X-shooter pipeline algorithms

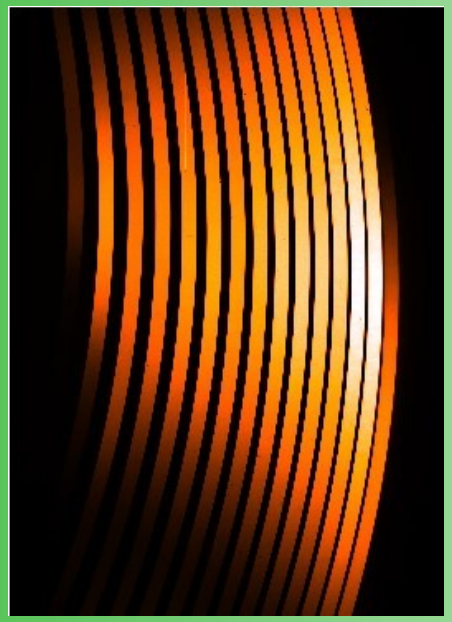
DRS: X-shooter consortium ➔ ESO
Physical model: P. Bristow
IFU: A. Modigliani, P. Bristow, J. Vernet.
Reflex upgrade: A. Modigliani, D. Bramich, S. Moehler

X-shooter pipeline recipes

xsh_detlin
xsh_mbias
xsh_mdark
xsh_predict
xsh_orderpos
xsh_mflat

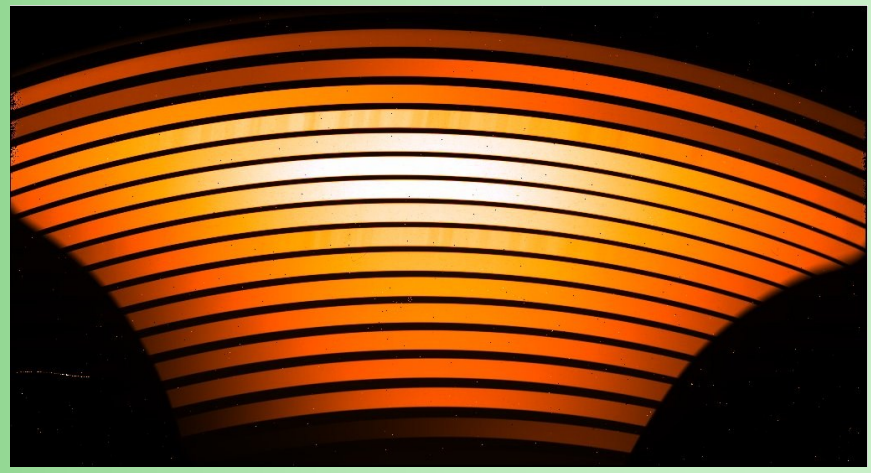
xsh_2dmap
xsh_wavecal
xsh_flexcomp
xsh_respon_<obs mode>
xsh_scired_<obs mode>

Different orientation



Rotation conventions:

- UVB: 180^0
- VIS: unchanged
- NIR: 90^0

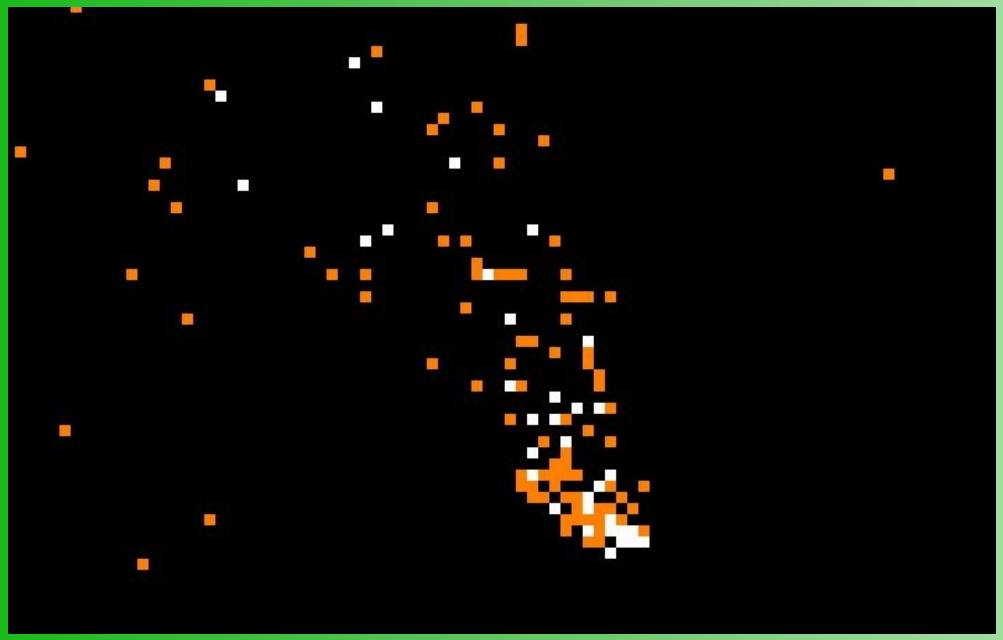


Frame preparation

associate error (photon and read out noise) and qualifier images

Errors and quality information are propagated thoroughly along the reduction chain

Image Qualifier Definition



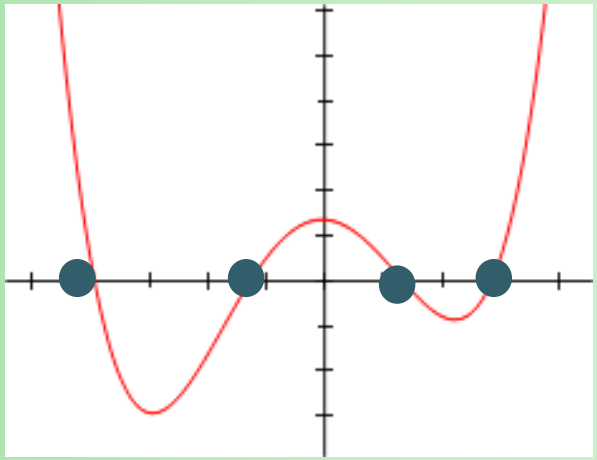
NIR comet
like spot

Flagged pixels are set by
parameter decode_bp

Polynomial model

Polynomials are the classical solution, but:

- Robust fit, but solution may not be good
- Requires homogeneous and dense coverage of calibrations data
- No info on the instrument
- No predictive power

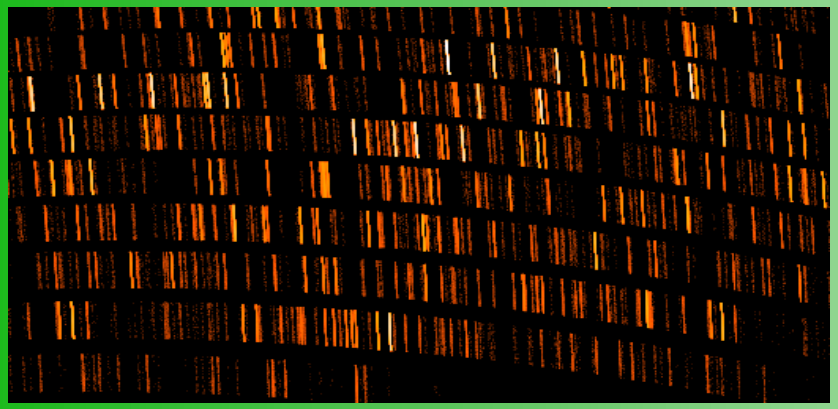


Physical Model

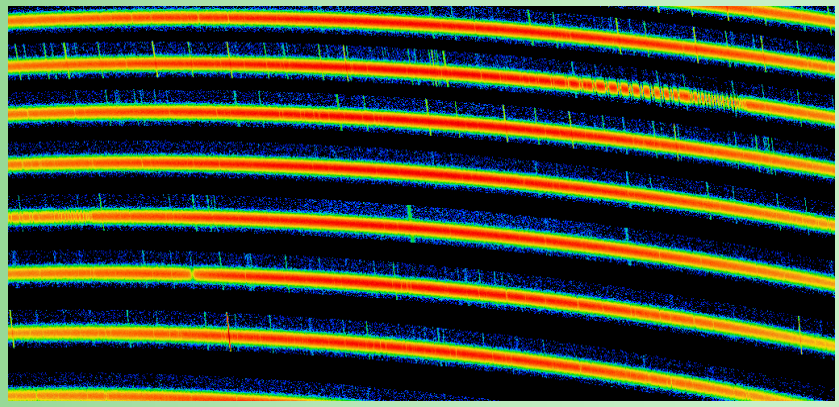
- Simple model, includes mechanical (flexures), thermal, electrostatic functionality.
- Includes all optical components, their dep. with p, n(T,λ). Predicts the spectral format.
- Can interpolate/extrapolate over wide ranges.
- To understand the physics of the instrument.

Reduce X-shooter data with the physical model mode

Applications: simulate data



ThAr spectrum
(portion)



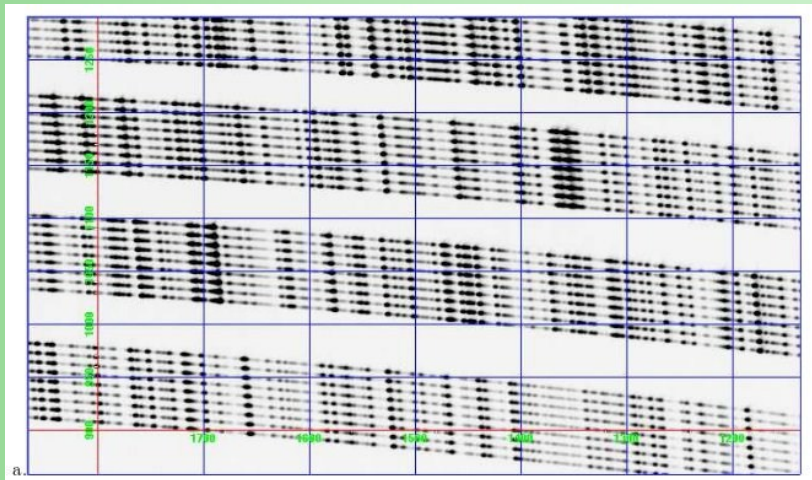
Solar+sky lines spectrum
(portion)

To simulate data to develop the DRS.

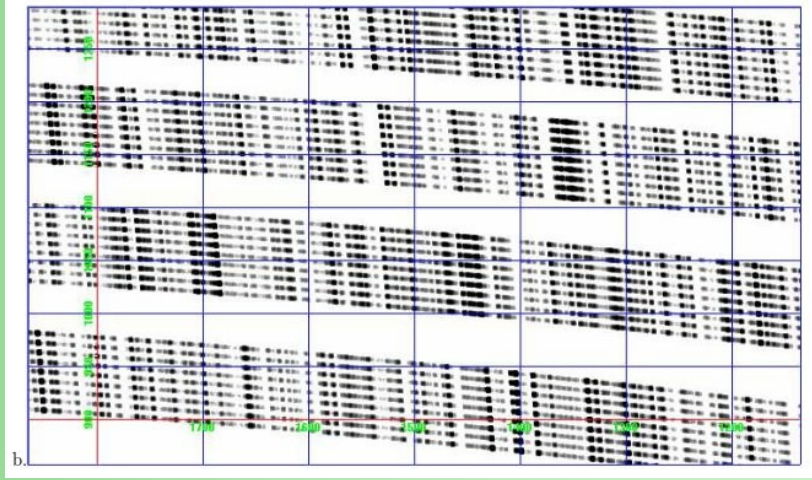
Applications: simulate data

To simulate data to develop the DRS.

