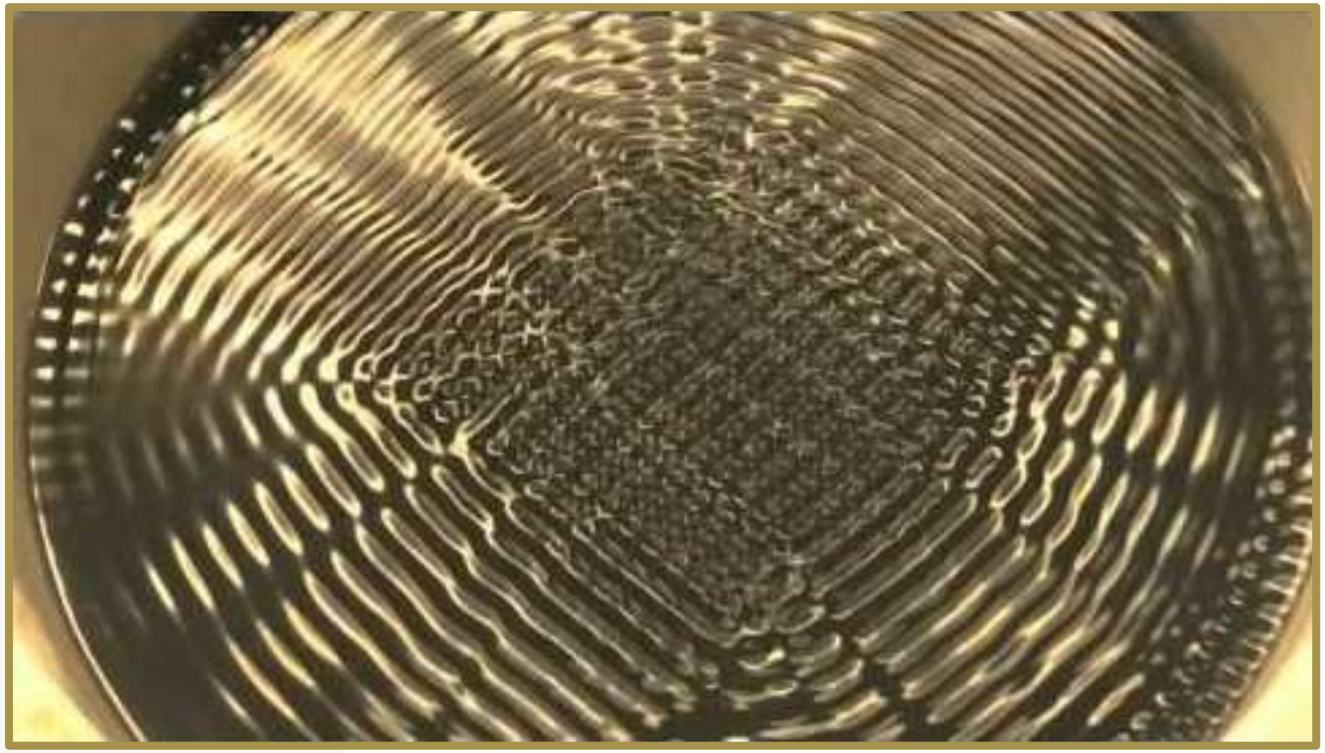
Exploration of Locally Induced Waves

Steven Tarr, Ashley Barnes, Alejandro Escontrela

Introduction to Faraday Waves

- Faraday waves are nonlinear standing waves that are most often generated by vibrating a system vertically and globally.
  - First observed by Michael Faraday in 1831



- The surface of the liquid exhibits pattern formation behavior.
- Patterns in the surface wave vary from concentric circles to polygon geometries.
- Researchers have shown that these patterns are depending on various factors.
  - Fluid viscosity, water depth, driving frequency, driving amplitude

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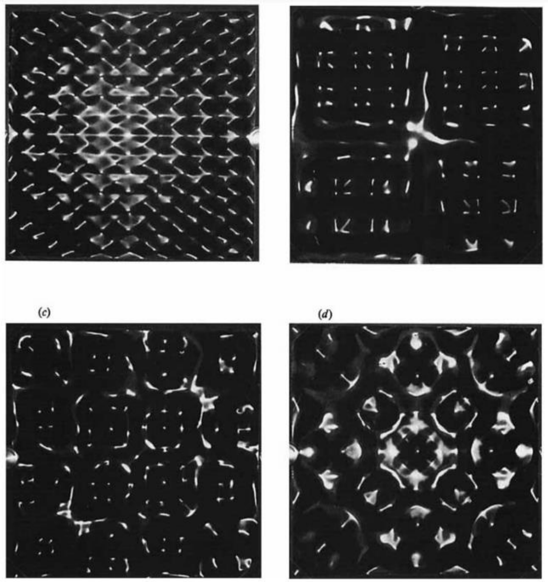
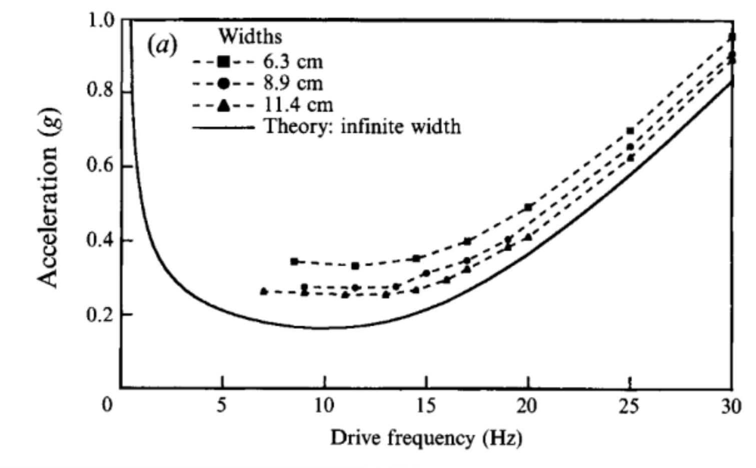
Prior Research

Faraday's Experiments → Douady → Bechhoeffer et. al.

