On MUSE data reduction: Exposures Alignment & useful tips

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Outline

- Where to look for information and help
- MUSE data reduction in a nutshell
- ESOrex vs ESOReflex
- Master calibrations: useful shortcut ..
- Interactive exposures alignment (Live Demo)
- Stacking exposures from multiple OBs

Information & Help

- User Manual and Instrument web pages

https://www.eso.org/sci/facilities/paranal/instruments/muse/doc.html

http://www.eso.org/sci/facilities/paranal/instruments/muse.html

- Pipeline Manual:

https://www.eso.org/sci/software/pipelines/

ftp://ftp.eso.org/pub/dfs/pipelines/instruments/muse/muse-pipeline-manual-2.8.3.pdf

- Reflex Manual:

https://www.eso.org/sci/software/pipelines/

ftp://ftp.eso.org/pub/dfs/pipelines/instruments/muse/muse-reflex-tutorial-16.0.pdf

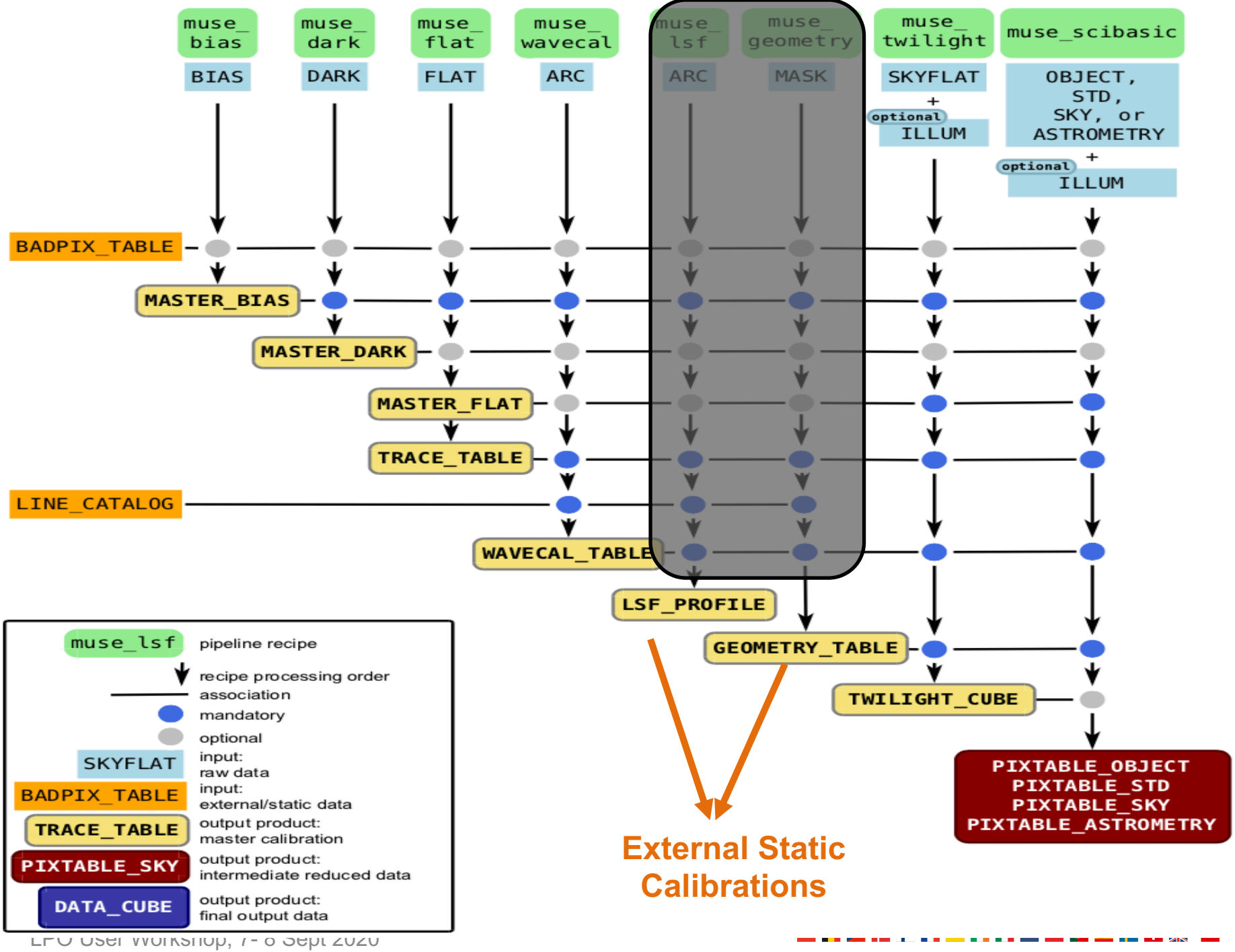
ftp://ftp.eso.org/pub/dfs/pipelines/instruments/muse/muse-zap-reflex-tutorial-5.0.pdf

