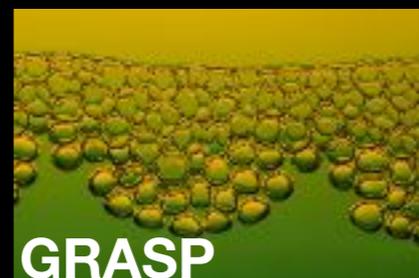


Petit medley de tentatives pédagogiques

- de la diffusion au grand public au master en physique -

Hervé CAPS | herve.caps@ulg.ac.be

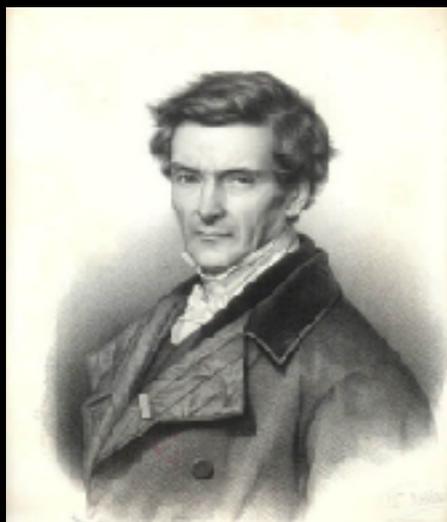


La production scientifique est humaine

Première année (L1) - mécanique et électromagnétisme



Chaque cours commence en musique.



Gaspard-Gustave CORIOLIS
(1792-1843 Paris)



Frédéric CHOPIN
(1810 Wola -1849 Paris)



Première année (LI) - mécanique et électromagnétisme



Chaque cours commence en musique.



1831-1879



1841-1904

In order to bring these results within the power of symbolical calculation, I then express them in the form of the General Equations of the Electromagnetic Field. These equations express—

- (A) The relation between electric displacement, true conduction, and the total current, compounded of both.
- (B) The relation between the lines of magnetic force and the inductive coefficients of a circuit, as already deduced from the laws of induction.
- (C) The relation between the strength of a current and its magnetic effects, according to the electromagnetic system of measurement.
- (D) The value of the electromotive force in a body, as arising from the motion of the

J. Clerk Maxwell

La production scientifique est codifiée

Deuxième année (L2) - physique des fluides

- *All in*, sans distinction TP, TD, cours.

~35 étudiants



Deuxième année - physique des fluides

Premier contact avec la littérature

On the shape of giant soap bubbles
 Caroline Coche^{1,2}, Dagine Darbois Texier^{2,3}, Etienne Reyssat^{2,3}, Jacco H. Snoeijer^{4,5}, David Quéré^{1,2}
 and Christophe Clanet^{1,2}

Abstract: We study the effect of gravity on giant soap bubbles and show that it becomes dominant above the critical size $\ell = \sqrt{\sigma/\rho_0}$, where σ is the mean thickness of the soap film and ρ_0 is the mean density of the liquid. We first show experimentally that large soap bubbles do not retain a spherical shape but flatten when increasing their size. A theoretical model is then developed to account for this effect. In stark contrast to liquid drops, we show that there is no mechanical limit of the height of giant bubble shapes. In practice, the physical limit is set by the glass bubble shaper, which can be reduced by large inflatable structures.

Introduction: Soap films and soap bubbles have had a long scientific history since Robert Hooke (1) first called the attention of the Royal Society and of Newton to optical phenomena (2). They have been of assistance in the development of capillarity (3) and of minimal surface problems (4). Bubbles have also served as efficient sensors for detecting the properties of gases (5) and elegant problems in chemistry (6), and as analog "computers" in solving torque problems (7, 8), compressible problems (10). Finally, in the domain of fluid mechanics, the role of soap films and bubbles in the development of airfoils (14, 15) and in the influence of animals on the shape of a soap bubble is classically obtained by minimizing the surface energy for a given volume, hence resulting in a spherical shape. However, the weight of the liquid contained in the soap film is always neglected, and it is the purpose of this article to discuss this effect.

For liquid drops, the transition from a spherical cap shape to a parabolic shape occurs when the gravitational energy, $\rho_0 g R^3$ (R is the typical size of the drop), becomes of the same order as the surface energy, σR^2 . That is, for a drop size of the order of the capillary length $\lambda = \sqrt{\sigma/\rho_0}$ ($\lambda \approx 2.7$ mm for water), the two asymptotic regimes may be distinguished. For small volumes, $\rho_0 g R^3 \ll \sigma R^2$, the drop is spherical, while for large volumes, $\rho_0 g R^3 \gg \sigma R^2$, the drop is flattened. In the intermediate regime, the drop is flattened and its shape is determined by the balance of surface tension and gravity. In particular, we measure the diameter, $2R$, and the height, h_0 , of the giant bubble. The center is at the same height as the center of the pool, and the center of the lens is at the same height as the center of the bubble, to minimize the surface energy.

