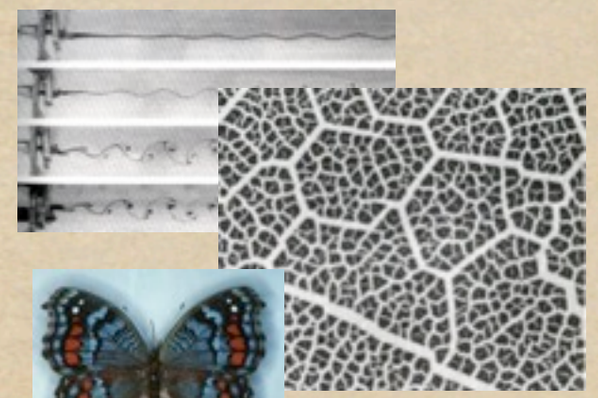
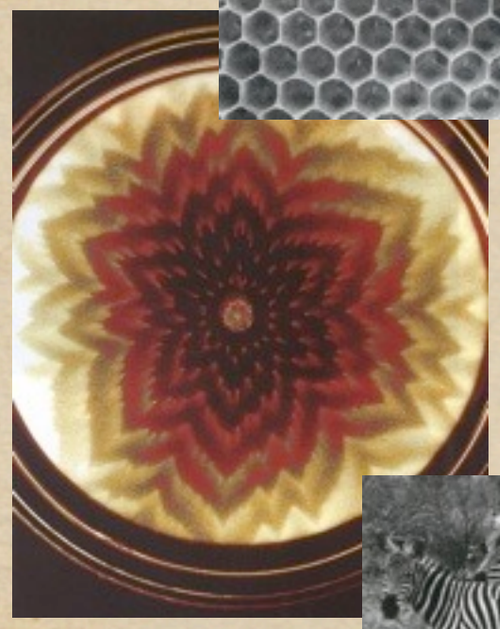
Computational Lab in Physics
Physics 102





