Plaut04 User's Guide

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"PLAUT04" is a graphic tool for AUTO data visualization. Here we explain how to view AUTO data sets with PLAUT04. An AUTO data set contains a solution file, "s.foo", a bifurcation file, "b.foo", and a diagnostic file, "d.foo". Here "foo" denotes a user-chosen data set name. This user's guide includes the following information:

1. A description of the PLAUT04 window system.
2. A list of PLAUT04 configuration options.
3. An example of using PLAUT04.

1 Quick start

1.1 Starting and stopping Plaut04

1.1.1 Starting

The starting command for PLAUT04 is: "plaut04". A short Unix command is also provided as "@pl". In the Python CLUI, one can start PLAUT04 by typing "plot3()", "p3()", or "commandPlotter3D()".

This command can have no argument, one argument, or two arguments.

If no argument is provided, then the system uses the AUTO default data files, fort.7, fort.8, and fort.9, as inputs.

If one argument is given, it must be the name of the data set which we want to view. This data set should be in the current directory.

When two arguments are given, the first is always the path to the data set, and the second is the data set name.

Note that the AUTO data set name does not mean the full name of an AUTO file. It refers to the postfix of AUTO data files. For example, if we have the AUTO data files: "s.H1", "b.H1", and "d.H1", the AUTO data file name is "H1".

1.1.2 Stopping

One can exit the system by clicking the cross at the top-right corner of the window or from the "File" menu of the system.

1.2 Changing the "Type"

Often one will frequently change between the solution diagram and the bifurcation diagram. The "Type" menu helps to complete this change. This menu includes two items, "Solution", and "Bifurcation". There is a marker beside the current diagram. For example, if the current diagram is the solution diagram, but we want to change to the bifurcation diagram, we can do so by clicking "Type → Bifurcation" to switch to the bifurcation diagram.

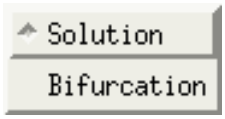


Figure 1: The Type Menu

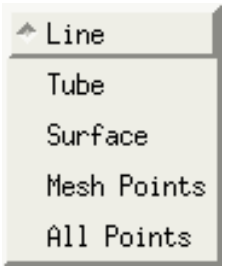


Figure 2: The Style Menu

1.3 Changing the "Style"

PLAUT04 provides four ways to draw the graphics, *i.e.*, using curves, tubes, points, or as a surface. One can select the style from the "Style" menu. The "Style" menu is shown in Figure 2.

1.4 Coordinate axes

Figure 3 shows the selections of the "Coord" menu. One may use this menu to select to show or not to show coordinate axes, and the type of coordinate axes, in the graphics.

1.5 Options

The "Options" Menu provides functions to add or remove widgets from the graphics. It also allows to start/stop solution or orbit animation. The "normalize data" normalizes the raw data to [0,1]. "Preference" lets us set preferences for the GUI (see Figure 4).

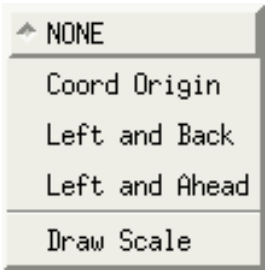


Figure 3: The Draw-Coordinate-Axes Menu

Figure 4: The Options Menu

1.6 CR3BP animation

The "Center" Menu allows to animate the motion of the three bodies in different coordinate systems. We can animate the motion in a large-primary-centered inertial coordinate system, or in a small-primary-centered inertial system, or in the bary-centered inertial system. Figure 5 displays the layout of the "Center" menu.

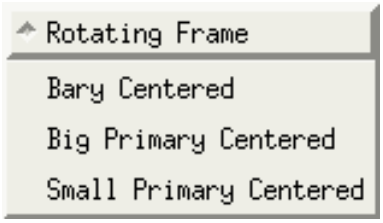


Figure 5: The Center Menu

Figure 6: The Help Menu

1.7 Help

The "Help" menu provides an on-line help on how to use PLAUT04.

