

20<sup>TH</sup>

ANNIVERSARY OF  
SCIENCE EXPLORATION WITH

# FORS

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**Programme**  
Wolfgang Hummel **The making of FORS**  
Oliver Hainaut **The solar system**  
Nikolay Nikolov **Exoplanets**  
Stefano Bagnulo **Biomarkers**  
Veronika Schallerroth **Binary stars**  
Magda Arnaboldi **Dynamics of galaxies**  
Laura Pentericci **High redshift galaxies**  
Ferdinando Patat **SNe, GRBs and GWs**  
12 March 2019 | ESO HQ, Garching, Germany

# Operations

- Outline

1 Instrument description

2 Instrument history and major events

3 Operations

- 3.1 calibration plan

- 3.2 data reduction pipeline

- 3.3 data processing and quality control

4 Statistics and Summary



- Two instruments
- focal reducer, imaging
- spectroscopy
- polarimetry

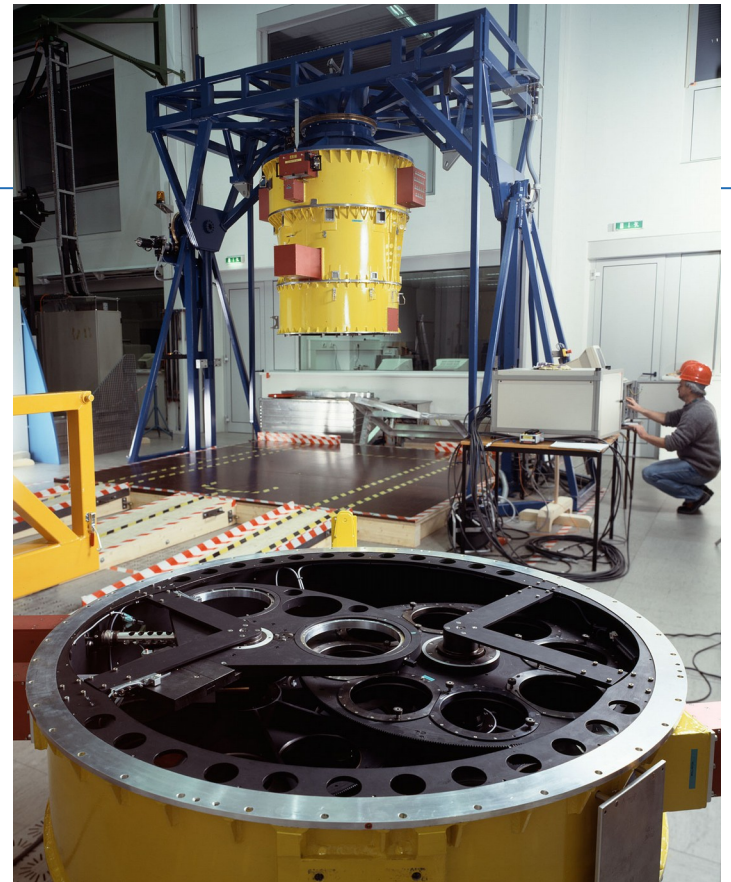
### FORS1

imaging  
 long slit spectroscopy  
 MOS 19 slitlets

IPOL  
 PMOS  
 HIT (3 modes)  
 ECHELLE (until 2005)

### FORS2

imaging  
 long slit spectroscopy  
 MOS 19 slitlets  
 mask exchange unit  
 → since 2009  
 → since 2009  
 HIT (3 modes)



- FORS description

20 years means  
40 observing periods,  
40 User Manual versions

(compressed here into 6 slides)

imaging, two collimators 6'.8 x 6'.8  
0".25/ pixel (SR, 2x2 binning)  
(plus HR collimator)

BB and NB filters (exchangeable)



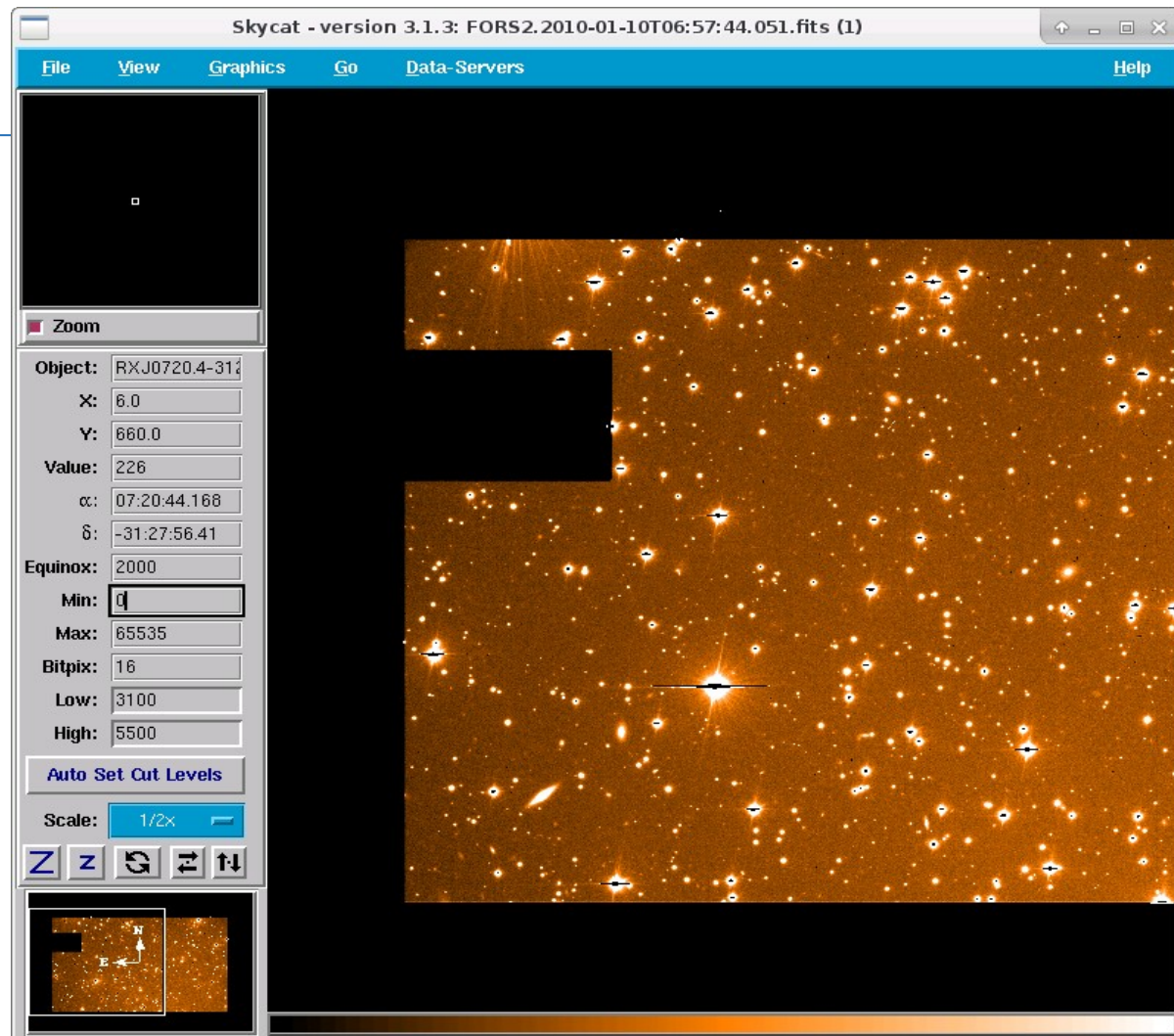
# FORS

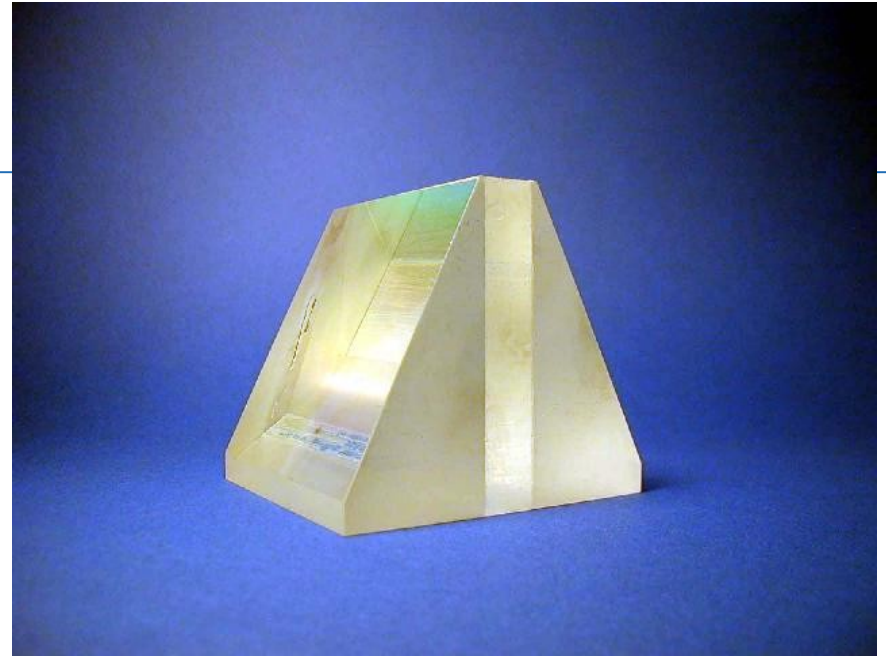
## description

Example raw frame,  
upper chip

**Imaging** with single or  
more MOS blades to  
**occult** bright saturating  
sources.

Preparation done via  
FIMS.





- FORS description

Low resolution **spectroscopy** with grisms

150l R= 260 eff = 80% surface rules  
 1400V R= 2100 eff = 90% VPH

volume phased holographic grism, plus optional order separation filters.

In the focal plane:

