



SIPGI: an interactive pipeline for spectroscopic data reduction

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Outline

- What is SIPGI;
- the concept behind SIPGI;
- the three SIPGI pillars;
 - the graphical interface
 - the instrument model
 - the recipes organization
- the SIPGI performances;
- SpectraPy

What is SIPGI

SIPGI → **S**pectroscopic **I**nteractive **P**ipeline and **G**raphical **I**nterface

A complete spectroscopic reduction environment for optical and near-IR through-slit spectra with an

high level of flexibility and efficiency

SIPGI is descended from VIPGI (*Scodeggio et al. 2005*), the VIMOS spectroscopic pipeline we developed and used for the official reduction of the major VIMOS spectroscopic extragalactic surveys.

(e.g. **VVDS**, **zCOSMOS**, **VUDS**, **VIPERS**, **VANDELS** - *Garilli et al. 2008, Le Fevre et al. 2013, Lilly et al. 2007, Le Fevre et al. 2015, Guzzo et al. 2014, Garilli et al. 2014, Scodeggio et al. 2018, McLure et al. 2018, Pentericci et al. 2018, Garilli et al. 2021*)

What SIPGI is

SIPGI inherits the main concepts of VIPGI and extends reduction recipes to the **near-infrared**.

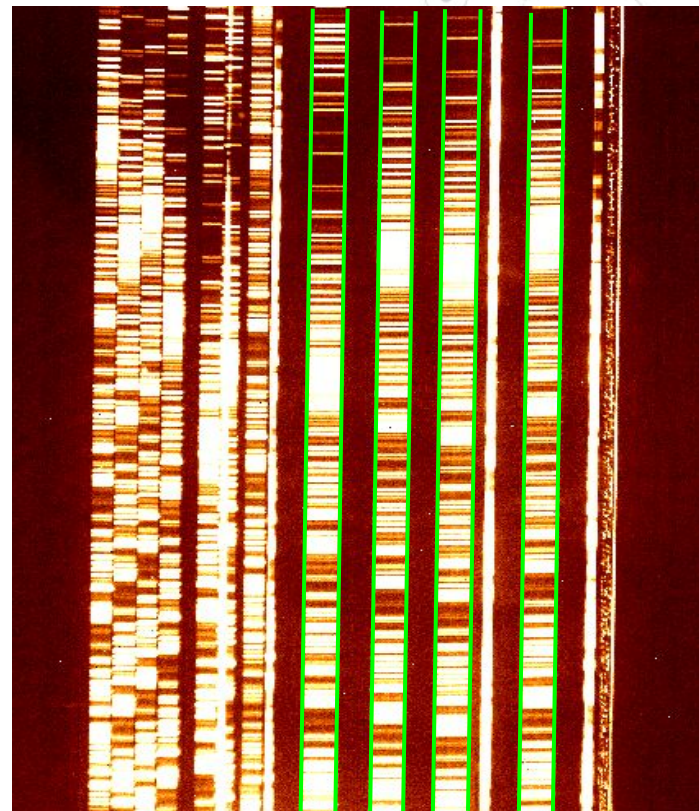
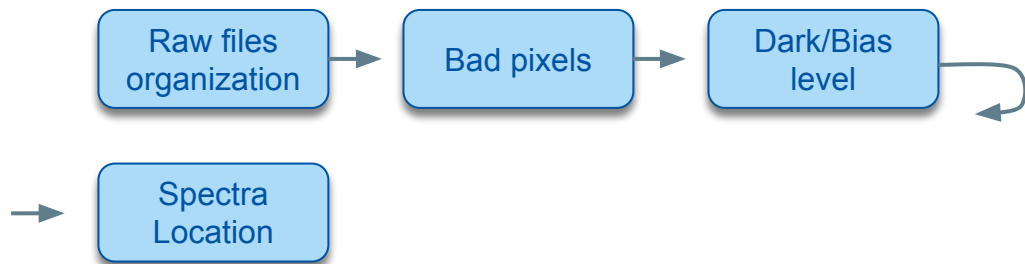


We customized SIPGI for the optical LBT/MODS and near-IR LBT/LUCI spectra → LBT spectroscopic reduction center @IASF-Mi

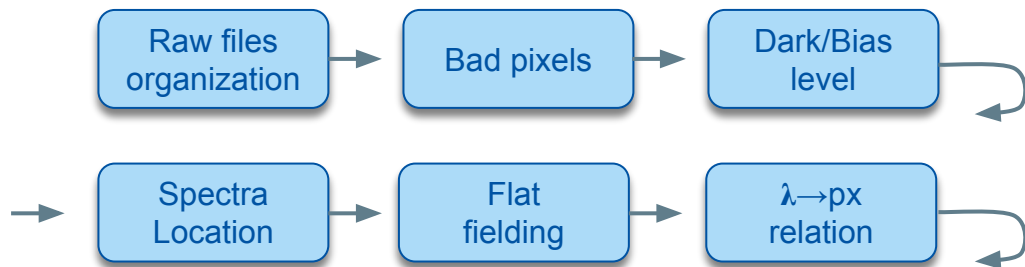


We released this LBT-customized SIPGI version
(*Gargiulo et al. submitted*)

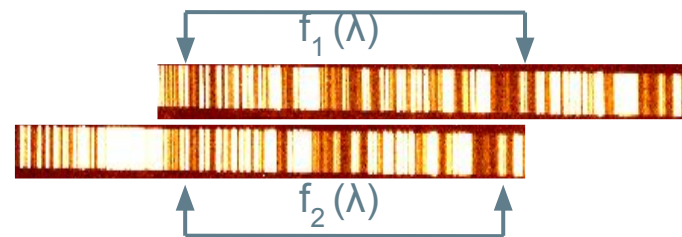
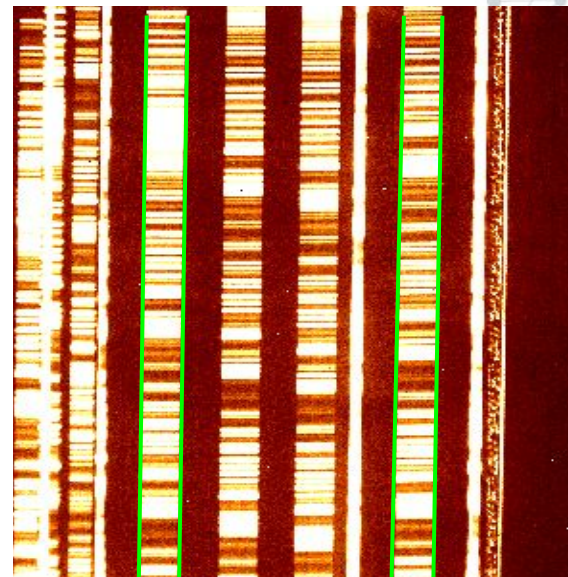
The main spectroscopic data-reduction steps



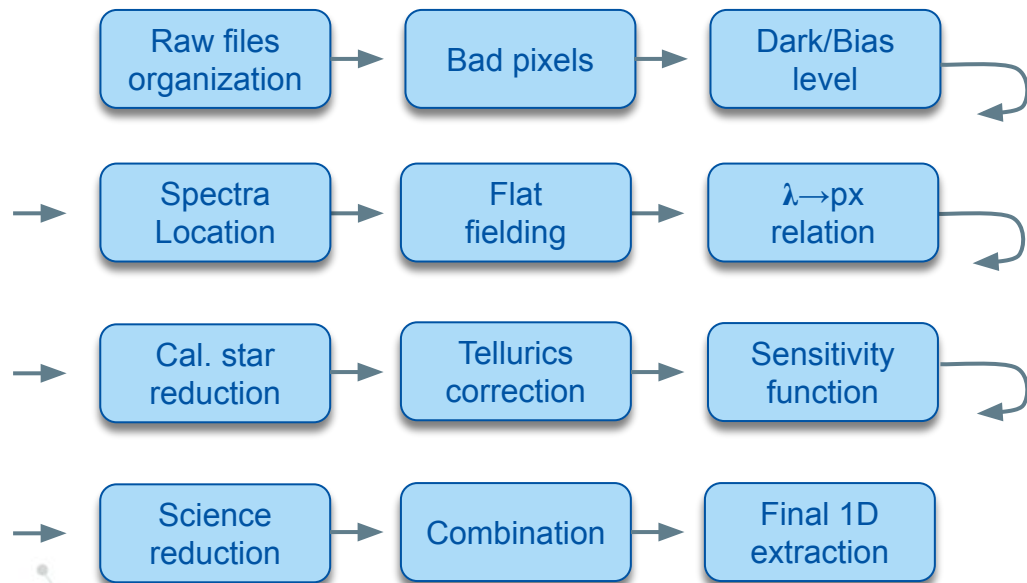
The main spectroscopic data-reduction steps



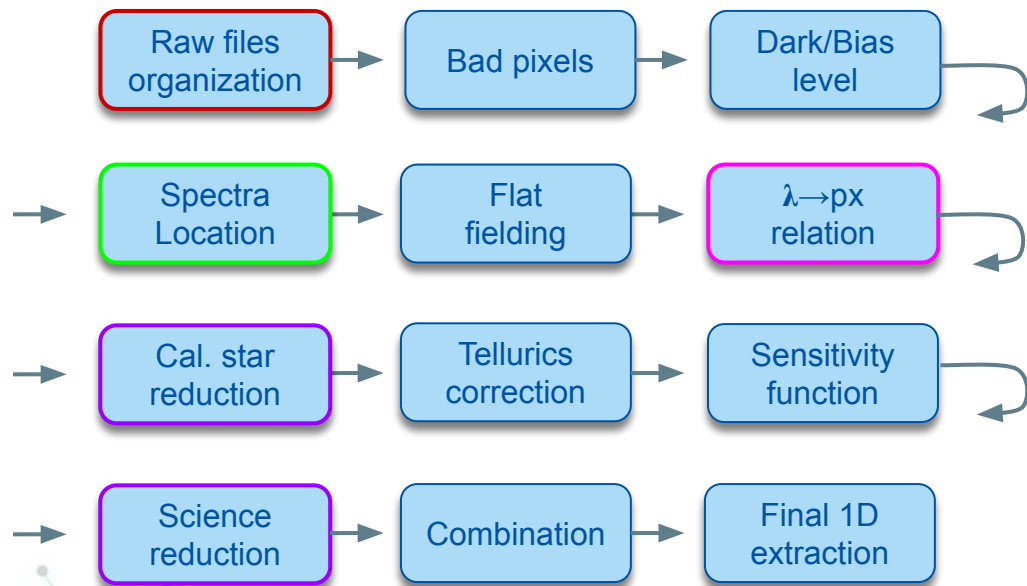
Both spectra location and $\lambda \rightarrow \text{px}$ relation must be estimated for each mask of the scientific project.



The main spectroscopic data-reduction steps



The concept behind SIPGI



Raw files organization:

identify science/star/lamp/flat frames;

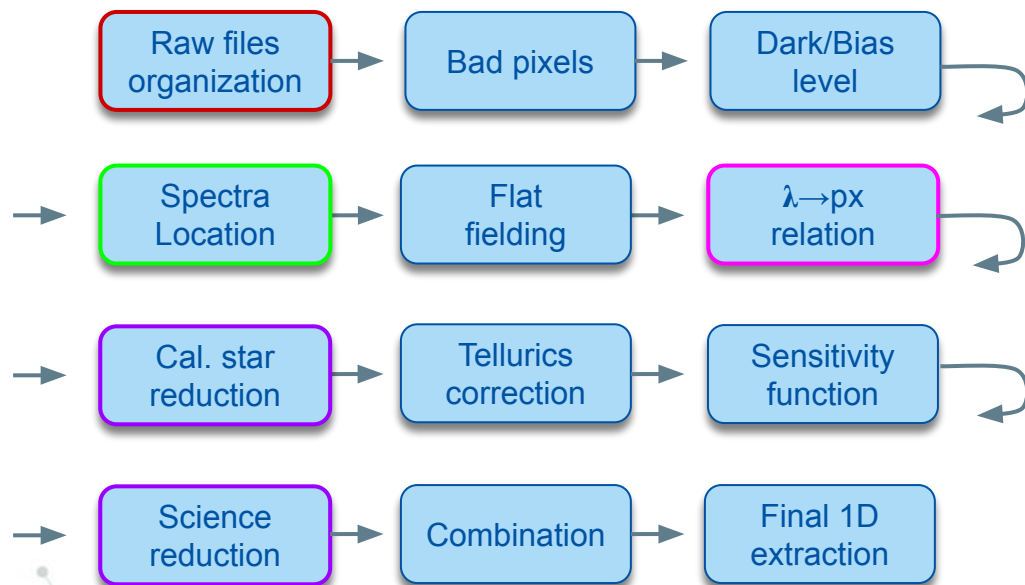
Spectra Location:

identify the location of each spectrum;

