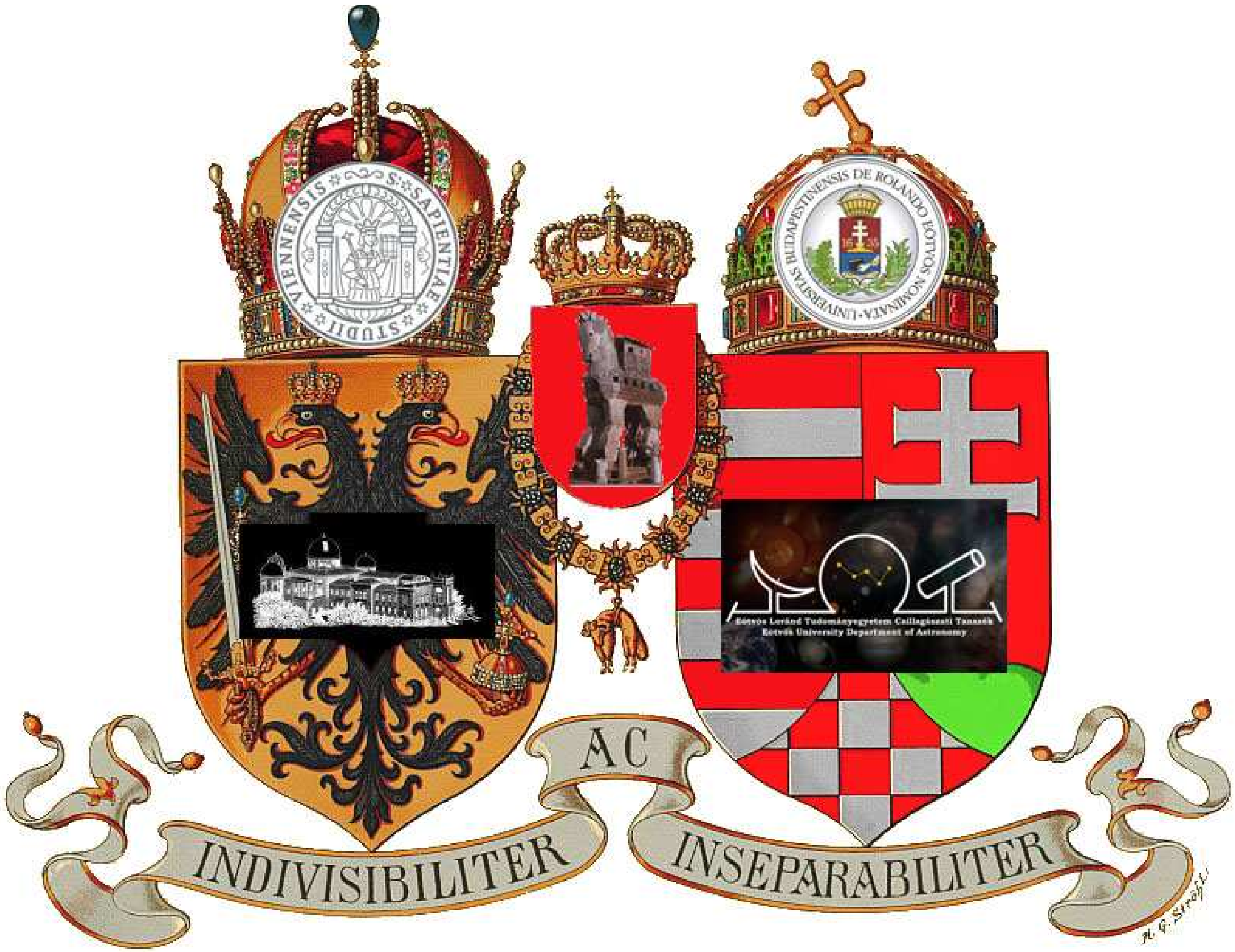
Dynamics of possible Trojan planets in double stars



Richard Schwarz

Former work:

Dynamics of possible Trojan planets in binary systems:
(MNRAS 2009)

We will investigate two different types:

Type1) binaries consist of two stellar objects and

Type2) binaries consist of a stellar and a substellar (brown dwarf) object

Former work:

Dynamics of possible Trojan planets in binary systems:
(MNRAS 2009)

$$\mu = \frac{m_1}{m_1 + m_2}$$

Table 1. Orbital elements of six binary candidates, with $\mu < 1/25$, m denotes the mass of the star expressed in solar mass units ($M_\odot$). In the upper part systems with known orbital parameters, whereas in the lower part systems with unknown orbital parameters are listed.

Name	m ($M_\odot$)	μ	a (au)	e
51 θ Vir	2.98	0.026	–	–
51 θ Vir	0.08	0.026	9.91	–
53 ξ Uma	1.1	0.035	–	–
53 ξ Uma	0.04	0.035	15.99	0.39
HD 223099		0.03	–	–
SB 152		0.035	–	–
SB 667		0.03	–	–
SB 831		0.03	–	–

Table 3. Orbital elements of all binaries with substellar candidates, sorted by increasing mass of the secondary.

Name	Spectral type	m_{star} ($M_\odot$)	$m_{planet} \sin(i)$ (M_J)	μ	a (au)	e	ω (°)
18 Del	G6 III	2.3	–	–	–	–	–
18 Del b	–	0.0098	10.30	0.0043	2.60	0.08	166.1
NGC 24233	–	2.4	–	–	–	–	–
NGC 24233 b		0.0101	10.60	0.0042	2.10	0.21	18.0
XO−3	F5 V	1.213	–	–	–	–	–
XO−3 b		0.0113	11.79	0.0092	0.045	0.26	345.8
HD 162020	K2 V	0.8	–	–	–	–	–
HD 162020 b		0.0131	13.75	0.0162	0.072	0.28	−27.3
HD 13189	K2 II	4.5	–	–	–	–	–
HD 13189 b		0.0134	14.00	0.0030	1.85	0.28	160.7
HD 168443	G5	1.06	–	–	–	–	–
HD 168443 b		0.0077	8.02	–	0.3	0.5286	172.9
HD 168443 c		0.0173	18.10	0.0160	2.91	0.21	65.1
NGC 4349 No127	–	3.9	–	–	–	–	–
NGC 4349 No127 b		0.0189	19.80	0.0048	2.38	0.19	61.0
CoRoT-Exo3	G0 V	1.37	–	–	–	–	–
CoRoT-Exo3 b		0.0207	21.66	0.0149	0.057	0.00	0.0

Results

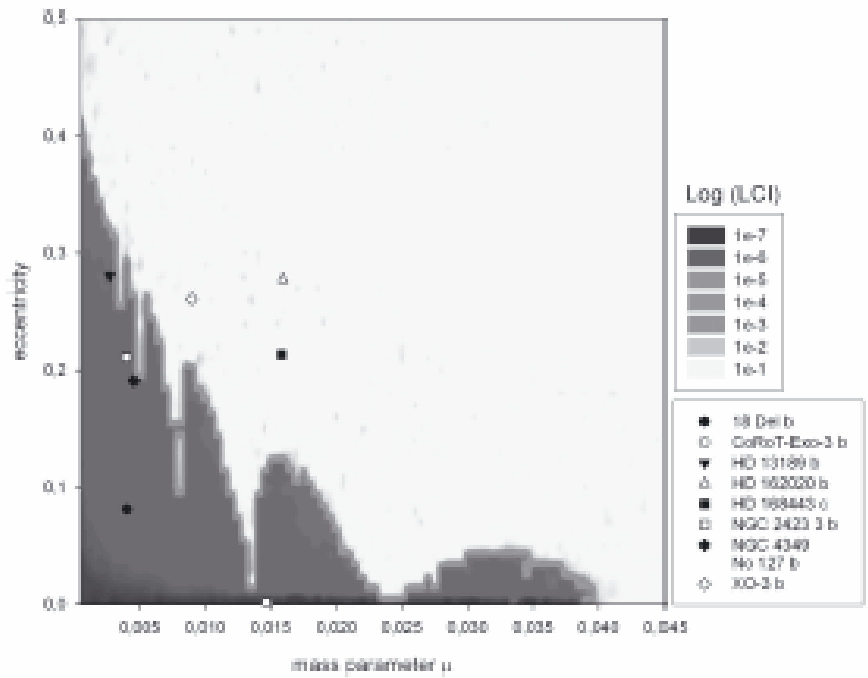


Figure 3. Stability of the Lagrangian point L_4 depending on the eccentricity and the mass parameter.

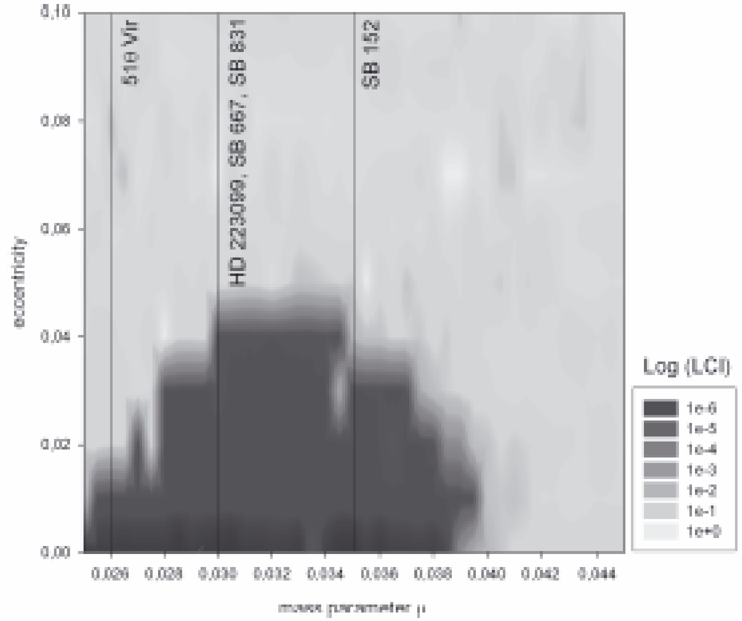


Figure 2. Stability in the Lagrangian point L_4 depending on the eccentricity and the mass parameter. 53 ξ Uma is not presented, because the initial eccentricity is too high.

Expand investigations to the 3 dimensional case

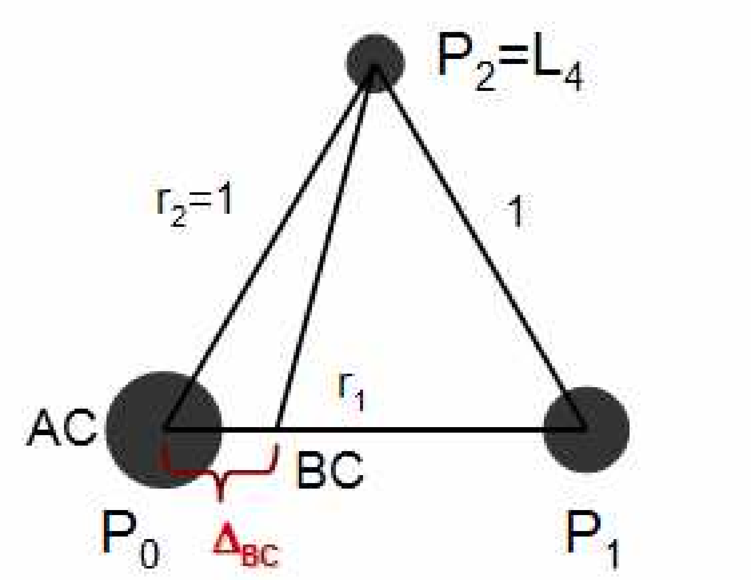
Initial conditions

.) R3BP and 3D-R3BP

.) Starting at L_4

.) AC, BC

.) integration time 1000years



Stability

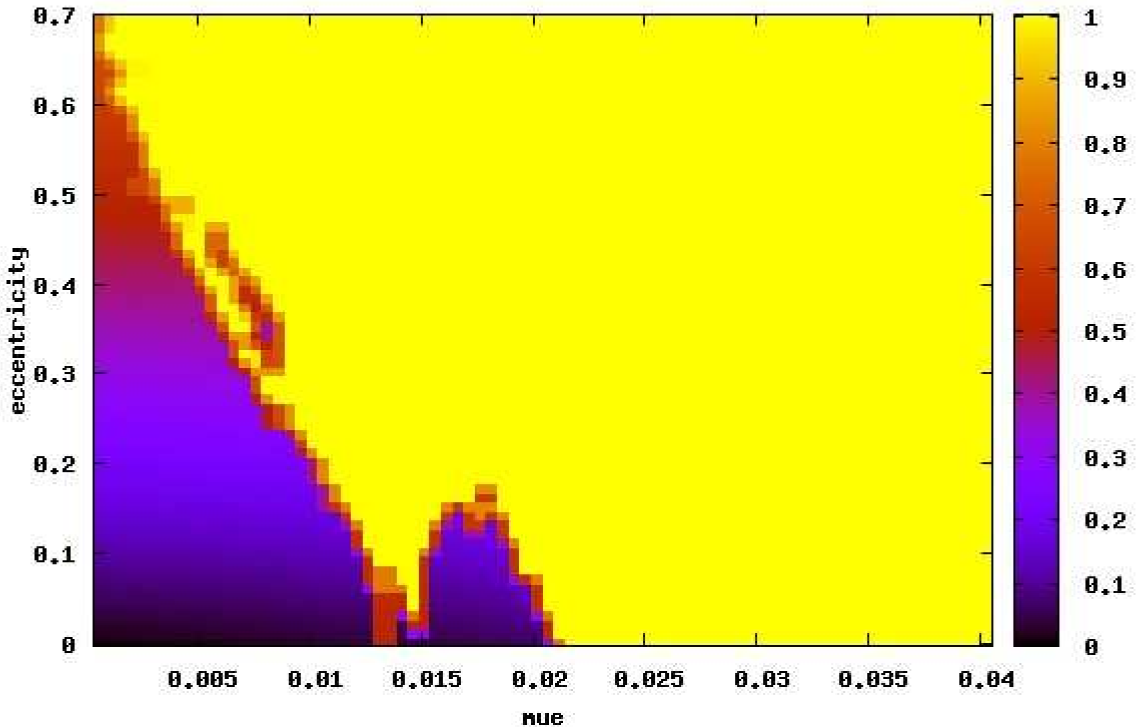
.) maximum eccentricity

.) Lyapunov indicator

Integrators:

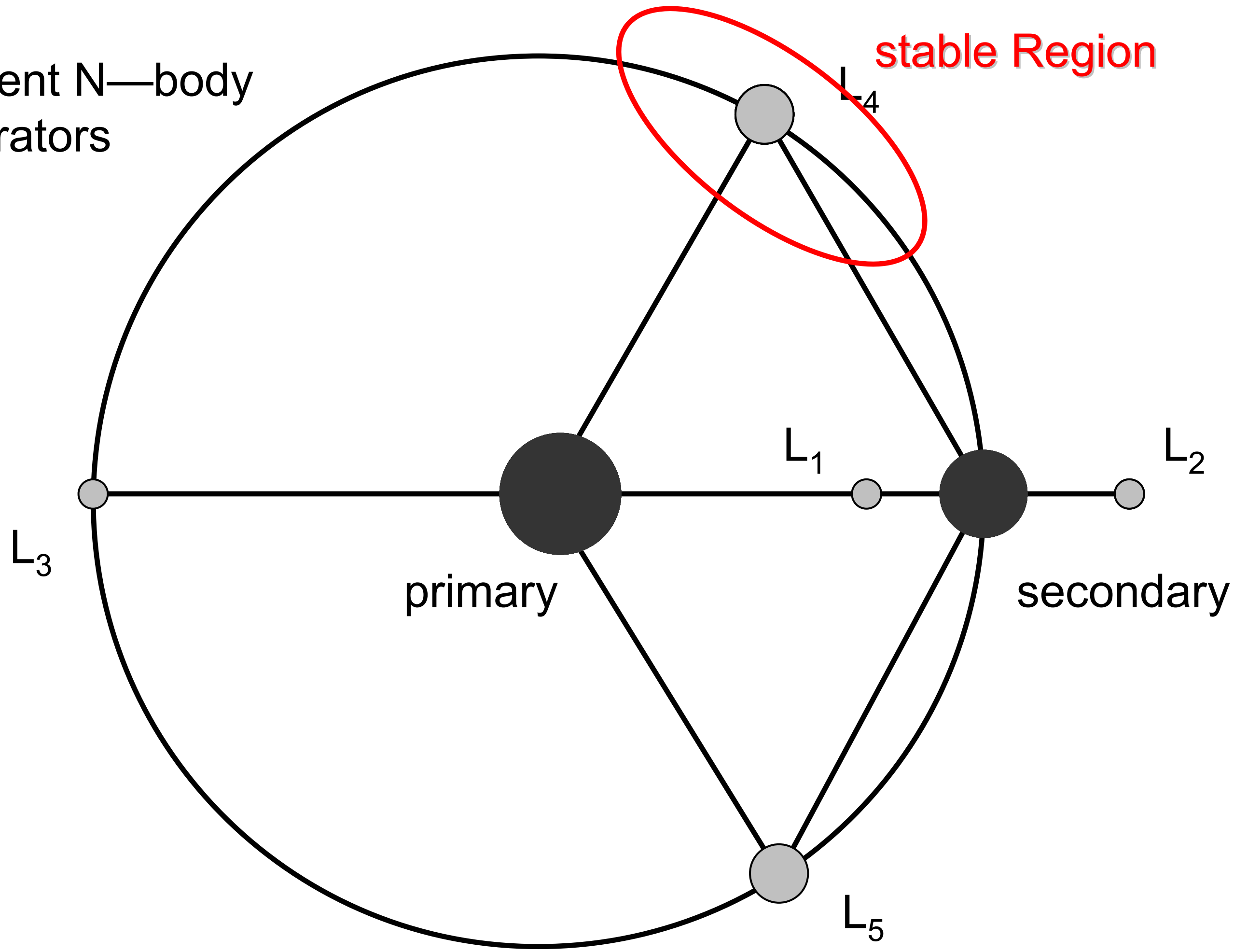
.) Burlirsch-Stoer
.) Lie
.) Nordsieck

Starting in Lagrangian point L_4

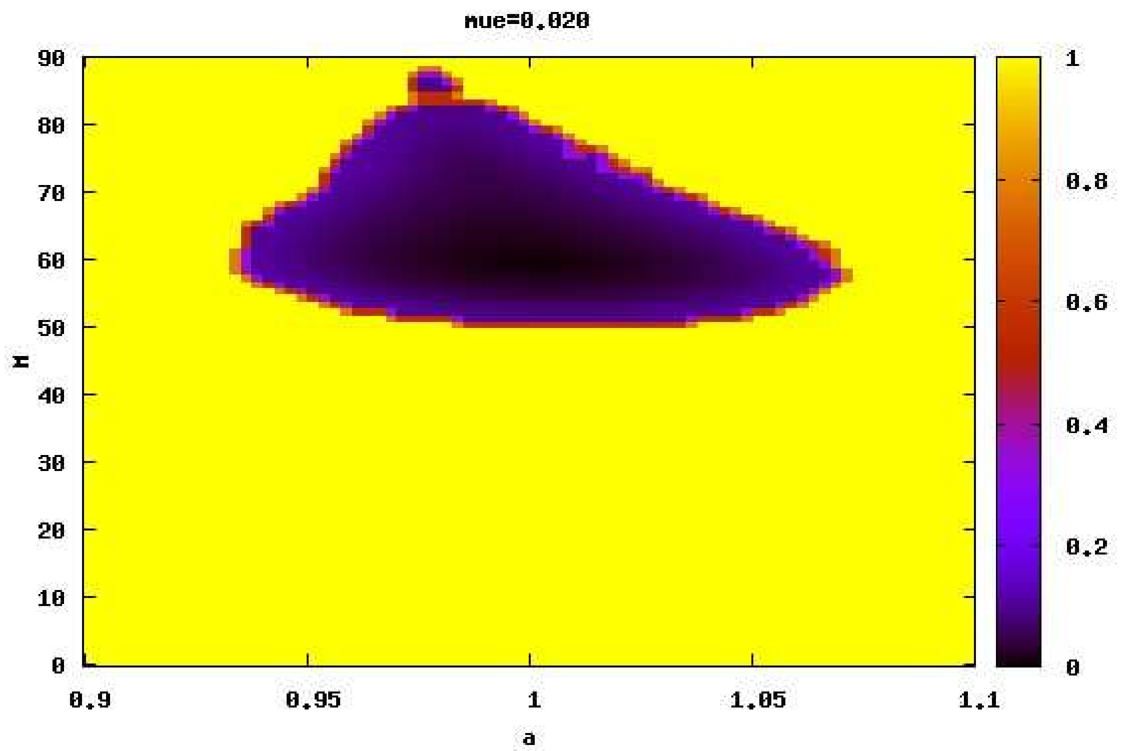


Trojan configuration of the Planar circular case

Used: Different N—body integrators



Stability map



Initial conditions:

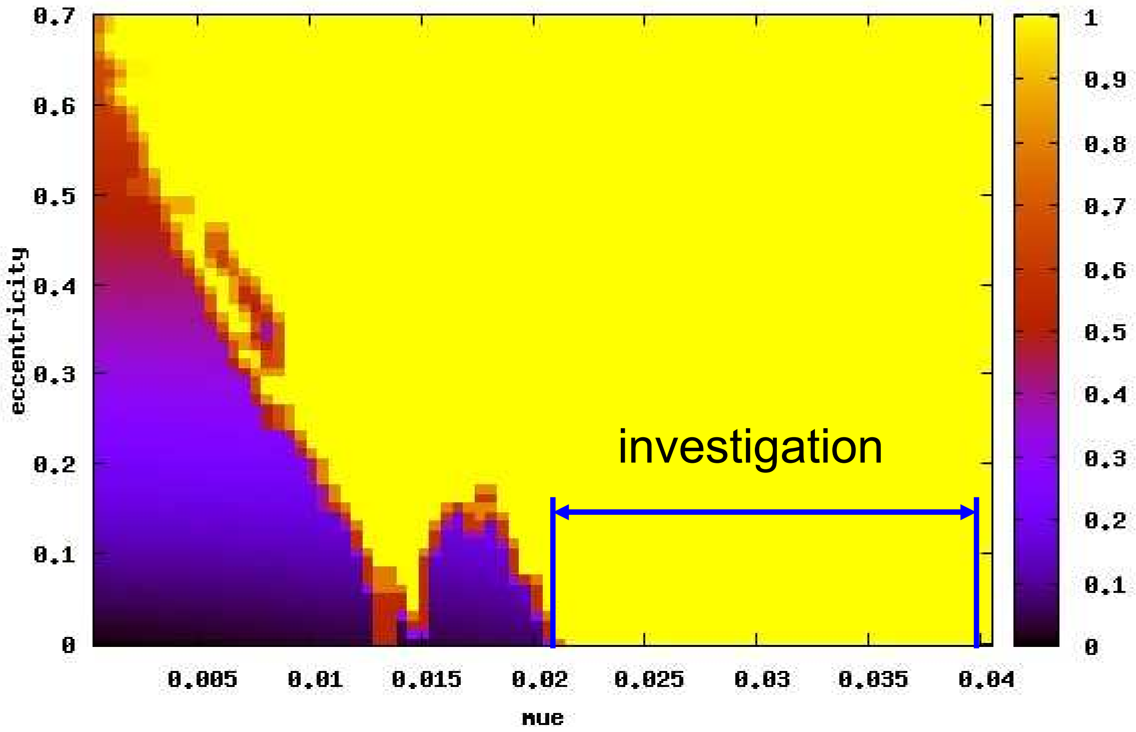
M=0-90° ΔM=1°

a=0.85-1.1 a_1=0.85-1.15 Δa=0.0025

e, i, ω, Ω =0

~11000orbits

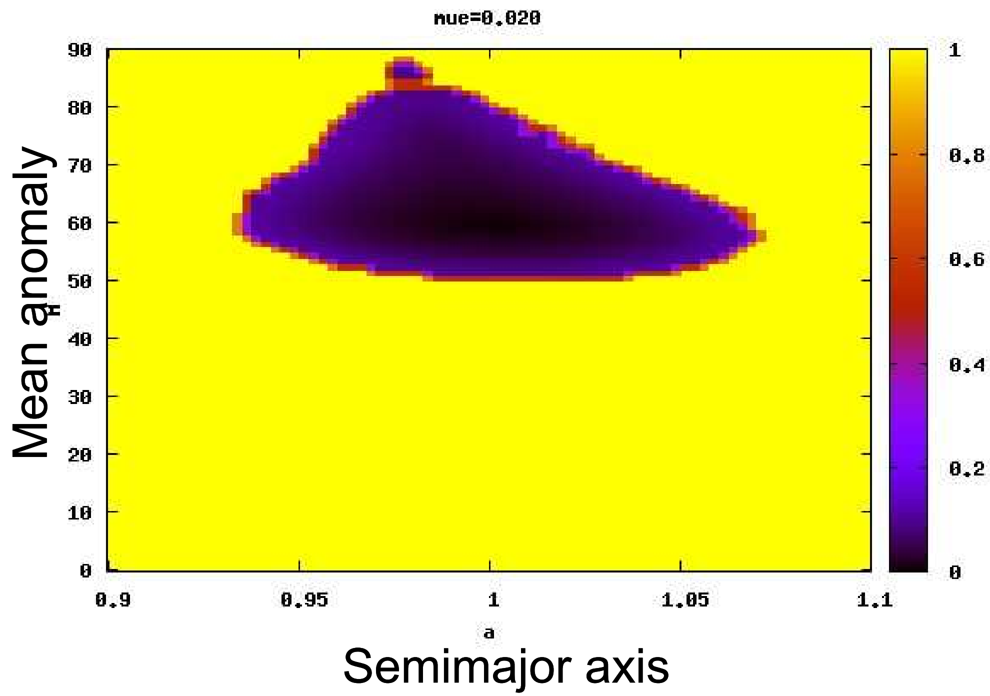
Intergration-time 1000 years



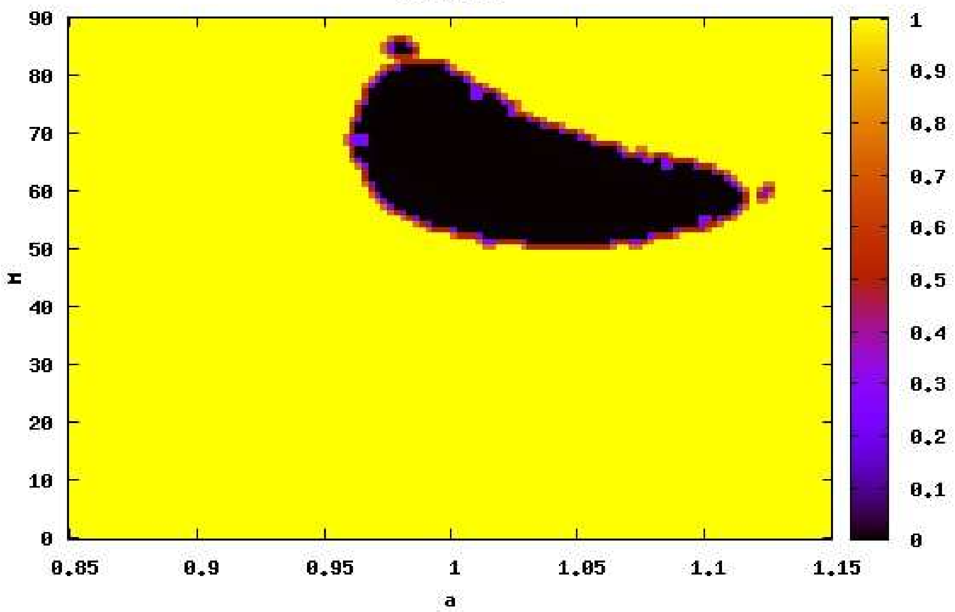
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
eccentricity
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
mue
investigation
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

