University of San Francisco

Science Programs in Context

University At a Glance

- Six Colleges
- Top 15 Entrepreneurship
- Top 15 student diversity
- Jesuit Education – Mission, Rigor, and *eloquentia perfecta*

University At a Glance

- 8,000 USF students
- Arts and Sciences:
  2,600 undergraduates,
  600 graduate students
  200 full-time faculty
- Sciences:
  600 undergrads,
  200 graduate students (MS)

Telecommunications Program

- MBA Elective -- Business & Tech.
- Active research program:
  - Convergence: voice, data, etc.
  - Impact of new tech. (e.g.broadband)
  - New tech. in emerging economies
  - Policy Research
    (e.g. Telecom Act reform)

Science Departments

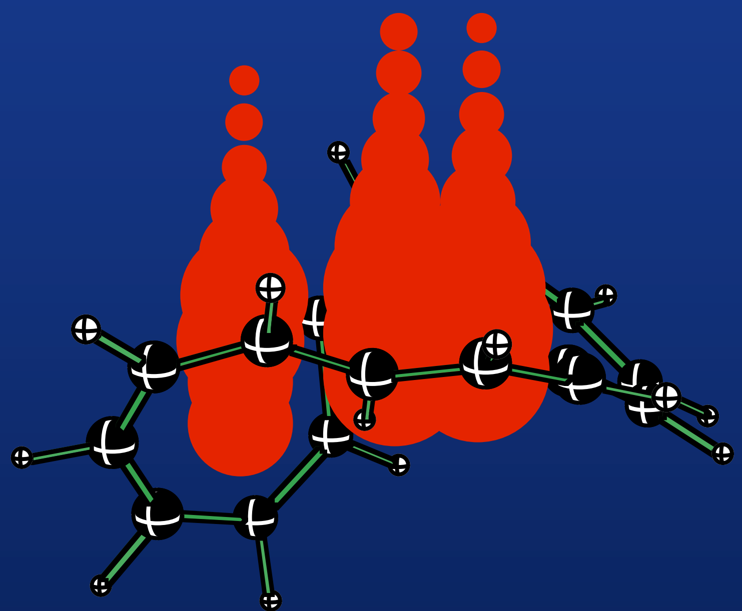
- Biology (MS)
- Chemistry (MS)
- Comp. Sci. (MSCS, MSIE, MS-Ent)
- Environmental Sci. (MSEM)
- Exercise & Sports Sci.
- Mathematics
- Physics (3/2, USC)

Science Capital

- Grants: NSF, NIH, DOE, NASA, etc.
- AFM, NMR, rt PCR, flow cytometry, etc.
- CS: Keck cluster & Kudlick classroom

Science Capital Future

Funded Research Sampler



- Polar programs
- Genetics of disease
- Wetlands restoration
- Black hole physics
- Bio-organic Chem.
- Global Environment

Bottom line: what's good?

- Faculty - student interaction
- Academic Rigor
- Equipment
- Research breadth & flexibility

Rivers:
Reliable Virtual Resources

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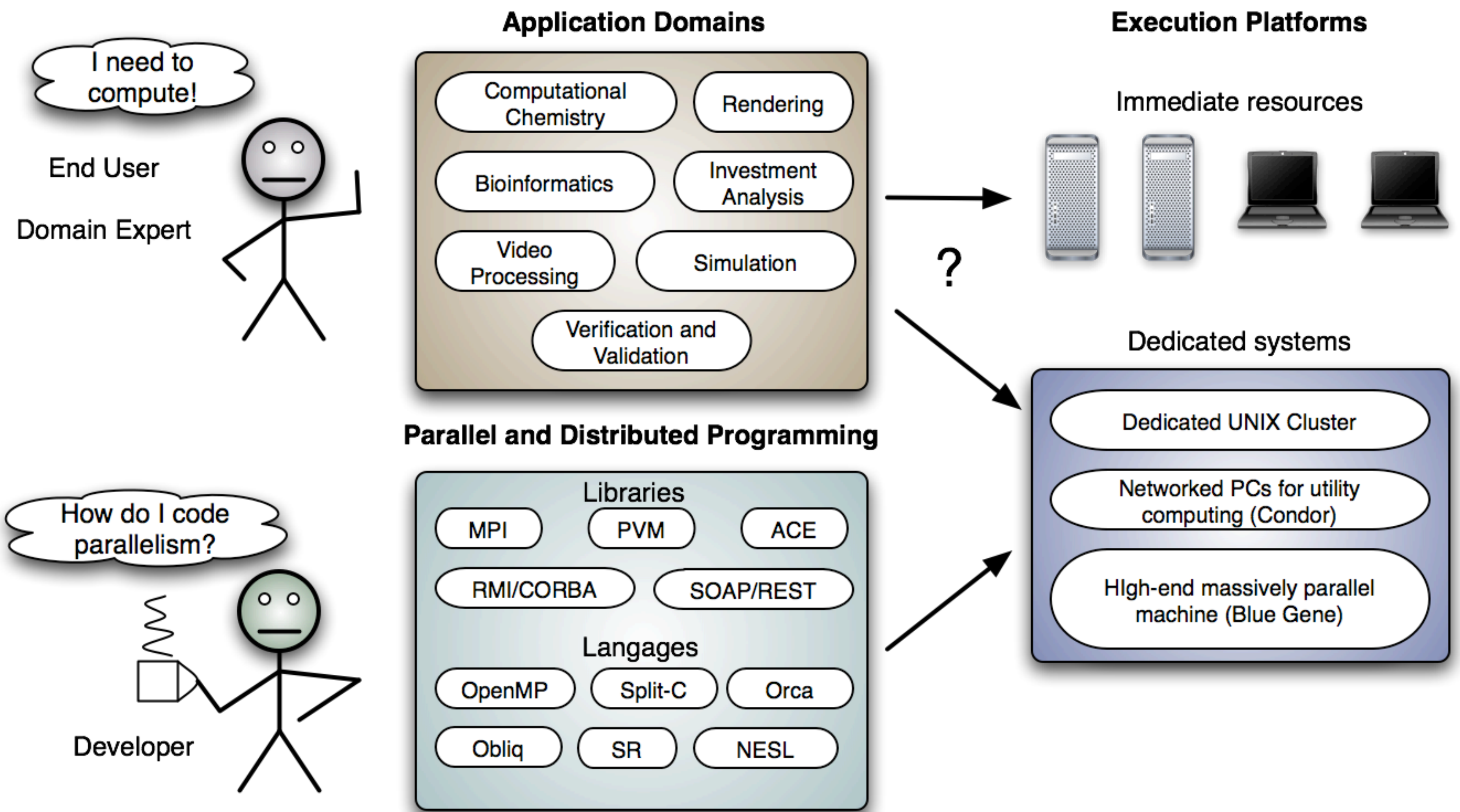
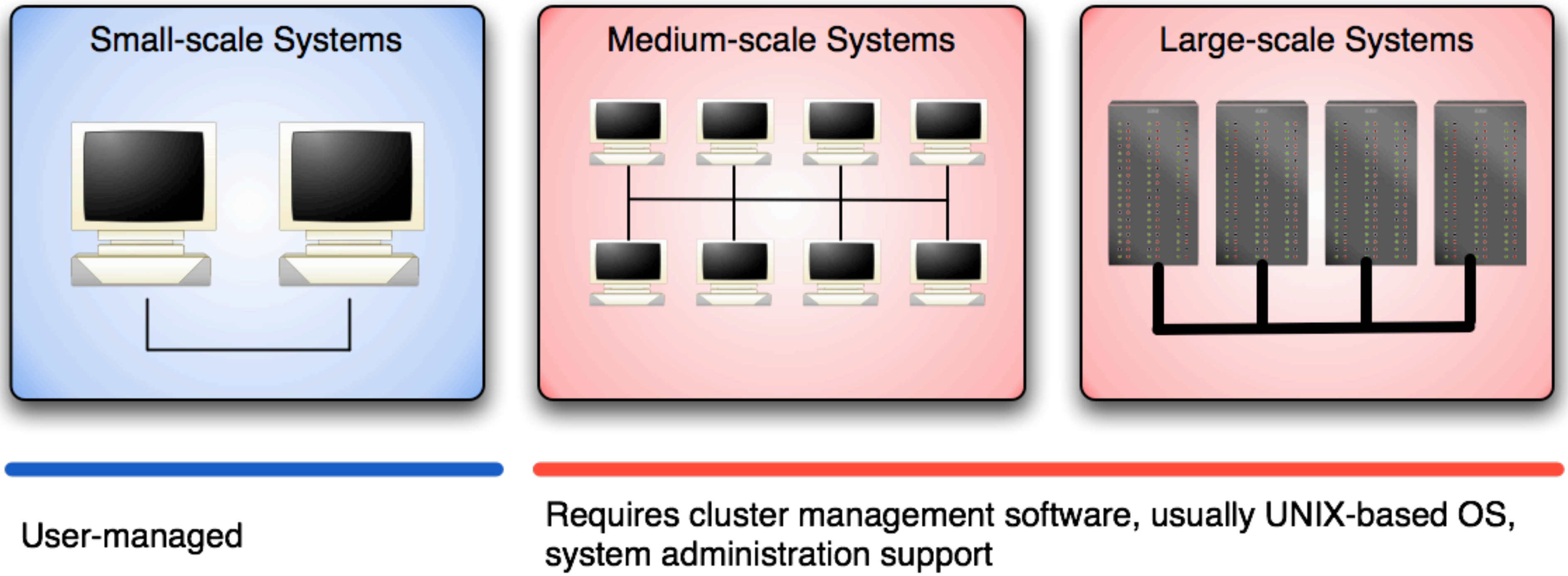
Parallelism for End Users