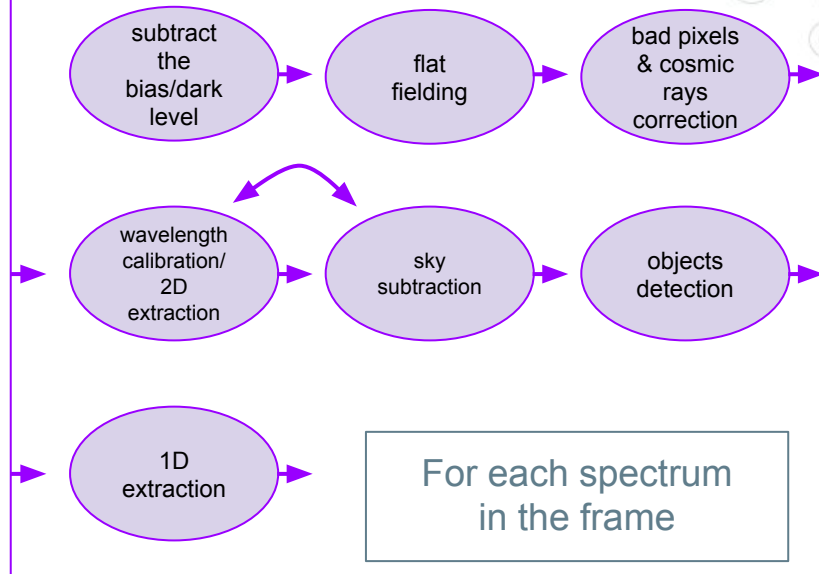
$\lambda \rightarrow px$ relation:

wavelength calibrate each slit;

The concept behind SIPGI



Single frame reduction:



The three main SIPGI pillars

1. The built-in data organizer and the graphical interface;

Raw files
organization

2. The instrument model;

Spectra
Location

$\lambda \rightarrow px$ relation

MOST INNOVATIVE
SIPGI ASPECT

3. The recipe organization


Frame
reduction

The three main SIPGI pillars

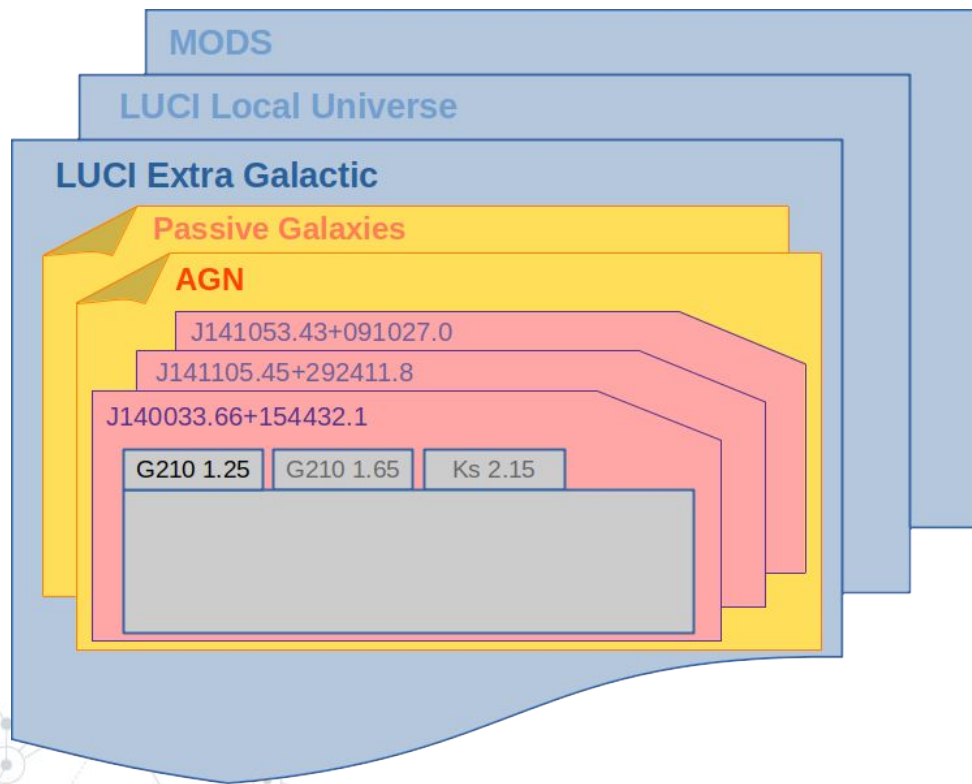


Raw files
organization

1. The built-in data organizer and the graphical interface

- Sipgi ingests raw data and, using FITS header keywords, categorizes them according to their data-type (bias/dark/flat/science/etc);
 - the graphical interface allows to easily browse across the categorized data and to provide the right input to the right recipe.
- 

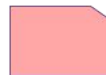
The three main SIPGI pillars - *the organizer*



workspace



project

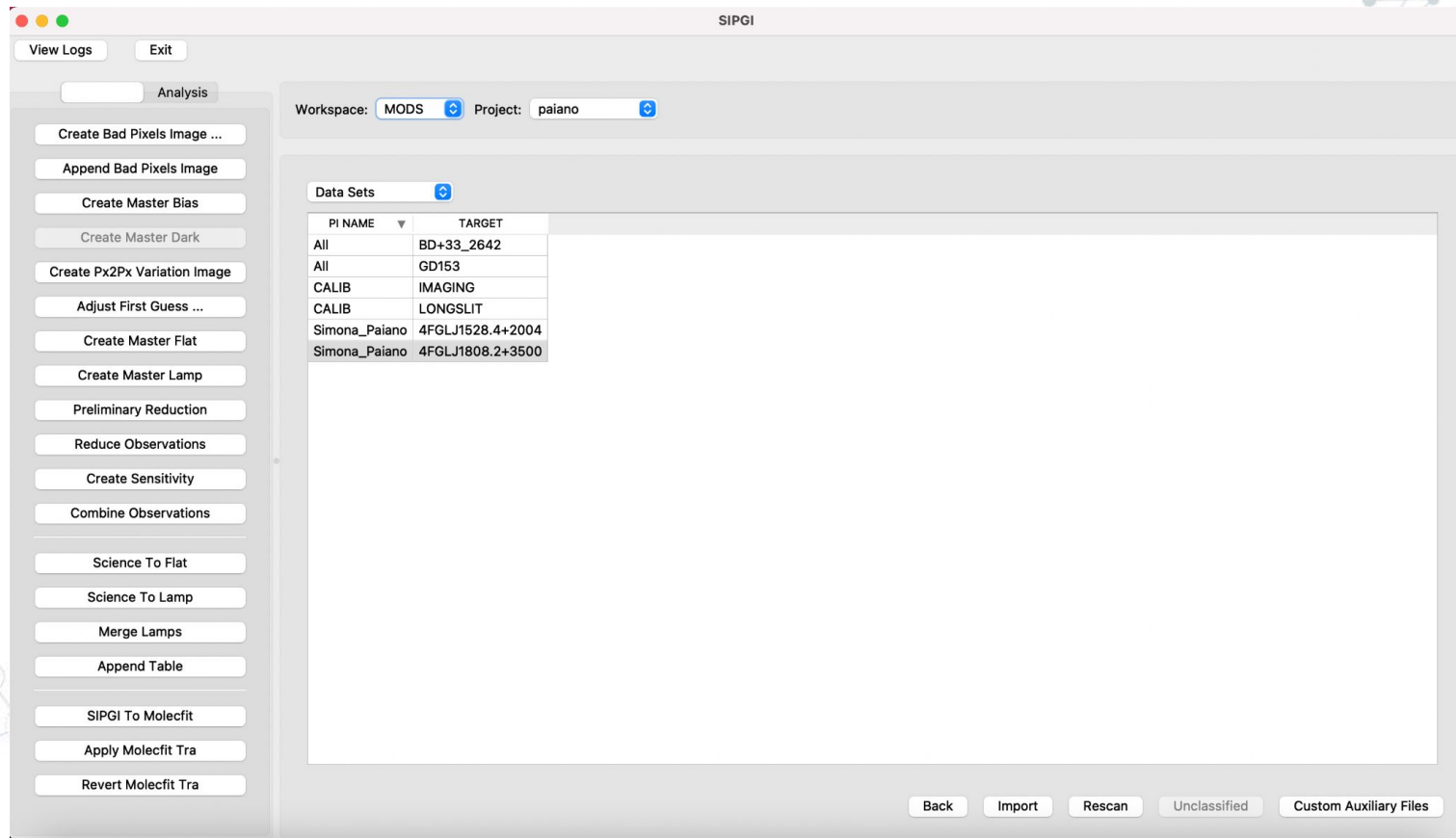


dataset

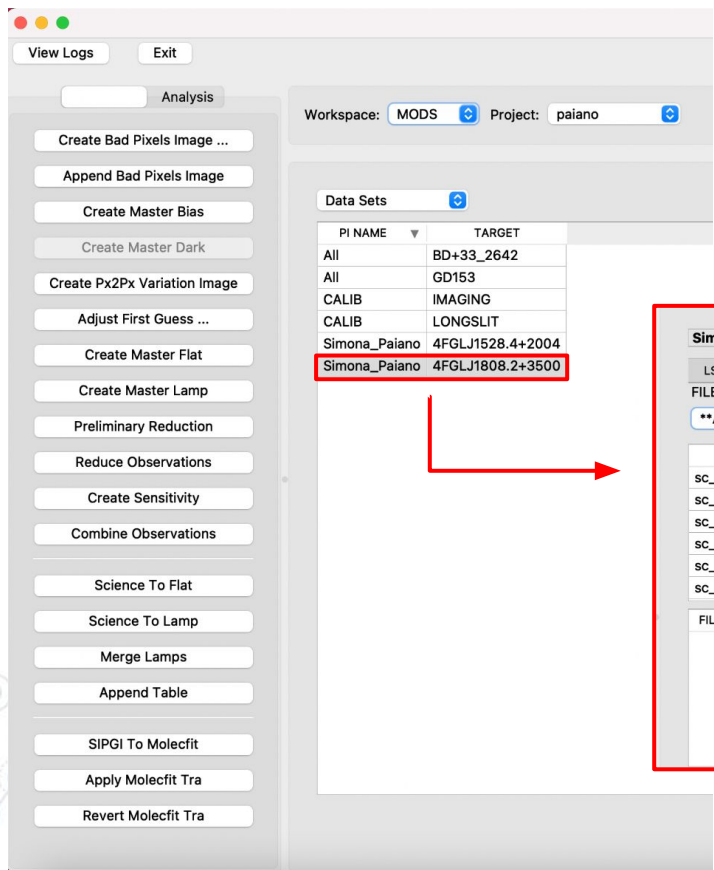


reduction unit

The three main SIPGI pillars - *the graphical interface*



The three main SIPGI pillars - *the graphical interface*



Simona_Paiano-4FGLJ1808.2+3500

FILETYPE	OBSERVING NIGHT	ORIGIN	EXPTIME	ARM
ALL	**ALL**	**ALL**	**ALL**	**ALL**

FILENAME	FILETYPE	FILTER NAME	ARM	EXPTIME	DATE OBS
sc_4FGLJ1808.2+3500_LS5x60x1.2_G400L_Dual_001.fits	SCIENCE	Clear	MODS1B	900.0	05/10/21 09:51:3
sc_4FGLJ1808.2+3500_LS5x60x1.2_G400L_Dual_002.fits	SCIENCE	Clear	MODS1B	900.0	05/10/21 10:09:0
sc_4FGLJ1808.2+3500_LS5x60x1.2_G400L_Dual_003.fits	SCIENCE	Clear	MODS1B	900.0	05/10/21 10:26:1
sc_4FGLJ1808.2+3500_LS5x60x1.2_G400L_Dual_004.fits	SCIENCE	Clear	MODS1B	900.0	05/10/21 10:43:3
sc_4FGLJ1808.2+3500_LS5x60x1.2_G400L_Dual_005.fits	SCIENCE	Clear	MODS1B	900.0	05/10/21 11:00:4
sc_4FGLJ1808.2+3500_LS5x60x1.2_G400L_Dual_006.fits	SCIENCE	Clear	MODS2B	900.0	05/10/21 09:56:4

Below the table, there are dropdown menus for 'FILENAME' and 'FILETYPE', and a label 'ARM'.

The three main SIPGI pillars

2. The instrument model

- an analytical description of the main calibration relations:
 - the **slit location** model;
 - the **spectra location** model;
 - the **lambda calibration** model.



Spectra
Location

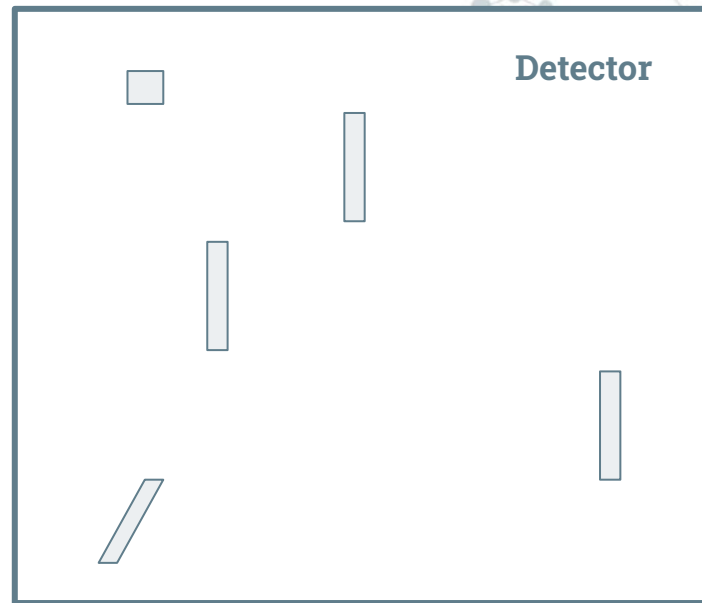


$\lambda \rightarrow px$ relation

The three main SIPGI pillars - *the instrument model*

2.1 The slit location model

Given the instrument configuration (e.g. grism, mask, detector...), it is possible to predict the nominal positions of the slits on the detector.

