

# Magnetische Strömungskontrolle in elektrolytischen Flüssigkeiten

Tom Weier

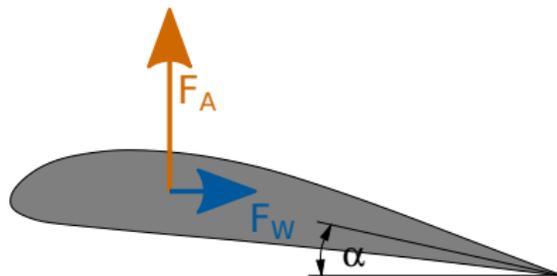
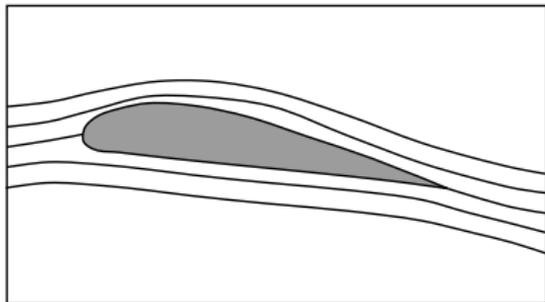
17. Februar 2012

**hzdr**

 HELMHOLTZ  
ZENTRUM DRESDEN  
ROSSENDORF



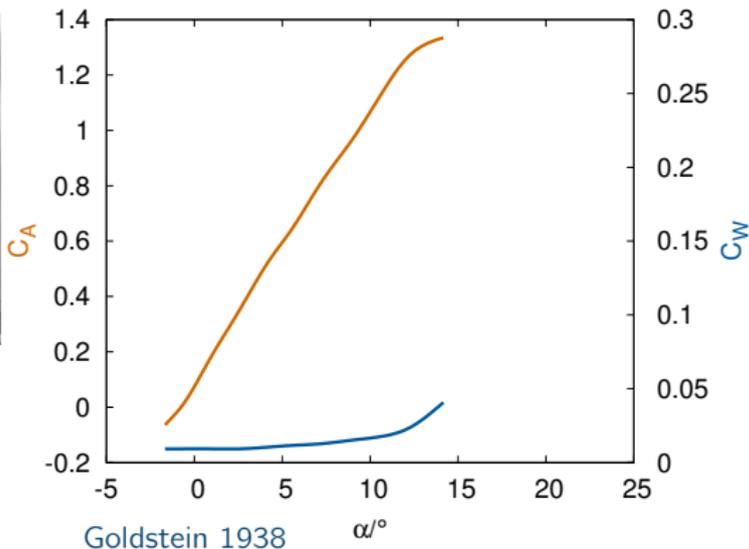
# Einleitung: Auftrieb und Strömungszustand



DLR 1937

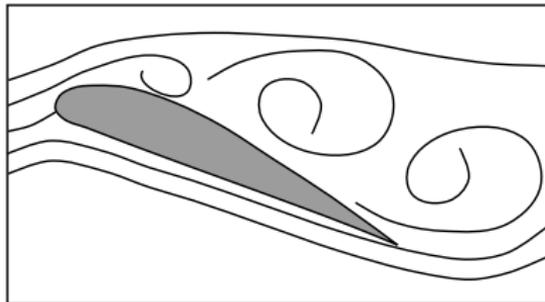
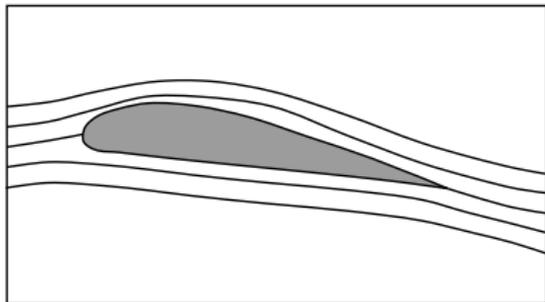
1909

$$C_A = \frac{F_A}{\frac{\rho}{2} U^2 c_s}$$



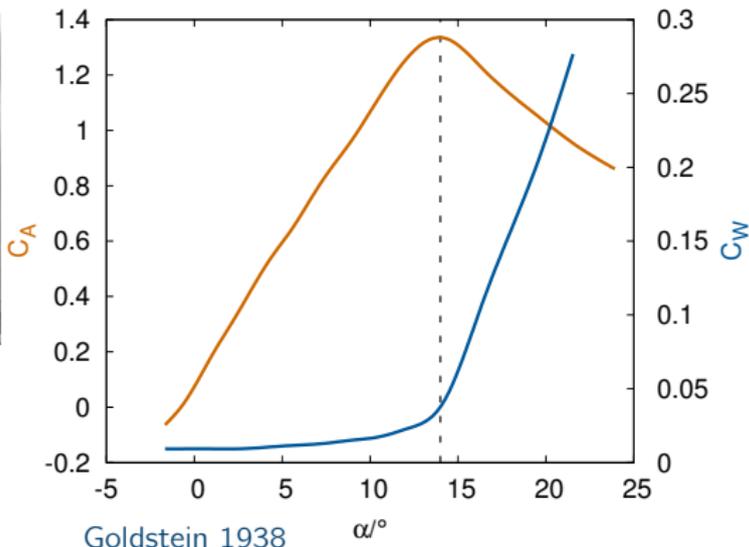
$$C_W = \frac{F_W}{\frac{\rho}{2} U^2 c_s}$$

# Einleitung: Auftrieb und Strömungszustand



DLR 1937

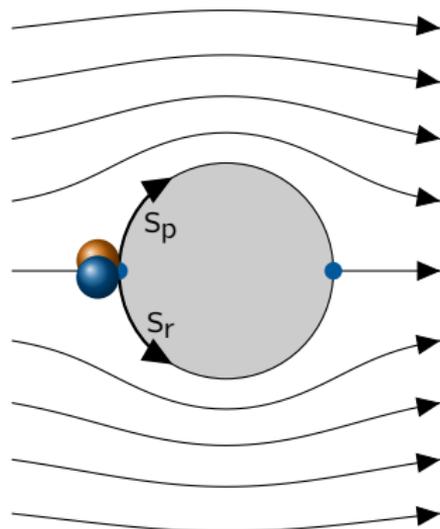
$$C_A = \frac{F_A}{\frac{\rho}{2} U^2 c_s}$$



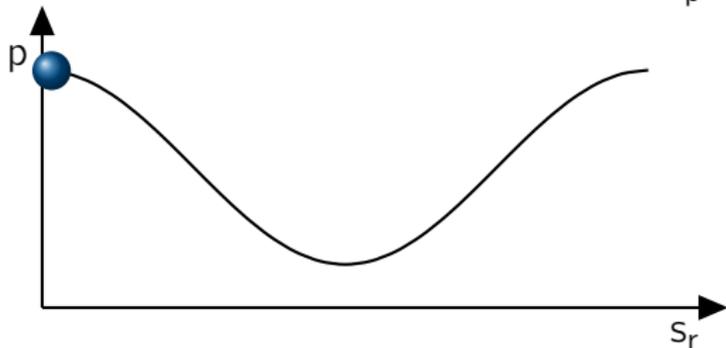
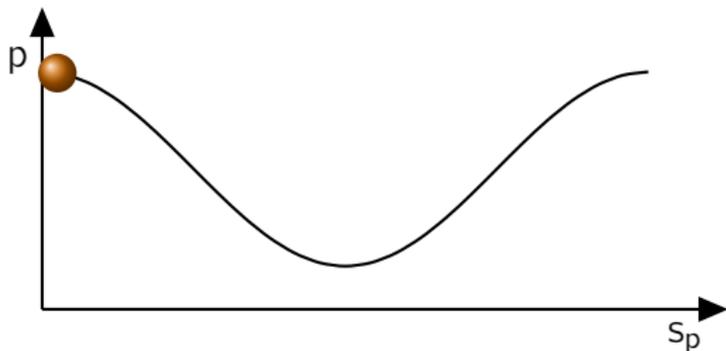
$$C_W = \frac{F_W}{\frac{\rho}{2} U^2 c_s}$$

# Ursache der Strömungsablösung

reibungsfrei



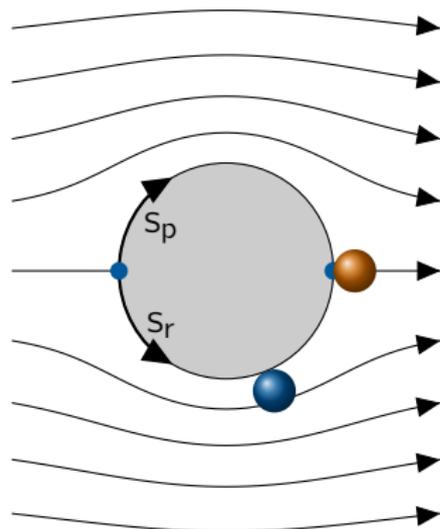
reibungsbehaftet



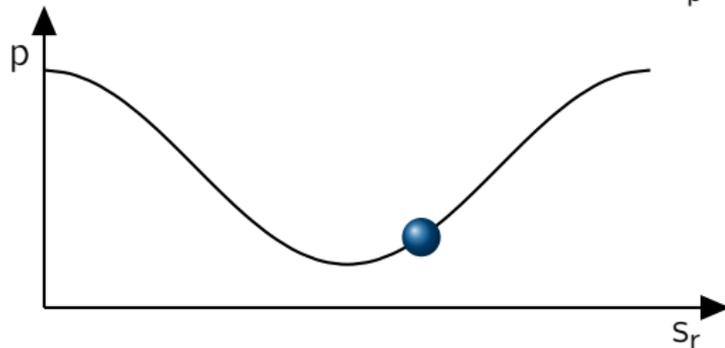
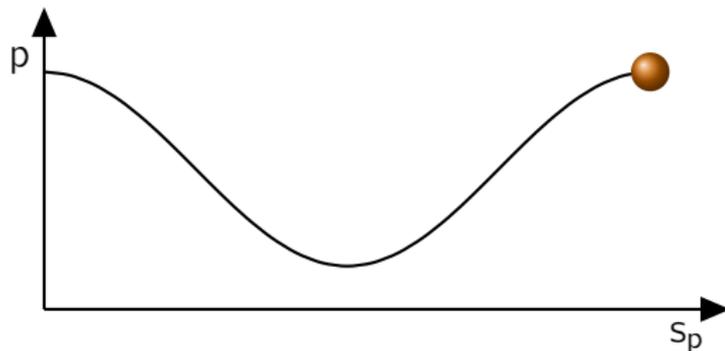
$$\frac{\rho}{2} u^2 + p = p_{\text{ges}} = \text{const.}$$

