APPENDIX A

A fast manual to use fargo_tools

This is a brief manual to introduce users who want to learn the use of fargo_tools, this includes how to get the data from the hydrodynamical simulation and to visualize 3D data with Paraview. It assumes you use some Linux distribution and you are familiarized with the terminal environment.

The text in verbatim after the $ symbol means the commands that you need enter in the terminal. If you copy these command lines one by one you could follow this tutorial very easy.

A.1 Creating some FARGO3D outputs

Let's start in our home directory, (this tutorial assumes that you have fargo_tools directory in your home and also that you will download fargo3d there)

```
$ cd
$ pwd
  /home/oscar
```

First of all you need to download the FARGO3D code

```
$ wget http://fargo.in2p3.fr/Download
```

the next step is to decompress it (the name can change depending on the FARGO3D version)

```
$ tar -xvf fargo3d-1.0.tar.gz
```

This will create a directory called fargo3d-1.0 (The name can vary depending on the version). Change to the fargo3d directory

```
$ cd fargo3d-1.0
```

Inside this directory you can compile the fargo3d code if you have the correct compilers (see FARGO3D's manual). Let's compile the default p3disof setup, which is a full 3D isothermal circumstellar disk

```
$ make SETUP=p3disof para
```

I decided to compile it to run in parallel with CPUs, but you can compile it with GPU or in the sequential slow way, again see `FARGO3D` manual. If the compilation does not mark an error you are ready to generate your data, if it does, you need to check your compilers.

It is time to run the simulation

```
$ mpirun -np 8 ./fargo3d -m setups/p3disof/p3disof.par
```

I ran the simulation with eight processors, this can vary depending on your computer or if you are using a sequential or GPU run. The `-m` flag is quite important to use, since this generate the data in the way that `fargo_tools` needs. Wait some time until the system evolves, let's stop the simulation after 10 outputs, you can do this typing `Ctrl + C`.

A.2 Using t2csv

The `fargo_tools` directory contains some directories, one of them is called `t2csv`, let's move there

```
$ cd ~/fargo_tools/t2csv
```

if you do a `ls` you will see a `makefile`, if you have `OPENMP` correctly installed it must compile, and if it does, an executable file called `t2csv` will be created and some `.o` files.

```
$ pwd
  /home/oscar/fargo_tools/t2csv
$ ls
  makefile
$ make
  mpif90 -cpp -finit-local-zero -fno-automatic -ffloat-store -c ../sources_f90/t2csv.f90
  mpif90 -cpp -finit-local-zero -fno-automatic -ffloat-store -c ../sources_f90/trans_coords.f90
  mpif90 -cpp -finit-local-zero -fno-automatic -ffloat-store -c ../sources_f90/create_names.f90
  mpif90 -cpp -finit-local-zero -fno-automatic -ffloat-store -c ../sources_f90/input_file.f90
  mpif90 -cpp -finit-local-zero -fno-automatic -ffloat-store t2csv.o trans_coords.o
  create_names.o input_file.o -o t2csv
$ ls
  create_names.o  input_file.o  makefile  t2csv  t2csv.o  trans_coords.o
```

If you obtained some like that in your computer, you are ready to use `t2csv`. The next step is to copy the `t2csv` file to your output file directory, this directory must be inside `fargo3d-1.0/outputs/p3disof/`

```
$ cp t2csv ~/fargo3d-1.0/outputs/p3disof/
$ cd ~/fargo3d-1.0/outputs/p3disof/
$ ls
  bigplanet0.dat   FG000008       gasenergy0.dat   gasvx2.dat   gasvy5.dat   gasvz8.dat
  density0_2d.dat  FG000009       gasenergy10.dat  gasvx3.dat   gasvy6.dat   gasvz9.dat
  dimensions.dat   FG000010       gasenergy1.dat   gasvx4.dat   gasvy7.dat   grid000.inf
  domain_x.dat     gasdens0.dat   gasenergy2.dat   gasvx5.dat   gasvy8.dat   grid001.inf
  domain_y.dat     gasdens10.dat  gasenergy3.dat   gasvx6.dat   gasvy9.dat   IDL.var
  domain_z.dat     gasdens1.dat   gasenergy4.dat   gasvx7.dat   gasvz0.dat   orbit0.dat
  FG000000         gasdens2.dat   gasenergy5.dat   gasvx8.dat   gasvz10.dat  planet0.dat
  FG000001         gasdens3.dat   gasenergy6.dat   gasvx9.dat   gasvz1.dat   t2csv
  FG000002         gasdens4.dat   gasenergy7.dat   gasvy0.dat   gasvz2.dat   torq_planet_0.dat
  FG000003         gasdens5.dat   gasenergy8.dat   gasvy10.dat  gasvz3.dat   tqwk0.dat
  FG000004         gasdens6.dat   gasenergy9.dat   gasvy1.dat   gasvz4.dat   variables.par
  FG000005         gasdens7.dat   gasvx0.dat       gasvy2.dat   gasvz5.dat   vx0_2d.dat
  FG000006         gasdens8.dat   gasvx10.dat      gasvy3.dat   gasvz6.dat   vy0_2d.dat
  FG000007         gasdens9.dat   gasvx1.dat       gasvy4.dat   gasvz7.dat   vz0_2d.dat
```

