

# SUPPLEMENTARY MATERIAL

## 1. Acknowledgements.

This is a work of the physics department, accordingly I needed help in the field of computer science, for example in writing out the simulation code in C++. I am grateful to all the caregivers who supported me.

## 2. Directory.

<b>Algebraic Model</b>	<b>Physical reality</b>
Frictionless	Internal friction and air resistance
Infinite accuracy	Optical evaluation
Valid at $t \rightarrow \infty$	Limited time span
six-dimensional original formulation	four-dimensional (after revision two-dimensional)
No centrifugal force	Centrifugal force increasing with frequency
Constant conditions	Small deviations

TABLE 1: Identification of relevant factors

<b>Extra Surface</b>	<b>Damping Factor</b>
16.68 cm <sup>2</sup>	0,145/s
33.36 cm <sup>2</sup>	0,178/s
50.04 cm <sup>2</sup>	0,204/s
66.72 cm <sup>2</sup>	0,305/s
83.40 cm <sup>2</sup>	0,497/s
100.08 cm <sup>2</sup>	0,600/s

TABLE 2: Damping Factor in dependence of Extra Surface

Damping factor	Chaos Entry Frequency
0.145/s	4.6370 rad/s
0.178/s	4.6496 rad/s
0.204/s	4.6684 rad/s
0.305/s	4.6873 rad/s
0.497/s	4.7250 rad/s
0.600/s	4.7501 rad/s

TABLE 3: Chaos Entry Frequency Damping Factor

Friction	Iterations to Periodicity
1	0
0,5	0
0,1	96
0,05	180
0,04	230
0,03	360
0,02	580
0,01	1.130
0,005	2.180

TABLE 4: Graphic illustration of FIGURE 19

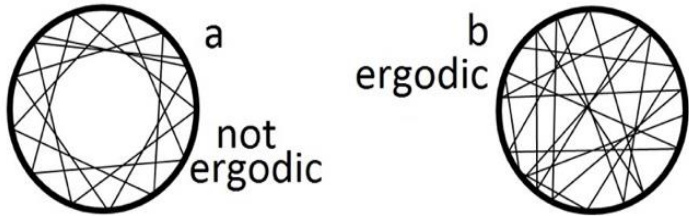


FIGURE 1: A simple scheme of an ergodic (b) and a not ergodic (a) thermodynamical system (Source: Wikipedia, Ergodic hypothesis)



