CENTRIFUGAL INSTABILITY
in
ROTATING FLOW

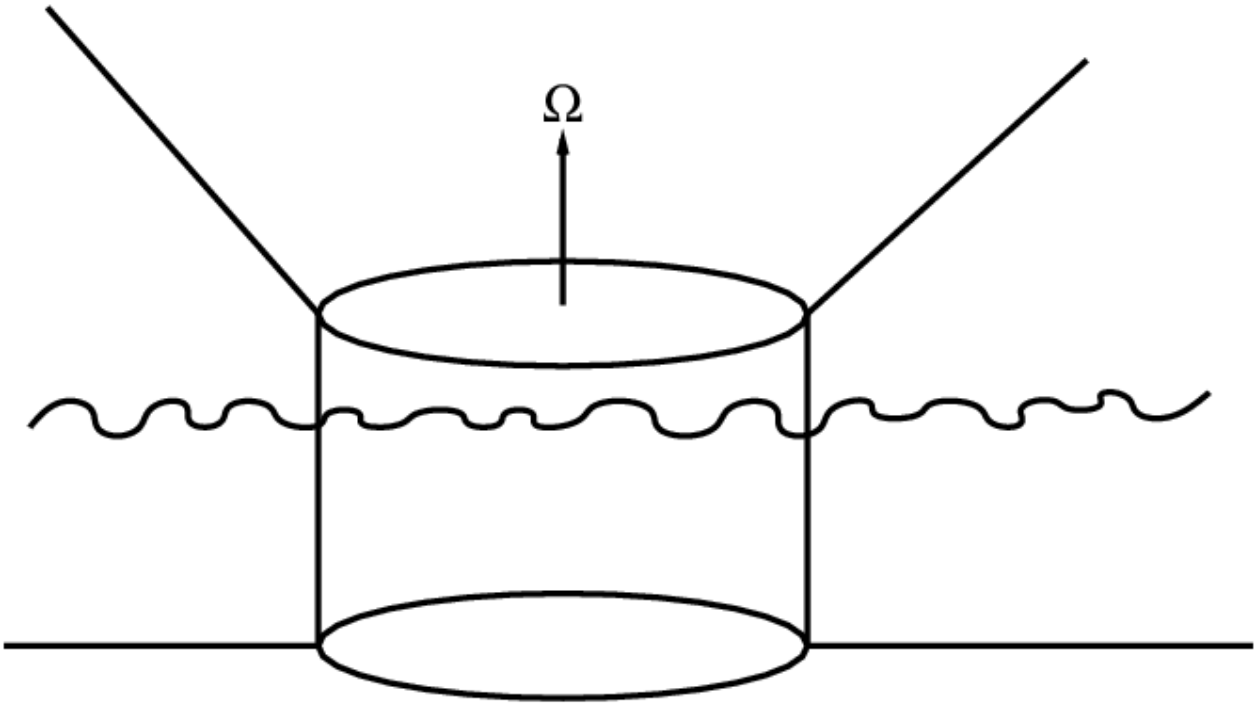
Carnevale

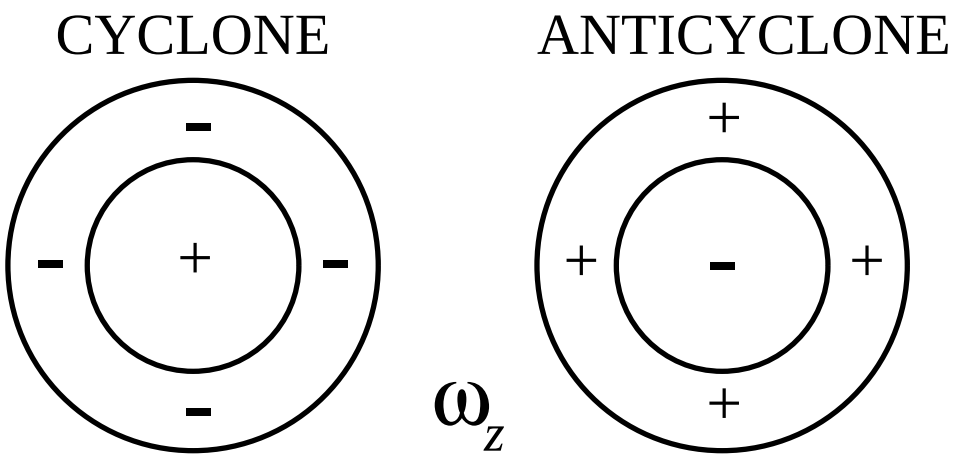
Kloosterziel

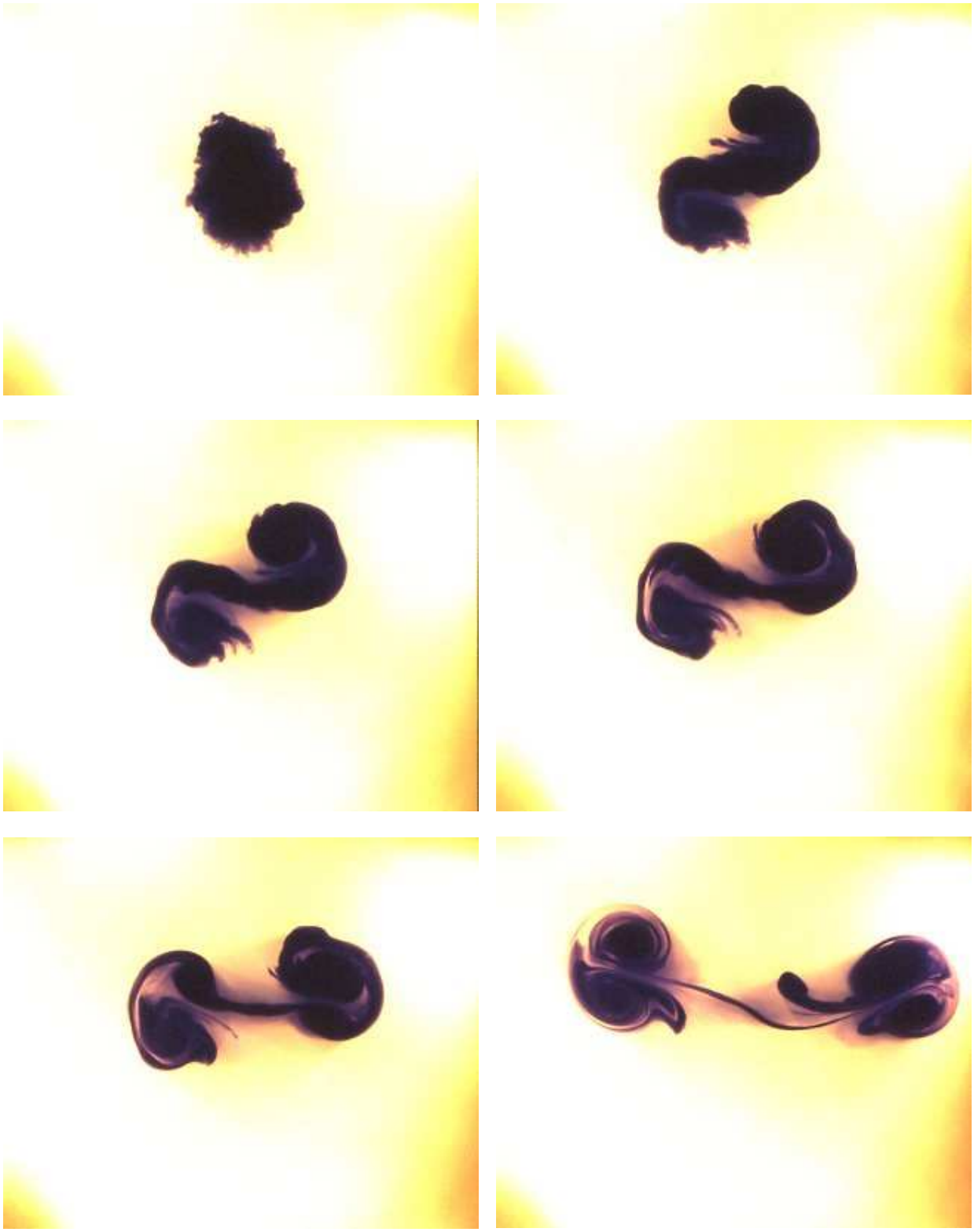
Orlandi

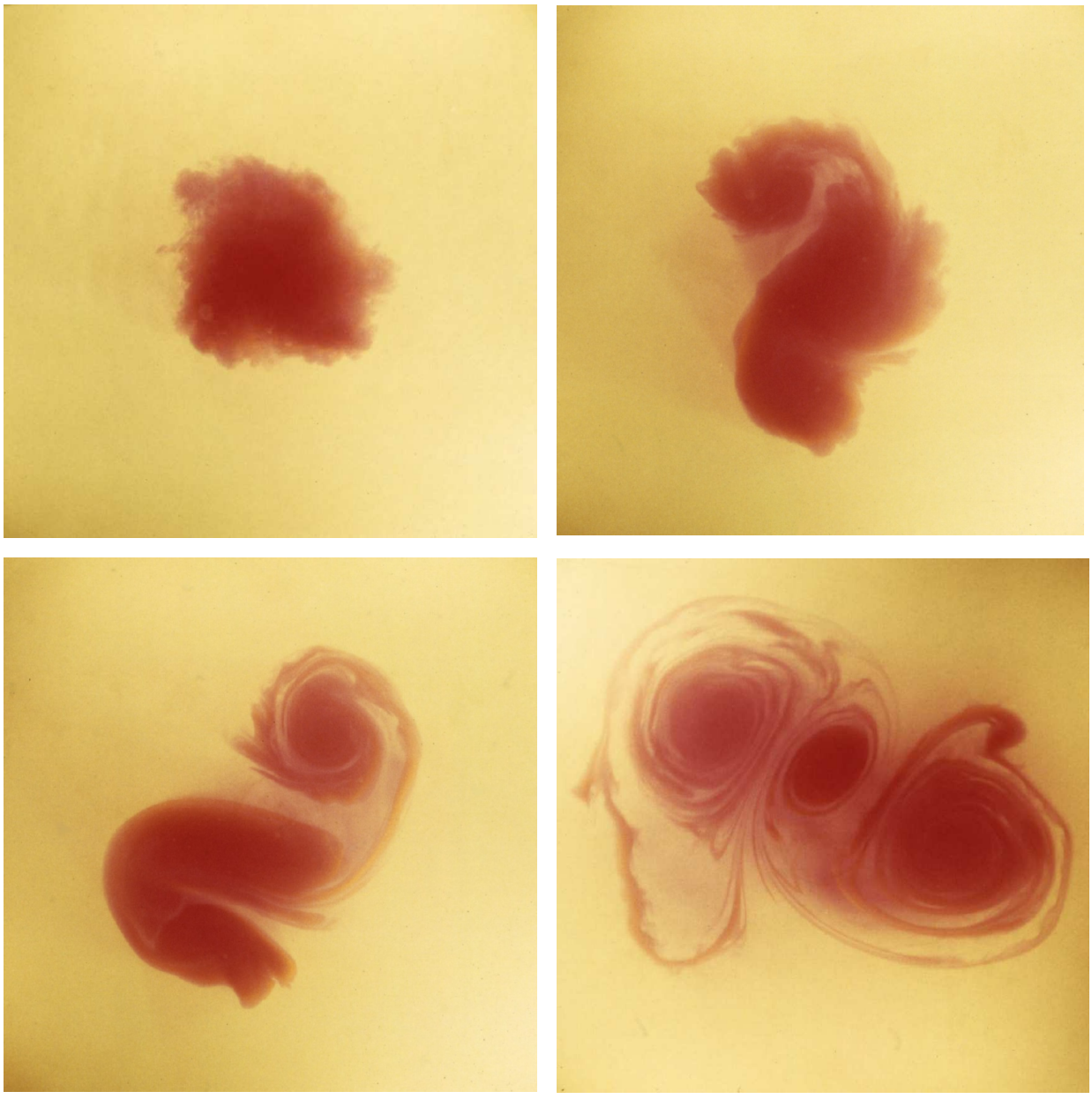
van Heijst

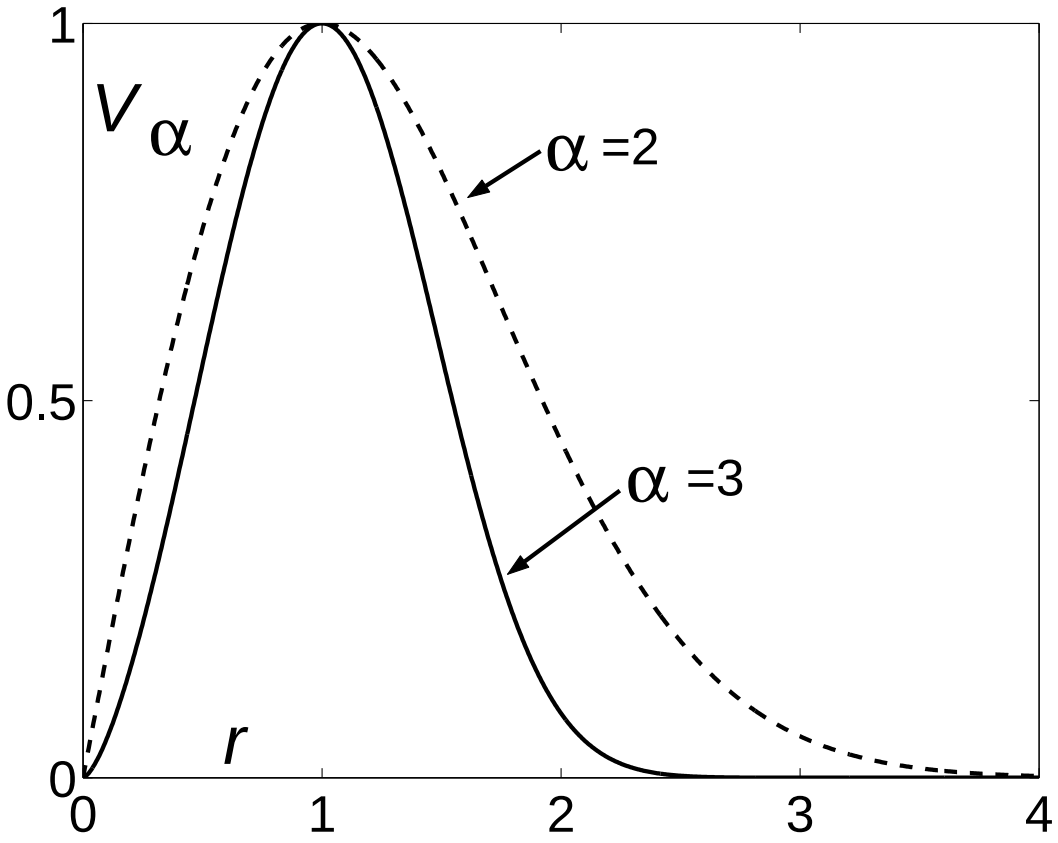