Before running `t2csv`, an input file must be created, this input file must be named `input.dat`, and it has to have the next data in the following order

1. Number of cells in the X direction
2. Number of cells in the Y direction
3. Number of cells in the Z direction
4. Minimum output file to be transformed
5. Maximum output file to be transformed
6. Size of the jump between output files to be transformed
7. Min value in X direction
8. Max value in X direction
9. Min value in Y direction
10. Max value in Y direction
11. Min value in Z direction
12. Max value in Z direction
13. Grid Geometry. s for spherical, c for cylindrical, r for cartesian

The values for 1-3, 7-12 can be obtained from the `.par` files, the 13 from the `.opt` files and the values for 4-6 are user defined. You can fill the `input.dat` file according to your simulation. For the `p3disof` setup, open a file called `input.dat` with your favorite text editor and fill it with the next lines

```
100      #Number of cells in the X direction
80       #Number of cells in the Y direction
40       #Number of cells in the Z direction
0        #minimum output file to be transformed
10       #maximum output file to be transformed
1        #size of the jump between output files to be transformed
-3.14159 #Min value in X direction
3.14159  #Max value in X direction
0.6      #Min value in Y direction
1.5      #Max value in Y direction
1.42     #Min value in Z direction
1.72     #Max value in Z direction
s        #s for spherical, c for cylindrical, r for cartesian
```

This mean that our grid has 100, 80 and 40 cells in the X, Y, Z coordinate, respectively. We want to transform the output files from the 0 to the 10 output, one by one (this means that the output files from 0,1,2,3,4,5,6,7,8,9,10 will be used, if we would want 0,2,4,6,8,10 we had specified 2 in the size of the jump, and so on). The domain of our grid goes from $[-\pi : \pi]$ in azimuth, $[0.6 : 1.5]$ in radius and $[1.42 : 1.72]$ in colatitude. The grid geometry is spherical so the `s` character is used. Now the `input.dat` file must be in the same directory as `t2csv`

```
$ ls
  bigplanet0.dat   FG000009        gasenergy1.dat  gasvx5.dat   gasvy9.dat   input.dat
  density0_2d.dat  FG000010        gasenergy2.dat  gasvx6.dat   gasvz0.dat   orbit0.dat
  dimensions.dat   gasdens0.dat    gasenergy3.dat  gasvx7.dat   gasvz10.dat  planet0.dat
  domain_x.dat     gasdens10.dat   gasenergy4.dat  gasvx8.dat   gasvz1.dat   t2csv
  domain_y.dat     gasdens1.dat    gasenergy5.dat  gasvx9.dat   gasvz2.dat   torq_planet_0.dat
  domain_z.dat     gasdens2.dat     gasenergy6.dat  gasvy0.dat   gasvz3.dat   tqwk0.dat
  FG000000         gasdens3.dat     gasenergy7.dat  gasvy10.dat  gasvz4.dat   variables.par
  FG000001         gasdens4.dat     gasenergy8.dat  gasvy1.dat   gasvz5.dat   vx0_2d.dat
  FG000002         gasdens5.dat     gasenergy9.dat  gasvy2.dat   gasvz6.dat   vy0_2d.dat
  FG000003         gasdens6.dat     gasvx0.dat      gasvy3.dat   gasvz7.dat   vz0_2d.dat
  FG000004         gasdens7.dat     gasvx10.dat     gasvy4.dat   gasvz8.dat
  FG000005         gasdens8.dat     gasvx1.dat      gasvy5.dat   gasvz9.dat
  FG000006         gasdens9.dat     gasvx2.dat      gasvy6.dat   grid000.inf
  FG000007         gasenergy0.dat   gasvx3.dat      gasvy7.dat   grid001.inf
  FG000008         gasenergy10.dat  gasvx4.dat      gasvy8.dat   IDL.var
```

Now `t2csv` can be executed

```
$ mpirun -np 4 ./t2csv
  Creating disk          0 .csv file by processor           1
  Creating disk          1 .csv file by processor           2
  Creating disk          3 .csv file by processor           4
  Creating disk          2 .csv file by processor           3
  Creating disk          6 .csv file by processor           3
  Creating disk          5 .csv file by processor           2
  Creating disk          4 .csv file by processor           1
  Creating disk          7 .csv file by processor           4
  Creating disk         10 .csv file by processor           3
  Creating disk          9 .csv file by processor           2
  Creating disk          8 .csv file by processor           1
  The csv files have been created inside csv_files directory
```

