X-shooter response function monitoring

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Quality Control Group

Overview

1 XSHOOTER and the VLT dataflow

2 flux standard stars, response, efficiency

3 results: NIR, VIS and UVB-arm

4 summary and outlook

XSHOOTER and VLT data flow 1/4

XSHOOTER overview 1/4

- XS is an intermediate resolution (R = λ / Δλ = 4000-7000)
  Echelle spectrograph with three arms covering a huge wavelength range of 300 – 2500 nm, (UV-B, VIS, NIR)
- XS is fully embedded within the VLT dataflow:
  - operated with a calibration plan
  - quality control loop
  - generation of certified master calibrations
  - monitoring over the full lifetime
  - archival of raw frames and products (calibrations and science*)

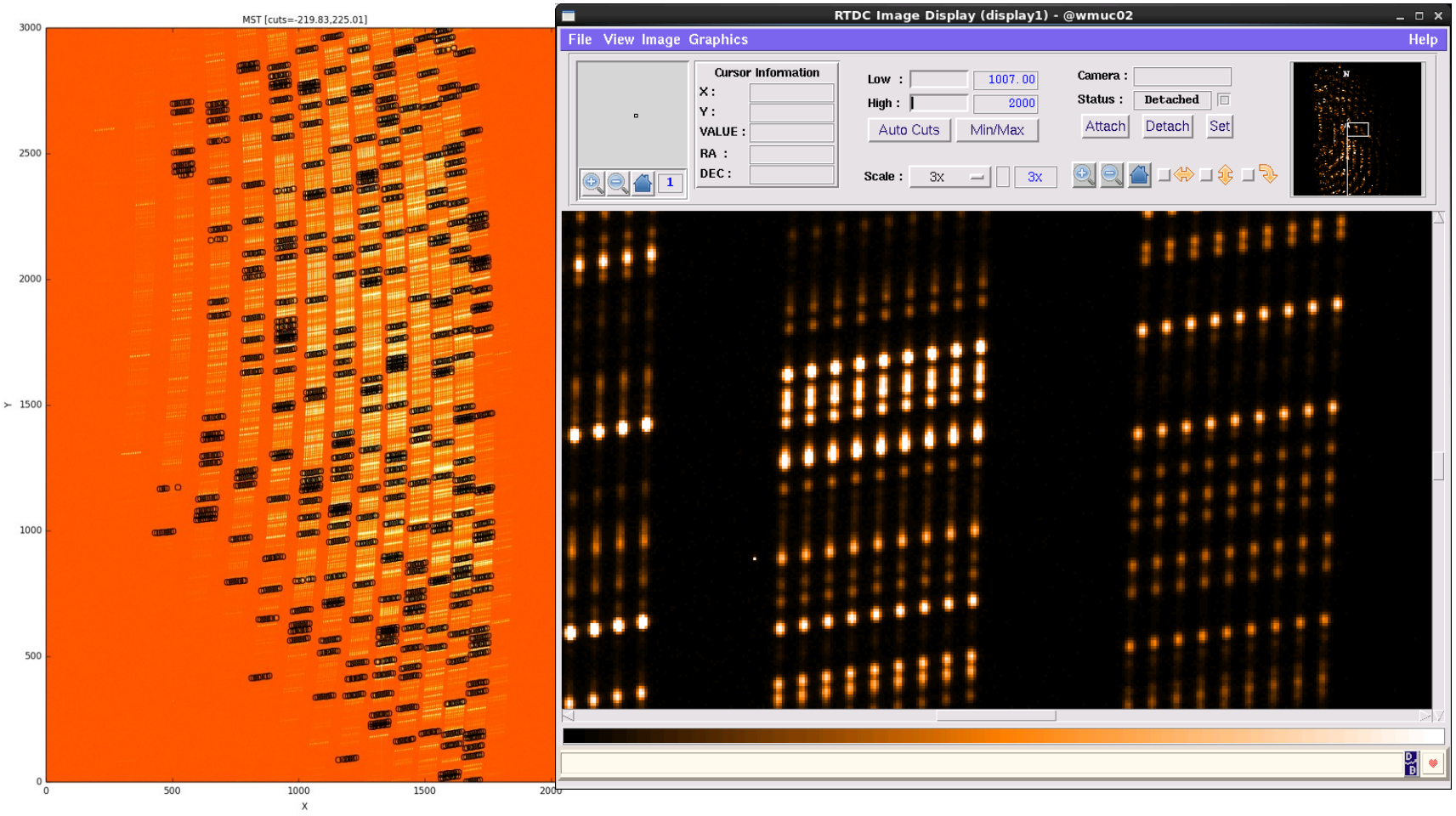
  ♠ atmospheric flexure compensation

  ♠ DRS uses physical model, (wrt polynomials)

XSHOOTER calibrations 1/4

XSHOOTER: WAVE_UVB 2017-01-02

r.XSHOO.2017-01-02T22:22:03.384_0002.fits[0]



XSH association map 1/4

XSHOOTER SCI_SLIT_NIR CALCHECKER calibration cascade

DFOS_OPS | CALCHECKER | CALSELECTOR (current) || select other instrument: OCA

OCA rule set:	XSHOOTER.RLS
Type of rule set:	**CALCHECKER** (no DO_CLASS defined; no gencalibs, no HC calibs defined; validity indicated)
Sub-cascades:	ALL SCI_SLIT_UVB | SCI_SLIT_VIS | SCI_SLIT_NIR | SCI_IFU_UVB | SCI_IFU_VIS | SCI_IFU_NIR | SCI_IMG
General comment:	

Mouse over ...
- a RAW_TYPE to check out the classification rule (M marks a multiple definition)
- a grouping rule to see the complete grouping rule
- a matching rule (e.g. '1,1') to see the product matching rule.

Product tags etc. might be cut off, in that case mouse over the cell to see the full entry.
|| 7.0 validity (max. accepted mjd_obs time difference) for this match

bottom | right — left

RAW_TYPE	DARK_NIR	FMTCHK_NIR	ORD_NIR	FLAT_SLIT_NIR	WAVE_NIR	ARC_SLIT_NIR	STD_TELL_SLIT_NIR	STD_FLUX_SLIT_NIR	SCI_SLIT_NIR	SCI_SLIT_NODRK_NIR
CATG	CALIB	CALIB	CALIB	CALIB	CALIB	CALIB	CALIB	CALIB	SCIENCE	SCIENCE
Grouping rule	TPL_A	TPL_A	TPL_A	TPL_A	TPL_A	TPL_A	*single*	TPL_A	*single*	*single*
Index	1	2	3	4	5	6	7	8	9	10
Calibration cascade:										
	calib matches:									
	1 DARK_NIR								1,1 || 3	
		2 FMTCHK_NIR							1,1 || 2	1,1 || 2
			3 ORD_NIR						1,1 || 2	1,1 || 2
				4 FLAT_SLIT_NIR					1,1 || 3	1,1 || 3
					5 WAVE_NIR				1,1 || 2	1,1 || 2
						6 ARC_SLIT_NIR			0,1 || 3	0,1 || 3
							7 *STD_TELL_SLIT_NIR*			
								8 STD_FLUX_SLIT_NIR	1,1 || 3	1,1 || 3
Comments:										
							telluric standards are associated if their airmass differs less than 0.22 from the airmass of the SCIENCE frame			
Analysis (technical consistency checks):										
products* (CALIB only)	OK	OK	OK	OK	OK	OK	OK	OK	*n/a*	*n/a*
mcalibs**	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	OK	OK