Data



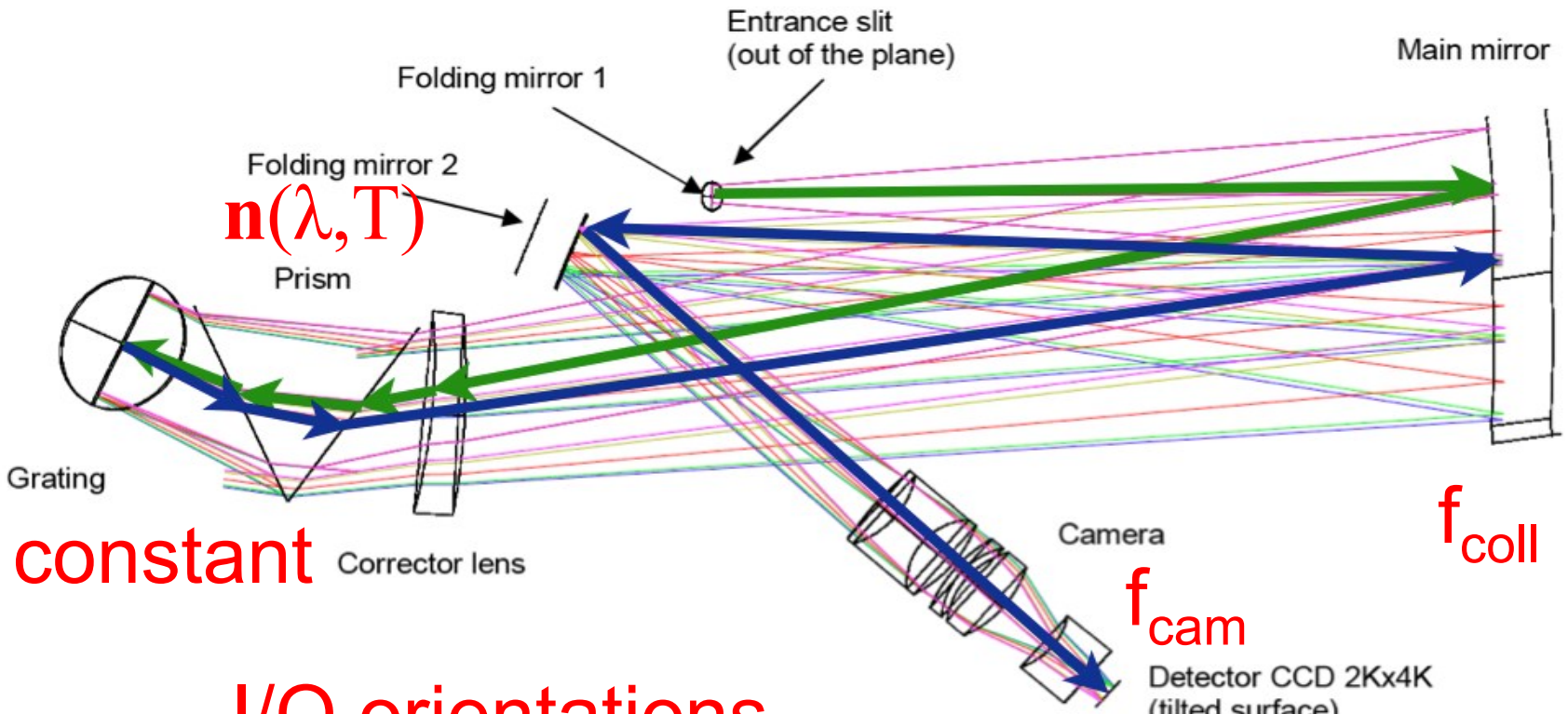
Simulation



Physical model use

- Automatic wavelength and spatial scale calibrations.
- Spectral and spatial resampling.
- Model the Sky in stare mode data (Kelson).
- IFU reduction (to resample data).
- Instrument quality control.
- To understand instrument upgrades.

Physical model parameters



constant

f_{coll}

f_{cam}

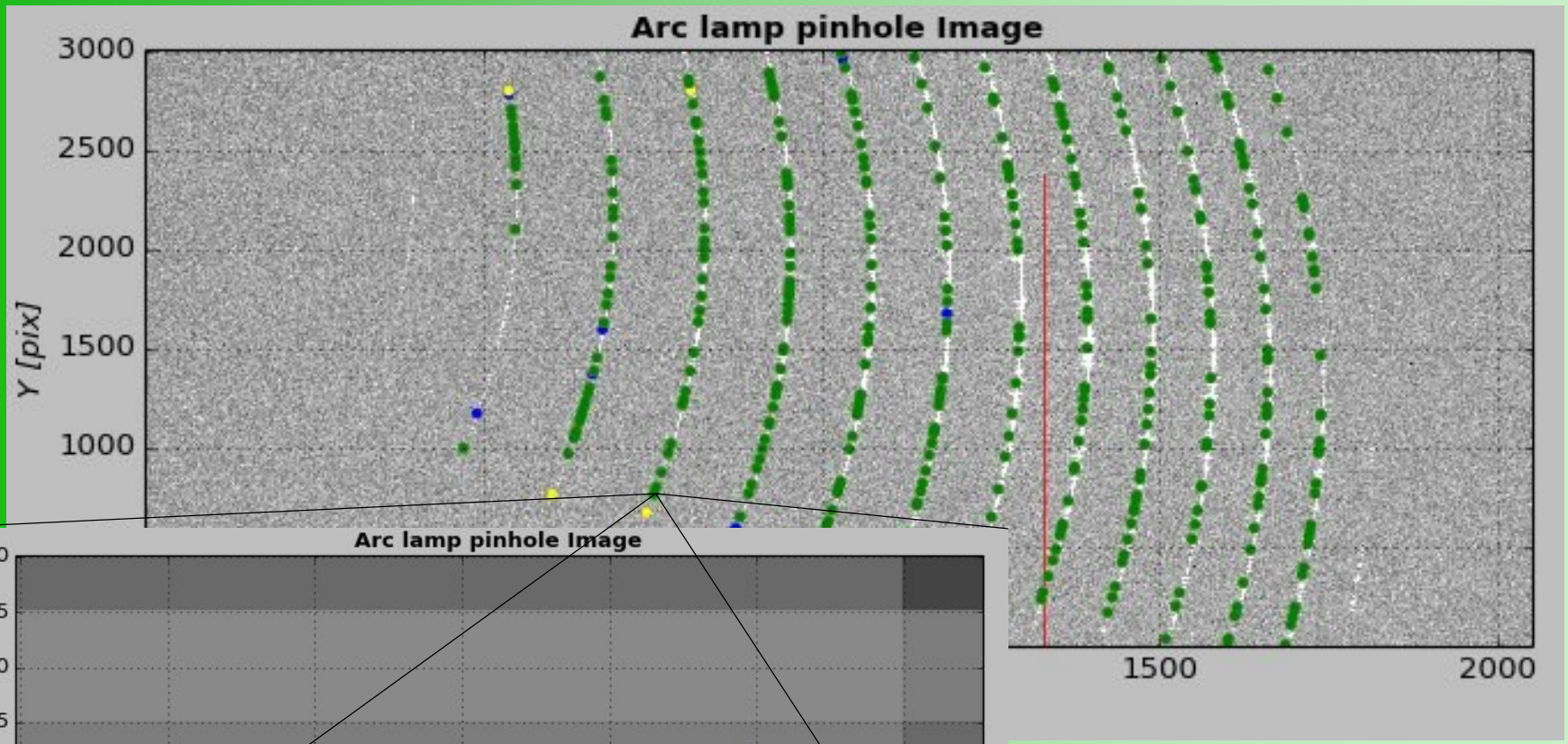
I/O orientations
(slit, prism, grating, detector)

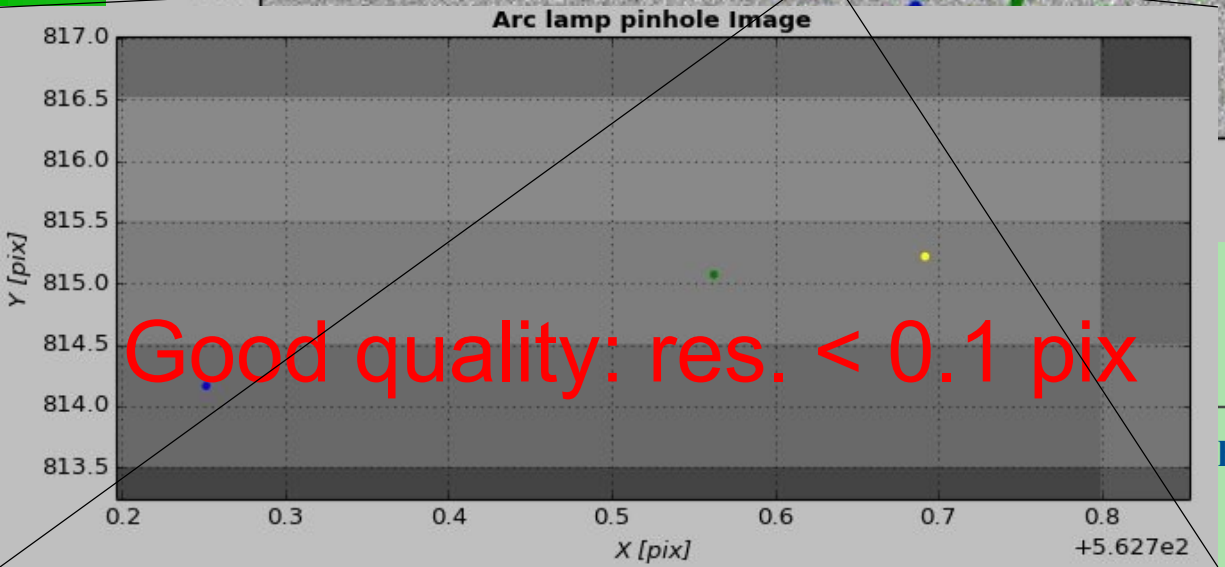
Pixel x,y size

Basic data reduction steps

- Detection of non-linear pixels
- Master bias
- Master dark
- Slit arc frames processing
- Response determination & flux calibration

Formatcheck data reduction



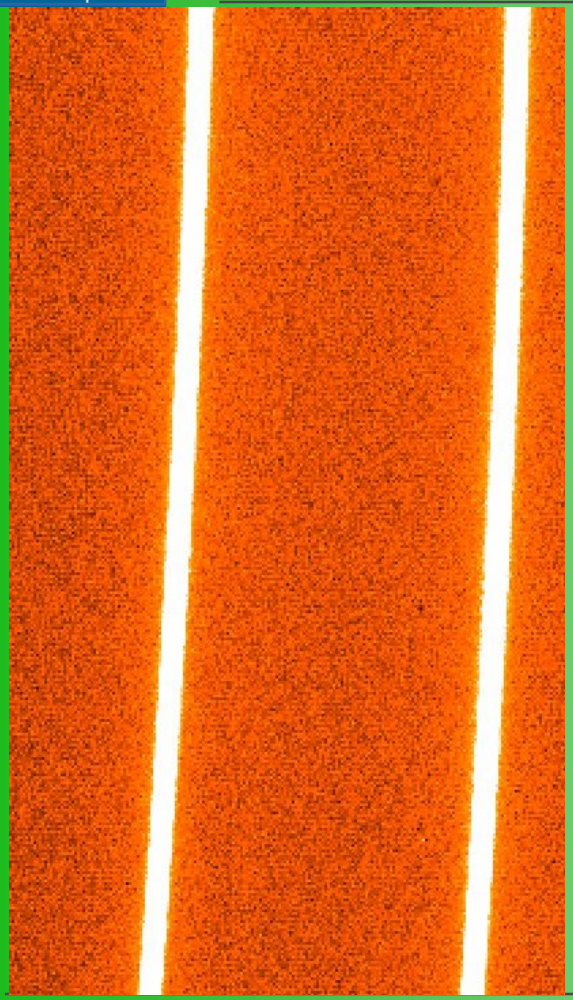


Good quality: res. < 0.1 pix

Formatcheck data reduction

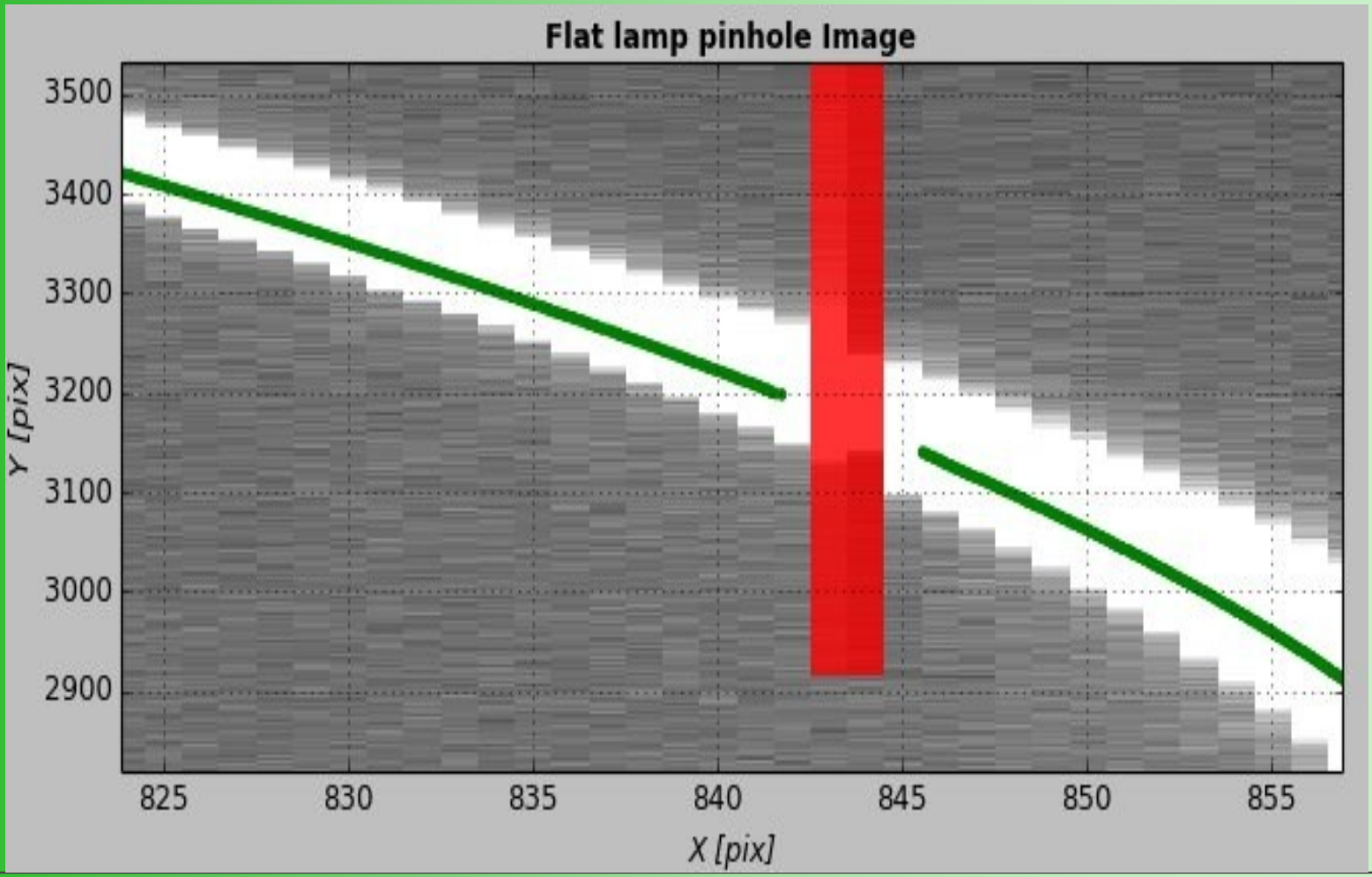
- Use ref. line list & model to predict line positions
- Search lines within a user defined-size box
- Gauss fit in box centered on predicted positions
- Clip low SNR lines
- Clip large residuals lines
- Optimise the physical model
- Fit a polynomial: guess wave and order tables