Once the bubble is at rest, the shape is analyzed by side view images as shown in Fig. 1. In particular, we measure the diameter, $2R$, and the height, h_0 , of the giant bubble. The center is at the same height as the center of the pool, and the center of the lens is at the same height as the center of the bubble, to minimize the surface energy.

Significance: Surface tension dominates the spherical shape of giant soap bubbles, whereas gravity flattens larger drops into hemispherical or parabolic shapes. However, we demonstrate experimentally that the transition to flattened bubbles does not happen at the capillary length, but is determined by the balance of surface tension and gravity. In practice, the physical limit of the height of giant soap bubbles is set by the glass bubble shaper, which can be reduced by large inflatable structures.

Author contributions: C. Coche, D. Darbois Texier, E. Reyssat, J. H. Snoeijer, and C. Clanet conceived the experiment, performed the experiments, analyzed the data, and wrote the paper. C. Coche, D. Darbois Texier, E. Reyssat, J. H. Snoeijer, and C. Clanet conceived the experiment, performed the experiments, analyzed the data, and wrote the paper. C. Coche, D. Darbois Texier, E. Reyssat, J. H. Snoeijer, and C. Clanet conceived the experiment, performed the experiments, analyzed the data, and wrote the paper.

Additional Information: Supplementary information related to this article is available at www.pnas.org.

Conflict of interest statement: No conflict of interest declared.

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Fig. 1. Presentation of a "glass" soap bubble and definition of its radius, R , and height, h_0 . (Here, $R = 1.09$ m, and $h_0 = 4.53$ m.)

grows because of unbalanced surface tension forces at the edge of the hole. The opening velocity v is constant and is given by the Dupré-Taylor-Culick law (18–20),

$$v = \frac{2\gamma}{\rho_0 \ell} = 2g\ell, \quad (1)$$

where $\gamma \approx 26$ mN/m, and $\rho_0 \approx 1,000$ kg·m⁻³. Examples of thickness measurements are presented in Fig. 2. In Fig. 2*a* and Fig. 2*b*, we present two sequences of four pictures showing the opening of a hole in two soap bubbles of different sizes. We use such sequences to extract the bursting velocity plotted as a function of time in Fig. 2*c*. We observe that v is almost constant and take the value of ℓ m/s for sequence in Fig. 2*a* and 2.8 m/s for sequence in Fig. 2*b*. From the value of v , we deduce $\ell \approx 0.61$ m and $\ell \approx 3.2$ m for Fig. 2*a* and $\ell \approx 0.65$ m and $\ell \approx 0.4$ m for Fig. 2*b*, using Eq. 1. Although it may seem surprising to find that the film thickness is homogeneous, earlier studies of drainage of almost spherical liquid shells have shown that the thickness approaches a profile with little spatial variation (15).

Model: We now consider the mechanical equilibrium of the membrane of surface area $rd\theta ds$ first considered along the s direction. To account for the experimentally observed slow draining and long bubble lifetimes, the air-liquid interface must strongly moderate the flow and behave as partially rigid, in contrast with the no-stress behavior of surfactant free interfaces. The main effect is that gradients in surface tension $\gamma(s)$, due to the presence of surfactants, have to balance viscous stresses applied by the flowing liquid along the interface. In reaction, viscous stresses balance the weight of the liquid in the film. Finally, the weight of liquid is fully transmitted to the walls through viscous stresses and balanced by surface tension gradients (15). The contribution due to surface tension on each side of the infinitesimal element gives a force $2\gamma ds \sin \theta$, where γ is a function of position s . The weight of the liquid inside the film is $\rho_0 g r ds \sin \theta$, when projected along the s direction. The balance of surface tension and weight thus gives

$$2r d\gamma[\gamma(s) - \gamma(s + ds)] = \rho_0 g r ds ds \sin \theta, \quad (2)$$

which, using $d\theta/ds = -\sin \theta / r \sin \theta$,

$$d\gamma = \frac{1}{2} \rho_0 g ds \sin \theta \Rightarrow \gamma(s) = \gamma_0 + \frac{1}{2} \rho_0 g h(s). \quad (3)$$

