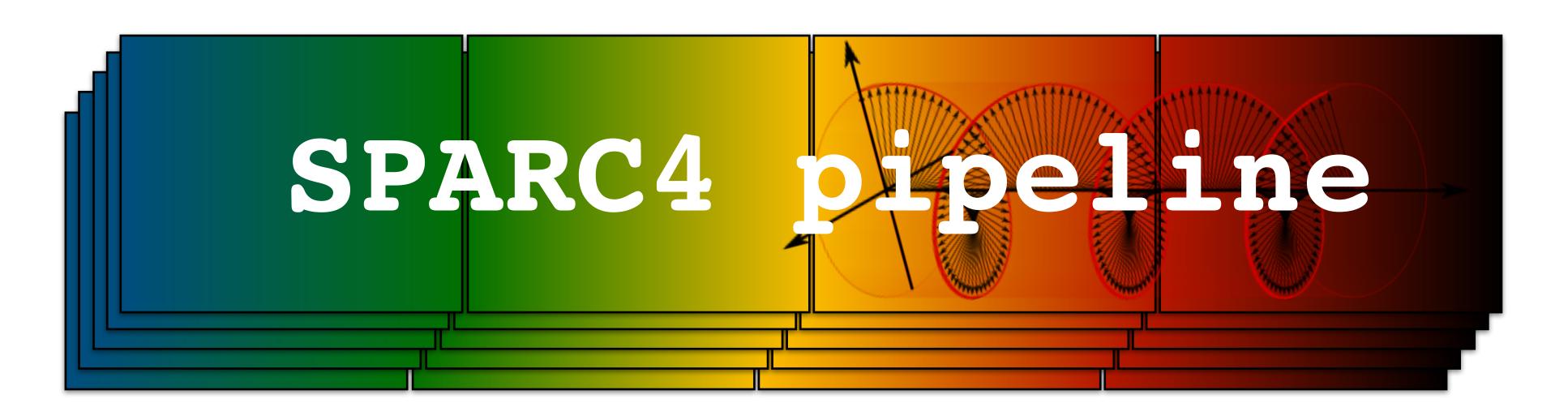
SPARC4 Pipeline: Hands-On Data Reduction for Multi-Band Photometry and Polarimetry with SPARC4



Equipe do pipeline da SPARC4:

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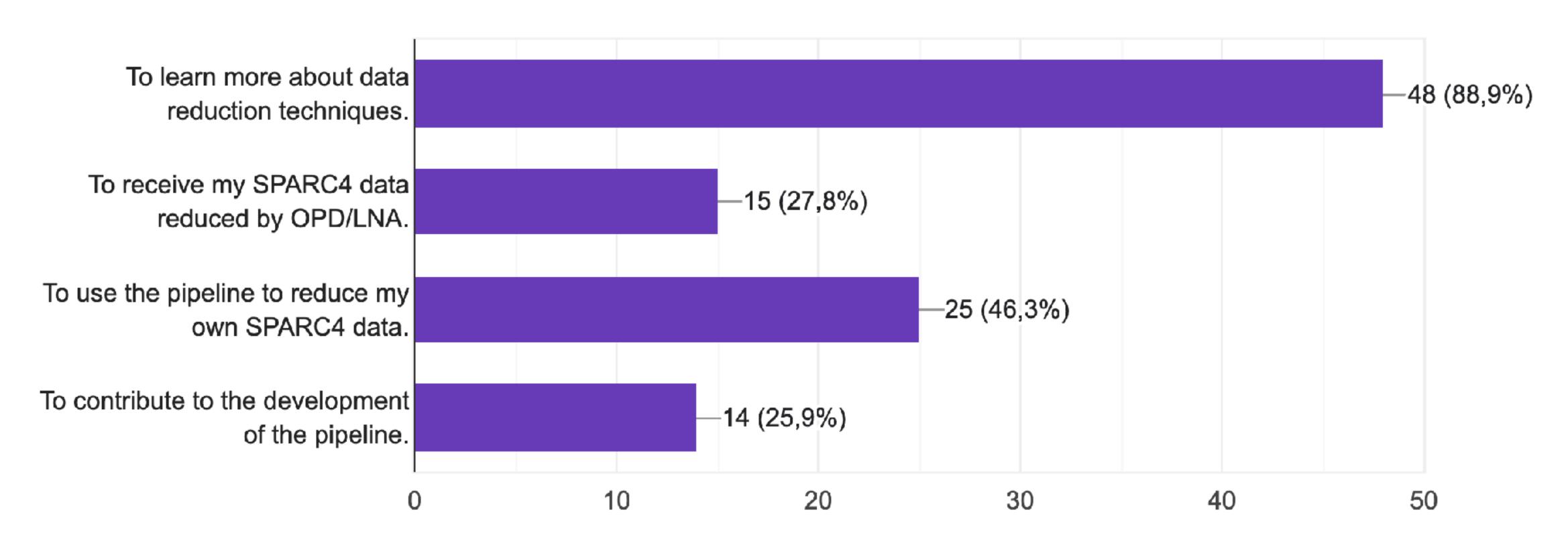
XLVII Reunião Anual da SAB, Águas de Lindoia, 26 de setembro de 2024

PROGRAM		
15:00 - 15:30	Introduction to and installation of the SPARC4 Pipeline.	
15:30 - 16:00	16:00 Preparatory steps: the structure of raw data and parameter files.	
16:00 - 16:20	Reduction of the minidata.	
16:20 - 16:30	Break.	
16:30 - 17:00	Products: calibrations, reduced images and stellar catalogs.	
17:00 - 17:20	Products: light curve.	
17:20 - 17:40	Products: polarimetry.	
17:40 - 18:00	Products: polarimetric time series and polarization map.	