If you obtained a similar output, there is a new directory called `csv_files`, inside that directory, there are some disk$m$.csv files, you must obtain some like

```
$ cd csv_files
$ ls
  disk0.csv   disk1.csv  disk3.csv  disk5.csv  disk7.csv  disk9.csv
  disk10.csv  disk2.csv  disk4.csv  disk6.csv  disk8.csv
$ head disk10.csv
  X, Y, Z, lden, vx, vy, vz, lenergy
  -0.59319105770894343      ,  -1.5740857362501043E-006 ,   9.0135281947011495E-002 ,
  -4.8342743671298392       ,   1.0866022838070270E-006 ,  -0.40948389480738567     ,
  0.0000000000000000        ,  -1.3010299956639813
  -0.59199667437804870      ,  -3.7624041166033385E-002 ,   9.0135281947011495E-002 ,
  -4.8342743696691226       ,   2.5972136210949341E-002 , -0.40865940464833644      ,
   0.0000000000000000       ,  -1.3010299956639813
                                            .
                                            .
                                            .
```

The `X, Y, Z` columns correspond to the rectangular coordinates, `lden` and `lenergy` to the base 10 logarithm of density and energy, respectively and `vx, vy, vz` to the velocity components in rectangular coordinates. These files can be used to visualize the data.

A.3 Visualizing 3D data with Paraview

In general, csv files can be opened with several programs with different proposes, in this work it is shown how to visualize 3D-data with Paraview (http://www.paraview.org/). Once you have installed it, you can open it from the terminal (you must be in your `csv_files` directory)

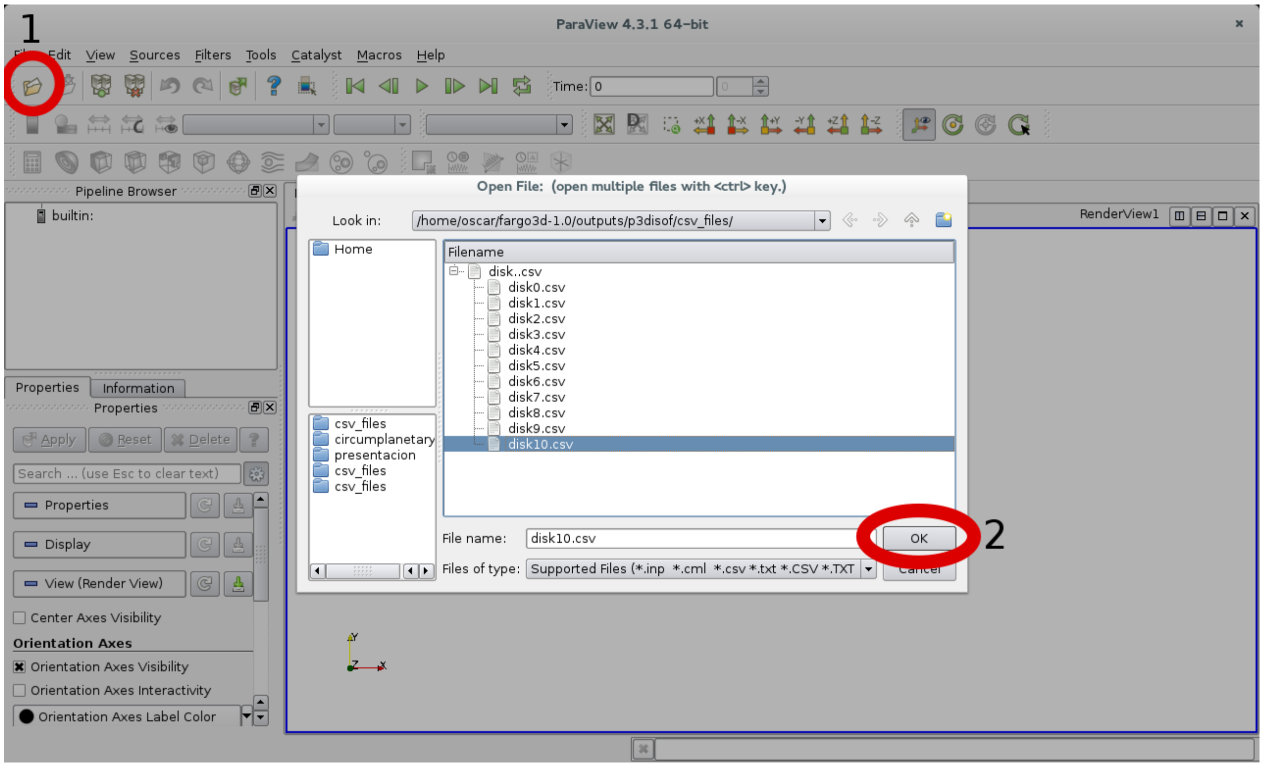
```
$ pwd
  /home/oscar/fargo3d-1.0/outputs/p3disof/csv_files
$ paraview &
```

The visual version of Paraview will start. To understand better how to visualize the data, follow the next steps following figures A.1, A.2, A.3, A.4, A.5, A.6 and the numbers labeled in them.

