SoXS day : the pipeline

soxspipe

https://soxspipe.readthedocs.io/

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soxspipe

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python 3.11 | pypi v0.13.4 | conda-forge v0.13.4 | downloads/month 705 | license GPL-3.0

coverage 90% | docs failing | bug issues 2 open

The data-reduction pipeline for the SOXS instrument (a python package with command-line tools).

Documentation for soxspipe is hosted by Read the Docs (development version and master version). The code lives on github. Please report any issues you find here.

Installation

The best way to install or upgrade soxspipe is to use `conda` to install the package in its own isolated environment, as shown here:

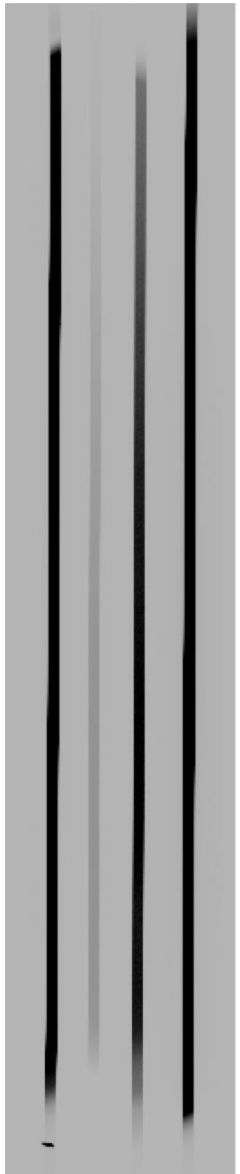
```
conda create -n soxspipe python=3.12 soxspipe -c conda-forge
conda activate soxspipe
```

If you have previously installed soxspipe, a warning will be issued stating that a conda environment already exists; select 'y' when asked to remove the existing environment.

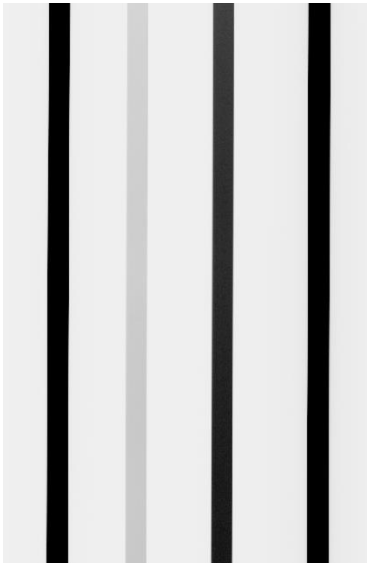
To check installation was successful run `soxspipe -v`. This should return the version number of the install.

soxspipe v0.13.1

- Easy installation, clear instructions for running
- Multiple installation methods – `miniforge, conda, pip, github`
- One documented installation problem (on Linux) – ***we will reply on github (only)***
- Calibration data required are well documented
- Data products produced are well documented



Quartz Lamp



Deuterium Lamp

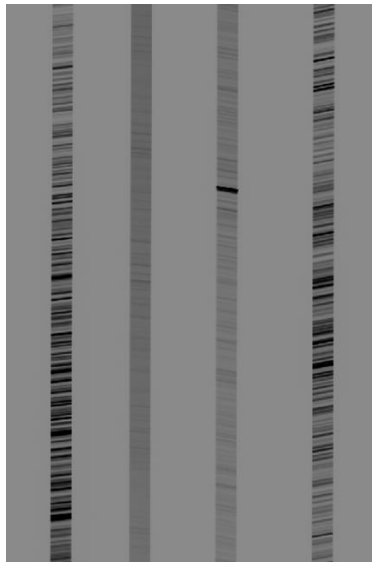
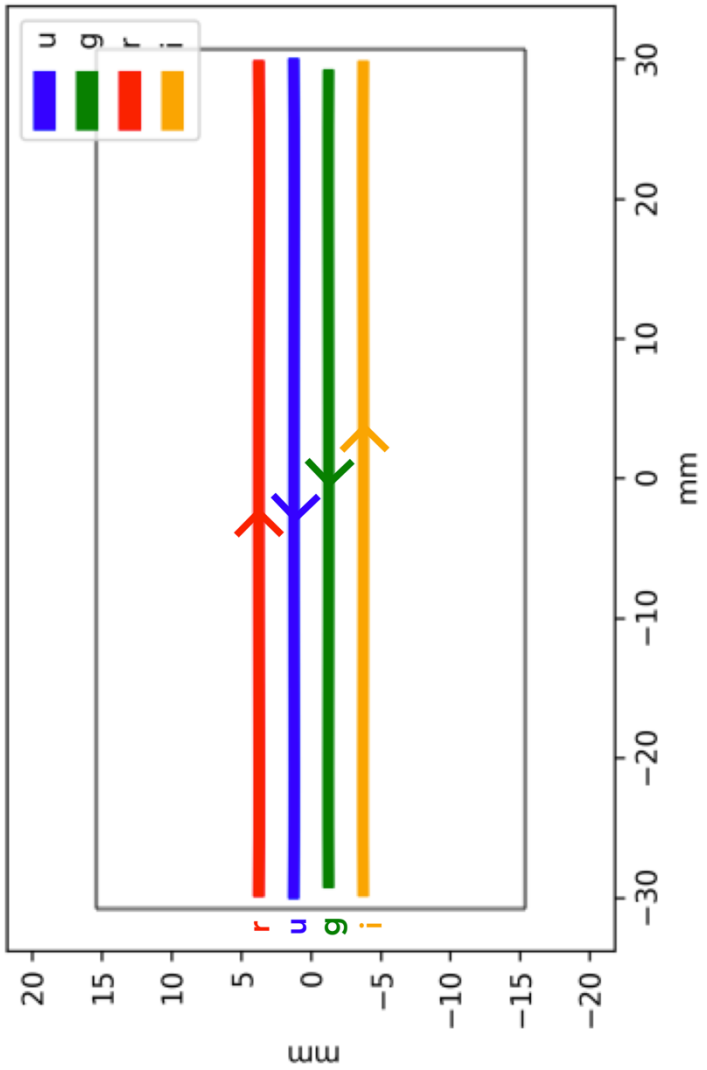


Table 1. Counts on images, measured at the centre of the order

Slit+Order	Exposure Time	Counts
1.0 *u*	10	160
1.0 *g*	10	860
1.0 *r*	10	3430
1.0 *i*	10	7930

Quartz Lamp counts in 10 sec with 1” slit



“rugi”

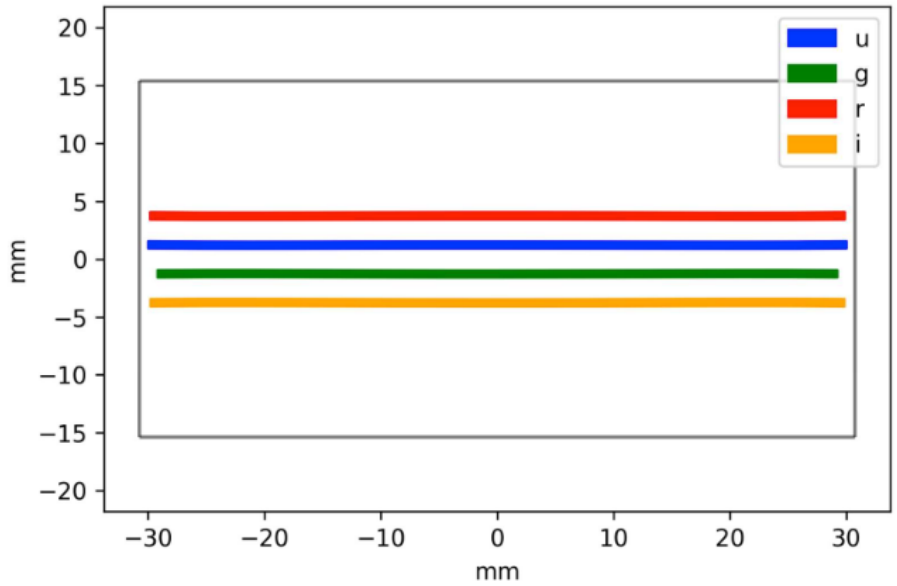
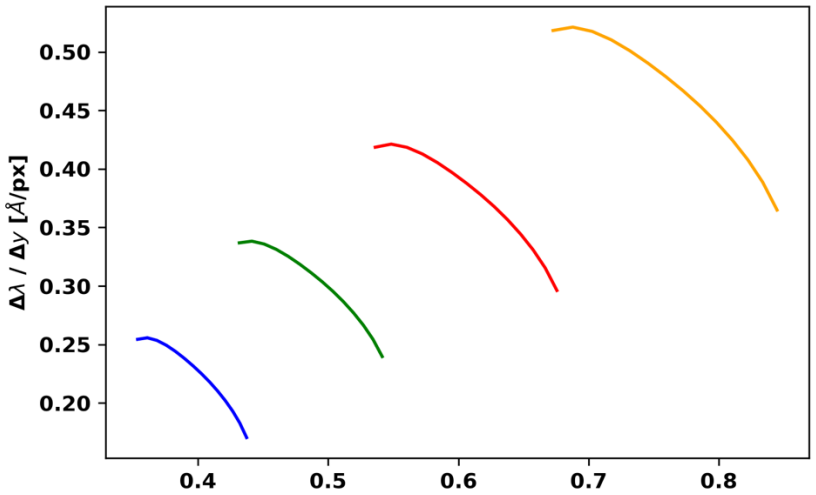


Figure 51: Spectral Format. The black rectangle represents the actual size of the CCD.

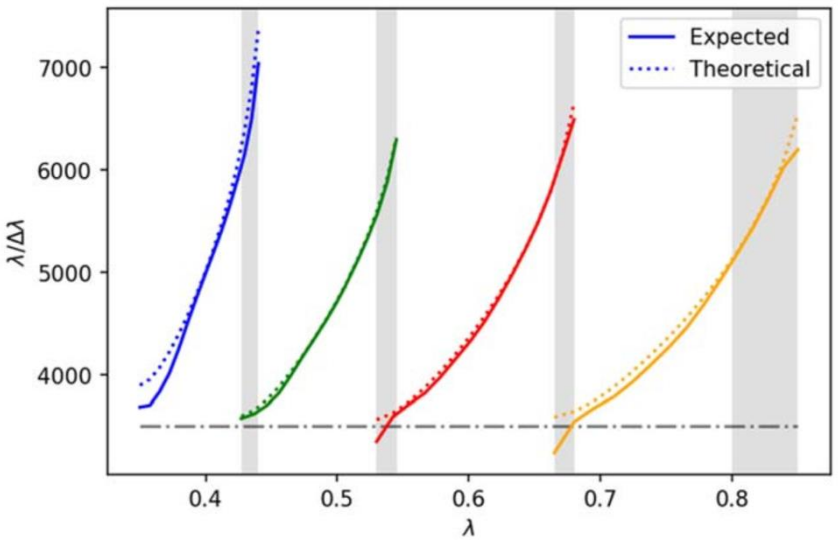
	Bottom margin		Top margin		Overlap
	mm	pixels	mm	pixels	
u	0.719	48	0.72	48	u to g: 13 nm (427-440)
g	1.51	101	1.511	101	g to r: 23 nm (522-545)
r	0.867	58	0.868	58	r to i: 24 nm (656-680)
i	0.901	60	0.902	60	i to NIR: 50 nm (800-850)

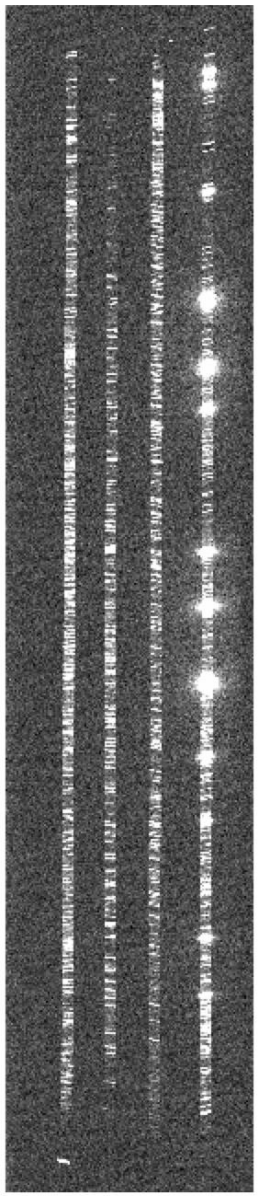
Table 25: Margins and spectral overlap.

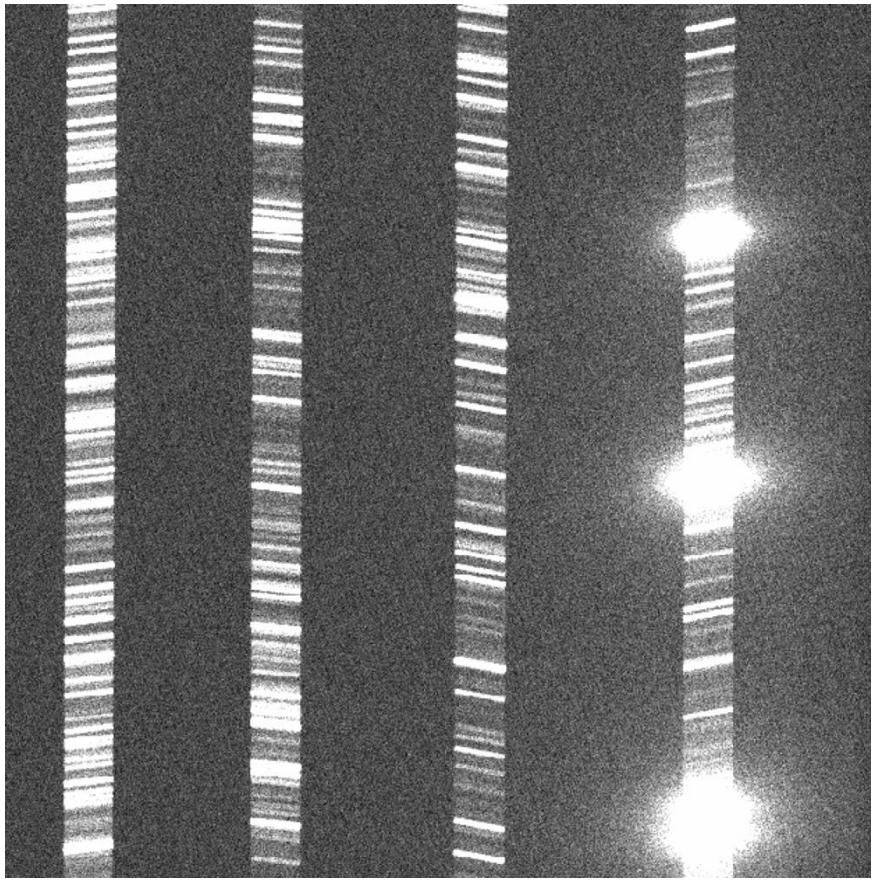
Dispersion :
Native pixel dispersion is 0.2 to 0.5 Angs per pix.
EFOSC2 with Gr#13 was 5.5 Angs per pix