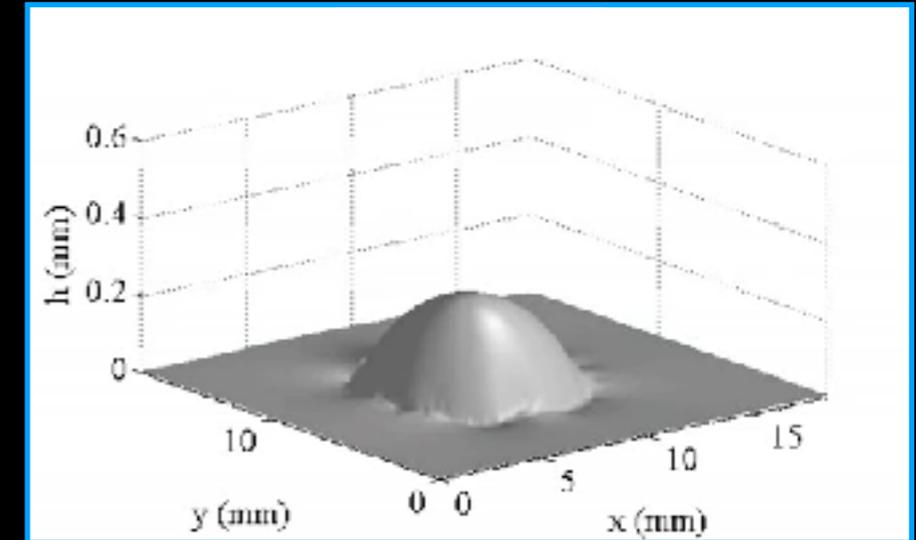
Here γ_0 is the surface tension of the soap solution at the base of the bubble ($h = 0$), and the surface tension is found to increase

Fig. 2. Bursting sequence of giant soap bubbles. (a) Image sequence of bursting bubbles, with a time step of 50 μ s between images, showing hole on each image (Scale bar: 50 cm). (b) Bursting sequence with a time step of 50 μ s between images, according to *a* and *b* is plotted versus time.

Fig. 3. Height of giant soap bubbles. (a) Plot of the height h_0 (m) versus the radius R (m). (b) Plot of the height h_0 (m) versus the radius R (m). (c) Plot of the height h_0 (m) versus the radius R (m).