Pinhole-flat to trace orders

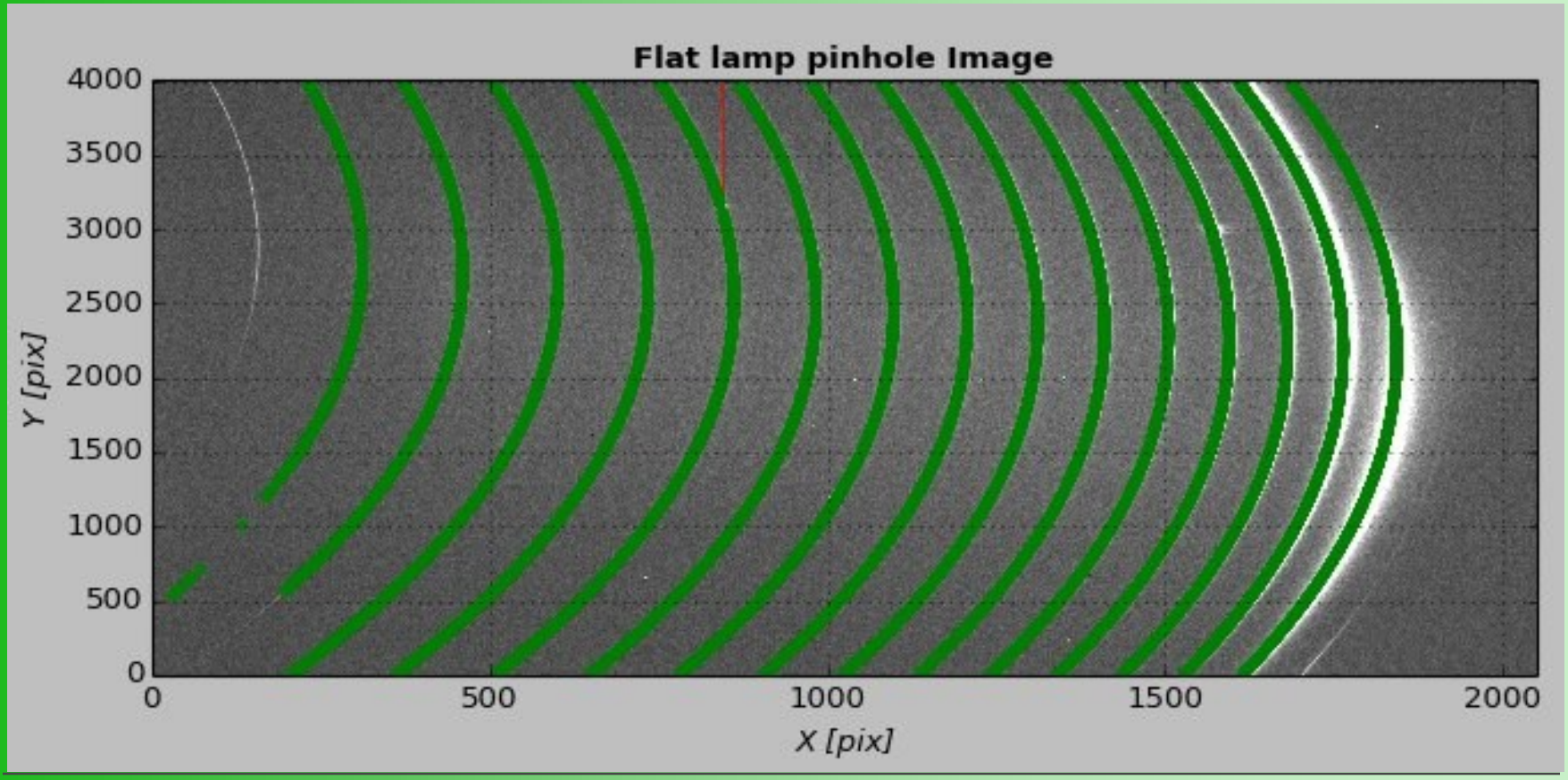


- Scan order (step-y)
- Filter CRH in box
- Get order X_{max}
- Gauss-fit X_{Gauss}
- Fit polynomial
- Clip residuals
- Iterate poly fit (sigma-clip)

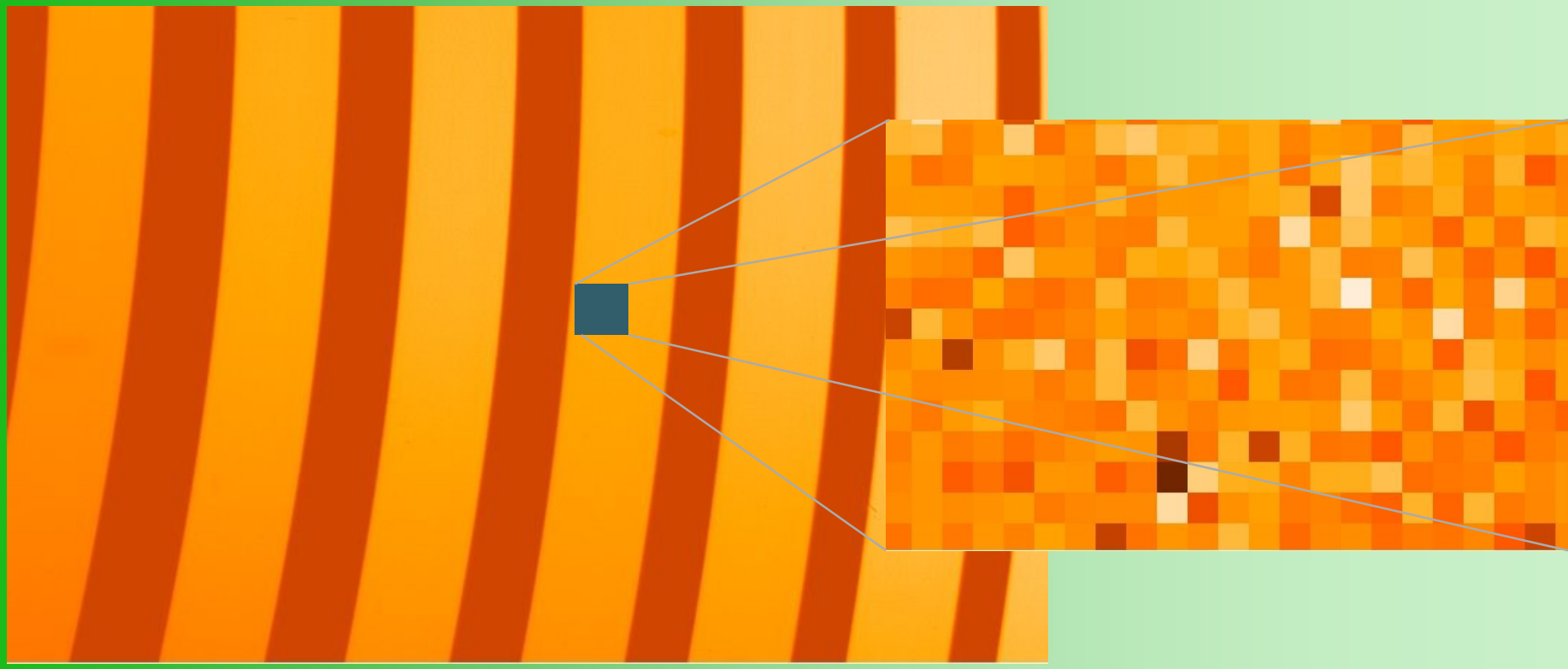
Robust to bad pixels



Orderdef traced orders



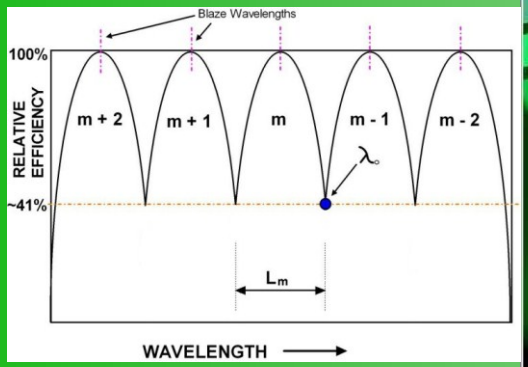
Flat-field use (1)

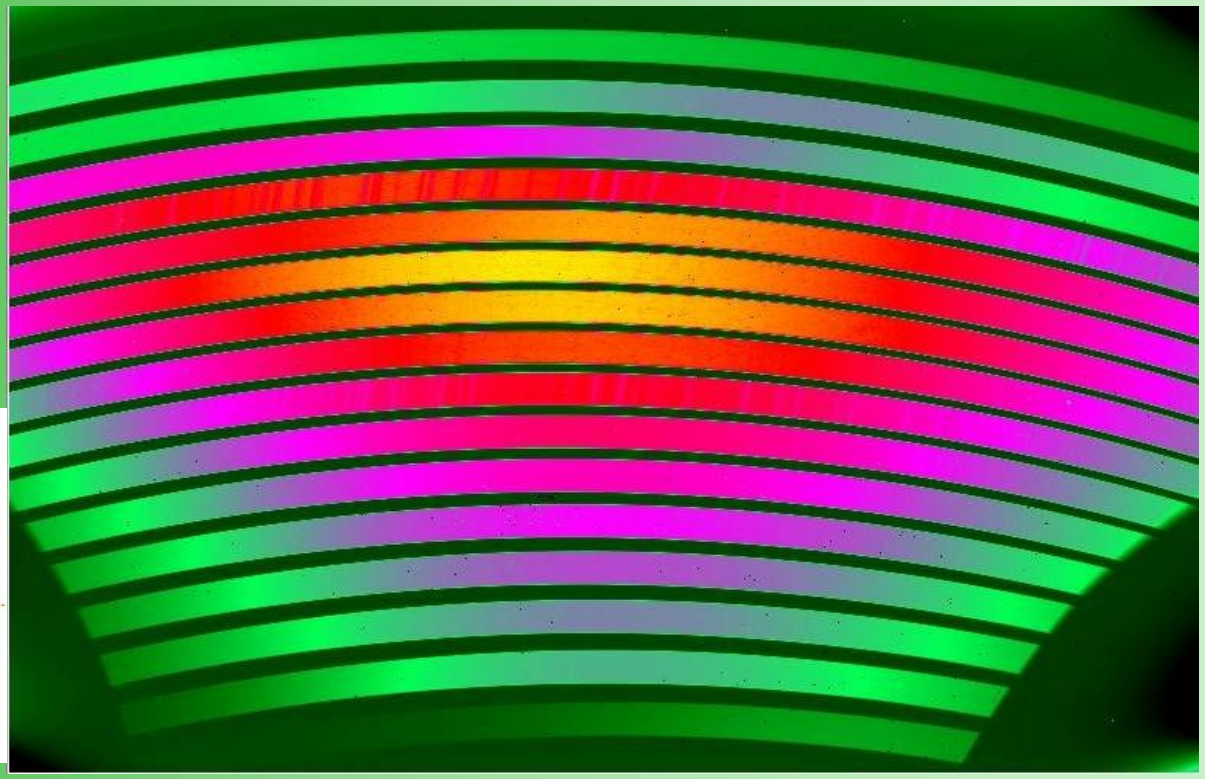


To correct pix-to-pix detector efficiency variations

Flat-field use (2)

Blaze Function





To correct blaze illumination (large scale)

Flat-field use (3)

