Advanced Visualization Techniques for a Model of Mixed-Mode Oscillations in Chemical Systems

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Overview

- **Introduction, Some Basics –**
  Dynamical systems – terminology

- **Classifying the Visualization of Dynamical Systems –**
  Four approaches on different levels of observation

- **Visualizing Mixed-Mode Oscillations –**
  Applied techniques, results and video

Dynamical Systems – Terminology

Continuous dynamical system (flow): $\dot{x} = f(x, p)$

System **variable**s (x) and **parameter**s (p),
phase space representation

Steady vs. **time-dependent** dynamical systems

Classification of "line" $C(t)$, $t \in [0, \tau]$, $C(0) = C_0$:
streamline ($C'(t) \parallel f(C(t))$), **timeline** ($C(\tau)$, varying C_0),
pathline (path of one particle), **streakline** (multiple particles)

Visualization of Dynamical Systems

- **Local Properties –** show attributes at a specific point in phase space (glyphs)

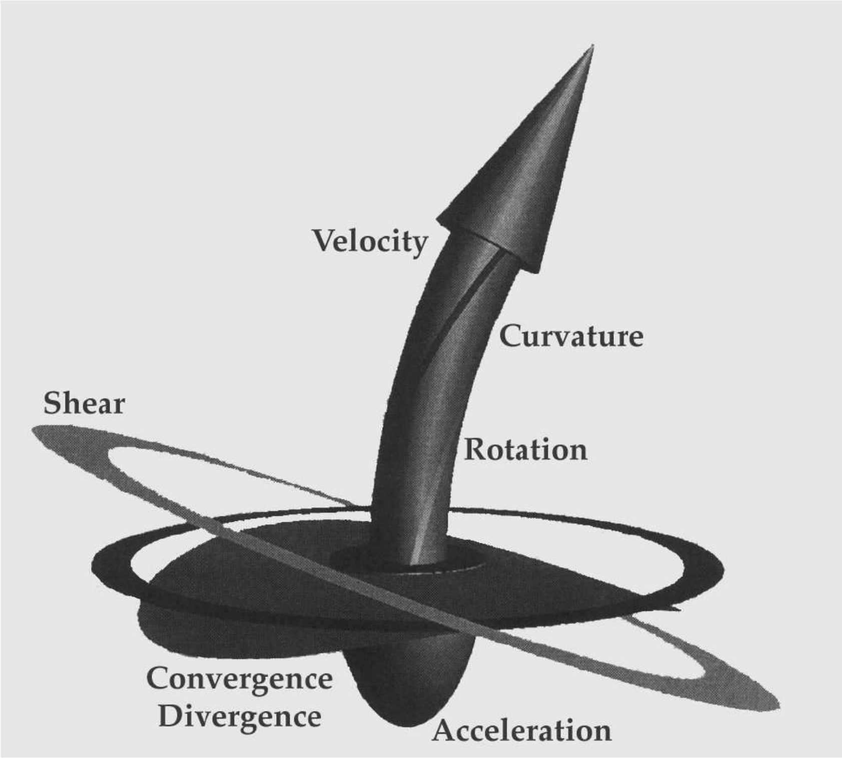
- **Topology of Behavior –** visualize qualitative structure of behavior (attractors, separatrices, ...)

- **Global Properties –** represent the evolution of a system directly (arrow plots, streamlines, ...)

- **Classes of DS –** sketch long-term behavior vs. parameter changes (bifurcation diagrams)