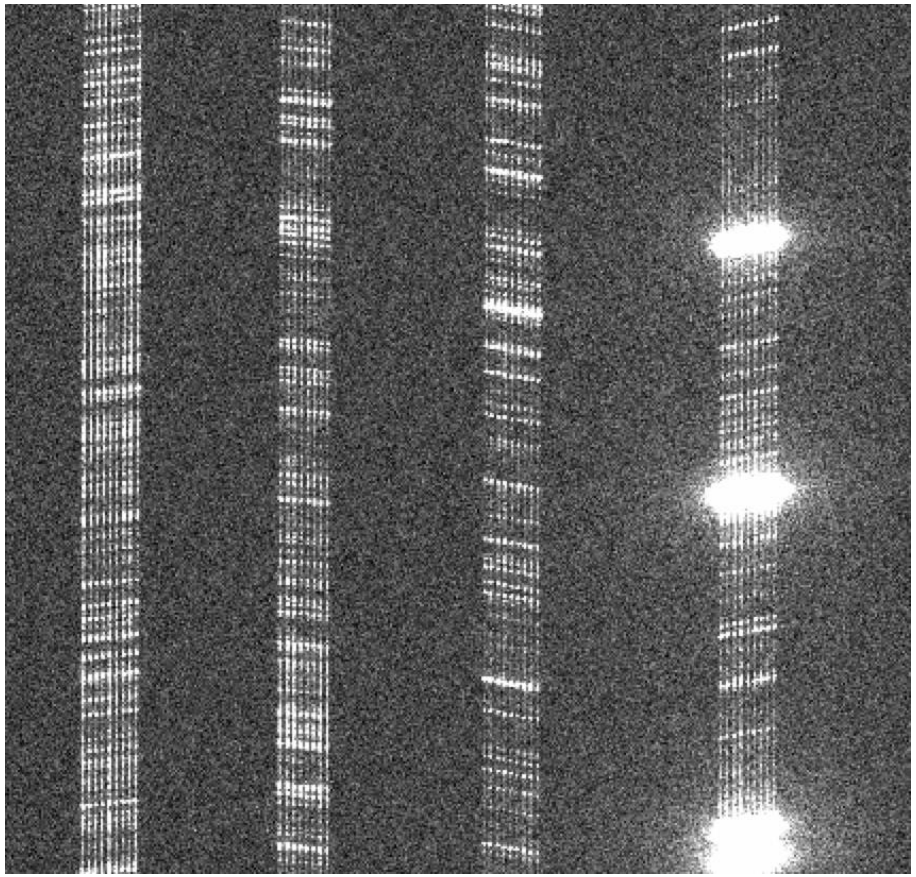


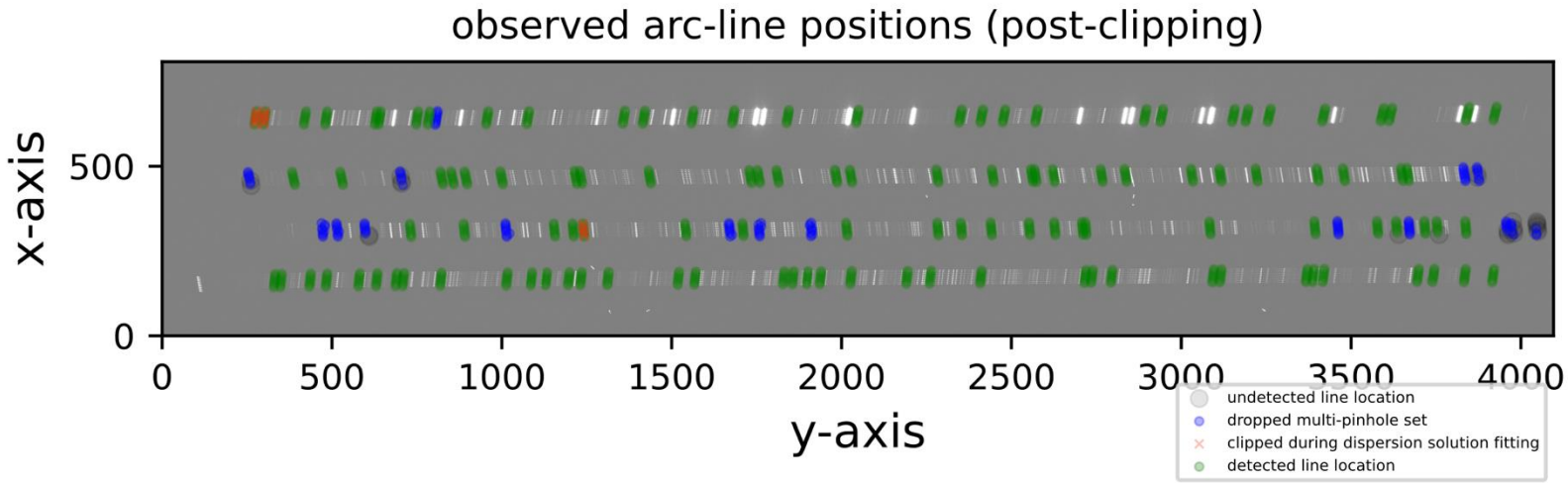
Resolution :

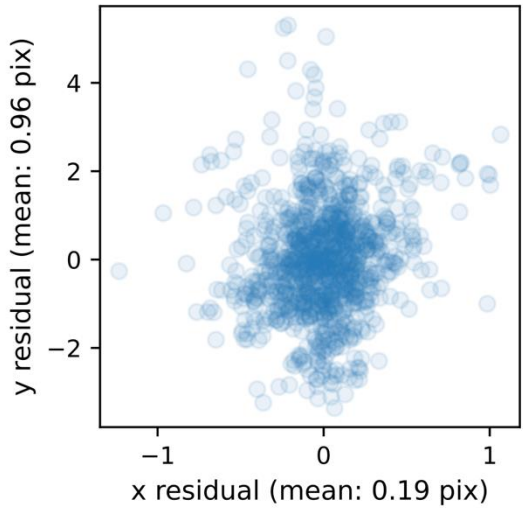


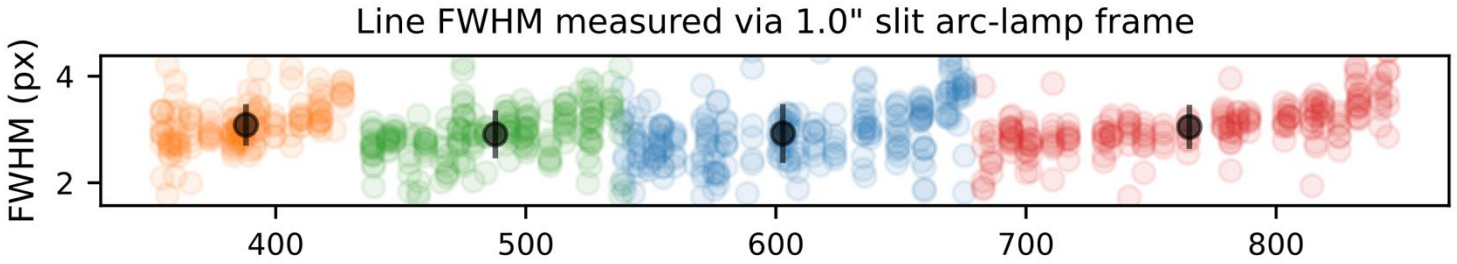


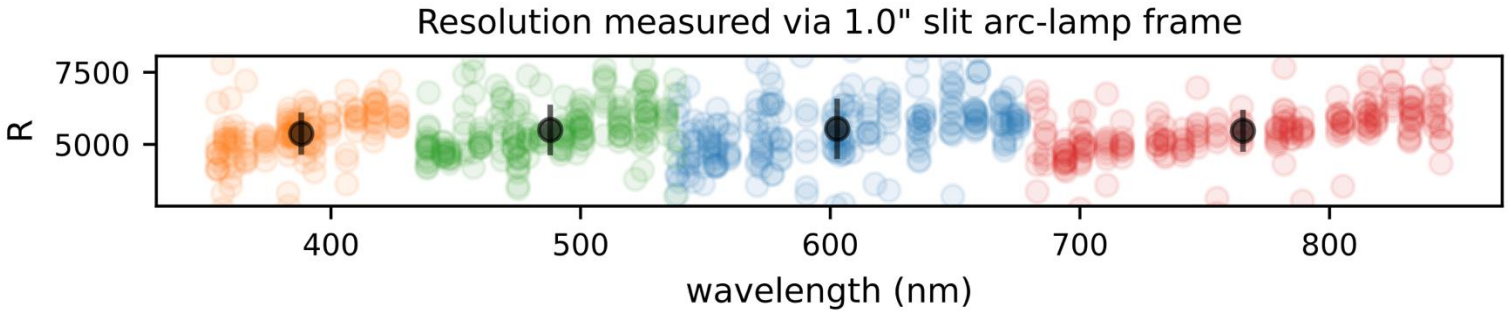












Data from SoXS Commissioning night on NTT 2025 06 05

QC Plots and products from `soxspipe` during standard pipeline reduction

Get all science frames and calibrations from the ESO SAF – the bias, flats, arc data frames from the SoXS calibration OBs

```
cd ~/soxs-workspace-one
soxspipe prep .
```

Once the workspace has been prepared, you should find it contains the following files and folders:

- `misc/` : a lost-and-found archive of non-fits files
- `raw/` : all raw frames to be reduced
- `sessions/` : directory of data-reduction sessions
- `sof/` : the set-of-files (sof) files required for each reduction step
- `soxspipe.db` : an SQLite database needed by the data-organiser; please do not delete
- `soxspipe.yaml` : file containing the default settings for each pipeline recipe

“Set of files” concept :

SOF dir contains an ascii file (.sof file) for each science frame

```
(soxspipe) bash$/Users/sjs/Dropbox/data/SoXS/20250608/sof>more 20250609T031911_VIS_1X1_1_STARE_SLIT5.0_300.0S_SOXS_EG274.sof
./raw/2025-06-08/SOXS.2025-06-09T03:19:11.588.fits                                  OBJECT,ASYNC_VIS
./reduced/2025-06-08/soxs-mbias/20250609T103007_VIS_1X1_1_MBIAS_SLIT0.5_SOXS.fits   MASTER_BIAS_VIS
./reduced/2025-06-08/soxs-spatial-solution/20250609T112256_VIS_1X1_1_SSOL_MULTPIN_30.0S_SOXS.fits        DISP_TAB_VIS
./reduced/2025-06-08/soxs-spatial-solution/20250609T112256_VIS_1X1_1_SSOL_MULTPIN_30.0S_SOXS_IMAGE.fits  DISP_IMAGE_VIS
./reduced/2025-06-08/soxs-mflat/20250609T104710_VIS_1X1_1_OLOC.fits                  ORDER_TAB_VIS
./reduced/2025-06-08/soxs-mflat/20250609T105737_VIS_1X1_1_MFLAT_SLIT5.0_2.0S_SOXS.fits  MASTER_FLAT_VIS
```

Also each calibration frame (e.g master flat) has a .sof

User can check these are the correct ones before starting the reductions

soxspipe.yaml

```
soxs-stare:
    # DIVIDE IMAGE BY MASTER FLAT FRAME
    use_flat: False
    # FIT AND SUBTRACT THE INTRA-ORDER BACKGROUND LIGHT
    subtract_background: True
     # THE SIGMA CLIPPING LIMIT USED WHEN STACKING FRAMES INTO A COMPOSITE FRAME
    stacked-clipping-sigma: 5
    # THE MAXIMUM SIGMA-CLIPPING ITERATIONS USED WHEN STACKING FRAMES INTO A COMPOSITE FRAME
    stacked-clipping-iterations: 5
    # USE LA COMSIC TO REMOVE CRHs BEFORE EXTRACTION
    use_lacosmic: True
    vis:
        # THE LENGTH OF THE 'SLIT' USED TO COLLECT OBJECT FLUX (IN PIXELS)
        horne-extraction-slit-length: 20
        # SIGMA CLIPPING LIMIT WHEN FITTING THE OBJECT PROFILE (GLOBAL OVER THE ORDER)
        horne-extraction-profile-global-clipping-sigma: 25
        # SIGMA CLIPPING LIMIT WHEN FITTING THE DISPERSION-DIRECTION PROFILES OF THE OBJECT
        horne-extraction-profile-clipping-sigma: 3.0
         # MAXIMUM NUMBER OF CLIPPING ITERATIONS WHEN FITTING DISPERSION-DIRECTION PROFILES
        horne-extraction-profile-clipping-iteration-count: 10
        detect-continuum:
            # NUMBER OF CROSS-ORDER SLICES PER ORDER
            order-sample-count: 100
            # LENGTH OF EACH SLICE (PIXELS)
            slice-length: 30
            # WIDTH OF EACH SLICE (PIXELS)
            slice-width: 5
            # HEIGHT GAUSSIAN PEAK MUST BE ABOVE MEDIAN FLUX TO BE "DETECTED" BY CODE (STD VIA MEDIAN ABSOLUTE DEVIATION).
            peak-sigma-limit: 2
            # DEGREE OF Y-COMPONENT OF GLOBAL POLYNOMIAL FIT TO ORDER CENTRES
            disp-axis-deg: 6
            # DEGREE OF ORDER-COMPONENT OF GLOBAL POLYNOMIAL FIT TO ORDER CENTRES
            order-deg: 3
            # CLIPPING LIMIT (MEDIAN AND MAD) WHEN FITTING GLOBAL POLYNOMIAL TO OBJECT TRACE
            poly-fitting-residual-clipping-sigma: 4
            # MAXIMUM NUMBER OF CLIPPING ITERATIONS WHEN FITTING GLOBAL POLYNOMIAL TO ORDER CENTRES
            poly-clipping-iteration-limit: 5
        sky-subtraction:
            # MODEL AND SUBTRACT THE SKY BEFORE OBJECT EXTRACTION
            subtract_sky: True
            # PERCENTILE CLIPPING SIGMA LIMIT USED TO CLIP THE OBJECT(S) BEFORE FITTING A SKY MODEL
            percentile_clipping_sigma: 3
```

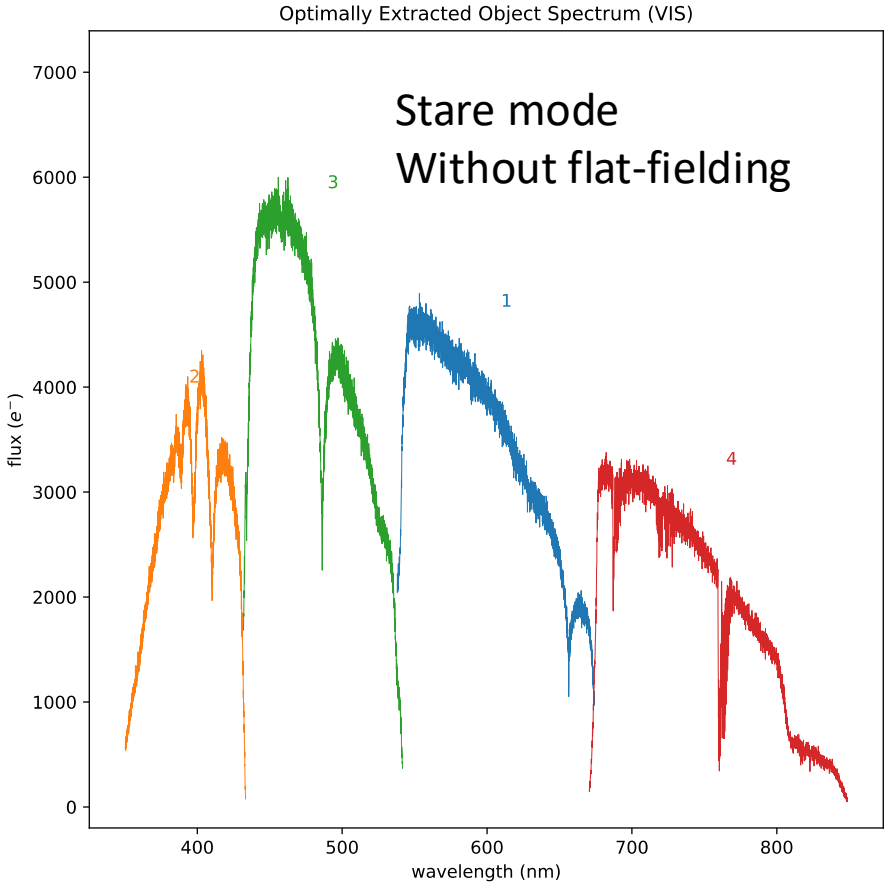
All settings documented and explained in the manual - side bar **"Pipeline Settings"**

Many settings - defaults reasonable, but we will see some of these need tuning with SoXS data and some more detailed with on-sky testing **and** informing the calibration OBs and detector settings (e.g what is the best binning ?)