# Ursache der Strömungsablösung

reibungsfrei



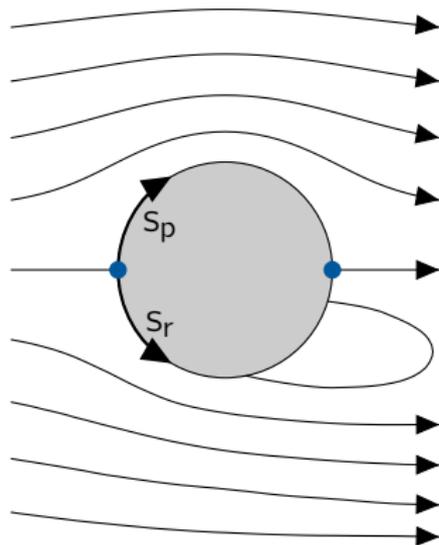
reibungsbehaftet



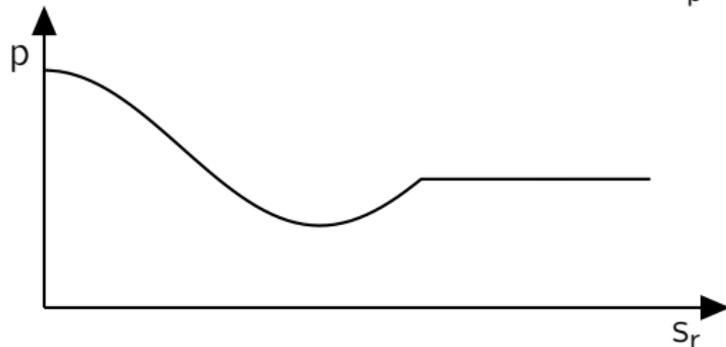
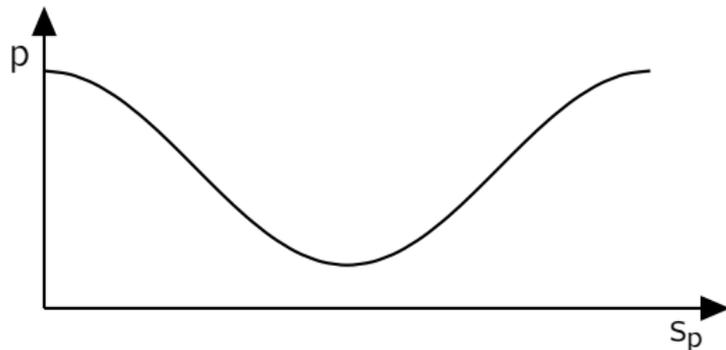
$$\frac{\rho}{2} u^2 + p = p_{\text{ges}} = \text{const.}$$

# Ursache der Strömungsablösung

reibungsfrei

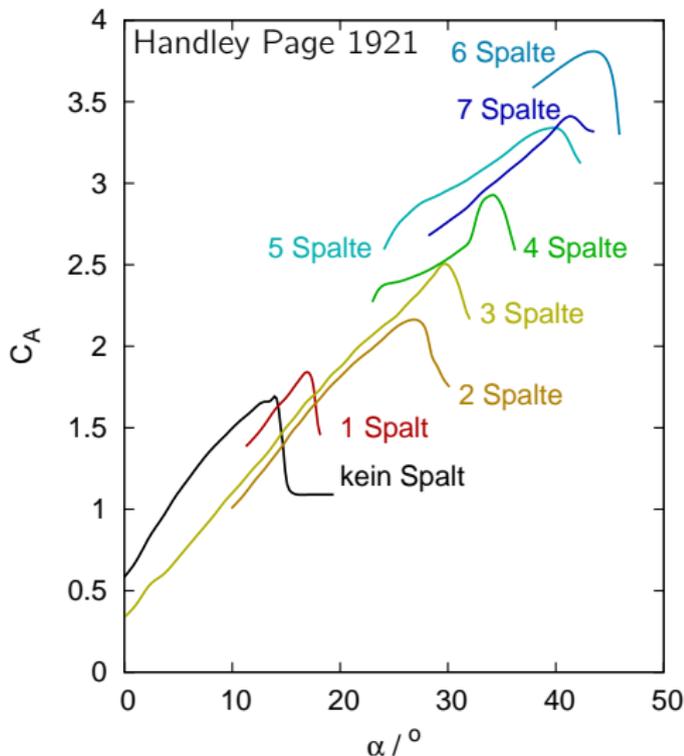
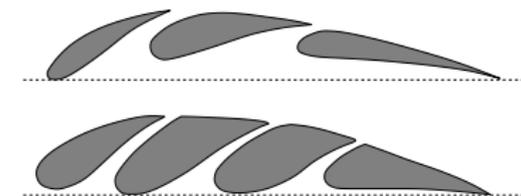
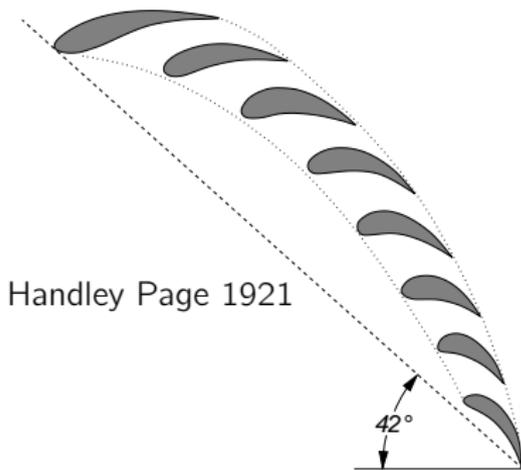


reibungsbehaftet

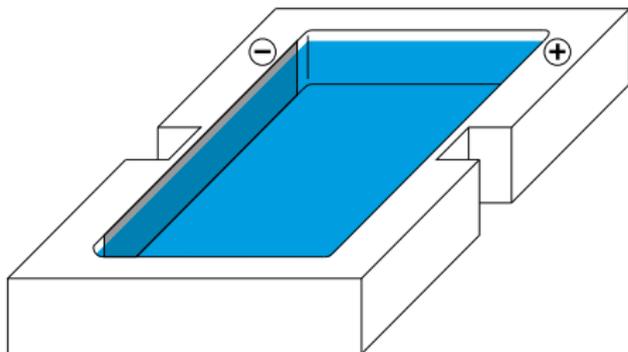


$$\frac{\rho}{2} u^2 + p = p_{\text{ges}} = \text{const.}$$

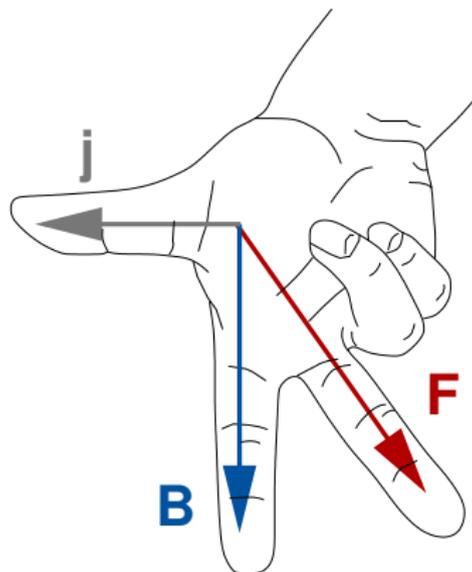
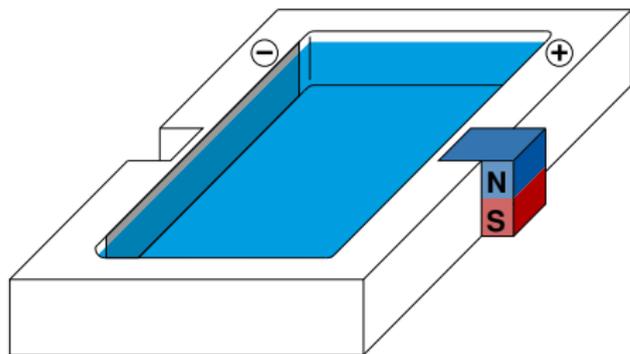
# Impulszufuhr – Schlitzflügel