- Researchers have studied both the theoretical and the experimental qualities of Faraday wave formation.
- A century after Faraday's initial experimentation, physicist Douady in France recreated his experiments.
  - Showed sensitivity to boundary conditions and described the dynamics with amplitude equations



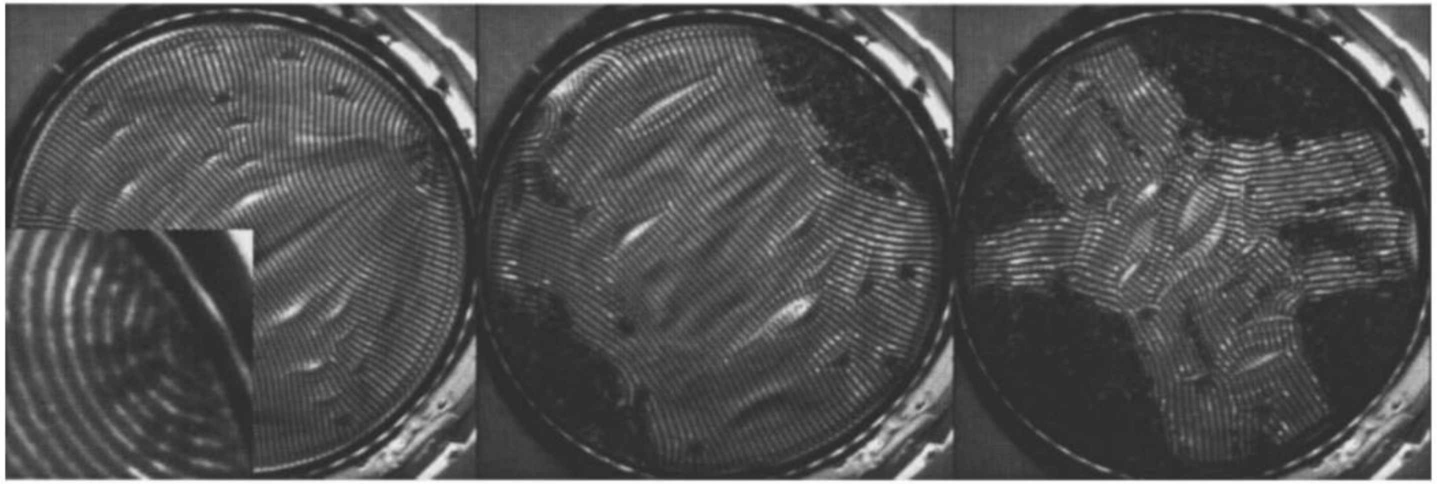


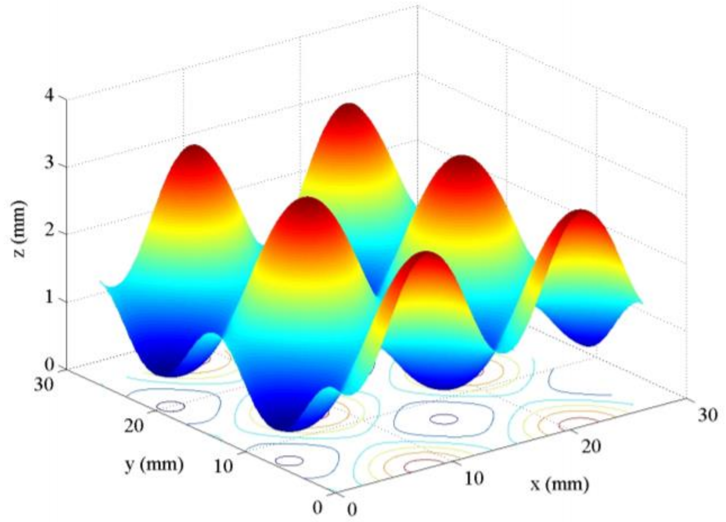
- Bechhoeffer et. al. decreased the discrepancies between previous theory and experimental results in their study of the Faraday instability.
  - Identified and controlled dissipative aspects in the experimental setup

Prior Research

Kudrolli and Gollub → Chen and Viñals → Périnet et. al.

- More recently, physicists have developed numerical and analytical analyses for the standing wave phenomenon.
- Kudrolli and Gollub explored the formation of spatiotemporal chaos on surface waves.
  - Documented the existence of a “mixed state” for surface waves
- Chen and Viñals developed method to determine the type of pattern formed when standing waves are generated in various fluids.
- A numerical simulation of Faraday waves was completed by Périnet et. al.





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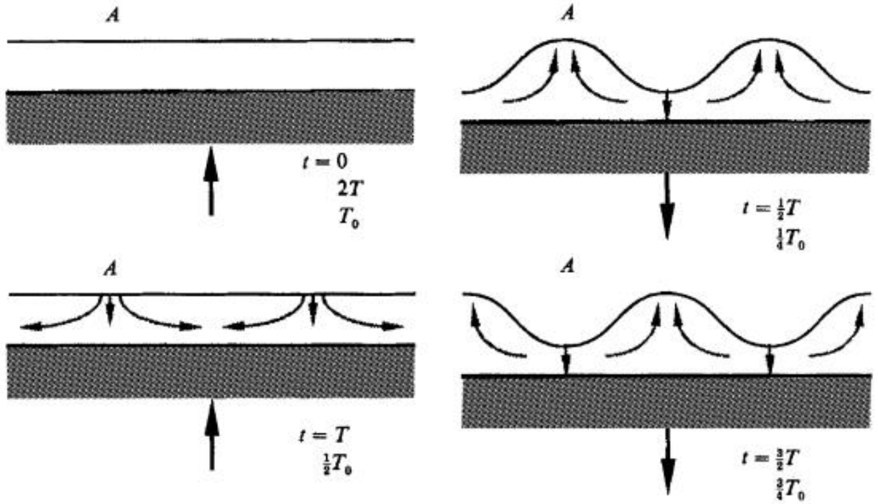
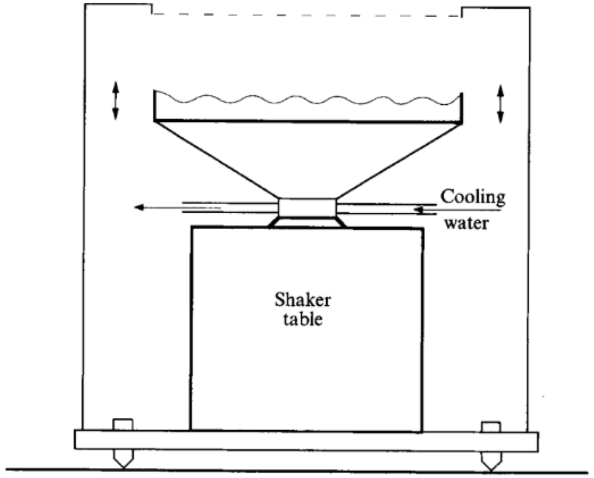
Locally Induced Waves

