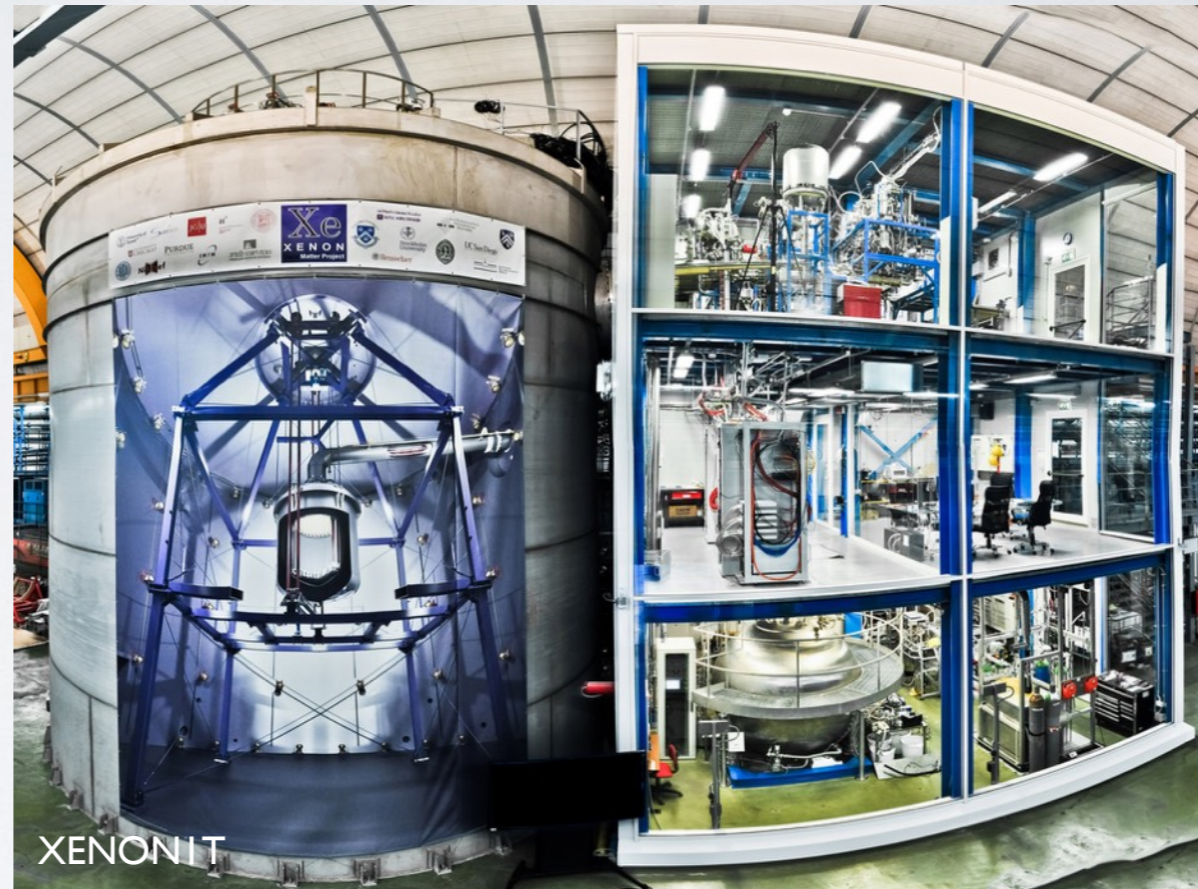
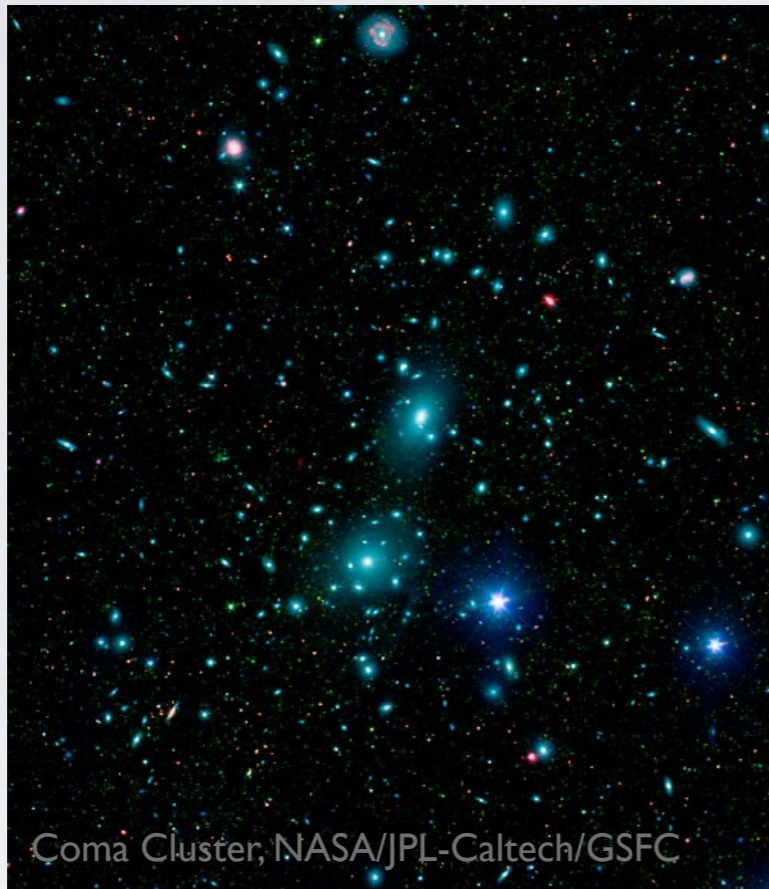


# Week 5 - #2

## Gravitation (I)



Today: Ch 5.1-5.3

Next Class: Ch 5.3-5.4

Ji-hoon Kim (Seoul National University)

#전문연,  
나도 가능할까?

\*  
대학원,  
등록금·생활비  
해결 가능할까?

랩실하루,  
출근부터  
퇴근까지  
현실은?

석사졸/박사졸  
취업 시 연봉차이  
많을까요?

연구 vs 분위기,  
나에게 맞는 랩실은?

취업 vs 진학,  
대학원 가도 괜찮을까?

어디 편한 곳  
없나요?



모르겠어~  
맨날 몰라서  
죄삼다

#참가신청



#진로탐색 #그것이 알고싶다 #대학원진학

#{맛있는}샌드위치. 음료 제공

물리천문학부 물리학전공 :

# 대학원 설명회

2026.4.3.(금), 11:30 ~ 13:30, 56-321

1부 11:30 ~ 12:30

물리학전공 재학생  
(신입생 제외)

2부 12:30 ~ 13:30

물리 다전공 학생  
(복.부전공)

※ 1부/2부 시간이 맞지 않을 경우, 다른 시간대 선택 가능

# Classical Mechanics I (Spring 2026): Quiz #9

— [ open book and open note, **but** no cellphone or laptop, drop it off as you leave the class ] —

Please write down your name and student ID in the top right corner. (0.0 pt: no paper found with your name / 0.5 pt: paper found with your name and some answers / 1.0 pt: good answers)

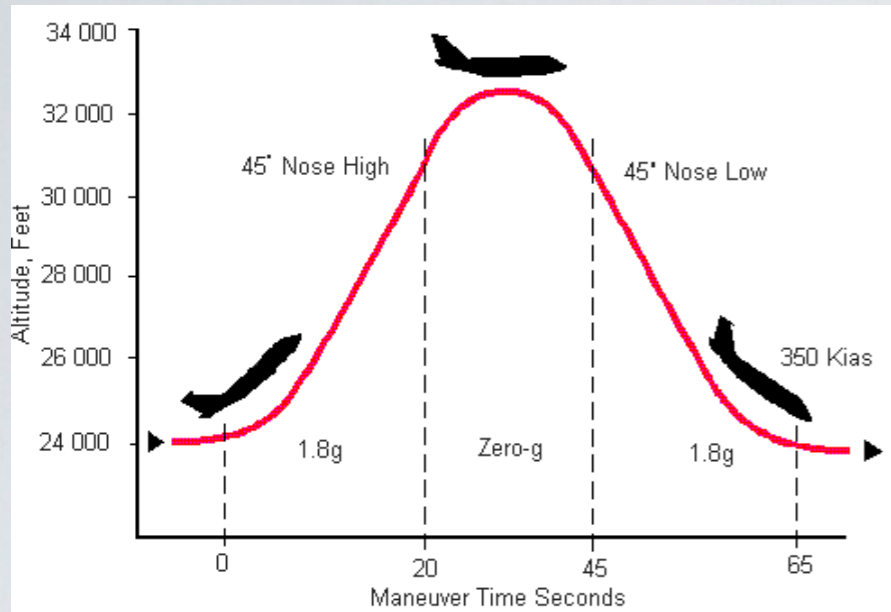
1. Thornton & Marion, Problem 5-3 (use your cellphone as a calculator if needed).
2. We know that you won't feel any gravity in a falling elevator. In commercial zero-G flights, however, passengers feel no gravity even when the plane is nose-up. Explain.



[www.esa.int](http://www.esa.int)

Infinite Challenge - Making Film,  
[Space-Affairs.com](http://Space-Affairs.com)

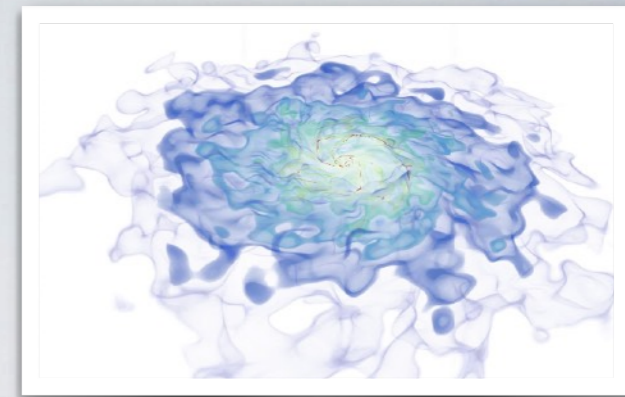
# “Parabolic” Zero-G Flight



NASA



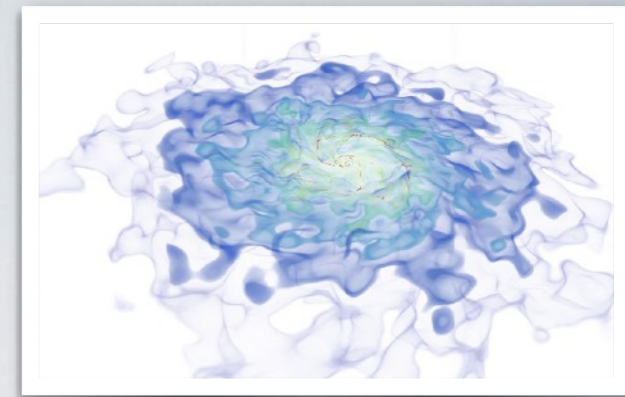
IB Times UK



# HW #2 will be posted!

(To be posted on [jihoonkim.org](http://jihoonkim.org), Due: **Apr. 13 (Mon), 23:00pm**,

Grader TA this time: 서선기, [supercap@snu.ac.kr](mailto:supercap@snu.ac.kr))



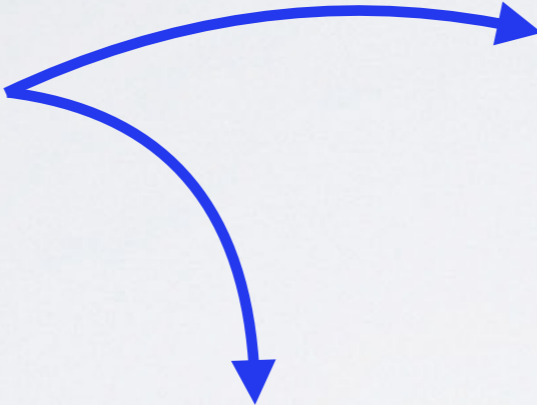
# Linearity vs. Chaos vs. Randomness: Lorenz System

