# Cavity collapse near porous plates

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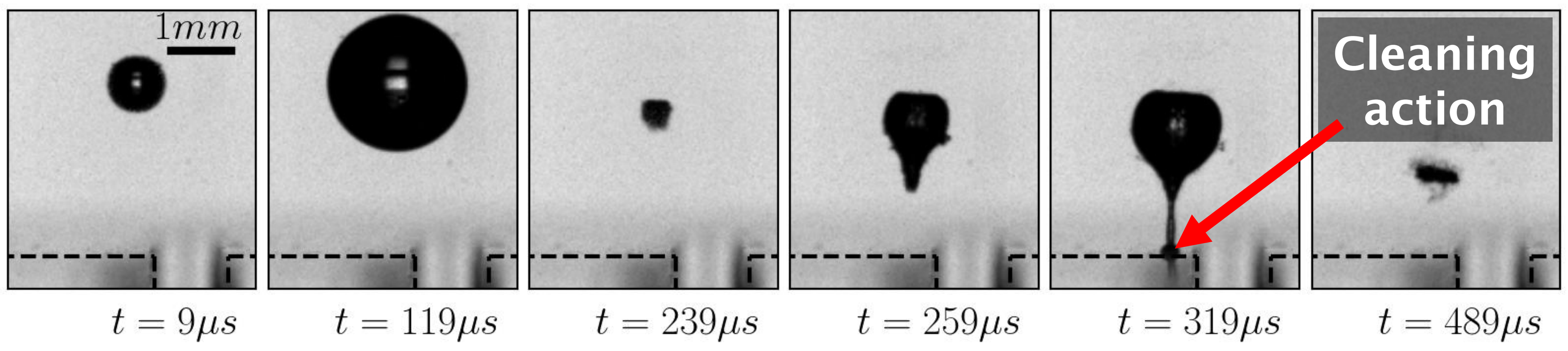
## Introduction

Collapsing bubbles can be used as a practical cleaning method[1] for complex geometries that are now more common due to developments of new manufacturing methods such as 3D printing.

A bubble collapsing in an infinite fluid collapses symmetrically. However, when a bubble collapses near a solid boundary, the bubble collapses highly asymmetrically and forms a high-speed jet that can be used to clean the surface.

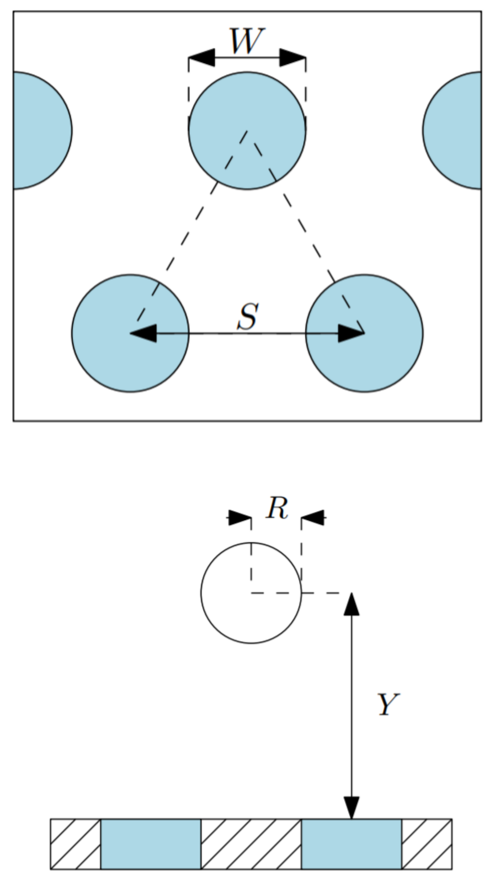



## Problem Definition

Porous materials, such as filters, are common and can be treated with ultrasonic cleaning[2]. We want to understand how these materials affect bubbles collapsing nearby.

