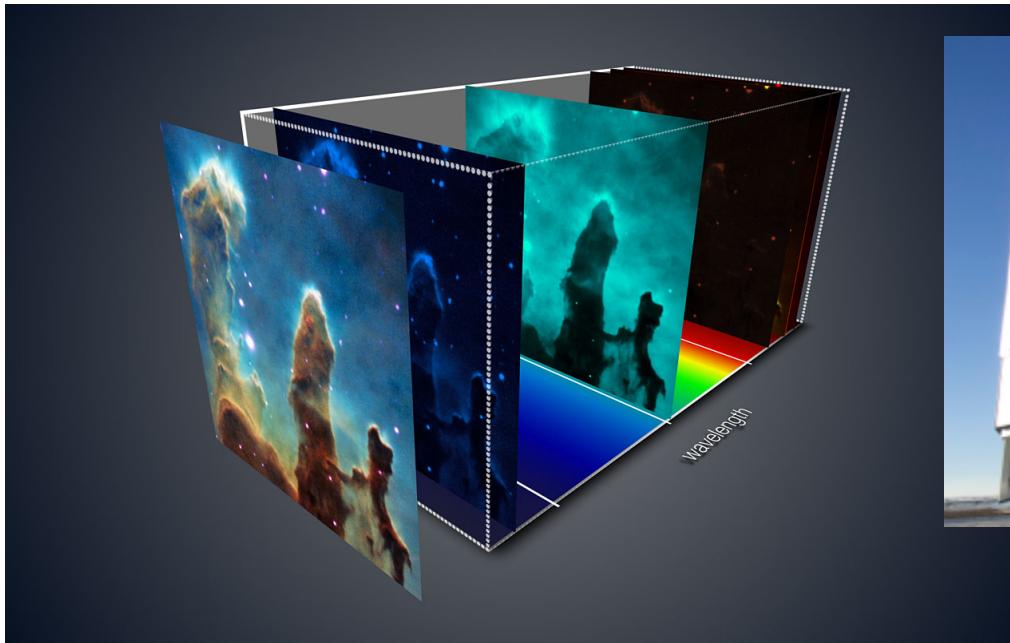


MUSE Monitoring and Calibration



Prepared by:

Fernando J. Selman, Evelyn Johnston, Frédéric Vogt

With help from MUSE IOT

Presented by: Evelyn Johnston and Frédéric Vogt



- The MUSE team
- Instrument characteristics
- Description of MUSE
- From raw data to the data cube: the MUSE pipeline
- Instrument monitoring and calibration plan
 - A pending issue
- MUSE challenges
- Current challenges
- Future Challenges



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The MUSE team

PI: R. Bacon, Lyon – ESO responsible: A. Glindeman – ESO Instrument
 Scientist: J. Vernet -- ESO Project Manager: A. Manescau

Institute	
Leibniz-Institut für Astrophysik Potsdam	
Centre de Recherche Astrophysique de Lyon	
ESO	
ETH – Institute of Astronomy (Zurich)	
Institut für Astrophysik Göttingen	
Institut de Recherche en Astrophysique et Planétologie (Toulouse)	
Leiden Observatory	

ESO Instrument Operation Team

- Paranal IOT Coordinator – Alain Smette
- Paranal Instrument Scientist – Fernando Selman/George Hau
- Paranal Instrument Fellows – Evelyn Johnston, Yara Jaffe, Frédéric Vogt (Honoris...)
- Paranal Instrument TIO – Susana Cerdá, Cristian Herrera
- Paranal Instrumentation Responsible – Nicolas Haddad
- Paranal Software Responsible – Pedro Baksai, Gerard Zins
- Garching Instrument Scientist – Joel Vernet
- Garching Quality Control Scientist – Danuta Dobryzyka
- Garching User Support Astronomer – Elena Valenti
- Garching Pipeline Responsible – Ralf Palsa
- Garching Advanced Data Products – Lodovico Coccato

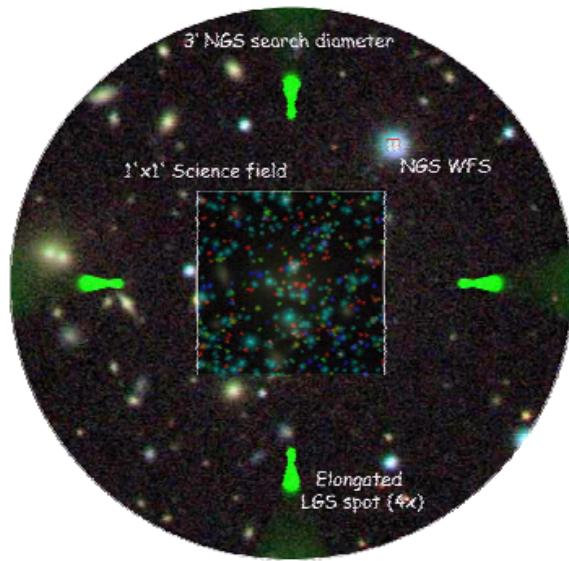
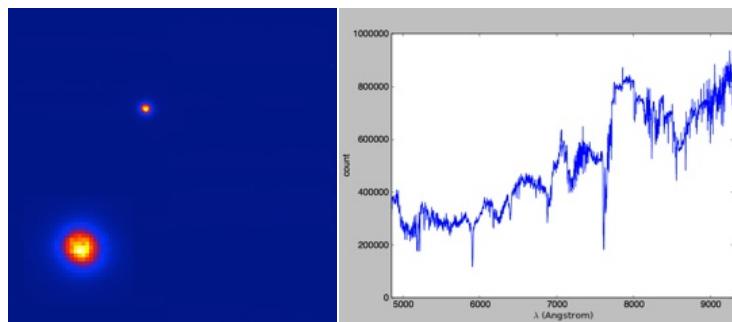


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MUSE parameters

First light: 31 Jan 2014

Kapteyn's star 13 ly away





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MUSE subsystems

■ Fore Optics

- Derotator
- Anamorphoser

■ Field splitter 24 strips 2.5"x1'

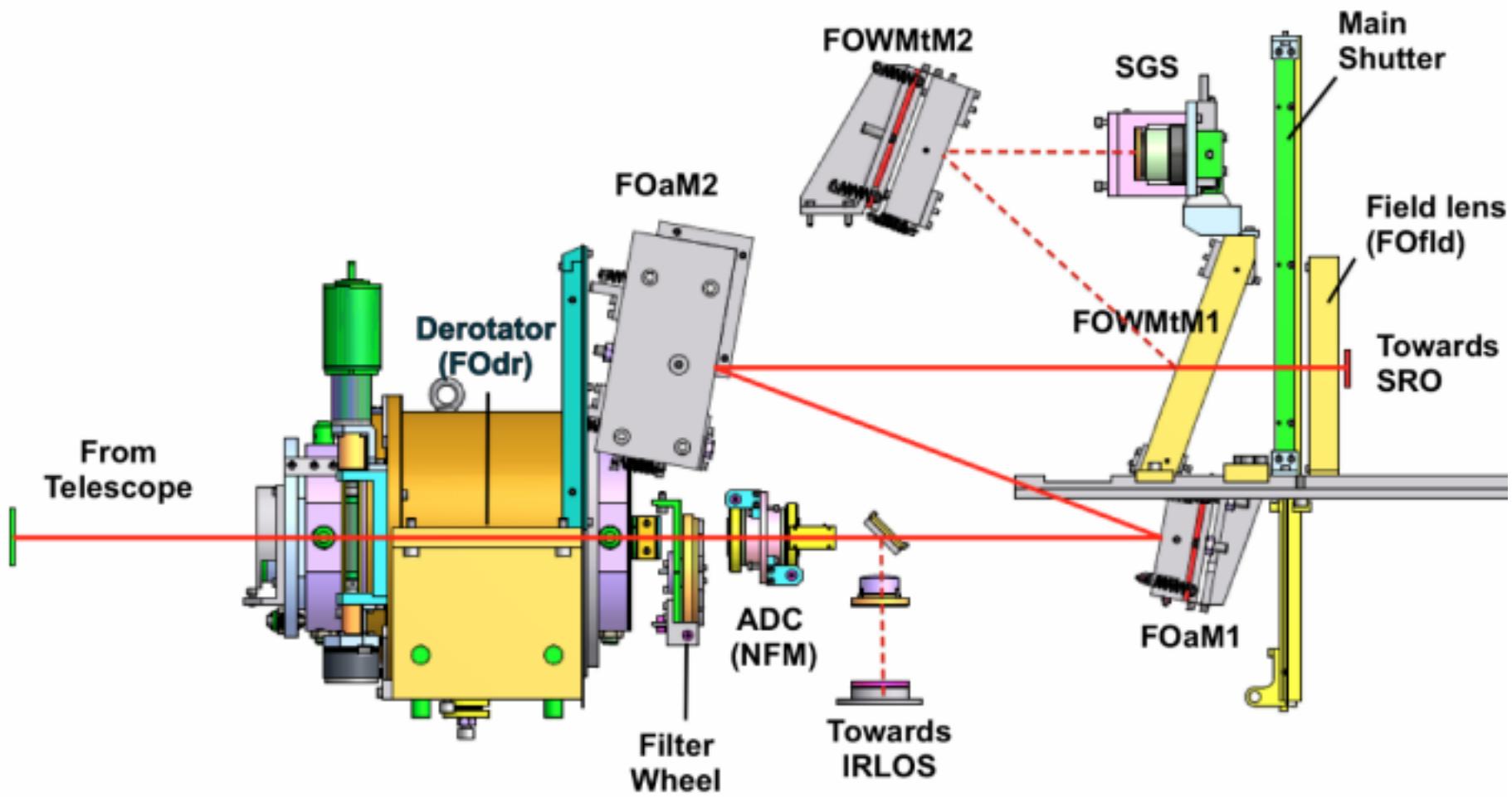
■ Relay optics

■ 24 independent Spectrograph/IFUs

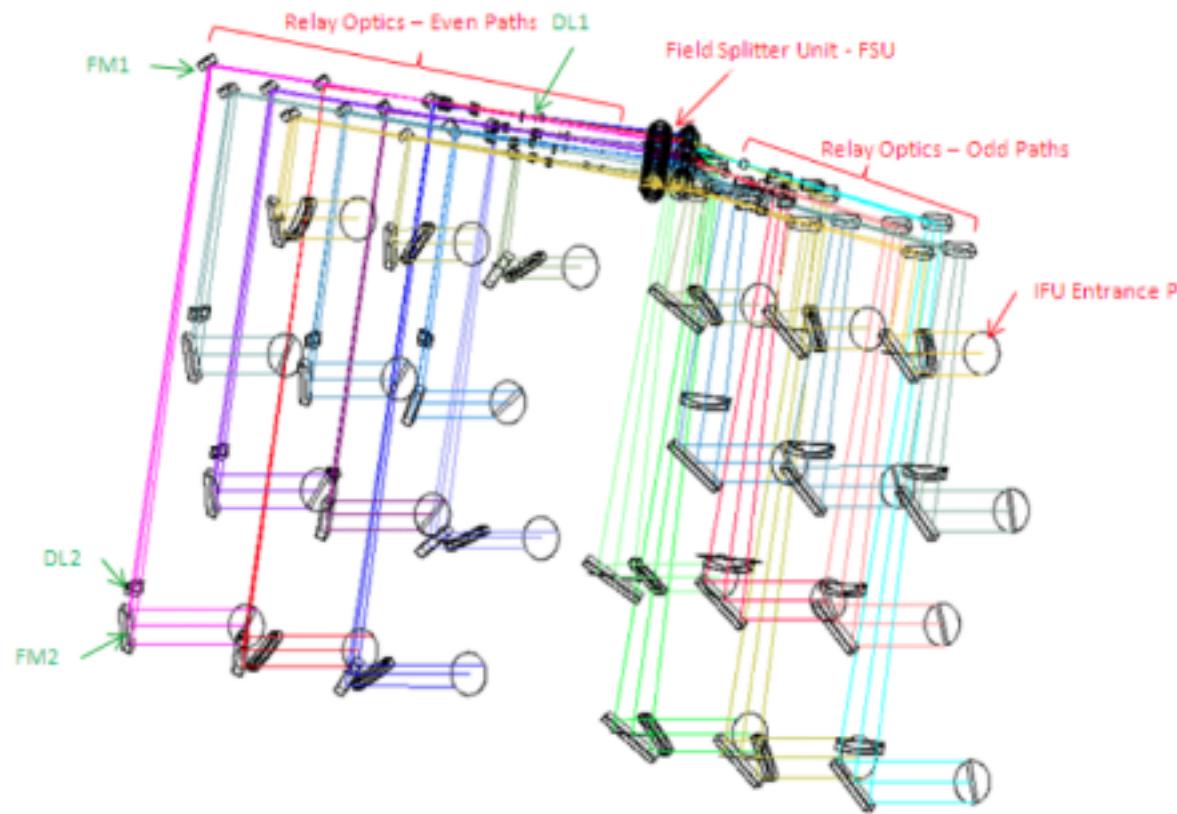
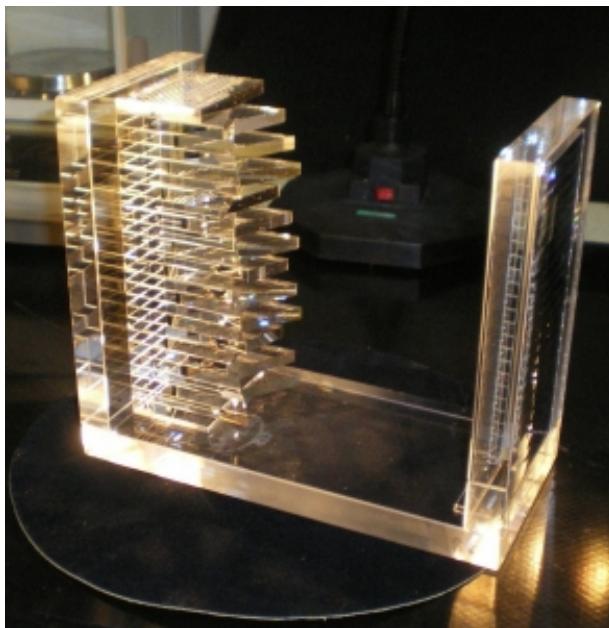
- Slicing each strip into 4x12 slices 0.2"x15"
- VPH grisms
- Imaged by f2 camera into 4kx4k detector
- Instrument with larger number of pixels at Paranal

