WEAVE Core Processing System

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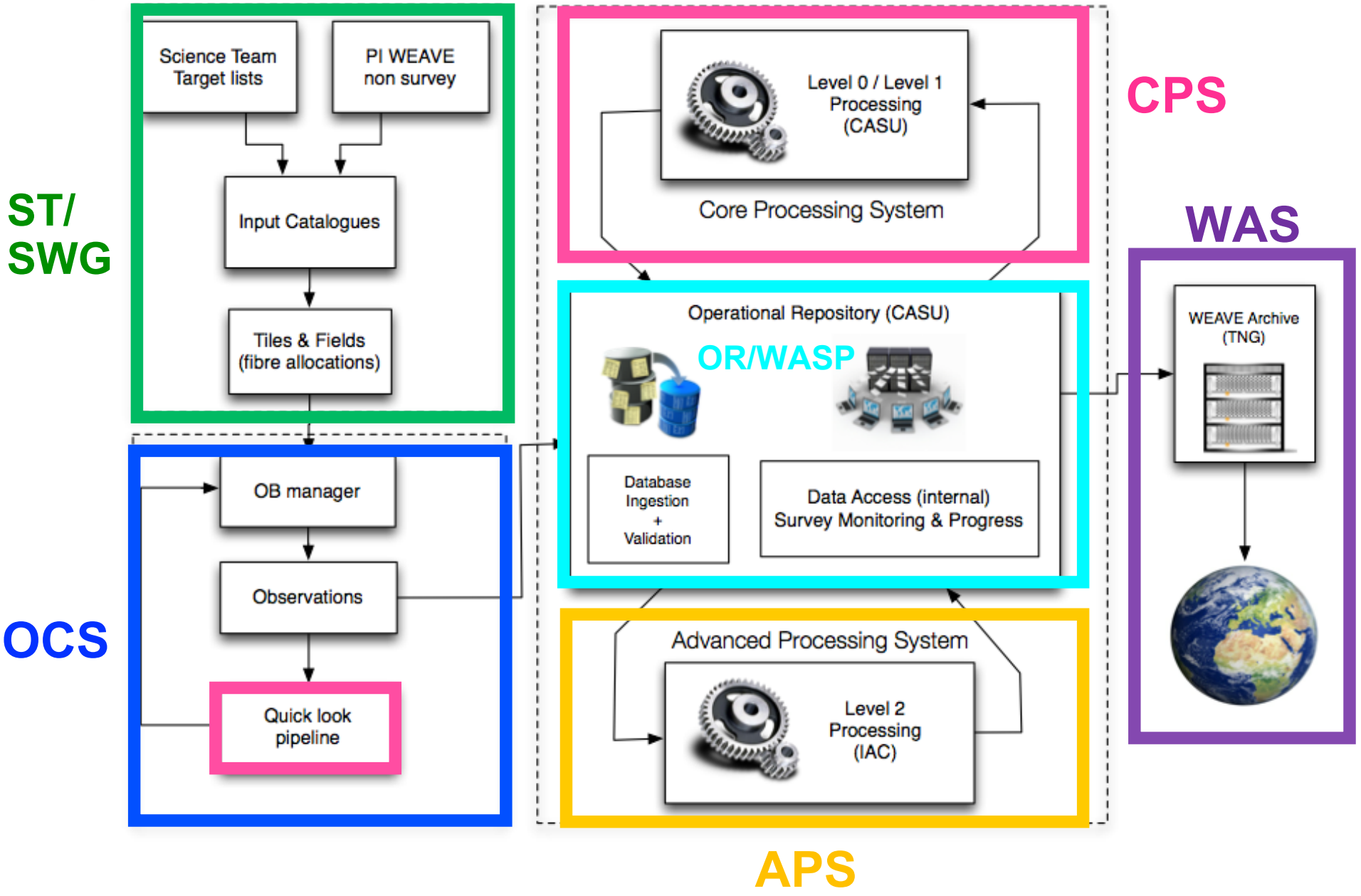
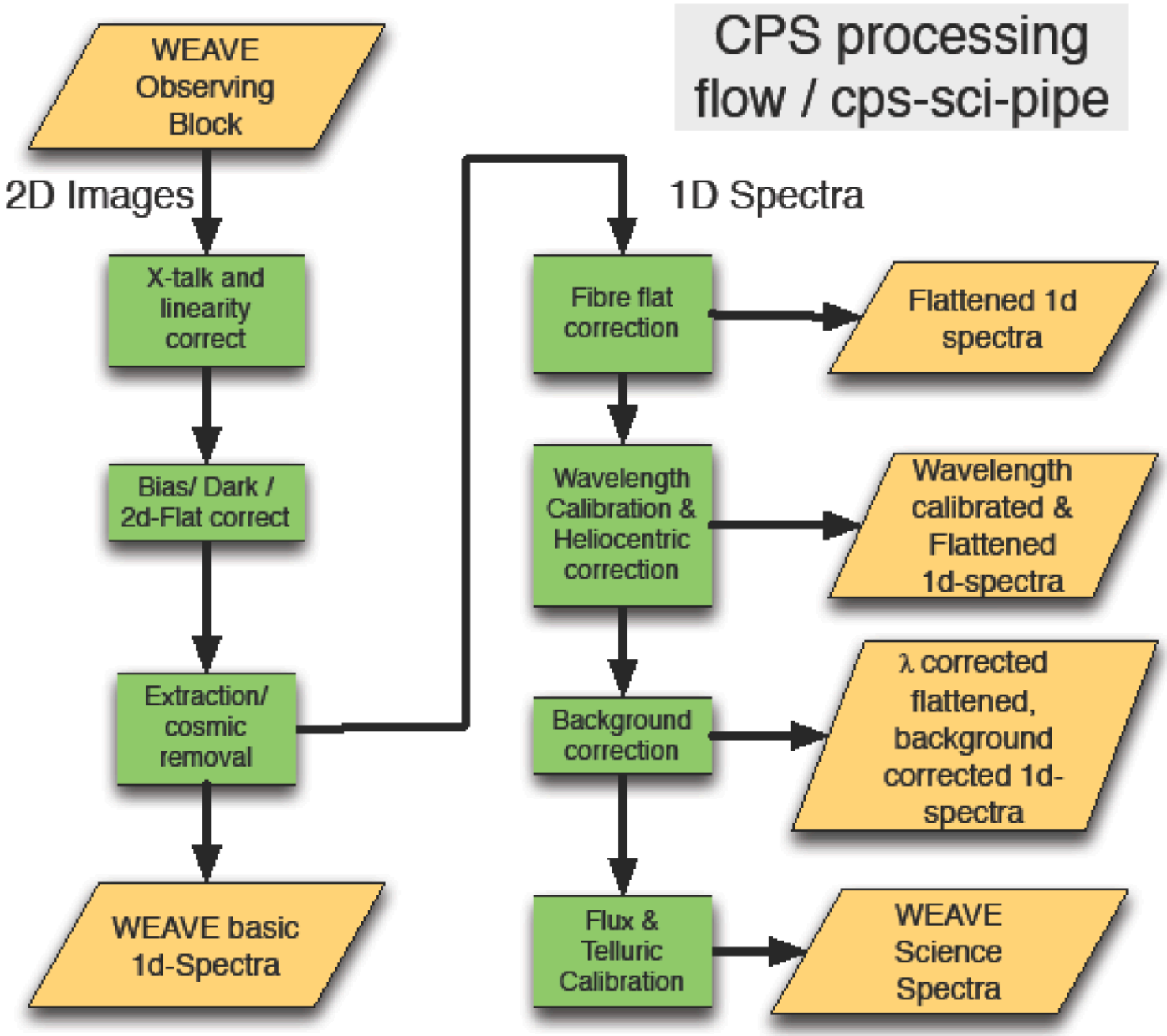
WEAVE Science Verification Workshop
IAC, Tenerife, 14th November 2019

WEAVE Science Processing & Analysis

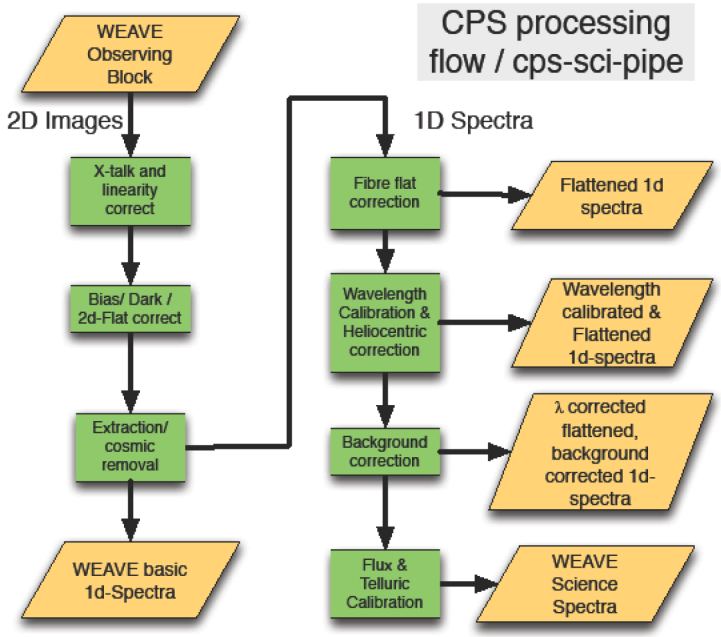


CPS Team

- Quick-Look and Level 1 Pipeline
  - Jim Lewis, Mike Irwin
- Quick-Look GUI
  - Luis Peralta de Arriba
- Operational Repository (OR)
  - David Murphy
- WEAVE Automated Submission Platform (WASP)
  - David Murphy, Clare Worley
- Quality Assurance
  - Mike Irwin, Clare Worley
- CPS Manager
  - Nic Walton


CPS processing flow / cps-sci-pipe
WEAVE Observing Block
2D Images
X-talk and linearity correct
Bias/ Dark / 2d-Flat correct
Extraction/ cosmic removal
WEAVE basic 1d-Spectra
1D Spectra
Fibre flat correction
Flattened 1d spectra
Wavelength Calibration & Heliocentric correction
Wavelength calibrated & Flattened 1d-spectra
Background correction
λ corrected flattened, background corrected 1d-spectra
Flux & Telluric Calibration
WEAVE Science Spectra

CPS design & development



- Quick-Look and Level 1 science pipelines
  - single code-base
- File I/O done via CFITSIO
- Processing modules written in C

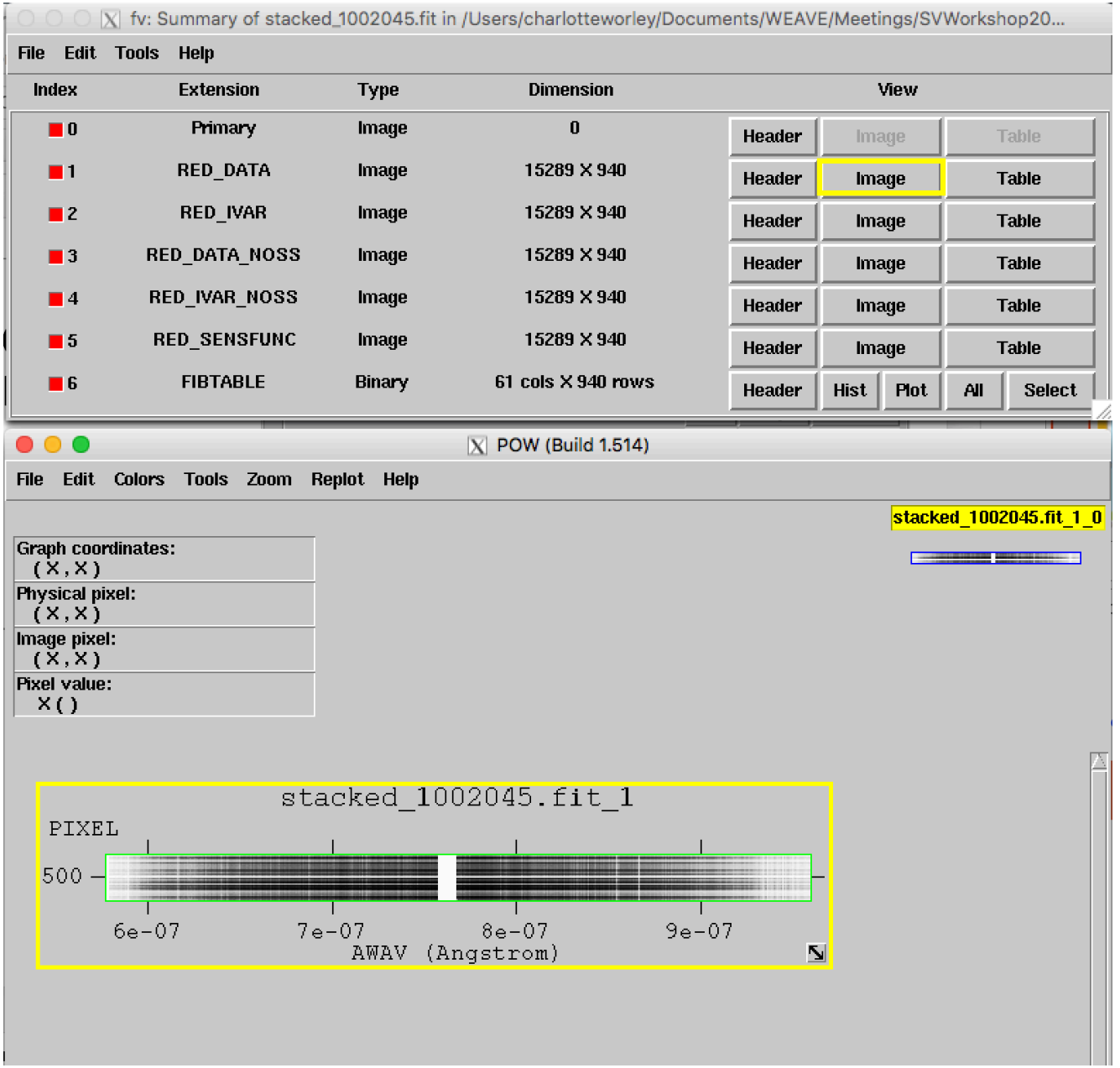
Modules combined into pipeline with intelligent “glue” (Python)

