Physically Based Sound for Computer Animation and Virtual Environments

Acceleration Noise

Doug James
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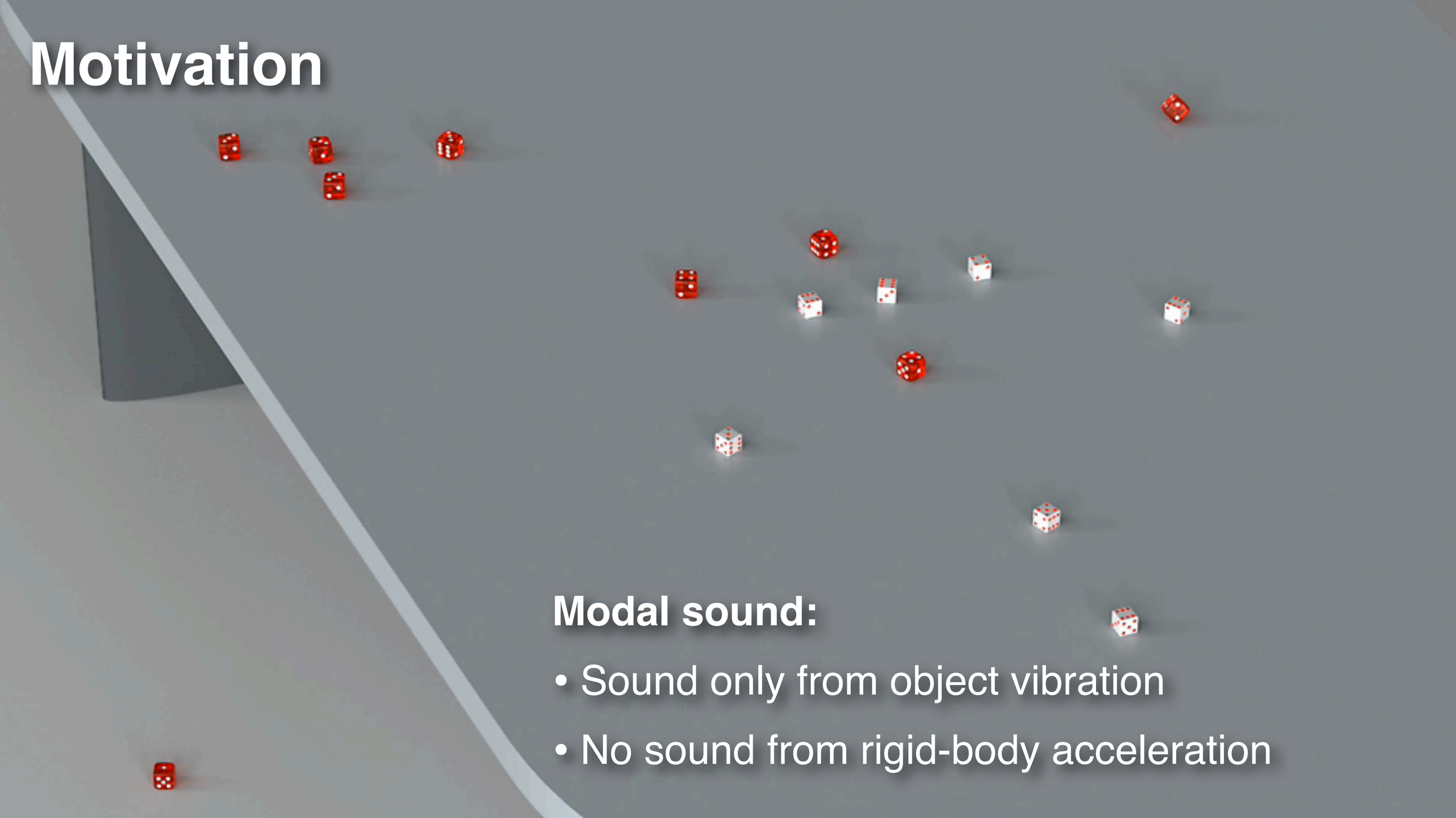
“Acceleration Noise” References:

Jeff Chadwick

- Jeffrey N. Chadwick, Changxi Zheng and Doug L. James, **Precomputed Acceleration Noise for Improved Rigid-Body Sound**, *ACM Transactions on Graphics (SIGGRAPH 2012 Conference Proceedings)*, August 2012.

- Jeffrey N. Chadwick, Changxi Zheng and Doug L. James, **Faster Acceleration Noise for Multibody Animations using Precomputed Soundbanks**, *ACM/Eurographics Symposium on Computer Animation*, July 2012.

Motivation



Modal sound:

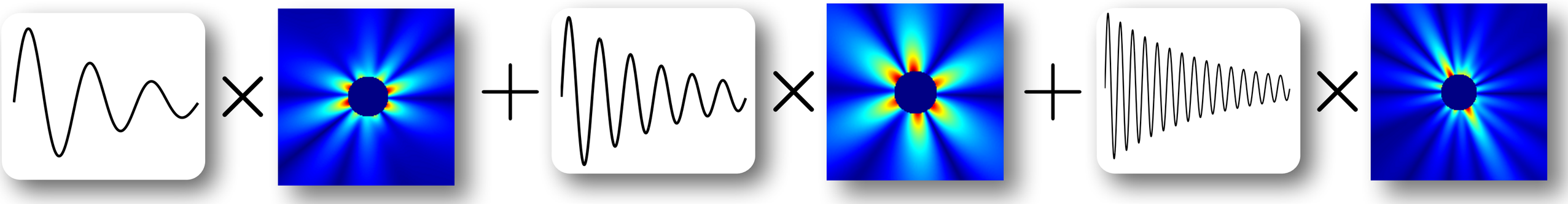
- Sound only from object vibration
- No sound from rigid-body acceleration

Table sound only

Dice sound only

Precomputed Acceleration Noise

Sound =



What's Missing?

$$\frac{1}{c^2}\frac{\partial^2 p(\mathbf{x},t)}{\partial t^2} = \nabla^2 p(\mathbf{x},t)$$

$$\nabla p(\mathbf{x},t)\cdot\mathbf{n} = -\rho a_n(\mathbf{x},t)$$

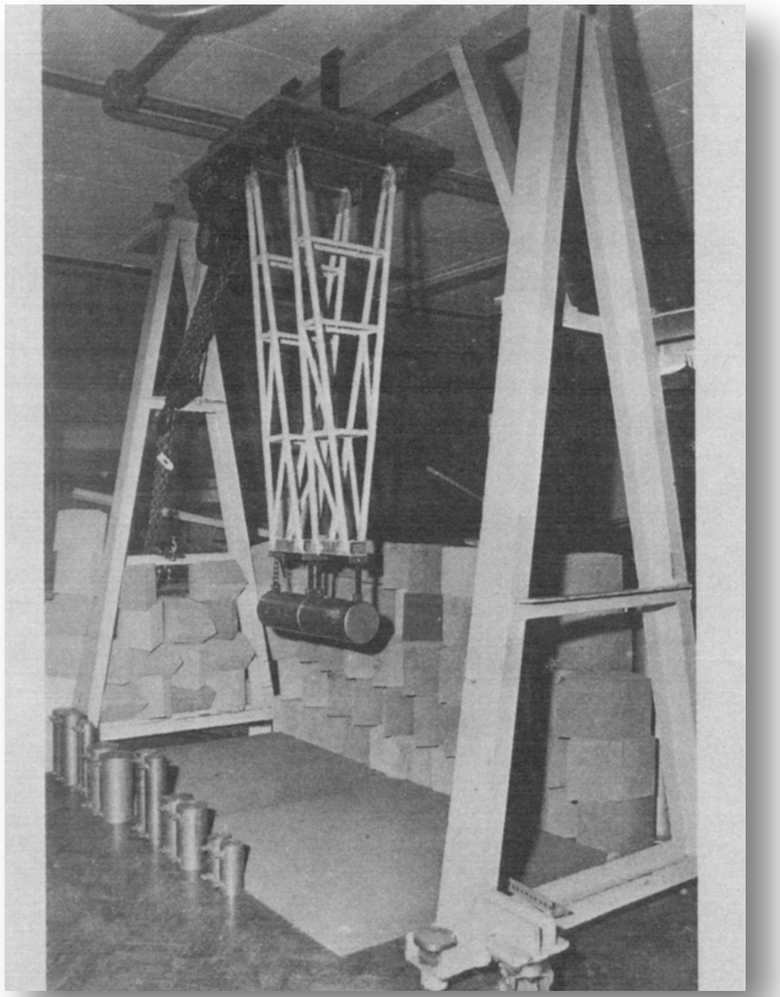
Acceleration Noise

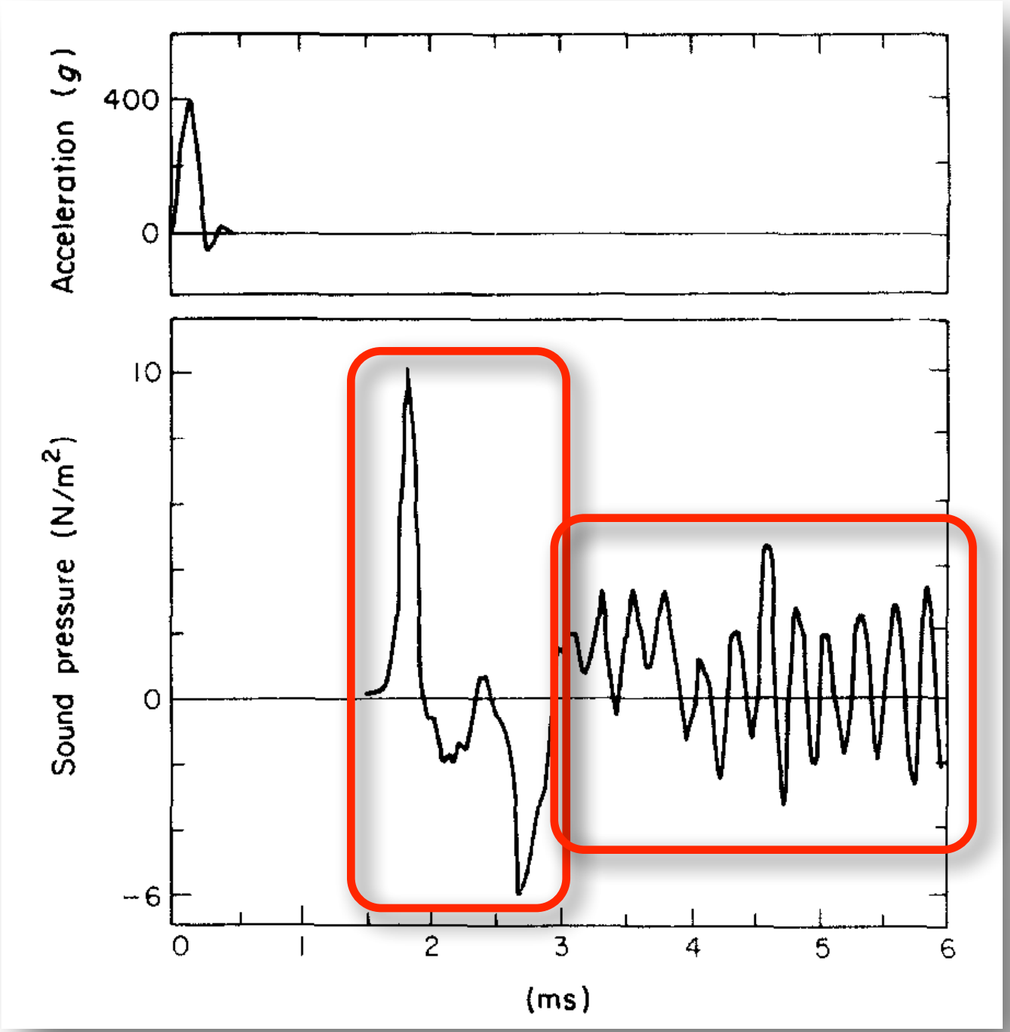
Sound produced when an object experiences rapid rigid-body acceleration

