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N-body problem with various integrators

Astrofysische simulaties

Ewoud Ketele

Hylke Damien

Osman Dönmez

Jeffrey De Rycke

Joren Van Nieuwenhuyse

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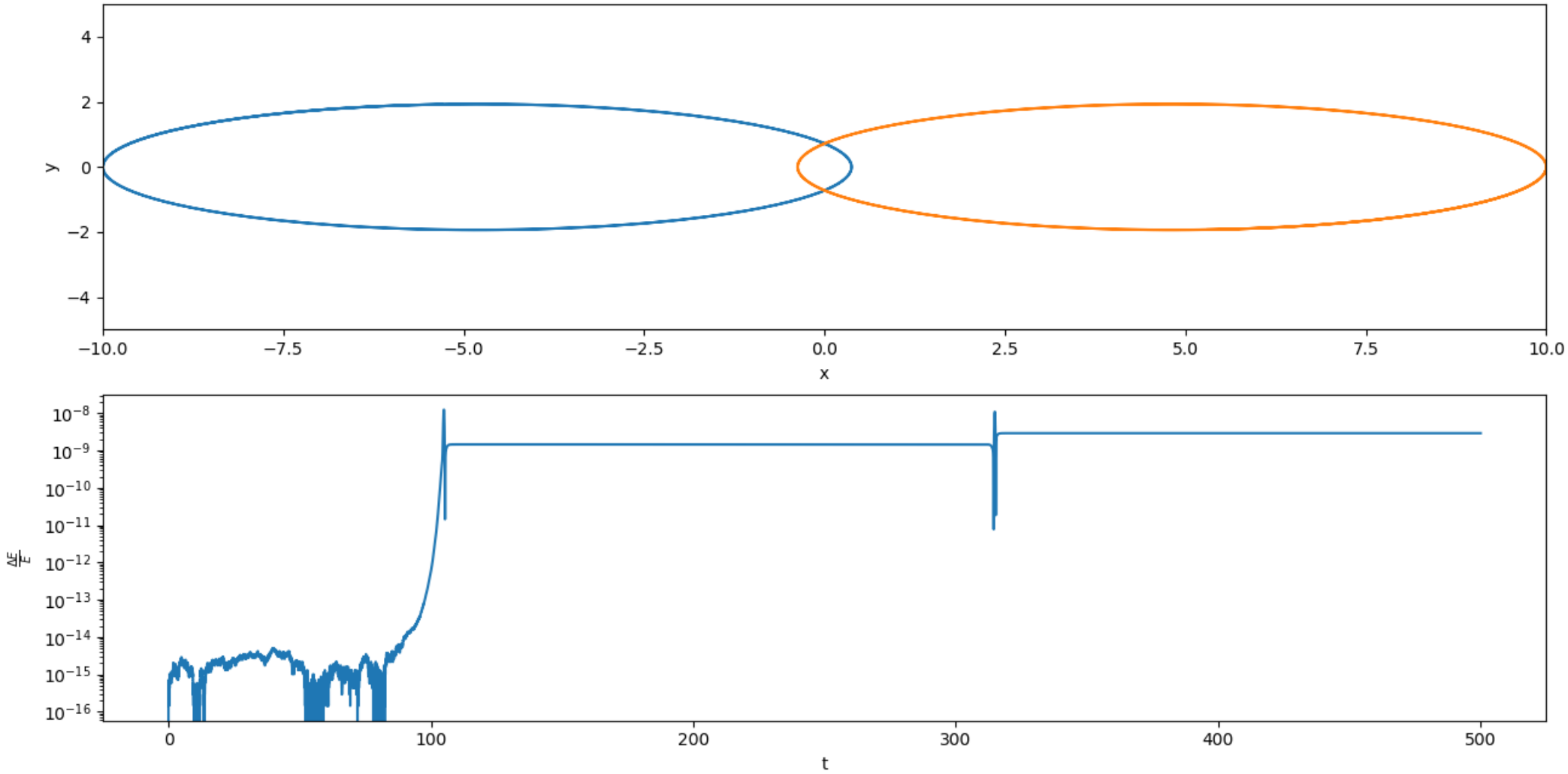
RK4: baan +energie



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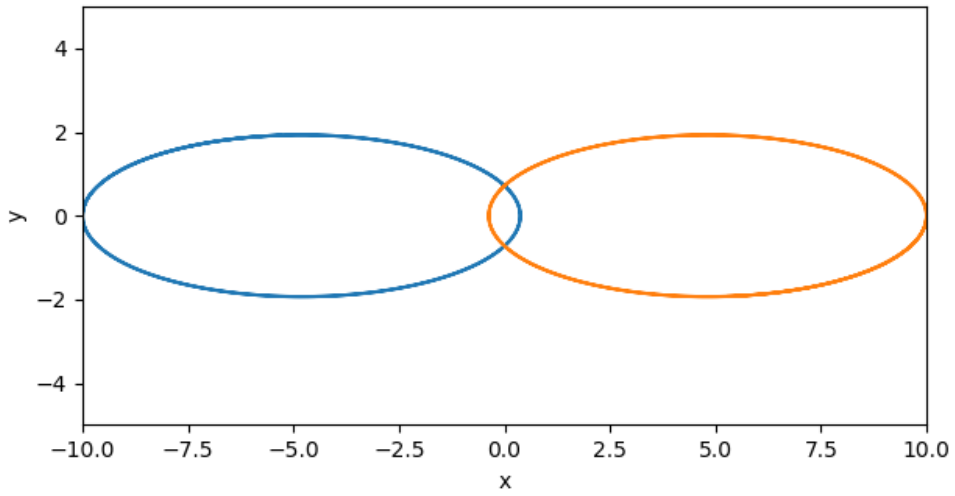
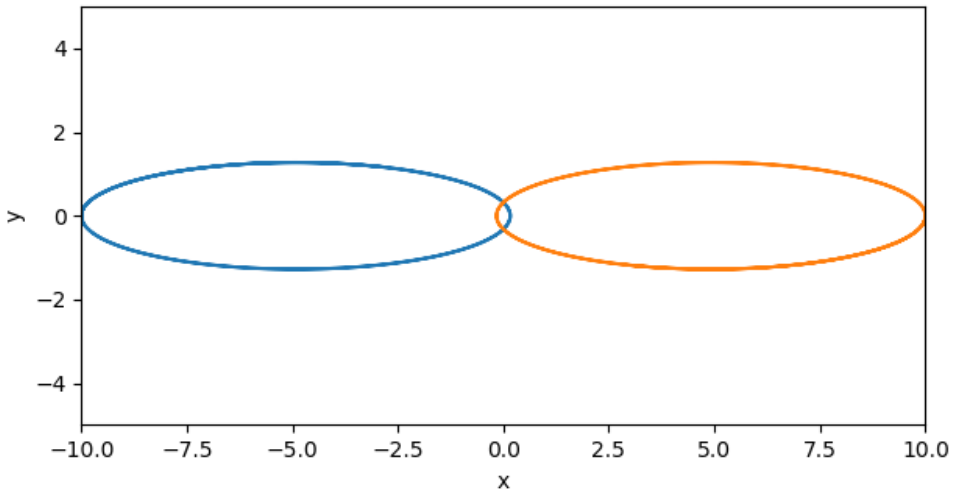
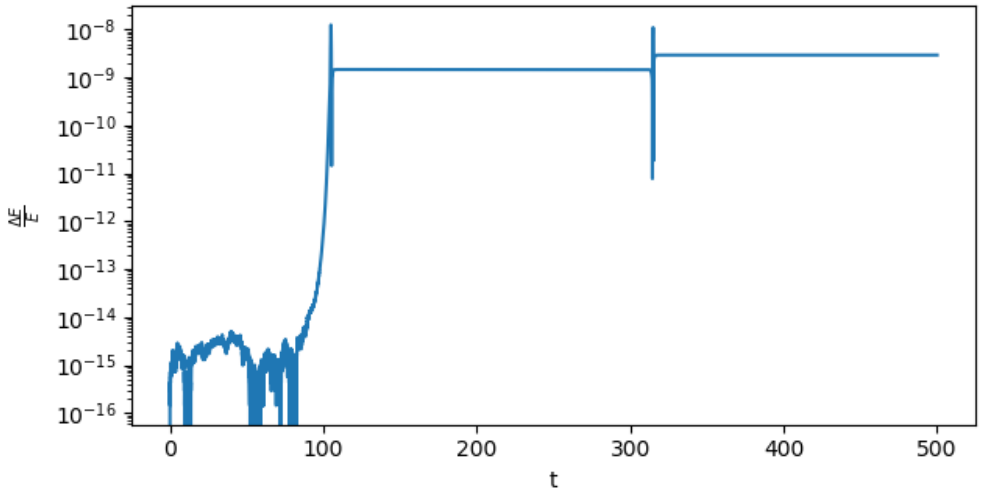
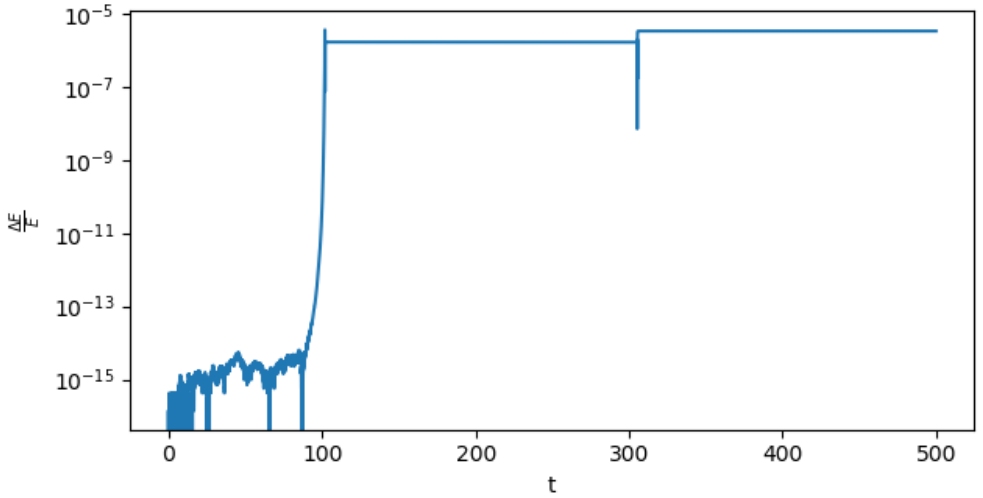
Eccentriciteit versus energie









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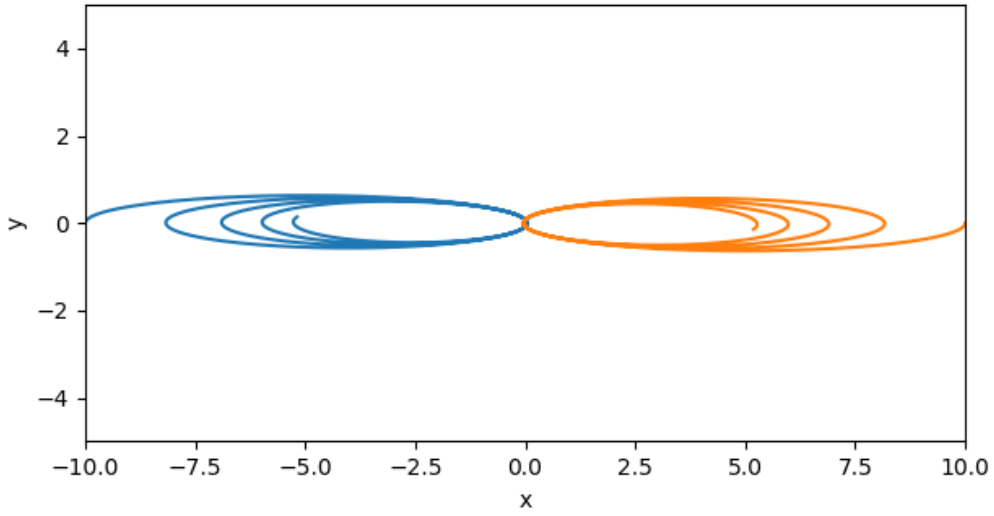
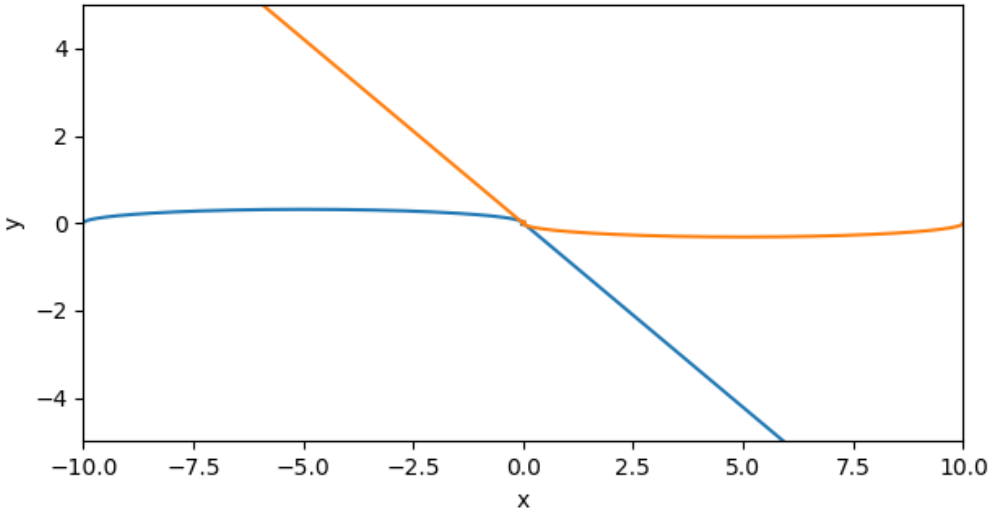
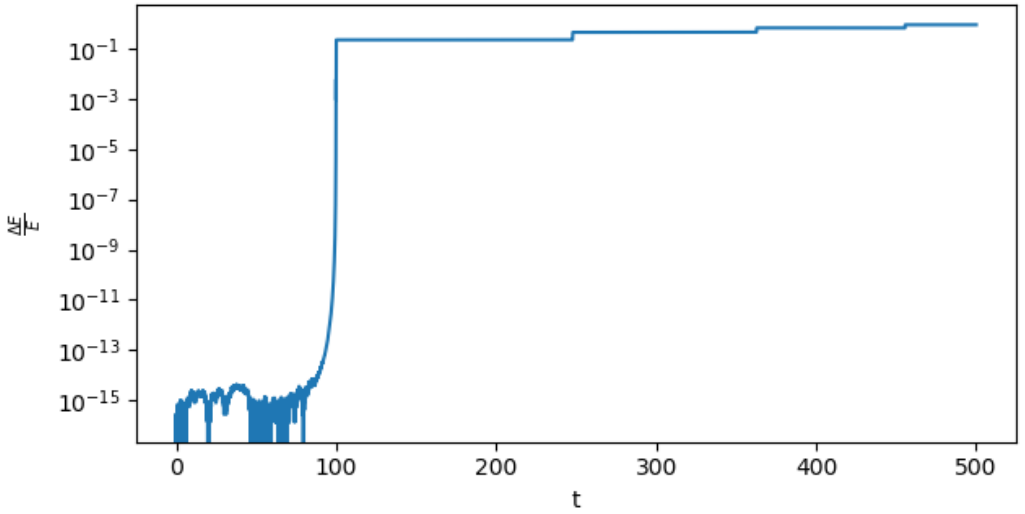
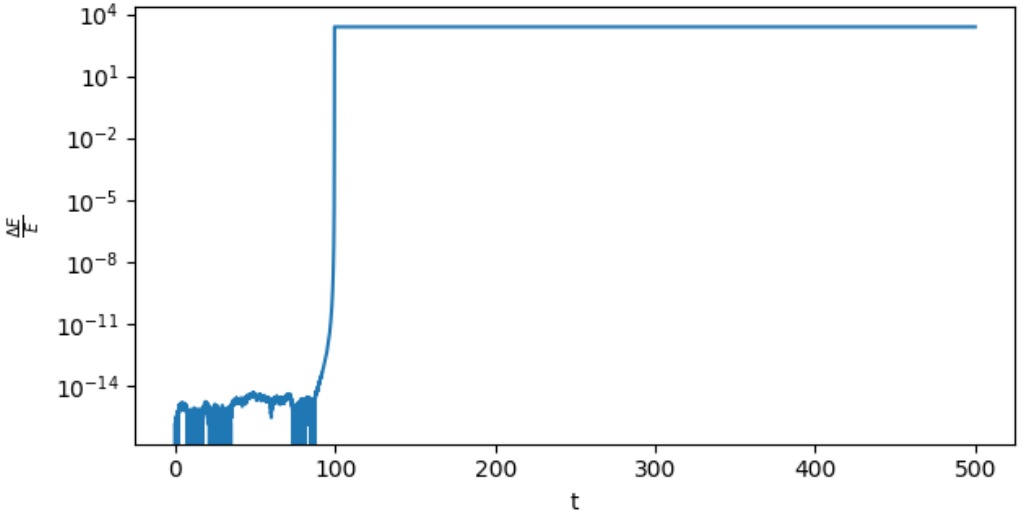
Eccentriciteit versus energie









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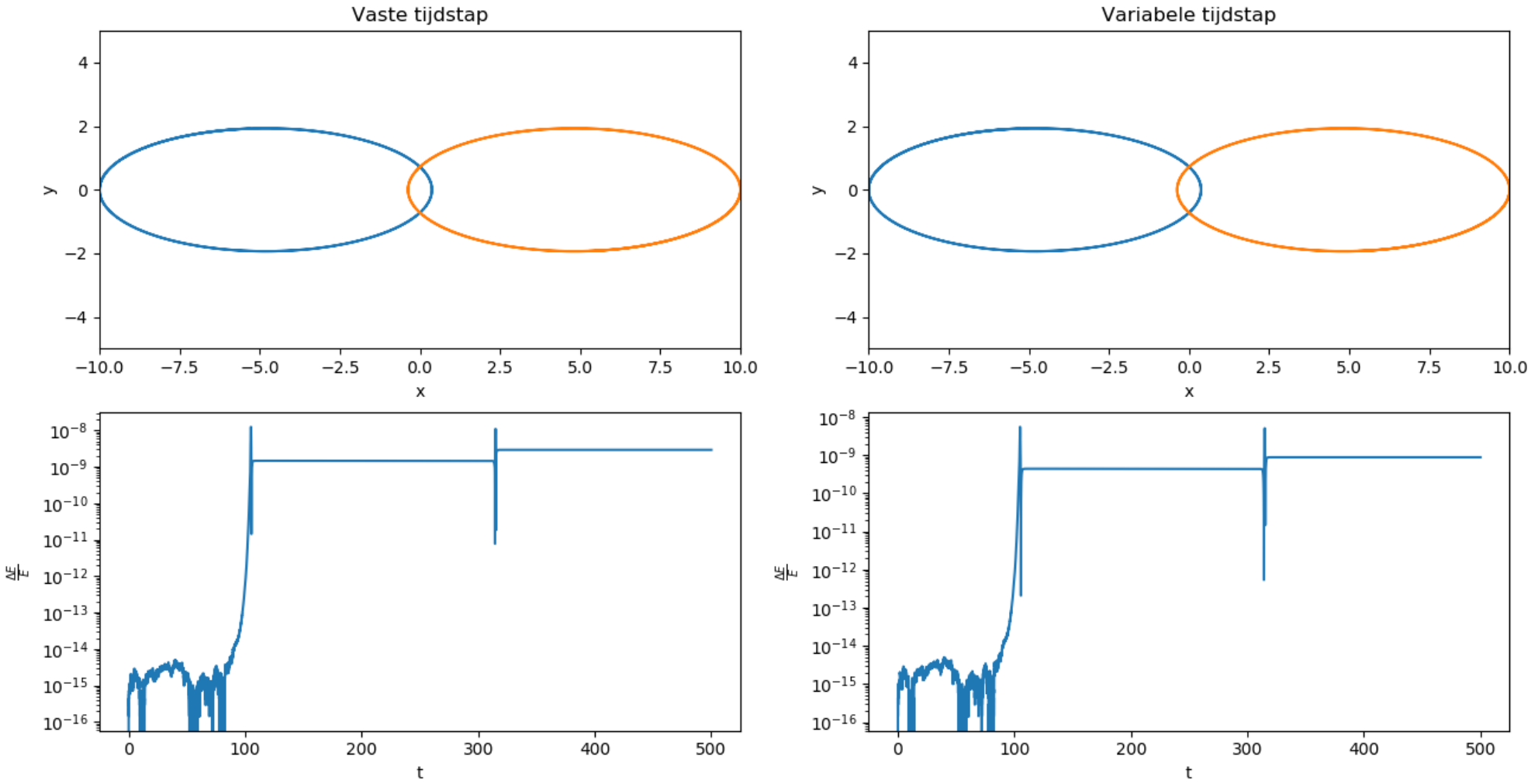
Vaste tijdstap versus variabele tijdstap



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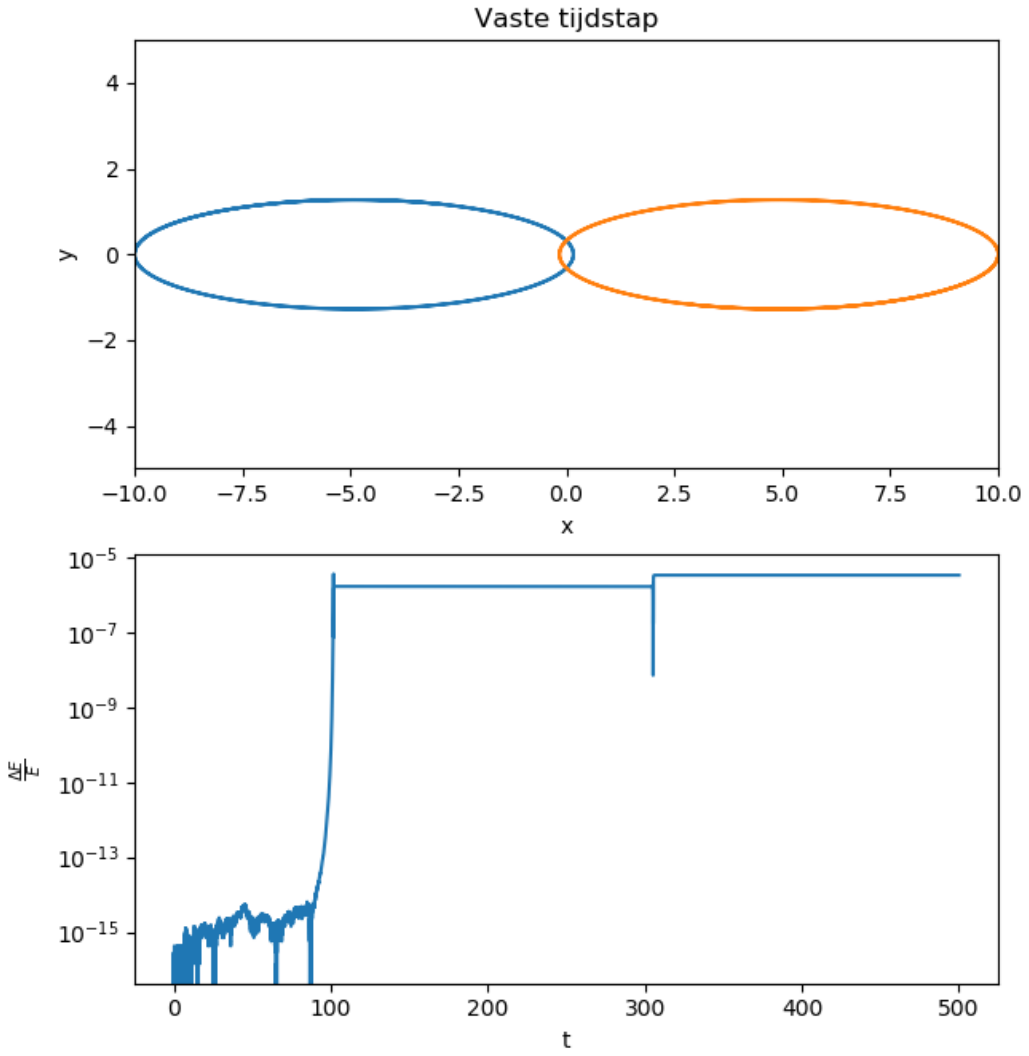
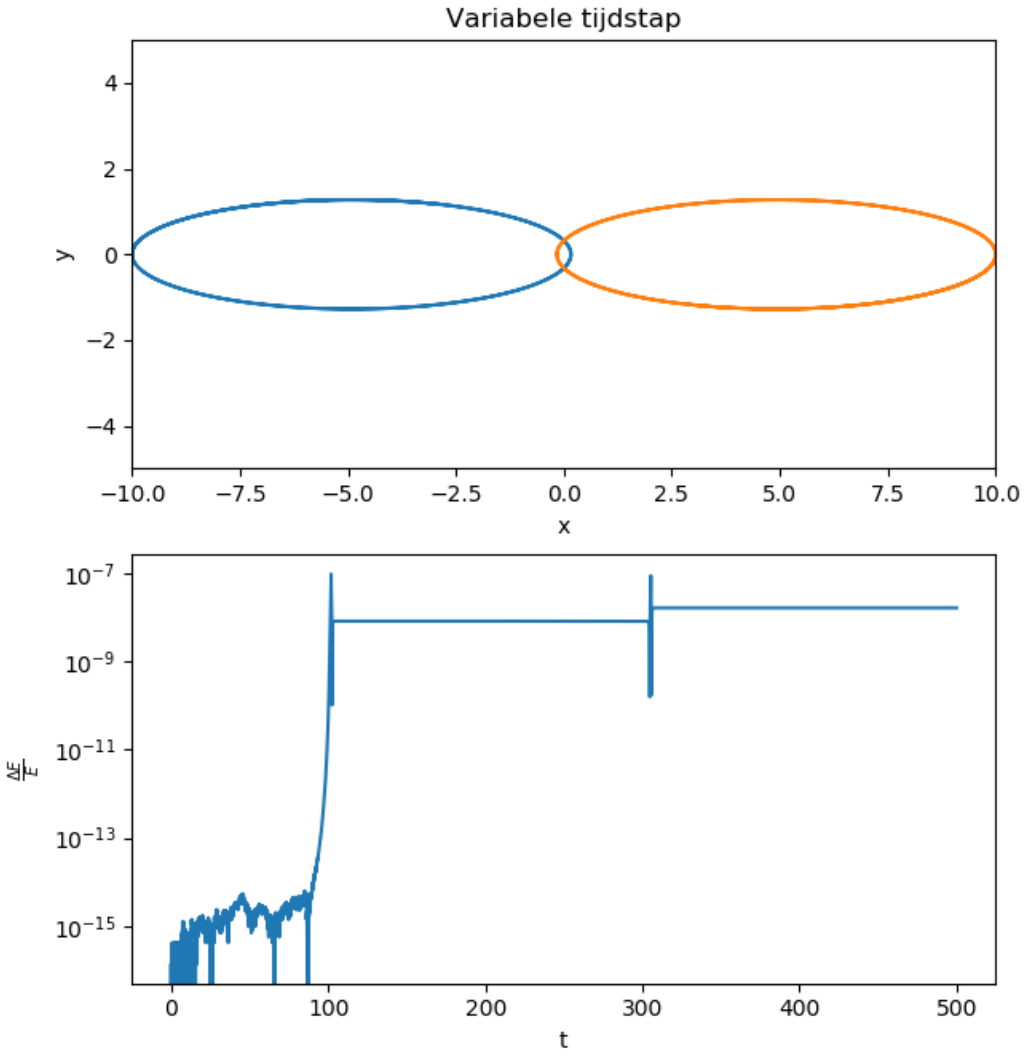
Vaste tijdstap versus variabele tijdstap