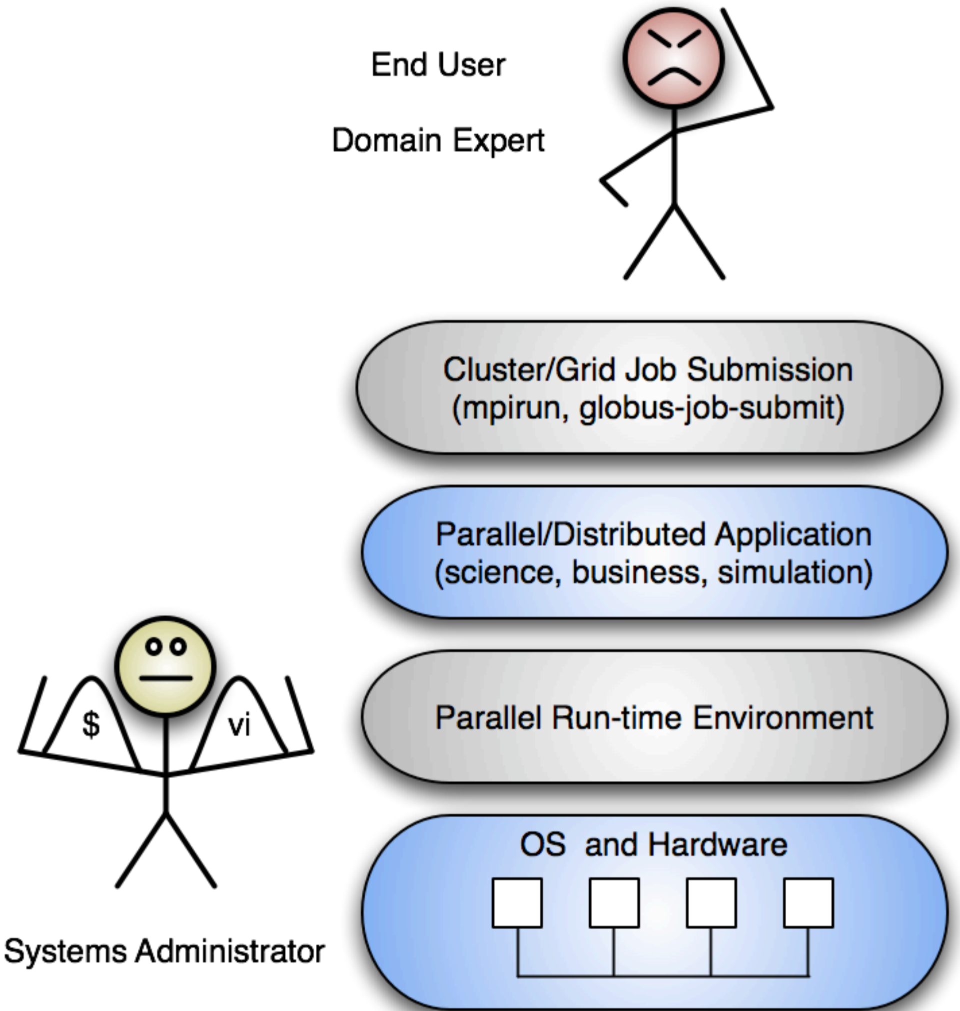


Hardware Trends



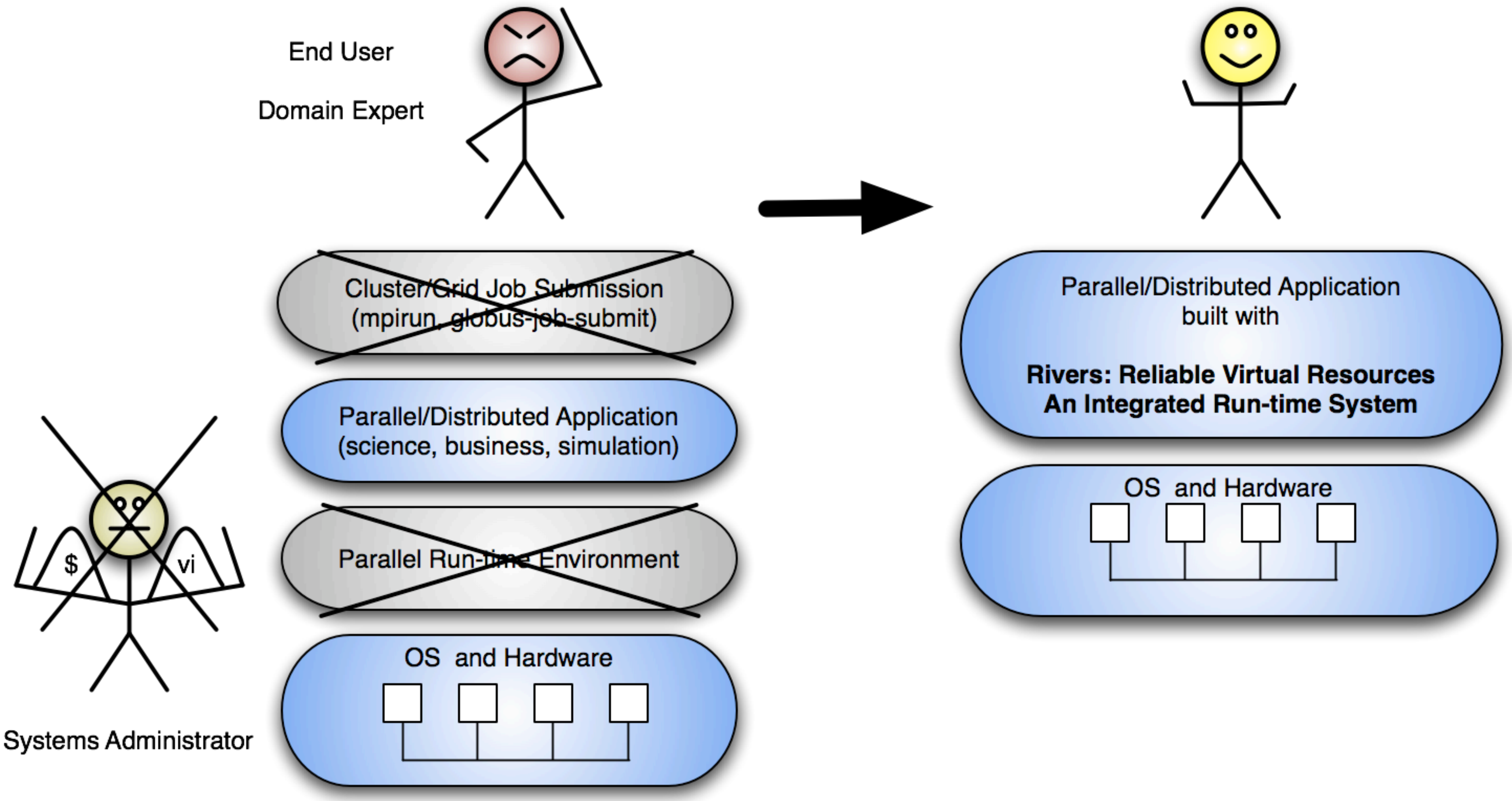
- Low cost: multi-core, multi-processors, fast switches
- Desktop systems are becoming mini-clusters

