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WP3-Coma Model for Comet Interceptor

To the attention of	Fabrice Cipriani - European Space Agency (ESA)
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LIST OF FIGURES

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SUMMARY

The following document reports a short but comprehensive guide on how to use the ComMoDE graphical user interface and exploit its functionalities. The aim of this document is to provide guidelines on how to interact with the application, namely:

1. compile forms of required inputs
2. run its main functionalities
3. retrieve the final numerical results produced.

Any details on the physical model that the application uses “under-hood” for simulations and the physical meaning of the inputs required and the outputs produced will not be object of the current guide and it will be reported elsewhere.

The current document is organized as follows:

1. INTRODUCTION: general description of “what is” ComMoDE and “what it does” is provided.
2. ComMoDE: WHAT IS A PROJECT: ComMoDE Interface has the capability to define and manage multiple work sessions, creating confined and self-consistent workspaces (project folders) onto the filesystem. The application can start a new work session from scratch, or recover information from a workspace previously created. Meaningful results produced by running application functionalities are stored into the session workspace. This section will describe in details how such workspaces are organized and guide the User how to navigate them.
3. HOW TO MANAGE A PROJECT: this section will show the User how:
    a. Create a new work-session
    b. Load a pre-existent work-session
    c. Save a work-session
    d. Clone or backup a work-session
4. RUN A COMETARY DUST SIMULATION: this section will show how to prepare a cometary dust simulation filling a form of required inputs and run it into the interface.
5. EVALUATE DUST IMPACT ON FLY-BY TRAJECTORIES: once the cometary simulation results are available, this section will show how to create spacecraft trajectories crossing the cometary simulation domain and run the post-processing job to evaluate the dust impact onto them.
6. VISUALIZE DUST IMPACT ONTO TRAJECTORIES: this section will show how to control the 2D visualization environment embedded into the interface, to plot dust impact data evaluated for one or multiple trajectories.

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INTRODUCTION

What is ComMoDE?

ComMoDE (Cometary Model for Dust Environments) is a comet dust emission calculator coming with a practical Graphical User Interface. Its main functionalities are:

1. Given a comet prototype, it provides a fast and accurate calculation of the comet dust emission field over a discrete volume domain, centered on the position of the comet.
2. Given one or more prototypes of fly-by spacecraft trajectories crossing the comet domain, it calculates the dust flux and cumulated fluence onto the spacecraft, along its trajectory.

A list of input is required from the User to customize the comet prototype and its emission model (dust particle distribution, material, etc..) and the spacecraft crossing trajectories (spacecraft frontal area, velocity, etc..).
ComMoDE has a simple but functional 2D viewer, embedded into the main window of the application, to report dust impact on trajectories data on cartesian plots.

A complete description of the Comet model (on which the application is based), as well as a full description of the physical quantities required in input to characterize it, are reported in a separate document.

Build and install notes

The full package deliverable of ComMoDE already provides two installation manuals INSTALL-Linux and INSTALL-Windows in both *.md(Markdown) and *.pdf extensions. Such manuals report in details all the steps to follow to build and install correctly the application onto your Linux system or Windows one. Moreover, instruction to run ComMoDE after its installation stage are reported. Please refer to them for any build and install issue.

Built-in tooltips: ease the interaction with the Graphical User Interface

The ComMoDE Interface widely use tooltips to report a brief description of the interactable components of the Interface (see Figure 1.). A tooltip is automatically displayed anytime the mouse cursor is left more than one second on the component, without clicking any button (mouse hovering). Aside reading the current document, we strongly recommend to rely also on the tooltips to have quick hints on how the use the application and improve the overall ComMoDE usage experience.

Accessing ComMoDE interface detailed code description

For developers who are interested in the detailed description of the Interface code, a full Doxygen manual can be generated at installation stage (please refer to the install manuals to know how to do it). Doxygen documentation can be opened and visualized with a regular browser.

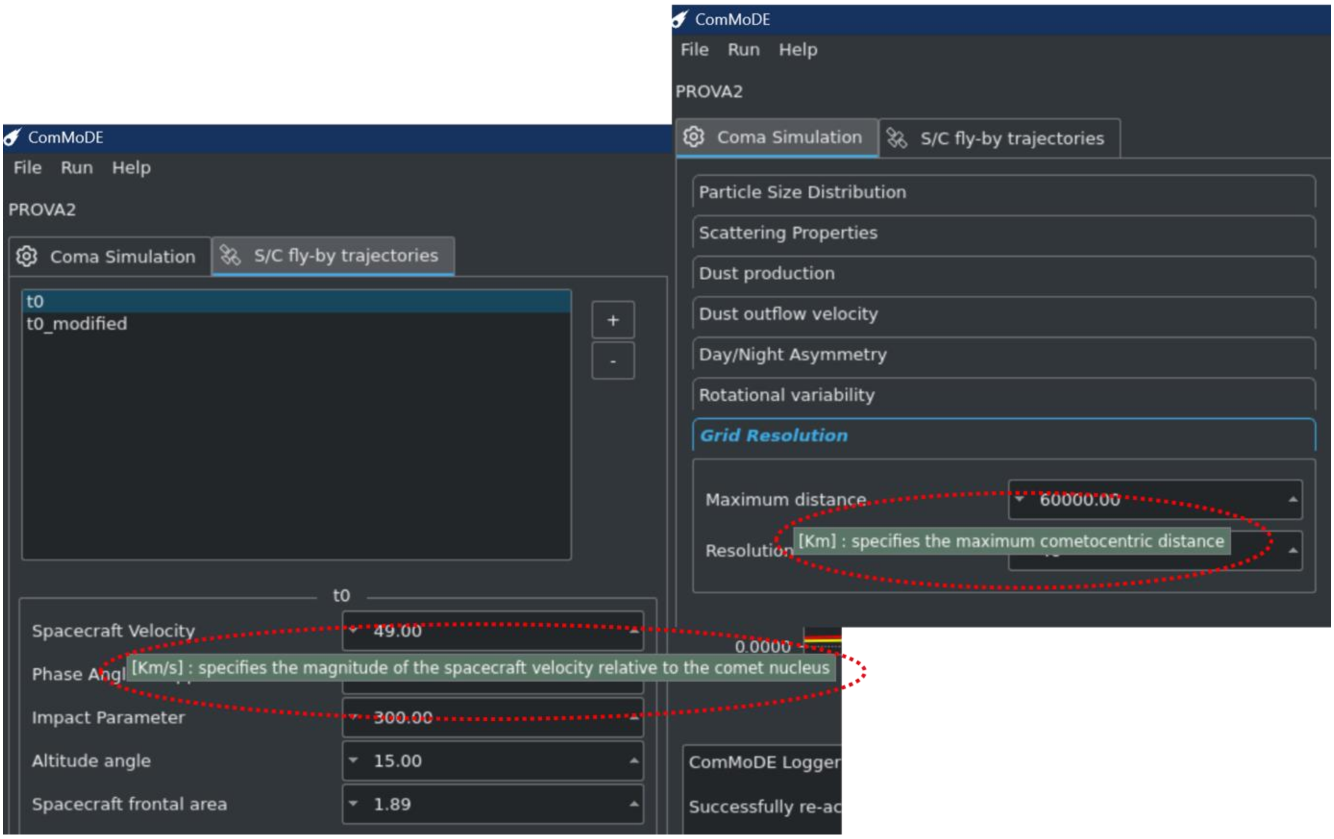

Figure 1: Showing tooltips (highlighted in red circles).

ComMoDE: WHAT IS A PROJECT ?

The generic architecture of the ComMoDE Interface is based on the possibility to dynamically manage multiple work sessions or, as they will be commonly referred in ComMoDE, projects.

