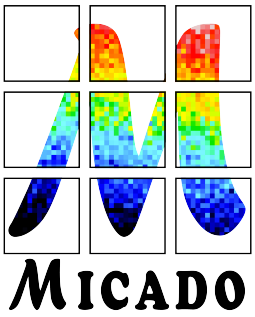


ELT – MICADO

Phase C

ScopeSim instrument packages for MICADO

ELT-TRE-MCD-56306-0059

Issue: 1.0

Date: 12. April 2021

Prepared:	K. Leschinski, O. Czoske, M. Verdugo	2021-12-04	
	Name	Date	Signature
Approved:			
	Name	Date	Signature
Released:			
	Name	Date	Signature

Change record

Issue/Rev.	Date	Section/Parag. affected	Reason/Initiation/Documents/Remarks
0.1	2020-10-15	All	(KL) Layout initialised
0.2	2020-12-04	All	(KL) Added new data, tables, plots to all sections
1.0	2021-04-12	All	(KL) Minor corrections

Contents

Chapter 1

Introduction

1.1 Applicable Documents

Nr	Doc. Nr	Doc. Title	Issue	Date
AD 1	ELT-MAN-MCD-56306-0058	SimCADO User Manual	1.0	2021-04-12
AD 2	ELT-TRE-MCD-56306-0060	ScopeSim - A modular astronomical instrument data simulation environment	1.0	2021-04-12
AD 3	ELT-TRE-MCD-56300-0014	MICADO Masks, Stops, and Filters Description	2.9	2020-12-04

1.2 Document Scope

This document aims to serve as a reference for the contents of the instrument packages relevant to the implementation of the MICADO instrument simulator using the ScopeSim package. The information provided here is a snapshot of the FDR release (Dec. 2020) of the these packages. It is possible that changes will made to files contained in the packages. For more up-to-date information, the reader is referred to the online GitHub repository.

This document does not provide an overview of how to use the MICADO packages with ScopeSim. For this the reader should consult the online documentation for ScopeSim or either of the two accompanying documents AD 1 and AD 2.

1.3 Overview of the Instrument Packages relevant to MICADO

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).

1.3.1 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

1.3.2 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.

1.3.3 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.

1.3.4 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	False	[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_ncpas_psf	NonCommonPathAberration	True	[241, 641]
MICADO	filter_wheel_1	FilterWheel	True	[124, 224, 524]
MICADO	filter_wheel_2	FilterWheel	True	[124, 224, 524]
MICADO	pupil_wheel	FilterWheel	True	[124, 224, 524]
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	False	[632, 232]
MICADO_IMG_HR	zoom_mirror_list	SurfaceList	True	[20, 120, 520]
MICADO_IMG_HR	micado_adc_3D_shift	AtmosphericDispersionCorrection	False	[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]

2.2 OpticalElement: "MICADO"

Element: instrument

Alias: INST

Description: Effects from the MICADO common optics

2.2.1 Global properties

```
       temperature : -190
filter_file_format : filters/TC_filter_\{\}.dat
      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_ncpas_psf	NonCommonPathAberration	True	[241, 641]
MICADO	filter_wheel_1	FilterWheel	True	[124, 224, 524]
MICADO	filter_wheel_2	FilterWheel	True	[124, 224, 524]
MICADO	pupil_wheel	FilterWheel	True	[124, 224, 524]

2.2.2.1 SurfaceList: "micado_static_surfaces"

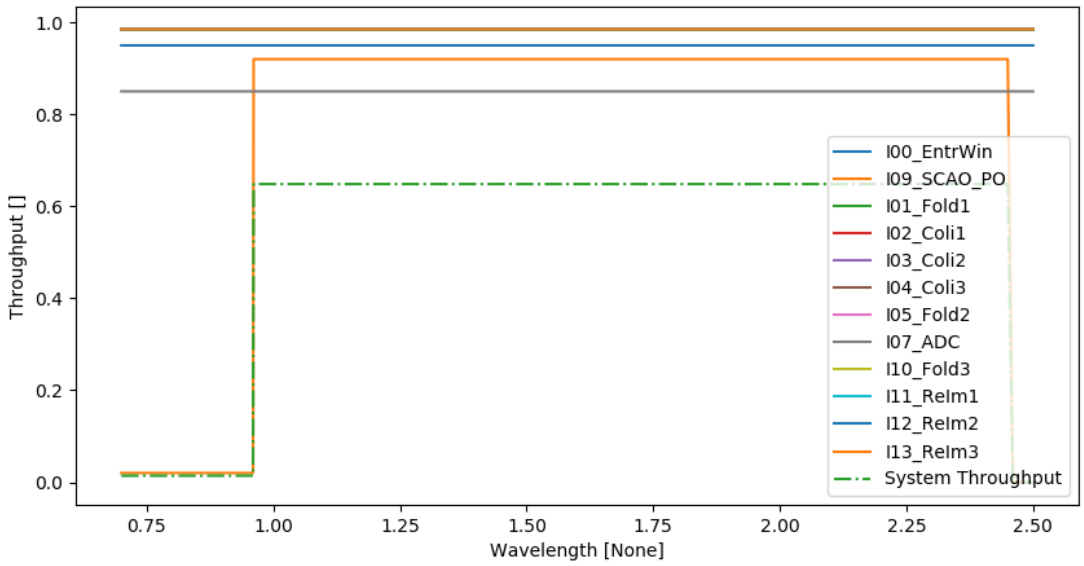
Included by default: `True`

File Description: surfaces list for wide field optics

Class Description: <no docstring>

Changes:

- 2019-01-28 (KL) Changed column names and added units to header
- 2019-07-10 (KL) Shortened the list to only the swappable mirrors
- 2020-08-25 (KL) Updated angle_unit to degree from degrees (why has astropy not complained until now?)
- 2020-10-10 (KL) Added SCAO pick-off dichroic after CM17 conversation



name	outer	inner	angle	temperature	action	filename
I00_EntrWin	0.5	0.0	0	0	transmission	TER_entrance_window.dat
I09_SCAO_PO	0.5	0.0	45	-190	reflection	TER_SCAO_dichroic.dat
I01_Fold1	0.5	0.0	45	-190	reflection	TER_mirror_gold.dat
I02_Coli1	0.4	0.0	10	-190	reflection	TER_mirror_gold.dat
I03_Coli2	0.2	0.0	10	-190	reflection	TER_mirror_gold.dat
I04_Coli3	0.2	0.0	10	-190	reflection	TER_mirror_gold.dat
I05_Fold2	0.2	0.0	45	-190	reflection	TER_mirror_gold.dat
I07_ADC	0.2	0.0	0	-190	transmission	TER_full_adc.dat
I10_Fold3	0.2	0.0	45	-190	reflection	TER_mirror_gold.dat
I11_ReIm1	0.2	0.0	10	-190	reflection	TER_mirror_gold.dat
I12_ReIm2	0.2	0.0	10	-190	reflection	TER_mirror_gold.dat
I13_ReIm3	0.2	0.0	10	-190	reflection	TER_mirror_gold.dat

Data

Meta-data

```
            filename : LIST_MICADO_mirrors_static.dat
                name : micado_static_surfaces
         temperature : -190
  filter_file_format : filters/TC_filter_\{\}.dat
```

```
        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
 report_plot_include : True
report_table_include : True
  minimum_throughput : !SIM.spectral.minimum_throughput
             etendue : !TEL.etendue
```

2.2.2.2 NonCommonPathAberration: "micado_ncpas_psf"

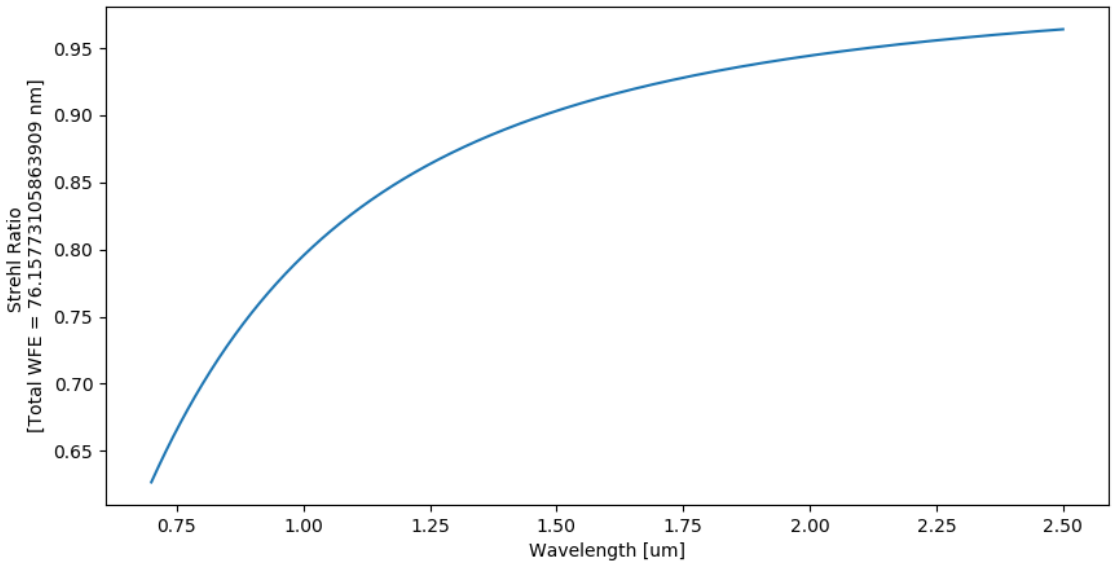
Included by default: `True`

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
  filter_file_format : filters/TC_filter_\{\}.dat
        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
 report_plot_include : True
```

```
report_table_include : False
        kernel_width : None
        strehl_drift : 0.02
            wave_min : !SIM.spectral.wave_min
            wave_max : !SIM.spectral.wave_max
```

2.2.2.3 FilterWheel: "filter_wheel_1"

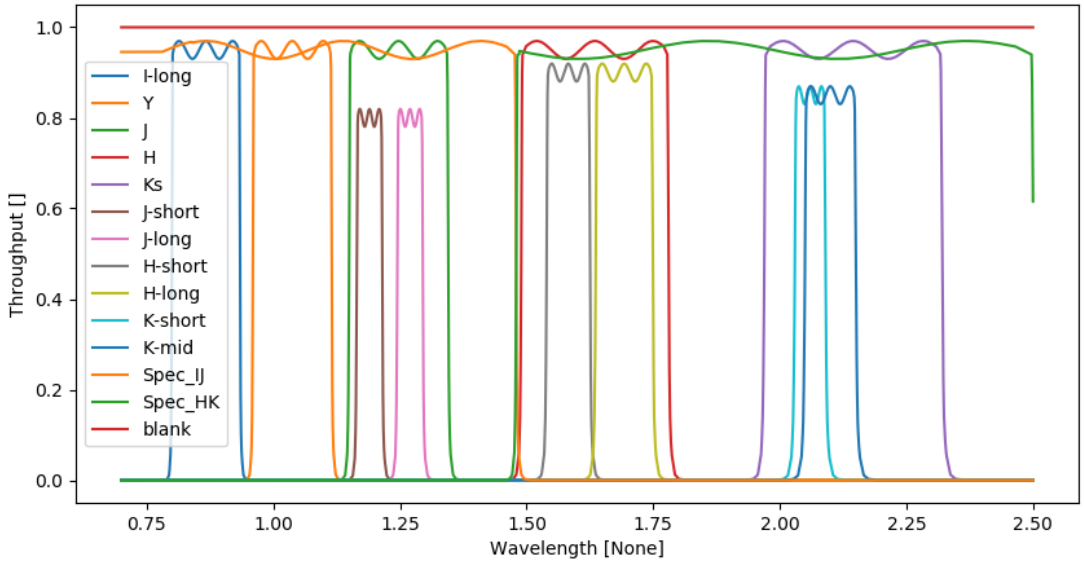
Included by default: `True`

File Description:

Class Description: Examples

Changes:

-



name	centre	width	blue cutoff	red cutoff
I-long	0.8689	0.1340	0.8019	0.9359
Y	1.0396	0.1550	0.9621	1.1171
J	1.2502	0.1950	1.1527	1.3477
H	1.6395	0.2900	1.4945	1.7845
Ks	2.1500	0.3500	1.9750	2.3250

... continued on next page

name	centre	width	blue cutoff	red cutoff
J-short	1.1902	0.0490	1.1657	1.2147
J-long	1.2702	0.0490	1.2457	1.2947
H-short	1.5830	0.0850	1.5405	1.6255
H-long	1.6937	0.1120	1.6377	1.7497
K-short	2.0602	0.0600	2.0302	2.0902
K-mid	2.1005	0.1000	2.0505	2.1505
Spec_IJ	1.1663	0.6990	0.8168	1.5158
Spec_HK	2.0345	1.0200	1.5245	2.5445
blank	2.7545	2.7000	1.4045	4.1045

