– Workshop on Volcanoacoustics, July 25-26th, Sakurajima, Japan –

Session 1-1

Impulsive acoustics (explosions and bubble bursting)

Sharing our experiences and surprises with bubbles in the laboratory !

by Mie Ichihara, Laura Pioli & Valérie Vidal

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Session 1-1

Impulsive acoustics (explosions and bubble bursting)

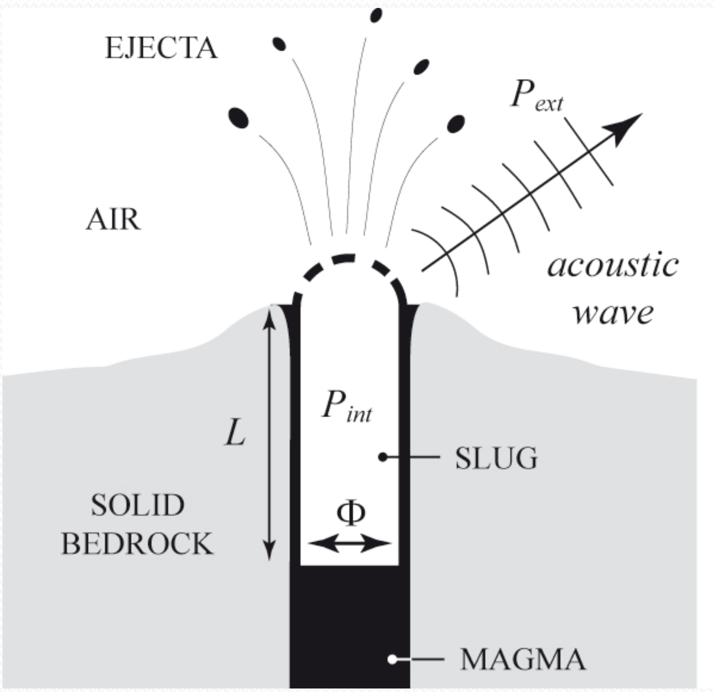
Sharing our experiences and surprises with bubbles in the laboratory !

(1) One bubble: Rupture process and amplitude effect (Valérie Vidal)
(2) Two bubbles: Bubble oscillation and interaction with a resonator (Mie Ichihara)
(3) Too many (?) bubbles: Slug and fluid column oscillations (Laura Pioli)

An interactive session: 10' each + 30' discussion

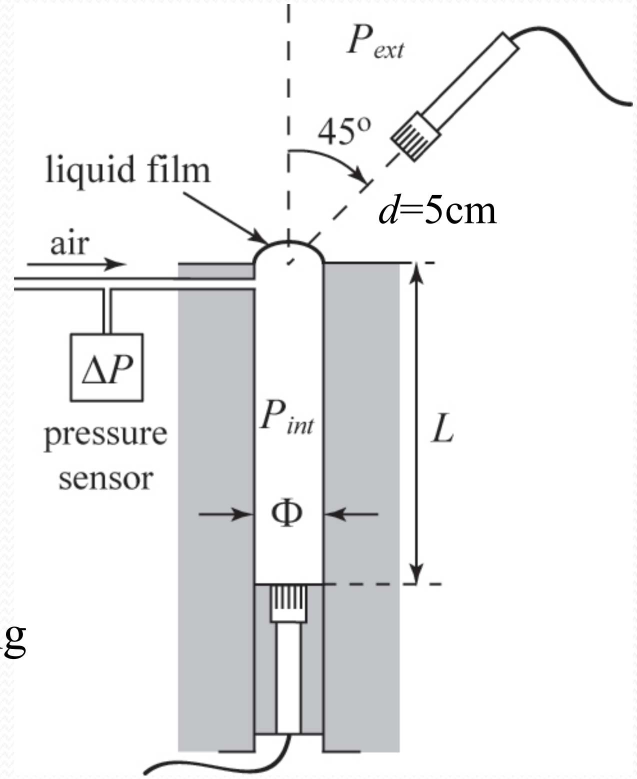
A simple experiment ?

J.-C. Géminard, T. Divoux, Lab. Physique, ENS de Lyon (France)
M. Ripepe, Univ. degli Studi di Firenze (Italy)
D. Legrand, Dep. Volcanología, UNAM (Mexico)
F. Melo, Lab. Física Non Lineal, Univ. Santiago de Chile (Chile)



model

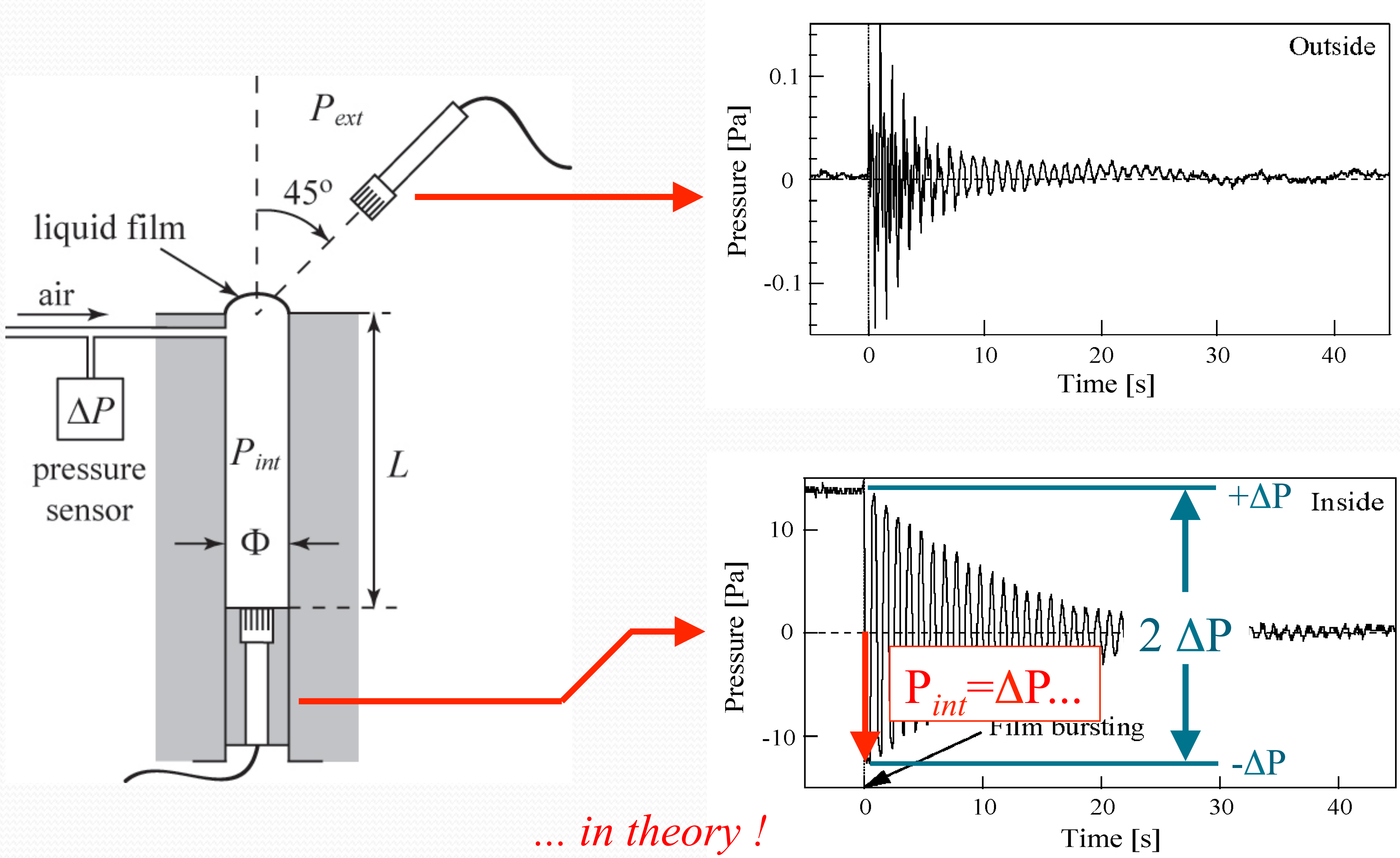
- initial overpressure ΔP
- drainage and film bursting
- we monitor P_{int} and P_{ext}



