The NIRSpec instrument performance simulator (IPS) software

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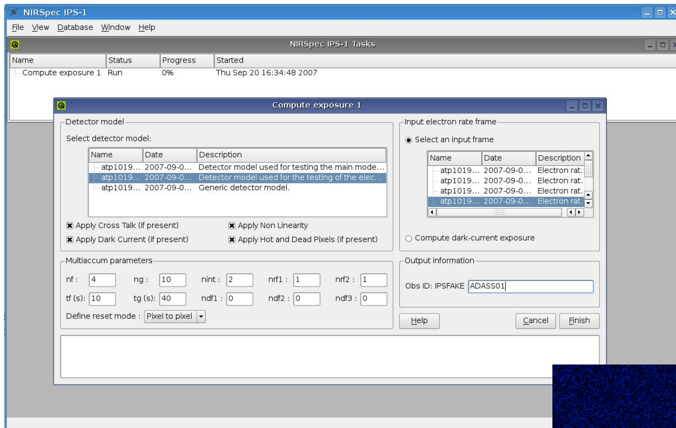
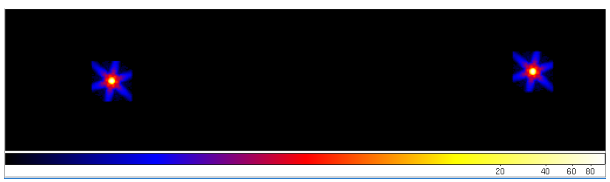
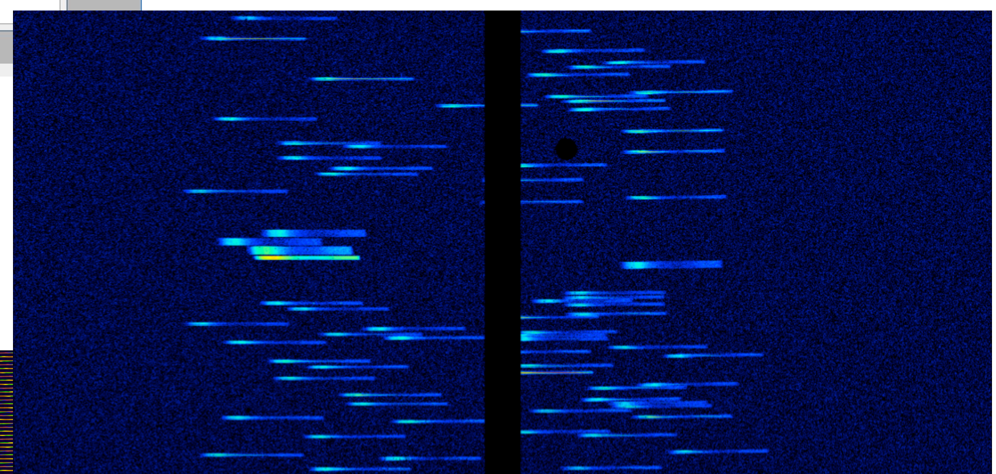
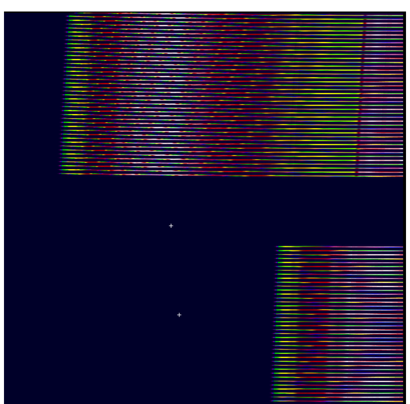
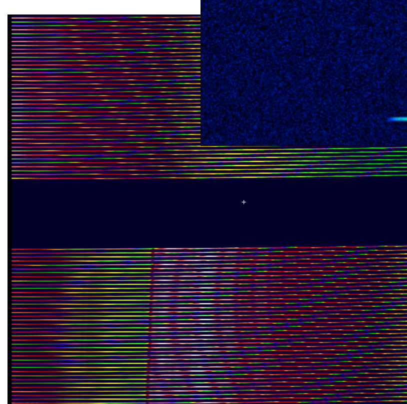


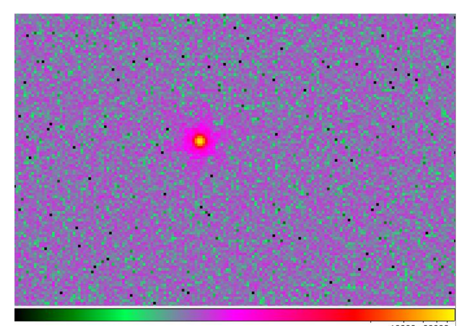
Based on a SPIE presentation by L. Piquéras et al. (2008)











Why developing an IPS?

