ESO instrument pipelines: what are they and how to use them

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http://www.eso.org/sci/software/pipelines/
Instruments are complex! Therefore we need pipelines. Pipelines (instrument-specific data processing software) are:

- designed, developed and delivered by the instrument consortia
- maintained and upgraded by ESO

Pipelines can be executed via: esorex, Gasgano and Reflex.
Classical data processing paradigm

- write scripts to sort, select, and process the data (shell+esorex, IDL, IRAF, python, C++, etc.).
- burn the HDD of your laptop
- realize that you have done it all wrong
- read the manual
- re-write the scripts (a few times)
- re-reduce the data (a few times)
Classical data processing paradigm

Now try this with KMOS or MUSE...
Three ways to run the pipelines:

- PRO: scripting
- CON: human labor intensive

```
vivanov@pc018251$ ./esorex --recipes

***** ESO Recipe Execution Tool, version 3.13.2 *****

List of Available Recipes:

  efosc_photometry : Compute corrected flatfield
  efosc_calib     : Determination of the extraction mask
  efosc_img_science : Reduce scientific exposure
  efosc_img_screen_flat : Compute master screen flat frame
  efosc_science   : Extraction of scientific spectra
  efosc_extract   : Extraction of scientific spectra
  efosc_img_sky_flat : Compute master img_sky_flat frame
  efosc_bias      : Compute the master bias frame
  efosc_zeropoint : Compute zeropoint
```

https://www.eso.org/sci/software/cpl/esorex.html
Three ways to run the pipelines:

vivanov@pc018251$ ./esorex --help efosc_bias

***** ESO Recipe Execution Tool, version 3.13.2 *****

Recipe: efosc_bias -- Compute the master bias frame

Usage: esorex [esorex-options] efosc_bias [efosc_bias-options] sof

Options:

--stack_method : Frames combination method. <average | median | minmax | ksigma> [minmax]
--minrejection : Number of lowest values to be rejected. [1]
--maxrejection : Number of highest values to be rejected. [1]
--klow : Low threshold in ksigma method. [3.0]
--khigh : High threshold in ksigma method. [3.0]
--kiter : Max number of iterations in ksigma method. [999]
--qc : Compute QC1 parameters. [TRUE]

vivanov@pc018251$
vivanov@pc018251$ ./esorex efosc_bias list_bias_01.sof

***** ESO Recipe Execution Tool, version 3.13.2 *****

https://www.eso.org/sci/software/cpl/esorex.html
Three ways to run the pipelines:

vivanov@pc018251$ /scratch/Duties/SofI_pipeline_Mod/bin/esorex sofi_spc_arc arcs.sof

***** ESO Recipe Execution Tool, version 3.12.3 *****
[ INFO ] sofi_spc_arc: Reducing set 1/4
[ INFO ] sofi_spc_arc: Apply the reduction
[ INFO ] sofi_spc_arc: Estimate the distortion
[ INFO ] sofi_spc_arc: Purged 154 of 173 arcs (1st purged=1)
[ INFO ] sofi_spc_arc: 19 detected arcs
[ INFO ] sofi_spc_arc: Create deformation grid
[ INFO ] sofi_spc_arc: Line 1 has center gradient -0.000297753
[ INFO ] sofi_spc_arc: Line 2 has center gradient -0.000305544
[ INFO ] sofi_spc_arc: Line 3 has center gradient -0.000180431
[ INFO ] sofi_spc_arc: Line 4 has center gradient -0.00047511
[ INFO ] sofi_spc_arc: Line 5 has center gradient -0.000153735
[ INFO ] sofi_spc_arc: Line 6 has center gradient -0.000174978
[ INFO ] sofi_spc_arc: Line 7 has center gradient -0.000153965
[ INFO ] sofi_spc_arc: Line 8 has center gradient -8.59044e-05
[ INFO ] sofi_spc_arc: Line 9 has center gradient -0.000104888
[ INFO ] sofi_spc_arc: Line 10 has center gradient -8.89941e-05
[ INFO ] sofi_spc_arc: Line 11 has center gradient -8.71959e-06

https://www.eso.org/sci/software/cpl/esorex.html
Three ways to run the pipelines:

vivanov@pc018251$ /scratch/Duties/SofI_pipeline_Mod/bin/esorex sofi_spc_arc arcs.sof

*** ESO Recipe Execution Tool, version 3.13.3

[ INFO ] sofi_spc_arc: Line 10 has center gradient -8.8994e-05
[ INFO ] sofi_spc_arc: Line 11 has center gradient -8.71959e-06

https://www.eso.org/sci/software/cpl/esorex.html
Three ways to run the pipelines:

https://www.eso.org/sci/software/cpl/esorex.html
Three ways to run the pipelines:

- zone: Zone to consider for normalisation (default is 250,250,708,708)
- offset: Offset to apply before the fitting (default is 40)

9.8 sofi_spc_arc

This recipe both computes the wavelength calibration and the slit curvature distortion using vertical lines.