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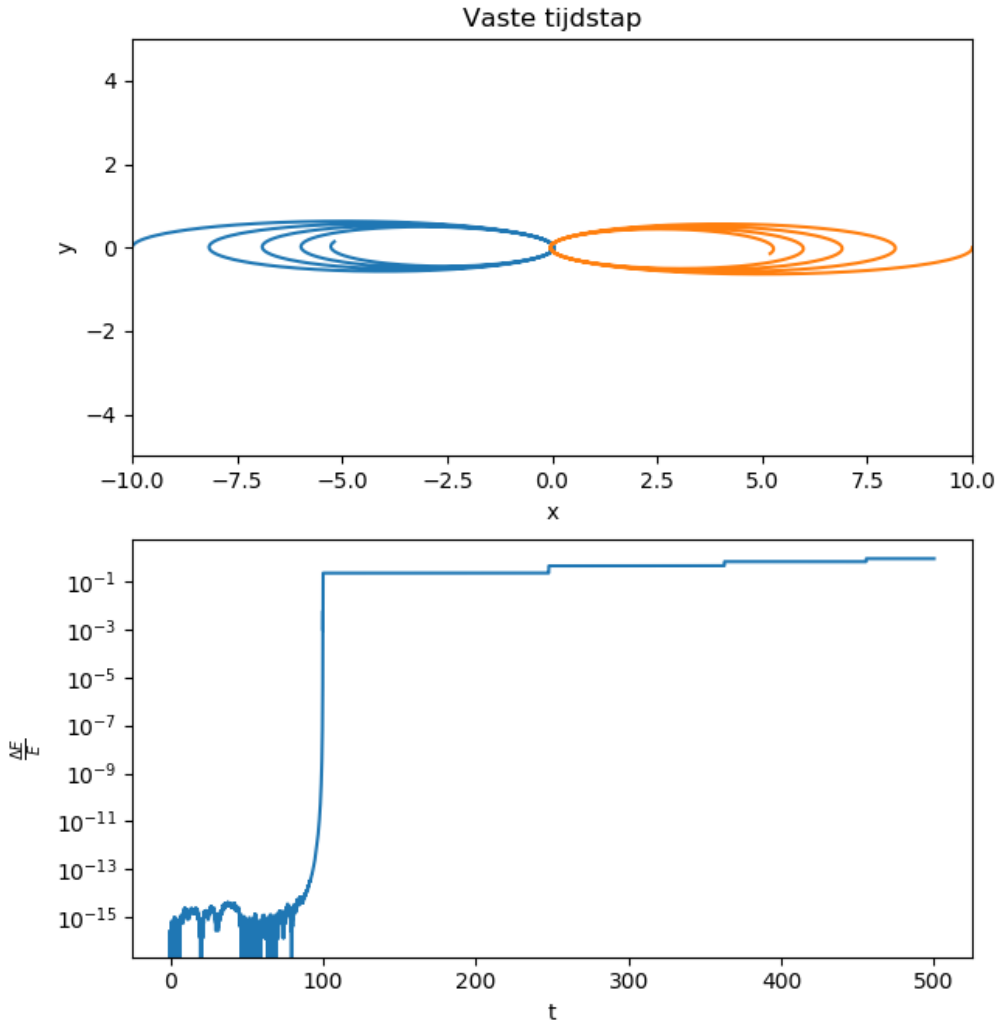
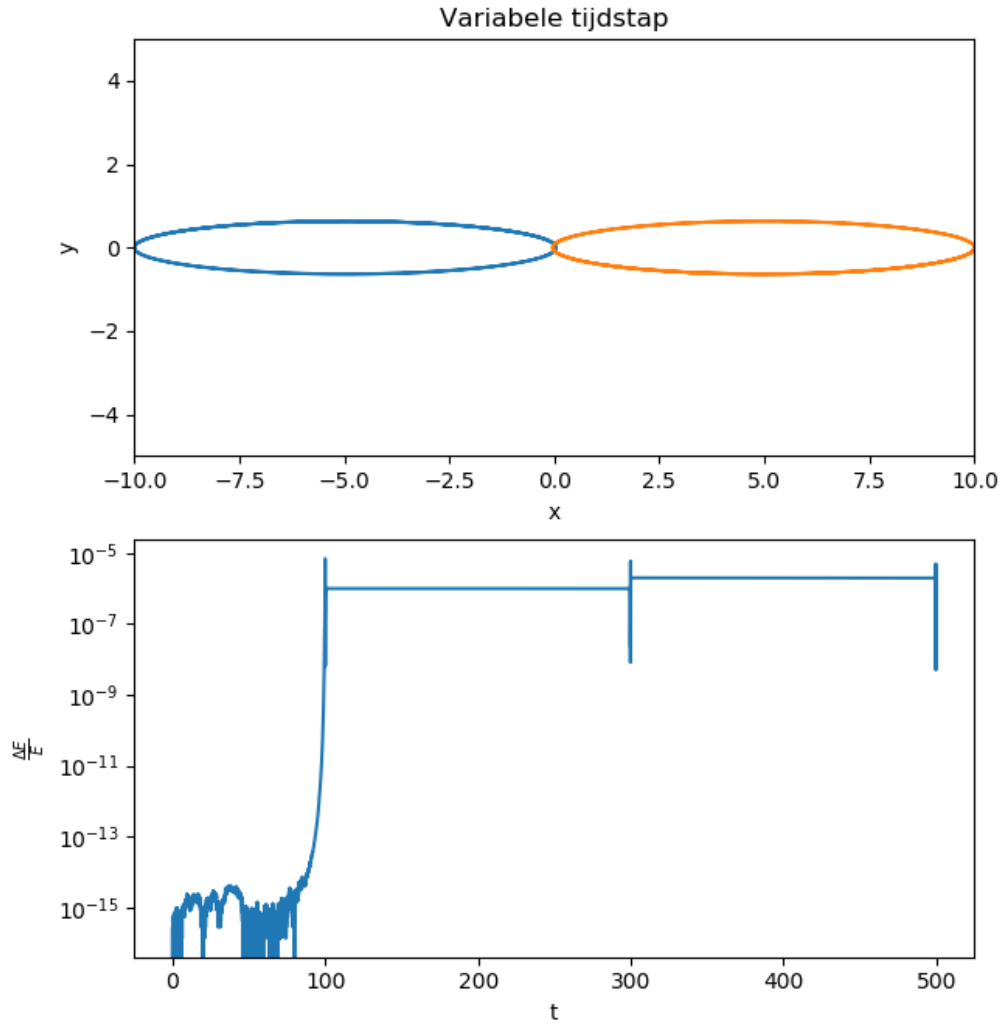
Vaste tijdstap versus variabele tijdstap





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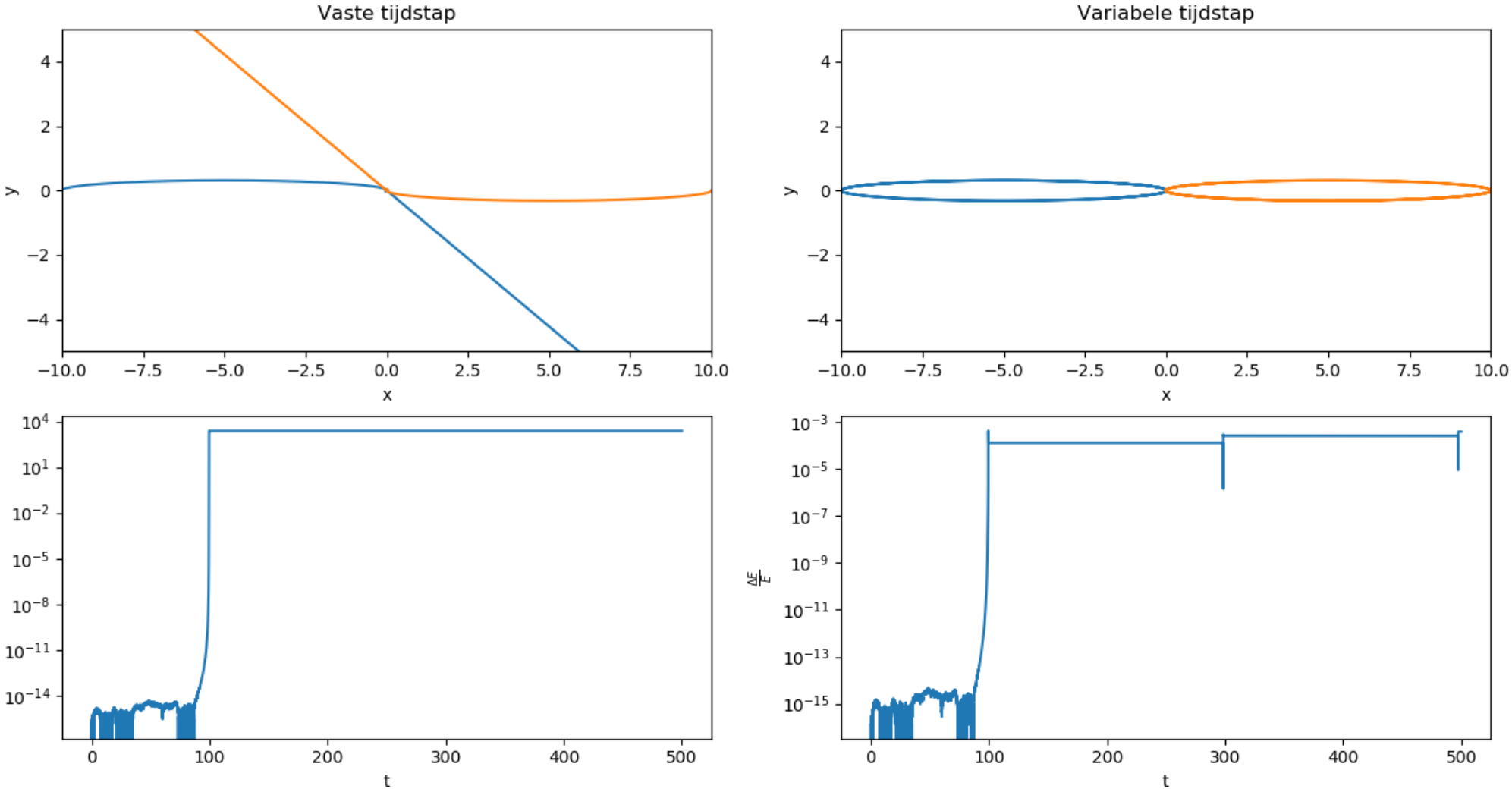
Vaste tijdstap versus variabele tijdstap



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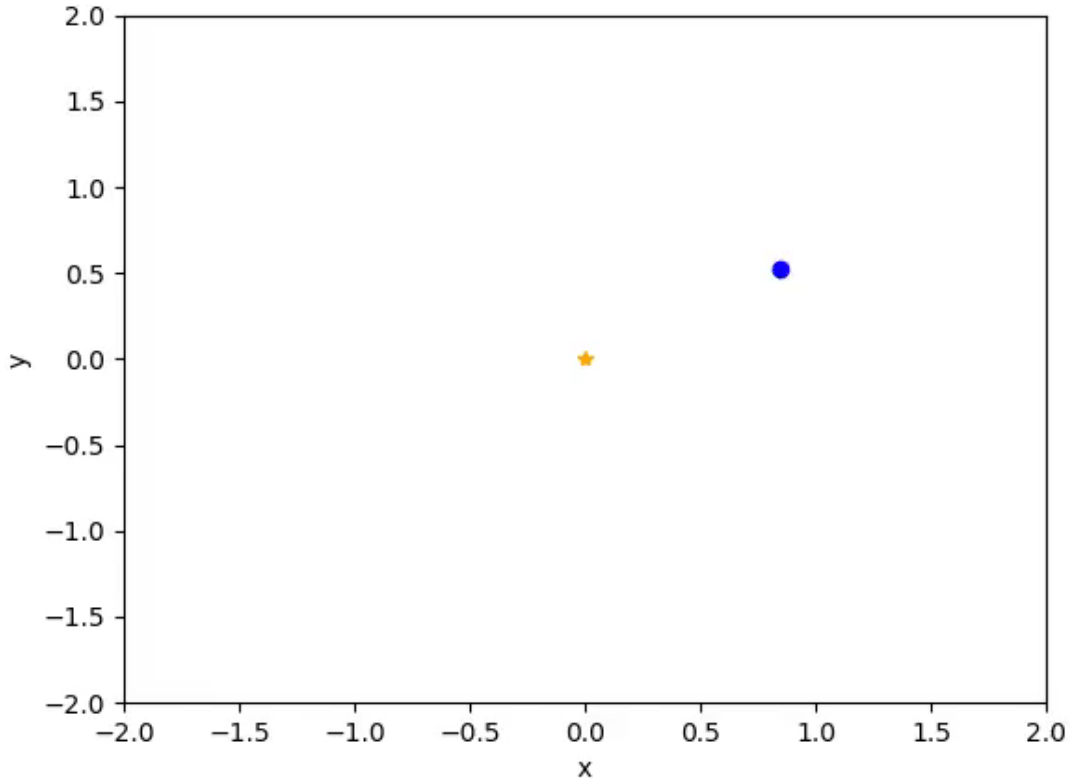
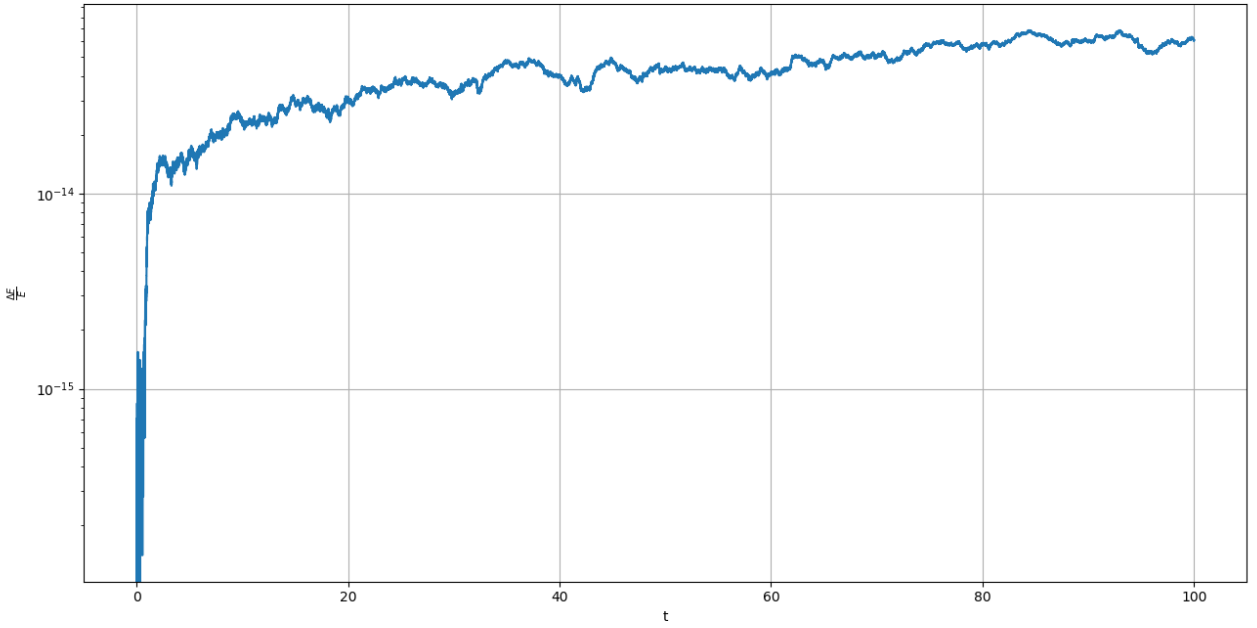
Zon - aarde





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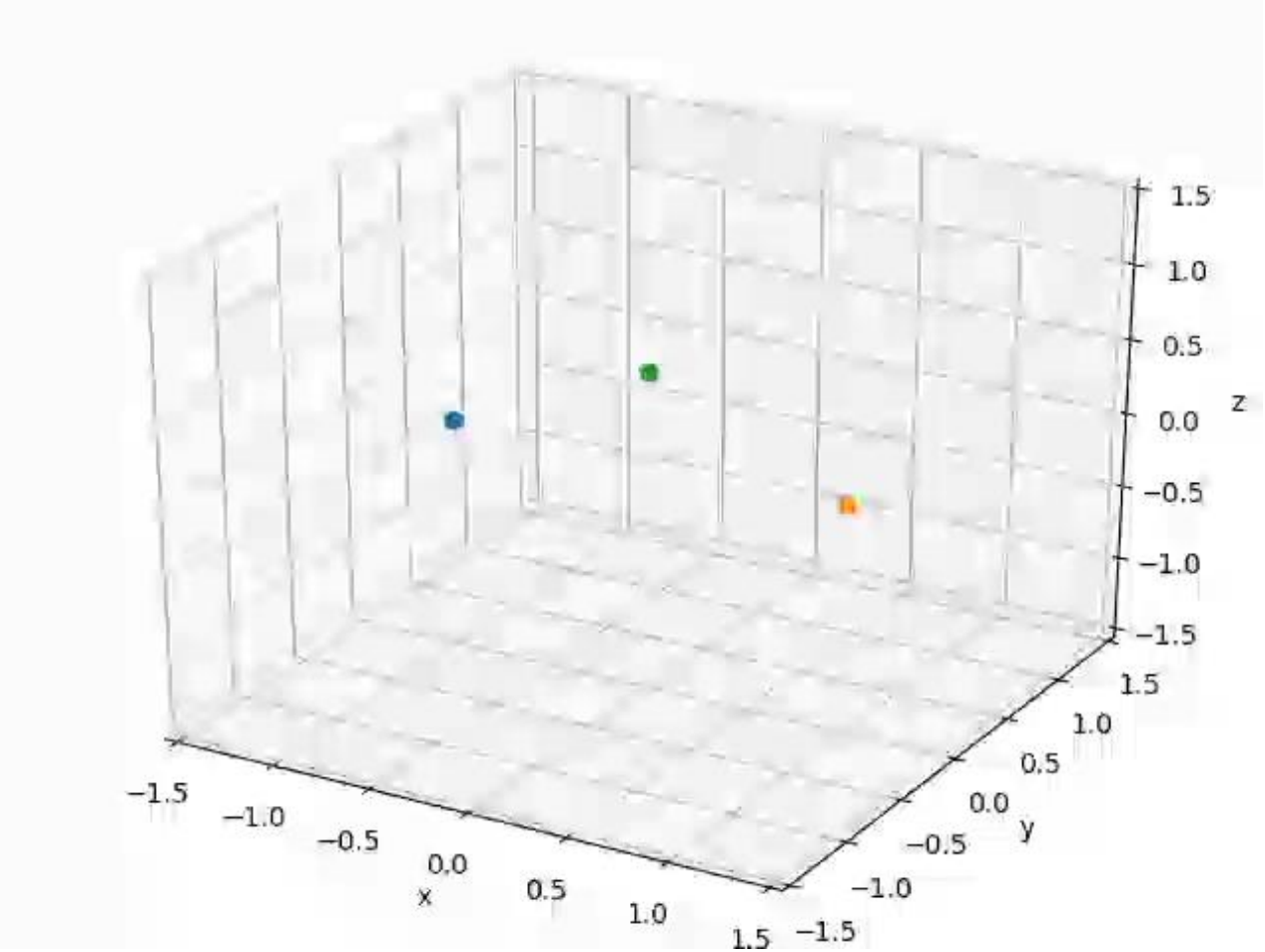
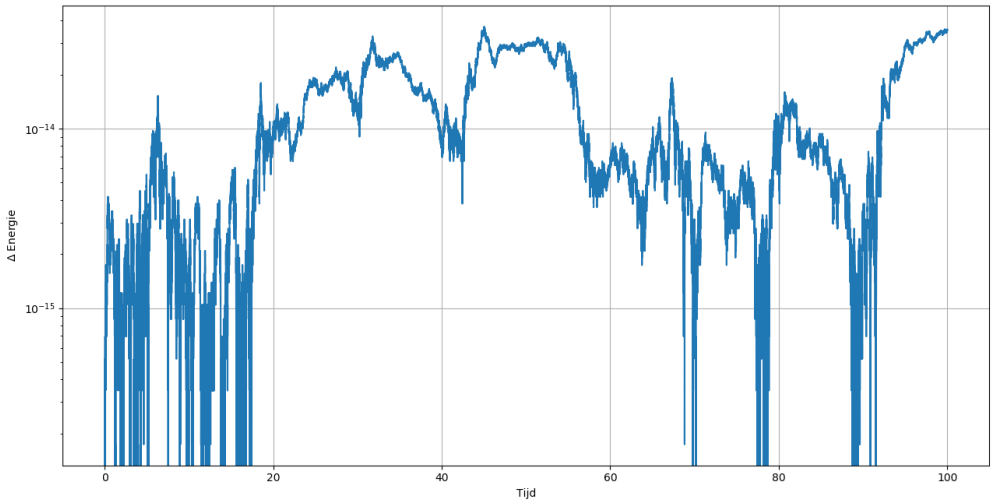
Sitnikov probleem





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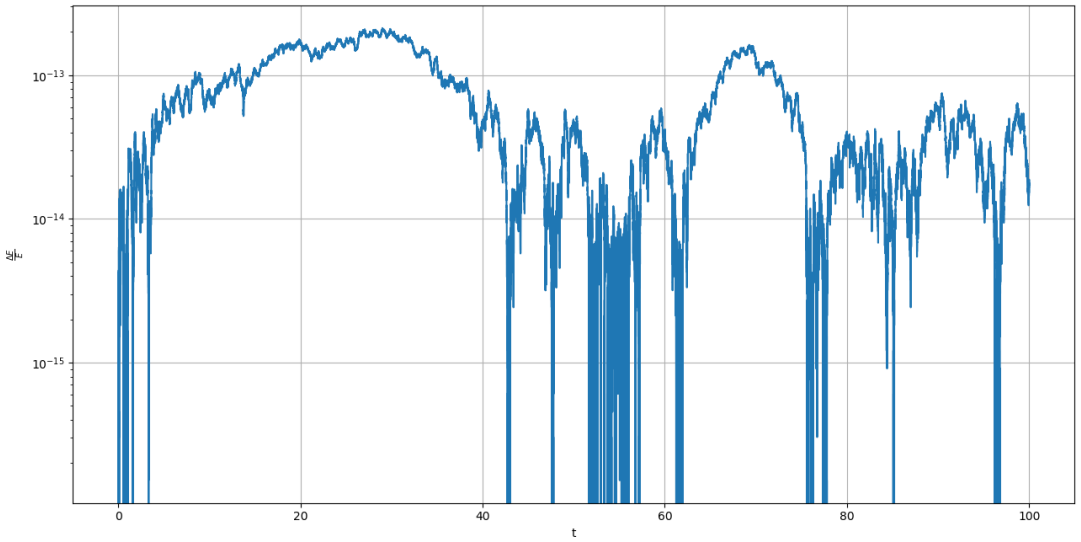
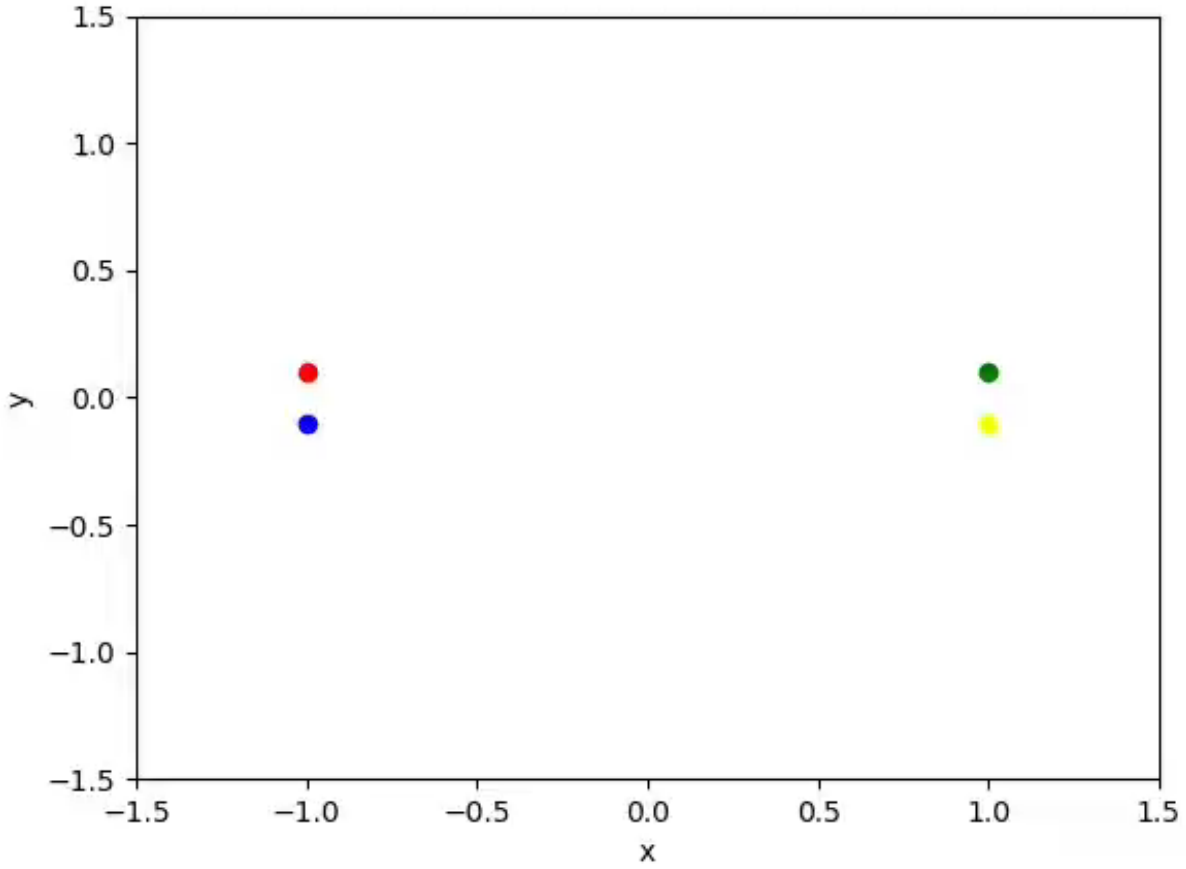
Dubbeldubbelster





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Hoe bepalen wanneer een “oplossing” correct is?

