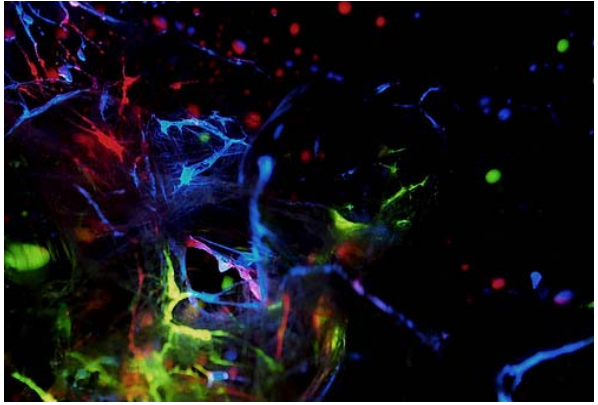
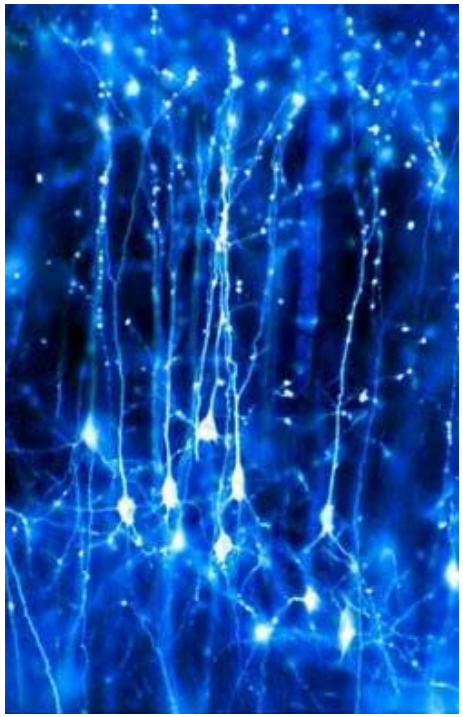
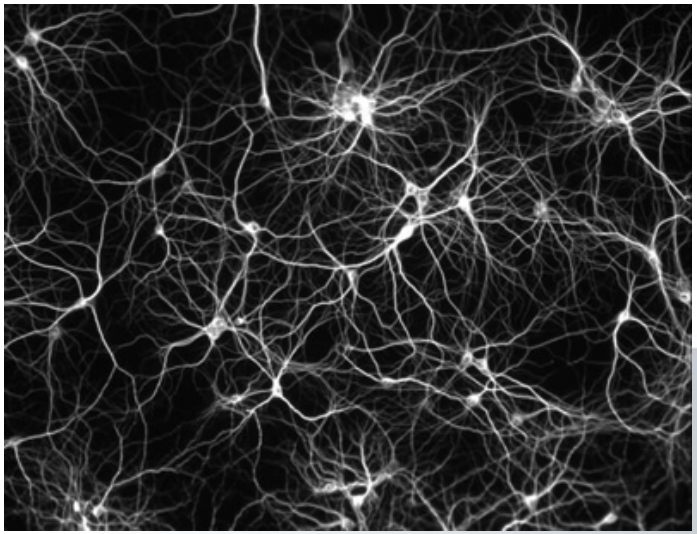
From *Dynamics* to *Structure*

and Back







张 捷， EIE Dept.

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Collaborators

- **Dr. Xu Xiaoke**

  Qingdao University
- **Dr. Zhang Kai**

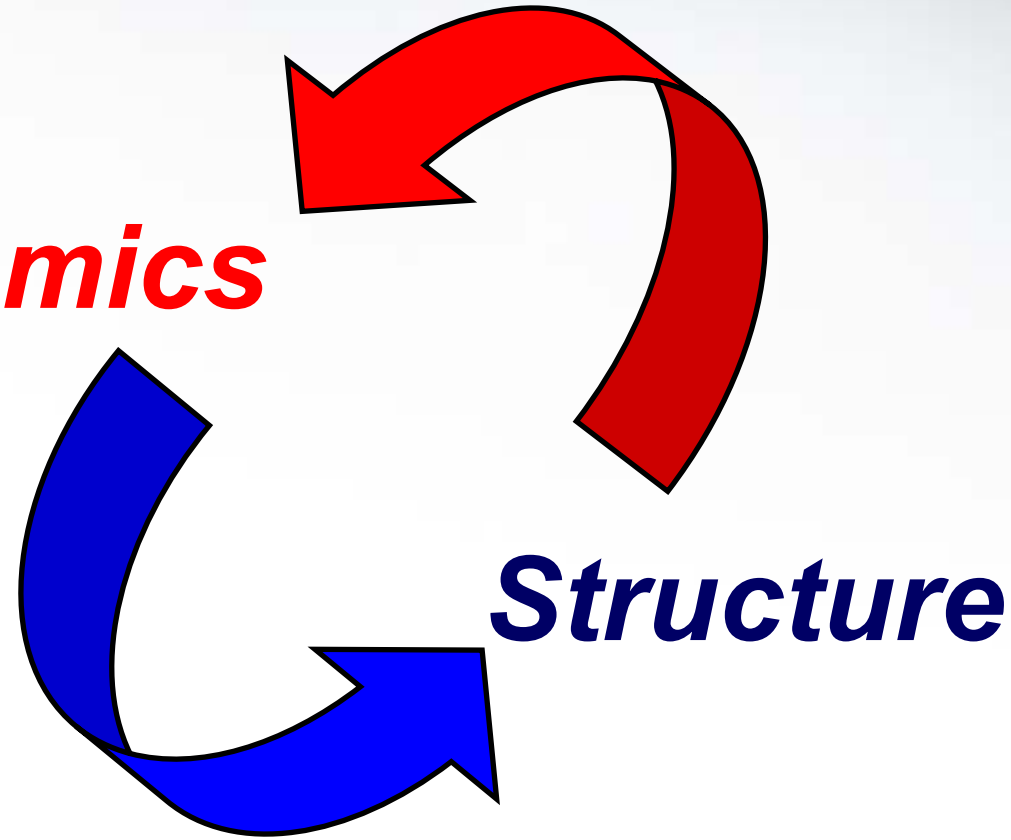
  Lawrence Berkeley National Laboratory
- **Prof. Changsong Zhou**