9.8.1 Input

The expected frames must be tagged with SP_ARC. They are either frames obtained with a Xenon lamp, an Neon lamp, with both, or none (dark). The recipe also needs the Xenon and Neon lines FITS catalogs (CALPRO_XE_CATALOG and CALPRO_NE_CATALOG).

9.8.2 Output

For each setting, the produced tables are named sofi_spc_arc_setxx_framexx.fits. It contains both the distortion polynomial and the dispersion relation as shown in Figure 9.8.1 (PRO CATG = ARC_COEF).

Additionally, the image with the distortion corrected arcs is produced under the name sofi_spc_arc_setxx_framexx_corr.fits (PRO CATG = ARC_CORRECT).
Three ways to run the pipelines:

- QC ARCSi FWHM: The FWHM of the arcs
- QC ARCSi FLUX: The flux of the arcs
- QC ARCS NUMGOOD: The number of valid arcs
- QC FWHM MED: The median of the FWHMs

9.8.4 Parameters

- rej: Left and Right zones of the image to reject (default is 100,100)
- subdark: Flag to apply an automatic dark subtraction (default is FALSE)
- arc_max_w: Arc maximum width in pixels (default is 33)
- out_corr: Flag to produce distortion corrected images (default is FALSE)
- display: Flag to activate plotting facility (only works if gnuplot is installed) (default is FALSE)
- degree: Requested degree for the wavelength calibration polynomial (default is 2)
- wl_nsamples: Number of samples for the best wavelength dispersion polynomial search (default is 100)
- wl_err: Wavelength search size in Angstroms for the best wavelength dispersion polynomial search (default is 1000.0)
- ppm: Flag to activate the Point Pattern Matching (default is FALSE)
Three ways to run the pipelines:

```
vivanov@pc018251$ /scratch/Duties/Sofi_pipeline_Mod/bin/esorex --help sofi_spc_arc

****** ESO Recipe Execution Tool, version 3.12.3  ******
Recipe: sofi_spc_arc -- SOFI Spectro arc recipe


Options:

--rej
--subdark
--arc_max_w
--out_corr
--display
--degree
--wl_nsamples
--wl_err
--lines
--ppm

: Left, right rejections [pixel]. [100,100]
: Enable dark subtraction. [FALSE]
: Maximum supported arc width [pixel]. [33]
: Enable correction of output images. [FALSE]
: Enable plotting. [FALSE]
: Degree of the wavelength dispersion polynomial. [2]
: Number of samples for the wavelength calibration. [100]
: The wavelength error [Angstrom]. [1e+03]
: Lines ASCII-file. []
: Enable Point Pattern Matching. [FALSE]

For help on the options of esorex itself, please use the command 'esorex --help' (that is, without specifying any recipe name). For more information about the recipe, one can also use the command 'esorex --man-page sofi_spc_arc'.

vivanov@pc018251$
```
Three ways to run the pipelines:

https://www.eso.org/sci/software/gasgano.html
Three ways to run the pipelines:

http://www.eso.org/sci/software/esoreflex/
Three ways to run the pipelines:

Pro:
- intuitive
- interactive
- configurable
- open to user routines
- optimized execution
- data organization
- bookkeeping
- designed by experts
- tested and improved
- documents, tutorials

Con:
- N.A.

http://www.eso.org/sci/software/esoreflex/
Three ways to run the pipelines:

**Pro:**
- intuitive
- interactive
- configurable
- open to user routines
- optimized execution
- data organization
- bookkeeping
- designed by experts
- tested and improved
- documents, tutorials

**Con:**
- steep learning curve
- tolerates black-box style usage
- Java

http://www.eso.org/sci/software/esoreflex/
Automated data reduction workflows for astronomy

The ESO Reflex environment


European Southern Observatory, Karl-Schwarzschild-Str. 2, 85748 Garching, Germany
e-mail: wfreudli@eso.org

Received 16 August 2013 / Accepted 14 October 2013

ABSTRACT

Context. Data reduction is complex even for modern astronomical instruments often consisting of several complex science and calibration pipelines. The reflex environment requires a variety of software tools. The execution of software tools in a reflex workflow that is executed on a regular basis provides an easy way to perform data reduction. In order to provide a reflex environment.