■ Pipeline reassembles field into data cubes

MUSE Foreoptics

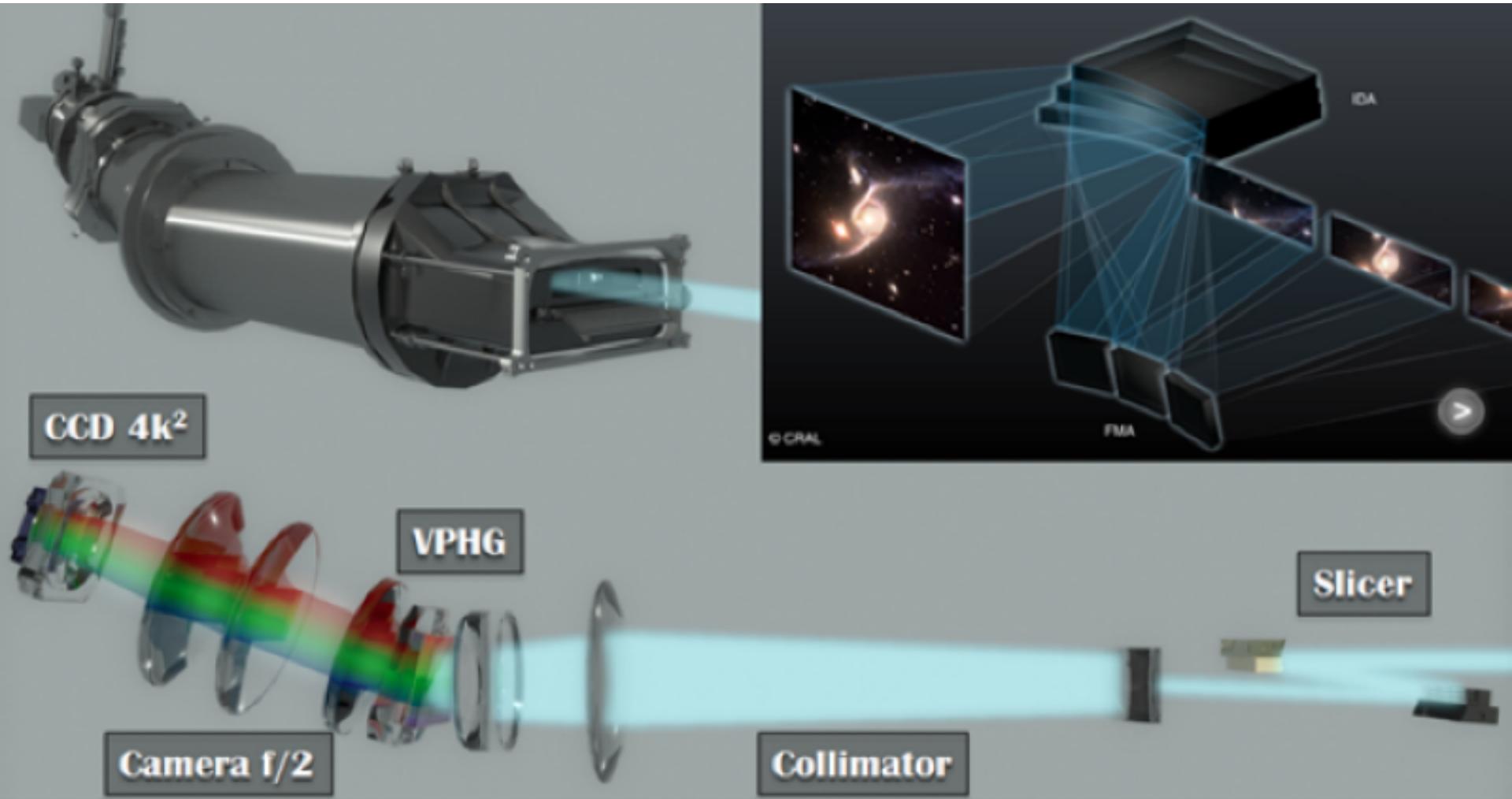


MUSE splitting and relay optics



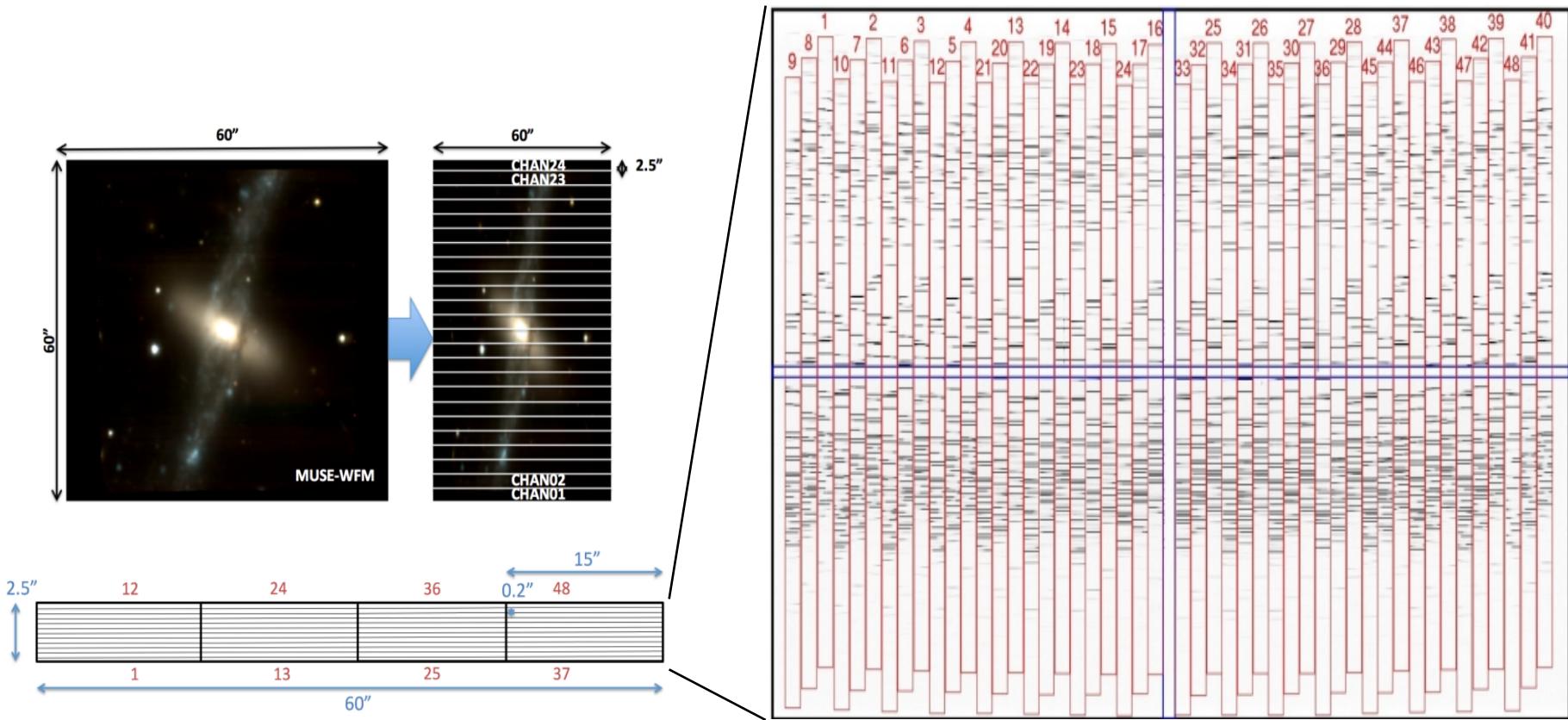
MUSE IFUs

IFUs

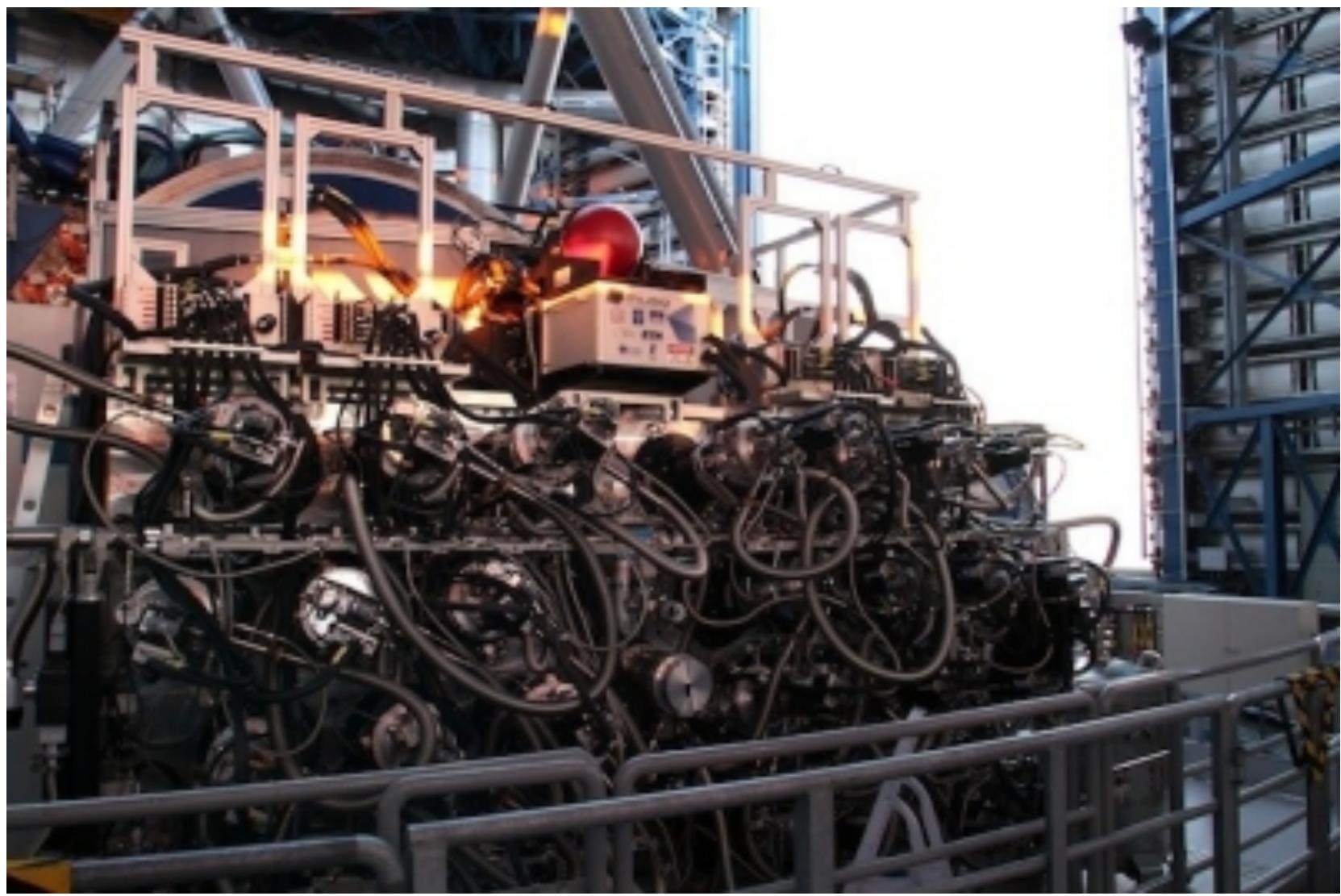


MUSE data

24 x



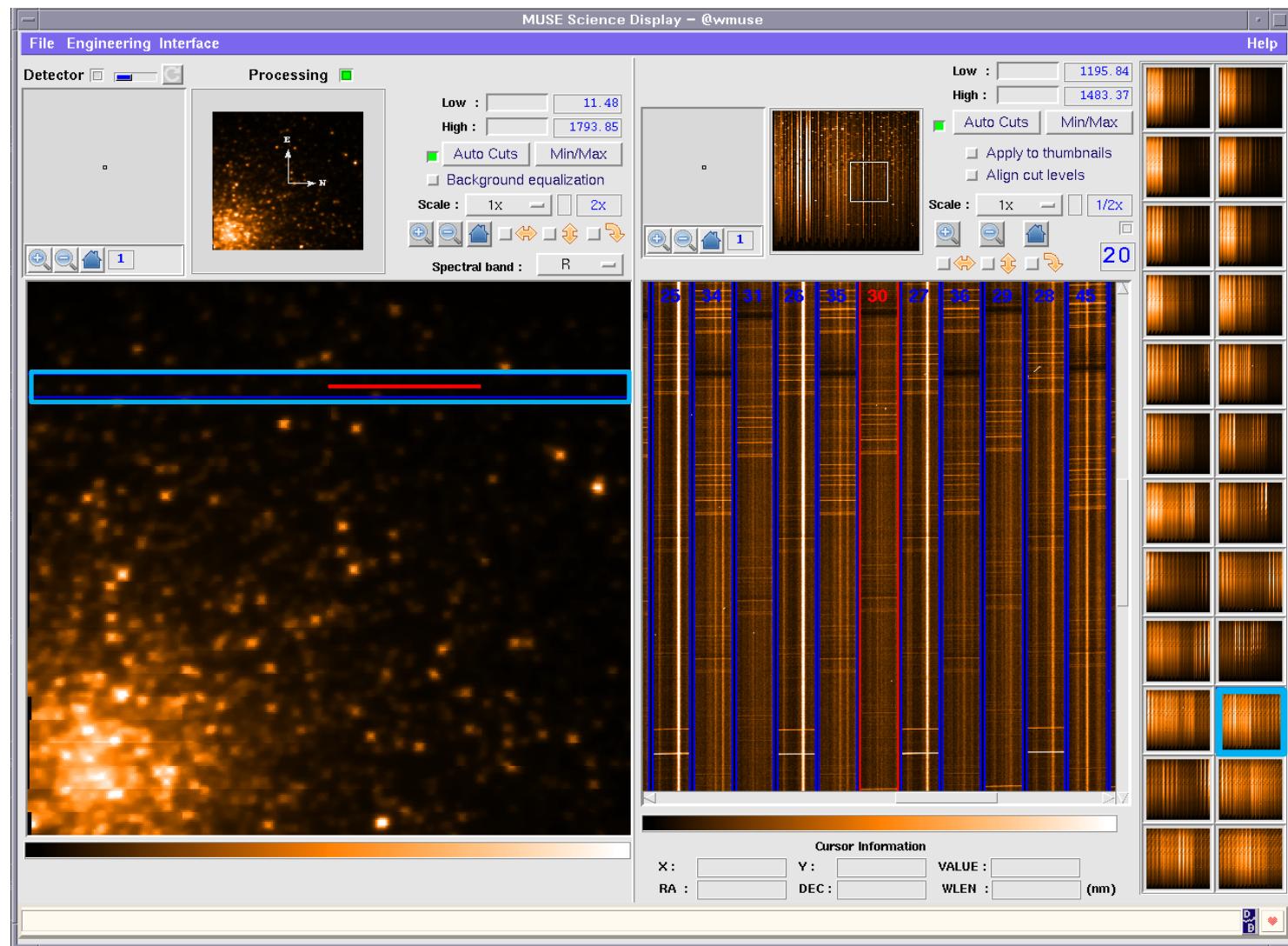
MUSE at the telescope



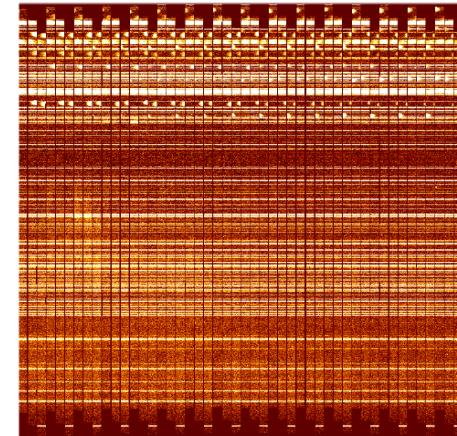
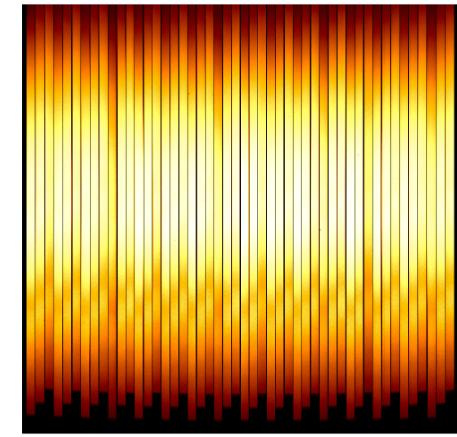
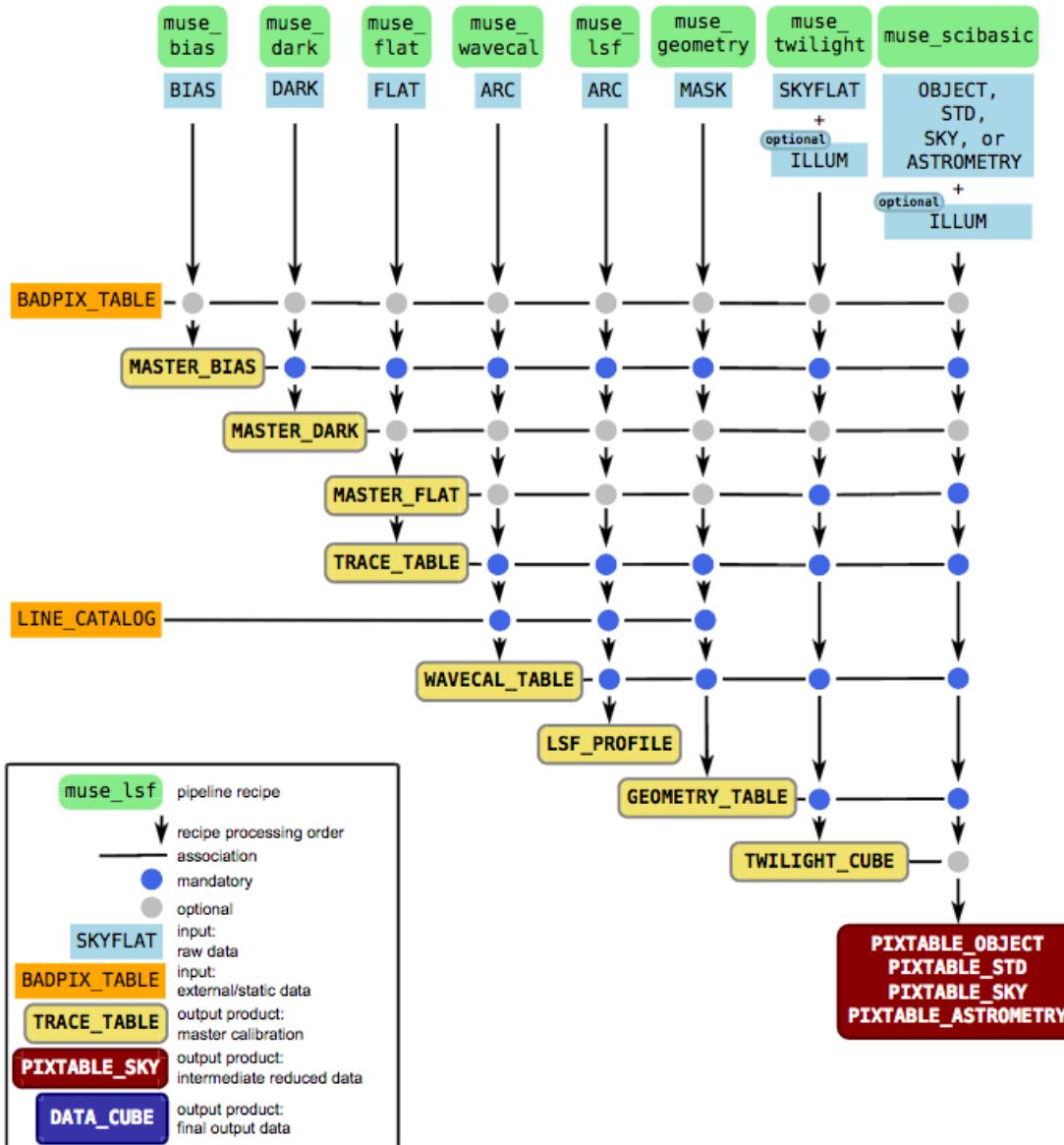


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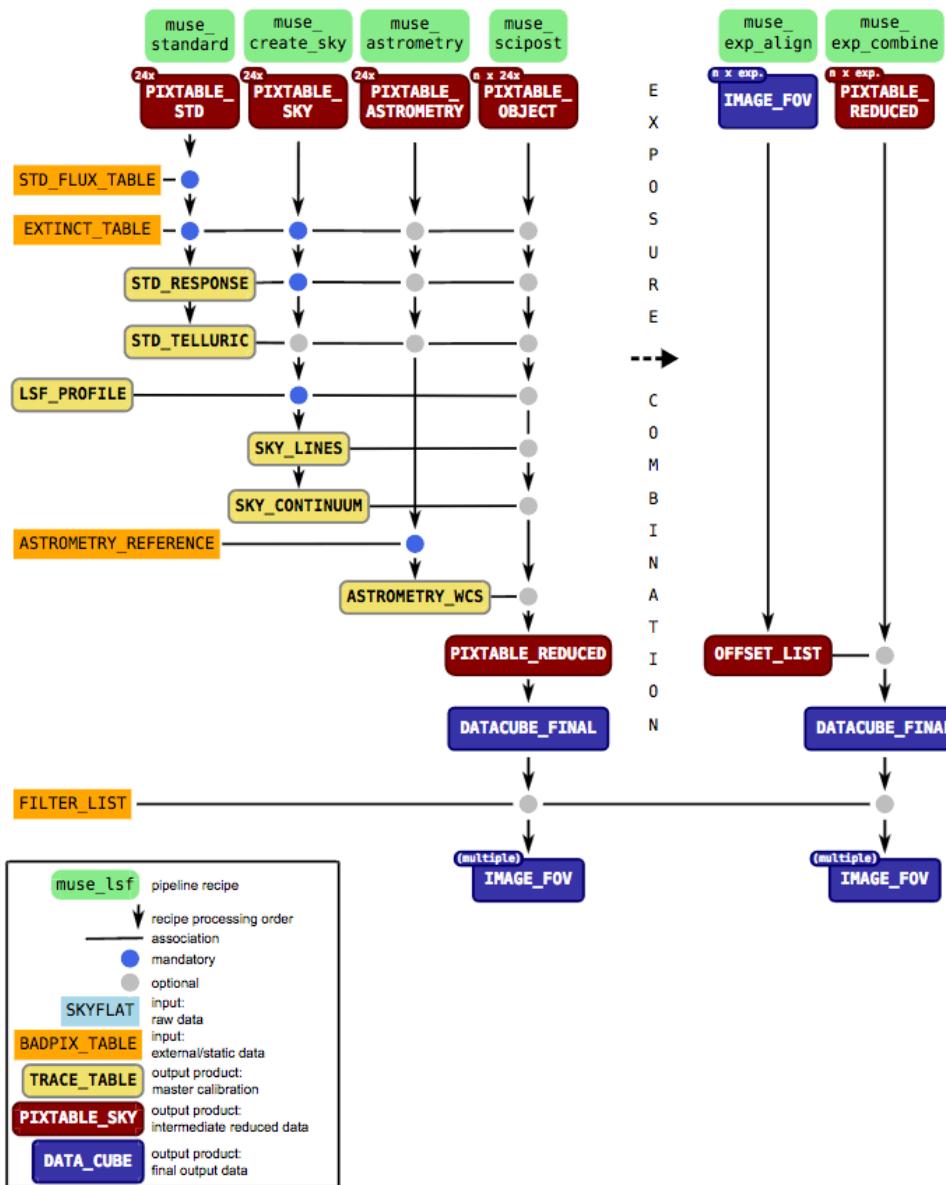
MUSE raw data RTD at console



