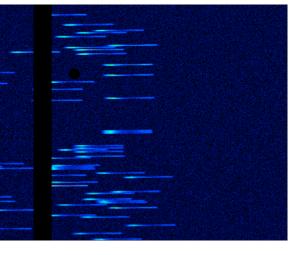
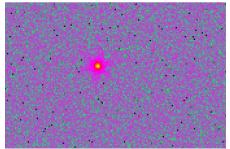
The NIRSpec instrument performance simulator (IPS) software

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





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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.

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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

- 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

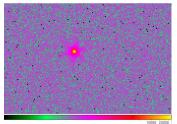
Instrument, simulation and exposure parameters

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

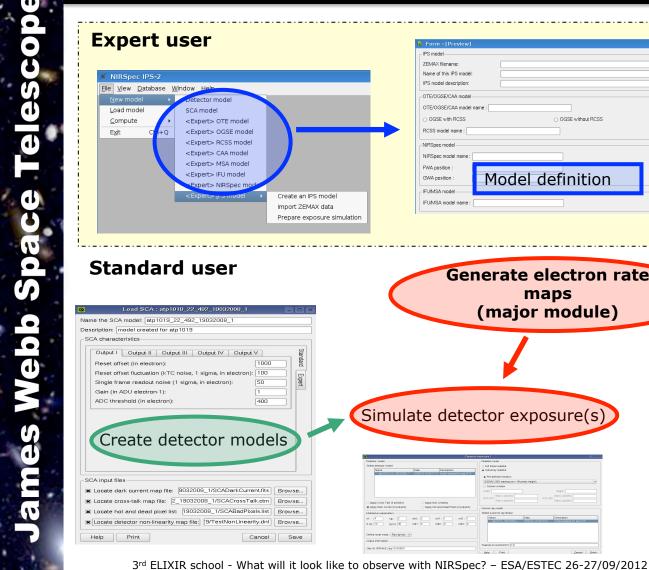
- 6 main software components:
 - a Fourier optics module
 - a coordinate transform computation and fitting software
 - a radiometric response / sensitivity computation tool
 - a PSF simulator
 - an exposure simulator
 - an instrument model database



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Display configuration			File specifications
Wavelength: 6e-07 -	Rotation angle: -41.5	 Forward fit 	File name: D-STOP_MSA2.pcf Model description:
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Help Cancel Finish			Define reset mode : Pixel to pixel V	Help Cancel Einish

The main IPS software components **Generic workflow**

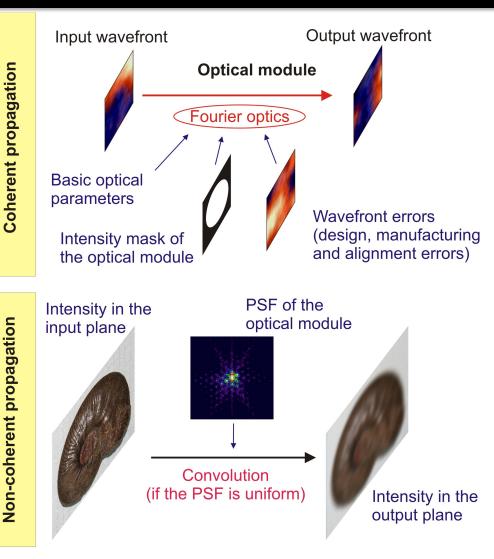


OGSE with PCSS OGSE with CCSS RCSS model name: NRSpec model NRSpec model NRSpec model NRSpec model FWA position: GWA position: FUMSA model	Image: Image
Generate electron rate maps (major module)	Compute and view distortion fit Compute and view PSF Compute and view radiometric response
Construction Construction Outer construction In different statution Outer construction In different statutio	Control and Production Register and Production Re

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Simulating coherent and noncoherent sources





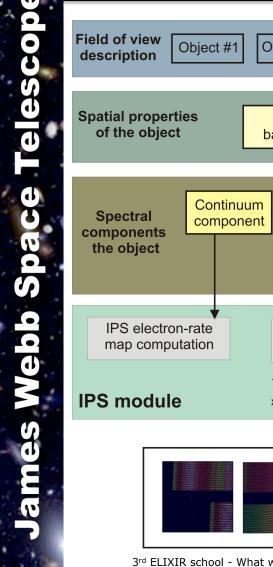
Coherent propagation

- 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"



Object #2 Object #k Object #n Point Smooth Spatially complex background object source Spectrally unresolved Spectrally complex components lines #1 #n #n IPS electron-rate IPS electron-rate IPS electron-rate IPS electron-rate **IPS** electron-rate IPS electron-rate map computation map computation xn xn Final (noiseless) electron-rate maps for the object #k - one per SCA (two detector arrays) - one for each grating order if relevant

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

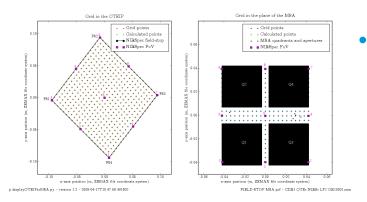
 Number of electrons per second for each detector pixel

Coordinate transforms from plane

- 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...

