

The Mechanism of Shrimpluminescence

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Snapping shrimp

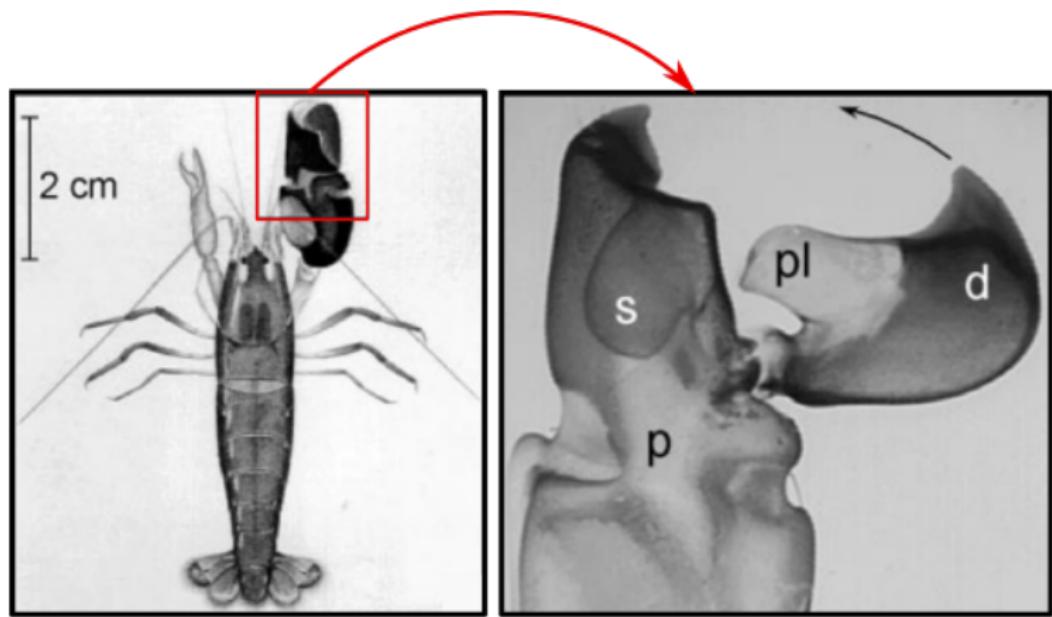


Figure: Adapted from Versluis et al. 2000

How do they snap?

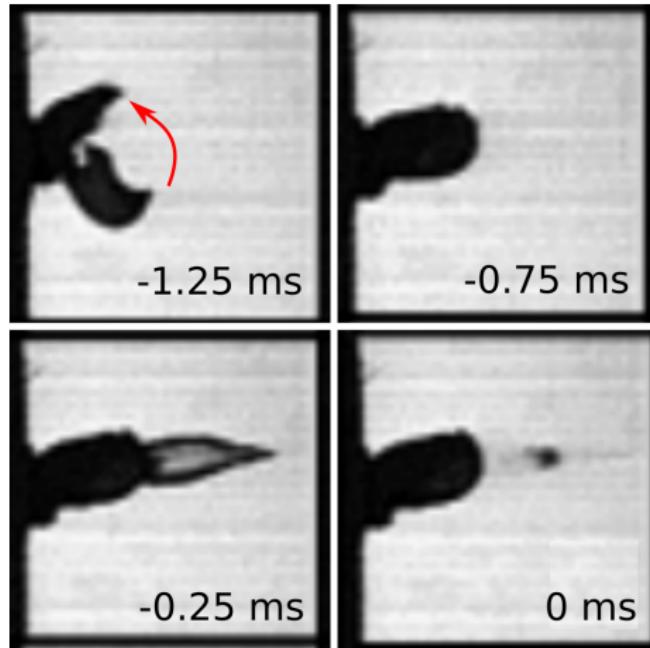


Figure: Adapted from Versluis et al. 2000

How do they snap?

