

SESHAT: The reduction pipeline for MAAT

Rubén GARCÍA-BENITO



WORKSHOP MAAT@GTC

5 May 2020



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CSIC

SESHAT

The title is just an excuse to
propose a name for the pipeline

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CSIC



SESHAT

- ✓ Her mother is MAAT
- ✓ Inventing writing
- ✓ Record keeper
- ✓ Goddess of:

- * Astronomy
- * Accounting
- * Surveying...



Just a regular talk on IFU reduction



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TALK



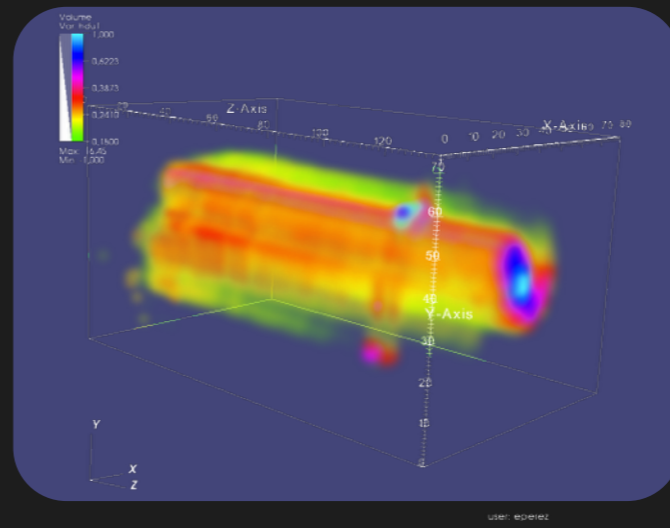
Seshat: a suggestion to the MAAT team for the name of a future pipeline



Just some tips about IFU reduction from the experience within CALIFA and as a MUSE user



FINAL DATACUBE CONTENT



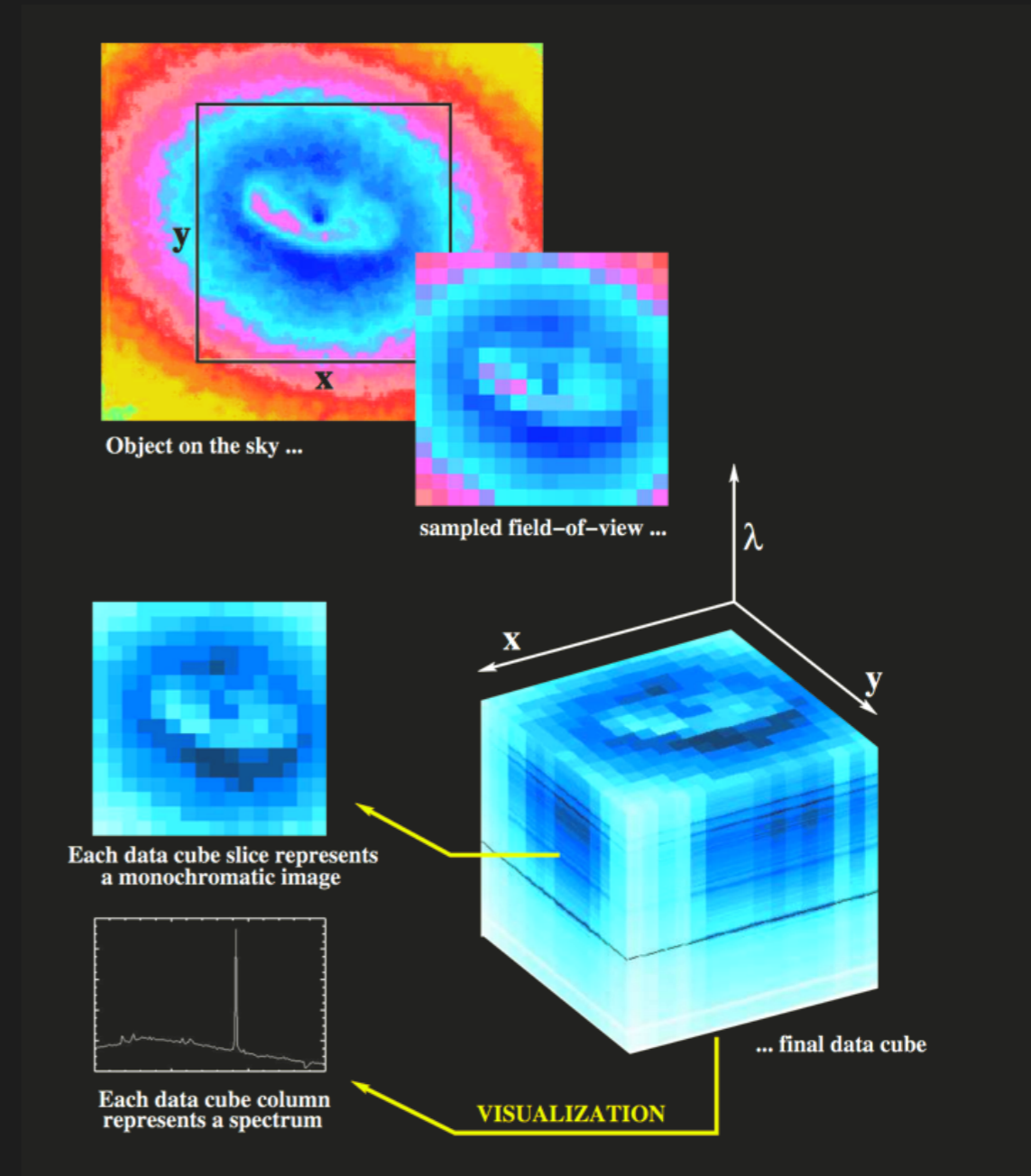
HDU	Extension name	Format	Content
0	Primary	32-bit float	flux density in units of $10^{-16} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ \AA}^{-1}$
1	ERROR	32-bit float	1σ error on the flux density
2	ERRWEIGHT	32-bit float	error weighting factor
3	BADPIX	8-bit integer	bad pixel flags (1=bad, 0=good)
4	FIBCOVER	8-bit integer	number of fibers used to fill each spaxel
5	FLAT	32-bit float	SDSSflat correction to the interpolation

Example CALIFA format
 Husemann+2013, García-Benito+2015 & Sánchez+2016

ERROR

Error and bad pixel propagation

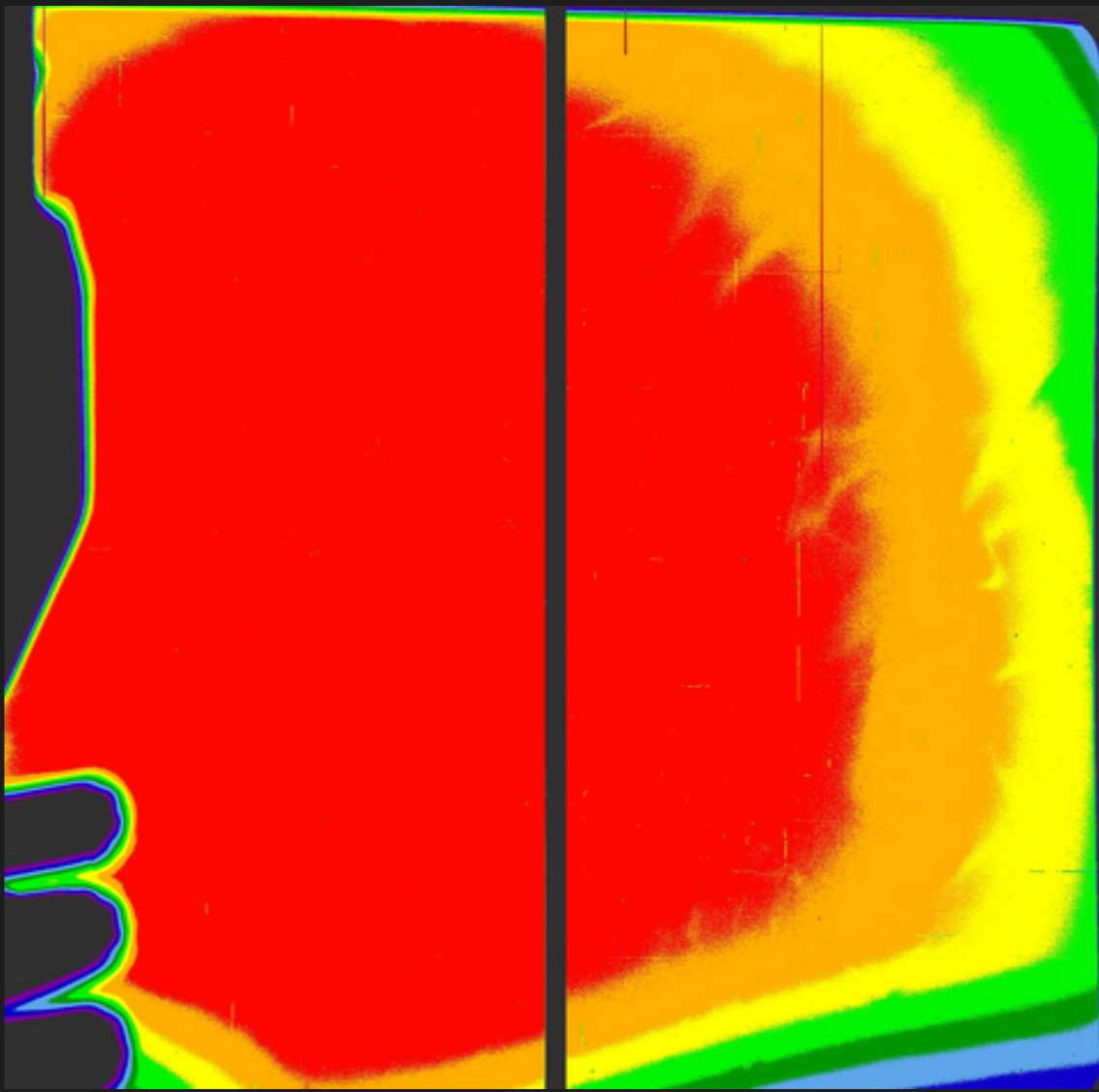
- ▶ Poisson noise
- ▶ Read-out noise
- ▶ Bad pixels:
 - ▶ Cosmic ray hits
 - ▶ Bad CCD columns
 - ▶ Vignetting



