Session: Casimir friction

Snowbird PQE, January 2014

Matthias Krüger (MPI Stuttgart, Germany) cancelled

Carsten Henkel (U Potsdam, Germany)

12h00 *Introduction to Casimir friction*

Stefan Scheel (U Rostock, Germany)

12h20 *Casimir-Polder forces on moving atoms, non-reciprocal media*

Javier G. de Abajo (ICFO Barcelona, Spain)

12h40 *Friction in rotating particles*

Per Delsing (Chalmers, Sweden)

13h00 *Dynamic Casimir radiation and relativistic motion*

(re)organized by: Carsten Henkel

Institute of Physics and Astronomy, Universität Potsdam, Germany
www.quantum.physik.uni-potsdam.de

Two-photon interference with a virtual polarizer ...

C. Henkel, D. Puhlmann, A. H[illegible]er, R. Menzel

Snowbi[illegible]uary 2014

→ poster session

R. Menzel & al, *Proc Natl Acad Sci* **109** (2012) 9314
M. Ostermeyer & al, *J mod Opt* **56** (2009) 1829–37

Institute of Physics and Astronomy, Universität Potsdam, Germany
www.quantum.physik.uni-potsdam.de

... a gentle introduction to Casimir friction

Carsten Henkel

Snowbird PQE, January 2014

thanks to:

G. Pieplow, V. E. Mkrtchian (Ashtarak, Armenia)

G. Pieplow & C.H., *New J Phys* **15** (2013) 023027

V. E. Mkrtchian & C.H., *Ann Phys* (*Berlin*) (2013)

Institute of Physics and Astronomy, Universität Potsdam, Germany
www.quantum.physik.uni-potsdam.de

Outline

friction

Casimir forces

Einstein 1917 (Kleppner, *Phys Today* Feb 2005)

$T = 0$: Cherenkov radiation (Frank & Tamm 1937; Ginzburg, *Phys Uspekhi* 1996)

unstable vacuum states = driven, non-equilibrium states

frictional literature

Casimir forces

rectification of fluctuations

$$\langle \mathbf{d} \rangle_g = 0$$
$$\langle \mathbf{E} \rangle_T = 0 \qquad \swarrow \text{ Lamb shift}$$
$$-\langle \mathbf{d} \cdot \mathbf{E} \rangle_{g,T} \sim \Delta E_g + U_{\mathrm{CP}}(\mathbf{r}, T) \neq 0$$
$$\nwarrow \text{ van der Waals–Casimir–Polder}$$

... vacuum fluctuations near a surface → Thu session P Kruger

... thermal fluctuations (density fluctuations in liquid*), ocean waves**

books Bordag & al, *Advances in the Casimir effect* (Oxford 2009)

Dalvit & al (eds.), *Casimir physics* (Springer 2011)

Buhmann, *Dispersion forces I+II* (Springer $\geq$ 2012)

* Fisher & de Gennes (*C R Acad Sci* 1978)

** Caussé, *Album du Marin* (Nantes 1836), Buks & Rourkes (*Nature* 2002, urban legend) → talk Scheel

Einstein: On the quantum theory of radiation (1917)

> Wenn die eingeführten Hypothesen über die Wechselwirkung von Strahlung und Materie das Richtige treffen, so müssen sie aber noch mehr liefern als die richtige statistische Verteilung der *inneren* Energie der Moleküle. Bei Absorption und Emission von Strahlung findet nämlich auch eine *Impuls*–Übertragung auf die Moleküle statt; diese führt dazu, daß sich durch die bloße Wechselwirkung von Strahlung und Molekülen eine bestimmte Geschwindigkeitsverteilung der letzteren einstellt. Diese muß offenbar dieselbe sein wie diejenige Geschwindigkeitsverteilung, welche die Moleküle bei alleiniger Wirkung gegenseitiger Zusammenstöße annahmen, d. h., sie muß mit der MAXWELLschen Verteilung übereinstimmen.