- The IPS is used to generate realistic on-ground or in-orbit synthetic exposures.
- The end-product for the simulation of an exposure is a set of 2 FITS files in NIRSpec raw-data format.
- It is used to provide:
  - Inputs to performance-related trade-offs and to the early verification of the instrument performances
  - Inputs and support for/to the preparation and execution of the verification and calibration campaigns
  - Inputs and support for/to the development of the data reduction software (pipeline, pipeline algorithms)
  - Simulated scientific exposure to support the preparation of the NIRSpec observation strategies / operation.

Models, models…

- Modelling exposures of NIRSpec in its 4 modes:
  - multi-object spectroscopy (MOS)
  - slit spectroscopy (SLIT)
  - integral field spectroscopy (IFU)
  - Imaging (IMA)
- Modelling the performances of the cryogenic test setup:
  - using the test equipment (telescope simulator)
  - using the internal NIRSpec calibration assembly
- Modeling the in-orbit performances of JWST/NIRSpec
  - for the observation of various astronomical scenes

Numerous challenges…

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- Several instruments in one…
    - Models for the MOS, IFU, SLIT and imaging modes…
- From **aberration-dominated** to **diffraction-limited** regimes (0.6 to 5.0 µm)
    - Going for Fourier optics modeling
- Going from the usual optical performance simulations to **exposure simulations**
    - Computation intensive, memory hungry software…
    - Make use of every object property that can simplify or speed up the computation…

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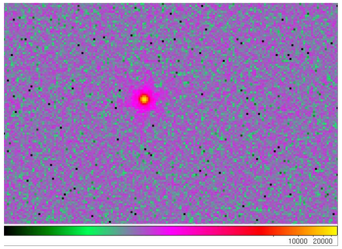
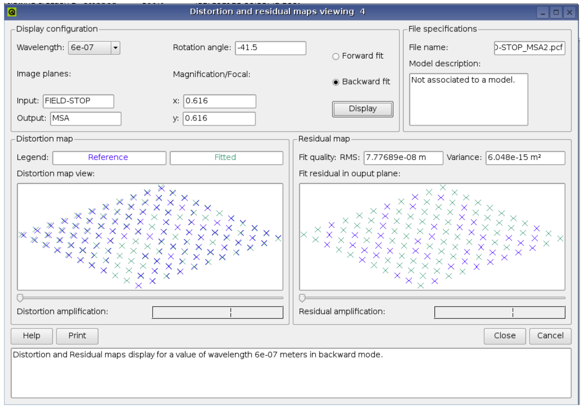
Numerous challenges...

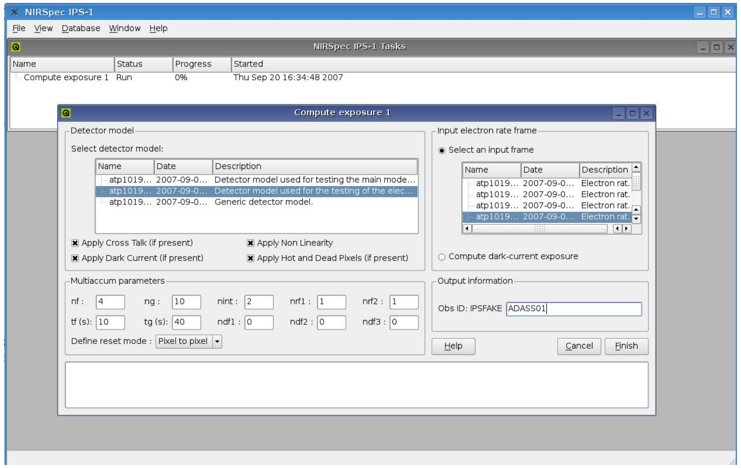
- Huge **number of input parameters**
  - Instrument, simulation and exposure parameters
- Need for a full **traceability** of the simulation inputs
  - Model and simulation database
- Additional development constraints
  - one or several user interfaces running simultaneously
  - MMI (GUI) for all IPS functions
  - (Industrial quality standards for development and documentation)