1.8 Picking a point in the diagram

The picking operation is useful when we want to know data corresponding to a certain point in the diagram. In order to execute a picking operation, we should follow these steps.

- Click the arrow icon to change the mouse to picking state.
- Move the mouse to the point of interest.
- Click the left button of the mouse to pick the point.

Once a point has been picked, a new window is popped up. In this new window, the Floquet multipliers of the point are shown in an x-y plane. Black crosses in the diagram indicate the Floquet Multipliers. The solution, and the values of the corresponding Floquet Multipliers, are given in the lower part of the window. A unit circle is drawn in the diagram. Figure 7 is an example of the picking operation. From this diagram, we can see that two Floquet Multipliers are outside the unit circle, two are on the unit circle, and the other two are inside the unit circle.

1.9 Choosing the variables

AUTO can generate large amounts of data. The CR3BP, for example, has 6 variables, *i.e.*, x, y, z, x', y', z', and time. One can choose to draw any combination of these variables in 2 or 3 dimensions using PLAUT04. On the list bar, we can see three dropdown lists with label "X", "Y", and "Z" (See Figure 8). Each of these three lists has the exact number of choices, namely, the number of variables of the system plus one. In our case, these lists have 7 choices, which are represented by the integers 0 to 6. 0 represents time. 1 to 6 stand for x, y, z, x', y', and z', respectively. "1" is selected for "X", which indicates that x is drawn on the X-axis. "2" is selected for "Y", which indicates that y is represented on the Y-axis. "3" is selected for "Z", which indicates that z is represented on the Z-axis.

We can also show multiple combinations at the same time. For example, if we want to show x-y-z and x'-y'-z' in the same diagram, we can input $1, 4$ in the "X" dropdown list to select x and x' being drawn on the X-axis, input $2, 5$ in the "Y" list to show y and y' on the Y-axis, and input $3, 6$ in the "Z" dropdown list to draw z and z' on the Z-Axis. Note that after finishing the input in the dropdown list box, we must type "ENTER" for the input to be