- While prior research has investigated multiple variables in the phenomenon (fluid viscosity, container width, boundary conditions), the theory and experimentation are all completed with globally driven waves in mind.

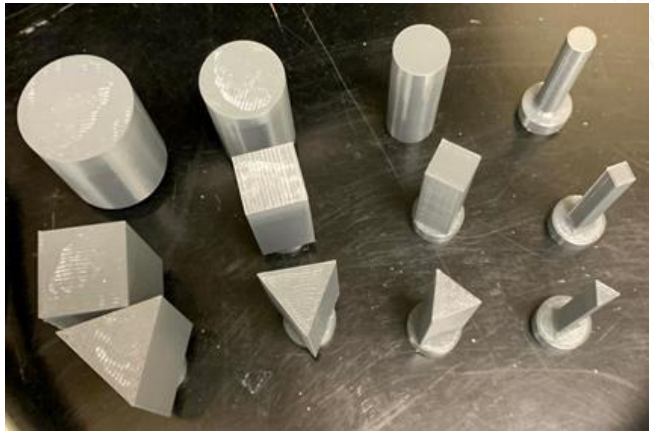




- Locally driven frequencies are more applicable to real life examples.
  - Alligators in bodies of water generate standing waves from mating calls.
- When the driving force is local, does the behavior of the instability change?

Experimental Setup – Test Apparatus

- Each member assembled a testing rig to evaluate the three piston shapes studied in this project: circle, triangle, and square.
- Four variants of each piston were printed; each of a different cross-sectional area.
  - Circle radii set to 5, 10, 15, 20 mm
  - Inscribed regular polygons used for squares and triangles
- The pistons were then attached to a EWA A106 Bluetooth speaker using rubber cement.



Different piston shapes

EWA A106 Speaker

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Experimental Setup – Test Apparatus

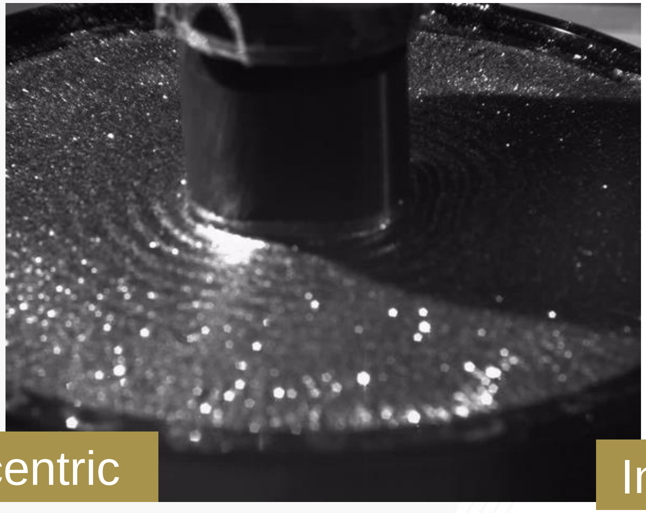
- We filled a 6" diameter container with ~0.9 L of water (50 mm depth) to serve as our testbed.
- The piston-driver assembly was attached to a rigid stand, enabling submersion of the piston to different depths.
- Control parameters: piston shape, submersion depth, and driver frequency