The main IPS software components

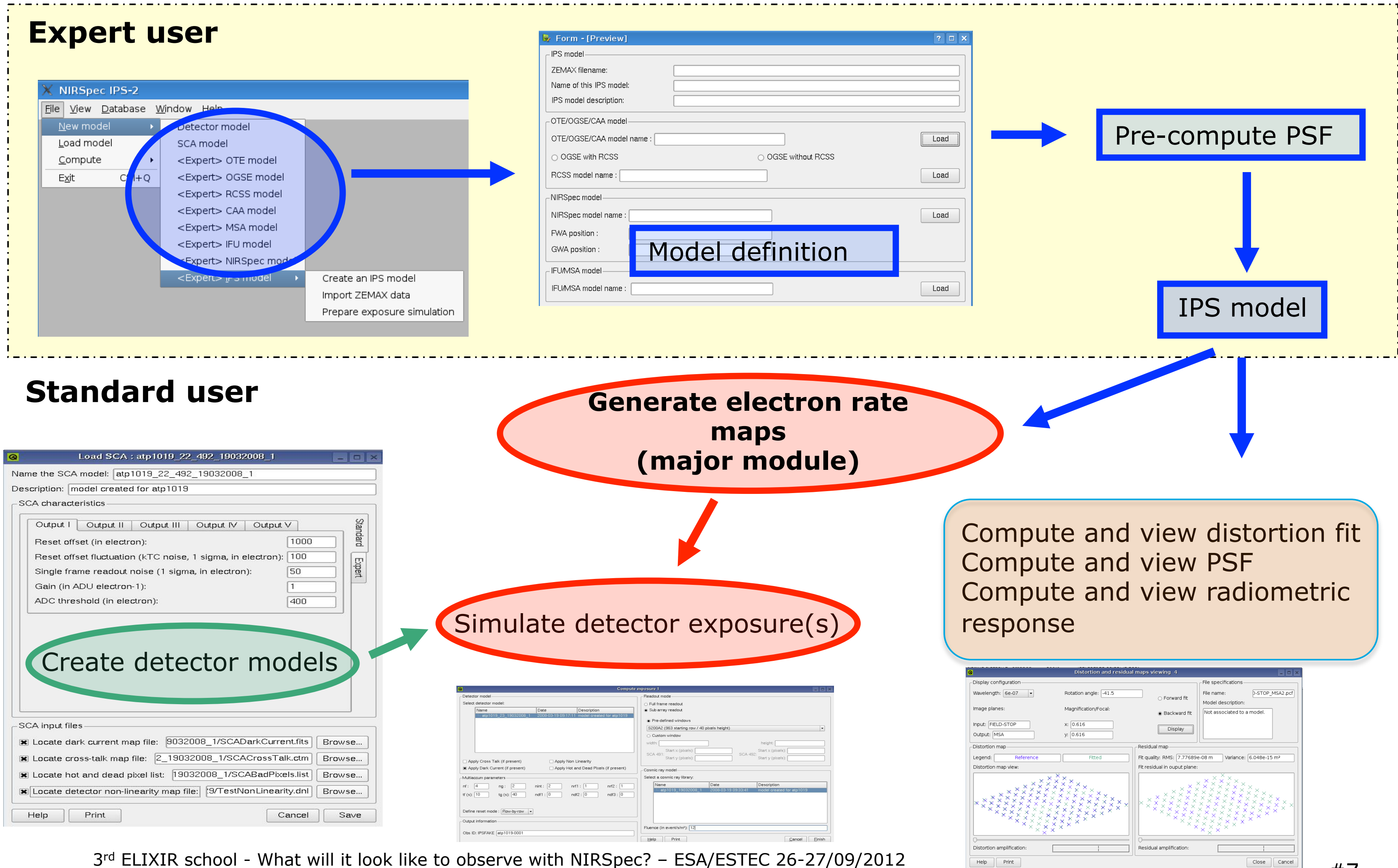
- 6 main software components:
  - a Fourier optics module
  - a coordinate transform computation and fitting software
  - a radiometric response / sensitivity computation tool
  - a PSF simulator
  - an exposure simulator
  - an instrument model database







