Description

G3RGraph application designed for numerical simulation the Three-body problem in both: classical and relativistic approaches. Algorithm developed by Professor Seppo Mikkola (http://www.astro.utu.fi/staff/MikkolaSeppo.shtml). Implementation by Alexei Pasechnik (http://www.astro.utu.fi/staff/PasechnikAlexey.shtml). The analyzed system represents a close binary system and external component. Problem solved in the Cartesian, oriented so that the z-axis is directed towards the observer. x-y plane is the same as the picture plane.

Installation

Windows

Application does not need installation procedure under the Microsoft Windows. Simply download executable file **G3RGraph.exe** into working folder and double-click it’s icon to run.

Linux

You need **wine** to be installed on you system to execute **G3RGraph.exe** application.

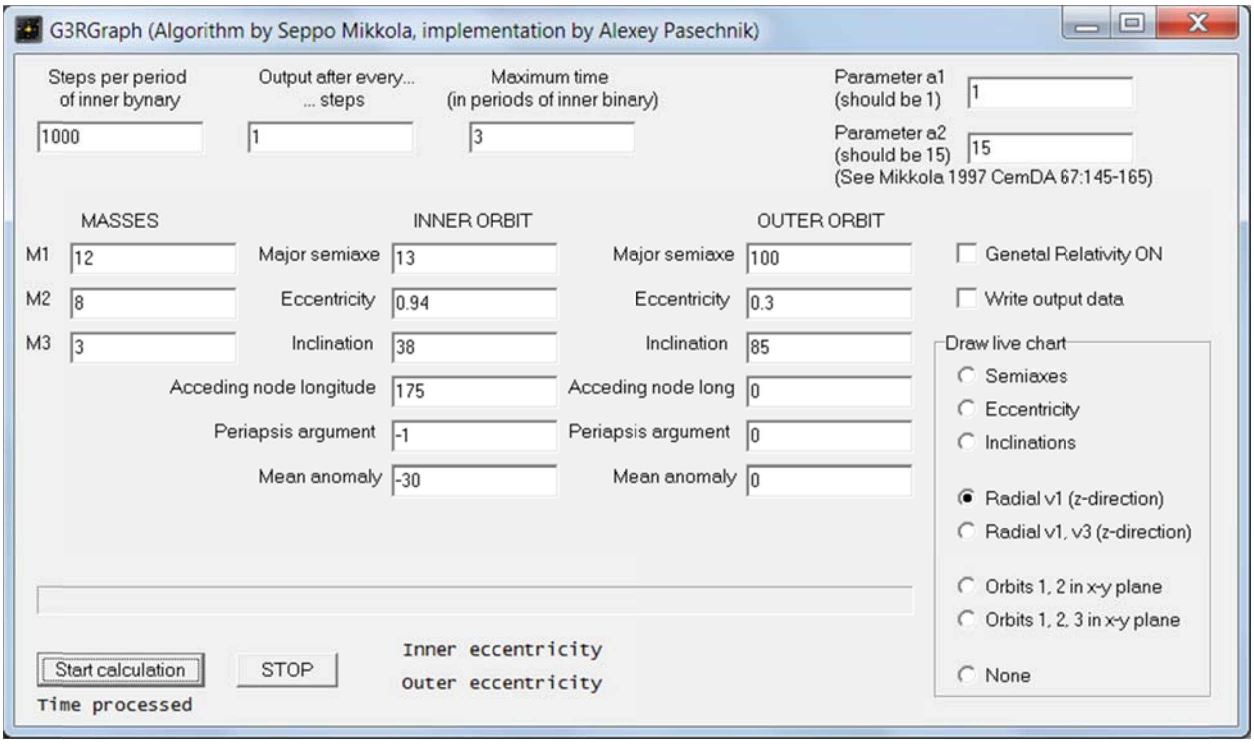
For example, to install **wine** in the Debian-based system type in the terminal window:

```
sudo apt-get install wine
```

After installation process completed go to the directory where you downloaded executable **G3RGraph.exe** and run application by typing in the terminal windows:

```
wine G3RGraph.exe
```

Main Interface



Main application’s window consists of 18 fields for initial parameters that completely describe the initial state of the studied system.

