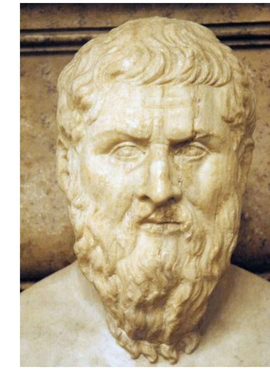
PLATO
Data Processing Algorithms (DPA)

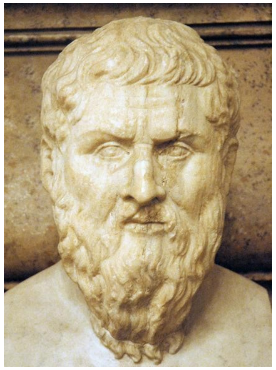


Réza Samadi (CNRS-LESIA, Observatoire de Paris)

and the members of the DPA - Working Group

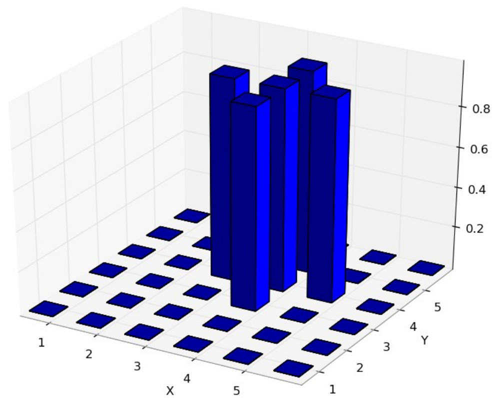
- The sources of perturbation
- Photometry methods
- Assessment of the expected photometry performance
- How to correct the differential aberration and the satellite jitter ?
- The configuration mode
- Organization of the DPA – Working Group

The sources of perturbation that we must deal with

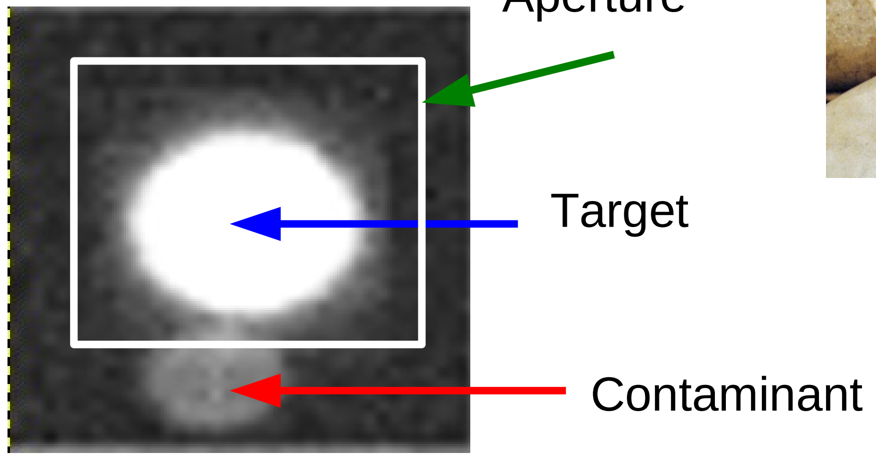


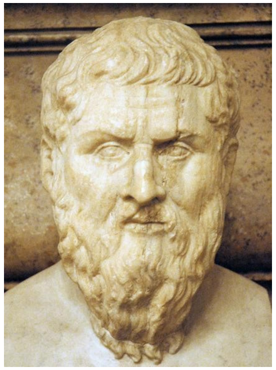
- *Cross-talk (electromagnetic interference) ⇒ on ground*
- Smearing (trailing) ⇒ on board
- Electronic offset ⇒ on board
- Background (sky background, scatter light) ⇒ on board
- Confusion (pollution due to the contaminants) ⇒ on board
- Differential aberration ⇒ on board & on ground
- Outliers (glitchs, proton impacts) ⇒ on board & on ground
- Satellite Jitter ⇒ *on ground*

The problem of confusion

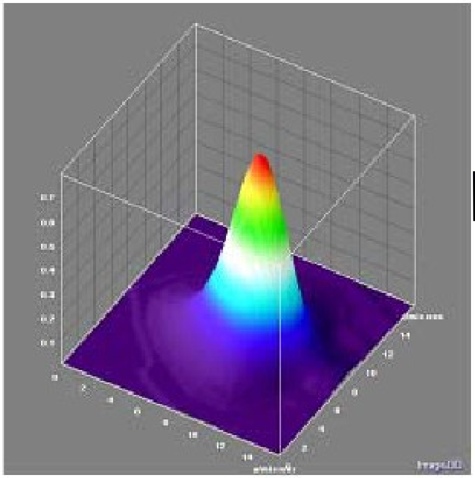


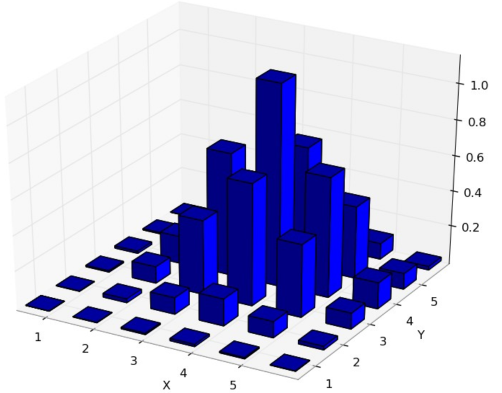
Binary mask





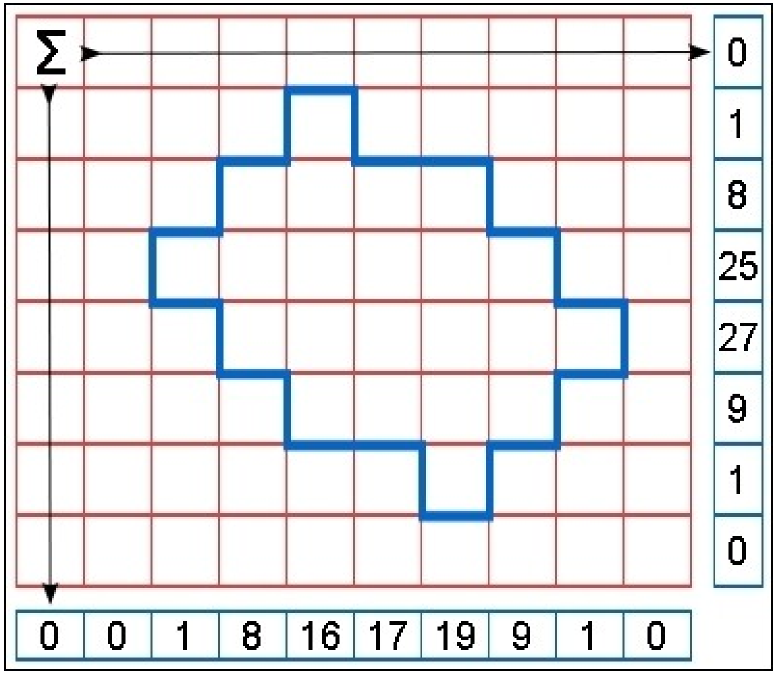
- To avoid confusion : use of a narrow binary mask or **weighted mask**
- Weighted mask: can be updated in a **continuous** manner
- If too narrow: important flux lost
- GAIA: positions and intensities of the contaminants known a priori
- optimization of the width of the mask

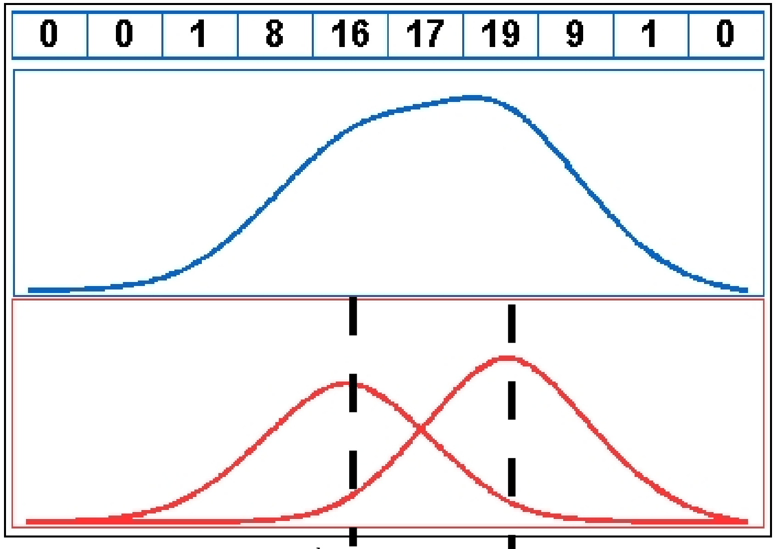


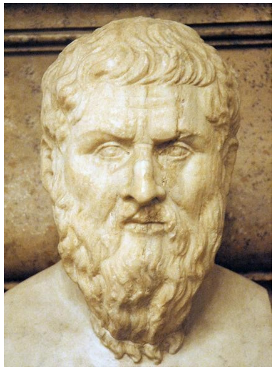


weighted mask
(e.g. Gaussian)

