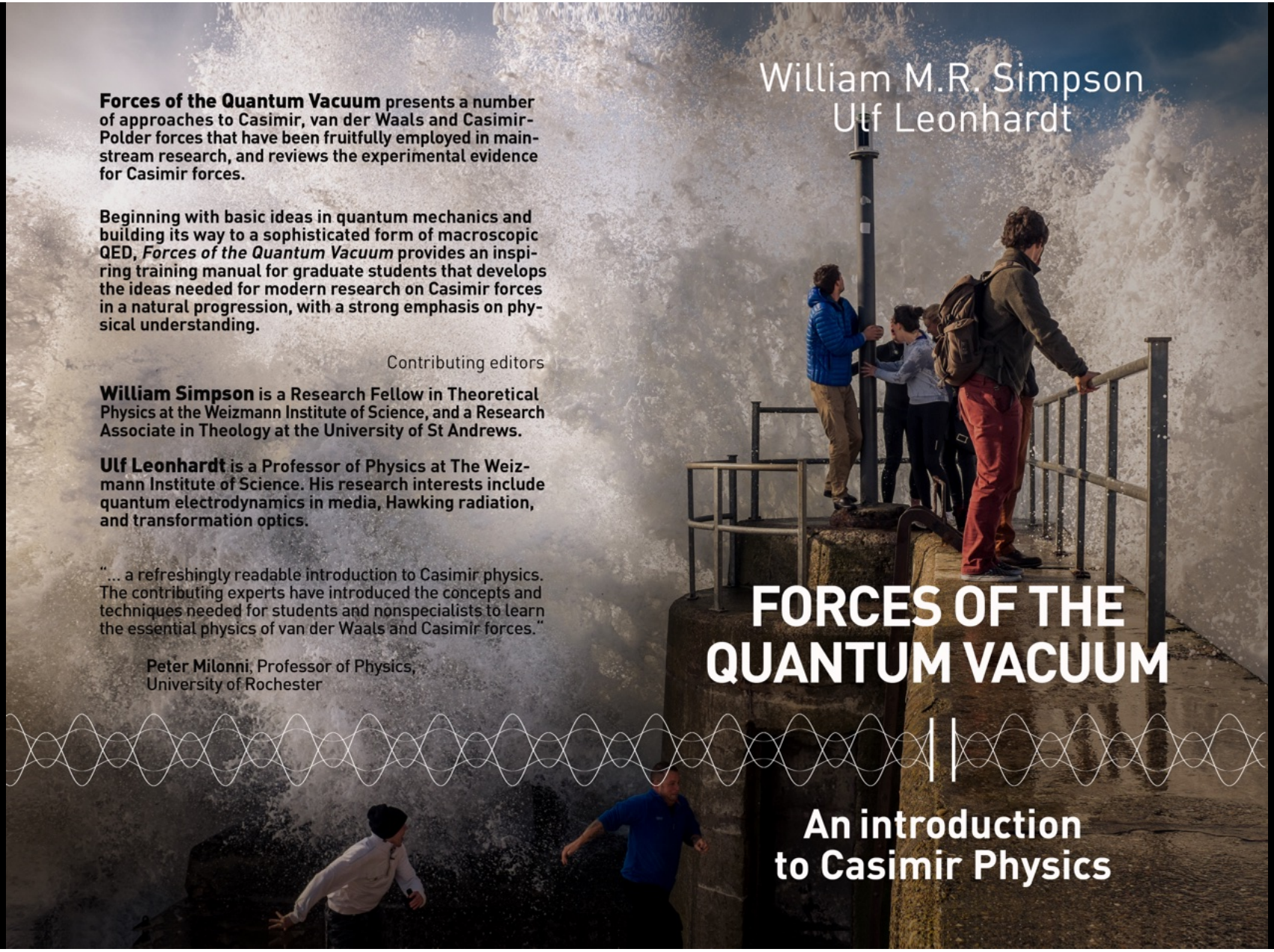


Forces of the Quantum Vacuum presents a number of approaches to Casimir, van der Waals and Casimir-Polder forces that have been fruitfully employed in mainstream research, and reviews the experimental evidence for Casimir forces.

Beginning with basic ideas in quantum mechanics and building its way to a sophisticated form of macroscopic QED, *Forces of the Quantum Vacuum* provides an inspiring training manual for graduate students that develops the ideas needed for modern research on Casimir forces in a natural progression, with a strong emphasis on physical understanding.

Contributing editors

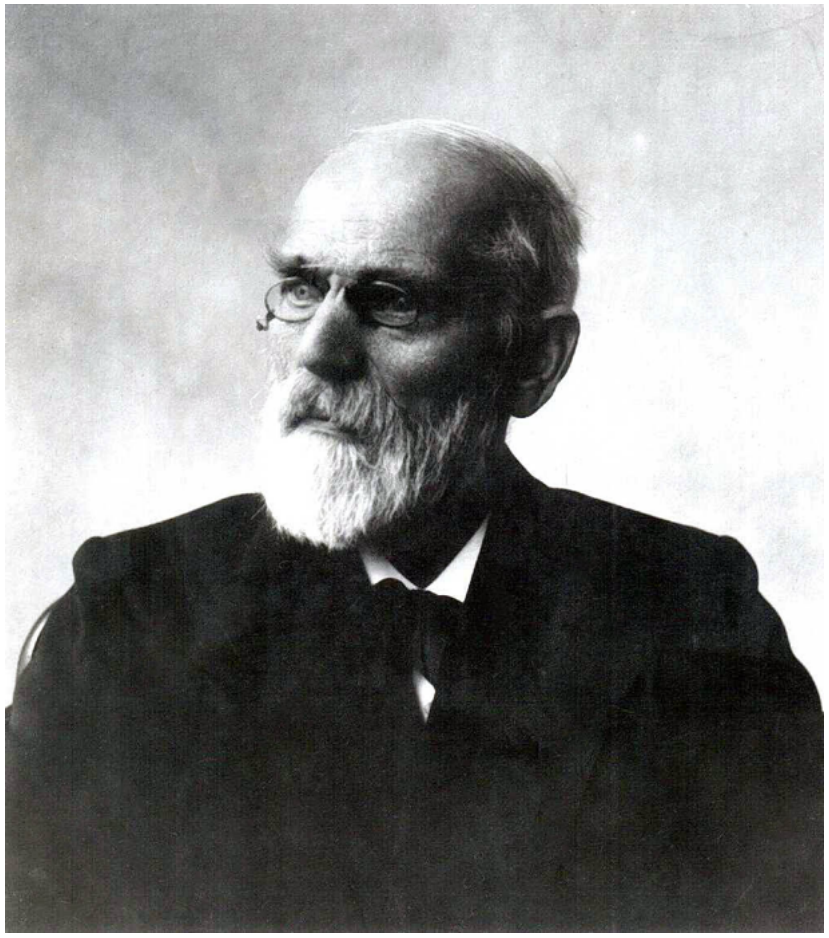
William Simpson is a Research Fellow in Theoretical Physics at the Weizmann Institute of Science, and a Research Associate in Theology at the University of St Andrews.

Ulf Leonhardt is a Professor of Physics at The Weizmann Institute of Science. His research interests include quantum electrodynamics in media, Hawking radiation, and transformation optics.

"... a refreshingly readable introduction to Casimir physics. The contributing experts have introduced the concepts and techniques needed for students and nonspecialists to learn the essential physics of van der Waals and Casimir forces."

Peter Milonni, Professor of Physics,
University of Rochester

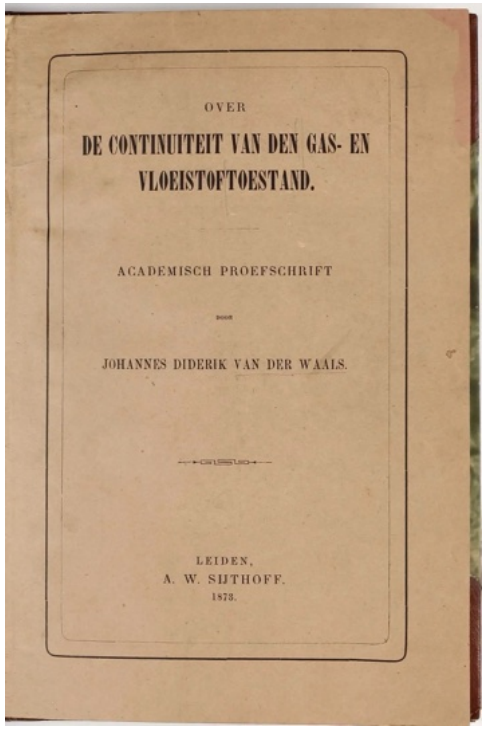
van der Waals: molecular forces 1873



$$(p + an^2/V^2)(V - nb) = nRT$$

b: molecular volume

$\varrho = n/V$



OVER

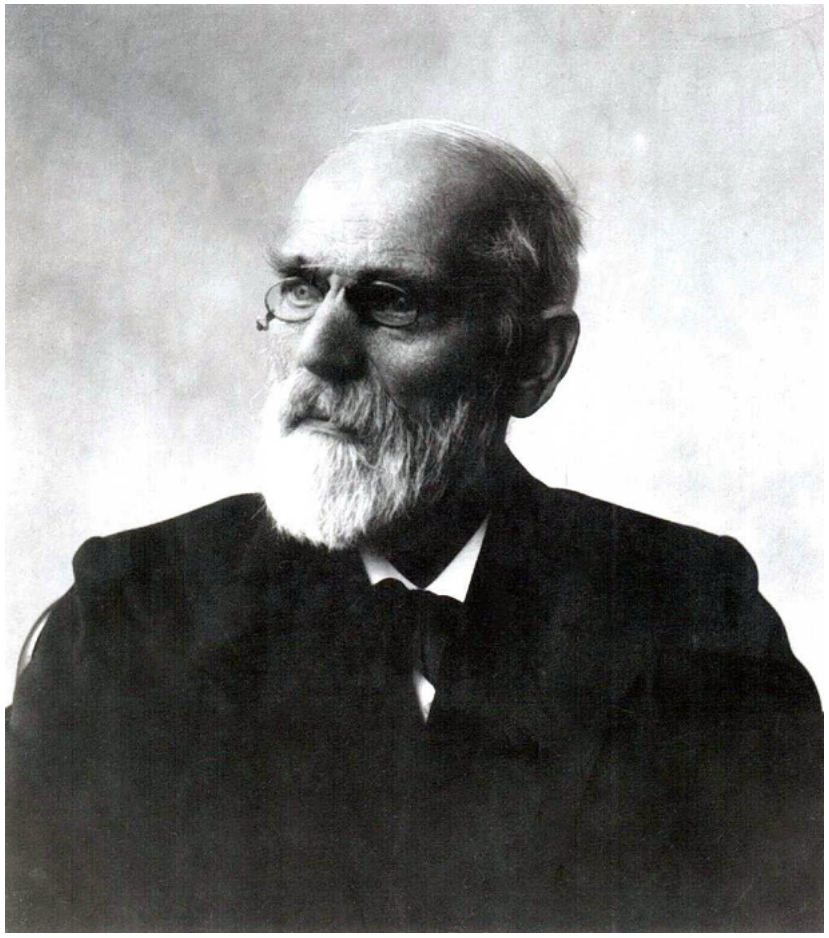
DE CONTINUITEIT VAN DEN GAS- EN VLOEISTOFTOESTAND.

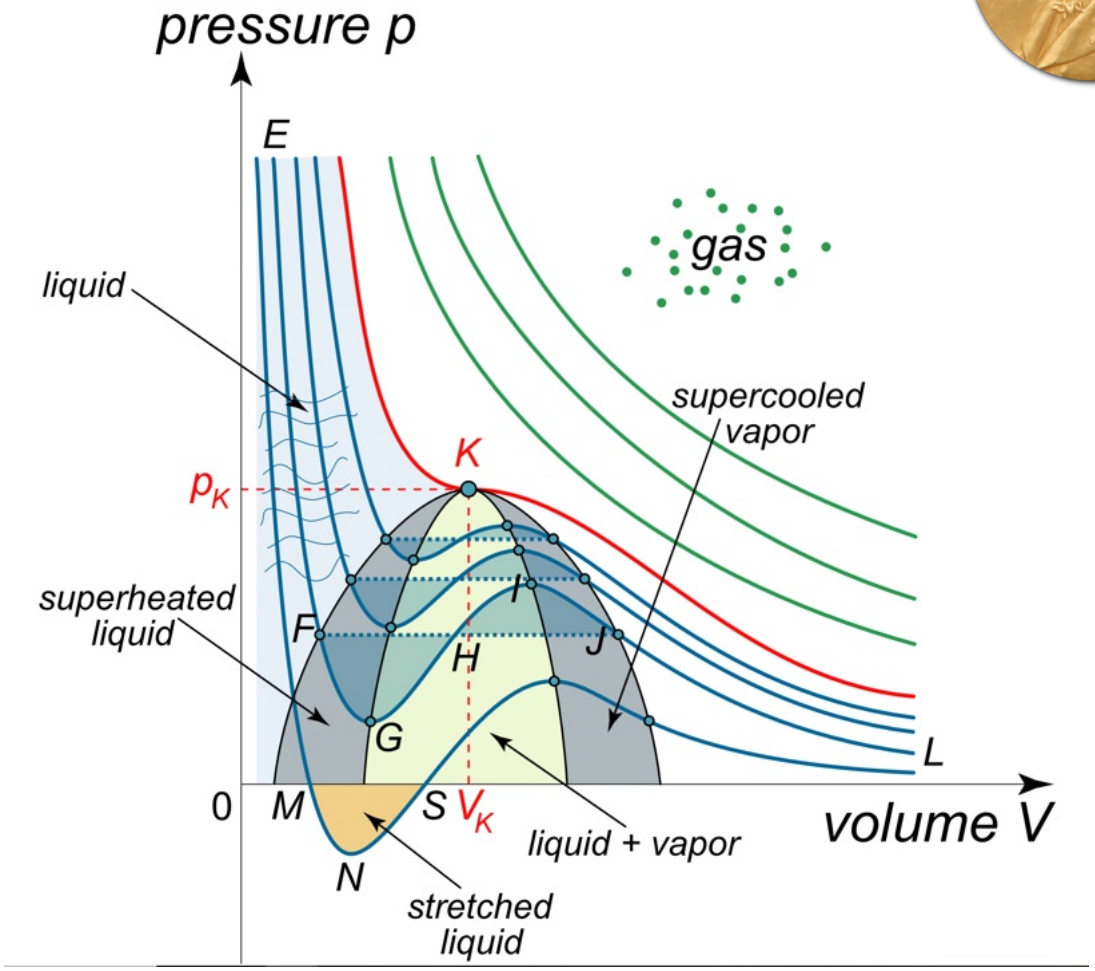
ACADEMISCH PROEFSCHRIFT

JOHANNES DIDERIK VAN DER WAALS.