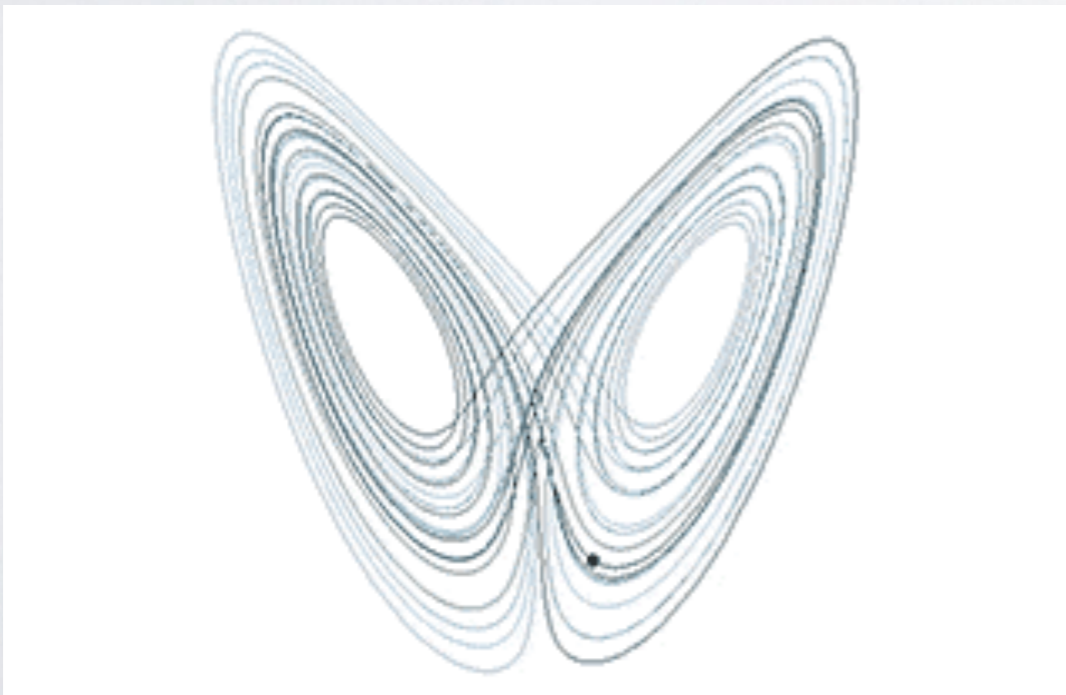
# Lorenz System, Lorenz Attractor

- Linearity vs. Chaos vs. Randomness

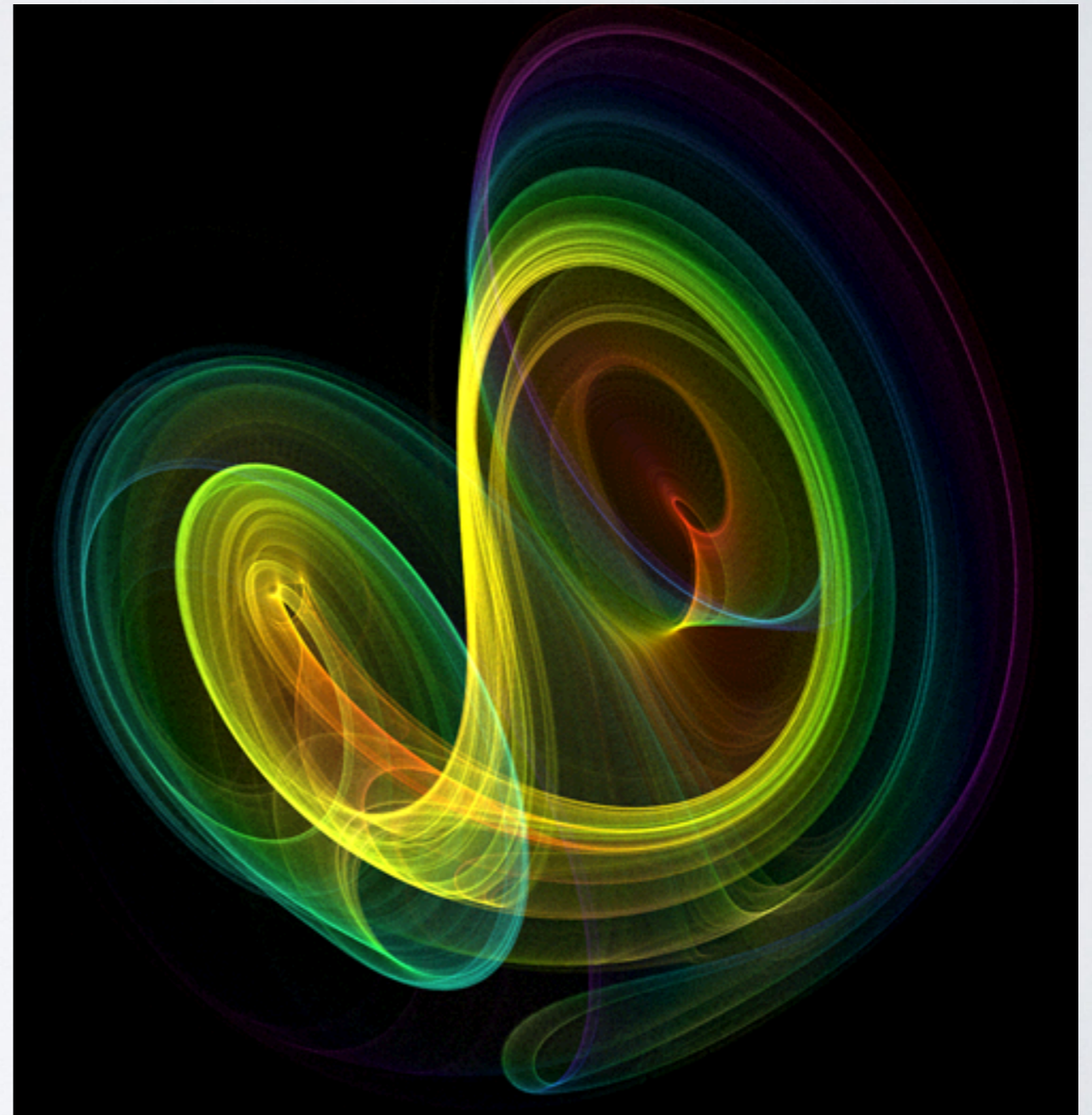
$$\begin{aligned}\frac{dx}{dt} &= a(y - x) \\ \frac{dy}{dt} &= x(b - z) - y \\ \frac{dz}{dt} &= xy - cz\end{aligned}$$

Lorenz (1963)





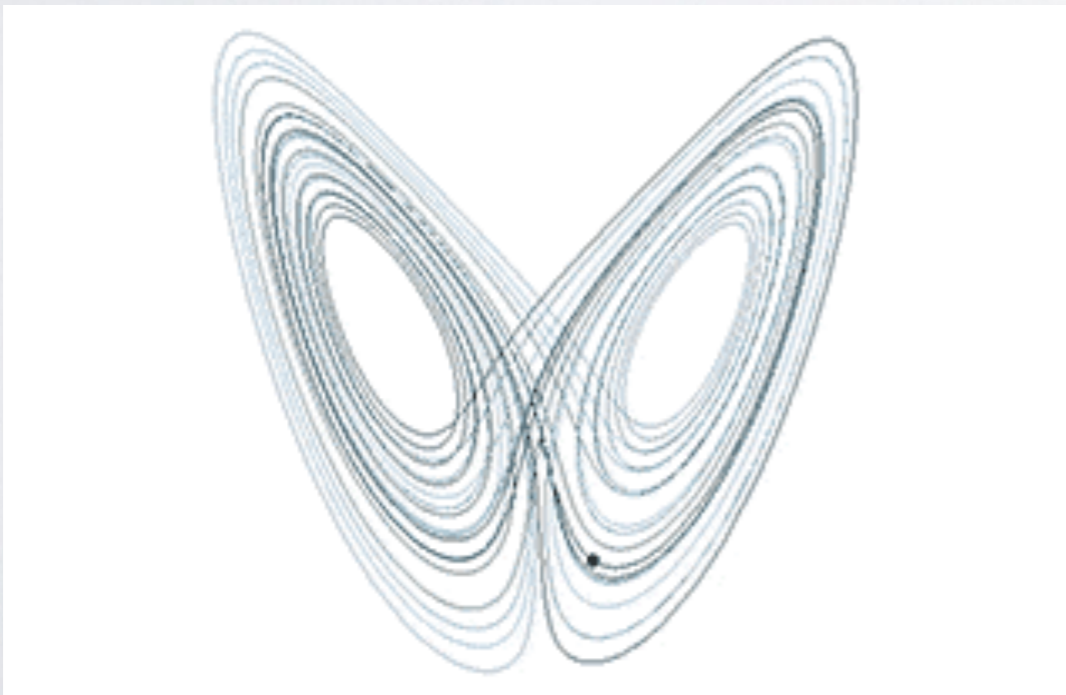
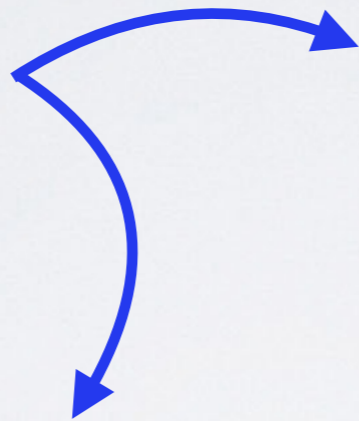
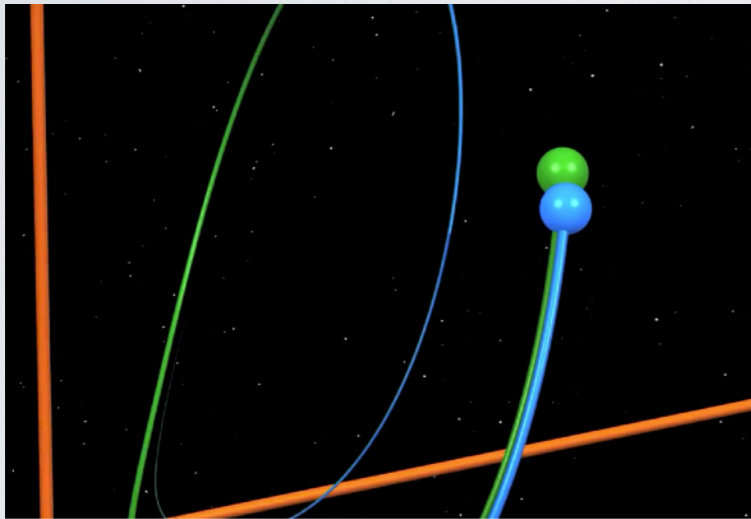
Wikipedia commons