Ashley's setup

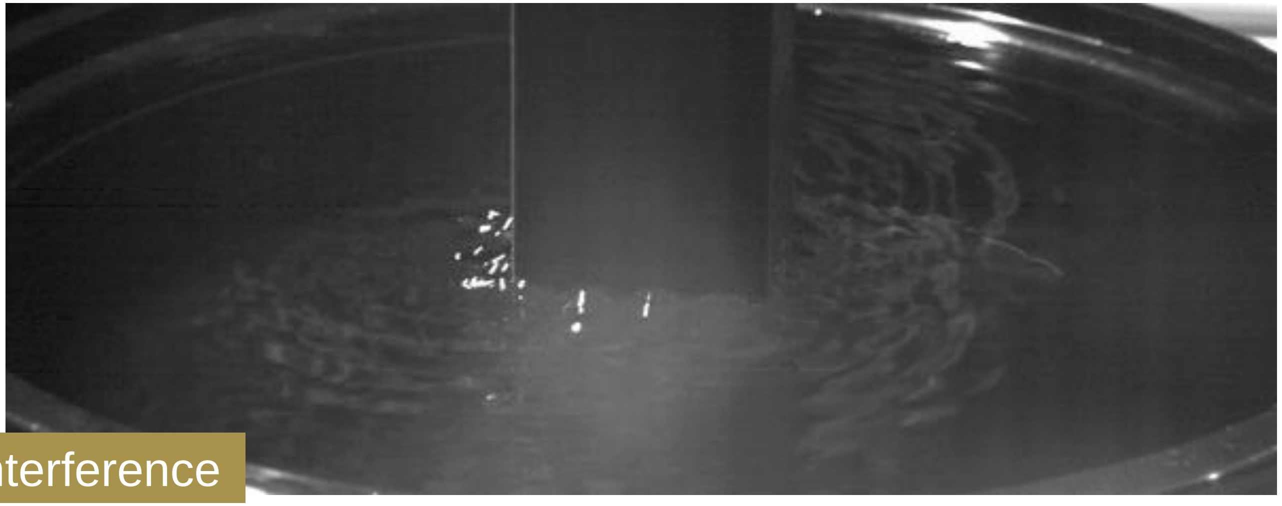
Steven's setup

Alejandro's setup

Emergent Wave Patterns

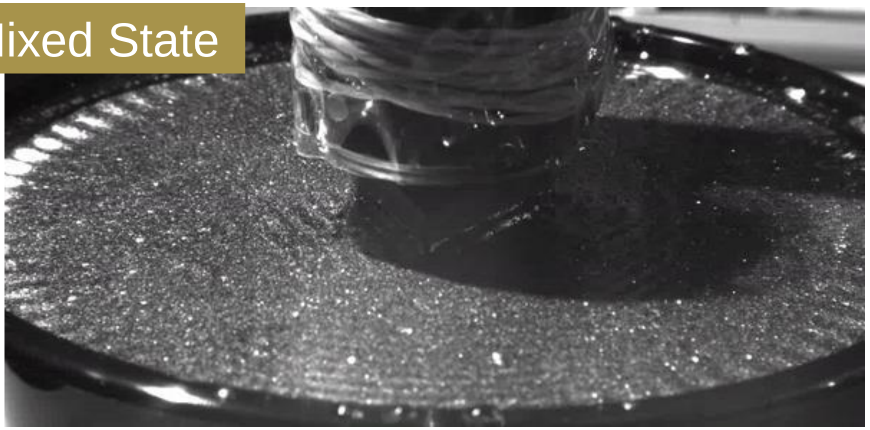


Concentric



Interference

Bubbly



Mixed State

