ScopeSim instrument packages for MICADO

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Chapter 1

Introduction

1.1 Overview of the Instrument Packages

The MICADO instrument simulator has moved from using the stand alone SimCADO package to using the generic astronomical instrument simulator ScopeSim. As the ScopeSim code is instrument agnostic, all data related to creating instrument models are contained inside instrument packages, which are hosted on the instrument reference database (IRDB).

1.1.1 Primary MICADO packages

This document is primarily concerned with describing the contents of the two major MICADO instrument descriptions: `MICADO` and `MICADO_Sci`. These two packages serve two different audiences:

1. The `MICADO` package contains all information available pertaining to the optical effects expected for the MICADO optical system. The primary user of this package will be the data flow system. The primary use case for this package is the creation of raw data frames for testing the algorithms of the reduction pipelines for the different modes of MICADO. This package is large and therefore computationally expensive and slow.
2. The `MICADO_Sci` package contains a subset of the effects in the `MICADO` package. The primary users of this package will be the science team and outside astronomers interested in simulating observations with the future MICADO instrument. The goal of this package is enable observations to be simulated quickly, so that the user can quickly iterate on observation strategies and/or target choices. As such this package contains only the effects which cause the major optical aberrations. It is by nature not complete, but aims to provide a level of detail sufficient for the majority of observation feasibility studies for MICADO

1.1.2 Support packages

The MICADO packages, as the names suggest, only describe the contents of the MICADO instrument. Observations with MICADO will however rely on the ELT infrastructure, which can be decomposed into several parts: Location, Telescope, Relay optics. Each of these additional parts can be considered as closed optical elements in the full observational optical system. Indeed the relay optics element is a replacable element in the optical path (with MAORY vs stand-alone mode) Hence each of these optical elements have been given their own instrument package, and are referred to as support packages.

The support packages needed to simulate MICADO observations are also described in this document. Specifically these are:

- Armazones
- ELT
- MAORY
- Stand-alone relay optics

For each observation the Armazones and ELT packages are required. However only one of MAORY or the stand-alone relay optics packages are required.

1.1.3 Adding content to the packages

The contents of the packages are currently in the public domain. The raw data is hosted on Github.

Periodically this data is compiled into an instrument package and uploaded to the ScopeSim server. It is these packages which are downloaded by ScopeSim when setting up an observation simulation.

New data or Effect objects can be added by submitting a pull request to the Github repository.

1.2 Contents of packages

Each package contains three types of files:

1. configuration,
2. effect descriptions, and
3. raw data

The configuration files are responsible for controlling which effects and which parameters and values are used when generating the optical model for an observation simulation The effect files describe which classes and which values should be used when applying an effect to the photon flux of the target object, e.g. which PSF kernel should be applied at which wavelength The raw dta files provide the raw data needed by the Effect objects, e.g. the bitmaps of the PSF kernels

In the following sections each optical element is described. Each optical elements contains a description of all the optical Effects associated with it, as well as a list of the configuration keywords and values required by the effect. If an Effect required data from an external file (e.g. PSF kernels, linearity curves, etc), these data are presented as part of each Effect object - either in the `Table` or `Data` sections.

> **Note**
> The raw data will not always be displayed directly.
> A representation of the data will be presented where available. For further details the reader is directed to the view the data directly on the IRDB

Chapter 2

MICADO Pipeline package

2.1 Summary of Effects in Optical Elements:

element	name	class	included	z_orders
armazones	armazones_atmo_default_ter_curve	AtmosphericTERCurve	True	[111, 511]
armazones	armazones_atmo_dispersion	AtmosphericDispersion	True	[231]
armazones	armazones_atmo_skycalc_ter_curve	SkycalcTERCurve	False	[112, 512]
ELT	scope_surface_list	SurfaceList	True	[20, 120, 520]
ELT	scope_vibration	Vibration	True	[244, 744]
ELT	eso_combined_reflection	TERCurve	False	[10, 110, 510]
MICADO	micado_static_surfaces	SurfaceList	True	[20, 120, 520]
MICADO	micado_filter	FilterCurve	True	[114, 214, 514]
MICADO	micado_ncpas_psf	NonCommonPathAberration	True	[241, 641]
micado_detector_array	full_detector_array	DetectorList	False	[90, 290, 390, 490]
micado_detector_array	detector_window	DetectorList	True	[90, 290, 390, 490]
micado_detector_array	qe_curve	QuantumEfficiencyCurve	True	[113, 513]
micado_detector_array	exposure_action	SummedExposure	True	[860]
micado_detector_array	dark_current	DarkCurrent	True	[830]
micado_detector_array	detector_linearity	LinearityCurve	True	[840]
micado_detector_array	shot_noise	ShotNoise	True	[820]
micado_detector_array	readout_noise	PoorMansHxRGReadoutNoise	True	[811]
default_ro	relay_psf	FieldConstantPSF	True	[262, 662]
default_ro	relay_surface_list	SurfaceList	True	[20, 120, 520]
MAORY	maory_surface_list	SurfaceList	True	[20, 120, 520]
MAORY	maory_generic_psf	FieldConstantPSF	True	[262, 662]
MICADO_IMG_LR	micado_wide_field_mirror_list	SurfaceList	True	[20, 120, 520]
MICADO_IMG_LR	micado_adc_3D_shift	AtmosphericDispersionCorrection	True	[632, 232]
MICADO_IMG_HR	zoom_mirror_list	SurfaceList	True	[20, 120, 520]
MICADO_IMG_HR	micado_adc_3D_shift	AtmosphericDispersionCorrection	True	[632, 232]
MICADO_SPEC	spec_mode_optics	SurfaceList	True	[20, 120, 520]
MICADO_SPEC	spectroscopic_slit_aperture	ApertureMask	True	[80, 280, 380]
MICADO_SPEC	micado_spectral_traces	SpectralTraceList	True	[70, 270]
MICADO_SPEC	spec_mode_optics	SurfaceList	True	[20, 120, 520]
MICADO_SPEC	spectroscopic_slit_aperture	ApertureMask	True	[80, 280, 380]
MICADO_SPEC	micado_spectral_traces	SpectralTraceList	True	[70, 270]
MICADO_SPEC	spec_mode_optics	SurfaceList	True	[20, 120, 520]
MICADO_SPEC	spectroscopic_slit_aperture	ApertureMask	True	[80, 280, 380]
MICADO_SPEC	micado_spectral_traces	SpectralTraceList	True	[70, 270]

