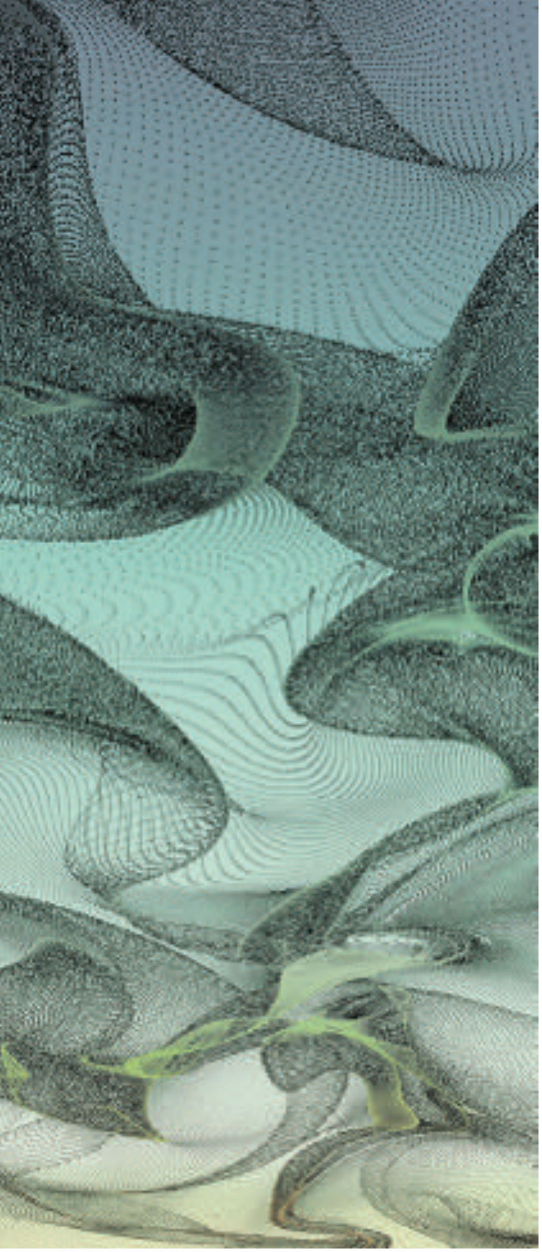
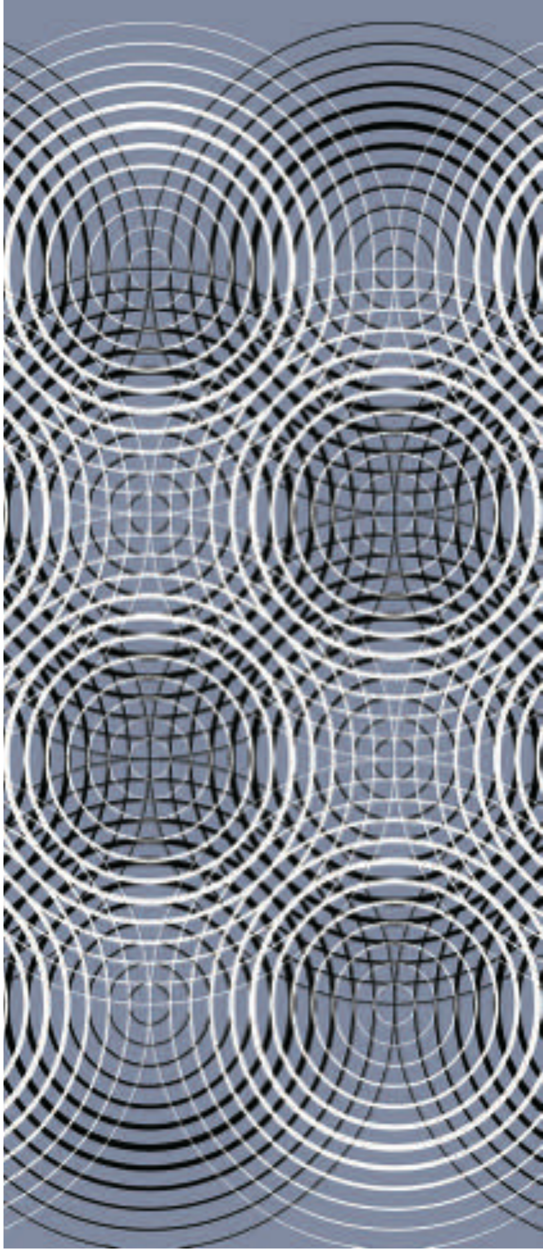




ART AND THE QUANTUM MOMENT

December 4, 2014 - January 29, 2015

Simons Gallery, The Simons Center for Geometry and Physics, Stony Brook University, NY

COVER:

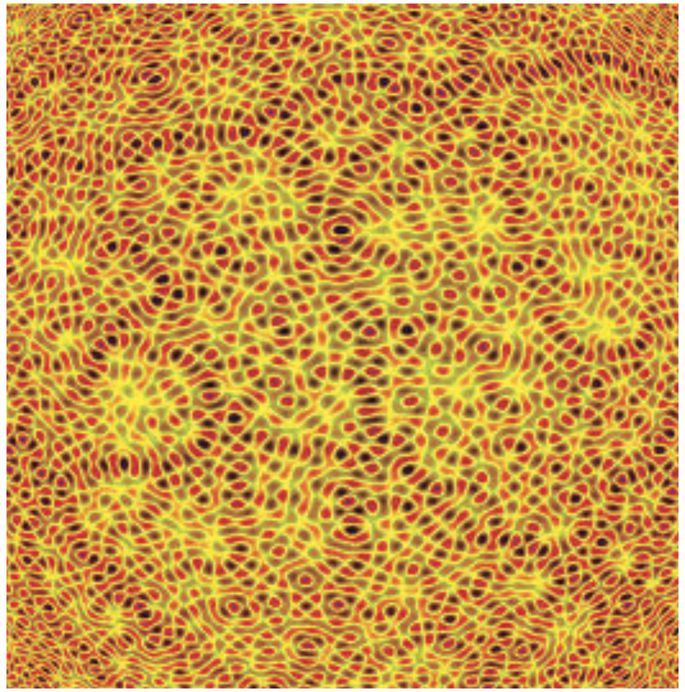
Eric J. Heller, *Caustic II,* 2001, Luminage Archival Digital Print, Edition: 6/250, 48” x 36” (91.5cm x 122cm)
Jacqueline Thomas, Heisenberg’s Uncertainty Principle. *Equations,* p 11.
Frédérique Swist, *Good Vibrations,* 2010, Archival pigment print on Somerset Velvet 330 gsm, Edition: 4 /10, 31.5” x 31.5” (80cm x 80cm)