- Help: usd-help@eso.org

Data reduction in a nutshell

- STAGE 1

7 basic calibration and a pre-processing recipes (i.e., basic science reduction) working on data of individual CCDs → characterize and remove the signature of each IFU


muse_bias
muse_dark
muse_flat
muse_wavecal
muse_lsf
muse_geometry
muse_twilight
muse_scibasic
BIAS
DARK
FLAT
ARC
ARC
MASK
SKYFLAT
+
optional
ILLUM
OBJECT, STD, SKY, or ASTROMETRY
+
optional
ILLUM
BADPIX_TABLE
MASTER_BIAS
MASTER_DARK
MASTER_FLAT
TRACE_TABLE
LINE_CATALOG
WAVECAL_TABLE
LSF_PROFILE
GEOMETRY_TABLE
TWILIGHT_CUBE
PIXTABLE_OBJECT
PIXTABLE_STD
PIXTABLE_SKY
PIXTABLE_ASTROMETRY
muse_lsf pipeline recipe
recipe processing order
association
mandatory
optional
SKYFLAT input: raw data
BADPIX_TABLE input: external/static data
TRACE_TABLE output product: master calibration
PIXTABLE_SKY output product: intermediate reduced data
DATA_CUBE output product: final output data
External Static Calibrations

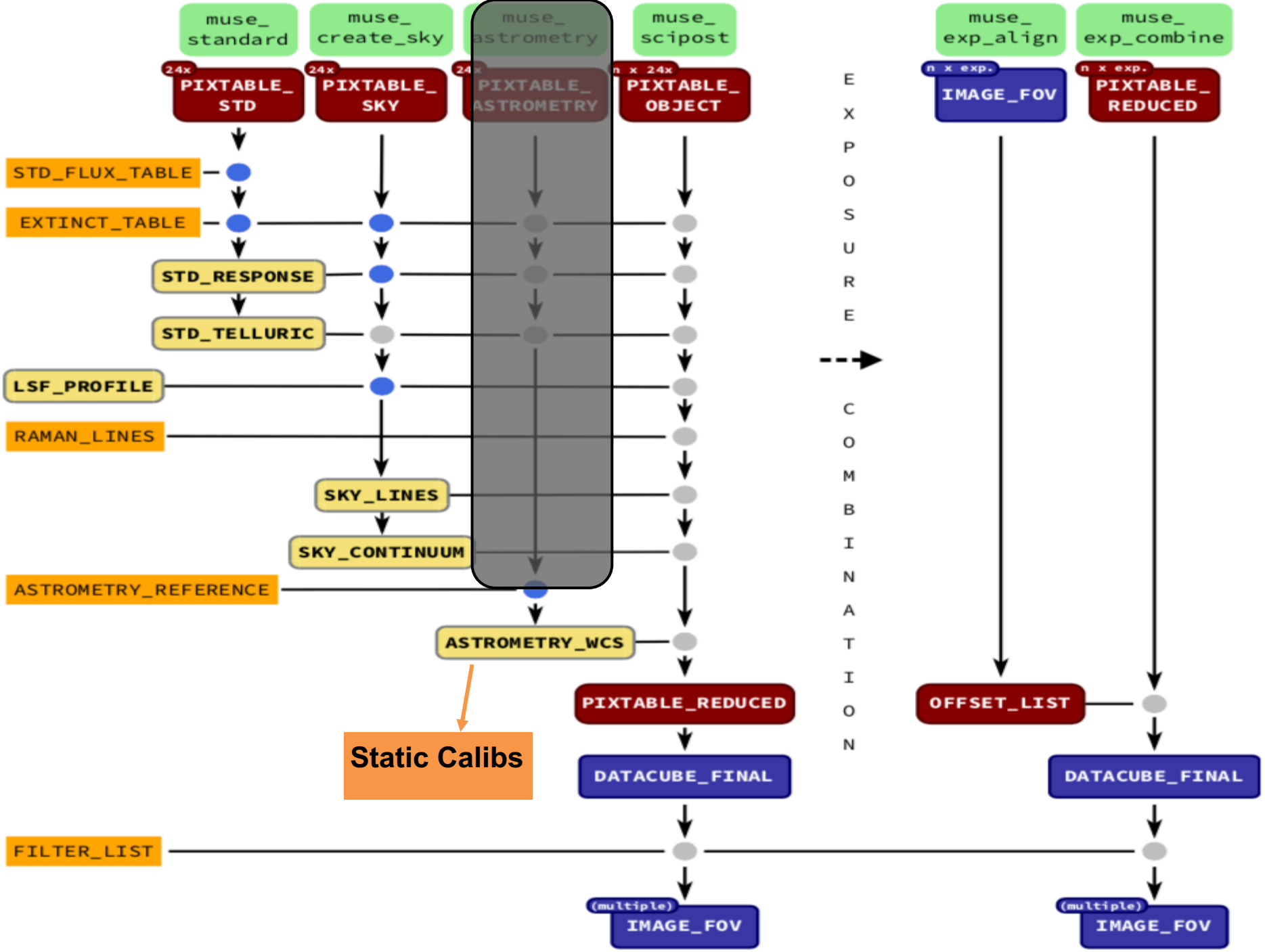
Data reduction in a nutshell

STAGE 1