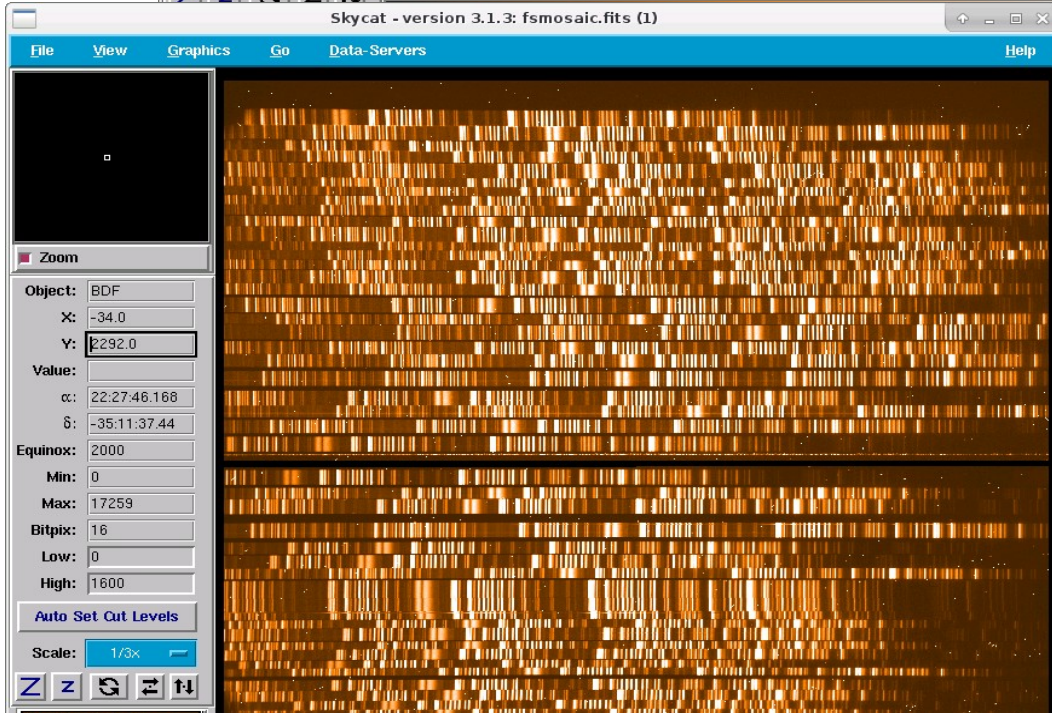
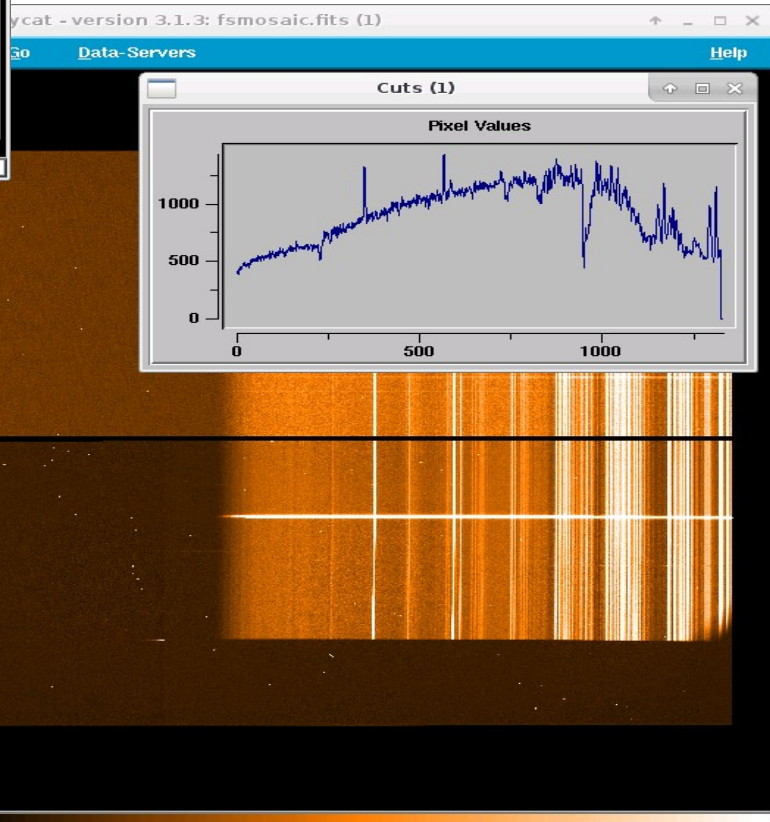
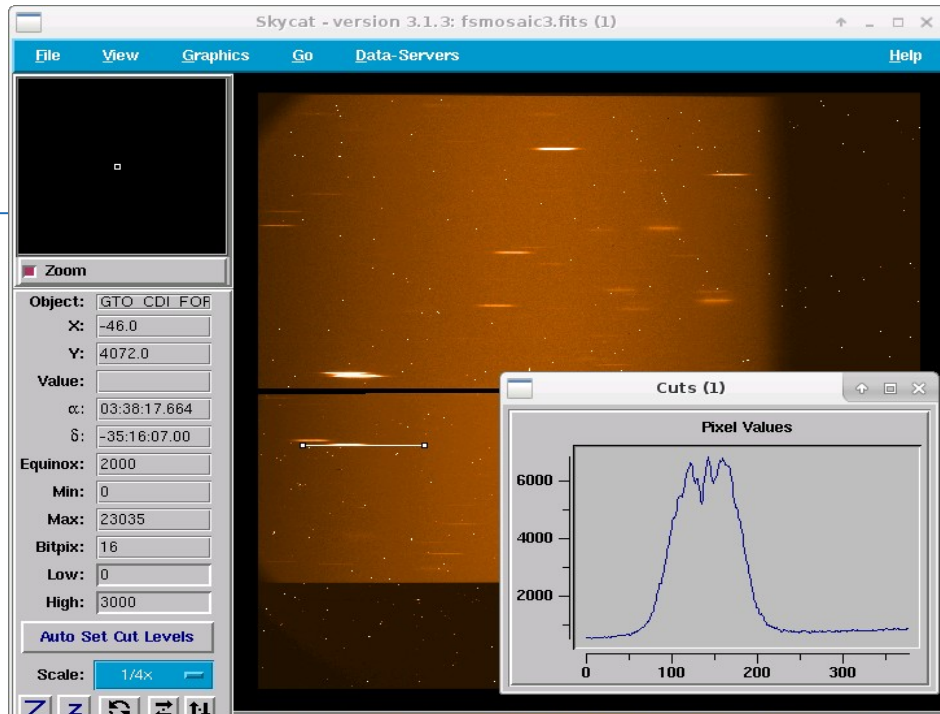
LSS : 9 slits from 0.3 – 2.5" at fixed position in the focal plane (extended objects)

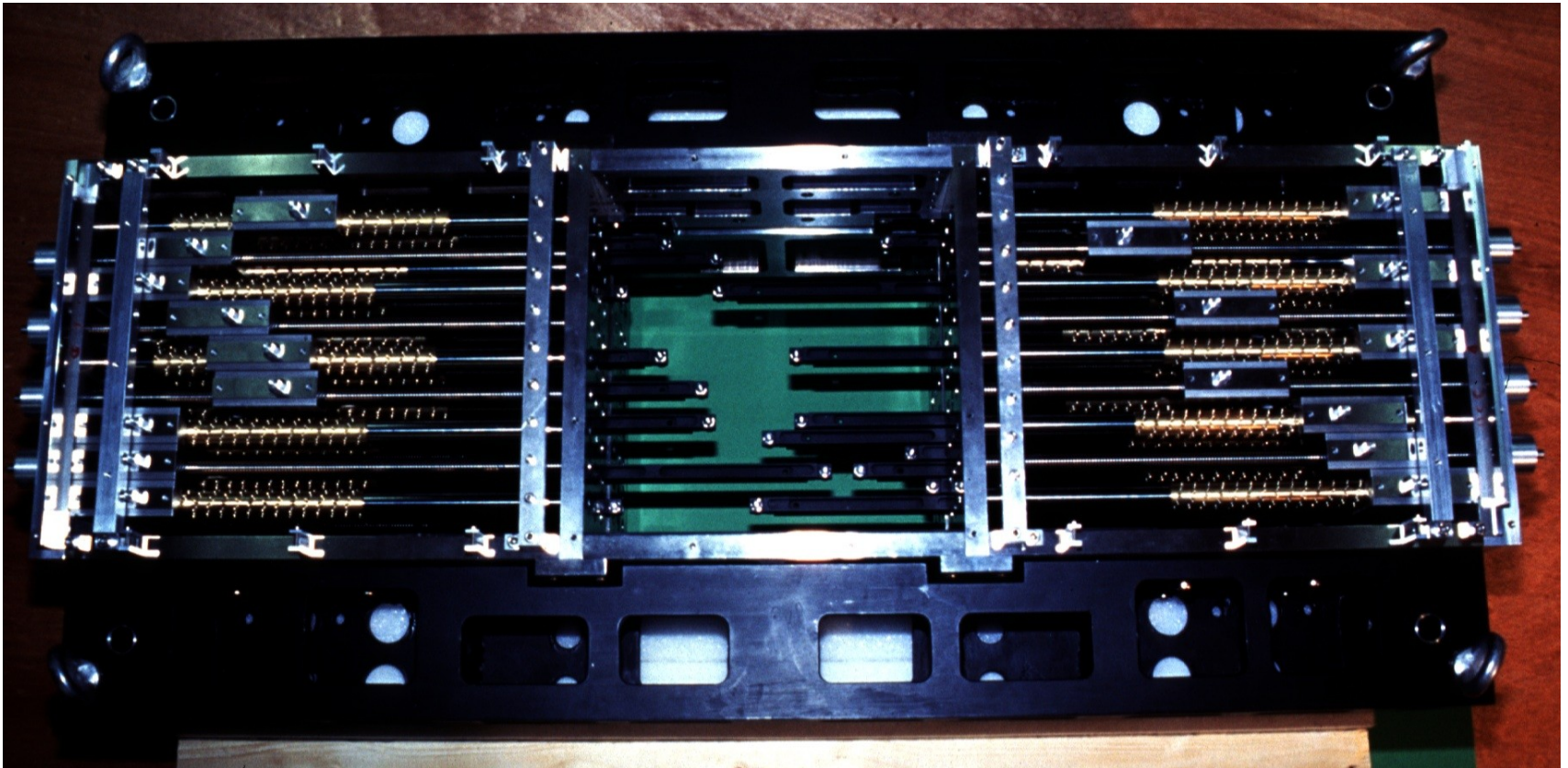
MOS: 19 slitlets, any slit width, 20" long

FORS2 only : MXU, any slit width and lengths, also tilted and curved slits

Mask prepared via FIMS,

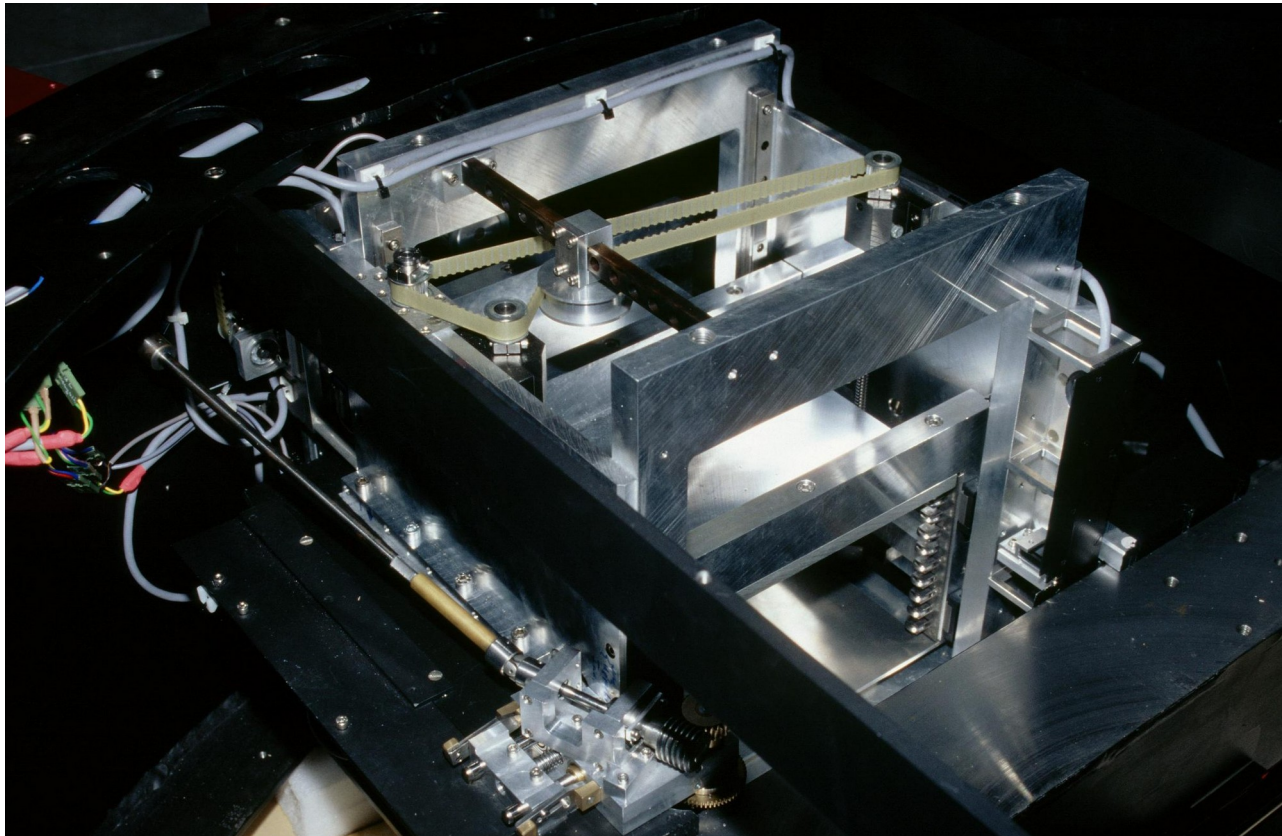
LASER cut on site by external MMU and inserted into the instrument