# Lorentzkraft

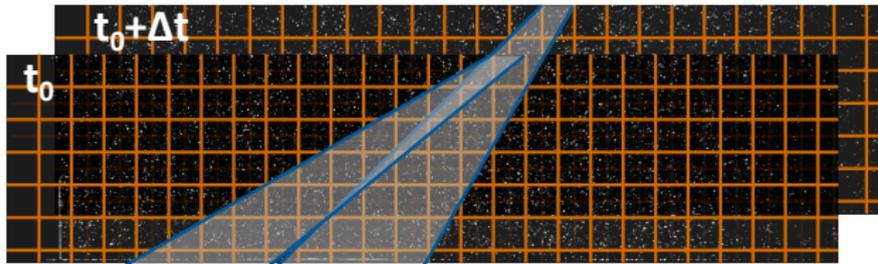
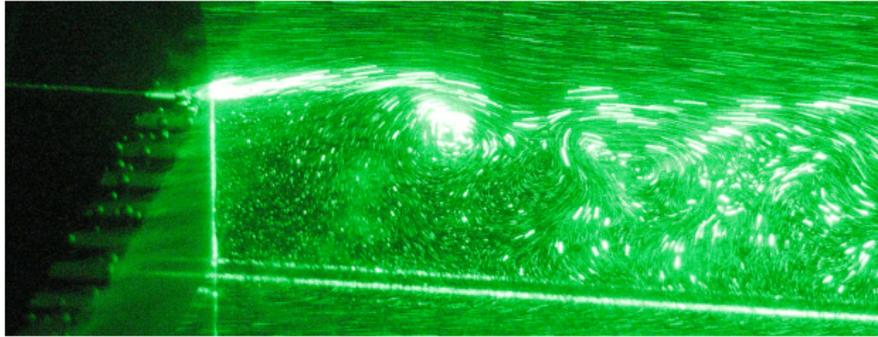


# Lorentzkraft



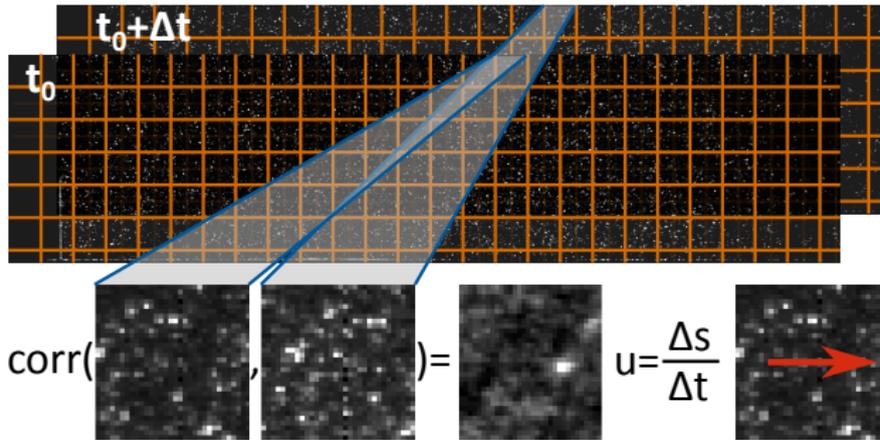
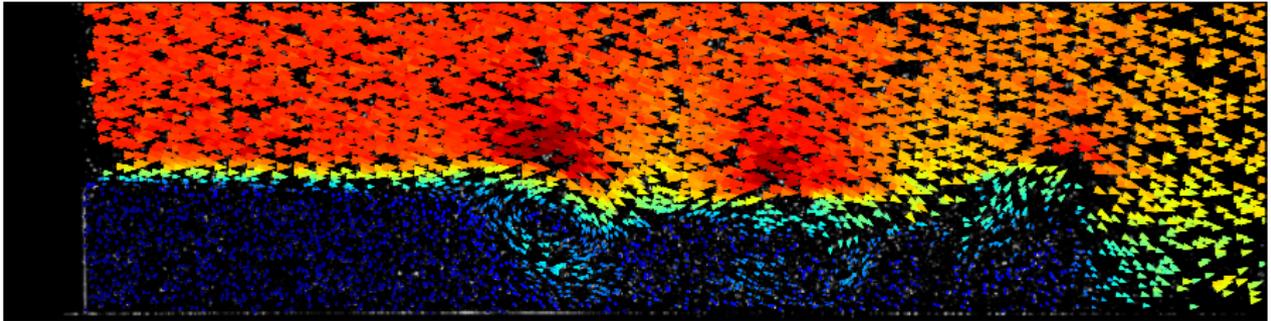
$$\mathbf{F} = \mathbf{j} \times \mathbf{B}$$

# Strömungsmessung: Particle Image Velocimetry

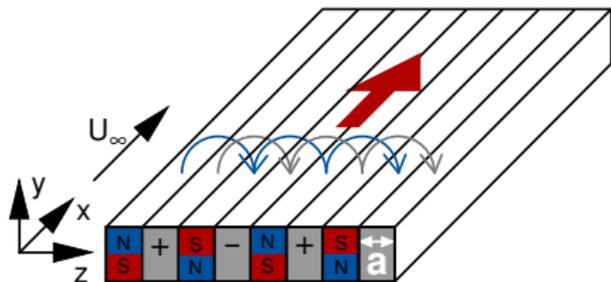


$\text{corr}(\text{frame}_1, \text{frame}_2) = \text{frame}_3$        $u = \frac{\Delta s}{\Delta t}$

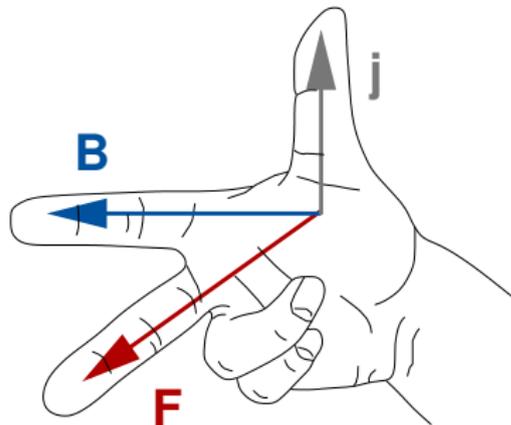
# Strömungsmessung: Particle Image Velocimetry



# Wandparallele Lorentzkraft



Gailitis, Lielausis 1961

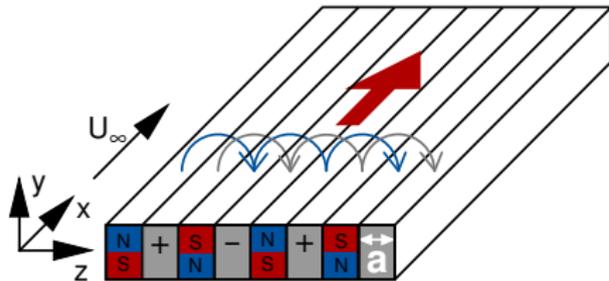


$$\mathbf{F} = \mathbf{j} \times \mathbf{B}$$

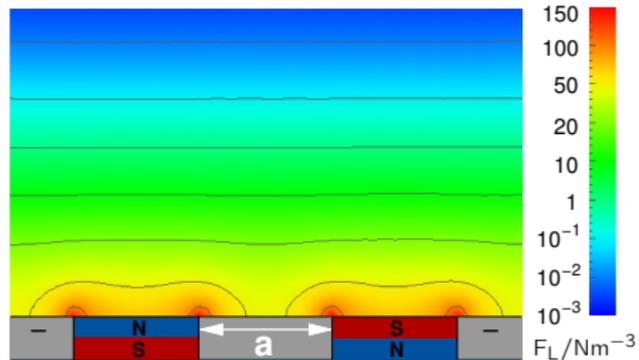
$$\mathbf{j} = \sigma(\mathbf{E} + \mathbf{u} \times \mathbf{B})$$

