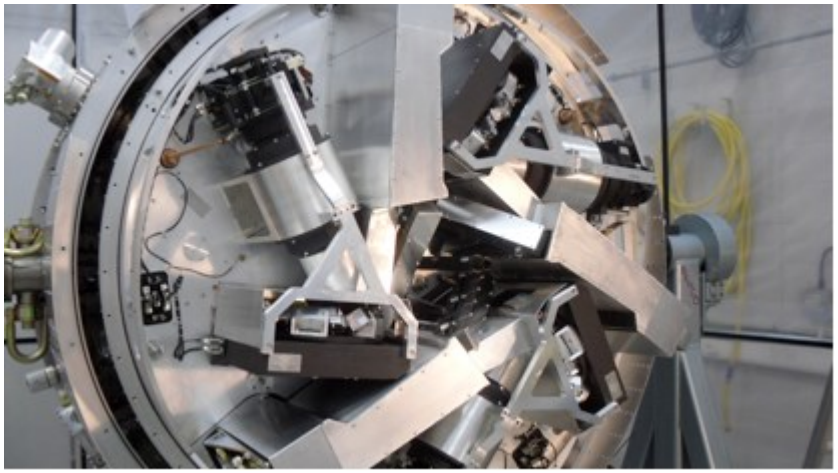
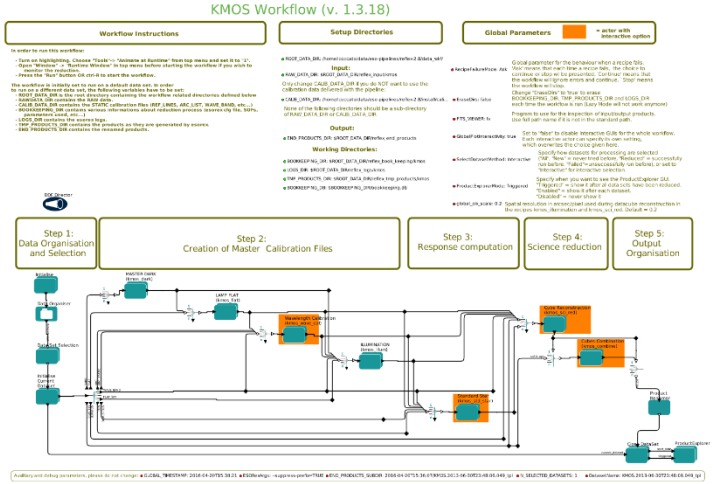
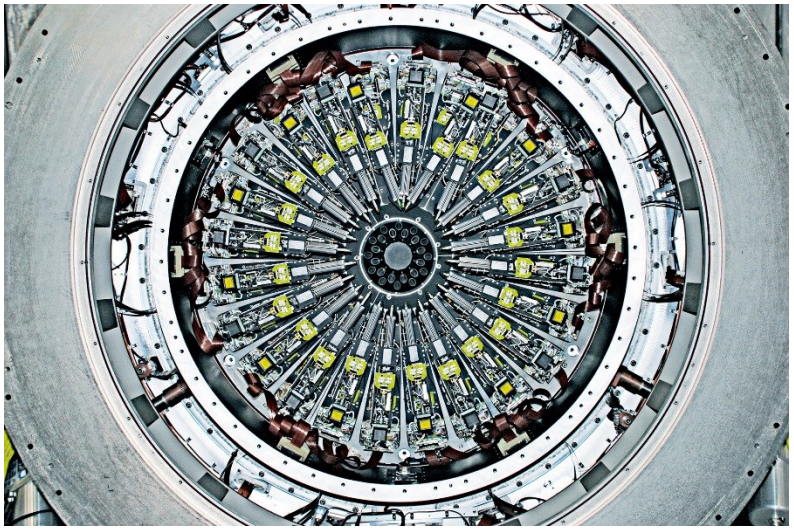
KMOS: K-band Multi Object Spectrograph data reduction overview

