CULTURAL PROGRAMS OF
THE NATIONAL ACADEMY OF SCIENCES

**October 2, 2023 – February 23, 2024**
NAS Building, Upstairs Gallery
2101 Constitution Ave., N.W. Washington, D.C.

# Chaosmosis

## Assigning Rhythm to the Turbulent

## Introduction

Curated by **Natalia Almonte** and **Nicole Economides**
Coordinated by **Azar Panah** and the American Physical Society's Division of Fluid Dynamics

*Chaosmosis: Assigning Rhythm to the Turbulent* is an art exhibition inspired by fluid dynamics, a discipline that describes the flow of liquids and gases. The exhibition draws from past submissions to the American Physical Society's Gallery of Fluid Motion, an annual program that serves as a visual record of the aesthetic and science of contemporary fluid dynamics. For the first time, the submissions have been curated into an educational art exhibition to engage viewers' senses.

The creators of these works, which range from photography and video to sculpture and sound, are scientists and artists. Their work enables us to see the invisible and understand the ever-moving elements surrounding and affecting us. Contributors to the exhibition include artists Rafael Lozano-Hemmer and Roman De Giuli, along with physicists Georgios Matheou, Alessandro Ceci, Philippe Bourrianne, Manouk Abkarian, Howard Stone, Christopher Clifford, Devesh Ranjan, Vigile Thievenaz, Yahya Modarres-Sadeghi, Alvaro Marin, Christophe Almarcha, Bruno Denet, Emmanuel Villermaux, Arpit Mishra, and Paul Branson.

Magnified frozen water droplets resemble shattered glass in a series of photographs. A video simulation depicts the confined friction occurring within a pipe with flowing liquid. In other works, the fluid motions portrayed are produced by human bodies: a video sheds light on the airflow of an opera singer while singing, and a 3D-printed sculpture reveals the flow of human breath using sound from the first dated human recording of human speech. Gases and liquids are in constant motion, advancing in seemingly chaotic ways, yet the works in this exhibition offer a closer look, revealing elegant and poetic patterns amid atmospheric turbulence.

The term *chaosmosis*, coined by the philosopher Félix Guattari in the 1990s, conveys the idea of transforming chaos into complexity. It assigns rhythm to the turbulent, linking breathing with the subjective perception of time, and concluding that respiration is what unites us all.

This exhibition is organized by The American Physical Society, Fluid Dynamics Division and Cultural Programs of the National Academy of Sciences.

**About Cultural Programs of the National Academy of Sciences**
Cultural Programs of the National Academy of Sciences sponsors exhibitions, salons, theatrical readings, and other events that explore relationships among the arts and sciences. The NAS is a private, nonprofit institution that recognizes achievement in science by election to membership, and — with the National Academy of Engineering and the National Academy of Medicine — provides science, technology, and health policy advice to the federal government and other organizations.

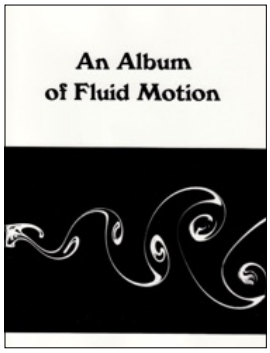
**About the American Physical Society**
The American Physical Society is a nonprofit membership organization working to advance and diffuse the knowledge of physics through its outstanding research journals, scientific meetings and education, outreach, advocacy, and international activities. APS represents more than 50,000 members, including physicists in academia, national laboratories, and industry in the United States and throughout the world.

**About the Division of Fluid Dynamics**
Established in 1947, the American Physical Society's Division of Fluid Dynamics exists for the advancement and diffusion of knowledge of the physics of fluids with special emphasis on the dynamical theories of the liquid, plastic, and gaseous states of matter under all conditions of temperature and pressure.

## A Journey Through the Gallery of Fluid Motion

The Gallery of Fluid Motion (GFM), a collection dating back to the 1980s, offers a captivating showcase of posters and videos contributed by Division of Fluid Dynamic (DFD) members at the American Physical Society (APS), Washington, D.C. These entries demonstrate the power of modern visualization methods and computational capabilities within the realm of fluid dynamics. The gallery acts as a prestigious stage for honoring and admiring the phenomena unveiled by fellow researchers, encompassing both computational and experimental submissions. It is not merely about science; it is also an exploration of the aesthetic pleasure offered by motion, color, sound, and light, revealing the undeniable aesthetic quality inherent in fluid dynamics. The exhibited videos and posters are diverse, ranging from vibrant simulations of hummingbird flight to meticulously crafted models depicting blood loss and hemorrhaging caused by a projectile passing through a human leg. Applied work featuring innovative spray nozzles shares the space with fundamental vortex ring dynamics. Submissions are evaluated by a panel of experts, who assess their blend of striking visual appeal and scientific significance. Awards are bestowed upon the best entries, and while technical relevance is expected, the primary focus remains on the aesthetic quality, making it a gallery with a unique blend of art and science. The top-ranked video and poster entries are designated as Milton Van Dyke Awardees or Gallery of Fluid Motion Winners, which are subsequently published in the Physical Review Fluids.

The inspiration for this gallery dates to the 1980s when the physicist Milton Denman Van Dyke (August 1, 1922 – May 10, 2010) compiled a photo album intended to aid in the teaching of fluid mechanics. Van Dyke, a prominent figure in the Department of Aeronautics and Astronautics at Stanford University, was celebrated for his contributions to fluid dynamics, especially in the application of perturbation analysis to aerodynamics. His influential work, known as the "Album of Fluid Motion," featured a curated selection of approximately 400 black-and-white photographs depicting flow visualization experiments contributed by researchers worldwide. Van Dyke's academic journey commenced with studies in Engineering Sciences at Harvard University from 1940 to 1943. He subsequently embarked on a career at NACA Ames Laboratory and continued his education at Caltech, attaining his MS in 1947 and a PhD with honors in 1949. His notable awards included a Guggenheim fellowship and a Fulbright grant, facilitating collaborations with George Batchelor at Cambridge University, and a visiting professorship at the University of Paris. In 1959, Van Dyke became a professor at Stanford University's newly established Aerodynamics department, further cementing his legacy. In 1976, he received the esteemed honor of being elected to the National Academy of Engineering. As a tribute to his enduring legacy, recipients of the annual Gallery of Fluid Motion competition are presented with a copy of his unique album, an item not commercially available.