  HK Baptist University
- **Prof. Michael Small**

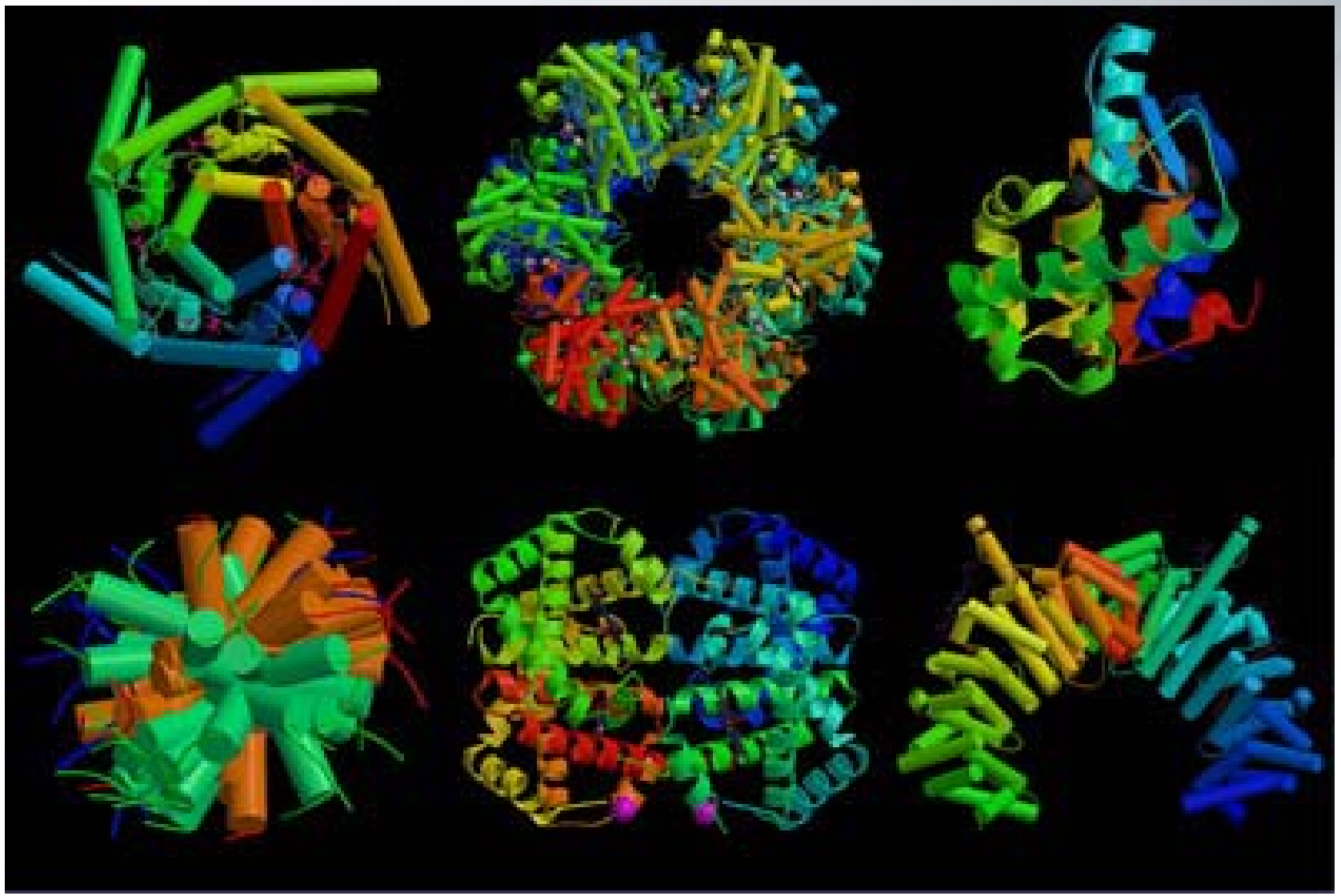
  HK PolyU

Understanding & Predicting

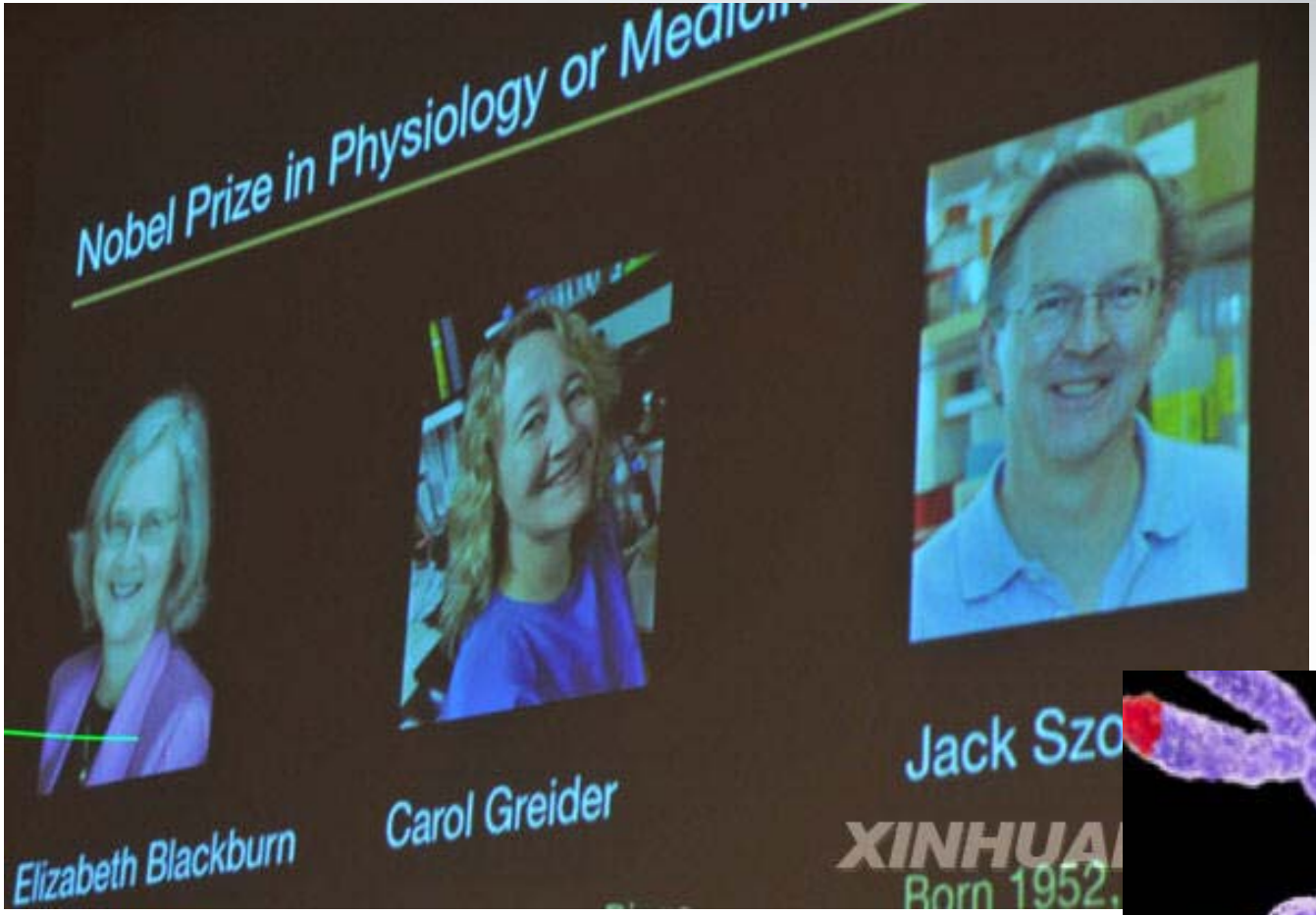
the complex dynamics of complex systems

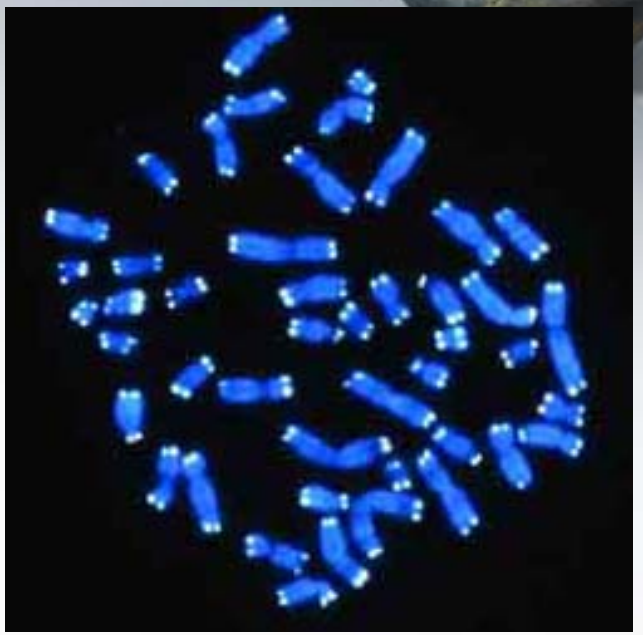


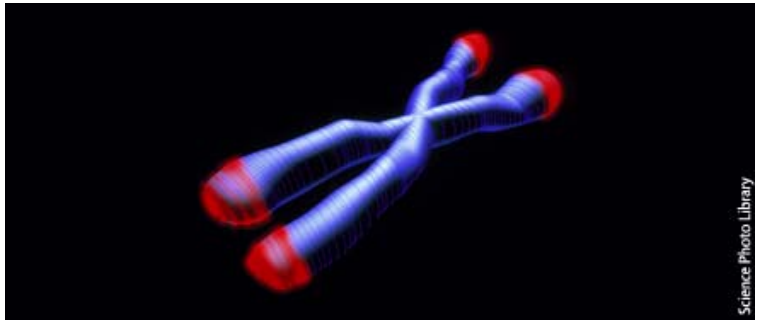
Protein – Structure vs. Function



2009 Nobel Prize in Physiology

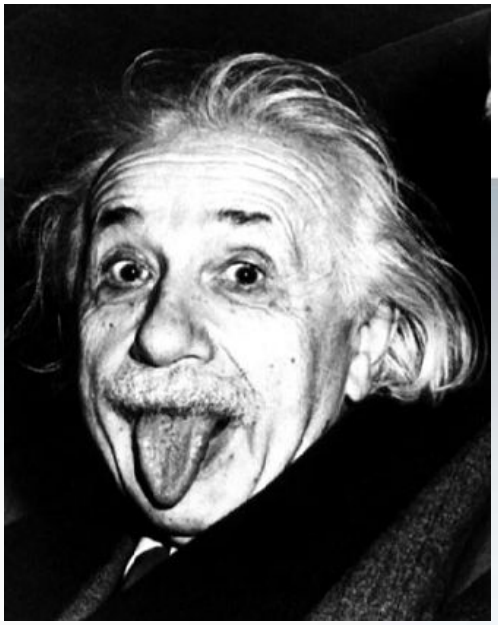






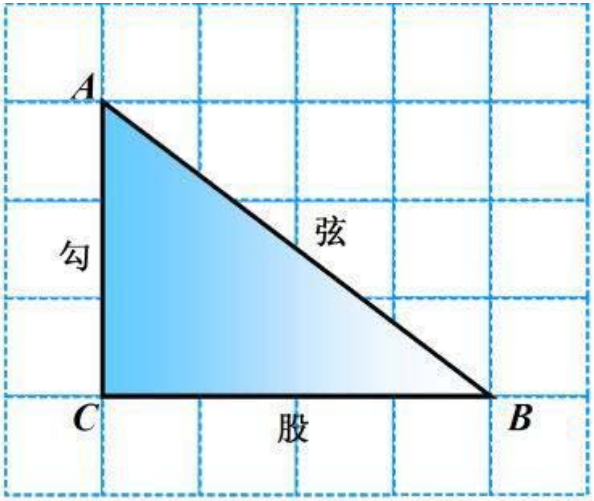
Human Brain

Structure vs. Function

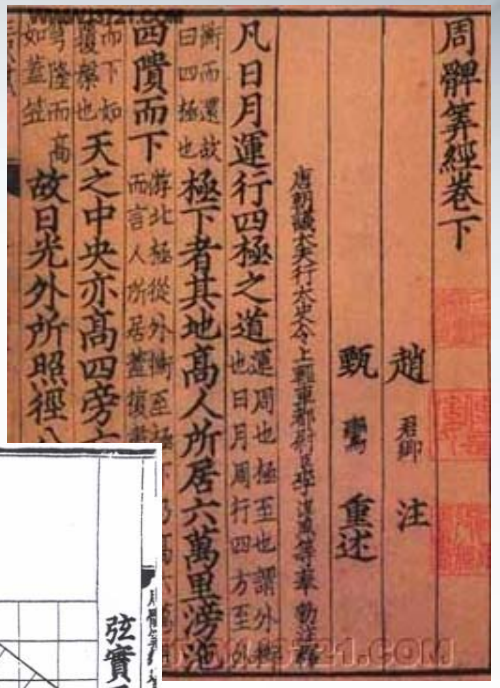


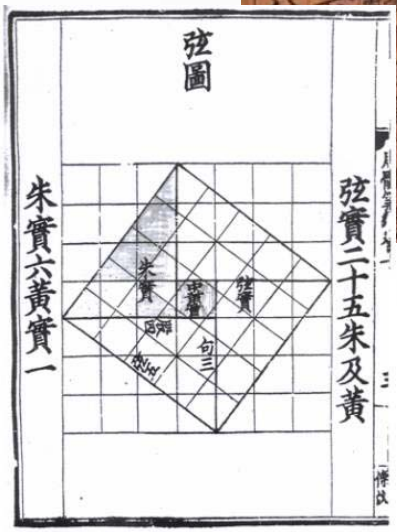
勾股定理 Pythagoras Theorem

Combination of
Numbers* and *Figures



$$AC^2 + BC^2 = AB^2 \Rightarrow AB = \sqrt{AC^2 + BC^2}$$

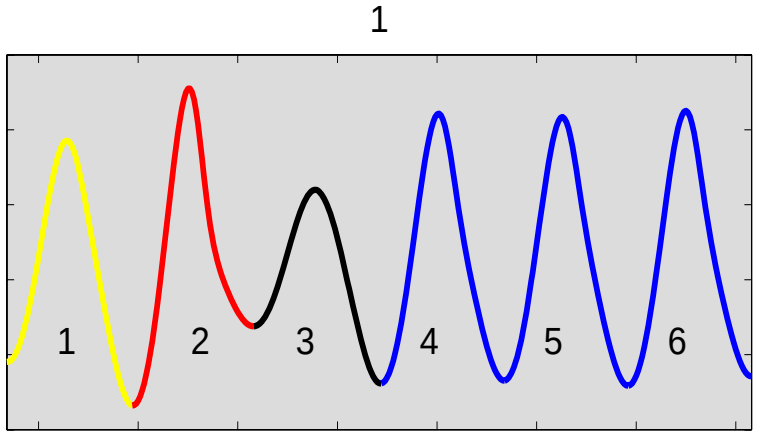

周髀算經卷下
趙君卿 注
甄鸞 重述

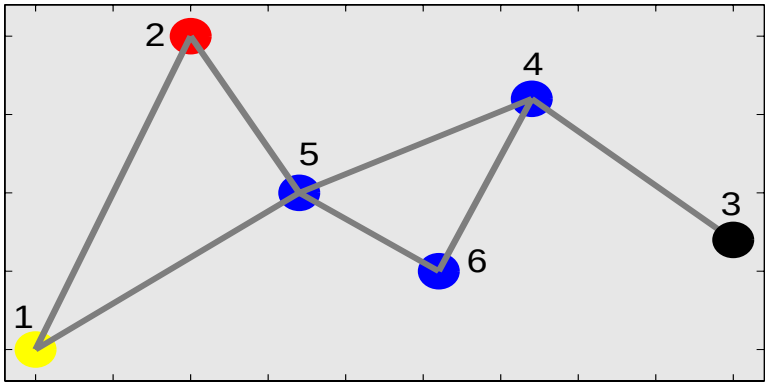


Algebra versus Geometry

Brief Outline

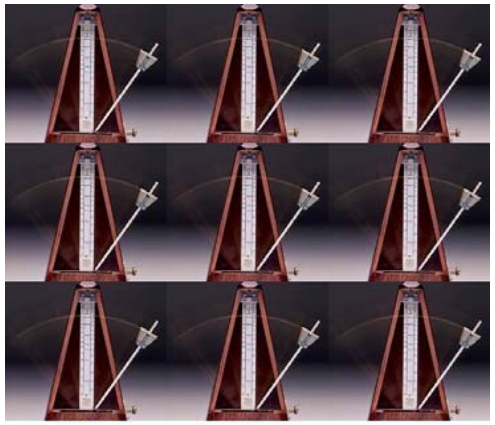
- **Part 1: From *Dynamics* to *Structure*:**