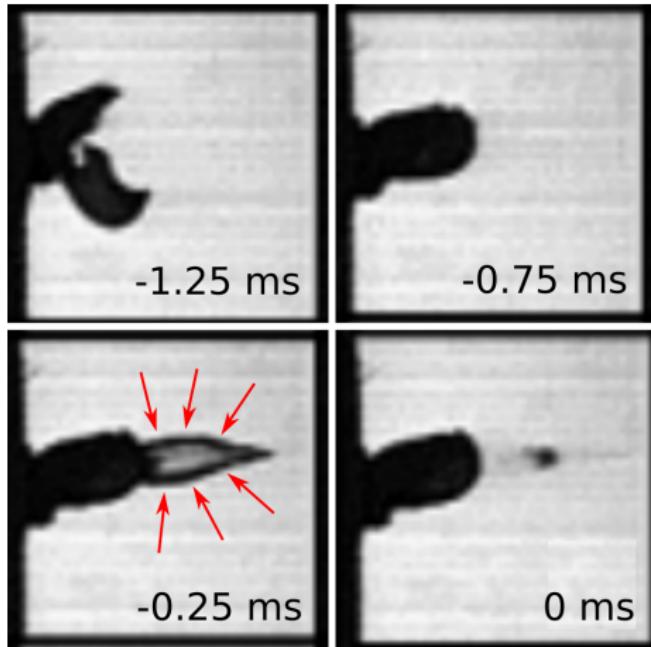


Figure: Adapted from Versluis et al. 2000

How do they snap?

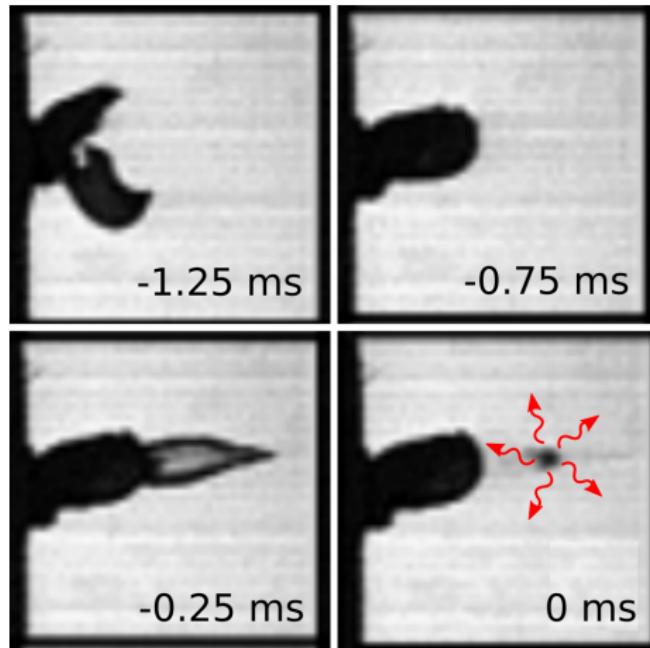


Figure: Adapted from Versluis et al. 2000

Sonoluminescence

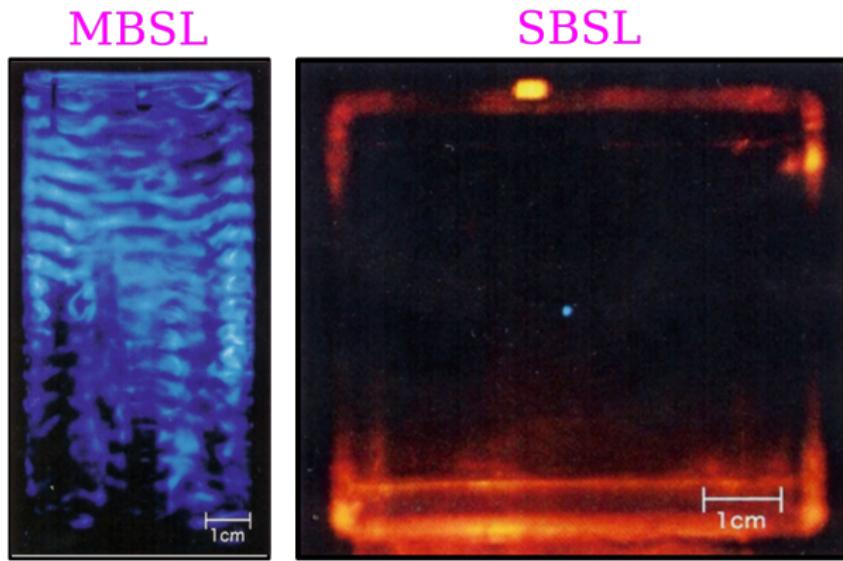


Figure: Adapted from Yasui 2018

Multi-bubble sonoluminescence (MBSL)