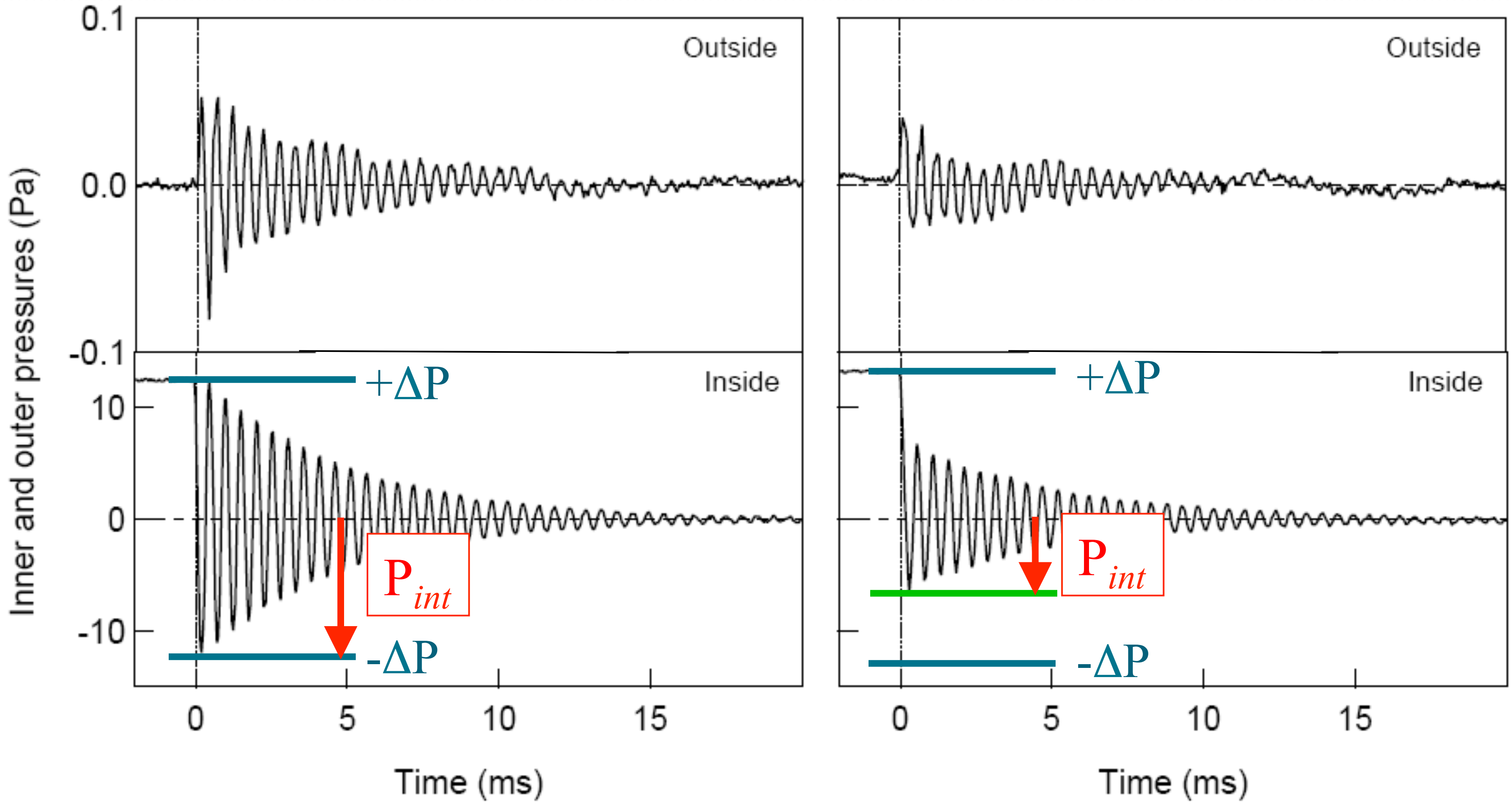
Tube : cylindrical cavity (L=2-23cm, Φ=6, 8 or 10mm, $\alpha=L/\Phi$)

Liquid film : soap+water / soap+water+glycerol

Acoustic signal associated with bubble bursting

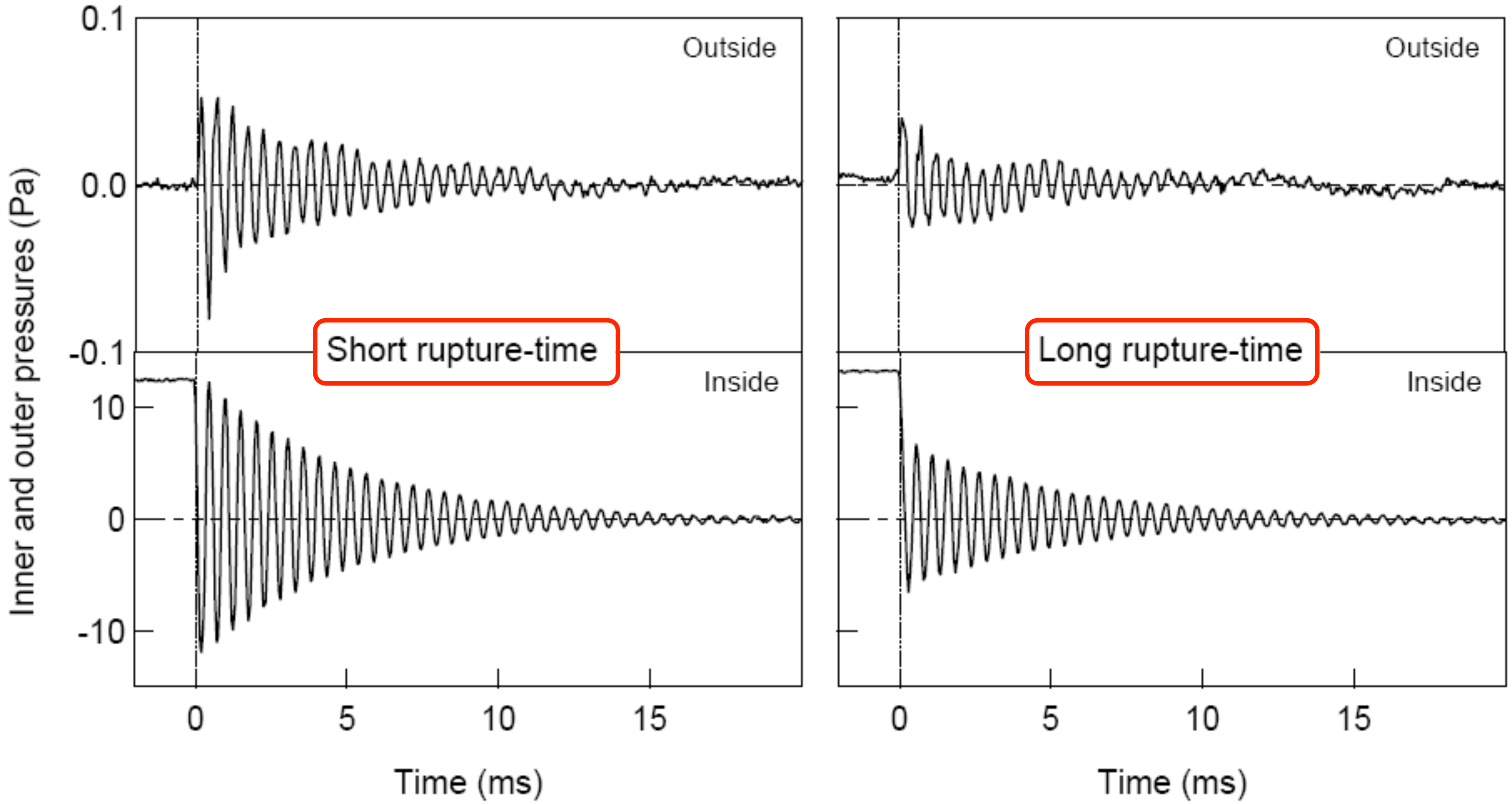


Acoustic signal associated with bubble bursting



Not reproducible without precaution !

Acoustic signal associated with bubble bursting



→ Importance of the film rupture time !!

What controls the acoustic signal amplitude and waveform ?

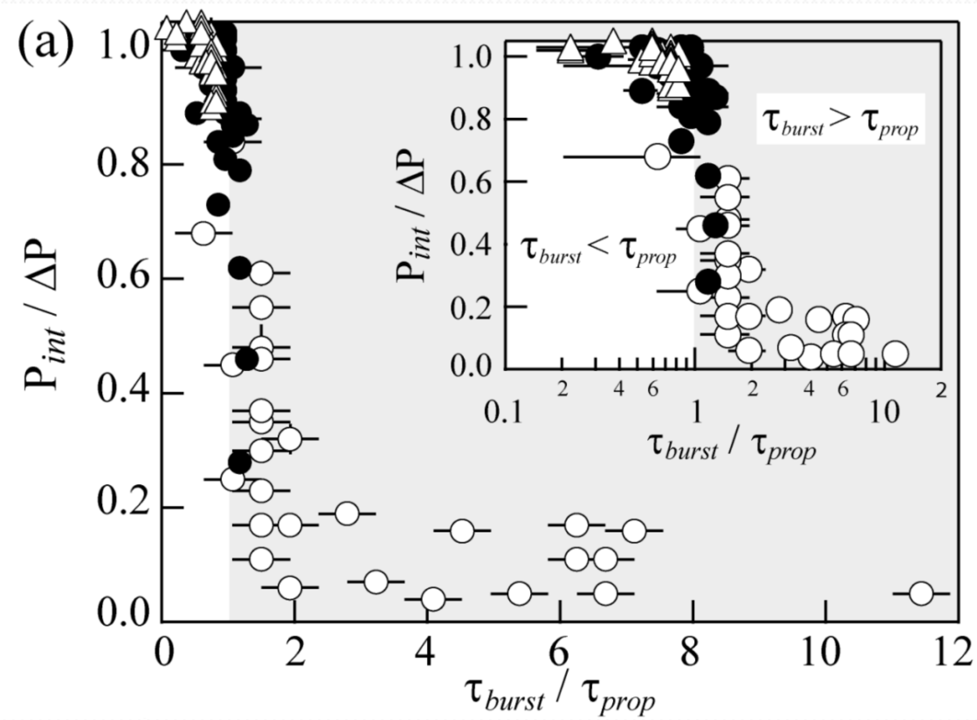
The film rupture time (and bubble shape) controls :