Local Properties

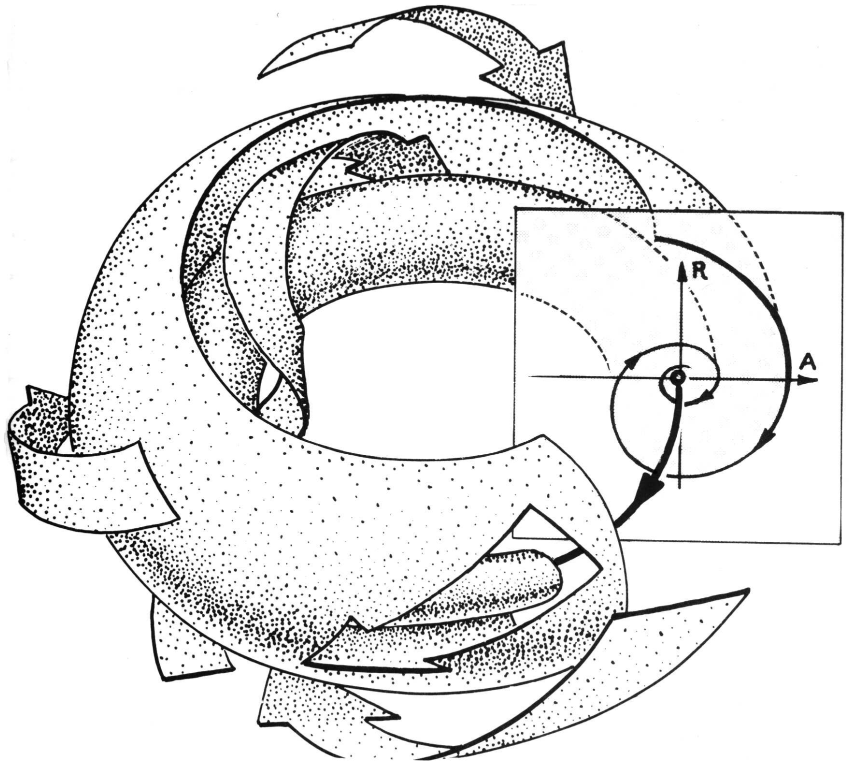
Glyphs – a representation of *local attributes* as, e.g., velocity, convergence, or rotation



[de Leeuw, van Wijk; 1993]

Topology of Behavior

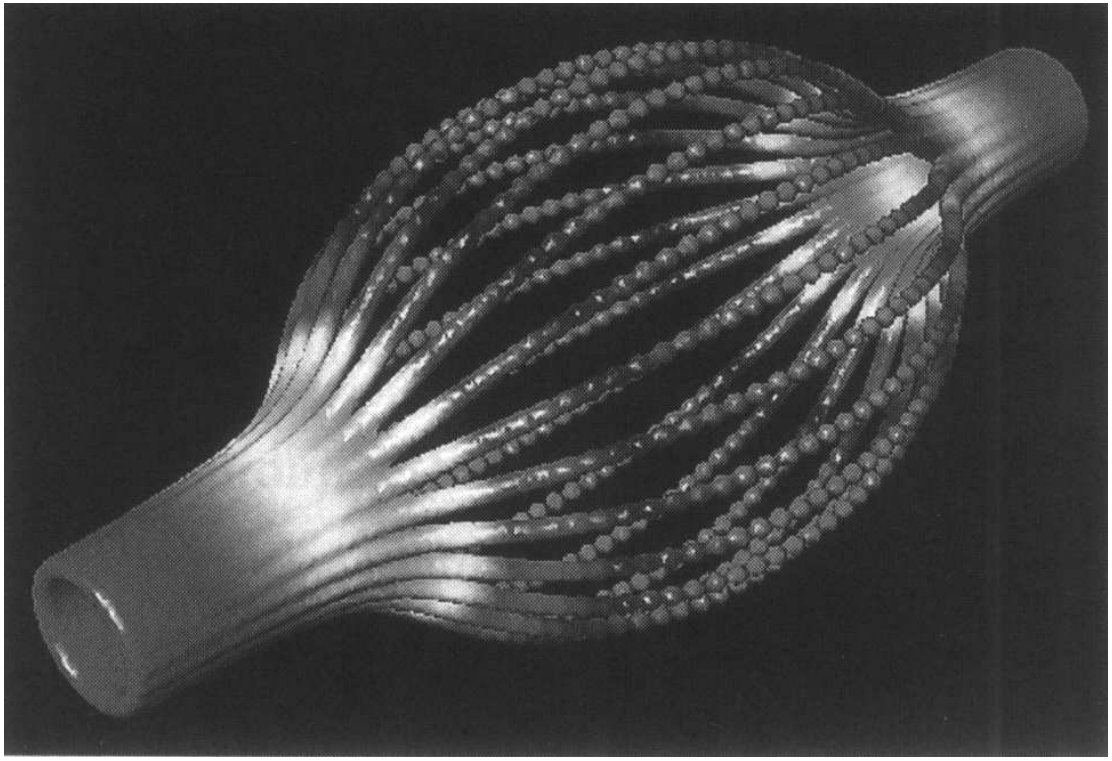
Characteristic structure – critical sets (e.g., attractors), separatrices (e.g., heteroclinic orbits)



[Abraham, Shaw; 1992]

