Post-processing for AO-corrected images

Inverse Problems in Imaging

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Summer school - Lake Como

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Summary

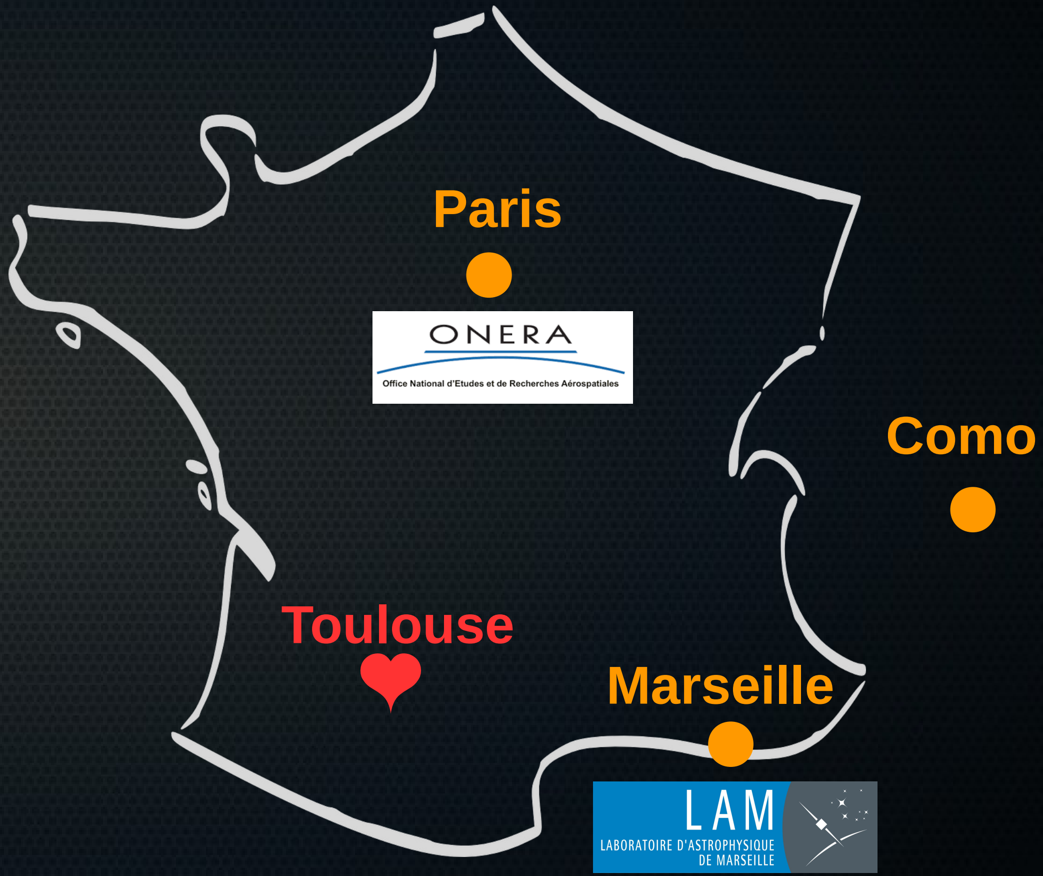
I. Imaging with adaptive optics in astronomy