Acceleration Noise

Motivation

- Missing sound phenomena — improper transient sound modeling



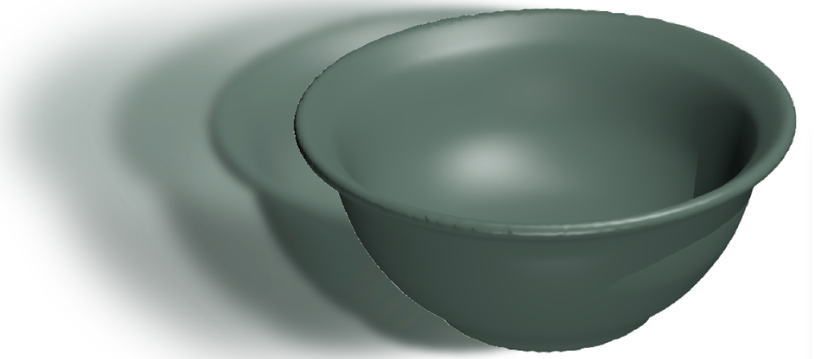


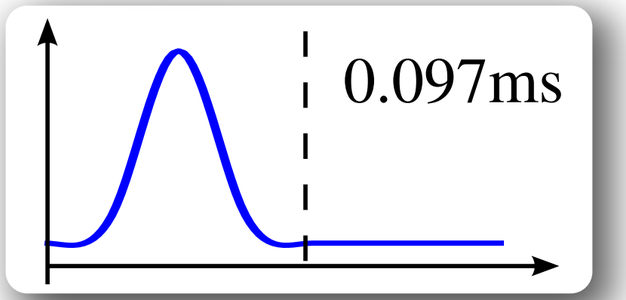
[Richards et al. 1978]

Problem Statement

Sound from rigid-body acceleration

- Complex wave phenomena, even for simple boundary conditions
- Modeling wave propagation over large domains is impractical

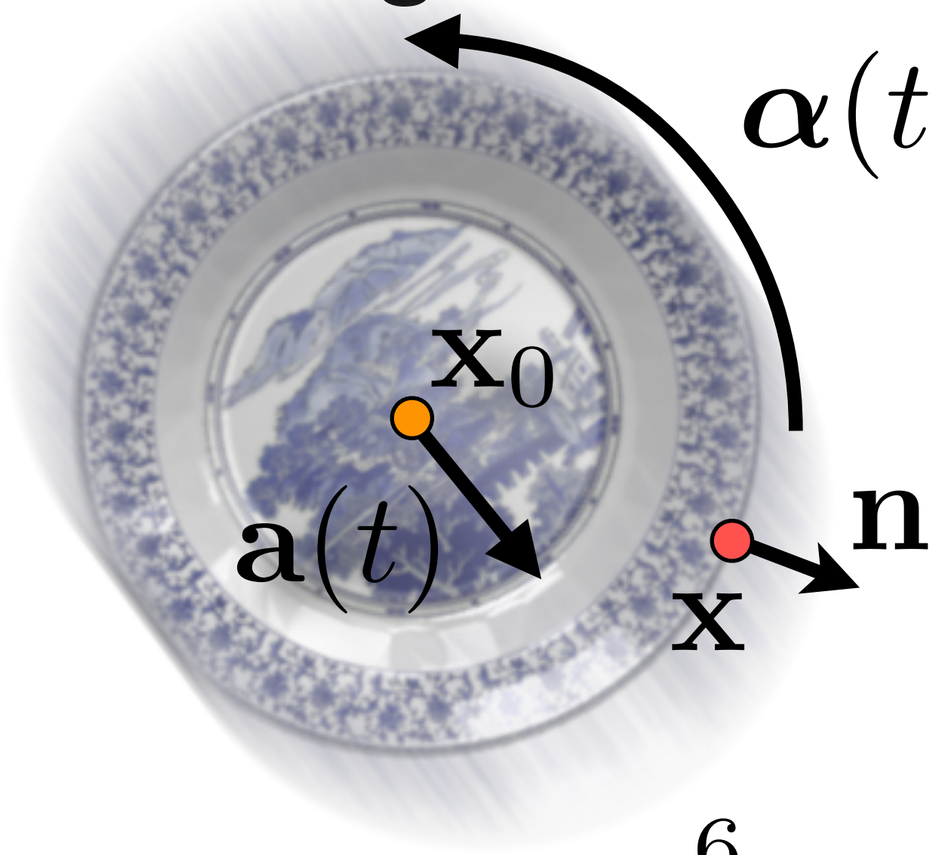




$a(t)$

Sim. time: ~7 minutes

Modeling Acceleration Noise Propagation



$$\frac{1}{c^2}\frac{\partial^2 p(\mathbf{x},t)}{\partial t^2} = \nabla^2 p(\mathbf{x},t)$$

$$\nabla p(\mathbf{x},t)\cdot\mathbf{n} = -\rho a_n(\mathbf{x},t)$$

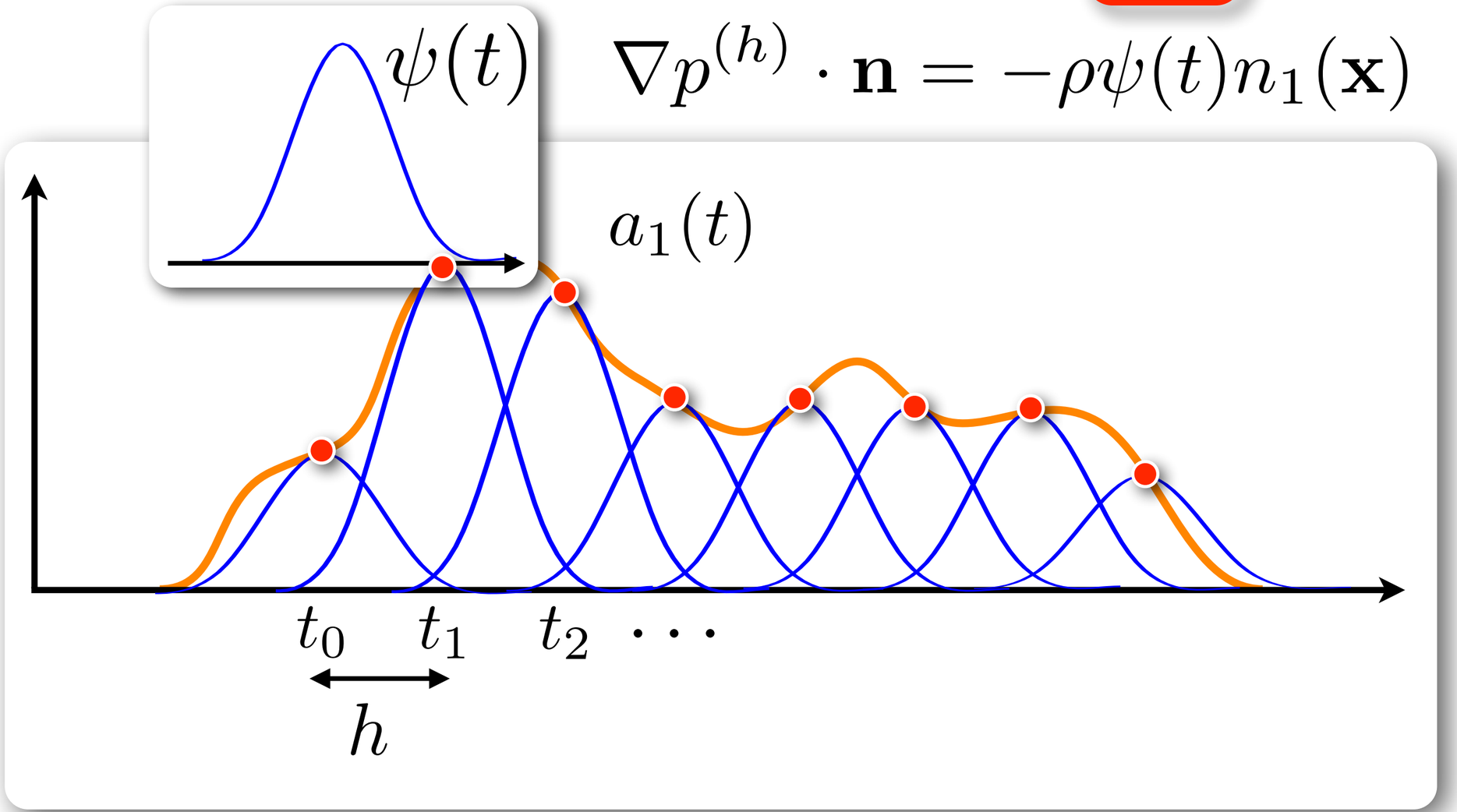
$$a_n(\mathbf{x},t) = \sum_{i=1}^{6} A_i(\mathbf{x},t) \qquad A_1(\mathbf{x},t) = a_1(t)n_1(\mathbf{x})$$

