Science Operations of ESO's La Silla Paranal Observatory: the back-end segment

Martino Romaniello
Head, Back-end Operations Department
ESO HQ - Garching bei München

(very kindly) presented by Magda Arnaboldi

The ESO Data Flow System

- The science operations of the La Silla Paranal Observatory are embedded in an end-to-end data flow system that encompasses the entire lifecycle of scientific data
  - From the preparation of observing proposals to telescope scheduling, from the detailed definition of observing strategies to their execution at the telescope, from data processing to archival exploitation of the data
- The goal is to deliver science data to users specs and feed the Science Archive Facility
- It is one of the pillars of the success of the VLT
- Engraved in the “VLT/VLTI Science Operations Policy” document by the ESO Council

The ESO back-end in a nutshell

- The back-end of the VLT Data Flow System begins when the data acquisition at the telescope ends
  - Data Transfer System
  - Data Processing
  - Quality Control
  - Science Archive Facility (SAF)
    - Data delivery to PIs, enable novel archive science
- Combination of operations and development
- Identify and exploit the similarities and synergies among the different activities and services
  - Reuse of concepts and bits and pieces of infrastructure in different context: cost effective and facilitates uniformity

From Chile to Garching in minutes: the Data Transfer System

The Data Transfer System

- Online transfer of data from the La Silla Paranal Observatory
  - Overflow system based on physical media (USB disks)
  - Configurable transfer priorities
  - About 200 GB (compressed) a day
- Typical transfer times
  - La Silla and Paranal (since April 2012): 50% of the files available for download within 30 minutes of acquisition, 90% within 3.5 hours, 99% within 8 hours
  - APEX (since April 2013): 100% of the data in 48 hours
- Allows to build operational and user services
  - Closed Quality Control loop
  - Quasi real-time user acces to time critical data (e.g. Targets of Opportunity, ...)
  - ...

Data processing

Data processing: the context

- ESO aims at supporting the production of science data products for all of its instruments
  - Immediate exploitation by the respective PIs
  - Re-use of the same data by the community at large through the ESO Science Archive Facility
- In support of the generation of data products, ESO enforces calibration plans for all the instruments and ensures that the instruments perform nominally
- ESO develops and exports data reduction tools for all of VLT/VLTI instruments to facilitate the exploitation of the data
  - Instrument specific algorithms
  - User oriented environment to execute and interact with the data reduction modules

