DMS L1 science processing at

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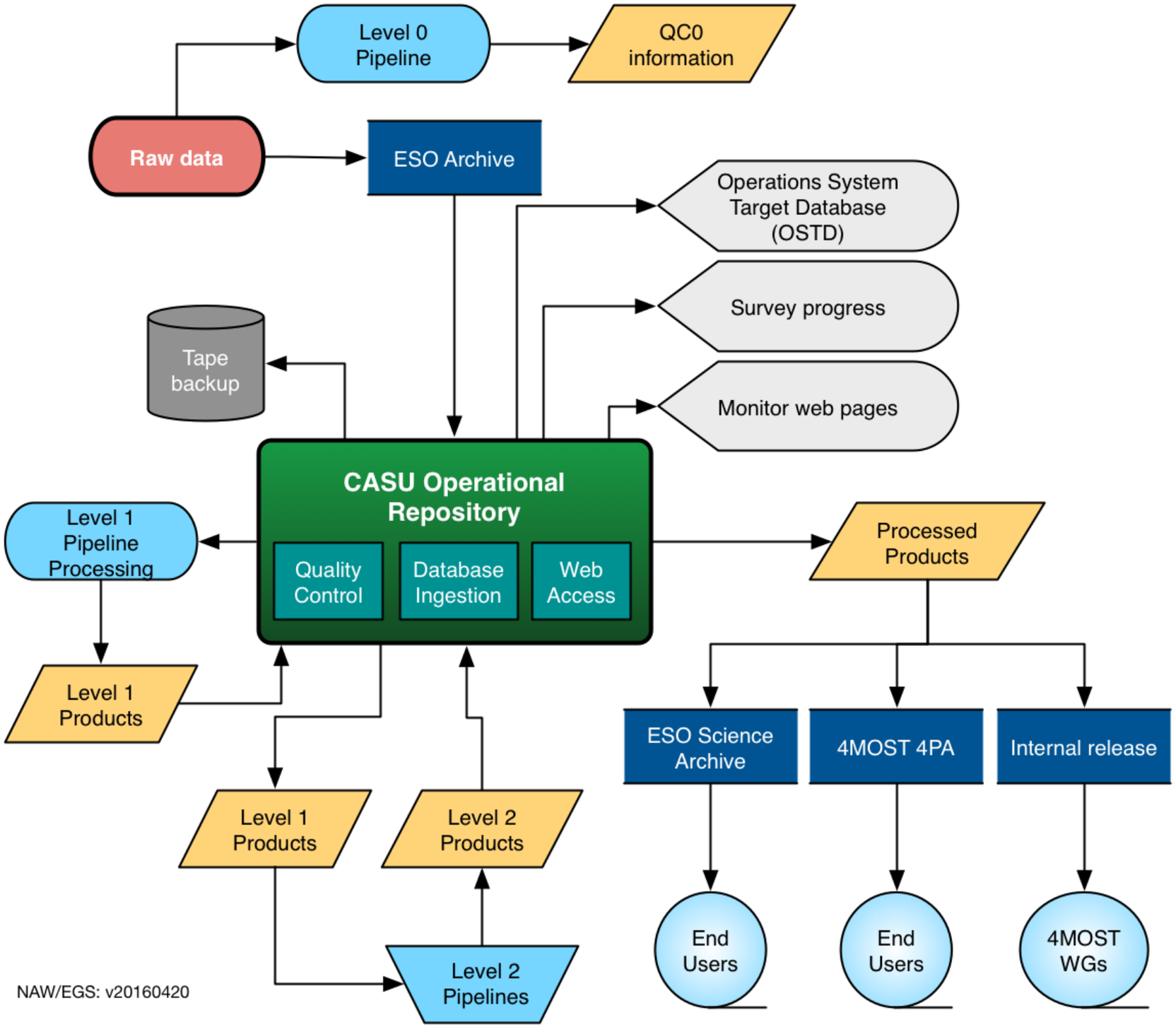

Level 0
Pipeline
QC0
information
Raw data
ESO Archive
Operations System
Target Database
(OSTD)
Survey progress
Tape
backup
Monitor web pages
CASU Operational
Repository
Quality
Control
Database
Ingestion
Web
Access
Level 1
Pipeline
Processing
Processed
Products
Level 1
Products
ESO Science
Archive
4MOST 4PA
Internal release
Level 1
Products
Level 2
Products
End
Users
End
Users
4MOST
WGs
Level 2
Pipelines
NAW/EGS: v20160420

