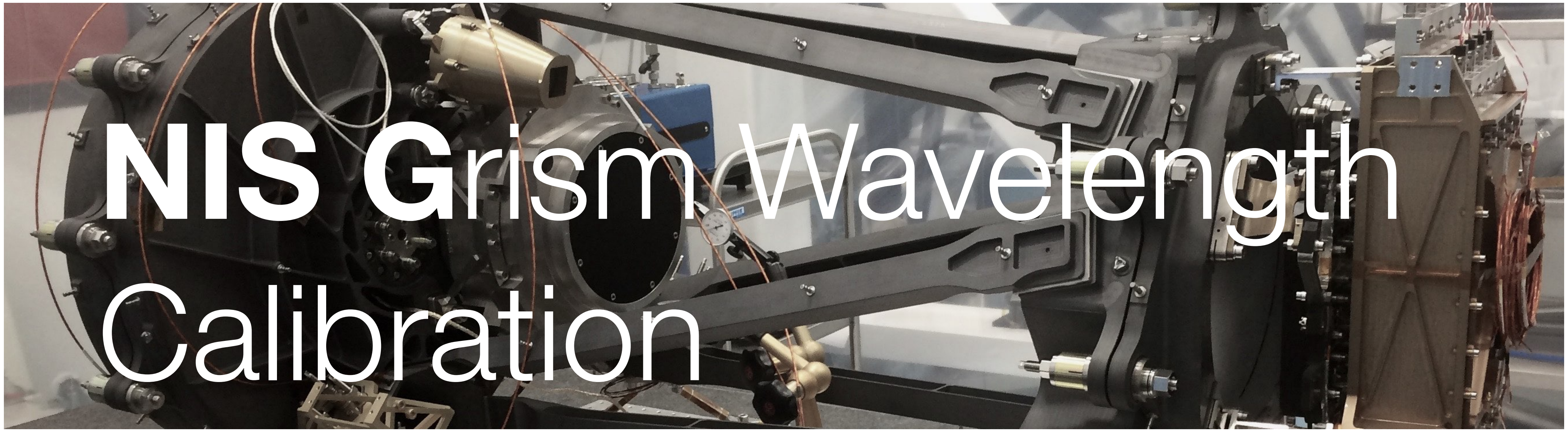

NIS Grism Wavelength Calibration

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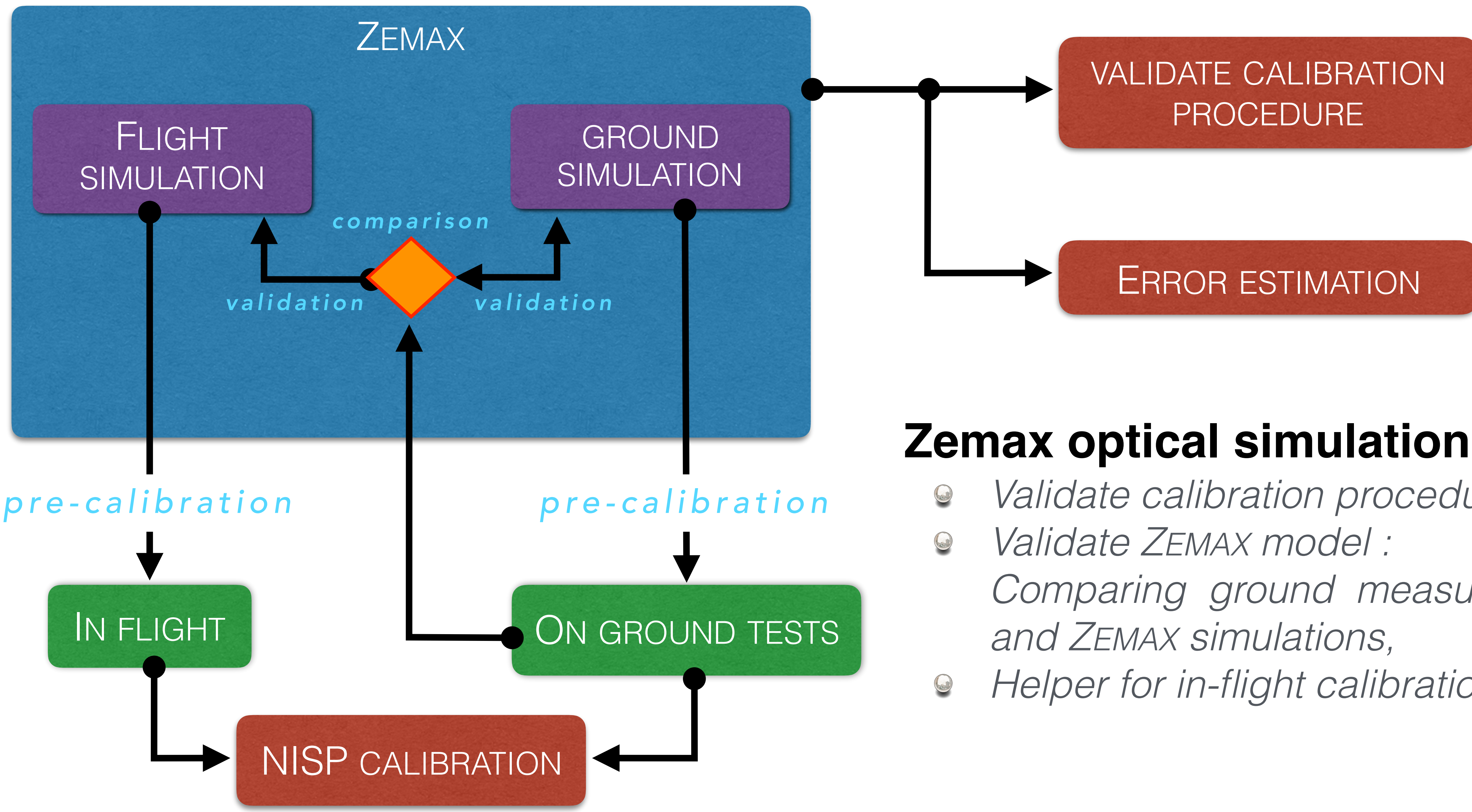
euclid consortium

2016 Euclid Photometric Calibration Workshop
Madrid, September 21st 2016

The wavelength calibration



Zemax optical simulations:

- *Validate calibration procedure,*
- *Validate ZEMAX model : Comparing ground measurement and ZEMAX simulations,*
- *Helper for in-flight calibration.*

The wavelength calibration

Two kind of ZEMAX optical simulations:

GROUND TEST SIM

ZEMAX model including NISP geometry and optical model of the equipments that will be used during ground test (optical telescope simulator).

- ↳ PSF images for different incident angle and wavelength
- ↳ 1st-order PSF library (under process @ LAM)

FLIGHT SIMULATION

ZEMAX 95 % model with NISP and flight telescope model.

- ↳ PSF images for different incident angle and wavelength
- ↳ Photo HJK, spectroscopy 0th-order, 1st-order, 2nd-order PSF library

Wavelength calibration

Overview of the wavelength calibration procedure

Loop over known spectra across FoV

Locate **local** spectra (0^{th} & 1^{st} order) → Extract their emission lines line @ (x_i, y_i) → Identify their emission lines line @ $(x_i, y_i) \rightarrow \lambda_i$ → calibrate **local** spectra $S(x,y) \rightarrow f_{loc}(\lambda)$

Wavelength calibration

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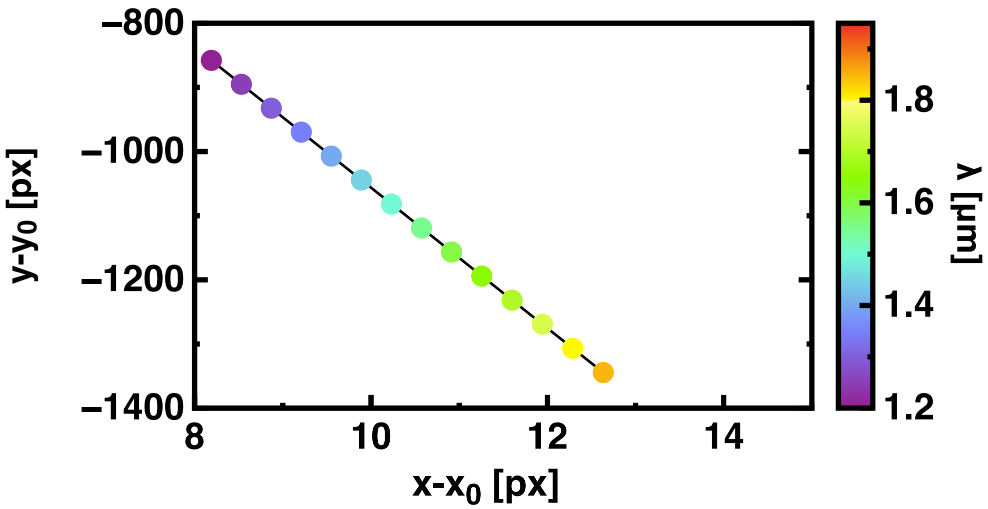


Trace-shape calibration

Local spectral trace are fitted by 2D Chebychev polynomial expansion

$$\begin{cases} x(\lambda) - x_0 = \sum_{n=0} c_n^x \times P_n^x(\lambda') \\ y(\lambda) - y_0 = \sum_{n=0} c_n^y \times P_n^y(\lambda') \\ \lambda' = \frac{\lambda - 0.5(2-1)}{0.5(2-1)} \end{cases}$$

c_n^i : the spectra dispersion coefficient for the Chebychev expansion P_n^i of the n^{th} order,

λ' : normalised wavelength $\lambda' = \frac{\lambda - 0.5(2-1)}{0.5(2-1)}$, with [1,2] μm the wavelength validity range of the Chebychev expansion.