Global Properties

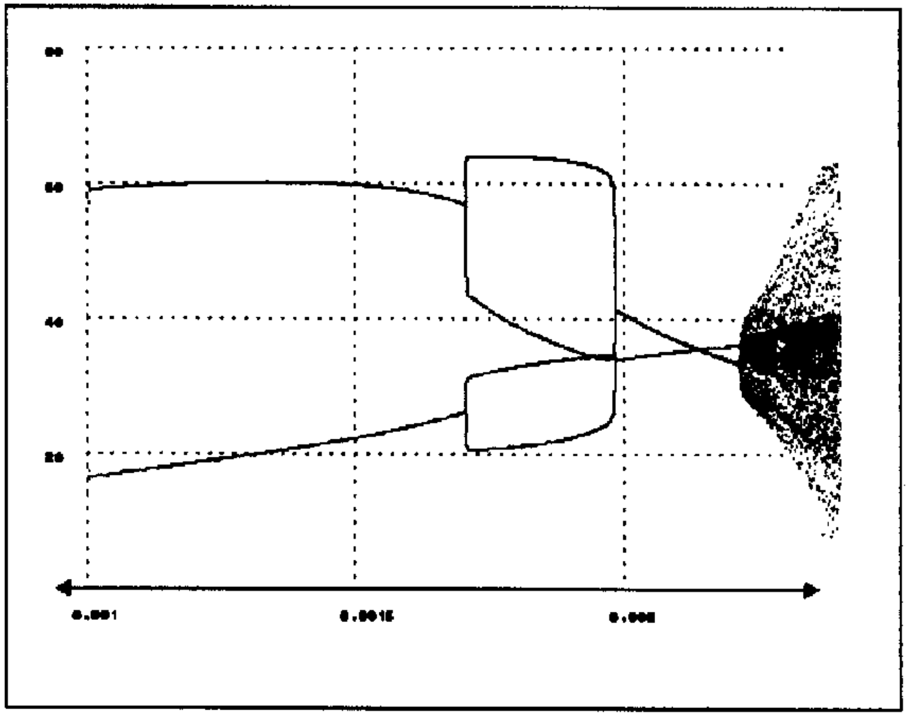
Direct visualization – Sketch of the overall behavior, e.g., arrow plots, streamlines, and streamsurfaces



[Brill et al.; 1994]

Classes of Dynamical Systems

Bifurcation diagrams –
long-term behavior vs. system parameters



Visualizing Mixed-Mode Oscillations

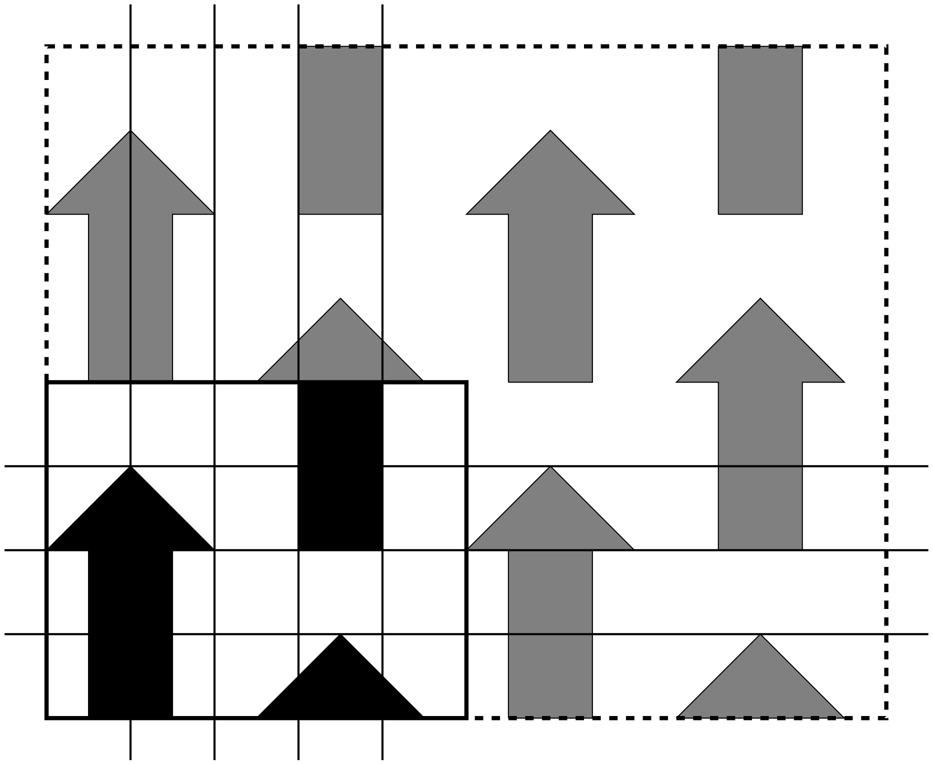
- **Streamarrows –** enhancing streamsurfaces
- **Anisotropic Spot-Noise –** visualizing streamlines and timelines
- **Selective Cuts –** providing additional insights
- **Animation –** augment the visualization