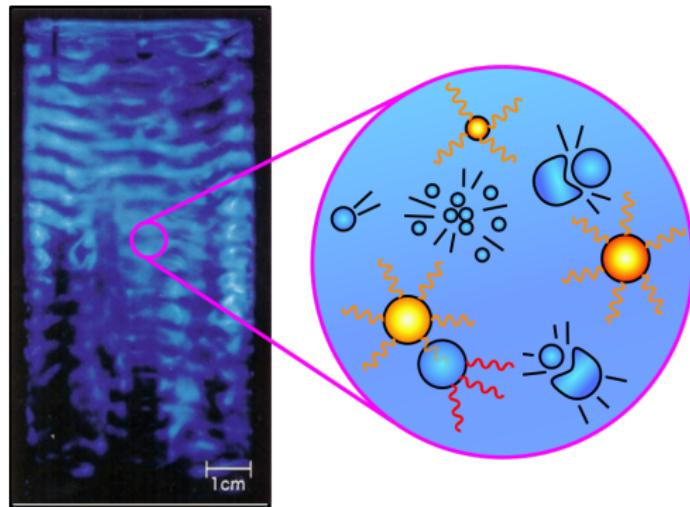


Figure: Adapted from Yasui 2018

Single-bubble sonoluminescence (SBSL)

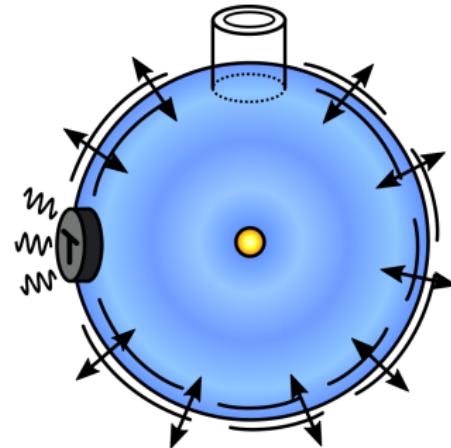
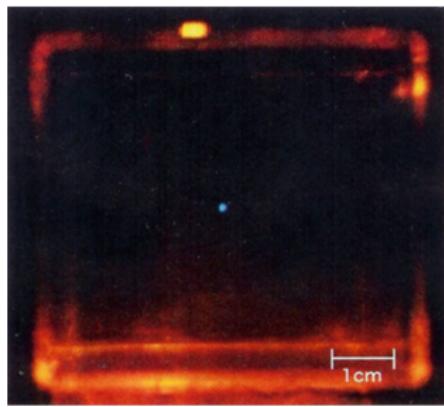


Figure: Adapted from Yasui 2018

“the hydrogen atom of sonoluminescence”¹

¹Brenner, Hilgenfeldt, and Lohse 2002.

Stable SBSL

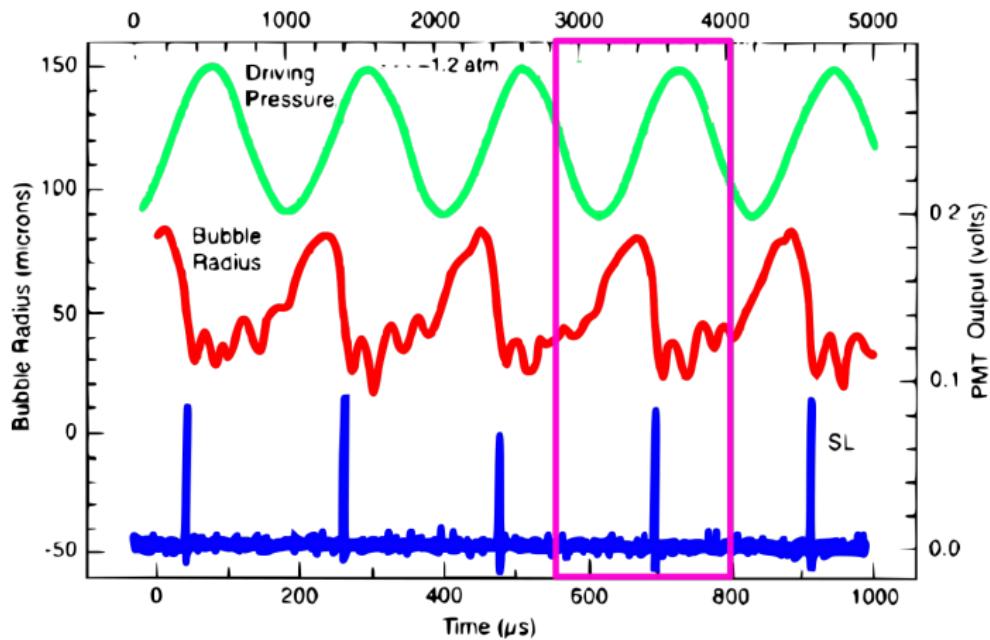
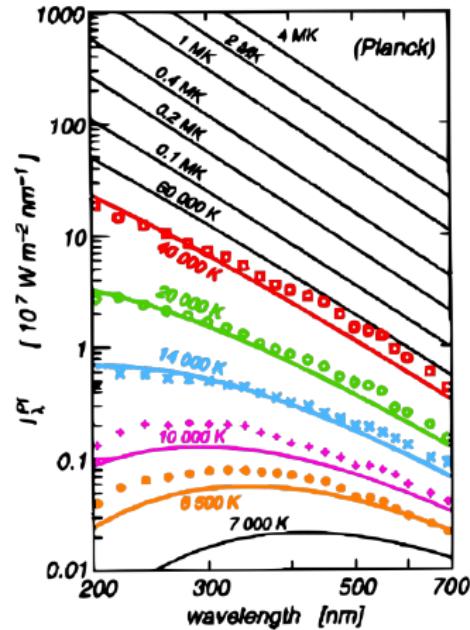