Prof. Jim Crutchfield

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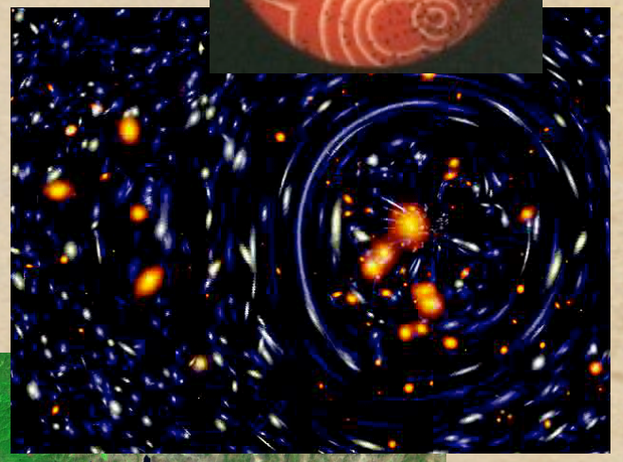
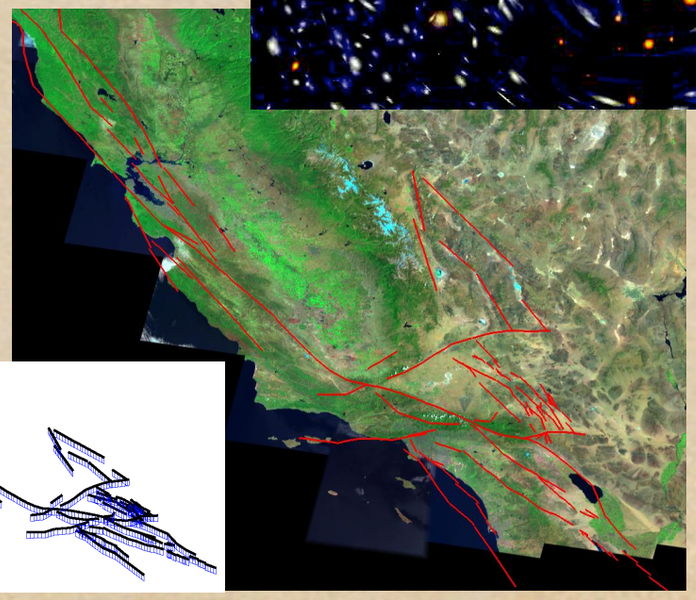
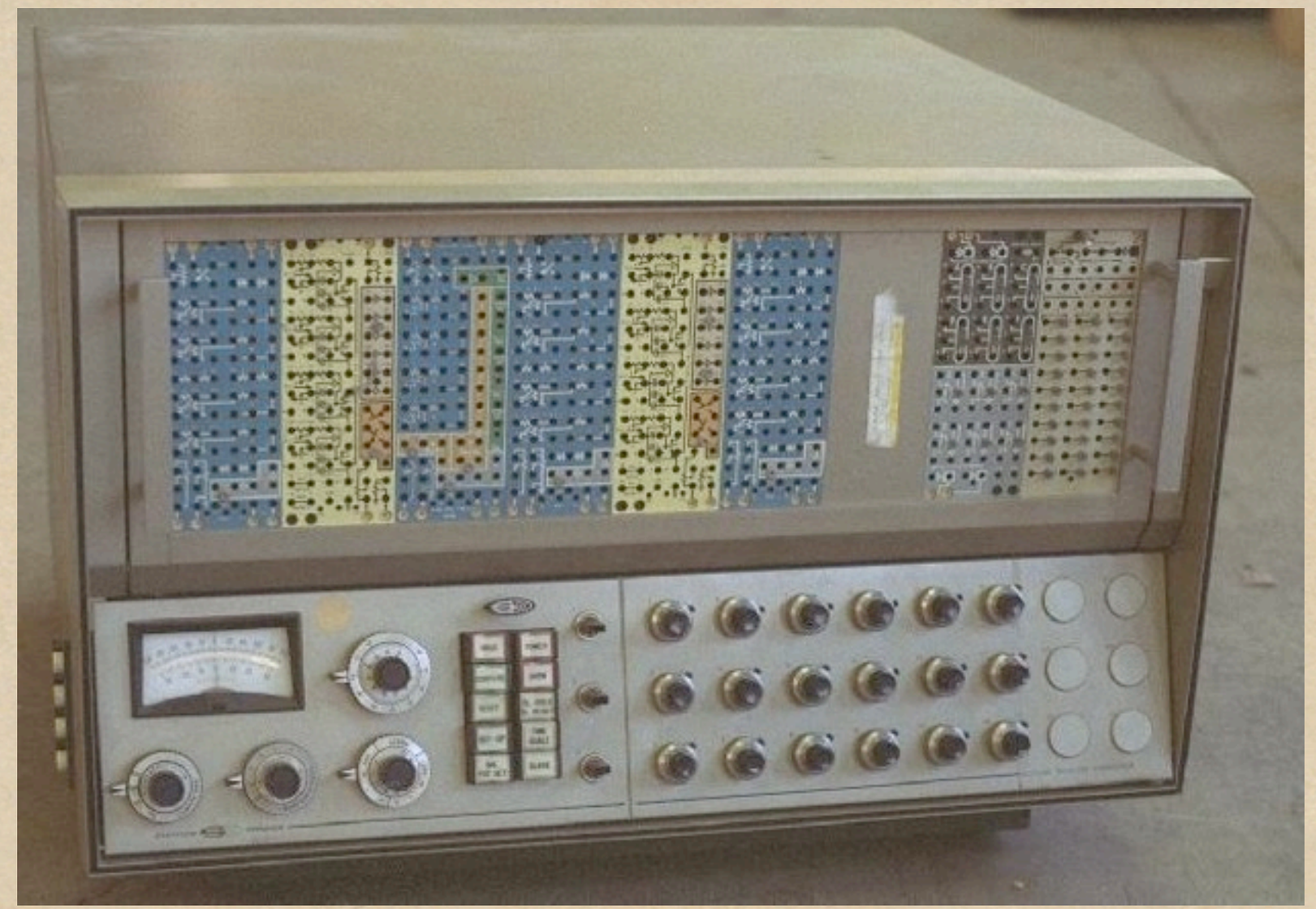




Why Compute?