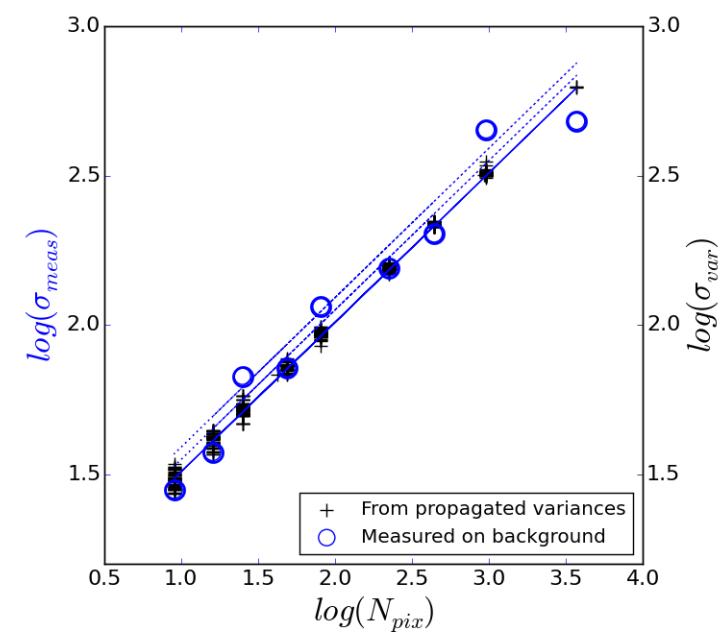
The MUSE Pipeline: pre-processing



The MUSE Pipeline: post-processing



Motivation: Combination of multiple exposures with a single resampling operation.

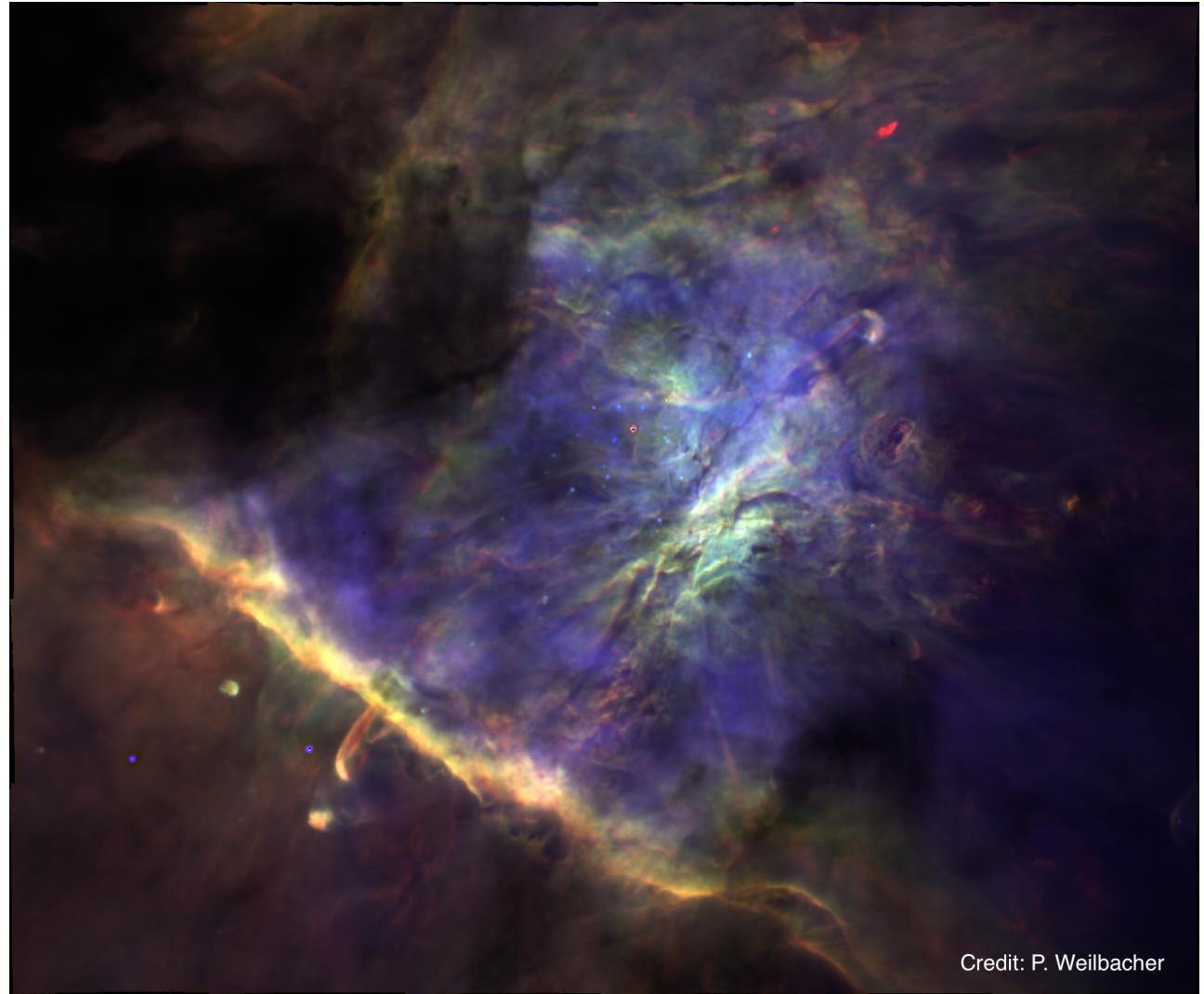


Orion MOSAIC with MUSE

A 3-colour composite
of the central Orion
Nebula

red: [SII],
green: [NII],
blue: Hbeta.

Credit: P. Weilbacher





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MUSE Calibration Plan

■ Monitor health of the instrument

- Health of cryostats
- Thermal stability of detectors
- Calibration lamp stability
- Stability of bias level and RON. Pickup noise?
- Stability of flat field RMS
- Stability of wavelength solution/**resolution**
- **Overall throughput (pending)**

■ Remove instrumental signatures

- Bad pixels, Bias, Darks, Flats, Format frames, LSF

■ Remove atmospheric signatures

- Spectrophotometry, telluric corrections

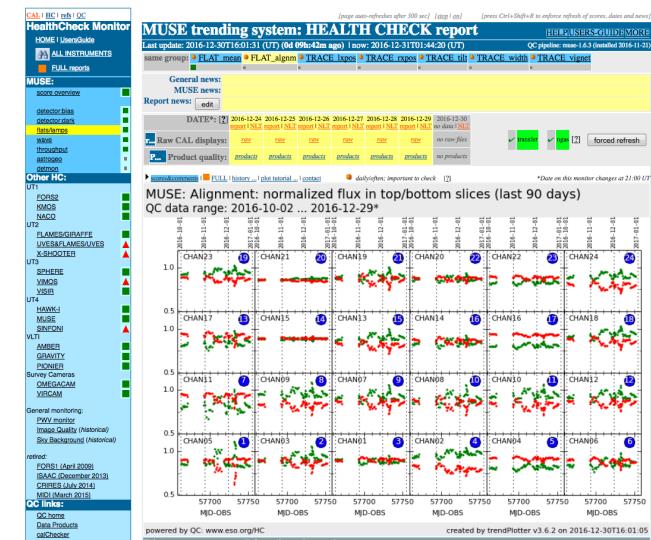
■ Calibration to physical units

- Day: Arcs
- Night: spectrophotometry, astrometry

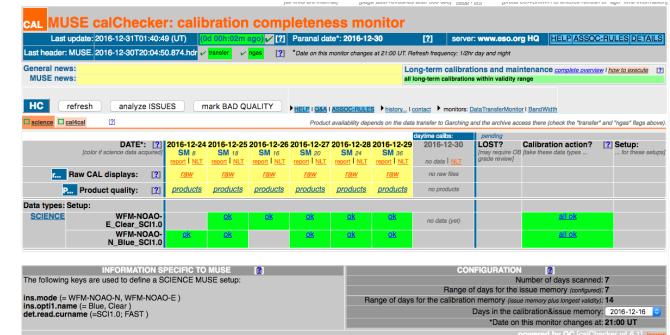
■ Monitor completeness of calibrations

- Daily: bias, flats, arcs
- Nightly: Illumination, standards
- Weekly: twilight flats
- Monthly: Darks, linearity
- Monthly night: astrometry

Health check monitor



Calibration completeness monitor



MUSE Calibration Plan

◀ ▶
bottom

MUSE raw files (date: 2017-01-10)

This is the raw file monitor with screenshots of raw calibration data. There is one page per raw data type. All files taken in the same template are displayed in the same row. The number of displayed files per template is limited depending on raw type and instrument. Files which are not displayed have a placeholder ("n/c", i.e. "not configured"). Files that could not be downloaded from the archive are marked as "not yet available". Use the 'jump' button to jump to a specific set of raw displays, labelled by their AB name. Click on the thumbnails to get a larger display together with histograms and cuts. Find more information in the help.

CAL report products NLT refs												HELP		
Available raw types: ARC BIAS LAMP_FLAT STD THROUGHPUT														
AB NAME	COMPL.	AB LOG	RECIPE	RAW_TYPE	SETUP	AB STATUS	P LOG	T_EXEC	QC REPORT	SCO	RE	CERTIF		
MUSE_2017-01-11T09:47:27.037_tpl.ab	compl.	OK	muse_flat	LAMP_FLAT	WFM-NOAO-N_Blue_SC11.0	OK	PLOG	7.6+20.6	QC COVER	✓ HC	(0/53)			
MUSE_2017-01-11T10:26.06393_tpl.ab	compl.	OK	muse_flat	LAMP_FLAT	WFM-NOAO-E_Clear_SC1.0	OK	PLOG	30.2+20.4	QC COVER	✓ HC	(0/53)			
AB NAME	COMPL.	AB LOG	RECIPE	RAW_TYPE	SETUP	AB STATUS	P LOG	T_EXEC	QC REPORT	SCORE	CERTIF			
▲ MUSE.2017-01-11T09:47:27.037_tpl.ab												INS.MODE=WFM-NOAO-N INS.OPTI1.NAME=Blue DET.READ.CURNAME=SC11.0		
MUSE_WFM_FLAT011_0001.fits MUSE.2017-01-11T09:47:27.037.fits FLAT (1/11)						n/c (2..10/11)	MUSE_WFM_FLAT011_0011.fits MUSE.2017-01-11T10:00:44.003.fits FLAT (11/11)							
EXT=01	EXT=02	EXT=03	EXT=04	EXT=05	EXT=06	...	EXT=01	EXT=02	EXT=03	EXT=04	EXT=05	EXT=06		
EXT=07	EXT=08	EXT=09	EXT=10	EXT=11	EXT=12	...	EXT=07	EXT=08	EXT=09	EXT=10	EXT=11	EXT=12		
EXT=13	EXT=14	EXT=15	EXT=16	EXT=17	EXT=18	...	EXT=13	EXT=14	EXT=15	EXT=16	EXT=17	EXT=18		
EXT=19	EXT=20	EXT=21	EXT=22	EXT=23	EXT=24	...	EXT=19	EXT=20	EXT=21	EXT=22	EXT=23	EXT=24		

- Weekly: twilight flats
- Monthly: Darks, linearity
- Monthly night: astrometry

The following keys are used to define a SCIENCE MUSE setup:	Range of days for the issue memory: 7	Number of days scanned: 7
ins.mode (= WFM-NOAO-N, WFM-NOAO-E)	Range of days for the calibration memory (issue memory plus longest validity): 7	Range of days for the calibration memory (issue memory plus longest validity): 7
ins.name (= Blue, Clear)	Days in the calibration&issue memory: 2016-12-16	Days in the calibration&issue memory: 2016-12-16
det.read.curname (=SC11.0;FAST)	Days on this monitor changes at: 21:00 UT	Days on this monitor changes at: 21:00 UT

MUSE Calibration Plan

◀ ▶
bottom

MUSE raw files (date: 2017-01-10)

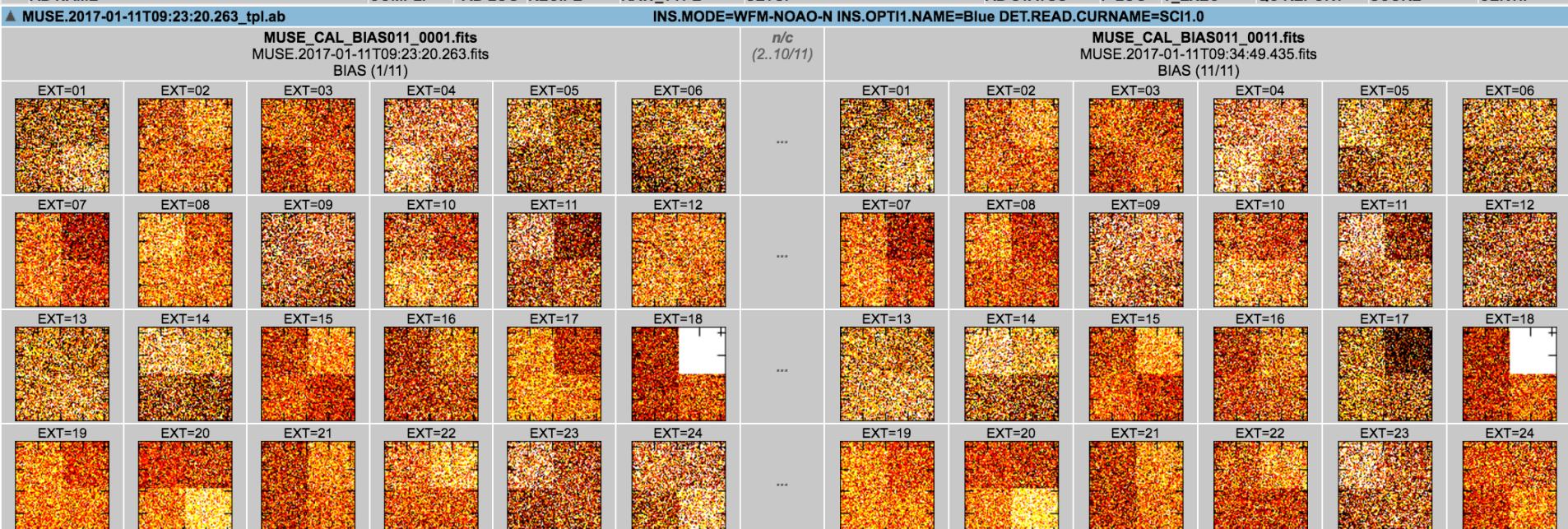
This is the raw file monitor with screenshots of raw calibration data. There is one page per raw data type. All files taken in the same template are displayed in the same row. The number of displayed files per template is limited depending on raw type and instrument. Files which are not displayed have a placeholder ("n/c", i.e. "not configured"). Files that could not be downloaded from the archive are marked as "not yet available". Use the 'jump' button to jump to a specific set of raw displays, labelled by their AB name. Click on the thumbnails to get a larger display together with histograms and cuts. Find more information in the help.

