The Behavior of Complex Systems: from Human Decision Making, through the Power Transmission Grid and on to Plasma Turbulence

(Trees are Complicated - Forests are Complex)

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Complex Systems are everywhere

-They have important "universal" characteristics

-Easy to study for fun and profit

Osher Lifelong Learning Institute
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Some of the students who have worked on these topics

Undergraduate

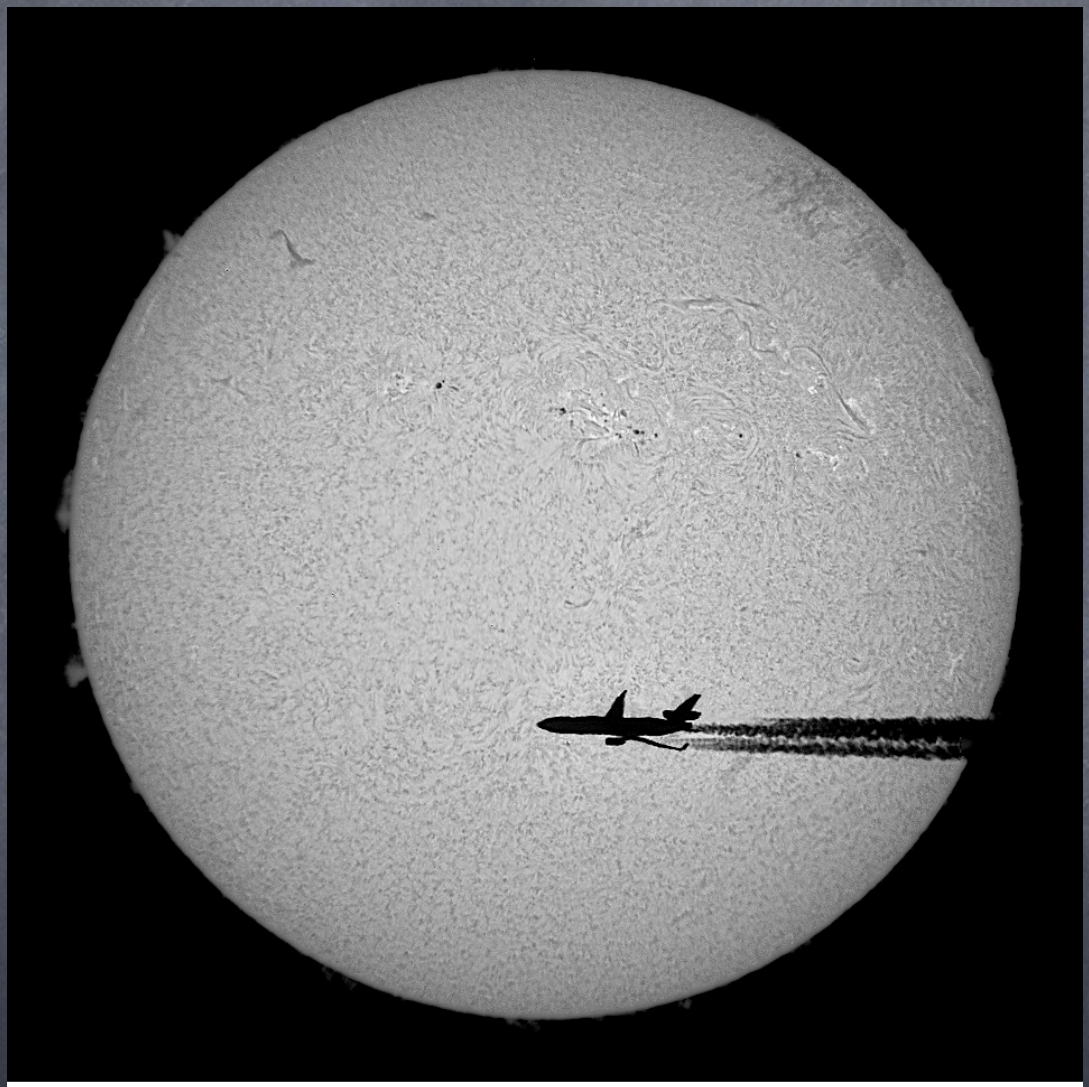
- Marc Kirchner
- Cheradan Fikstad
- John Broussard
- Keiko Ino
- Aaron Boyd
- David Benbennik
- Andy Lester
- Haiyin Chen