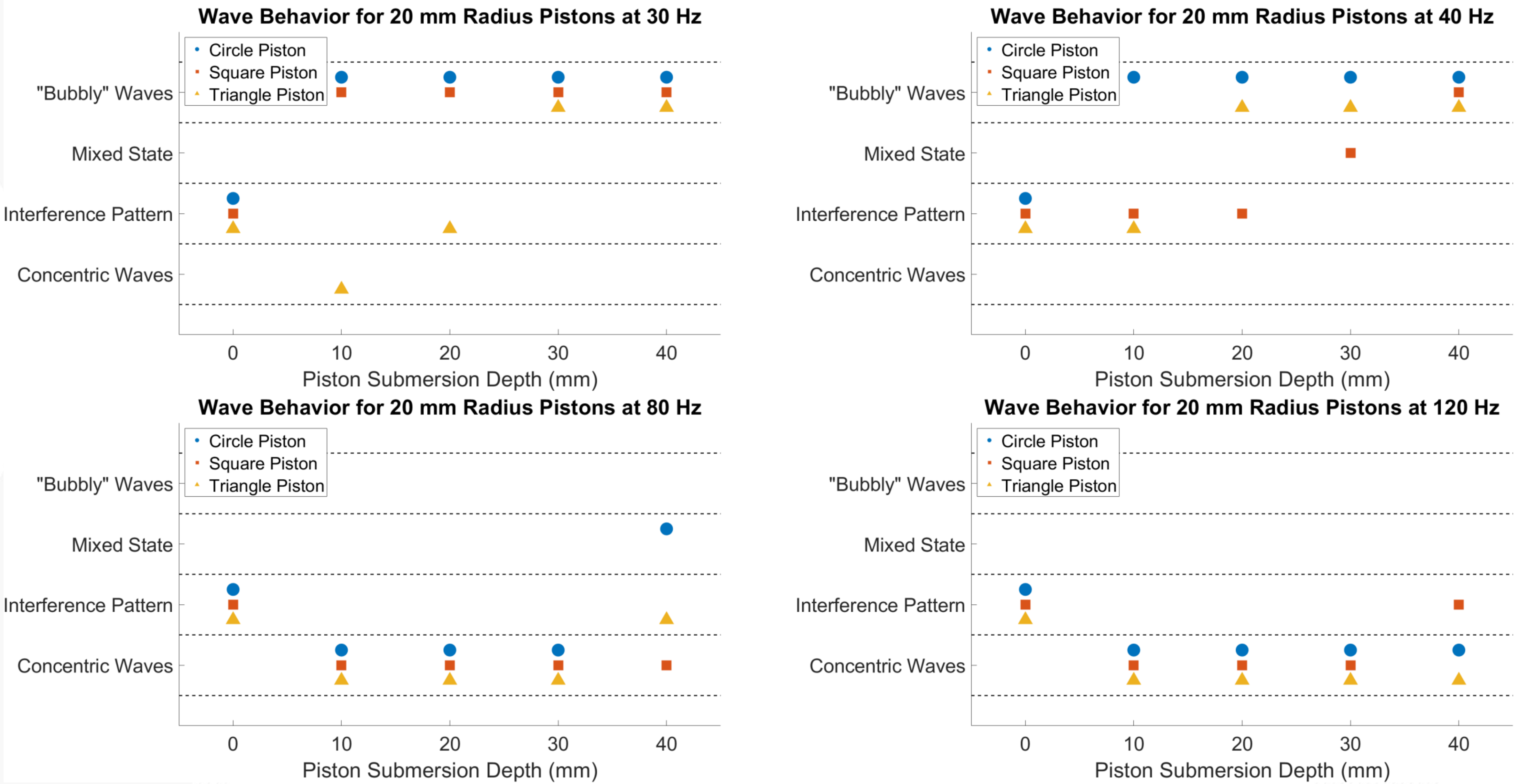
Comparing Source Shapes & Sizes

20 mm circle piston, 40 mm depth, 40 Hz

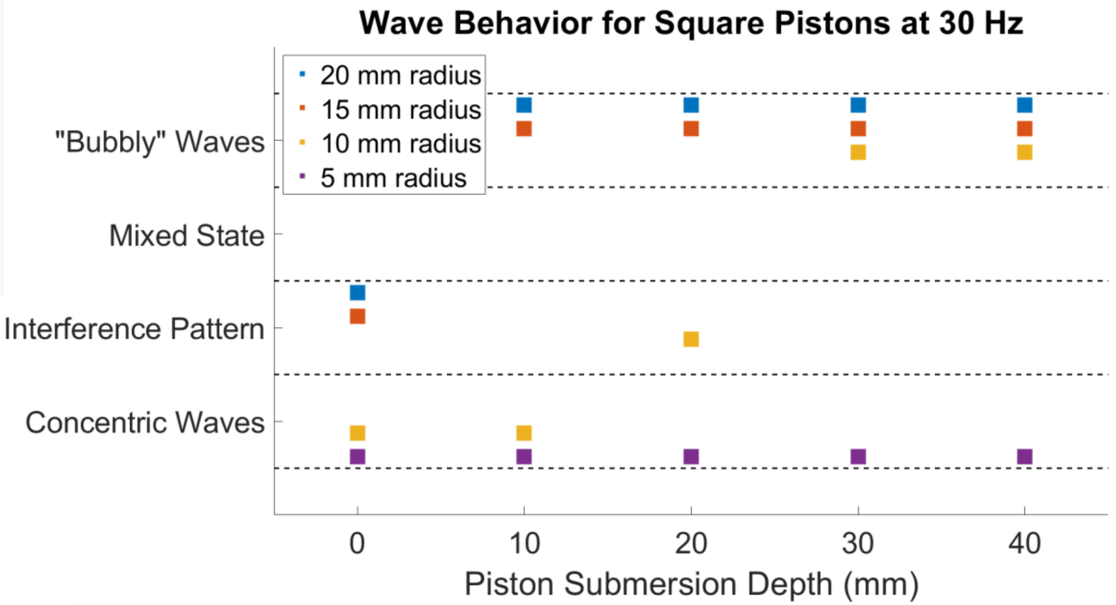
20 mm triangle piston, 40 mm depth, 40 Hz