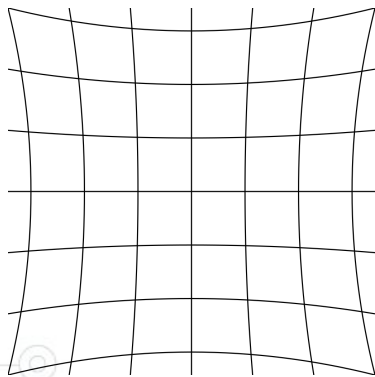


□ Slits nominal positions on detector

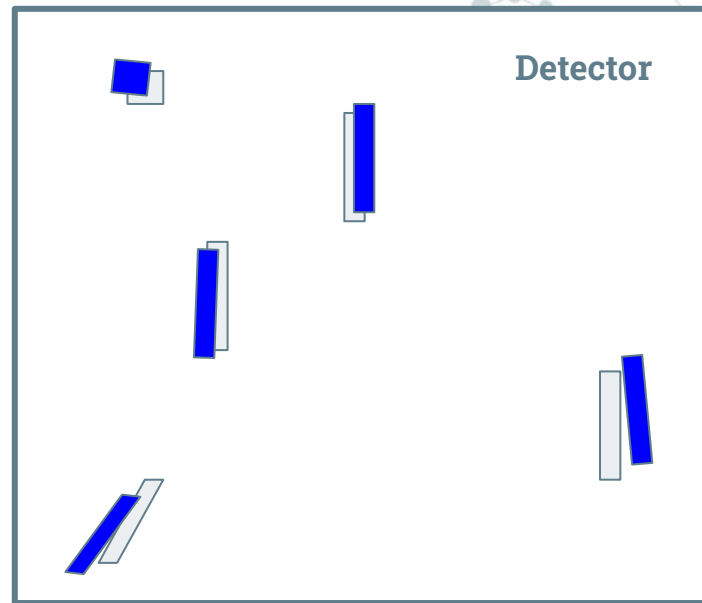
The three main SIPGI pillars - *the instrument model*

2.1 The slit location model

Instrument **optical distortions** affect these positions.



Instrument optical distortions representation

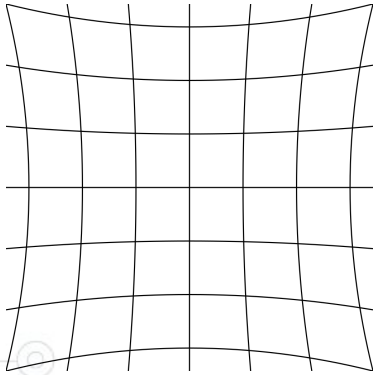


- Slits nominal positions on detector
- Real slits positions on detector

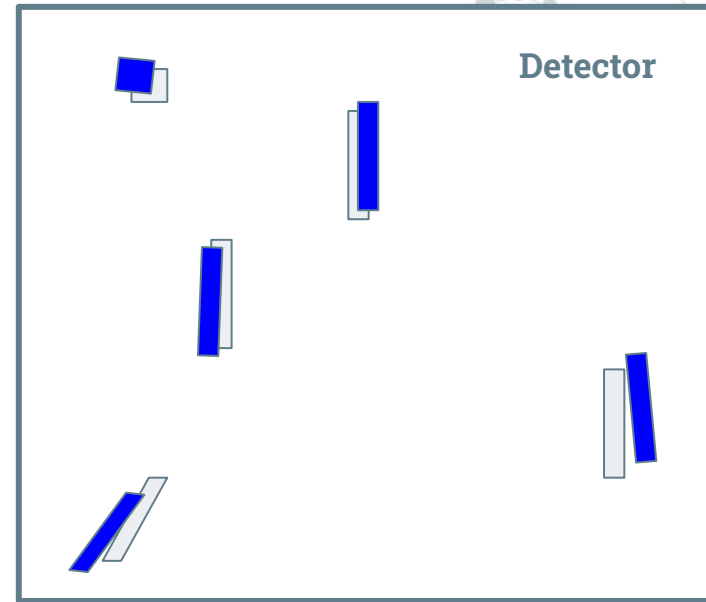
The three main SIPGI pillars - *the instrument model*

2.1 The slit location model

The **slit location model** analytically describes the **optical distortions**: it provides the real position of the slits on the detector.



Instrument optical distortions representation

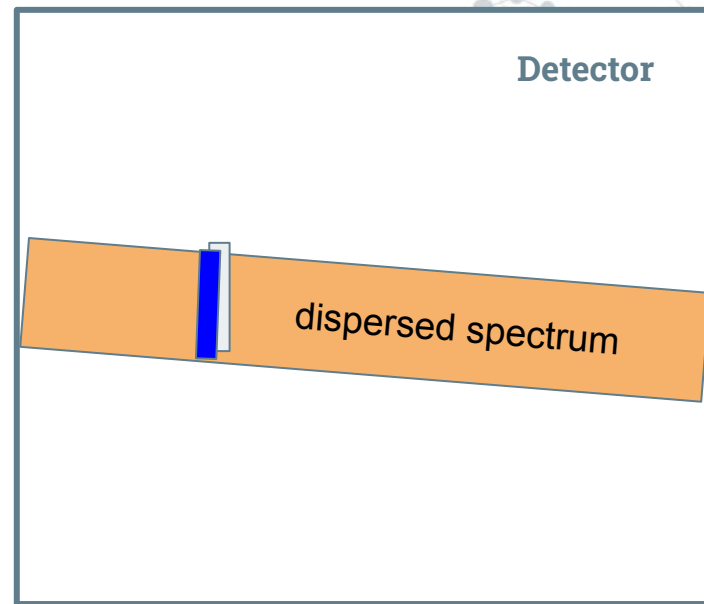


- Slits nominal positions on detector
- Real slits positions on detector

The three main SIPGI pillars - *the instrument model*

2.2 The spectra location model

Once known the real slit position, in principle we can predict the spectra location.

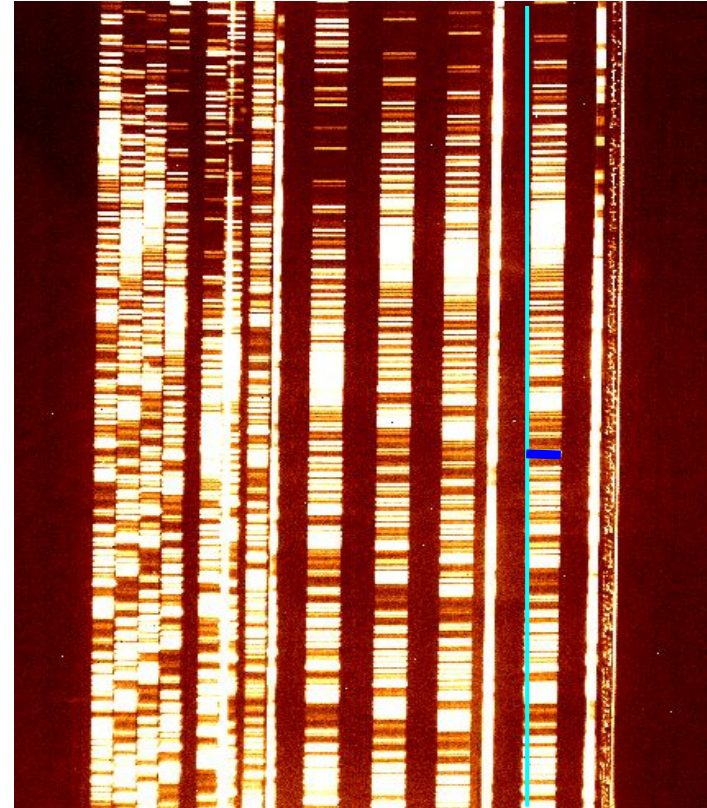
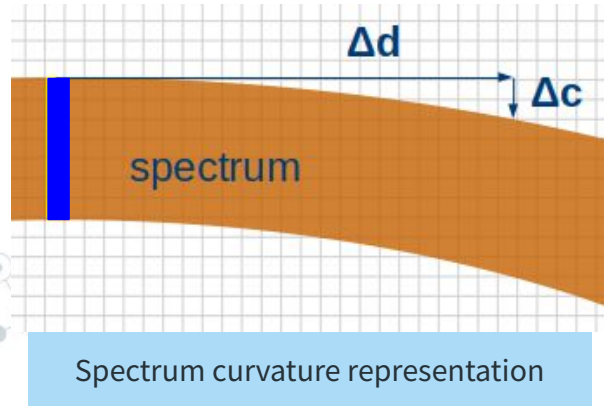


- Slits nominal positions on detector
- Real slits positions on detector

The three main SIPGI pillars - *the instrument model*

2.2 The spectra location model

The **spectra location model** analytically describes the spectra **displacement** (Δc) wrt the **ideal dispersion direction** as a function of the distance from the slit position (Δd).

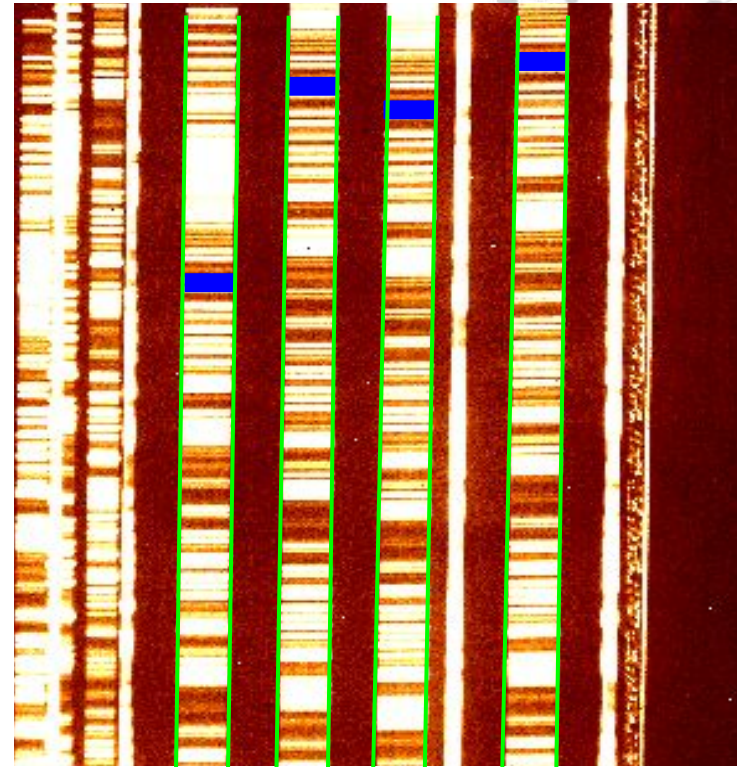


The three main SIPGI pillars - *the instrument model*

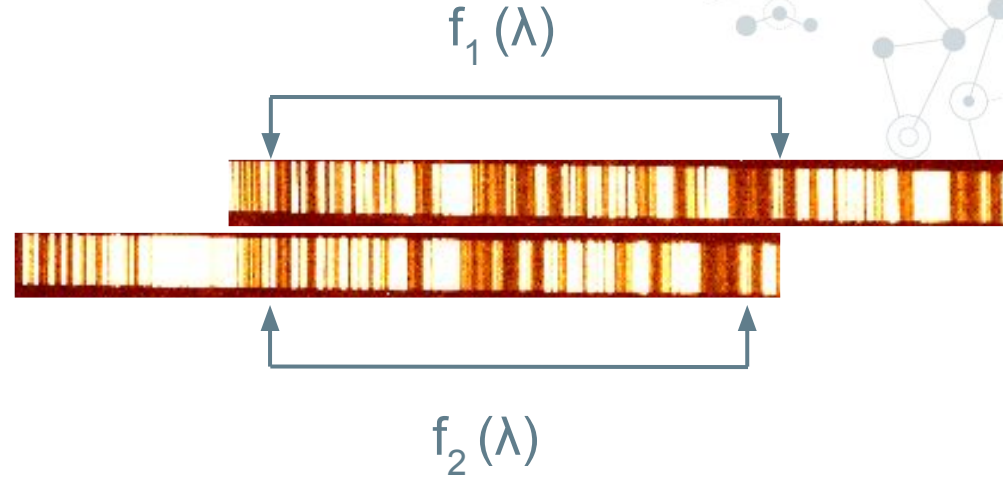
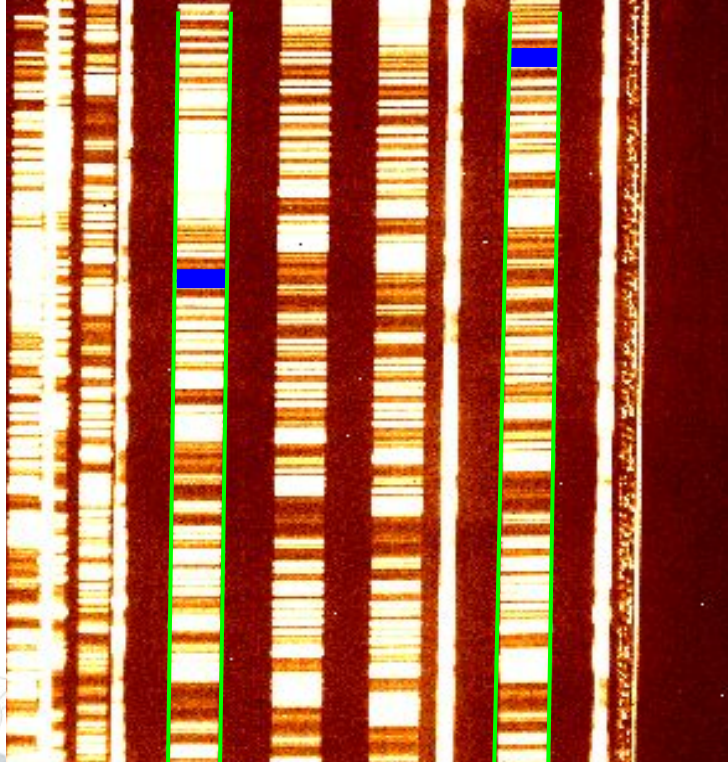
2.3 The lambda calibration model

Once known the instrument configuration, the slits positions, and the spectra location, we could exactly predict the λ to be associated to each pixel of the slits.