powered by QC [createCalibMap v2.0.2] last update: 2015-10-27T13:11:29

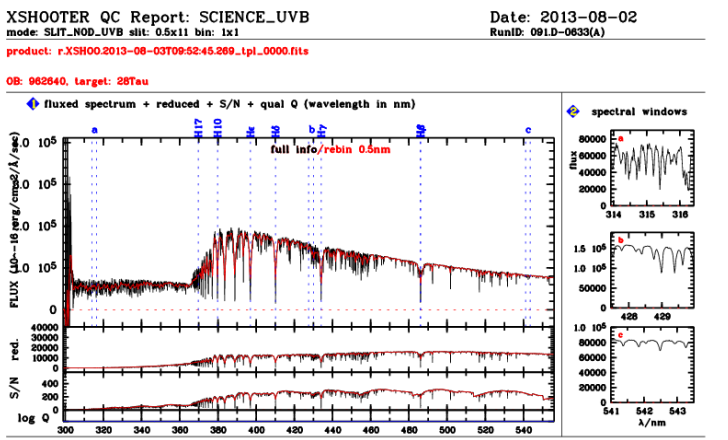
*products: does raw type have a product? (CALIB only)

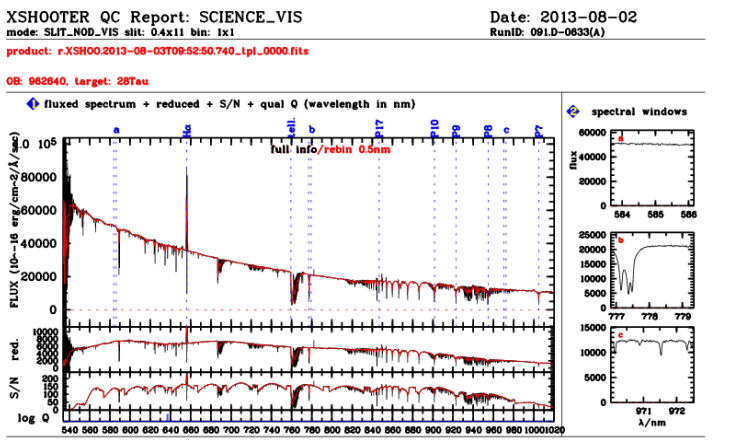
XSH science products 1/4

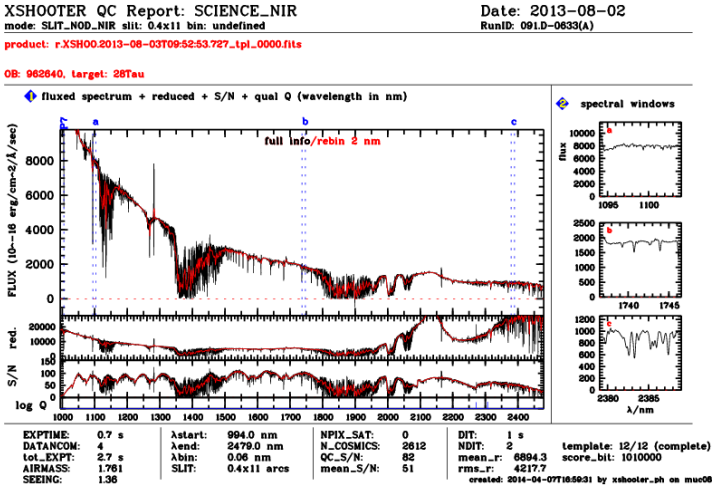
ESO quality control group processes XSH science SLIT data and provides **flux-calibrated** science products via the archive to users, respecting the propriety period.

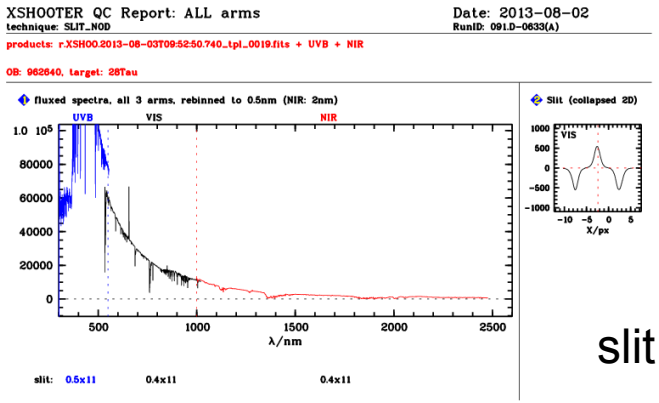
- certified data reduction pipeline generating science grade data products (see talk Freudling, poster Modigliani)
- stable instrument and smooth operation (see talk Mehner)
- sufficient deep calibration cascade and complex data processing and data handling (not simple imaging, benefit for users)*

XSH science products 1/4









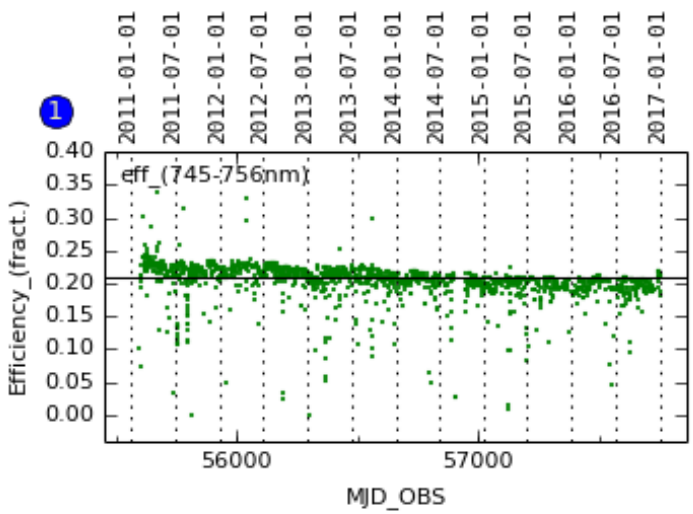
slit losses

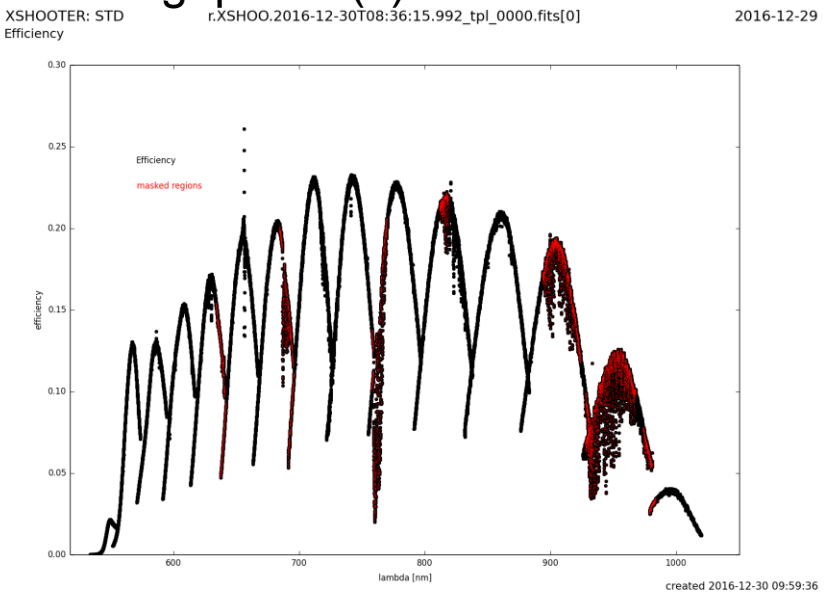
response curve 2/4

efficiency versus response 2/4

The pipeline generates two products out of the (nearly nightly acquired) flux standard star observations:

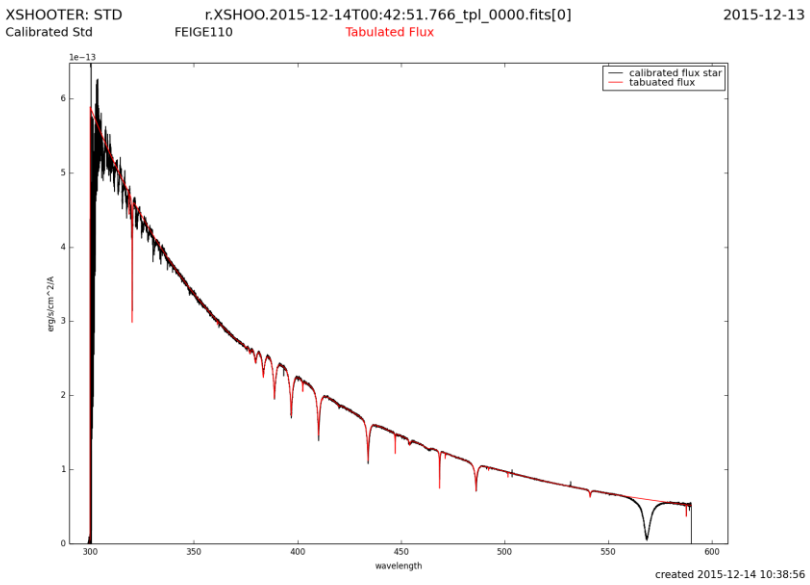
- A technical quantity **efficiency**, not flat fielded: star * blaze
- eff = model / std_star * blaze
- equivalent to a photometric zero-point or throughput = f(λ)

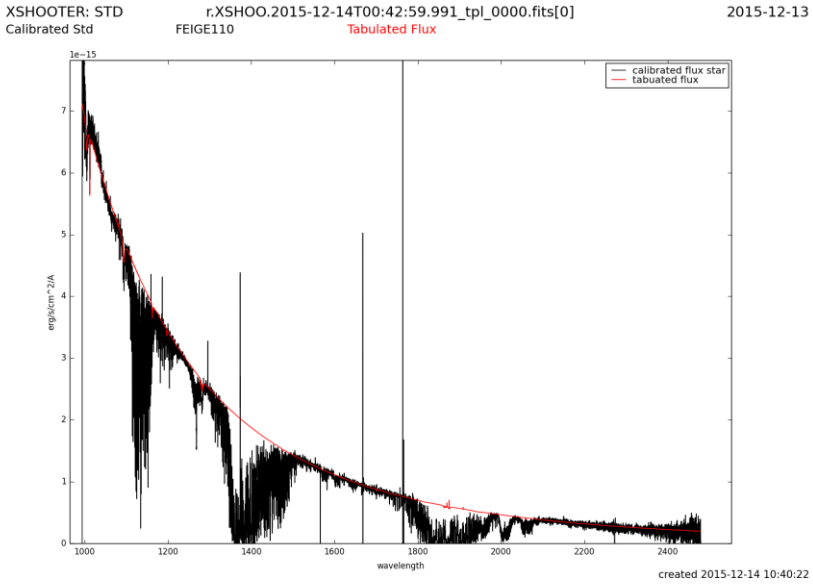




efficiency versus response 2/4

- response function to flux-calibrate science data
- to convert counts into physical units
- response(λ) = model / [(std_star * blaze) / (**lamp** * blaze)]
- examples of self-calibration:





master response 2/4

In 2013, pipeline upgrade with improvements in the response function recipe.

A master response was generated out of the re-processed individual responses,

A weighted and clipped average of all responses over a larger period

- pro master:

  non-photometric nights do not contribute (clipping),

  not perfect flux std acquisitions do not contribute

  photon noise does not contribute (for UVES only, XSHOOTER uses splines)

- pro individual:

  difference in flats minimized, frequently acquired

  easier maintenance

efficiency versus response 2/4

- flat used to calibrate science ≠ flat used to calibrate flux std (difference in slit and time; time is minimized)

- lamp aging and replacements
- UVB-arm uses two lamps: D2 [300-350] and QTH [350-500]

  with different spectroscopic characteristics (slopes) and life times

  (largest challenge)

In 2013, with the new response recipe: reprocessing of 2009-2013 individual response functions, generate a master response and the start of generating science products. But the future (t > 2013) monitoring of the response function was missing. In 2015 we started to cover this item.

parametrisation 2/4

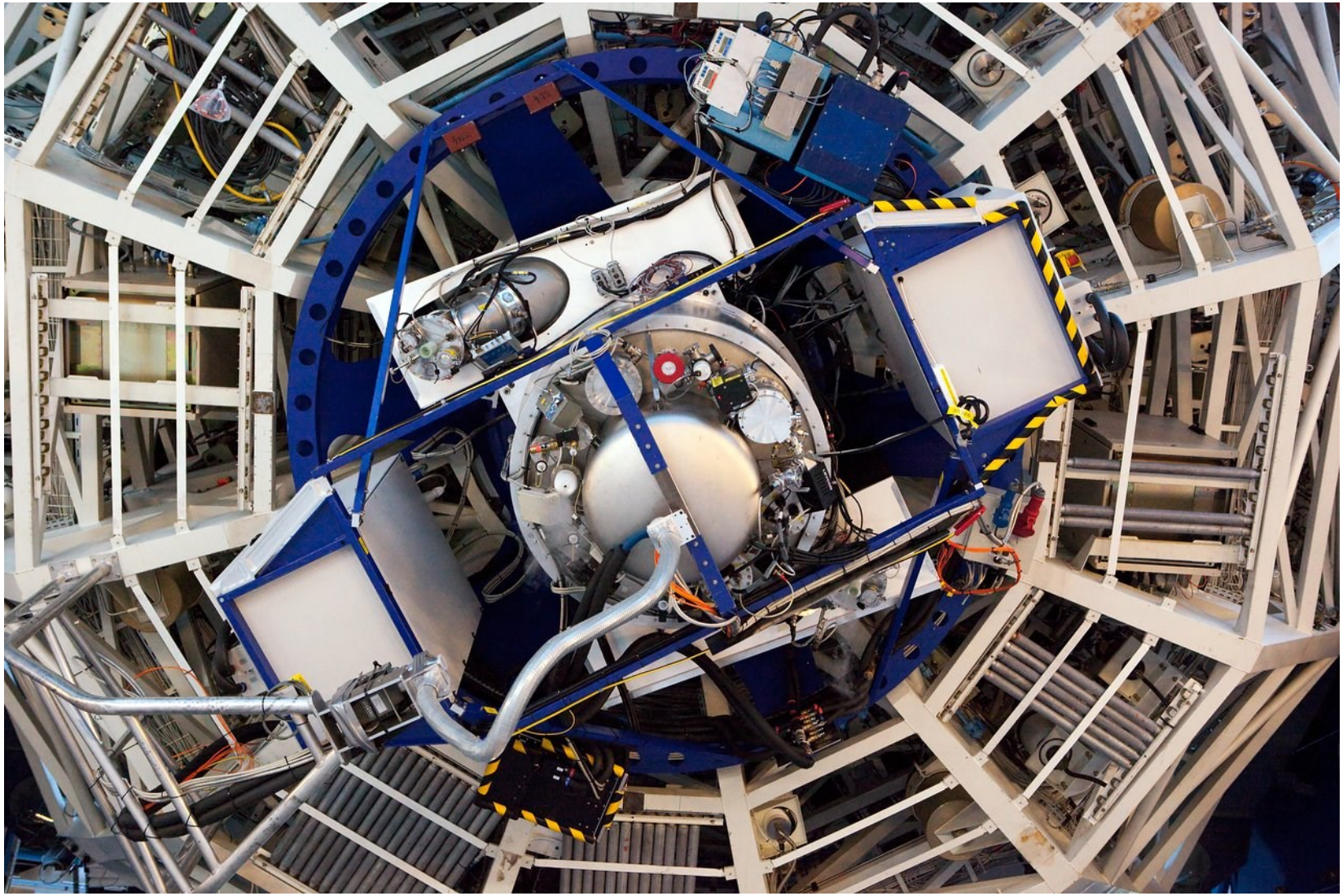
We fit the individual response to the master response via