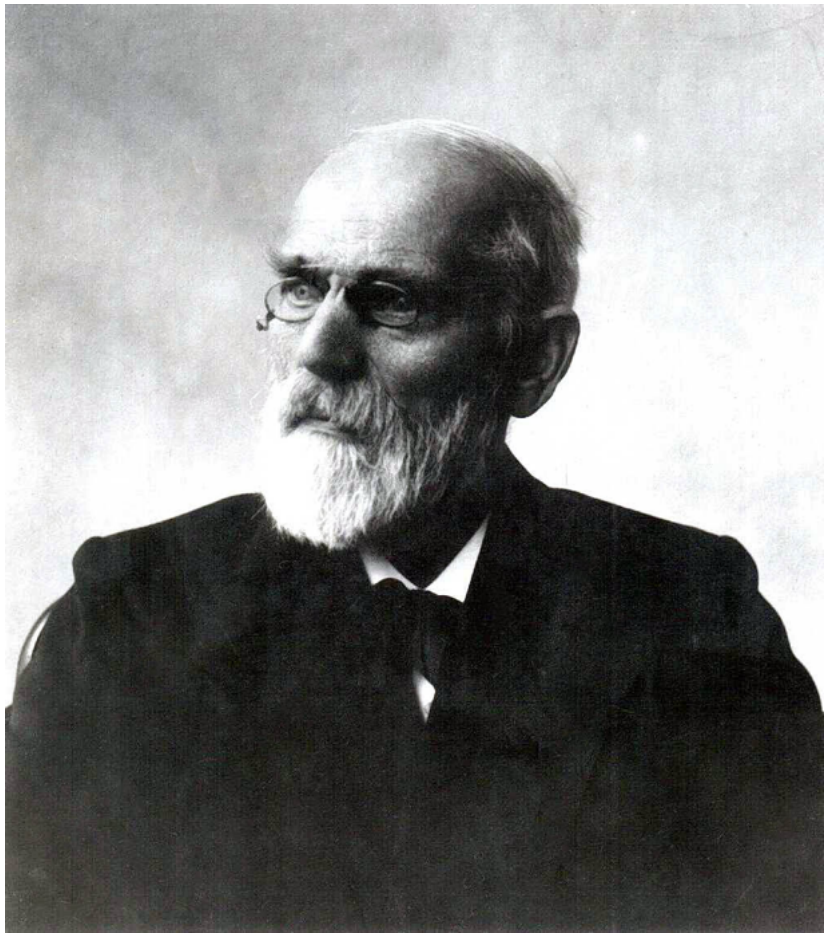
LEIDEN,
A. W. SIJTHOFF.
1873.