2.2 OpticalElement: "MICADO"

Element: instrument

Alias: INST

Description: Effects from the MICADO common optics

2.2.1 Global properties

```
 temperature : -190
element_name : MICADO
```

2.2.2 Effects

Summary of Effects included in this optical element:

element	name	class	included	z_orders
MICADO	micado_static_surfaces	SurfaceList	True	[20, 120, 520]
MICADO	micado_filter	FilterCurve	True	[114, 214, 514]
MICADO	micado_ncpas_psf	NonCommonPathAberration	True	[241, 641]

2.2.2.1 SurfaceList: "micado_static_surfaces"

Included by default: `True`

File Description: surfaces list for wide field optics

Class Description: <no docstring>

Changes:

- {datetime.date(2019, 1, 28): '(KL) Changed column names and added units to header'}
- {datetime.date(2019, 7, 10): '(KL) Shortened the list to only the swappable mirrors'}
- {datetime.date(2020, 8, 25): '(KL) Updated angle_unit to degree from degrees (why has astropy not complained until now?)'}

Data

Meta-data

```
            filename : LIST_MICADO_mirrors_static.dat
                name : micado_static_surfaces
         temperature : -190
        element_name : MICADO
              author : Kieran Leschinski
              source : Ric's SPIE 2018 PPT presentation
        date_created : 2018-11-19
       date_modified : 2019-07-10
              status : Design - pre PDR list of all static MICADO surfaces
                type : mirror:list
```

```
          outer_unit : m
          inner_unit : m
          angle_unit : degree
    temperature_unit : deg_C
             z_order : [20, 120, 520]
             include : True
       ignore_wings : False
           wave_min : !SIM.spectral.wave_min
           wave_max : !SIM.spectral.wave_max
          wave_unit : !SIM.spectral.wave_unit
           wave_bin : !SIM.spectral.spectral_resolution
  minimum_throughput : !SIM.spectral.minimum_throughput
            etendue : !TEL.etendue
```

2.2.2.2 FilterCurve: "micado_filter"

Included by default: `True`

File Description: transmission curve for filter

Class Description: Other Parameters

Changes:

-

Data

Meta-data

```
            filename : filters/TC_filter_Spec_HK.dat
                name : micado_filter
         temperature : -190
        element_name : MICADO
         filter_name : !OBS.filter_name
     filename_format : filters/TC_filter_{}.dat
  minimum_throughput : 0.000101
               outer : 0.2
          outer_unit : m
              author : Ric Davies
              source : Ric Davies
        date_created : 2017-11-20
       date_modified : 2017-11-20
              status : Design - pre PDR list of filters
             z_order : [114, 214, 514]
             include : True
       ignore_wings : False
           wave_min : !SIM.spectral.wave_min
           wave_max : !SIM.spectral.wave_max
          wave_unit : !SIM.spectral.wave_unit
           wave_bin : !SIM.spectral.spectral_resolution
             action : transmission
```

```
        position : -1
    wing_flux_level : None
```

2.2.2.3 NonCommonPathAberration: "micado_ncpas_psf"

Included by default: `True`

File Description: Effective NCPA induced PSF kernel

Class Description: Needed: pixel_scale

Changes:

- 2018-11-19 (KL) updated meta data to new format

Data

Meta-data

```
          filename : INST_MICADO_wavefront_error_budget.dat
              name : micado_ncpas_psf
       temperature : -190
      element_name : MICADO
       pixel_scale : 0.004
            author : Kieran Leschinski
           sources : Ric Davies email
      date_created : 2016-11-21
     date_modified : 2018-11-19
              type : instrument:wavefront_errors_list
            status : Idea - based on the WFE budget and emails with Ric
      wfe_rms_unit : nm
           z_order : [241, 641]
           include : True
     flux_accuracy : 0.001
    sub_pixel_flag : False
     convolve_mode : full
          wave_key : WAVE0
 normalise_kernel : True
      kernel_width : None
      strehl_drift : 0.02
          wave_min : !SIM.spectral.wave_min
          wave_max : !SIM.spectral.wave_max
```

2.3 OpticalElement: "MICADO_IMG_LR"

Element: instrument

Alias: INST

Description: additional effects for the wide-field imaging mode

2.3.1 Global properties

```
     pixel_scale : 0.004
     plate_scale : 0.26666666666
    element_name : MICADO_IMG_LR
```

2.3.2 Effects

Summary of Effects included in this optical element:

element	name	class	included	z_orders
MICADO_IMG_LR	micado_wide_field_mirror_list	SurfaceList	True	[20, 120, 520]
MICADO_IMG_LR	micado_adc_3D_shift	AtmosphericDispersionCorrection	True	[632, 232]

2.3.2.1 SurfaceList: "micado_wide_field_mirror_list"

Included by default: `True`

File Description: list of extra mirrors needed for the wide field mode

Class Description: <no docstring>

Changes:

- {datetime.date(2019, 1, 28): '(KL) Changed column names and added units to header'}
- {datetime.date(2019, 7, 10): '(KL) Shortened the list to only the swappable mirrors'}

Data

Meta-data

```
            filename : LIST_MICADO_mirrors_wide.dat
                name : micado_wide_field_mirror_list
          pixel_scale : 0.004
          plate_scale : 0.26666666666
         element_name : MICADO_IMG_LR
               author : Kieran Leschinski
               source : Ric's SPIE 2018 PPT presentation
         date_created : 2018-11-19
        date_modified : 2019-07-10
               status : Design - pre PDR list of MICADO mirrors for wide-field mo
                 type : mirror:list
           outer_unit : m
           inner_unit : m
```

```
        angle_unit : degree
  temperature_unit : deg_C
           z_order : [20, 120, 520]
           include : True
      ignore_wings : False
          wave_min : !SIM.spectral.wave_min
          wave_max : !SIM.spectral.wave_max
         wave_unit : !SIM.spectral.wave_unit
          wave_bin : !SIM.spectral.spectral_resolution
minimum_throughput : !SIM.spectral.minimum_throughput
          etendue : !TEL.etendue
```

2.3.2.2 AtmosphericDispersionCorrection: "micado_adc_3D_shift"

Included by default: `True`

File Description: atmospheric disperson corrector

Class Description: <no docstring>

Changes:

-

Data

Meta-data

```
      filename : None
          name : micado_adc_3D_shift
   pixel_scale : 0.004
   plate_scale : 0.26666666666
  element_name : MICADO_IMG_LR
      altitude : !ATMO.altitude
     longitude : !ATMO.longitude
      latitude : !ATMO.latitude
       airmass : !OBS.airmass
   temperature : !ATMO.temperature
      humidity : !ATMO.humidity
      pressure : !ATMO.pressure
   pupil_angle : !OBS.pupil_angle
    efficiency : 1
      wave_mid : !SIM.spectral.wave_mid
    quick_adc : True
      z_order : [632, 232]
      include : True
```

2.4 OpticalElement: "MICADO_IMG_HR"

Element: instrument

Alias: INST

Description: additional effects for the zoom imaging mode

2.4.1 Global properties

```
     pixel_scale : 0.0015
     plate_scale : 0.1
    element_name : MICADO_IMG_HR
```

2.4.2 Effects

Summary of Effects included in this optical element:

element	name	class	included	z_orders
MICADO_IMG_HR	zoom_mirror_list	SurfaceList	True	[20, 120, 520]
MICADO_IMG_HR	micado_adc_3D_shift	AtmosphericDispersionCorrection	True	[632, 232]

2.4.2.1 SurfaceList: "zoom_mirror_list"

Included by default: `True`

File Description: list of extra mirror needed for the zoom imaging mode

Class Description: <no docstring>

Changes:

- {datetime.date(2019, 1, 28): '(KL) Changed column names and added units to header'}
- {datetime.date(2019, 7, 10): '(KL) Shortened the list to only the swappable mirrors'}

Data

Meta-data

```
            filename : LIST_MICADO_mirrors_zoom.dat
                name : zoom_mirror_list
         pixel_scale : 0.0015
         plate_scale : 0.1
        element_name : MICADO_IMG_HR
              author : Kieran Leschinski
              source : Ric's SPIE 2018 PPT presentation
        date_created : 2018-11-19
       date_modified : 2019-07-10
              status : Design - pre PDR list of swappable mirrors for zoom mode
                type : mirror:list
               ETYPE : SURFLIST
                EDIM : 1
```

```
        outer_unit : m
        inner_unit : m
        angle_unit : degree
  temperature_unit : deg_C
           z_order : [20, 120, 520]
           include : True
      ignore_wings : False
          wave_min : !SIM.spectral.wave_min
          wave_max : !SIM.spectral.wave_max
         wave_unit : !SIM.spectral.wave_unit
          wave_bin : !SIM.spectral.spectral_resolution
minimum_throughput : !SIM.spectral.minimum_throughput
          etendue : !TEL.etendue
```

2.4.2.2 AtmosphericDispersionCorrection: "micado_adc_3D_shift"

Included by default: `True`

File Description: atmospheric disperson corrector

Class Description: <no docstring>

Changes:

-

Data

Meta-data

```
     filename : None
         name : micado_adc_3D_shift
  pixel_scale : 0.0015
  plate_scale : 0.1
 element_name : MICADO_IMG_HR
     altitude : !ATMO.altitude
    longitude : !ATMO.longitude
     latitude : !ATMO.latitude
      airmass : !OBS.airmass
  temperature : !ATMO.temperature
     humidity : !ATMO.humidity
     pressure : !ATMO.pressure
  pupil_angle : !OBS.pupil_angle
     wave_mid : !SIM.spectral.wave_mid
   efficiency : 1
    quick_adc : True
      z_order : [632, 232]
      include : True
```

2.5 OpticalElement: "MICADO_SPEC"

Element: instrument

Alias: INST

Description: additional effects for the spectroscopy mode

2.5.1 Global properties

```
    pixel_scale : 0.004
    plate_scale : 0.2666666667
   element_name : MICADO_SPEC
```

2.5.2 Effects

Summary of Effects included in this optical element:

element	name	class	included	z_orders
MICADO_SPEC	spec_mode_optics	SurfaceList	True	[20, 120, 520]
MICADO_SPEC	spectroscopic_slit_aperture	ApertureMask	True	[80, 280, 380]
MICADO_SPEC	micado_spectral_traces	SpectralTraceList	True	[70, 270]

2.5.2.1 SurfaceList: "spec_mode_optics"

Included by default: `True`

File Description: list of extra mirrors needed for the spectroscopy mode

Class Description: <no docstring>

Changes:

- {datetime.date(2019, 1, 28): '(KL) Changed column names and added units to header'}
- {datetime.date(2019, 7, 10): '(KL) Shortened the list to only the swappable gratings'}

Data

Meta-data

```
            filename : LIST_MICADO_mirrors_spec.dat
                name : spec_mode_optics
          pixel_scale : 0.004
          plate_scale : 0.2666666667
        element_name : MICADO_SPEC
              author : Kieran Leschinski
              source : Ric's SPIE 2018 PPT presentation
        date_created : 2018-11-19
       date_modified : 2019-07-10
              status : Design - pre PDR list of swappable optics for spectroscop
                type : mirror:list
               ETYPE : SURFLIST
```

```
              EDIM : 1
       outer_unit : m
       inner_unit : m
       angle_unit : degree
  temperature_unit : deg_C
         z_order : [20, 120, 520]
         include : True
     ignore_wings : False
         wave_min : !SIM.spectral.wave_min
         wave_max : !SIM.spectral.wave_max
        wave_unit : !SIM.spectral.wave_unit
         wave_bin : !SIM.spectral.spectral_resolution
minimum_throughput : !SIM.spectral.minimum_throughput
          etendue : !TEL.etendue
```

2.5.2.2 ApertureMask: "spectroscopic_slit_aperture"

Included by default: `True`

File Description: Slit mask for the short, narrow slit (3 arcsec x 20 mas)

Class Description: Only provides the on-sky window coords of the Aperture

Changes:

- {datetime.date(2019, 7, 10): '(KL) Created the file'}
- {datetime.date(2020, 3, 24): '(KL) Changed geometry to 3000x20mas'}

Data

Meta-data

```
      filename : !OBS.slit_file
          name : spectroscopic_slit_aperture
   pixel_scale : 0.004
   plate_scale : 0.2666666667
  element_name : MICADO_SPEC
        author : Kieran Leschinski
        source : My imagination
  date_created : 2019-07-10
 date_modified : 2019-07-10
        status : Guess - in the train on the way home from CM13
          type : aperture:slit_geometry
        x_unit : arcsec
        y_unit : arcsec
       z_order : [80, 280, 380]
       include : True
       no_mask : True
         angle : 0
         shape : rect
conserve_image : True
            id : 0
```

