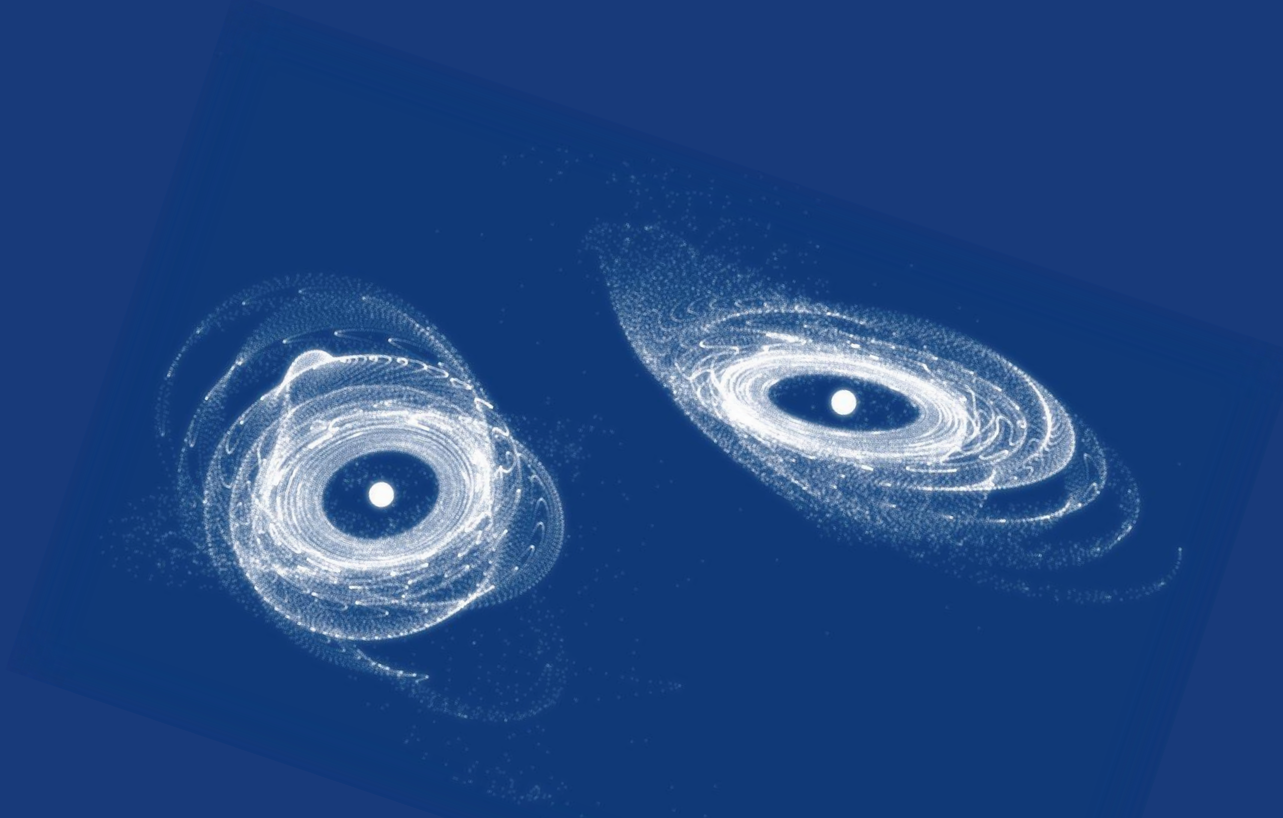
Haus der Astronomie



Eine einfache Computersimulation kollidierender Galaxien

Michael Thiel
Manuel Brea-Carreras
Dr. Markus Pössel
MPIA-Campus Heidelberg

Galaxienentstehung und -entwicklung

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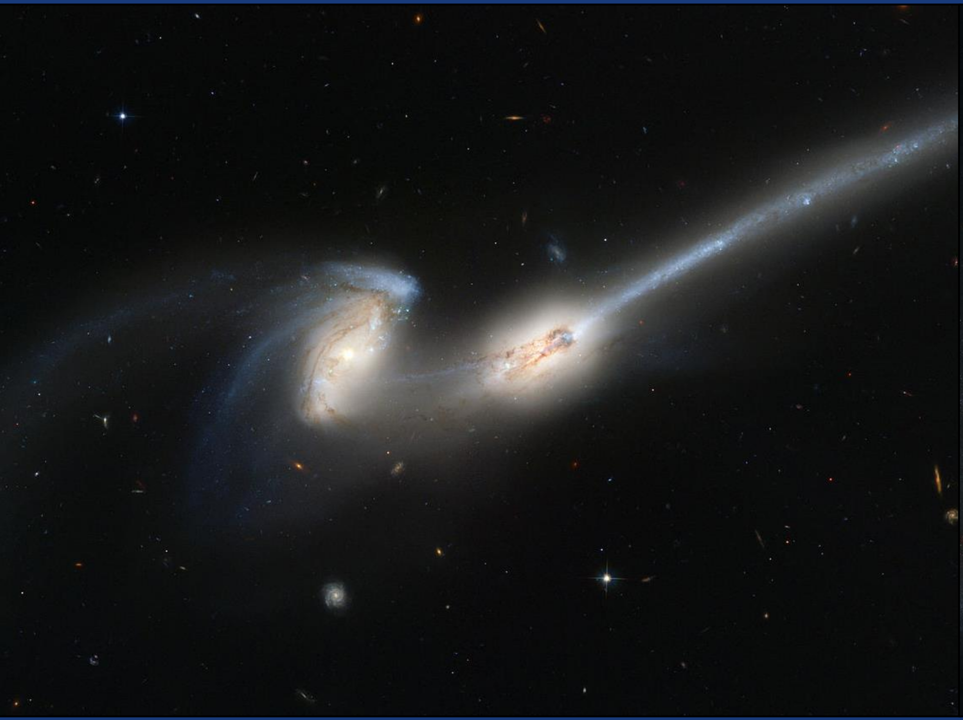
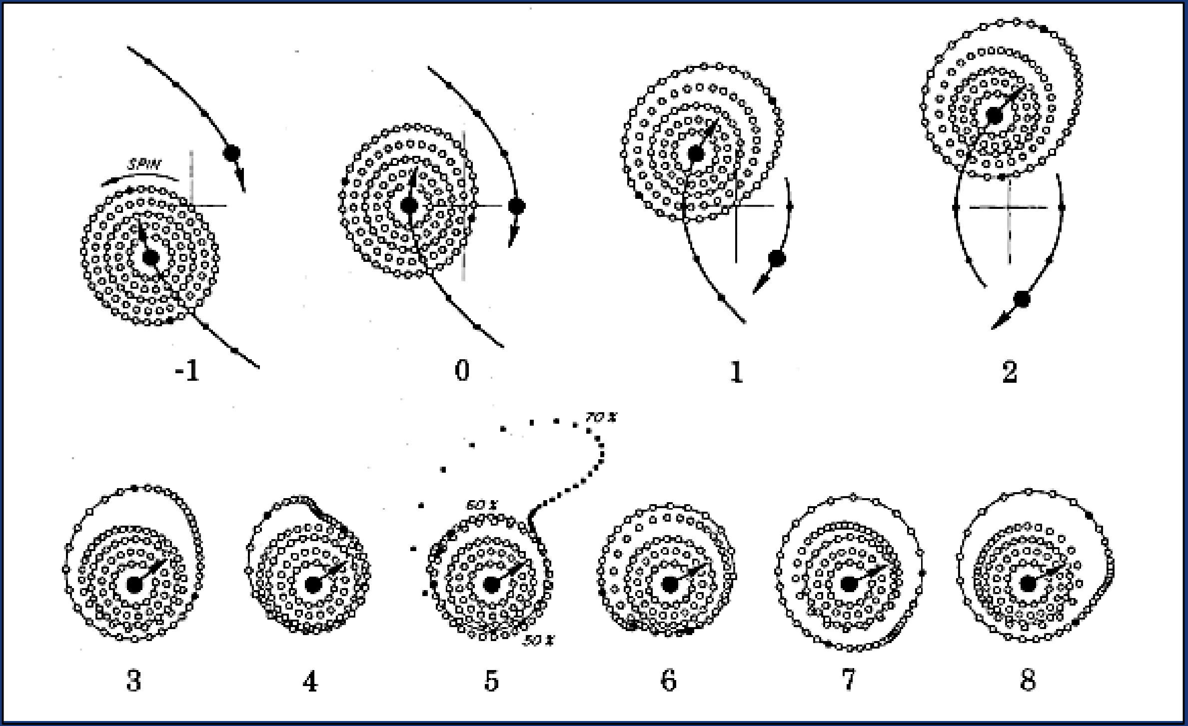
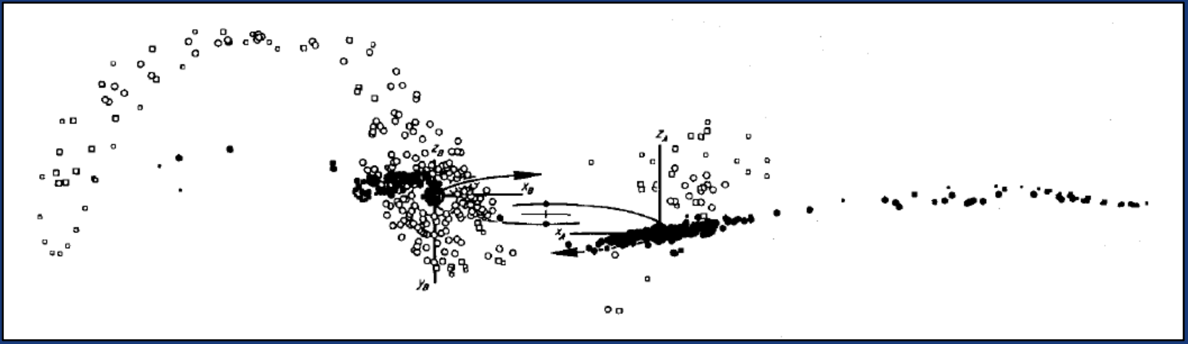