Phys Zeitschr 1917
Kleppner
(*Phys Today* Feb 2005)

emission & absorption: exchange of energy & momentum

equilibrium distributions

photon energies = Planck $\bar{E}(\mathbf{k}) = \frac{\hbar\omega_k}{2} + \frac{\hbar\omega_k}{\exp(-\hbar\omega_k/k_BT) - 1}$

atomic populations = Boltzmann $p_a = \frac{\exp(-E_a/k_BT)}{Z}$

(detailed balance)

atomic velocities = Maxwell-Boltzmann $p(\mathbf{v}) = \frac{\exp(-mv^2/2k_BT)}{Z}$

(friction vs diffusive recoil)

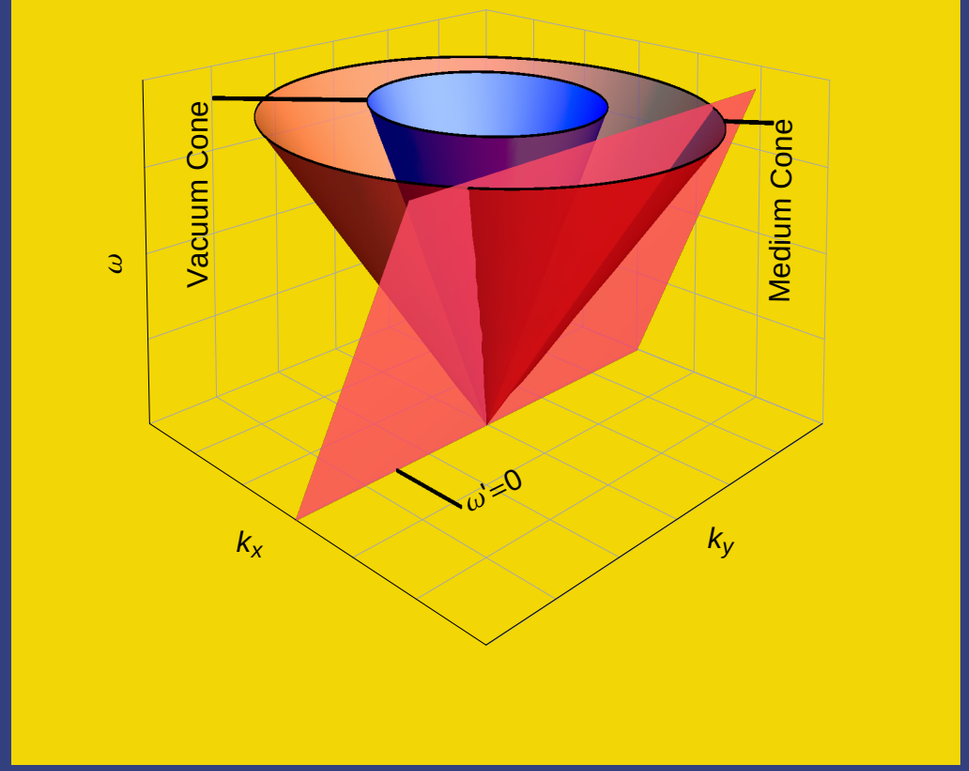
Mkrtchian & al (*Phys Rev Lett* 2003)

Quantum friction

... moving through empty space ...

Quantum friction

... moving through a medium: Cherenkov emission



→ Thu plenary talk D Faccio

anomalous Doppler effect $\omega' = \gamma(\omega - \mathbf{k}\cdot\mathbf{v}) < 0$

free lunch = photon-polariton pair $\omega'_1 + \omega'_2 = 0$

Frank & Tamm (*Dokl Akad Nauk* 1937)

kinetic energy . . . pays the bill = friction

reviews Ginzburg (*Phys Uspekhi* 1996)

Davies (*J Opt B* 2005)

Maghrebi, Golestanian & Kardar (*Phys Rev A* 2013)