$$E_0 \gg U_\infty B_0$$

# Wandparallele Lorentzkraft



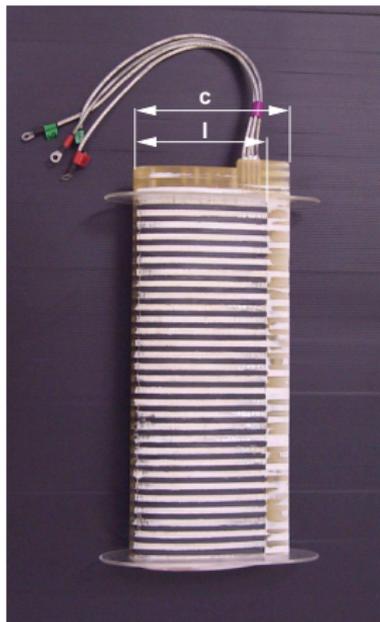
Gailitis, Lielausis 1961



$$\mathbf{F} = \mathbf{j} \times \mathbf{B}$$

$$\bar{F} = \frac{\pi}{4} j_0 B_0 e^{-\frac{\pi}{a} y}$$

# Profile mit Lorentzkraftaktoren



## **NACA 0015 (links):**

$$c = 0.667\text{m}$$

$$a/c = 0.015$$

$$B_0 = 0.58\text{T}$$

Edelstahlelektroden

## **PTL IV<sub>5</sub> (rechts):**

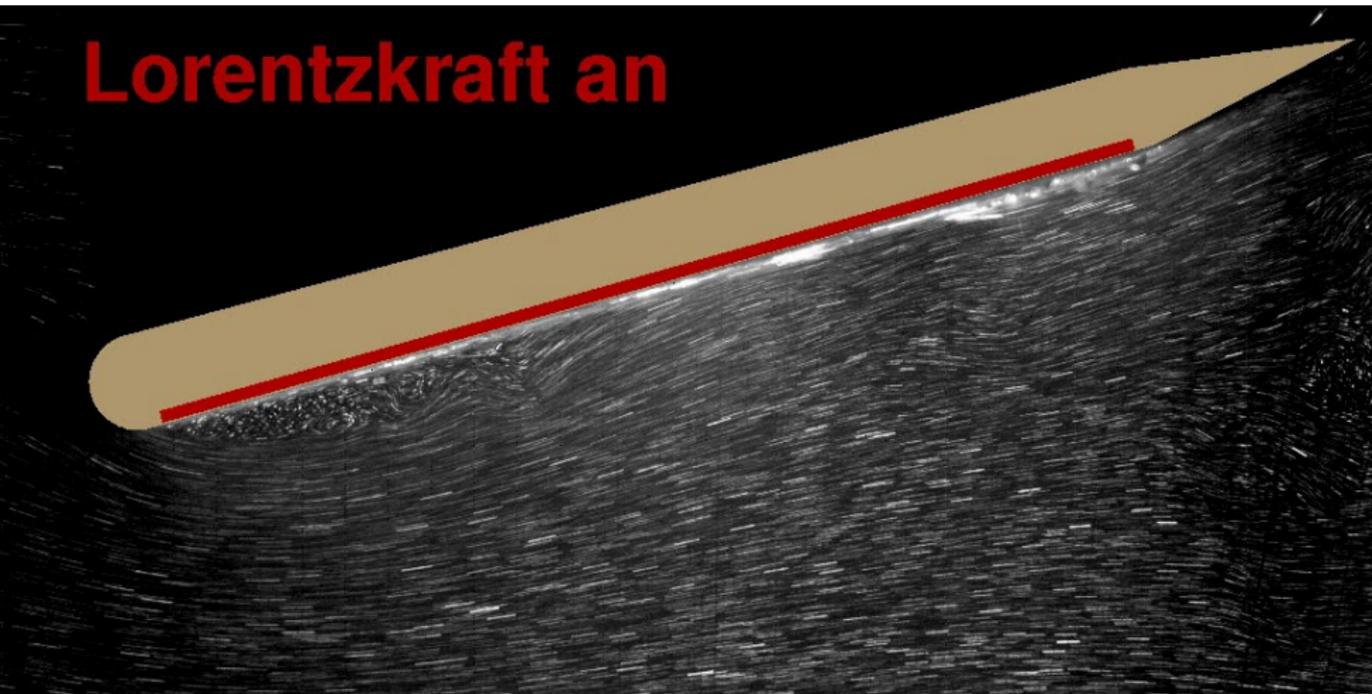
$$c = 0.158\text{m}$$

$$a/c = 0.03$$

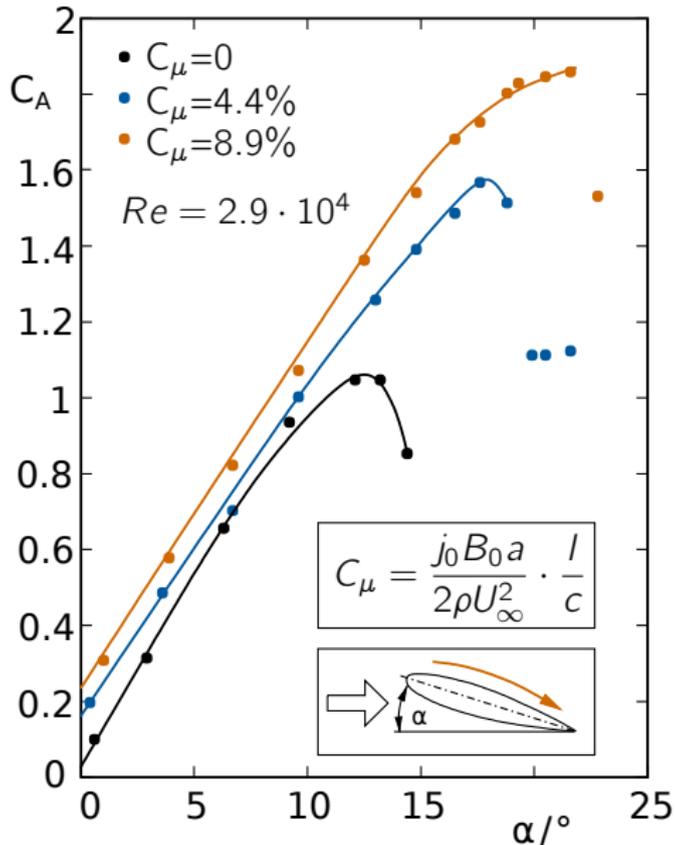
$$B_0 = 0.2\text{T}$$

Ti mit RuO<sub>2</sub>/IrO<sub>2</sub>  
(DSA)