Wavelength calibration

Overview of the wavelength calibration procedure

Loop over known spectra across FoV

Locate **local** spectra (0^{th} & 1^{st} order) → Extract their emission lines line @ (x_i,y_i) → Identify their emission lines line @ $(x_i,y_i) \rightarrow \lambda_i$ → calibrate **local** spectra $S(x,y) \rightarrow f_{loc}(\lambda)$

Local calibration calibration is done by fitting the spectral trace as function of the wavelength:

- ☑ Dispersion solution
- ☑ Optical distortion estimation

Wavelength calibration

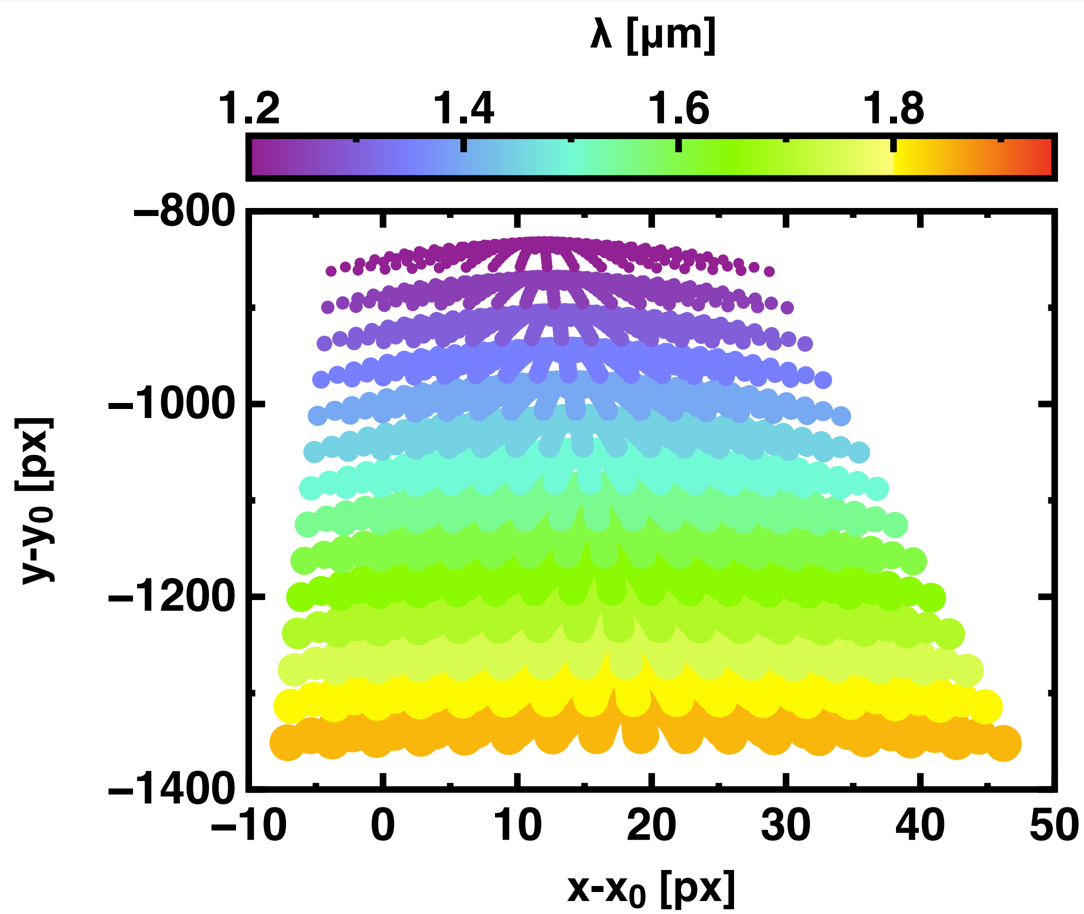
Overview of the wavelength calibration procedure

Loop over known spectra across FoV

Locate **local** spectra (0^{th} & 1^{st} order) → Extract their emission lines, line @ (x_i, y_i) → Identify their emission lines, line @ $(x_i, y_i) \rightarrow \lambda_i$ → calibrate **local** spectra, $S(x,y) \rightarrow f_{loc}(\lambda)$

Stack of relative position of emission line with respect to the spectral 0^{th} order position (95 % Zemax model simulation).

0^{th} order where homogeneously distributed across the entire FoV.

