IN·NOMINE·PATRIS

Radboud University Nijmegen

Behavioural Science Institute

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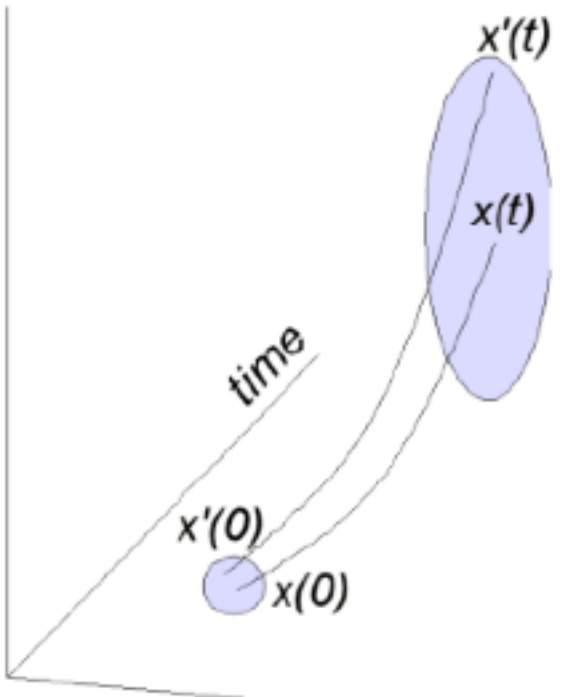
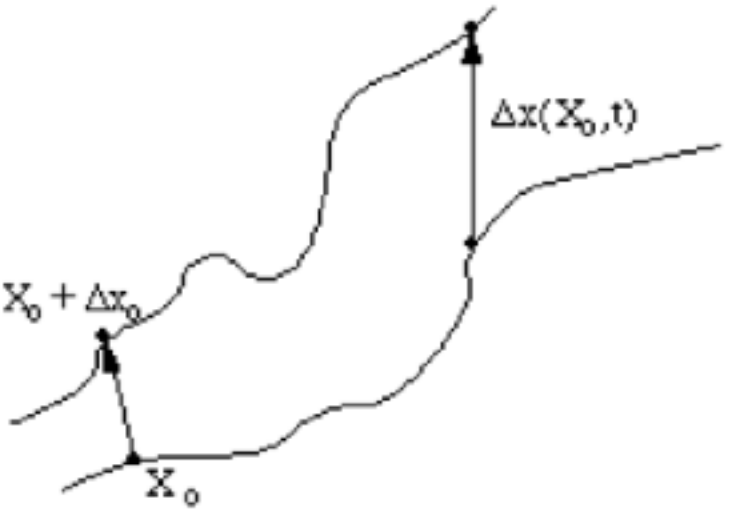
CHAOS, TURBULENCE
and other unsolved mysteries

What *can* we say about chaos?

4. Sensitive dependence on initial conditions

The *Lyapounov Exponent* characterises (quantifies) the rate of separation of two infinitesimally close trajectories in state space.


x'(t)
x(t)
time
x'(0)
x(0)


Δx(X0,t)
X0 + Δx0
X0

Calculate if you have a model

May be experimentally accessible

Analytic techniques (in R) are available

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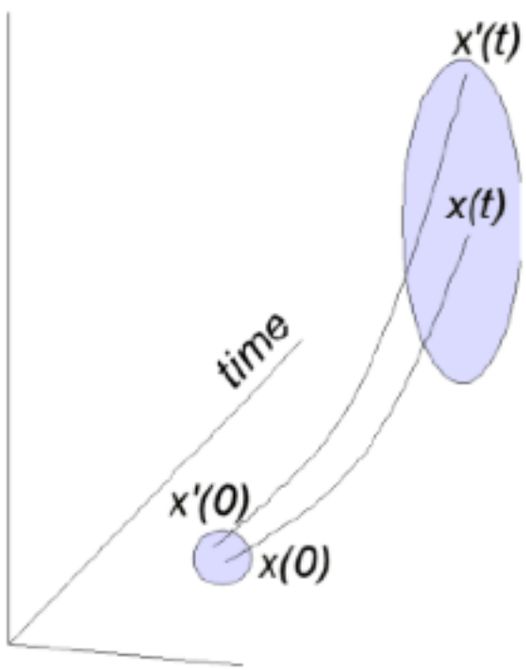