$$\text{indiv}(\lambda) / \text{master}(\lambda) = \mathbf{a} + \mathbf{b} * (\lambda - \lambda o)$$

- **a** = night-to-night extinction variations
- **b** = first order chromatic variation (= spectral gradient)

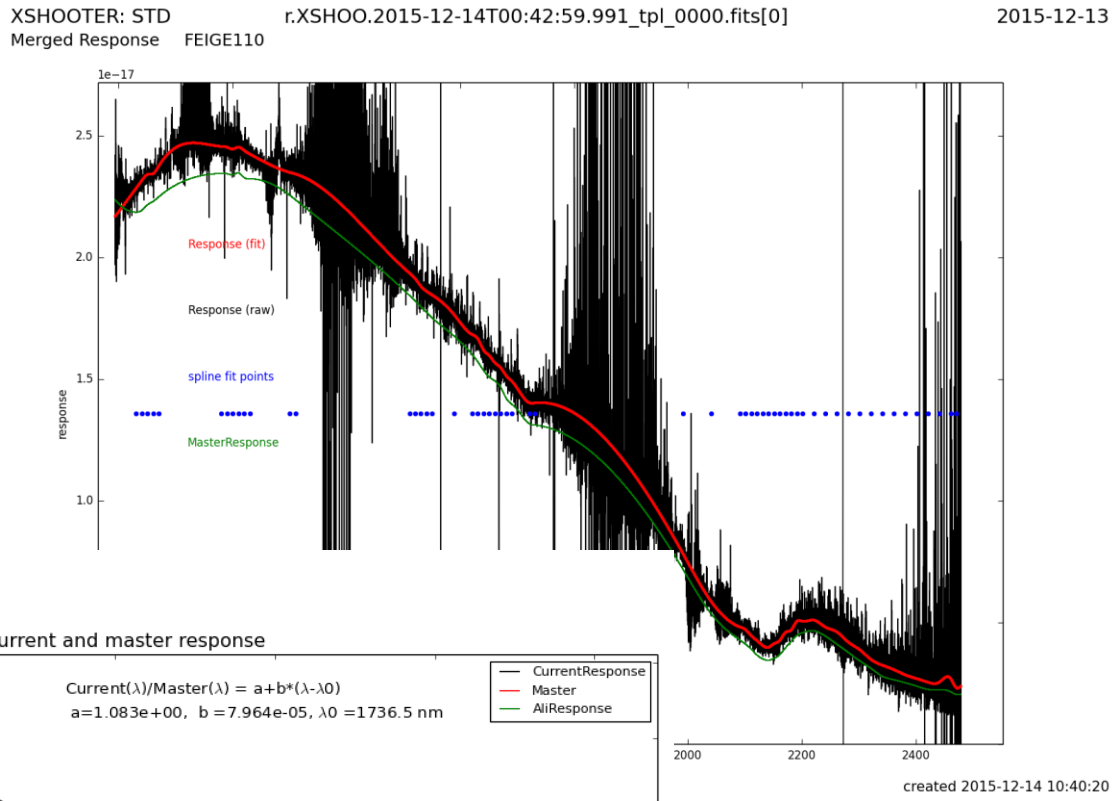
- since the chromatic variations in the response function can be due to the lamp spectrum, we generate flat lamp spectra (not directly supported by the pipeline) and apply the same parametrization to flat lamp spectra to monitor the lamp strength via a and the chromatic variations via **b**.
- since the four blue orders of the XS UVB-arm are illuminated by the D2 lamp while the red orders are exposed to the QTH lamp, the parametrization is applied to both lamps individually