Execution in a Cluster/Grid



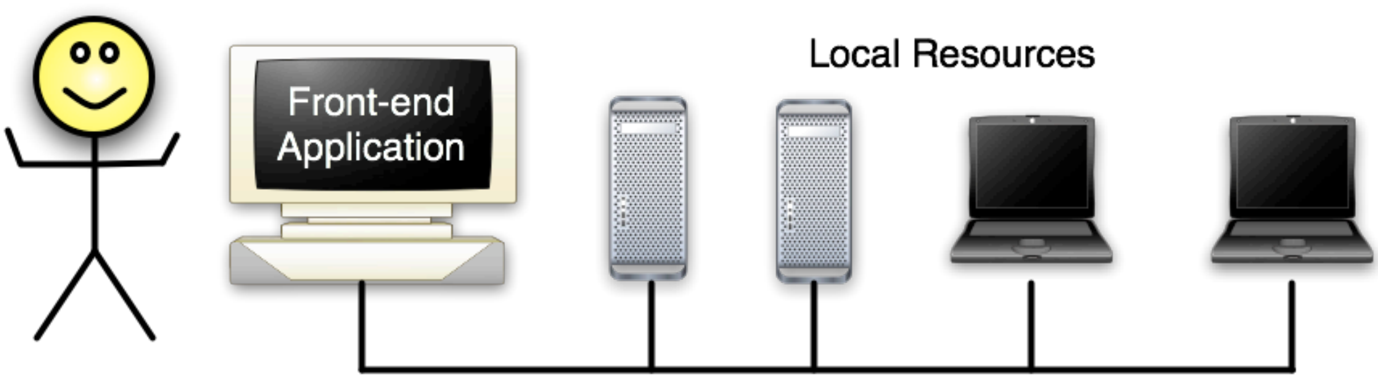
- Users must be cluster savvy
- Application tied to platform
- Costs
  - Learning curve
  - Hardware
  - Staff

Self-contained Applications



Rivers-based Applications

- Utilize hardware without a conventional cluster OS
- Dynamic *virtual* and *reliable* execution environment
- Integrated compute and storage resources
- Expose progress and faults in a sensible manner
- Minimal administration and configuration (wizards)



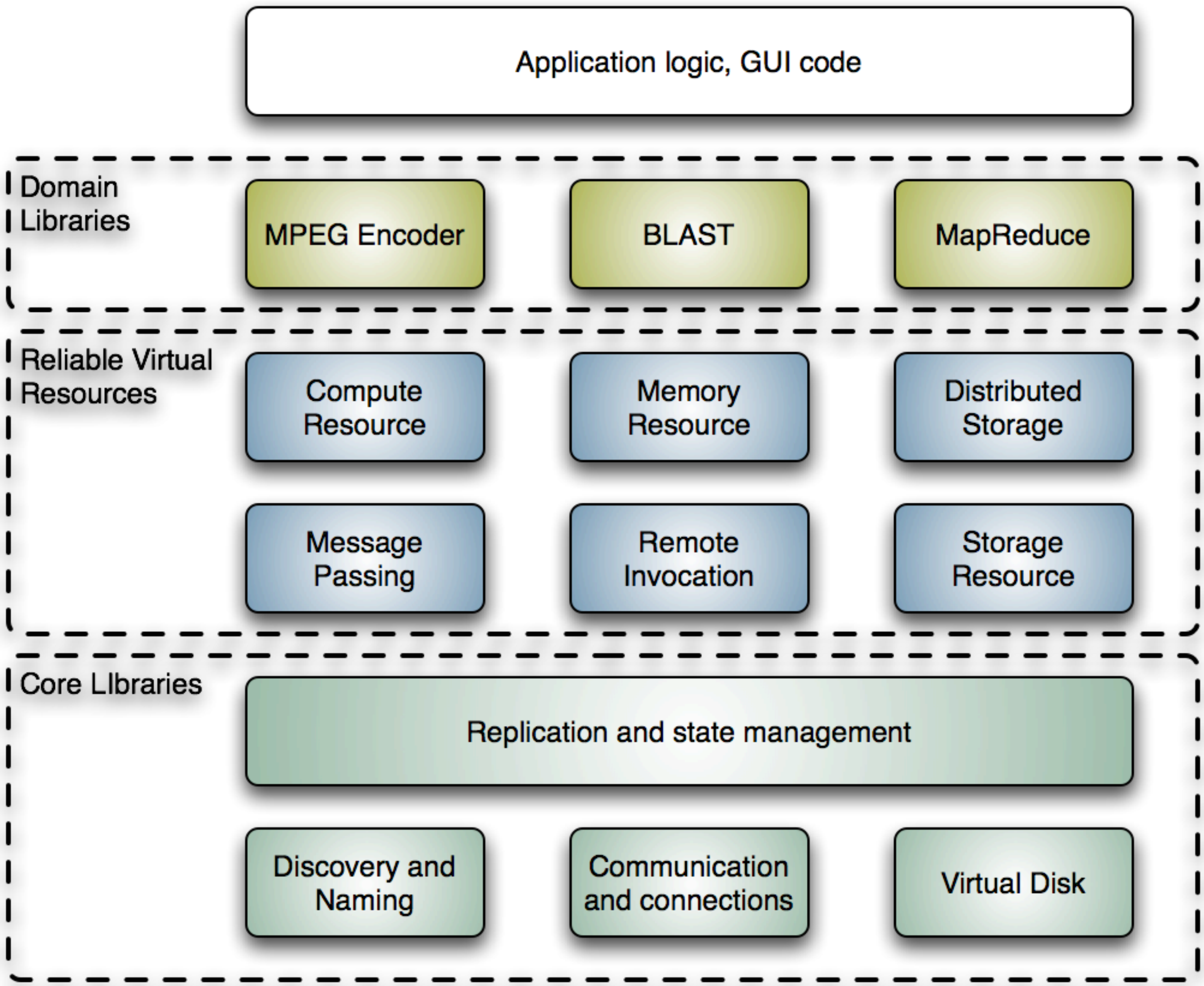
Done Before?

- Decades of research in
  - Parallel/distributed programming languages
  - Parallel/distributed libraries
  - Distributed-shared memory
  - Reliable distributed systems
  - Parallel File Systems
  - Virtual Machines

- Previous work focuses on specific issues

- Our goal: leverage of existing work to provide a complete approach to parallel execution

The Rivers Framework



Virtual Resources

- Virtual resources implemented as *virtual machines*
  - State comprehension
  - Suspension, checkpointing, and migration
  - Replication and mirroring
  - Callbacks for progress and fault detection
- Distributed-memory programming model
  - Support for higher-level models
- Virtual storage
  - Aggregation for distributed software RAID

Rivers Prototype

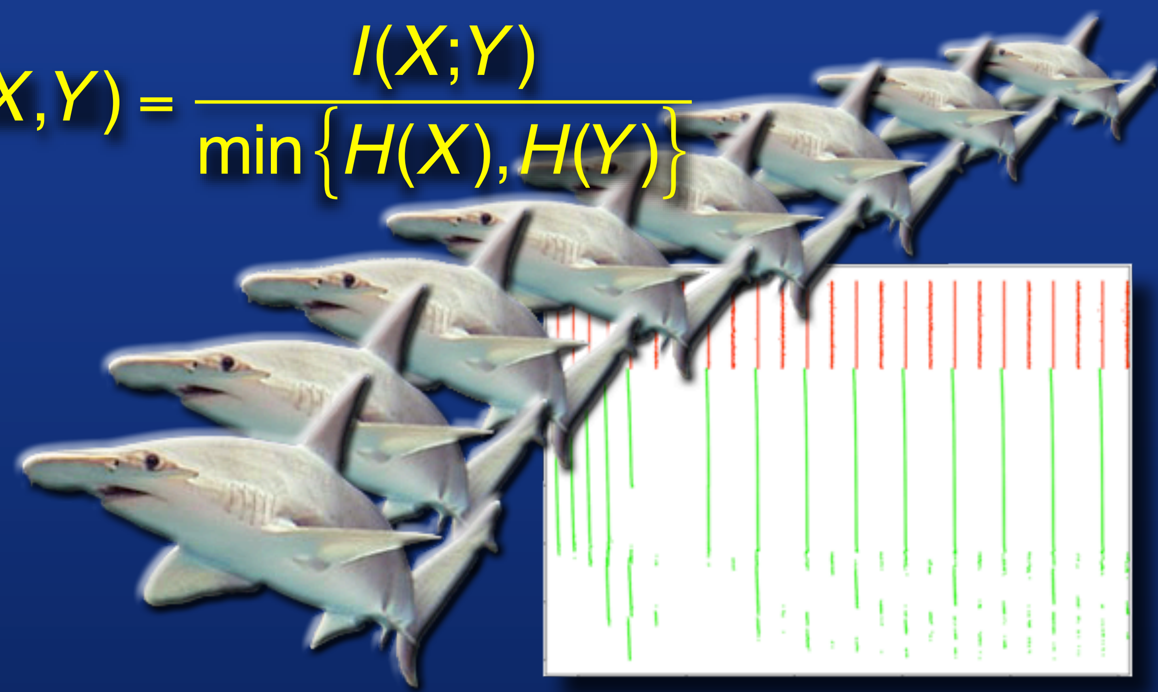
- Python as the VM engine and programming language
  - Rapid development, platform independence
  - Stackless Python
- Communication
  - Multicast for discovery and naming (embedded zeroconf)
  - TCP with connection caching
- Compute resource
  - Message passing and replication
  - Subset of MPI with MPI-style process naming
- Virtual disk
  - File system within a single host OS file
  - Virtual file system format will support software RAID
- Not focusing on
  - Sequential performance, strict resource control, security

Other USF CS Projects

- Parallel Systems and Applications
  - FlashMob Computing
  - USFMPI: A multi-threaded MPI library
  - An MPI debugger
  - VPI: Linux kernel support for user-level threads
  - Neurosys: a biologically accurate neuron simulator
- Programming Languages
  - ANTLR: A Java-based top-down parser generator
  - StringTemplate for source-level code generation
- Internet Technology
  - Blogosphere: analyzing the effectiveness of tags
  - Slashpack: web text retrieval and preprocessing
  - WebTop: Integrated desktop and Internet search and discovery

Of Synchrony and Sharks:

$$\psi(X,Y) = \frac{I(X;Y)}{\min\{H(X),H(Y)\}}$$



A Tale of Mutual Information

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Collaborators

- Brandon Brown *(USF)*
- Cosma Shalizi *(Carnegie Mellon)*
- Kristina Klinkner *(Carnegie Mellon)* *(USF alumna)*
- Tim Tricas *(University of Hawaii)*

Synchrony and Information

- The importance of being in synch
- The importance of knowing about being in synch
- The importance of relying on how you know about being in synch.