- "Big Theory"
- Delivered at Microsoft Research
- 12 September 2012
- Keynote at AstroInformatics 2012

A beginning



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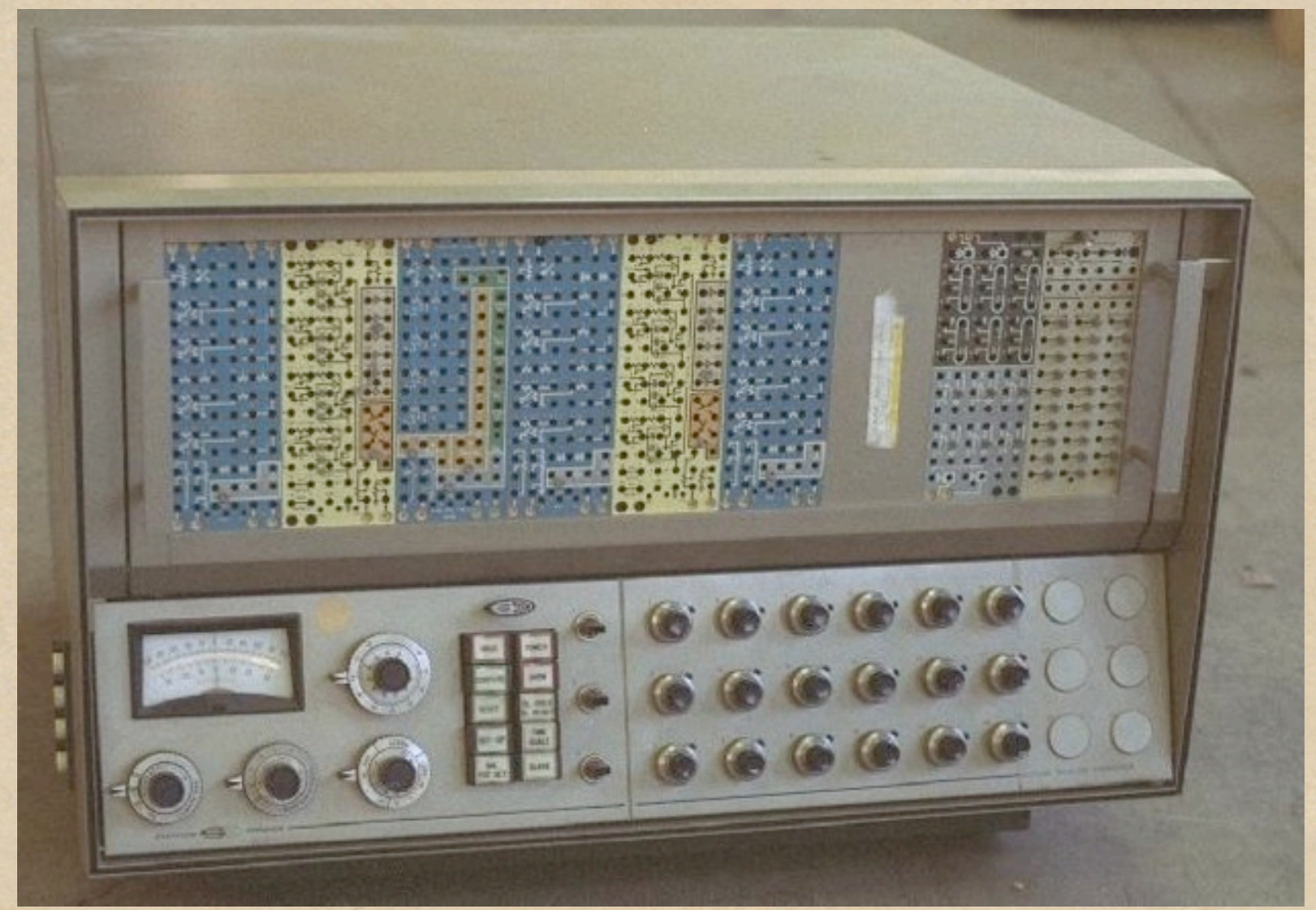