Bad column

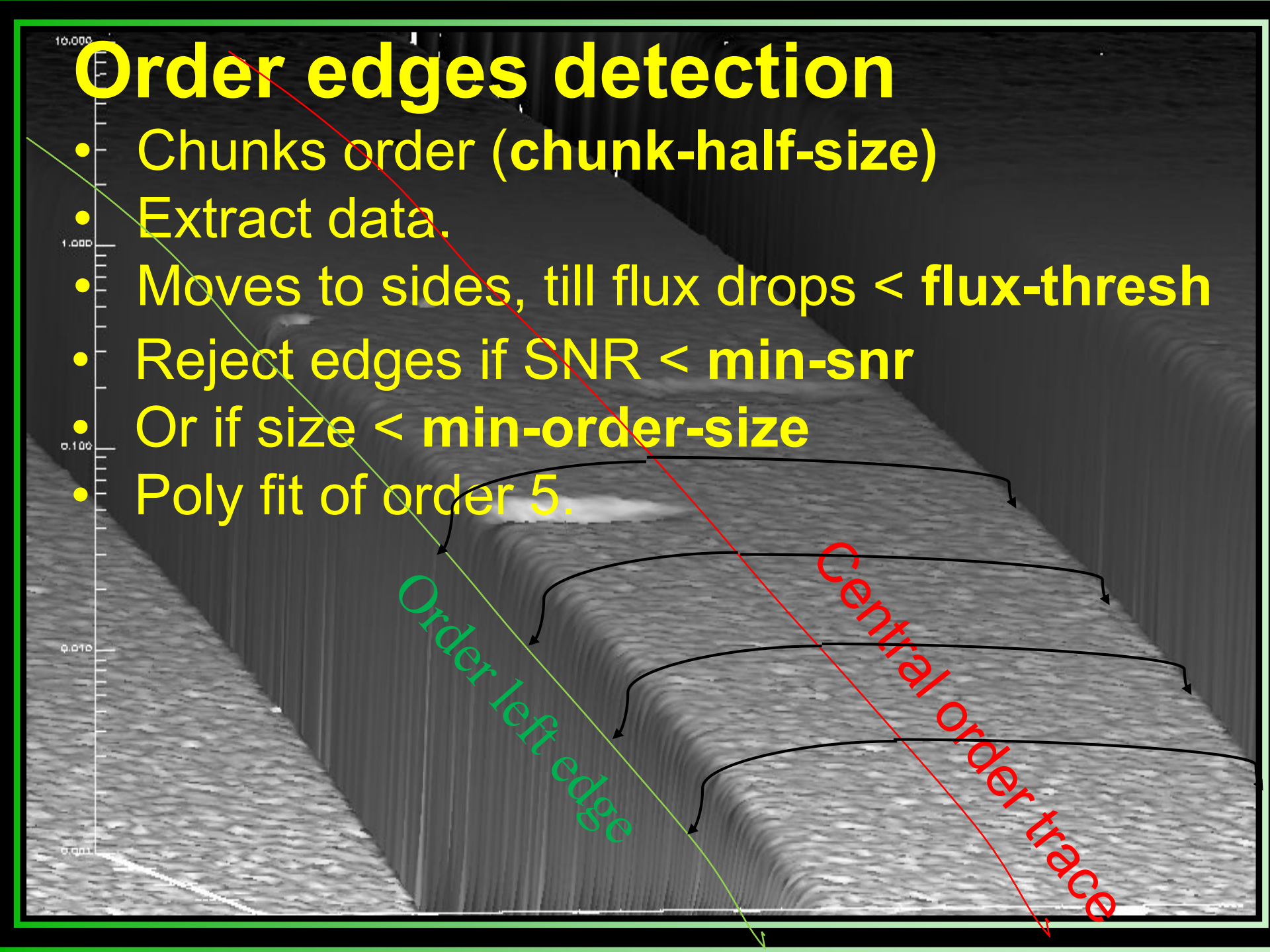
Dead pixels

Slit-flat frames processing

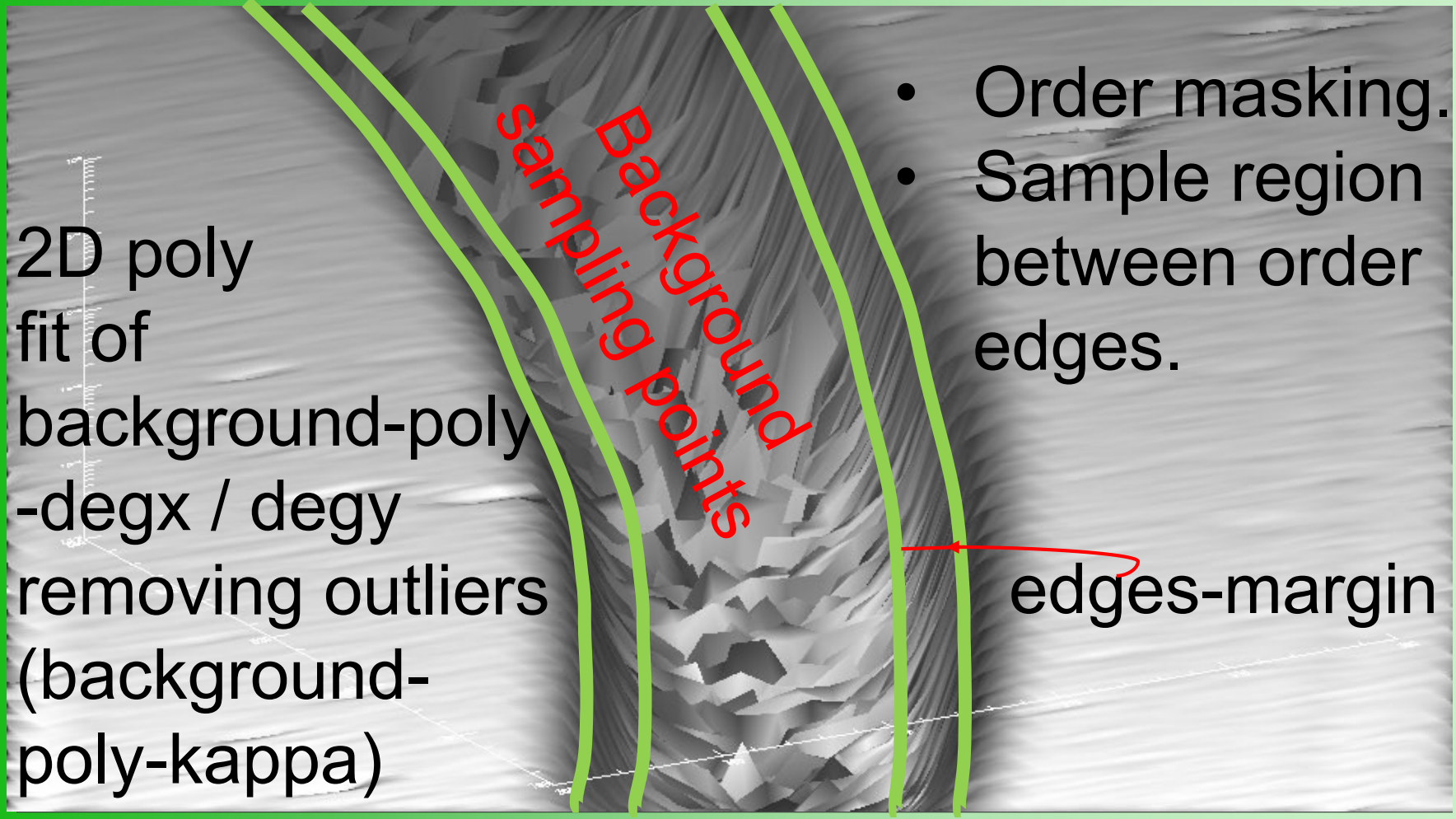
- UVB,VIS: corrects oscan. NIR: frame on-off
- Determines & correct each raw for exp. level
- Median stack. Detects order edges traces
- Determines and subtract inter-order backg.
- Detects cold pixels and blemishes

Order edges detection

- Chunks order (**chunk-half-size**)
- Extract data.
- Moves to sides, till flux drops < **flux-thresh**
- Reject edges if SNR < **min-snr**
- Or if size < **min-order-size**
- Poly fit of order 5.



Inter-order background (1)

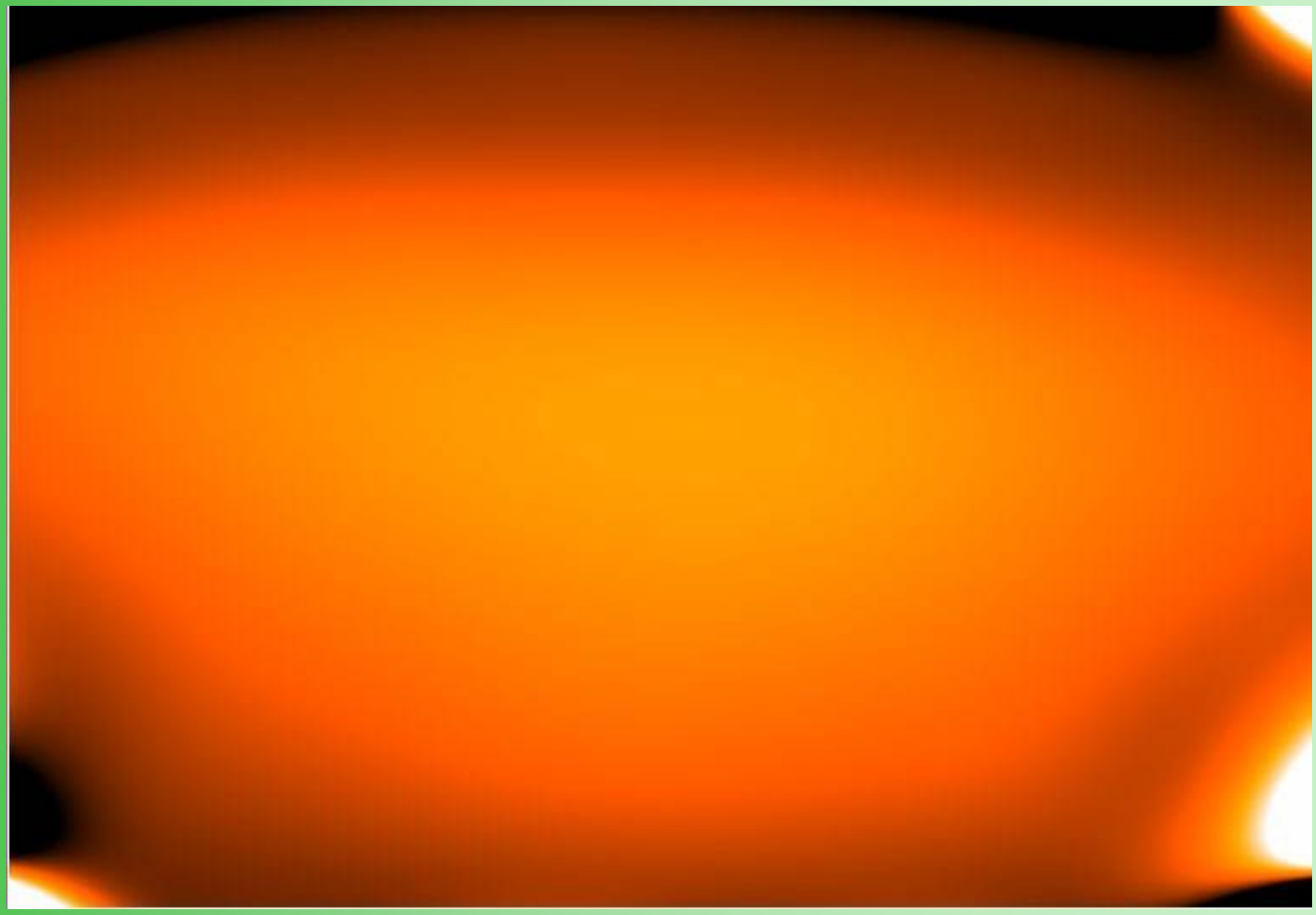


Inter-order background (2)

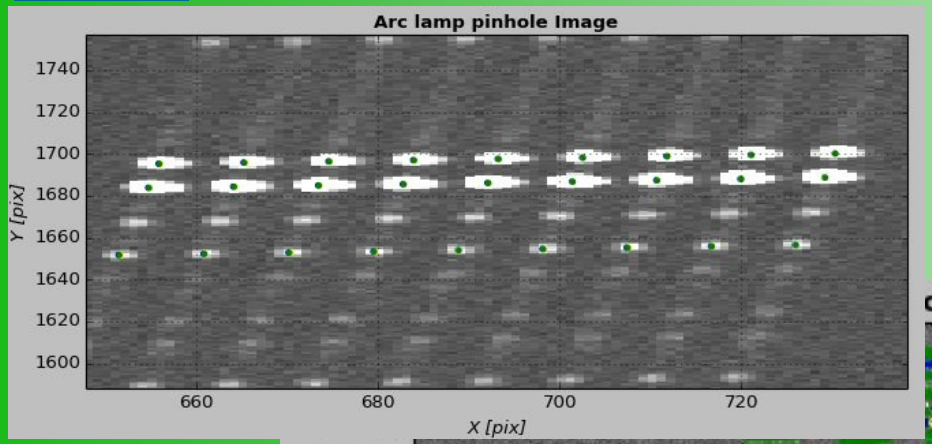
Master flat

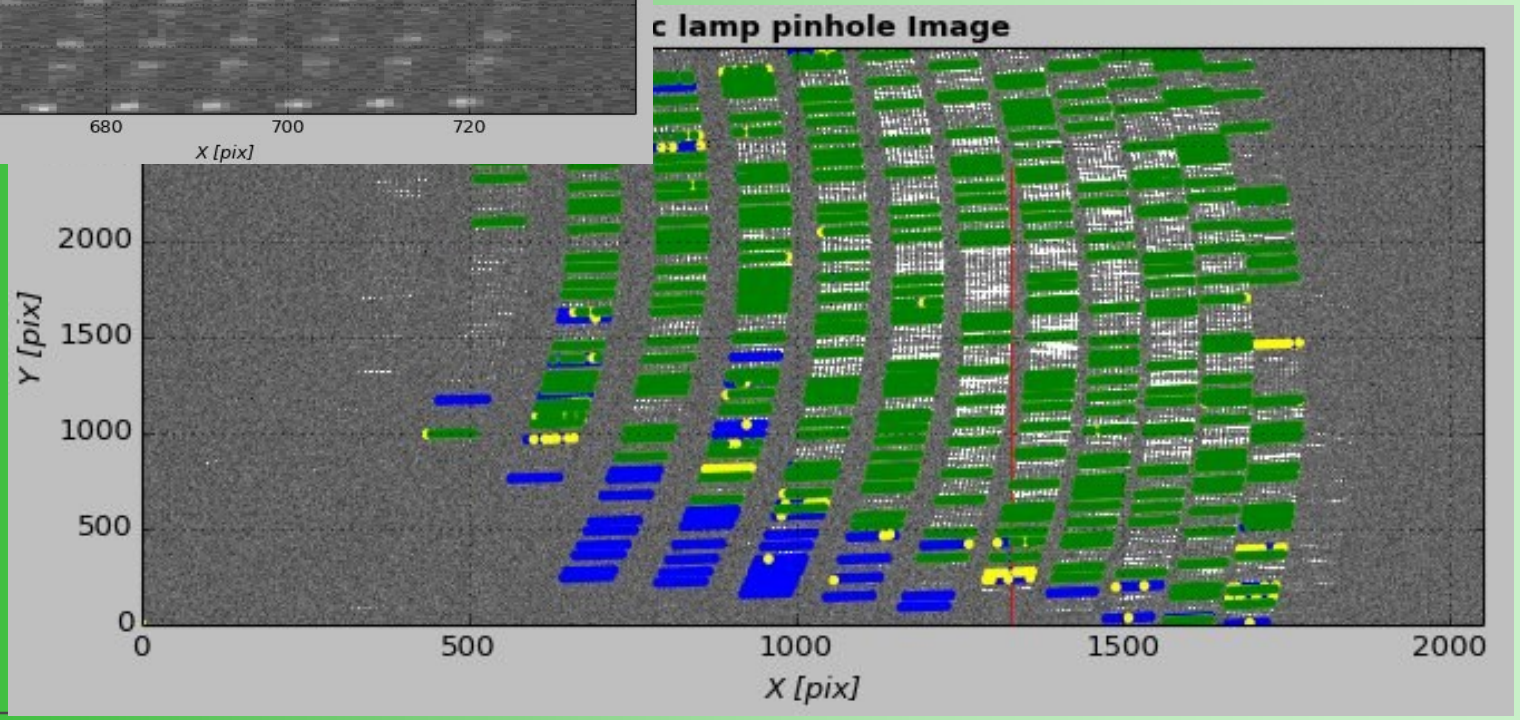
Inter-order background (3)