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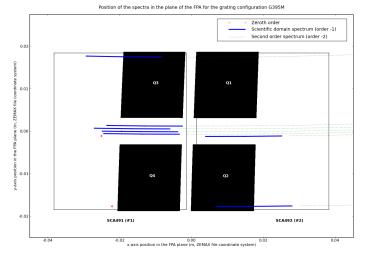
Coordinate transforms from plane



From sky to the plane of the MSA

- JWST telescope
- NIRSpec fore-optics

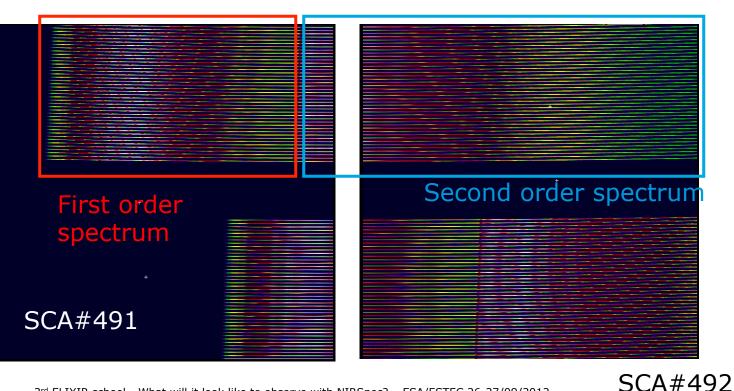
- From the plane of the MSA to the detectors
 - Collimator and camera
 - Disperser
 - Micro-shutter and slit positions
 - Focal plane layout



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 μ m domain





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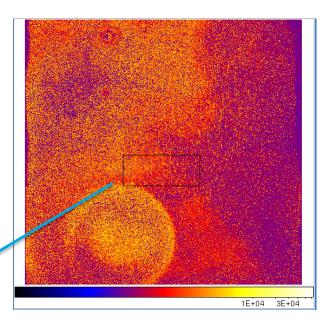
- Simulated detector exposure generated from a (noiseless) map of the electron rates per pixel
- Detector effects that can be included:
 - Detector non-linearity
 - Detector saturation
 - Detector bad pixels list
 - Dark-current
 - Reference pixels
 - Cross-talk

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Cosmic rays



Zoom on pinholes in the electron rate map.

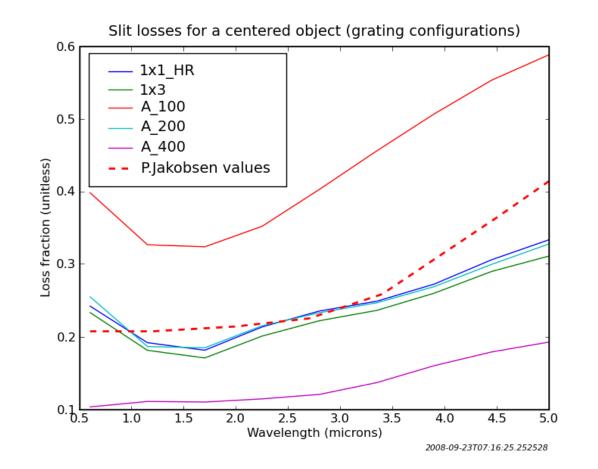


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Conclusion

- 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.

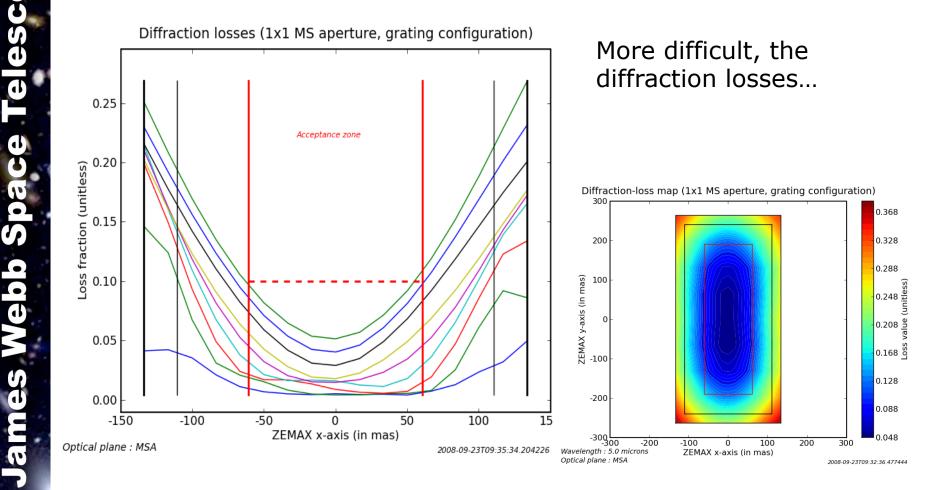
White board experience... Slit and diffraction losses



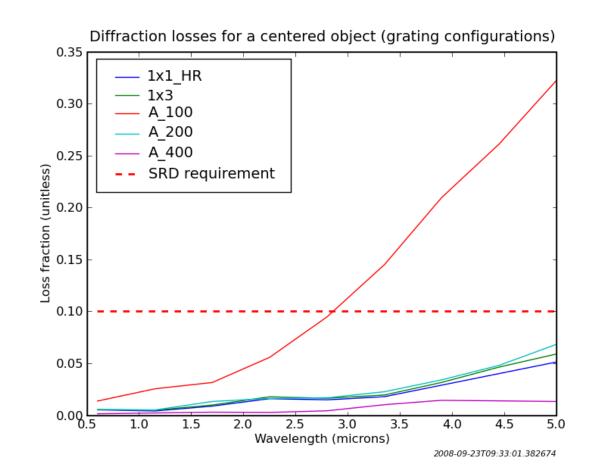
The easy one, the slit losses.

White board experience... **Slit and diffraction losses**

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White board experience... Slit and diffraction losses



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