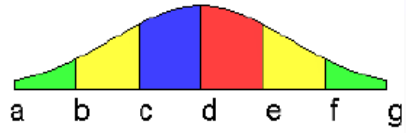


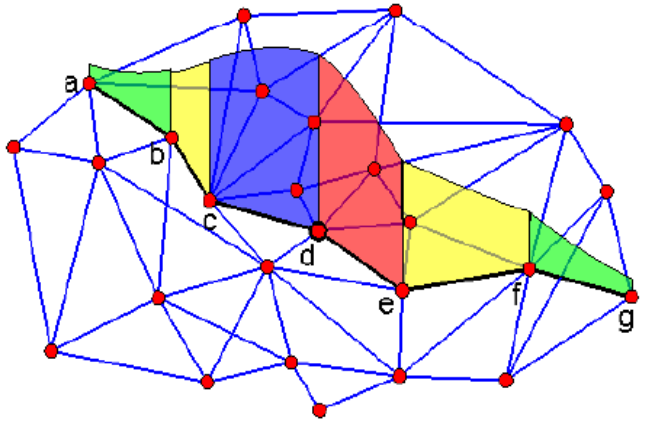


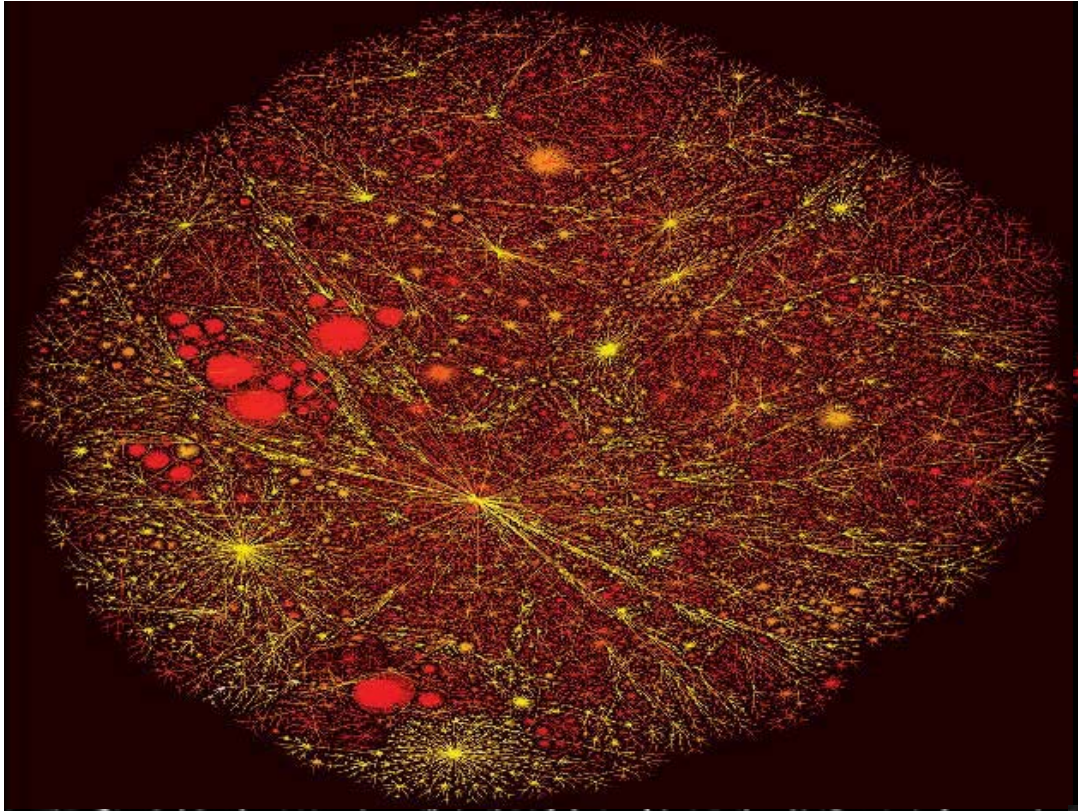
- **Part 2: From *Structure* back to *Dynamics:***

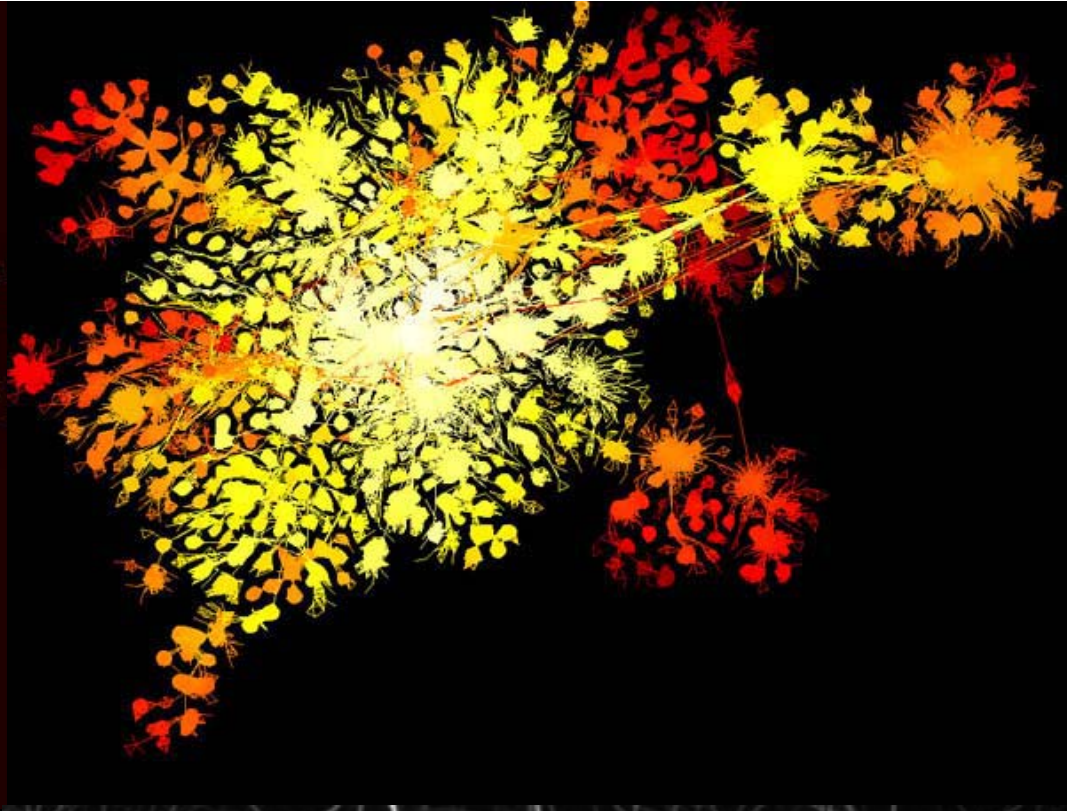
Predicting collective dynamics emergent on networks