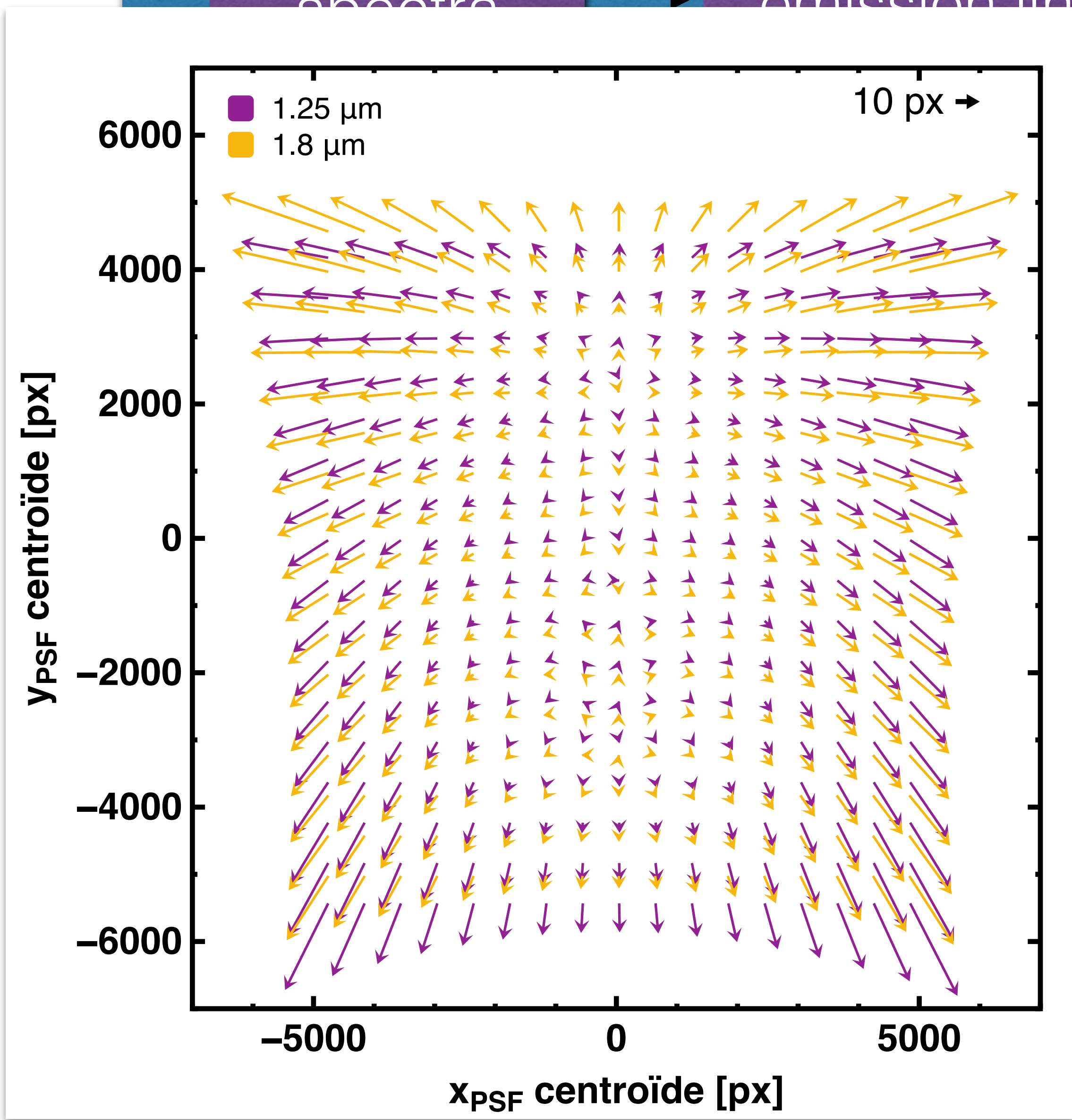


Wavelength calibration

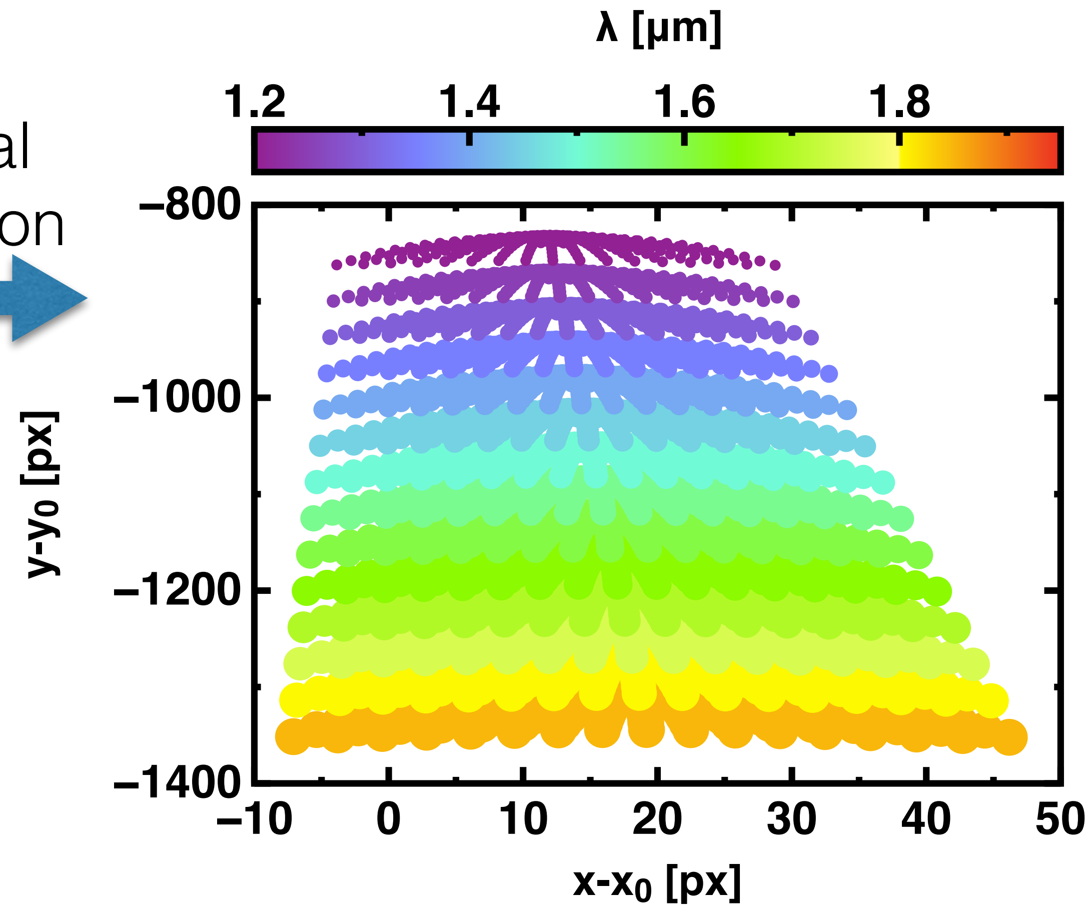
Overview of the wavelength calibration procedure

Loop over known spectra across FoV

Locate **local** spectra → Extract their emission lines → Identify their emission lines line @ $(x_i,y_i) \rightarrow \lambda_i$ → calibrate **local** spectra $S(x,y) \rightarrow f_{loc}(\lambda)$

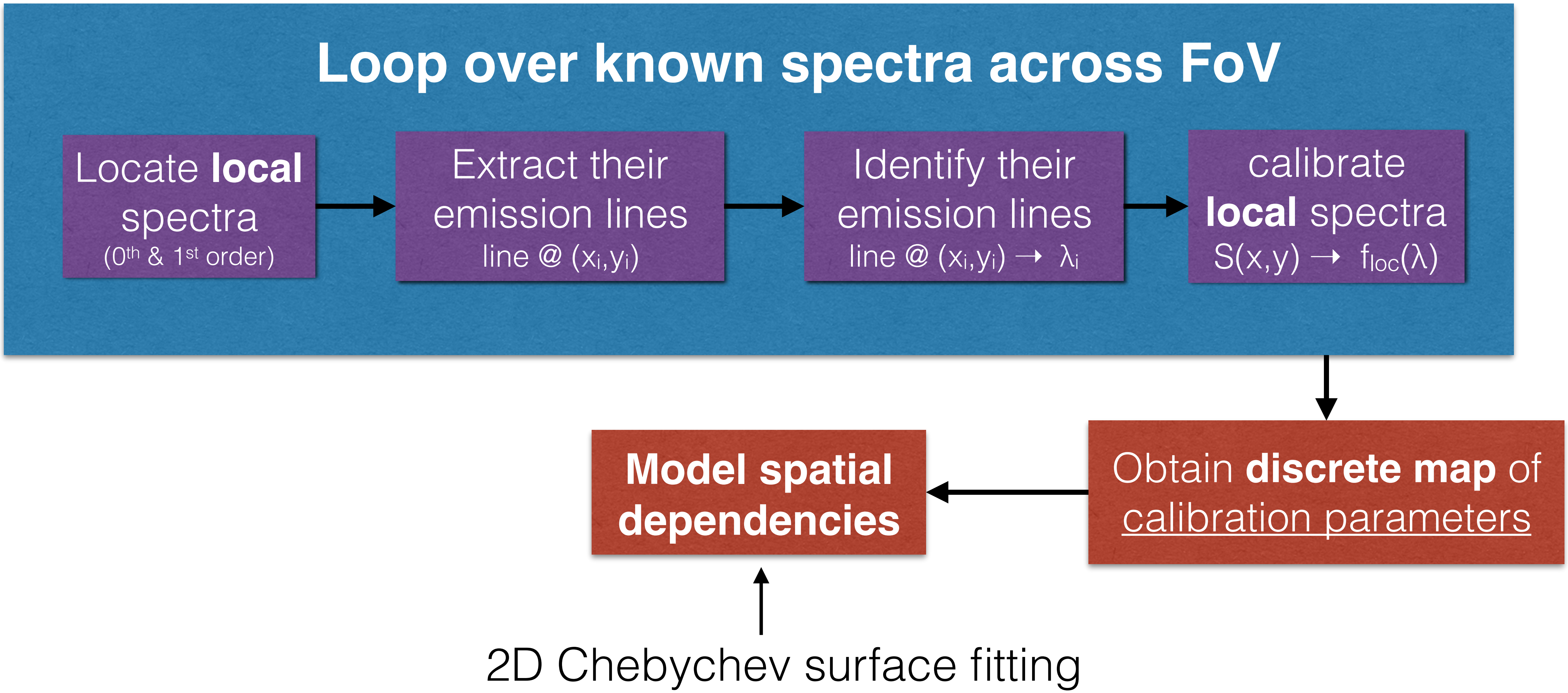


optical distortion



Wavelength calibration

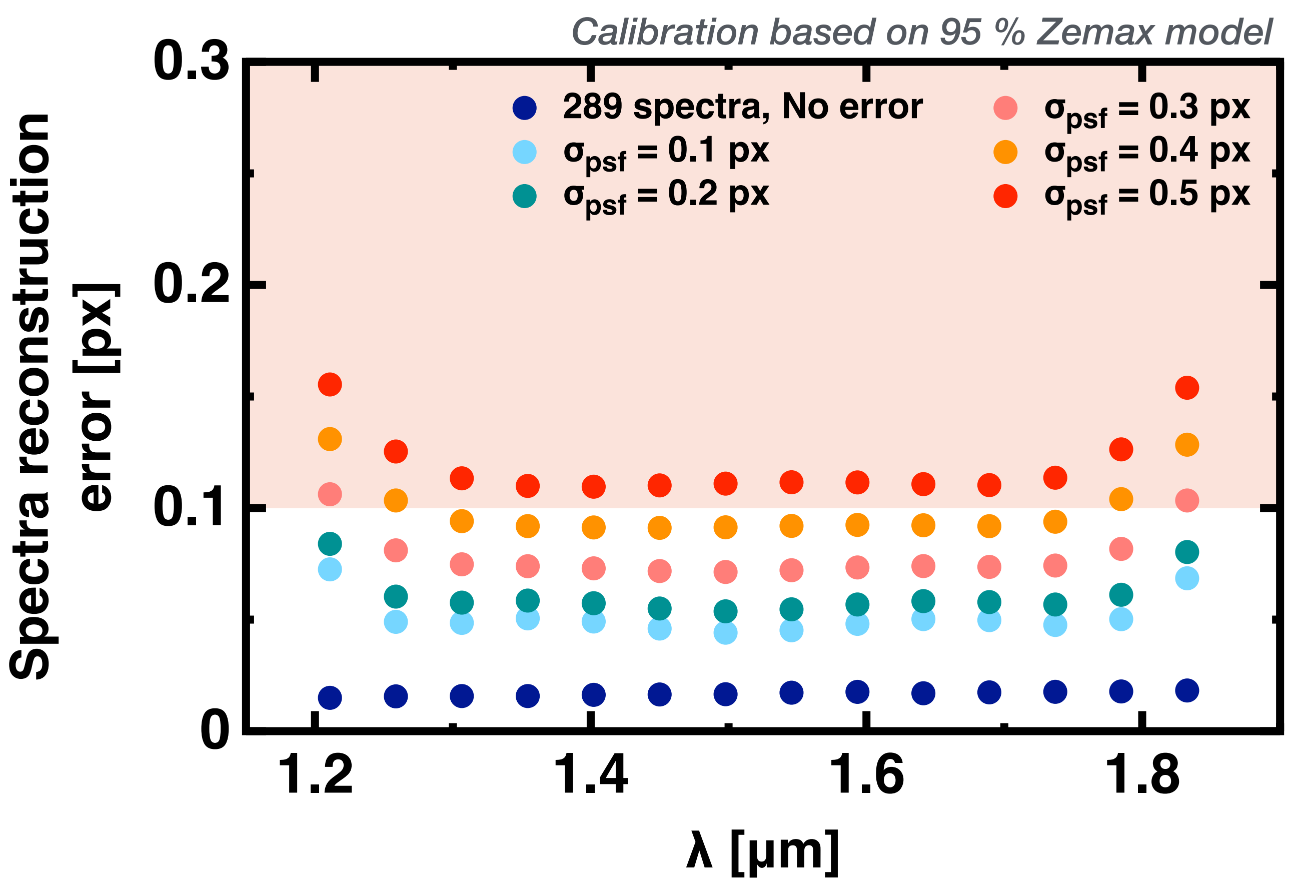
Overview of the wavelength calibration procedure