<SpectralTrace> "list of spectral order trace geometry on the focal plane" : [1.93, 2.46]um : Ext 2 : Aperture 0 : ImagePlane 0 <SpectralTrace> "list of spectral order trace geometry on the focal plane" : [1.45, 1.85]um : Ext 3 : Aperture 0 : ImagePlane 0 <SpectralTrace> "list of spectral order trace geometry on the focal plane" : [1.16, 1.48]um : Ext 4 : Aperture 0 : ImagePlane 0 <SpectralTrace> "list of spectral order trace geometry on the focal plane" : [1.16, 1.39]um : Ext 5 : Aperture 0 : ImagePlane 0 <SpectralTrace> "list of spectral order trace geometry on the focal plane" : [0.97, 1.23]um : Ext 6 : Aperture 0 : ImagePlane 0 <SpectralTrace> "list of spectral order trace geometry on the focal plane" : [0.97, 1.23]um : Ext 7 : Aperture 0 : ImagePlane 0 <SpectralTrace> "list of spectral order trace geometry on the focal plane" : [0.83, 1.05]um : Ext 8 : Aperture 0 : ImagePlane 0 <SpectralTrace> "list of spectral order trace geometry on the focal plane" : [0.83, 1.05]um : Ext 9 : Aperture 0 : ImagePlane 0 <SpectralTrace> "list of spectral order trace geometry on the focal plane" : [0.83, 0.92]um : Ext 10 : Aperture 0 : ImagePlane 0 <SpectralTrace> "list of spectral order trace geometry on the focal plane" : [0.73, 0.92]um : Ext 11 : Aperture 0 : ImagePlane 0 <SpectralTrace> "list of spectral order trace geometry on the focal plane" : [0.73, 0.92]um : Ext 12 : Aperture 0 : ImagePlane 0 <Spectral-Trace> "list of spectral order trace geometry on the focal plane" : [0.65, 0.82]um : Ext 13 : Aperture 0 : ImagePlane 0 <SpectralTrace> "list of spectral order trace geometry on the focal plane" : [0.65, 0.82]um : Ext 14 : Aperture 0 : ImagePlane 0 <SpectralTrace> "list of spectral order trace geometry on the focal plane" : [0.6, 0.74]um : Ext 15 : Aperture 0 : ImagePlane 0 <SpectralTrace> "list of spectral order trace geometry on the focal plane" : [0.6, 0.73]um : Ext 16 : Aperture 0 : ImagePlane 0 <SpectralTrace> "list of spectral order trace geometry on the focal plane" : [0.6, 0.67]um : Ext 17 : Aperture 0 : ImagePlane 0 <SpectralTrace> "list of spectral order trace geometry on the focal plane" : [0.6, 0.67]um : Ext 18 : Aperture 0 : ImagePlane 0
****

Included by default: `True`

File Description: list of spectral order trace geometry on the focal plane

Class Description: List of spectral trace geometries for the detector plane

Changes:

-

Data

Meta-data

```
           filename : !OBS.trace_file
               name : micado_spectral_traces
        pixel_scale : 0.004
        plate_scale : 0.2666666667
      element_name : MICADO_SPEC
      wave_colname : lam
         s_colname : xi
  col_number_start : 1
     invalid_value : 0
            SIMPLE : True
            BITPIX : 8
             NAXIS : 0
            EXTEND : True
          FILETYPE : Spectral Layout Definition
            AUTHOR : Oliver Czoske
              DATE : 2018-09-16
            SOURCE : Frank Grupp
```

```
 ORIGDATE : 2018-06-29
   STATUS : Design PDR
     ECAT : 1
    EDATA : 2
 DESCRIPT : Maps spectral traces from long slit aperture to detector im
 DATE_CRE : 2018-06-29
 DATE_MOD : 2019-09-16
  HISTORY : 2019-09-16 : (KL) Added aperture-imagePlane table to EXT 1
  z_order : [70, 270]
  include : True
 wave_min : !SIM.spectral.wave_min
 wave_max : !SIM.spectral.wave_max
x_colname : x
y_colname : y
    dwave : 0.002
```

2.6 OpticalElement: "micado_detector_array"

Element: detector

Alias: DET

Description: A set of 9 H4RG detectors

2.6.1 Global properties

```
image_plane_id : 0
   temperature : -230
           dit : !OBS.dit
          ndit : !OBS.ndit
  element_name : micado_detector_array
```

2.6.2 Effects

Summary of Effects included in this optical element:

element	name	class	included	z_orders
micado_detector_array	full_detector_array	DetectorList	False	[90, 290, 390, 490]
micado_detector_array	detector_window	DetectorList	True	[90, 290, 390, 490]
micado_detector_array	qe_curve	QuantumEfficiencyCurve	True	[113, 513]
micado_detector_array	exposure_action	SummedExposure	True	[860]
micado_detector_array	dark_current	DarkCurrent	True	[830]
micado_detector_array	detector_linearity	LinearityCurve	True	[840]
micado_detector_array	shot_noise	ShotNoise	True	[820]
micado_detector_array	readout_noise	PoorMansHxRGReadoutNoise	True	[811]

2.6.2.1 DetectorList: "full_detector_array"

Included by default: `False`

File Description: MICADO detector array list

Class Description: A description of detector positions and properties

Changes:

- {datetime.date(2017, 8, 12): '(OC) id changed to conform with spectroscopy report'}
- {datetime.date(2018, 7, 26): '(OC) large gap (chips 5 and 6) reduced to 8 mm'}
- {datetime.date(2018, 11, 19): '(KL) updated meta data to new format'}
- {datetime.date(2019, 1, 28): '(KL) moved units into header'}

id	x_cen	y_cen	x_size	y_size	x_len	y_len	pixel_size	angle	gain
1	-63.84	63.84	61.44	61.44	4096	4096	0.015	0.0	1.0
2	0.0	63.84	61.44	61.44	4096	4096	0.015	0.0	1.0