Background



9-pinhole processing

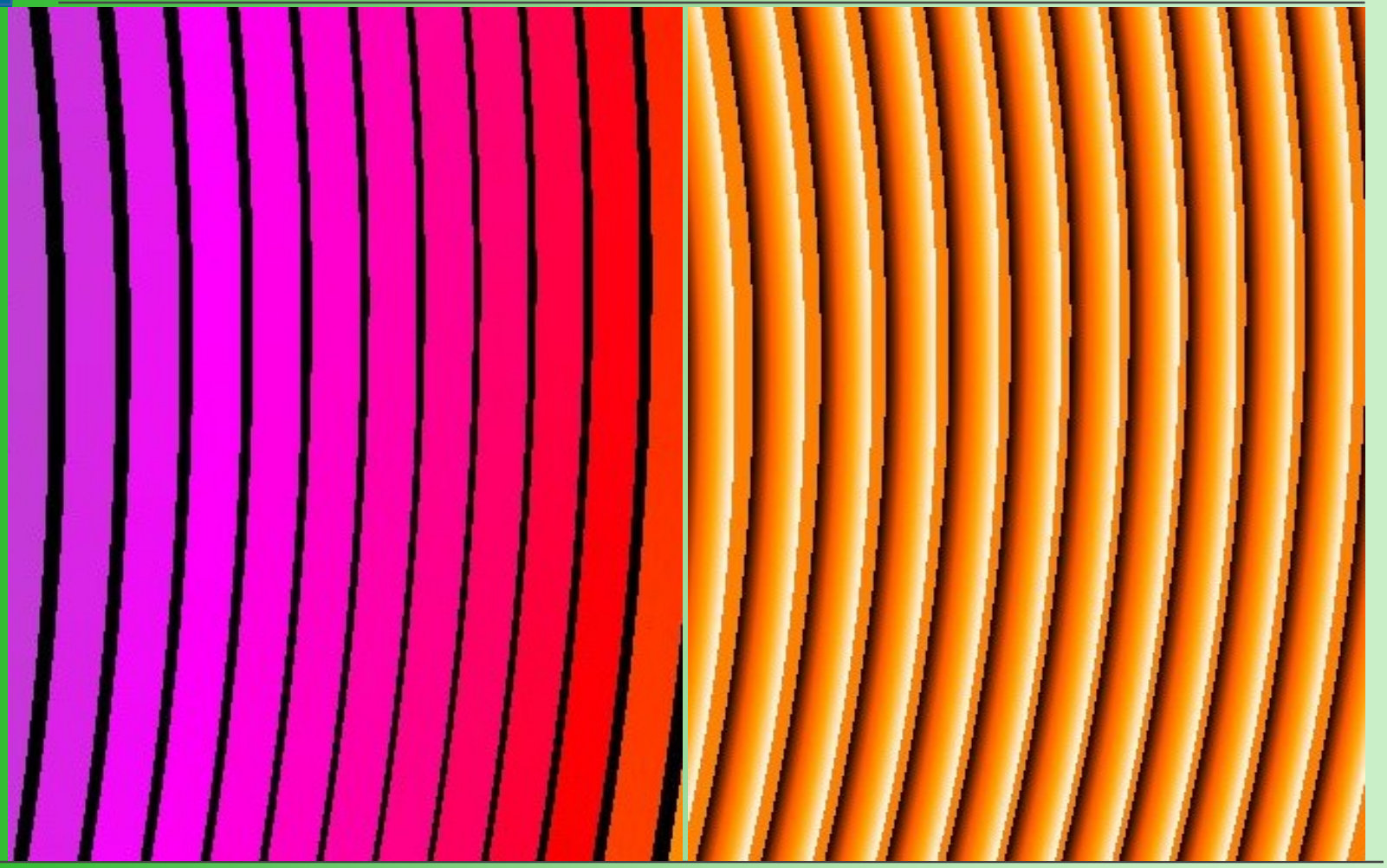




9-pinhole processing

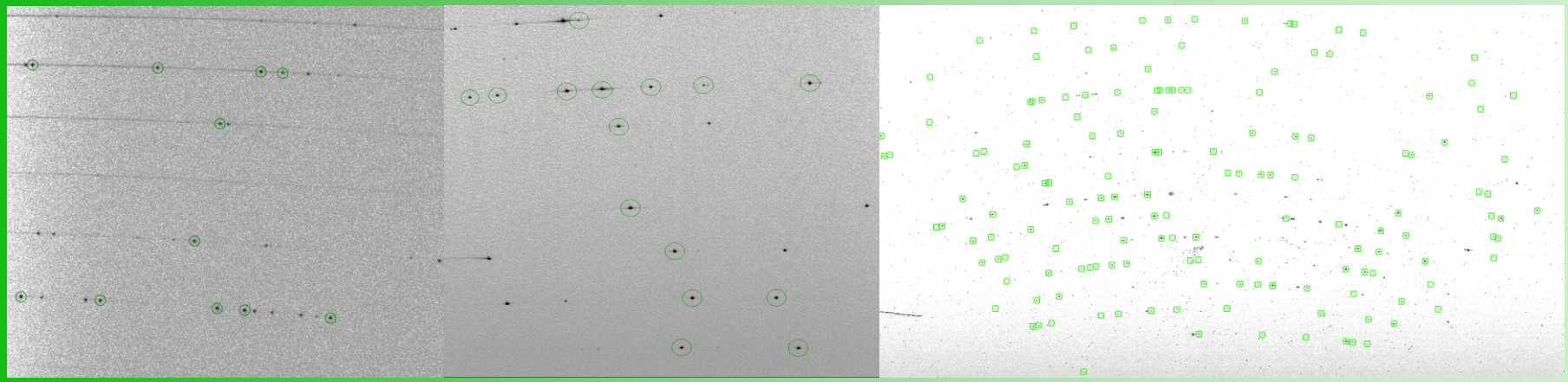
- Use ref. line list and FMTCK-optimised model
- Optimise physical model solution
- Get wavelength & spatial dispersion solutions
- Create wavelength and slit maps

Wave & Slit maps



Flexure corrections

Measured on AFC frames (pinhole + Pen-ray).
Removed at 1st order.



UVB, VIS: 1000x1000 pix window =>shift

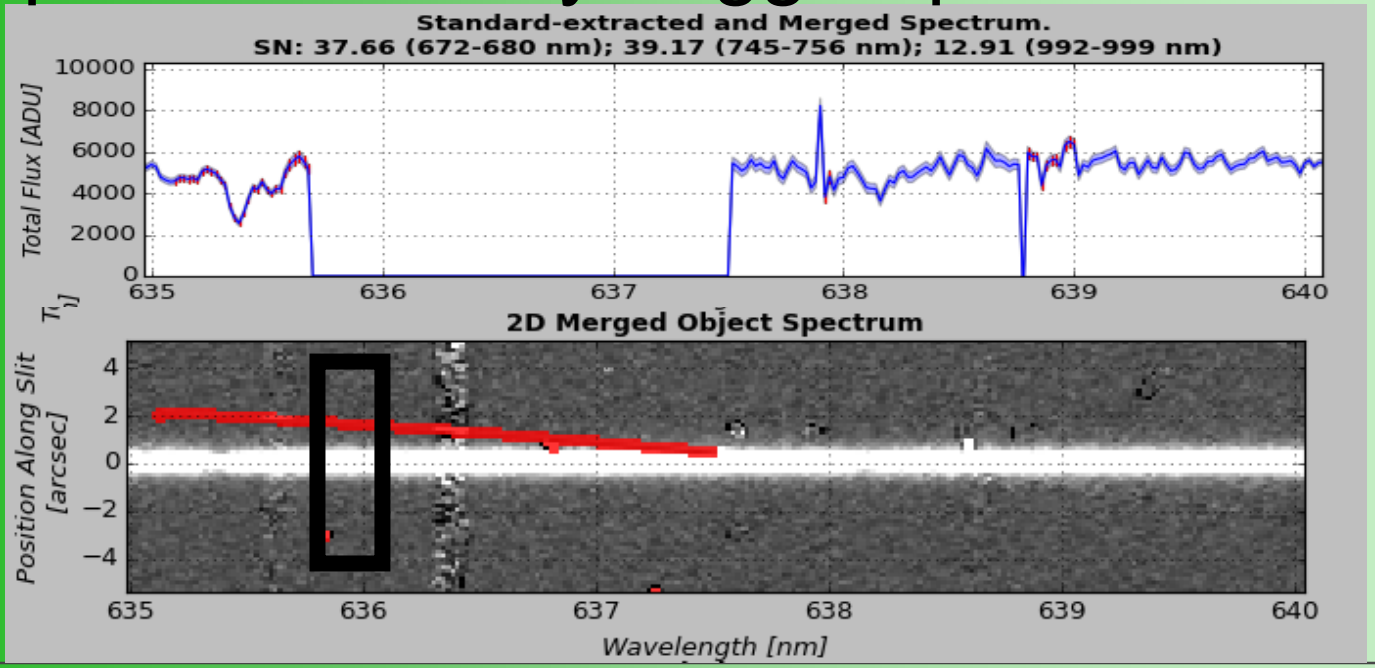
NIR: entire array =>anneal

Common obj reduction steps

- Overscan correction (UVB, VIS).
- CRH detection.
- Flat-fielding.
- Resampling, extraction, order merging, flux calibration.

Standard extraction

- Extraction slit centered on object trace
- Integrate bad pixels (**stdextract-interp-hsize**)
- Gaps where many flagged pixels