- glue decides grouping of files
- matches files with calibration data etc..
- decisions made only using contents of the FITS headers

CPS L1 Data Products

Stacked_1002045.fit

Example from OpR3
Calibration Co-ordination Group (CCG) OB

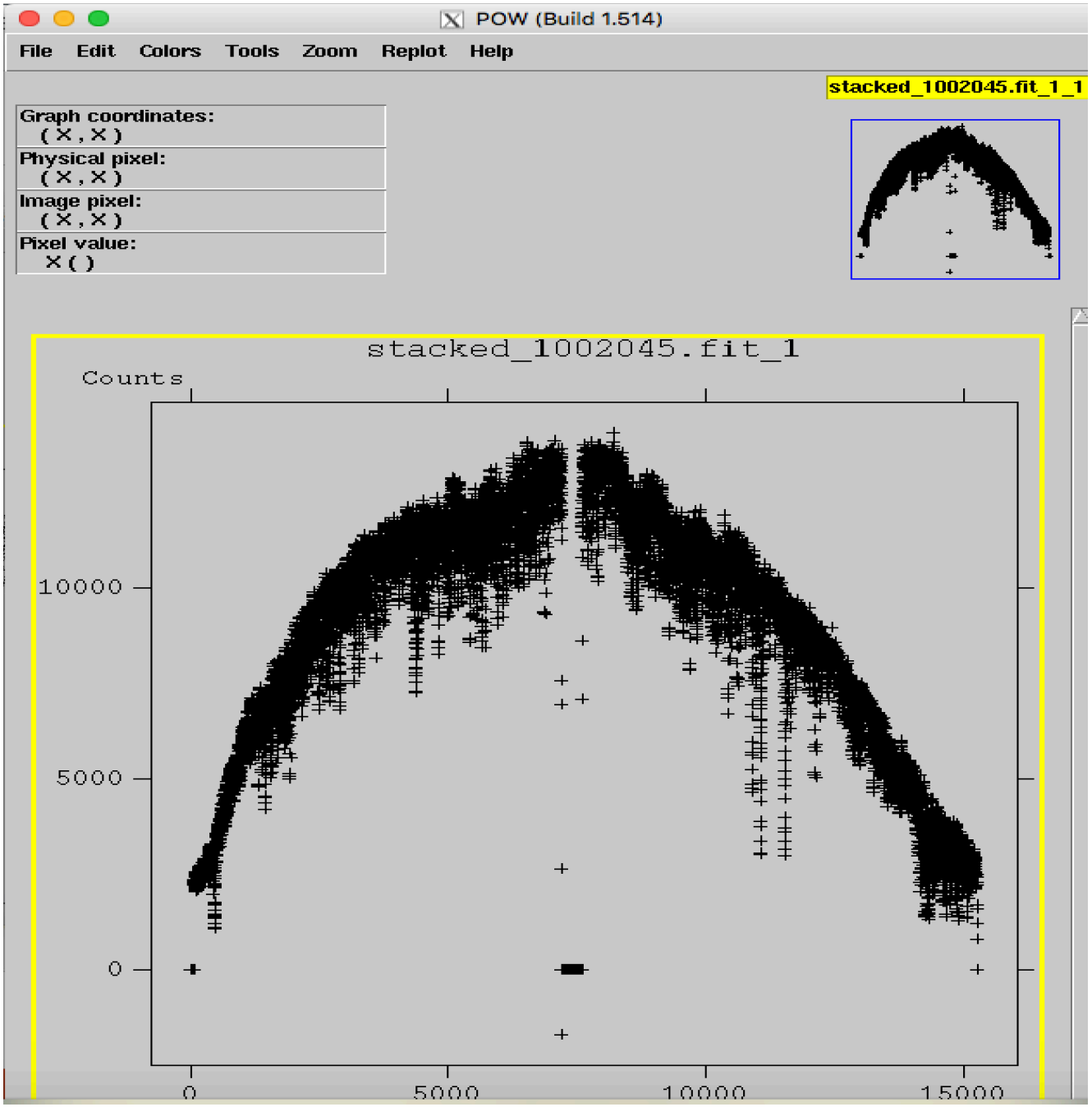


Using fv - https://heasarc.gsfc.nasa.gov/ftools/fv/

CPS L1 Data Products

Stacked_1002045.fit

Example from OpR3
Calibration Co-ordination Group (CCG) OB



WEAVE Processing Overview

- Data characterisation
  - biases, linearity, darks, fibre flats, arcs, twilight flats
  - detector (2D) flats, “salsa” flats & arcs -> Point Spread Functions (PSF)

- Physical calibration
  - wavelength calibration -> arcs, skylines, telluric lines
  - relative flux calibration -> fibre flats; White Dwarf spectra
  - absolute flux calibration -> White Dwarfs, Gaia BP/RP spectra

- Survey verification & external calibration
  - FGKM benchmark stars -> fairly infrequent
  - RV standards -> fairly infrequent (+e.g. M67)
  - standard fields e.g. Kepler, open clusters …
  - overlap with other surveys (APOGEE, 4MOST …)

WEAVE calibration needs & timescales

		OB updates	Master calfile updates
• Detector characterisation			
- biases			daily
- darks			weekly
- linearity sequence	On-chip Binning 1x1 1x2 1x4 ……	fast/slow r/o?	monthly
- 2D detector flats			weekly
• Spectrograph characterisation			
- continuum 1D fibre flats	Fibre Modes MOS-A MOS-B LIFU MIFU	OB-level +	weekly
			monthly
- twilight flats			
- ThAr arcs		OB-level +	weekly
- salsa flats	Spectrograph modes LR, HRb,r, HRg,r LR, HRb,r, HRg,r LR, HRb,r HRg,r LR, HRb,r HRg,r		monthly

Optimal Spectral Extraction & Reduction

Recent developments include:

- Improved generation of 1D fibre flats via master calibration files
- Wavelength calibration via master calibration files (with OB-level updates)
- Sky subtraction residual reduction using PCA
- Telluric removal using MOLECFIT model atmosphere template basis
- Improved crosstalk performance from better PSF characterisation
- Additional CPS L0 and L1 Quality Assurance checks
- Flux calibration from White Dwarf (WD) model atmosphere templates

MOS flux calibration

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

- External calibration with White Dwarf (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 absolute flux conversion
  - NB. individual object magnitudes not used yet
  - differential atmospheric extinction correction needed

LIFU, mIFU flux calibration

- Consistent internal calibration as for MOS
- Monthly cadence for overall “average” relative flux conversion

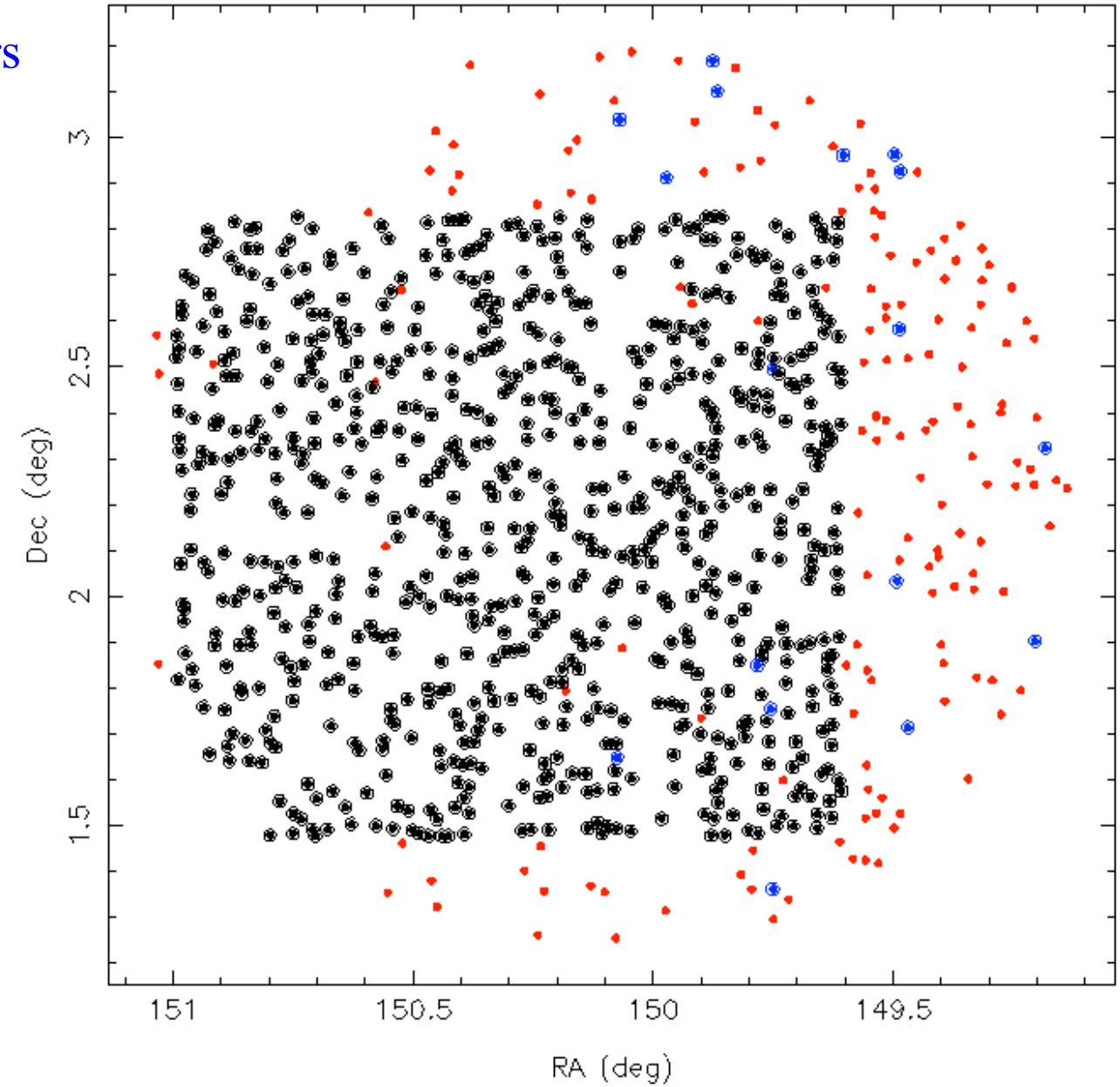
- LIFU
  - single star flux standards + dithers to capture all flux
  - extended source flux standards
  - absolute -v- relative i.e. dither or not
  - differential atmospheric extinction correction

- mIFU
  - single star mIFU same issue with dithering
  - full field of 20 mIFUs e.g. WDs
  - absolute -v- relative (as above)
  - differential atmospheric extinction correction