Optical distortions affect this relation.



The three main SIPGI pillars - *the instrument model*



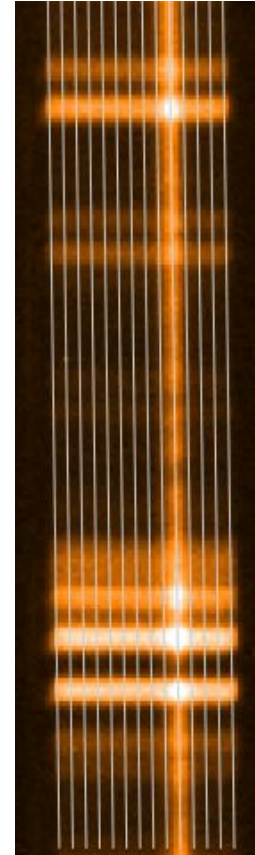
The wavelength solution continuously changes moving along the cross dispersion direction.

The three main SIPGI pillars - *the instrument model*

2.3 The lambda calibration model

We treat each pixel-column of each slit as a 1D spectrum.

The **lambda calibration model** analytically describes
the $\lambda \rightarrow$ pixel relation



A decorative network diagram at the top of the slide, featuring a complex web of interconnected nodes and lines. The nodes are represented by circles of varying sizes and shades of gray, some with concentric circles. The lines are thin and gray, connecting the nodes in a non-uniform, organic pattern.

Models are mask independent

- **Given an instrument configuration:** grism, camera, dichroic, ... models are mask independent. Once the models are calibrated, **if the instrument is stable, they describe every mask.**
- We **calibrated** each model on **real data** for all the standard LBT-MODS/LUCI configurations.
- The SIPGI version we released includes all these instrument models.

The three main SIPGI “pillars”

Distortions can change on nightly basis.

The **models** can be **checked and adjusted** using a graphical tool.

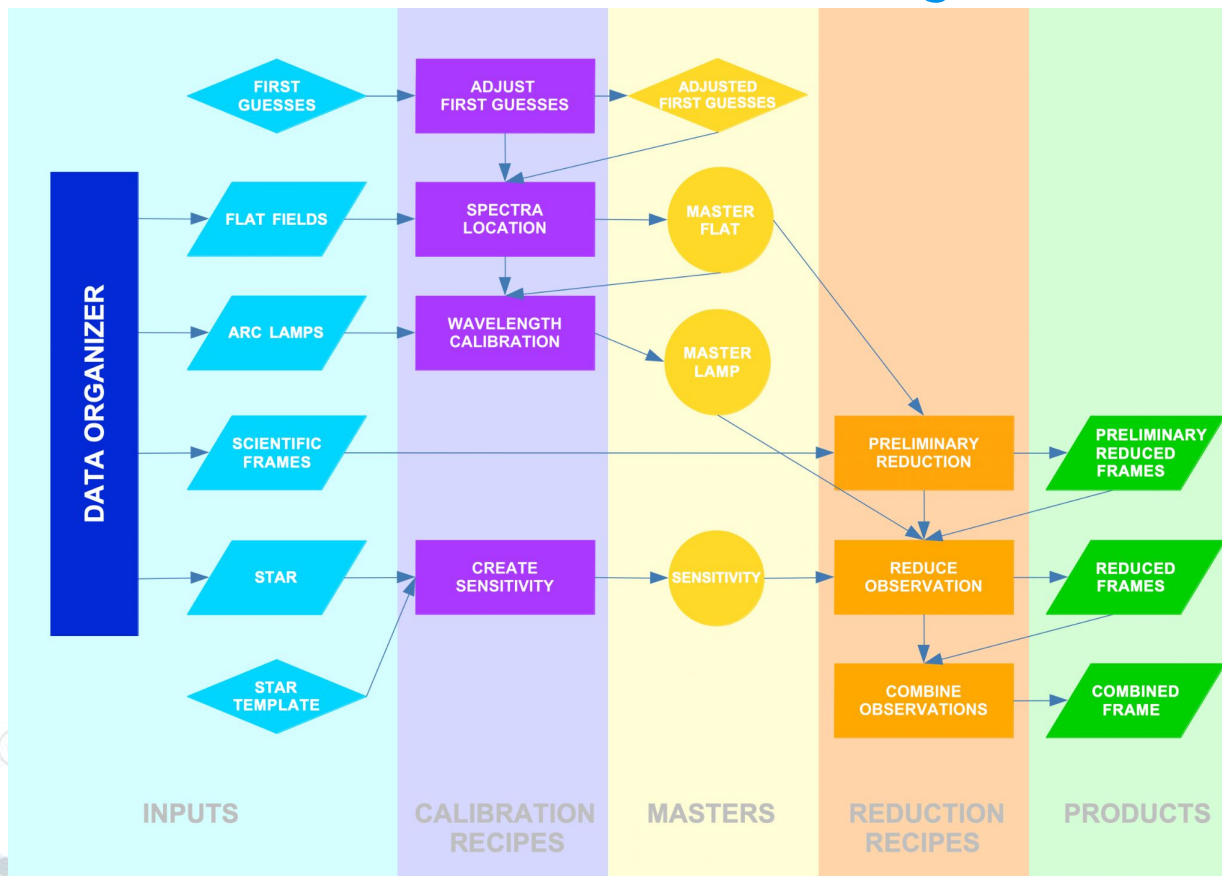


The three main SIPGI “pillars”

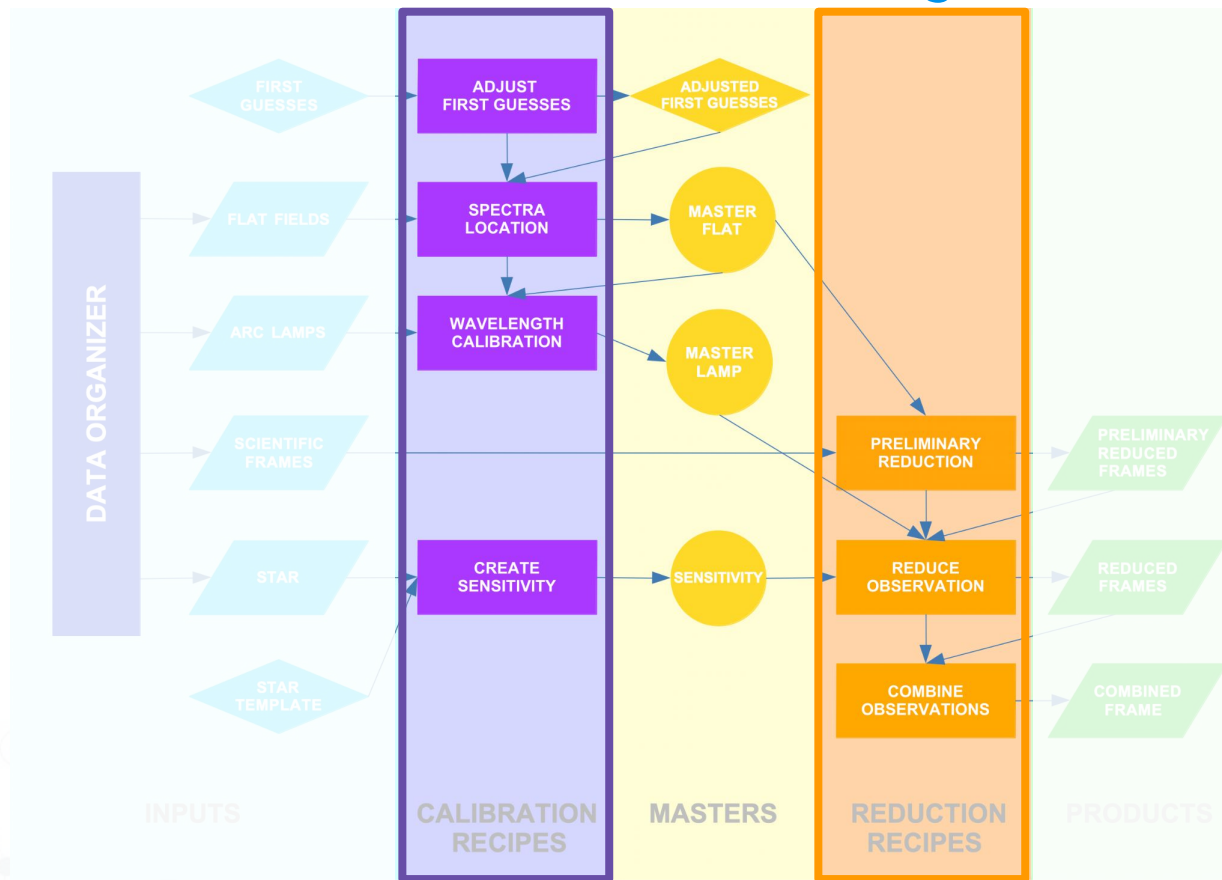
3. The recipe organization

- a complete reduction can be performed executing just 7 recipes;
- the recipes number is minimized while preserving the possibility to verify the main stages of data-reduction process with provided tools;
- the specific behaviour of each recipe is controlled through a set of input parameters set by the user.

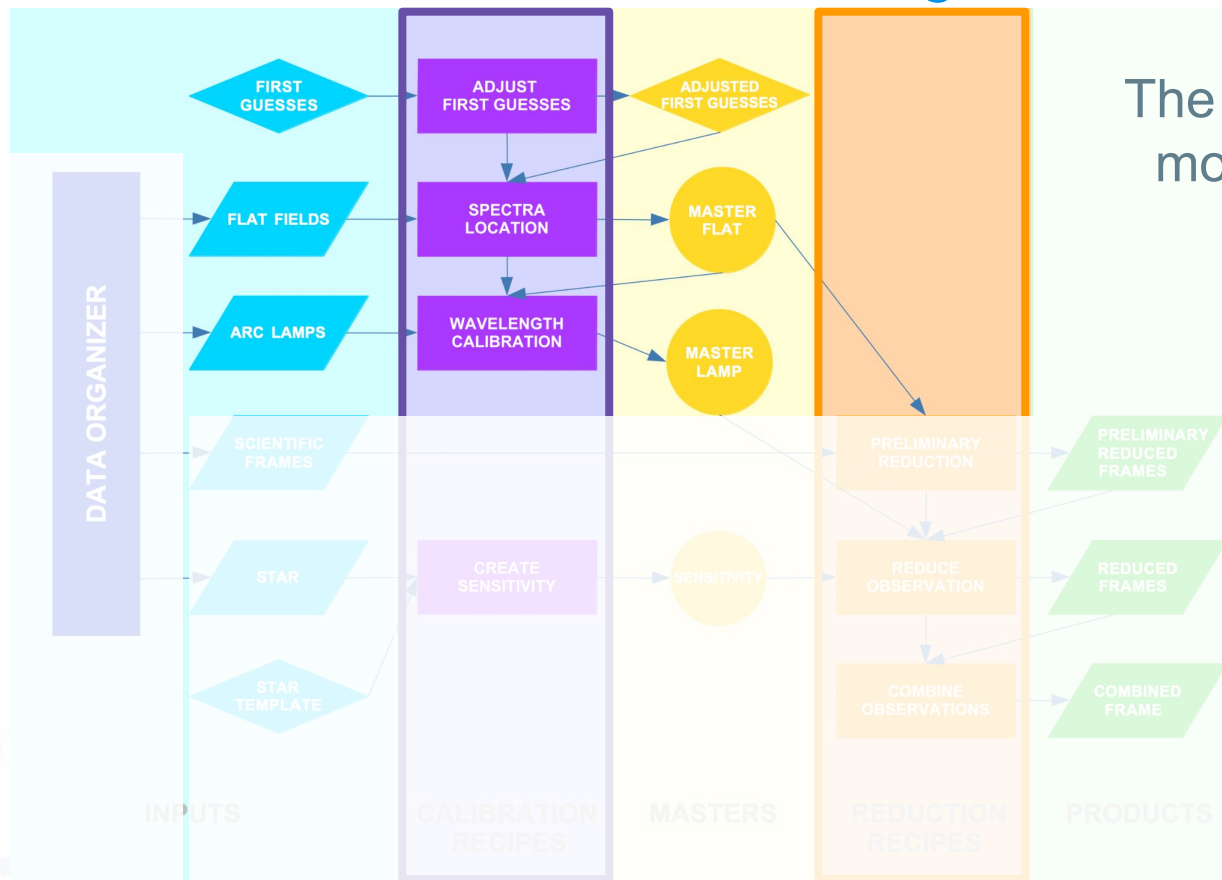
The logical scheme of SIPGI functioning



The logical scheme of SIPGI functioning

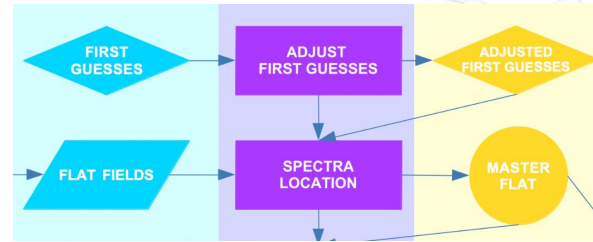


The logical scheme of SIPGI functioning



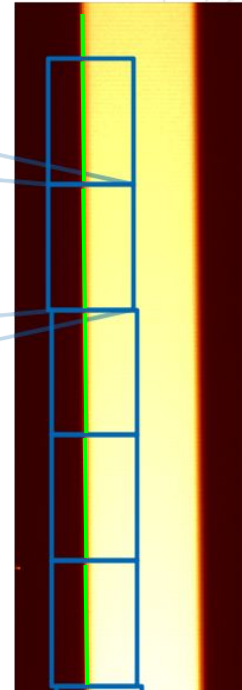
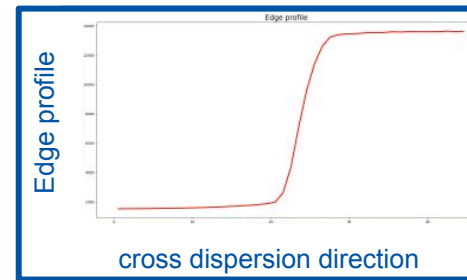
The instrument
model realm

Spectra tracing refinement (Create Master Flat)

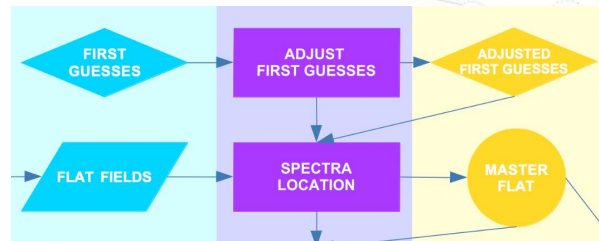


The Create Master Flat recipe refines the spectral tracing for each slit.