van Sommeren


Ω


CYCLONE
ANTICYCLONE
-
-
+
-
-
+
-
+
+
+
ω_z





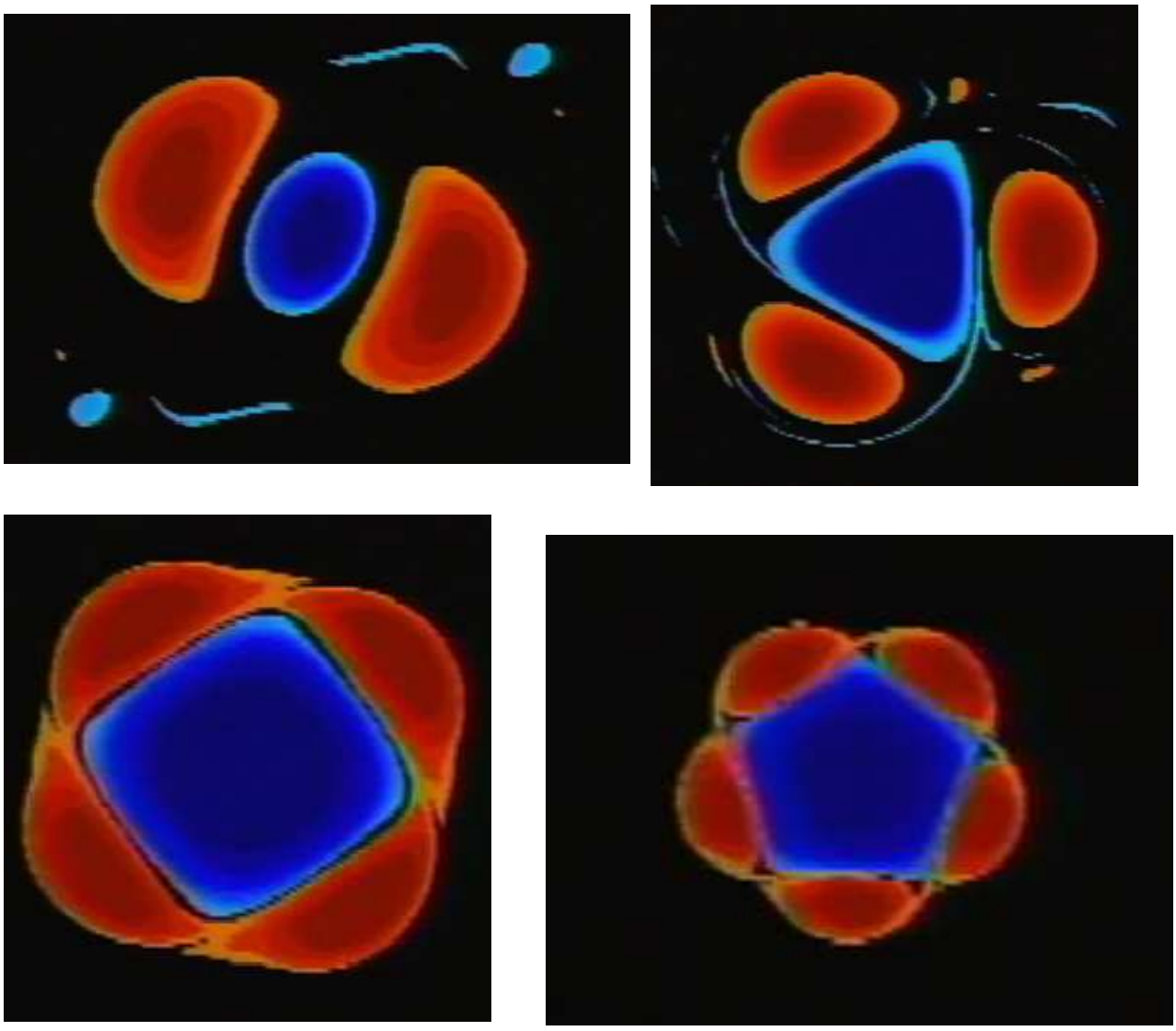


Model Profile

$$V(r) = U\mathbf{V}_\alpha(\mathbf{r}/\mathbf{L})$$

$$Ro = U/fL \qquad Re = UL/\nu$$

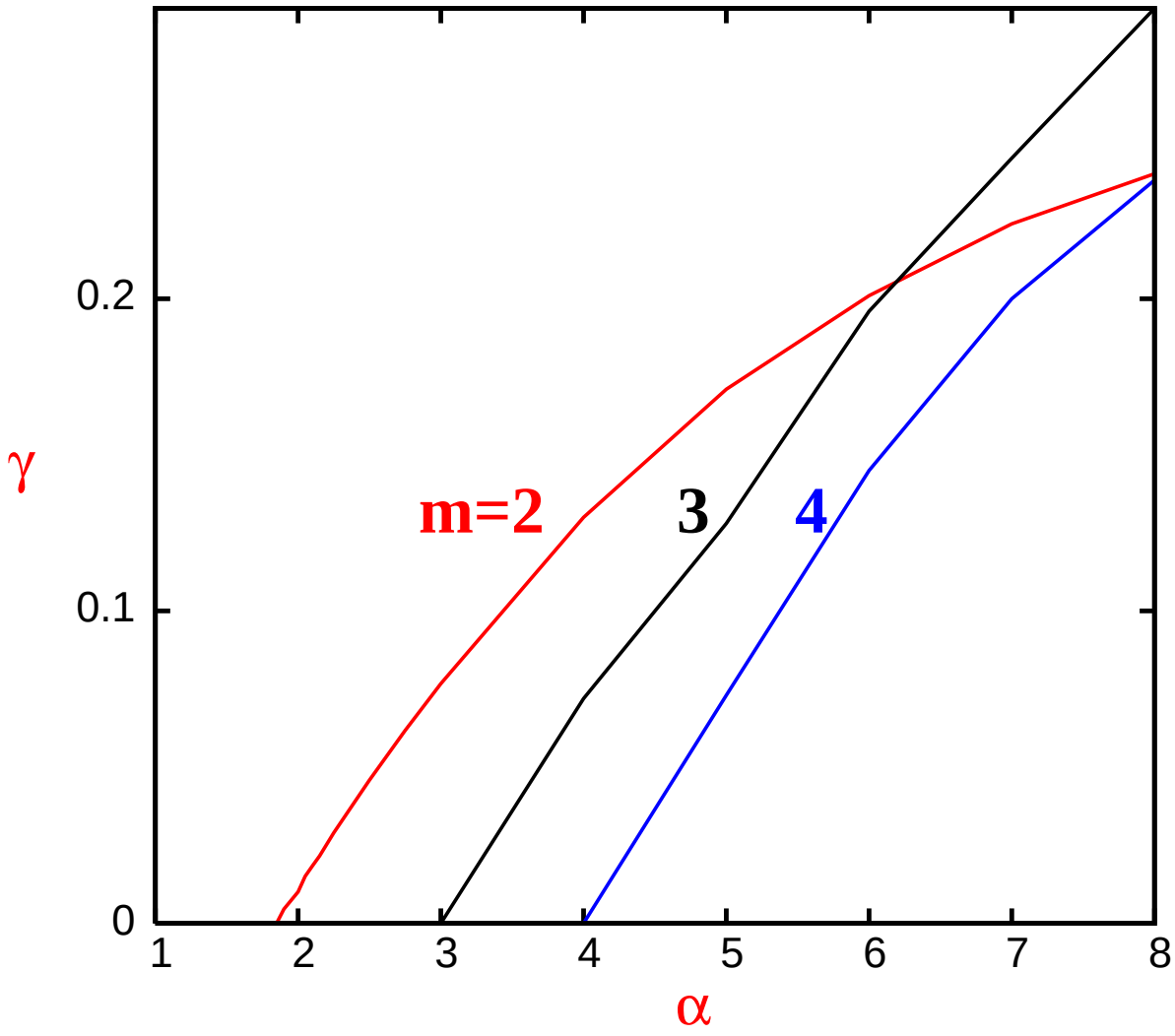
BAROTROPIC INSTABILITY