FIGURE 2: My experimental setu

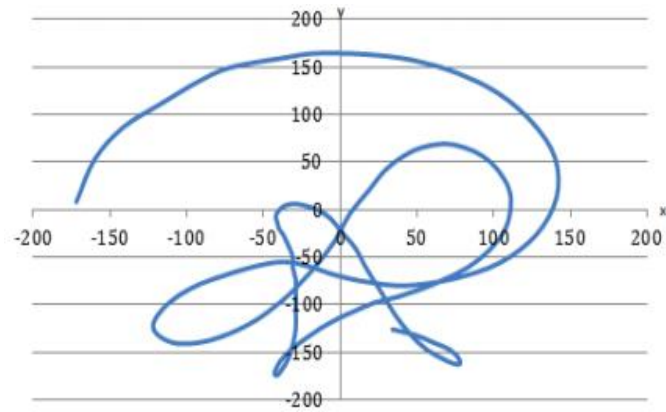


FIGURE 3: First 100 measuring points

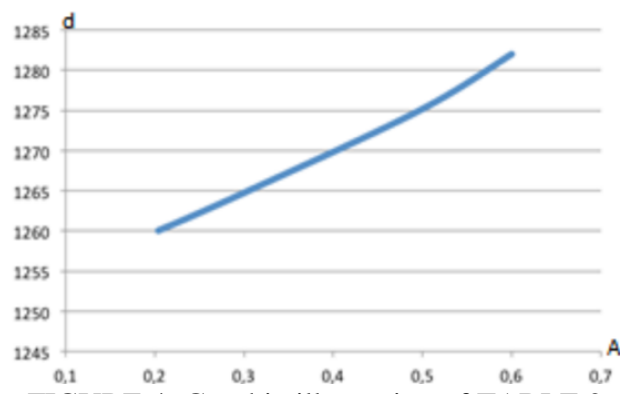


FIGURE 4: Graphic illustration of TABLE 2

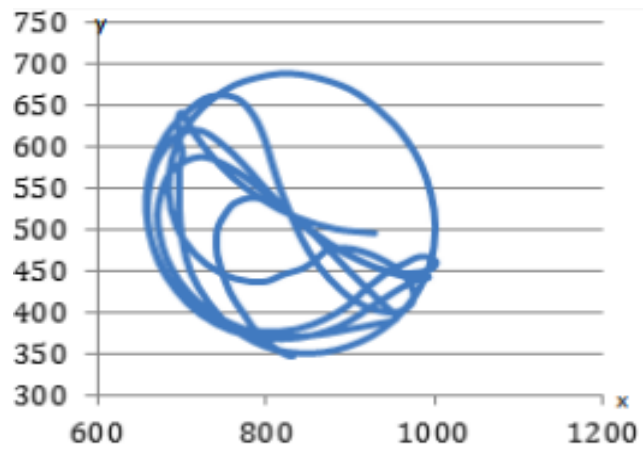


FIGURE 5: First 100 measuring points

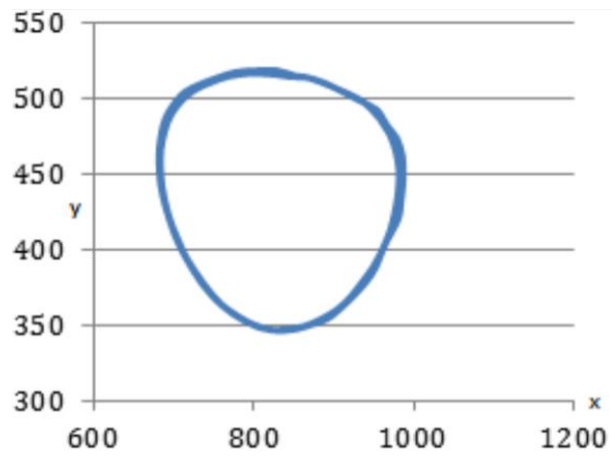


FIGURE 8: Scheme of my Computer Simulation

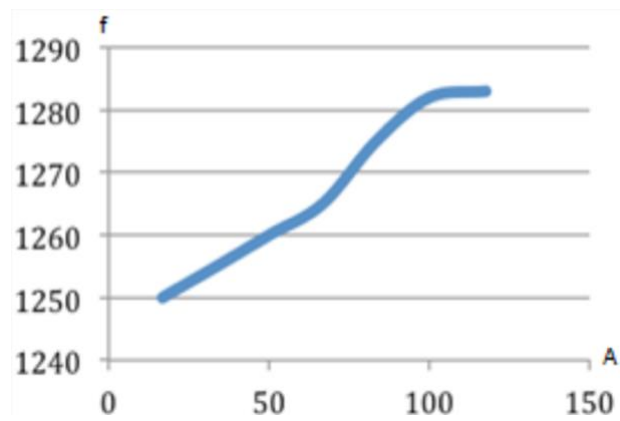