Unstable vacuum states

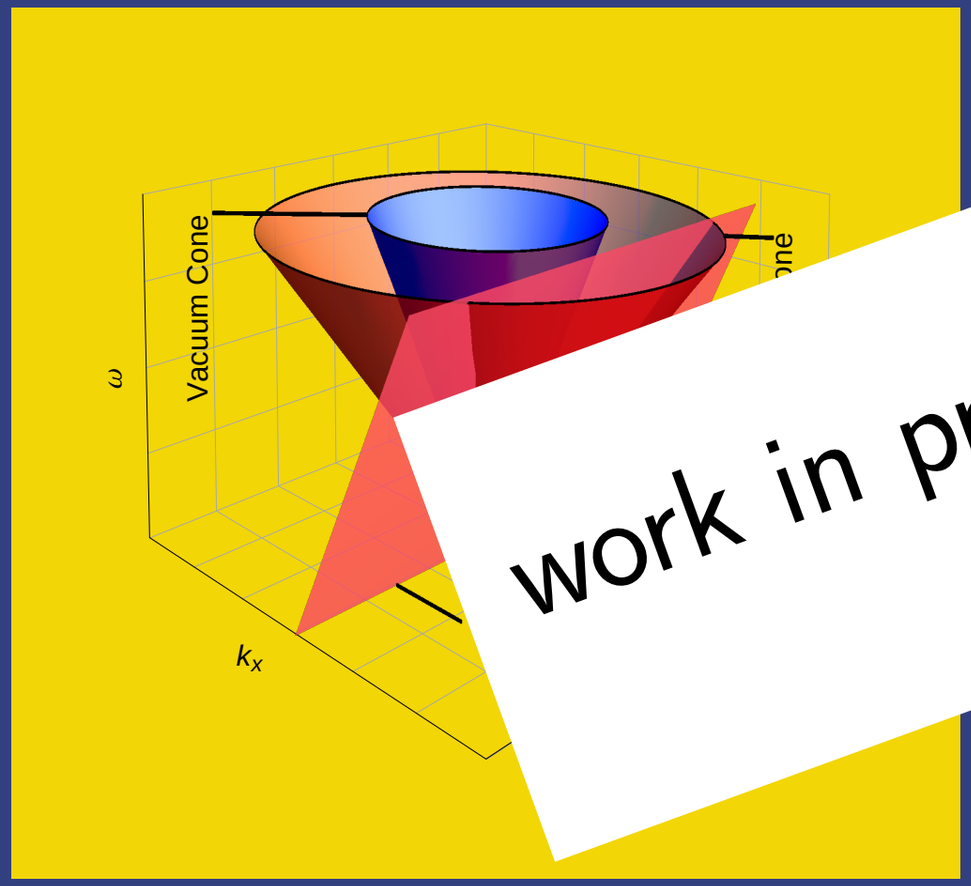
- forced motion of particle (Cherenkov, Unruh, Fulling–Davies) → talk Delsing
- shearing the vacuum between two surfaces (Polevoi, Pendry)
- electric potential $e\Delta\phi > 2m_e c^2$ (Klein, Schwinger)
- black hole horizon (Hawking)
- expanding Universe (Linde, Smolin, Hu)

driven, non-equilibrium state
— quantum optics
— statistical mechanics & quantum thermodynamics