7 basic calibration and a pre-processing recipes (i.e., basic science reduction) working on data of individual CCDs → characterize and remove the signature of each IFU

STAGE 2

3 additional calibration and a final science recipe that combine the data from all IFUs of one or more exposures into a final unique data cube


muse_ standard
muse_ create_sky
muse_ astrometry
muse_ scipost
muse_ exp_align
muse_ exp_combine
24x PIXTABLE_ STD
24x PIXTABLE_ SKY
24x PIXTABLE_ ASTROMETRY
n x 24x PIXTABLE_ OBJECT
n x exp. IMAGE_FOV
n x exp. PIXTABLE_ REDUCED
STD_FLUX_TABLE
EXTINCT_TABLE
STD_RESPONSE
STD_TELLURIC
LSF_PROFILE
RAMAN_LINES
SKY_LINES
SKY_CONTINUUM
ASTROMETRY_REFERENCE
ASTROMETRY_WCS
Static Calibs
PIXTABLE_REDUCED
DATACUBE_FINAL
FILTER_LIST
(multiple) IMAGE_FOV
EXPOSURE COMBINATION
OFFSET_LIST
DATACUBE_FINAL
(multiple) IMAGE_FOV

ESOrex

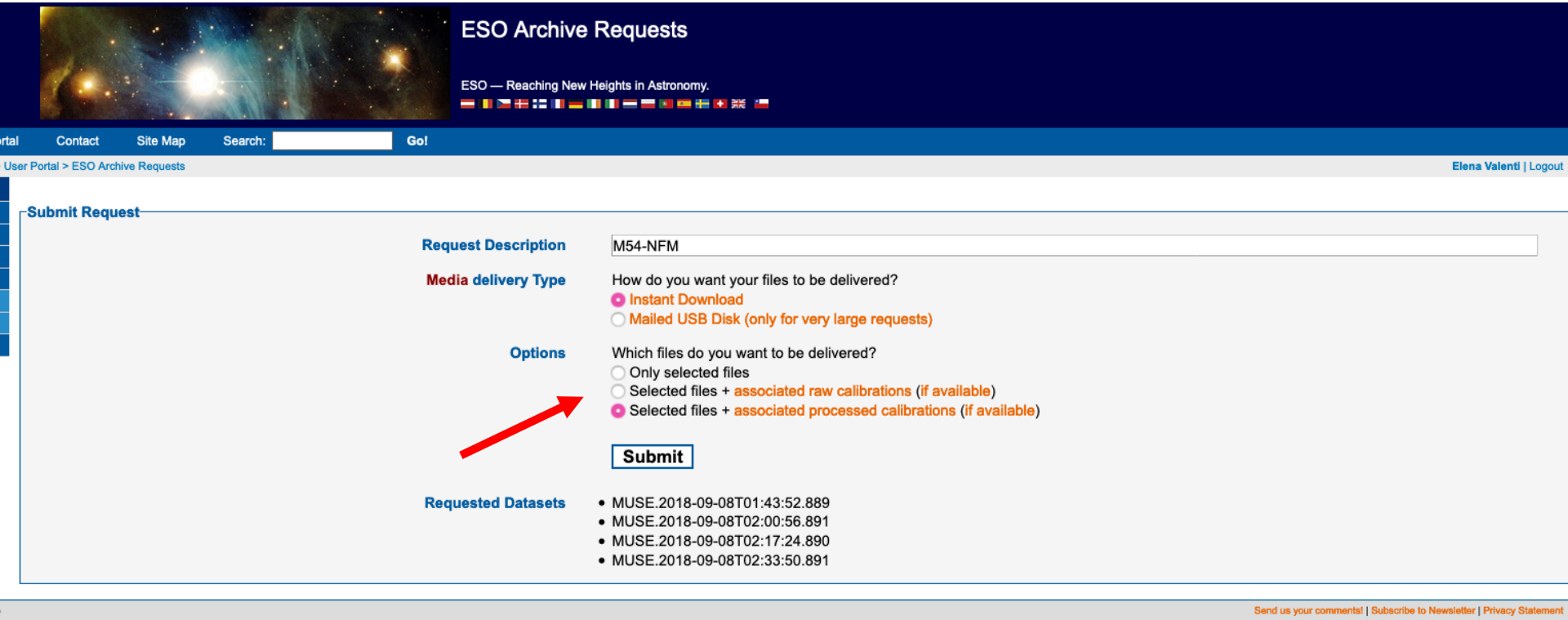
- Command line tool
  - esorex [esorex options] [recipe [recipe options] [sof [sof]..]]
  - esorex --log-file=align.log muse_exp_align --rsearch=4,2,0.8,0.2 --nbins=8 align.sof
- Very versatile
- Manual data classification