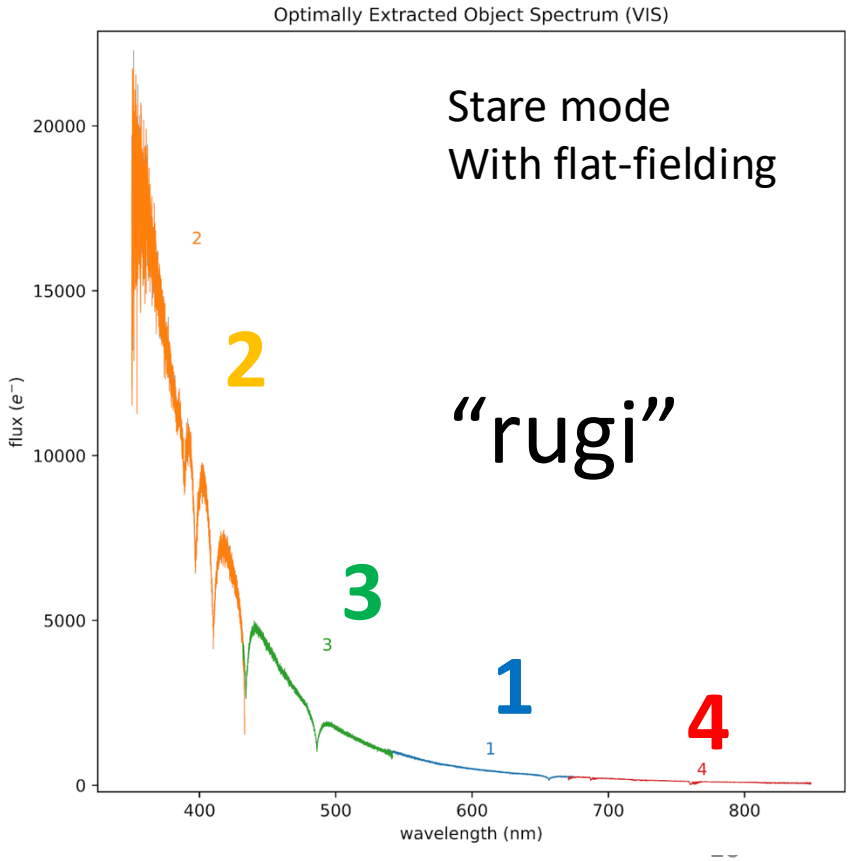
Status of pipeline – functional (both VIS and NIR) but not yet tuned for science operations

After the preparation of the workspace :

```
$ soxspipe reduce all .
```



EG274 spectrophotometric standard



SOXS

INAF ISTITUTO NAZIONALE DI ASTROFISICA

מכון ויצמן למדע WEIZMANN INSTITUTE OF SCIENCE

Queen's University Belfast

INSTITUTO MILENIO DE ASTROFÍSICA

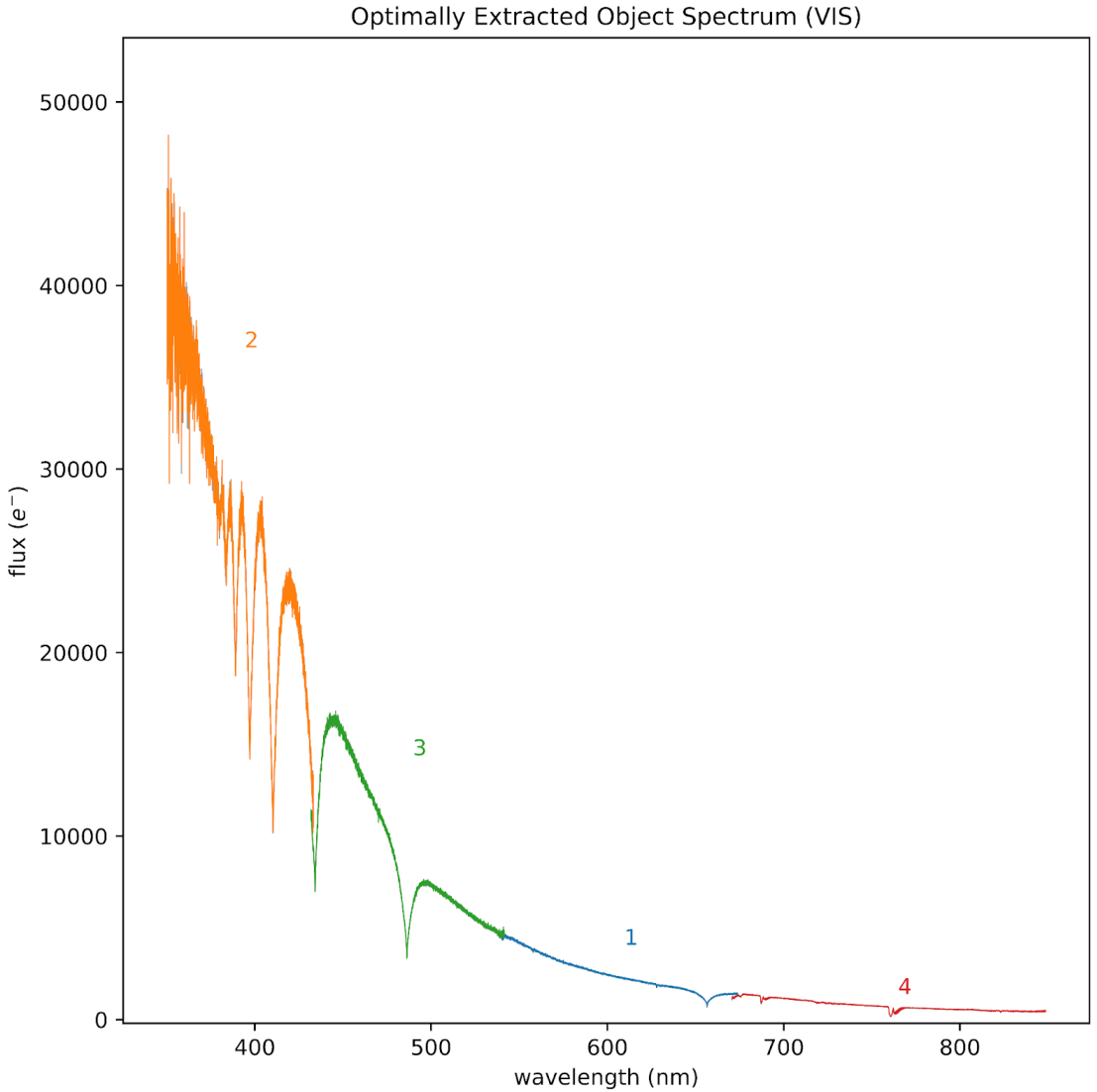
Turun yliopisto University of Turku

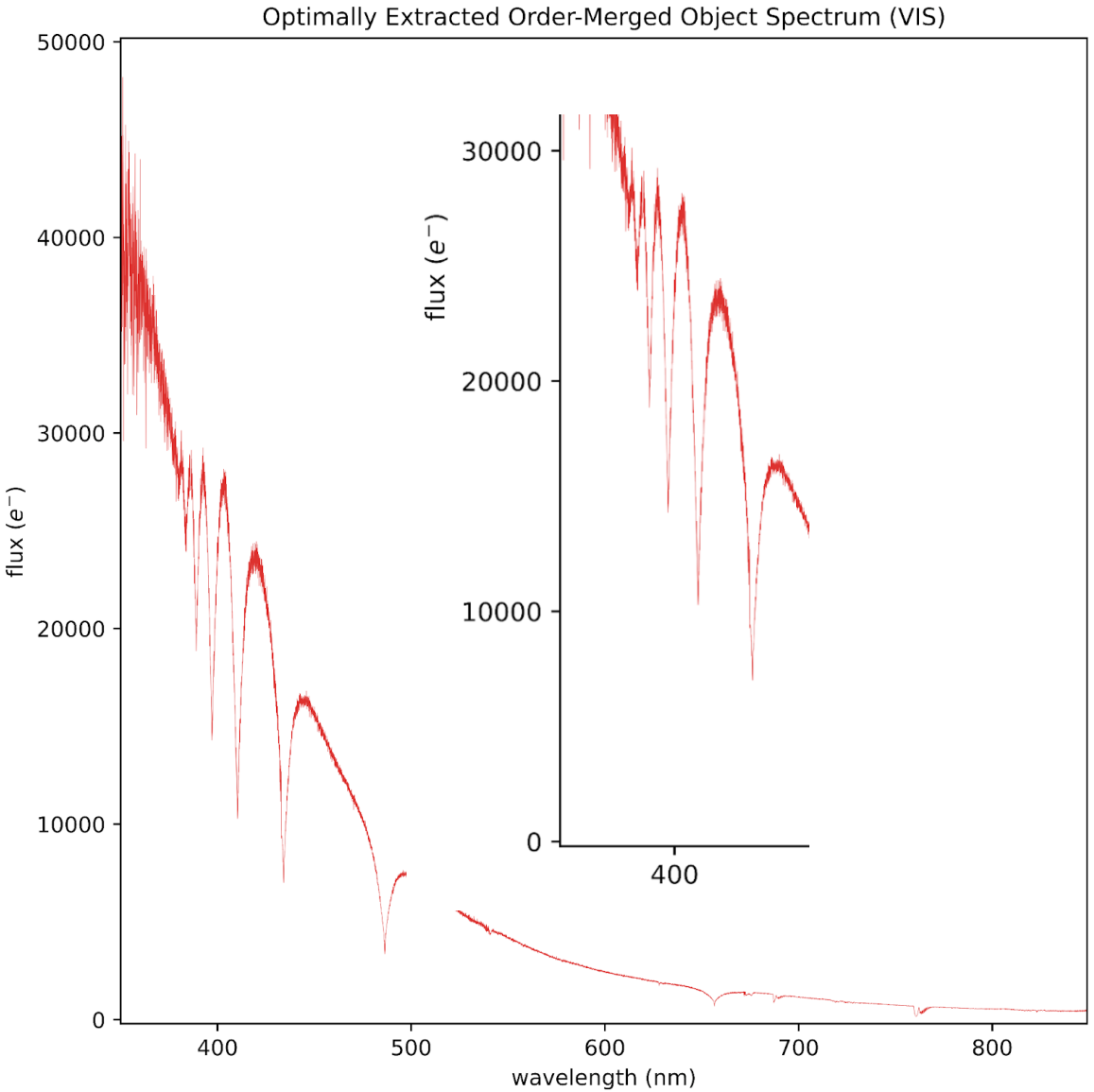
TEL AVIV UNIVERSITY

Dark Cosmology Centre

UNIVERSITY OF OXFORD

ESO





Summary of pipeline products :

Label	Content	Data Type	PRO CATG	PRO TYPE	PRO TECH
EXTRACTED ORDERS TABLE	Table of the extracted source in each order	FITS	SCI_SLIT_FLUX_NIR	REDUCED	ECHELLE,SLIT
EXTRACTED MERGED TABLE	Table of the extracted, order-merged	FITS	SCI_SLIT_FLUX_NIR	REDUCED	ECHELLE,SLIT
SKY SUBTRACTED OBJECT	The sky-subtracted object	FITS	-	-	-
SKY MODEL	The sky background model	FITS	-	-	-
SKY SUB RESIDUALS	The sky subtraction residuals	FITS	-	-	-
EXTRACTED MERGED ASCII	Ascii version of extracted source spectrum	TXT	-	-	-
BKGROUND	Fitted intra-order image background	PDF	-	-	-
SKY MODEL QC PLOTS	QC plots for the sky-background modelling	PDF	-	-	-
SKY SUBTRACTION QUICKLOOK	Sky-subtraction quicklook	PDF	-	-	-
OBJECT TRACE RES	Residuals of the object trace polynomial fit	PDF	-	-	-
EXTRACTED ORDERS QC PLOT	QC plot of extracted source	PDF	-	-	-
EXTRACTED MERGED QC PLOT	QC plot of extracted order-merged source	PDF	-	-	-

Main product FITS table : extracted spectra at native pixel resolution, each order separate

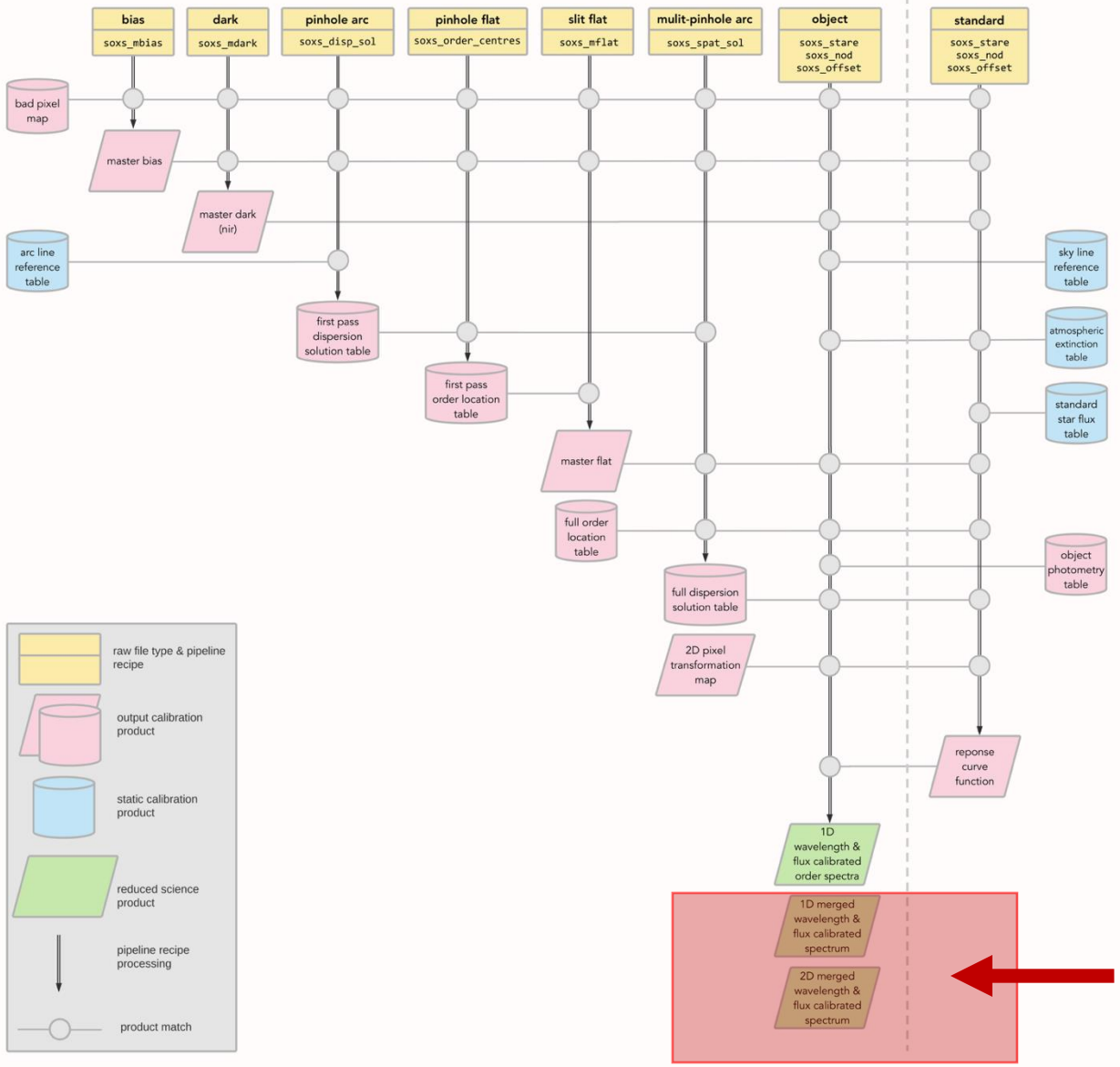
Merged spectrum : FITS table and ascii file, uniform pixel scale of 0.2 Angs per pix