ERROR

Error and bad pixel propagation

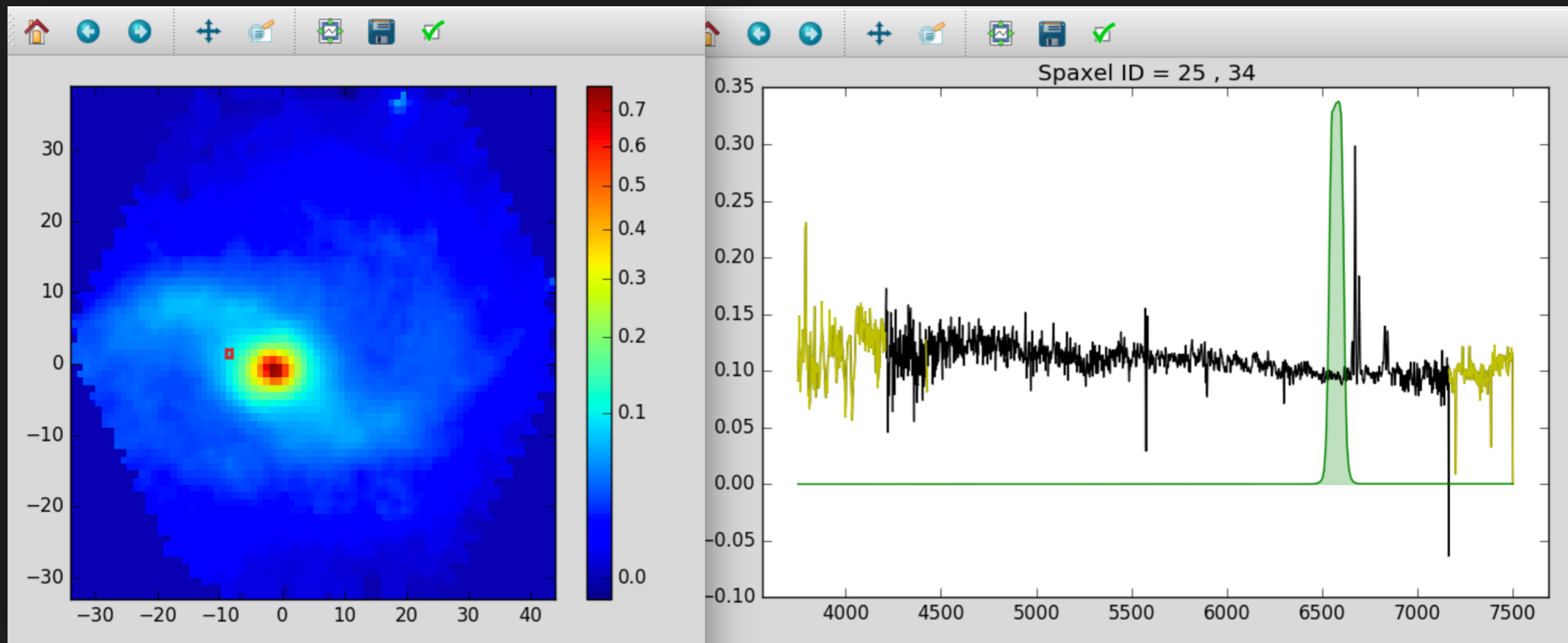
- ▶ Poisson noise
- ▶ Read-out noise
- ▶ Bad pixels:
 - ▶ Cosmic ray hits
 - ▶ Bad CCD columns
 - ▶ Vignetting



Slight vignetting to the edge of the FOV with a 5-10% flux decrease @OSIRIS

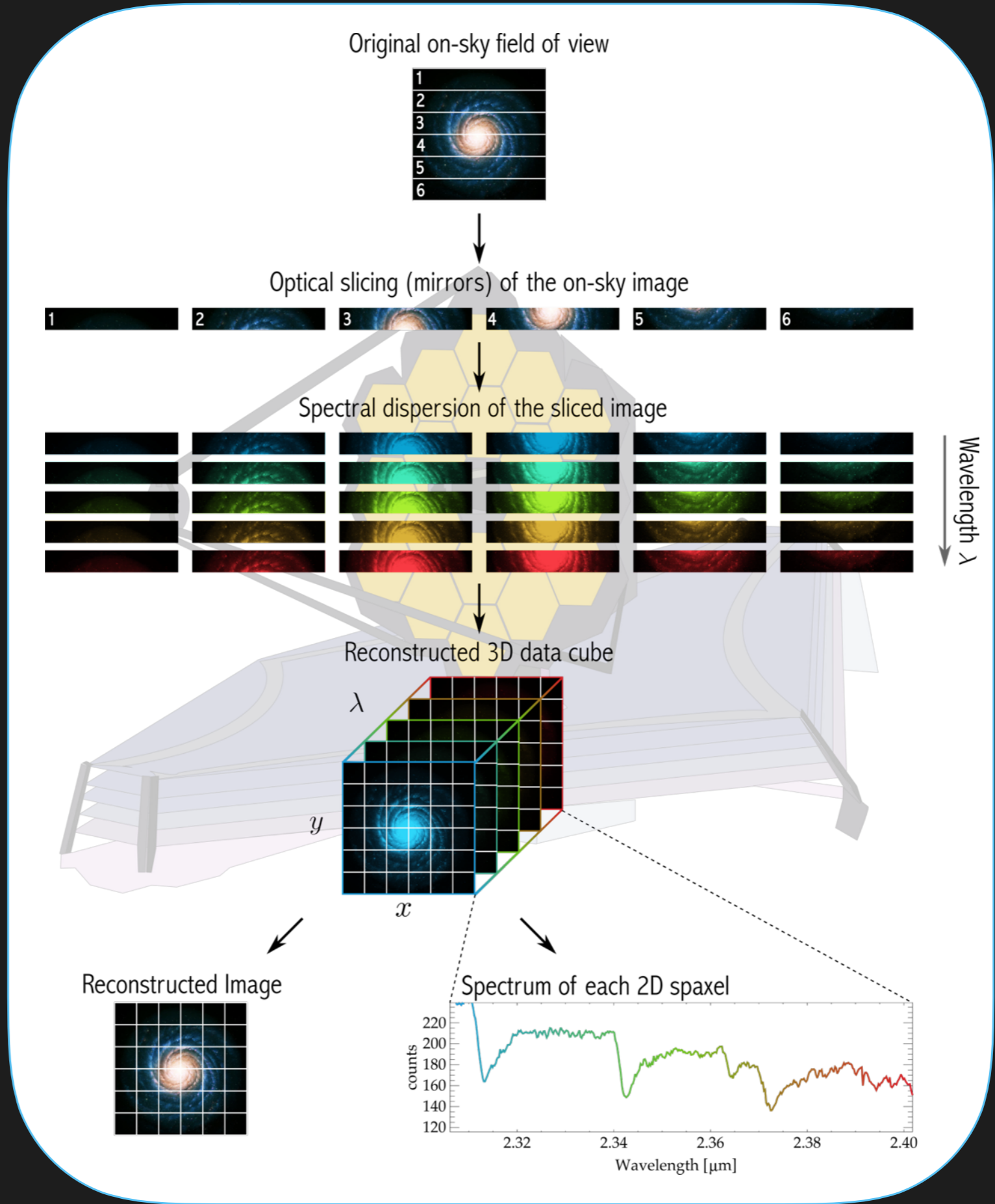
FLAGS

FLAGS (BADPIX)