μ=0.020

2D-starting
in the AC



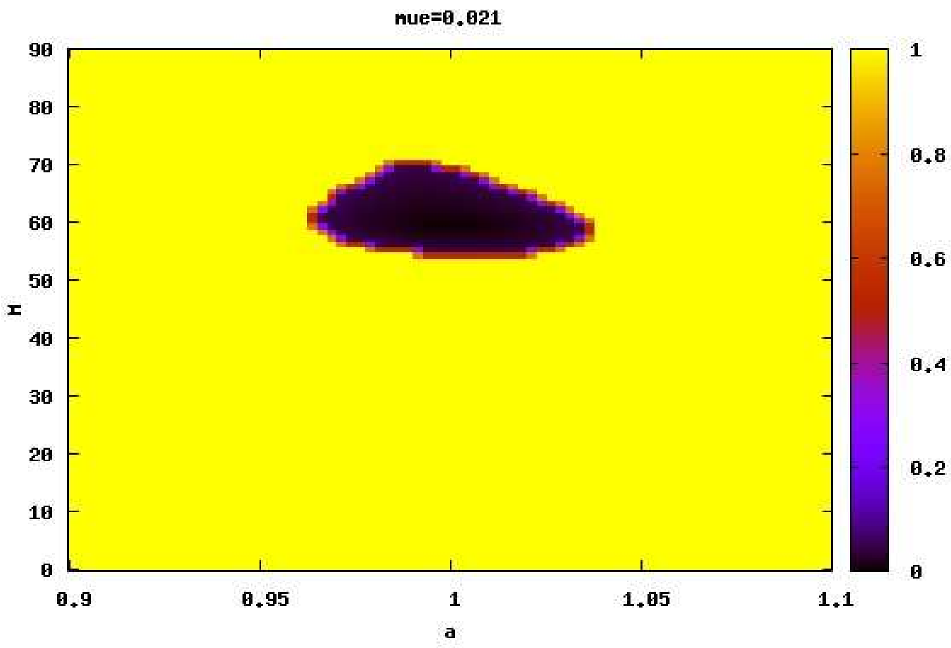
3D-starting
BC



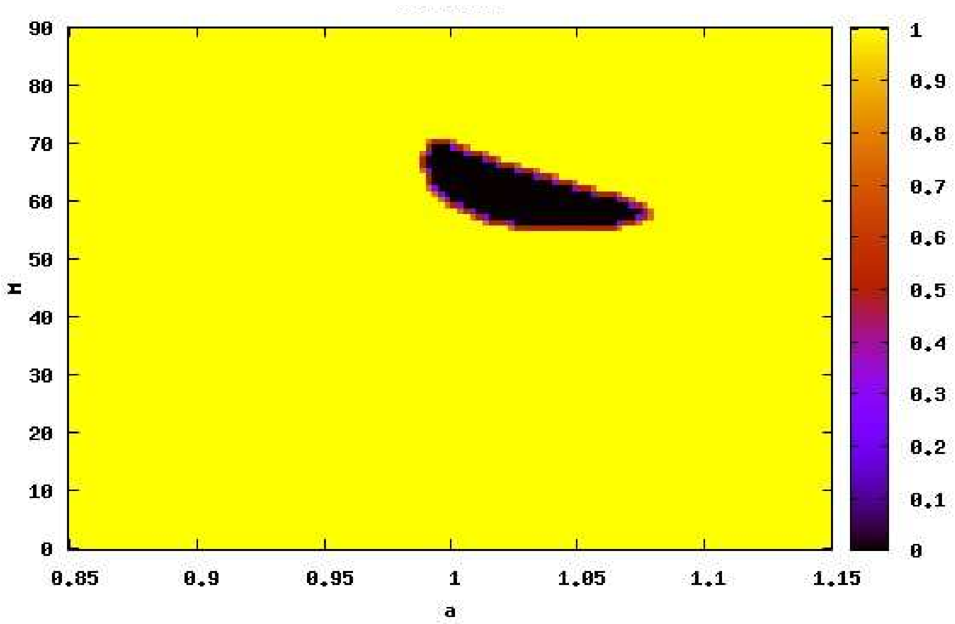
Integrationtime
= 1000 periods

$\mu=0.021$

2D-starting
in the AC

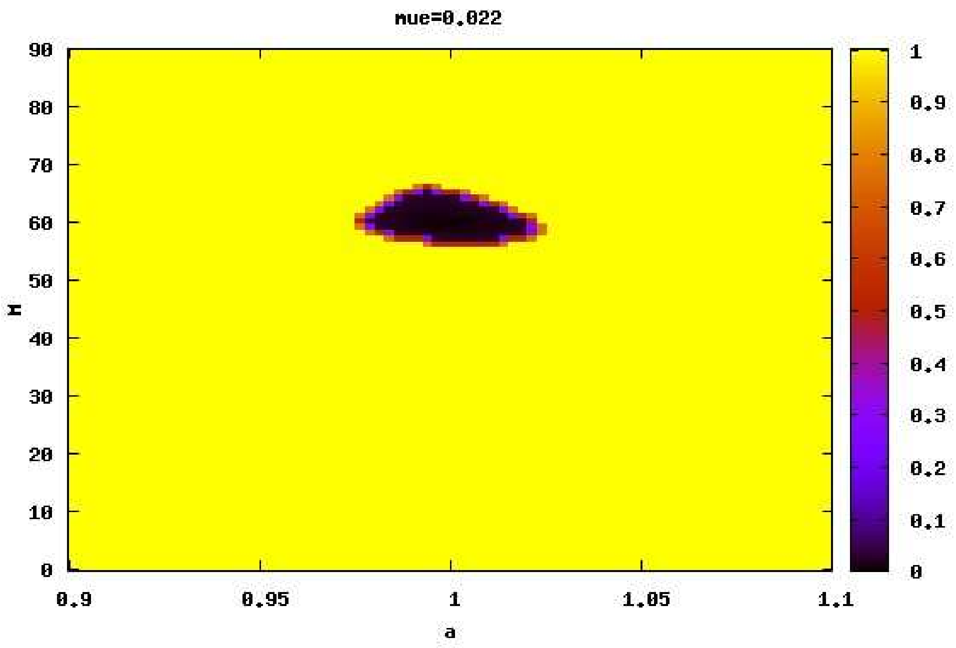


3D-starting
BC

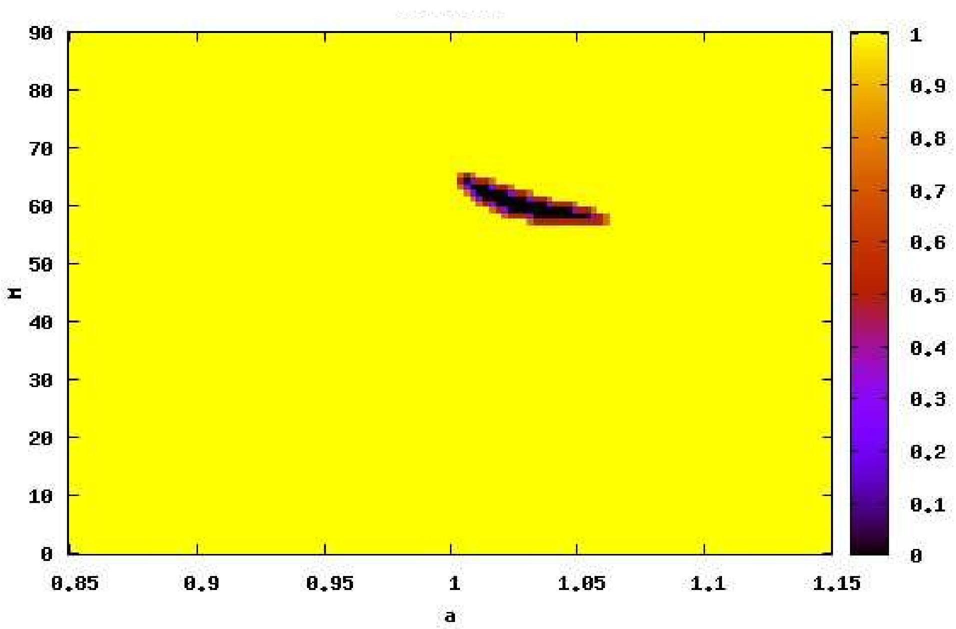


μ=0.022

2D-starting
in the AC



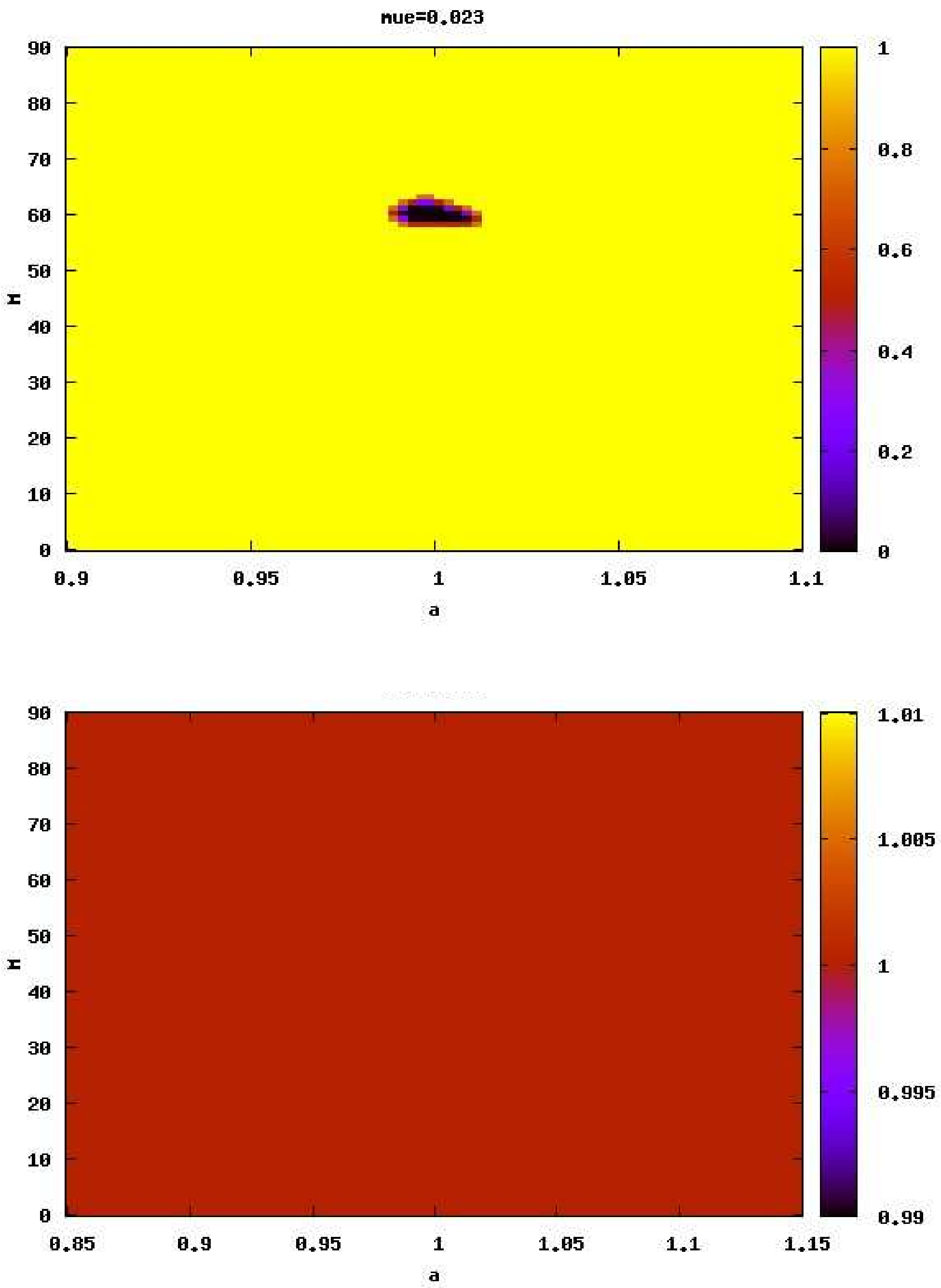
3D-starting
BC



μ=0.023

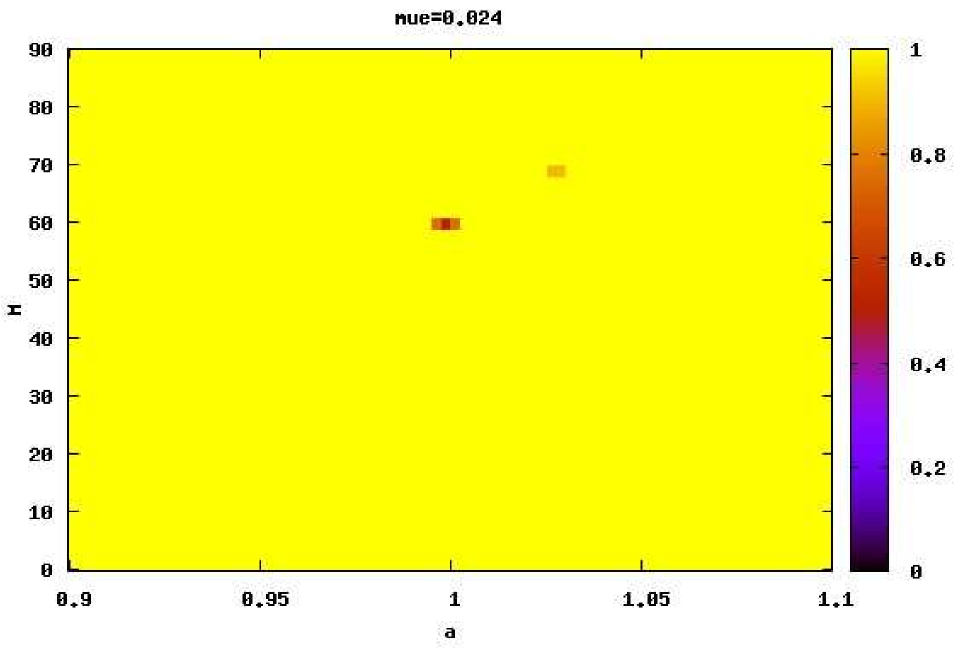
2D-starting in the AC

3D-starting BC

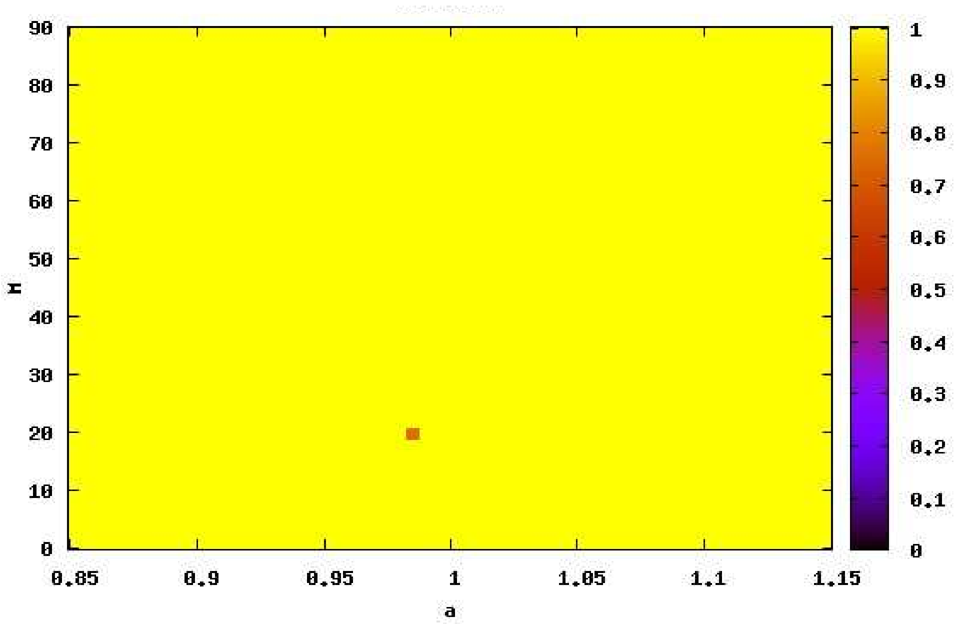


μ=0.024

2D-starting
in the AC

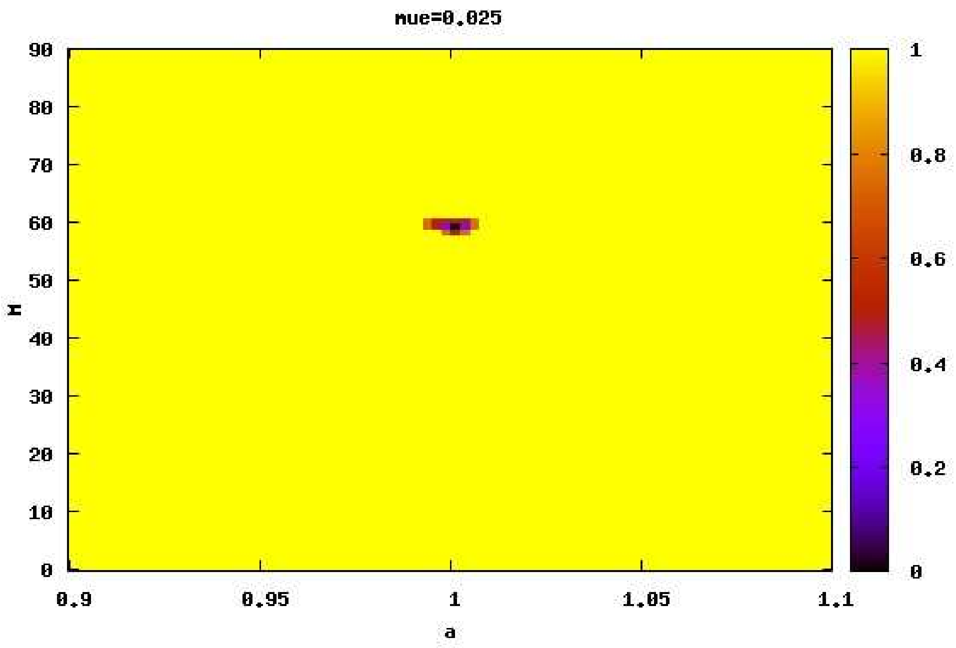


3D-starting
BC

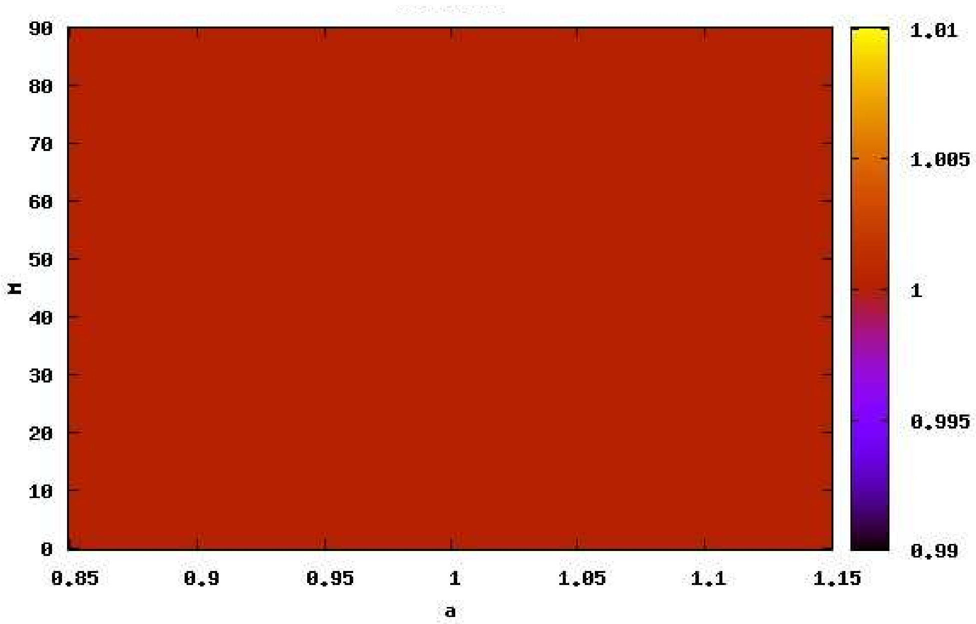


μ=0.025

2D-starting in the AC

