HELMHOLTZ ZENTRUM
DRESDEN ROSSENDORF

Casimir effect's constraints on (Quantum) Gravity

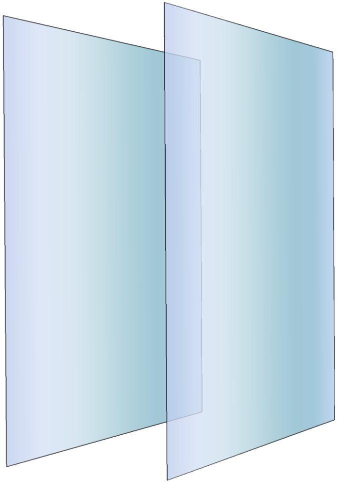
S. Franchino-Viñas

COST CA18108 Third Annual Conference, Napoli, July 2022

Outline

The vacuum

Classical vacuum



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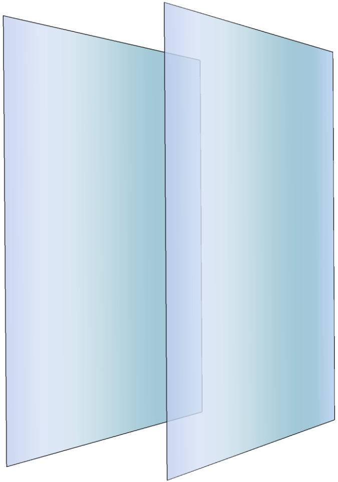

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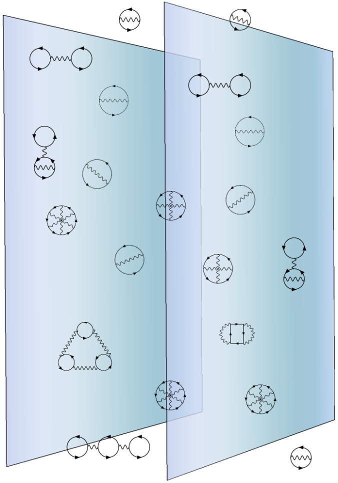
Quantum vacuum



Casimir effect

Mathematics. — *On the attraction between two perfectly conducting plates.* By H. B. G. CASIMIR.

(Communicated at the meeting of May 29, 1948.)

In a recent paper by POLDER and CASIMIR 1) it is shown that the interaction between a perfectly conducting plate and an atom or molecule with

meaning but the *difference* between these sums in the two situations, $\frac{1}{2}(\Sigma\hbar\omega)_I - \frac{1}{2}(\Sigma\hbar\omega)_{II}$, will be shown to have a well defined value and this value will be interpreted as the interaction between the plate and the xy face.

The possible vibrations of a cavity defined by

$$0 \leqslant x \leqslant L, \quad 0 \leqslant y \leqslant L, \quad 0 \leqslant z \leqslant a$$

have wave numbers

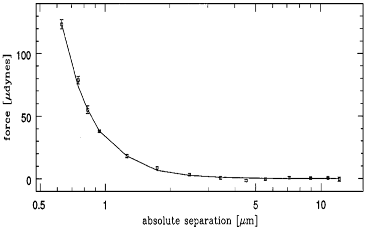
$$k_x = \frac{\pi}{L} n_x, \quad k_y = \frac{\pi}{L} n_y, \quad k_z = \frac{\pi}{a} n_z,$$

$$\frac{F}{A} = \frac{1}{2}\sum_n \omega_n = \frac{\pi^2}{240}\frac{\hbar c}{a^4}$$

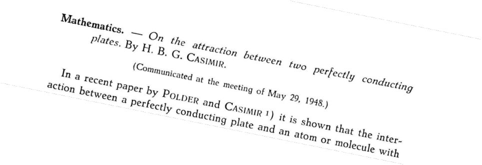
$$\sim \frac{0.016}{a^4}\frac{\text{dyn}\,\mu\text{m}^4}{\text{cm}^2}$$

$\Rightarrow$

Lamoreaux (1997)



Casimir effect



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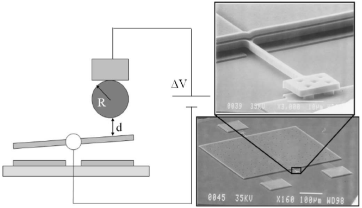
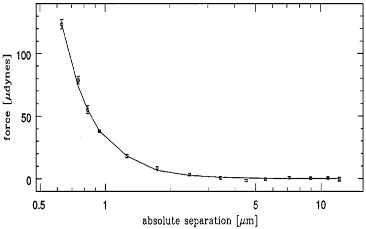


Capasso et al (2007)

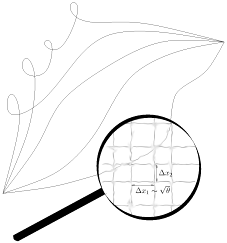
⇒

Lamoreaux (1997)