1. Introduction and Installation

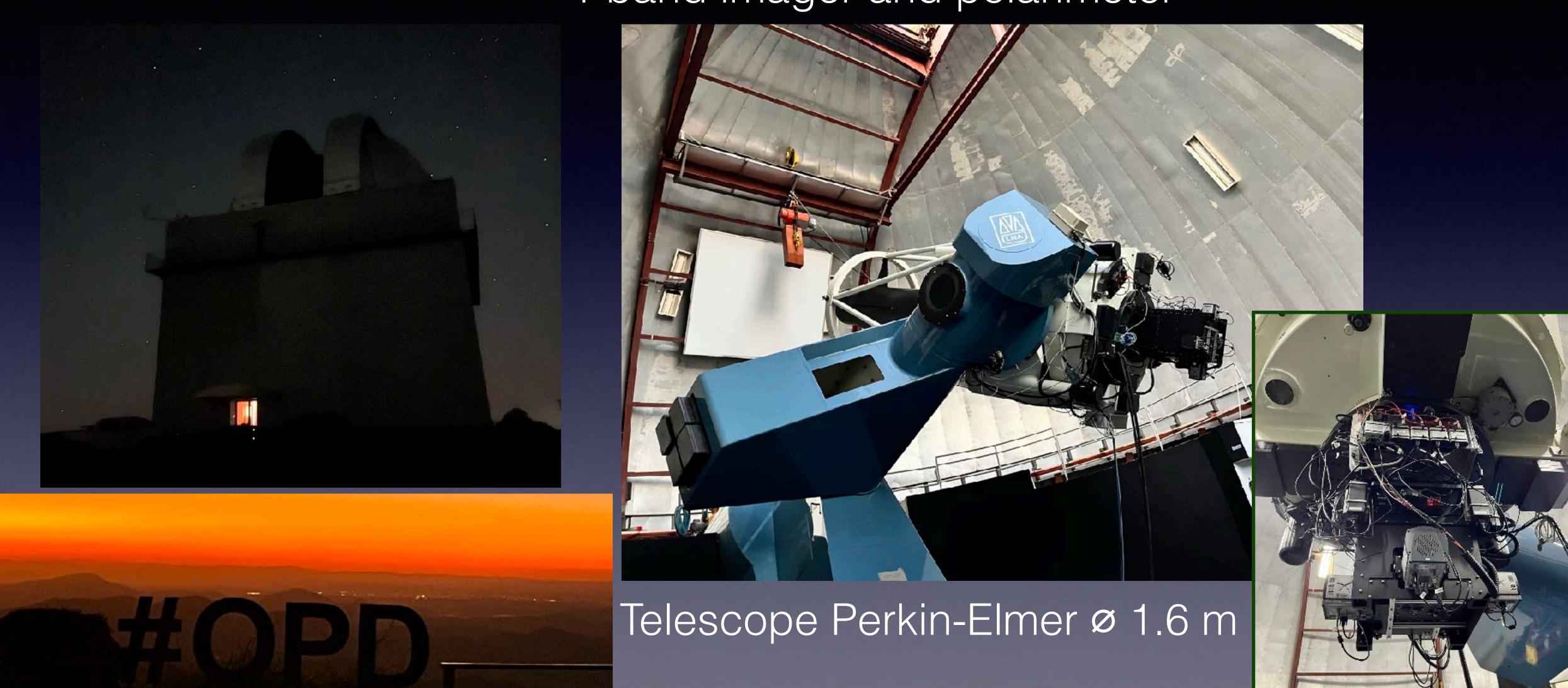
You're here for ...