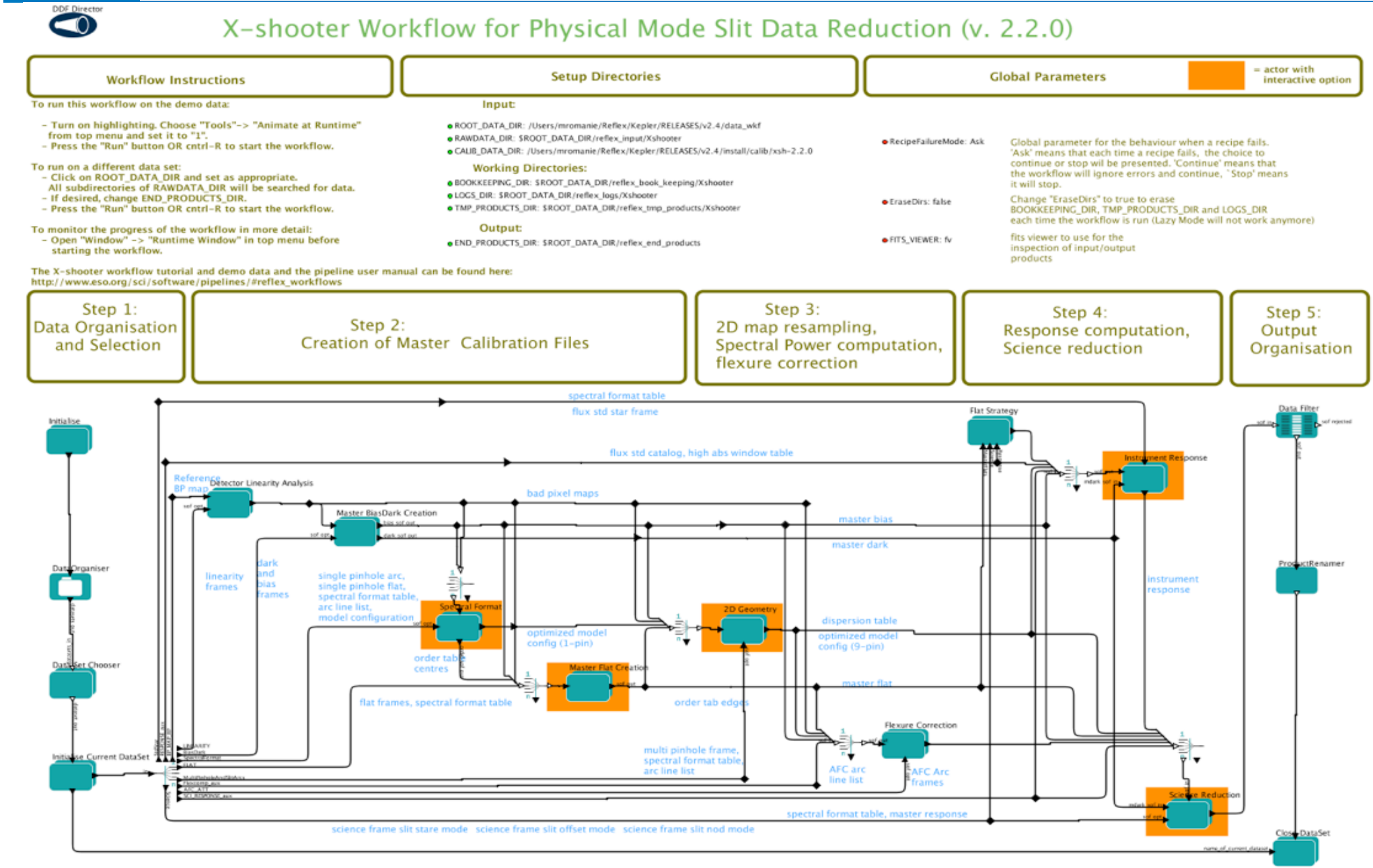
User science data processing: Reflex

User science processing: Reflex

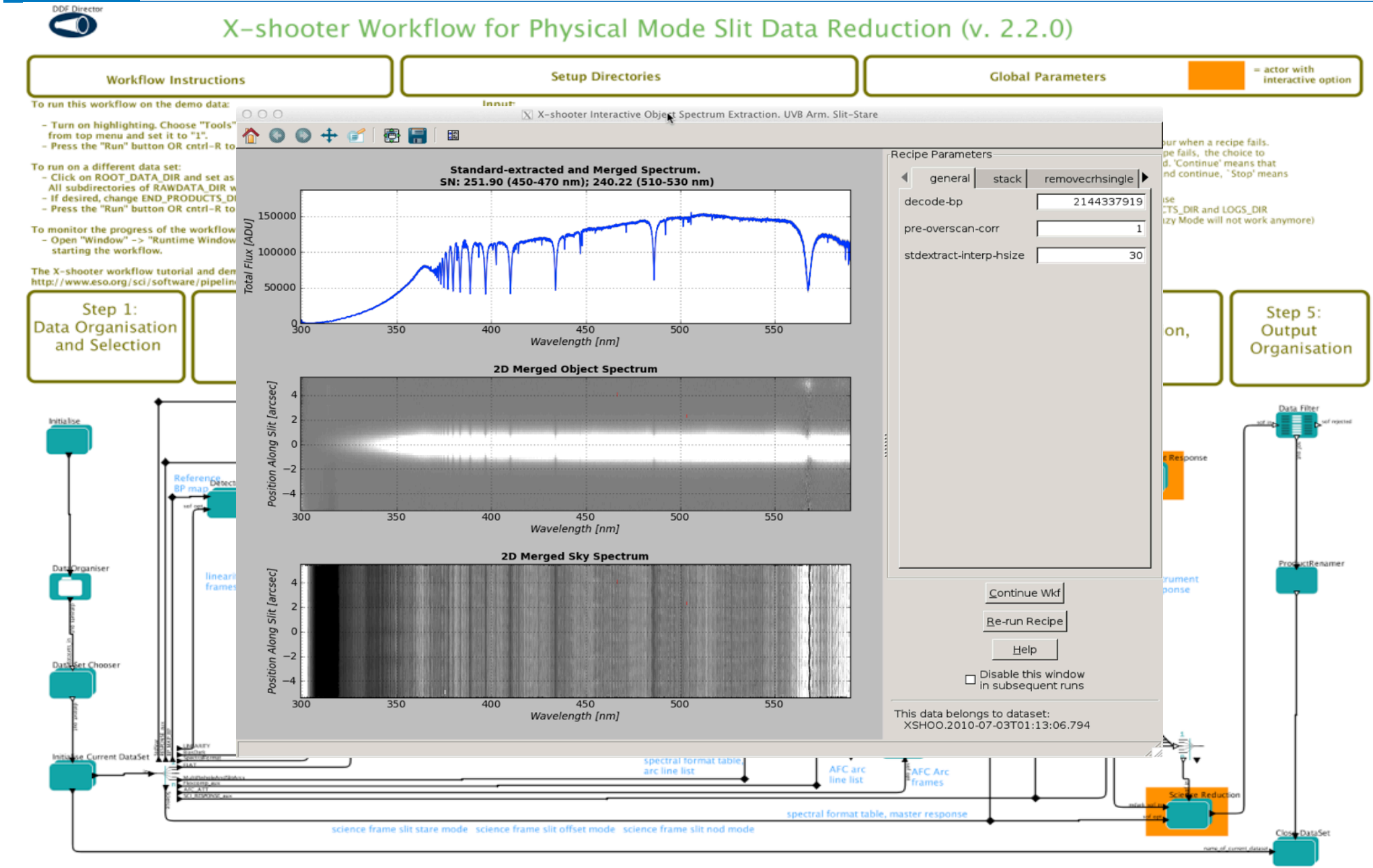
User science processing: Reflex

- Reflex is an environment that allows an easy and flexible way to execute VLT/I data reduction modules
  - Collection of scientific workflows executed by the Kepler workflow engine
    - A workflow is a graphical representation of the data reduction chain that allows for easy visualization, documentation and control of the execution
- In addition to the native Kepler modules (maths, logic, workflow control, I/O, etc.), Reflex workflows are based on customized ones for specific functionalities
  - Fully automatic data organization (full calibration cascade supported)
  - Support for multi OB processing
  - Conditional branches, loops and conditional stops
  - Interfaces to Python (hence IRAF and MIDAS) and IDL
- ESO releases fully functional workflows. Sources of workflows:
  - ESO, in kind contributions, 2nd generation instrument consortia, users (?)
  - Strategy: mixture of fully scientific validated and interactive workflows (UVES, X-Shooter, KMOS) and simpler ones to speed-up data organization and basic reduction (VIMOS spectroscopy, FORS2 MXU)
- More at this conference
  - Posters: Bramich (#5)

