Experimental study of bubbles behaviour

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Outline

Biphasic flows: Motivation

Space technology:

- Bioreactors: homogeneous oxygenation of cell growing medium.
- Chemical contactors: maximization of contact area to volume ratio.
- Environmental Control and Life Support Systems: improved efficiency and reliability.

Fundamental Physics:

- Questions on the Gas-Liquid interface: topological singularities (coalescence, pinch-off).
- Questions on collective behaviour: hydrodynamic interactions, clustering, transport.

Generation of bubbles in μg

In normal gravity. . .

http://www.jupiterimages.com/

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Generation of bubbles in μg

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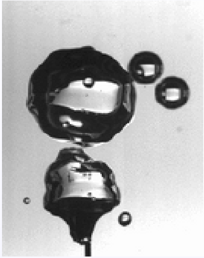
In microgravity...



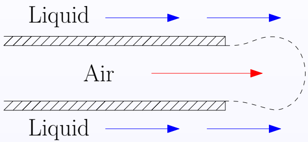
http://www.ieec.fcr.es/

...there is no buoyancy force.
$\Rightarrow$ Difficult control of size and frequency!

Which methods can we use to create bubbles?

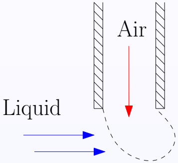
Coflow & Crossflow configurations

Coflow



- The Gas-Liquid interface tends to keep spherical shape. When the air zone is growing up, the liquid coming from the back breaks the interface.

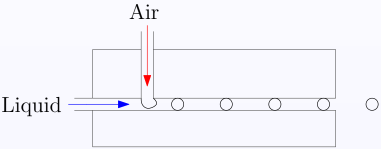
Crossflow



- The liquid forces the bubble to high lateral stresses that can break the Gas-Liquid interface.

BUBGEN (BUBble GENerator)

Main idea: A simple device to inject bubbles in a liquid using crossflow configuration inside a capillary T-junction.



J. Carrera et al. *"Generation of a monodisperse microbubble jet in microgravity"*, submitted to AIAA Journal, 2007.

- Bubble size is fixed essentially by capillary diameter.
- We can control the frequency of bubble formation, by varying liquid (Q_l) and gas (Q_g) flow rates.
- Insensitive to gravity level for low Bond numbers ($Bo = \rho g L^2/\sigma \ll 1$).

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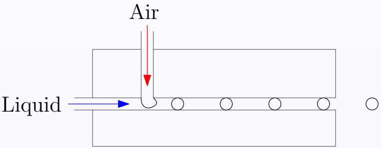

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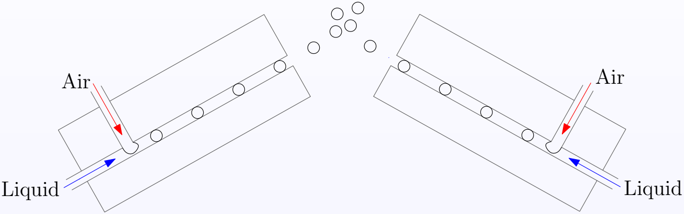
More info can be seen at Santiago Arias presentation *"Experimental characterization of a microbubble injector"*.

BUBCOA (BUBble COAlescence)

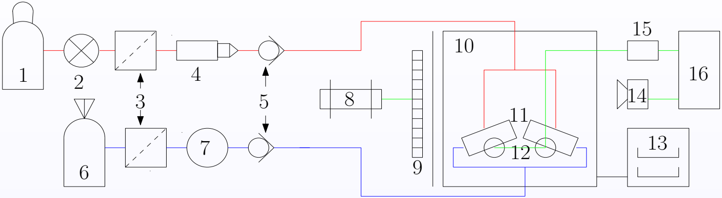
Main Idea: Bubble coalescence and jet impact by placing two BUBGEN injectors face to face, varying the angle of incidence.