II. Theory on deconvolution and myopic deconvolution

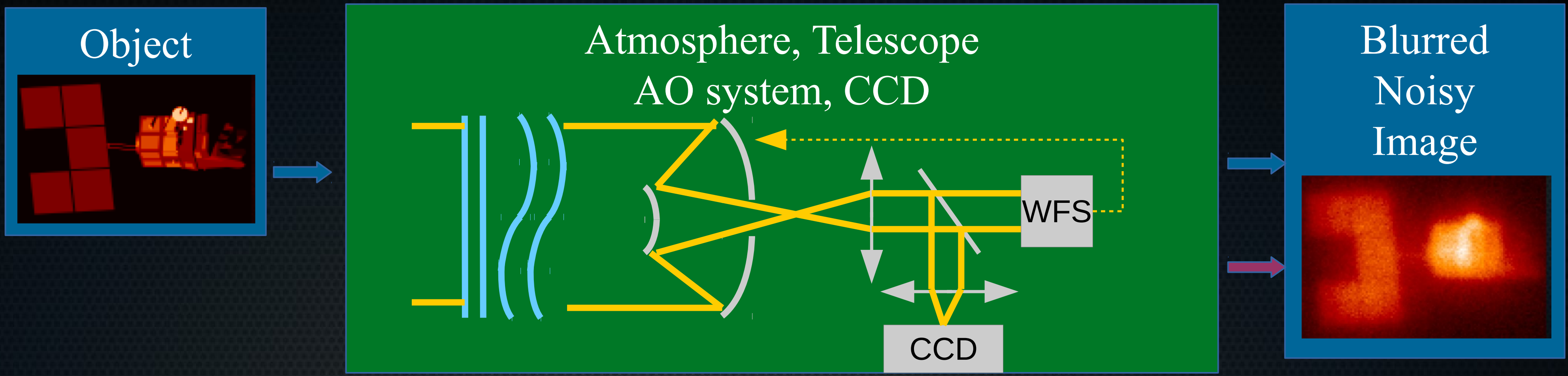
III. PSF parametrization

IV. Tests on VLT SPHERE and MUSE data

V. Future developments



Observation with Adaptive Optics



Context

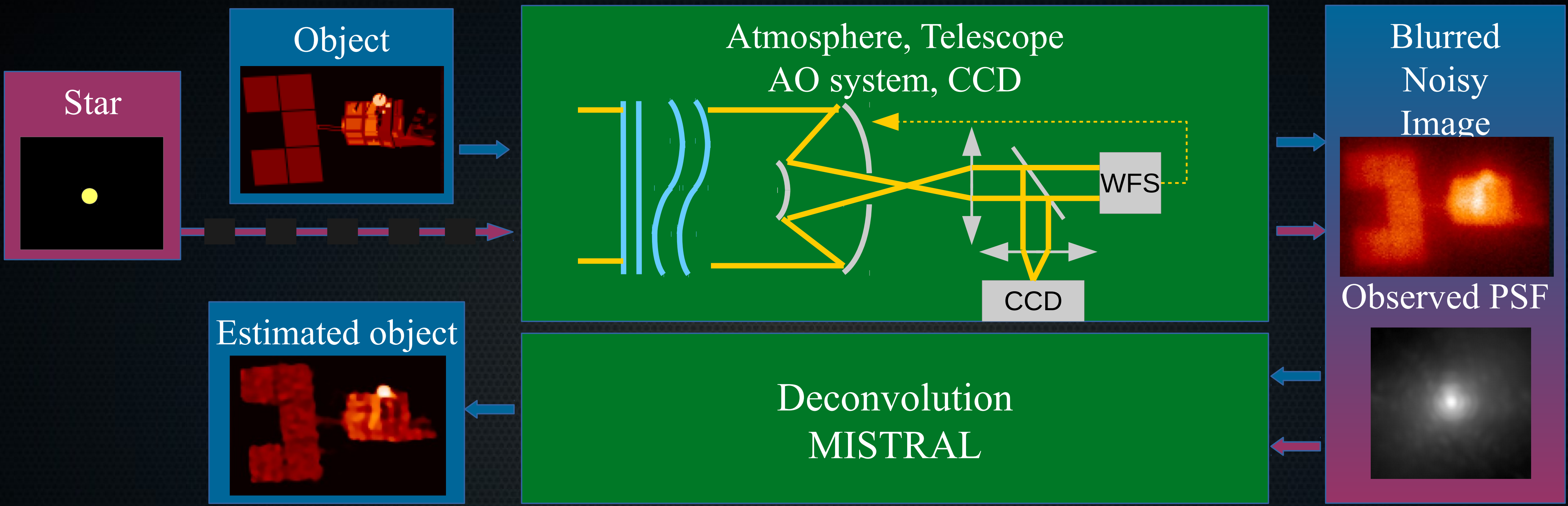
- Observation of satellites and asteroids
- Adaptive Optics (AO) partially corrects the atmospheric turbulence
- AO greatly improves imaging performances