To come :
Flux calibration
2D rectified, calibrated image for user to do own extractions

TOPCAT(1): Table Browser

Table Browser for 1: 20250609T031911_VIS_1X1_1_STARE_SLIT5.0_300.0S_S...

	order	xcoord_centre	ycoord	wavelengthMedian	pixelScaleNm	varianceSpectrum	snr	extractedFluxOptimal	extractedFluxBoxcar	extractedFluxBoxcarRobust
3546	4	316.26439	4012	350.05597	0.02619	2768.74996	134.32249	7067.90337	6821.6	6821.60303
3547	4	316.27378	4011	350.08216	0.02619	1942.42562	173.33971	7639.59382	7587.75	7587.75195
3548	4	316.28314	4010	350.10835	0.02619	1681.28411	186.36861	7641.75856	7594.83	7594.82764
3549	4	316.29246	4009	350.13454	0.02619	1617.28132	184.90593	7436.07278	7557.1	7557.1001
3550	4	316.30175	4008	350.16073	0.02619	2445.29201	152.10637	7521.64405	7463.06	7463.06201
3551	4	316.311	4007	350.18692	0.02609	1825.53241	180.13875	7696.65313	7683.66	7683.6582

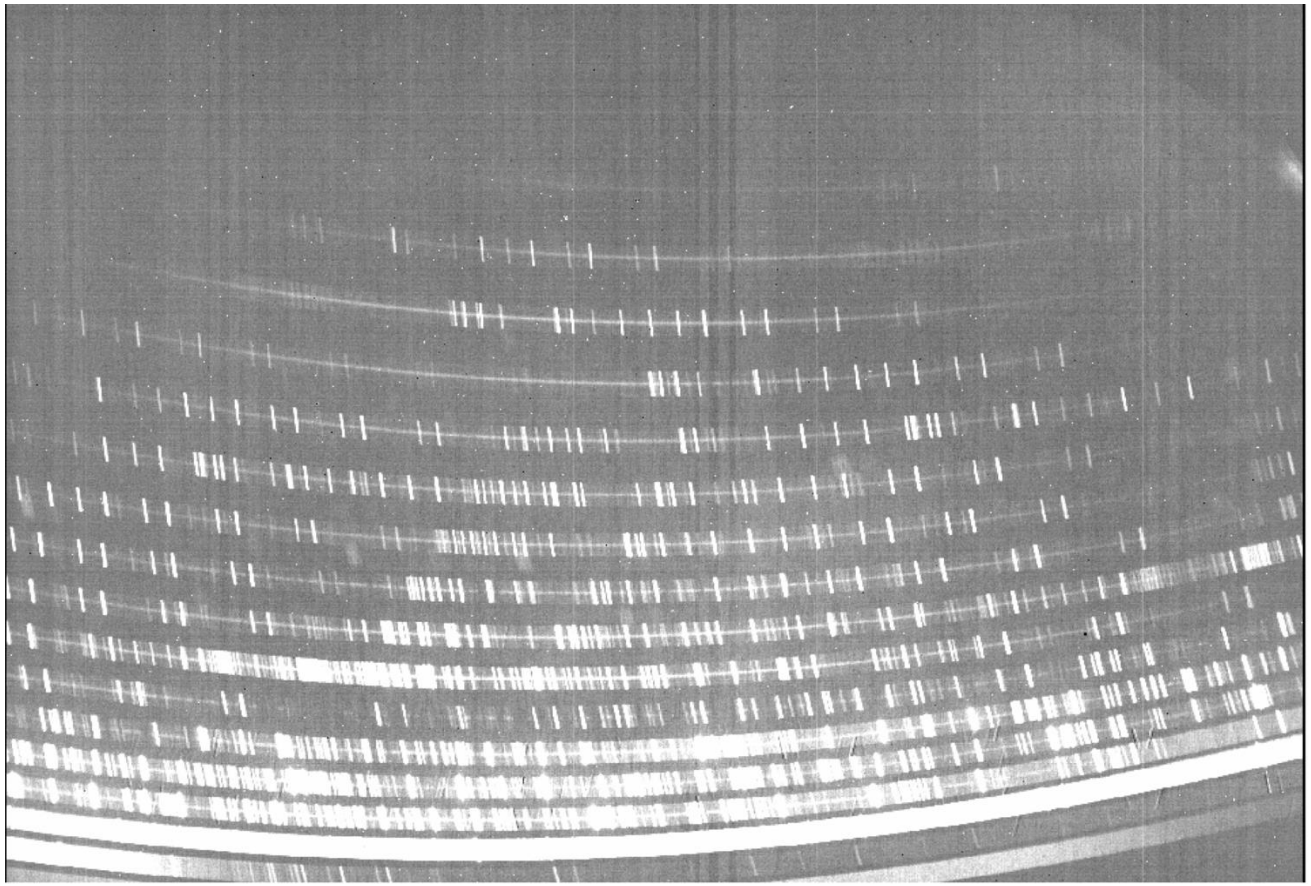


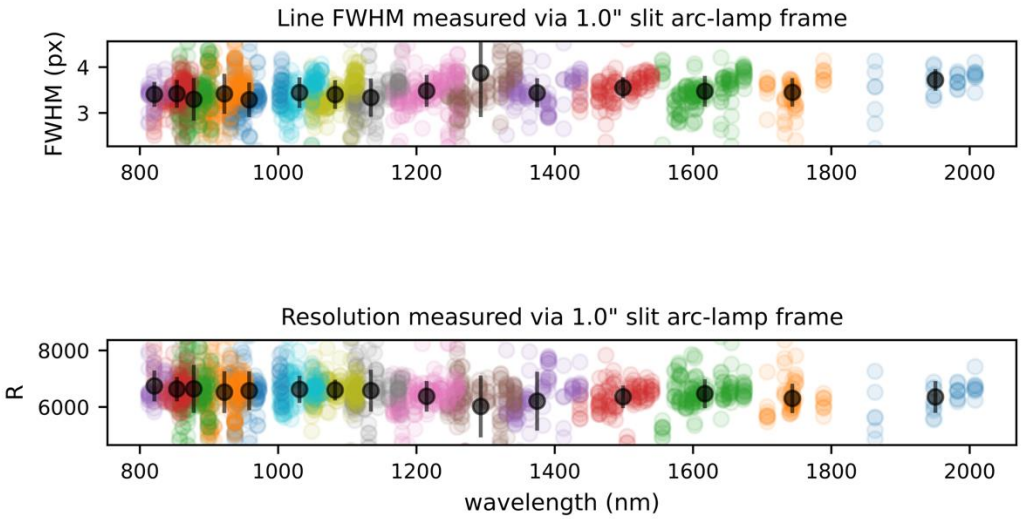
- Low object counts (particularly in u-band) cause extraction window not to trace
- Flat-fielding of the u-band order (large number of QLAMP, or normalise DLAMP?)
- Wavelength stability – requires skylines/telluric tweaks
- Flux calibration checks - consistency
- Throughput checks with narrow (1.0”) slits - confirmation that acquisition and guiding work well and that slit losses vs seeing as expected

Pipeline Todo with high priority

1. Get flux calibration in stare and nodding working
2. Optimise settings in yaml file for good sky subtraction in both stare and nodding modes
3. Verify soxspipe for NIR and implement flux calibration for both UV-VIS+NIR
4. Produce 2D order merged FITS image for stare and nodding - allowing user to re-extract

NIR data : limited data from May. Early results look in spec.





`soxspipe` : was tested with xshooter,

You can use pipeline, documented xhsooter use for all three xshooter modes

Performance demonstration : SN2025mlo

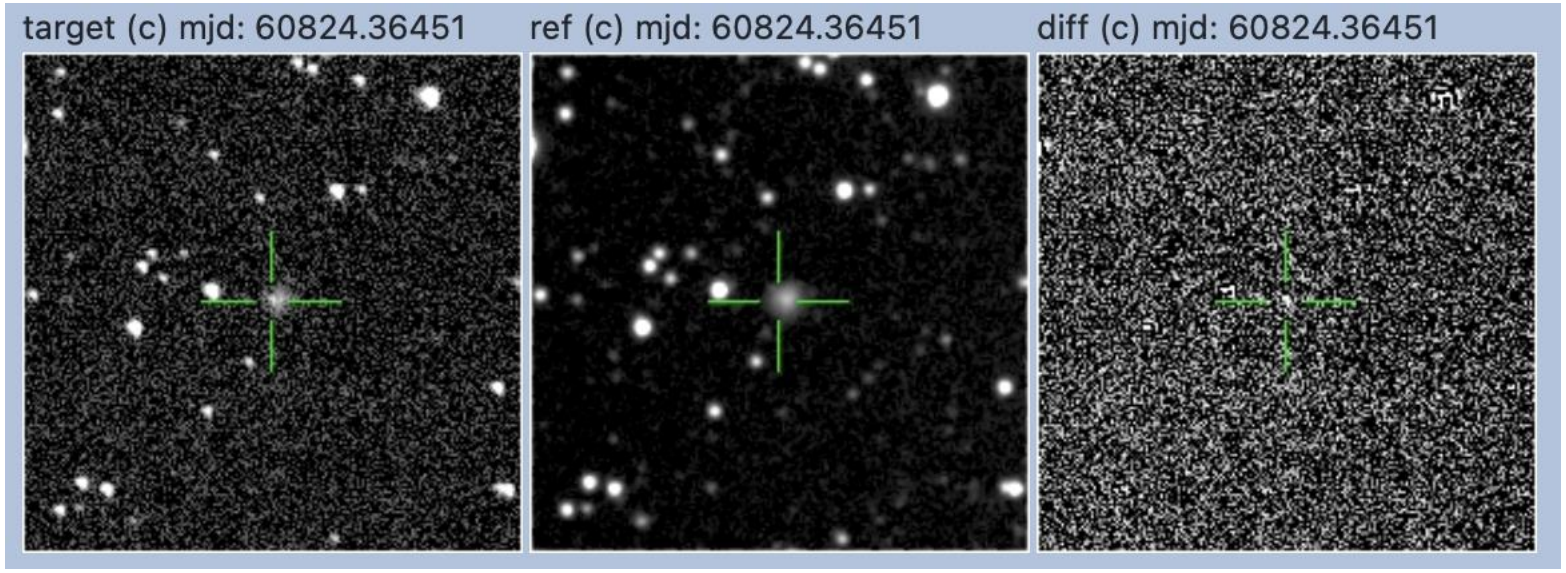
NEW : spectral and time resolution for NTT

