Spectrograph simulation and data processing

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Motivation

- The SNAP spectrometer is designed for the SN program; requires high precision measurements :

  Spectral features determination;
  Contribution to the calibration of the imager : transfer standard stars

- Systematic errors should be controlled at the % level :
  redshift (wavelength) dependent effects must be eliminated

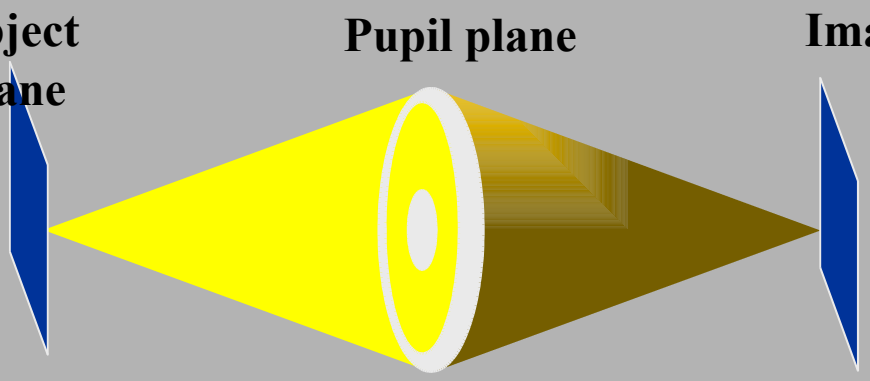
Motivation

- Provee the feasibility of the mission and optimize the instrument
- Develop and test the processing algorithms
- Need a complete simulation of the mission and data analysis
- Evaluate and compare the competitors : Destiny, Jedi ...

The simulation will be validated by comparison with the demonsrator

The data analysis software will be used to process the demonstrator data

General principle of the simulation



$A^0_{obj}(x, y, \lambda)$

$A_P = Ft(A^0_{obj})$

$I = A^*_P A_P$

$\varepsilon_1 = I_{out} / I_{in}$

$A_I = Ft(A_P e^{2\pi . Ze(x,y,\lambda)}) \otimes F_{Pupil}$

$I = A^*_I A_I$

$\varepsilon_2 = I_{out} / I_{in}$

x, y

$x_i, y_i = f_{Zee\max}(x, y, \lambda)$

- **Diffraction: Fourier optic**
- **Aberration: Zernike (Zemax)**
- **Distortion: Stray light on a discrete grid (Zemax)**

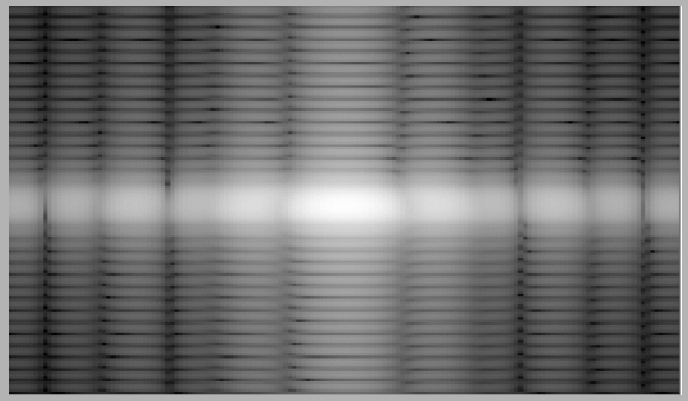
Psf parametrization

- **Library of PSF's difficult to manage**
  200k PSF's to describe the full spectrograph on adequate grid

- **Use shapelets decomposition (Hermite polynoms)**
  - **Some coefficients have geometrical meaning**
    Comparison between data and simulation
  - **Easy convolution:**
    galaxy*psf $\rightarrow$ focal plane image
  - **Analytical expression of shapelets integral. Easy and fast integration on pixel detector**
  - **Limit shapelets re-composition to lower order**
    trade speed versus precision (fast simulation)