User science processing: Reflex



User science processing: Reflex



Pipeline development in 2013

Courtesy of Pascal Ballester

Active development					
Phase A to PAE	**Commissioning to PAC**	**Data Products Upgrades**	**Instrument Upgrades**	**On Hold**	**End of Maintenance**
SPHERE	KMOS	VISIR	VISIR	FORS IMG	WFI
MUSE	PRIMA	VIMOS SPEC	VIMOS	CRIRES	EFOSC
GRAVITY		FORS SPEC		MIDI	SOFI
MATISSE		FLAMES-UVES		AMBER	FEROS
ESPRESSO		HAWK-I		NACO	ISAAC
ERIS		VIMOS IMG		SINFONI	
4MOST		VIRCAM		UVES	
MOONS				GIRAFFE	
		OB combination		X-Shooter	
CUBES		Sky modeling		OCAM	
		Cal. issues		Det. Monitor	

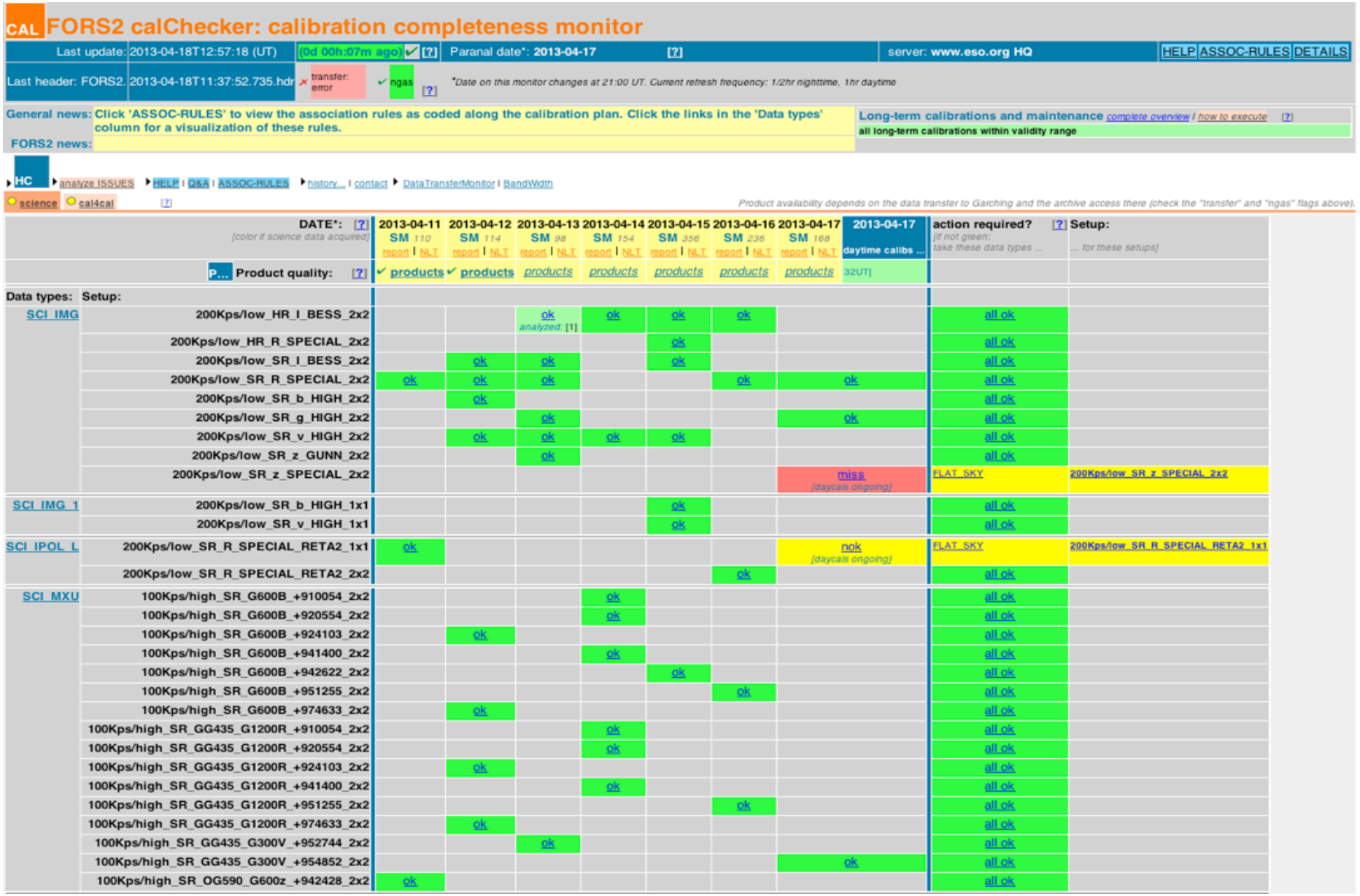
Instrument health, data completeness and quality: the Quality Control loop

The Quality Control loop

The Quality Control loop

- Quality Control loop with Paranal closed in minutes
- Data is transferred online to Garching, automatically processed and analyzed
  - Calibration completeness, instrument health indicators extracted from dedicated calibrations and trended
- The results fed back to Paranal for follow up
  - Follow up as shared process
  - Information on demand to highlight only critical situations

The Quality Control loop



CAL FORS2 calChecker: calibration completeness monitor

Last update: 2013-04-18T12:57:18 (UT) (0d 00h:07m ago) [?] Paranal date*: 2013-04-17 [?] server: www.eso.org HQ HELP ASSOC-RULES DETAILS

Last header: FORS2. 2013-04-18T11:37:52.735.hdr transfer: error ngas [?] *Date on this monitor changes at 21:00 UT. Current refresh frequency: 1/2hr nighttime, 1hr daytime

General news: Click 'ASSOC-RULES' to view the association rules as coded along the calibration plan. Click the links in the 'Data types' column for a visualization of these rules.