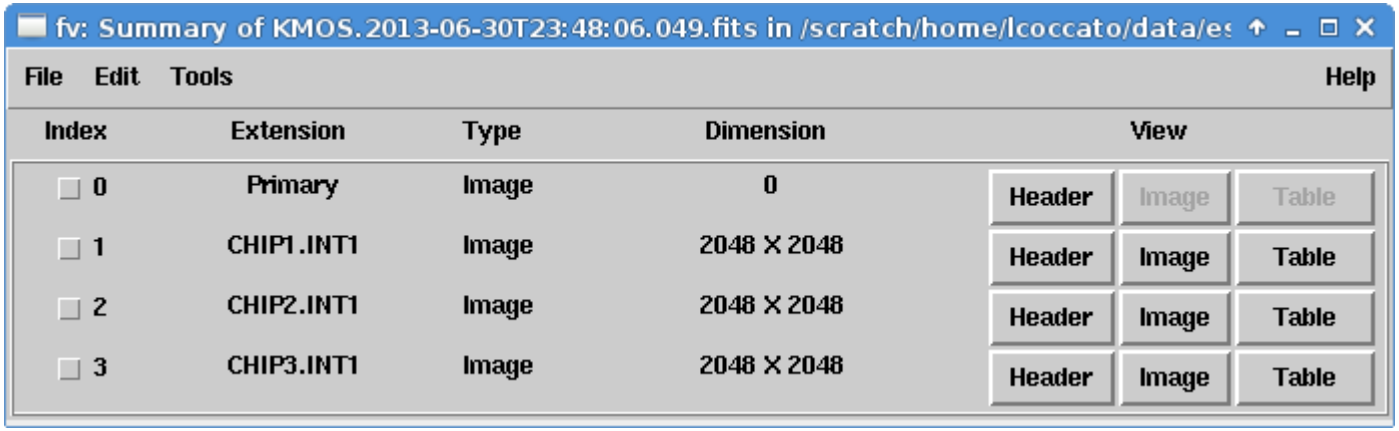






Data reduction

Structure of a single RAW science frame

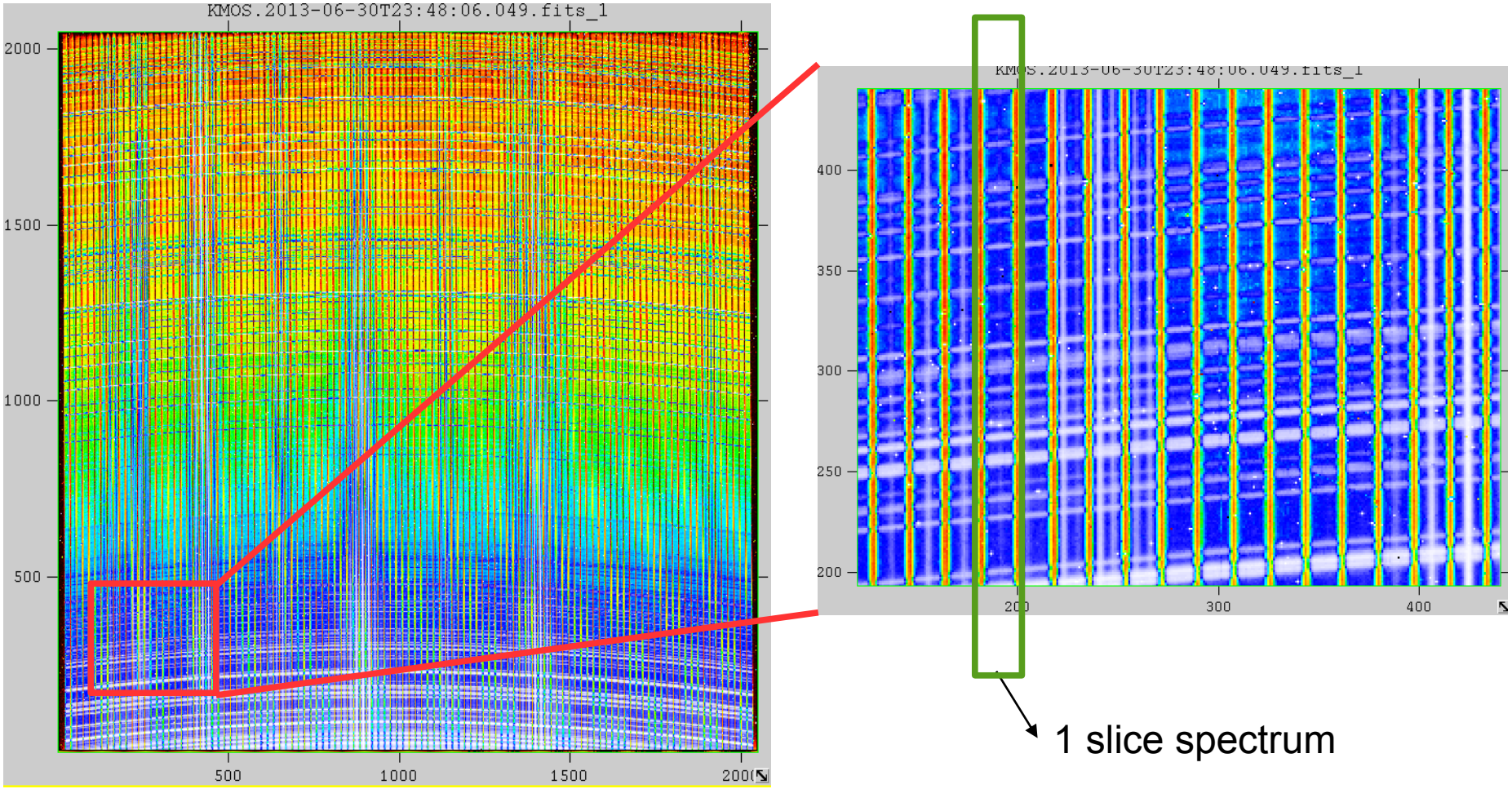


Each obervational dataset consists of a set of Science frames plus calibration frames.
Header contains some key arm-related information for data reduction, such as pointing coordinates, type (object or sky), object name.

Data reduction

How do you go from 3 collections of photons...

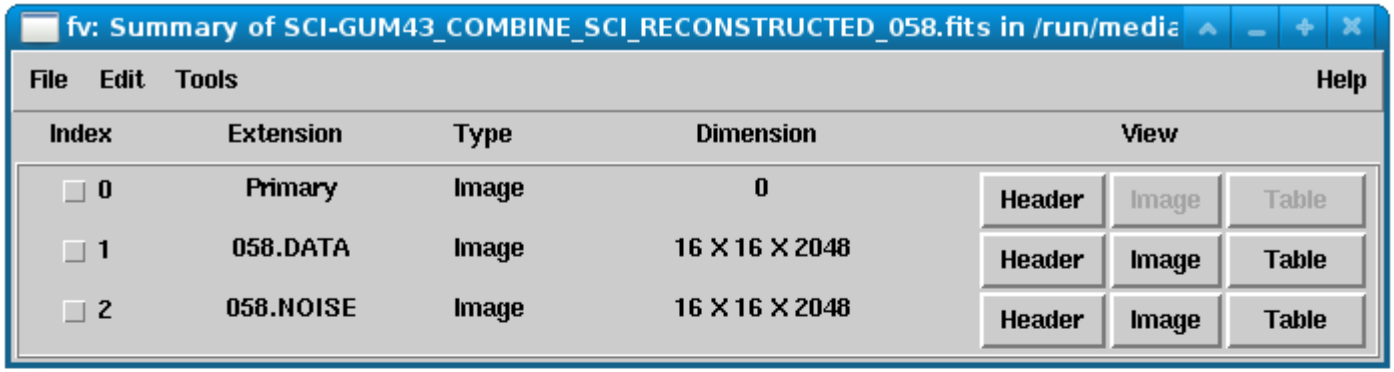
Content of 1 extension of a single RAW science frame



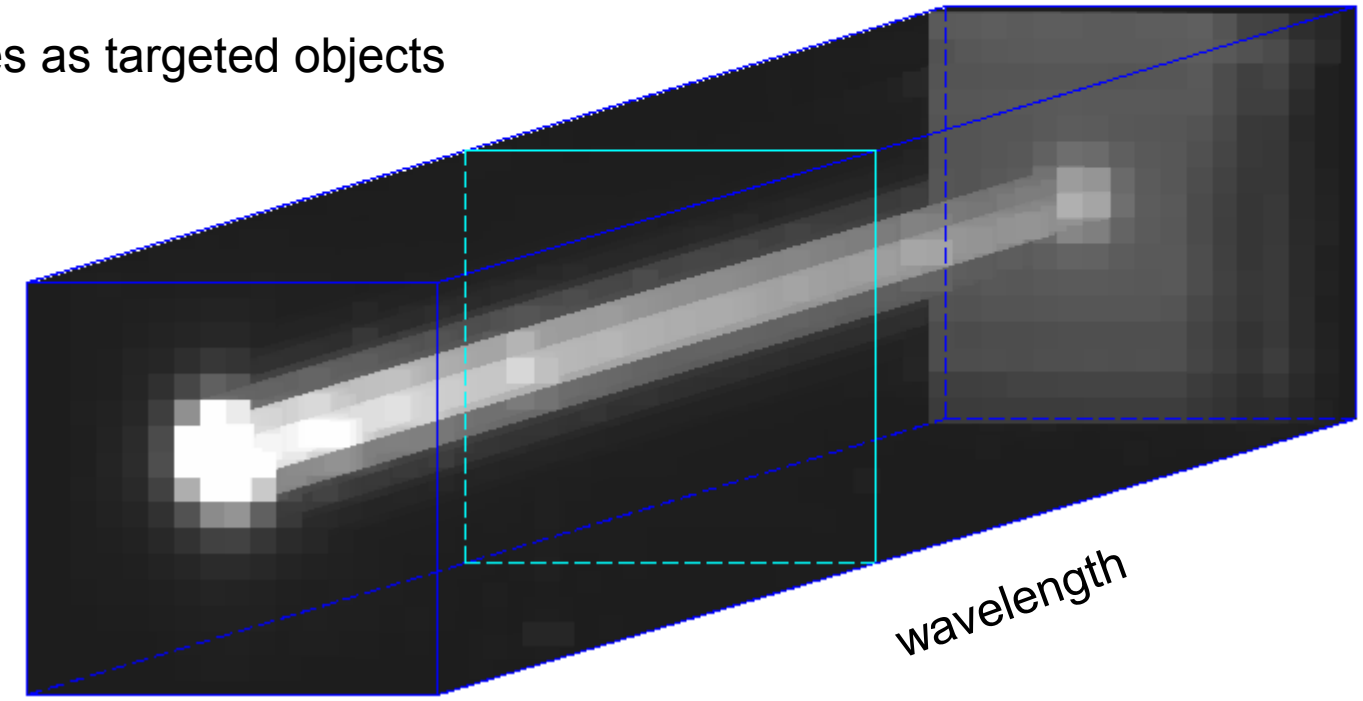
Data reduction

… to the final datacube(s) ?