Parameters of integration

Steps per period of inner binary specifies the number of steps of numerical integration that is split period of the internal binary. Increasing the number of steps of a split leads to the more precisely (and slower) calculations. The number in this field must be positive integer.

Output after every … steps the value in this field specifies after how many steps of integration will be output. Results displayed in a separate graphical window as chart, or written to the files. The number in this field must be positive integer.

Maximum time (in periods of inner binary) — the maximum modeling time. Number of periods of inner binary, after which the calculations will be stopped. The number in this field may be float, but definitely positive.

Masses

Group **MASSES** consist of three fields: **M1**, **M2** и **M3**, that is masses of the inner binary components — M_1 и M_2, and the mass of the outer component — M_3. All masses are measured in the units of *Solar mass*.

Orbital elements

Group **INNER ORBIT** consists of six fields for the inner binary's Keplerian orbital elements.

- **Major semiaxe** — measured in the *astronomical units*.
- **Eccentricity**;
- **Inclination** — inner binary orbit inclination to the picture plane (*x-y*), *degree*;
- **Acceding node longitude** — zero value points to x-direction, *degree*;
- **Periapsis argument** — *degree*;
- **Mean anomaly** — initial mean anomaly, *degree*.

Group **OUTER ORBIT** consists of six fields for outer component's Keplerian orbital elements. Description the same as for inner orbit.

General Relativity

General Relativity ON checkbox switches calculations into General Relativity Mode (5PN-7PN approach). In this case all results are interpreted for the infinity far observer in the z-direction. Algorithm based on the paper by Thierry Mora and Clifford M. Will [Physical Review D 69, 104021 (2004)]

Store output in the file

If the **Write output data** checkbox is set, all outputs will written into files. Each time you start calculation will be created eight files with the unique number prefix based on the internal computer clock. For example:

```
1327942367_inputdata.txt
1327942367_coor.txt
1327942367_taei.txt
1327942367_gnuplotdata_axes.plt
1327942367_gnuplotdata_ecce.plt
1327942367_gnuplotdata_incl.plt
1327942367_gnuplotdata_orbits.plt
1327942367_gnuplotdata_RadialV1&V3.plt
```

…_inputdata.txt file stores initial conditions in the form of ascii text table.

…_coor.txt file stores coordinates and velocities of the all three components in the ascii text rows. Each row consists of 20 space-separated values:

1. *Number of periods* of inner binary since start calculations
2. Time in *years*
3. Coordinate *x* of 1st star (*a. u.*)
4. Coordinate *y* of 1st star (*a. u.*)
5. Coordinate *z* of 1st star (*a. u.*)
6. Coordinate *x* of 2st star (*a. u.*)
7. Coordinate *y* of 2st star (*a. u.*)
8. Coordinate *z* of 2st star (*a. u.*)
9. Coordinate *x* of 3st star (*a. u.*)
10. Coordinate *y* of 3st star (*a. u.*)
11. Coordinate *z* of 3st star (*a. u.*)
12. V_x of 1st star (*km/s*)
13. V_y of 1st star (*km/s*)
14. V_z of 1st star (*km/s*)
15. V_x of 2st star (*km/s*)
16. V_y of 2st star (*km/s*)
17. V_z of 2st star (*km/s*)
18. V_x of 3st star (*km/s*)
19. V_y of 3st star (*km/s*)
20. V_z of 3st star (*km/s*)

…taei.txt file stores "instant" orbital elements, which are calculated based on current coordinates and velocities of the bodies by finding the Keplerian orbit that best fits the current trajectory and speed. The data in the file is stored in row-major order. Each ascii text row contains 10 values separated with spaces:

1. *Number of periods* since start calculations
2. Time in *millions of years*
3. Inner major semiaxe (*a. u.*)
4. Inner eccentricity
5. Inner inclinations to *x-y* plain *(degree)*
6. Outer major semiaxe (*a. u.*)
7. Outer eccentricity
8. Outer inclinations to *x-y* plain *(degree)*
9. Mutual inclination (*degree*)
10. Inner argument of pericenter

.plt files are ascii text files that store instructions for **gnuplot**.