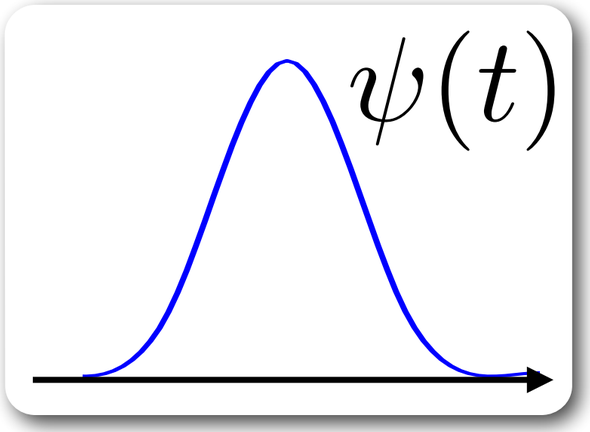
Modeling Acceleration Noise Propagation

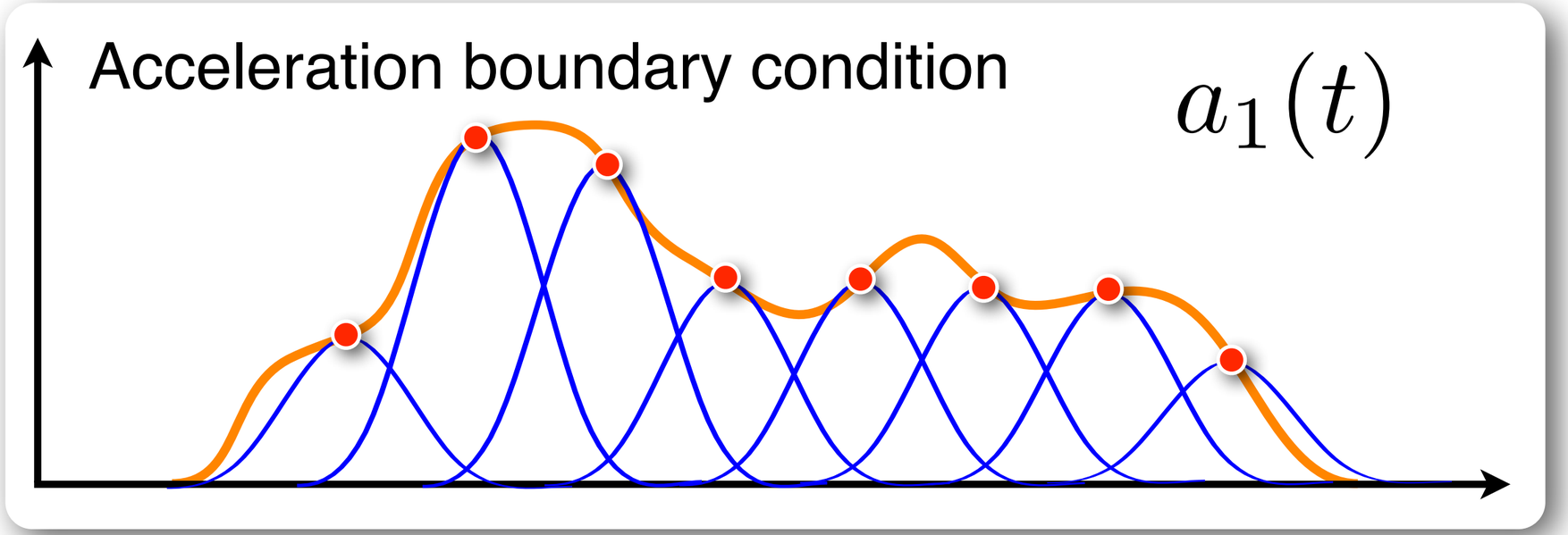
$$\frac{1}{c^2}\frac{\partial^2 p(\mathbf{x},t)}{\partial t^2} = \nabla^2 p(\mathbf{x},t)$$

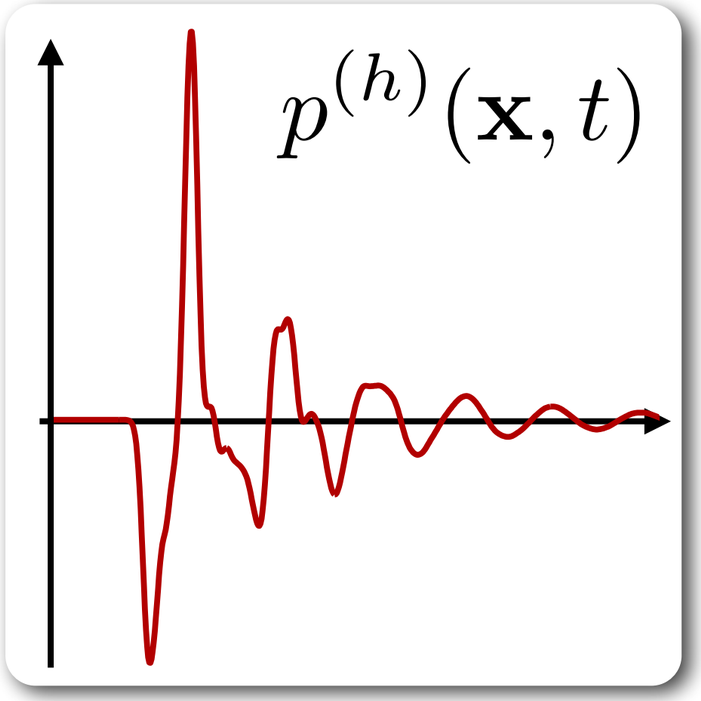
$$\nabla p \cdot \mathbf{n} = -\rho a_1(t) n_1(\mathbf{x})$$

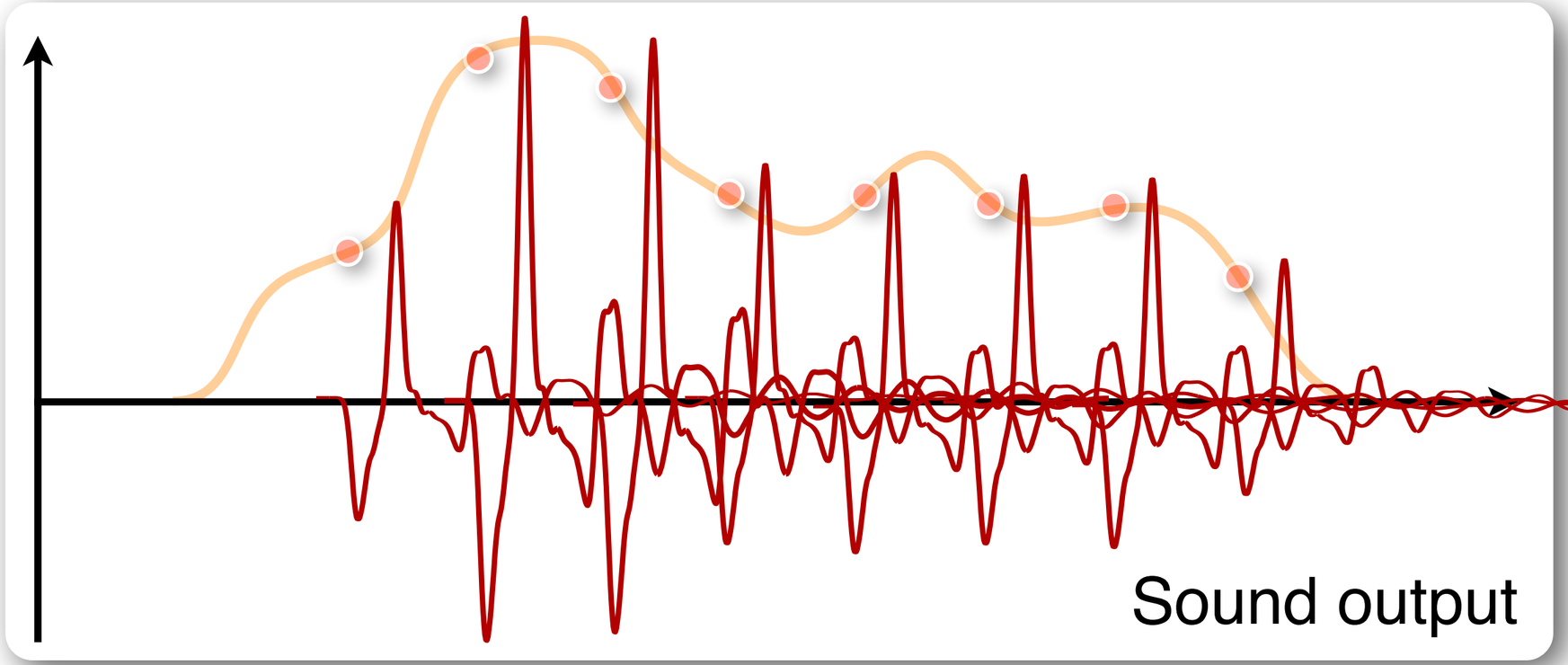
$$\nabla p^{(h)} \cdot \mathbf{n} = -\rho \psi(t) n_1(\mathbf{x})$$