FORS2 news:

Long-term calibrations and maintenance complete overview | how to execute [?]
all long-term calibrations within validity range

HC analyze ISSUES HELP | Q&A | ASSOC-RULES history... | contact DataTransferMonitor | BandWidth

science cal4cal [?]

Product availability depends on the data transfer to Garching and the archive access there (check the "transfer" and "ngas" flags above).

DATE*: [?] [color if science data acquired]		2013-04-11 SM 110 report | NLT	2013-04-12 SM 114 report | NLT	2013-04-13 SM 98 report | NLT	2013-04-14 SM 154 report | NLT	2013-04-15 SM 356 report | NLT	2013-04-16 SM 236 report | NLT	2013-04-17 SM 168 report | NLT	2013-04-17 daytime calibs ...	action required? [?] [if not green: take these data types ...]	Setup: [... for these setups]
P... Product quality: [?]		✔ products	✔ products	products	products	products	products	products	32UT]		
Data types:	Setup:										
SCI_IMG	200Kps/low_HR_I_BESS_2x2			ok analyzed: [1]	ok	ok	ok			all ok	
	200Kps/low_HR_R_SPECIAL_2x2					ok				all ok	
	200Kps/low_SR_I_BESS_2x2		ok	ok		ok				all ok	
	200Kps/low_SR_R_SPECIAL_2x2	ok	ok	ok			ok	ok		all ok	
	200Kps/low_SR_b_HIGH_2x2		ok							all ok	
	200Kps/low_SR_g_HIGH_2x2			ok				ok		all ok	
	200Kps/low_SR_v_HIGH_2x2		ok	ok	ok	ok				all ok	
	200Kps/low_SR_z_GUNN_2x2			ok						all ok	
	200Kps/low_SR_z_SPECIAL_2x2							miss [daycals ongoing]		FLAT_SKY	200Kps/low_SR_z_SPECIAL_2x2
SCI_IMG_1	200Kps/low_SR_b_HIGH_1x1					ok				all ok	
	200Kps/low_SR_v_HIGH_1x1					ok				all ok	
SCI_IPOL_L	200Kps/low_SR_R_SPECIAL_RETA2_1x1	ok						nok [daycals ongoing]		FLAT_SKY	200Kps/low_SR_R_SPECIAL_RETA2_1x1
	200Kps/low_SR_R_SPECIAL_RETA2_2x2						ok			all ok	
SCI_MXU	100Kps/high_SR_G600B_+910054_2x2				ok					all ok	
	100Kps/high_SR_G600B_+920554_2x2				ok					all ok	
	100Kps/high_SR_G600B_+924103_2x2		ok							all ok	
	100Kps/high_SR_G600B_+941400_2x2				ok					all ok	
	100Kps/high_SR_G600B_+942622_2x2					ok				all ok	
	100Kps/high_SR_G600B_+951255_2x2						ok			all ok	
	100Kps/high_SR_G600B_+974633_2x2		ok							all ok	
	100Kps/high_SR_GG435_G1200R_+910054_2x2				ok					all ok	
	100Kps/high_SR_GG435_G1200R_+920554_2x2				ok					all ok	
	100Kps/high_SR_GG435_G1200R_+924103_2x2		ok							all ok	
	100Kps/high_SR_GG435_G1200R_+941400_2x2				ok					all ok	
	100Kps/high_SR_GG435_G1200R_+951255_2x2						ok			all ok	
	100Kps/high_SR_GG435_G1200R_+974633_2x2		ok							all ok	
	100Kps/high_SR_GG435_G300V_+952744_2x2			ok						all ok	
	100Kps/high_SR_GG435_G300V_+954852_2x2							ok		all ok	
	100Kps/high_SR_OG590_G600z_+942428_2x2	ok								all ok	

The Quality Control loop

CAL **FORS2 calChecker: Calibration report for all science files, date 2013-04-17**

close window | setup table | search full table

- This is the detailed calChecker report about the calibrations for all science OBs for the indicated date.
- All science data with PROG_ID starting with 60. or 060. are ignored.
- This report flags calibrations that are formally missing (marked in yellow or red). In exceptional cases, this formal result may be overridden by the analysis of the QC scientist (as indicated in the ANALYSIS notes). Then this analysis result, as displayed on the main calChecker interface, is the final word.

- OB comments are truncated after 40 characters. Point your mouse on the comment field to read the full comment, or check the nightlog ('NLT').
- Multiple comments for the same OB in the same night are all displayed, separated by '||'.
- The table can be sorted and filtered.
- Press Shift key for multiple column sorting (default is DATA_TYPE, SETUP and RAW_FILE).

bottom | report | NLT

OBs: 867746 868225 930624 934790 934793 934909 935004 935034 936335 959312 964564 964567 964570 964573 964768

The table can be searched and filtered. Restore default content with the browser refresh button.