gnuplot for Linux could be installed from http://www.gnuplot.info/. If you are using Debian Linux, use following command:

```
sudo apt-get install gnuplot
```

gnuplot for Windows could be installed from http://www.tatsuromatsuoka.com/gnuplot/Eng/winbin/

To build, for example, radial velocities chart, use following command:

Windows

```
C:\gnuplot\bin\wgnuplot.exe 1327942367_gnuplotdata_RadialV1&V3.plt
```

(if you installed gnuplot into the folder other than **C:\gnuplot**, use your installation path instead)

Linux

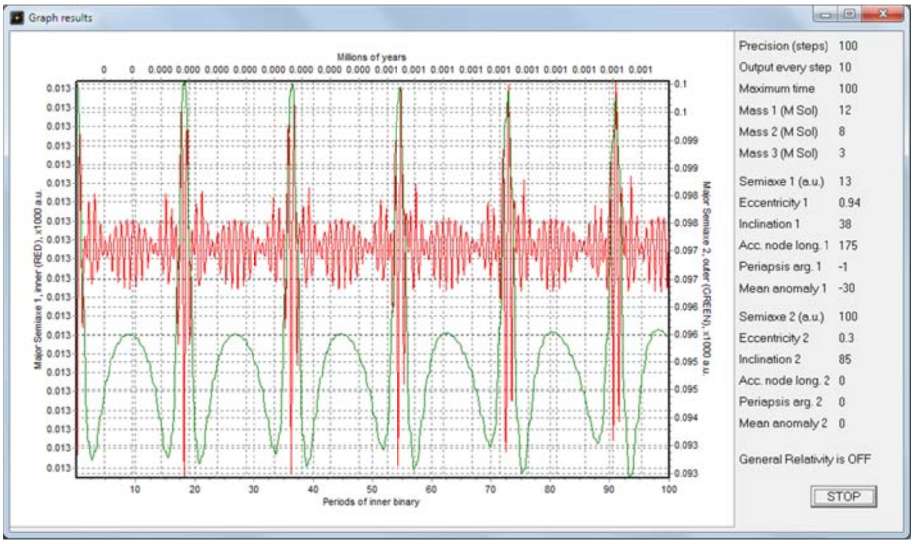
```
gnuplot 1327942367_gnuplotdata_RadialV1&V3.plt
```

It is convenient (under Windows) to associate **.plt** extension with **wgnuplot.exe** and then plot chart by double click on file ***.plt**.

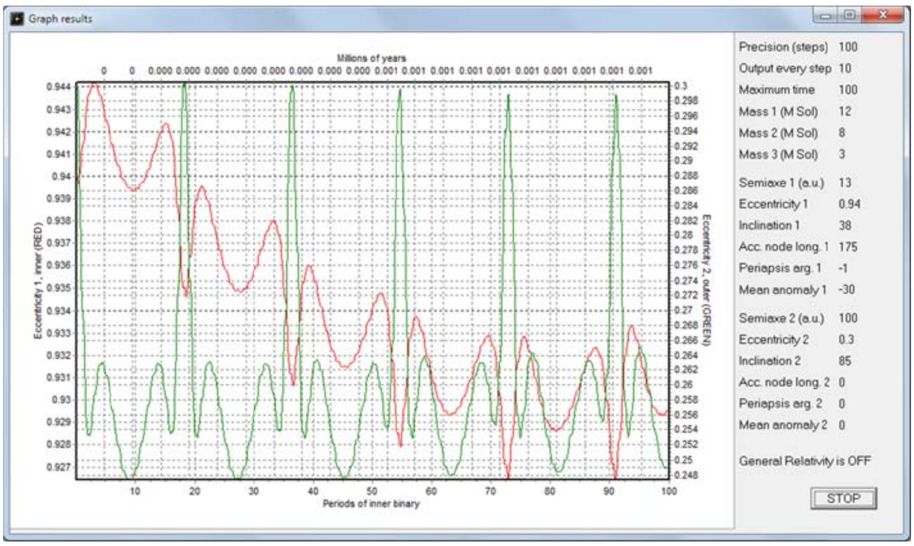
- **…_gnuplotdata_axes.plt** has instructions for drawing the chart of major semiaxes as a functions of time;
- **…_gnuplotdata_ecce.plt** has instructions for drawing the chart of eccentricities as a functions of time;
- **…_gnuplotdata_incl.plt** has instructions for drawing the chart of inclinations as a function of time;
- **…_gnuplotdata_orbits.plt** has instructions for drawing the 3D orbits of all three bodies;
- **…_gnuplotdata_RadialV1&V3.plt** has instructions for drawing the chart of radial velocities (z-components of velocities) as a function of time.