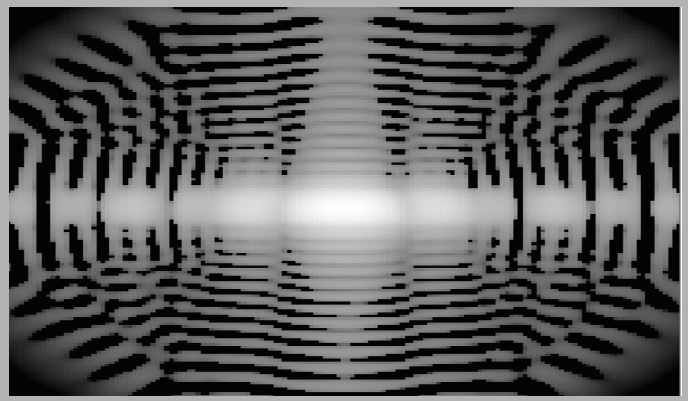
Shapelets

Original



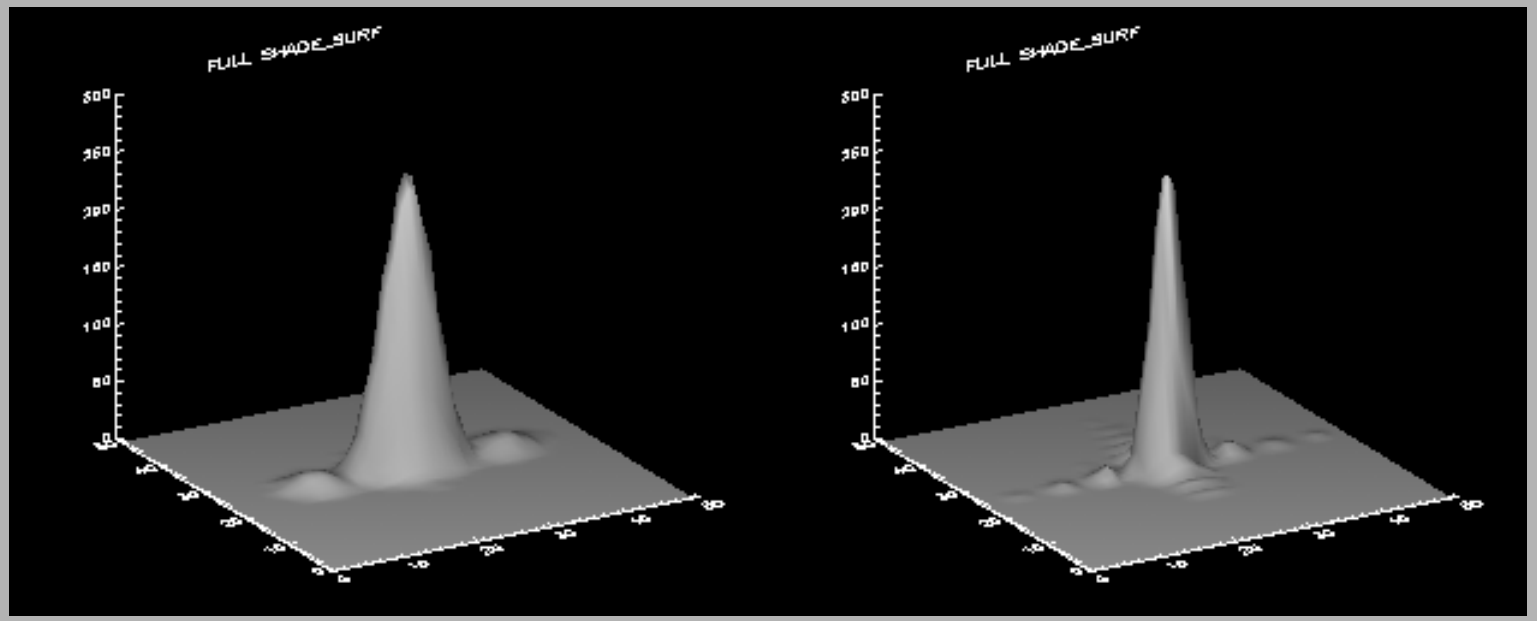
40^{th} order decomposition