Configured field Examples

Examples of WEAVE OpR2.5 fibre configurations

Calibrators
Skies
Target



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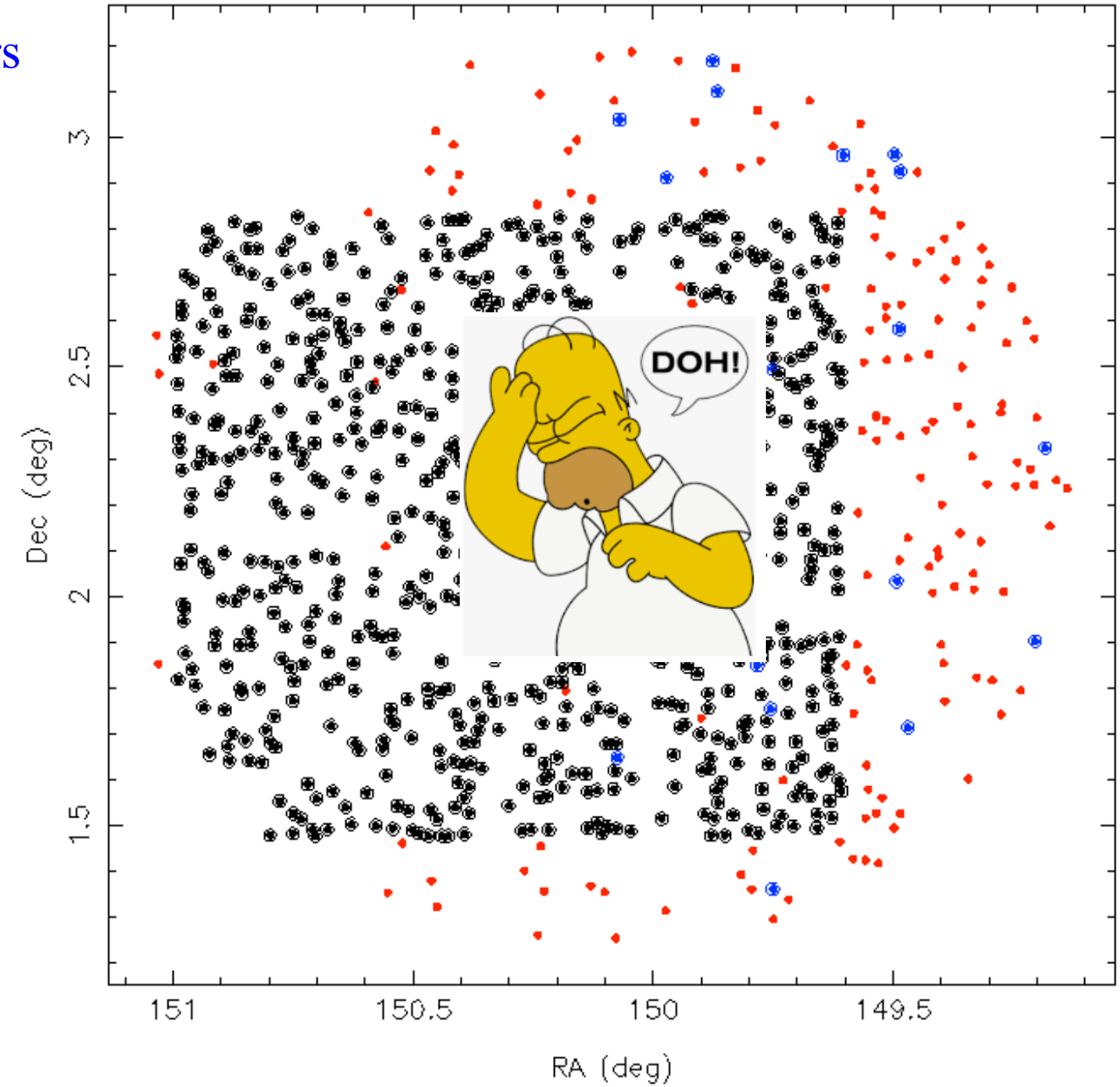
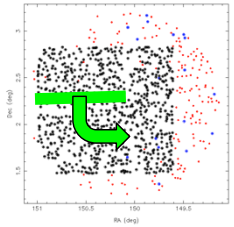
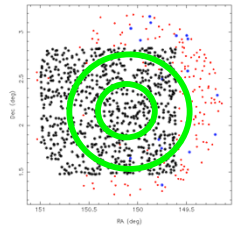
Skies
Target

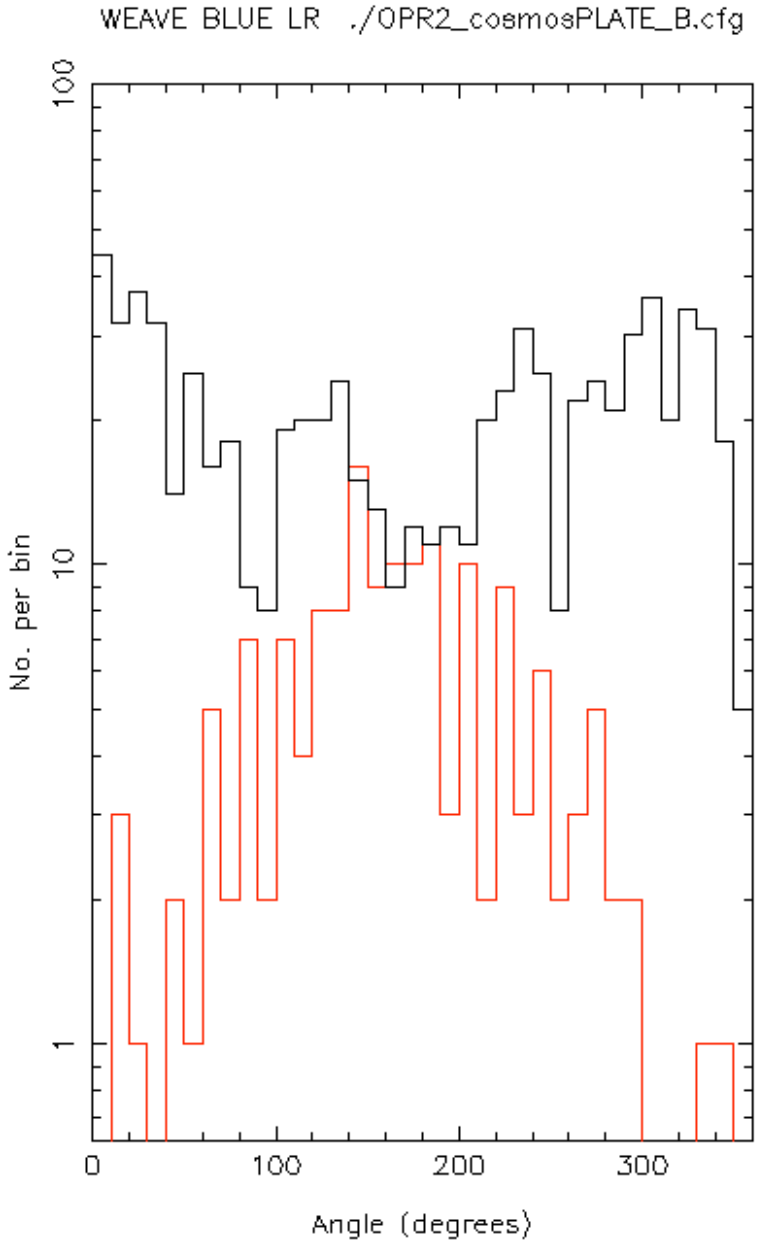


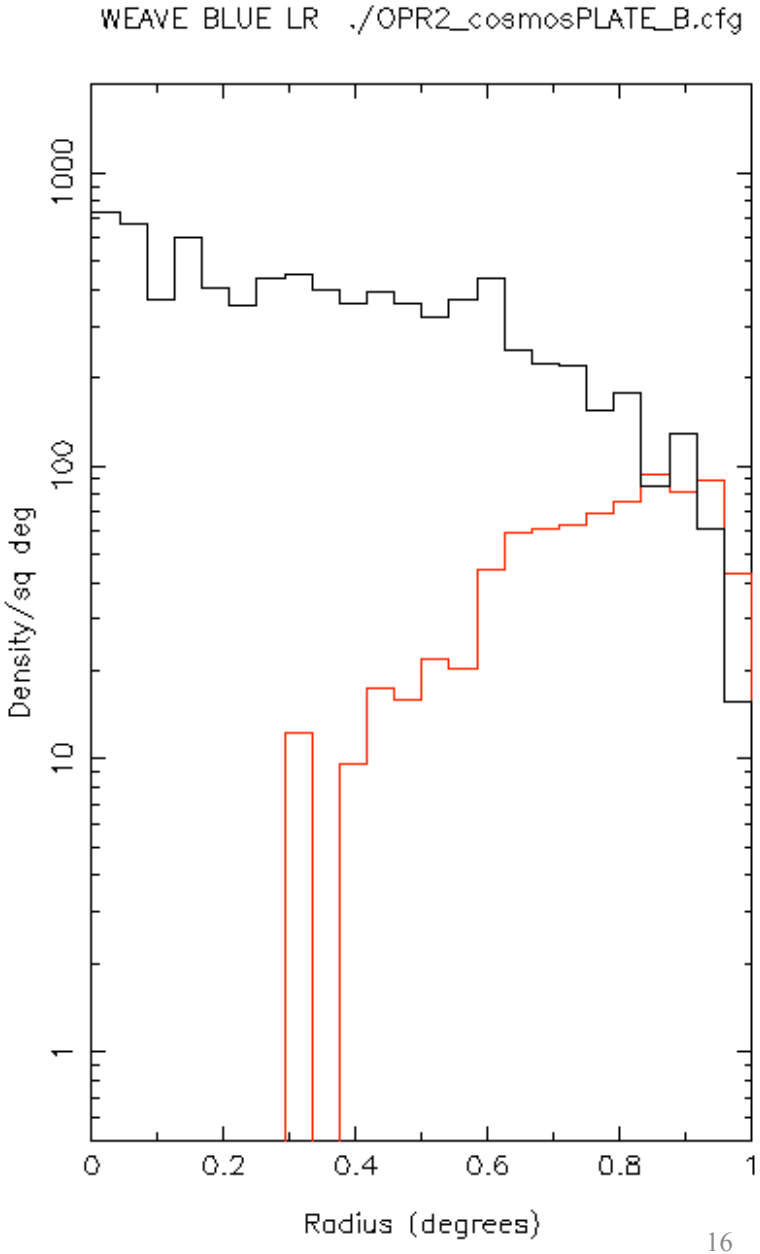
Examples of assessing sky fibre distribution

Target
Skies









Examples of WEAVE OpR2.5 fibre configurations

Calibrators
Skies
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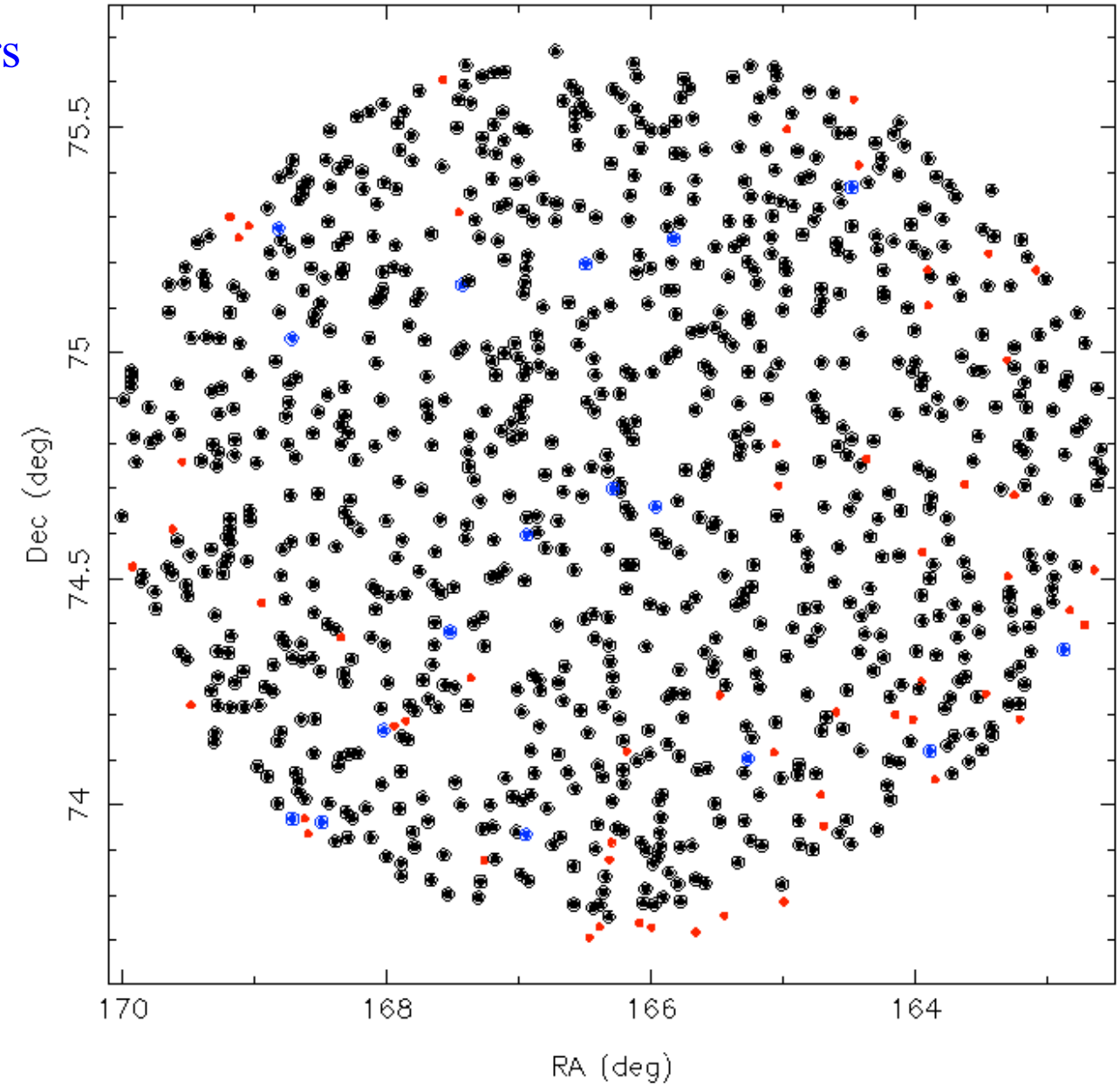