ART AND THE QUANTUM MOMENT

ERIC J. HELLER . FRÉDÉRIQUE SWIST . JACQUELINE THOMAS

ART AND THE QUANTUM MOMENT

The atoms or elementary particles themselves are not real; they form a world of potentialities or possibilities rather than one of things or facts. — Werner Heisenberg


Detail, *Random Sphere 1,* Eric J. Heller

Heisenberg's idea of a world of potentialities and possibilities certainly resides at the intersection of art and science. These two disciplines, each in their own way, both investigate the unseen. In this spirit, the artists in the exhibition *Art and The Quantum Moment* take quantum matter as their subject in order to reveal the beauty that arises when art and science meet.

Quantum means "how much" in Latin. It's the core of Max Planck's thesis describing quantized energy in quantum theory. The revolutionary part of this idea is that energy, which appears to be emitted in wavelengths, is discharged in small quantifiable packets (quanta). Following Planck's theory, Werner Heisenberg introduced his Uncertainty Principle in 1927. Since then, scientists and non-scientists alike have embraced the concept of quantum in their work.

The quanta-inspired exhibition, *Art and The Quantum Moment,* features the work of three artists: Eric J. Heller, Frédérique Swist and Jacqueline Thomas. Their art offers distinct perspectives on quantum theory. Approaches range from illustrative visualization of scientific concepts to artistic interpretation as influenced by science.

Inspired by the world we cannot see directly, the artist and scientist Dr. Eric Heller says he creates art "as a way to communicate the semi-knowable world to larger groups of people than specialized research allows." His quantum realm of electrons, atoms, and molecules yields forms conveying the mystery of quantum physics. Heller visualizes the physics with vivid color that activates waveforms in high-resolution digital prints. He cites the artist Sol LeWitt as an important influence, whose meticulous and often geometric and algorithmic creations he admires.

The art of Dr. Frédérique Swist references physics and phenomena that relate to extreme scale, distance, and mathematical abstraction. She states: "the visual supersedes the factual and technical language of science; it becomes powerful through a highly structured combination of forms and colors, thereby moving from the science toward the realm of visual art and aesthetic experience." Swist's work is an amalgam of richly saturated color and gridded geometric abstraction.

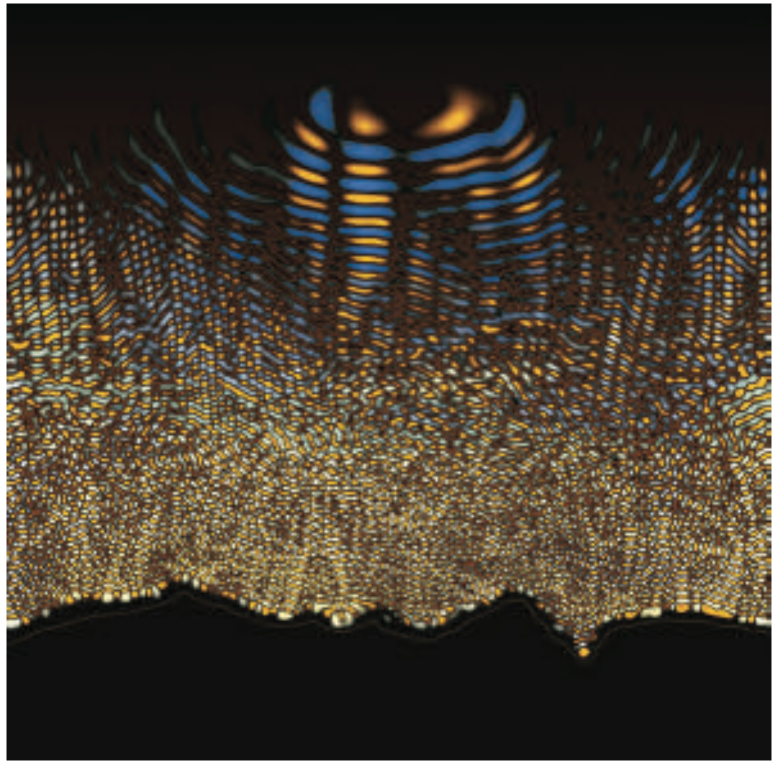
Jacqueline Thomas honors science by depicting the fundamental laws of the universe in hand bound limited edition books. Seeing the graphic beauty in equations, she describes them as "visual masterpieces that explain the world we live in." Thomas combines some of these equations with images from a book on Sociography, which details and draws the elegant complexities of shadows. On her web site, she cites astrophysicists, mathematicians and instrument makers as her muses.

Finally, this exhibition was inspired by the book *The Quantum Moment: How Planck, Bohr, Einstein, and Heisenberg Taught Us to Love Uncertainty,* by Robert P. Crease and Alfred Scharff Goldhaber. These Stony Brook University authors—one a philosopher, the other a physicist—provided the initial imagination to ignite *Art and The Quantum Moment.*

Lorraine Walsh
Art Director and Curator

ERIC J. HELLER

Eric Johnson Heller is the Abbott and James Lawrence Professor of Chemistry and Professor of Physics at Harvard University, where he received his PhD in 1973. Dr. Heller is an elected Fellow of the American Academy of Arts and Sciences, the American Association for the Advancement of Science, the American Physical Society, The National Academy of Science, and the American Academy of Arts and Sciences. His research involves theoretical investigation of wave behavior, chaos and quantum mechanics, condensed matter physics including electron flow in semiconductors and electronic spectroscopy of crystals, including graphene. He lives in Plymouth, MA, and teaches at Harvard University, Cambridge, MA.



A quantum electron wave that was once tidy and collected at the top of the frame was dropped onto the rough surface in a gravitational field. Starting compactly in the sky, it accelerated toward the mountain, wavelengths growing shorter as it sped toward the mountain below. It then bounced elastically off the mountain, and reached its former height (on average) at the moment this image was recorded, i.e. after one bounce. The wave now looks disheveled. This work is part of an ongoing study of scattering of quantum waves from rough surfaces.