- It uses the **adjusted first guesses** of the spectra location model to locate the spectrum position on flat frame;
- It cuts thumbnails along the edge and collapses them in the dispersion direction to create the edge profile;
- It computes the numerical derivative of the profile and identifies the edge position as the point of maximum curvature;
- It fits the edge positions to define the **real spectrum trace**;

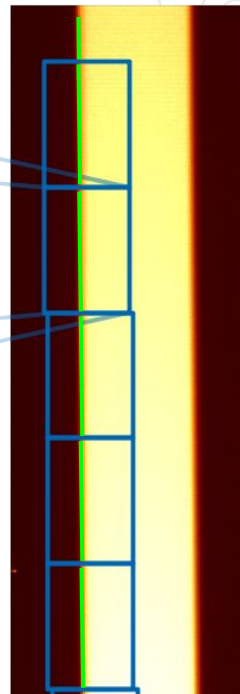
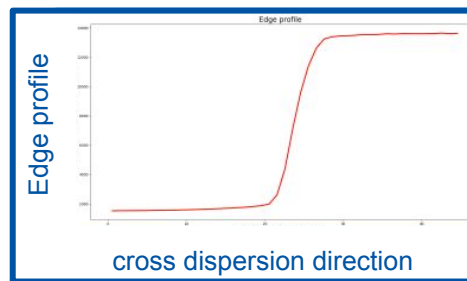


Spectra tracing refinement (Create Master Flat)

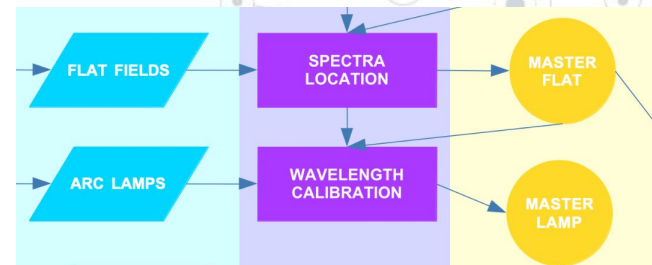


Output: Master Flat (first calibrator)

- spectra location;
- px-to-px variation;
- the adjusted first guesses of the lambda calibration model.

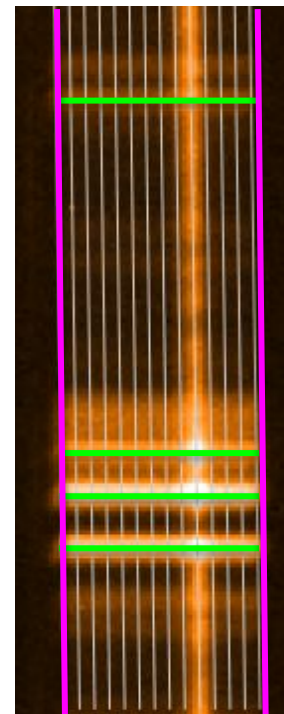


Lambda calibration refinement (Create Master Lamp)

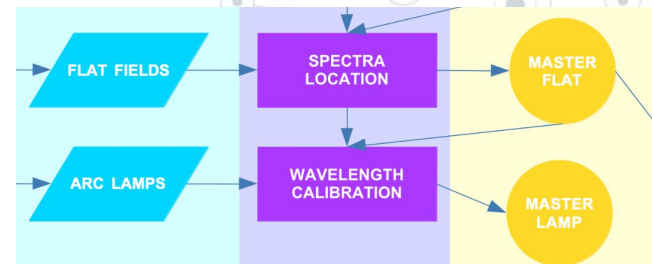


The Create Master Lamp recipe refines the wavelength solution for each pixel-column of each slit

- It applies the adjusted lambda calibration model to locate the lines;
- It slices the 2D spectra in 1-pixel spectra;

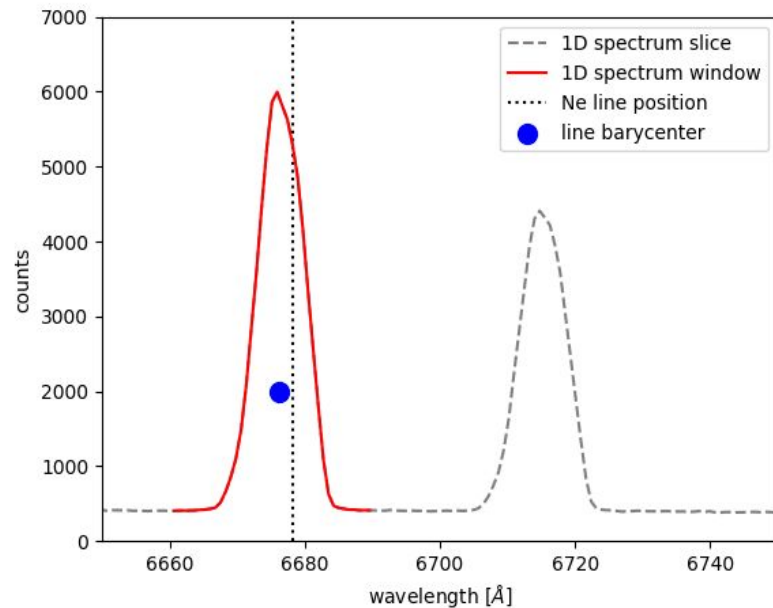


Lambda calibration refinement (Create Master Lamp)

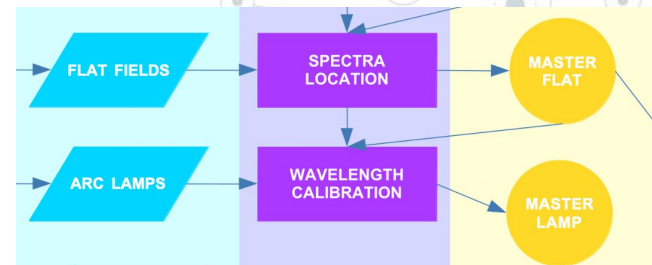


The Create Master Lamp recipe refines the wavelength solution for each pixel-column of each slit

- It applies the adjusted lambda calibration model to locate the lines;
- It slices the 2D spectra in 1-pixel spectra;
- It lambda-calibrates the 1d-spectra applying the adjusted model;
- It measures the **real line position** as the barycenter of a spectrum region set by the user;

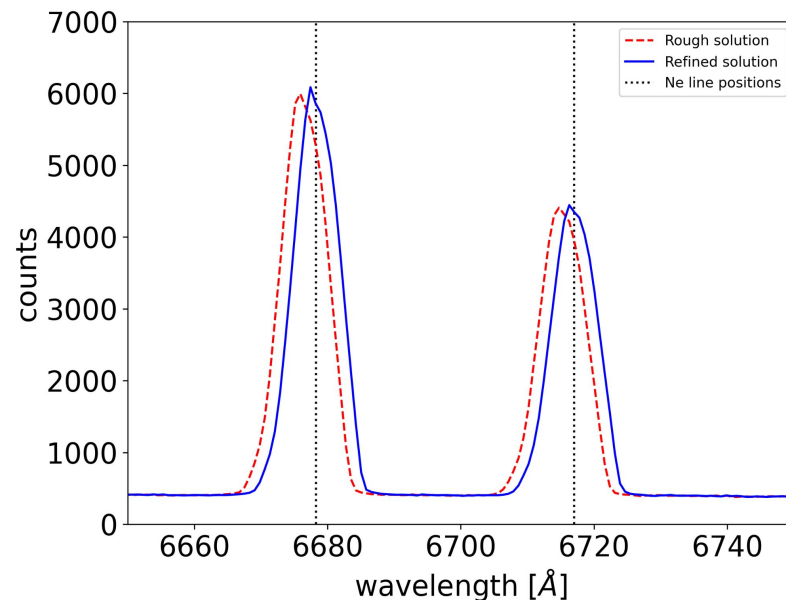


Lambda calibration refinement (Create Master Lamp)

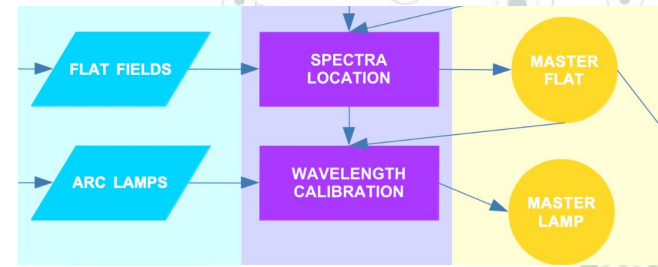


The Create Master Lamp recipe refines the wavelength solution for each pixel-column of each slit

- It applies the adjusted lambda calibration model to locate the lines;
- It slices the 2D spectra in 1-pixel spectra;
- It lambda-calibrates the 1d-spectra applying the adjusted model;
- It measures the **real line position** as the barycenter of a spectrum region set by the user;
- It fits the real lines positions (i.e. all the ●) to defines the real lambda-calibration relation.



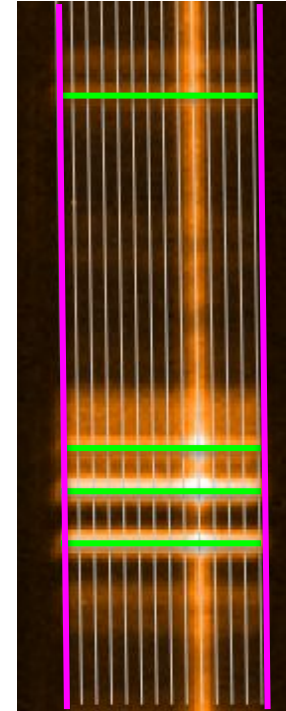
Lambda calibration refinement (Create Master Lamp)



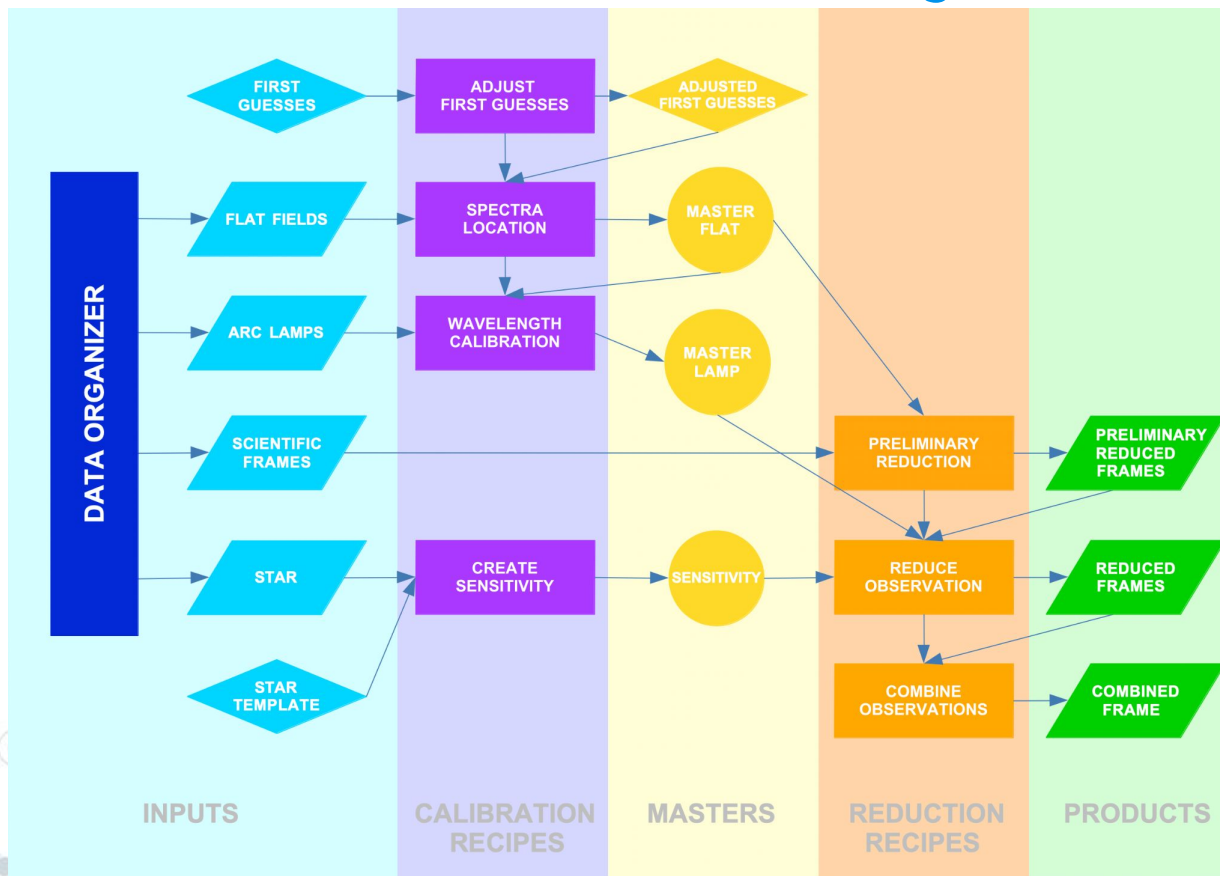
Output: Master Lamp (second calibrator)