... continued on next page

id	x_cen	y_cen	x_size	y_size	x_len	y_len	pixel_size	angle	gain
3	63.84	63.84	61.44	61.44	4096	4096	0.015	0.0	1.0
4	63.84	0.0	61.44	61.44	4096	4096	0.015	0.0	1.0
5	0.0	0.0	61.44	61.44	4096	4096	0.015	0.0	1.0
6	-69.44	0.0	61.44	61.44	4096	4096	0.015	0.0	1.0
7	-63.84	-63.84	61.44	61.44	4096	4096	0.015	0.0	1.0
8	0.0	-63.84	61.44	61.44	4096	4096	0.015	0.0	1.0
9	63.84	-63.84	61.44	61.44	4096	4096	0.015	0.0	1.0

Data

Meta-data

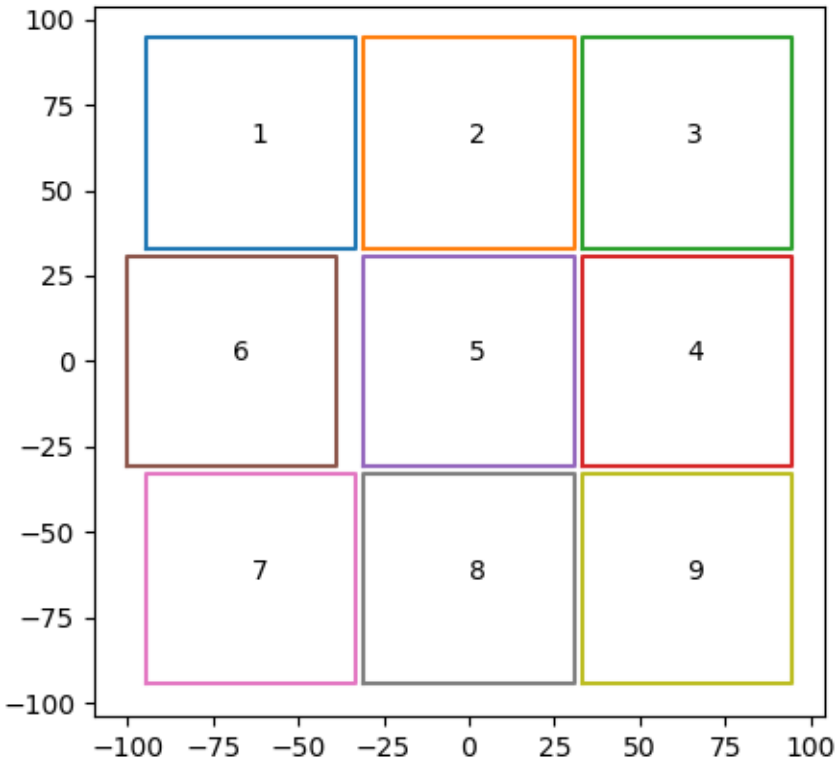
```
                filename : FPA_array_layout.dat
                    name : full_detector_array
                 include : False
          image_plane_id : 0
             temperature : -230
                     dit : !OBS.dit
                    ndit : !OBS.ndit
            element_name : micado_detector_array
        active_detectors : all
                  author : Oliver Czoske
                 sources : E-MCD-FPA-572089EB.uda, ELT-TRE-MCD-56300-0011
            date_created : 2017-06-28
           date_modified : 2018-07-26
                    type : detector:chip_list
               x_cen_unit : mm
               y_cen_unit : mm
                 xhw_unit : mm
                 yhw_unit : mm
               x_len_unit : pix
               y_len_unit : pix
             pixsize_unit : mm
               angle_unit : deg
                gain_unit : electron/adu
                  z_order : [90, 290, 390, 490]
             pixel_scale : !INST.pixel_scale
    report_plot_include : True
   report_table_include : True
            x_size_unit : mm
            y_size_unit : mm
```

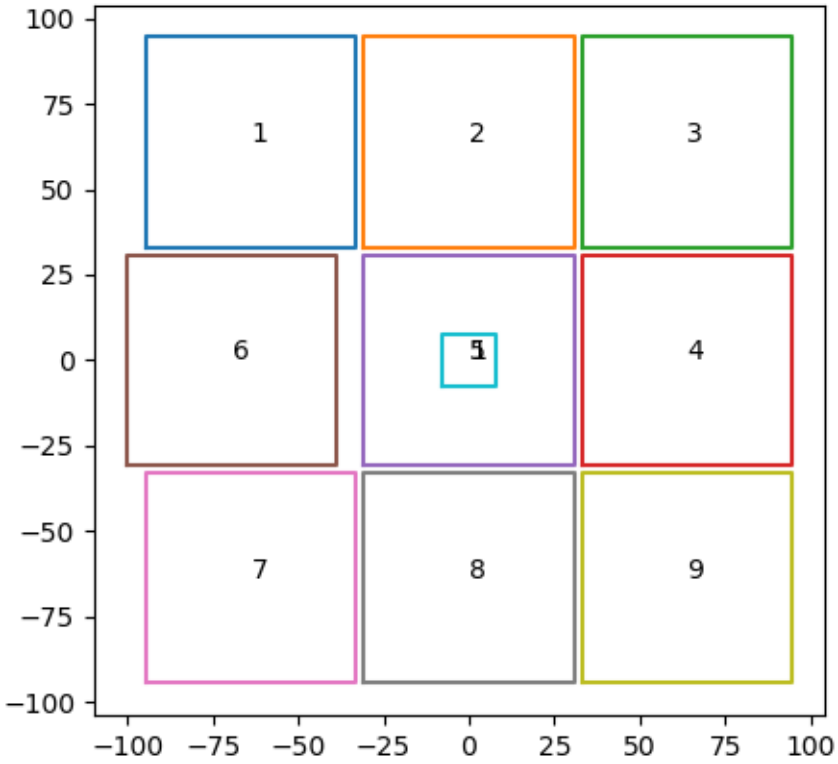
2.6.2.2 DetectorList: "detector_window"

Included by default: `True`

File Description:

Class Description: A description of detector positions and properties


100
75
50
25
0
−25
−50
−75
−100
−100
−75
−50
−25
0
25
50
75
100
1
2
3
6
5
4
7
8
9



Changes:

-

id	pixel_size	angle	gain	x_cen	y_cen	x_size	y_size
1	0.015	0.0	1.0	0.0	0.0	15.36	15.36

Data

Meta-data

```
              filename : None
                  name : detector_window
               include : True
        image_plane_id : 0
           temperature : -230
                   dit : !OBS.dit
                  ndit : !OBS.ndit
          element_name : micado_detector_array
            x_cen_unit : mm
            y_cen_unit : mm
              xhw_unit : mm
              yhw_unit : mm
            pixsize_unit : mm
              angle_unit : deg
               gain_unit : electron/adu
                 z_order : [90, 290, 390, 490]
              array_dict : {'id': [1], 'pixsize': [0.015], 'angle': [0.0], 'gain':
             pixel_scale : !INST.pixel_scale
    active_detectors : all
report_plot_include : True
```