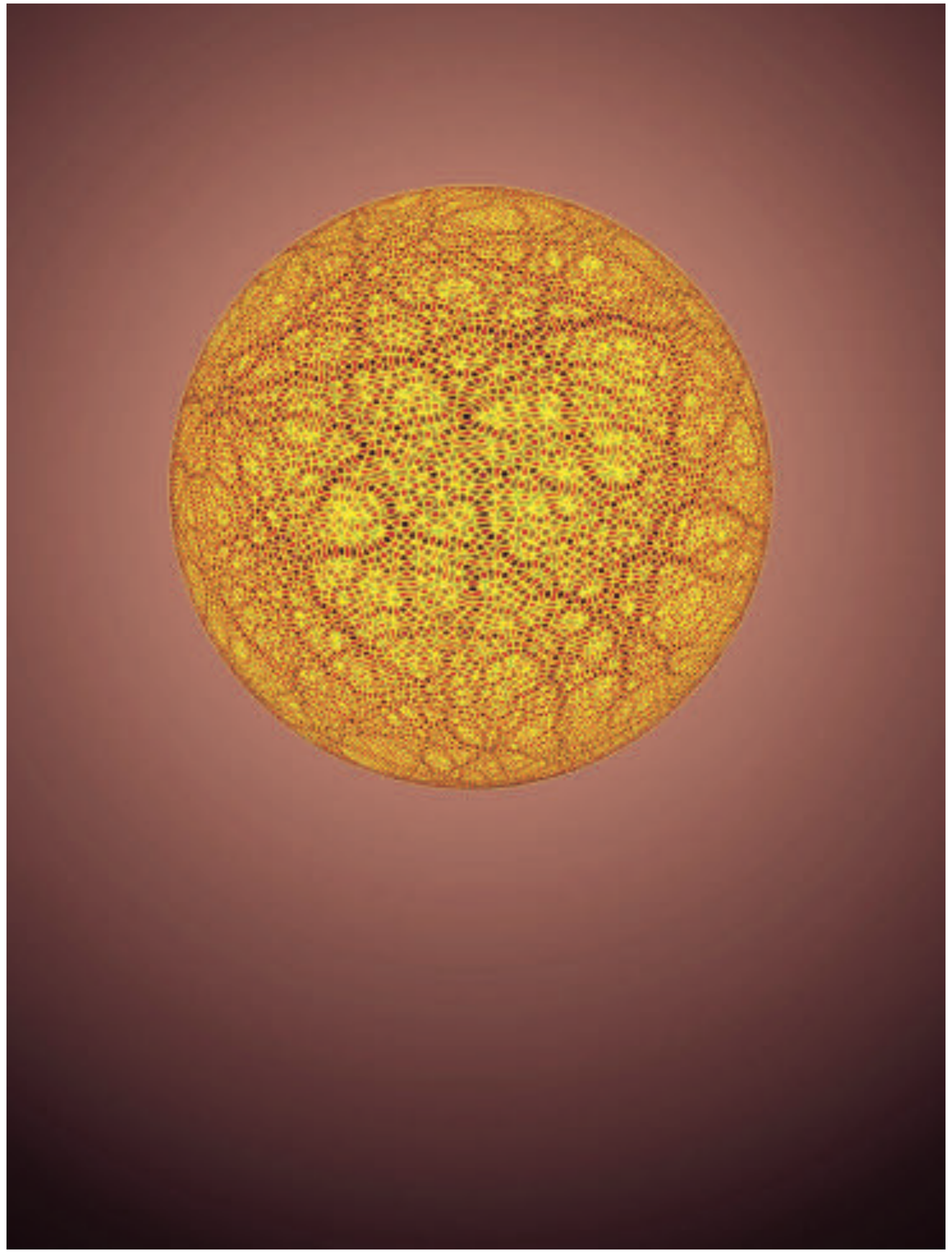
One Bounce, 2003
Luminage Archival Digital Print
Edition: 6/250
22” x 22” (56cm x 56cm)

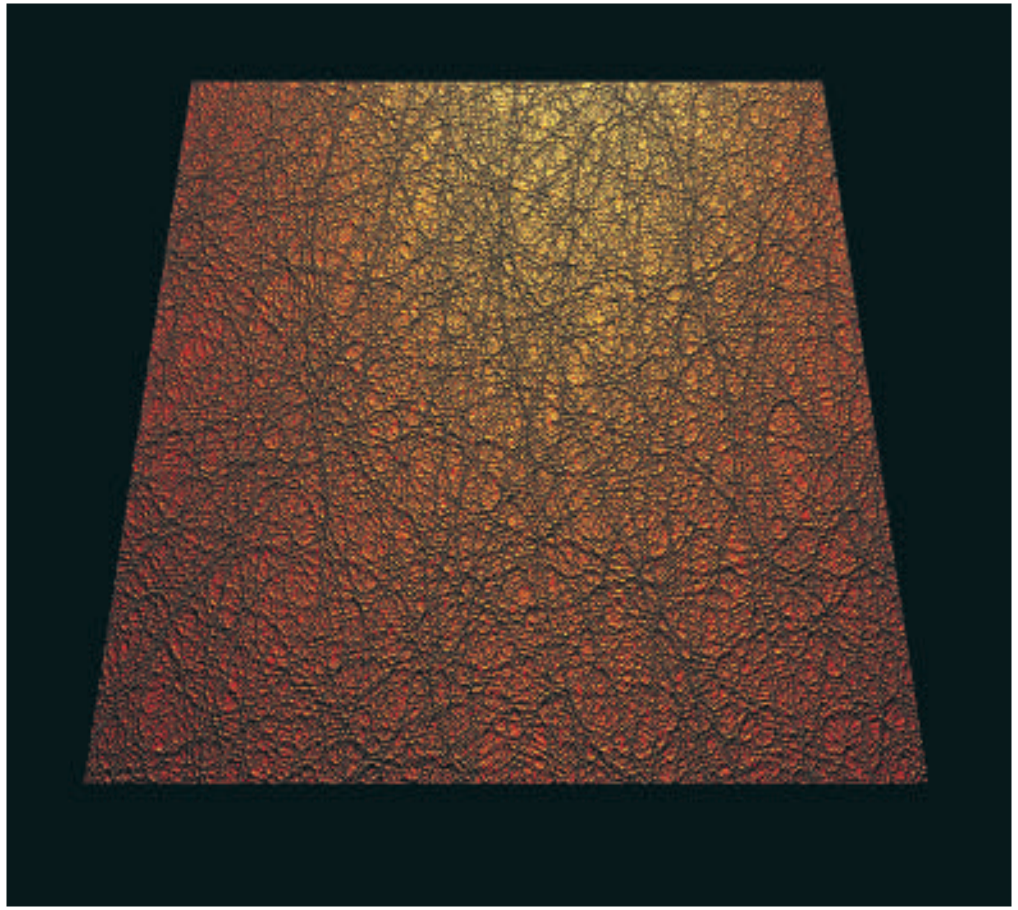
Caustics are places where things accumulate; in this case light is accumulating. We often think of focal points as places where light gathers after passing through a lens, but more generally, for "random" lenses, there are many more interesting patterns of accumulation to examine. In *Caustic II,* we are seeing the flow of light in three dimensions as it is interrupted by the sea bottom surface. This pattern is not possible for a true sea, because the light has passed through seven consecutive wavy refracting surfaces.