$\Rightarrow$ ***Informational Coherence***

Synchrony or Coherence?

Usual ways to measure network synchrony:

Ad Hoc:
- strict synchrony

Systematic:
- cross correlation
- mutual information
- generalized synchrony

Informational Coherence

We combine the concept of mutual information with the notion of state reconstruction:

mutual information
$\left(I(X;Y) \leq \min\left\{H(X),H(Y)\right\}\right)$

$$\underbrace{\psi(X,Y)}_{} = \frac{\overbrace{I(X;Y)}^{}}{\min\left\{\underbrace{H(X)}_{},\underbrace{H(Y)}_{}\right\}} \quad \left(\text{with } \frac{0}{0} = 0\right)$$

IC: normalized state mutual information

Shannon's information content of a state variable

State-Space Reconstruction

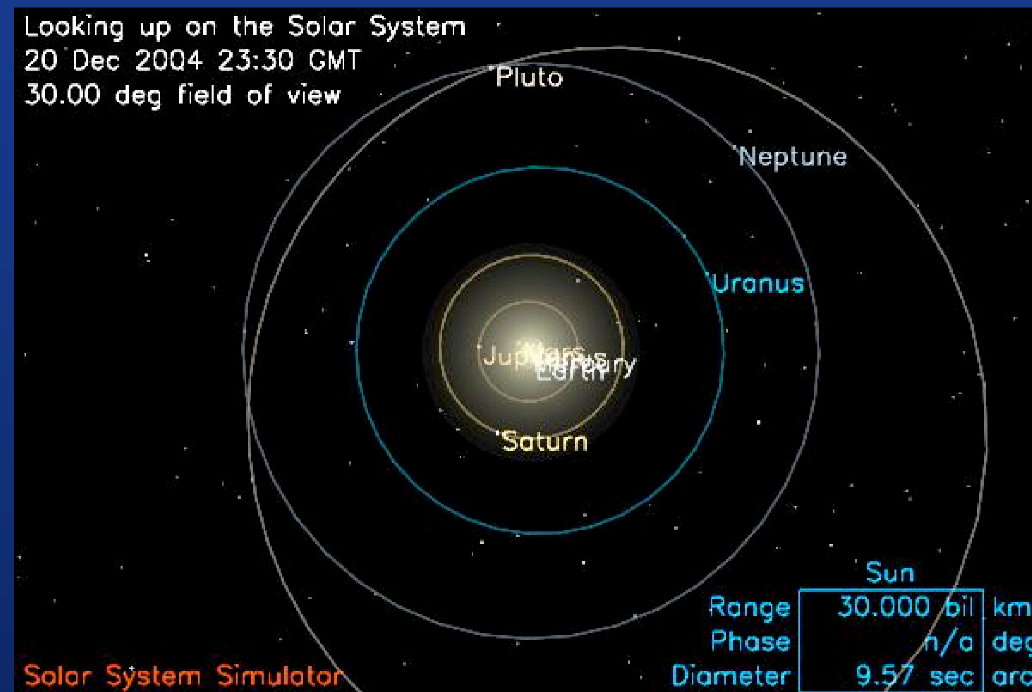
causal state models
stochastic automata / hidden markov models

state-space
reconstruction

mutual
information

`http://bactra.org/CSSR`

In search of a metaphor…



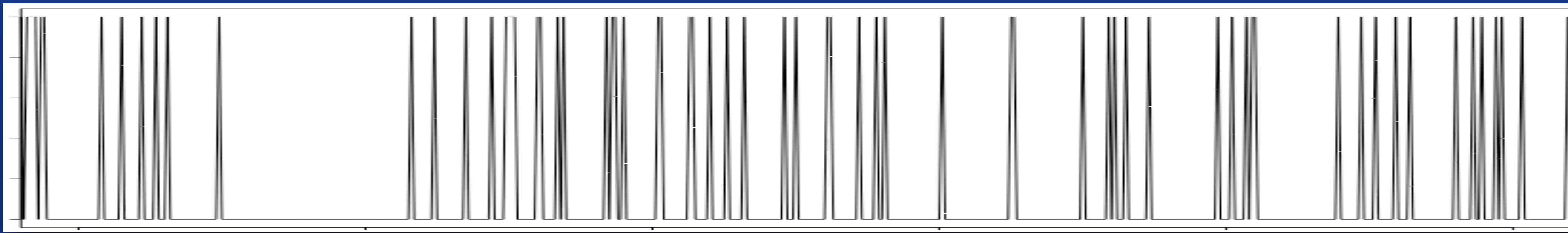
Observables:
lights in sky

Measurement / algorithm →

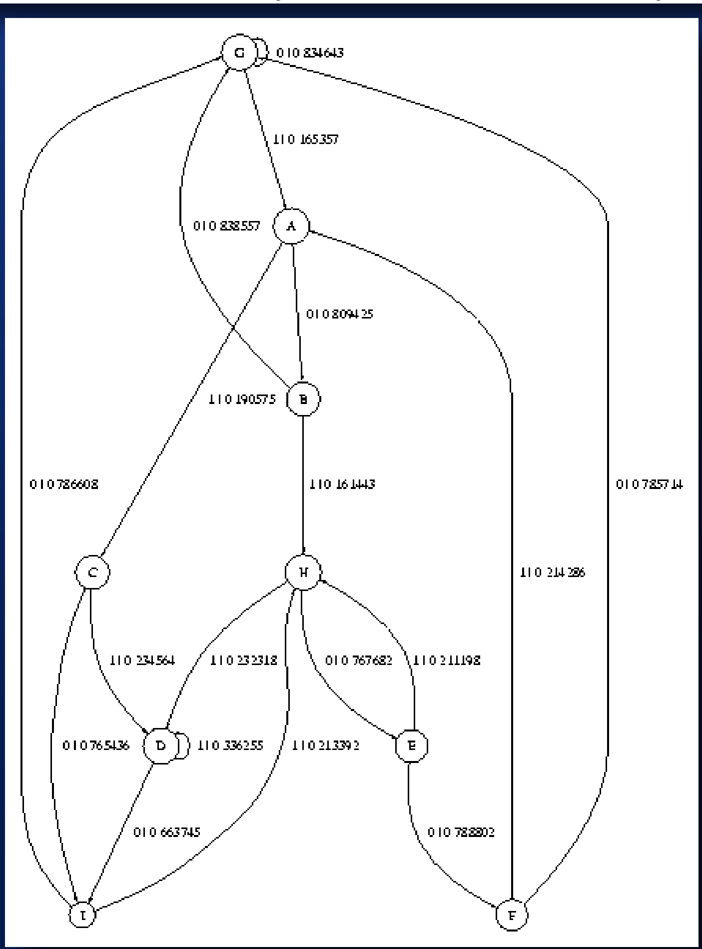
State:
planets and
stars in space

Background
Light resolution
Instrument noise
Atmospheric distortion
Anatomical distortion
Physiological noise
Caffeination level, etc.

