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# *Numerical Simulations of Spherical Gap Flows*

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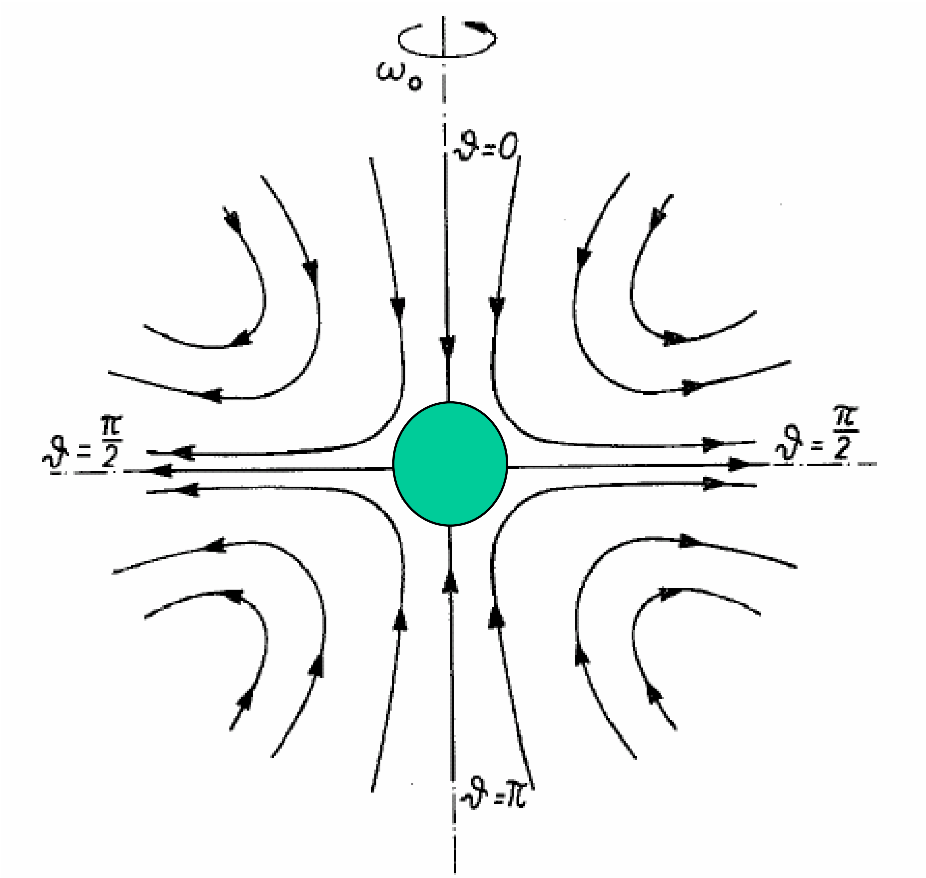
# Overview

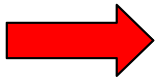
- Problem description
- Geometry parameter
- Basic flow field
- Numerical simulations
- Comparison of simulations with experiments
- Conclusions

# Introduction

Analytical solution for a single sphere

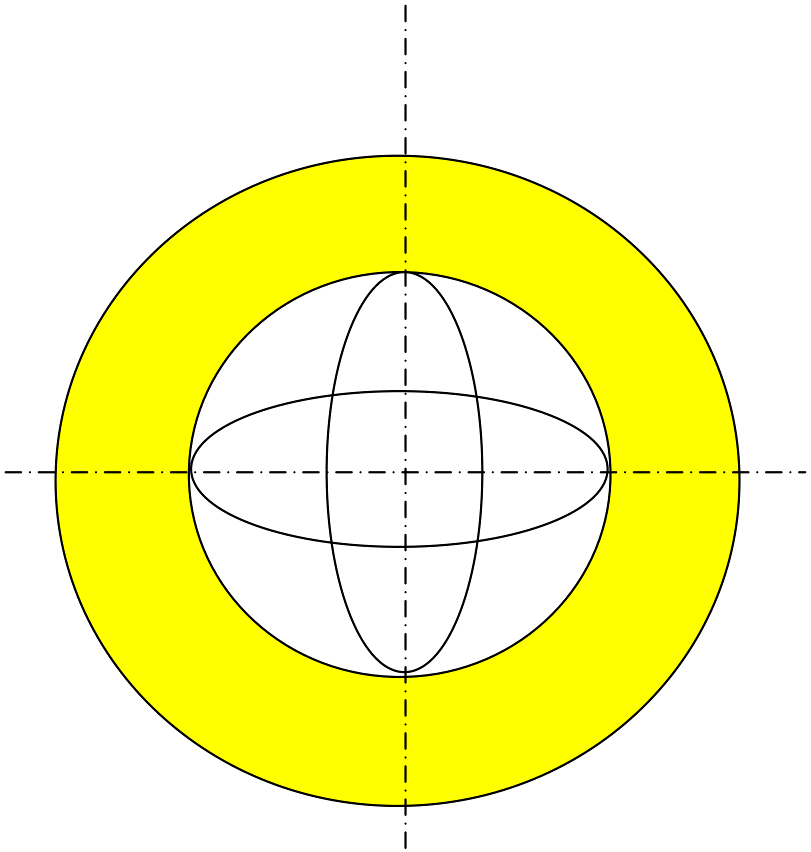
(Thomas & Walters, 1962)



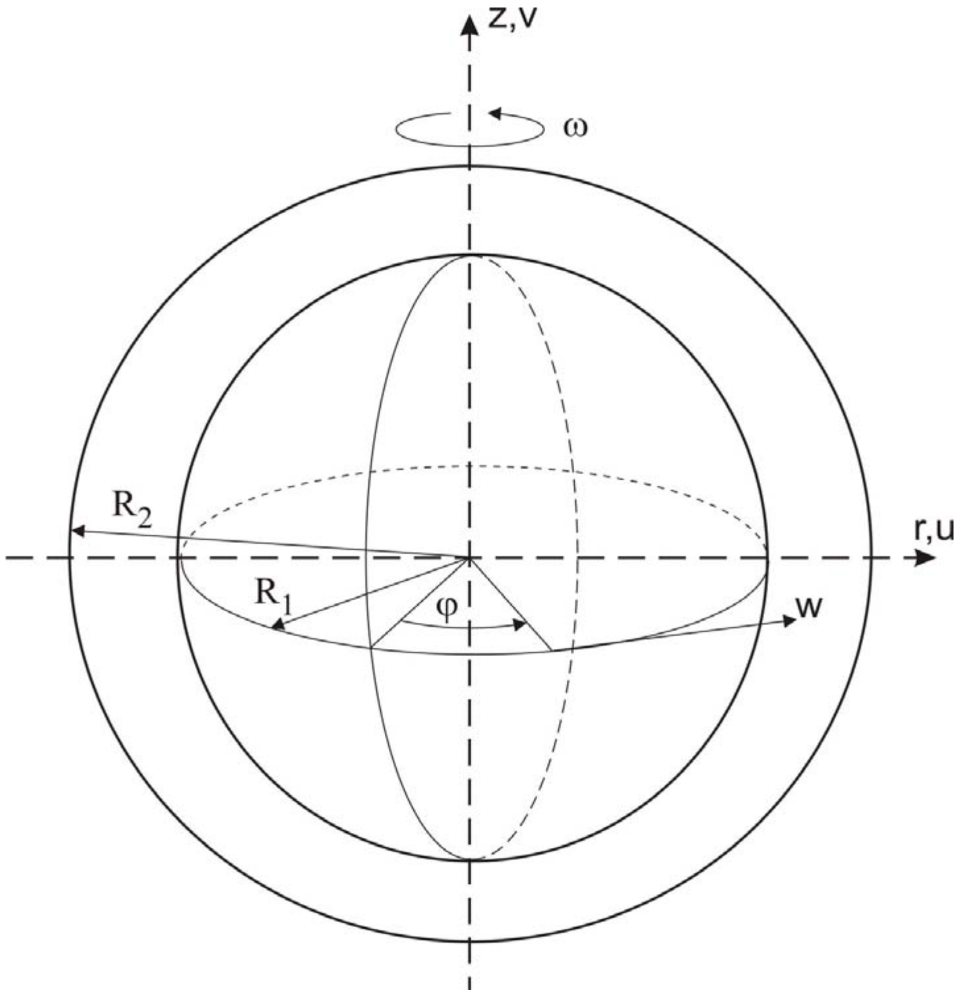



Solution for the flow between two concentric spheres

(Habermann, 1962)