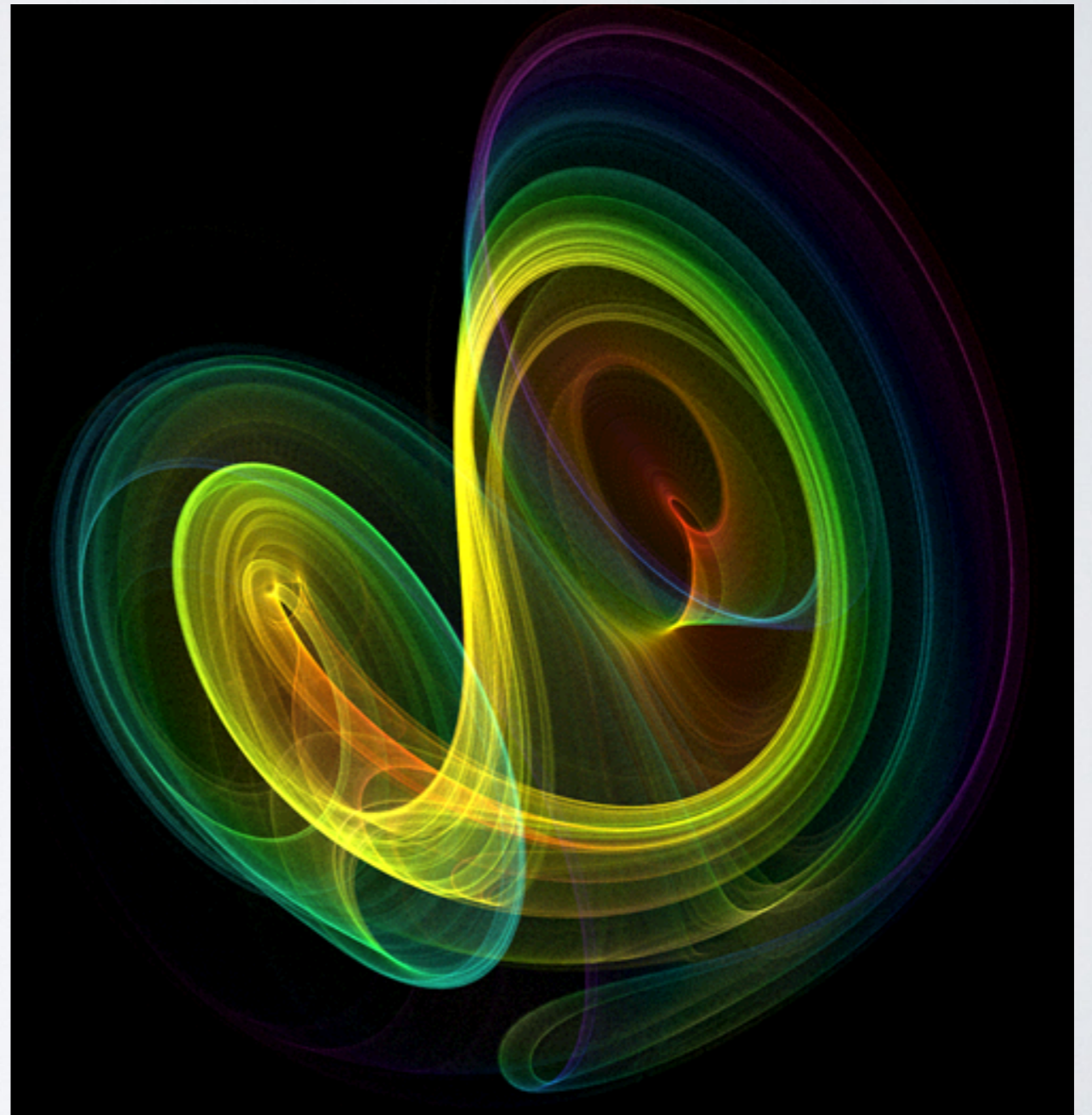
[www.metabluedb.com/lorenz-attractor.html](http://www.metabluedb.com/lorenz-attractor.html)

# Lorenz System, Lorenz Attractor

- Linearity vs. Chaos vs. Randomness



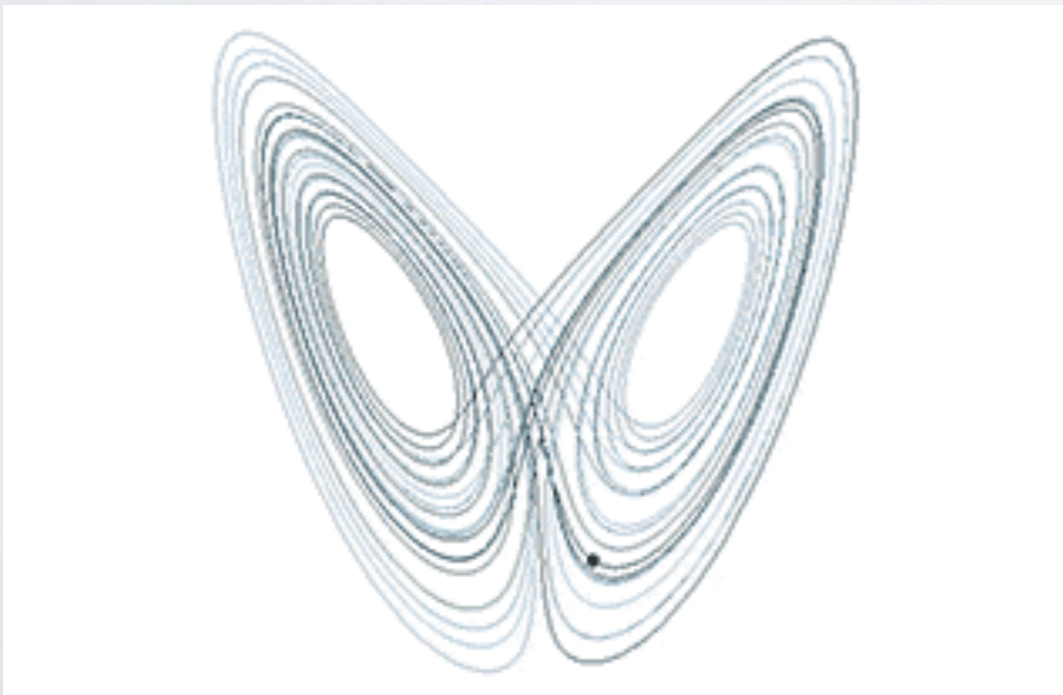
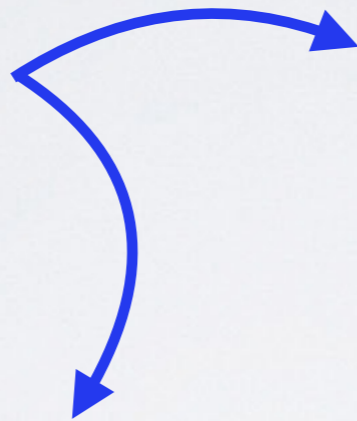
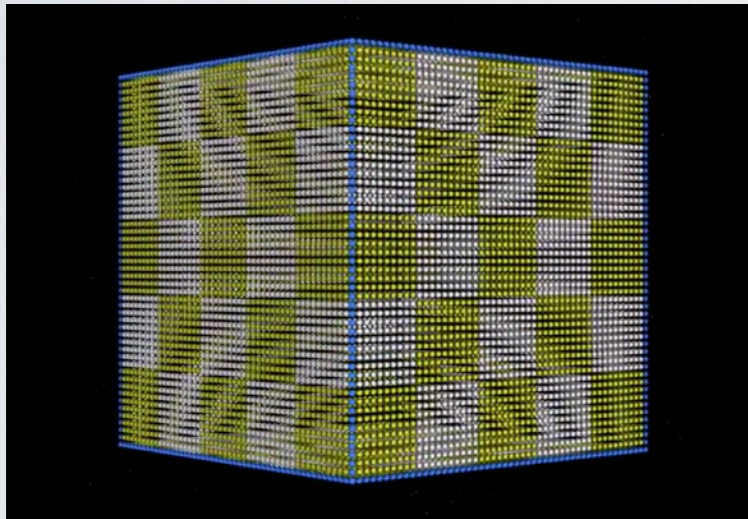
Wikipedia commons

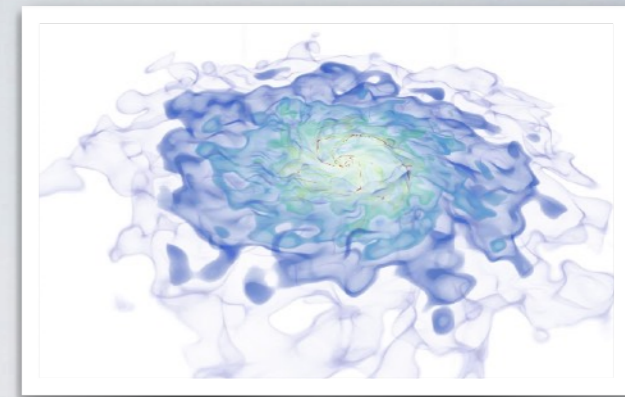


[www.metabluedb.com/lorenz-attractor.html](http://www.metabluedb.com/lorenz-attractor.html)