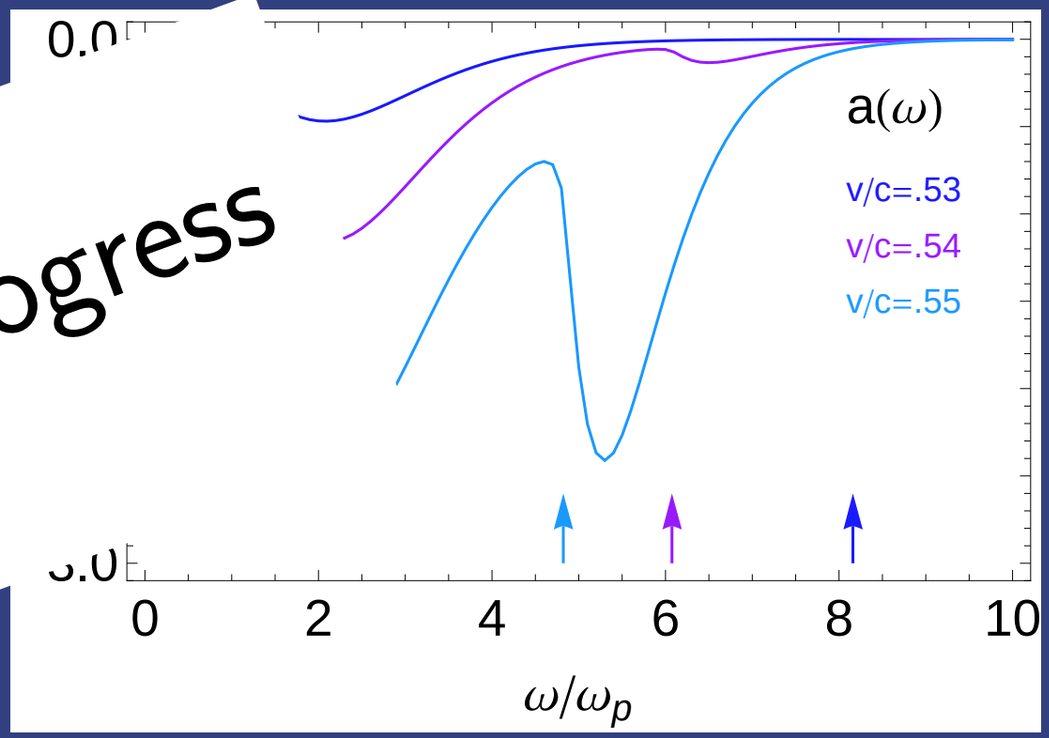
→ talk G. de Abajo

controversies Philbin & Leonhardt (*New J Phys* 2009)
vs Pendry (*J Phys Cond Matt* 1997)
Barton (*Ann Phys* (*NY*) 1996; *New J Phys* 2010)
Mkrtchian & CH (*Ann Phys* (*Berlin*) 2013)

Cherenkov friction above a dielectric



spectrum of acceleration on metallic nano-particle



work in progress

G. Pieplow & C. H., in preparation

Volokitin & Persson (*Rev Mod Phys* 2007)

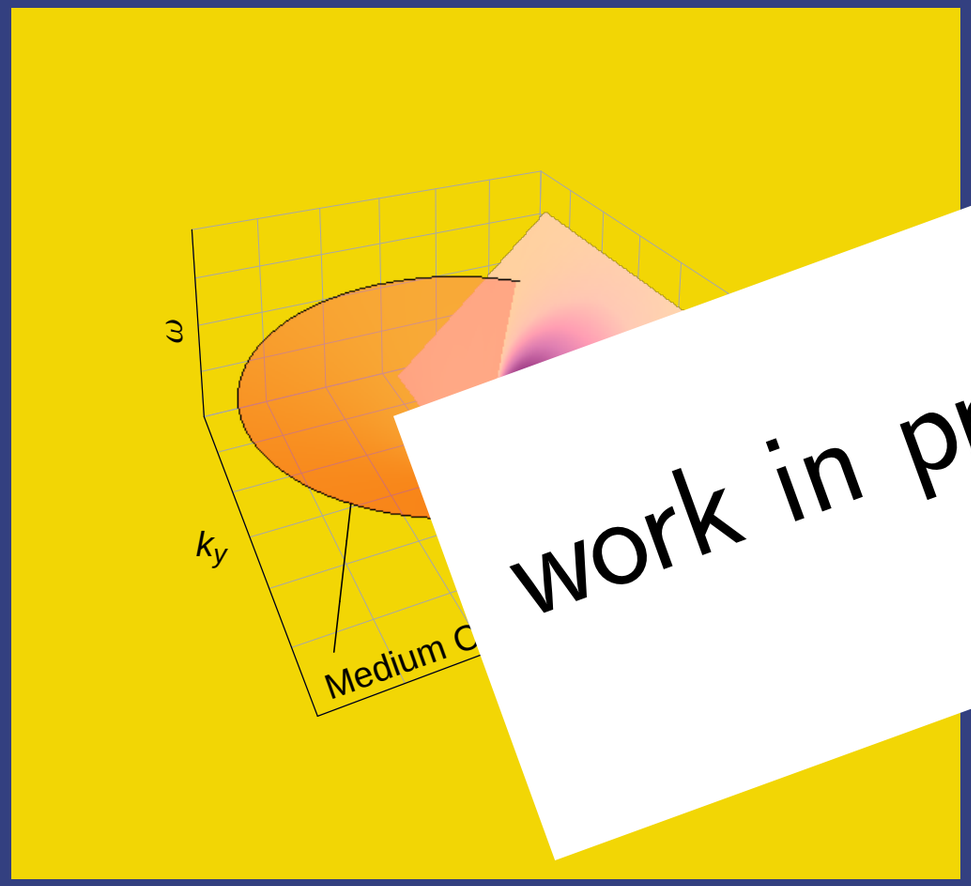
Zurita-Sánchez & al (*Phys Rev A* 2004)