-Via gekende begincondities en uitkomsten? -> gelijkzijdige driehoek

-Kleinere en kleinere h (verbetert truncuation error)

-Behoud energie, dichtste nadering, plot posities

-Uiteindelijk rounding error > truncation error

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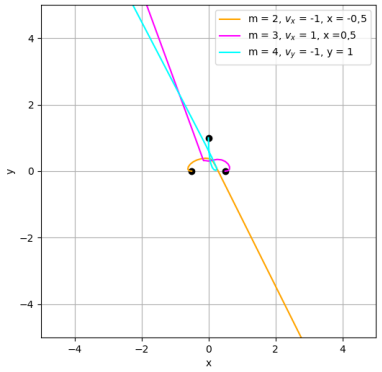
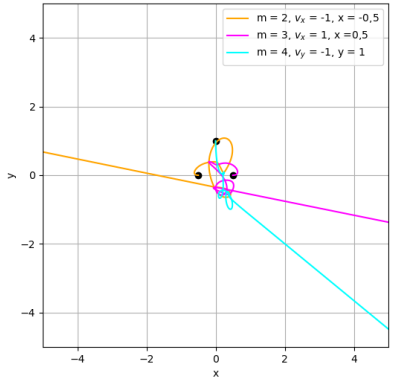
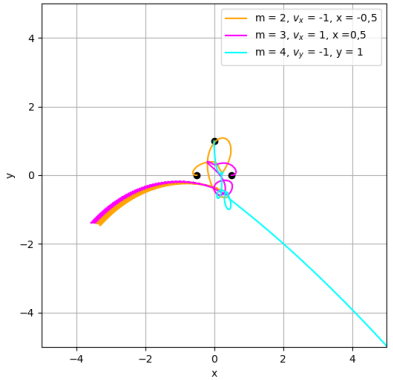
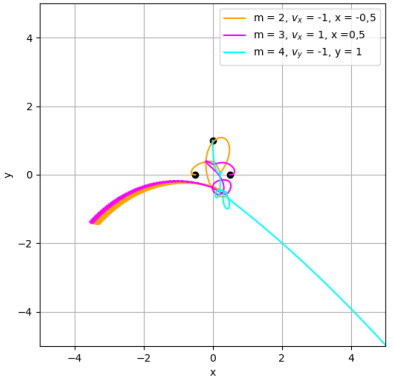
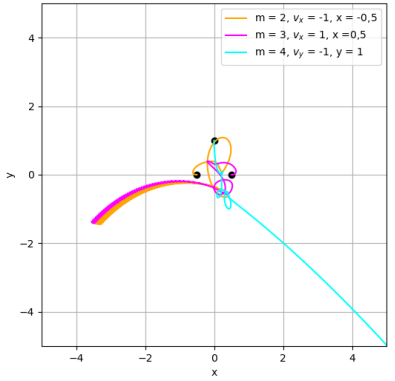
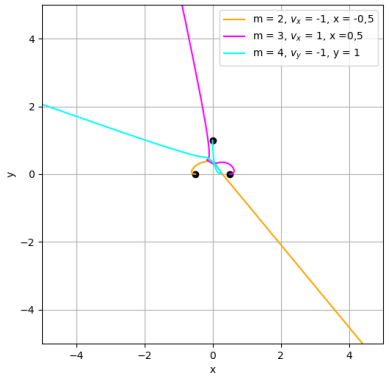
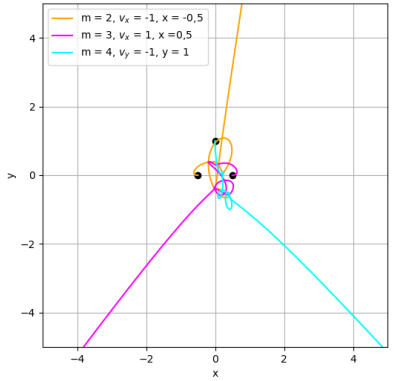
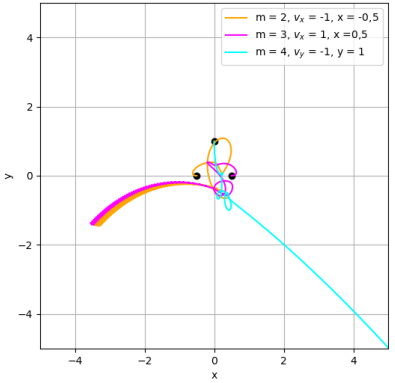
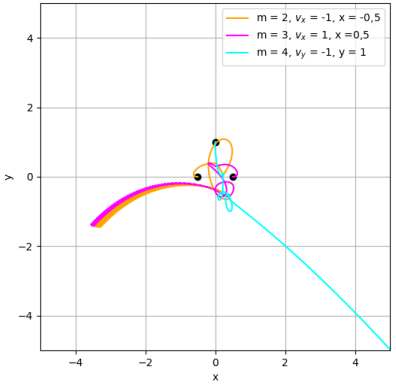
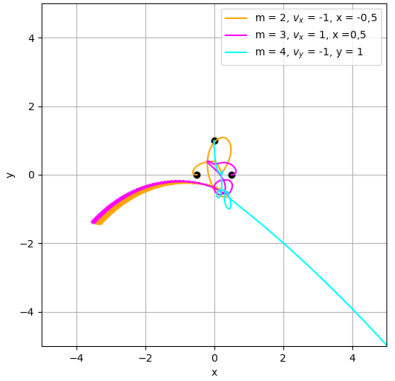
Gelijkbenige driehoek probleem, t = 10 (adaptieve h)

	h = 0,1	h = 0,01	h = 0,001	h = 0,0001	h = 0,00001
RK4					
PEFRL					

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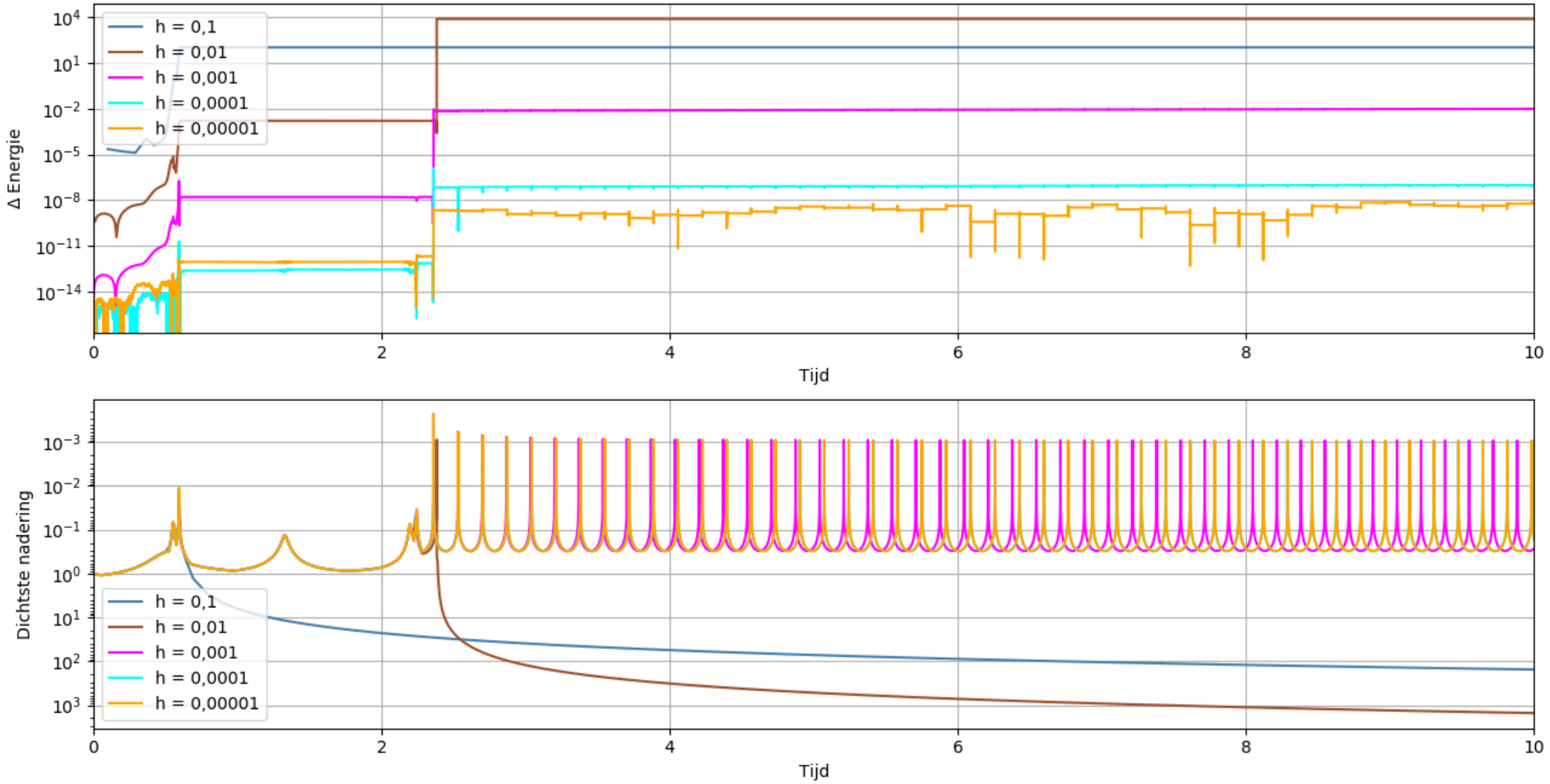
Vergelijking van relatieve energiefout bij verschillende stappen (RK4)



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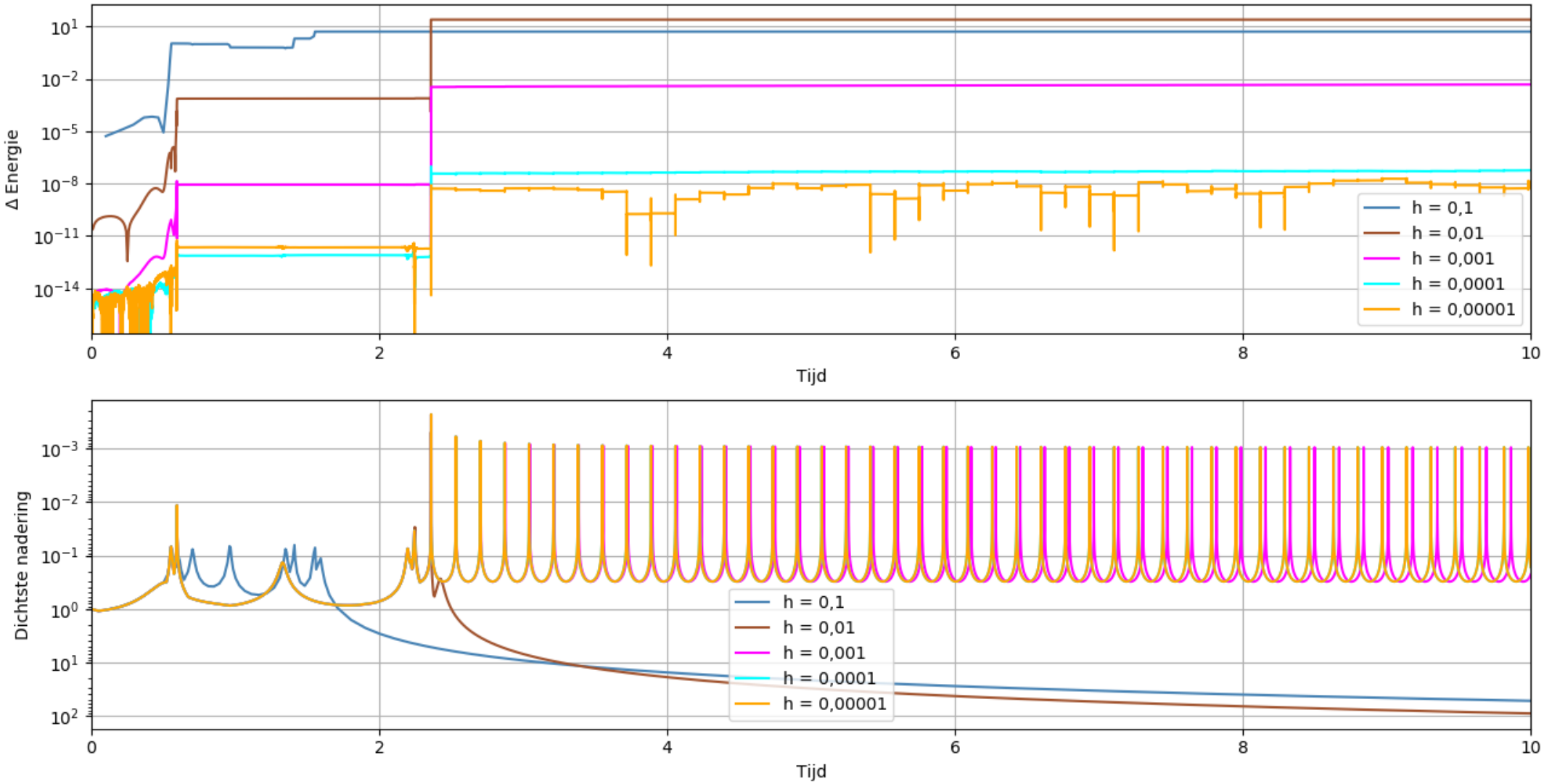
Vergelijking van relatieve energiefout bij verschillende stappen (RKF45)



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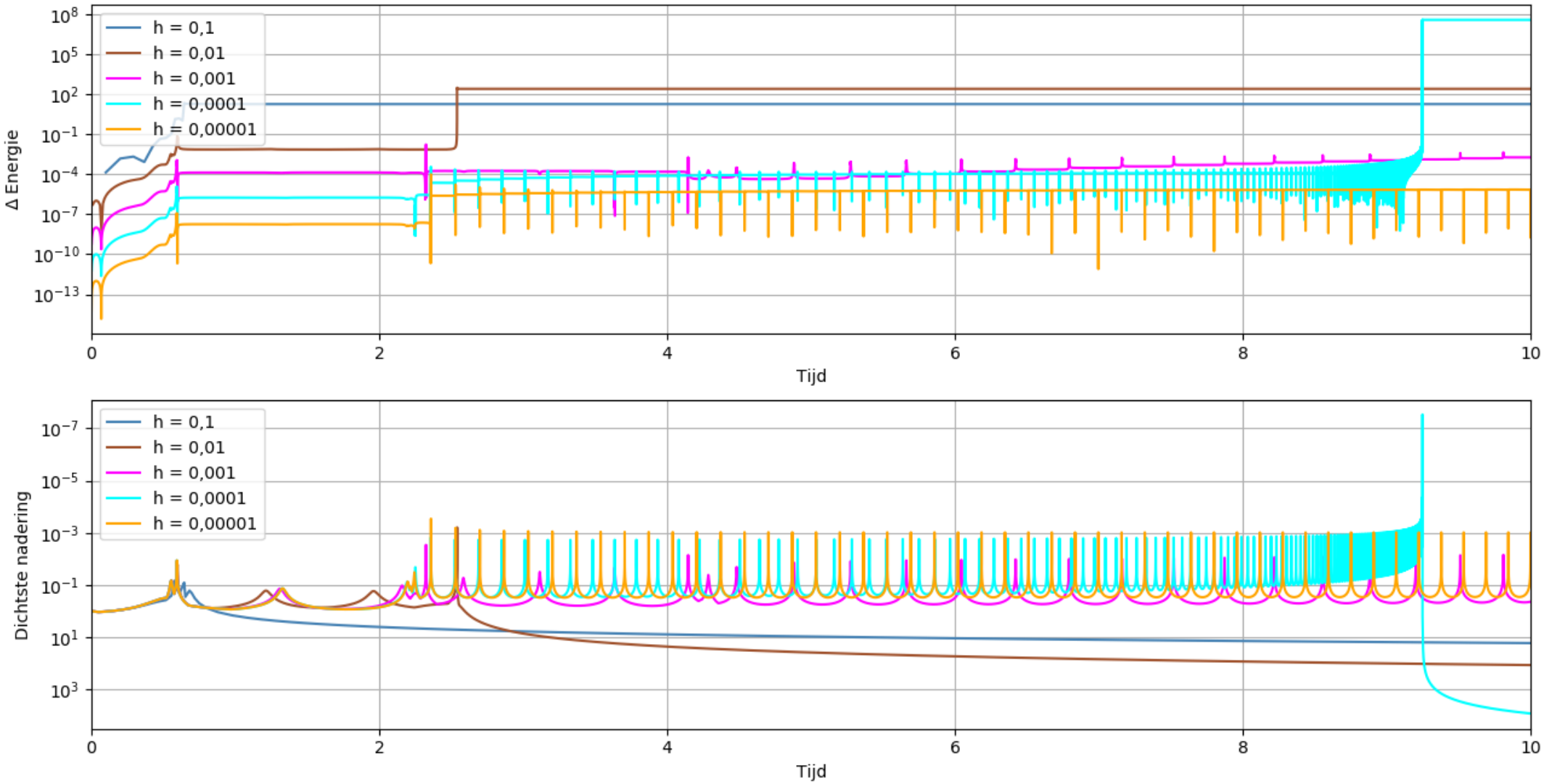
Vergelijking van relatieve energiefout bij verschillende stappen (Verlet)



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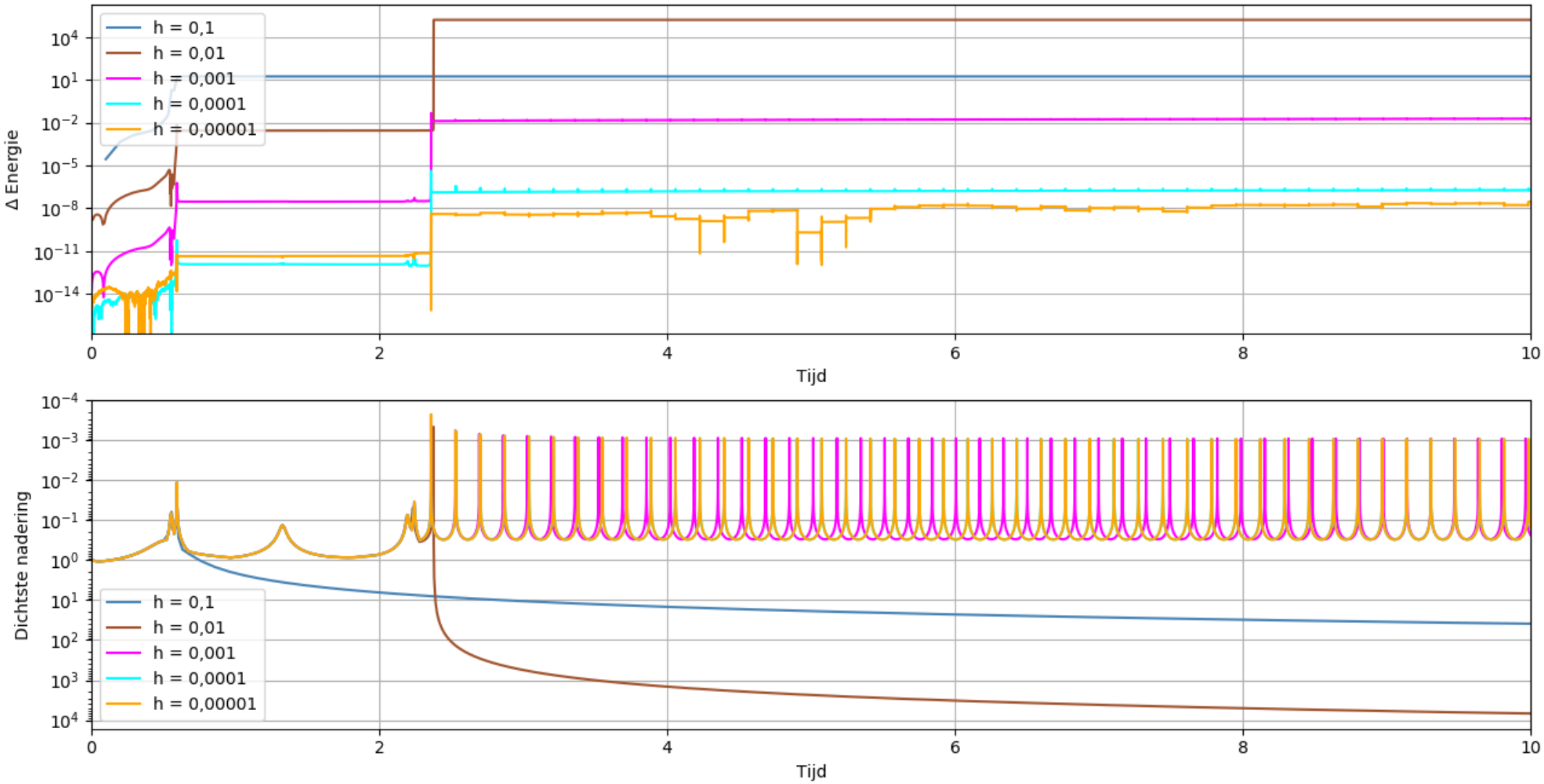
Vergelijking van relatieve energiefout bij verschillende stappen (Forest-Ruth)