1. Open the file manager clicking on the button marked in figure A.1.
2. Select the file disk10.csv and click on the "ok" button.
3. When the file is opened, it appears in the pipeline browser, select it as it is shown in figure A.2.
4. Click on the apply button, and the csv file will be displayed as a table (see figure A.2).
5. The next step is convert the data into a grid form. Click on the Filters button and search for Table to Structured Grid.
6. Now it appears a new attribute in the pipeline browser called TableToStructuredGrid1, select it(Fig. A.3).
7. You need to fill correctly the Whole Extent section and the X, Y, Z columns. The Whole extent must coincide with the original grid dimension, let's remember that our simulation had 100, 80, 40 cells in X, Y, Z, then we fill the Whole Extent section with these values (see figure A.3). The X, Y, Z columns must coincide with the csv columns labeled as X, Y, Z (see figure A.3). When this is done, click on the apply button, now the data is displayed as figure A.3.
8. Click on the + button to create another layout to visualize the data.
9. Click on the eye shape symbol (see figure A.4) and you will see the outline grid visualization as the one showed in figure A.4.
10. To visualize a field data, change outline to surface view (see A.5).
11. Select lden to visualize the density logarithm data, you must obtain something like figure A.5.
12. To finish, let's make a cut on the grid to visualize the density profile. Select the cut icon (see Fig. A.6).
13. Select a cut normal to Y.
14. Press apply, you must obtain something like in the figure A.6. This is the typical 3D-density profile of an isothermal circumstellar disk.

Now you can manipulate a circumstellar disk with your own hands! These are the basic for Paraview visualization, there a lot more that you can do with these csv files and this program. To learn more about Paraview capabilities, read the online documentation in `http://www.paraview.org/Wiki/The_ParaView_Tutorial`.

Another powerful characteristic of Paraview, is that allows to create python scripts to analyze multiple files. This is very useful in analyzing `FARGO3D` data. To learn more about to this check this `http://www.paraview.org/Wiki/ParaView/Python_Scripting`.



Open File: (open multiple files with <ctrl> key.)

Look in: /home/oscar/fargo3d-1.0/outputs/p3disof/csv_files/

Home

csv_files
circumplanetary
presentacion
csv_files
csv_files

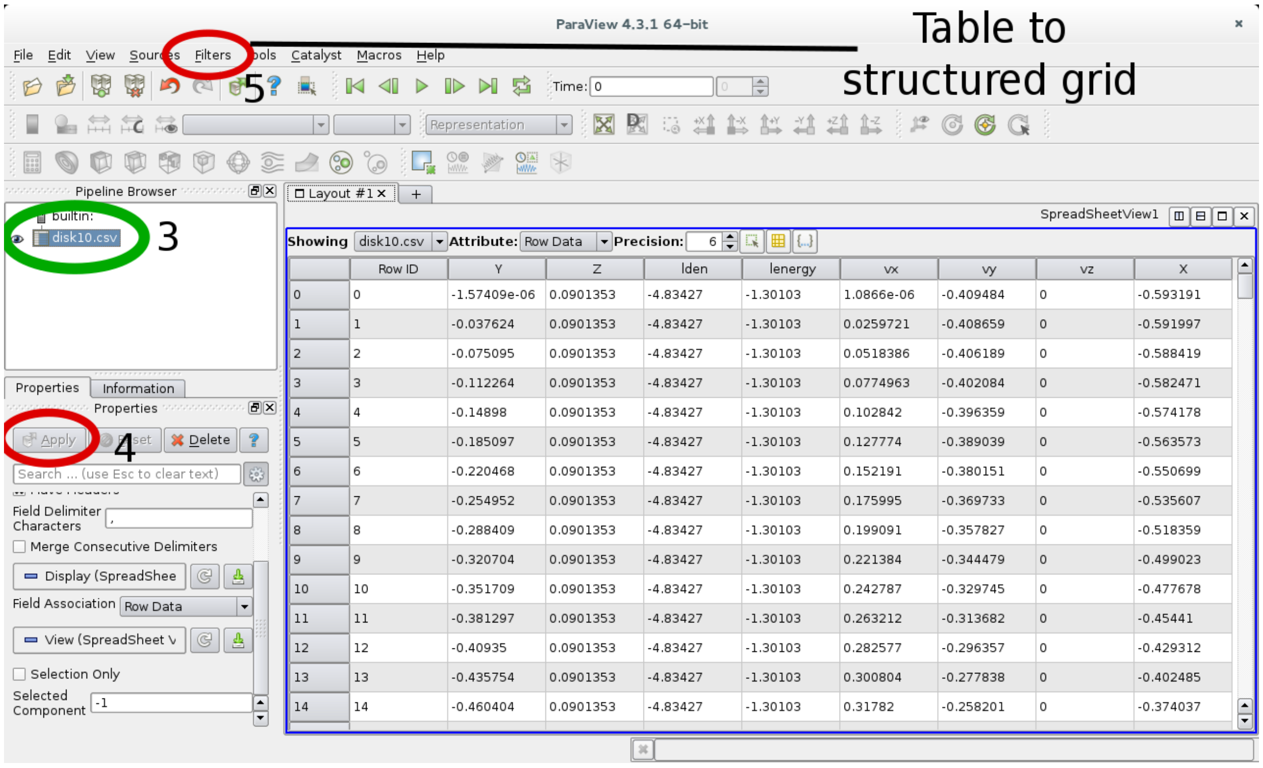
Filename
disk..csv
disk0.csv
disk1.csv
disk2.csv
disk3.csv
disk4.csv
disk5.csv
disk6.csv
disk7.csv
disk8.csv
disk9.csv
disk10.csv