Reconstructed



Log scale, Differences of order 10^{-4}

Spectrograph: R&D Manpower



On the detector

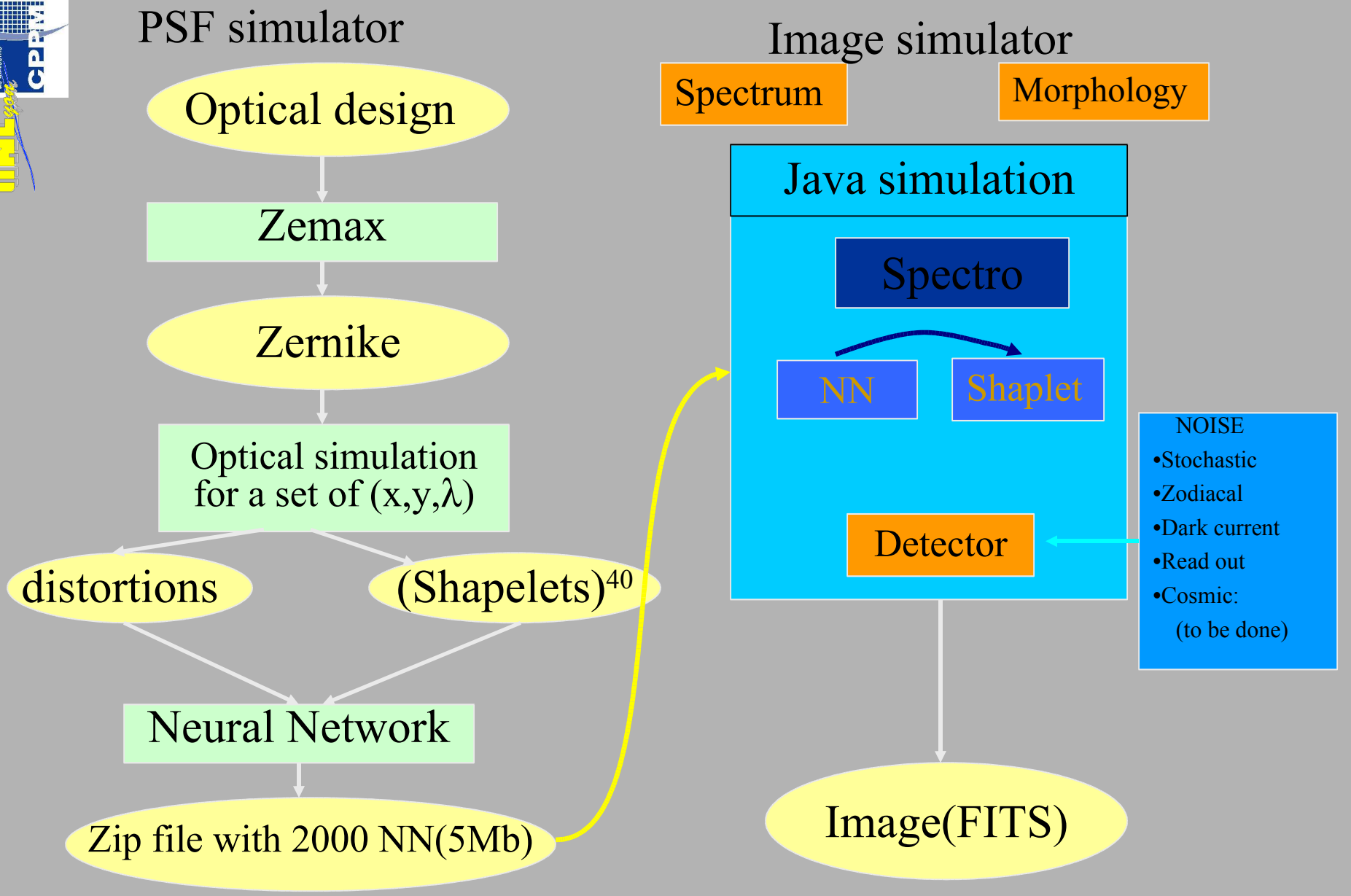
