

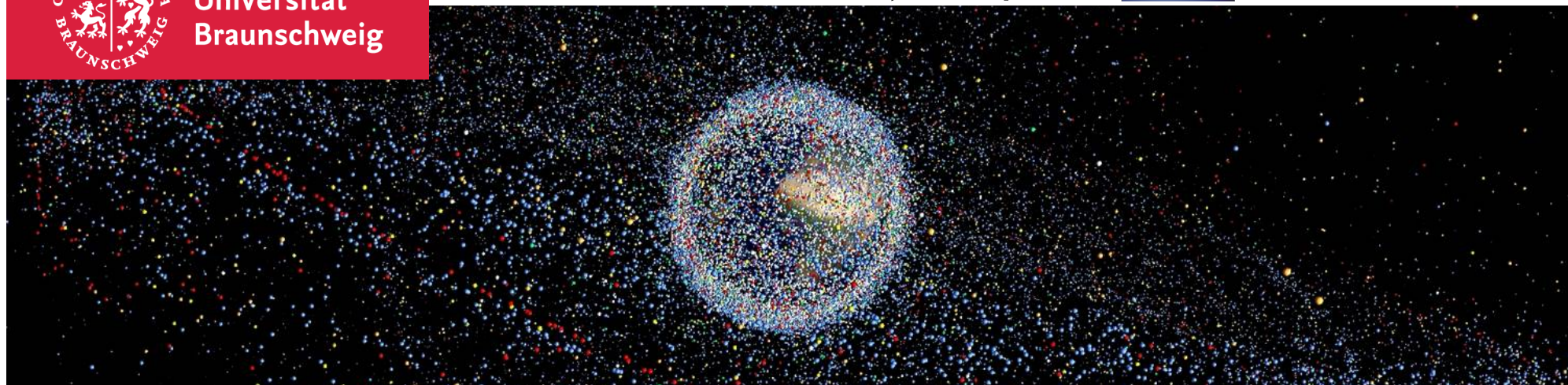


Technische  
Universität  
Braunschweig

Institute of  
Space Systems



esa



## Final Presentation ESA-MASTER: Hands-on

Enhancement of S/C Fragmentation and Environment Evolution Models

March 21<sup>st</sup>, 2019

Presenter: André Horstmann and Sebastian Hesselbach

# Things covered during this demo presentation

- Basics: General overview
- Basics: Spatial Density in LEO
- Basics: Lagrange flux calculation
- Basics: Flux evaluation ( $d > 1\text{mm}$ ) on a SSO
- Basics: Comparison of collision probability for different size thresholds
  
- Advanced: Impact velocity/azimuth on defined oriented surface (2D + 3D)
- Advanced: Spatial density – declination vs. altitude (3D)

# Basics: General overview



# Basics: General Overview

ESA MASTER is available as download from:

<https://sdup.esoc.esa.int/>

Supported platforms are:

- Windows
- Linux (32bit / 64 bit)
- macOS/OSX

To make the MASTER installer leaner, it contains only the reference population (November 11, 2016 for MASTER-8). To add additional population files, download them here and unzip them into <MASTER installation directory>/data/.

# Basics: General Overview

ESA MASTER is available as download from:

<https://sdup.esoc.esa.int/>

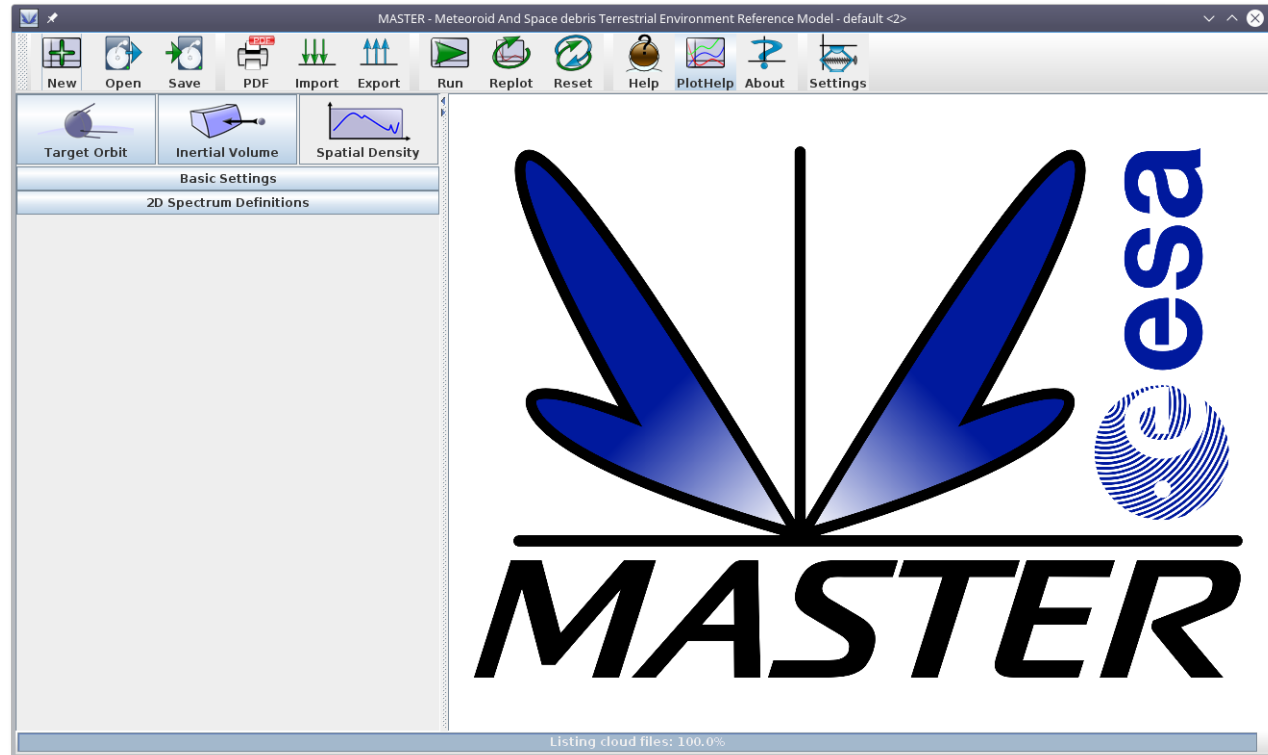
**Also available:**

- **Software User Manual**
- **License Agreement**

→ **Launching ESA MASTER ...**

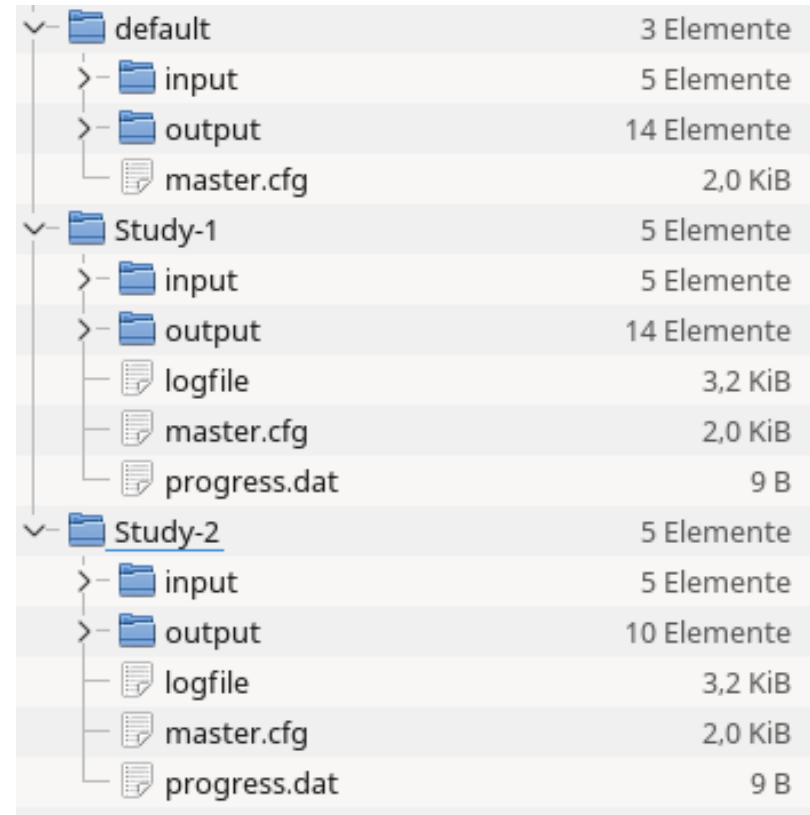
# Basics: General Overview

- New MASTER Logo
- Clean user interface
- Left: User input
  - Basic Settings
  - 2D-Spectrum definitions
- Middle: Presentation of results
- Right: Output selection
- Three Scenarios



# Basics: General Overview

- Handing of multiple projects
- Clean workspace environment
- Output includes raw data output

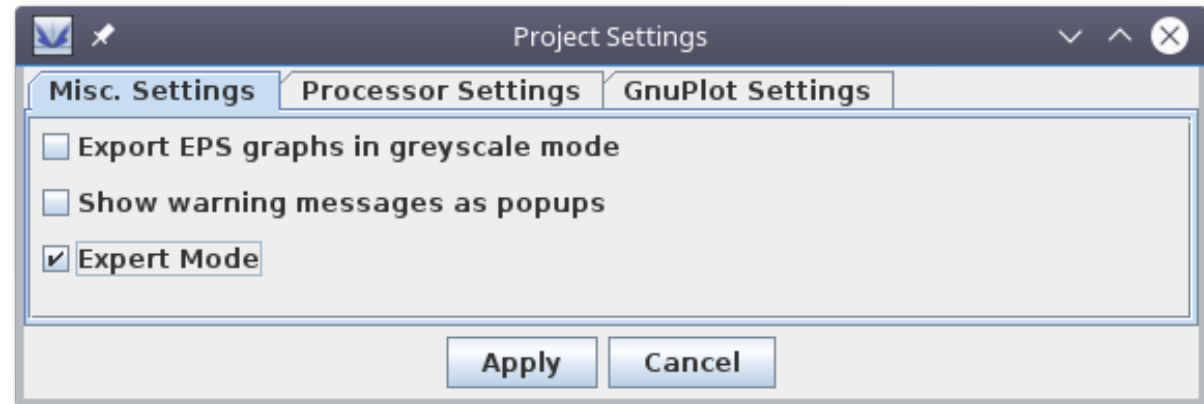


The image shows a file explorer view of a workspace. The root directory contains three main folders: 'default', 'Study-1', and 'Study-2'. Each folder has a sub-structure of 'input' and 'output' folders, along with configuration and data files. The 'default' folder contains a 'master.cfg' file. 'Study-1' contains 'logfile', 'master.cfg', and 'progress.dat'. 'Study-2' contains 'logfile', 'master.cfg', and 'progress.dat'. The 'output' folders contain 14 elements each, while the 'input' folders contain 5 elements each.

Folder/Item	Count/Size
default	3 Elemente
input	5 Elemente
output	14 Elemente
master.cfg	2,0 KiB
Study-1	5 Elemente
input	5 Elemente
output	14 Elemente
logfile	3,2 KiB
master.cfg	2,0 KiB
progress.dat	9 B
Study-2	5 Elemente
input	5 Elemente
output	10 Elemente
logfile	3,2 KiB
master.cfg	2,0 KiB
progress.dat	9 B

# Basics: General Overview

- Handing of multiple projects
- Clean workspace environment
- Output includes raw data output
- Two different modes:
  - Basic Mode
  - Expert Mode





# Basics: Spatial Density in LEO



# Basics: Spatial Density in LEO

**Task** Obtain a 2D Spatial Density plot for LEO (200 km – 2000 km) and objects larger than 1cm in diameter at November 1<sup>st</sup>, 2016

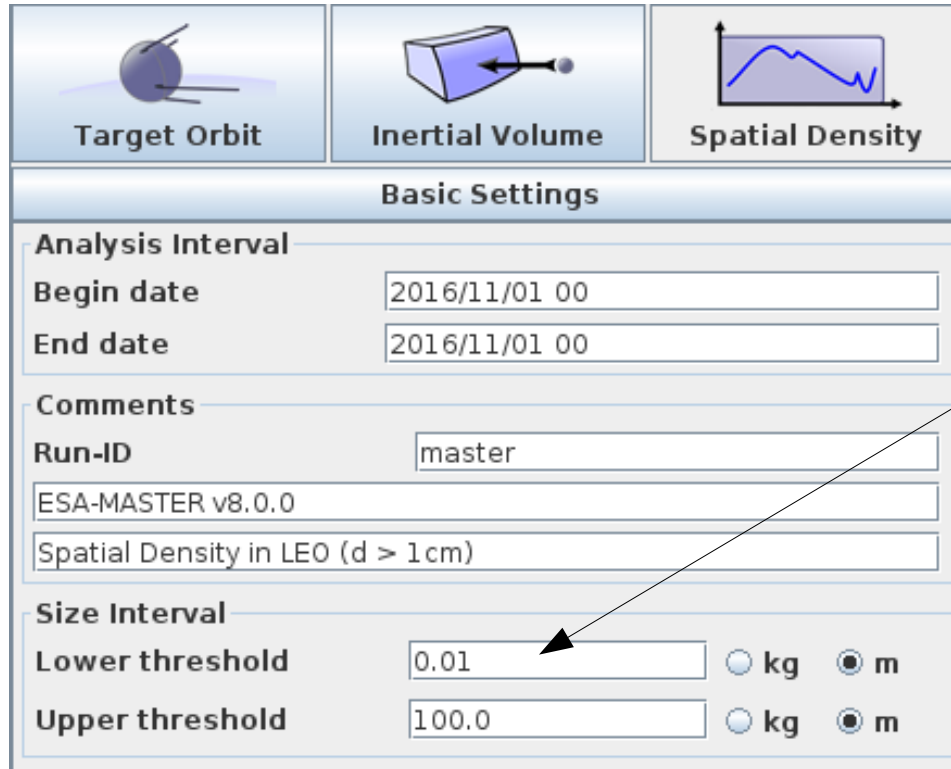
**Steps**

- 1) Set object size intervall in 'Basic Settings'
- 2) Set desired output spectrum in '2D Spectrum Definitions'
- 3) Click 'Run'

**Result** A 2D-plot showing Spatial Density vs. Altitude in LEO at November 1<sup>st</sup>, 2016 (with and without uncertainty bars).