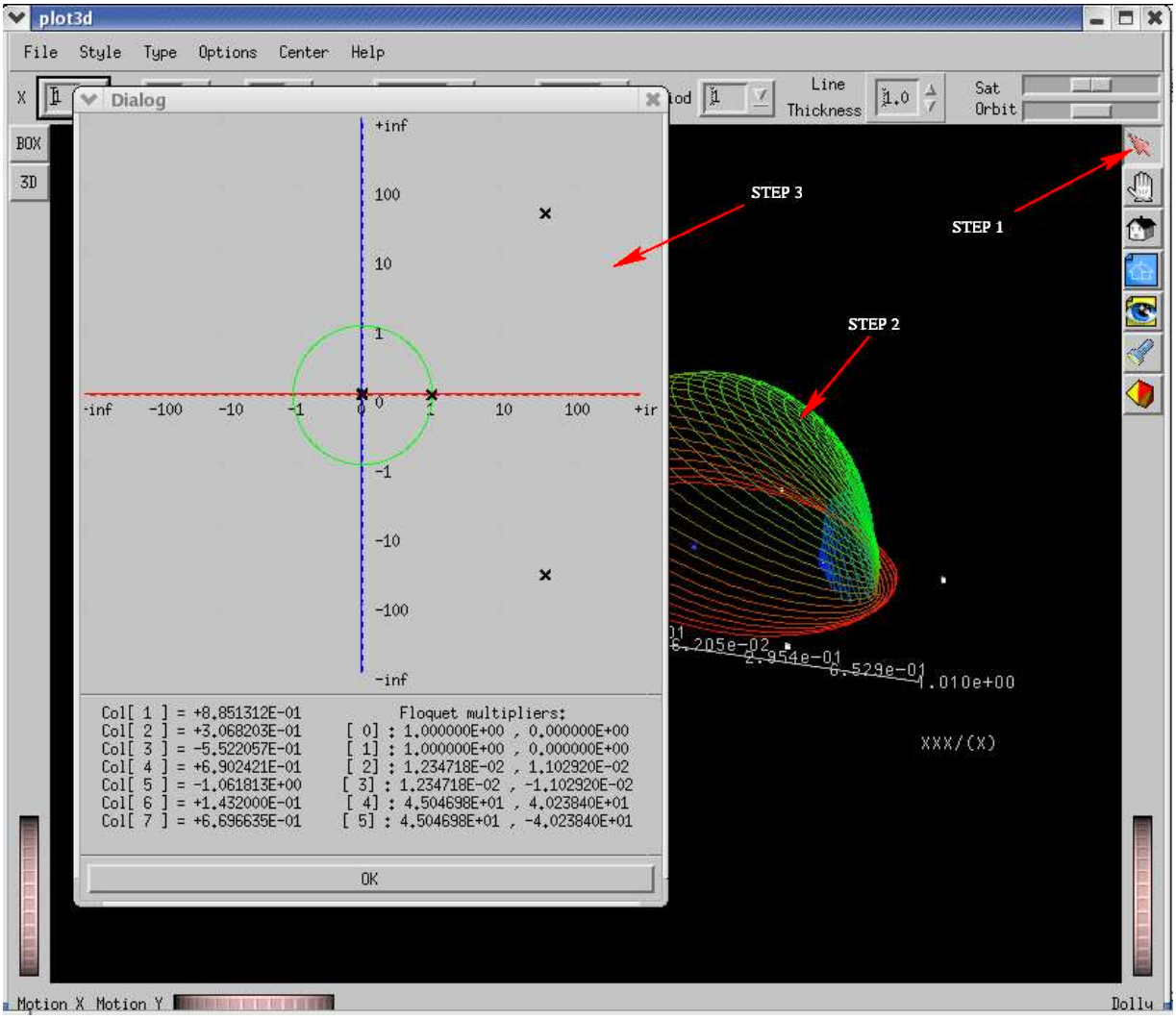


Figure 7: Picking a point

accepted by the system. Figure 9 shows the results of the above choices. The combination is flexible. For example, if X is 1, Y is $3, 5$, and Z is $4, 5, 6$, the system will automatically reorganize them to $1-3-4$, $1-5-5$, $1-3-6$ and show the results. If X is $1, 5$, Y is 2, and Z is $3, 4$, the system reorganizes them to $1-2-3$, $5-2-4$.

Different components are drawn with different colors from blue to red.

