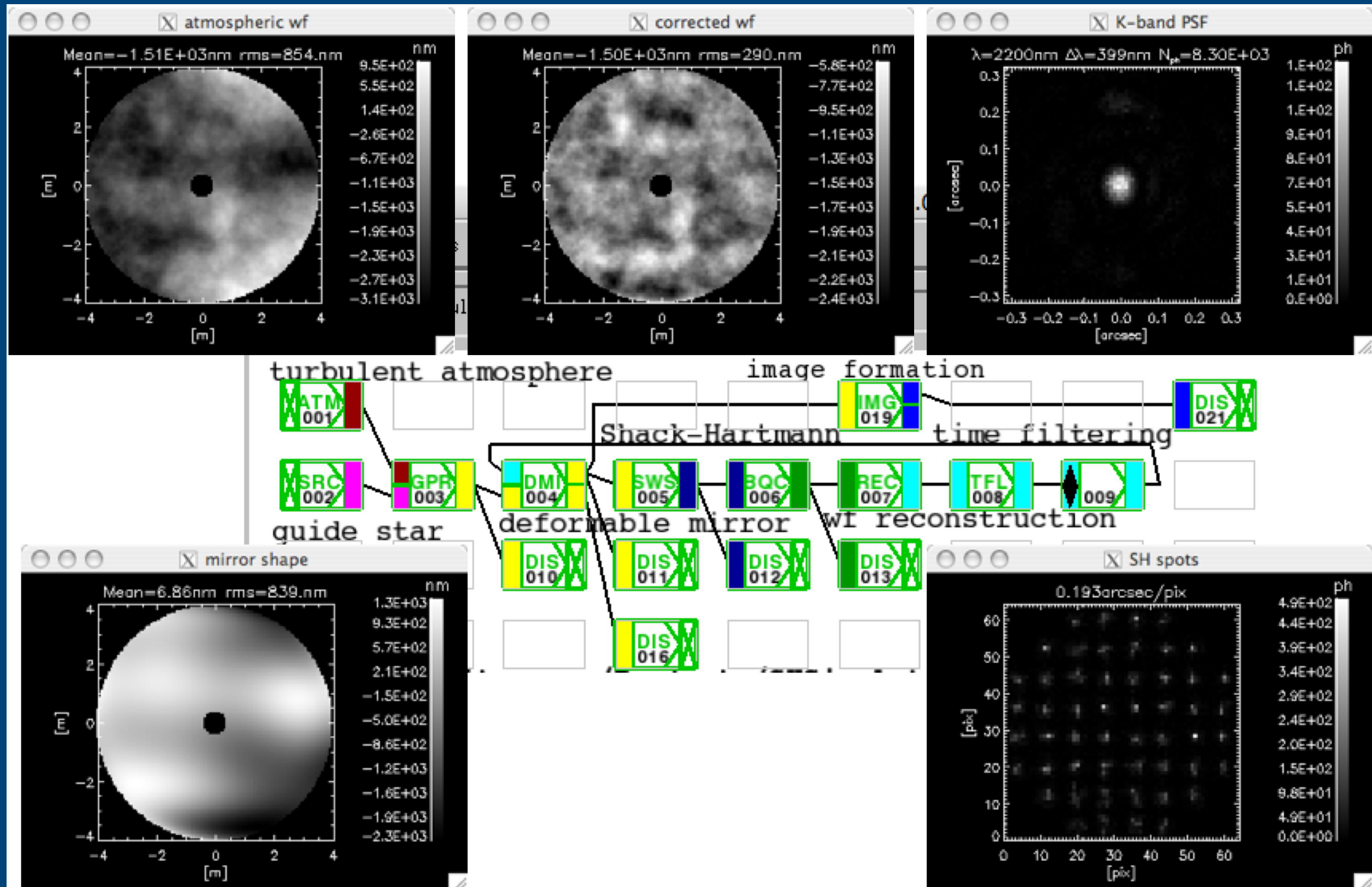
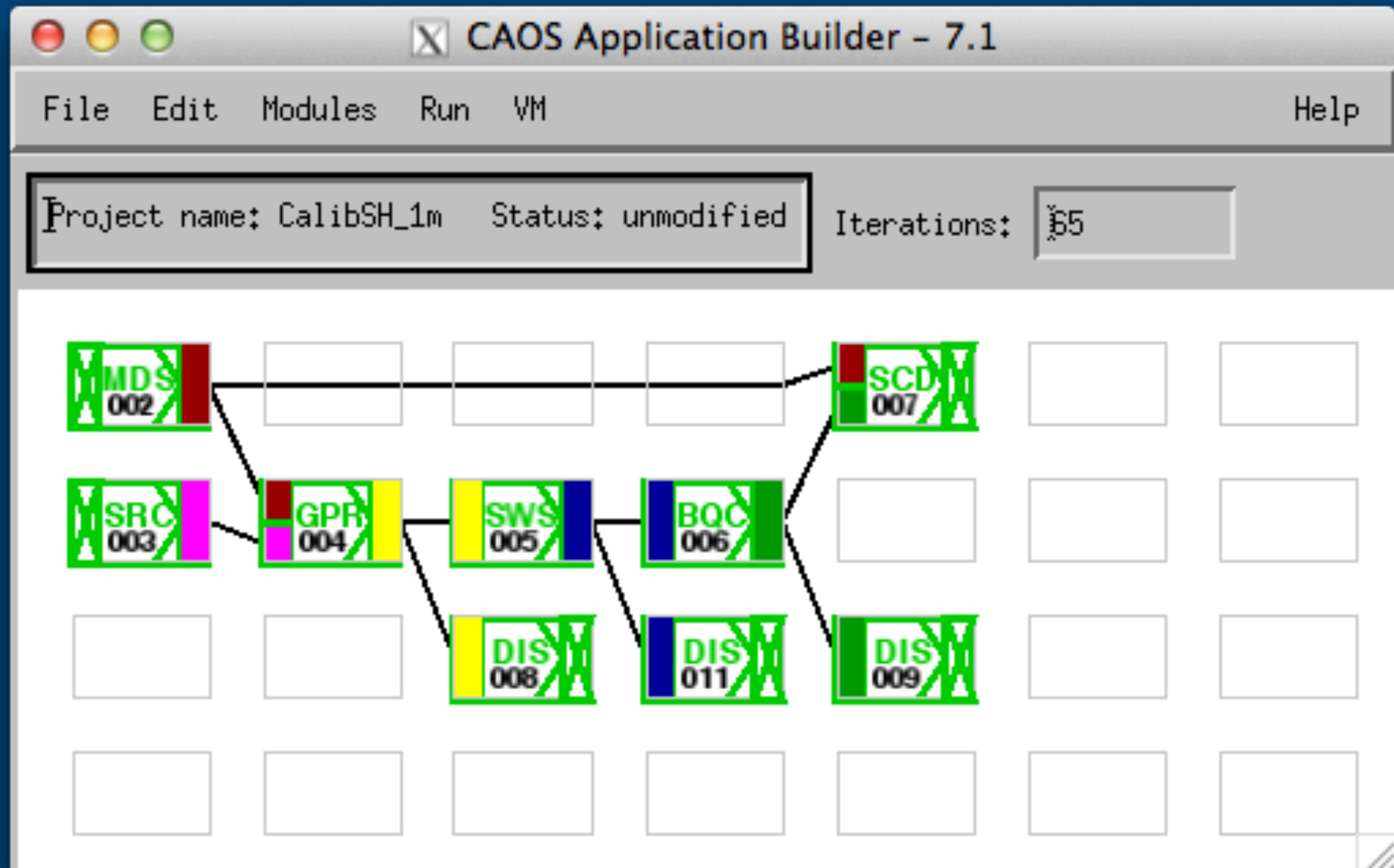


Table 1. The 31 modules of the Software Package CAOS, version 7.0.

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 deformatives)
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 SPplitter	-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

End-to-end simulation of a complete AO system: calibration



End-to-end simulation of a complete AO system: running...