(1) the amplitude of the acoustic signal

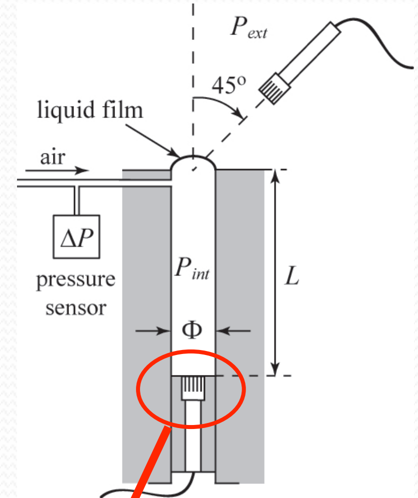
(2) the waveform

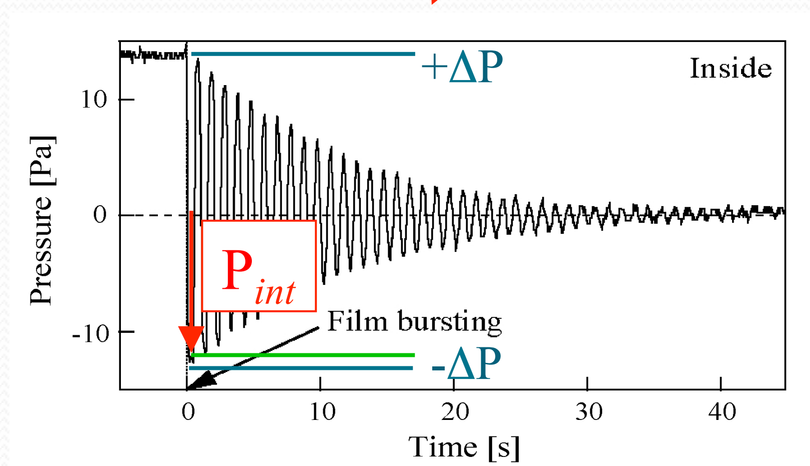
(1) Influence of the film rupture time

- Results for soap films



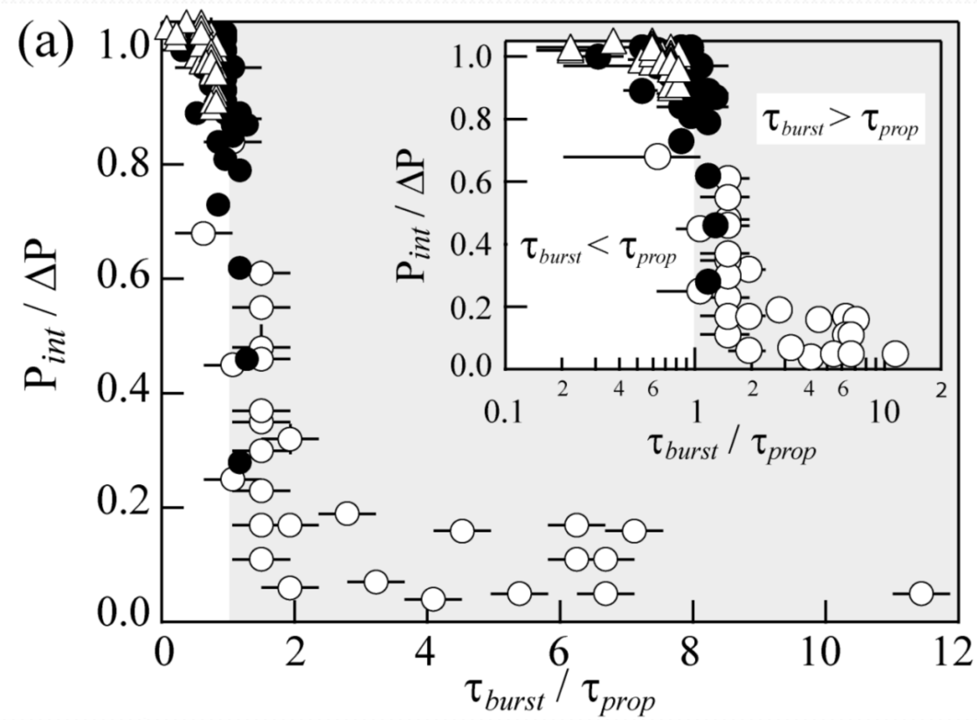
[Symbol,α]: [o,2]; [•,8]; [△,23].





(1) Influence of the film rupture time

- Results for soap films



[Symbol,α]: [o,2]; [•,8]; [△,23].

Competition between two characteristic times

wave propagation

$$\tau_{prop} \sim \frac{2L}{c}$$

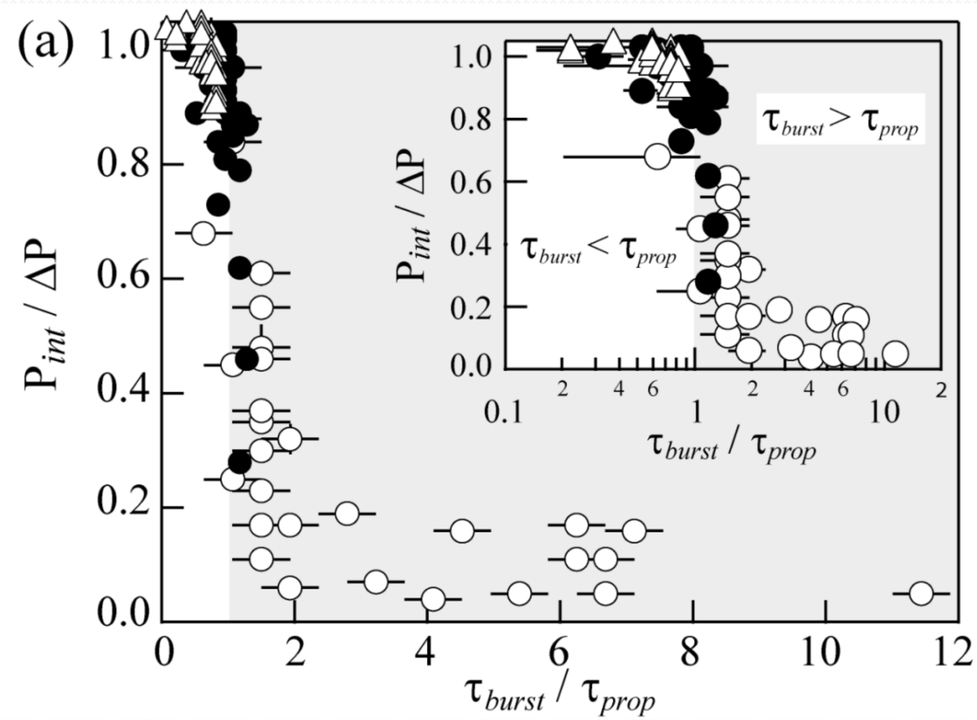
VS.

$$\tau_{burst}$$

film rupture time

(1) Influence of the film rupture time

- Results for soap films



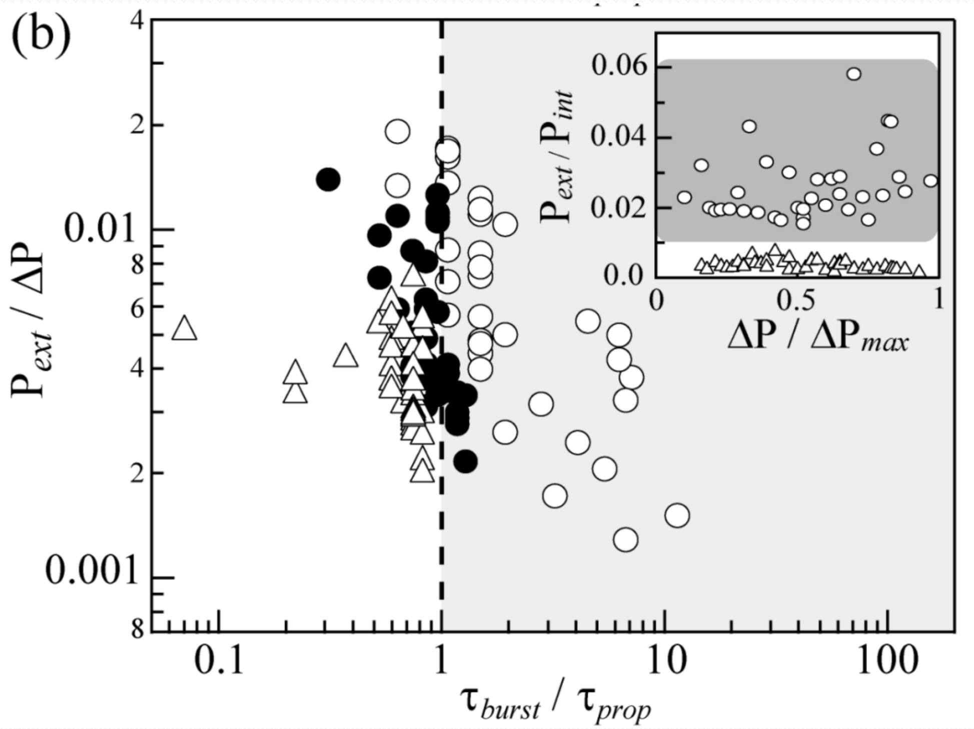
[Symbol,α]: [o,2]; [•,8]; [△,23].

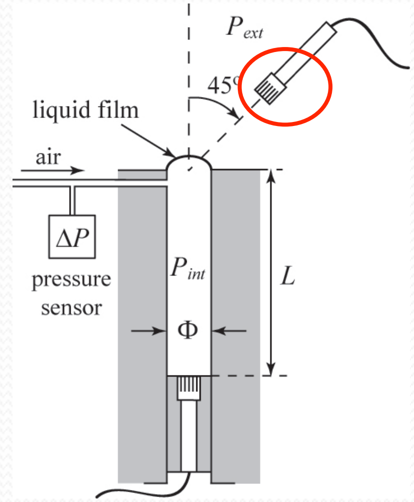
When $\tau_{burst} / \tau_{prop} > 1$
(« slow » rupture),
the amplitude of the acoustic signal produced at bursting drastically decreases !

[*Geophys. Res. Lett.* **37**, L07302, 2010]

(1) Influence of the film rupture time

- Results for soap films





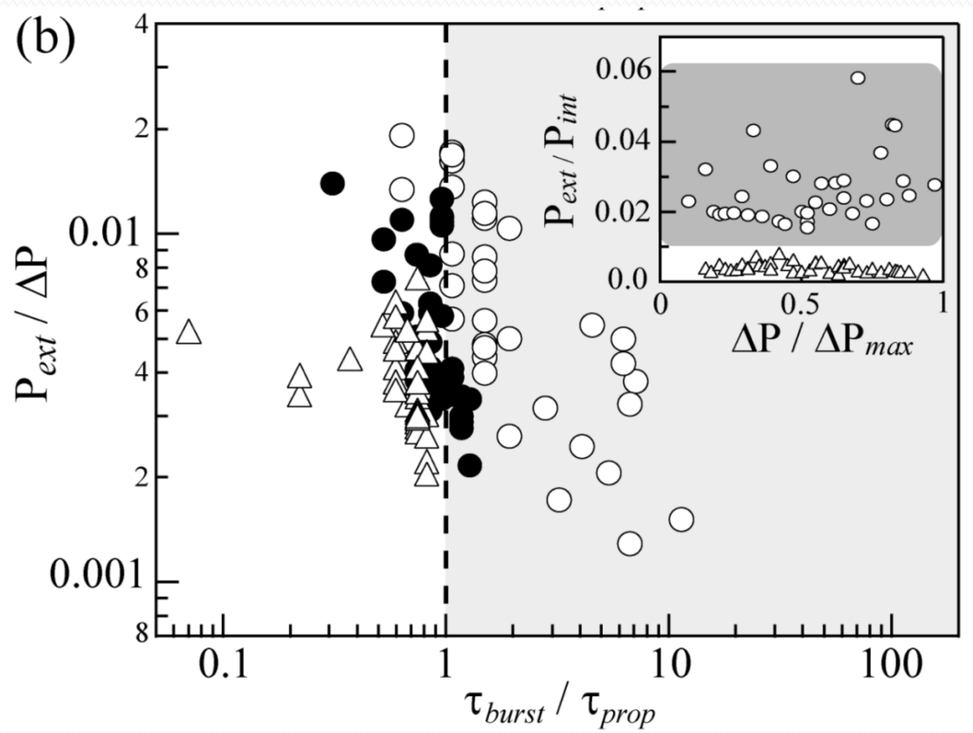
[Symbol,α]: [o,2]; [•,8]; [△,23].

