MS Thesis | Summary

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Contents

Introduction

The purpose of this document is to be evidence of and support the steps taken in the direction of innovating for the master's thesis.

Part I
Perfunctory Systematics of Research

1 Reg, Topic Decision, Multi-Mode Paper | August 3-8, 2015

Motivation: Construct a Bell like test for the case where the system is not two level, but d-level.

Setup: Consider a 4 mode light. One direction is $\mathbf{k}$ and the other is $\mathbf{k}'$. The annihilation operators are $a_1 = a_k^{\parallel}$ and $a_2 = a_k^{\perp}$ and similarly a_3 and a_4 are defined.
Next, we also allow some photon number conserving transformations. One possibility would be $a \to Ua$, where

Recall: Single mode light: Take a plane wave like solution for a cavity and quantize it to get quantum optics. In this you'll get a and $a^\dagger$ corresponding to the k and direction of E (or B) of this classical solution.
N mode light: You allow arbitrary plane waves. You'll get $a_k, a_k^\dagger$ but for a given direction, you can have two polarizations (which are enough to generate all polarizations)

2 Ideas, Bohmian Mechanics started | August 10-15

- [GRE] Subject GRE, vocab GRE and quant GRE were done in full swing
- [Research/ms] Made a presentation about Arvind sir's paper, discussed about uncertainty in speed of light with Bhati being the chief guest, started reading Bohmian Mechanics from Holland, thought about Bohmian Mechanics and how to make it relativistic; (figured that there must be non locality in built as it is, because even in QFT this nonlocality doesn't disappear. However, in
- [protocol f]

3 arXiv and Hamilton Jacobi for Bohmian | August 17-22

3.1 Monday | Aug 17

- [official] Summer project form
  - had to get the certificate from Ali/Otfried
  - had to get Arvind sir's signatures
- [research/summer] Started proof reading the paper
  - Had issues with the discussion section; definition $X = E_+ - E_-$ having only two values as outcomes :(

3.2 Tuesday | Aug 18

- [research/ms] Met with Arvind sir
  - Kichoo finalized his project. He's not doing Bohmian Mechanics
  - I finalized my project (as I had earlier) to Bohmian Mechanics and Contextuality
- [research/summer] Read Haridichi's paper about measuring a bounded observable using a two level system
  - Implicitly it had used results from POVMs; so had to read about POVMs from Nielsen's book
  - Couldn't still fully understand what Ali was doing, I figured that $A_i^\dagger A_i$ type of operators if they satisfy $\sum A_i^\dagger A_i = \mathbb{I}$, then one can talk about probability of getting the i^{th} input as $\left\langle A_i^\dagger A_i \right\rangle$. Ali was using $E_\pm$ and the fact that $E_+ + E_- = \mathbb{I}$ as his scheme. However, for projectors, since $P^2 = P$ and if $P^\dagger = P$, then the condition stated earlier essentially becomes $\sum P_i = \mathbb{I}$ and that makes sense. However, they aren't projectors. So I wasn't sure what was happening.
- [gre] Vocab and Quant

3.3 Wednesday | Aug 19

- [research/ms] nill :'(
- [research/summer] Put the paper on arXiv
  - Ali updated the minor modifications slightly (I still wasn't comfortable with $A^{two} = E_+ - E_-$ having only two possible values) | wasn't very happy intially but figured it today that this statement is not quite needed and had sent the update to Ali, who while made minor changes, wasn't too happy :(
  - Putting it on arxiv required some debugging etc. | moral of the story is to use PDF as images instead and not using hyperref defiend explicitily
  - Ali was happy by the end of it
- [research/official] Presentation of work at the QCQI group meet
  - Went reasonably well
- [GRE] words + little bit of quant

3.4 Thursday | Aug 20

- [official] Registration/course add/drop etc. taken care of
- [research/] The $E_{\pm}$ issue was understood in more detail after talking to Arvind sir
- [research/ms] Read some more things from Holland
  - Looked at the section on propogation fo the S function
  - started reading the section on Classical Statistical Mechanics
    - He talks about how in CStat Mech, we use the function $f(x,p,t)$ to describe a probability, whereas here we use the less general density $\rho(x,t)$ where the p has been specified.
    - Derives the continuity equation (by demanding the the particles be conserved)
    - He talks about some special cases; viz. specific solutions making some assumptions about the dynamics
- [GRE] words/vocab, reading section from Manhattan.
- [protocol f] Earthlings