Meta-data

```
          filename : QE_detector_H2RG.dat
              name : qe_curve
     image_plane_id : 0
       temperature : -230
               dit : !OBS.dit
              ndit : !OBS.ndit
      element_name : micado_detector_array
            author : Kieran Leschinski
           sources : Finger+ 2008 SPIE
      date_created : 2016-01-01
     date_modified : 2019-08-09
              type : detector:quantum_efficiency
            status : Design - guestimated by reading off the graph in Finger+ 200
    wavelength_unit : um
            action : transmission
           z_order : [113, 513]
           include : True
      ignore_wings : False
          wave_min : !SIM.spectral.wave_min
          wave_max : !SIM.spectral.wave_max
         wave_unit : !SIM.spectral.wave_unit
          wave_bin : !SIM.spectral.spectral_resolution
          position : -1
```

2.6.2.4 SummedExposure: "exposure_action"

Included by default: `True`

File Description: Summing up sky signal for all DITs and NDITs

Class Description: <no docstring>

Changes:

-

Data

Meta-data

```
          filename : None
              name : exposure_action
    image_plane_id : 0
       temperature : -230
               dit : !OBS.dit
              ndit : !OBS.ndit
      element_name : micado_detector_array
           z_order : [860]
           include : True
```

2.6.2.5 DarkCurrent: "dark_current"

Included by default: `True`

File Description: MICADO dark current

Class Description: required: dit, ndit, value

Changes:

-

Data

Meta-data

```
        filename : None
            name : dark_current
    image_plane_id : 0
       temperature : -230
               dit : !OBS.dit
              ndit : !OBS.ndit
      element_name : micado_detector_array
             value : 0.1
           z_order : [830]
           include : True
```

2.6.2.6 LinearityCurve: "detector_linearity"

Included by default: `True`

File Description: Linearity characteristics of H4RG chips

Class Description: <no docstring>

Changes:

- 2018-11-19 (KL) updated meta data to new format
- 2019-08-14 (KL) replaced long 1000000000 with 1e99

Data

Meta-data

```
        filename : FPA_linearity.dat
            name : detector_linearity
    image_plane_id : 0
       temperature : -230
               dit : !OBS.dit
              ndit : !OBS.ndit
      element_name : micado_detector_array
            author : Kieran Leschinski
           sources : Ingraham+ 2014 - Gemini Calibrations II for H2RG
      date_created : 2016-01-01
     date_modified : 2018-11-19
```

```
          type : detector:linearity
        status : Design - approximated from the H2RG
 incident_unit : ph
 measured_unit : ph
       z_order : [840]
       include : True
```

2.6.2.7 ShotNoise: "shot_noise"

Included by default: `True`

File Description: apply poisson shot noise to images

Class Description: <no docstring>

Changes:

-

Data

Meta-data

```
       filename : None
           name : shot_noise
 image_plane_id : 0
    temperature : -230
            dit : !OBS.dit
           ndit : !OBS.ndit
   element_name : micado_detector_array
        z_order : [820]
        include : True
    random_seed : !SIM.random.seed
```

2.6.2.8 PoorMansHxRGReadoutNoise: "readout_noise"

Included by default: `True`

File Description: Readout noise frames

Class Description: <no docstring>

Changes:

-

Data

Meta-data

```
           filename : None
               name : readout_noise
     image_plane_id : 0
        temperature : -230
                dit : !OBS.dit
```

```
             ndit : !OBS.ndit
     element_name : micado_detector_array
        noise_std : 12
       n_channels : 64
          z_order : [811]
          include : True
pedestal_fraction : 0.3
    read_fraction : 0.4
    line_fraction : 0.25
 channel_fraction : 0.05
      random_seed : !SIM.random.seed
```

2.7 OpticalElement: "MICADO_simulation_paramters"

Element: simulation

Alias: SIM

Description: RC simulation paramters which need to change for a MICADO run

2.7.1 Global properties

```
          random : {'seed': 9001}
        spectral : {'wave_min': 0.7, 'wave_mid': 1.6, 'wave_max': 2.5}
       computing : {'preload_field_of_view': True}
         reports : {'preamble_file': '../docs/preamble.rst'}
    element_name : MICADO_simulation_paramters
```

2.7.2 Effects

Summary of Effects included in this optical element:

element	name	class	included	z_orders

Chapter 3

MICADO Science package

Chapter 4

Supoort packages

4.1 OpticalElement: "armazones"

Element: atmosphere

Alias: ATMO

Description: Atmosphere and location details for Cerro Armazones

4.1.1 Global properties

```
       altitude : 3060
      longitude : -70.1918
       latitude : -24.5899
    temperature : 7
       humidity : 0.1
       pressure : 0.755
            pwv : 2.5
        airmass : !OBS.airmass
    pupil_angle : !OBS.pupil_angle
    pixel_scale : !INST.pixel_scale
   element_name : armazones
```

4.1.2 Effects

Summary of Effects included in this optical element:

element	name	class	included	z_orders
armazones	armazones_atmo_default_ter_curve	AtmosphericTERCurve	True	[111, 511]
armazones	armazones_atmo_dispersion	AtmosphericDispersion	True	[231]
armazones	armazones_atmo_skycalc_ter_curve	SkycalcTERCurve	False	[112, 512]

4.1.2.1 AtmosphericTERCurve: "armazones_atmo_default_ter_curve"

Included by default: `True`

File Description: atmospheric emission and transmission

Class Description: <no docstring>

Changes:

- 2019-07-24 (KL) Created file
- 2019-08-09 (KL) Updated values for airmass 1.2, pwv 2.5