# Basics: Spatial Density in LEO

1) Set object size intervall in 'Basic Settings'



The screenshot shows the 'Basic Settings' panel for 'Spatial Density' analysis. The 'Size Interval' section is highlighted with an arrow pointing to the 'Lower threshold' field, which contains the value '0.01'. The 'Upper threshold' field contains '100.0'. The units are set to 'm' (meters) for both thresholds.

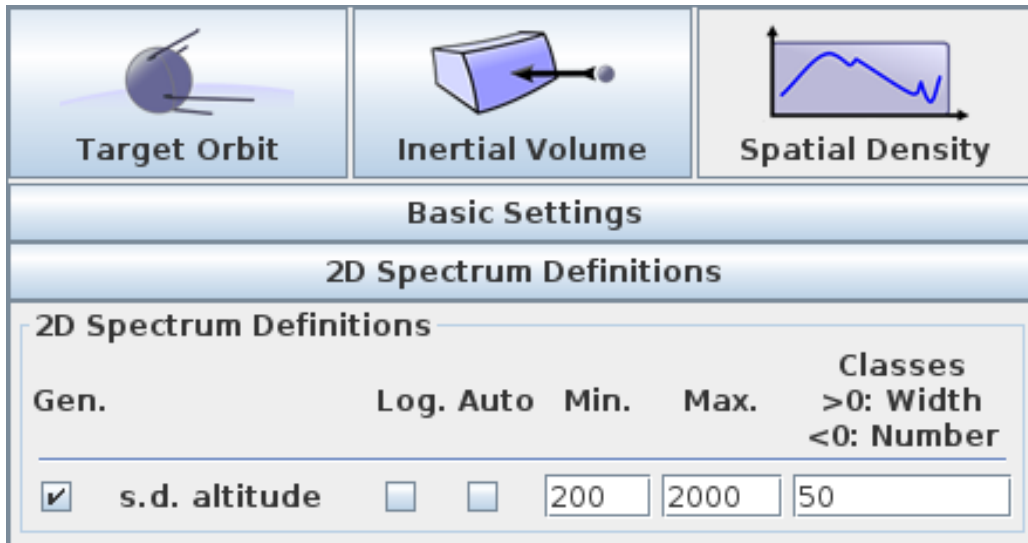
Section	Field	Value	Unit
Analysis Interval	Begin date	2016/11/01 00	
	End date	2016/11/01 00	
Comments	Run-ID	master	
		ESA-MASTER v8.0.0	
		Spatial Density in LEO (d > 1cm)	
Size Interval	Lower threshold	0.01	m
	Upper threshold	100.0	m

0.01 meters

**Click 'Apply' to save changes!**

# Basics: Spatial Density in LEO

2) Set desired output spectrum in '2D Spectrum Definitions'

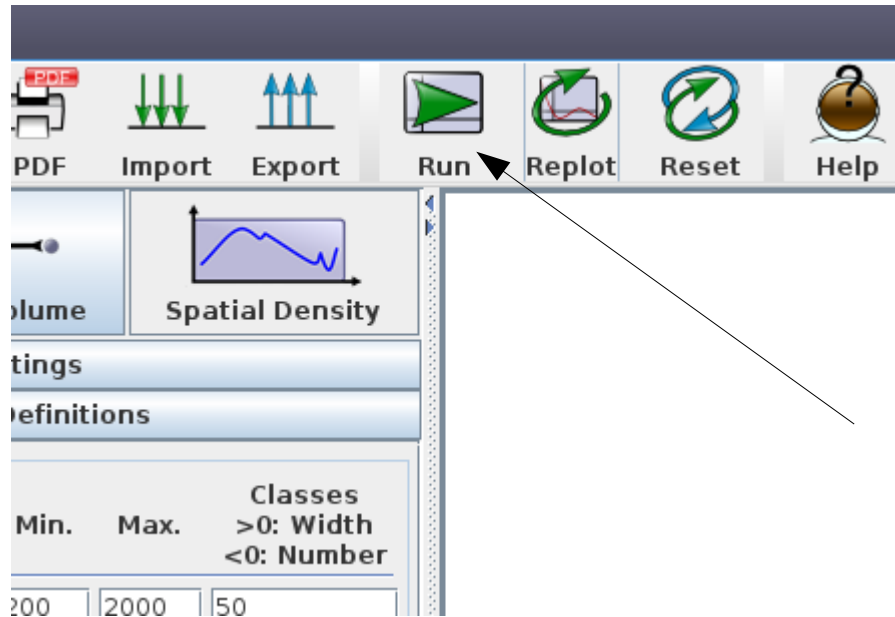


Minimum altitude: 200 km  
Maximum altitude: 2000 km  
Altitude stepwidth: 50 km  
Linear scale

**Click 'Apply' to save changes!**

# Basics: Spatial Density in LEO

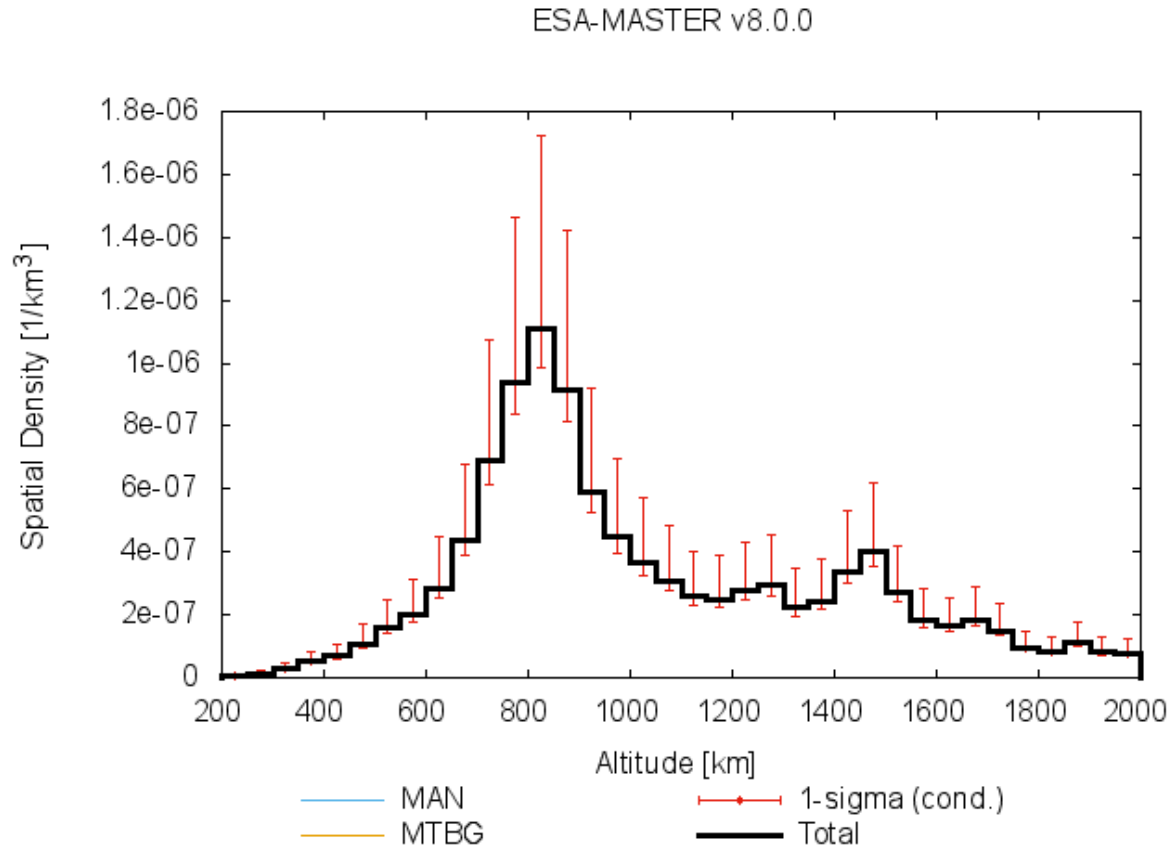
3) Click 'Run'



# Basics: Spatial Density in LEO

## Result:

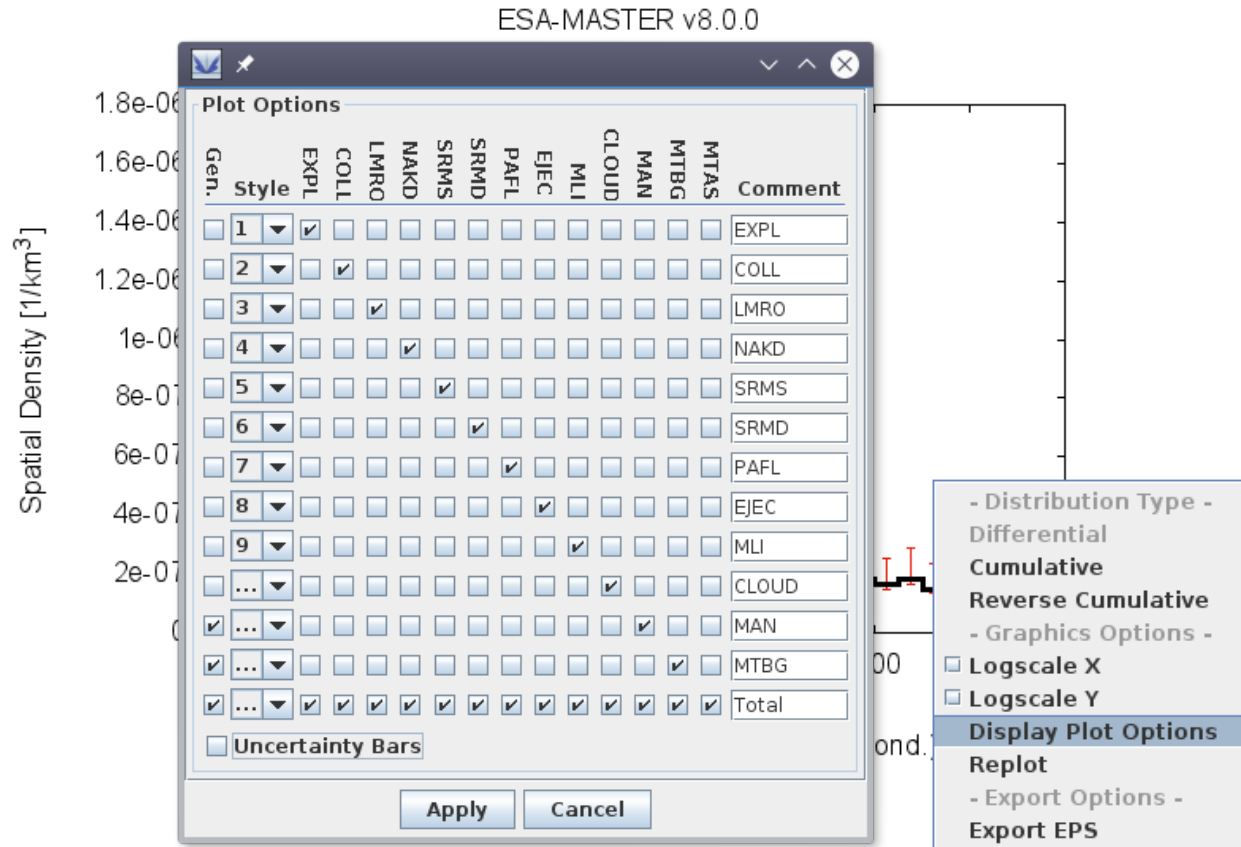
Spatial density in LEO (200 km to 2000 km) for objects with diameter  $d > 1\text{cm}$  at November 2016 (with uncertainty bars).



# Basics: Spatial Density in LEO

## Result:

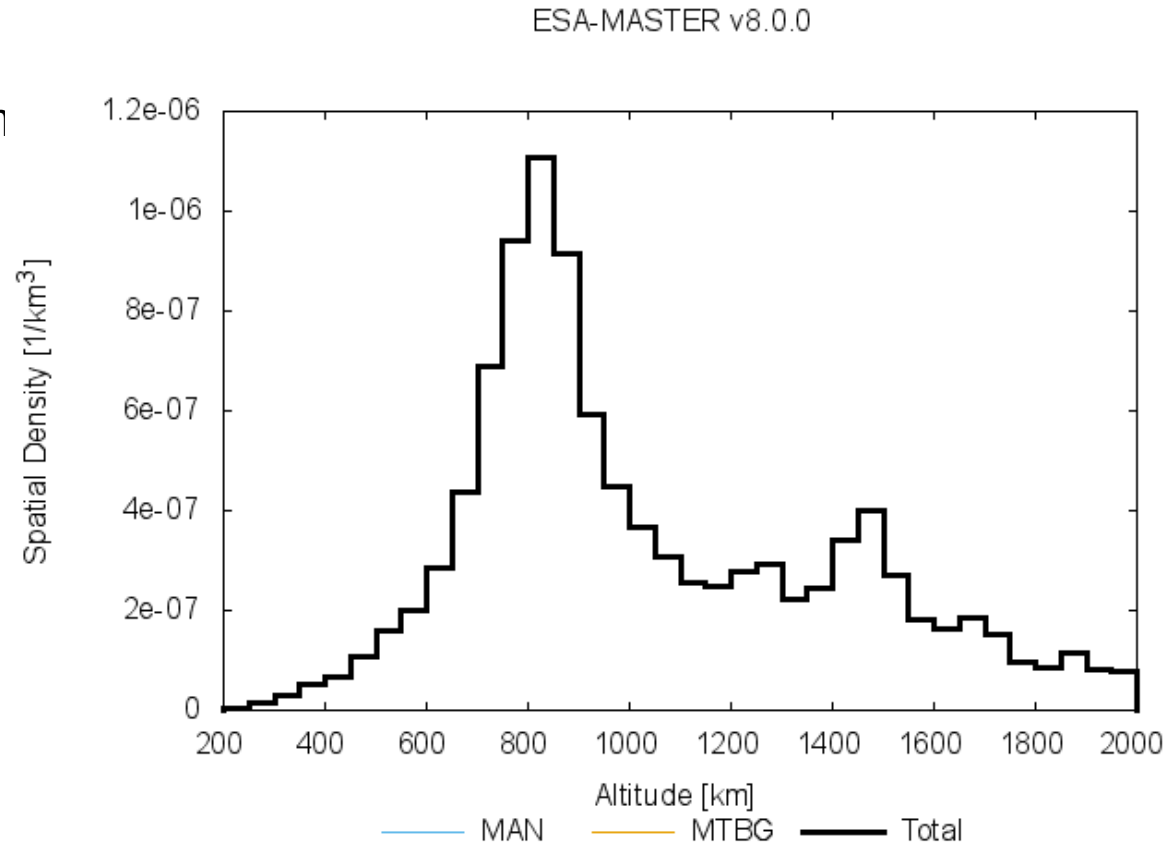
if you do not want to show the uncertainty bars →  
Right-click on the plot area



# Basics: Spatial Density in LEO

## Result:

Spatial density in LEO (200 km to 2000 km) for objects with diameter  $d > 1\text{cm}$  at November 2016 (without uncertainty bars).