$$\omega_z{}' \propto [A\cos(m\theta) + B\sin(m\theta)]$$

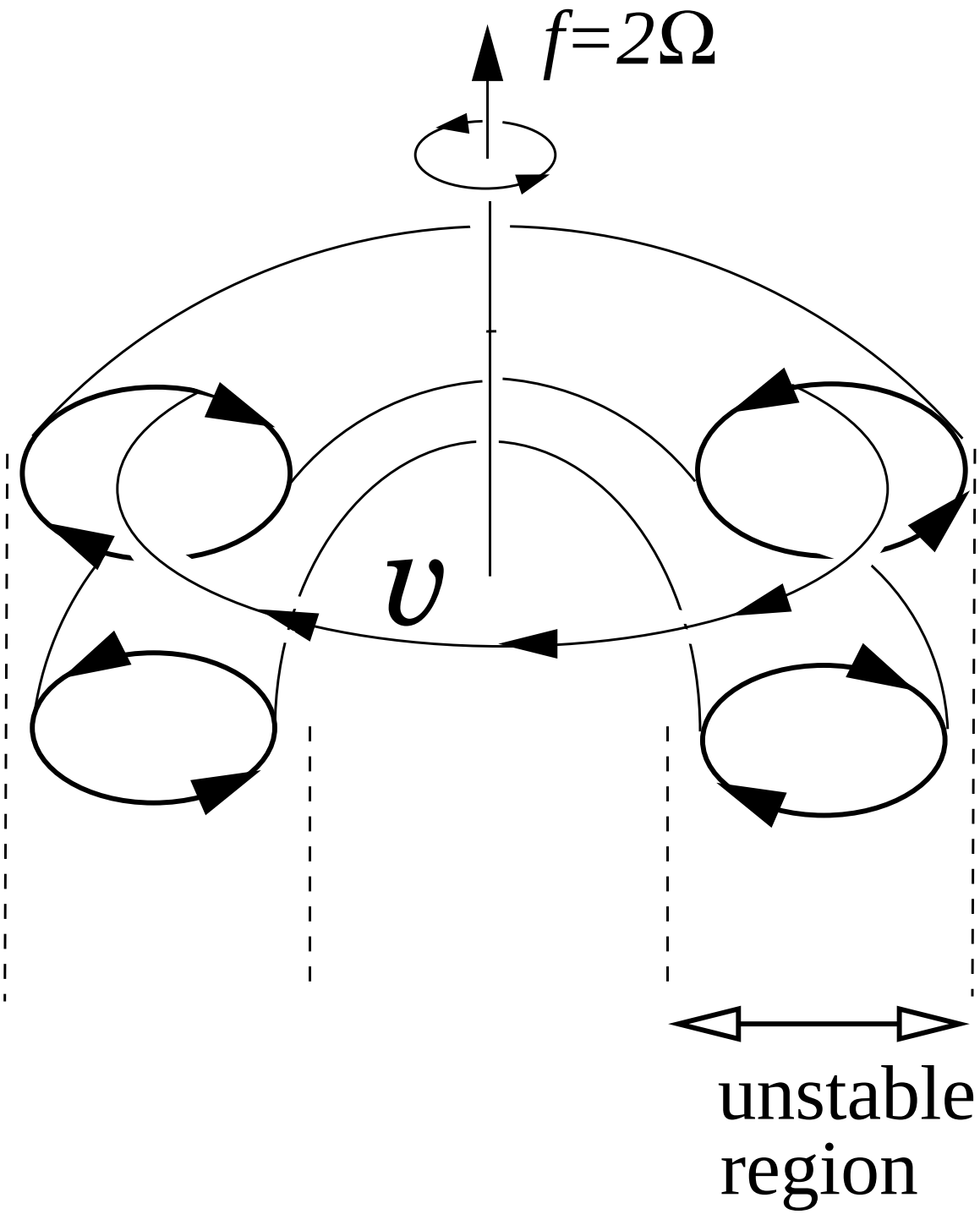
Barotropic Instability Growth Rates

$\mathbf{Re} \to \infty$

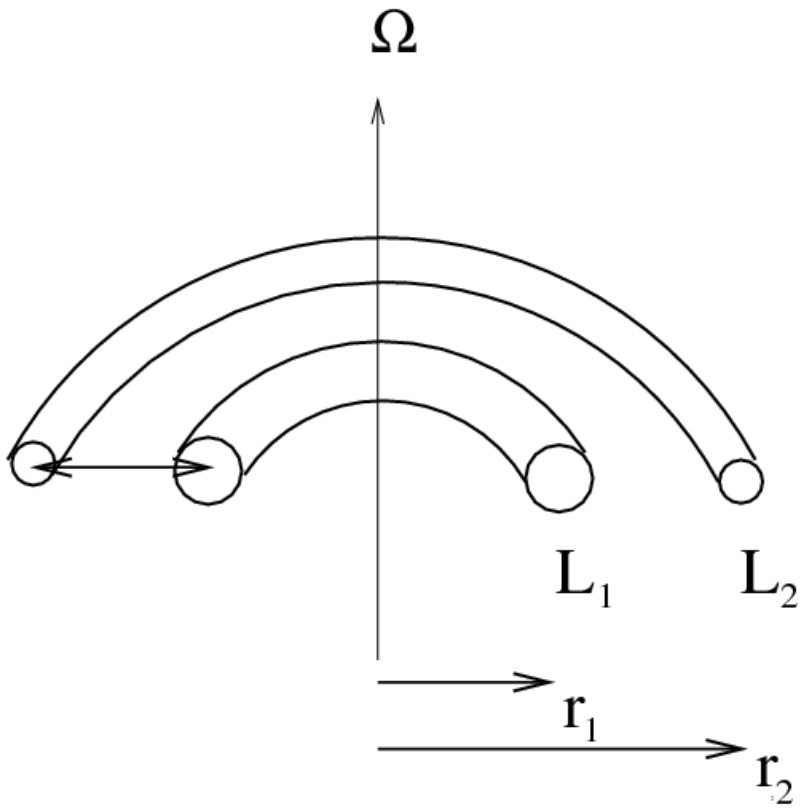


$\alpha \lesssim 1.8$ **STABLE**

CENTRIFUGAL INSTABILITY



Rayleigh: Axisymmetric Flow