Previous approaches often had an individual research that is provided by the individual researchers that are improved by using reflex. In order to improve the reflex environment, we designed a system that is provided by the European Southern Observatory (ESO) has developed Reflex, an automation tool for data reduction. The reflex environment is a reflex-informed environment that is provided as a package of customized components for the Kepler workflow. It uses the reflex environment to create an executable flowchart-like representation of the data reduction process. The reflex environment includes a data organiser, infrastructure to re-use results, thorough book-keeping, data progeny tracking, and version control. Reflex includes novel concepts to exploit information created during data organisation for the workflow execution.

Results. Automated workflows can greatly increase the efficiency of astronomical data reduction. In Reflex, the reflex environment is provided interactively as a first step. Subsequent optimization can then be carried out while transparently re-using all results and metadata. We found that such workflows enable the reduction of complex data by non-expert users and minimize the risk of mistakes and failures due to book-keeping errors.

Conclusions. Reflex includes novel concepts to increase the efficiency of astronomical data processing. While Reflex is a specific
Seeking help

https://www.youtube.com/channel/UCCq4rxr30ydNyV94OWmLrMA
Reflex highlights

http://www.eso.org/sci/software/esoreflex/
Quick start
Basic Reflex Workflow

Workflow components:
- actors – basic data organization or processing “units”
- relations – lines of communication between actors (black lines)

- Reflex uses SOFs (Set Of Files) and SOPs (Set of Parameters) as tokens
- SOFs include files, categories (e.g. darks, flats, etc) + purpose
- Data Organizer organizes data in “DataSets” (saves a lot of time!)
- A DataSets are SOFs that include everything needed to process one set of science observations + relevant recipe parameters
Step 1: Data Organisation and Selection

- Initialise
- Inspect previously reduced data
- Data Organiser

Step 2: Creation of Master Calibration Files

- Master Dark Creation
- Master Bias Creation
- Spectrum Locator
- Master Flat Creator

Edit parameters for DataOrganizer

- OCA File: /scratch/Duties/Pipeline_UVES/install/share/esopipes/uves-5.10.4/reflex/uves_wkf.oca
- Keywords to be displayed:
  OBJECT, INS_PATH, DET.CHIPS, DET.WIN1.BINX, DET.WIN1.BINY, DET.READ.SPEED, INS.MODE, INS.SLIT1.NAME, INS.
- Lazy Mode:
- Use CalSelector associations:
- Association preference:
- Bookkeeping Dir:
  $BOOKKEEPING_DIR
- class:
  org.eso.DataOrganizer

Commit  Add  Remove  Defaults  Preferences  Help  Cancel
REFLEX Data Organisation

Dataset

science file  associated calibration files

science image  bias  flat  bias  dark  bias  dark  bias

DataOrganizer  datasets out

proc_dark  processed_dark

proc_flat  processed_flat

proc_image
REFLEX OCA Rules

Data organisation defined in “OCA rules” (text file)

• Three types of rules:
  – Classification (“This is a Raw Dark”)
  – Organization (“These Raw Darks are processed together”)
  – Association (“Processing of Raw Darks need these Biases”)

• DO produces DataSets

• Each file in DataSet has a category (e.g. “raw bias”) and a purpose action1/action2/... (e.g. „bias subtract:“, :flatfield“, etc)
//Classification
if DPR.CATG=="CALIB" and DPR.TYPE=="BIAS" and DET.CHIPS==1 and INSTRUME=="UVES" then
{
    RAW.TYPE = "BIAS_BLUE";
    REFLEX.CATG = "BIAS_BLUE";
    PACK.DIR = "DET";
    CATG = "CALIB";
}
if DPR.CATG=="CALIB" and DPR.TYPE=="BIAS" and DET.CHIPS==2 and INSTRUME=="UVES" then
{
    RAW.TYPE = "BIAS_RED";
    REFLEX.CATG = "BIAS_RED";
    PACK.DIR = "DET";
    CATG = "CALIB";
}
if DPR.CATG=="CALIB" and ( (DPR.TYPE=="BIAS,DETCHAR" and TPL.ID=="UVES_blue_tec_ccdflat") and DET.CHIPS==1 and INSTRUME=="UVES" ) then
{
    RAW.TYPE = "CCDTEST_BLUE";
    REFLEX.CATG = "BIAS_DETCHAR_BLUE";
    PACK.DIR = "NONE";
}

OCA rules file
Editing parameters
Hierarchical structure – sub-workflows
Hierarchical structure – sub-workflows
Configurable!

