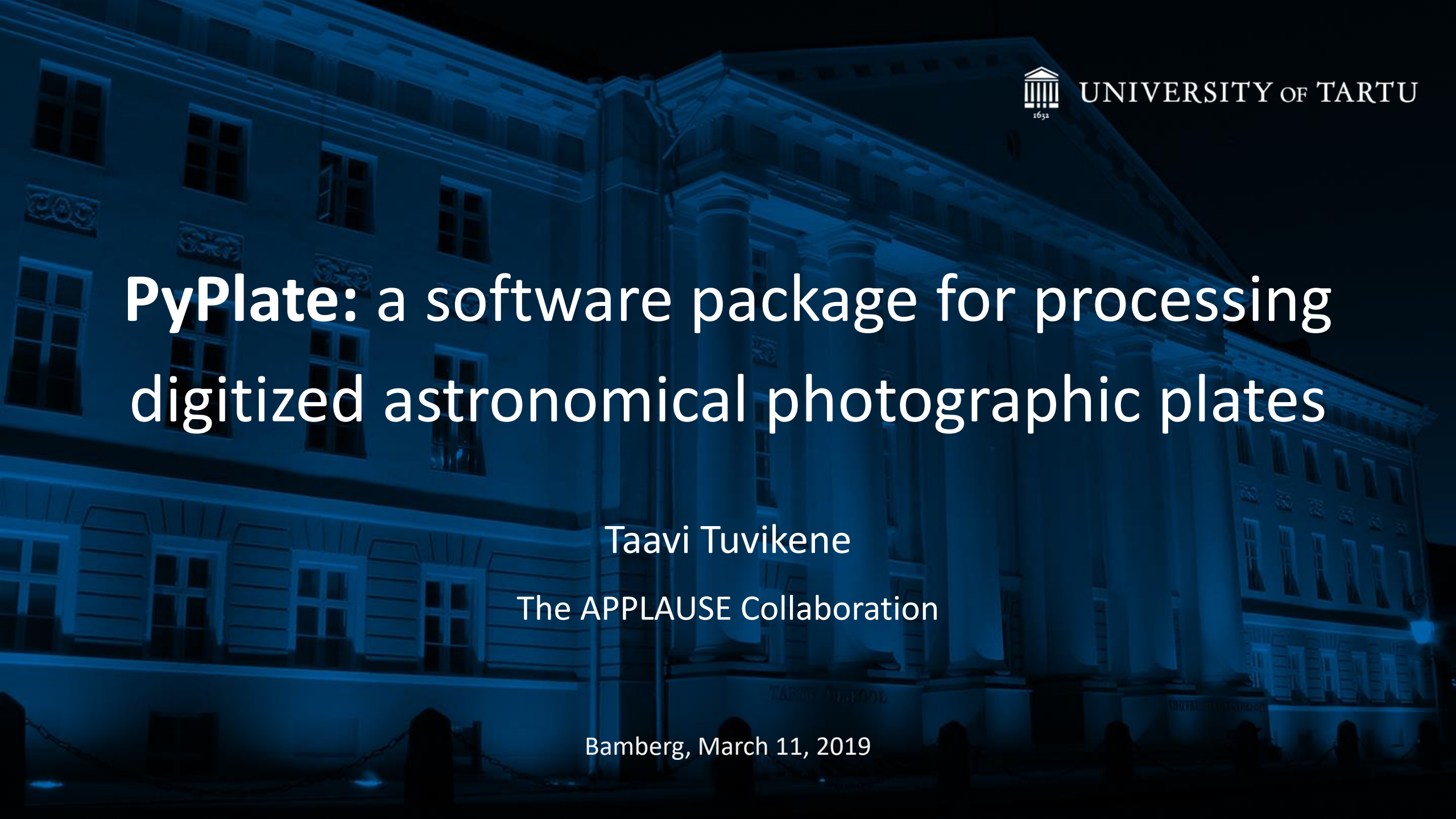


UNIVERSITY OF TARTU

PyPlate: a software package for processing digitized astronomical photographic plates

Taavi Tuvikene

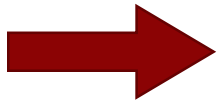
The APPLAUSE Collaboration

Bamberg, March 11, 2019

What do we want to accomplish?