What is your motivation for participating in this workshop? 54 respostas



SPARC4 at Pico dos Dias Observatory

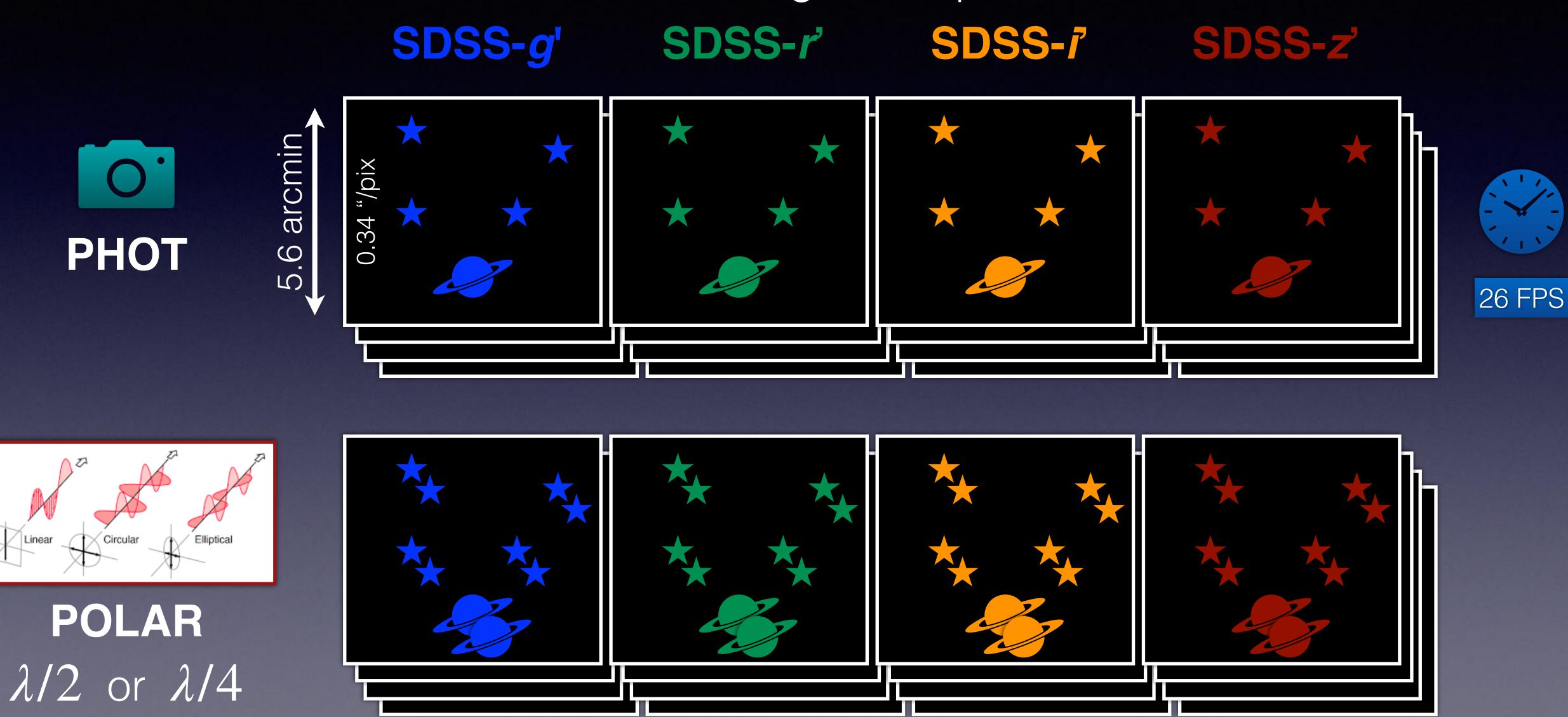
√ 4-band imager and polarimeter



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SPARC4 at Pico dos Dias Observatory