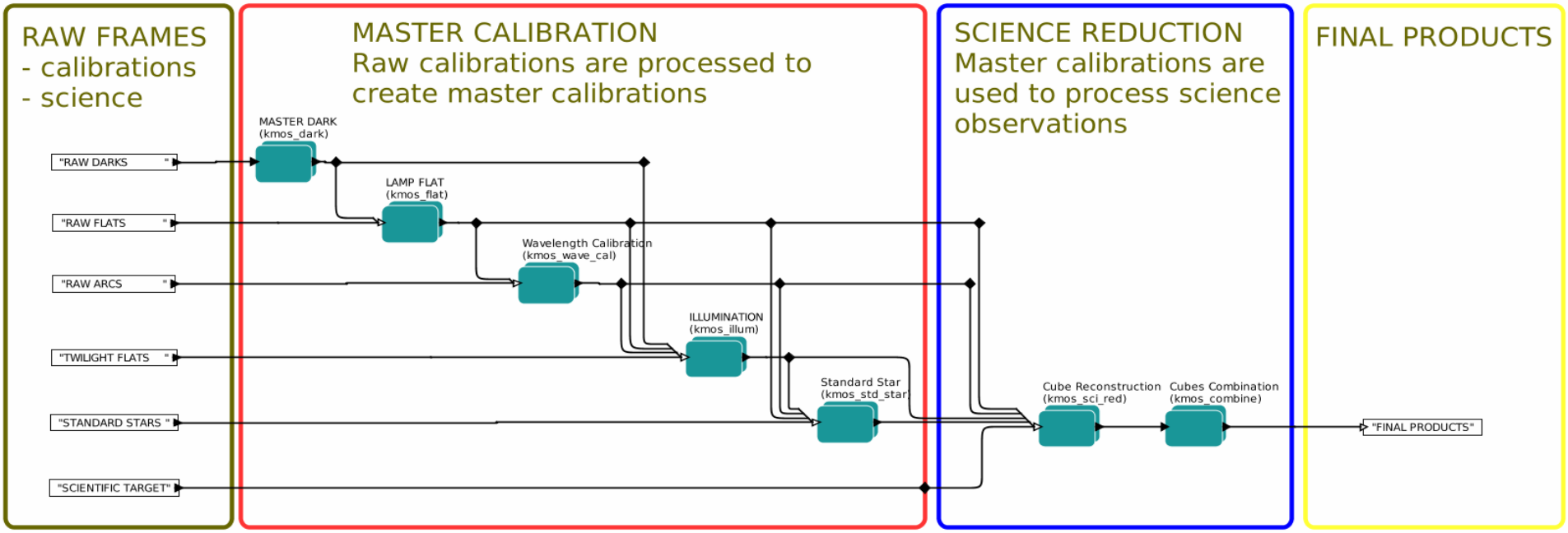
Final DATACUBE(s)