But what is a project?
Let's consider the following simple use case.
Suppose the User want to perform an analysis on the dust emission of a certain comet prototype: it prepares the set-up to simulate the dust emission, run the simulation and evaluate the dust impact on a couple of spacecraft trajectories crossing the comet simulated domain.
Now the User decides to create a whole new comet prototype and perform another analysis.
At this point he wants to return again on the first analysis and access its results. He wants to do some changes, like adding a new trajectory to evaluate, or run again the coma dust emission simulation, modifying a couple of input parameters.

What is happening here?

Basically the User has implicitly defined two distinct work sessions where:

- He performed two distinct analysis on two different comet prototypes.
- Analysis are **independent** from each other: the input injected and the results produced in the first session should be preserved and must not be polluted by inputs injected and results produced by the second one and vice-versa.
- When the User switch to another work-session or decide to close the application, the work done in the last active session must be "**frozen**" as it is, waiting to be safely re-loaded anytime by the User.

So, in order to respond to such requirements, during a singular work-session, the application needs to collect all the information provided in input and produced in output into a confined **workspace**, stored somewhere. And according to the data present in the workspace, it must be capable to restore the work-session connected to it.

Here we come to the definition of a ComMoDE **project** : it is a workspace connected to a work-session of the User and stored onto the filesystem (a folder) in which:

- All inputs provided by the User to set up the comet dust emission simulation and dust impact trajectories post-processing are stored.
- All results coming from comet dust emission simulation and dust-impact post-processing are stored.
- All eventual inputs internally used by the application and not flowing from the User interaction are stored.

- The status of the comet simulation and trajectories post-processing is stored.

So, whenever the User starts ComMoDE, as first action, he needs to create a new project or open a pre-existent project. This implicitly means: from now on, all the work done into the application will be tracked onto a filesystem folder, named as the name of the project. Changing from a project to another in the application will mean tracking the work done into the application, moving from a filesystem folder to another.

Organization of the project folder onto filesystem

The ComMoDE template project folder is organized as follow:

- **coma-results**: it is a folder that will host results of the comet dust emission simulation. Results will come as n binary files, one for each bin defined by the dust size distribution input, in binary format (not human readable). They will store the emitted dust density in every cell of a cometocentric volume discretized mesh. The name of such file will be dust_density_gridX.txt, where X is the identifier integer of the relative dust size bin in the distribution. A human readable ASCII file header.txt will be produced too, collecting all the relevant quantities used to define the current coma simulation.
- **flyby-results**: it is a folder that will host results of the comet dust impact evaluation onto one or multiple spacecraft fly-by trajectories. Since the application can process one or multiple trajectories at the time, the current folder will be populated by sub-folders, one for each trajectory processed. Inside each subfolder, results for that particular trajectory will be stored, that is n human readable ASCII file, in table format, one for each bin defined by the dust size distribution input. Result files are named as dust_density_along_trajectoryX.txt, where X is the identifier integer of the relative dust size bin in the distribution. In each file, the table will be composed by relevant quantities calculated along the trajectory like dust flux, dust cumulated fluences, time to the closest approach etc..[1], one for each column. A final ASCII header.txt file will be produced too, collecting all relevant quantities used to define the current dust impact on trajectory post-processing.
- **databases**: it is a folder, collecting input used internally by the application and needed to define the scattering properties of dust materials supported in the ComMoDE context. They are read-only data, and should never been modified by anyone. Every time a new project is created, the application will copy this folder from its internal data to the target project folder.

[1] For a detailed explanation of quantities tabulated in the trajectory results file, please refer to the ComMoDE Comet Model Guide.

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- **inputComa.xml**: it is a file, in xml format, collecting all the input required to the User to set up the comet dust emission simulation[2]. An example of this file can be found in Figure 3. Its role in the project is to act as backup/restore point, saving the User input filled in the application graphical form every time the project is closed or switched to another one, and restoring them in the graphical form, when the User try to load again the project.
- **inputFlyBy.xml**: it is a file, in xml format, collecting all the input required to the User to set up the dust impact on fly-by trajectories post-processing[3]. An example of this file can be found in Figure 2. The role is identical to inputComa.xml, but for input required on the trajectories part only.
- **.status-project**: internal service file to track the status of the main jobs[4] of the application, that is the coma simulation and the fly-by post-processing.

inputComa.xml | inputFlyBy.xml ×

home > rocco > ESA-ComMoDE_v1.0 > PROVA2 > inputFlyBy.xml

```xml
<?xml version="1.0" ?>
<root>
    <FlyByForm>
        <FlyByTrajectories>
            <t0>
                <SpacecraftVelocity>49.00</SpacecraftVelocity>
                <PhaseAngleOfApproach>0.00</PhaseAngleOfApproach>
                <ImpactParameter>300.00</ImpactParameter>
                <AltitudeAngle>15.00</AltitudeAngle>
                <SpacecraftFrontalArea>1.89</SpacecraftFrontalArea>
                <Status>True</Status>
            </t0>
            <t0_modified>
                <SpacecraftVelocity>80.00</SpacecraftVelocity>
                <PhaseAngleOfApproach>30.00</PhaseAngleOfApproach>
                <ImpactParameter>300.00</ImpactParameter>
                <AltitudeAngle>15.00</AltitudeAngle>
                <SpacecraftFrontalArea>1.89</SpacecraftFrontalArea>
                <Status>True</Status>
            </t0_modified>
        </FlyByTrajectories>
    </FlyByForm>
</root>
```

Figure 2: Example of inputFlyBy.xml file inside project folder

[2] For a detailed explanation of all input required to set up a comet dust emission simulation, please refer to ComMoDE Comet Model Guide.

[3] For a detailed explanation of all input required to set up a fly-by trajectories post-processing, please refer to ComMoDE Comet Model Guide.

[4] Job status will be considered successful or not if the job run without errors and produced valid results.

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inputComa.xml × inputFlyBy.xml

home > rocco > ESA-ComMoDE_v1.0 > PROVA2 > inputComa.xml


```xml
<?xml version="1.0" ?>
<root>
    <ComaForm>
        <ComaParameters>
            <SizeDistribution>
                <default>False</default>
                <NumberOfSizeBins>10</NumberOfSizeBins>
                <PowerLawIndex>3.60</PowerLawIndex>
                <SmallestSize>-7</SmallestSize>
                <LargestSize>-1</LargestSize>
            </SizeDistribution>
            <ScatteringProperties>
                <Material>astro-silicate</Material>
                <HeliocentricDistance>1.00</HeliocentricDistance>
                <PhaseAngle>90</PhaseAngle>
            </ScatteringProperties>
            <DustProduction>
                <UseAfrho>True</UseAfrho>
                <DustProductionRate>30000.00</DustProductionRate>
                <Afrho>25.00</Afrho>
            </DustProduction>
            <DustOutflowVelocity>
                <GasProductionRate>15000.00</GasProductionRate>
                <expert>True</expert>
                <NucleusRadius>5000.00</NucleusRadius>
                <NucleusSurfaceTemperature>317.00</NucleusSurfaceTemperature>
                <DustBulkDensity>533.00</DustBulkDensity>
            </DustOutflowVelocity>
            <DayNightAsymmetry>
                <active>False</active>
                <AngularAsymmetryFunction>cosine</AngularAsymmetryFunction>
                <CosineAmplitude>0.00</CosineAmplitude>
            </DayNightAsymmetry>
            <RotationalVariability>
                <active>False</active>
                <RotationalPeriod>0.00</RotationalPeriod>
                <RotationalAmplitude>0</RotationalAmplitude>
            </RotationalVariability>
            <GridResolution>
                <MaximumDistance>60000.00</MaximumDistance>
                <Resolution>40</Resolution>
            </GridResolution>
        </ComaParameters>
    </ComaForm>
</root>
```


Figure 3: Example of inputComa.xml file inside the project folder

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ComMoDE INTEFACE AT GLANCE:

A sketch of the ComMoDE interface is reported in Figure 4.

