AURIGA "Unveiling the Riddles of Gas-Liquid Fluid Dynamics: Towards Novel Carbone Dioxide Absorption Systems" project: current status and perspectives

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Introduction. The transition toward a low-carbon society requires more effective technologies for CO_2 separation. Bubble columns are an attractive reactor configuration, particularly suitable for large-scale CO_2 absorption processes, due to their simple design, lack of moving parts, efficient gas–liquid mass transfer, and ease of scale-up [1]. Despite the simple column layout, the multiscale phenomena characterizing the flow are extremely complex and not yet fully understood [2]. Although it is widely accepted that local phenomena govern macroscopic behavior, a consistent framework to describe these multi-scale interactions is still lacking. As a result, current models rely largely on empirical or semi-empirical correlations, which are difficult to extend beyond the conditions for which they were developed. Within this context, the *AURIGA* project aims to develop a novel theoretical framework that establishes a rigorous link between local and global flow properties, enabling the a priori prediction of flow regimes. The proposed approach results in an analytical formulation of the bubble column operating curve (i.e., the relationship between global hydrodynamic parameters (Fig. 1)) while also capturing its inherently multi-dimensional nature. This framework is designed to describe the complex interdependencies between local and global flow characteristics across different flow regimes. To bridge the existing gap in understanding these interdependencies, dedicated experimental facilities are being developed, spanning scales from individual bubbles to full reactor systems.

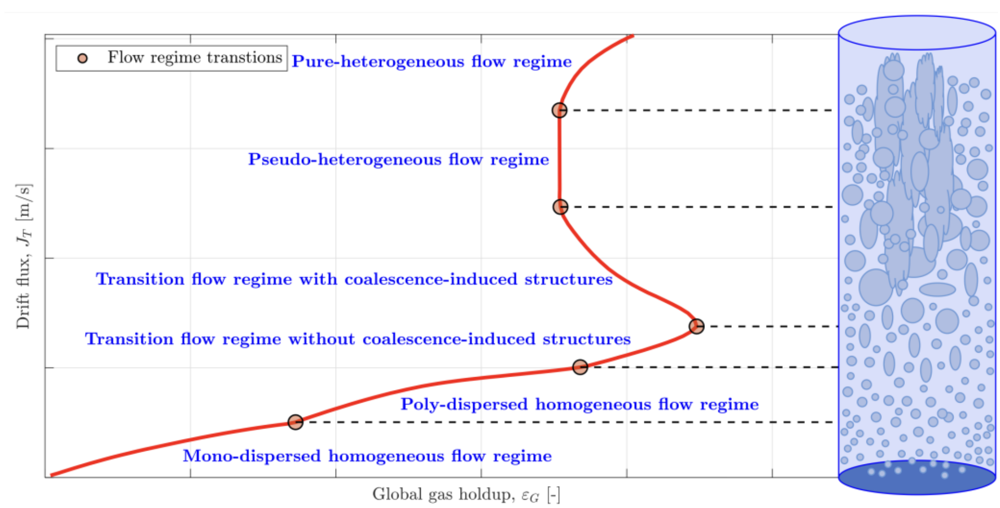

Figure 1. Bubble column operating curve. In the graphical representation of bubble column fluid dynamics (right), each vertical position represents a time-averaged condition for fixed drift-flux values [3].

In parallel, the project investigates the use of ionic liquids as alternative solvents in bubble column reactors for CO_2 capture. Ionic liquids are considered promising due to their negligible vapor pressure, high thermal and chemical stability, and tuneable physicochemical properties [4]. The project is expected to deliver both a physically based framework for multiphase reactor design and a proof-of-concept CO_2 absorption system based on ionic-liquid bubble columns. Overall, this approach has the potential to reduce the energy demand of current capture technologies and to provide a more robust basis for their scale-up.

Status of the research. The analytical formulation of the bubble column operating curve has been initiated by analyzing different methodologies to interpret and understand the physics underlying the transition from the poly-dispersed homogeneous flow regime to the transition flow regime without coalescence-induced structures. In parallel, a property-based methodology for the selection of ionic liquids has been developed, based on a sequential pre-screening of thermodynamic and transport properties to identify suitable candidates for CO_2 absorption. Two ionic liquids were selected, namely 1-butyl-3-methylimidazolium tetrafluoroborate ([Bmim][BF_4]) and 1-ethyl-3-methylimidazolium acetate ([Emim][OAc]). The experimental analysis began at the bubble scale, focusing on single-bubble shape and terminal velocity in different [Bmim][BF_4]-water and [Emim][OAc]-water mixtures, as well as on mass transfer characterization to determine the liquid-side mass transfer coefficient.

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