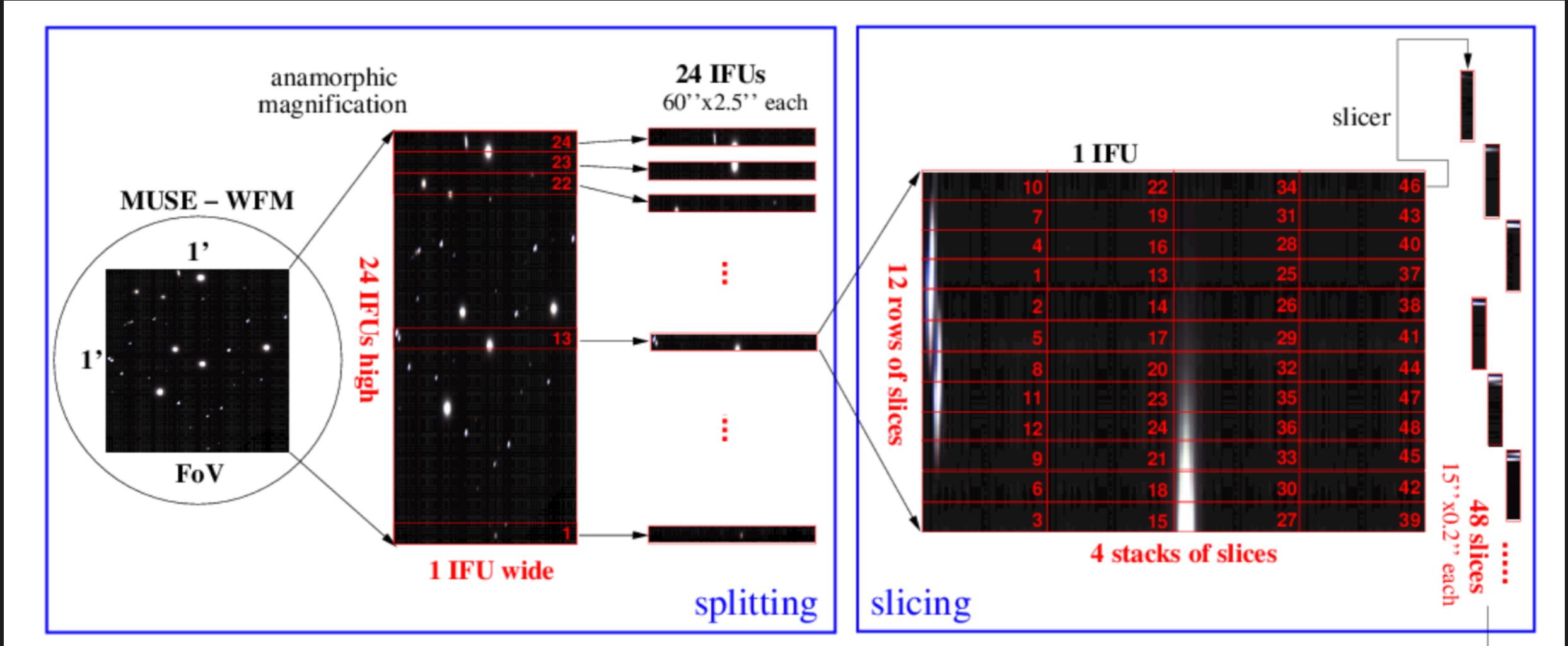


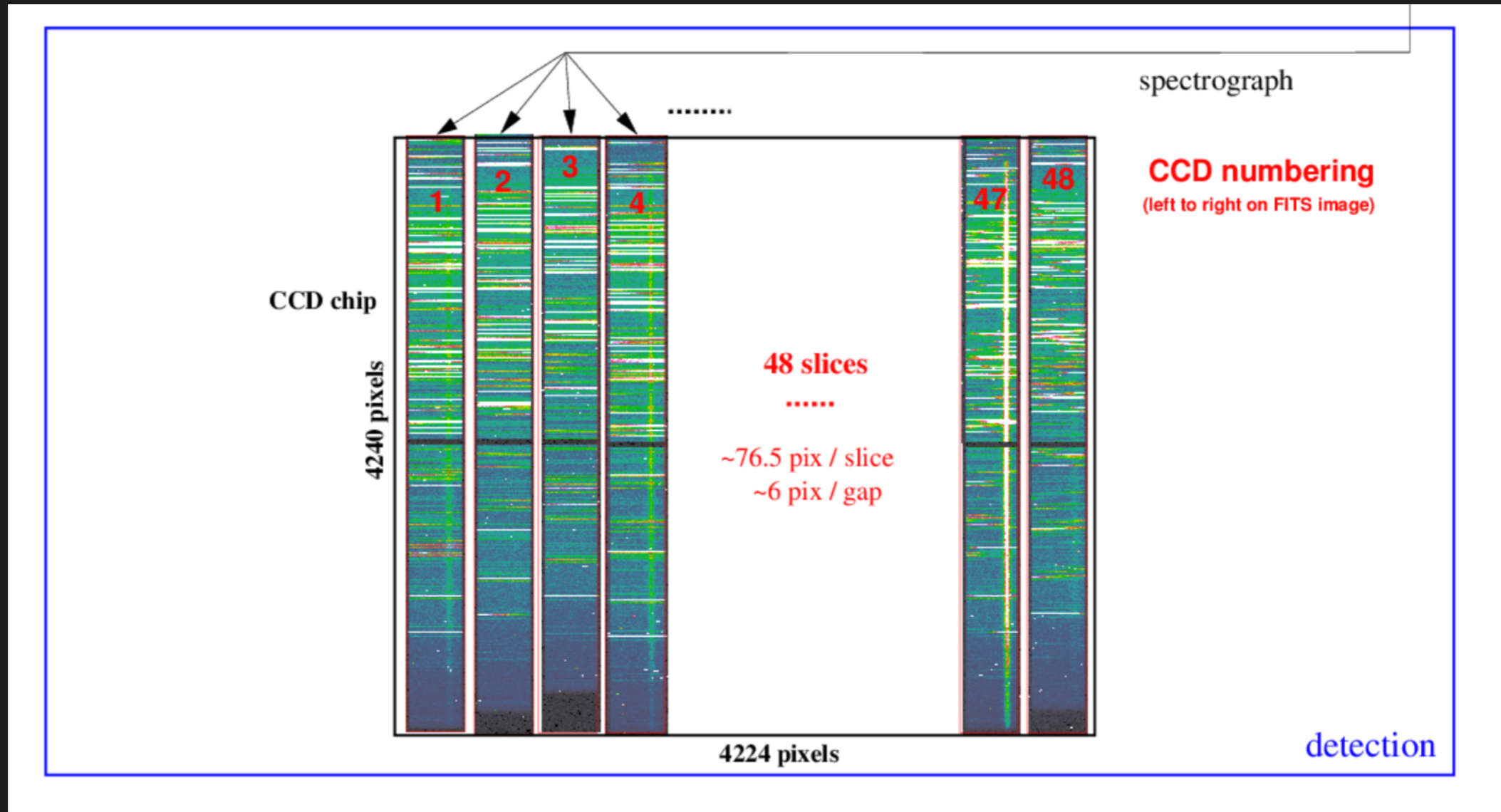
```
In [3]: s.info()
Filename: IC0944.V500.rscube.fits
No.   Name      Type      Cards  Dimensions  Format
0     PRIMARY   PrimaryHDU  486    (77, 72, 1877) float32
1     ERROR     ImageHDU    9      (77, 72, 1877) float32
2     ERRWEIGHT ImageHDU    9      (77, 72, 1877) float32
3     BADPIX    ImageHDU    9      (77, 72, 1877) uint8
4     FIBCOVER  ImageHDU    9      (77, 72, 1877) uint8
```

IMAGE SLICER



MUSE - SLICER



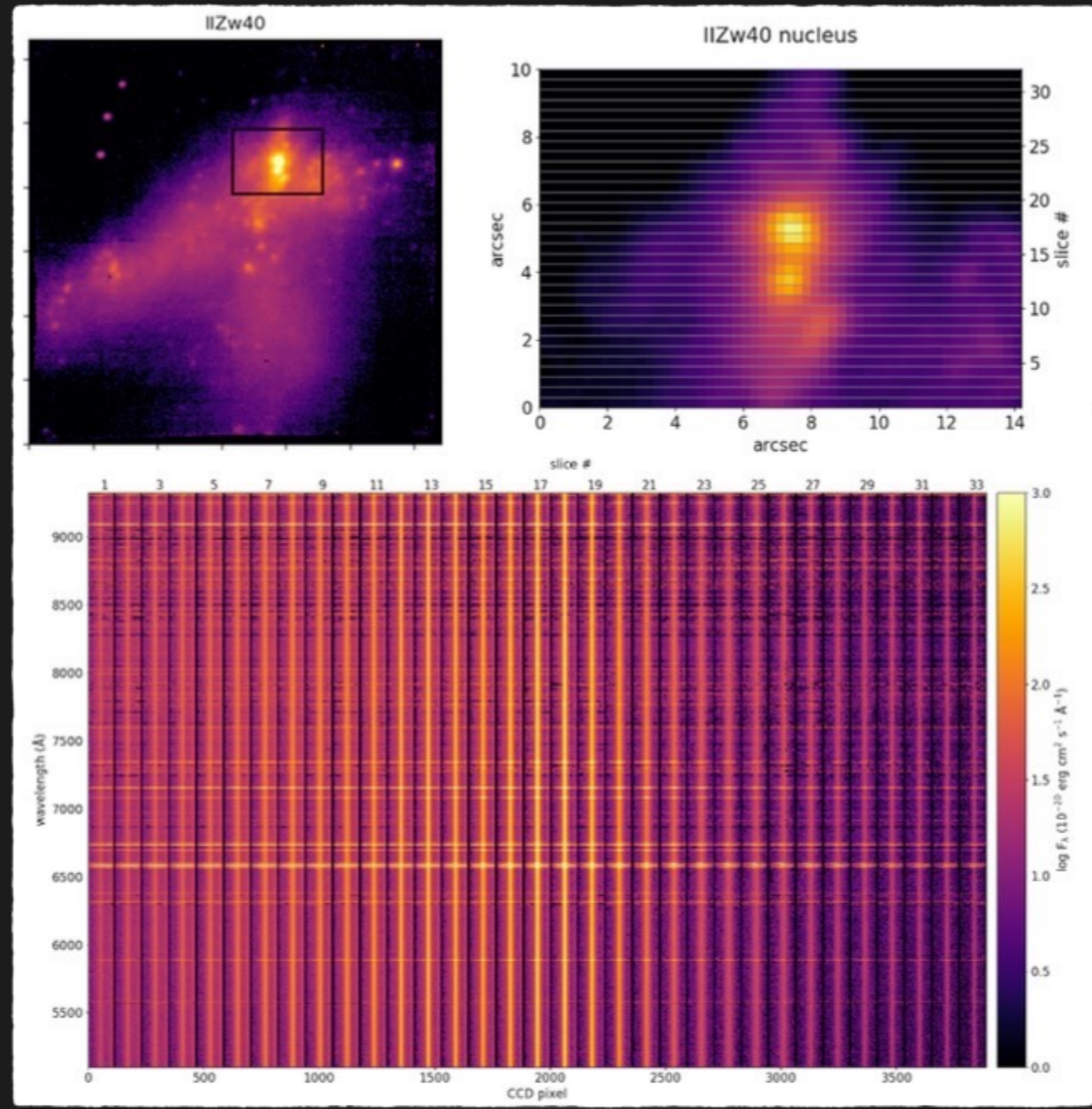


MAAT - SLICER

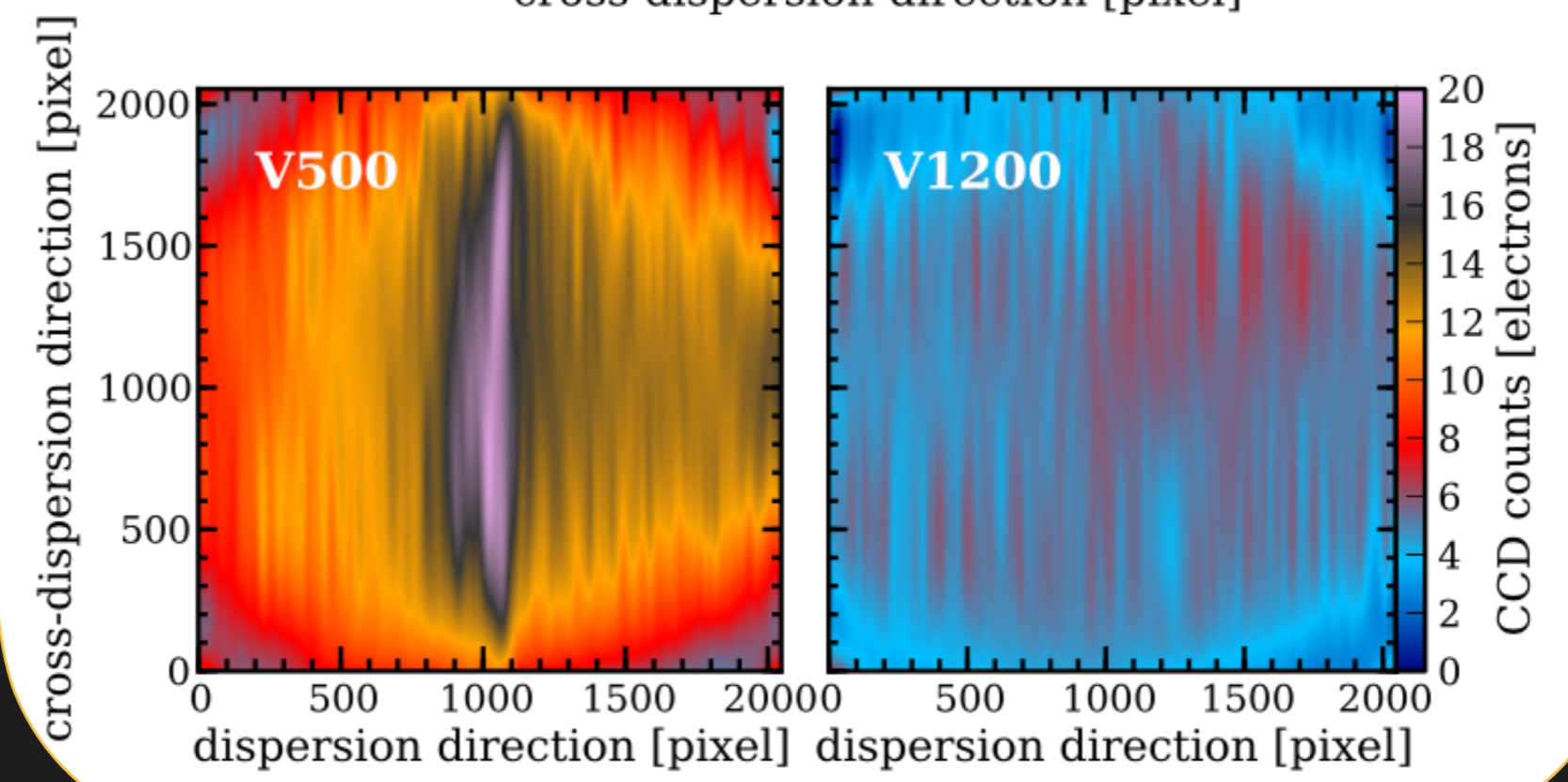
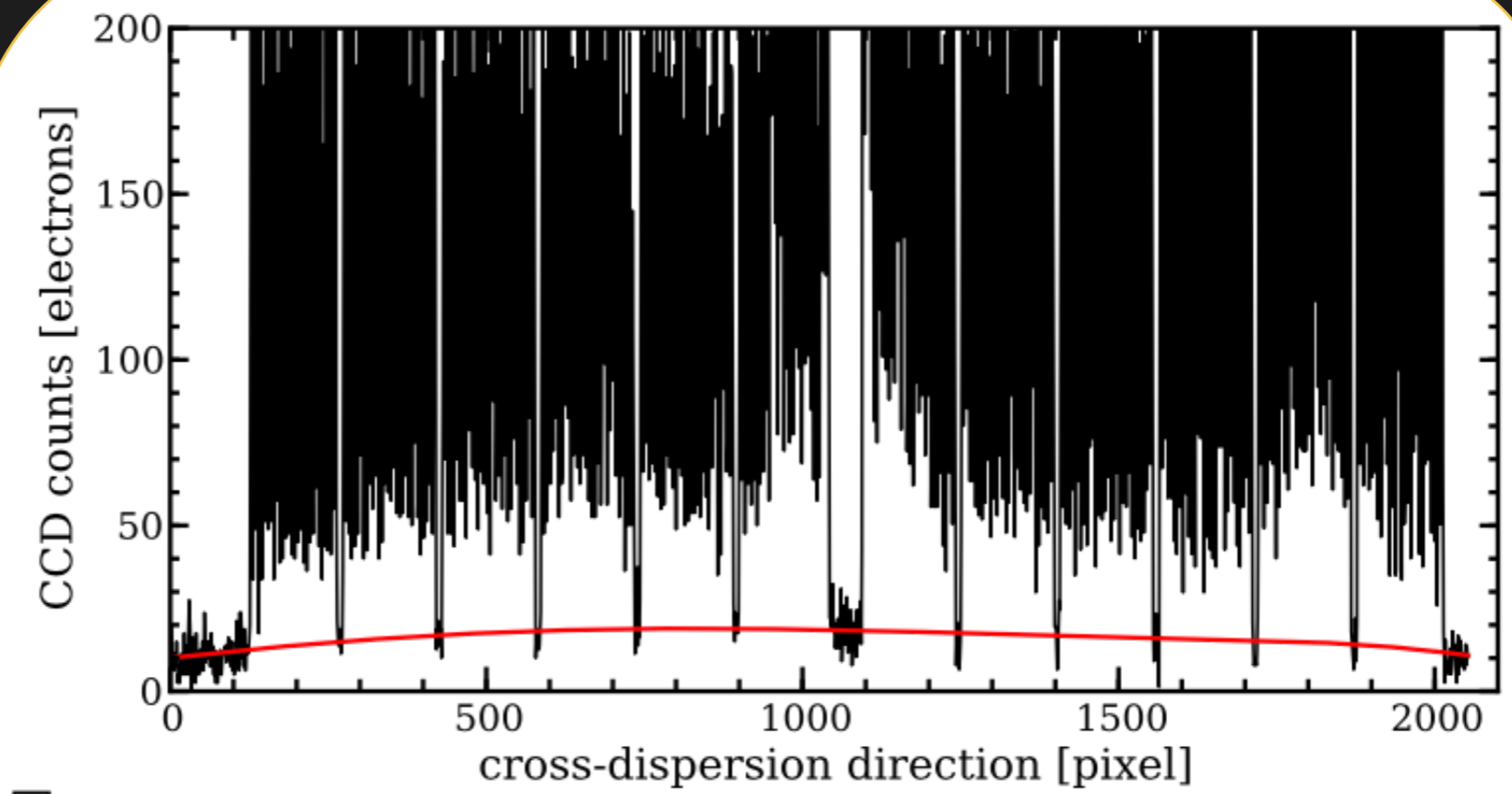
Basic reduction:

- Bias
- Dark
- Flat
- λ cal

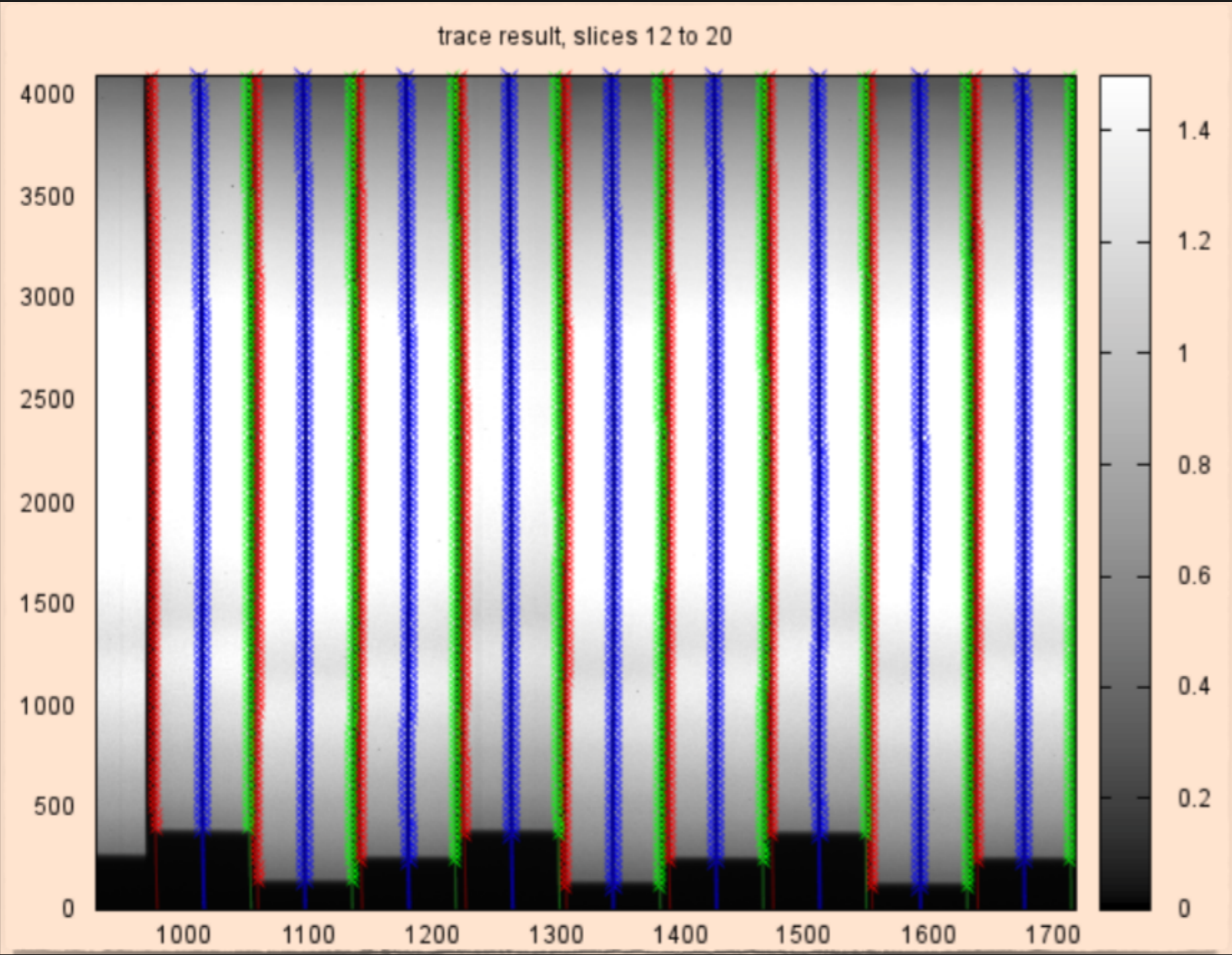
+ masking

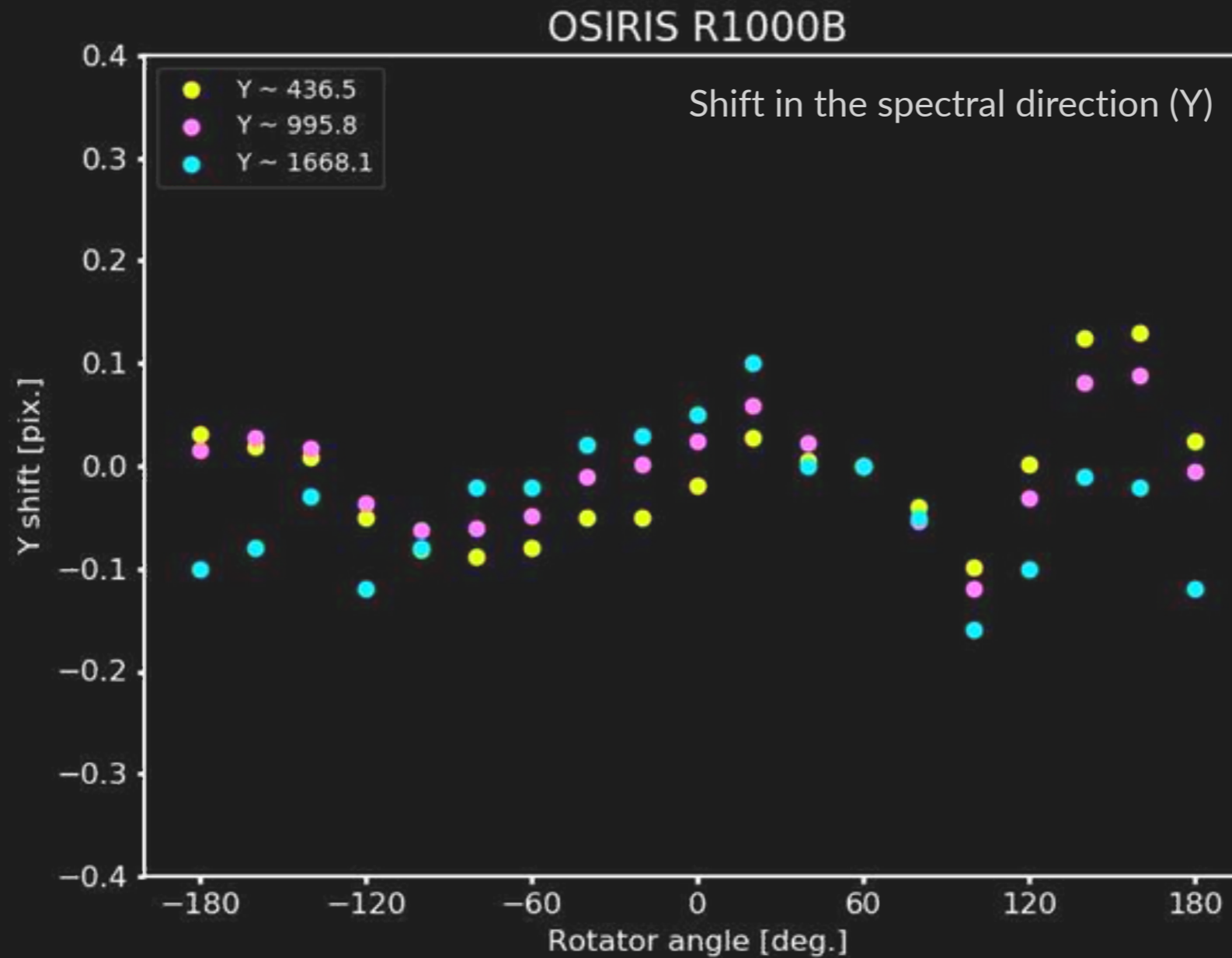


STRAYLIGHT



TRACE, LSF & λ CAL





Very stable
No significant drifts with rotator position (<0.3 pix)