# Dimensionless Parameters



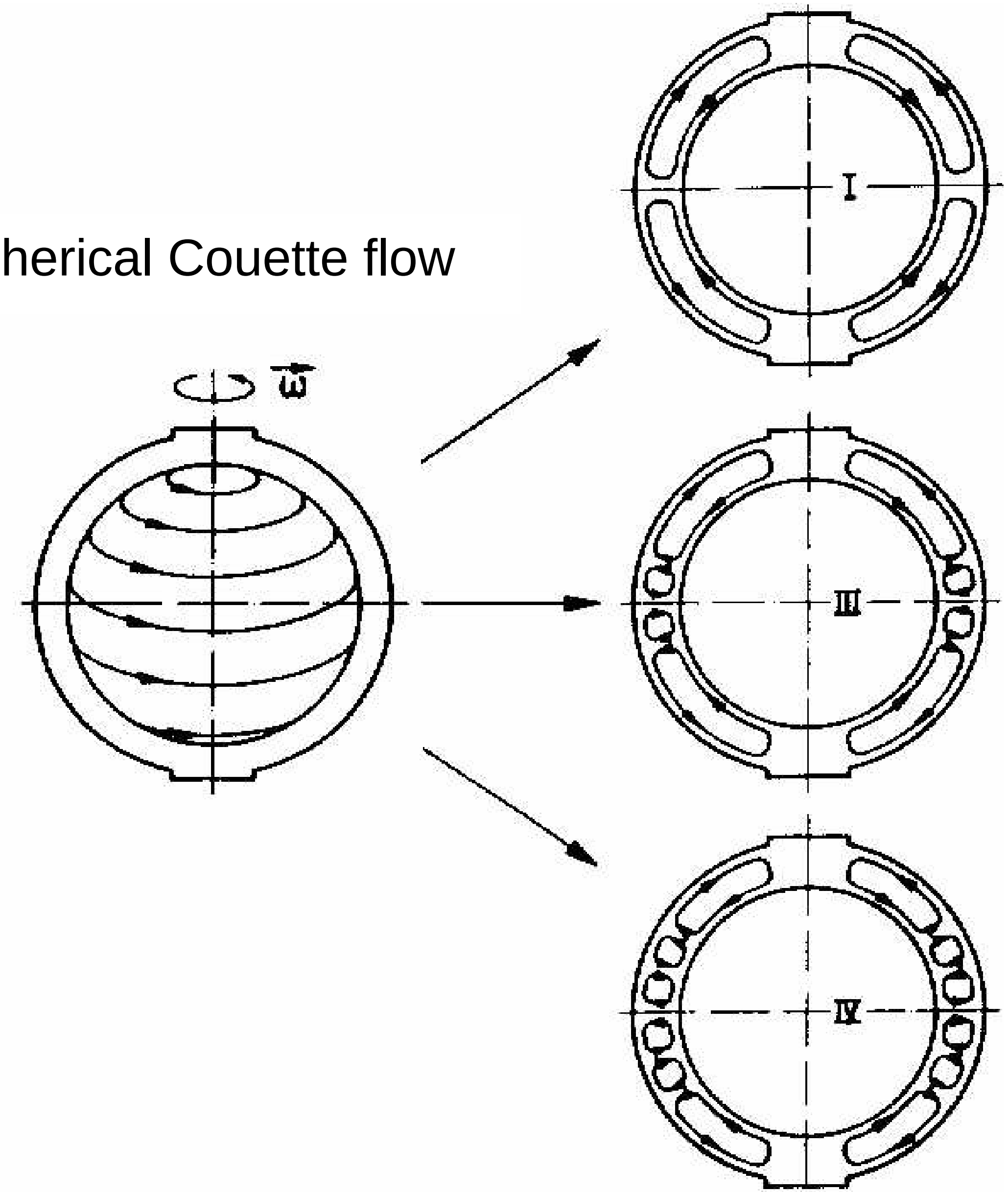

- Reynolds number $Re = \frac{R_1^2 \cdot \omega}{\nu}$
- Gap with $\sigma = \frac{R_2 - R_1}{R_1}$
- Velocity components