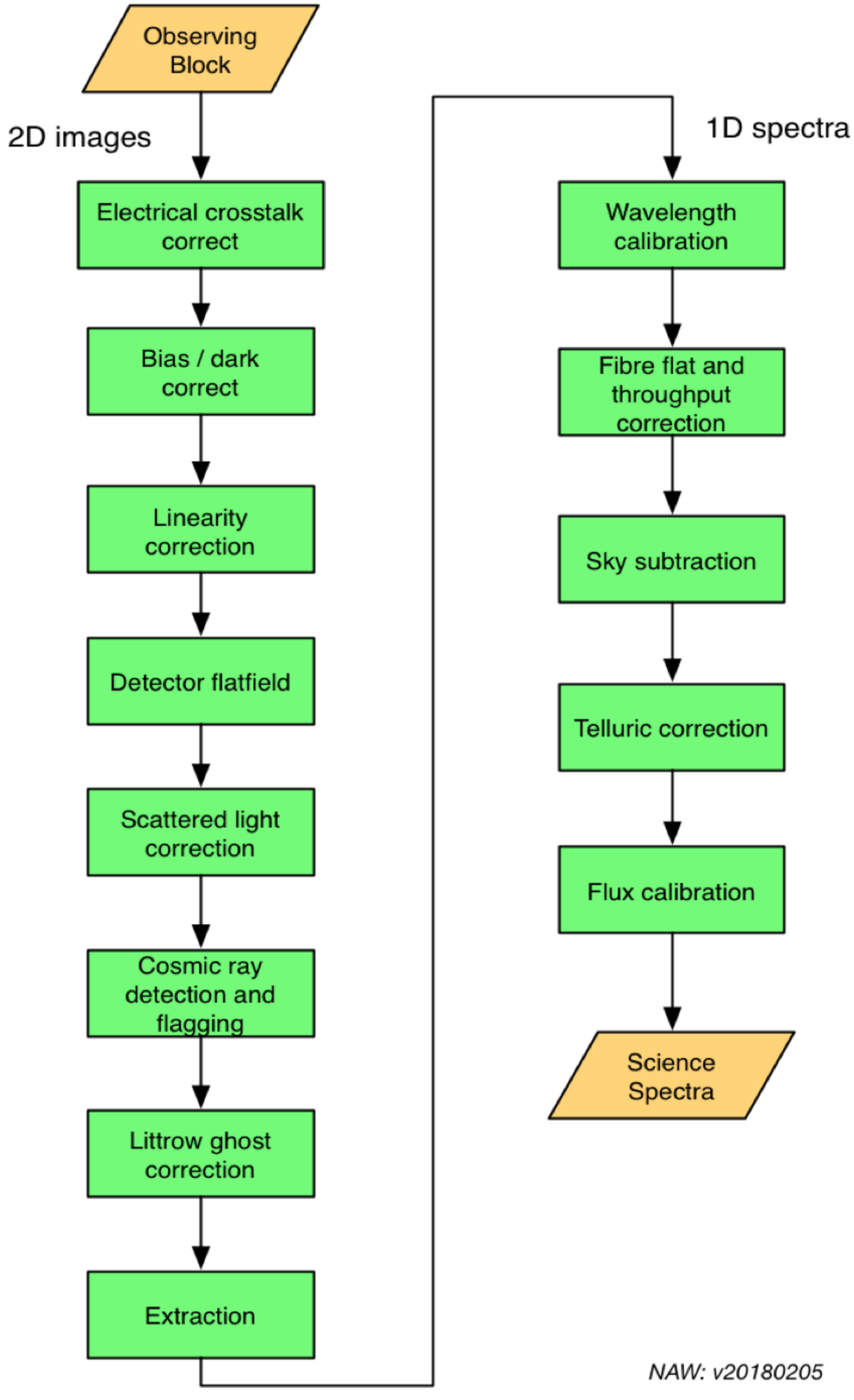
Wavelength coverage and sampling

LRS-A,B	**Blue camera**	**3700 - 5540A**	**~ 0.30A/pixel**
	Green camera	**5240 - 7210A**	**~ 0.33A/pixel**
	Red camera	**6910 - 9500A**	**~ 0.43A/pixel**

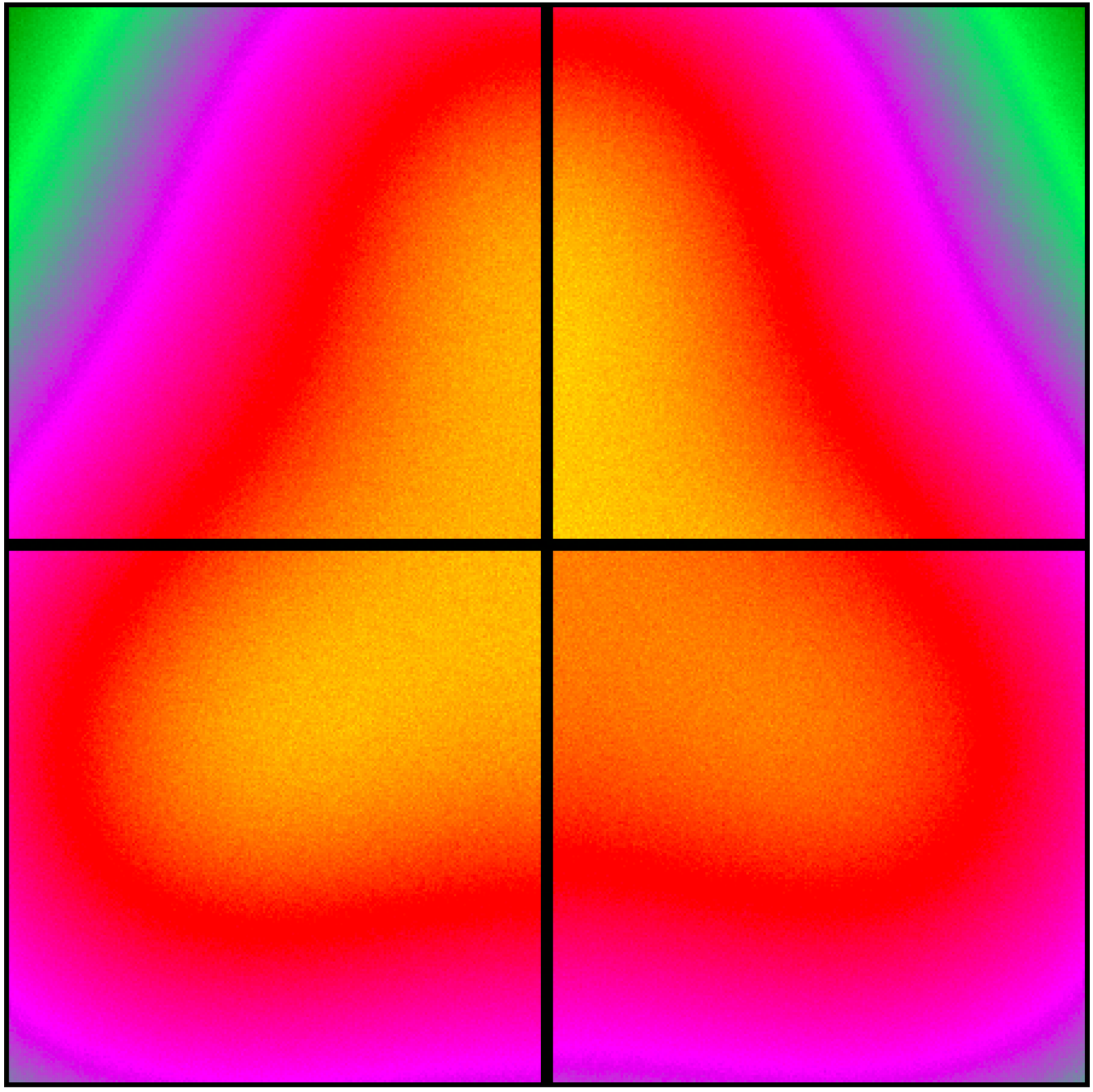
HRS	**Blue camera**	**3920 - 4350A**	**~ 0.07A/pixel**
	Green camera	**5150 - 5730A**	**~ 0.09A/pixel**
	Red camera	**6100 - 6790A**	**~ 0.11A/pixel**