Toomre & Toomre (1972): Galactic Bridges and Tails

Astrophysical Journal, 178:623-666





Aufbau der Simulation

Aufbau der Galaxie

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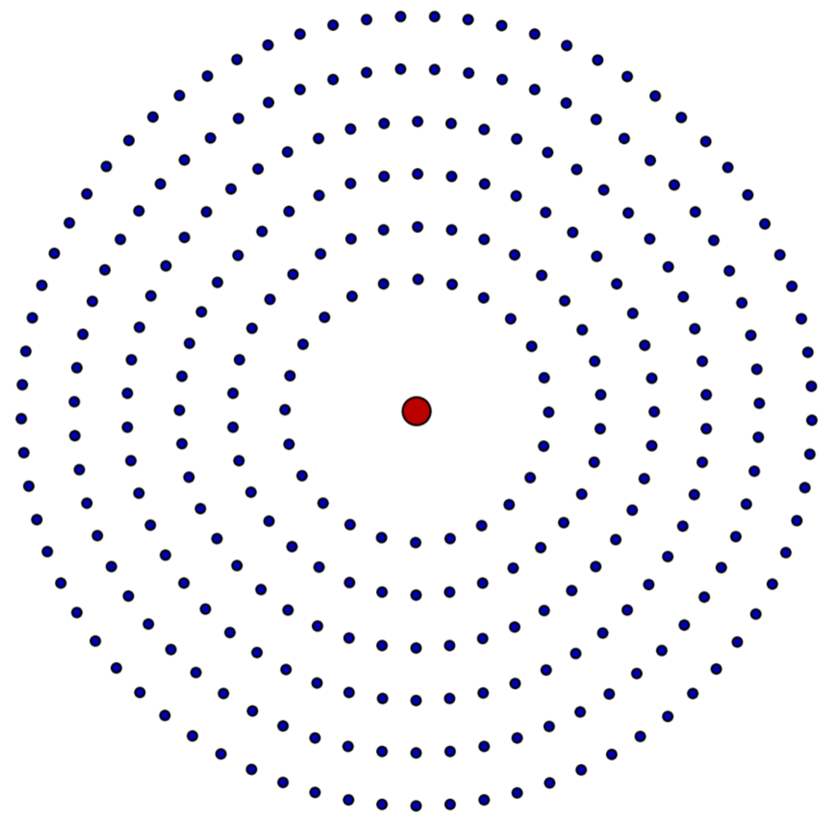
Galaxie

- Zentrum
  - Position
    x, y, z
  - Geschwindigkeit
    x, y, z
  - Masse
    m
- Testpartikel
  - Position
    x, y, z
  - Geschwindigkeit
    x, y, z