CAL report products NLT | refs

HELP

Available raw types: [ARC](#) | [BIAS](#) | [LAMP_FLAT](#) | [STD](#) | [THROUGHPUT](#)

AB NAME	COMPL.	AB LOG	RECIPE	RAW_TYPE	SETUP	AB STATUS	P LOG	T_EXEC	QC REPORT	SCO	RE	CERTIF
MUSE_2017-01-11T09:23:20.263_tpl.ab	compl.	OK	muse_bias	BIAS	WFM-NOAO-N_Blue_SCI1.0	OK	PLOG	5.9+8.0	QC COVER	✓HC	[0/104]	
AB NAME	COMPL.	AB LOG	RECIPE	RAW_TYPE	SETUP	AB STATUS	P LOG	T_EXEC	QC REPORT	SCORE		CERTIF



last update: 2017-01-11 19:33:14 (UT)

top

created on muc09 by getStatusAB v3.8.1, a dfos tool
number of days selected: 7
Range of days for the issue memory (combined): 7
ins.mode (=WFM-NOAO-N) Range of days for the calibration memory (issue memory plus longest validity): 14
ins.recipe_name (=Blue_Cross)
det.read.curname (<SCI1.0>:FAST)
Days in the calibration&issue memory: 2016-12-16
*Date on this monitor changes at 21:00 UT
powered by GeG (getstatus v4.8.1) [more]

- Weekly: twilight flats
- Monthly: Darks, linearity
- Monthly night: astrometry

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- Stability of flat field RMS
- Stability of wavelength solution/**resolution**
- **Overall throughput (pending)**

■ Remove instrumental signatures

- Bad pixels, Bias, Darks, Flats, Format frames, LSF

■ Remove atmospheric signatures

- Spectrophotometry, telluric corrections

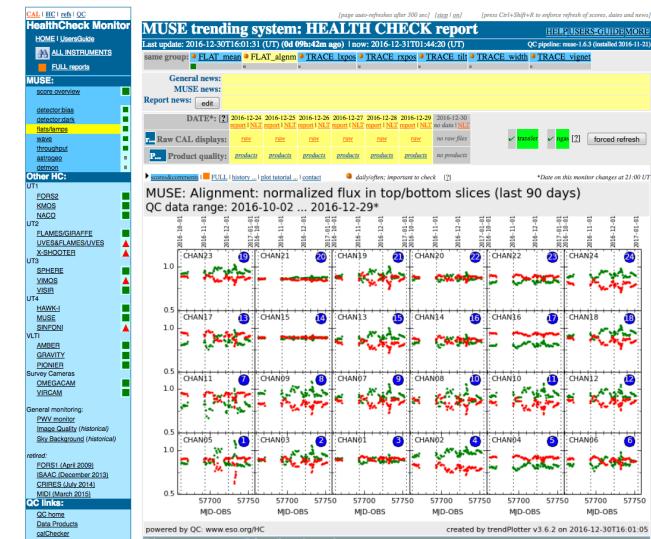
■ Calibration to physical units

- Day: Arcs
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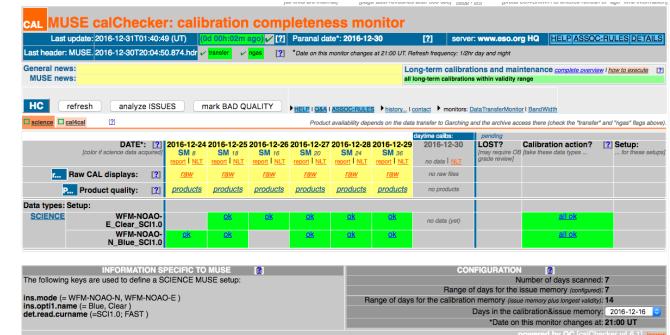
■ Monitor completeness of calibrations

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- Weekly: twilight flats
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- Monthly night: astrometry

Health check monitor



Calibration completeness monitor

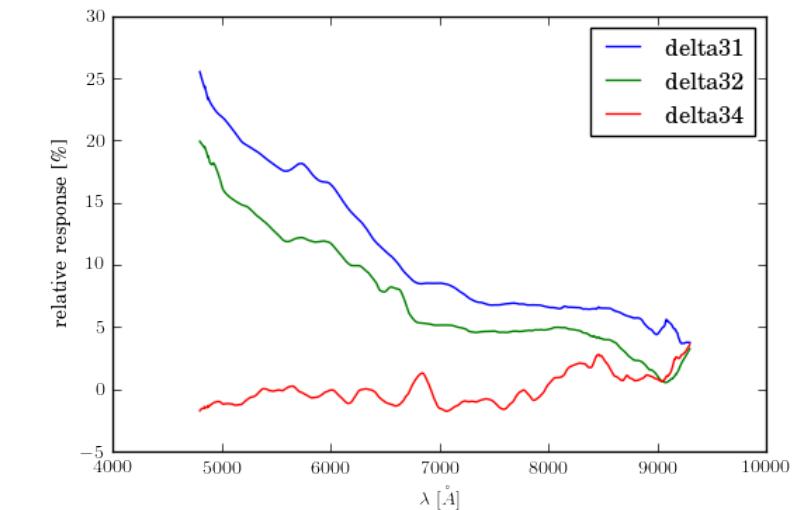
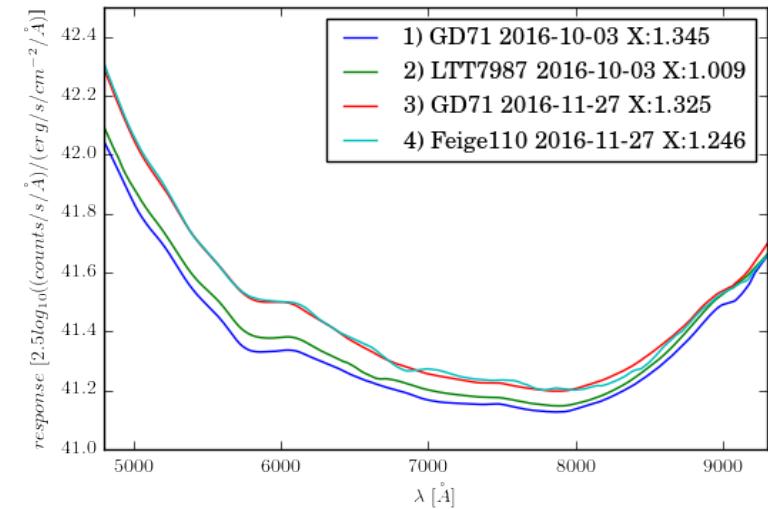




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Overall throughput monitoring

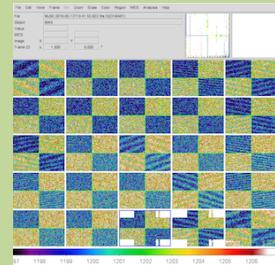
- How to compare standards taken at two different epochs? The flat field lamp changes with time...
- A new version of the pipeline is being developed that will permit the proper comparison.



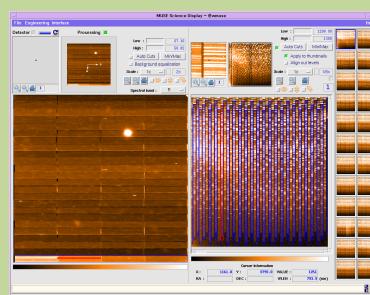


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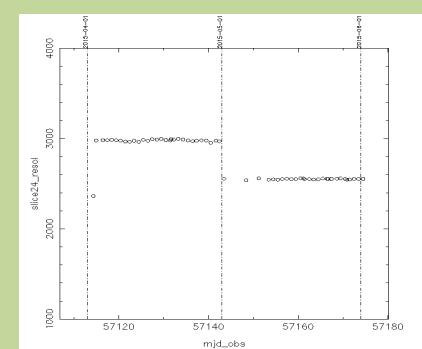
MUSE challenges



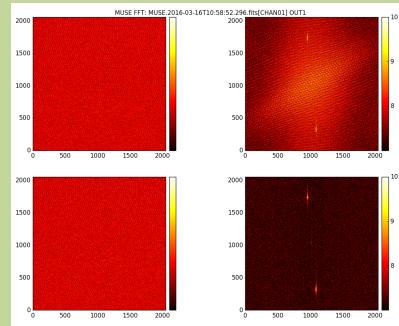
Bias instabilities



Amplifier glow



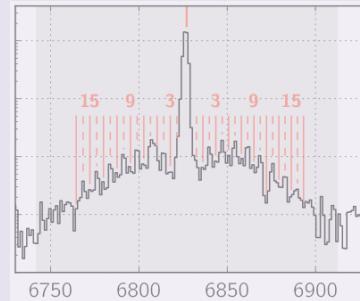
Electronically induced
loss of resolution



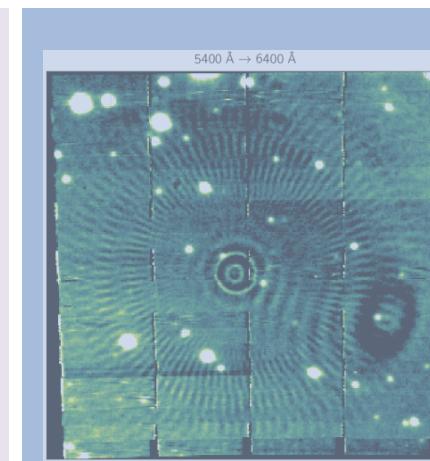
Pickup noise

PAST

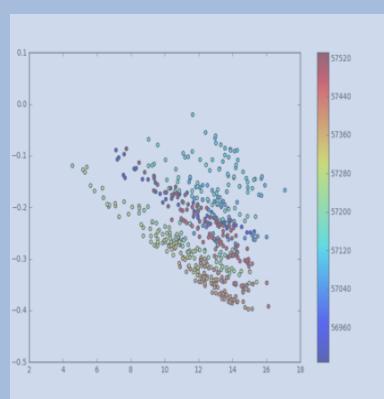
FUTURE



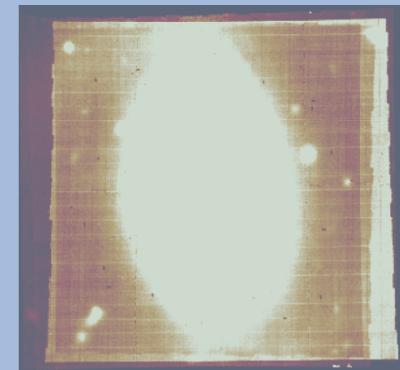
Raman scattering



Ferris wheel



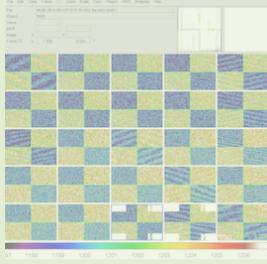
T-dependent flat field



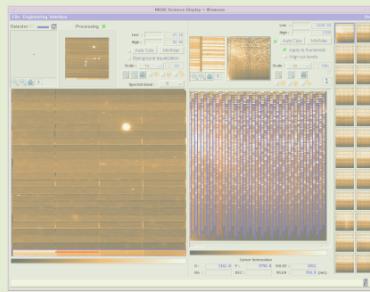
Large scale residuals

PRESENT

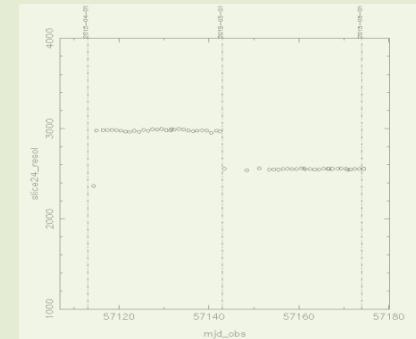
MUSE challenges



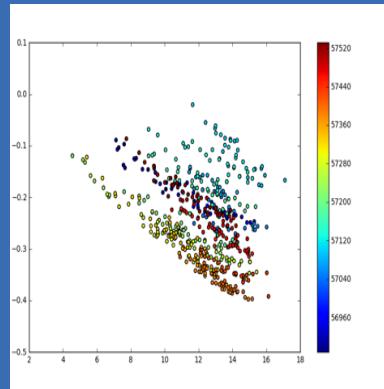
Bias instabilities



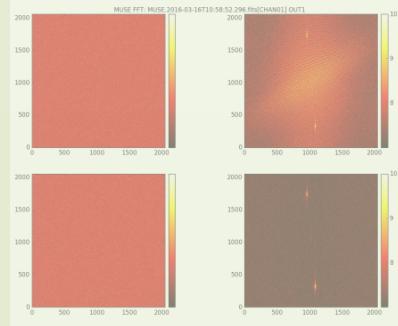
Amplifier glow



Electronically induced loss of resolution

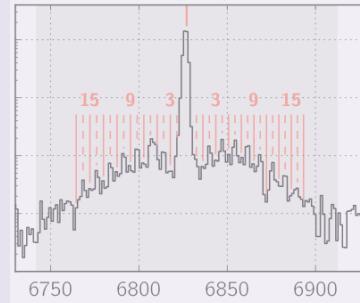


T-dependent flat field

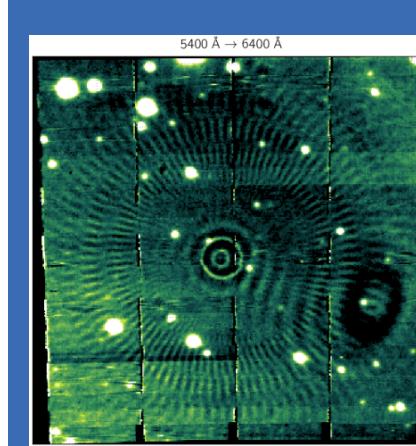


Pickup noise

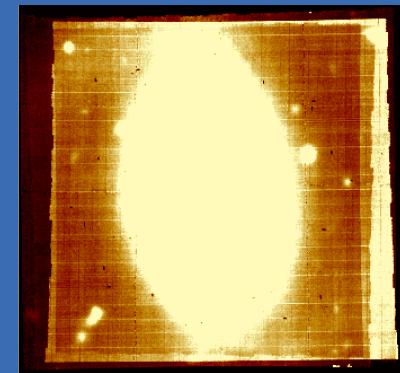
FUTURE



Raman scattering



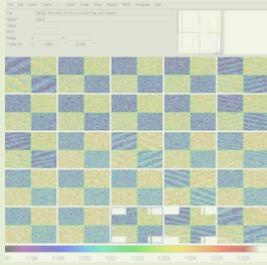
Ferris wheel



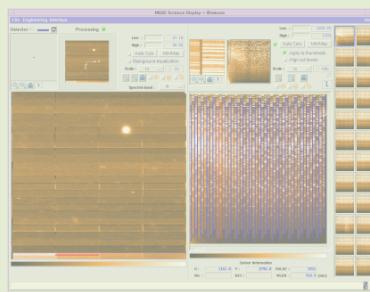
Large scale residuals

PAST

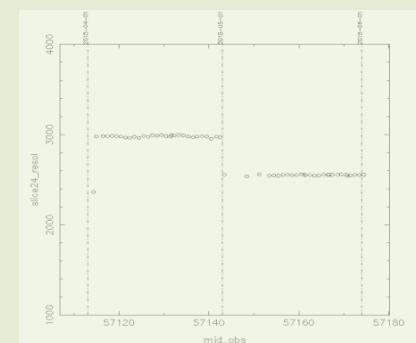
MUSE challenges



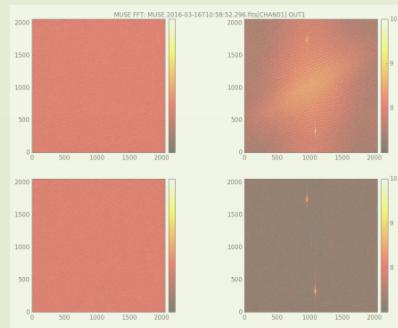
Bias instabilities



Amplifier glow



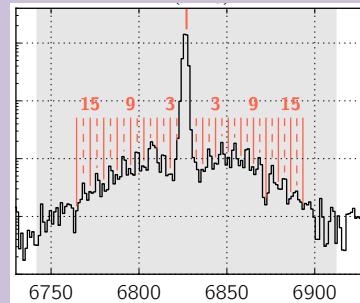
Electronically induced loss of resolution



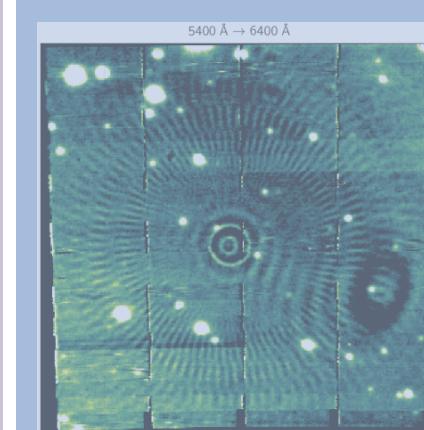
Pickup noise

PAST

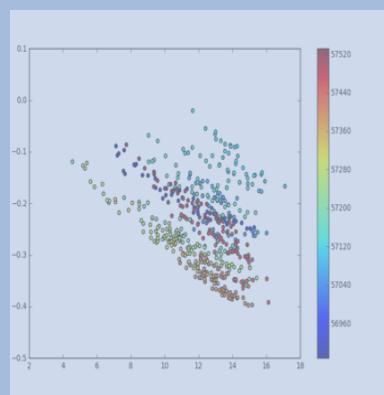
FUTURE



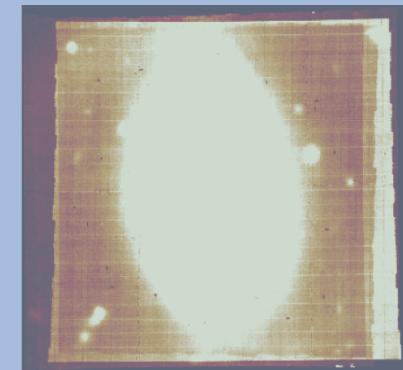
Raman scattering



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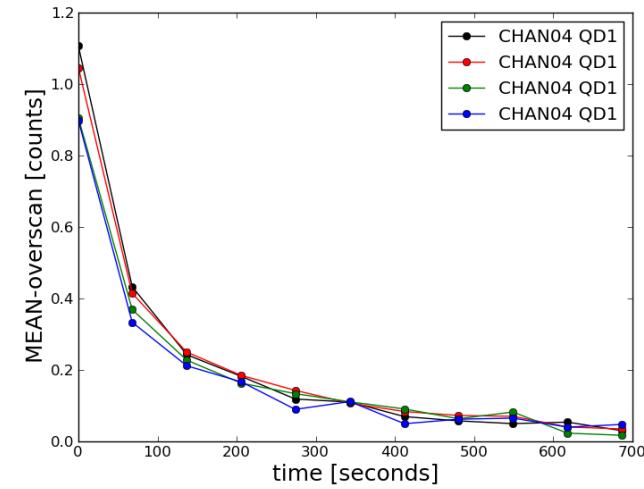
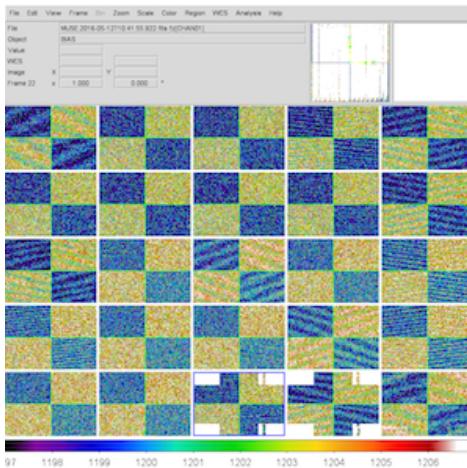
T-dependent flat field



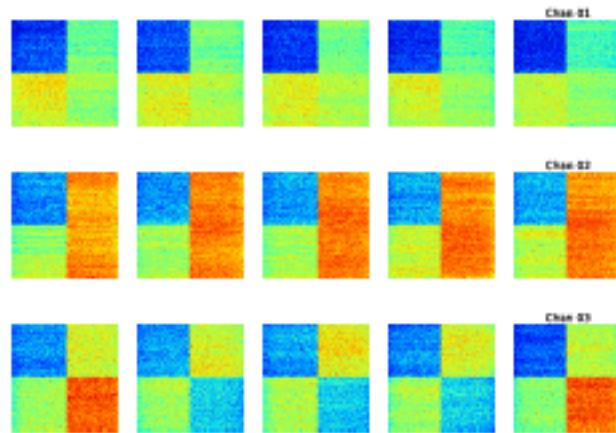
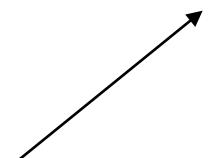
Large scale residuals

PRESENT

Initially bias issues in all channels



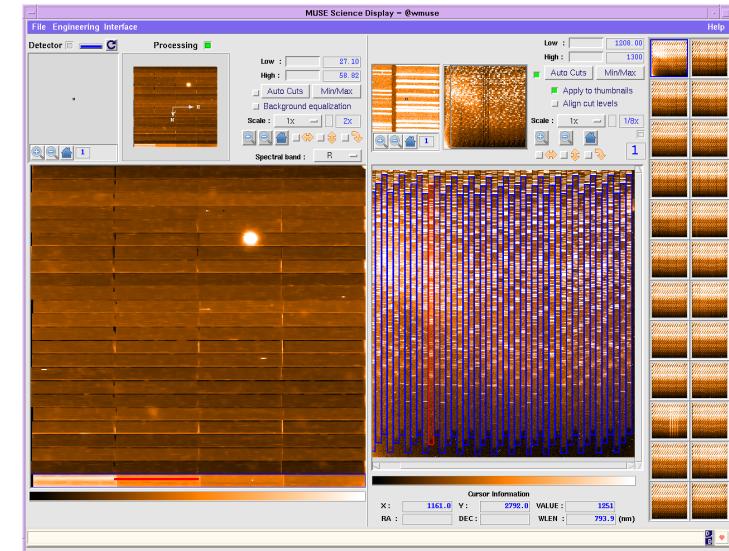
- At the start of operations an important challenge came from bias instabilities.
- The bias showed all kind of structures. Even subtracting overscan there was an unexplained time evolution.
- This issue was finally solved by continuous clocking the detectors.



