Symposium on Fascinating Nonlinear Physics, 27:th August, 2006, Trieste, Italy

Unruh-radiation - and how to detect it, a work in progress.

By

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Collaborators: Mattias Marklund, Bob Bingham + possibly others .

Outline

- Background – What is Unruh radiation?
- How can it be detected – some previous suggestions.
- Problems with previous suggestions.
- An alternative road to detection.
- Conclusions and outlook

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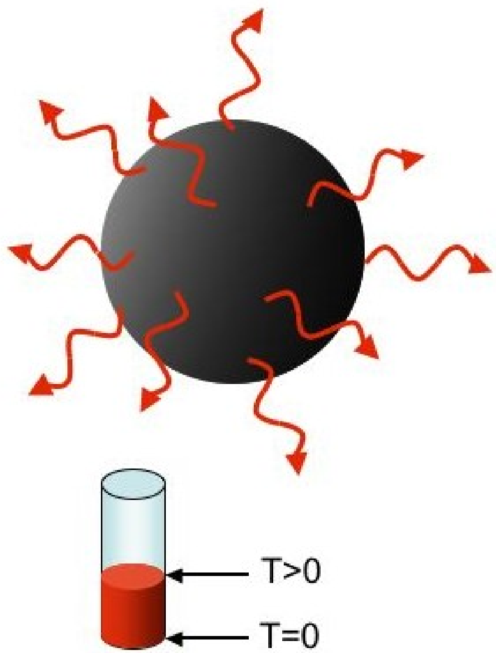
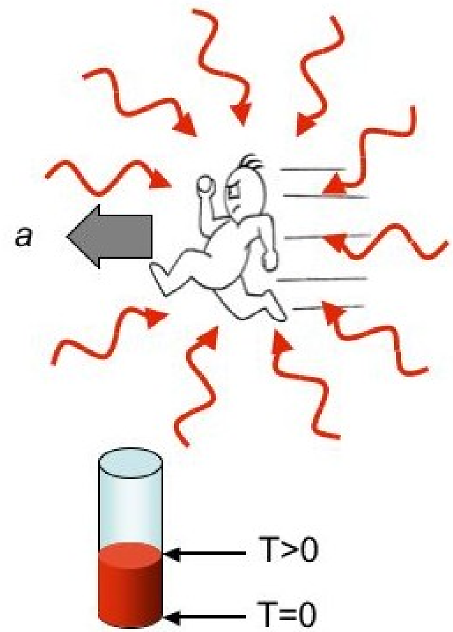
Background

A phenomenon closely related to Unruh radiation is Hawking radiation.





Temperature of Hawking radiation: $KT = \hbar a_g / c$ where a_g is the gravitational acceleration felt by a stationary observer at the event horizon of a black hole

Temperature of thermal heat bath $KT = \hbar a / c$ where a is the acceleration of the accelerated observer.

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Background

Putting in numbers shows that an acceleration of $a \approx 3\times10^{18} g$ is needed to produce a heat bath of temperature 1 K.

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Note that the concept of Unruh radiation is controversial to some extent. Some views met in the literature:

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- The thermal heat bath felt by an accelerated observer is not a real effect.
- The Unruh effect depends on the existence on an event horizon, which in principle exists for an accelerated observer, but only if the acceleration continues an infinite time.

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- The Unruh effect depends on the existence on an event horizon, which in principle exists for an accelerated observer, but only if the acceleration continues an infinite time.
- The heat bath is there, but an accelerated system does not respond to this heat bath by emitting radiation in turn. (This emitted radiation is most often referred to as “the Unruh radiation” - the heat bath itself is referred to as “the Unruh effect”).

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How can Unruh radiation be detected?

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- Testing the effect through the crystal channeling phenomena (Darbinyan et al. JETP Lett, 1990)
- Testing the effect using ultraintense lasers (Chen and Tajima, PRL,1999).

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Problems with detection proposals

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- The proposals of Yablonovich (PRL, 1989)and Darbinyan et al. (JETP Lett. 1990) simply give signals due to the Unruh effect that are several orders of magnitude to small to even be near the detection limit (and this holds true for some other suggestions as well.)

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- Due to the enormous accelerations of electrons in ultraintense laser fields (electrons are considered as the "observers"), $a \approx 10^{25} g$, corresponding to an Unruh temperature of $T \approx 10^4 K$, the proposal of Chen and Tajima (PRL, 1999) could in principle give a detectable signal.

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- The combined EM-field of two Petawatt lasers give a standing wave that produces a constant acceleration of electrons for sufficiently long times τ (i.e $a\tau \gg c$).

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- The combined EM-field of two Petawatt lasers give a standing wave that produces a constant acceleration of electrons for sufficiently long times τ (i.e $a\tau \gg c$).
- The radiation emitted in response to the beat bath should be detected. Note, however, that this radiation is several orders of magnitude smaller than the standard Larmor radiation.