Search (case-insensitive):

Showing 1 to 70 of 70 entries

DATE	PROG_ID	MODE	OBS_ID	GRD	OB Comm.	(first) RAW FILE	DATA TYPE	SETUP	CALIBRATIONS		
2013-04-17	091.D-0904(A)	SM	936335	A		FORS2.2013-04-17T23:46:25.603.fits	SCI_IMG	200Kps/low_SR_g_HIGH_2x2	BIAS: 0.47	FLAT_SKY: -3.04	STD_IMA: 0.14
2013-04-17	091.D-0904(A)	SM	936335	A		FORS2.2013-04-17T23:51:41.850.fits	SCI_IMG	200Kps/low_SR_g_HIGH_2x2	BIAS: 0.47	FLAT_SKY: -3.04	STD_IMA: 0.14
2013-04-17	091.D-0904(A)	SM	936335	A		FORS2.2013-04-17T23:57:04.109.fits	SCI_IMG	200Kps/low_SR_g_HIGH_2x2	BIAS: 0.47	FLAT_SKY: -3.04	STD_IMA: 0.14
2013-04-17	091.D-0904(A)	SM	936335	A		FORS2.2013-04-18T00:02:19.876.fits	SCI_IMG	200Kps/low_SR_g_HIGH_2x2	BIAS: 0.46	FLAT_SKY: -3.05	STD_IMA: 0.13
2013-04-17	091.D-0904(A)	SM	936335	A		FORS2.2013-04-18T00:07:43.984.fits	SCI_IMG	200Kps/low_SR_g_HIGH_2x2	BIAS: 0.46	FLAT_SKY: -3.05	STD_IMA: 0.13
2013-04-17	091.D-0904(A)	SM	936335	A		FORS2.2013-04-18T00:12:59.902.fits	SCI_IMG	200Kps/low_SR_g_HIGH_2x2	BIAS: 0.46	FLAT_SKY: -3.05	STD_IMA: 0.12
2013-04-17	091.D-0904(A)	SM	936335	A		FORS2.2013-04-18T00:18:23.070.fits	SCI_IMG	200Kps/low_SR_g_HIGH_2x2	BIAS: 0.45	FLAT_SKY: -3.06	STD_IMA: 0.12
2013-04-17	091.D-0904(A)	SM	936335	A		FORS2.2013-04-18T00:23:38.907.fits	SCI_IMG	200Kps/low_SR_g_HIGH_2x2	BIAS: 0.45	FLAT_SKY: -3.06	STD_IMA: 0.12
2013-04-17	091.D-0904(A)	SM	936335	A		FORS2.2013-04-18T00:29:01.116.fits	SCI_IMG	200Kps/low_SR_g_HIGH_2x2	BIAS: 0.45	FLAT_SKY: -3.06	STD_IMA: 0.11
2013-04-17	091.D-0904(A)	SM	936335	A		FORS2.2013-04-18T00:34:16.873.fits	SCI_IMG	200Kps/low_SR_g_HIGH_2x2	BIAS: 0.44	FLAT_SKY: -3.07	STD_IMA: 0.11
2013-04-17	091.C-0687(A)	SM	934909	A	00:48 Target saturated. Restarted OB wi...	FORS2.2013-04-18T00:58:11.113.fits	SCI_IPOL_L	200Kps/low_SR_R_SPECIAL_RETA2_1x1	BIAS: 0.43	FLAT_SKY: -5.09	STD_IPOL: -6.62
2013-04-17	091.C-0687(A)	SM	934909	A	00:48 Target saturated. Restarted OB wi...	FORS2.2013-04-18T01:00:26.059.fits	SCI_IPOL_L	200Kps/low_SR_R_SPECIAL_RETA2_1x1	BIAS: 0.43	FLAT_SKY: -5.09	STD_IPOL: -6.62
2013-04-17	091.C-0687(A)	SM	934909	A	00:48 Target saturated. Restarted OB wi...	FORS2.2013-04-18T01:10:38.101.fits	SCI_IPOL_L	200Kps/low_SR_R_SPECIAL_RETA2_1x1	BIAS: 0.42	FLAT_SKY: -5.09	STD_IPOL: -6.63
2013-04-17	091.C-0687(A)	SM	934909	A	00:48 Target saturated. Restarted OB wi...	FORS2.2013-04-18T01:11:57.131.fits	SCI_IPOL_L	200Kps/low_SR_R_SPECIAL_RETA2_1x1	BIAS: 0.42	FLAT_SKY: -5.09	STD_IPOL: -6.63
2013-04-17	091.C-0687(A)	SM	934909	A	00:48 Target saturated. Restarted OB wi...	FORS2.2013-04-18T01:13:16.220.fits	SCI_IPOL_L	200Kps/low_SR_R_SPECIAL_RETA2_1x1	BIAS: 0.42	FLAT_SKY: -5.10	STD_IPOL: -6.63
2013-04-17	091.C-0687(A)	SM	934909	A	00:48 Target saturated. Restarted OB wi...	FORS2.2013-04-18T01:14:35.069.fits	SCI_IPOL_L	200Kps/low_SR_R_SPECIAL_RETA2_1x1	BIAS: 0.42	FLAT_SKY: -5.10	STD_IPOL: -6.63
2013-04-17	091.C-0687(A)	SM	934909	A	00:48 Target saturated. Restarted OB wi...	FORS2.2013-04-18T01:16:02.150.fits	SCI_IPOL_L	200Kps/low_SR_R_SPECIAL_RETA2_1x1	BIAS: 0.42	FLAT_SKY: -5.10	STD_IPOL: -6.63
2013-04-17	091.C-0687(A)	SM	934909	A	00:48 Target saturated. Restarted OB wi...	FORS2.2013-04-18T01:17:30.090.fits	SCI_IPOL_L	200Kps/low_SR_R_SPECIAL_RETA2_1x1	BIAS: 0.42	FLAT_SKY: -5.10	STD_IPOL: -6.63
2013-04-17	091.C-0687(A)	SM	934909	A	00:48 Target saturated. Restarted OB wi...	FORS2.2013-04-18T01:18:57.190.fits	SCI_IPOL_L	200Kps/low_SR_R_SPECIAL_RETA2_1x1	BIAS: 0.41	FLAT_SKY: -5.10	STD_IPOL: -6.63
2013-04-17	091.C-0687(A)	SM	934909	A	00:48 Target saturated. Restarted OB wi...	FORS2.2013-04-18T01:20:25.091.fits	SCI_IPOL_L	200Kps/low_SR_R_SPECIAL_RETA2_1x1	BIAS: 0.41	FLAT_SKY: -5.10	STD_IPOL: -6.64
2013-04-17	091.D-0090(B)	SM	867746	A		FORS2.2013-04-18T01:31:22.048.fits	SCI_PMOS	200Kps/low_SR_G1200B_RETA4_0_1x1	FLAT_PMOS: MISS	WAVE_PMOS: MISS	BIAS: 0.40
2013-04-17	091.D-0090(A)	SM	868225	A		FORS2.2013-04-18T02:28:00.952.fits	SCI_PMOS	200Kps/low_SR_G1200B_RETA4_0_1x1	FLAT_PMOS: MISS	WAVE_PMOS: MISS	BIAS: 0.36
2013-04-17	091.C-0687(A)	SM	935034	C	03:16 Target magnitude strongly variabl...	FORS2.2013-04-18T03:24:29.461.fits	SCI_IPOL_L	200Kps/low_SR_R_SPECIAL_RETA2_1x1	BIAS: 0.33	FLAT_SKY: -5.19	STD_IPOL: -6.72