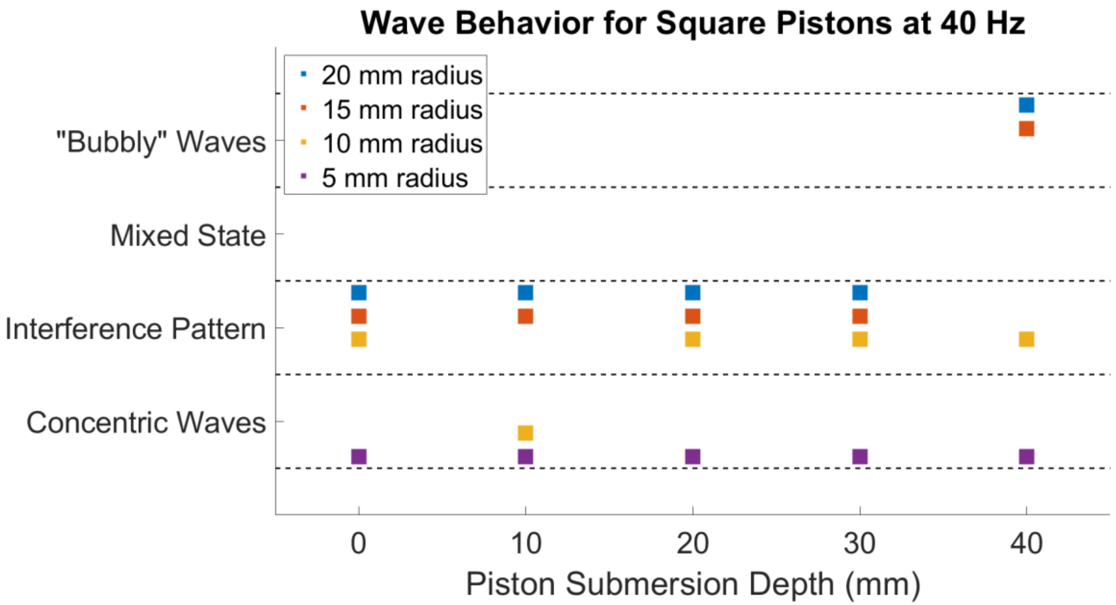
20 mm square piston, 40 mm depth, 40 Hz

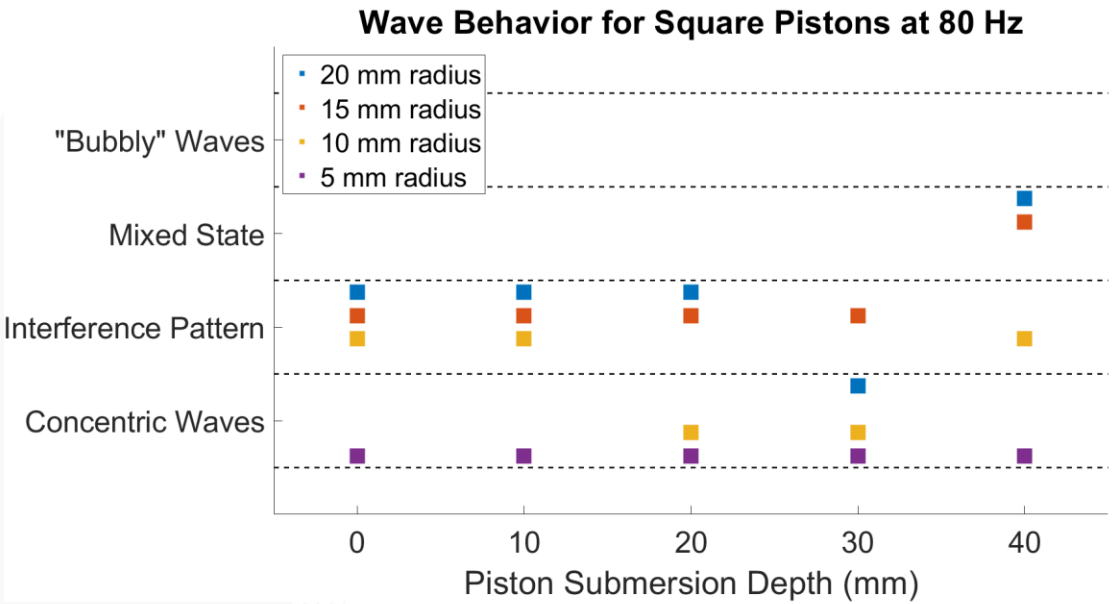
Comparing Source Shapes

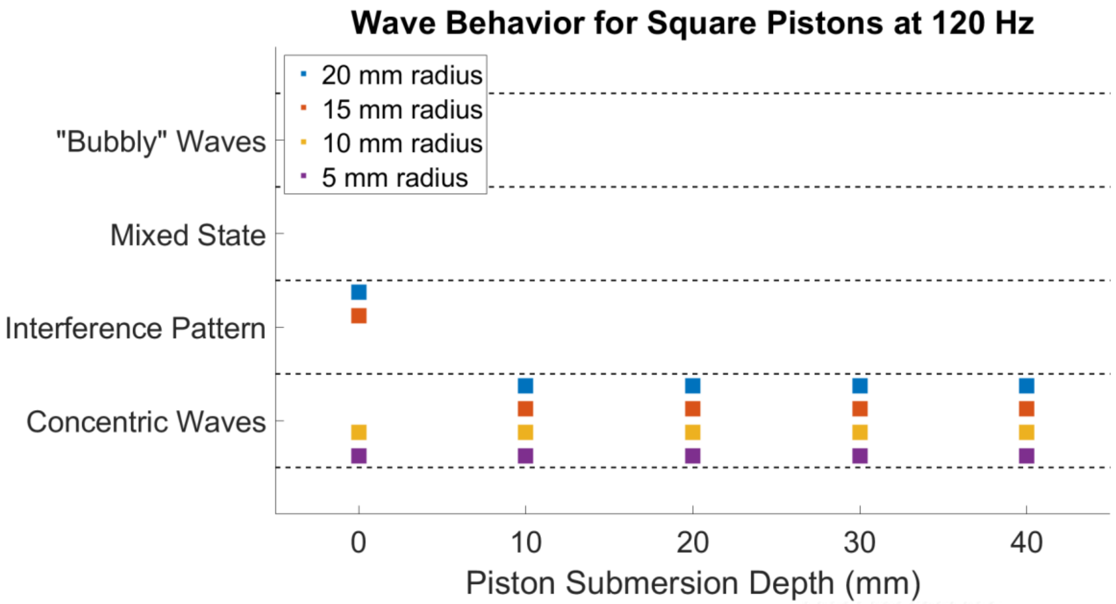


Comparing Source Sizes









Glitter – a visualization tool hints at viscosity dependence

20 mm circle piston, 40 mm depth, 30 Hz

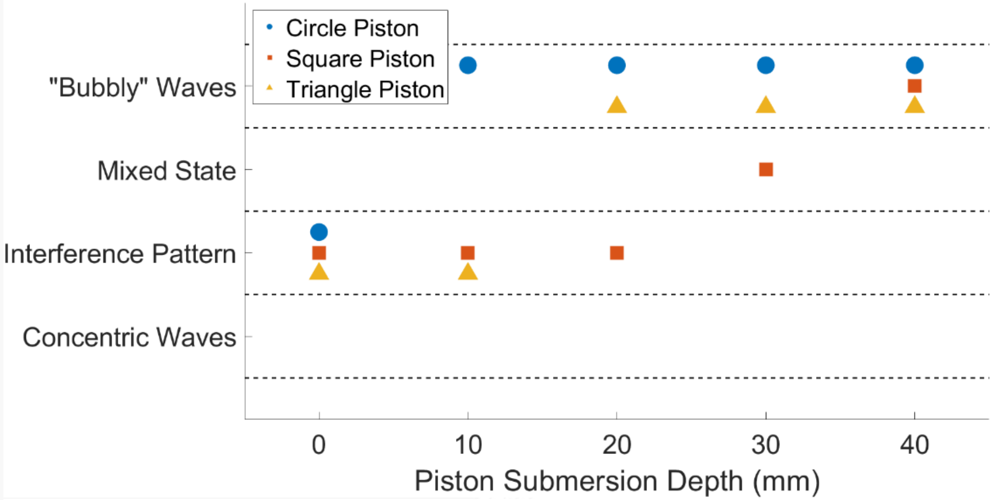
20 mm triangle piston, 10 mm depth, 40 Hz