| | |
|---|---|
| Radial | r, u |
| Axial | z, v |
| Circumferential | φ, w |

- Rotational symmetric $\frac{\partial}{\partial \varphi} = 0$
- Swirl flow mode

# Non-uniqueness of supercritical solutions

Spherical Couette flow




- Mode I

  supercritical flow without vortices

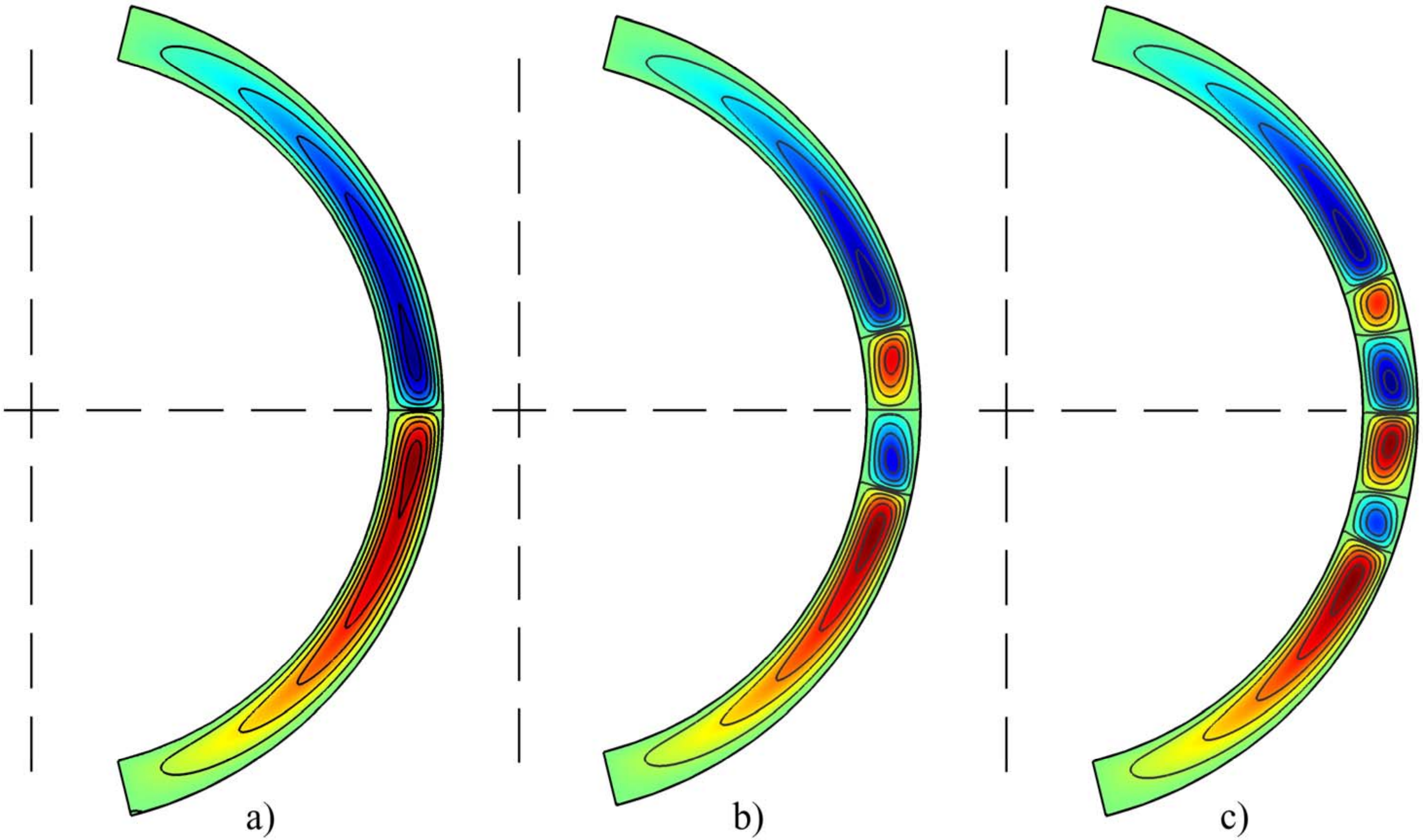
- Mode III

  two vortices near the equator

- Mode IV

  four vortices near the equator

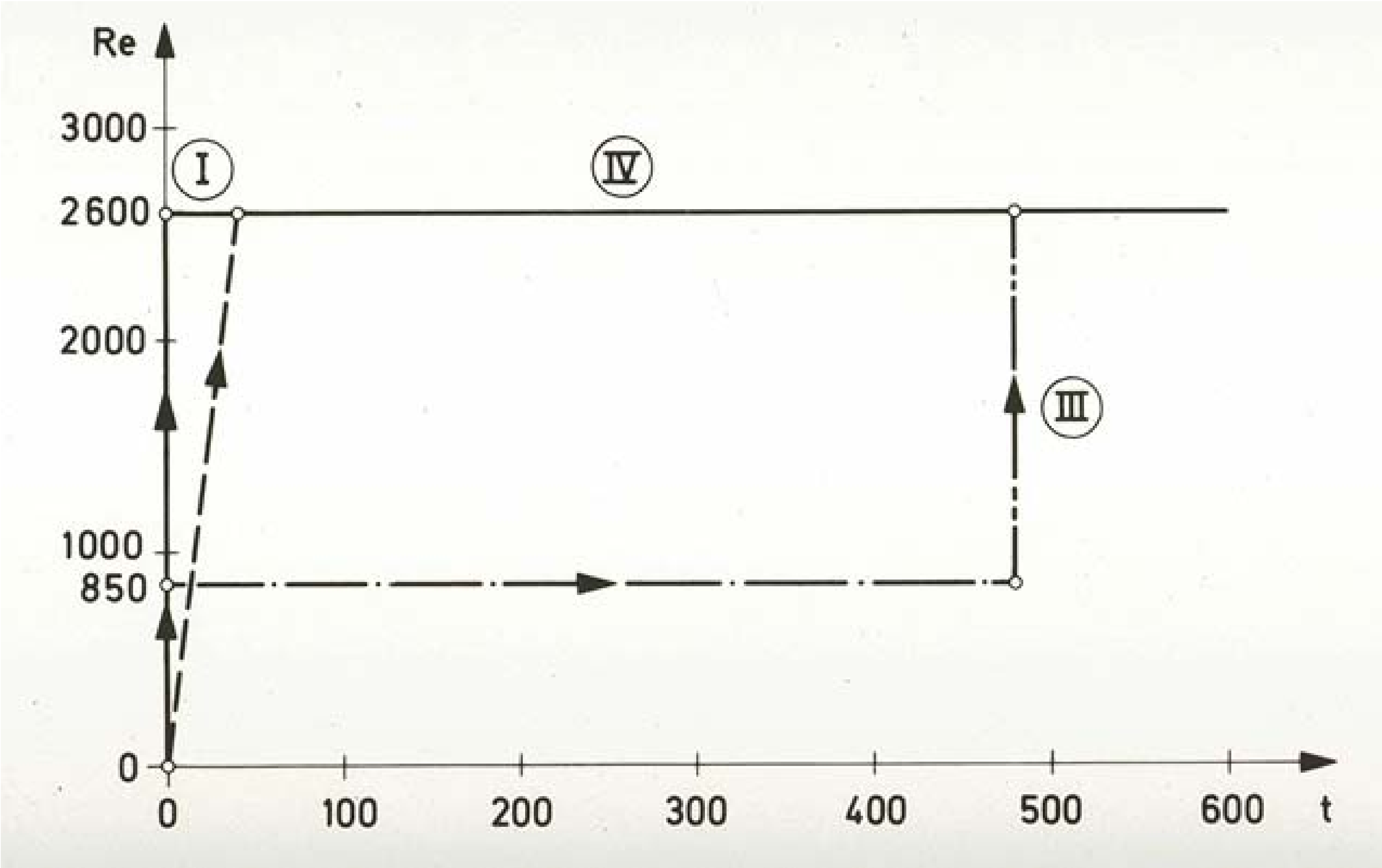
# Simulated flow structure in the r,z-plane




*Mode I* *Mode III* *Mode IV*

$Re = R_1^2 \cdot \omega / \nu = 2600$ , $\sigma = (R_2 - R_1)/R_1 = 0.154$

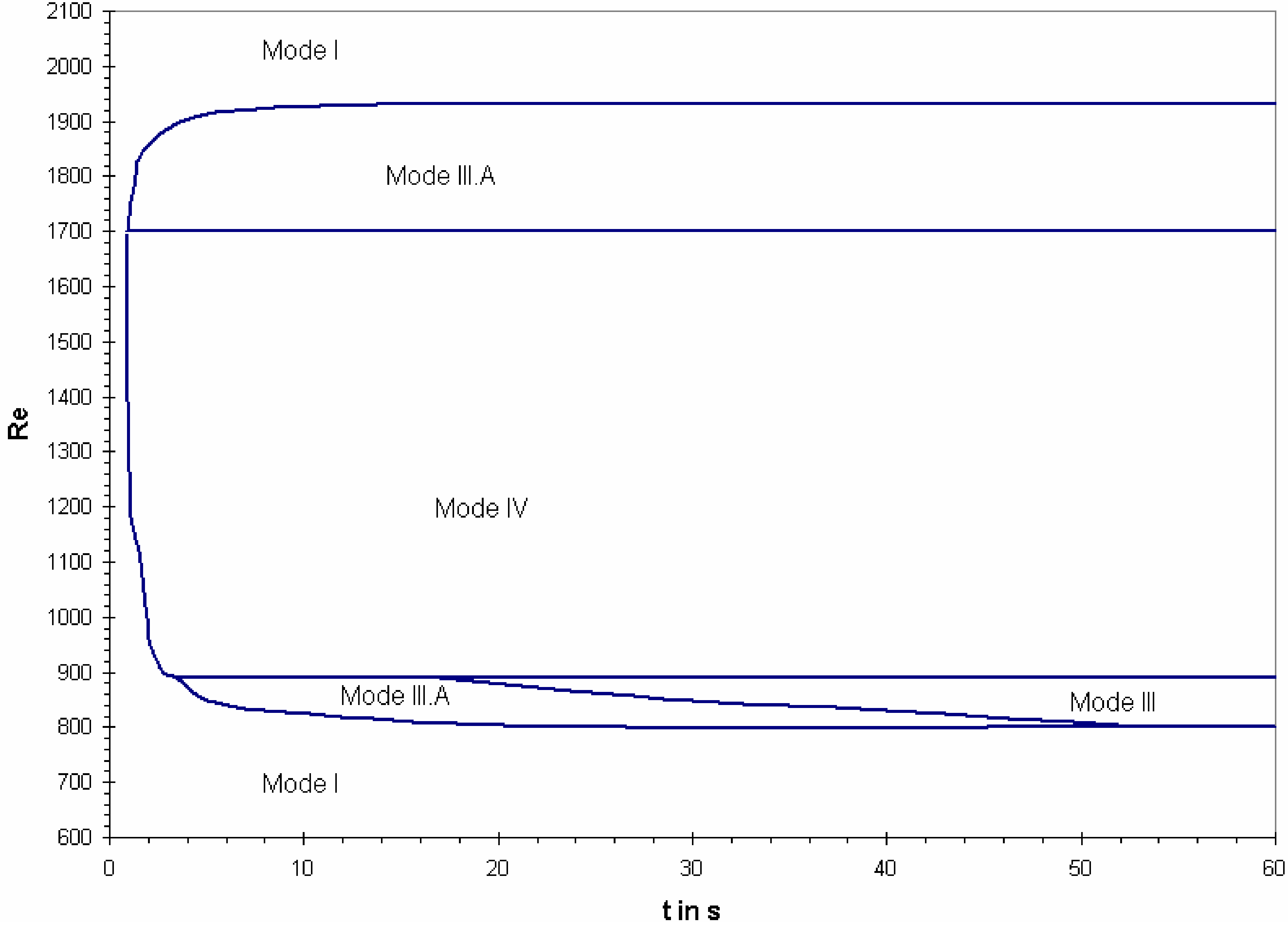
# Bifurcation from rest to supercritical Reynolds number