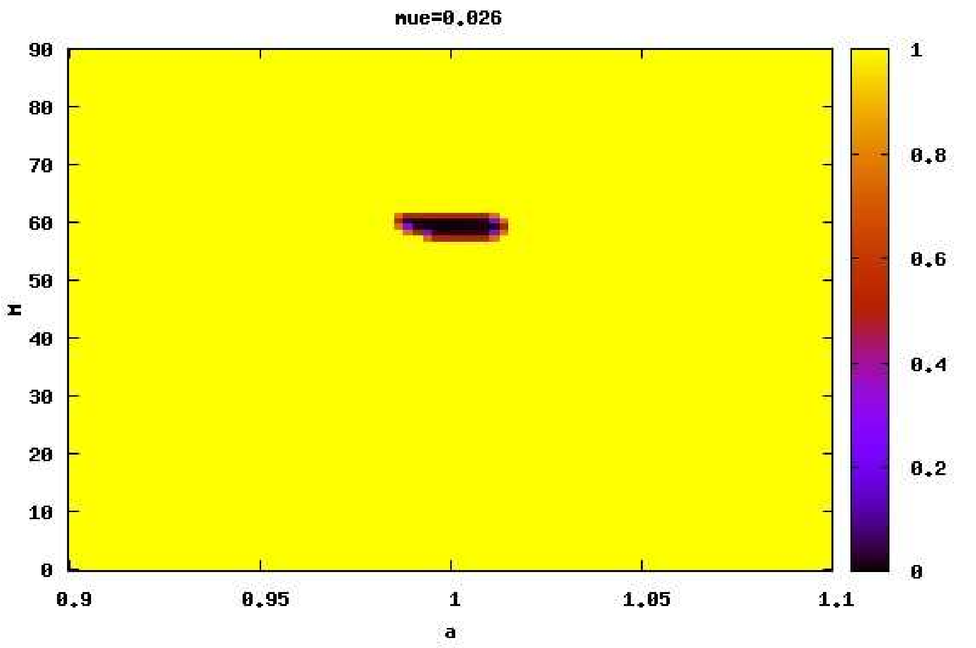


3D-starting BC

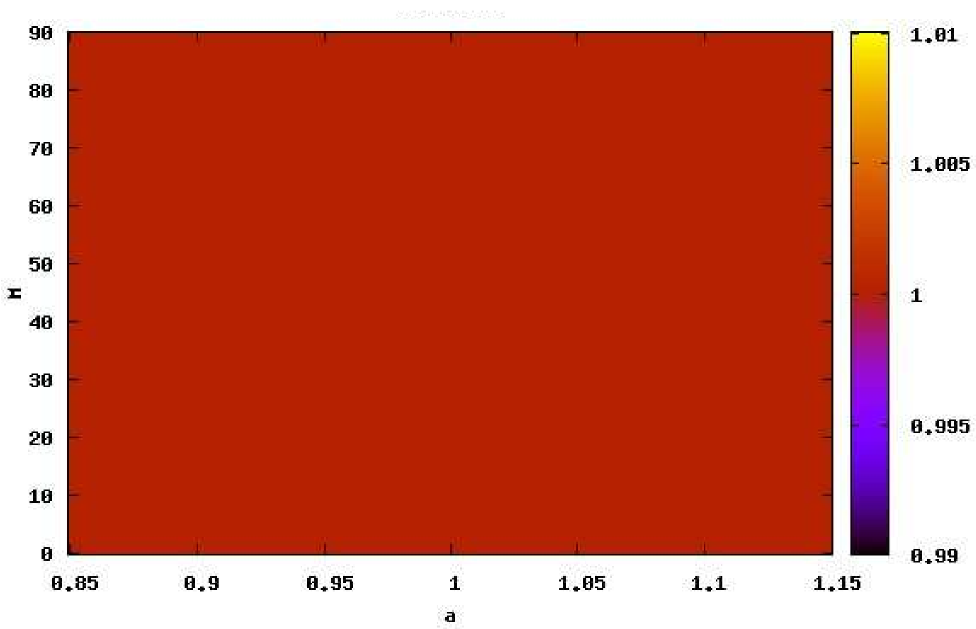


μ=0.026

2D-starting
in the AC

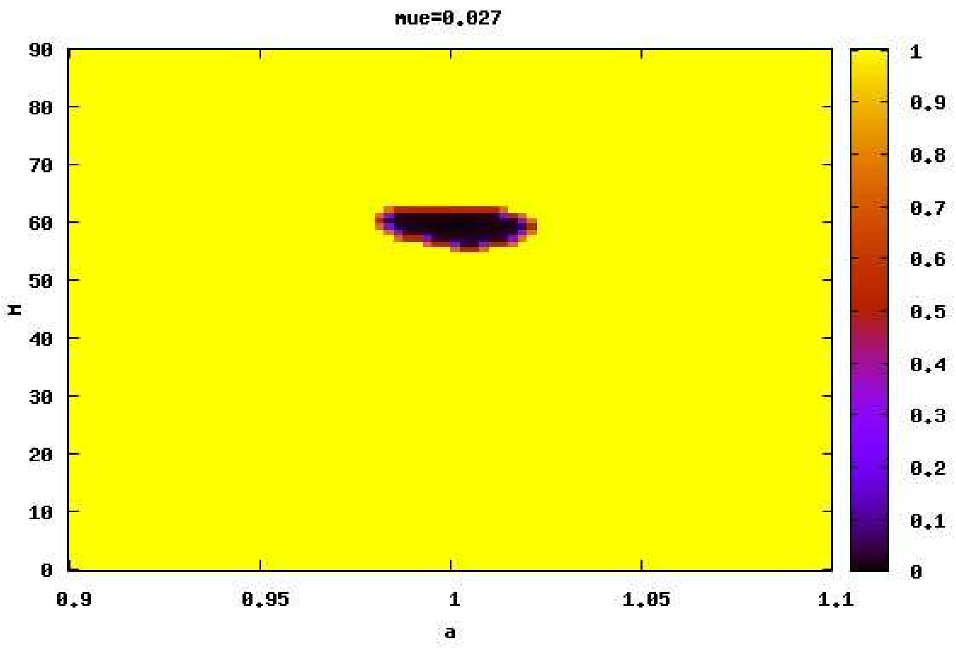


3D-starting
BC

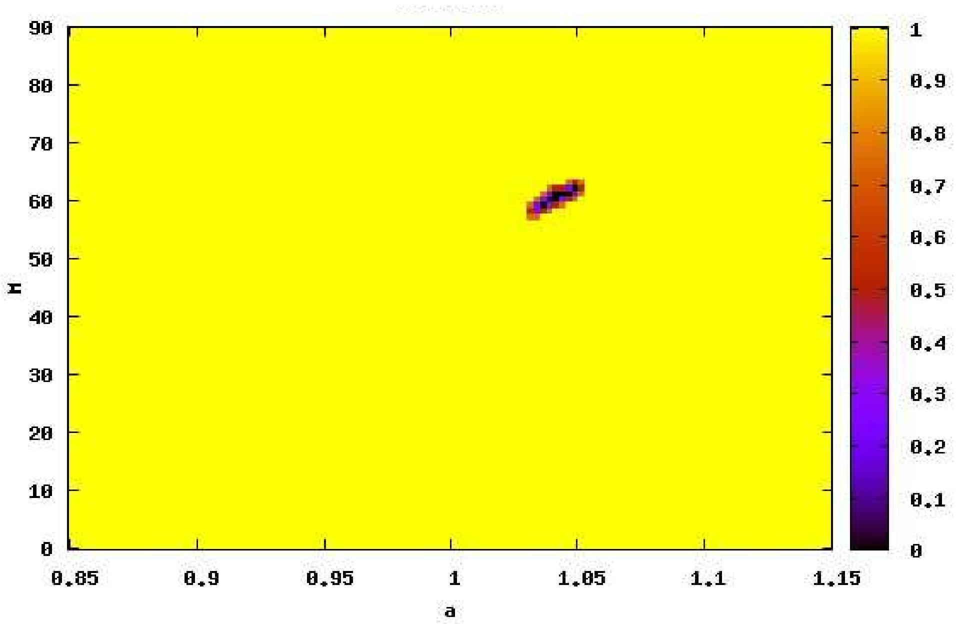


μ=0.027

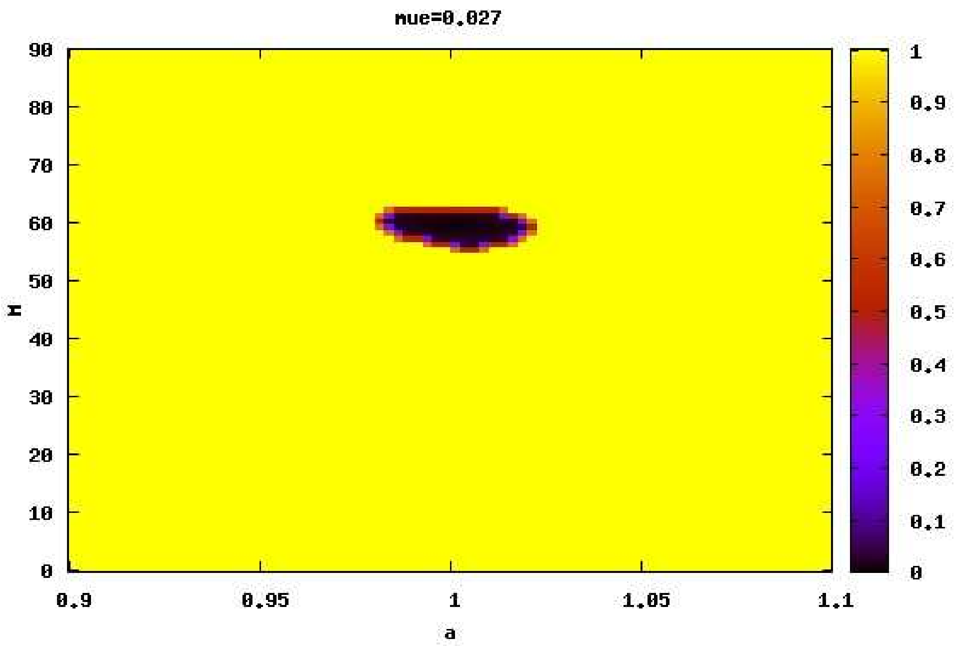
2D-starting
in the AC



3D-starting
BC

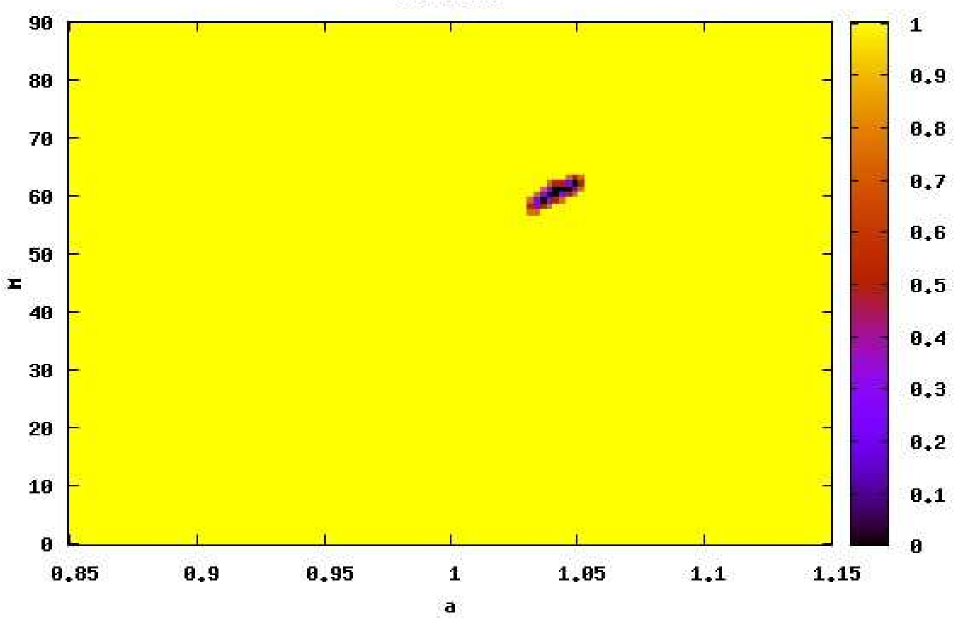


2D-starting
in the AC



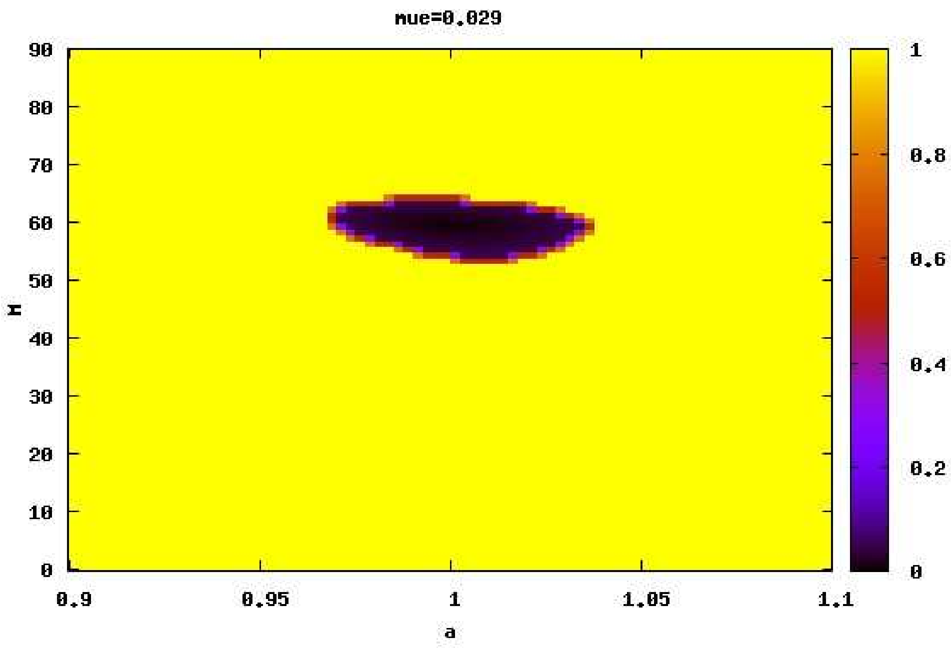
μ=0.028

3D-starting
BC

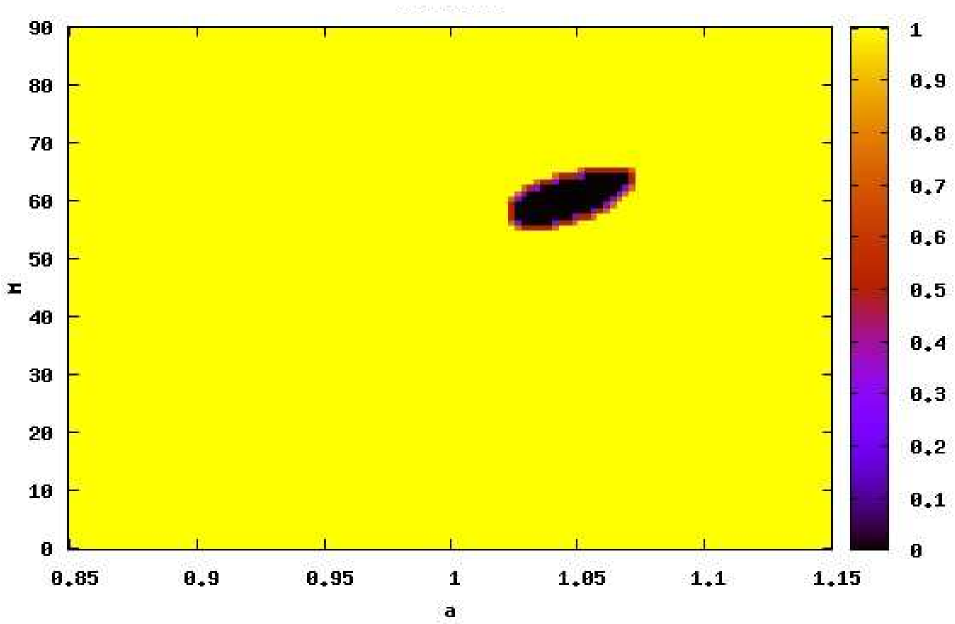


μ=0.029

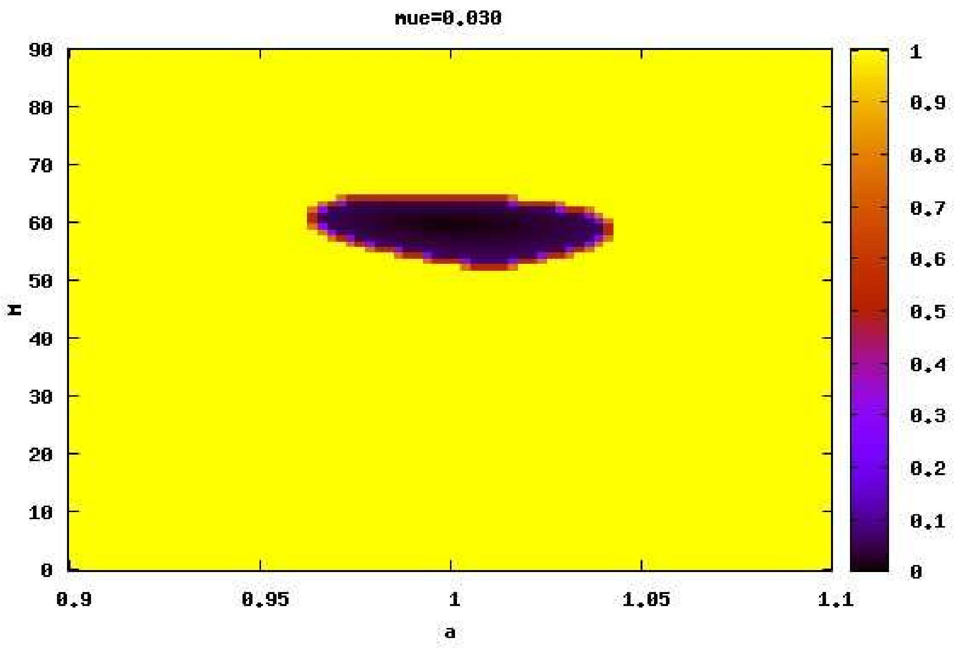
2D-starting in the AC



3D-starting BC

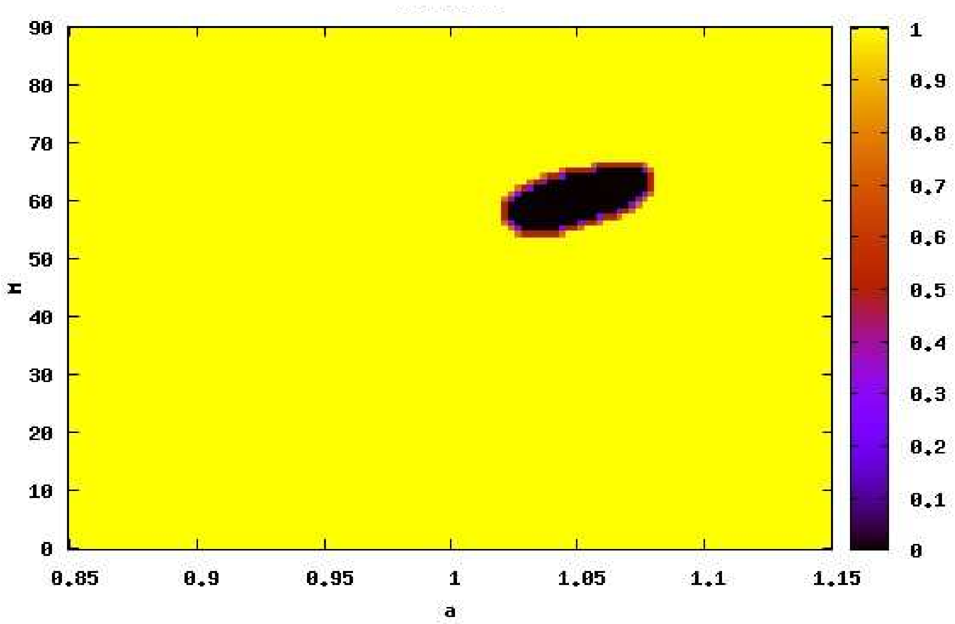


2D-starting
in the AC

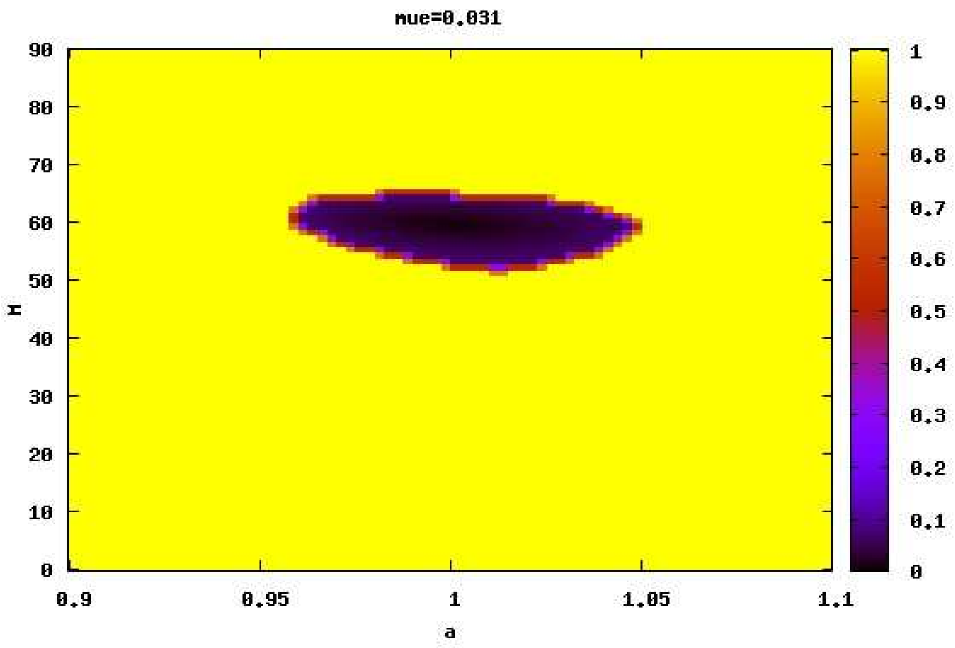


