**Proposal: Workshop on Relativistic Quantum Information**

**Timing:**  4 days in the summer of 2012

**Subject Area:** Mathematical Physics

**Scientific summary**

Over the past few years, a new field of high research intensity has emerged, known as Relativistic Quantum Information (RQI). The field of RQI aims to understand the relationship between special and general relativity, and quantum information. In particular, so-called quantum entanglement bits (e-bits) are a necessary resource in all of quantum communication and quantum computation. One of the key goals of the field of RQI is to develop the mathematical theory of e-bits in realistic spacetimes described by Lorentzian manifolds. This offers exciting new mathematical challenges because it combines information theory with functional analytic (namely quantum theoretic) and differential geometric (namely general relativistic) questions, which leads, for example, to deep questions of spectral geometry.

**Objectives of the workshop**

Results over the past few years have shown that new phenomena arise when quantum entanglement is combined with relativity. Since entanglement that is merely non-relativistic is already known to be a crucial resource for quantum communication and quantum computation, the study of entanglement when combined with relativity is highly significant.

For example, it has been shown that quantum teleportation fidelity is affected between observers in uniform relative acceleration. Entanglement was also found to be an observer-dependent property that is degraded from the perspective of accelerated observers moving in flat spacetime. Further, it was shown that entanglement can be obtained from the vacuum of relativistic quantum field theories. Entanglement can also be used to distinguish peculiar motion from cosmological expansion. While entanglement has long been known to play a key role in the Unruh and Hawking effects, the new quantum information-theoretic framework of quantum channels in terms of completely positive maps and operator algebras now provides powerful tools for studying matters of causality and information flow in quantum field theory in curved spacetimes.

To mention one issue in more detail: The relative alignment of reference frames around spacelike-separated events, e.g., in EPR-type setups is highly nontrivial in Lorentzian manifolds. Indeed, it is expected that their proper alignment is not given by the geodesic transport between the two events. Rather, it is believed that the parallel transport that links the frames is to trace back the past paths that the EPR subsystems took. Even this is nontrivial in cases where the past paths are quantum delocalized on a scale that is affected by curvature. One of the ideas that is being discussed is, for example, whether this could be probed, in the medium term, e.g., involving EPR-type experiments with a satellite, and perhaps photons passing the sun when eclipsed. A proposal to the Canadian Space Agency for testing this idea has been submitted in 2011. At present, the mathematical tools are lagging behind in this field.

The workshop will aim to explore the theoretical and mathematical underpinnings of entanglement phenomena in curved space. This involves, for example, techniques of spectral geometry, a mathematical discipline of high significance for the field of quantum gravity - because it naturally combines the languages of quantum theory, i.e., functional analysis, and the language of general relativity, i.e., differential geometry.

**Workshop description for the general public**

The greatest challenge in contemporary mathematical physics is the unification of general relativity with quantum theory. Mathematically, the key challenge is to bridge between the very different mathematical languages in which the two theories are formulated. Recent research has shown that information theoretic concepts can help bridge these two mathematical descriptions of nature. In this context, this workshop mathematically explores the impact of quantum and gravitational effects on the propagation and transformation of information.

To this end, the workshop will bring together the most prominent researchers in the subject of relativistic quantum information, as well as some of their best postdoctoral fellows and graduate students. The workshop is timely because of recently-emerged prospects for experimental tests of phenomena of relativistic quantum information, for example, using quantum communication with satellite-based instruments or Berry’s phase tests of the Unruh effect.

**Contact Organizer:**

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**Supporting Organizer:**

Prof. Robert B. Mann, Department of Physics, University of Waterloo

**Budget:**

The field of relativistic quantum information has become very active, with an annual winter RQI meeting in the southern hemisphere and with an annual summer RQI meeting in the northern hemisphere (in 2011 held in Australia and in Spain). The workshop we herewith apply for is to bring the summer RQI meeting of 2012 for the first time to Canada. We are planning to hold the workshop either in Waterloo or (if funding and logistics permit) in a more secluded location in the Muskoka region. Presentations will consist of 40 minute talks by invited experts and 20 minute contributed talks. A poster session will be held during one of the evenings of the workshop. The timing will allow for open discussion in between the more formal seminar times. We are anticipating the typical number of participants in the RQI workshops, which is about 45-50 participants.

We expect that a budget of 37K$ will suffice to invite some of the key international speakers as well as to subsidize the travel of some promising postdoctoral fellows and graduate students. We anticipate partial support from sources at the University of Waterloo, estimated at a total of 9K$.

We are herewith applying for support from the Fields Institute for 28K$.

List of some key participants and their institutions:

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1. Kempf, Achim, University of Waterloo, Canada (Organiser)

2. Mann, Robert, Univ. of Waterloo, Canada (Organiser)

3. Milburn, Gerard, Univ. of Queensland, Australia

4. Ralph, Tim, Univ. of Queensland, Australia

5. Leon, Juan, Univ. of Madrid, Spain

6. Fuentes, Ivette, Univ. of Nottingham, England

7. Lloyd, Seth, MIT, Cambridge, USA

8. Menicucci, Nicolas, Perimeter Institute, Canada

9. Ver Steeg, Greg, USC, Los Angeles, USA

10. Terno, Daniel, Mcquarrie University, Sydney, Australia

11. Laflamme, Raymond, University of Waterloo, Canada

12. Adesso, Gerardo, Dept. of Mathematics, Univ. of Salerno, Italy

13. Kent, Adrian, Univ. of Cambridge, UK

14. Unruh, William, Univ. of British Columbia, Canada

15. Schuetzhold, Ralf, Univ. of Duisburg-Essen, Germany

16. Weinfurtner, Silke, Univ. of British Columbia, Canada

17. Hu, Bei-Lok, Univ. of Maryland, USA

18. Lin, Shih-Yuin, National Center for Theoretical Sciences, Taiwan

19. Sanders, Barry, Univ. of Calgary, Canada

20. Hayden, Patrick, McGill University, Montreal, Canada

21. Ghose, Sohini, Wilfried laurier University, Canada

22. Bradler, Kamil, McGill University, Montreal, Canada

23. Rideout, David, Perimeter Institute, Canada

24. Jennewein, Thomas, University of Waterloo, Canada

25. Oh, C.H., National University of Singapore

26. Reznik, Benni, Tel-Aviv University, Israel

27. Rovelli, Carlo, Marseille, France

28. Alsing, Paul, Univ. of New Mexico, USA

29. Brukner, Caslav, Univ. of Vienna, Austria

30. Dragan, Andrejz, Univ. of Warsaw, Poland

31. Oppenheim, Johnathan, Cambridge University, U.K.

32. Ahn, David, Seoul Univ., Korea

33. Leon, Juan, Univ. of Madrid, Spain

34. Louko, Jorma, Univ. of Nottingham, U.K.

35. Faccio, Daniel, Heriot-Watt University, U.K.