Research report for International Office

~ Valérie Vidal ~

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The aim of my project at ERI was to understand, based on laboratory experiments, the physical mechanisms responsible for acoustic waves on volcanoes. I have been warmly welcomed in Kurita-san's research team, and I worked more specifically on experiments with Ichihara-san.

In order to mimic in the laboratory the dynamics of bubbles rising in magma and volcanic explosions, we have setup the experiment described as follows. A plexiglas cell containing a fluid is connected to a constant air flux supply, adjusted with an air flow controller, and monitored by a pressure sensor. This air flux supply constantly generates bubbles in the fluid. The bubbles rise, and then burst at the surface of the fluid. A series of four microphones, including two Brüel & Kjær low-frequency microphones, located a few centimeters above the fluid surface at different distances and angles, monitor the sound produced by the successive bubbles bursting. Both bubble rising and explosion dynamics (surface motion and film rupture at bursting) are monitored by a normal and a high-speed video camera, respectively.

Two fluids have been used in our experiments. First, sugar syrup (90% concentration), representative of newtonian behaviour. Second, hair gel (60% and 50% concentrations), which displays a strong visco-elastic behaviour, and memory effect due to the fluid rheology. The shape of the bubbles varies strongly, depending on the newtonian or non-newtonian fluid rheology. For the sugar syrup, we observed almost spherical bubbles, that mostly remain trapped at the surface before bursting, whereas for hair gel, the bubbles are elongated, and burst immediately when reaching the surface. The importance of the use of these two fluids is underlined by the fact that at present day, the rheology of lava (newtonian or non-newtonian), and therefore, the bubble shape and dynamics on the magma column and at bursting, is still under debate. Two different fluxes, with an order of magnitude difference, have been used for each fluid.

Many interesting results have been found from these experiments. First, we observed different acoustic waveforms, depending on the fluids and/or bubble explosion. In the sugar syrup, most of the burstings are "silent", with no acoustic wave generation. The near-field microphones register the air jet ("puffing") associated with the bursting, which disappears quickly with the distance (no signal on the far-field microphones). On the contrary, all bubbles bursting at the surface of hair gel generate a sound wave. We found

Laboratoire de Physique
Ecole Normale Supérieure de Lyon
46, Allée d'Italie
69364 Lyon cedex 07 – FRANCE
Phone : ++33-4-72-72-85-61
Email : Valerie.Vidal@ens-lyon.fr

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that the waveform of this acoustic wave varies from one bubble to the other, even when keeping all experimental parameters (fluid concentration, air flux) constant. Images taken by the high-speed video camera showed that the film rupture time (bubble opening characteristic time) strongly affects the waveform. Moreover, more careful observations of the acoustic signals made it possible to find the existence of a “precursor” acoustic signal, occurring before bursting. The time delay between this precursor and the bursting signal varies with time, presenting peaks with a characteristic periodicity in the stationary regime. Time-frequency analysis (spectrogram) showed clearly the correlation between this variation and the variation of the bursting waveform. Observations pointed out a potential mechanism by coalescence of the rising bubble with a small bubble trapped under the surface, left by the previous bubble bursting. The spectrograms also pointed out gliding frequency of the higher harmonics, a feature observed on volcanoes, but still unexplained at present day. A last interesting result of our study is the observation of isolated waveforms between two successive burstings, associated either with the formation of a plug at the bottom of the liquid column (for newtonian fluid), or with bubble coalescence while rising (for non-newtonian fluid).

In conclusion, I would like to emphasize the complexity of the acoustics of bubble bursting, depending on the fluid rheology, but also varying from one bubble to the other inside the same “bubbling” series. These experiments made it possible to understand some of the physical mechanisms at stake in the dynamics and acoustics of bubble bursting at the top of a liquid column.

The collaboration at the origin of this project was very fruitful. I would like to underline the efficiency, helpfulness and kindness of all the laboratory members, and in particular, Mie Ichihara, who shared with me all the experimental work and analysis. I strongly hope our collaboration will go on, as the many experimental results obtained are very promising for the understanding of volcano acoustics.

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Valérie Vidal

Laboratoire de Physique
Ecole Normale Supérieure de Lyon
46, Allée d’Italie
69364 Lyon cedex 07 – FRANCE
Phone : ++33-4-72-72-85-61
Email : Valerie.Vidal@ens-lyon.fr

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