Even more complicated !

- reflexion
- viscous dissipation
- radiation
- etc...

(1) Influence of the film rupture time

- Results for soap films



The energy partition is more efficient for small aspect ratio (dark gray zone)

[Symbol,α]: [o,2]; [•,8]; [△,23].

What controls the film opening dynamics ?

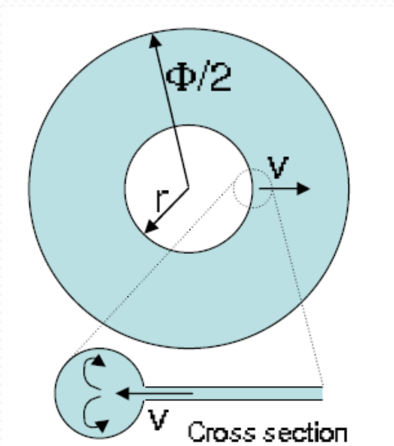
Inertial regime

vs.

The kinetics is entirely driven by inertia

$$v = \sqrt{\frac{2\gamma}{\rho e}}$$

constant velocity



Note: conservation of momentum... factor ½ if conservation of energy !! (due to the rim dynamics)

[Culick, 1960; Frankel & Mysels, 1969]

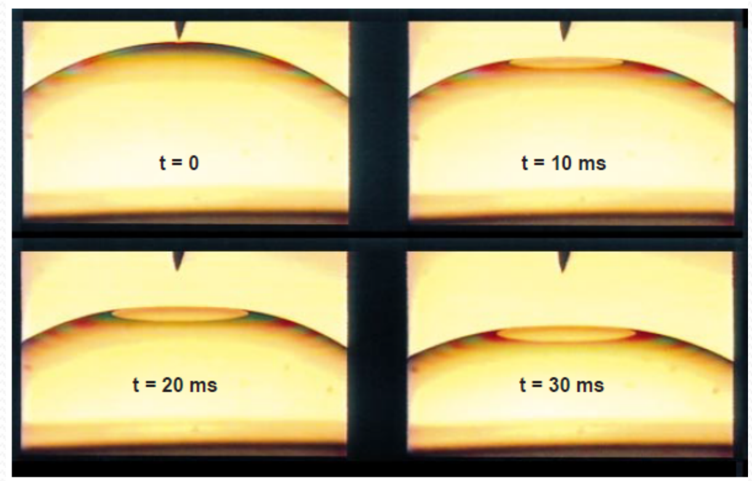
Viscous regime

Viscous dissipation dominates

$$R(t) = R_0 e^{\frac{t}{\tau}}$$

exponential hole opening

with $\tau = \frac{\eta e}{\gamma}$



[Debregeas et al., 1995; 1998; Roth et al., 2005]

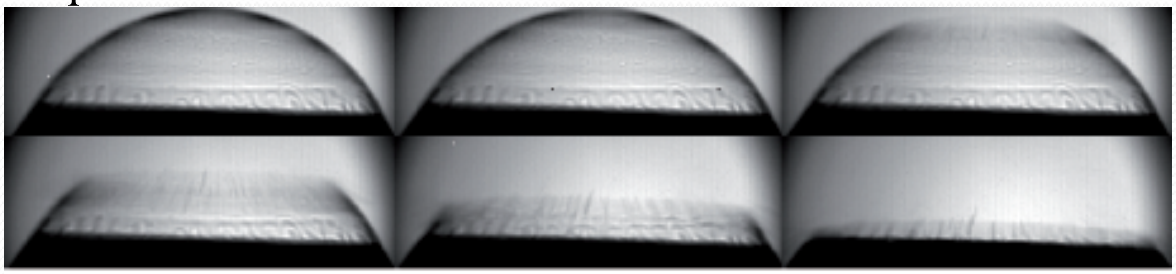
[*γ = surface tension / ρ = density / e = film thickness / η = dynamic viscosity*]

Inertial vs. viscous regime

[ΔP=20Pa, Φ=8cm, 8000 img/s
for both experiments]

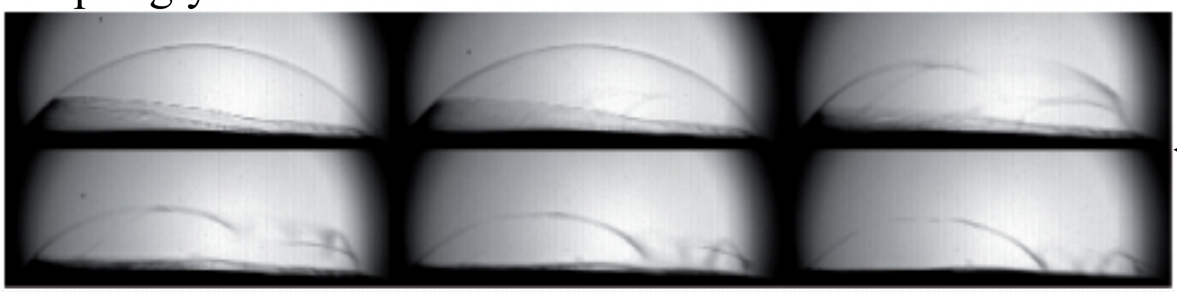
- Role of viscosity

soap

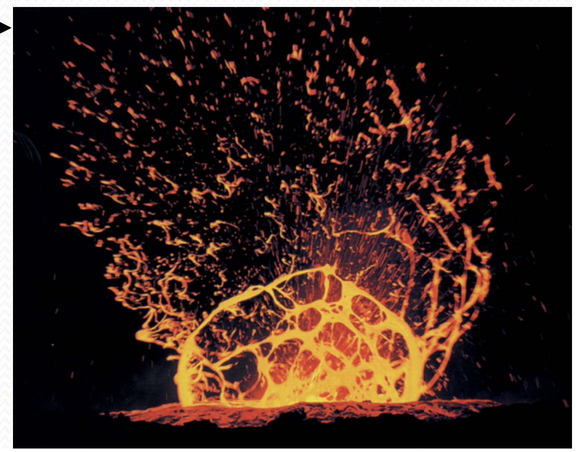


symmetric opening

soap + glycerol



different dynamics !



Kilauea (Hawai'i)

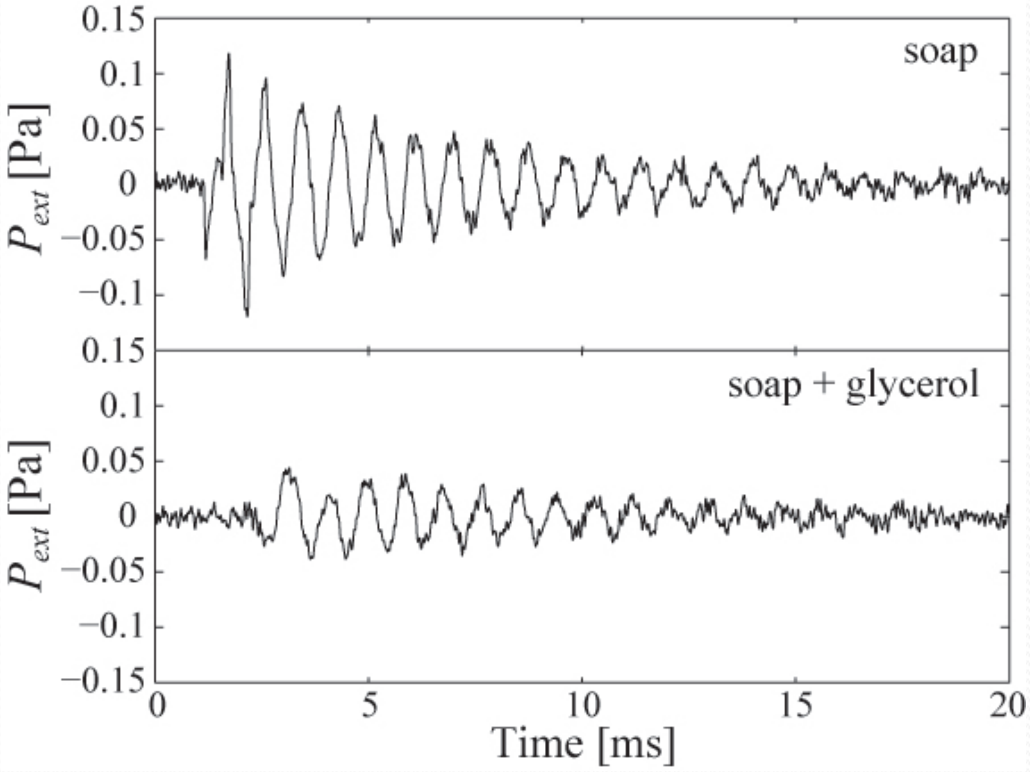
For very viscous films, the film opens
by stretching filaments

Inertial vs. viscous regime

- Role of viscosity

soap

soap + glycerol



The amplitude of the acoustic signal decreases !

What controls the film opening dynamics ?

vs.