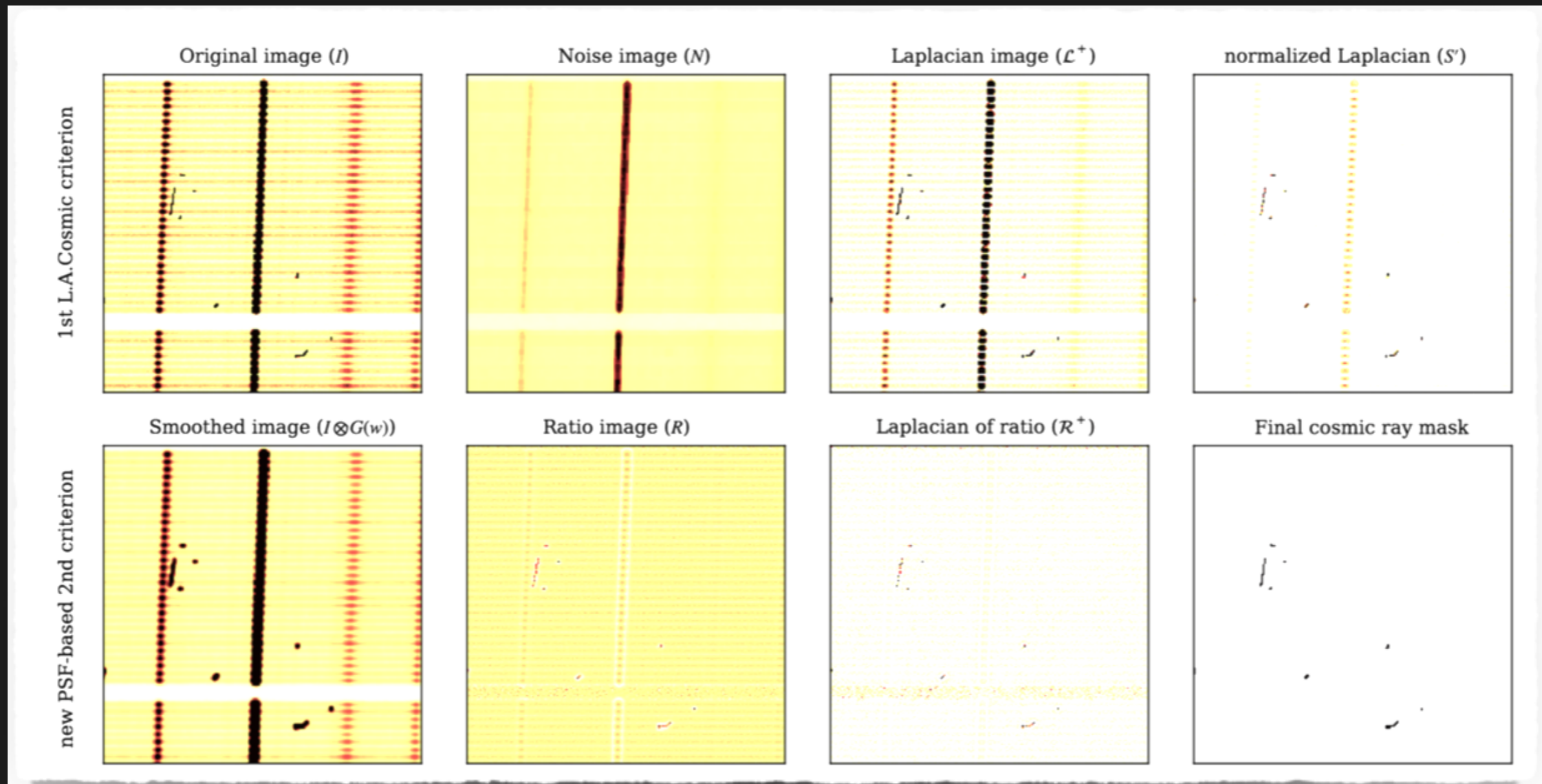
MAAT λ RANGE

ID	λ_c (Å)	$\Delta\lambda$ (Å)	D (Å/pix)	R (LS ¹)	Peak Efficiency	Type
R300B	4405	3600-7200	2.60	575 (360)	70%	Grism
R300R	6635	4800-10000	4.02	560 (348)	70%	Grism
R500B	4745	3600-7200	1.87	860 (537)	68%	Grism
R500R	7165	4800-10000	2.58	940 (587)	67%	Grism
R1000B	5455	3630-7500	1.13	1630 (1018)	65%	Grism
R1000R	7430	5100-10000	1.40	1795 (1122)	65%	Grism
R2000B	4755	3950-5700	0.46	3465 (2165)	87%	VPH
R2500U	3975	3440-4610	0.33	4090 (2555)	70%	VPH
R2500V	5185	4500-6000	0.44	4025 (2515)	80%	VPH
R2500R	6560	5575-7685	1.56	3960 (2475)	80%	VPH
R2500I	8650	7330-10000	1.73	4005 (2503)	80%	VPH

¹Resolving power for the OSIRIS 0.6'' long-slit (LS) mode.

COSMIC RAYS

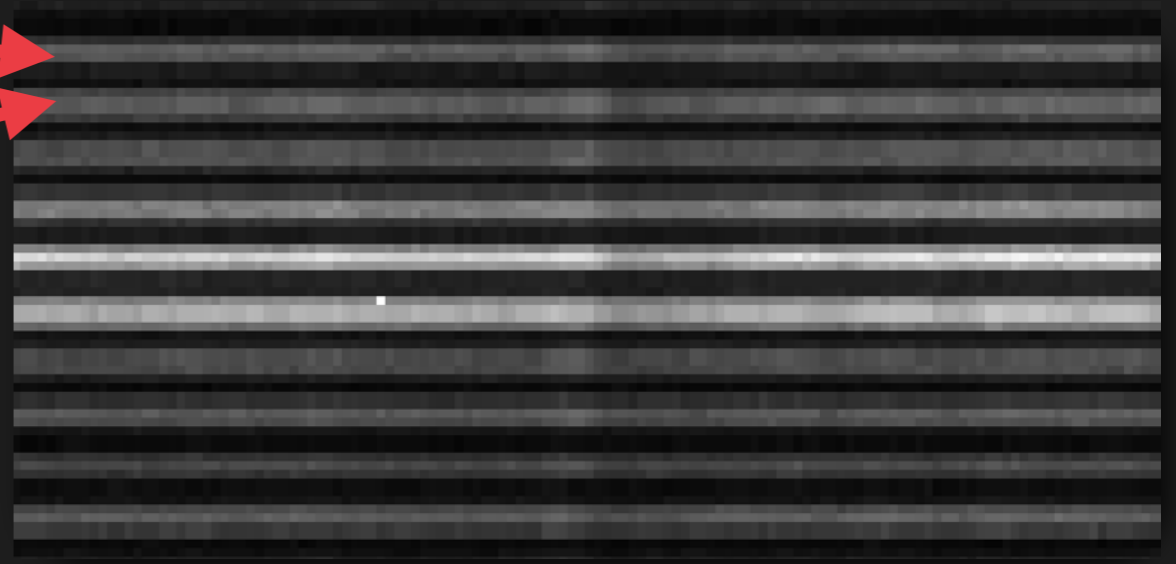
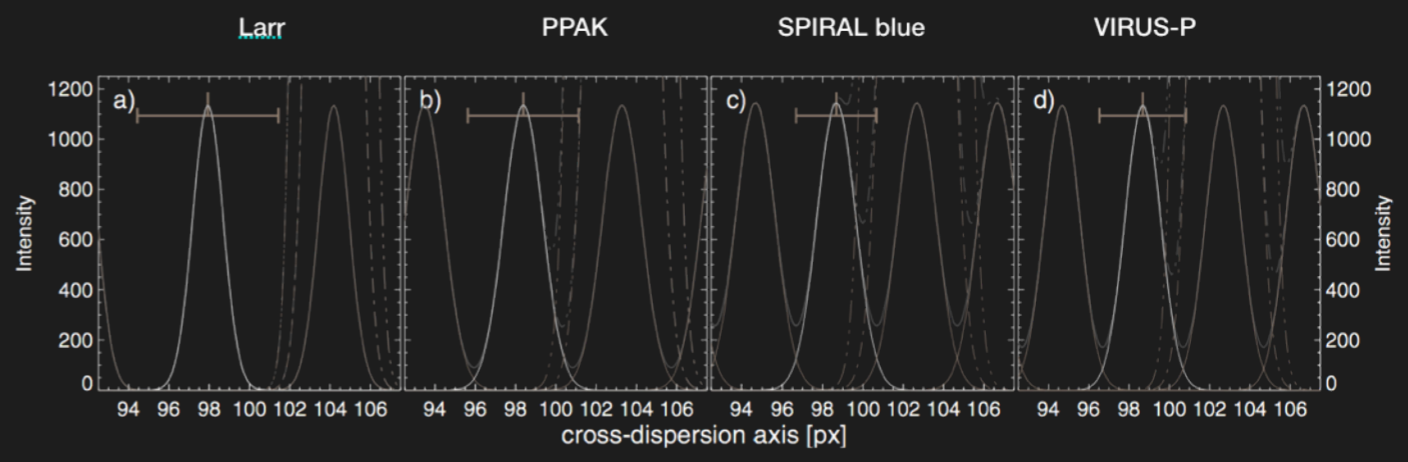
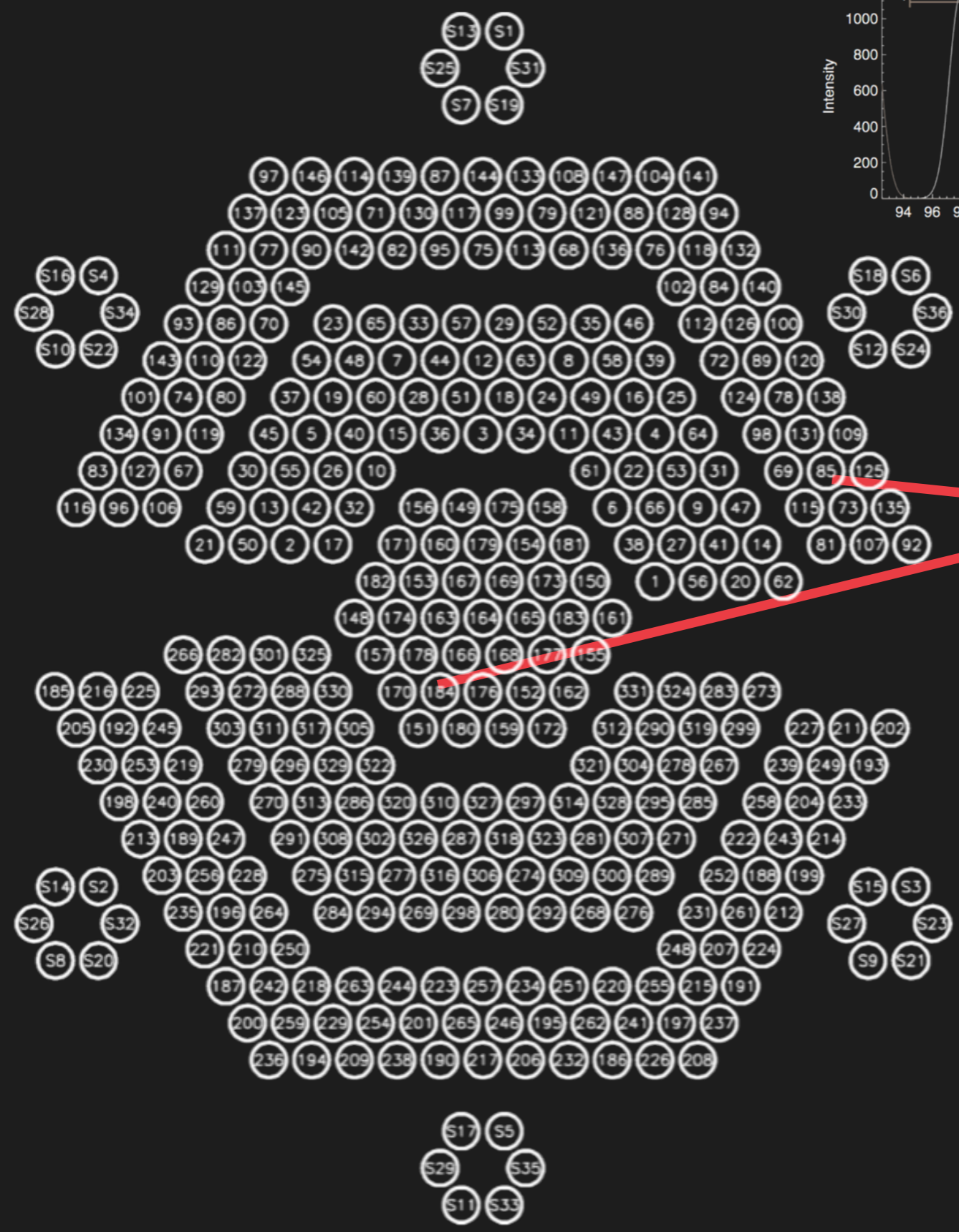
edge-detection algorithm of L.A. Cosmic
+
point spread function convolution