Data

Meta-data

```
             filename : None
                 name : filter_wheel_1
          temperature : -190
   filter_file_format : filters/TC_filter_\{\}.dat
         element_name : MICADO
         filter_names : ['I-long', 'Y', 'J', 'H', 'Ks', 'J-short', 'J-long',
      filename_format : !INST.filter_file_format
       current_filter : !OBS.filter_name_fw1
   minimum_throughput : 0.000101
                outer : 0.2
           outer_unit : m
              z_order : [124, 224, 524]
              include : True
                 path :
  report_plot_include : True
 report_table_include : True
report_table_rounding : 4
```

2.2.2.4 FilterWheel: "filter_wheel_2"

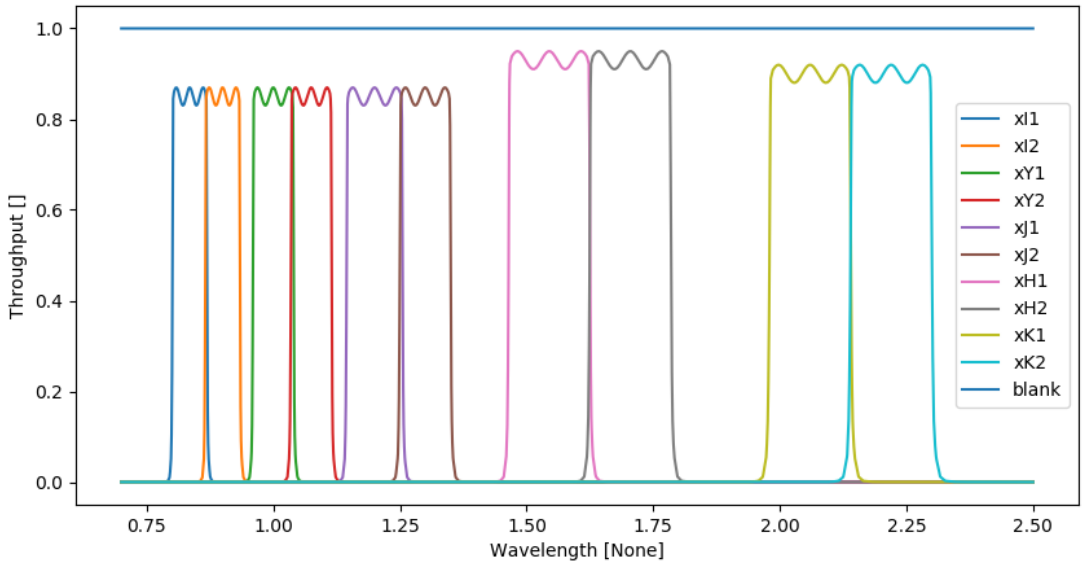
Included by default: `True`

File Description:

Class Description: Examples

Changes:

-



name	centre	width	blue cutoff	red cutoff
xI1	0.8355	0.0680	0.8015	0.8695
xI2	0.9005	0.0680	0.8665	0.9345
xY1	1.0006	0.0800	0.9606	1.0406
xY2	1.0756	0.0800	1.0356	1.1156
xJ1	1.2009	0.1100	1.1459	1.2559
xJ2	1.3007	0.1000	1.2507	1.3507
xH1	1.5465	0.1600	1.4665	1.6265
xH2	1.7064	0.1600	1.6264	1.7864
xK1	2.0612	0.1600	1.9812	2.1412
xK2	2.2211	0.1600	2.1411	2.3011
blank	2.7545	2.7000	1.4045	4.1045

Data

Meta-data

```
            filename : None
                name : filter_wheel_2
```

```
          temperature : -190
   filter_file_format : filters/TC_filter_\{\}.dat
         element_name : MICADO
         filter_names : ['xI1', 'xI2', 'xY1', 'xY2', 'xJ1', 'xJ2', 'xH1', 'xH
      filename_format : !INST.filter_file_format
       current_filter : !OBS.filter_name_fw2
   minimum_throughput : 0.000101
                outer : 0.2
           outer_unit : m
              z_order : [124, 224, 524]
              include : True
                 path :
  report_plot_include : True
 report_table_include : True
report_table_rounding : 4
```

2.2.2.5 FilterWheel: "pupil_wheel"

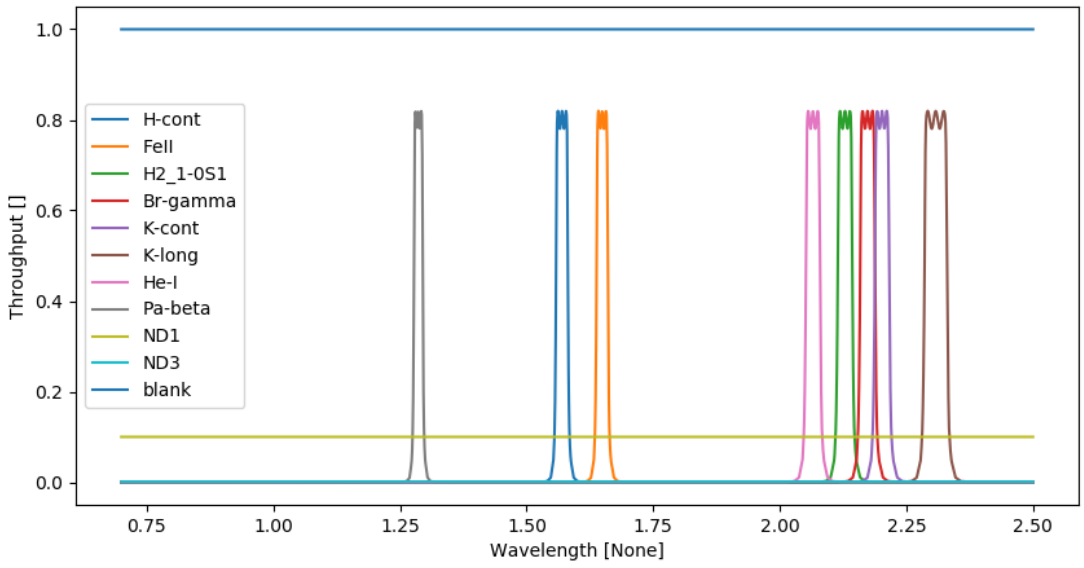
Included by default: `True`

File Description:

Class Description: Examples

Changes:

-



name	centre	width	blue cutoff	red cutoff
H-cont	1.5701	0.0220	1.5591	1.5811
FeII	1.6495	0.0210	1.6390	1.6600
H2_1-0S1	2.1289	0.0280	2.1149	2.1429
Br-gamma	2.1734	0.0280	2.1594	2.1874
K-cont	2.2019	0.0270	2.1884	2.2154
K-long	2.3081	0.0440	2.2861	2.3301
He-I	2.0656	0.0270	2.0521	2.0791
Pa-beta	1.2865	0.0170	1.2780	1.2950
ND1	2.7529	0.0000	2.7529	2.7529
ND3	2.7529	0.0000	2.7529	2.7529
blank	2.7545	2.7000	1.4045	4.1045

Data

Meta-data

```
             filename : None
                 name : pupil_wheel
          temperature : -190
   filter_file_format : filters/TC_filter_\{\}.dat
         element_name : MICADO
         filter_names : ['H-cont', 'FeII', 'H2_1-0S1', 'Br-gamma', 'K-cont',
      filename_format : !INST.filter_file_format
       current_filter : !OBS.filter_name_pupil
   minimum_throughput : 0.000101
                outer : 0.2
           outer_unit : m
              z_order : [124, 224, 524]
              include : True
                 path :
  report_plot_include : True
 report_table_include : True
report_table_rounding : 4
```

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	False	[632, 232]

2.3.2.1 SurfaceList: "micado_wide_field_mirror_list"

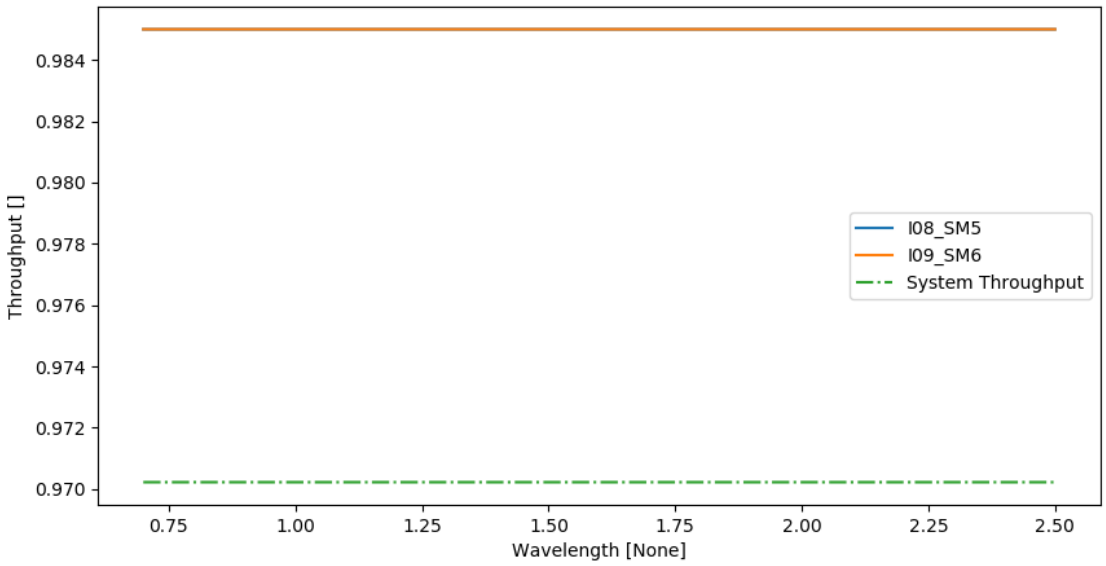
Included by default: `True`

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

Class Description: <no docstring>

Changes:

- 2019-01-28 (KL) Changed column names and added units to header
- 2019-07-10 (KL) Shortened the list to only the swappable mirrors



name	outer	inner	angle	temperature	action	filename
I08_SM5	0.2	0.0	0	-190	reflection	TER_mirror_gold.dat
I09_SM6	0.2	0.0	0	-190	reflection	TER_mirror_gold.dat

Data The list of surfaces from the rotating optics wheel that are added to the optical train when observing in the wide field mode

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
                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
 report_plot_include : True
report_table_include : True
  minimum_throughput : !SIM.spectral.minimum_throughput
             etendue : !TEL.etendue
```

2.3.2.2 AtmosphericDispersionCorrection: "micado_adc_3D_shift"

Included by default: `False`

File Description: atmospheric disperson corrector

Class Description: <no docstring>

Changes:

-

Data

Meta-data

```
            filename : None
                name : micado_adc_3D_shift
             include : False
         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]
 report_plot_include : True
report_table_include : False
```

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	False	[632, 232]

2.4.2.1 SurfaceList: "zoom_mirror_list"

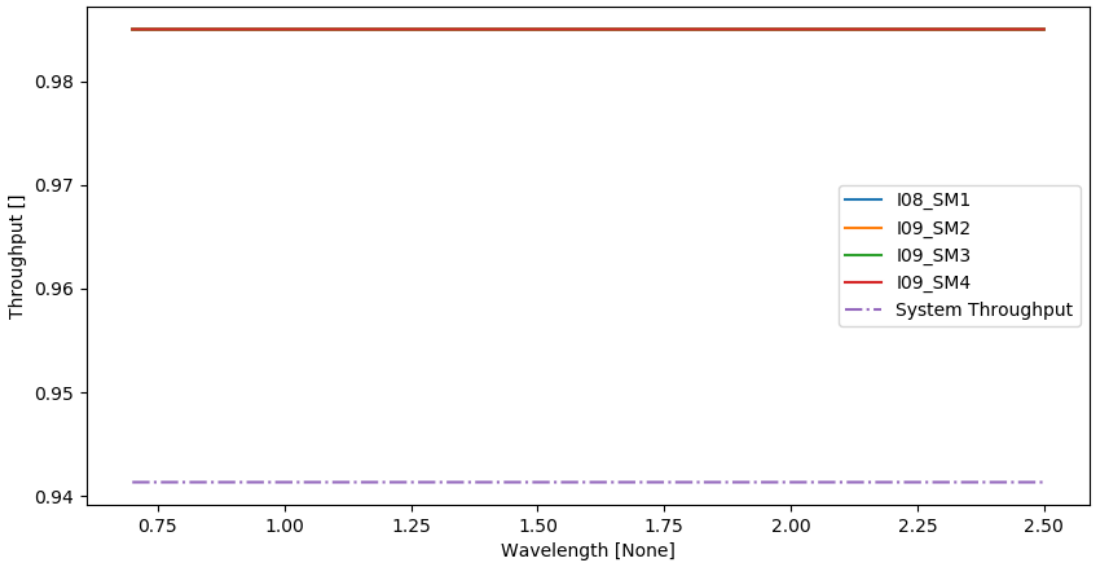
Included by default: `True`

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

Class Description: <no docstring>

Changes:

- 2019-01-28 (KL) Changed column names and added units to header
- 2019-07-10 (KL) Shortened the list to only the swappable mirrors



name	outer	inner	angle	temperature	action	filename
I08_SM1	0.2	0.0	0	-190	reflection	TER_mirror_gold.dat
I09_SM2	0.2	0.0	0	-190	reflection	TER_mirror_gold.dat
I09_SM3	0.2	0.0	0	-190	reflection	TER_mirror_gold.dat
I09_SM4	0.2	0.0	0	-190	reflection	TER_mirror_gold.dat

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 mod
                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
 report_plot_include : True
report_table_include : True
  minimum_throughput : !SIM.spectral.minimum_throughput
             etendue : !TEL.etendue
```