An alternative photometry methods: *Line Spread Function (LSF) fitting*



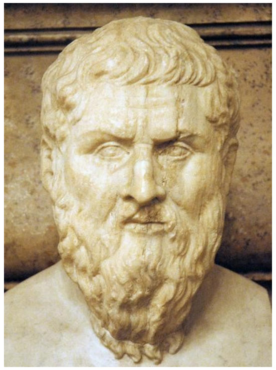




- Original method proposed by GEPI – Observatoire de Paris
- **LSF-fitting**: flux estimation of individual components
- **Advantages**:
  - Improved management of confusion
  - No sensitive to jitter
  - No need to update the mask ⇒ continuous photometry

➔ **But need for a representative PSF**

Performances of different photometry methods



Method	Noise level (ppm/1h)	
	PSF 0°	PSF 14°
Binary mask	29.2	32.7
Binary mask + jitter correction	28.6	32.5
Weighted mask	28.2	32.4
Weighted mask + jitter correction	**27.9**	**32.2**
LSF - Gauss	*28.4*	*33.6*
LSF - PSF	*31.8*	*36.7*

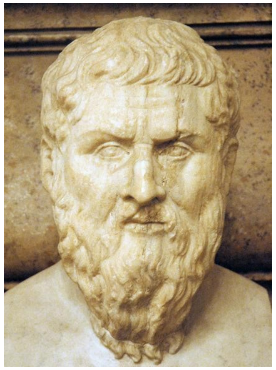
- Time series of simulated images (PLATOSim)
- Target: mag =11
- A single contaminant (mag=13 ; 1 pixel far from the target)
- Gaussian weighted mask

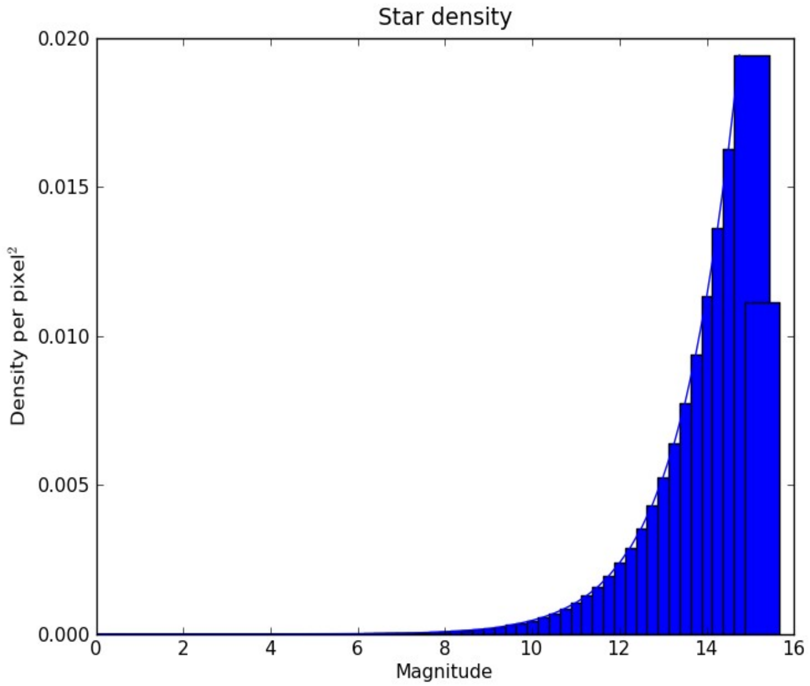
In all cases:

➔ Best performances with the weighted mask

➔ Results to be consolidated trough independent investigations

A tool to assess the global performances





Included perturbations:

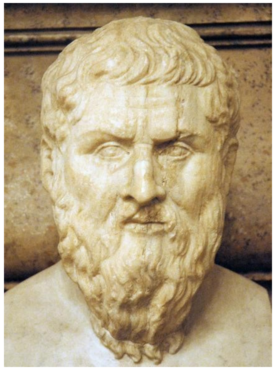
- Photon noise target
- Photon noise contaminants
- Sky background (constant)
- Readout noise
- Quantification noise
- Smearing
- Jitter noise:
  - Target
  - Contaminants
- Jiitter correction (residues):
  - Target
  - Contmaninants

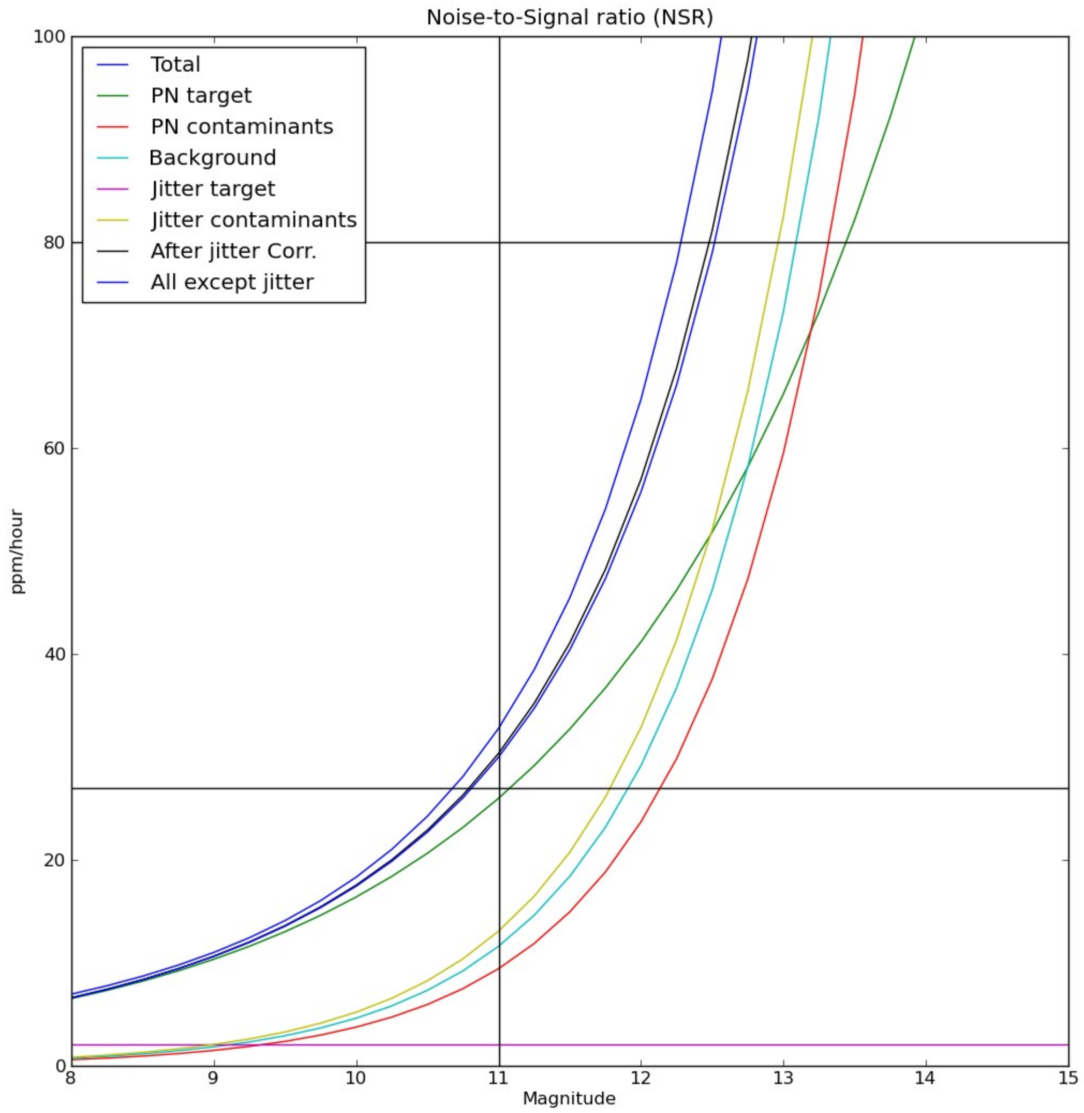
Inputs:

- Star density (star number per pixel²)
- PSF (e.g from the optic model)
- Mask (e.g. binary or weighted)
- PDF of the jitter (e.g. normal distribution)