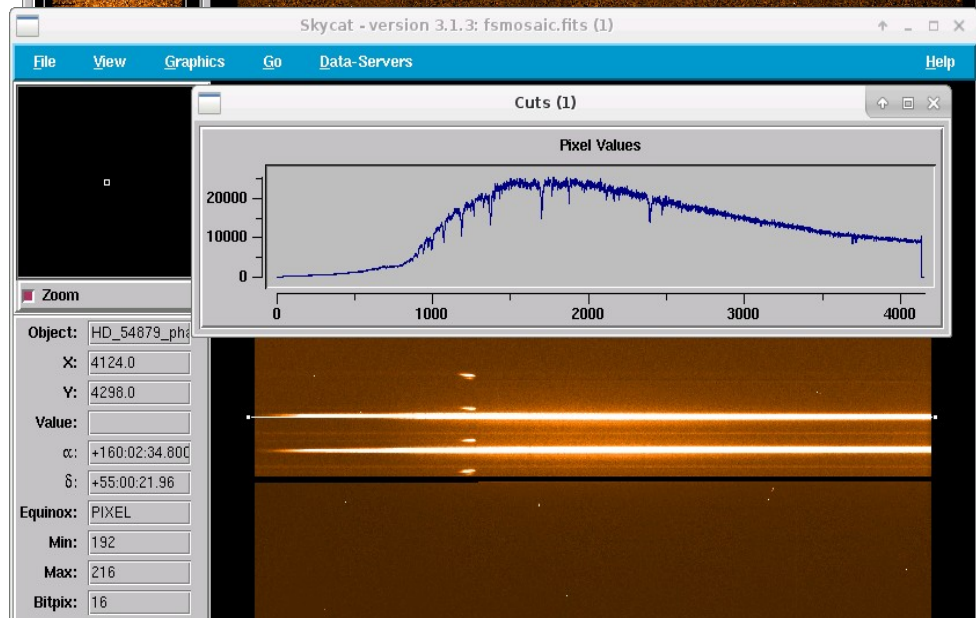
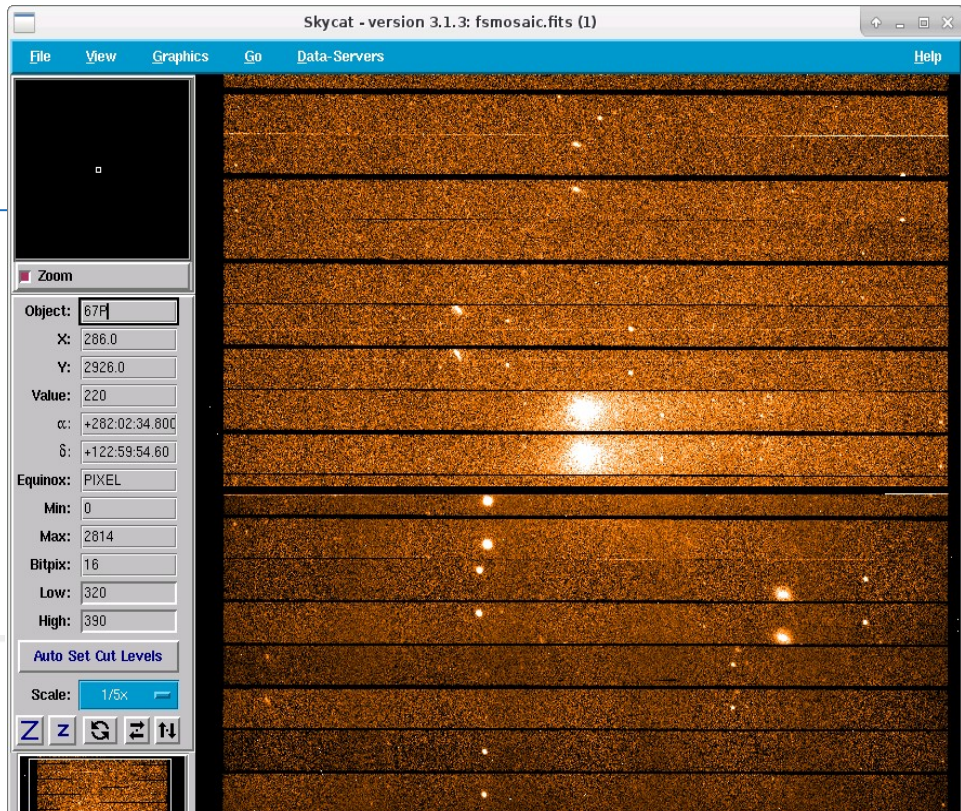
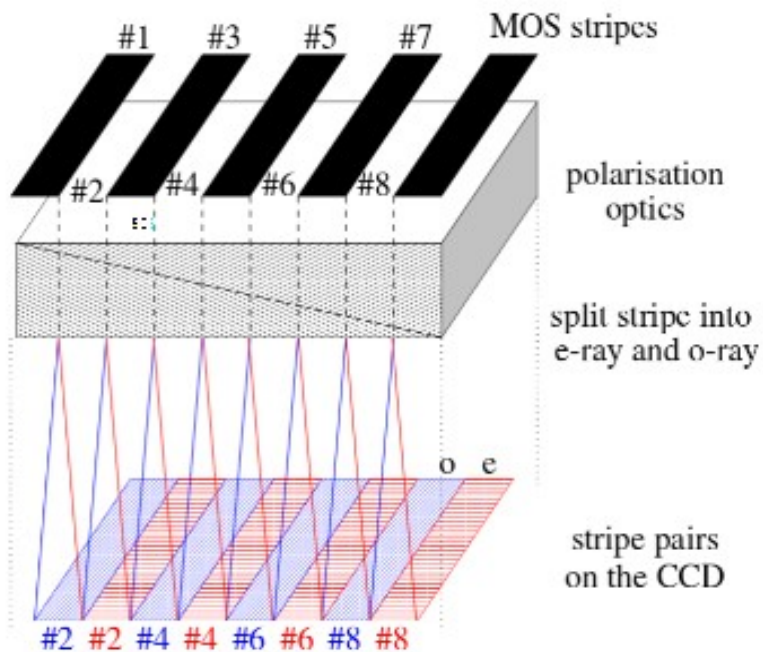
MXU hardware, 10 masks container inside, elevator





- PMOS, IPOL

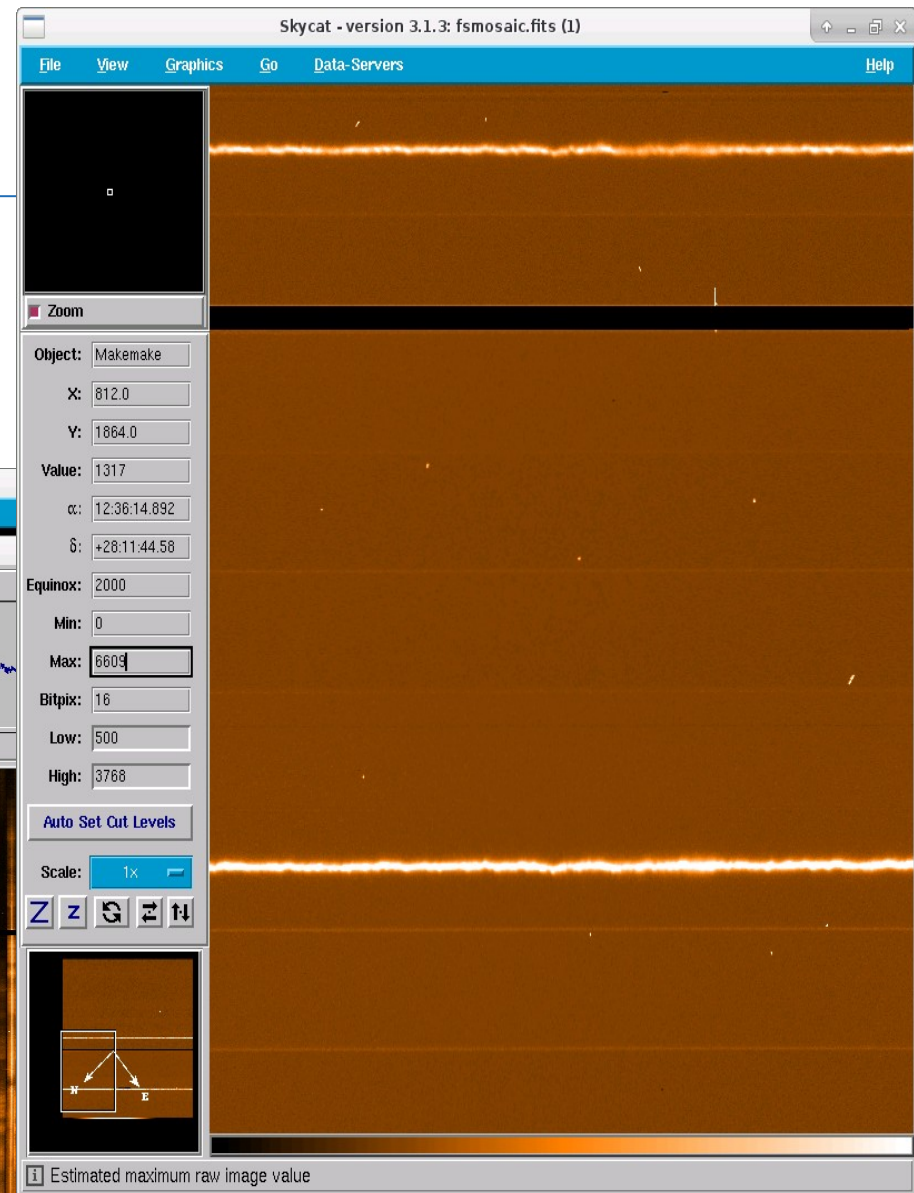
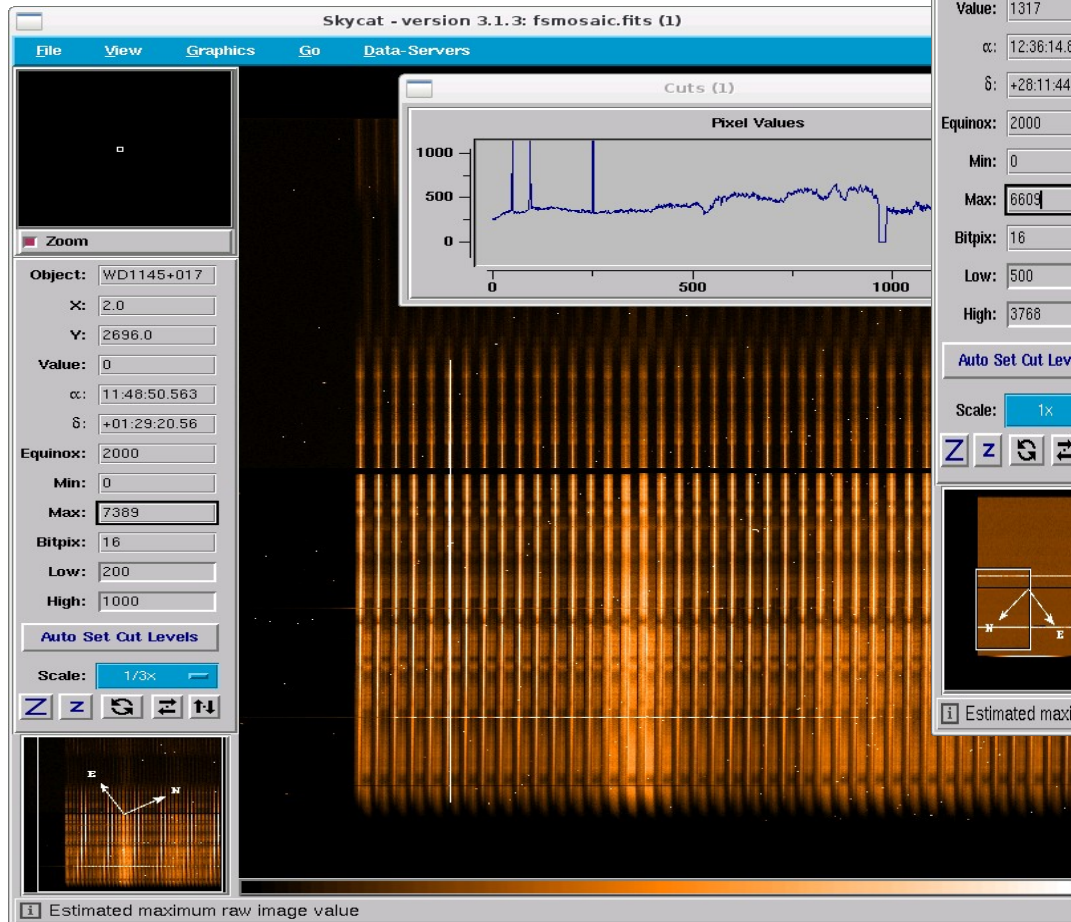
odd MOS slit-blades occult sky,  
even free MOS slit-blades  
split up in two projected slices





Imaging,  
spectroscopy,  
reference slit spectroscopy

- HIT modes



Two prisms, that move between 30mm to 1100mm,  
 the first one corrects the dispersion, second one corrects pupil tilt.  
 Up to airmass = 1.5