Caustic II, 2001
Luminage Archival Digital Print
Edition: 6/250
48” x 36” (91.5cm x 122cm)

***Random Sphere* is a spherical surface with a random wave living on it.** Random waves are a paradigm for quantum chaos, the quantum analog of classical chaos. The randomness associated with such a wave is as close as quantum mechanics can come to the extremes of classical chaos. Classical chaos leads to a trajectory or ray path heading in every possible direction, revisiting every location (from different directions) over time. Corresponding to this, we see the random addition of wave sets traveling in all directions. The resulting wave additions always look qualitatively like the wave on *Random Sphere.* Darker zones represent places where the waves happened to build up constructively; this is relevant to quantum waves or ocean waves, for that matter.

Random Sphere I, 2000
Luminage Archival Digital Print
Edition: 12/250
48" x 36" (91.5cm x 122cm)



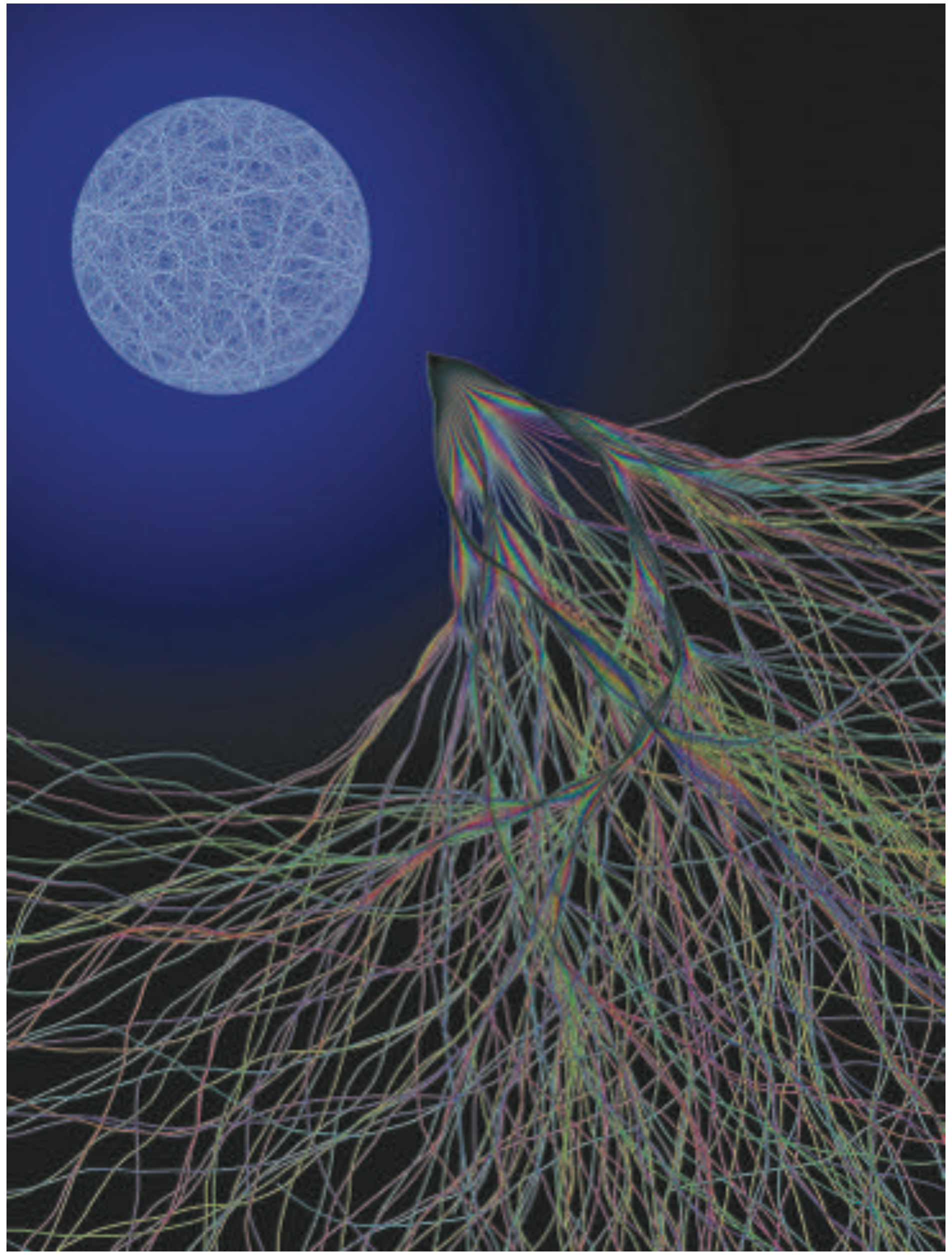


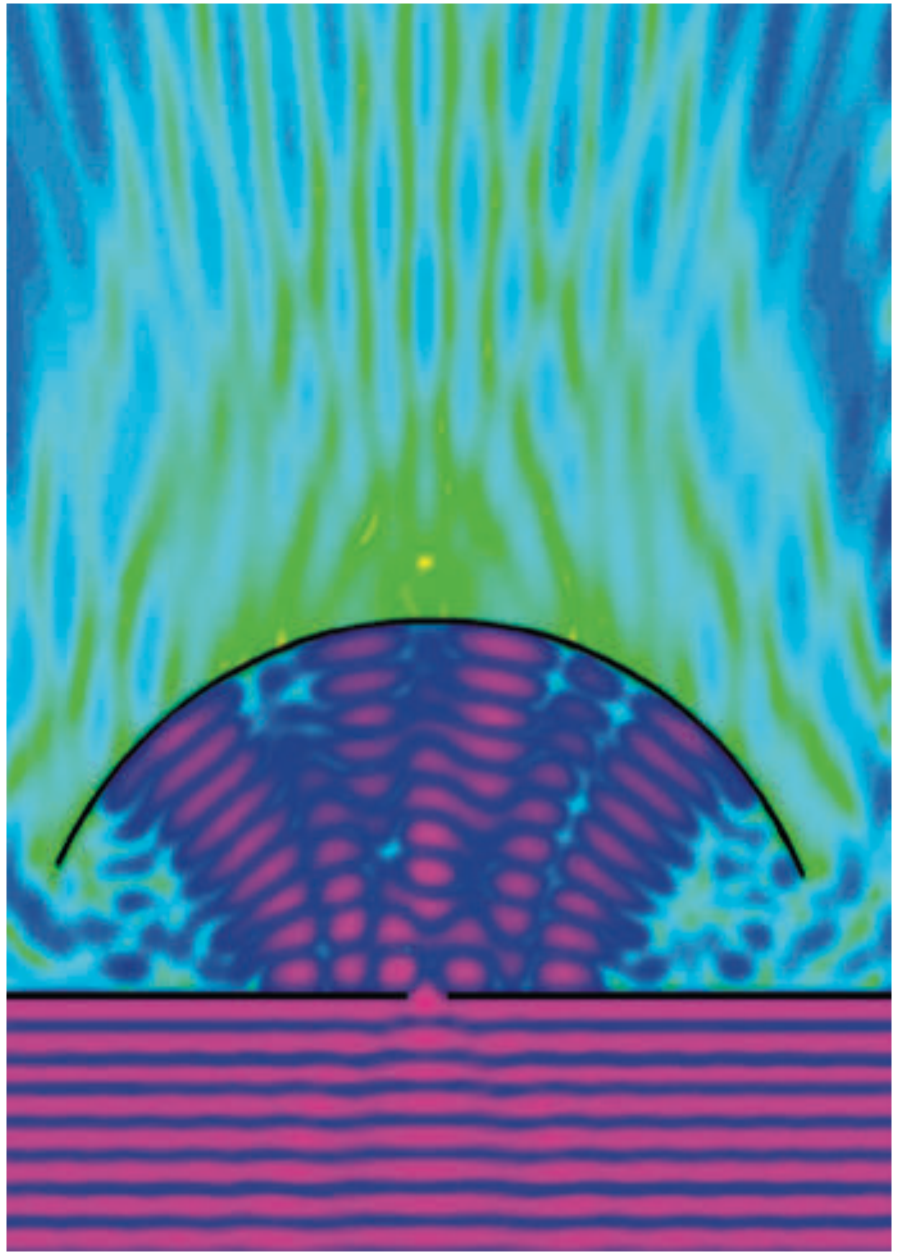
Monolith* is related to *Random Sphere; both depict random quantum waves, here on a flat surface and rendered in 3D perspective. Random waves are the paradigm for quantum chaos. Classical chaos amounts to individual trajectories visiting every place many times, and traveling through each place heading in every possible direction, seemingly randomly over time. Corresponding to this we see the random addition of waves traveling in all directions and present everywhere. A lumpy random pattern emerges; adding more waves won't smooth it out, although the positions of the lumps will shift.