The Quality Control loop

- Quality Control loop with Paranal closed in minutes
- Data is transferred online to Garching, automatically processed and analyzed
  - Calibration completeness, instrument health indicators extracted from dedicated calibrations and trended
- The results fed back to Paranal for follow up
  - Follow up as shared process
  - Information on demand to highlight only critical situations
- Wealth of information available to users

www.eso.org/qc

- More at this conference
  - Talks: Hanuschik (Wednesday at 16:30)
  - Posters: Dobrzycka (#8)

The ESO Science Archive Facility (SAF)

Data access through the SAF

- The Science Archive Facility is now **the** access point to ESO data
  - Online self service (w/ CalSelector) vs media pushed to users
    - Media at the Observatories discontinued
  - Time critical data access: Target of Opportunity/Rapid Response Mode, pre-imaging, transients, planets, ...
  - Proprietary access to PIs and delegates
  - Subscription service to notify users of observation execution
  - (Limited) programmatic access

http://archive.eso.org

Data access through the SAF

To browse the archive

Currently, **raw data** and various types of **data products** can be reached via different interfaces:

Category	Query Forms	Data collection	Data Type	Instruments
LPO Raw Data	**Raw data** query form (all instruments) **Instrument specific** query forms **Direct** retrieval of raw data by file name	All ESO raw data	Various	Many La Silla Paranal instruments
LPO Data Products	**Phase 3 main** query form **Phase 3 imaging** query form **Phase 3 instrument specific** query form	Phase 3 Data Products (ESO Public Surveys)	Currently, Imaging	Currently, VISTA/VIRCAM
	Catalogue Facility query interface	Phase 3 Catalogues [ESO User Portal authentication required also when browsing]	Catalogues	Currently, VISTA/VIRCAM
	Advanced Data Products query form	GOODS (C.Cesarsky)	Imaging, Spectroscopy	FORS2/ISAAC/VIMOS
		zCOSMOS (S.Lilly)	Spectroscopy	VIMOS
		Observation of Corot astroseismologically-selected HD stars (E.Poretti)	Spectroscopy (time series)	FEROS
		UVES reprocessed	Spectroscopy	UVES
		Time-domain survey of NGC 2547 (S.Aigrain)	Imaging	FEROS
	FEROS/HARPS pipeline processed data query form	FEROS/HARPS pipeline processed data	Spectroscopy	FEROS, HARPS
	Science Verification, Commissioning, EIS, etc.	Full list of available data packages	Various	Many
APEX Quick Look Products	**APEX** query form	APEX	Heterodyne, Bolometer	APEX-2A, LABOCA, SABOCA, SHeFI
ALMA Data Products	**ALMA Science Verification**	All ALMA SV data	Cube	ALMA

http://archive.eso.org

CalSelector

CalSelector

- Archive service to associate to raw science files all the raw and static calibrations needed for processing, plus ancillary files (e.g. acquisition frames), night log excerpts and a description of the association itself (xml format)
  - Designed to reproduce the Calibration Plans and work with Reflex
- v1.0 deployed in November 2011
- Complete coverage from 2009, effort to extend as far back as possible
  - The look-back time will likely depend on instrument and mode
- **http://www.eso.org/sci/archive/calselectorInfo.html**