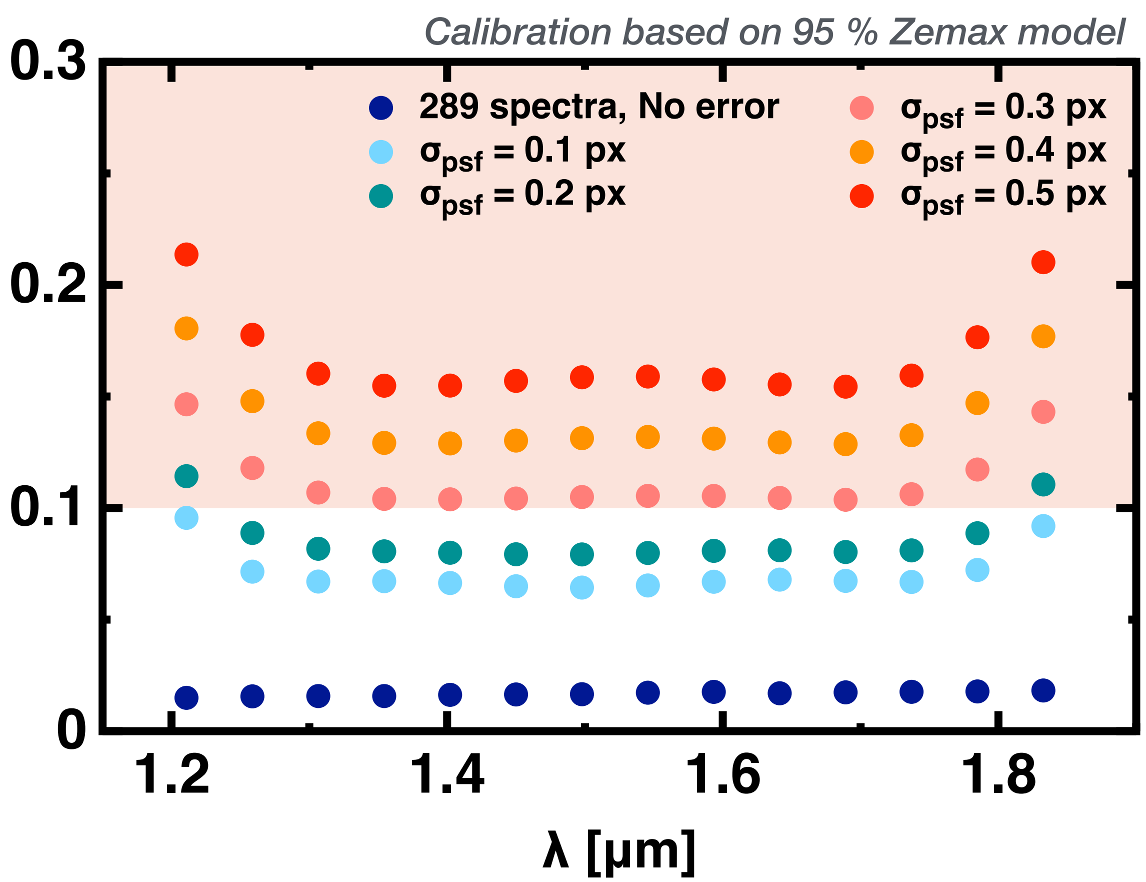


Wavelength calibration

Requirement for the wavelength calibration on ground:

1. Telescope simulator shall point a homogeneous grid onto FoV to calibrate NISP at any point, with enough point for precise calibration.
2. Calibration precision depends on the accuracy for the line extraction





12×12 spectra

⇒ As planed for ground campaign

⇒ 9 spectra/det.

5×16 spectra

⇒ As planned for in-flight calibration

⇒ 5 spectra/det.

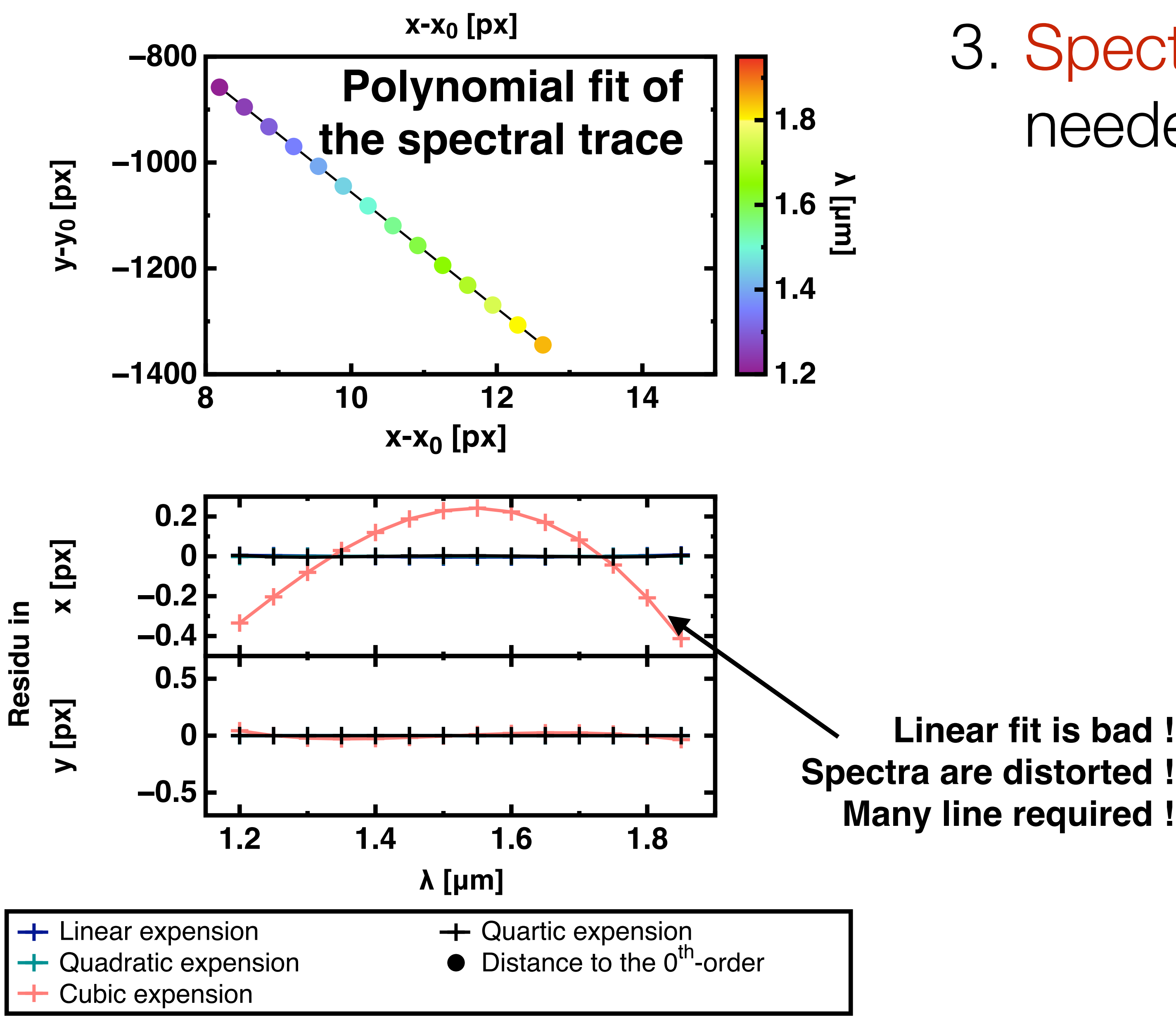
Wavelength calibration

Requirement for the wavelength calibration on ground:

1. Telescope simulator shall point a homogeneous grid onto FoV to calibrate NISP at any point ⇒ **At least a grid of 12×12 spectra.**

2. Emission line position shall be measured with precision better than 0.1 pixel

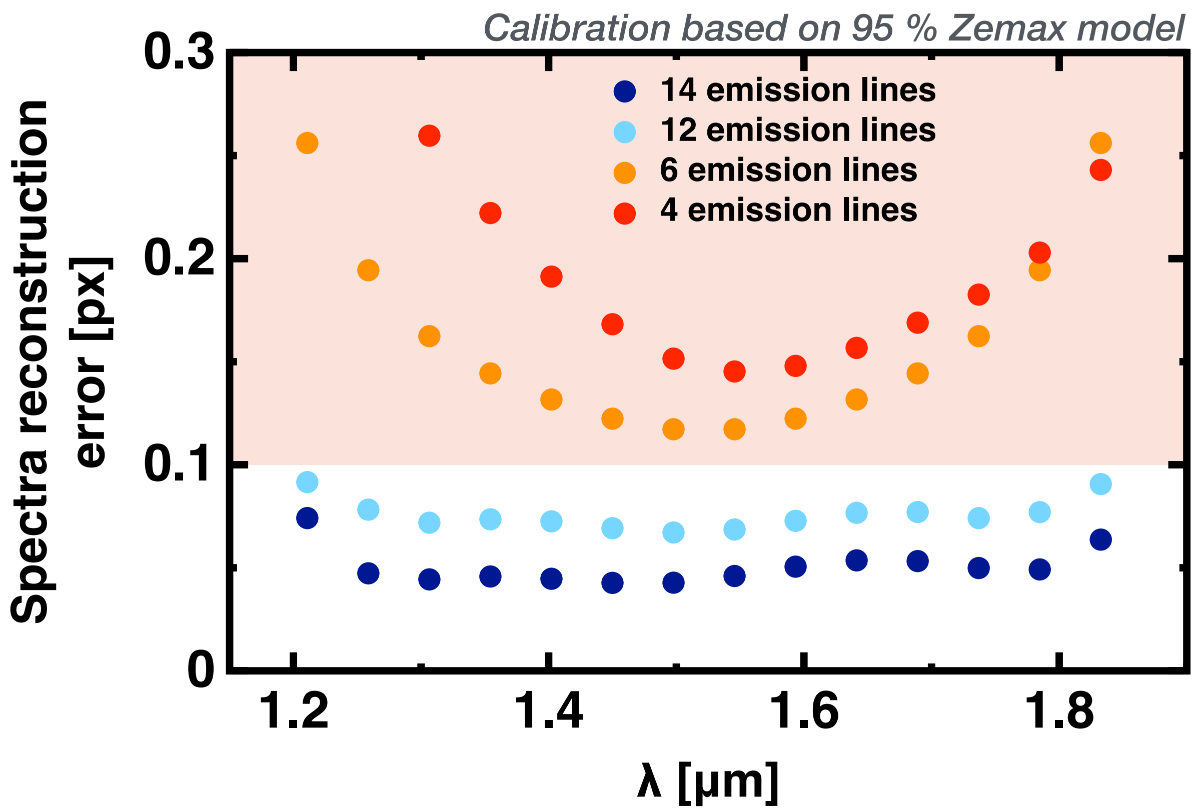
3. Spectra aren't linear → many line are needed for precise calibration

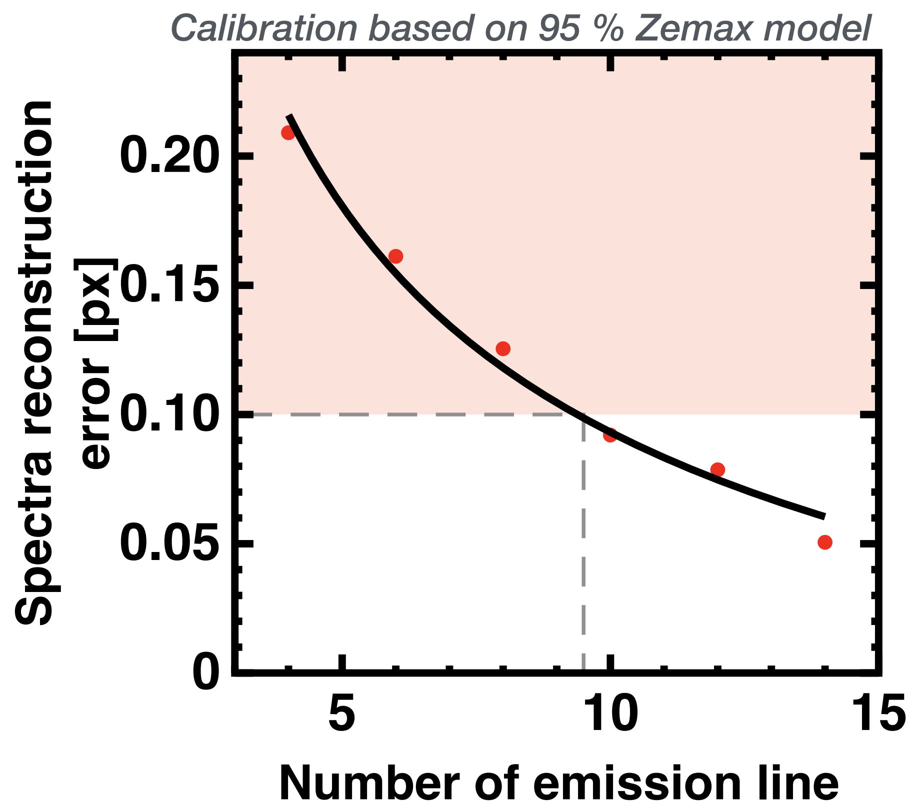


Wavelength calibration

Requirement for the wavelength calibration on ground:

1. Telescope simulator shall point a homogeneous grid onto FoV to calibrate NISP at any point ⇒ **At least a grid of 12×12 spectra.**
2. Emission line position shall be measured with precision better than 0.1 pixel
3. At least 12 emission line per spectra required.





The **NISP** verification ground System

NI-VGS :

- **Aims :** Verify the NISP performance and thermal environment of the instrument.

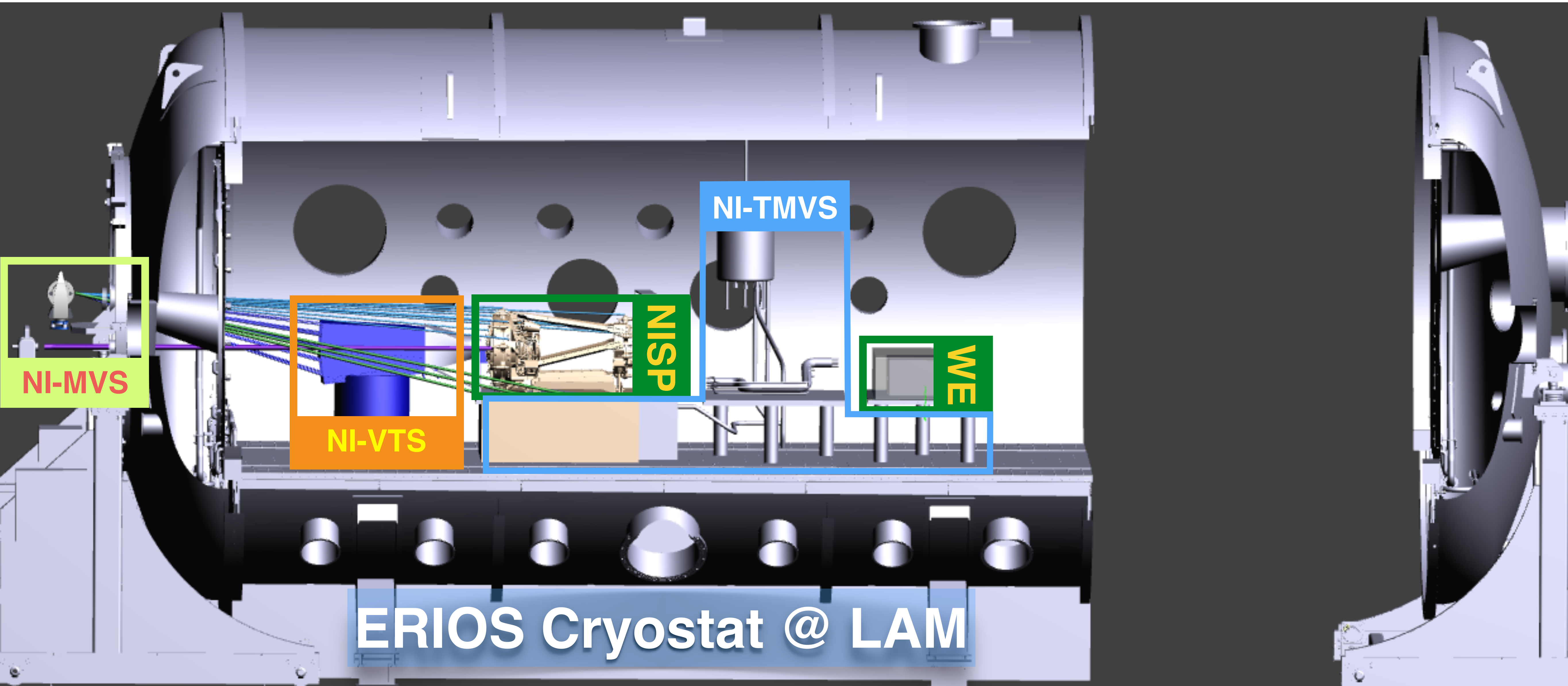
- **Operation verification:**
  - Thermal Balance : *Verification of the instrument response to different operation temperature,*
    Verification of the thermal control of the instrument.
  - Operation verif. : *Verify instrument operational sequence,*
    Verify House keeping and Data flow,
    Verify wheels performance and operation.