# Lorenz System, Lorenz Attractor

- Linearity vs. Chaos vs. Randomness

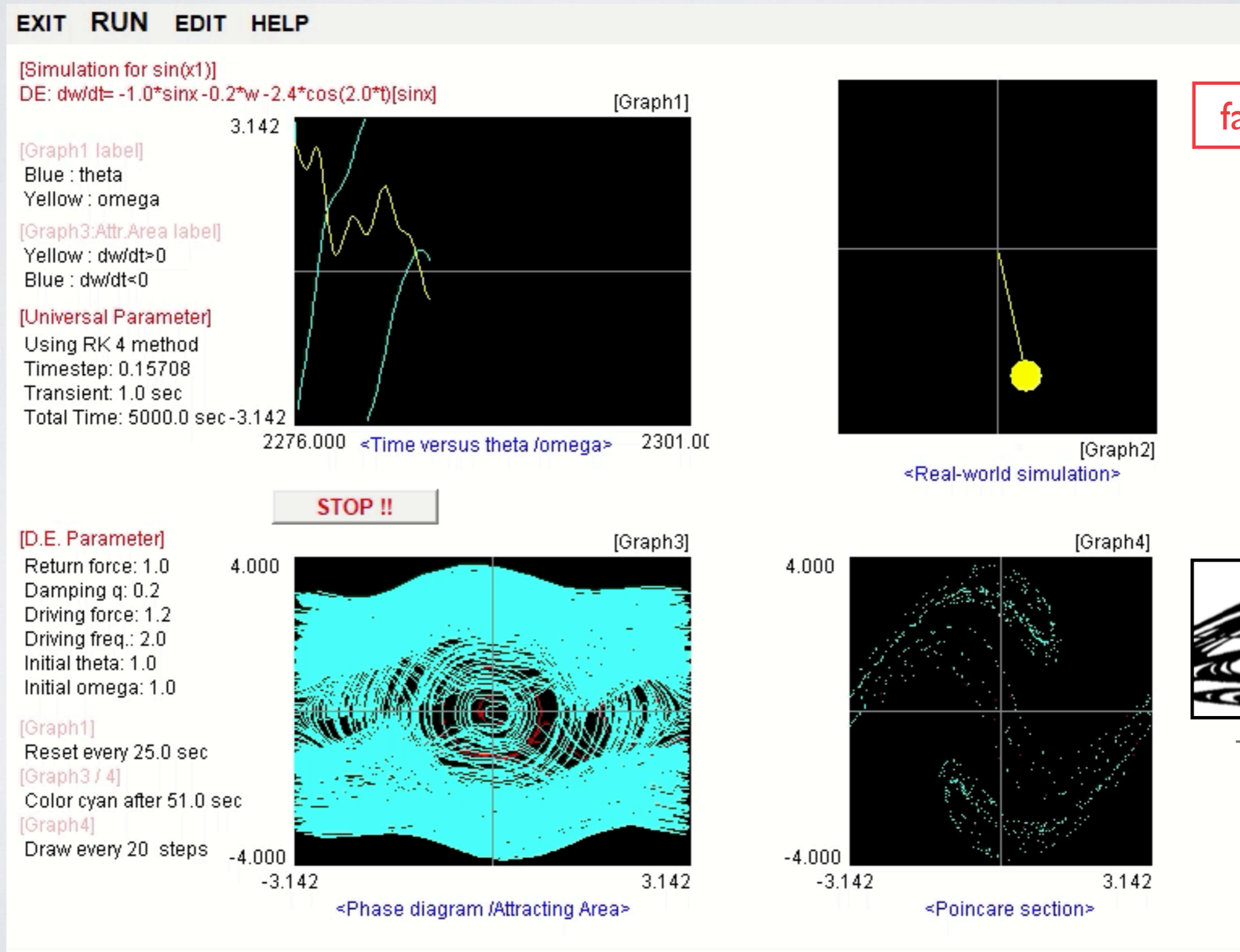




# Nonlinear Plane Pendulum: Phase Diagram & Poincaré Section

# Pendulum: Numerical Simulation

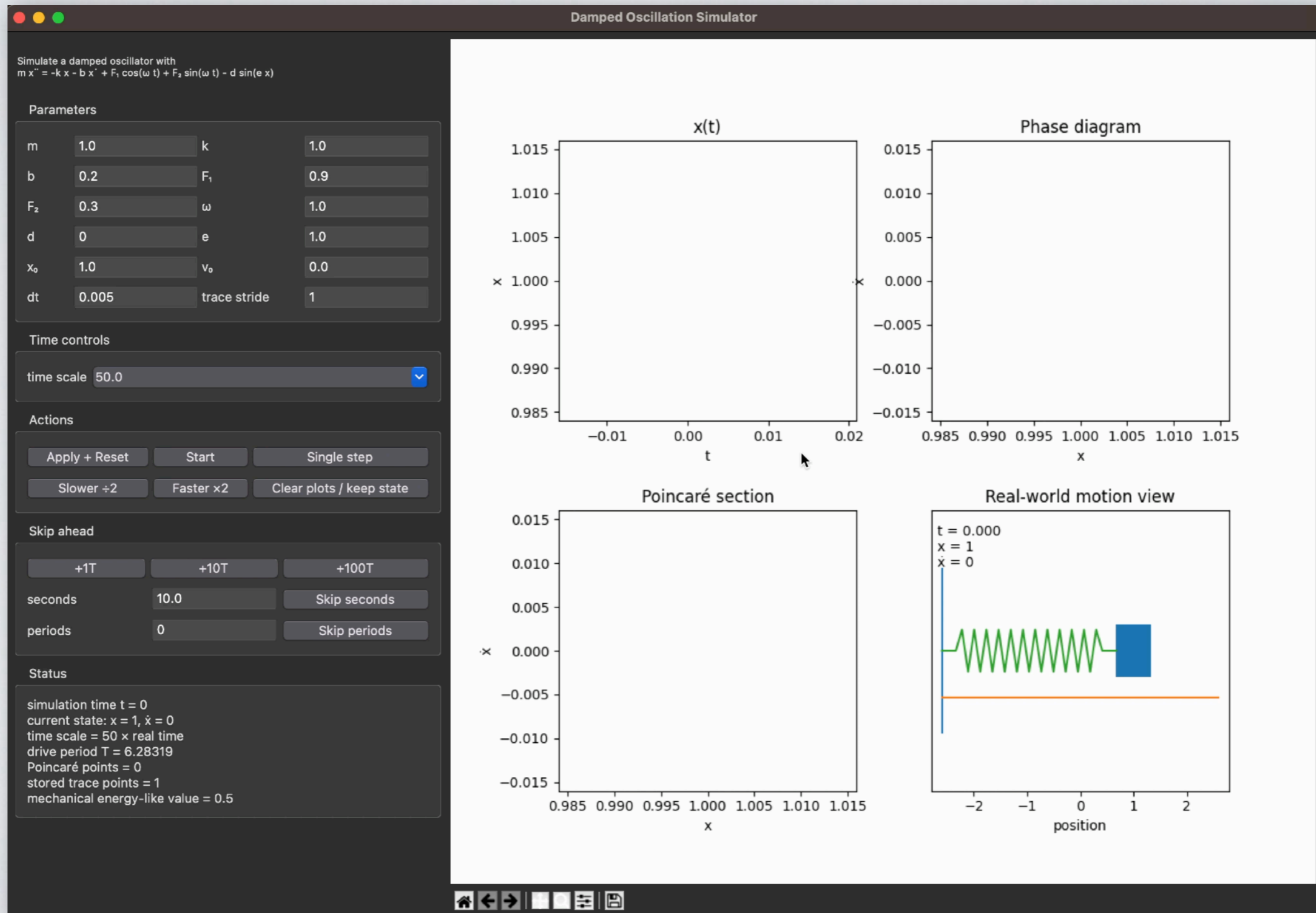
- Damped, driven oscillator (chaotic behavior, filling phase space)



Thornton & Marion  
Fig. 4-19

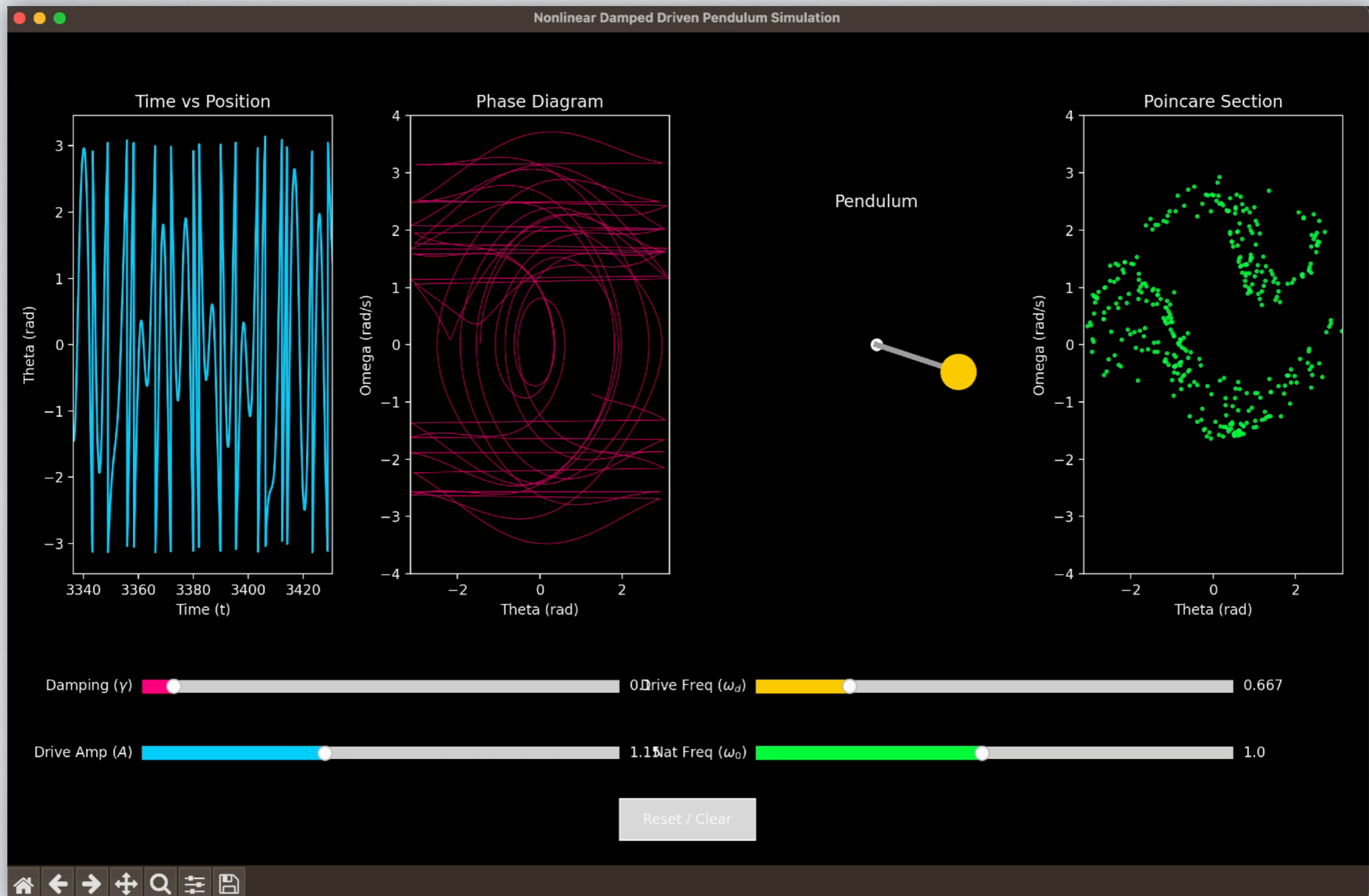
# Pendulum: Numerical Simulation

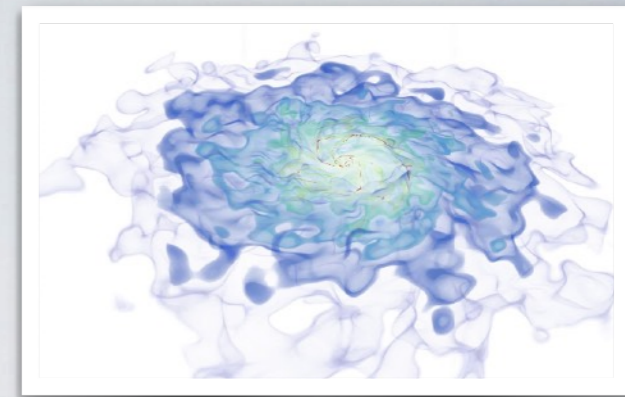
- Damped, driven oscillator



# Pendulum: Numerical Simulation

- Damped, driven oscillator

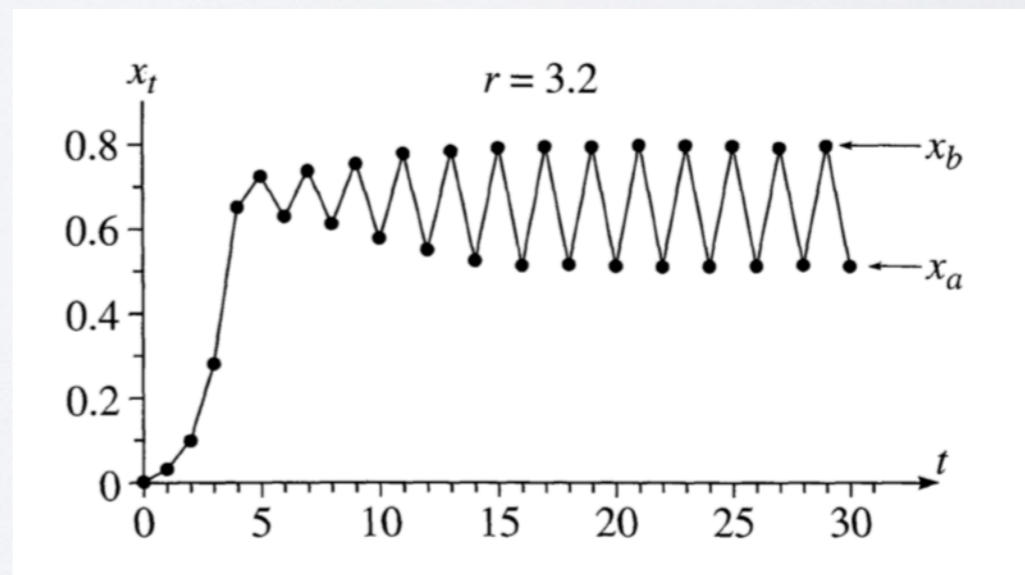
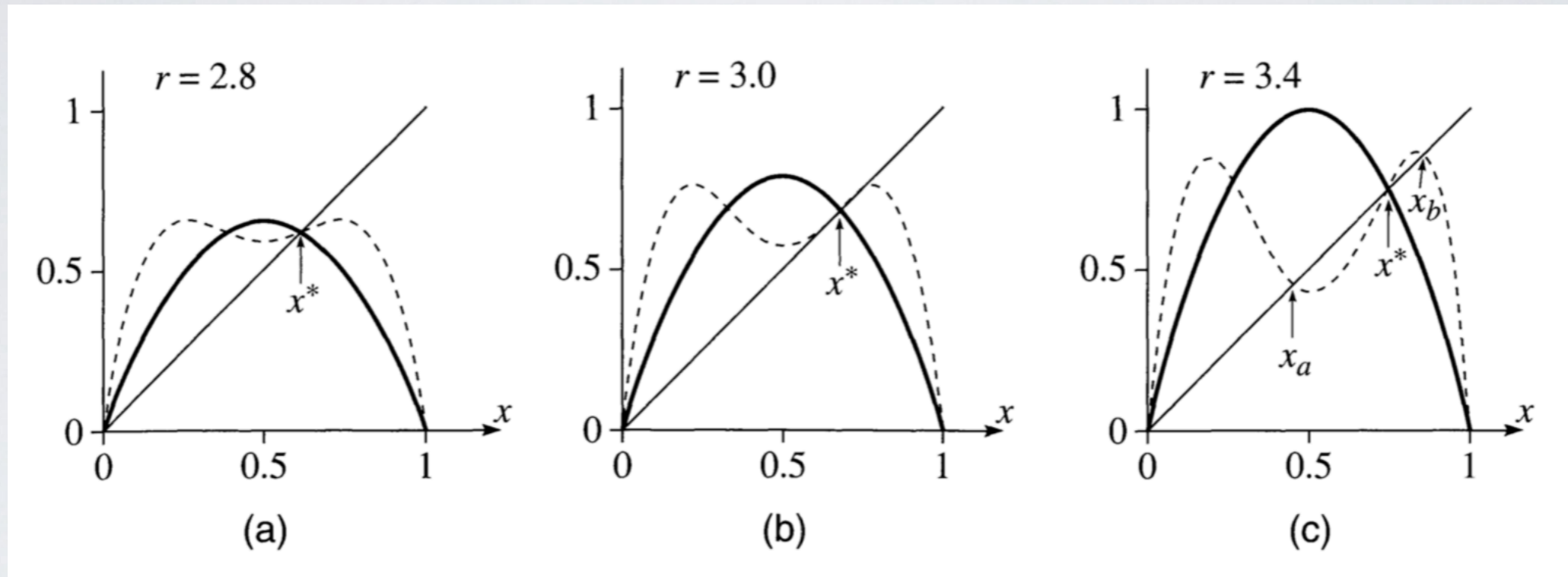