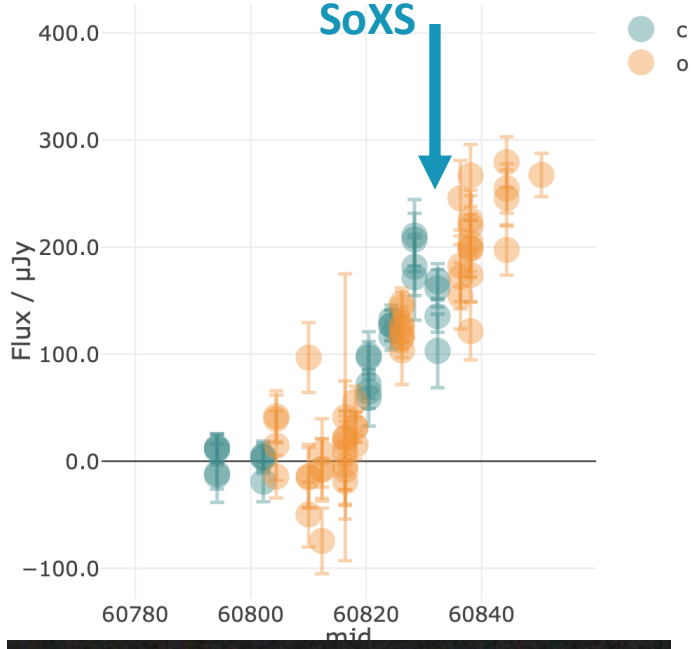
ATLAS discovery

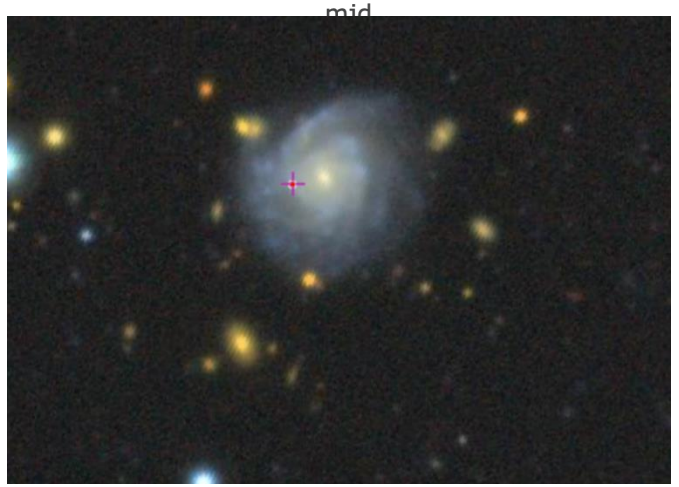
Declination -70 : Legacy Survey host

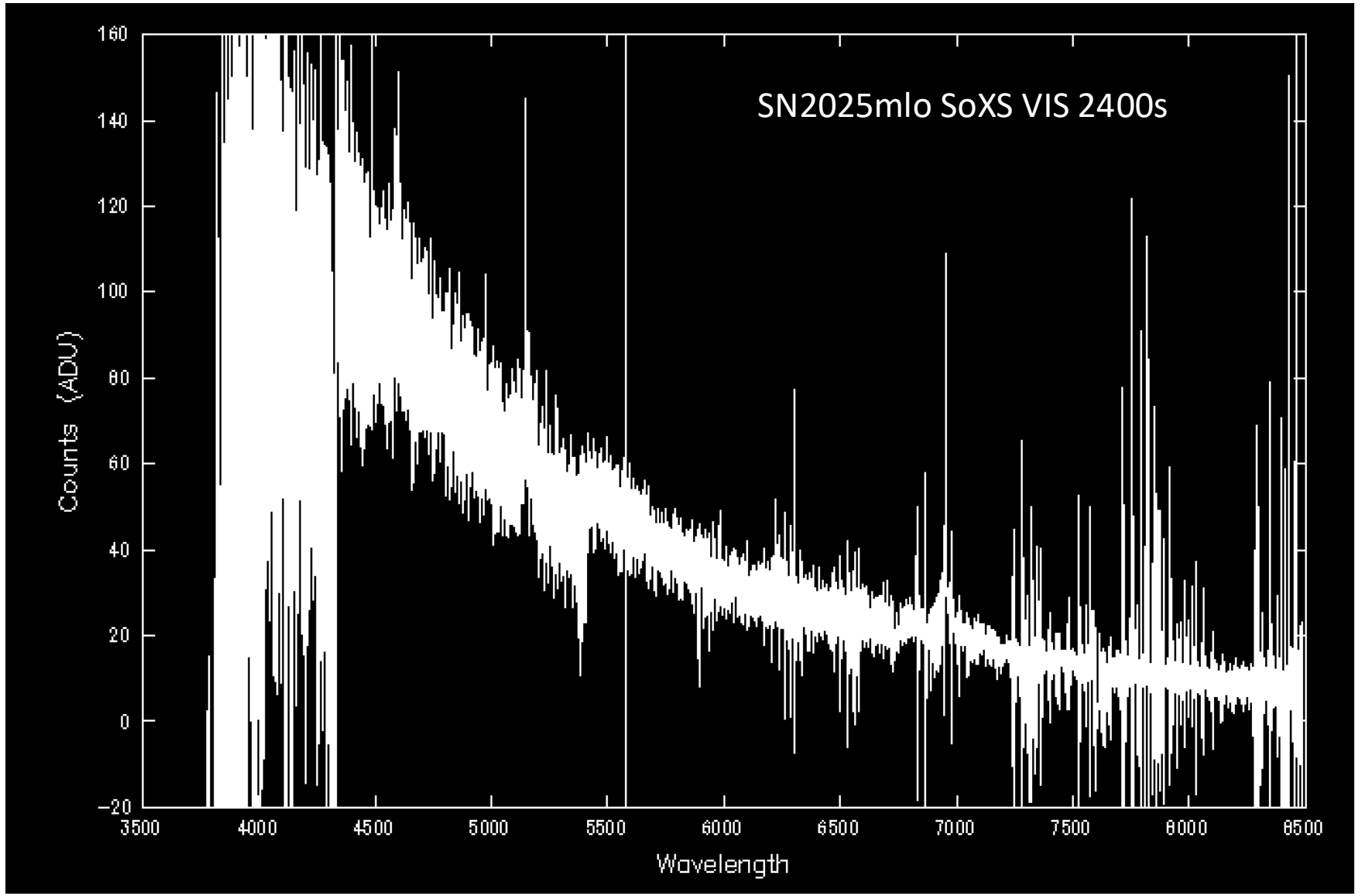
SoXS spectrum 2025 06 06

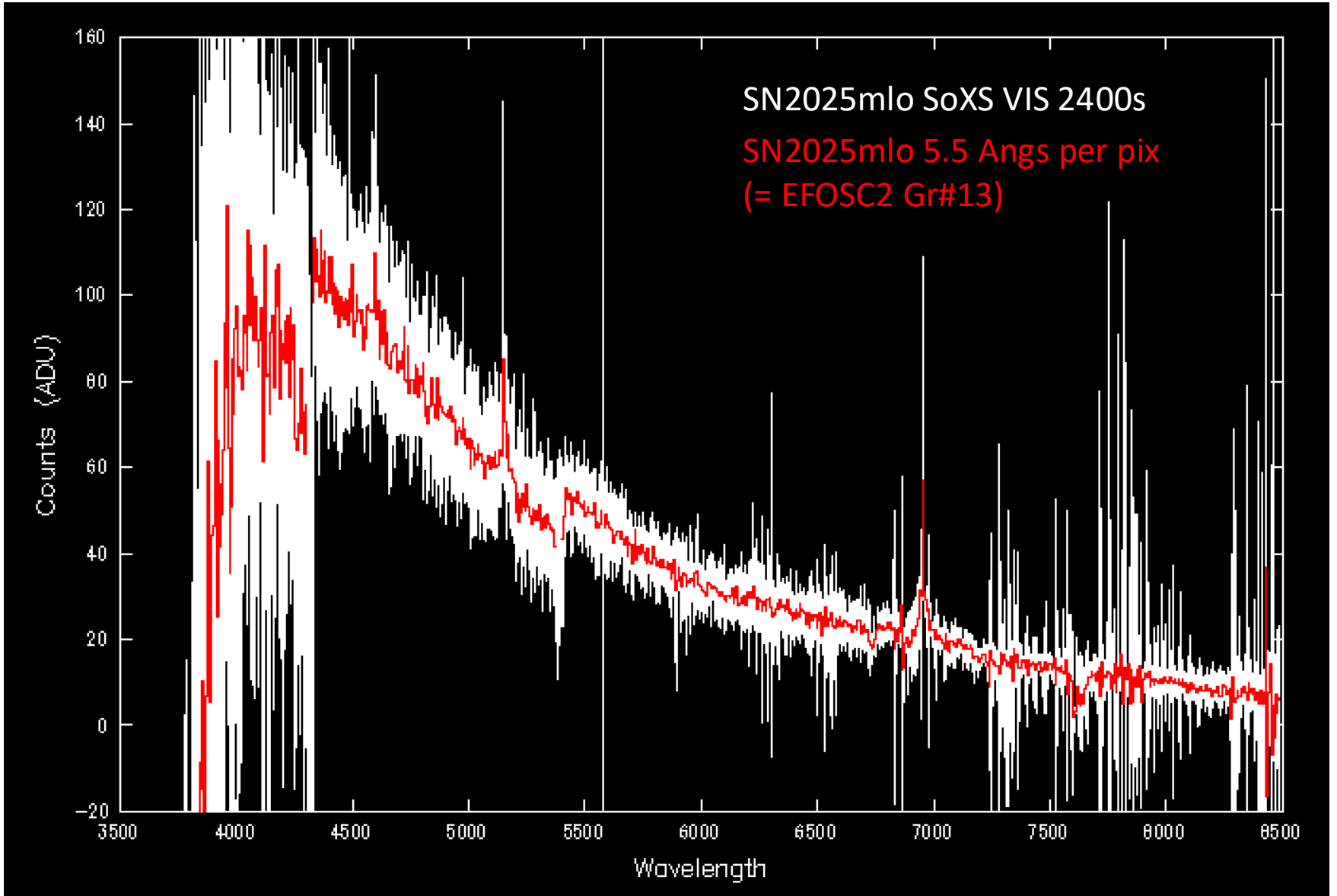
r = 18.6 AB mag when spectrum taken

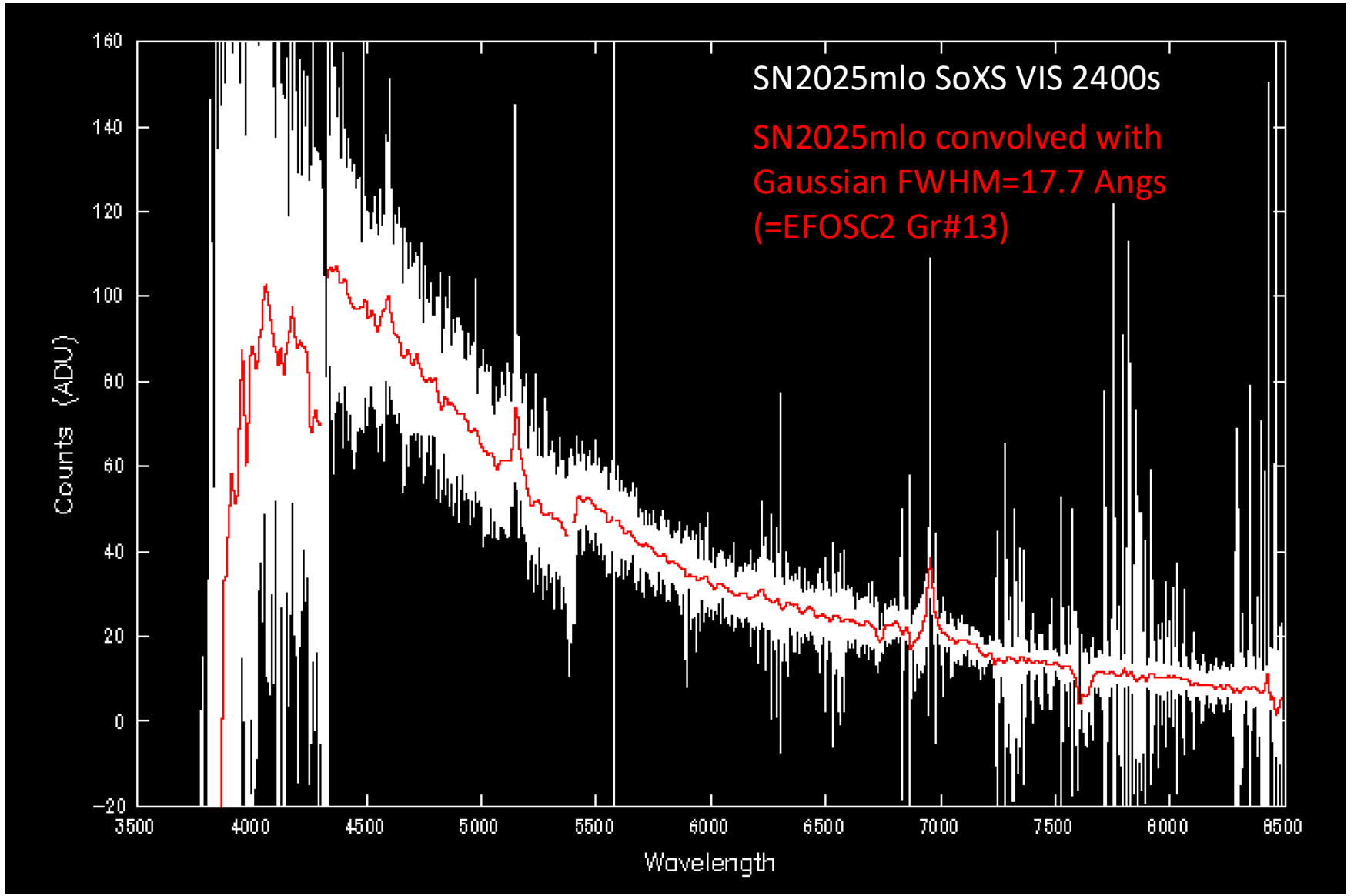




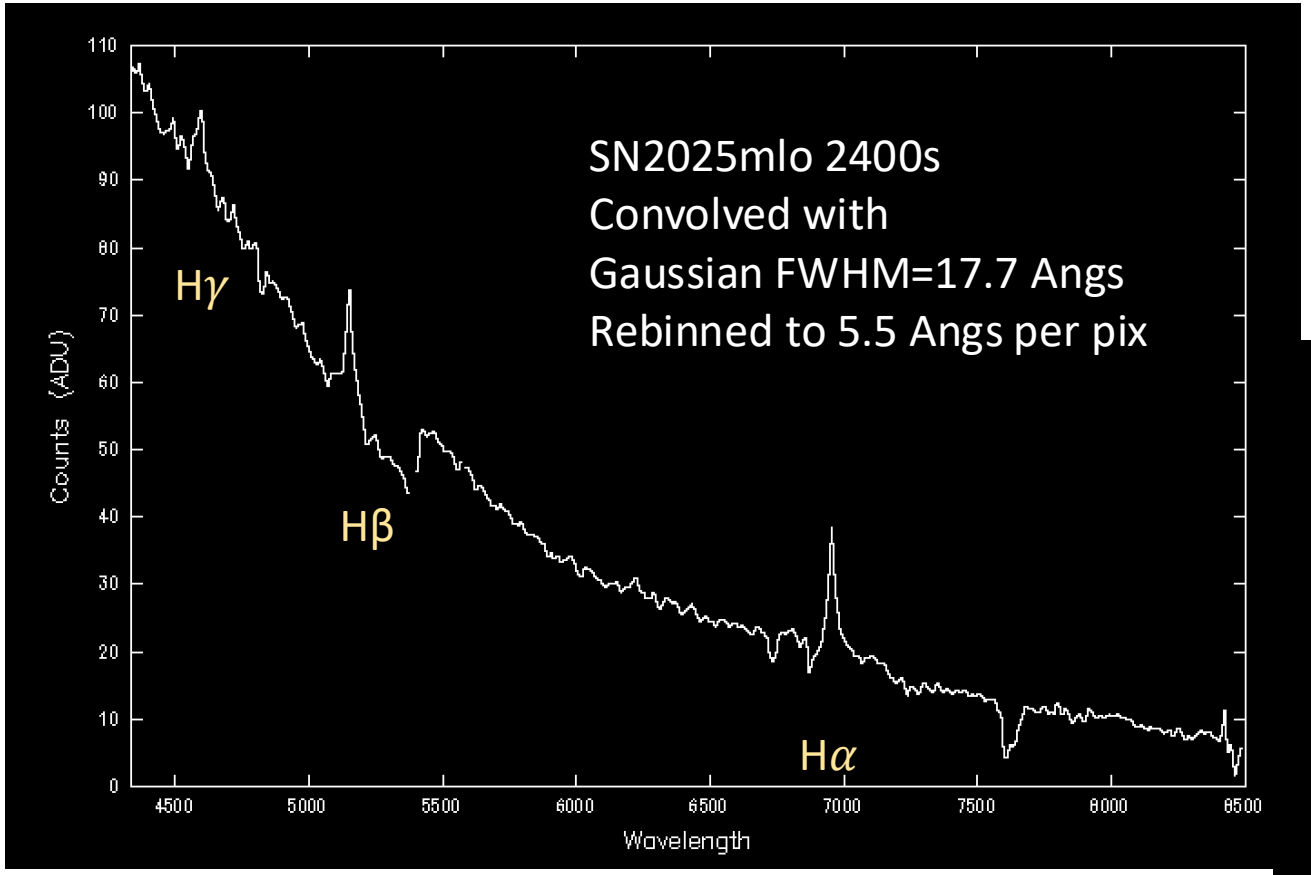


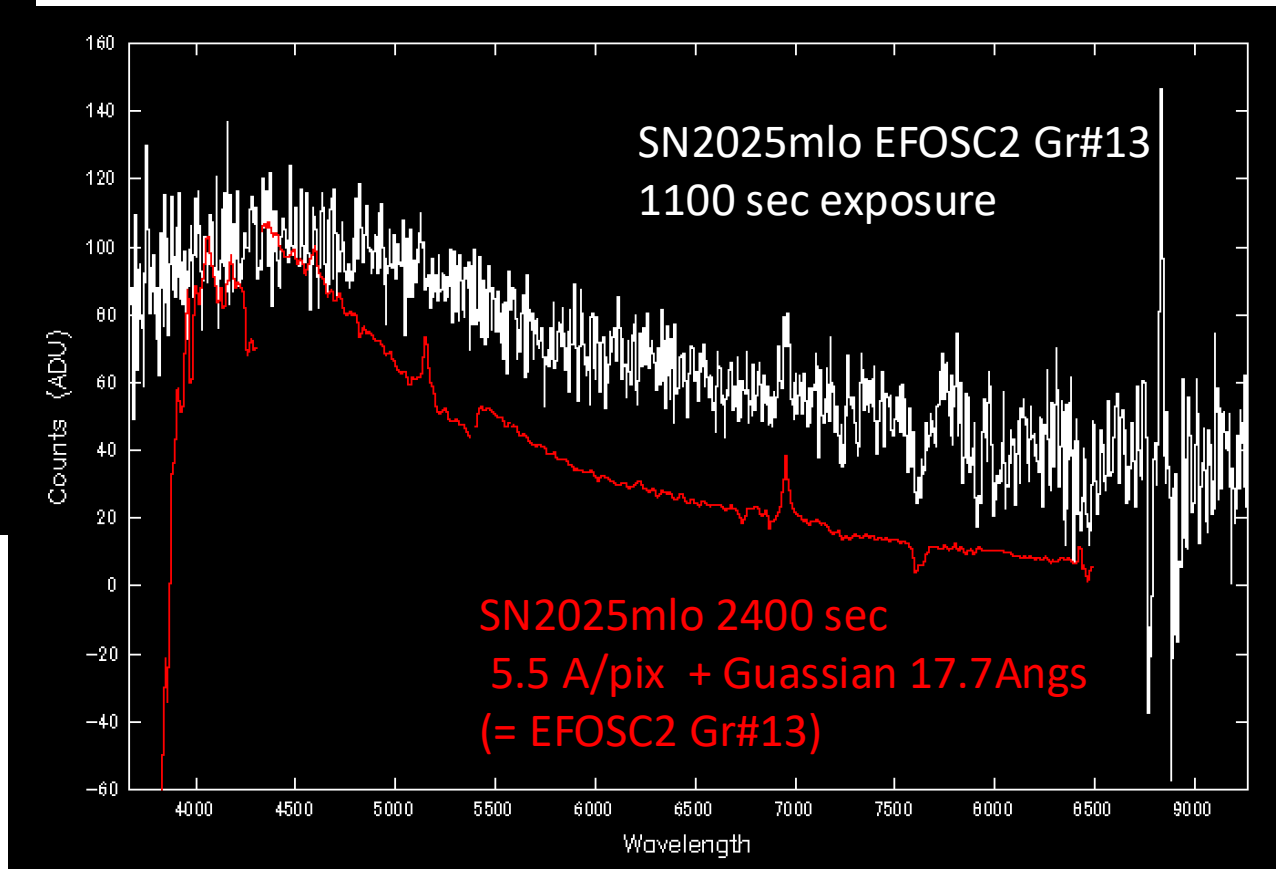

SN2025mlo SoXS VIS 2400s
Counts (ADU)
Wavelength
160
140
120
100
80
60
40
20
0
-20
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500

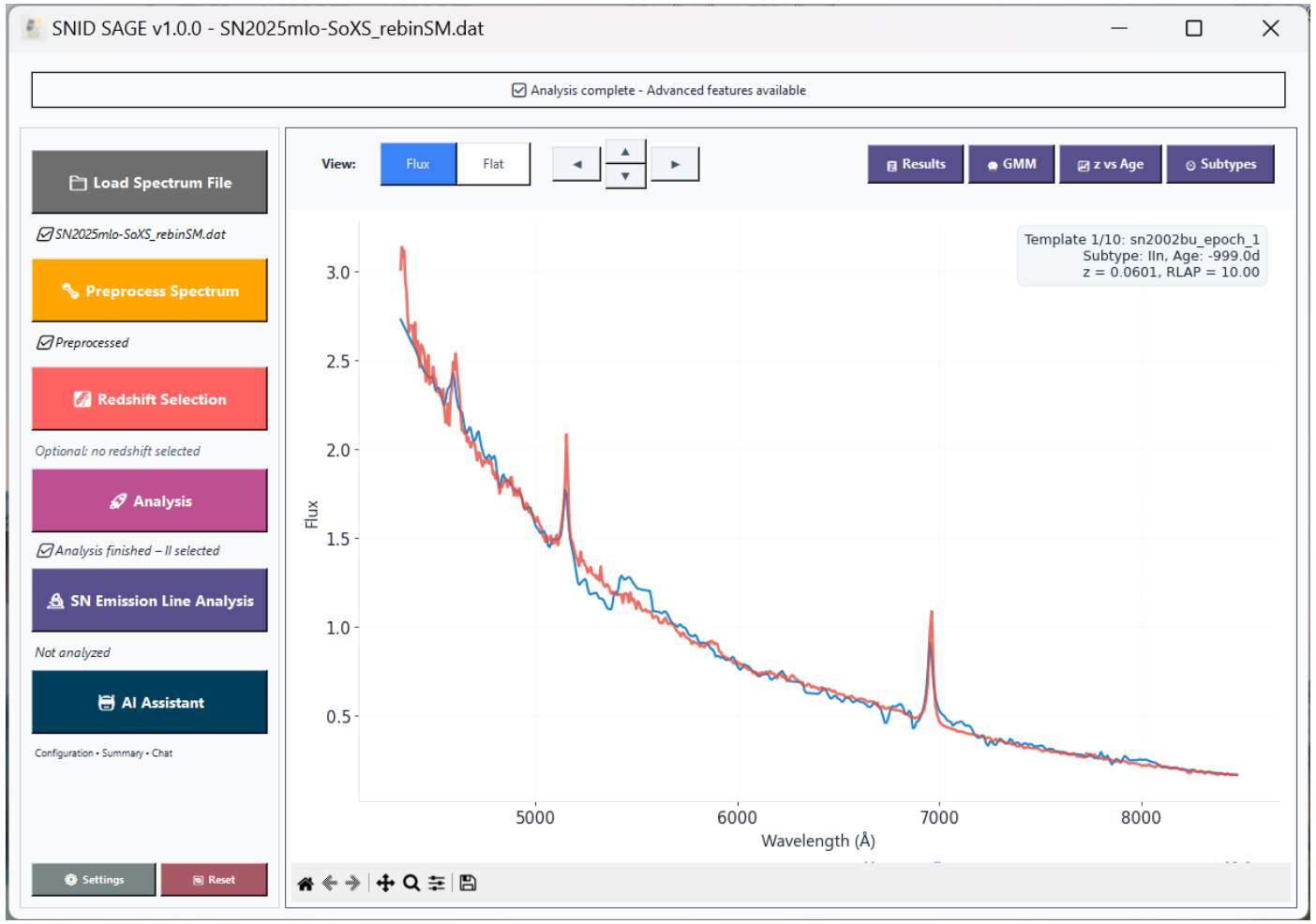

SN2025mlo SoXS VIS 2400s
SN2025mlo 5.5 Angs per pix
(= EFOSC2 Gr#13)
Counts (ADU)
Wavelength
160
140
120
100
80
60
40
20
0
−20
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500


SN2025mlo SoXS VIS 2400s
SN2025mlo convolved with
Gaussian FWHM=17.7 Angs
(=EFOSC2 Gr#13)
Counts (ADU)
Wavelength
160
140
120
100
80
60
40
20
0
-20