Examples of WEAVE OpR2.5 fibre configurations

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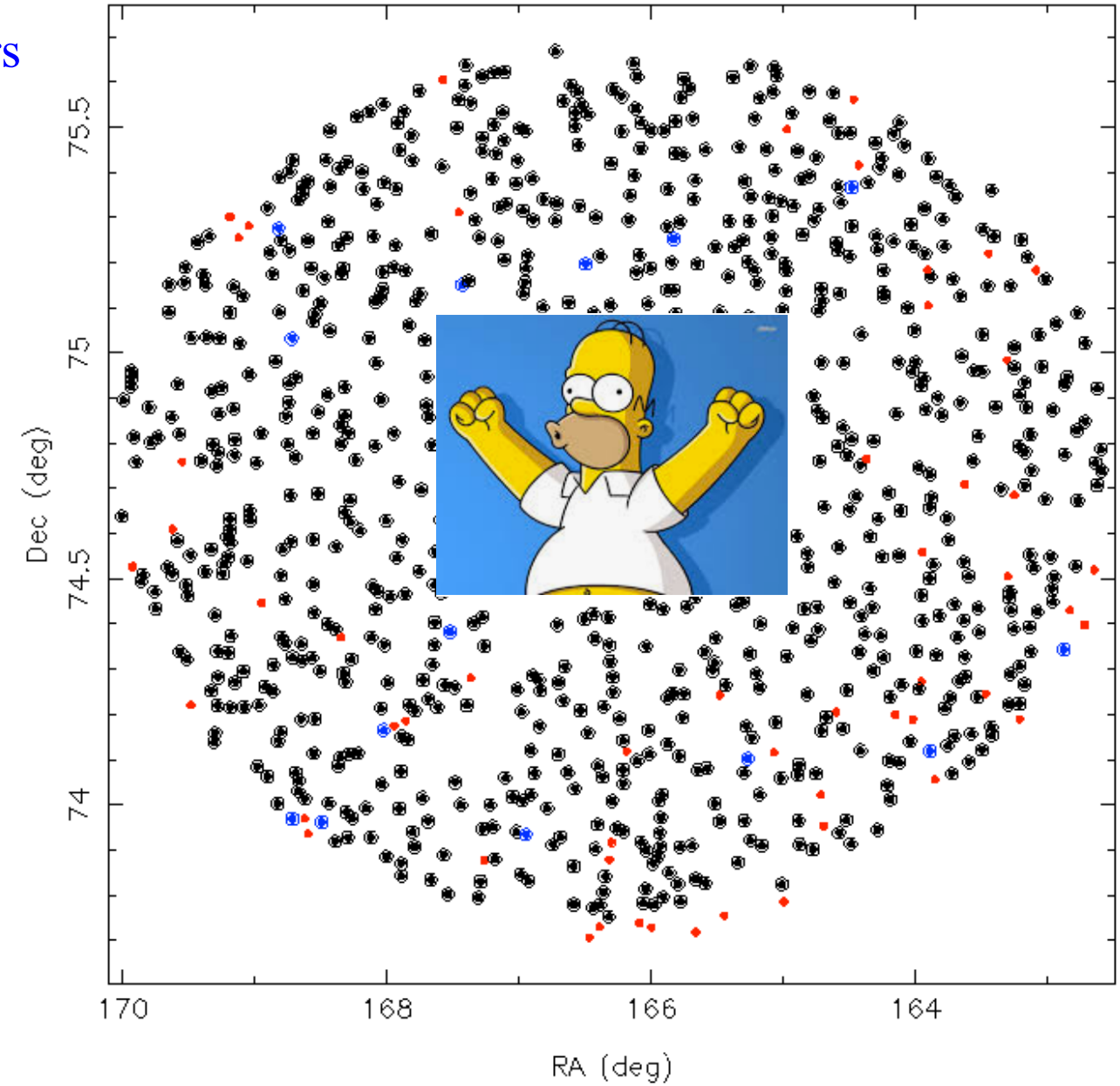
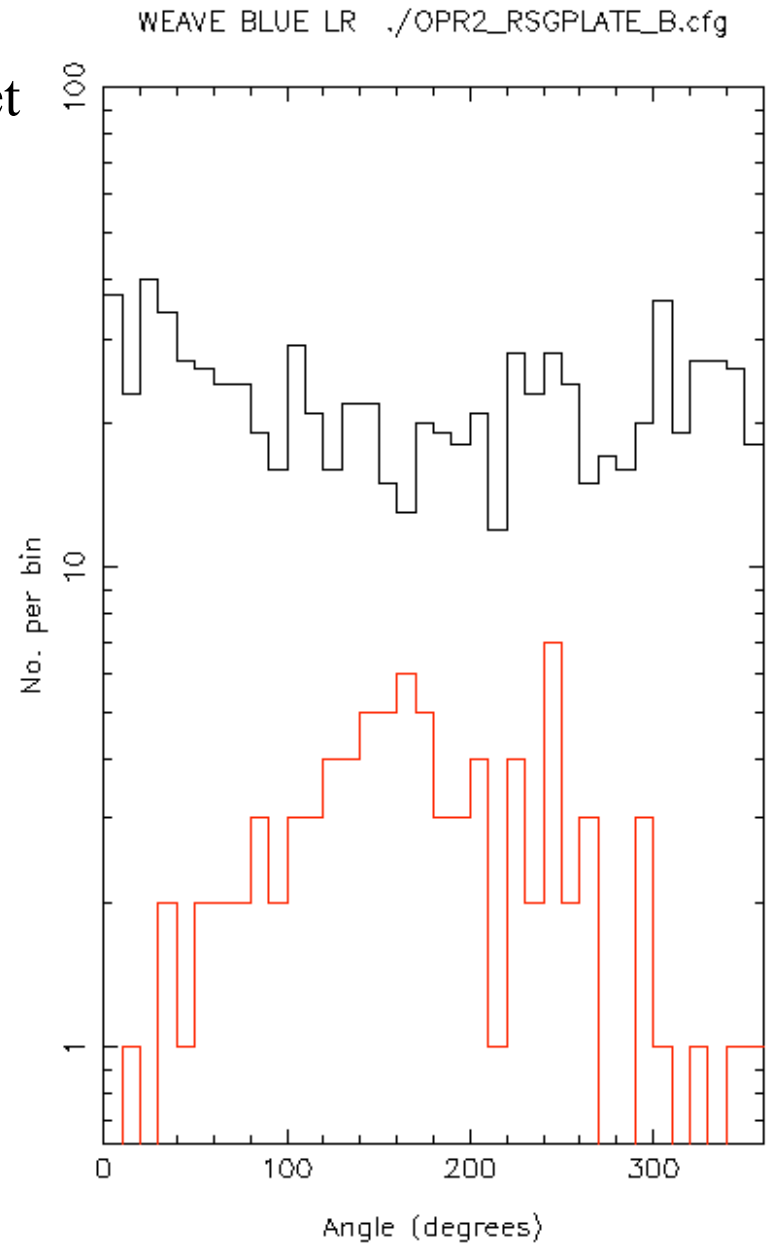
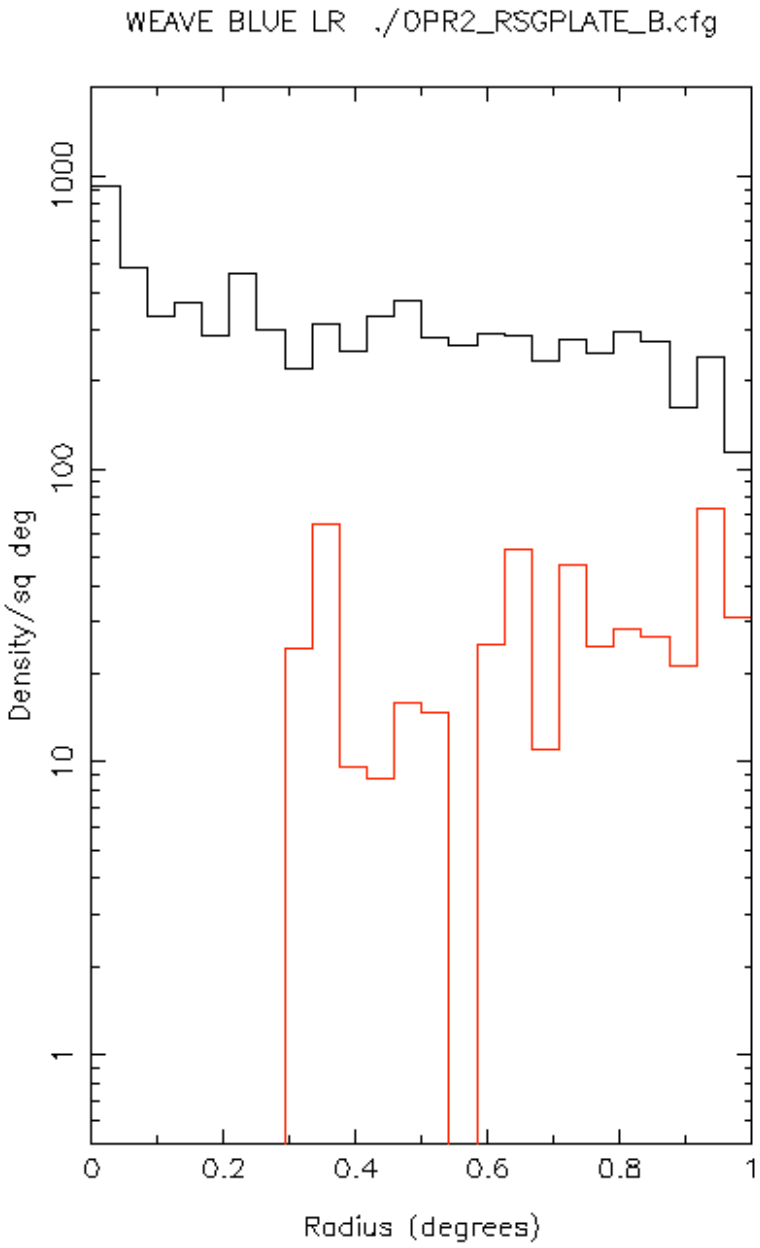
Skies
Target