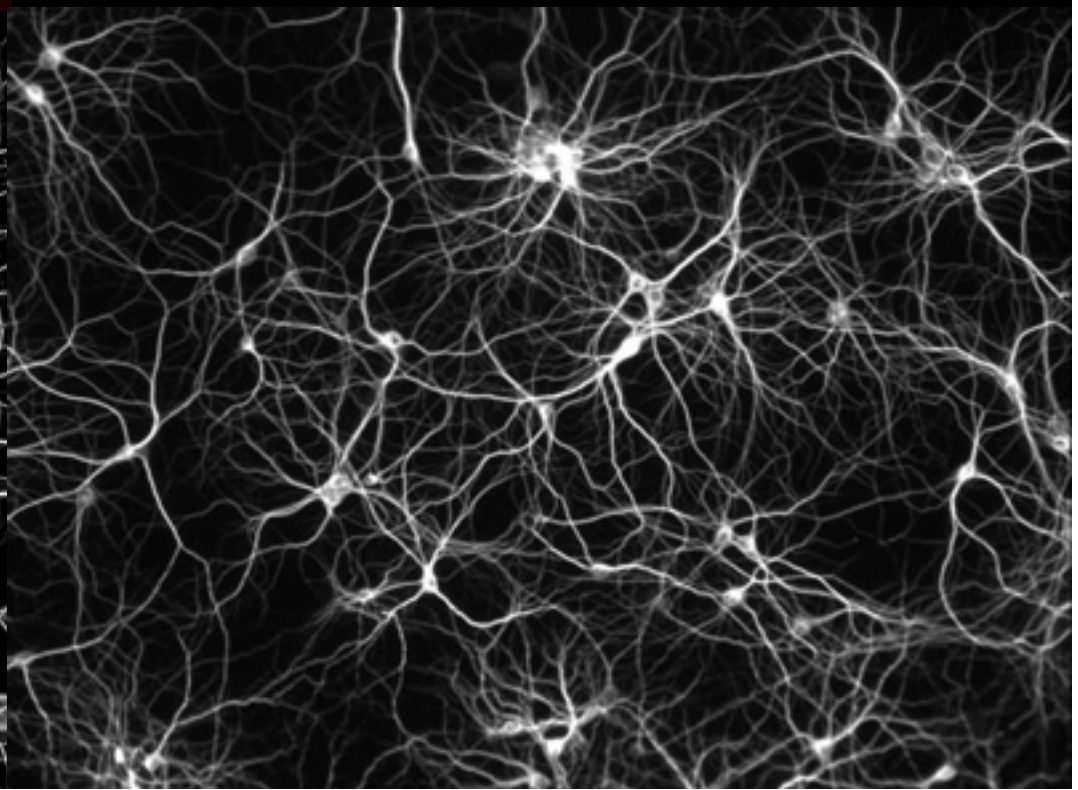




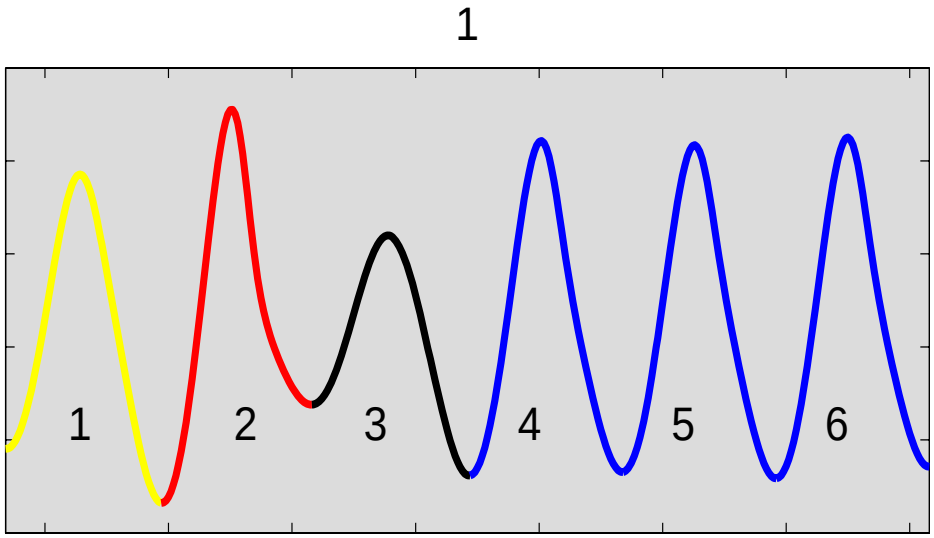








1. From *Dynamics* to *Structure*

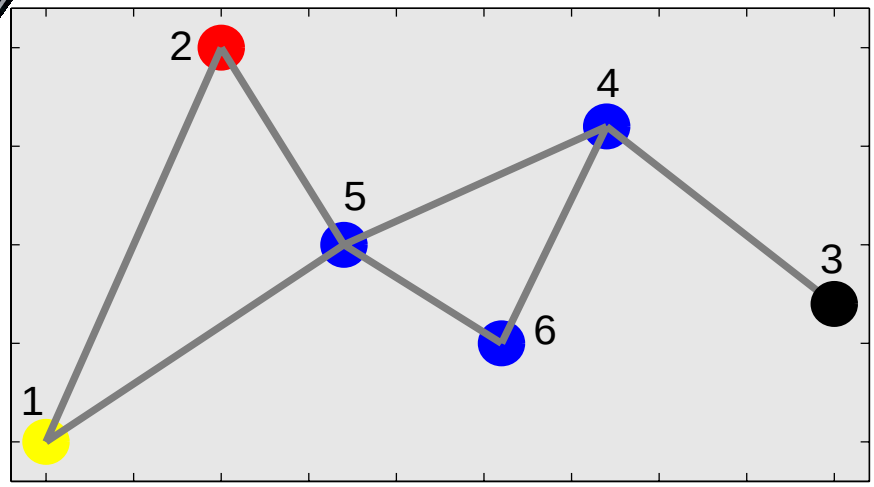


Complex Networks from Pseudoperiodic Time Series: Topology vs. Dynamics

J. Zhang, M. Small

Physical Review Letters 96, 2006

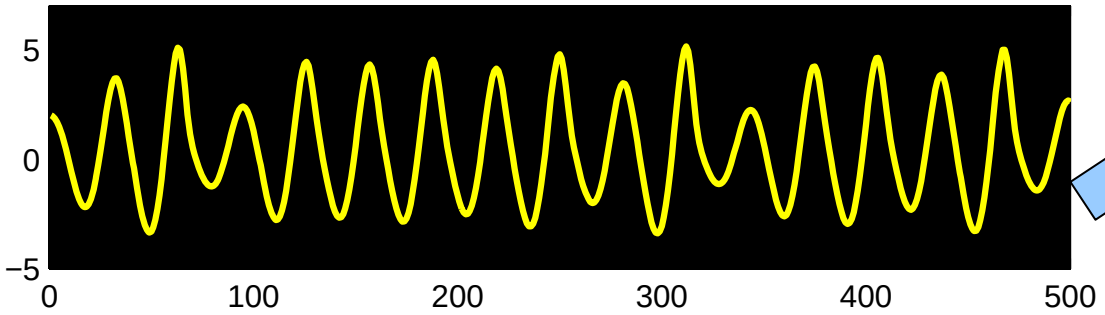
- Segment the signal into individual cycles *Ci, i=1,2,3,…N.*
- Calculate the correlation among *Ci* and *Cj (Wij)*, and connect them if highly correlated.

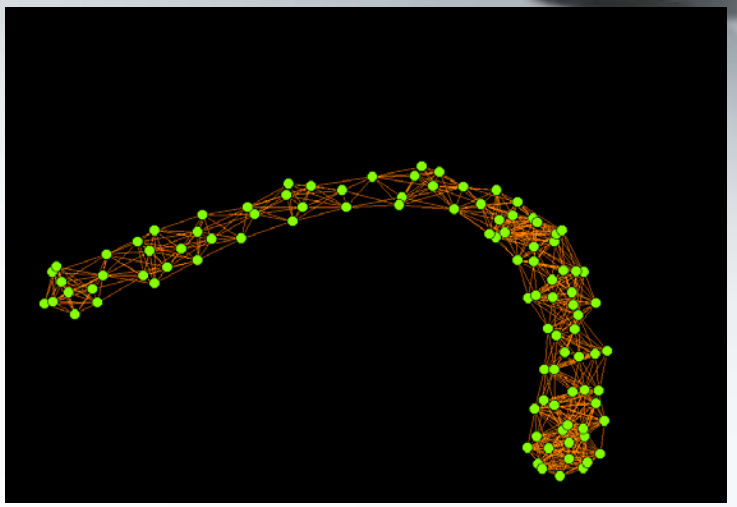


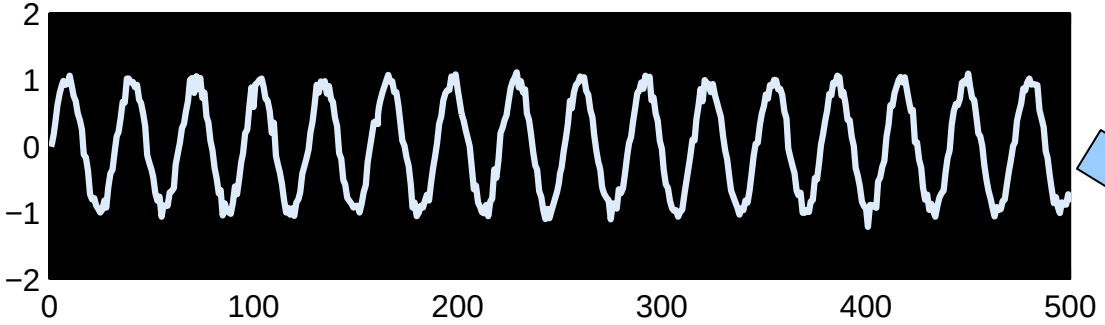
Chaotic Rossler series (x component) vs. Sine signal plus noise