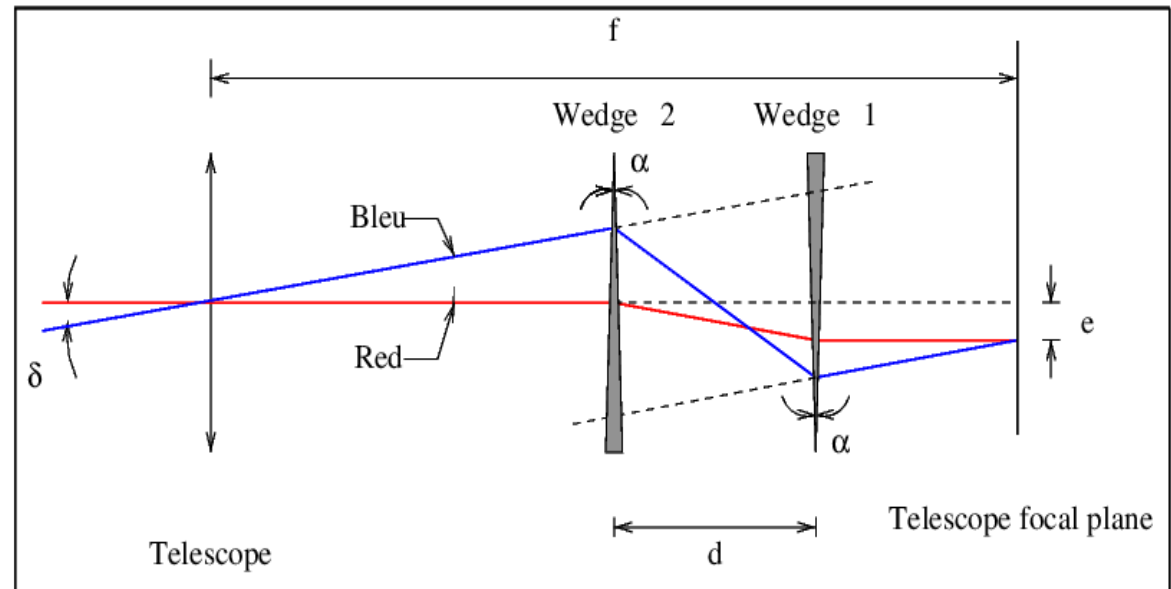


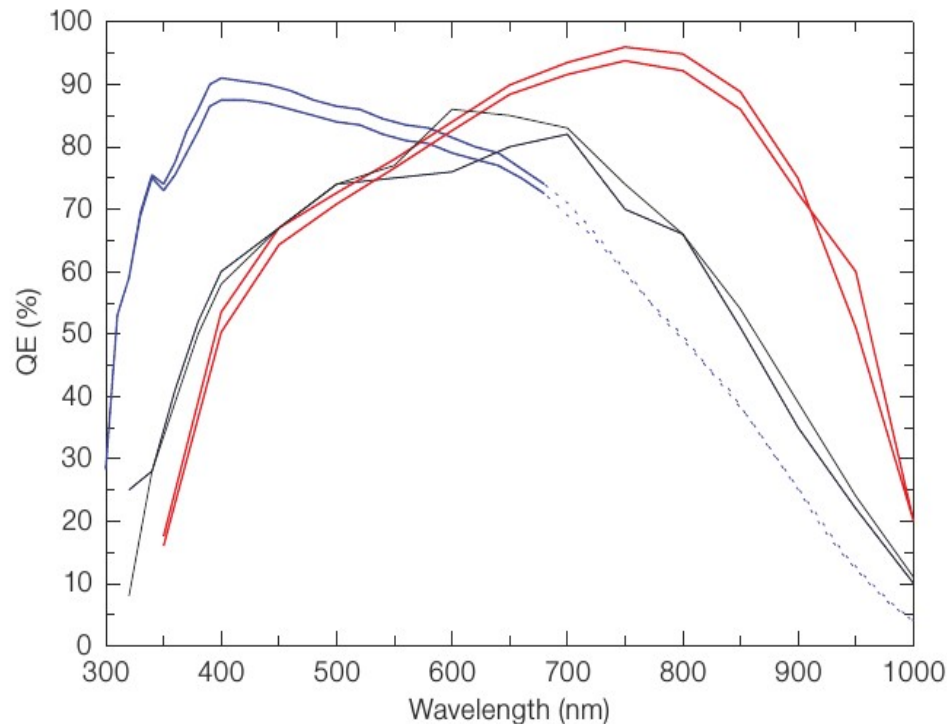
Figure 5: Optical design of the LADC

## 2.0 History

- 1998 09 FORS1 first light
- 1999 04 start of operations FORS1
- 2000 04 start of operations FORS2 with MXU and MMU
- 2002 04 **FORS2 upgrade red-optimized mosaic CCD**, VPH prism 1200B
- (2003 04 VIMOS, competitive instrument start)
- 2004 FORS1 → UT2, FORS2 → UT1, (first of more moves)  
operated with RRM
- 2005 Echelle mode decommissioned
- 2006 FORS1: new grism 1200B, LADC cleaning, new HIT mode multiple shift
- 2007 **FORS1 upgrade blue-sensitive mosaic CCD**

## 2.0 History ...

- Higher QE, lower RON, faster readout, 4k x 4k , larger spectral range
- cryostat, template modification, FIMS modification (already for FORS2), ETC, pipeline
- New UVB<sub>g</sub> Bessel and uvbgriz SDDS filter set
- Fringes at > 700 nm
- Szeifert et al., 2010,  
ESO Messenger, 128



**Figure 1:** Comparison of the CCD efficiencies of FORS1 and FORS2 before and after the respective upgrades. Black: Tektronix CCDs; Red: FORS2 MIT CCDs; Blue: FORS1 E2V CCDs. The dotted part indicates the range affected by fringing (see text).

## 2.0 History

- 2007 multi-object spectroscopy pipeline released
- 2008 calibration plan modified: Landolt stars → Stetson fields
- 2009 **FORS1 decommissioned** (XSHOOTER requires UT2 Cassegrain)  
polarimetric optics -> FORS2  
high throughput BB filters and VPH grisms -> FORS2  
close out calibrations  
Rupprecht et al., 2010, ESO Messenger 140  
default: MIT (red) and visitor mode: E2V (blue) detectors used
- 2013 LADC anti-reflection coating removed
- 2014 virtual slit 6.0" offered for LSS
- 2015 major pipeline overhaul
- 2017 FIMS upgraded to work on Mac
- 2018 HIT modes decommissioned, VIMOS decommissioned
- 2019 \*\*\* 20<sup>th</sup> anniversary \*\*\*



# Observation preparation Software

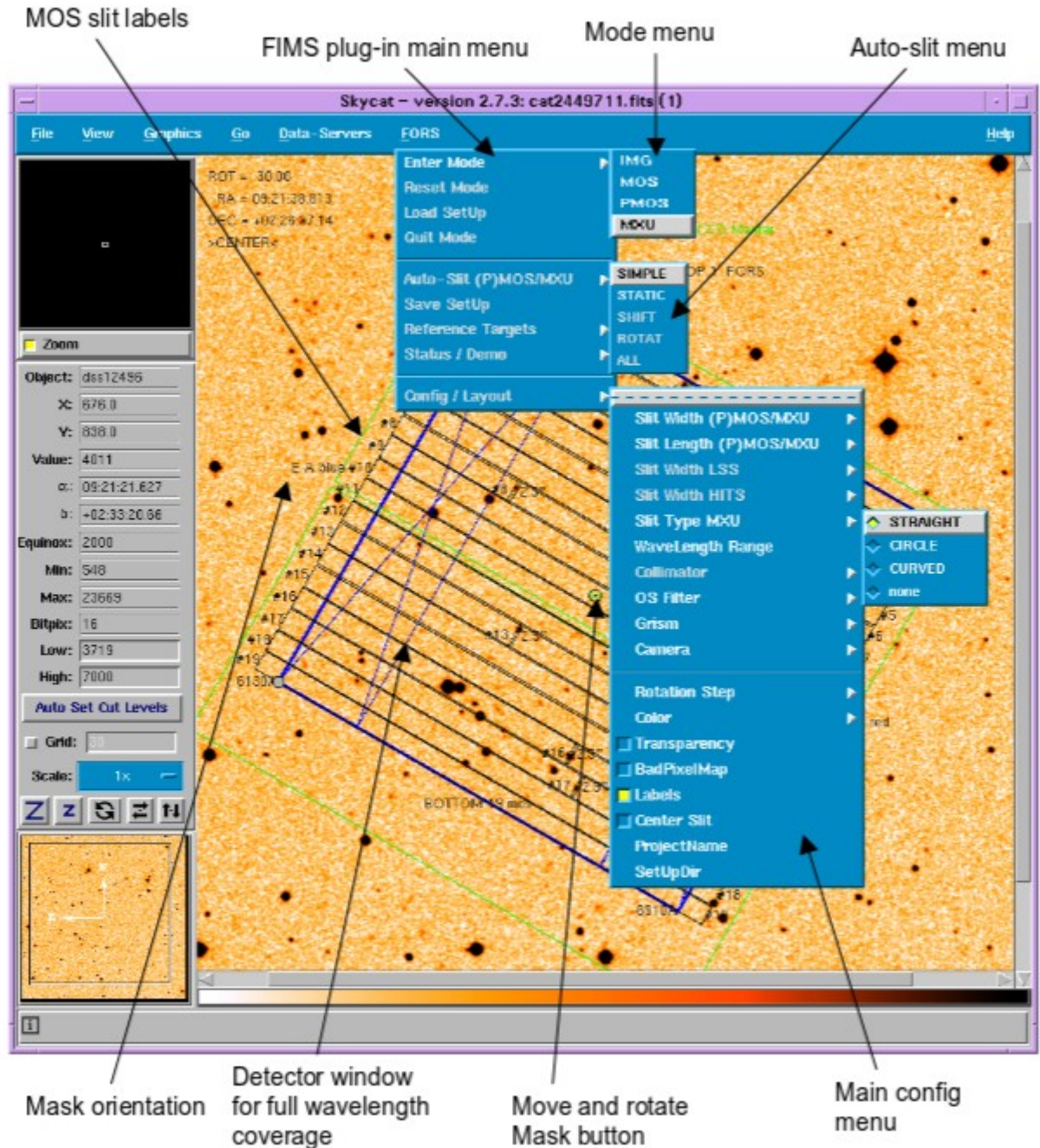
Plugin to SkyCat

Linear transformation between

Sky (RA, Dec)  
focal plane (mm)  
CCD (pixel)

Justified: LADC,  
differential refraction at  
7' x 7' and Z < 60deg  
negligible

(different for  
Flames, VIMOS)





# Operations



## 3.0 Operations

- 3.1 calibration plan
- 3.2 pipeline
- 3.2 quality control

Both instruments fully integrated  
in VLT dataflow: phase1/2, p2pp  
(now web-based p2),