Monolith, 2000
Luminage Archival Digital Print
Edition: 6/250
22" x 22" (56cm x 56cm)

***Transport XIII* reveals two kinds of chaos:** a random quantum wave on the surface of a sphere, and chaotic electron paths launched over a range of angles from a particular point. This too is quantum mechanical in nature, and the electron paths seen here are a ray tracing approximation to the quantum. The different angles of the launch of the rays were assigned different colors, so that one could more readily see the mechanisms by which the electrons spread out. The increasingly random paths of the electrons as they travel farther from the launching point is a classical analog of the chaos seen on the sphere.

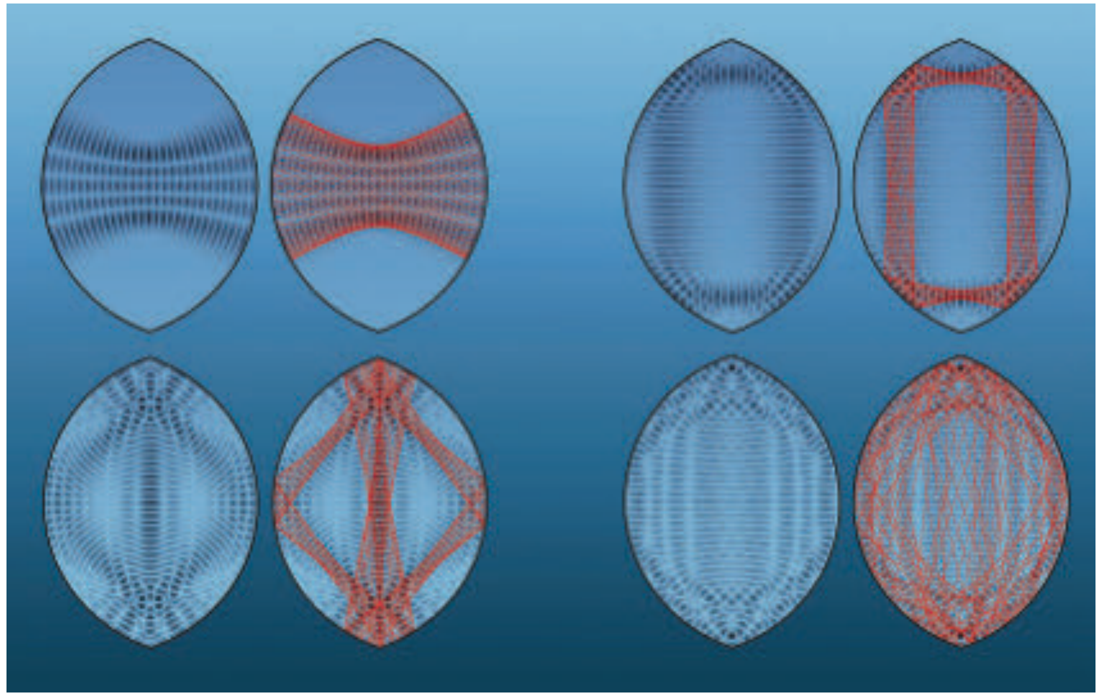
Transport XIII, 2000
Luminage Archival Digital Print
Edition: 6/250
31" x 22" x (56cm x 79cm)





A quantum wave builds up in a resonant cavity between the straight and curved walls, as waves arrive from below through a small hole. Most of the wave energy, coming from below, is reflected back from the wall with a small hole in it, but a surprisingly large fraction of it gets through the tiny hole if the wavelength is just right to make the cavity beyond the hole resonant. Professor Robert Westervelt and his research group at Harvard University invented this "Westervelt Resonator" around 1995, for the purpose of investigating electron quantum waves. In this picture, you see various heralded aspects of waves all present: reflection, diffraction, and resonance. The actual Westervelt resonator was smaller than a bacterium.