Dedkov & Kyasov (*Phys Solid St* $\geq$ 2001)

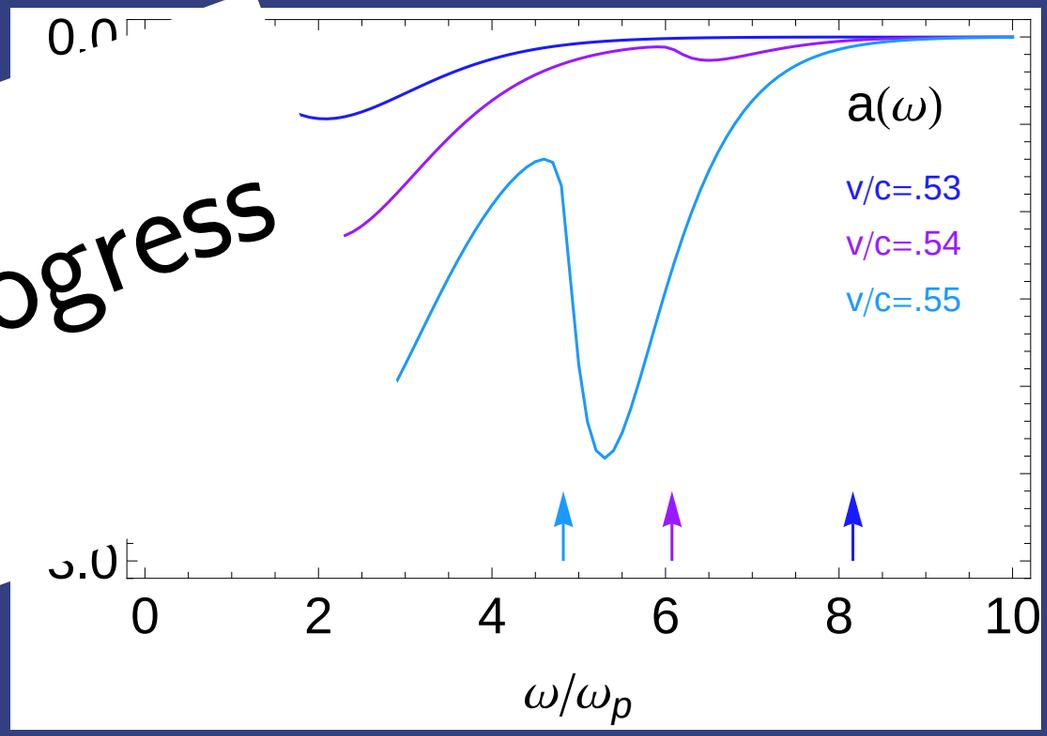
Dorofeyev & al (*Phys Rev B* 2001)

Tomassone & Widom (*Phys Rev B* 1997)

Cherenkov friction above a dielectric



spectrum of acceleration on metallic nano-particle



work in progress

Volokitin & Persson (*Rev Mod Phys* 2007)

G. Pieplow & C. H., in preparation

Zurita-Sánchez & al (*Phys Rev A* 2004)

Dorofeyev & al (*Phys Rev B* 2001)

Dedkov & Kyasov (*Phys Solid St* $\geq$ 2001)

Tomassone & Widom (*Phys Rev B* 1997)

Levitov (*Europhys Lett* 1989)

Schaich & Harris (*J Phys F* 1981)

Teodorovich (*Proc Roy Soc (London) A* 1978)

Session: Casimir friction

Snowbird PQE, January 2014

Carsten Henkel (U Potsdam, Germany)
A gentle introduction to Casimir friction

Stefan Scheel (U Rostock, Germany)
12h20 *Casimir-Polder forces on moving atoms, non-reciprocal media*

Javier G. de Abajo (ICFO Barcelona, Spain)
12h40 *Friction in rotating particles*

Per Delsing (Chalmers, Sweden)
13h00 *Dynamic Casimir radiation and relativistic motion*

(re)organized by: Carsten Henkel

Institute of Physics and Astronomy, Universität Potsdam, Germany
www.quantum.physik.uni-potsdam.de