File name: disk10.csv
Files of type: Supported Files (*.inp *.cml *.csv *.txt *.CSV *.TXT

Figure A.1: 3D visualization with Paraview. Steps 1-2.

A.4 Using extracter

....



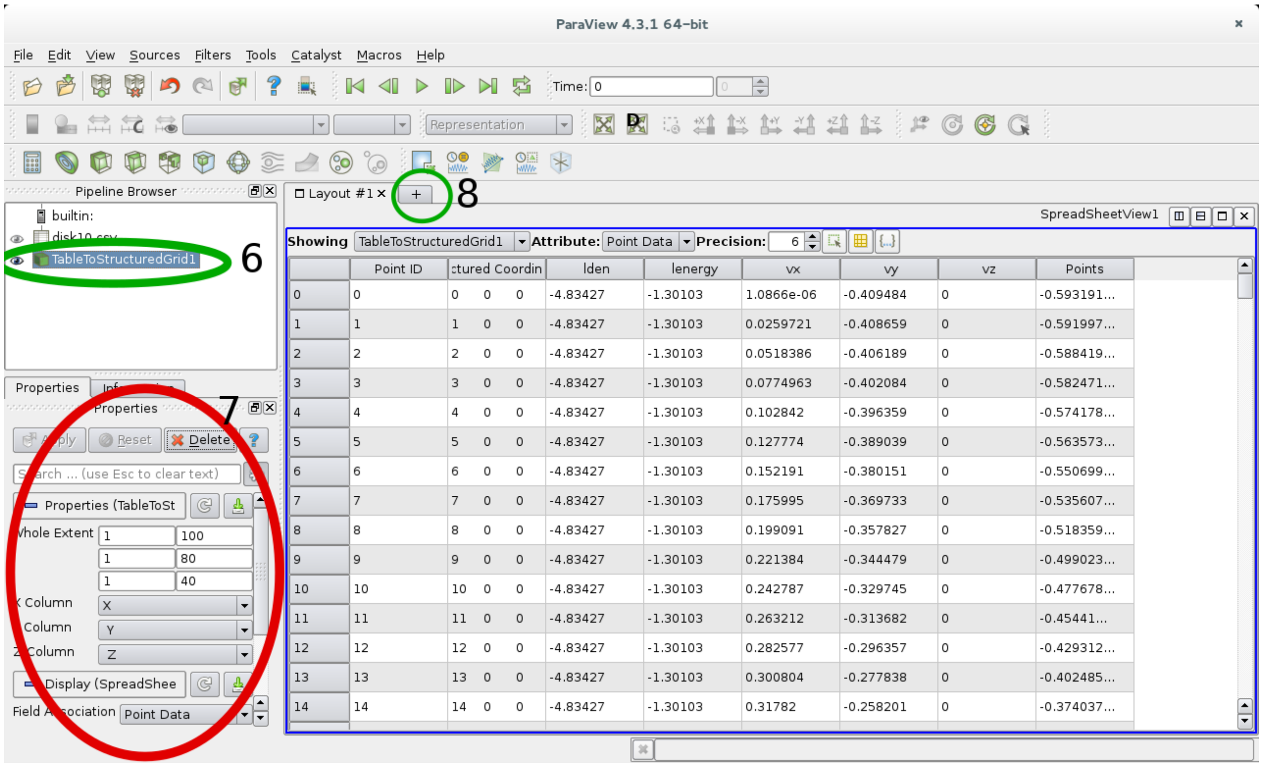
Time: 0

Showing disk10.csv Attribute: Row Data Precision: 6

Field Delimiter Characters: ,
Merge Consecutive Delimiters
Display (SpreadSheet)
Field Association: Row Data
View (SpreadSheet View)
Selection Only
Selected Component: -1