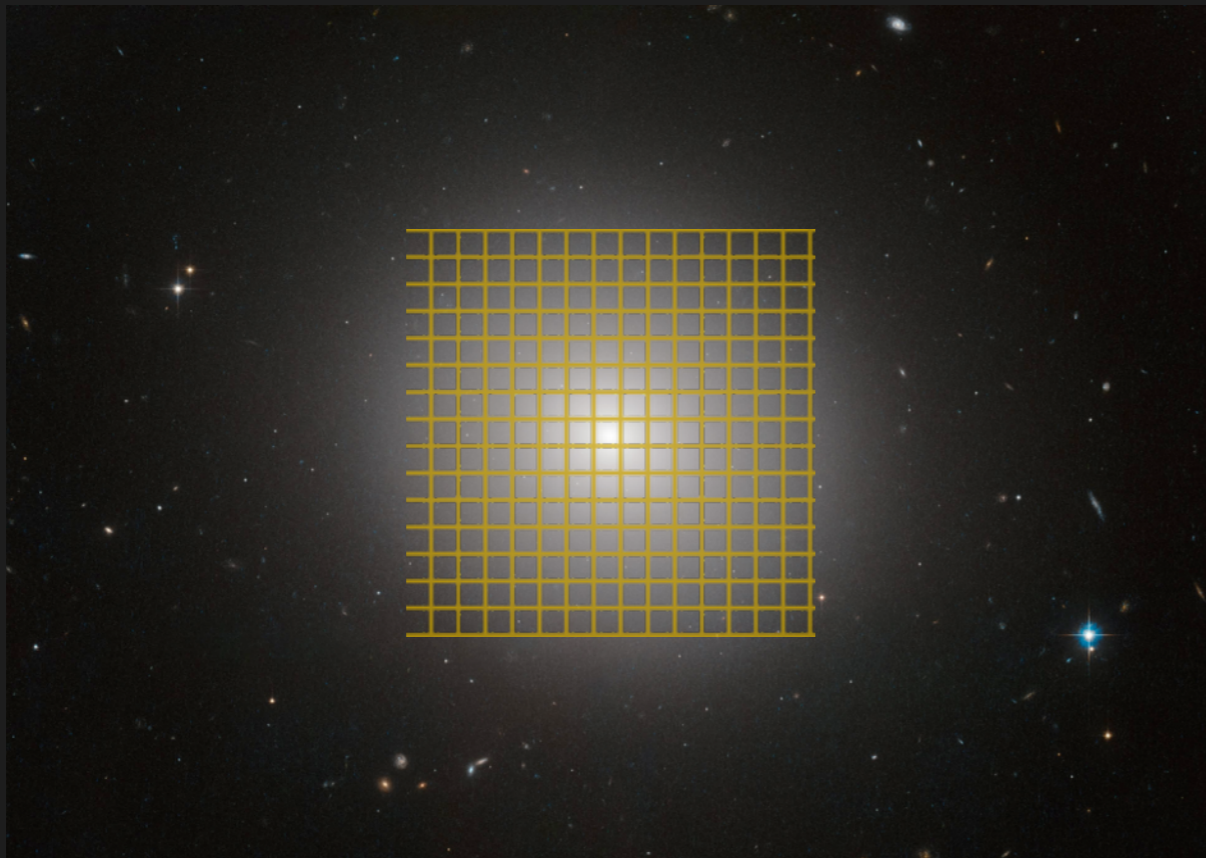
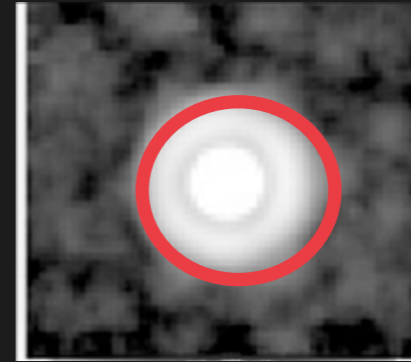
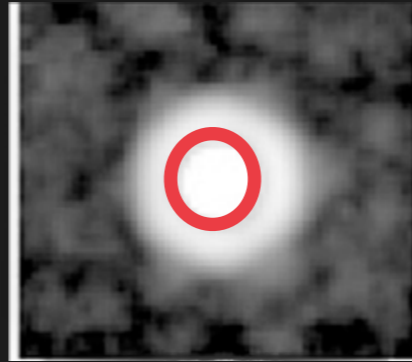
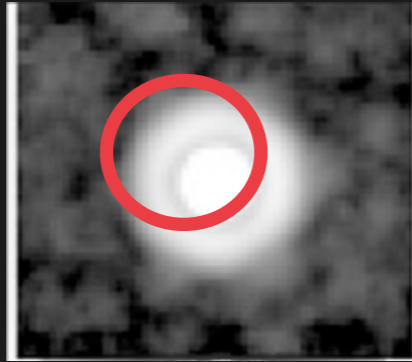
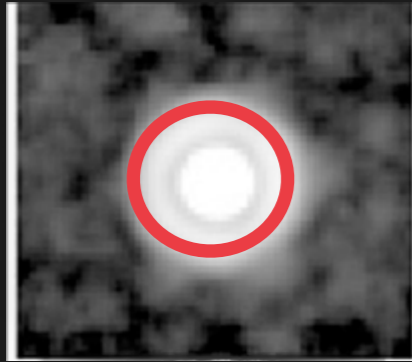
PyCosmic

Husemann, Kamann, Sandin, Sánchez, García-Benito, Mast (2012)