## Lorentzkraft an

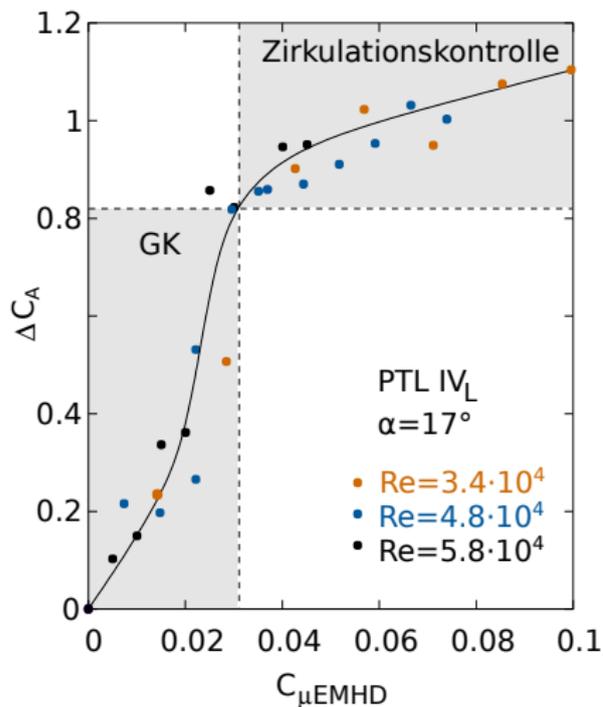


# Auftriebserhöhung am Profil

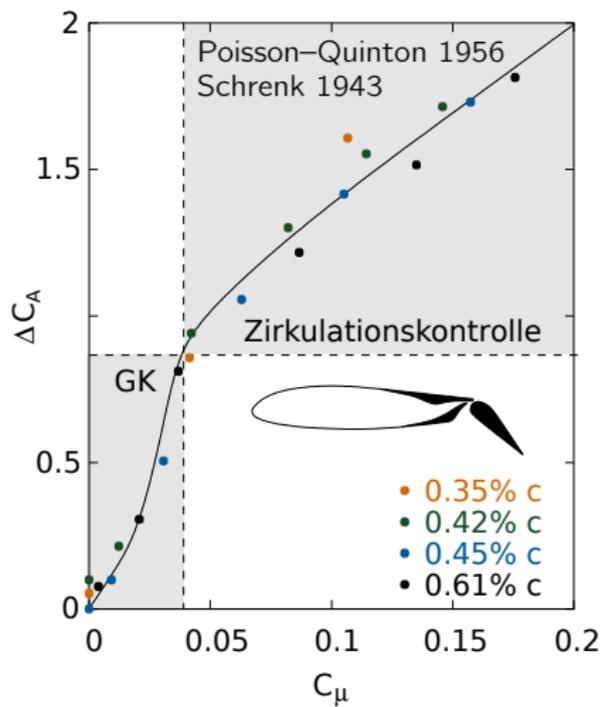


# Wiederanlegen: Vergleich mit Ausblasen

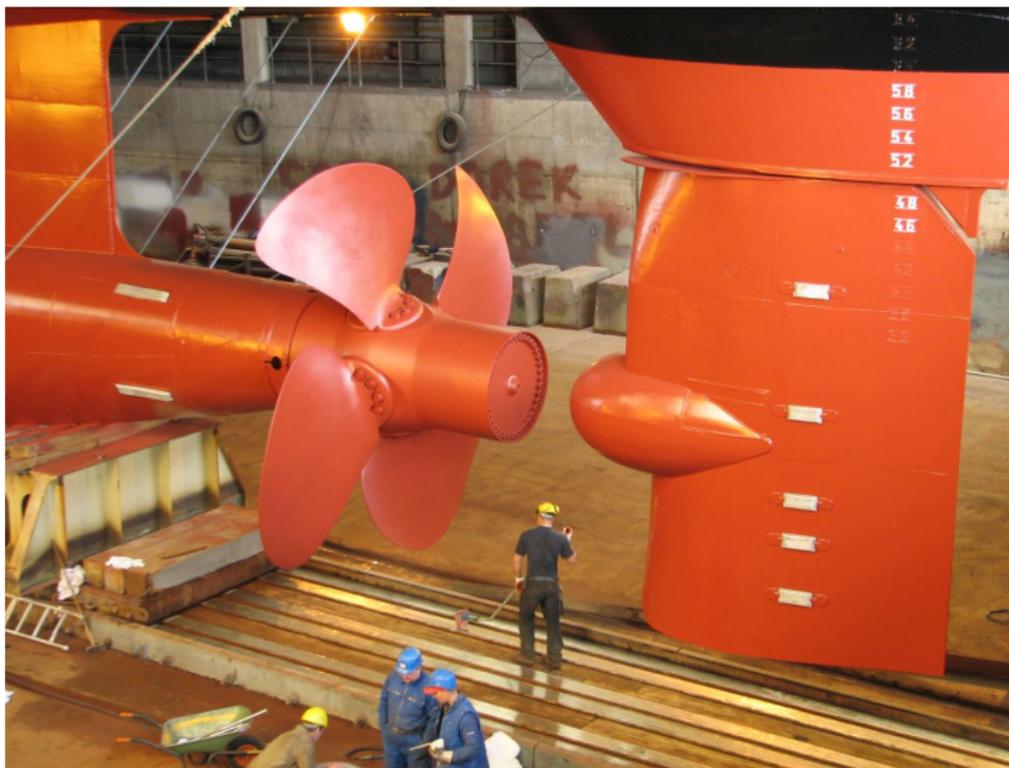
## Lorentzkraft



## Ausblasen

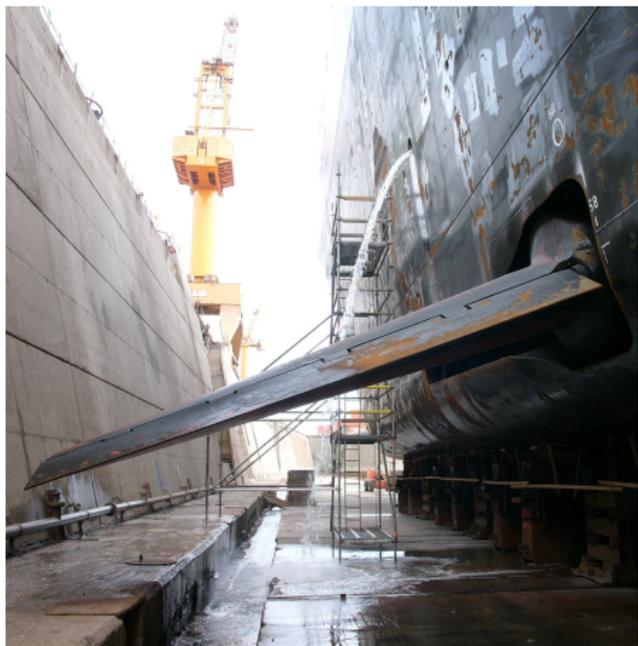
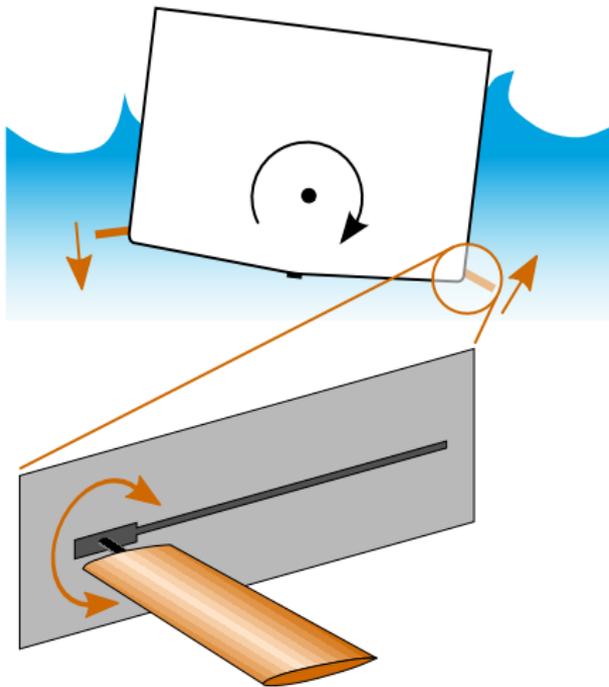


# Mögliche Anwendung: Steuerruder



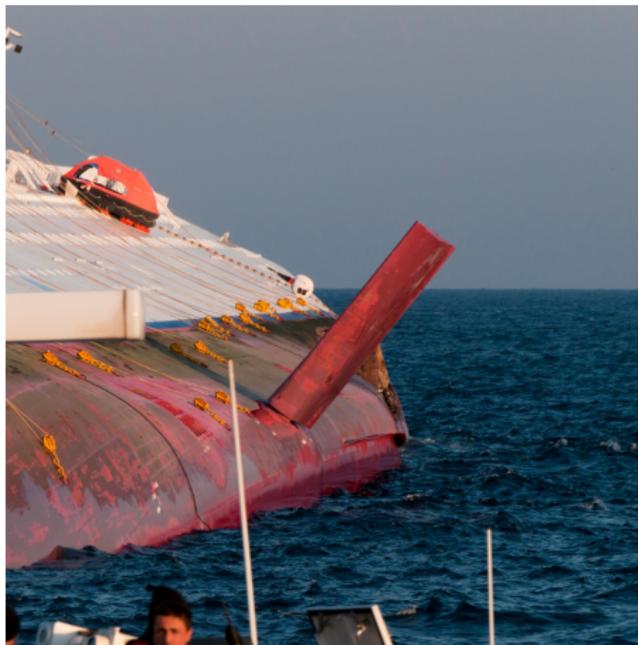
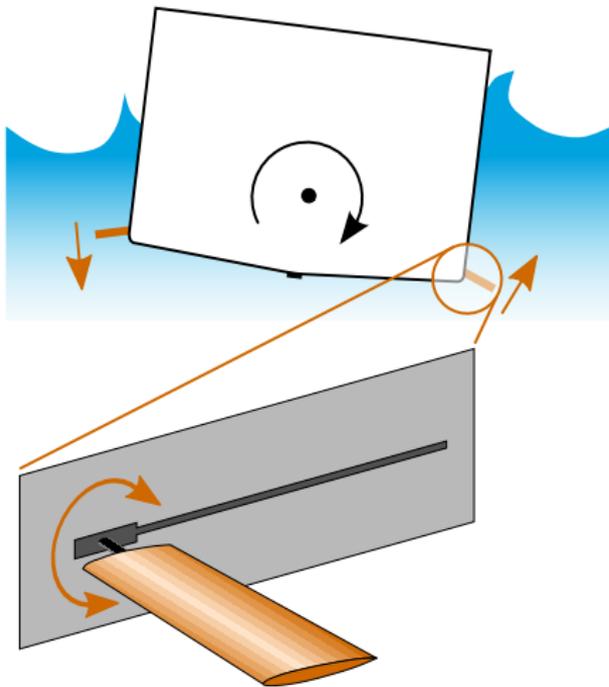
Markus Brinkmann, 2007

# Mögliche Anwendung: Stabilisierungsflossen



Hannes Grobe, 2007

# Mögliche Anwendung: Stabilisierungsflossen



Roberto Vonglier, 2012

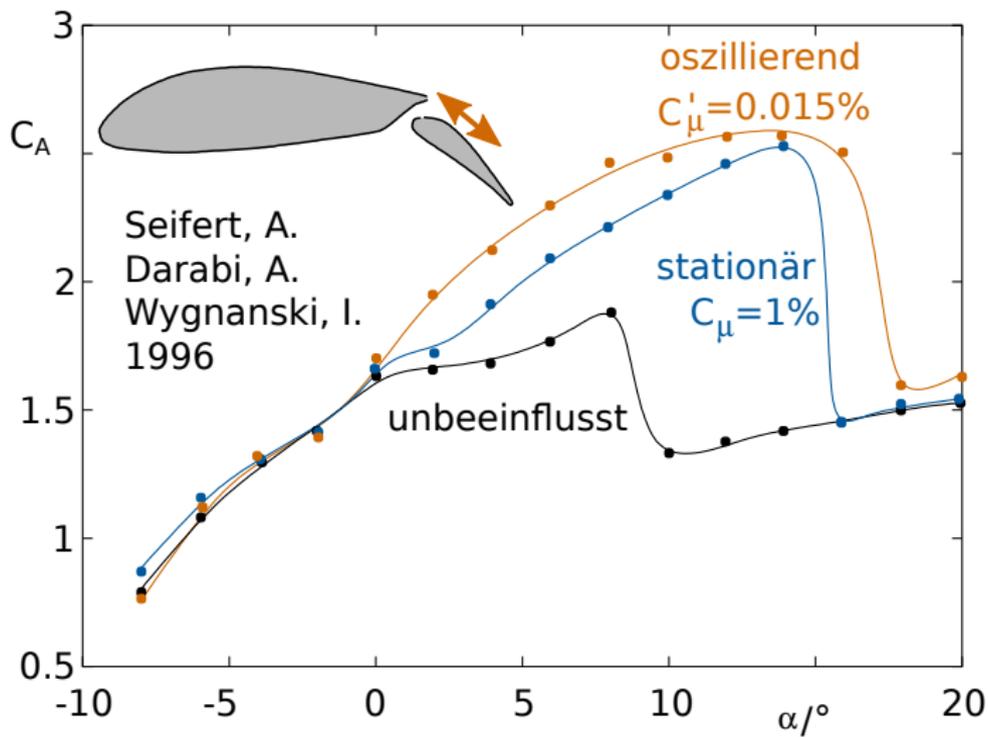
# Showstopper: Energieaufwand

**Impulskoeffizient**  $C_\mu \sim \frac{j_0 B_0}{U_\infty^2}$

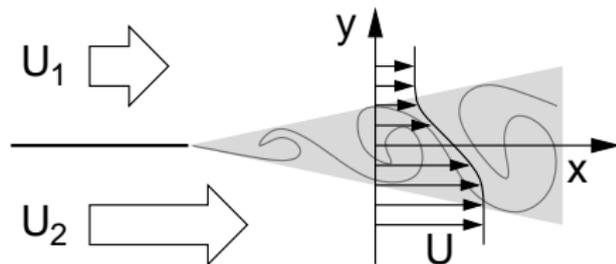
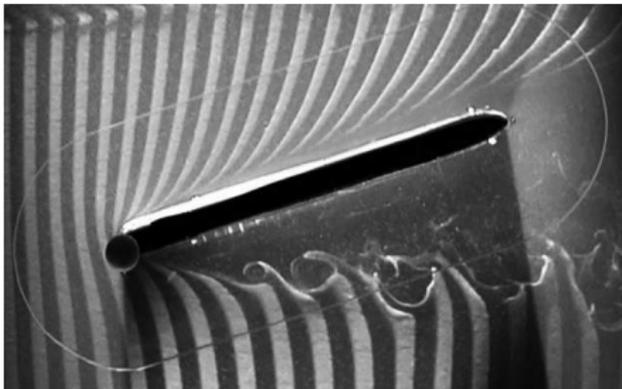
⇒ bei konstantem  $C_\mu$  (d.h.  $\sim$  konstantem  $\Delta C_A$ ):