- **Optical verification:**
  - Focus verification : *Determination of object plane position with respect to the NIS.*
  - PSF verification :*Verify quality of the PSF for each grisms and filter.*
  - Ghost, Stray-light : *Evaluate ghost & Stray-light.*
  - Wavelength calib. : *Provide pre-flight dispersion solution of the grisms*

The **NISP** verification ground System

NI-VGS :

- **How :** The VGS is made of 4 subsystem.



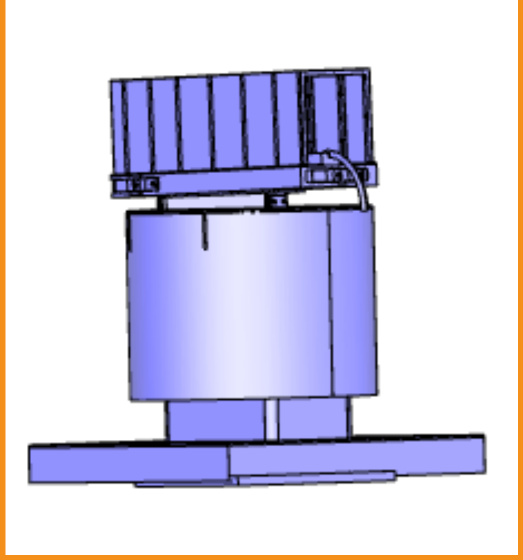
The **NISP** verification ground System

NI-VGS :

- **How :** The VGS is made of 4 subsystem.

NI-VTS: *NISP Verification Telescope System*

- NI-TS: Telescope simulator:
  - Pointing adjustable in translation and rotation to illuminate any point of the NISP FoV
  - Point source for the instrument with image quality better than 30 nm (rms),
  - Illuminate the NISP with monochromatic, multi-line or continuum spectra.
  - **Key component to any test !**



The **NISP** Telescope Simulator: Light source **[EUCL-SSC-NOTE-7-002]**

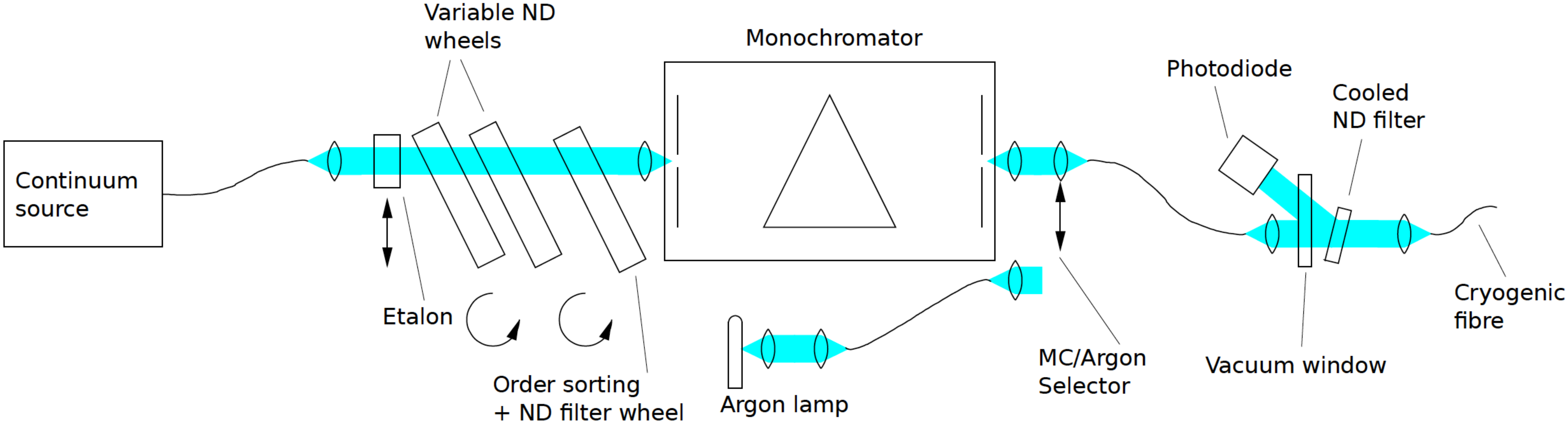


Illustration 1: Schematic of the non-cryogenic part of the illumination system and the cryogenic interface. **[EUCL-SSC-NOTE-7-002]**

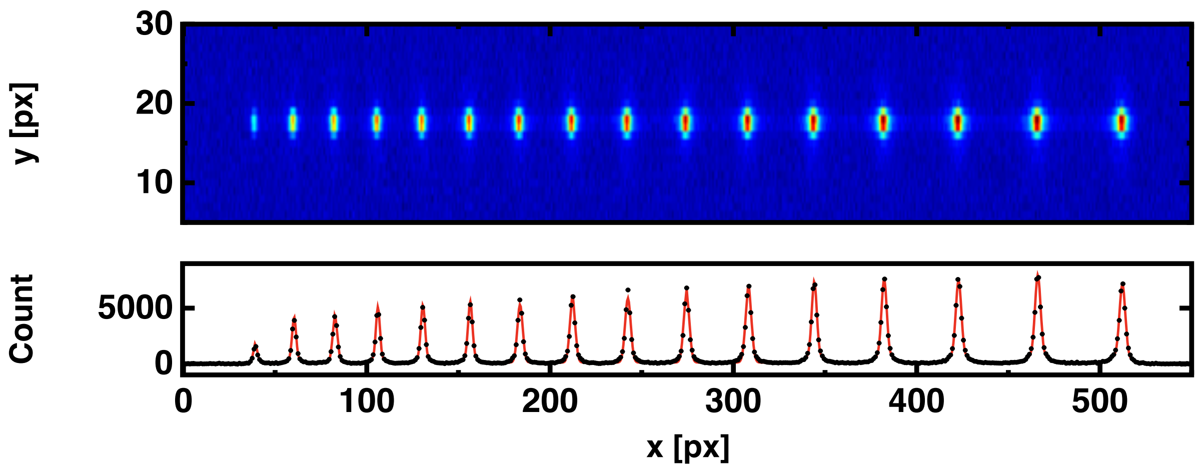
1. **Continuum source** illuminate a **monochromator**,
2. Monochromator deliver light flux to cryogenic fiber,
3. Output of the fibre is a **pinhole** located at the focal plan of the **telescope simulator**
4. Telescope simulator project the pinhole onto the NISP object focal plan, illuminating the detector plane.
5. **Spectral lamp** as well as **Etalon** are available for the **wavelength calibration**

The NISP Telescope Simulator: Light source

1. **The Etalon**

- Two kind of Etalon will be provided :

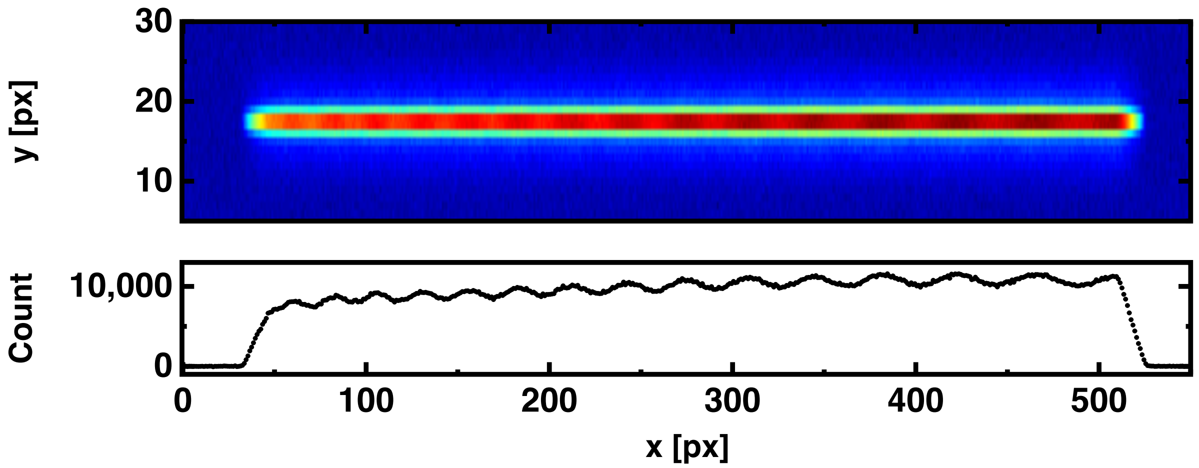
1 Coated etalon for high finesse: Fabry-Perot



NISP-TIPS simulation of Fabry-Perot spectral dispersion (GRed) under ground condition (PLM removed)

Ideal for wavelength calibration

1 Uncoated etalon for low amplitude sinusoidal modulation



NIS-TIPS simulation of transmission modulated spectra (GRed) under ground condition (PLM removed).