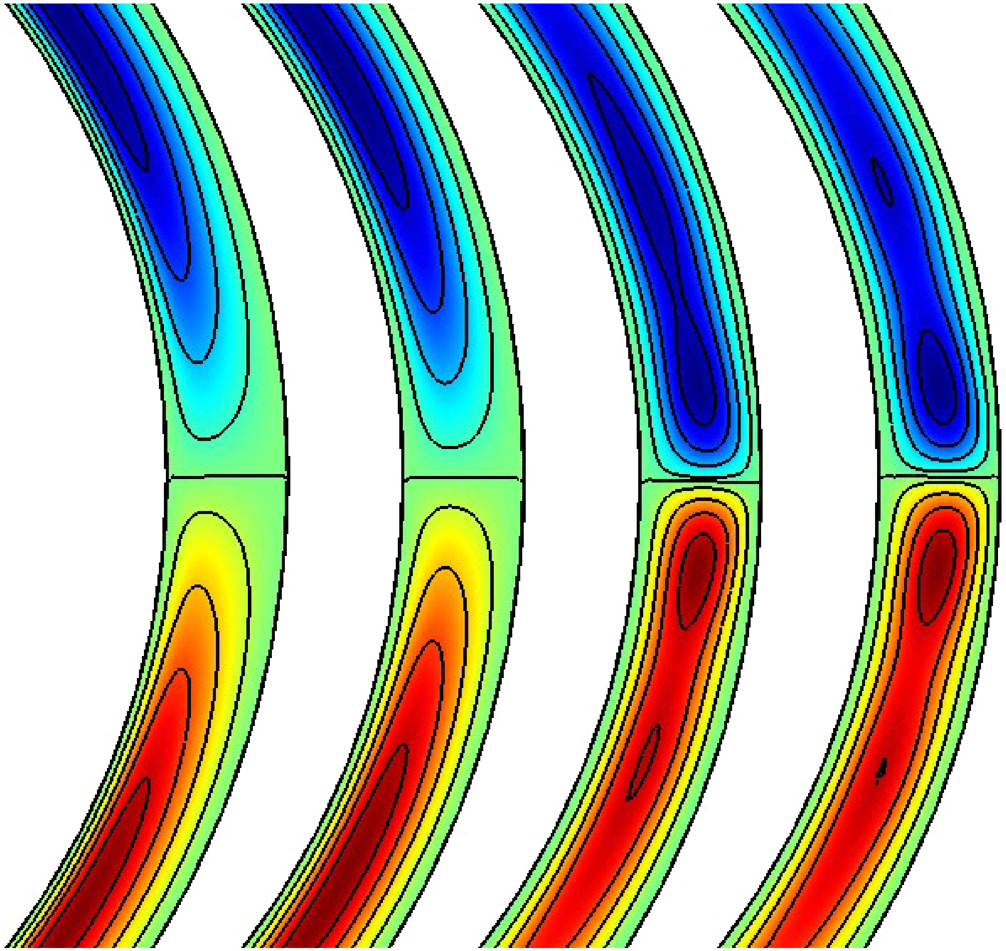

*Mode I* *Mode III* *Mode IV*

$Re = R_1^2 \cdot \omega / \nu = 2600$ , $\sigma = (R_2 - R_1)/R_1 = 0.154$

# Existence ranges after sudden start from rest



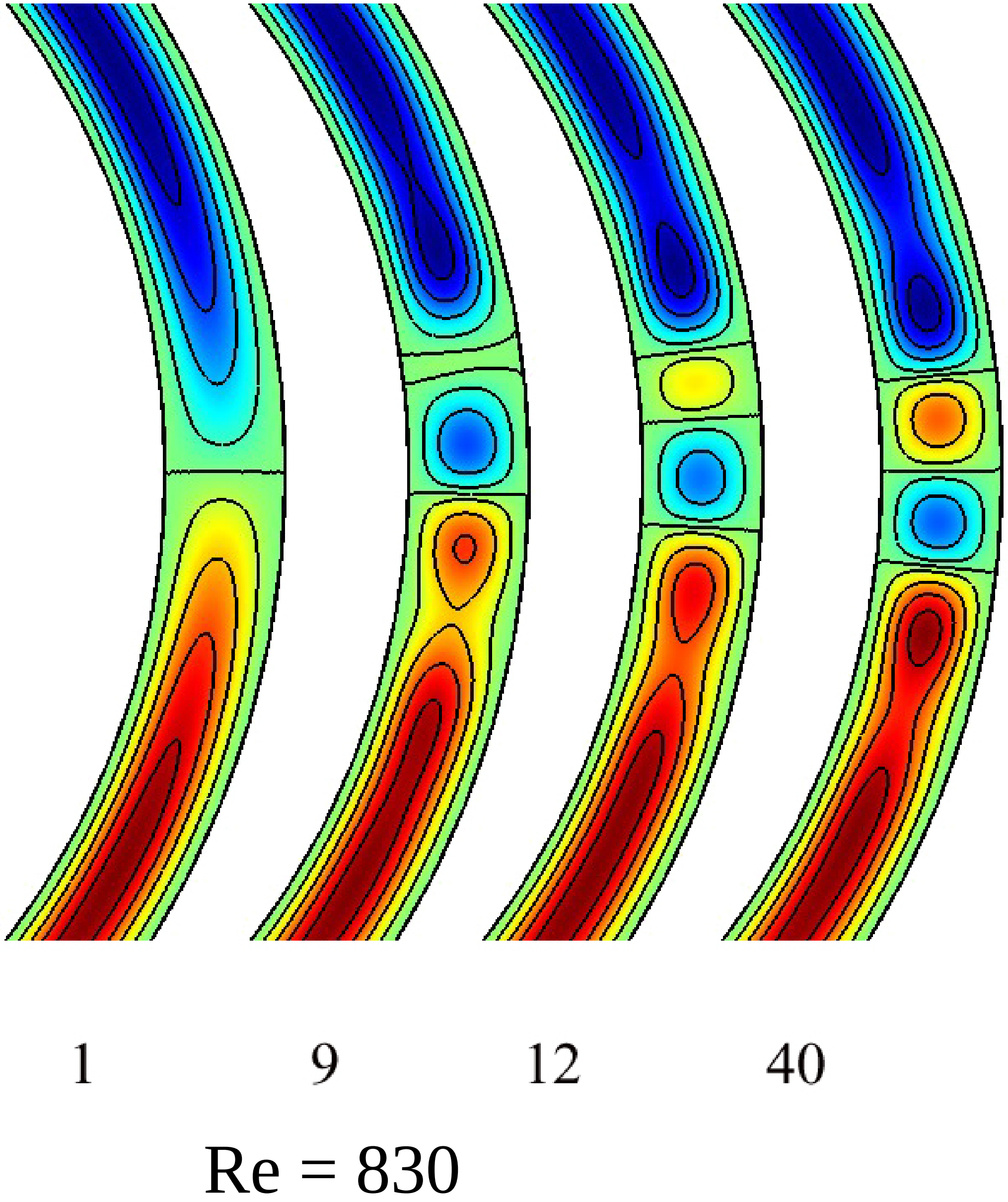
# Symmetric transition from rest into Mode I