Examples of assessing sky fibre distribution

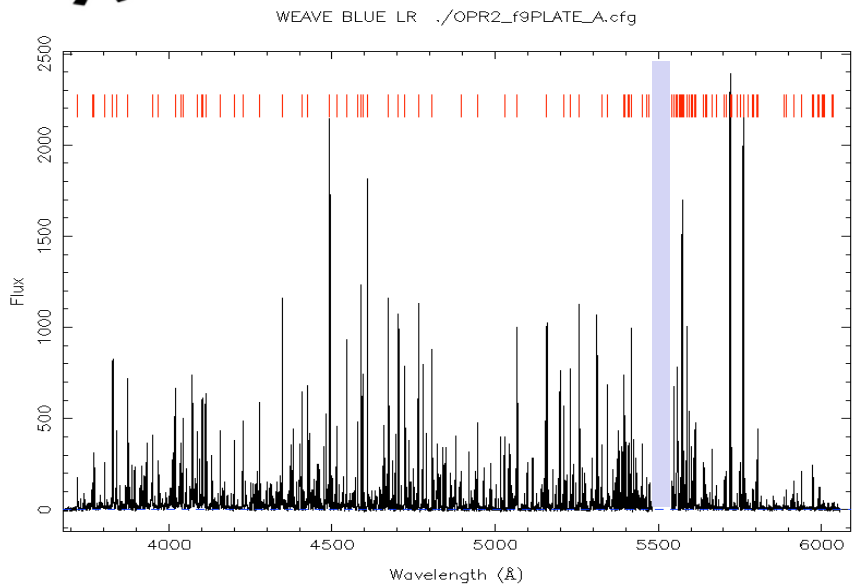
Target
Skies

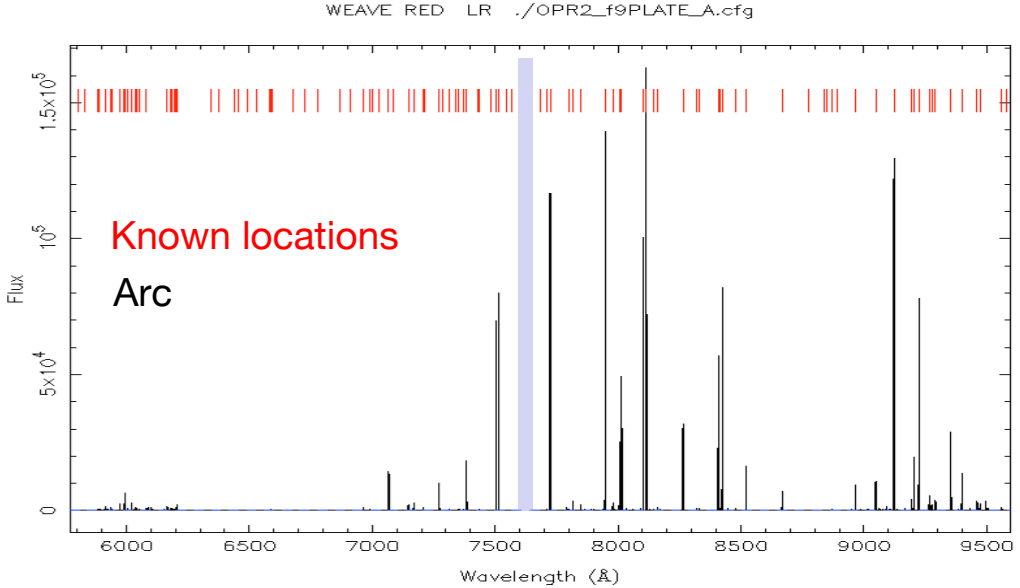


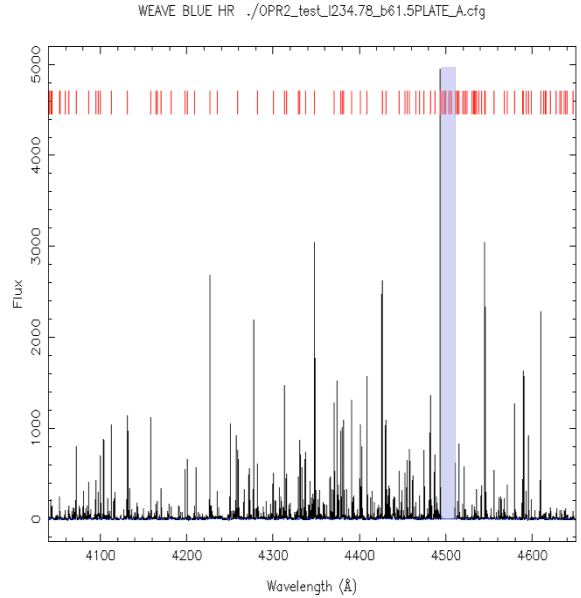


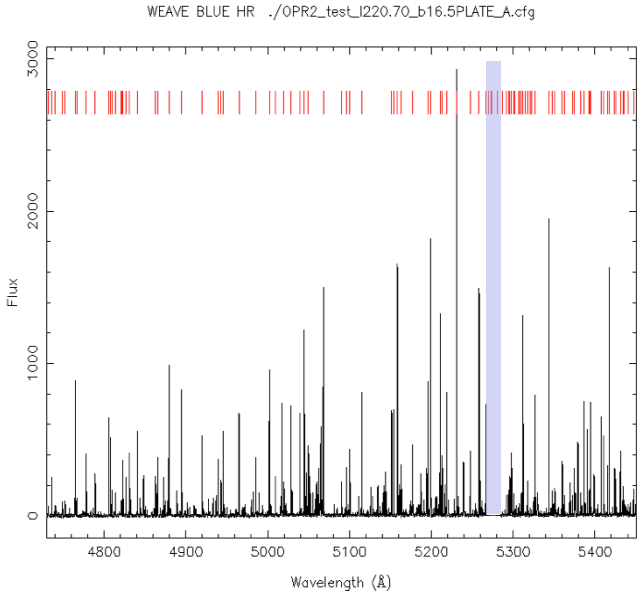
Wavelength Calibration and Sky Subtraction