$\psi(t)$

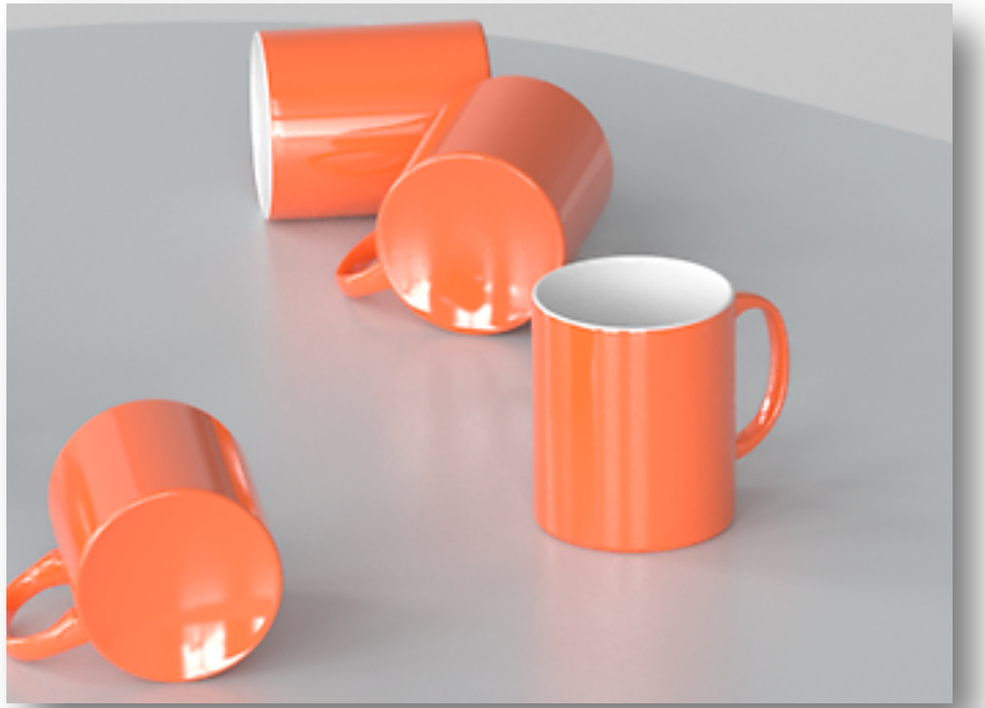

Acceleration boundary condition
$a_1(t)$

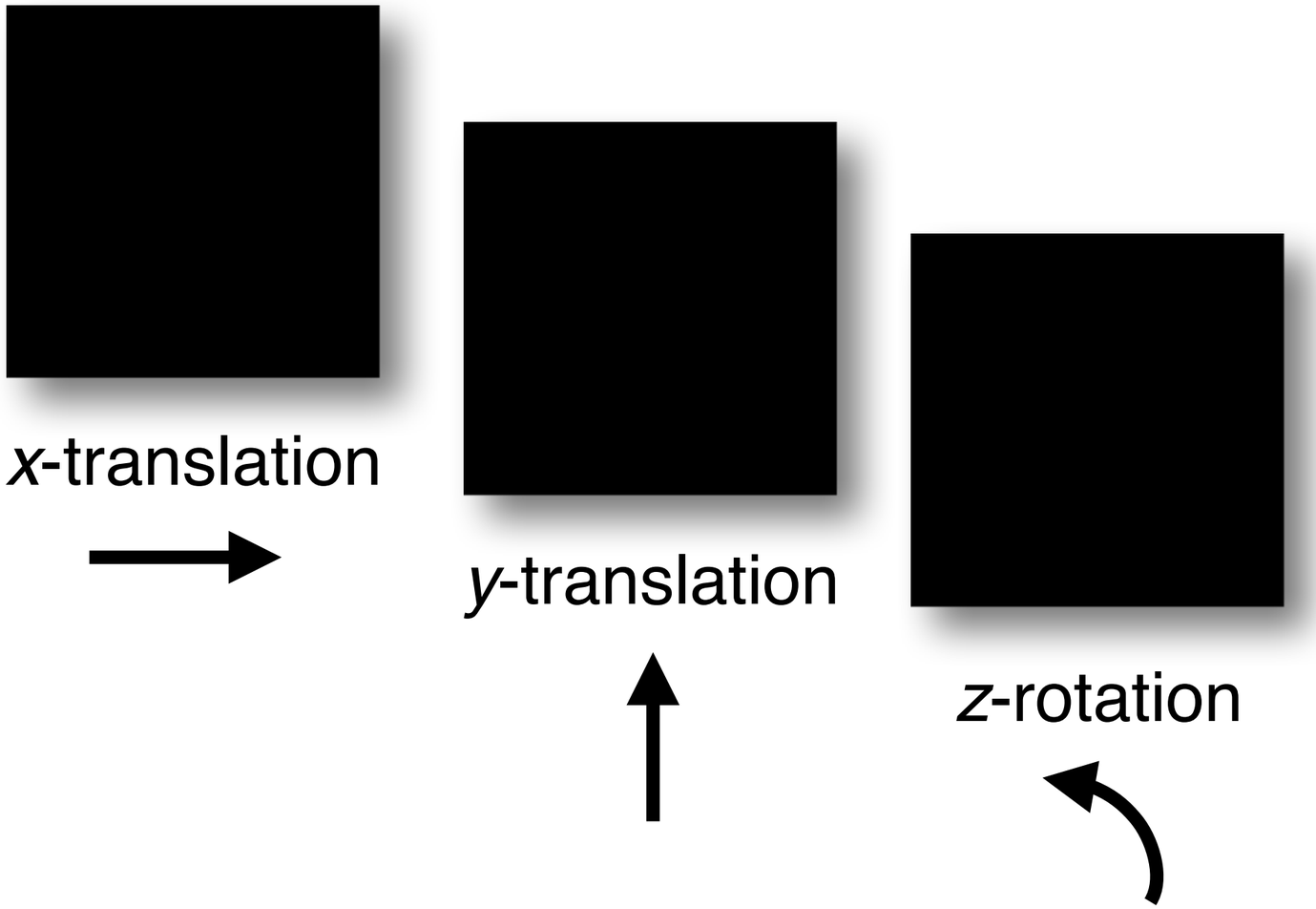

$p^{(h)}(\mathbf{x}, t)$


Sound output

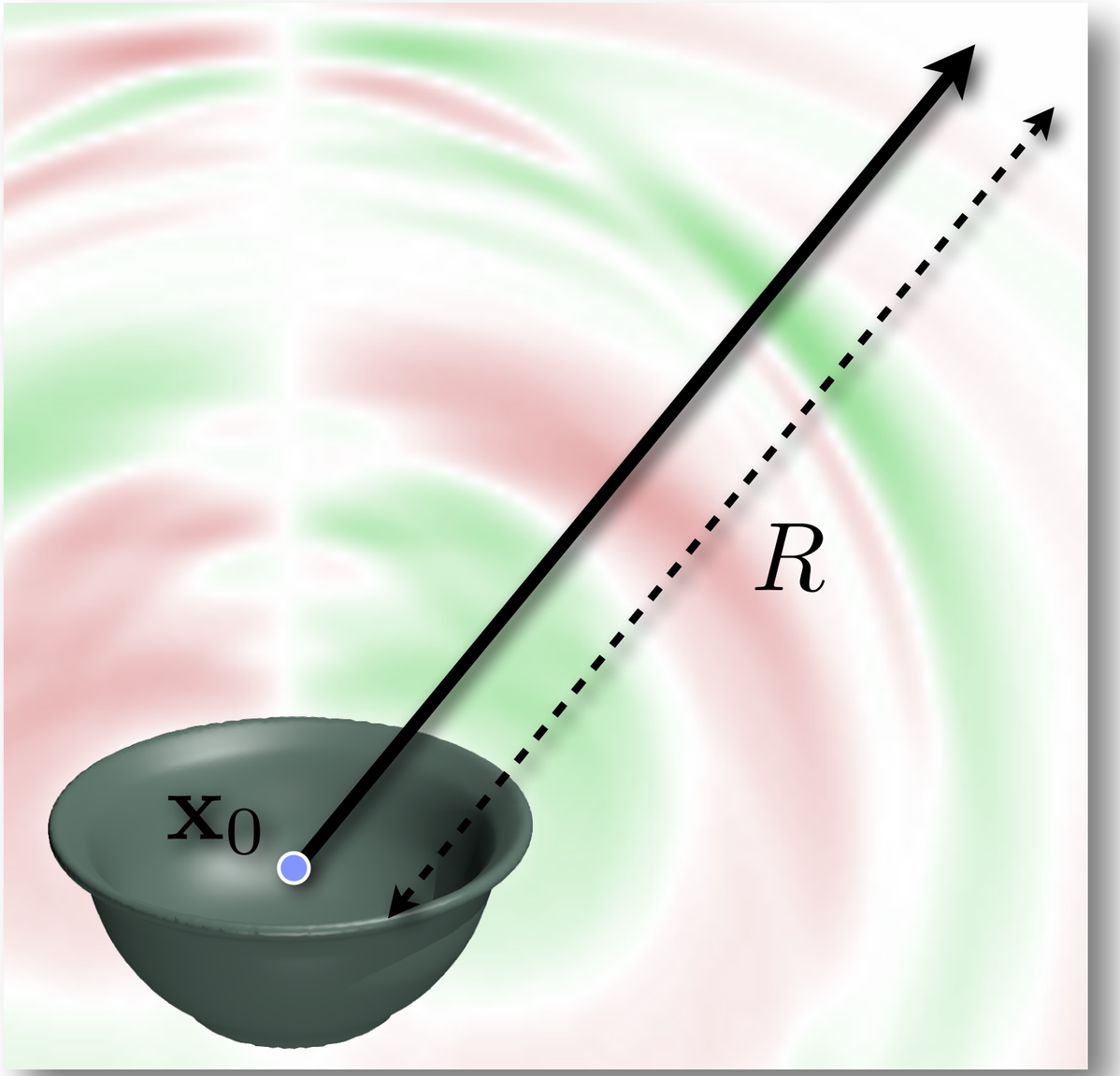
Modeling Acceleration Noise Propagation

$$\frac{1}{c^2}\frac{\partial p(\mathbf{x},t)}{\partial t^2} = \nabla^2 p(\mathbf{x},t) \qquad \nabla p \cdot \mathbf{n} = -\rho\psi(t)g_i(\mathbf{x})$$





Precomputed Acceleration Noise

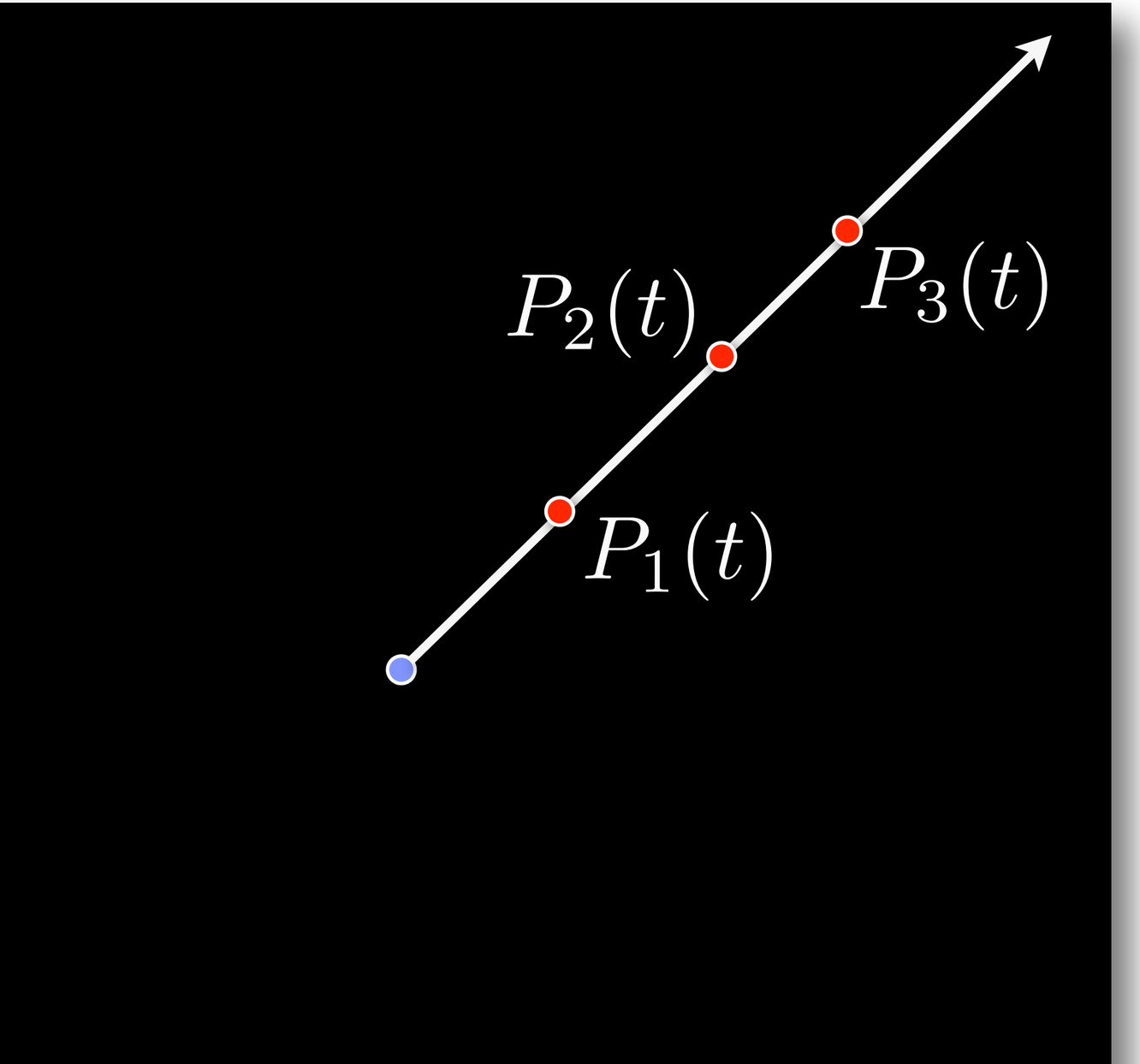


$$\frac{1}{c^2}\frac{\partial^2 p(\mathbf{x},t)}{\partial t^2} = \nabla^2 p(\mathbf{x},t)$$

$$\nabla p \cdot \mathbf{n} = -\rho\psi(t) n_1(\mathbf{x})$$

$$p(\mathbf{x},t) = \sum_{k=1}^{N} \frac{1}{R^k} q_k\left(t - \frac{R}{c}\right)$$