In 1983, the Gallery of Fluid Motion was born when renowned fluid dynamicist Helen Reed (Professor Emeritus of Aerospace Engineering at Texas A&M University) organized the first Gallery at the 1983 DFD meeting. Remarkably, they received 70 entries, a significant number when one considers that four decades ago, the conference had only 400 attendees, in stark contrast to today's over 3000 participants. Reed, a distinguished American aerospace engineer specializing in hypersonics, energy-efficient aircraft, laminar-turbulent transition, and small satellite design, holds fellowships with esteemed organizations such as the American Society of Mechanical Engineers, American Physical Society, and American Institute of Aeronautics and Astronautics. Her career began at Langley Research Center, and

she later transitioned to academia, teaching at Stanford University and Texas A&M University, where she also led the aerospace engineering department. Notable accolades include the Presidential Young Investigator Award in 1984 and the J. Leland Atwood Award.

In the early years, the Gallery entries were solely poster presentations. Video entries made their debut a decade later, although their inclusion was somewhat cumbersome. Submissions had to be made on VHS tapes, which local organizers would then dub onto a master tape for looping in a VCR—a tedious process. However, after grappling with tapes for a few years, the division reached out to APS, which now hosts the gallery online. At contemporary DFD meetings, videos are presented on twelve flat screen monitors alongside poster displays. Viewers are even provided with red/green glasses, enabling them to experience 3D videos and immerse themselves in the dynamic world of fluid motion.

After Reed concluded her role as the annual gallery's organizer in 1987, the responsibility was passed on to local organizers. Then, James H. Duncan, Distinguished Professor of Mechanical Engineering at the University of Maryland who was the chair of the 2000 DFD meeting in Washington, D.C., had discussions with the Executive Committee that led to the creation of a Gallery Coordinator position to ensure rule consistency from year to year. He held this position from 2001 to 2011, and subsequently, Ken Kiger, Professor of Mechanical Engineering at the University of Maryland, took over for a decade until 2021. As of July 2021, I have assumed the role of Gallery Coordinator.

In 2023, for the first time, a museum-like display of the GFM submissions has been curated to bridge the gap between art and science, fostering public engagement in the intricate field of fluid dynamics. By harnessing the power of visual artistry, this project seeks to make fluid dynamics more accessible and captivating for a broader audience, sparking curiosity and deepening appreciation for the scientific wonders of fluid motion. In today's complex and ever-evolving world, there is a growing need to bridge the gap between scientific knowledge and public understanding. This initiative recognizes this need and strives to blend art and science in exhibitions that promote scientific literacy, particularly in the field of fluid dynamics. "Chaosmosis: Assigning Rhythm to the Turbulent" is a new exhibition inspired by previous Gallery of Fluid Motion submissions. For this initiative, a selection of past submissions to the Gallery of Fluid Motion by Natalia Almonte and Nicole Economides has been curated into an educational art exhibition designed to engage the senses of viewers' senses. Their creative touch and poetic writings have made the exhibition truly stand out and will leave a lasting mark on everyone who checks it out. The 11 works in the exhibition encompass photography, video, sculpture, and sound, representing collaborative efforts between scientists and artists. These works enable us to perceive the invisible and understand the ever-moving elements that surround and influence us.

We would like to acknowledge Roy Thompson, who generously assisted with pedestals and shipping at Penn State. He volunteered his time and resources for us. Also we wish to express appreciation to Drew Doucette for his skill in helping us video installation and presentation.

*—Azar Panah*

**Dr. Azar Panah** is an Associate Professor in Mechanical Engineering at Penn State University at Berks. She completed her Ph.D. thesis at the University of Iowa on flow structures of flapping wings to understand how birds fly and how engineers can design a robot to fly like birds more efficiently. She loves fluid dynamics and is fascinated by the mechanics of flying birds. Her research vision is to understand natural locomotion in fluids such as air and water, and if possible to design novel unmanned vehicles. She is always game to investigate an interesting question in fluid mechanics, especially if she can recruit her undergraduate students to sleuth around and wonder with her. She also teaches the science and photography of Flow Visualization to make the physics of fluid flows (gases, liquids) visible. In 2021, Dr. Panah became the Coordinator of Gallery of Fluid Motion at the American Physical Society's Division of Fluid Dynamics (APS DFD), and she serves the community in this capacity.

# Chaosmosis
## Assigning Rhythm to the Turbulent



**CHAOS**

**OS**

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**OS**

OH SO WHAT CHAOS? *chachacha.* WHY NOT CHAOS? *chachacha.* STREAM OF CONSCIOUS CHAOS. *chachacha.* TURBULENT WATER STREAMING. *chachacha.* TEARS STREAMING. *chachacha.* CONTINUE STREAMING? CLICK. *chachacha.* STAY IN THE DARK COCOON IF YOU DON'T WANT TO WATCH THE ***BLUE***. BUT, BECOME THE BUTTERFLY TO WITNESS THE BUTTERY CHAOS BLOOM. *chachacha.* OK, CHAOS. *chachacha.* OK, STREAM. *chachacha.* TAKE FLIGHT INTO THE CLOUDS. *chachacha.* STAY AFLOAT IN THE SEA. *chachacha.* TAKE ME WITH YOU INTO THE BIG ***BLUE*** DREAM. *Chachacha.*

It seems like the world is generating a lot of noise lately. Noise, instead of music. According to Félix Guattari, noise is the byproduct of a status quo that has become nearly impossible to trust[1]. We hear dissonant voices and not enough harmony. Harmony is the music. However, harmony is not antithetical to chaos, noise is. Noise stifles, paralyzes, and provokes spasms[2] that ripple across borders and the ocean's ***blue***. Our collective nervous system is latently on high alert, leaving us constantly trying to catch our breath. Those in power hide their true intentions and technology piles on invisible layers that further us more and more from reality. Reality is already a complex concept since it is truly in the eye of the beholder. Perception, as well as the memory of each individual, is subjective, and differs from one human to the next. With over 8 billion people living on this pale ***blue*** dot, "that's here, that's home, that's us,"[3] there are 8 billion varying realities, some parallel, yet many colliding. This collision, cacophony, and contradiction of truths, leads some to sink into the unknown ***blue*** in despair, while others can swim through the operatic chaos. There is no one way to do this, but many of us become scientists, and many of us become artists.