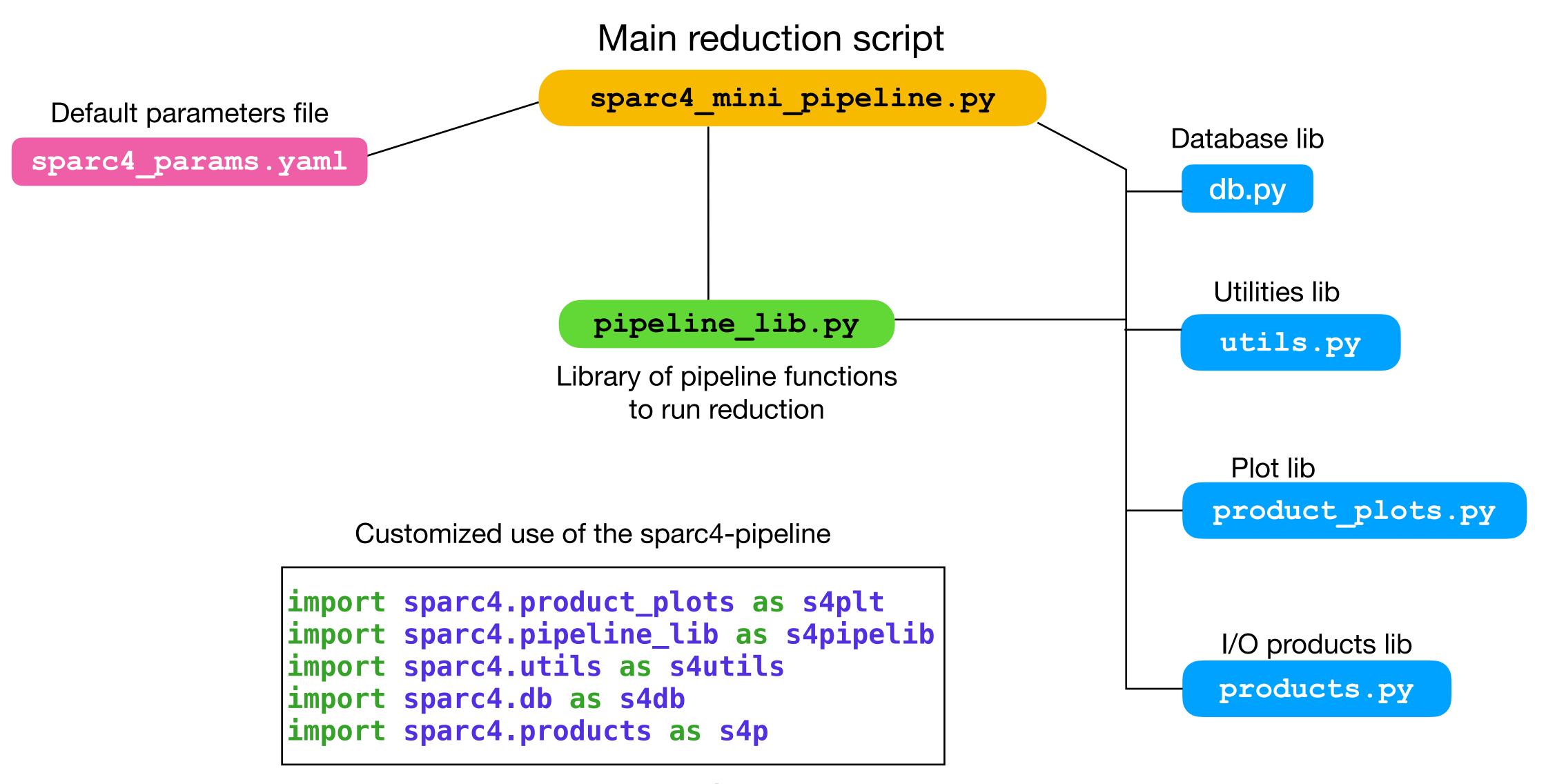
√ 4-band imager and polarimeter



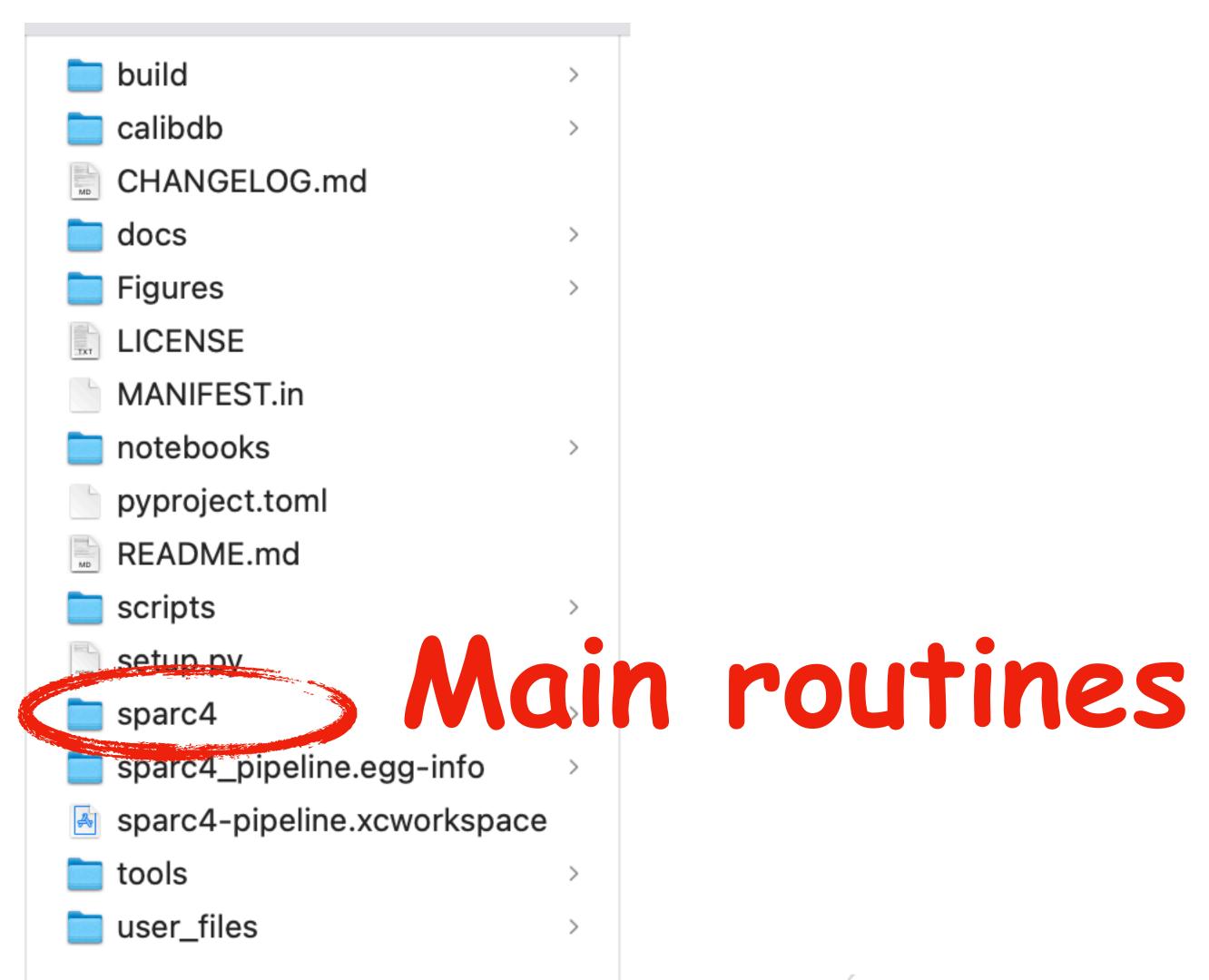
Pipeline concept

- The SPARC4 Pipeline is a suite of Python routines designed to automate the reduction and instrumental calibration processes for SPARC4 data collected in specific, pre-defined observation modes.
- External libraries used by the SPARC4 Pipeline:
 - ASTROPOP
 - ASTROPY
 - NUMPY, SCIPY, ETC. (ANACONDA)
- Open source and available to everyone, but its main purpose is to run at LNA. Unfortunately, we cannot currently provide external user support; data reduction quality is of PI's responsibility.