Raw digitized data

- High-resolution scans
- Low-resolution preview images
- Digitized logbook pages
- Transcribed metadata
- APPLAUSE: ~ 100 000 scans in 24 archives (~ 50 TB)



PyPlate

Processed data / publication

- Scans in FITS format
- Metadata in FITS headers and in a relational database
- Sources extracted from scans + calibrated coordinates and magnitudes
- Astrometric solution in FITS

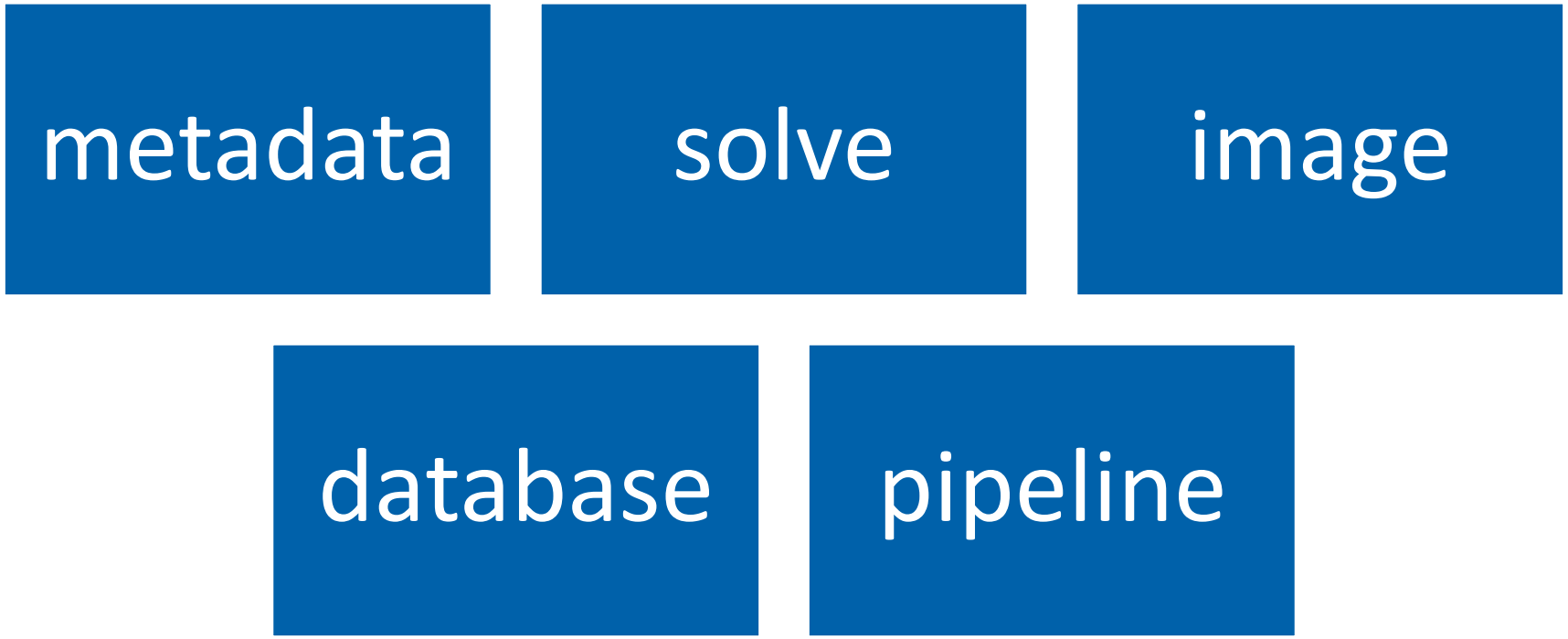
Development started in 2013...

- Harvard DASCH pipeline was described in couple of papers
  - Laycock et al. (2010), Tang et al. (2013)
- SExtractor, Astrometry.net, SCAMP were available
- Python was coming into wide use in astronomy
- Astropy version was 0.2.x

PyPlate versions

PyPlate	APPLAUSE	Release
1.0	DR1	2015-02-14
2.0	DR2	2015-12-23
3.0	DR3	2017-10-23
3.1	–	2019-03-09
4.0	DR4	Summer 2019

PyPlate modules



metadata | solve | image | database | pipeline

- Read CSV files — Metadata on plates, scans, logbooks, logpages
- Read WFPDB files — Wide-Field Plate Database (Tsvetkov et al. 1997)
- Handle relations — Associations between plates, scans, previews, logbooks, logpages
- Calculate exposure times — From original (sidereal time, local time) to UT, JD, and HJD. Calculate mid-exposure times.
- Create FITS headers — Following FITS standard and grouping keywords for better readability. Each keyword is documented with a comment.

metadata

- Read CSV files
- Read WFPDB files
- Handle relations
- Calculate exposure times
- Create FITS headers

solve

- Extract sources
- Flag artefacts
- Apply proper motions
- Solve astrometry
- Photometric calibration
- Crossmatch with ext. catalogs

image

database

pipeline

Using the SExtractor software

Machine learning: following talk by Gal Matijevic

Currently using Tycho-2 and UCAC4. Soon: *Gaia* DR2

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Initially with Astrometry.net, then with SCAMP in subfields.
Getting rid of wave pattern caused by flatbed scanners.