These two fields have significant intersections. Firstly, an interest in questions and experimentation, seeking answers that might never come, therefore the search itself is of value, a reflection of life and its endless surprises. The failed attempts often lead to unexpected conclusions. Is this not, in part, the beauty of the human experience? Would love and joy feel as expansive, if heartbreak and sorrow were predictable? Would we empathize with others if we could calculate our future? Would we get out of bed if we had all the answers? Would hope even be in our vocabulary, if we knew how our story ends?

Science provides us with a curious understanding of the marvel of our planet, about the cracks, nooks, and crevices we brush past when walking down a busy street. What is buried beneath our feet? What is floating above our heads? Music is. Music is above and below, creating sense and rhythm to our lives. *chachacha.*

> *Where is my mind? Way out in the water, see it swimmin'. With your feet on the air and your head on the ground. Try this trick and spin it, yeah. Your head will collapse if there's nothing in it. (Where is My Mind*, by Pixies, 1988*)*[4]

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[1]Félix Guattari, *Chaosmosis: An Ethico-Aesthetic Paradig*m, trans. Paul Bains and Julian Pefanis (Bloomington: Indiana University Press, 1995).
[2]Ibid.
[3] Carl Sagan, *Pale Blue Dot: A Vision of the Human Future in Spac*e, (New York: Random House, 1994).
[4]*Where is My Mind* was a successful song by the alternative rock ban Pixies and was from the band's 1988 debut album titled *Surfer Rosa*

Science keeps our minds afloat, thriving in the chaos. While our minds are swimming in the ***blue***, mind your head and mind your step. Just because we are provided with the science, does not mean we feel it. In fact, it is often said that humans misremember quite often, yet we can recall how we felt vividly. When science is distilled as art, it can expedite a poetic impression in our guts. Science strives to connect the mind and the body, the physical and the abstract, the known and the yet unknown.

Secondly, science and art require humility and open-mindedness. While science acts as a teacher, art acts as a therapist: the collective, emotional, human mirror. Science is the grounding force, and art is the spiritual force, both resisting politics, the controlling force: "the boundless intensification of noise."* Guattari claims that "social sound is turned into white noise and white noise becomes social order," the noise we are conditioned to no longer hear, but experience as a lingering looming phantom while sleeping in the ***blue*** undertow.

As if inside a JMW Turner oil painting, we are aboard a sinking ship, but despite apocalyptic trends, science and art provide the lifeboats that reclaim our stardusty power that reminds us not to ignore the toxic white noise.

> *Who is right? Who can tell, and who gives a damn right now? What means to you, what means to me, and we will meet again. (Disorder,* by Joy Division, 1979)[5]

In order to connect within the disorder, we must remain humble, we must remain open, and we must remain permeable, harmonizing to the music through

James Mallord William Turner, *Snow Storm - Steam-Boat off a Harbour's Mouth Making Signals in Shallow Water, and going by the Lead*, 1842, oil on canvas, 91 cm × 122 cm (Tate Britain, London)

[5] Joy Division was a punk rock band formed in 1976. Disorder is from the debut studio album titled *Unknown Pleasures* which was releasead in 1979.

corespiration*. Curiosity flexes and fluxes our empathy muscles, those muscles we use to dance and to move fluidly through space to avoid colliding with each other.

Lastly, science and art thrive off creativity and imagination. Without imagining the impossible, a utopia beyond the big ***blue***, we will persist in the white noise swamp water.

> ***Blue*** *has no dimensions; it is beyond dimensions, whereas the other colors are not… All colors arouse specific associative ideas… while* ***blue*** *suggests at most the sea and the sky, and they, after all, are in actual, visible nature what is most abstract. (From lecture at the Sorbonne in Paris, Yves Klein, 1959)*[6]

Art concretizes the abstract through unique expression, infinite choices of materiality, and mischievous rule-breaking. Similarly, simulation allows scientists to fail without consequence, allowing for the boundlessness of thought.

Like tornados, scientists and artists sweep up ideas, data, and whatsits to interrupt up the noise, the established order, and the limitations to the stretch beyond the ***blue***. What better metaphor for expansive thought than the nature of fluids? The word fluid itself demands compassion for revision, for transformation, and for variation, characteristics often feared, suppressed, and oppressed. Fluid motion can appear disruptive and turbulent, but in fact, it is chameleonic, rhythmic, in flux, and in search of harmony. *chachacha*. We can choose to perceive chaos as nonsense, or we can choose to read it as inevitable poetry, like the imperceivable music of flapping butterfly wings.

*—Natalia Almonte and Nicole Economides*

**Natalia Almonte** (b. 1988) is an artist and independent curator based in Brooklyn, New York. She holds an MFA in Fine Arts from Parson's, The New School, and an MA in Art History and the Art Market: Modern and Contemporary Art from Christie's Education, where she was granted the Alumni Association Award for Contemporary Art Connoisseurship. Almonte has exhibited her work in New York, Puerto Rico, Seattle, and Greece. She has also done residencies in France, Mexico, and the United States.

**Nicole Economides** (b. 1992) is an artist and independent curator based in Athens and New York. She holds an MFA in Fine Arts from Parsons, The New School and a BFA from the Department of Fine Arts and Art Sciences at the University of Ioannina (2015). Economides is a recipient of the Stavros Niarchos Foundation Artist Fellowship by ARTWORKS (2022), the Gerondelis Foundation Scholarship (2019), and the Elizabeth Greenshields Grant for Painters (2018). Her work has been exhibited in numerous exhibitions and festivals in Greece, Berlin, Paris, and New York.

In 2018, Economides and Almonte co-founded Paradoxluxe, a collective that critically engages with the reductive representations of Greece and Puerto Rico. They co-curated the exhibition, *We Are Here To Serve You* (2020), at the Arnold & Sheila Aronson Galleries in Manhattan, that is traveling to San Juan, Puerto Rico and Athens, Greece. They also curated the group exhibition *What is Real?* (2021) at The Real House, an ephemeral artist house in Brooklyn, New York.

[6] Conférence à la Sorbonne, June 3, 1959. Klein gave two historically noted lectures at the Grand Amphithéâtre de l'Université de la Sorbonne (Paris, France): *The Evolution of Art Toward the Immaterial*, and *The Architecture of the Air*.