Glitter – a visualization tool hints at viscosity dependence

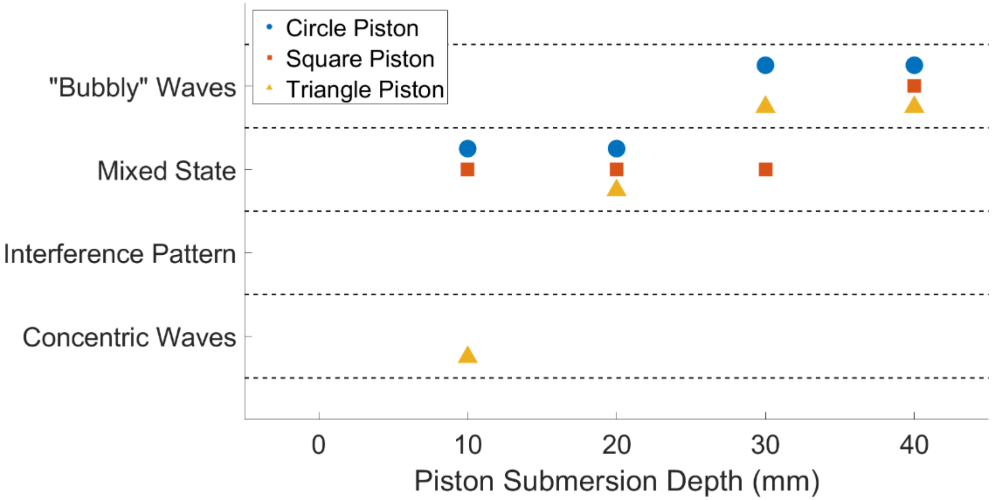
Without Glitter

With Glitter

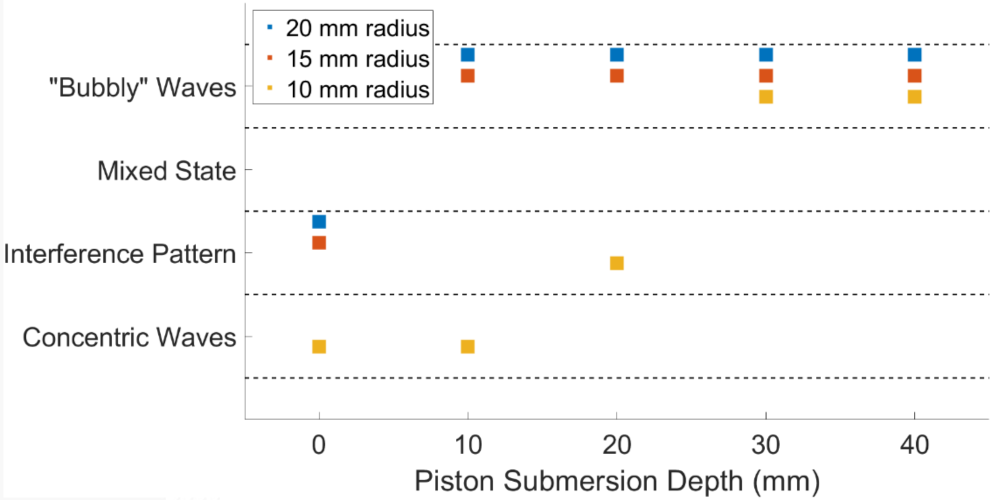
Wave Behavior for 20 mm Radius Pistons at 40 Hz



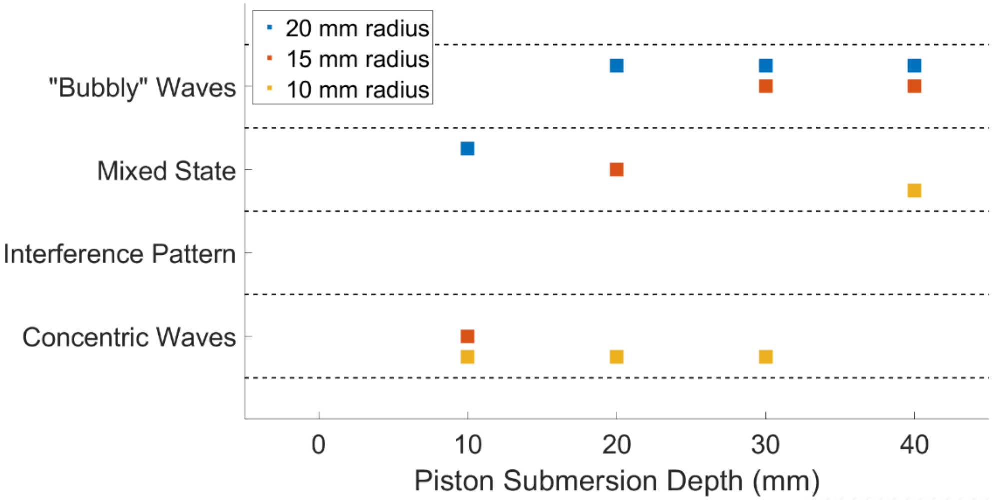
Glittered Wave Behavior for 20 mm Radius Pistons at 40 Hz



Wave Behavior for Square Pistons at 30 Hz



Glittered Wave Behavior for Square Pistons at 30 Hz



Glitter – a visualization tool hints at viscosity dependence

Chen, P. and Viñals, J., *Phys Rev E* (1999)