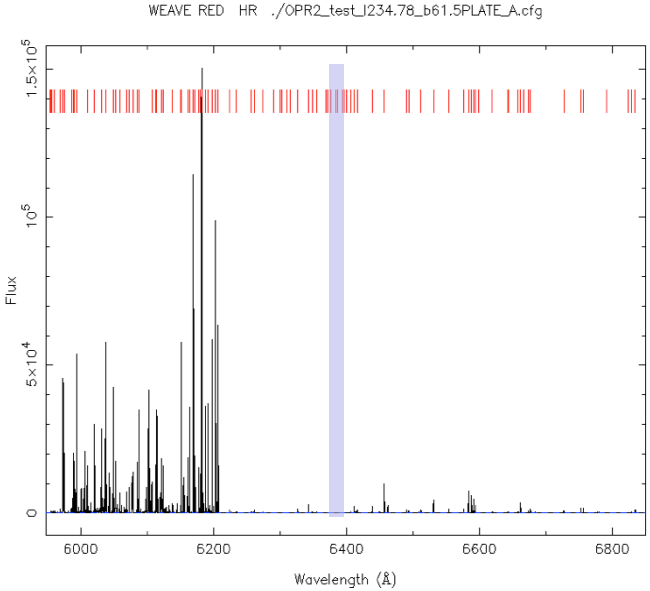
WEAVE - Arc Lines



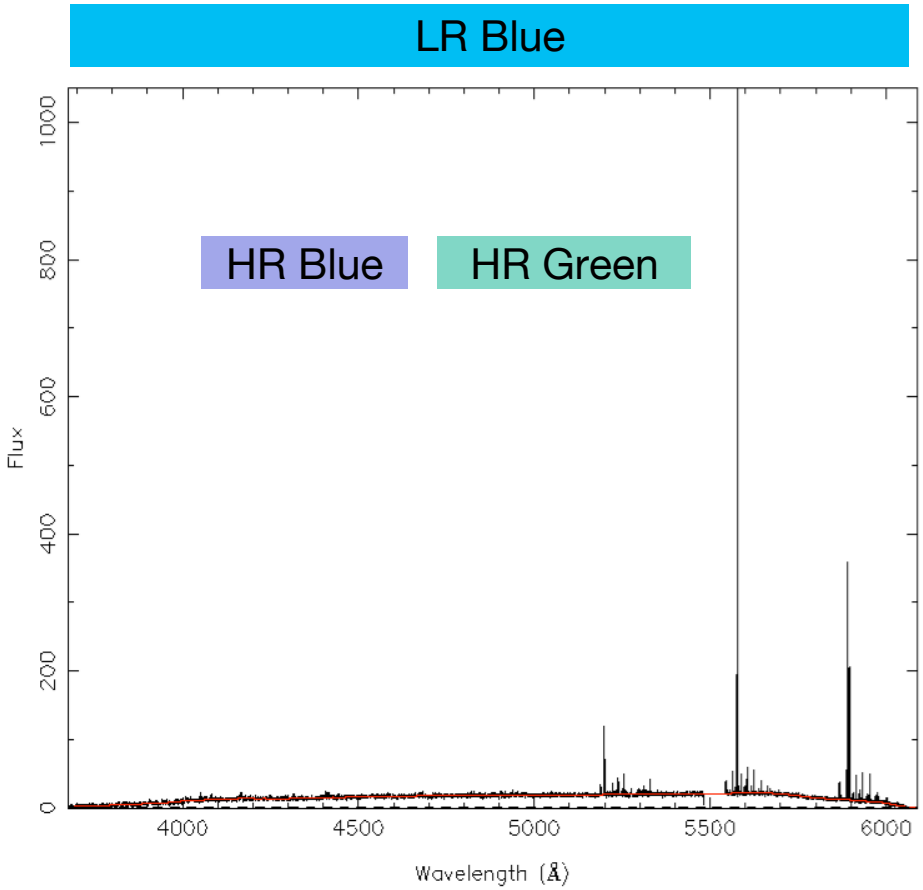


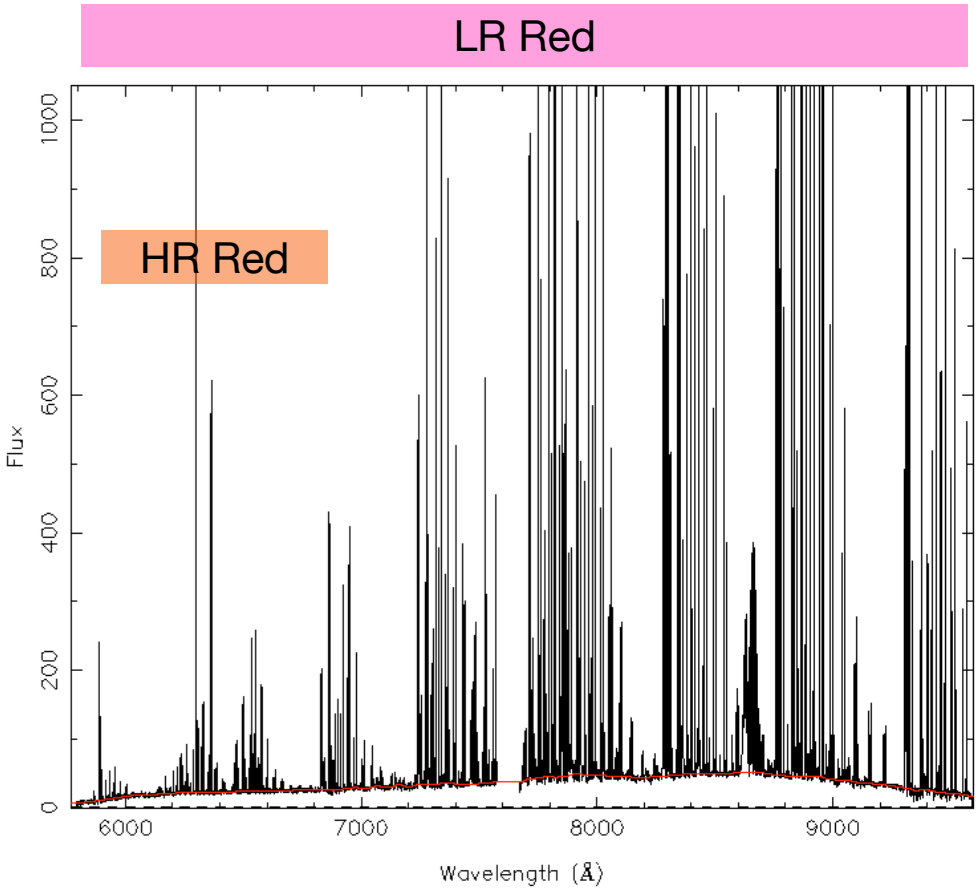




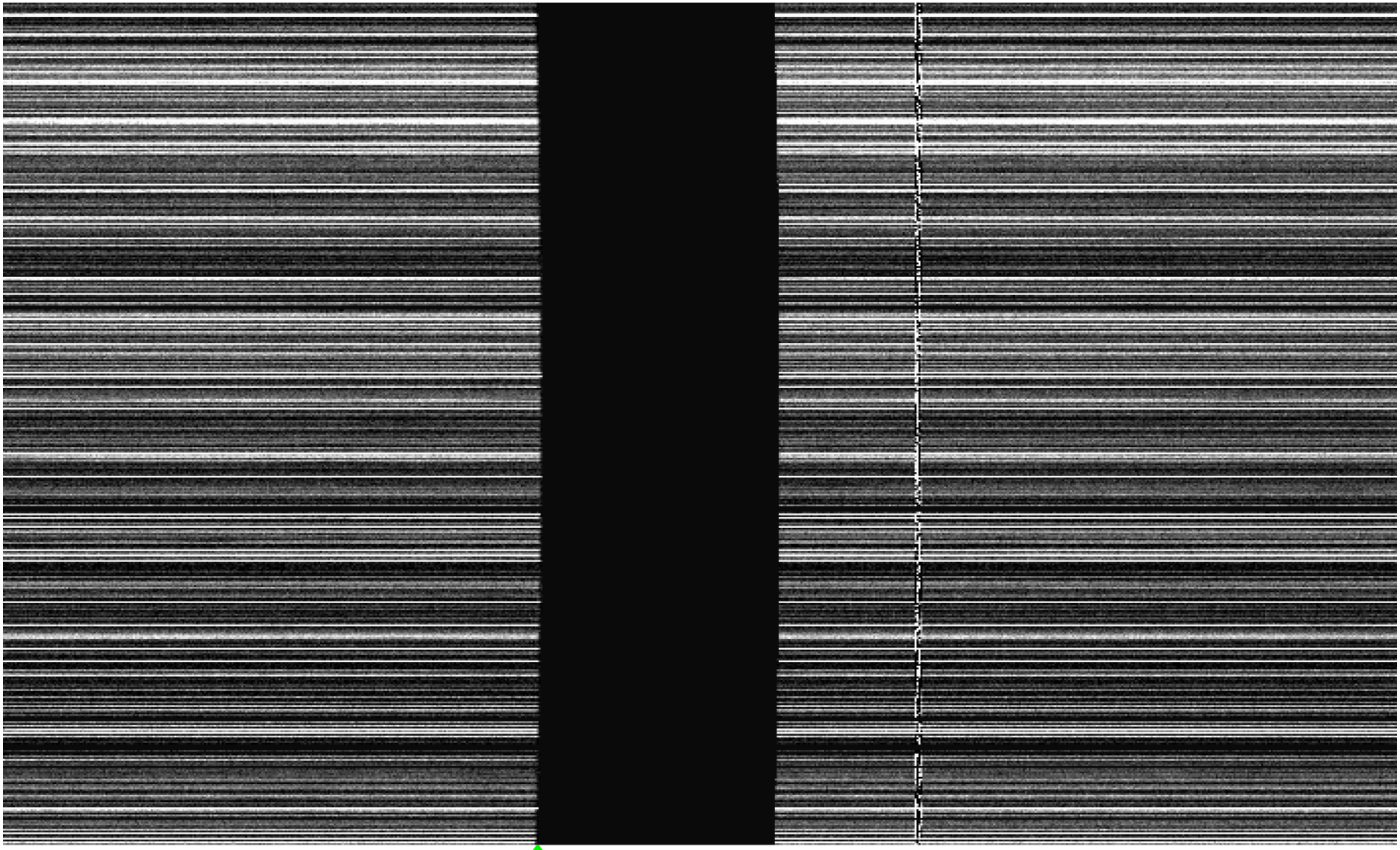


WEAVE - Sky Emission Lines



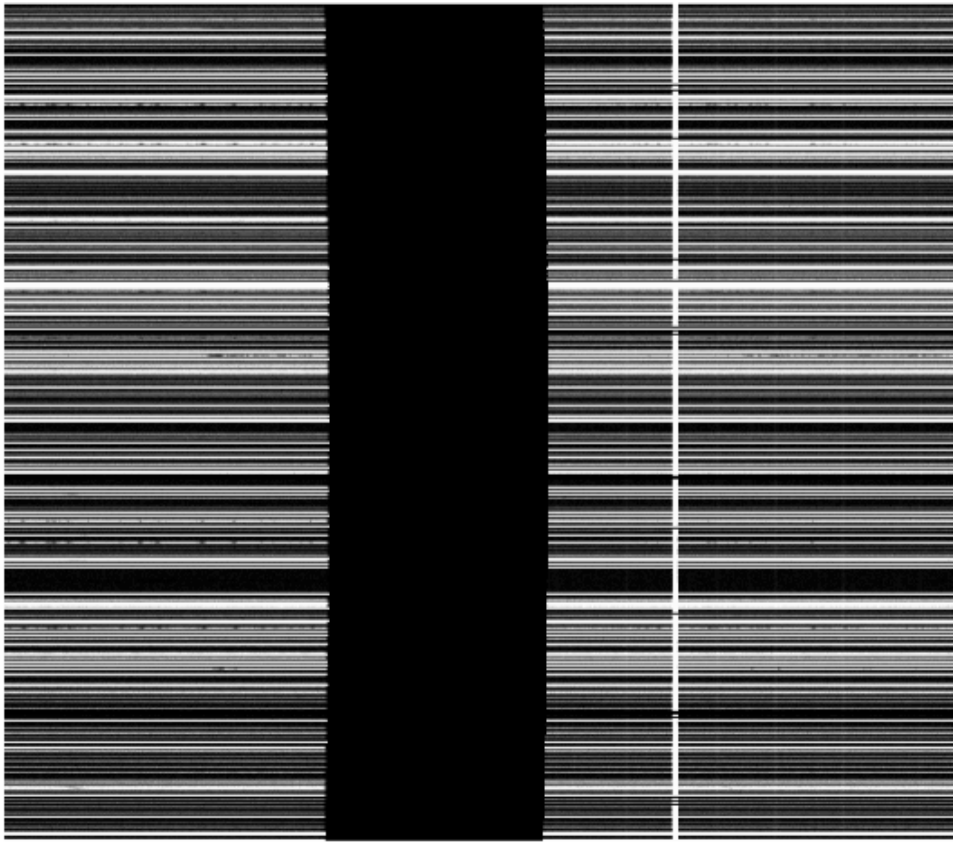


Using detector gaps to check wavelength calibration

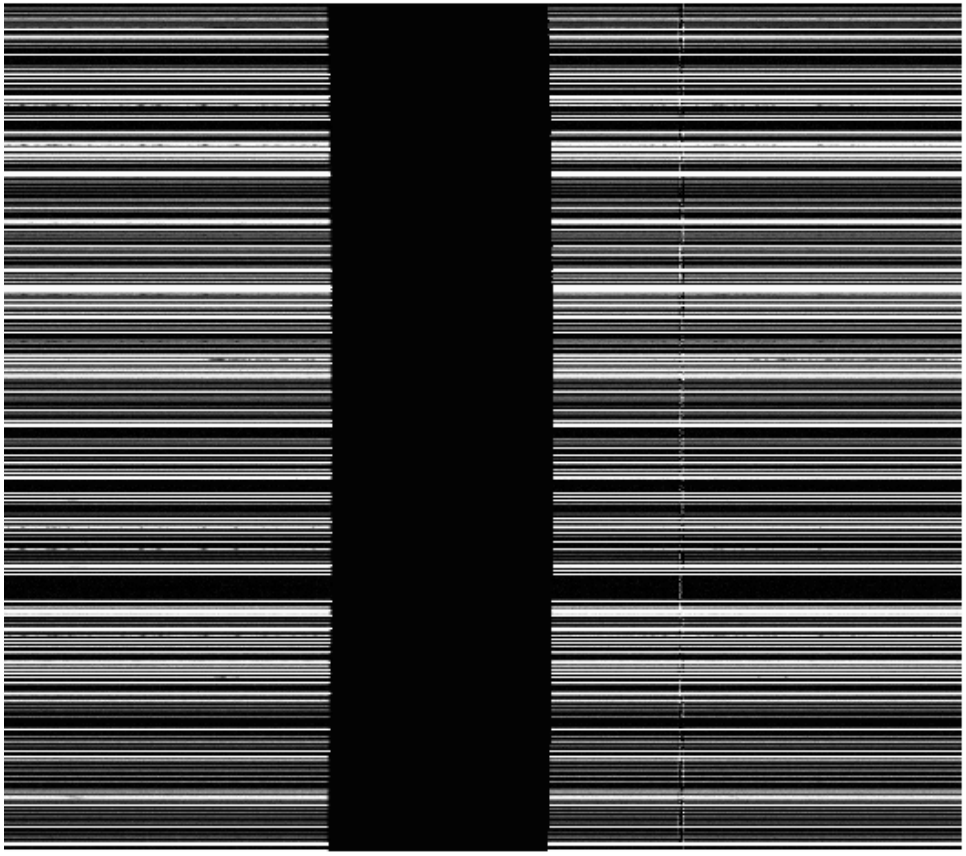


Wavelength Calibration & Sky Subtraction Checks - Blue Arm

sky line:
before

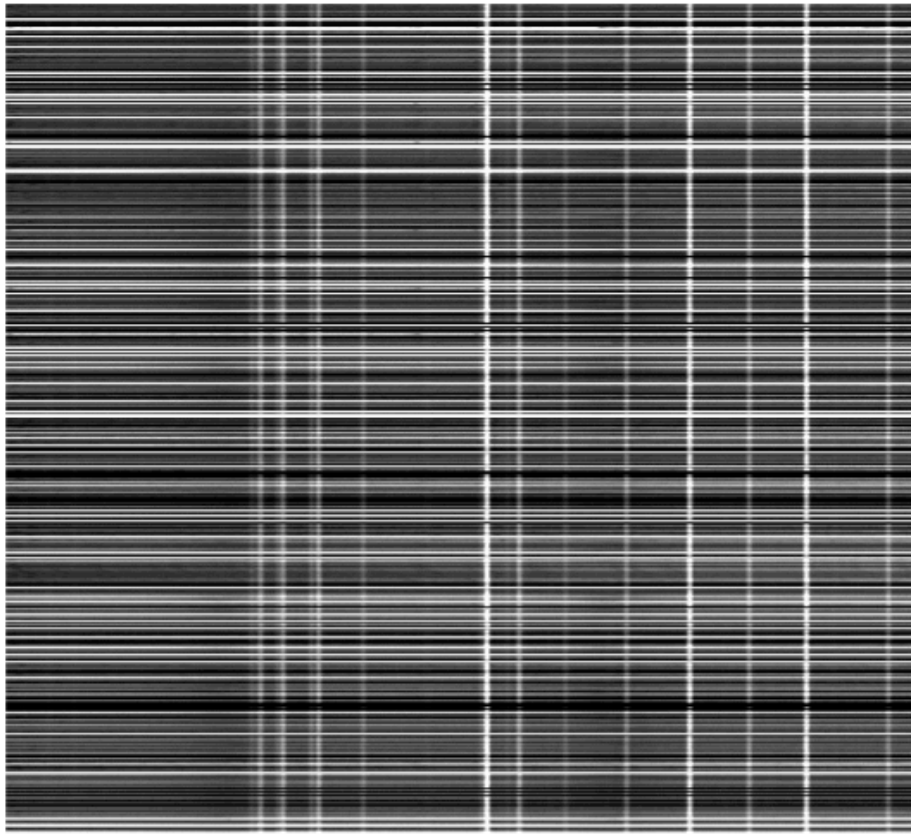


sky line:
after

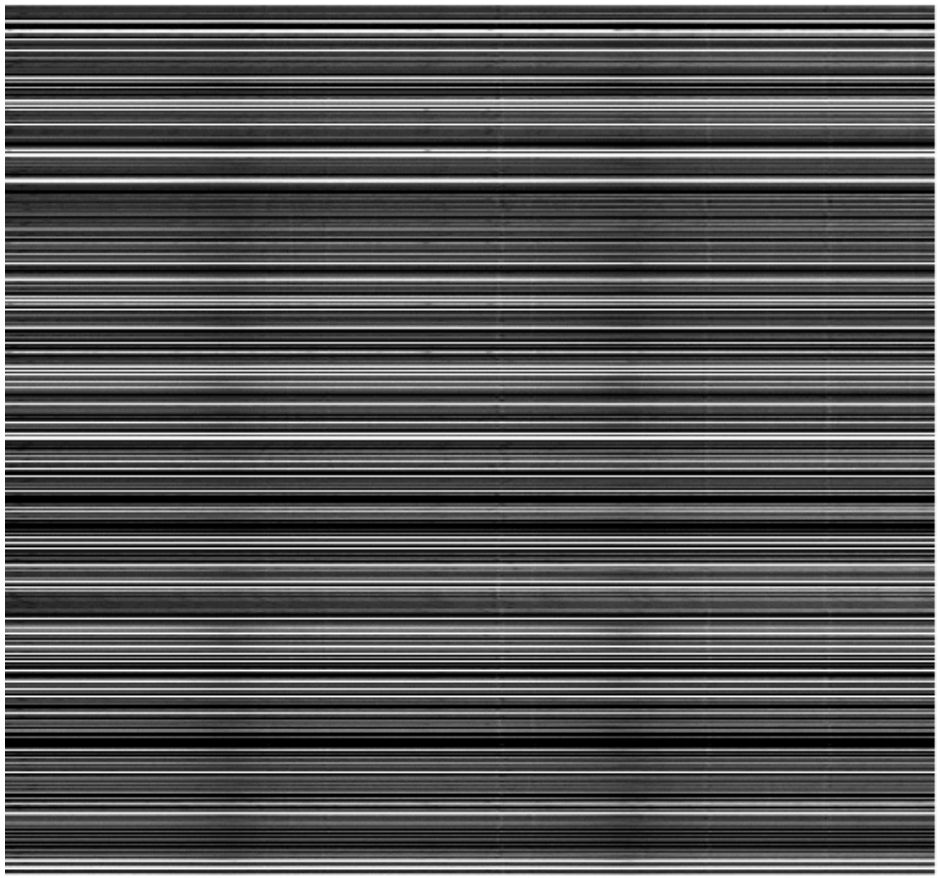


Wavelength Calibration & Sky Subtraction Checks - Red Arm

sky lines:
before



sky lines:
after



Development of Sky Subtraction procedure

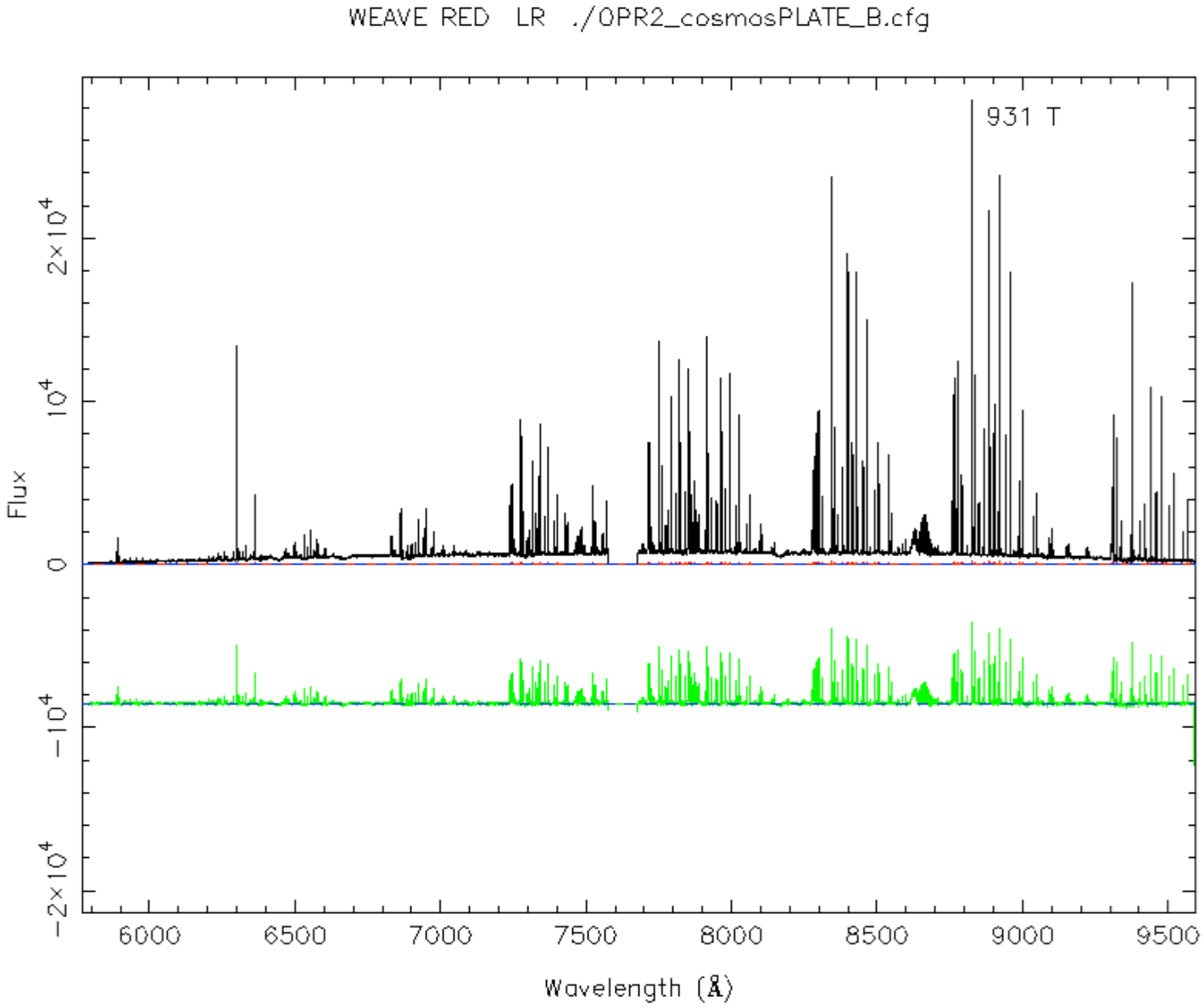
StePS COSMOS
Elliptical galaxy
z = 0.6
r = 21
Deep stack (7 OBs)