Draw Live Chart radio-button group

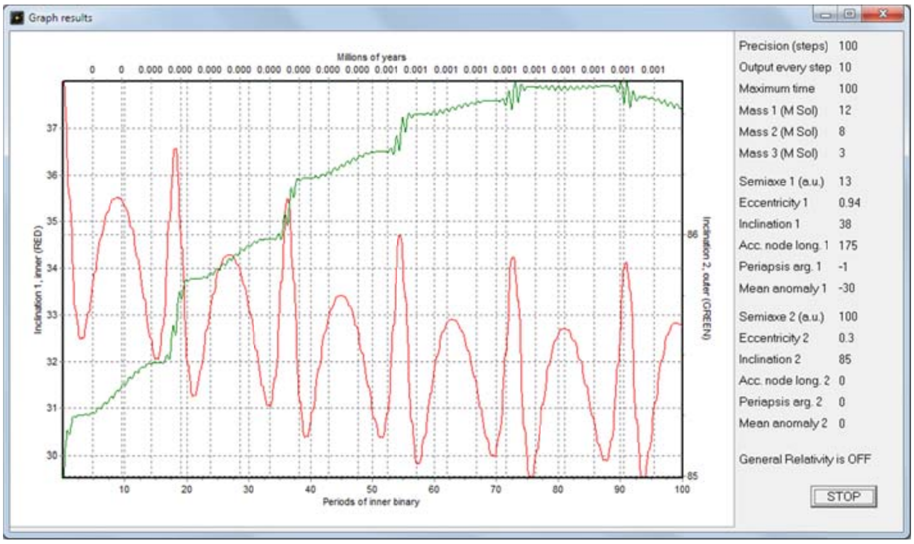
Depending on the radio-button checked in this group, corresponding chart will draw in a separate window. These switches are useful only for the pre-studying behavior of the system with the different initial settings.

- 

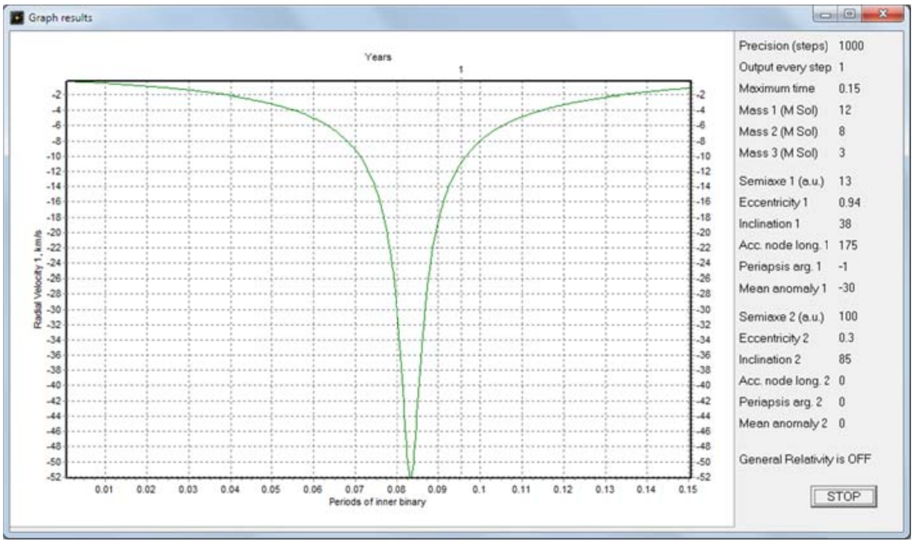
  Semiaxes — drawing the chart of major semiaxes as a functions of time