Figure 4: Sketch of ComMoDE interface. Red numbers identify interface macro-sections

The ComMoDE interface can be ideally divided into six parts:

1. **Menus of controllers**: collecting all the commands (actions) that can be performed in the application. Three types of menus are exposed, namely File, Run and Help. The File menu collects all the commands to create a new ComMoDE project or upload a pre-existent one. Options to save the state of a project or to clear the project are exposed too. Finally an exit command to exit the application is provided[5]. The Run menu collects commands to start and stop the main jobs of the application, that are the comet dust emission simulation and the fly-by spacecraft trajectories dust impact evaluation. Help menu collects commands to display meaningful information of what ComMoDE is and instructions to access the Doxygen documentation of the code.

[5] Exiting the application is also possible clicking the X button of the graphical window (top right)

2. **Label of active project**: this is a read-only, non-interactable section that warns the User on what ComMoDE project is currently active in the application. It is usually filled automatically, once the User create a new project or open a pre-existent project. If no label appears in this section, it means ComMoDE has not yet a project to work on.
3. **Input forms**: this section displays two input forms to be filled by the User, to set up the comet dust emission simulation and the fly-by trajectories post-processing respectively. The User can access one form clicking on its relative tab. More details on how to navigate each form are reported in the RUN COMETARY DUST SIMULATION section and EVALUATE DUST IMPACT ON FLY-BY TRAJECTORIES section, respectively.
4. **Visualization environment**: this section is dedicated to the visualization of results produced by the fly-by trajectories post-processing. It comes with a 2D cartesian plot canvas and a toolbar on top, collecting controllers to :
    a. select the data to visualize in the plot
    b. navigate the plot (zooming, panning, etc..)
    c. visualize data from multiple processed trajectories in the same plot.
    d. save a screenshot of the plot to file
5. **Logger** : this is a read-only section, collecting all verbose feedbacks from the application that may be useful to the User. Among these, it will report messages (and errors if they occur) to inform the User on the coma simulation and fly-by trajectories post-processing job status. The logger section has two buttons to :
    a. Dump to file the logger contents: providing the log file will be useful to integrate documentation of a possible bug report to ComMoDE maintainers.
    b. Clear the logger contents: just throw away all the contents inside the section, and start writing the logger from scratch.
6. **Progress bar**: the progress bar is a graphical widget that visually tracking progresses of the main jobs runnable in the application, namely the coma simulation and the trajectories post-processing.

In order to guarantee the correct functionality of the application and avoid misusage errors, the ComMoDE interface implements a quite rigid protocol of actions to be performed. If the User accidentally breaks it, warning and errors will be returned to help him get back on track.
The protocol sequence can be summarized as following:

1. **Having always an active project**: to access functionalities of the application a project must be created from scratch or loaded. If no project is active, the GUI will remain in a "disabled" state, meaning the User can interact with nothing except controllers of the File menu.
2. **Run a valid coma simulation**: once 1 is satisfied, the User needs to perform the coma simulation, filling its input form and running the job. A coma simulation job will be

considered valid if it runs without errors and populate the coma-results subfolder of the project with its data file. Modifications to the input form will not affect the status of previous coma-simulation jobs, until the run command is pressed again.

3. **Run a valid evaluation of dust impact on trajectories** : once 1 and 2 are satisfied, the User needs to evaluate the dust impact evaluation on trajectories, filling its input form and running the job. A trajectories evaluation job will be considered valid if at least one trajectory is processed without errors and its relative folder inside the flyby-results project folder is populated with data file. Modifications to the trajectory input form will not affect the status of previous fly-by post-processing jobs, until the run command is pressed again. ***Please note***: once valid trajectories results are produced, if the User run successfully a completely new coma simulation in the same project, the trajectories results will be automatically erased, since they are no more consistent with the new coma dust emission results. In such cases, the stage 3 of the protocol will be considered unsatisfied and the User needs to re-evaluate the trajectories again.
4. **Visualizing trajectory data results**: once 1,2 and 3 are satisfied, the User can interact with the visualization environment and navigate the trajectory results. The visualization environment constantly monitors the flyby-results folder of the project, seeking for visualizable results. If nothing is available, nothing will be visualized.

HOW TO MANAGE A PROJECT

As already mentioned in the previous sections, the starting point to use ComMoDE is to enable a project and start tracking the User work session. Management of projects is accomplished by commands collected in the File Menu section of the Interface. Main commands of the file menu are discussed below.

Creating a new project

The command will create a new ComMoDE project from scratch. Once pressed, a directory dialog widget (Figure 5) will appear requiring to select a root directory onto filesystem where to store the project folder. One click “selects” the directory (the name should appear in the Directory form), double click “accesses” the content of the directory. Here it is required to “select” the directory. Once selected, press the button “Choose” to confirm the choice.
After that, another dialog widget will appear requiring to set a name for the new project folder (Figure 6). Once done, press ok. If the project is successfully created, the name of the project will appear in the project label section of the GUI, under the Menu controllers.

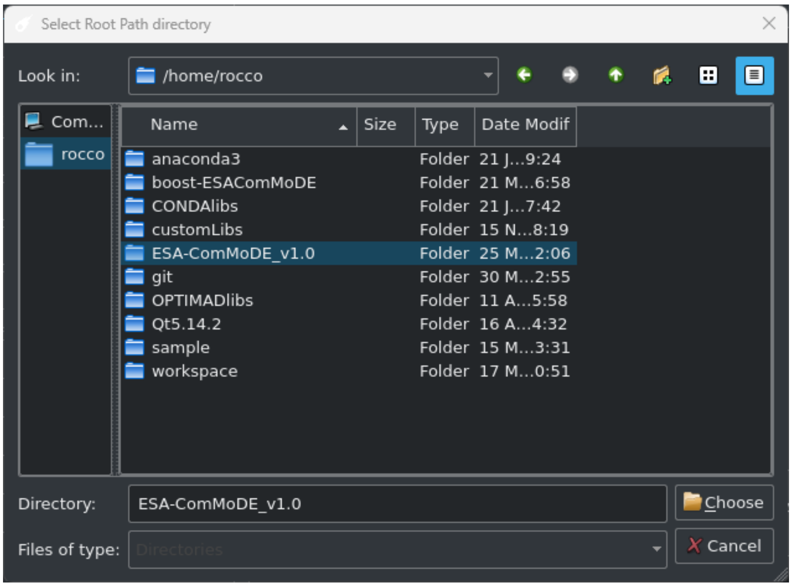

Figure 5: Pop-up widget to choose a directory

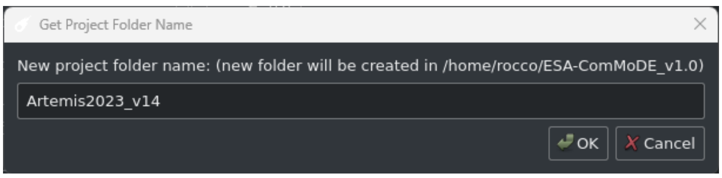

Figure 6: Pop-up widget to choose the name of the project folder

Open an existent project

The command will reload a pre-existent project, previously created in ComMoDE. Once pressed, a directory dialog widget (similar to Figure 5) will appear requiring to select the project folder to reload onto the filesystem. Selection rules are the same as those explained for the root directory of the Create a new project command. If the project is successfully loaded, the name of the project will appear in the project label section of the GUI, under the Menu controllers.
Input forms will be restored using backup information of project folder inputComa.xml and inputFlyby.xml. Job status for coma simulation and fly-by trajectories will be restored from project folder .status_project file.