2.4.2.2 AtmosphericDispersionCorrection: "micado_adc_3D_shift"

Included by default: `False`

File Description: atmospheric disperson corrector

Class Description: <no docstring>

Changes:

-

Data

Meta-data

```
            filename : None
                name : micado_adc_3D_shift
             include : False
         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]
 report_plot_include : True
report_table_include : False
```

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"

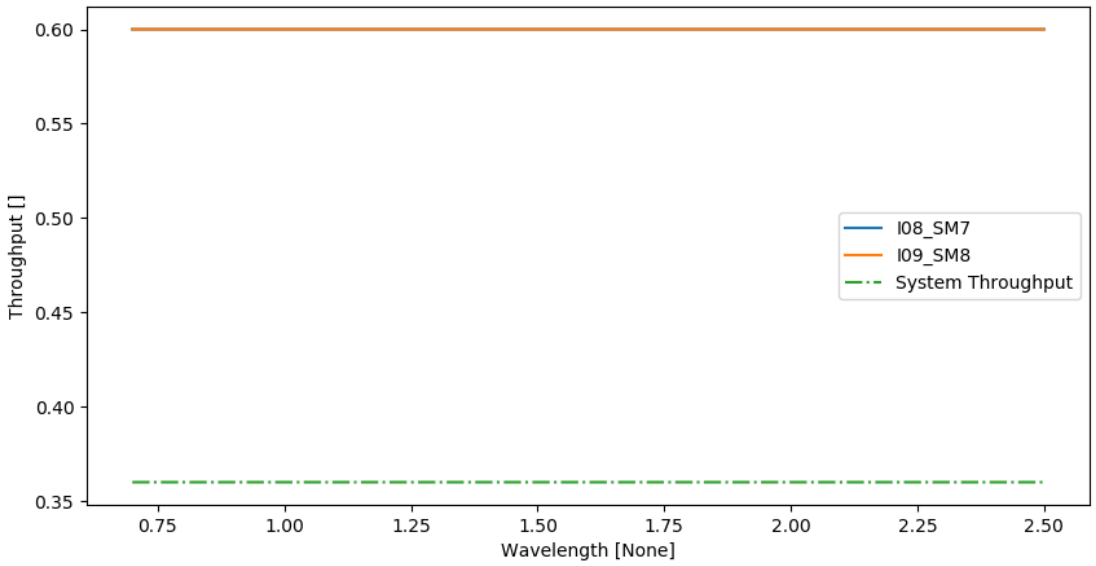
Included by default: `True`

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

Class Description: <no docstring>

Changes:

- 2019-01-28 (KL) Changed column names and added units to header
- 2019-07-10 (KL) Shortened the list to only the swappable gratings



name	outer	inner	angle	temperature	action	filename
I08_SM7	0.2	0.0	0	-190	reflection	TER_grating.dat
I09_SM8	0.2	0.0	0	-190	reflection	TER_grating.dat

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 spectrosc
                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
 report_plot_include : True
report_table_include : True
  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, wide slit (3 arcsec x 50 mas)

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

Changes:

- 2019-07-10 (KL) Created the file
- 2020-03-24 (KL) Changed geometry to 3000x50mas

Data

x	y
-1.5000	-0.0250
1.5000	-0.0250
1.5000	0.0250
-1.5000	0.0250

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
  report_plot_include : False
 report_table_include : True
report_table_rounding : 4
```

2.5.2.3 SpectralTraceList: "micado_spectral_traces" : 17 traces

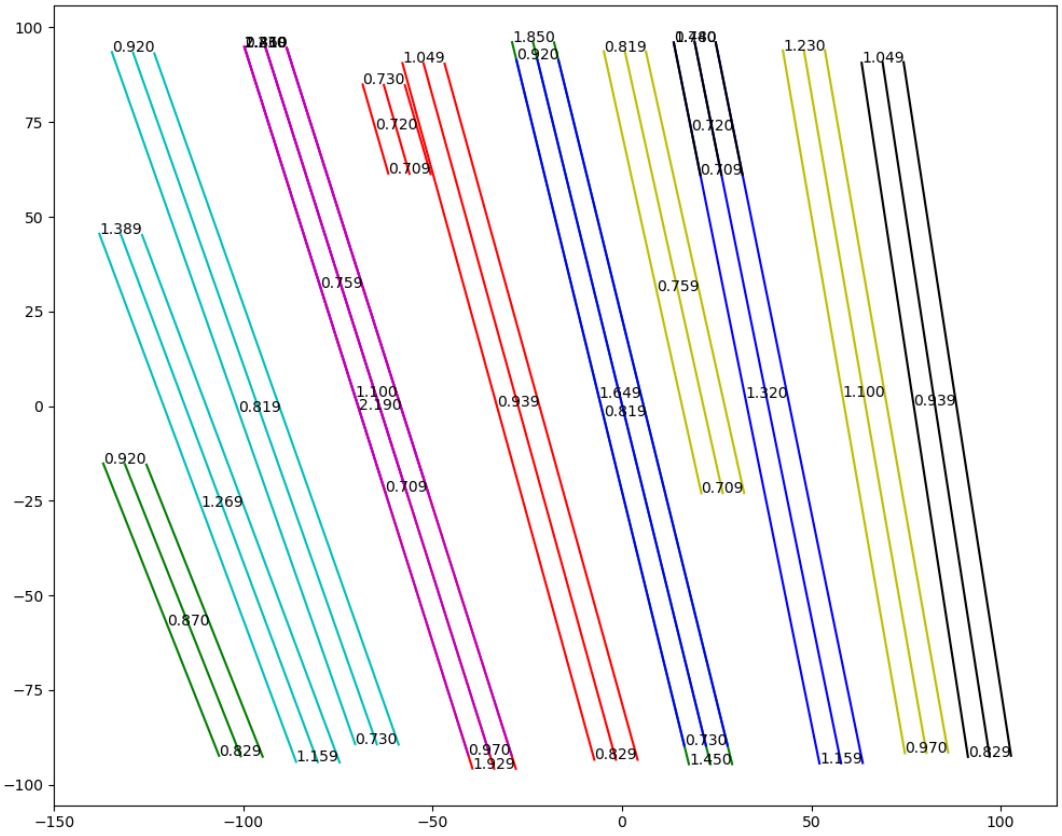
Included by default: `True`

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 detect
            DATE_CRE : 2018-06-29
            DATE_MOD : 2019-09-16
             HISTORY : 2019-09-16 : (KL) Added aperture-imagePlane table to E
             z_order : [70, 270]
             include : True
            wave_min : !SIM.spectral.wave_min
            wave_mid : !SIM.spectral.wave_mid
            wave_max : !SIM.spectral.wave_max
           x_colname : x
           y_colname : y
  center_on_wave_mid : False
               dwave : 0.002
 report_plot_include : True
report_table_include : False
```

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`

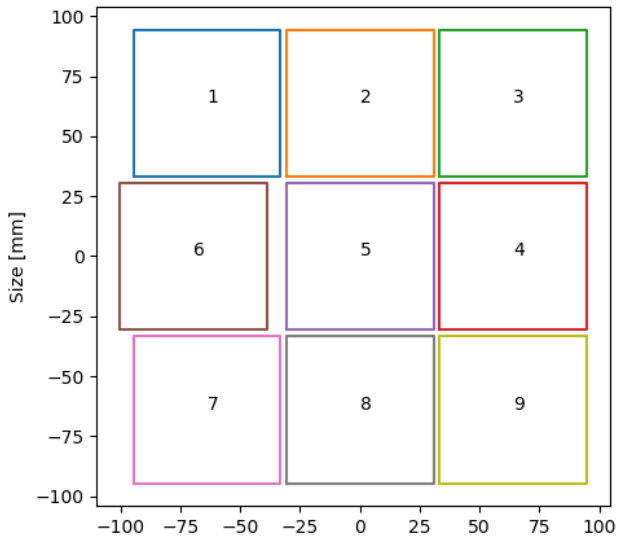
File Description: MICADO detector array list

Class Description: A description of detector positions and properties

Changes:

- 2017-08-12 (OC) id changed to conform with spectroscopy report
- 2018-07-26 (OC) large gap (chips 5 and 6) reduced to 8 mm
- 2018-11-19 (KL) updated meta data to new format

- 2019-01-28 (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"

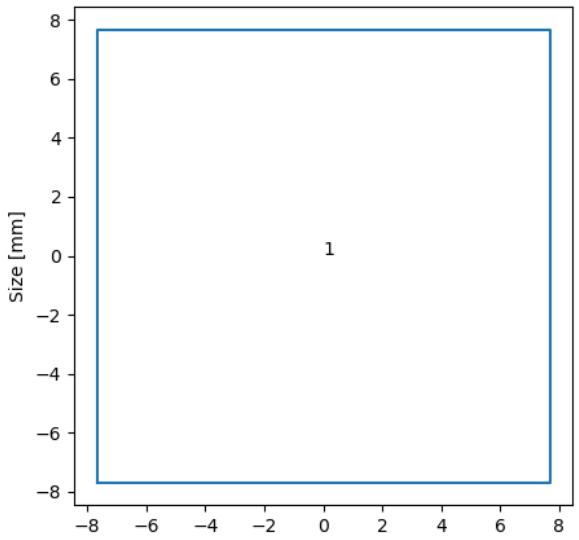
Included by default: `True`

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
          x_size_unit : mm
          y_size_unit : mm
     pixel_size_unit : mm
          angle_unit : deg
           gain_unit : electron/adu
             z_order : [90, 290, 390, 490]
          array_dict : \{'id': [1], 'pixel_size': [0.015], 'angle': [0.0], 'g
```

```
         pixel_scale : !INST.pixel_scale
    active_detectors : all
 report_plot_include : True
report_table_include : True
```

2.6.2.3 QuantumEfficiencyCurve: "qe_curve"

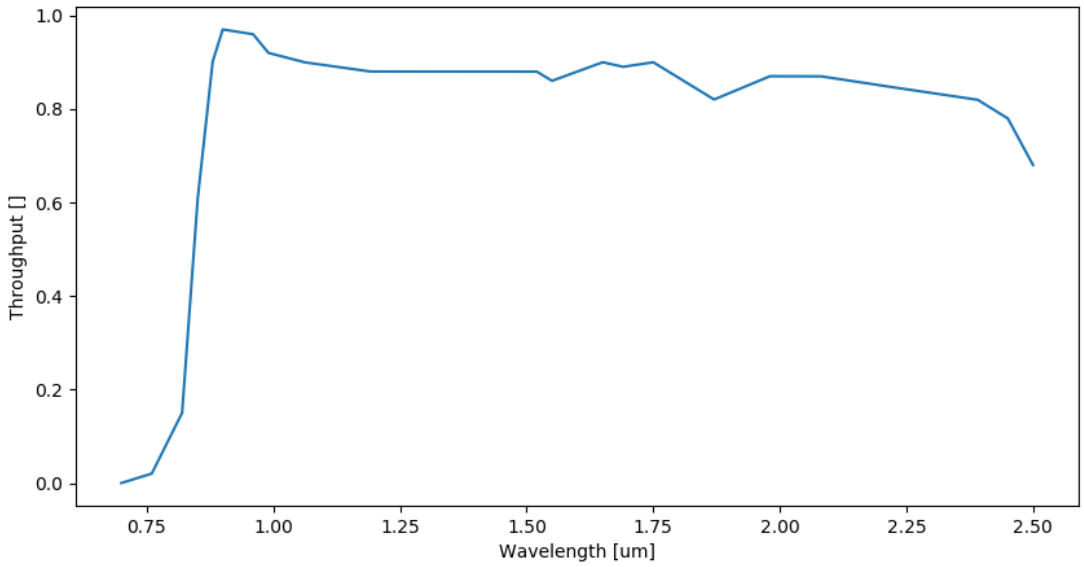
Included by default: `True`

File Description: Quantum efficiency curves for each detector

Class Description: <no docstring>

Changes:

- 2018-11-19 (KL) updated meta data to new format
- 2019-08-09 (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 : 60
                ndit : 1
        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
     wavelength_unit : um
              action : transmission
             z_order : [113, 513]
             include : True
        ignore_wings : False
            wave_min : 0.7
            wave_max : 2.5
           wave_unit : um
            wave_bin : 0.0001
 report_plot_include : True
report_table_include : False
            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: Simulates a summed stack of `ndit` exposures

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"

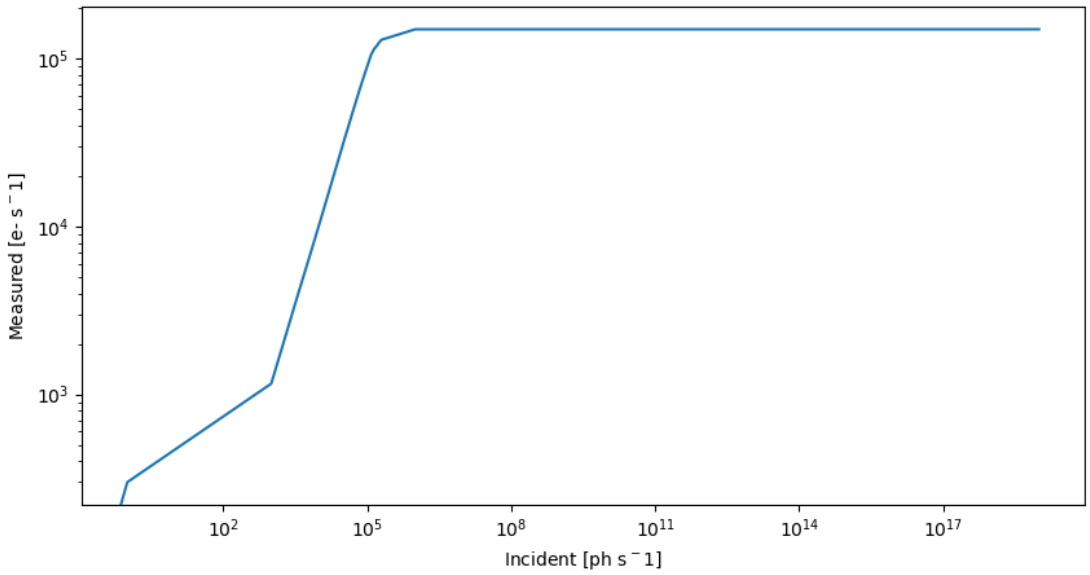
Included by default: `True`

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
 report_plot_include : True
report_table_include : False
```

