COMPUTER & COMPUTATIONAL SCIENCES

# Subgrid Scale Mixture Models for Hybrid Miscible/Immiscible Multifluid/Multimaterial Simulations

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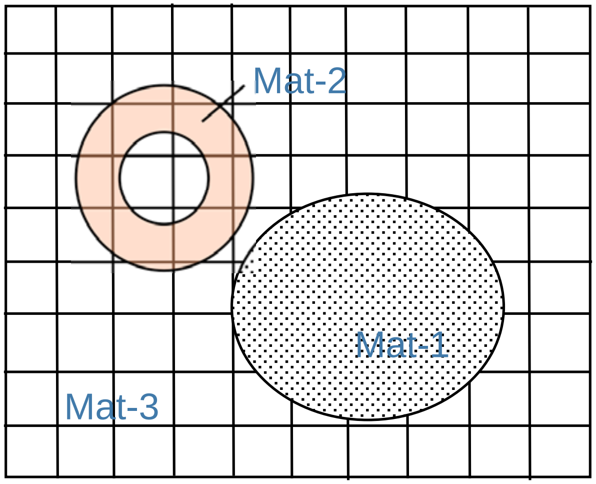
# Overview

- Flow Regimes
- Formulation Issues – mean strain rate with void compression
  - Basic Equations
  - Mixture Model
  - Void Compression
- Multimaterial Formulation – pressure equilibration extensions
  - Pressure Relaxation
  - Strain Partitioning (*omitted*)
- Multispecies Formulation
  - General EOS closure
  - Gamma-law gas EOS closure
- Hybrid models
- Summary

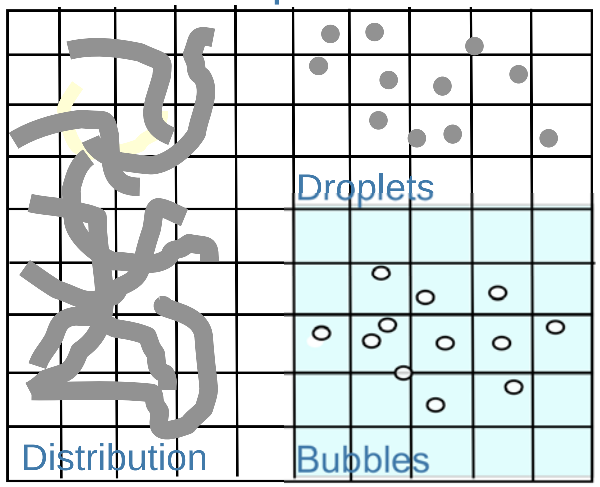
# Multifluid, multimaterial and hybrid problems span a spectrum of flow regimes

## Multimaterial/Multifluid



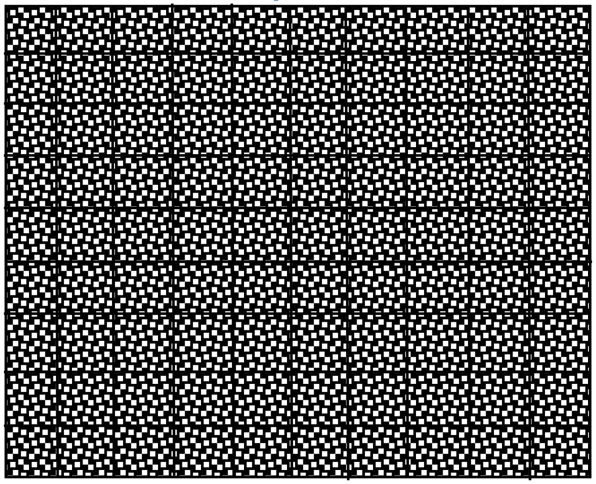

- Materials are immiscible
- Modest number of sharp interfaces are represented numerically
- Typically relies on the “mean-strain” approximation -- Each material has a unique stress and energy
- Incorporates treatment of void
- Sub-cell pressure equilibrium can be enforced, but it can be expensive to do so exactly
- Can also be extended to partition deviatoric strain