van der Waals: molecular forces 1873

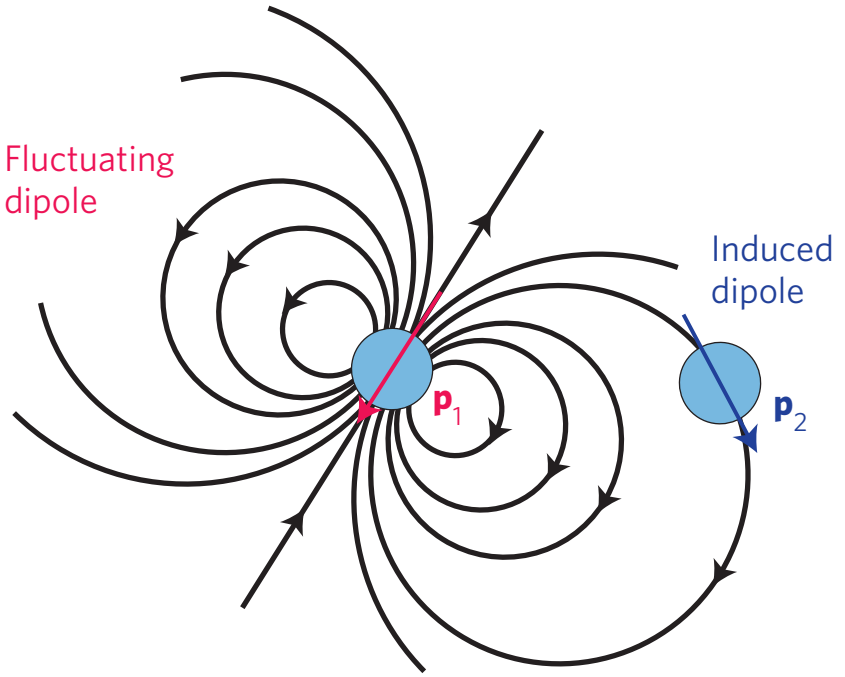




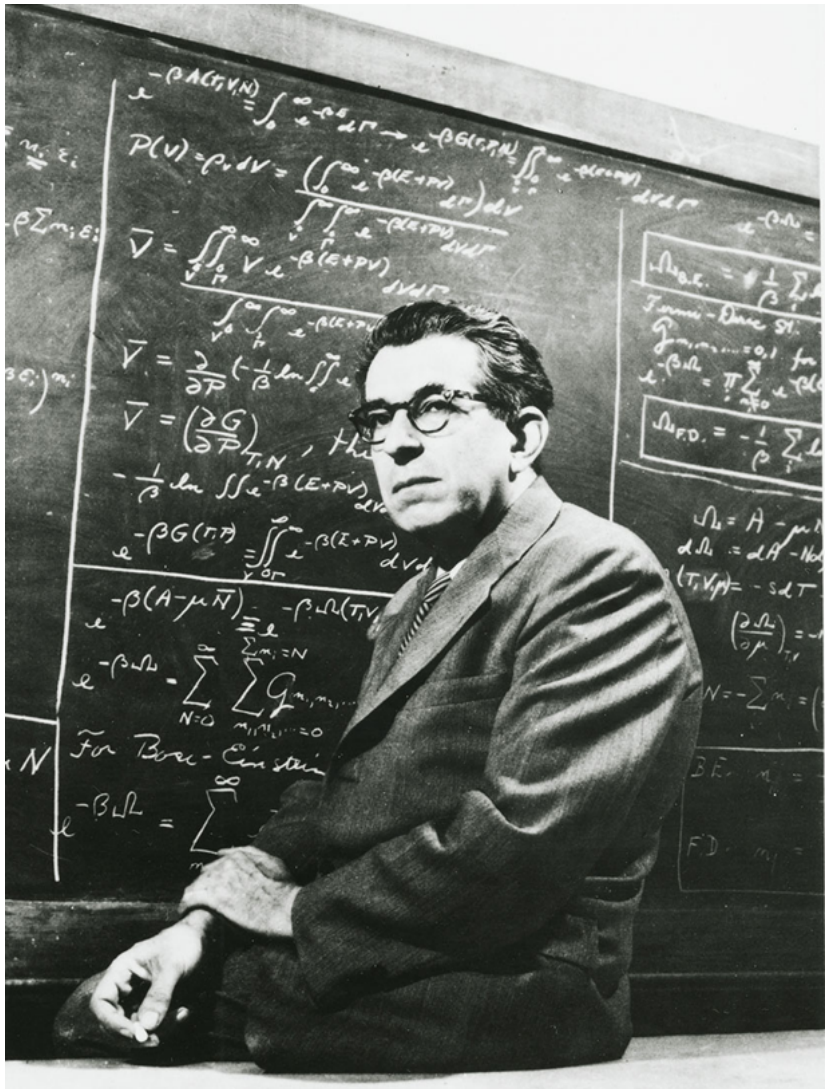
van der Waals: molecular forces 1873

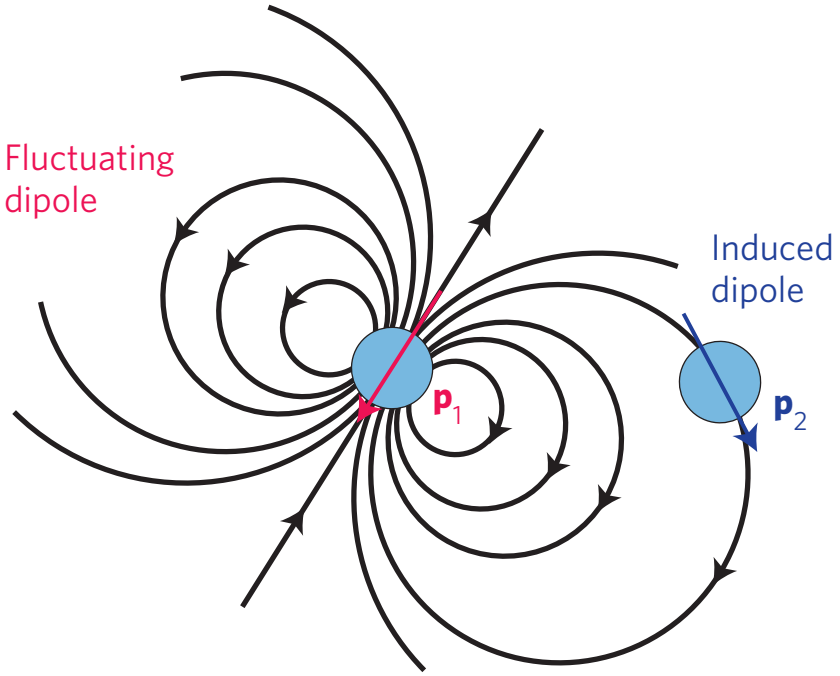


$$(p + an^2/V^2)(V - nb) = nRT$$



Fritz London: dispersion forces 1930



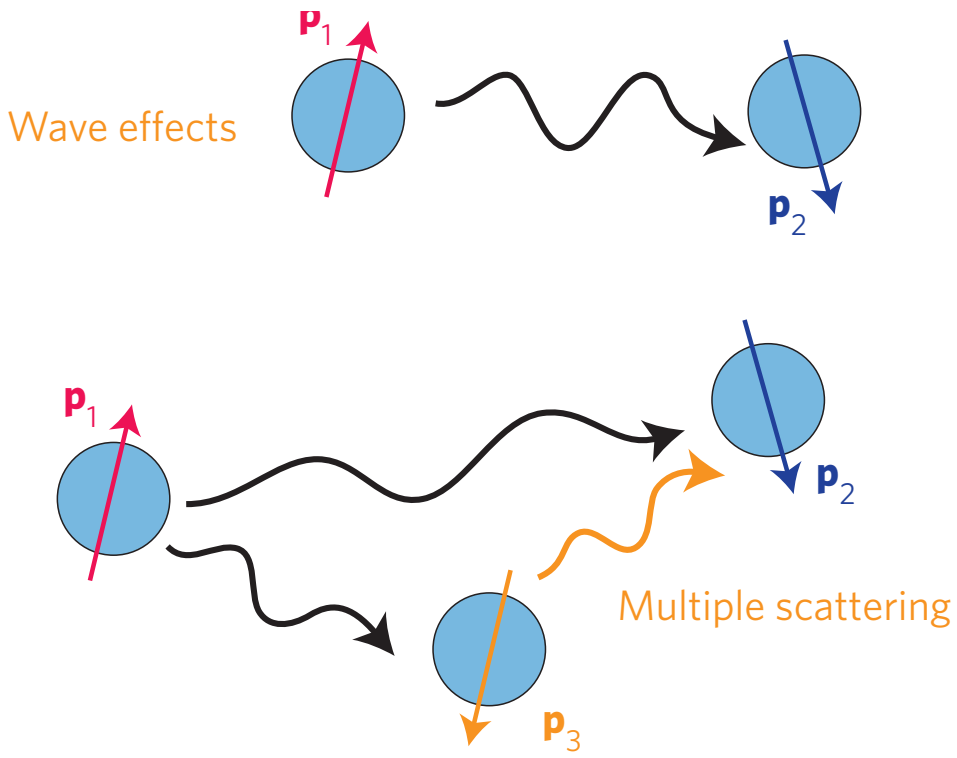


Hendrik Casimir: chief scientist 1946-1972

PHILIPS

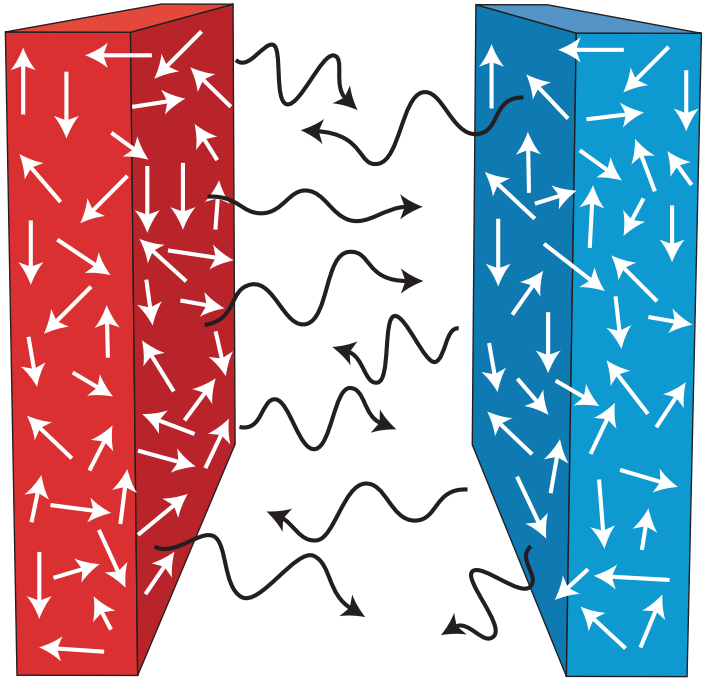
Hendrik Casimir: liquid paint 1940s

Casimir & Polder: waves & retardation 1948

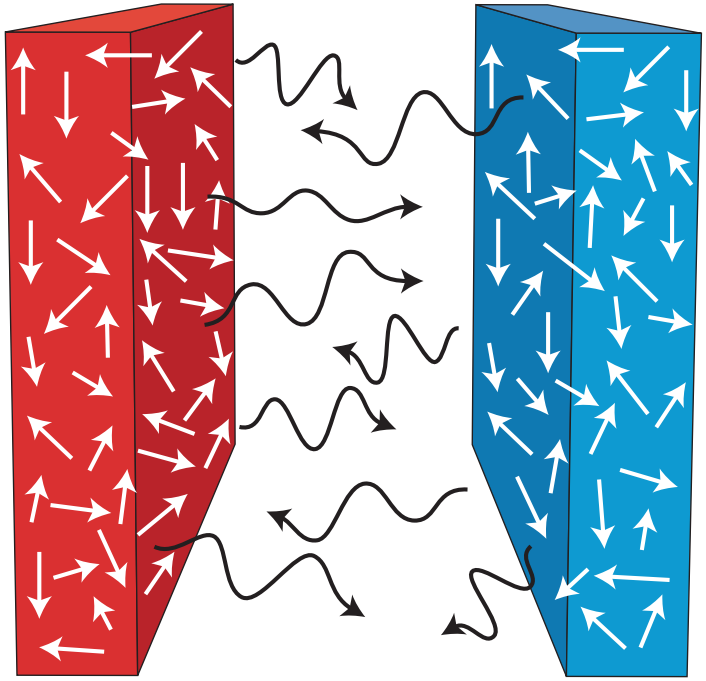


Bohr versus Pauli: quantum vacuum

Hendrik Casimir: macroscopic bodies 1948

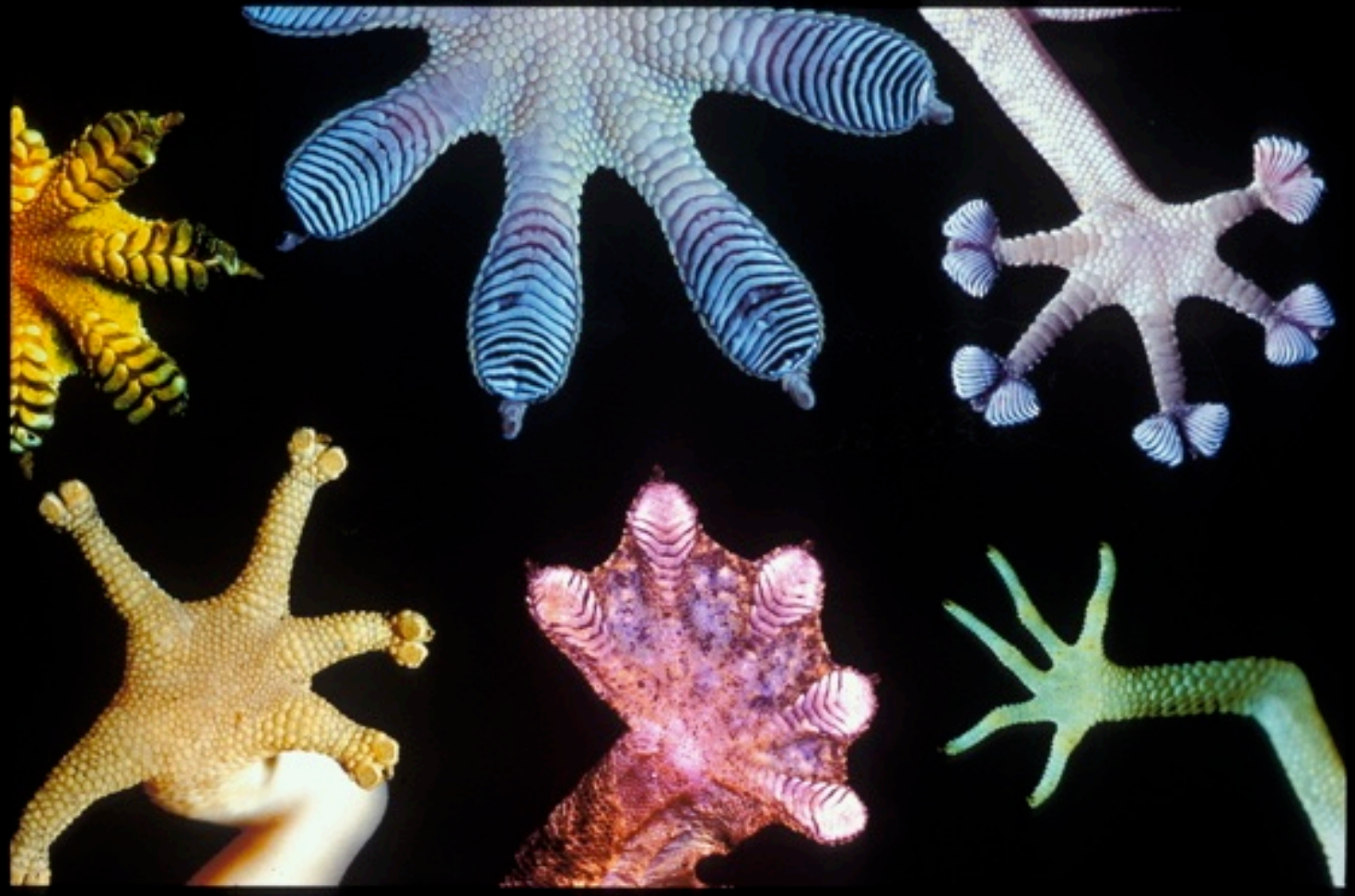


Hendrik Casimir: macroscopic bodies 1948



10nm corresponds to 1atm

Casimir/ van der Waals forces



Lifshitz theory

SOVIET PHYSICS

USPEKHI

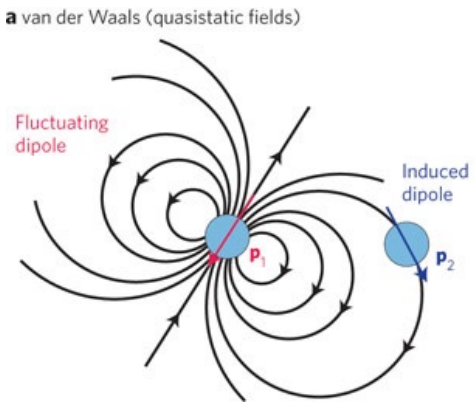
A Translation of Uspekhi Fizicheskikh Nauk

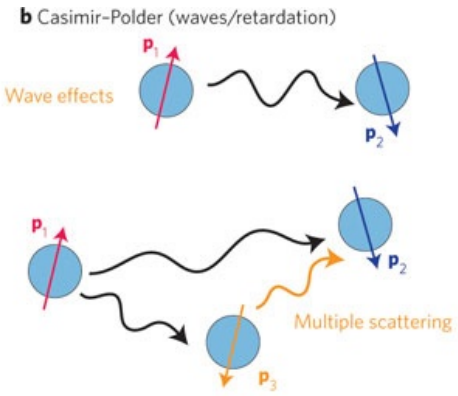
SOVIET PHYSICS USPEKHI (Russian Vol. 73, Nos. 3-4 SEPTEMBER-OCTOBER 1961

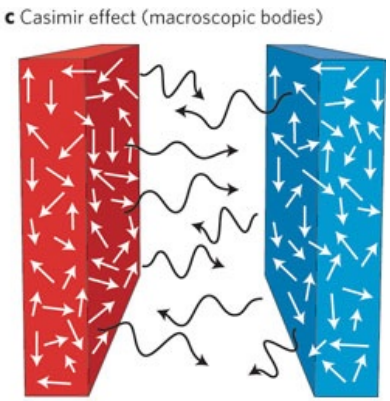
GENERAL THEORY OF VAN DER WAALS' FORCES

I. E. DZYALOSHINSKII, E. M. LIFSHITZ, and L. P. PITAEVSKII

Usp. Fiz. Nauk **73**, 381-422 (March, 1961)







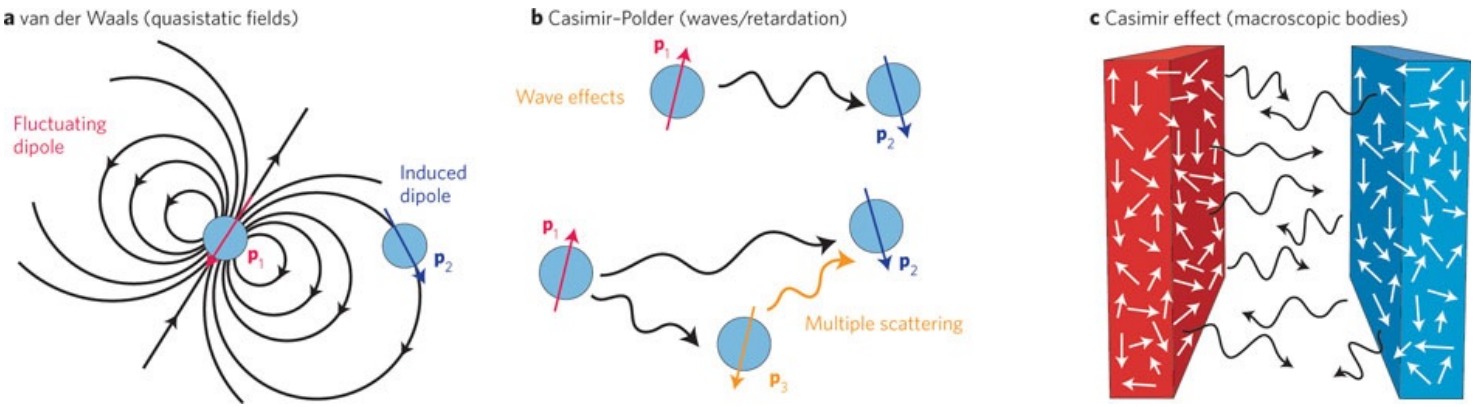
nature photonics

FOCUS | REVIEW ARTICLES

PUBLISHED ONLINE: 31 MARCH 2011 | DOI: 10.1038/NPHOTON.2011.39

The Casimir effect in microstructured geometries

Alejandro W. Rodriguez[1,2], Federico Capasso[1]* and Steven G. Johnson[2]



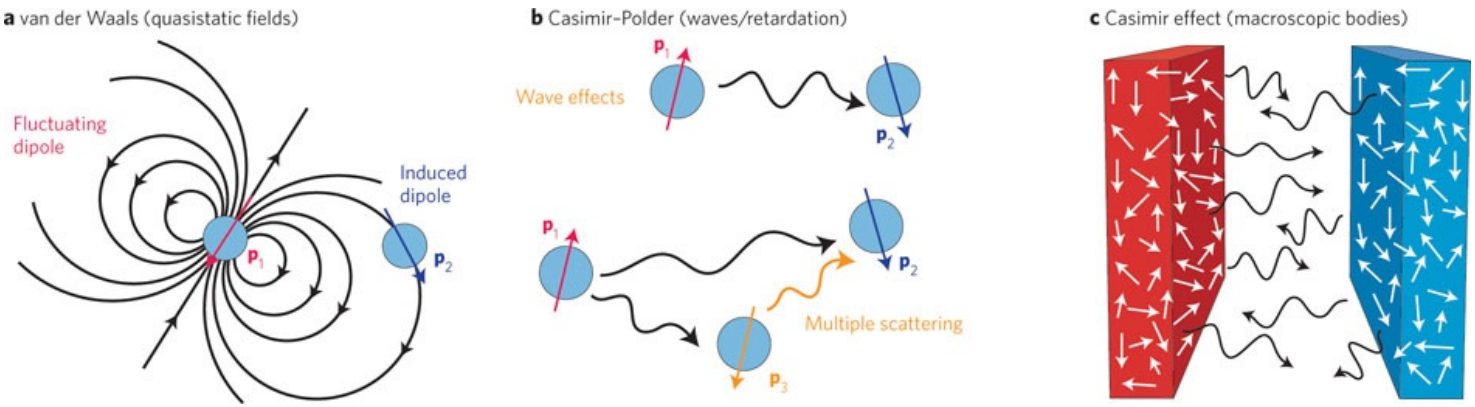
nature photonics

FOCUS | REVIEW ARTICLES

PUBLISHED ONLINE: 31 MARCH 2011 | DOI: 10.1038/NPHOTON.2011.39

The Casimir effect in microstructured geometries

Alejandro W. Rodriguez[1,2], Federico Capasso[1]* and Steven G. Johnson[2]