Graduate

- Douglas Ogata
- Joseph Ditommaso
- Adam Cornachione
- Satish Degala
- Debasmita Samaddar
- Oralee Nudson
- Seth Underwood
- Erin Boyd
- Willis Ferenbaugh
- Ryan Woodard

+ R. Sanchez, BA Carreras, JN Leboeuf, PW Terry, I. Dobson, JM Barredo and many others

Perception



Date: January 13 2001 Time: 11:11 UT Carrington N°: 1971 Central meridian: 53.11 deg
70mm (2.75") Pronto refractor at F/D 10 & KAF-1602E CCD camera & Daystar 0.6Å T-Scanner H-alpha filter
Thierry Legault (Elancourt, France) legault@club-internet.fr http://perso.club-internet.fr/legault/

Imagination

The Turing machine vs the Brain

(the rational vs imagination?)

Sir Roger Penrose does not believe the brain can be modeled by a Turing machine (a serial rule based computer)

- Leaps of faith (imagination??)
  - » Quantum mechanical basis in microtubuls??

- Use your imagination: look at things in many ways
- Don't get caught in the "this is how it's always been done trap".

Outline

- Motivation
  - What are Complex Systems
  - Dynamics of complex systems
  - Universality
  - Fusion
- Motivation for simple models
  - What is SOC
  - Models exhibiting SOC
  - Characteristics of Sandpile model
  - Forest fire model
  - Infrastructure models
  - Human behavior
- Summary

What is the goal of science? Why are we building models?

We want to understand nature

- Remember models are at best a representation of the the physical world
  - ➡keep their limitations in mind
- To be useful models must have either a predictive capability or an explanatory capability
  - ➡Predict something new (regime etc)
  - ➡Clarify some physical process (Occam's razor)

Complex Systems

- What we mean by a Complex System
  - Many nonlinearly interacting parts => overall behavior (dynamics) not the sum of the individual behaviors
- Importance of nonlinear terms (dynamics)
  - Temporal evolution (dynamics) and steady state (equilibrium)
- Low dimensional vs. high dimensional dynamics
  - Chaos vs. complex dynamics
- Usefulness of study of "Complex Systems"
  - Fashionable
  - Universality of dynamics
    - Implies universality of underlying physics?
    - Predictive capabilities?