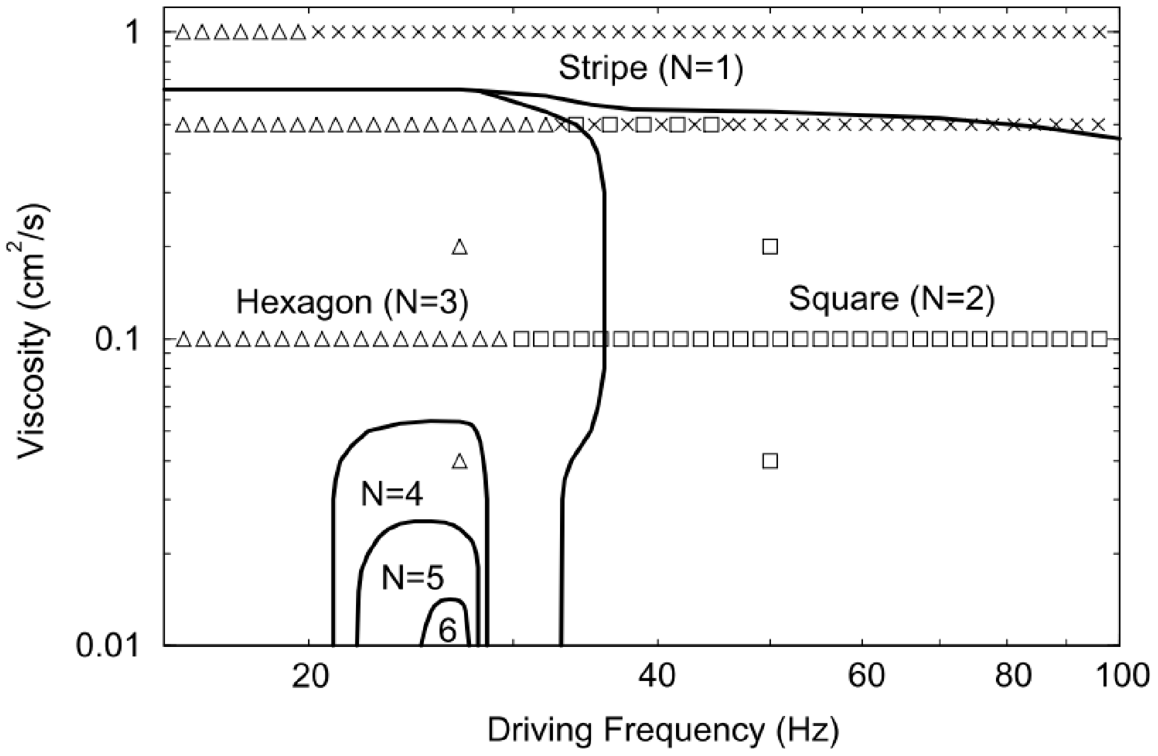


FIG. 1. Preferred patterns in viscosity-driving frequency space. Symbols represent the experimental results. ×=stripe, □=square, and △=hexagon. Alternating × and □ indicate mixed-stripe-square states.

For many frequencies, an increase in viscosity corresponds to a decrease in wave complexity.

Our results qualitatively mimic established theory on globally excited Faraday waves.

Damped Apparatus

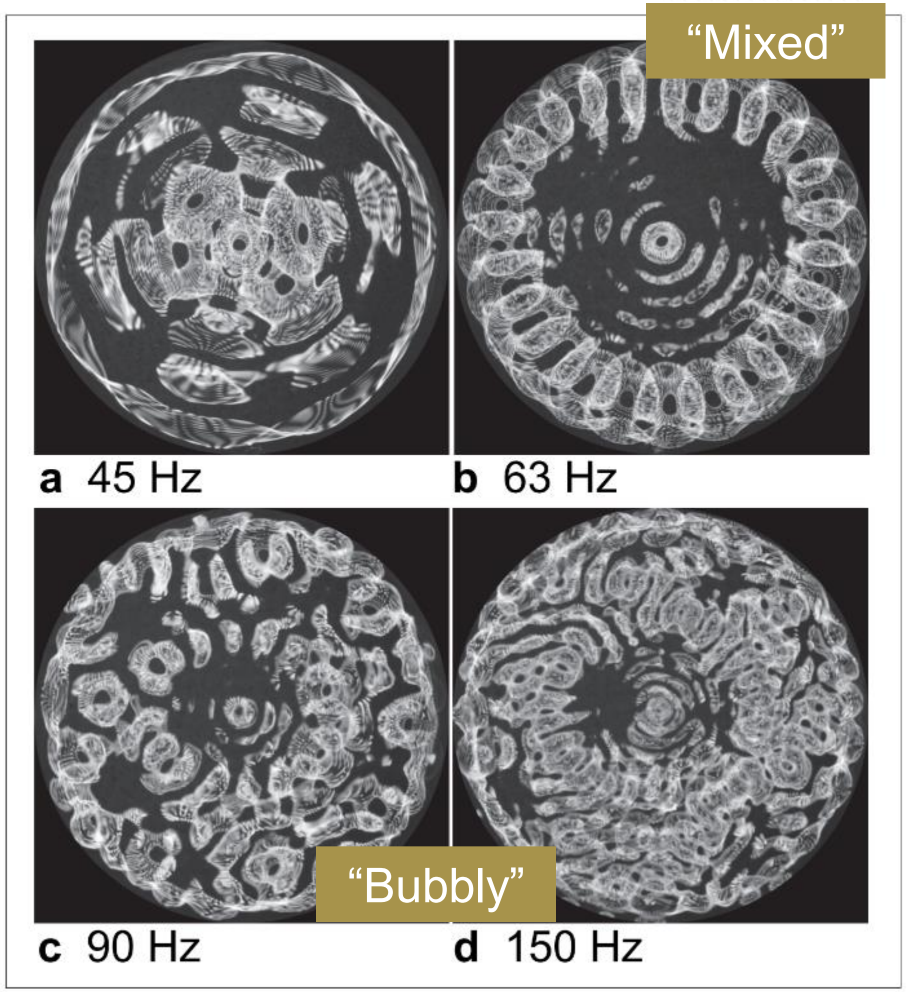
Variation in behavior of the weighted container suggests that the original setup is not absolved of global vibrations and traditionally induced Faraday waves.

20 mm circle piston, 30 mm depth, 30 Hz.
The rim of the container shakes dramatically in response to the local forcing even though the base is fixed to the table.

20 mm circle piston, 30 mm depth, 50 Hz.
The wave complexity reduces dramatically once the 1 kg weights are added to damp the bowl’s response.

Discussion

- Able to recreate some surface wave patterns as explored by Sheldrake
  - For larger containers, they identified a few main patterns.
- Correlation between the complexity of the standing waves and different variables was observed:
  - Piston size/area – larger areas seemed to provide more complex patterns.
  - Piston shape – Edges on the piston shape could cause interesting boundary condition problems, leading to interesting patterns in the glitter.
  - Depth – Deeper submersion led to more complex patterns.



Conclusions

- Induced standing waves are a complex nonlinear dynamical phenomenon that can be easily created and observed.
- This project explored the concept of inducing the waves with variable experimental setups, determined how the variables affected the wave complexity, and discussed possible physical explanations to the system behavior.
- Future Work:
  - Determine if locally induced standing waves is truly local, or the result of container resonance by adapting the experimental setup.
  - Test how boundary conditions play a part by using a global forcing experimental setup and holding various shapes in the water surface.
  - Re-evaluate the current theory without the assumption that the waves are globally forced.

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Q&A