VOLUME 78, NUMBER 1 PHYSICAL REVIEW LETTERS 6 JANUARY 1997

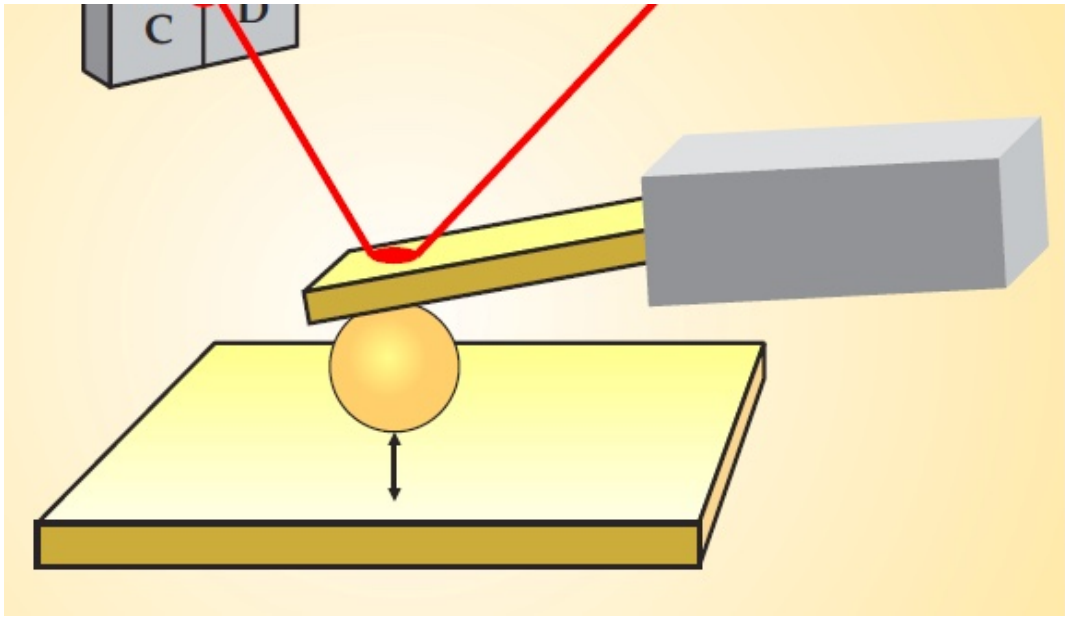
Demonstration of the Casimir Force in the 0.6 to 6 μm Range

S. K. Lamoreaux*

Physics Department, University of Washington, Box 35160, Seattle, Washington 98195-1560

(Received 28 August 1996)

Precision measurements and manipulations of Casimir forces



RESEARCH

PHYSICS

Science **364**, 984–987 (2019) 7 June 2019

Stable Casimir equilibria and quantum trapping

Rongkuo Zhao[1]*, Lin Li[1]*, Sui Yang[1]*, Wei Bao[1]*, Yang Xia[1], Paul Ashby[2], Yuan Wang[1], Xiang Zhang[1,3]†

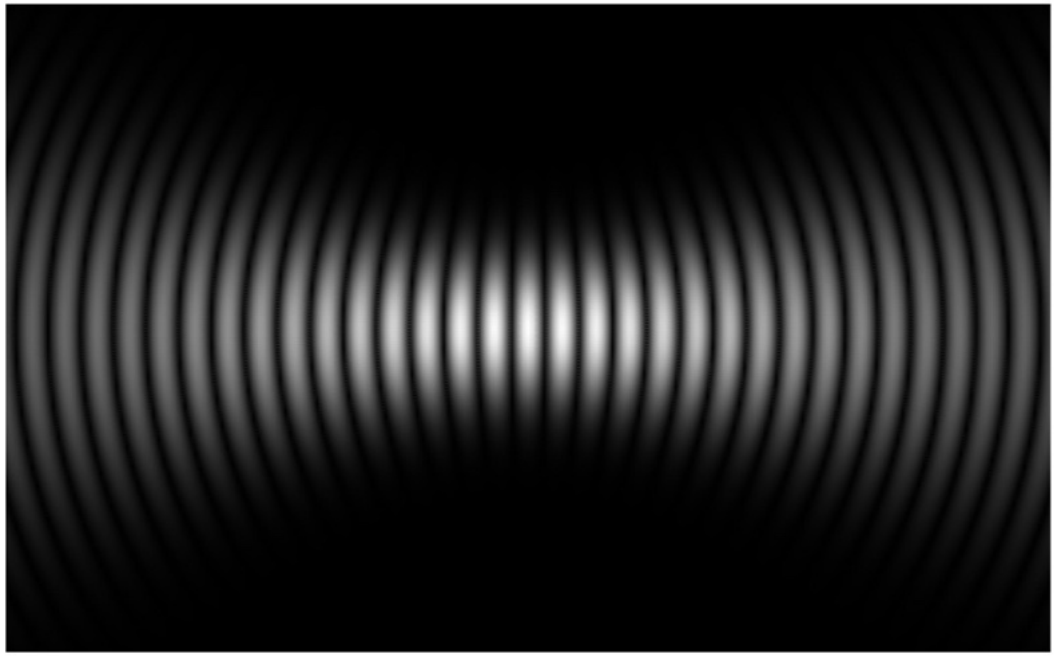
Quantum fields: mode expansion

$$\hat{A} = \sum_k \hat{a}_k A_k(x,t) + \hat{a}_k^\dagger A_k^*(x,t)$$

Quantum fields: mode expansion

$$\hat{A} = \sum_k \hat{a}_k A_k(x,t) + \hat{a}_k^\dagger A_k^*(x,t)$$

$$A_k(x,t) \ :$$



Quantum fields: mode expansion

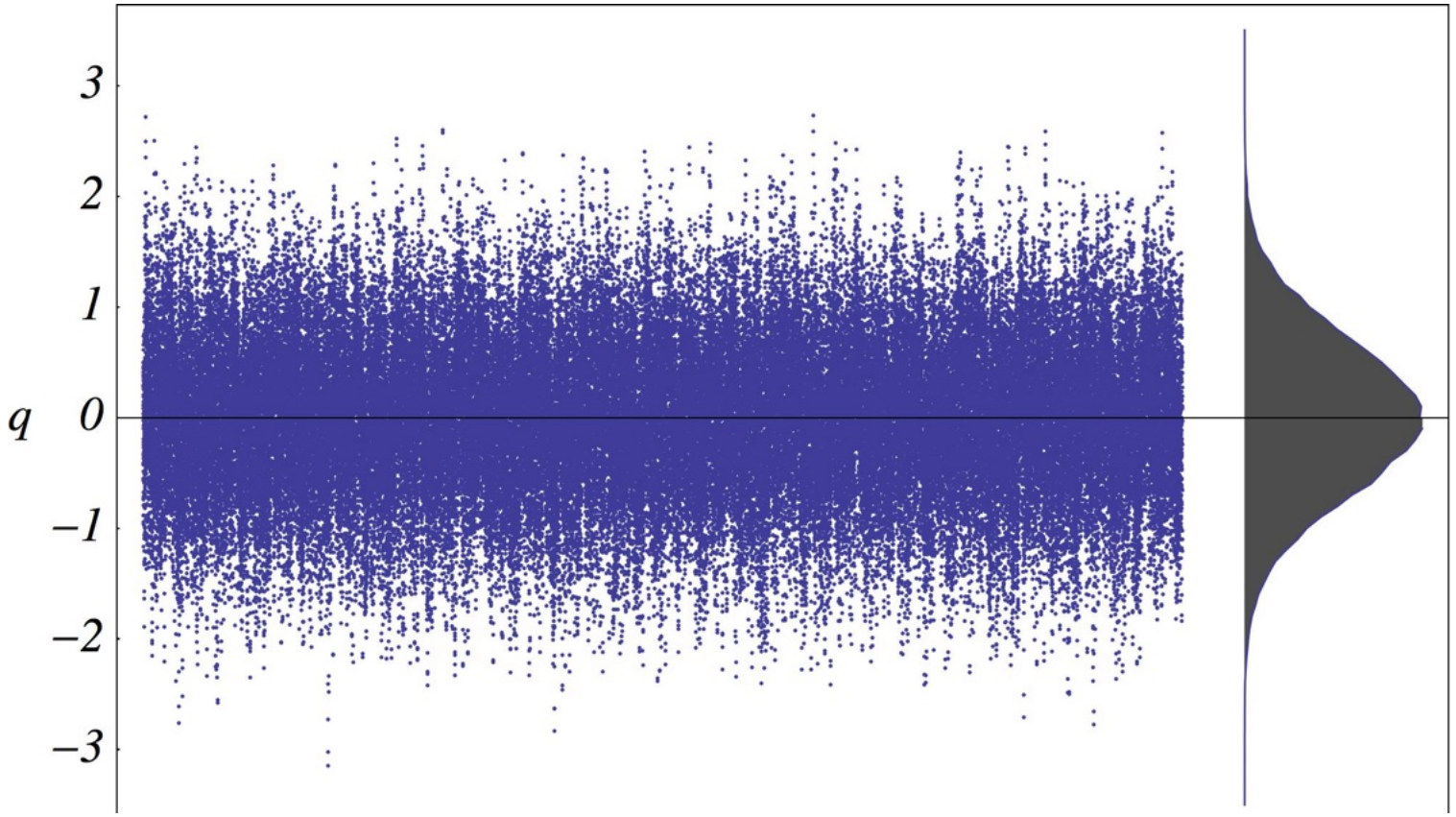
$$\hat{A} = \sum_k \hat{a}_k A_k(x,t) + \hat{a}_k^\dagger A_k^*(x,t)$$

$$[\hat{a}_k, \hat{a}_{k'}^\dagger] = \delta_{kk'}$$

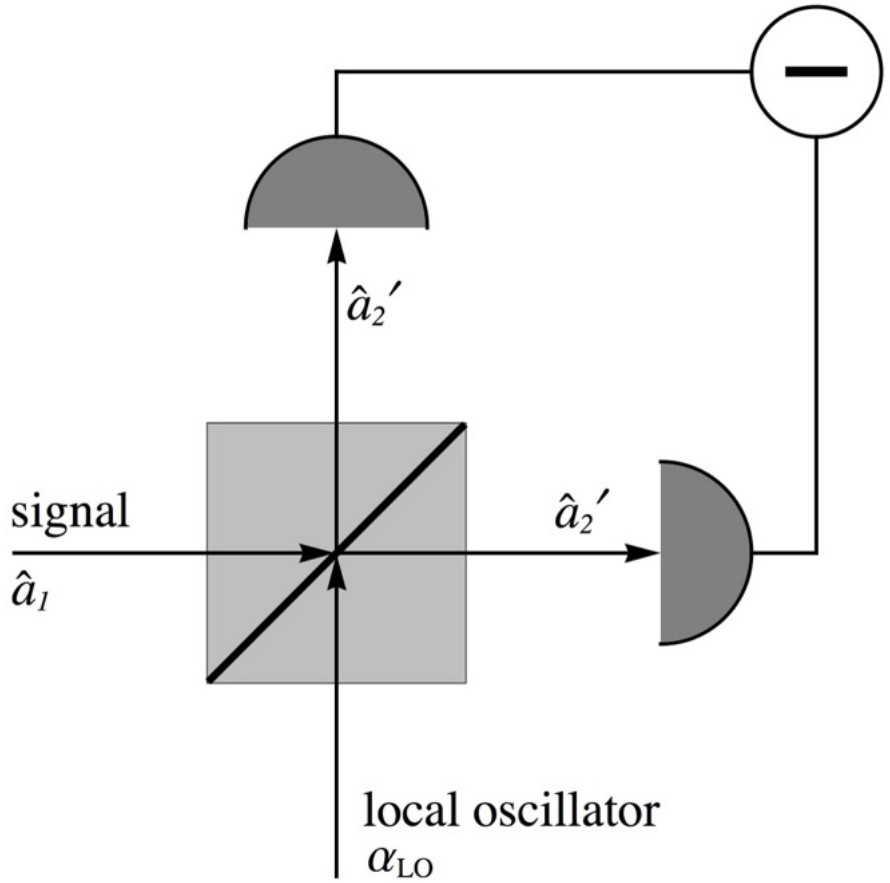
$$\hat{a} = 2^{-1/2}(\hat{q} + i\hat{p})$$