Resonator I, 1997
Luminage Archival Digital Print
Edition: 7/250
31" x 22" (56cm x 79cm)



***Correspondence* is a kind of Rosetta Stone; a visual translation between classical and quantum dynamics.** The quantum standing waves in black and the red ray traces of classical trajectories after many elastic, specular bounces off the walls are quite analogous. Nodal lines (zeros in the wave near regions of large wave amplitudes) follow a certain pattern predictable from the ray paths. There are four types of classical motion for this lemon-shaped billiard, including the chaotic motion seen in the lower right. The motion depends only on the initial "launch" the trajectory is given. There is a stable back and forth motion on the upper left that is a mode used for laser cavities, using circular mirrors spaced closer together than their radius of curvature. As seen in black, the standing waves (quantum wave functions) also fall into the four classes, and closely resemble the trajectories.

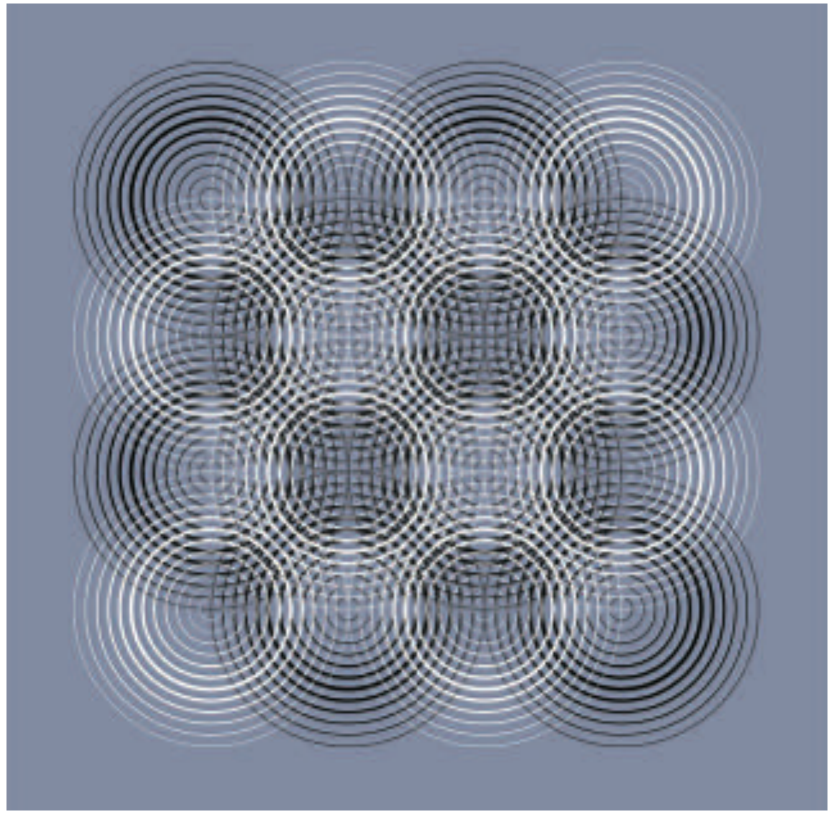
Correspondence, 1997
Luminage Archival Digital Print
Edition: 6/250
14" x 22" (56cm x 35.5cm)

***Nodal Domains I* is a quantum version of a mass held by springs in two-dimensions;** the quantum wave seen here is a random combination of solutions all of the same energy. We discovered that the number of nodes (lines between white and green seen in the background) grow as the square root of the energy. In *Nodal Domains I,* the classically allowed region is mapped onto a sphere, and the forbidden region (where a classical mass held by the spring could not go) remains in the background plane.

Nodal Domains I, 2005
Luminage Archival Digital Print
Edition: 5/250
22" x 22" (56cm x 56cm)

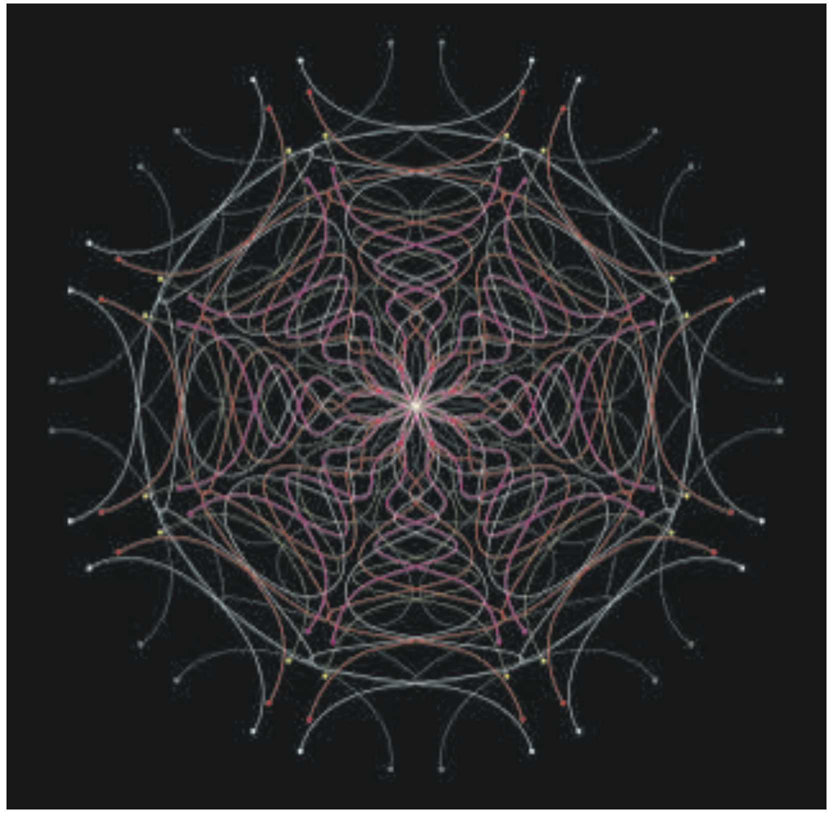
FRÉDÉRIQUE SWIST

Frédérique Swist is an artist, and a senior graphic designer for the academic science publisher IOP Publishing, owned by the UK Institute of Physics. She recently completed a practice-based PhD at the University of the West of England in Bristol (UK). Swist's work has been exhibited in Bristol, York, London, St Petersburg and Budapest, and acquired by Aston University and York St John University. She has received several notable commissions including one from the Centre of Nanoscience and Quantum Information, University of Bristol. In 2013 and 2014, IOP Publishing commissioned her work for display at its Washington, Philadelphia and Beijing offices. She lives and works in Bristol, UK.