The default values can be set in the resource file. If no resource file exists,

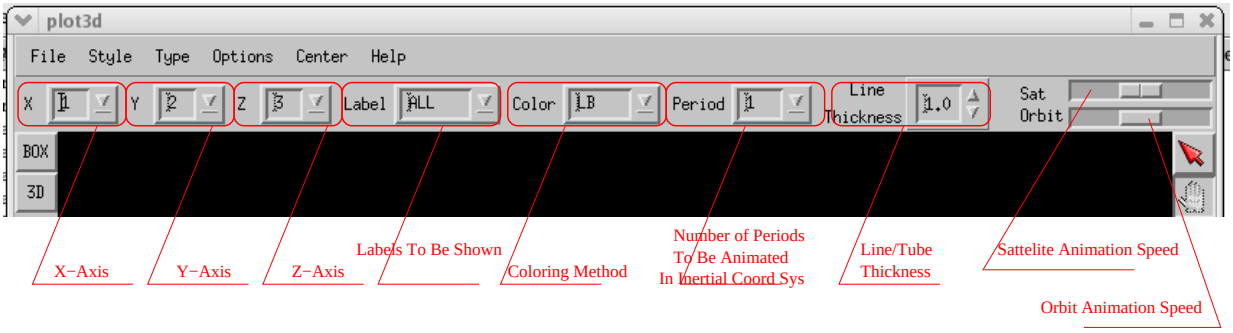


Figure 8: Menu-bar layout

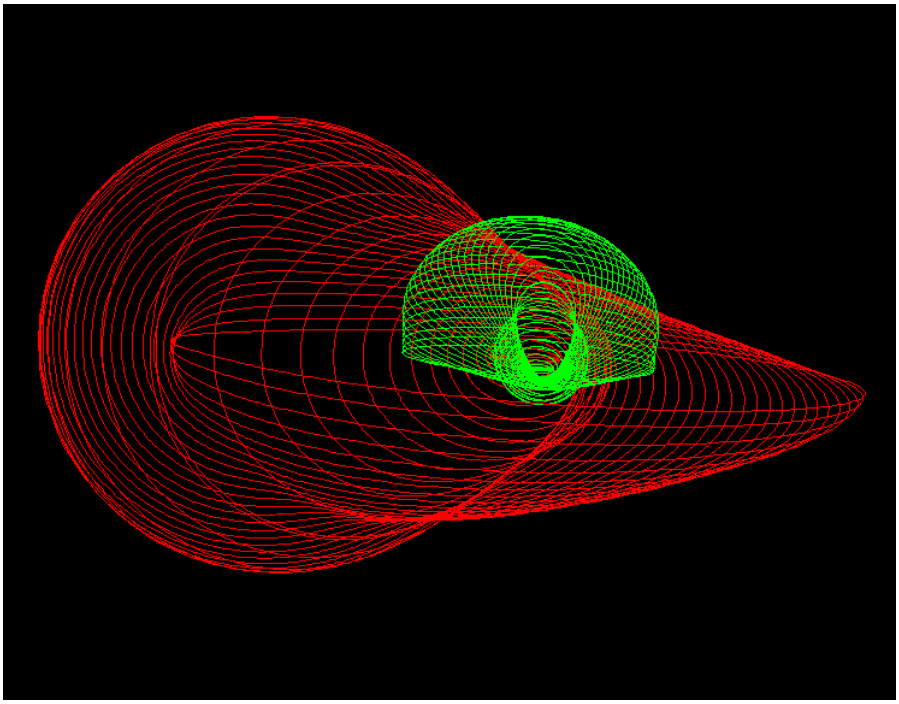


Figure 9: Displaying multiple components

then the system will use “1” for X-axis, “2” for Y-axis, and “3”for Z-axis for both the solution and the bifurcation diagrams.

1.10 Choosing labels

From the Label list, we can choose the label of the solution to be drawn. If "ALL" is chosen, all solutions are shown in the diagram. If "NONE" is chosen, none of the solutions is shown. "HALF" shows the solutions with odd labels and special solutions only. "SPEC" lets the system show the special solutions only. We can also show selected solutions by inputting their labels in the list box separated by commas. For example, typing 1, 10, 15, 20 will lead the system to show only the solutions with label 1, 10, 15 and 20.

We can set the default value for this list in the PLAUT04 resource file.