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500

SOXS


SN2025mlo 2400s
Convolved with
Gaussian FWHM=17.7 Angs
Rebinned to 5.5 Angs per pix
Hγ
Hβ
Hα
Counts (ADU)
Wavelength


SN2025mlo EFOSC2 Gr#13
1100 sec exposure
SN2025mlo 2400 sec
5.5 A/pix + Guassian 17.7Angs
(= EFOSC2 Gr#13)
Counts (ADU)
Wavelength



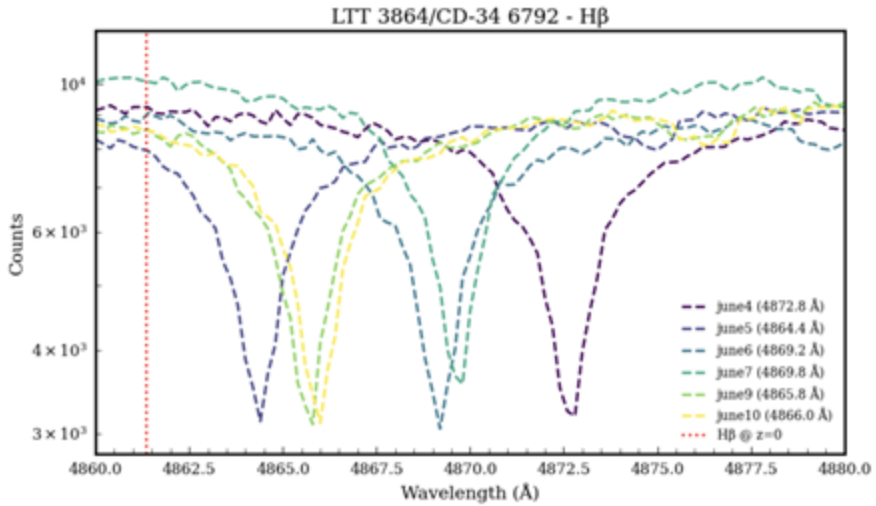
SNID classification :
SoXS spectrum give IIn classification
EFOSC2 spectrum gives II-P

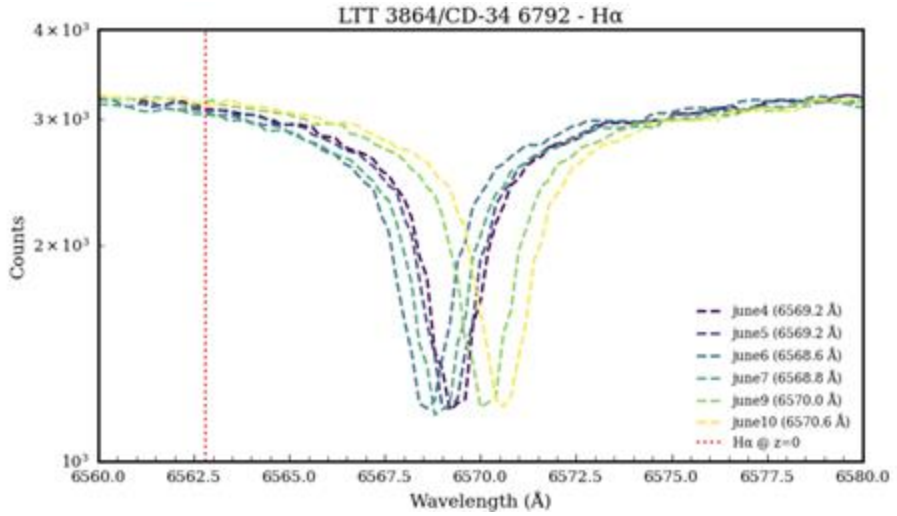
SNID – SAGE
The SNID (Blondin & Tonry) cross-correlation algorithm, coded in python, user interface, up to date templates, AI module, many user tools (clipping, line IDs)

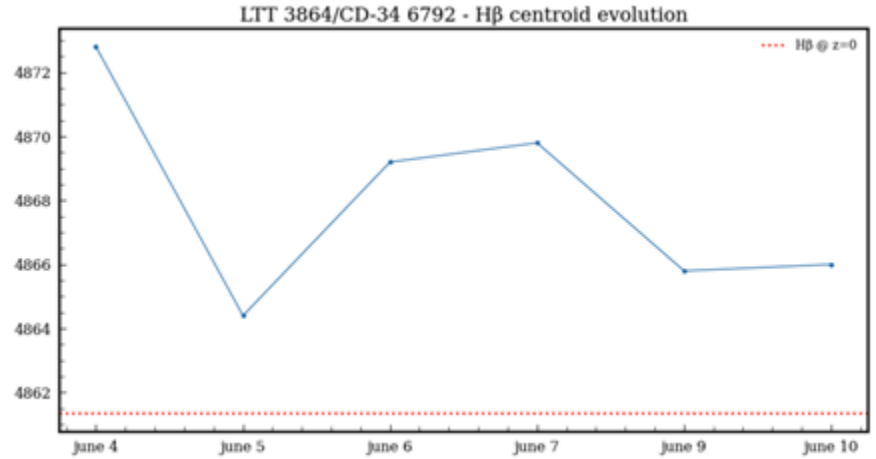
Fiore Stoppa et al. (University of Oxford), in prep., undergoing user tests

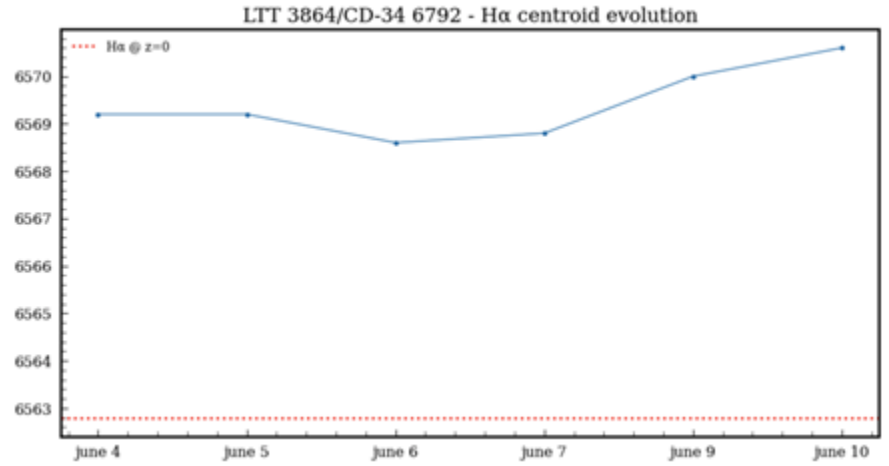
Stability of calibrations – investigations by Geza Csoernyei

We verified the stability of calibrations (bias, flat fields, wavelength solution) over time