Pipeline concept

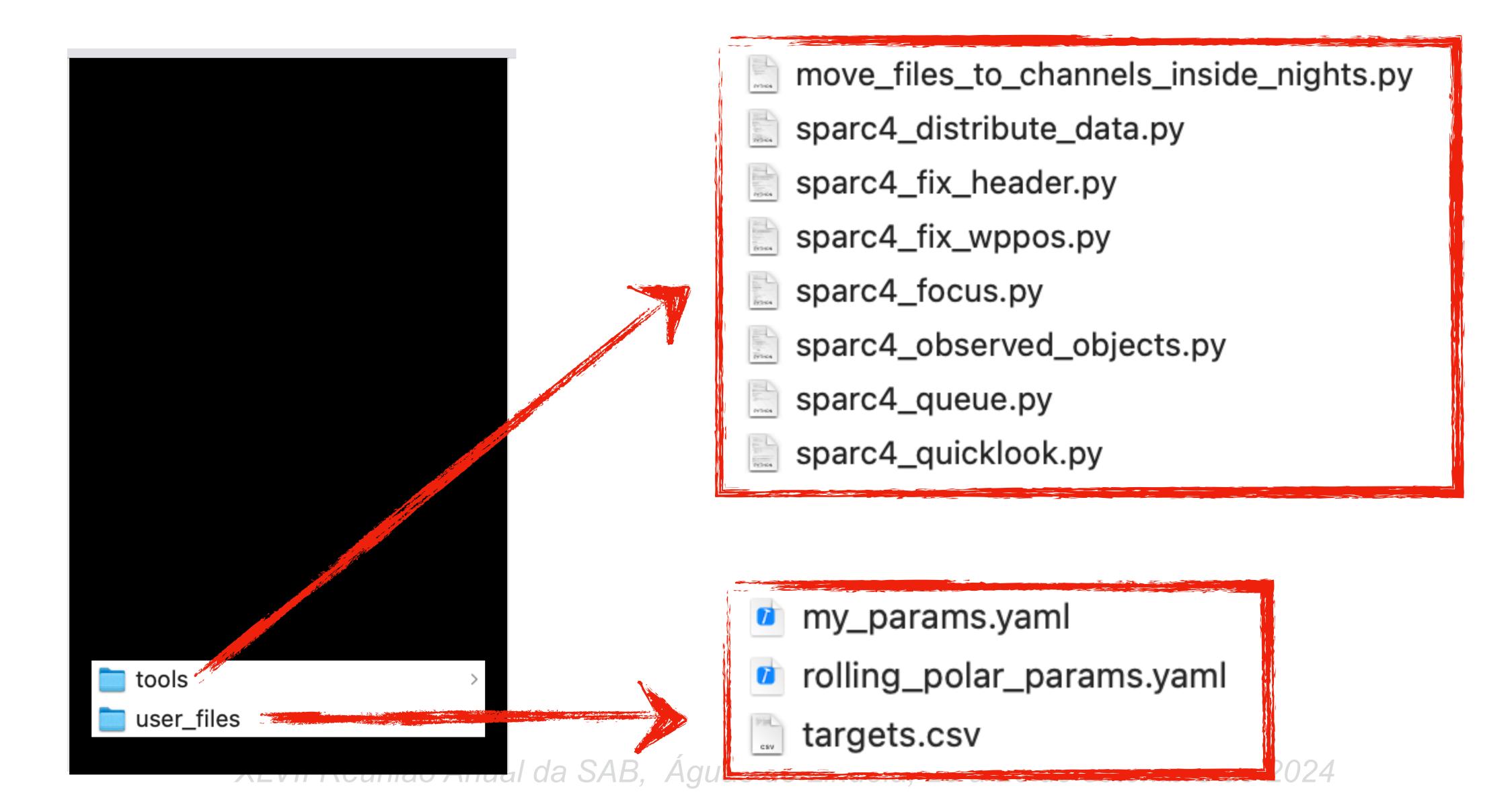


Code structure



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Code structure



Code structure





opd_mini_pipeline.py



sparc4_mini_pipeline.py

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Observing modes

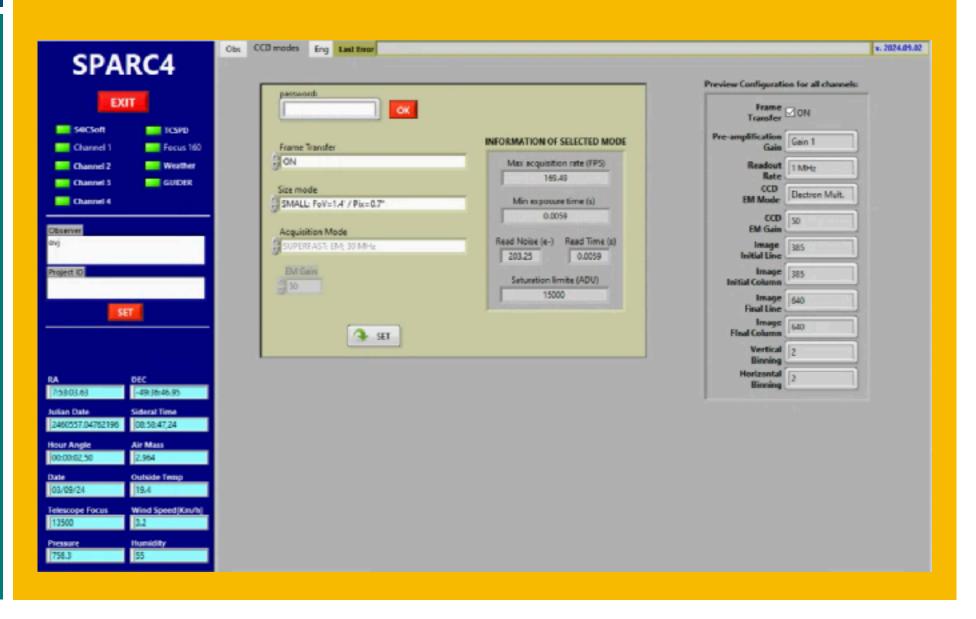
PHOT