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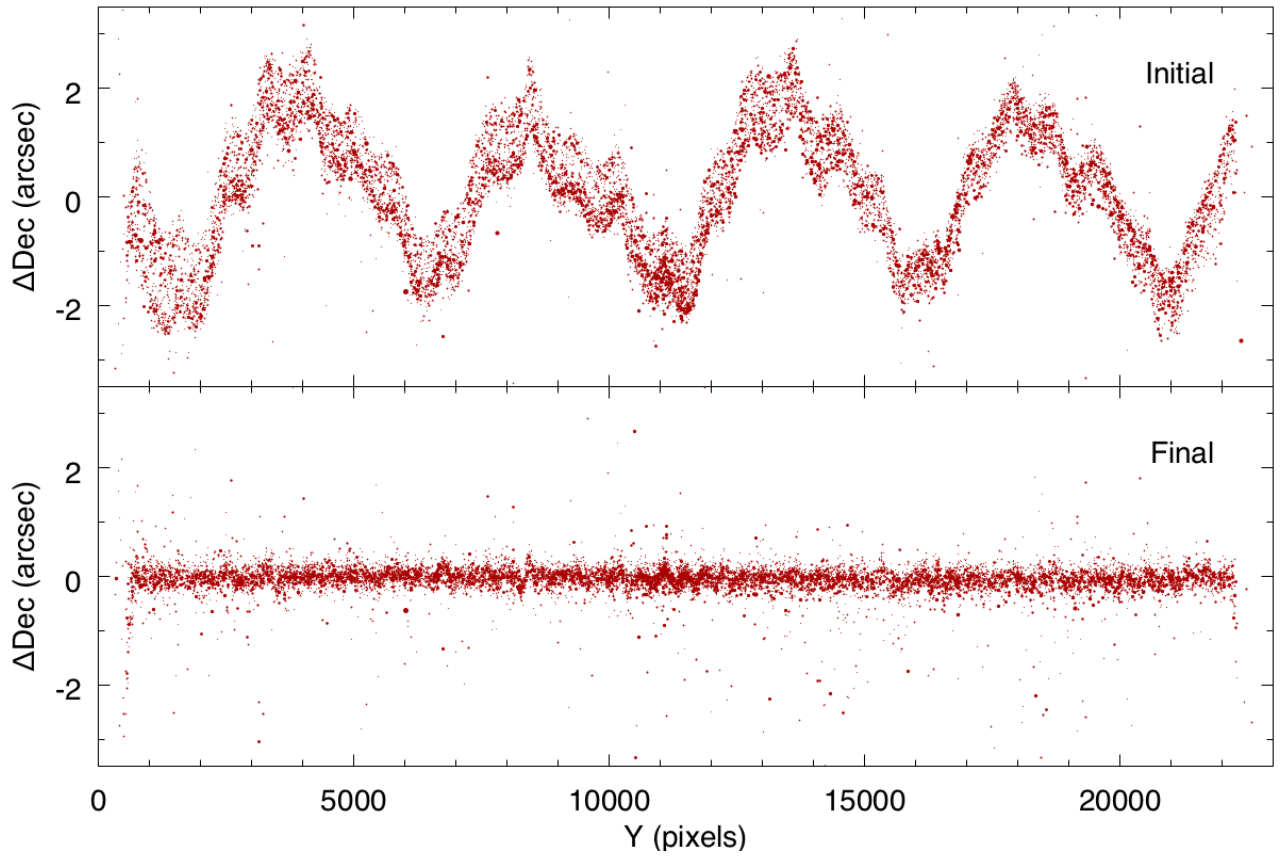