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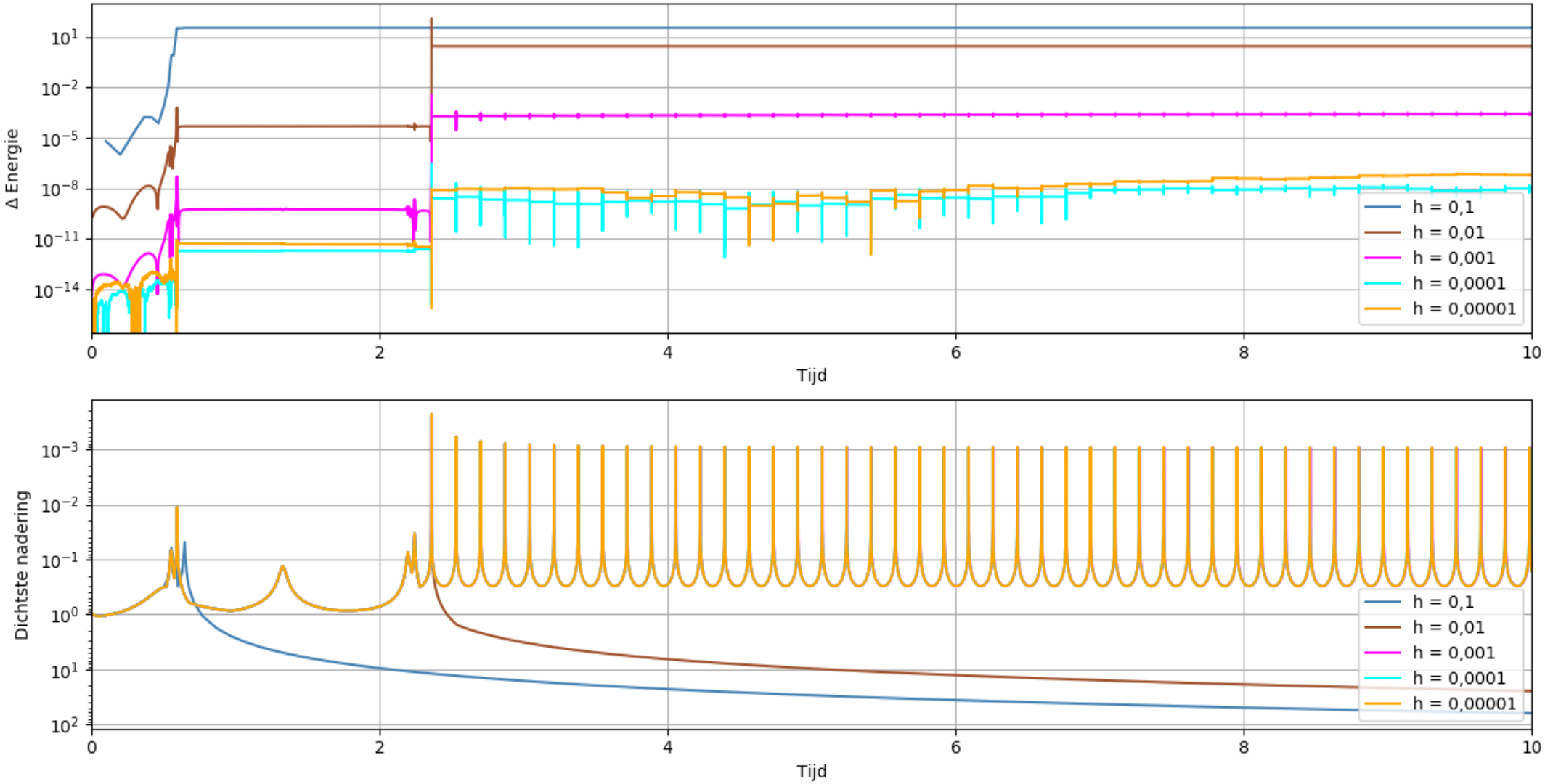
Vergelijking van relatieve energiefout bij verschillende stappen (PEFRL)



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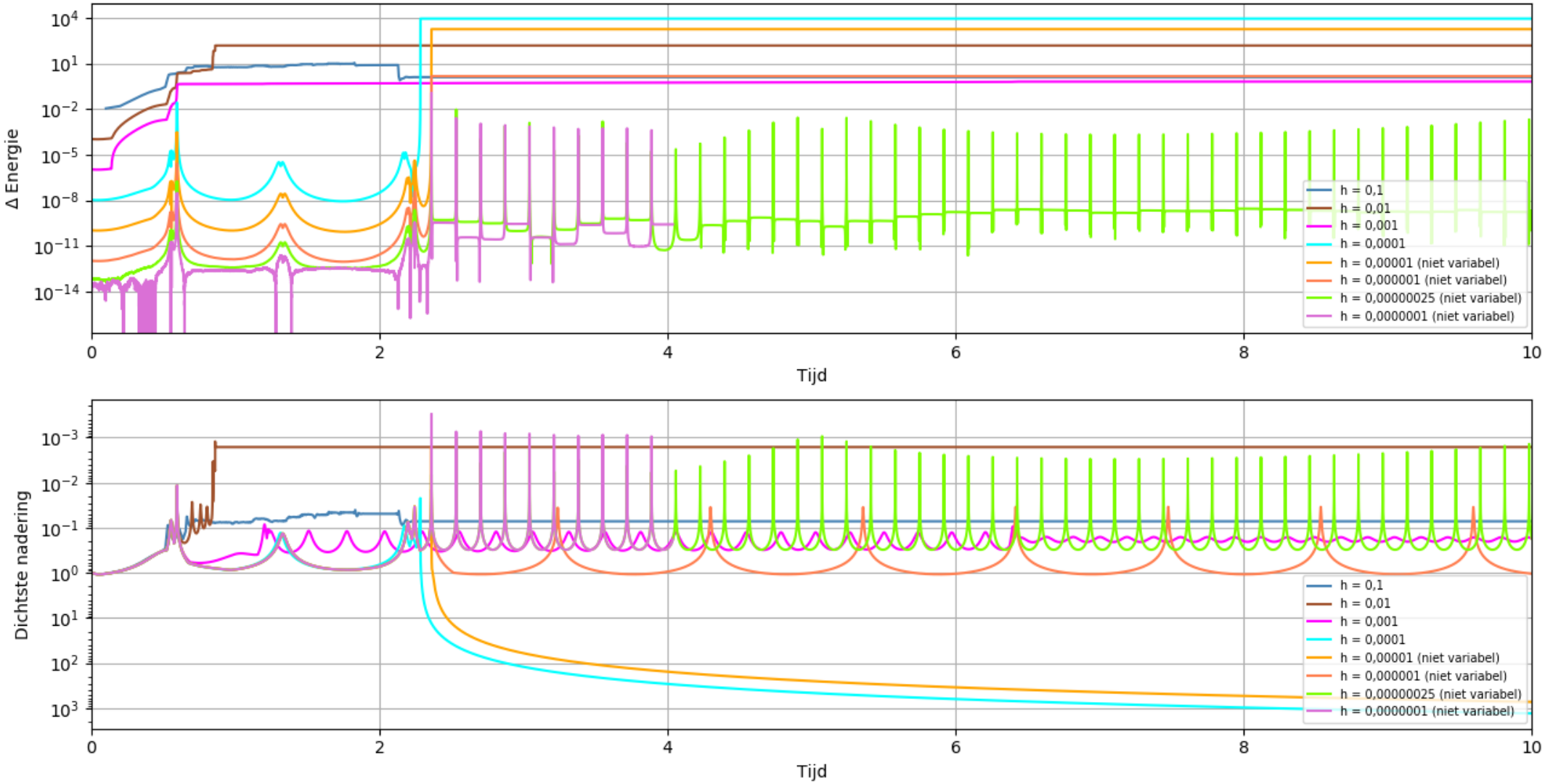
Vergelijking van relatieve energiefout bij verschillende stappen (Leapfrog)



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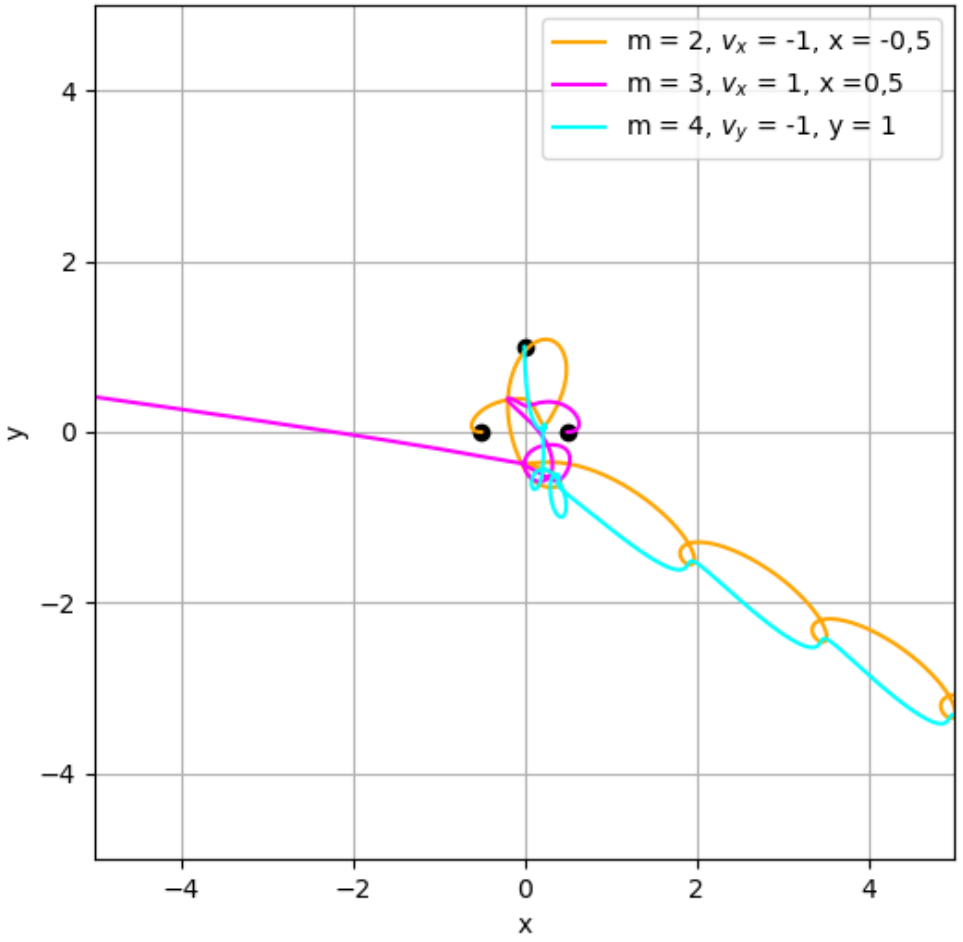
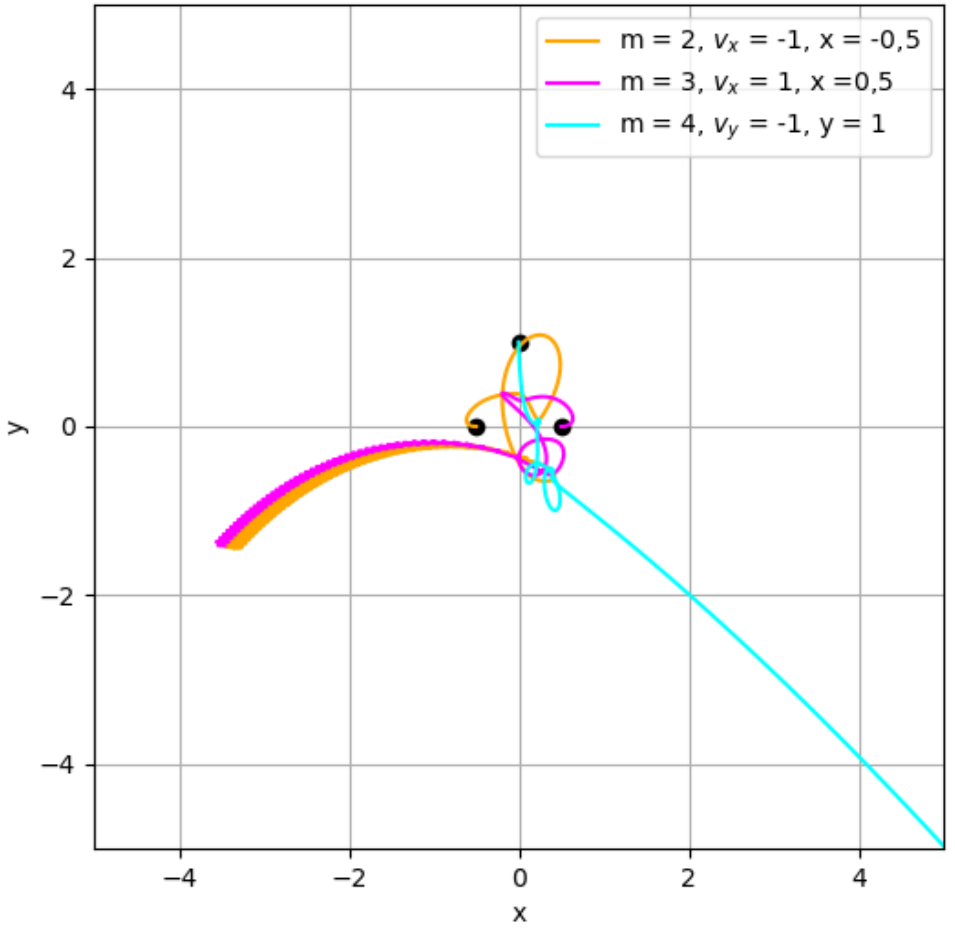
Plot van gelijkbenige driehoek (Leapfrog)

h = 0,000001



h = 0,00000025



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Random begincondities

-Waarom

-Hoe genereren

-Waarom herschalen

-herschalen

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Waarom?

-Testen integratoren

-Geen bias (orbit versus botsingen)

-Integratietijden volgende stuk

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Hoe genereren?

-Via potentiaalmodel?

-Klein aantal deeltjes

-uniform [0,1] en met seed

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Waarom herschalen?

-Centreren van alle “actie”

-Compatibel met standaardeenheden (G= M = r_vir = 1)

-E_pot = -1/2, E_tot = -1/4 (scale radius = 1)

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Herschalen

-Centreren positie

-Genereren van paren?

-Waarom niet uit [-0.5 ; 0.5] ?

-Centreren snelheid

-Centreren van de “actie”

-Normeren massa

-Herschalen positie (zelfde factor) voor gewenste E_pot

-Herschalen snelheden (zelfde factor) voor gewenste E_kin

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Integratietijd van simulatie in functie van aantal deeltjes

-Verwacht: $O(N^2)$

-Data van 2 t.e.m. 100 deeltjes

-Fit data met functie: $f(x) = ax^2 + bx$

-Controleer fit met gereduceerde chi-kwadraat

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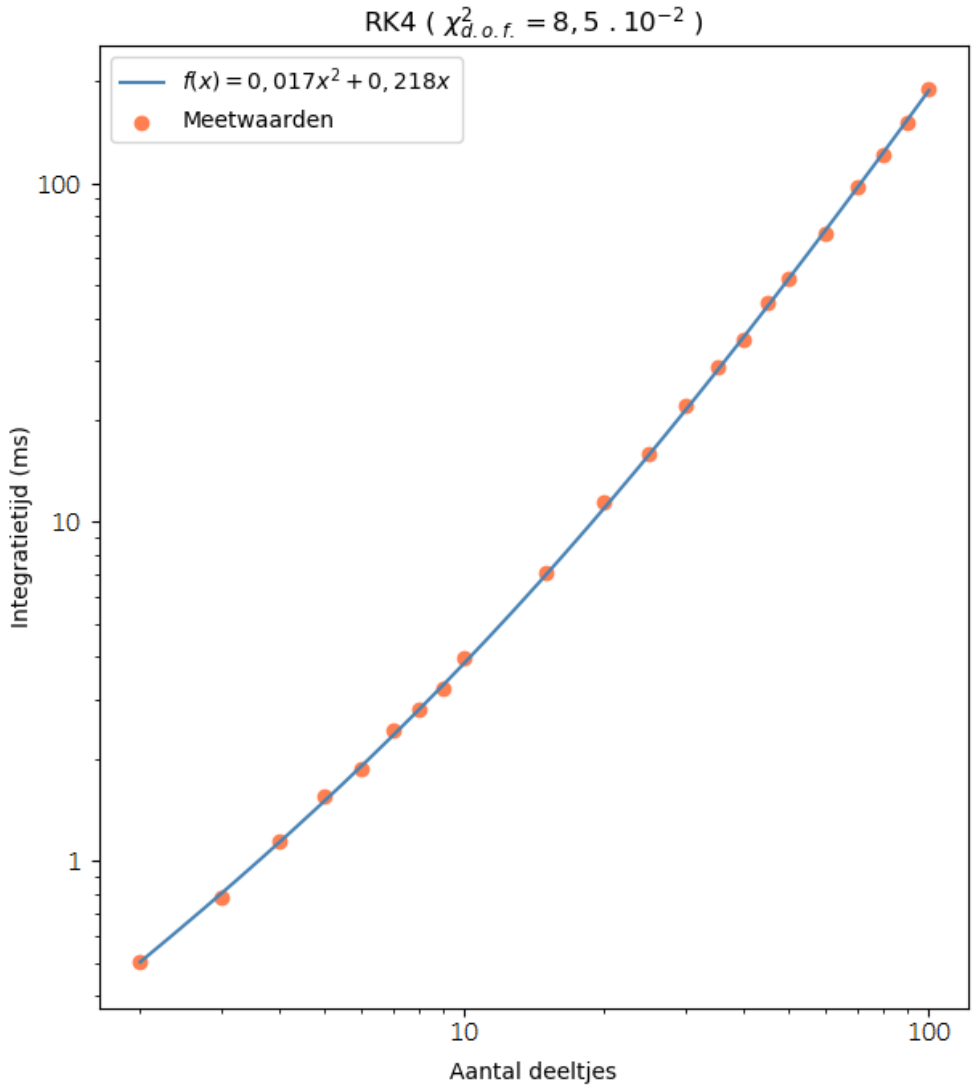
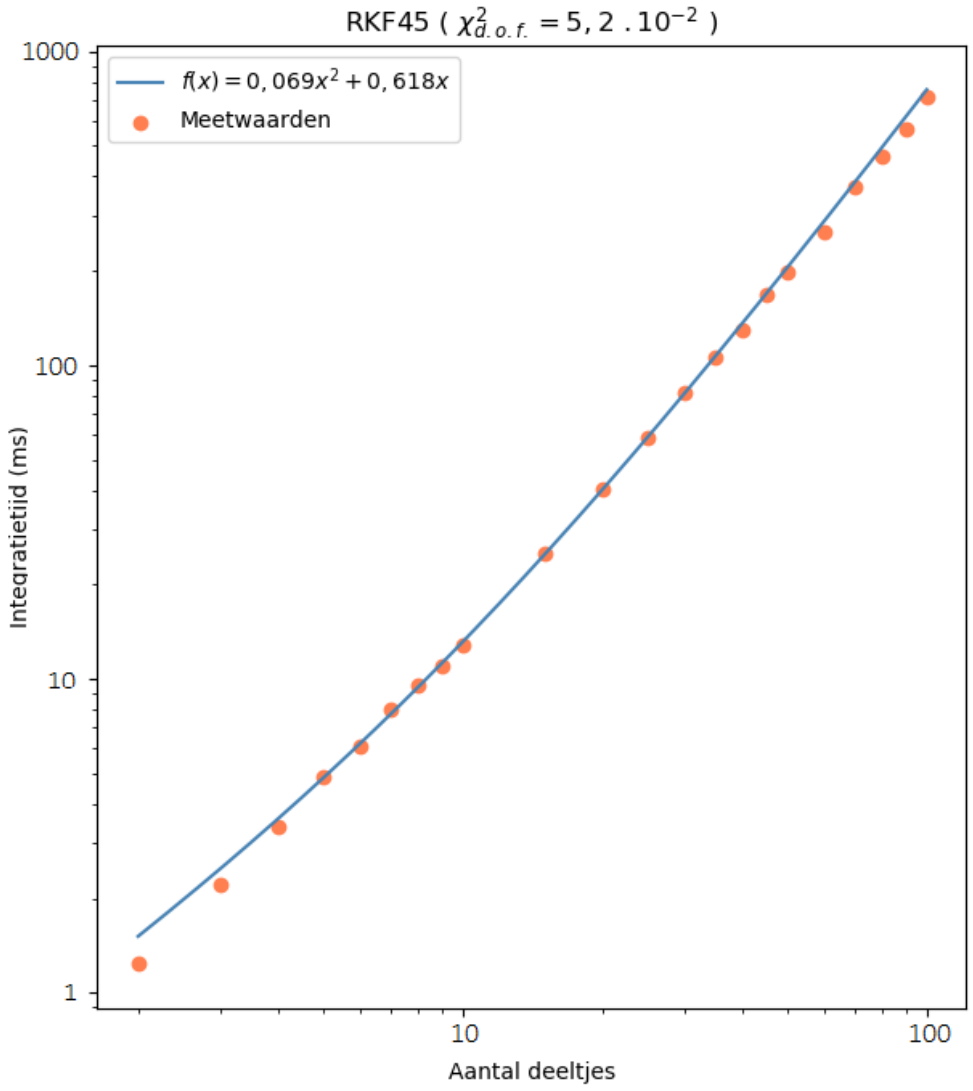
Integratietijd van simulatie in functie van aantal deeltjes





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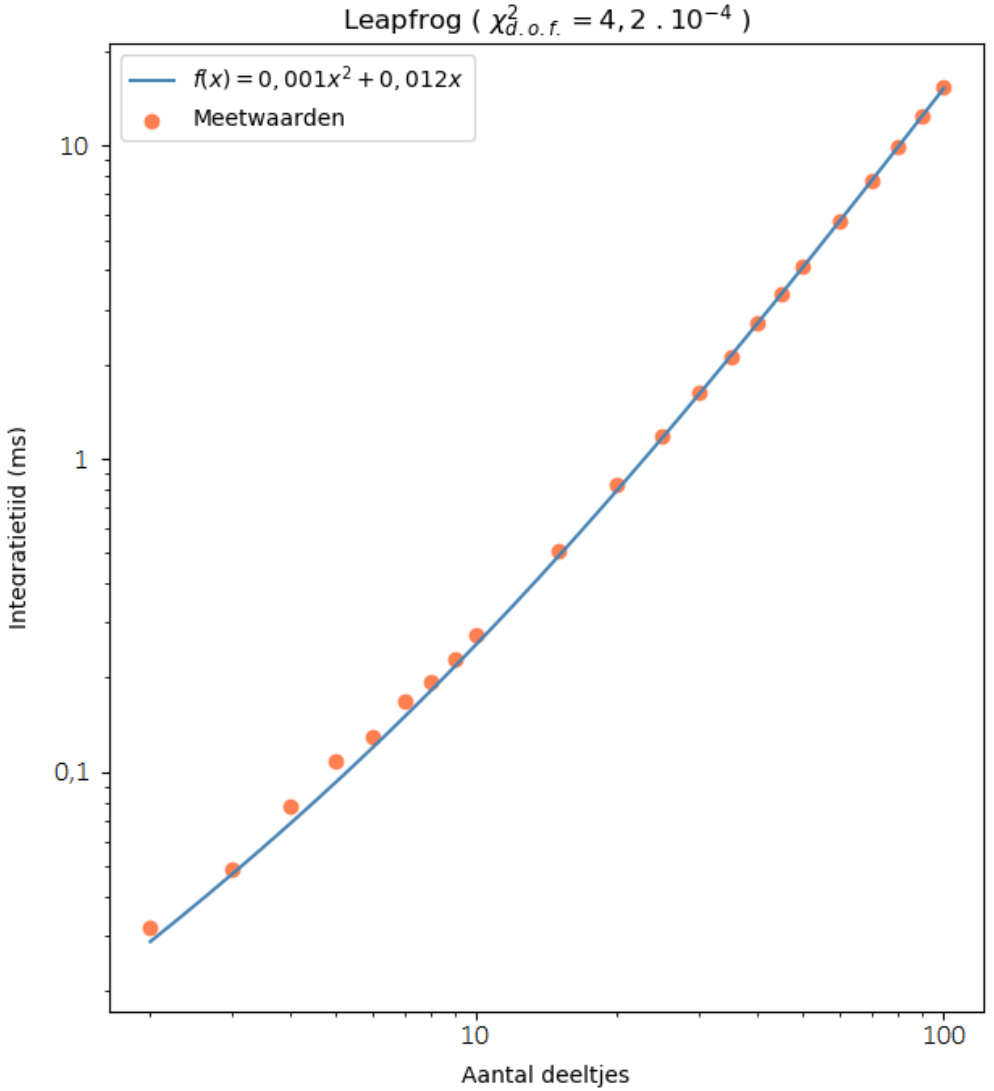
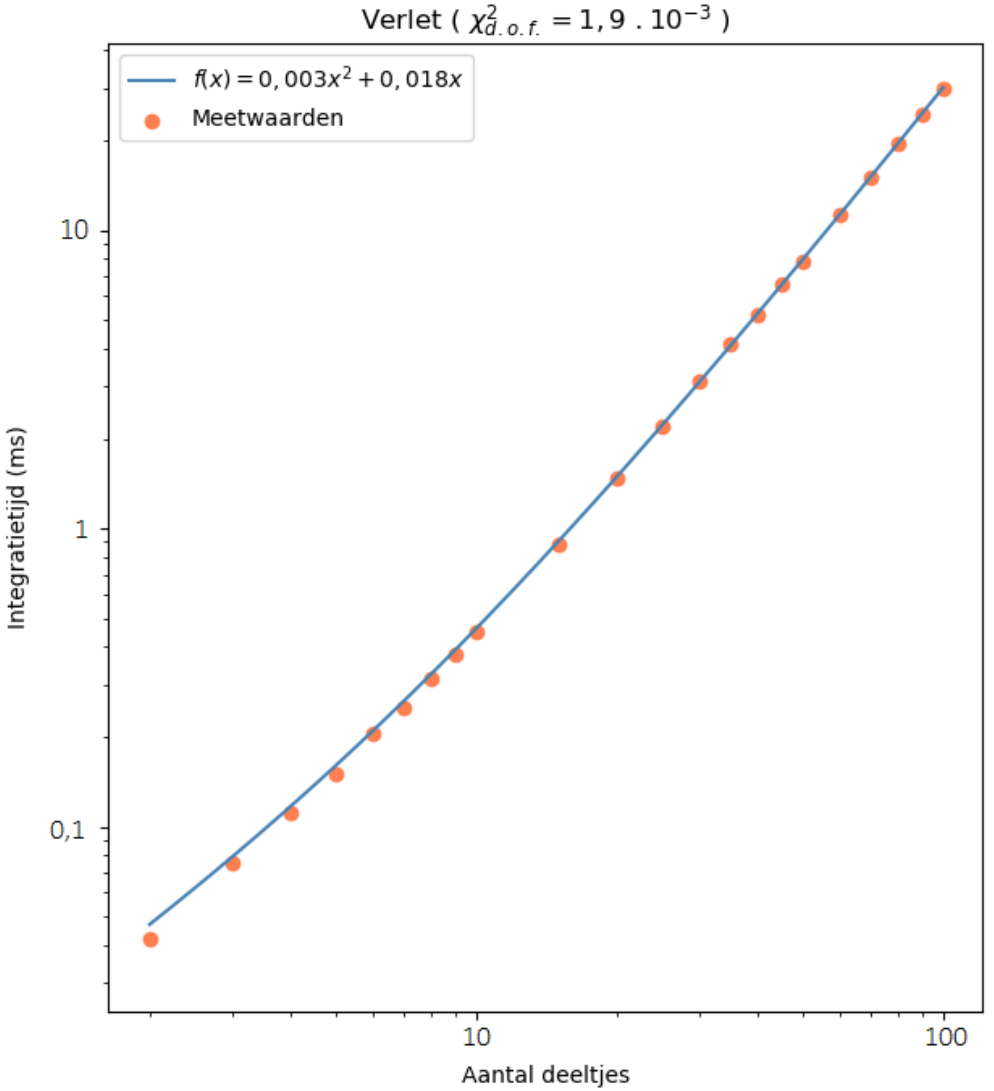
Integratietijd van simulatie in functie van aantal deeltjes