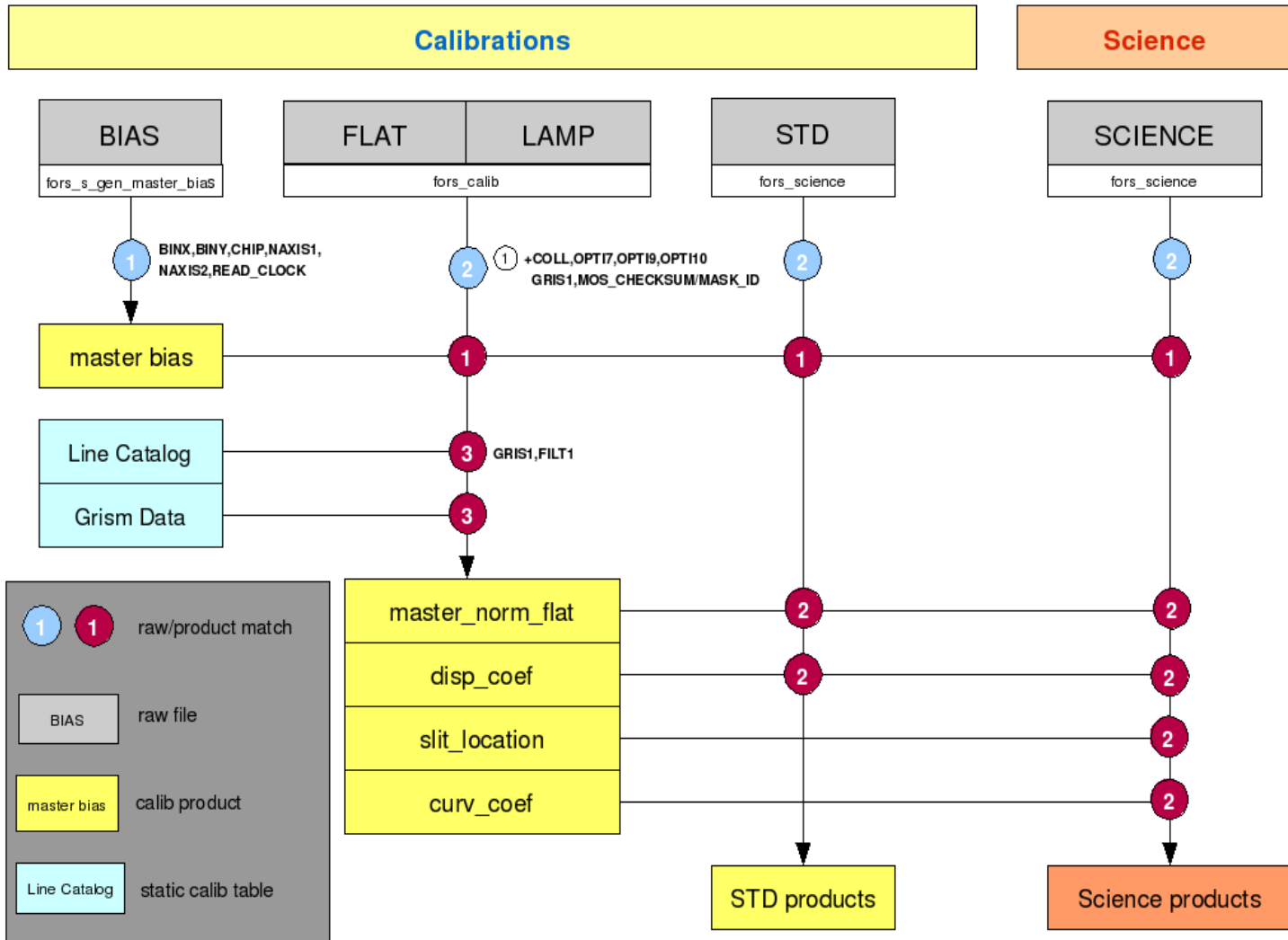
FIMS, OB execution by SciOps on P.

calChecker, QC0, QC1,

master calibrations, instrument  
monitoring, health check ...



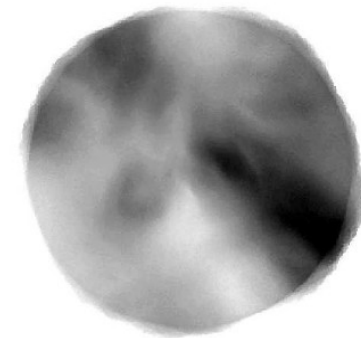
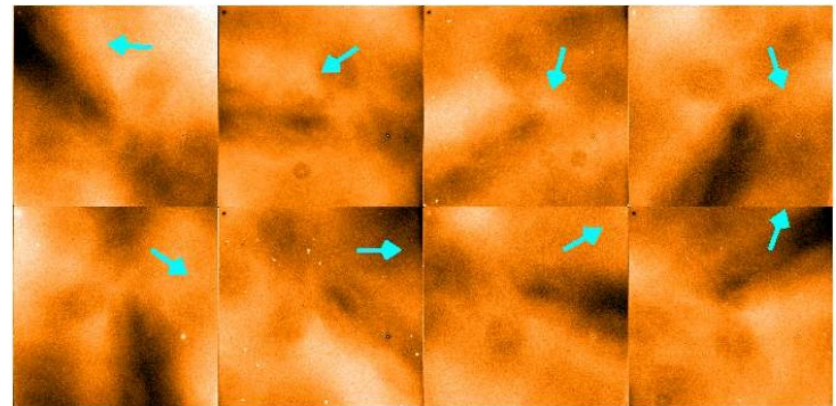
## FORS2 MOS/MXU



## FORS photometry (FAP)

- FORS1 IOT secondary standards WG (Moeller, P. et al., 2005) reported:  
FORS calibration plan shows  $\pm 0.03$  mag variation across the field  
- change the calibration plan, use Stetson instead of Landolt  
- investigate flat field strategy via FORS absolute photometry project.
- FAP project report (Freudling et al.)  
3% accuracy can be achieved when using a correction of the flat field. Use more than one Stetson field in a night. (not clear if additive stray light or multiplicative transmission)

*Freudling et al.*

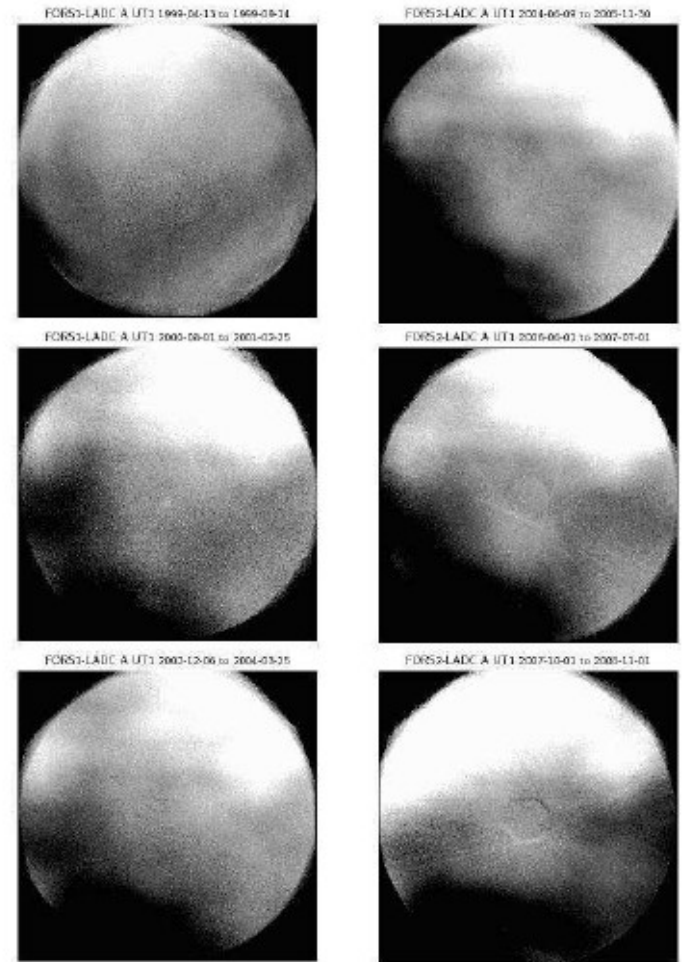


stacked B flat, rotation corrected

- Flat field structure has one component rotating
  - structure moves with the LADC
  - is visible on the LADC surface
  - multiplicative (not stray light)

Moehler, S. et. al., 2009, PASP 122

UT1, left FORS1, right FOR2,  
twilight flats,  
rotated to rot.angle = 0



- Illumination corrections: static and rotating component, two time ranges (Coccatto et al., 2013, MNRAS)

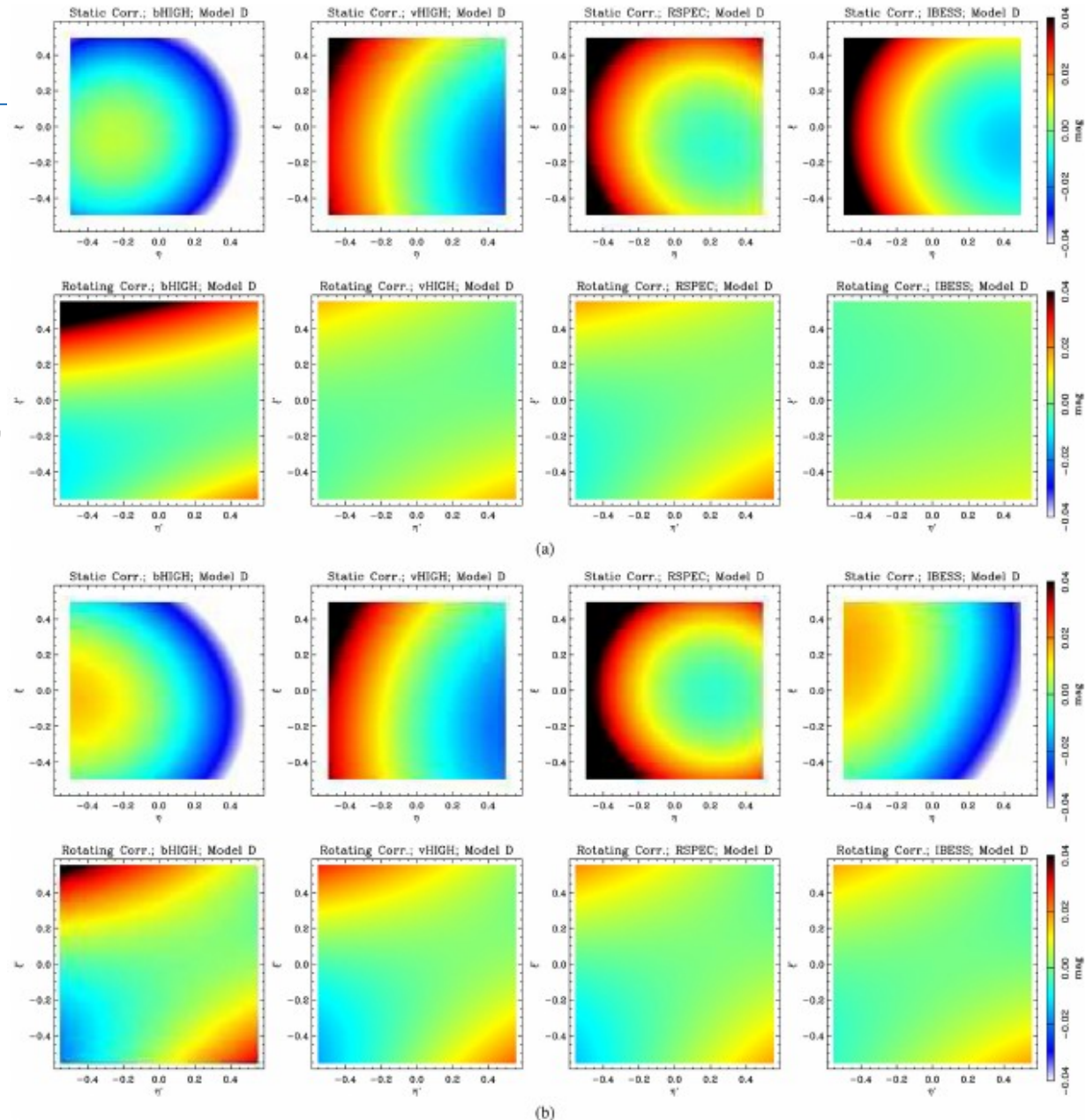
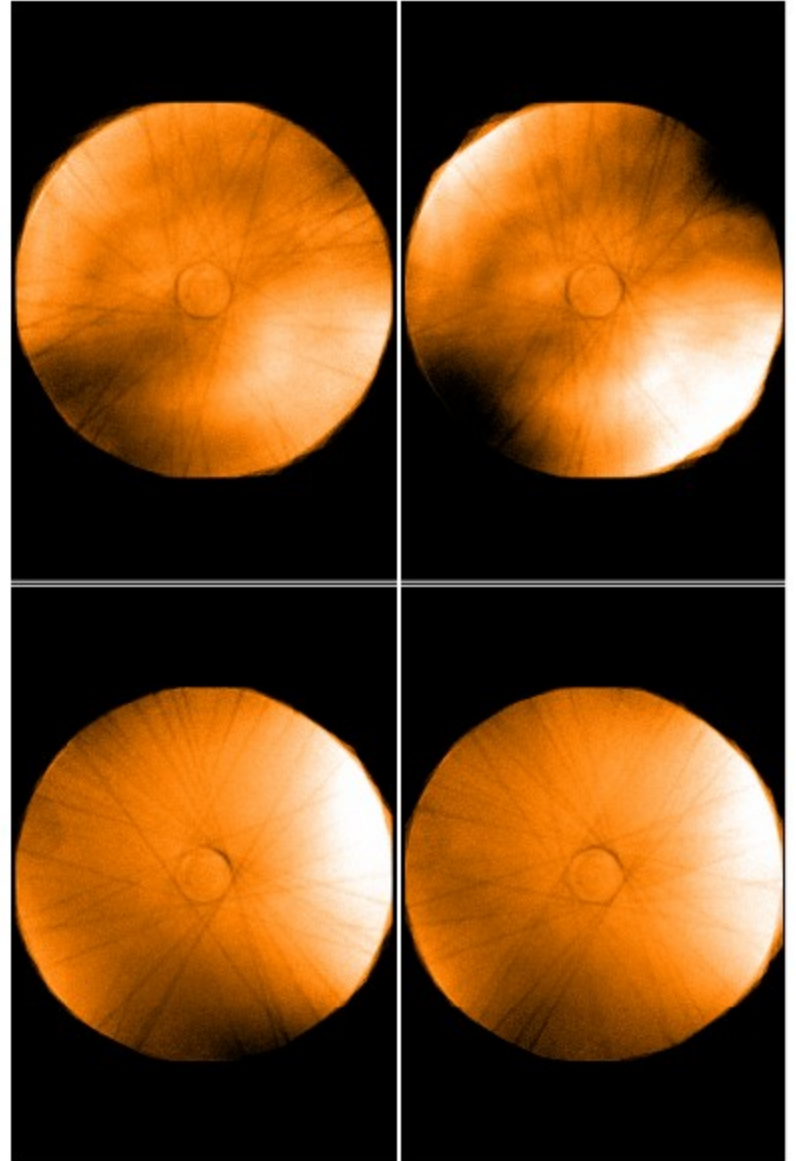


Figure 2. Best-fitting polynomial surfaces (model D) representing the static illumination corrections  $\Delta F^{static}$  (upper panels) and the rotating illumination corrections  $\Delta F^{rot}$  (lower panels) for different filters. Illumination correction surfaces in panels (a) refer to time range A, whereas surfaces in panels (b) refer to time range B.