Figure: Adapted from Brenner, Hilgenfeldt, and Lohse 2002

The light spectrum

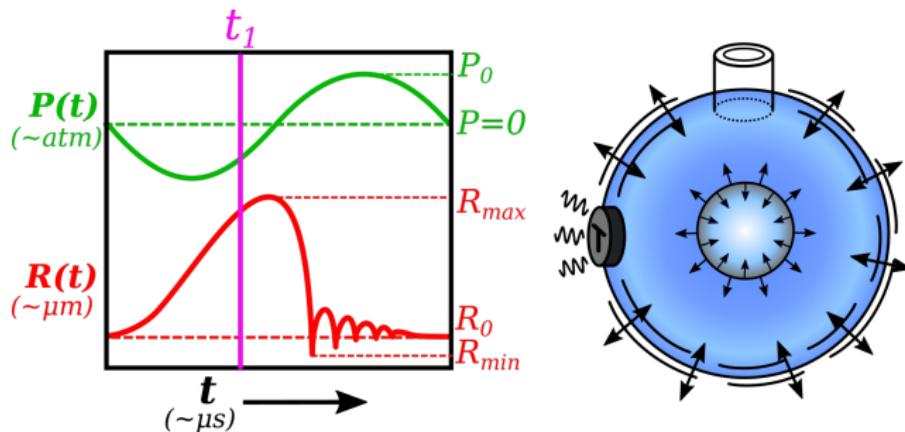
$$\frac{P_{Theory}}{P_{Exp.}} \sim 10^2$$



“...featureless spectra of unknown origin”²

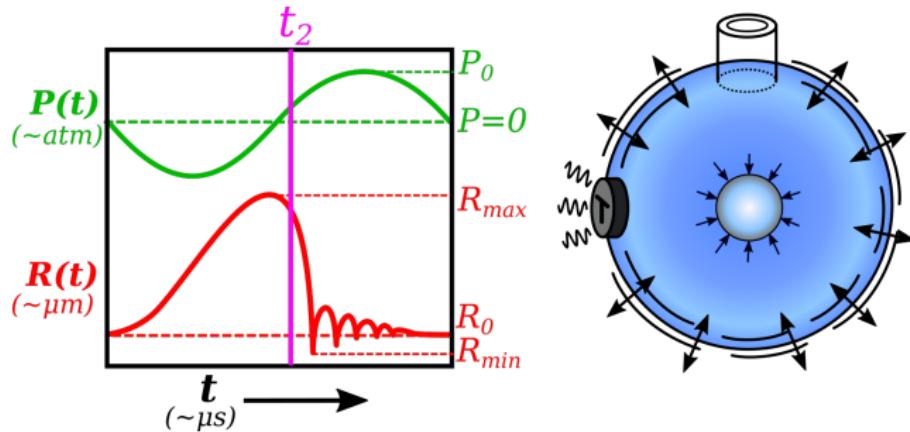
²Suslick and Flannigan 2008

Bubble dynamics: expansion



$$\underbrace{\rho(R\ddot{R} + \frac{3}{2}\dot{R}^2)}_{\text{"kinetic energy"}} = \underbrace{p_g(t) - P_a \sin(\omega t) - \frac{2\sigma}{R}}_{\text{"work}} + \dots$$