The main IPS software components
Generic workflow



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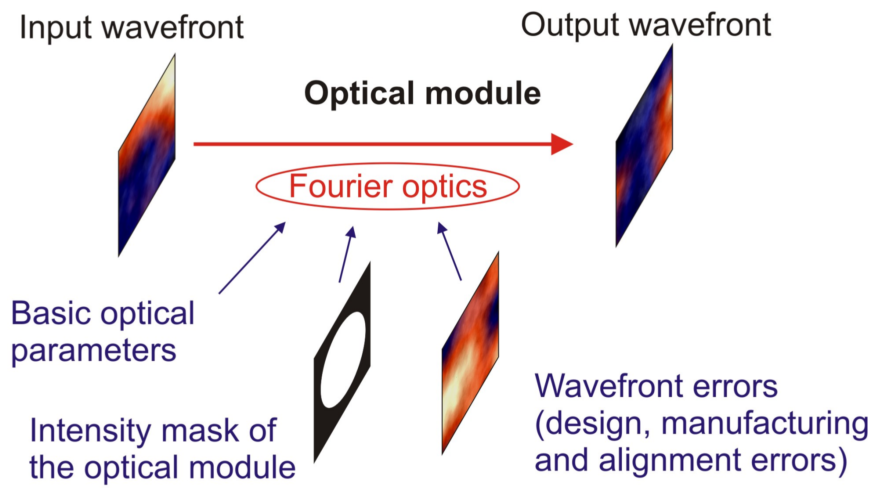
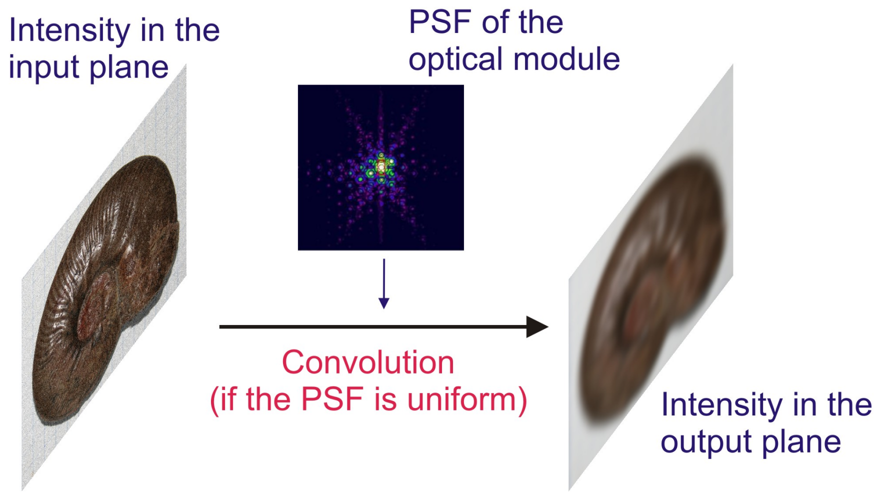
Simulating coherent and non-coherent sources