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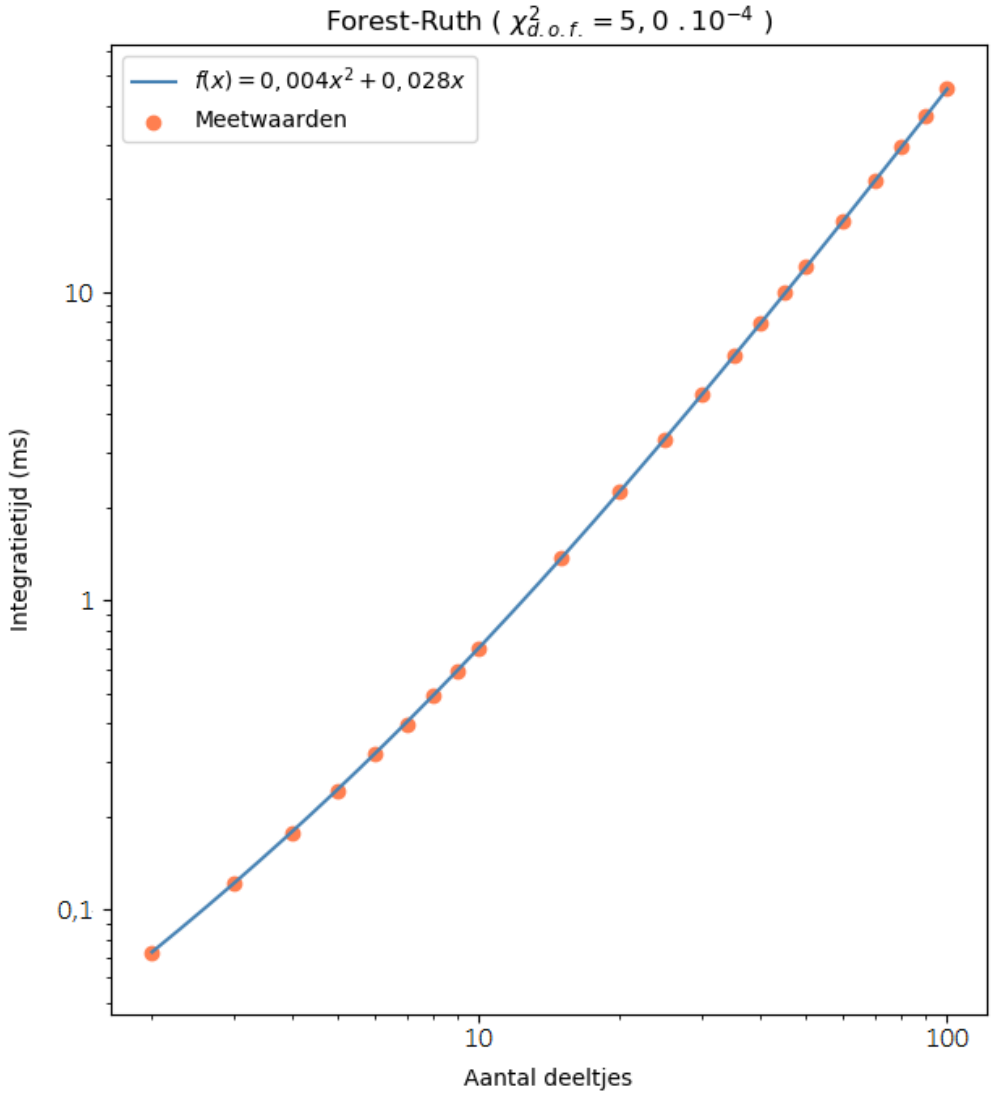
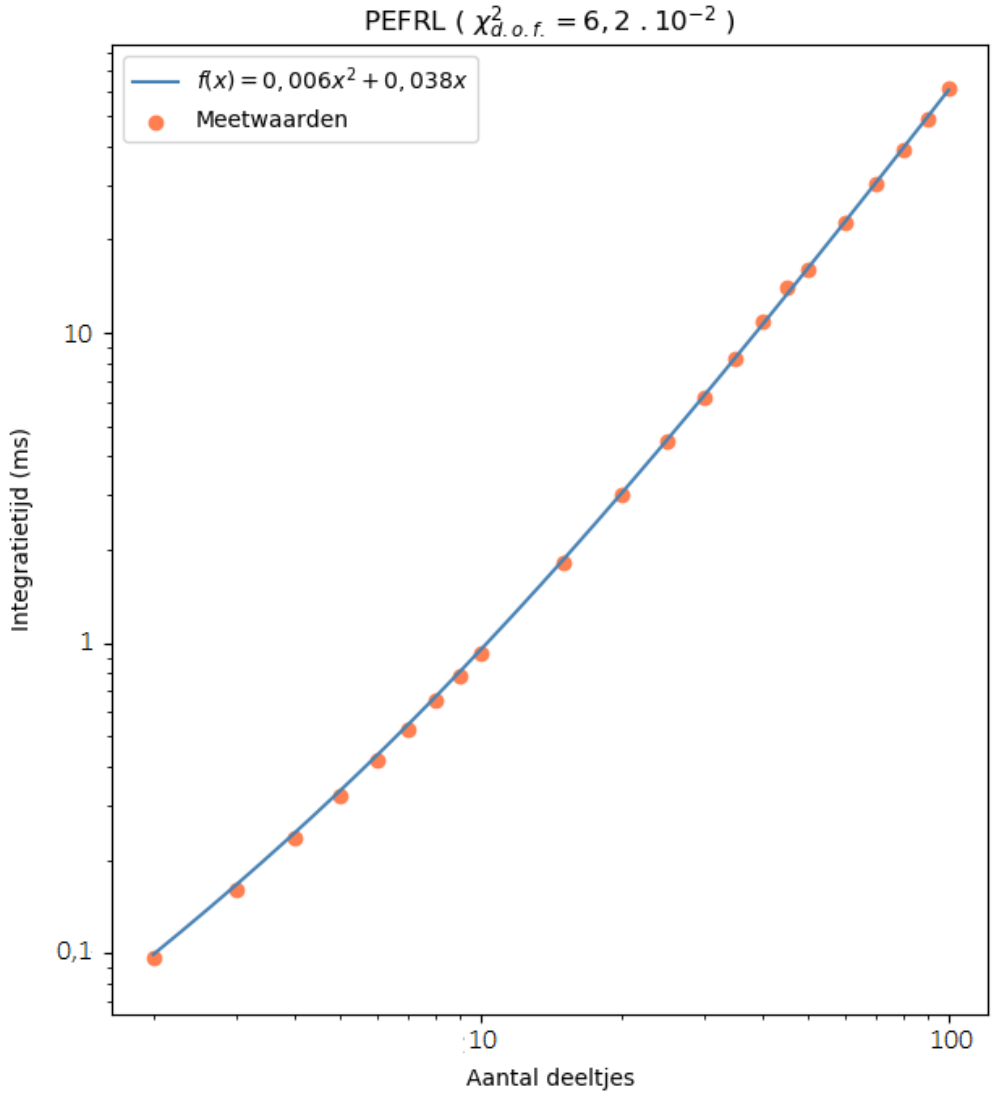
Integratietijd van simulatie in functie van aantal deeltjes





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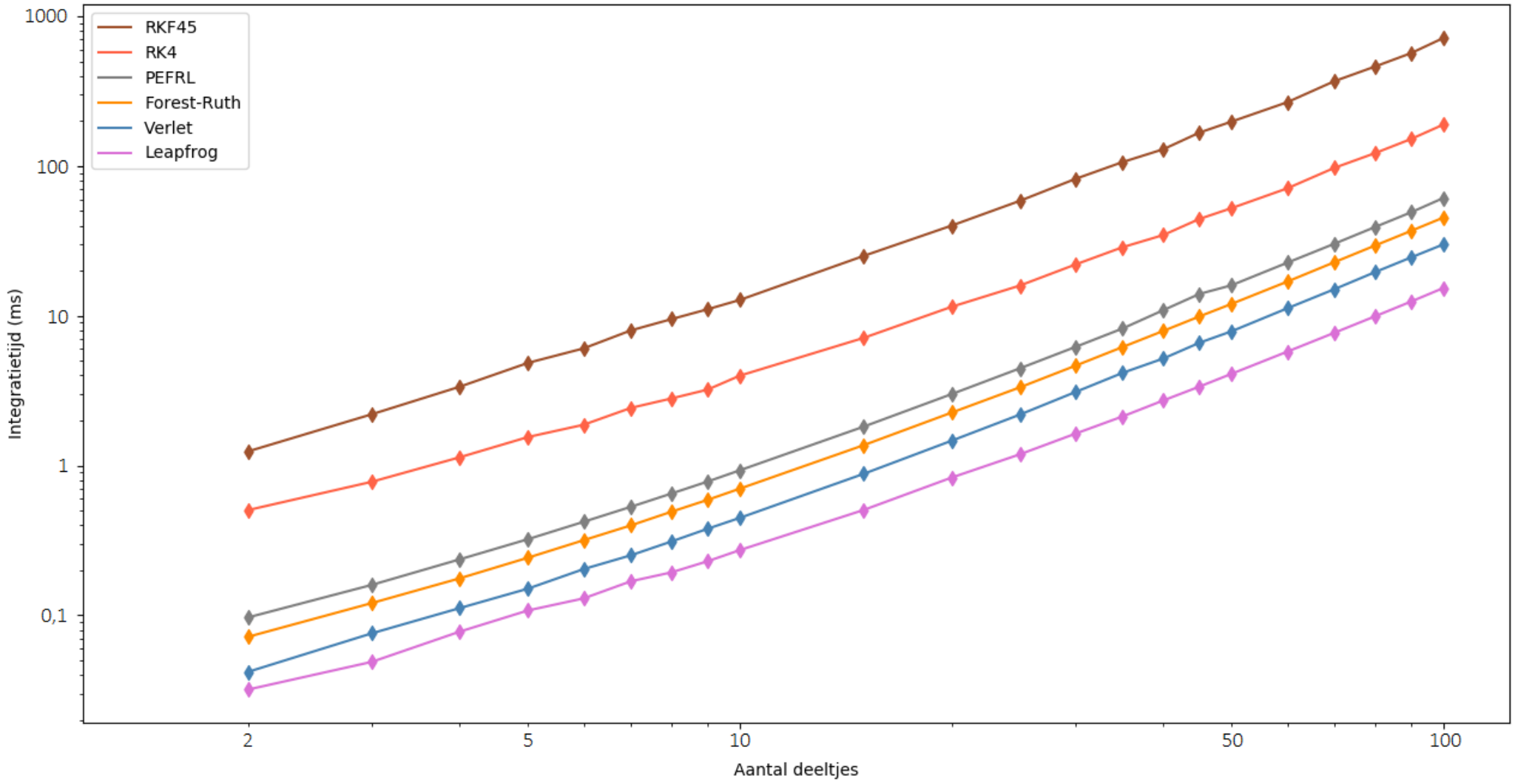
Vergelijking van de snelheden van de methodes



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Burrau's probleem

-Pythagoriaans 3-deeltjes probleem

-Veel close encounters

-Gebruik adaptieve tijdstap

-Controleer m.b.v. relatieve energiefout

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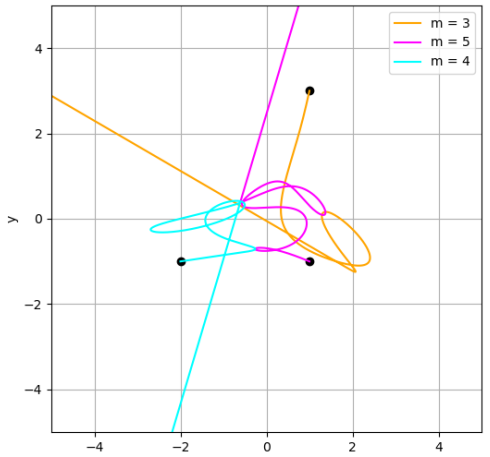
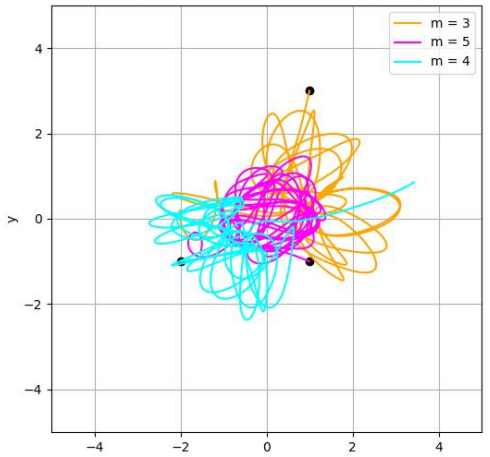
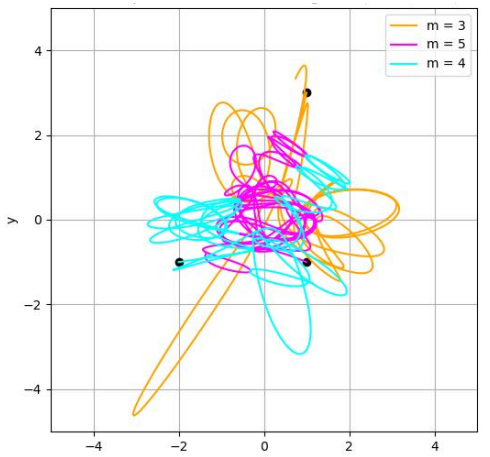
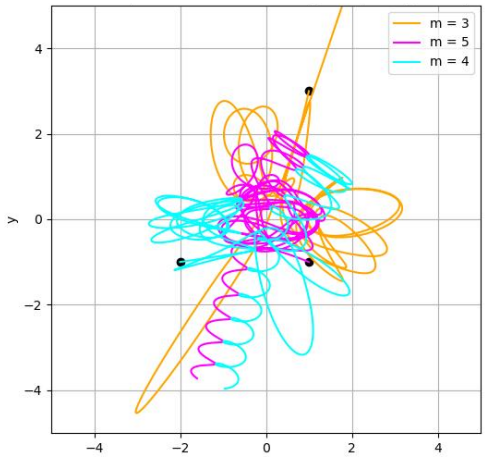
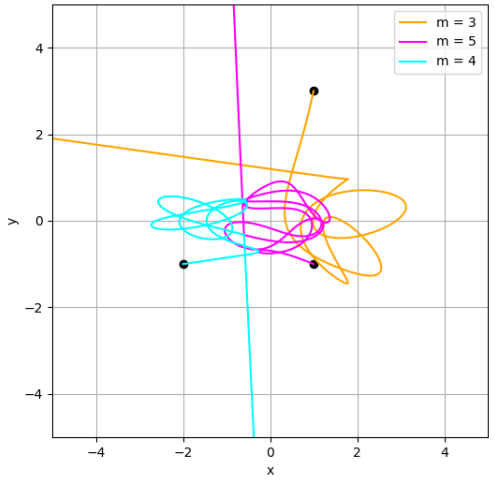
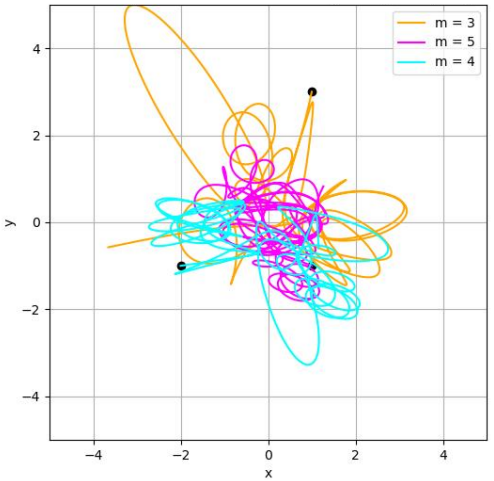
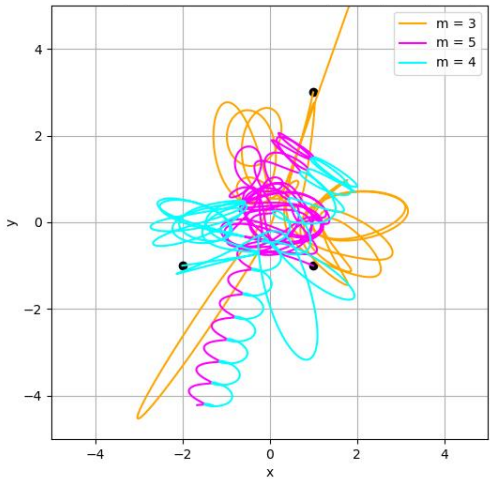
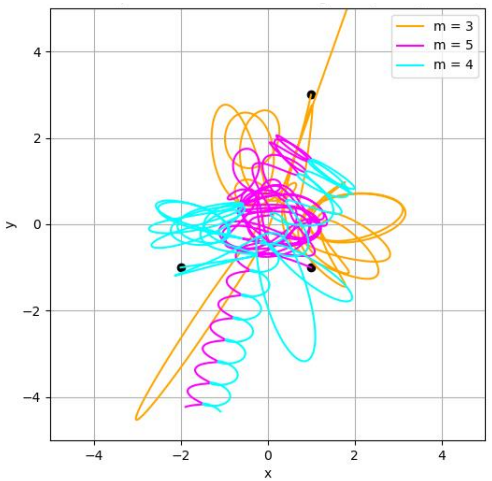
Burrau's probleem

	$h = 10^{-2}$	$h = 10^{-3}$	$h = 10^{-4}$	$h = 10^{-5}$
RK4				
PEFRL				

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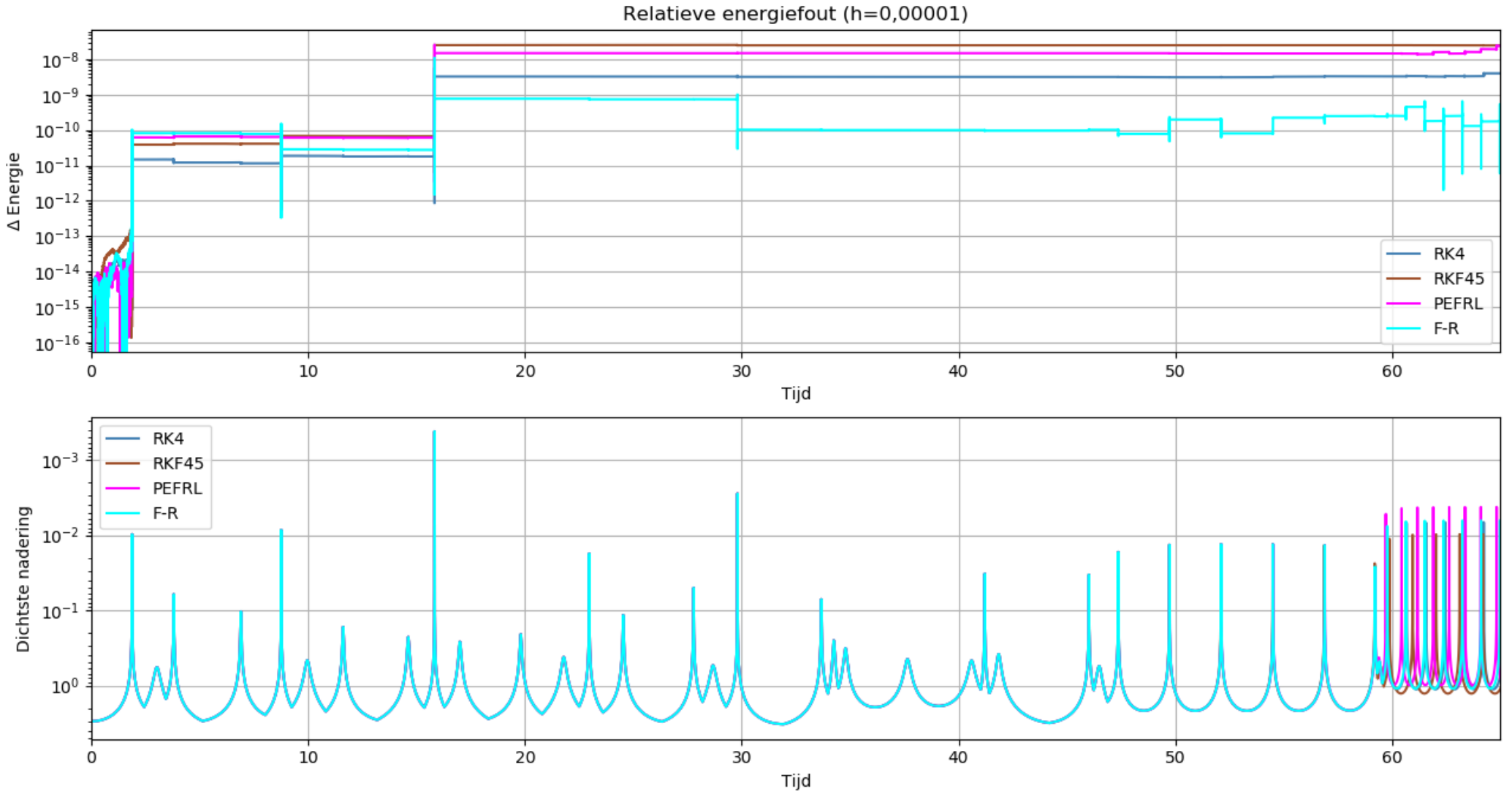
Burrau's probleem: vergelijking van de methodes