***SENSE OF SCALE*, 2022**

**Roman De Giuli**
Video, 00:06:24

Through the intricate interplay of paints, inks, and various substances of different densities, pigments, and binders, De Giuli presents a video that evokes a bird's-eye-view of the flow of melting glacial waters interspersed with islands of rock, earth, and sediment. The title, *Sense of Scale*, alludes to the consistent nature and physics of fluid motion, regardless of the scale. Shifting perspectives, he creates an immersive experience revealing beautiful melting walls that can highlight the pure sensuality of paint or contrastingly, the news on changing ocean temperatures vividly depicted by warm and cool color tributaries. De Giuli succeeds in capturing the immensity of landscapes on a tiny piece of paper.

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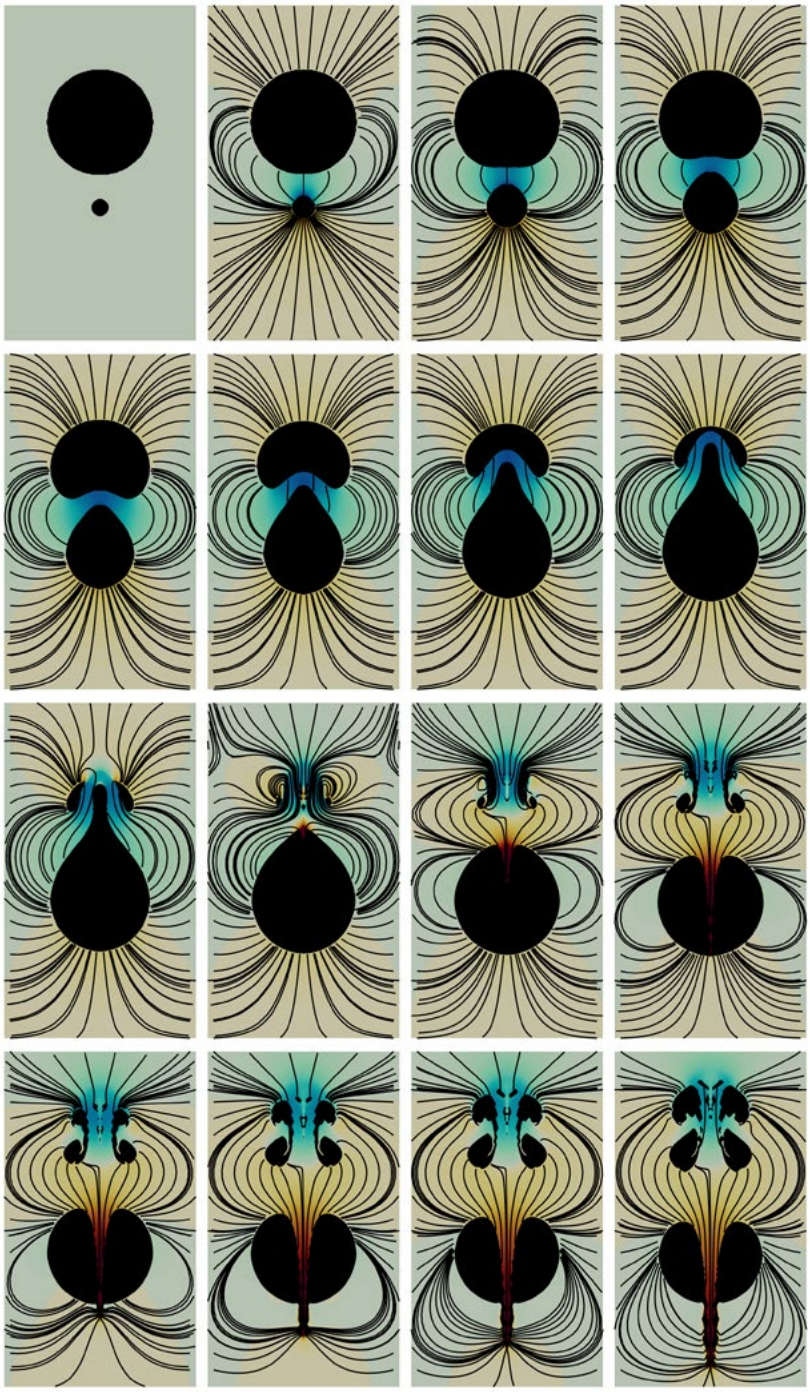
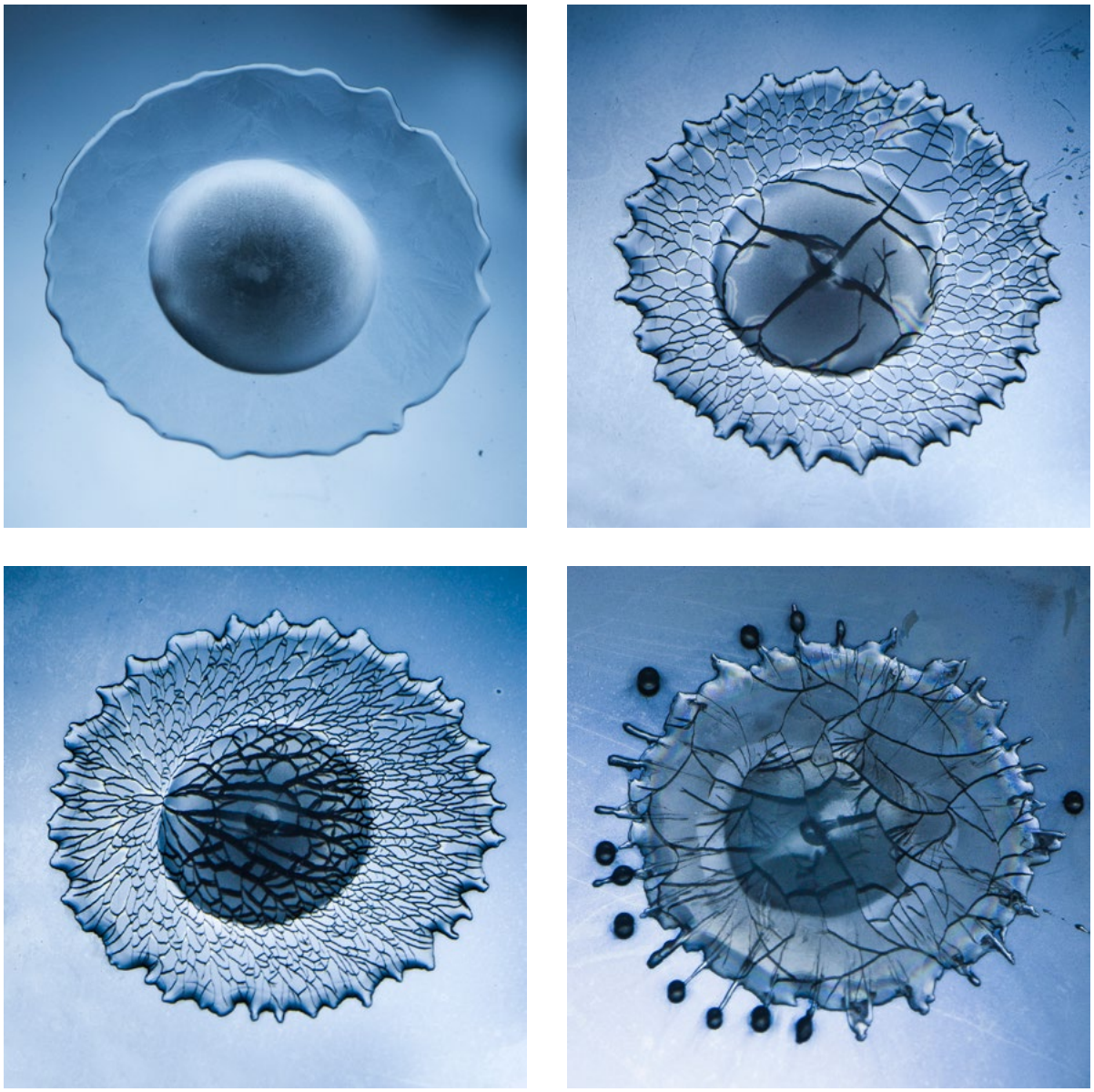