# Basics: Lagrange flux calculation



# Basics: Lagrange flux calculation

<b>Task</b>	Obtain a 2D-Flux plot for a Lagrange point and objects larger than $1\mu\text{m}$ in diameter
<b>Steps</b>	<ol style="list-style-type: none"><li>1) Selecting 'Target Orbit' as scenario</li><li>2) Switching from 'Earth-bound' to 'Lagrange point'</li><li>3) Set desired output spectrum in '2D Spectrum Definitions'</li><li>4) Click 'Run'</li></ol>
<b>Result</b>	A 2D-plot showing 2D-flux vs. Diameter in a Lagrange point.

# Basics: Lagrange flux calculation

Target Orbit    Inertial Volume    Spatial Density

**Basic Settings**

Analysis Interval

Begin date    2016/11/01 00

End date    2016/11/01 00

Comments

Run-ID    master

ESA-MASTER v8.0.0

Lagrange point calculation

Selection

Earth-bound     Lagrange point

Target Orbit Settings

Lower argument of true latit... 0.0

1) Switching to 'Target Orbit'

2) Selecting 'Lagrange point'

**Click 'Apply' to save changes!**

# Basics: Lagrange flux calculation

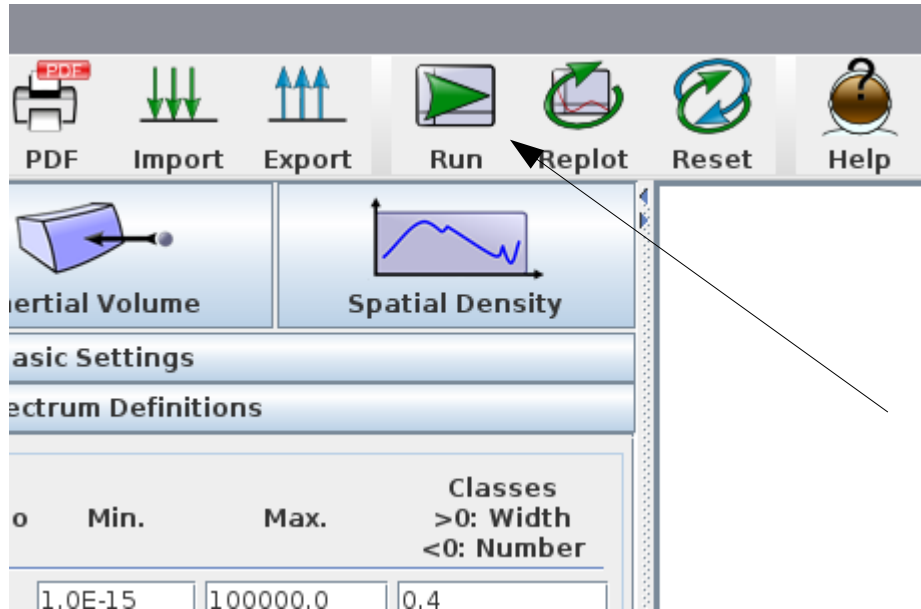
Gen.	Log.	Auto	Min.	Max.	Classes >0: Width <0: Number
<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1.0E-15	100000.0	0.4
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1.0E-6	100.0	-100
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1957.0	2016.0	-200.0

- 3)  
Logarithmic scale  
Minimum diameter: 1  $\mu\text{m}$   
Maximum diameter: 100 m  
Diameter steps: 100 steps!

**Click 'Apply' to save changes!**

# Basics: Lagrange flux calculation

4) Click 'Run'

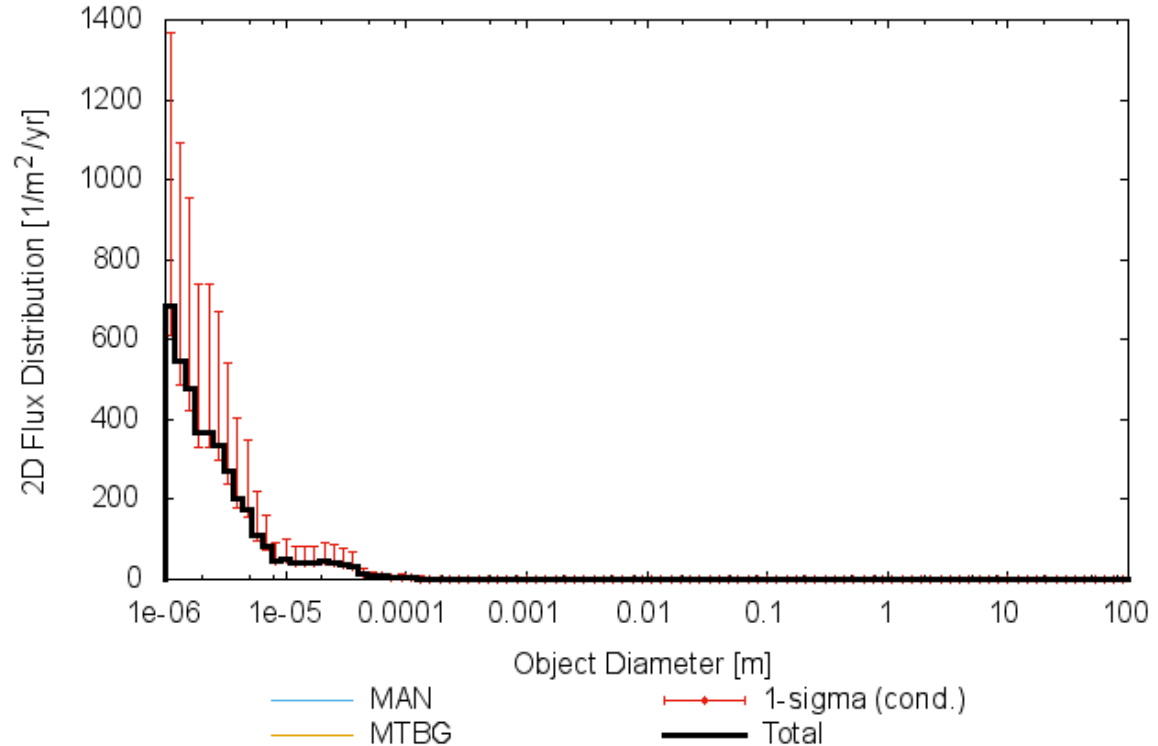


# Basics: Lagrange flux calculation

## Result:

2D-plot showing 2D-flux vs. Diameter in a Lagrange point.

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# Basics: Lagrange flux calculation

## Result:

2D-plot showing 2D-flux vs. Diameter in a Lagrange point.

(optional)

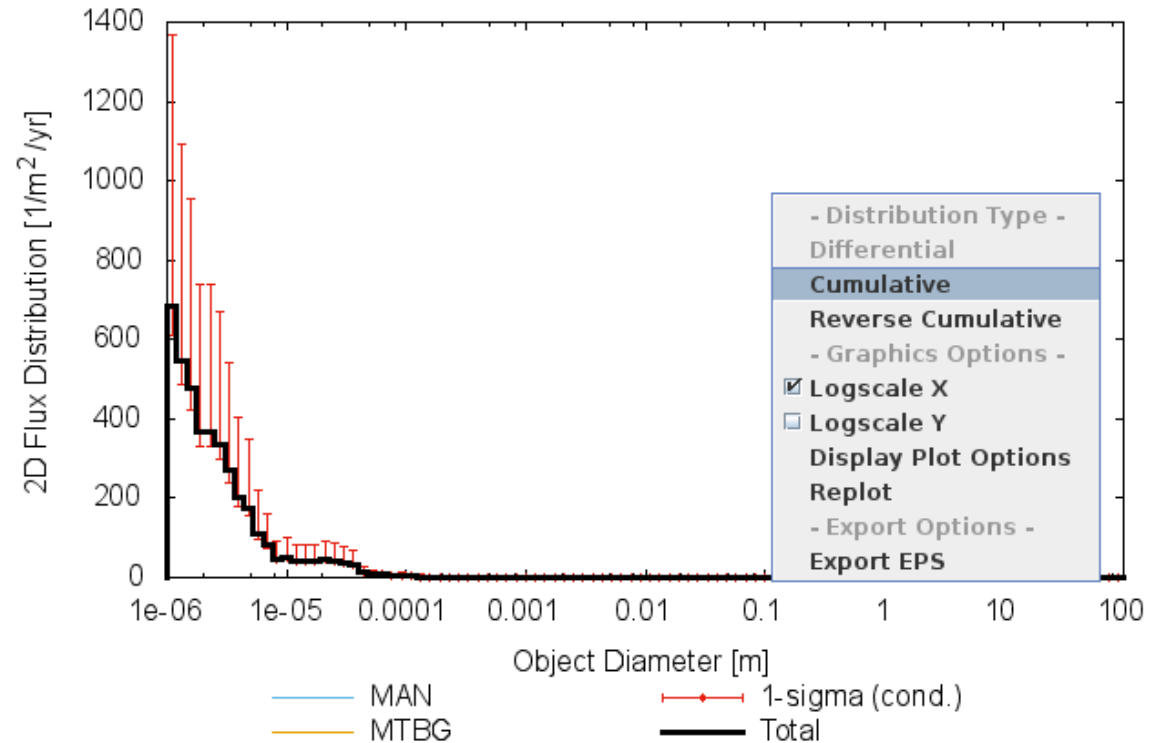
→ *Right-click on plot area*

→ *Select 'Cumulative'*

→ *Right-click on plot area*

→ *Select 'Logscale Y'*

ESA-MASTER v8.0.0



# Basics: Lagrange flux calculation

## Result:

2D-plot showing 2D-flux vs. Diameter in a Lagrange point.

(optional)

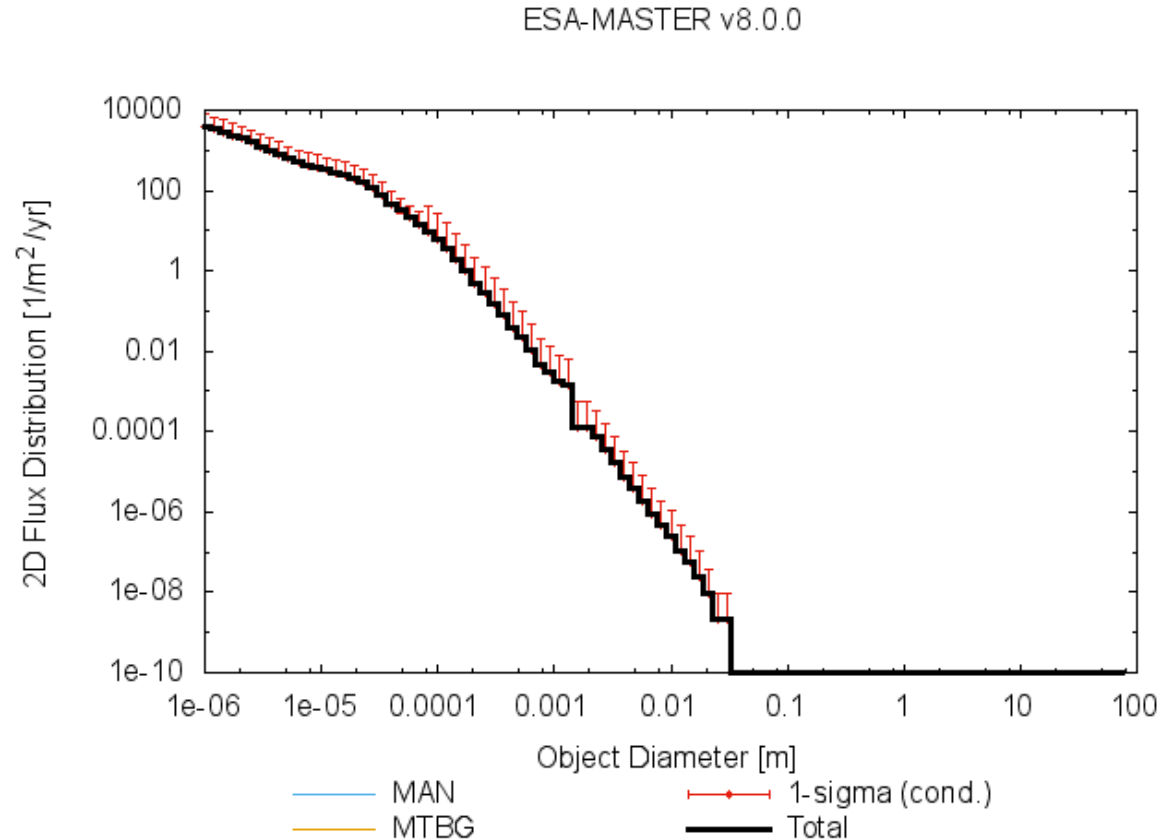
→ Right-click on plot area

→ Select 'Cumulative'

→ Right-click on plot area

→ Select 'Logscale Y'

Done!





