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TECHNICAL NOTE

An introduction to the IFU coordinate transforms in the context of the NIRSpec parametric model

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1 INTRODUCTION

NIRSpec (Near Infrared Spectrograph) is the near infrared spectrograph of the James Webb Space Telescope (JWST). The main elements and basic characteristics of the instrument are listed in Table 1 of NTN-2013-011 (Giardino 2013).

For simulation purposes and to accurately assess the instrument performances, it is necessary to be able to compute the path followed by the light entering NIRSpec. As detailed in Dorner (2012) and NTN-2013-011 (Giardino 2013), the NIRSpec parametric model provides the algorithm and reference hardware geometry to be able to make predictive forward simulations of NIRSpec data and to compute backward transformations that enable the extraction of NIRSpec spectra.

A general introduction to the NIRSpec parametric model is given in NTN-2013-011, which describes the coordinate transforms to be applied to a light ray entering any of NIRSpec high-contrast fixed slits or one of the configurable aperture of the NIRSpec micro-shutter array (MSA) in order to follow its path within the instrument. In this note, we focus on the additional coordinate transforms that have to be applied to a light ray entering the the NIRSpec Integral Field Unit (IFU). Hereafter, it is assumed that the reader is fully acquainted with the concepts and formalism introduced in NTN-2013-011 and references therein.

The Integral Field Unit (IFU) entrance aperture is located in the MSA plane. IFU and MSA observations are, in most cases¹, mutually exclusive as their spectra share the same detector area, so all shutters have to be closed during IFU operations, and the IFU has to be blocked for multi-object exposures using the MSA. As schematically illustrated in Fig. 1, a light ray in NIRSpec Optical Telescope Image Plane (OTEIP) is transformed to the MSA slit plane using the FORE-optics coordinate transform. If the ray enters a fixed-slits or a micro shutter, the coordinate of the light ray in the Focal Plane Array (FPA) can be computed from its coordinates at the MSA plane by 1) applying the collimator transform (COL), 2) computing the effect of the dispersive element (or the mirror) at the Grating Wheel Array (GWA) and 3) applying the camera transform (CAM), as specified in NTN-2013-011 and references therein.

If the ray enters the IFU, the IFU-FORE transform and the IFU-POST coordinate transforms have to be applied to derive the position of the ray within one of the IFU virtual slit at the MSA plane, before proceeding with steps 1) to 3). The IFU FORE re-images and scales the MSA plane onto the slicer, and the IFU POST part, picks up the 30 image parts, and creates a virtual slit image for each slice at the MSA plane. Once the position of the light ray in one of the IFU virtual-slit plane is computed, the rest of the computation is performed in a identical manner to that for the other observation modes.

These transforms and the necessary reference files are outlined in Sect. 2.

2 IFU-SPECIFIC COORDINATE TRANSFORMS AND REFERENCE FILES

The IFU specific reference files are the following:

- `IFU_slicer.sgd` – This file in FITS format provides the absolute position and rotation of the slicer within the exit plane of the IFU-FORE coordinate transform and, for each slicer, the relative position of its center and its size in x and y.
- `IFU_FORE.pcf` – This file provides the parameters (Paraxial and distortions coefficients) for the coordinate transforms from the MSA plane (in) to the plane of the IFU slicer.
- `IFU_POST_0.pcf`, `IFU_POST_1.pcf`, ... , `IFU_POST_29.pcf` – Each of these files provides the parameters (Paraxial and distortions coefficients) for the coordinate transforms from the slicer plane to the MSA plane (out), that is the plane of the IFU virtual slits.

¹The exception here is low resolution spectroscopy: when using the prism one can combine a IFU and a specially configured MSA

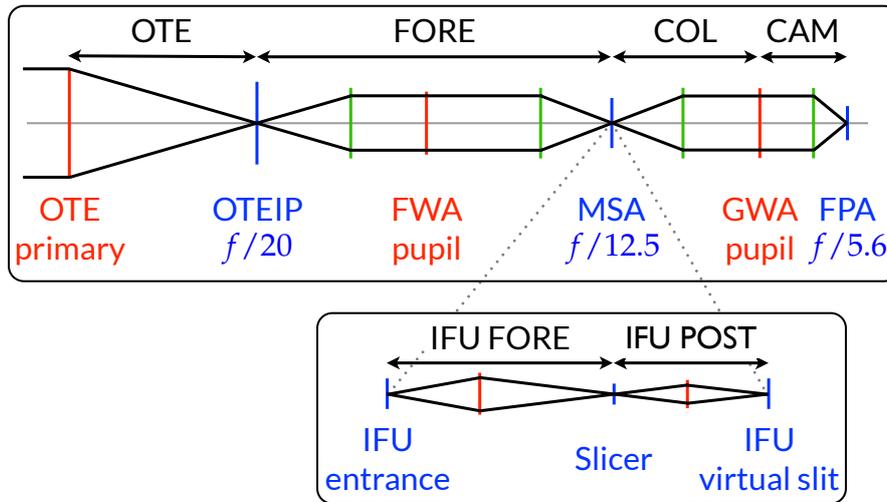


Figure 1: Paraxial layout of the NIRSpec optical train with the main modules and nominal focal ratios. Pupils are indicated in red, focal planes in blue, the optical modules are indicated by black arrows. The system field stop is located at the OTEIP. The IFU optics is coupled into the beam at the MSA focal plane (Dorner 2012)