This gridded image visually depicts the collision of two vapor bubbles. A high-speed liquid jet, propelled by intense pressure, punctures the skin. As one bubble expands, the other one shrinks due to a “slingshot” shockwave effect. With this process, scientists aim to revolutionize vaccination, making it more accessible, affordable, and less daunting, especially for children or needle-phobic individuals. Although the method is not ready for widespread use, the endemic phase of COVID-19 urges innovative prevention. A needle-free or minimally invasive system could boost vaccination rates and lower contamination risks, especially in developing nations. The cavitation process, resembling orbits, orchids, or a Hilma af Klint painting, is printed on translucent fabric, symbolizing the porous nature of our bodies and surroundings.

***FLOW-FOCUSING FROM INTERACTING CAVITATION BUBBLES*, 2021**

**Arpit Mishra, Claire Bourquard, Arnab Roy, Rajaram Lakkaraju, Outi Supponen, Parthasarathi Ghosh**
Laser print on fabric
84 x 48.5 inches

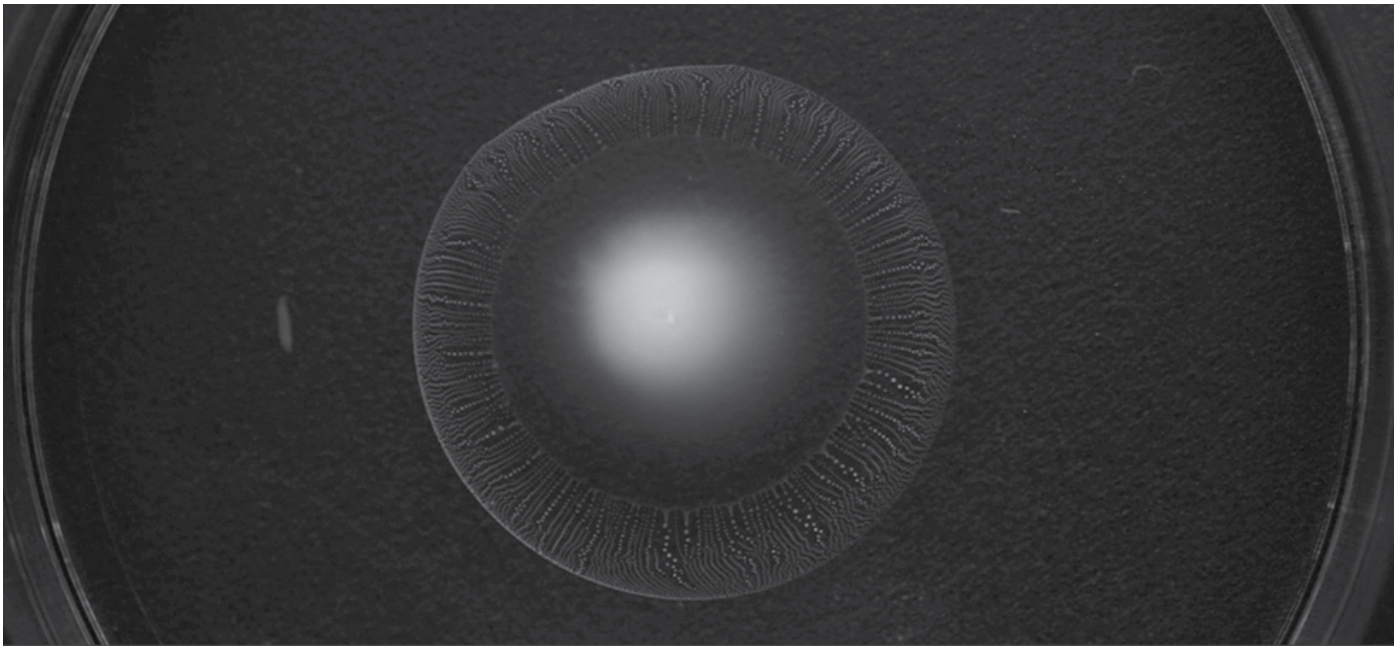


***CRACK PATTERNS IN FREEZING WATER DROPLETS*, 2016**

**Virgile Thiévenaz, Christophe Josserand, Thomas Séon**
Four laser prints on paper
24 x 24 inches each

During winter, raindrops occasionally land on cold surfaces and freeze upon impact, leading to intriguing shapes akin to fried eggs or ravioli. To study these shapes, scientists observed water droplets on a silicon wafer—a very smooth and highly heat-conductive object used to manufacture computer chips—cooled down with liquid nitrogen.