PRNU: neglected

Global performances : results for the N-Telescopes





Weighted mask (width: 1 pix)

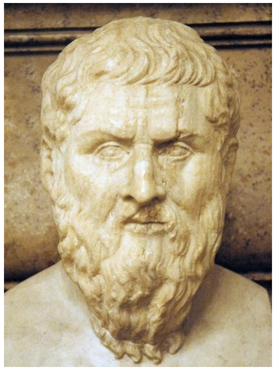
PSF 0° (center)

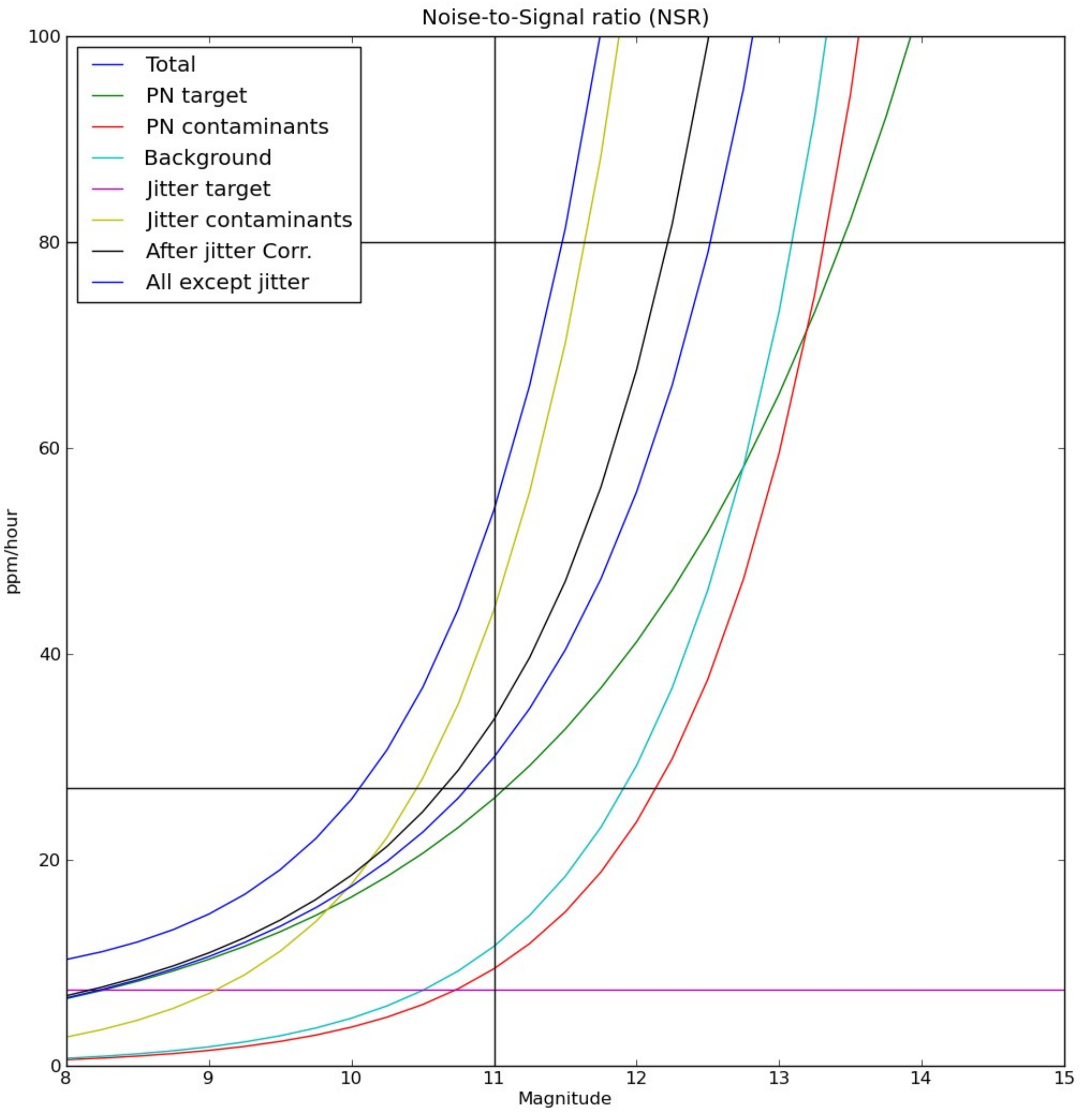
32 telescopes

Jitter:

- ➔ Uncorrelated between telescopes
- ➔ As low as the spec.

Global performances : results for the N-Telescopes





Weighted mask (width: 1 pix)

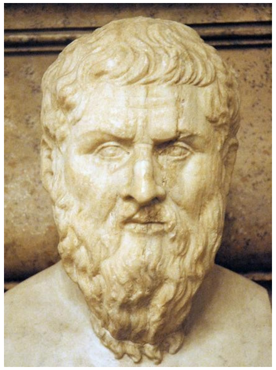
PSF 0° (center)

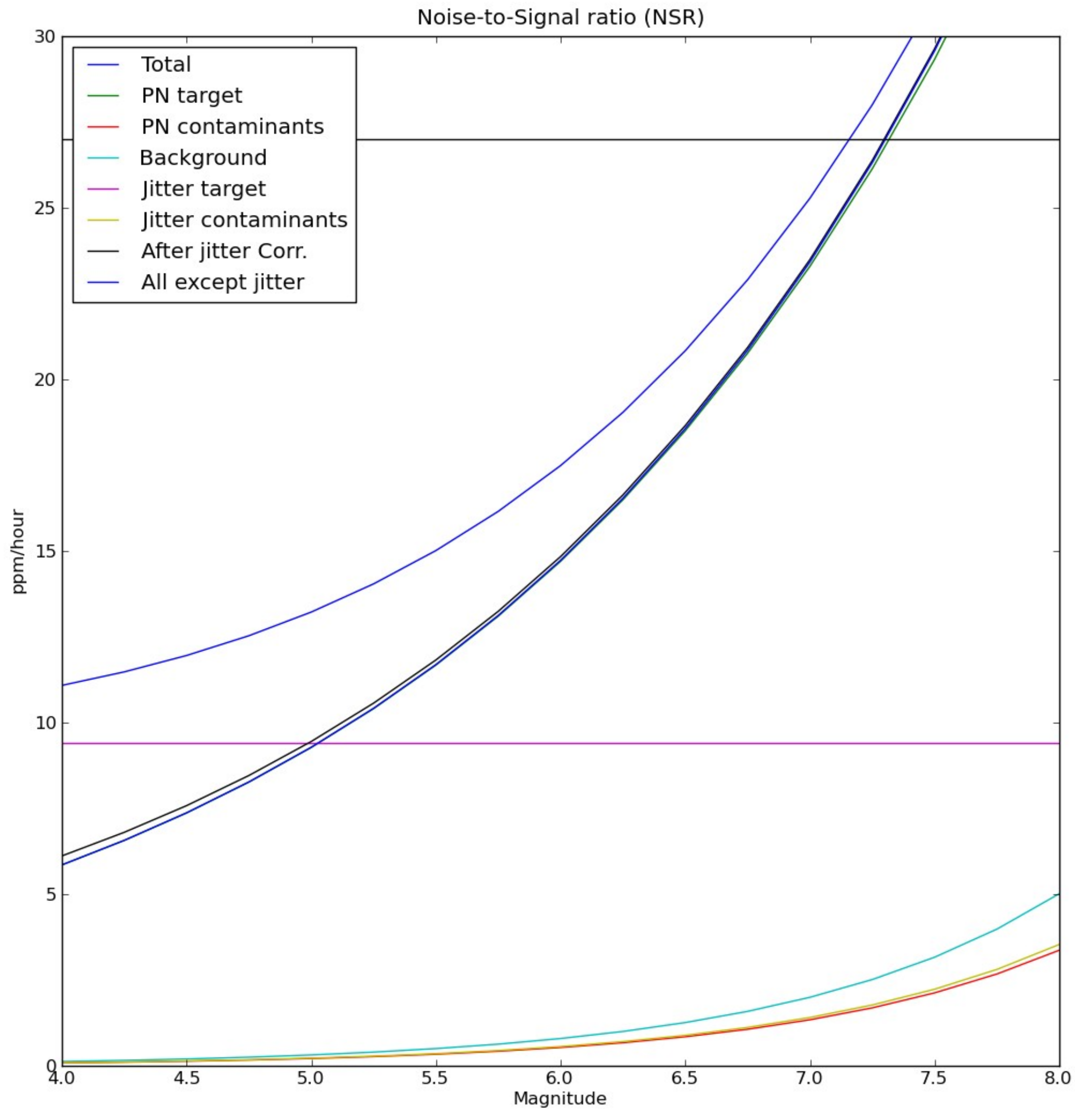
32 telescopes

Jitter:

- ➔ Uncorrelated between telescopes
- ➔ 5 times larger than the spec.