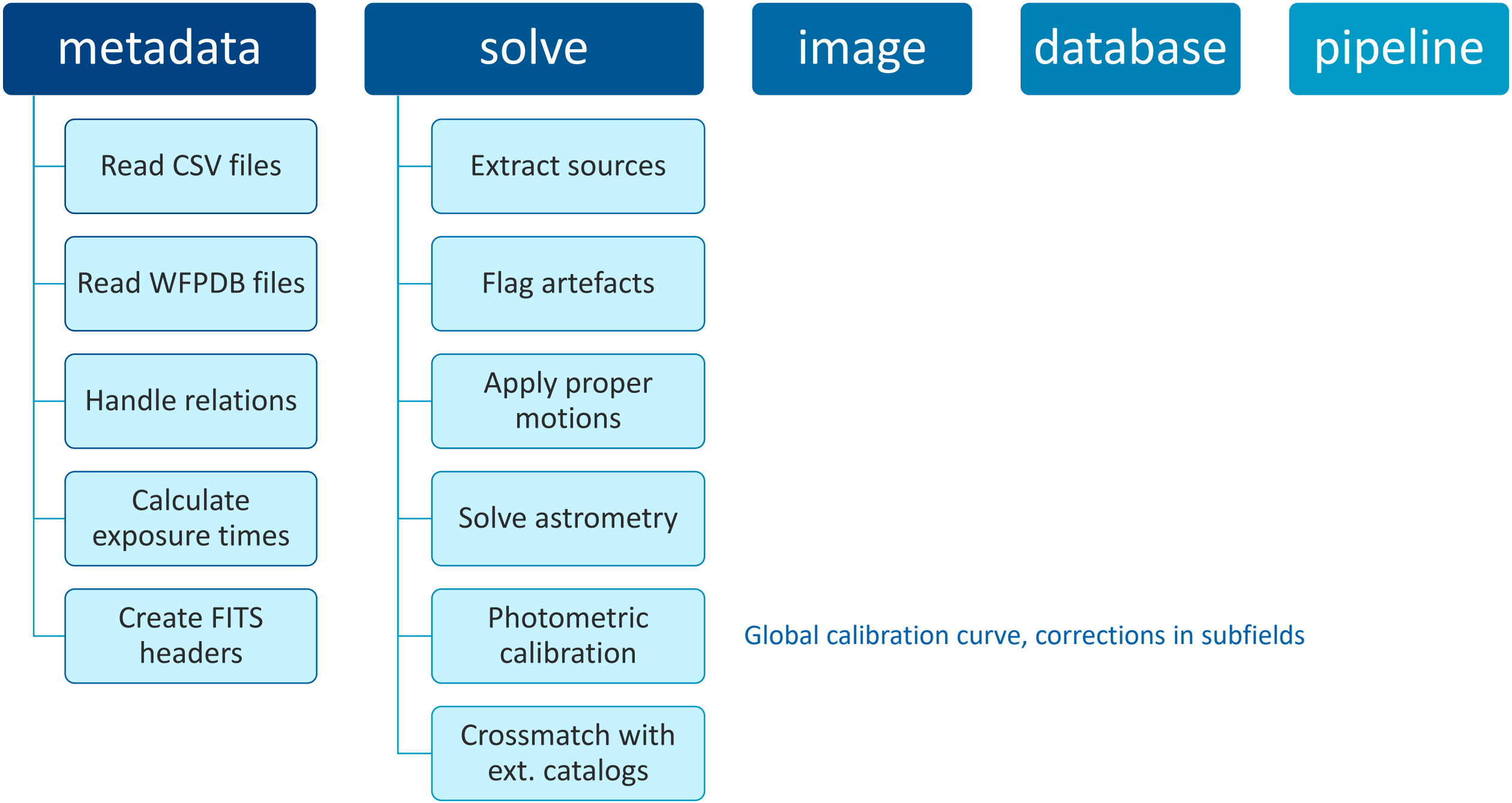
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Global calibration curve, corrections in subfields

