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## **JWST Project - Instrument Performance Simulator of the NIRSpec Spectrograph**

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**Abstract.** The future James Webb space telescope (JWST), developed jointly by the American, European and Canadian space agencies (NASA, ESA and CSA), is scheduled for launch in 2013. The near-infrared spectrograph NIRSpec will be a major element of its instrument suite and is built by EADS Astrium for ESA. NIRSpec is a multi-object spectrograph allowing astronomers to obtain the spectra of more than one hundred objects in one shot. Given the complexity of the NIRSpec instrument, it was found necessary to develop an instrument performance simulator (IPS) software.

In this context, the Centre de Recherche Astrophysique de Lyon (CRAL) is responsible of the development of this simulator that will serve as a basis for early performance verification purposes; provide inputs and support for the verification and calibration campaigns, as well as for the development of the instrument calibration, target acquisition and data reduction procedures.

In this paper, we will present this IPS software that will be able to generate simulated NIRSpec detector exposures for the various modes of the instrument (multi-object, integral field unit, fixed slits) and for a large variety of situations (test, calibration, scientific observations).

### **1. Introduction to the JWST-NIRSpec Project**

NASA and ESA – joined by the Canadian Space Agency (CSA) – have since 1996 collaborated on the definition of a successor to Hubble space telescope, the James Webb Space Telescope (JWST). JWST is foreseen to be a passively cooled, 6.5m aperture class telescope, optimised for diffraction limited performance in the near-infrared wavelength region ( $1 - 5\mu m$ ), but with extensions to either side into the visible ( $0.6 - 1\mu m$ ) and Mid-IR ( $5 - 28\mu m$ ) regions. To achieve the scientific program for the JWST mission, the observatory will be capable of high-resolution imaging and spectroscopy. The definition, procurement and commissioning of the near-infrared spectrograph (NIRSpec) will be responsibility of ESA with hardware procured through European industry (EADS ASTRIUM).

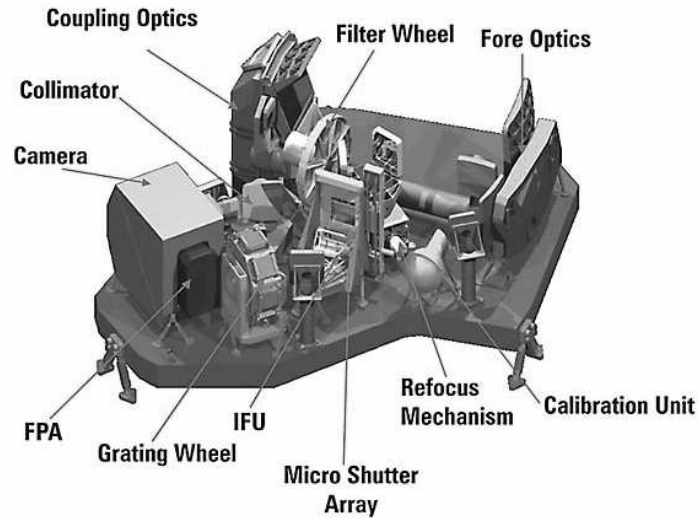


Figure 1. Mechanical design of the NIRSpec instrument.

## 2. Goals of the NIRSpec Instrument Performance Simulator

Given the complexity of the NIRSpec instrument, it was found necessary to develop an instrument performance simulator (IPS). This simulator (hardware and software) is part of NIRSpec electrical ground support equipment and will serve as a basis for early verification of the instrument performances providing inputs for trade-offs, predicting the performances; provide inputs and support for the verification and calibration campaigns comparing synthetic and real verification and calibration data, inputs for the analysis of the test results; provide inputs and support for the development of the instrument calibration, target acquisition and data reduction procedures (e.g. provide inputs for the development and tuning of the TA algorithms and for the verification of the NIRSpec quick-look, calibration and analysis software).

## 3. Software Environment

The IPS hardware contents 8 processors and more than 1To of hard disk drive storage. The IPS software is implemented with UML, C++ and Python languages. Some open source libraries are used (GSL, g++, STL, Qt4.3, CCFits, CppUnit, FFTW). Operating system and workbench are Debian Sid, Red Hat 5, Qemu, Eclipse 3.3.0, Visual Paradigm for UML, QtDesigner, Mantis, SAO DS9, Doxygen. Data are structured in a database using SQLite library. The collaborative and versioning tool is SVN.

The team is composed of a project manager/instrument scientist, a project assurance manager and 5 developers.

#### 4. IPS Software Description

In order to simulate the instrument, the code has been divided into modules. Each of them simulates some aspects of the instrument or of its behaviour (Gnata, & Ferruit 2008).

A module simulates the distortion. The distortion map fit consists in two successive fits: first the output image points are fitted as a function of space. The result is a bi-dimensional polynomial for each wavelength. Second these points are fitted as a function of the wavelength. The same operation is done for the reverse distortion, i.e. when going from the output plane to the input plane. Figure 2 shows the distortion viewing.