	Row ID	Y	Z	lden	lenergy	vx	vy	vz	X
0	0	-1.57409e-06	0.0901353	-4.83427	-1.30103	1.0866e-06	-0.409484	0	-0.593191
1	1	-0.037624	0.0901353	-4.83427	-1.30103	0.0259721	-0.408659	0	-0.591997
2	2	-0.075095	0.0901353	-4.83427	-1.30103	0.0518386	-0.406189	0	-0.588419
3	3	-0.112264	0.0901353	-4.83427	-1.30103	0.0774963	-0.402084	0	-0.582471
4	4	-0.14898	0.0901353	-4.83427	-1.30103	0.102842	-0.396359	0	-0.574178
5	5	-0.185097	0.0901353	-4.83427	-1.30103	0.127774	-0.389039	0	-0.563573
6	6	-0.220468	0.0901353	-4.83427	-1.30103	0.152191	-0.380151	0	-0.550699
7	7	-0.254952	0.0901353	-4.83427	-1.30103	0.175995	-0.369733	0	-0.535607
8	8	-0.288409	0.0901353	-4.83427	-1.30103	0.199091	-0.357827	0	-0.518359
9	9	-0.320704	0.0901353	-4.83427	-1.30103	0.221384	-0.344479	0	-0.499023
10	10	-0.351709	0.0901353	-4.83427	-1.30103	0.242787	-0.329745	0	-0.477678
11	11	-0.381297	0.0901353	-4.83427	-1.30103	0.263212	-0.313682	0	-0.45441
12	12	-0.40935	0.0901353	-4.83427	-1.30103	0.282577	-0.296357	0	-0.429312
13	13	-0.435754	0.0901353	-4.83427	-1.30103	0.300804	-0.277838	0	-0.402485
14	14	-0.460404	0.0901353	-4.83427	-1.30103	0.31782	-0.258201	0	-0.374037

Figure A.2: 3D visualization with Paraview. Steps 3-5.