Quantum vacuum: zero amplitude

$$\hat{a}_k |0\rangle = 0$$

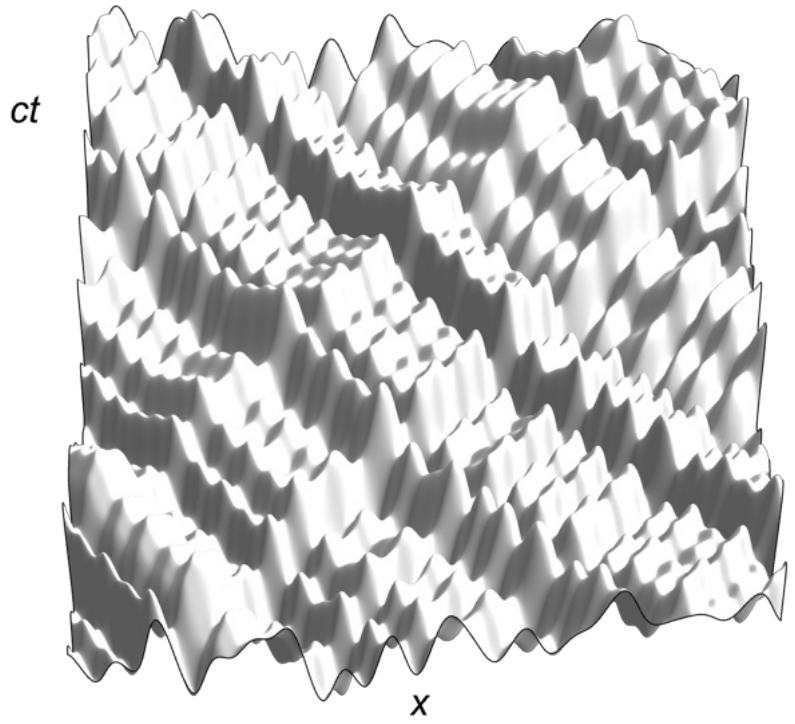


Amplitude measurements: homodyne detection



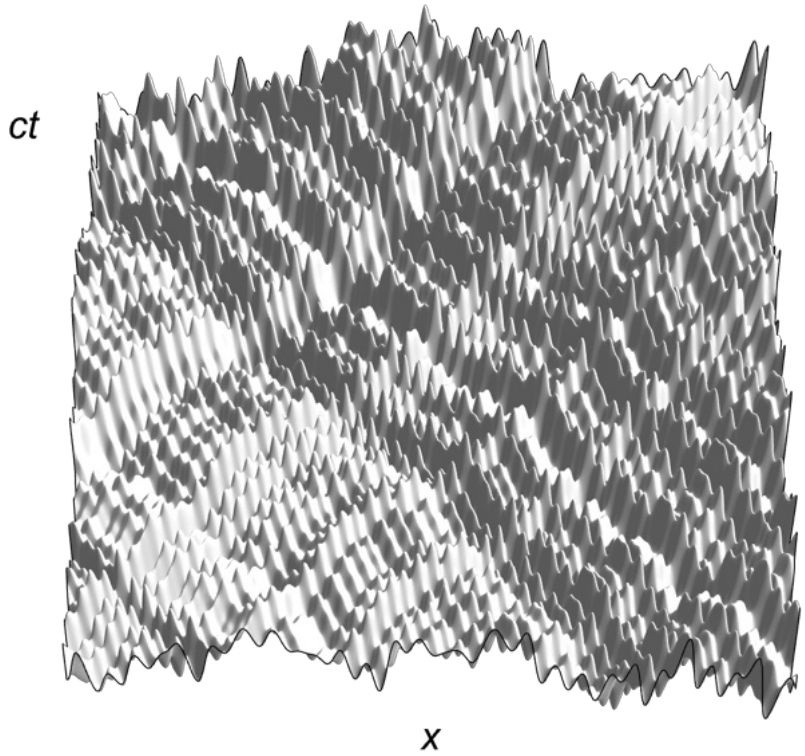
Quantum fields: 32 plane waves

$$\hat{A} = \sum_k \hat{a}_k A_k(x,t) + \hat{a}_k^\dagger A_k^*(x,t)$$



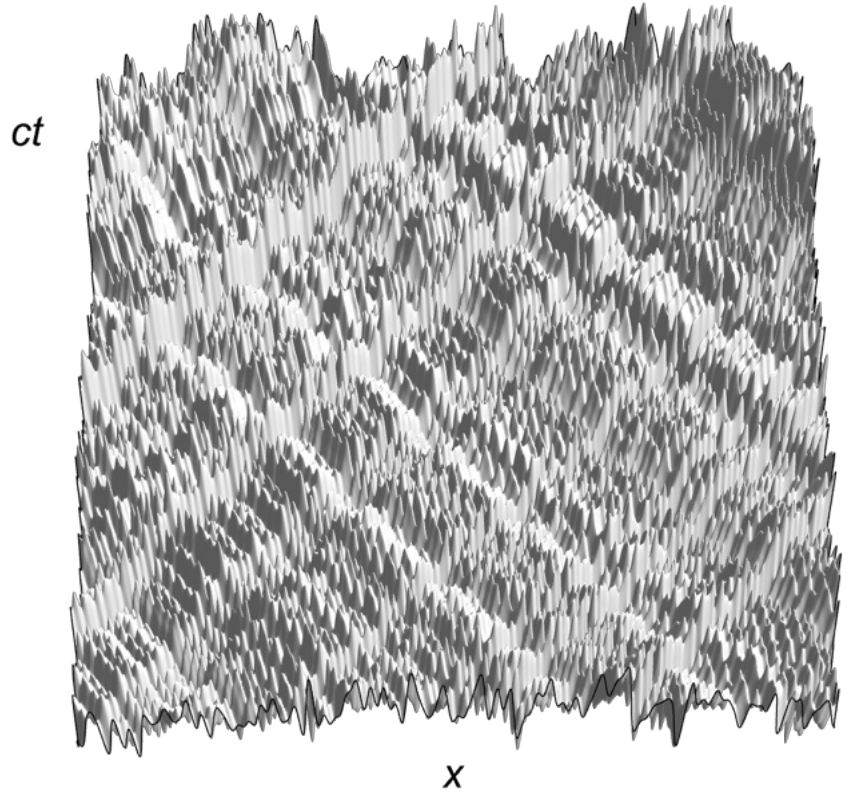
Quantum fields: 64 plane waves

$$\hat{A} = \sum_k \hat{a}_k A_k(x,t) + \hat{a}_k^\dagger A_k^*(x,t)$$



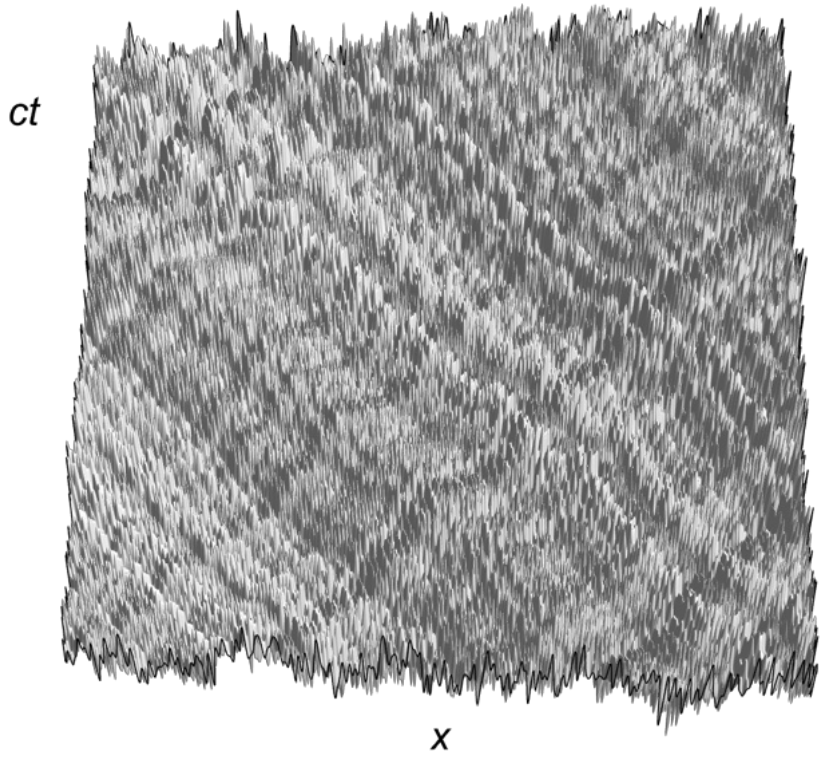
Quantum fields: 128 plane waves

$$\hat{A} = \sum_k \hat{a}_k A_k(x,t) + \hat{a}_k^\dagger A_k^*(x,t)$$



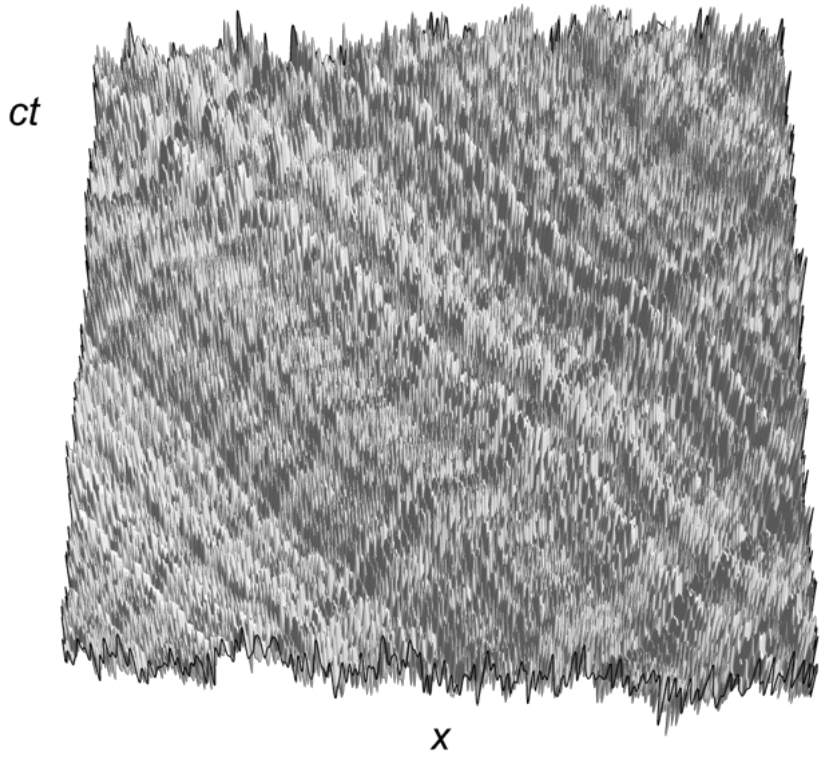
Quantum fields: 256 plane waves

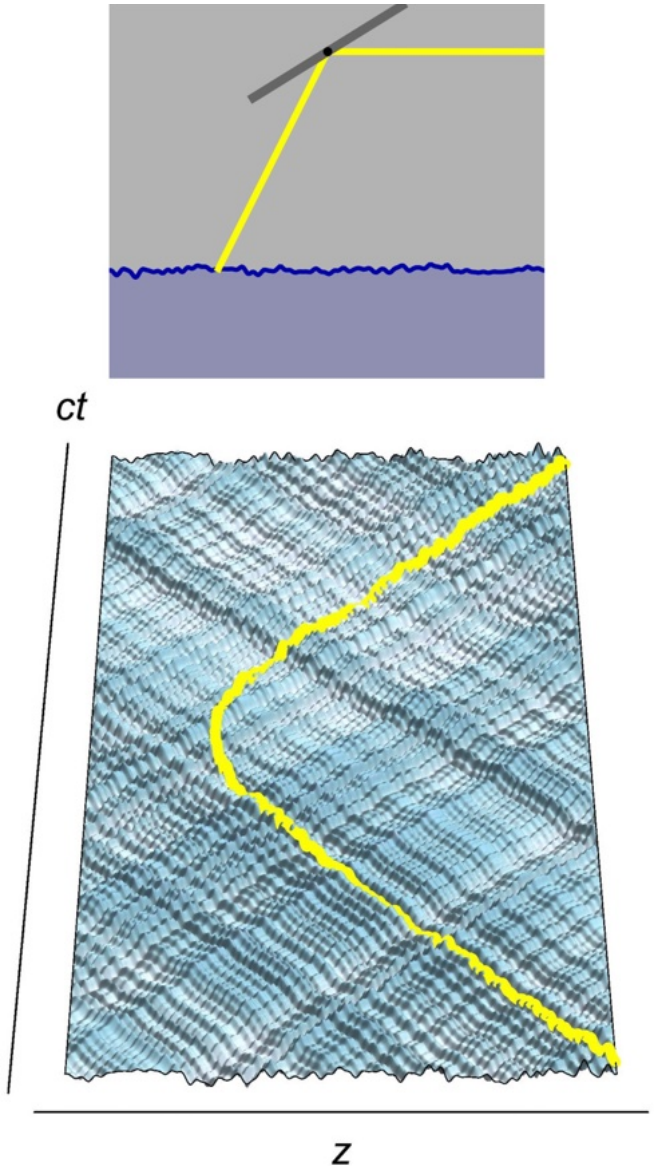
$$\hat{A} = \sum_k \hat{a}_k A_k(x,t) + \hat{a}_k^\dagger A_k^*(x,t)$$



Vacuum noise is organised

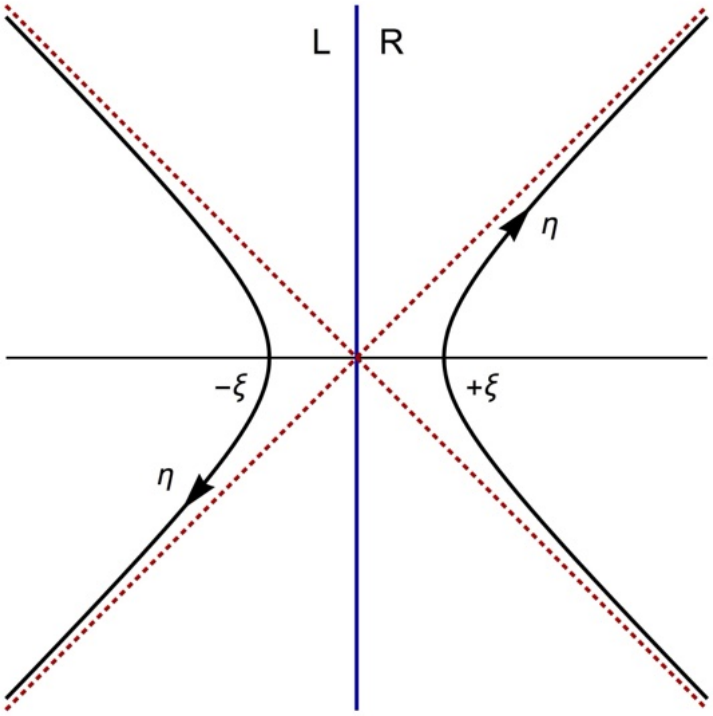
$$\hat{A} = \sum_k \hat{a}_k A_k(x,t) + \hat{a}_k^\dagger A_k^*(x,t)$$