Bubble dynamics: cavitation

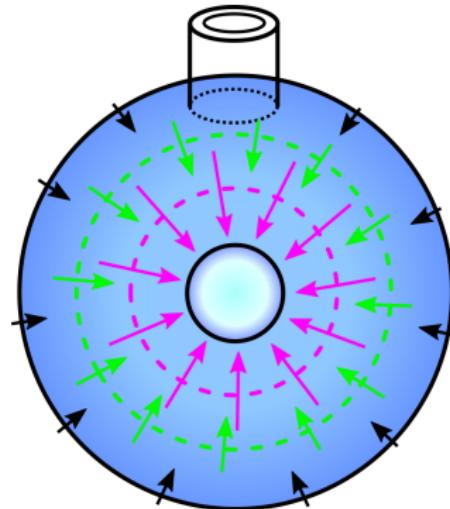


$$\dot{R} \sim \left(1 - \frac{t}{\tau}\right)^{-3/5}$$

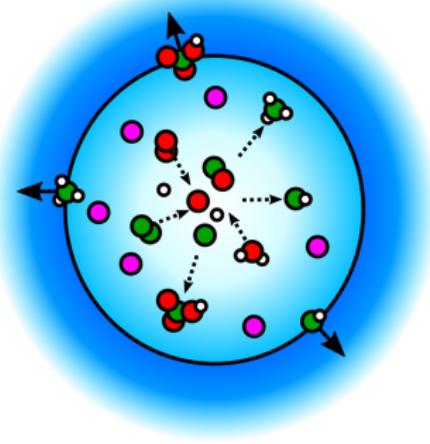
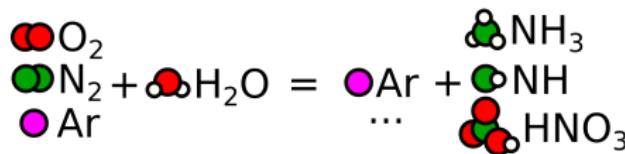
Interlude: cavitation

$$\rho_0 4\pi R_1^2 \cdot u(R_1) \equiv \rho_0 4\pi R_2^2 \cdot u(R_2)$$

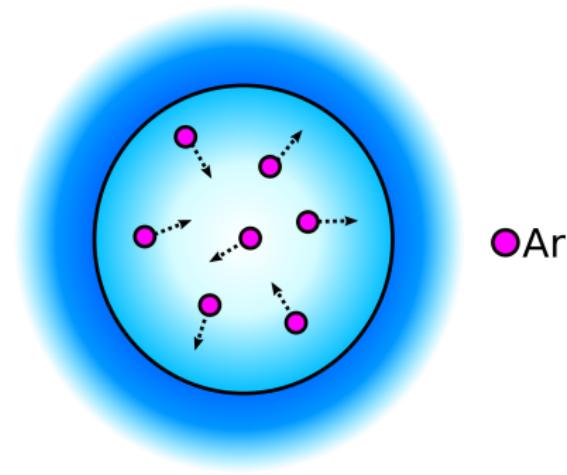
$$u(R_1) = u(R_2) \left(\frac{R_2}{R_1} \right)^2$$



Argon rectification



The bubble's interior



$$p_g(t) = \underbrace{\left(p_0 + \frac{2\sigma}{R_0} \right)}_{P_i} \underbrace{\left[\frac{R_0^3 - h^3}{R^3(t) - h^3} \right]^\gamma}_{V_i/V(t)}$$

The bubble's interior

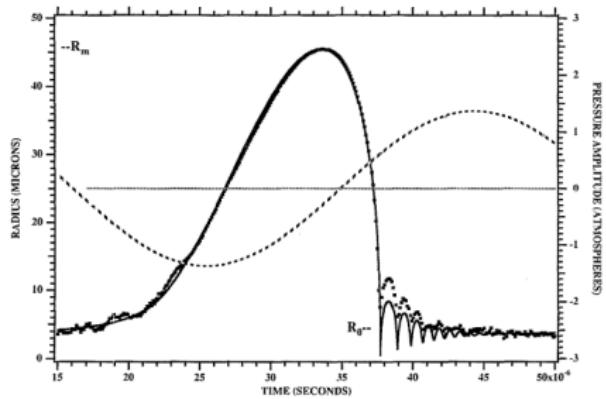


Figure: $R_0 = 4.5 \mu\text{m}$ and $T_{max} = 8,500 \text{ K}$. From Löfstedt, Barber, and Putterman 1993