As many datacubes as targeted objects

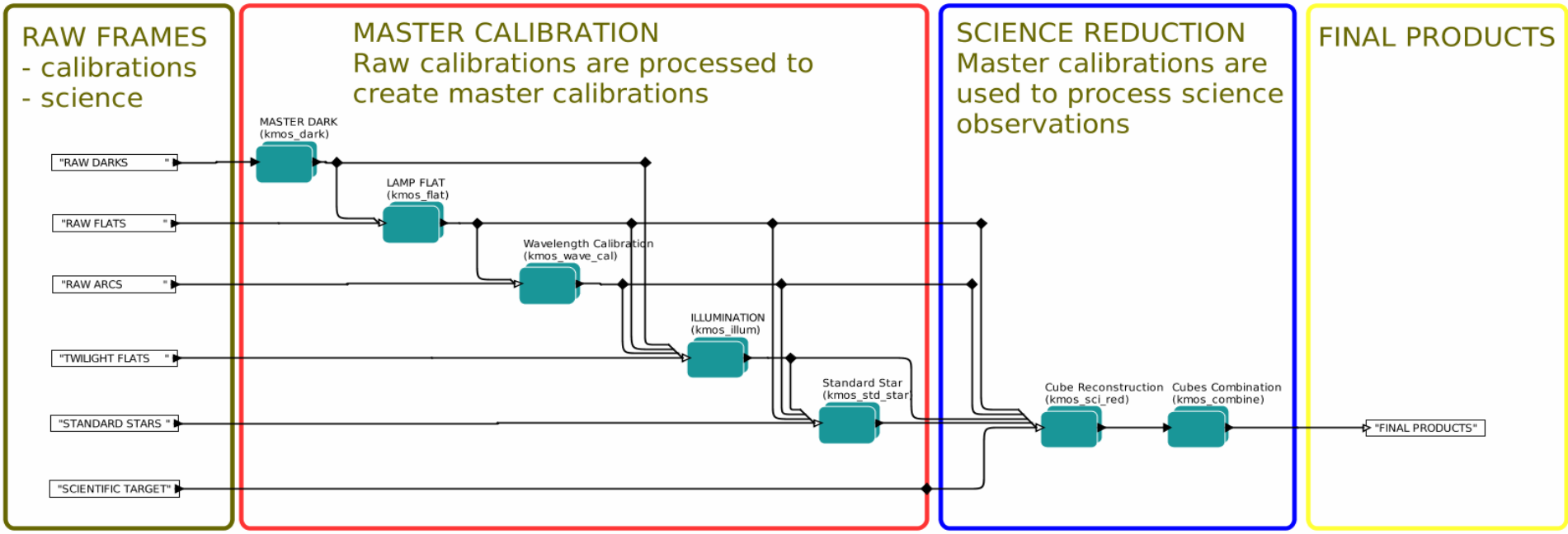


KMOS DATA REDUCTION CASCADE



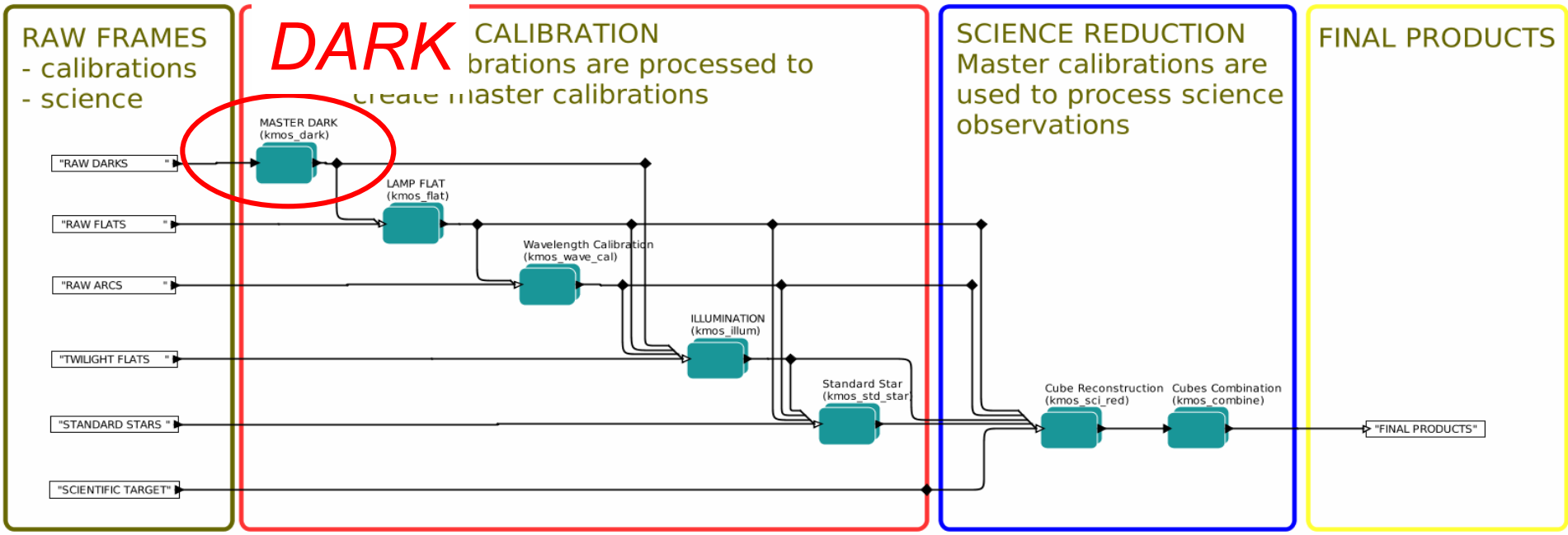
Raw calibration (e.g., darks, flats) plus static calibration files (e.g. arc line list) are processed to create MASTER CALIBRATIONS.
MASTER CALIBRATIONS are used to reduce the raw science exposures (collection of photon signal onto 2D detectors) to get the final products (datacubes), which are fully calibrated in astrometric, wavelength, and flux units.

KMOS DATA REDUCTION CASCADE



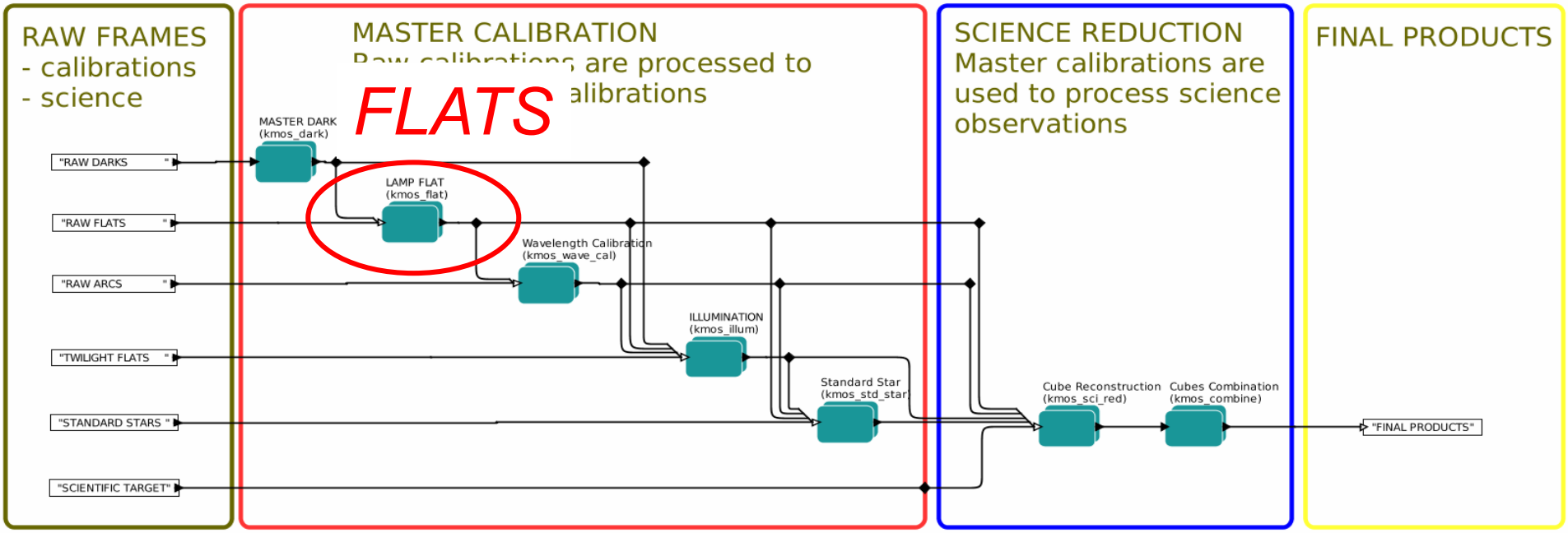
Each step of the data reduction cascade triggers a pipeline recipe. Each recipe is designed to process a set of frames and provide the inputs to the next recipes. The process is automatic from the raw data till the final products. It can be customized by setting the recipe parameters.

KMOS DATA REDUCTION CASCADE



Dark frames are exposures taken with 0 sec integration time. They are used to map the bad pixels in the detector.
Main products: MASTER_DARK; BADPIXEL_DARK