Streamarrows 1/2

Cyclic (tiled) **texture**

Vertical alignment: **streamlines**
Horizontal alignment: **timelines**

Representation of
– **direction of flow**
– **velocity and acceleration**
– **convergence/divergence**

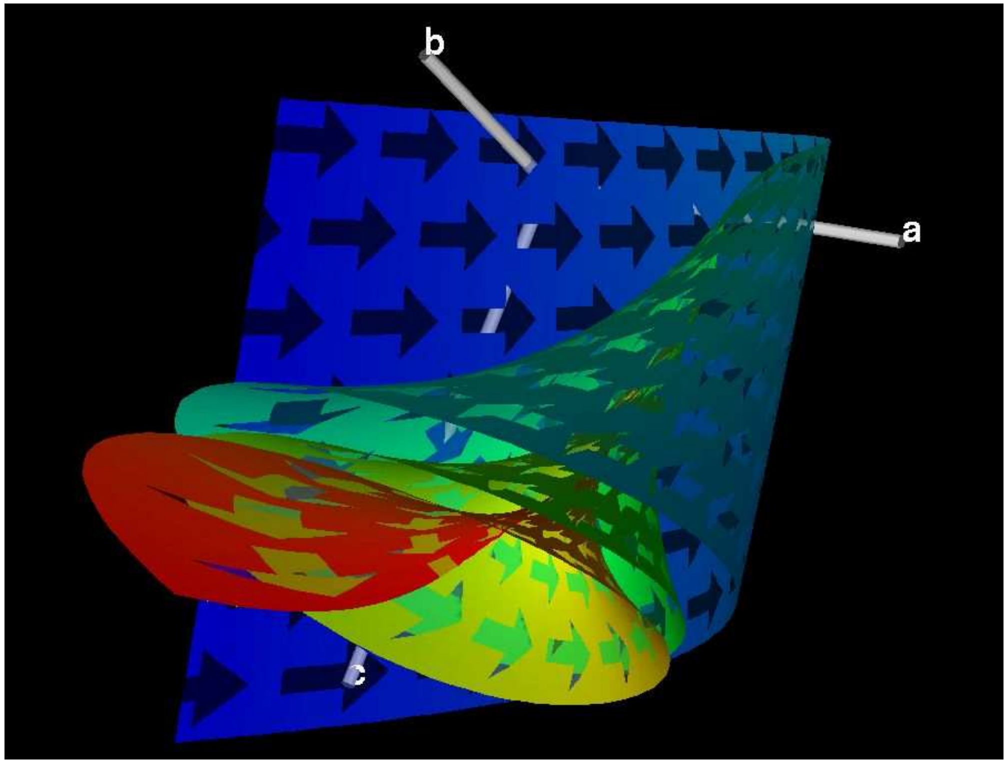


Streamarrows 2/2

Semitransparent arrows

Possible implementations:
- **alpha-texture**
- **geometric segmentation**

Additional cue: **color**
$\cong$ **age** of streamsurface



Anisotropic Spot-Noise

Spot noise SN at "pixel" p

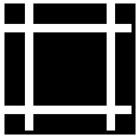
$$SN(p) = \sum_{i=1}^{n} I_i \cdot S(p, p_i)$$