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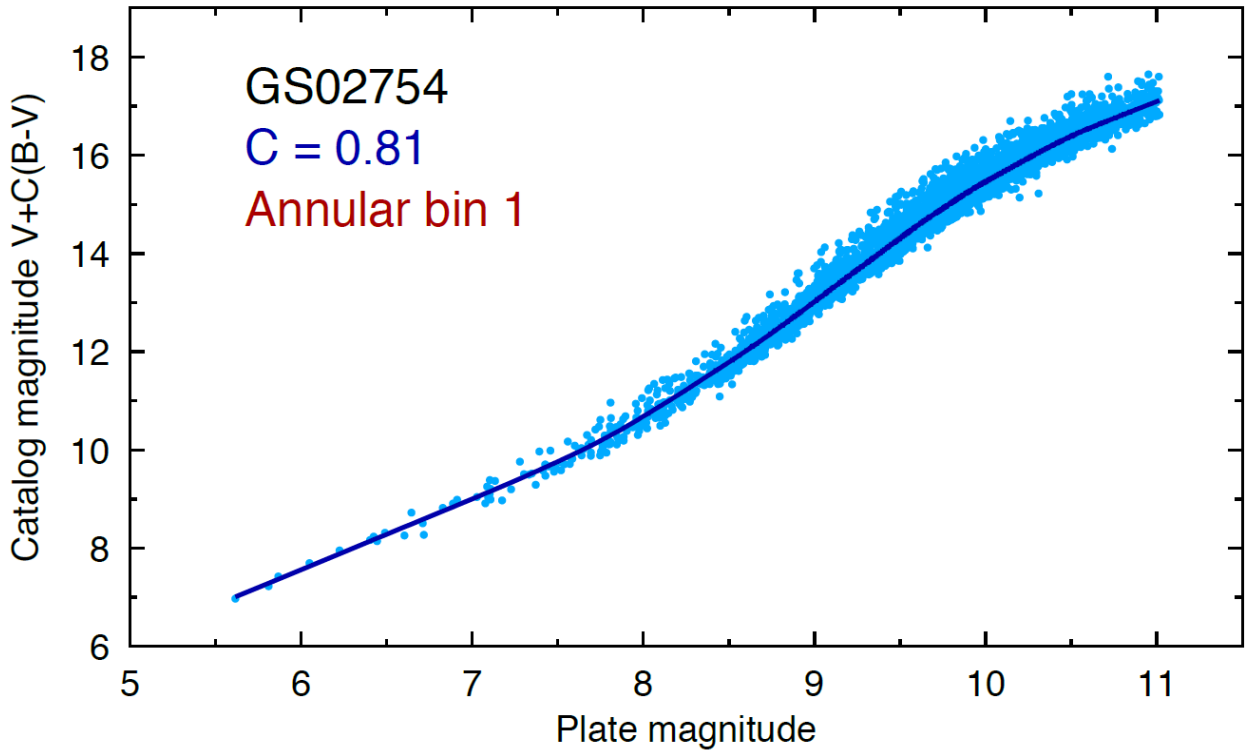

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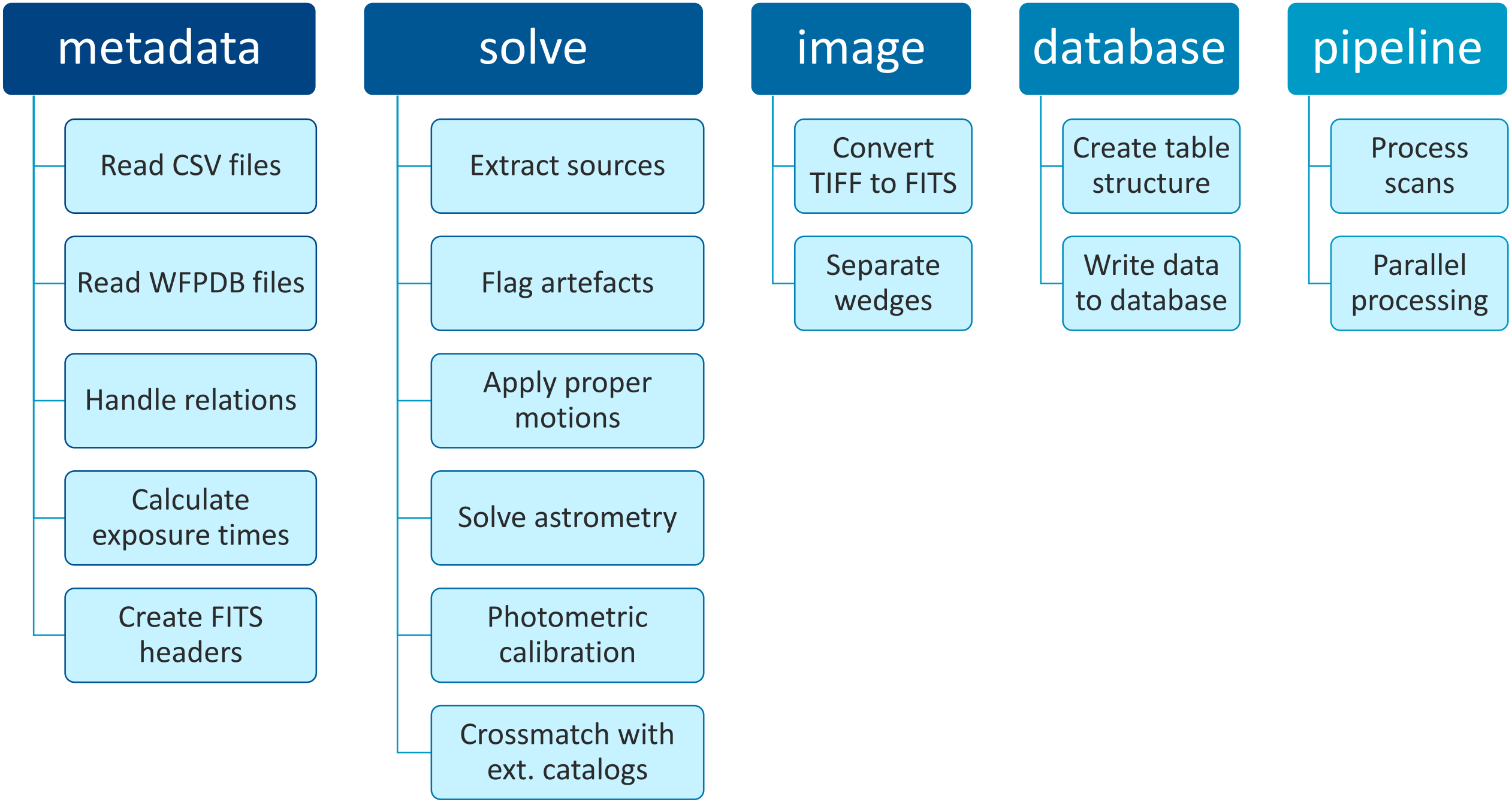
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Handle relations
Calculate exposure times
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Extract sources
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Photometric calibration
Crossmatch with ext. catalogs
image
Convert TIFF to FITS
Separate wedges
database
Create table structure
Write data to database
pipeline
Process scans
Parallel processing