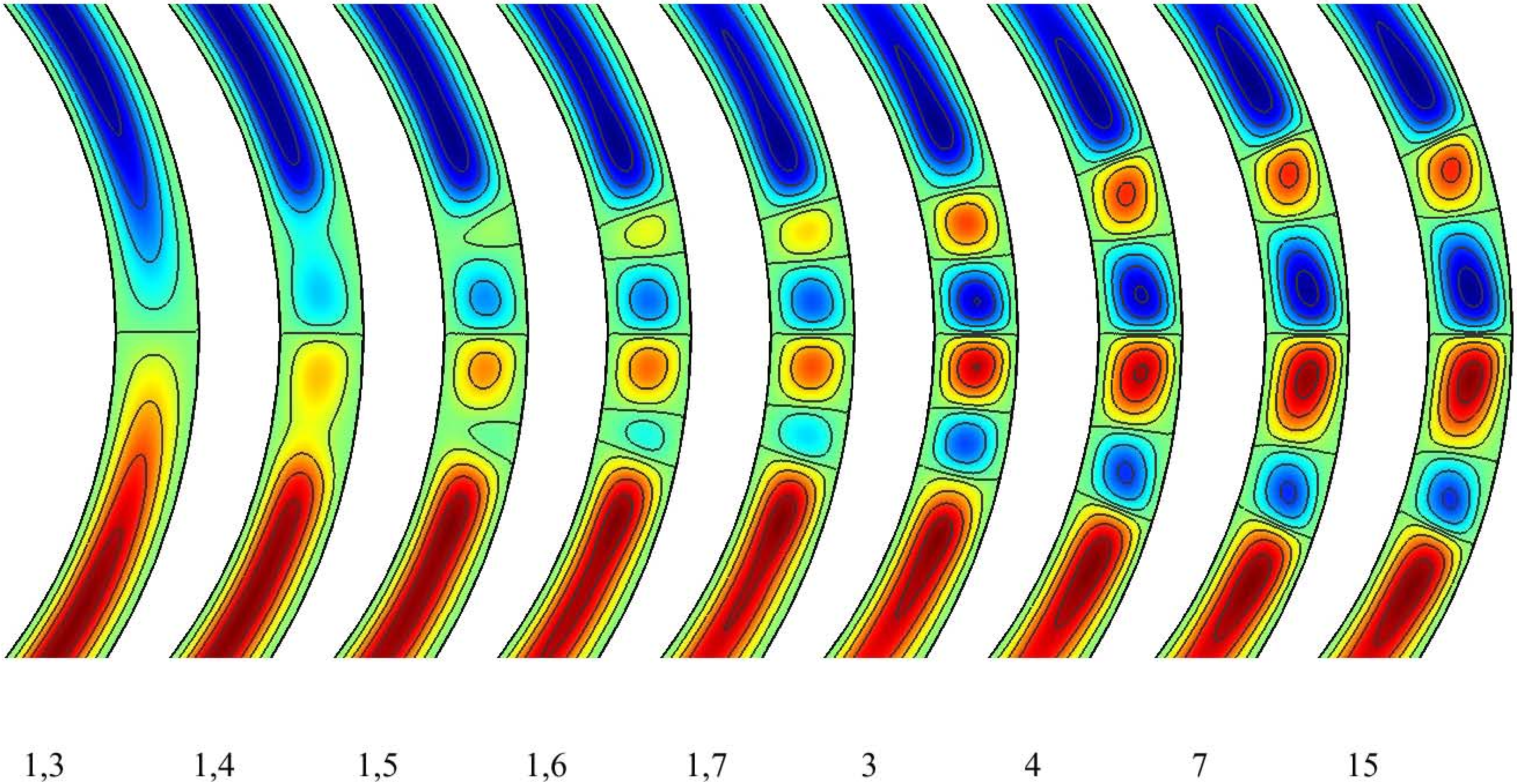
0,05 0,1 0,5 5

Re = 2000

# Asymmetric transition from rest into Mode III

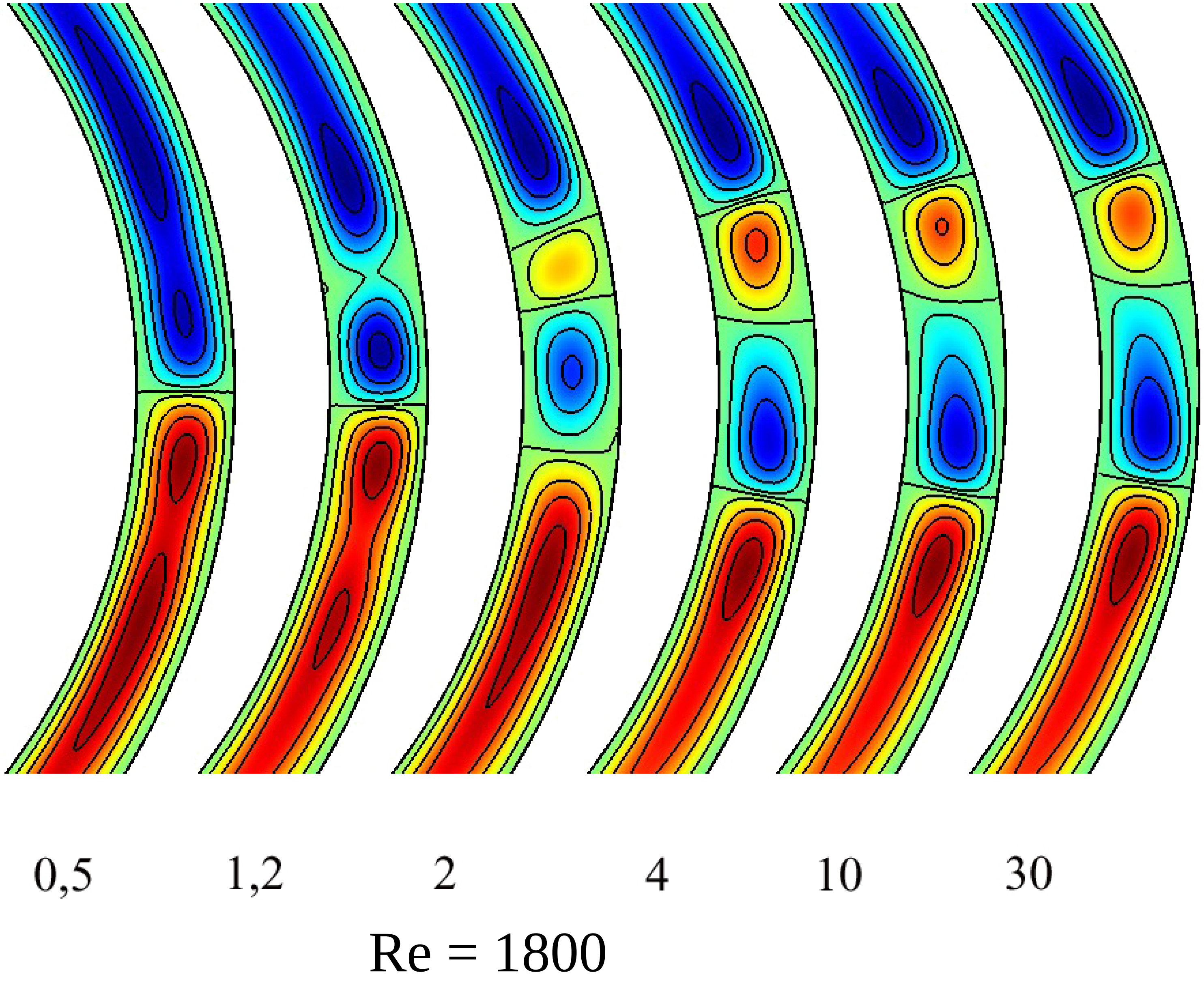