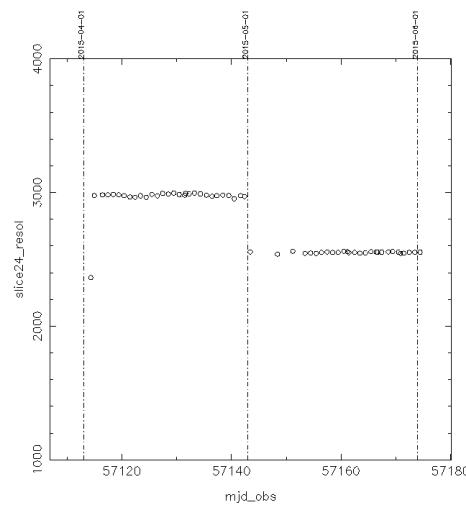
CHAN01 amplifier glow

These plots illustrate three challenges:

- First, the drop in resolution, which occurred initially after exchanging the CHAN01 original cryostat and detector which had an output amplifier glowing – this operation requires to refocus the channel;
- Second, the first thing that comes to mind as a possible origin of a problem is not always the actual cause;
- And last, it is a major challenge to keep configuration under control.



2015-05-01



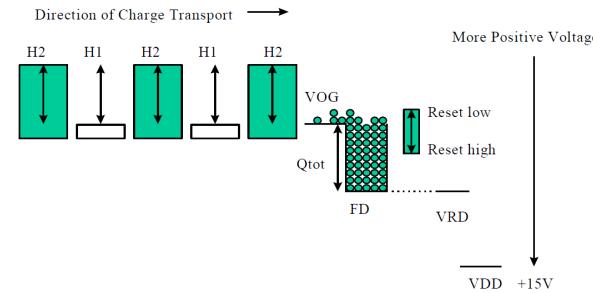
CHAN01 resolution drop

These plots illustrate three challenges:

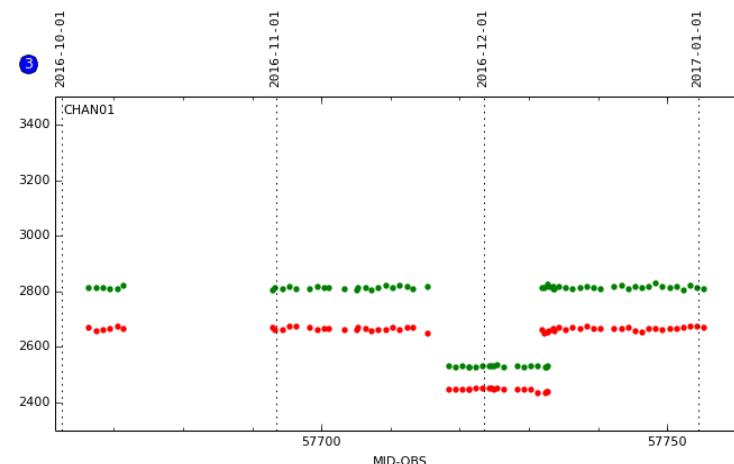
- First, the drop in resolution, which occurred initially after exchanging the CHAN01 original cryostat and detector which had an output amplifier glowing – this operation requires to refocus the channel;
- Second, the first thing that comes to mind as a possible origin of a problem is not always the actual cause;
- And last, it is a major challenge to keep configuration under control.

9.0 Saturated Video Output Signal

Charge is dumped onto the Floating Diffusion (FD) on the falling edge of H2. If enough electrons are present, they can flow back over the output gate if VOG is set too positive. Figure 11 illustrates the effect this has on the video output.



MUSE: RESOLUTION in slice24 and slice1 per channel (last 90 days, close-up)
QC data range: 2016-10-05 ... 2017-01-01*



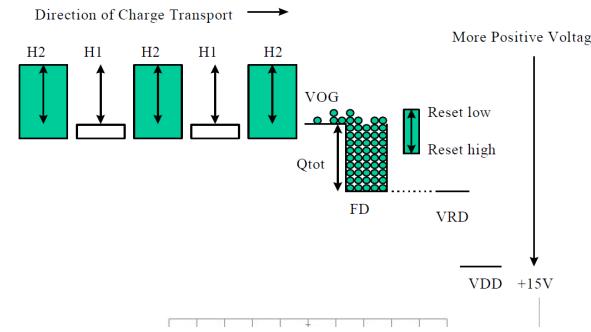
CHAN01 resolution drop

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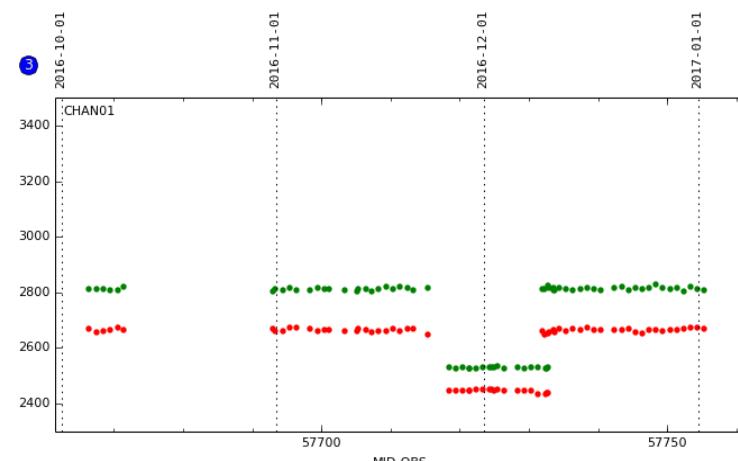
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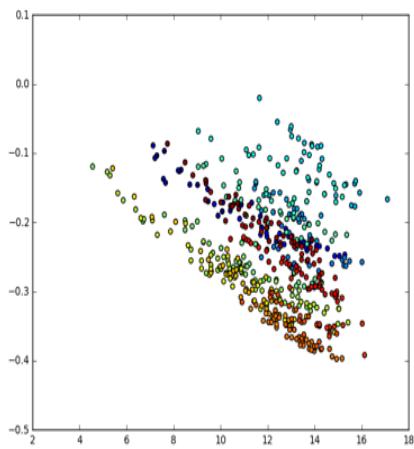
MUSE: RESOLUTION in slice24 and slice1 per channel (last 90 days, close-up)
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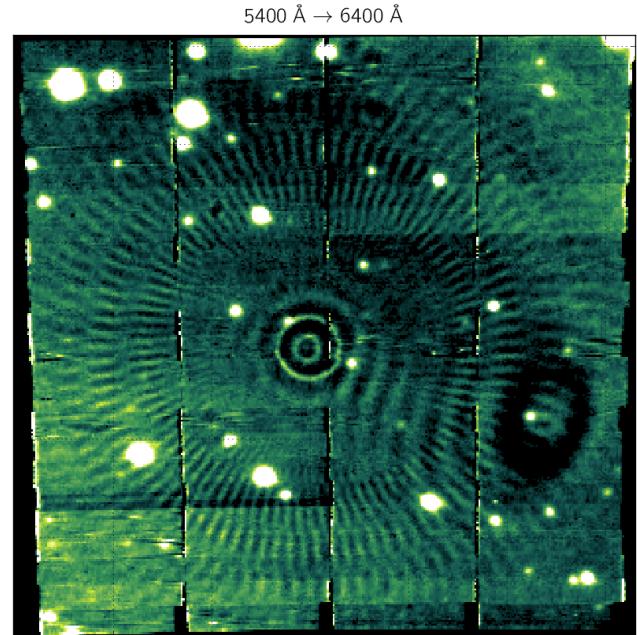
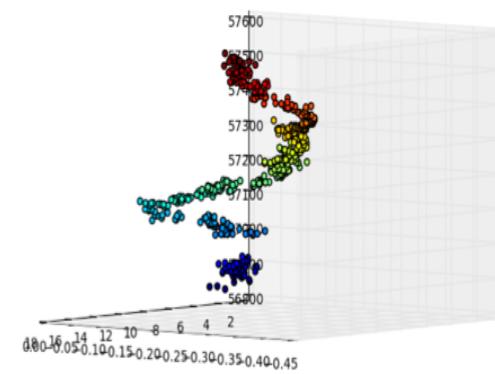


- The MUSE team
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 - A pending issue
- MUSE challenges
- Current challenges
- Future Challenges

Current challenges

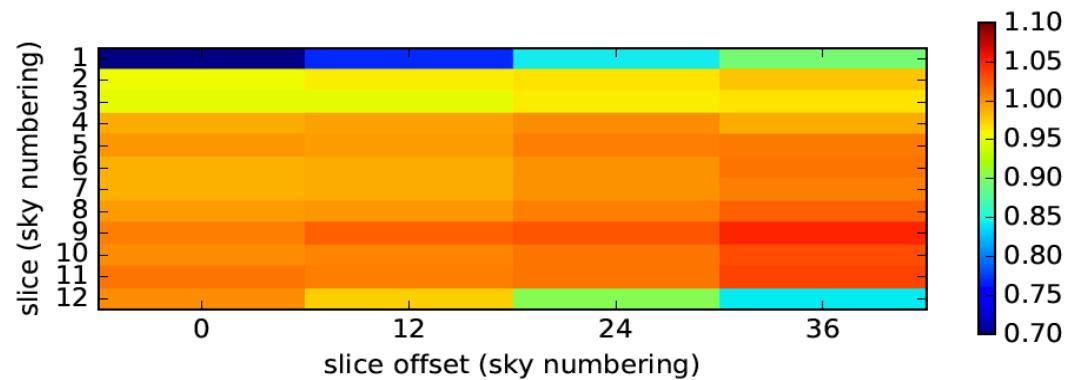


T dependent flat field

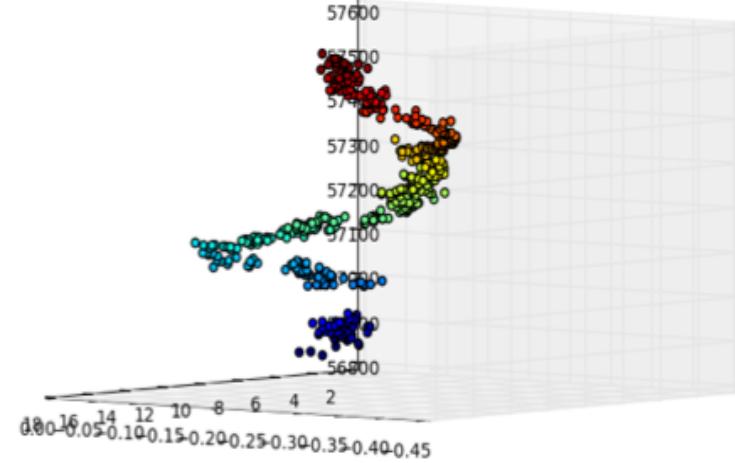
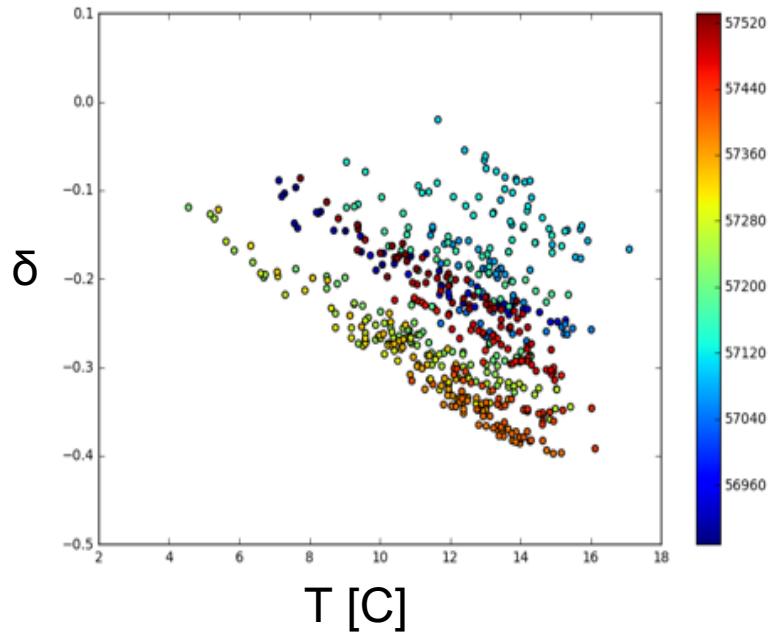


Ferris wheel

Day calibrations: flat field



$$\delta = 2 \times (\text{upper} - \text{lower}) / (\text{upper} + \text{lower})$$

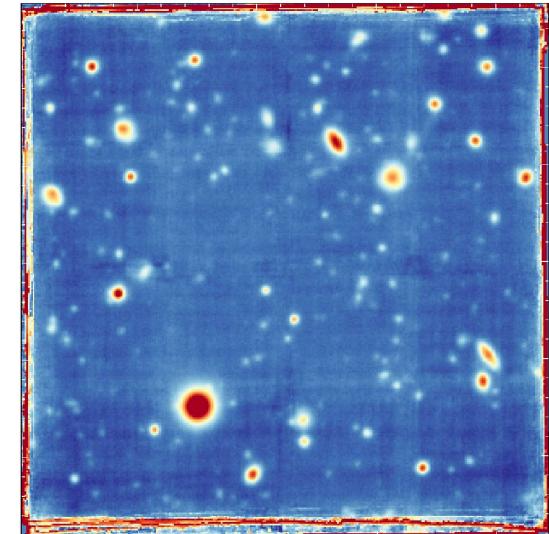
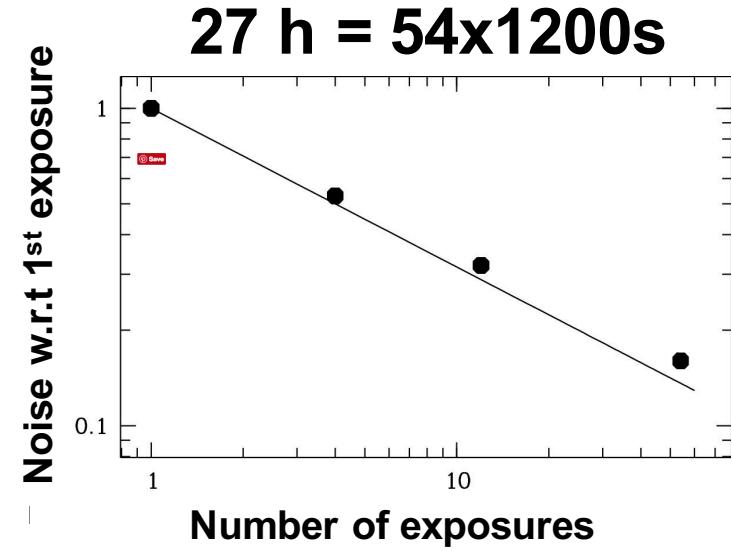
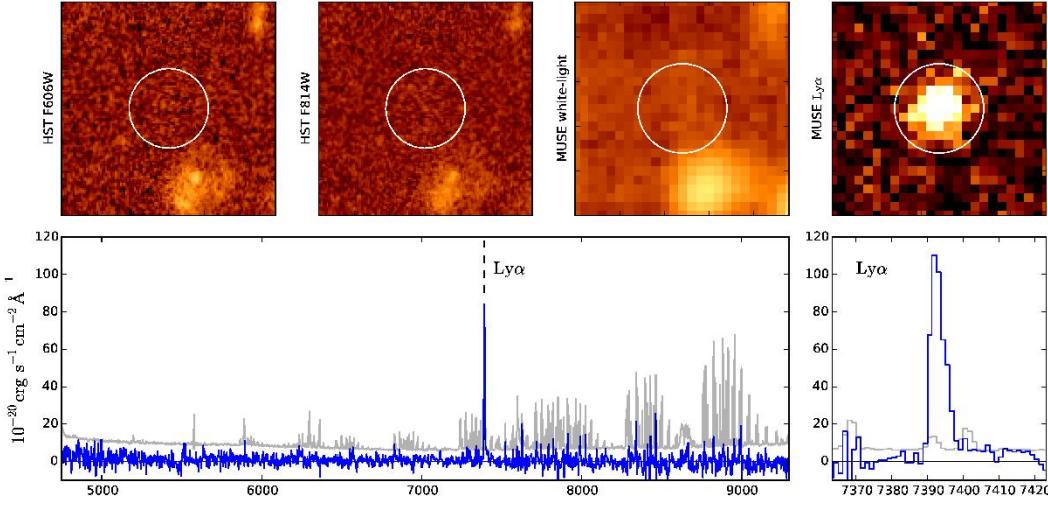


δ vs T vs time

Flat field: why do we care?