Data

Meta-data

```
          filename : TER_armazones_default_NIR_IMG.dat
              name : armazones_atmo_default_ter_curve
           include : True
          altitude : 3060
```

```
        longitude : -70.1918
         latitude : -24.5899
      temperature : 7
         humidity : 0.1
         pressure : 0.755
              pwv : 2.5
          airmass : !OBS.airmass
      pupil_angle : !OBS.pupil_angle
      pixel_scale : !INST.pixel_scale
     element_name : armazones
           author : Kieran Leschinski
           source : skycalc website for standard Armazones conditions
     date_created : 2019-07-24
    date_modified : 2019-08-09
           status : Design
             type : atmosphere:ter_curve
           season : entire year
             time : entire night
           action : transmission
wavelength_unit : um
  emission_unit : ph s-1 m-2 um-1 arcsec-2
        z_order : [111, 511]
     ignore_wings : False
         wave_min : !SIM.spectral.wave_min
         wave_max : !SIM.spectral.wave_max
        wave_unit : !SIM.spectral.wave_unit
         wave_bin : !SIM.spectral.spectral_resolution
             area : !TEL.area
        area_unit : m2
         position : 0
```

4.1.2.2 AtmosphericDispersion: "armazones_atmo_dispersion"

Included by default: `True`

File Description: atmospheric dispersion

Class Description: Used to generate the wavelength bins based on shifts due to the atmosphere

Changes:

-

Data

Meta-data

```
             filename : None
                 name : armazones_atmo_dispersion
             altitude : 3060
            longitude : -70.1918
             latitude : -24.5899
```

```
     temperature : 7
        humidity : 0.1
        pressure : 0.755
             pwv : 2.5
         airmass : !OBS.airmass
     pupil_angle : !OBS.pupil_angle
     pixel_scale : !INST.pixel_scale
    element_name : armazones
         z_order : [231]
         include : True
        wave_min : !SIM.spectral.wave_min
        wave_mid : !SIM.spectral.wave_mid
        wave_max : !SIM.spectral.wave_max
sub_pixel_fraction : !SIM.sub_pixel.fraction
     num_steps : 1000
```

4.1.2.3 SkycalcTERCurve: "armazones_atmo_skycalc_ter_curve"

Included by default: `False`

File Description: atmospheric spectra pulled from the skycalc server

Class Description: <no docstring>

Changes:

-

Data

Meta-data

```
    filename : None
        name : armazones_atmo_skycalc_ter_curve
     include : False
    altitude : 3060
   longitude : -70.1918
    latitude : -24.5899
 temperature : 7
    humidity : 0.1
    pressure : 0.755
         pwv : 2.5
     airmass : !OBS.airmass
 pupil_angle : !OBS.pupil_angle
 pixel_scale : !INST.pixel_scale
element_name : armazones
 observatory : armazones
        wmin : 699.9999999999999
        wmax : 2499.9999999999995
       wunit : um
      wdelta : 0.09999999999999999
     z_order : [112, 512]
```

```
ignore_wings : False
    wave_min : !SIM.spectral.wave_min
    wave_max : !SIM.spectral.wave_max
   wave_unit : !SIM.spectral.wave_unit
    wave_bin : !SIM.spectral.spectral_resolution
      action : transmission
        area : !TEL.area
   area_unit : m2
    position : 0
```

4.2 OpticalElement: "ELT"

Element: telescope

Alias: TEL

Description: The extremely large telescope

4.2.1 Global properties

```
 temperature : !ATMO.temperature
element_name : ELT
```

4.2.2 Effects

Summary of Effects included in this optical element:

element	name	class	included	z_orders
ELT	scope_surface_list	SurfaceList	True	[20, 120, 520]
ELT	scope_vibration	Vibration	True	[244, 744]
ELT	eso_combined_reflection	TERCurve	False	[10, 110, 510]

4.2.2.1 SurfaceList: "scope_surface_list"

Included by default: `True`

File Description: list of ELT surfaces

Class Description: <no docstring>

Changes:

- 2018-11-19 (KL) Added meta data, added Action column
- 2019-01-28 (KL) Fixed YAML format in meta data
- 2020-08-17 (KL) Updated M1 and M4 dimensions according to ESO-253082_4 sect 4.7 "all-glass" diameter
- 2020-08-17 (KL) Pegged temperature to the atmosphere

Data

Meta-data

```
            filename : LIST_mirrors_ELT.tbl
                name : scope_surface_list
         temperature : !ATMO.temperature
        element_name : ELT
              author : Oliver Czoske, Kieran Leschinski
              source : ESO ELT DRM, ESO-253082_4
        date_created : 2018-11-19
       date_modified : 2020-08-17
              status : Design - pre MICADO-FDR mirror list
```

```
        outer_unit : m
        inner_unit : m
        angle_unit : degree
  temperature_unit : deg_C
             notes : ['2020-08-17 (KL) Coatings match those described in ESO-2
          z_order : [20, 120, 520]
           include : True
      ignore_wings : False
          wave_min : !SIM.spectral.wave_min
          wave_max : !SIM.spectral.wave_max
         wave_unit : !SIM.spectral.wave_unit
          wave_bin : !SIM.spectral.spectral_resolution
minimum_throughput : !SIM.spectral.minimum_throughput
          etendue : !TEL.etendue
```

4.2.2.2 Vibration: "scope_vibration"

Included by default: `True`

File Description: residual vibration of telescope

Class Description: Creates a wavelength independent kernel image

Changes:

-

Data

Meta-data

```
          filename : None
              name : scope_vibration
       temperature : 7
      element_name : ELT
              fwhm : 0.001
       pixel_scale : 0.004
           z_order : [244, 744]
           include : True
    flux_accuracy : 0.001
   sub_pixel_flag : False
    convolve_mode : full
         wave_key : WAVE0
normalise_kernel : True
   width_n_fwhms : 4
```

4.2.2.3 TERCurve: "eso_combined_reflection"

Included by default: `False`

File Description: single combined reflection curve for clean ELT 5 mirror combination

Class Description: Transmission, Emissivity, Reflection Curve

Changes:

- 2019-11-06 (KL) Converted from .xlsx to .dat file, added ScopeSim meta data
- 2020-07-09 (KL) Added inner and outer dimensions to meta, for use with MICADO-Sci
- 2020-08-17 (KL) Added emissivity column according to ESO-253082_4, sect 4.12.2

Data

Meta-data

```
          filename : TER_ELT_system_20190611.dat
              name : eso_combined_reflection
           include : False
       temperature : !ATMO.temperature
      element_name : ELT
        temperture : !ATMO.temperature
            author : R. Holzloehner
            source : See ESO-306070 and ESO-293390 for background.
      date_created : 2018-09-18
     date_modified : 2019-06-11
              type : TERCurve
            status : design
            action : reflection
             outer : 37.3
        outer_unit : m
             inner : 11.1
        inner_unit : m
  wavelength_unit : um
             notes : ['Baseline coatings.', 'Fresh coatings without contamination
           z_order : [10, 110, 510]
     ignore_wings : False
         wave_min : !SIM.spectral.wave_min
         wave_max : !SIM.spectral.wave_max
        wave_unit : !SIM.spectral.wave_unit
         wave_bin : !SIM.spectral.spectral_resolution
```