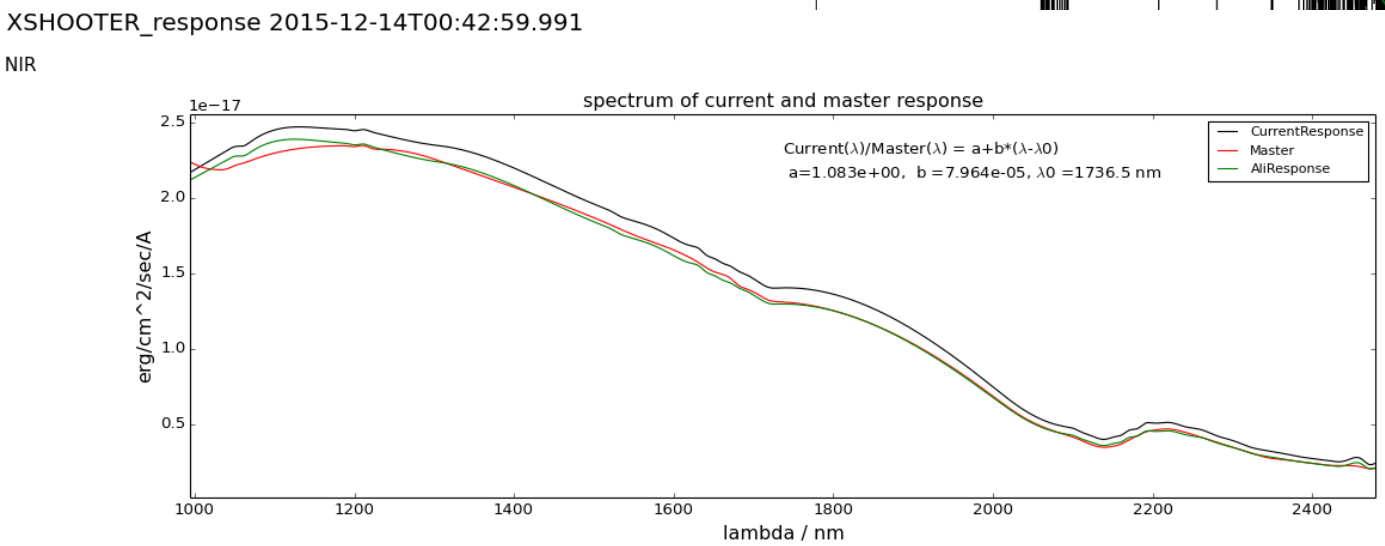
results 3/4



Results NIR-arm 3/4

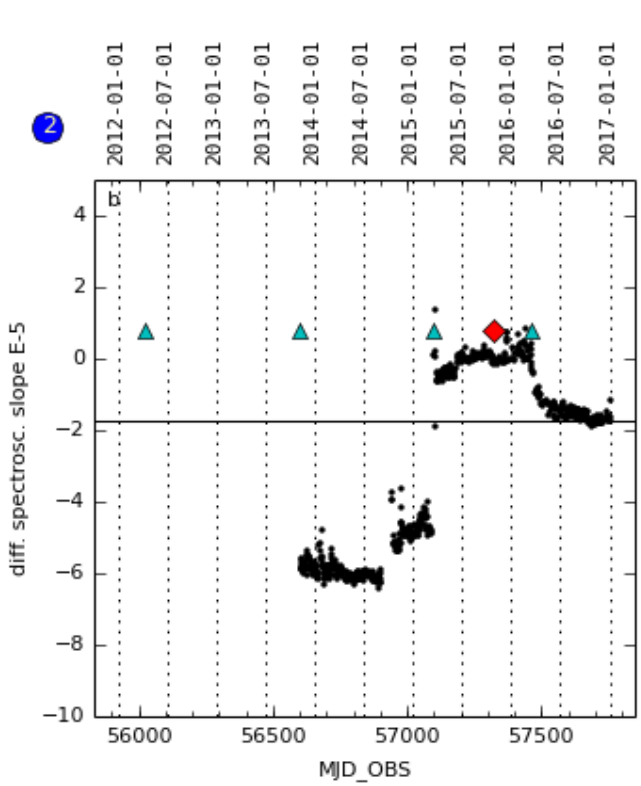
Results on the NIR arm:

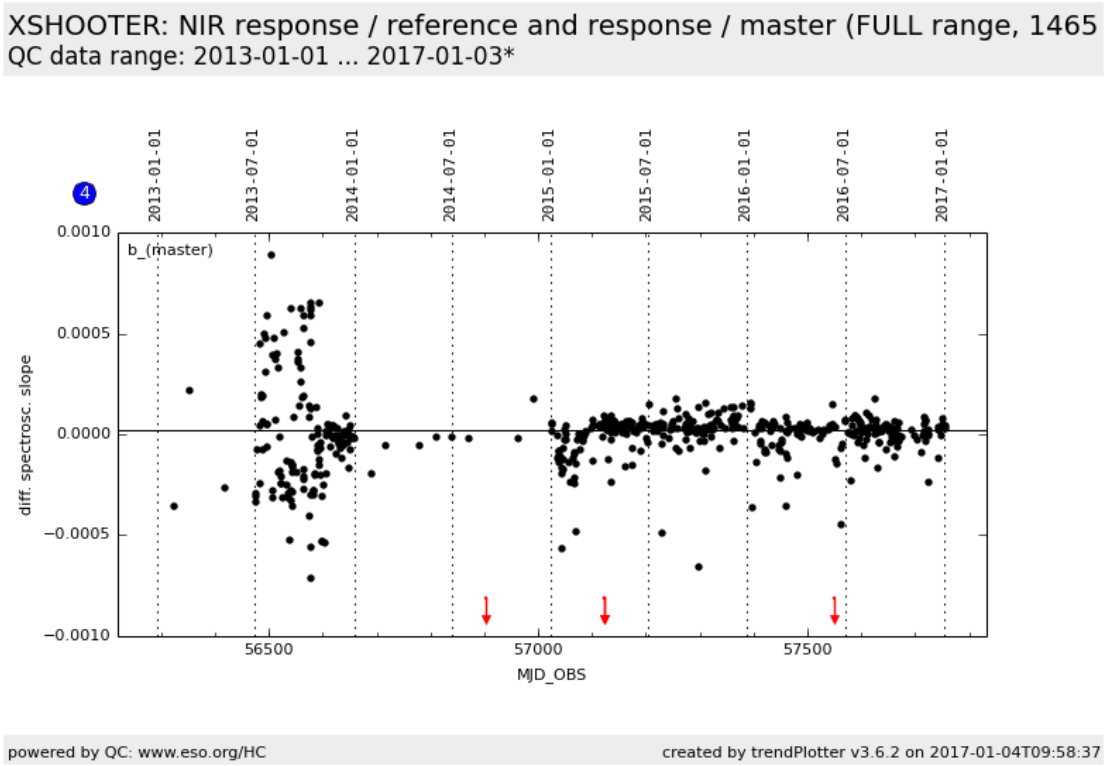




Results NIR-arm 4/4

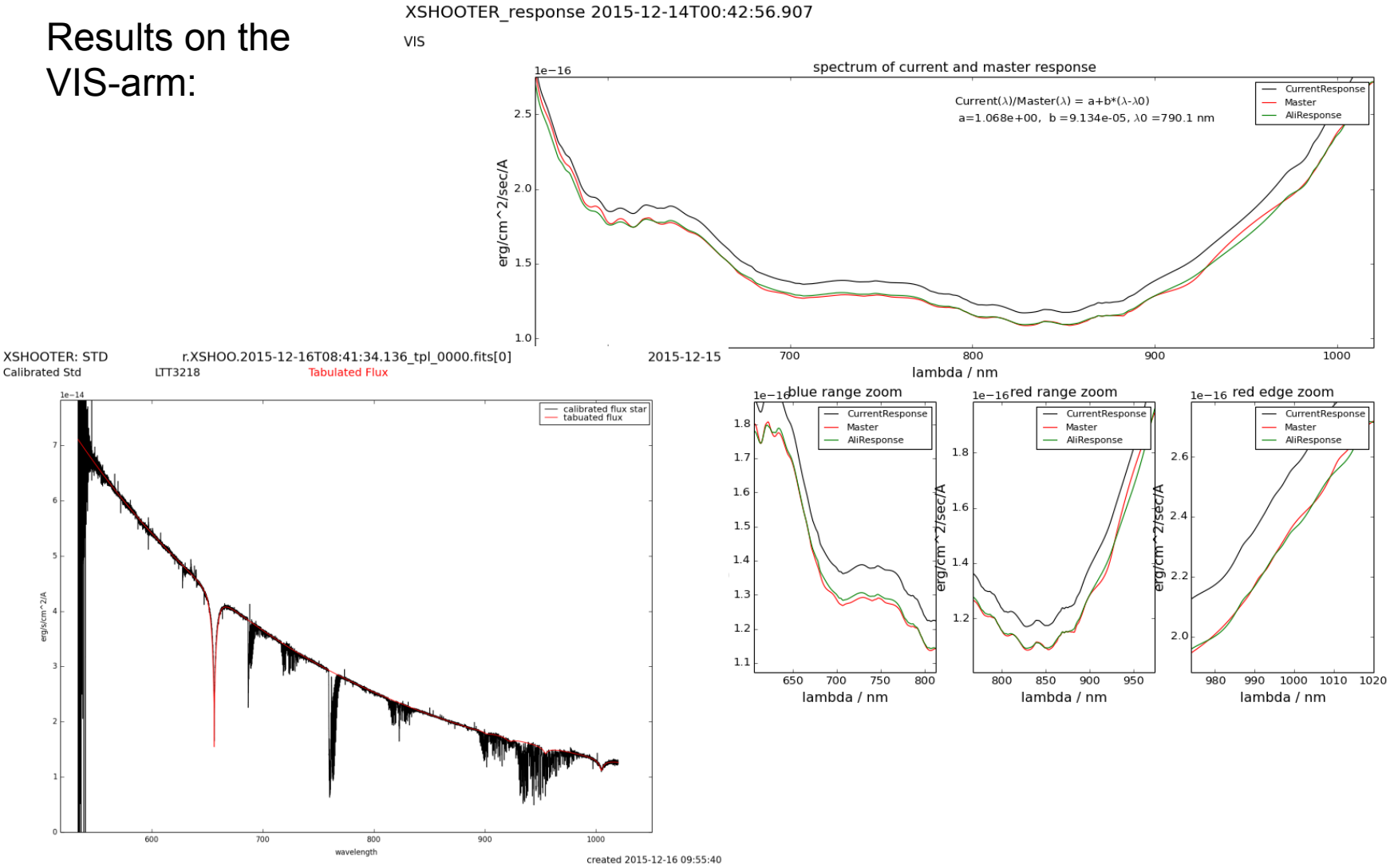
- On 2013-11-06 NIR-arm flat lamp was exchanged with significant spectrum change: new master response. Later lamp exchanges had little impact
- **b** ~ 4E-5, b = Δy / Δλ, => b = 1E-5 ~ 1.2% in y