4MOST raw FITS file layout

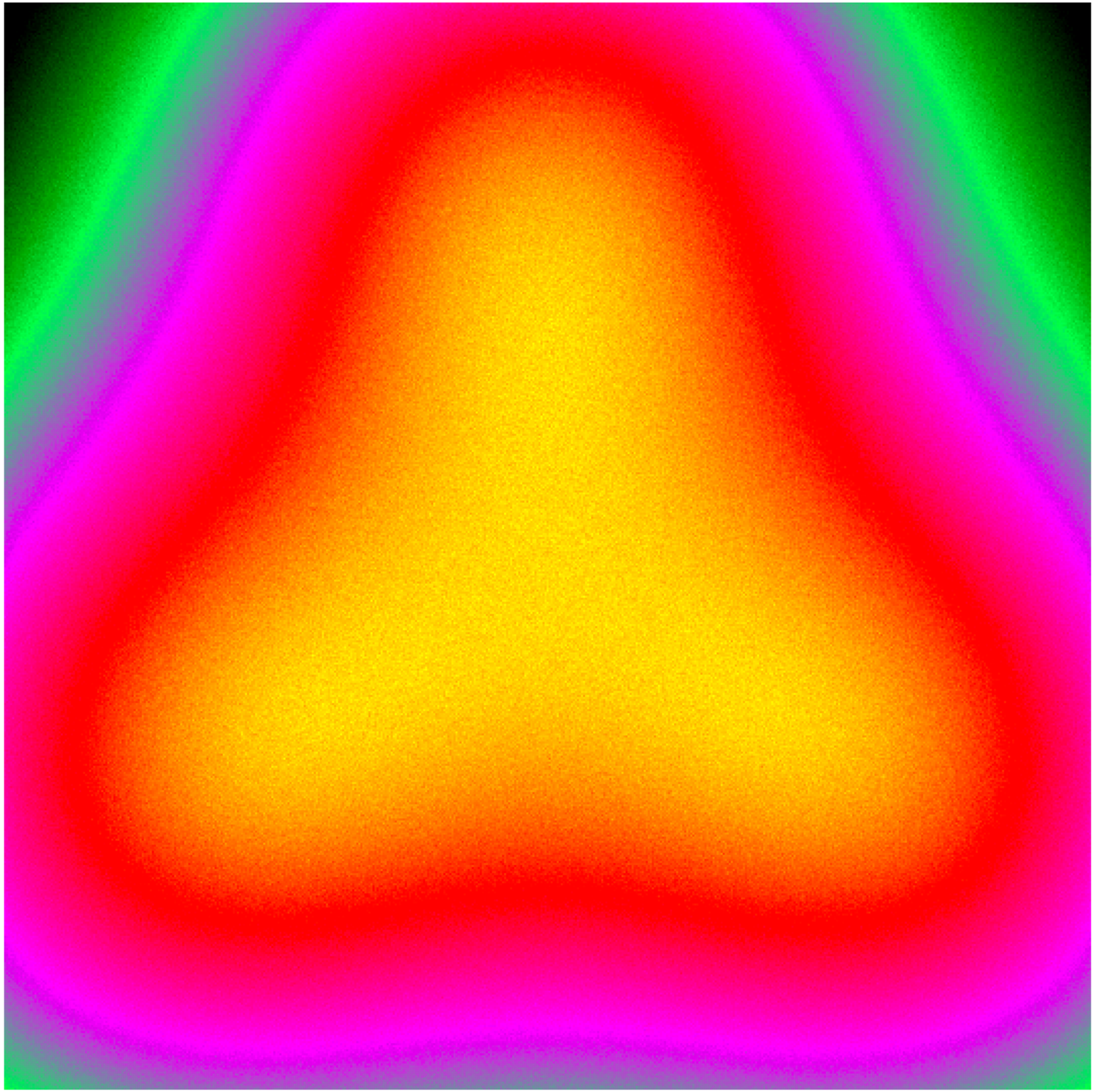
#	Name	Description
0	PRIMARY	Primary HDU containing all top level information common to the observation
1	CCD1	An image extension containing the image data for the first detector interleaved with the four amplifier readouts as a single 16-bit unsigned integer image. The header contains detector specific information.
2	CCD2	An image extension with the image data and header for the second detector.
3	CCD3	An image extension with the image data and header for the third detector.
4	FIBRE_CONFIG	The fibre configure information stored in a binary FITS table extension.
5	METROLOGY	A binary FITS table extension with results from the final metrology exposure.