## Multiphase




- Large number of small material domains that are not resolved by a single element
- Too many interfaces to treat individually
- Relies on spatially-averaged mixture approximations, i.e., homogenized equations
- Multiphase fluid formulations may be used in the multimaterial limit, but still a research area with few production-level codes

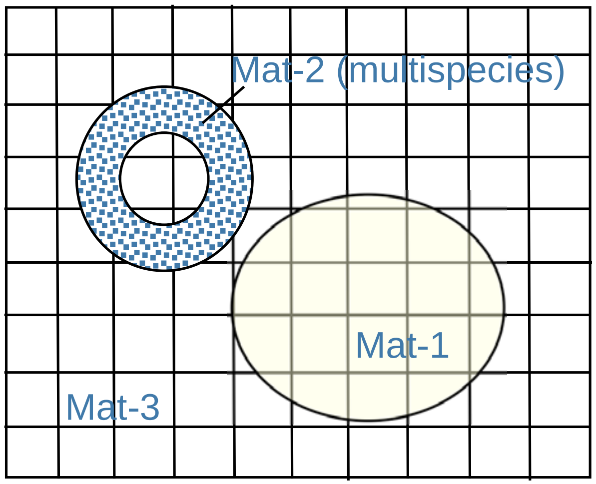
## Multispecies



- Components are completely miscible from a continuum view
- Typically applied to gases or materials at high temperatures, i.e., plasmas
- Use pressure-temperature equilibrium, i.e., Amagat model for gases
- Extensible to a carrier material with stress deviator and advective transport of multiple species
- Can include reaction chemistry

# The hybrid approach permits multiple mixture models to coexist

- Multimaterial and Multispecies
  - Individual materials can be designated as multispecies in the formulation
  - Requires material model definitions with multispecies EOS and species concentrations as state variables
  - Species cannot advect (or diffuse) between a multispecies material and “conventional” material

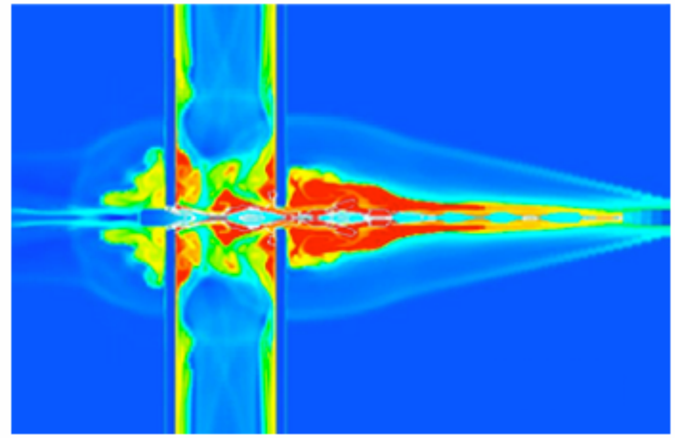



- Multimaterial and Multiphase
  - Multiphase materials, represented via homogenization, may be used in the multimaterial formulation, e.g., embedded rebar
  - State variables for multiphase (homogenized) materials can not mix with single phase materials or multispecies materials
- Materials can not be redefined as a problem evolves

# The development of multifluid/multimaterial methods have evolved with volume-tracking

- KRAKEN, de Bar (1974)
- SLIC, Noh & Woodward (1976)
- Youngs (1982, 1987)
  Parker and Youngs (1992)
- MESA, Mandell, et al. (1989)
- CTH, McGlaun, et al. (1990),
  Bell & Hertel (1992)
- ALEGRA, Peery & Carrol (2000) } started ~ 1990
- ALE3D, Sharp (2004)
- LS-DYNA, Hallquist, et al. (~2005)

  … and too many others to mention here



- Virtually all these multimaterial codes rely on:
  - A Lagrangian phase and a volume-tracking/remap phase
  - Some form of Young's reconstruction algorithm
  - Onion-skin approach to reconstructing multiple material interfaces, i.e., order-dependent material advection