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
 report_plot_include : False
report_table_include : False
```

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
```

Chapter 3

MICADO Science package

3.1 Summary of Effects in Optical Elements:

element	name	class	included	z_orders
MICADO_Sci	micado_common_optics	TERCurve	True	[10, 110, 510]
MICADO_Sci	filter_wheel	FilterWheel	True	[124, 224, 524]
micado_sci_detector	micado_detector_window	DetectorWindow	True	[90, 290, 390, 490]
micado_sci_detector	h4rg_qe_curve	QuantumEfficiencyCurve	True	[113, 513]
micado_sci_detector	exposure_action	SummedExposure	True	[860]
micado_sci_detector	dark_current	DarkCurrent	True	[830]
micado_sci_detector	shot_noise	ShotNoise	True	[820]
micado_sci_detector	h4rg_detector_linearity	LinearityCurve	False	[840]
micado_sci_detector	readout_noise	PoorMansHxRGReadoutNoise	True	[811]
MICADO_SPEC	micado_adjustable_slit	RectangularApertureMask	True	[80, 280, 380]
MICADO_SPEC	spectral_trace_3000x50mas	SpectralTraceList	True	[70, 270]
MICADO_SCAO	scao_relay_optics_ter	TERCurve	True	[10, 110, 510]
MICADO_SCAO	scao_const_psf	AnisocadoConstPSF	True	[42, 652]
MICADO_MCAO	maory_mms_ter	TERCurve	True	[10, 110, 510]
MICADO_MCAO	maory_const_psf	AnisocadoConstPSF	True	[42, 652]

3.2 OpticalElement: "MICADO_Sci"

Element: instrument

Alias: INST

Description: base configuration for MICADO

3.2.1 Global properties

```
       temperature : -190
filter_file_format : filters/TC_filter_\{\}.dat
      element_name : MICADO_Sci
```

3.2.2 Effects

Summary of Effects included in this optical element:

element	name	class	included	z_orders [3]
MICADO_Sci	micado_common_optics	TERCurve	True	10 .. 510
MICADO_Sci	filter_wheel	FilterWheel	True	124 .. 524

3.2.2.1 TERCurve: "micado_common_optics"

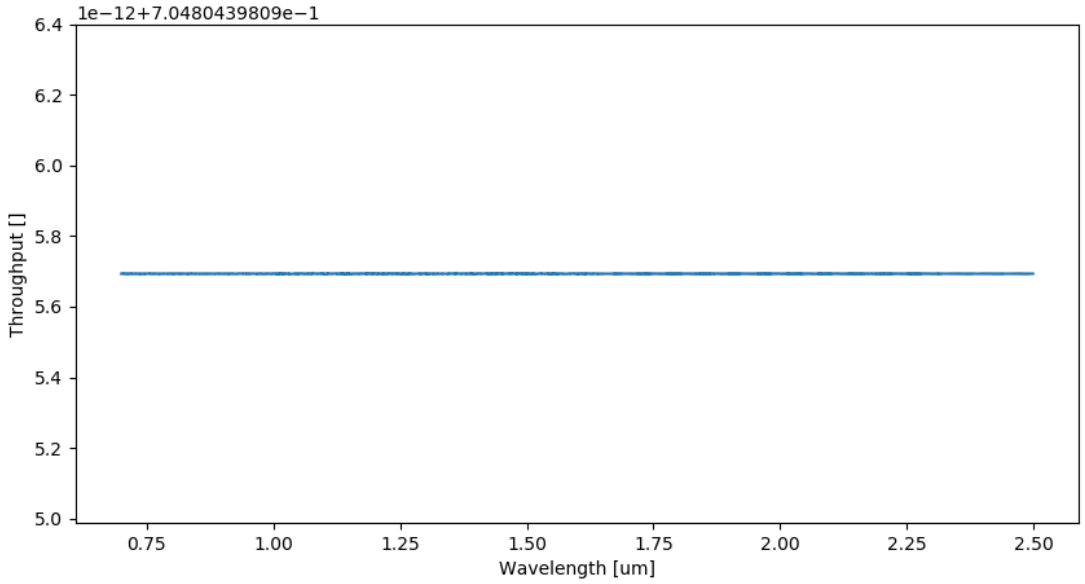
Included by default: `True`

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
 filter_file_format : filters/TC_filter_\{\}.dat
       element_name : MICADO_Sci
              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 : 0.7
            wave_max : 2.5
           wave_unit : um
            wave_bin : 0.001
report_plot_include : True
```

```
report_table_include : False
```

3.2.2.2 FilterWheel: "filter_wheel"

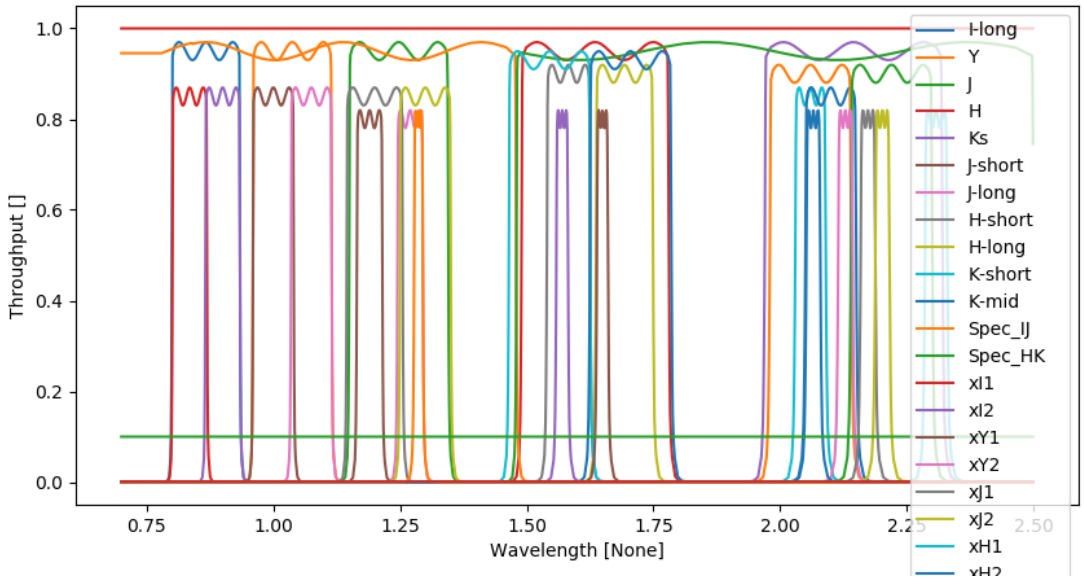
Included by default: `True`

File Description:

Class Description: Examples

Changes:

-



name	centre	width	blue cutoff	red cutoff
I-long	0.8689	0.1340	0.8019	0.9359
Y	1.0396	0.1550	0.9621	1.1171
J	1.2502	0.1950	1.1527	1.3477
H	1.6395	0.2900	1.4945	1.7845
Ks	2.1500	0.3500	1.9750	2.3250
J-short	1.1902	0.0490	1.1657	1.2147
J-long	1.2702	0.0490	1.2457	1.2947
H-short	1.5830	0.0850	1.5405	1.6255

... continued on next page

name	centre	width	blue cutoff	red cutoff
H-long	1.6937	0.1120	1.6377	1.7497
K-short	2.0602	0.0600	2.0302	2.0902
K-mid	2.1005	0.1000	2.0505	2.1505
Spec_IJ	1.1663	0.6990	0.8168	1.5158
Spec_HK	2.0345	1.0200	1.5245	2.5445
xI1	0.8355	0.0680	0.8015	0.8695
xI2	0.9005	0.0680	0.8665	0.9345
xY1	1.0006	0.0800	0.9606	1.0406
xY2	1.0756	0.0800	1.0356	1.1156
xJ1	1.2009	0.1100	1.1459	1.2559
xJ2	1.3007	0.1000	1.2507	1.3507
xH1	1.5465	0.1600	1.4665	1.6265
xH2	1.7064	0.1600	1.6264	1.7864
xK1	2.0612	0.1600	1.9812	2.1412
xK2	2.2211	0.1600	2.1411	2.3011
blank	2.7545	2.7000	1.4045	4.1045
H-cont	1.5701	0.0220	1.5591	1.5811
FeII	1.6495	0.0210	1.6390	1.6600
H2_1-0S1	2.1289	0.0280	2.1149	2.1429
Br-gamma	2.1734	0.0280	2.1594	2.1874
K-cont	2.2019	0.0270	2.1884	2.2154
K-long	2.3081	0.0440	2.2861	2.3301
He-I	2.0656	0.0270	2.0521	2.0791
Pa-beta	1.2865	0.0170	1.2780	1.2950
ND1	2.7529	0.0000	2.7529	2.7529
ND3	2.7529	0.0000	2.7529	2.7529

Data

Meta-data

```
            filename : None
                name : filter_wheel
         temperature : -190
  filter_file_format : filters/TC_filter_\{\}.dat
        element_name : MICADO_Sci
        filter_names : ['I-long', 'Y', 'J', 'H', 'Ks', 'J-short', 'J-long',
     filename_format : !INST.filter_file_format
```

```
       current_filter : !INST.filter_name
   minimum_throughput : 0.000101
                outer : 0.2
           outer_unit : m
              z_order : [124, 224, 524]
              include : True
                 path :
  report_plot_include : True
 report_table_include : True
report_table_rounding : 4
```

3.3 OpticalElement: "SCAO"

Element: instrument

Alias: INST

Description: SCAO optical system

3.3.1 Global properties

```
element_name : SCAO
```

3.4 OpticalElement: "MICADO_SCAO"

Element: instrument

Alias: INST

Description: MICADO SCAO mode effects

3.4.1 Global properties