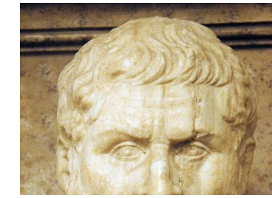
Global performances : results for the F-Telescopes

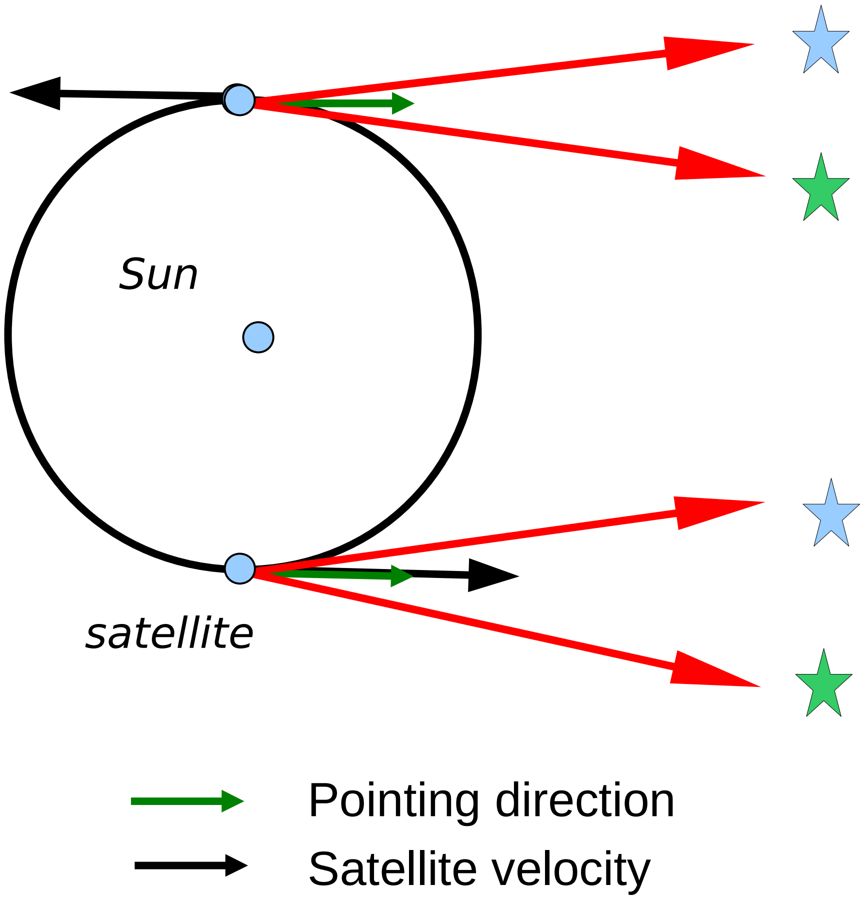


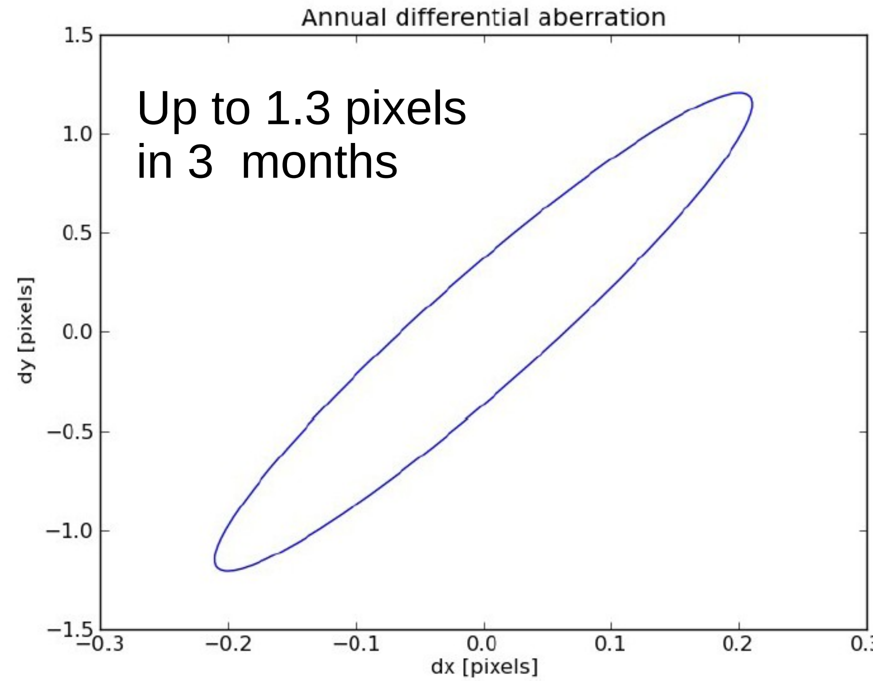


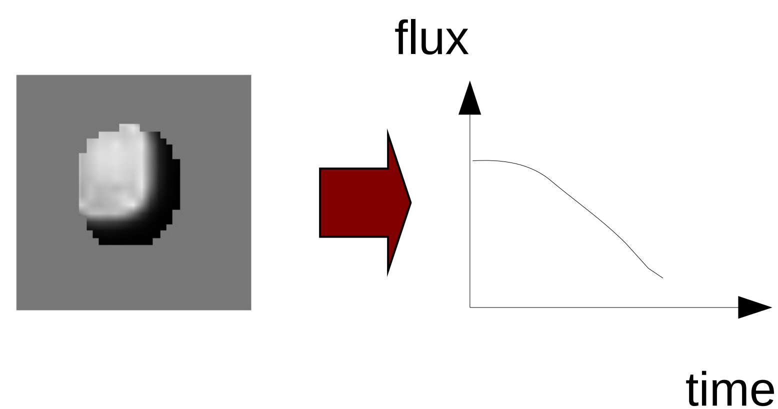
- Weighted mask (width: 1 pix)
- PSF 0° (center)
- 2 telescopes
- Jitter: **5 times larger** than the spec.