# Logistic Map

# Logistic Map: One- and Two-cycle

- $1 < a < 3$ : One-cycle,  $3 < a < 1 + \sqrt{6}$ : Two-cycle



# Logistic Map: Cobweb Diagram

- $3 < a < 1 + \sqrt{6}$ : Two-cycle

The screenshot shows a Scratch project interface. At the top, the Scratch logo and navigation links (Create, Ideas, About, Join Scratch, Sign in) are visible. The project title is "Interactive Logistic Map" by "-Jie-". A "See inside" button is present. The main area contains a cobweb diagram on the left, a slider for parameter 'r' set to 3.2, and a text box with instructions. Below the diagram is a small plot with 'x' and 'r' axes. The right sidebar contains "Instructions" and "Notes and Credits" sections. At the bottom, there are engagement metrics (10 hearts, 5 stars, 0 comments, 431 views), a copyright notice for Feb 23, 2014, and a "Copy Link" button. The footer includes "Comments", "Studios", and "View all" links.

$\alpha = 3.2$

2 attractors →

Scratch Create Ideas About Join Scratch Sign in

Interactive Logistic Map by -Jie- See inside

Instructions

After you see the first example, choose a new value of  $r$  and see what it does. You can also choose to draw the full map (turbo mode recommended (SHIFT+green flag)). For the final result, the program starts with a

Notes and Credits

If you don't know about the logistic map, check out [http://en.wikipedia.org/wiki/Logistic\\_map](http://en.wikipedia.org/wiki/Logistic_map). The notations are consistent with the wikipedia page.

10 5 0 431 © Feb 23, 2014 Copy Link

Comments Studios View all

scratch.mit.edu/projects/18225394

# Logistic Map: Cobweb Diagram

- $1 + \sqrt{6} < a$  : Four-cycle and more

**Scratch** Create Ideas About Join Scratch Sign in

**Interactive Logistic Map**  
by -Jie- [See inside](#)

**Instructions**

After you see the first example, choose a new value of  $r$  and see what it does. You can also choose to draw the full map (turbo mode recommended (SHIFT+green flag)). For the final result, the program starts with a

**Notes and Credits**

If you don't know about the logistic map, check out [http://en.wikipedia.org/wiki/Logistic\\_map](http://en.wikipedia.org/wiki/Logistic_map). The notations are consistent with the wikipedia page.

© Feb 23, 2014 [Copy Link](#)

**Comments** **Studios** [View all](#)

$$a = 3.45$$

4 attractors →

# Logistic Map: Bifurcation Diagram

- $2.8 < a < 4$

The screenshot shows a Scratch project titled "Interactive Logistic Map" by user "-Jie-". The interface includes a top navigation bar with "Scratch", "File", "Edit", "Tutorials", and "See Project Page" buttons. The main workspace is divided into three panels: "Code", "Costumes", and "Sounds".

The "Code" panel shows the following script:

- when green flag clicked: hide
- when I receive "calcul done": show, go to front layer, wait until touching mouse-pointer and key space pressed, broadcast "full graph", hide
- when I receive "one more": hide

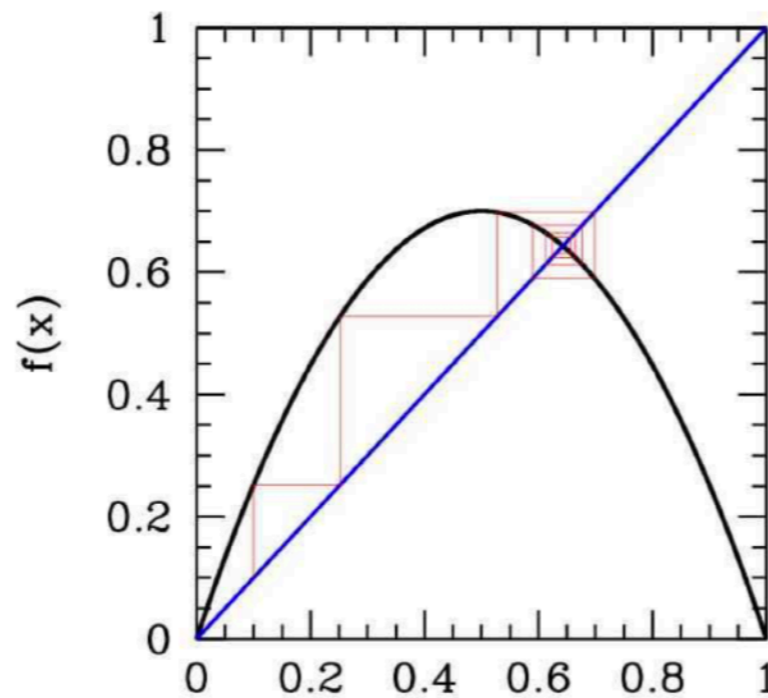
The "Stage" panel displays a bifurcation diagram with a slider for parameter  $r$  set to 3.75. The diagram shows a blue curve representing the logistic map  $x_{n+1} = r x_n (1 - x_n)$  and a red diagonal line  $y = x$ . The bifurcation diagram shows a period-doubling cascade as  $r$  increases. Below the diagram, there are instructions: "Choose a new value for r and click here for another go" and "Or, click here for the full graph (turbo mode recommended)".

The "Sprite" panel shows the "Full graph" sprite with coordinates (125, -25), size 100, and direction 90. The "Stage" panel shows a single backdrop.