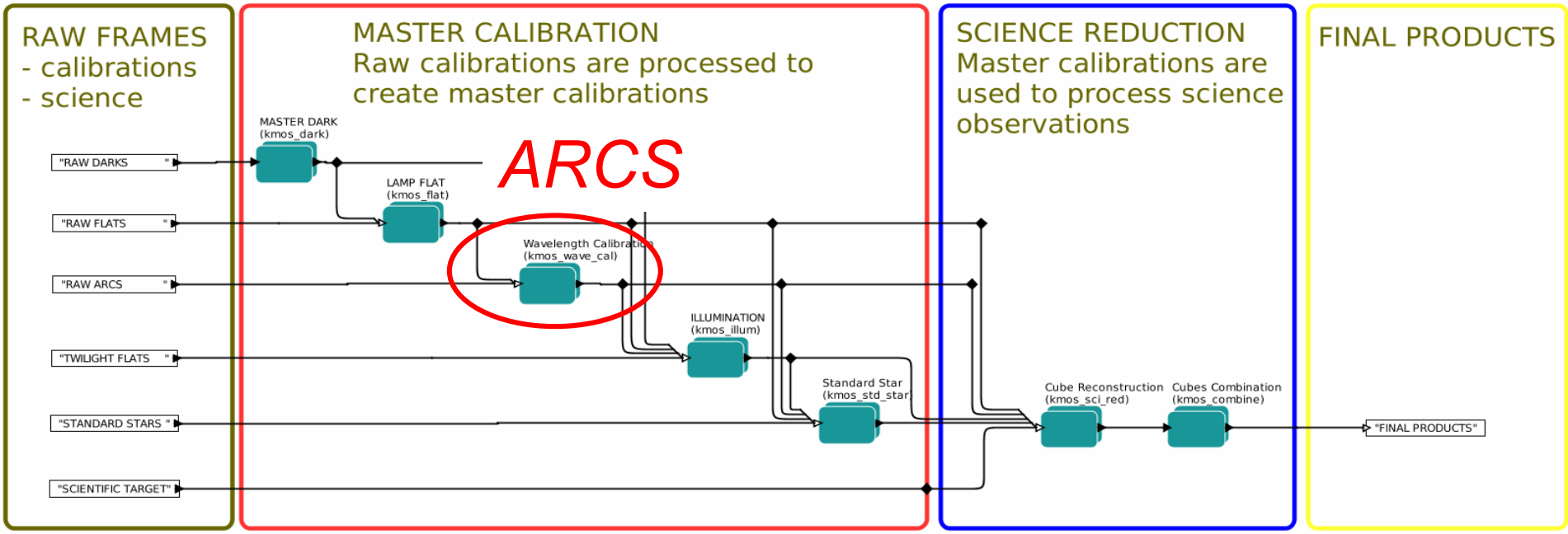
KMOS DATA REDUCTION CASCADE



Flat fields are used to:

- Map the pixel-to-pixel sensitivity variation through the detector (FLAT_EDGE)
- Detect bad pixels additional to that of dark frames (BADPIXEL_FLAT)
- Identify the position of the slices in the detector → to which position on the sky each spectrum belongs (XCAL, YCAL).

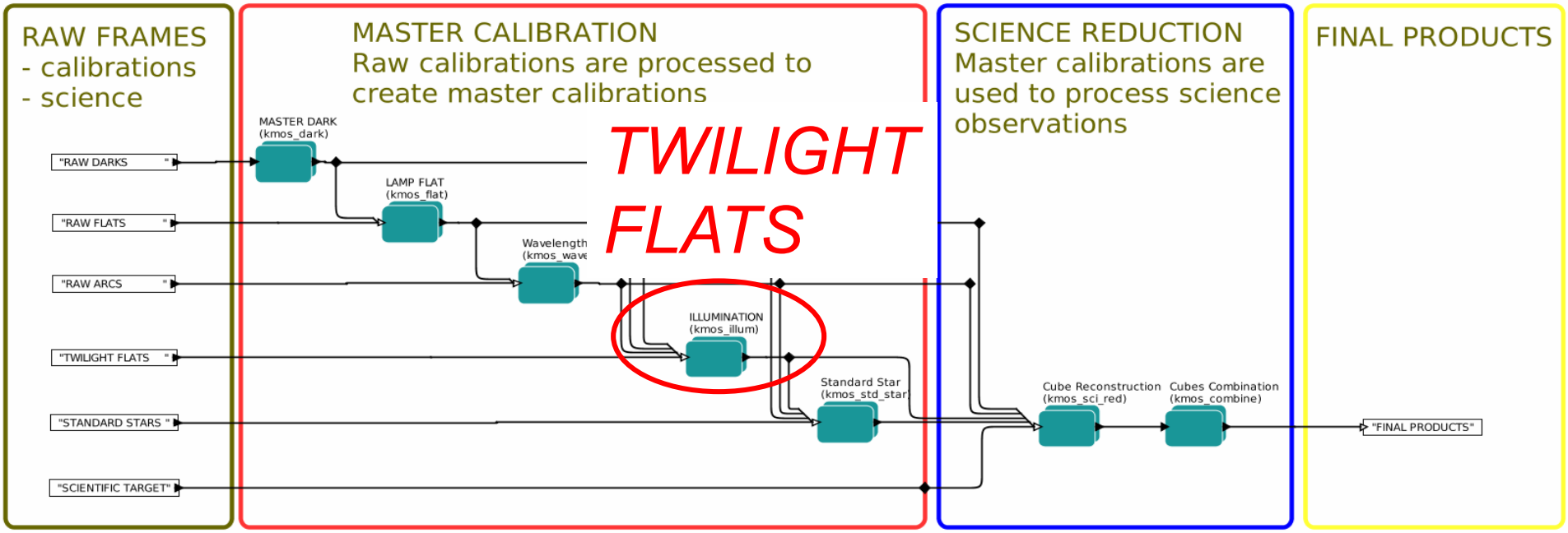
KMOS DATA REDUCTION CASCADE



Comparison arcs are used to map each pixel in the detector to a precise wavelength. The transformation is computed by comparing the detected emission lines to a reference list.

Main products: LCAL (tells the wavelength for each pixel of the detector)

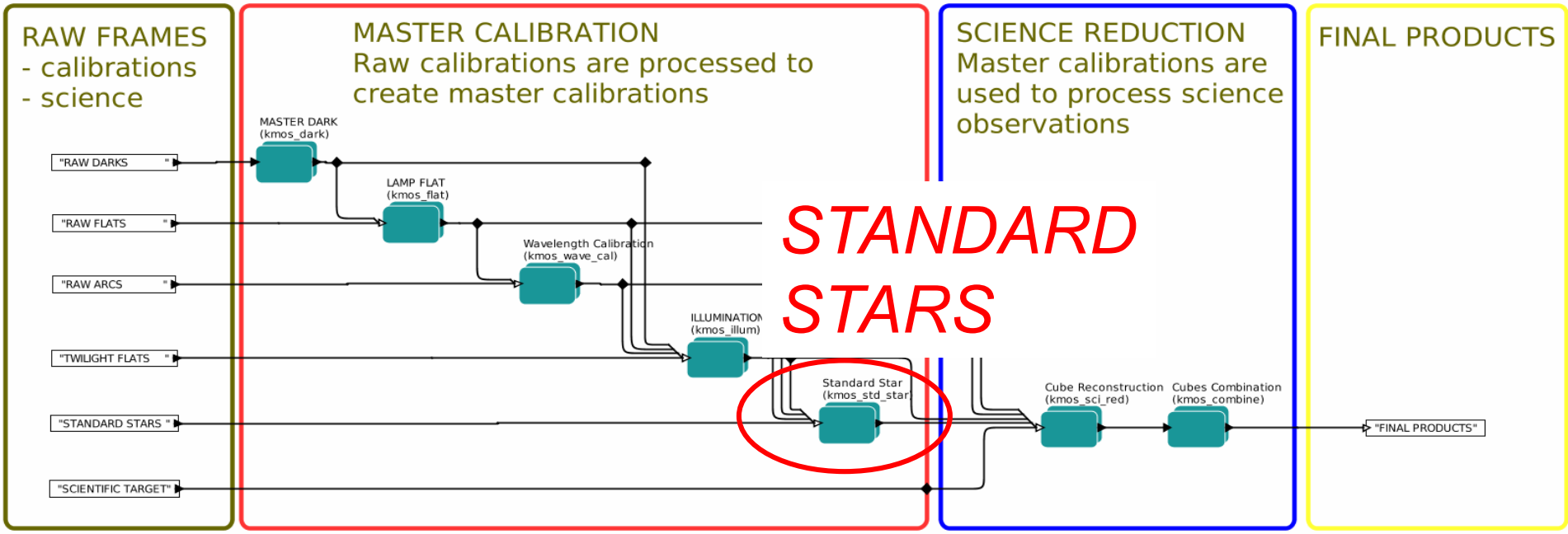
KMOS DATA REDUCTION CASCADE



Twilight flats are used to correct for the non-homogeneous illumination of the field of view.