Deuxième année - physique des fluides

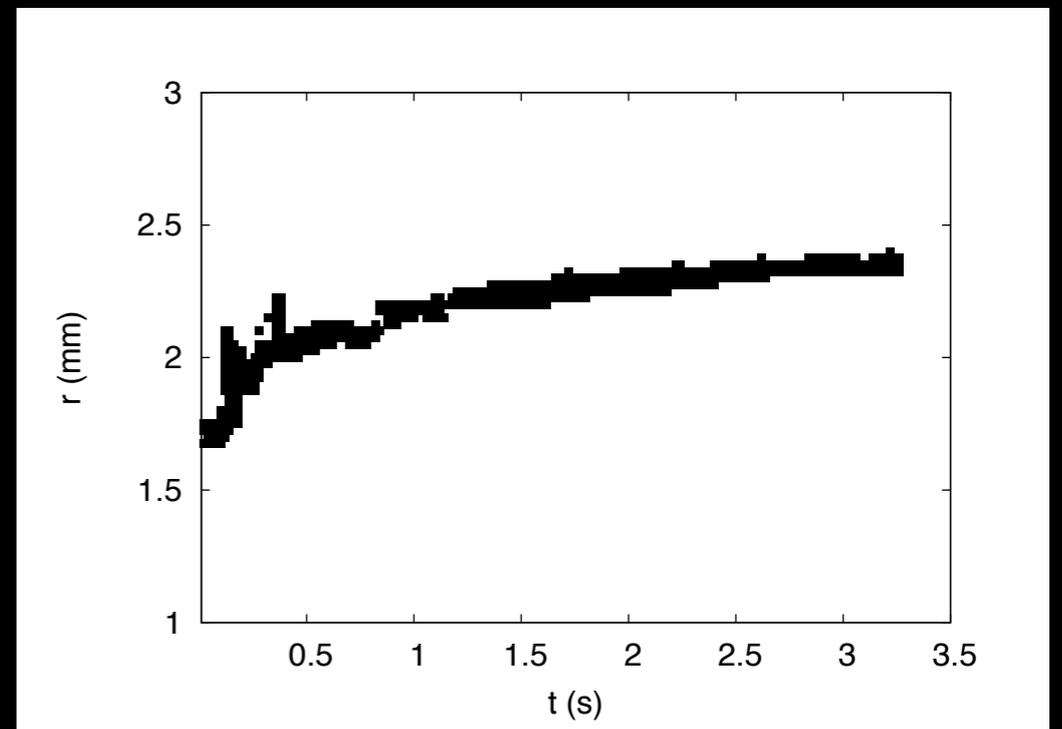
- Situation problème _____
à partir d'un papier,
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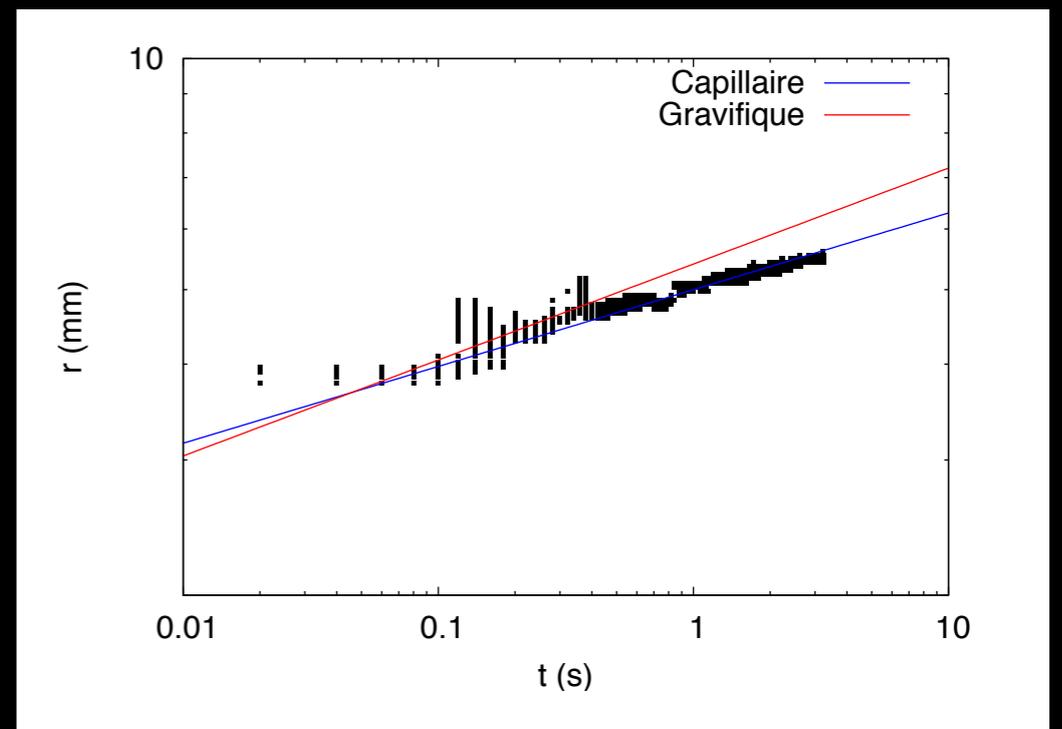
F. Moisy, M. Rabaud, K. Salsac,
Exp. in Fluids **46** (6), 1021 (2009).

- Hypothèses _____ Tens. Surf. ? Gravité ?
collégialement
- Répartition en groupes _____ $R(T)$?
présentation à l'ensemble

- Données expérimentales



- Confrontation



- Discussion

Enseigner la démarche scientifique ... à qui ?