For each slice of each slit, user has now
a model that describes the wavelength solution

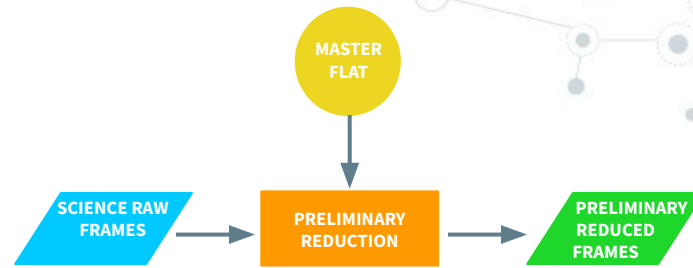
$$m_{\text{slit}}(n_{\text{slice}}, \lambda)$$



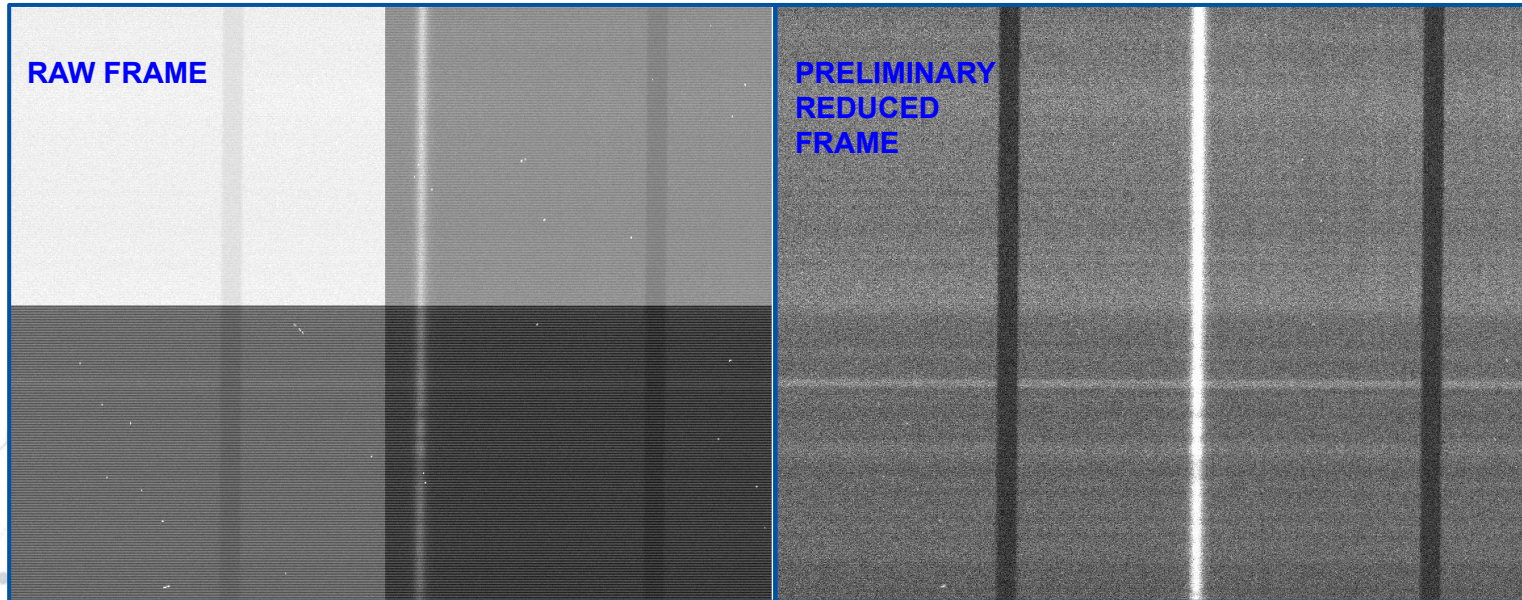
The logical scheme of SIPGI functioning



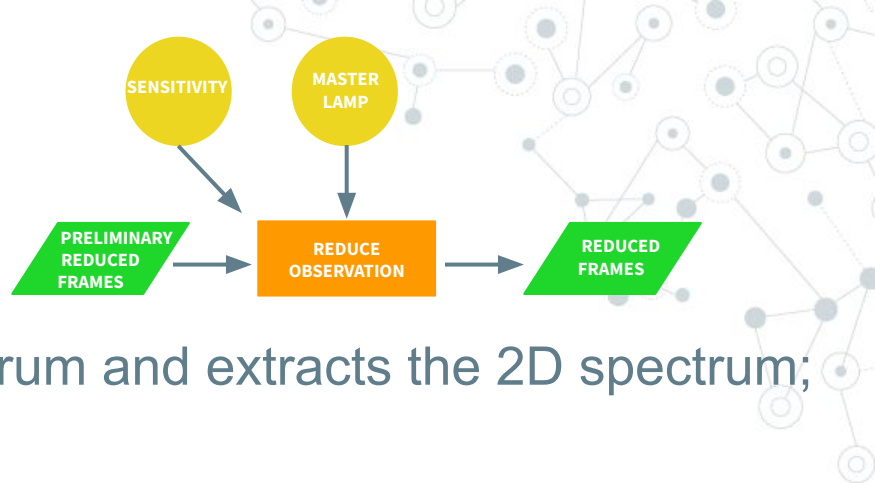
The preliminary reduction



The recipe: **1.** subtracts the bias/dark level; **2.** corrects for px-to-px variation; **3.** corrects bad pixels and cosmic rays.



Reduce Observation



The recipe:

- **wavelength calibrates** each spectrum and extracts the 2D spectrum;
- **detects objects**;
- **extracts 1D spectrum**.

Optionally:

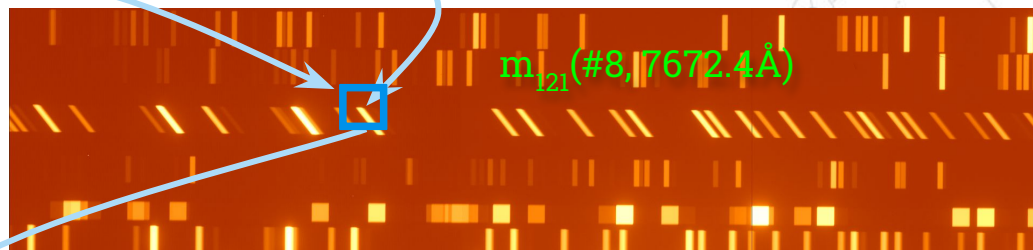
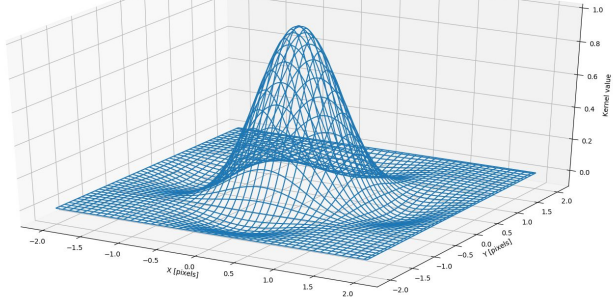
- **performs the sky subtraction** (both on wavelength-calibrated and not calibrated frames). It can estimate the background level:
 - from the frame itself;
 - from dithered frames, e.g. ABBA/Davies (Davies only for LUCI wavelength calibrated frames);
- **flux calibrates 1D spectra** (and possibly also 2D spectra)

2D extraction

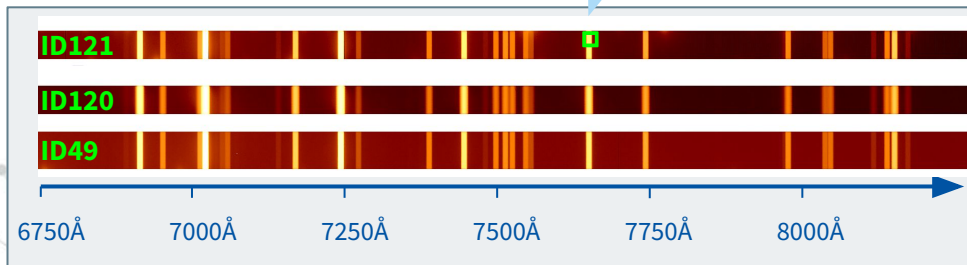
Models: $m_{\text{slit}}(n_{\text{slice}}, \lambda) \rightarrow \text{pixel}$

$$\lambda \in [\lambda_{\min}, \lambda_{\max}]$$
$$\Delta\lambda = \lambda_{n+1} - \lambda_n$$

The resampling kernel



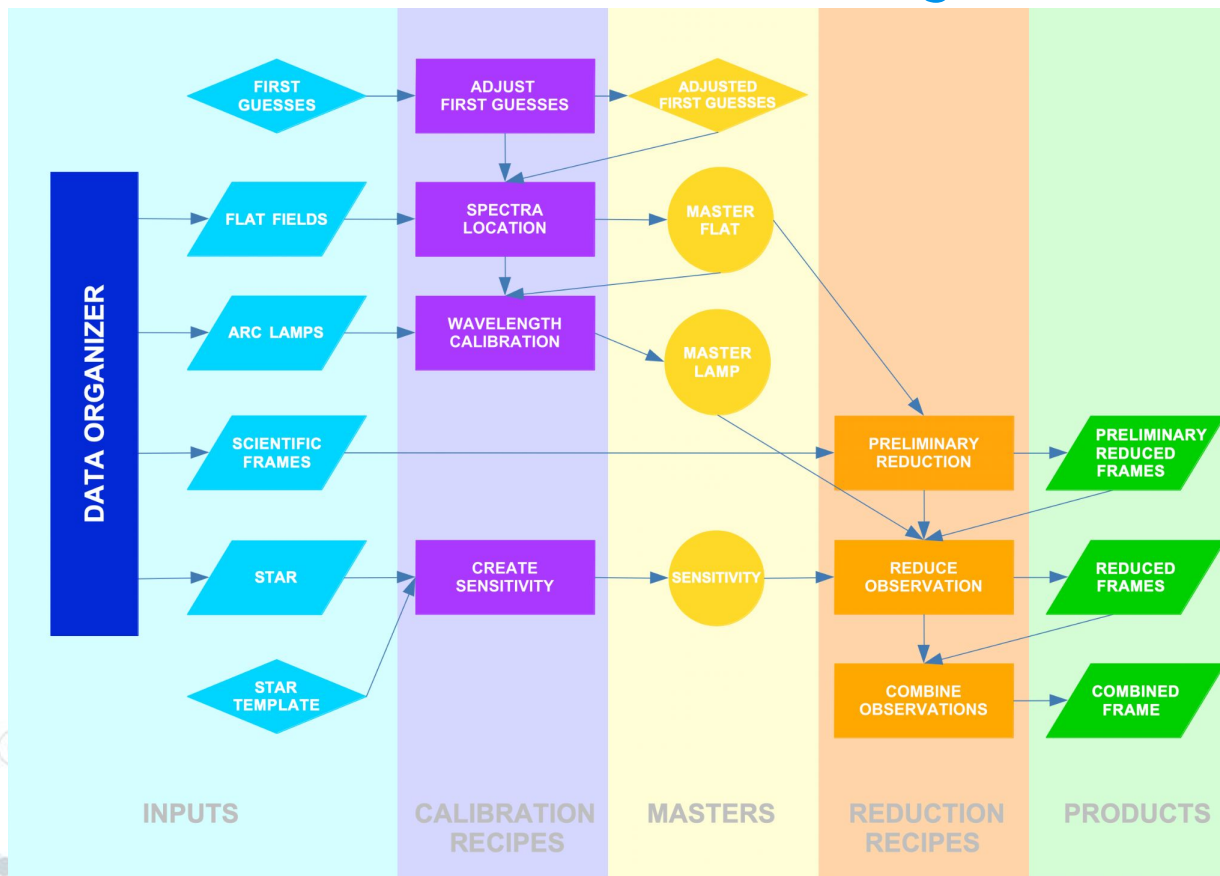
4



SIPGI:

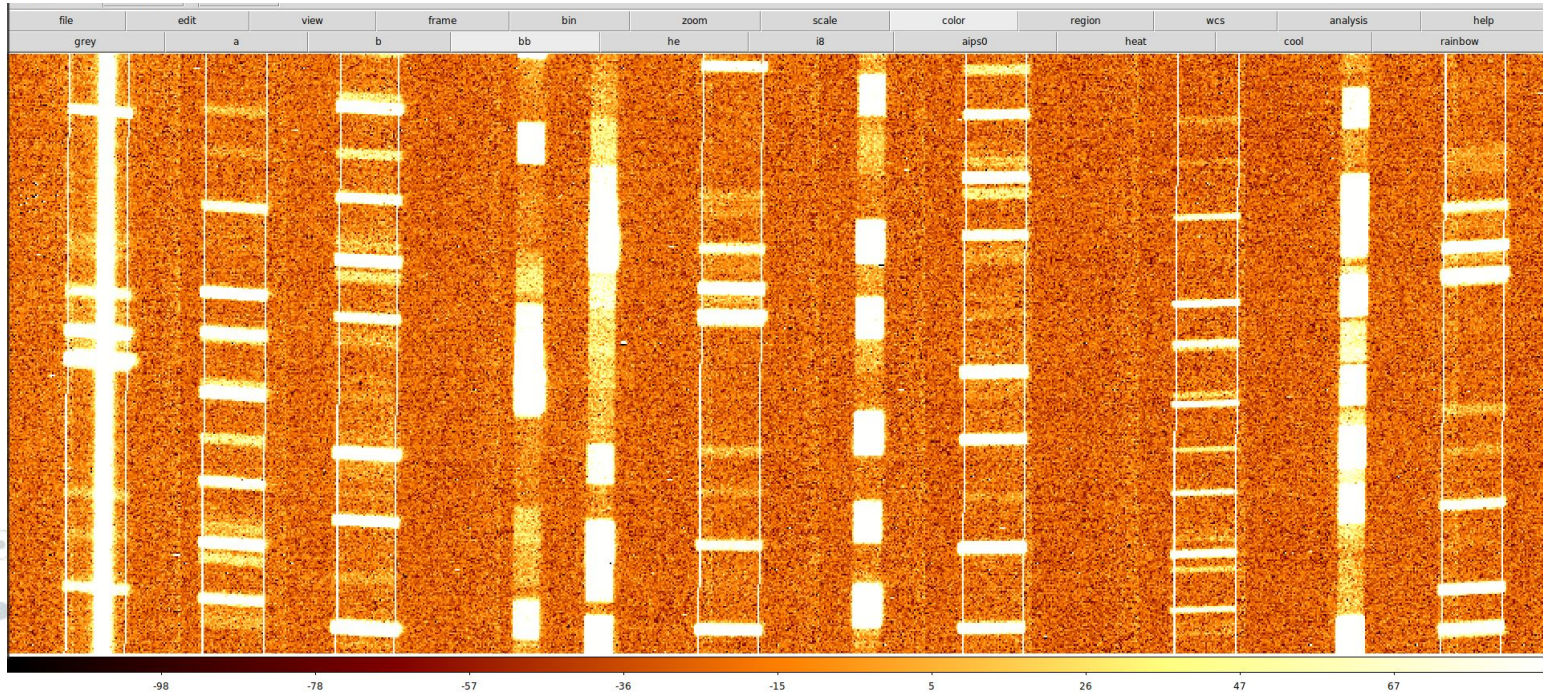
1. ingests the λ -range and $\Delta\lambda$;
2. for each slit, uses its **refined models** (m_{slit}) to locate wavelengths (of the current slice) on the frame;
3. applies the 2D **resampling kernel**;
4. extracts 2D spectra **λ -calibrated** and **corrected by distortions**.

The logical scheme of SIPGI functioning



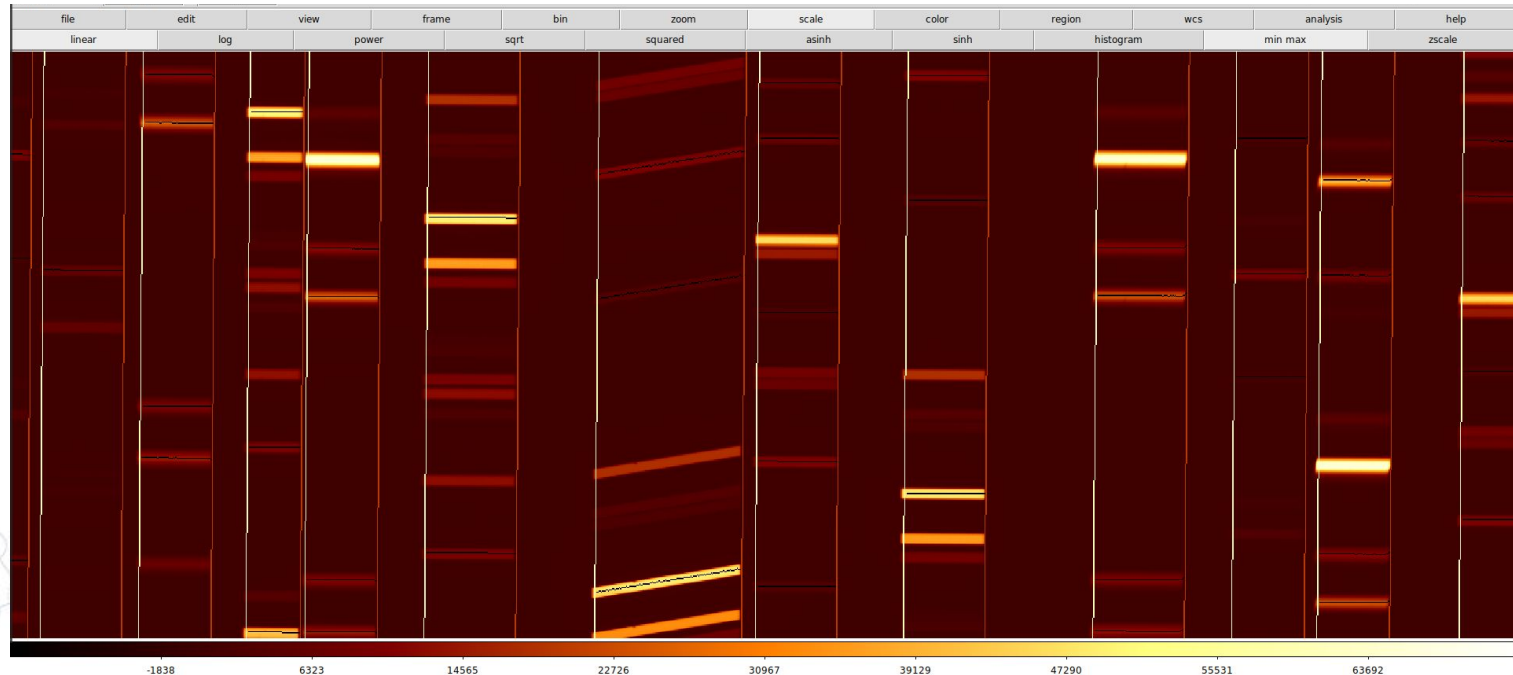
The quality control tools - the first calibrator: MsFlat

- **Show Spectra Location:** it allows to check the quality of MsFlat



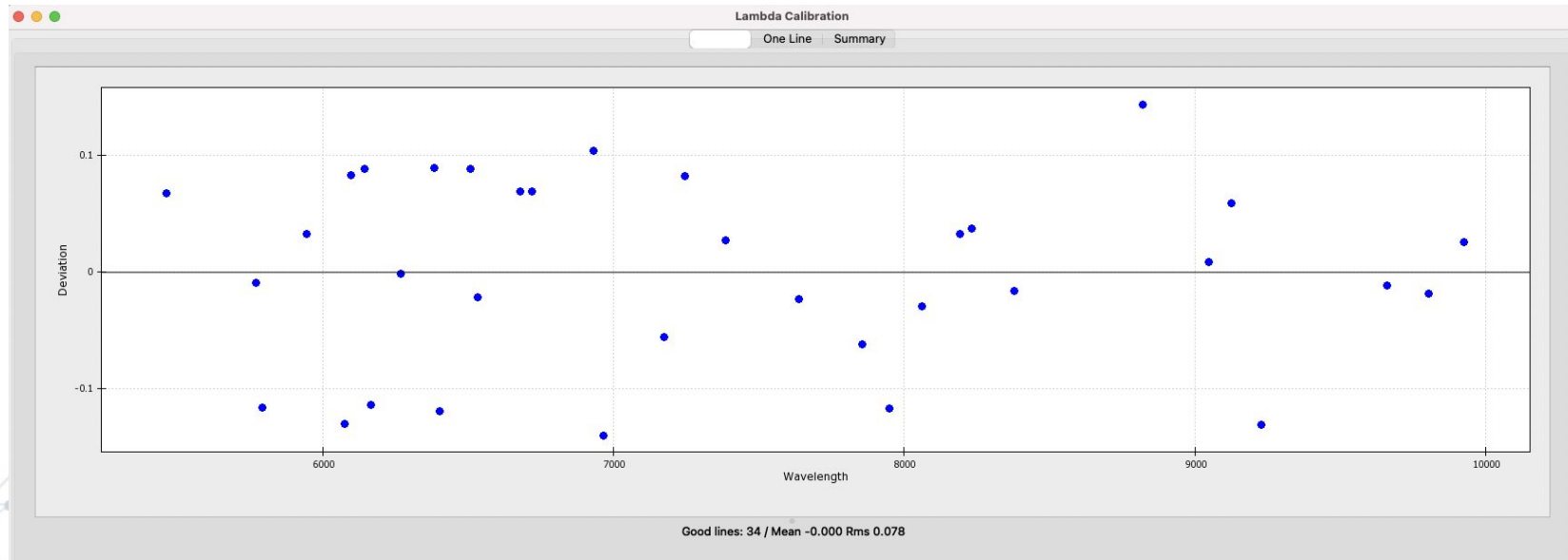
The quality control tools - the second calibrator: MsLamp

- **Show Lambda Cal:** it allows to *qualitatively* check the MsLamp



The quality control tools - the second calibrator: MsLamp

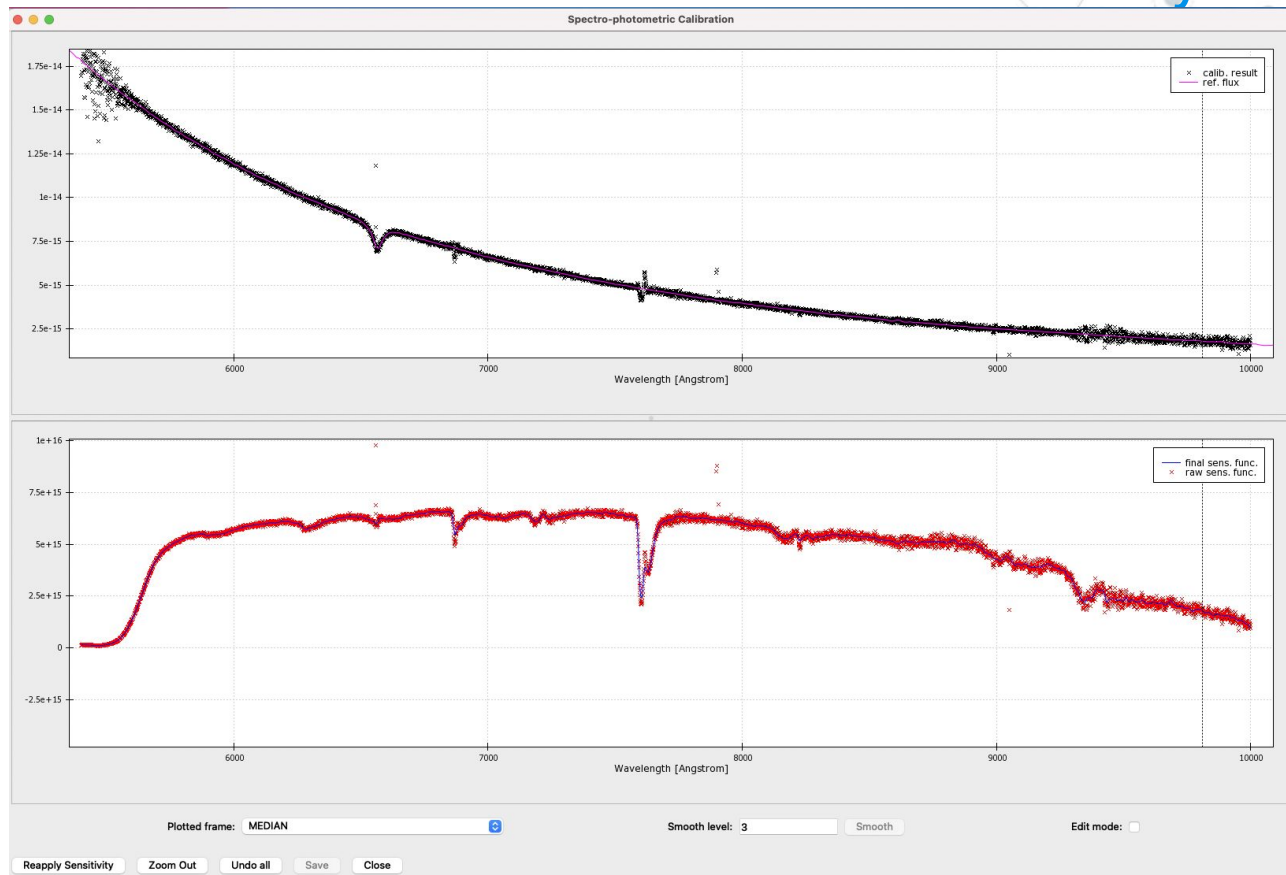
- **Check Lambda Cal & Plot Lambda Cal:** they allow to *quantitatively* check the MsLamp