Ablauf der Simulation

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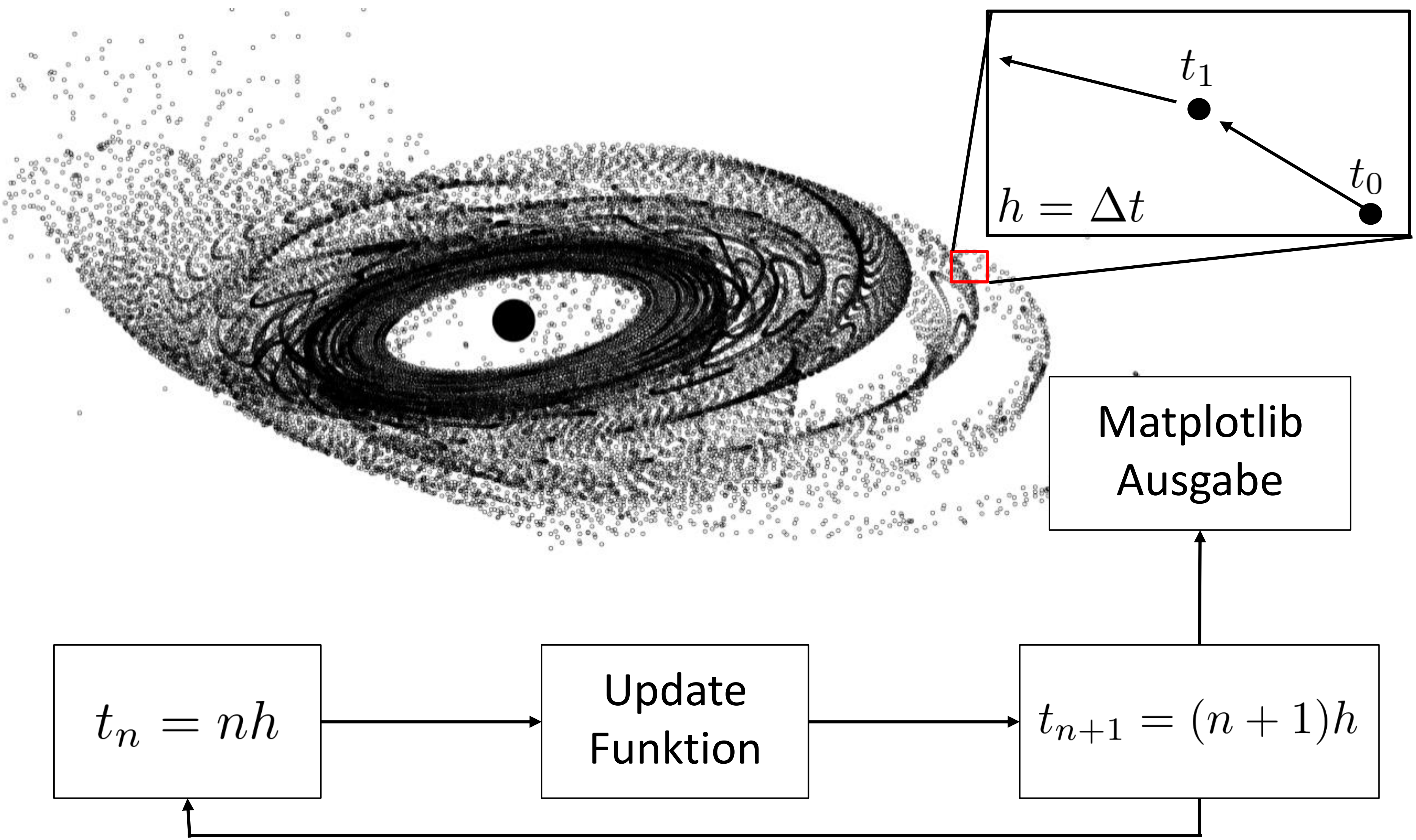


Update Funktion

Zweikörperproblem: Analytische Lösung

Dreikörperproblem (Allgemeiner Fall): Numerische Lösung

$$F = \frac{GM_1 \cdot M_2}{r^2}$$

$$\ddot{\vec{x}}_j(t) = -G \sum_{i \neq j} m_i \cdot \frac{\vec{x}_j(t) - \vec{x}_i(t)}{|\vec{x}_j(t) - \vec{x}_i(t)|^3}$$

Numerische Lösungsverfahren:

Explizites Euler-Verfahren

Haus der Astronomie

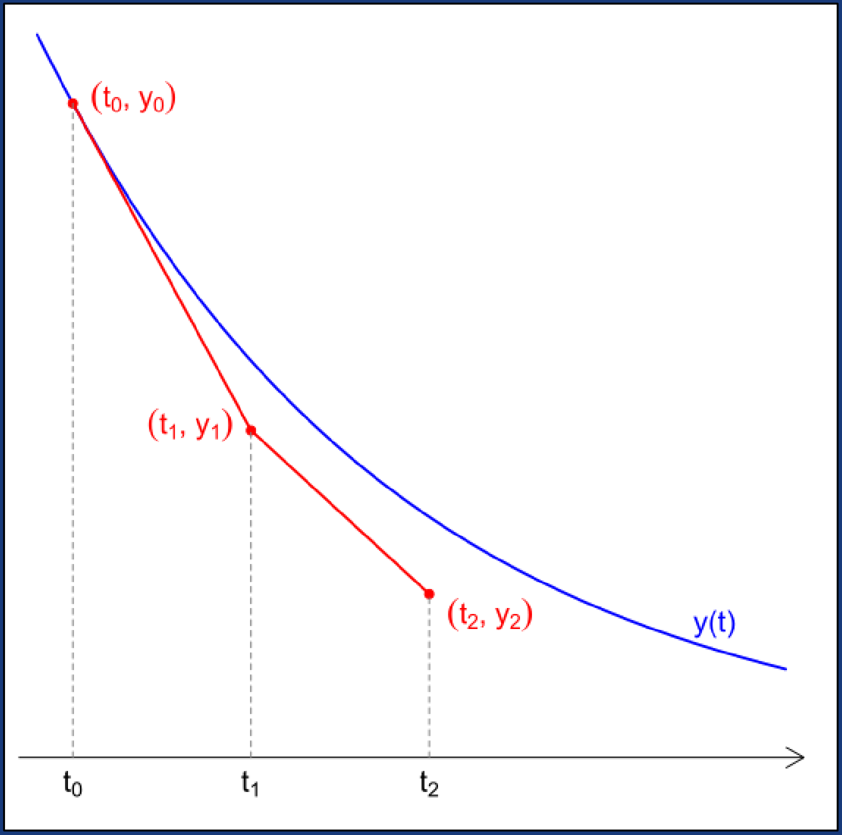
- Velocity update

$$\dot{\vec{x}}_j(t_{n+1}) \quad = \quad \dot{\vec{x}}_j(t_n) + h\ddot{\vec{x}}_j(t_n)$$