Setup Directories

Input:
- ROOT_DATA_DIR: $HOME/reflex_data
- RAW_DATA_DIR: /scratch/Duties/Pipeline_UVES/data_wkf/reflex_input/uves

Only change CALIB_DATA_DIR if you do NOT want to use the calibration data delivered with the pipeline:
- CALIB_DATA_DIR: /scratch/Duties/Pipeline_UVES/install/share/esopipes/datastatic/uves-5.10.4/

None of the directories below should be a subdirectory of RAW_DATA_DIR or CALIB_DATA_DIR

Output:
- END_PRODUCTS_DIR: $ROOT_DATA_DIR/reflex_end_products

Working Directories:
- BOOKKEEPING_DIR: $ROOT_DATA_DIR/reflex_bookkeeping/uves
- LOGS_DIR: $ROOT_DATA_DIR/reflex_logs/uves
- TMP_PRODUCTS_DIR: $ROOT_DATA_DIR/reflex_tmp_products/uves
- BOOKKEEPING_DB: $BOOKKEEPING_DIR/bookkeeping.db

Global Parameters

Global parameter for the behaviour when a recipe fails. 'Ask' means that each time a recipe fails, the choice to continue or stop will be presented. 'Continue' means that the workflow will ignore errors and continue. 'Stop' means the workflow will stop.

- RecipeFailureMode: Ask
- EraseDirs: false

Change "EraseDirs" to 'true' to erase BOOKKEEPING_DIR, TMP_PRODUCTS_DIR and LOGS_DIR each time the workflow is run (Lazy Mode will not work anymore)

- FITS_VIEWER: fv
- GlobalReduceFFmethod: extract
- GlobalPlotInteractivity: true
- SelectDatasetMethod: Interactive
- ProductExplorerEnabled: true
- ProductExplorerMode: Triggered
- MaximumFlatNumber: 12

Fits viewer to use for the inspection of input/output products

- Flat-fielding method. If set to 'pixel', flat-fielding is performed in pixels. If set to 'extract', flat-fielding is performed in pixels. Overides in subworkflows have precedence.
- Disable interactive GUs for the whole workflow.
- Selection method for the Data Set Chooser
- Show Product Explorer window
- ProductExplorer pops up after all datasets are fit

Maximum number of input raw flats tolerated by the setup. You may increase this value if you have more than...
### Execution

![Image of software interface showing a table and options to select datasets.]
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Execution
Execution
vivanov@pc018251$ pwd
/scratch/Duties/Pipline_VISIR/data_wkf
vivanov@pc018251$ ls -l
total 20
drwxr-xr-x 3 vivanov SG-HQ-CADPlot 4096 Jan 7 17:02 reflex_book_keeping
drwxr-xr-x 9 vivanov SG-HQ-CADPlot 4096 Jan 10 17:07 reflex_end_products
drwxr-xr-x 4 vivanov SG-HQ-CADPlot 4096 Jan 10 16:46 reflex_input
drwxr-xr-x 3 vivanov SG-HQ-CADPlot 4096 Jan 7 17:02 reflex_logs
drwxr-xr-x 3 vivanov SG-HQ-CADPlot 4096 Jan 7 17:02 reflex_tmp_products

vivanov@pc018251$ pwd
vivanov@pc018251$ ls -l
total 32
-rwxr--r-- 1 vivanov SG-HQ-CADPlot 1730 Apr 9 2019 cmdline.sh
-rwxr--r-- 1 vivanov SG-HQ-CADPlot 248 Apr 9 2019 data.sof
-rwxr--r-- 1 vivanov SG-HQ-CADPlot 1 Apr 9 2019 exitcode.txt
-rwxr--r-- 1 vivanov SG-HQ-CADPlot 533 Apr 9 2019 input_sof.json
-rwxr--r-- 1 vivanov SG-HQ-CADPlot 0 Apr 9 2019 kmos_median_response.rc
-rwxr--r-- 1 vivanov SG-HQ-CADPlot 2 Apr 9 2019 output_sof.json
-rwxr--r-- 1 vivanov SG-HQ-CADPlot 2 Apr 9 2019 parameters.json

More goodies
More goodies
A few final words

- All data is different.

- The best results will be obtained trying various data reduction approaches. Again. And again. And again.

- Don't trust your first try, especially in the infrared where the observing conditions vary much more than in the optical.

- There is so much more...

- Cry for help at: usd-help@eso.org