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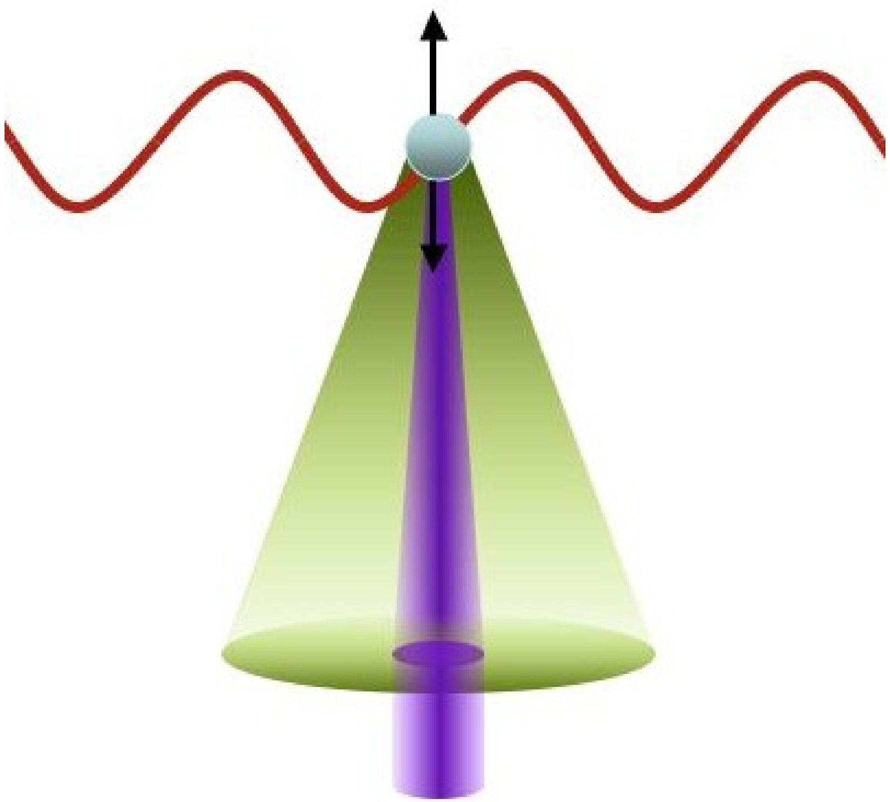
The proposal of Chen and Tajima



Chen and Tajima propose to see the Unruh-response by looking in the direction where the Larmor radiation approaches zero, in a small angle parallel to the acceleration vector.

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- When evaluating the ratio of the Unruh radiation and the Larmor power, unfortunately Chen and Tajima use a wrong expression for the angular dependence of the Larmor radiation. This makes the scaling of the ratio with γ (the relativistic gamma factor) wrong. Unfortunately this means that the ratio is decreased by a factor of the order γ^4, compared to the formula used by Chen and Tajima.

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- Of much interest is how the Unruh radiation and the conventional radiation compares when the number density of electrons, N, is increased. A problem is that the conventional radiation increases as a collective process (i.e. scales as N^2), whereas the Unruh contribution is incoherent (i.e. scales as N). This limits the possible number density of electrons severely. When compensating for the incorrect γ-scaling, the conclusion is that Unruh-signal will be too low to be detectable (of the order 10^{-10} photons/shot or smaller).

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Alternative road to detection

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Alternative road to detection

Note that

- To overcome the difference in scaling with particle number, we need a way to clearly distinguish the standard radiation from the Unruh contribution.

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- To overcome the difference in scaling with particle number, we need a way to clearly distinguish the standard radiation from the Unruh contribution.

- Contrary to what is often assumed, the acceleration does not need to be rectilinear and in the direction of motion for the Unruh effect to apply. In particular, circular motion is possible, as long as $a\tau \gg c$, where τ is the orbit period time.

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- The standard synchrotron response of relativistic electrons moving in circular orbit with a constant frequency is to produce discrete radiation (multiples of the fundamental frequency).

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- Particles exposed to counter-propagating laser beams of the same frequency and amplitude may undergo periodic circular motion.

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Outline for a model detection scheme

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Outline for a model detection scheme

- Chose the polarization of counter-propagating lasers such as to generate circular periodic electron motion.

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Outline for a model detection scheme

- Chose the polarization of counter-propagating lasers such as to generate circular periodic electron motion.

- Put detectors covering wide angels optimized to detect the electron Unruh response (note that this is not precisely a thermal radiation spectrum to be measured, as we must make a Lorentz boost from the electrons rest frame to the laboratory frame to get the spectrum.)

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- Put filters to remove the discrete frequency components due to the periodic motion.
- Make sure that the electron density is high enough to give a measurable Unruh signature.

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Conclusion and outlook

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- To detect this effect is a great challenge.

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- Previous proposals need to be much improved.

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- To detect this effect is a great challenge.
- Previous proposals need to be much improved.
- The ideas outlined here may be a step forward.

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- To detect this effect is a great challenge.
- Previous proposals need to be much improved.
- The ideas outlined here may be a step forward.
- Many difficulties remain before a successful experiment can be made.

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Thank you for your attention!

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