# FORS photometry, Linear ADC, coating removed



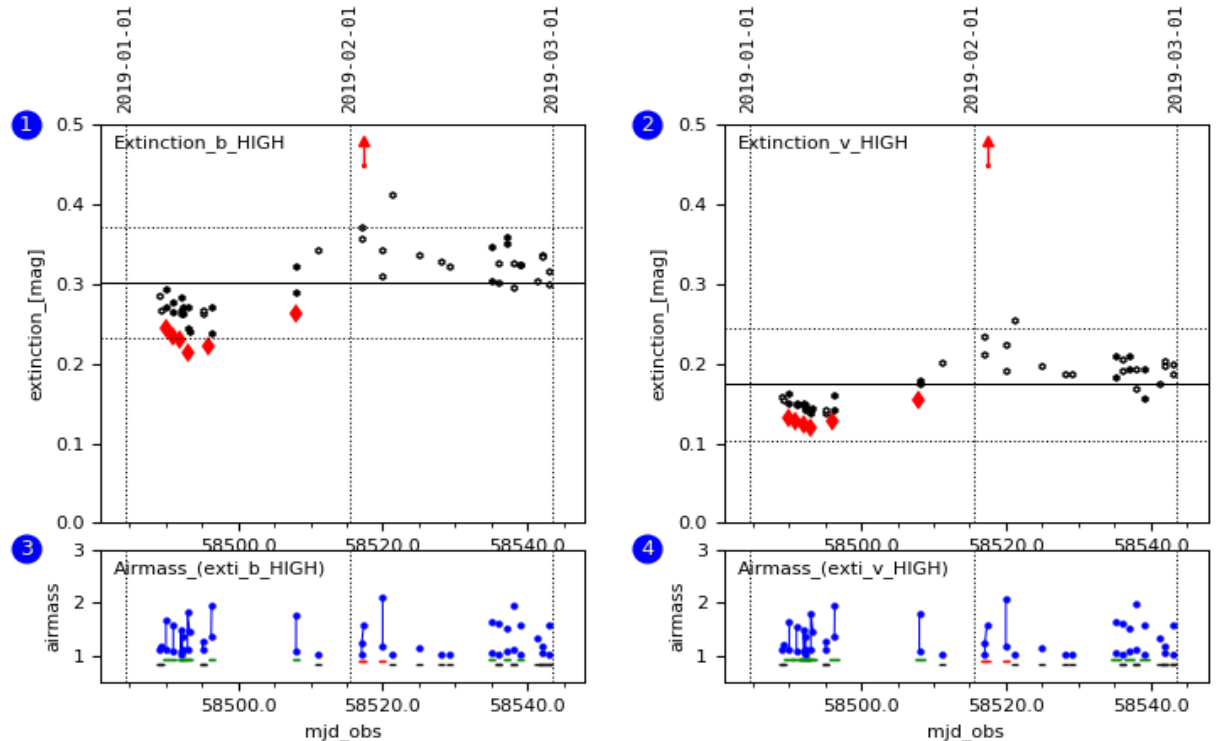
2014 anti-reflection coating removed from LADC, better zero-points, FF structure is gone, FORS is ready for exo-planet transition science (Boffin et al. 2016, SPIE 9989)



Following a simulation of Bramich et al. 2011: the calibration plan was modified: use two STDs at different air mass 18 photometric nights for the modeling: 1.4-1.8% accuracy can be achieved. (FAP final report)

Annual FAP verification report.

FORS2: Frame and night extinction (last 60 days)  
QC data range: 2019-01-01 ... 2019-02-28\*



powered by QC: [www.eso.org/HC](http://www.eso.org/HC)

created by trendPlotter v3.7 on 2019-03-01T14:00:19





- Data reduction pipelines play a critical role in the quality control of the instrument and the quality of the science observations
- 1999 data reduction SW delivered by LSW Heidelberg (Stahl, O., Szeifert) as an ESO-MIDAS context for IPOL MOS and PMOS including a graphical user interface and a data reduction cook book.

### 2.7 MOS Cookbook - A typical session

#### 2.7.1 Starting the whole thing

Before you start the MOS context you should have done the following preparations:

- average your bias frames
- average your dark frames
- average all flat-fields of the same setup
- correct the object frames for bias, overscan, and dark
- make sure that the dispersion direction in all your frames is along the x-axis

## 3.2 data reduction pipeline

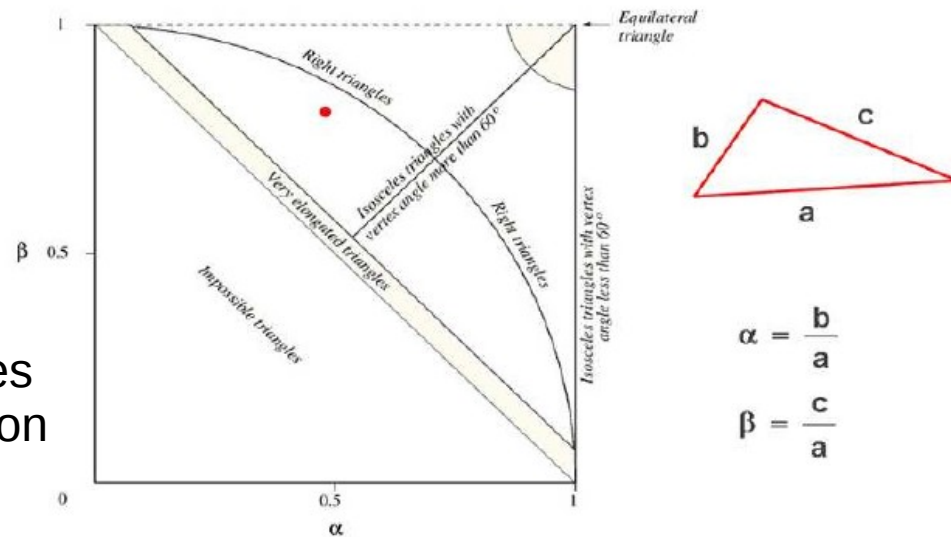
- 1999 ESO-MIDAS based imaging/spectroscopy pipeline
- 2006 pipeline rewritten (Izzo C., et al. 2010.SPIE) for imaging: pattern matching using bottom-up approach (= from data to model), SourceExtractor, error propagation, flat field correction, least square fit of photometric equations

MOS / MXU / LSS:

arc line pattern matching,  
global distortion corrected,  
day-time arcs aligned to sky lines  
optimum extraction, flux calibration

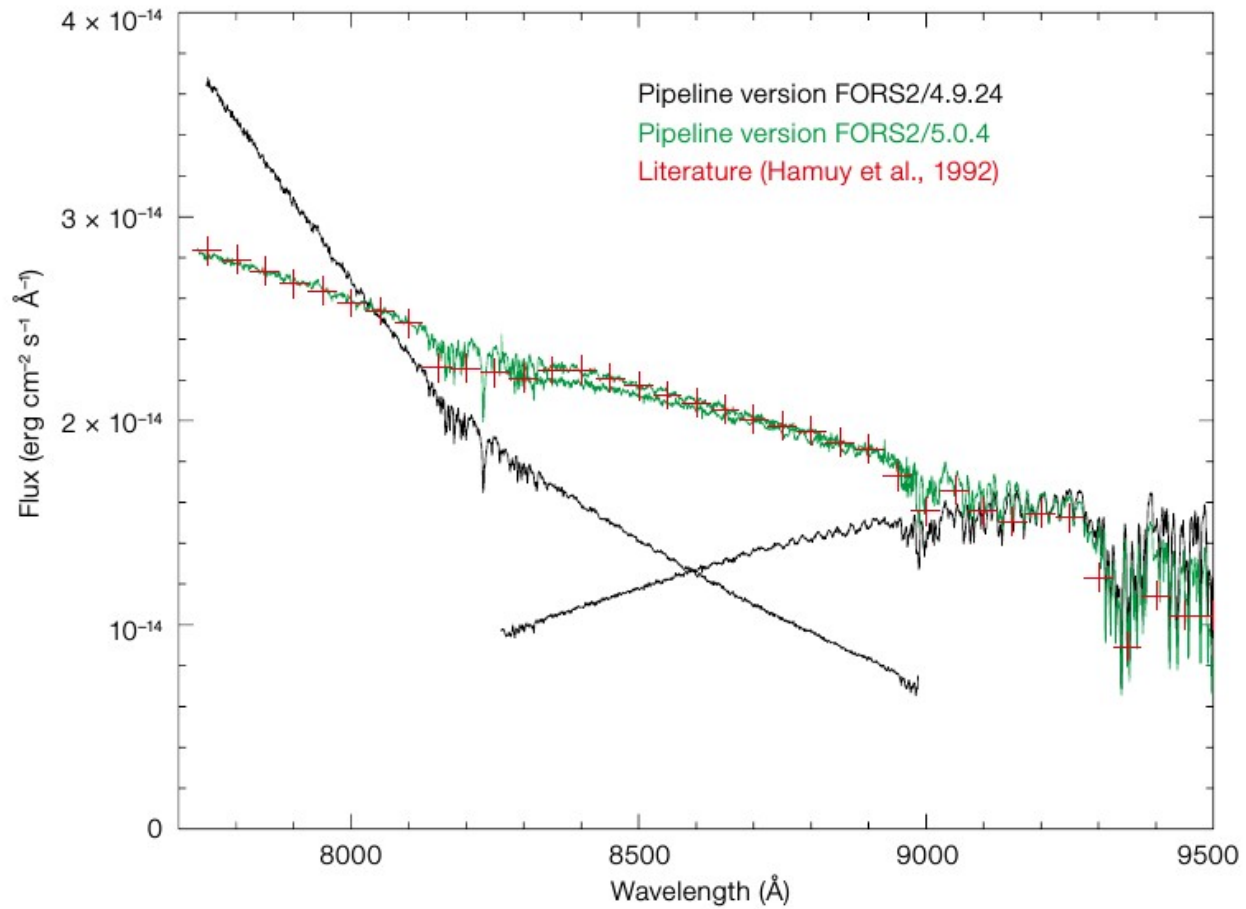
- 2009 PMOS support, (Bagnulo, S., et.al 2009,PASP 121), handles exposures with of different retarder plate rotation angles.  
linear and circular polarimetry supported.

194 C. Izzo et al.



- 2015 VLT-ANR-ESO-13112-6270 (Moehler et. al.)
  - reflex workflow for spectroscopy (push one button)
  - bias level based on pre/over scan, 20 raw frames for a better RON and error propagation
  - revision of grism-specific parameters (grism tables): random error in WLC reduced from 0.15 to 0.12 pixel
  - spectroscopic flats normalized before stacking to compensate for blue flat lamp SED variations ~10% within the stack
  - investigated: spatial illumination of LSS data is very similar: screen flats, twilight flats, science data
  - spectral masking regions for stellar and telluric features included, when deriving the response function from Hamuy (50Ang binned) and observed flux std.
  - the VPH grism response varies with slit position.
    - LSS: take 5" flux std at position of the long slit
    - MOS/MXU: divide off-center science and flux std by their own flat SED to construct sensitivity function.

