Voyage to Alpha Centauri: degradation, creation and detection of cavity mode entanglement due to motion.

David Edward Bruschi

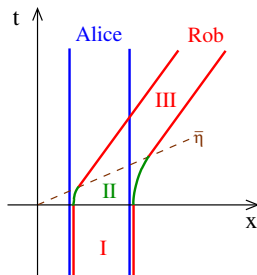School of Mathematical Sciences, University of Nottingham

April 2, 2012

The University of Nottingham

Outline

Britgrav 12, Southampton, UK - Voyage to Alpha Centauri: degradation, creation and detection of cavity mode entanglement due to motion.   3/1
Aims (an introduction)
Aims

What we wanted to do

Figure: Basic Building Block
- Rob is inertial (I),
accelerates (II) and becomes
inertial again (III)

i Analyse entangled fields in (one or more) cavities

Britgrav 12, Southampton, UK - Voyage to Alpha Centauri: degradation, creation and detection of cavity mode entanglement due to motion.   3/1
Aims (an introduction)
Aims

What we wanted to do

Figure: Basic Building Block - Rob is inertial (I), accelerates (II) and becomes inertial again (III)

i Analyse entangled fields in (one or more) cavities

ii Study **effect of motion** on entanglement

Britgrav 12, Southampton, UK - Voyage to Alpha Centauri: degradation, creation and detection of cavity mode entanglement due to motion.   3/1
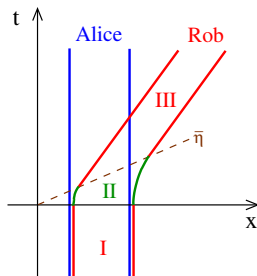Aims (an introduction)
Aims

What we wanted to do

Figure: Basic Building Block - Rob is inertial (I), accelerates (II) and becomes inertial again (III)

i Analyse entangled fields in (one or more) cavities

ii Study **effect of motion** on entanglement

iii Describe **"general"**, "realistic" trajectories

Britgrav 12, Southampton, UK - Voyage to Alpha Centauri: degradation, creation and detection of cavity mode entanglement due to motion.   3/1

Aims (an introduction)

Aims

What we wanted to do

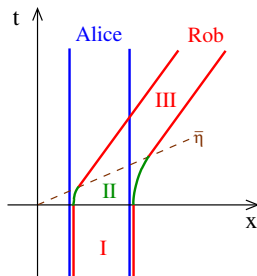
Figure: Basic Building Block - Rob is inertial (I), accelerates (II) and becomes inertial again (III)

i Analyse entangled fields in (one or more) cavities

ii Study **effect of motion** on entanglement

iii Describe **"general"**, "realistic" trajectories

iv Model **feasible experimental settings**

Britgrav 12, Southampton, UK - Voyage to Alpha Centauri: degradation, creation and detection of cavity mode entanglement due to motion.   4/1
Aims (an introduction)
Motivations

Why we wanted to do it

  i Cavities model experimental settings

  ii Cavities are local in spacetime

  iii **NO** global fields

  iv **NO** Unruh effect, only motion

  v **NO** infinite times of acceleration

  vi Can test equivalence principle

  vii Suggest **gravity** affects entanglement

Figure: Rob traveling with our cavity

Britgrav 12, Southampton, UK - Voyage to Alpha Centauri: degradation, creation and detection of cavity mode entanglement due to motion.   5/1
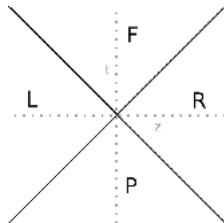Aims (an introduction)
Review

What had previously been done

Figure: Minkowski spacetime
- Rindler wedges

i Entanglement degradation for Rindler observers
(Milburn, Alsing, Fuentes, Mann, etc...)

ii Unruh effect $\Rightarrow$ Global fields

iii Rindler observer $\Rightarrow$ no general trajectory

iv Rindler observer $\Rightarrow$ effect of motion?
(analogy with eternal BH)

v Vast literature on the Casimir effect

What we did: 2 boxes

i Two Dirichlet cavities in 3+1D

ii Bosonic massive OR massless fields

iii Entanglement between Alice's fields and Rob's fields via maximally entangled state

iv Rob's linear acceleration

v Travel scenarios built using basic building block (BBB)
(see next slide)

vi Low acceleration approximation: one-to-one corresepondence In to Out frequencies

vii Compute negativity after trip: function of periods of acceleration and coast

Britgrav 12, Southampton, UK - Voyage to Alpha Centauri: degradation, creation and detection of cavity mode entanglement due to motion.   7/1

Our results

Two cavities

What we did: 2 boxes

Figure: Basic Building Block

Britgrav 12, Southampton, UK - Voyage to Alpha Centauri: degradation, creation and detection of cavity mode entanglement due to motion.   8/1
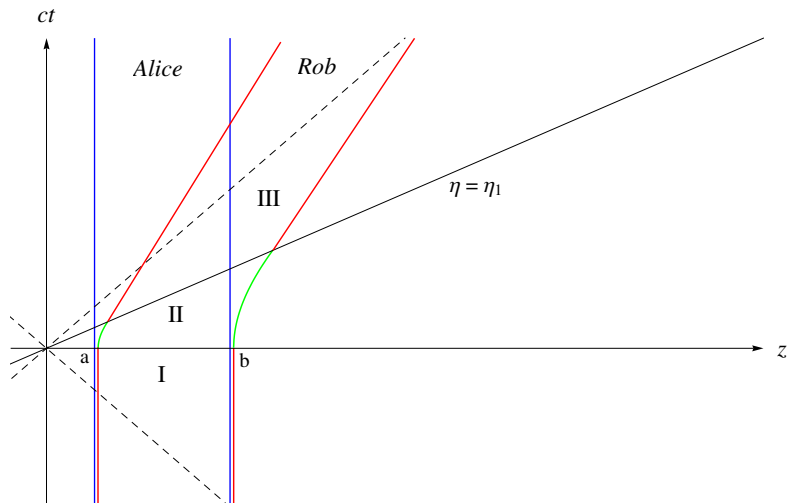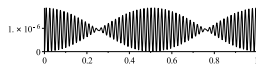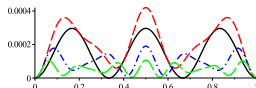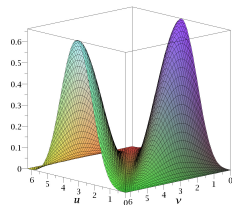
Our results