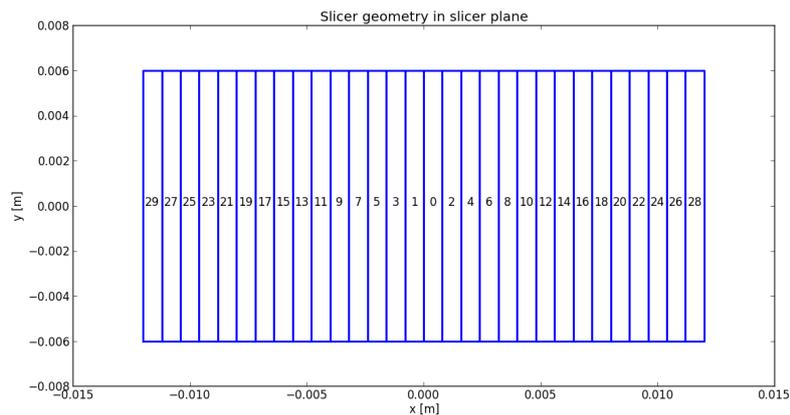


Figure 2: IFU geometry in the slicer plane.

The detailed format for these files is specified in NTN-2013-013 (Giardino & Team 2013). Within the structure of the model directory, file `IFU_slicer.sgd` is located in subdirectory `Description/`, while all the IFU-specific coordinate transform files (`.pcf`) are located in subdirectory `CoordTransform/IFU/`.

In file `IFU_slicer.sgd` the center coordinates and x and y size of each IFU slice are listed in order of slice number, that is a number from 0 to 29. The relative position of each slice and the slicer geometry in the slicer plane (that is the output plane of the `IFU_FORE` transform) are illustrated by Fig. 2. The slicer projection on the sky in the V2-V3 telescope coordinate system is given in Fig. 3. Finally, Fig. 4 provides a view of the image profile of each IFU slice at the FPA, in detector pixel coordinates. Note that only SCA419 is illuminated by the IFU in imaging mode.

When a light ray arrives in the MSA plane at the IFU entrance $(x_{msa}^{in}, y_{msa}^{in})$, the steps to compute the ray location in the MSA exit plane of the IFU virtual slits are the following.

- From $x_{msa}^{in}, y_{msa}^{in}$ compute the ray coordinate in the slicer plane x_S, y_S , using the coefficients stored in `IFU_FORE.pcf` and the operations detailed in Ferruit & IPS development team (2006)

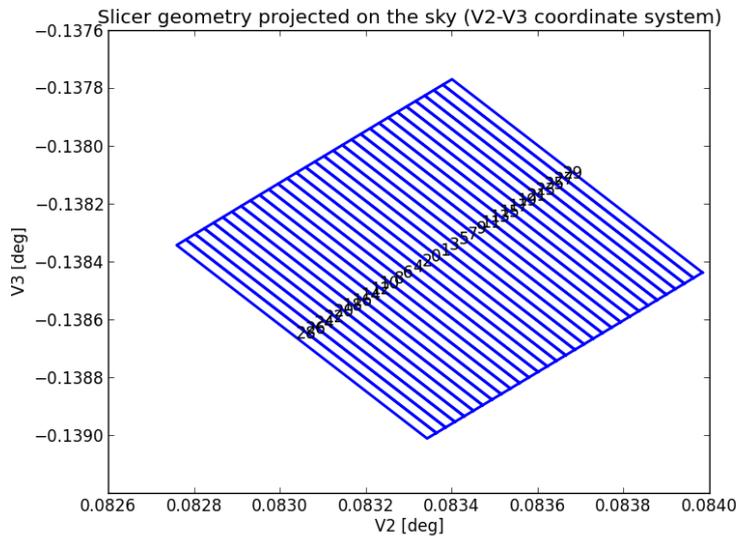


Figure 3: IFU slicer geometry projected on the sky (coordinates system is JWST telescope V2-V3).

- Using the slices' individual positions and sizes stored in `IFU_slicer.sgd`, establish the ID of the slice in which the ray falls into. The slicer IDs range from 0 to 29.
- From x_S, y_S compute the ray coordinates at the virtual-slit MSA plane, $x_{msa}^{out}, y_{msa}^{out}$, using the coefficients stored in one of the slicer-specific IFU-POST coordinate transformation files, i.e. using the slice-appropriate file among `IFU_POST_0.pcf`, `IFU_POST_1.pcf`, ... , `IFU_POST_29.pcf`, and the operations detailed in Ferruit & IPS development team (2006)

From the exit coordinates in the MSA plane the computation of the light path to the FPA coordinates follows exactly the same steps as for light exiting the MSA from a fixed slit or a micro shutter (see NTN-2013-011 and reference therein).

3 REFERENCES

Dorner, B. 2012, PhD thesis, Universite de Lyon

Ferruit, P. & IPS development team. 2006, Parameterization of the coordinate transforms in NIRSpec, Memo NIRS-CRAL-MO1004, CRAL, Lyon

Giardino, G. 2013, An introduction to the NIRSpec parametric model, NIRSpec Technical Note NTN-2013-011, ESA/ESTEC

Giardino, G. & Team, I. D. 2013, ICD for NIRSpec parametric model, NIRSpec Technical Note NTN-2013-013, ESA/ESTEC

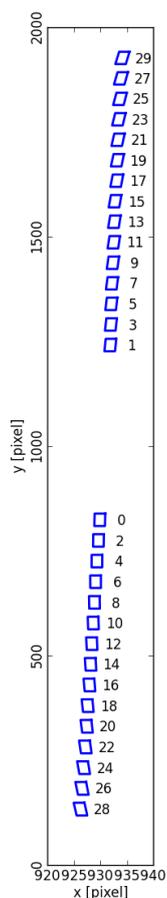


Figure 4: The image profile of the IFU slices at the focal plane in detector coordinates (pixel number). Note that the x-axis scale range is only 20 pixels.