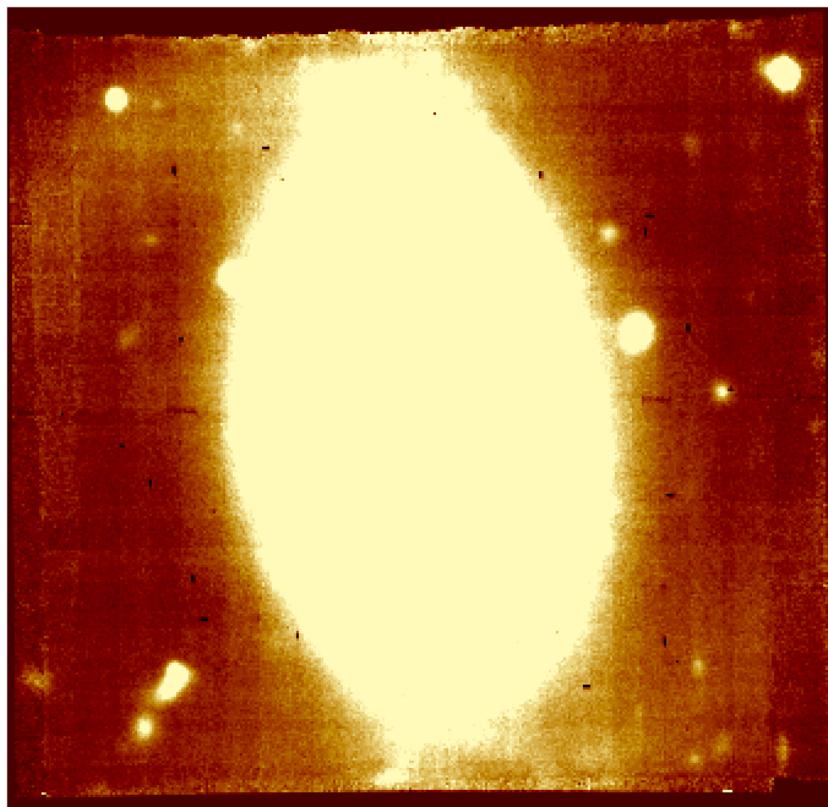
*Need for low noise background
on SMALL scales*

A&A 575, A75 (2015)
**The MUSE 3D view of the
Hubble Deep Field South**
Bacon et al.

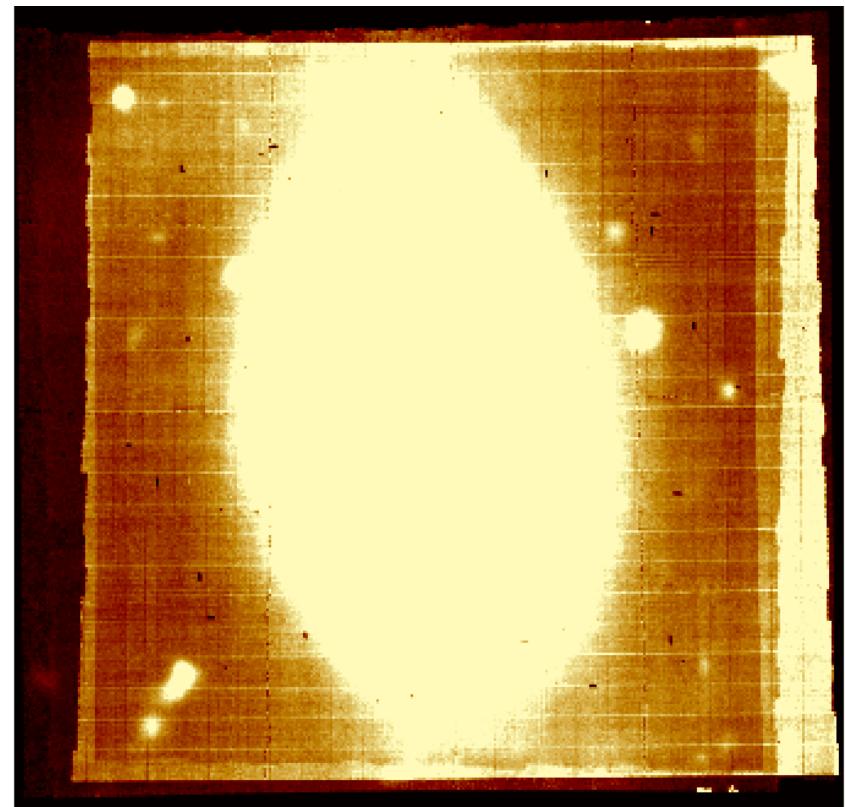


Low level large scale residuals

Recent geometry/astrometry
[continuum 600-700 nm]



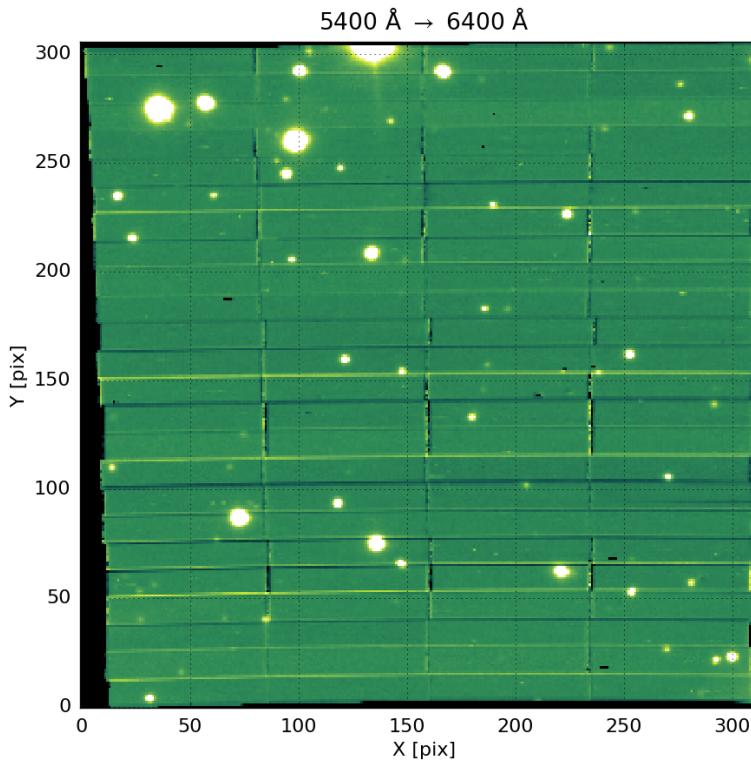
Older geometry/astrometry
[continuum 600-700 nm]



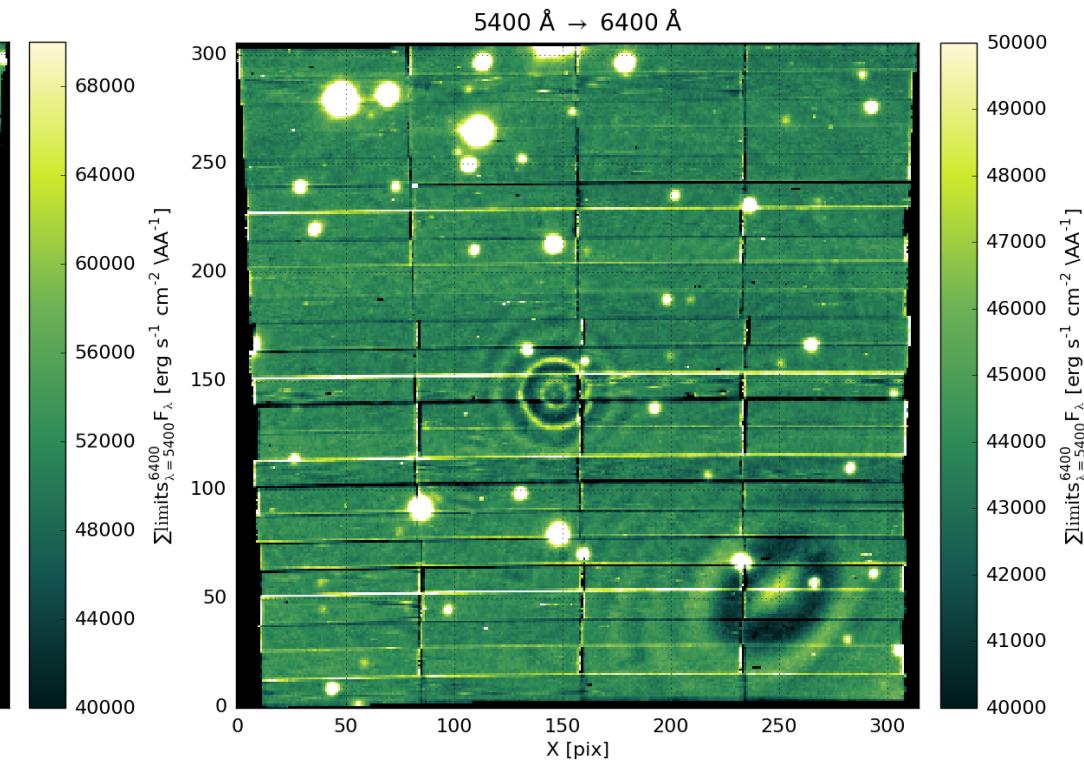
Need low noise background on LARGE scales

Ferris wheel

October 2016 at closeout,
no Ferris Wheel



November recomm: it is back.

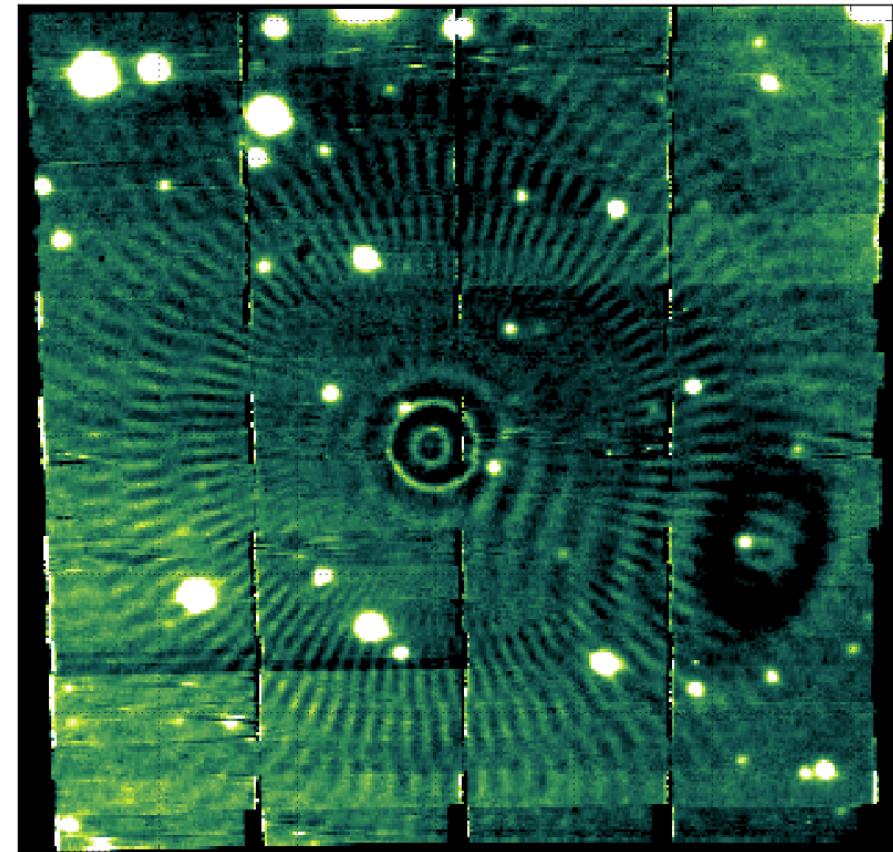


■ The artefact comes and go. We know that the guide probe position does have an effect. WIP...

The Ferris wheel

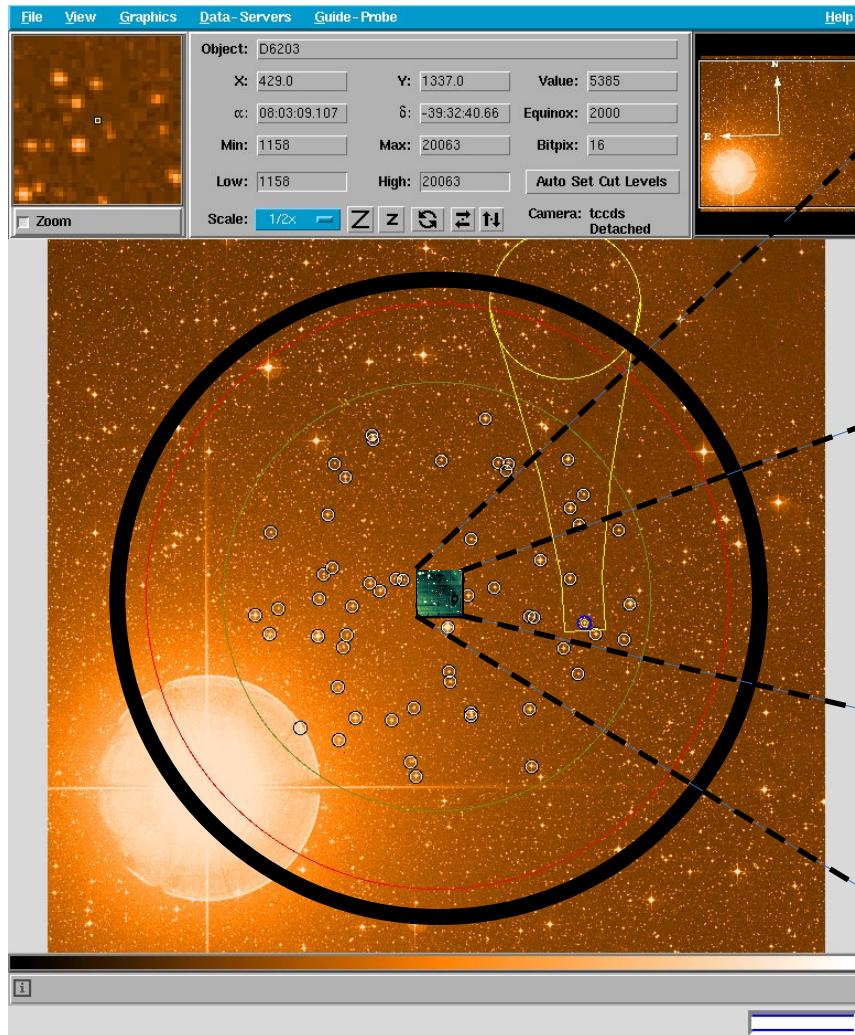
MUSE field-of-view

5400 Å → 6400 Å

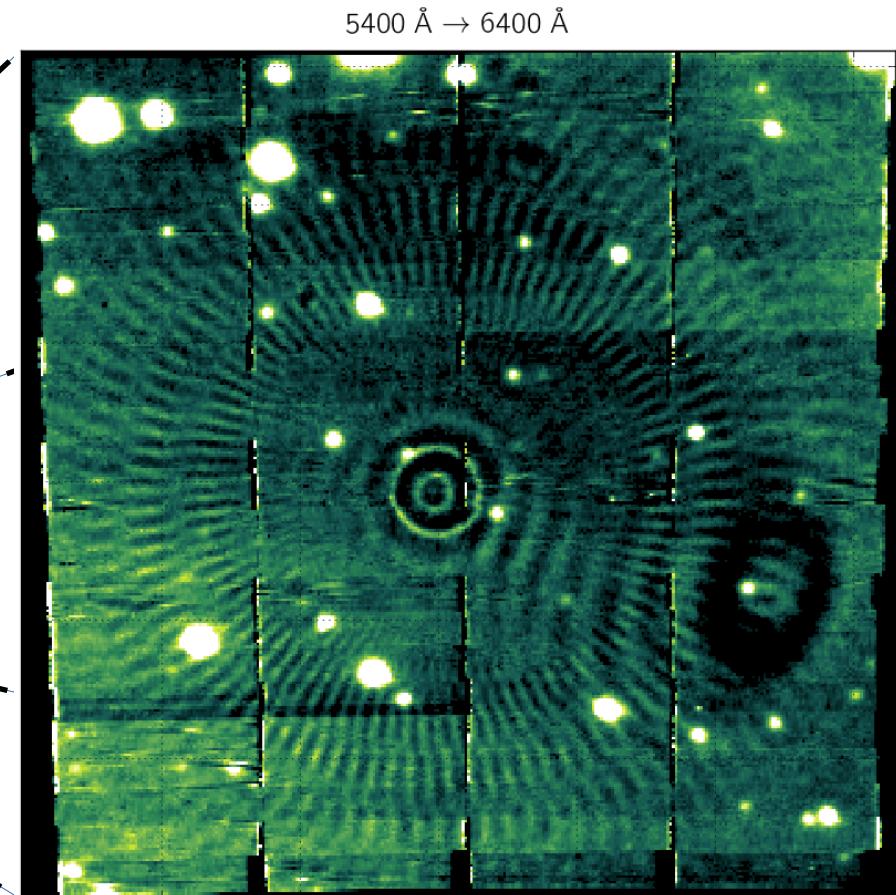


The Ferris wheel

VLT field-of-view



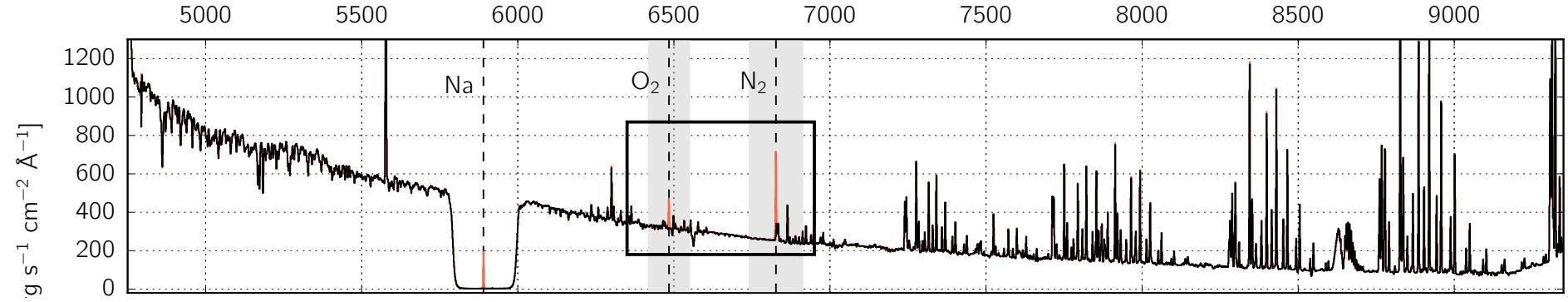
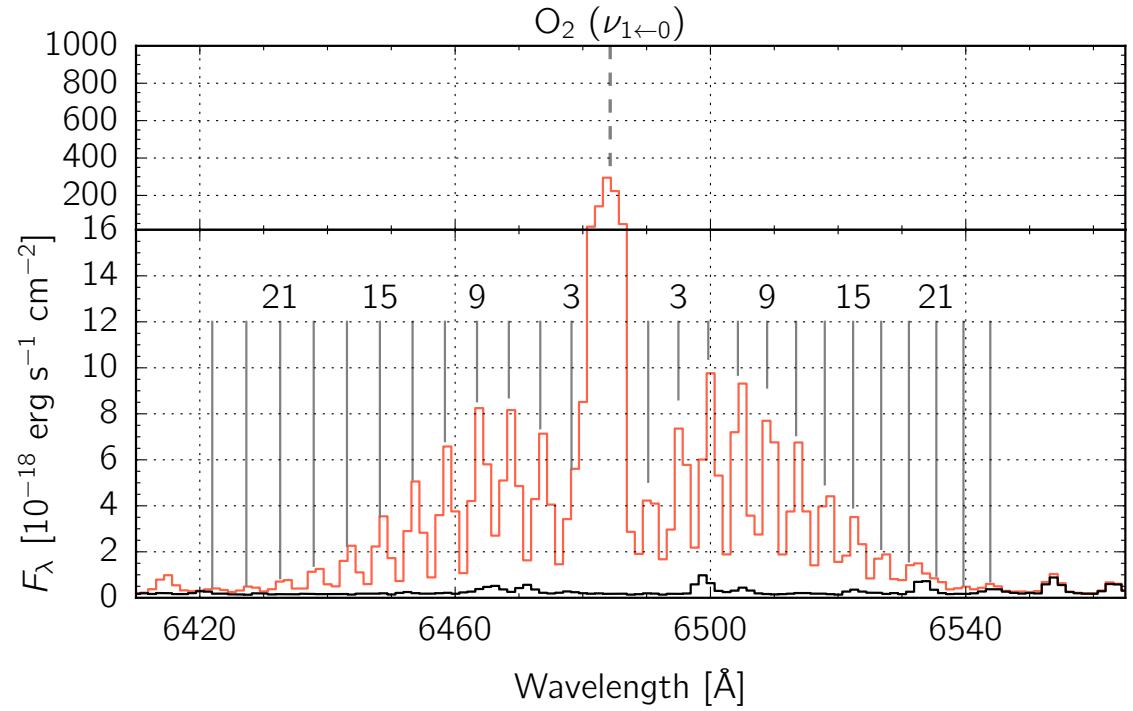
MUSE field-of-view