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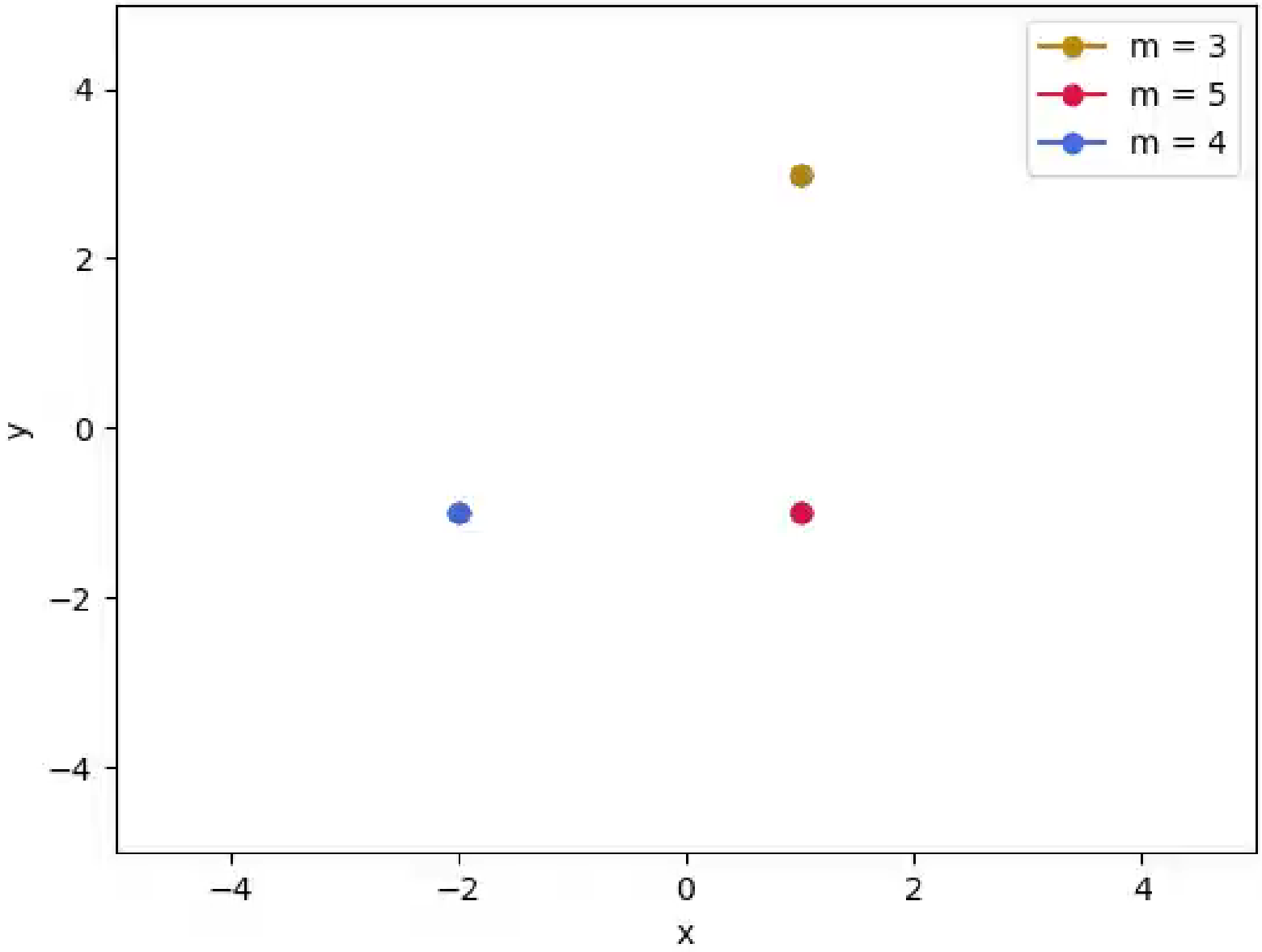
Burrau's probleem: PEFRL (h = 1.10^{-5})



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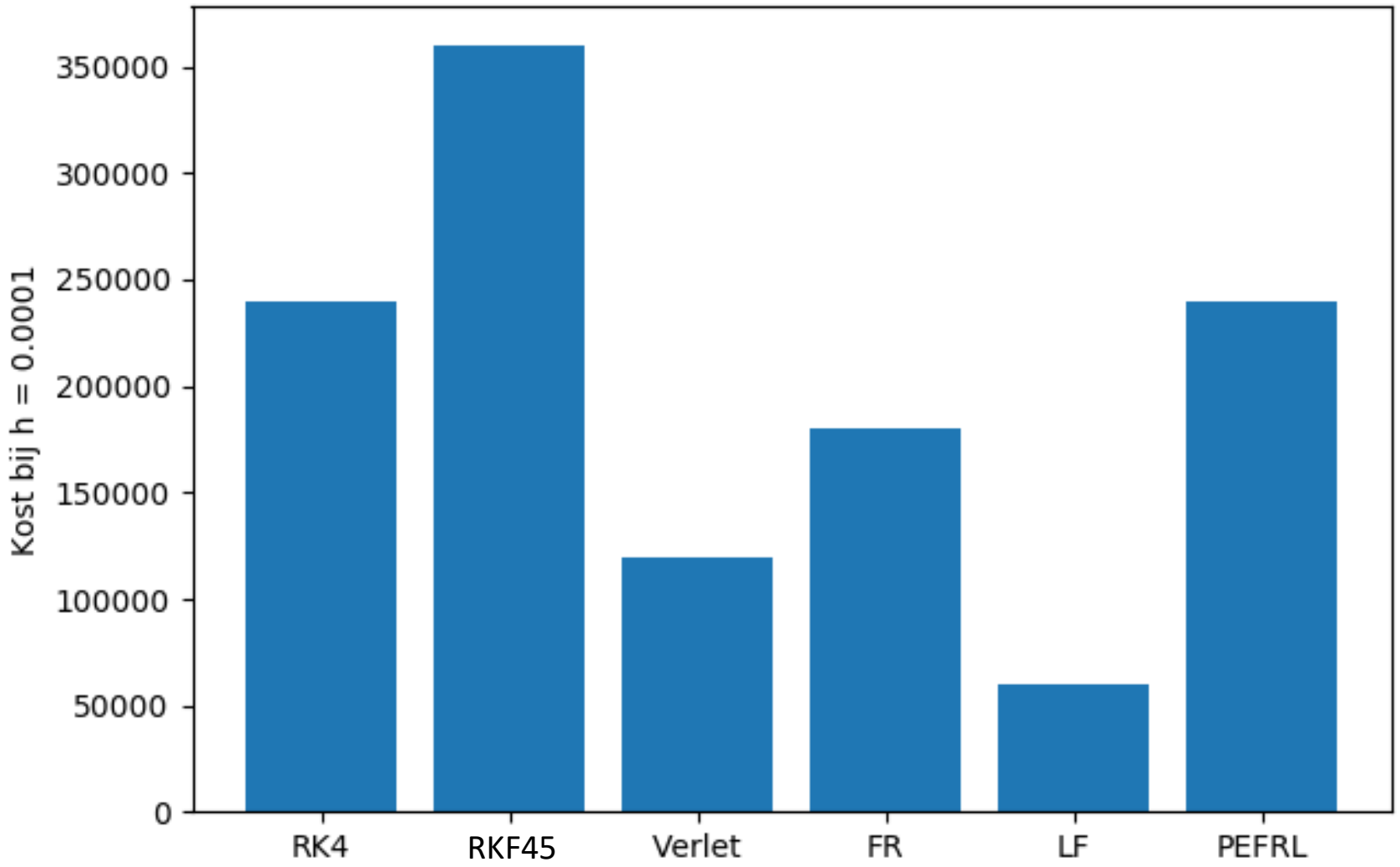
Kost versus nauwkeurigheid



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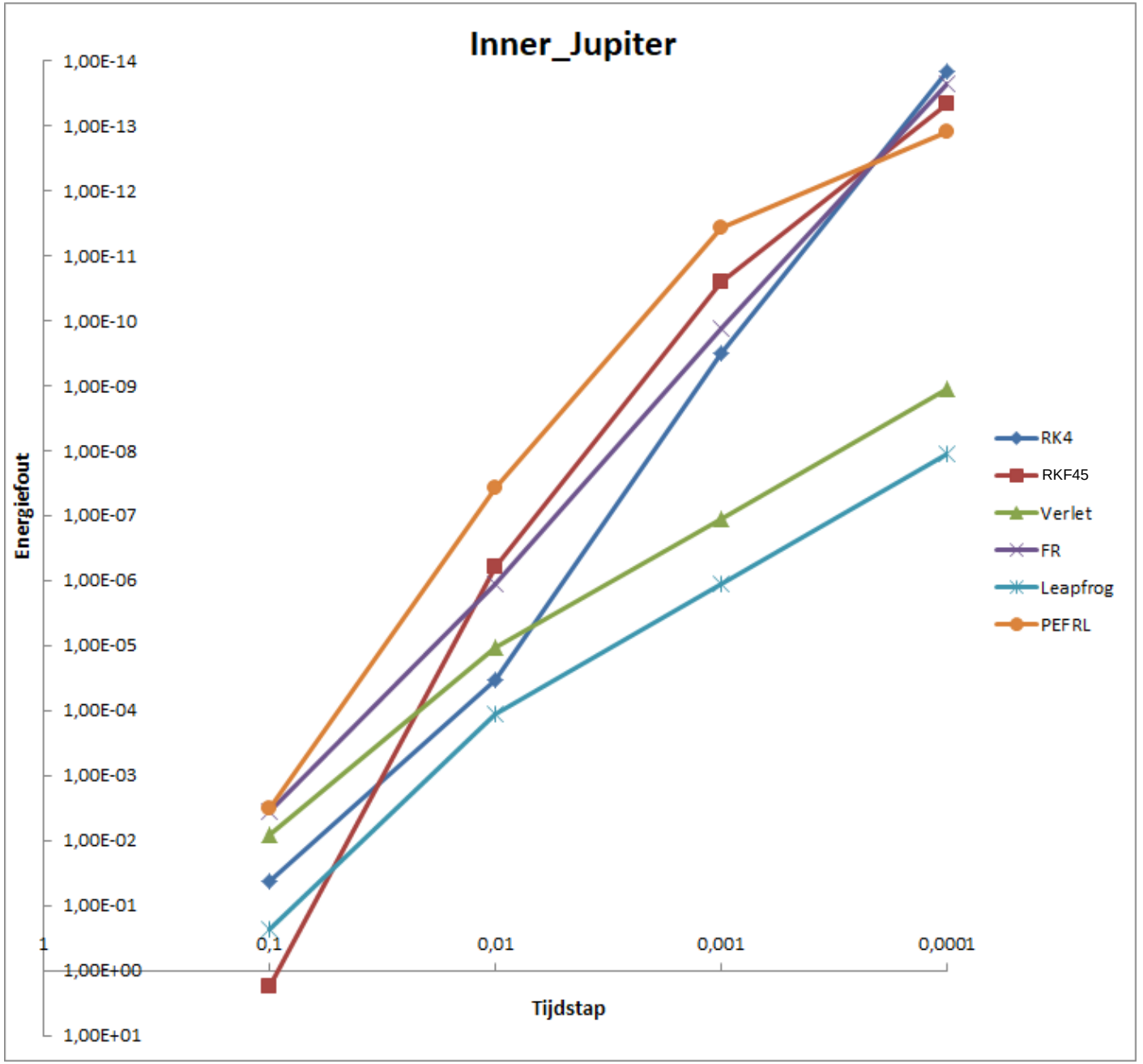

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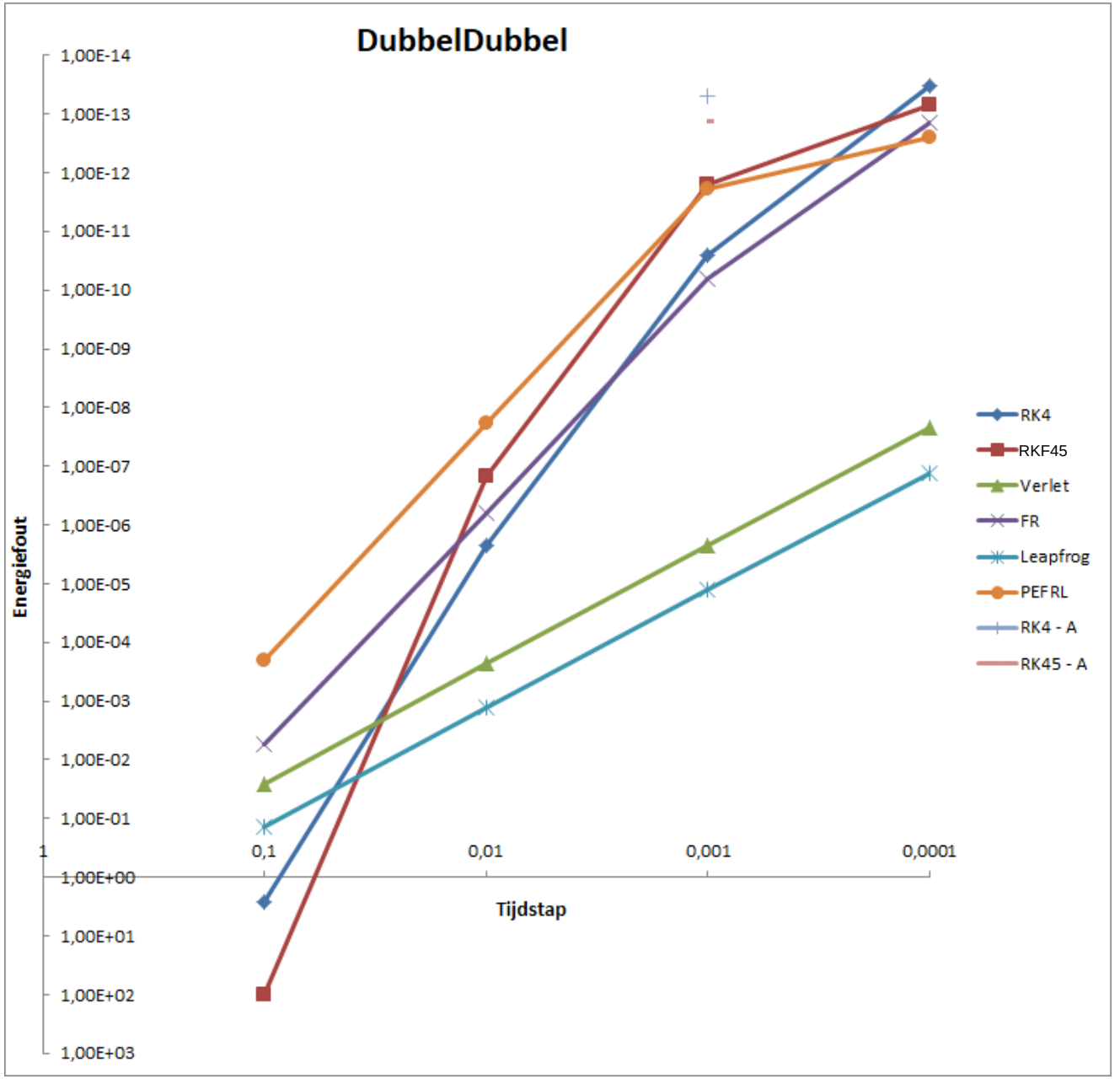

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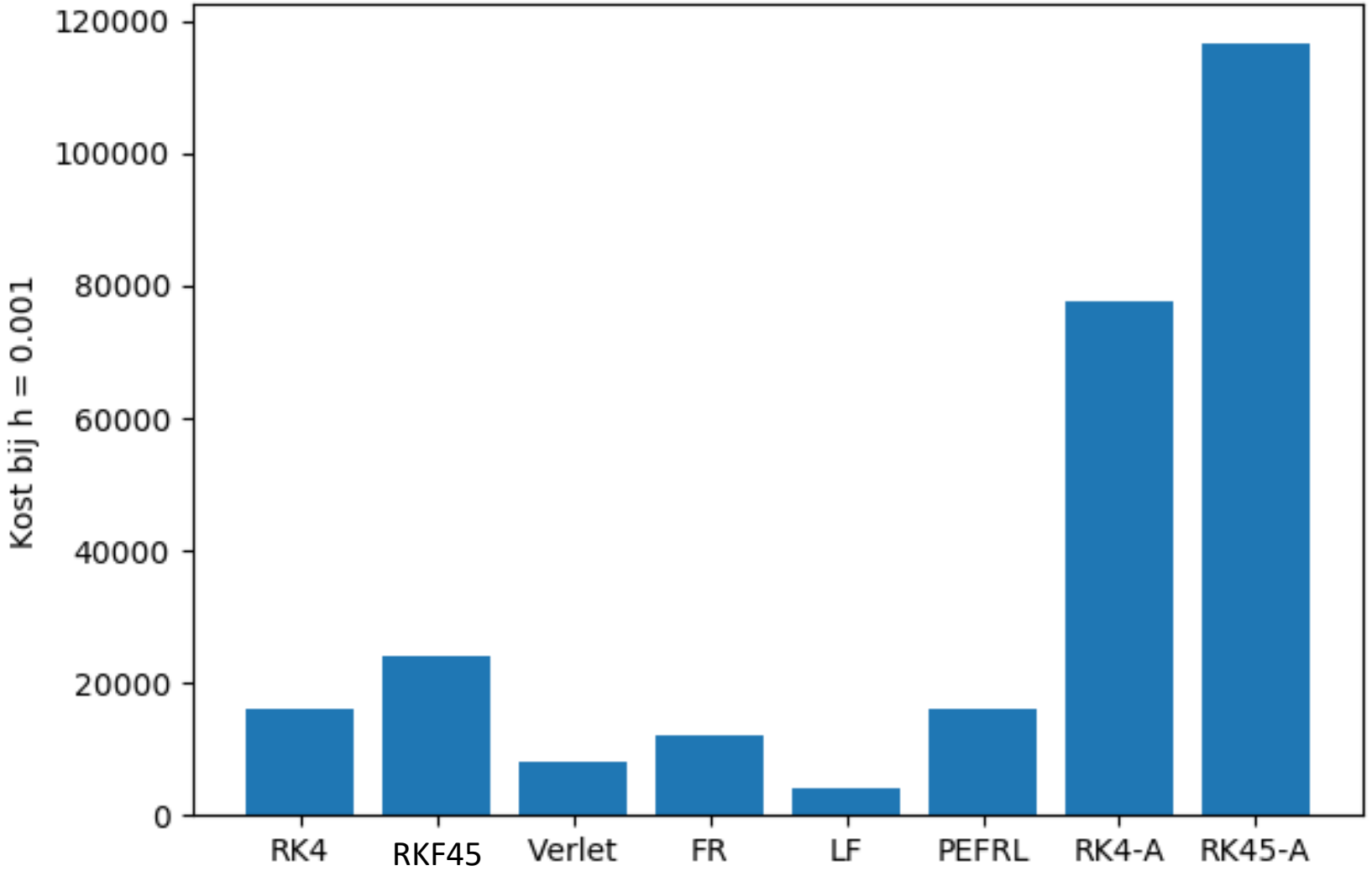

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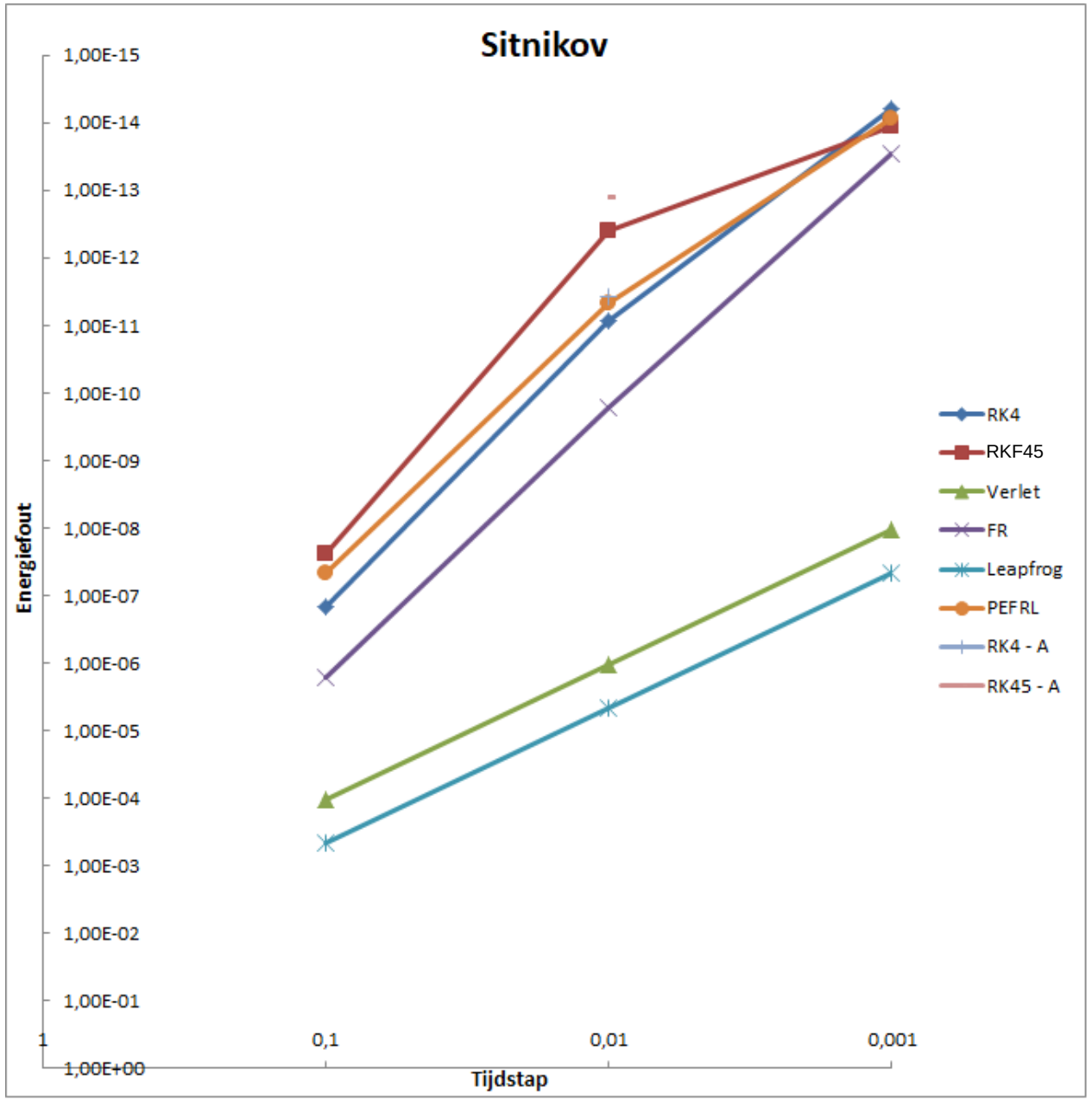

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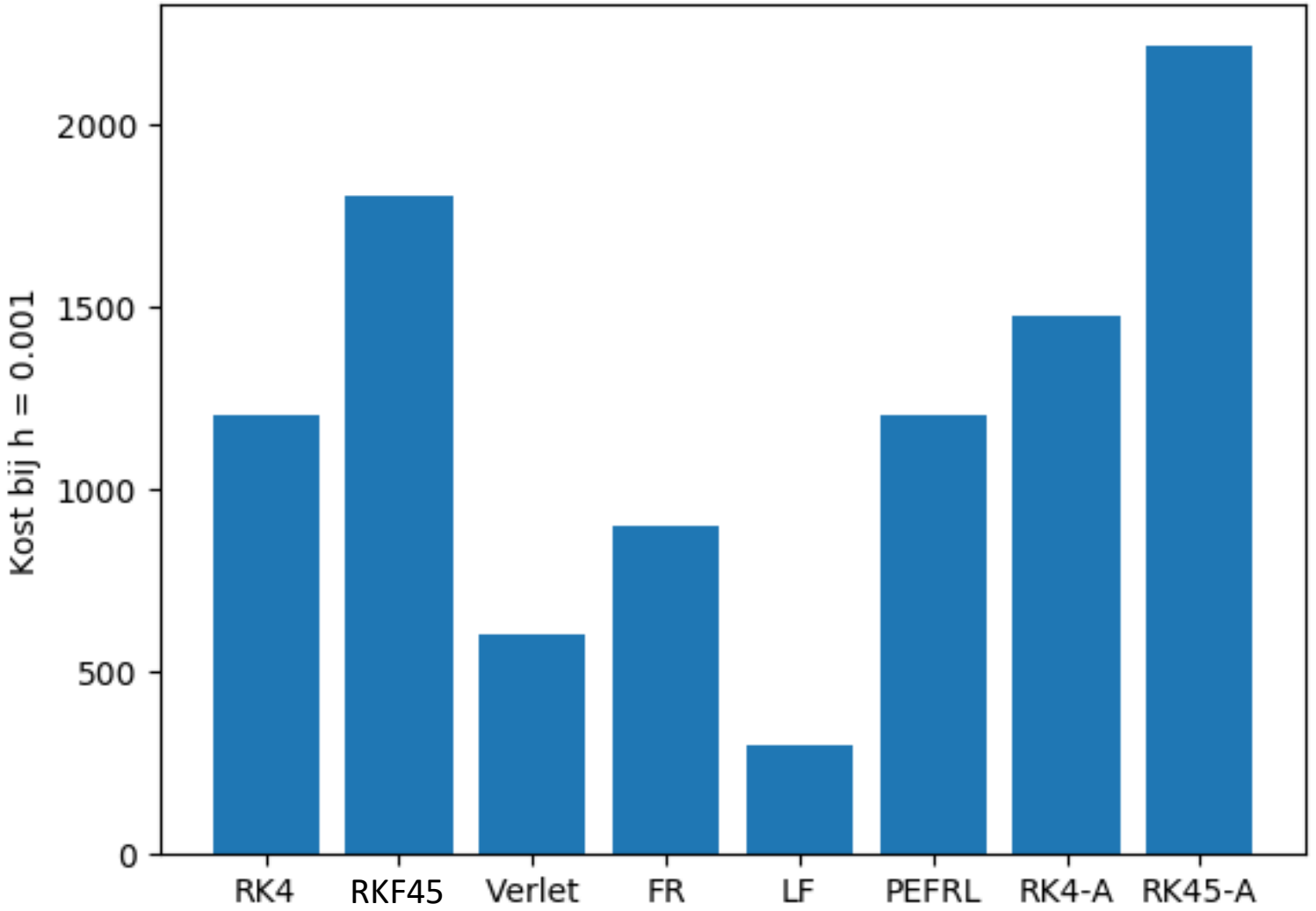