CalSelector

Select	Dataset	File (Category)	Size	Access
☐	⊟ ✔ SAF+UVES.2008-04-28T06:43:54.974			
☐		UVES.2008-04-28T06:43:54.974.fits.Z (SCI_POINT_RED)	16.2MB	✔
☐		M.UVES.2012-03-07T17:01:05.530.tfits (LINE_REFER_TABLE)	33.8KB	✔
☐		M.UVES.2012-03-07T17:02:30.714.tfits (LINE_INTMON_TABLE)	8.4KB	✔
☐		M.UVES.2012-03-07T17:04:35.088.tfits (EXTCOEFF_TABLE)	8.4KB	✔
☐		UVES.2008-04-28T06:43:46.615.fits.Z (ACQ_ECH)	317.0KB	✔
☐		UVES.2008-04-28T10:27:16.099.fits.Z (BIAS_RED)	8.5MB	✔
☐		UVES.2008-04-28T10:28:02.813.fits.Z (BIAS_RED)	8.5MB	✔
☐		UVES.2008-04-28T10:28:49.547.fits.Z (BIAS_RED)	8.5MB	✔
☐		UVES.2008-04-28T10:29:36.261.fits.Z (BIAS_RED)	8.5MB	✔
☐		UVES.2008-04-28T10:30:22.975.fits.Z (BIAS_RED)	8.5MB	✔
☐		UVES.2008-04-28T12:23:04.986.fits.Z (EFLAT_RED)	30.0MB	✔
☐		UVES.2008-04-28T12:24:26.823.fits.Z (EFLAT_RED)	29.9MB	✔
☐		UVES.2008-04-28T12:25:48.881.fits.Z (EFLAT_RED)	30.0MB	✔
☐		UVES.2008-04-28T12:27:10.808.fits.Z (EFLAT_RED)	30.0MB	✔
☐		UVES.2008-04-28T12:28:32.795.fits.Z (EFLAT_RED)	30.1MB	✔
☐		UVES.2008-04-28T12:30:02.093.fits.Z (ECH_ARC_LAMP_RED)	21.3MB	✔
☐		UVES.2008-04-28T12:31:47.652.fits.Z (ORDER_FLAT_RED)	16.2MB	✔
☐		UVES.2008-04-28T12:33:24.621.fits.Z (ECH_ARC_LAMP_FORM_RED)	11.6MB	✔
☐		UVES.2008-04-28T06:43:54.974.NL.txt (NIGHTLOG_INFO)	332B	✔
☐		UVES.2008-04-28T06:43:54.974.xml (ASSOCIATION_TREE)	7.6KB	✔

Data products & the Archive

- ESO's high level strategy
  - Advanced Data Products from the community
    - Phase 3
      - –Public Surveys, Large Programmes, et al.
  - Science Grade Data Products generated in-house
    - Service and Visitor Mode
    - The data products and tools are evolving to support this
  - Data products through the Science Archive Facility
    - The archive services are evolving to support this

Internal Data Products

- Science grade data products generated in-house by running the corresponding instrument pipelines
  - Driven by data, rather then by a specific science goal
  - Uniform processing with a standard set of processing parameters
- Seamless archive experience with External Data Products, e.g. from Public Surveys
  - Full integration in the Science Archive Facility
- Timeline
  - Publication of UVES Echelle data in Q4 2013 (backlog+stream of new data)
  - Then (*preliminary*): X-Shooter-Echelle, FLAMES-MEDUSA, and HAWK-I and VIMOS imaging (UK in-kind contribution), KMOS, MUSE
- More at this conference
  - Talks: Retzlaff (Friday at 11:40)
  - Posters: Hanuschik (#11)

External Data Products (Phase 3)

- Phase 3 – PIs of ESO observing programmes return data products to ESO
  - Storage in the ESO Archive
  - Publication to the scientific community
- ESO's policies governing Phase 3 are specific to the type of observing programme
- Phase 3 is mandatory for ESO Public Surveys and for ESO Large Programmes since period 75; available also for other ESO observations
- Further allocation of telescope time for Public Surveys is conditional to the submission of data products via Phase 3
- More at this conference
  - Talks: Arnaboldi (Friday at 9:50) and Retzlaff (Friday at 11:40)
  - Posters: Micol (#19), Delmotte (#20), Retzlaff (#26)