## 3.2 data reduction pipeline

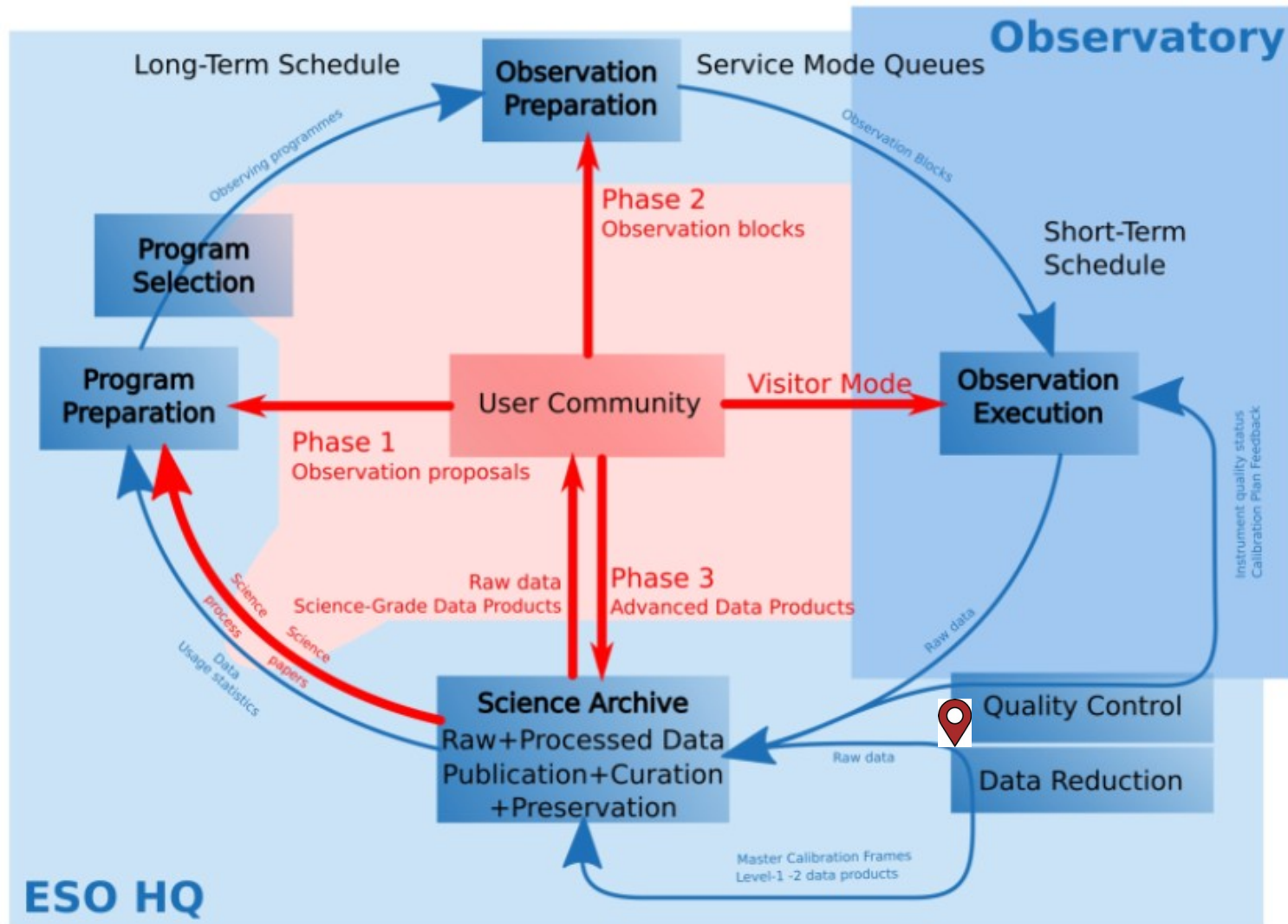




### 3.3 Data Processing and Quality Control



# Data Flow System: today





- FORS2 is operated within the VLT dataflow system
- Quality Control Group:
- Checking the completeness of calibrations (hourly)
- Processing all calibrations (except IPOL and HIT)
- Certify master calibrations, ingest them in the archive for public usage
- Extract Quality Control Parameters from pipeline products, continuous monitoring of the performance of the instrument, scoring system
- QC loop is closed hourly
- Maintain association rules



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

**CALCHECKER**

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[ALL INSTRUMENTS](#)

**UT1**

[FORS2](#)

[KMOS](#)

[NACO](#)

**UT2**

[FLAMES/GIRAFFE](#)

[UVES&FLAMES/UVES](#)

[X-SHOOTER](#)

**UT3**

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**UT4**

[HAWK-I](#)

[MUSE](#)

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**VLTI**

[GRAVITY](#)

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**ICCF (Incoh. comb. Coude focus)**

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**Survey Cameras**

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**QC links:**

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[calChecker](#)

[HealthChecks](#)

[Reference Frames](#)

[QC1 database](#)

[Paranal autrep database](#)  
(ESO internal)

# CAL FORS2 calChecker: calibration completeness monitor

Last update: 2019-03-08T23:56:32 (UT) (0d 00h:30m ago) [?] Paranal date\*: 2019-03-08 [?] server: www.eso.org HQ [HELP](#)

Last header: FORS2, 2019-03-08T23:46:38.110.hdr ✓ transfer ✓ ngas [?] \*Date on this monitor changes at 21:00 UT. Refresh frequency: 1/2hr day and night

**General news:**

**FORS2 news:** Long-term calibrations and maintenance [complete overview](#) | [all long-term calibrations within validity range](#)

**HC** refresh analyze ISSUES mark BAD QUALITY [HELP](#) | [Q&A](#) | [ASSOC-RULES](#) | [history...](#) | [contact](#) | monitors: [DataTransferMonitor](#) | [BandWidth](#)

[science](#) [cal4cal](#) [?] Product availability depends on the data transfer to Garching and the archive access there (check the "tran

DATE*:	2019-03-01	2019-03-02	2019-03-03	2019-03-04	2019-03-05	2019-03-06	2019-03-07	daytime calibs:	finished 20.02UT	LOST?	Calibration action?	Setup
<i>[color if science data acquired]</i>	SM 38 <a href="#">report</a>   <a href="#">NLT</a>	SM 60 <a href="#">report</a>   <a href="#">NLT</a>	SM VM 894 <a href="#">report</a>   <a href="#">NLT</a>	SM 78 <a href="#">report</a>   <a href="#">NLT</a>	SM 80 <a href="#">report</a>   <a href="#">NLT</a>	SM 62 <a href="#">report</a>   <a href="#">NLT</a>	SM 62 <a href="#">report</a>   <a href="#">NLT</a>	2019-03-08 <a href="#">report</a>   <a href="#">NLT</a>		[may require OB grade review]	[Take these data types ...]	[?] Setup ... for th
<b>Raw CAL displays:</b>	<a href="#">raw</a>	<a href="#">raw</a>	<a href="#">raw</a>	<a href="#">raw</a>	<a href="#">raw</a>	<a href="#">raw</a>	<a href="#">raw</a>	no CAL raw files				
<b>CAL product quality:</b>	✓ products	✓ products	✓ products	✓ products	✓ products	✓ products	products	no CAL products				

Data types:	Setup:	2019-03-01	2019-03-02	2019-03-03	2019-03-04	2019-03-05	2019-03-06	2019-03-07	2019-03-08	LOST?	Calibration action?	Setup
<b>SCI_IMG</b>	200Kps/low_HR_R_SPECIAL_2x2		ok								all ok	
	200Kps/low_SR_I_BESS_2x2						ok				all ok	
	200Kps/low_SR_R_SPECIAL_2x2						ok				all ok	
	200Kps/low_SR_b_HIGH_2x2		ok								all ok	
	200Kps/low_SR_z_SPECIAL_2x2						miss preliminary comment: [1]				FLAT_SKY	200K
<b>SCI_IPOL_L</b>	200Kps/low_SR_b_HIGH_RET2_2x2			ok	ok			nok preliminary comment: [2]			FLAT_SKY	200Kps
	<b>SCI_MXU</b>	100Kps/high_SR_G300V_+931333_2x2					ok				all ok	
	100Kps/high_SR_G300V_+993009_2x2			ok			ok				all ok	
	100Kps/high_SR_OG590_G600z_+955629_2x2			ok			ok				all ok	
<b>SCI_MOS</b>	100Kps/high_SR_OG590_G300I_-11074_2x2							ok			all ok	
<b>SCI_LSS</b>	100Kps/high_SR_GG435_G1200R_0_7_2x2			ok			ok				all ok	
	100Kps/high_SR_GG435_G150I_1_3_2x2	ok	ok	ok							all ok	
	100Kps/high_SR_GG435_G300V_1_3_2x2	ok	ok		ok						all ok	
	100Kps/high_SR_GG435_G600RI_0_7_2x2	ok				ok	ok				all ok	
	100Kps/high_SR_OG590_G300I_1_0_2x2						ok				all ok	
<b>SCI_PMOS</b>	100Kps/high_SR_G300V_RET2_0_2x2			ok							all ok	
	100Kps/high_SR_GG435_G1200R_RET2_0_2x2							ok			all ok	
	200Kps/low_SR_G300V_RET2_0_1x1		ok	ok		ok		ok			all ok	

**ANALYSIS NOTES:**

Index	data type	setup	date	flag	analysis
[1]	SCI_IMG	200Kps/low_SR_z_SPECIAL_2x2	2019-03-06	MISS	preliminary comment: last sky flat outdated, new one required (analyzed by qc_fors2@eso.org)
[2]	SCI_IPOL_L	200Kps/low_SR_b_HIGH_RET2_2x2	2019-03-07	NOK	preliminary comment: last sky flat outdated, new one required (analyzed by qc_fors2@eso.org)



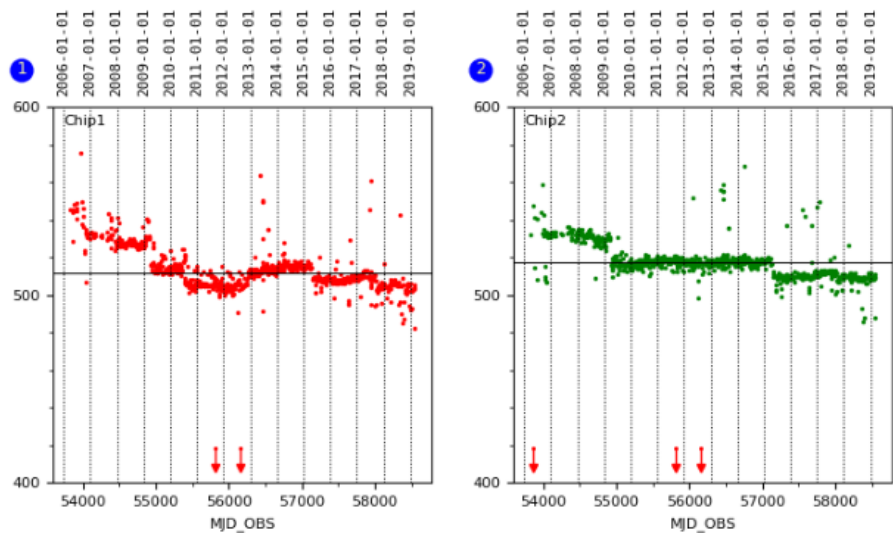
## FOR2 trending system: FULL report [HELPUS](#)

Last update: 2019-03-08T17:10:17 (UT) (0d 07h:23m ago) | now: 2019-03-09T00:33:16 (UT) QC pipeline: fors-5.3.3

history: 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 **2019** HEALTH **FULL**

close window \*Date on this mon

**FORS2: MOS average resolution (FULL range, 4725 days)**  
 QC data range: 2006-04-01 ... 2019-03-07\*



powered by QC: [www.eso.org/HC](http://www.eso.org/HC) created by trendPlotter v3.7 on 2019-03-08T17:10:14

png: [Information and research:](#)  
 - [png file](#) - [advanced studies:](#) [QC1 browser](#) | [QC1 plotter](#)

Plot	Symb	Source	Average		Thresholds		N_data	QC1 parameter	Data downloads	Remarks
			method	value	unit	method				
1	•	QC1DB	MEDIAN	512	NONE	none	826	central_resol	<a href="#">all (full time range)</a>	average resolution at cent
2	•	QC1DB	MEDIAN	517	NONE	none	823	central_resol	<a href="#">all (full time range)</a>	average resolution at cent

\*Data sources: QC1DB: QC1 database; LOCAL: local data source

**This plot**  
 From a wavelength calibrated MOS arc lamp exposure, the mean spectral resolution from all lines in catalog is computed. Each single resolution is computed as the ratio between the arc lamp line wavelength and its FWHM. The values trended here are for the 300V g width of 1.0" and the order separation filter GG435. Data have been acquired using the red-sensitive MIT detector.