**Leistungsbedarf**  $P_E \sim j_0^2 \sim U_\infty^4$

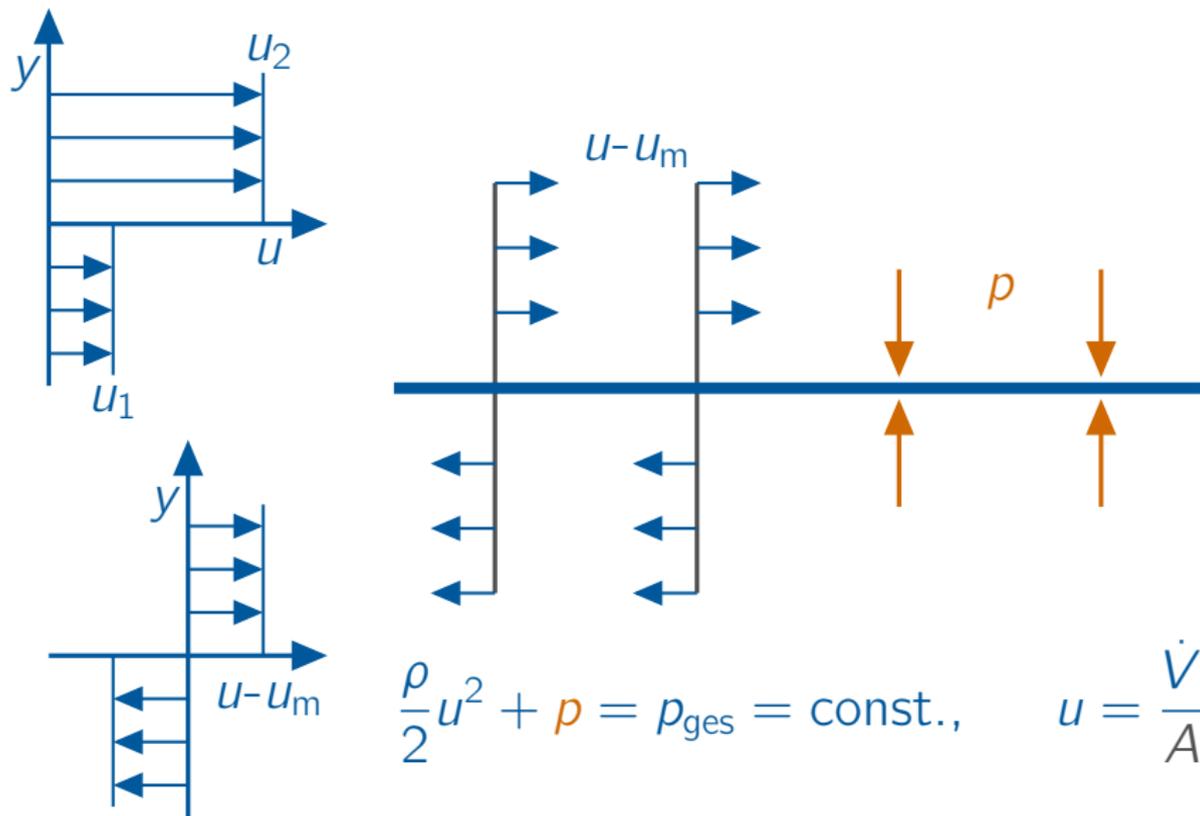
# Oszillierendes Ausblasen/Absaugen



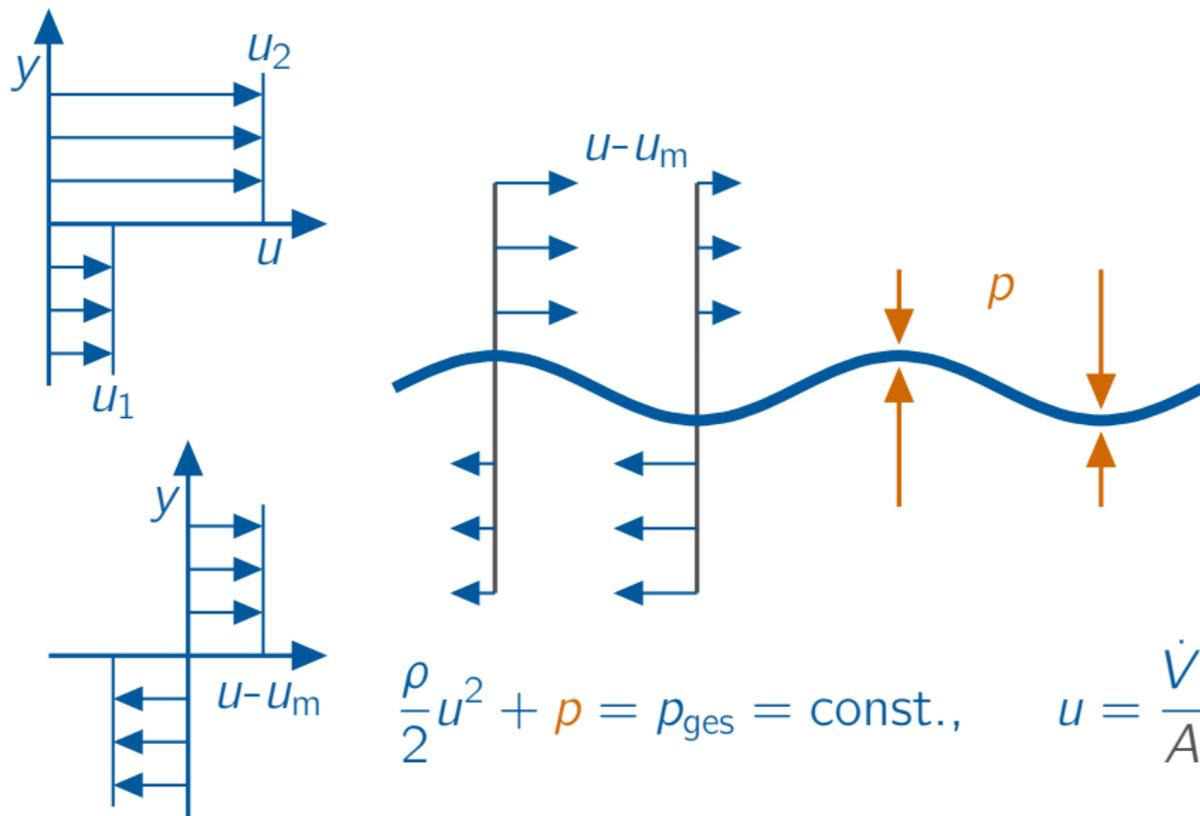
# Ablösegebiet und Scherschchicht



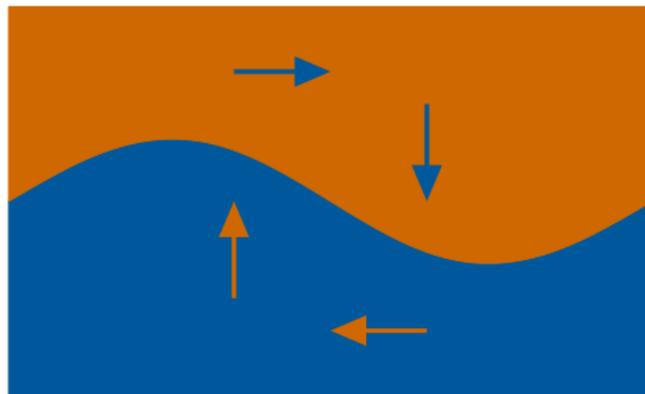
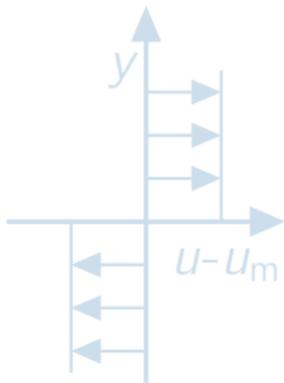
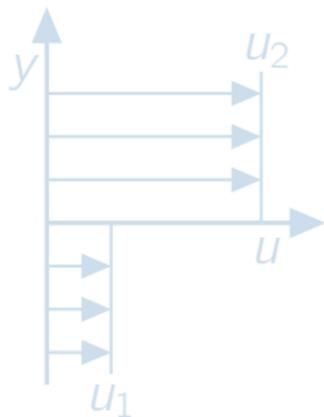
# Kelvin-Helmholtz Instabilität



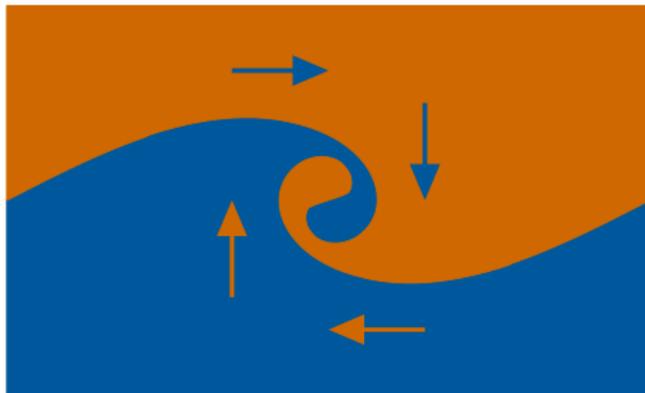
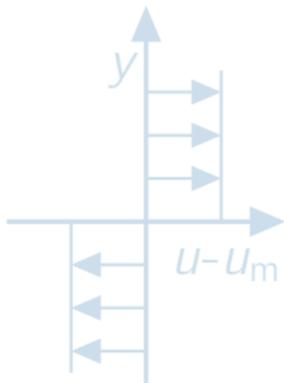
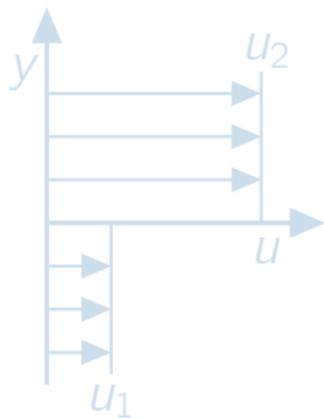
# Kelvin-Helmholtz Instabilität