CROSS-TALK ✓



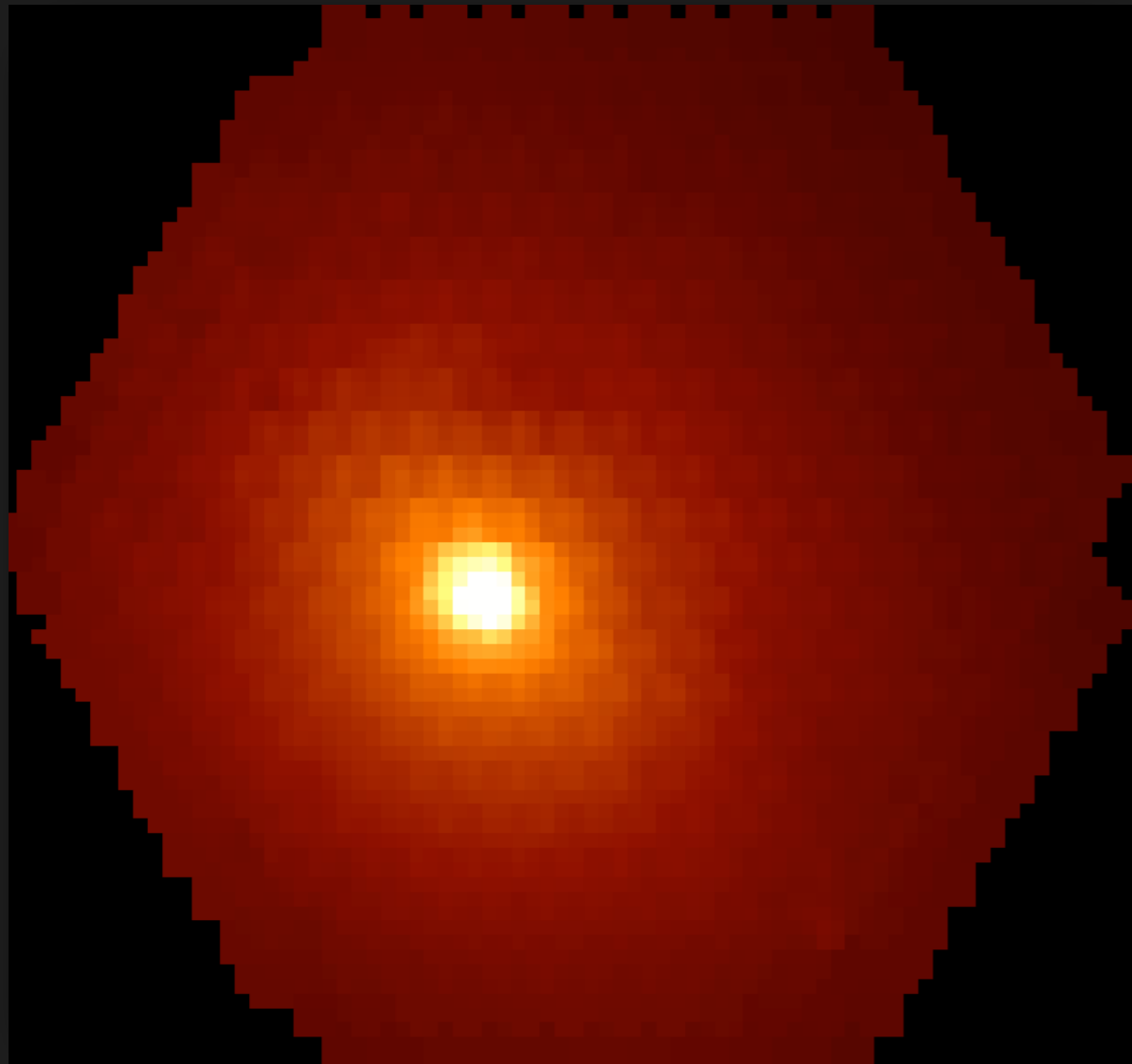
SENSITIVITY CURVE



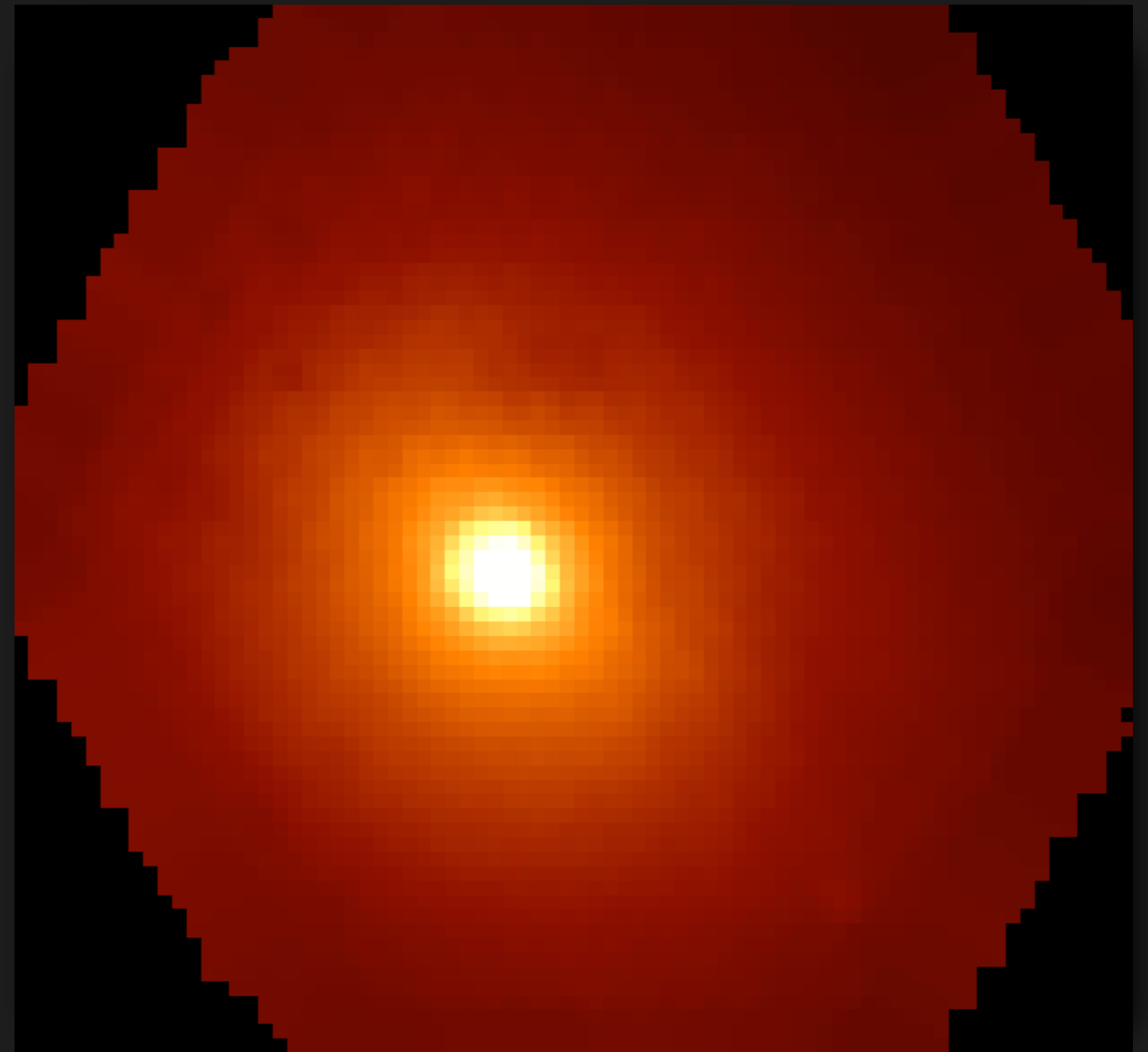
Ex: Elliptical galaxies as secondary calibrators using LensArray in CALIFA

INTERPOLATION ✓

Goal: reduce the number of interpolation steps

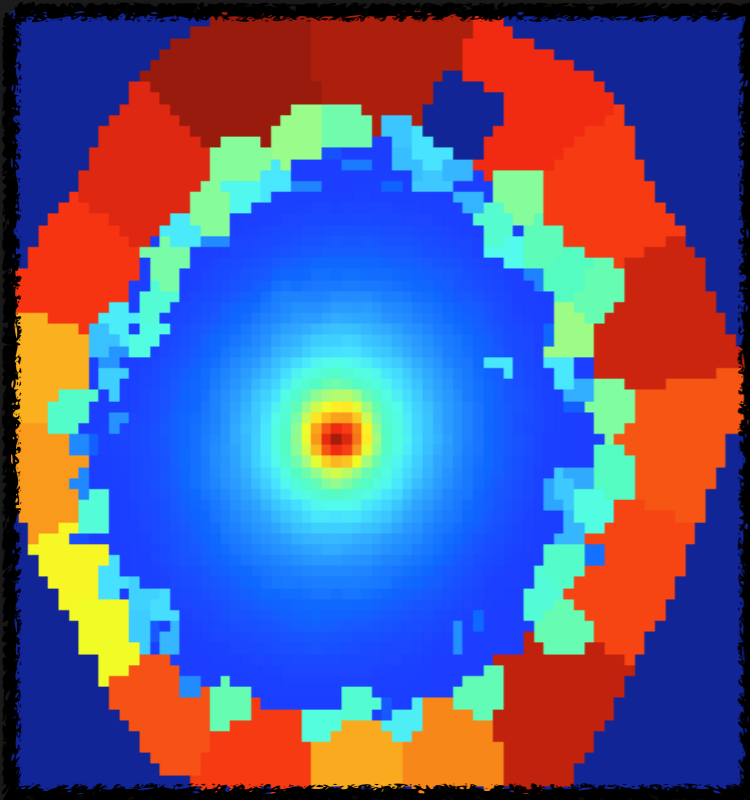


Drizzle

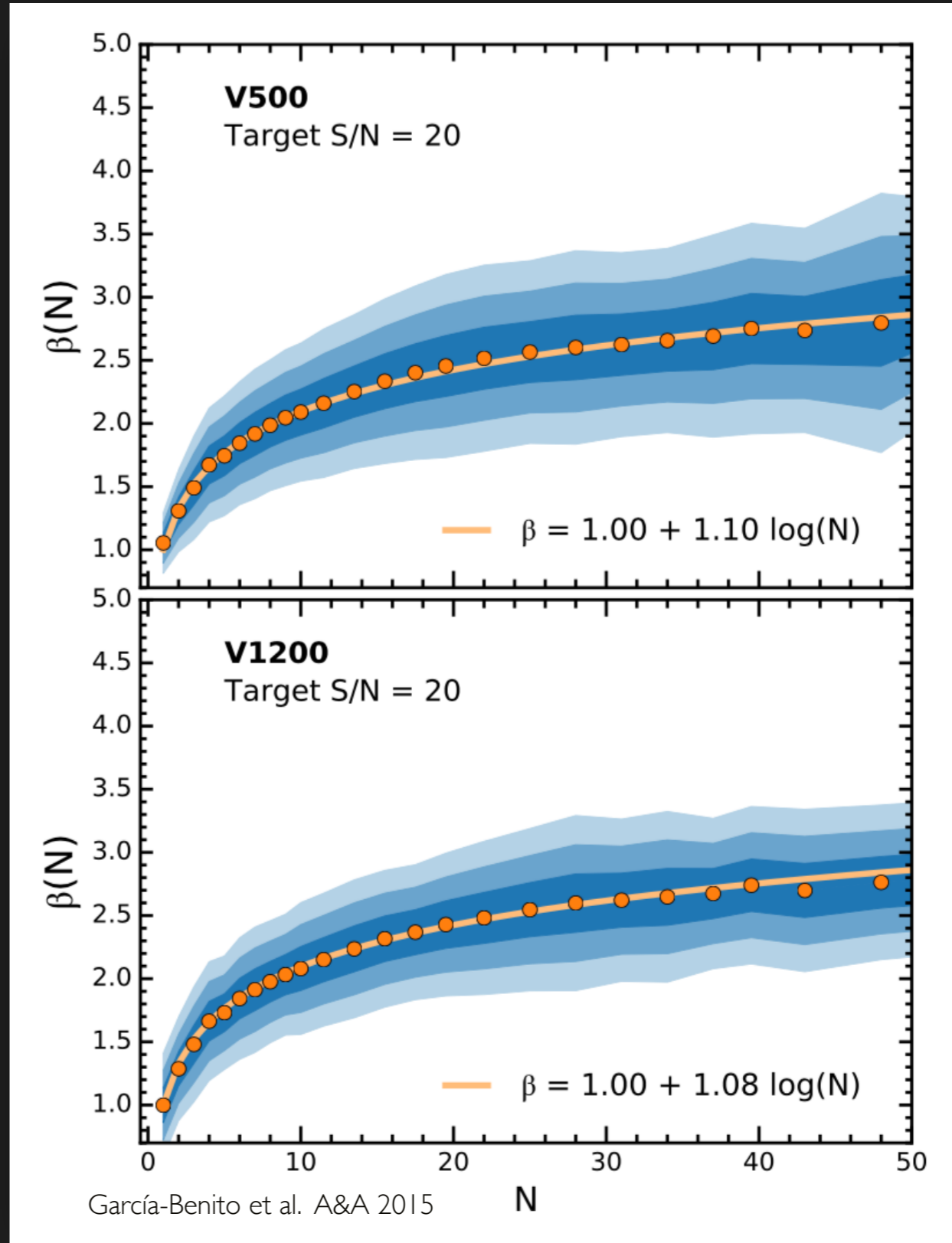


Inverse-distance weighting

COVARIANCE ✓



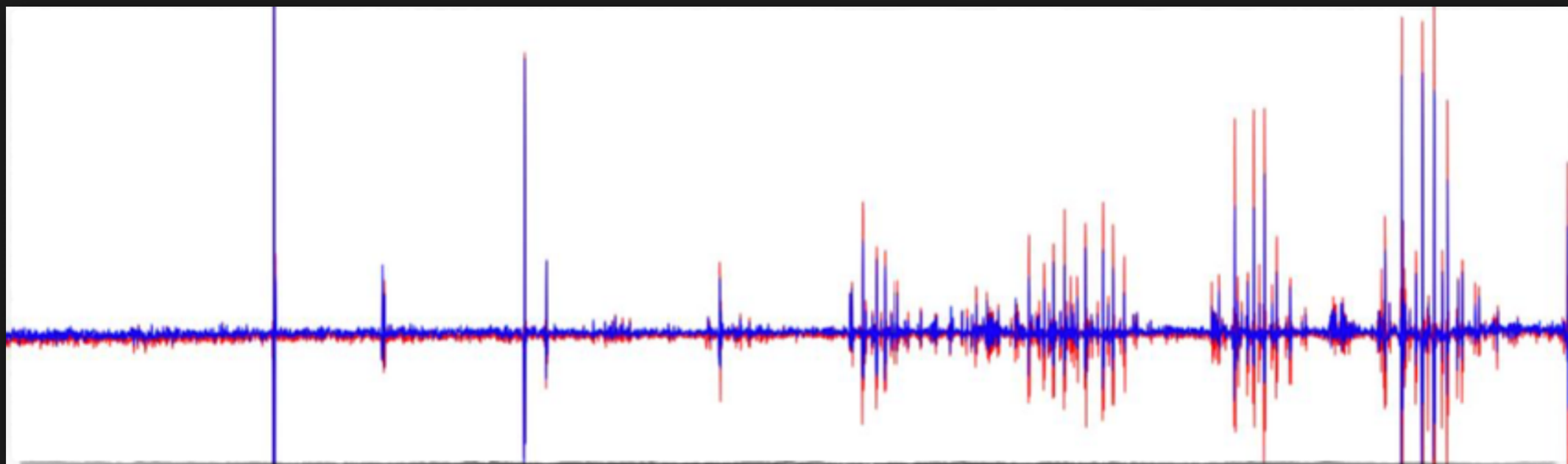
$$\epsilon_B^2 = \sum_{k=1}^N \beta_k^2 \times \epsilon_k^2$$