```
         psf : \{'strehl': 0.8, 'wavelength': 'Ks'\}
element_name : MICADO_SCAO
```

3.4.2 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, 652]

3.4.2.1 TERCurve: "scao_relay_optics_ter"

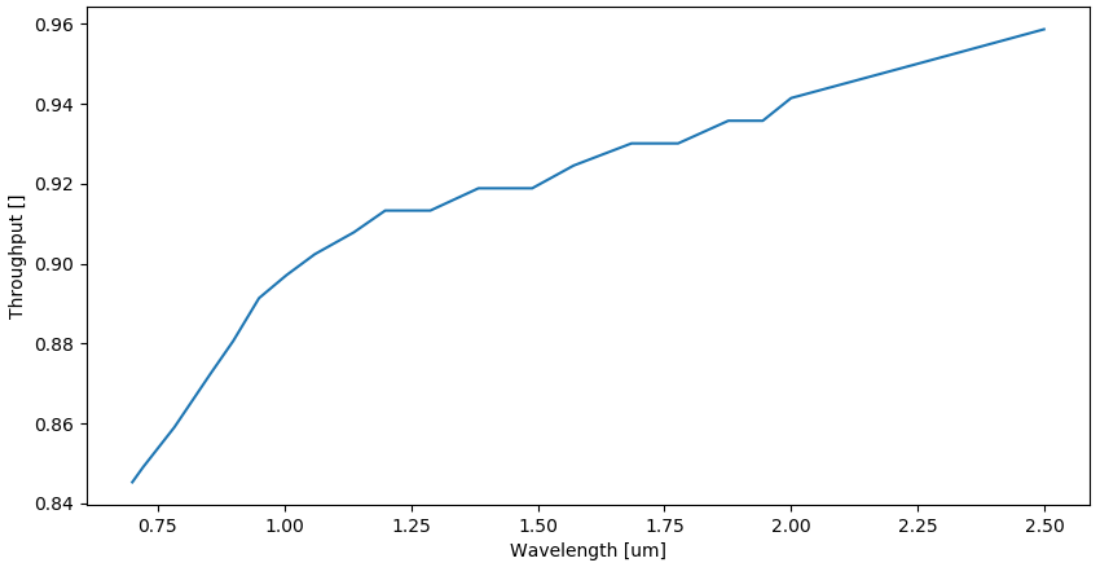
Included by default: `True`

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': 0.8, '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 : 0.7
            wave_max : 2.5
           wave_unit : um
            wave_bin : 0.001
 report_plot_include : True
report_table_include : False
```

3.4.2.2 AnisocadoConstPSF: "scao_const_psf"

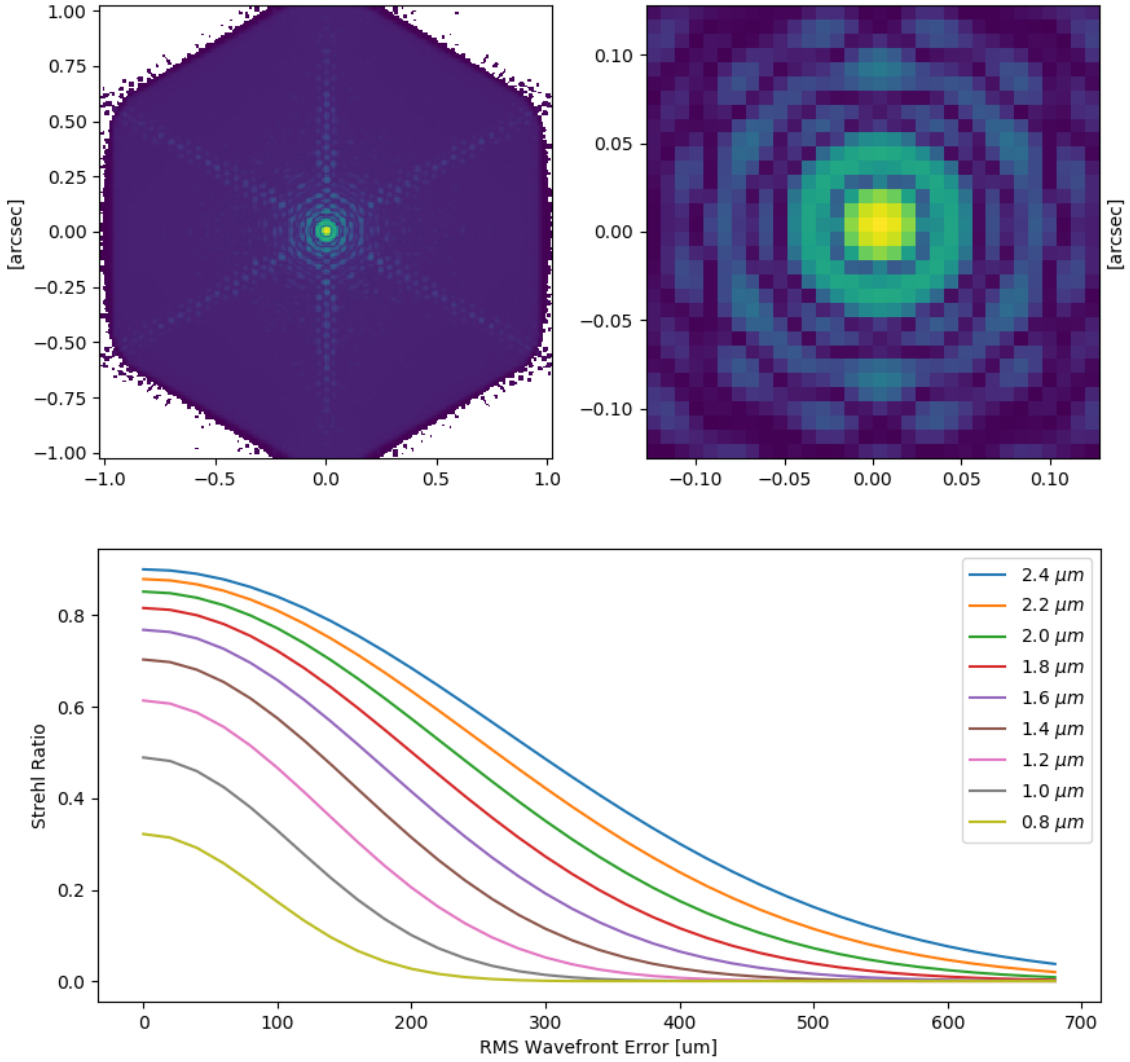
Included by default: `True`

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': 0.8, '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 error
               ETYPE : SRMAP
                ECAT : -1
               EDATA : 0
             XOFFSET : 0
             YOFFSET : 0
             z_order : [42, 652]
             include : True
       flux_accuracy : 0.001
      sub_pixel_flag : False
            wave_key : WAVE0
    normalise_kernel : True
 report_plot_include : True
report_table_include : False
```

3.5 OpticalElement: "MICADO_Sci_SCAO_detector_override"

Element: detector

Alias: DET

Description: A settable window on the detector plane

3.5.1 Global properties

```
       width : 1024
      height : 1024
element_name : MICADO_Sci_SCAO_detector_override
```

3.6 OpticalElement: "MCAO"

Element: instrument

Alias: INST

Description: MCAO optical system

3.6.1 Global properties

```
element_name : MCAO
```

3.7 OpticalElement: "MICADO_MCAO"

Element: instrument

Alias: INST

Description: MICADO MCAO mode effects

3.7.1 Global properties

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

3.7.2 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, 652]

3.7.2.1 TERCurve: "maory_mms_ter"

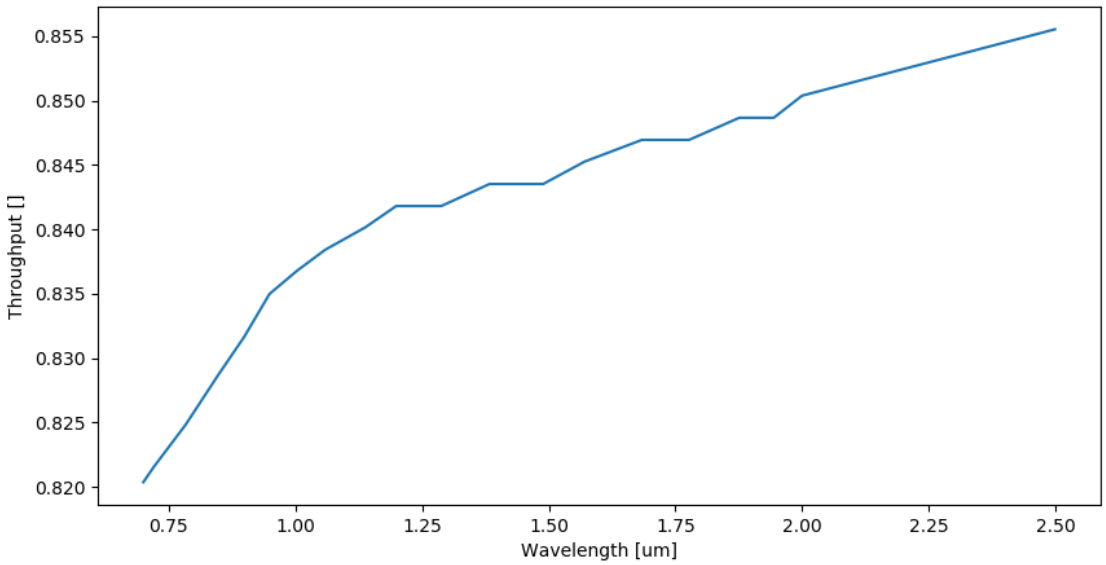
Included by default: `True`

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 : 0.7
            wave_max : 2.5
           wave_unit : um
            wave_bin : 0.001
 report_plot_include : True
report_table_include : False
```

3.7.2.2 AnisocadoConstPSF: "maory_const_psf"

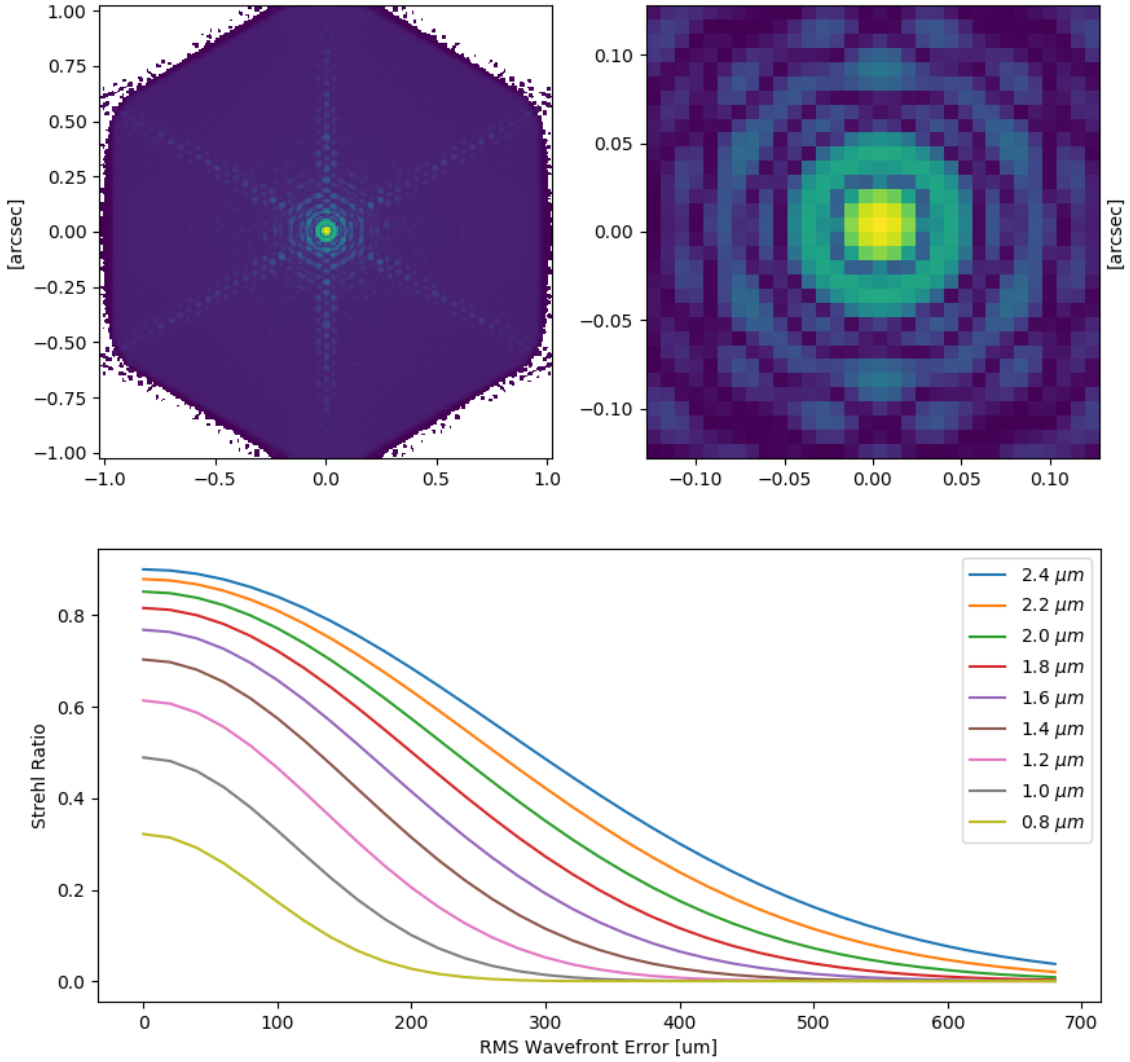
Included by default: `True`

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 error
               ETYPE : SRMAP
                ECAT : -1
               EDATA : 0
             XOFFSET : 0
             YOFFSET : 0
             z_order : [42, 652]
             include : True
       flux_accuracy : 0.001
      sub_pixel_flag : False
            wave_key : WAVE0
    normalise_kernel : True
 report_plot_include : True
report_table_include : False
```

3.8 OpticalElement: "MICADO_Sci_MCAO_detector_override"

Element: detector

Alias: DET

Description: A settable window on the detector plane

3.8.1 Global properties