# Symmetric transition from rest into Mode IV

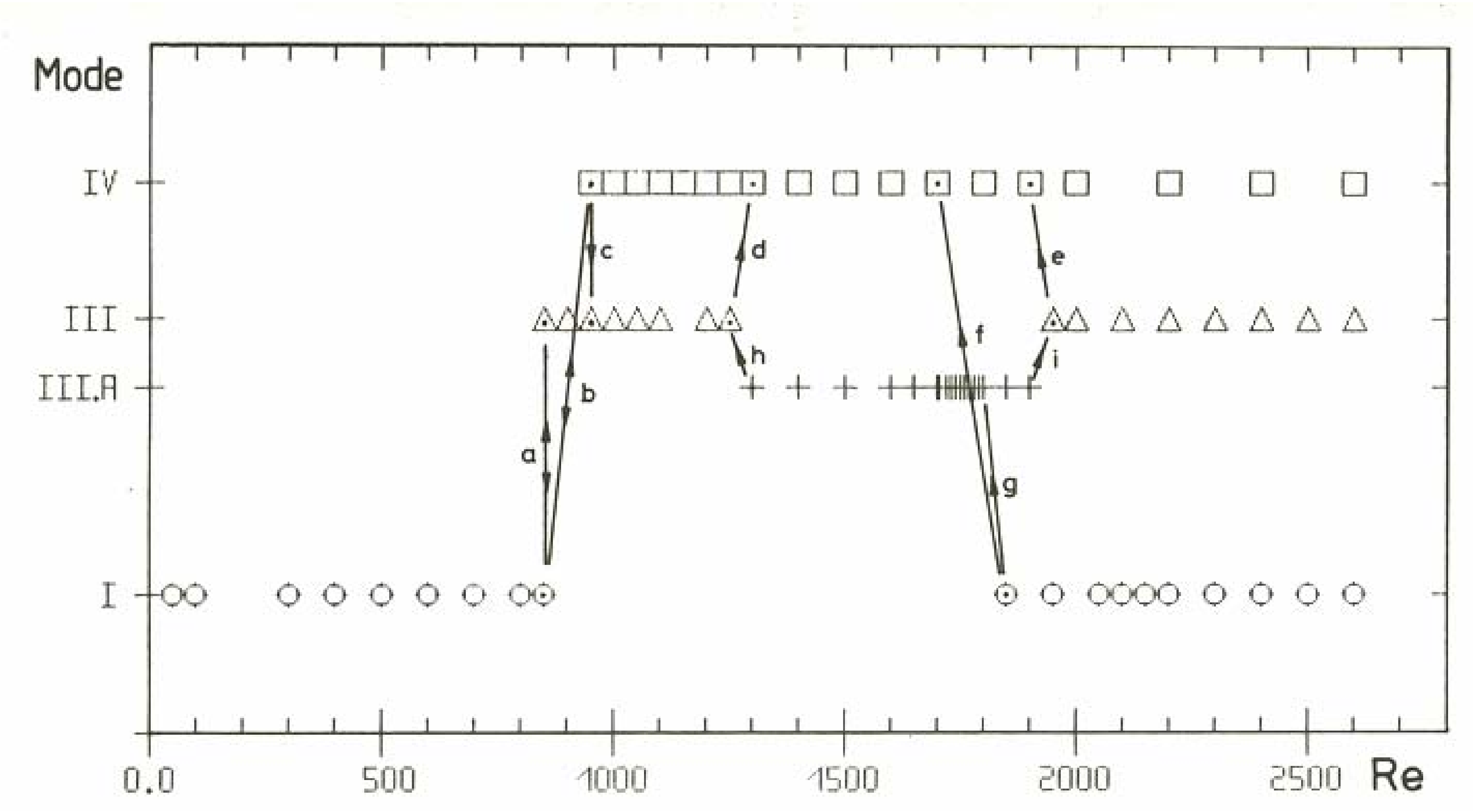



Re = 2600

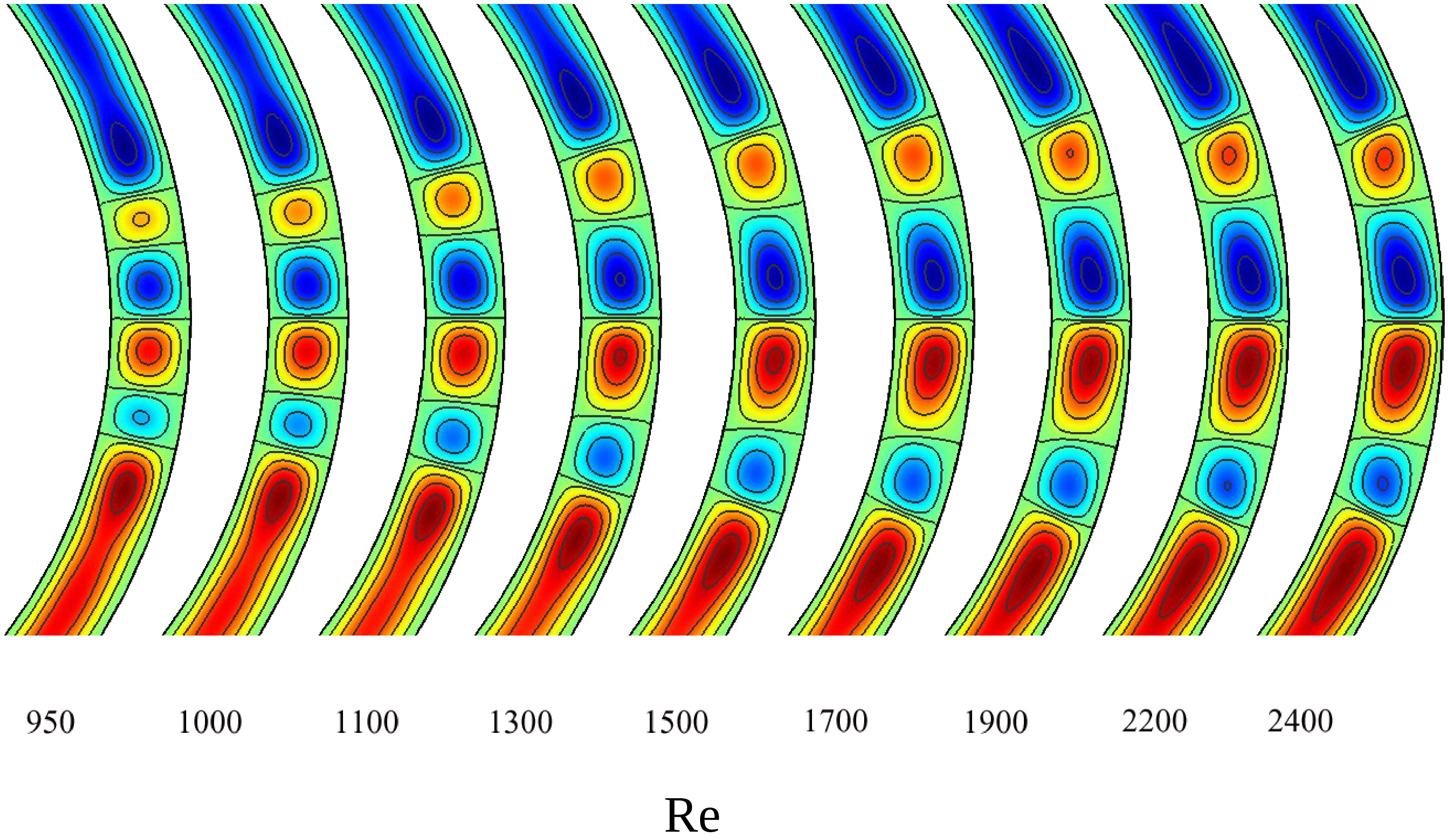
# Asymmetric transition from rest into Mode $III_A$



