# Dynamic Systems

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# Mathematics

- Beautiful models.
- Sometimes describes the real world.
- Solution of one problem can help with a completely different problem.

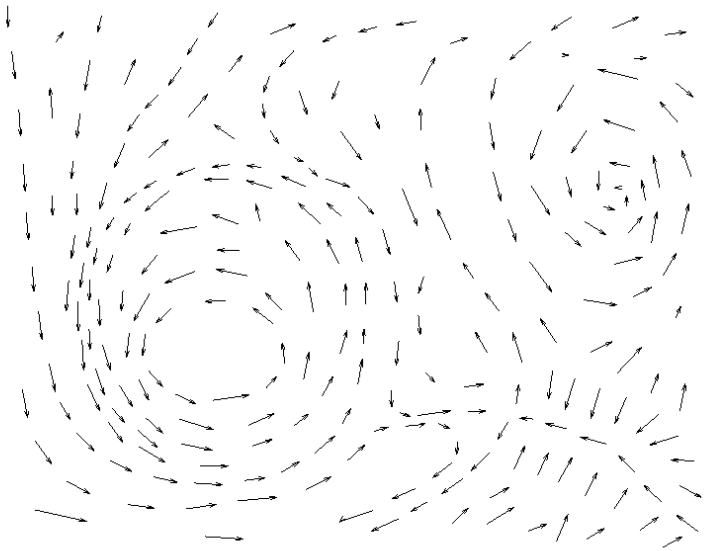
In the most general sense, a **dynamical system** is a tuple $(T, M, \Phi)$ where $T$ is a monoid, written additively, $M$ is a set and $\Phi$ is a function

$$\Phi : U \subset T \times M \to M$$

with

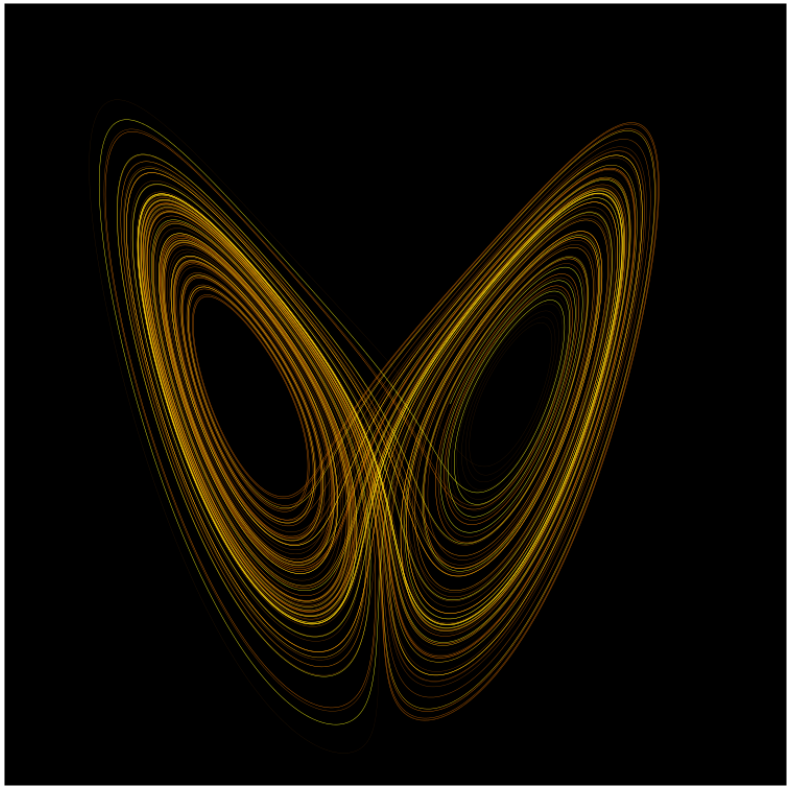
$$I(x) = \{t \in T : (t, x) \in U\}$$
$$\Phi(0, x) = x$$
$$\Phi(t_2, \Phi(t_1, x)) = \Phi(t_1 + t_2, x), \text{for } t_1, t_2, t_1 + t_2 \in I(x)$$

# Dynamic System



- “Particle” has given “position and velocity” within time and space.
- Next “position and velocity” is fully determined by the current state.
- A crone is mixing honey.

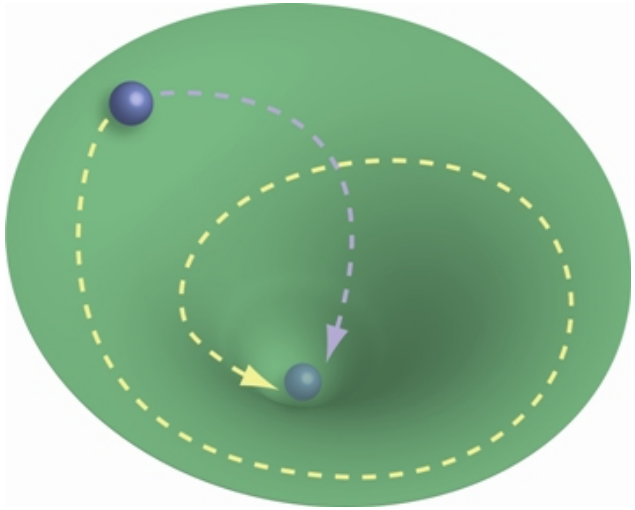
# Properties

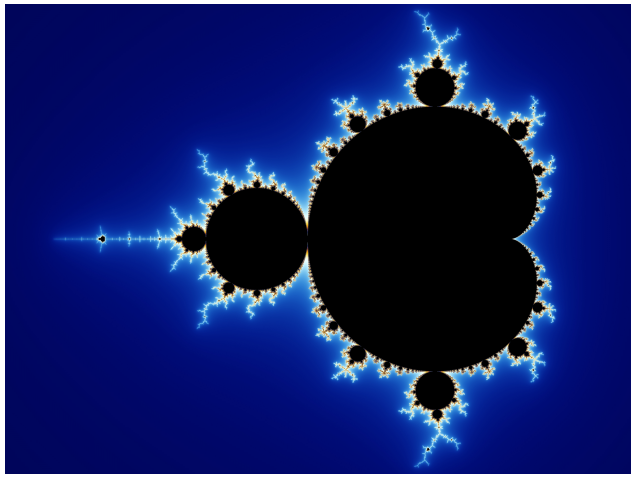


- **Orbit** — complete path of a particle through the space.
- **Attractor** — point or path in the space where particles converge and are "trapped".
- Point attractors, cycle attractors, strange attractors.
- **Chaotic system** — small difference in initial conditions results in huge differences as time passes.

# Practice

- Physics — Weather, fluids, circuits, gravitation, ...
- Biology — Population sizes, neuron potentials, stem cells.
- Cellular automatons — e.g. game of life.
- Fractals





# Thanks

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