Normal

No telescope

PSF width mainly due to the telescope

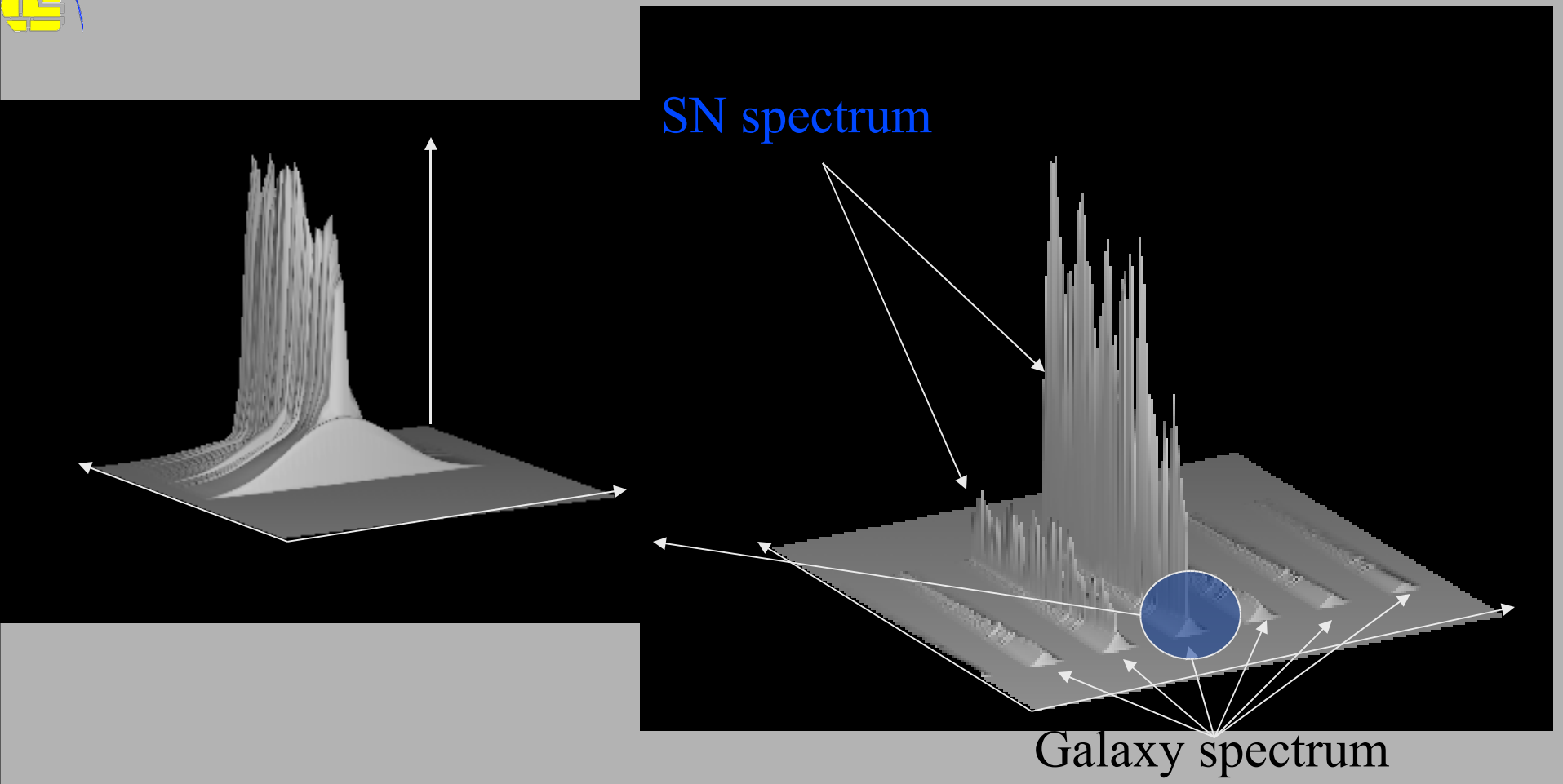
Airy function truncated by slice.