A state reconstruction example

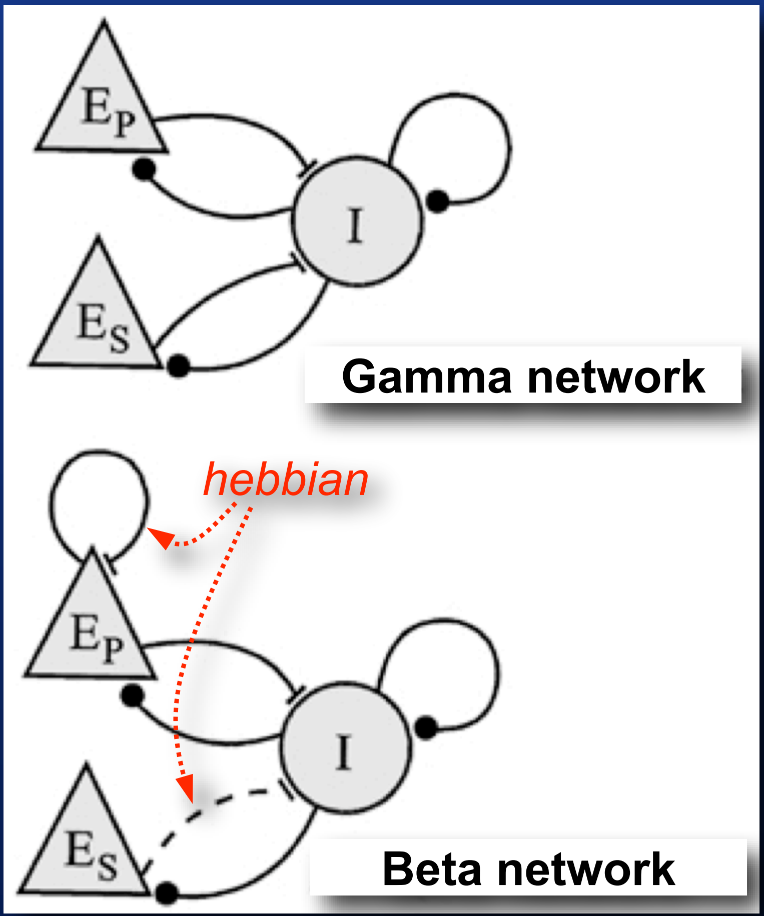


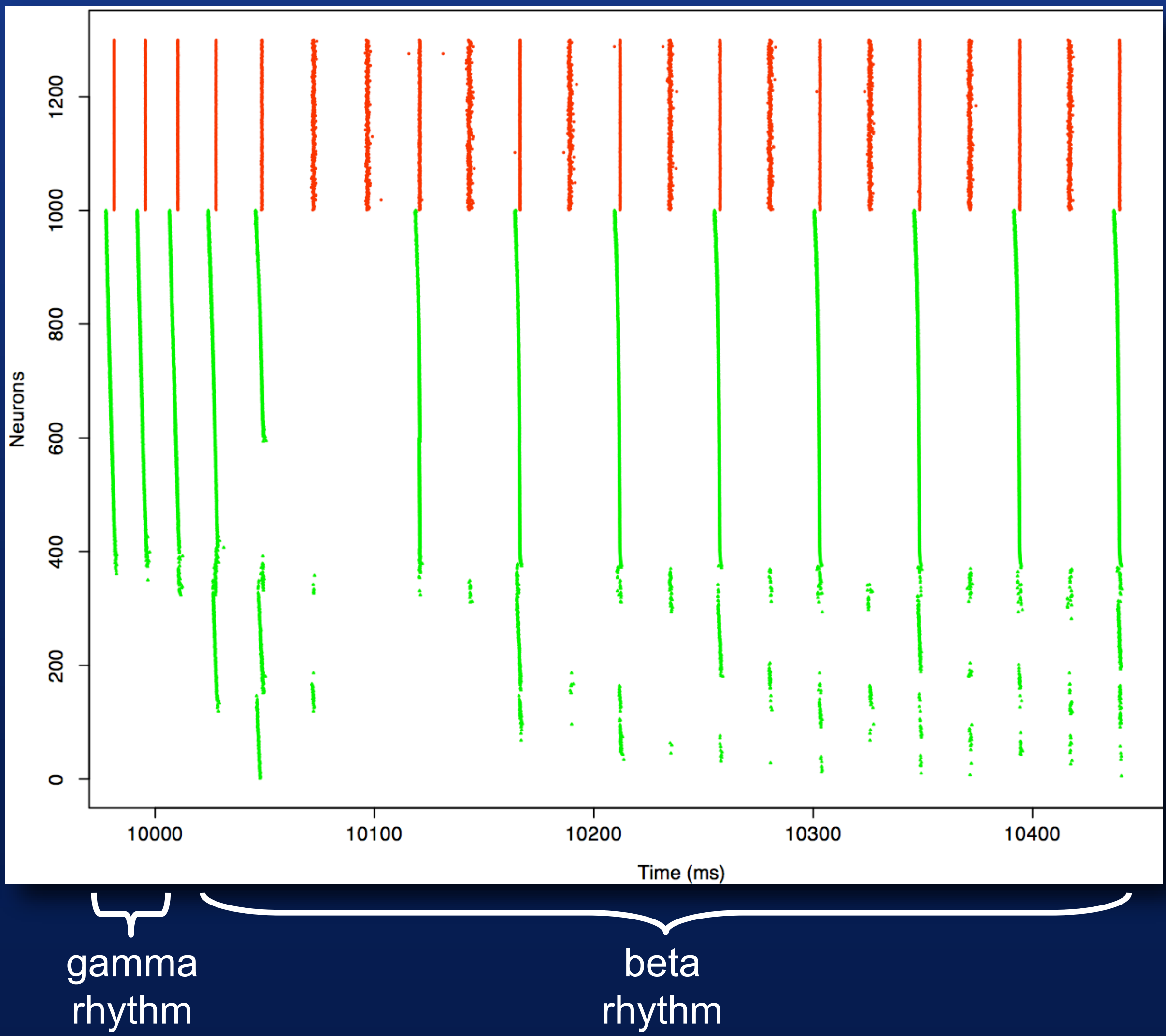
a neuron in the rat motor cortex (in vivo recording)