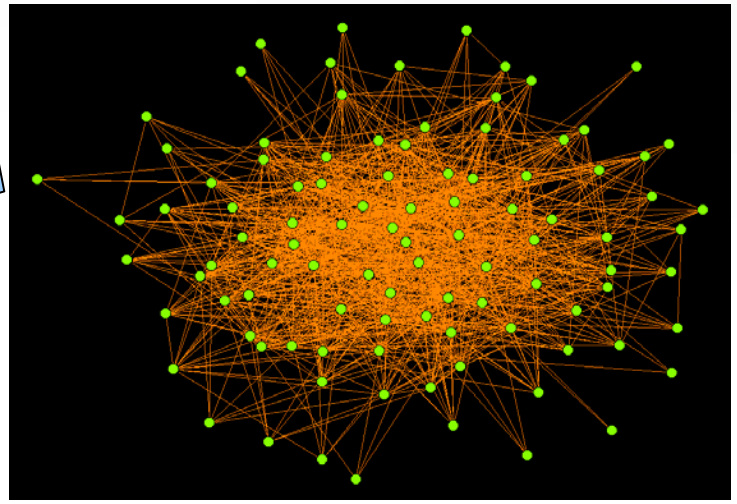
Rossler System

$$\begin{cases} x' = -(z+y) \\ y' = x + ay \\ z' = b + xz - cz \end{cases}$$

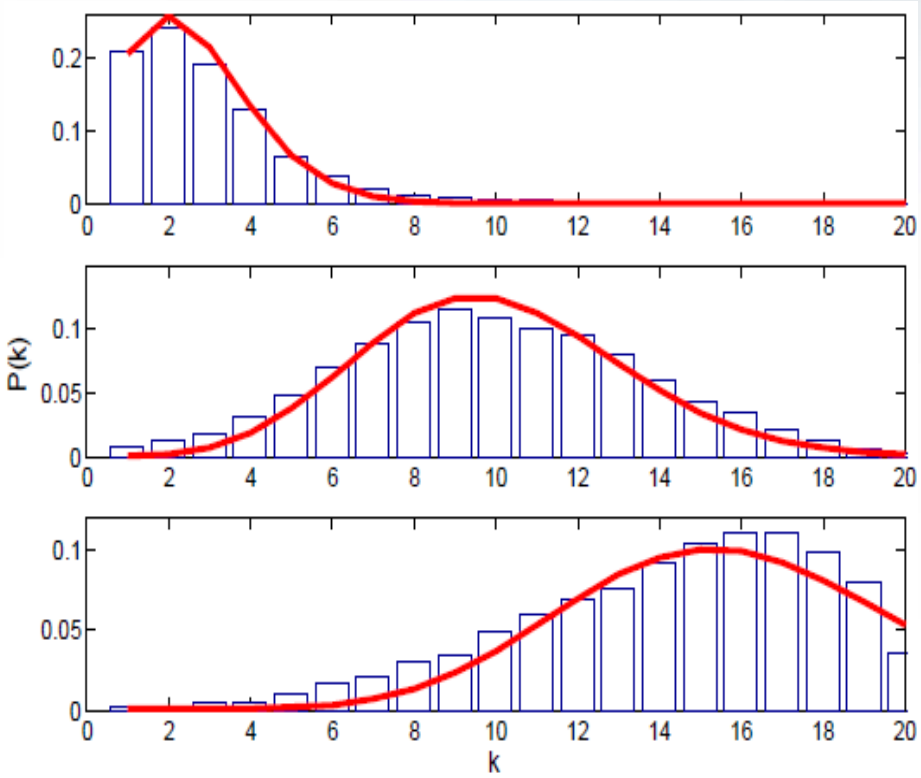




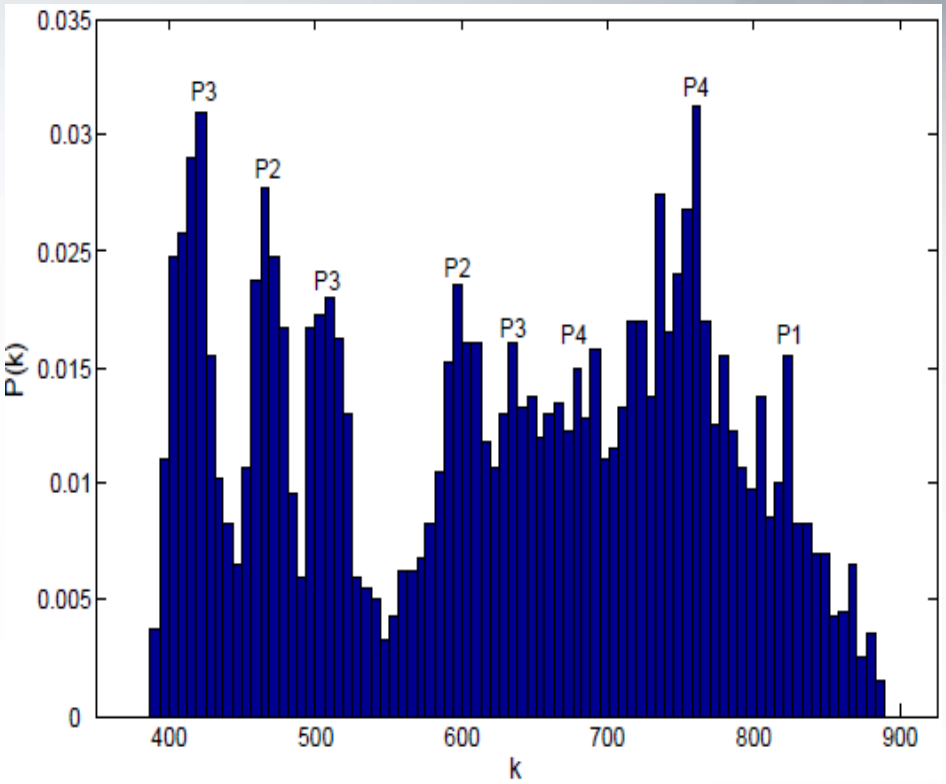




Degree distribution *P(k)*

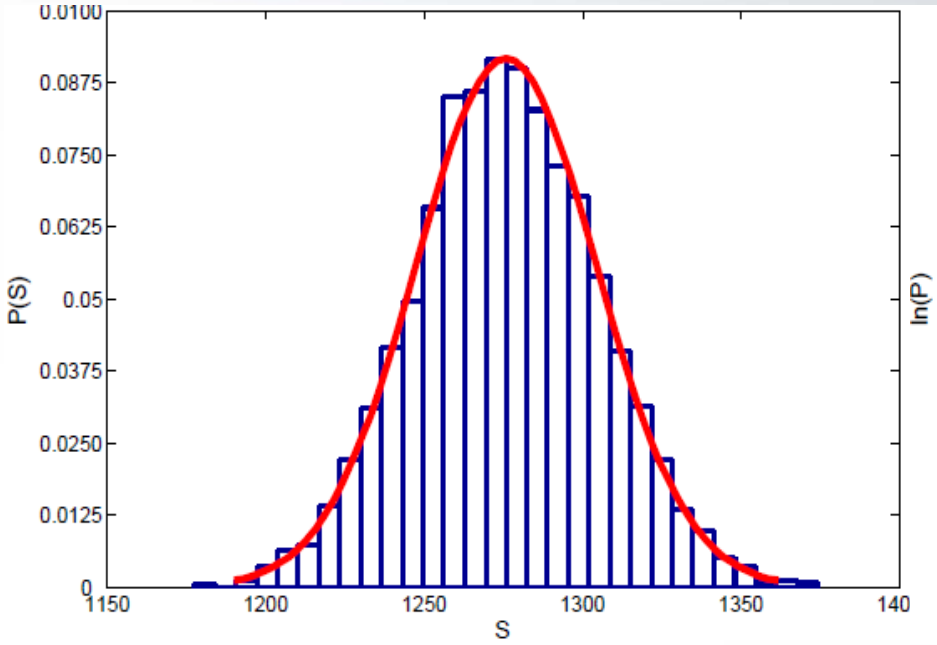


Degree distribution for noisy sine signal at different thresholds

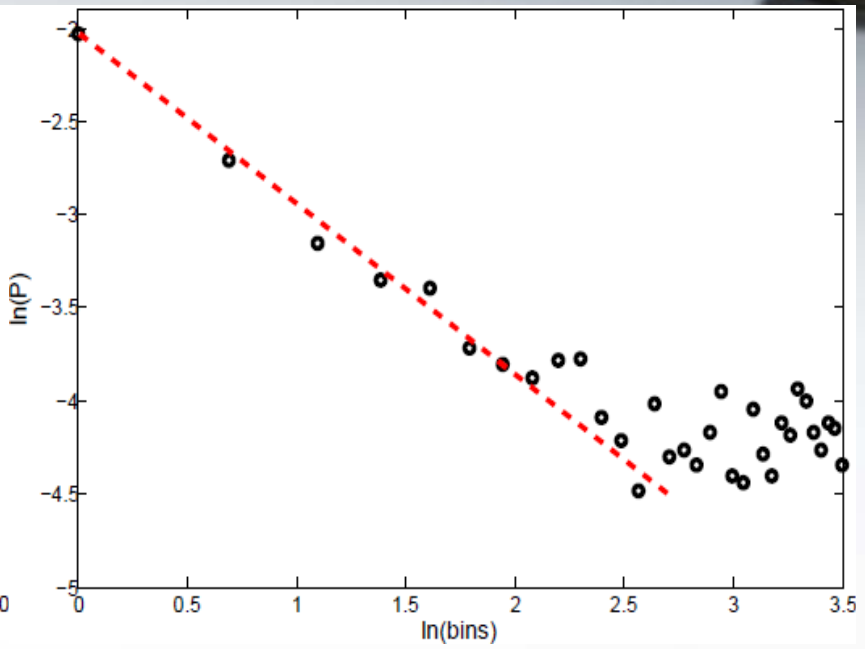


Degree distribution for Rossler series at threshold=0.27

Vertex Strength distribution ($S_i = \sum_{j \in G} W_{ij}$)



noisy sine signal



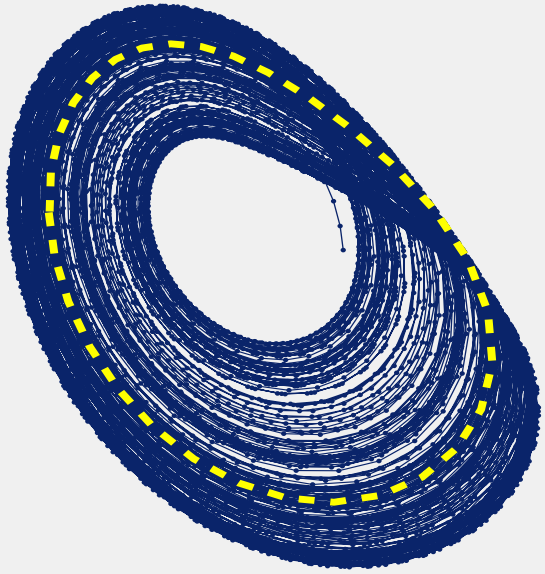
Chaotic Rossler series

Scale free distribution of *S* for chaotic system: Different role played by different nodes (Rich gets richer)

Skeleton of chaotic attractor: Unstable Periodic Orbit (UPO)

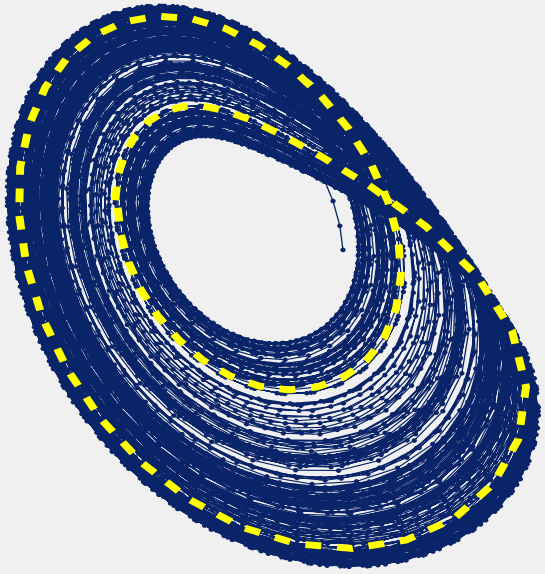
UPO-1 Unstable Periodic Orbit

Order−1

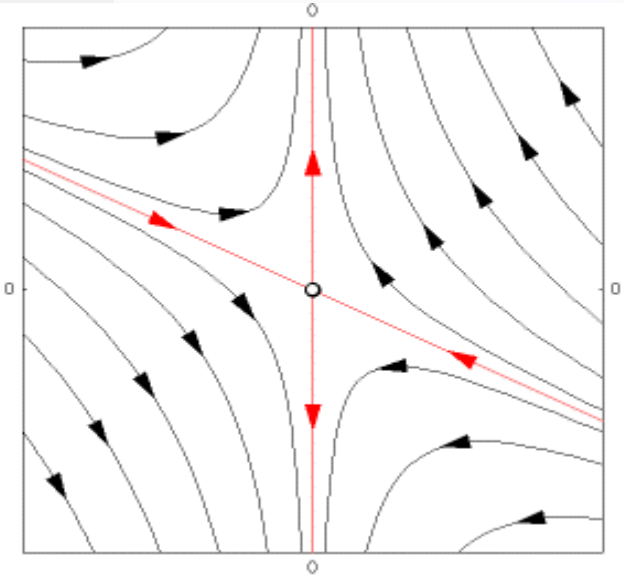


UPO-2

Order−2

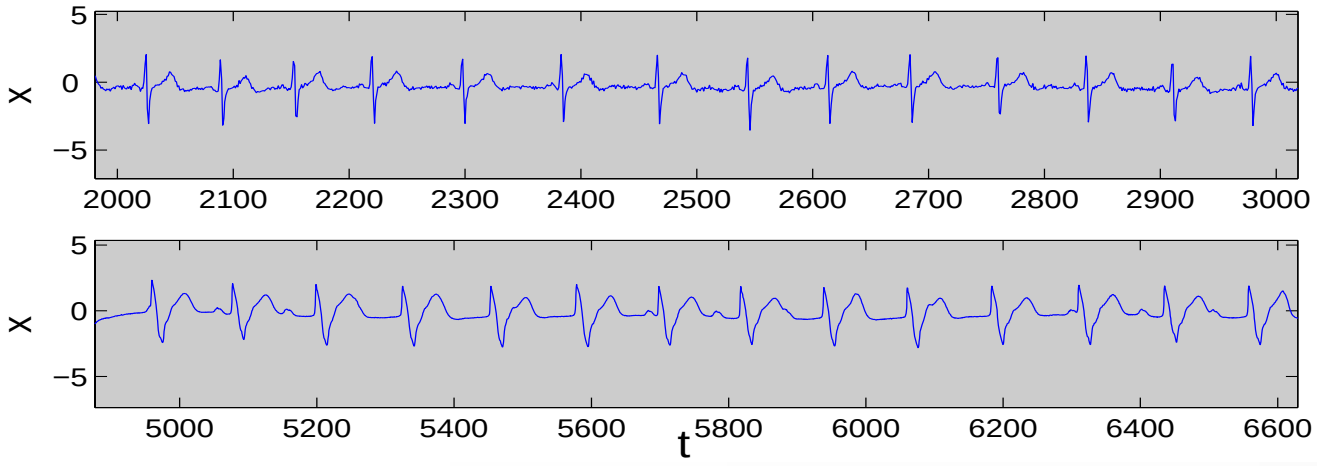


Stable & Unstable Manifold of UPO



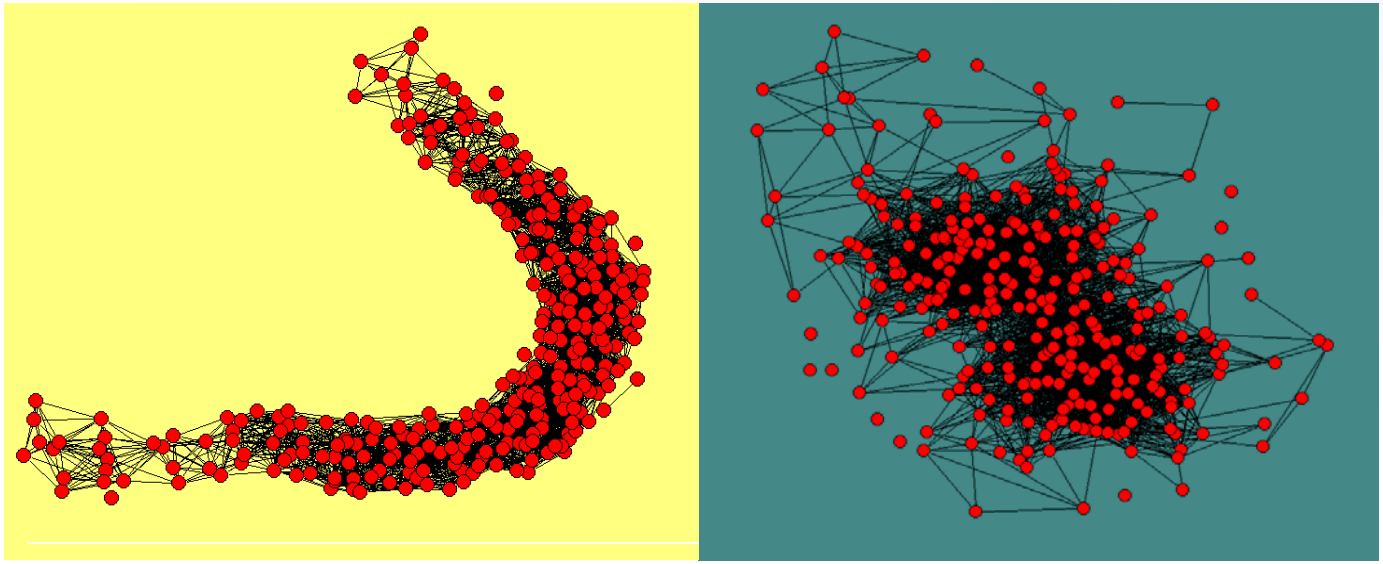
Application: Complex networks from human ECGs

