Introduction
The laminar mixing process can be improved by introducing chaos in the flow. Time-periodic flows produce chaotic trajectories and the chaos is determined by periodic points. Figure 1 represents the flow geometry and the front and back wall induce the time-periodic motion.

Objectives
- study chaotic mixing using periodic point analysis
- develop numerical tools to analyze mixing

Chaotic Mixing
Chaos in the flow is determined by the periodic points. Periodic points return to their original position after one period $T$ and are classified into two groups:

- **Elliptic**: center of non-mixing regions (islands)
- **Hyperbolic**: center of stretching and folding

Governing Equations
The flow is described by the Stokes equations:
\[
\begin{align*}
\frac{\partial u}{\partial t} &= \nabla^2 u - \nabla p + f & \text{in } \Omega, \\
\nabla \cdot u &= 0 & \text{in } \overline{\Omega}, \\
u &= g & \text{on } \Gamma = \partial \Omega,
\end{align*}
\]

Numerical Techniques
- Time discretization: Pressure correction method
- Space discretization: Spectral element method

Mixing Analysis
In symmetrical flows, periodic lines cross the plane of symmetry $x = 0$ at the times $t_1 = T/4$ and $t_2 = 3T/4$. This plane is tracked from $t_1$ and $t_2$.

Conclusions
Periodic structures, which consist of lines, are found and classified in 3D cavity flows.