12th Summer School on SCIENTIFIC VISUALIZATION

Case History Visualization in external aerodynamics and multiphase CFD

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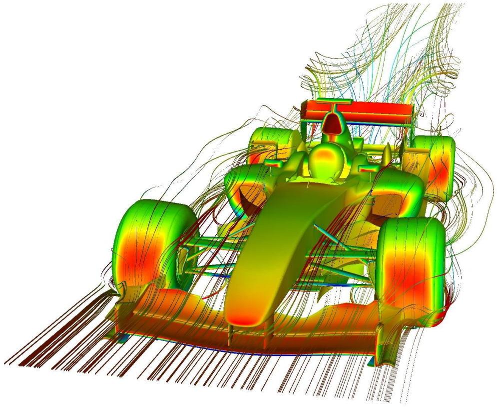
OUTLINE

- CFD and visualization a wedding of interest
- Success stories examples
- Tools: Paraview
- Hands-on session

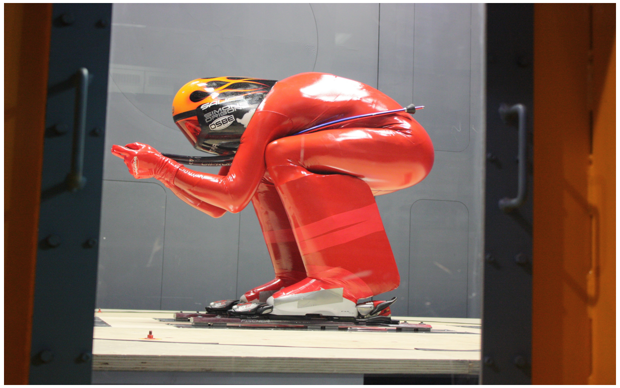
Why CFD ?

CFD: Computational Fluid Dynamics



CFD vs Wind Tunnel

- Different costs
- Different times
- Different accuracy
- Different reliability
- Different risks (??)



CFD exploits HPC capabilities to investigate high non-linear fluids phenomenon

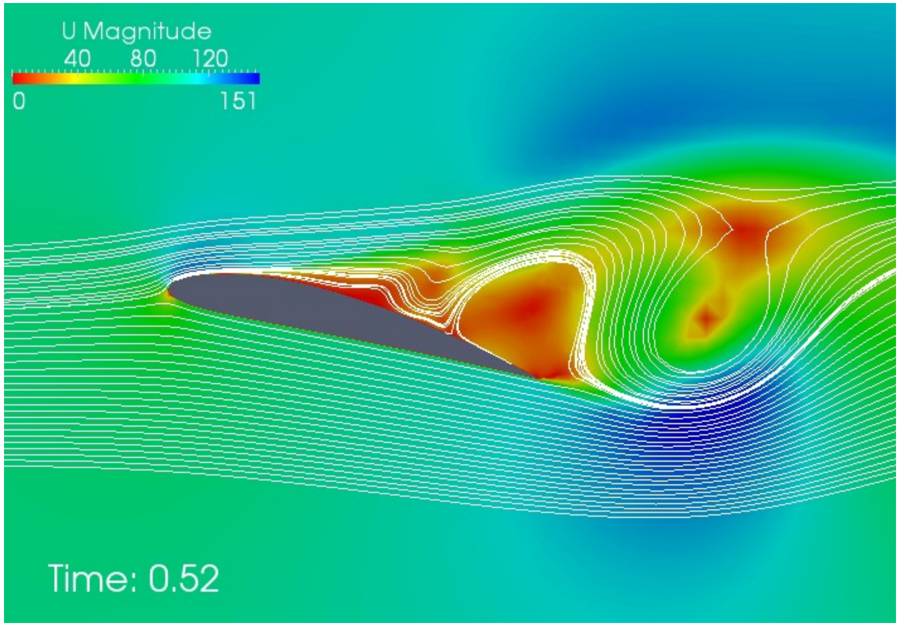
Why Scientific Visualization ?