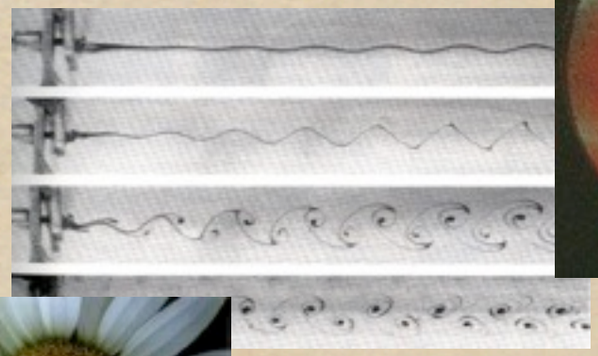
Systron Donner
SD 10/20

Why We Must Compute I

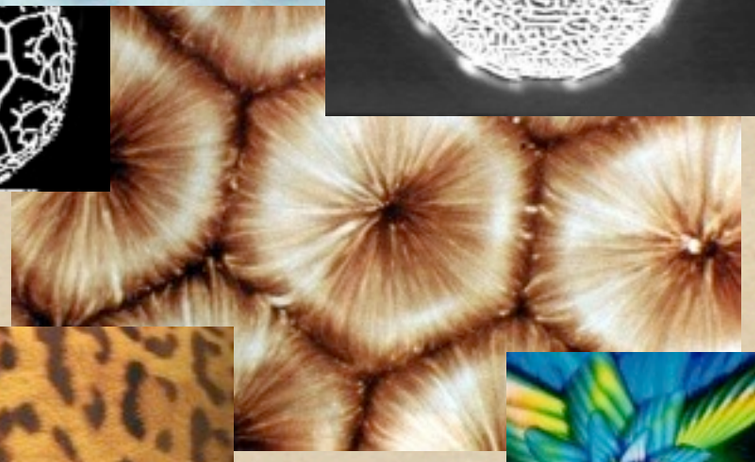
- Fundamental science:
  - Emergent structures
    - Nature spontaneously organizes

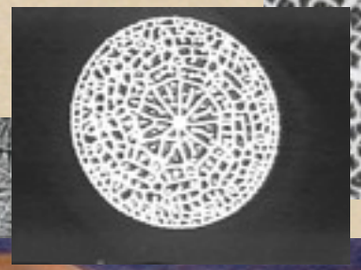
Emergent structures

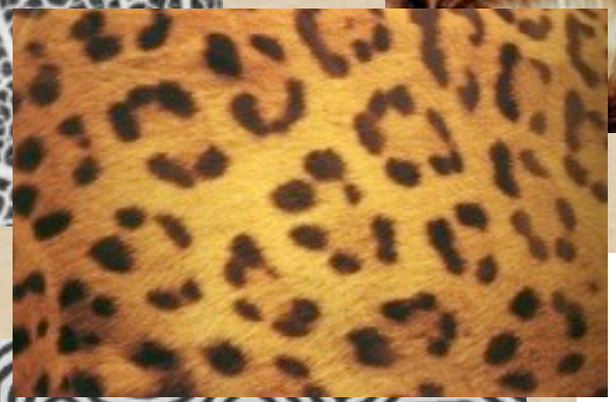
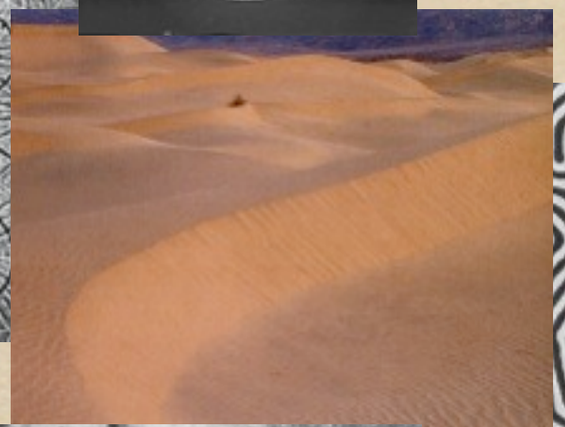


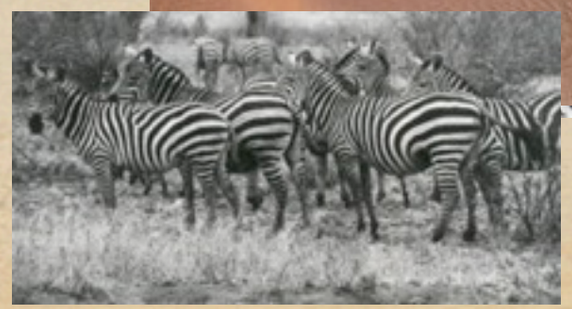








Emergent structures

- Engineered systems also spontaneously organize
  - Internet route flapping
  - Power-law Internet organization
  - Financial markets crash
  - Power grids fail spectacularly
  - Social pattern formation on the web
  - ...

Consequence

- Each system needs its own function basis
- Emergent structures not given directly by the governing equations of motion

- We must compute to explore the possible

Why we must compute II

Pierre Simon de Laplace, Calculus of Probabilities (1776).