Coherent propagation



Non-coherent propagation



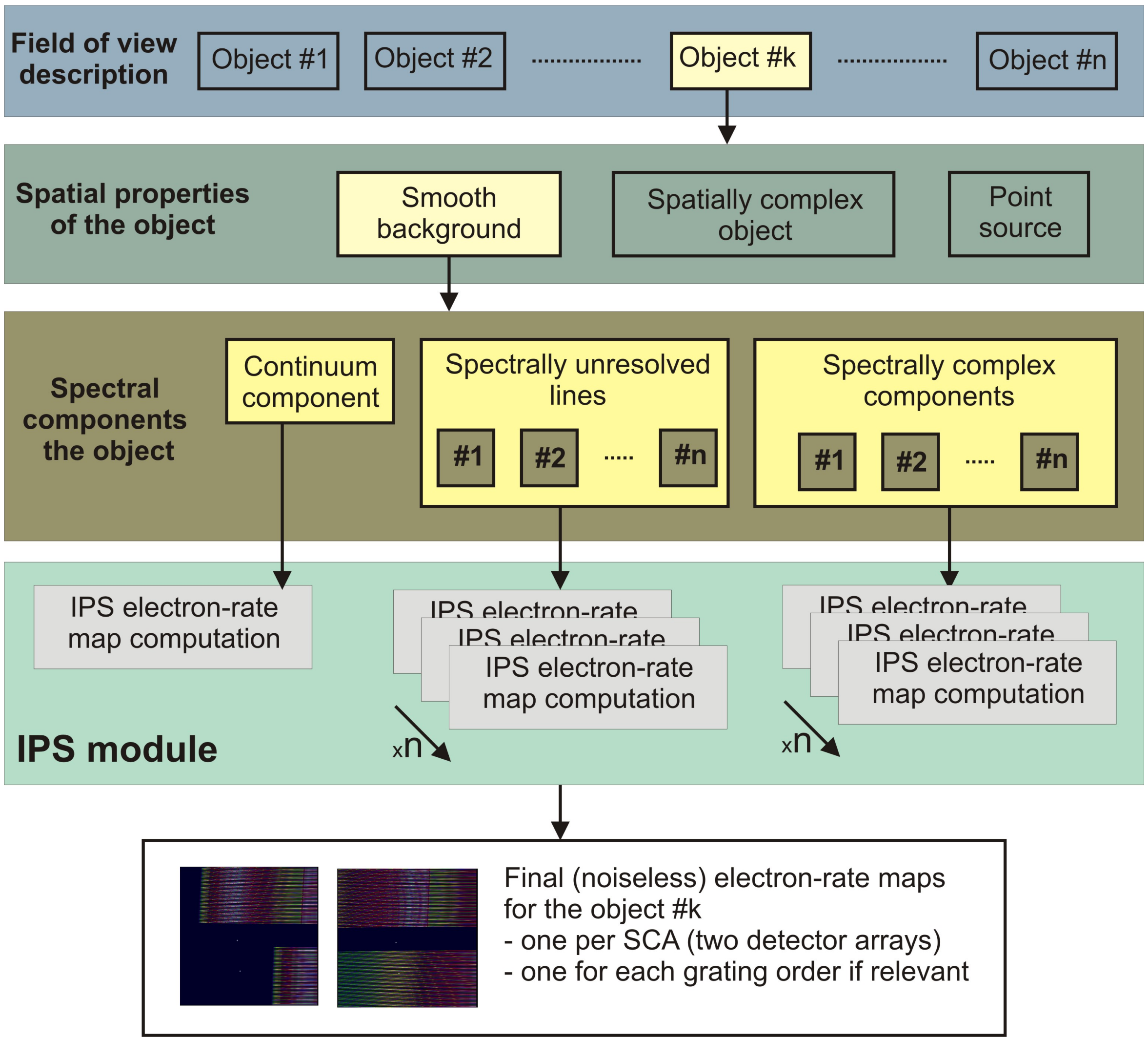
Coherent propagation

- Used for point sources
- Used for the computation of the light losses in the pupil plane (so-called diffraction losses)

Non-coherent propagation

- Other objects
- Must take into account the actual coordinate transform of the optical modules
- PSF non-uniformity is to be taken into account when necessary

Computing the (noiseless) electron rate map for a "scene"



A "scene" is made of a collection of objects

- 3 different "spatial" types

Each object contains a collection of spectral components

- 3 different "spectral" types

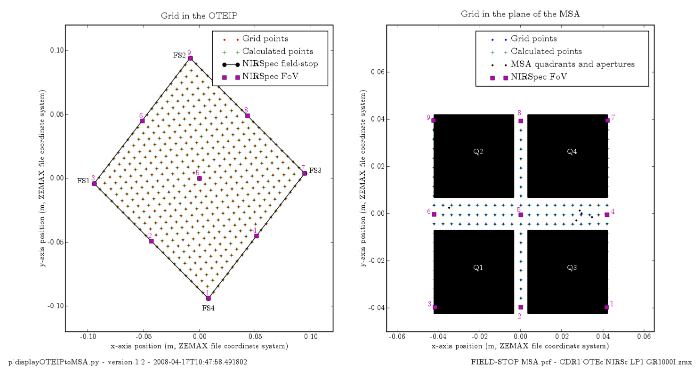
Generating "noiseless" electron rate maps

- Number of electrons per second for each detector pixel

Coordinate transforms from plane to plane

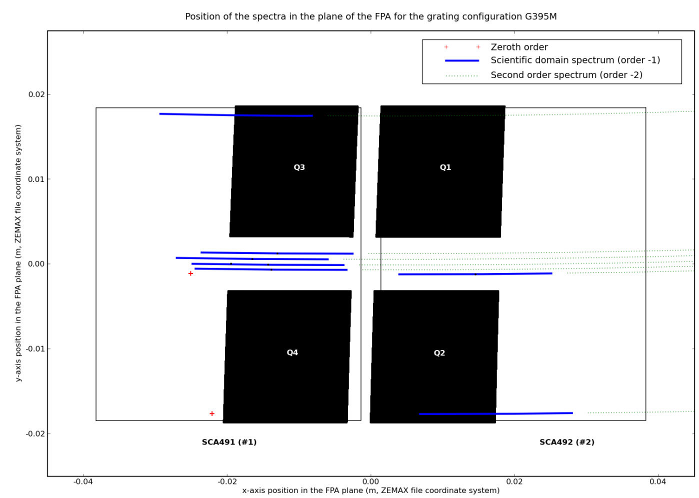
- Need to track the position of an object from the entrance of NIRSpec to the detector
- A dedicated formalism has been developed based on the combination of two transforms:
    - A transform corresponding to the equivalent "ideal" paraxial system
    - Fifth degree polynomial functions corresponding to the "distortion" of the actual system
- Includes a modeling of the dispersers
    - Mirror, gratings, prism…

Coordinate transforms from plane to plane



- From sky to the plane of the MSA
  - JWST telescope
  - NIRSpec fore-optics

- From the plane of the MSA to the detectors
  - Collimator and camera
  - Disperser
  - Micro-shutter and slit positions
  - Focal plane layout