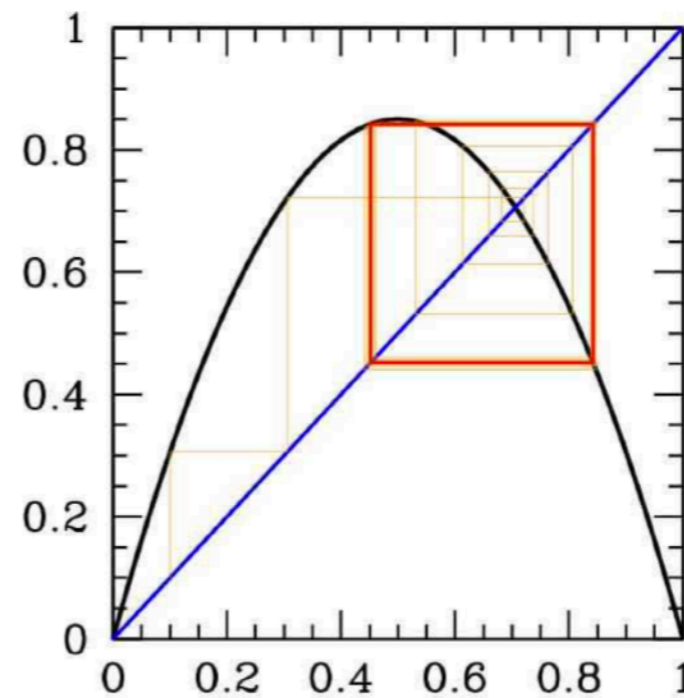
# Logistic Map: Long-term Behavior

- $2.4 < a < 4$

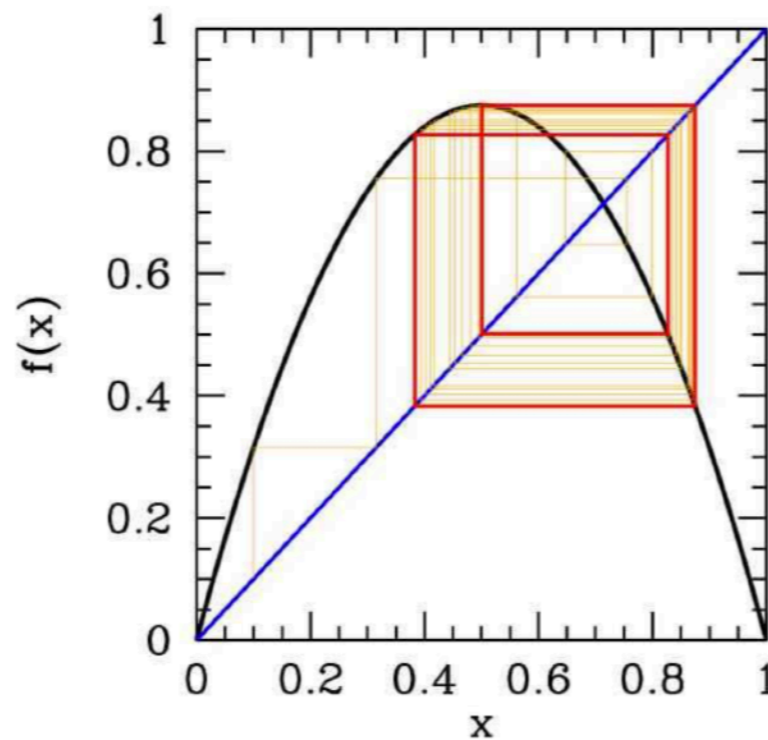
$a = 2.8$



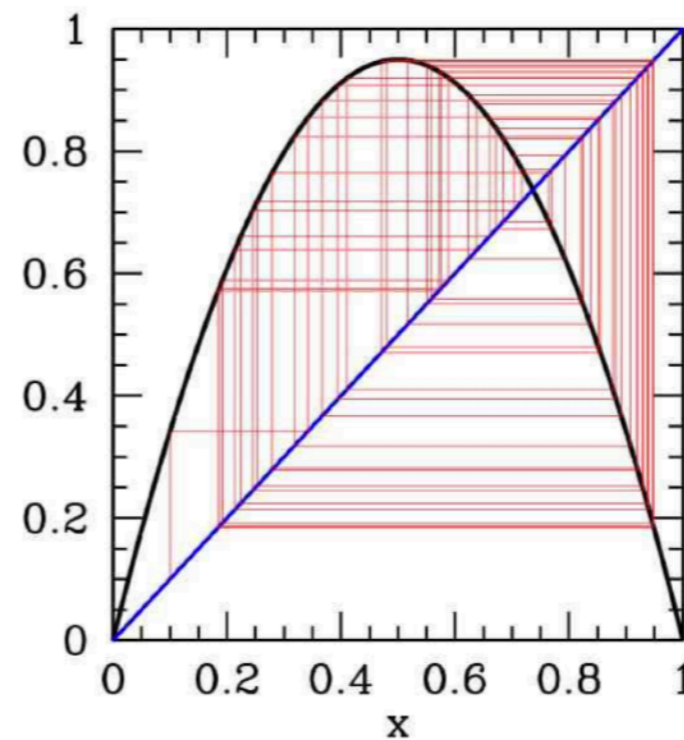
$a = 3.4$



$a = 3.5$

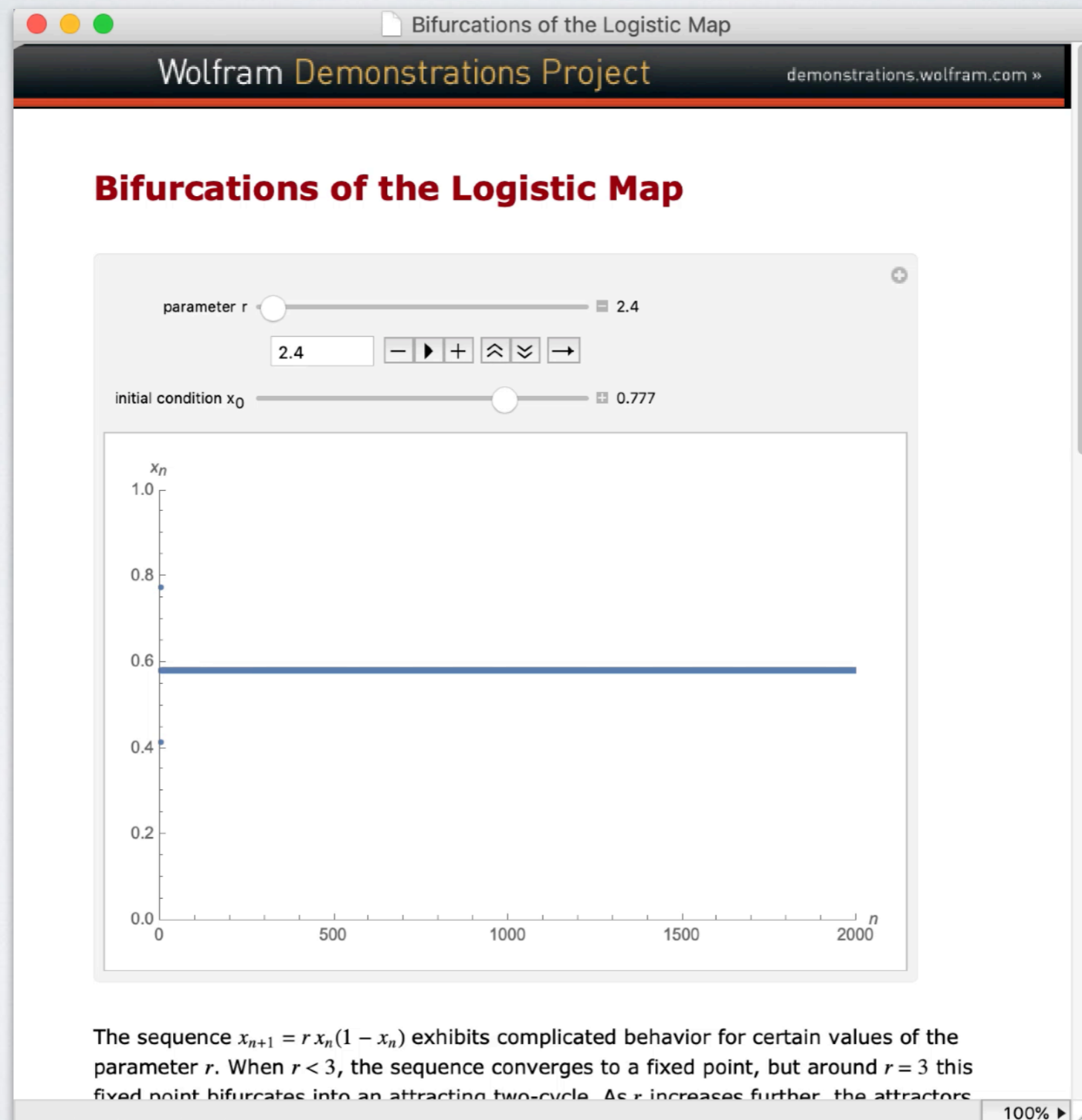


$a = 3.8$

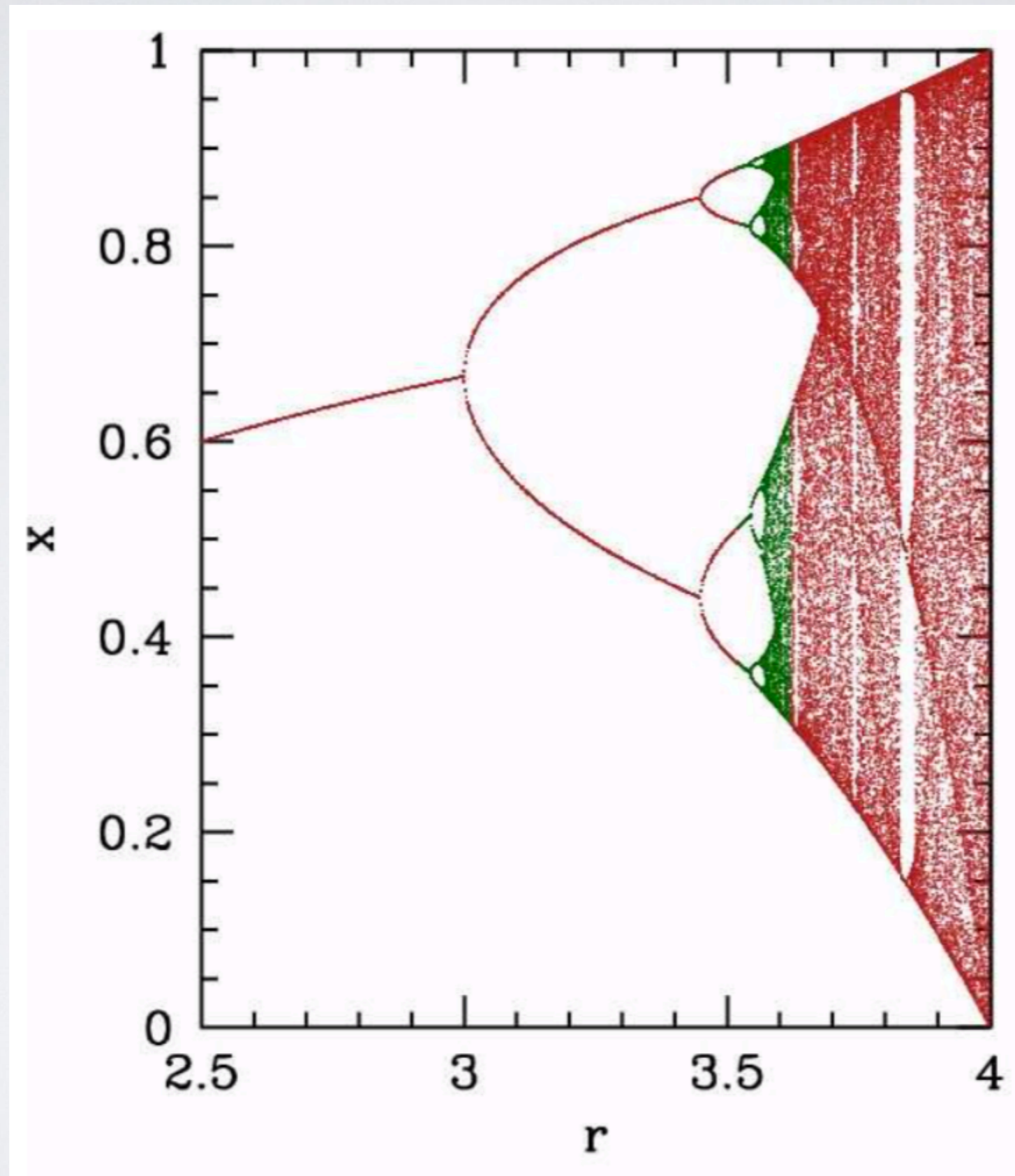


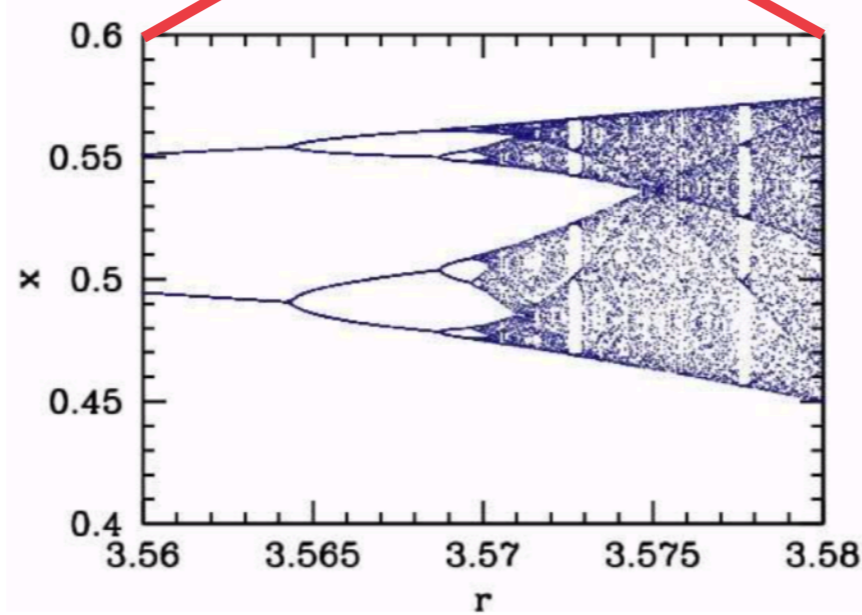
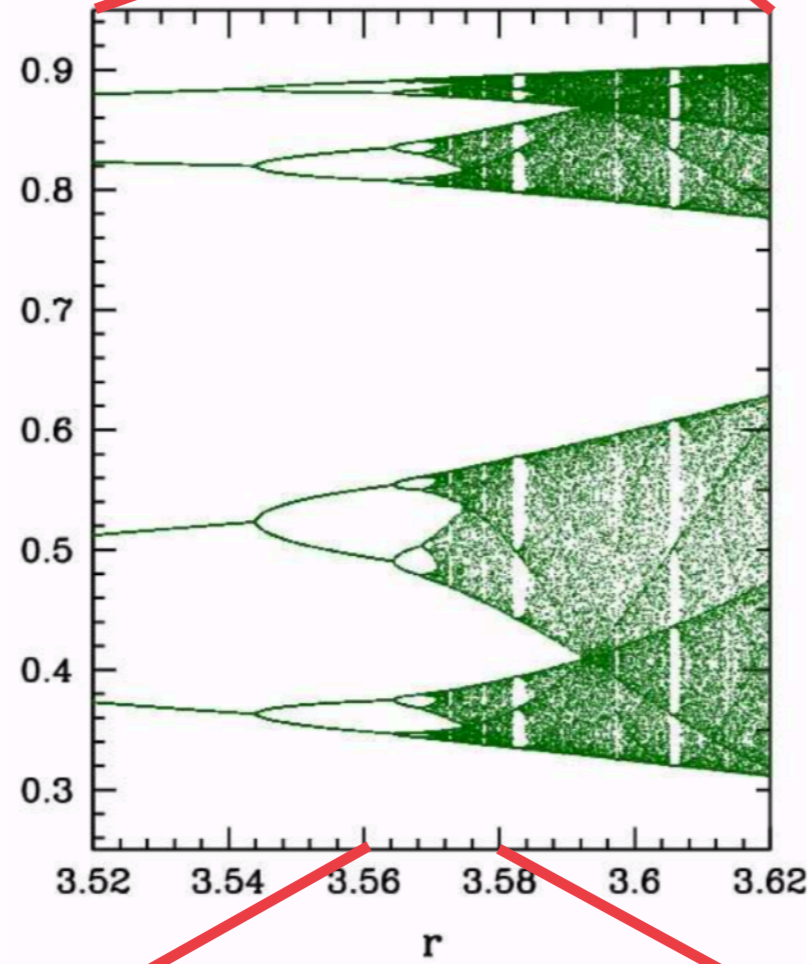
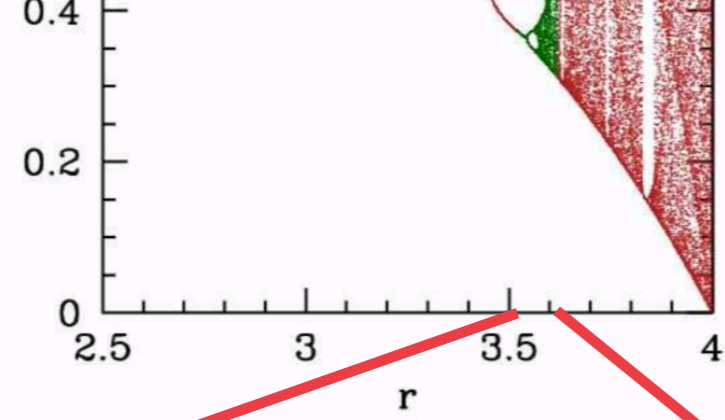
# Logistic Map: Long-term Behavior