The Archive as Science Resource

- Refereed publications from ESO facilities

Source: ESO Telescope Bibliography Query Form
http://telbib.eso.org

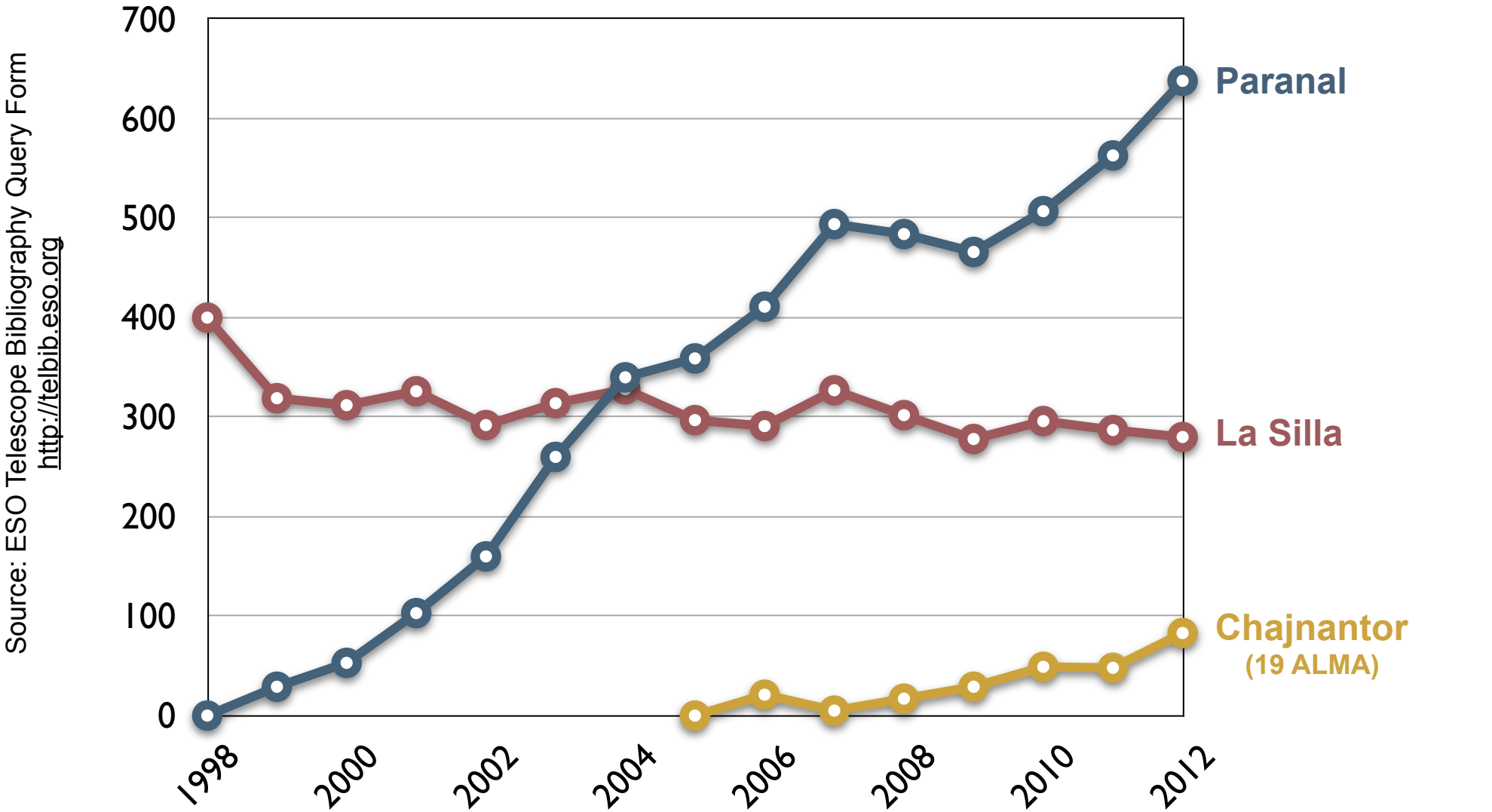
Paranal

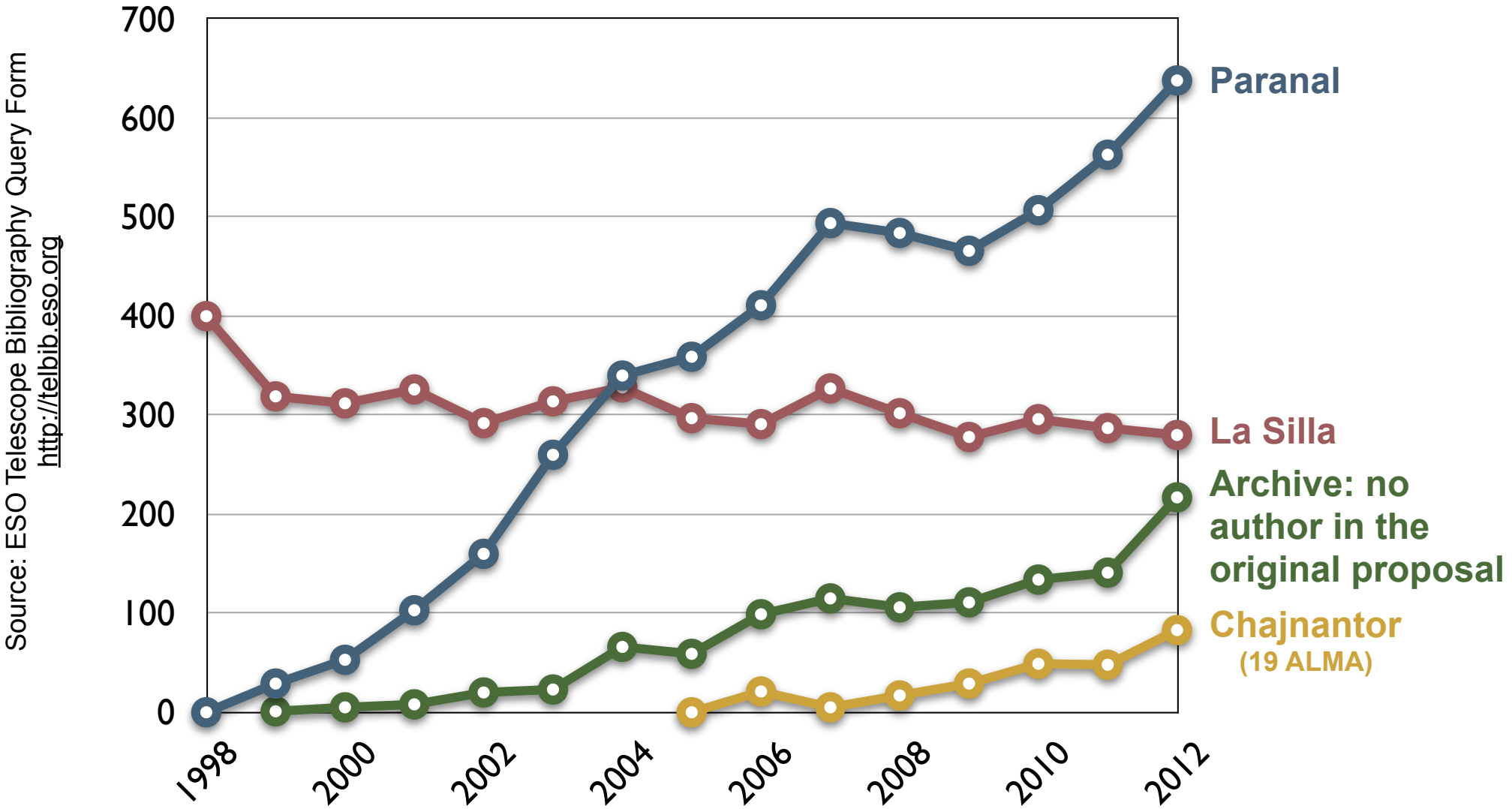
La Silla

Chajnantor
(19 ALMA)

The Archive as Science Resource

- Refereed publications from ESO facilities



The Archive as Science Resource

- Refereed publications from ESO facilities