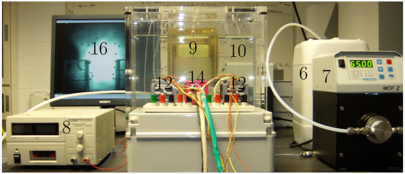
Main Goals:

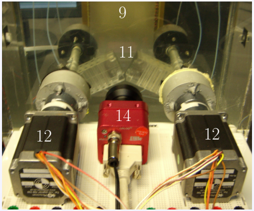
1. Impact of a large number of bubbles at different angles of incidence, and study the effects of bubble sizes, velocities and angles on coalescence.
2. Study the dynamics and interactions of bubble jets.

Experimental Setup



Connections: — Air, — Liquid, — Electric.
1: Air bottle, 2: Pressure regulator, 3: Filters, 4: Choked orifice, 5: Anti-return valve, 6: Liquid tank, 7: Pump, 8: DC supply, 9: Leds, 10: Cavity, 11: Injectors, 12: Motors, 13: Tank, 14: Camera, 15: μcontroller, 16: PC.

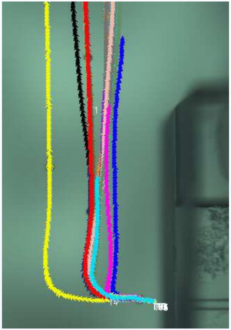


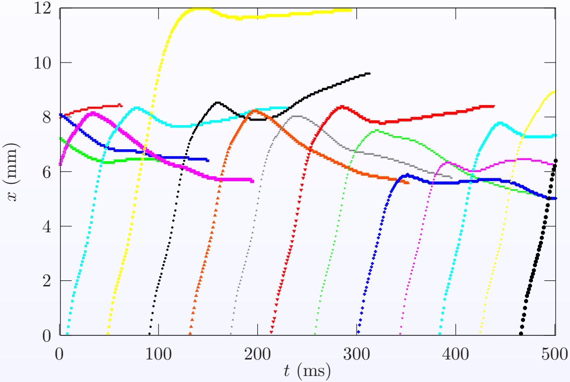


Experimental results in $1g$

$Q_l = 50$ ml/min, $Q_g = 10$ ml/min, angle=22°.

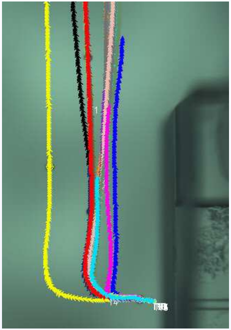
Bubble trajectories: $x(t)$

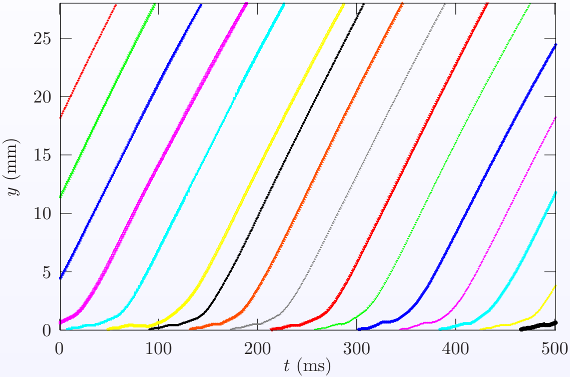




$Q_g = 0.5$ ml/min, $Q_l = 16.7$ ml/min.