Differential aberration



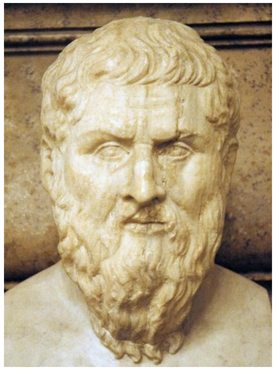


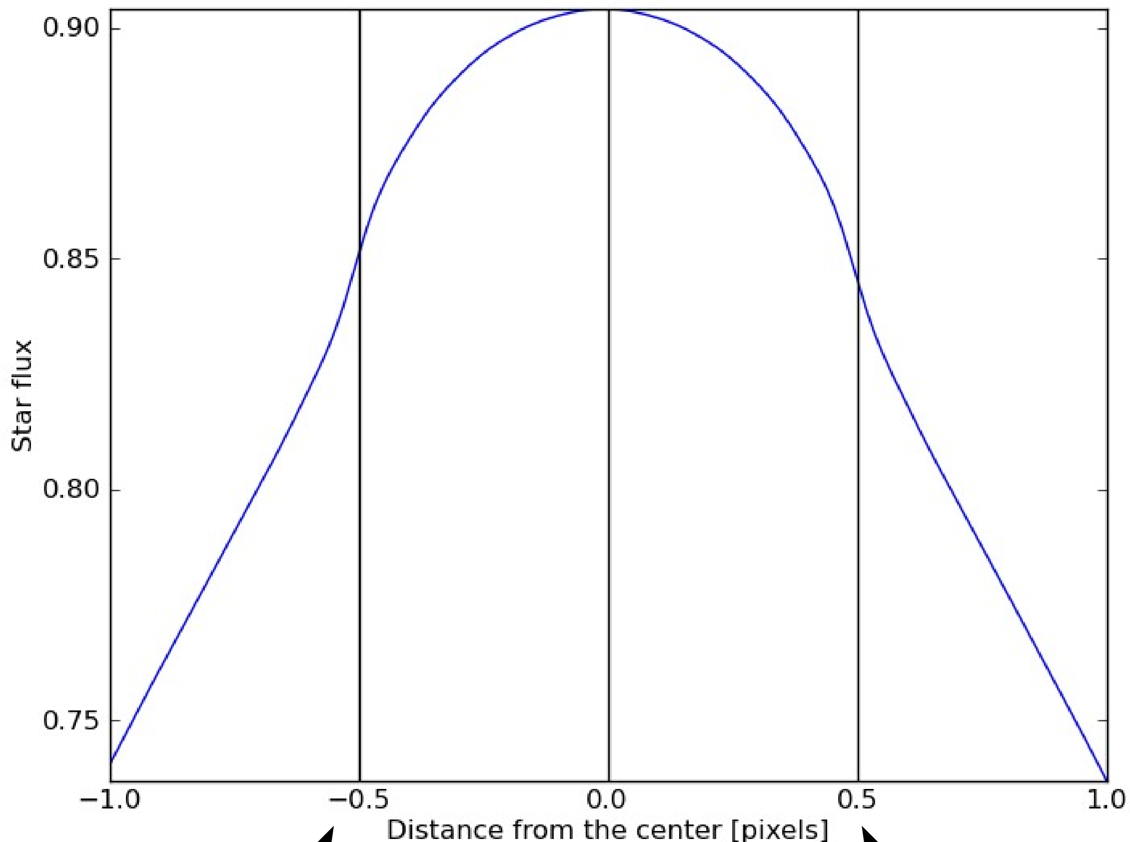




- *In addition*: Thermoelastic variations of the telescope pointing direction

Differential aberration and mask updates





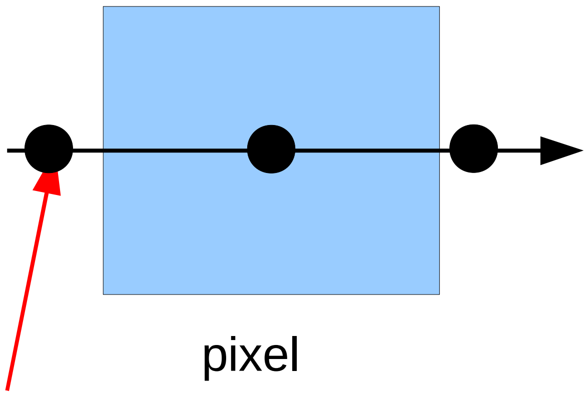
Pixel border (left)

Pixel center

Pixel border (right)

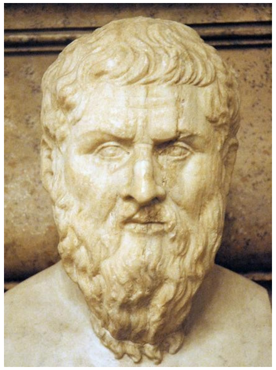
Gaussian weighted mask centered at the middle of a pixel

1 pixel = ~ 70 days



Star centroid

Updates of the masks: how to proceed (on board) ?



$$M(x,y) = F(x-x_{0,}y-y_0)$$

(X_0,Y_0) : star centroid at a given instant

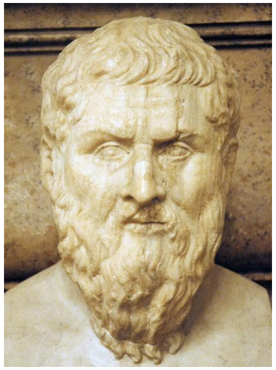
$$x_0 = f(t) \qquad y_0 = g(t)$$

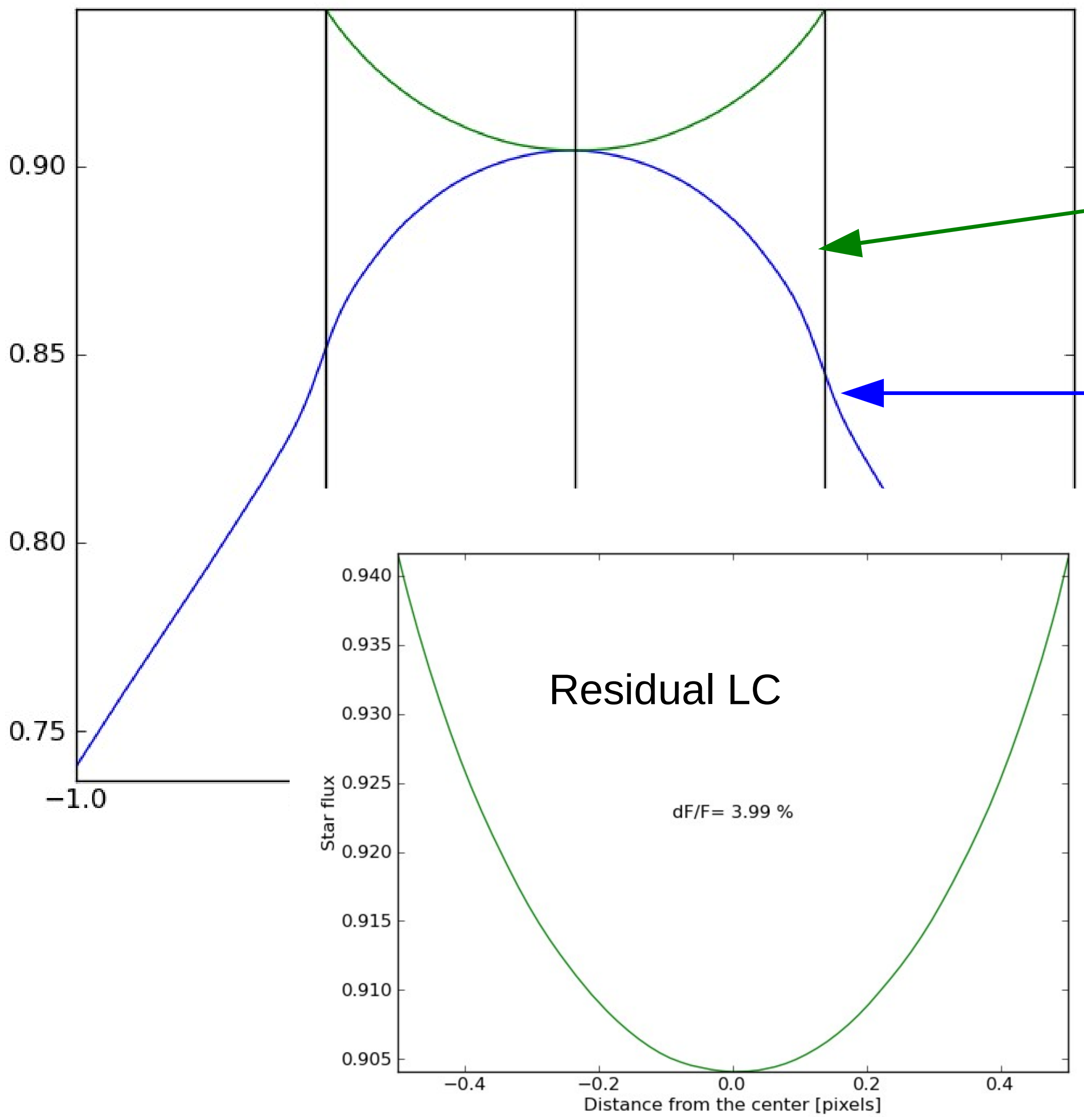
➔ The mask is computed on the basis of an analytical function (e.g. Gaussian)

The star centroid (x_0,y_0) moves due to:

- The kinematic differential aberration ⇒ *fully predictable*
- The movements of the satellite (jitter) ⇒ corrected a posteriori on-ground
- The thermoelastic differential aberration

Mask updated using a weighted mask computed with a Gaussian function





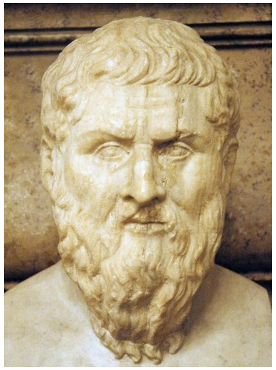
Gaussian mask updated every 1/128 pixels (resolution of the PSF)