Complex vs Complicated

Cars are complicated, traffic is complex

Trees, forest

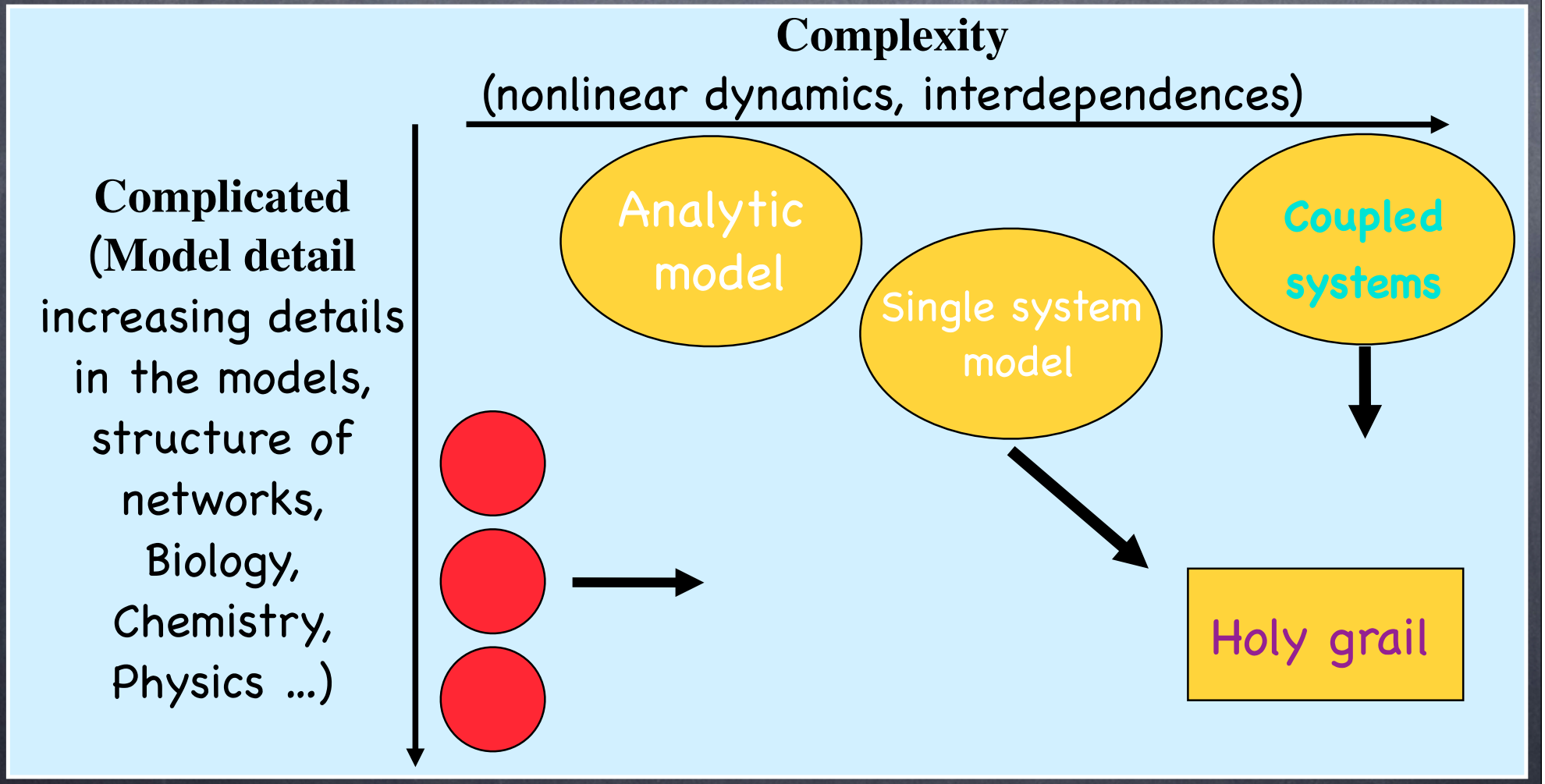
Neurons, the brain

Computers, the internet

- Systems can be complicated without being complex and complex without being complicated