Bubble trajectories: $y(t)$



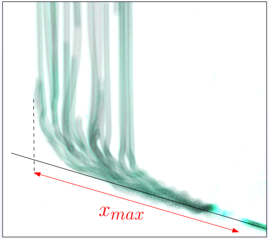


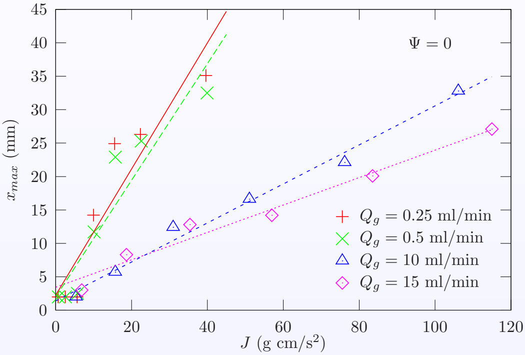
$$Q_g = 0.5 \text{ ml/min}, \; Q_l = 16.7 \text{ ml/min}.$$

Maximum distance reached

Neglecting the gas density, the injected momentum rate can be computed as

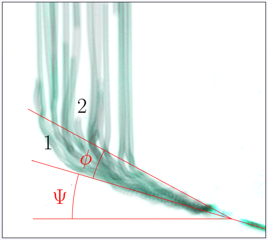
$$J = \rho_l Q_l (Q_l + Q_g)/A$$

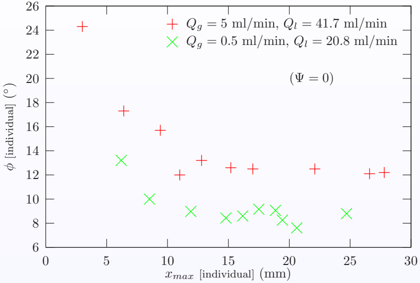


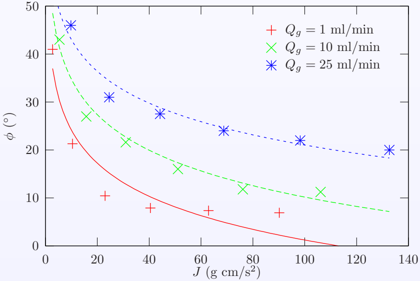


Buoyancy and turbulent zones

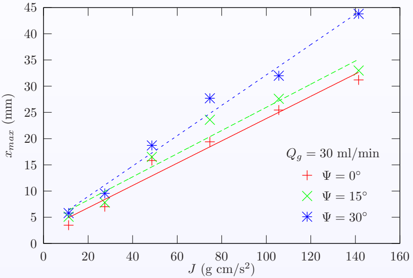
Distinction of two principal zones: in the first one (1) the turbulence is important, in the second one (2) the buoyancy is predominant.

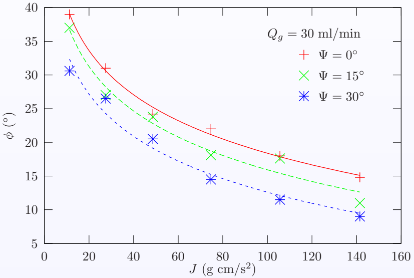






Influence on Ψ: $x_{max}(J)$, $\phi(J)$





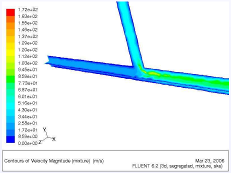
Increasing Ψ the maximum reach x_{max} increases for a fixed value of J, and the angle ϕ decreases.

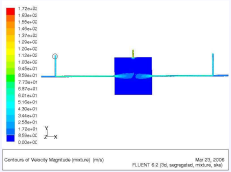
Conclusions:

- New setup design to study bubble dynamics and coalescence.
- Bubble size, frequency and angle of incidence can be controlled.
- Several tests carried out in $1g$ for further use in $0g$.

Further work:

- Analysis of the relevant parameters in jet and bubble dynamics and coalescence.
- Theoretical approach and CFD analysis in $1g$ and $0g$.





- Experiment in microgravity platforms.

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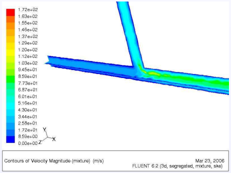

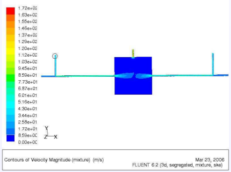

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Thank you!