Schematic of the various processing steps required to produce L1 science spectra



Simulated
2D detector
flatfield
from TOAD



Overscan, trimmed & gain-corrected flatfield

4MOST processing overview

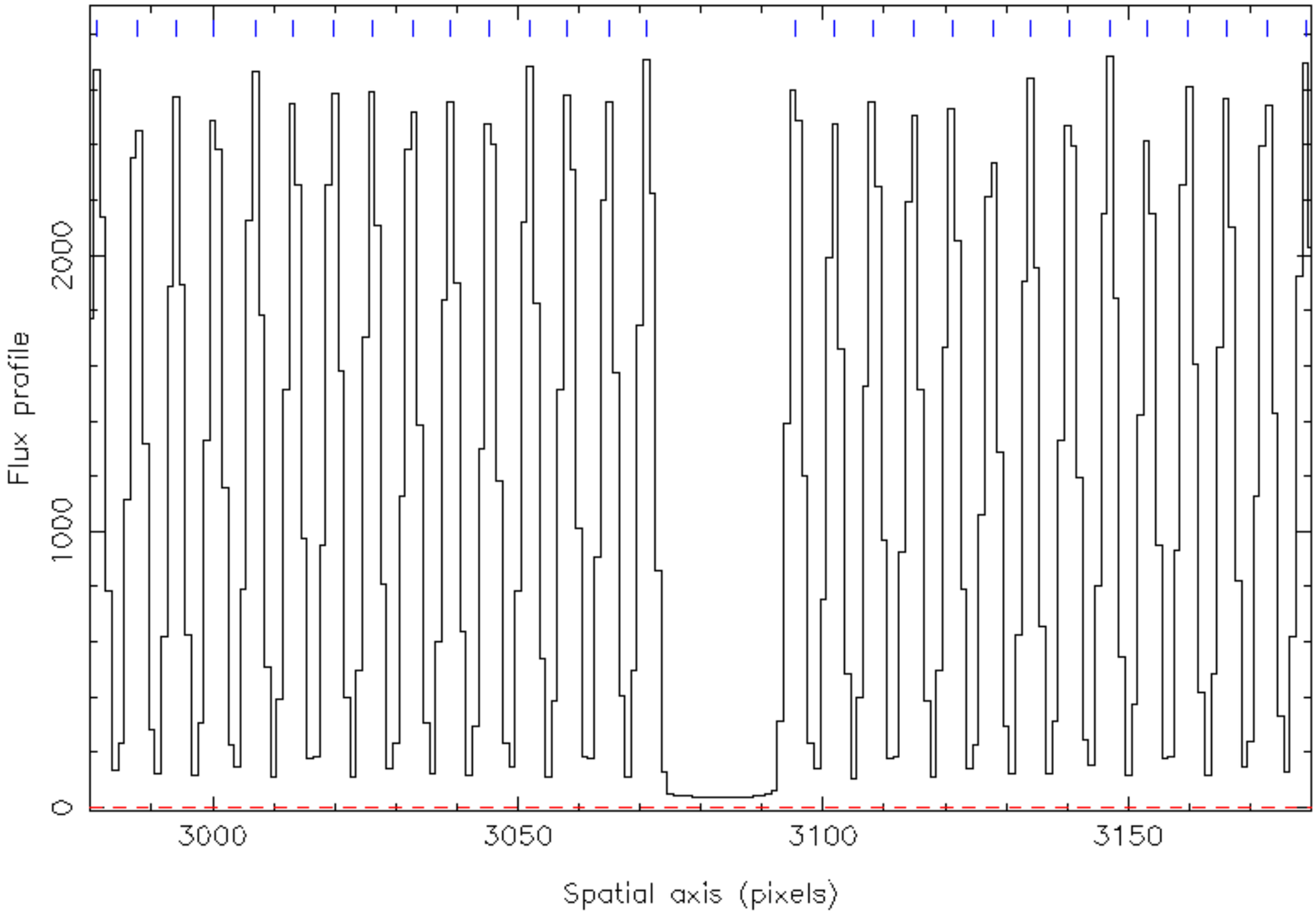
- data characterisation
  - biases, linearity, darks, fibreflats, arcs, twilight flats
  - detector (2D) flats, fibre flats & arcs -> PSFs & LSFs
- physical calibration
  - wavelength calibration -> arcs, skylines, telluric lines
  - relative flux calibration -> fibreflats; WD spectra
  - absolute flux calibration -> WDs, Gaia BP/RP spectra
- survey verification & external calibration
  - benchmark stars (Gaia) -> fairly infrequent
  - RV standards -> ditto (+ e.g M67)
  - standard fields e.g. Kepler, open clusters ...
  - overlap with other surveys (APOGEE, WEAVE ...)