DB Name: fors2\_mos\_wave  
 TPL.ID: FOR2\_specphot\_cal\_daycalib



Available raw types: BIAS | FLAT\_SKY | LAMP\_CHECK | LAMP\_HC\_LSS | LAMP\_LSS | LAMP\_MXU | LAMP\_PMOS | LAMP\_STD | STD\_IMA | STD\_IPOL | STD\_MOS\_C1 | STD\_MOS\_C2

Definition of this raw type (per DO class, multiple definitions possible): SCREEN\_FLAT\_MXU: DPR.CATG=="CALIB" and DPR.TYPE=="FLAT,LAMP" and INS.MODE=="MXU" and INS.GRIS1.NAME!="XGRIS\_600B" and INS.GRIS1.NAME!="XGRIS\_300I" and INS.MASK.NAME!="M012Distorti" LAMP\_MXU: DPR.CATG=="CALIB" and DPR.TYPE=="WAVE,LAMP" and INS.MODE=="MXU" and INS.GRIS1.NAME!="XGRIS\_600B" and INS.GRIS1.NAME!="XGRIS\_300I" and INS.MASK.NAME!="M012Distorti"

Table with columns: AB NAME, COMPL., AB LOG, RECIPE, RAW\_TYPE, SETUP, AB STATUS, P LOG, T\_EXEC, QC REPORT, SCO, RE, CERTIF. Rows include FOR2\_2019-03-05T12:10:49.145\_tpl.ab and FOR2\_2019-03-05T12:10:49.146\_tpl.ab.

Table with columns: AB NAME, COMPL., AB LOG, RECIPE, RAW\_TYPE, SETUP, AB STATUS, P LOG, T\_EXEC, QC REPORT, SCORE, CERTIF. Rows include FOR2\_2019-03-05T12:10:49.145\_tpl.ab and FOR2\_2019-03-05T12:10:49.146\_tpl.ab.

Table with columns: AB NAME, COMPL., AB LOG, RECIPE, RAW\_TYPE, SETUP, AB STATUS, P LOG, T\_EXEC, QC REPORT, SCORE, CERTIF. Rows include FOR2\_2019-03-05T12:10:49.146\_tpl.ab and FOR2\_2019-03-05T12:21:09.124\_tpl.ab.

Table with columns: AB NAME, COMPL., AB LOG, RECIPE, RAW\_TYPE, SETUP, AB STATUS, P LOG, T\_EXEC, QC REPORT, SCORE, CERTIF. Rows include FOR2\_2019-03-05T12:21:09.124\_tpl.ab and FOR2\_2019-03-05T12:21:09.125\_tpl.ab.

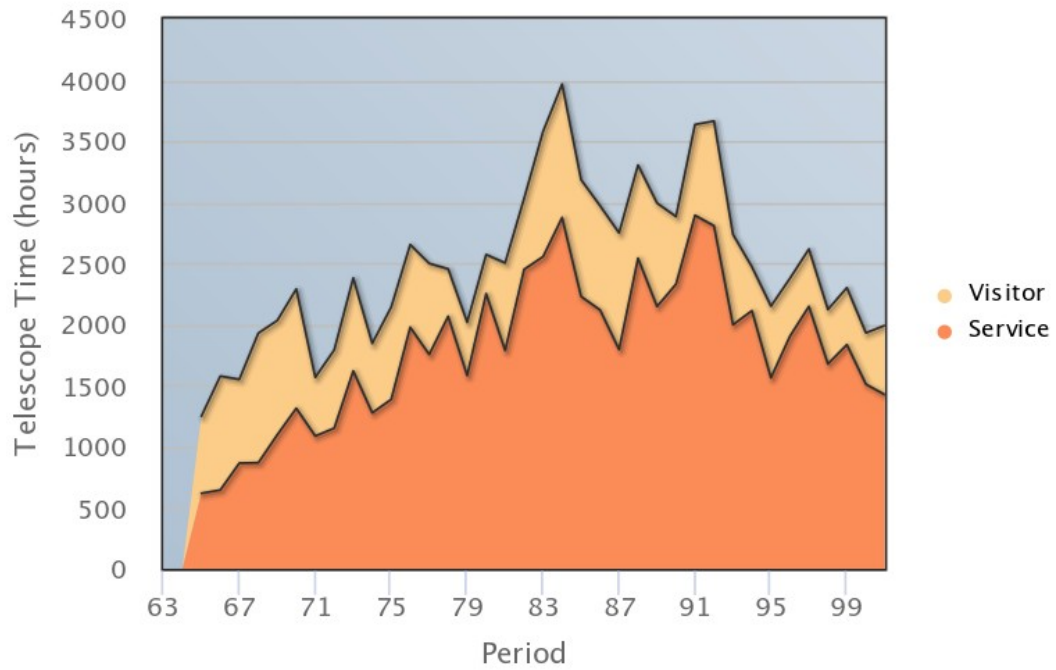
Table with columns: AB NAME, COMPL., AB LOG, RECIPE, RAW\_TYPE, SETUP, AB STATUS, P LOG, T\_EXEC, QC REPORT, SCORE, CERTIF. Rows include FOR2\_2019-03-05T12:21:09.125\_tpl.ab and FOR2\_2019-03-05T12:21:09.125\_tpl.ab.



Statistics



Requested Time: Service vs. Visitor Mode – FORS2



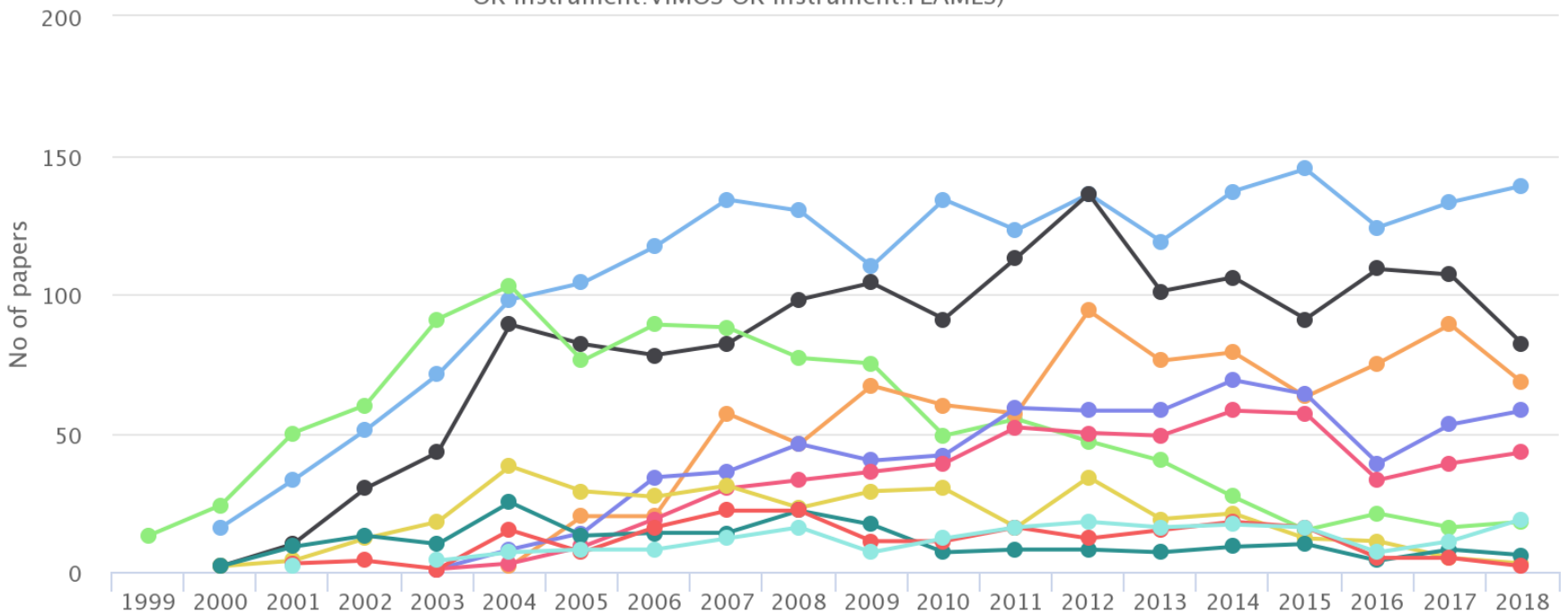
# ESO Annual Report 2017: requested time , pressure

Telescope	Instrument	Requested runs	Scheduled runs	Requested time	%	Scheduled time	%	Pressure	Total allocation	%
UT1	NACO	75	35	70	11.8%	19	15.8%	3.7	55	24.8%
	FORS2	345	101	376	63.9%	88	73.7%	4.3	109	49.3%
	KMOS	74	10	143	24.2%	13	10.6%	11.3	57	26.0%
<b>Total</b>		<b>494</b>	<b>146</b>	<b>588</b>		<b>119</b>		<b>4.9</b>	<b>221</b>	
UT2	FLAMES	88	17	145	15.5%	29	14.7%	5.0	49	21.2%
	UVES	206	45	298	32.0%	46	23.0%	6.5	53	22.8%
	X-SHOOTER	376	122	489	52.5%	124	62.3%	4.0	130	56.0%
<b>Total</b>		<b>670</b>	<b>184</b>	<b>931</b>		<b>199</b>		<b>4.7</b>	<b>233</b>	
UT3	SPHERE	219	104	220	60.3%	55	59.8%	4.0	118	47.3%
	VIMOS	21	13	33	9.0%	1	1.4%	25.1	85	34.2%
	VISIR	94	45	112	30.7%	35	38.8%	3.2	46	18.5%
<b>Total</b>		<b>334</b>	<b>162</b>	<b>364</b>		<b>91</b>		<b>4.0</b>	<b>248</b>	
UT4	SINFONI	146	22	177	26.5%	29	36.8%	6.0	48	32.8%
	MUSE	369	41	419	62.6%	42	52.3%	10.0	87	59.5%
	HAWK-I	86	17	72	10.8%	9	10.9%	8.3	11	7.8%
<b>Total</b>		<b>601</b>	<b>80</b>	<b>669</b>		<b>80</b>		<b>8.4</b>	<b>147</b>	

## No. of papers per instrument per year

Source: telbib

Query: year:[1999 TO 2018] and site:Paranal and (telescope:"VLT") and (instrument:FORS1 OR instrument:FORS2 OR instrument:UVES OR instrument:VIMOS OR instrument:FLAMES)

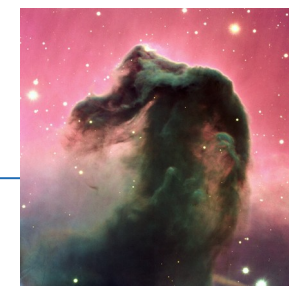


- UVES
- FORS2
- FORS1
- VIMOS
- FLAMES
- GIRAFFE
- ISAAC
- SOFI
- WFI
- FEROS
- HARPS
- EFOSC2
- XSHOOTER
- EMMI
- HAWKI
- VIRCAM
- SINFONI
- SUSI2
- GROND
- NACO
- MUSE
- ALMA\_Bands
- Decomm.Inst.
- LABOCA
- CRIRES
- OMEGACAM
- VISIR
- ULTRACAM\_VLT
- KMOS
- PIONIER
- SABOCA
- Z-Spec
- AMBER
- SPHERE
- OSIRIS
- SHFI
- TIMMI2
- ULTRACAM\_NTT
- SPIFFI
- FLASH
- MIDI
- SEPIA
- Special3.6
- VINCI
- VLT\_TestCam

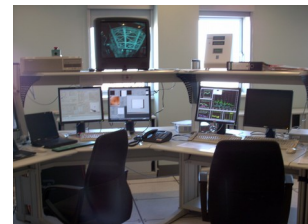
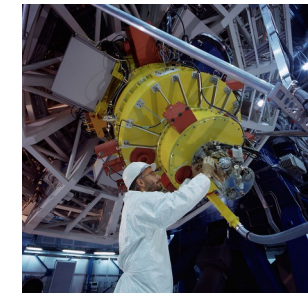




# Summary



- Overview of what ESO and the community has provided to support day-to-day operations of the instrument maintain and keep it competitive investigate problems and improve the instrument higher quality of astronomical data.



~ 50% of ESO staff once contributed to one of the FORSes

For the beautiful science of which we will hear in the next talks.