- Imaging
- Photometric time series (light curve)

POLAR

- $\lambda/2$ (L2) or $\lambda/4$ (L4) using up to 16 wave plate positions
- Imaging
- Polarimetric time series

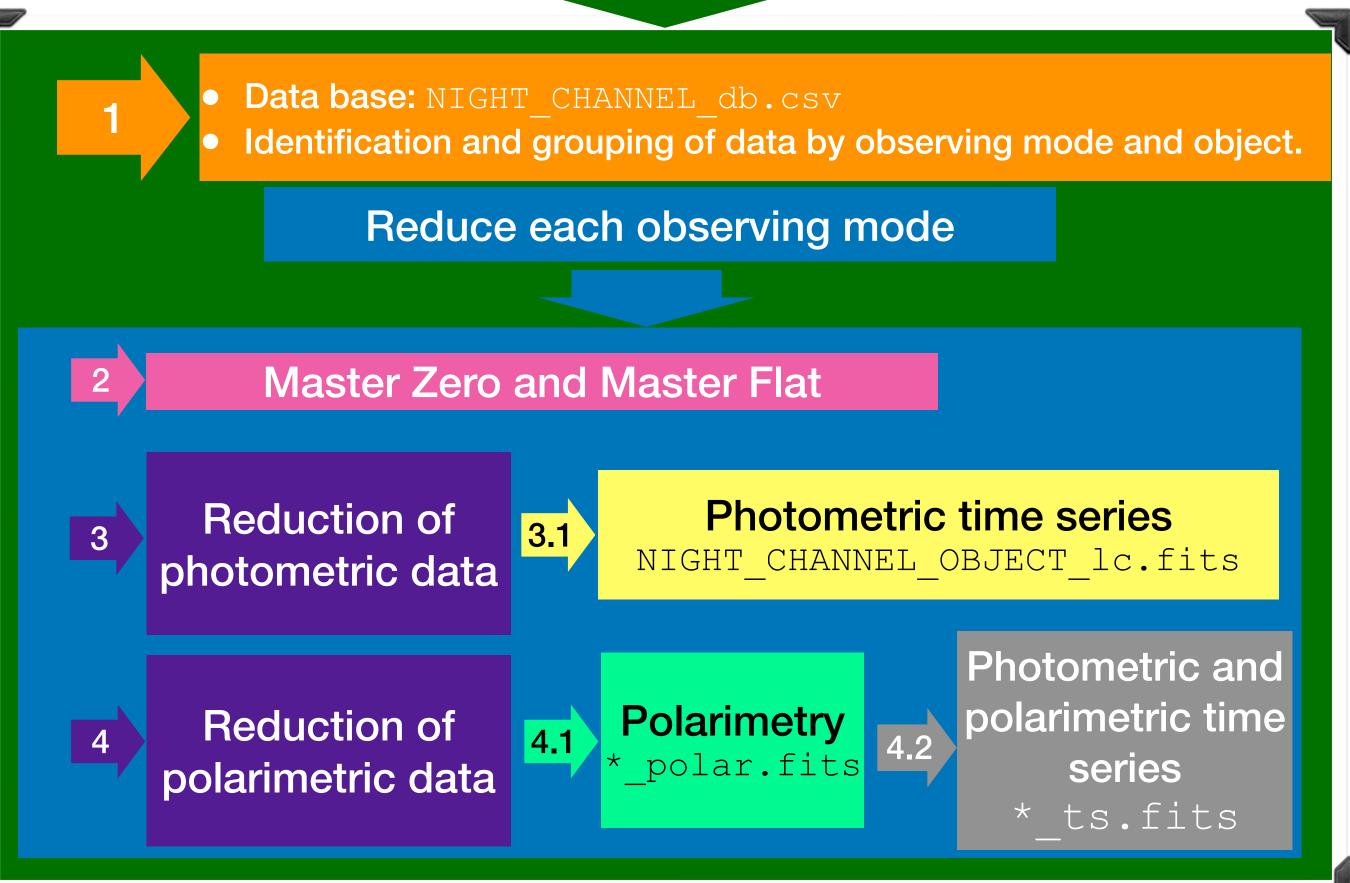
- Frame transfer ON/OFF
- ROI: 1024x1024, 512x512, 256x256
- Binning: 1x1, 2x2
- Conv: 0.1 or 1 MHz. EM:10, 20, 30 MHz