Inertial regime

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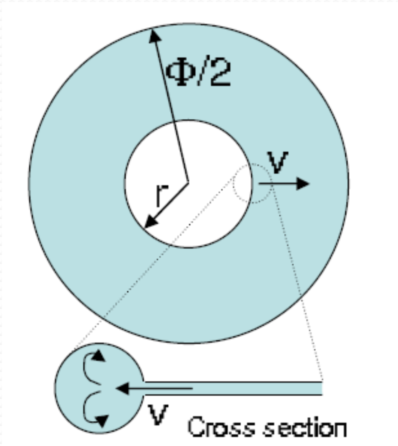
constant velocity



Note: conservation of momentum... factor ½ if conservation of energy !! (due to the rim dynamics)

[Culick, 1960; Frankel & Mysels, 1969]

Viscous regime

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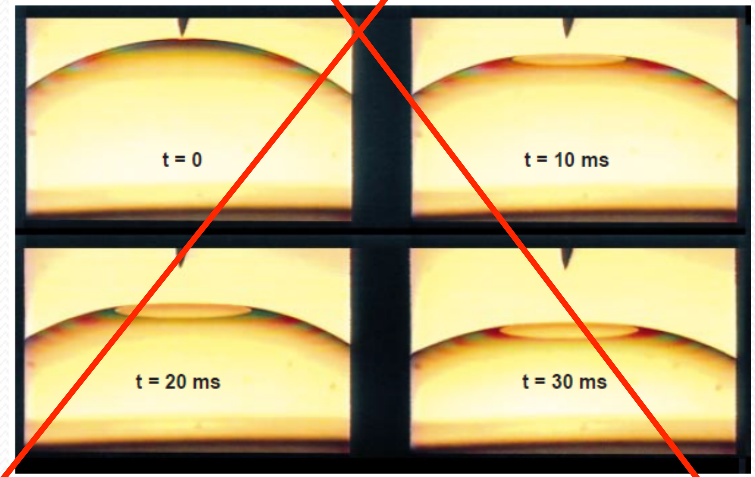
exponential hole opening

with $\tau = \frac{\eta e}{\gamma}$

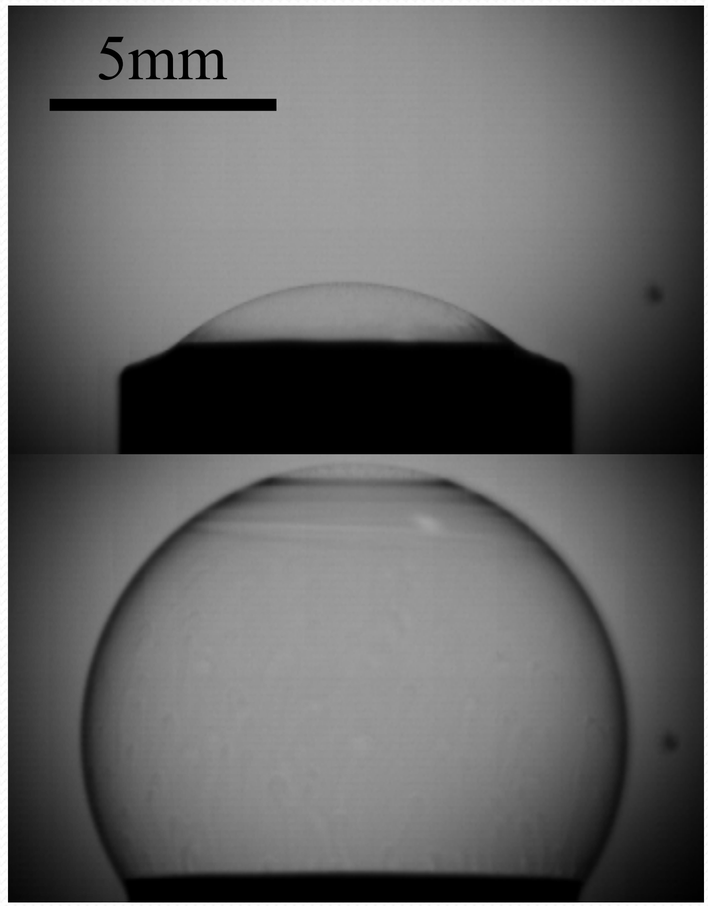


[Debregeas et al., 1995; 1998; Roth et al., 2005]

[*γ = surface tension / ρ = density / e = film thickness / η = dynamic viscosity*]

(2) Influence of the bubble shape

Same initial overpressure, two possible bubble geometries !



ΔP=15Pa
[Exp.A]

MOVIE

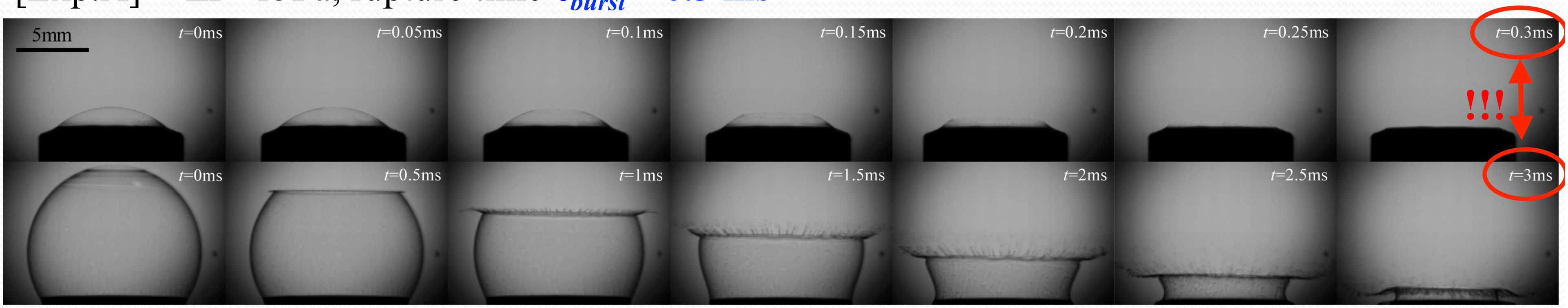
ΔP=15Pa
[Exp.B]

MOVIE

[ΔP=15Pa, Φ=1cm, *L*=15cm, 60000 img/s]

(2) Influence of the bubble shape

[Exp.A] – ΔP=15Pa, rupture time τ_{burst} **= 0.3 ms**



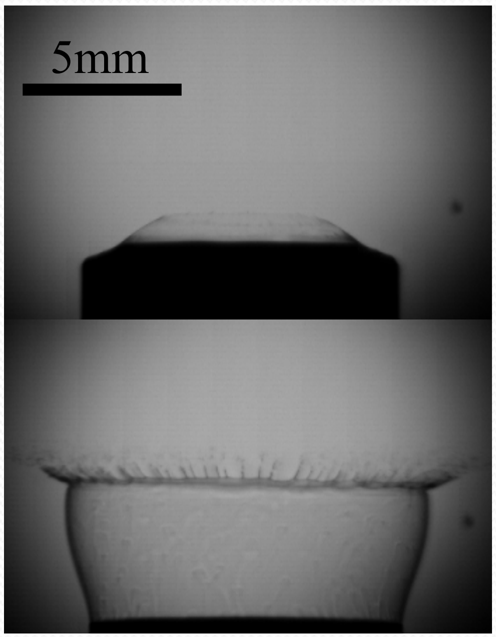
[Exp.B] – ΔP=15Pa « overshoot », rupture time τ_{burst} **= 3 ms**

– the film shape is different
– the rupture time is an order of magnitude different !

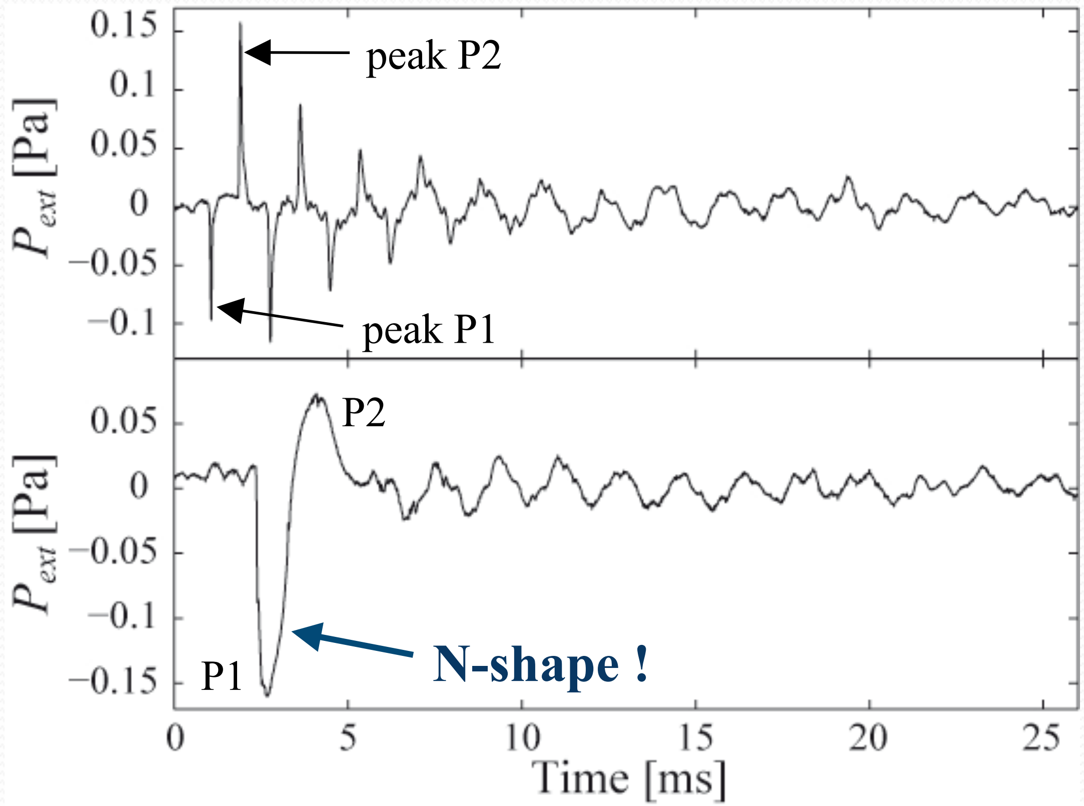
Influence on the acoustic waveform ?