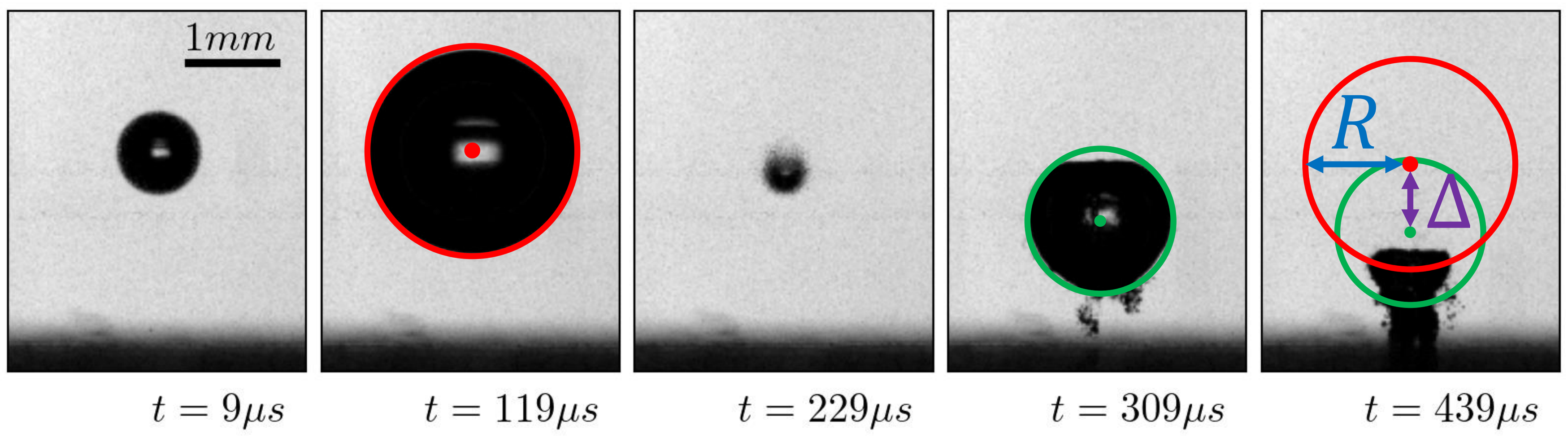
To do this, we investigate the simplest form of porous material: a thin plate with circular through-holes (pictured right).

Qualitatively, we would predict that a porous plate would cause a stronger asymmetry than a solid plate because it is effectively somewhere between a solid plate and an open fluid.



