Using VODML in MICADO Pipeline Design

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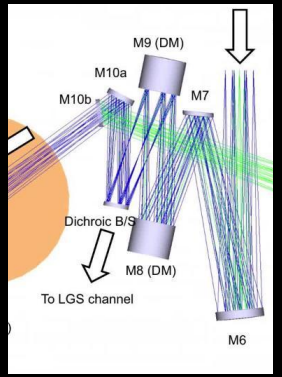
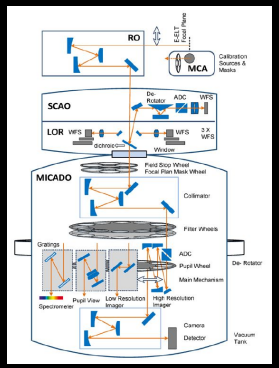
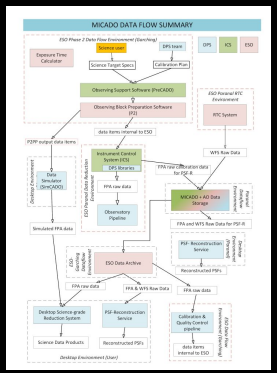
Observatory + ELT + AO + MICADO + **Data Flow System**







2018: Preliminary Design

2020: Final Design

2025: First Light

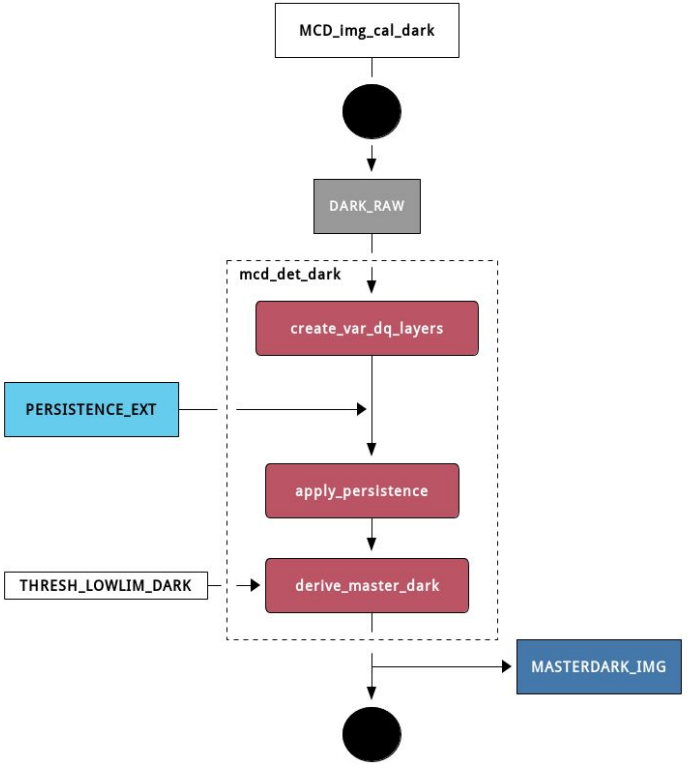
Pipeline Specification: Data Centric Design

Data Reduction Library Specification

- Highly Structured:
- mostly Tables & Diagrams

Design is Data Centric

- Raw Data contains Instrument Configuration
- Science Data contains Processing Parameters



Data Flow Team Deliverables

Data Reduction Library Specification (**PDF**, Tables, Diagrams)

Prototypes (**Python** Classes/Objects)

Data (**FITS** Headers)

Archive (**SQL** Tables/Rows)

Simulator Input (**YAML** Dictionaries)

How to tie all of this together?

Data Reduction Library Specification (**PDF**, Tables, Diagrams)

Astronomical Data-Centric Standard to Model this?

Prototypes (**Python** Classes/Objects)

Data (**FITS** Headers)

Archive (**SQL** Tables/Rows)

Simulator Input (**YAML** Dictionaries)

VO-DML to the rescue!