The quality control tools - the third calibrator: Sensitivity

- **Plot Sensitivity:**

it allows to check the Sensitivity Function

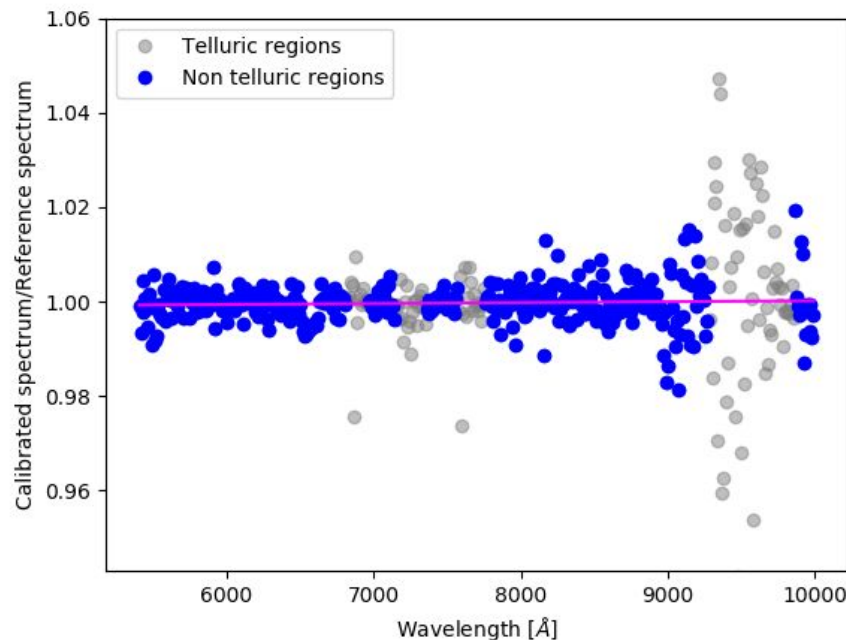


The SIPGI performances - the wavelength calibration

- **Wavelength calibration accuracy better than $\frac{1}{2}$ px in 90% of the cases;**
- It does not depend on the position of the slit within the FoV;

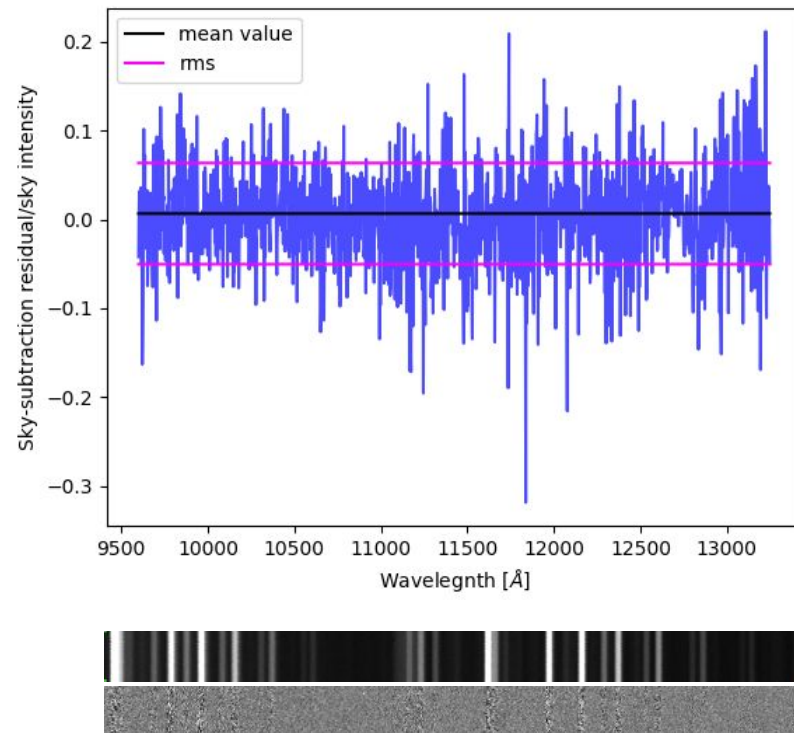
The SIPGI performances - the flux calibration

- The typical sensitivity function is able to **fully recover the shape of the spectrum**;
- The typical rms in the flux calibration is 0.4%(0.5%) in the regions not affected by telluric absorption for MODS(LUCI) data and 2%(5%) in regions affected by telluric absorptions.



The SIPGI performances - the sky subtraction

- The mean value of sky-subtraction residuals relative to the sky intensity as a function of the wavelength for a typical LUCI observation with $R = 1000$ is 0.006 with a rms of ~6%.



The SIPGI performances



Blazar da record sotto gli occhi di Lbt - MEDIA INAF

Pso J030947+27 è il blazar a oggi più distante mai osservato. La sua luce che riceviamo ora è stata emessa quando l'universo aveva meno di un miliardo di anni, ovvero circa il 7 per cento della sua...

<https://www.media.inaf.it>

Belladitta et al. 2020

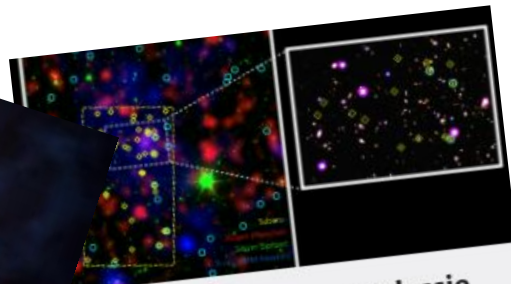


Nella tana di un buco nero antichissimo - MEDIA INAF

C'è una gigantesca struttura cosmica, composta da un buco nero supermassiccio circondato da sei galassie, già presente quando l'universo aveva meno di un miliardo di anni, ovvero il sette per cento...

<https://www.media.inaf.it>

Mignoli et al. 2020



Un proto-ammasso di galassie prodigioso - MEDIA INAF

Lo studio, guidato da Mari Polletta dell'Istituto nazionale di astrofisica e basato su osservazioni effettuate con il Large Binocular Telescope, ha scoperto un proto-ammasso di galassie proprio...

<https://www.media.inaf.it>

Polletta et al. 2021



Quella galassia s'è fatta tutta da sé - MEDIA INAF

Grazie alle osservazioni condotte con il Large Binocular Telescope, un team internazionale di ricercatori coordinati da Paolo Saracco dell'Inaf è riuscito a ricostruire la forsennata storia evolutiva...

<https://www.media.inaf.it>

Saracco et al. 2021

From SIPGI to SpectraPy

- We are now working to extend SIPGI to other optical/near-IR through-slit spectrographs;
- However, the interaction we had with PIs during these 10 years has highlighted that the most “demanding” task is to obtain the **2D spectra lambda calibrated and free of distortions**;
- **This has led to the development of SpectraPy.**

SpectraPy (by Marco Fumana)

SpectraPy is a spectrograph independent Python library

focused on the **extraction of 2D wavelength calibrated spectra.**

It is not a standalone software (differently from SIPGI).

It inherits the SIPGI **instrument model concept**, and allows to apply it to data acquired with all the through-slit spectrographs.

Differently from SIPGI, it does not provide the instrument model, but **allows PIs to derive them.**

SpectraPy (by Marco Fumana)

1. Instrument configuration file

- Detectors description
- Grism description
- File description
- Mask

2. Mask description file

Required to automatically locate spectra on the frames

```
[Description]
instrument = MODS1R/2R
grism = G670L

[Detector]
pixel_scale = 0.123
pixel_size = 0.015
xpixels = 8288
ypixels = 3088

[Grism]
dispersion_direction = RL
linear_dispersion = 0.8 #A/pixels
reference_lambda = 6929.47 #Ne line

[Files]
data_hdu = Primary
```

#ID	DIMX	DIMY	X	Y	ROT	WID	LEN	REF
49	0.720	3.600	-73.62	-86.11	0.0	1.2	6.0	0
85	0.720	6.000	-40.32	-91.09	0.0	1.2	10.0	0
119	0.720	3.600	-86.62	-48.47	40.0	1.2	6.0	0
Ref1	2.400	2.400	-20.70	74.29	0.0	4.0	4.0	1

SpectraPy models calibration workflow

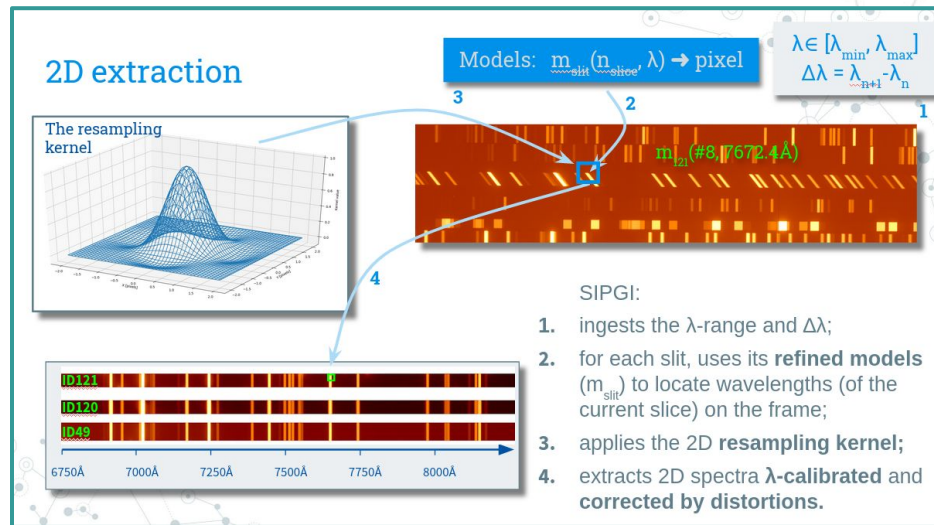
Calibration workflow is the same for each model:

- SpectraPy displays data as **DS9 frames**, and it visualizes models **creating DS9 regions** on expected positions;
- User **manually adjusts** the location of these regions;
- SpectraPy **refits** these new positions, **updating the global model solution**

SpectraPy 2D extraction

SpectraPy follows the same SIPGI 2D extraction scheme.

- It provides 2D spectra wavelength calibrated.
- It does not take into account:
 - bias/dark subtraction;
 - bad pixels/cosmic rays correction;
 - px-to-px variation;
 - sky subtraction;
 - flux calibration;
 - 1D extraction.



Why this choice?

Astropy provides packages for spectra analysis (specutils, linetools, pyspeckit, ...), but spectra reduction package is *missing*.

SpectraPy wants to be the 1st brick of this missing package.

SIPGI download

- Pandora page

<http://pandora.lambrate.inaf.it/sipgi/>

- SIPGI DOI:

[10.20371/inaf/sw/2021_00002](https://doi.org/10.20371/inaf/sw/2021_00002)



The screenshot shows the Pandora website interface. At the top, the 'pandora' logo is displayed in green and blue. To the right of the logo is a navigation bar with links: 'Home', 'Get The Code', 'Legal', and 'Contacts'. Below the navigation bar is a header image featuring a green spectral line plot over a dark background with a keyboard pattern. The main content area is titled 'pandora suite' and includes a sidebar with a list of components: 'SIPGI' (highlighted), 'EZ', and 'python modules' (with 'SpectraPy' listed below it). The main text area contains the following information:

SIPGI: an interactive pipeline for spectroscopic data reduction

The Spectroscopic Interactive Pipeline and Graphical Interface (SIPGI) is a complete spectroscopic data reduction environment based on the VIMOS Interactive Pipeline and Graphical Interface (VIPGI), the pipeline our group designed to carry out the reduction of optical spectroscopic data acquired with the VIMOS spectrograph.

The VIPGI efficiency and the quality of its data reduction products were such to make it the reduction pipeline of the major extragalactic surveys carried out with VIMOS (e.g. VVDS, zCosmos, VUDS, VIPERS, VANDELs). As a result of this long-lasting experience and thanks to the intrinsic adaptability of its design and capabilities, about ten years ago VIPGI was reshuffled into SIPGI, a new pipeline capable of reducing both optical and near-infrared spectroscopic data.

SIPGI has been used by the LBT spectroscopic data reduction center located at INAF-IASF Milan to reduce all the MODS and LUCI spectra acquired during the Italian time in the last ten years. This LBT-customized SIPGI version is now distributed as a stand-alone program.

For any question, comment, suggestion or for any request of help in the reduction of MODS/LUCI spectra with SIPGI, please contact us at lbt-italia-spec@inaf.it

SIPGI 1.1 (ChangeLog) is available on the [DOWNLOAD](#) page

SIPGI documentation is distributed with the code and available [HERE](#)

SpectraPy download



- SpectraPy is an **Astropy affiliated package**

<https://www.astropy.org/affiliated/>

- Open gitlab repository

<https://gitlab.com/mcfuman/SpectraPy/>

- Pandora page

<http://pandora.lambrate.inaf.it/SpectraPy/>

- Documentation

<https://mcfuman.gitlab.io/SpectraPy/>

- SpectraPy DOI:

[10.20371/inaf/sw/2021_00001](https://doi.org/10.20371/inaf/sw/2021_00001)

GitLab

SpectraPy

Project information

Repository

Files

Commits

Branches

Tags

Contributors

Graph

Compare

Locked Files

Issues 12

Merge requests 0

CI/CD

Security & Compliance

Deployments

Monitor

Infrastructure

Packages & Registries

examples Added LUCI extraction table example

scripts Removed useless channel parameter

spectrapy Bug fixed in catalog type check

tests Improved tests coverage

.gitignore Updated setup.py

gitlab-ci.yml Changed master branch into main

LICENSE.txt Added license file

MANIFEST.in Updated MANIFEST template

README.md Updated readme

setup.py Added python requirements

README.md

SpectraPy

pipeline passed coverage 91.00% Python 3.7 powered by Astropy

SpectraPy is an Astropy affiliated package, which collects algorithms and methods for data reduction of i through slits spectrograph.



Thank you for your attention.

*For those interested, after the seminar,
Susanna Bisogni
holds a practical tutorial on using SIPGI.
The tutorial will be uploaded at*

<http://pandora.lambrate.inaf.it/sipgi/>