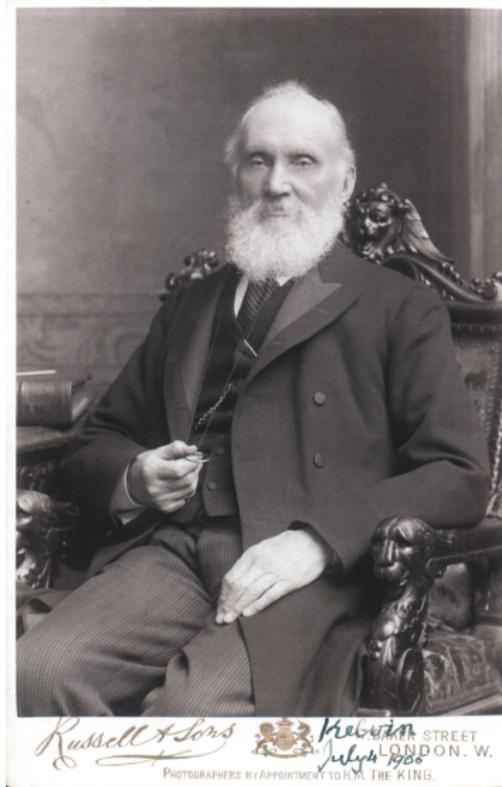
# Kelvin-Helmholtz Instabilität



# Kelvin-Helmholtz Instabilität



# H. von Helmholtz und Lord Kelvin



# Kelvin-Helmholtz Instabilität: Wogenwolken



Greg O'Berne, 2009



GRAHAMUK

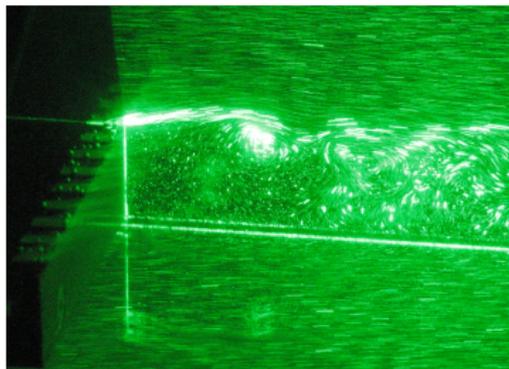
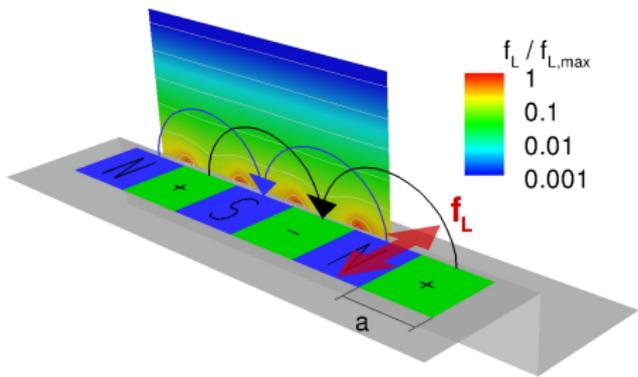
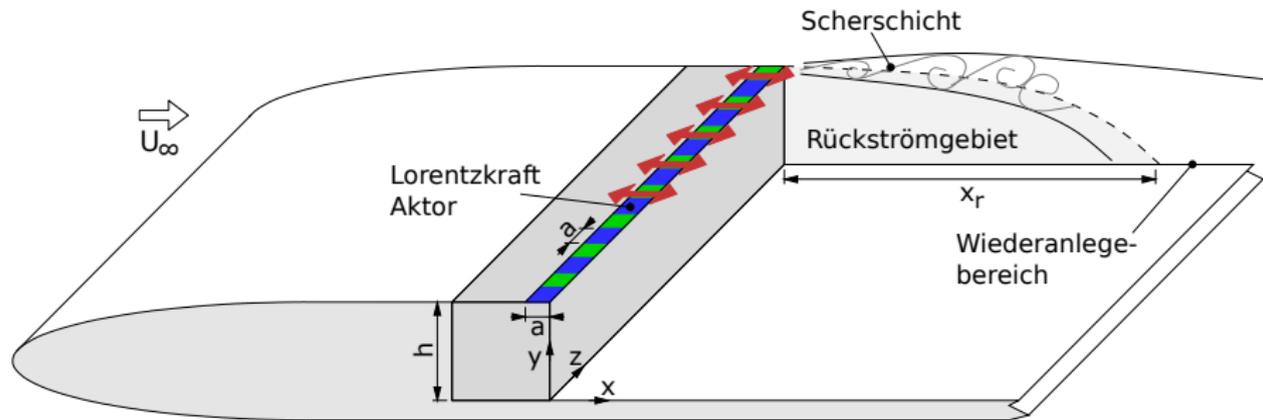
Altostratus  
undulatus

# Kelvin-Helmholtz Instabilität



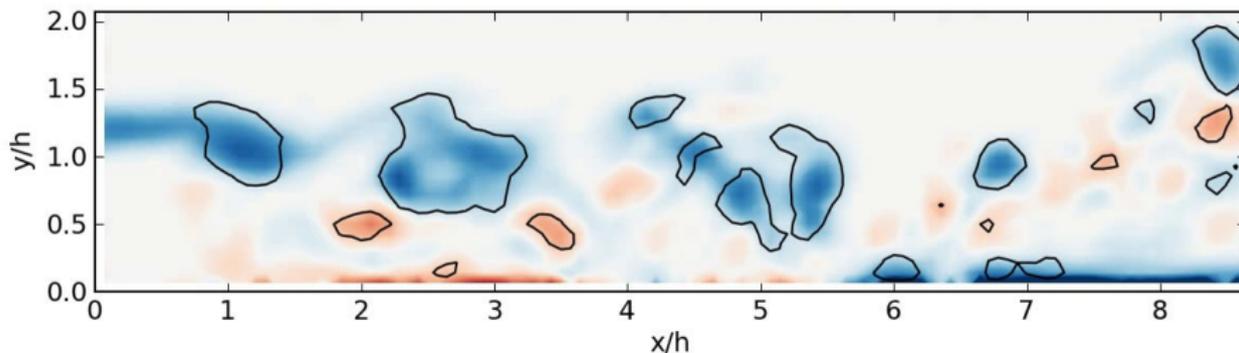
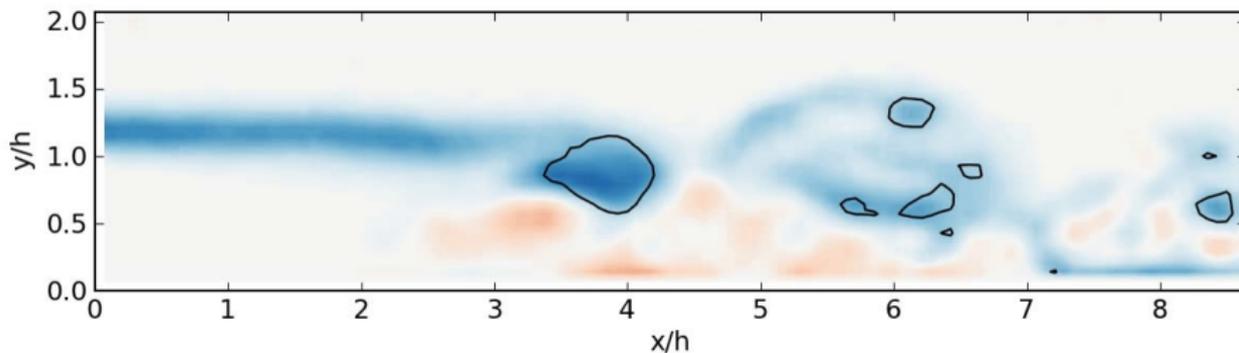
Vincent van Gogh (1889) Sternennacht