- Determinism: "... if we conceive of an intelligence which at a given instant comprehends all the relations of the entities of this universe, it could state the respective positions, motions, and general affects of all these entities at any time in the past or future."
- A paradigm: "Physical astronomy, the branch of knowledge which does the greatest honor to the human mind, gives us an idea, albeit imperfect, of what such an intelligence would be."
- Ignorance: "So it is that we owe to the weakness of the human mind one of the most delicate and ingenious of mathematical theories, the science of chance or probability."

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Deterministic chaos: "... it may happen that small differences in the initial conditions produce very great ones in the final phenomena. A small error in the former will produce an enormous error in the latter. Prediction becomes impossible ...

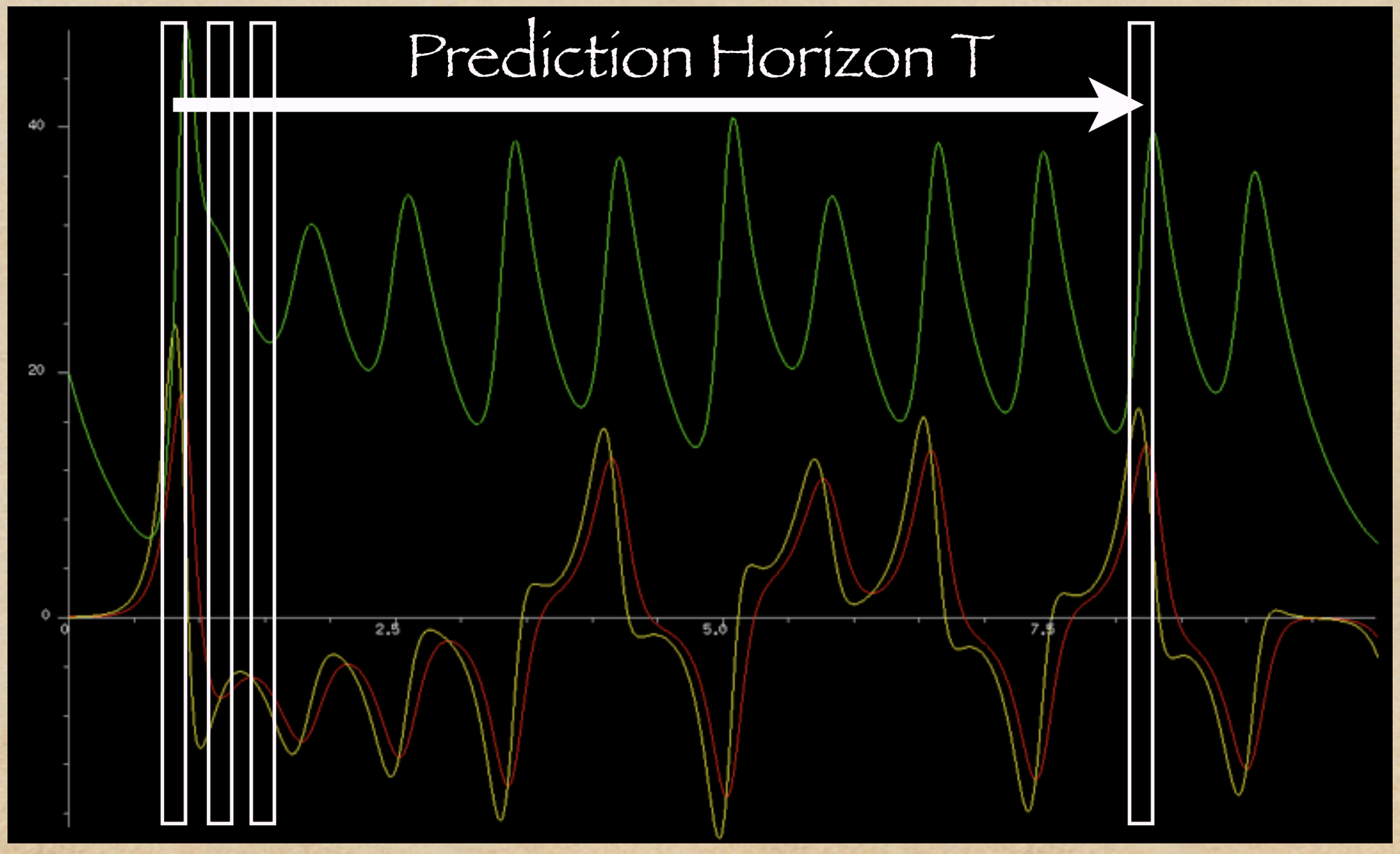
Henri Poincaré, Les Methodes Nouvelles de la Mecanique Celeste (1892).