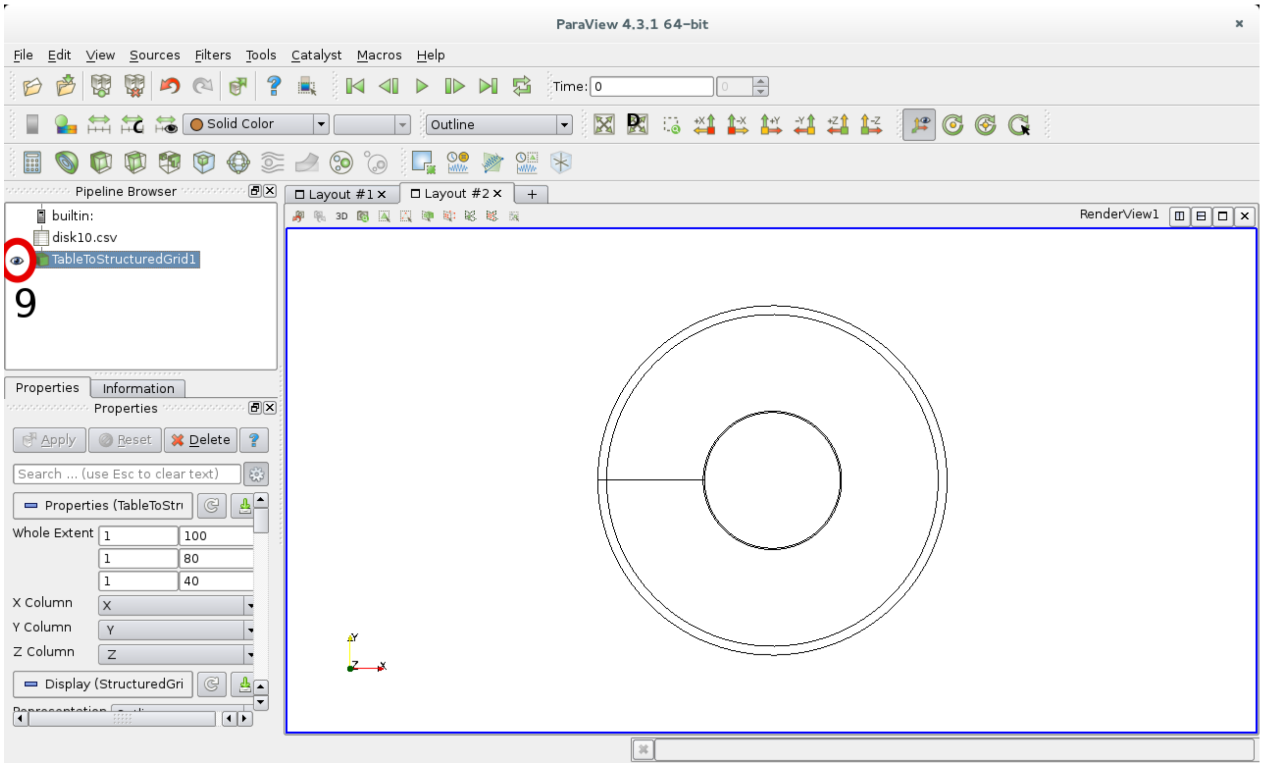
Time: 0

Showing TableToStructuredGrid1 Attribute: Point Data Precision: 6

Properties (TableToStructuredGrid1)
Whole Extent: 1 100 / 1 80 / 1 40
X Column: X
Y Column: Y
Z Column: Z
Display (SpreadSheet)
Field Association: Point Data

	Point ID	ctured Coordin			lden	lenergy	vx	vy	vz	Points
0	0	0	0	0	-4.83427	-1.30103	1.0866e-06	-0.409484	0	-0.593191...
1	1	1	0	0	-4.83427	-1.30103	0.0259721	-0.408659	0	-0.591997...
2	2	2	0	0	-4.83427	-1.30103	0.0518386	-0.406189	0	-0.588419...
3	3	3	0	0	-4.83427	-1.30103	0.0774963	-0.402084	0	-0.582471...
4	4	4	0	0	-4.83427	-1.30103	0.102842	-0.396359	0	-0.574178...
5	5	5	0	0	-4.83427	-1.30103	0.127774	-0.389039	0	-0.563573...
6	6	6	0	0	-4.83427	-1.30103	0.152191	-0.380151	0	-0.550699...
7	7	7	0	0	-4.83427	-1.30103	0.175995	-0.369733	0	-0.535607...
8	8	8	0	0	-4.83427	-1.30103	0.199091	-0.357827	0	-0.518359...
9	9	9	0	0	-4.83427	-1.30103	0.221384	-0.344479	0	-0.499023...
10	10	10	0	0	-4.83427	-1.30103	0.242787	-0.329745	0	-0.477678...
11	11	11	0	0	-4.83427	-1.30103	0.263212	-0.313682	0	-0.45441...
12	12	12	0	0	-4.83427	-1.30103	0.282577	-0.296357	0	-0.429312...
13	13	13	0	0	-4.83427	-1.30103	0.300804	-0.277838	0	-0.402485...
14	14	14	0	0	-4.83427	-1.30103	0.31782	-0.258201	0	-0.374037...

Figure A.3: 3D visualization with Paraview. Steps 6-8.