μ=0.030

3D-starting
BC

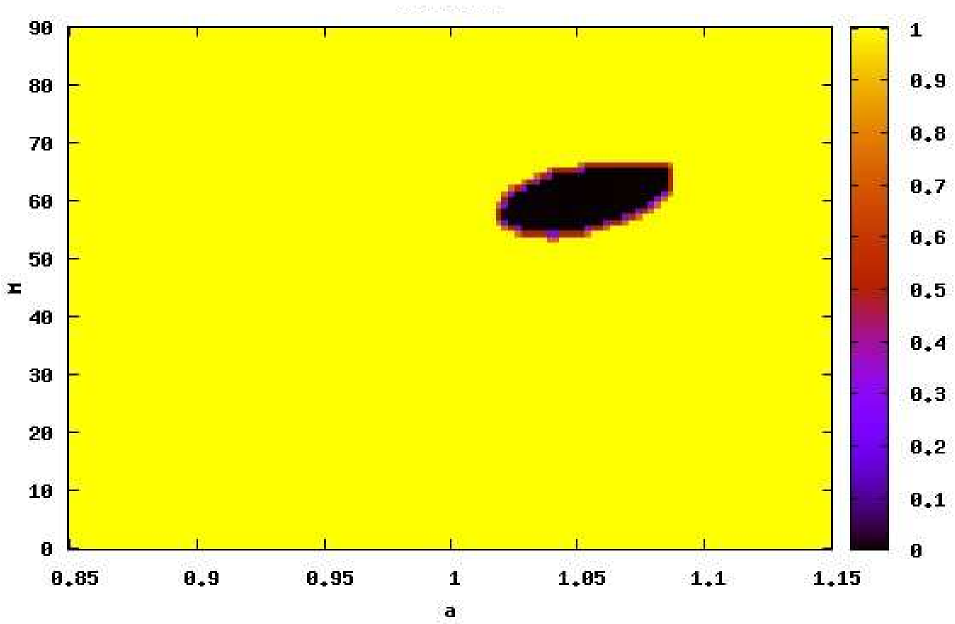


2D-starting
in the AC



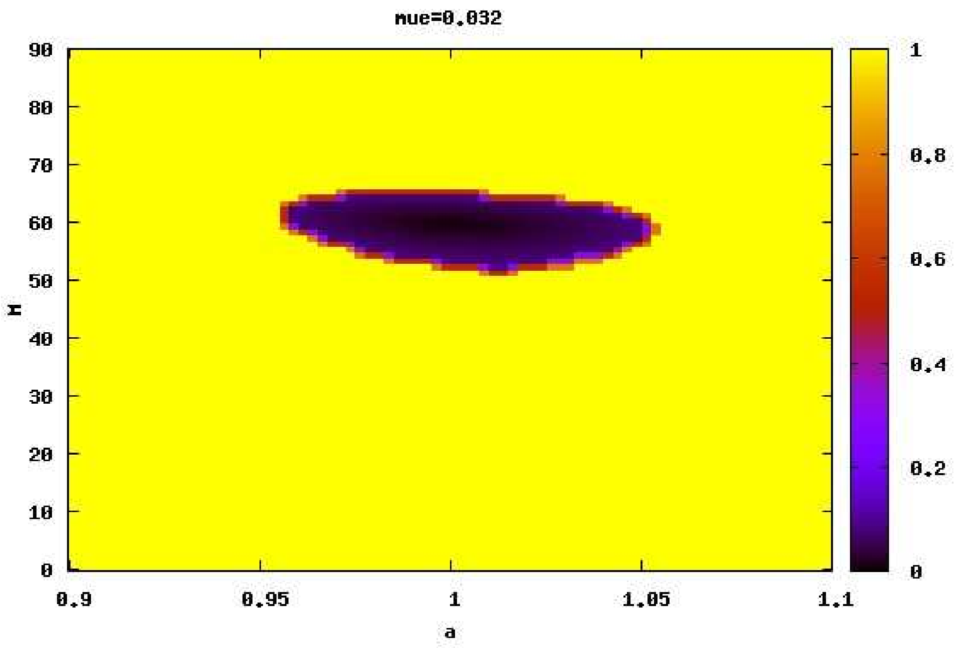
μ=0.031

3D-starting
BC

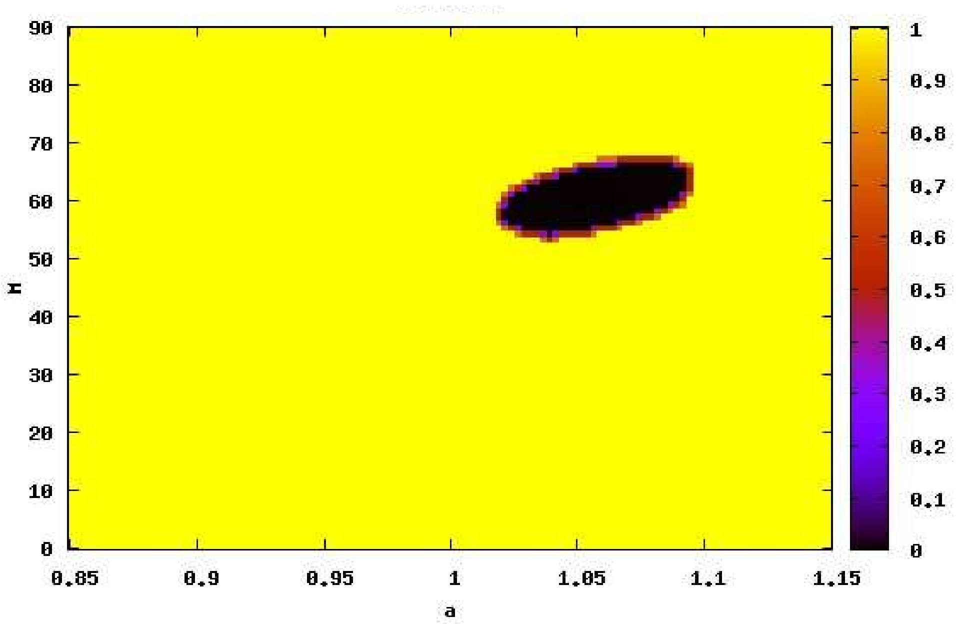


μ=0.032

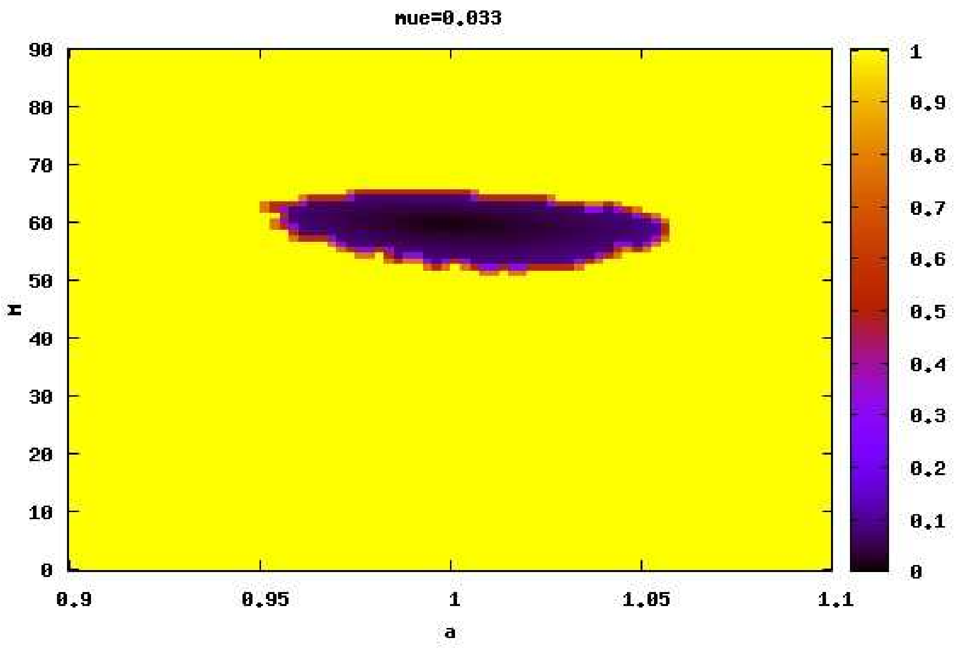
2D-starting in the AC



3D-starting BC

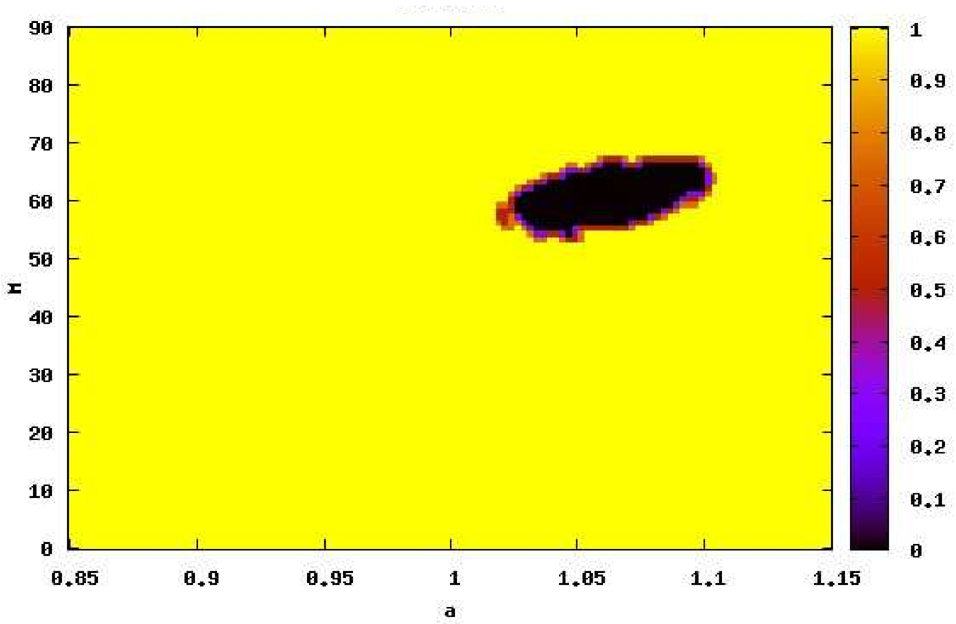


2D-starting
in the AC

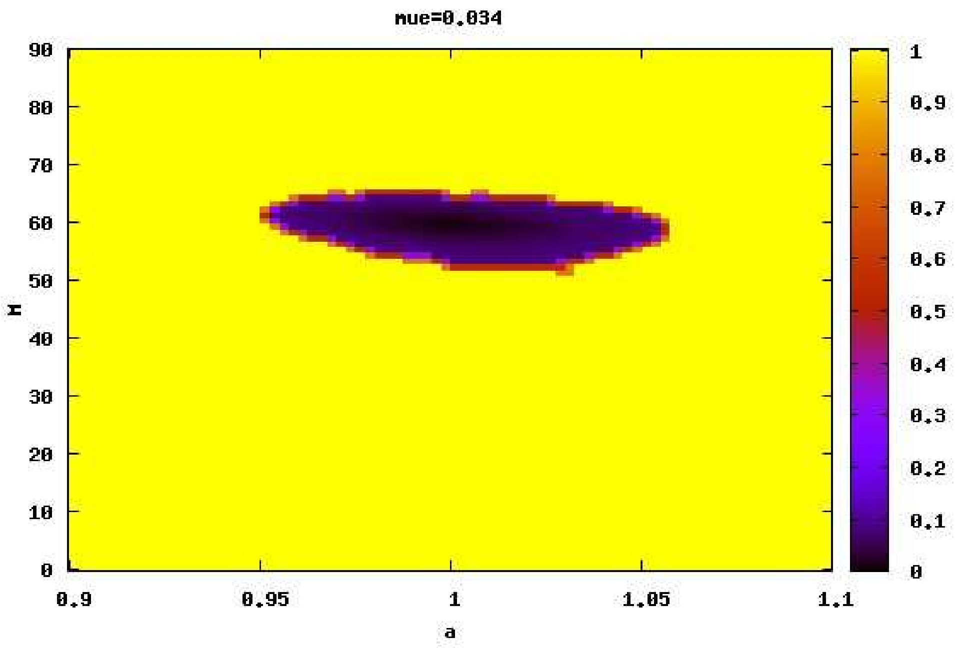


μ=0.033

3D-starting
BC

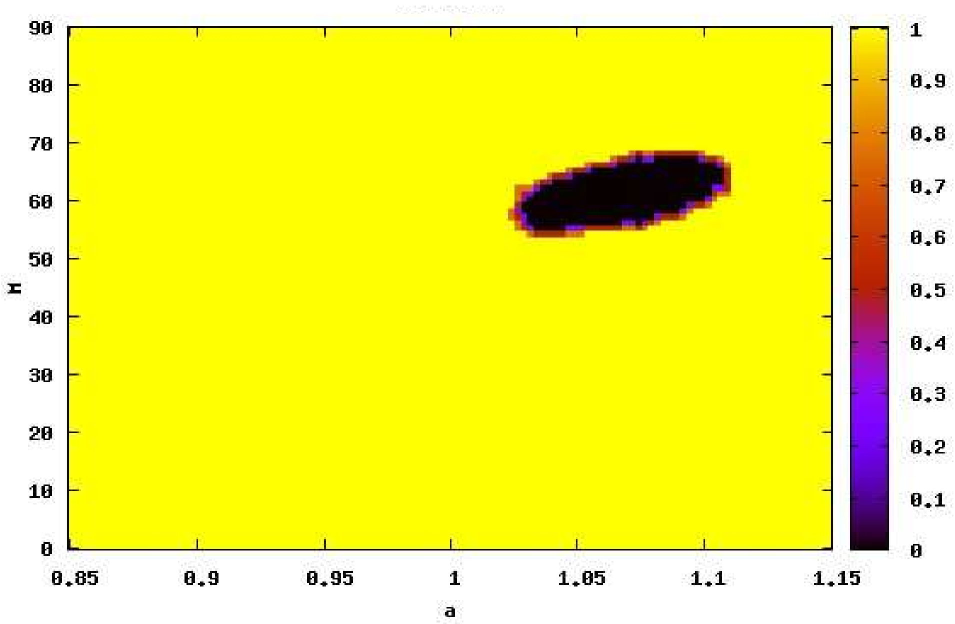


2D-starting
in the AC



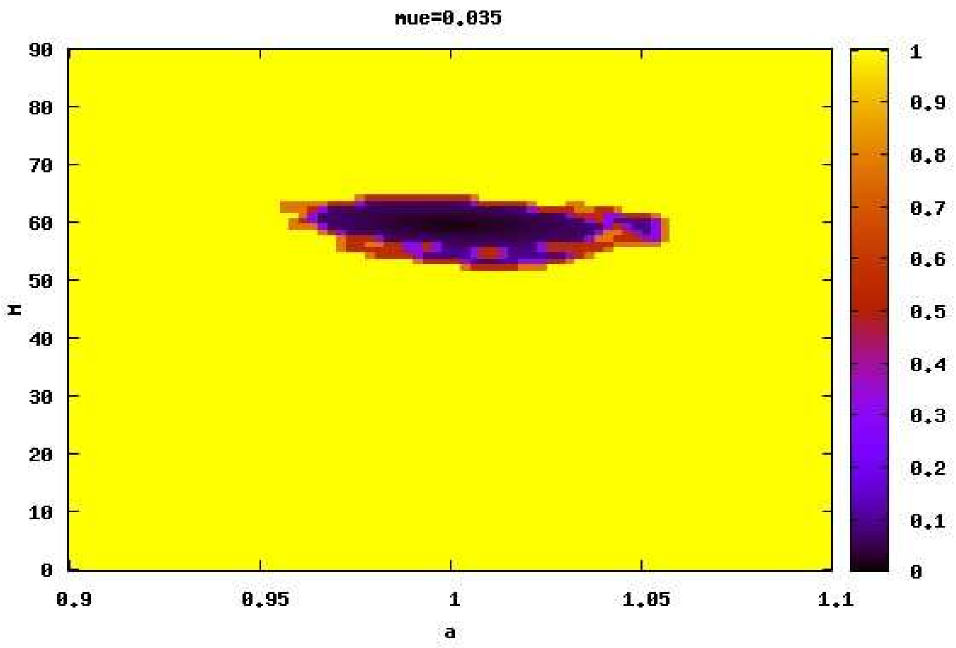
μ=0.034

3D-starting
BC

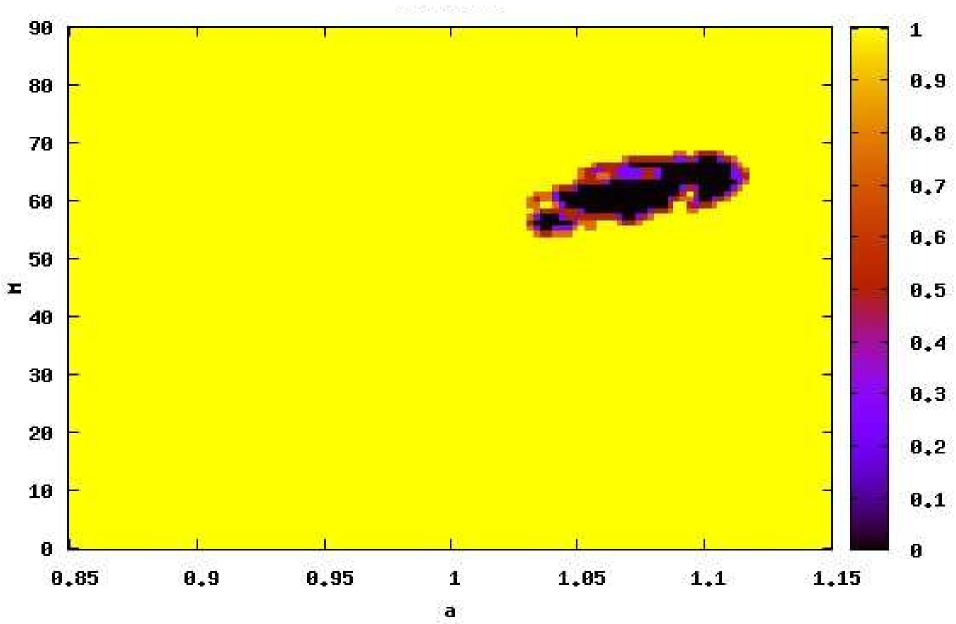


μ=0.035

2D-starting
in the AC

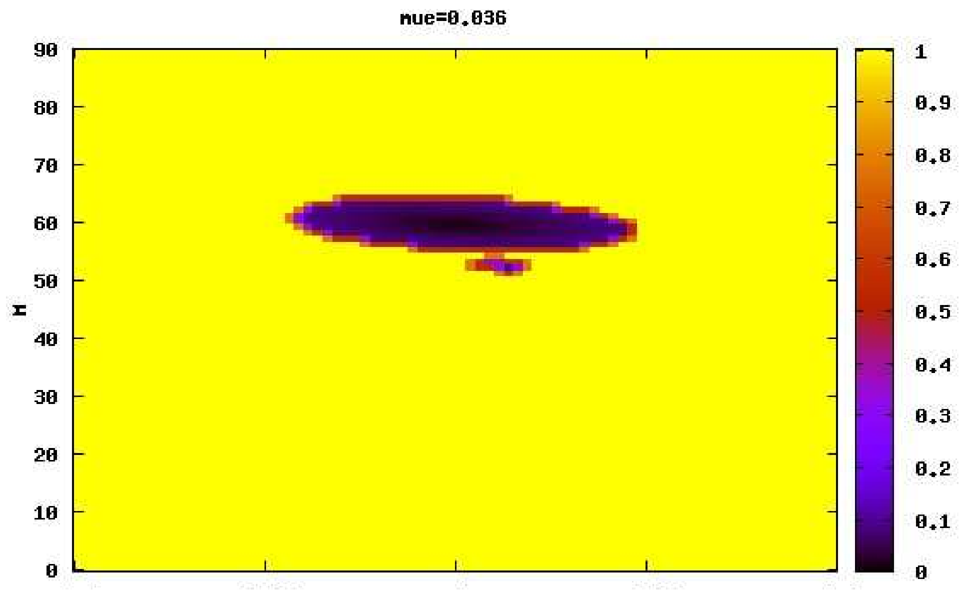