Without mask update

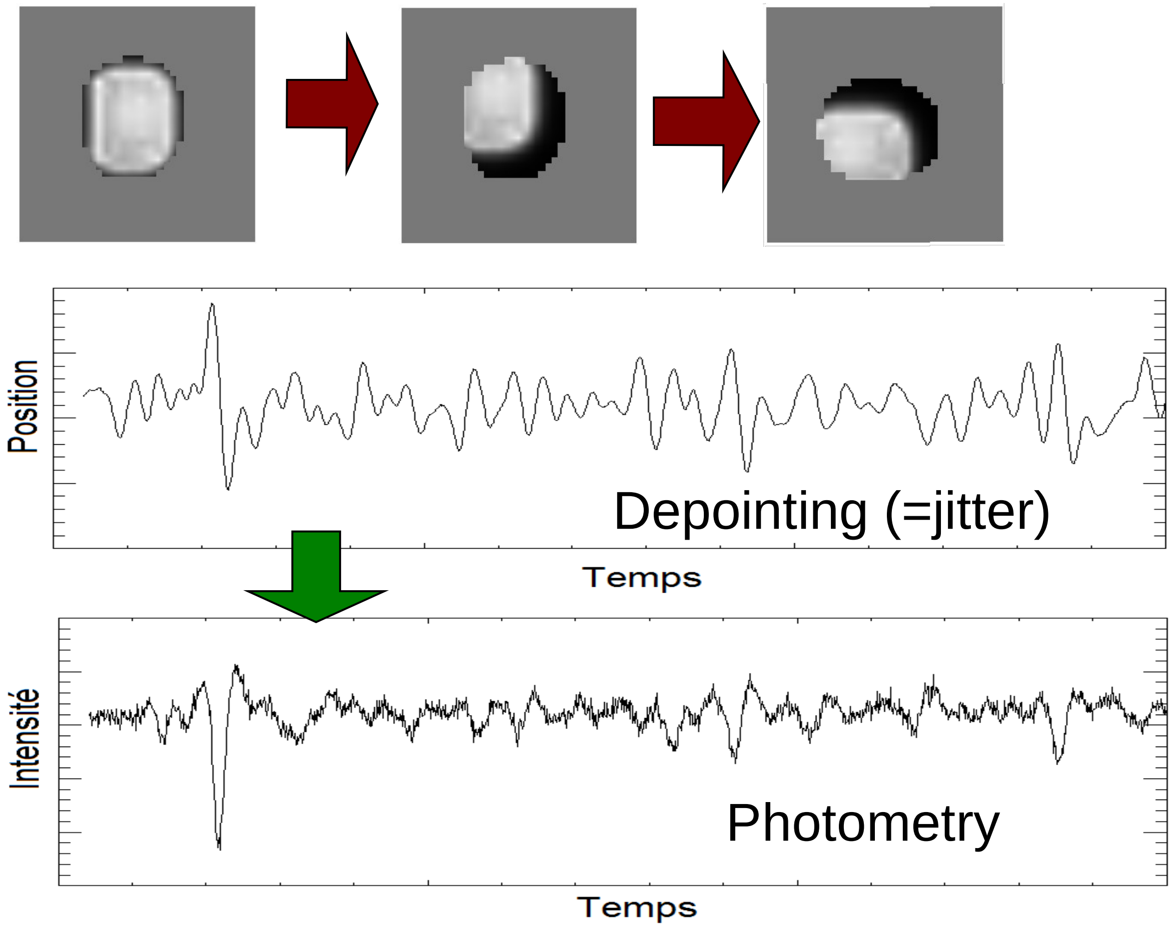
Can be reduced on board using a **PSF model**

- Can be corrected as we do the **jitter correction**
- In both case, the quality of the correction will **strongly depends on the quality of the PSF model**
- Can also be reduced if we **change adequately the width of the weighted mask**

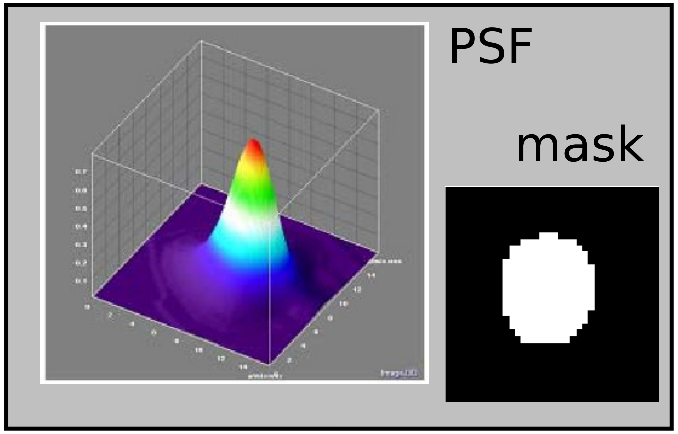
Satellite jitter and its impact on the photometry

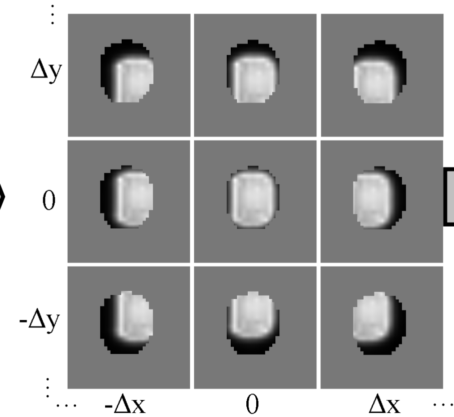


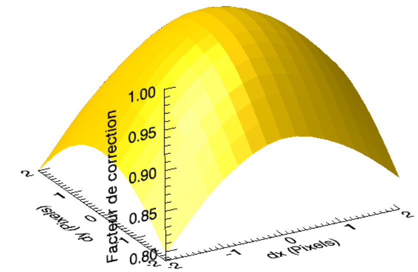
The satellite moves ! (=jitter)

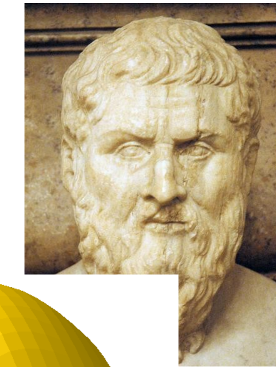


Jitter noise : correction (on ground)









Surface for the jitter correction

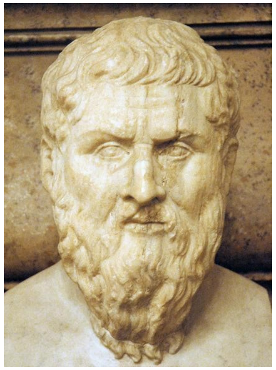
- From the PSF, we can predict the perturbations induced by any displacements :

$$F_{c_i} = K(\Delta x_i, \Delta y_i).F_{m_i}$$

Fialho et al (2007, PASP)

- This method also corrects the differential aberration
- But we need to derive accurately the star displacements (Δx, Δy) as well as the PSF !
- The surface used for jitter correction must take the presence of contaminants into account.
- GAIA : positions and intensities of the contaminants known a priori

The configuration mode

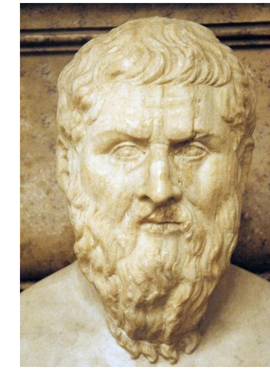


➔ The observation sequence can started as soon as – for each target - the windows and the masks are attributed and the background estimated

Requirements:

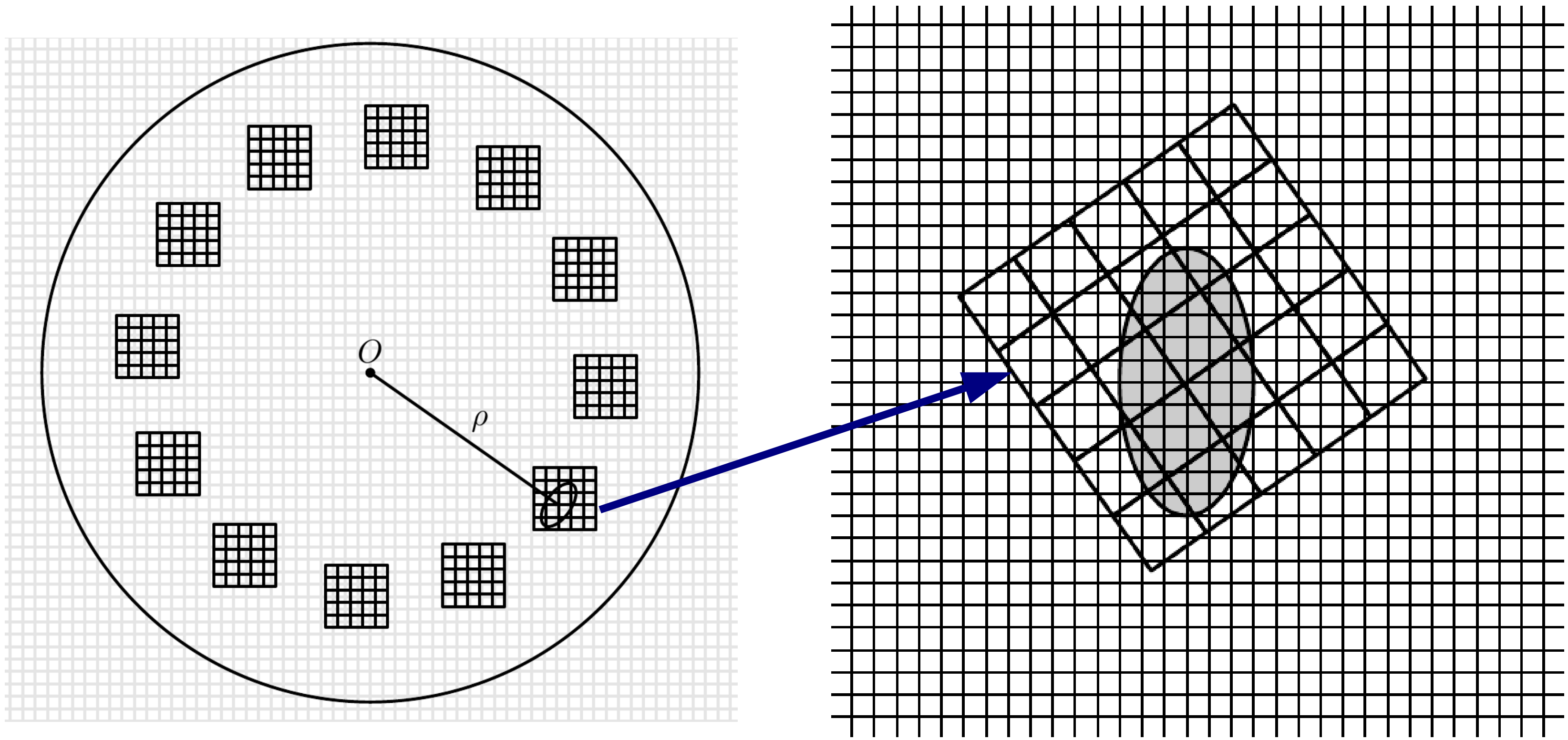
- Recognition of the field of view and identification of the targets
- For each star :
  - Determine initial position of the centroid
  - Derive a representative PSF
  - Derivation of the initial parameters of the LSF
- Calibration of the background model