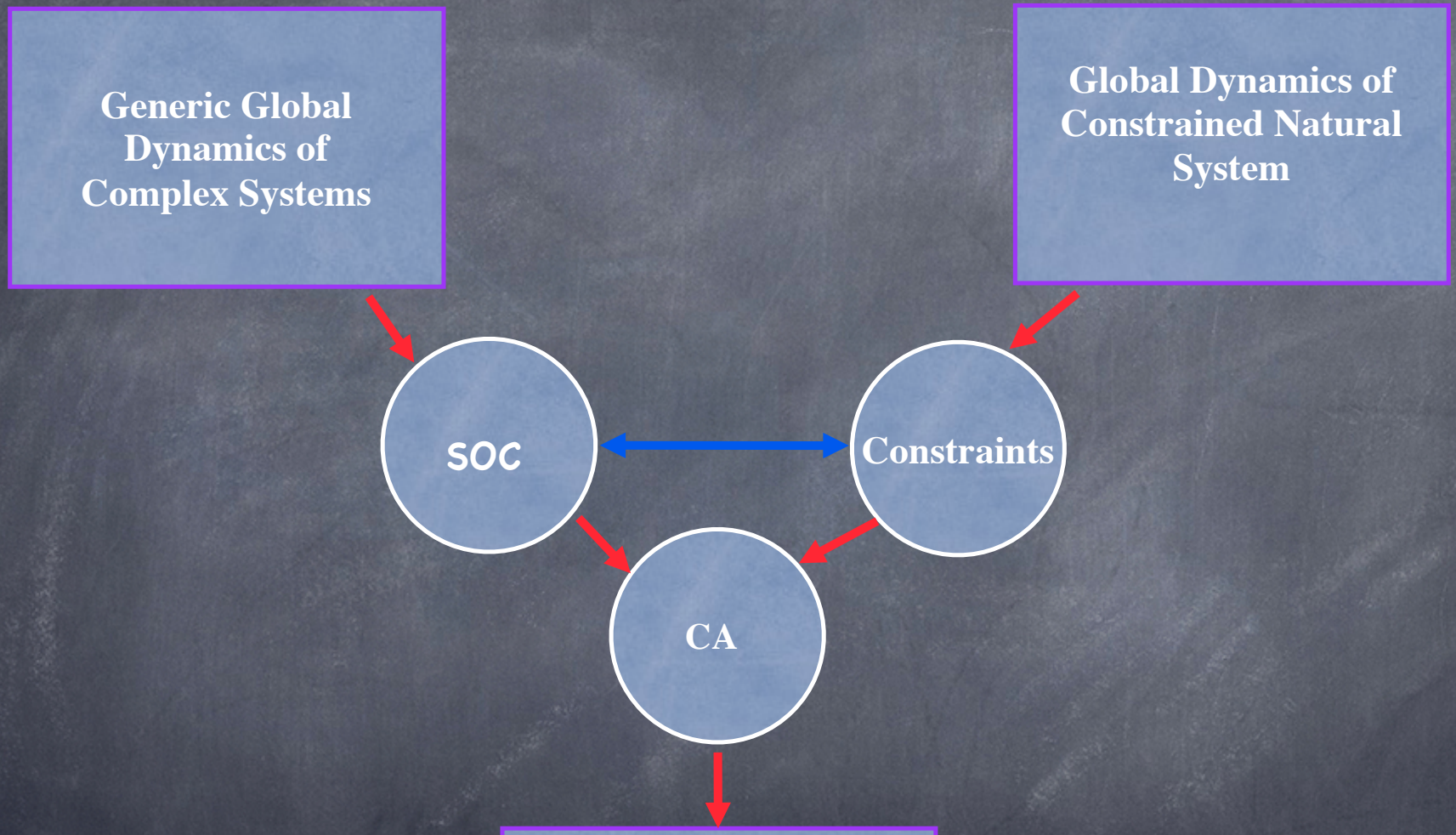
The real world is usually both

Complex vs. Complicated: Complimentary approaches to modeling System Dynamics



By using models with fewer details => can investigate the complex behavior to extract universal features (critical points, power tails, measures...).

Reductionist Philosophical Approach



Note this is not the classical definition of reductionist modeling

Interdisciplinary Synergy

- Different approaches to complex systems have come from many different disciplines (mathematics, physics, biology, economics, social sciences etc)
- It's easier to apply an idea developed in another field then it is to reinvent it
    - Complex systems research has diffused across fields
- Interaction between Systems often "belonging" to different disciplines needs both to get it right
- It is often easier to ask "stupid" questions and to question "accepted truths" as an outsider (with a connection!)

Complex Systems

- Include among others
  - Infrastructure systems
    - Power transmission
    - Communication (IT)
    - Pipelines
    - Transportation
  - Human systems
    - Markets
    - Policy and decision making
    - Social behavior - trends, learning and reacting
- Physical
  - Plasmas
  - materials
  - biological
  - ecological
  - chemical
  - meteorological and climatological
- Coupled systems
  - Take any from the above and mix and match

Some of these have complicated parts, some do not