- CFD and scientific visualization is a wedding of interest
- Visualization is **mandatory**, in order to exploit the high level of detail available in CFD datasets.
- HPC servers are employed: dedicated large-RAM node
- Remote visualization large used

Success stories examples: 2D airfoil aerodynamics

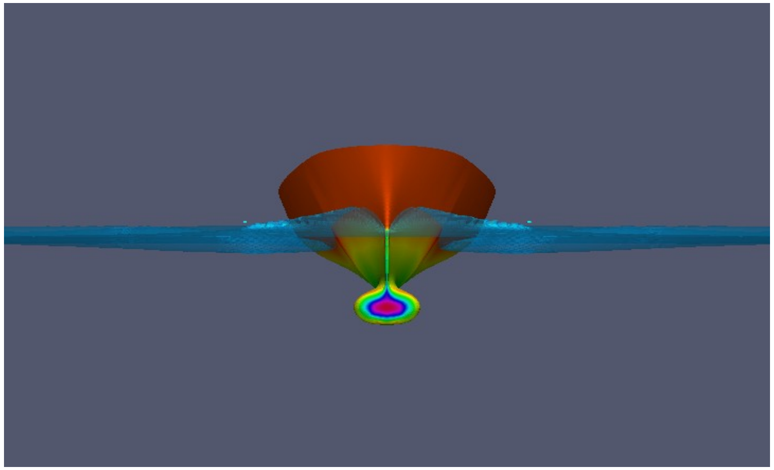
1. pressure distribution
2. streamlines
3. separated flow
4. stall limit

(movie)