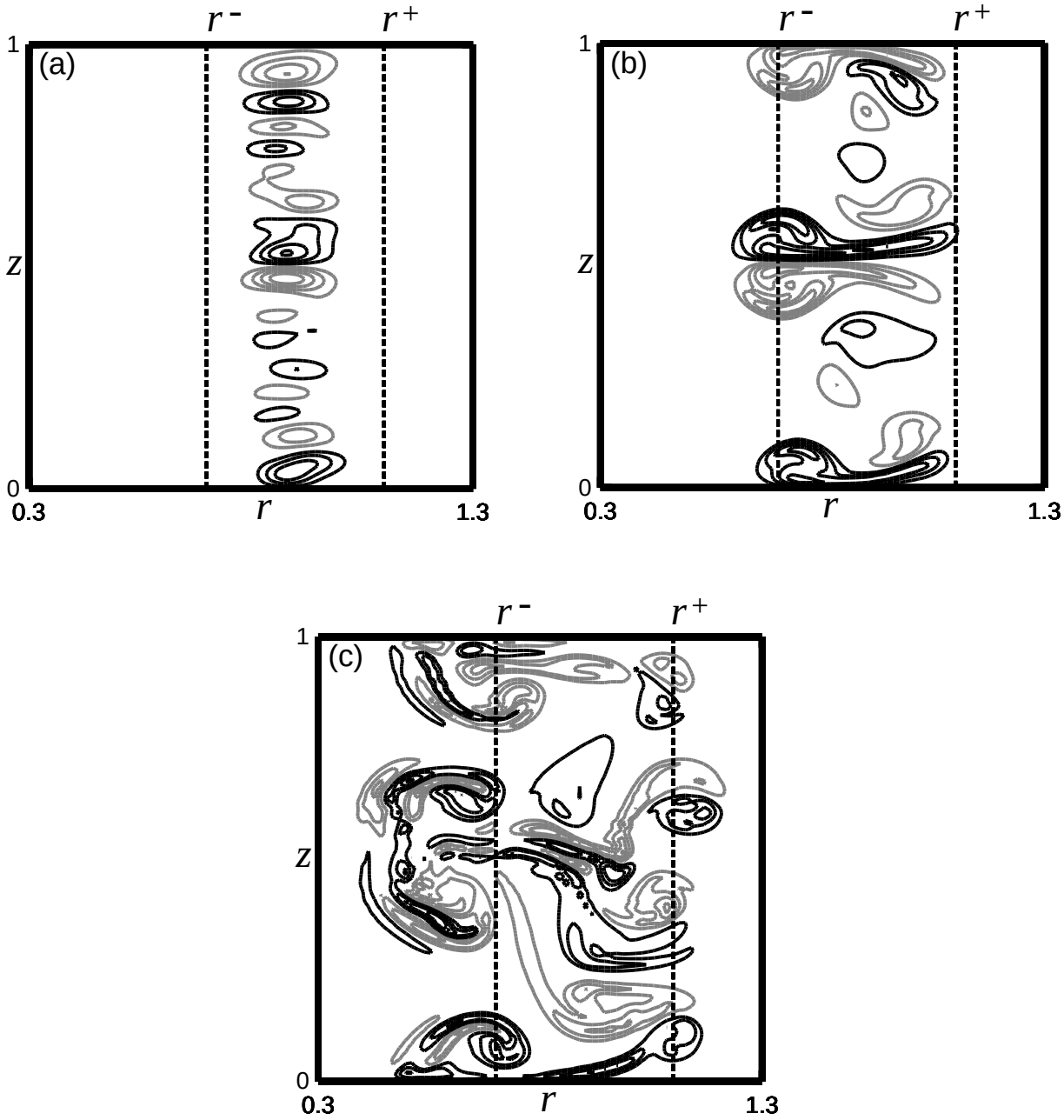


$$\text{Instability} \Leftrightarrow \frac{dL^2}{dr} = 2LL_r < 0$$

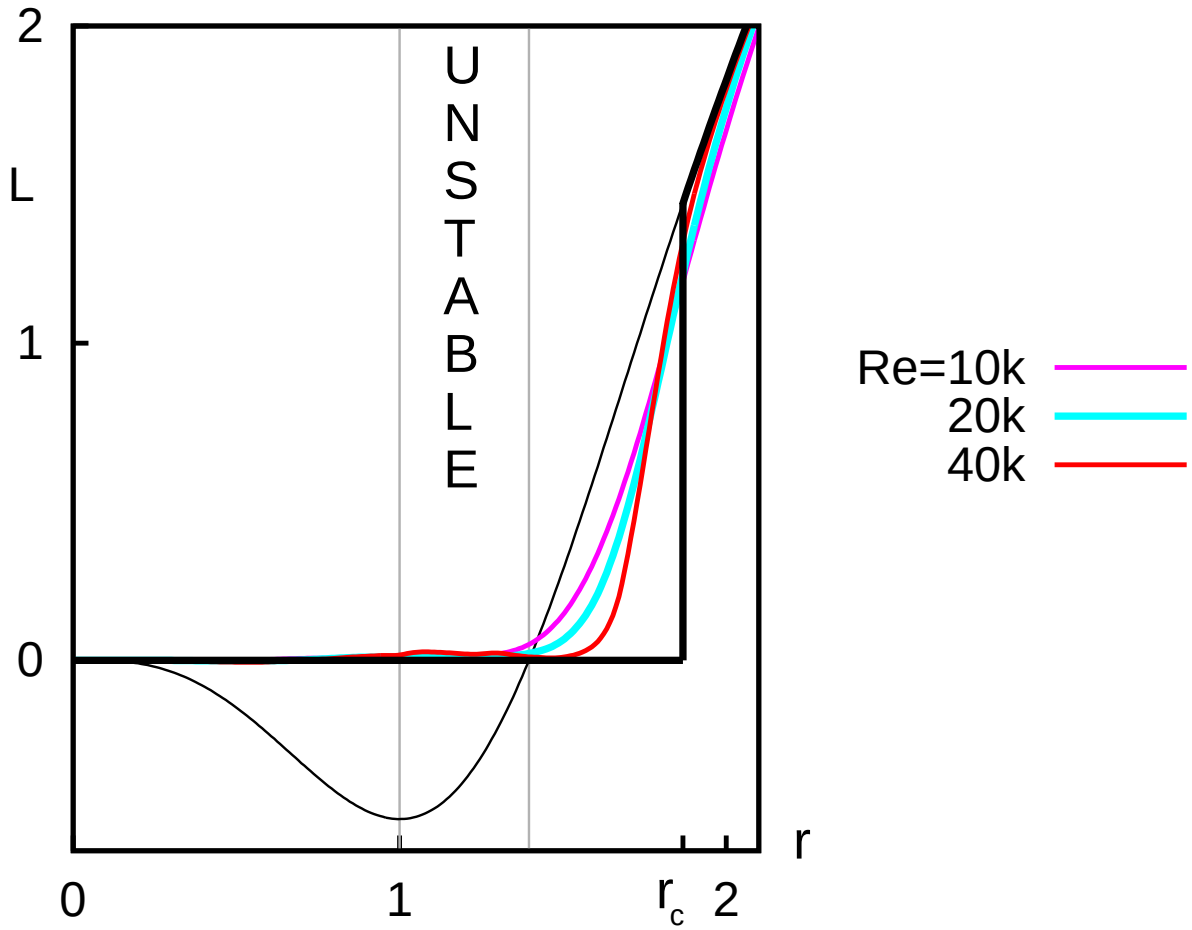
$L = r(v + \Omega r)$ **Abs. ang. momentum**

Axisymmetric Simulation
Ro=-4

ω_θ



ANTICYCLONE $\mathbf{Re \to \infty}$



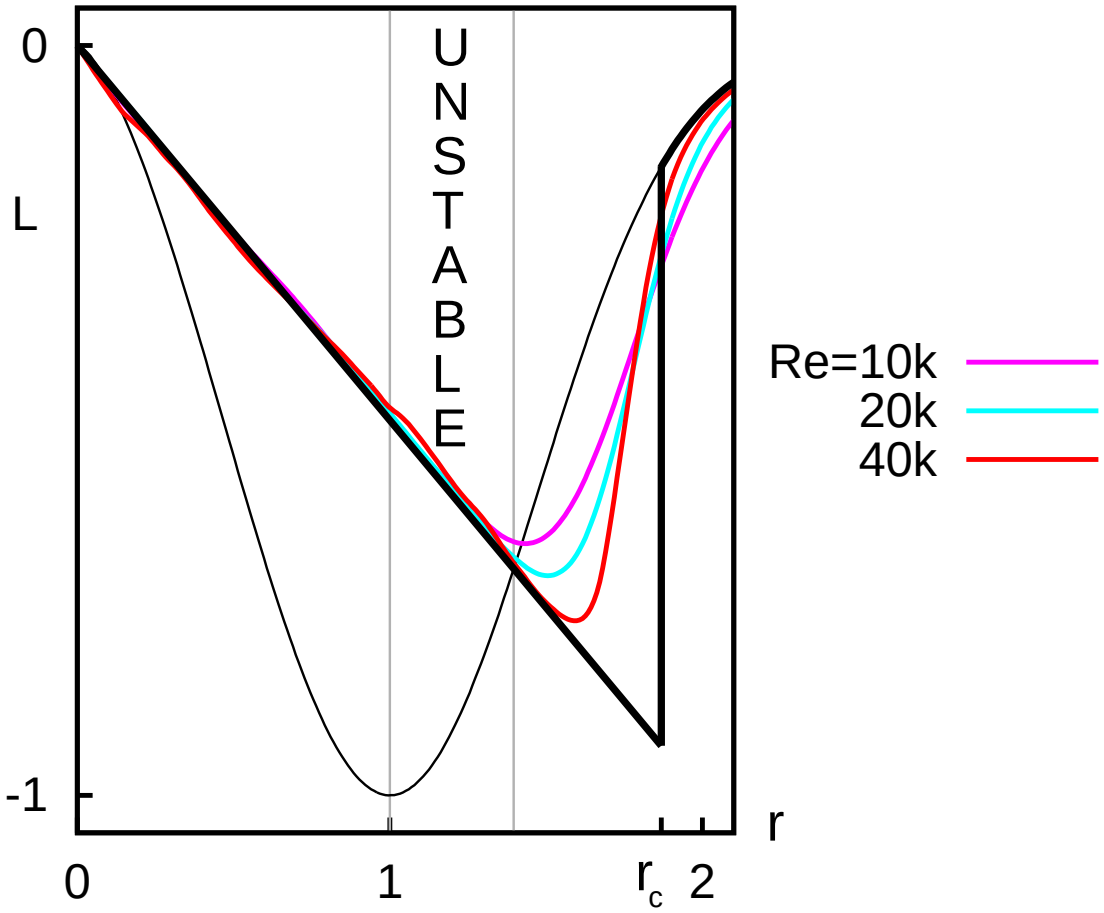
