Physics - Geology 30: Fractals, Chaos and Complexity

Course Syllabus - Winter Quarter, 2020

Lecture Times: MWF 1:10 - 2:00 pm Lecture Room: 1348 Geology GEL 30 Section 001 CRN PHY 30 Section 001 CRN	Instructor: John Rundle, Professor of Physics and Geology Offices: 534B Physics Building 2131 Earth & Planet Sci. Building Office Hours: 2-3 MWF or by appointment

Recommended Course Text:

David Peak and Michael Frame, Chaos Under Control, WH Freeman, NY, 1994
Currently out of print, but can be obtained from the following vendors:

Amazon
http://www.amazon.com/Chaos-Under-Control-Science-Complexity/dp/0716724294/ref=sr_1_1?ie=UTF8&s=books&qid=1195085929&sr=1-1

Barnes and Noble
https://www.barnesandnoble.com/w/chaos-under-control-david-peak/1119266031?ean=9780716724292

AbeBooks
https://www.abebooks.com/9780716724292/Chaos-Under-Control-Art-Science-0716724294/plp

Highly Recommended Text:

Manfred Schroeder, Fractals, Chaos, Power Laws, Minutes from an Infinite Paradise
(Available from Amazon)

Optional Texts:

David Feldman, Introduction to Chaos and Fractals, Oxford, 2012

Richard Kautz, Chaos, The Science of Predictable Random Motion, Oxford University Press, 2011

Other Optional Texts:

Briggs, J., Fractals, the Patterns of Chaos, Discovering a New Aesthetic of Art, Science, and Nature, Simon and Schuster, 1992

Gleick, J., Chaos, Making a New Science, Viking, New York, 1987.

Waldrop, M.M., Complexity, The Emerging Science at the Edge of Order and Chaos, Simon and Schuster, New York, 1992.

G.L. Baker and J.P. Gollub, Chaotic Dynamics, An Intrduction, Cambridge University Press, 1990

General Chaos Web Sites

Frame_Home_Page (Some links are broken)

Wolfram Demo Sites (Includes many types of demos - search for chaos)

Game_of_Life

Fractint

http://hypertextbook.com/chaos/

Logistic Map

http://brain.cc.kogakuin.ac.jp/~kanamaru/Chaos/e/Logits/ (.jar file)

http://www.egwald.ca/nonlineardynamics/logisticsmapchaos.php

Lorenz Attractor (.jar file)

https://www.compadre.org/osp/items/detail.cfm?ID=8986

Mandelbrot Set Generator

http://math.hws.edu/eck/jsdemo/jsMandelbrot.html

Guide to the Mandelbrot Set

Anatomy of the Mandelbrot and Julia Sets

Fractal Basin Boundaries

http://brain.cc.kogakuin.ac.jp/~kanamaru/Chaos/e/Newton/ (.jar file)

http://www.personal.psu.edu/faculty/m/x/mxm14/fractal.htm

>

Cellular Automata

Wolfram Mathworld

Logic Gates

https://en.wikipedia.org/wiki/Logic_gate

Turing Machines

http://morphett.info/turing/turing.html

http://www.turing.org.uk/turing/scrapbook/tmjava.html

Neural Networks (Develop Yourself Using Neuroph)

https://developer.ibm.com/tutorials/cc-artificial-neural-networks-neuroph-machine-learning/

Probability

http://onlinestatbook.com/stat_sim/ (Note JAVA code won't run)

http://www.rossmanchance.com/applets/OneProp/OneProp.htm

Cluster Growth: Dimension d = 2 Random Site Percolation

http://www.ibiblio.org/e-notes/Perc/perc.htm (JAVA code won't run)

Cluster Growth: Diffusion Limited Aggregation in d = 2

http://paulbourke.net/fractals/dla/

Cluster Growth: Random Walk

http://dananne.org/dart/randomwalk/web/randomwalk.html

https://demonstrations.wolfram.com/search.html?query=random+walk

Forest Fire Model

http://www.eddaardvark.co.uk/svg/forest/forest.html

Artificial Life

http://www.aridolan.com/ofiles/alife.aspx

Prerequisites

None

General Comments:

This course will introduce students to the ideas of Fractals, Chaos, Complexity and Computation. We will begin with the examples of objects, such as trees, river networks, coastlines, weather, earthquakes, the human body, the stock market, evolution, and others that display examples of fractal geometry. We will then explore many of the fascinating ideas popularized by B. Mandelbrot and others about self-similarity across different geometric scales. Chaos, how it arises in familiar everyday systems, and the link with fractal geometry, will be discussed. We will talk about how processes of "self-organization" arise in systems with feedback, and the ways in which those processes lead to the emergence of coherent space-time structures for systems with no natural length or time scales. We will discuss the idea of Cellular Automata and its relationship to computation. We will examine how chaos and order are inextricably linked with a kind of strange duality. Many of these ideas are having a profound effect in fields far from their point of origin. As a result, we will explore the profound philosophical implications of these ideas, including their effects on modern art and architecture, and especially on the definition of life itself.

Course Content

Topics to be Covered Include:

1. Geometry, self similarity, and patterns
2. Making fractals through recursive iteration
3. Measuring fractals - fractal dimension
4. Chaos, randomness, and noise - similarities and differences
5. Iterated maps - the logistic and tent maps - fixed points
6. Complex numbers and the Mandelbrot set
7. Edge of chaos, fractal boundaries, and fractal domains
8. Cellular automata and information processing
9. Applications to real systems

Homework and Grading:

1. Class Participation -- 20%
2. Final Project -- 65%
3. Homework and labs -- 15%.

Late Homework will be accepted (within reason)

Class Project

1-paragraph description of the project -
Should be a paper of 5 pages or longer researching some topic in chaos/complexity/fractals, preferably involving some computer calculation/graphics, demonstrating and understanding of the basic scientific ideas. It can also be an application to a real system.

Examples might include

1. A discussion of the fractal nature of river networks, trees, bronchial tubes, or the like.
2. A small project on chaotic maps, such as the logistic map, and how they can be applied to real systems
3. A project on fractal art, generating images like trees, mountains, rivers, or other fractals
4. An investigation of neural network learning models, and how these can be used in real applications
5. A research project on the theory of computation, and how dynamical systems can carry out computation