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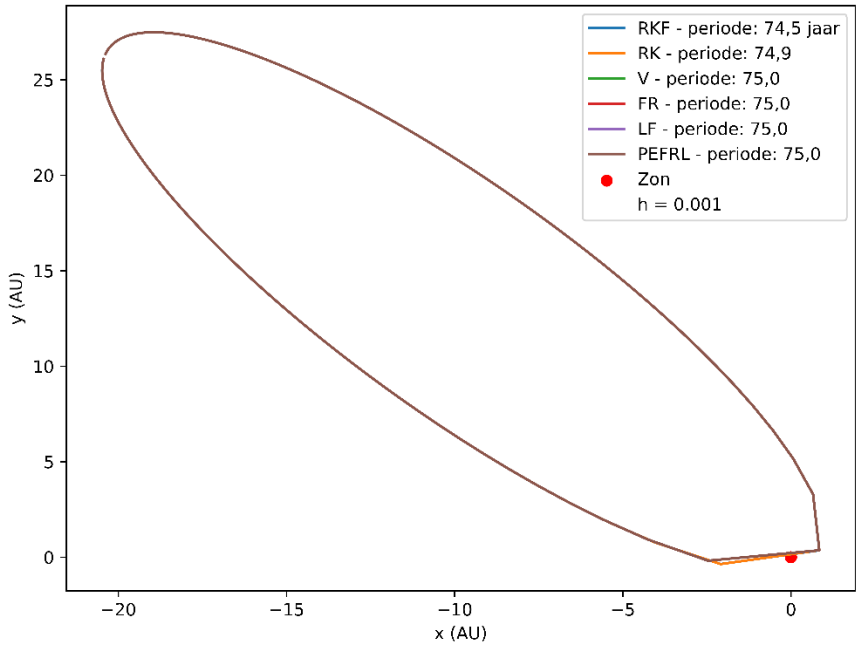
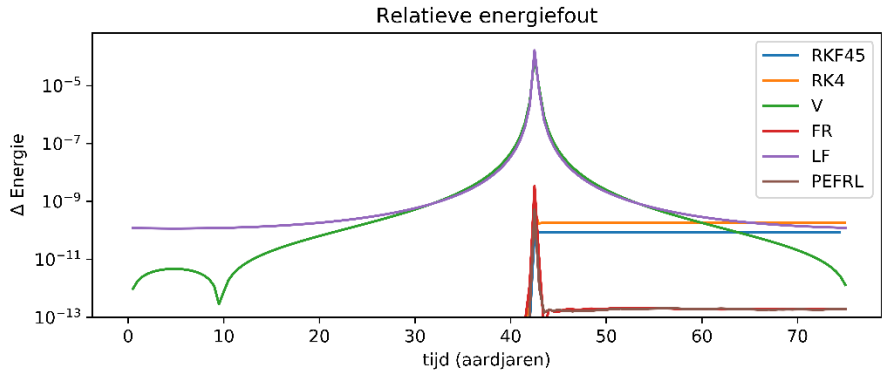
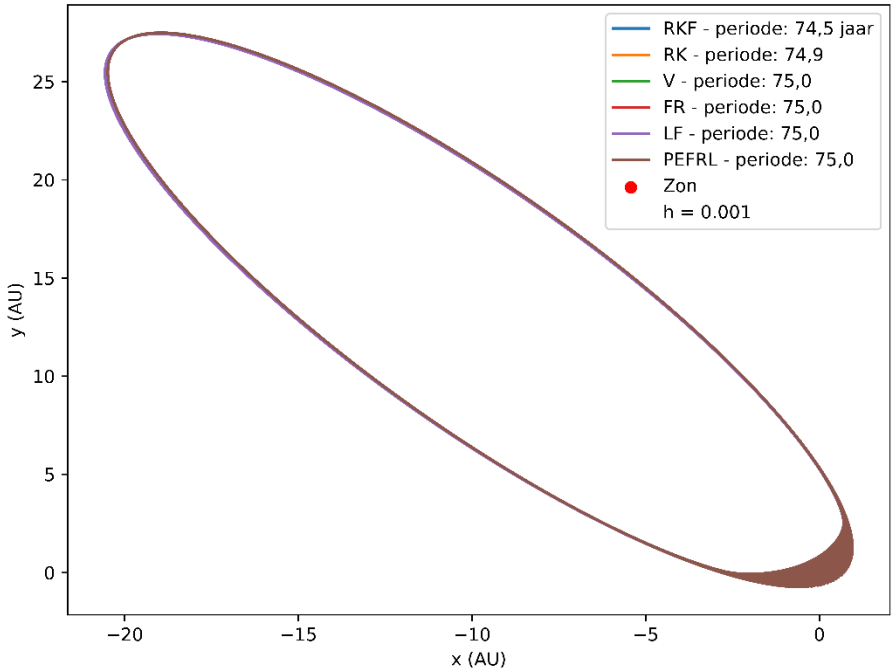
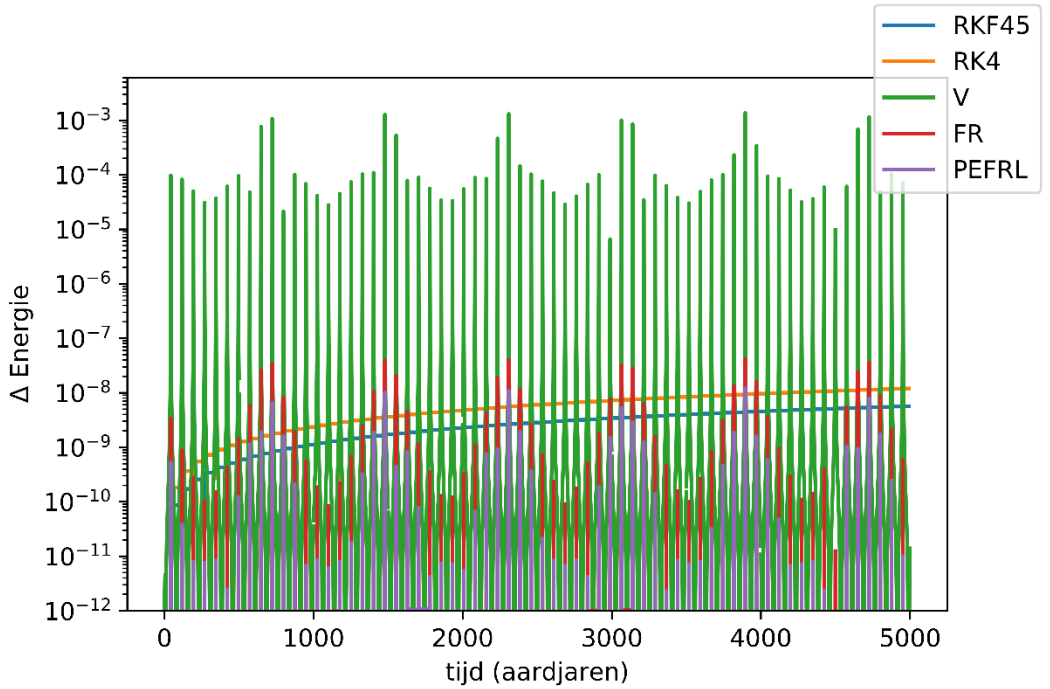
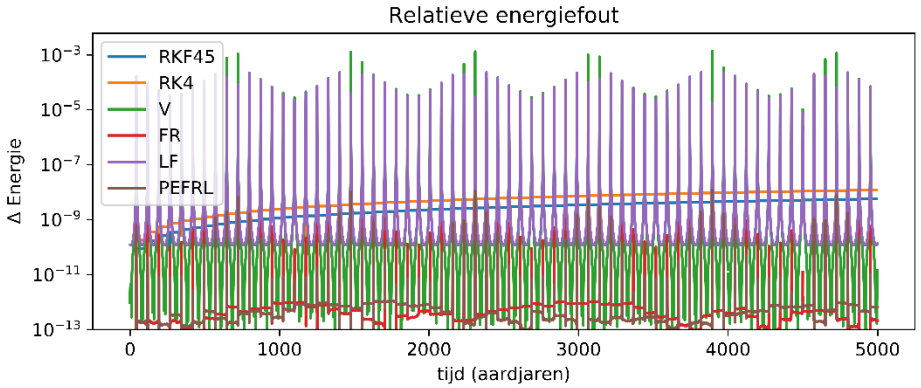
Eccentrisch 2-lichamen probleem

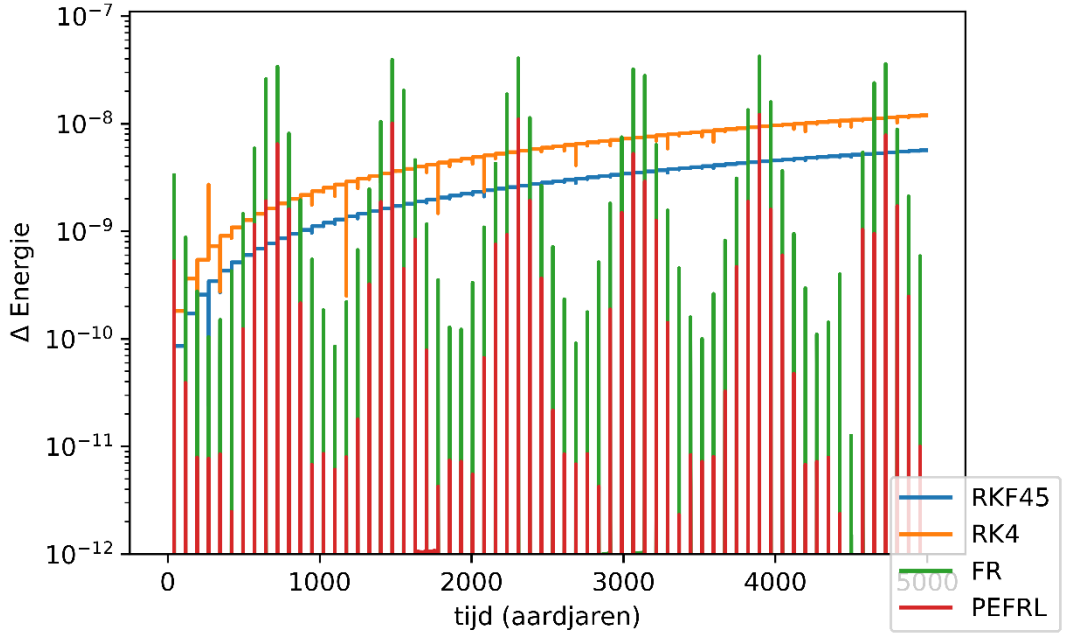





RKF - periode: 74,5 jaar
RK - periode: 74,9
V - periode: 75,0
FR - periode: 75,0
LF - periode: 75,0
PEFRL - periode: 75,0
Zon
h = 0.001
y (AU)
x (AU)


RKF45
RK4
V
FR
PEFRL
Δ Energie
tijd (aardjaren)


Relatieve energiefout
RKF45
RK4
V
FR
LF
PEFRL
Δ Energie
tijd (aardjaren)


RKF45
RK4
FR
PEFRL
Δ Energie
tijd (aardjaren)

UNIVERSITEIT
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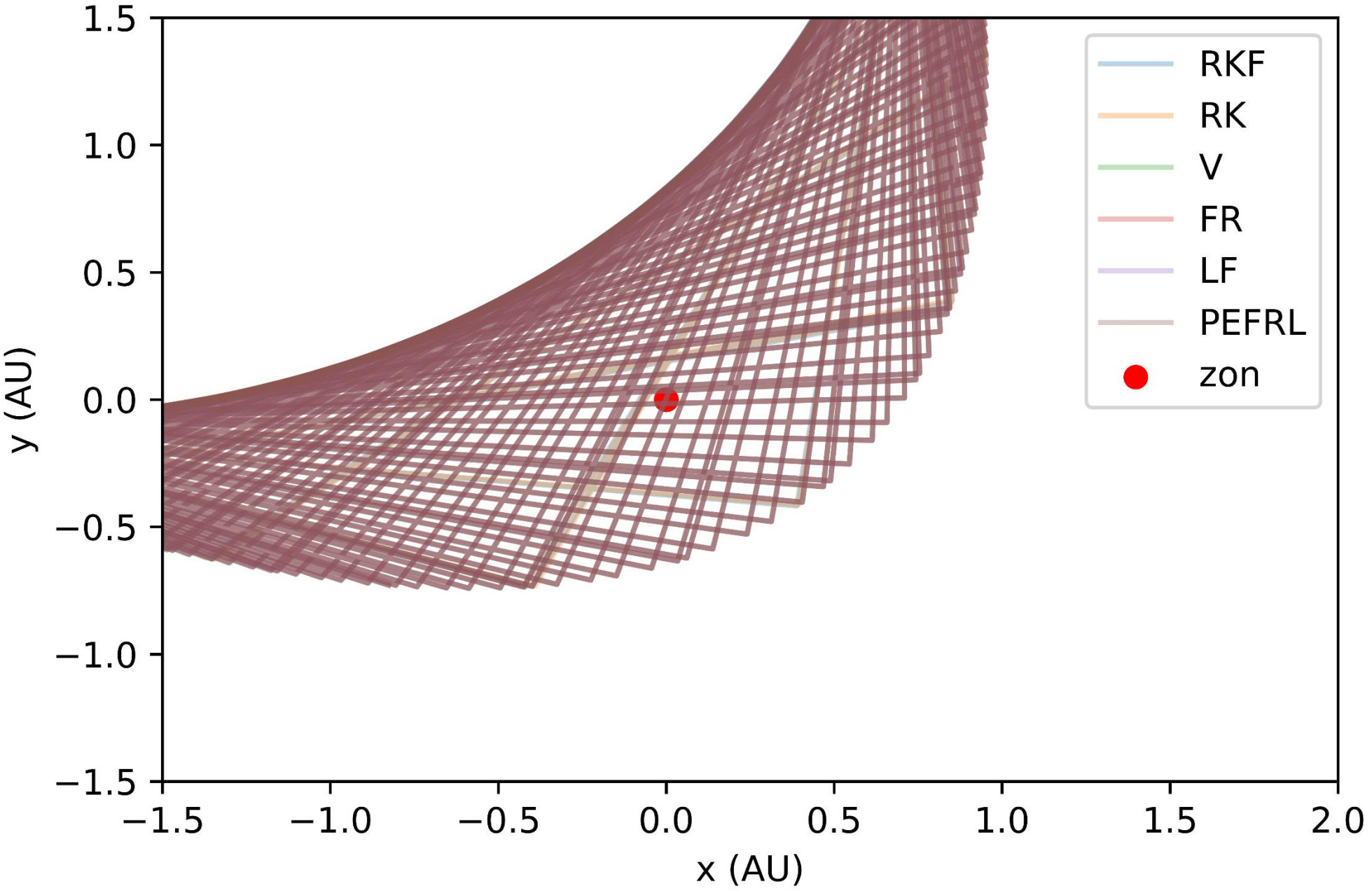

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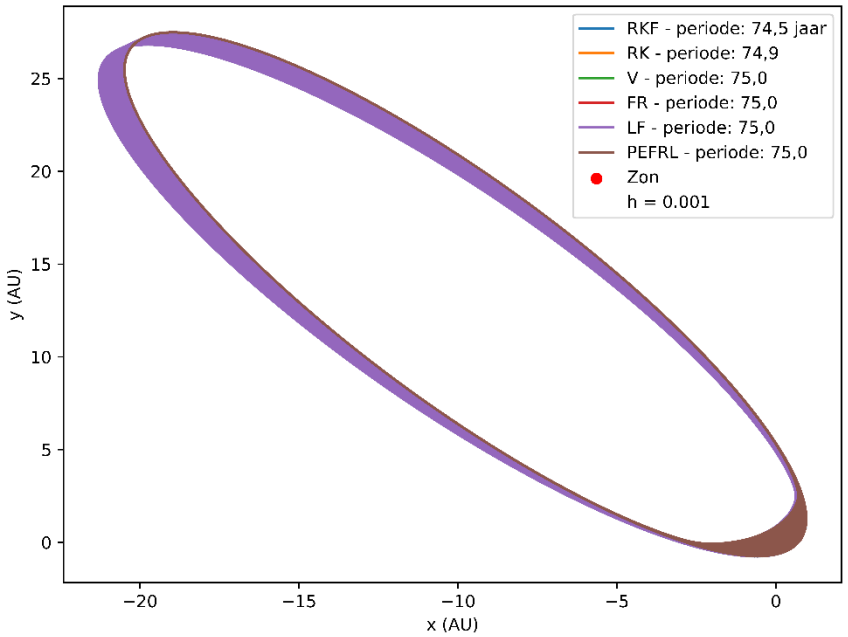