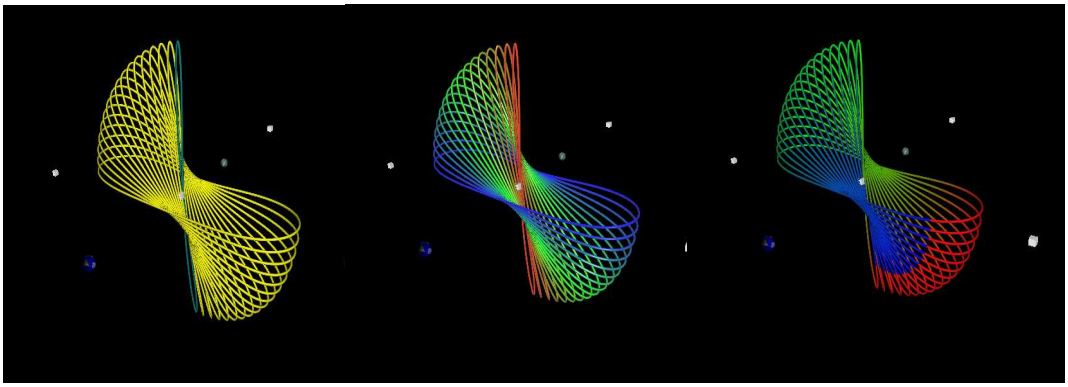
1.11 Coloring

Many coloring methods are provided. They can be classified into three groups. The first group is coloring by variables. This group provides as many choices as the number of variables of a problem plus 1 for the time. The second group is coloring by parameters. These parameters are defined by the AUTO user. in the AUTO constants file. There are as many choices as the number of parameters defined in the AUTO constants file. The third group includes "TYPE", type of solution, "PONT", point number, "BRAN", the branch to which the solution belongs, and "LABL", label of the solution. Different coloring methods cannot be used at the same time. Figure 10 shows the difference between coloring by type and coloring by label. From Figure 10(a), we can see that there is only one branching orbit in this family, which is shown in cyan. In Figure 10(b), the start solution is colored in blue, and the last solution is colored in red. When using time to color the diagram, 0 is set to blue, while 1 is set to red.

We can set the default value in the PLAUT04 resource file.

1.12 Number of periods to be animated

Generally only one period is animated when we animate the solution in the inertial frame. However, the SpinBox allows us to change the default value. This is a specially designed function for the CR3BP. It is useful when we animate the motion in the three bodies in the inertial frame.



(a) Coloring by "Type" (b) Coloring by "Label" (c) Coloring by "Time"

Figure 10: Coloring

1.13 Changing the line/tube thickness

The "Line Thickness" spinbox allows us to increase or decrease the line/tube thickness in the diagram. The PLAUT04 resource file also provides a way to change the default values of the line/tube thickness.

1.14 Changing the animation speed

The "Sat" and "Orbit" scale bar allow us to change the animation speed. Their Maximum and Minimum value can be set in the resource file.

1.15 Changing the background picture

A user can set the background with his favorite picture. To do this, a user should copy the picture to the directory "$AUTO_DIR/plaut04/widgets", and then change the name of the file to "background.rgb".

2 Setting up the resource file

The PLAUT04 resource file sets default values for almost all controls of PLAUT04. PLAUT04 allows us to write our own resources files and put them in the same directory as the AUTO data files. PLAUT04 first looks for the resource file in the current directory. If it cannot find a resource file

there, then it will try to use the one installed in the AUTO root directory. If both these searches fail, then the internal default values will be used.

In order to write a usable resource file, one should follow the following rules:

1. Comment lines start with "#". Comments may take as many lines as desired.

2. Between the "variable name" and the default value, we must use "=" to tell the system that the left side is the "variable name", and the right side is its corresponding default value.

3. If a "variable" has aggregate values, a comma "," must be used between two values.

4. The line type is set using 4-digit hexadecimals, starting with "0x". Its values can range from 0 (invisible) to "0xffff" (solid). The system default is "0xffff" for stable solutions, and "0x3333" for unstable ones. The line pattern is determined by the number of 1s and 0s when the hexadecimal is converted to a 16-bit binary. A "1" indicates that the drawing occurs, and "0" that it does not, on a pixel by pixel basis. For example, the pattern "0xAAAA", in binary is 0000100010001000, and PLAUT04 interprets this as drawing 3 bits off, 1 bit on, 3 bits off, 1 bit on, 3 bits off, 1 bit on and finally 4 bits off. The pattern is read backward because the low order bits are used first.

5. Some variables can only be set to "Yes" or "No". They cannot be assigned other values.

6. No "variable name" should be modified.

It is strongly recommended that the default resource file is used as a template when writing a custom resource file.