Central section from simulated fibre flat

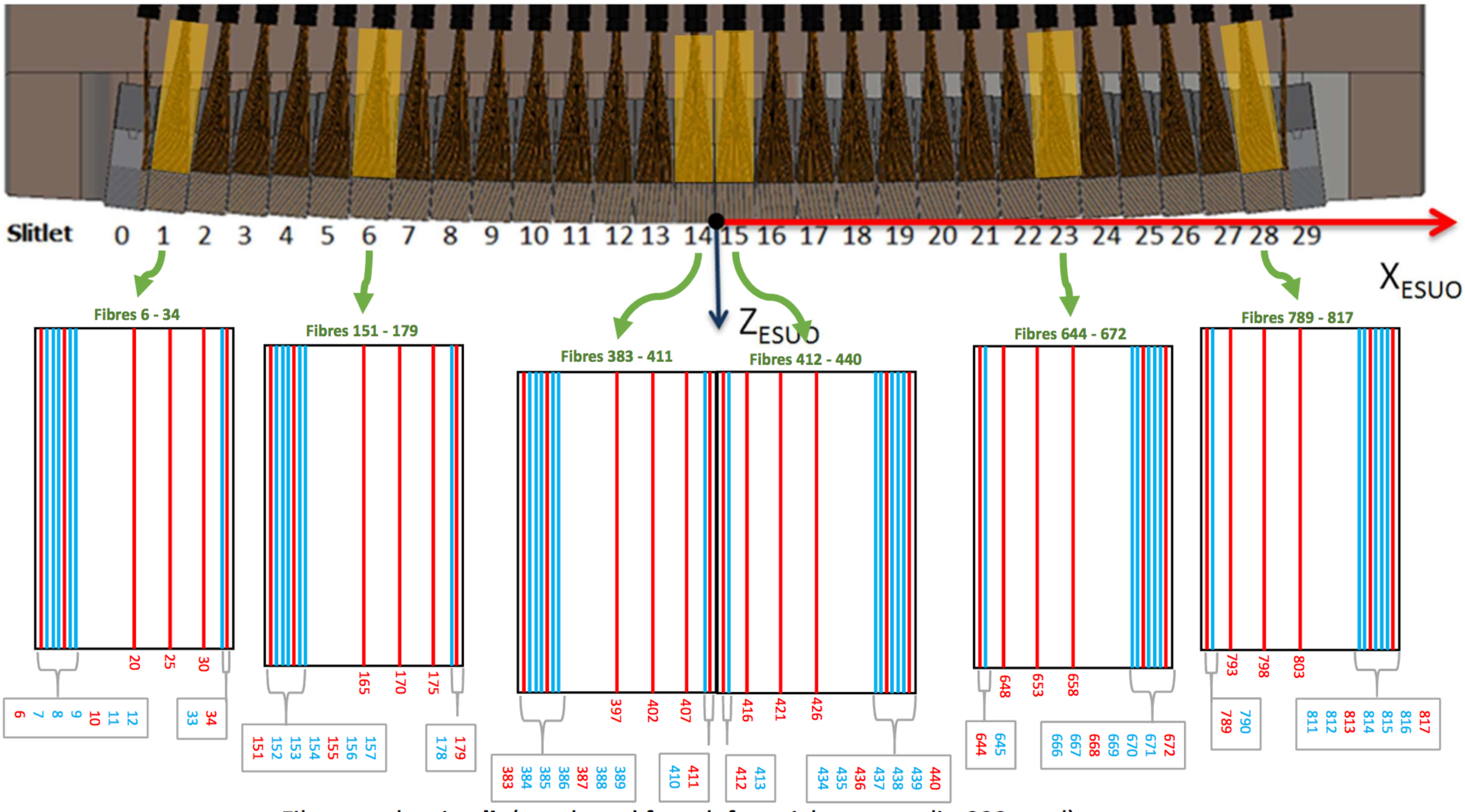
->

spatial PSFs fibre tracing

PSF cross-sections from fibre flat

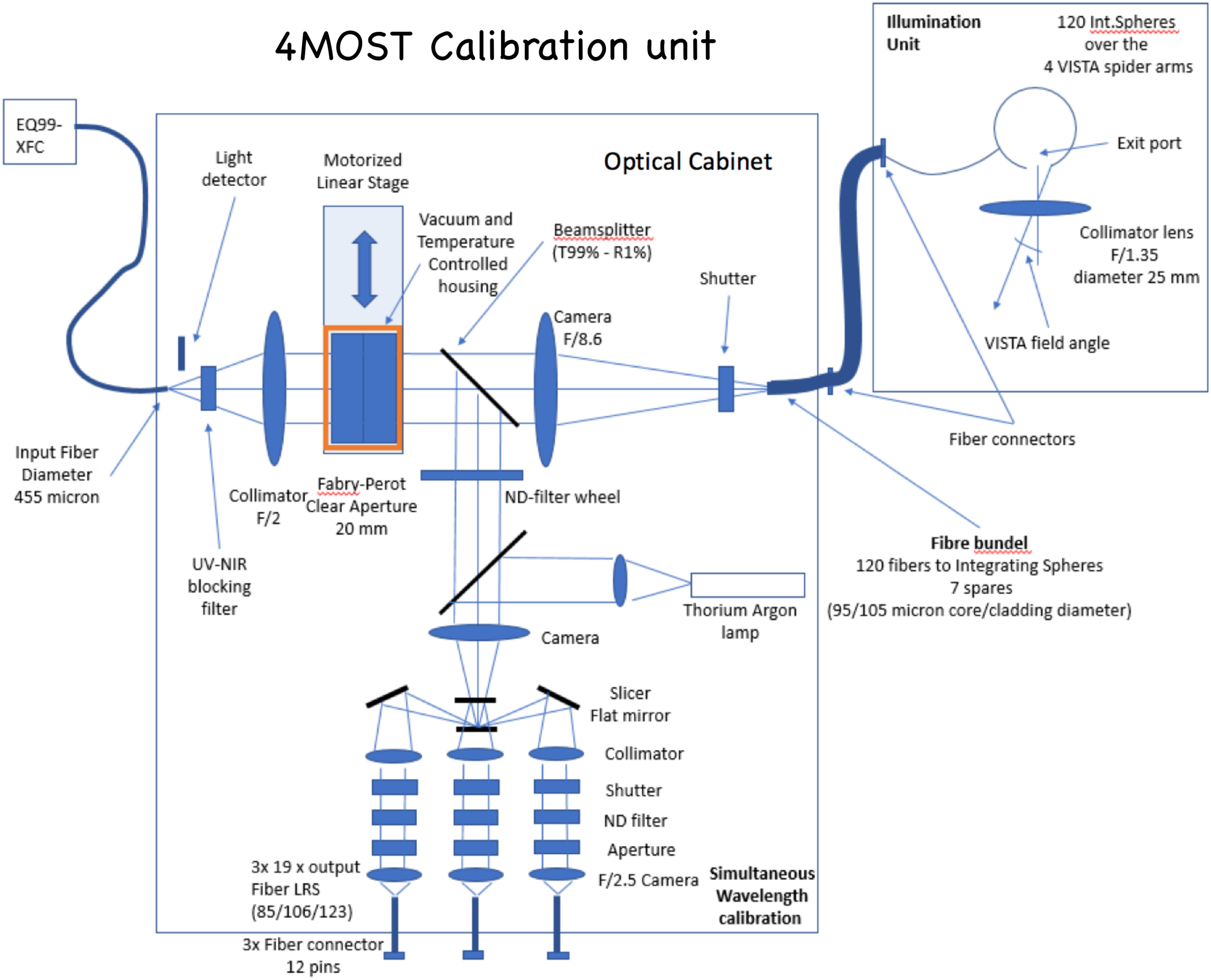