Reduction overview

Input parameters for reduction:
sparc4_params.yaml

Reduce each channel: g [1], r [2], i [3], z [4]



Basic reduction (steps 3 and 4 — all modes):

- 1. CCD gain correction;
- 2. Master Zero subtraction;
- 3. Master Flat correction;
- 4. Image registering;
- 5. Build stack:
 - NIGHT_CHANNEL_CCDMODE_OBJECT_INSTMODE_stack.fits
- 6. Source detection build master catalog;
- 7. Astrometry: new WCS;
- 8. Multi-aperture photometry;
- 9. Calculation of BJD and HJD;
- 10. Save data in a FITS file *_proc.fits (reduced image, catalogs, and new calibrations).

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Installation

Install dependencies:

- Anaconda3 (recommended)
- AstroPoP 0.9.X
- astropy, astroquery, photutils, aafitrans, twirl, yaml, regions, uncertainties, time, signals, glob, functools
- astrometry.net (optional).
 Require index files: http://data.astrometry.net (for SPARC4 we use only index-5200 a index-5205)

Obtaining the sparc4-pipeline:

- Download SPARC4 Pipeline package in the link sparc4-pipeline or
- On github: https://github.com/edermartioli/sparc4-pipeline. Use the following git command:

```
git clone https://github.com/edermartioli/
sparc4-pipeline.git
```

 Download the minidata package with SPARC4 data to test the pipeline.

2. Preparatory steps

Directory structure

Raw data:

```
$ROOTDATADIR/sparc4acs1/$NIGHTDIR/
$ROOTDATADIR/sparc4acs2/$NIGHTDIR/
$ROOTDATADIR/sparc4acs3/$NIGHTDIR/
$ROOTDATADIR/sparc4acs4/$NIGHTDIR/
```

\$ROOTDATADIR is the root directory where raw data are saved **\$NIGHTDIR** is the night directory of observations

Reduced data (nights inside channels):

\$ROOTREDUCEDIR/sparc4acs1/\$NIGHTDIR/ \$ROOTREDUCEDIR/sparc4acs2/\$NIGHTDIR/ \$ROOTREDUCEDIR/sparc4acs3/\$NIGHTDIR/ \$ROOTREDUCEDIR/sparc4acs4/\$NIGHTDIR/

Reduced data (channels inside nights):

```
$ROOTREDUCEDIR/$NIGHTDIR/sparc4acs1/
$ROOTREDUCEDIR/$NIGHTDIR/sparc4acs2/
$ROOTREDUCEDIR/$NIGHTDIR/sparc4acs3/
$ROOTREDUCEDIR/$NIGHTDIR/sparc4acs4/
```