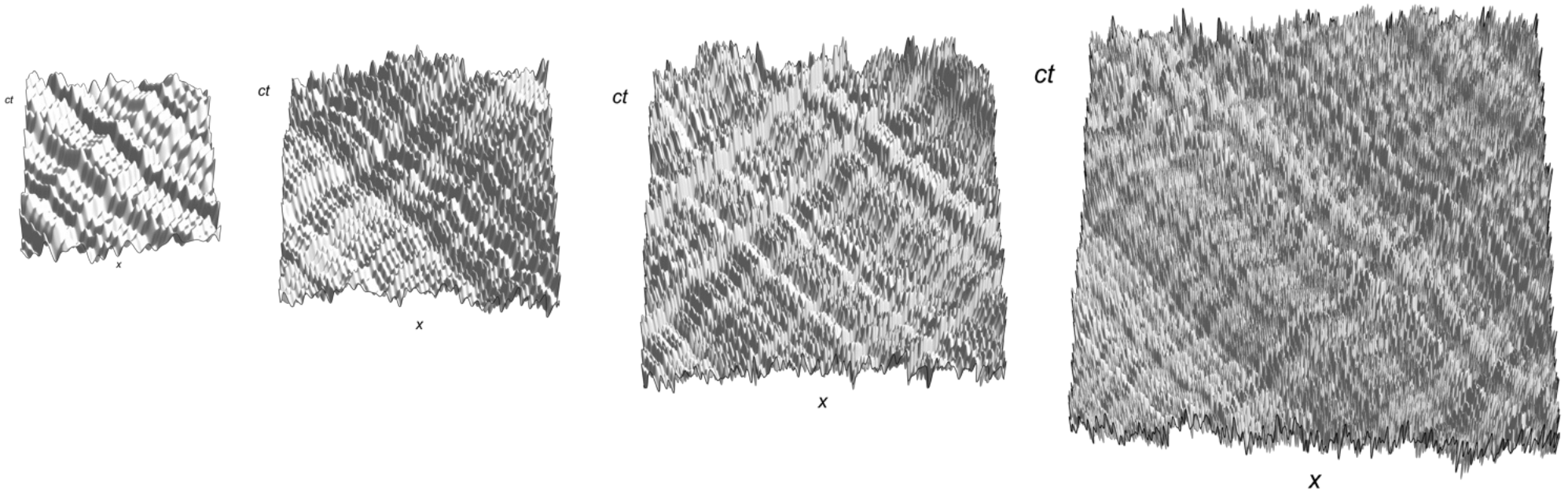
Classical analog of the Unruh effect

Ulf Leonhardt,[1] Itay Griniasty,[1] Sander Wildeman,[2] Emmanuel Fort,[2] and Mathias Fink[2]

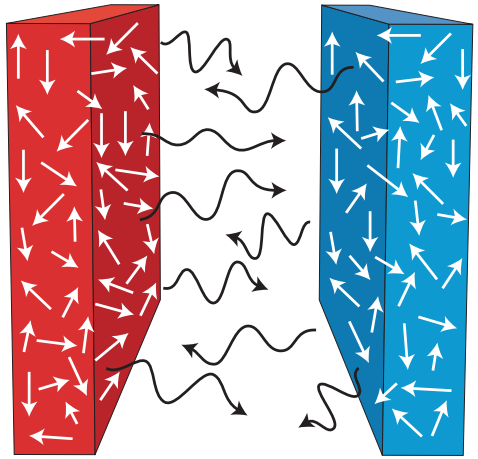


Vacuum noise is infinite

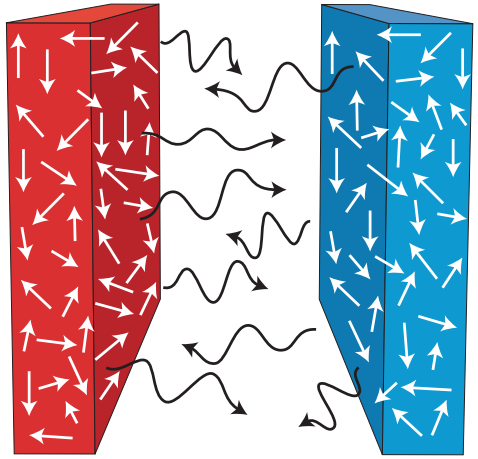
$$\hat{A} = \sum_k \hat{a}_k A_k(x,t) + \hat{a}_k^\dagger A_k^*(x,t)$$



Renormalization: bare vacuum energy is infinite

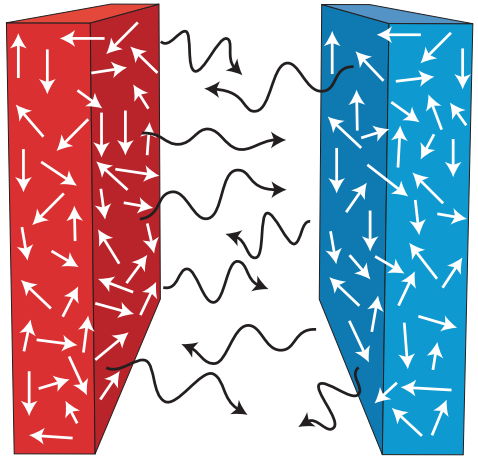


Renormalization: compare vacuum energy at finite distance

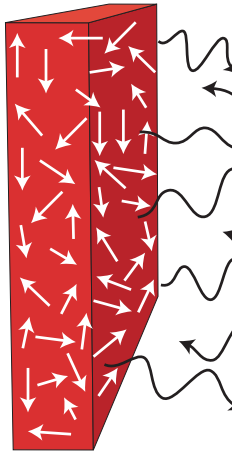


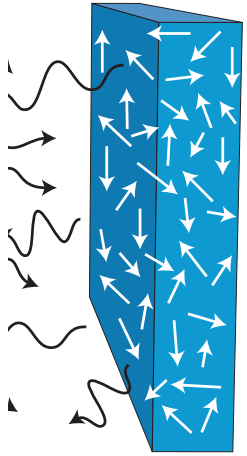
with

Renormalization: compare vacuum energy at finite distance



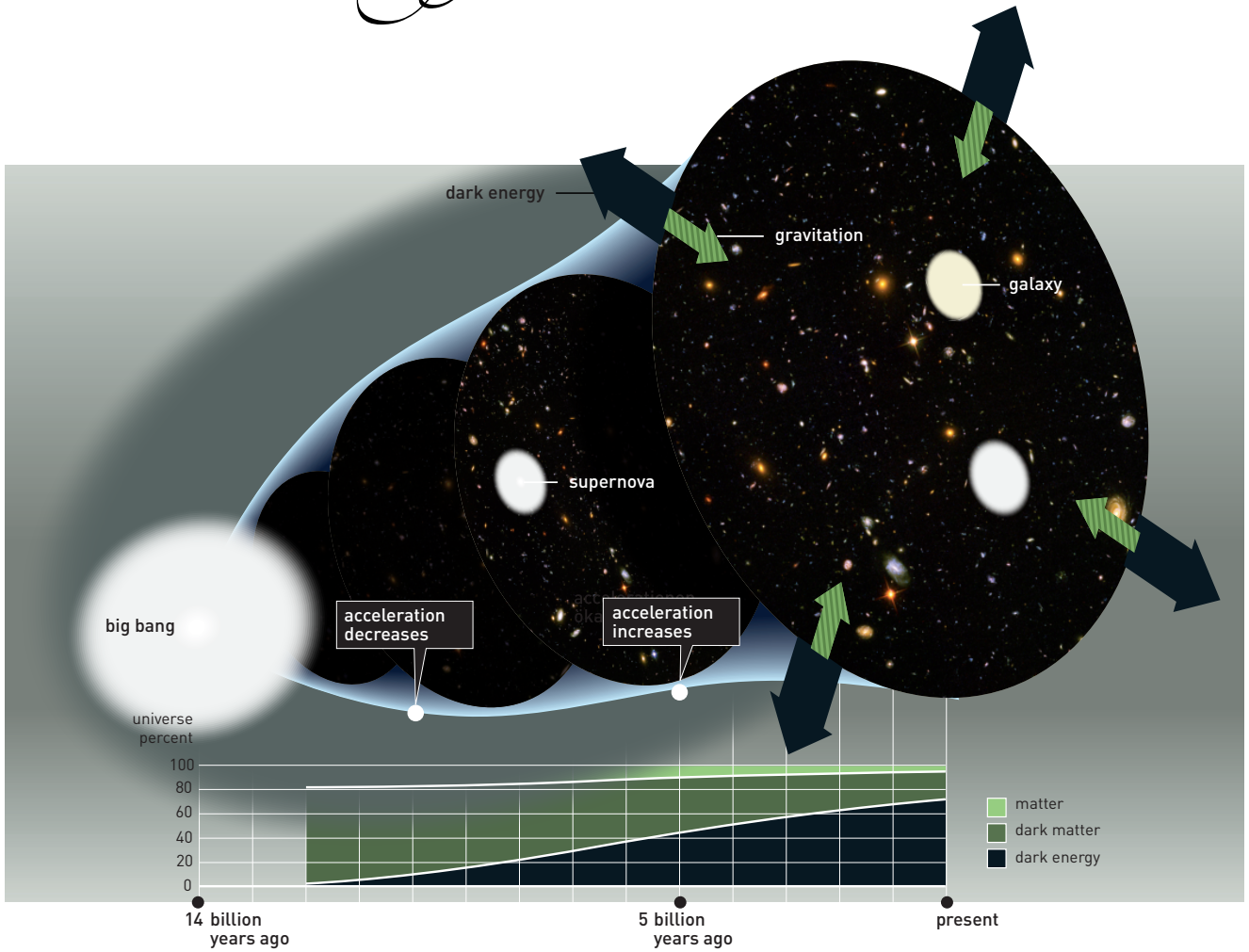
with

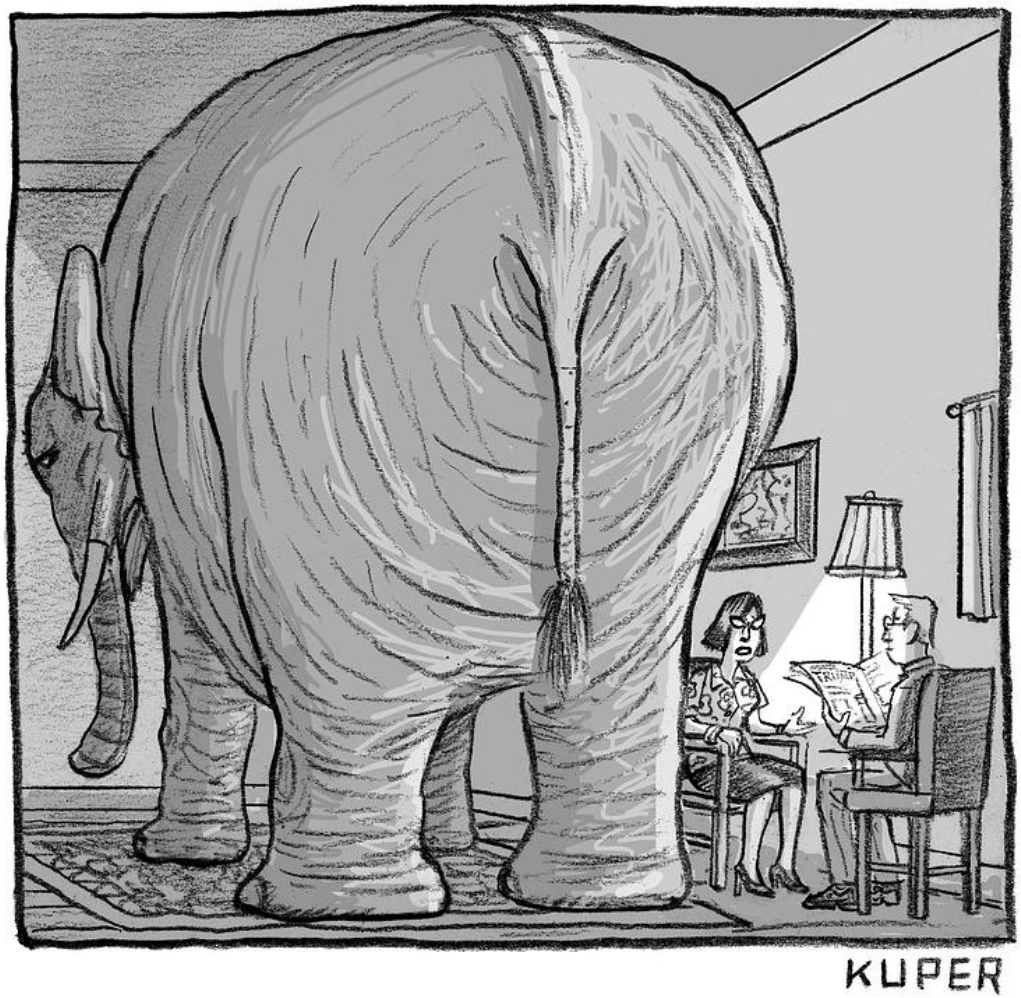




Dark energy – cosmological constant

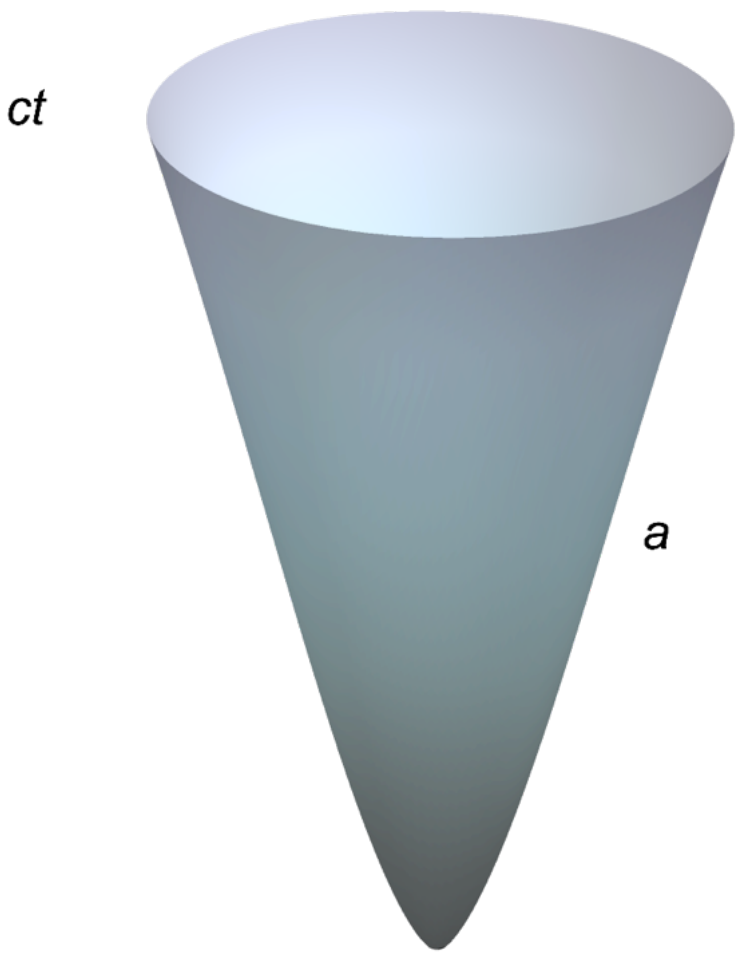
2011





"Actually, it's all we ever talk about."