$$\int_0^{r_c} L_0(r) r dr = 0$$

$$L_0(r) = r(V(r) + \Omega r)$$

new $L(r) = 0 \qquad 0 < r < r_c$

$= L_0(r) \qquad r_c < r$

ANTICYCLONE $\mathbf{Re \to \infty}$



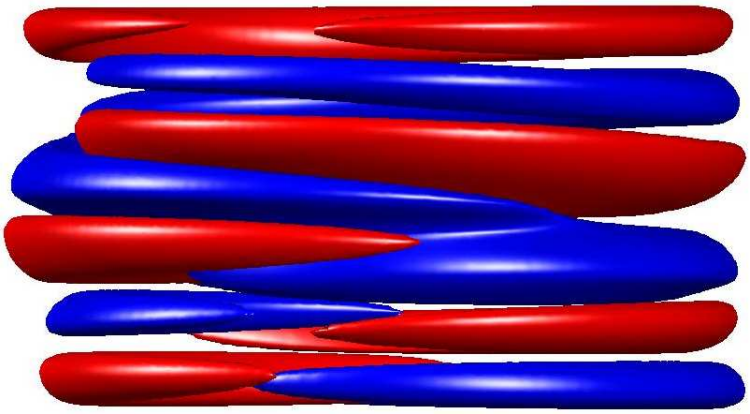
$$\mathbf{v(r) = -\Omega r} \qquad \textbf{for } \mathbf{0 < r < r_c}$$