- 

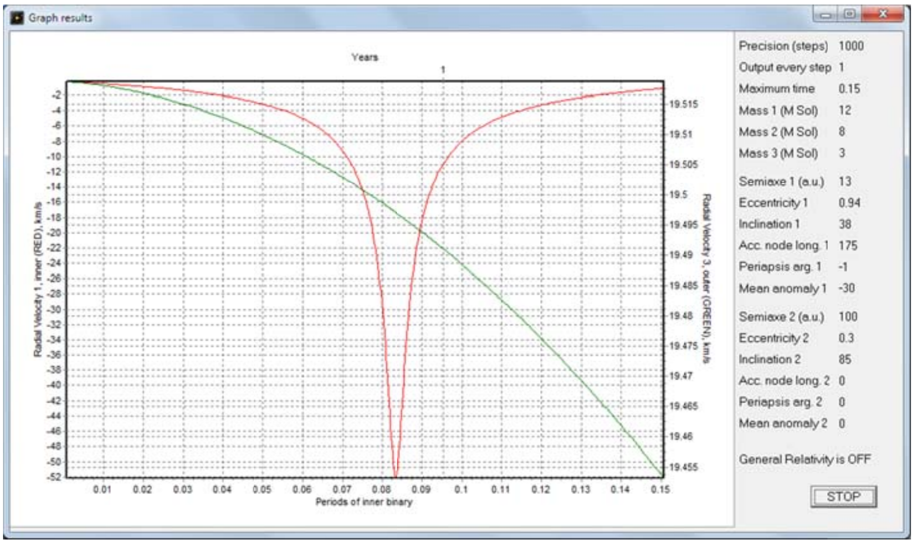
Eccentricity — drawing the chart of eccentricities as a functions of time



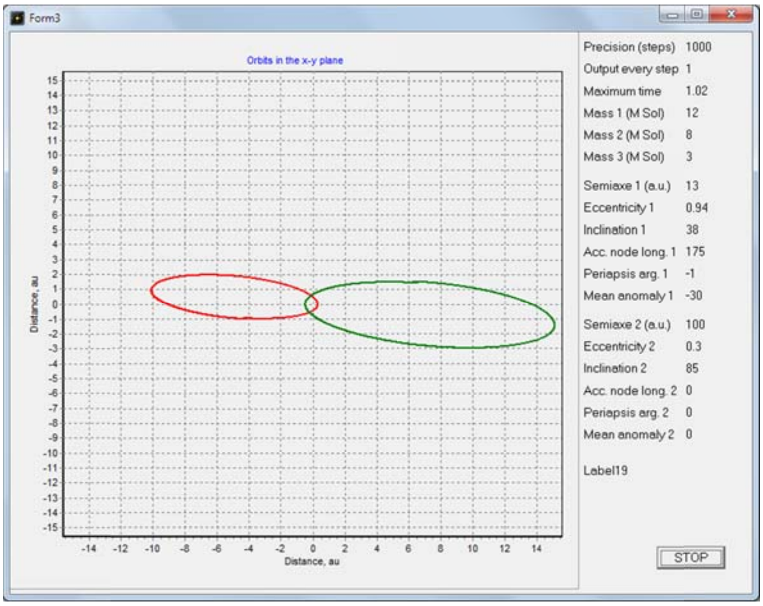
- **Inclinations** — drawing the chart of inclinations as a functions of time