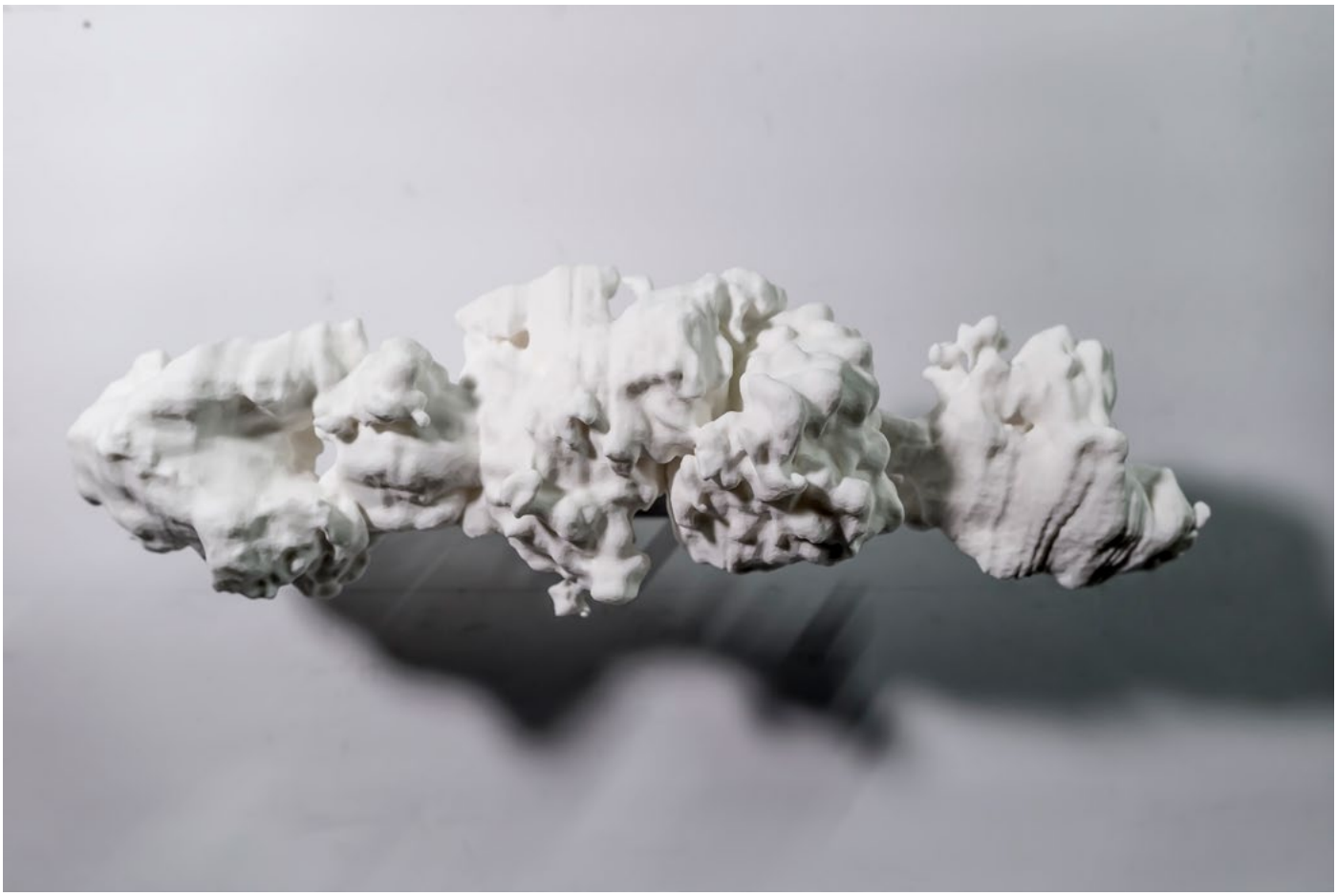
Surprisingly, the frozen drops did not only take these odd shapes, but they also fragmented, forming patterns that look like broken glass. This phenomenon occurs because the droplets freeze from the edges too quickly and the ice continues to cool after freezing, causing it to contract until reaching a breaking point where further shrinking is impossible.



***THE YARNING DROPLET*, 2021**

**Carola Seyfert and Alvaro Marin**
4 Videos on a loop, 00:00:42, 00:00:49, 00:01:08, 00:01:41

In *The Yarning Droplet*, a droplet composed of water and alcohol rests on top of a common household oil in a Petri dish. This droplet expands and releases numerous miniature daughter droplets due to a complex equilibrium of forces between the liquid surfaces and the surrounding air. By introducing a polymer into the water-alcohol droplet, a captivating display unfolds—an ever-expanding, rhythmic dance of explosive petals that transform into diverse shapes, resembling a wishbone, an iris, a tree trunk, or even the merging of human forms. This phenomenon is called the Marangoni Bursting effect, and it is exhibited in coffee rings, “tears of wine,” soap films, and ink printers, to name a few examples.



***VOLUTE 1: AU CLAIR DE LA LUNE*, 2016**

**Stephen R. Johnston, Jessica B. Imgrund, Dan Fries, Rafael Lozano-Hemmer, Stephan Schulz, Kyle C. Johnson, Johnathan T. Bolton, Christopher J. Clifford, Brian S. Thurow, Enrico Fonda, Katepalli R. Sreenivasan and Devesh Ranjan**
3D-printed filament, sound
26 x 7 x 8 inches

*Volute* is the world's first 3D-printed speech bubble. In 1860, Édouard-Léon Scott de Martinville recorded the phrase "Au Clair de la Lune'' on his phonautograph, making the first known recording of human speech. In *Volute 1: Au Clair de la Lune*, the same phrase is materialized with a new method developed by Lozano-Hemmer's studio in conjunction with fluid dynamic scientists from Georgia Institute of Technology, Auburn University, and New York University. Breath exhaled while speaking is scanned by a custom-made laser tomograph, then converted into a 3D shape using photogrammetry and, finally, printed in 3D printer filament. This piece is inspired by Charles Babbage's 1837 statement that the atmosphere is a vast library that contains all the words that have been spoken in the past.

The QR code found after the prompt to touch the sculpture contains a YouTube link to the original recording, followed by the progression of its restoration.

***LARGE-EDDY SIMULATION OF CUMULUS CLOUDS*, 2021**

**Georgios Matheou**
3 Videos, 00:00:16, 00:00:18, 00:00:14

Clouds are one of the largest sources of uncertainty in climate projections since they quickly develop into storms. When making measurements in the atmosphere and ocean, it is understood that the variables cannot be fully controlled. In recent years, advancements in computing power have enabled scientists and engineers to reproduce complex phenomena using computer simulations. Simulation is an additional tool for discovery, enabling us to conduct controlled experiments that offer unprecedented insights into the intricate nature of clouds, particularly as our planet's climate becomes more volatile.