- $2.4 < r < 4$



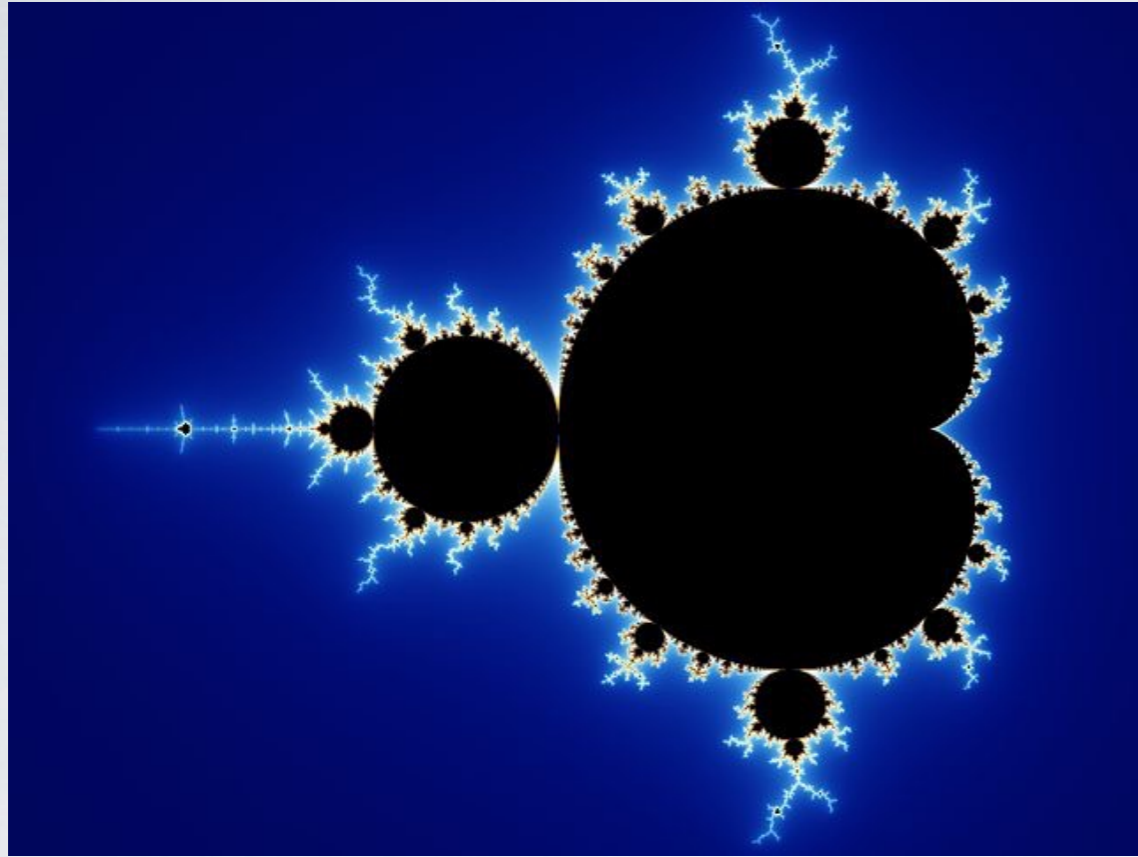
# Logistic Map: Bifurcation Diagram



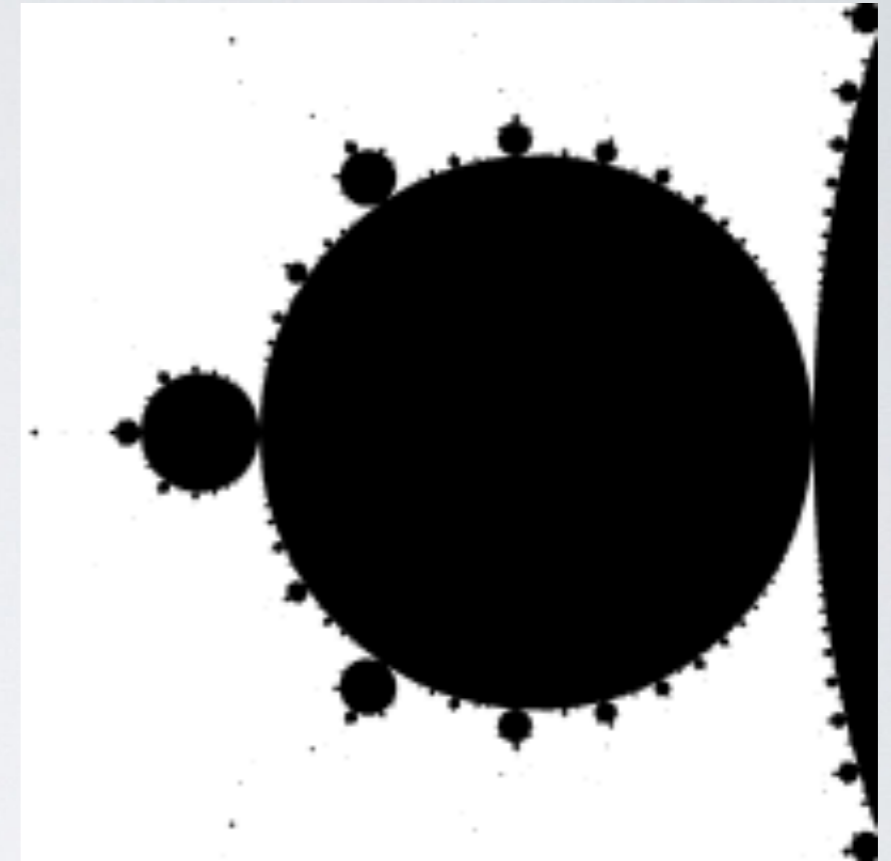


“self-similarity” or “fractal”  
(the whole is similar to or  
the same as a part of itself)

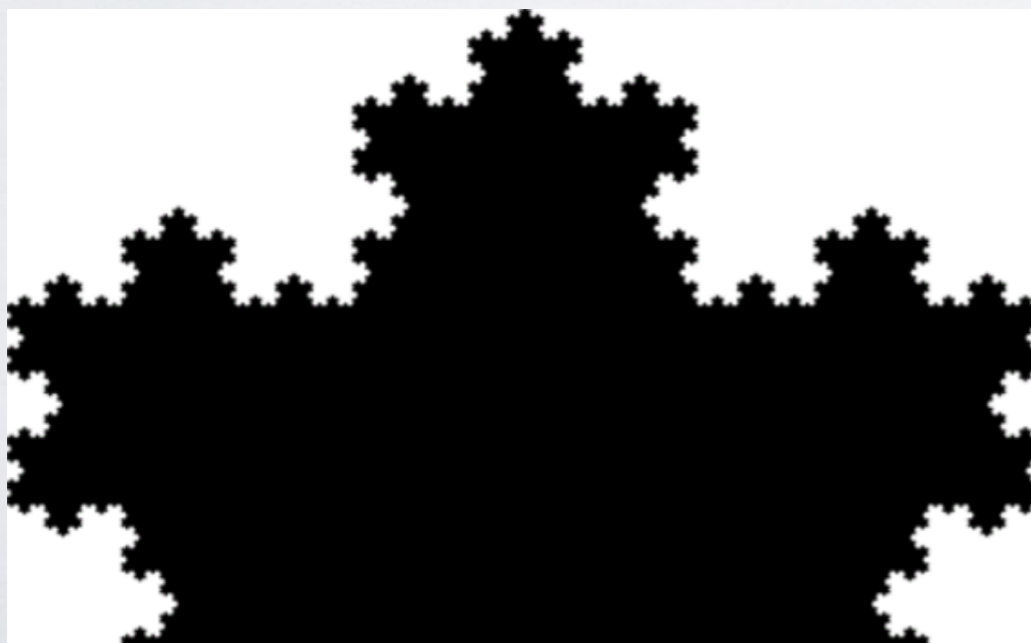
# Self-similarity and Fractal



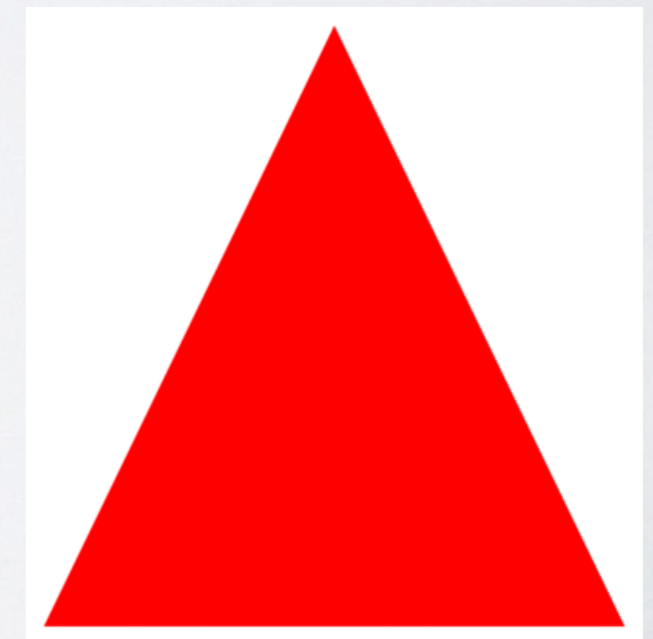
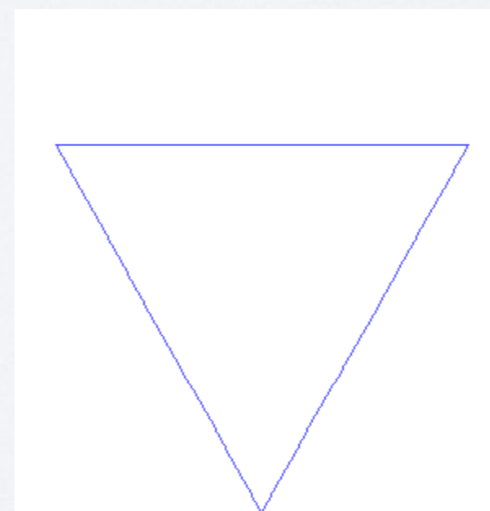
Mandelbrot set, Wikipedia commons