3D-starting
BC

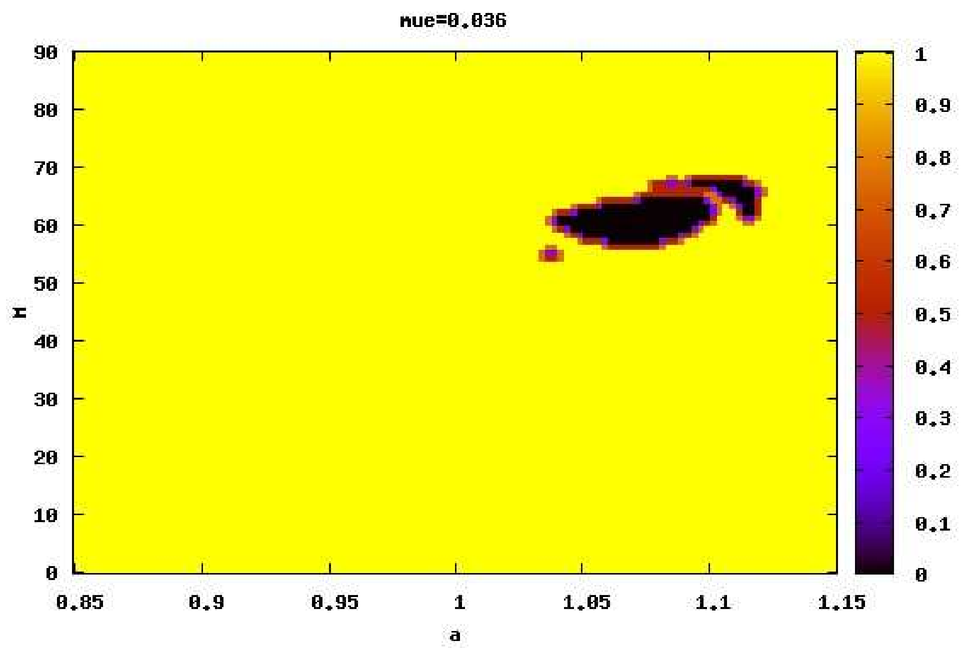


μ=0.036

2D-starting
in the AC

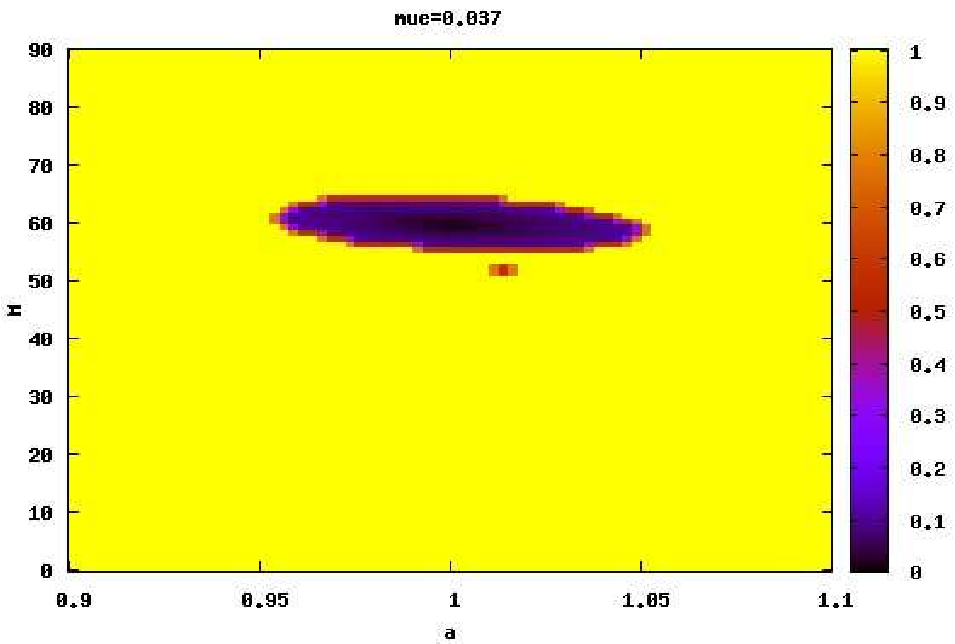


3D-starting
BC

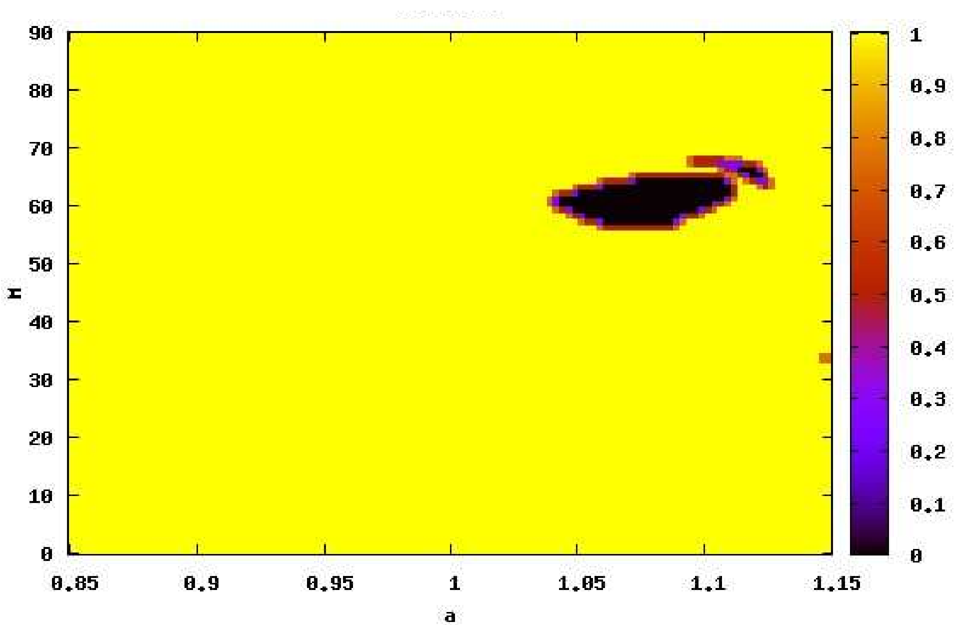


μ=0.037

2D-starting
in the AC

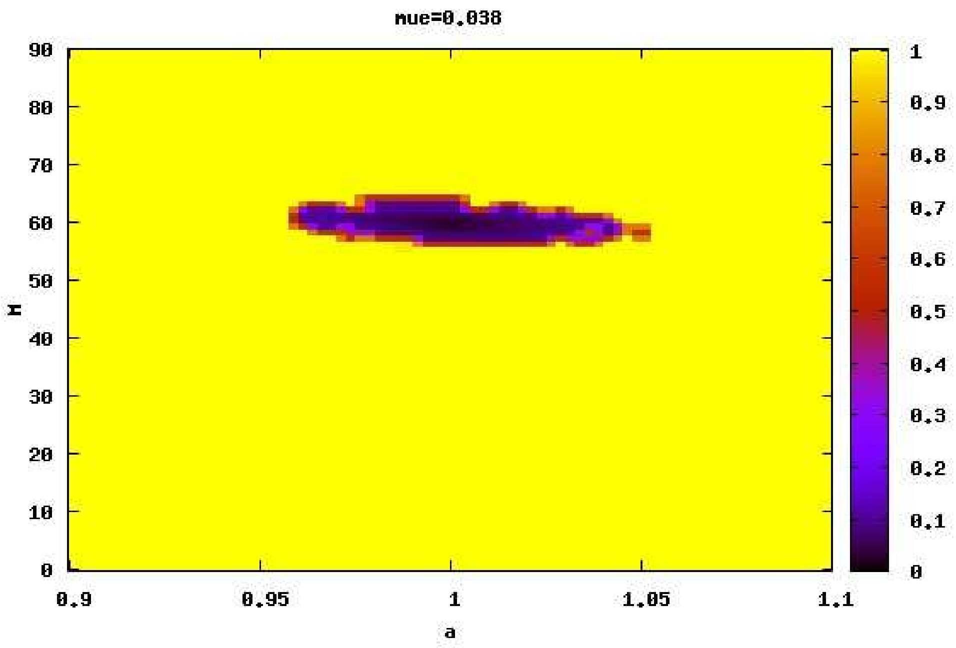


3D-starting
BC

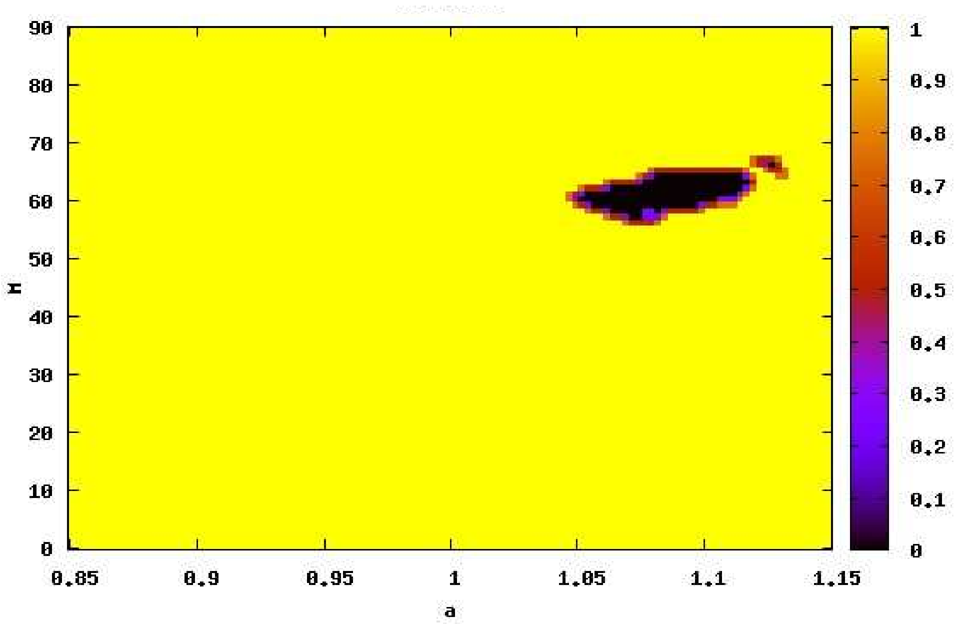


μ=0.038

2D-starting
in the AC

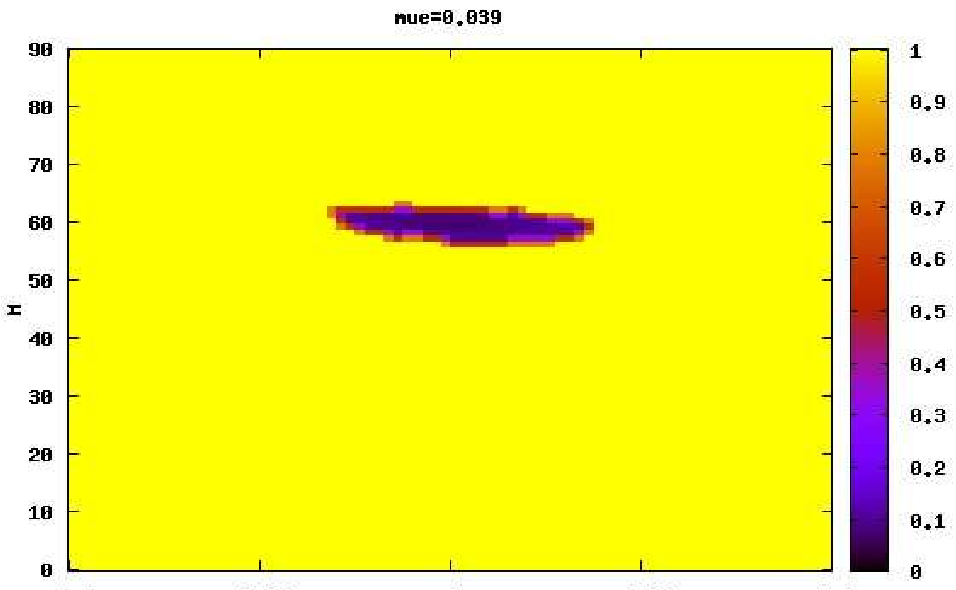


3D-starting
BC

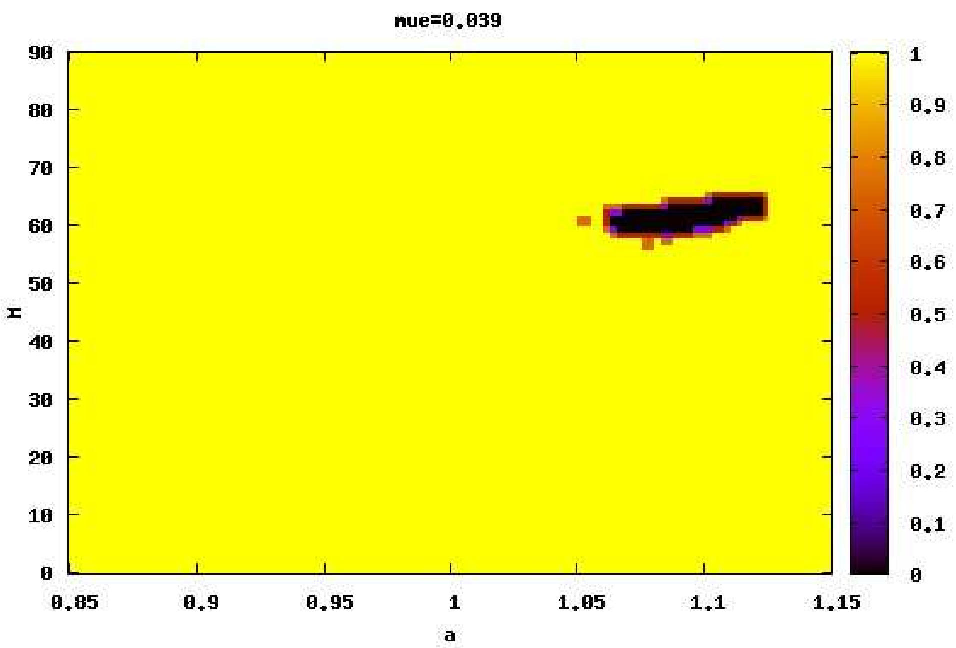


μ=0.039

2D-starting
in the AC

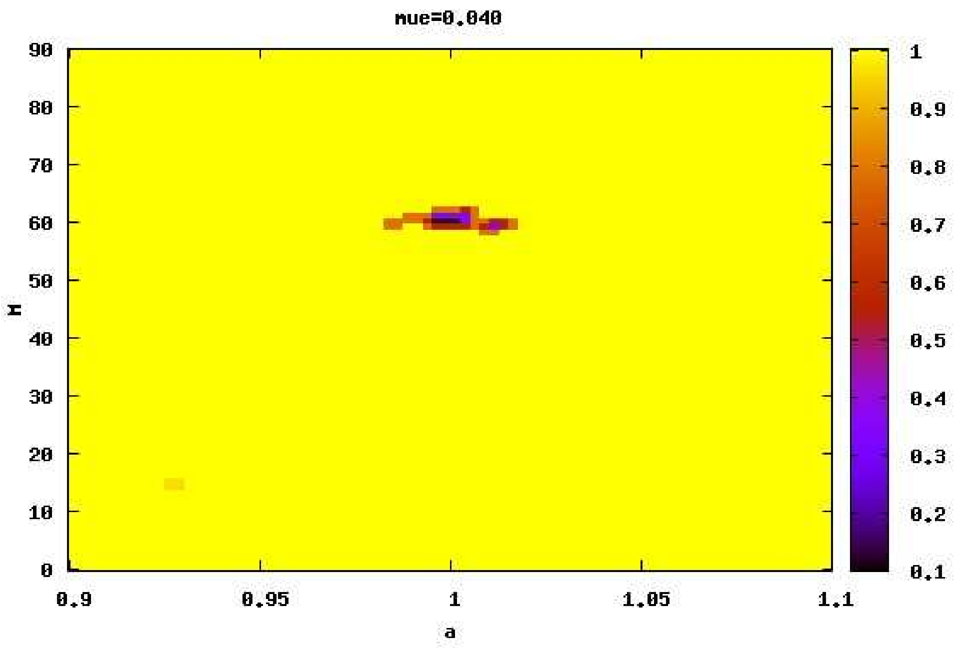


3D-starting
BC

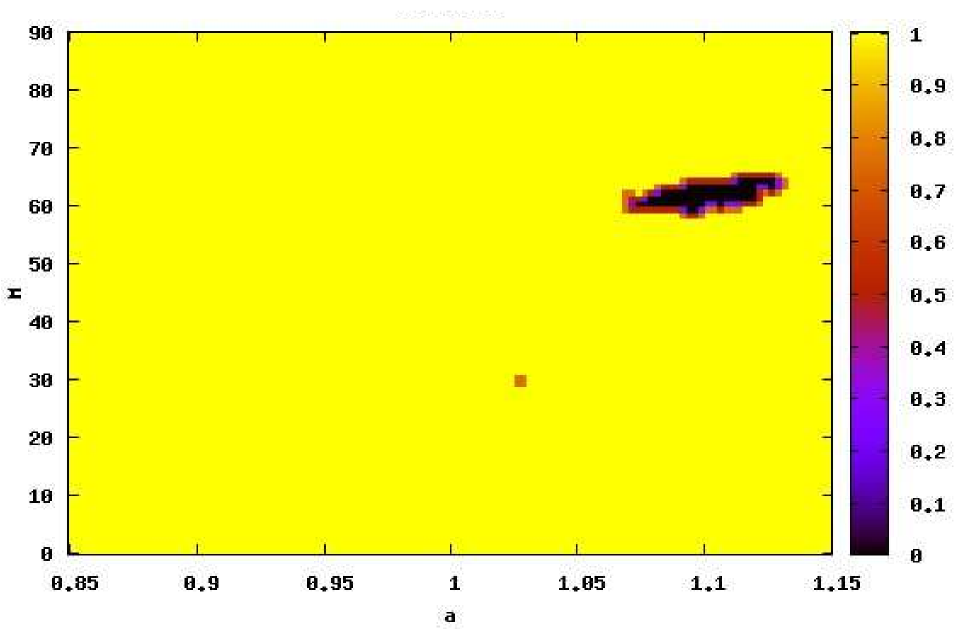


μ=0.040

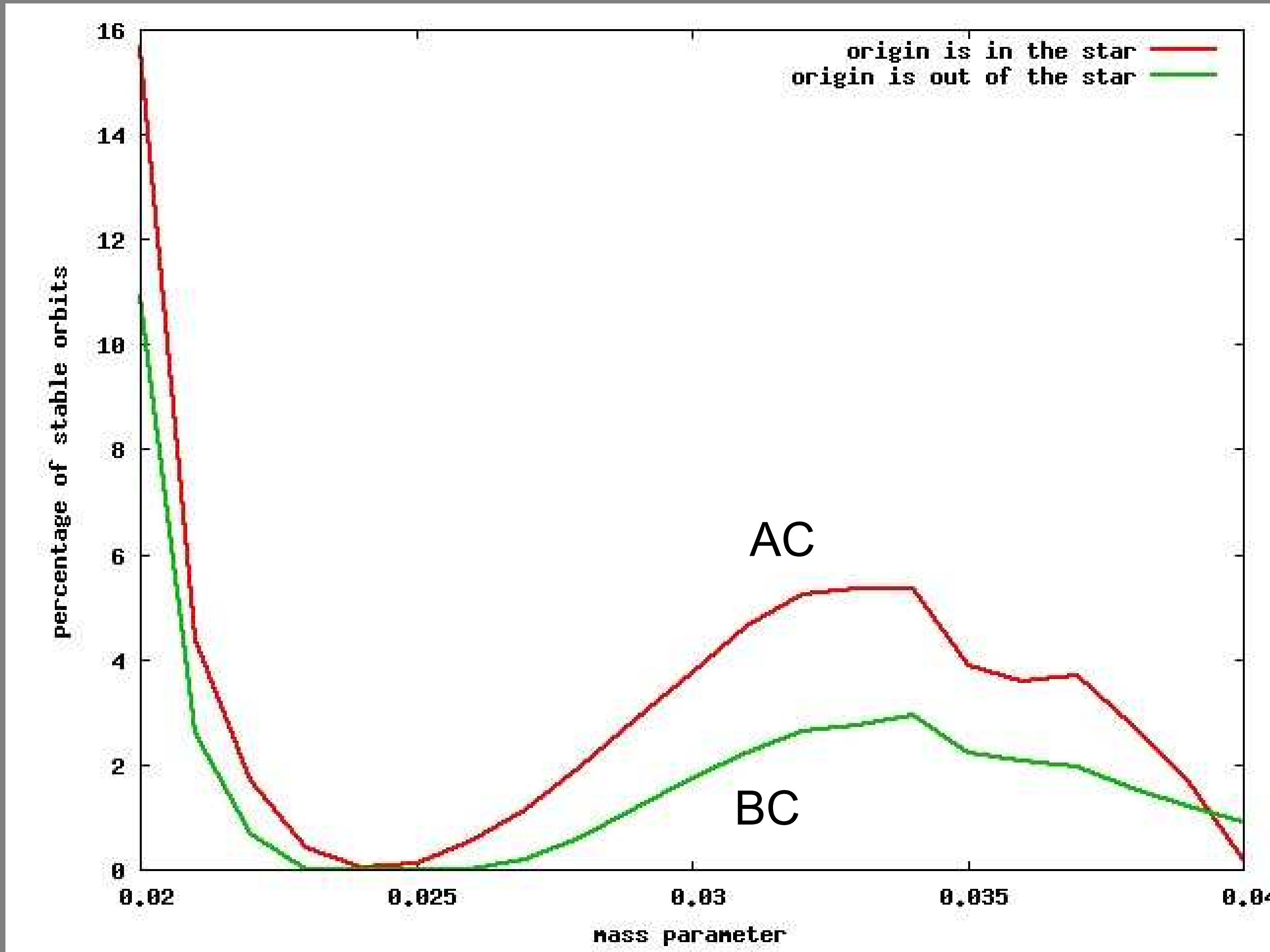
2D-starting
in the AC



3D-starting
BC