Simulation dataflow

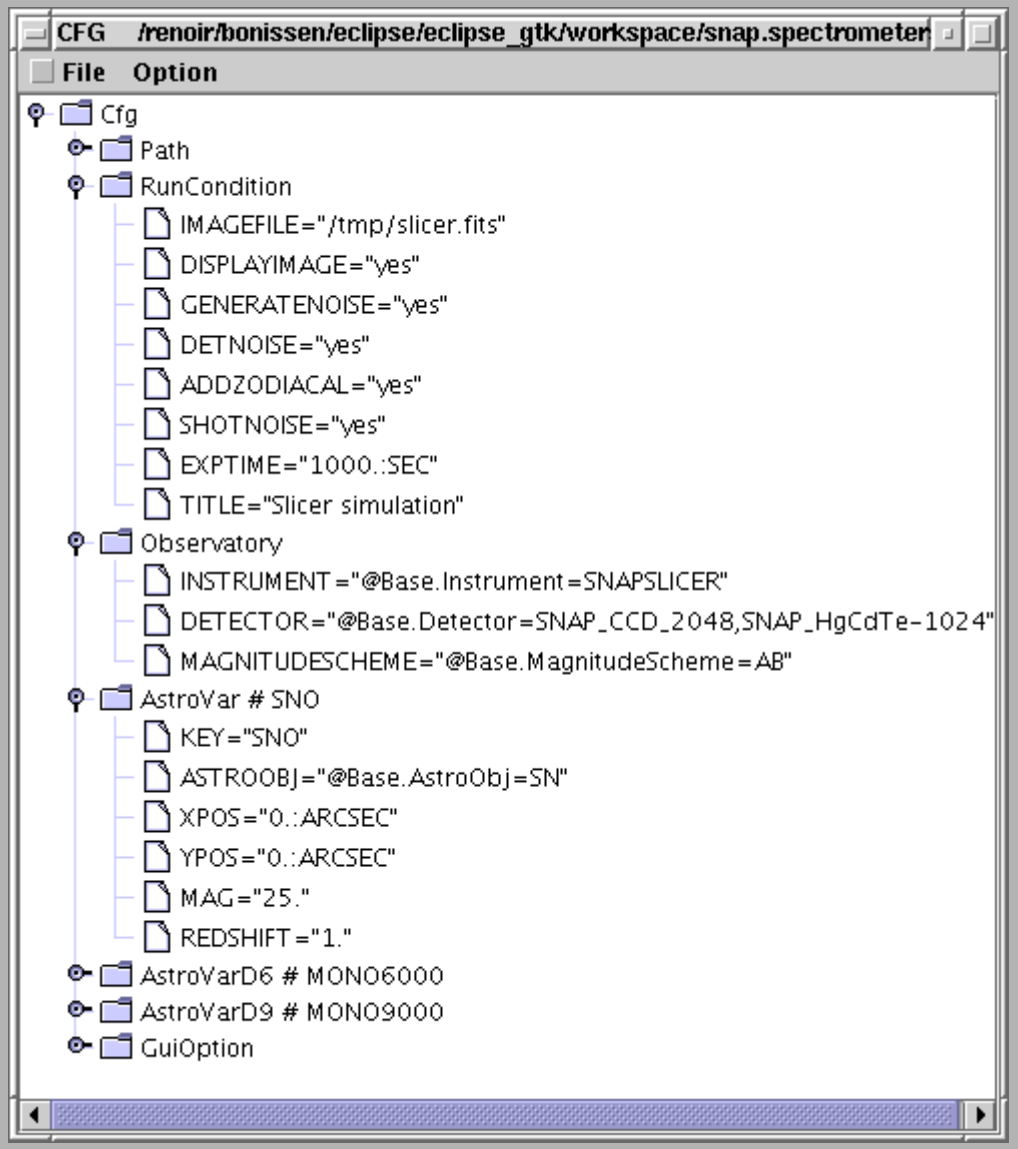


SN and Galaxy (no noise)