FIGURE 7: Graphic illustration of TABLE 3

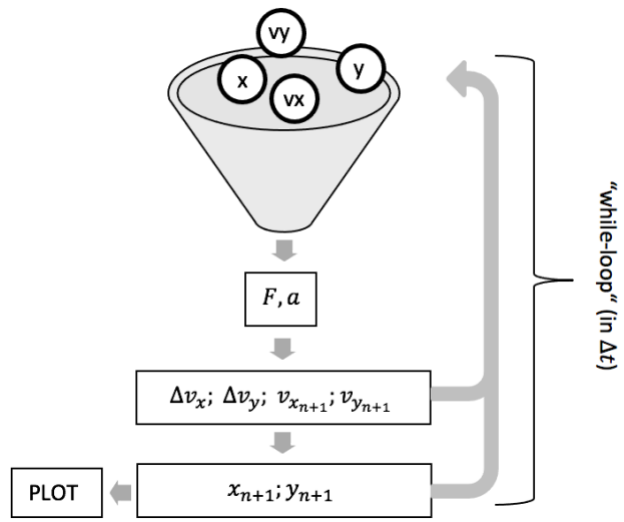


FIGURE 8: Scheme of my Computer Simulation

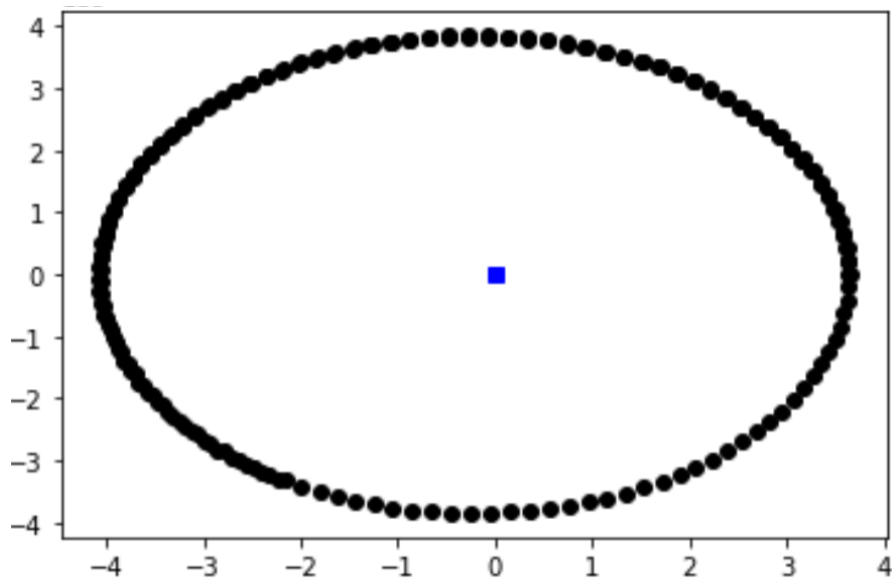


FIGURE 9: Computer simulation of the orbit of the Moon (black) around the Earth (blue).

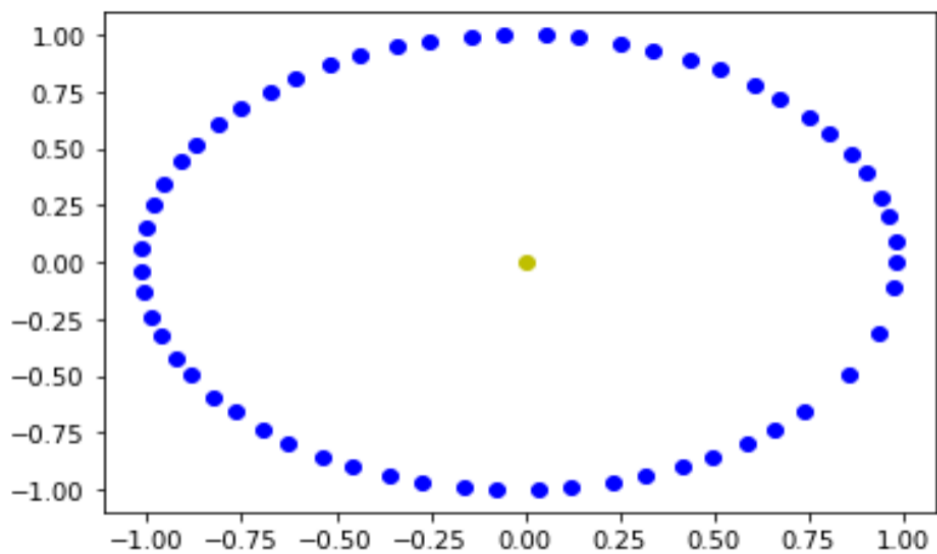


FIGURE 10: Computer simulation of the Earth's orbit (blue) around the Sun (yellow).