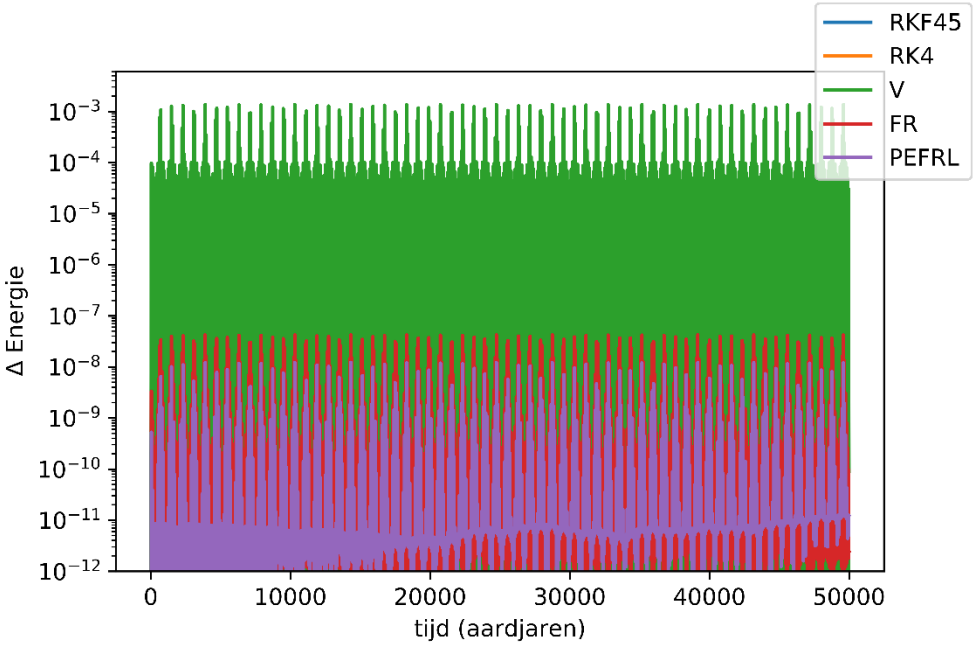

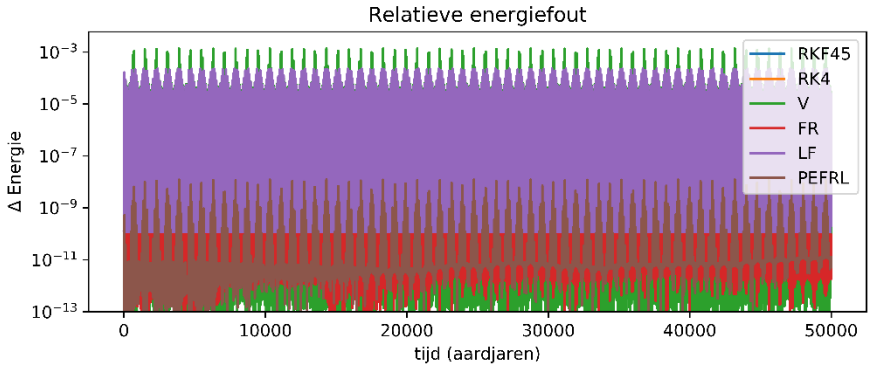

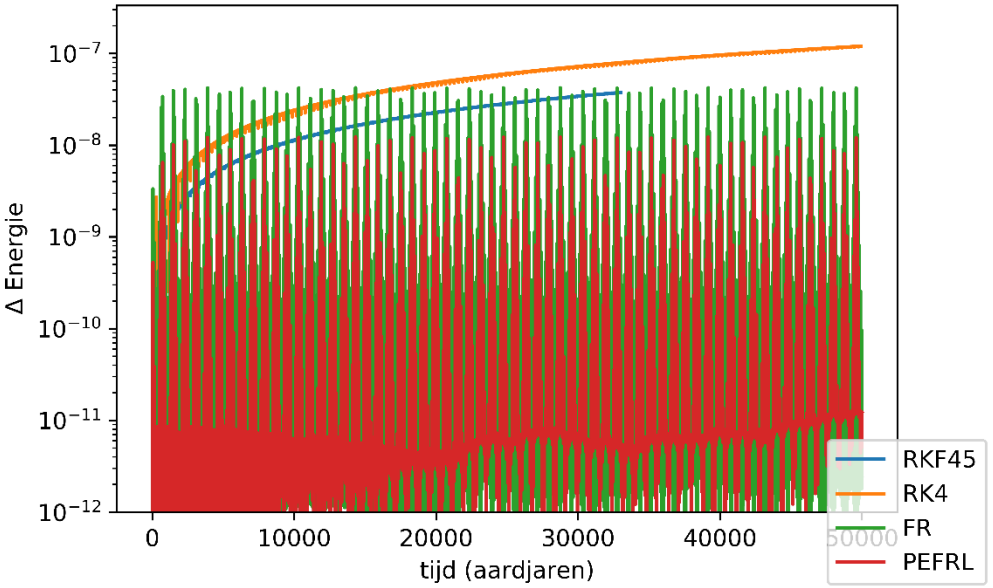

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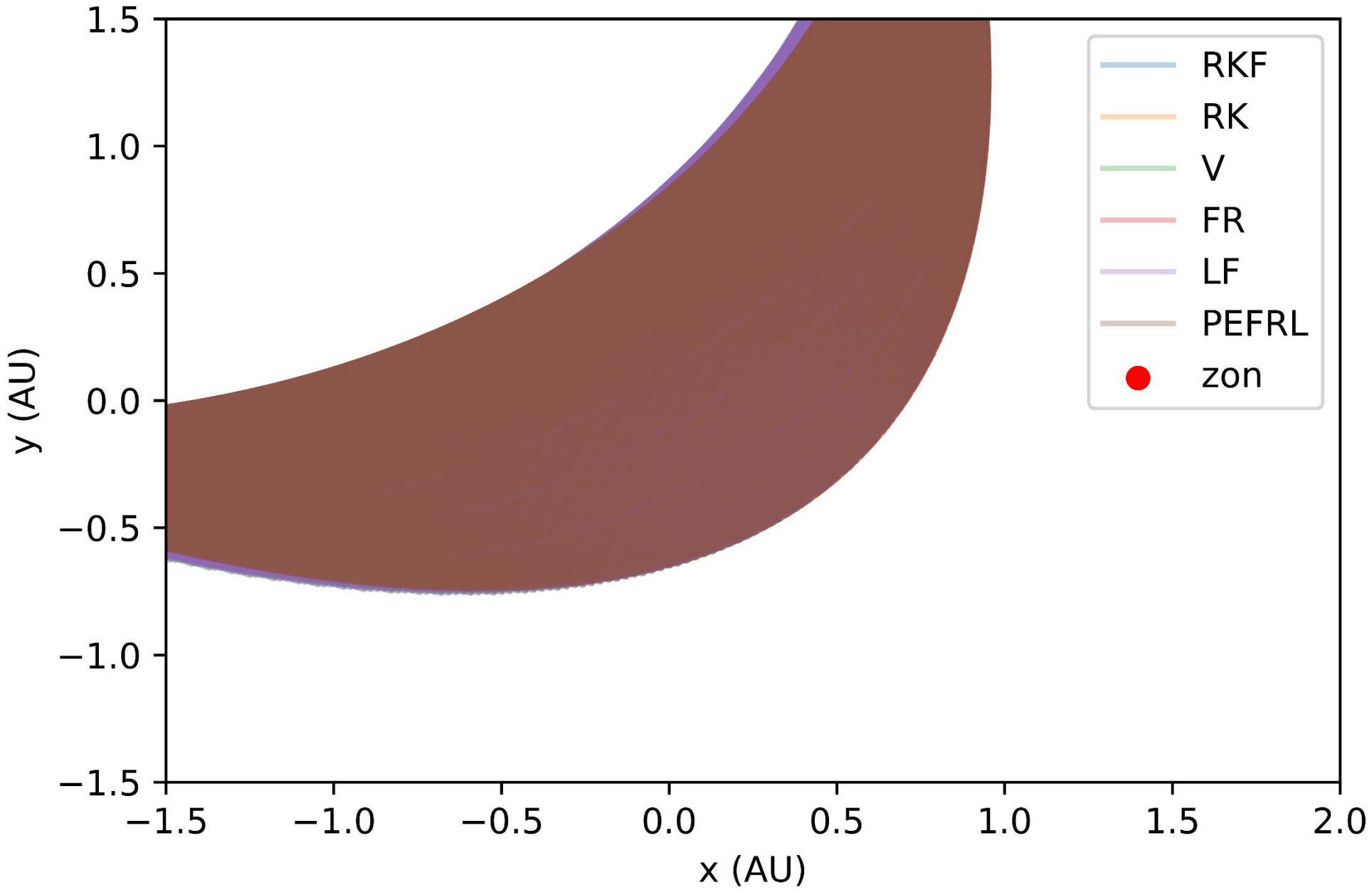
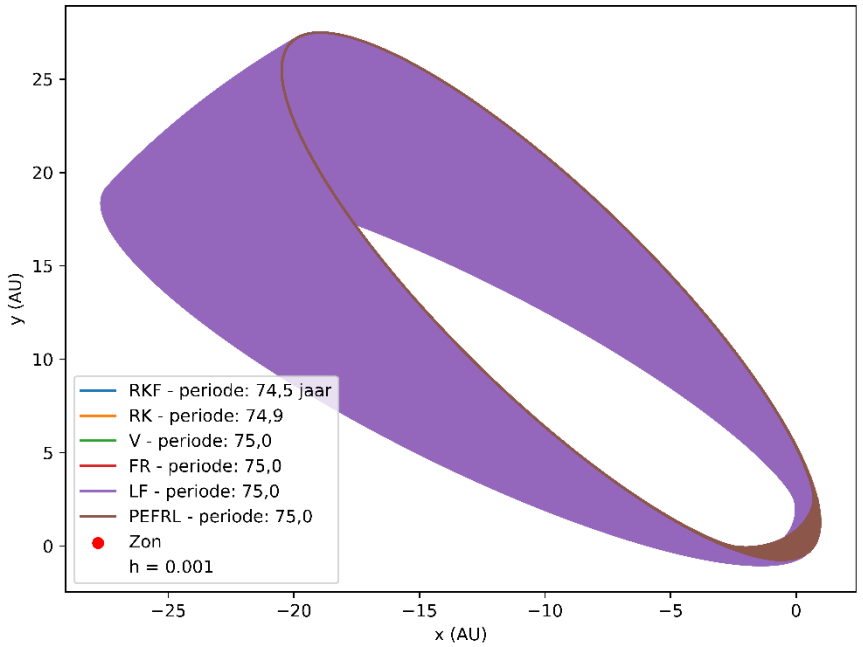
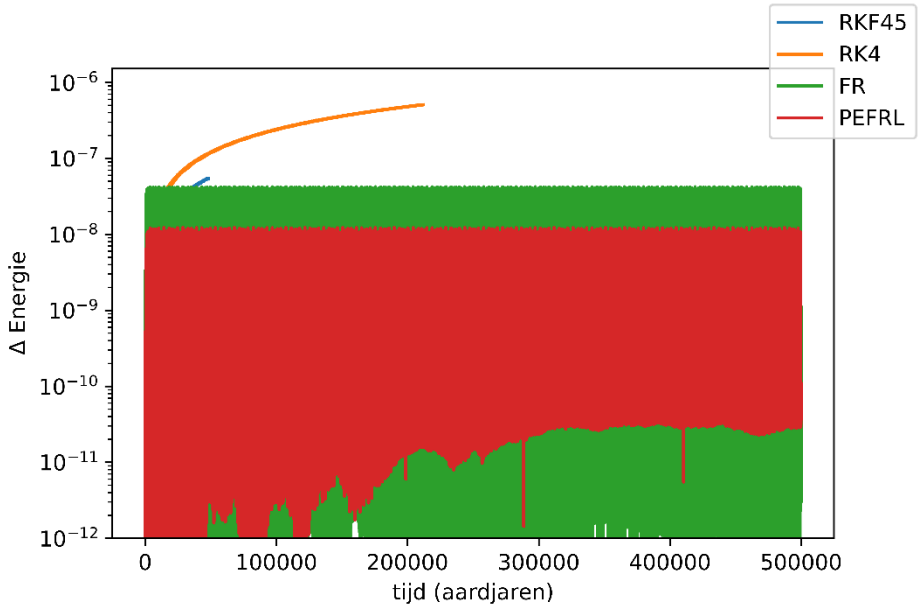
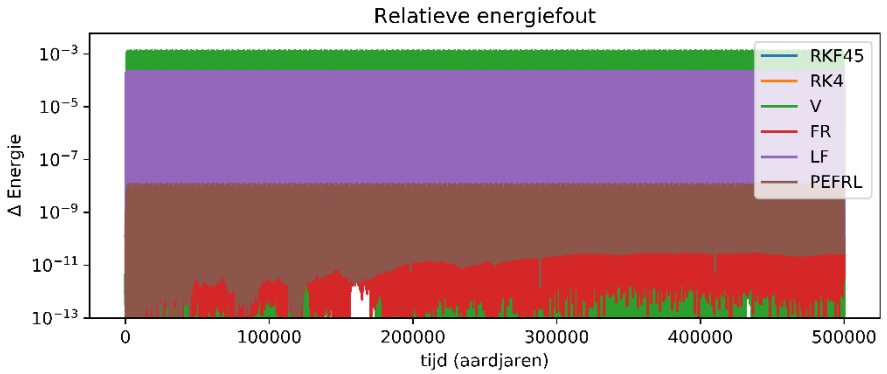
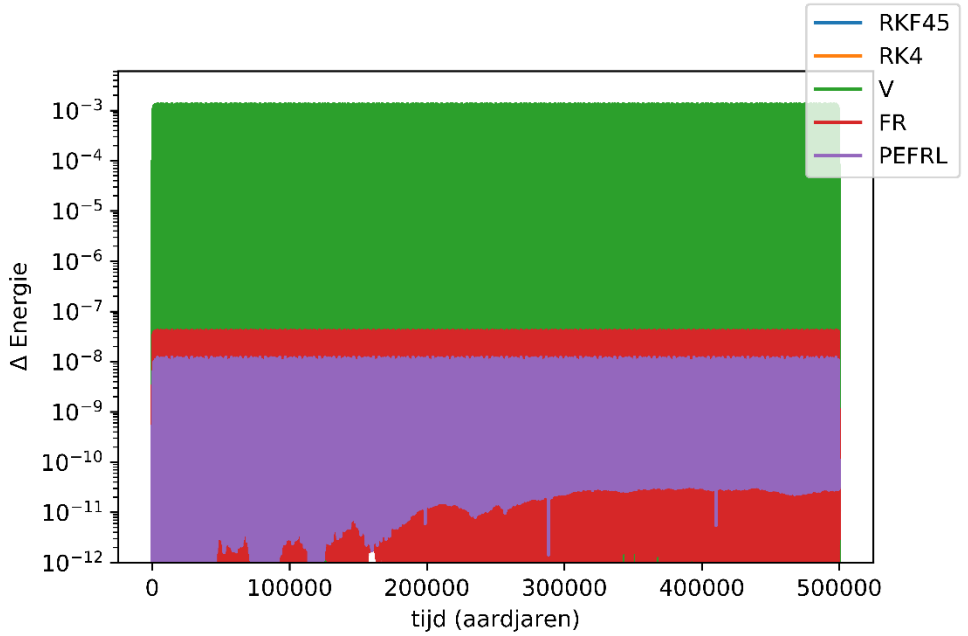



RKF - periode: 74,5 jaar
RK - periode: 74,9
V - periode: 75,0
FR - periode: 75,0
LF - periode: 75,0
PEFRL - periode: 75,0
Zon
h = 0.001
y (AU)
x (AU)


RKF45
RK4
FR
PEFRL
Δ Energie
tijd (aardjaren)


Relatieve energiefout
RKF45
RK4
V
FR
LF
PEFRL
Δ Energie
tijd (aardjaren)


RKF45
RK4
V
FR
PEFRL
Δ Energie
tijd (aardjaren)

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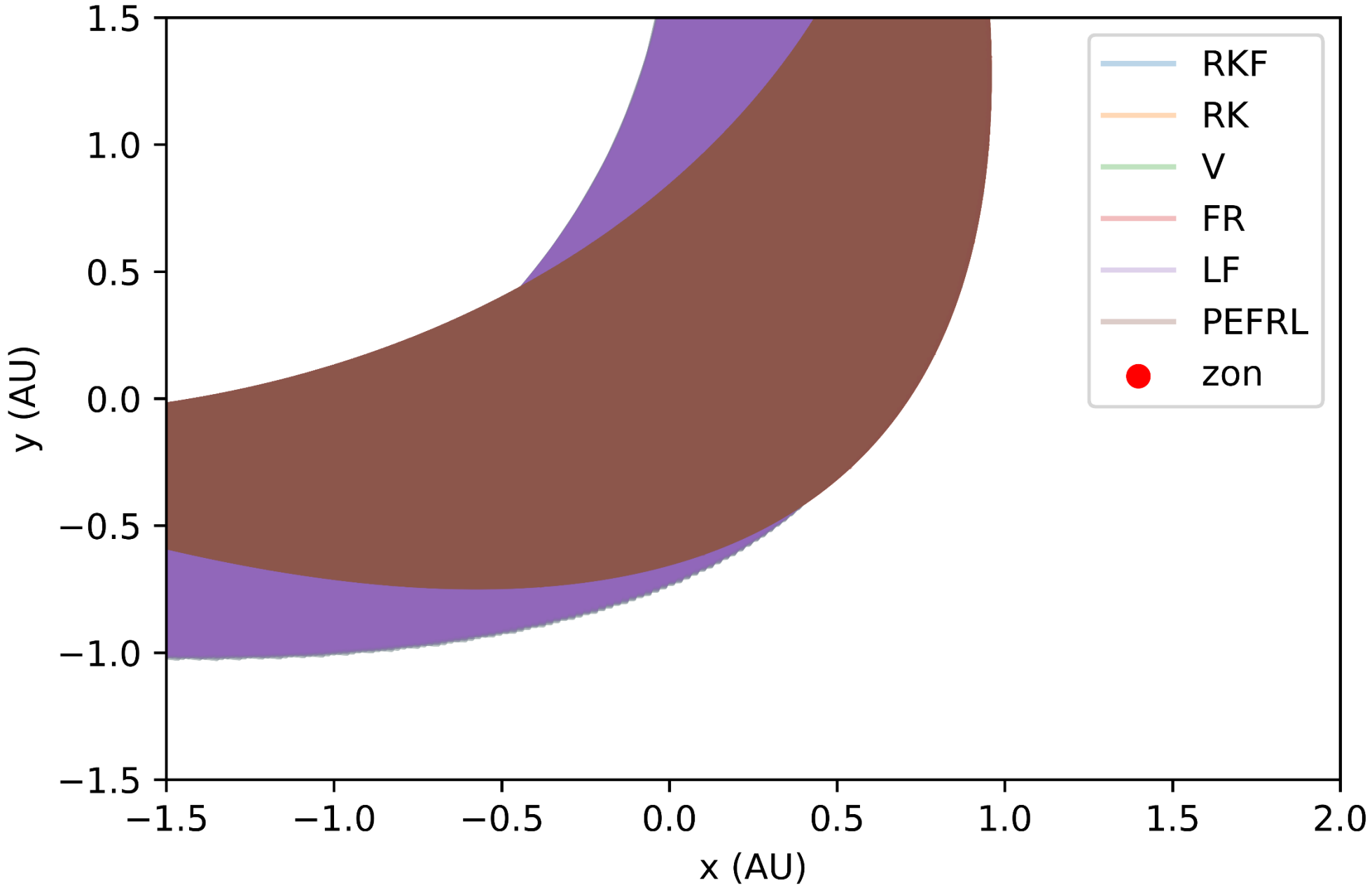
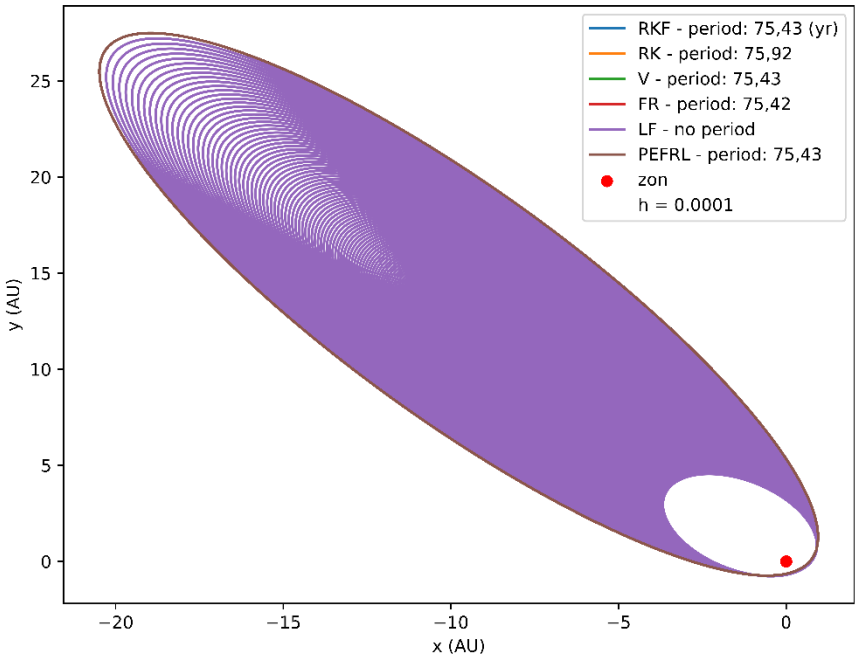
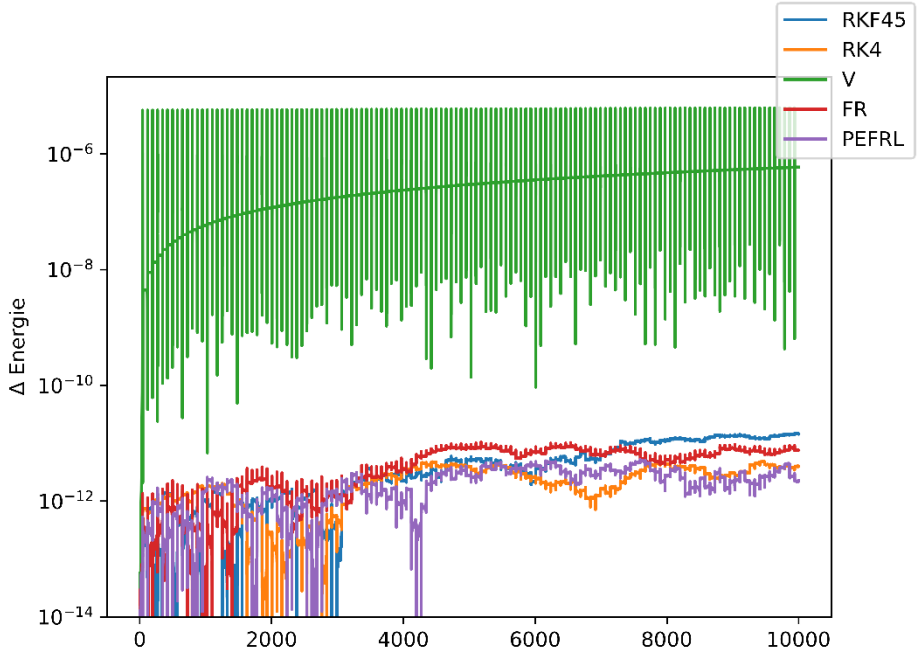
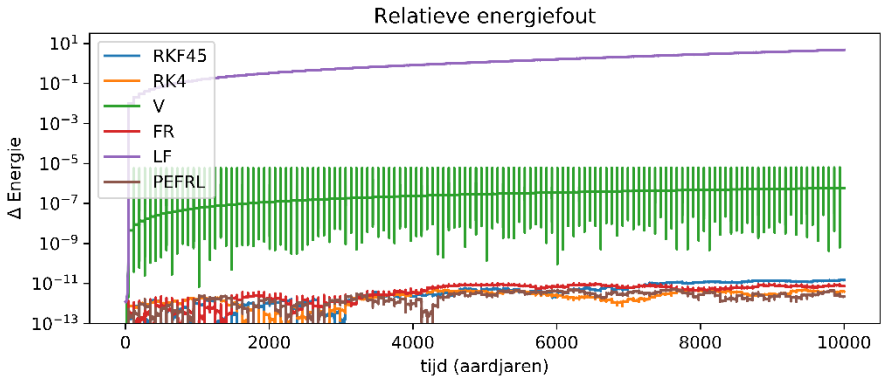
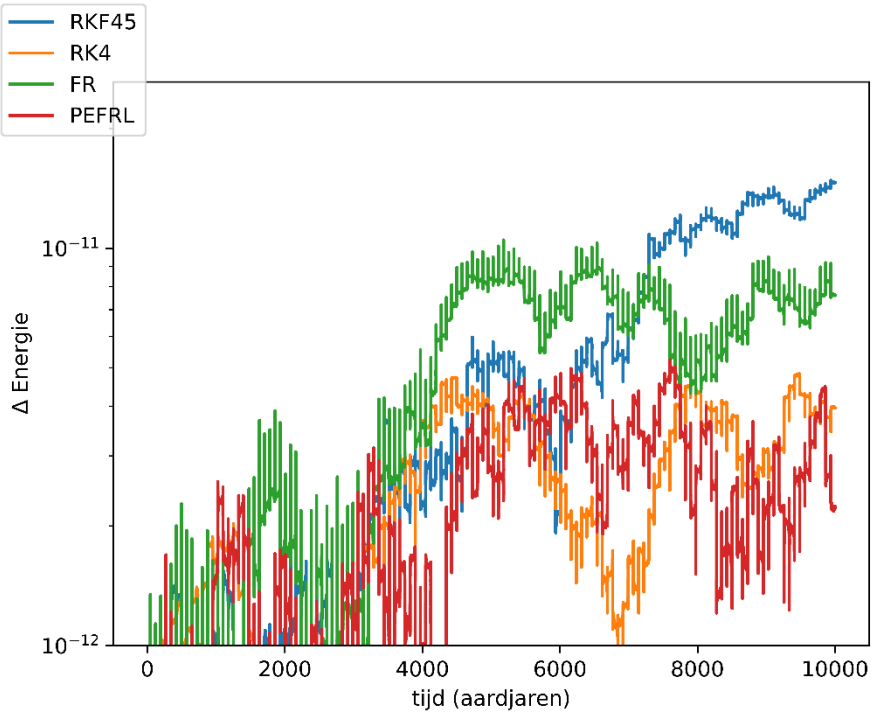



RKF - period: 75,43 (yr)
RK - period: 75,92
V - period: 75,43
FR - period: 75,42
LF - no period
PEFRL - period: 75,43
zon
h = 0.0001
y (AU)
x (AU)


RKF45
RK4
V
FR
PEFRL
Δ Energie


Relatieve energiefout
RKF45
RK4
V
FR
LF
PEFRL
Δ Energie
tijd (aardjaren)


RKF45
RK4
FR
PEFRL
Δ Energie
tijd (aardjaren)

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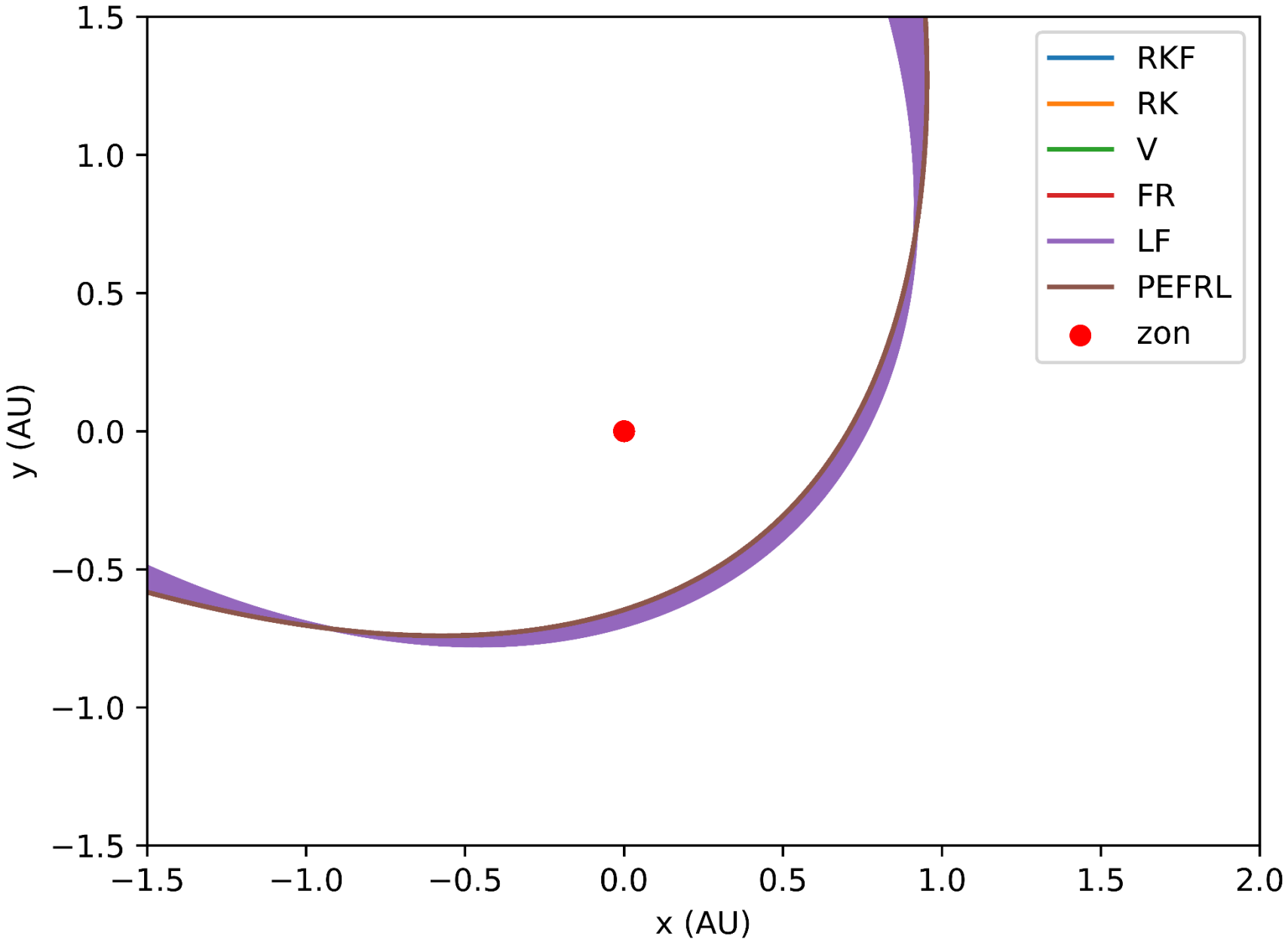
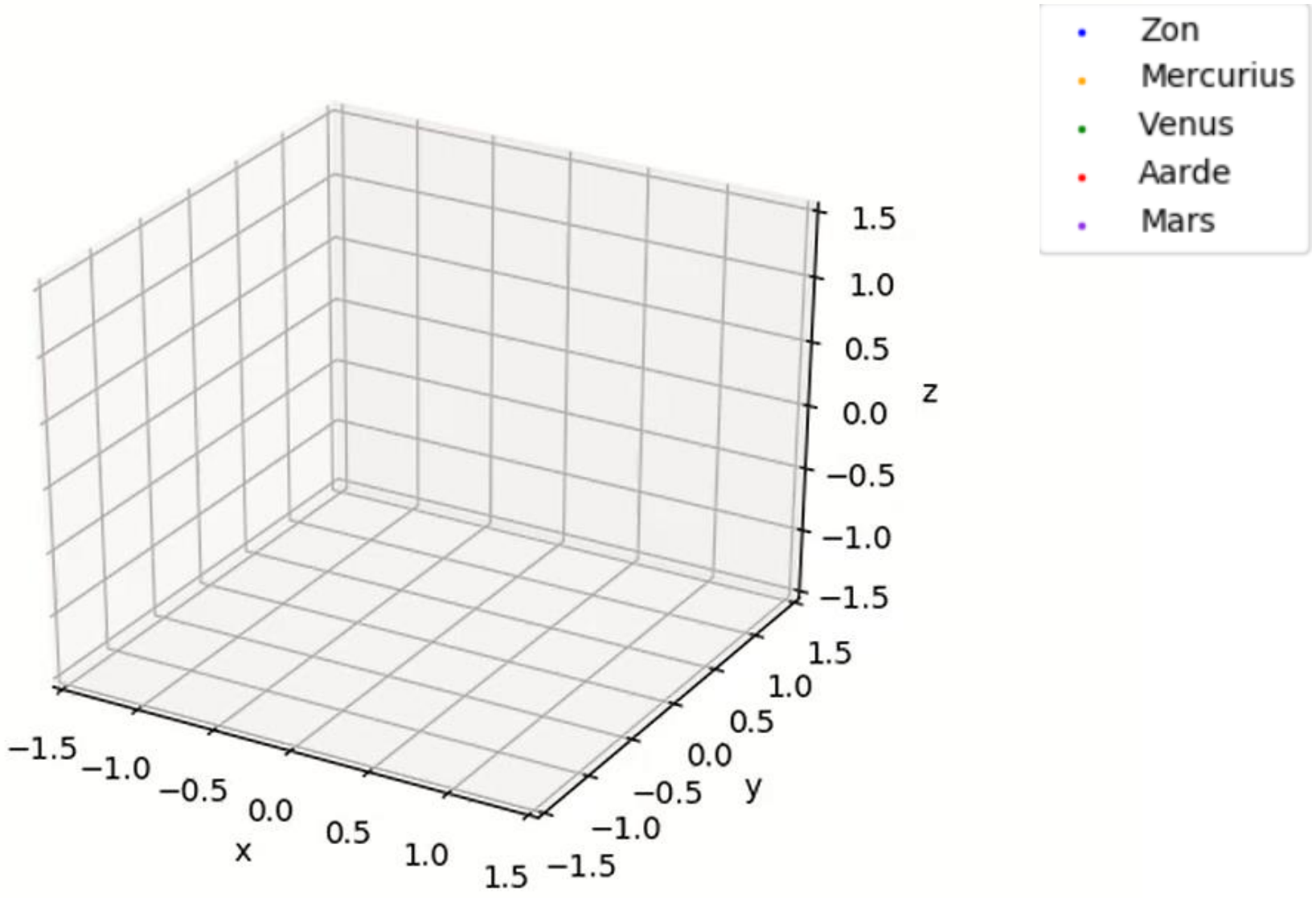


Binnenplaneten



Buitenplaneten + Pluto + Halley