Prototypes
(**Python** Classes/Objects)

Data Reduction
Library Specification
(**PDF**,
Tables, Diagrams)

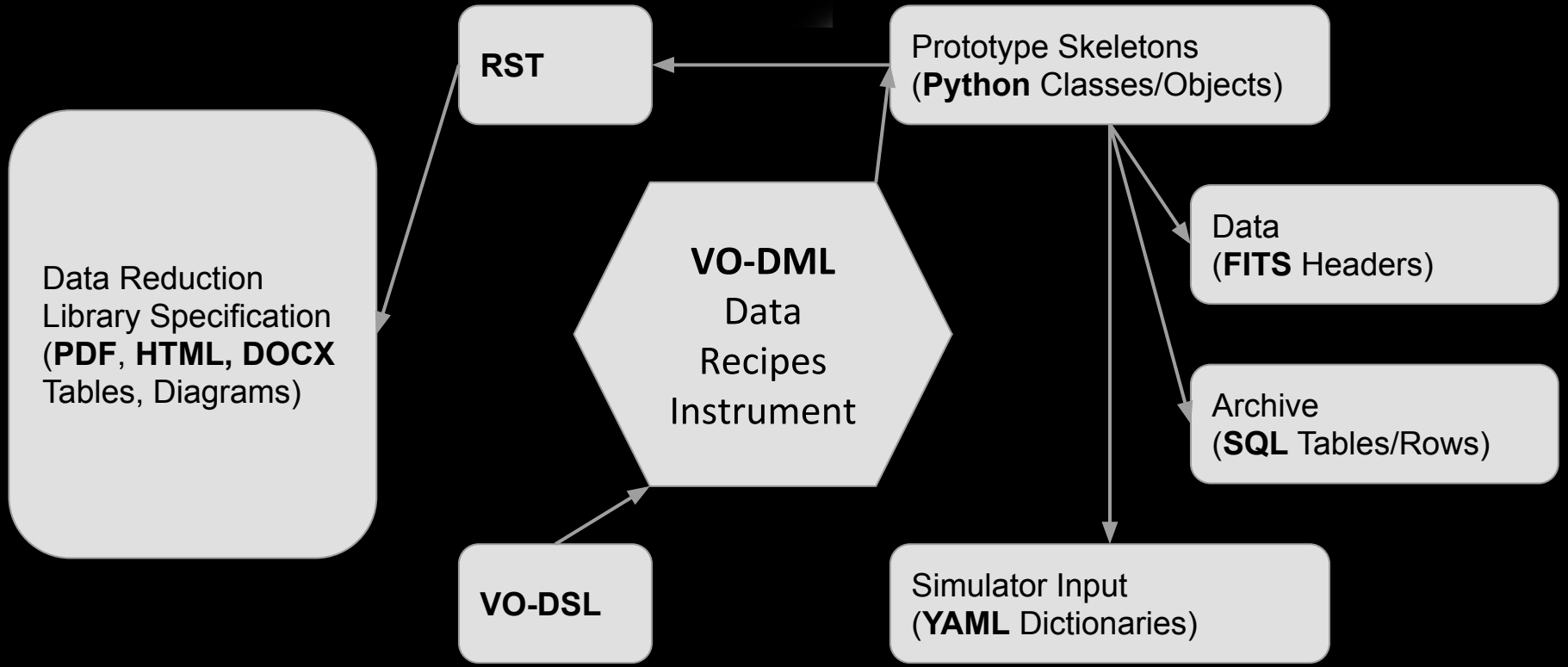
VO-DML!

Data
(**FITS** Headers)

Archive
(**SQL** Tables/Rows)

Simulator Input
(**YAML** Dictionaries)