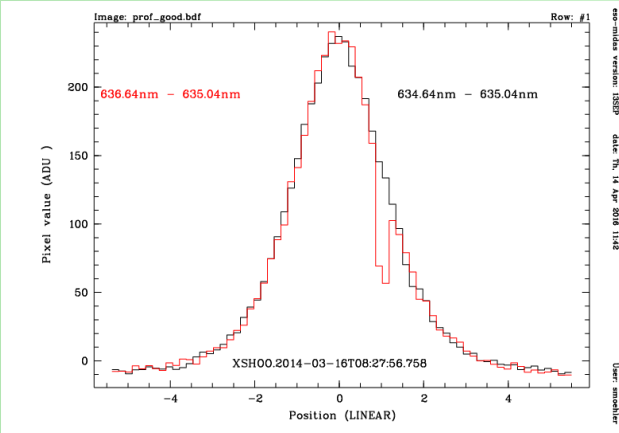


Flagged pixels handling

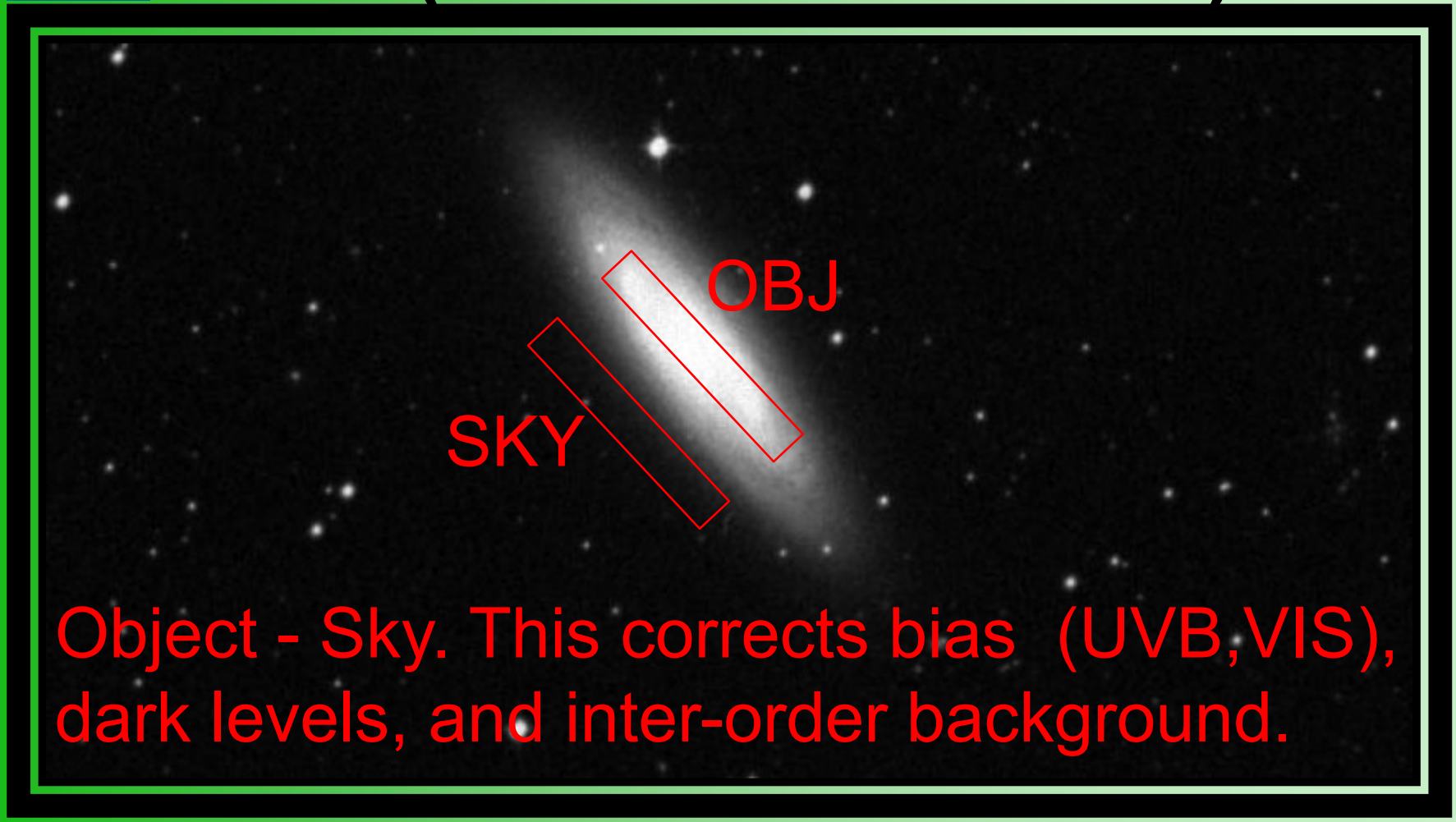
1. No flagged pixels: sum over all pixels.
2. All pixels flagged: S=0, V=0, Q='missing data'
3. Some pixel are flagged use only good columns:

- No column➔ S=0, V=0, Q='missing data'.
- Some good columns:

1. Profile from good cols,
2. Opt. scaling factor,
3. S= good pix + Interpol.
   Q='interpolated flux'

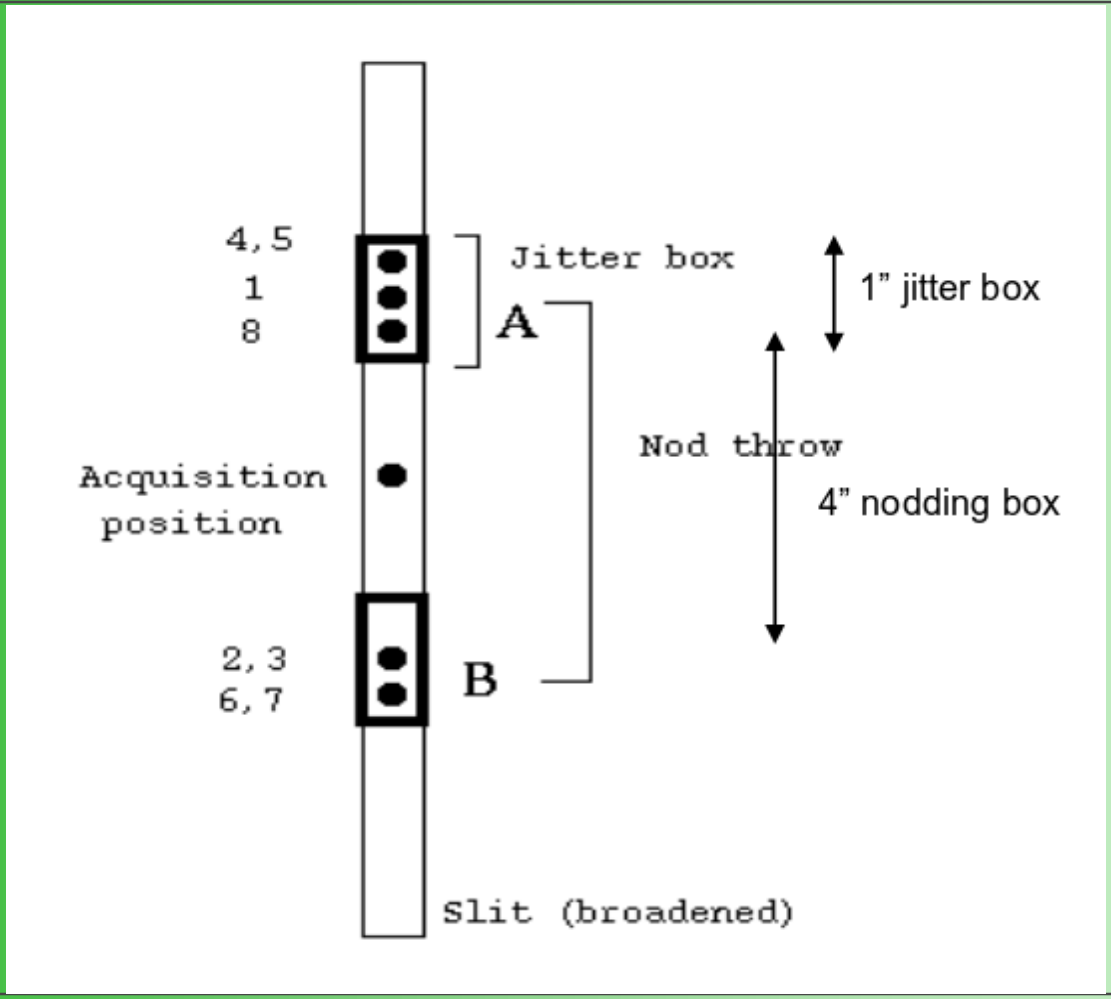


Offset reduction (extended source)



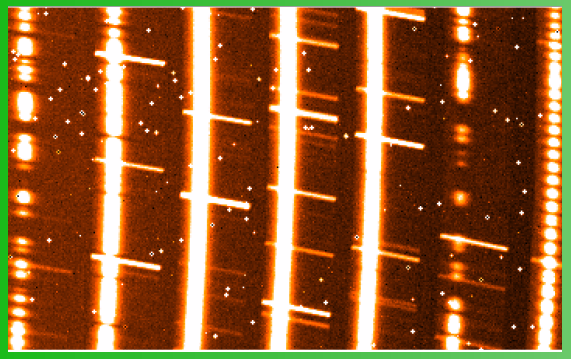
Object - Sky. This corrects bias (UVB,VIS), dark levels, and inter-order background.

Nodding (point-source)

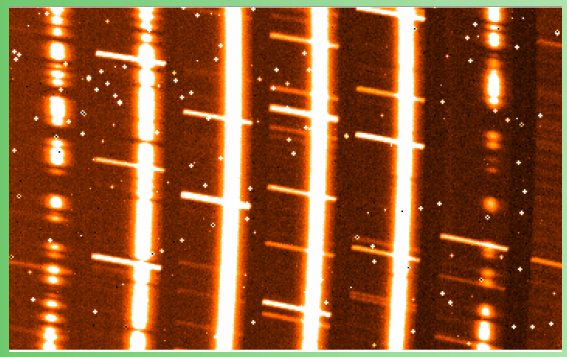


Nodding sky correction

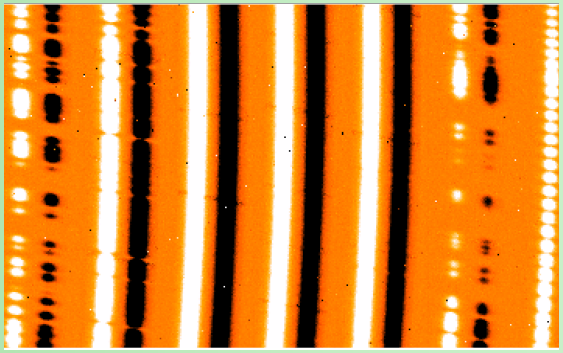
A



B

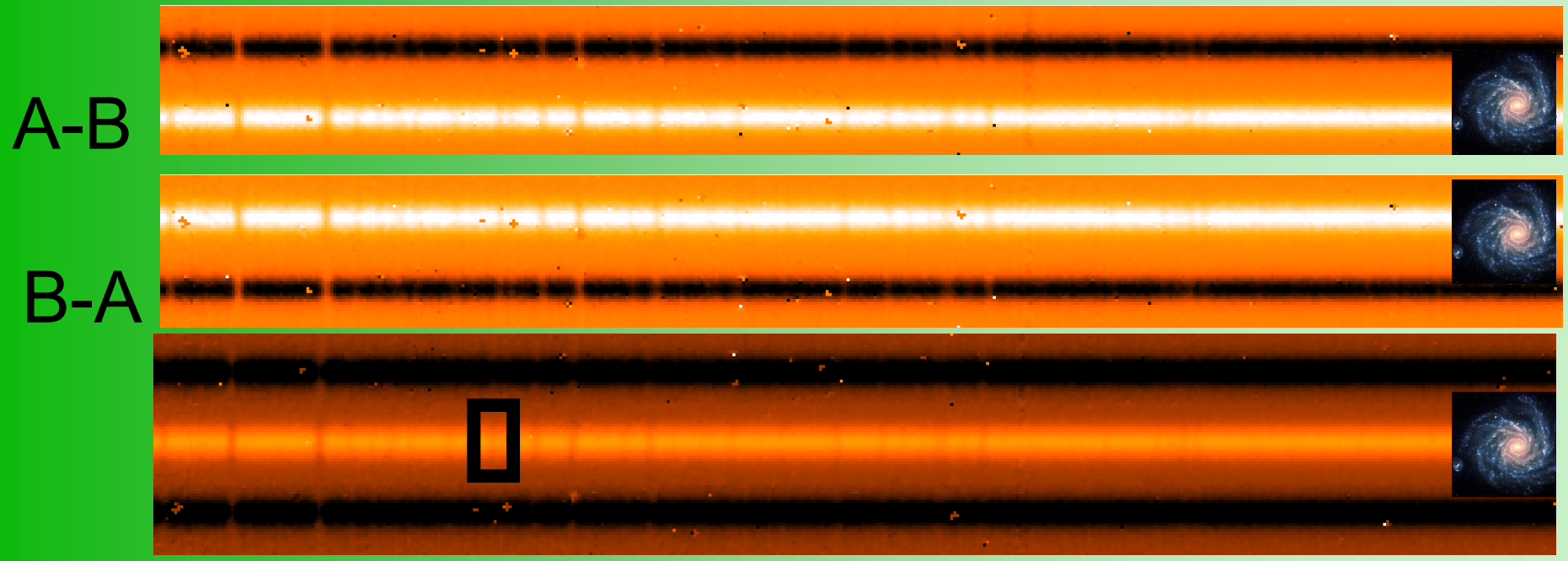


A-B



- A: sky(posA) + source
- B: sky(posB) + source
- A-B (B-A) corrects bias, dark, inter-order background, sky on each source spectrum, but leaves positive and negative

Nodding extraction



A-B-shift(B-A)