Good Vibrations refers to individual but intertwined sub-systems, from which optical effects emerge that can be described as a visual rhythm, intended to be experienced as a resonance that transcends the binarity normally associated with oscillation. This artwork belongs to a series published in the multidisciplinary journal Parallax 16:3 (2010), pp. 55–59, exploring the theme of affirmation/positivity.

Good Vibrations, 2010
Archival pigment print on Somerset Velvet 330 gsm
Edition: 4 /10
31.5" x 31.5" (80cm x 80cm)

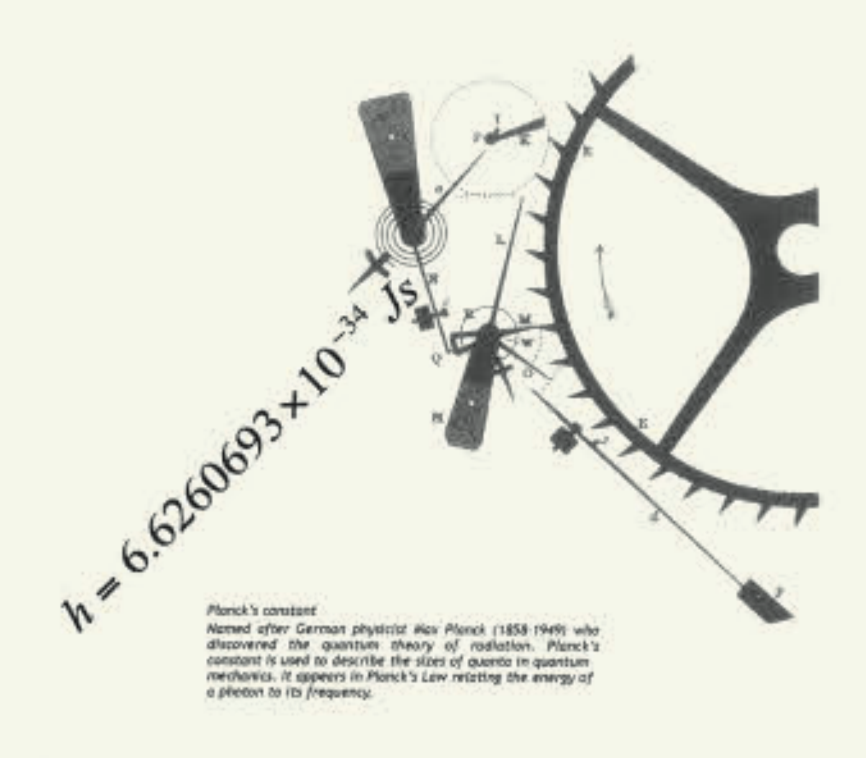


Excitable Waves is an artistic interpretation of the distribution of excitation functions in the study of the adhesion between biological cells and physical surfaces. This piece is inspired by a figure in an article titled "Excitable waves at the margin of the contact area between a cell and a substrate" by Oliver Ali, et al. (2009), Physical Biology 6 025010.

Excitable Waves, 2010/2014
Edition: 4/25
Archival pigment print on Somerset Velvet 330 gsm
31.5" x 31.5" (80cm x 80cm)