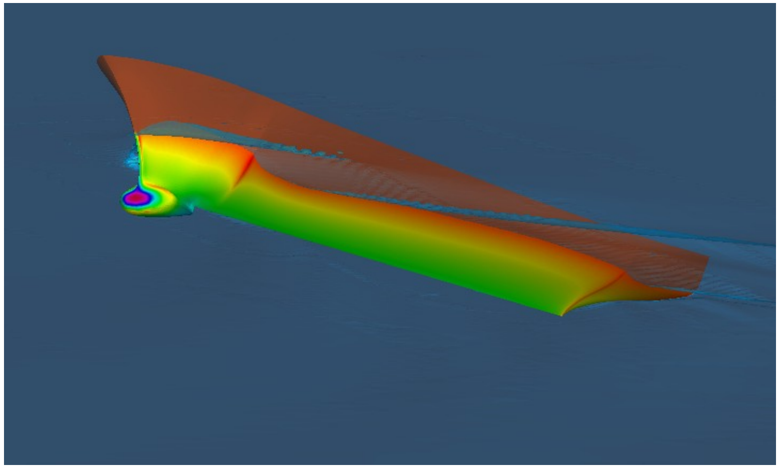


Success stories examples: multiphase flow for hull analysis

- Free surface position



- Hull stress visualization

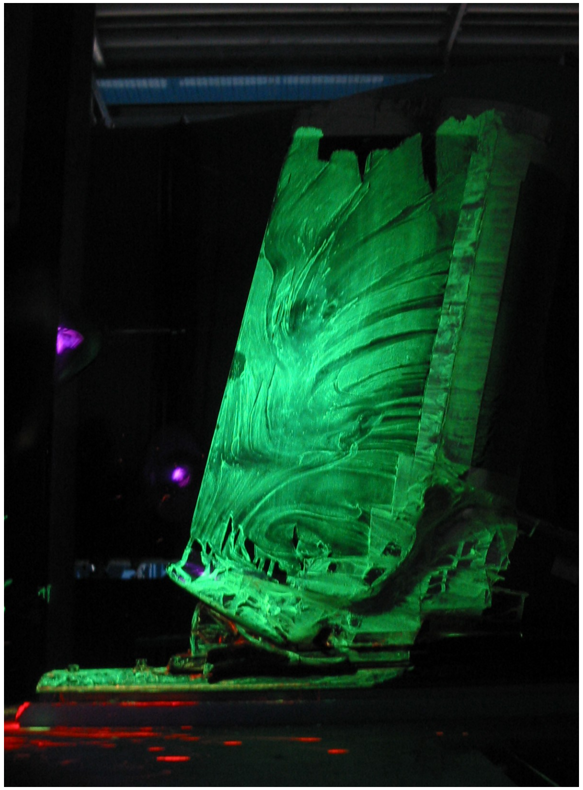


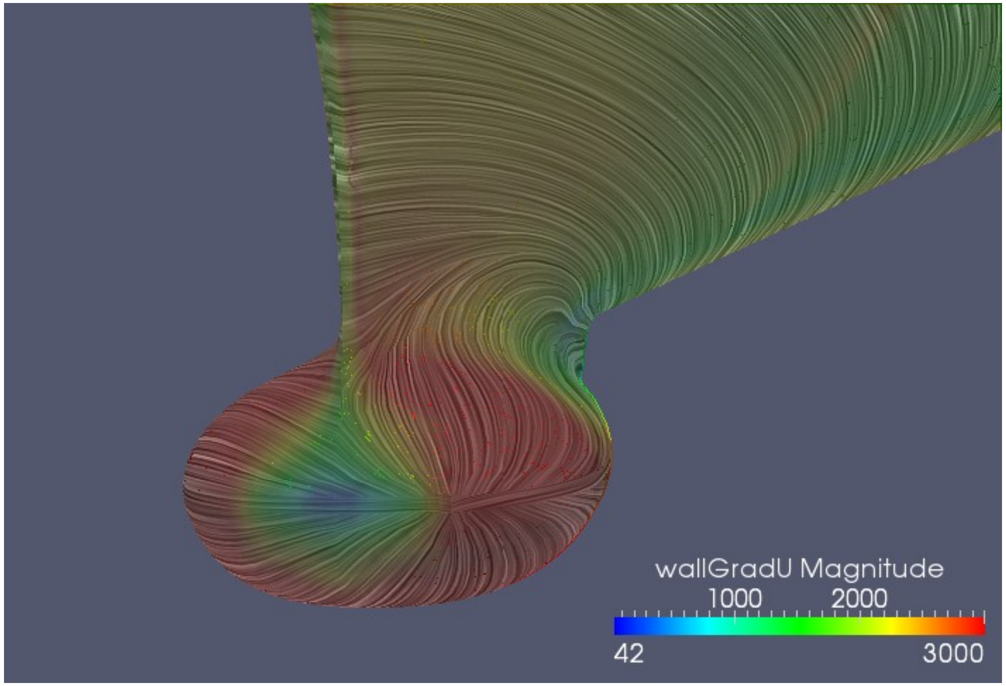
Tools

ParaView
Parallel Visualization Application

- **Open-source**, multi-platform data analysis and visualization application
- User-**friendly** interface
- Wide range of data format **supported**
- Very large **used**

Tools: observing fluids phenomenon





...from real phenomenon to simulated phenomenon !!

Hands-on session:

Presented case:

Part I: External Aerodynamics:

2D airfoil motion

Part II: Multiphase flow:

standard DTMB 5415 bare hull

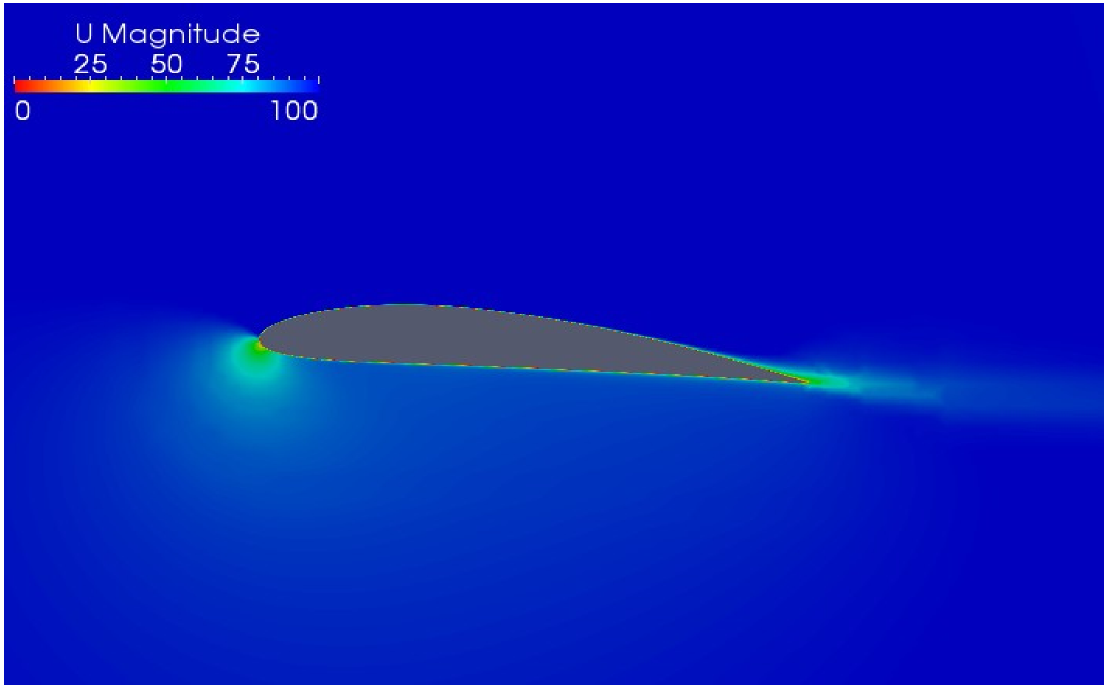
Hands-on (part I): 2D airfoil motion aerodynamics

Focus on:

1. Stagnation point
2. Streamlines
3. Flow separation (bubble)
4. Stall

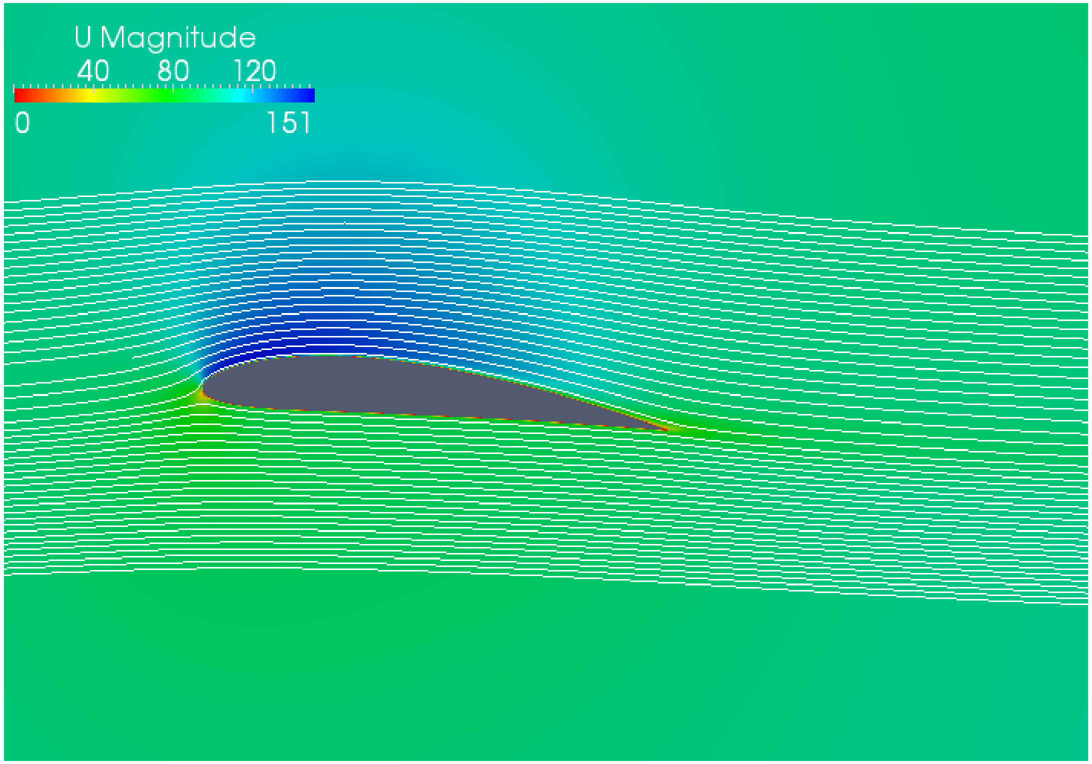
Hands-on (part I): 2D airfoil motion aerodynamics