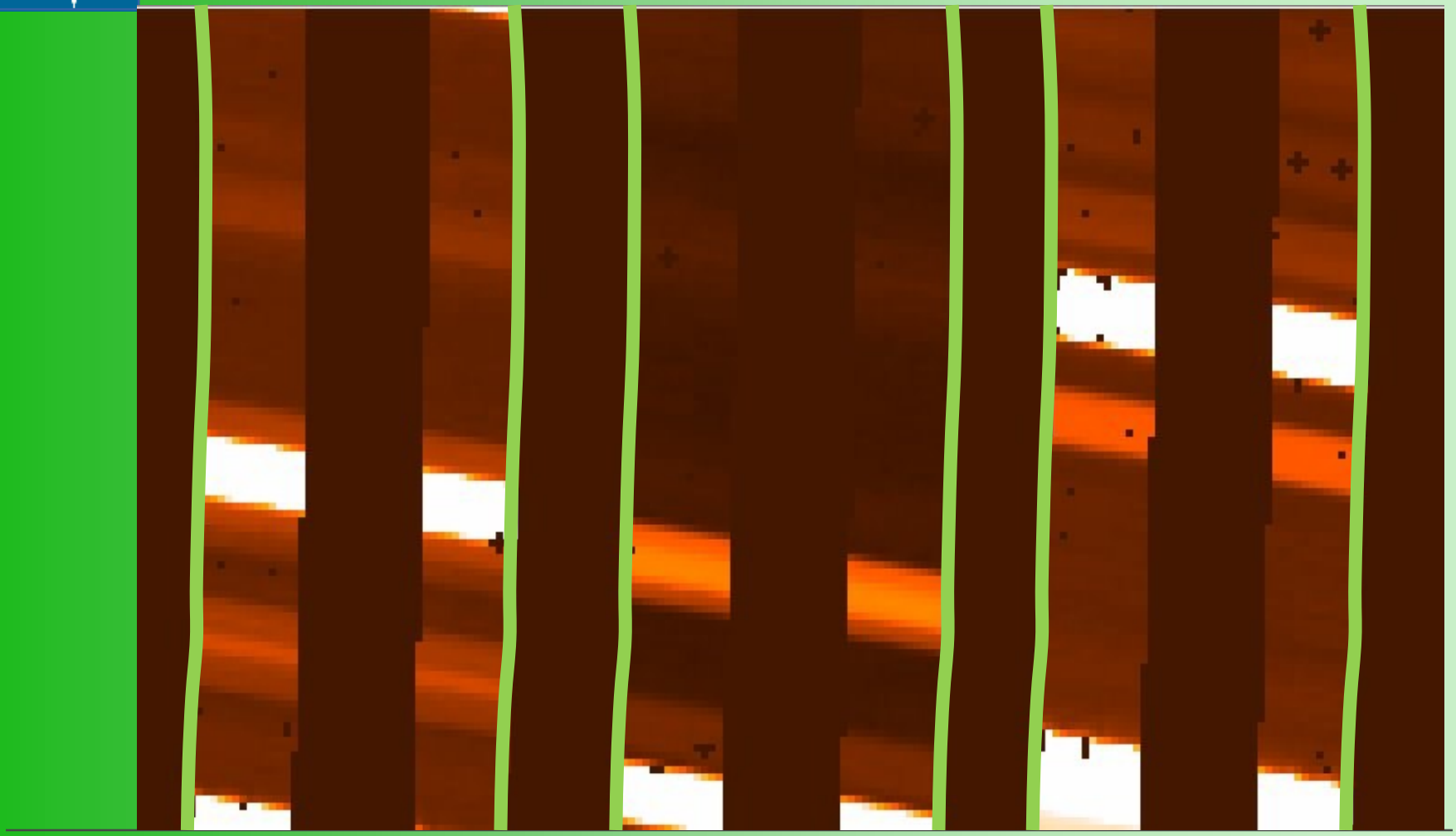
Rectify. At this point one can shift and do

A-B- shifted(B-A)= 2*source + negatives

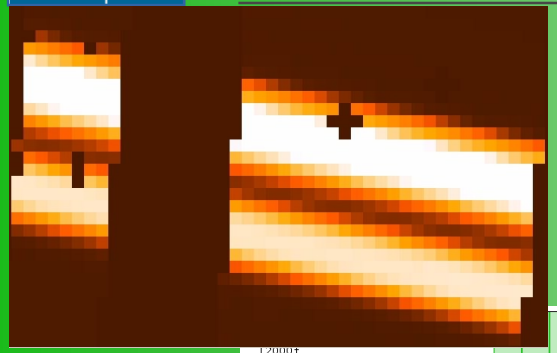
Stare mode (point source)

- Remove instrument signature.
- The sky model is determined on the object masked frame, using the full information along the slit➔ sky lines over-sampling.
- Allowed methods: MEDIAN or a BSPLINE (smooth) fit. On current release we recommend MEDIAN.

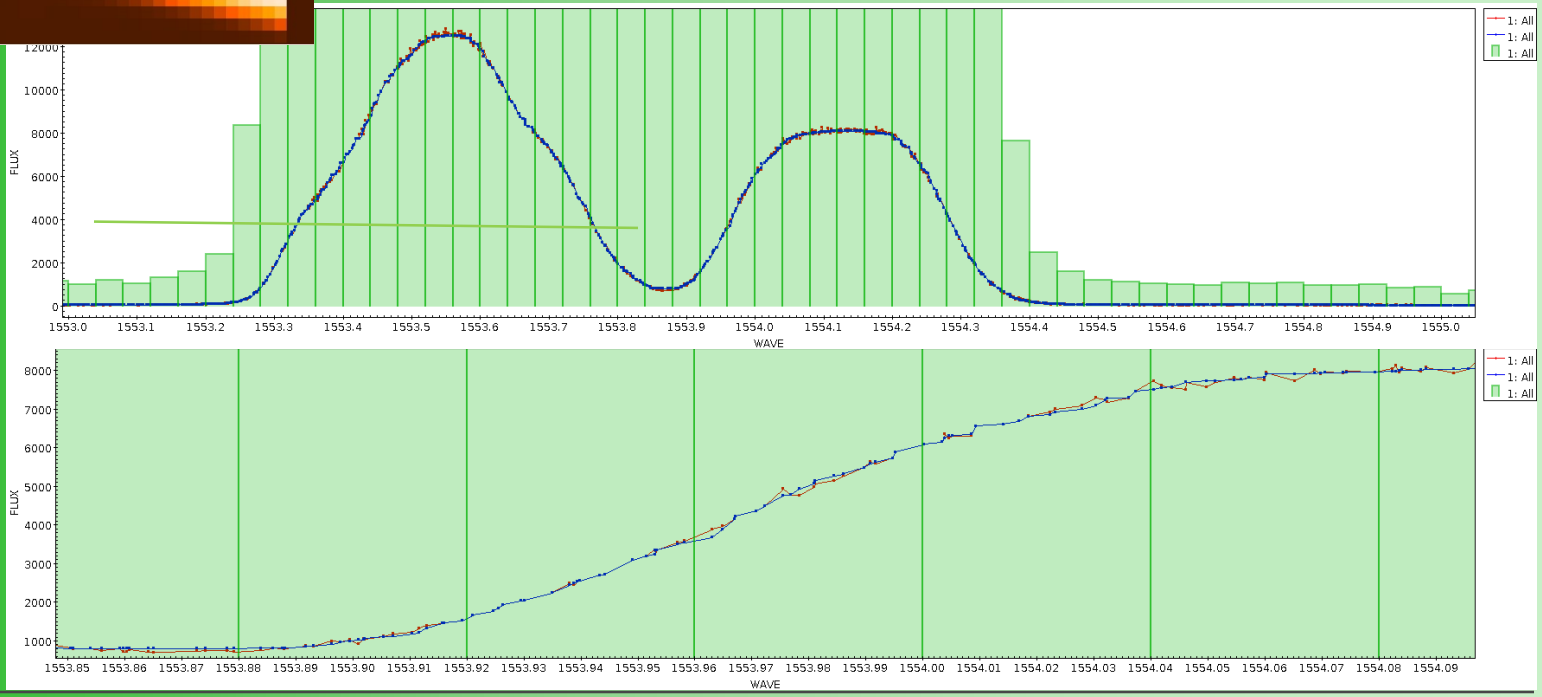
Stare Kelson (sky region)



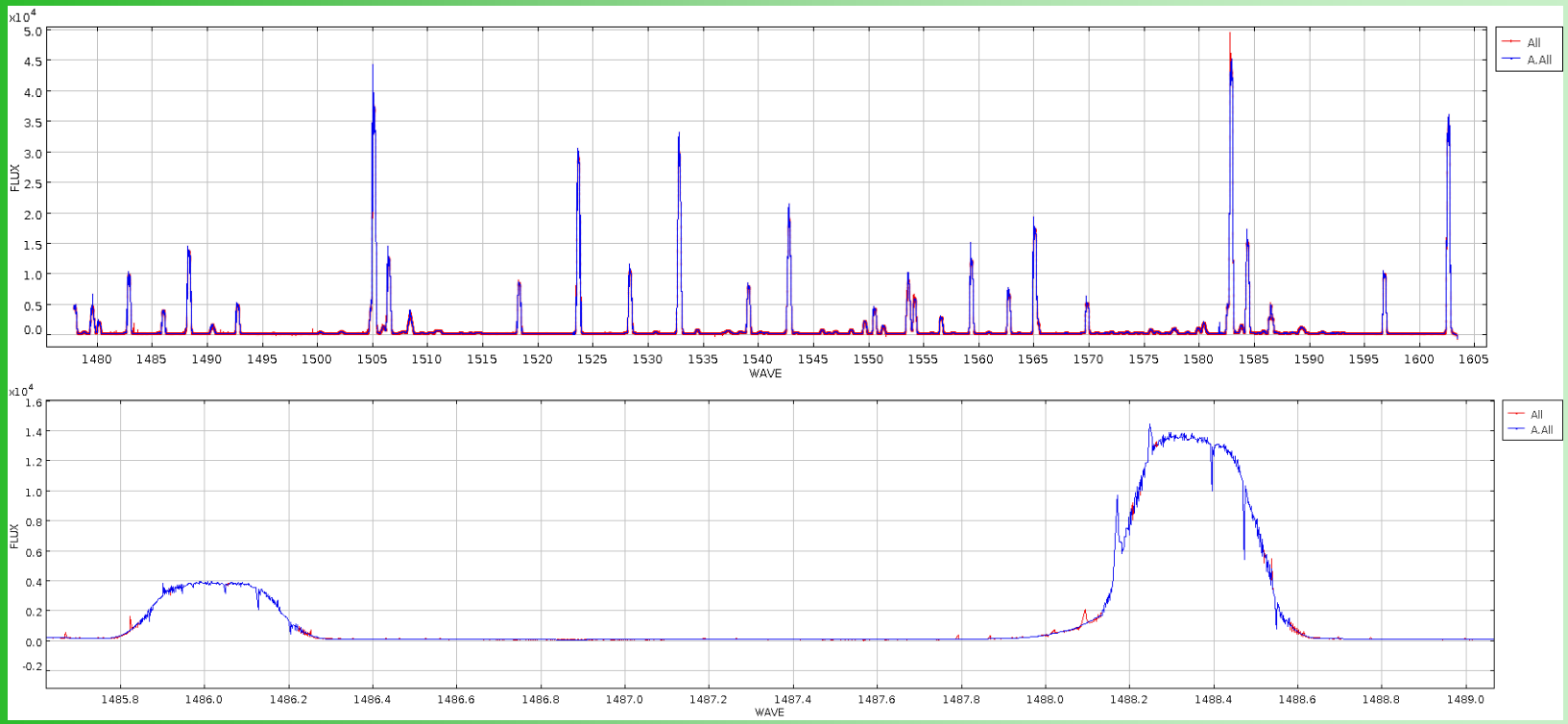
Sky line oversampling



Sky data sorted by wavelength
Wavelength axis not parallel to columns ➔ oversampling



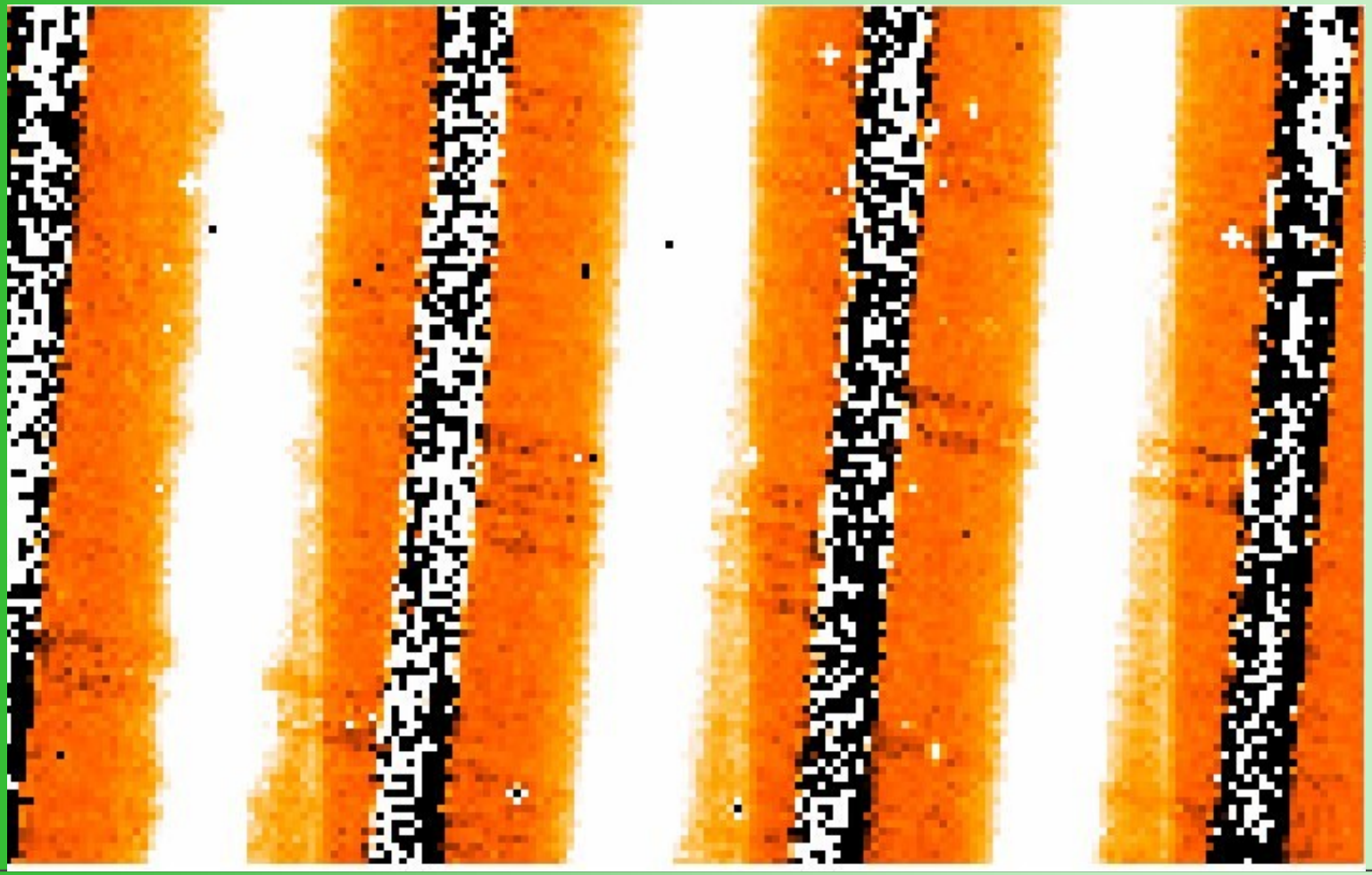
Sky model (Kelson)