10-12 ans - école primaire

Susciter l'intérêt



Expérimenter

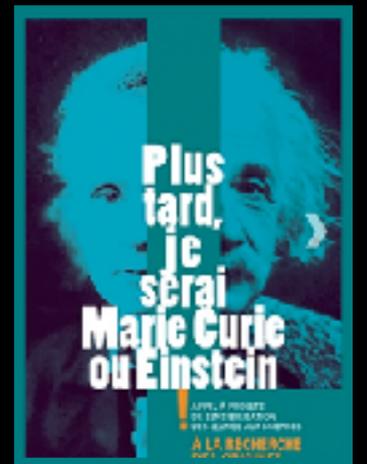


Expérimenter



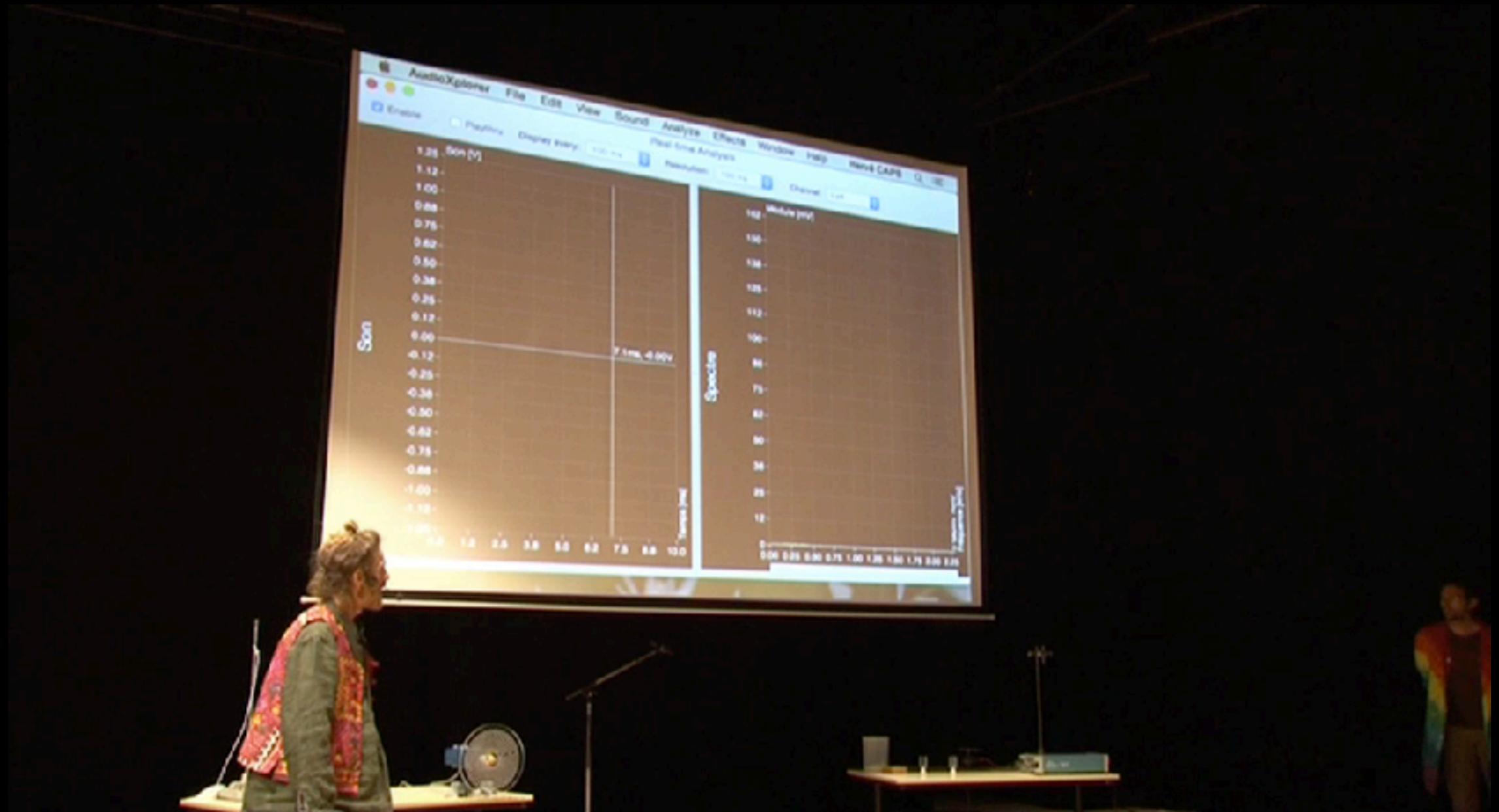
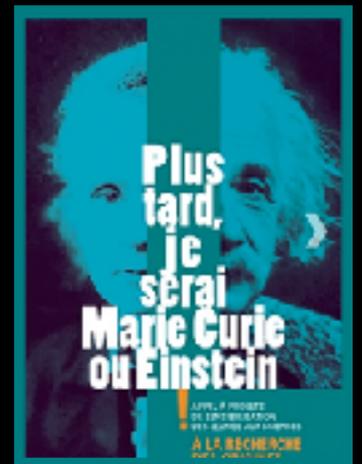
14-16 ans - second cycle secondaire

Décloisonner



14-16 ans - second cycle secondaire

Décloisonner



¡ Merci !

Hervé CAPS | herve.caps@ulg.ac.be