# Basics: Flux evaluation ( $d > 1\text{mm}$ ) on a SSO



# Basics: Flux evaluations ( $d > 1\text{mm}$ ) on a SSO

**Task** Obtain a 2D-Flux plot for a Sun-synchronous orbit and objects larger than 1mm in diameter in November 2016.

- Steps**
- 1) 'Target Orbit' scenario already selected
  - 2) Switching from 'Lagrange point' to 'Earth-bound' in Basic Settings
  - 3) Define a SSO of your choice, e.g. **Envisat** Orbit
    - Semi-major axis: 7136 km
    - Eccentricity: 0.001
    - Inclination:  $98.6^\circ$
    - RAAN:  $110.0^\circ$
    - AoP:  $200.0^\circ$
  - 4) Set desired output spectrum in '2D Spectrum Definitions'
  - 5) Click 'Run'

**Result** A 2D-plot showing 2D-flux vs. Diameter on a SSO, here: on an Envisat orbit.

# Basics: Flux evaluations ( $d > 1\text{mm}$ ) on a SSO



- **Environment Satellite**
- Launched in 2002
- 8110 kg (incl. 319 kg hydrazine)
- Average cross-section: 75 m<sup>2</sup>
- Un-controlled state
- Current altitude: 765 km
- 150 years remaining lifetime (aerodynamic decay)
- Top priority target for active debris removal missions

# Basics: Flux evaluations ( $d > 1\text{mm}$ ) on a SSO

Target Orbit

Inertial Volume

Spatial Density

Basic Settings\*

Analysis Interval

Begin date: 2016/11/01 00

End date: 2016/11/01 00

Comments

Run-ID: master

ESA-MASTER v8.0.0

Flux ( $d > 1\text{mm}$ ) on Sun-synchronous orbit (Envisat)

Selection

Earth-bound  Lagrange point

Target Orbit Settings

Lower argument of true latitud...: 0.0

Upper argument of true latitud...: 360.0

Target orbits (Singly Averaged Elements)

Prop.	Start epoch	End epoch	SMA	ECC	INC	RAAN	AoP
<input type="checkbox"/>	2016 11 01 00	2016 11 01 00	7136	0.001	98.6	110.0	200.0

Resolution: 1 Year

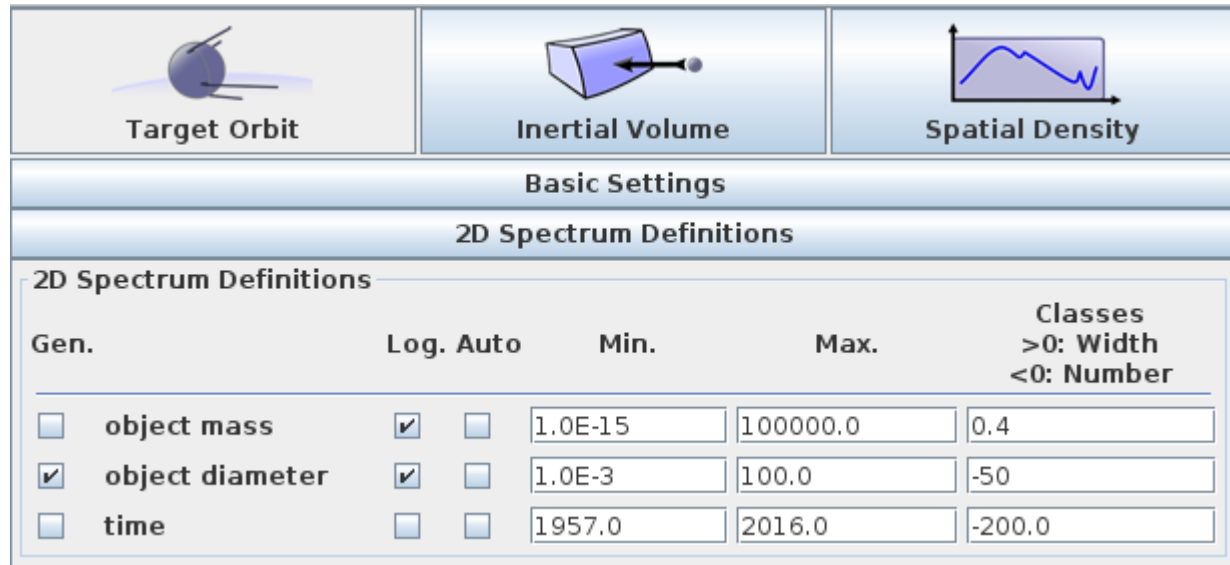
Add mission phase

1) 'Target Orbit' selected

2) Switching back to 'Earth-bound'

3)  
SMA / km: 7136  
ECC / -: 0.001  
INC / °: 98.6  
RAAN / °: not used  
AoP / °: 200

# Basics: Flux evaluations ( $d > 1\text{mm}$ ) on a SSO



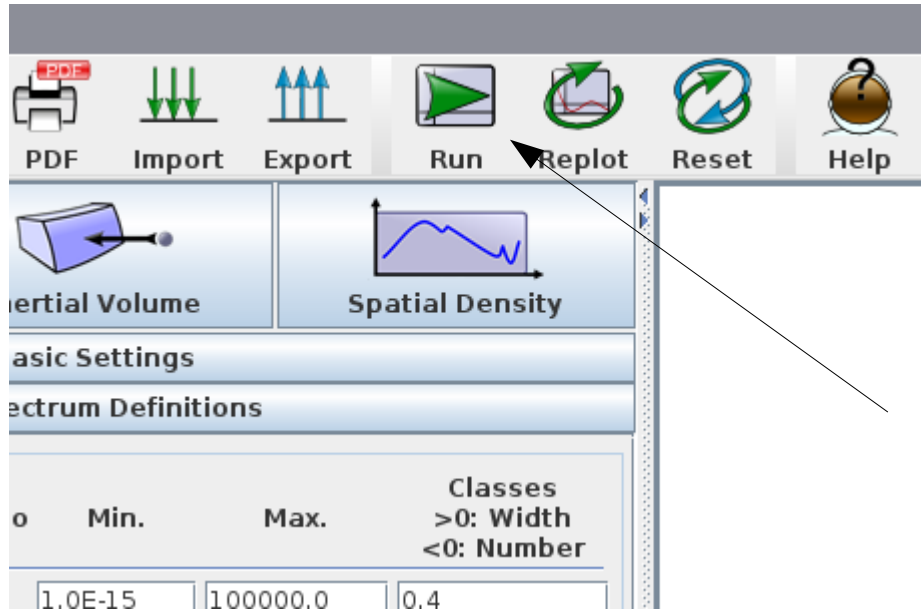
The screenshot shows the '2D Spectrum Definitions' window in the ESA-Master software. It features three tabs at the top: 'Target Orbit', 'Inertial Volume', and 'Spatial Density'. Below the tabs are sections for 'Basic Settings' and '2D Spectrum Definitions'. The '2D Spectrum Definitions' section contains a table with the following data:

Gen.	Log.	Auto	Min.	Max.	Classes >0: Width <0: Number
<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1.0E-15	100000.0	0.4
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1.0E-3	100.0	-50
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1957.0	2016.0	-200.0

- 4)  
Minimum diameter: 1 mm  
Maximum diameter: 100 m  
Diameter steps: 50 steps!  
Logarithmic scale

# Basics: Flux evaluations ( $d > 1\text{mm}$ ) on a SSO

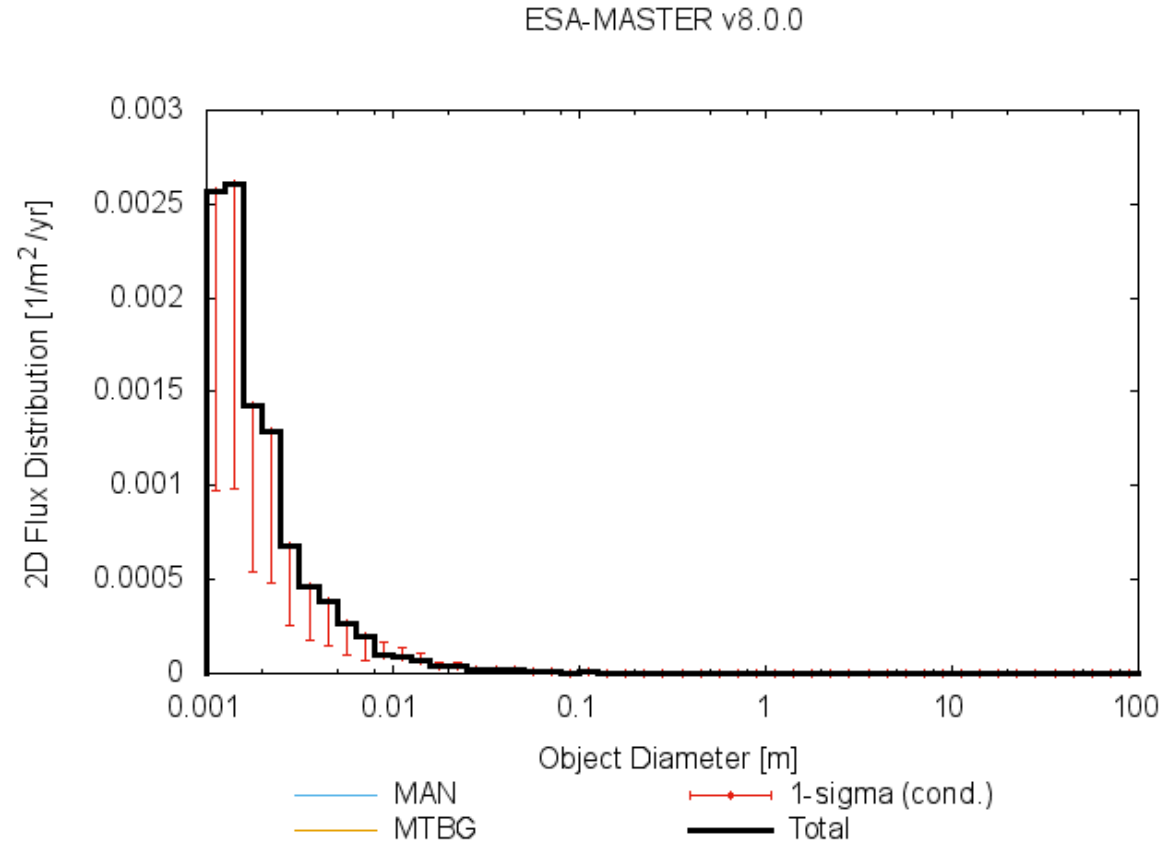
5) Click 'Run'



# Basics: Flux evaluations ( $d > 1\text{mm}$ ) on a SSO

## Result:

2D-plot showing 2D-flux vs. Diameter on a SSO orbit in November 2016. In this example on an Envisat orbit.



# Basics: Flux evaluations ( $d > 1\text{mm}$ ) on a SSO

## Result:

2D-plot showing 2D-flux vs. Diameter on a SSO orbit in November 2016. In this example on an Envisat orbit.

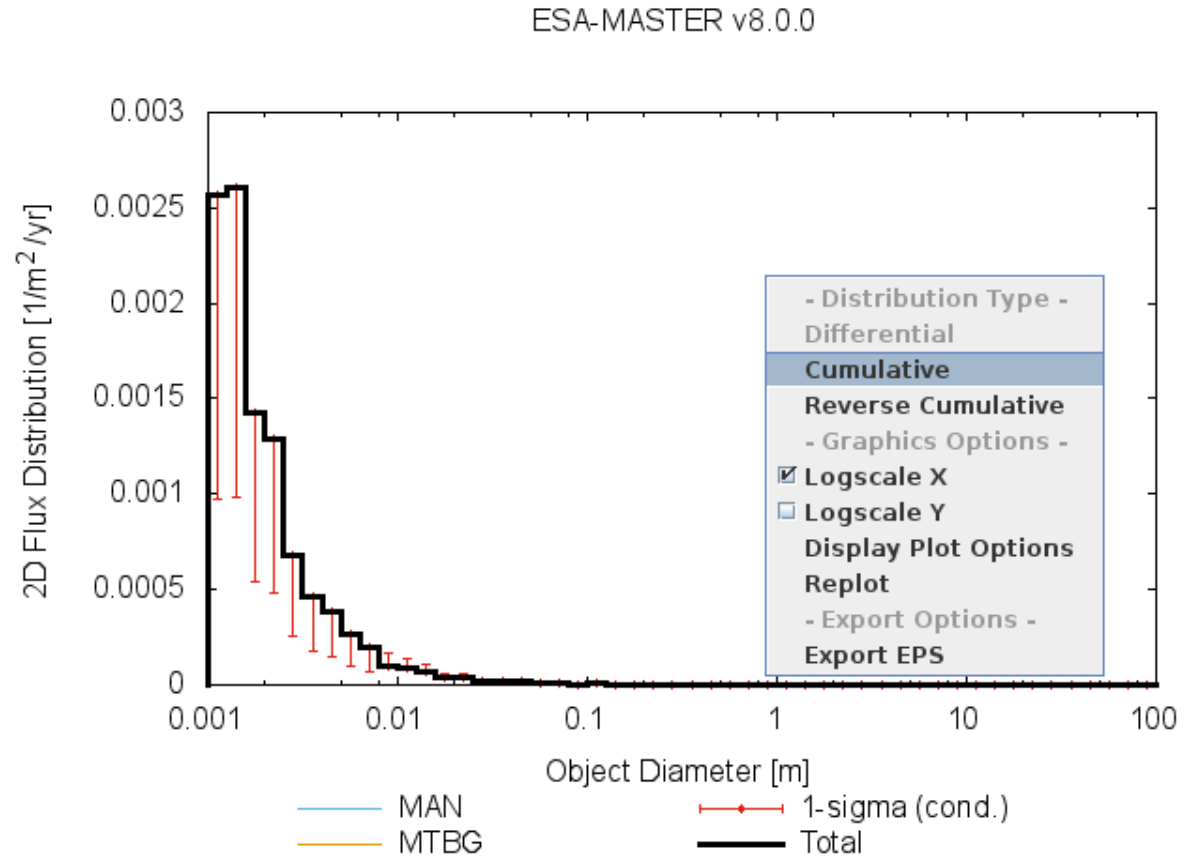
(optional)

→ Right-click on plot area

→ Select 'Cumulative'

→ Right-click on plot area

→ Select 'Logscale Y'