Save a project

The command will save the status of the current active project. Once pressed, input forms will be backed up onto project folder files inputComa.xml and inputFlyby.xml. The coma simulation and fly-by trajectories post-processing will be backed up onto the project folder .status_project file.

Clone/Backup a project

The command will save the current active project in a new independent one, attaching a custom name. The cloned project will preserve the status of the original project and from that point on it can be used as a totally independent project. Once the command is pressed, the same procedure as Create new project will apply: the User needs to choose the root directory to store the cloned project and define a name for it.

Exit the application

The command will exit the application. If the application is running a coma simulation or a fly-by post-processing job, a pop-up dialog will appear asking the User if we want to wait for the job completion or force the exit. Before exiting, a Save project will be enforced on the current active project.

RUN A COMETARY DUST SIMULATION

This section will show how to set up and run the comet dust emission simulation job.

Fill in the comet dust emission simulation input form

The input form to set up a coma simulation can be accessed clicking on the "Coma Simulation" tab of the input forms section (see figure 7). For a detailed explanation of the inputs presented in this section please refer to the ComMoDE Comet Model Guide.

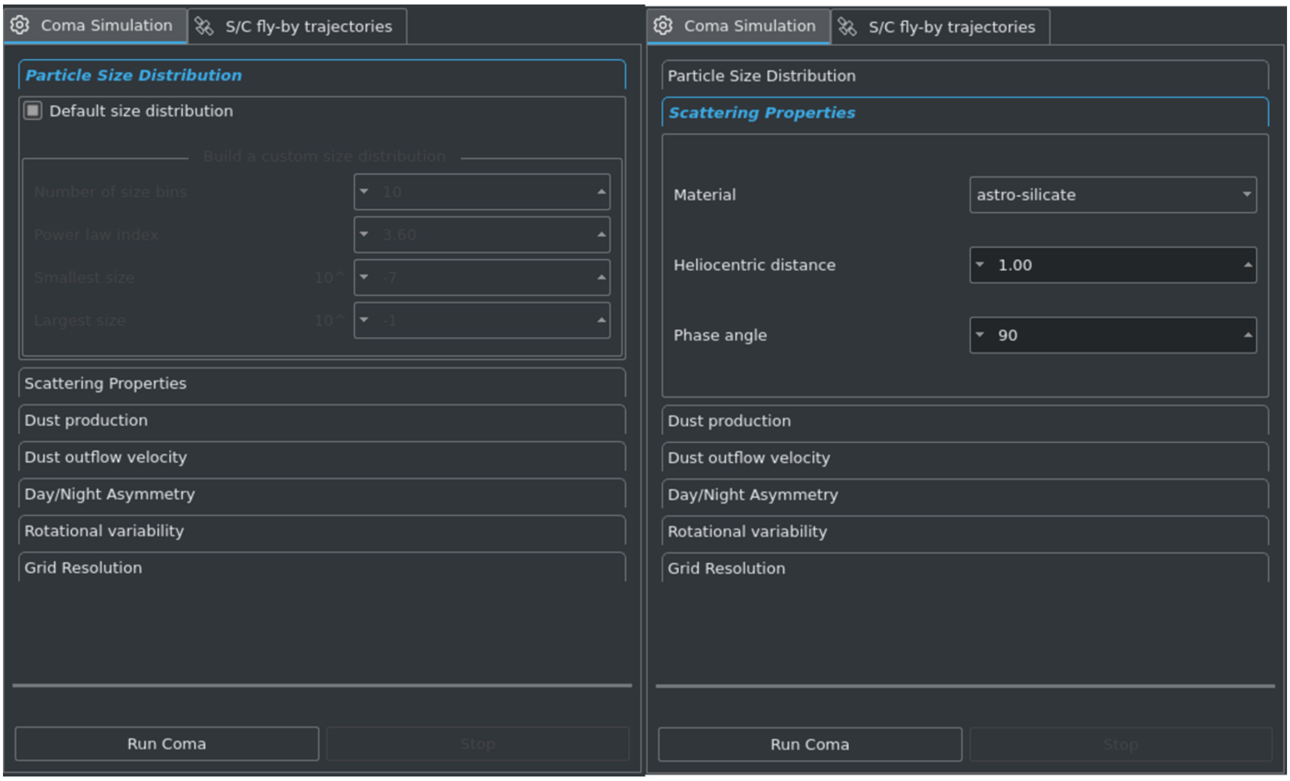

Figure 7: Coma Simulation input form: dust particle size and scattering properties

The input form is ideally subdivided into thematic sections to characterize the dust properties, the comet properties, the external conditions that may affect the dust emission[6] and the computational domain of the simulation.
Such sections are grouped in foldable tabs: clicking on a section tab will expand the widget and show the peculiar parameters to set up for that section.

[6] like day/night asymmetry environmental conditions or effect of rotation of the comet nucleus

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Size Distribution section

The following section (Figure 7) allows to define a particle size distribution for the dust prototype. The User can choose between a default size distribution or a custom one by defining:

- Number of total bins in the distribution
- Size of the smallest particle in the distribution
- Size of the largest particle in the distribution
- Exponent of the power law function characterizing the distribution

For both default and custom distributions, the only distribution function type allowed is a power law[7]. The default distribution is a particular custom distribution built with the following parameters: Number of bins : 18, Smallest size : 10^{-7} m, Largest size : 10^{-1} m, Power law exponent : 3.8.

Scattering Properties section

The following section (Figure 7) allows to define the dust material and its scattering properties. The User can choose between a pre-set list of materials, then, in order to characterize properly the scattering, he needs to specify the distance between the emitting comet and the sun (heliocentric distance), and the relative phase angle.

Dust Production section

The following section (Figure 8) allows to define the comet global dust production rate. The User can choose to set the production rate in two ways:

- Setting directly the value of production rate (in Kg/s)
- Specifying alternatively the Afρ[8] rate.

Dust Outflow velocity section

The following section (Figure 8) allows to define the comet outflow condition when emitting the gas/dust mixture. The main parameter here to set is the gas production rate [Kg/s]. Optionally the User can choose to characterize further the comet emission model (“enable other options” check box), specifying:

- The comet nucleus radius [m]
- The comet nucleus surface temperature [K]
- The dust bulk density [Kg/m^3]

[7] Please refer to the ComMoDE Comet Model Guide for further details.
[8] Please refer to the ComMoDE Comet Model Guide for further details.

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If such parameters are not specified, the following default values will be taken into account: nucleus radius 5000 [m], nucleus surface temperature 314 [K], dust bulk density 533 [Kg/m^3].