While the three simulations seem to be in fast motion, two of the videos are from a static point of view, and the third, *Cloud Surfing*, feels like a video game, providing a dreamlike sensation of flying. The grounded horizons rest on the carpet, an extension of the ocean. When we approach the shore, the shadow of our bodies becomes part of an infinite perspective, which emphasizes the existential consistency and reliability of the horizon line, and the inconsistency of everything else.

***AIR FLOWS IN ORCHESTRA*, 2020**

**Philippe Bourrianne, Paul Kaneelil, Isabel Leonard, Angel Blue, Christine Goerke, Stephanie Mortimore, Dean LeBlanc, Barbara Currie, Pedro Díaz, Demian Austin, Ray Riccomini, Manouk Abkarian, Howard Stone**
Video, 00:04:38

During the COVID-19 pandemic, clusters of contaminations were identified during rehearsals within a choir or an orchestra. Activities such as singing or playing wind instruments are accompanied by an enhanced release of droplets, carried by expiratory flows, and so can contaminate other musicians of an orchestra, or perhaps members of the audience. By working with members of the MET Orchestra in New York City, the air exhaled by individual professional performers was tracked using an infrared camera and other flow visualization techniques, concluding that air flows from musicians could potentially increase the risk of contamination within an orchestra. The beauty of the operatic audio becomes ominous when the prospect of the smoke-shaped air produced by the singer might be contaminated. This inescapable sound playing throughout the gallery opens a portal for visitors to become part of the performance and to experience the rest of the exhibition with the melancholic shroud of the lullaby.

***TURBULENT PIPE FLOW AT HIGH REYNOLDS NUMBER*, 2021**

**Alessandro Ceci, Sergio Pirozzoli, Joshua Romero, Massimiliano Fatica, Roberto Verzicco, Paolo Orlandi**
3 Videos, 00:00:16, 00:00:21, 00:00:12

There is no existing equipment to register the turbulent activity within pipes. To address this issue, *Turbulent Pipe Flow at High Reynolds Number* simulates the confined friction happening within a pipe with flowing liquid. Pipe flow was the subject of the landmark 1883 study by Osborne Reynolds, which first highlighted the importance of what was later called the Reynolds number in determining the passage from a laminar to a turbulent regime. When the Reynolds number is below 2300, the flow is parallel and smooth with no mixing, but when the number rises above 2300, the flow starts to become turbulent. The flow animations in these videos depict friction under conditions with a Reynolds number of 6000. These simulations can help determine density, viscosity, speed, and temperature, which could be used to measure flow in blood vessels, cooling in refrigerators or cars, as well as in oil transfers. What if these vessels and pipes were transparent? Capturing videos of actual flow in transparent pipes through experimentation becomes highly challenging due to the change in refractive index. Therefore, simulations can provide a front-row seat to the movement happening inside one of the most common modes of transport of fluids.

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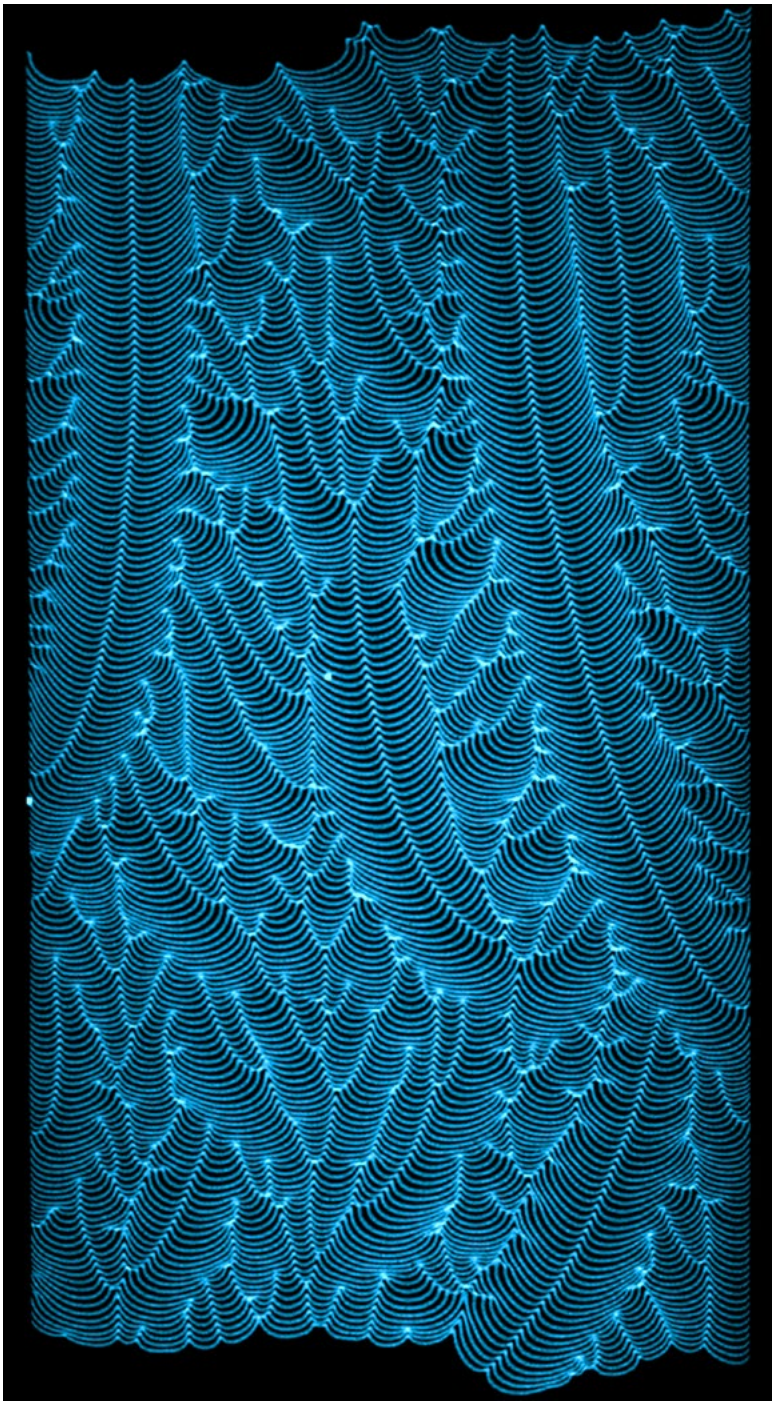
In addition to its scientific significance, this setup of two glass plates separated by a thin gap of 5 mm in width, allows us to analyze the shape and dynamics of flames, including the formation and merging of cells, in order to understand the steady statistical features that determine propagation speed, and influence pollutant formation. Premixed flames, where fuel and oxidizer are combined before combustion, are widely used in applications such as gas turbines and internal combustion engines, offering practical control over combustion rates and pollutant formation. The resulting fluorescent blue pattern creates an optical illusion of volume, reminiscent of an organic weblike structure.