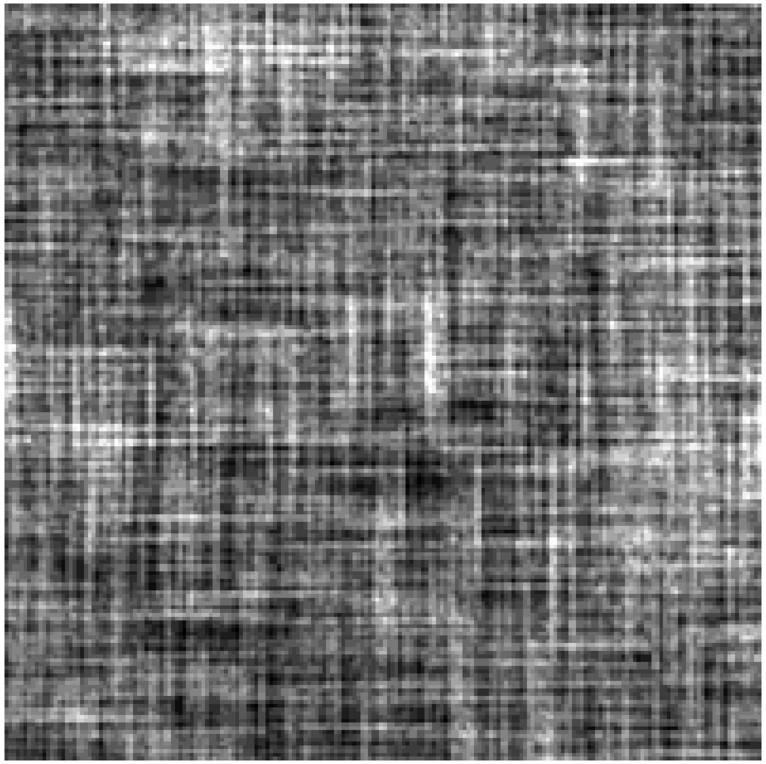
n ... number of spots

p_i ... random locations of spot i

I_i ... random intensity of spot i

$S(p, p_i)$ ... local spot-function





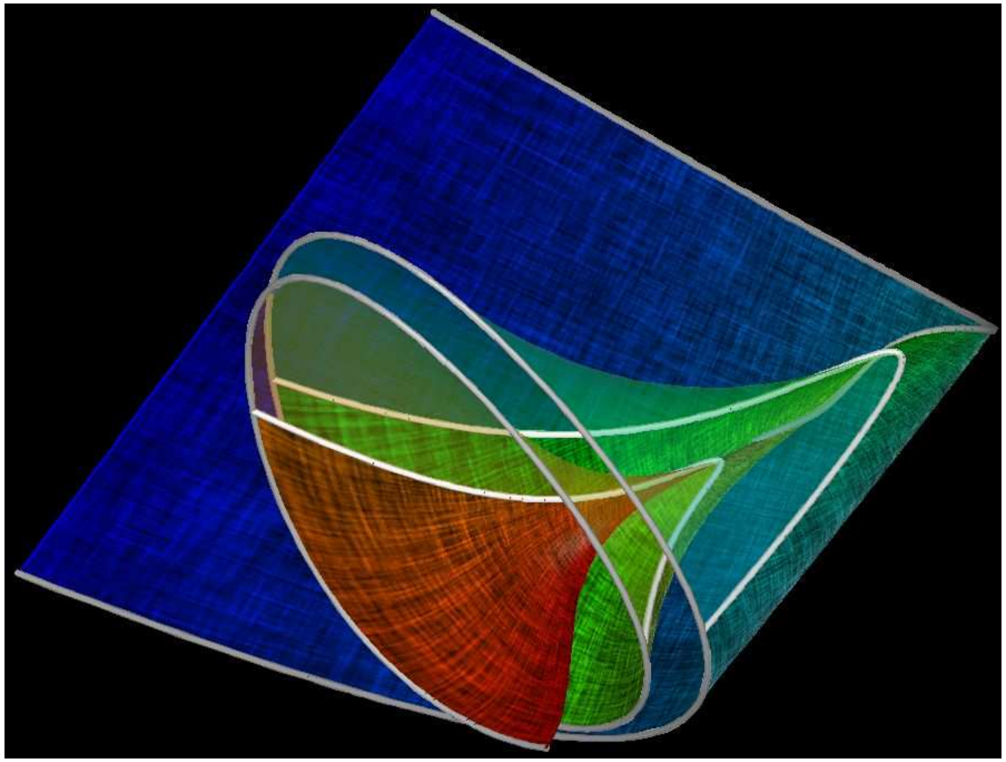
[van Wijk; 1991]