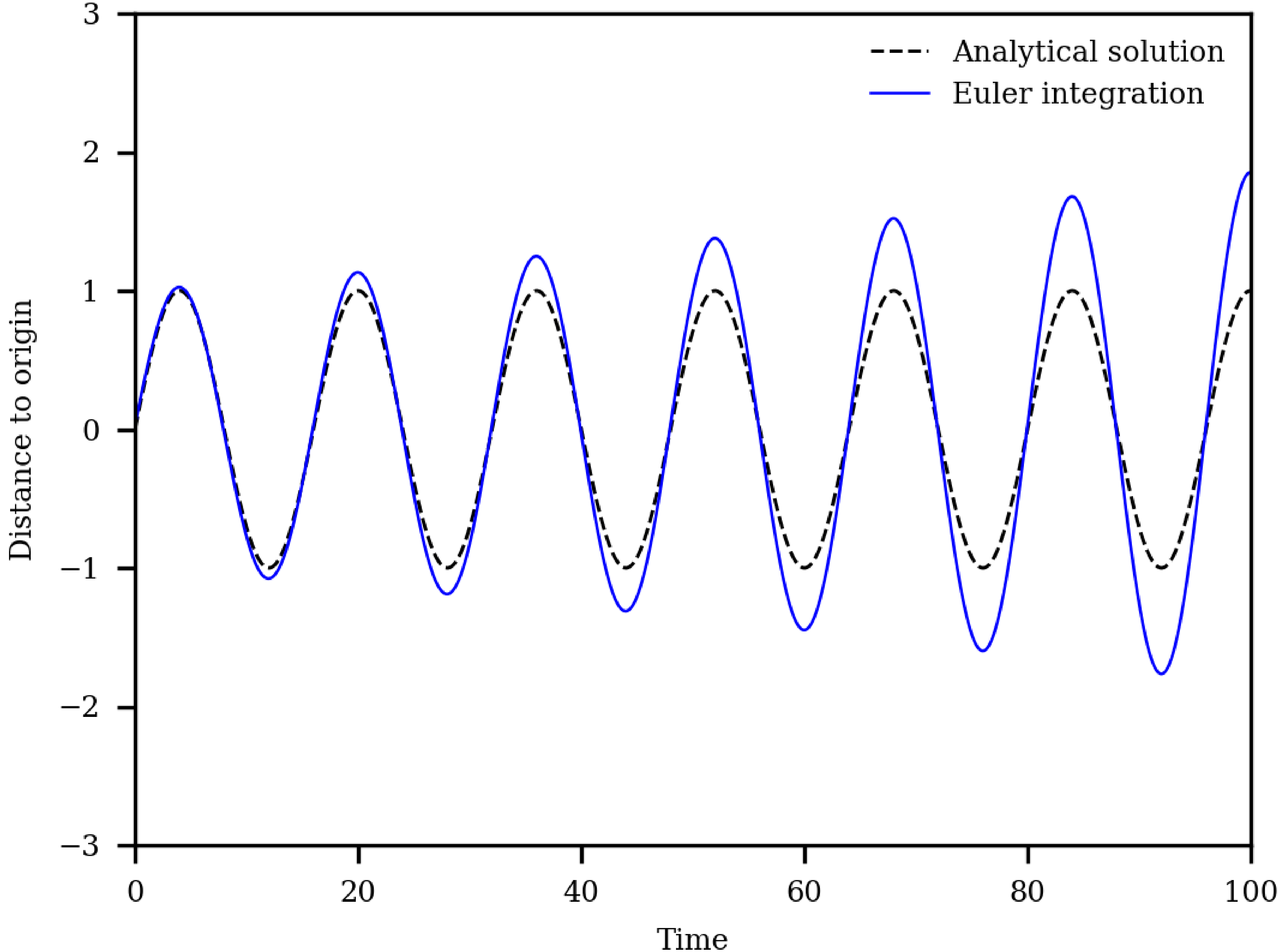
- Position update

$$\vec{x}_j(t_{n+1}) \quad = \quad \vec{x}_j(t_n) + h\dot{\vec{x}}_j(t_n)$$

Für $n = 1, 2, 3...$



1D Bewegung eines harmonischen Oszillators



Numerische Lösungsverfahren:

Velocity Verlet

- Velocity update (Half-Step)

$$\dot{\vec{x}}_j(t_{n+1/2}) = \dot{\vec{x}}_j(t_n) + \frac{h}{2}\ddot{\vec{x}}_j(t_n)$$

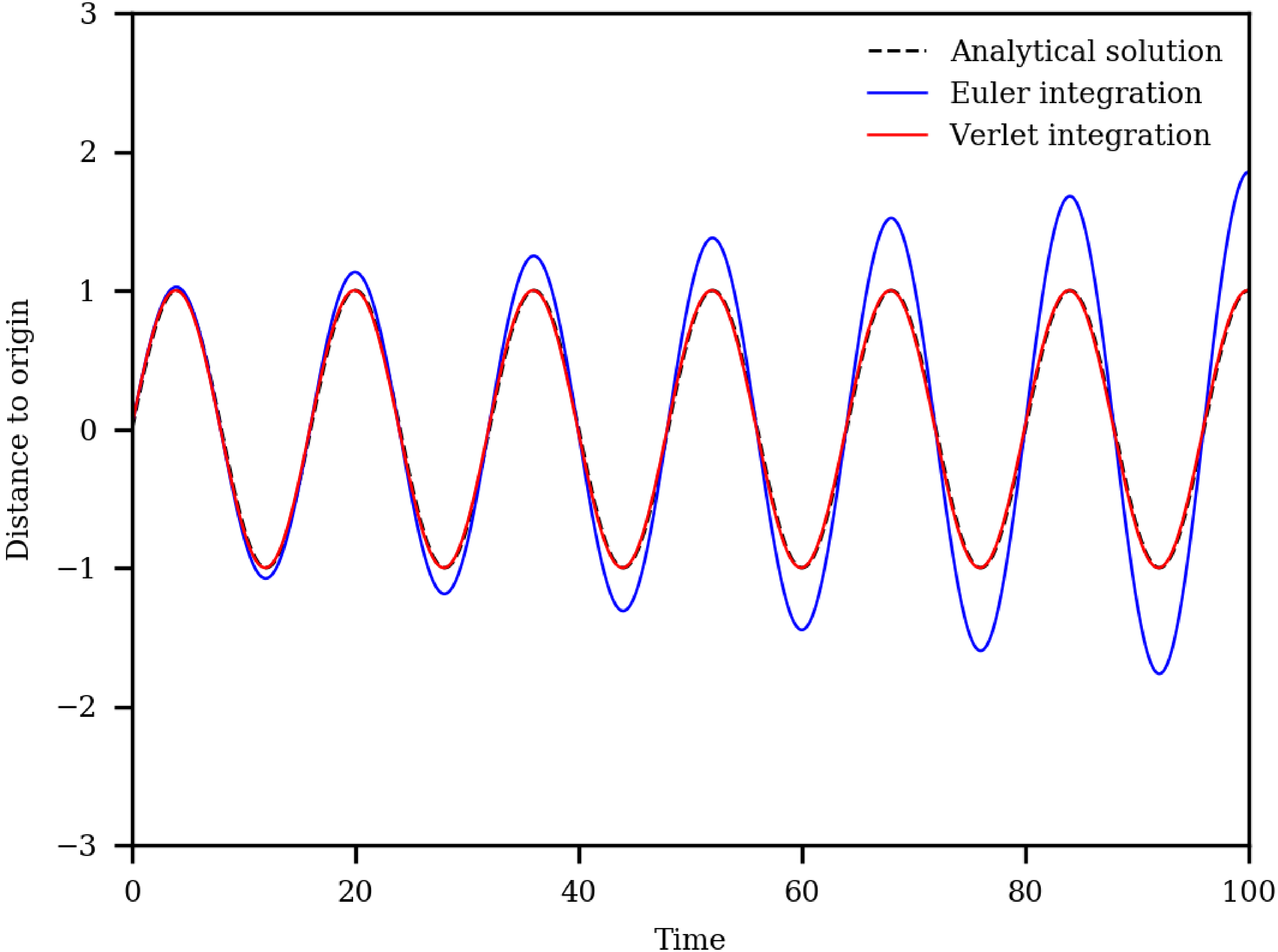
- Position update

$$\vec{x}_j(t_{n+1}) = \vec{x}_j(t_n) + h\dot{\vec{x}}_j(t_{n+\frac{1}{2}})$$

- Velocity update

$$\dot{\vec{x}}_j(t_{n+1}) = \dot{\vec{x}}_j(t_{n+\frac{1}{2}}) + \frac{h}{2}\ddot{\vec{x}}_j(t_{n+1})$$