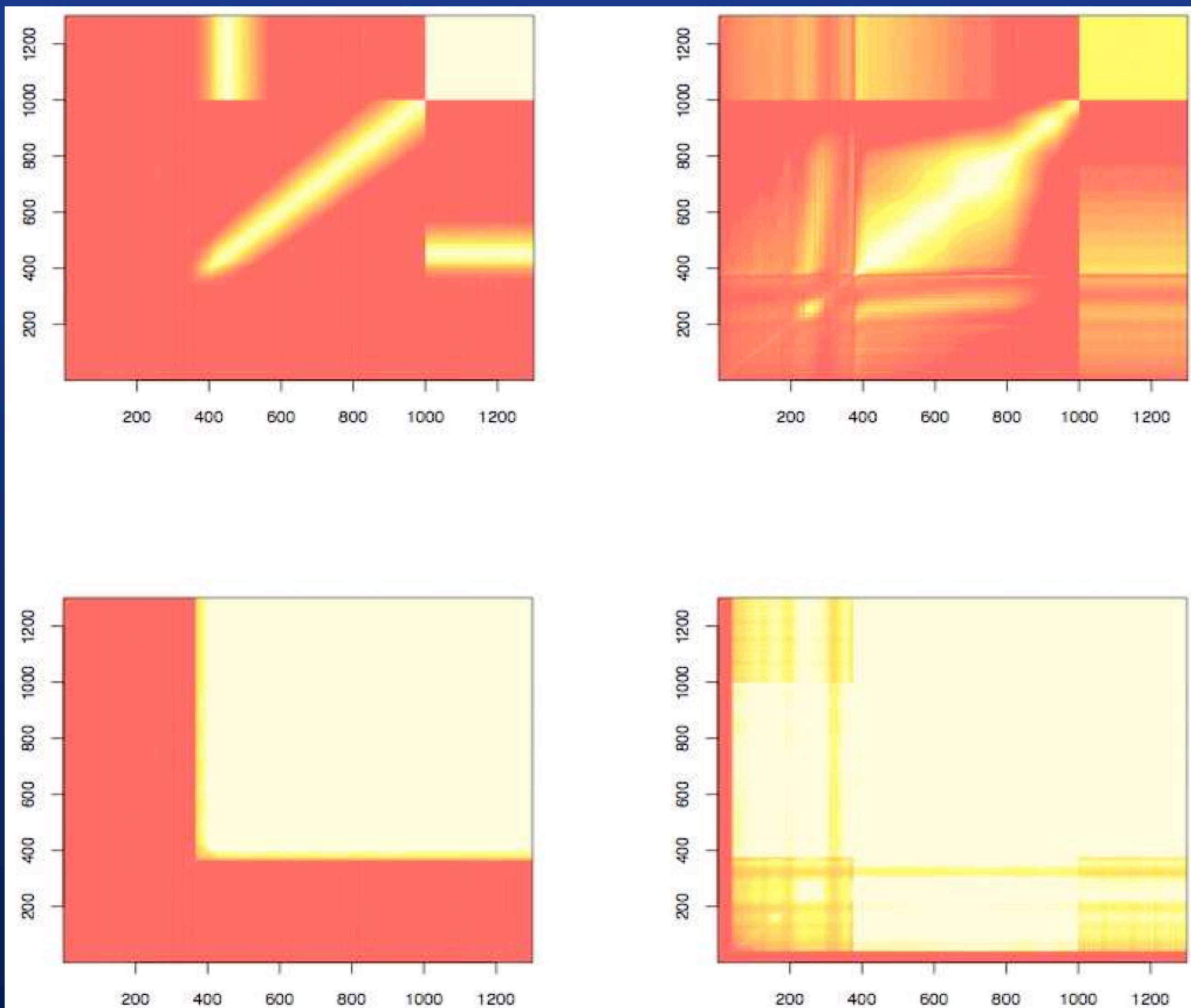
A test model

A model network with 1000 pyramidal cells and 300 interneurons





Results



zero-lag cross correlation

informational coherence

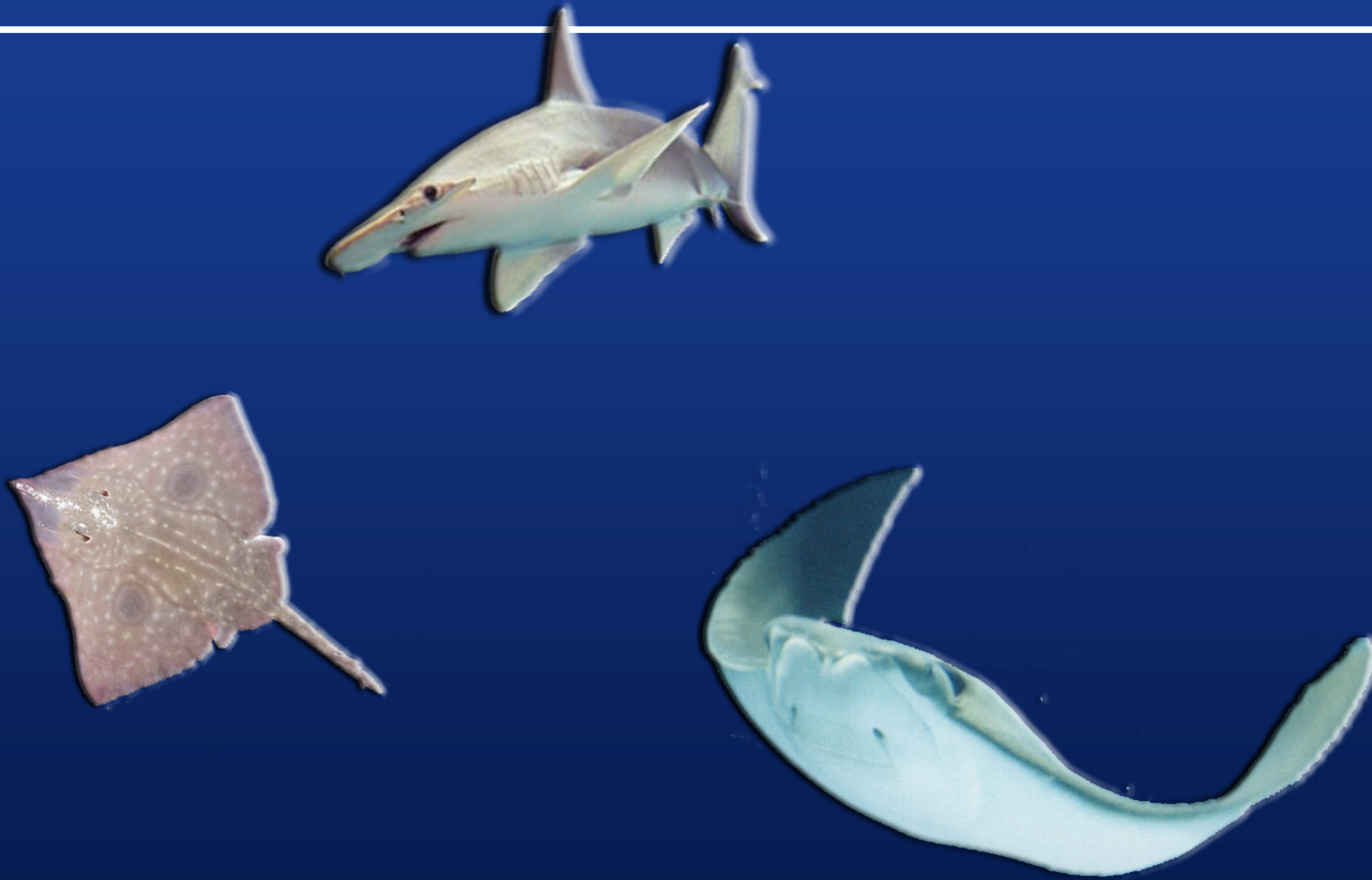
gamma

beta

no coordination

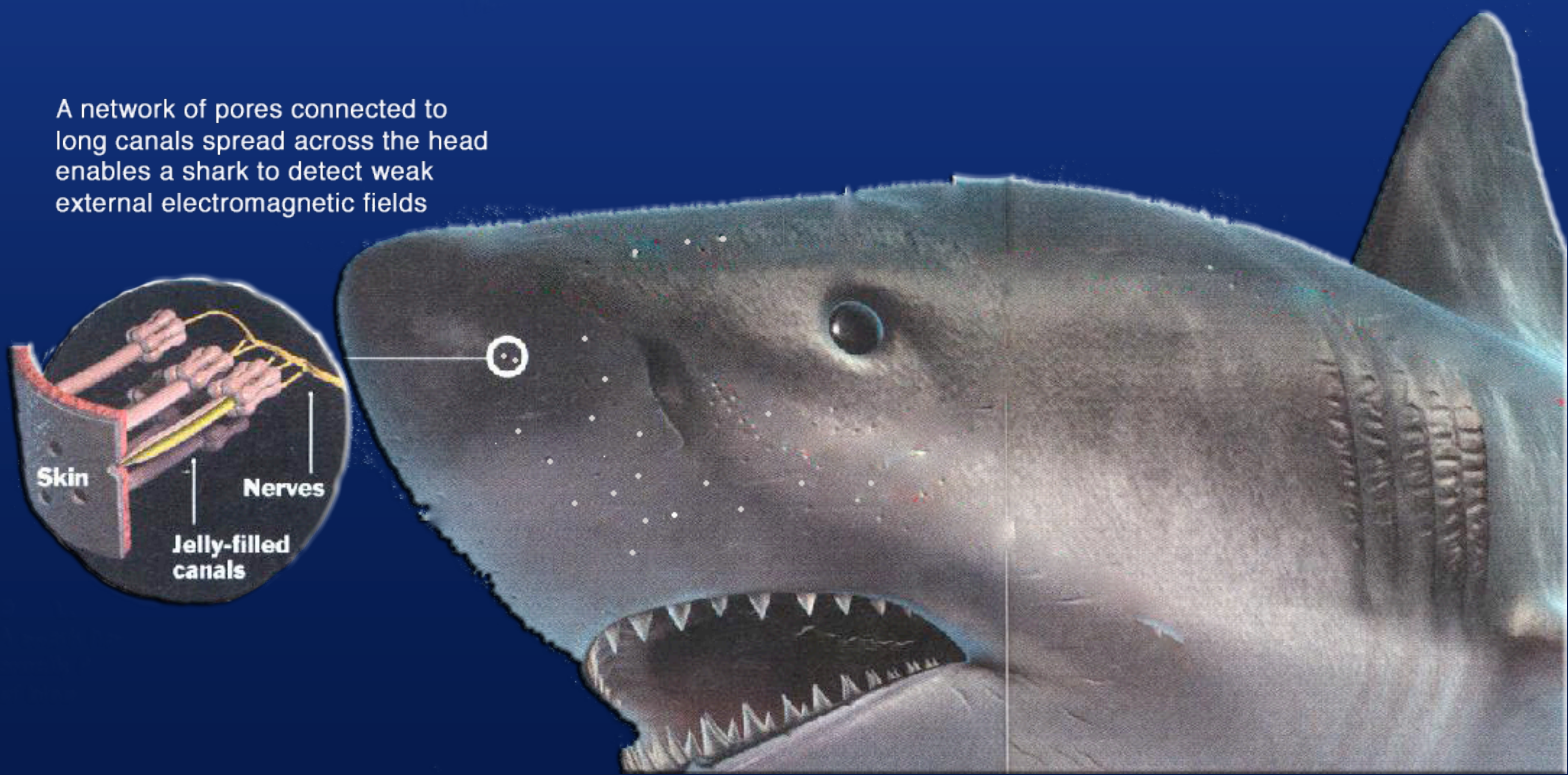
maximum coordination

How can this be related to elasmobranchs?…

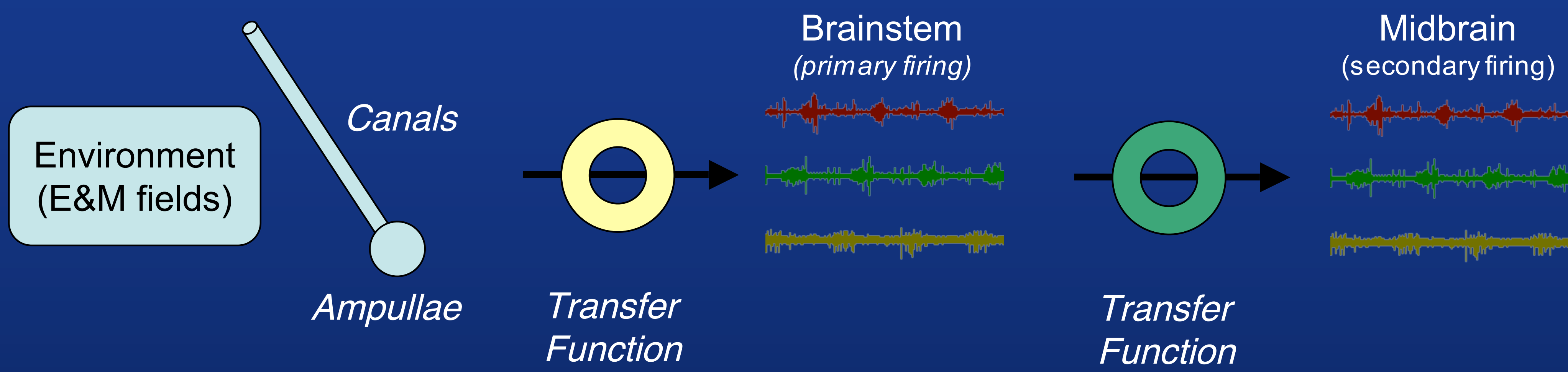


Elasmobranch electrosensory system

Sharks, skates, and rays can sense the electromagnetic landscape via gel-filled canals and ampullae of Lorenzini



The Electrodynamic Neural Code Model



How canals interact with external electric and magnetic field, producing a certain canal voltage.