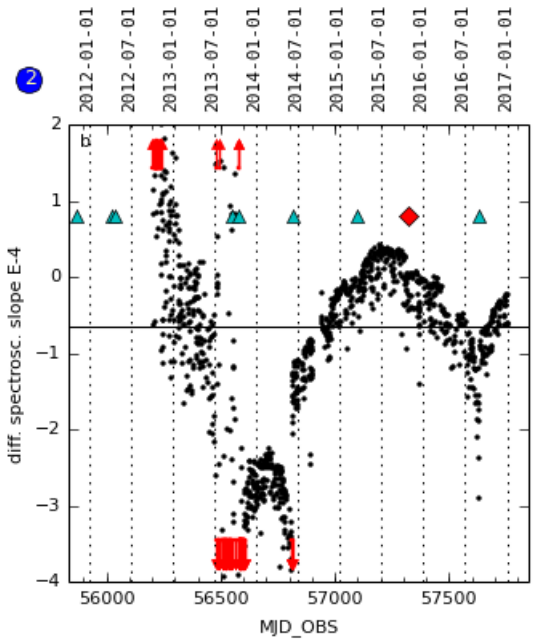
Results VIS-arm 3/4

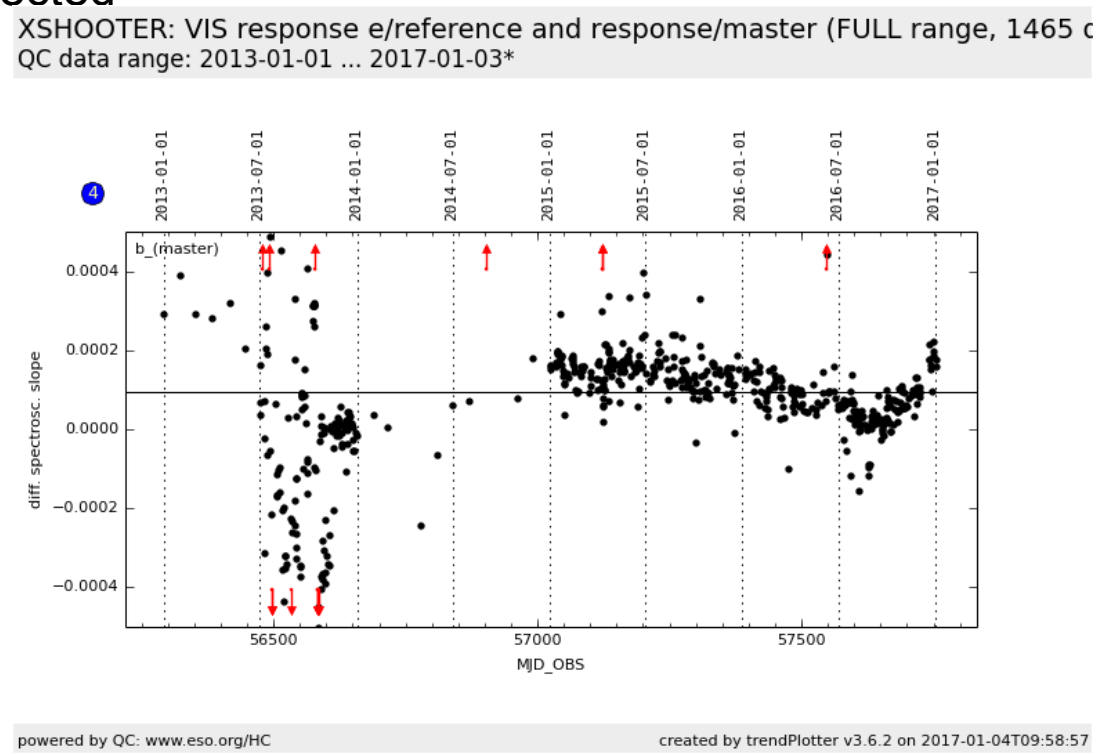
Results on the VIS-arm:



Results VIS-arm 3/4

- **b** ~ 2E-4, b = Δy / Δλ (=200 nm), => b = 1E-4 ~ 2% in y
- lamp replacements can have minor impact on flat spectrum slope,
- response slope is not affected