Main product: ILLUM_CORR

KMOS DATA REDUCTION CASCADE

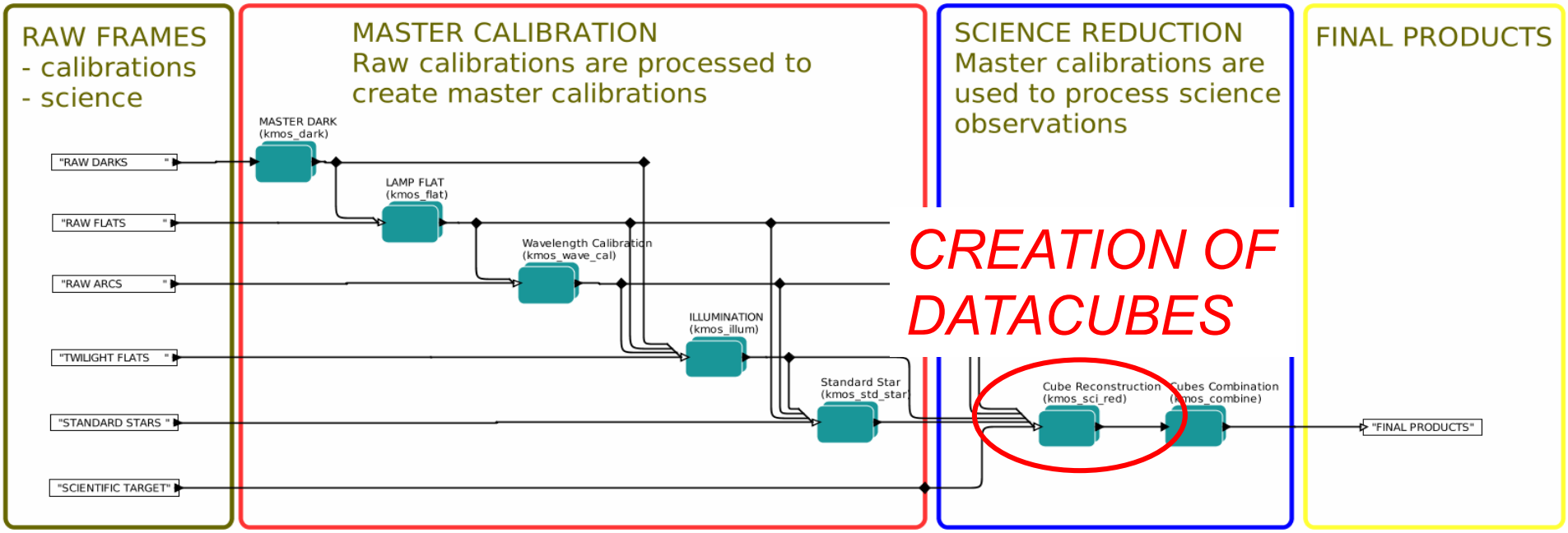


Standard stars are used to:

- Flux calibration (convert photon counts into physical units such as ergs/sec/cm^2/Å
- Derive the telluric correction to account for atmospheric extinction.

Main product: TELLURIC

KMOS DATA REDUCTION CASCADE



Each exposure will be calibrated using the master calibrations. The reduced exposure contains 24 extensions (one per IFU). Each extension contains a reduced datacube. Main product: SCI_RECONSTRUCTED

IFUs targeting empty sky regions will be used to subtract the sky from IFU targeting objects.

KMOS DATA REDUCTION CASCADE

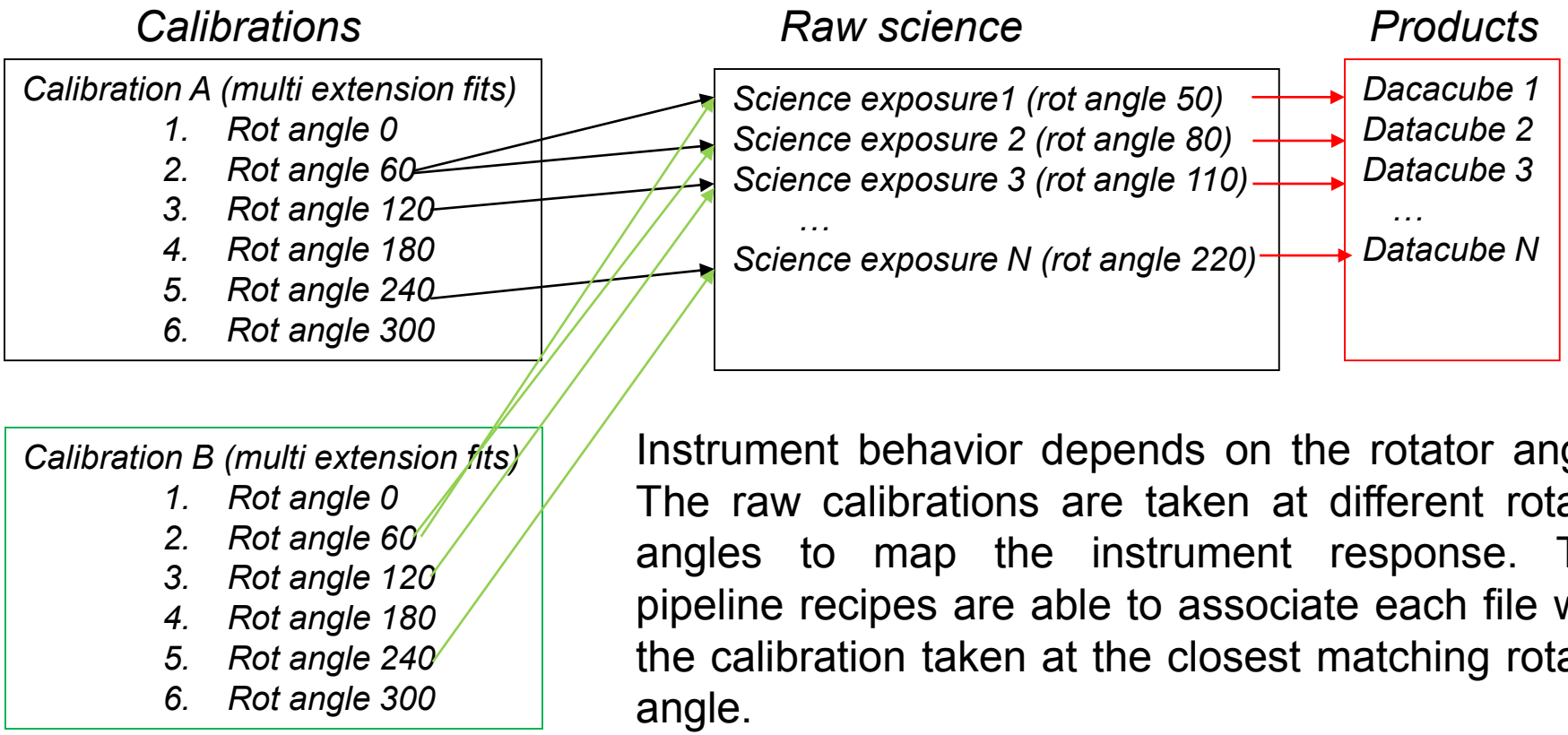
Datacube reconstruction

Raw science (3 extensions)
Calibrations

- xcal,ycal, ycal
- flat_fields, illumination
- Telluric and response

Science recipe

Datacubes. Calibrated and sky subtracted.
1 file per exposure with 24 extensions.