- ✓ *Basic E&M theory*
- ✓ *Canal geometry*
- ✓ *Electrical properties of canal filling*

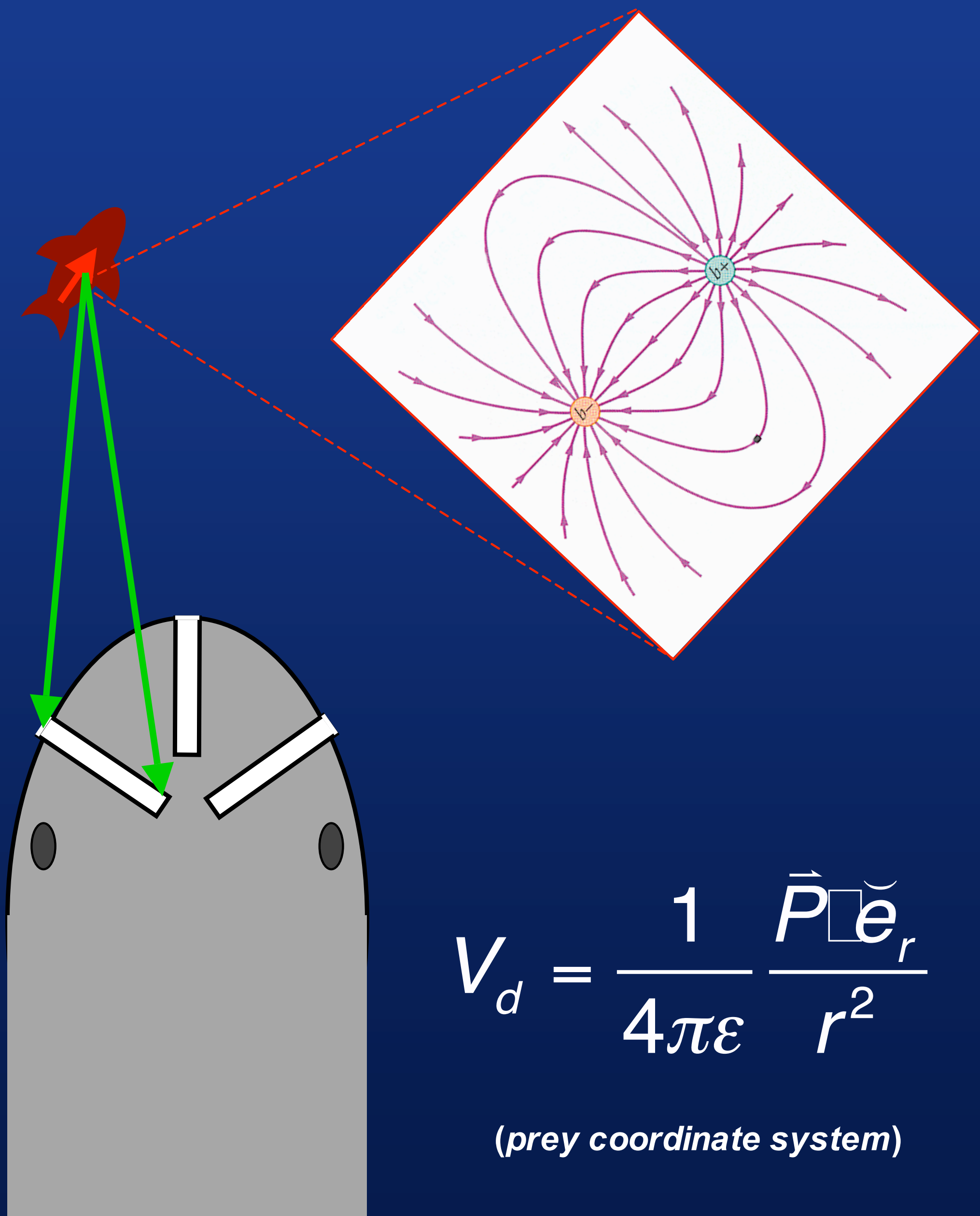
How voltages at the Ampullae of Lorenzini trigger firing at the Brainstem level.

- ✓ *Reference voltage*
- ✓ *Gain (nV/μV $\rightarrow$ mV)*
- ✓ *Primary afferents*
- ✓ *Sub-clustering*
- ✓ *Inhibition*

How primary firing triggers firing at the Midbrain level.

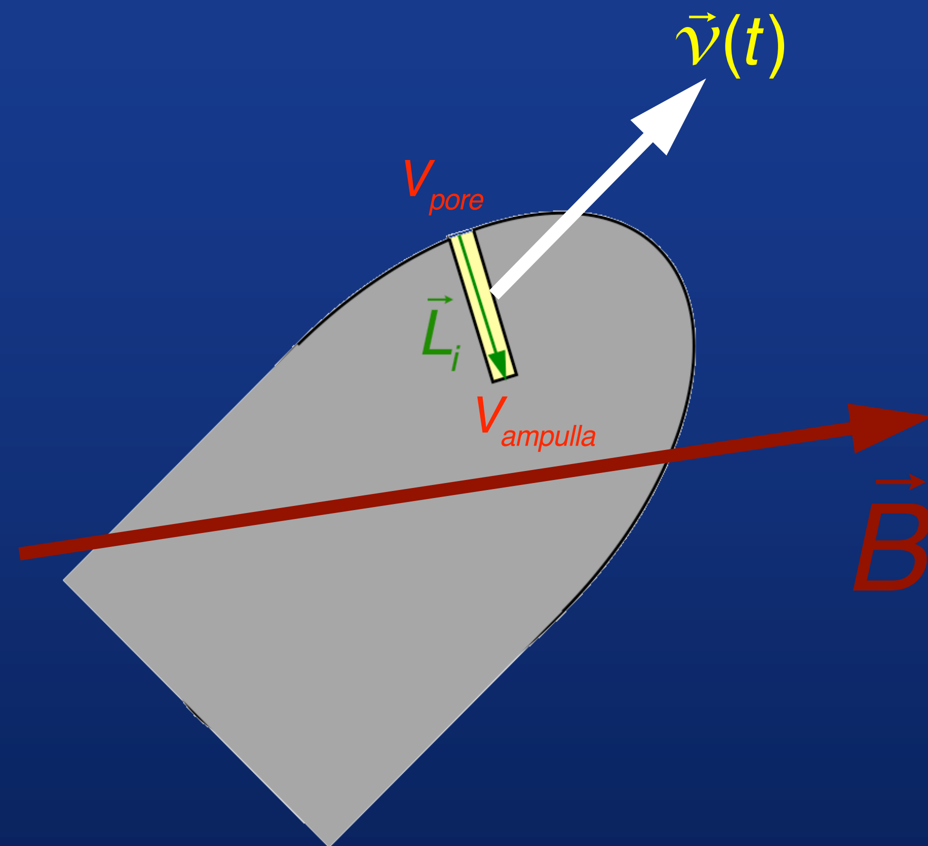
- ✓ *X $\rightarrow$ 1*
- ✓ *Signal-to-Noise ratio*
- ✓ *Sub-clustering*
- ✓ *Excitation*