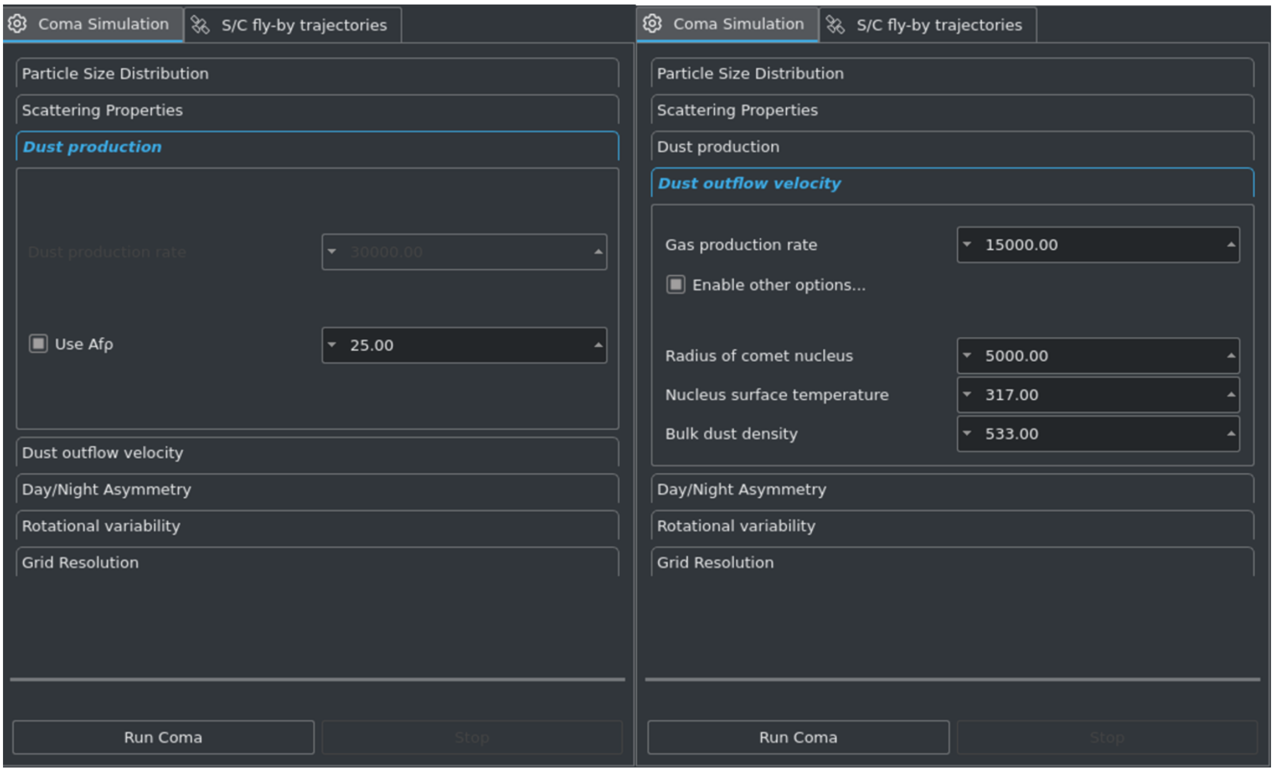

Figure 8: Coma Simulation input form : comet dust production and outflow velocity

Day/Night asymmetry section

The following section (Figure 9) is totally optional, and let the User to characterize the effect of different day/night duration onto the dust emission model. Please note that taking into account the day/night asymmetry will increase the simulation computational time by orders of magnitude. The default choice of the application is to skip this section and always consider isotropic day/night conditions.

In case the User activates the asymmetry option, he needs to choose a function among a list of pre-set choices to model the angular asymmetry. ComMoDE makes available the following functions : *gaussian*, *half-maxwell*, *cosine*. In case a cosine function is chosen , the User must specify also the amplitude of the cosine function[9].

[9] Please refer to the ComMoDE Comet Model Guide for further details.

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Rotational variability section

The following section (Figure 9) is totally optional, and let the User to characterize the effect of the inner comet nucleus rotation onto the dust emission model. Please note also, that accounting for rotation variability makes sense if and only if a day/night asymmetry is previously activated. The default choice of the application is to skip this section and always ignore the comet nucleus rotation. In case the User activates the rotational variability option, he needs to define the Rotational Period of the comet nucleus and the rotational amplitude[10].

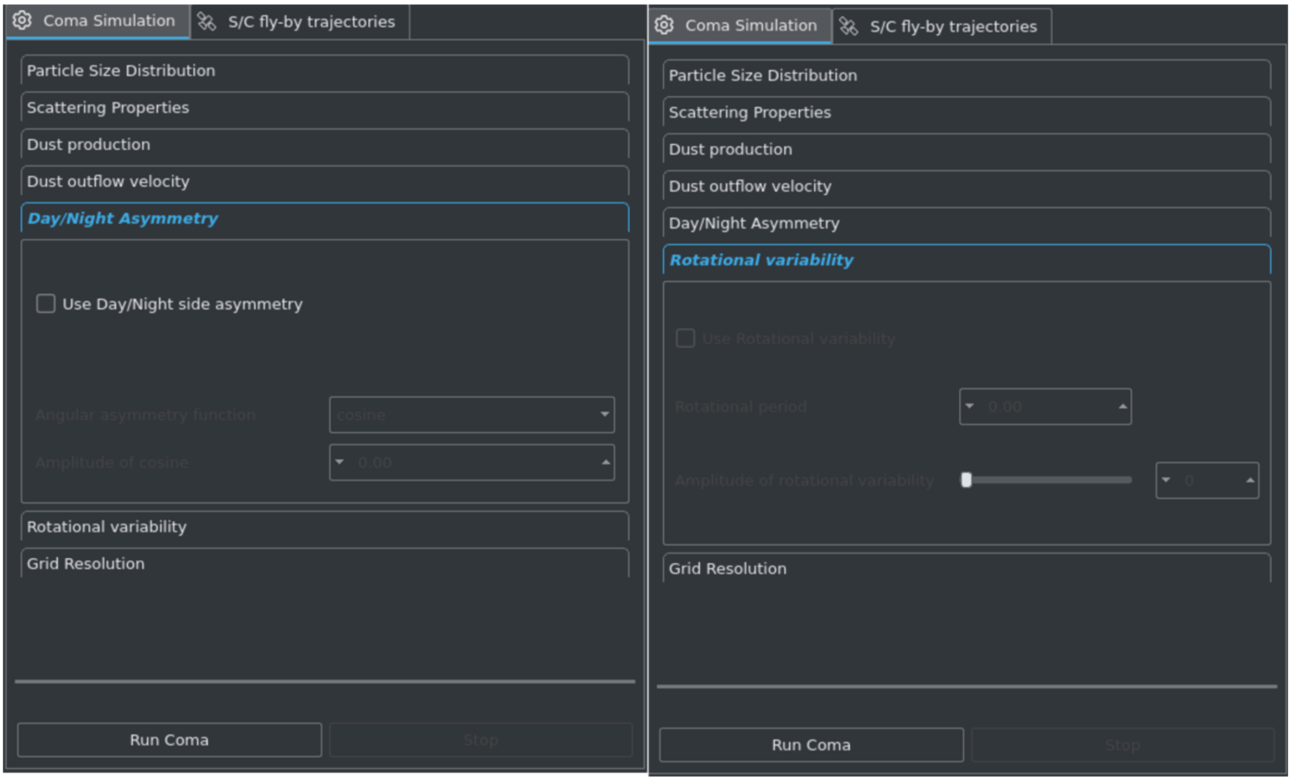

Figure 9: Coma Simulation Input form : day/night asymmetry and rotational variability

Grid resolution section

The following section (Figure 10) allow the User to define the size of the computational domain around the comet and pick up a resolution of the final computational mesh. The User needs to set the maximum distance from comet [Km], that quantifies the extension of the domain and the typical side-length of a computational mesh cell (resolution) in Km.

[10] Please refer to the ComMoDE Comet Model Guide for further details.

Submit the cometary simulation job

Once the User is done editing the Coma Simulation form, he can start the simulation pressing the button “Run Coma” at the bottom of the form, or alternatively pressing the “Run Coma Simulation” command in the Run menu. The simulation can be stopped anytime by the User, pressing on the button “Stop”, present at the bottom of the section. Please note, once manually stopped the simulation job is always put into an invalid status and all the progress eventually made before aborting will be irreversibly lost. If the User re-run the simulation, the job will always start from scratch. While the simulation job is running, all the meaningful messages produced during the job execution will be displayed in the application logger section, the progresses made by the job will be tracked by the application progress bar.