Aufbau der Simulation



Ergebnisse

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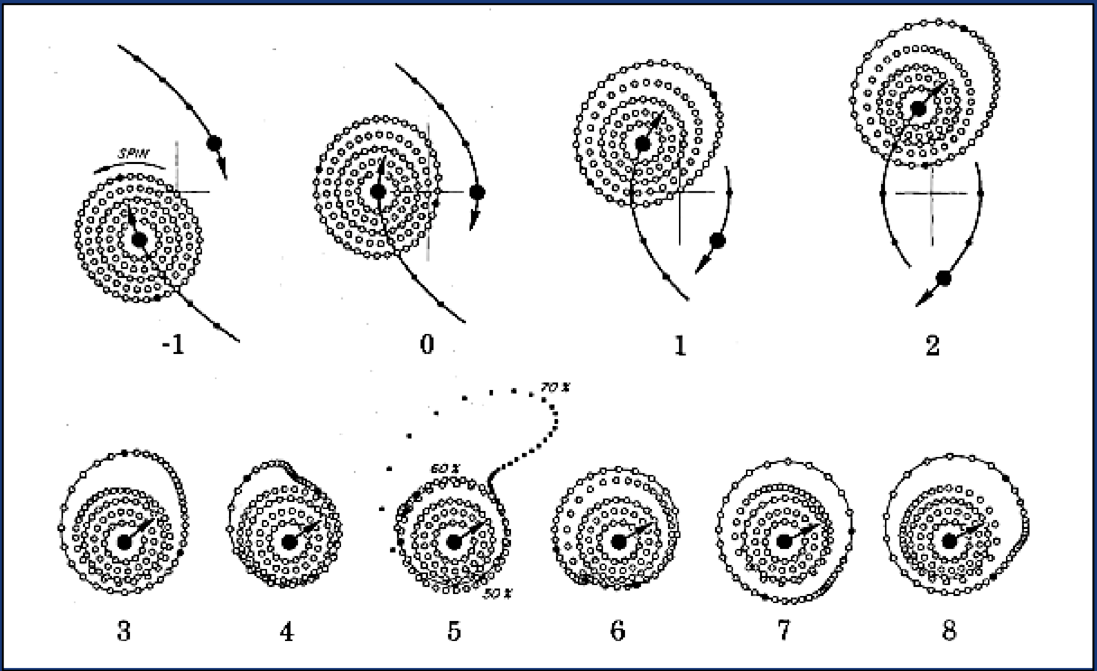
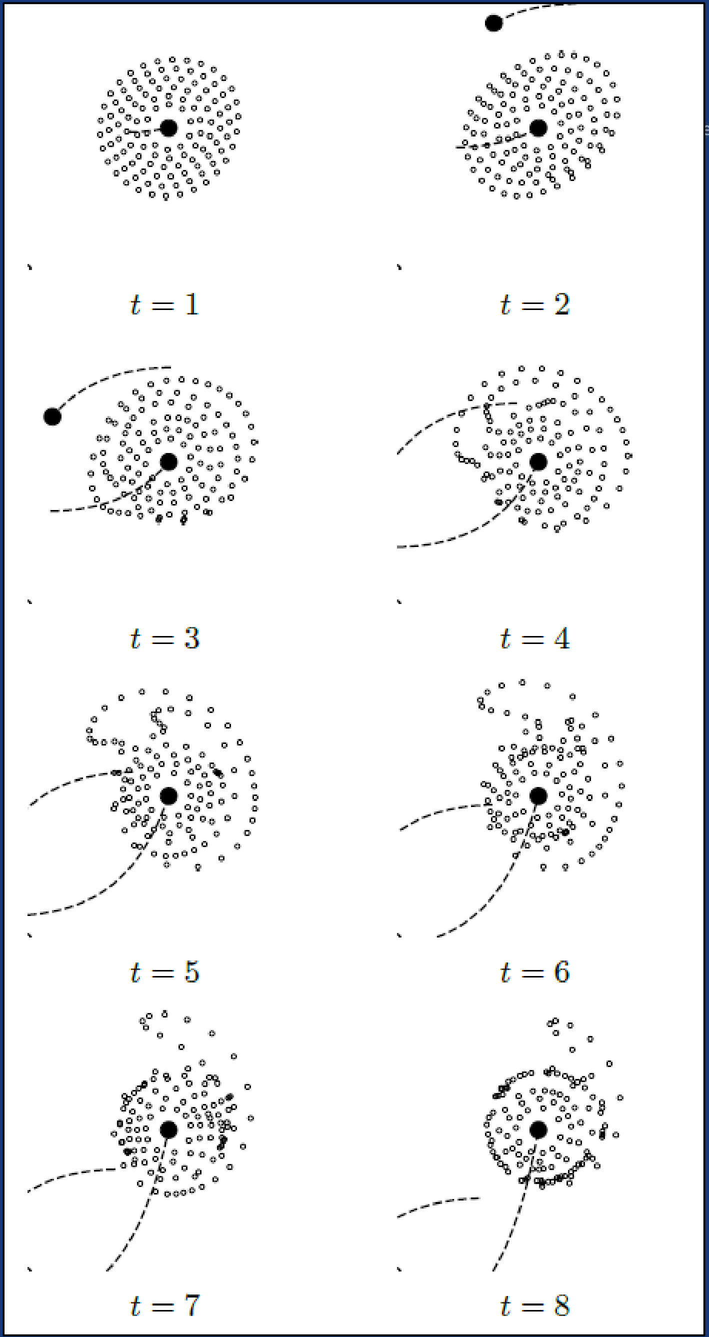
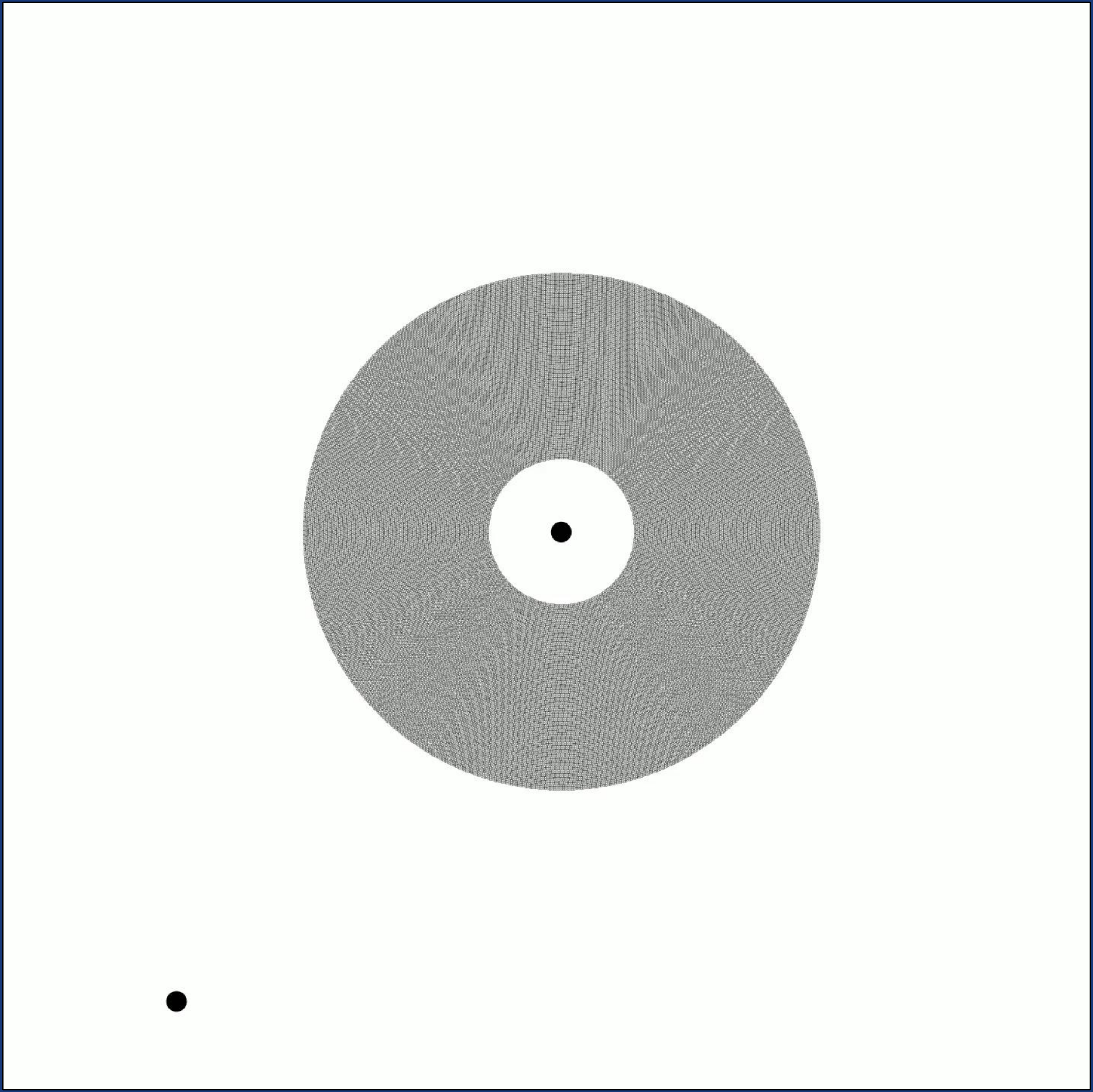
Ergebnisse:
1. Retrograde Begegnung