Two cavities discussion

What we learned: 2 boxes

i **Degradation** due to **motion**

ii Choice **NOT** to have it for 1+1 massless fields

iii **Mass** and/or **transverse momenta** $\Rightarrow$ **enhancing** effect

iv $a \sim 1$g, $L \sim 10$m $\Rightarrow$ transverse massless bosons $\lambda \sim 600$nm **observable**

v $a \sim 10^{-9}$g, $L \sim 1$m $\Rightarrow$ kaon-massive bosons **observable**

LEFT, top to bottom: Negativity as a function of periods of acceleration for the $1+1$ massless one way trip (first) and the $3+1$ Basic Building Block (second and third)

Britgrav 12, Southampton, UK - Voyage to Alpha Centauri: degradation, creation and detection of cavity mode entanglement due to motion.   9/1

Our results

One cavity

What we did: 1 box

   i One Dirichlet cavity in 3+1D (1+1 for fermions)

  ii Bosonic massive OR massless fields and fermionic massless fields

 iii NO initial entanglement - vacuum or pure state

 iv Linear accelerations

  v Travel scenarios built using basic building block (BBB) or "oscillatory motion"

 vi Look for entanglement between two GENERIC modes at the end of the trip

 vii Look at entanglement between two lowest mode for "shaking" trajectory

viii Compute entanglement created through negativity

Britgrav 12, Southampton, UK - Voyage to Alpha Centauri: degradation, creation and detection of cavity mode entanglement due to motion. 10/1

Our results

One cavity discussion

What we learned: 1 box

i **Creation** due to **motion** between two ARBITRARY modes

ii $\mathcal{N} \propto h$ for two modes n, m such that $n + m = 2q + 1$

iii $\mathcal{N} \propto h^2$ for two modes n, m such that $n + m = 2q$
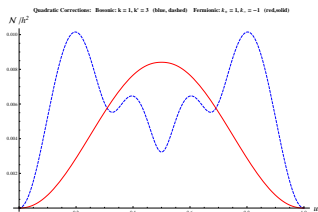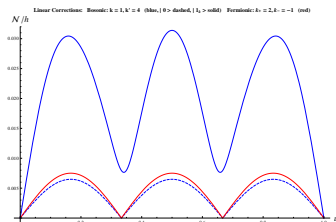

Figure: FERMIONS and BOSONS. Initial state is vacuum. Left - $\mathcal{O}(h)$ creation of negativity as a function of time of acceleration ($n + m = 2q + 1$). Right - $\mathcal{O}(h^2)$ ($n + m = 2q$)

Britgrav 12, Southampton, UK - Voyage to Alpha Centauri: degradation, creation and detection of cavity mode entanglement due to motion. 11/1

Our results

One cavity discussion

What we learned: 1 box

i Look at any two modes ω_1, ω_2

ii Resonance for cavity oscillating with frequency $\Omega = \omega_1 + \omega_2$

iii Generation of Two Mode Squeezed state with squeezing parameter $\log \mathcal{N} \equiv r \propto ALN$ (Acceleration, Length, Number of shakes)
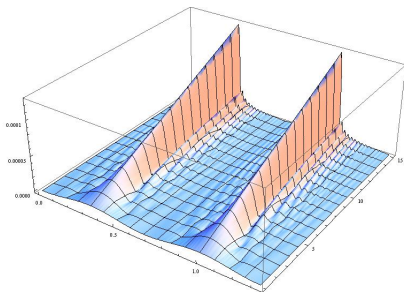

Figure: The Twin Shark Fin: Logarithmic Negativity as a function of period of shake and number of shakes

Conclusions...

i **Motion affects** entanglement

Britgrav 12, Southampton, UK - Voyage to Alpha Centauri: degradation, creation and detection of cavity mode entanglement due to motion.   12/1

Conclusions and Future work

Conclusions...

   i **Motion affects** entanglement

   ii **Experimentally feasible**

Conclusions...

i **Motion affects** entanglement

ii **Experimentally feasible**

iii Test **equivalence principle**

Conclusions...

  i **Motion affects** entanglement

  ii **Experimentally feasible**

 iii Test **equivalence principle**

 iv Suggests **gravity affects** QI tasks

...and beyond!

i Propose an experiment for detection (contacts with D. Faccio at Heriot Watt and C. Binns in Leicester)

ii Build model for quantitative predictions of gravitational effects

iii Cavity trajectories of specific experimental interest

iv Quantum gates by moving!

v Multipartite entanglement within cavities (joint work with, N.Friis, M. Huber I. Fuentes and J. Louko in progress)

Britgrav 12, Southampton, UK - Voyage to Alpha Centauri: degradation, creation and detection of cavity mode entanglement due to motion.   14/1

Conclusions and Future work

Thank You.