Below is a copy of the default resource file.

```
#version 0.0

# Line colors are represented by RGB values from 0 to 1.0.
# DEFAULT color is also used when animationLabel == 0, i.e.,
# when showing all solutions and animating the solution change.
# Point Type    RED  GREEN  BLUE PATTERN
DEFAULT       = 1.0,  1.0,  1.0, 0xffff
```

```
BP            = 1.0,  0.0,  0.0, 0xffff
LP ALG        = 0.0,  1.0,  0.0, 0xffff
HB            = 0.0,  0.0,  1.0, 0xffff
UZ4           = 1.0,  1.0,  0.0, 0xffff
UZ-4          = 0.5,  0.5,  0.0, 0xffff
LP DIF        = 0.0,  0.0,  0.5, 0xffff
BP DIF        = 0.0,  0.5,  0.5, 0xffff
PD            = 1.0,  0.0,  1.0, 0xffff
TR            = 0.0,  1.0,  1.0, 0xffff
EP            = 0.3,  0.0,  0.3, 0xffff
MX            = 0.6,  0.0,  0.6, 0xffff
OTHERS        = 1.0,  1.0,  1.0, 0xffff

# Initialize the line pattern for showing stability
UNSTABLE LINE PATTERN = 0xffff
STABLE LINE PATTERN   = 0xffff

# Initialize the default options:
Draw Reference Plane  = No
Orbit Animation       = No
Satellite Animation   = No
Draw Primaries        = No
Draw Libration Points = No
Normalize Data        = Yes
Draw Background       = No

# Initialize the default coordinate axes:
#  0 --- None,
#  1 --- at origin
#  2 --- at left and behind
#  3 --- at left and ahead
Coordinate Type = 3

# Draw Scale on the Aexs
Draw Scale = Yes

#  Initialize the default graph type:
#  0 --- Solution (fort.8)
#  1 --- Bifurcation (fort.7)
Graph Type    = 0

# Initialize the default graph style:
#  0 --- LINES,
#  1 --- TUBES,
#  2 --- SURFACE
```

```
Graph Style  =  0

# Set the window width and height:
Window Width        = 1000
Window Height       = 1000

# Set X, Y, Z axes for the solution diagram:
# 0 is Time for X,Y,Z.
X Axis Solution             = 1
Y Axis Solution             = 2
Z Axis Solution             = 3

# Set X, Y, Z axes for the bifurcation diagram:
X Axis Bifurcation          = 4
Y Axis Bifurcation          = 5
Z Axis Bifurcation          = 6

#Labeled solutions:
Labels              = 0

# Set coloring method:
# -5 --- STABILITY
# -4 --- POINT
# -3 --- BRANCH
# -2 --- TYPE
# -1 --- LABEL
# Otherwise, according to the data in the ith column of the solution file.
# It can only be set to an integer value.
Coloring Method           = -2
Number of Period Animated = 1

# Line Width Scaler adjusts the thickness of curves:
Line Width Scaler         = 1.0

# The AniLine Thickness Scaler sets the thickness of animated solution curves:
AniLine Thickness Scaler  = 3.0

# Background color:
Background Color  = 0.0,  0.0,   0.0

# Background transparency:
Background Transparency = 0.0

# Disk transparency
# IF you turn Disk From File to "Yes", you should change the transparency there.
```

```
Disk Transparency = 0.7

# Read Disk From File
Disk From File = No

# Axes color:
X Axis Color    = 1.0,  0.0,   0.0
Y Axis Color    = 0.0,  1.0,   0.0
Z Axis Color    = 0.0,  0.0,   1.0

# Color of the satellite, large primary, and small primary in animation:
satellite Color             = 1.0,  0.0,   0.0
large primary Color         = 0.0,  1.0,   0.0
large primary tail Color    = 0.0,  1.0,   1.0
small primary Color         = 0.0,  0.0,   1.0
small primary tail Color    = 0.5,  0.5,   0.0

# Stable solution color:
Stable Solution Color = 0.0, 0.0, 1.0

# Stable solution color:
Unstable Solution Color = 1.0, 0.0, 0.0

# Set the radius of the satellite, large primary, and small primary:
# The normal size is 1.0.
# For smaller radius, use 0.xxx
# For bigger radius, use  X.XXX
Satellite Radius        = 1.0
Large Primary Radius    = 1.0
Small Primary Radius    = 1.0
Libration Point Size    = 1.0

# Set the maximum and minimum satellite animation speed:
Sat Max Animation Speed = 100
Sat Min Animation Speed = 0

# Set the maximum and minimum orbit-change animation speed:
Orbit Max Animation Speed = 100
Orbit Min Animation Speed = 0

# Set the active AUTO parameter indices:
parameter ID = 10

# Choose 3D or 2D graph:
3D  = Yes
```