Precomputed Acceleration Noise

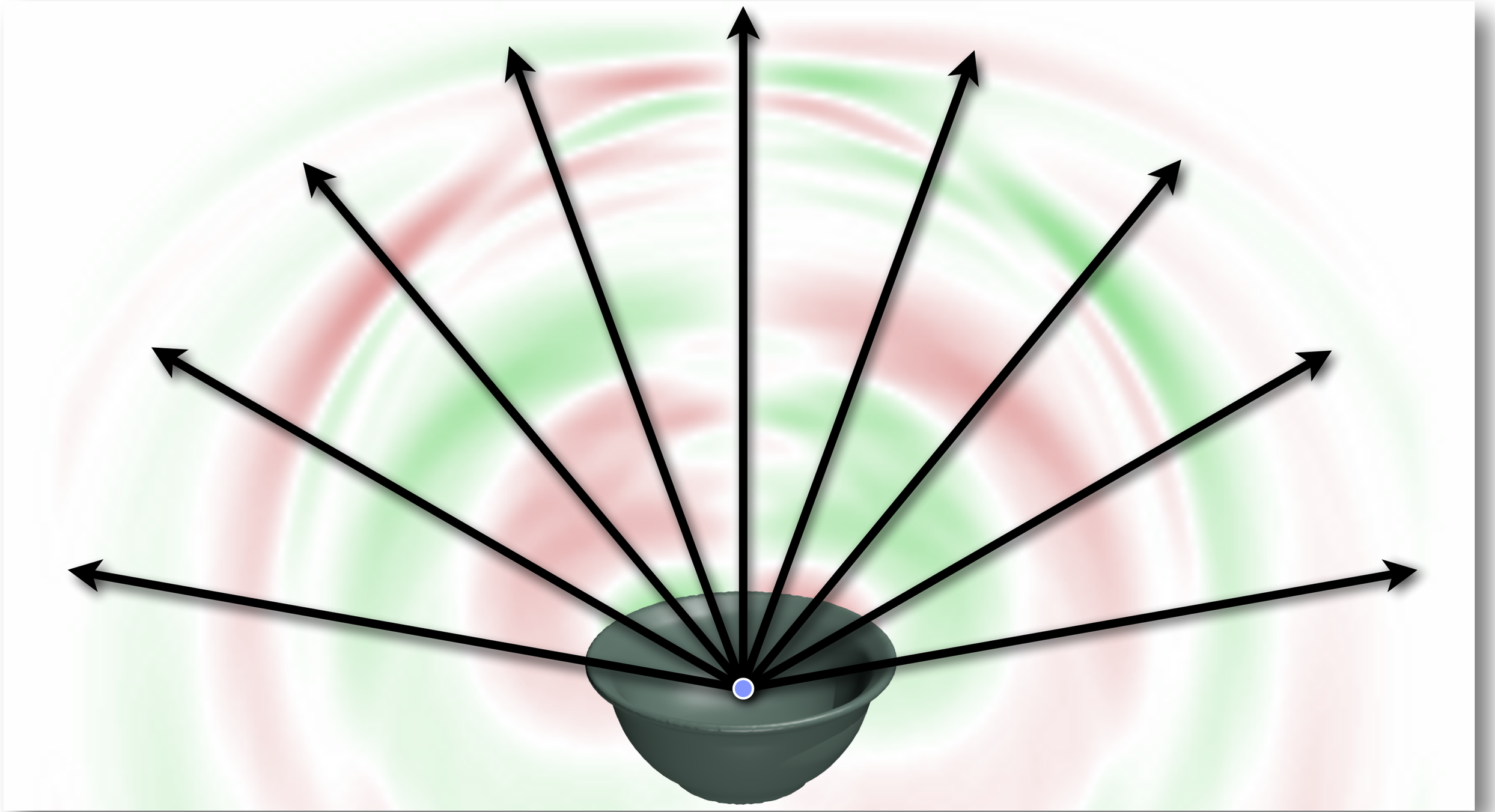


Solve on finite difference grid with perfectly matched layers
[Liu and Tao 1997]

$$\sum_{k=1}^{N} \frac{1}{R_1^k} q_k \left(t - \frac{R_1}{c} \right)$$

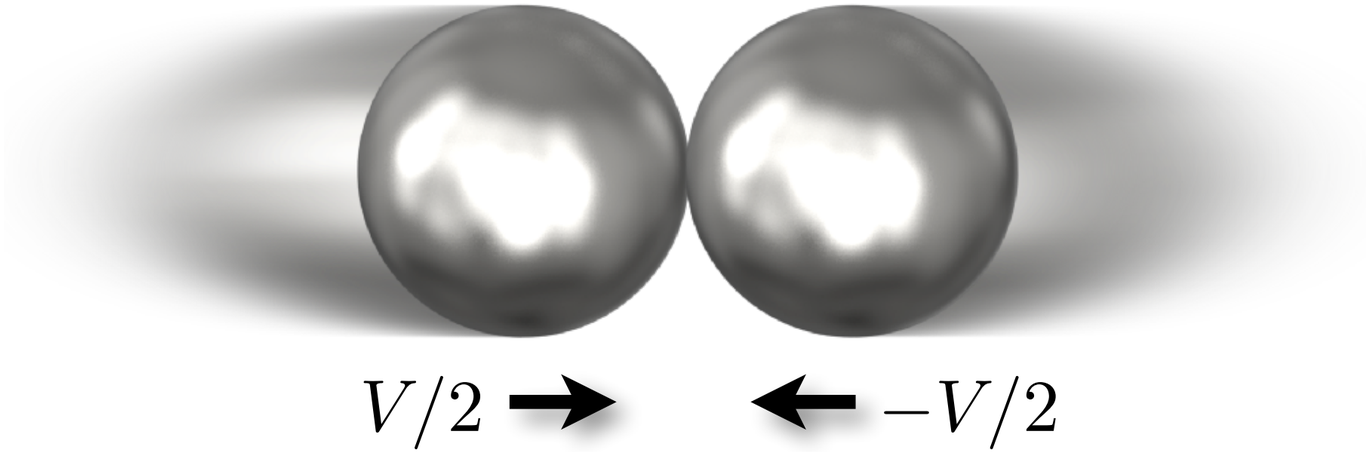
$$\sum_{k=1}^{N} \frac{1}{R_2^k} q_k \left(t - \frac{R_2}{c} \right)$$

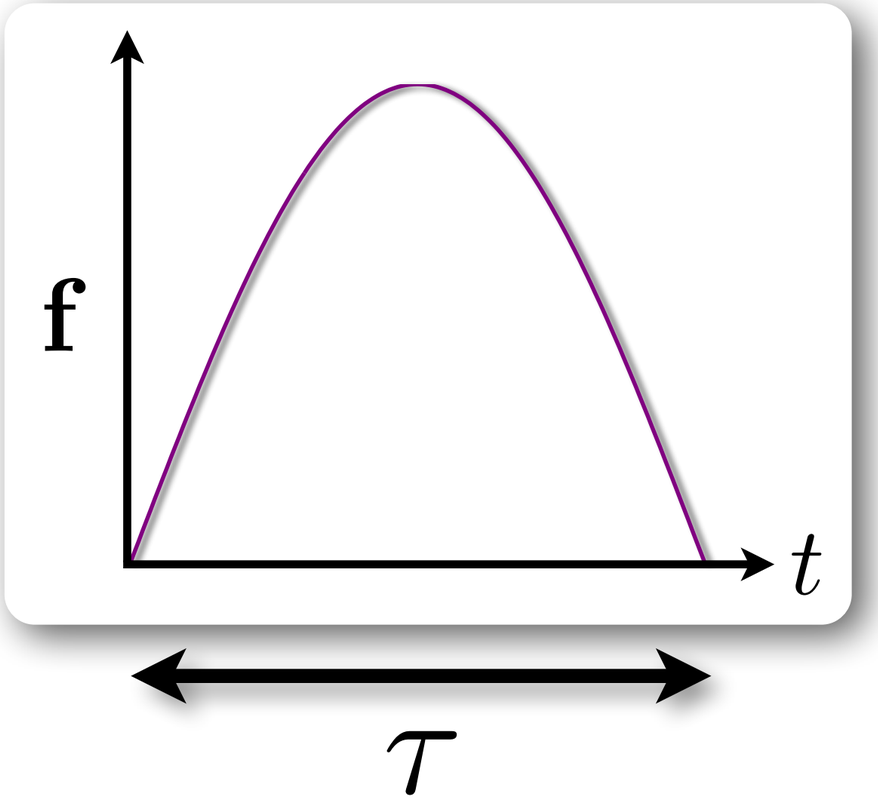
$$\sum_{k=1}^{N} \frac{1}{R_3^k} q_k \left(t - \frac{R_3}{c} \right)$$



Modeling Contact Acceleration

Hertz Contact Theory [Johnson 1985]

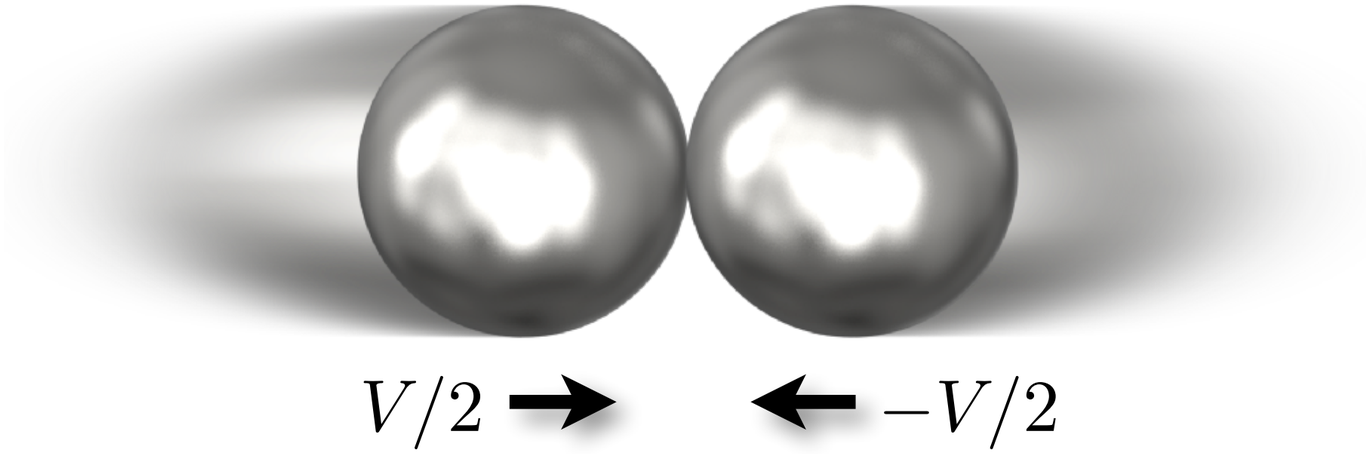


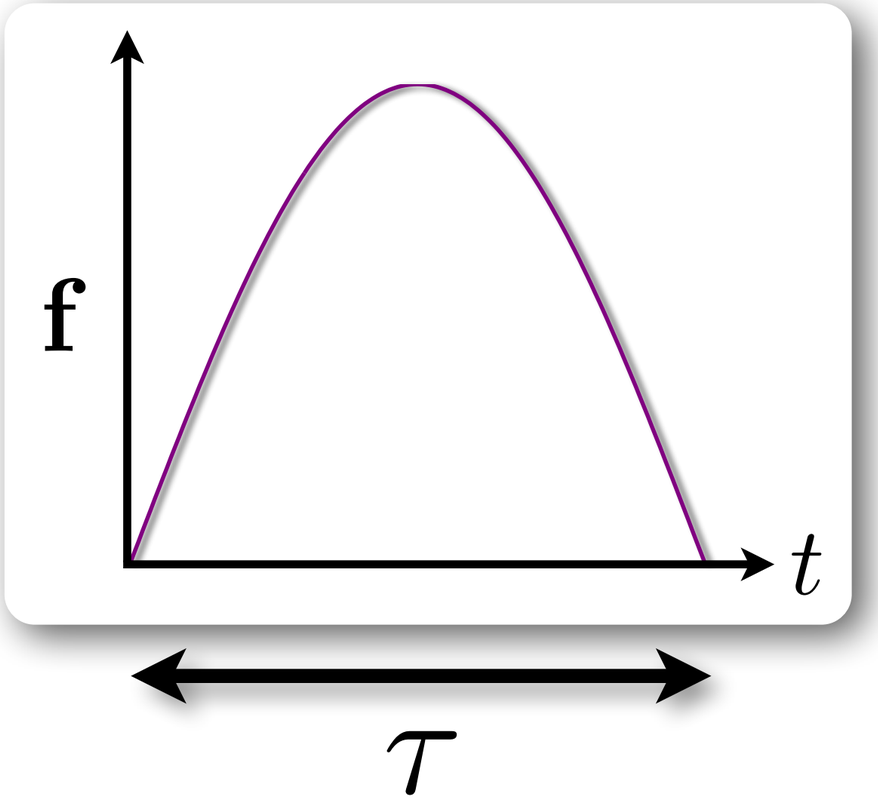


$$\tau = \tau \left(\begin{array}{c} \text{masses, velocities} \\ \text{material parameters, radii} \end{array} \right)$$

Modeling Contact Acceleration

Hertz Contact Theory [Johnson 1985]





$$\tau \approx 2.87 \left(\frac{m^2}{r E^2 V} \right)^{1/5}$$

$$\frac{1}{r} = \frac{1}{r_1} + \frac{1}{r_2}$$

$$\frac{1}{m} = \frac{1}{m_1} + \frac{1}{m_2}$$

$$\frac{1}{E} = \frac{1 - \nu_1^2}{E_1} + \frac{1 - \nu_2^2}{E_2}$$

(see [Chadwick et al. 2010] for details.)