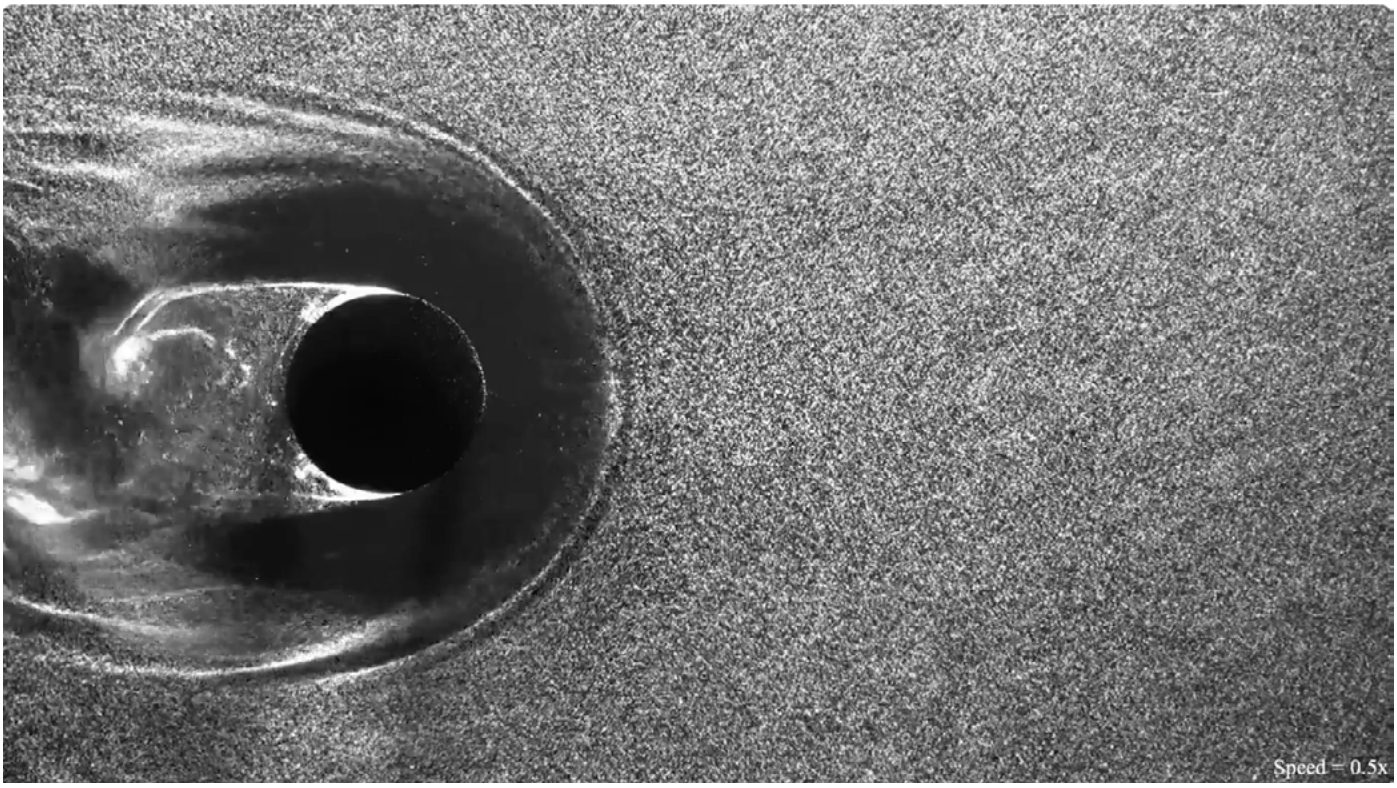
***EXPERIMENTAL TWO-DIMENSIONAL CELLULAR FLAMES*, 2014**

**Christophe Almarcha, Joel Quinard, Bruno Denet, Jean-Marie Laugier, Emmanuel Villermaux**
Laser print on fabric
84 x 46 inches

*Walking in the Wake* is a multifaceted project and collaboration between engineers and architects. This 3D-printed sculpture is one iteration created to explore ways of visually experiencing the flow behind an oscillating cylinder. The sculpture acts as an artifact and residue of motion that represents the wake as it evolves in time—where time is manifested as a third dimension, the z-axis.

***WALKING IN THE WAKE*, 2022**

**Pieter Boersma, Adrian Carleton, Fey Thurber, Cami Quinteros, Erica DeWitt, Pari Riahi, Yahya Modarres-Sadeghi**
3D printed sculpture




***COEXISTENCE OF ORDER AND CHAOS IN C-MAJOR*, 2017**

**Paul Branson, Matthew Rayson, Marco Ghisalberti, Gregory Ivey**
Video QR code, 00:02:58

In a controlled flume experiment, a reversible pump propels water over a flat glass surface. Visible particles, slightly heavier than the fluid, settle on the bed. Initially, the fluid starts from rest and is gradually accelerated to a defined peak velocity within a fixed oscillation period. Simultaneously, a boundary layer forms on the flat plate, expanding spatially, while an oscillatory boundary layer evolves over time, exhibiting a phase difference between the bed and the upper layer. This spatial frequency content of the images is translated into four octaves of the C-major chord, producing an auditory representation of the smooth, laminar flow. Sound frequencies are created by movement every day. For example, on windy days, taut electric cables make a whistling sound when they come in contact, and the crinkle of sand moving on the ocean floor produces a certain chord. These natural occurrences embody the concept of *Coexistence of Order and Chaos in C-Major*, assigning rhythm to the mundane.

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