Same magnitude SN and galaxy



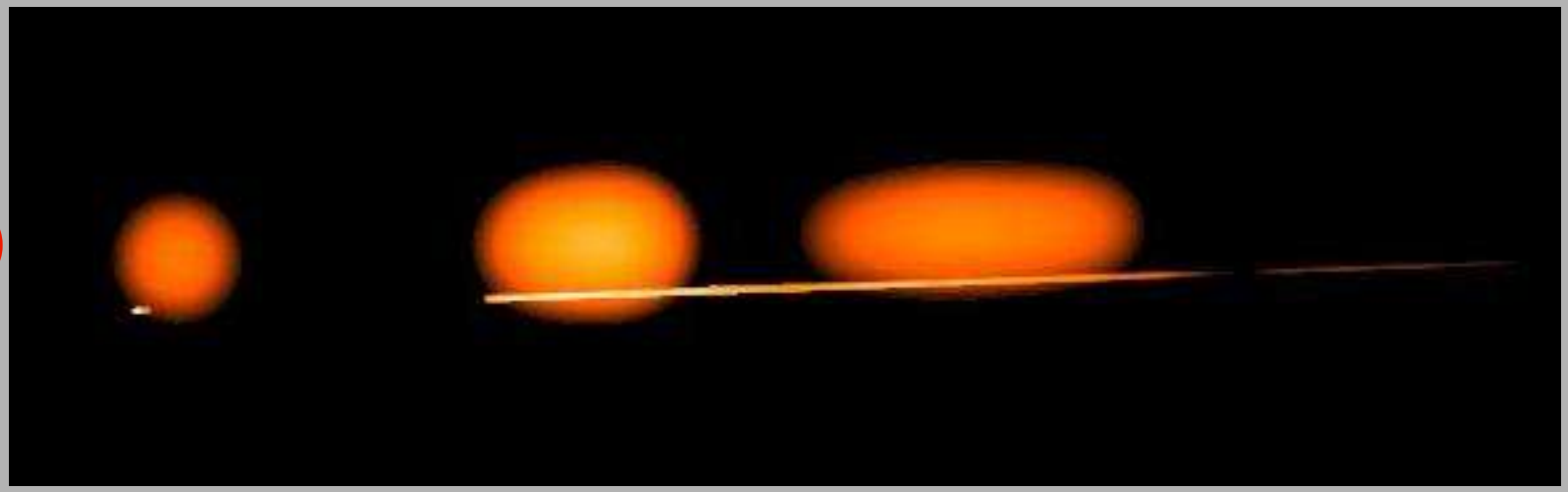
Configuration GUI



Fields can be edited

Slicer simulation adapted to slitless spectrometer

SLIM(ACS)



