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 <SpectralTrace> "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"

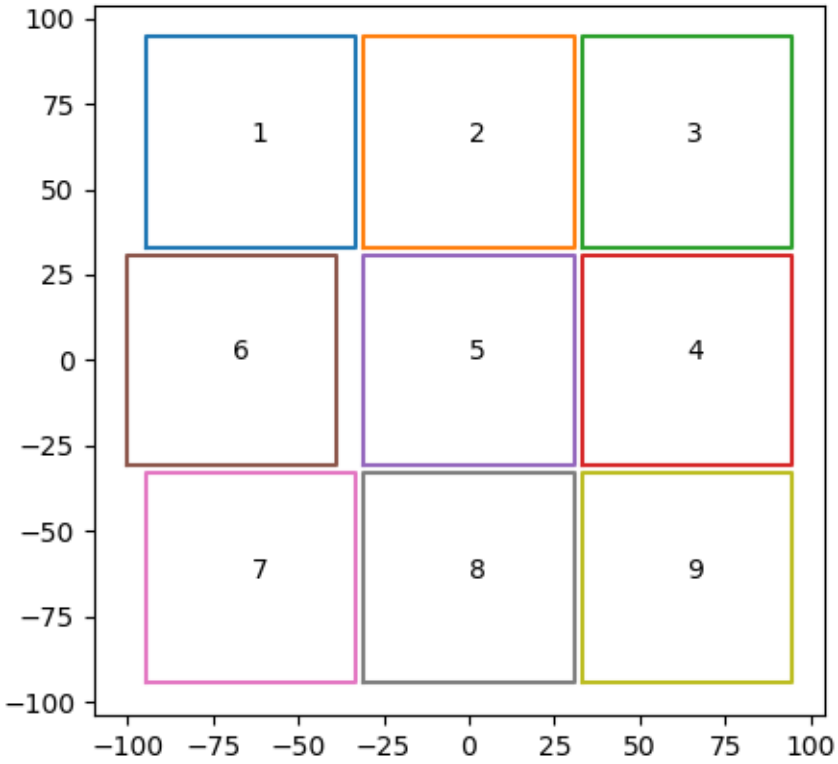
Included by default: `False`

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
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"

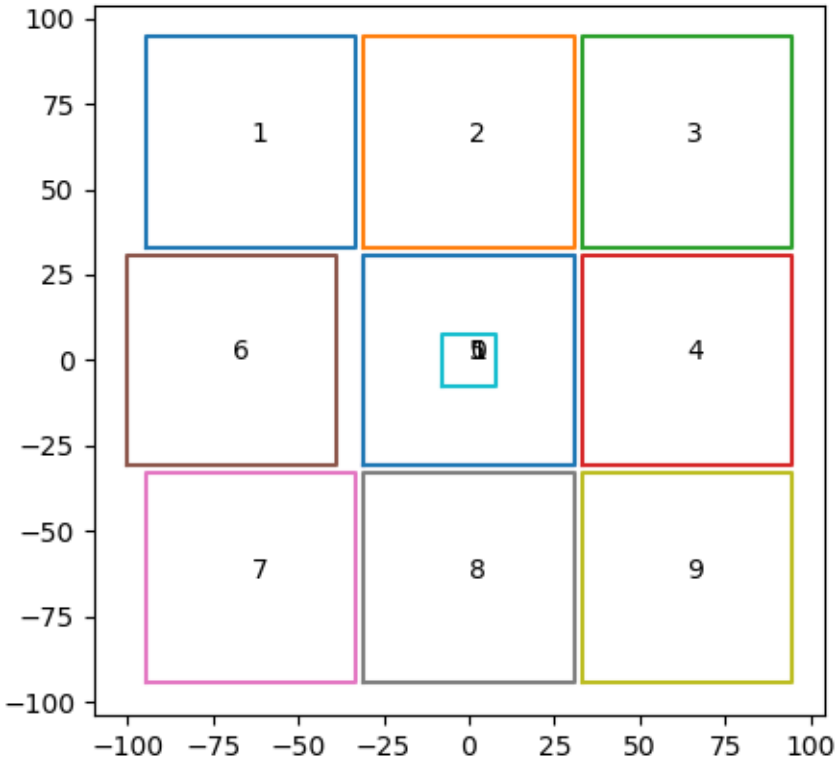
Included by default: `True`

File Description:

Class Description: A description of detector positions and properties

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
report_table_include : True
        x_size_unit : mm
        y_size_unit : mm
```

2.6.2.3 QuantumEfficiencyCurve: "qe_curve"

Included by default: `True`

File Description: Quantum efficiency curves for each detector

Class Description: <no docstring>

Changes:

- {datetime.date(2018, 11, 19): '(KL) updated meta data to new format'}
- {datetime.date(2019, 8, 9): '(KL) Added action keyword to meta data'}

Data

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

3.1 OpticalElement: "MICADO"

Element: instrument

Alias: INST

Description: base configuration for MICADO

3.1.1 Global properties

```
    temperature : -190
filename_format : filters/TC_filter_\{\}.dat
   element_name : MICADO
```

3.1.2 Effects

Summary of Effects included in this optical element:

element	name	class	included	z_orders [3]
MICADO	micado_filter	FilterCurve	True	114 .. 514
MICADO	micado_common_optics	TERCurve	True	10 .. 510

3.1.2.1 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_Ks.dat
              name : micado_filter
       temperature : -190
   filename_format : !INST.filename_format
      element_name : MICADO
       filter_name : !INST.filter_name
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
              type : filter:transmission
            center : 2.144876984095012
             width : 0.3470169216021642
       blue_cutoff : 1.97136852329393
        red_cutoff : 2.3183854448960943
           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
```

3.1.2.2 TERCurve: "micado_common_optics"

Included by default: `True`

File Description: combined transmission for MICADO common optics

Class Description: Transmission, Emissivity, Reflection Curve

Changes:

-

Data

Meta-data

```
       filename : TER_MICADO_IMG_common.dat
           name : micado_common_optics
    temperature : -190
filename_format : filters/TC_filter_\{\}.dat
   element_name : MICADO
         author : Auto-compiled from source
         source : LIST_MICADO_mirrors_static.dat
   date_created : 2020-08-25
  date_modified : 2020-08-25
           area : 0.19634954084936207
      area_unit : m2
wavelength_unit : um
  emission_unit : photlam
```

```
      z_order : [10, 110, 510]
      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
```

3.2 OpticalElement: "MICADO_SCAO"

Element: instrument

Alias: INST

Description: MICADO SCAO mode effects

3.2.1 Global properties

```
         psf : \{'strehl': 0.4, 'wavelength': 'Ks'\}
element_name : MICADO_SCAO
```

3.2.2 Effects

Summary of Effects included in this optical element:

element	name	class	included	z_orders
MICADO_SCAO	scao_relay_optics_ter	TERCurve	True	[10, 110, 510]
MICADO_SCAO	scao_const_psf	AnisocadoConstPSF	True	[42]

3.2.2.1 TERCurve: "scao_relay_optics_ter"

Included by default: `True`

File Description: Combined TER curve for stand-alone relay optics module

Class Description: Transmission, Emissivity, Reflection Curve

Changes:

-

Data

Meta-data

```
       filename : TER_MICADO_RO.dat
           name : scao_relay_optics_ter
            psf : \{'strehl': 0.4, 'wavelength': 'Ks'\}
   element_name : MICADO_SCAO
         author : Auto-compiled from source
         source : LIST_RO_SCAO_mirrors.dat
   date_created : 2020-08-25
  date_modified : 2020-08-25
           area : 0.22061834409834324
      area_unit : m2
wavelength_unit : um
```

```
emission_unit : photlam
      z_order : [10, 110, 510]
      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
```

3.2.2.2 AnisocadoConstPSF: "scao_const_psf"

Included by default: `True`

File Description: field constant PSF as produced by stand-alone SCAO

Class Description: Makes a SCAO on-axis PSF with a desired Strehl ratio at a given wavelength

Changes:

-

Data

Meta-data

```
            filename : MICADO_AnisoCADO_rms_map.fits
                name : scao_const_psf
                 psf : \{'strehl': 0.4, 'wavelength': 'Ks'\}
        element_name : MICADO_SCAO
              strehl : !INST.psf.strehl
          wavelength : !INST.psf.wavelength
    psf_side_length : 256
              offset : [0, 0]
      rounded_edges : True
      convolve_mode : full
              SIMPLE : True
              BITPIX : -64
               NAXIS : 2
              NAXIS1 : 35
              NAXIS2 : 9
              EXTEND : True
              CRVAL1 : 0
              CRVAL2 : 0.8
              CRPIX1 : 1.0
              CRPIX2 : 1.0
              CDELT1 : 20
              CDELT2 : 0.2
              CUNIT1 : nm
              CUNIT2 : um
```

```
                CTYPE1 : LINEAR
                CTYPE2 : LINEAR
                LABEL1 : nmRMS
                LABEL2 : wavelength
                AUTHOR : Kieran Leschinski
              DATE_CRE : 2019-07-30
              DATE_MOD : 2019-07-30
                SOURCE : AnisoCADO
                STATUS : Strehl as a function of wavelength and wavefront erro
                 ETYPE : SRMAP
                  ECAT : -1
                 EDATA : 0
               XOFFSET : 0
               YOFFSET : 0
               z_order : [42]
               include : True
         flux_accuracy : 0.001
        sub_pixel_flag : False
              wave_key : WAVE0
      normalise_kernel : True
filter_filename_format : !INST.filename_format
```