```
       width : 4096
      height : 4096
element_name : MICADO_Sci_MCAO_detector_override
```

3.9 OpticalElement: "SPEC"

Element: instrument

Alias: INST

Description: Spectroscopy

3.9.1 Global properties

```
 filter_name : Spec_HK
 pixel_scale : 0.004
 plate_scale : 0.26666666666
element_name : SPEC
```

3.10 OpticalElement: "MICADO_SPEC"

Element: instrument

Alias: INST

Description: MICADO SPEC mode effects

3.10.1 Global properties

```
         psf : \{'wavelength': '!INST.filter_name', 'strehl': 0.4\}
    aperture : \{'x': 0, 'y': 0, 'width': 3, 'height': 0.05\}
element_name : MICADO_SPEC
```

3.10.2 Effects

Summary of Effects included in this optical element:

element	name	class	included	z_orders
MICADO_SPEC	micado_adjustable_slit	RectangularApertureMask	True	[80, 280, 380]
MICADO_SPEC	spectral_trace_3000x50mas	SpectralTraceList	True	[70, 270]

3.10.2.1 RectangularApertureMask: "micado_adjustable_slit"

Included by default: `True`

File Description:

Class Description: <no docstring>

Changes:

-

Data

x	y
-1.5000	-0.0250
1.5000	-0.0250
1.5000	0.0250
-1.5000	0.0250

Meta-data

```
             filename : None
                 name : micado_adjustable_slit
                  psf : \{'wavelength': 'Ks', 'strehl': 0.4\}
             aperture : \{'x': 0, 'y': 0, 'width': 3, 'height': 0.05\}
         element_name : MICADO_SPEC
                width : !INST.aperture.width
               height : !INST.aperture.height
                    x : !INST.aperture.x
                    y : !INST.aperture.y
              z_order : [80, 280, 380]
              include : True
           pixel_scale : !INST.pixel_scale
              no_mask : True
                angle : 0
                shape : rect
       conserve_image : True
                   id : 0
  report_plot_include : False
 report_table_include : True
report_table_rounding : 4
               x_unit : arcsec
               y_unit : arcsec
```

3.10.2.2 SpectralTraceList: "spectral_trace_3000x50mas" : 1 traces

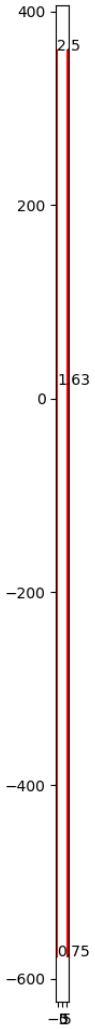
Included by default: `True`

File Description:

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

Changes:

-



Data

Meta-data

```
            filename : TRACE_SCI_3arcsec.fits
                name : spectral_trace_3000x50mas
                 psf : \{'wavelength': 'Ks', 'strehl': 0.4\}
```

```
            aperture : \{'x': 0, 'y': 0, 'width': 3, 'height': 0.05\}
        element_name : MICADO_SPEC
  center_on_wave_mid : True
              SIMPLE : True
              BITPIX : 8
               NAXIS : 0
              EXTEND : True
                ECAT : 1
               EDATA : 2
             z_order : [70, 270]
             include : True
         pixel_scale : !INST.pixel_scale
         plate_scale : !INST.plate_scale
            wave_min : !SIM.spectral.wave_min
            wave_mid : !SIM.spectral.wave_mid
            wave_max : !SIM.spectral.wave_max
          x_colname : x
          y_colname : y
          s_colname : s
        wave_colname : wavelength
    col_number_start : 0
               dwave : 0.002
       invalid_value : None
 report_plot_include : True
report_table_include : False
```

3.11 OpticalElement: "MICADO_Sci_SPEC_detector_override"

Element: detector

Alias: DET

Description: A settable window on the detector plane

3.11.1 Global properties

```
       width : 800
      height : 1024
element_name : MICADO_Sci_SPEC_detector_override
```

3.12 OpticalElement: "4mas"

Element: instrument

Alias: INST

Description: wide-field imager : 4mas/pix

3.12.1 Global properties

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

3.13 OpticalElement: "1.5mas"

Element: instrument

Alias: INST

Description: zoom imager : 1.5mas/pix

3.13.1 Global properties

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

3.14 OpticalElement: "micado_sci_detector"

Element: detector

Alias: DET

Description: List of MICADO detector effects relevant for astronomers

3.14.1 Global properties

```
image_plane_id : 0
   temperature : -230
           dit : !OBS.dit
          ndit : !OBS.ndit
         width : 4096
        height : 4096
             x : 0
             y : 0
  element_name : micado_sci_detector
```

3.14.2 Effects

Summary of Effects included in this optical element:

element	name	class	included	z_orders
micado_sci_detector	micado_detector_window	DetectorWindow	True	[90, 290, 390, 490]
micado_sci_detector	h4rg_qe_curve	QuantumEfficiencyCurve	True	[113, 513]
micado_sci_detector	exposure_action	SummedExposure	True	[860]
micado_sci_detector	dark_current	DarkCurrent	True	[830]
micado_sci_detector	shot_noise	ShotNoise	True	[820]
micado_sci_detector	h4rg_detector_linearity	LinearityCurve	False	[840]
micado_sci_detector	readout_noise	PoorMansHxRGReadoutNoise	True	[811]

3.14.2.1 DetectorWindow: "micado_detector_window"

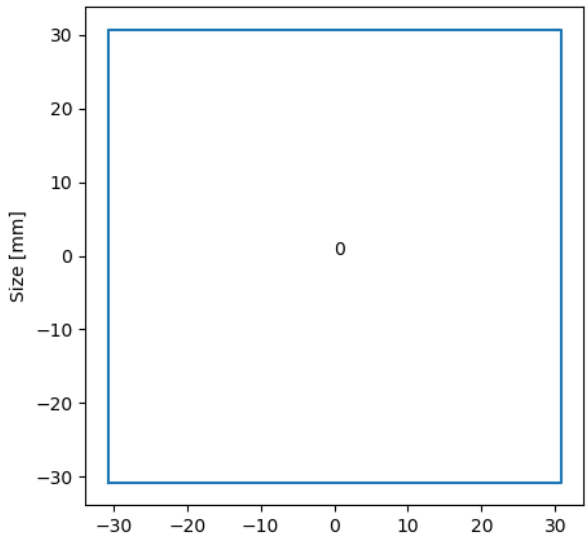
Included by default: `True`

File Description:

Class Description: For when a full DetectorList if too cumbersome

Changes:

-



id	x_cen	y_cen	x_size	y_size	angle	gain	pixel_size
0	!DET.x	!DET.y	!DET.width	!DET.height	0	1	0.015

Data

Meta-data

```
            filename : None
                name : micado_detector_window
          orig_units : pixel
          x_cen_unit : pixel
          y_cen_unit : pixel
         x_size_unit : pixel
         y_size_unit : pixel
     pixel_size_unit : mm
          angle_unit : deg
           gain_unit : electron/adu
      image_plane_id : 0
         temperature : -230
                 dit : !OBS.dit
                ndit : !OBS.ndit
        element_name : micado_sci_detector
             z_order : [90, 290, 390, 490]
             include : True
```

```
         pixel_scale : !INST.pixel_scale
    active_detectors : all
 report_plot_include : True
report_table_include : True
```

3.14.2.2 QuantumEfficiencyCurve: "h4rg_qe_curve"

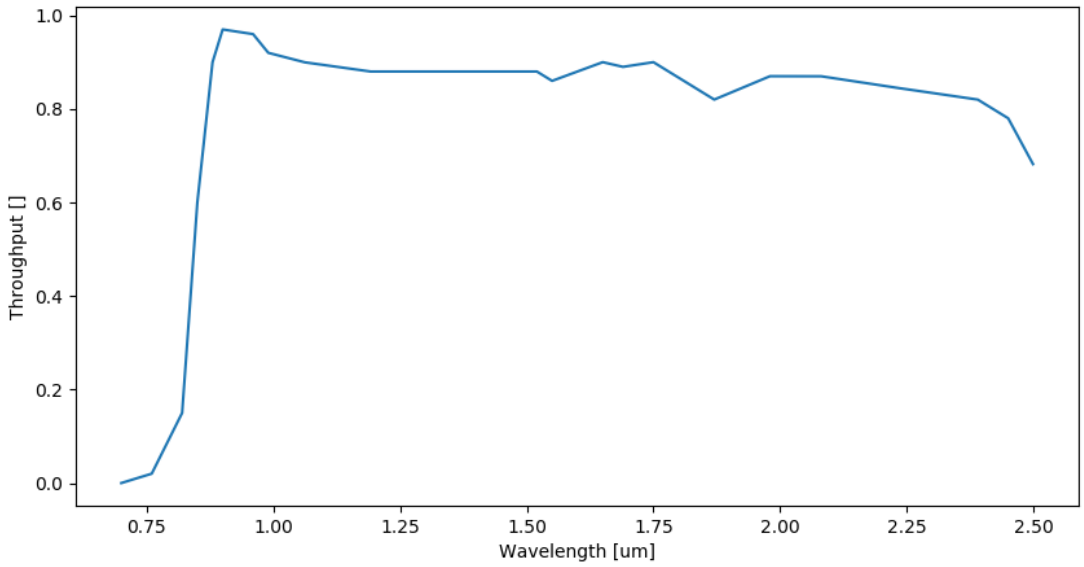
Included by default: `True`

File Description: Quantum efficiency curves for each detector

Class Description: <no docstring>

Changes:

- 2018-11-19 (KL) updated meta data to new format
- 2019-08-09 (KL) Added action keyword to meta data



Data

Meta-data

```
            filename : QE_detector_H2RG.dat
                name : h4rg_qe_curve
```

```
      image_plane_id : 0
         temperature : -230
                 dit : 60
                ndit : 1
               width : 4096
              height : 4096
                   x : 0
                   y : 0
        element_name : micado_sci_detector
              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
     wavelength_unit : um
              action : transmission
             z_order : [113, 513]
             include : True
        ignore_wings : False
            wave_min : 0.7
            wave_max : 2.5
           wave_unit : um
            wave_bin : 0.001
 report_plot_include : True
report_table_include : False
            position : -1
```

3.14.2.3 SummedExposure: "exposure_action"

Included by default: `True`

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

Class Description: Simulates a summed stack of `ndit` exposures

Changes:

-

Data

Meta-data

```
      filename : None
```

```
          name : exposure_action
image_plane_id : 0
   temperature : -230
           dit : !OBS.dit
          ndit : !OBS.ndit
         width : 4096
        height : 4096
             x : 0
             y : 0
  element_name : micado_sci_detector
       z_order : [860]
       include : True
```

3.14.2.4 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
         width : 4096
        height : 4096
             x : 0
             y : 0
  element_name : micado_sci_detector
         value : 0.1
       z_order : [830]
       include : True
```

3.14.2.5 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
         width : 4096
        height : 4096
             x : 0
             y : 0
  element_name : micado_sci_detector
       z_order : [820]
       include : True
   random_seed : !SIM.random.seed
```

3.14.2.6 LinearityCurve: "h4rg_detector_linearity"

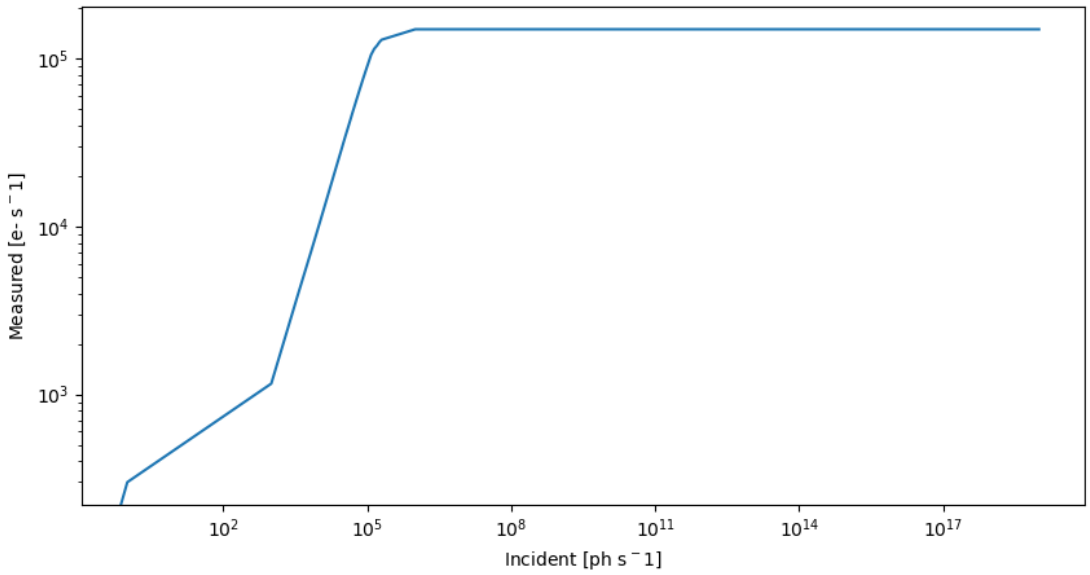
Included by default: `False`

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 : h4rg_detector_linearity
             include : False
       image_plane_id : 0
         temperature : -230
                 dit : !OBS.dit
                ndit : !OBS.ndit
               width : 4096
              height : 4096
                   x : 0
                   y : 0
        element_name : micado_sci_detector
              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]
```

```
 report_plot_include : True
report_table_include : False
```