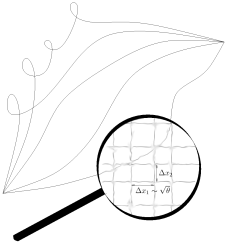


Outline

NC and Casimir effect



NC and Casimir effect

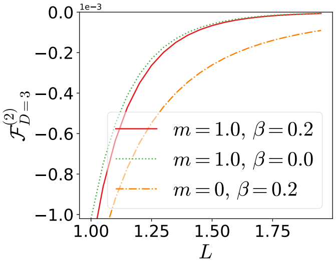


"Soft confinement" through a potential (SF and Mignemi, 2020)

$$H_V = \hat{p}^2 + VH(\hat{x}_\perp - L) + VH(-\hat{x}_\perp - L)$$

$\Downarrow$ Scalar field, time $\times$ anti-Snyder$_{D-1}$ ($[\hat{x}_i, \hat{x}_j] = -i\beta^2 \hat{J}_{ij}$)

$$\mathcal{F} = \frac{\Omega_{D-2}}{2(2\pi)^{D-1}} \int_0^{1/\beta} \frac{dp\, p^{D-2}}{(1-\beta^2 p^2)^{D/2-1/2}} \left(\sum_{n=1}^{\infty} f_n(p) - \int_0^{\infty} dn\, f_n(p) \right),$$



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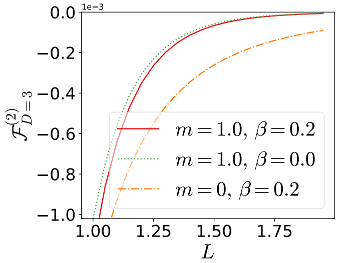
- Momentum space
- Divergences
- Invariant under realizations
- Spectral geometry



Casimir and (Q)G

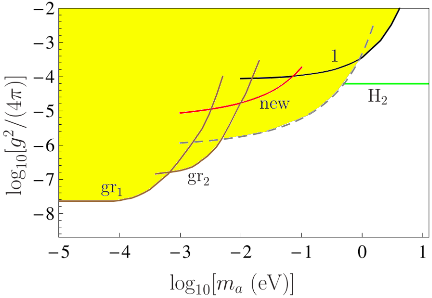
- Noncommutativity, see previous slide, $\mathcal{F} = -\frac{\pi^2}{7680}\frac{1}{L^4} - \frac{\pi^4}{48384}\frac{\beta^2}{L^6} + \mathcal{O}(\beta^4)$.
- First graviton corrections (Donoghue et al), $V(r) = -\frac{Gm_1 m_2}{r}\left(1 - \frac{G(m_1+m_2)}{rc^2} - \frac{127}{30\pi^2}\frac{G\hbar}{c^3 r^2}\right)$
- Dark scalar ϕ (Brax et al., 2021), $\mathcal{O}_1 = \Lambda^{-3}\bar{N}N\phi^2$, $\mathcal{O}_2 = \Lambda^{-2}\bar{N}\gamma^\mu N\phi^* \mathrm{i}\partial_\mu\phi$, $\ldots$): UV $r^{-\alpha}$, IR $e^{-2mr}r^{-\beta/2}$
- Axion a (Klimchitskaya et al., 2021) , $-\mathrm{i}g_a\bar{\psi}\gamma^5\psi a(x)$, $V(r) = -\frac{g_{an}^4}{32\pi^3 m^2}\frac{m_a}{r^2}K_1(2m_a r)$

$\vdots$

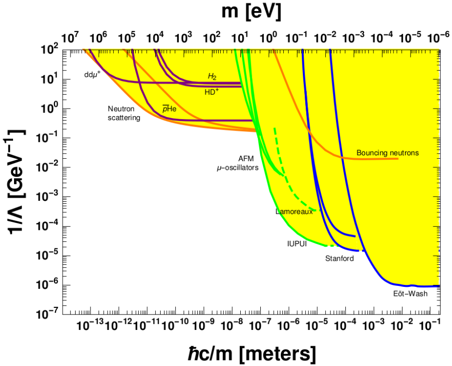
Casimir and (Q)G

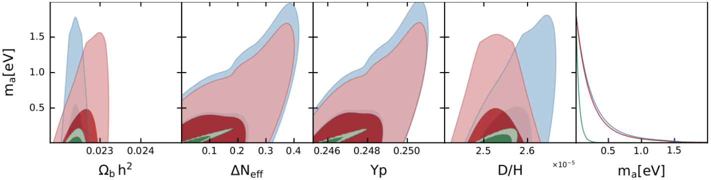
Klimchitskaya et al. (2021),

$$V(r) = -\frac{g_{an}^4}{32\pi^3 m^2}\frac{m_a}{r^2}K_1(2m_a r)$$



Fichet et al. (2021), $\mathcal{O}_1 = \Lambda^{-3}\bar{N}N\phi^2$



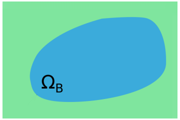


D'Eramo et al. (2022), BBN, Kim-Shifman-Vainshtein-Zakharov axion, $\mathcal{L} \sim \mathcal{J}_\pi \partial_\mu a$

Outline

Conclusions

- Casimir experiments provide valuable constraints for (Q)G; for an axion, specially for $m_a \sim 10^{-1}$eV.
- Constraints on QG: Tan et al (2020), $\alpha_{Donoghue}/\alpha_{exp\ bound} \sim 10^{-57}$.
  Extrapolation to our Casimir in Snyder: $\beta M_P \lesssim 10^{56}$.
- Experiment vs. observations.
- More general situations. Lifshitz configurations as in Milton et al. (2019), Fulling et al. (2021), SF, Mazzitelli and Mantiñan (2022).



- Bonus track: Archimedes experiment. Calloni et al. (2022).