ESOReflex

- GUI based tool that calls individual reduction recipes via the esorex command
- Automatic data classification (OCA rules)
- Automatic execution of all processing steps in the right order
- Rigid (i.e., limited flexibility)

Calibrations: raw vs master

- Raw science data can be associated to a set of raw or master calibration frames



Calibrations: raw vs master

- Raw science data can be associated to a set of raw or master calibration frames
- Master calibs (i.e., master bias, flats, arc, twilight flat, std)→saving lot of time
- Master calibs are obtained shortly after observations were taken → quality depends upon pipeline version
- SV data(http://www.eso.org/sci/activities/vltsv/musenfmsv.html) → best to go for raw calibs
- Data taken within the first 6 months since the new mode was offered → best to go for raw calibs

WFM-NOAO: 01.10.2014 (P94); WFM-AO: 01.10.2017 (P100);

NFM: 01.10.2018 (P102)

ESOReflex

..... **LIVE DEMO** .....

Stacking exps from multiple OBs

Use case:

You want to combine science raw frames belonging to different OBs, which may have been executed in different nights or even within different runs. Of course all exposures must share the same instrument mode (i.e., WFM-AO/NOAO-N, or WFM-AO/NOA-E, or NFM)

Remember:

the pipeline combines PIXELTABLE_REDUCED files not DATACUBE_FINAL!

Exposures must be first aligned → i.e., for each exp an IMAGE_FOV file is needed in order to find the X/Y shifts (i.e., OFFSET_LIST).

Only then, the pipeline applies the OFFSET_LIST on the PIXELTABLE_REDUCED and it combines them into a single finale DATACUBE_FINAL

Stacking exps from multiple OBs

Esorex:

Procedure-wise, stacking exposures from a single or multiple OBs is pretty much irrelevant.

The pipe cascade must be performed entirely following STAGE 1 and STAGE 2. From the creation of master bias (recipe: `muse_bias`) to the combination of the `PIXELTABLE_REDUCED` corresponding to each exposure (i.e, recipe: `muse_exp_combine`).

If OBs were executed in different nights, remember to create and associate the correct set of master calibs to each exp.

Stacking exps from multiple OBs

ESOReflex:

The OCA rules are responsible for the data organization.

Exps are grouped together according to the object name (i.e.,header keyword: `HIERARCH ESO OBS TARG NAME`) and their instrument setup (i.e., `HIERARCH ESO INS MODE`)