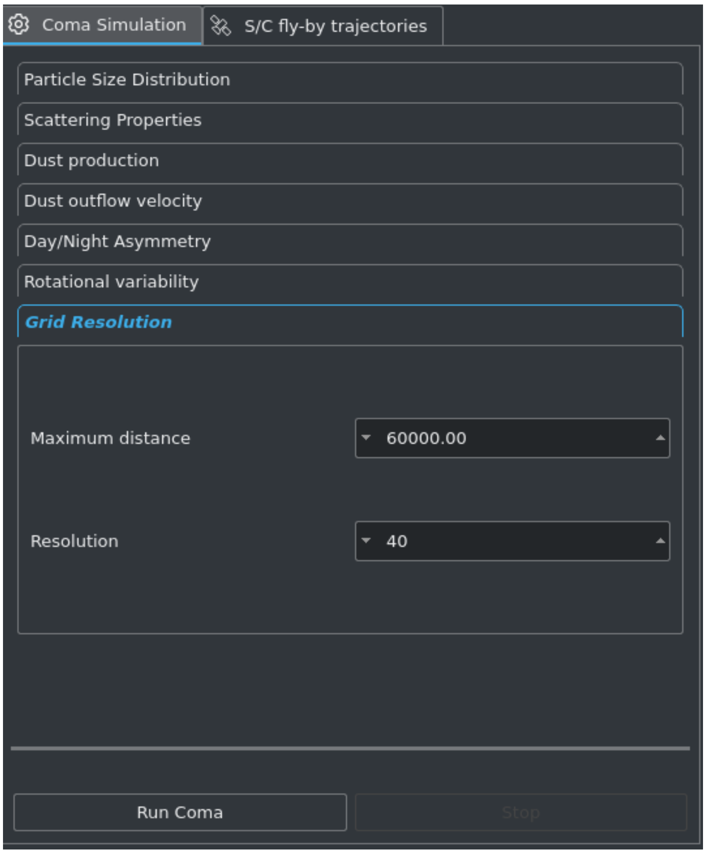

Figure 10: Coma Simulation Input form: grid resolution

EVALUATE DUST IMPACT ON FLY-BY TRAJECTORIES

Manage spacecraft fly-by trajectories creation

The input form to set up the dump impact evaluation on fly-by trajectories can be accessed clicking on the “S/C fly-by trajectories” tab of the input forms section (see figure 11). For a detailed explanation of the inputs needed to build a trajectory please refer to the ComMoDE Comet Model Guide.

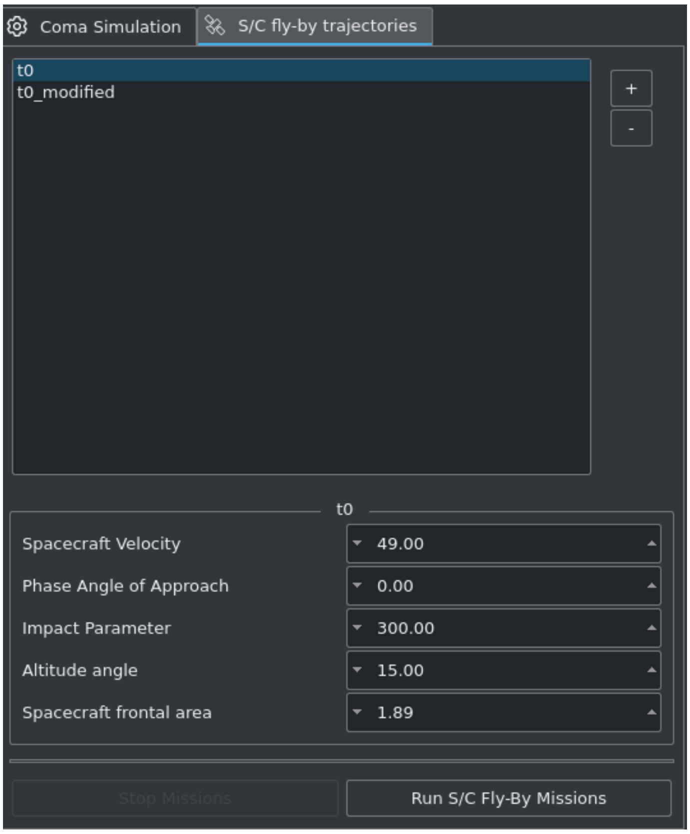

Figure 11 : S/C fly-by trajectories input form

The input form is ideally subdivided into two sections: the first part (on the top) is dedicated to the definition of how many trajectories must be evaluated, the second part the form to insert the constitutive parameters that characterize each trajectory. The workflow is extremely easy and intuitive, and let the User to define how may trajectories he wants, in the same session:

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1. The User can add a new trajectory to evaluate using the **+** button on top-right corner of the section.
2. A pop-up widget will appear asking to assign a name to the trajectory (t0, t0_modified, my-trajectory, etc..).
3. If the trajectory is successful created, the trajectory name will appear in the widget on the top-left corner, who list all the possible trajectories created by the User in the session.
4. The User can single-click on a trajectory name in the list and select it. In this case, in the constitutive parameters form located below, the User can access all the constitutive parameters of the selected trajectory and edit them. Please note, once a trajectory is selected, its name will appear also in the parameters form box, just to help the User to quickly recognize which trajectory parameters is editing.
5. A trajectory can also be removed from the list. To do so: click on the trajectory name on the list widget and press the **–** button on top-right corner of the section.

The trajectory constitutive parameters form reports the following needed inputs:

- Spacecraft velocity: magnitude of spacecraft velocity with respect to the comet nucleus velocity, in m/s
- Phase Angle of approach: of the spacecraft with respect to the comet, in degrees
- Altitude Angle: the phase angle of the spacecraft at the point it crosses the sun/comet line, in degrees
- Impact parameter: cometocentric distance of the spacecraft at closest approach to the comet, in Km
- Spacecraft frontal area: frontal area of the spacecraft, exposed to the dust wind, in m^2

Submit dust impact evaluation on trajectories job.

Once the User is done creating and editing trajectories, he can start the dust impact on trajectories post-processing, pressing the button “Run S/C fly-by missions” at the bottom of the section, or alternatively pressing the “Run S/C fly-by missions” command in the Run menu. The post-processing will evaluate dust-impact on all the trajectories created in the form.
The post-processing can be stopped anytime by the User, pressing on the button “Stop” present at the bottom of the section.
Differently from the coma simulation job, if the post-processing job is manually stopped at the certain point, but it already produced valid results for some of the target trajectories, it will keep such results. So, if the User re-run the post-processing[11], the job will recognize which trajectories

[11] Provided that he did not modify the constitutive parameters relative to the trajectories already successfully evaluated. If he did alter the constitutive parameter form, the application will recognize that some trajectories are modified, and force again their evaluation.

are already processed and safely avoid to re-process them twice. While the post-processing job is running, all the meaningful messages produced during the job execution will be displayed in the application logger section, the progresses made by the job will be tracked by the application progress bar.

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VISUALIZE DUST IMPACT DATA ONTO TRAJECTORIES

Manage data visualization of dust impact on a trajectory

Once the trajectories post-processing produced valid results[12], the User can access the visualization environment (figure 12,13).