Mandelbrot set, Wikipedia commons



Koch snowflake, Wikipedia commons

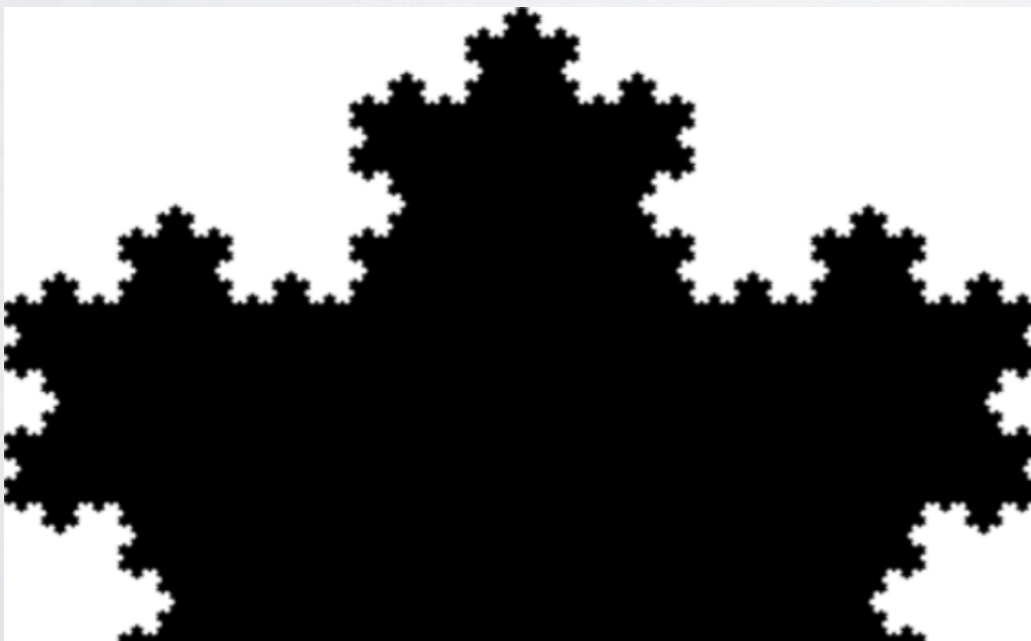


Sierpinski triangle

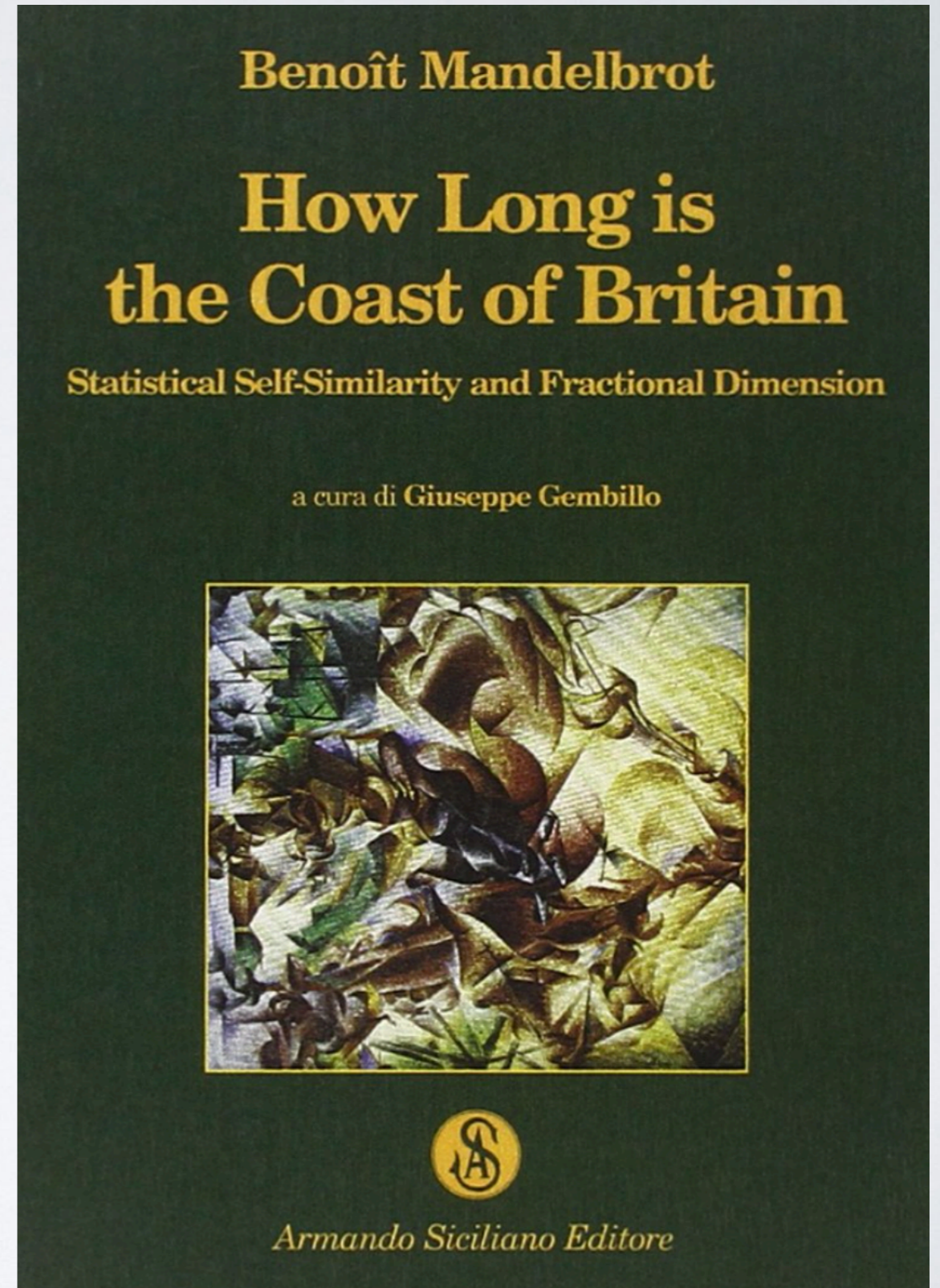
# Self-similarity and Fractal



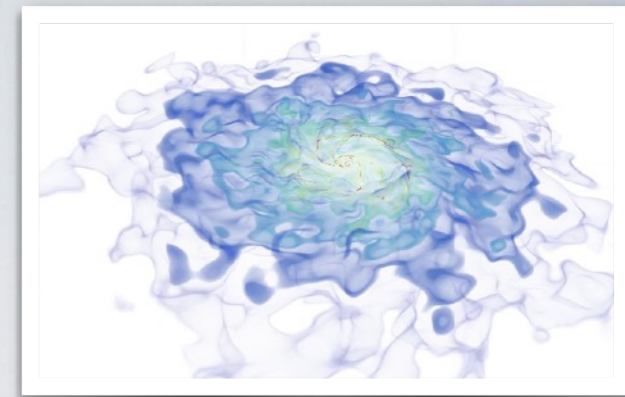
sience4all.org



Koch snowflake, Wikipedia commons



Mandelbrot (1967)

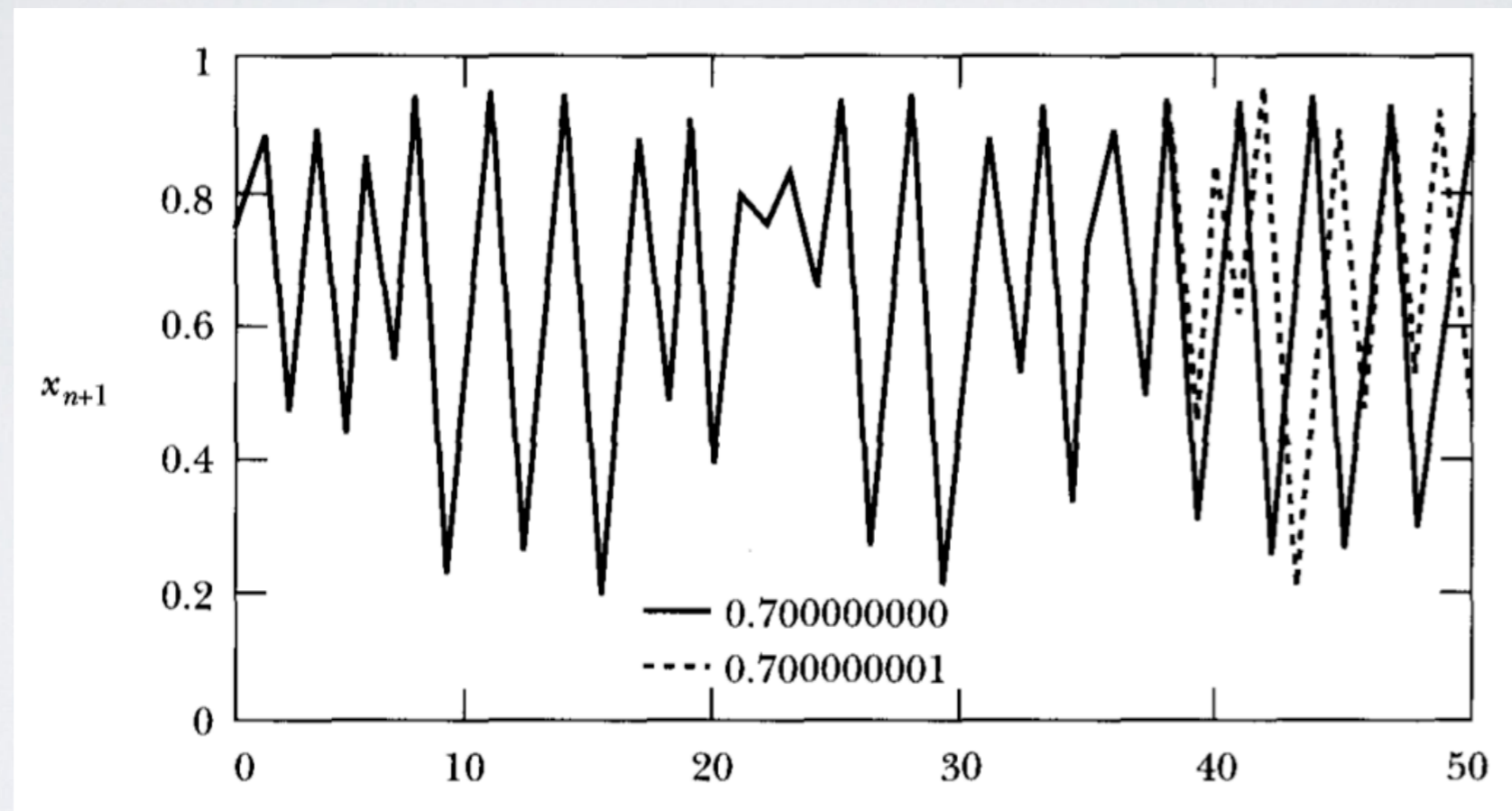


# Quantifying Chaos

# Quantifying Chaos: Exponential Growth

- $\alpha = 2.5$  in  $x_{n+1} = \alpha x_n(1 - x_n^2)$

Thornton & Marion, Eq.(4.48)



Thornton & Marion Fig 4-24

# Lyapunov Exponent

- $3.5 < a < 4$