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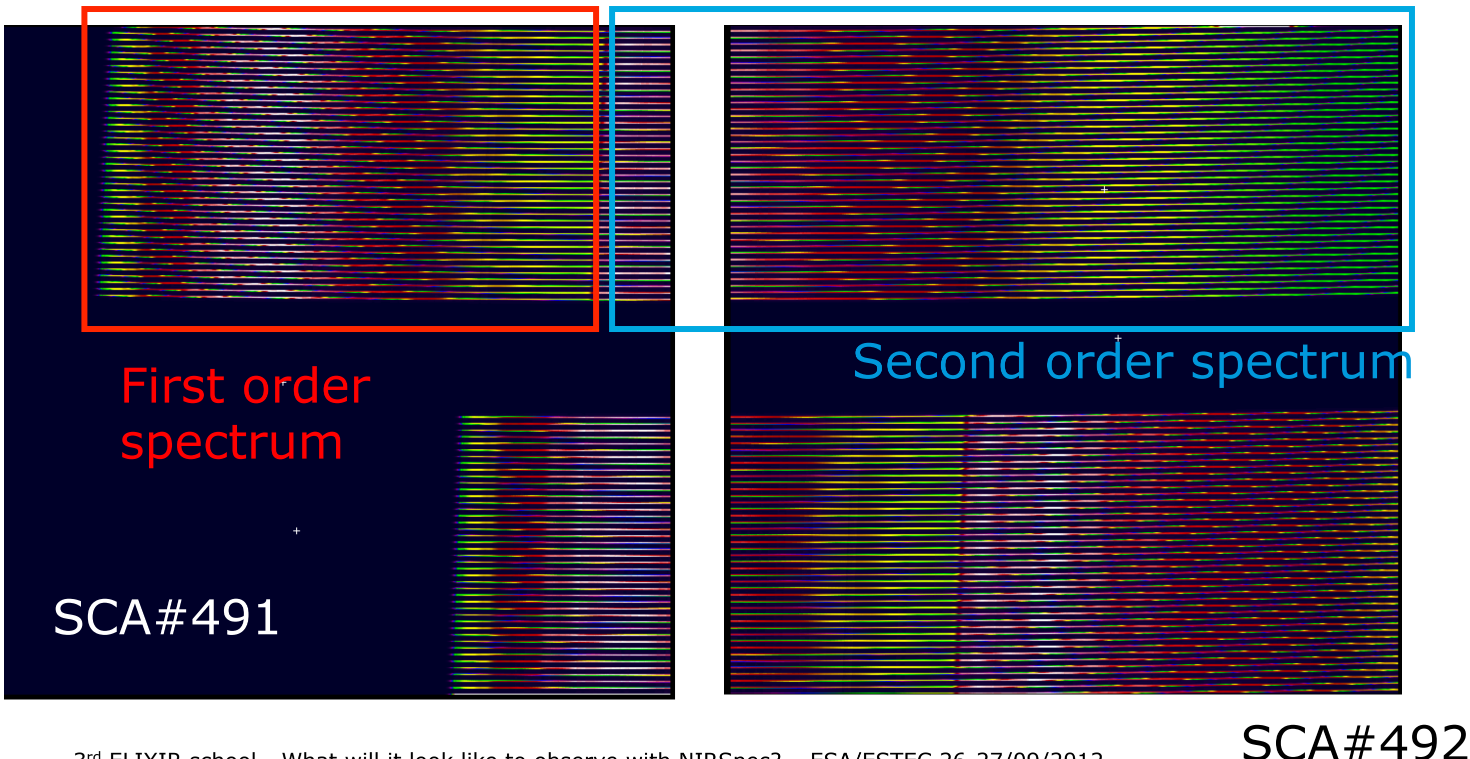
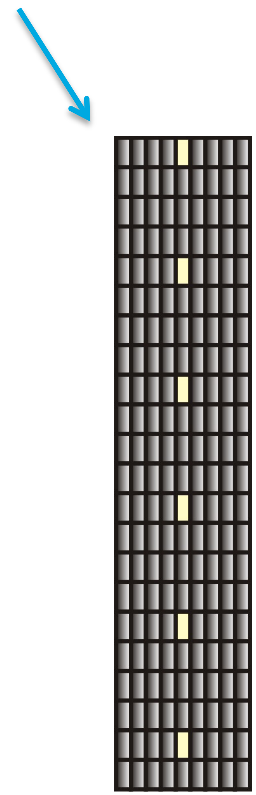
Example of the simulation of a calibration exposure

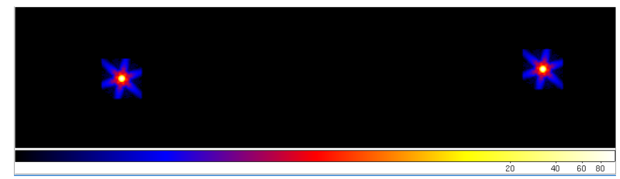
- Simulation of a calibration exposure
  - One micro-shutter out of 4 is opened to make a “dashed-slit”
  - Flat-field illumination with a continuum spectrum
  - R=1000 grating (G140M) in the 1.0-1.8 μm domain