No sky subtraction

L1 reduced stacked spectrum

Scaled Sky

Normalised residuals



Development of Sky Subtraction procedure

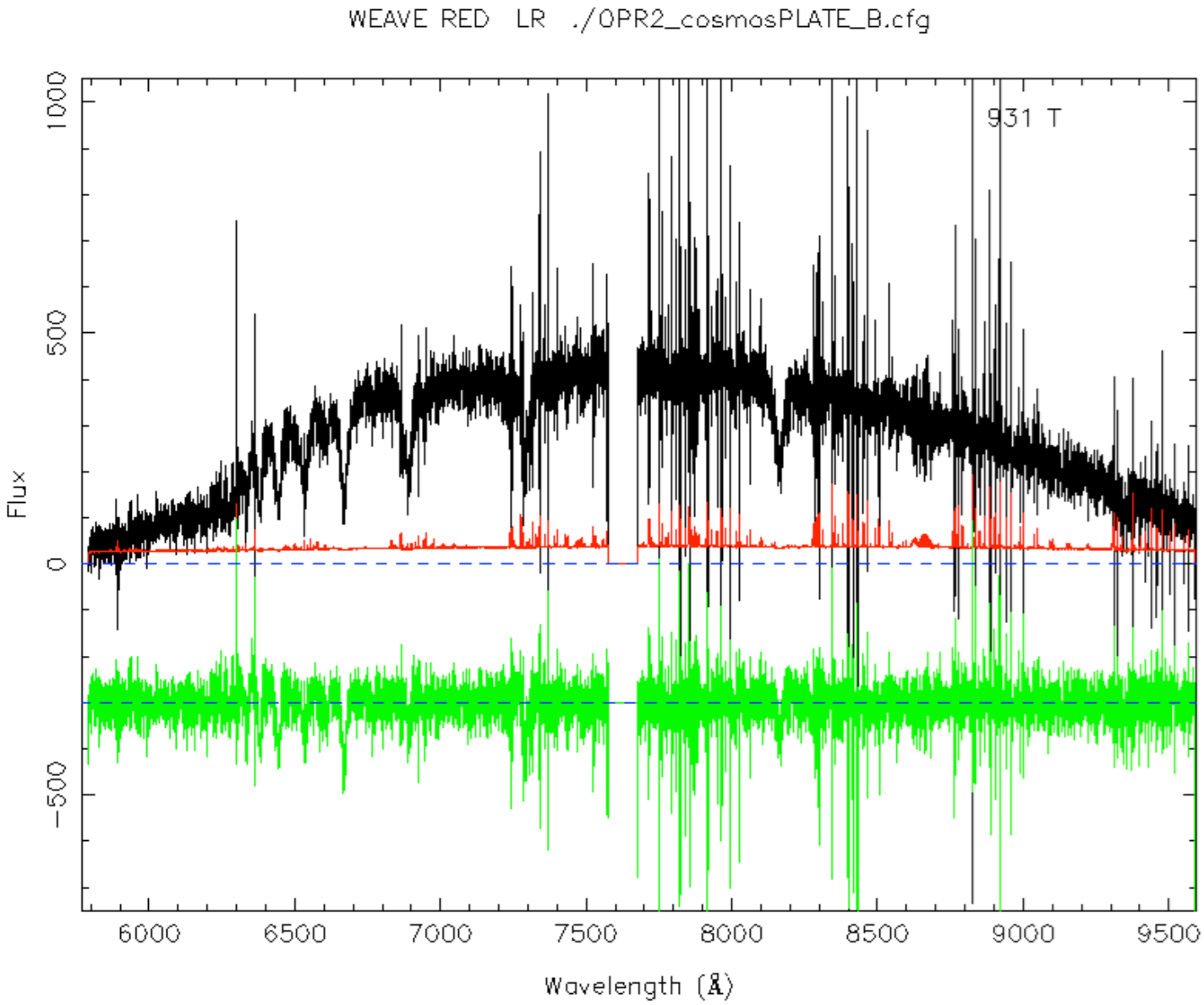
StePS COSMOS
Elliptical galaxy
z = 0.6
r = 21
Deep stack (7 OBs)

Sky subtraction from scaled master sky

L1 reduced stacked spectrum

Scaled Sky

Normalised residuals



Development of Sky Subtraction procedure

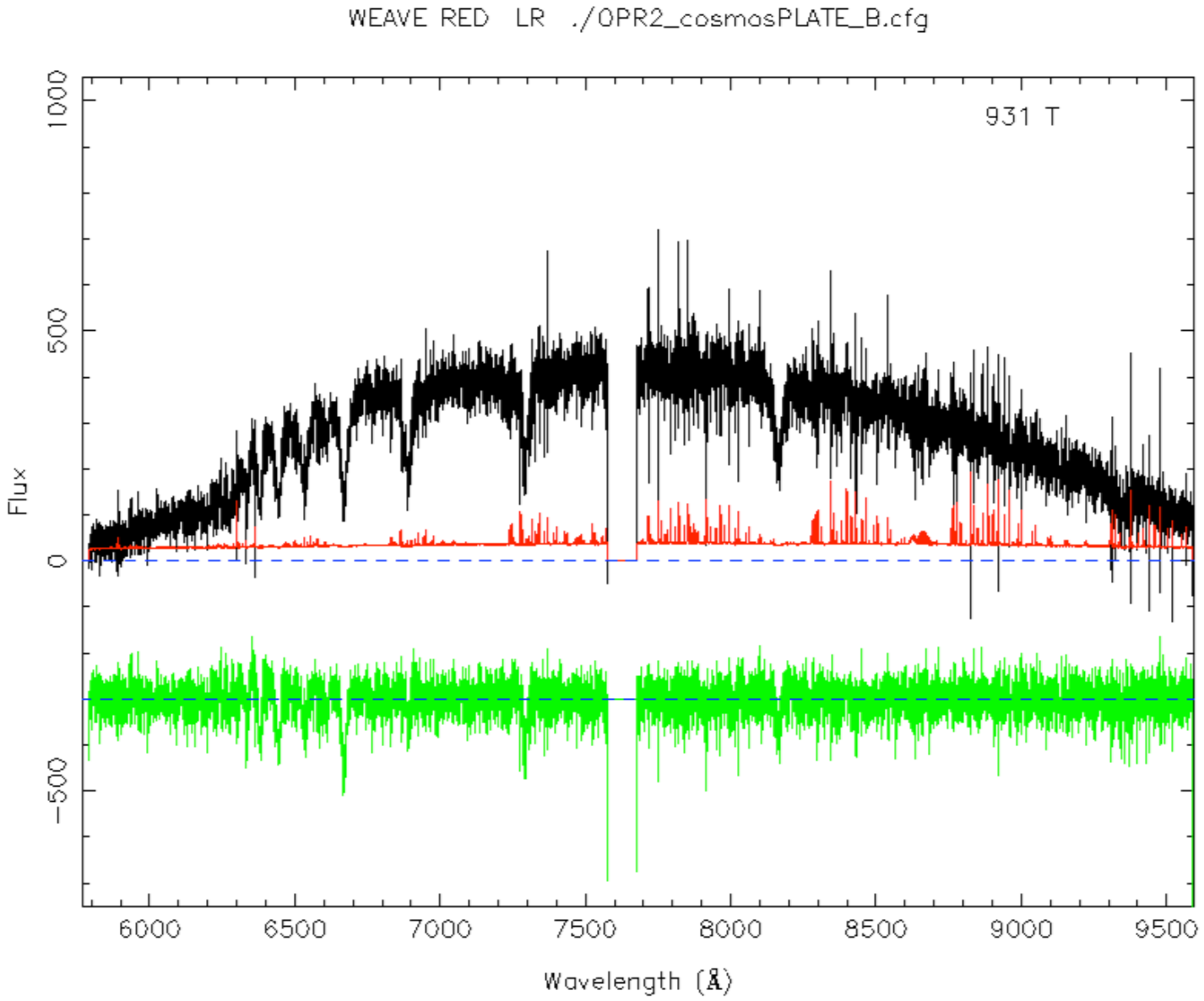
StePS COSMOS
Elliptical galaxy
z = 0.6
r = 21
Deep stack (7 OBs)