MICADO Pipeline Design Workfow



VODSL & VODML

```
otype DarkExtension -> main.DataExtensionImage "Dark FITS Extension" {
    detector @? references hardware.Detector "Detector";
}

otype Dark -> main.Raw "The Dark represents a raw dark image." {
    detector @? references hardware.DetectorArray "Detector Array";
    template @? references templates.MCD_img_cal_dark "The template";
    extensions: DarkExtension @* as composition "DarkExtensions";
}

// TODO: processed data have VAR and DQ extensions
otype MasterDarkExtension -> main.DataExtensionImage "MasterDark FITS Extension"

otype MasterDark -> main.Img "A MasterDark calibration frame." {
    recipe @? references recipes.McdDetDark "The recipe";
    darks @* references dataitems.Dark "A list of raw Darks";
    extensions: MasterDarkExtension @* as composition "MasterDarkExtensions";
}

otype FlatExtension -> main.DataExtensionImage "Flat FITS Extension" {
    detector @? references hardware.Detector "Detector";
}
```

```
<objectType>
  <vodml-id>dataitems.MasterDark</vodml-id>
  <name>MasterDark</name>
  <description>A MasterDark calibration frame.</description>
  <extends>
    <vodml-ref>micado:main.Img</vodml-ref>
  </extends>
  <composition>
    <vodml-id>dataitems.MasterDark.extensions</vodml-id>
    <name>extensions</name>
    <description>MasterDarkExtensions</description>
    <datatype>
      <vodml-ref>micado:dataitems.MasterDarkExtension</vodml-ref>
    </datatype>
    <multiplicity>
      <minOccurs>0</minOccurs>
      <maxOccurs>-1</maxOccurs>
    </multiplicity>
  </composition>
  <reference>
    <vodml-id>dataitems.MasterDark.recipe</vodml-id>
    <name>recipe</name>
    <description>The recipe</description>
    <datatype>
```

Python & Database

```
# -*- coding: utf-8 -*-
"""
A MasterDark calibration frame.

This file is automatically generated. Do not modify!
"""

from micado.main.Img import Img, persistent
from micado.recipes.McdDetDark import McdDetDark
from micado.dataitems.Dark import Dark
from micado.dataitems.MasterDarkExtension import MasterDarkExtension


class MasterDark(Img):
    """
    A MasterDark calibration frame.
    """

    dummy_masterdark = persistent("dummy [None]", int, 42)

    recipe = persistent("The recipe [None]", McdDetDark, None)

    darks = persistent("A list of raw Darks [None]", Dark, [])
```

```
CREATE TABLE baseframe (object_id TEXT DEFAULT upper(replace(gen_random_uuid()::text, '-', '')) P
  "+CREATOR" DOUBLE PRECISION  DEFAULT -1,"+PROJECT" DOUBLE PRECISION  DEFAULT -1,"+PRIVILEGES" D
  DEFAULT 1,"+CREATED" TIMESTAMP DEFAULT NOW_UTC(),"+MODIFIED" TIMESTAMP DEFAULT NOW_UTC(),"+VERS
    DEFAULT -1,"+ORIGIN" DOUBLE PRECISION  DEFAULT -1,BITPIX DECIMAL(38) DEFAULT 8,NAXIS DECIMAL(
   DECIMAL(38) DEFAULT 1,dummy9 VARCHAR(297) DEFAULT '',dummy_baseframe DECIMAL(38) DEFAULT 0,dum
  DECIMAL(38) DEFAULT 0,filename VARCHAR(297) DEFAULT '',globalname VARCHAR(297) DEFAULT '')
CREATE TABLE simulatorrun (object_id TEXT DEFAULT upper(replace(gen_random_uuid()::text, '-', ''
  "+CREATOR" DOUBLE PRECISION  DEFAULT -1,"+PROJECT" DOUBLE PRECISION  DEFAULT -1,"+PRIVILEGES" D
  DEFAULT 1,"+CREATED" TIMESTAMP DEFAULT NOW_UTC(),"+MODIFIED" TIMESTAMP DEFAULT NOW_UTC(),"+VERS
    DEFAULT -1,"+ORIGIN" DOUBLE PRECISION  DEFAULT -1,dummy9 VARCHAR(297) DEFAULT '',filename VAR
  '',globalname VARCHAR(297) DEFAULT '',machine_dns VARCHAR(297) DEFAULT '',run_date TIMESTAMP DE
  ('1990-01-01 00:00:00','YYYY-MM-DD HH24:MI:SS'),run_duration DOUBLE PRECISION DEFAULT 'Nan',ver
  DEFAULT '')
CREATE TABLE hardware (object_id TEXT DEFAULT upper(replace(gen_random_uuid()::text, '-', '')) PR
   DOUBLE PRECISION  DEFAULT -1,"+PROJECT" DOUBLE PRECISION  DEFAULT -1,"+PRIVILEGES" DOUBLE PREC
  1,"+CREATED" TIMESTAMP DEFAULT NOW_UTC(),"+MODIFIED" TIMESTAMP DEFAULT NOW_UTC(),"+VERSION" DOU
  DEFAULT -1,"+ORIGIN" DOUBLE PRECISION  DEFAULT -1,dummy VARCHAR(297) DEFAULT '',dummy9 VARCHAR(
  '',filename VARCHAR(297) DEFAULT '',globalname VARCHAR(297) DEFAULT '')
CREATE TABLE template_ (object_id TEXT DEFAULT upper(replace(gen_random_uuid()::text, '-', '')) P
  "+CREATOR" DOUBLE PRECISION  DEFAULT -1,"+PROJECT" DOUBLE PRECISION  DEFAULT -1,"+PRIVILEGES" D
  DEFAULT 1,"+CREATED" TIMESTAMP DEFAULT NOW_UTC(),"+MODIFIED" TIMESTAMP DEFAULT NOW_UTC(),"+VERS
    DEFAULT -1,"+ORIGIN" DOUBLE PRECISION  DEFAULT -1,dummy1 DECIMAL(38) DEFAULT -4,dummy9 VARCHA
  '',filename VARCHAR(297) DEFAULT '',globalname VARCHAR(297) DEFAULT '')
CREATE TABLE observingblock (object_id TEXT DEFAULT upper(replace(gen_random_uuid()::text, '-',
  KEY,"+CREATOR" DOUBLE PRECISION  DEFAULT -1,"+PROJECT" DOUBLE PRECISION  DEFAULT -1,"+PRIVILEGE
  DEFAULT 1,"+CREATED" TIMESTAMP DEFAULT NOW_UTC(),"+MODIFIED" TIMESTAMP DEFAULT NOW_UTC(),"+VERS
    DEFAULT -1,"+ORIGIN" DOUBLE PRECISION  DEFAULT -1,dummy9 VARCHAR(297) DEFAULT '',filename VAR
  '',globalname VARCHAR(297) DEFAULT '',instrument VARCHAR(297) DEFAULT '',name  VARCHAR(297) DEF
```