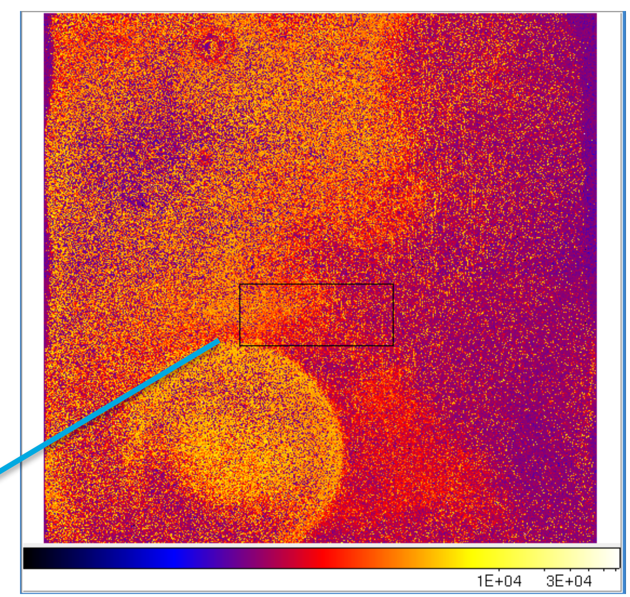
Detector exposure simulation

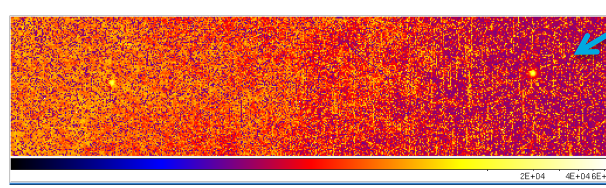
- Simulated detector exposure generated from a (noiseless) map of the electron rates per pixel



Zoom on pinholes in the electron rate map.

- Detector effects that can be included:
  - Detector non-linearity
  - Detector saturation
  - Detector bad pixels list
  - Dark-current
  - Reference pixels
  - Cross-talk
  - Cosmic rays



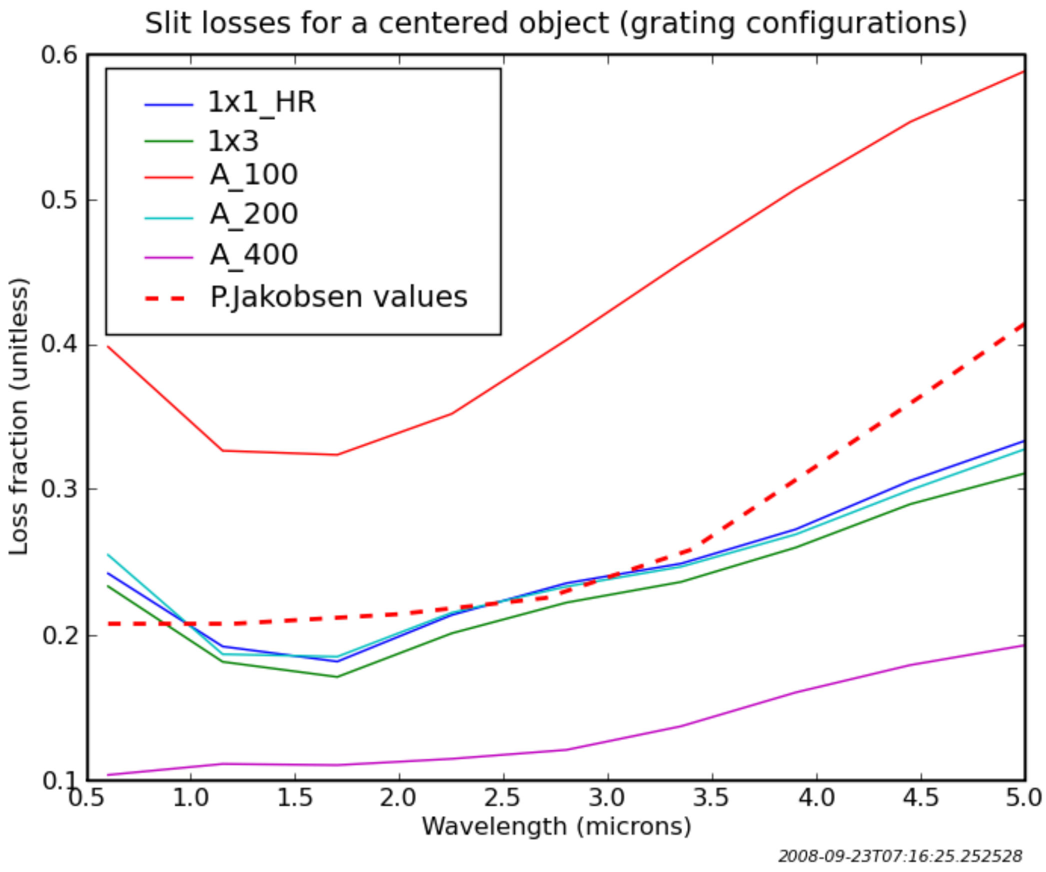


Conclusion

- A complex instrument performance simulator
- Based on the Fourier optic formalism but going much further than the usual “performance evaluation” type of software
- Exposure simulations including detector effects

- Next steps:
    - Still quite a lot of things to be improved (fidelity of the detector simulation; optimization of the computation times…
    - Generate more simulations of scientific exposures.