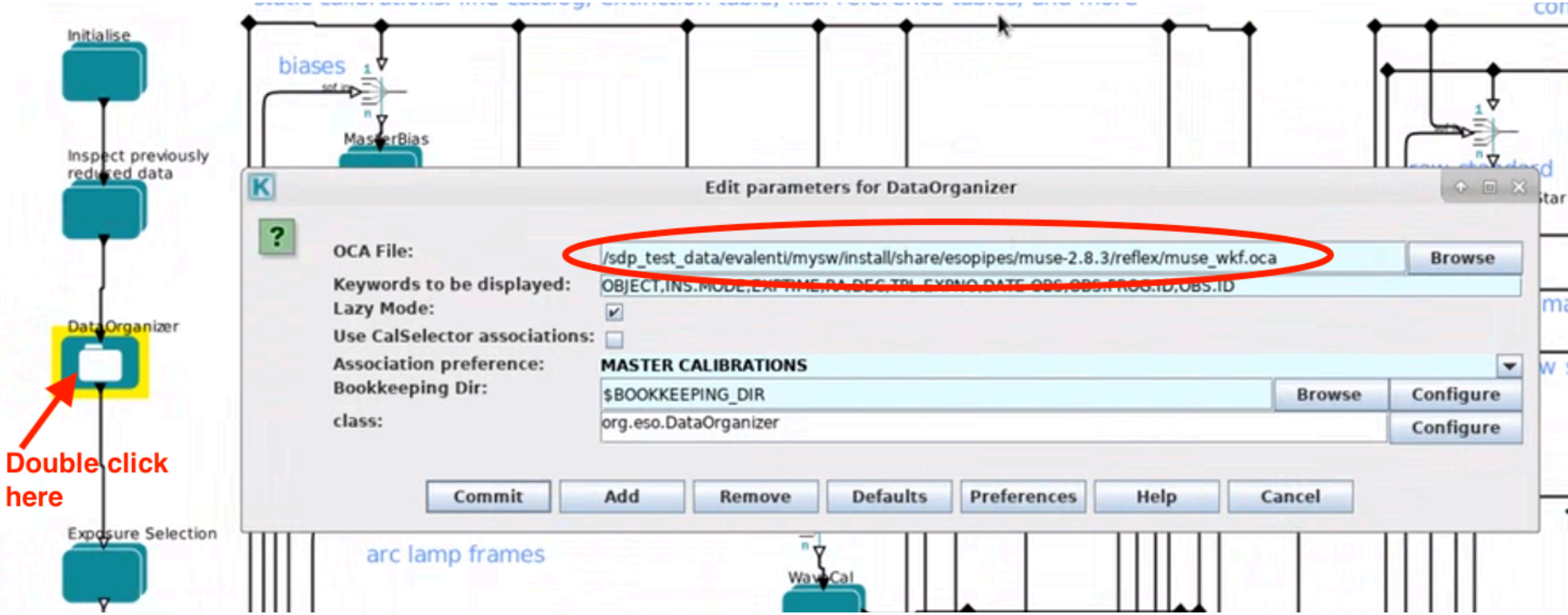
→ if exps from multiple OBs have the same obj name ESOReflex will automatically process them together

→ Otherwise you have 2 choices:

1. Editing the exps keyword: `HIERARCH ESO OBS TARG NAME`
2. Changing the OCA rules

Changing OCA rules

- All frames (science and calibs) in the same directory
- Editing the `muse_wkf.oca` file



Changing OCA rules

Default OCA

```
495
496
497  minRet=2;
498  select execute(muse_exp_combine) from inputFiles
499      where REFLEX.CATG == "OBJECT" or REFLEX.CATG == "PIXTABLE_REDUCED" group by
         OBS.TARG.NAME, INS.MODE as (TPL_A, combined_cubes);
500
```

Modified OCA

```
495
496
497  minRet=2;
498  select execute(muse_exp_combine) from inputFiles
499      where REFLEX.CATG == "OBJECT" or REFLEX.CATG == "PIXTABLE_REDUCED" group by
         INS.MODE as (TPL_A, combined_cubes);
500
```

```
1526
1527  action muse_exp_combine
1528  {
1529      minRet = 2;  maxRet = 2000;
1530      select file as PIXTABLE_REDUCED from calibFiles where REFLEX.CATG ==
          "PIXTABLE_REDUCED"
1531          and inputFile.INS.MODE==INS.MODE
1532          and inputFile.OBS.TARG.NAME==OBS.TARG.NAME;
1533
1534      minRet = 2;  maxRet = 2000;
1535      select file as IMAGE_FOV from calibFiles where REFLEX.CATG == "IMAGE_FOV"
1536          and inputFile.INS.MODE==INS.MODE
1537          and inputFile.OBS.TARG.NAME==OBS.TARG.NAME;
1538
1539      minRet = 0; maxRet = 1;
```

```
1526
1527  action muse_exp_combine
1528  {
1529      minRet = 2;  maxRet = 2000;
1530      select file as PIXTABLE_REDUCED from calibFiles where REFLEX.CATG ==
          "PIXTABLE_REDUCED"
1531          and inputFile.INS.MODE==INS.MODE;
1532
1533      minRet = 2;  maxRet = 2000;
1534      select file as IMAGE_FOV from calibFiles where REFLEX.CATG == "IMAGE_FOV"
1535          and inputFile.INS.MODE==INS.MODE;
1536
1537      minRet = 0; maxRet = 1;
1538      select file as FILTER_LIST from calibFiles where REFLEX.CATG == "FILTER_LIST"
1539          and inputFile.INSTRUME==INSTRUME;
```

By removing OBS.TARG.NAME, ESOReflex will automatically process all frames tagged by the same INS.MODE keyword contained in the same working directory you setup