Mostly continuum emission with low contrasted and broad line.

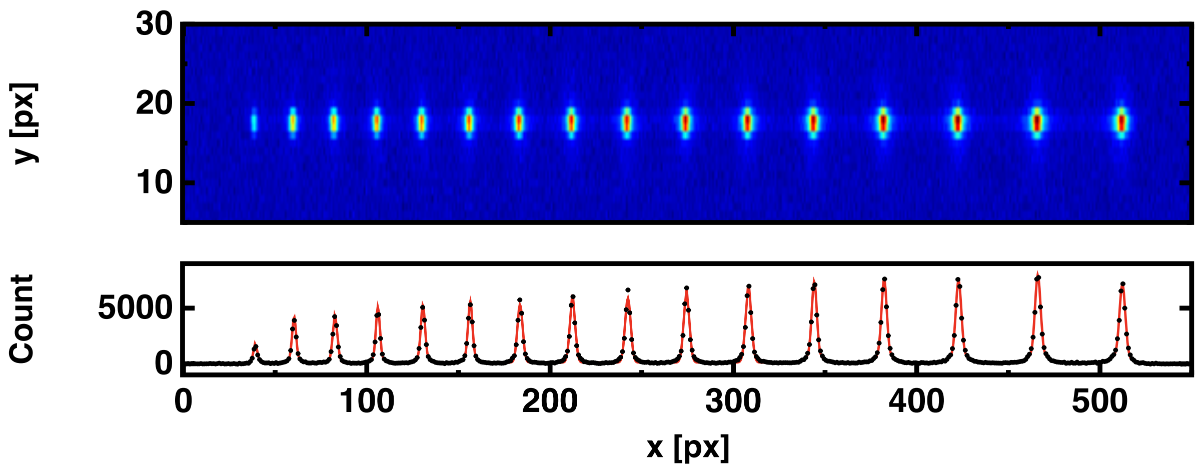
Ideal for the optical distortion verification

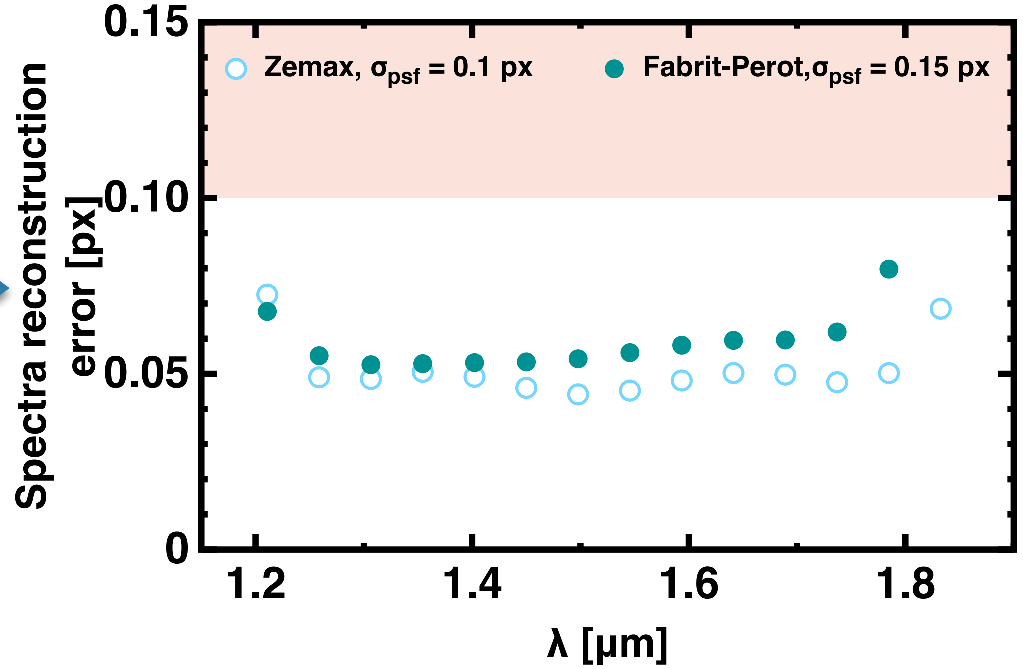
The **NISP** Telescope Simulator: Light source

1. **The Etalon**

- Two kind of Etalon will be provided :

1 Coated etalon for high finesse: Fabry-Perot





NISP-TIPS simulation of Fabry-Perot spectral dispersion (GRed) under ground condition (PLM removed)

Ideal for wavelength calibration

2. **The pinhole source**

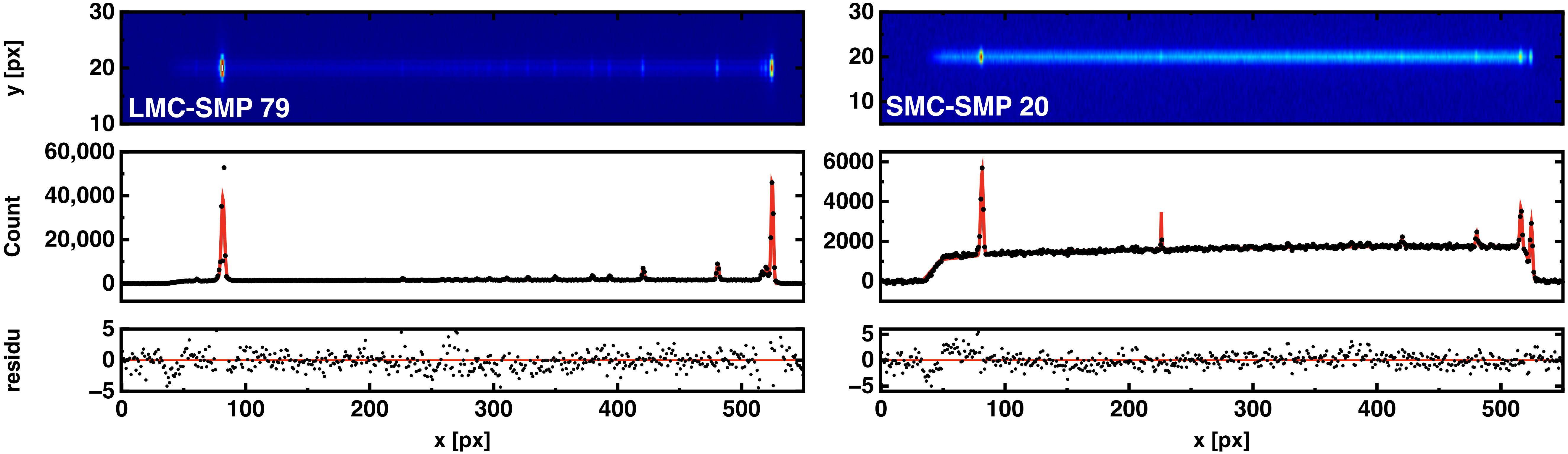
- Illuminate NISP detector plane with 1 single point like source

Require many pointing of the telescope simulator to scan the entire FoV

In Flight calibration

1. **Alternative Source**
   - Planetary nebulae → Few strong and well known emission line in the red band

NISP-TIPS simulation of Planetary nebulae spectral dispersion (GRed)



Based on ZEMAX model for optical distortion and dispersion, we synthesised many PN spectra in the entire FoV, introducing errors on the line position to mimic spectral line extraction error.