4MOST test slit unit

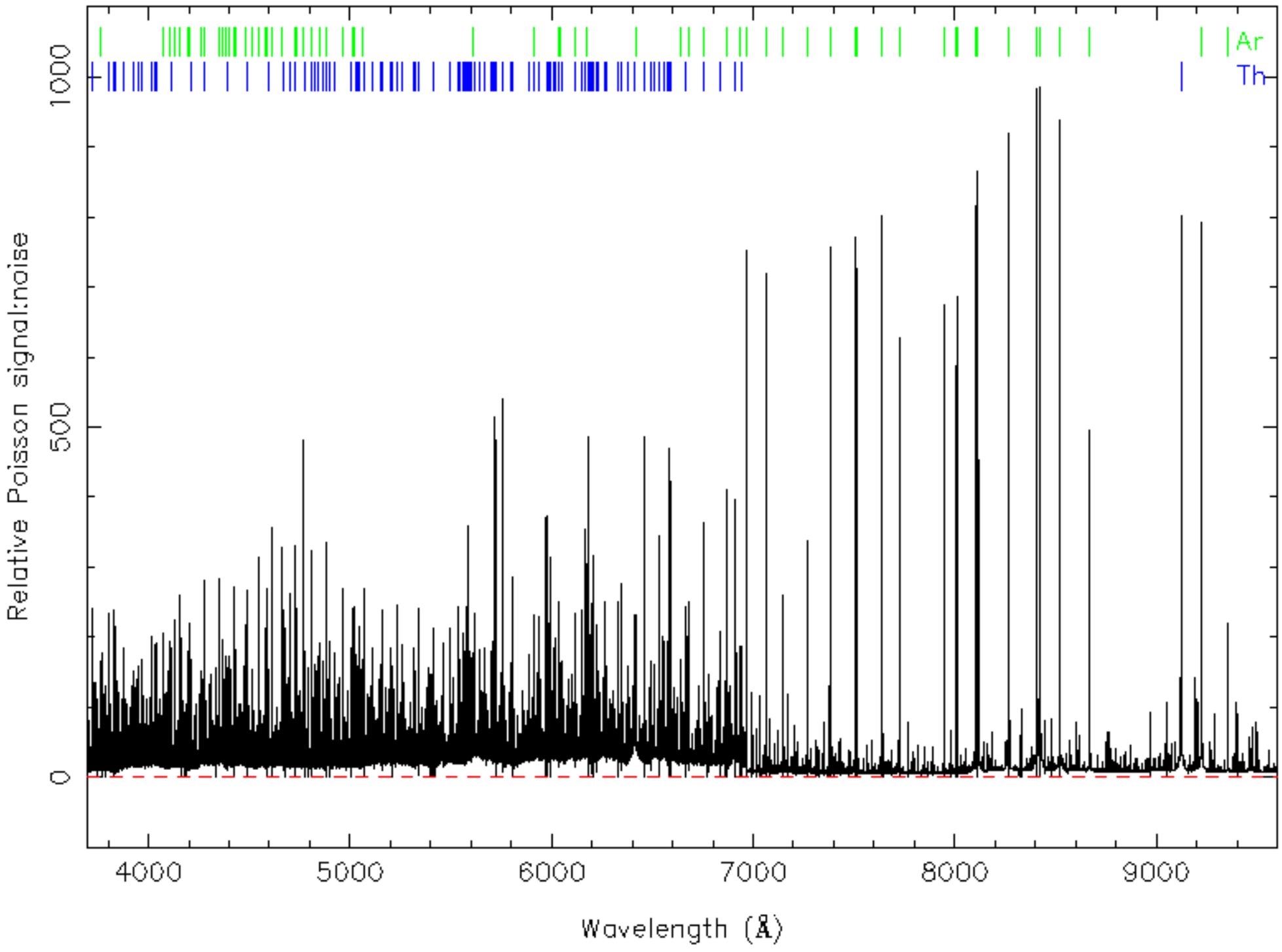


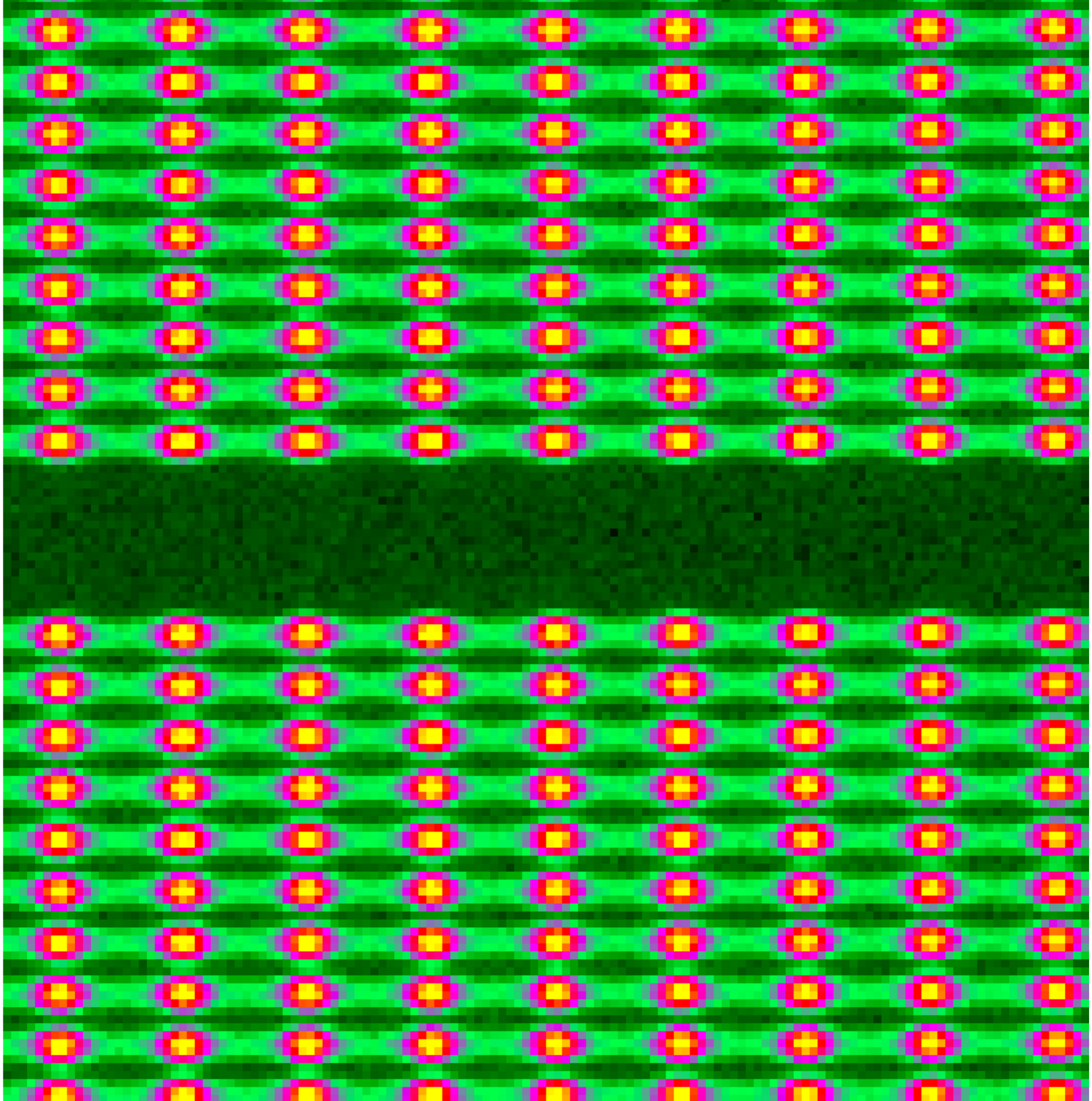
Fibre number in ***slit*** (numbered from left to right across slit, 822 total)