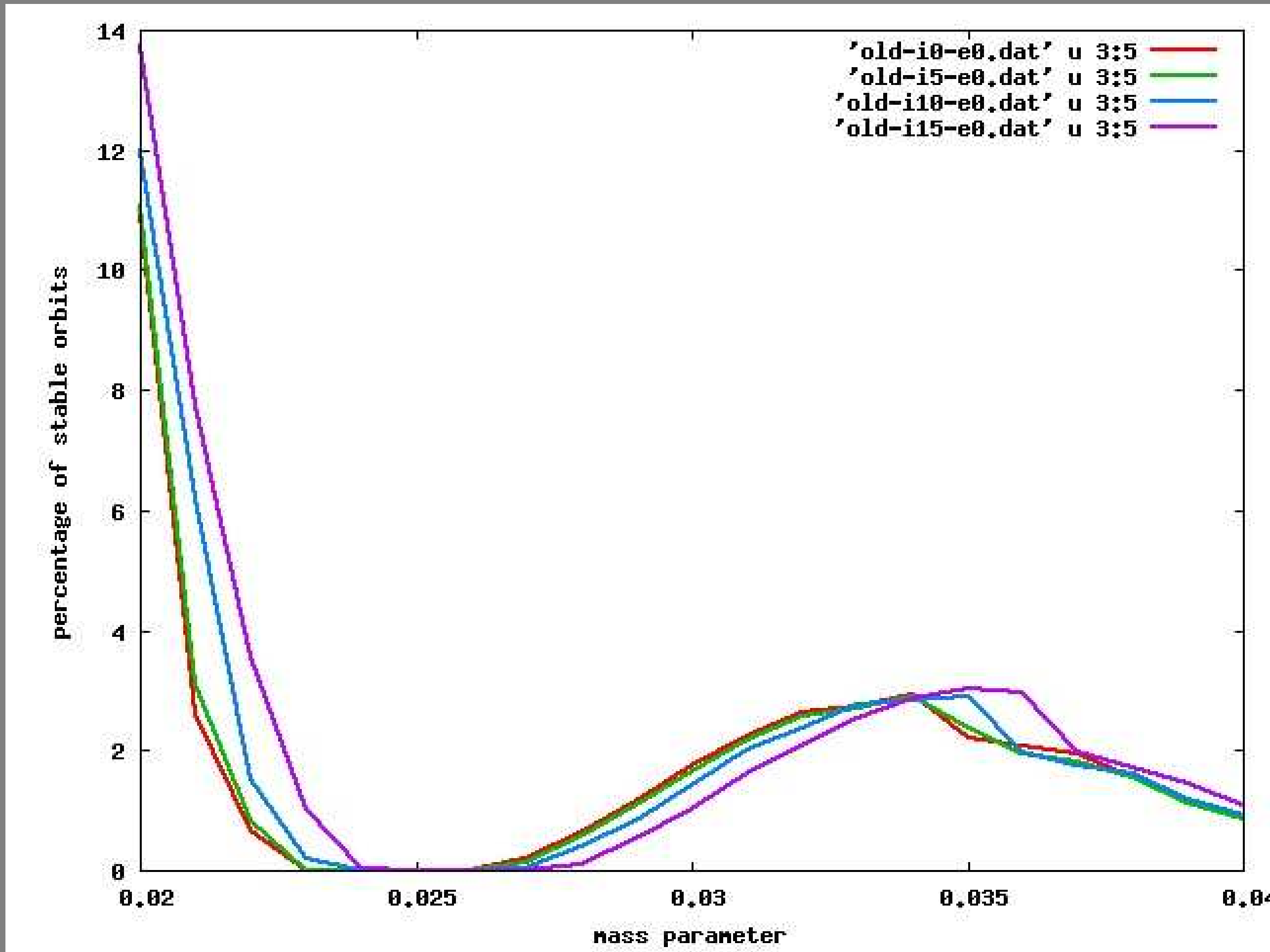


Stable region around L_4 for different mass ratios μ



Integrationtime = 1000 periods

Starting in the Barycenter



Some tests for 1Myrs

Barycentric shift =initial condition problem

1) AC $\vec{r}_2', \dot{\vec{r}}_2'$

2) BC

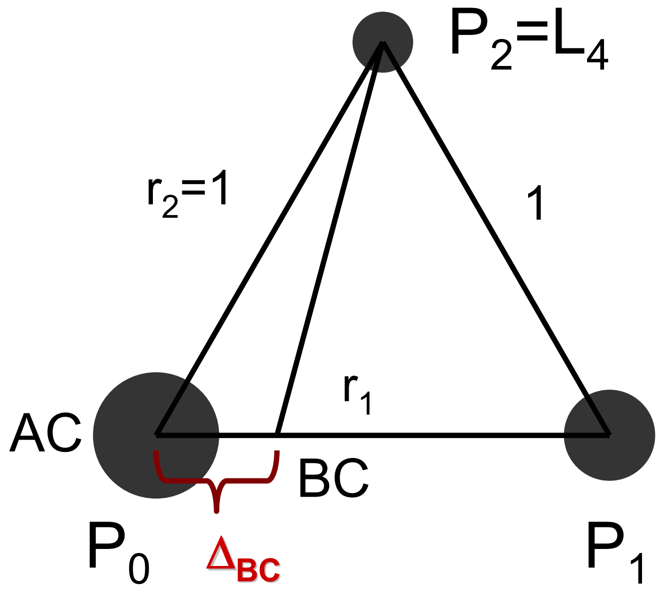
$$\vec{r}_2 = m_1 \cdot \vec{r}_1 + r_2'$$

$$\dot{\vec{r}}_2 = m_1 \cdot \dot{\vec{r}}_1 + \dot{r}_2'$$

$$\dot{x}_2 = m_1 \cdot \dot{x}_1 + \dot{x}'_2$$

$$\dot{y}_2 = m_1 \cdot \dot{y}_1 + \dot{y}_2'$$

$$\dot{z}_2 = 0$$



Barycentric shift

1) **AC** $\vec{r}_2', \dot{\vec{r}}_2'$

2) **BC**

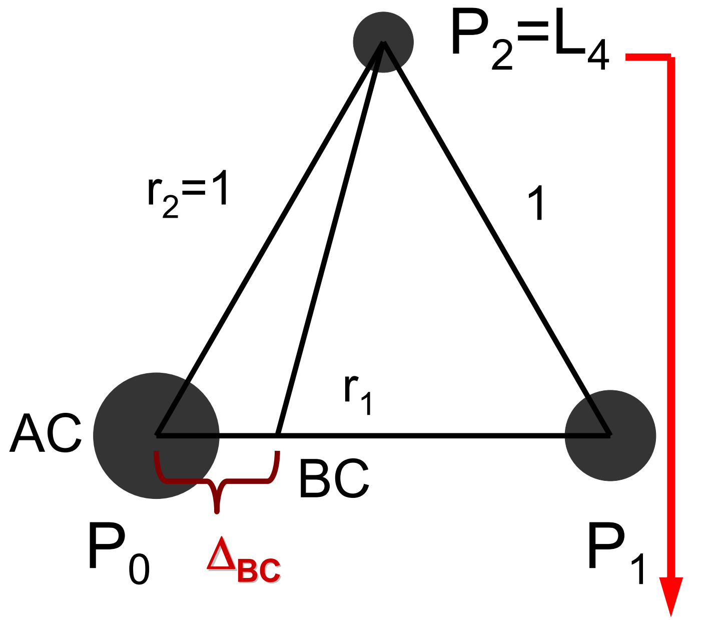
$$\vec{r}_2 = m_1 \cdot \vec{r}_1 + r_2'$$