Issues

- Residual turbulence with AO still produces “blurring“
- Photon and detector read-out noise
- Better images required (noiseless, sharp edges, visible structures)

➡ **Post-processing required to further improve image quality**

Deconvolution



→ Noise statistics
→ A priori on object

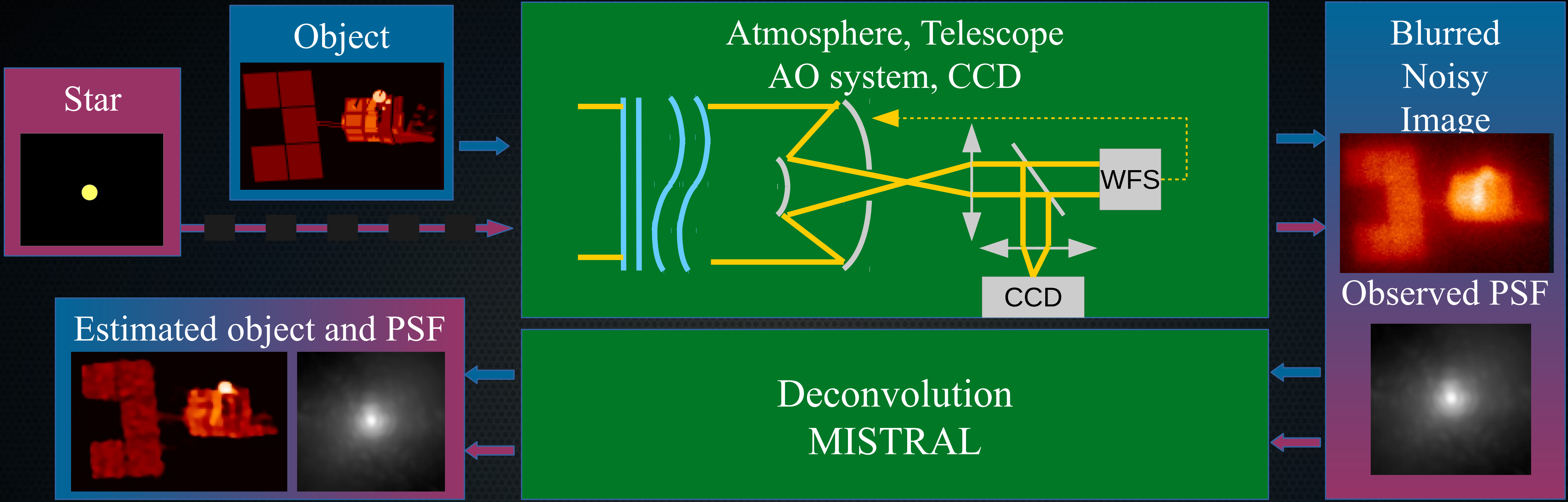
Criterion to minimize

$$J(Obj) = \frac{1}{2}\left\|\frac{Im - Obj \star PSF}{\sigma}\right\|^2 + \mu \cdot \Phi\left(\frac{\nabla Obj}{\delta}\right)$$

Data fidelity — A priori

- Observed PSF may significantly differ from the real system PSF
- Errors on estimated object