$$T(t) = T_0 \left(\frac{R_0^3 - h^3}{R^3(t) - h^3} \right)^{\gamma-1}$$

The bubble's interior: redux

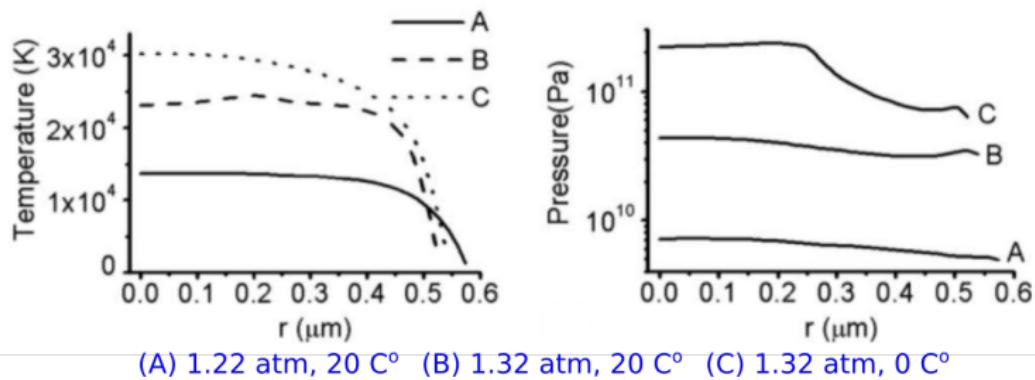
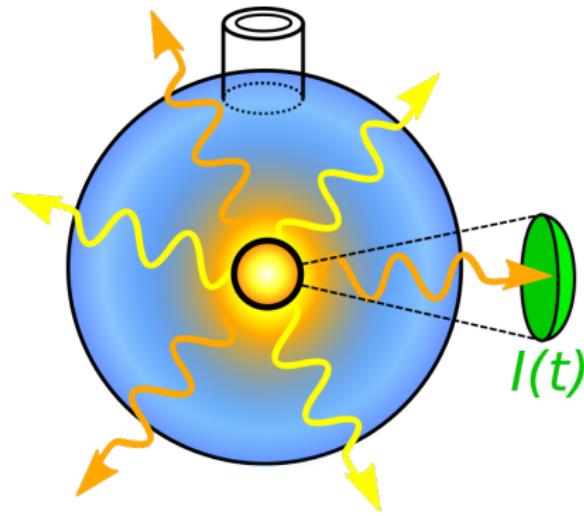


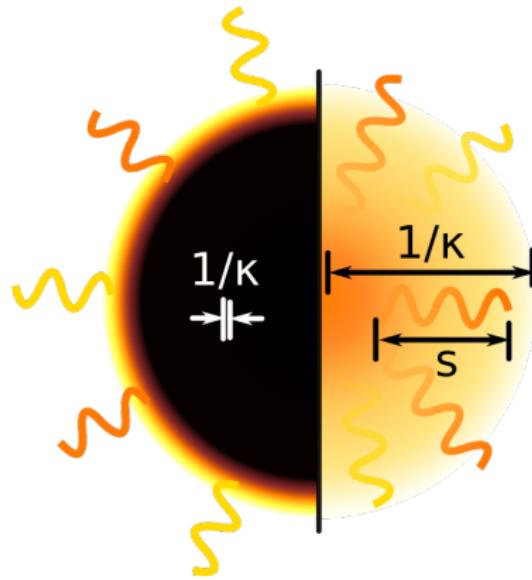
Figure: From An and Li 2009

Sonoluminescence



$$I(T(t), \lambda) = \underbrace{I_B(T(t), \lambda)}_{\text{Black-body spectrum}} [1 - \exp(-\underbrace{\kappa[T(t), \lambda] \cdot s}_{\text{optical "thickness"}})]$$

Where does the light come from?