Reconstitution of the PSF across the field



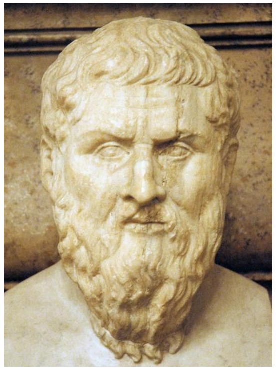
Voxel concept discretisation

Rotate all ”imagettes” at fixed ρ into the PSF representation grid for discretisation



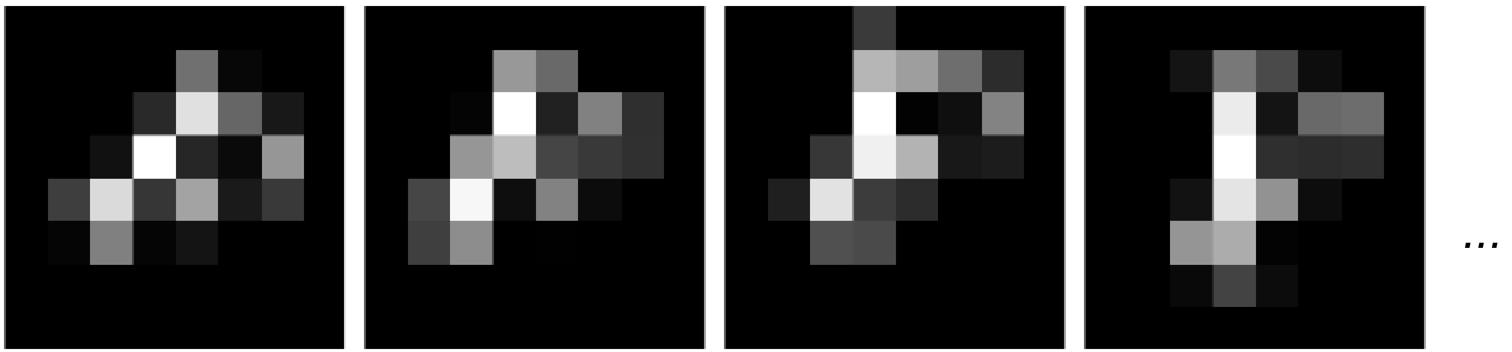
Result: A large sparse linear system A x = y where y is a vector of imagette pixel fluxes, x a vector of PSF representation coefficients

Credit:
J. Green



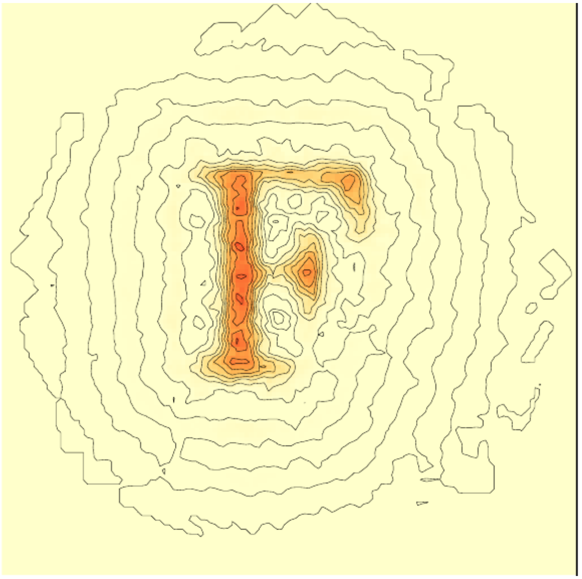
Reconstitution of the PSF across the field

Toy example – PSF of the letter “F”, 36 x (8 × 8) imagettes



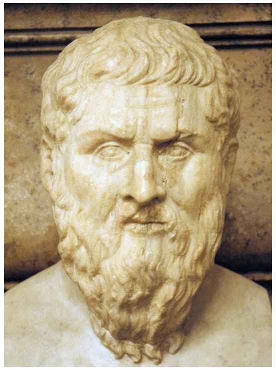
Star 1 Star 2 Star 3 Star 4 ...

Inverted using
Algebraic
Reconstruction
Technique



Credit:
J. Green

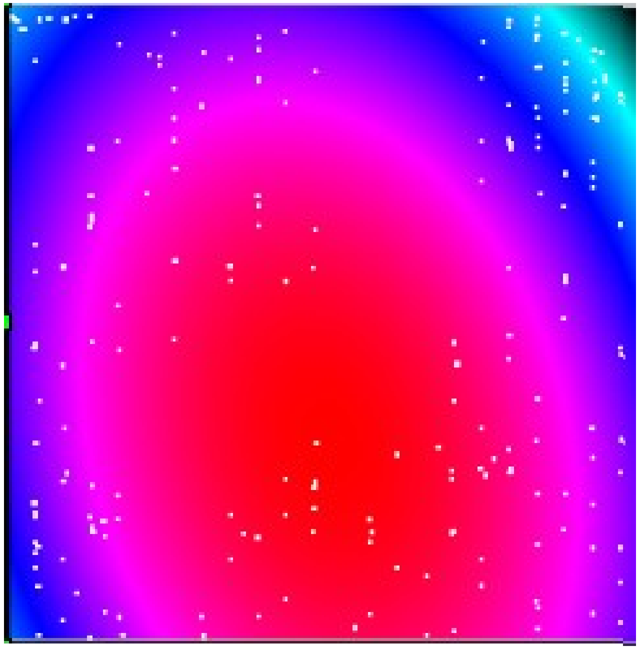
Modeling the sky background



- We set ~ 400 background windows per telescope (100 per CCD)

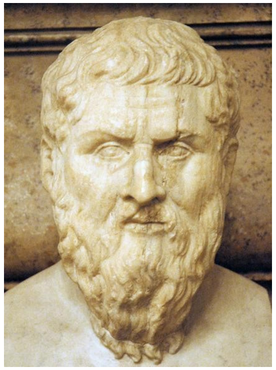
- **During the configuration mode**
  - we collect a long enough time series of background measurements
  - We model te background using a 2D polynomial fit