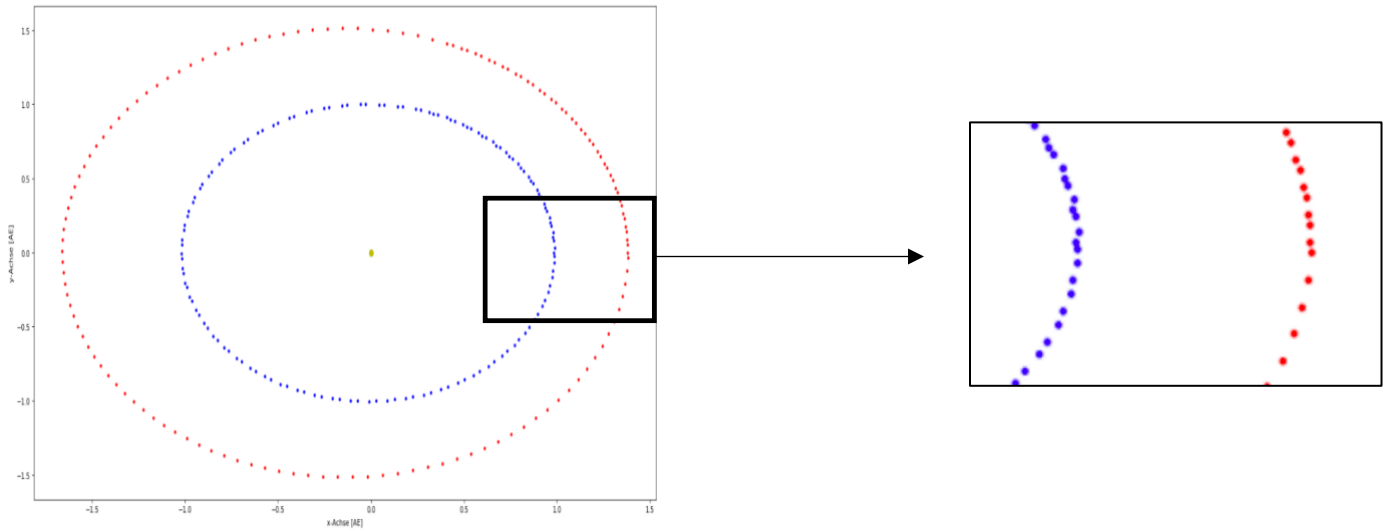


FIGURE 11: Three-body simulation of Sun (yellow), Earth (blue), and Mars (red). The nonlinearities can be seen with the naked eye for the Earth and Mars orbits.

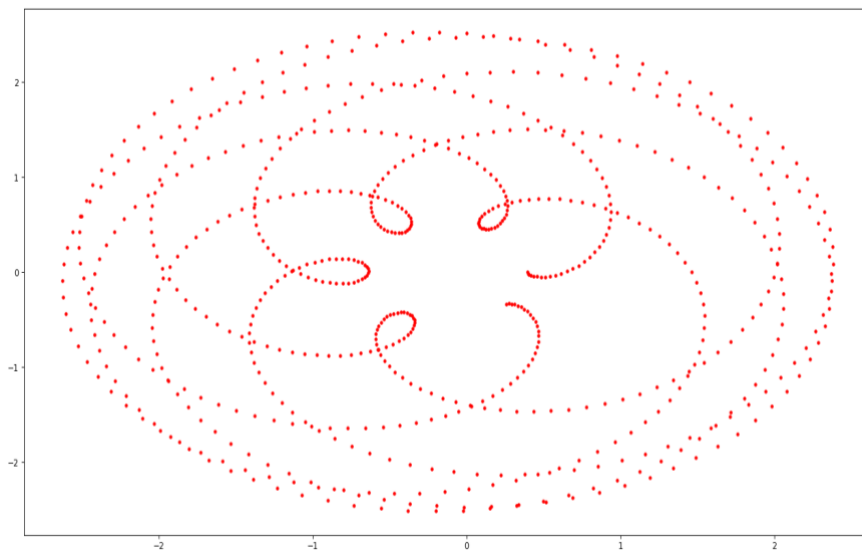


FIGURE 12: Three-body simulation of Sun (yellow), Earth (blue) and Mars (red) with Earth as coordinate origin. The result is the motion of Mars relative to the Earth, corresponding to its motion in the night sky.