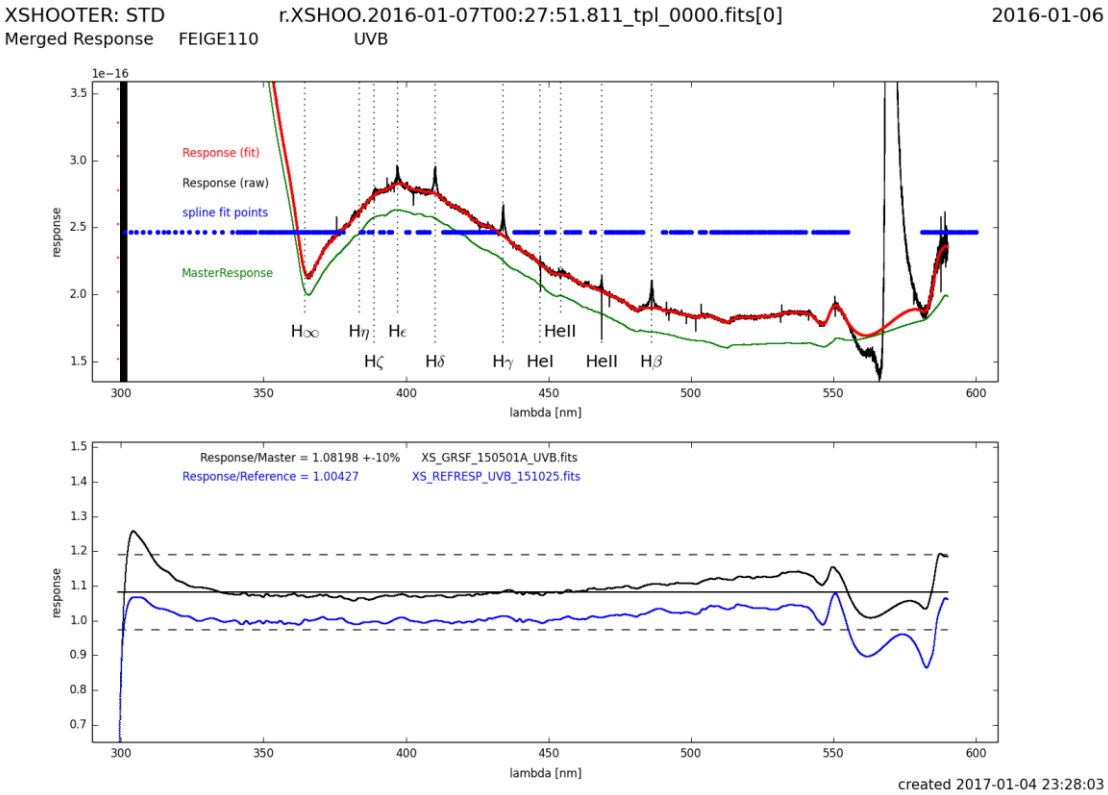




Results UVB-arm 4/4

Results on the UVB arm: - variable sharp bend (kink) at 360nm due to 2 lamps

- D2 lamp range with strong gradient and very low flux

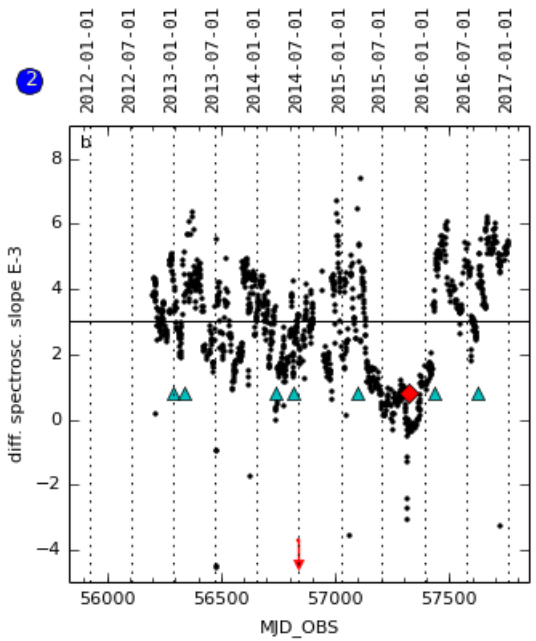


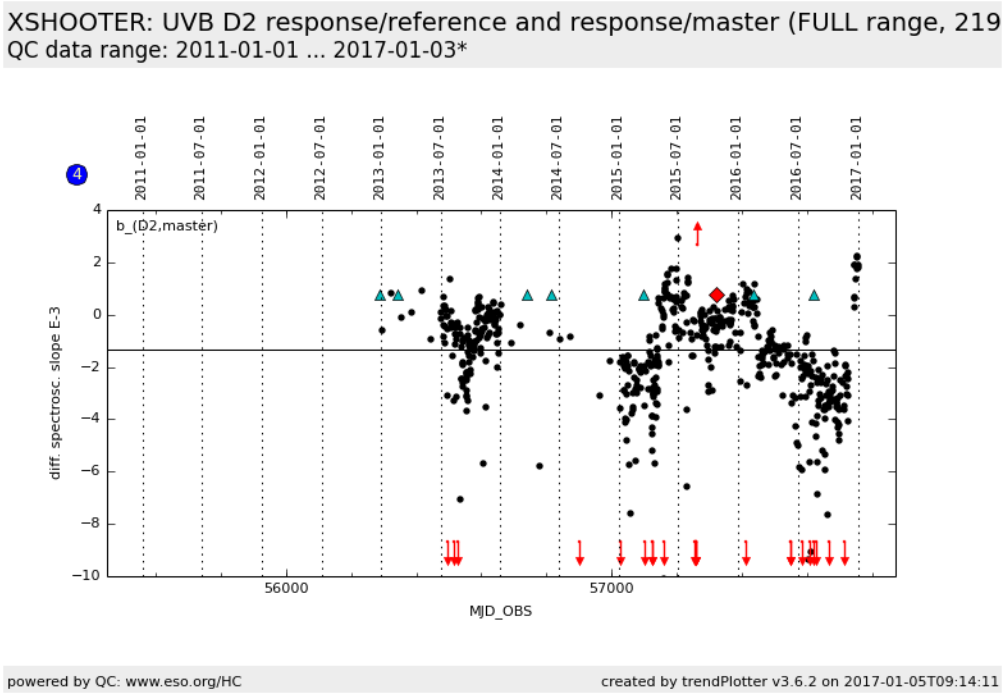
Results UVB-arm 4/4

D2 lamp (300-360nm)

b(lamp) = 4e-3 = 12%

b(response) = 2e-3 = 6%



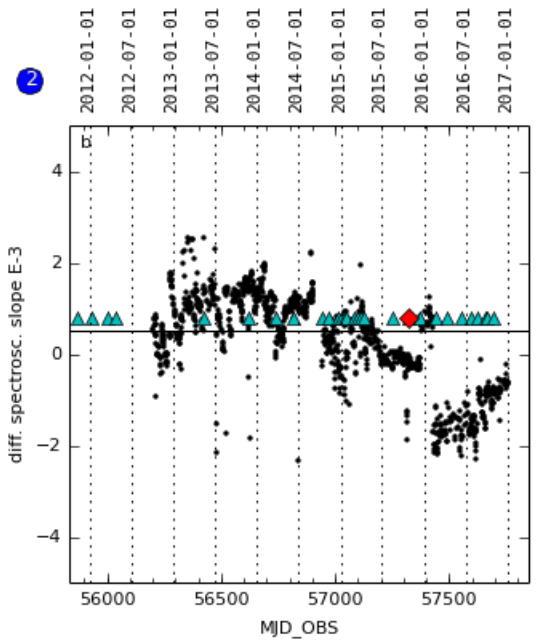


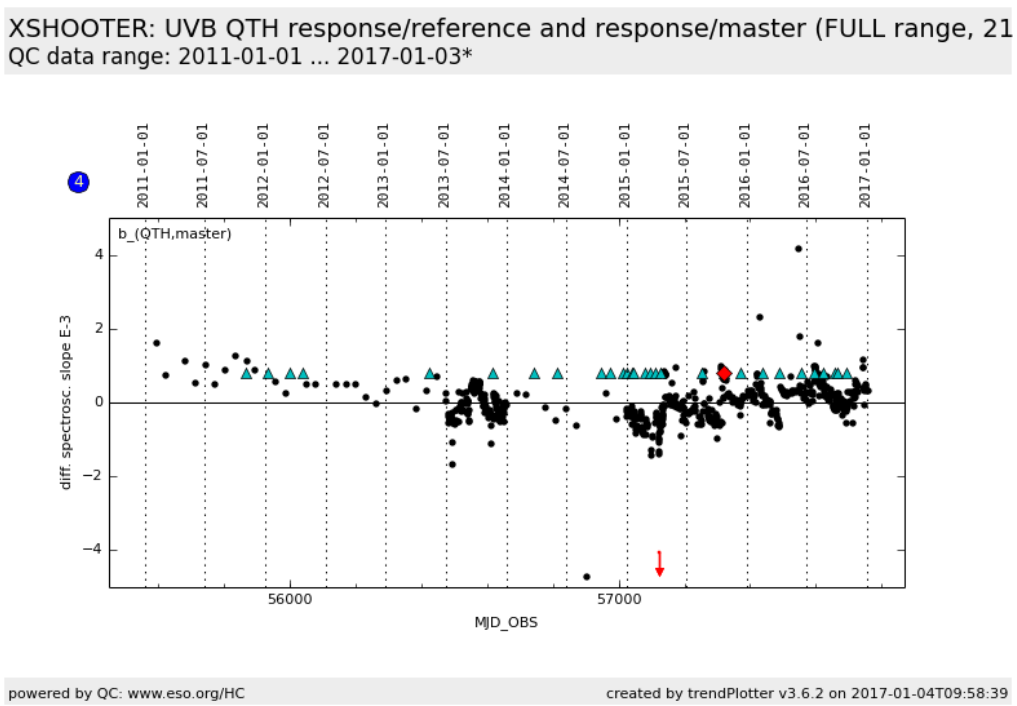
Results UVB-arm 4/4

QTH lamp (360-550nm) : numerous lamp replacements,

not documented in frame headers but in problem report system (PPRS)