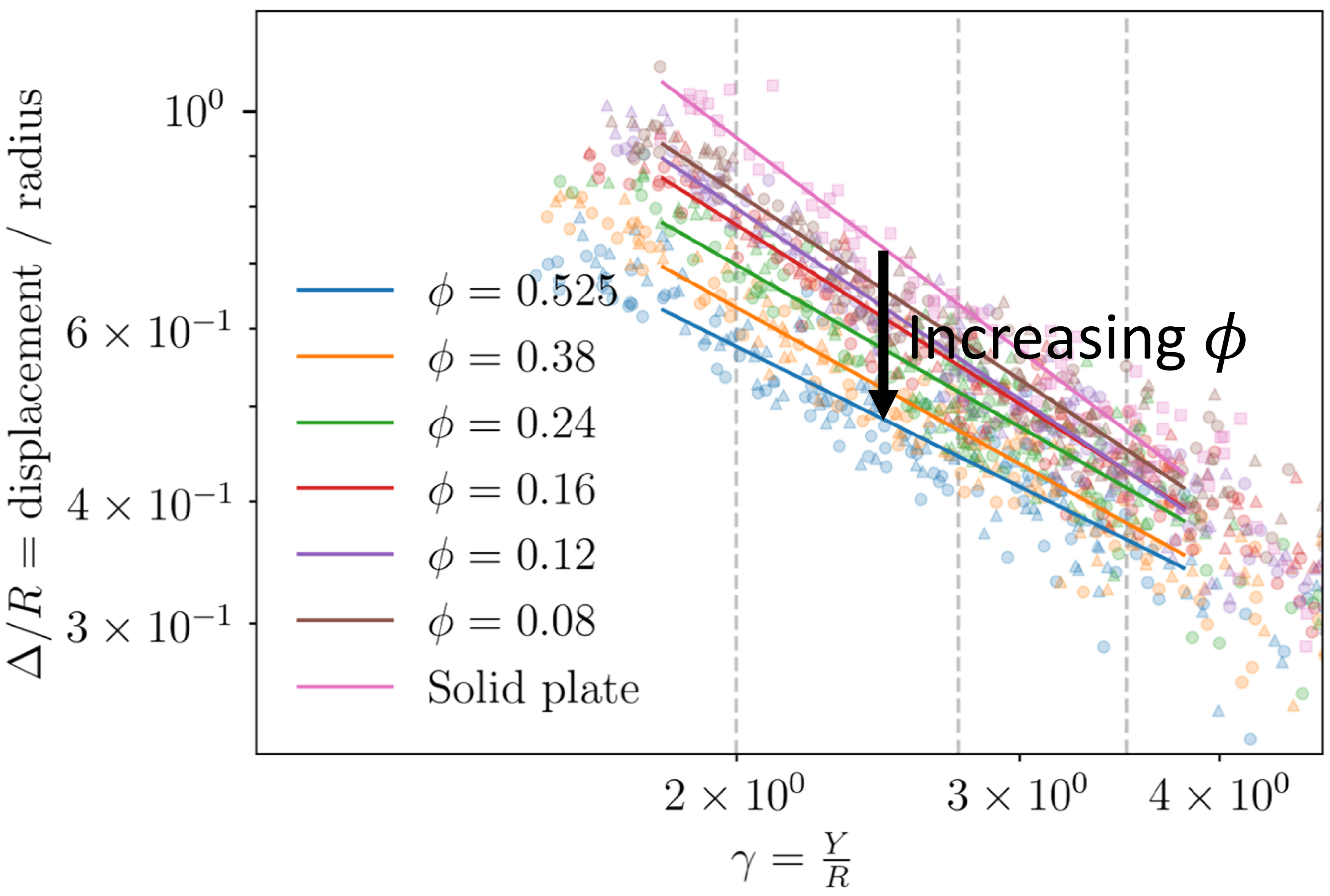

## Measuring Displacement

Bubble collapses close to boundaries have a stronger asymmetry than collapses far from boundaries. We quantify the asymmetry by measuring the displacement ($\Delta$) of the bubble between its first ($R$) and second radius maxima.




## Effect Of Standoff And Void Fraction

This plot shows the variation of dimensionless displacement with dimensionless standoff distance $\gamma$.




For each plate, as the standoff distance increases, the bubble displacement decreases.

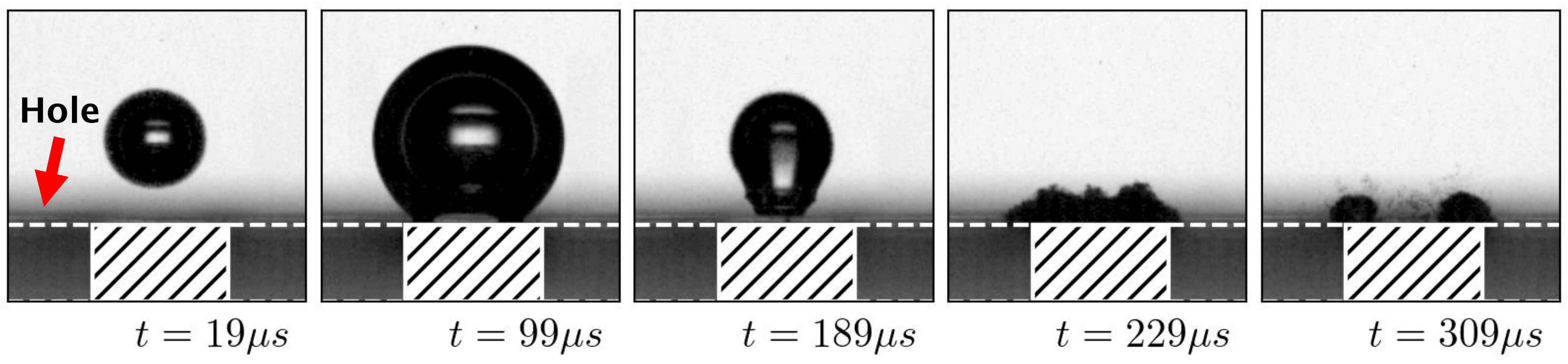
A solid plate causes the largest bubble displacements, with the bubble displacement decreasing as the void fraction of the plate, $\phi$, increases.