human Electrocardiograms



ECG Waveform being morphologically similar

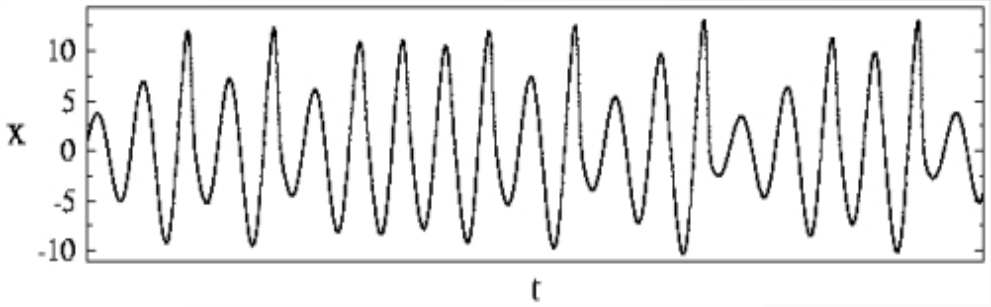
Significant difference in the constructed networks

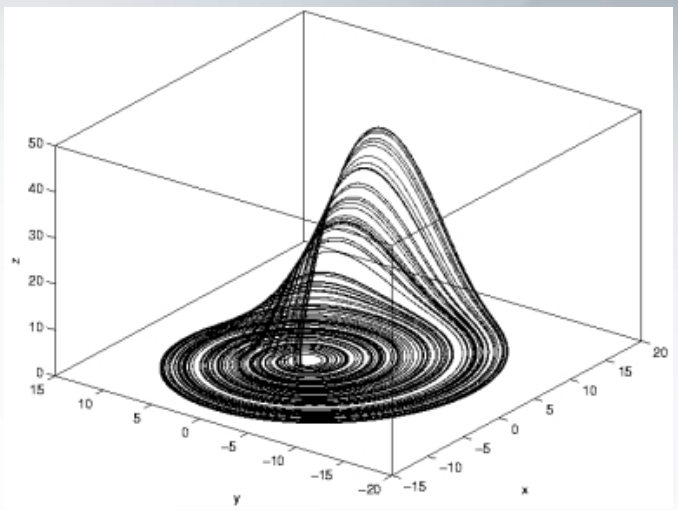


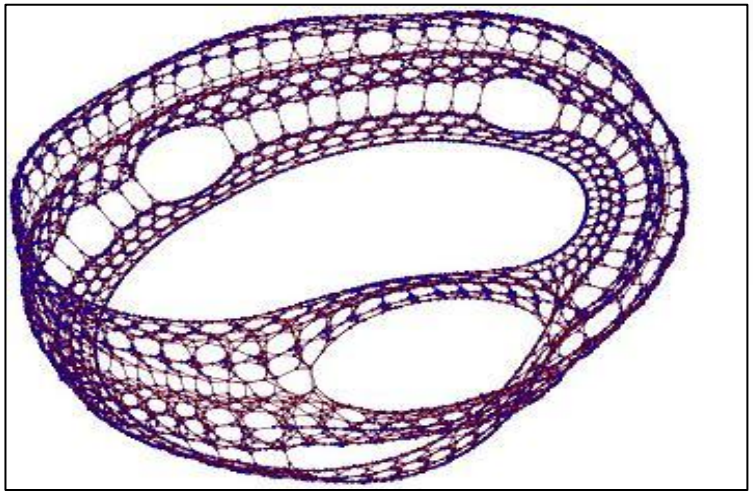
Healthy Subject **Arrhythmia Patient**

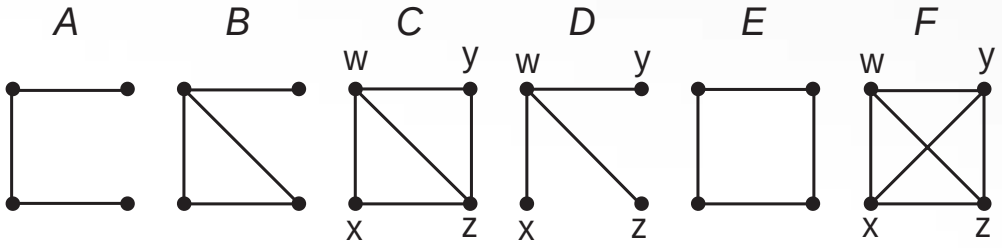
A more General framework to transform time series into networks

$$x_1, x_2, x_3, x_4, x_5, x_6, x_7, \ldots x_n \rightarrow (x_t, x_{t-\tau}, x_{t-2\tau}, \ldots, x_{t-(m-1)\tau}) \qquad (x_5, x_3, x_1), (x_6, x_4, x_2), (x_7, x_5, x_3), \ldots$$





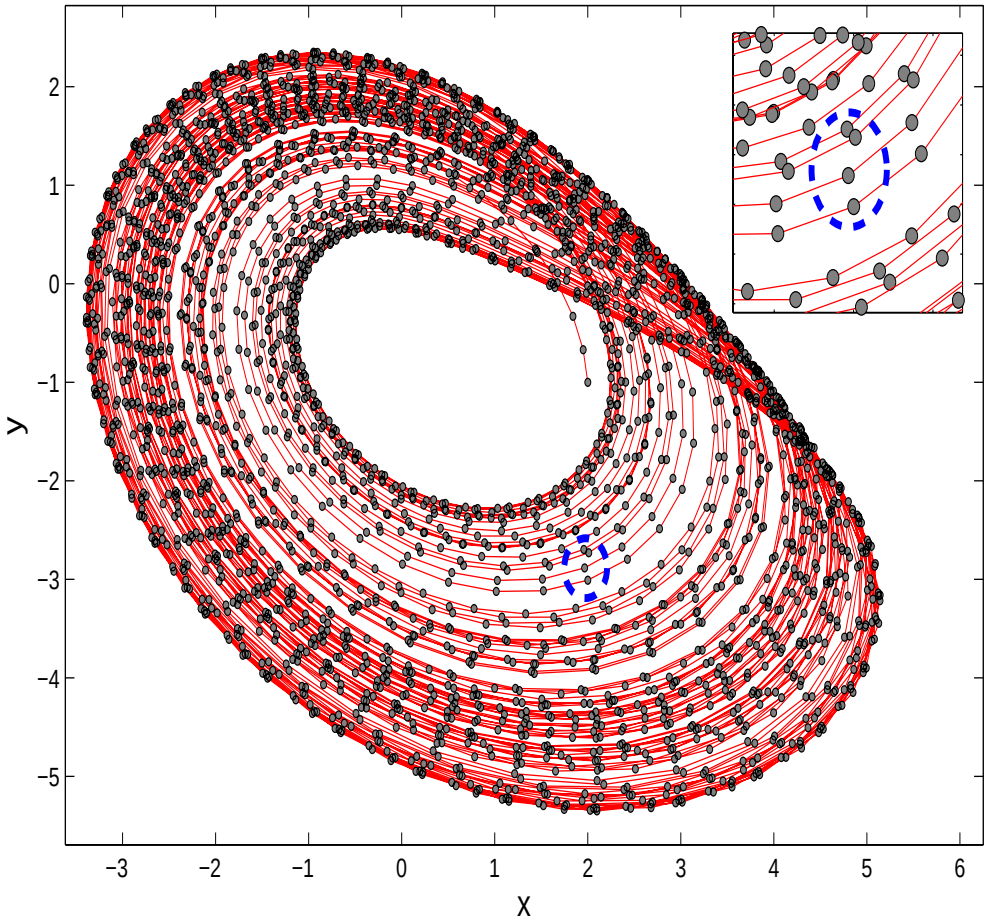




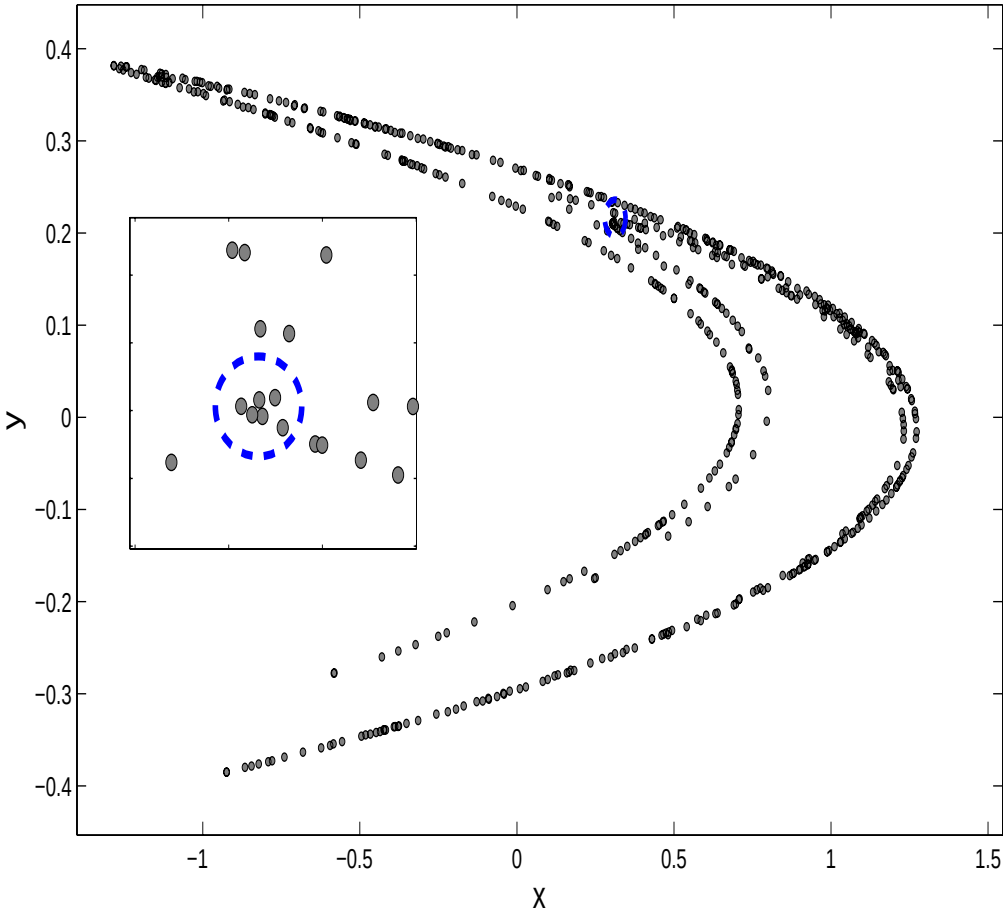
"Superfamily phenomena and motifs of networks induced from time series" X. Xu, J. Zhang & M. Small *PNAS, 2008*