1. **Stagnation point**: velocity is zero, while pressure is max



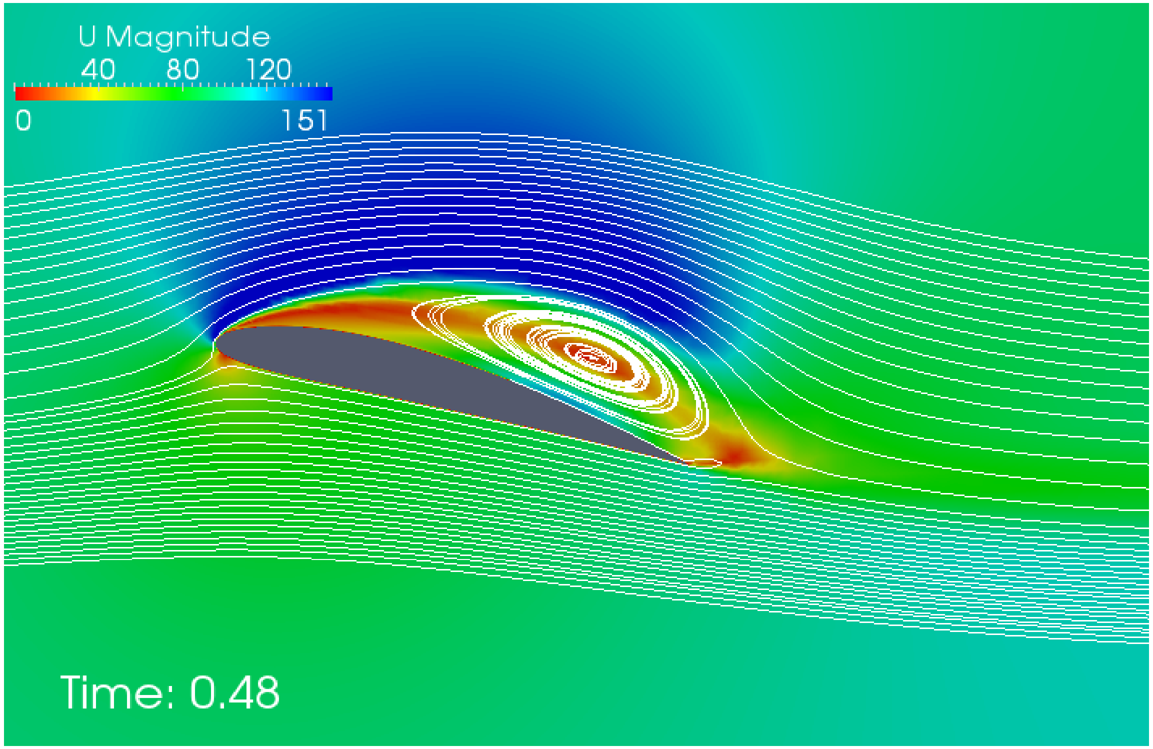
Hands-on (part I): 2D airfoil motion aerodynamics