Essentially, the less plate there is, the more symmetric the bubble collapse.

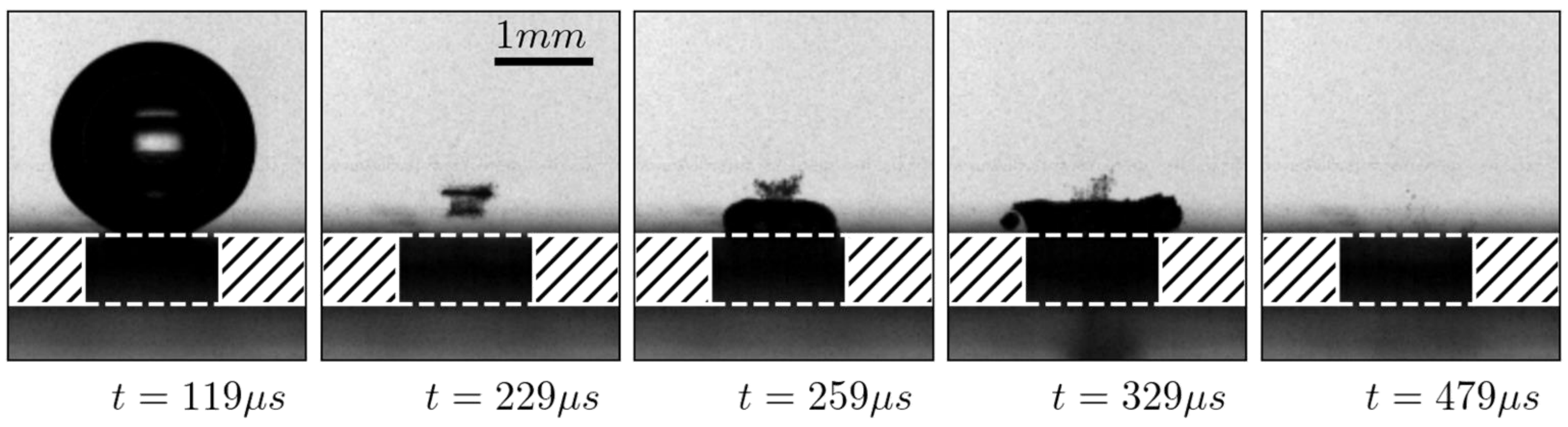
## Effect Of Horizontal Position

At the extremes, bubbles can be above a hole or between three holes. Surprisingly, these two cases produce indistinguishable collapse displacements.

Bubbles expand more towards holes when collapsing between holes.

