Feedback project 1

- Reports are being looked at, results should come end of next week.
- If completions are needed, the deadline for submitting those is a week after you got your feedback

Feedback on reports & presentations

- Reports:
  - Most are clear and good
    - Right amount of information and detail
  - Some issues:
    - Avoid pages with only figures and try to place figures close to the relevant text
    - Avoid very small font for (axis-)labels in plots
- Presentations:
  - Generally very good!
  - Some slides did not mention an important parameter like the time step

Project feedback

- Accuracy of integrators: Euler $O(\Delta t)$, Velocity Verlet $O(\Delta t^2)$, RK4 $O(\Delta t^4)$
- But only VV is symplectic
  - So RK4 is more accurate over short times
  - For Hamiltonian dynamics VV is more accurate for energy conservation over long times (but can have worse accuracy)
- Verlet does not support velocity dependent acceleration
- Some students saw bad energy conservation with RK4 over 30 steps, either too fast drop of energy or an increase; likely cause: a bug in the code

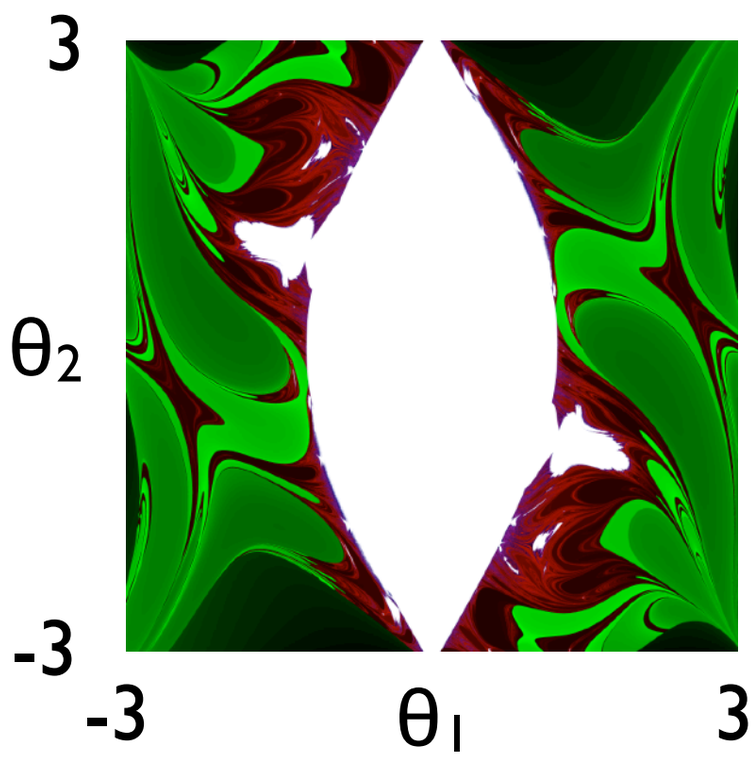
Chaotic behaviour

- Main criterion: sensitivity to initial conditions
  - No check for sensitivity in this particular exercise
- Chaotic behaviour can depend on:
  - values of parameters (e.g. energy)
  - initial conditions
  - the regime in the simulation, and can thus vary over time

Double pendulum

- One source of chaotic behaviour: flips no/yes
- A flip needs an energy of $2\,m\,g\,l$
  - You observed chaotic behaviour from an energy of 12 to 15
    - So there are other sources of chaotic behaviour, such as (non-)alignment of rods

Time to first flip vs initial conditions for pendulum with mass along rod



green: flip within $10\sqrt{g/l}$

red: flip within $100\sqrt{g/l}$

white: no flips