SKY SUBTRACTION

Decompose sky spectrum = emission line + continuum (Kelson 2003 + Davies 2007)

Use (per-slice) Line Spread Function (LSF)



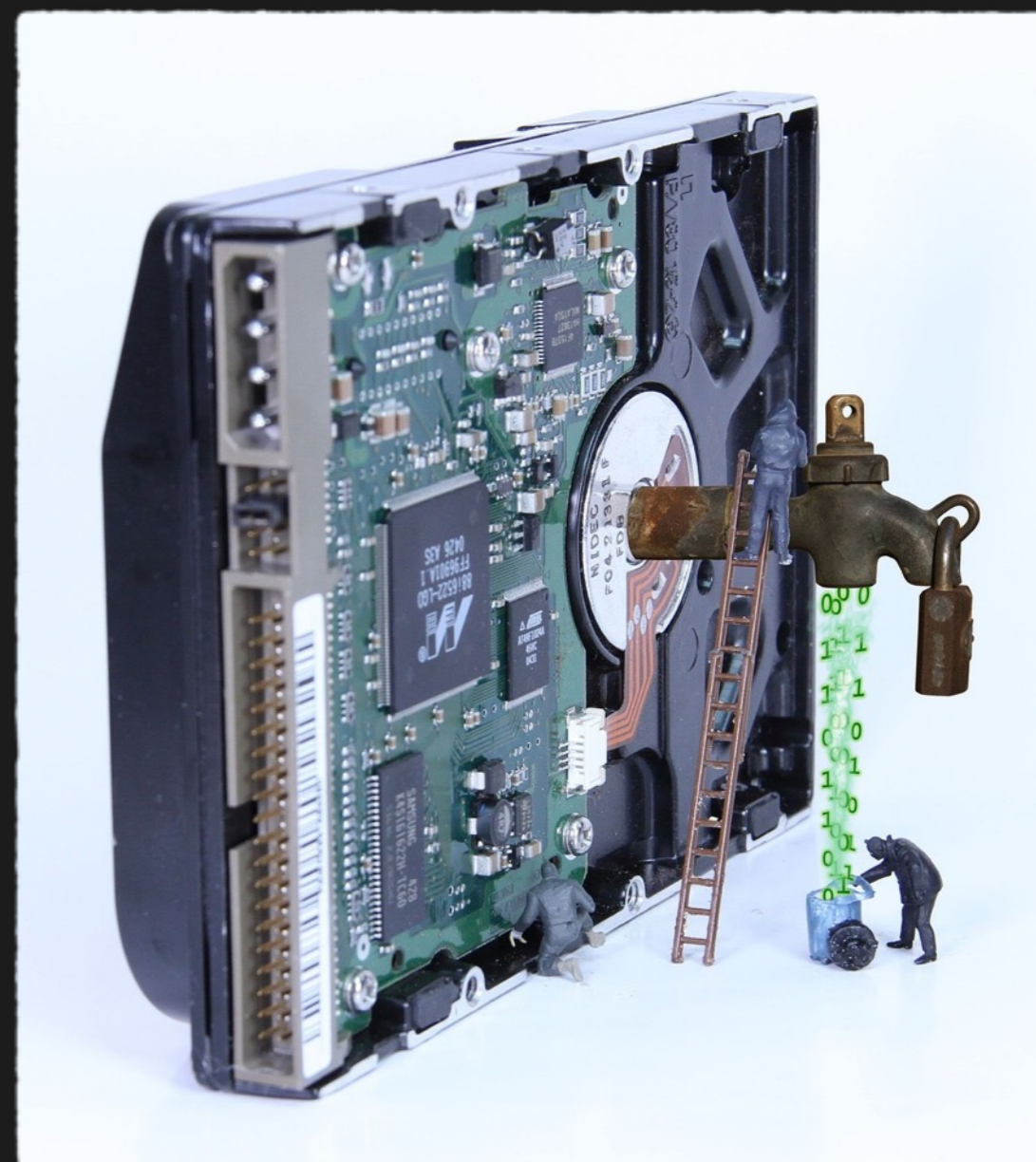
★ ~3% accuracy

★ Contributions:

- slice-to-slice variations in flux calibration
- flux behavior of OH line groups

HELP THE PIPELINE - SYSTEMATIC HEADER

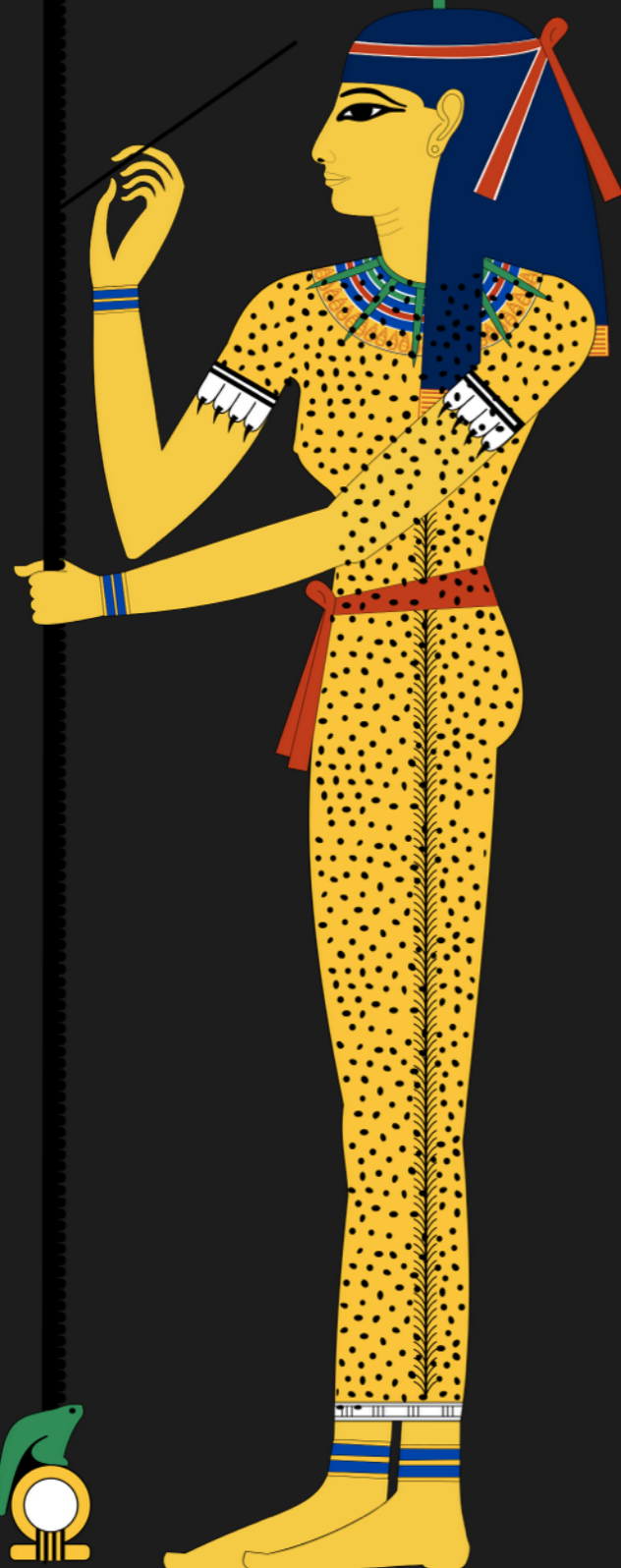
RFILE	OBJECT
0001698764-20180816-OSIRIS-OsirisBias.fits	BIAS
0001698765-20180816-OSIRIS-OsirisBias.fits	BIAS
0001698766-20180816-OSIRIS-OsirisBias.fits	BIAS
0001698767-20180816-OSIRIS-OsirisBias.fits	BIAS
0001698768-20180816-OSIRIS-OsirisBias.fits	BIAS
0001698769-20180816-OSIRIS-OsirisBias.fits	BIAS
0001698770-20180816-OSIRIS-OsirisBias.fits	BIAS
0001698771-20180816-OSIRIS-OsirisBias.fits	BIAS
0001698772-20180816-OSIRIS-OsirisBias.fits	BIAS
0001698774-20180816-OSIRIS-OsirisBias.fits	BIAS
0001698775-20180816-OSIRIS-OsirisBias.fits	BIAS
0001698776-20180816-OSIRIS-OsirisBias.fits	BIAS
0001698855-20180816-OSIRIS-OsirisLongSlitSpectroscopy.fits	SPSTD_Ross640
0001698856-20180816-OSIRIS-OsirisLongSlitSpectroscopy.fits	SPSTD_Ross640
0001698861-20180816-OSIRIS-OsirisLongSlitSpectroscopy.fits	SPSTD_Ross640
0001698911-20180816-OSIRIS-OsirisLongSlitSpectroscopy.fits	TXS2116077
0001698912-20180816-OSIRIS-OsirisLongSlitSpectroscopy.fits	TXS2116077
0001698913-20180816-OSIRIS-OsirisLongSlitSpectroscopy.fits	TXS2116077
0001698914-20180816-OSIRIS-OsirisLongSlitSpectroscopy.fits	TXS2116077
0001698915-20180816-OSIRIS-OsirisLongSlitSpectroscopy.fits	TXS2116077
0001698916-20180816-OSIRIS-OsirisLongSlitSpectroscopy.fits	TXS2116077
0001698917-20180816-OSIRIS-OsirisLongSlitSpectroscopy.fits	TXS2116077
0001698958-20180816-OSIRIS-OsirisCalibrationLamp.fits	ArcLamp_HgAr
0001698959-20180816-OSIRIS-OsirisCalibrationLamp.fits	ArcLamp_Ne
0001698960-20180816-OSIRIS-OsirisCalibrationLamp.fits	ArcLamp_Xe
0001698961-20180816-OSIRIS-OsirisSpectralFlat.fits	SpectralFlat
0001698962-20180816-OSIRIS-OsirisSpectralFlat.fits	SpectralFlat
0001698963-20180816-OSIRIS-OsirisSpectralFlat.fits	SpectralFlat
0001698964-20180816-OSIRIS-OsirisSpectralFlat.fits	SpectralFlat
0001698965-20180816-OSIRIS-OsirisSpectralFlat.fits	SpectralFlat





SESHAT

pipeline



- ✓ Good background thanks to OSIRIS
- ✓ Need a number of characterization static files for the different λ ranges
- ✓ Good chances to be quasi-automatic