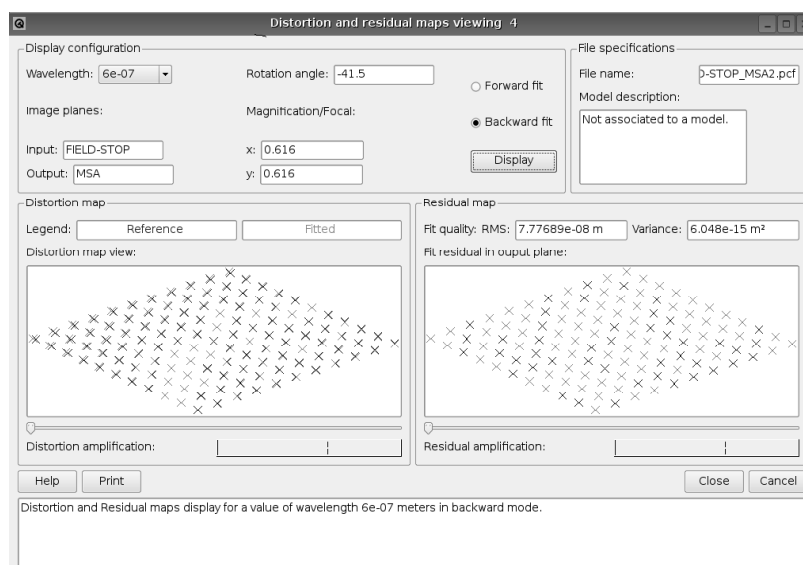


Figure 2. The distortion map.

The IPS performance simulations include also PSF (system response to a point-source) computation. A stand alone mode has been implemented to generate PSF. A library of PSF is also pre-computed during the instrument model creation phase. This is used later on for the detector exposure computation.

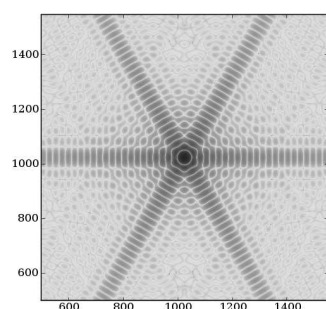


Figure 3. Point Spread Function located at position (1024,1024).

The modeling of the system radiometric response and the computation of the instrument absolute sensitivity to point sources and in the case of uniformly

illuminated aperture are also implemented in the IPS software.

The IPS produces 2D map of the photon rates per pixel from an instrument model and a file describing the field of view. The IPS generates synthetic detector exposures from a previously computed map of the photon rates per pixel. Detector effects applied are common offset applied to all the detector pixels (Gaussian distribution), detector non-linearity, detector saturation, detector bad pixels list, dark current and reference pixels (Rauscher et al. 2007).

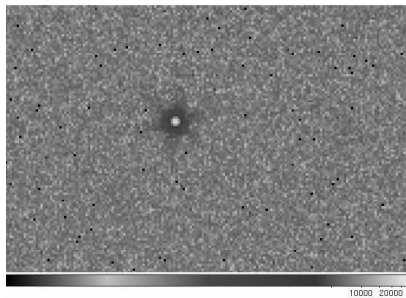
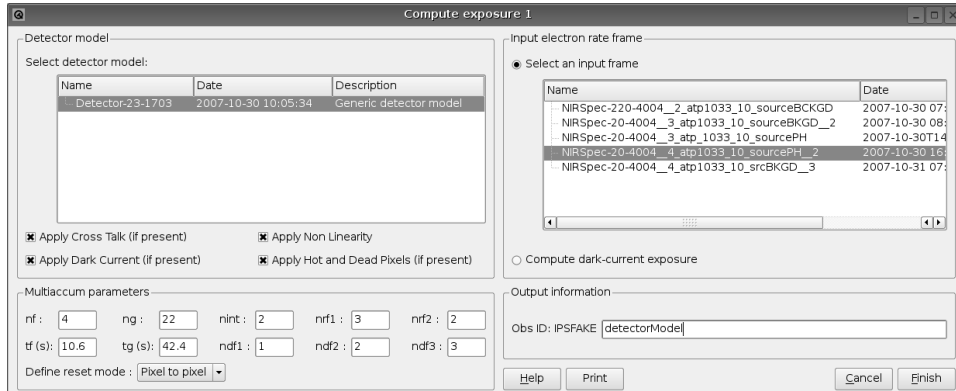


Figure 4. Detector exposure (in ADU).

## 5. Software Status

IPS hardware (IPS-0) has been successfully delivered at ASD. IPS-1 software, dedicated to the modeling of the NIRSspec Development Model Test phase will be delivered to ASD in fall 2007. IPS-2 software, dedicated to the modeling of the NIRSspec Flight Model Design is being under development and will be delivered to ASD in 2008. IPS-3 will correspond to the as-built instrument will be delivered to ASD and ESA a few months after the end of the cryogenic tests of the instrument.

## References

- Gnata, X. & Ferruit, P. 2008, in ASP Conf. Ser. XXX, ADASS XVII, ed. J. Lewis, R. Argyle, P. Bunclark, D. Evans, & E. Gonzalez-Solares (San Francisco: ASP), [P1.014]
- Rauscher, B.J. et al. 2007, PASP, 119, 768