2. **Streamlines:** filter Streamtracer



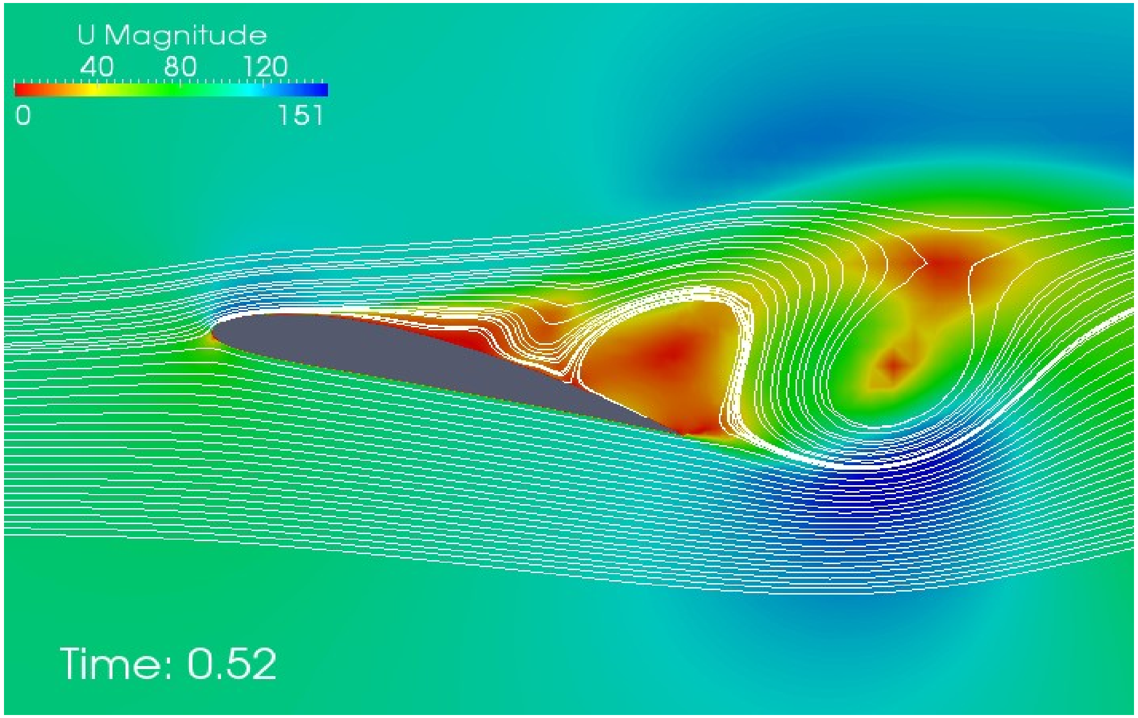
Hands-on (part I): 2D airfoil motion aerodynamics

3. **Flow separation:** when the opposite pressure gradient grows up and a recirculation bubble exists



Hands-on (part I): 2D airfoil motion aerodynamics

4. **Stall:** when a decrease of lift coefficient happens.



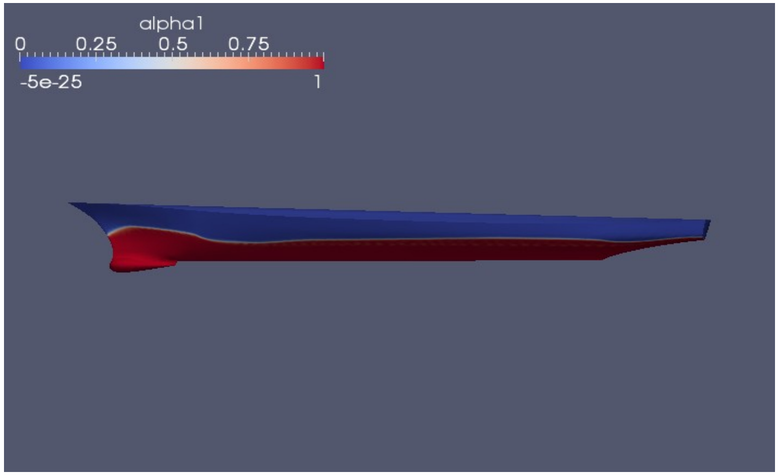
Hands-on (part II): multiphase flow over DTMB5415 hull