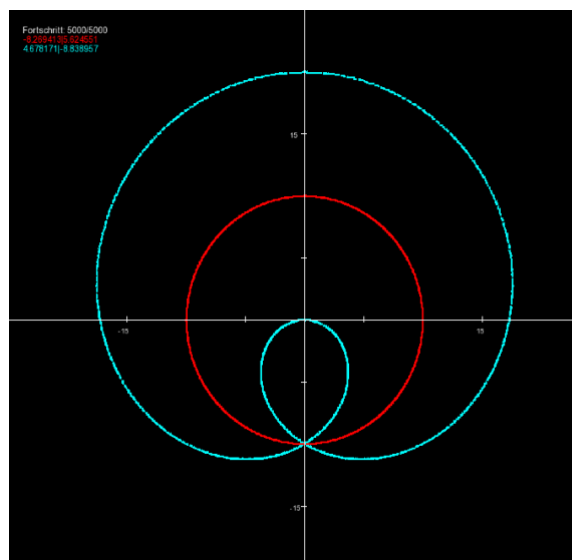


FIGURE 13:  $\frac{f_2}{f_1} = 1$

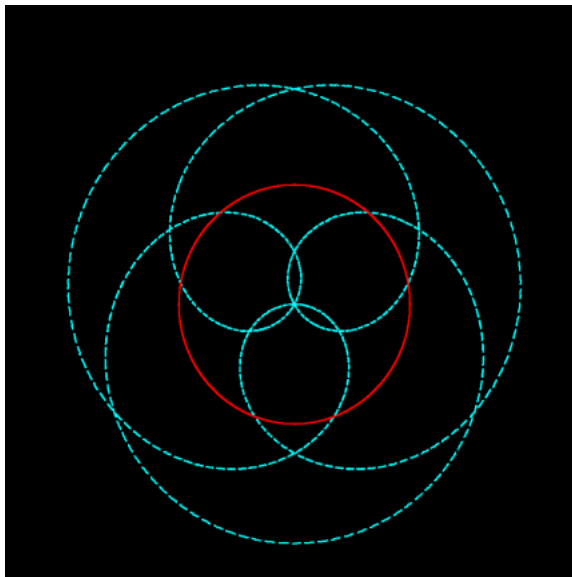


FIGURE 14:  $\frac{f_2}{f_1} = 4$

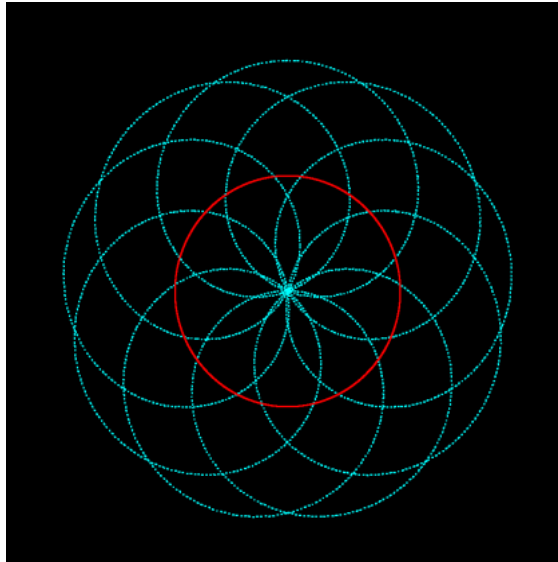


FIGURE 15:  $\frac{f_2}{f_1} = 10$

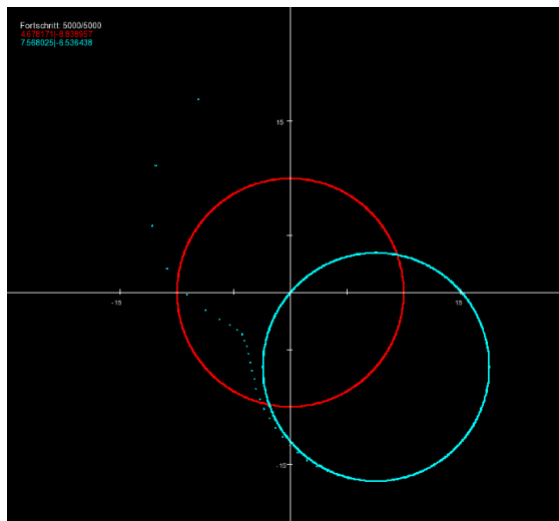


FIGURE 16:  $\mu = 0,1$