Instrument behavior depends on the rotator angle. The raw calibrations are taken at different rotator angles to map the instrument response. The pipeline recipes are able to associate each file with the calibration taken at the closest matching rotator angle.

KMOS DATA REDUCTION CASCADE

Datacube reconstruction

Raw science (3 extensions)
Calibrations

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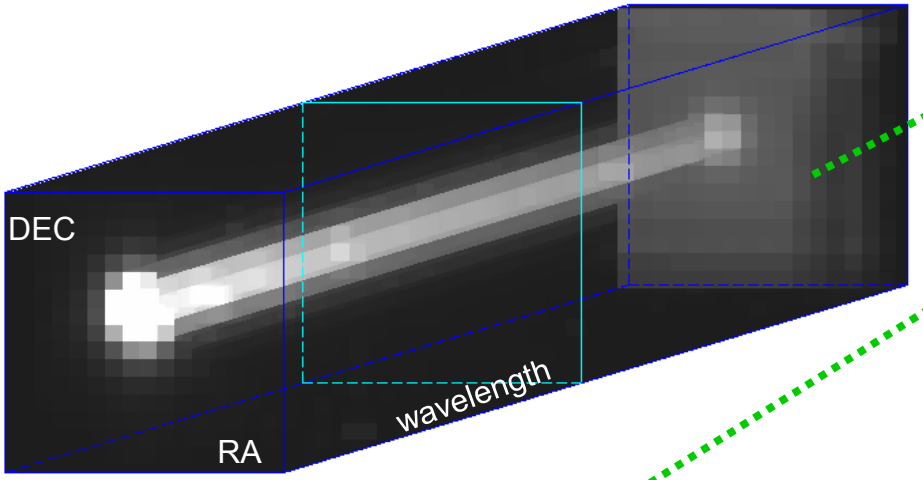


fv: Summary of sci_reconstructed_KMOS.2014-02-21T02:45:45.986.fits in /scratch/home/lcc

File Edit Tools Help

Index	Extension	Type	Dimension	View
0	Primary	Image	0	Header Image Table
1	IFU.1.DATA	Image	0	Header Image Table
2	IFU.2.DATA	Image	14 X 14 X 2048	Header Image Table
3	IFU.3.DATA	Image	14 X 14 X 2048	Header Image Table
4	IFU.4.DATA	Image	0	Header Image Table
5	IFU.5.DATA	Image	0	Header Image Table
6	IFU.6.DATA	Image	0	Header Image Table
7	IFU.7.DATA	Image	0	Header Image Table
8	IFU.8.DATA	Image	14 X 14 X 2048	Header Image Table
9	IFU.9.DATA	Image	14 X 14 X 2048	Header Image Table
10	IFU.10.DATA	Image	0	Header Image Table
11	IFU.11.DATA	Image	0	Header Image Table
12	IFU.12.DATA	Image	0	Header Image Table
13	IFU.13.DATA	Image	0	Header Image Table
14	IFU.14.DATA	Image	14 X 14 X 2048	Header Image Table
15	IFU.15.DATA	Image	14 X 14 X 2048	Header Image Table
16	IFU.16.DATA	Image	0	Header Image Table
17	IFU.17.DATA	Image	0	Header Image Table
18	IFU.18.DATA	Image	0	Header Image Table
19	IFU.19.DATA	Image	0	Header Image Table
20	IFU.20.DATA	Image	14 X 14 X 2048	Header Image Table
21	IFU.21.DATA	Image	14 X 14 X 2048	Header Image Table
22	IFU.22.DATA	Image	0	Header Image Table
23	IFU.23.DATA	Image	0	Header Image Table
24	IFU.24.DATA	Image	0	Header Image Table

Empty arm (sky or not active)

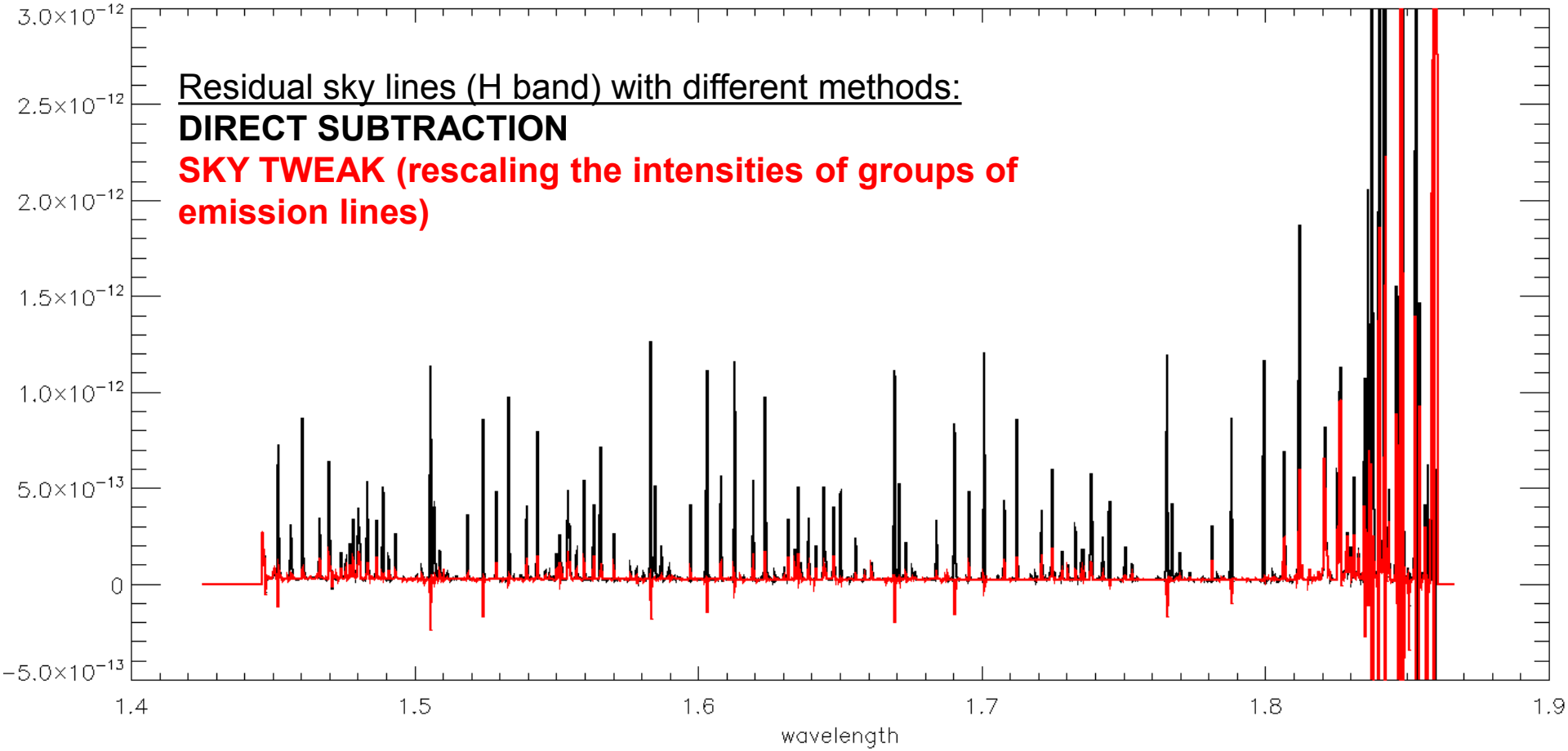
KMOS DATA REDUCTION CASCADE
Sky subtraction