# Rückspringende Stufe



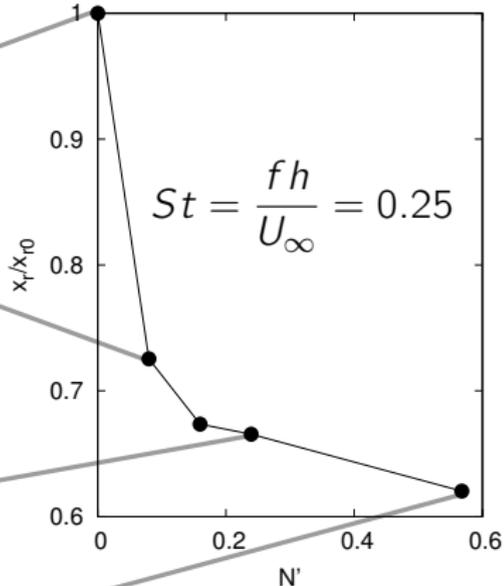
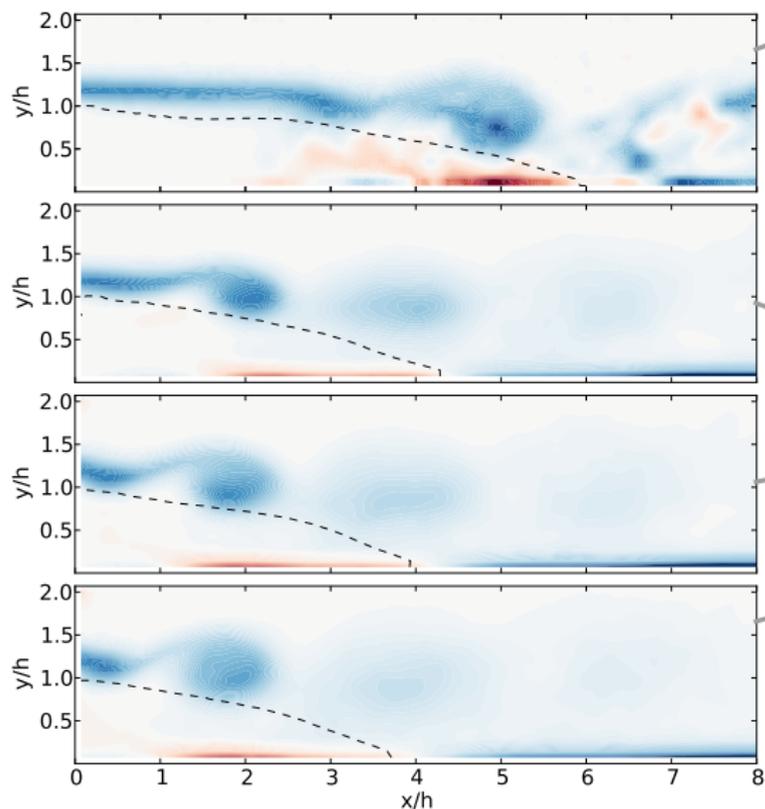
# Strömung über rückspringende Stufe

unbeeinflusst



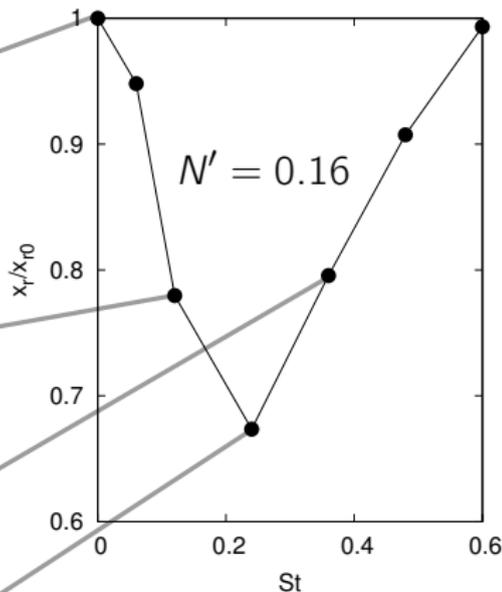
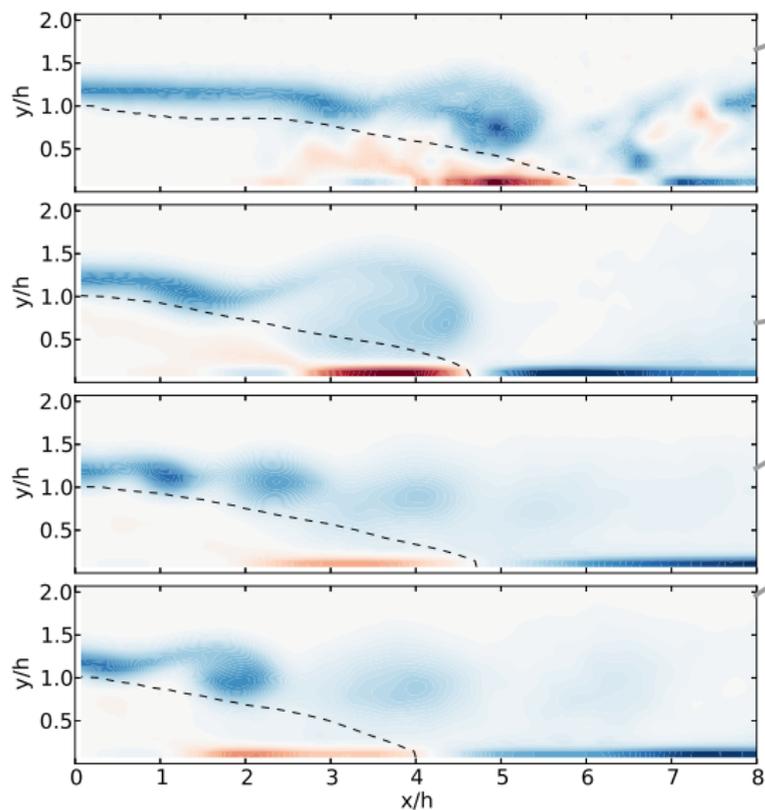
angeregt

# Einfluss der Anregungsamplitude



$$N' = \frac{j'_0 B_0 a}{\rho U_\infty^2}$$

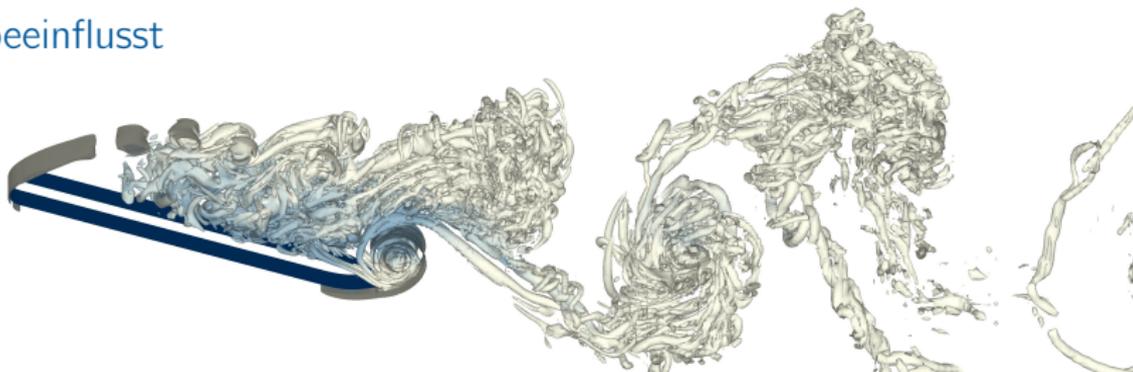
# Einfluss der Anregungsfrequenz



$$St = \frac{fh}{U_\infty}$$

# Tragfläche mit Lorentzkraftfaktor

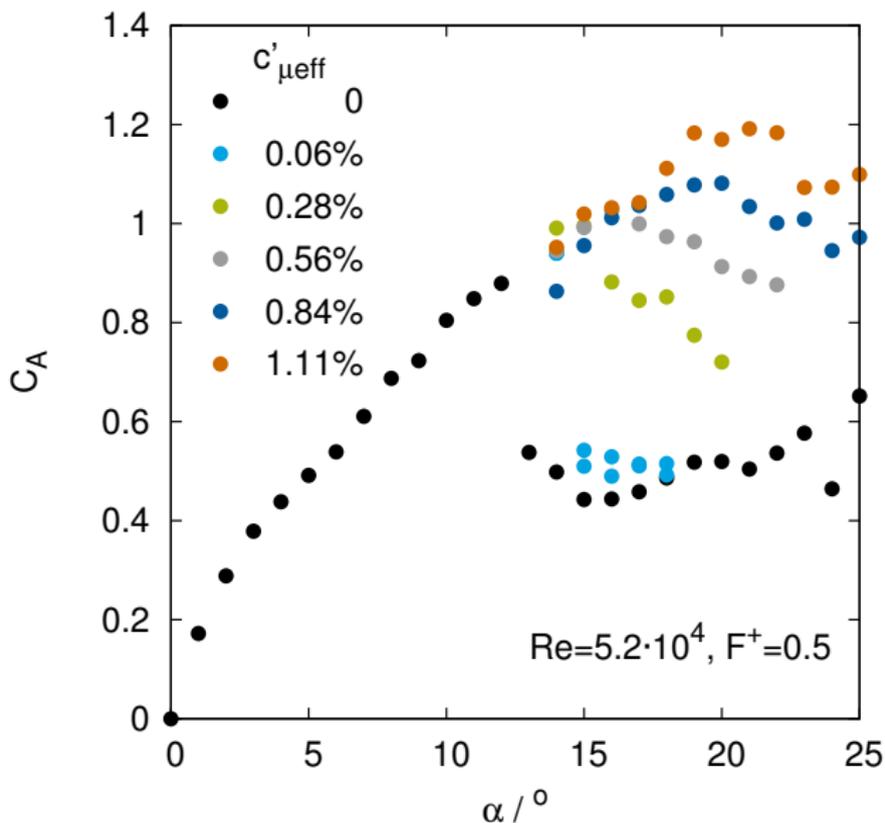
unbeeinflusst



angeregt



# Auftriebserhöhung mit oszillierenden Kräften



- Grund für Strömungsablösung: Reibungsverluste
- Impulszufuhr → Wiederanlegen
- stationäre Lorentzkraft wirksam, aber hoher Energiebedarf
- Strömungsinstabilitäten weit verbreitet
- Instabilitäten können Anregungen verstärken
- Energieaufwand für Beeinflussung sinkt
- Beeinflussung/Strömung sind/bleiben instationär