# Basics: Flux evaluations ( $d > 1\text{mm}$ ) on a SSO

## Result:

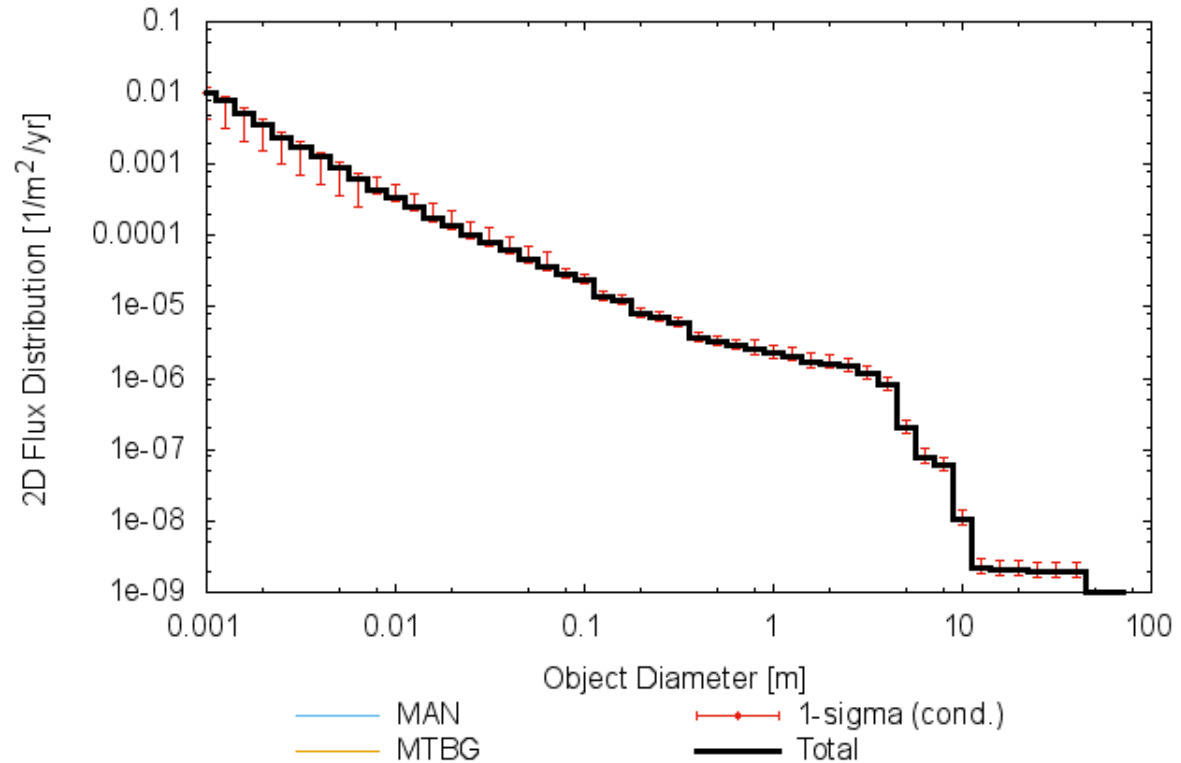
2D-plot showing 2D-flux vs. Diameter on a SSO orbit in November 2016. In this example on an Envisat orbit.

(optional)

- Right-click on plot area
- Select 'Cumulative'
- Right-click on plot area
- Select 'Logscale Y'

Done!

ESA-MASTER v8.0.0



# Basics: Using MASTER to calculate flux-based collision probability



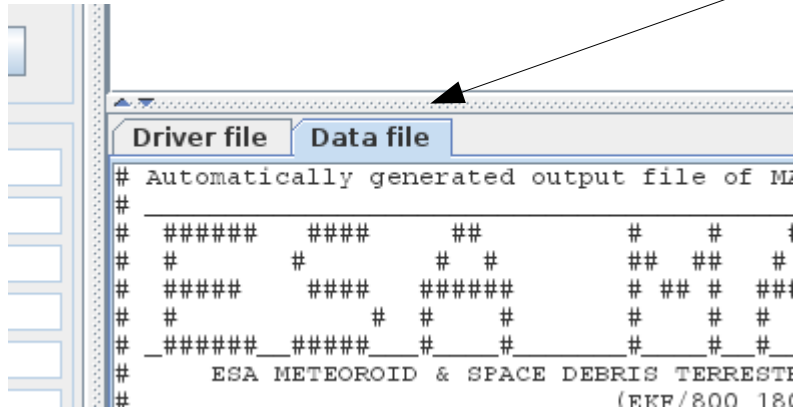
# Basics: Using MASTER to calculate flux-based collision probability

<b>Task</b>	Calculate the flux-based collision probability for different size thresholds on Envisat using the MASTER output of 2D-flux.
<b>Steps</b>	<ol style="list-style-type: none"><li>1) Make sure to use cumulative spectrum (flux values for <math>d &gt; d^*</math>)</li><li>2) Access the MASTER output datafile</li><li>3) Isolating flux values for selected diameter thresholds <math>d^*</math>, e.g. for 1mm, 5mm, 1cm, 5cm and 10cm.</li><li>4) Lookup required satellite properties</li><li>5) Making assumption that flux was constant over the mission duration(!)</li><li>6) Use flux-based collision probability formula to calculate collision probability</li></ol>
<b>Result</b>	Collision probabilities for Envisat covering different threshold diameters

# Basics: Using MASTER to calculate flux-based collision probability

1) Cumulative spectrum still selected

2) Select 'Data file' to access the MASTER output



# Basics: Using MASTER to calculate flux-based collision probability

1) Cumulative spectrum still selected

Driver file Data file

```
#
# Title:          2D flux distribution vs. Object Diameter
#-----
# Scale:          logarithmic
# x Data:         Object Diameter [m]
# y Data:         Object Flux [1/m^2/yr]
# Discretisation: 50 classes from 0.10000E-02 m to 0.10000E+03 m, 0.10000E+00 logarithmic class width
#-----
# Diameter      Expl-Fragm Coll-Fragm Launch/Mis NaK-Drops SRM-Slag SRM-Dust Paint Flks Ejecta MLI
# [m]           [1/m^2/yr]_[1/m^2/yr]_[1/m^2/yr]_[1/m^2/yr]_[1/m^2/yr]_[1/m^2/yr]_[1/m^2/yr]_[1/m^2/yr]_[1/m^2/yr]
# 0.001000     0 0 0 0 0 0 0 0 0
# 0.001259     0 0 0 0 0 0 0 0 0
# 0.001585     0 0 0 0 0 0 0 0 0
# 0.001995     0 0 0 0 0 0 0 0 0
# 0.002512     0 0 0 0 0 0 0 0 0
# 0.003162     0 0 0 0 0 0 0 0 0
# 0.003981     0 0 0 0 0 0 0 0 0
# 0.005012     0 0 0 0 0 0 0 0 0
# 0.006310     0 0 0 0 0 0 0 0 0
# 0.007943     0 0 0 0 0 0 0 0 0
# 0.010000     0 0 0 0 0 0 0 0 0
# 0.012589     0 0 0 0 0 0 0 0 0
# 0.015849     0 0 0 0 0 0 0 0 0
#
#
#
#
```

0.001000

0.005012

0.010000



3) Isolating lines for desired diameter thresholds

# Basics: Using MASTER to calculate flux-based collision probability

Driver file | Data file

```
# Title: 2D flux distribution vs. Object Diameter
#-----
# Scale: logarithmic
# x Data: Object Diameter [m]
# y Data: Object Flux [1/m^2/yr]
# Discretisation: 50 classes from 0.10000E-02 m to 0.10000
```

Diameter [m]	Expl-Fragm [1/m^2/yr]	Coll-Fragm [1/m^2/yr]	Launch/Mis [1/m^2/yr]	NaK-Drops [1/m^2/yr]	SRM-r [1/m^2/yr]	Cloud 5 [1/m^2/yr]	Man-made [1/m^2/yr]	Meteoroids [1/m^2/yr]	Streams [1/m^2/yr]	Total [1/m^2/yr]
0.001000	0	0	0	0	0	0	0.1031E-01	0	0	0.1031E-01
0.001259	0	0	0	0	0	0	0.7742E-02	0	0	0.7742E-02
0.001585	0	0	0	0	0	0	0.5134E-02	0	0	0.5134E-02
0.001995	0	0	0	0	0	0	0.3707E-02	0	0	0.3707E-02
0.002512	0	0	0	0	0	0	0.2419E-02	0	0	0.2419E-02
0.003162	0	0	0	0	0	0	0.1743E-02	0	0	0.1743E-02
0.003981	0	0	0	0	0	0	0.1277E-02	0	0	0.1277E-02
0.005012	0	0	0	0	0	0	0.8943E-03	0	0	0.8943E-03
0.006310	0	0	0	0	0	0	0.6280E-03	0	0	0.6280E-03
0.007943	0	0	0	0	0	0	0.4360E-03	0	0	0.4360E-03
0.010000	0	0	0	0	0	0	0.3330E-03	0	0	0.3330E-03
0.012589	0	0	0	0	0	0	0.2485E-03	0	0	0.2485E-03
0.015849	0	0	0	0	0	0	0.1801E-03	0	0	0.1801E-03

3) Isolating lines for desired diameter thresholds

# Basics: Using MASTER to calculate flux-based collision probability

## Flux-based collision probability

$$P(d>d^*) = 1 - \exp(- F(d>d^*) * A * \Delta t)$$

Collision probability

MASTER flux Output (cumulative)

Mean area of Envisat

Applicable mission duration

4) Satellite properties:  
 $A = 75 \text{ m}^2$   
 $\Delta t = 14 \text{ years (2002 - 2016)}$

# Basics: Using MASTER to calculate flux-based collision probability

$$P(d>d^*) = 1 - \exp(- F(d>d^*) * A * \Delta t)$$

Diameter d*	Cum. Flux	Mean area	Mission duration	Coll. Prob.
1 mm	$0.1031 * 10^{-1} \text{ 1/(m}^2\text{a)}$	75 m <sup>2</sup>	14 a	99.99 %
5 mm	$0.8943 * 10^{-3} \text{ 1/(m}^2\text{a)}$			60.89 %
1 cm	$0.3330 * 10^{-3} \text{ 1/(m}^2\text{a)}$			29.50 %
5 cm	$0.4693 * 10^{-4} \text{ 1/(m}^2\text{a)}$			4.80 %
10 cm	$0.2392 * 10^{-4} \text{ 1/(m}^2\text{a)}$			2.48 %



# Advanced: Impact velocity/azimuth on defined oriented surface

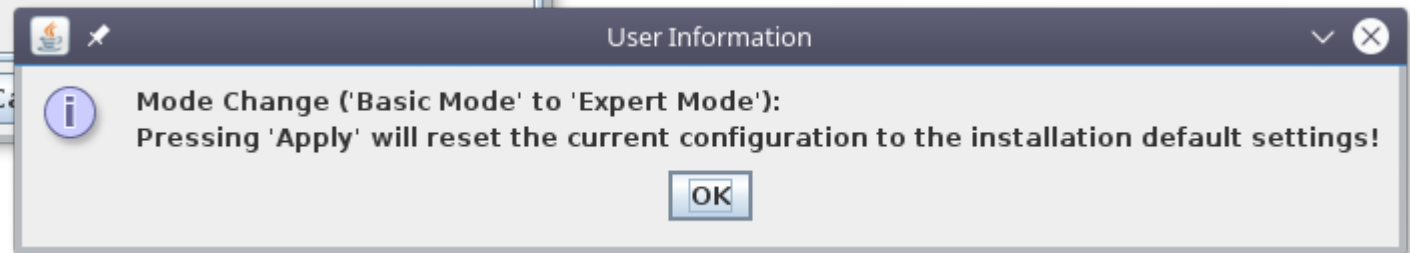
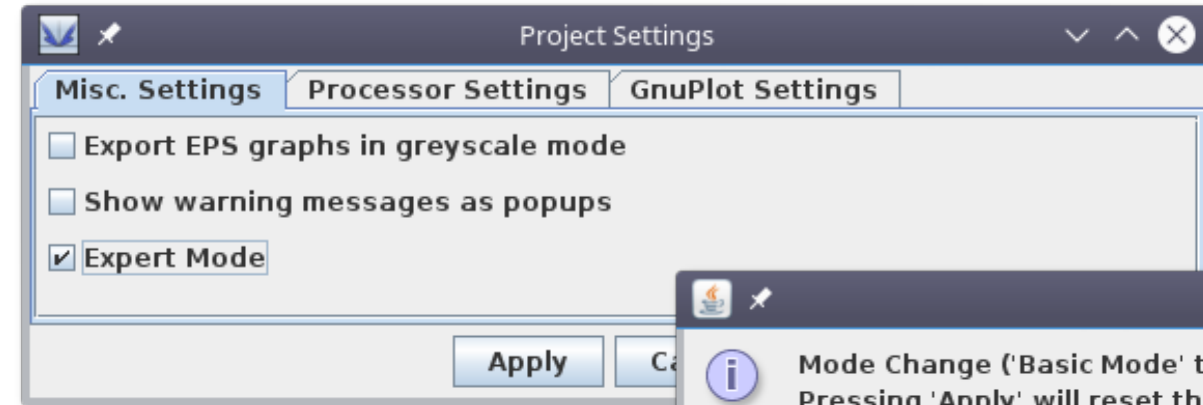
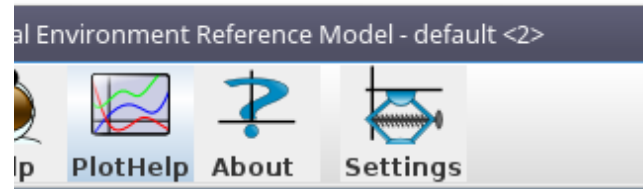


# Advanced: Impact velocity/azimuth on defined oriented surface

<b>Task</b>	Calculate the 2D-flux ( $d > 1\text{cm}$ ) dependent on impact velocity and impact azimuth on a oriented surface in LEO, facing the leading direction (in direction of motion).
<b>Steps</b>	<ol style="list-style-type: none"><li>1) Enabling 'Expert Mode'</li><li>2) Switch to 'Target Orbit' Mode</li><li>3) Define target orbit, e.g. <b>ISS</b> Orbit</li><li>4) Set diameter size interval to larger then 1cm</li><li>5) Define oriented surface</li><li>6) Set desired output spectrum in '2D Spectrum Definitions' and '3D Spectrum Definitions'</li><li>7) Click 'Run'</li></ol>
<b>Result</b>	Three plots showing (1) 2D-flux vs. impact velocity (2) 2D-flux vs. impact azimuth and (3) 3D-flux vs. impact velocity vs. impact azimuth

# Advanced: Impact velocity/azimuth on defined oriented surface

1) Enabling 'Expert Mode'



