Internet Appendix A11: Physics

Figure A11.1 Illustrative Pitch Template in Theoretical Physics

Pitcher's Name	Harry Mulgrew, Date Completed: 19/09/2014
(A)Working Title	Going Around the Loop: Modelling fermions in a Sagnac Interferometer
(B)Basic Research Question	Can fermions produce better interference fringes than bosons when modelled in a Sagnac interferometer?
(C)Key Papers	Cronin, A., Scmiedmayer, J. and Pritchard, D. 2009. *Optics and Interferometry with atoms and molecules.* **American Physical Society** 81 1051. Hasselbach, F. and Nicklaus, M. 2008. *Sagnac experiment with electrons: Observation of the rotational phase shift of electron waves in vacuum*. **Phys. Rev. A 48**, 143 Neutze, R. and Hasselbach, F. 1998. *Sagnac experiment with electrons: Reanalysis of a rotationally induced phase shift for charged particles.* **Phys. Rev. A 58**, 557Phys. Rev. A **58**, 557 Don Hyun K. 2004. *Sagnac loop interferometer based on polarization maintaining photonic crystal fiber with reduced temperature sensitivity.* **Optics Express,** Vol. 12, Issue 19, pp. 4490-4495
(D)Motivation/Puzzle	Interferometers are devices of extreme precision used to measure rotations, control particles and test theories of gravity through interference. In the past, bosons have been used to exhibit interference as they are easier to model and control. Despite this, recent research suggests that fermions may be able to display interference with finer precision, thus leading to more sensitive experiments in these fields. In this project, I examine fermions as the new 'particle of choice' by attempting to model their interference in a Sagnac interferometer.
Three	Three core aspects of any empirical research project i.e. the "IDioTs" guide
(E)Idea?	**"Core" idea:** Using quantum mechanics, one can describe the wavefunction of the particle as it travels around the loop. We can derive the intensity from the wavefunction and plot this numerically on MATLAB to view interference. Central hypothesis: The interference due to fermions will respond more readily to a phase-shift.
(F)Data?	This is an entirely theoretical project so there is no data per se. However, if the project generates some interesting results, it is not hard to envisage the theory being tested in a laboratory. In this case, the data would be obtained from experiment by using optical traps to separate the particles and send them individually or in groups around the loop. One would then directly measure the interference on a screen and use these data to determine whether the model is correct.
(G)Tools	For the current theoretical project the only real tool needed is MATLAB software. In a follow-up experimental project, the tools required would be an optics table, a Sagnac interferometer, lasers and optical tweezers to control the fermions and a screen to detect interference fringes.

Two	
(H)What's New?	**Idea is novel** – This project considers a new type of particle for interferometer use which will result in highly sensitive interference.
(I)So what?	By constructing greater precision interferometers this will allow scientists to perform experiments which are currently unachievable. Many experiments require interferometry including those which are testing new theories of gravity.
One	
(J)Contribution?	I hope to obtain an analytical expression for the interference as a function of space and time for any number of fermions.
(K)Other Considerations	There is a wide number of ways in which one can characterise the interference fringes. Once the expression has been derived there will be many different avenues down which one can pursue the research question. Risk assessment: As this has not been done before there is first and foremost the risk that it is not possible to obtain an analytical expression for the evolved wavefunction of each fermion. If this is the case however, there are many different factors which one can investigate. Secondly, the competitor risk of this project is fairly low as it is in quite a specific niche. My supervisor has derived the wavefunctions numerically and has given me the project to investigate an explanation for the numerical data. Finally, a risk of obsolescence is possible as it may be shown that fermions are not a good candidate for interferometry. However, even a no vote in this case will be publishable as it informs scientists that bosons are the better alternative.