Myopic deconvolution



→ Noise statistics
→ A priori on object
→ PSD on the PSF

Criterion to minimize

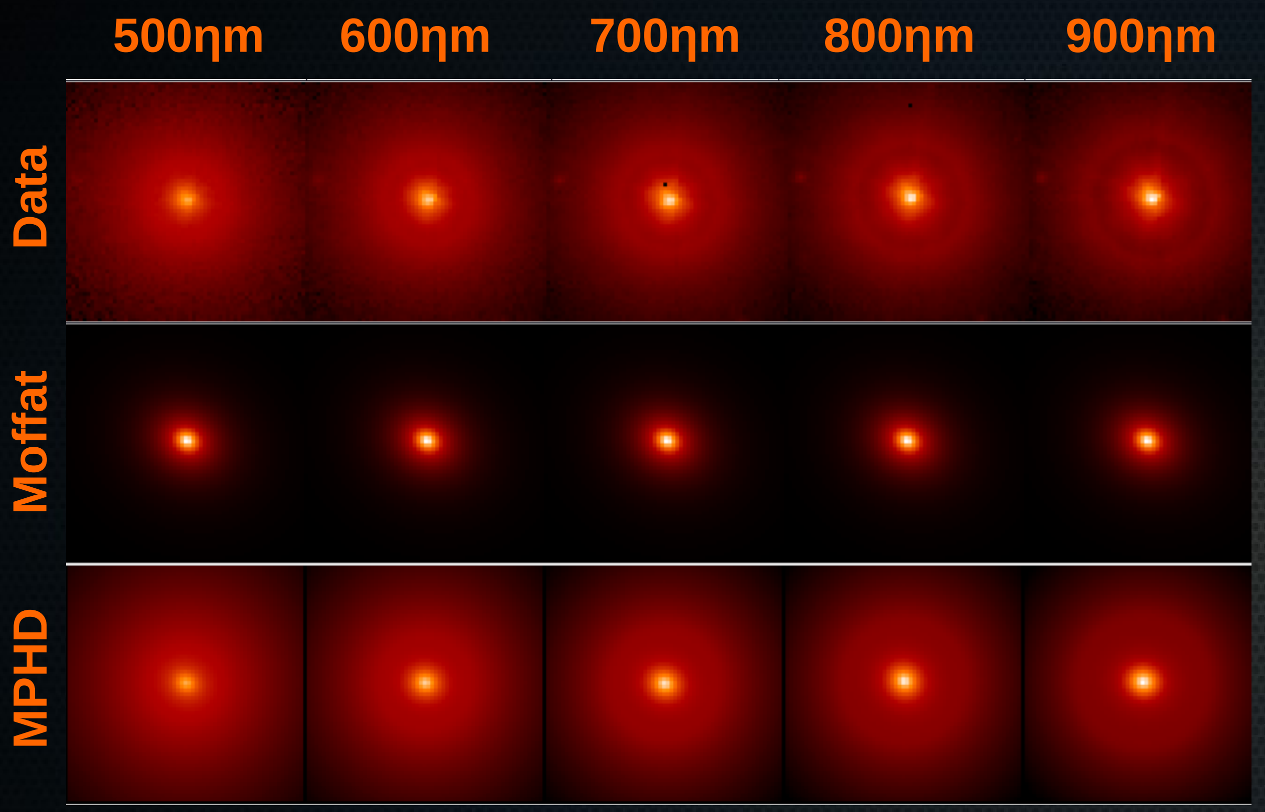
$$J(Obj, PSF) = \frac{1}{2}\left\| \frac{Im - Obj \star PSF}{\sigma} \right\|^2 + \mu \cdot \Phi\left(\frac{\nabla Obj}{\delta}\right) + \mu_{FTO} \sum_f \frac{|FTO(f) - \overline{FTO}(f)|^2}{2 \cdot DSP(f)}$$