$$\dot{\vec{r}}_2 = m_1 \cdot \dot{\vec{r}}_1 + \dot{r}_2'$$

$$\dot{x}_2 = m_1 \cdot \dot{x}_1 + \dot{x}'_2$$

$$\dot{y}_2 = m_1 \cdot \dot{y}_1 + \dot{y}_2'$$

$$\dot{z}_2 = 0$$



BC $x = \frac{1}{2} - r_1, y = \pm\frac{\sqrt{3}}{2}$

AC $r_1 = 1$

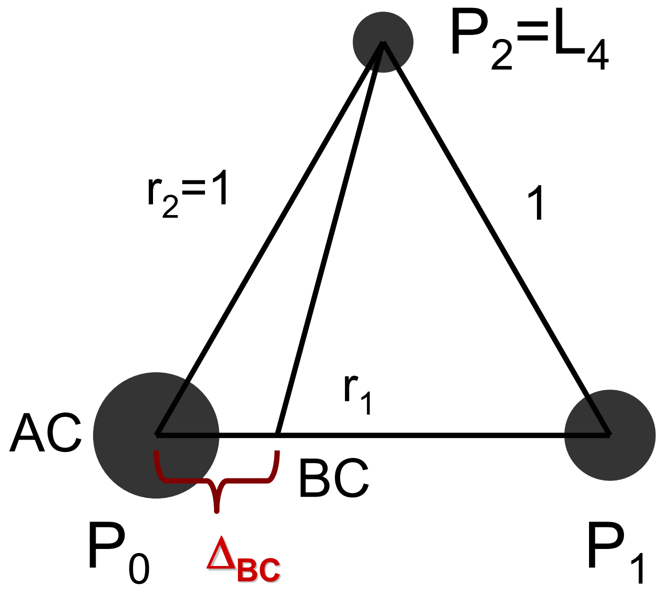
Barycentric shift

1) **AC** $\vec{r}_2', \dot{\vec{r}}_2'$

2) **BC**

$$\vec{r}_2 = m_1 \cdot \vec{r}_1 + r_2'$$

$$\dot{\vec{r}}_2 = m_1 \cdot \dot{\vec{r}}_1 + \dot{r}_2'$$



Example:Jupitermass

$$\dot{x}_2 = m_1 \cdot \dot{x}_1 + \dot{x}'_2 = 0.001 \cdot 0 + (-0.866025)$$

$$\dot{y}_2 = m_1 \cdot \dot{y}_1 + \dot{y}_2' = 0.001 \cdot 1 + 0.5 = 0.501$$

$$\dot{z}_2 = 0$$

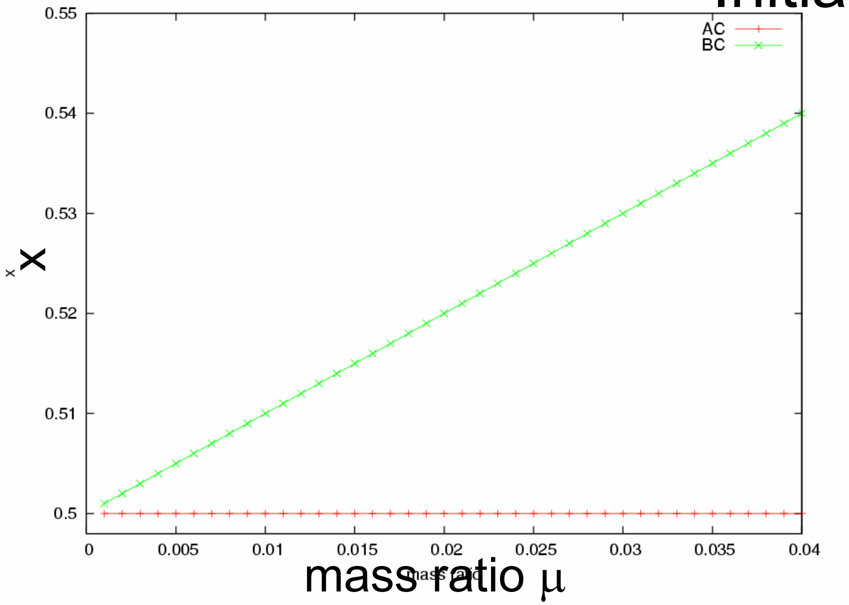
BC $x = \frac{1}{2} - r_1, y = \pm \frac{\sqrt{3}}{2}$

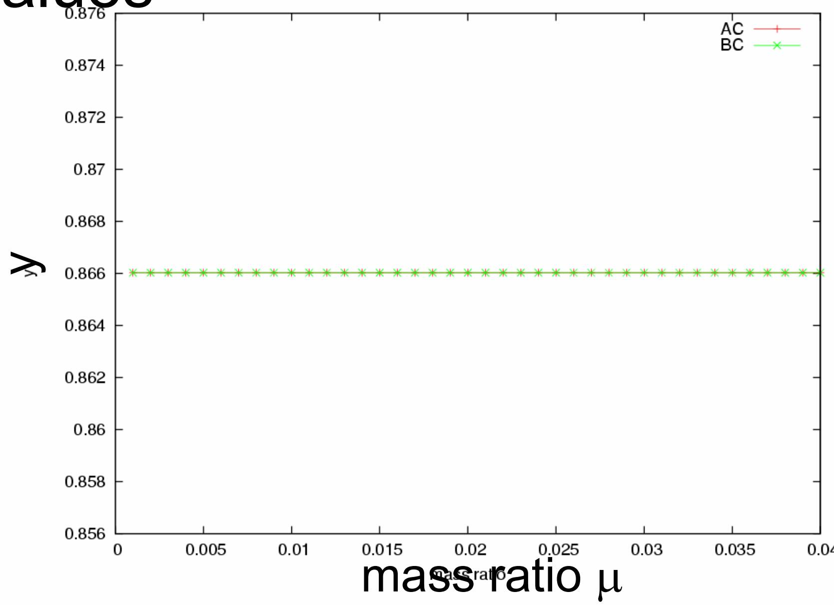
AC $r_1 = 1$

Initial values

The values changes with the mass!

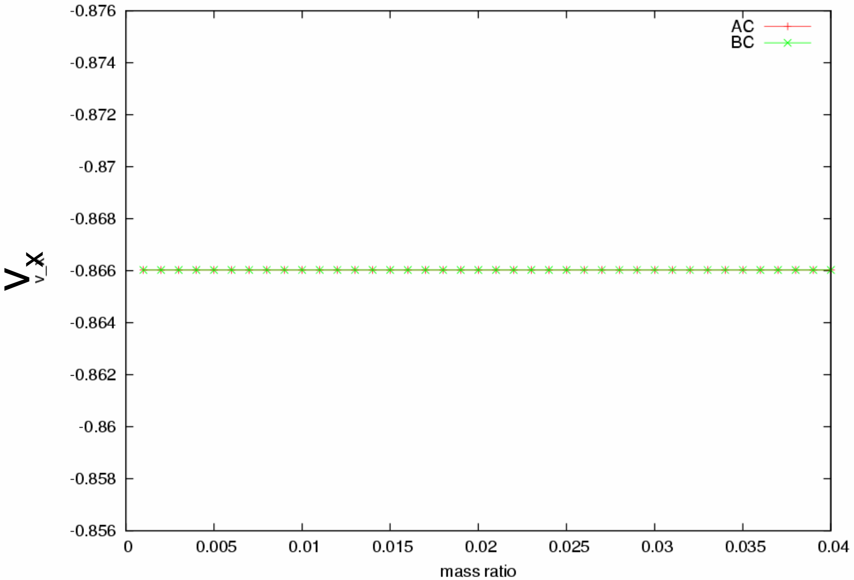
Initial values

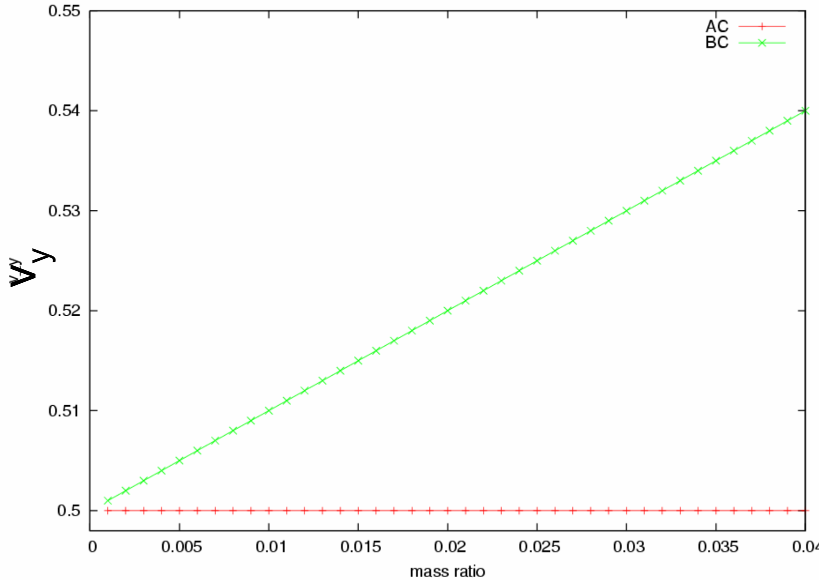




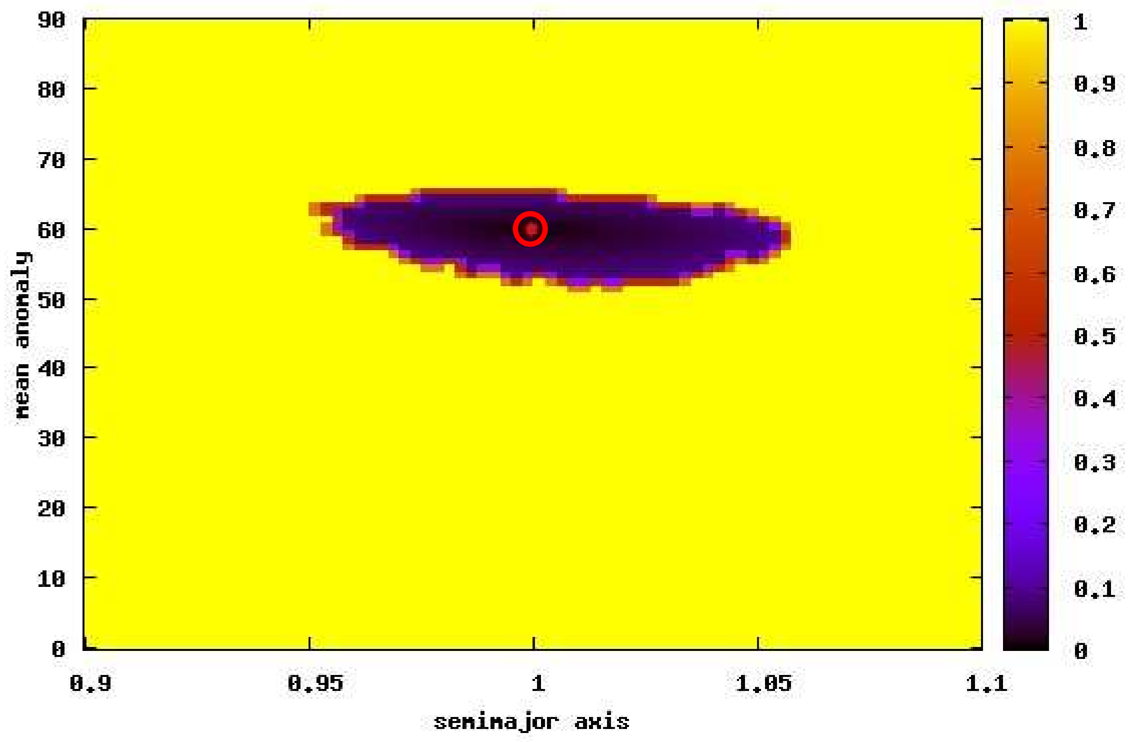
The values changes with the mass!

velocity



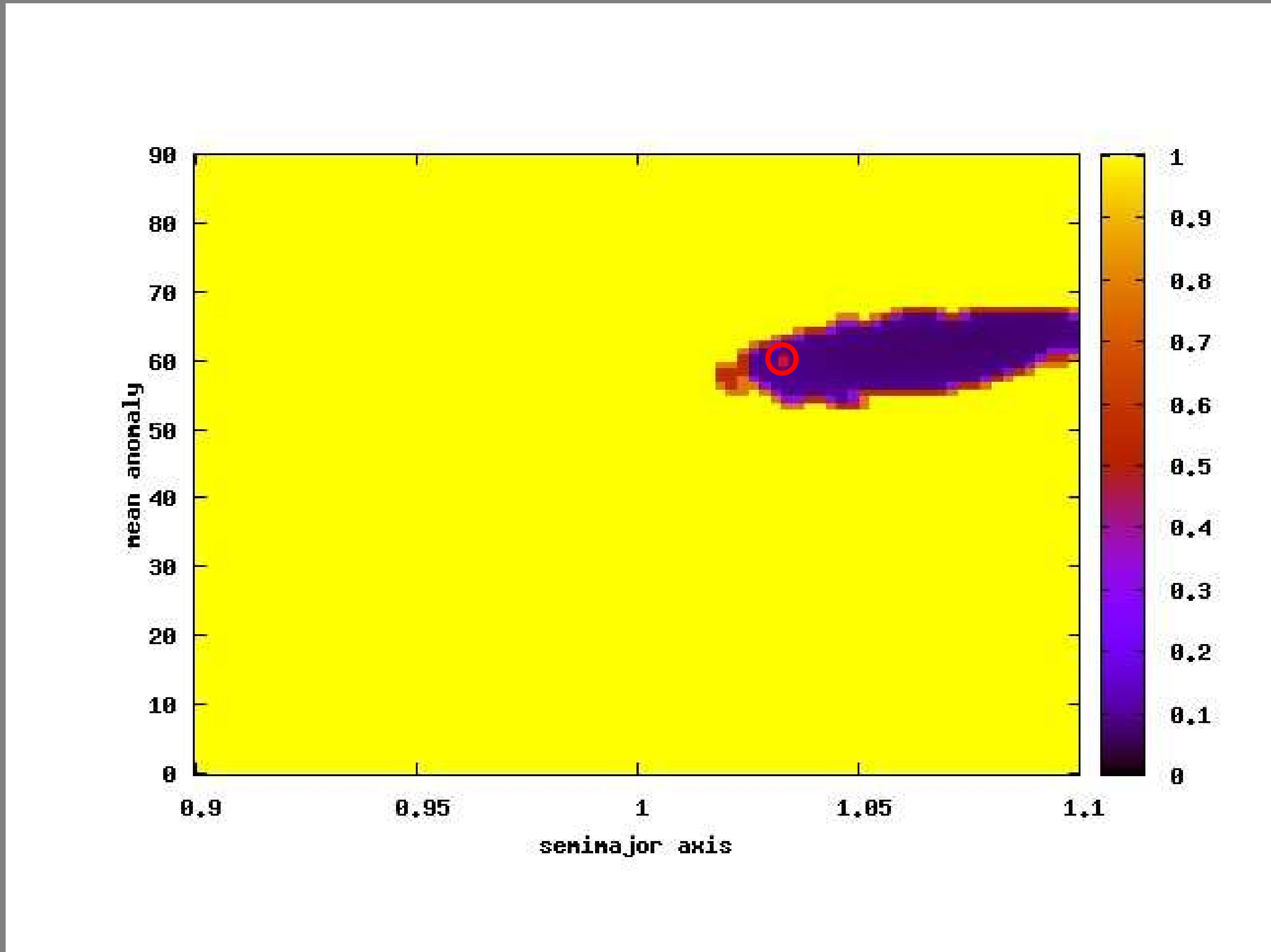


Lagrange point L_4 (AC)



Mass ratio μ=0.033

Possible Lagrange point L_4 (BC)



Mass ratio μ=0.033

Conclusions

.) Barycentric shift is an initial condition problem

.) The investigations showed that the initial conditions for AC and BC have large variations, for large mass ratios μ

.) The differences are expressed at :x and v_y

.) The difference grow with the mass ratio.

.)The stable regions shifted out (BC) and the stability limit at 0.04 also shifted out

Thank you for your attantion!

Menelaus. Paris. Diomedes. Odisseus. Nestor. Achilles. Agamemnon.