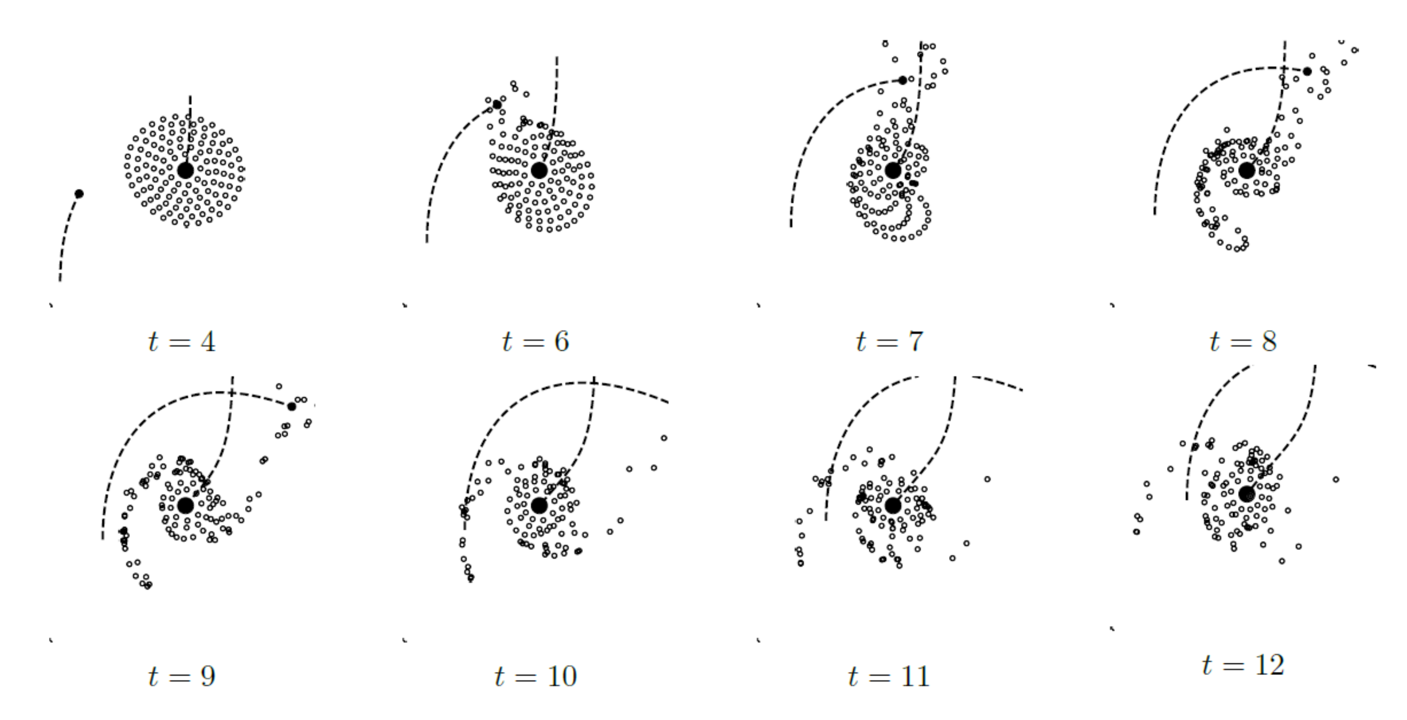


Größe	Toomre & Toomre	Eigene Parameter
$m1, m2\ [M_\odot]$	10^{11}	10^{11}
$R_{min}\ [kpc]$	25	30,46
e	1	1,21
$\Delta t\ [Jahre]$	10^8	10^8

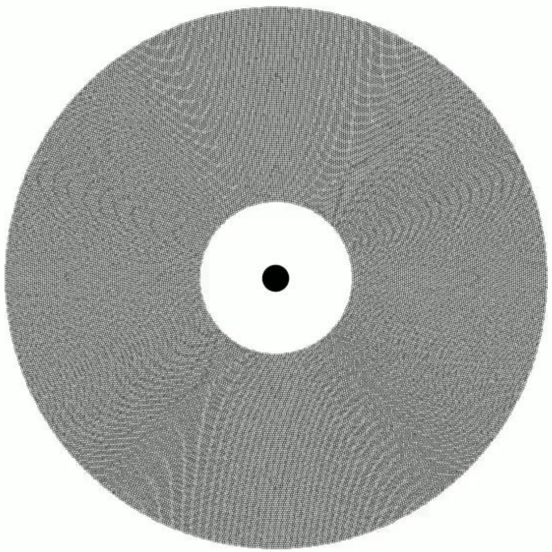




Ergebnisse:
2. Prograde Begegnung



Größe	Toomre & Toomre	Eigene Parameter
$m1, m2\ [M_\odot]$	10^{11} , $0.25 * 10^{11}$	10^{11} , $0.25 * 10^{11}$
$R_{min}\ [kpc]$	25	27,02
e	1	1,04
$\Delta t\ [Jahre]$	10^8	10^8