$$\mathbf{v(r) = V_\alpha(r)} \qquad \textbf{for } \mathbf{r > r_c}$$

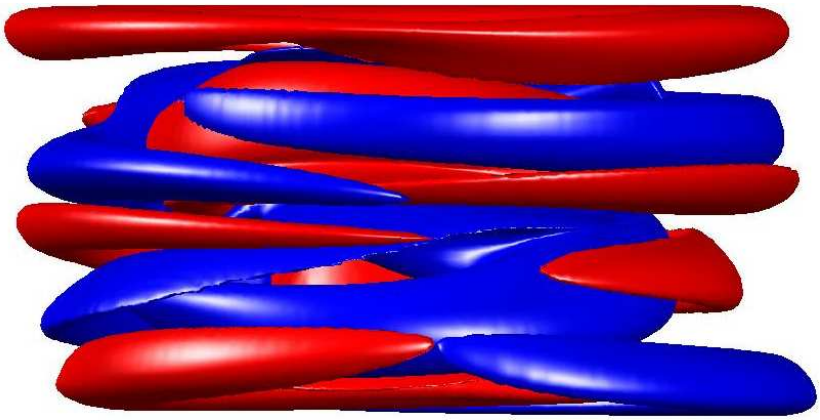
3D SIMULATION

ω_θ

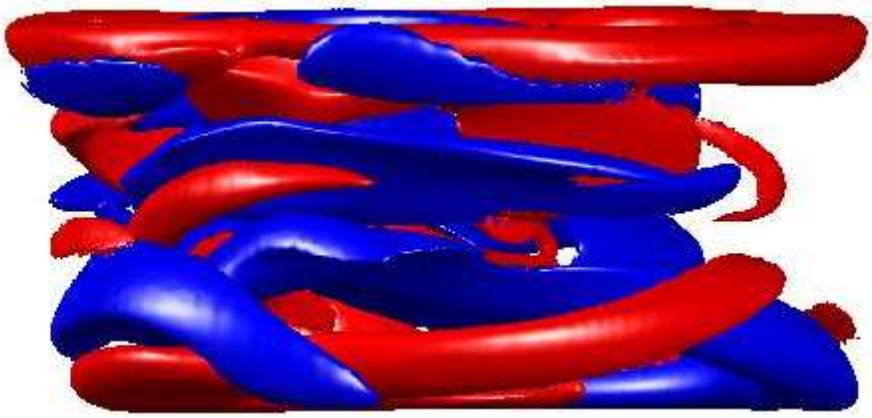
t = 40



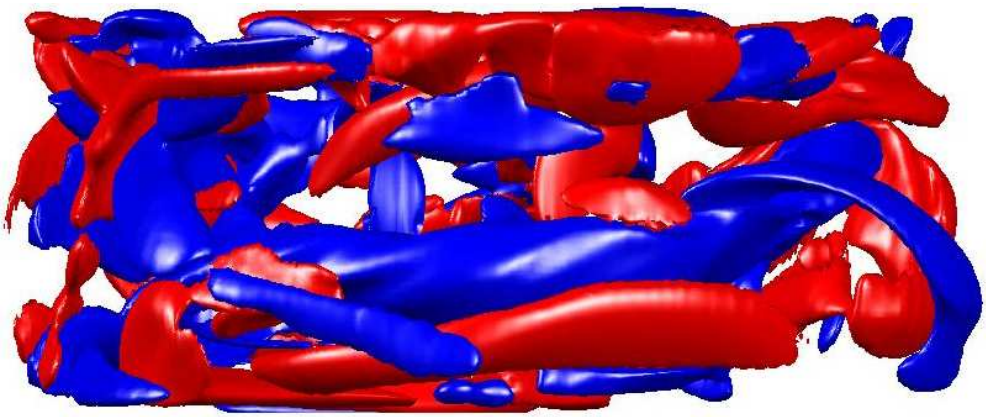
t = 50



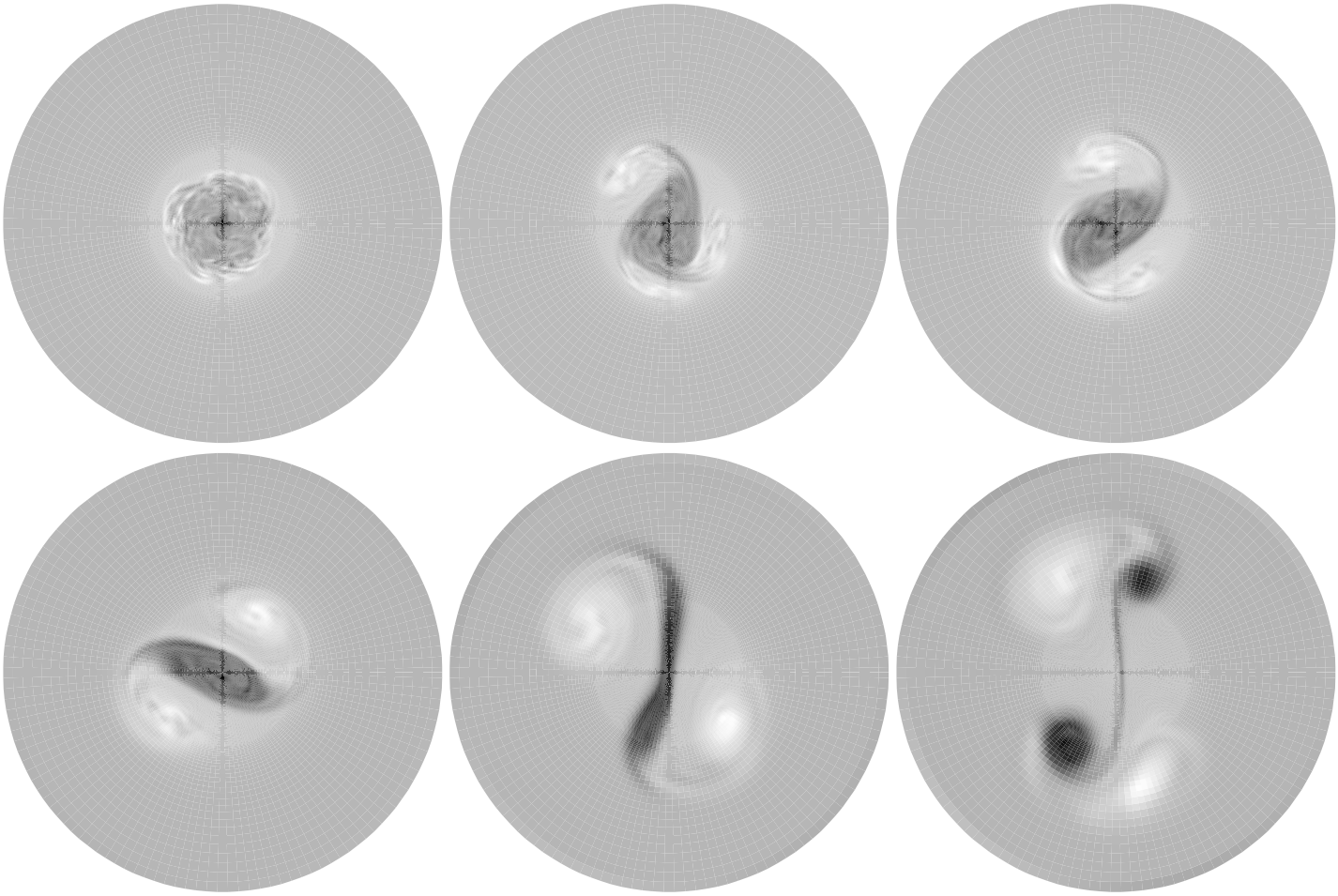
t = 60



t = 80

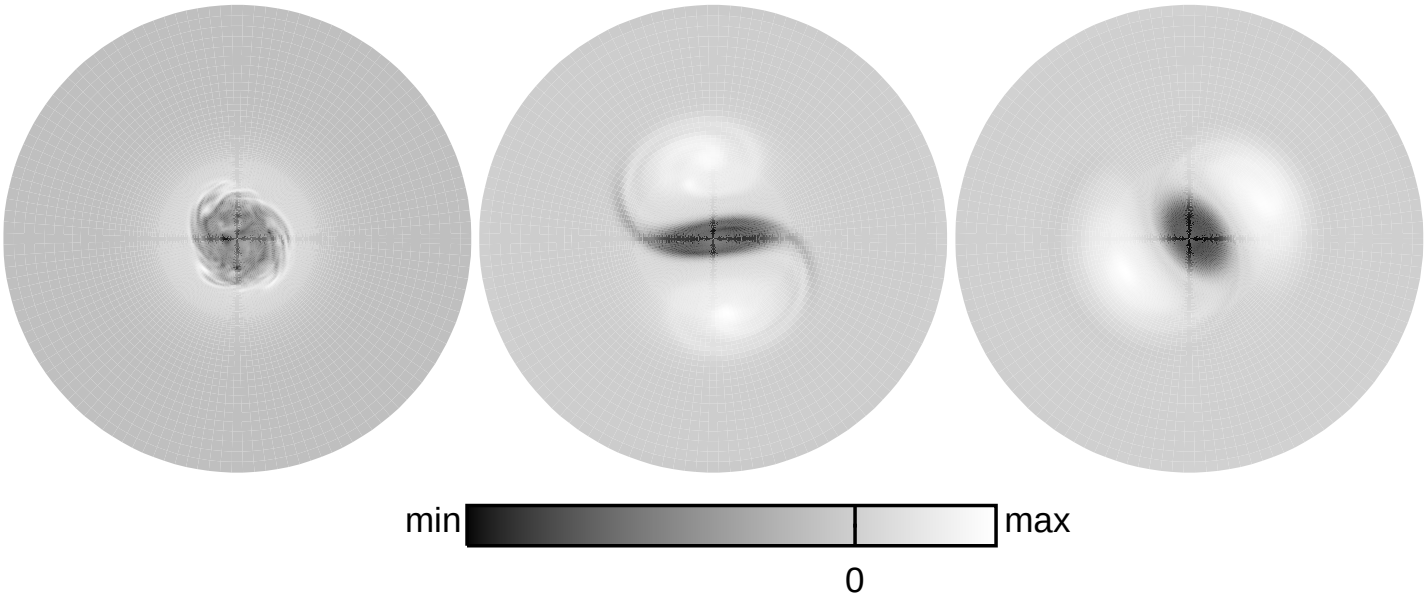