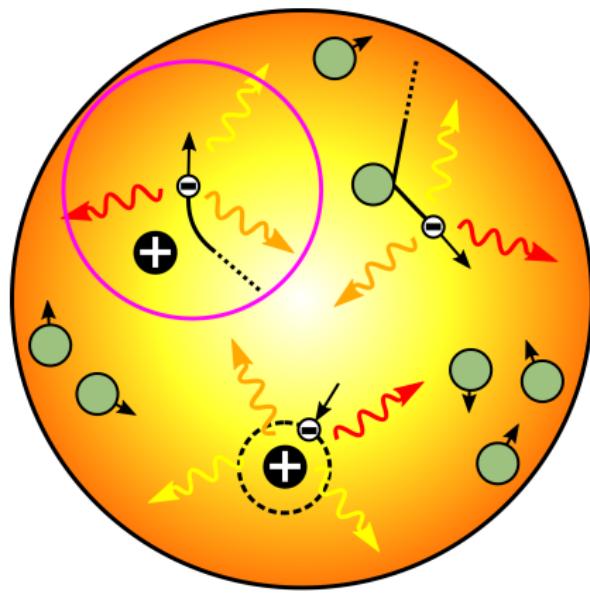
$$\kappa s \gg 1$$

$$I(T, \lambda) \approx I_B(T, \lambda)$$

$$\kappa s \ll 1$$

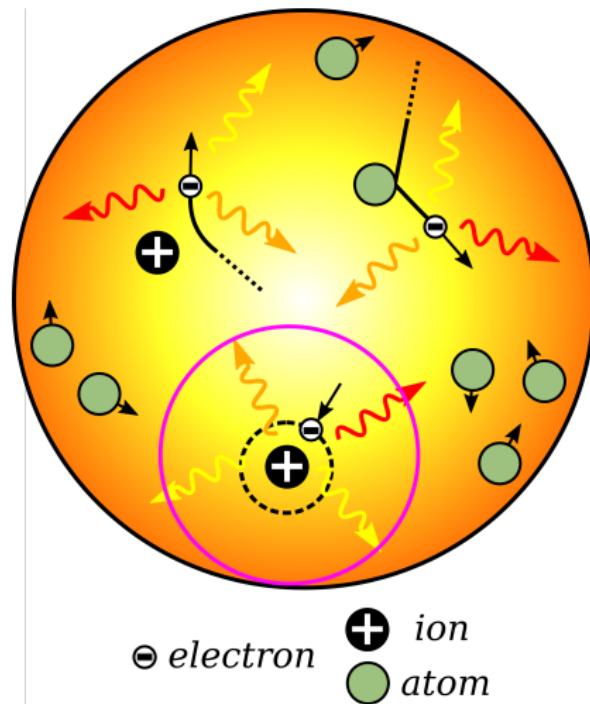
$$I(T, \lambda) \approx I_B(T, \lambda) \cdot \kappa s$$