\$ROOTREDUCEDIR is the root directory where reduced data are saved

Pipeline configuration

Create a new parameter file and edit it. Make a copy of the file: sparc4-pipeline/user files/my params.yaml

```
5 #### DIRECTORIES W#####
                                                                            ROOTDATADIR: "/Volumes/Sansung_T5/Data/SPARC4/comissioning_nai23/"
                                                                            ROOTREDUCEDIR: "/Volumes/Samsung_T5/Data/SPARC4/comissioning_mai23/reduced"
                                             sparc4_products
                                                                         9 #-define SPARC4 channel numbers = 
                                                                         10 CHANNELS: [1, 2, 3, 4]
                                                                         11 # define SPARC4 channel labels
                                                                         12 CHANNEL_LABELS: ['g','z','i','z']
                                                                         14 #### NIGHT DATA BASE #####
                                                                         15 #-define-SPARC4-keywords-used-to-select-reduction-groups—
                                                                         16 DB_KEYS: ["DATE-OBS", "EXPTINE", "
                                                                         17 "OBJECT", "OBSTYPE", "INSTMODE", "CHANNEL", "
                                                                         18 .....vering, "Heing, "Heing, "InitLing, "InitColg, "FinalLing, "FinalColg, "
                                                                               "VSHIFT", "VCLKAMP", "CCDSERN",
                                                                              "PREAMP", "READRATE", "EMMODE", "EMGAIN", "
                                                                             "WPPOS", "WPSEL", "CALW", "ASEL"]
                                                                         23 #-list of header keywords to define a detector mode-
                                                                         24 DETECTOR_MODE_KEYWORDS: ["PREAMP", "READRATE", "EMMODE", "EMDAIN"]
                                                                         26 # include image statistics in database (slower but more complete)
                                                                            INCLUDE_IMG_STATISTICS: False
                                                                         29 # include full frames only
                                                                         33 #### CALIBRATIONS #####
                                                                         34 # wild cards to identify calibration images
                                                                         35 CALIB_WILD_CARDS: ['*.fits']
                                                                         36 #-Method-to-combine-calibration-images-
                                                                            CALIB_IMCOMBINE_METHOD: 'median'
                                                                         38 # Number of sigmas to clip if using method mean
                                                                         39 #NSIGMA INCOMBINE METHOD: -5-
                                                                         41 BIAS_OBSTYPE_KEYVALUE: 'ZERO'-
                                                                         42 # Value of obstype keyword used to identify flat images -
                                                                         48 FLAT_OBSTYPE_KEYVALUE: * 'FLAT'-
                                                                         44 #FLAT_OBSTYPE_KEYVALUE: "DFLAT"
                                                                         ^{45} # Value of obstype keyword used to identify focus images \rightarrow
                                                                         46 FOCUS_OBSTYPE_KEYVALUE: *FOCUS**
                                                                         47 #-Value of obstype keyword used to identify dark images -
                                                                         48 DARK_OBSTYPE_KEYVALUE: "DARK"
                                                                         49 # 'Value of obstype keyword used to identify object images -
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                                                                         50 OBJECT_OBSTYPE_KEYVALUE: - 'OBJECT'
```

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3. Reduction of minidata

I suggest two ways to reduce your data

- Run pipeline script in the command line
- Run pipeline functions in a Jupyter notebook or make your own scripts.

4	edermartioli Update product_plots.py		57
	Figures	Delete Figures/notes.txt	
	calibdb	Delete 20221104_s4c4_CR7_stack.fits	
	docs	Add files via upload	
	notebooks	Updates and new lightcurve notebook	
	scripts	Add files via upload	
	sparc4	Update product_plots.py	
	tools	Included sync of raw data	
	user_files	Add files via upload	

Execution in the terminal

python sparc4_mini_pipeline.py ...

```
--datadir='/Users/eder/Data/SPARC4/minidata/'
                                                 (Data root directory)
--reducedir='/Users/eder/Data/SPARC4/minidata/reduced/' (Reduced data root directory)
--channels='1,3' (Seletected SPARC4 channels)
--nightdir='20230604' (Name of night directory common to all channels)
--object='Hilt 652' (Object ID - same as in header key OBJECT - to restrict reduction)
--params='/Users/eder/sparc4-pipeline/user_files/my_params.yaml' (Input yaml parameter file)
--target_list='/Users/eder/sparc4-pipeline/user_files/targets.csv' (Input target list)
-f (Force reduction)
     (Activate plotting)
```

Execution in the terminal

```
python sparc4_mini_pipeline.py --nightdir=20230604
```

```
python -W ignore /Users/eder/sparc4-pipeline/
scripts/sparc4_mini_pipeline.py --params=/Users/
eder/Desktop/my params.yaml --nightdir=20230604
```

How long it takes to reduce the minidata?

On a MacBook Pro 2023 M2 Max 32Gb:

• 20230604 : 10m44s

• 20230605 : 2m09s

• 20230606 : 9m27s

• 20240618 : 3m50s

Break

SPARC4 reduction products

- NIGHT+CHANNEL DATABASE (db.csv) night database;
- MASTER ZERO (MasterZero.fits) combined image of all zero images;
- MASTER FLAT (MasterDomeFlat.fits) combined image of all flat images;
- PROCESSED FRAME (proc.fits) calibrated scientific image;
- STACK FRAME (stack.fits) combined image of a number of scientific processed images;
- PHOTOMETRIC LIGHT CURVE (lc.fits) time series file containing all photometric quantities;
- **POLARIMETRY** (polar.fits) polarimetry results for all sources obtained from a sequence of many $\lambda/2$ or $\lambda/4$ wave plate positions;
- POLARIMETRIC TIME SERIES (ts.fits) time series file containing all photometric and polarimetric quantities.