# Advanced: Impact velocity/azimuth on defined oriented surface

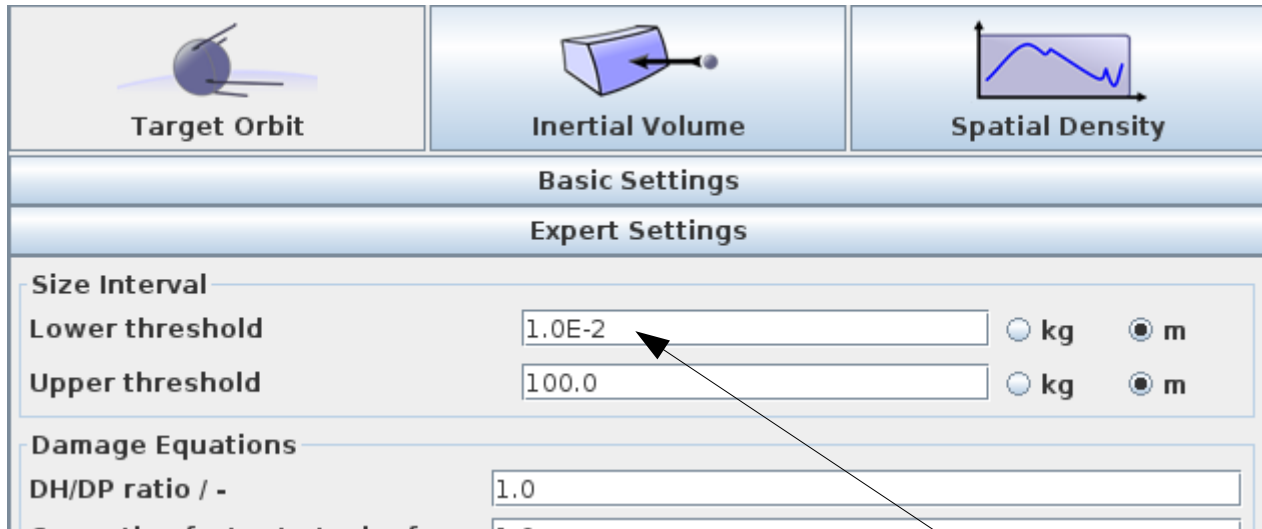
The screenshot shows the ESA-MASTER software interface. At the top, there are three tabs: 'Target Orbit' (selected), 'Inertial Volume', and 'Spatial Density'. Below the tabs is the 'Basic Settings\*' section, which includes:

- Analysis Interval:** Begin date (2016/11/01 00), End date (2016/11/01 00)
- Comments:** Run-ID (master), ESA-MASTER v8.0.0, Surface in leading direction on ISS orbit
- Selection:** Earth-bound (selected), Lagrange point
- Target Orbit Settings:** Lower argument of true latitu... (0.0), Upper argument of true latitu... (360.0)
- Target orbits (Singly Averaged Elements):** A table with columns for Prop., Start epoch, End epoch, SMA, ECC, INC, RAAN, and AoP. The first row contains: , 2016 11 01 00, 2016 11 01 00, 6780.0, 0.001, 51.6, 110.0, 200.0, and +/- buttons.

2) Switch to 'Target Orbit Mode'

3) Define **ISS** Orbit:  
SMA / km: 6780  
ECC / -: 0.001  
INC / °: 51.6  
RAAN / °: not used  
AoP / °: 200

# Advanced: Impact velocity/azimuth on defined oriented surface



4) Set simulation minimum to 1cm

# Advanced: Impact velocity/azimuth on defined oriented surface

Surface Definitions

Target Surface

Target type: oriented surface (as defined below)

Surface Definitions

Switch	Orientation	Angle A	Angle h	Designation
<input checked="" type="checkbox"/>	Earth oriented	0.0	0.0	Surface-01
<input type="checkbox"/>	Earth oriented	0.0	90.0	Surface-02
<input type="checkbox"/>	Sun oriented	180.0	0.0	Surface-03
<input type="checkbox"/>	Inertially fixed			

5) Define oriented surface

Select 'oriented surface'

Check only a single surface

Orientation 'Earth oriented'

Orientation angles:

Azimuth:  $0^\circ$

Elevation:  $0^\circ$

→ in direction of motion

# Advanced: Impact velocity/azimuth on defined oriented surface

2D Spectrum Definitions*						
2D Spectrum Definitions						
Gen.	Log.	Auto	Min.	Max.	Classes >0: Width <0: Number	
<input type="checkbox"/>	object mass	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1.0E-15	100000.0	0.4
<input type="checkbox"/>	object diameter	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1.0E-6	100.0	-200.0
<input type="checkbox"/>	time	<input type="checkbox"/>	<input type="checkbox"/>	1957.0	2016.0	-200.0
<input type="checkbox"/>	object semi m...	<input type="checkbox"/>	<input type="checkbox"/>	6500.0	45000.0	-25.0
<input type="checkbox"/>	object eccentr...	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1.0E-4	1.0	0.1
<input type="checkbox"/>	object inclinat...	<input type="checkbox"/>	<input type="checkbox"/>	0.0	150.0	1.0
<input type="checkbox"/>	object raan	<input type="checkbox"/>	<input type="checkbox"/>	-180.0	180.0	5.0
<input type="checkbox"/>	impact arg. of ...	<input type="checkbox"/>	<input type="checkbox"/>	0.0	360.0	5.0
<input type="checkbox"/>	object perihel ...	<input type="checkbox"/>	<input type="checkbox"/>	1500000.0	1.5E8	8000000.0
<input type="checkbox"/>	impact eclipt. l...	<input type="checkbox"/>	<input type="checkbox"/>	0.0	360.0	5.0
<input type="checkbox"/>	impact eclipt. l...	<input type="checkbox"/>	<input type="checkbox"/>	-90.0	90.0	5.0
<input checked="" type="checkbox"/>	impact velocity	<input type="checkbox"/>	<input type="checkbox"/>	0.0	40.0	1.0
<input checked="" type="checkbox"/>	impact azimuth...	<input type="checkbox"/>	<input type="checkbox"/>	-180.0	180.0	5.0
<input type="checkbox"/>	impact elevati...	<input type="checkbox"/>	<input type="checkbox"/>	-90.0	90.0	5.0

6a) Set desired output spectrum in '2D Spectrum Definitions'

← disable

← enable

# Advanced: Impact velocity/azimuth on defined oriented surface

3D Spectrum Definitions		
Gen.	X-Axis	Y-Axis
<input type="checkbox"/>	object mass	impact velocity
<input type="checkbox"/>	impact right ascension	impact declination
<input checked="" type="checkbox"/>	impact velocity	impact azimuth angle
<input type="checkbox"/>	impact velocity	impact eclipt. longitude
<input type="checkbox"/>	object semi major axis	object eccentricity
<input type="checkbox"/>	object semi major axis	object inclination
<input type="checkbox"/>	object inclination	impact arg. of true lat.
<input type="checkbox"/>	object diameter	impact arg. of true lat.
<input type="checkbox"/>	s.d. right ascension	s.d. time
<input type="checkbox"/>	s.d. declination	s.d. right ascension

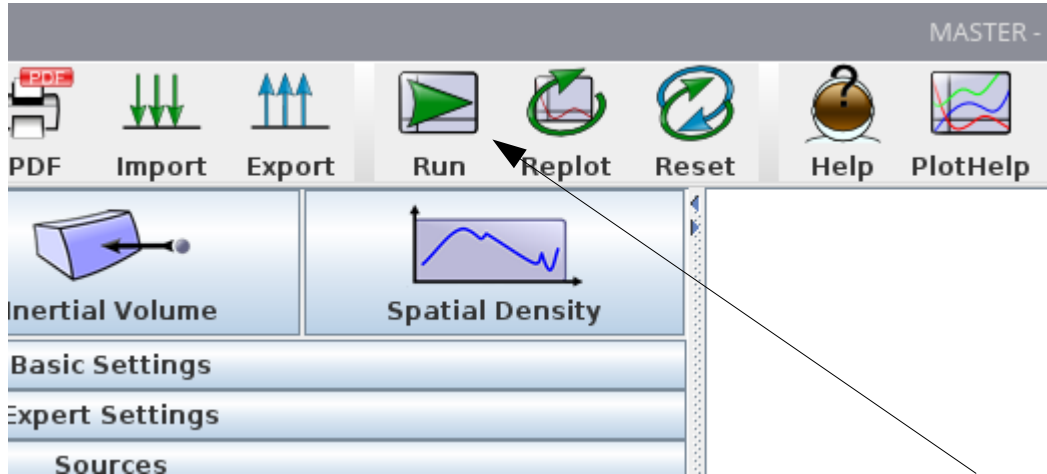
6b) Set desired output spectrum in '3D Spectrum Definitions'

← enable



# Advanced: Impact velocity/azimuth on defined oriented surface

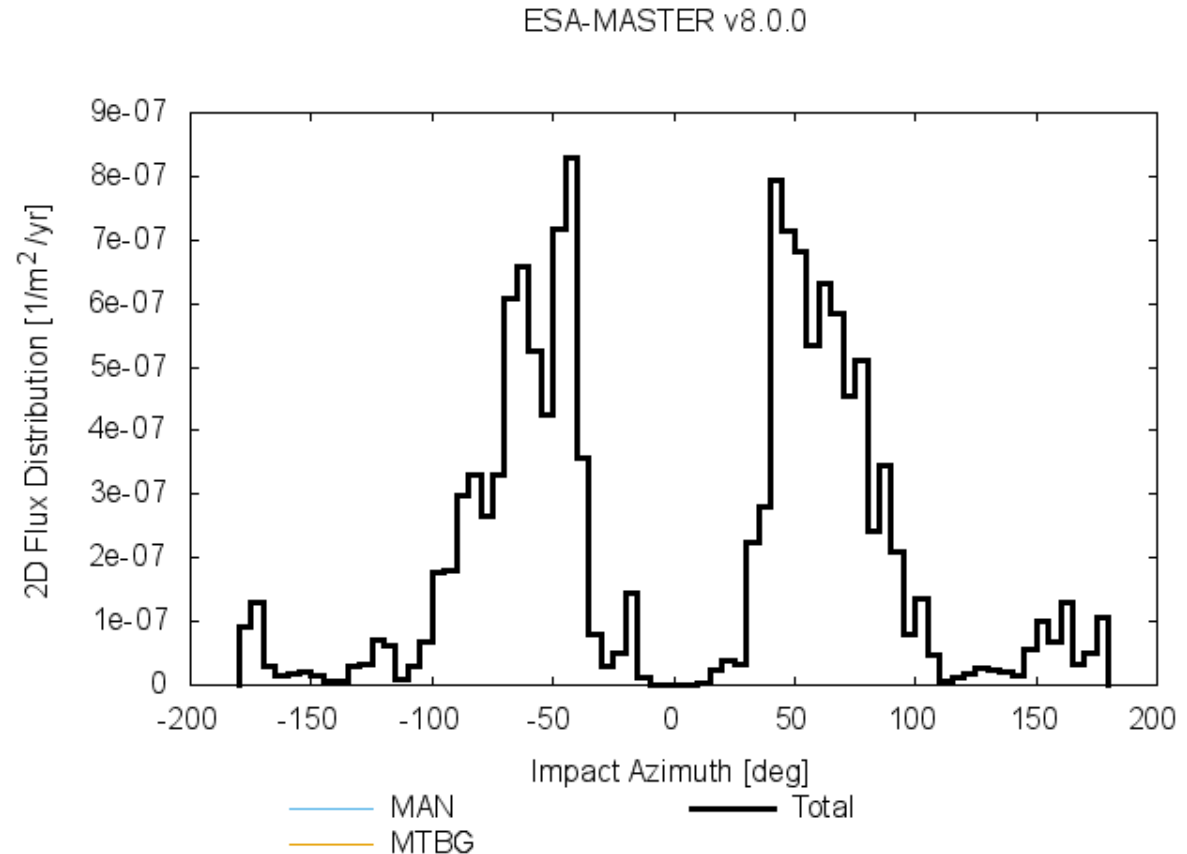
7) Click 'Run'



# Advanced: Impact velocity/azimuth on defined oriented surface

## Result:

- (1) 2D-Flux vs. impact azimuth
- (2) 2D-Flux vs. impact velocity
- (3) 3D-Flux vs. impact velocity vs. impact azimuth