Data fidelity — **A priori** — **Myopic term**

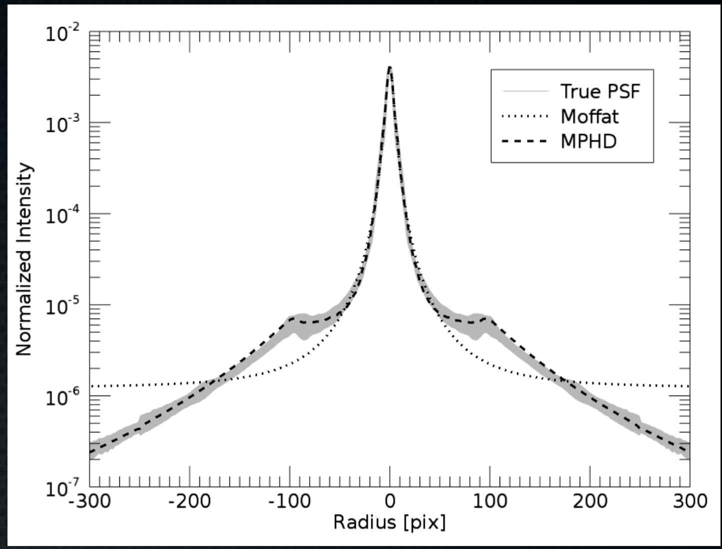
- **Better results than fixed-PSF**
- **High number of unknowns**

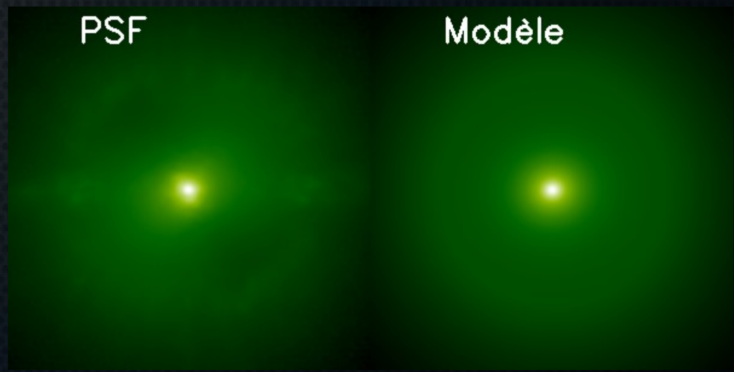
Solution: parametrize the PSF

VLT / MUSE



VLT / SPHERE





$$PSF(r) = \{M_{Pic}(r)|_{r<R_C} + M_{Halo}(r)|_{r>R_C} + A_D \cdot \delta(r)\} \star P(r)$$

- M_{Pic} → **AO correction quality**
- M_{Halo} → **Turbulence Kolmogorov**
- A_D → **Strehl**
- $P(r)$ → **Diffraction & static artifacts**