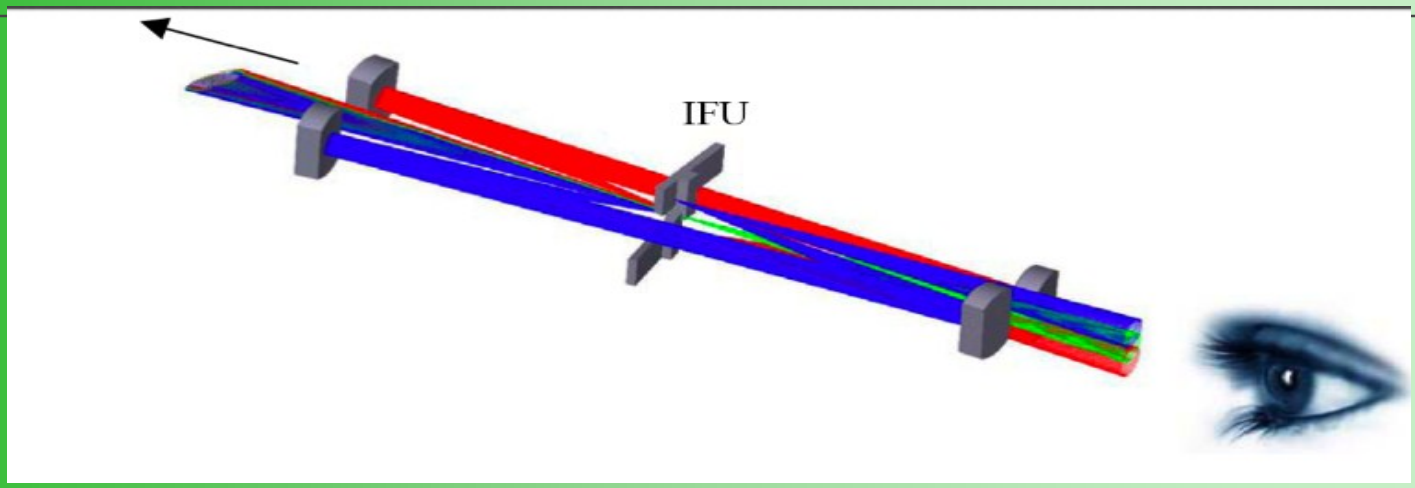
Flag additional bad pixels after sky correction

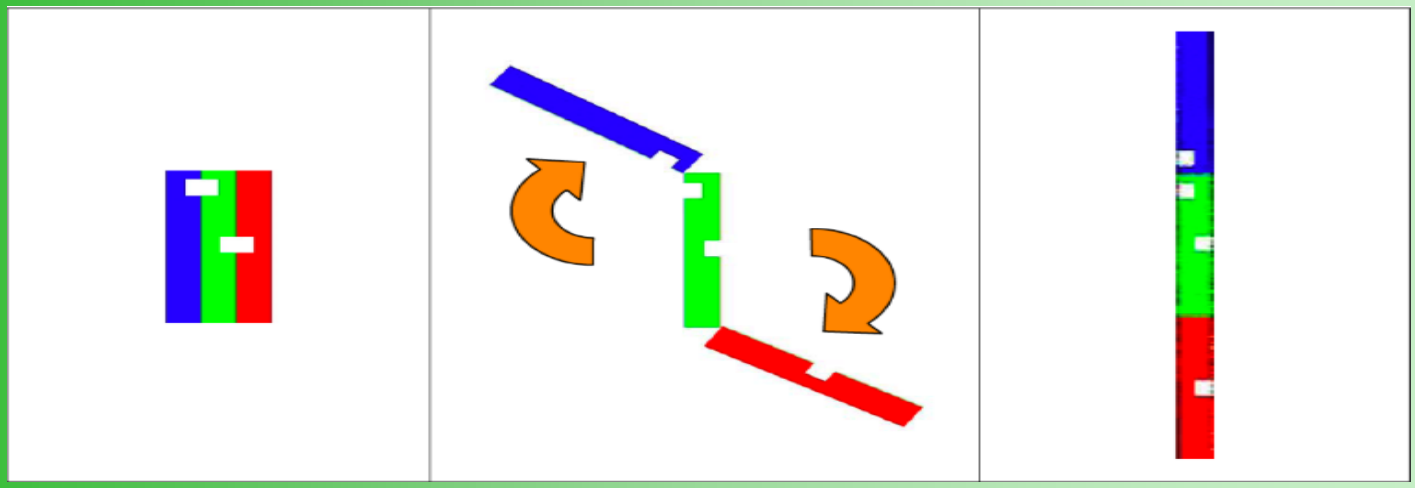
Kelson: obj-sky residuals

Kelson: obj-sky residuals (1553 nm)

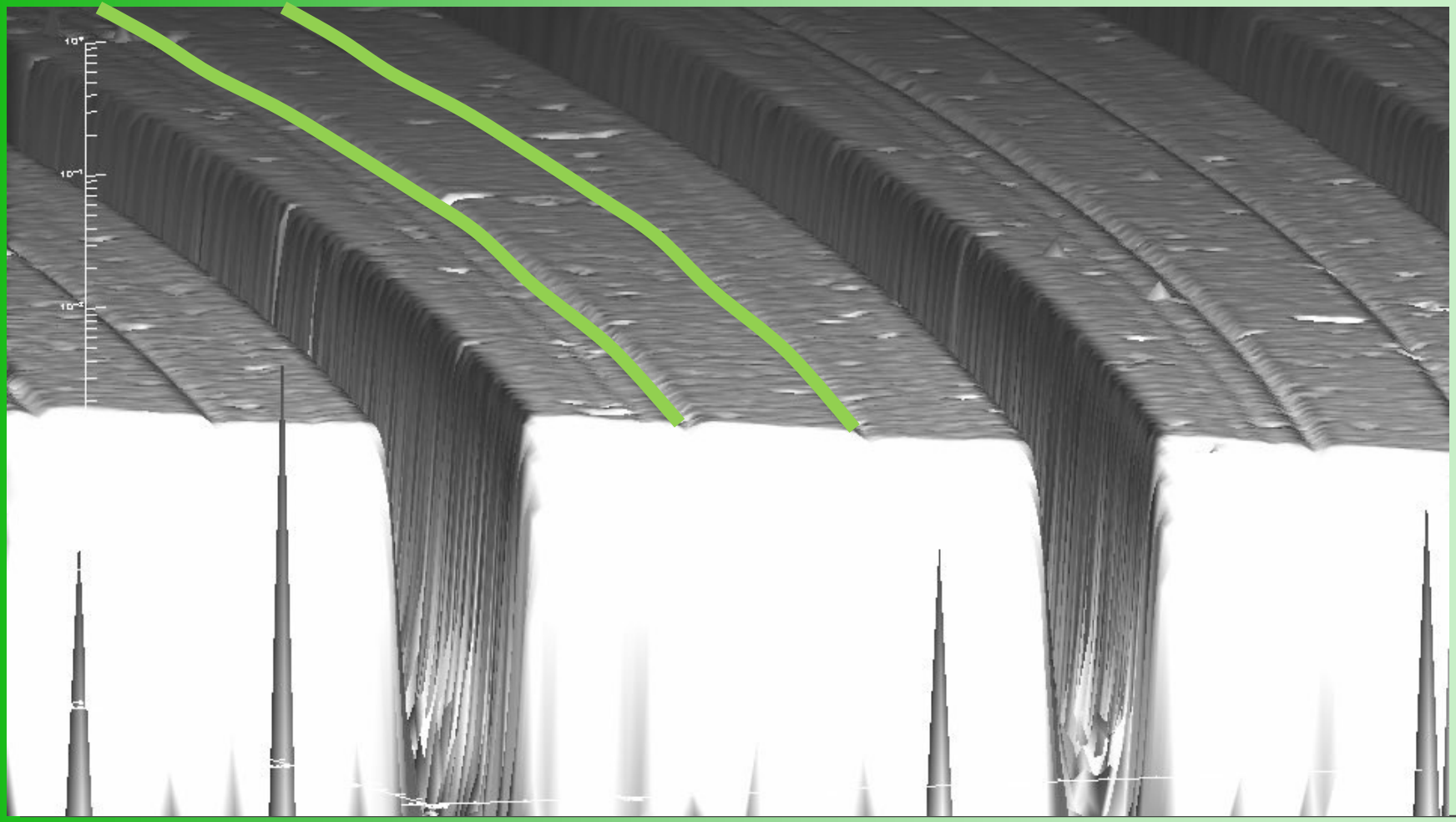


IFU Geometry





IFU flat slice edges tracing (Scharr filter)

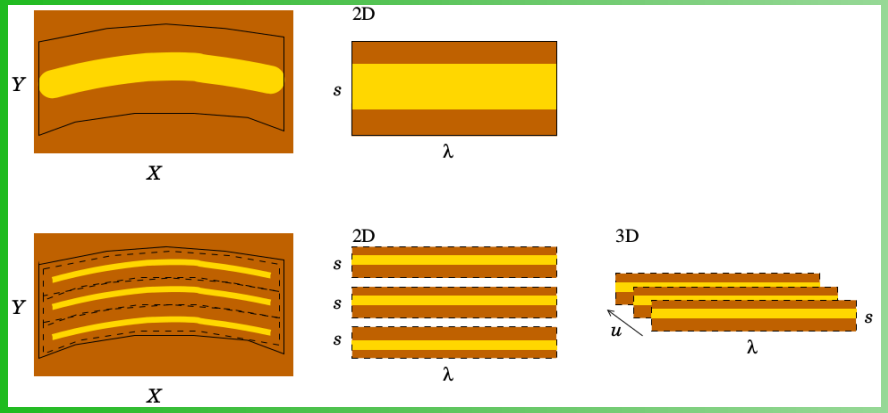


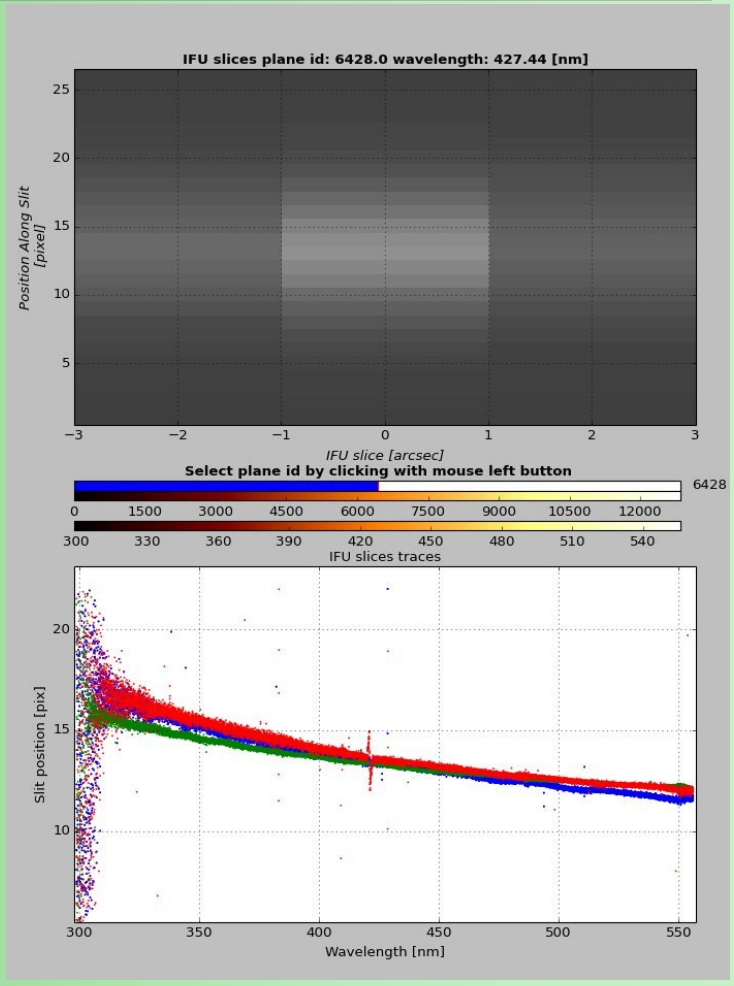
IFU data reduction

- Loop over order(m), λ, s:
- Use wave & slit maps to do (m, x, y)➔map(m, s,λ)
- Flux, errors, qual. determined interp. over a kernel
- If order overlaps, fluxes are averaged
- For QC object traces are determined

IFU Data Reduction

No sky correction.
No extraction.
Planes: spatial information
Z-axis: λ





SOS pipeline help

- Docs: **www.eso.org/pipelines**, recipe man, reflex tutorial, manual, FAQ, slides/hand-outs
- email usd-help@eso.org: description of your problem (doc? Reflex/pipeline reduction?)

For data reduction problems please provide:

- Rec id, reflex data set ID, input filenames
- Recipe log, command line (param. values)
- HW, OS specifications, pipe id
- More info: image display, spectrum plots.