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ON THE SOUND OF BUBBLES AND SHRIMP

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The oceans may be deep, but they are not at all quiet. Sounds in the ocean include those of waves, produced by tides, winds and thunderstorms, and those of falling rain, hail and snow. In addition, one can hear biological sounds of fish, dolphins, whales and snapping shrimp. The latter, in particular, produce the dominant level of ambient noise in (sub)tropical shallow waters throughout the world. These shrimp live in colonies in such large numbers that there is continuous snapping, providing a permanent crackling background noise.

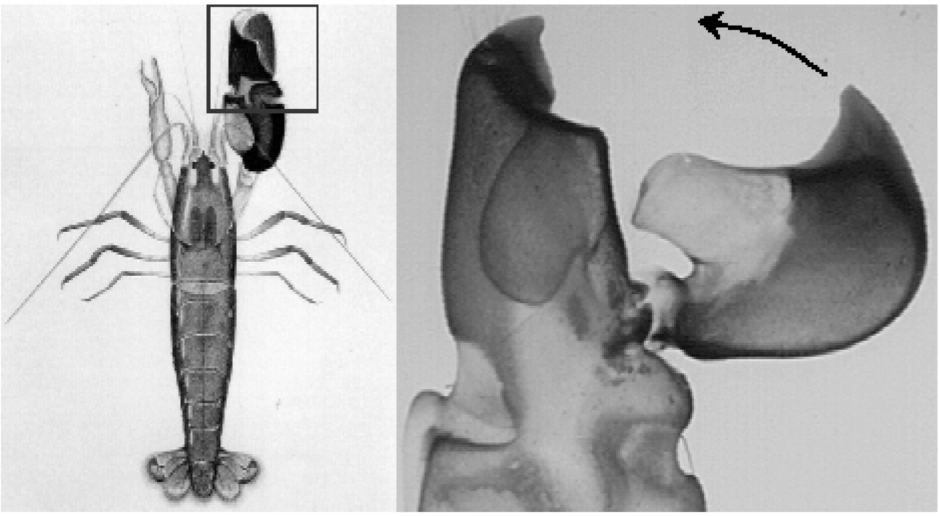

Fig. 1 (left) Drawing of a snapping shrimp (Alpheus heterochaelis), approximately 55 mm in size, with its snapper claw on the right-hand side. (right) Photograph of the snapper claw, made transparent by a special chemical process. The moveable part of the claw closes within 300 microseconds.

The snapping sound can be heard day and night, with source levels as high as 200 dB which severely limits the use of underwater acoustics for active and passive sonar, both in scientific and naval applications. The frequency spectrum of a snap is extremely broad, ranging from tens of hertz to beyond 200 kHz. The snapping shrimp produces the impulsive click by an extremely rapid closure of its so-called snapper claw. It was commonly believed that the sound is generated when the two claw halves hit each other.

In this talk we will in fact see that the sound of snapping shrimp originates solely from the collapse of a cavitation bubble that is generated by the fast water jet resulting from the rapid claw closure. The water jet velocity is so high that the corresponding pressure drops below the vapor pressure of water and a cavitation bubble is generated which will initially grow in size, then it collapses violently when the pressure rises again.

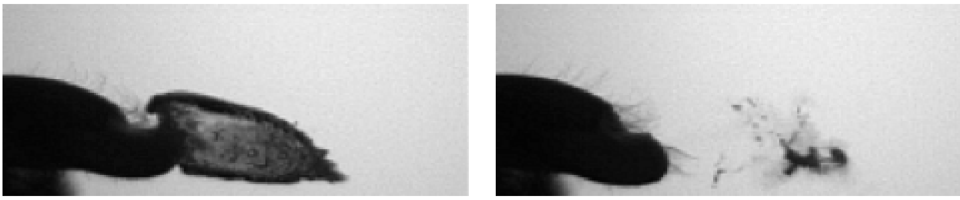

Figure 2. Two snapshots of the collapse of the cavitation bubble. The loud snap of the snapping shrimp coincides with the bubble collapse.

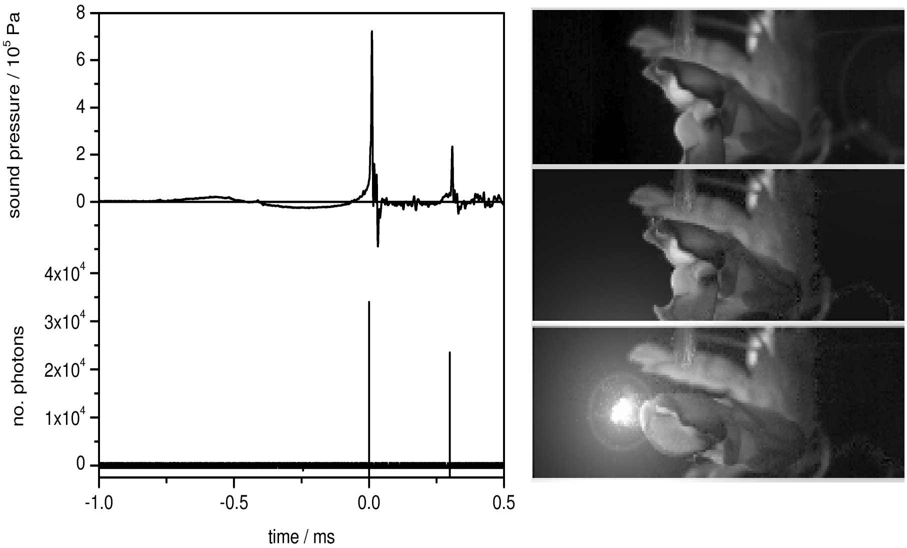

Figure 3. (left) Sound and light of a snapping shrimp - Hydrophone signal (top) and light emission (bottom) of a snap of an Alpheus heterochaelis snapping shrimp. The main light emission coincides with the bubble collapse at t = 0. A second light flash coincides with the subsequent collapse of a cloud of bubbles, formed upon collapse. (right) Artist's impression of shrimpoluminescence. The actual amount of light emitted by the bubble is too weak to be observed by the naked eye.

In the course of our experiments on snapping shrimp sound we also discovered a short intense flash of light emitted at bubble collapse. The light emission reveals the extreme pressures and temperatures of at least 5000 K in the bubble interior at bubble collapse. In light of the apparent similarity with sonoluminescence, the light emission of a bubble periodically driven by ultrasound, we have termed this phenomenon *shrimpoluminescence*.

Papers to read:

Michel Versluis, Barbara Schmitz, Anna von der Heydt, and Detlef Lohse
How snapping shrimp snap: through cavitating bubbles
Science **289**, 2114-2117 (2000)

Detlef Lohse, Barbara Schmitz, and Michel Versluis
Snapping shrimp make flashing bubbles
Nature **413**, 477-478 (2001)

Websites to visit

Physics of Fluids Twente - http://www.tn.utwente.nl/pof
Snapping shrimp - http://stilton.tnw.utwente.nl/shrimp