MPHD PSF modelling

State of the art

PSF from star

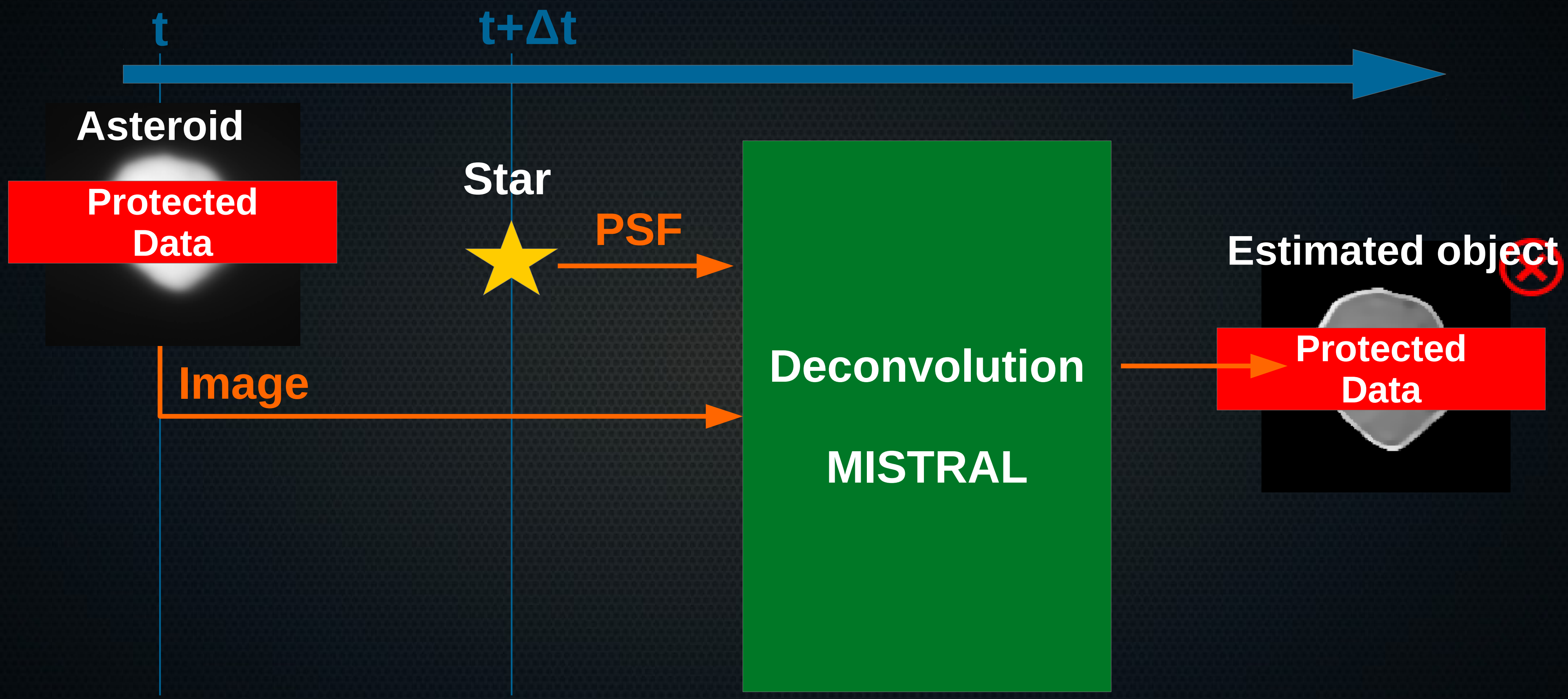
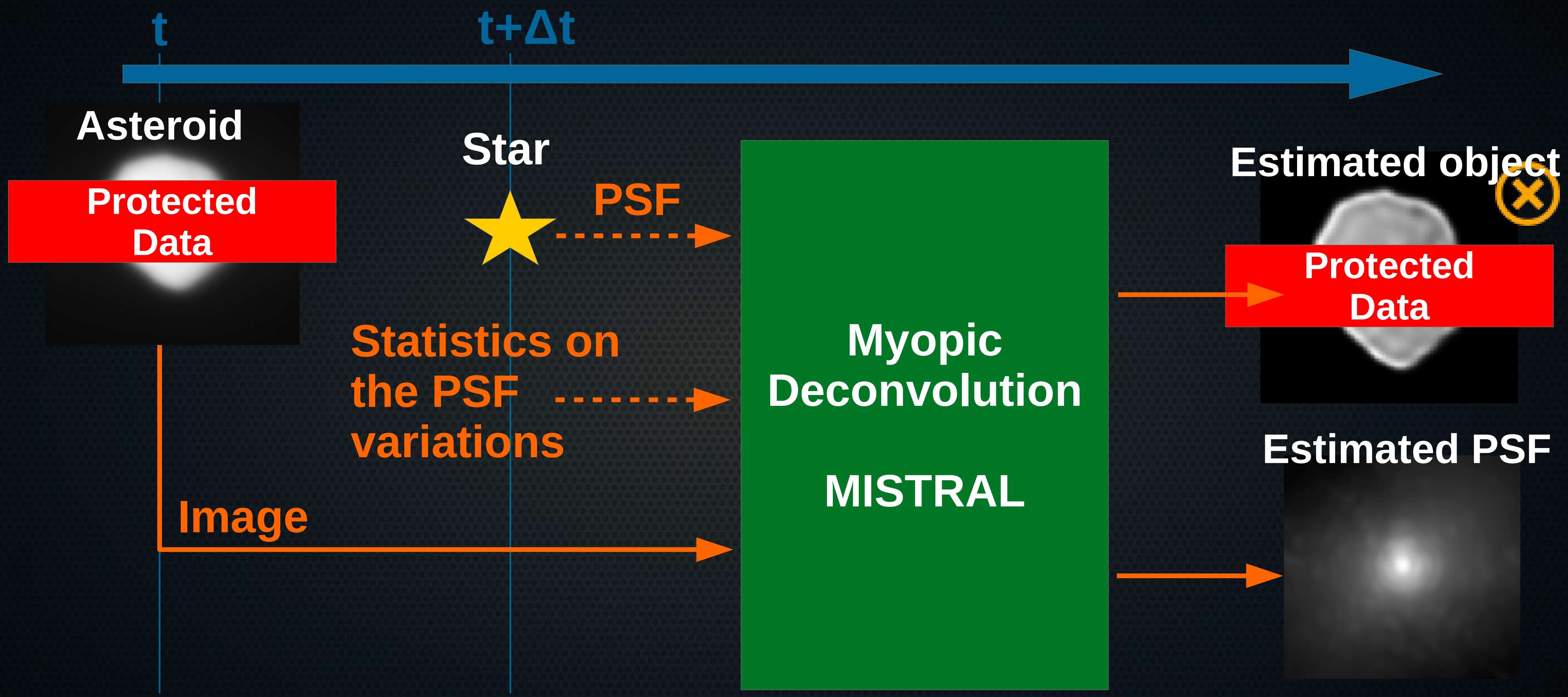