3D Simulation ω_z



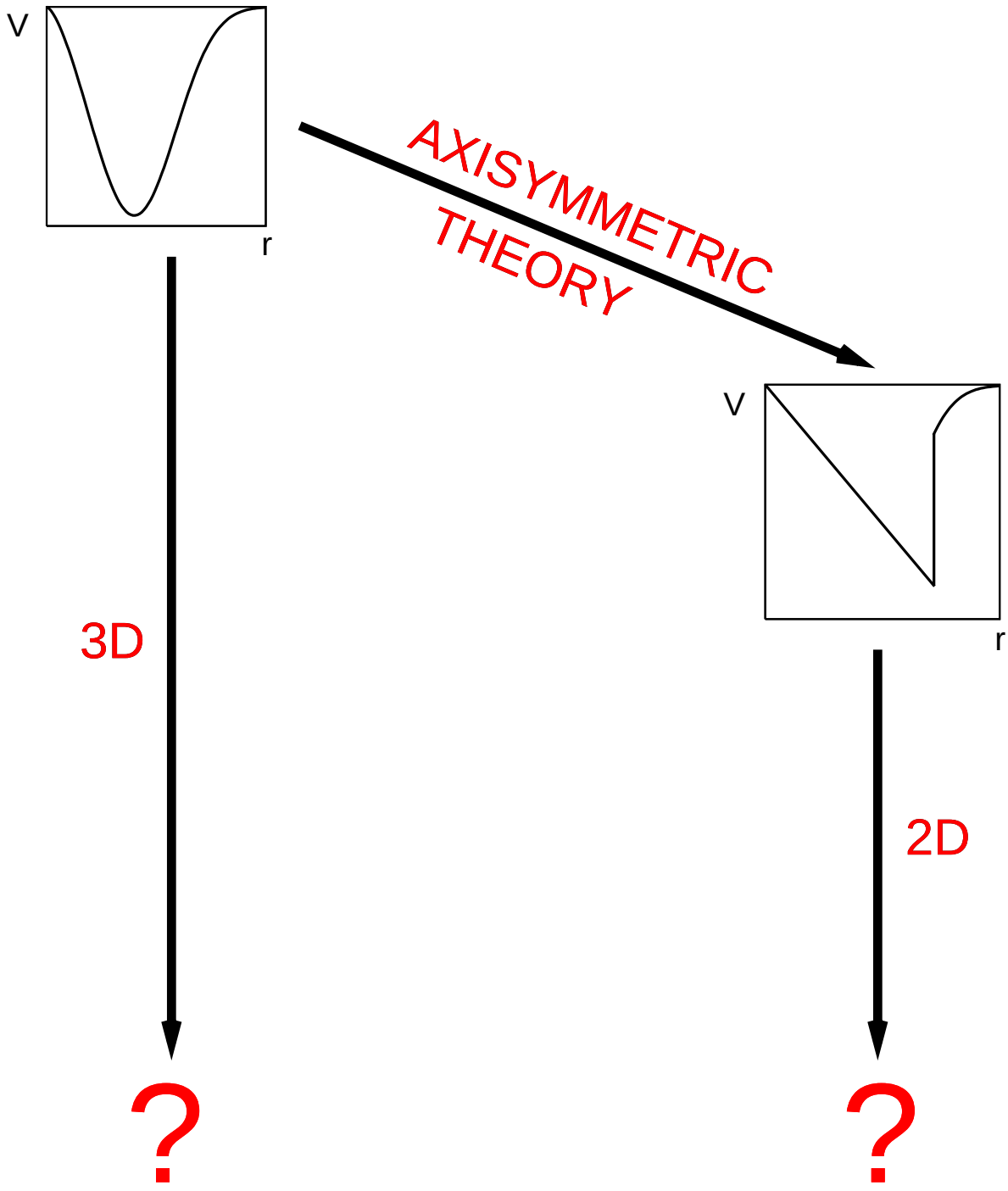
α=1.8 Ro=-3 Re=15k

3D Simulation ω_z



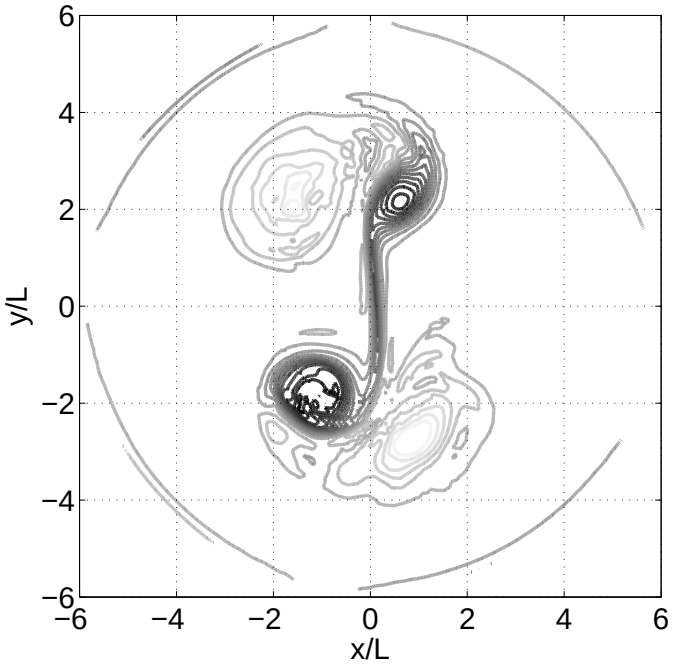
α=1.8 Ro=-2.35 Re=15k

FULL 3D vs. PREDICTION

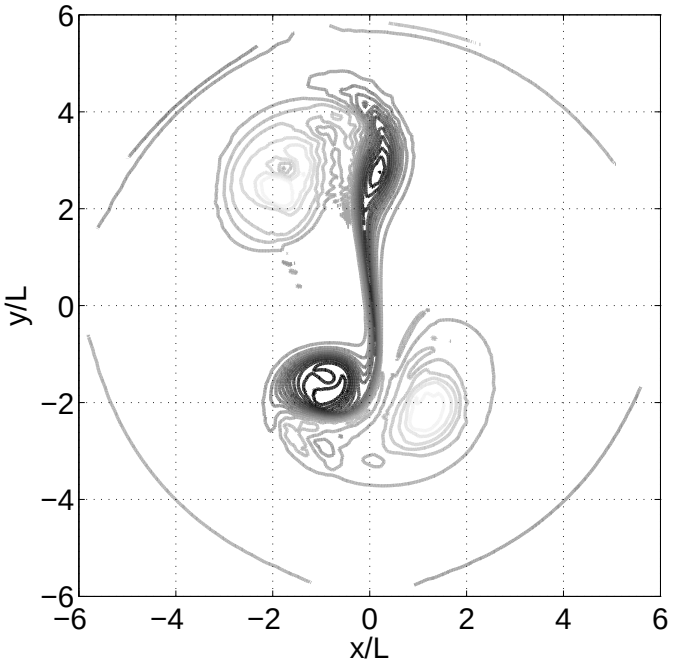


α=1.8 Ro=-3 Re = 15k

3D SIMULATION

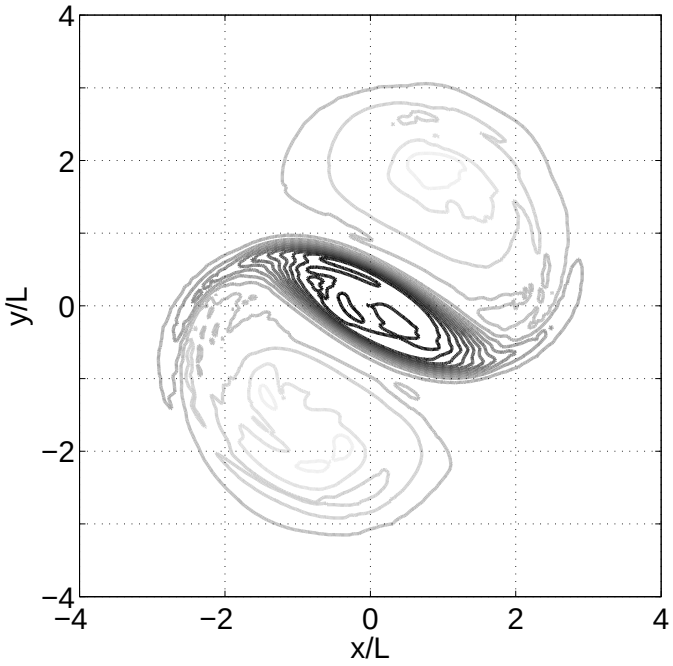


PREDICTION