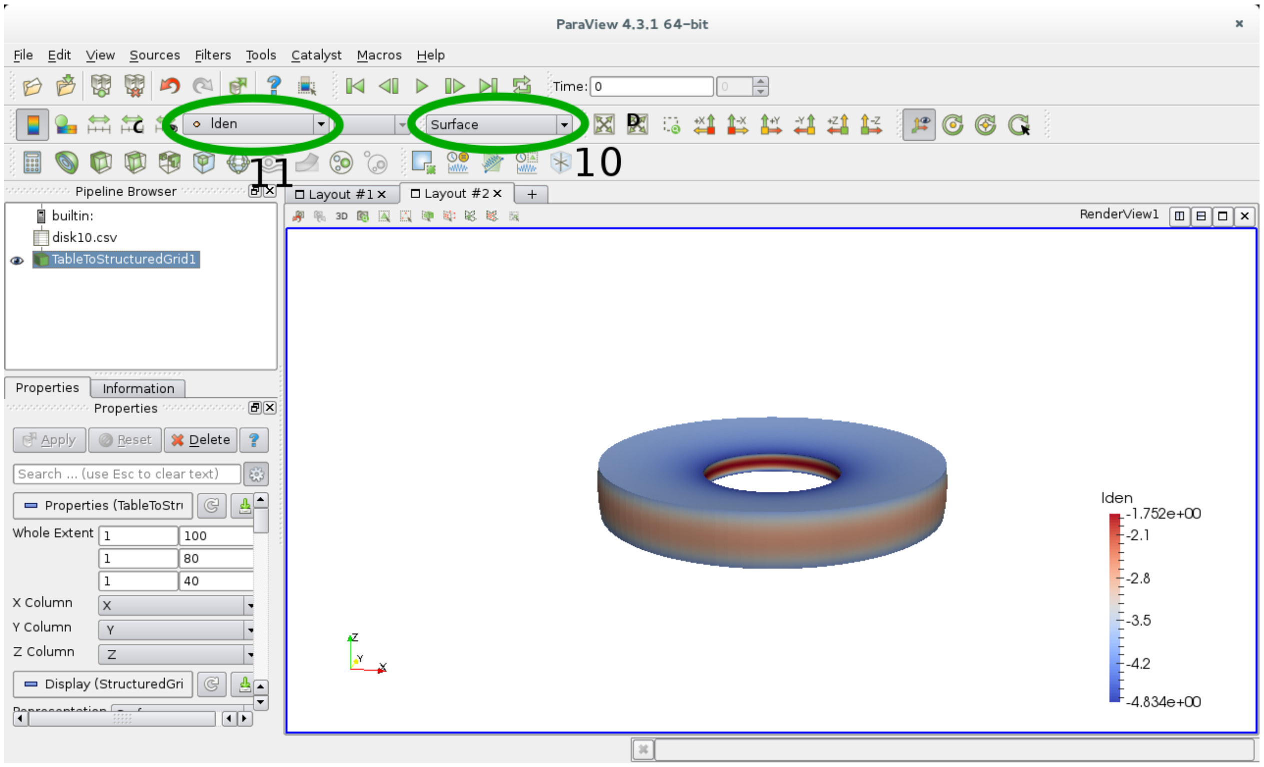
Solid Color

Outline

Whole Extent 1 100
1 80
1 40

X Column X
Y Column Y
Z Column Z

Figure A.4: 3D visualization with Paraview. Step 9.



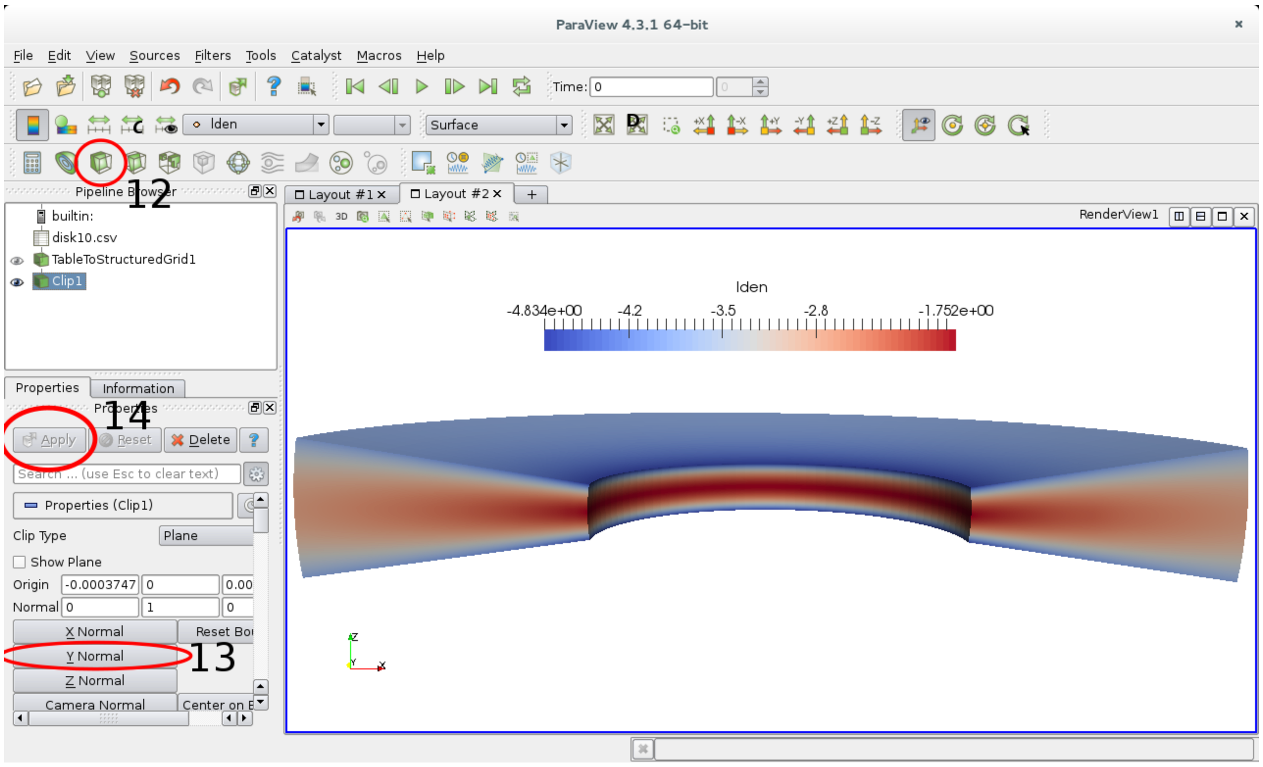
Iden

Surface

Whole Extent 1 100
1 80
1 40

X Column X
Y Column Y
Z Column Z

Figure A.5: 3D visualization with Paraview. Steps 10-11.



Clip Type Plane
Show Plane
Origin -0.0003747 0 0.00
Normal 0 1 0

Figure A.6: 3D visualization with Paraview. Steps 12-14.