

Offer of research internship 2026, 6 months

Extension of Variational-ALE Methodology to Multi-Fluid Flows

K. Kozhanova, S. Zhao, and P. Boivin

Aix Marseille Univ, CNRS, Centrale Méditerranée, M2P2, Marseille, France

The modelling of multi-phase and multi-fluid flows remains a key challenge in both academia (astrophysics, geophysics, meteorology, etc.) and industry (combustion, nuclear, health, etc.) due to the complexity of dispersed phases and their interactions. The “backbone” multi-fluid model, based on Euler-like equations for mass, momentum, and energy, provides a simplified framework that can be discretized numerically using the recently developed Geometry, Energy, and Entropy Compatible (GEEC) approach. This internship will be dedicated to extending the GEEC methodology to multi-fluid applications through systematic numerical validation on 1D and 2D academic test cases.

THE INTERNSHIP

This internship will focus on the extension and application of the GEEC numerical scheme to multi-fluid problems, with the incorporation of an Arbitrary Lagrangian–Eulerian (ALE) framework^{1–4}. Starting from the discretized density, energy, and transport fields, the GEEC method ensures conservation of mass, momentum, and energy, preserves isentropic behaviour, and maintains thermodynamic consistency for each fluid. The internship will focus on implementing and validating these capabilities in a 2D parallelized solver for multi-fluid flows.

The internship will be structured around the following objectives:

- Study and implementation of numerical methods derived from a variational approach, particularly within the ALE framework.
- Proposal and execution of academic multi-fluid test cases in a 2D parallelized solver, with systematic comparison against benchmark solutions.
- Enhancement of the ALE framework to address stiff multi-fluid problems.
- Exploration and implementation of artificial viscosity strategies tailored for multi-fluid simulations.

The internship will be conducted within the M2P2 team, in collaboration with CEA researchers and engi-

neers, combining theoretical, numerical, and practical aspects of multi-fluid simulations.

THE CANDIDATE

You are a final year École d’Ingénieur or Master 2 student specializing in fluid mechanics, numerical simulations, or applied mathematics. Knowledge of multi-phase flows is a plus. The candidate must have experience or interest in programming, particularly C++, and basic knowledge of parallelisation paradigms is welcome. Excellent English communication skills, both spoken and written, are required.

Your CV, cover letter, and grades for the last two years are to be sent to:

pierre.boivin@univ-amu.fr

ksenia.kozhanova@univ-amu.fr

BIBLIOGRAPHY

¹T. Vazquez-Gonzalez, *Schémas numériques mimétiques et conservatifs pour la simulation d’écoulements multiphasiques compressibles*, Ph.d. thesis, Université Paris–Saclay (2016), ph.D. thesis 2016SACLC051.

²T. Vazquez-Gonzalez, A. Llor, and C. Fochesato, “A mimetic numerical scheme for multi-fluid flows with thermodynamic and geometric compatibility on an arbitrarily moving grid,” *European Journal of Mechanics B/Fluids* **65**, 494–514 (2017).

³T. Vazquez-Gonzalez, A. Llor, and C. Fochesato, “A mimetic numerical scheme for multi-fluid flows with thermodynamic and geometric compatibility on an arbitrarily moving grid,” *International Journal of Multiphase Flow* **132**, 103324 (2020).

⁴Heulhard de Montigny and A. Llor, “Taming the “stiff stiffness” of pressure work and equilibration in numerical schemes for compressible multi-fluid flows,” *International Journal of Multiphase Flow* **153**, 104078 (2022).