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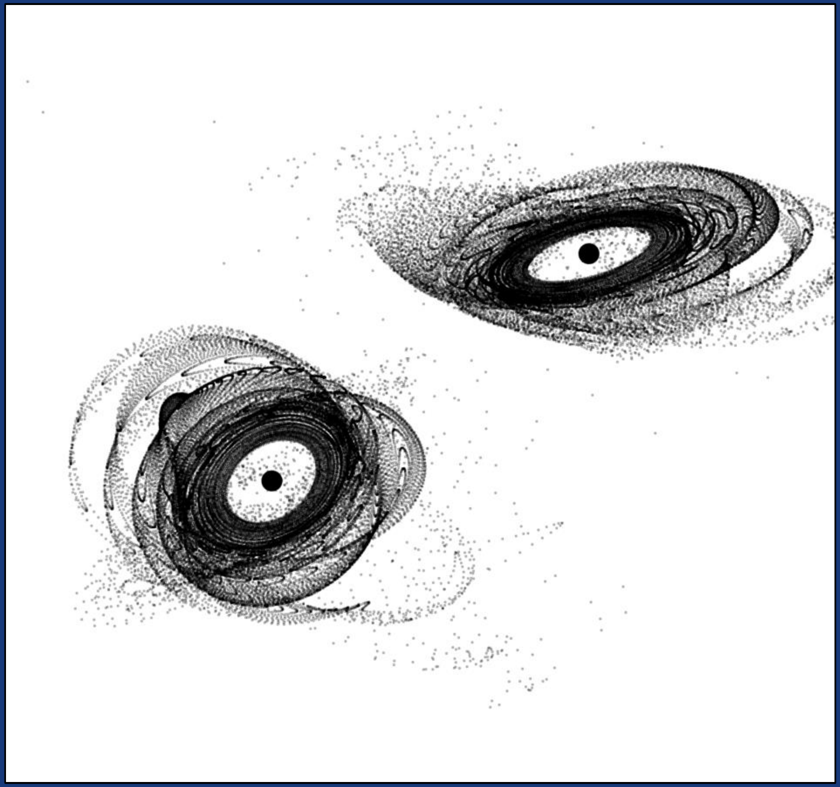
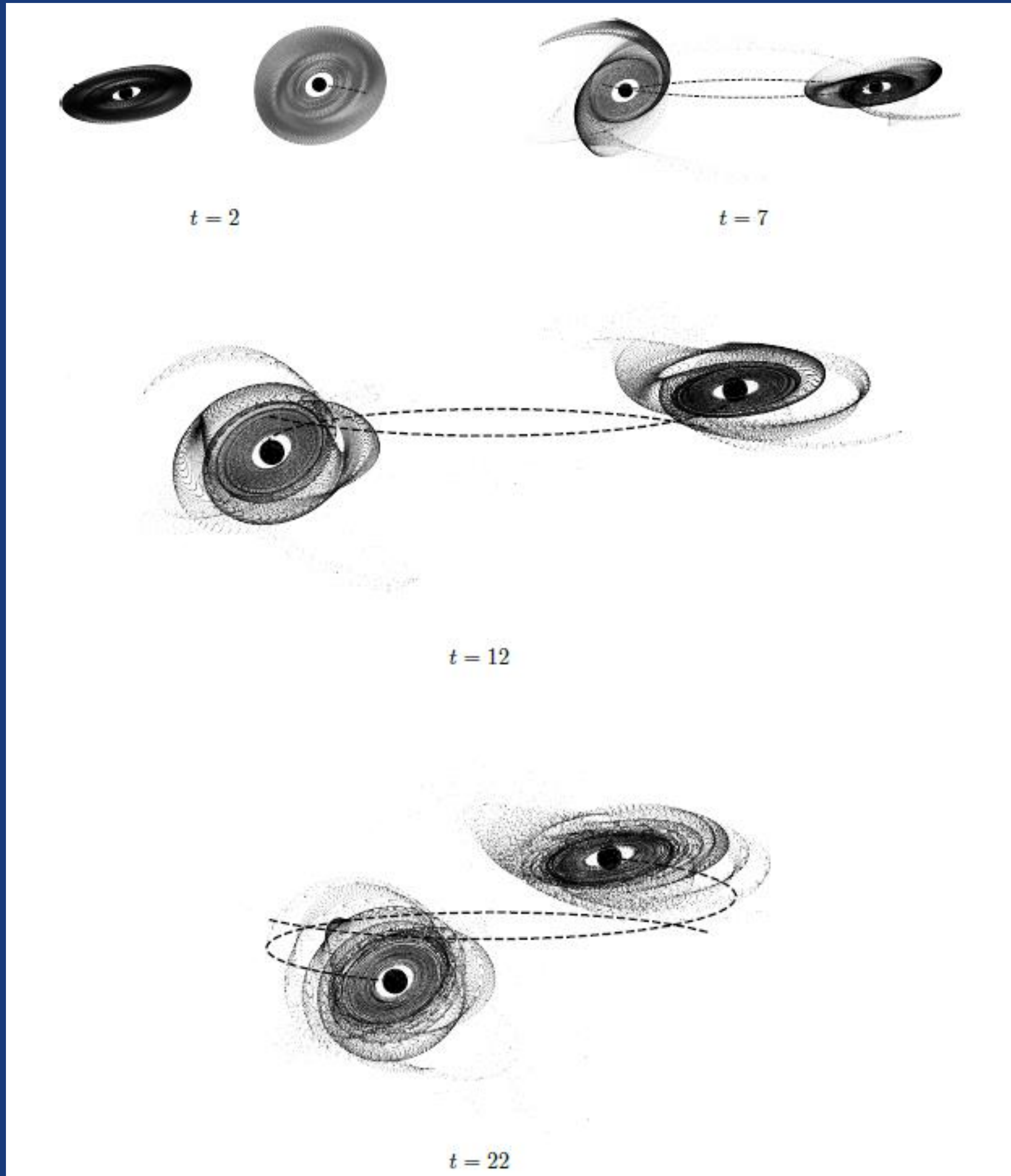
Ergebnisse - Simulation des NGC 5426/7 Paars



$$e \approx 0.67 \quad R_{min} \approx 28.16 kpc$$



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Ergebnisse - Simulation des NGC 4038/9 Paars