White board experience...
Slit and diffraction losses



The easy one, the slit losses.

White board experience…
Slit and diffraction losses

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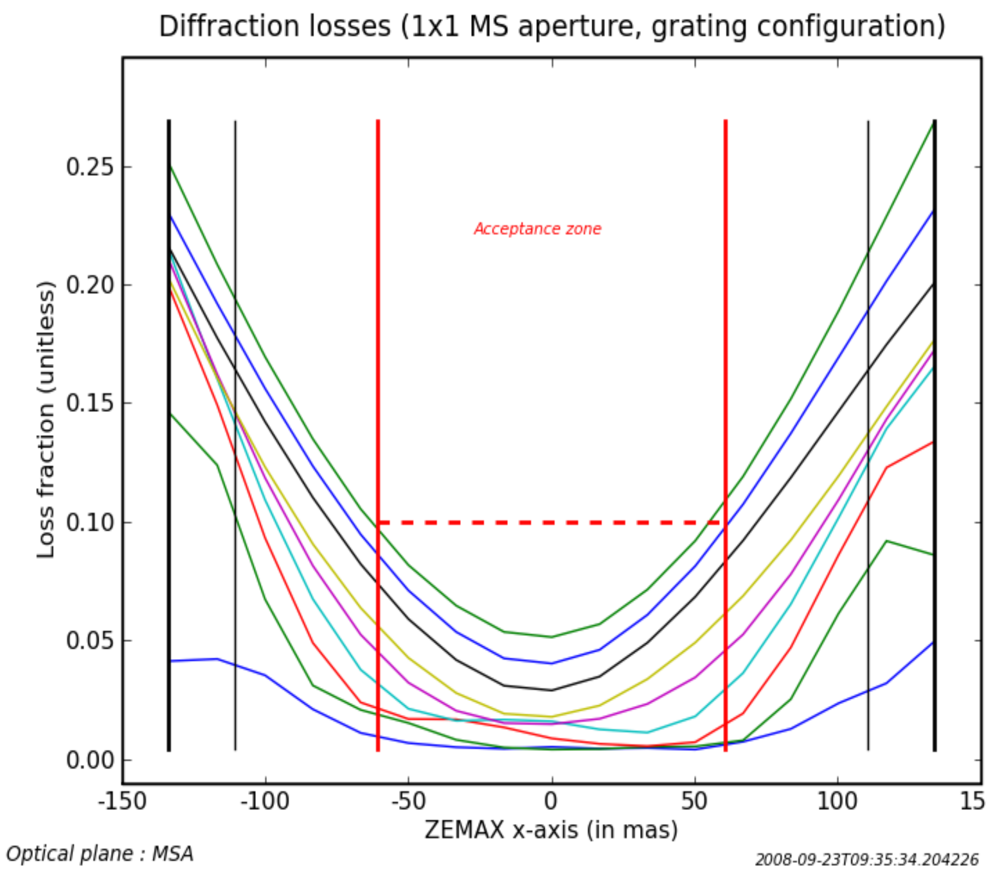
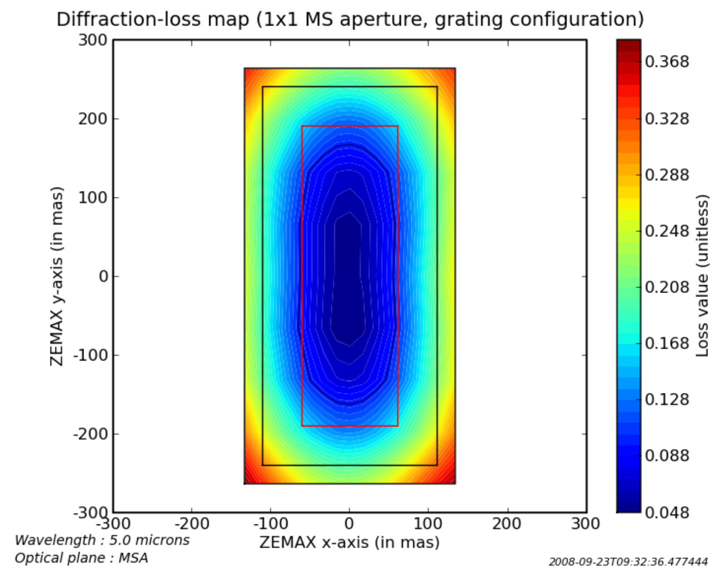


More difficult, the diffraction losses…



White board experience…
Slit and diffraction losses