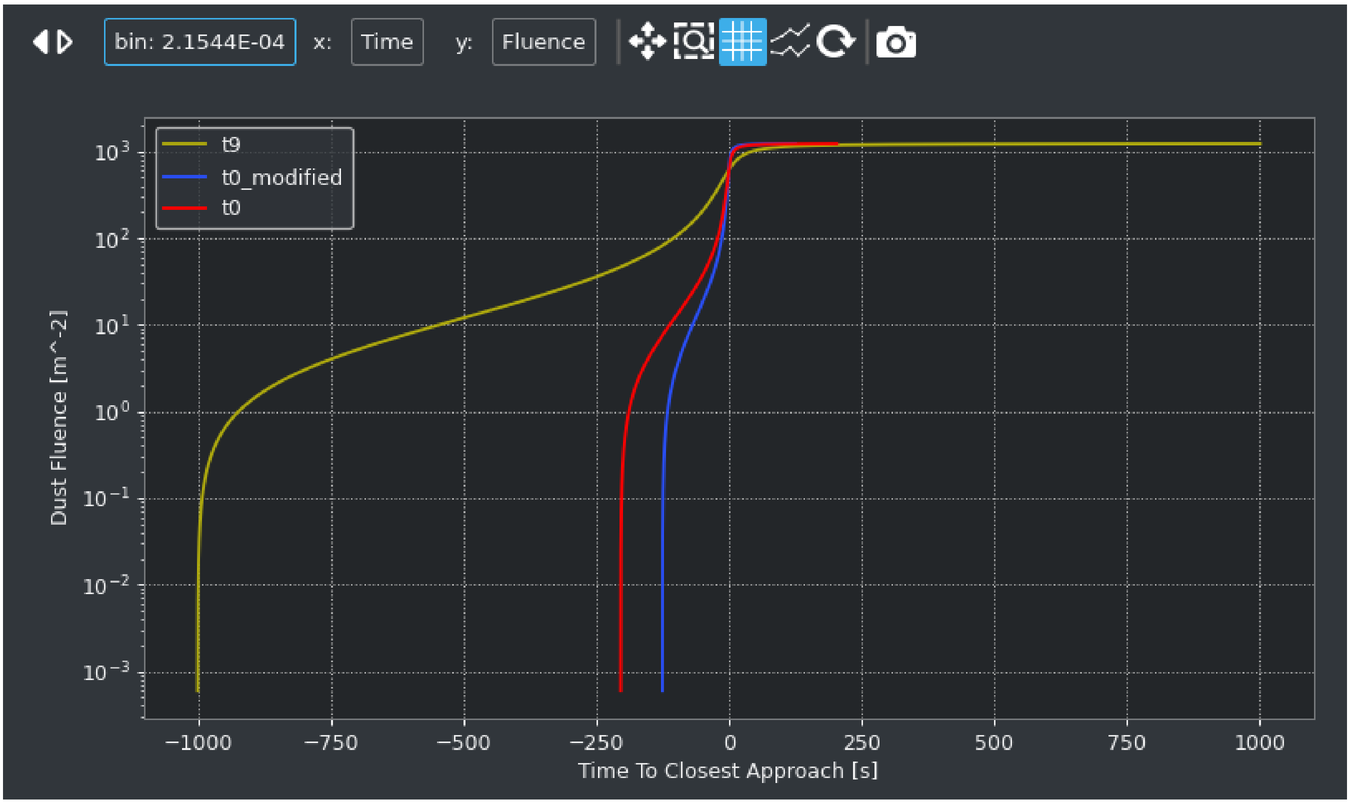

Figure 12: ComMoDE Visualization Environment - trajectory mode

The main section of the environment is the cartesian plane where the trajectories data will be plot. On top of that, a toolbar of commands to control the data visualization is reported.
Trajectories calculated data are divided by dust sizes, that means a specific result file is produced for each bin of the dust particle size distribution, previously defined in the coma simulation.
In each result file, six quantities referring to the dust impact onto the trajectory are tabulated. These quantities are: dust density, dust flux, dust fluence, R and S spatial coordinates of the

[12] At least one trajectory must be successfully evaluated.

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spacecraft trajectory with respect to the comet and time to closest approach of the spacecraft, as it travels along its trajectory[13].

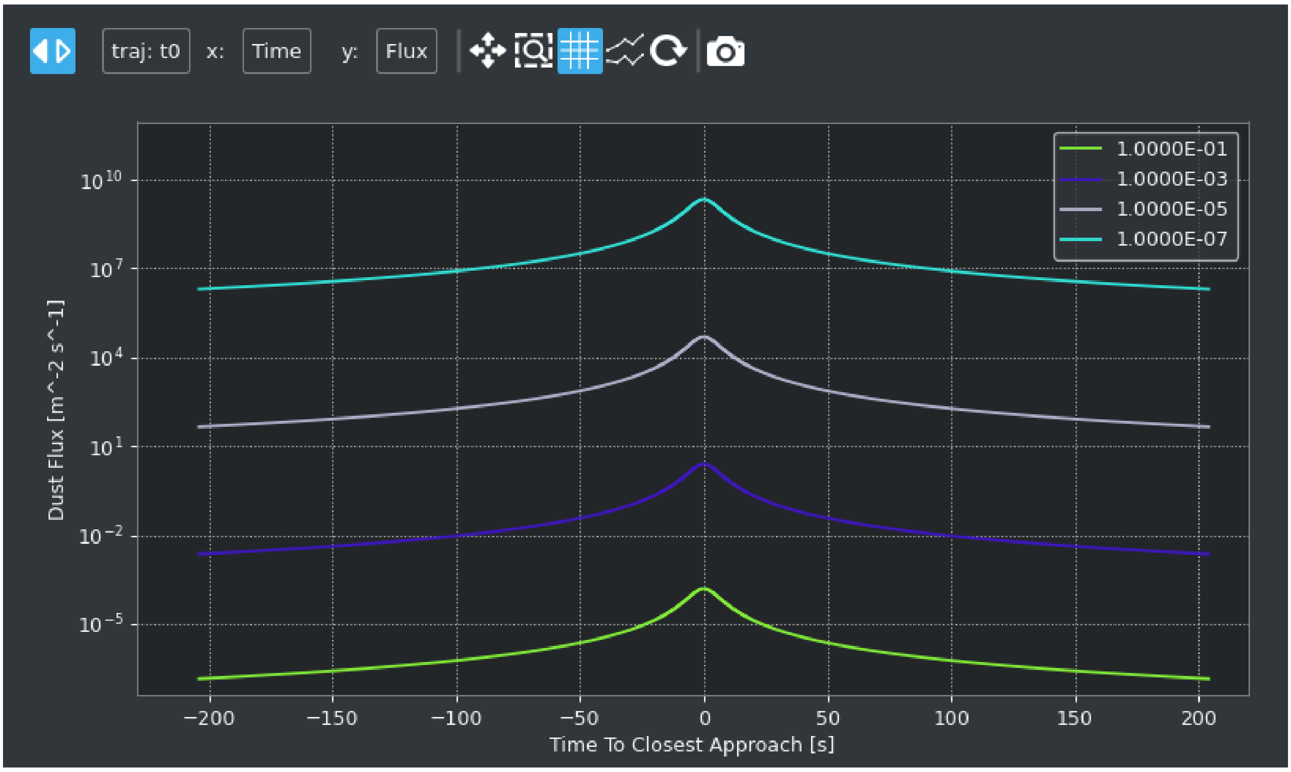

Figure 13: ComMoDE Visualization Environment - bin sizes mode

The very first button  (Visualization Mode Switch) of the toolbar controls the visualization mode of the application.

- Toggled OFF: enable the default mode of visualization (*trajectories*), e.g. once a particular bin size of the particle size distribution is fixed, the User can plot simultaneously data referring to one or multiple trajectories. See an example in figure 12.
- Toggled ON: enable the specular visualization mode (*bin sizes*), e.g. once a particular trajectory is fixes, the User can plot simultaneously data referring to one or multiple bin sizes of the particle size distribution. See an example in figure 13.

After the Visualization Mode Switch, three other interactable items follows in the command toolbar, namely:

---

[13] For a detailed explanation of the dust impact quantities calculated along the trajectory, please refer to the ComMoDE Comet Model Guide.