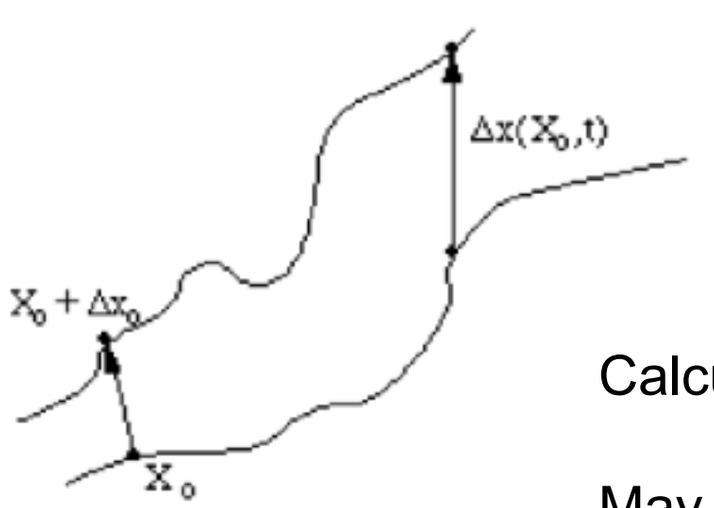

Calculate if you have a model

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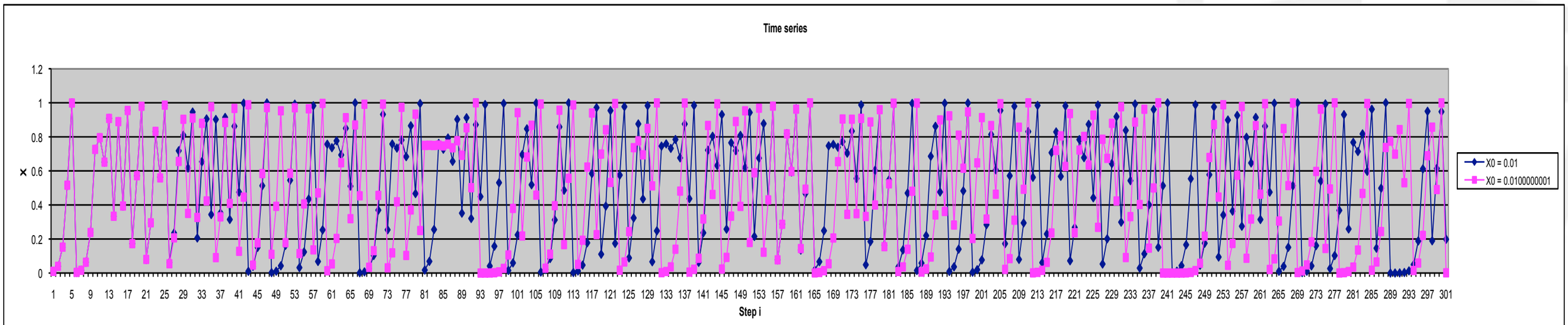
Sensitive Dependence on Initial Conditions

What *can* we say about deterministic chaos and complexity?

$X_0 = 0.01$ **$X_0 = 0.01000000001$**



Tiny differences in initial conditions can yield diverging time-evolutions of system states

Lorenz observed this in his models of the upper atmosphere:
The divergence was so extreme it resembled a butterfly flapping its wings -or not-
could be the difference between weather developing as a hurricane or a summer breeze