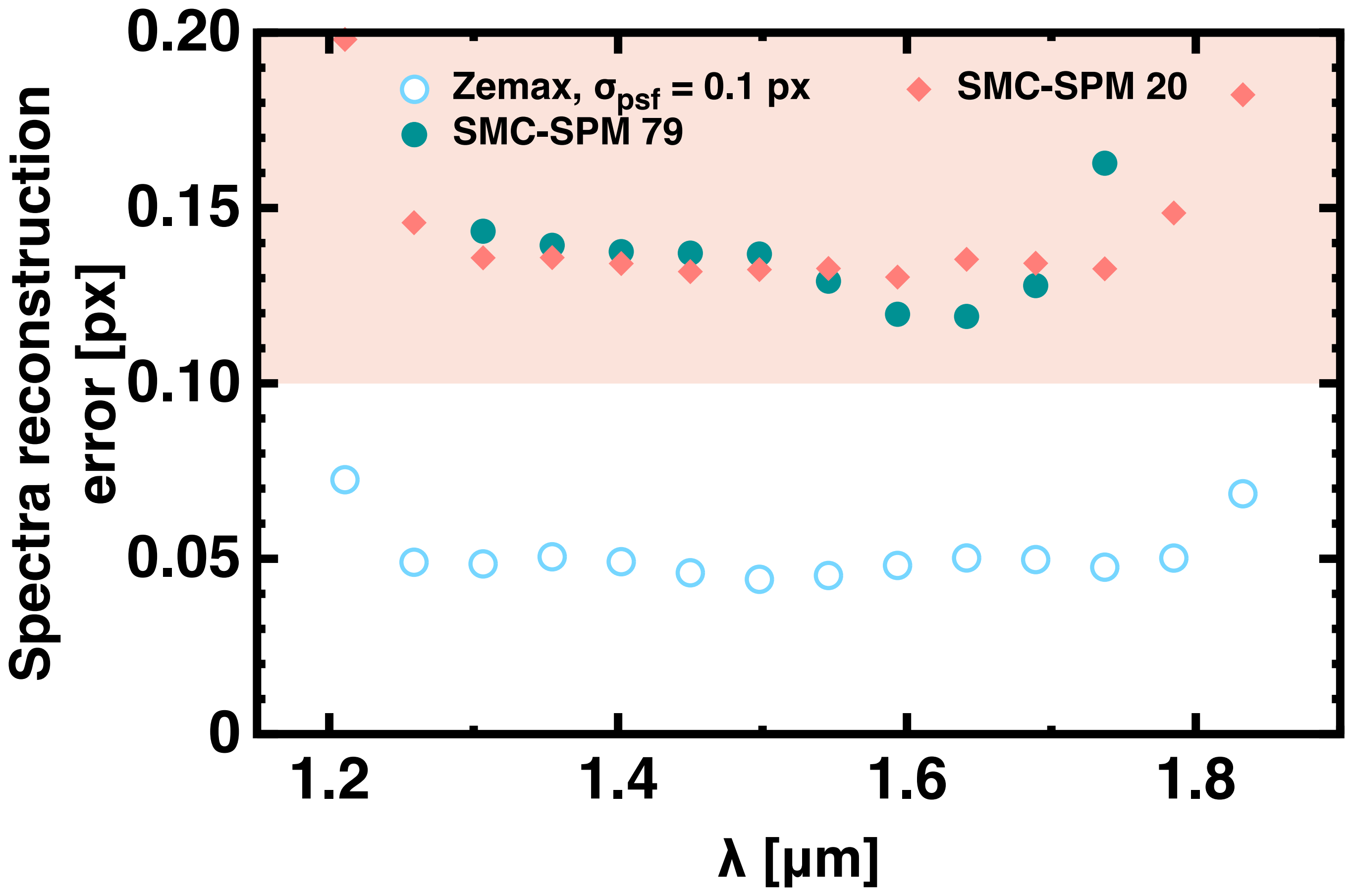
Synthesised spectra where used to calibrate the wavelength dispersion and calibration was tested upon the ZEMAX simulation.

In Flight calibration

1. **Alternative Source**

- Planetary nebulae → Few strong and well known emission line in the red band

The same PN was distributed on a grid of 5 PN/det (⚄). Misalignment correction error were added to the spectra to mimic the grism wheel misalignment in between each exposure.



- Despite they have both interesting line for calibration, most of the line are weak and difficult to extract
  - ⇒ Calibration error is high

How could we improve ?

In Flight calibration

1. Alternative Source

- Planetary nebulae → Few strong and well known emission line in the red band

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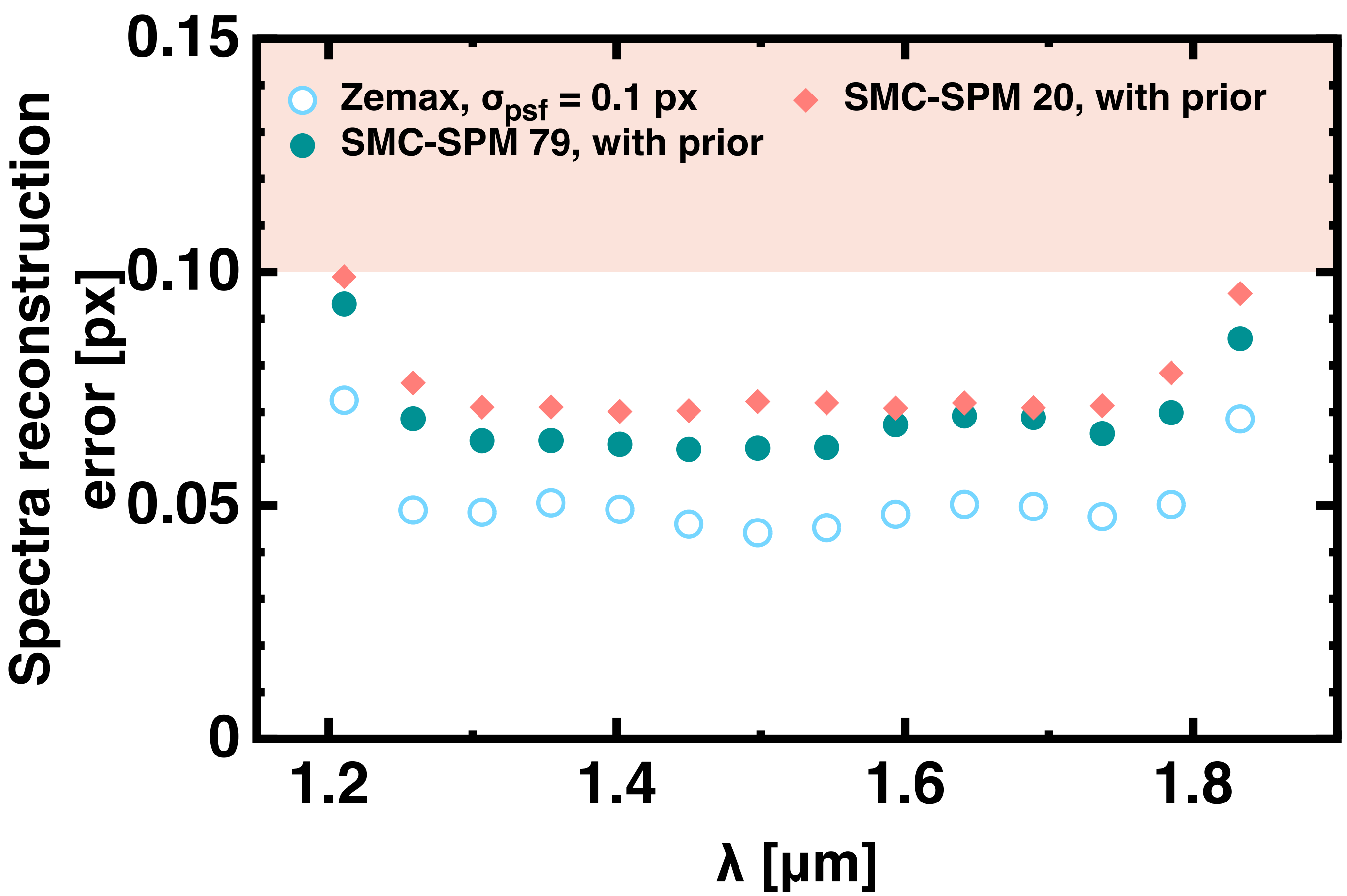

- Despite they have both interesting line for calibration, most of the line are weak and difficult to extract
  - ⇒ Calibration error is high

How coule we improve ?

- Assuming the calibration is stable, one could inject prior assumption, based on the ground calibration, to improve the calibration.

2. **In-flight calibration verification**

During PV-phase

- Planetary nebulae → Select targets, dither telescope to acquire multiple spectra of the PN at various position onto the FoV
- Wavelength calibration with Planetary nebulae shall be repeated at least two time during the first year of operation

Follow-on

- Direct slit less exposure of old stellar cluster, cross calibrating and verification of the instrument calibration using late type star (K-M classes)
- Monitoring stability of the dispersion solution using deep filed (every 6 month).

Summary

1. **Wavelength calibration philosophy**

Build up Zemax library for PSF

- Use ZEMAX optical simulation of the instrument to validate procedure
- Validate optical ZEMAX model with ground measurements,
- Use ZEMAX library as helper for in-flight calibration and monitoring.

Wavelength Calibration

- We developed a prototype procedure and test it onto ZEMAX optical simulation
  - Global fitting over the entire Field of View
- Fabry-Perot light source simulation permit to achieve a calibration precision better than 0.1 px,
- The lake of astrophysical object with many strong line in the red grism band require to propagate ground calibration to flight.