3.3 OpticalElement: "MICADO_MCAO"

Element: instrument

Alias: INST

Description: MICADO MCAO mode effects

3.3.1 Global properties

```
         psf : \{'strehl': 0.4, 'wavelength': 'Ks'\}
element_name : MICADO_MCAO
```

3.3.2 Effects

Summary of Effects included in this optical element:

element	name	class	included	z_orders
MICADO_MCAO	maory_mms_ter	TERCurve	True	[10, 110, 510]
MICADO_MCAO	maory_const_psf	AnisocadoConstPSF	True	[42]

3.3.2.1 TERCurve: "maory_mms_ter"

Included by default: `True`

File Description: Combined TER curve for MAORY MMS relay optics module

Class Description: Transmission, Emissivity, Reflection Curve

Changes:

-

Data

Meta-data

```
       filename : TER_MAORY_MMS.dat
           name : maory_mms_ter
            psf : \{'strehl': 0.4, 'wavelength': 'Ks'\}
   element_name : MICADO_MCAO
         author : Auto-compiled from source
         source : LIST_mirrors_maory_mms.tbl
   date_created : 2020-08-25
  date_modified : 2020-08-25
           area : 0.9503317777109126
      area_unit : m2
wavelength_unit : um
```

```
emission_unit : photlam
      z_order : [10, 110, 510]
      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
```

3.3.2.2 AnisocadoConstPSF: "maory_const_psf"

Included by default: `True`

File Description: field constant PSF as produced by MAORY

Class Description: Makes a SCAO on-axis PSF with a desired Strehl ratio at a given wavelength

Changes:

-

Data

Meta-data

```
            filename : MICADO_AnisoCADO_rms_map.fits
                name : maory_const_psf
                 psf : \{'strehl': 0.4, 'wavelength': 'Ks'\}
        element_name : MICADO_MCAO
              strehl : !INST.psf.strehl
          wavelength : !INST.psf.wavelength
    psf_side_length : 256
              offset : [0, 0]
      rounded_edges : True
      convolve_mode : full
              SIMPLE : True
              BITPIX : -64
               NAXIS : 2
              NAXIS1 : 35
              NAXIS2 : 9
              EXTEND : True
              CRVAL1 : 0
              CRVAL2 : 0.8
              CRPIX1 : 1.0
              CRPIX2 : 1.0
              CDELT1 : 20
              CDELT2 : 0.2
              CUNIT1 : nm
              CUNIT2 : um
```

```
                CTYPE1 : LINEAR
                CTYPE2 : LINEAR
                LABEL1 : nmRMS
                LABEL2 : wavelength
                AUTHOR : Kieran Leschinski
              DATE_CRE : 2019-07-30
              DATE_MOD : 2019-07-30
                SOURCE : AnisoCADO
                STATUS : Strehl as a function of wavelength and wavefront erro
                 ETYPE : SRMAP
                  ECAT : -1
                 EDATA : 0
               XOFFSET : 0
               YOFFSET : 0
               z_order : [42]
               include : True
         flux_accuracy : 0.001
        sub_pixel_flag : False
              wave_key : WAVE0
      normalise_kernel : True
filter_filename_format : !INST.filename_format
```

3.4 OpticalElement: "4mas"

Element: instrument

Alias: INST

Description: wide-field imager : 4mas/pix

3.4.1 Global properties

```
 filter_name : Ks
 pixel_scale : 0.004
 plate_scale : 0.26666666666
element_name : 4mas
```

3.4.2 Effects

Summary of Effects included in this optical element:

element	name	class	included	z_orders

3.5 OpticalElement: "1.5mas"

Element: instrument

Alias: INST

Description: zoom imager : 1.5mas/pix

3.5.1 Global properties

```
 filter_name : Ks
 pixel_scale : 0.0015
 plate_scale : 0.1
element_name : 1.5mas
```

3.5.2 Effects

Summary of Effects included in this optical element:

element	name	class	included	z_orders

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_winds : 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
```