- It is performed during the datacube reconstruction step.
- The pipeline associates to each ARM the most appropriate SKY exposure. Override is possible.
- Best results are seen if object-sky association is for the same arm. Arm consistency is important than time variations.
- Several algorithms for sky subtraction
  - Direct subtraction – a sky spectrum is constructed from the arm poiting to the sky, and the subtracted from the corresponding science.
  - Sky tweaking method (Davies 2007, MNRAS, 375, 1099). Groups of emission lines are defined on the sky spectrum. Each group has a scaling factor which is applied before subtraction.
  - Stretching of wavelength solution for the sky spectrum (either with or without sky tweak) to minimize residuals (implementation on-going).

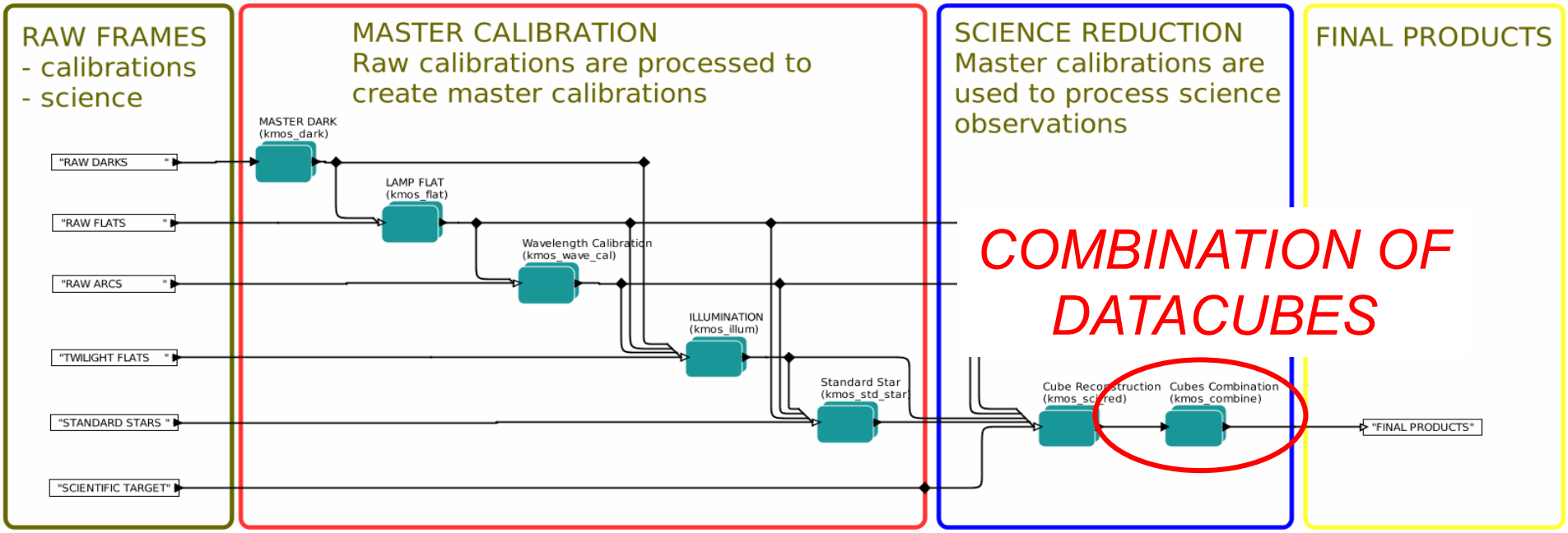
KMOS DATA REDUCTION CASCADE

Sky subtraction

In some cases, sky tweaking makes really a substantial improvement



KMOS DATA REDUCTION CASCADE



All the extensions (datacubes) of all the exposures that target the same object on the sky will be combined together to create a single datacube.
One datacube per targeted object will be produced.
Main products: COMBINED_SCI_RECONSTRUCTED

KMOS DATA REDUCTION CASCADE

Datacube combination

RECONSTRUCTED CUBES
INDIVIDUAL EXPOSURES (each file has 24 extensions)

sci_reconstructed_KMOS.2013-06-30T23:48:06.049.fits
sci_reconstructed_KMOS.2013-06-30T23:59:09.586.fits
sci_reconstructed_KMOS.2013-07-01T00:04:22.390.fits
sci_reconstructed_KMOS.2013-07-01T00:09:35.560.fits
sci_reconstructed_KMOS.2013-07-01T00:20:10.285.fits
sci_reconstructed_KMOS.2013-07-01T00:25:24.507.fits
sci_reconstructed_KMOS.2013-07-01T00:30:37.274.fits
sci_reconstructed_KMOS.2013-07-01T00:41:13.785.fits
sci_reconstructed_KMOS.2013-07-01T00:46:26.588.fits

Exposure identification

FINAL PRODUCTS
DATACUBE (1 cube per object)

combine_sci_reconstructed_001.fits
combine_sci_reconstructed_002.fits
combine_sci_reconstructed_003.fits
combine_sci_reconstructed_004.fits
combine_sci_reconstructed_007.fits
combine_sci_reconstructed_010.fits
combine_sci_reconstructed_014.fits
combine_sci_reconstructed_018.fits
combine_sci_reconstructed_020.fits
combine_sci_reconstructed_021.fits
combine_sci_reconstructed_027.fits
combine_sci_reconstructed_029.fits
combine_sci_reconstructed_030.fits
combine_sci_reconstructed_048.fits
combine_sci_reconstructed_058.fits
combine_sci_reconstructed_069.fits
combine_sci_reconstructed_100.fits
combine_sci_reconstructed_101.fits
combine_sci_reconstructed_103.fits

Object name

KMOS DATA REDUCTION WORKFLOW

The easiest way to reduce KMOS data