Results

Modal Sound Comparisons

1. Modal sound only (***without*** acceleration sound)

2. Acceleration sound only

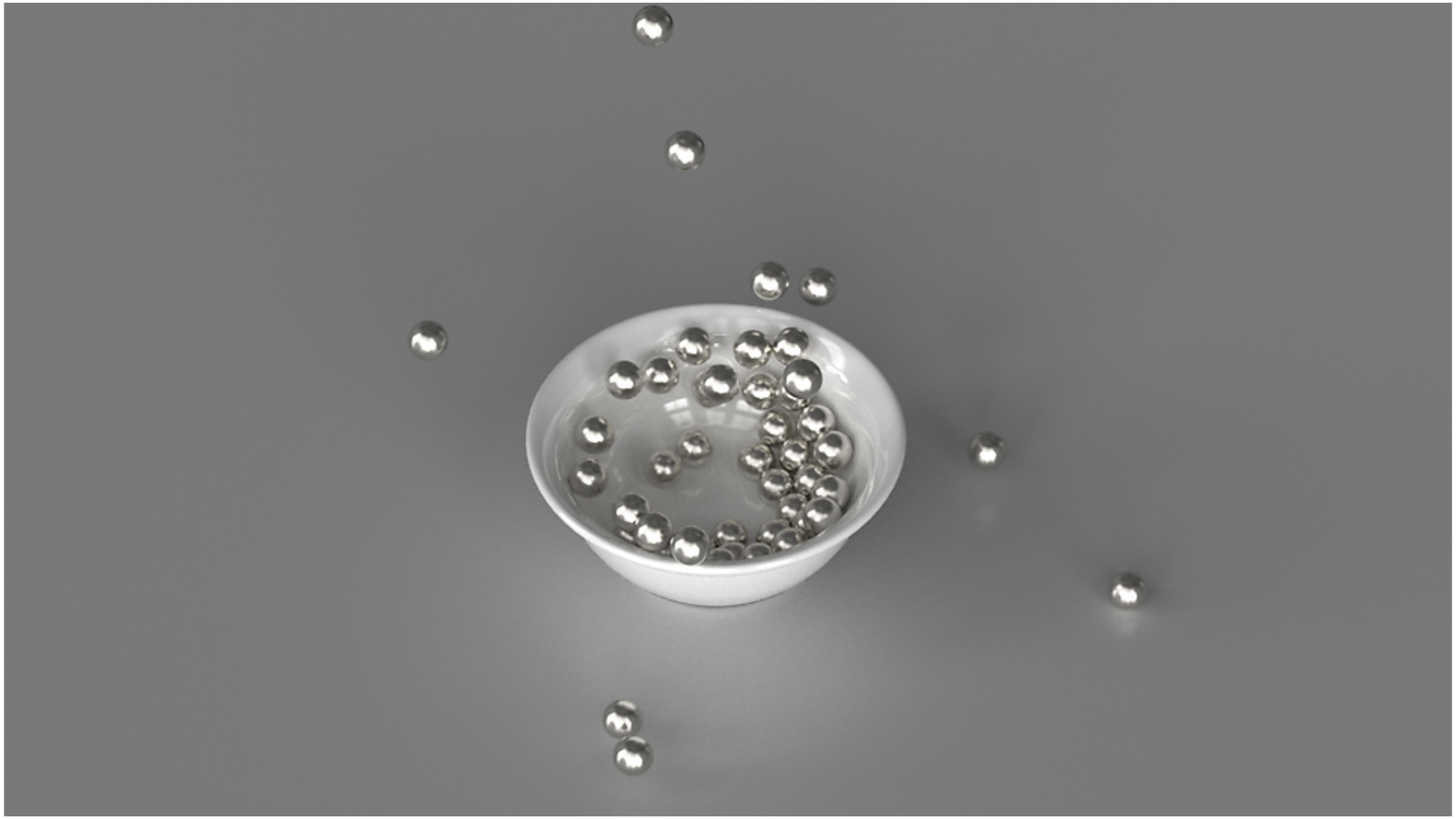
3. Full sound (modal sound ***with*** acceleration sound)

4. Before and after comparison (***with*** and ***without*** acceleration sound)

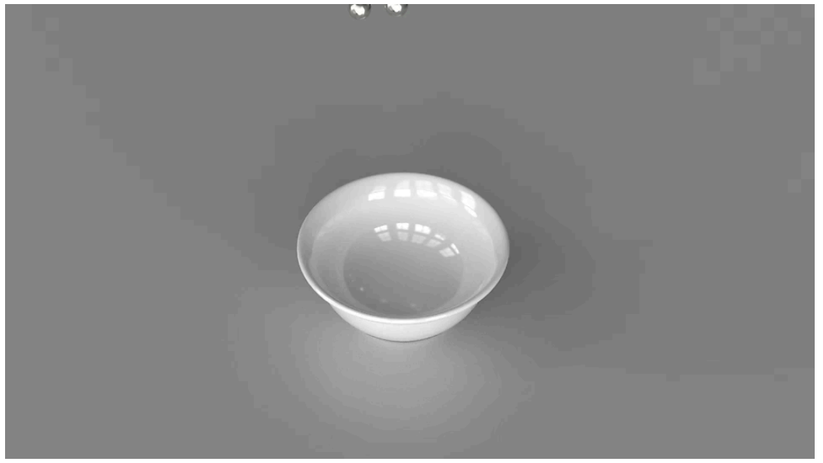
Ball Bearings

Acceleration noise synthesis time: 8 seconds

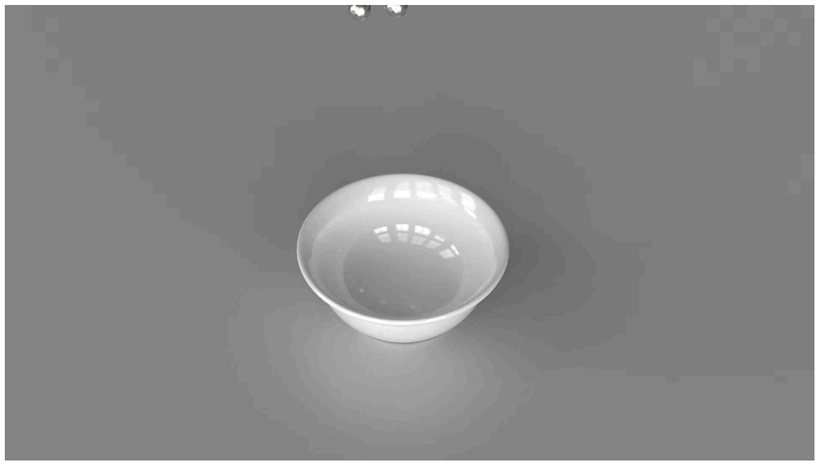
Rigid-body impulses: 23411



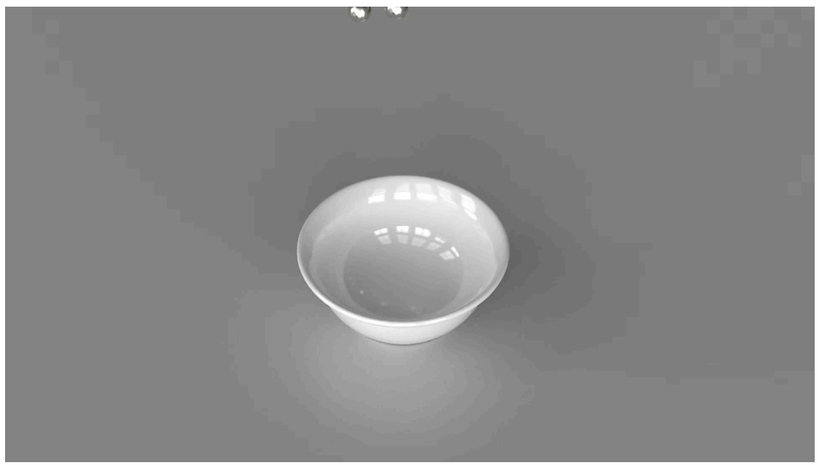
Modal sound only
(***without*** acceleration sound)



Acceleration sound only



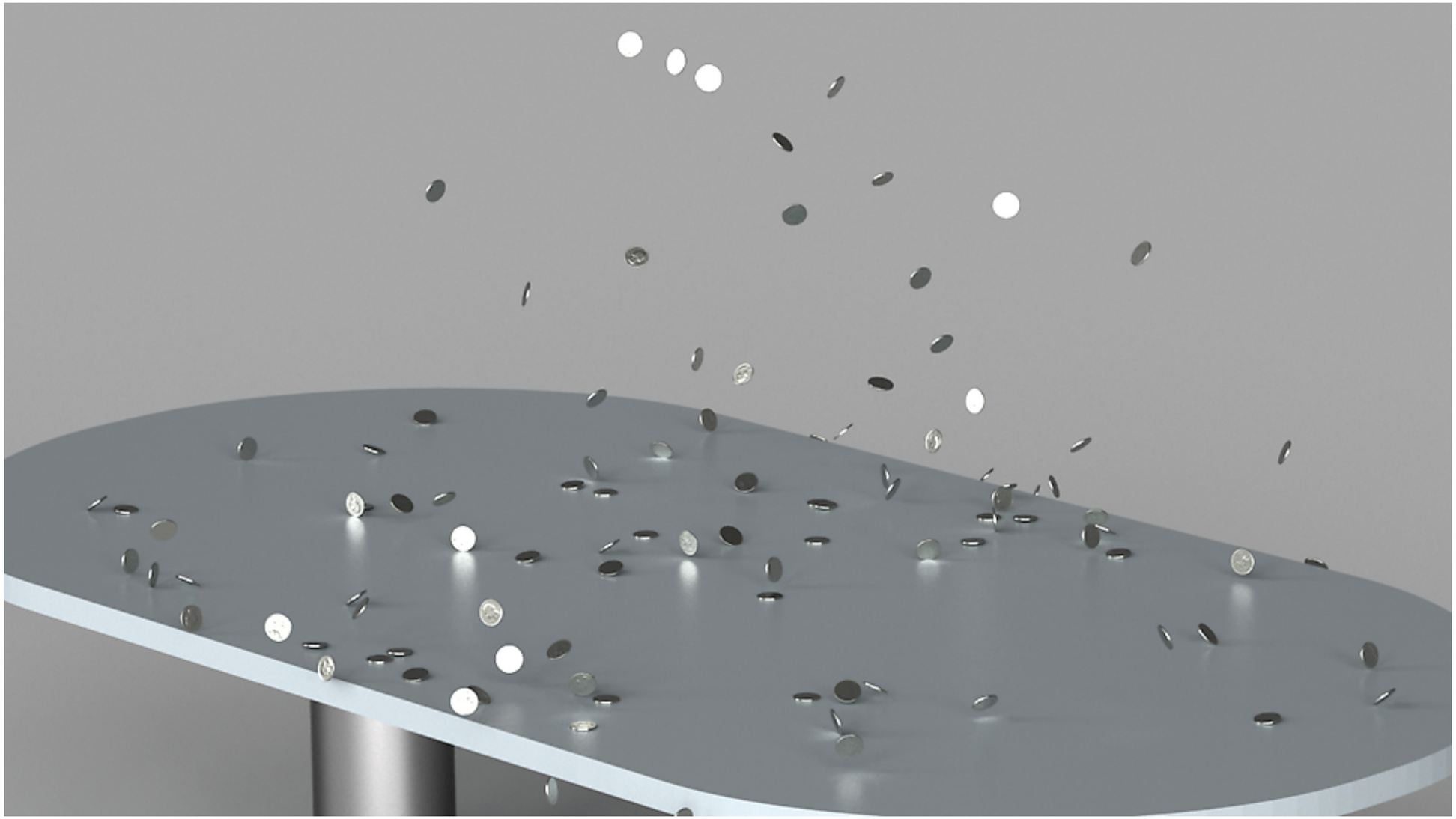
Combined sound
(***with*** acceleration sound)