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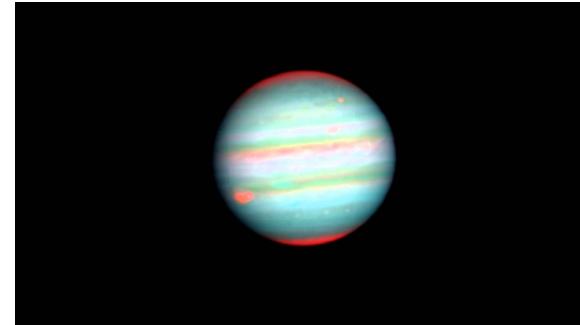
Raman scattering



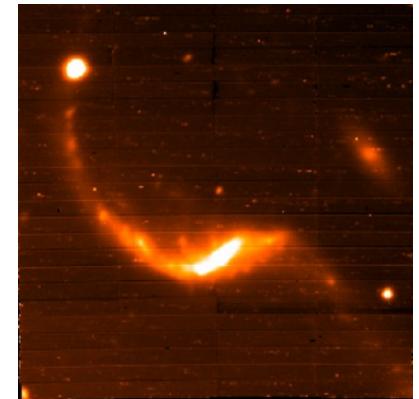
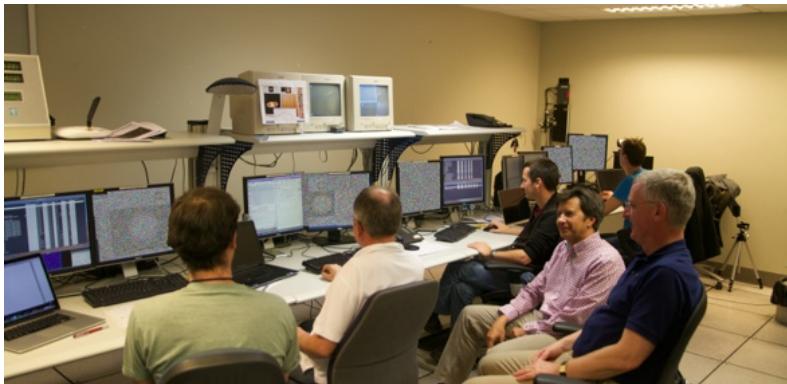
Concluding remarks

- Since first light on 31 Jan 2014 MUSE has been delivering science quality data, operating with almost no technical downtime.
- One of the keys for the success was to have a pipeline quite mature at commissioning time. This permitted prompt monitoring of the system.
- Despite the success we were not trouble free. The main operating challenges came initially from the detector system. Close monitoring allowed us to detect the problems in time, although not always correct them rapidly.
- A problem that was anticipated very early on was the need to calibrate the flat field response frequently enough. Flat fielding and sky subtraction are among the main challenges to data quality and sensitivity.
- Current instrumental challenge include the understanding of the light contamination of the focal plane, which might give the ultimate limit to sensitivity.
- Future operation challenges include a) keeping the configuration control during GALACSI installation and b) the characterization of the possible Raman contamination in laser operation, specially in NFM.

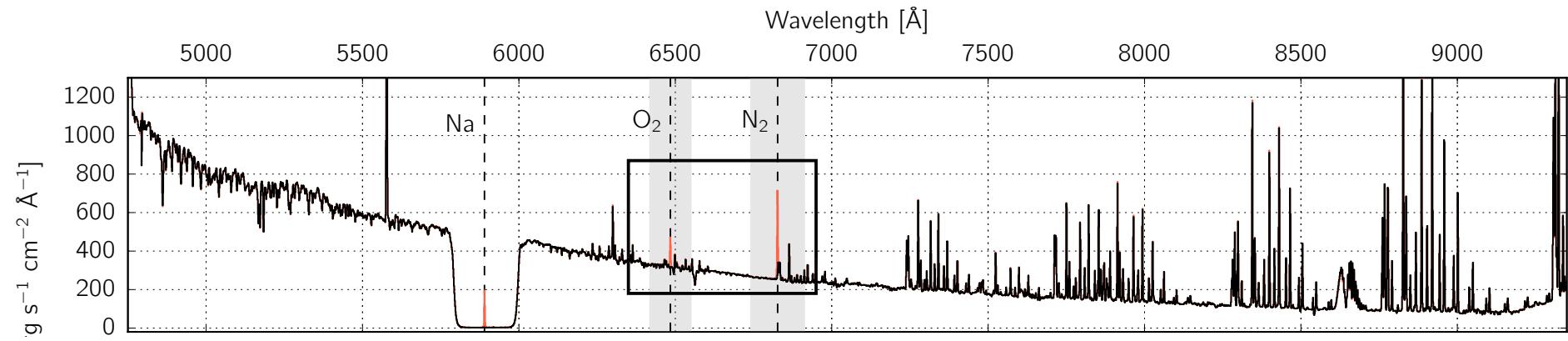
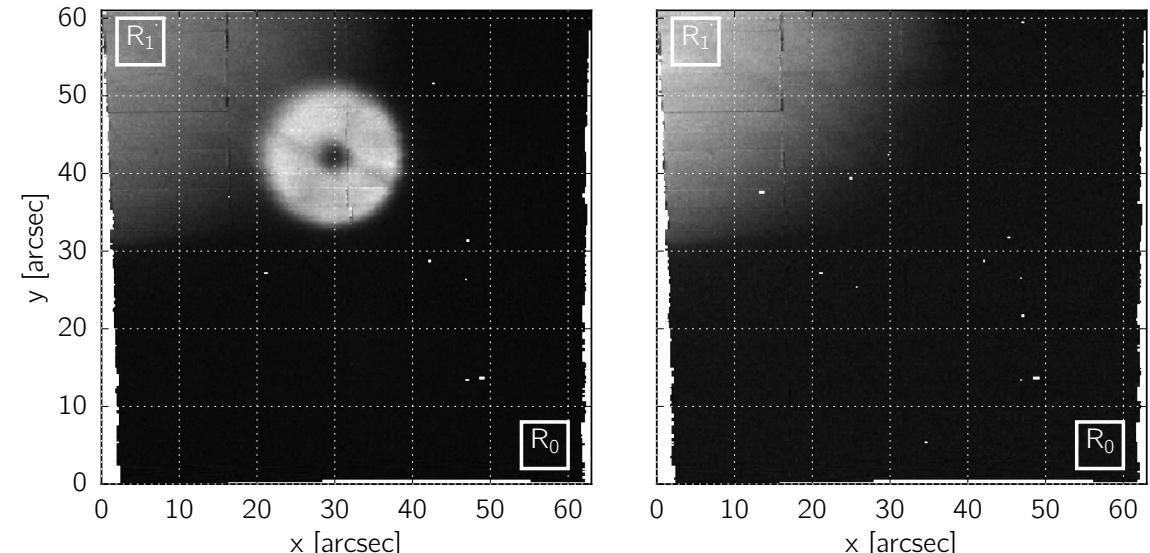
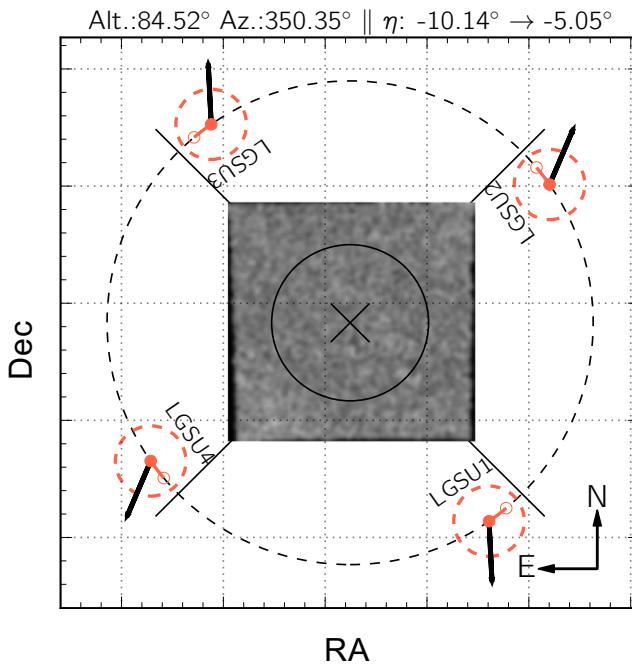
Reconstructed image of one strip in the Trifid nebulae. Only 1 million of spectra in this exposure, but already a huge physical content to explore.



THE END



Raman scattering



The MUSE team

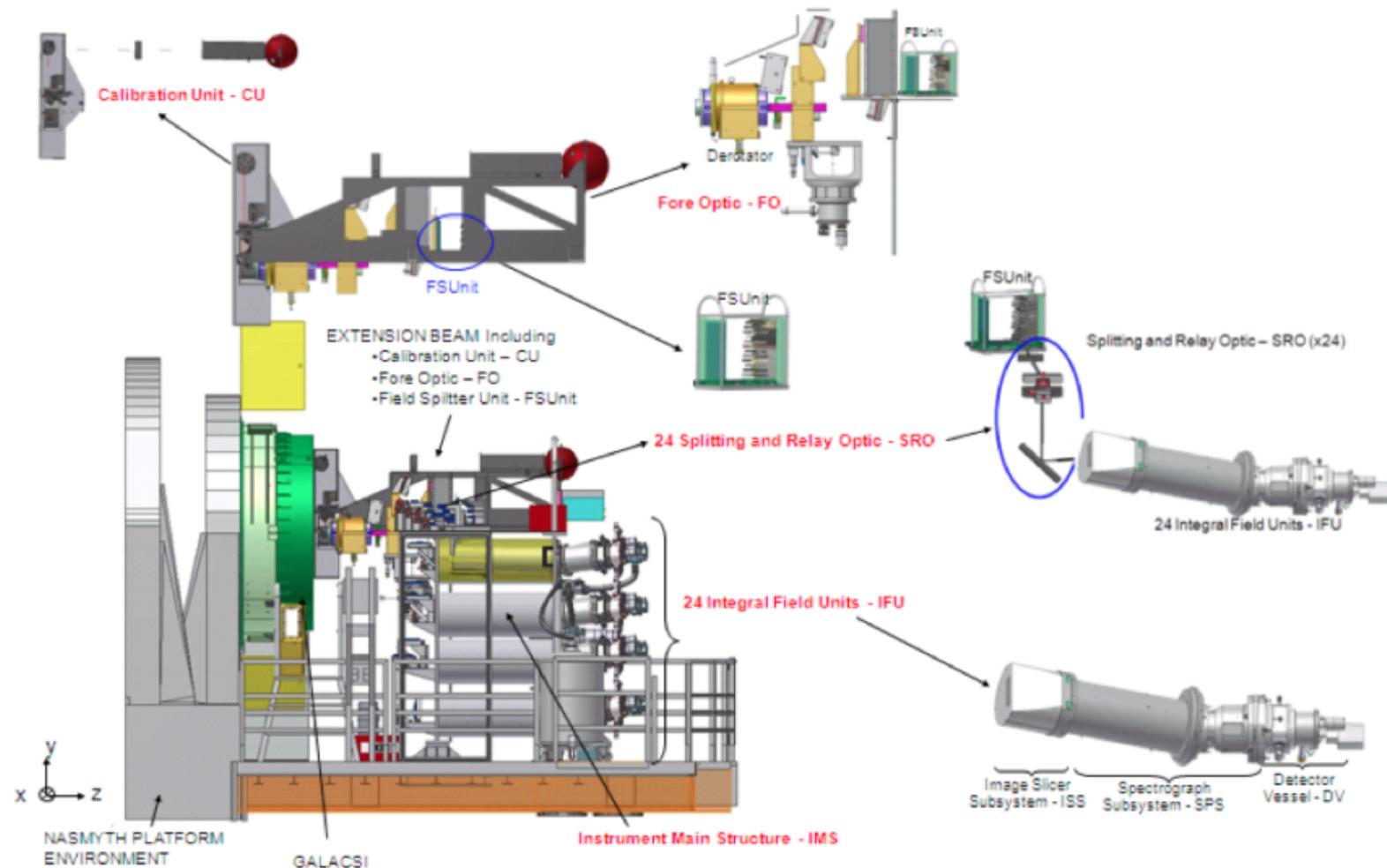
PI: R. Bacon, Lyon – ESO responsible: A. Glindeman – ESO Instrument
 Scientist: J. Vernet -- ESO Project Manager: A. Manescau

Institute		Responsibility
Leibniz-Institut für Astrophysik Potsdam		Development of the Calibration Unit, testing of the preassembled spectrograph -- detector units, data reduction software.
Centre de Recherche Astrophysique de Lyon		Overall management of the project, image slicer sub system, spectrograph opto--mechanical design and integration, data analysis software.
ESO		Detector systems (24 detectors and their cryogenic environment), GALACSI.
ETH – Institute of Astronomy (Zurich)		Procurement of the 24 spectrographs.
Institut für Astrophysik Göttingen		Design, analysis and procurement of the instrument mechanics, the support and handling structures as well as for the optics that apply the field splitting and the relay optics.
Institut de Recherche en Astrophysique et Planétologie (Toulouse)		Electronic and Software Control of the whole Instrument, Opto--mechanical development of the Fore--Optics module.
Leiden Observatory		Interface between the MUSE spectrograph and the adaptive optics system, definition of the top--level requirements for the adaptive optics system.