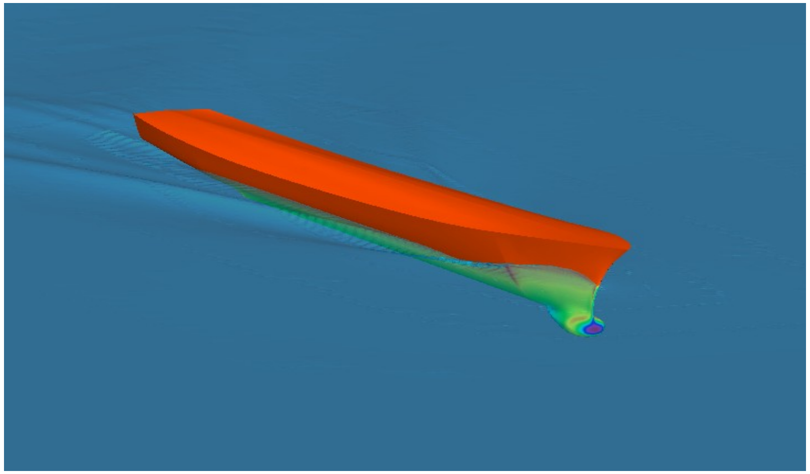
Focus on:

1. Waves position & hull loads
2. Wall shear stress
3. Turbulent coherent structures

Hands-on (part II):
2D airfoil motion aerodynamics

1. **Waves elevation**: position of free surface is crucial in computing loads on hull

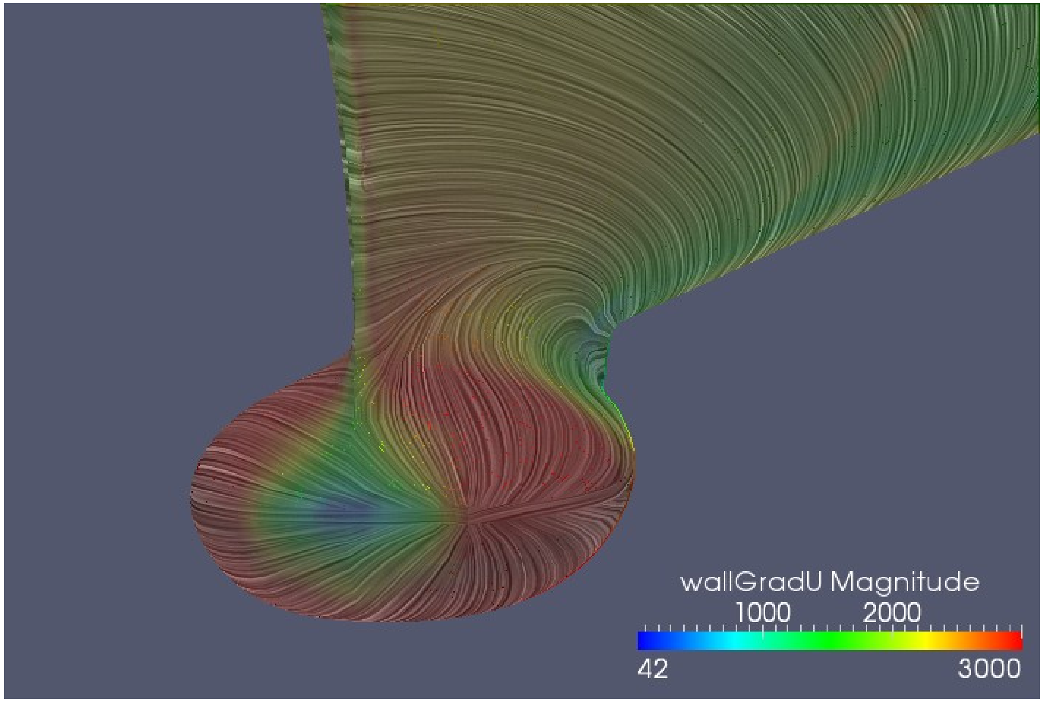




Filter: contour

Hands-on (part II):
2D airfoil motion aerodynamics

2. **Near wall velocity**:



Filter: LIC surface

Hands-on (part II): 2D airfoil motion aerodynamics

3. **Turbulent coherent structures**: Q criterion

*Hunt et al. (1988) identify vortices of an incompressible flows as connected fluid regions with a positive second invariant of grad(**U**)*

$$Q \equiv \frac{1}{2}(u_{i,i}^2 - u_{i,j}u_{j,i}) = -\frac{1}{2}u_{i,j}u_{j,i}$$