3.14.2.7 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
               width : 4096
              height : 4096
                   x : 0
                   y : 0
        element_name : micado_sci_detector
           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
 report_plot_include : False
report_table_include : False
```

Chapter 4

Support 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
  background : \{'filter_name': 'Ks', 'value': 13.6, 'unit': 'mag'\}
    spectrum : \{'filename': 'TER_armazones_default_FULL_IMG.dat'\}
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	False	[231]
armazones	armazones_atmo_skycalc_ter_curve	SkycalcTERCurve	False	[112, 512]

4.1.2.1 AtmosphericTERCurve: "armazones_atmo_default_ter_curve"

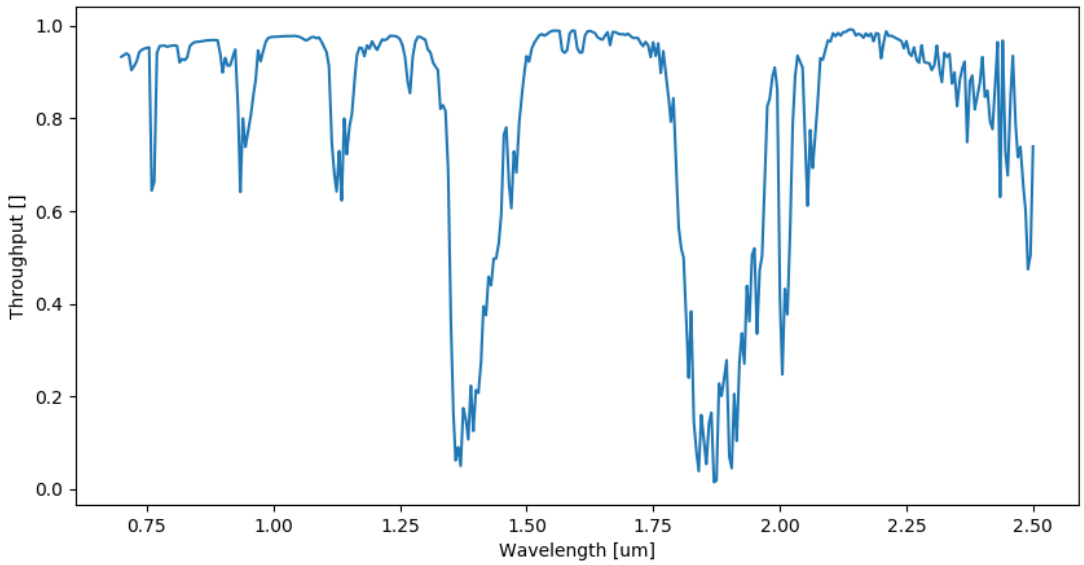
Included by default: `True`

File Description: atmospheric emission and transmission

Class Description: <no docstring>

Changes:

- 2020-10-29 (MV) Created file



Data

Meta-data

```
            filename : TER_armazones_default_FULL_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 : 1.2
         pupil_angle : 0
         pixel_scale : 0.004
          background : \{'filter_name': 'Ks', 'value': 13.6, 'unit': 'mag'\}
            spectrum : \{'filename': 'TER_armazones_default_FULL_IMG.dat'\}
        element_name : armazones
                area : 0
    rescale_emission : \{'filter_name': 'Ks', 'filename_format': 'filters/TC_
              author : Miguel Verdugo
              source : skycalc_ipy tool for standard Armazones conditions
        date_created : 2020-10-29
```

```
       date_modified : 2020-10-29
              status : Design
                type : atmosphere:ter_curve
              wdelta : 10
                wmin : 300
                wmax : 15000
              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 : 0.7
            wave_max : 2.5
           wave_unit : um
            wave_bin : 0.0001
 report_plot_include : True
report_table_include : False
            position : 0
```

4.1.2.2 AtmosphericDispersion: "armazones_atmo_dispersion"

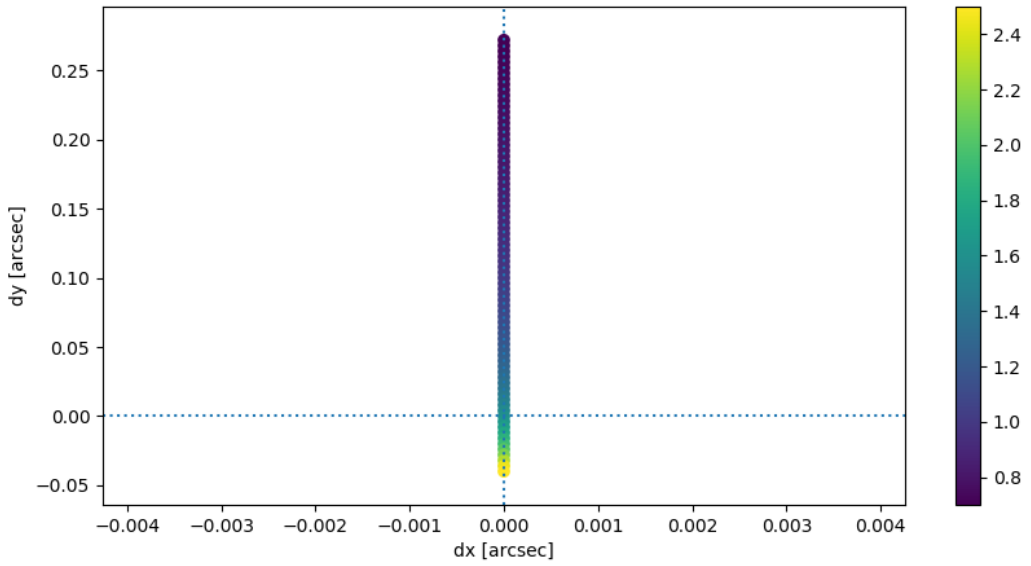
Included by default: `False`

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
             include : False
            altitude : 3060
           longitude : -70.1918
            latitude : -24.5899
         temperature : 7
            humidity : 0.1
            pressure : 0.755
                 pwv : 2.5
             airmass : 1.2
         pupil_angle : 0
         pixel_scale : 0.004
          background : \{'filter_name': 'Ks', 'value': 13.6, 'unit': 'mag'\}
            spectrum : \{'filename': 'TER_armazones_default_FULL_IMG.dat'\}
        element_name : armazones
             z_order : [231]
 report_plot_include : True
report_table_include : False
            wave_min : 0.7
            wave_mid : 1.6
```

```
           wave_max : 2.5
sub_pixel_fraction : 1
         num_steps : 1000
                z0 : 33.55730976192071
              temp : 7
           rel_hum : 10.0
              pres : 755.0
               lat : -24.5899
                 h : 3060
```

4.1.2.3 SkycalcTERCurve: "armazones_atmo_skycalc_ter_curve"

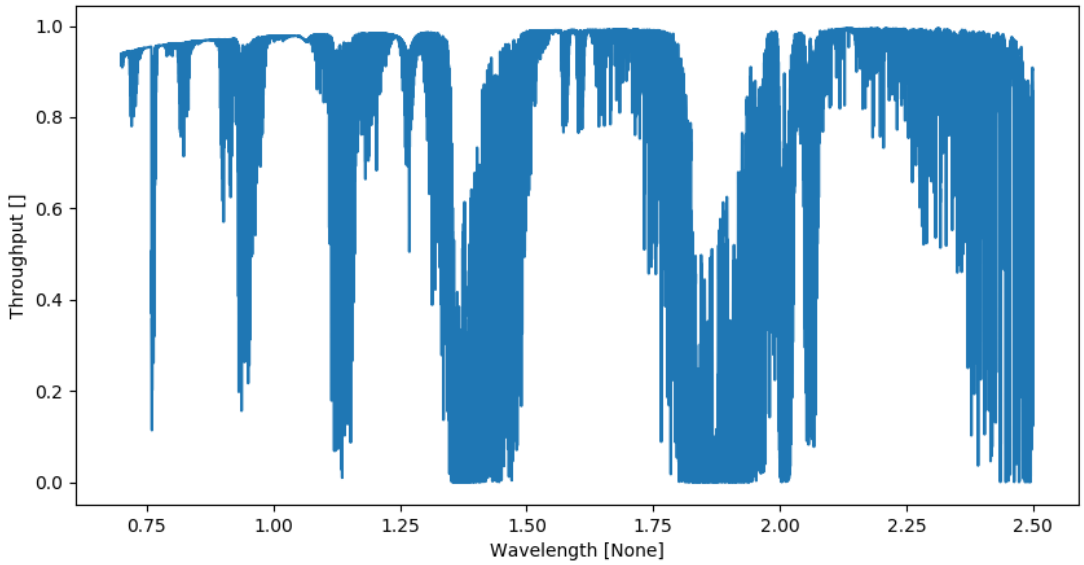
Included by default: `False`

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 : 1.2
         pupil_angle : 0
         pixel_scale : 0.004
          background : \{'filter_name': 'Ks', 'value': 13.6, 'unit': 'mag'\}
            spectrum : \{'filename': 'TER_armazones_default_FULL_IMG.dat'\}
        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 : 0.7
            wave_max : 2.5
           wave_unit : um
            wave_bin : 0.0001
 report_plot_include : True
report_table_include : False
              action : transmission
            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"

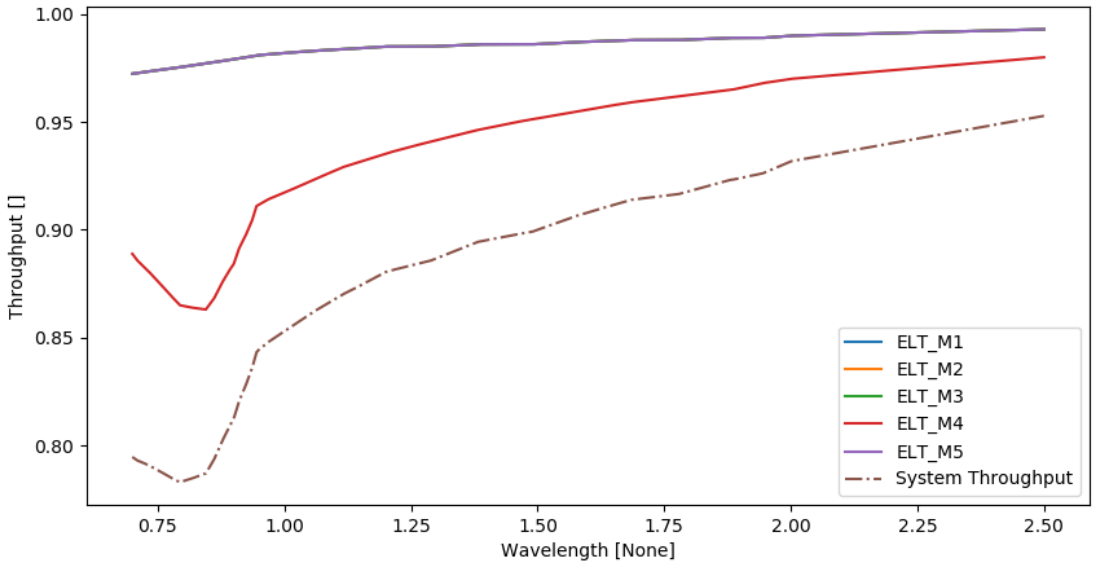
Included by default: `True`

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



name	outer	inner	angle	temperature	action	filename
ELT_M1	36.9	10.95	0.0	!ATMO.temperature	reflection	TER_ELT_mirror_mgf2agal.dat
ELT_M2	4.2	0.545	0.0	!ATMO.temperature	reflection	TER_ELT_mirror_mgf2agal.dat
ELT_M3	3.8	0.14	0.0	!ATMO.temperature	reflection	TER_ELT_mirror_mgf2agal.dat
ELT_M4	2.54	0.536	7.75	!ATMO.temperature	reflection	TER_ELT_mirror_aluminium.da
ELT_M5	2.66	0.0	37.25	!ATMO.temperature	reflection	TER_ELT_mirror_mgf2agal.dat