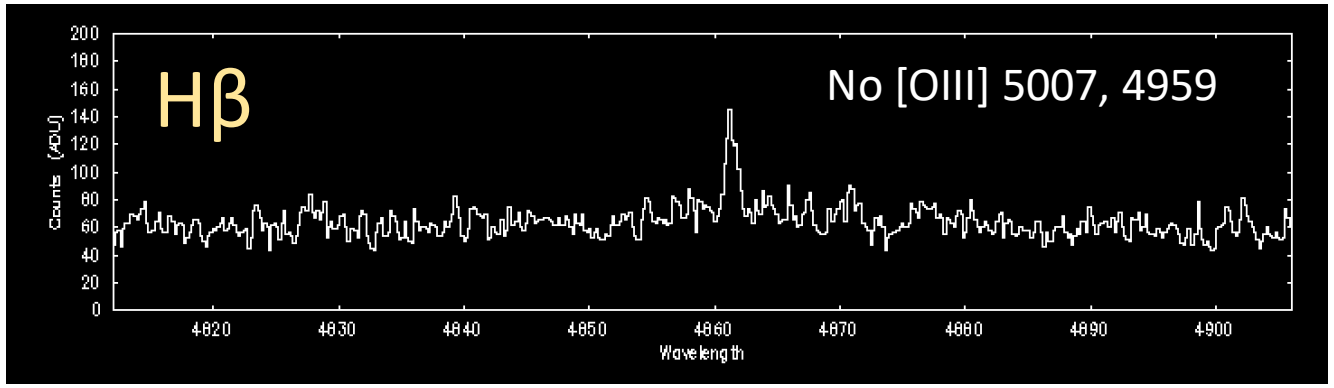


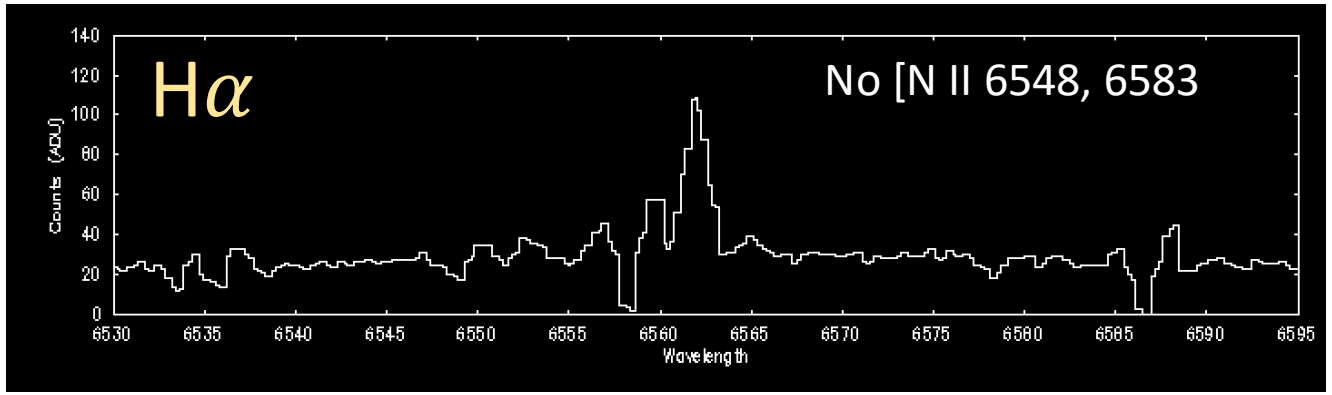


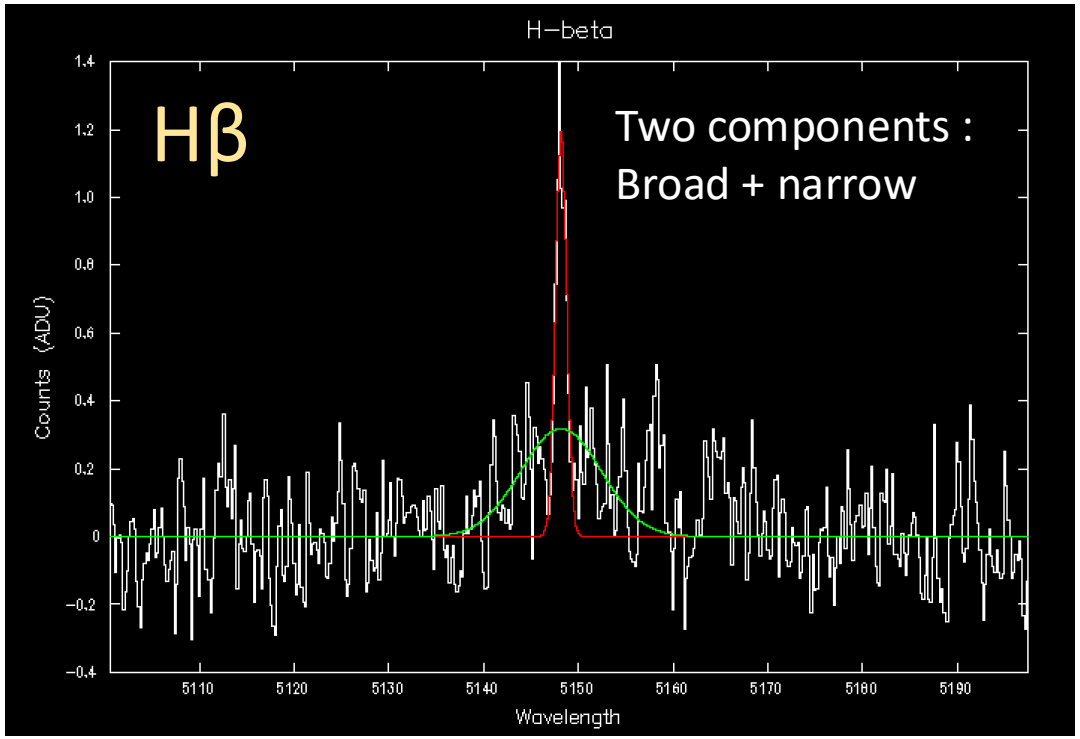


Wavelength solution not really stable (few AA shift). Better situation in the red, worse in the blue.

To be investigated







Narrow component of H : FWHM = 1.39 Angs v = 76 km/s

Broad component of H : FWHM = 10 Angs v = 760 km/s

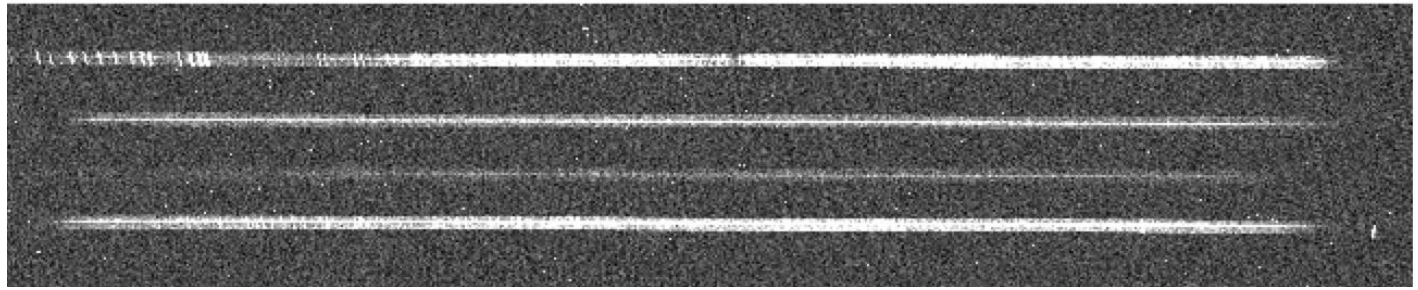
With EFOSC2 we would have concluded v ~ 1000 km/s single component

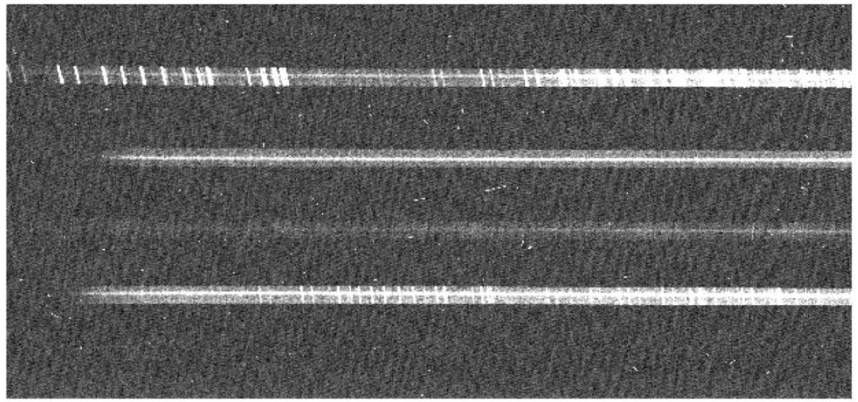
Probably still a SN IIn classification – but multiple components, or ionized CSM ?

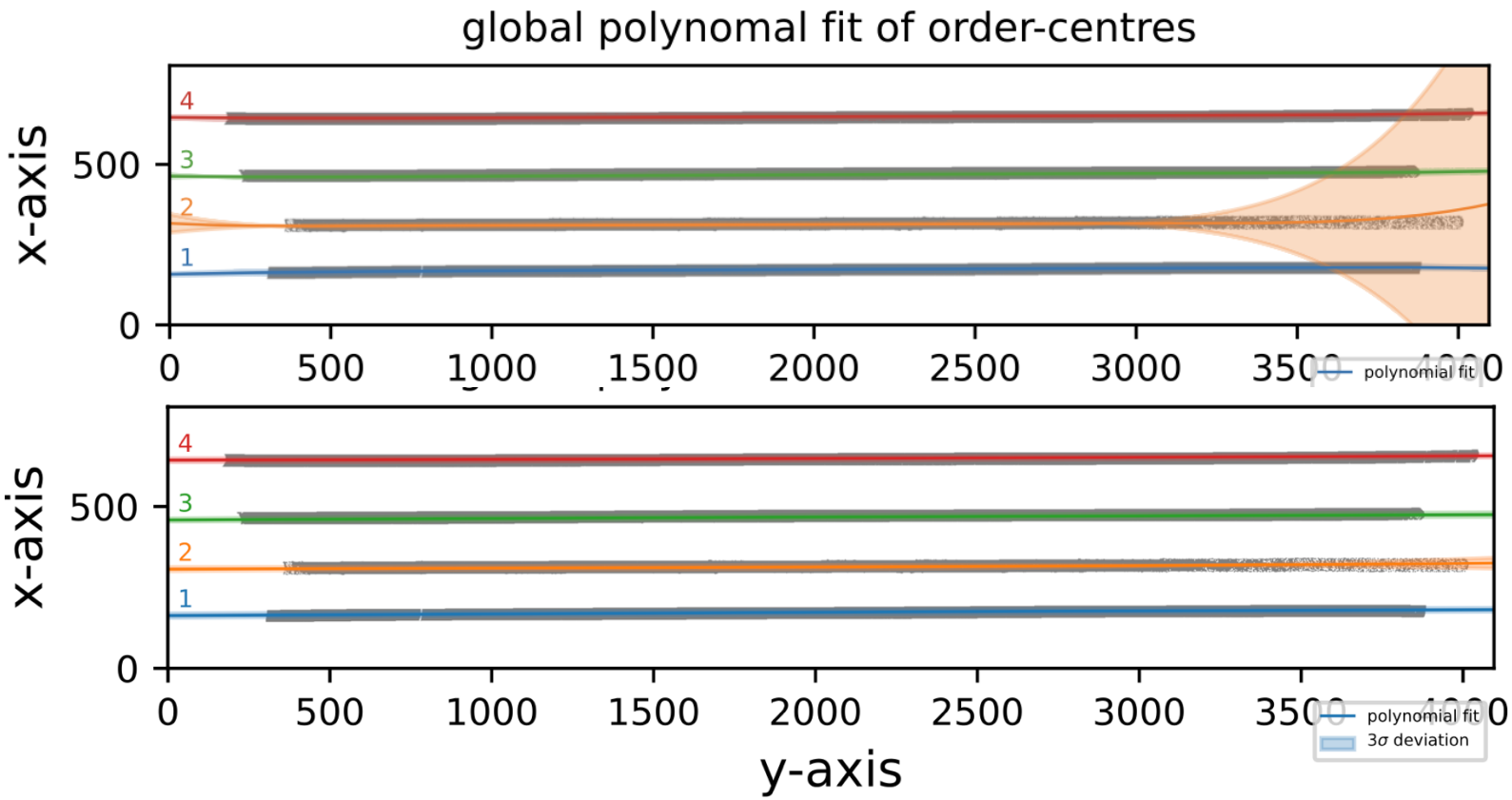
<u>Probably have been missing these types of SN ejecta parameters for years : SoXS provides new spectral and time resolution</u>

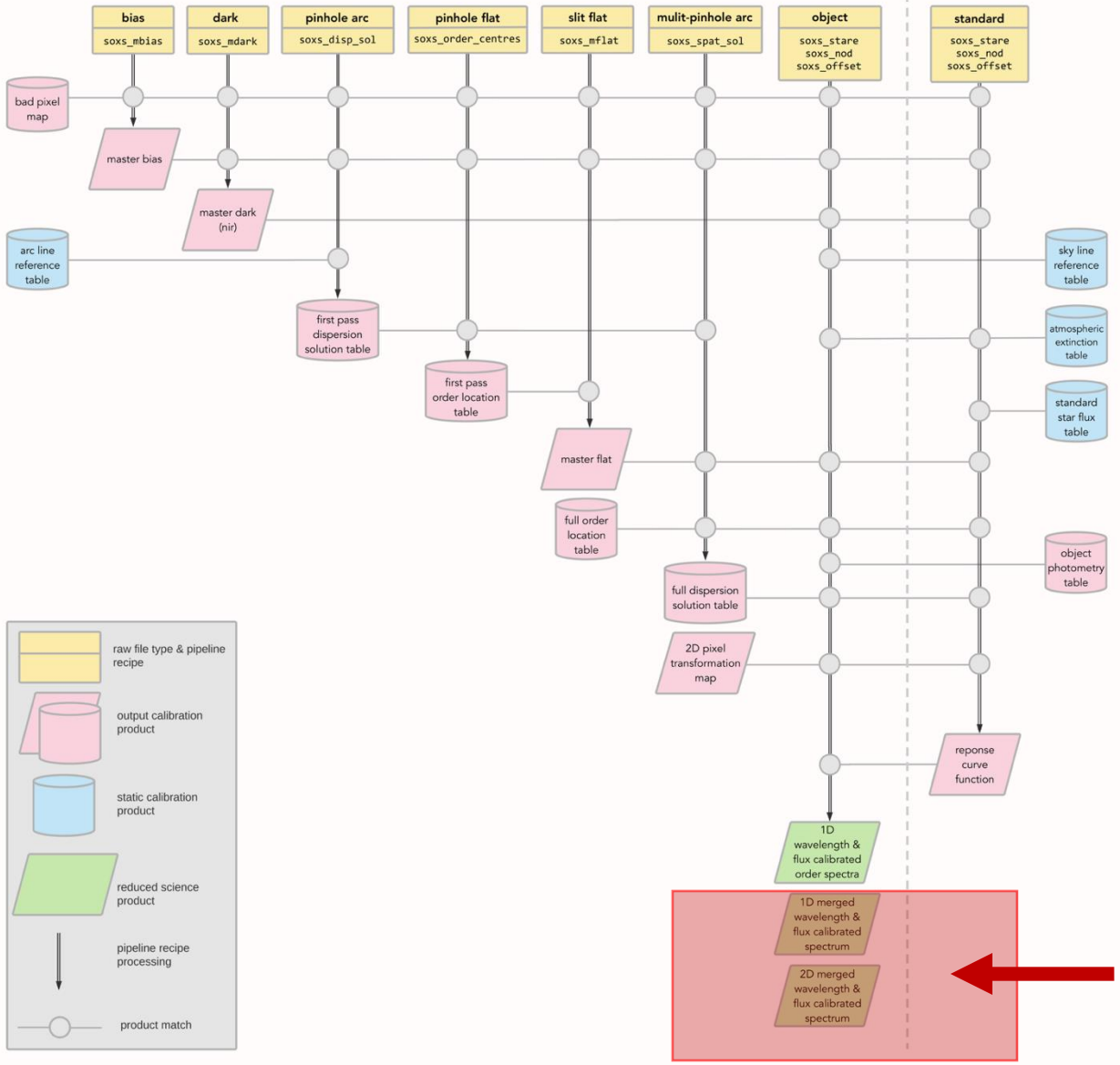
u-band order tracing problem and edges of the orders

We think tuning of the yaml file (possibly binning 2 x 2) will solve it in operations. Similarly with sky subtraction in stare