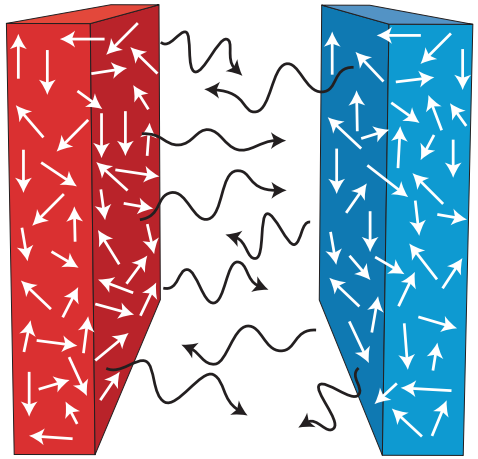
Optical analogue of expanding, spatially flat universe



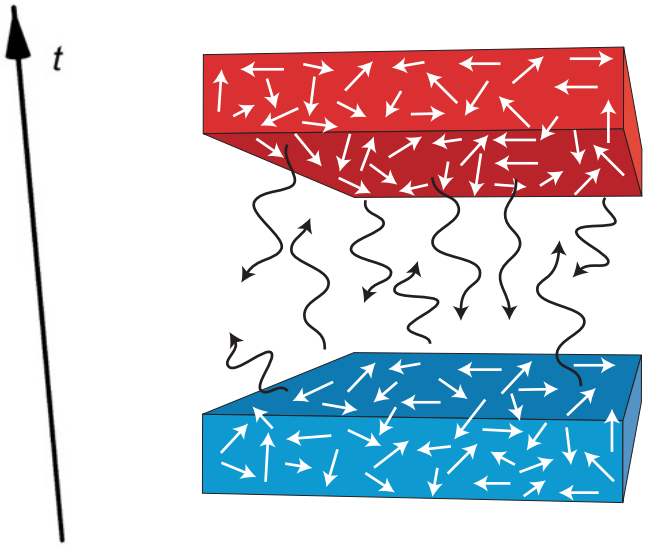
$$dl = a(t)\,dr$$

$$n = a$$

Casimir cosmology: turn from space

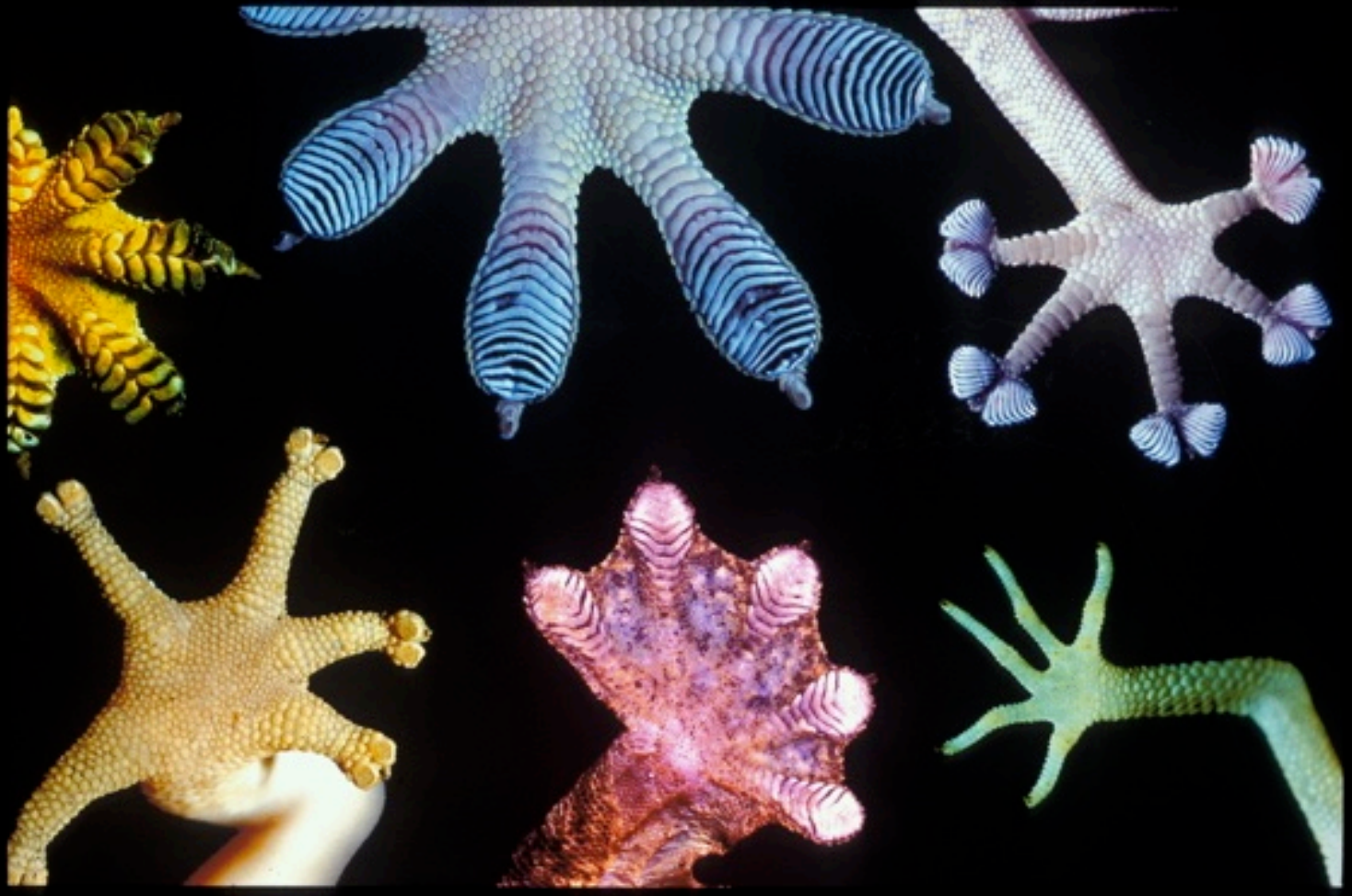


Casimir cosmology: turn from space to time

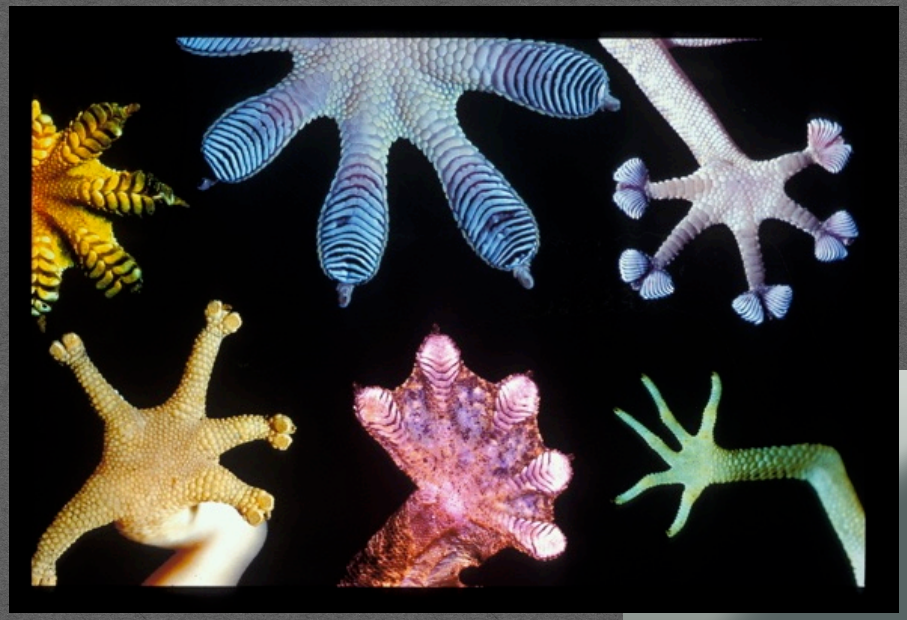


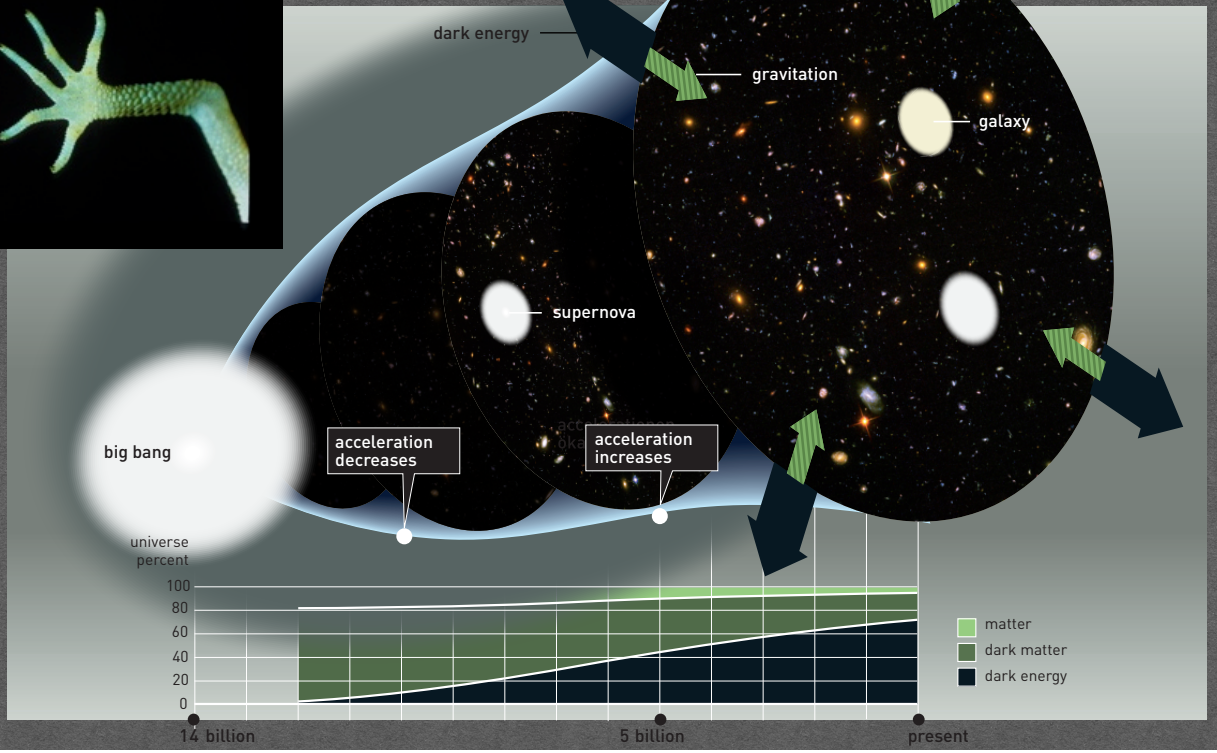
Casimir cosmology: continuous *n(t)*

Casimir force in cosmology?

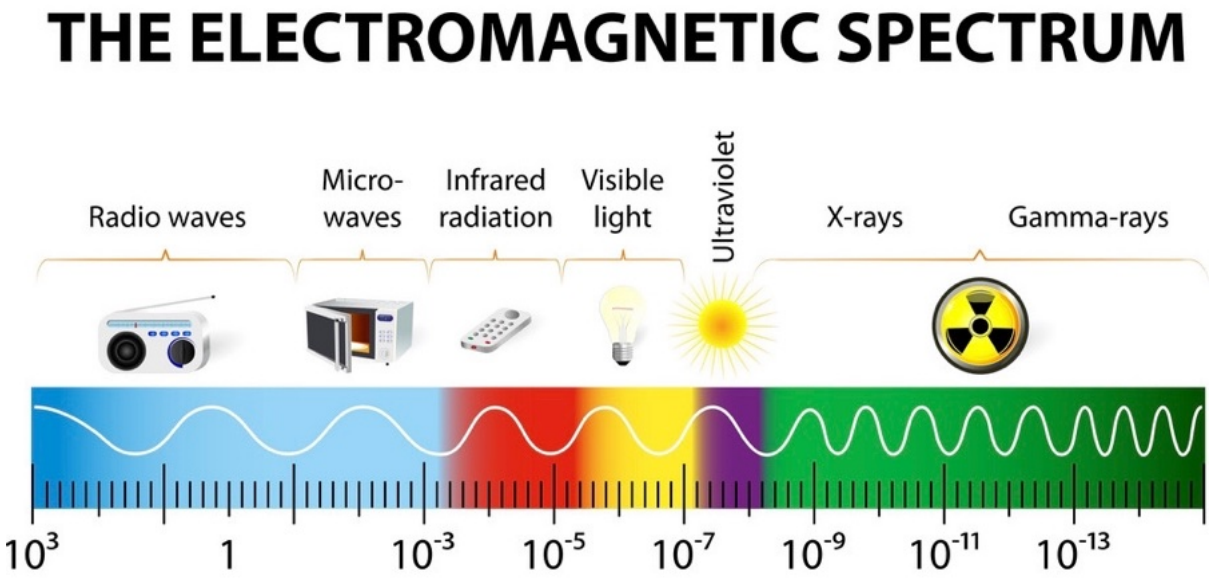


What's the difference?