Influence on the acoustic waveform

- Same initial overpressure...

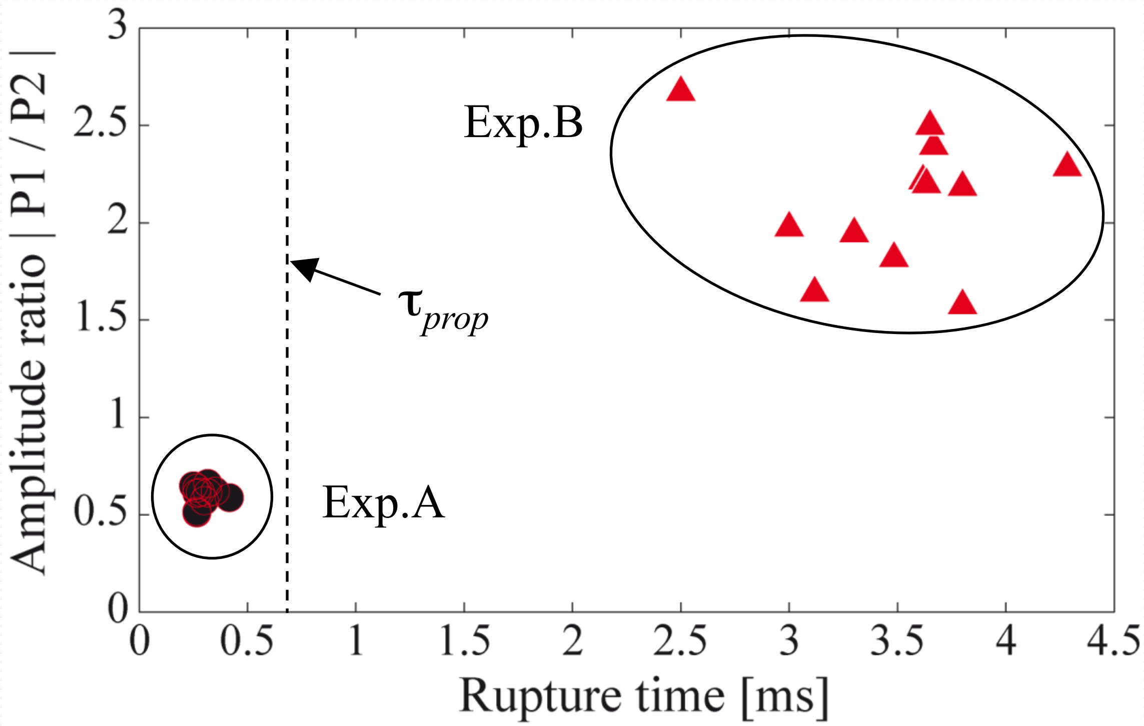


[ΔP=15Pa, Φ=1cm, *L*=15cm]



... different acoustic waveforms !

Influence on the acoustic waveform



Amplitude ratio of the two first peaks

... to be continued

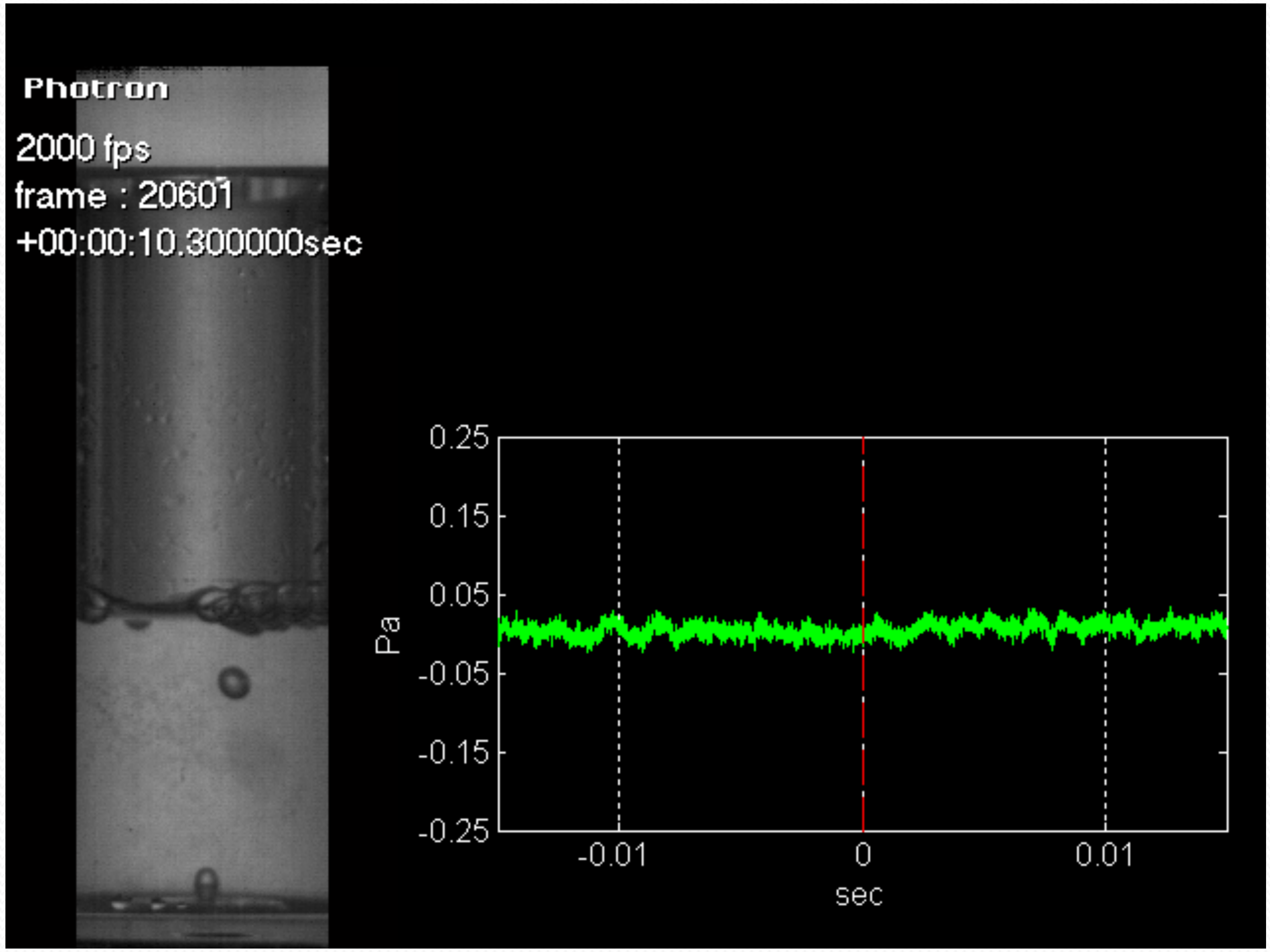
In conclusion...

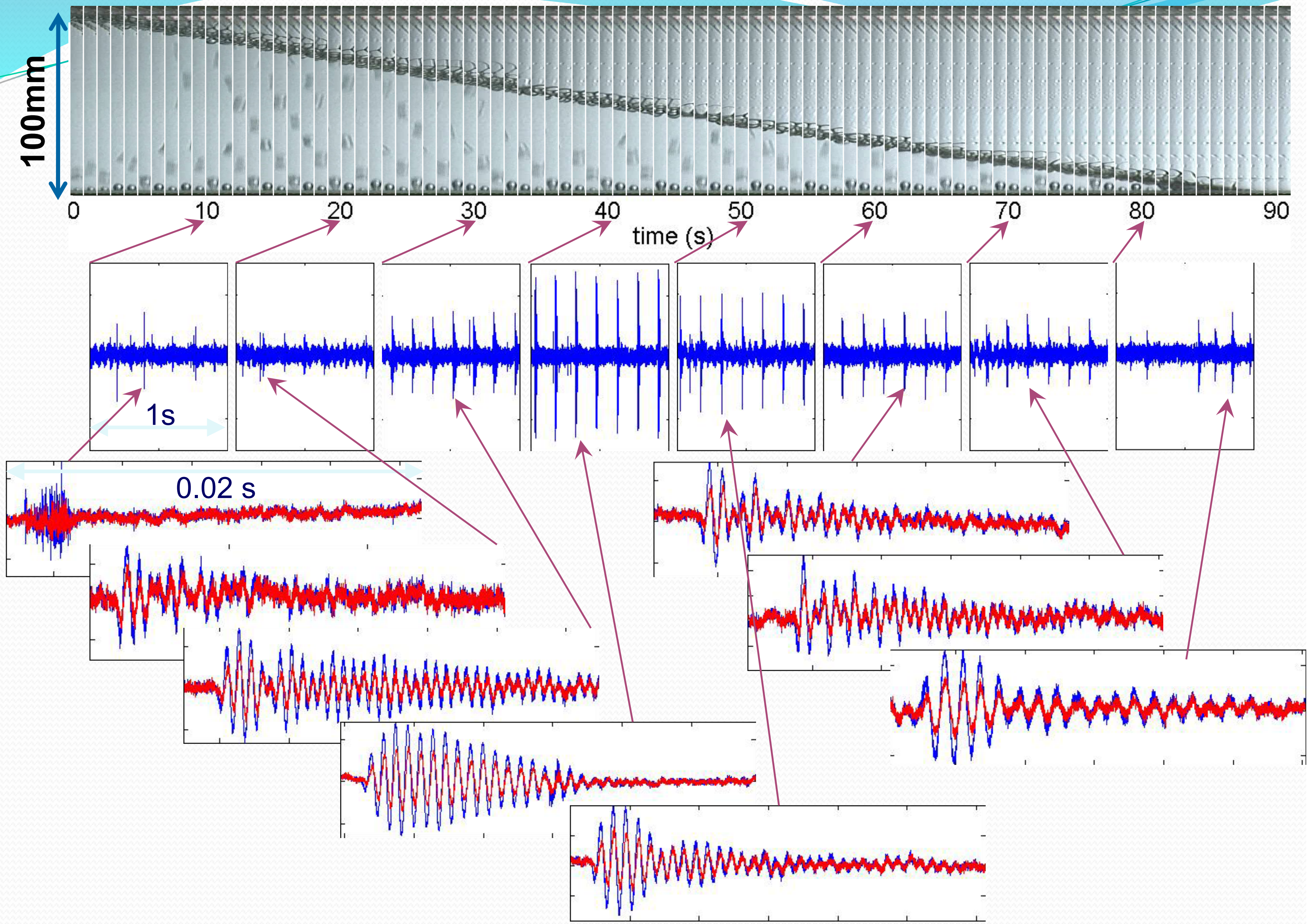
Acoustic signal of (a single) bubble bursting:

Dynamics matters!