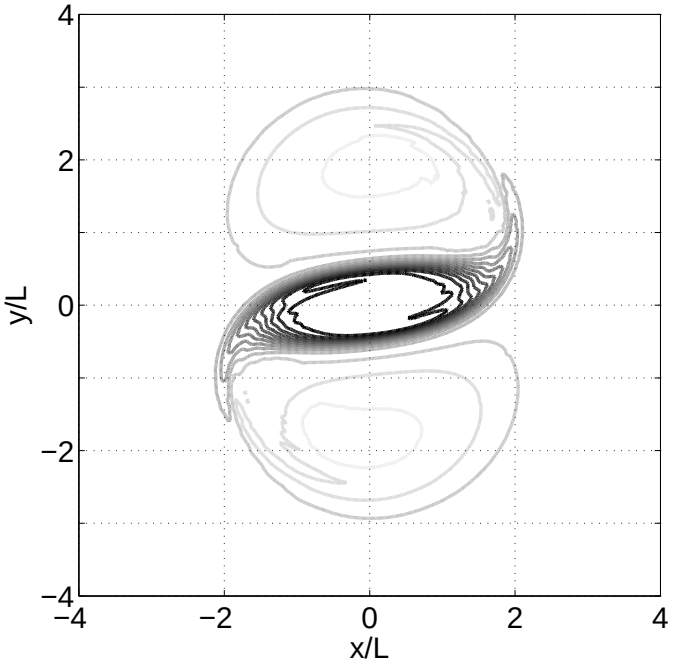


α=1.8 Ro=-2.3 Re=15k

3D SIMULATION



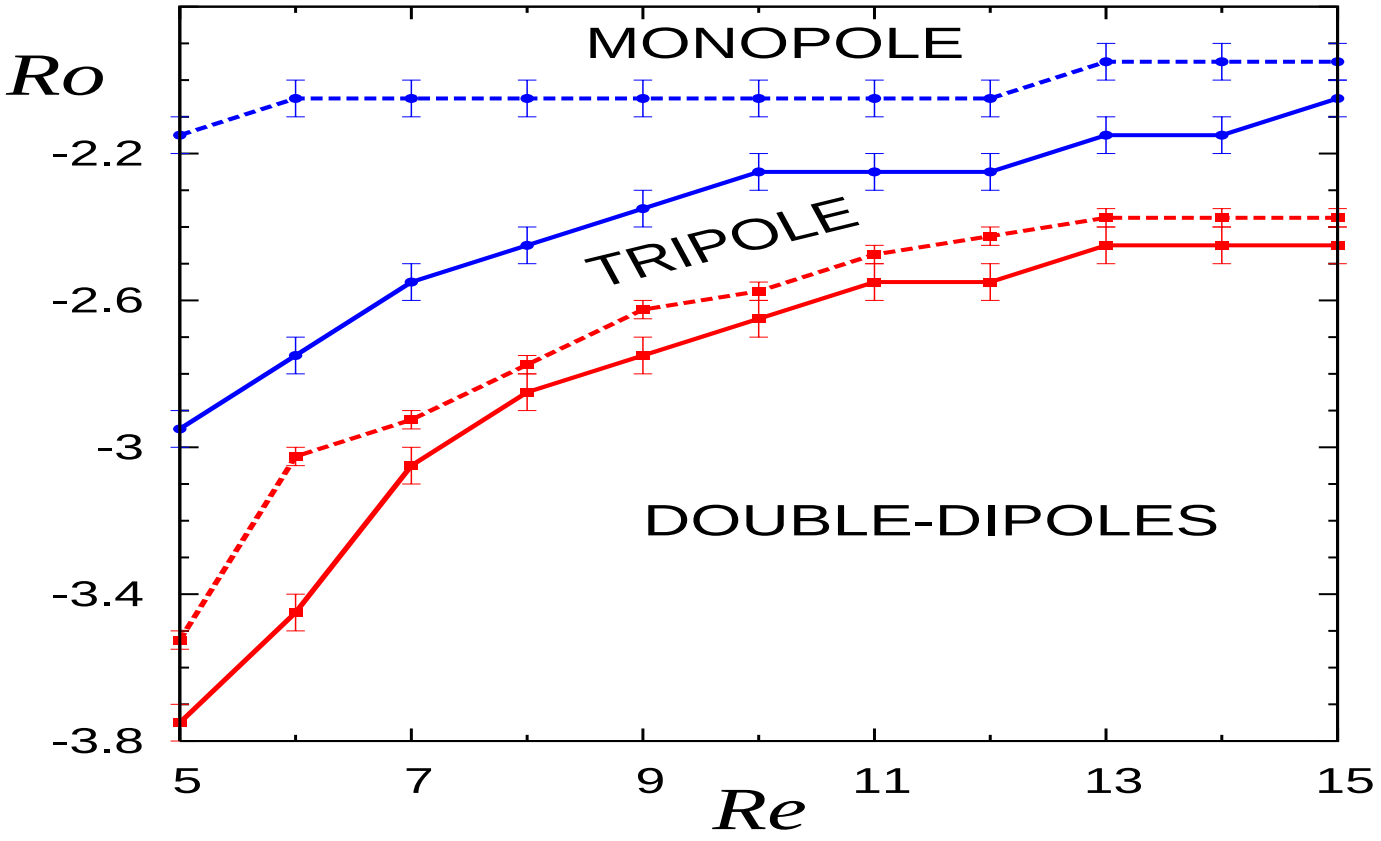
PREDICTION



REGIME BOUNDARIES

α=1.8

Barotropic Growth Rate = 0



REGIME BOUNDARIES

$\mathbf{Re = 15k}$

for $\alpha \approx 3$

Barotropic Inst. Growth Rate

$\approx$ Centrifugal Inst. Growth Rate