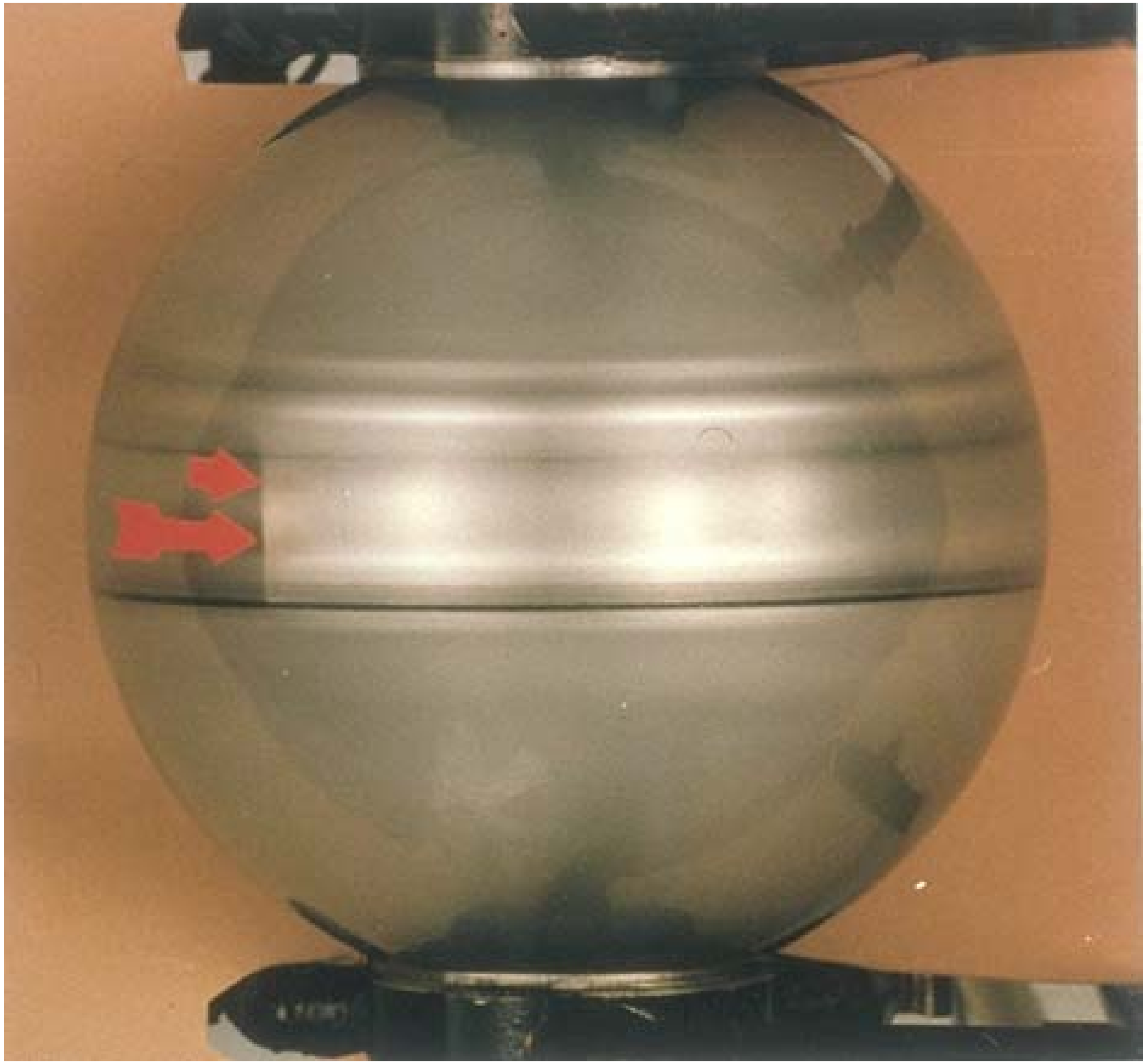
# Existence ranges and transitions

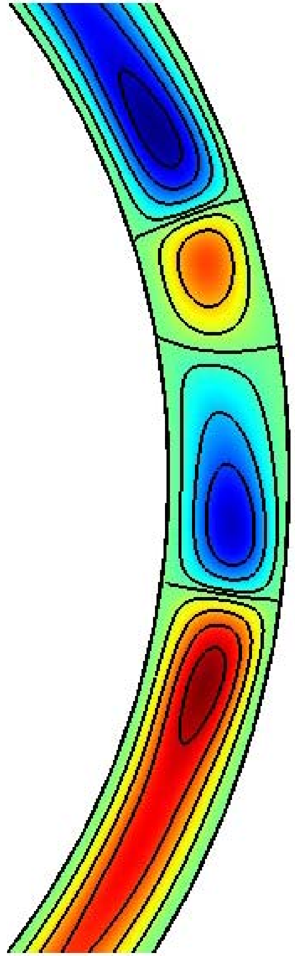


# Steady states of Mode IV at different Re numbers

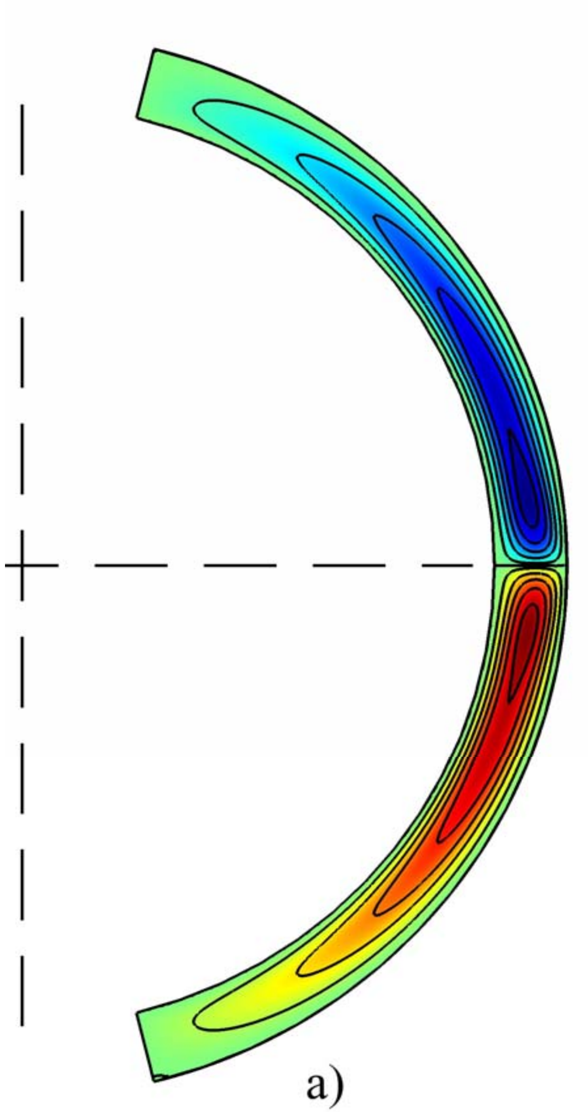


# Supercritical Mode $III_A$ at Re=1800

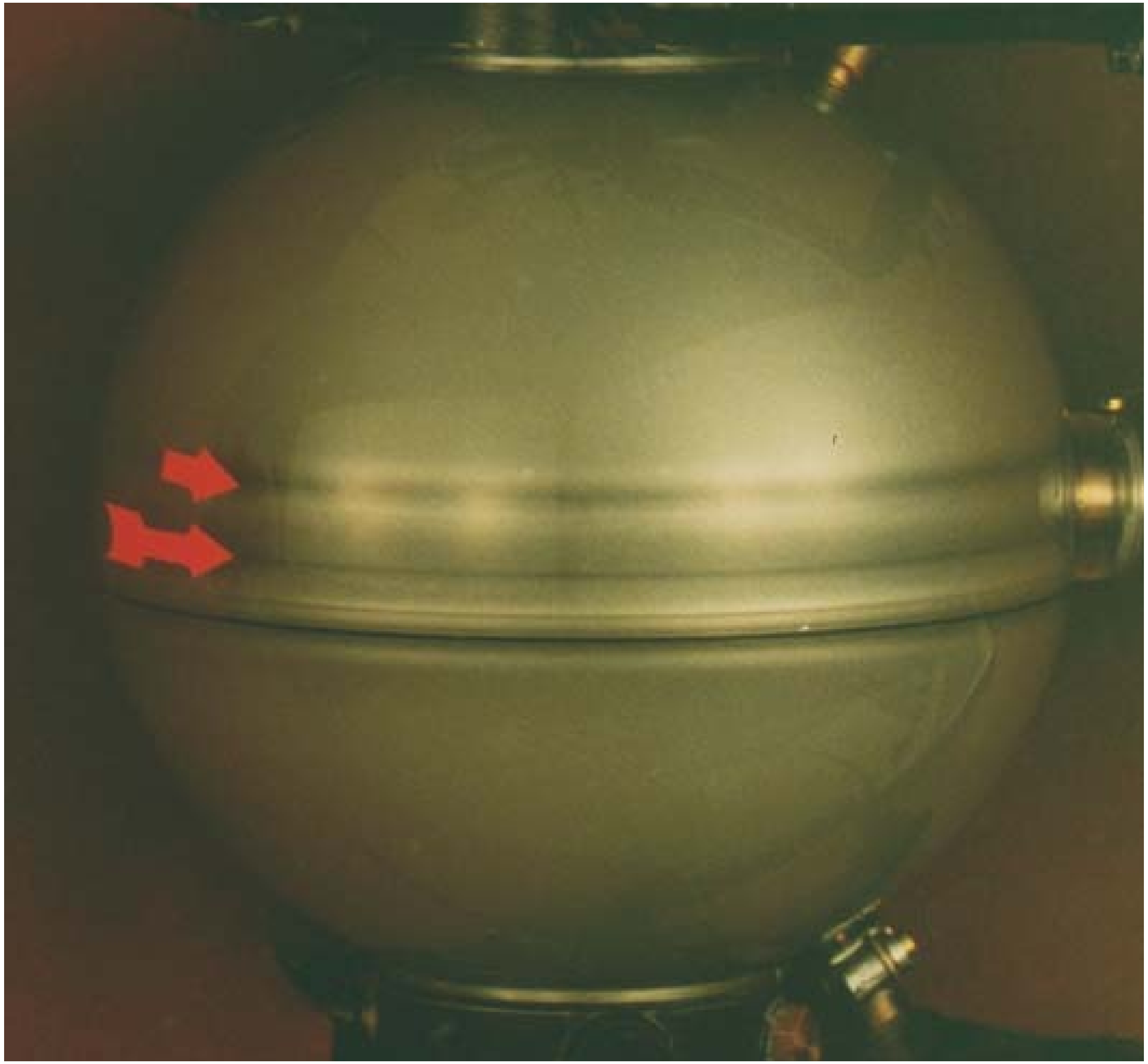


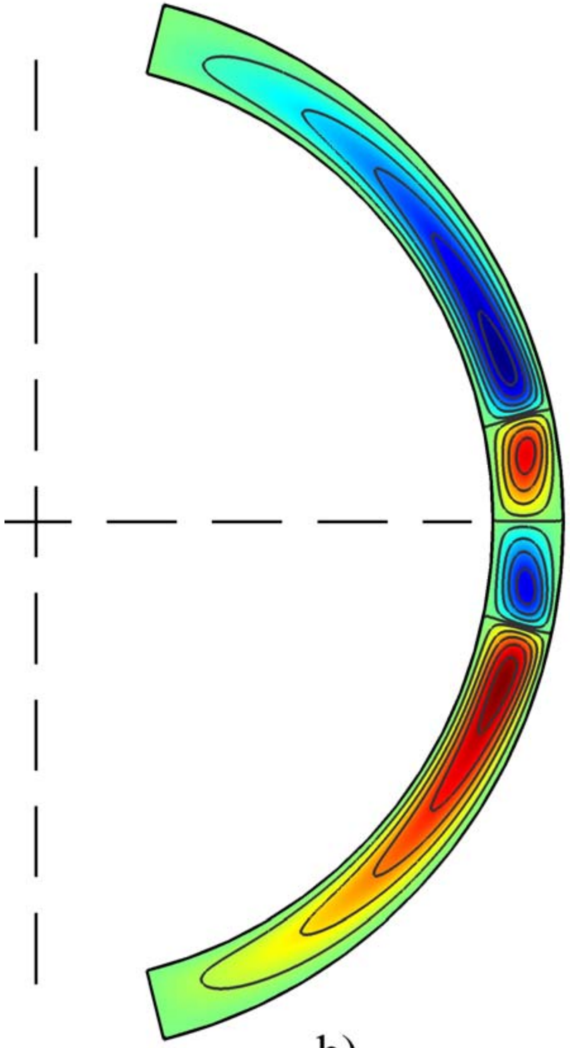


# Supercritical Mode I at Re=2600



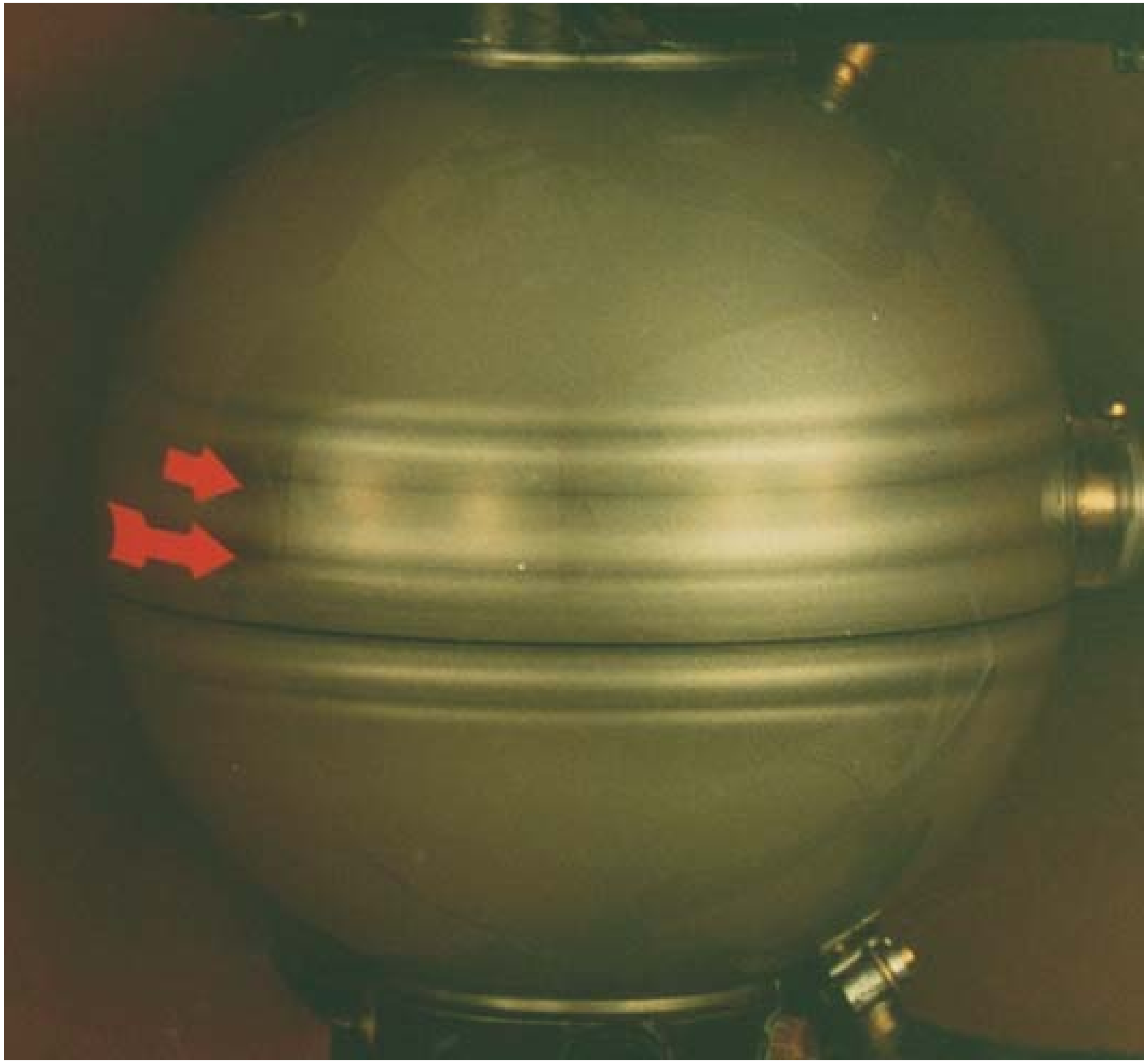