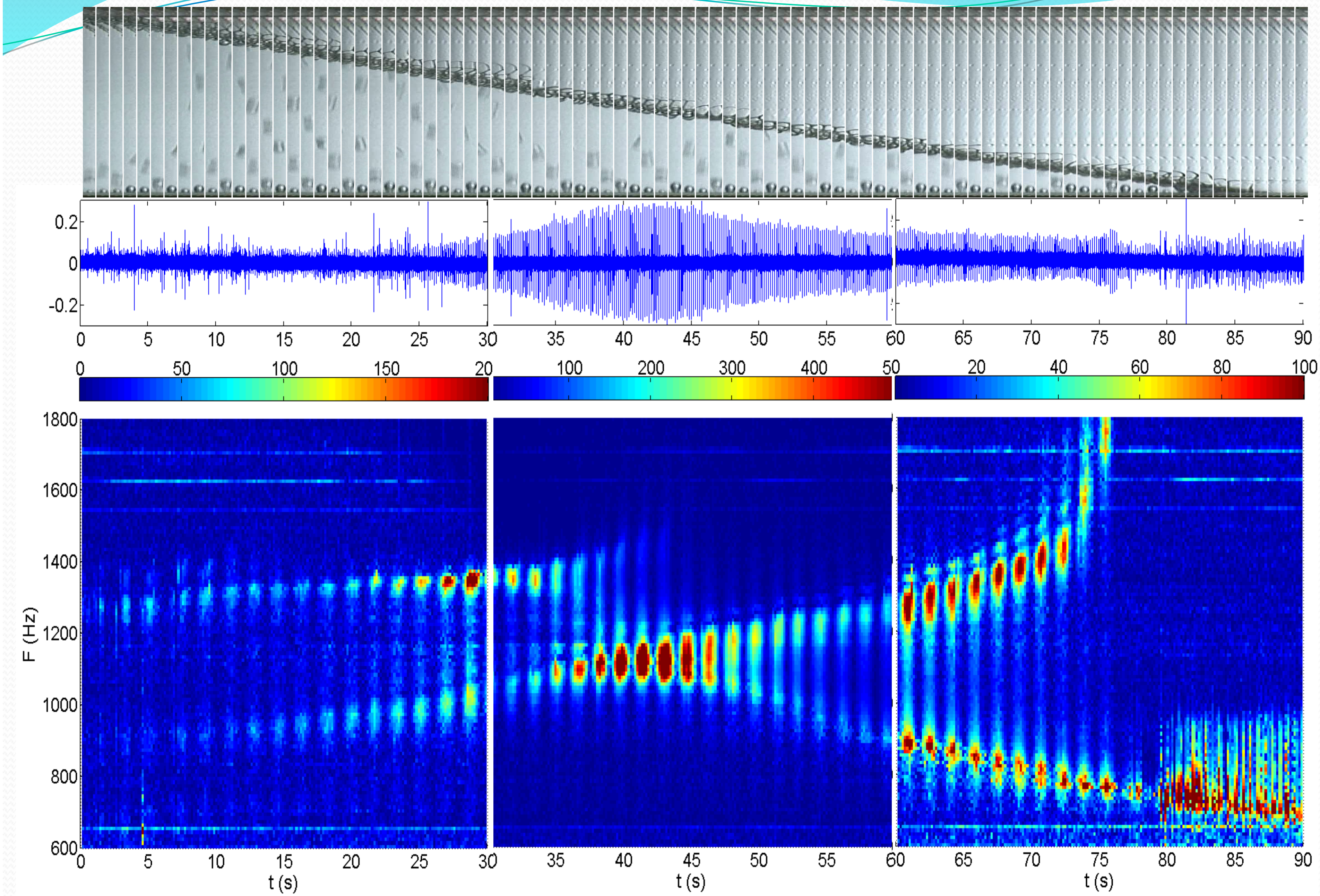
... to be continued

Bubble pulse and resonance

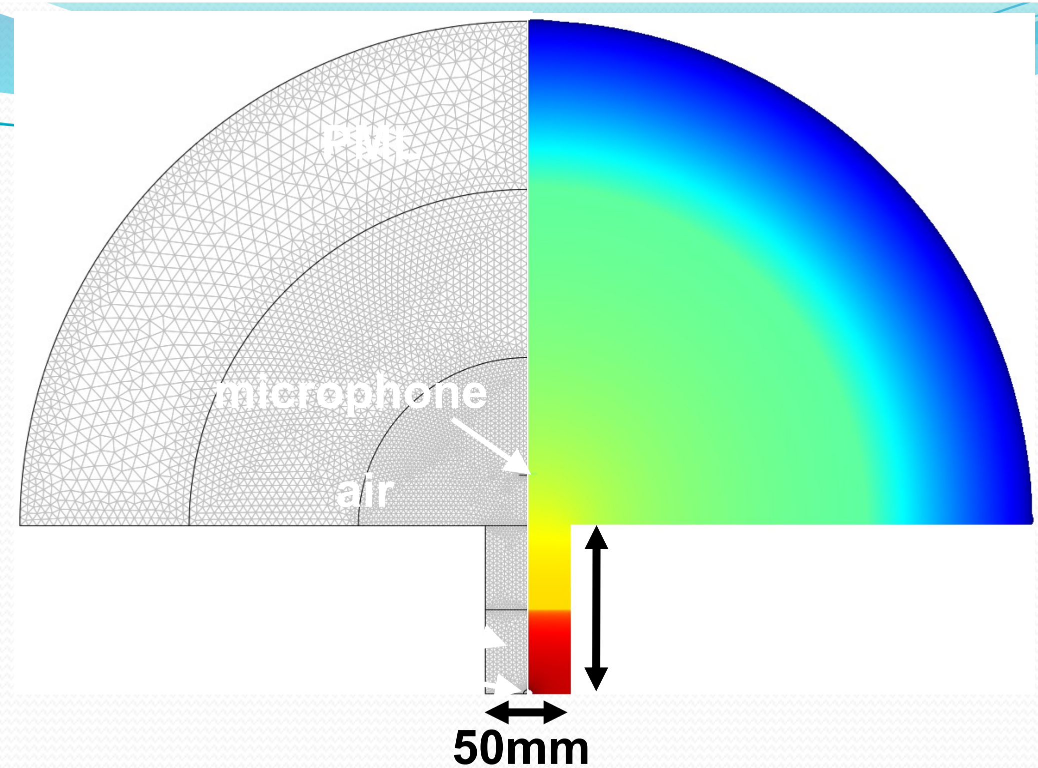


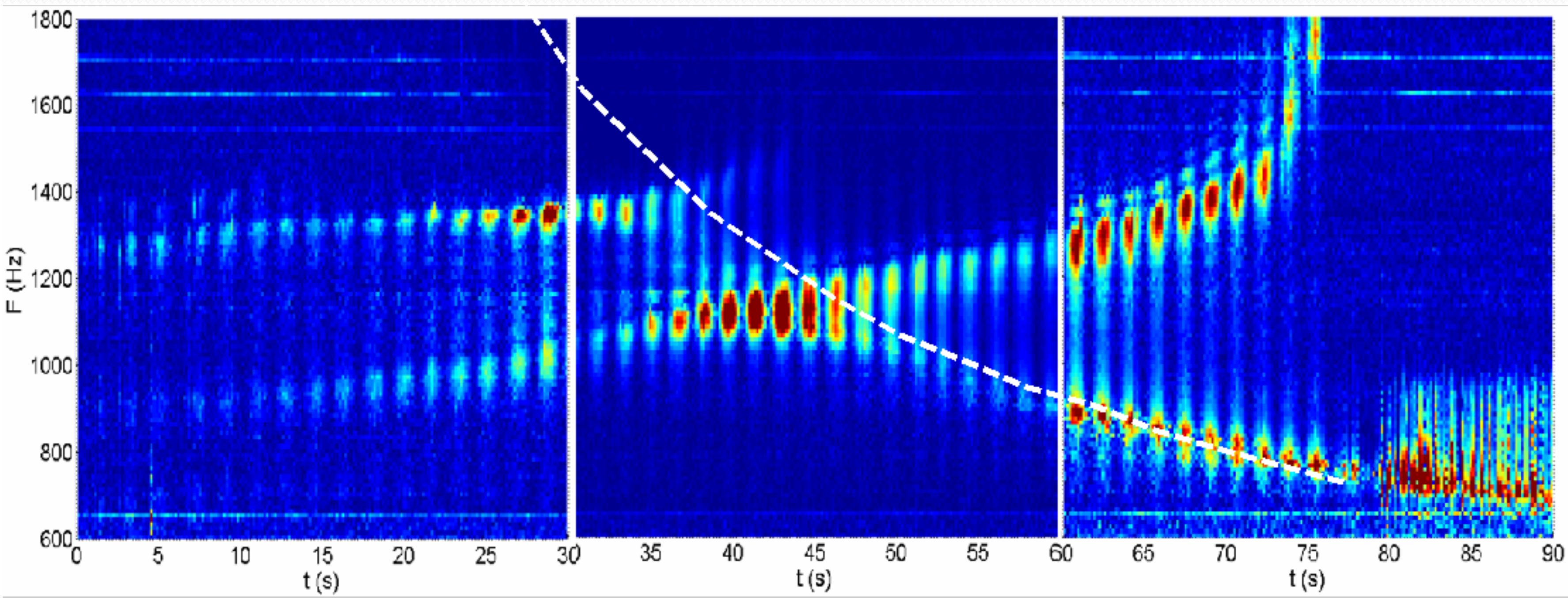

100mm
0
10
20
30
40
50
60
70
80
90
time (s)
1s
0.02 s

Spectrogram



Conduit resonance

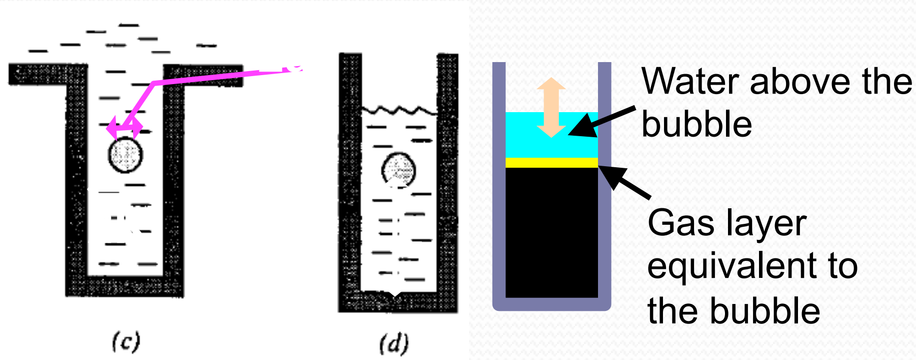


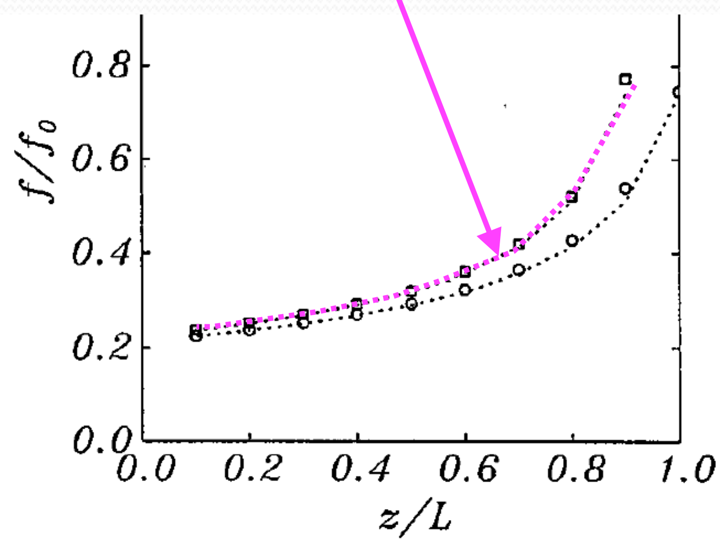


Bubble oscillation