Constructing the network : ε – neighborhood

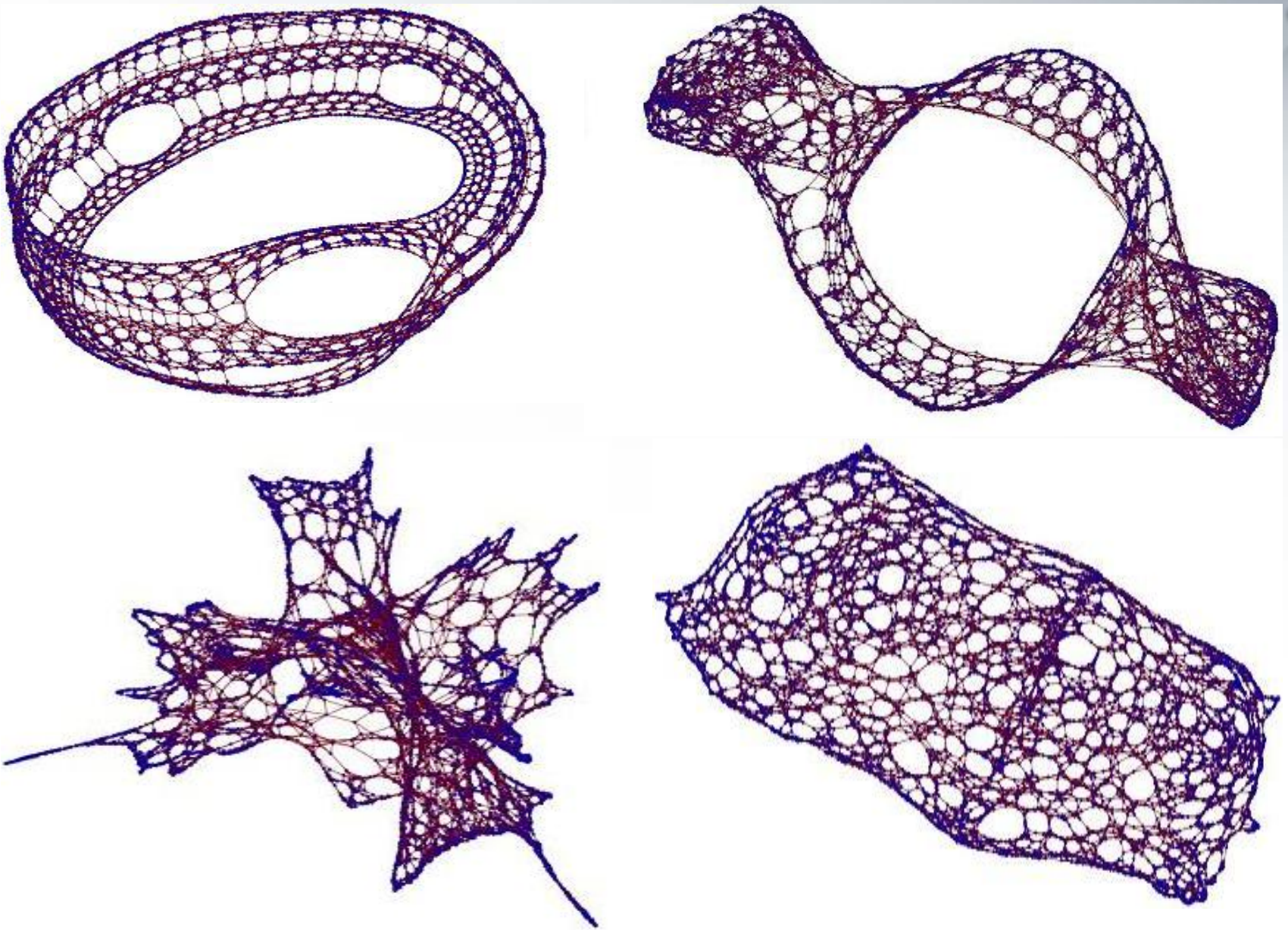
Continuous systems



Iterative maps



Complex Networks constructed from various chaotic systems

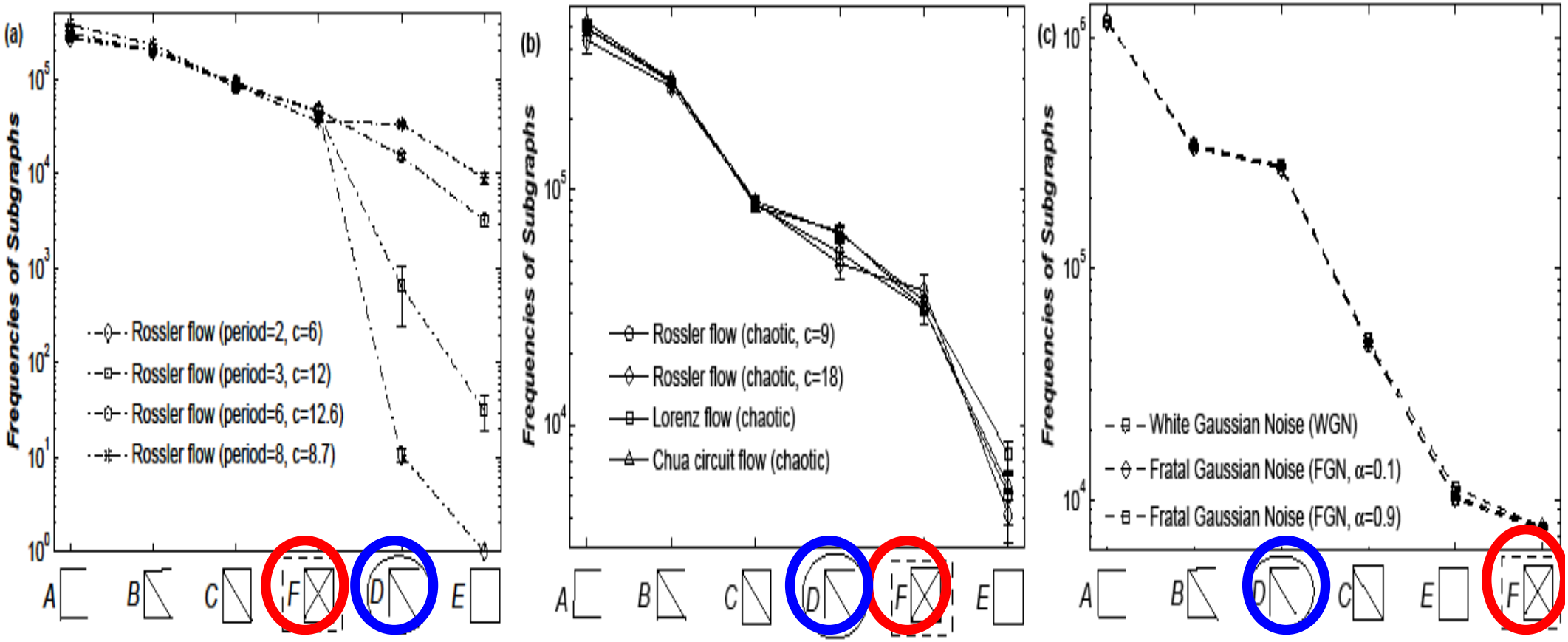


Motif ranking distinguishes different dynamics: Continuous systems

Periodic

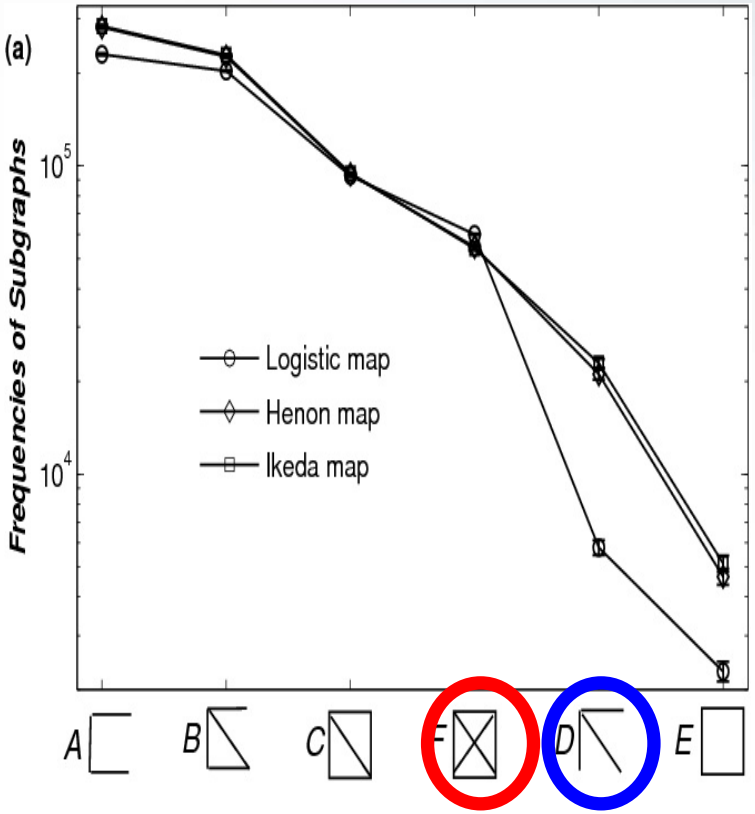
Chaotic

Noise

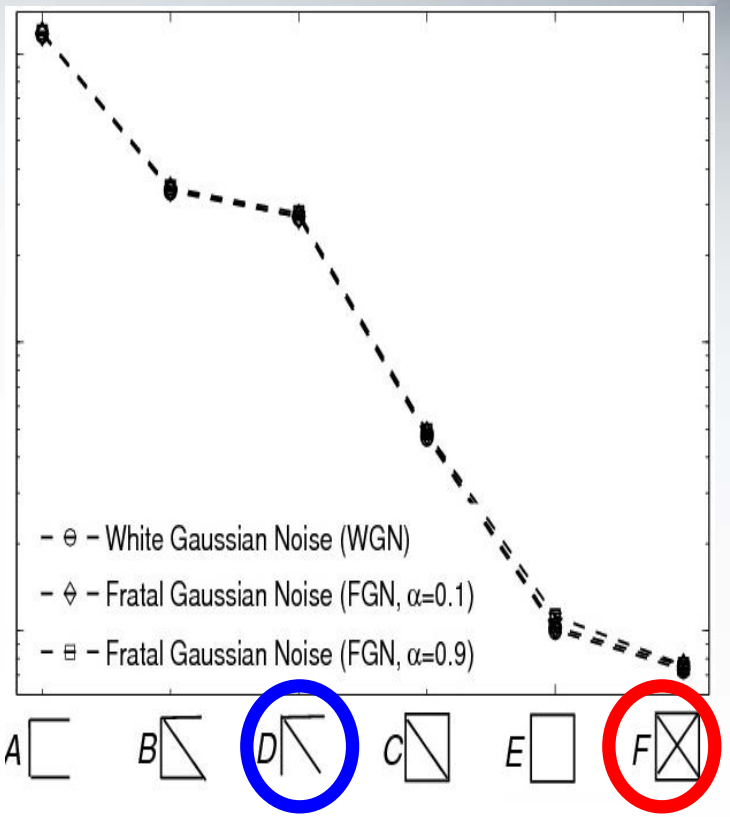


Iterative Maps

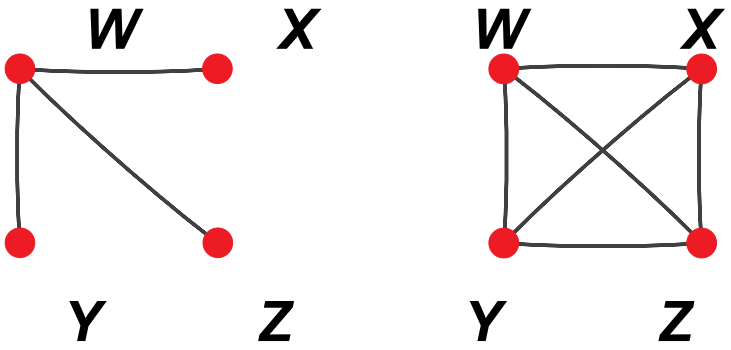
Chaotic



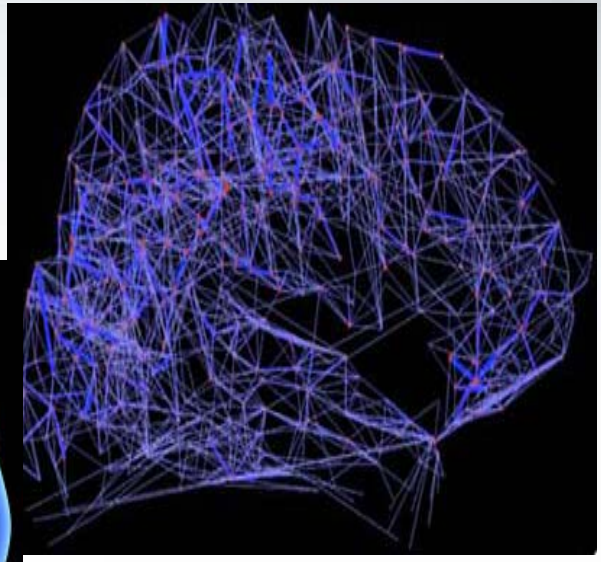
Noise

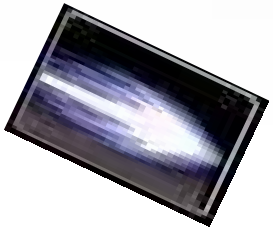


Motif vs. local structure of the Manifold