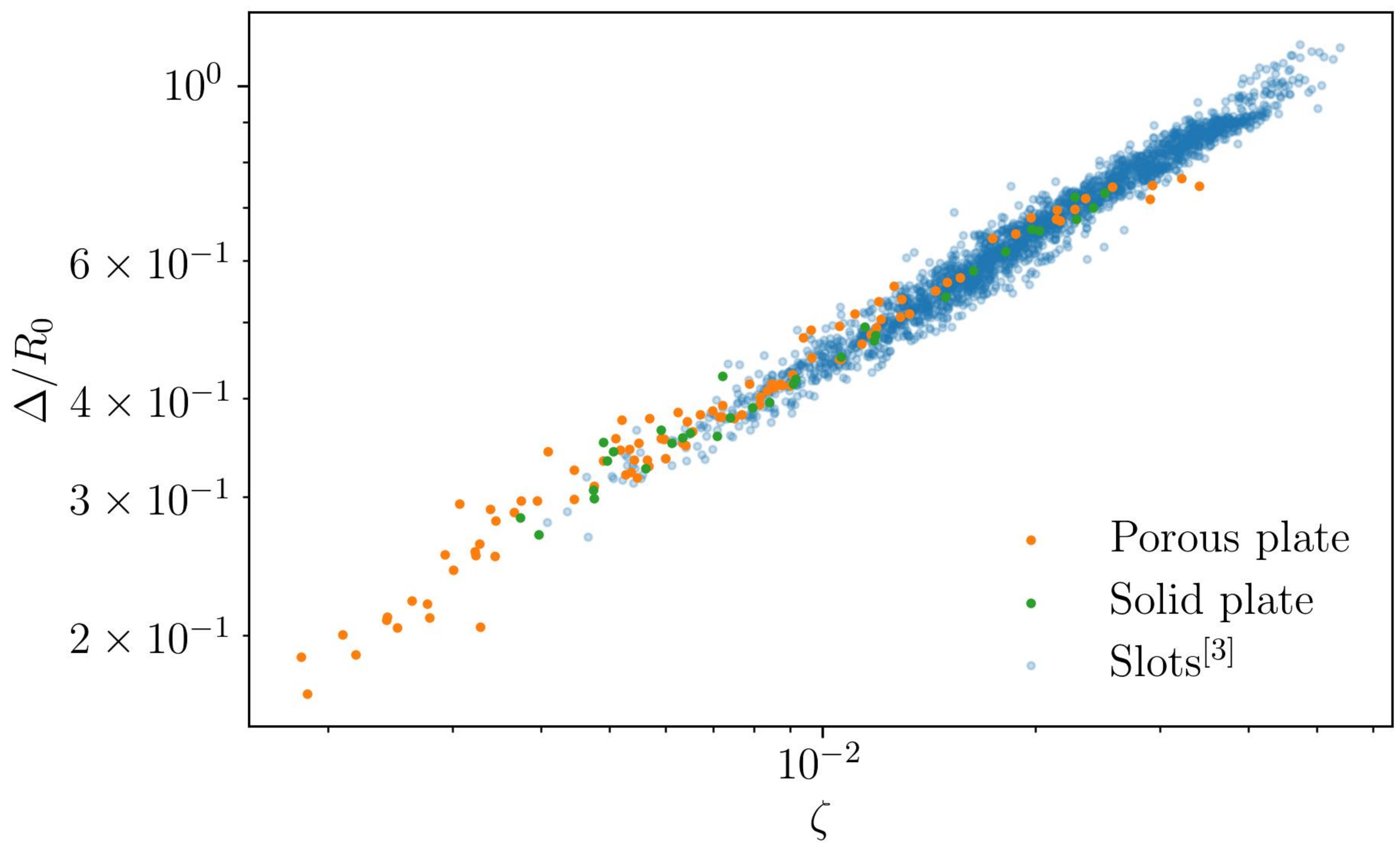



When the bubble is above a hole, it collapses through the hole.




## Numerical Modelling

We have extended our previous BEM model[3] to produce a parameter $\zeta$ that has been used to predict collapse properties.[4] $\zeta$ is a measure of the asymmetry present in the system. This plot (below) shows how our model for $\zeta$ causes the dimensionless bubble displacement to collapse onto a single curve.




## Conclusion

In this work, we have shown how holes in a boundary reduce the asymmetry of bubble collapse near a boundary. Surprisingly, the horizontal position of the bubble does not have a significant effect. We have developed a numerical model capable of predicting this behaviour that we will use to quantify the relationship between void fraction and bubble displacement.

## References

[1] B. Verhaagen, T. Zanderink, D. Fernandez Rivas, Ultrasonic cleaning of 3D printed objects and Cleaning Challenge Devices. *Applied Acoustics*. **103**, 172–181 (2016).
[2] F. Reuter, S. Lauterborn, R. Mettin, W. Lauterborn, Membrane cleaning with ultrasonically driven bubbles. *Ultrasonics Sonochemistry*. **37**, 542–560 (2017).
[3] E. D. Andrews, D. Fernandez Rivas, I. R. Peters, Cavity collapse near slot geometries. *Journal of Fluid Mechanics*, **901**, 29–29. (2020).
[4] O. Supponen *et al.* Scaling laws for jets of single cavitation bubbles. *Journal of Fluid Mechanics*. **802**, 263–293 (2016).

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