Electron-ion bremsstrahlung

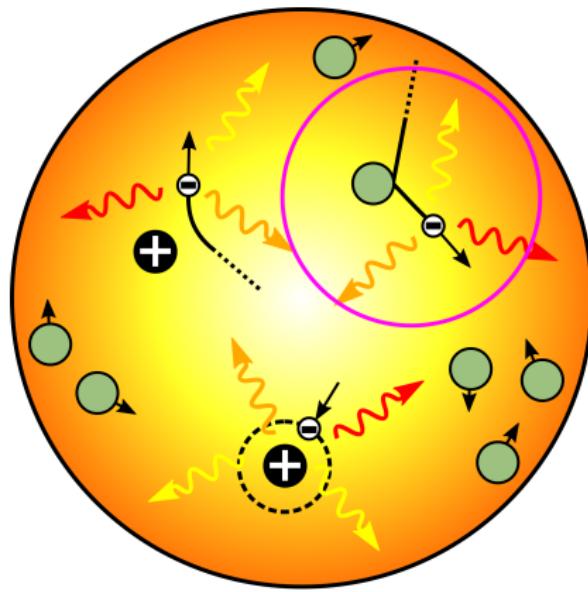


\ominus electron $+$ ion
atom

Electron-ion recombination



Electron-atom bremsstrahlung



\ominus electron $+$ ion
atom

SBSL in H_2SO_4

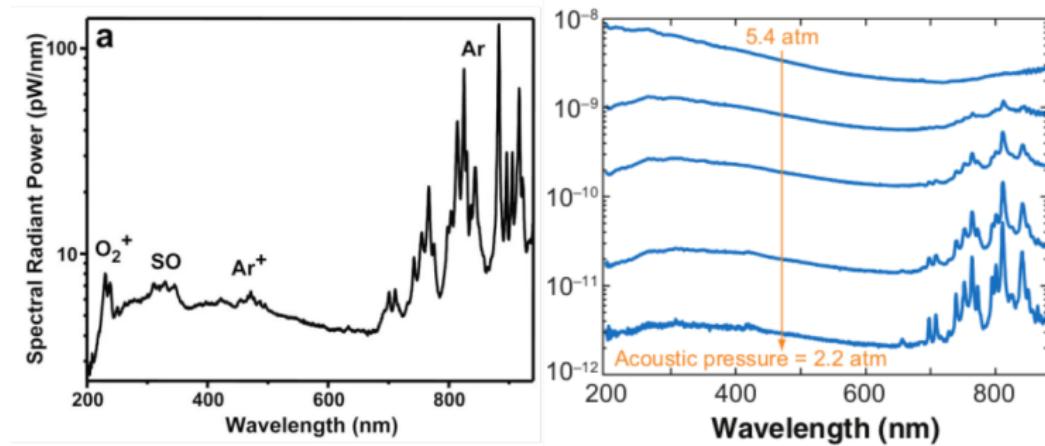


Figure: From Suslick and Flannigan 2008 and Flannigan and Suslick 2005

Theoretical results

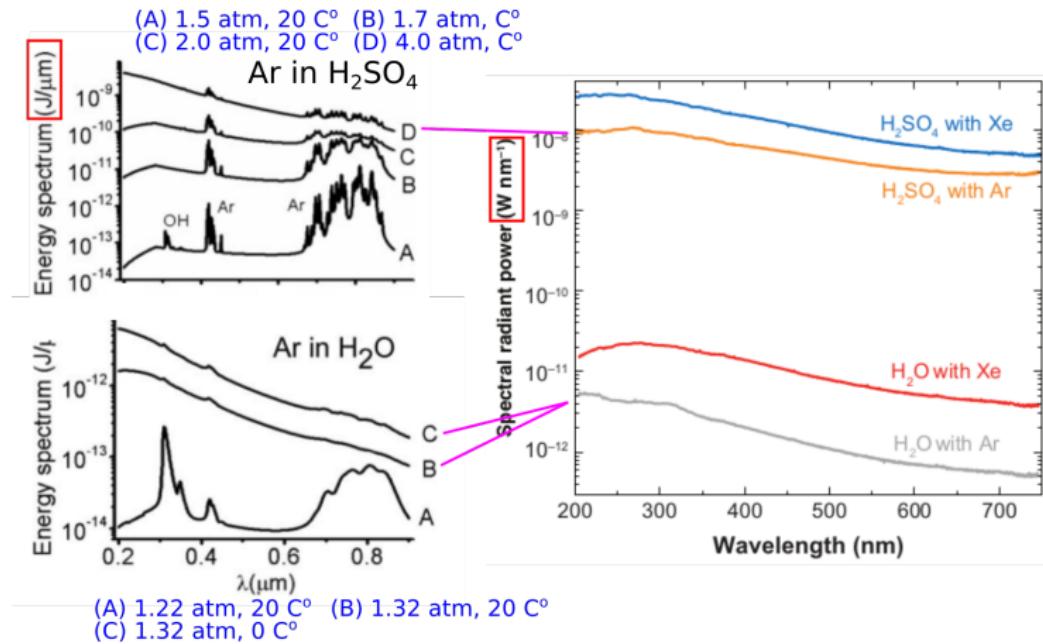


Figure: From An and Li 2009 and Suslick and Flannigan 2008

Theoretical results

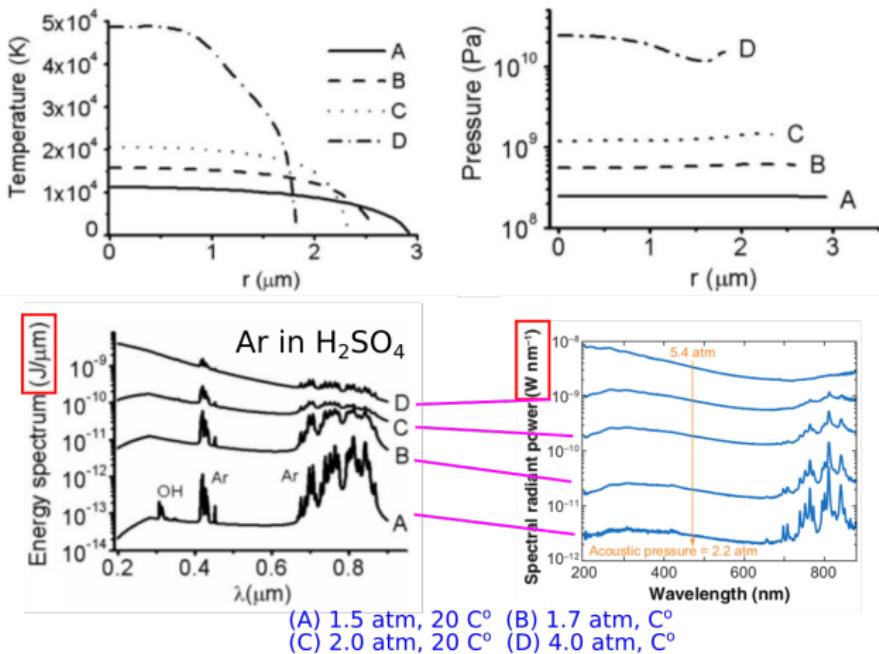


Figure: From An and Li 2009 and Suslick and Flannigan 2008

Concluding remarks

connect back to shrimp