4MOST Calibration unit



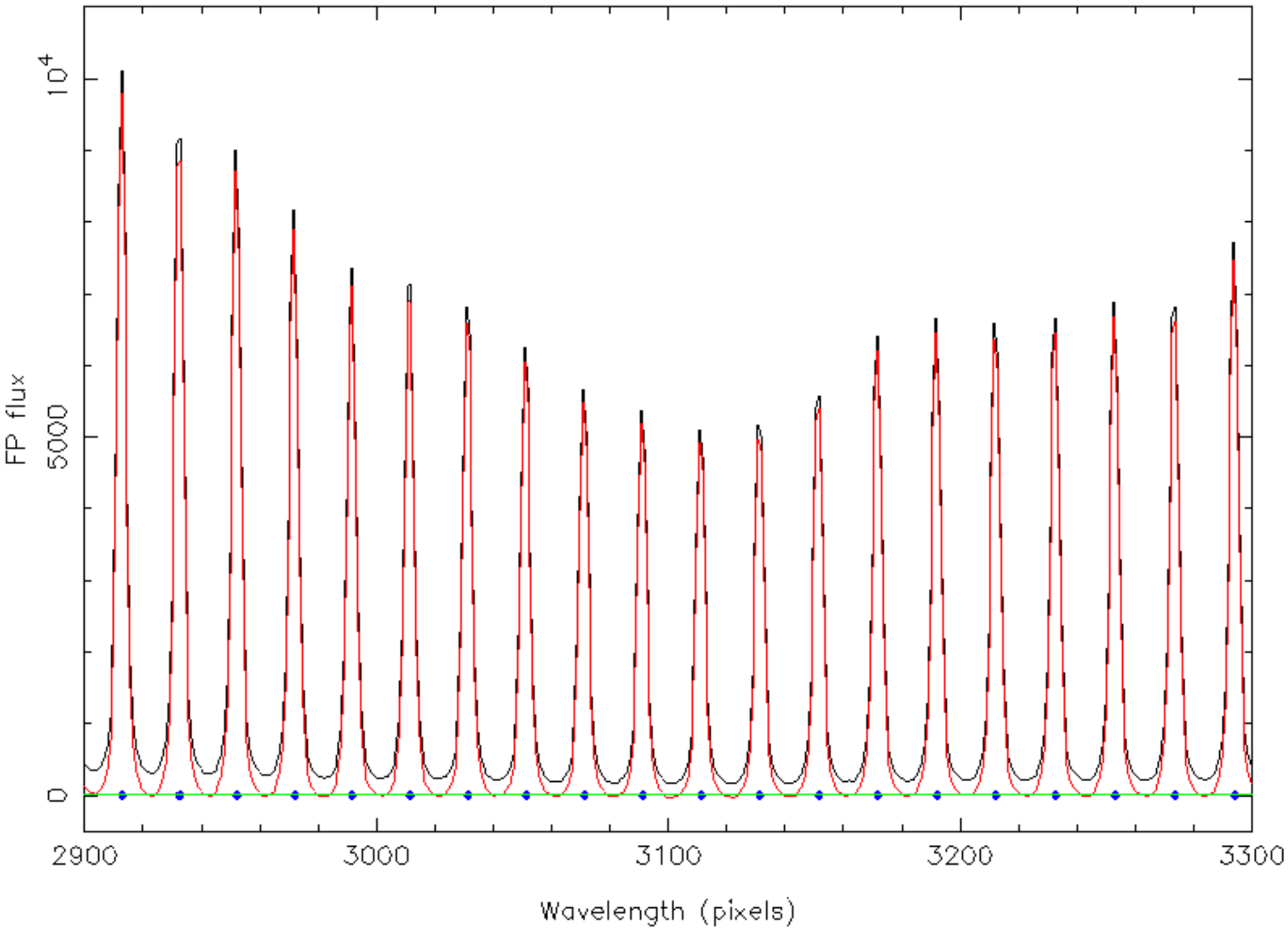
ThAr arc


Ar
Th
1000
500
0
Relative Poisson signal:noise
4000
5000
6000
7000
8000
9000
Wavelength (Å)