Exponential Increase in Prediction Resources

$$\text{Accuracy} \propto e^{-T}$$

$$|\text{Measurements}| \propto e^{T}$$

$$|\text{Compute time}| \propto e^{T}$$



Consequence

- No short cuts!
- No closed-form solutions
- No computational speed-ups

- We must compute full trajectory

Why We Must Compute

- Computing is a response:
  - Emergent organization
  - Unpredictability
  - Limited epistemology

Consequence

- Computationalists will be employed

(We just proved guaranteed employment.)

Logic of the Course

- Basic introduction to computing for physics
- Tool Building: Programming
- Uses: Exploration & analysis

How to do this?

- Computing methods:
  - Numerical analysis
  - Simulation
  - Interactive visualization
  - Symbolic analysis (optional)

Practical Goals

- Able to program sufficiently well for upcoming physics classes
- Learn to build *your* own physics tools

Prerequisities

- Interest in analyzing physical phenomena
- Mathematics:
  - Vector calculus
  - Linear algebra
  - Lower division Math, Physics, or CS courses
- Programming:
  - Experience with C/C++, Java, or ...
  - We will use Python
- Preferred environment:
  - Laptop with Python v. 2.7 running

Why Python?

- Open source & free!
- Hierarchy of programming structures:
  - Procedural (like C/Fortran)
  - Object oriented (like C++/Java)
  - Functional programming (like Haskell/Lisp)
- Interpreted, not compiled:
  - Easy to test code, interactive
  - Scriptable (like Perl)
  - Can be slow!
- Excellent libraries: OS, numerical, WWW, parallel, ...
- Wide range of tools available:
  - Development: e.g., Eclipse, Wing IDEs
  - WWW

Course Organization

Tools-for-Physics Labs (in order):

- Programming
- Simulation
- Graphics
- Interaction

Organization ...

- Each week:
  - Lecture (Tuesday): Go over basic concepts
  - Lab (anytime!): Work online labs, do homeworks

Who are we?

- Me: JPC
- Assistant: Alec Boyd
- You: (Please fill out questionnaire.)
  - Interests
  - Background
  - Abilities

Course logistics

- Course Website:

  csc.ucdavis.edu/~chaos/courses/clab/

- Readings: Assignments on website
- Labs: Exercises on website

  Due at beginning of Tuesday lecture

- Grading:
  - 6 or 7 lab homeworks

Staying in touch

- Course Website:

  csc.ucdavis.edu/~chaos/courses/clab/

- Email

  chaos@ucdavis.edu & alecboy@gmail.com

- Office hours

  JPC: Wednesday 3-4 PM, 197 Physics (in lab, on request)

  AB: In lab M, W, Th (5-6 PM)

Materials

- Suggested Books

[Python] Learning Python, M. Lutz, Fourth Edition, O'Reilly & Associates (2009).

- Lecture Notes & Labs online

Software

- Goal: Learn via Numerical Analysis and Coding
- Python Tools & Development:
  - Python v. 2.7
  - Packages:
    - Numerical: NumPy & SciPy
    - Graphics: matplotlib & MayaVi & PyGlet
    - Images: PIL
    - Development: iPython and others
- See course web pages for configuration help:

  csc.ucdavis.edu/~chaos/courses/clab/Software/

Enthought Python Distribution 7.3: Windows, Linux's, & Mac

Who has what?

- Fill out questionnaire
- Laptop?
- OS:
  - Windows?
  - OS X?
  - Linux?

Physics computer lab is in 106 Physics:

Work there any time its open.

You have an account already, if registered last week.

Use campus Kerberos account name and password.

Others need accounts?

OS is Linux: Who needs help with Unix/Linux?

Tasks to do this week

- Get your own machine(s) running Python 2.7
  (Enthought Python Distribution 7.3)
- Test your computing lab account.
- Set up EPD 7.3 on lab account:
  Login & Run: 122setup
  Browser to use: firefox16
- Familiarize yourself with Linux/Unix:
  See tutorials on course website.

Reading To Do

- "Chaos", Scientific American (online)

Homework 0

- Log onto *your* computer account. Make sure it works.
- If *you* are not already familiar with an editor, read one of the tutorials on vi commands here.
- Type in simple Python programs to a file.
- Run *your* programs.
- Practice using basic Unix commands.
- Send *your* files to Alec.