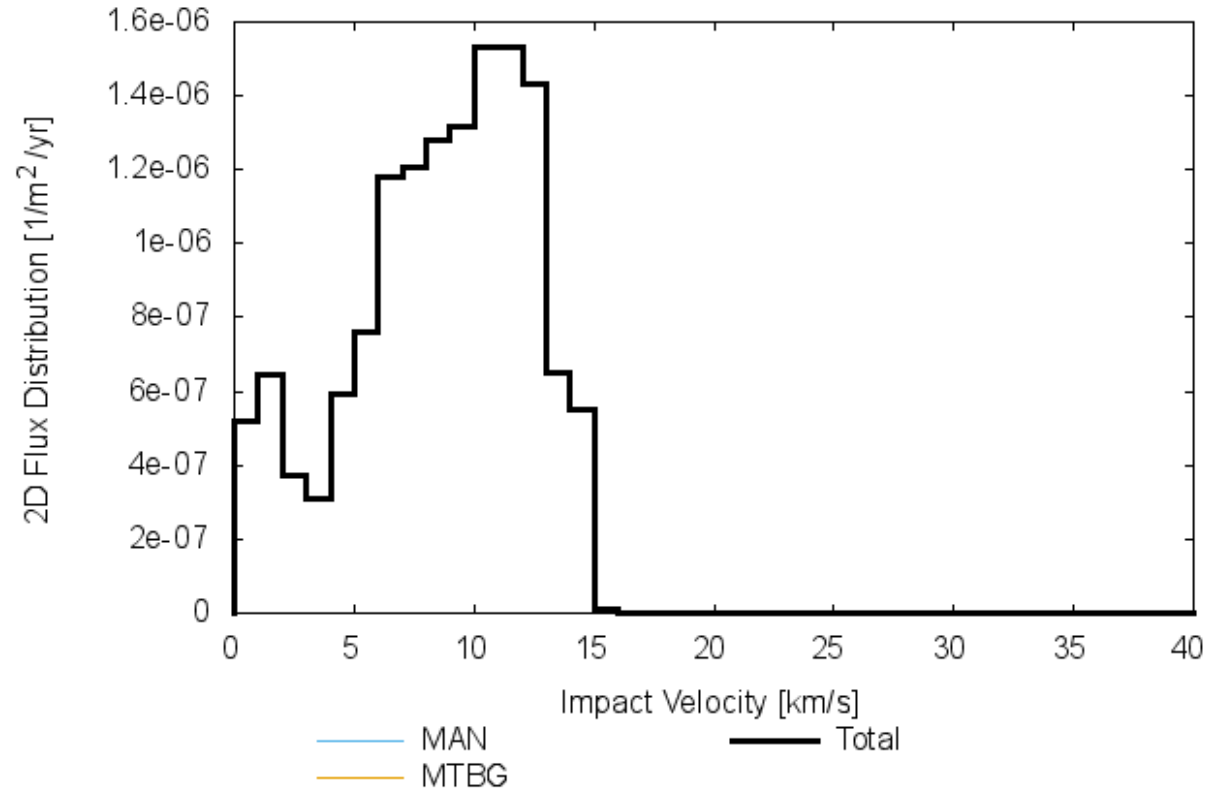


# Advanced: Impact velocity/azimuth on defined oriented surface

ESA-MASTER v8.0.0

## Result:

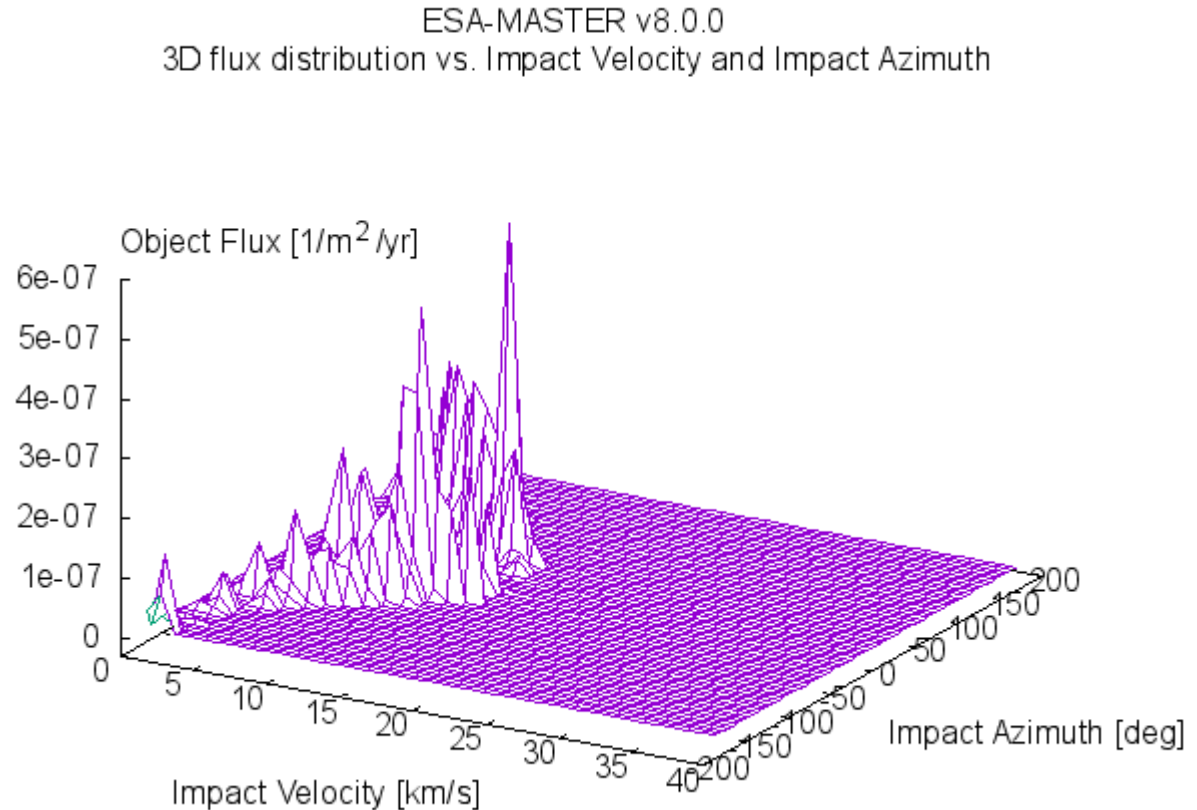
- (1) 2D-Flux vs. impact azimuth
- (2) 2D-Flux vs. impact velocity
- (3) 3D-Flux vs. impact velocity vs. impact azimuth



# Advanced: Impact velocity/azimuth on defined oriented surface

## Result:

- (1) 2D-Flux vs. impact velocity
- (2) 2D-Flux vs. impact azimuth
- (3) 3D-Flux vs. impact velocity vs. impact azimuth

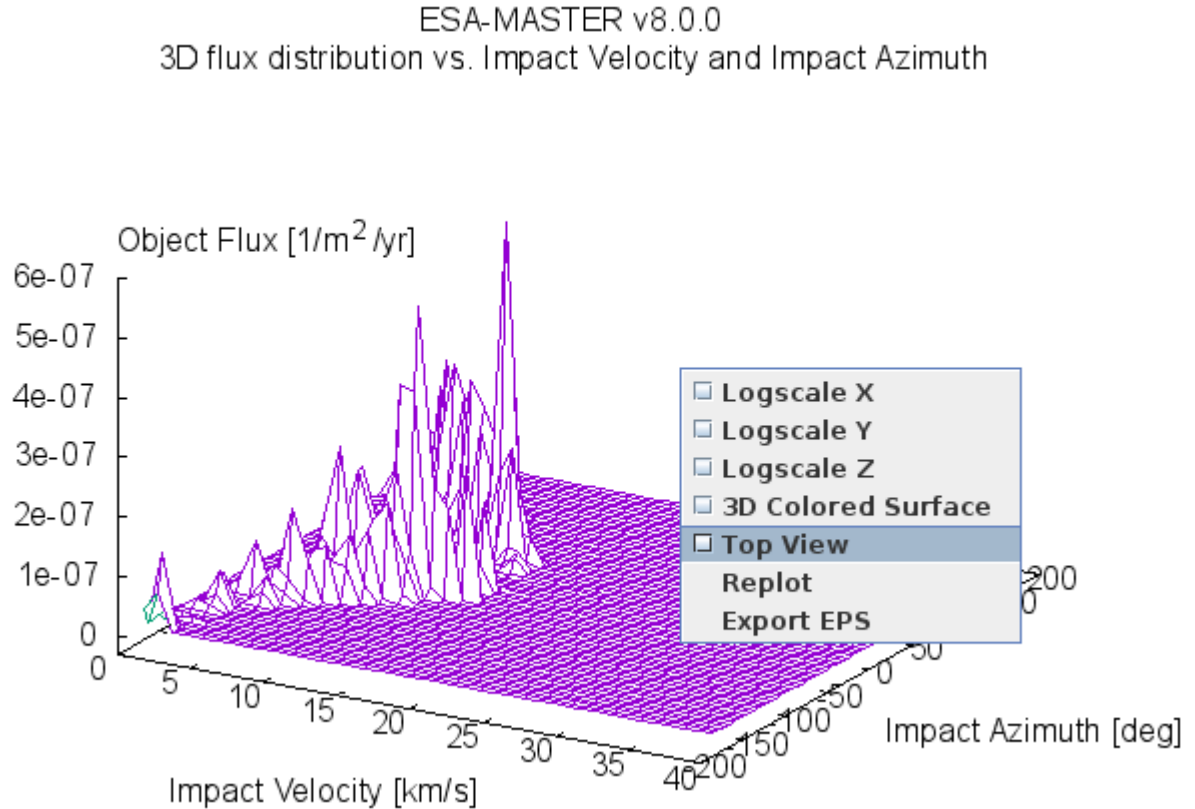


# Advanced: Impact velocity/azimuth on defined oriented surface

## Result:

- (1) 2D-Flux vs. impact velocity
- (2) 2D-Flux vs. impact azimuth
- (3) 3D-Flux vs. impact velocity vs. impact azimuth

- *Right click on plot area*
- *Select 'Top View'*



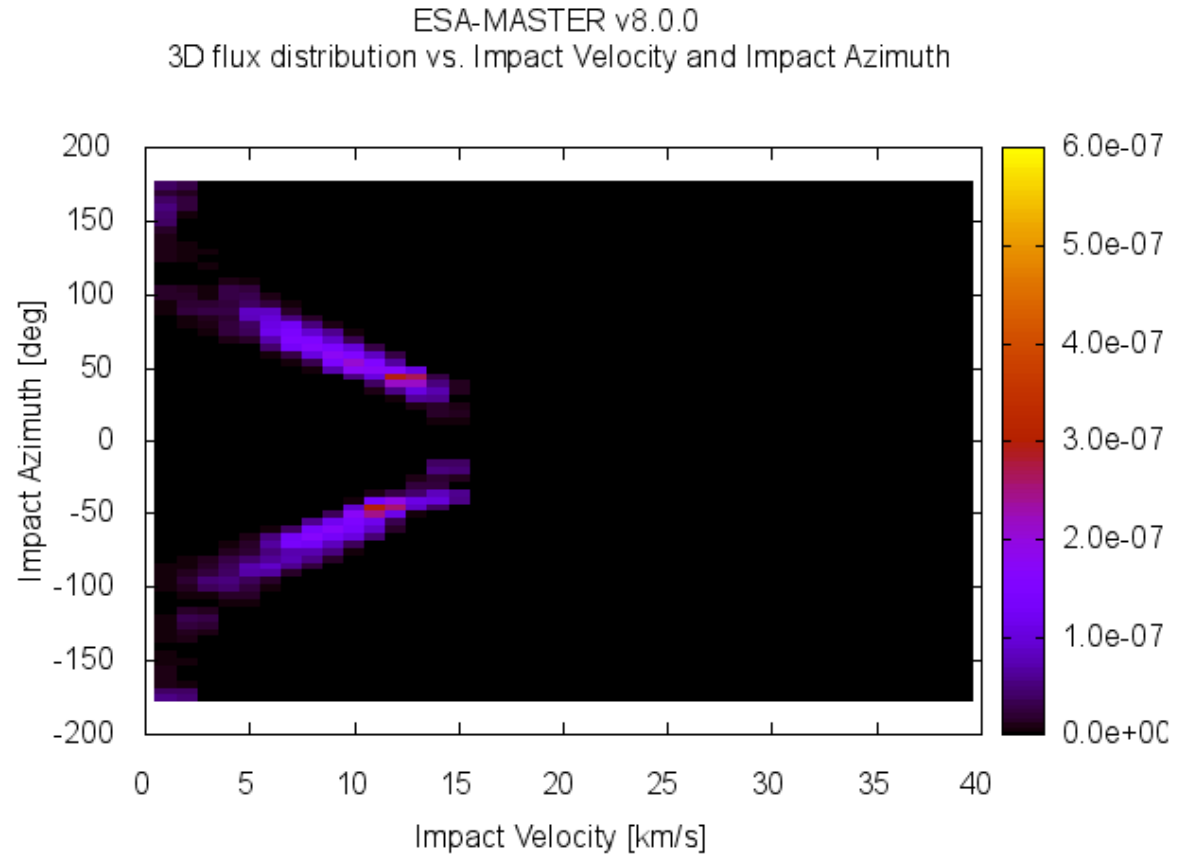
# Advanced: Impact velocity/azimuth on defined oriented surface

## Result:

- (1) 2D-Flux vs. impact velocity
- (2) 2D-Flux vs. impact azimuth
- (3) 3D-Flux vs. impact velocity vs. impact azimuth

- *Right click on plot area*
- *Select 'Top View'*

Done!



# Advanced: Spatial density – declination vs. altitude

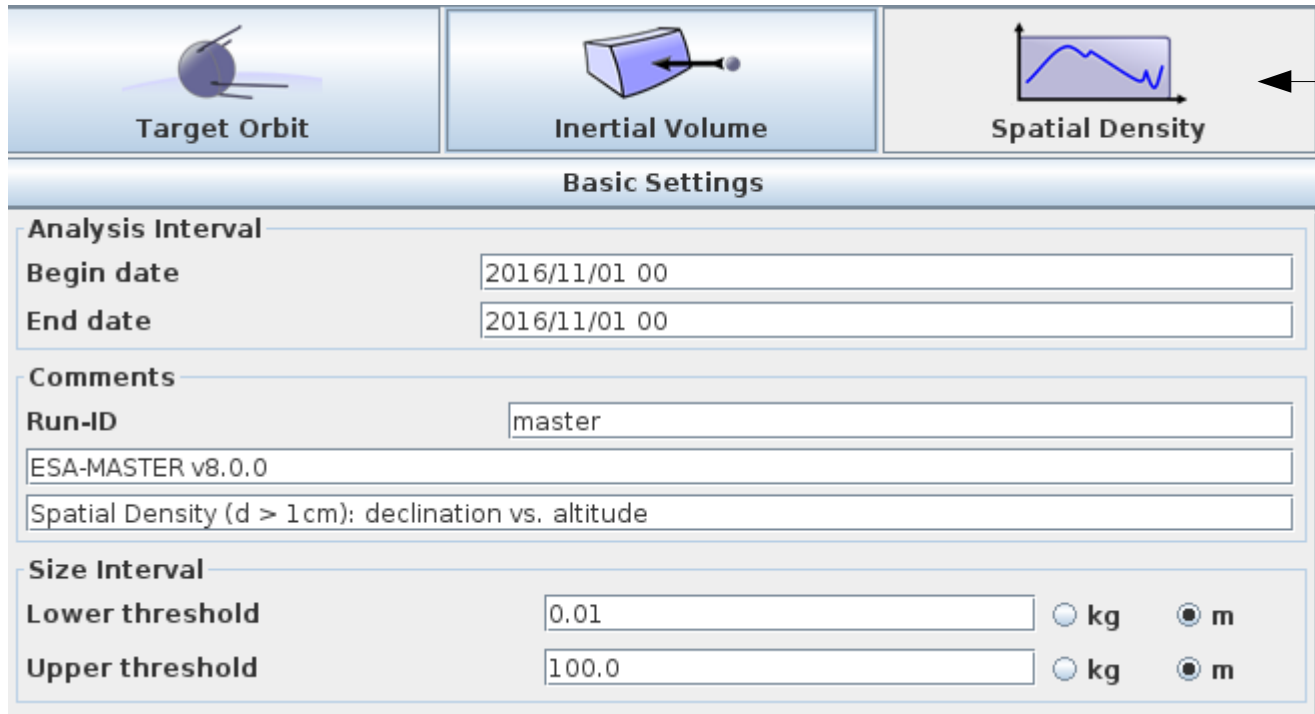


# Advanced: Spatial density – declination vs. altitude

<b>Task</b>	Calculate the 3D-Spatial density ( $d > 1\text{cm}$ ) dependent on declination and altitude in LEO.
<b>Steps</b>	<ol style="list-style-type: none"><li>1) Switch back to 'Spatial Density' Mode</li><li>2) Set desired output spectrum in '3D Spectrum Definitions'</li><li>3) Click 'Run'</li></ol>
<b>Result</b>	Single plot showing 3D-Spatial Density vs. declination vs. altitude