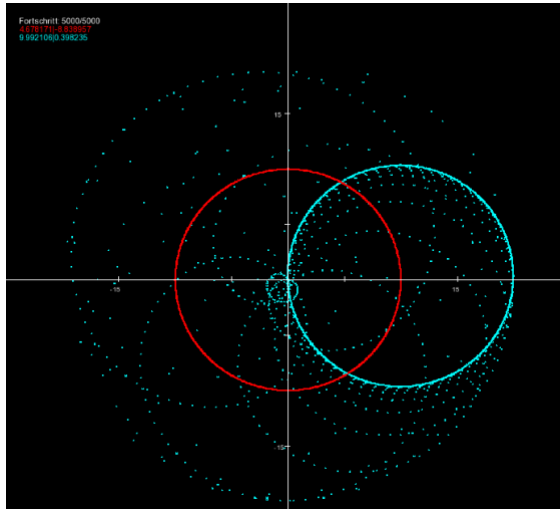


FIGURE 17:  $\mu = 0,05$

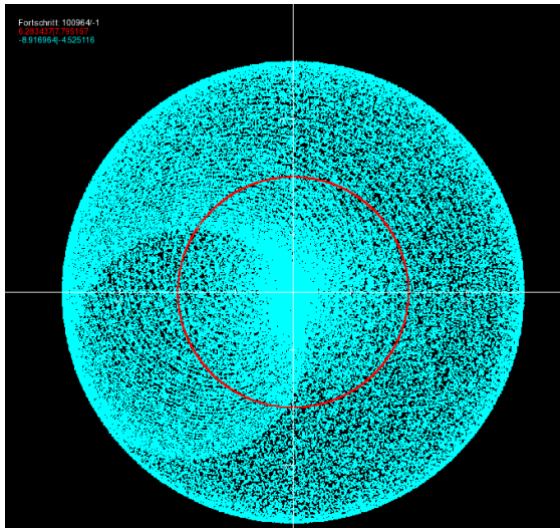


FIGURE 18:  $\mu = 0,005$

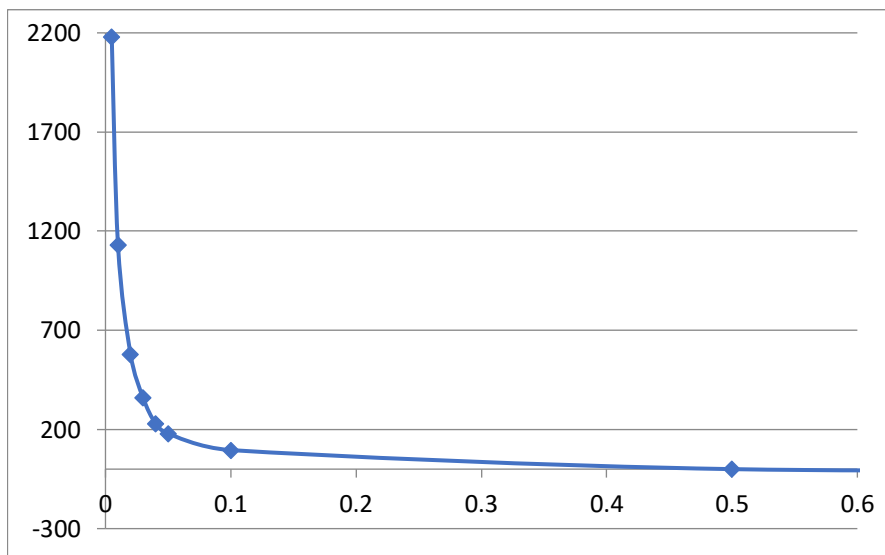


FIGURE 19: Iterations to periodicity in dependence of friction



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