Easy to install

Requires Python installation, then

```
pip install pyplate
```

Example: plate metadata (CSV file)

```
plate1, 1956-03-11, 21:11:30, 600, Observer Name, Europe/Berlin
plate2, 1956-03-11, 21:30:00, 1800, Observer Name, UT
plate3, 1956-03-12, 23:05:00, 1200, Observer Name, ST
```

Example: scan metadata (CSV file)

```
plate_0001.fits, plate1, Scan Author, 2018-10-12
plate_0002.fits, plate2, Scan Author, 2018-10-12
plate_0003.fits, plate3, Scan Author, 2018-10-13
```

Example: configuration file

```
[Files]
csv_dir = /path/to/csv/dir
plate_csv = my_plates.csv
scan_csv = my_scans.csv
```

```
[my_plates.csv]
plate_id = 1
date_orig = 2
tms_orig = 3
exptime = 4
observer = 5
tz_orig = 6
```

```
[my_scans.csv]
filename = 1
plate_id = 2
scan_author = 3
datescan = 4
```

Example: reading metadata

```
import pyplate
archive = pyplate.metadata.Archive()
archive.assign_conf('/path/to/my_archive.conf')
archive.read_csv()
```

Example: metadata calculations

```
plate_list = archive.get_platelist()
# Iterate over the plate list
for pid in plate_list:
        plate = archive.get_platemeta(plate_id=pid)
        plate.calculate()
        # Then do something with the metadata
        print(plate['jd_avg'])
```