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- A clickable button to access a list widget to “fix” the data for the current Visualization Mode. In *trajectories* mode the list will report all the particle size bins available, and it will let the user to choose one singular size bin each time. On the other hand, in *bin sizes* mode, the list will report all possible trajectories, and let the user to choose one of them each time.
- A clickable button to access the X-axis options widget. Typically the User can customize the quantity to represent on the cartesian plot abscissas choosing from a list, and change the axis scaling (logarithmic or regular). See figure 14.
- A clickable button to access the Y-axis options widget. Typically the User can customize the quantity to represent on the cartesian plot ordinates choosing from a list, and change the axis scaling (logarithmic or regular). See figure 14.

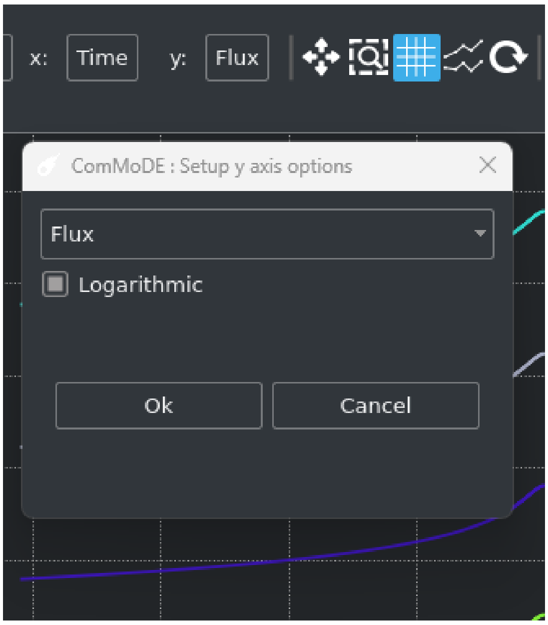

Figure 14: Axis Options Dialog

Then, there are commands to customize the visualization of the cartesian plot. In particular:

-  *Panning action*: it is button to activate/deactivate the mouse interaction with the cartesian plane viewport, to translate or zoom the view. When the panning mode is activated:
  - Left-click and keep pressed the mouse, then moving the mouse around in the cartesian plane will allow to translate the view focus around the cartesian plane.

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- Right-Click and keep pressed the mouse, then move horizontally or vertically the mouse, will enable the zoom on the cartesian plane x-axis or y-axis respectively.

- *Zooming drawing a Rect action*: it is a button to activate/deactivate the possibility to zoom in a sub-portion of the cartesian plane, drawing a rectangle. Once the mode is active, left-click and keep pressed the mouse, then move the mouse: a dashed rectangle will appear. Once the mouse button is released, the view will be zoomed in the rectangle drawn.
- *Reset view action*: click the button to restore the original default view.
- *Toggle grid action*: it is a button to activate/deactivate the grid visualization on the cartesian plane.

Finally the last two commands available are:

- *Save screenshot on file*: it is a command to save the current view of the cartesian plot to file. When pressed, a pop-up widget will appear asking the file name and extension onto which the picture must be saved.
- Multiple Data Visualization Manager: pressing this button, a pop-up widget will appear to let the User choose which data must be visualized into the cartesian plot, according to the visualization mode currently active.

Activate multiple data visualization.

As already mentioned in the previous section, pressing the button , will allow to enter the Multiple Data Visualization Manager of ComMoDE (see figure 15, 16).
Suppose the User is in *trajectories* Visualization mode (a bin size is fixed) and he has processed more than one trajectory. He wants to visualize simultaneously data coming from multiple trajectories in the same plot. Accessing this environment, the User can select from the list of all the trajectories available those he wants to visualize in the plot.

Moreover pressing on the button he can modify the color of trajectory data, to improve the visibility of the compared data. Then, to confirm his choice, the User must press the Ok button to apply the modifications.

Figure 15: Data Visualization manager in trajectories mode

Similar behavior is granted if the User is in *bin size* Visualization mode (a trajectory is fixed). In this particular case, the User can visualize data referring to multiple bin sizes of the particle distribution, with the same color customization capability (see figure 16).

In order to have always a manageable and clear navigation of the data, the maximum number of multiple trajectories data visualizable in the same cartesian plot is fixed to 10, in both visualization mode.

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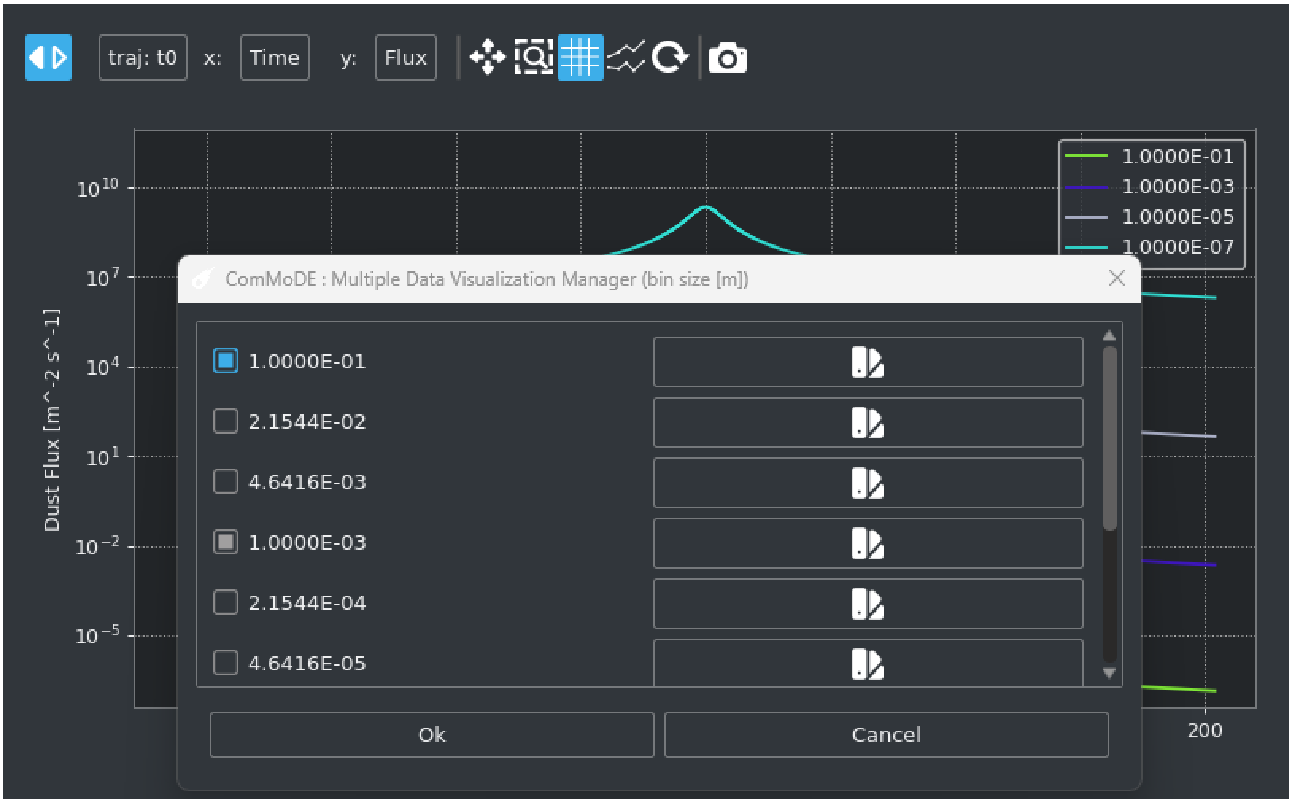

Figure 16: Data Visualization manager in bin-sizes mode