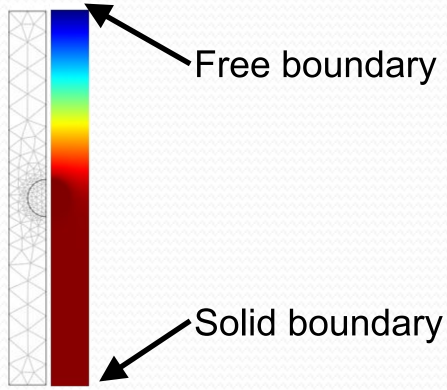
The natural frequency of oscillation of gas bubbles in tubes
Oguz and Prosperetti, 1998, JASA.

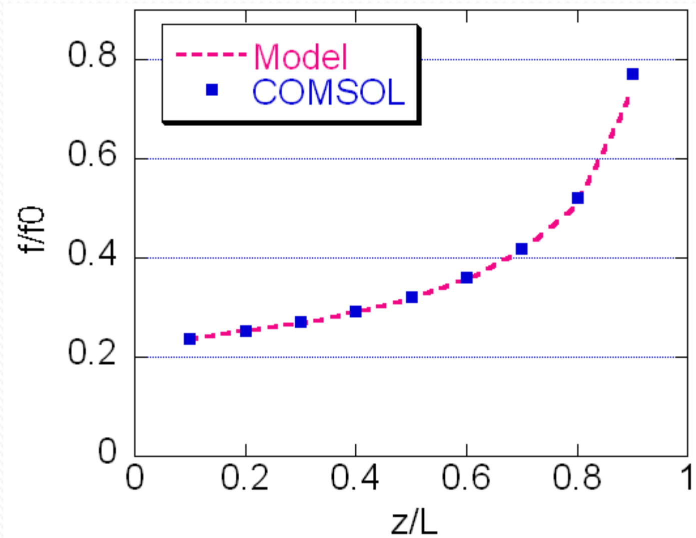
Model vs. Boundary Integral Calc.



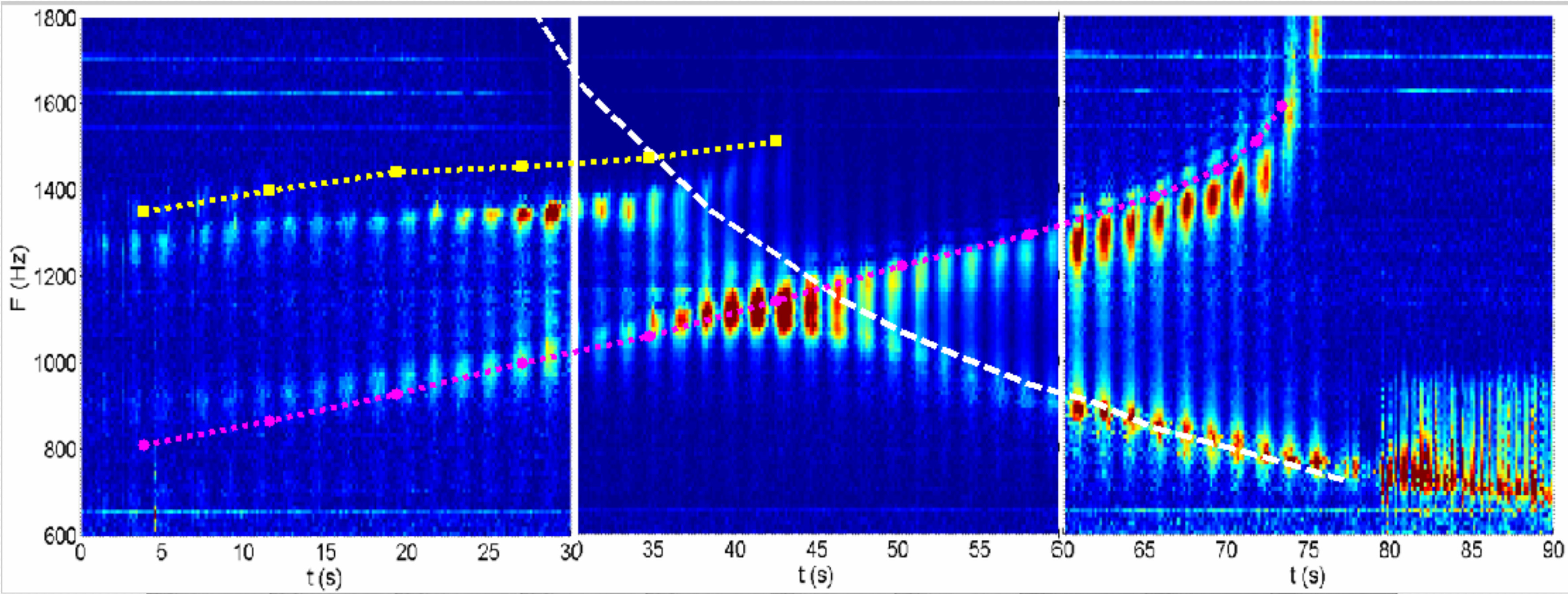


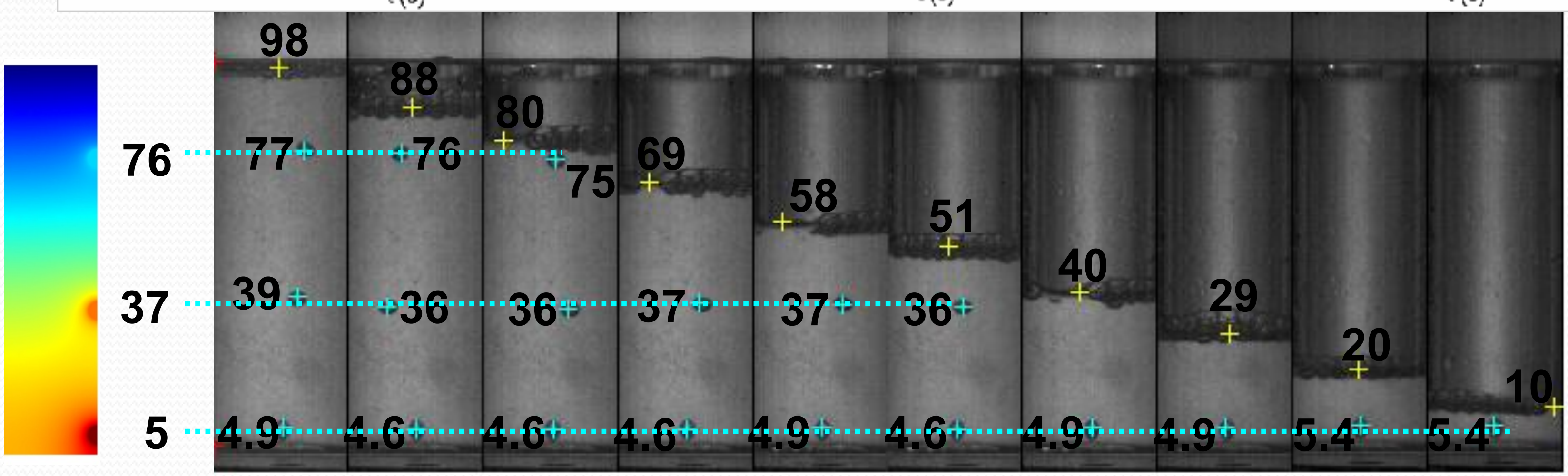
Model vs. COMSOL solution





Natural frequency of a bubble





Bubble oscillation and conduit resonance