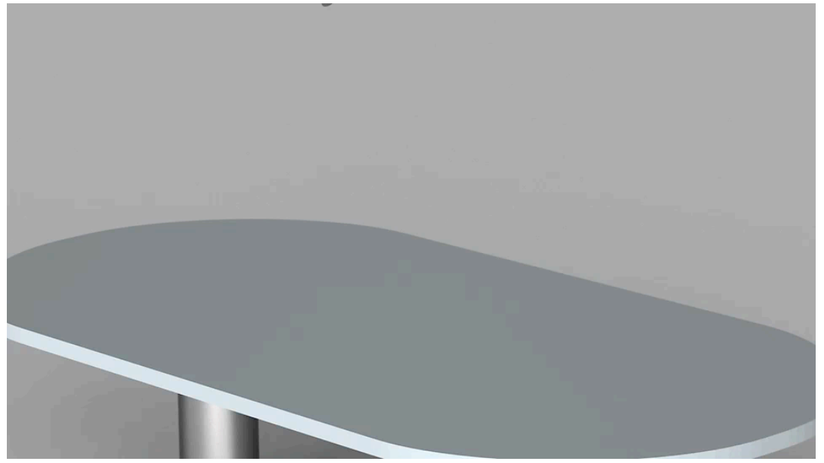
Coins

Acceleration noise synthesis time: 18 seconds

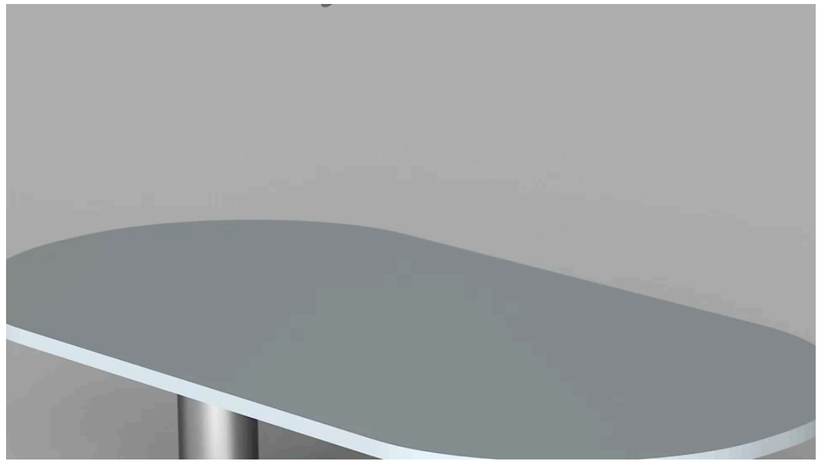
Rigid-body impulses: 24045



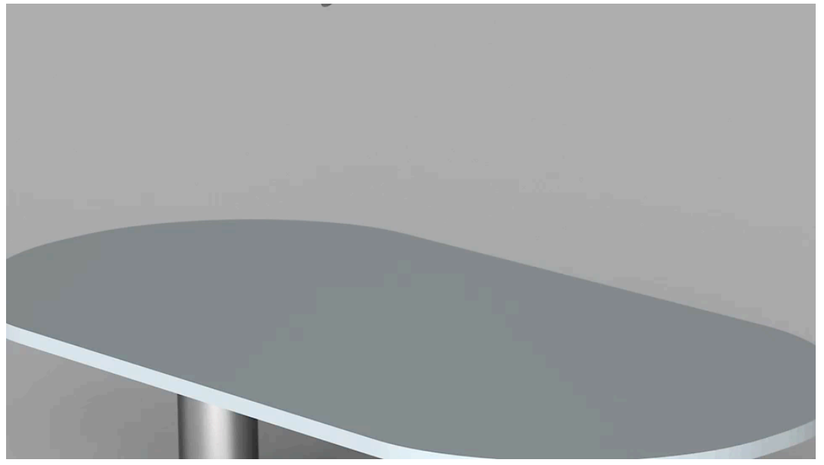
Modal sound only
(***without*** acceleration sound)



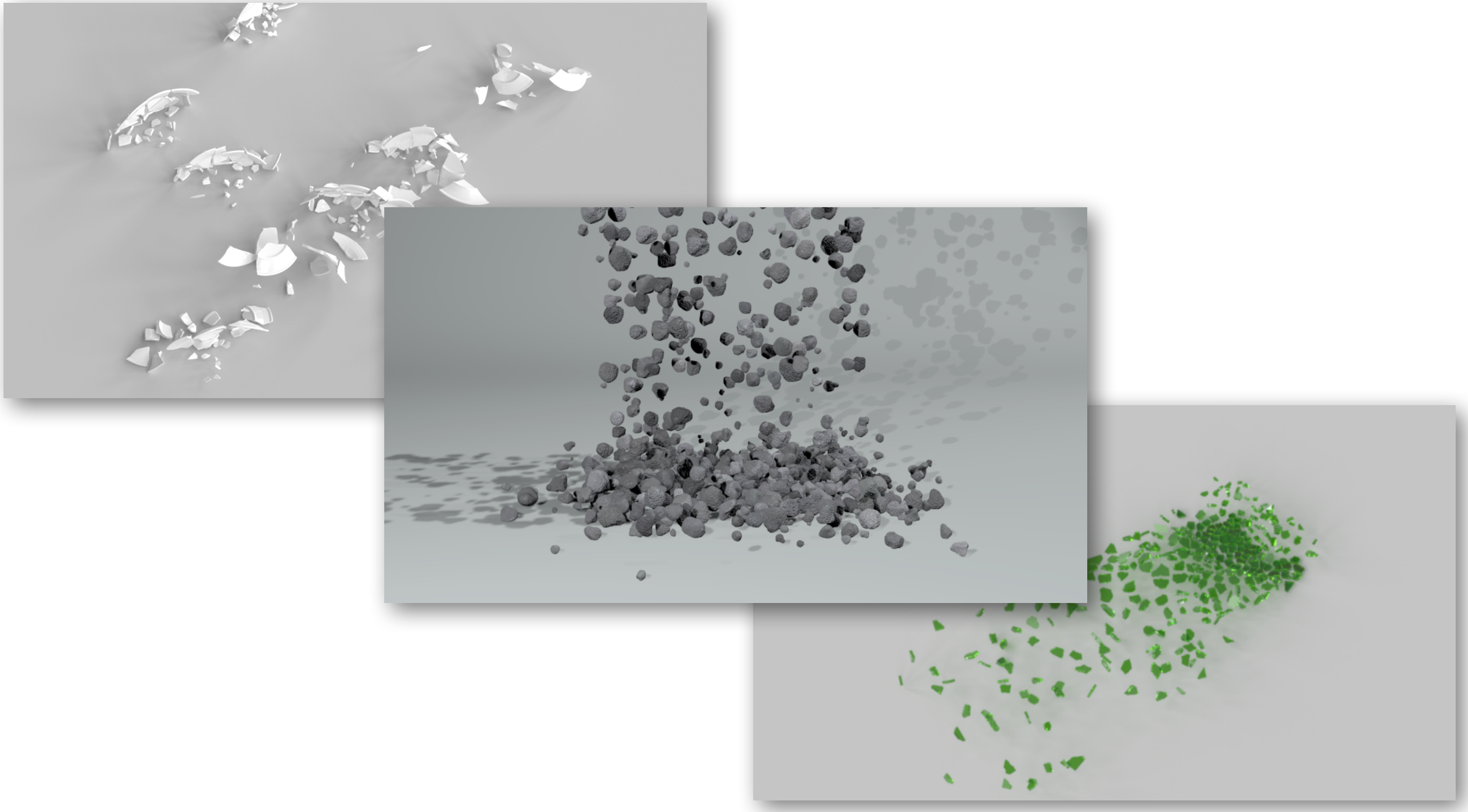
Acceleration sound only



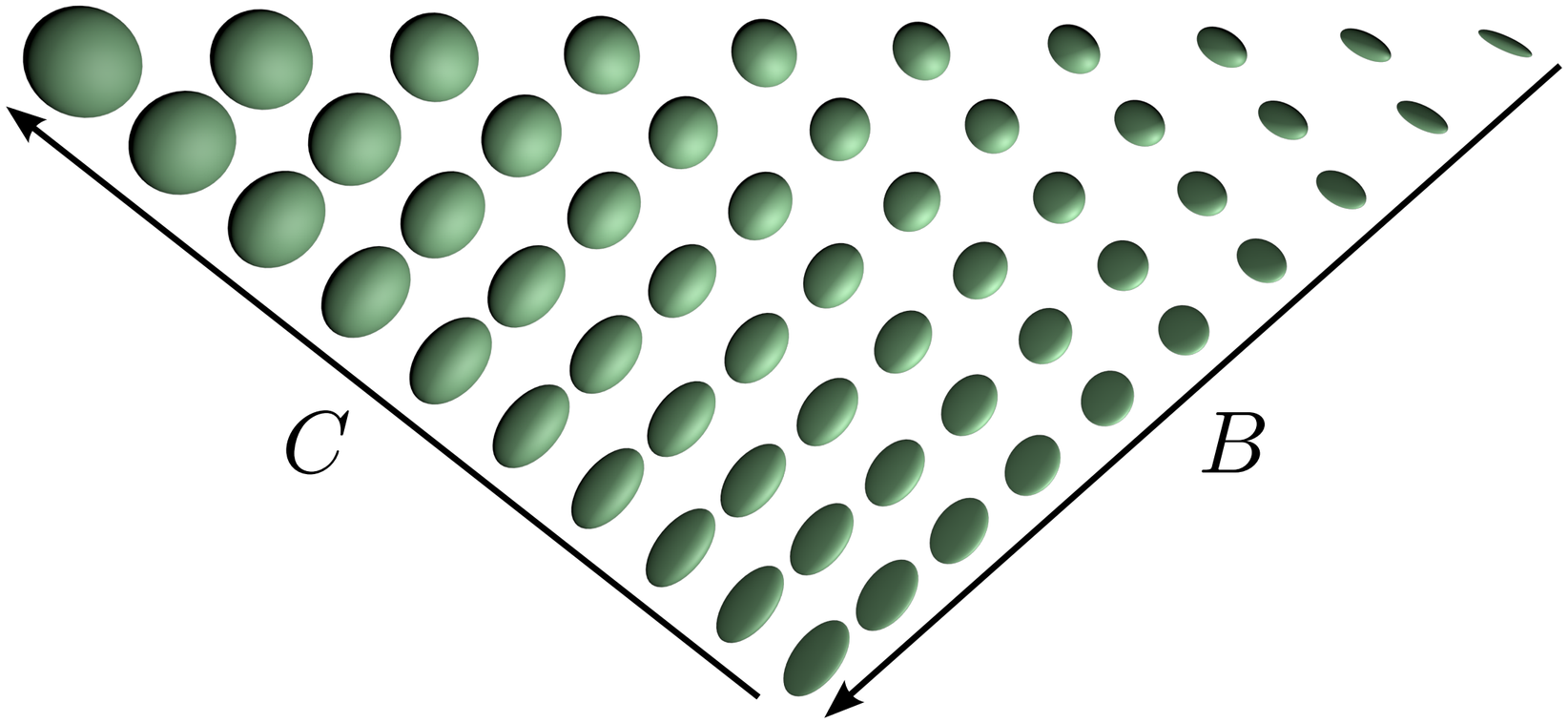
Combined sound
(***with*** acceleration sound)