Example: create FITS header

```
header = pyplate.metadata.PlateHeader()
header.assign_conf(archive.conf)
header.populate()
plate1 = archive.get_platemeta(plate_id='plate1')
header.update_from_platemeta(plate1)
header.output_to_fits('plate_0001.fits')
```

```
SIMPLE  =                    T / file conforms to FITS standard
BITPIX  =                   16 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                    0 / length of data axis 1
NAXIS2  =                    0 / length of data axis 2
BSCALE  =                  1.0 / physical_value = BZERO + BSCALE * array_value
BZERO   =                32768 / physical_value = BZERO + BSCALE * array_value
MINVAL  =                      / minimum image value
MAXVAL  =                      / maximum image value
EXTEND  =                    T / file may contain extensions
        ---------------------------------------- Original data of the observation
DATEORIG= '1956-03-11'         / recorded date of the observation
TMS-ORIG= '21:11:30'           / recorded time of the start of exposure 1
TME-ORIG= '        '           / recorded time of the end of exposure 1
JDA-ORIG=                      / recorded Julian date, mid-point of exposure 1
TIMEFLAG= '        '           / quality flag of recorded time
RA-ORIG = '        '           / recorded right ascension of exposure 1
DEC-ORIG= '        '           / recorded declination of exposure 1
COORFLAG= '        '           / quality flag of recorded coordinates
OBJECT  = '        '           / observed object or field (exposure 1)
OBJTYPE = '        '           / object type
EXPTIME =                  600 / [s] exposure time of exposure 1
NUMEXP  =                    1 / number of exposures of the plate
```

```
       ---------------------------------------- Computed data of the observation
DATE-OBS= '1956-03-11T20:11:30' / UT date of the start of exposure 1
DATE-AVG= '1956-03-11T20:16:30' / UT date of the mid-point of exposure 1
DATE-END= '        '            / UT date of the end of exposure 1
YEAR    =       1956.19258404 / decimal year of the start of exposure 1
YEAR-AVG=       1956.19259354 / decimal year of the mid-point of exposure 1
YEAR-END=                     / decimal year of the end of exposure 1
JD      =       2435544.34132 / Julian date at the start of exposure 1
JD-AVG  =       2435544.34479 / Julian date at the mid-point of exposure 1
JD-END  =                     / Julian date at the end of exposure 1
HJD-AVG =                     / heliocentric JD at the mid-point of exposure 1
RA      = '        '          / right ascension of pointing (J2000) "h:m:s"
DEC     = '        '          / declination of pointing (J2000) "d:m:s"
RA_DEG  = '        '          / [deg] right ascension of pointing (J2000)
DEC_DEG = '        '          / [deg] declination of pointing (J2000)
       ------------------------------------------------------------ Scan
SCANNER = 'Epson Expression 10000XL' / scanner name
SCANRES1=                 2400 / [dpi] scan resolution along axis 1
SCANRES2=                 2400 / [dpi] scan resolution along axis 2
PIXSIZE1=              10.5833 / [um] pixel size along axis 1
PIXSIZE2=              10.5833 / [um] pixel size along axis 2
DATESCAN= '2018-10-12'         / scan date and time
SCANAUTH= 'Scan Author'        / author of scan
```

```
       ---------------------------------------------------------- Data files
FILENAME= 'plate_0001.fits'    / filename of the plate scan
FN-WEDGE= '        '           / filename of the wedge scan
FN-PRE  = '        '           / filename of the preview image
FN-COVER= '        '           / filename of the plate cover image
ORIGIN  = '        '
DATE    = '2019-03-09T20:44:27' / last change of this file
       ------------------------------------------------------------- WCS
       ------------------------------------------------------------ Licence
LICENCE = '        '
       ------------------------------------------------------ Acknowledgements
       ------------------------------------------------------------ History
HISTORY Header created with PyPlate v3.1.0 at 2019-03-09T20:44:27
HISTORY Header updated with PyPlate v3.1.0 at 2019-03-09T20:44:27
       ---------------------------------------------------------- Checksums
CHECKSUM= '        '
DATASUM = '        '
       ------------------------------------------------------------------
```

Example: parallel processing

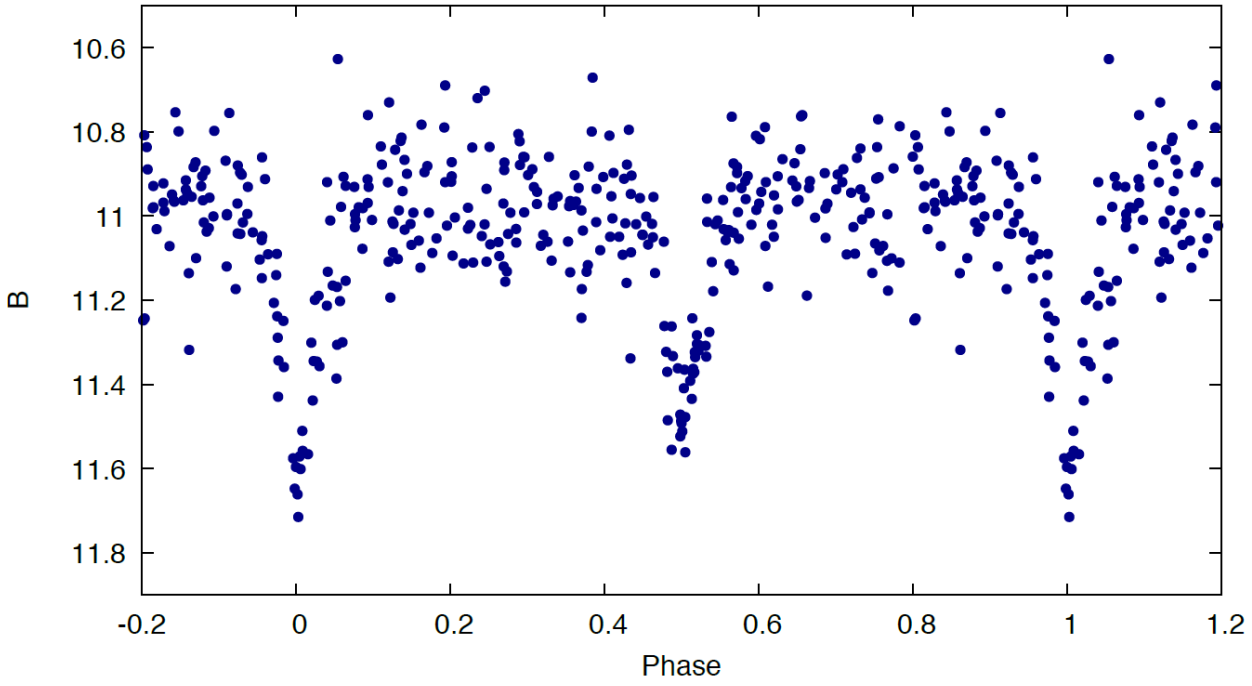
```
filenames = archive.get_scanlist()
pipeline = pyplate.pipeline.PlatePipeline()
pipeline.assign_conf(archive.conf)
pipeline.parallel_run(filenames)
```