4.3 OpticalElement: "MAORY"

Element: relay_optics

Alias: RO

Description: MAORY AO relay module

4.3.1 Global properties

```
 temperature : !ATMO.temperature
psf_filename : None
element_name : MAORY
```

4.3.2 Effects

Summary of Effects included in this optical element:

element	name	class	included	z_orders
MAORY	maory_surface_list	SurfaceList	True	[20, 120, 520]
MAORY	maory_generic_psf	FieldConstantPSF	True	[262, 662]

4.3.2.1 SurfaceList: "maory_surface_list"

Included by default: `True`

File Description: list of surfaces in MAORY

Class Description: <no docstring>

Changes:

- 2018-11-19 (KL) Added meta data, changed Dichr. filename
- 2019-01-28 (KL) Fixed YAML format in meta data
- 2020-06-22 (KL) Obsolete. Use LIST_mirrors_maory_mms.tbl from now on.

Data

Meta-data

```
            filename : LIST_mirrors_MCAO_MAORY.tbl
                name : maory_surface_list
         temperature : !ATMO.temperature
        psf_filename : None
        element_name : MAORY
              author : Kieran Leschinski
              source : Ciliegi+ 2018 SPIE, "MAORY for ELT - preliminary design o
        date_created : 2018-11-19
       date_modified : 2018-11-19
              status : Design - pre PDR list of MAORY mirrors
                type : mirror:list
          outer_unit : m
```

```
      inner_unit : m
      angle_unit : degree
temperature_unit : deg_C
         z_order : [20, 120, 520]
         include : True
    ignore_wings : False
        wave_min : !SIM.spectral.wave_min
        wave_max : !SIM.spectral.wave_max
       wave_unit : !SIM.spectral.wave_unit
        wave_bin : !SIM.spectral.spectral_resolution
minimum_throughput : !SIM.spectral.minimum_throughput
          etendue : !TEL.etendue
```

4.3.2.2 FieldConstantPSF: "maory_generic_psf"

Included by default: `True`

File Description: MAORY field varying MCAO PSF

Class Description: <no docstring>

Changes:

-

Data

Meta-data

```
        filename : PSF_MCAO_ConstPSF_40_18_6.fits
            name : maory_generic_psf
     temperature : 7
    psf_filename : None
    element_name : MAORY
         warning : Default PSF is not Field Varying. See Documentation
          SIMPLE : True
          BITPIX : 8
           NAXIS : 0
          EXTEND : True
          AUTHOR : Kieran Leschinski
        DATE_CRE : 2019-07-30
        DATE_MOD : 2019-07-30
          SOURCE : AnisoCADO
          STATUS : Best guess for a MAORY ConstantPSF with AnisoCADO
           ETYPE : CONSTPSF
            ECAT : -1
           EDATA : 1
         XOFFSET : 0
         YOFFSET : 0
         z_order : [262, 662]
         include : True
   flux_accuracy : 0.001
```

```
  sub_pixel_flag : False
   convolve_mode : full
        wave_key : WAVE0
normalise_kernel : True
```

4.4 OpticalElement: "default_ro"

Element: relay_optics

Alias: RO

Description: Simple stand-alone relay optics module

4.4.1 Global properties

```
 temperature : !ATMO.temperature
psf_filename : None
element_name : default_ro
```

4.4.2 Effects

Summary of Effects included in this optical element:

element	name	class	included	z_orders
default_ro	relay_psf	FieldConstantPSF	True	[262, 662]
default_ro	relay_surface_list	SurfaceList	True	[20, 120, 520]

4.4.2.1 FieldConstantPSF: "relay_psf"

Included by default: `True`

File Description: SCAO PSF

Class Description: <no docstring>

Changes:

-

Data

Meta-data

```
        filename : PSF_SCAO_ConstPSF_0_5off.fits
            name : relay_psf
     temperature : 7
    psf_filename : None
    element_name : default_ro
         warning : Default PSF is NOT field varying. See documentation.
          SIMPLE : True
          BITPIX : 8
           NAXIS : 0
          EXTEND : True
          AUTHOR : Kieran Leschinski
        DATE_CRE : 2019-07-30
        DATE_MOD : 2019-07-30
          SOURCE : AnisoCADO
          STATUS : Best guess for a standard observations
```

```
            ETYPE : CONSTPSF
             ECAT : -1
            EDATA : 1
          XOFFSET : 0
          YOFFSET : 5
          z_order : [262, 662]
          include : True
    flux_accuracy : 0.001
   sub_pixel_flag : False
    convolve_mode : full
         wave_key : WAVE0
normalise_kernel : True
```

4.4.2.2 SurfaceList: "relay_surface_list"

Included by default: `True`

File Description: list of surfaces in the relay optics

Class Description: <no docstring>

Changes:

- 2018-11-19 (KL) Added meta data
- 2019-01-28 (KL) Fixed YAML format in meta data
- 2020-07-18 (KL) Added all 6 mirrors from the CM16 update pdf
- 2020-07-18 (KL) Pegged temperature to atmosphere

Data

Meta-data

```
            filename : LIST_RO_SCAO_mirrors.dat
                name : relay_surface_list
         temperature : !ATMO.temperature
        psf_filename : None
        element_name : default_ro
              author : Oliver Czoske, Kieran Leschinski
              source : P12_RelayOptics_Status_2020-06-23-MICADO-CM16-RO-v2.pdf
        date_created : 2018-11-19
       date_modified : 2020-08-17
              status : Design - pre FDR list of stand-alone SCAO relay optics mi
                type : mirror:list
          outer_unit : m
          inner_unit : m
          angle_unit : degree
    temperature_unit : deg_C
             z_order : [20, 120, 520]
             include : True
        ignore_wings : False
            wave_min : !SIM.spectral.wave_min
```

```
           wave_max : !SIM.spectral.wave_max
          wave_unit : !SIM.spectral.wave_unit
           wave_bin : !SIM.spectral.spectral_resolution
minimum_throughput : !SIM.spectral.minimum_throughput
            etendue : !TEL.etendue
```