Image VLT - SPHERE
Credit: P. Vernazza (LAM)

→**Deconvolutional issues:**
mismatch true PSF (linked to object) / observed PSF (star)

State of the art

Myopic deconvolution

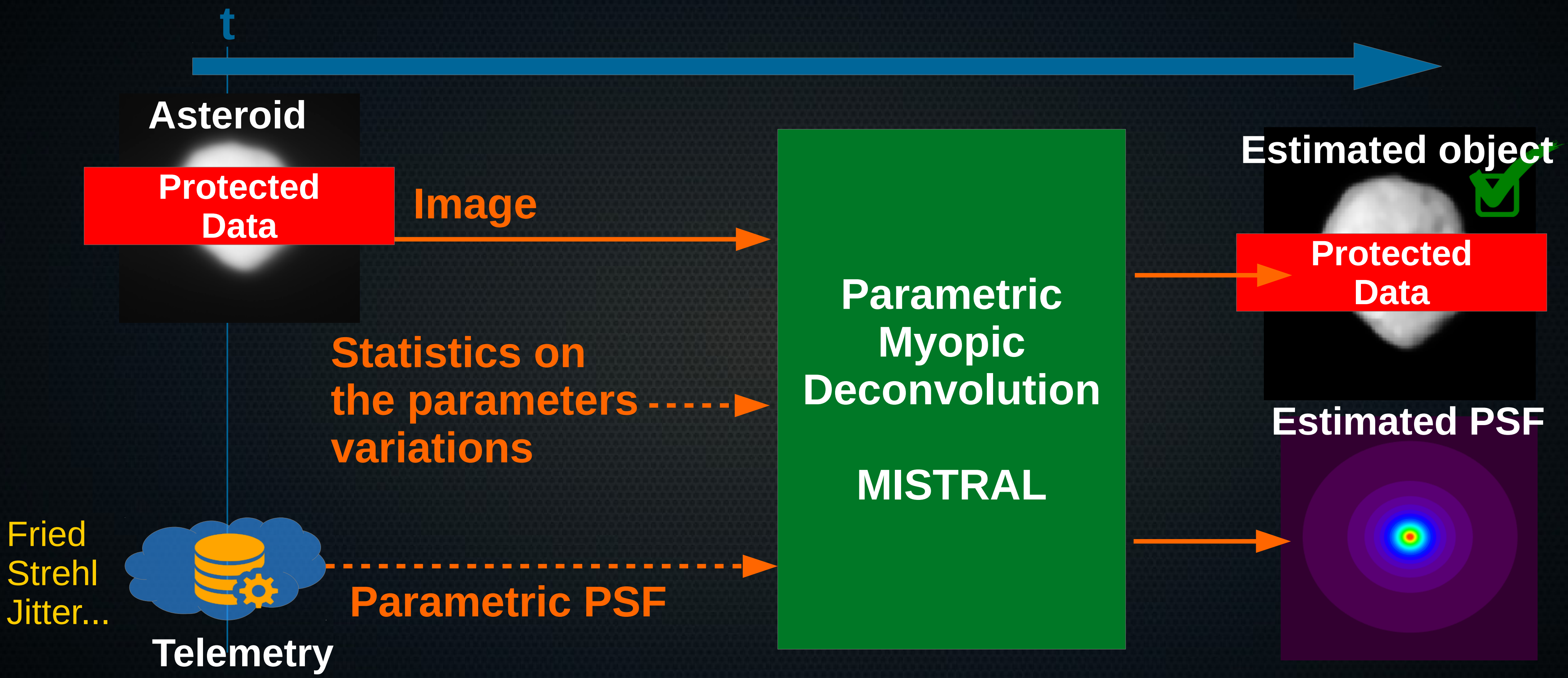


→ Deconvolutional issues

→ Low statistical contrast: data (N pixels) << unknown (2 x N)

Goals of the thesis

Parametric myopic deconvolution

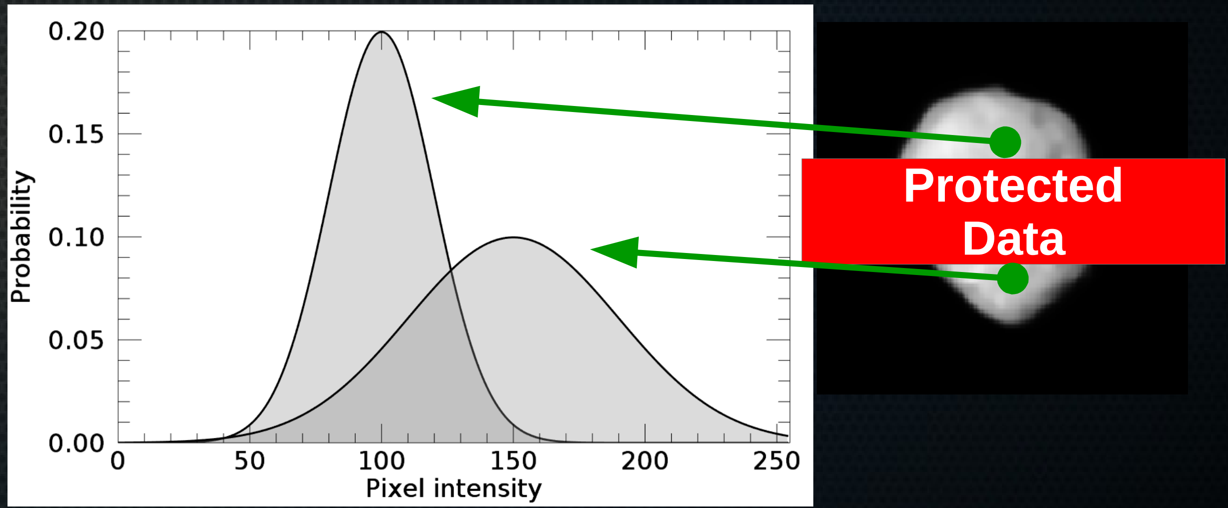


- → Suitable PSF for deconvolution
- → Physical meaning of the PSF's parameters
- → High statistical contrast: data (N pixels) ≈ unknown (N+10)
- → No need for on-sky PSF observation: astronomical & military usage

Work objectives

- Evaluate improvements of deconvolution using parametric PSF
- Stability toward parameters
- Myopic deconvolution
- Apply method on data
  - Simulations
  - VLT (asteroids)
  - ONERA (satellites)

- Error maps on estimated objects



Toulouse