# Supercritical Mode III at  Re=2600

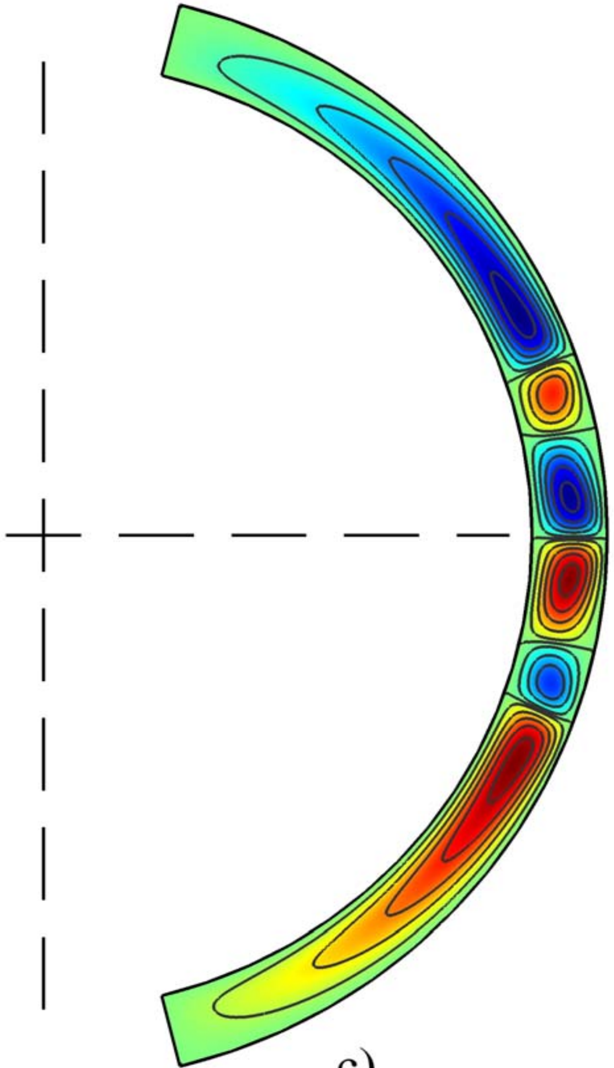




b)

# Supercritical Mode IV at  Re=2600





c)

# Conclusions

- Numerical simulation of spherical gap flows
- Influence of Reynolds number for constant spherical gap with
- Non-uniqueness of supercritical solutions
- Transitions between different modes
- Comparison with experiments
- Future directions

  - into time dependent regime

  - superimposed throughflow