Anisotropic Spot-Noise and Selective Cuts

Color: **age** of streamsurface

Anisotropic spot-noise:
streamlines, timelines

Horizontal cut-plane:
semi-transparent parts above,
white cross-section curves

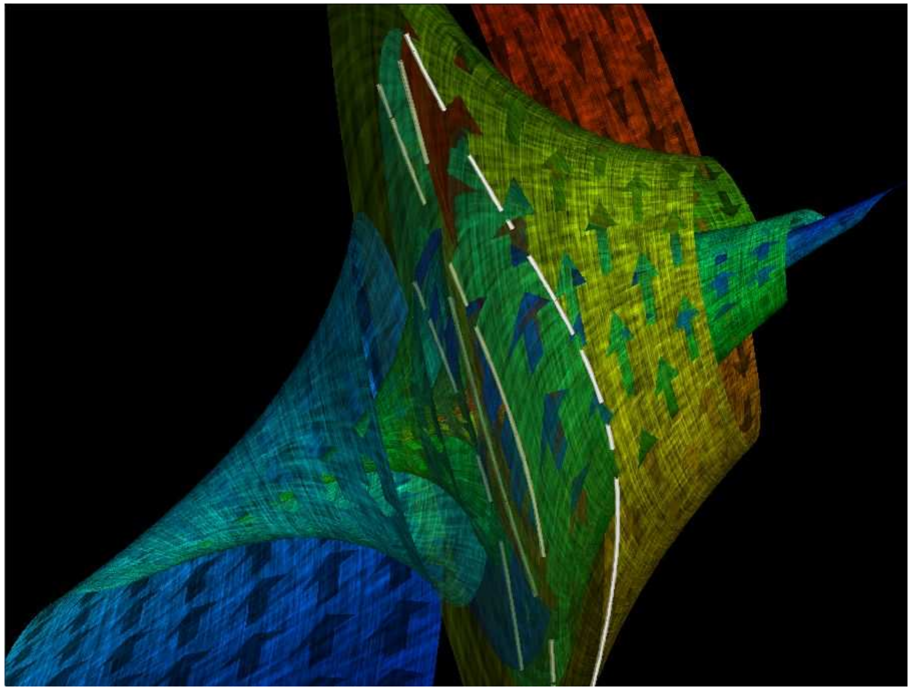


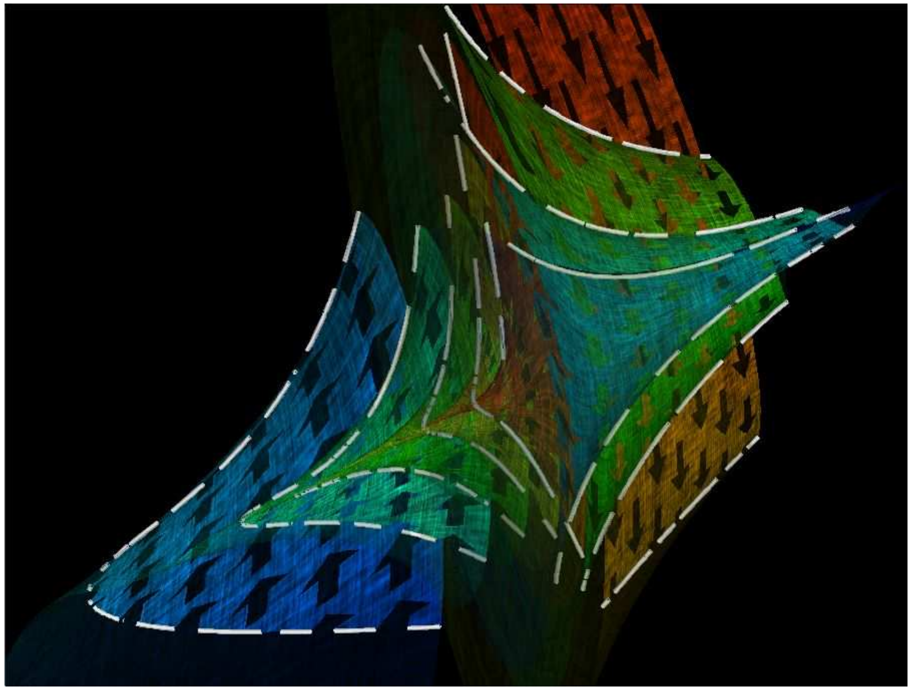
Animation 1/2

Animated components:
– moving streamarrows (cyclic texture animation)
– length of streamsurface (animated construction)
– location of cut-plane (successive removal)

Further possibilities:
– viewpoint animation (camera pan)
– location of seed-points (varying streamsurfaces)
– location of enhanced streamlines

Animation 2/2





VIDEO

Conclusio

- **Four Classes of Dynamical System Visualization –**
  - ▷ local properties
  - ▷ topology of behavior
  - ▷ global properties
  - ▷ classes of dynamical systems

- **Visualization of a Model of Mixed-Mode Oscillations –**
  - ▷ streamarrows
  - ▷ anisotropic spot-noise
  - ▷ selective cuts
  - ▷ animation