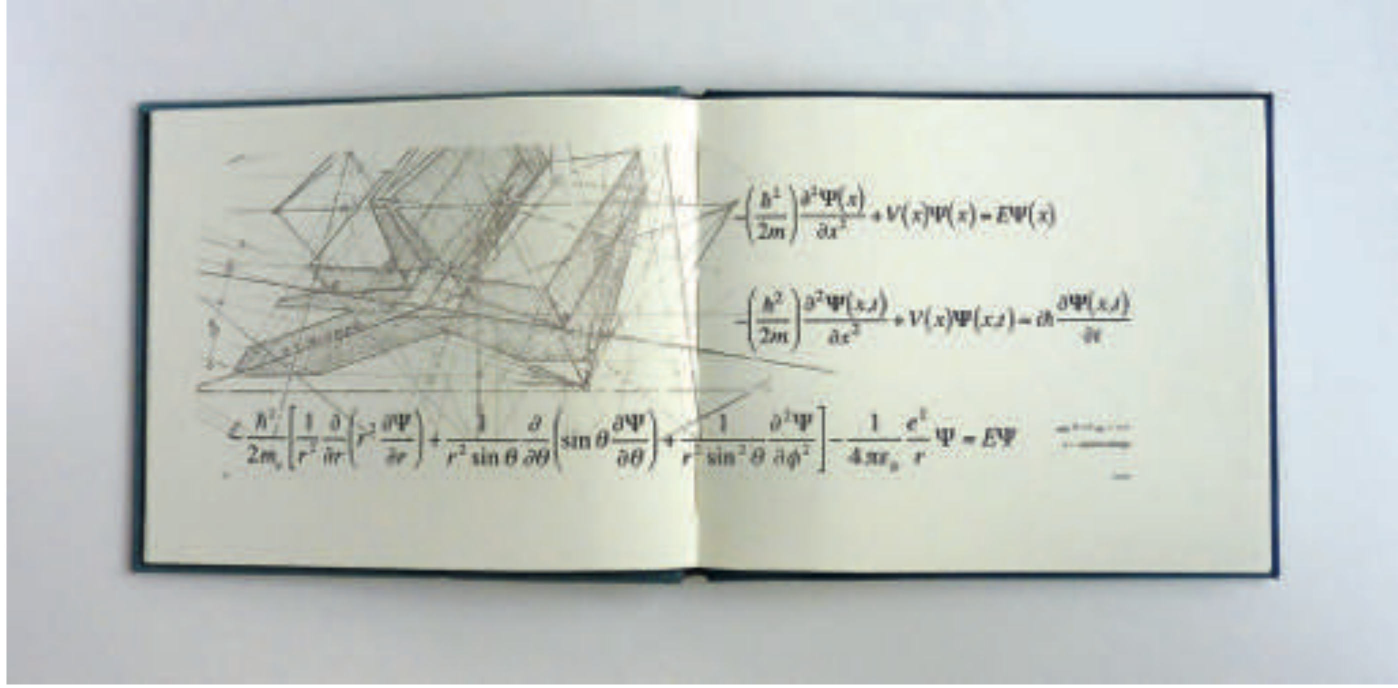
JACQUELINE THOMAS

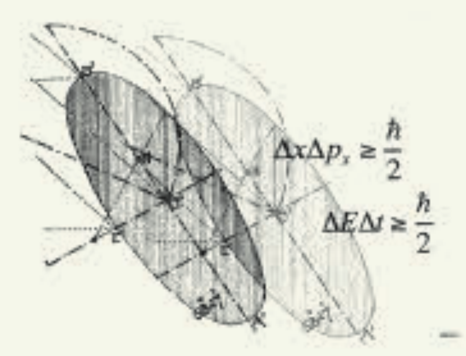
Jacqueline Thomas is an artist and designer of handmade limited edition books. She studied the art of bookmaking and binding at the University of the Arts, London College of Communication, where she graduated with a degree in Art and Design History. Thomas has been creating handmade limited edition books for over a decade. She prints digitally collaged pages, compiling them into books that are hand-sewn, bound and trimmed in time-honored book arts custom. University and private collections in the UK and abroad, including the British Library Contemporary Collection, own Thomas's limited edition books. She lives and works in London, UK.



Pictured in the book *Constants* is Planck's Constant and Remontoir Escapement. Planck's constant, symbolized h, is the fundamental constant of quantum mechanics. The constant relates the ratio of energy in one quantum (photon) of electromagnetic radiation to the frequency of that radiation. The dimension of Planck's constant is the product of energy multiplied by time, a quantity called action. The constant is equal to approximately 6.626176 x 10-34 joule-seconds.

Constants, 2006
Handmade Limited Edition Book
Edition of 15
8.25" x 10" (25.4 cm x 21cm)





Pictured above from the book *Equations* is Heisenberg's Uncertainty Principle

The spread above depicted in the book *Equations* is the Schrödinger equation, an equation fundamental to the study of wave mechanics, is seen here in three forms, with the topmost equation described first:
1. Equation for a solution with fixed energy (motion in one space dimension only).
2. Equation for a solution that may have more than one energy so one relates the space dependence (on the left) to the time dependence (on the right).
3. Equation for solution (again with definite energy) of the motion of an electron (negative electric charge) around a proton (positive electric charge).

Equations, 2005
Handmade Limited Edition Book
Edition of 15
8.25" x 10" (25.4 cm x 21cm)

EXHIBITION CHECKLIST . ALL WORK COURTESY OF THE ARTISTS

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Archival pigment print on
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ART AND THE QUANTUM MOMENT
December 4, 2014 – January 29, 2015

Eric J. Heller
Frédérique Swist
Jacqueline Thomas

Curated by Lorraine Walsh,
with Robert Crease and Alfred Goldhaber

SCHEDULE OF EVENTS

PRE-EXHIBITION TALK
by ARTHUR I MILLER
University College London
Title: *Colliding Worlds: How Cutting-Edge Science is Redefining Contemporary Art*
Wednesday November 5th, 2014
Reception at 5:00pm
5:30pm, SCGP Room 102

OPENING RECEPTION
Thursday, December 4th, 2014
Wine and Cheese Reception: 5:00pm

DELLA PIETRA LECTURE
by ERIC J. HELLER
Harvard University
Title: *The Art of Listening. Carefully.*
Thursday, December 4th, 2014
Lecture: 5:45pm, Simons Center
Auditorium, Room 103

CLOSING RECEPTION
Thursday, January 29th, 2015
Wine and Cheese Reception: 5:00pm

CLOSING TALK by ROBERT CREASE and ALFRED GOLDHABER
Stony Brook University
Title: *Art and The Quantum Moment*
Thursday, January 29, 2015
5:30 pm, SCGP Room 102

ACKNOWLEDGEMENTS

I'd like to express my gratitude and special thanks to Robert Crease and Alfred Goldhaber for providing the inspiration for the exhibition, the Simons Center Art Advisory Board: Tony Phillips, Stephanie Dinkins, George Hart, Christopher Herzog, John Lutterbie, Phil Palmedo, Zabet Patterson, Meg Schedel and Daniel Weymouth, and all the SCGP staff including Maria Froehlich, Elyce Winters and Tim Young. Finally, a tremendous thanks to the artists for sharing their innovative and beautiful quantum-inspired art with all at the Simons Center and Stony Brook University.

The exhibition coincides with the Della Pietra Lectureship Series honoring Dr. Eric J. Heller, the James Lawrence Professor of Chemistry and Professor of Physics at Harvard University. These lectures are made possible by a generous donation from brothers Stephen and Vincent Della Pietra.

- Lorraine Walsh

All lectures and receptions are free and open to the public

Simons Center Gallery
Gallery Hours
Monday- Friday 10:00 am – 5:00 pm; Closed Saturday, Sunday, and Holidays

Directions to Simons Center for Geometry and Physics
http://scgp.stonybrook.edu/about/directions

Information http://scgp.stonybrook.edu or call 631-632-2800

Catalog Design macomea@optonline.net

SIMONS CENTER FOR GEOMETRY AND PHYSICS   Stony Brook University

$$-\left(\frac{\hbar^2}{2m}\right)\frac{\partial^2\Psi(x)}{\partial x^2}+V(x)\Psi(x)=E\Psi(x)$$

$$-\left(\frac{\hbar^2}{2m}\right)\frac{\partial^2\mathbf{\Psi}(x,t)}{\partial x^2}+V(x)\mathbf{\Psi}(x,t)=i\hbar\frac{\partial\mathbf{\Psi}(x,t)}{\partial t}$$

$$\frac{1}{r^2\sin^2\theta}\frac{\partial^2\Psi}{\partial\phi^2}\Bigg]-\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}\Psi=E\Psi$$

with $\Psi \to 0$ as $r \to \infty$

e = electron charge

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