b = 2e-3 -> Δy = 20% b(response) = 1e-10 = 10%

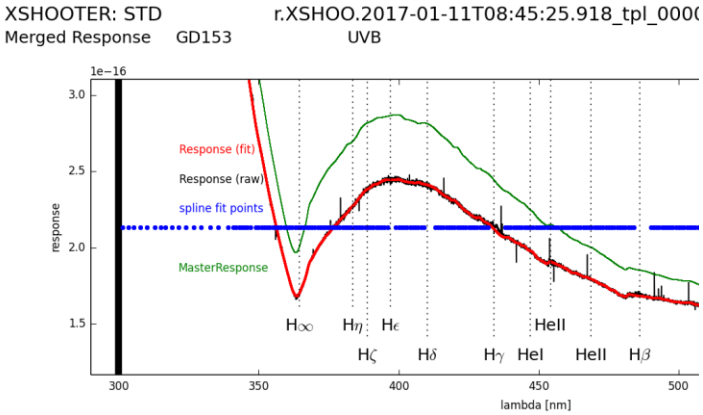


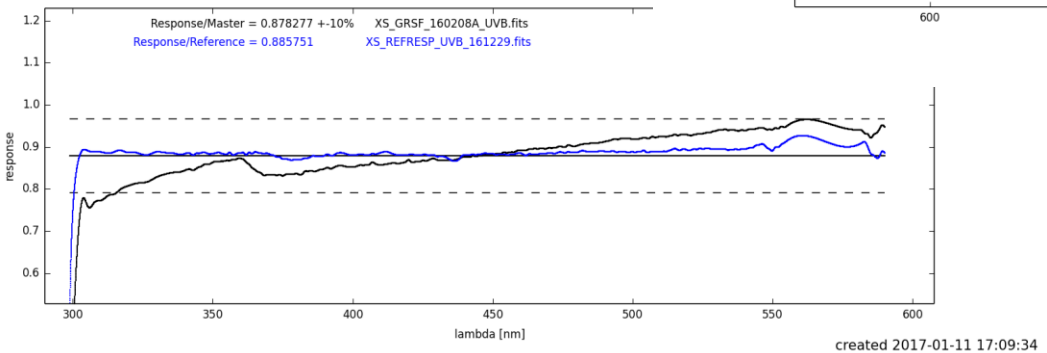


Results UVB-arm 4/4

- Both lamps with different life times and aging effects, means D2-lamp calibrated region and QTH lamp calibrated region with different normalization and response level produced a jump.
- For the UVB-arm a maintenance of a high frequency master response (a weekly or a monthly master response) update not feasible.
- UVB-arm science data from 2015-04 on calibrated with the current/individual response, VIS and NIR arm (and early UVB-arm) science data calibrated with the master response
- UT2 M1 re-coating in Dec 2016: new master response take the chromatic change in reflectivity into account.

Results M1 recoating 2016-12 4/4





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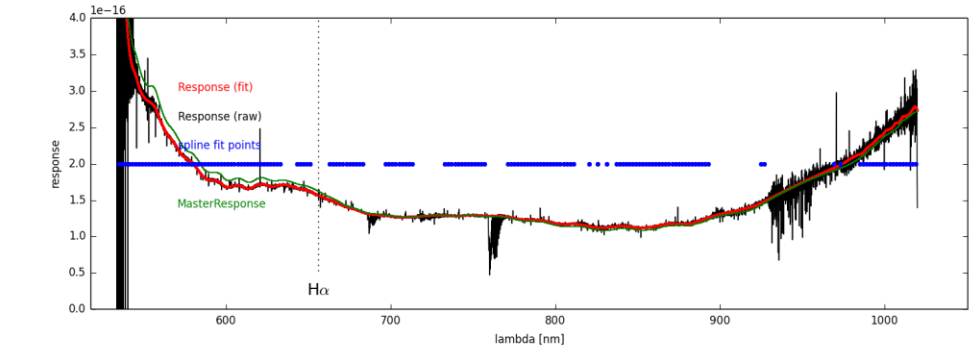

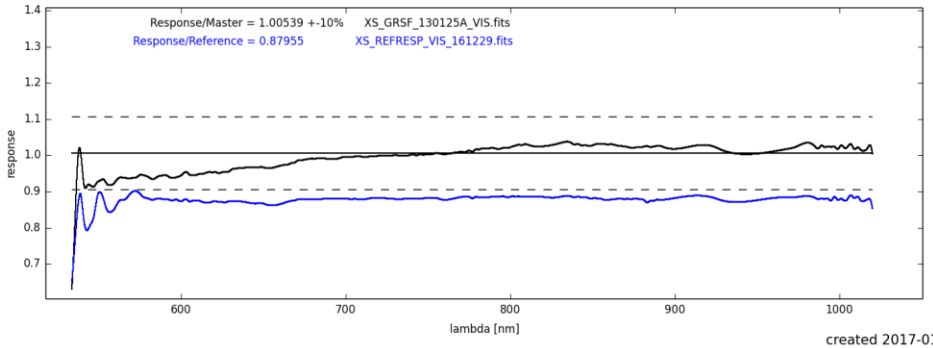

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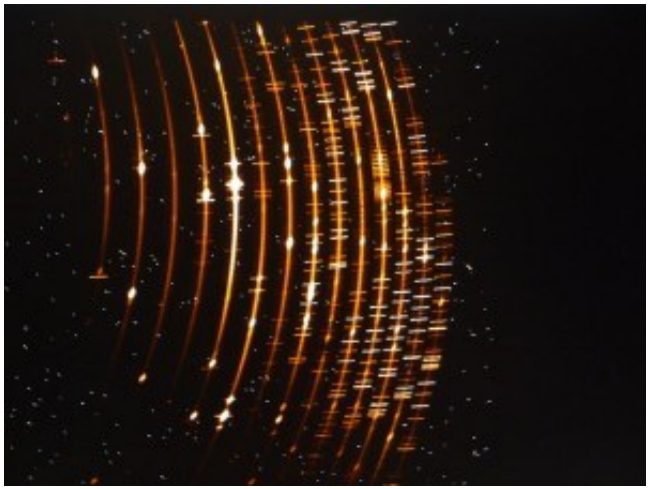
Summary 4/4

- We have extended the coverage of the XSHOOTER QC loop
- We have characterized the response function via the first order chromatic deviation (**b** = spectral gradient)
- We have reprocessed the last year's flat's and flux STD
- We have found that physical lamp exchanges can impact on the lamp spectrum, but have negligible impact on the response spectral slope
- We have verified that the NIR-arm and VIS-arm response functions and the master response are within an acceptable range
- For the UVB-arm: two-lamp problem, sharp bend
- Better understanding of the instruments throughput
- Increase confidence in flux calibration of XS science products

Thanks

Many thanks to

- Sabine Möhler,
- Reinhard Hanuschik
- Andrea Modigliani



Further reading:

S. Mőhler et al. 2014, A&A 568, A9

R. Hanuschik: XSHOOTER IDP release description

XSHOOTER pipeline user manual

XSHOOTER user manual