Sky subtraction scaled + PCA on residuals

L1 reduced stacked spectrum

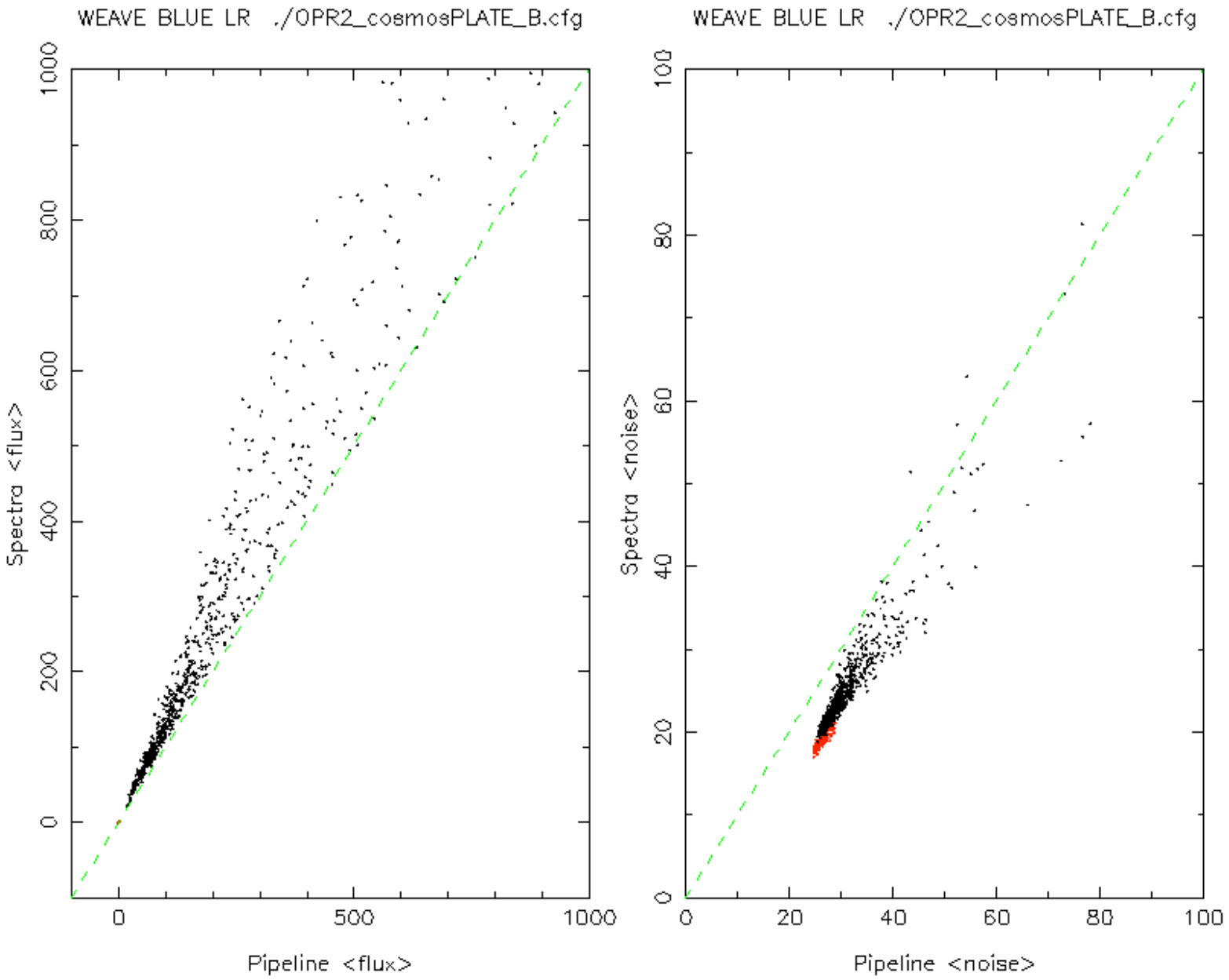
Scaled Sky

Normalised residuals

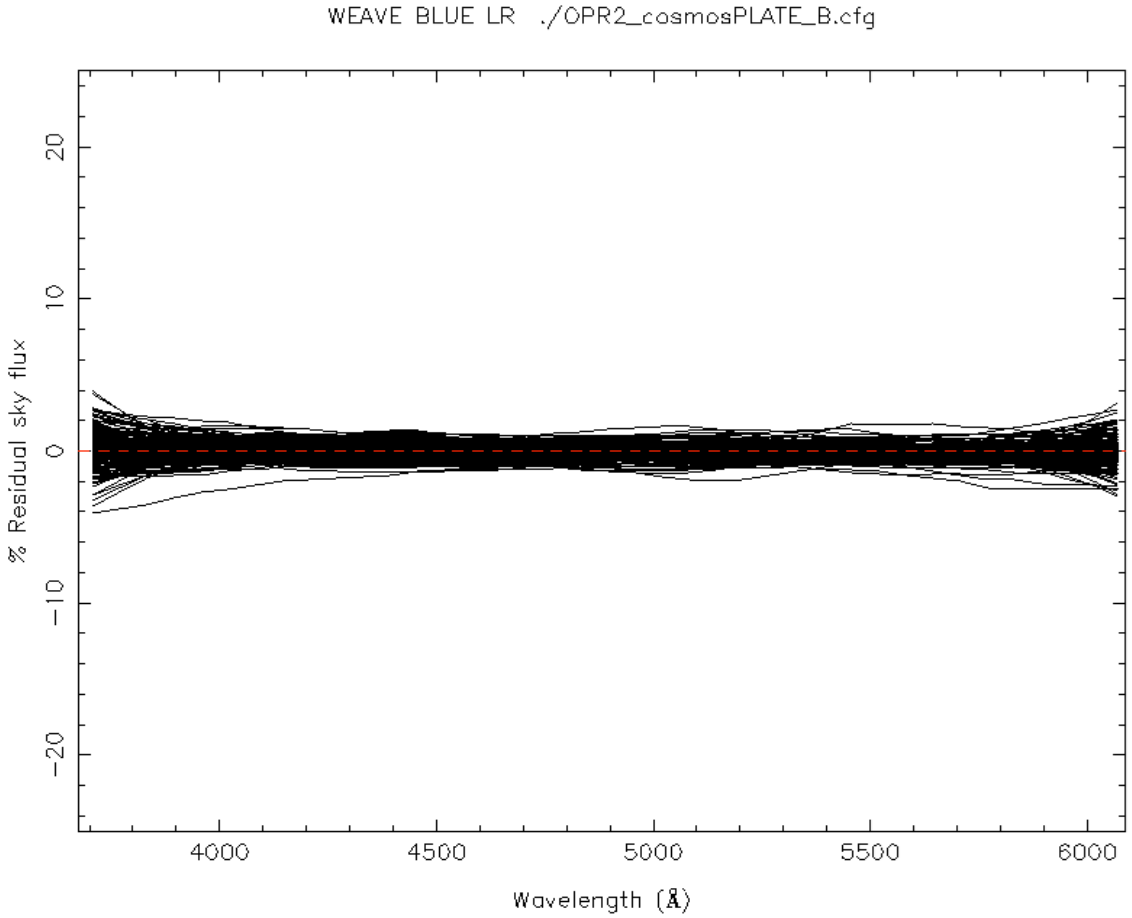


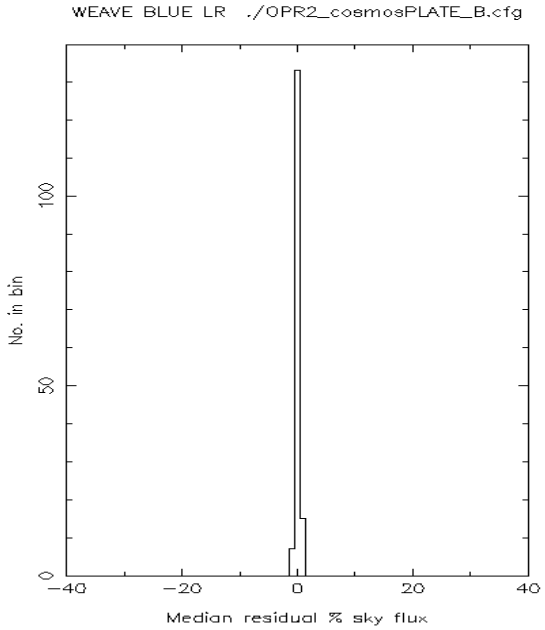
CPS Quality Assurance

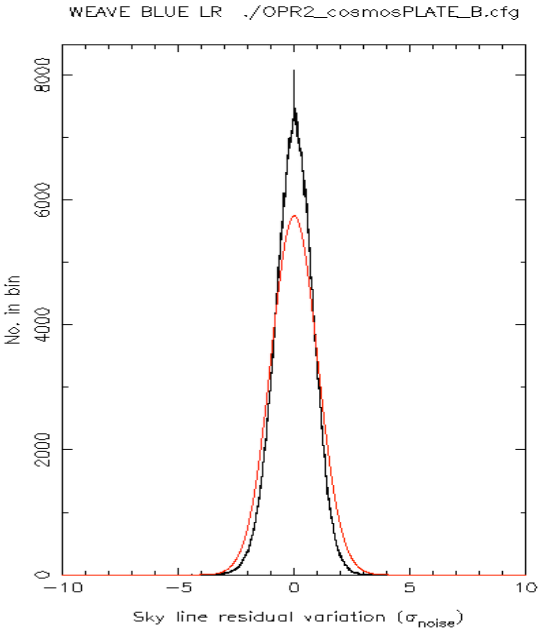
Comparison of average flux and noise



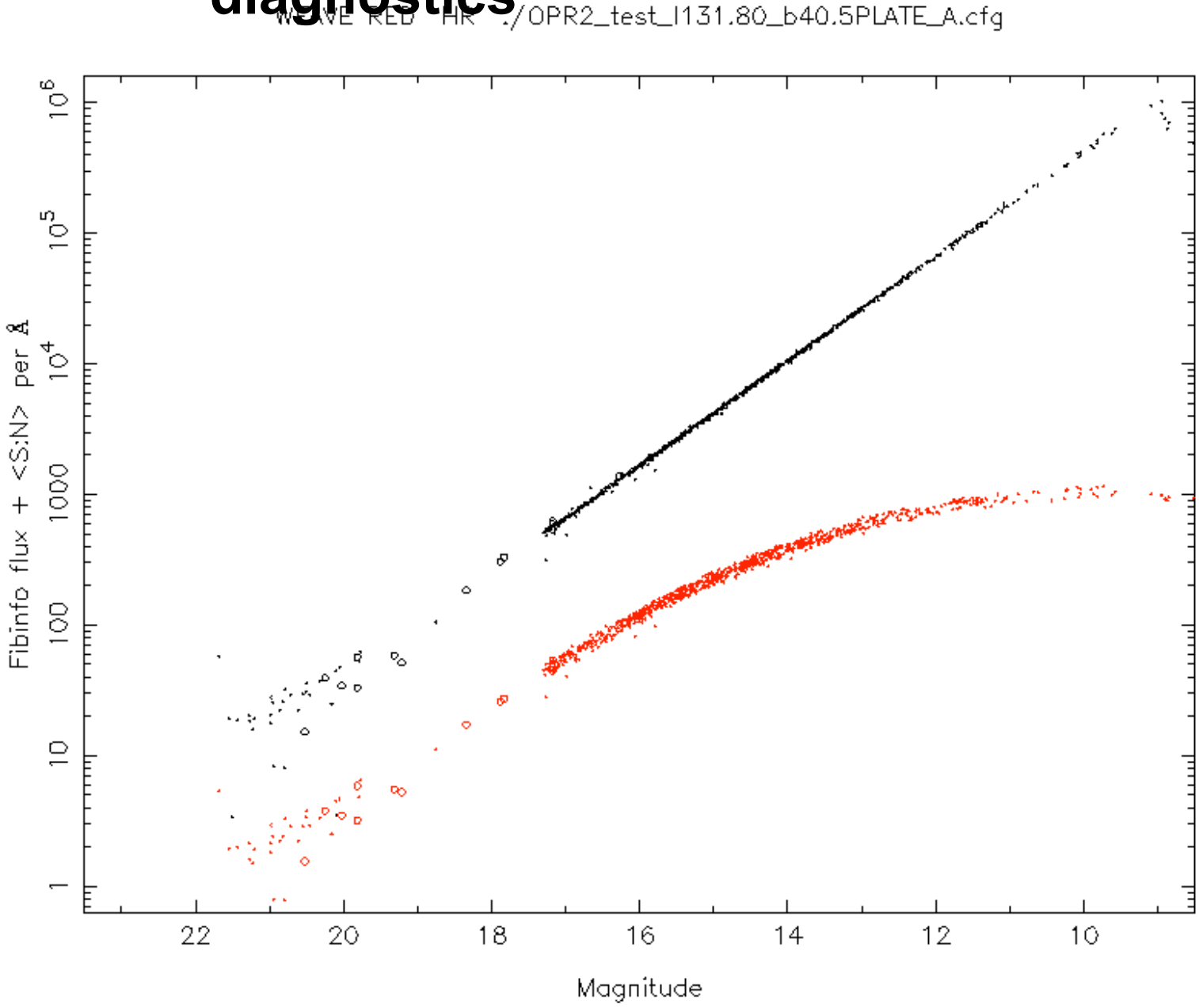
Median flux residuals in sky-subtracted skies



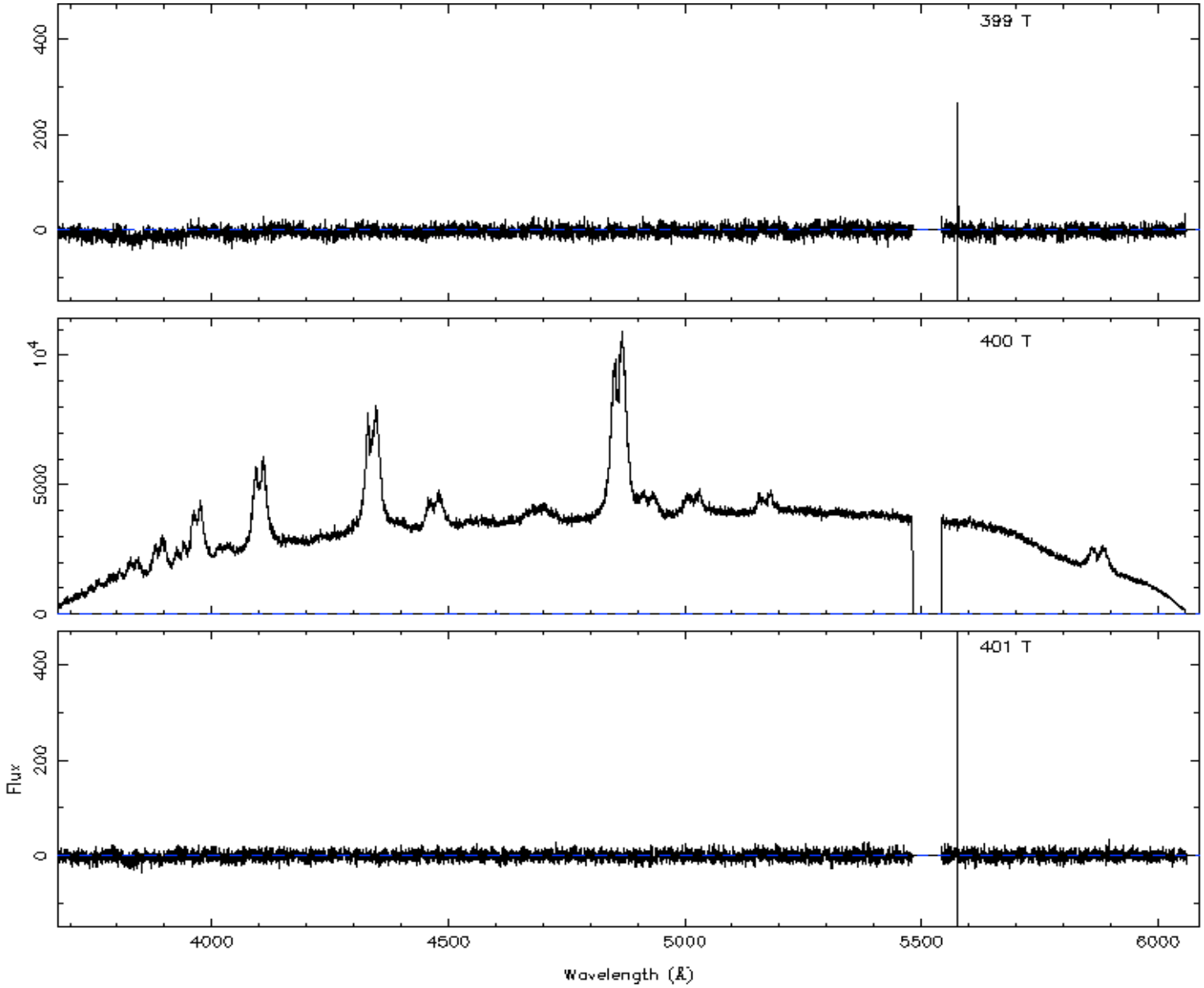




Flux and Signal-to-Noise diagnostics



Cross-talk


399 T
400 T
401 T
400
200
0
10^4
5000
Flux
4000
4500
5000
5500
6000
Wavelength (Å)

Anticipated on-sky updates required

- Extraction
  - removal of scattered light and ghosts over focal plane
  - accurately determining relative gain of 2x4 readout amplifiers
  - handling cosmic-rays in single/multiple exposures
  - electrical cross-talk between amplifiers/detectors

- Sky subtraction
  - telluric lines -> better modelling MOLECFIT; reference stars
  - sky continuum variations over field-of-view <- OB fibre flats
  - sky emission line variations over field-of-view
  - dealing with sky subtraction in nebular regions
  - pixellation -v- oversampling of master skies

- Flux calibration
  - correcting for differential atmospheric extinction

WEAVE Core Processing System