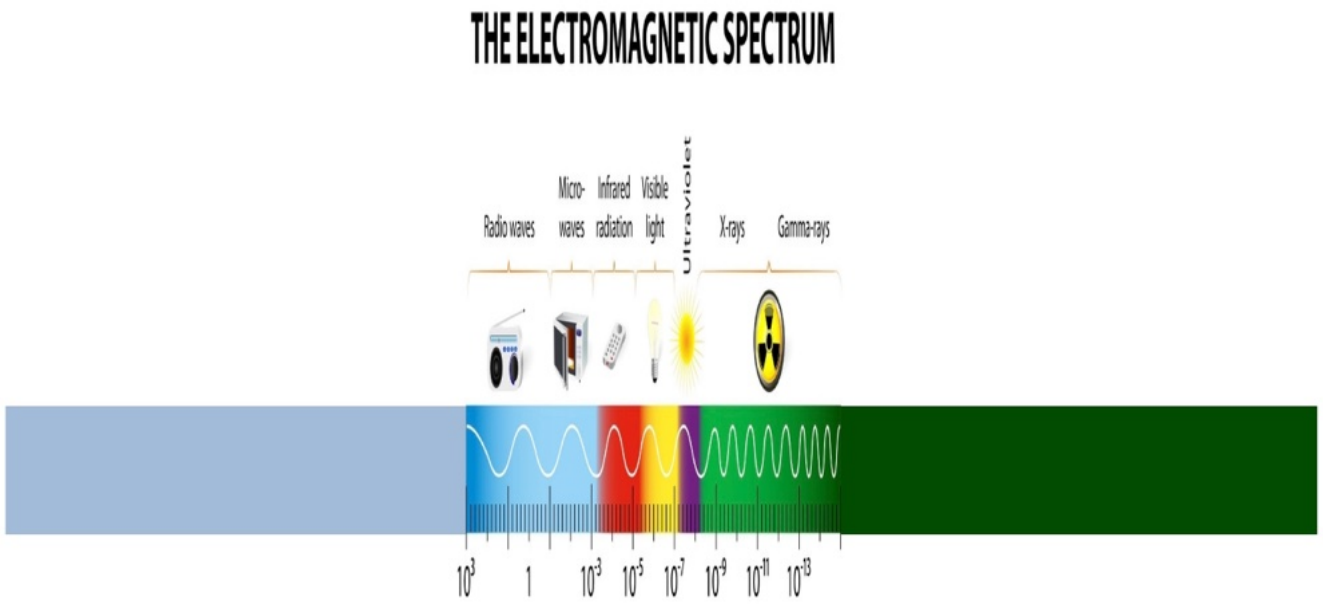




Equivalence principle: space-time is the same for everything



Equivalence principle: space-time is the same for everything



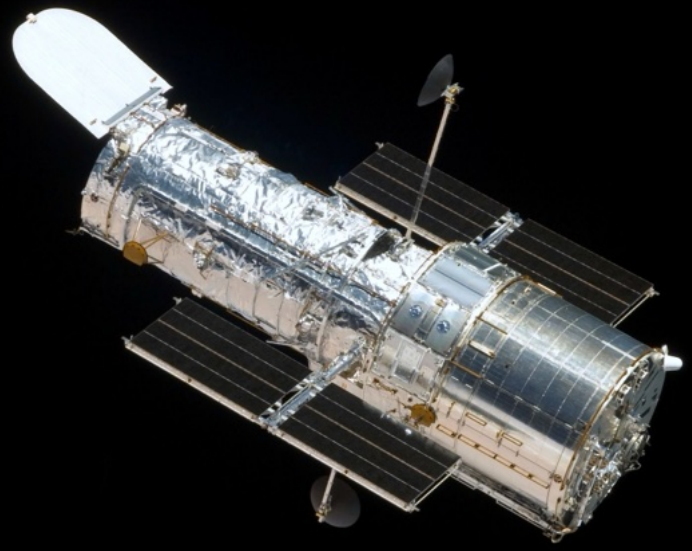
Horizon

Planck

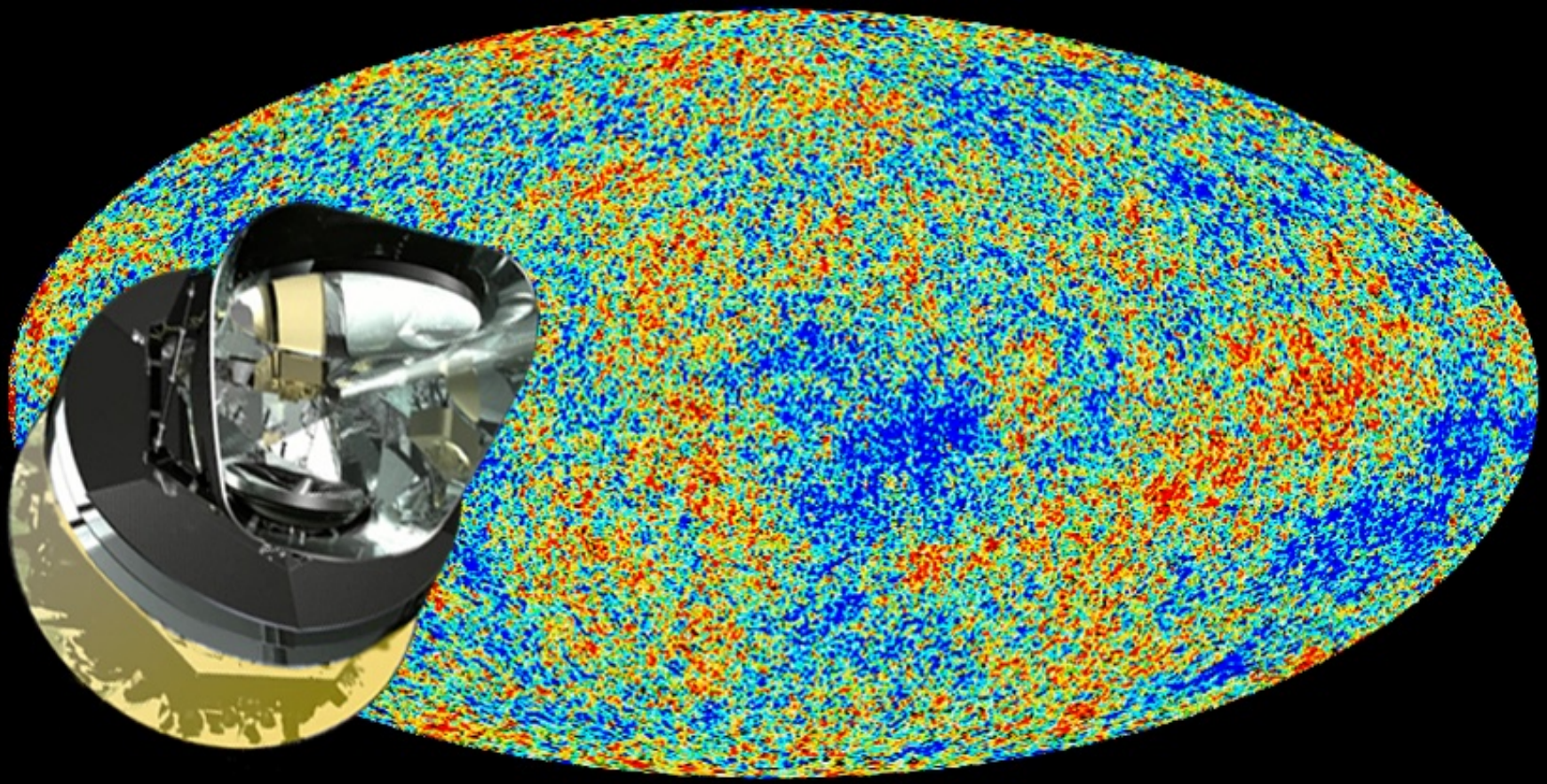
A Comprehensive Measurement of the Local Value of the Hubble Constant with 1 km s^{-1} Mpc^{-1} Uncertainty from the *Hubble Space Telescope* and the SH0ES Team

Adam G. Riess,[1,2] Wenlong Yuan,[2] Lucas M. Macri,[3] Dan Scolnic,[4] Dillon Brout,[5] Stefano Casertano,[1] David O. Jones,[6] Yukei Murakami,[2] Gagandeep S. Anand,[1] Louise Breuval,[2] Thomas G. Brink,[7] Alexei V. Filippenko,[7,8] Samantha Hoffmann,[1] Saurabh W. Jha,[9] W. D'arcy Kenworthy,[2] John Mackenty,[1] Benjamin E. Stahl,[7] and Weikang Zheng[7]

Astrophys. J. Lett. **934**, L7 (2022)



Indirect determination of Hubble constant from Cosmic Microwave Background



PHYSICAL REVIEW B **110**, 224202 (2024)

Editors' Suggestion

Quantum noise in time-dependent media and cosmic expansion

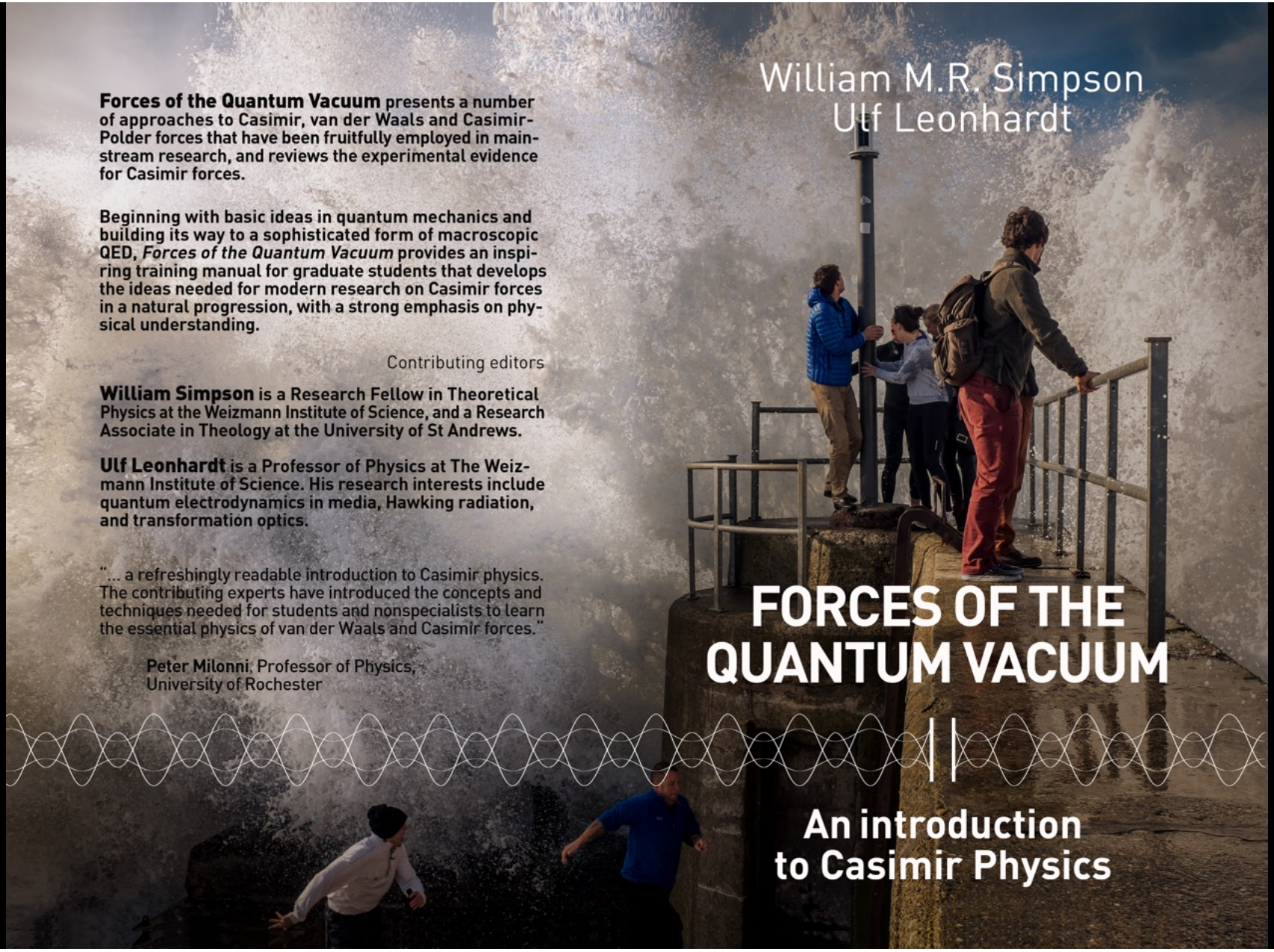
Ziv Landau [1,2,*] and Ulf Leonhardt [1,†]

[1] *Department of Physics of Complex Systems, Weizmann Institute of Science, Rehovot 761001, Israel*

[2] *St John's College, University of Cambridge, St John's St., Cambridge CB2 1TP, United Kingdom*

Quantum buoyancy:

Observed Hubble constant is consistent with Lifshitz theory



Forces of the Quantum Vacuum presents a number of approaches to Casimir, van der Waals and Casimir-Polder forces that have been fruitfully employed in mainstream research, and reviews the experimental evidence for Casimir forces.

Beginning with basic ideas in quantum mechanics and building its way to a sophisticated form of macroscopic QED, *Forces of the Quantum Vacuum* provides an inspiring training manual for graduate students that develops the ideas needed for modern research on Casimir forces in a natural progression, with a strong emphasis on physical understanding.

Contributing editors

William Simpson is a Research Fellow in Theoretical Physics at the Weizmann Institute of Science, and a Research Associate in Theology at the University of St Andrews.

Ulf Leonhardt is a Professor of Physics at The Weizmann Institute of Science. His research interests include quantum electrodynamics in media, Hawking radiation, and transformation optics.

"... a refreshingly readable introduction to Casimir physics. The contributing experts have introduced the concepts and techniques needed for students and nonspecialists to learn the essential physics of van der Waals and Casimir forces."

Peter Milonni, Professor of Physics,
University of Rochester