YAML & FITS

```
src/micado/test/functional/Dark_test.py {'!INST.pixel_scale': 0.004,
 '!INST.plate_scale': 0.2666667,
 '!OBS.dit': 1,
 '!OBS.ndit': 0}
[{'class': 'DetectorArray',
  'description': 'A detector array',
  'effects': [{'class': 'DarkCurrent',
               'description': 'Dark Current',
               'kwargs': {'dit': '!OBS.dit',
                          'ndit': '!OBS.ndit',
                          'value': 10000.0},
               'name': 'dark_current'},
              {'class': 'DetectorList',
               'description': 'A single Detector',
               'kwargs': {'array_dict': OrderedDict([('angle', [0.0]),
                                                     ('filename', ['']),
                                                     ('gain', [1.0]),
                                                     ('globalname', ['']),
                                                     ('id', ['']),
                                                     ('pixsize', [0.015]),
```

```
SIMPLE  =                    T / conforms to FITS standard
BITPIX  =                    8 / array data type
NAXIS   =                    0 / number of array dimensions
EXTEND  =                    T
HIERARCH ESO DET DAR FILENAME = ''
HIERARCH ESO DET DAR VALUE = 10000.0
HIERARCH ESO DET DET1 ANGLE = 0.0
HIERARCH ESO DET DET1 FILENAME = ''
HIERARCH ESO DET DET1 GAIN = 1.0
HIERARCH ESO DET DET1 ID = ''
HIERARCH ESO DET DET1 PIXSIZE = 0.015
HIERARCH ESO DET DET1 X_CEN = 0.0
HIERARCH ESO DET DET1 XHW = 30.72
HIERARCH ESO DET DET1 Y_CEN = 0.0
HIERARCH ESO DET DET1 YHW = 30.72
HIERARCH ESO DET FILENAME = ''
HIERARCH ESO DET NAME = 'testdetector'
FILENAME= '/tmp/tmp7vljizz0.fits'
HIERARCH ESO OBS FILENAME = ''
```

VO-DML during Design, a Success!

Lessons Learned / Questions

How to annotate Attributes (e.g. ivoa:RealQuantity)?

- How to specify unit?
- How to specify defaults/range?
  (actually ‘least informative prior’)

How to constrain attributes in subtypes to specific values?

Inspiration

- Omar Laurino
- Markus Demleitner
- Ole Streicher
- Paul Harrison

Next?

- DAL?