Calculating the canal voltages



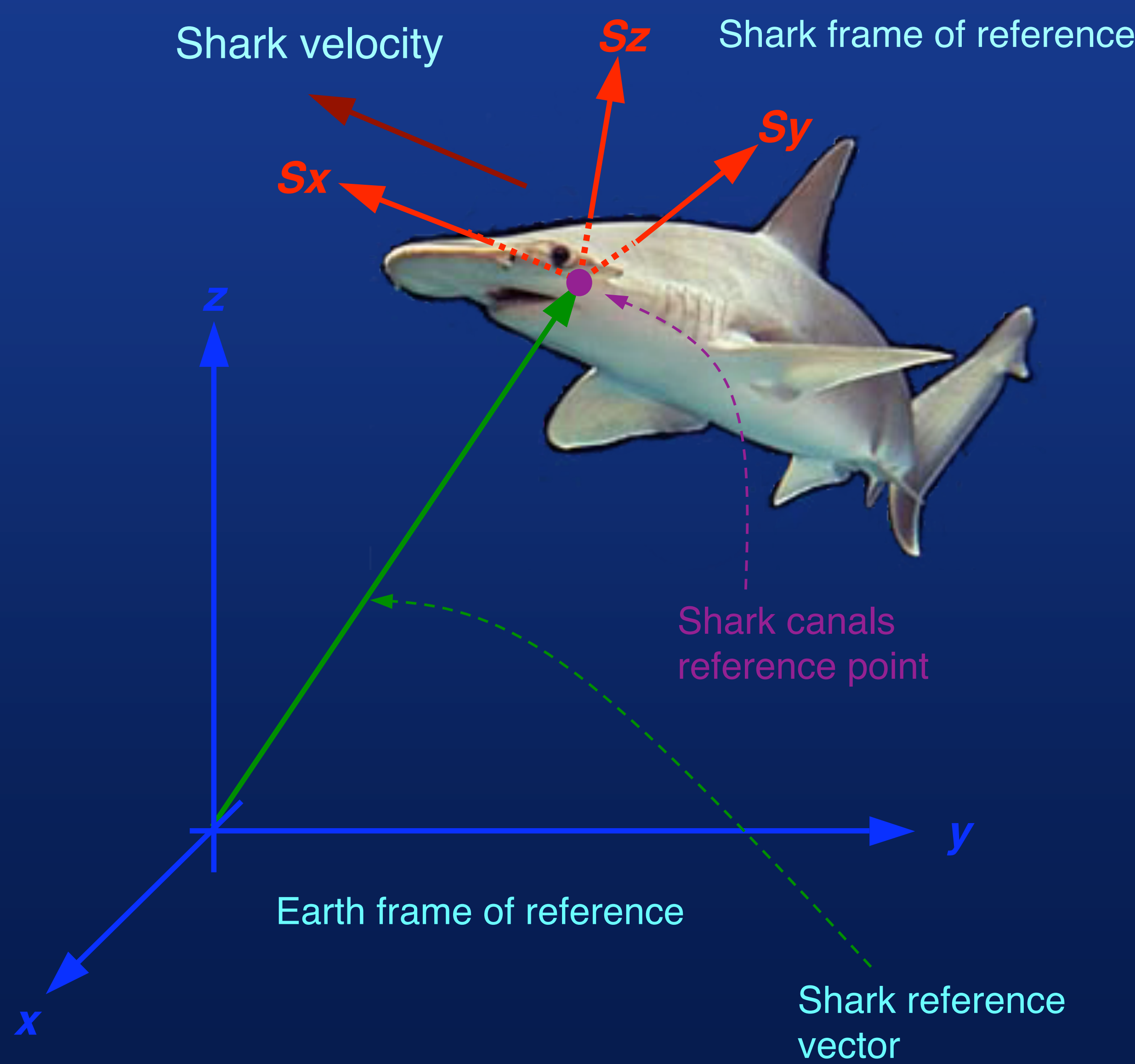
$$V_d = \frac{1}{4\pi\varepsilon}\frac{\vec{P}\cdot\breve{e}_r}{r^2}$$

(*prey coordinate system*)



$$V_{ampulla} - V_{pore} = -\underbrace{\left(\vec{v}\times\vec{B}\right)}_{\text{induced } \vec{E}}\cdot\vec{L}_i$$

A bit of necessary geometry

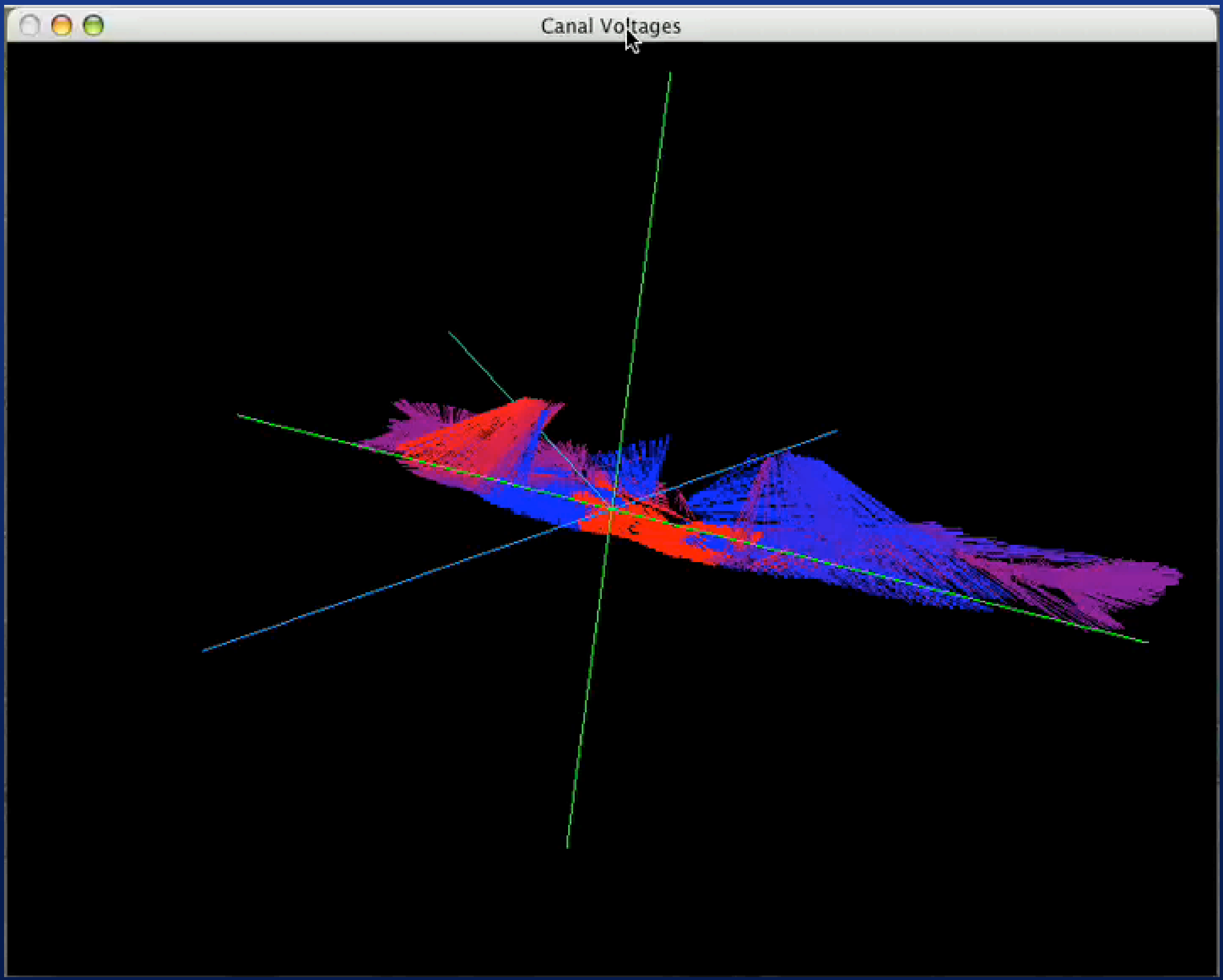


Canal geometry is known in the shark frame of reference

Coordinate transformation

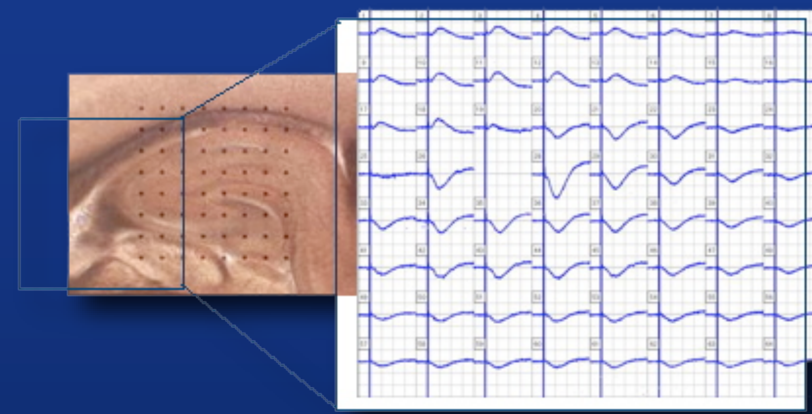
Canal geometry is now known in the earth frame of reference too!

A circling shark on an constant magnetic field



And the connection is…

Time-varying pore E&M landscape or ampulla spiking



Multielectrode midbrain spike recording

Informational Coherence provides the mapping!

THANKS!