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 ES
             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
 report_plot_include : True
report_table_include : True
  minimum_throughput : !SIM.spectral.minimum_throughput
             etendue : !TEL.etendue
```

4.2.2.2 Vibration: "scope_vibration"

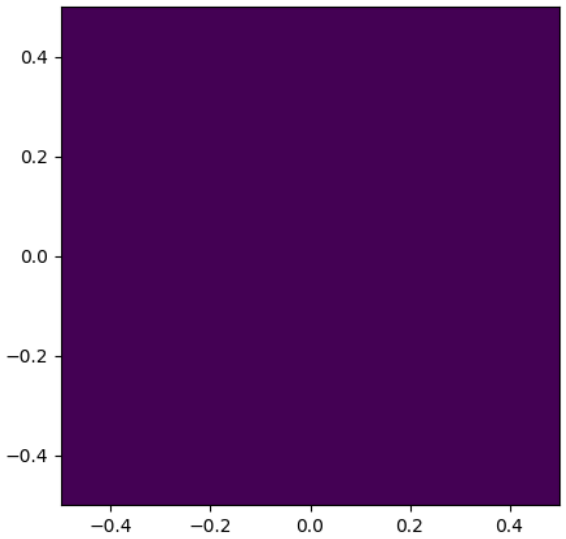
Included by default: `True`

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
 report_plot_include : True
report_table_include : False
       width_n_fwhms : 4
```

4.2.2.3 TERCurve: "eso_combined_reflection"

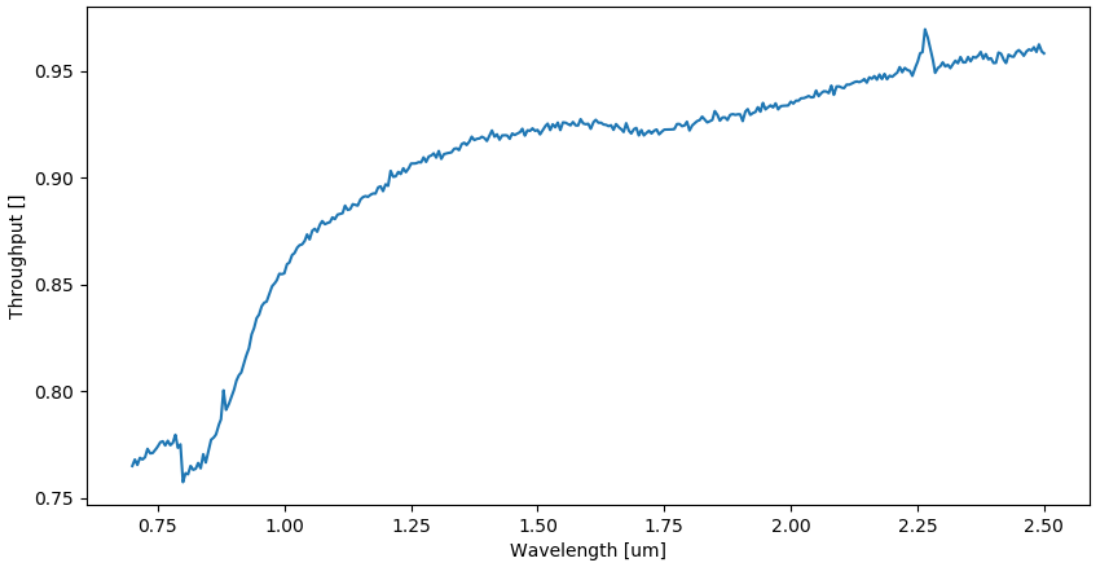
Included by default: `False`

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 : 7
        element_name : ELT
          temperture : 7
              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 contami
             z_order : [10, 110, 510]
       ignore_wings : False
```

```
            wave_min : 0.7
            wave_max : 2.5
           wave_unit : um
            wave_bin : 0.0001
 report_plot_include : True
report_table_include : False
```

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"

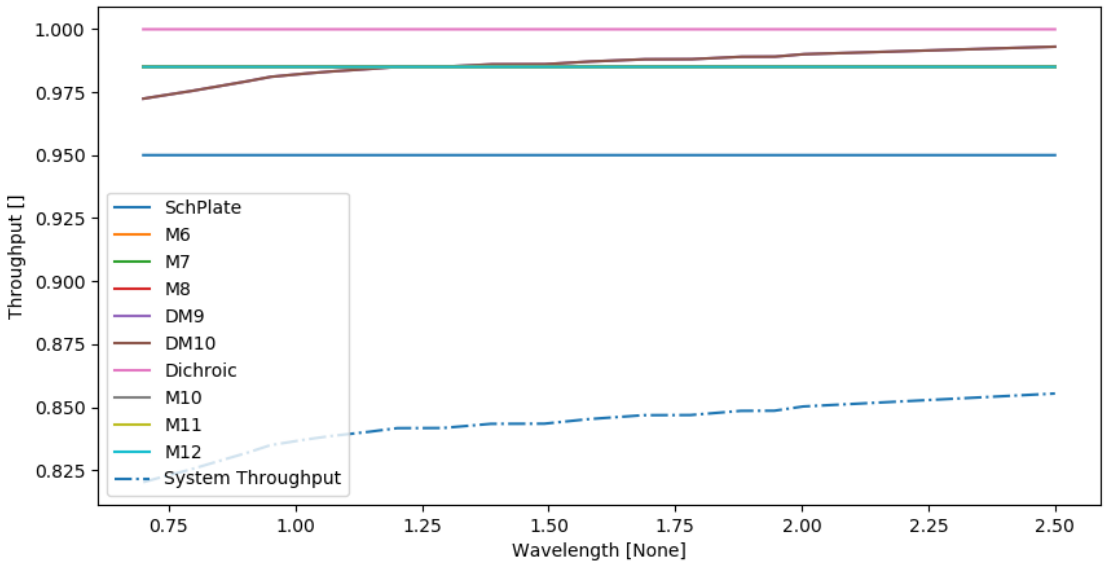
Included by default: `True`

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) Updated file to match the MMS configuration from Carmelo
- 2020-08-17 (KL) Pegged temperature to atmosphere
- 2020-12-03 (KL)



name	outer	inner	angle	temperature	action	filename
SchPlate	1.1	0.0	0.0	!ATMO.temperature	transmission	TER_entrance_window.dat
M6	1.1	0.0	0.0	!ATMO.temperature	reflection	TER_MAORY_mirror_silver.da
M7	0.7	0.0	0.0	!ATMO.temperature	reflection	TER_MAORY_mirror_silver.da
M8	0.85	0.0	0.0	!ATMO.temperature	reflection	TER_MAORY_mirror_silver.da
DM9	0.75	0.0	0.0	!ATMO.temperature	reflection	TER_MAORY_mirror_mgf2aga
DM10	0.75	0.0	0.0	!ATMO.temperature	reflection	TER_MAORY_mirror_mgf2aga
Dichroic	0.6	0.0	0.0	!ATMO.temperature	reflection	TER_MAORY_lgs_dichroic.dat
M10	0.6	0.0	0.0	!ATMO.temperature	reflection	TER_MAORY_mirror_silver.da
M11	0.8	0.0	45.0	!ATMO.temperature	reflection	TER_MAORY_mirror_silver.da
M12	0.8	0.0	0.0	!ATMO.temperature	reflection	TER_MAORY_mirror_silver.da

Data

Meta-data

```
            filename : LIST_mirrors_maory_mms.tbl
                name : maory_surface_list
         temperature : !ATMO.temperature
       psf_filename : None
       element_name : MAORY
             author : Kieran Leschinski
```

```
              source : Carmelo Archidiacono private email
        date_created : 2018-11-19
       date_modified : 2020-06-22
              status : Design, new MAORY MMS design
          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
 report_plot_include : True
report_table_include : True
  minimum_throughput : !SIM.spectral.minimum_throughput
             etendue : !TEL.etendue
```

4.3.2.2 FieldConstantPSF: "maory_generic_psf"

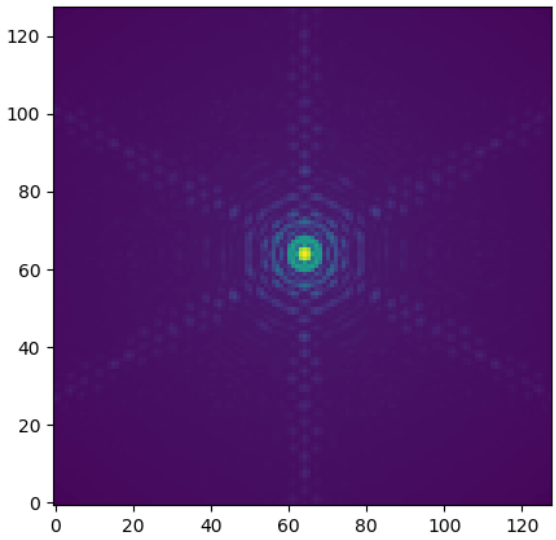
Included by default: `True`

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
 report_plot_include : True
report_table_include : False
```

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"

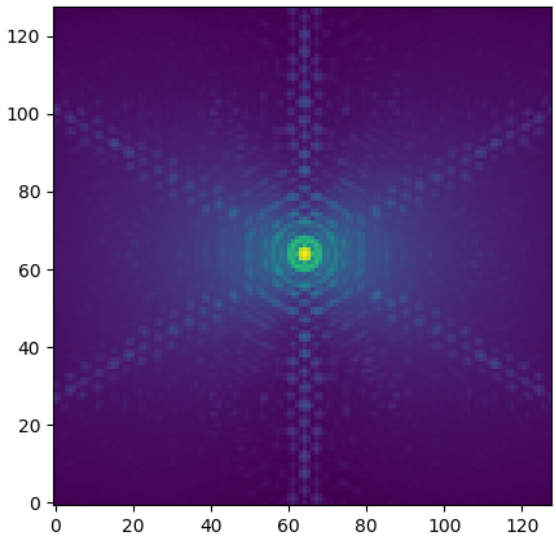
Included by default: `True`

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
 report_plot_include : True
report_table_include : False
```

4.4.2.2 SurfaceList: "relay_surface_list"

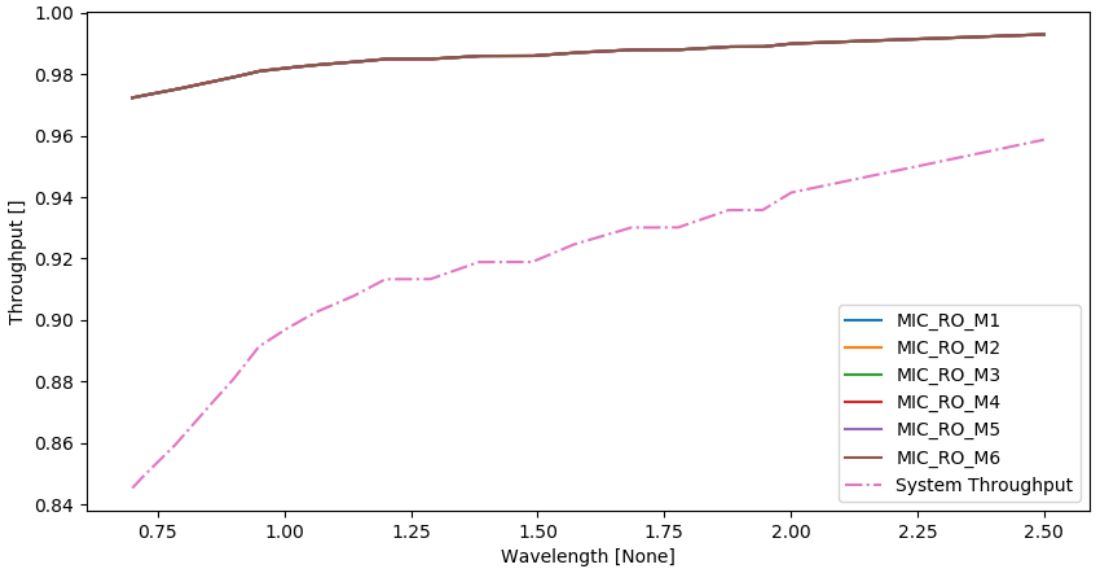
Included by default: `True`

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



name	outer	inner	angle	temperature	action	filename
MIC_RO_M1	0.505	0.0	45.0	!ATMO.temperature	reflection	TER_MICADO_mirror_mgf2aga
MIC_RO_M2	0.51	0.0	10.0	!ATMO.temperature	reflection	TER_MICADO_mirror_mgf2aga
MIC_RO_M3	0.184	0.0	10.0	!ATMO.temperature	reflection	TER_MICADO_mirror_mgf2aga
MIC_RO_M4	0.53	0.0	10.0	!ATMO.temperature	reflection	TER_MICADO_mirror_mgf2aga
MIC_RO_M5	0.406	0.0	20.0	!ATMO.temperature	reflection	TER_MICADO_mirror_mgf2aga
MIC_RO_M6	0.406	0.0	35.0	!ATMO.temperature	reflection	TER_MICADO_mirror_mgf2aga

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.pd
        date_created : 2018-11-19
       date_modified : 2020-08-17
              status : Design, pre FDR list of stand-alone SCAO relay optics
                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
 report_plot_include : True
report_table_include : True
  minimum_throughput : !SIM.spectral.minimum_throughput
             etendue : !TEL.etendue
```