GRISiM

Spectrum extraction software

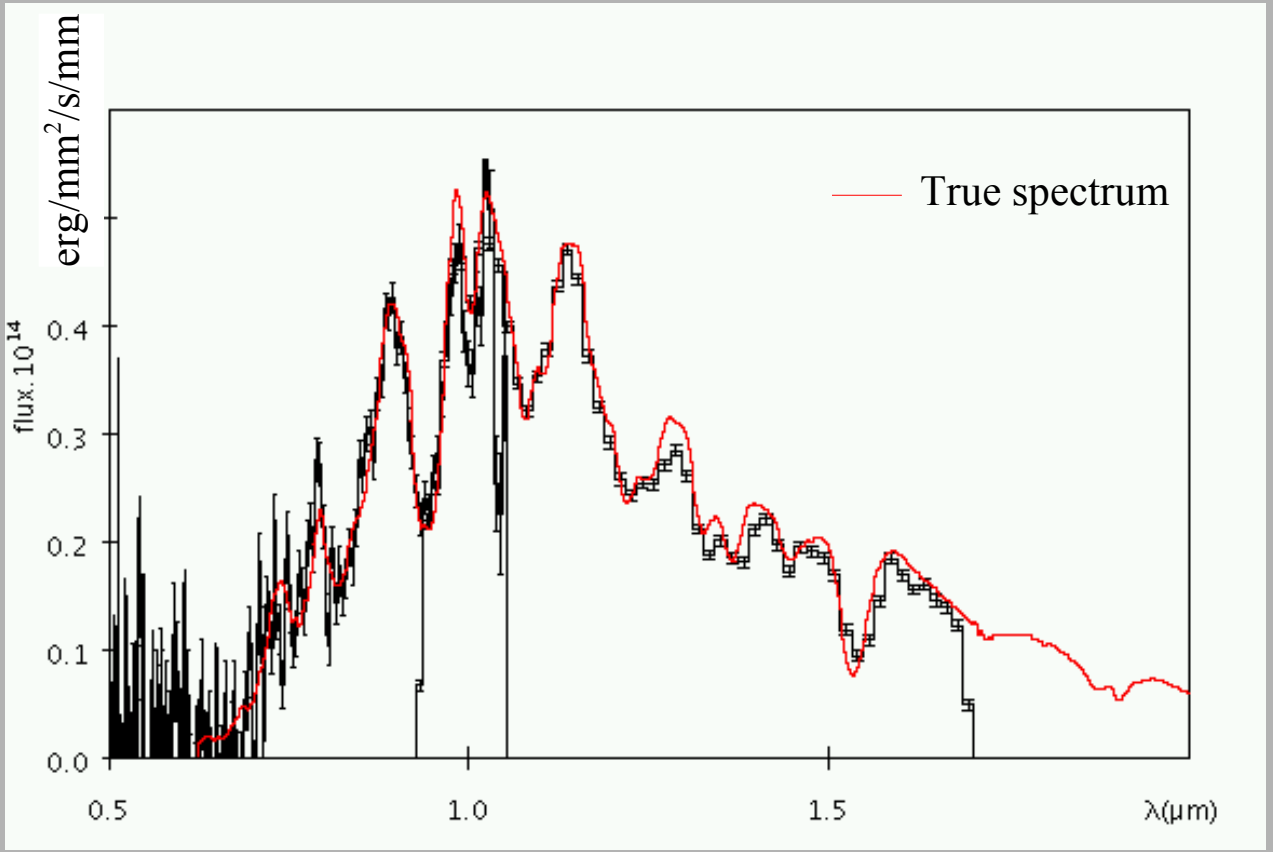
- Aperture photometry :
  Easy to develop,
  robust,
  Needs little knowledge of the instrument properties

- Psf photometry
  More precise
  Optimal for S/N ratio
  Requires a precise knowledge of psf and distorsions (Syst. Errors)

- So far : Only aperture photometry

- Procedure :
  1-Project on spatial coordinates →SN position;
  2-Project on spectral coordinate →spectrum, binning = pixel size

Spectrum extraction SN no galaxy



z =1 .5

Demonstrator context

- Validate optical simulation : compare simulated and measured PSFs;

- Simulate the calibration setup; analyze data
  →Demonstrate ability to perform calibration:
    Wavelength (0.1 pixel);
    Spatial distorsions :
      effect on spectrum extraction (Required < 1%)
      SN position and how it affects galaxy subtraction

- Validate the spectrum extraction software on simulated realistic spectra

Make sure that we understand the instrument

To do

- Spectrum extraction with underlying galaxy;
- Simulate telescope imperfections (jitter, polishing ...)
- Validate noise models, exposure times;
- Study the effect of detector characteristics;

- Extraction of spectral features, evaluate performances

- Simulate the new spectrometer design

- Simulate calibration system and procedure

- Compare simulation with prototype
  psf size and shape, resolutions

Summary

A simulator has been realized

Spectrum extraction : first version

Both will be validated on demonstrator data

And will be used to prove that expected performance can be achieved

First application to physics studies : NASA AO 2006