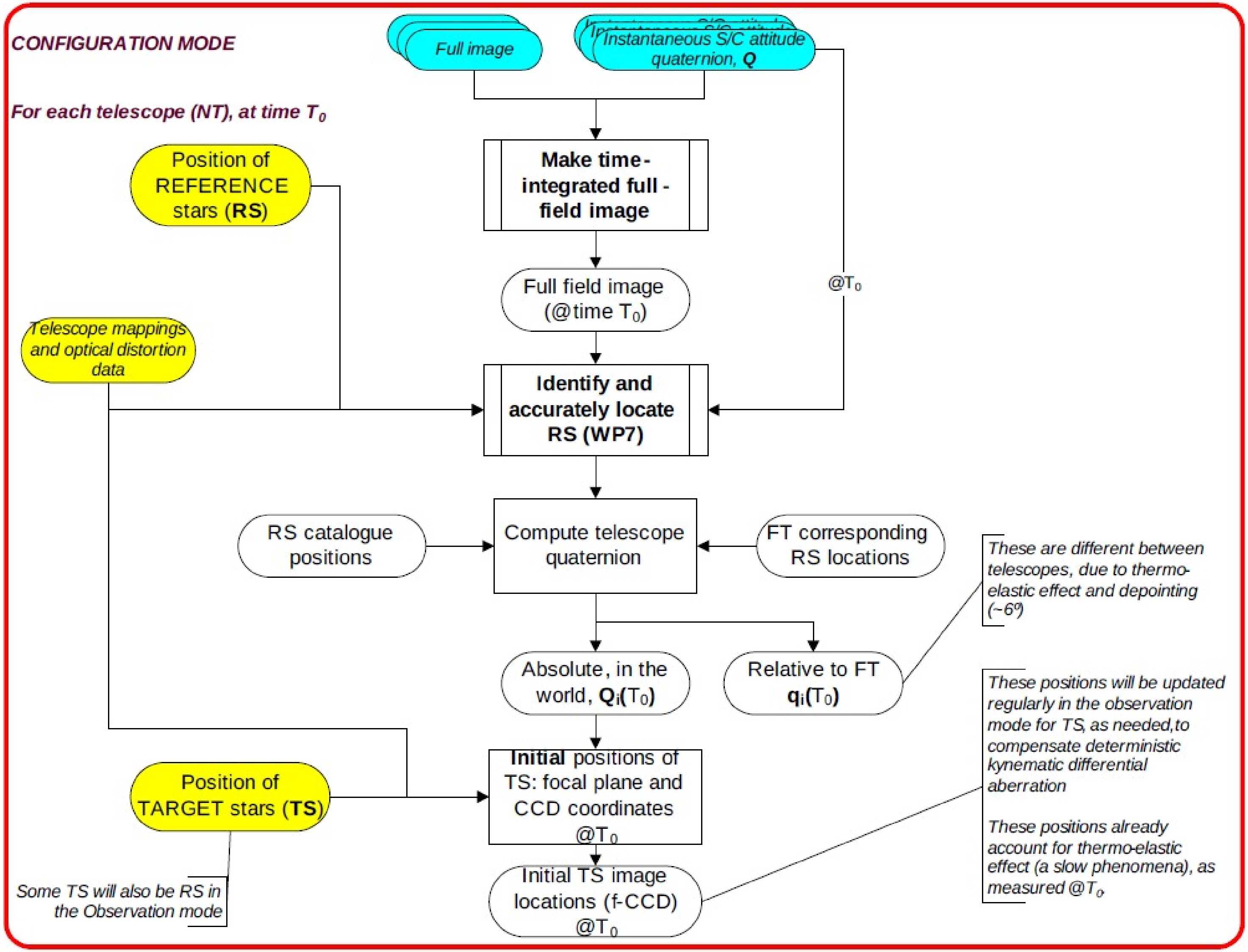
- The sky background level can then be estimated at any position, then for any target



Credit: R. Drummond (Phd Thesis)

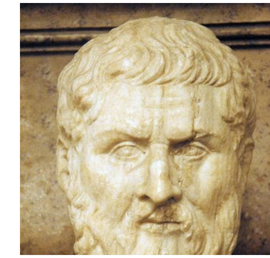
Calibration of the telescope line of sight and initial position of the target

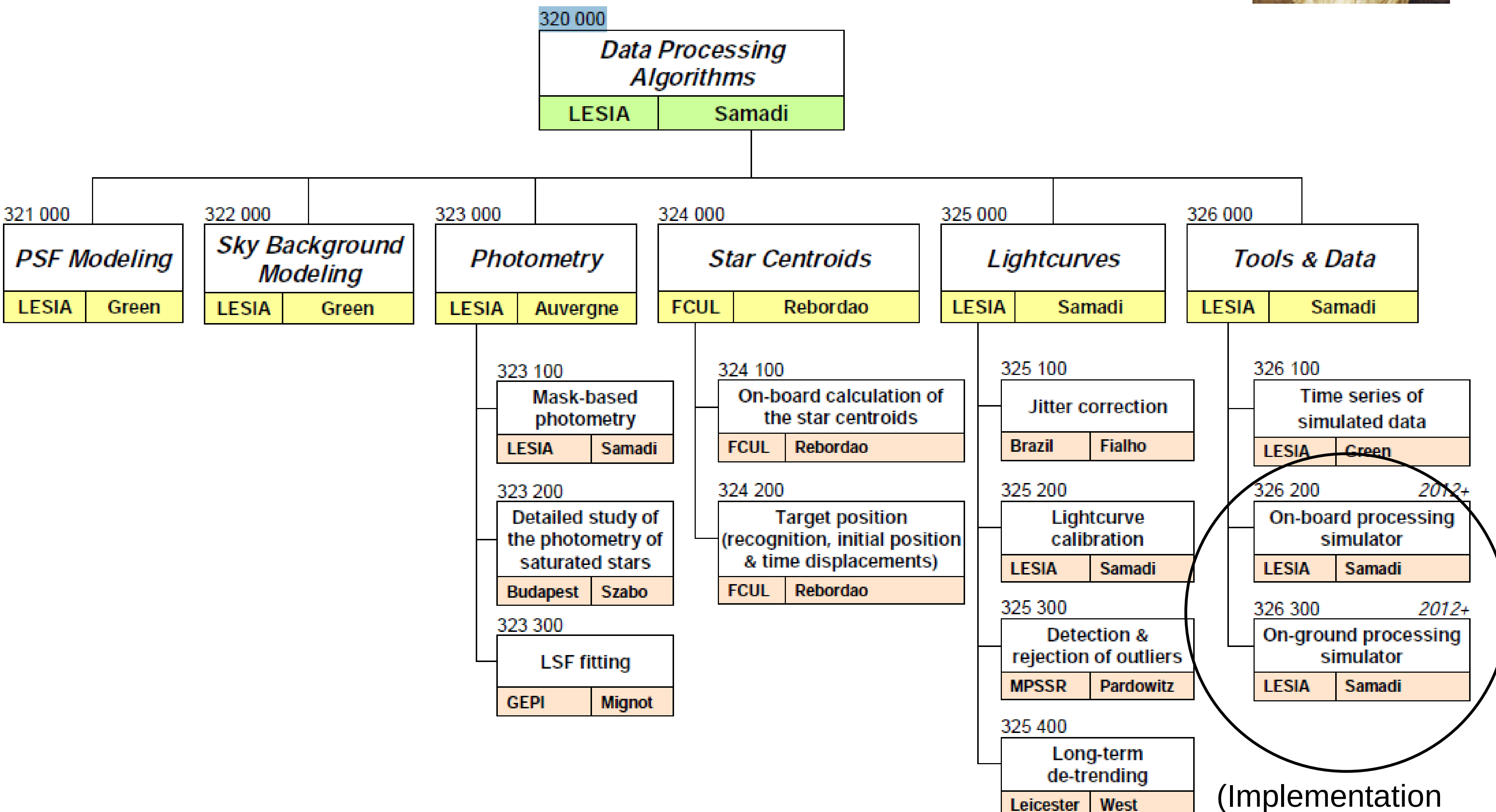




Credit:
J. Rebordao

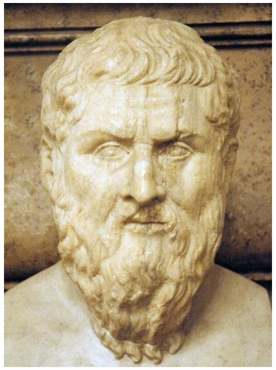
The DPA – WG (WP 32X XXX)





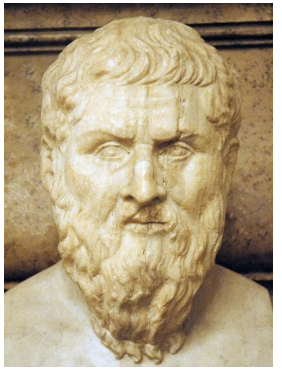
(Implementation phase)

Overall objectives of the DPA – WG during the definition phase



- To **study and define** all the algorithms to be implemented (board+ground)
  - ➔ *Priority to the on-board processing*
  - ➔ *Development of prototypical codes*
- To **define the share** between the **board** and the **ground**
- To **perform a global assessment** of the expected performance

Organization and planning



- Phase A: *until May 2011*
  - Specification and development of the *on-board* processing (priority to the Observation mode) as well as the main components of the on-ground processing (e.g. jitter correction)
  - Preliminary assessment study

- Phase B1: *from May to December 2011*
  - Specification and development of the *on-ground* processing
  - Continue the specification and development of the *on-board* processing (Configuration mode)
  - Global assessment study
  - Specification of the on-board processing simulator