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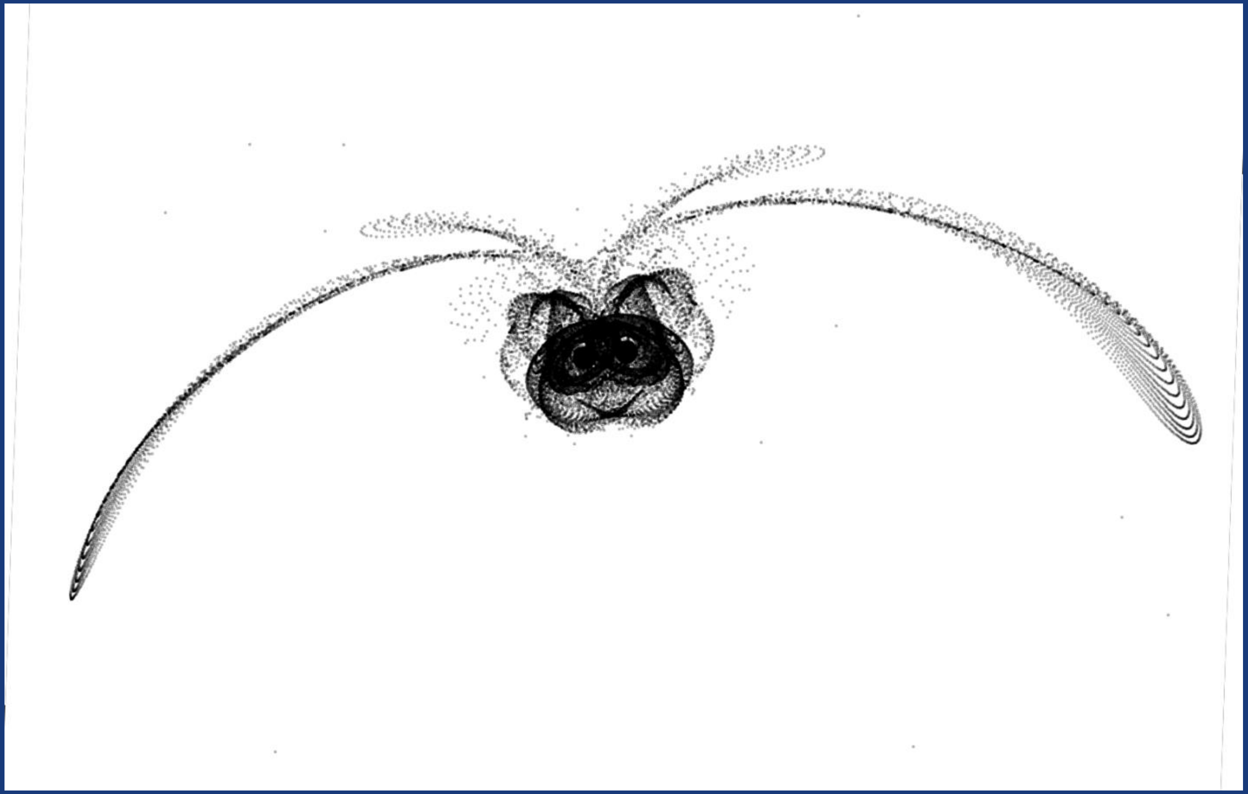
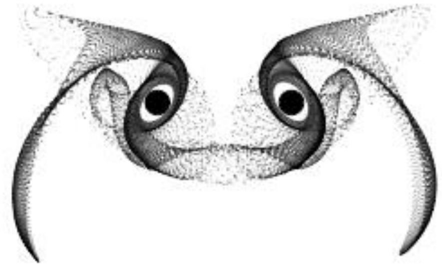
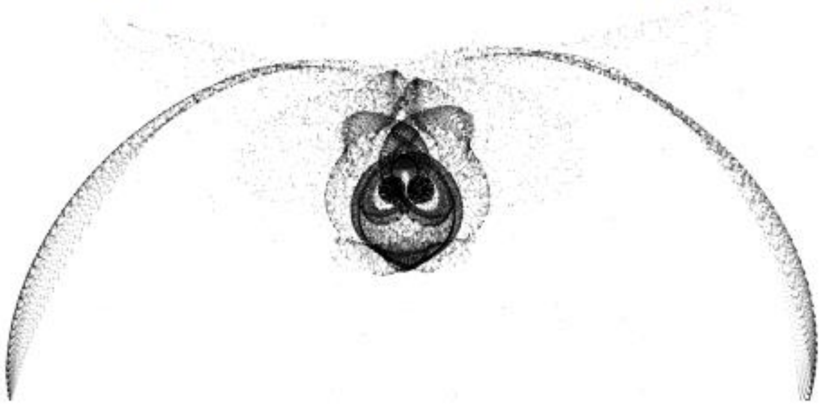


$$e \approx 0.44 \qquad R_{min} \approx 18.57kpc$$

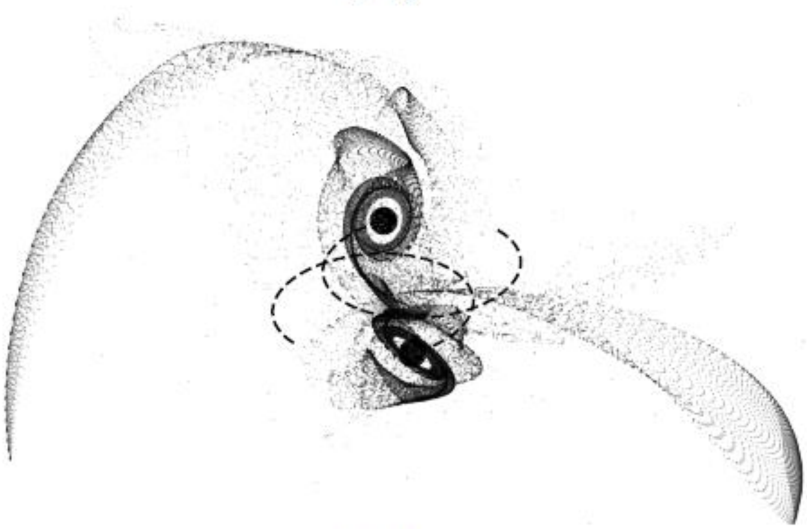
$t = 4$



$t = 7$



$t = 9$



$t = 9$

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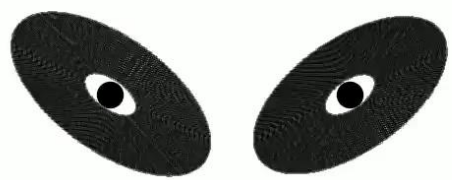

Haus der Astronomie

Fazit und Ausblick

Haus der Astronomie

- Bedeutung des Projekts
  - Gut geeignet auch für Schüler der Oberstufe
  - Anschauliche Ergebnisse
- Schwierigkeiten
  - Hoher Zeitaufwand
  - Motivation erforderlich
- Github Zugang
  - bit.ly/2NmdBQe

Internationales Sommerpraktikum am Haus der Astronomie 2017

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bit.ly/2NmdBQe

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Haus der Astronomie
MPIA-Campus Heidelberg

Haus der Astronomie

DANKE