Performance: APPLAUSE DR3

- Extracted ~3.5 billion sources from ~70 000 scans
- Robust: only 17 processes out of 70730 had problems
- Processing time: ~900 CPU core-days
- Used 20 processes in parallel

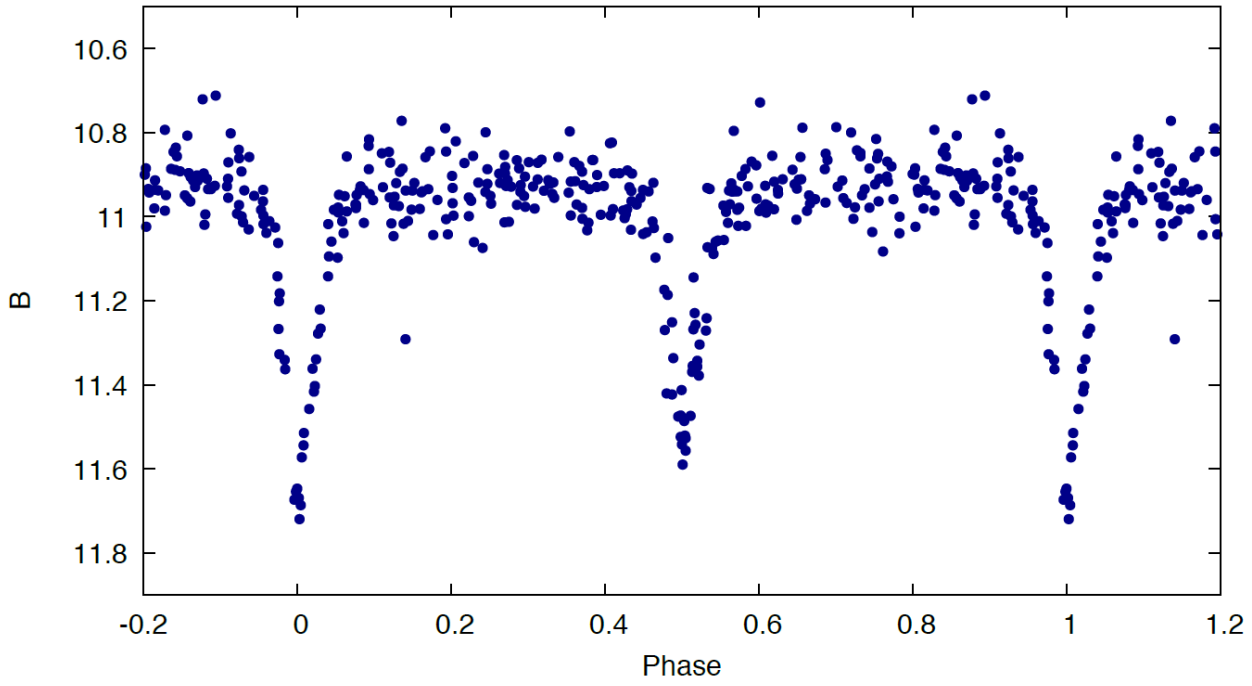
Results: V466 Cyg light curve

APPLAUSE DR2 (PyPlate 2.0)



Calibration in annular bins

APPLAUSE DR3 (PyPlate 3.0)



Calibration in sub-fields

PyPlate

- It is open source!
- Install: pip install pyplate
- Use it as a library for your needs
- Check documentation: pyplate.readthedocs.io
- Contribute: www.github.com/astrotuvi/pyplate
  Report bugs, feature requests, etc

UNIVERSITY OF TARTU

Thank you!

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GitHub: astrotuvi