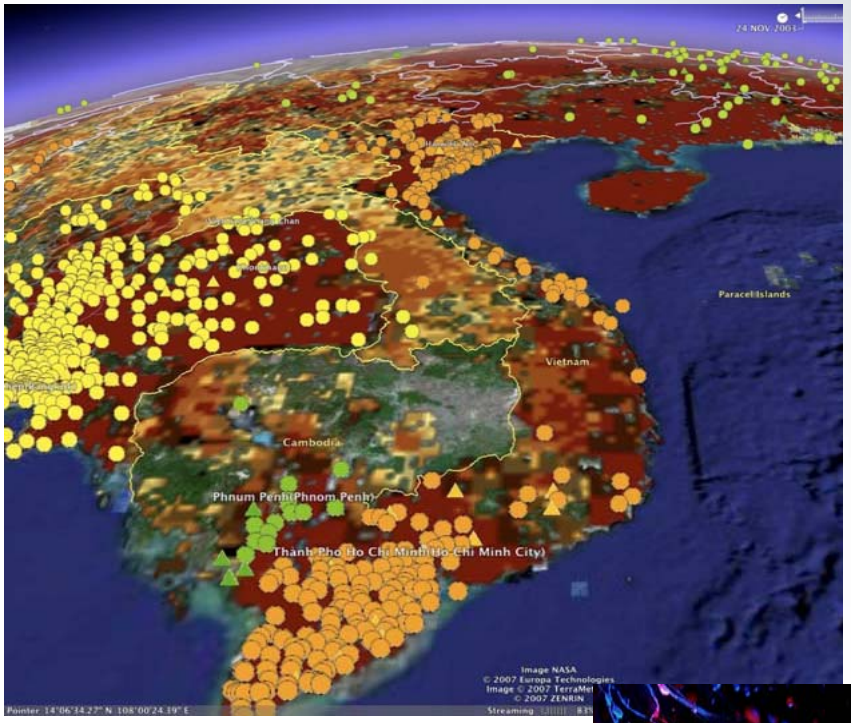


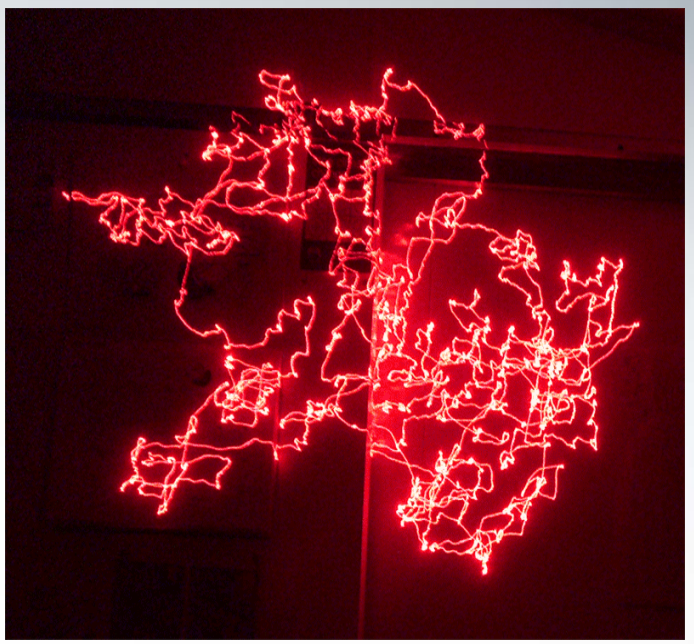
2. From *Structure* to *Dynamics*

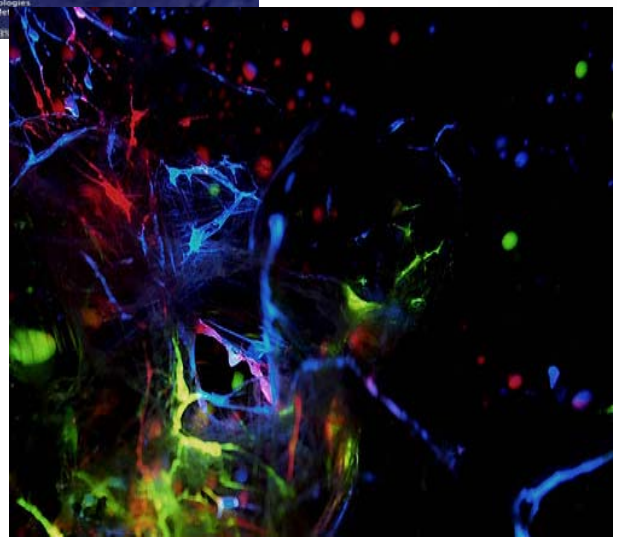


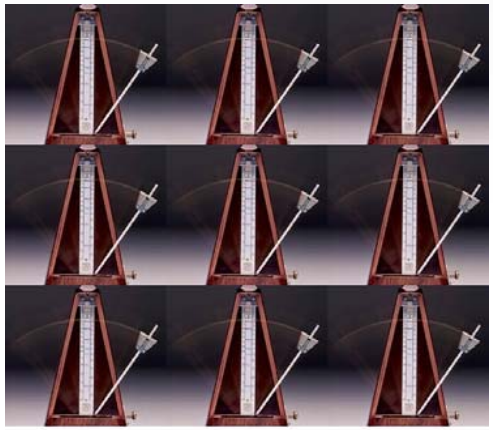


Predicting the collective dynamics on Complex networks





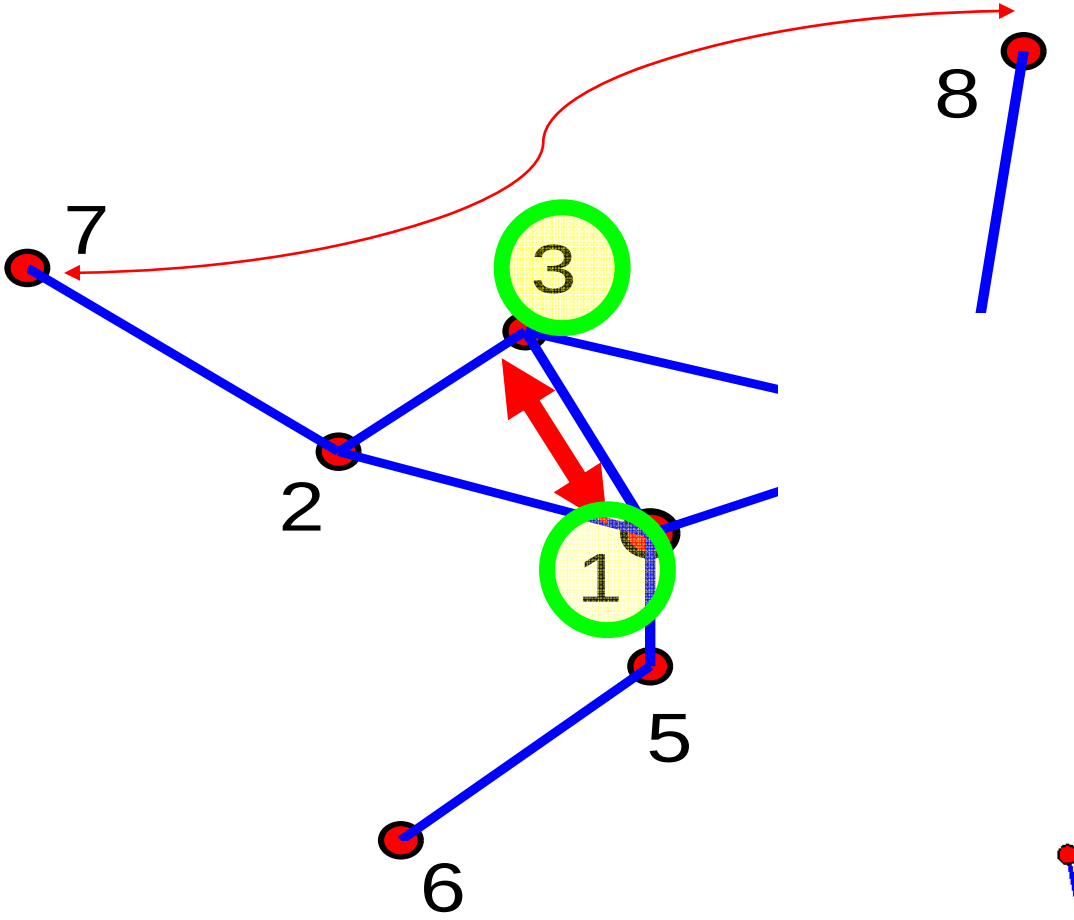




Outline

- Method: A new framework proposed to infer, or predict, the dynamics on networks
- Validation: Various dynamical processes on networks are unified under this framework
- New insights: Fundamental law that governs the evolution of physical networks

Basic idea: seeding Kernels in Graph



Kernel Function:

$$x^2$$