3 Example

In this example, we want to view a CR3BP data set. We want the diagram to show the "x" component on the X-axis, "y" component on the Y-axis, and "z" component on the Z-axis for the solution diagram. In the CR3BP, we use the parameters "1 2 3 10 21 22 23" in the AUTO calculations, and we also want to be able to use these to color the diagram, so we set the "parameter indices".

Other preferences include

- The diagram is drawn using Tubes.
- Coordinate axes are not drawn.
- No animation.
- Reference plane, libration points, and primaries are drawn.
- All labels are shown.
- Data is not normalized.

The settings are the settings in the resource file are then as follows:

```
#  Initialize the default options
Draw Reference Plane  = Yes
Orbit Animation       = No
Satellite Animation   = No
Draw Primaries        = Yes
Draw Libration Points = Yes
Normalize Data        = No
Draw Background       = No

#  Initialize the default graph type
#  0 --- Solution(fort.8)  1 --- Bifurcation(fort.7)
Graph Type    = 0

# initialize the default graph style
#  0 --- LINES,  1 --- TUBES, 2 ---- SURFACE  3--- nurbs curve
graph Style  =  1
```

```
# set X, Y, Z, and Label
# 0 is Time for X,Y,Z. 0 is "All" for Label

Solution X Axis              = 1
Solution Y Axis              = 2
Solution Z Axis              = 3

Labels                       = 0

#set the parameter indices
parameter ID = 1,  2,  3, 10,  15, 21, 22,  23
```

Based on the above settings, the solution diagram for the CR3BP family Ł1 for $\mu = 0.01215$ appears in Figure 11.

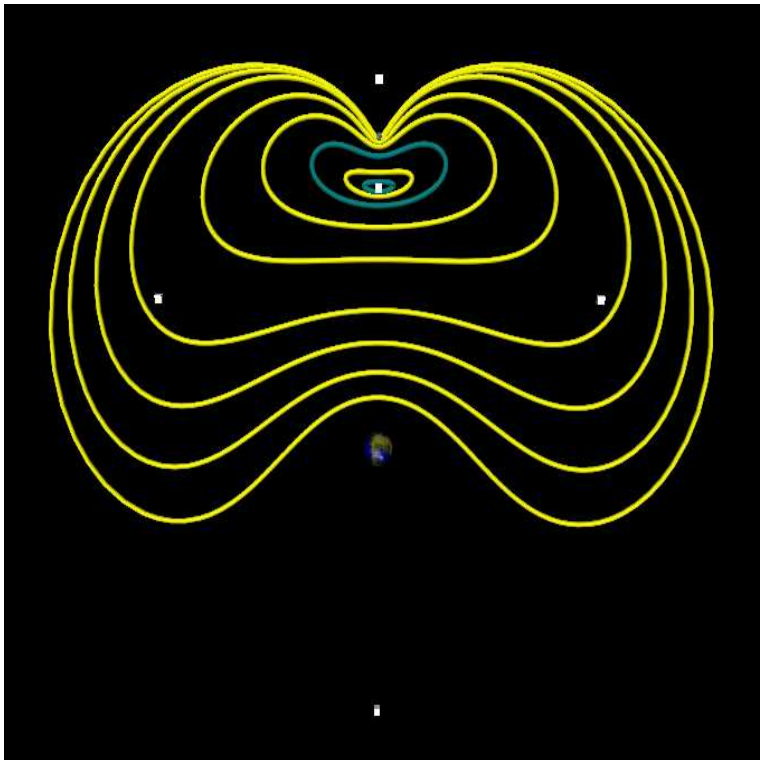


Figure 11: Example