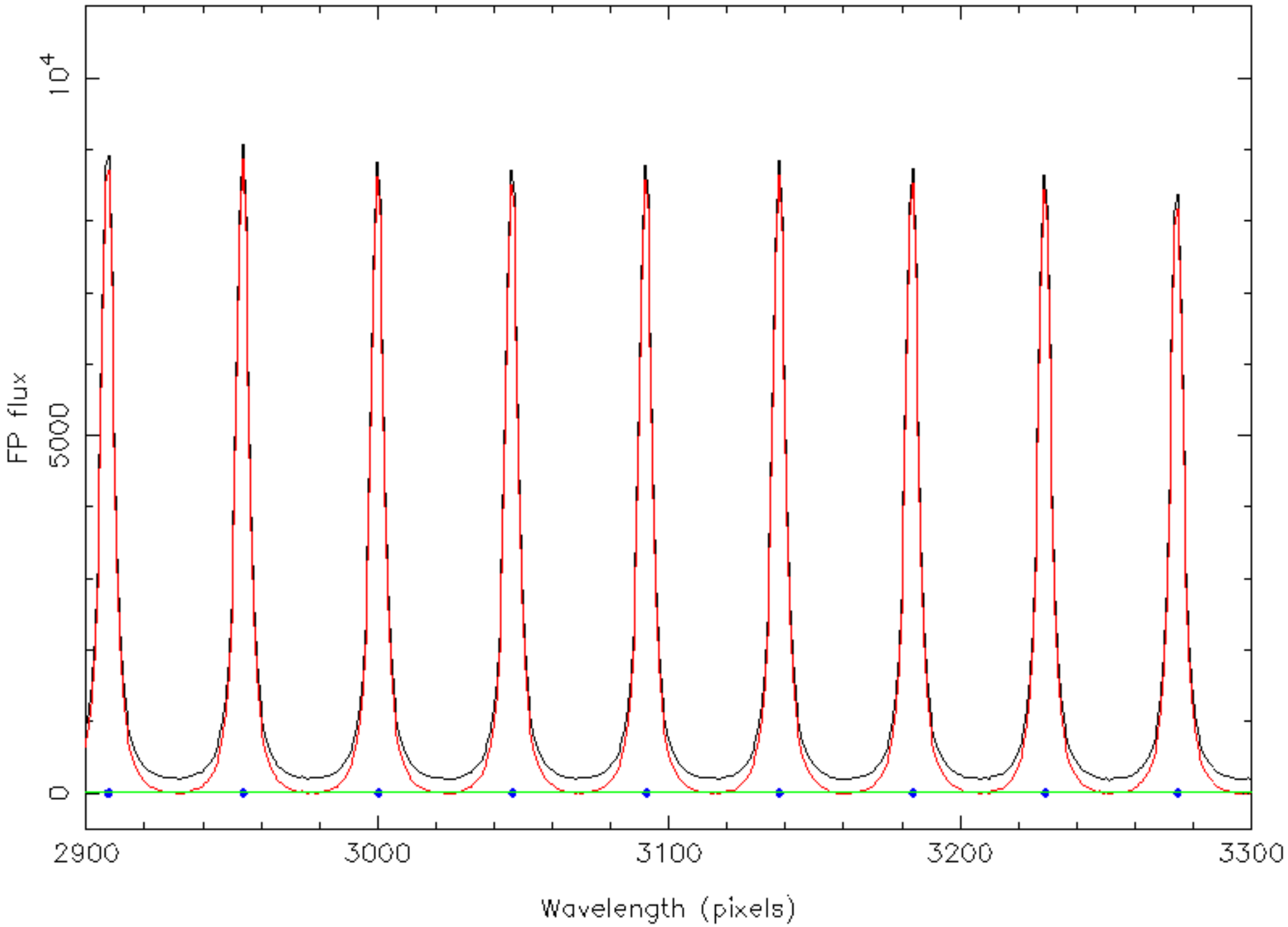


Central section
simulated FP
Etalon "arc"

Section of FP Etalon "arc" LRS (red)



Section of FP Etalon "arc" HRS (red)



L1 processing issues overview

- extraction issues
  - overscan, bias, gain correction at quadrant level
  - characterise (LSFs/PSFs) and dealing with fibre crosstalk
  - fibreflats for consistent internal system
  - dealing with scattered light and ghosts
  - wavelength calibration
- sky issues
  - sky emission line spatial and temporal variation (scaling & PCA)
  - sky continuum spatial and temporal variation (fibre flat scaling)
  - oversampling of master skies (reduce pixellation & PCA)
  - subtraction in nebular regions (specialist - incl. imaging)
- quality measures
  - estimates of sky continuum residual levels (skysub skies, faint obj)
  - estimates of noise residuals at sky line locations (cf. Poisson)

L1 flux calibration

- consistent internal calibration system (ADUs)
  - primary reference <twilight flats> all fibres
  - secondary reference daytime <1D fibre cal flats>
  - tertiary reference OB-level nighttime 1D fibre cal flats

- external calibration with WD templates (ergs/cm^2/s/A)
  - select out ALL WDs for any given setup (monthly cadence)
  - apply current flux calibration -> relative flux conversion
  - fit template spectra to individual WDs
  - use robust average fit to update relative flux calibration (monthly)
  - iterate as needed until convergence
  - use WD magnitude information -> average OB-level absolute flux conversion
  - OB-level differential atmospheric extinction correction Gaia Bp, Rp spectra
  - individual object magnitudes/Gaia Bp, Rp spectra -> tailored absolute flux

Extn#	Extension Name	Description
0	Primary	The primary header unit. This will have no data, but will have a full FITS header with information about the observations that went into these science spectra
1	SPECTRA_BLUE	An image extension for the blue arm with wavelength calibrated sky subtracted spectra on a consistent internal flux system in ADUs.
2	IVAR_BLUE	An image extension with the inverse variance array for the above
3	SPECTRA_GREEN	An image extension for the green arm with wavelength calibrated sky subtracted spectra on a consistent internal flux system in ADUs.
4	IVAR_GREEN	An image extension with the inverse variance array for the above
5	SPECTRA_RED	An image extension for the red arm with wavelength calibrated sky subtracted spectra on a consistent internal flux system in ADUs.
6	IVAR_RED	An image extension with the inverse variance array for the above
7	SPECTRA_BLUE_NOSS	An image extension for the blue arm with wavelength calibrated spectra that have not been background sky corrected
8	IVAR_BLUE_NOSS	An image extension with the inverse variance array for the above
9	SPECTRA_GREEN_NOSS	An image extension for the green arm with wavelength calibrated spectra that have not been background sky corrected
10	IVAR_GREEN_NOSS	An image extension with the inverse variance array for the above
11	SPECTRA_RED_NOSS	An image extension for the red arm with wavelength calibrated spectra that have not been background sky corrected
12	IVAR_RED_NOSS	An image extension with the inverse variance array for the above
13	SENSFUNC_BLUE	The sensitivity function for each spectrum in the blue arm – converts ADUs to ergs/s/cm^2/Å
14	SENSFUNC_GREEN	As above but for the green arm
15	SENSFUNC_RED	As above but for the red arm
16	FIBINFO	A fibre information table (see section 7.2 in DRPD)

L1 pipeline output FITS file structure

Phase 3 1D spectrum FITS file structure

Extn#	Extension Name	Description
0	Primary	The primary header unit. This will have no data, but will have a full FITS header with information about the observations that went into these science spectra
1	PHASE3SPECTRUM	An binary table extension for the specified arm(s) with wavelength calibrated sky subtracted spectra on a consistent internal flux system in ADUs.

TTYPE	TTYPE comment	TFORM#	TFORM comment	TCOMM*	TUNIT*
WAVE	Wavelength Array	NE	data format of field: ASCII Character	Wavelength	Angstrom
FLUX	Spectral Flux	NE	data format of field: 4-byte REAL	Spectral Flux	adu
ERR_IVAR	Inverse Variance	NE	data format of field: 4-byte REAL	Inverse Variance	1/adu^2
QUAL	Quality Mask	NJ	data format of field: 4-byte INTEGER	Quality Mask	--
FLUX_NOSS	Spectral Flux - NO Sky Subtraction	NE	data format of field: 4-byte REAL	Spectral Flux	adu
ERR_IVAR_NOSS	Inverse Variance - NO Sky Subtraction	NE	data format of field: 4-byte REAL	Inverse Variance	1/adu^2
SENSFUNC	Sensitivity Function	NE	data format of field: 4-byte REAL	Sensitivity Function	erg(s*cm^2*Angstrom*adu)