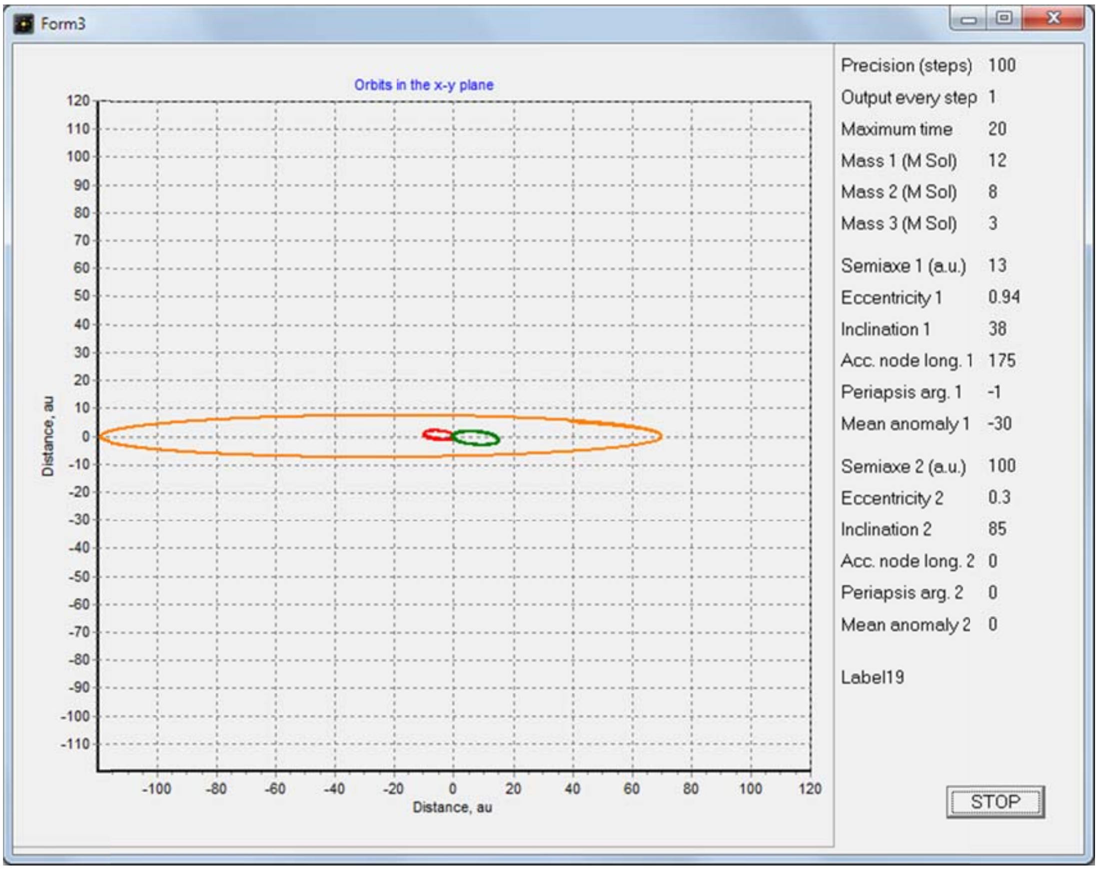
- **Radial v1 (z-direction)** — drawing the chart of first component's radial velocity as a function of time



- **Radial v1, v3 (z-direction)** — drawing the chart of first and third component's radial velocities as a functions of time

- 

Orbits 1, 2 in x-y plane — drawing the projection of the first and second component's orbits on the picture plane (x-y plane)

- 

Orbits 1, 2, 3 in x-y plane — drawing the projection of the all three component's orbits on the picture plane (x-y plane)

- **None** — No drawing. Should be set together with **Write output data** checkbox for increase the calculations speed.

Chart scaling

Any part of the chart could be enlarged. To do this click left mouse button in the upper-left corner of the area you want to enlarge and drag mouse pointer to the lower-right corner of the selected area. Increasing could be repeated several times. To restore the original scale, click the left mouse button anywhere and drag mouse pointer to the upper-left corner.

Start and Stop Calculations

Run the calculation by pressing the button **Start calculation**. If you set one of the radio buttons other than **None**, a new window with new chart will open. In the right pane of the window displays the table of initial parameters of the system. You can stop calculations any time, without waiting for the finish by clicking the **STOP** button in either the main window or in a chart window. Chart window remains open until it is forcibly closed by the user. At the same time you can plot multiple charts: every time you click on the **Start calculation** button a new chart window will open.

Additional information

Calculation's progress indicated by the progress-bar in main window and amount time in seconds, as well as the minimum and maximum values of the inner and outer orbits eccentricities.

a1 and a2 parameters

These are two parameters are the adjustable coefficients in the time transformation in the General Relativity mode. The roughly optimal values $A_1 = 1$ and $A_2 = 15$ were found by experiments. For more information see Seppo Mikkola, "*Practical symplectic methods with time transformation for the few-body problem*" [Mikkola 1997 CemDA 67:145-165].