Pipeline Todo with high priority

1. Get flux calibration in stare and nodding working
2. Optimise settings in yaml file for good sky subtraction in both stare and nodding modes
3. Verify soxspipe for NIR and implement flux calibration for both UV-VIS+NIR
4. Produce 2D order merged FITS image for stare and nodding - allowing user to re-extract

https://soxspipe.readthedocs.io

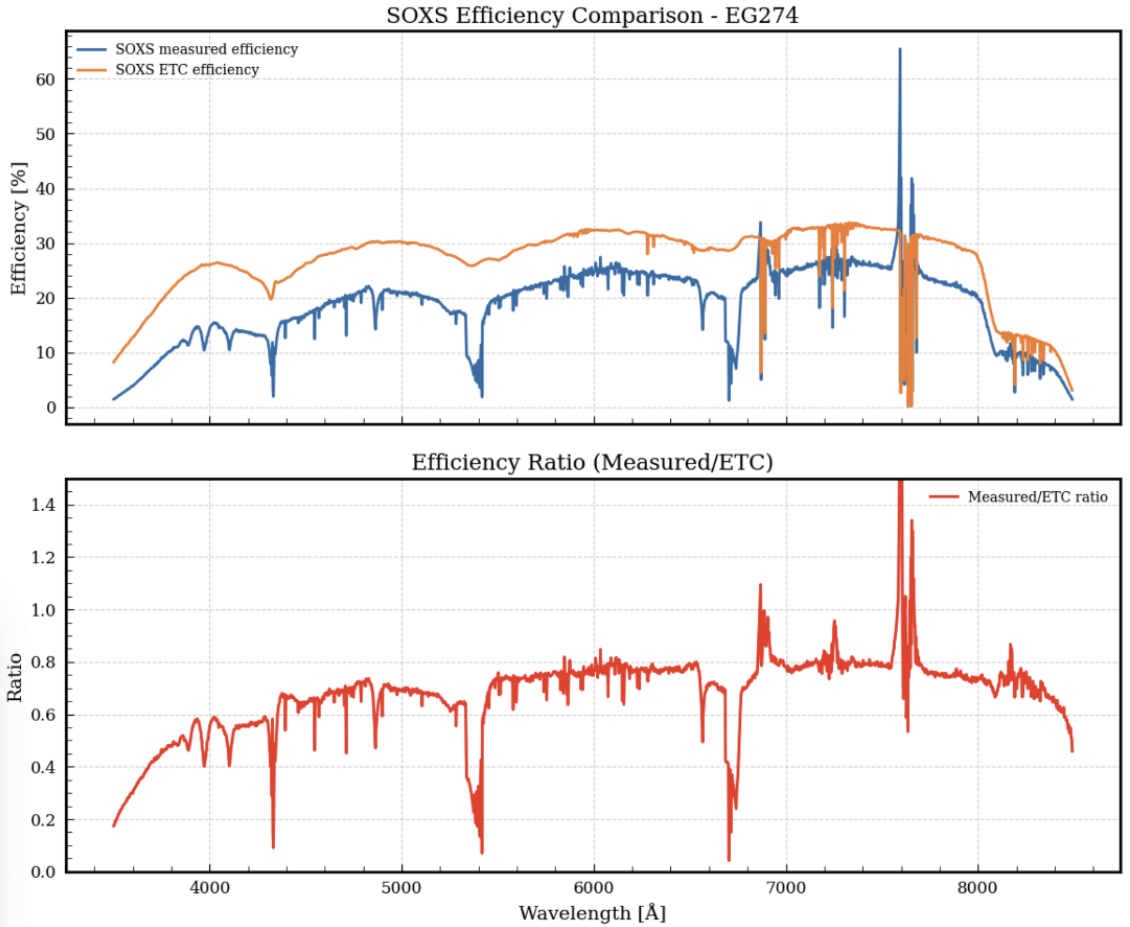
Please use the github issues page. We will communicate through this and prioritise pipeline development

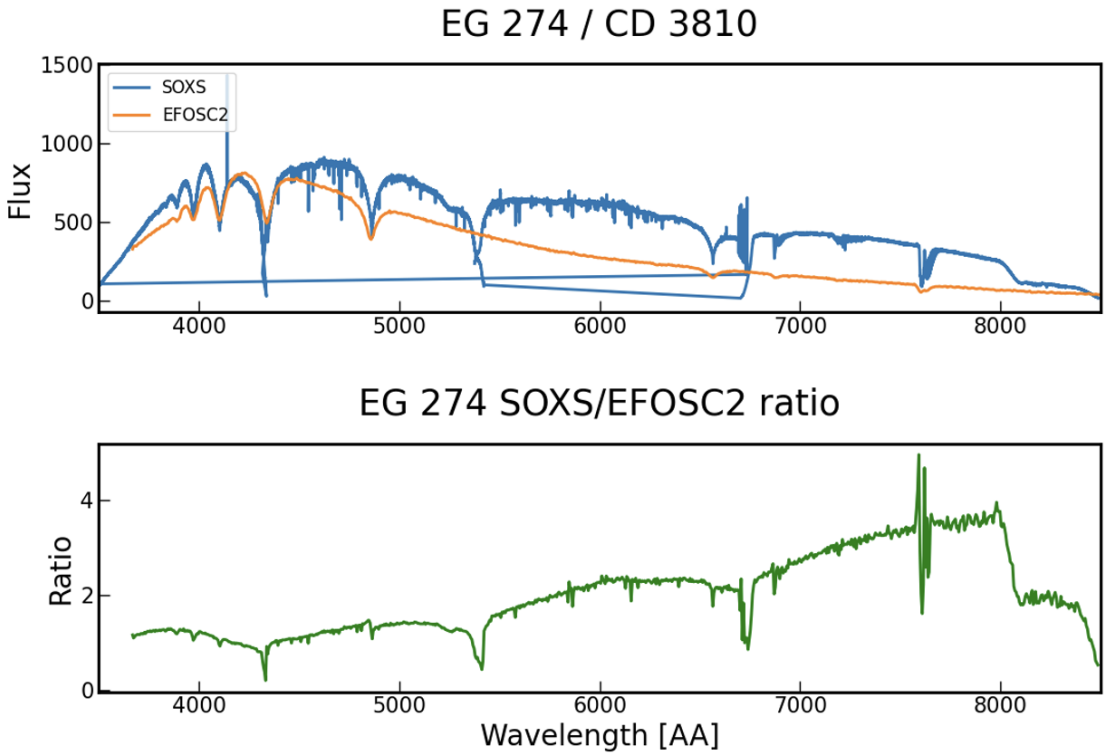
Status of Commissioning - SOXS-UV-VIS throughput comparisons with respect to EFOSC2

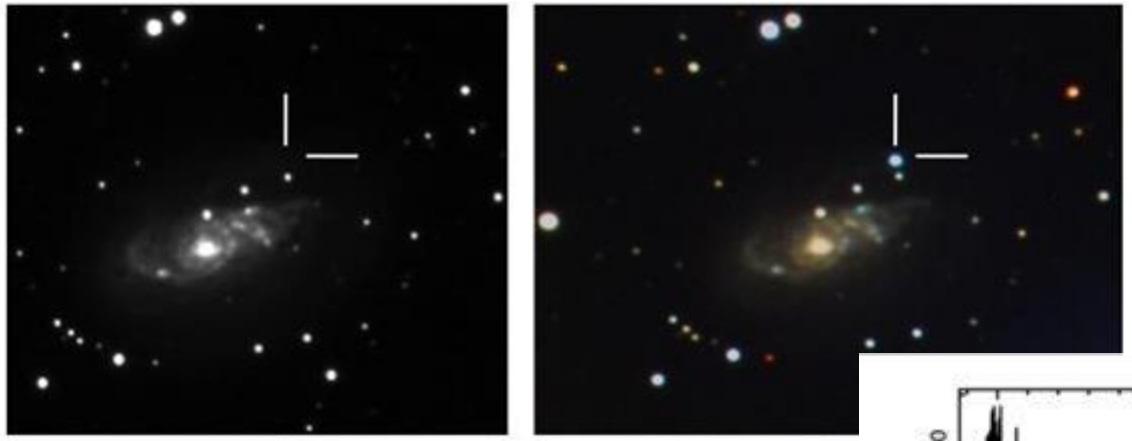
June commissioning run: 2025-06-08
Contemporaneous observations with EFOSC2 and SOXS-UV-VIS
Back to back - similar sky conditions, although still some uncertainty

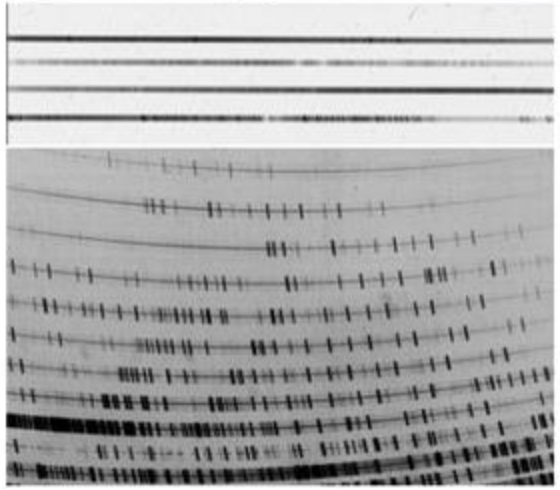
Table 2. Observing log of exposures taken to compare EFOSC2 and SoXS throughput on night beginning UT 2025-06-08.

Star	*V* (Vega)	File name	MJD-OBS (sec)	Extpime (arcsec)	Slit	Airmass	Read Mode (e-/ADU)	Gain
EG274	11.04	SOXS.2025-06-09T03:19:11.588.fits	60835.14	300	5.0	1.023	Slow High Gain	1.1
LTT7379	10.23	SOXS.2025-06-09T03:48:22.541.fits	60835.16	300	5.0	1.18	Slow High Gain	1.1
LTT7379	10.23	EFOSC.2025-06-09T04:38:08.411.fits	60835.19	10	5.0	1.09	normal/fastL	1.1
EG274	11.04	EFOSC.2025-06-09T04:50:38.046.fits	60835.20	10	5.0	1.04	normal/fastL	1.1

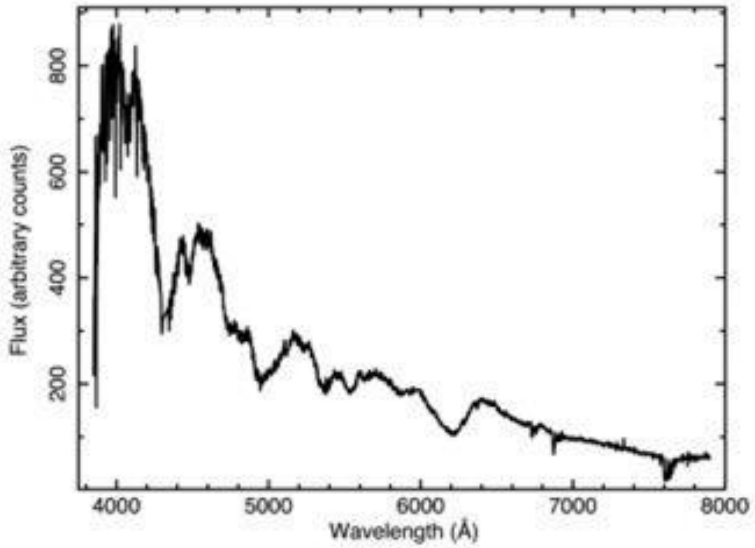

SOXS Efficiency Comparison - EG274
SOXS measured efficiency
SOXS ETC efficiency
Efficiency [%]
Efficiency Ratio (Measured/ETC)
Measured/ETC ratio
Ratio
Wavelength [Å]

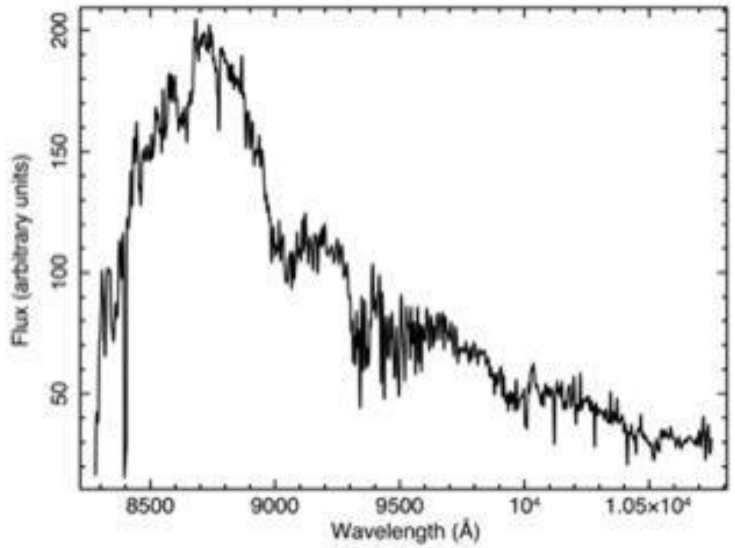

EG 274 / CD 3810
SOXS
EFOSC2
Flux
EG 274 SOXS/EFOSC2 ratio
Ratio
Wavelength [AA]





soxspipe v0.13.1





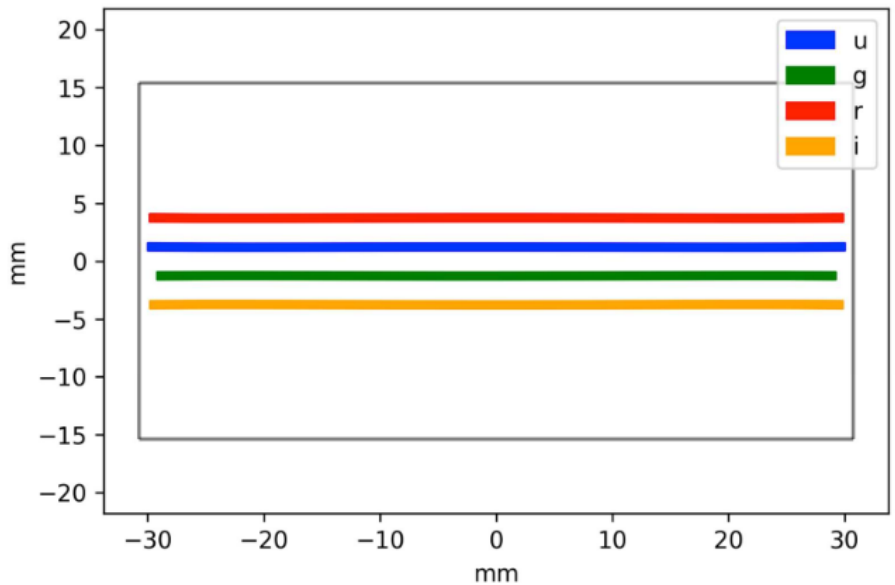


Figure 51: Spectral Format. The black rectangle represents the actual size of the CCD.

	Bottom margin		Top margin		Overlap
	mm	pixels	mm	pixels	
u	0.719	48	0.72	48	u to g: 13 nm (427-440)
g	1.51	101	1.511	101	g to r: 23 nm (522-545)
r	0.867	58	0.868	58	r to i: 24 nm (656-680)
i	0.901	60	0.902	60	i to NIR: 50 nm (800-850)

Table 25: Margins and spectral overlap.