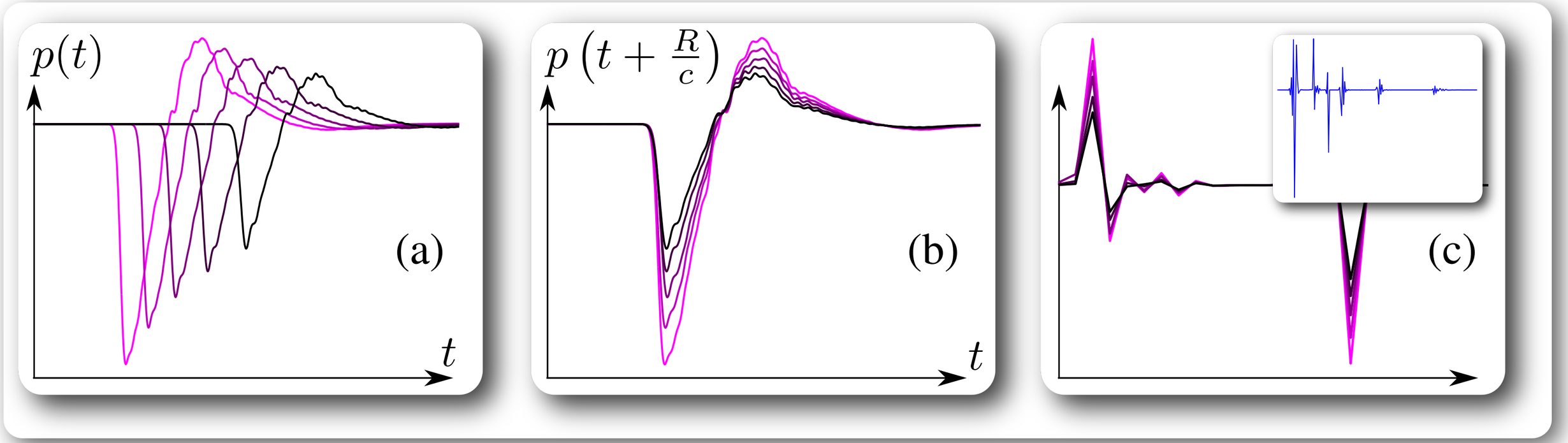
More Results

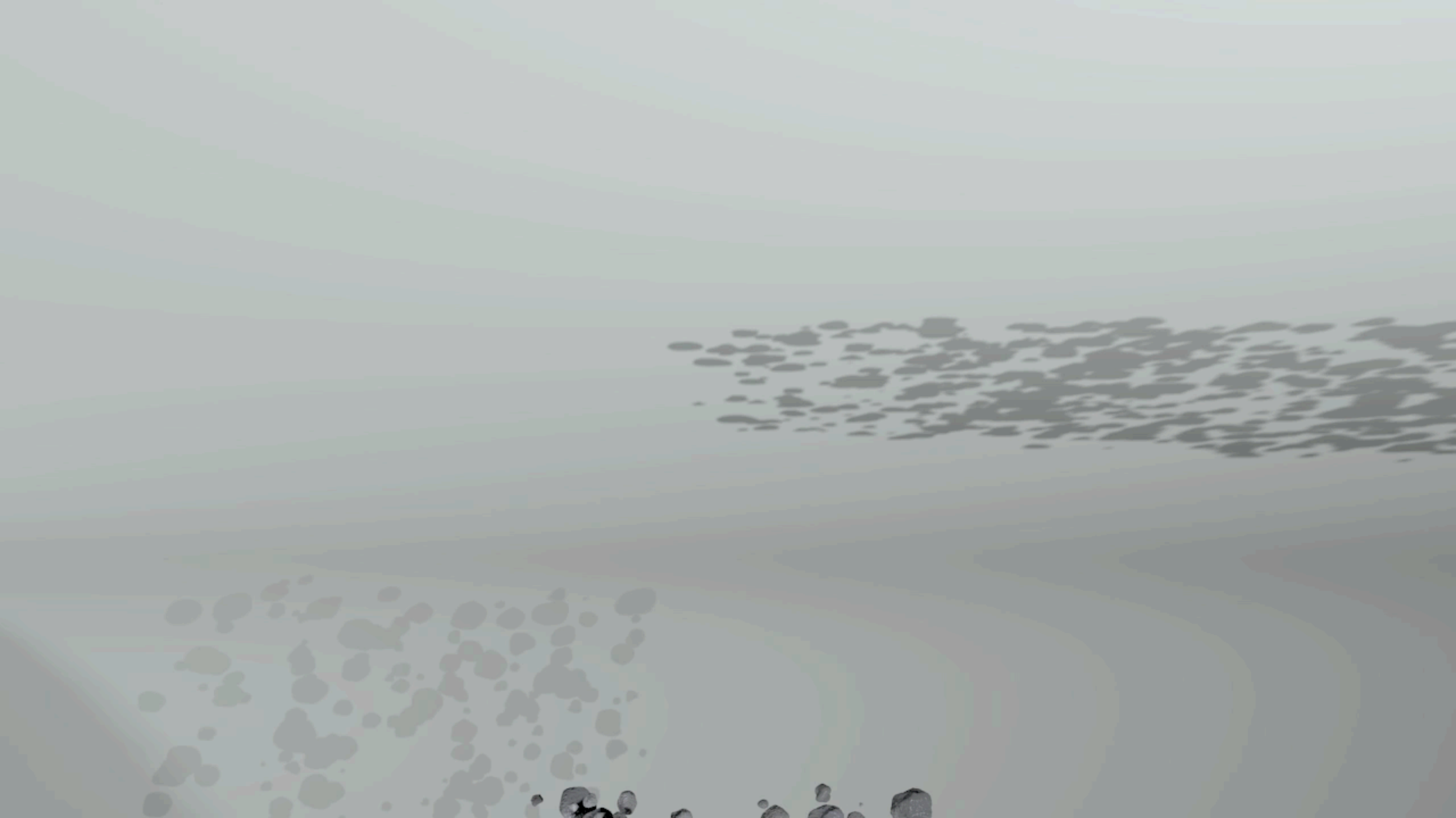


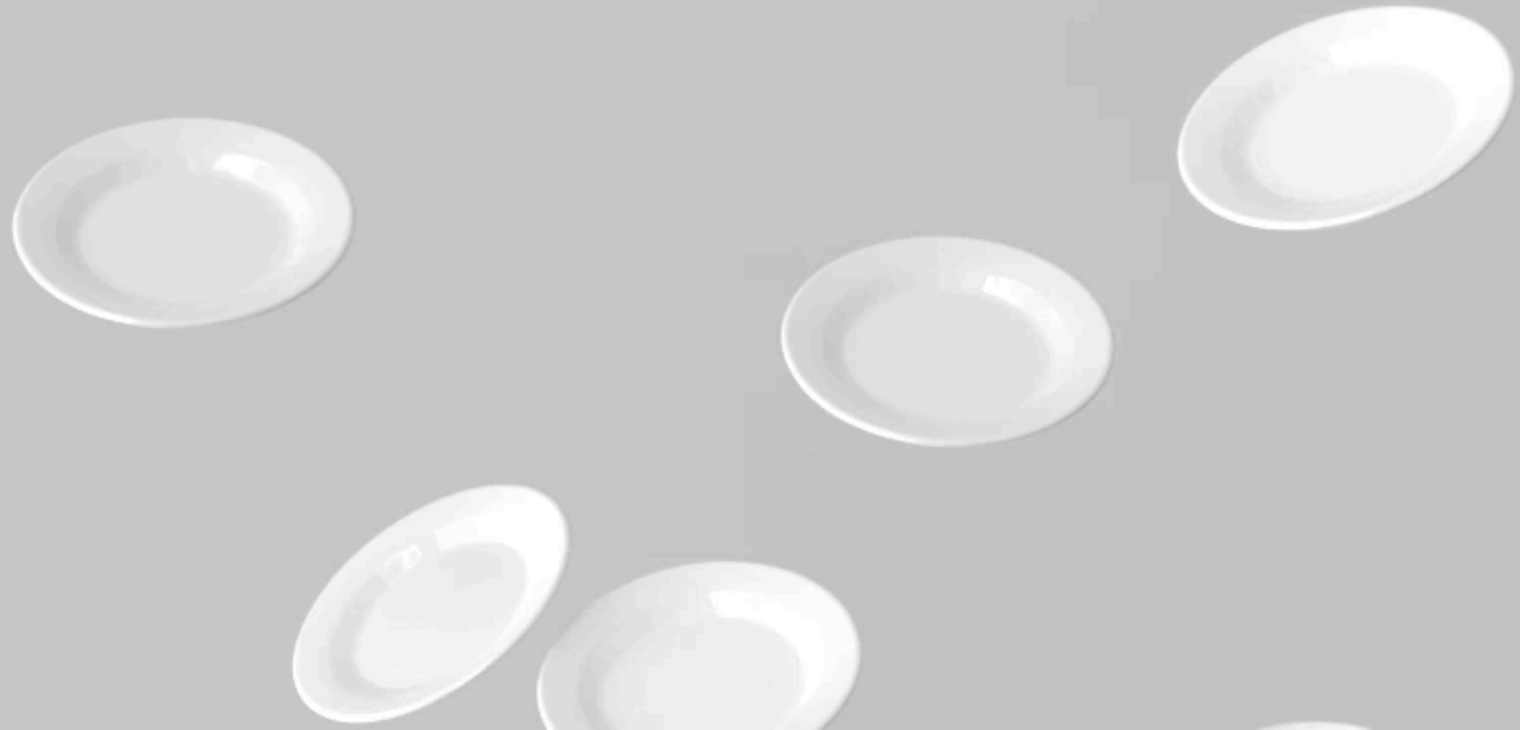
Precomputed Soundbank



Wavelet Compression







Acknowledgements

Webpage http://www.cs.cornell.edu/~chadwick

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