The ESO MUSE IOT: operates

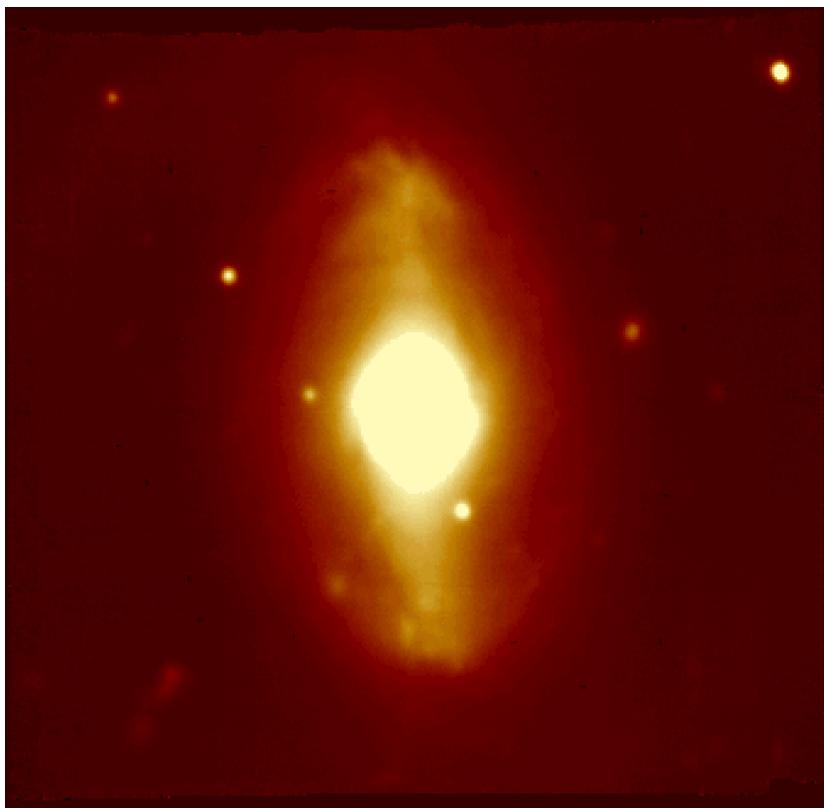
- Paranal IOT Coordinator – Alain Smette
- Paranal Instrument Scientist – Fernando Selman
- Paranal Instrument Fellows – Evelyn Johnston, Yara Jaffe, Vogt (Honoris...)
- Paranal Instrument TIO – Susana Cerda, Cristian Herrera
- Paranal Instrumentation Responsible – Hicolas Haddad
- Paranal Software Responsible – Pedro Baksai, Gerard Zins
- Garching Instrument Scientist – Joel vernet
- Garching Quality Control Scientist – Danuta Dobryzyka
- Garching User Support Astronomer – Elena Valenti
- Garching Pipeline Responsible – Ralf Palsa
- Garching Advanced Data Products Responsible – Lodovico Coccato

The MUSE Instrument

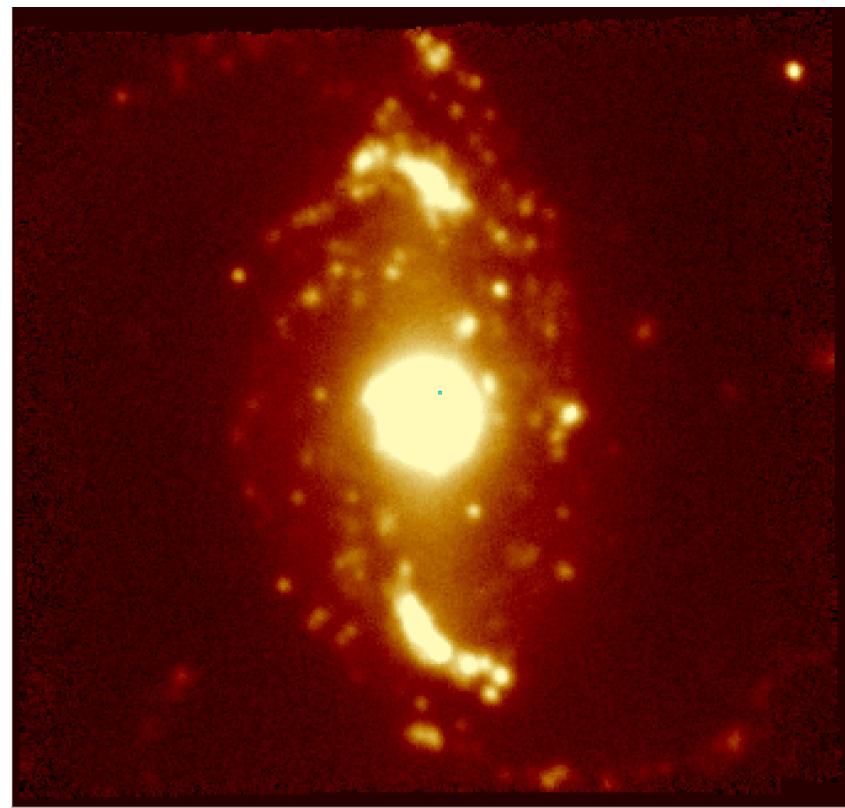


From observation to reduced data

Continuum 700 nm



H-alpha



Seq: O S O O S O

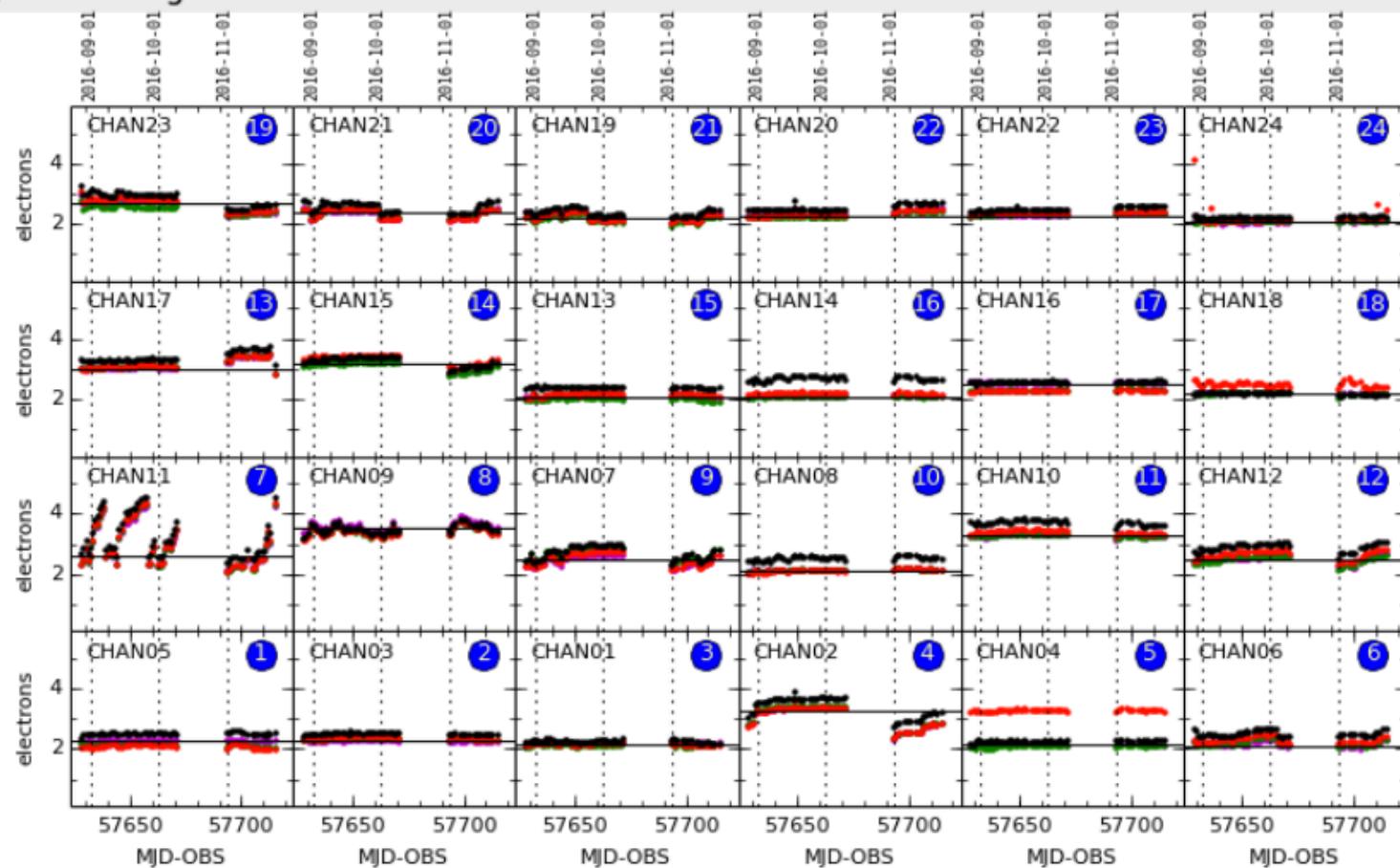
UIT: 480 120 480 480 120 480

DROT: 0 0 90 90 0 90

Day calibrations: RON instabilities

MUSE: RON_master for each detector (last 90 days)

QC data range: 2016-08-28 ... 2016-11-22*



powered by QC: www.eso.org/HC

created by trendPlotter v3.6.2 on 2016-11-25T16:00:28

Day calibrations: flat field

[CAL](#) | [HC](#) | [refs](#) | [QC](#)

HealthCheck Monitor

[HOME](#) | [UsersGuide](#)

[ALL INSTRUMENTS](#)
[FULL reports](#)

MUSE:
[score overview](#)
[detector_bias](#)
[detector_dark](#)
flats/lamps
[wave](#)
[throughput](#)
[astrokeo](#)
[detmon](#)

Other HC:
UT1
[FORS2](#)
[KMOS](#)
[NACO](#)
UT2
[FLAMES/GIRAFFE](#)
[UVES&FLAMES/UVES](#)
[X-SHOOTER](#)
UT3
[SPHERE](#)
[VIMOS](#)
[VISIR](#)
UT4
[HAWK-I](#)
[MUSE](#)
[SINFONI](#)
VLTI
[AMBER](#)
[GRAVITY](#)
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[PWV monitor](#)
[Image Quality \(historical\)](#)
[Sky Background \(historical\)](#)
retired:
[FORS1 \(April 2009\)](#)
[ISAAC \(December 2013\)](#)
[CRIRES \(July 2014\)](#)
[MIDI \(March 2015\)](#)

QC links:
[QC home](#)
[Data Products](#)
[calChecker](#)

{page auto-refreshes after 300 sec} {stop | on} {press Ctrl+Shift+R to enforce refresh of scores, dates and news}

MUSE trending system: HEALTH CHECK report

Last update: 2016-12-30T16:01:31 (UT) (0d 09h:42m ago) | now: 2016-12-31T01:44:20 (UT) QC pipeline: muse-1.6.3 (installed 2016-11-21)

same group: [FLAT_mean](#) [FLAT_alignm](#) [TRACE_lxpos](#) [TRACE_rxpos](#) [TRACE_tilt](#) [TRACE_width](#) [TRACE_vignet](#)

[HELP](#) [USERS-GUIDE](#) [MORE](#)

General news:
MUSE news:
Report news: [edit](#)

DATE*: [2] 2016-12-24 2016-12-25 2016-12-26 2016-12-27 2016-12-28 2016-12-29 2016-12-30 no data [NLT]

R... Raw CAL displays: [raw](#) [raw](#) [raw](#) [raw](#) [raw](#) [raw](#) no raw files

P... Product quality: [products](#) [products](#) [products](#) [products](#) [products](#) [products](#) no products

transfer ngas [2] [forced refresh](#)

[scores&comments](#) | [FULL](#) | [history ...](#) | [plot tutorial ...](#) | [contact](#) ● daily/often; important to check [2] *Date on this monitor changes at 21:00 UT

MUSE: Alignment: normalized flux in top/bottom slices (last 90 days)
QC data range: 2016-10-02 ... 2016-12-29*

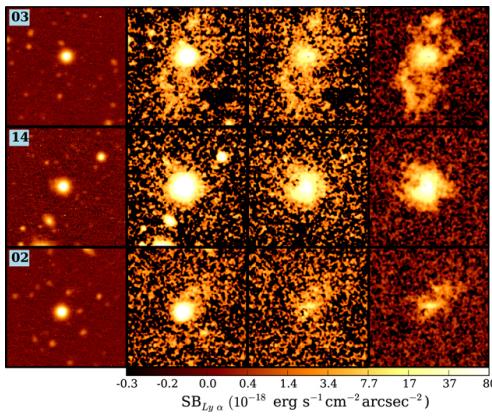
powered by QC: [www.eso.org/HC](#) created by trendPlotter v3.6.2 on 2016-12-30T16:01:05

Flat field: why do we care?

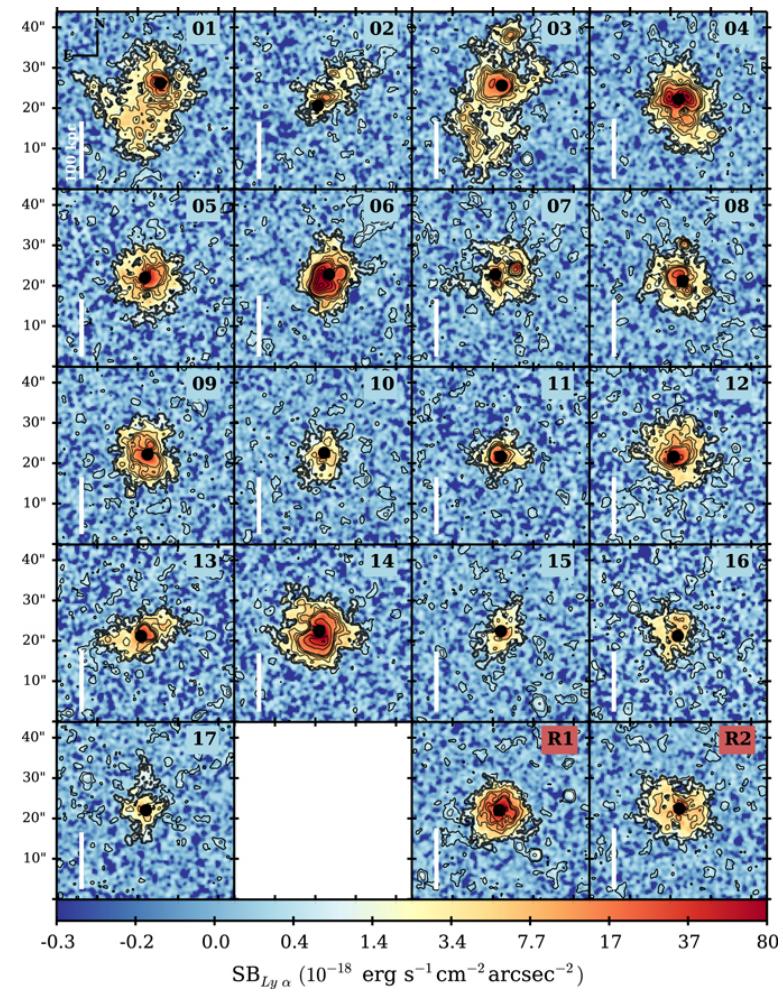
Need for accurate background estimates in scales of several arcsecs

ApJ, 831, 39 (2016)

**UBIQUITOUS GIANT Ly α NEBULAE
AROUND THE BRIGHTEST
QUASARS AT $z \sim 3.5$ REVEALED
WITH MUSE**
Borisova et al.

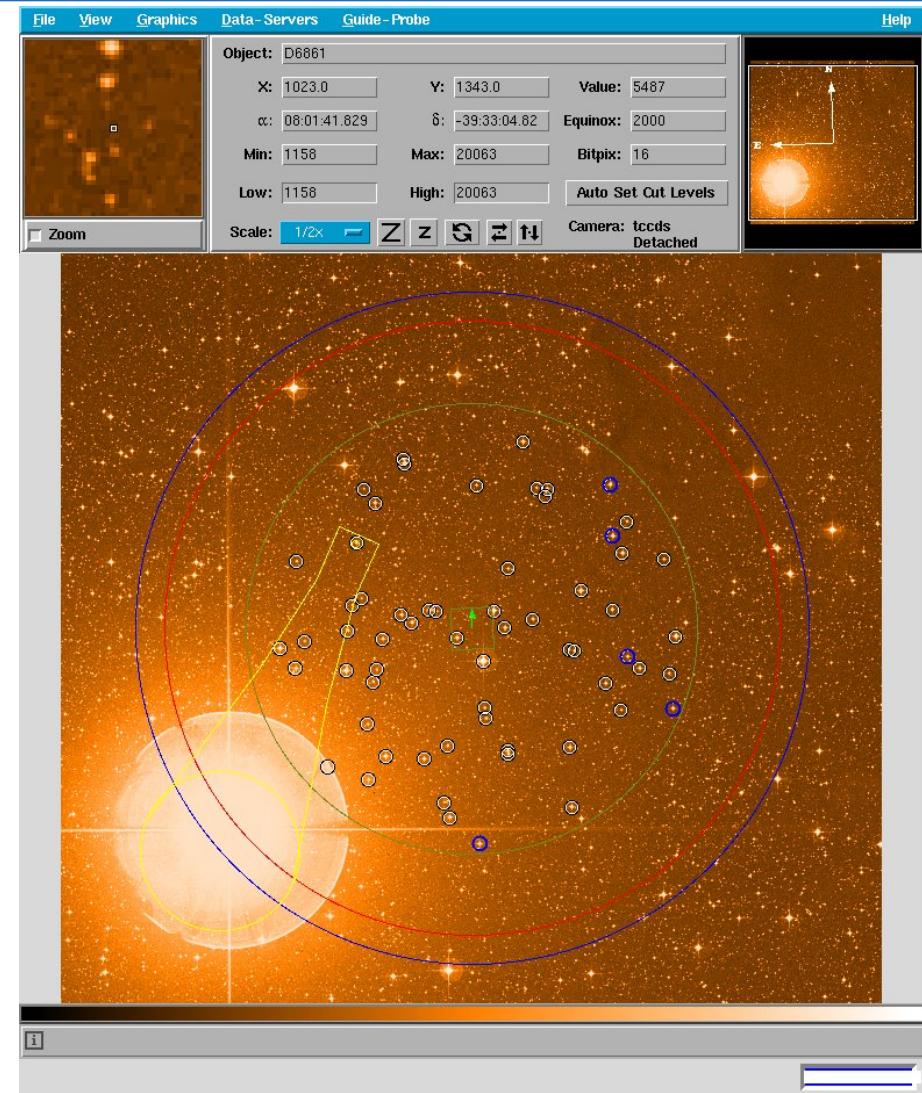
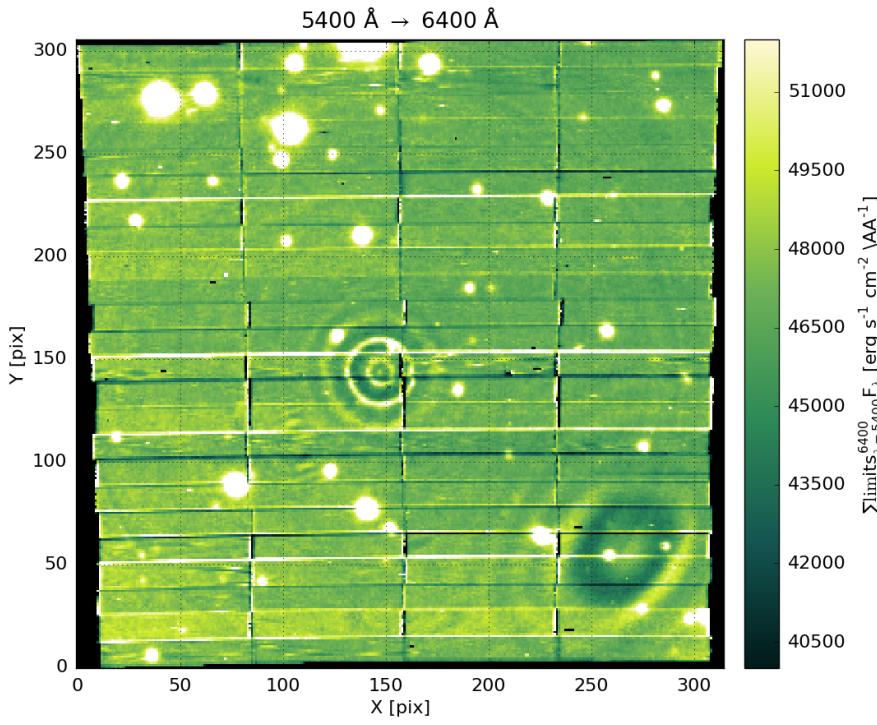


1 h = 4x900s



Ferris wheel II

No spokes!



Ferris wheel III

We move closer to star and artifact disappear!