# Advanced: Spatial density – declination vs. altitude



The screenshot shows the ESA-MASTER software interface. At the top, there are three tabs: 'Target Orbit', 'Inertial Volume', and 'Spatial Density'. The 'Spatial Density' tab is selected, indicated by a blue highlight and a blue arrow pointing to it from the text '1) Select Spatial Density'. Below the tabs is a 'Basic Settings' section with the following fields:

- Analysis Interval**
  - Begin date: 2016/11/01 00
  - End date: 2016/11/01 00
- Comments**
  - Run-ID: master
  - ESA-MASTER v8.0.0
  - Spatial Density (d > 1cm): declination vs. altitude
- Size Interval**
  - Lower threshold: 0.01 (kg , m )
  - Upper threshold: 100.0 (kg , m )

1) Select Spatial Density

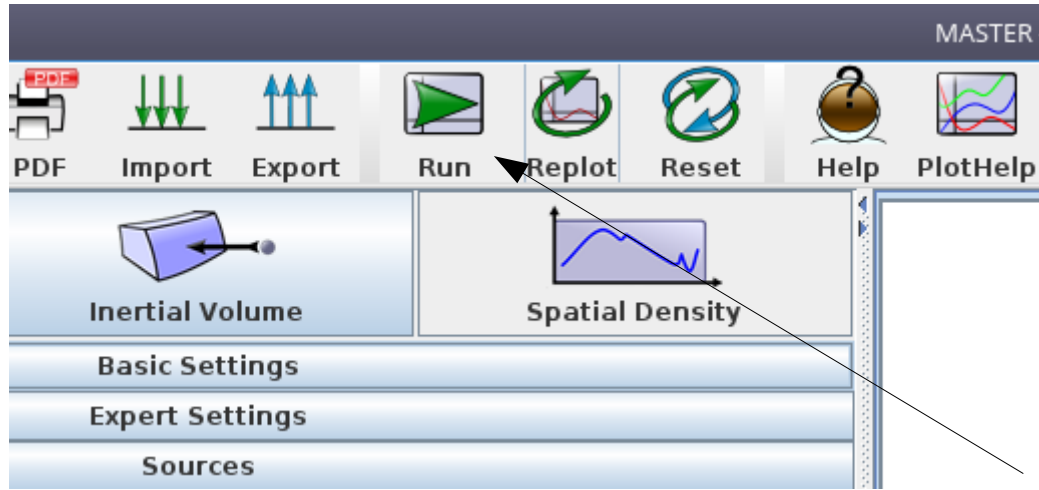
# Advanced: Spatial density – declination vs. altitude

3D Spectrum Definitions		
Gen.	X-Axis	Y-Axis
<input type="checkbox"/>	object mass	impact velocity
<input type="checkbox"/>	impact right ascension	impact declination
<input type="checkbox"/>	impact velocity	impact arg. of true lat.
<input type="checkbox"/>	impact velocity	impact eclipt. longitude
<input type="checkbox"/>	object semi major axis	object eccentricity
<input type="checkbox"/>	object semi major axis	object inclination
<input type="checkbox"/>	object inclination	impact arg. of true lat.
<input type="checkbox"/>	object diameter	impact arg. of true lat.
<input checked="" type="checkbox"/>	s.d. declination	s.d. altitude
<input type="checkbox"/>	s.d. declination	s.d. right ascension

← 2) Set desired output spectrum

# Advanced: Spatial density – declination vs. altitude

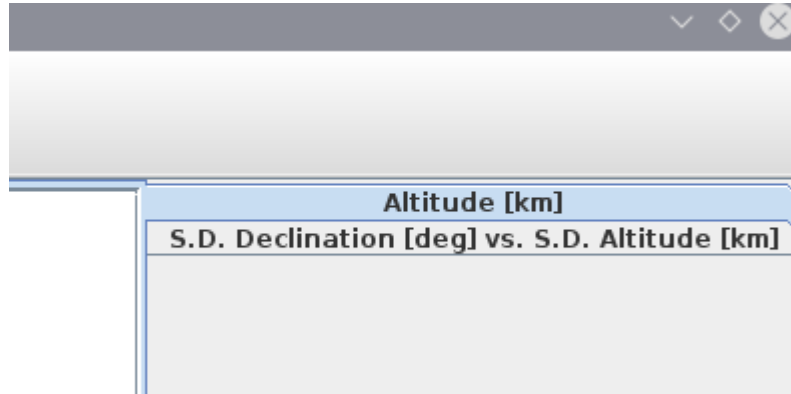
3) Click 'Run'



# Advanced: Spatial density – declination vs. altitude

## Result:

Plot showing  
3D-Spatial  
Density vs.  
declination vs.  
altitude



Default spectrum in  
2D Spectrum  
definitions

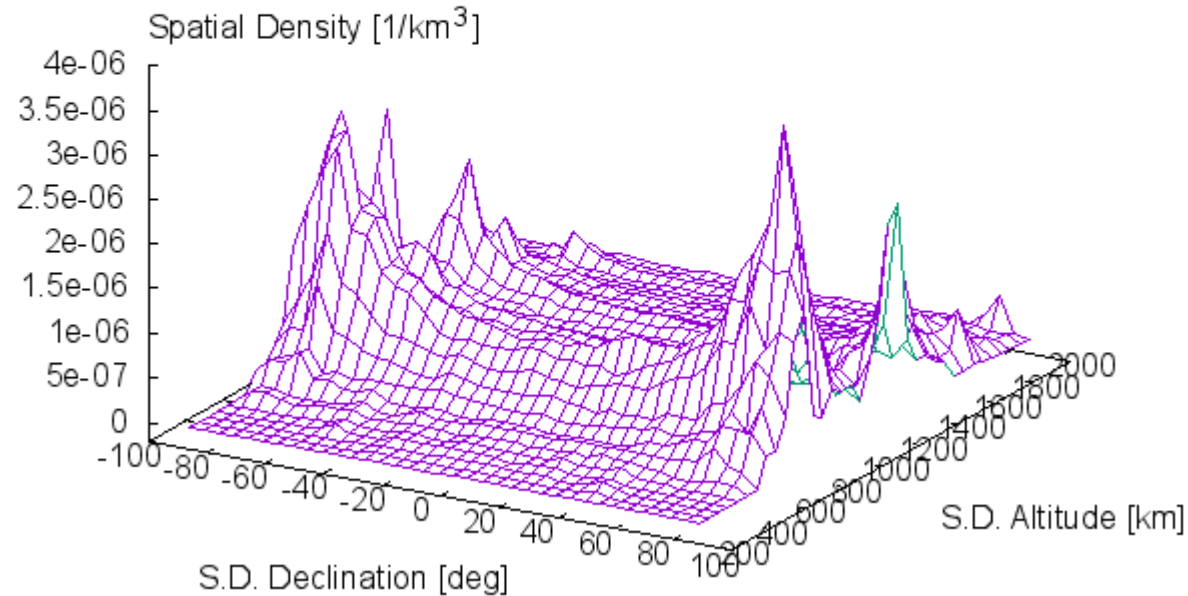
Requested 3D spectrum

# Advanced: Spatial density – declination vs. altitude

## Result:

Plot showing  
3D-Spatial  
Density vs.  
declination vs.  
altitude

ESA-MASTER v8.0.0  
3D spatial density distribution vs. S.D. Declination and S.D. Altitude



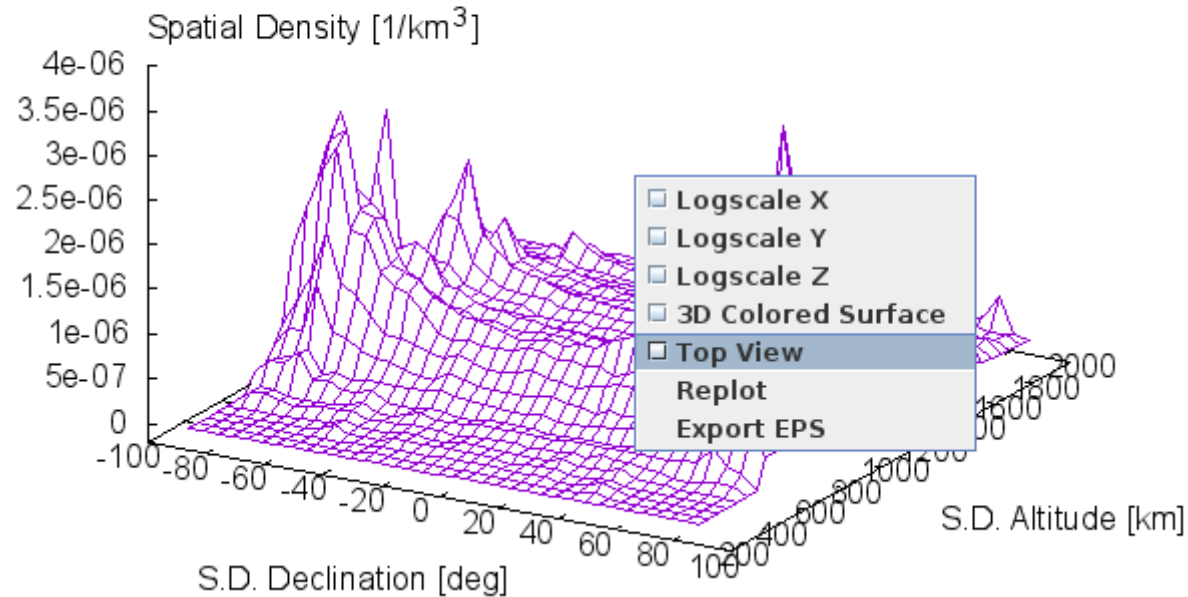
# Advanced: Spatial density – declination vs. altitude

## Result:

Plot showing  
3D-Spatial  
Density vs.  
declination vs.  
altitude

- *Right click on plot area*
- *Select 'Top View'*

ESA-MASTER v8.0.0  
3D spatial density distribution vs. S.D. Declination and S.D. Altitude



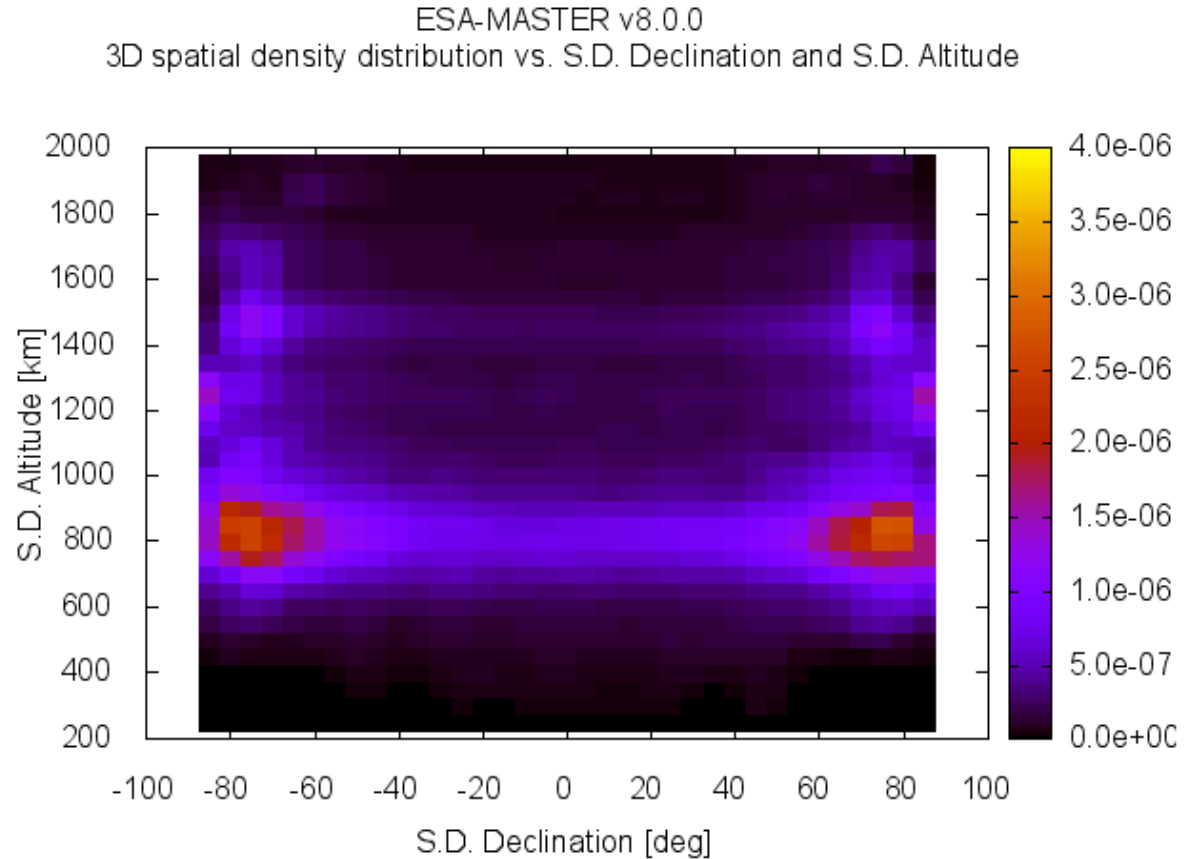
# Advanced: Spatial density – declination vs. altitude

## Result:

Plot showing  
3D-Spatial  
Density vs.  
declination vs.  
altitude

- *Right click on plot area*
- *Select 'Top View'*

Done!



# Thank you!



More information:  
Software User Manual

Additional population data:  
<https://sdup.esoc.esa.int/>