3.5 Friday | Aug 21

- [official] KVPY report printed, printed the form again, submitted it to the dean's office
  - Went to the bank for NET
- [research/ms] Holland
  - Finally figured why $\frac{d}{dt}d\Omega = (\nabla.v)d\Omega$; just looked at Aris and it was right there. The idea was to use the jacobian to describe the change in volume and then everything follows.
  - Tried to look up papers related to Bohmian Mechanics and Contextuality (couldn't find too many papers related to this)
    - In Quantum Physics without Quantum Philosophy, 3.8.3 talks about contextuality (looks very wordy)
    - In Bohmian Mechanics and Quantum Theory, page 67 is a chapter on contextuality
  - Can I think of a way of constructing a theory that's local, but not real? Can reality then be emergent? Does it mean that the moment I say I don't assume reality, then it must mean that my theory must have some sort of measurement and then it is essentially a combination of worst of both worlds?
  - Found the following interesting overview of Bohmian Mechanics: http://philsci-archive.pitt.edu/3026/1/bohm.pdf
- [GRE] words/vocab, quant (finished the geometry section)

3.6 Saturday | Aug 22

- [official] Some silly German Research Opportunity thing
- [research/ms] Why must contextuality only be talked about in the context of spins? What about phase space contextuality? Reading Holland; following is a summary.

1. To understand the continuity equation $\rho + \nabla.(\rho v) = 0$, examples of v are taken
   (a) $v = v(x)$, a solution is obtained as
   $$\rho(x,t) = \frac{1}{v(x)} v\left[x\left(t - \int \frac{dx}{v}\right)\right] \rho_0\left[x\left(t - \int \frac{dx}{v}\right)\right]$$
   in which further assuming that $\rho(x)$ results in $\rho = A/|v(x)|$
      i. $v = v(t)$ then we get
      $$\rho(x,t) = \rho_0\left(x - \int v dt\right)$$
      which means that ρ is constant along particle trajectories
   (b) connection with Liuoville's equation

i. $f(x,p,t)$ is defined instead of $\rho(x,t)$. Pure and mixed states are defined accordingly as $f(x,p,t) = \rho(x,t)\delta(p - \nabla S(x,t))$ being pure and the remaining as mixed.

ii. $\frac{df}{dt} = \partial_t f + \frac{1}{m}\sum p_i \partial_{x_i} f - \sum \partial_{x_i} V \partial_{p_i} f = 0$ is the Liuoville's equation (which holds since we can show that the volume doesn't change under Hamiltonian evolution and particles inside the volume stay inside; $f(p',q',t+\delta t) = f(p,q,t)$ is essentially the statement $\frac{df}{dt} = 0$) which is linear in f.

iii. One may project out the moment space. They define equivalent of ρ as $P(x) = \int f d^3p$, mean momentum as $\overline{p_i(x)} = \frac{\int p_i f d^3p}{P(x)}$ and $\overline{p_i p_j(x)} = \frac{\int p_i p_j f d^3p}{P(x)}$. The louvielle equation can then be expressed in terms of these spatial variables. Integrating it we get

$$\partial_t P + \frac{1}{m}\sum \partial_{x_i}(P\overline{p_i}) = 0.$$

To get the momentum transport equation, after multiplying the louvielle equation with p_i and integrating, we get

$$\partial_t(P\overline{p_i}) + \frac{1}{m}\sum \partial_{x_j}(P\overline{p_i p_j}) + P\partial_{x_i} V = 0$$

(apparently integrated by parts and assumed $f \to 0$ as $p_i \to \infty$)
While f is constant along a phase space trajectory, the spatial density P (equivalent of ρ) is not. It's apparent from the derivation of the continuity equation; either we start with a fixed volume or a fixed number of particles, not both.
If you substitute $f = \rho\delta(p - \nabla S)$ as stated earlier, you'd get $P = \rho$, $\overline{p_i} = \partial_{x_i} S$, $\overline{p_i p_j} = \partial_{x_i} S \partial_{x_i} S$ as expected. The substitution also yields what's called a field theoretic version of Newton's Laws given by

$$\partial_t \rho + \frac{1}{m}\nabla.(\rho \nabla S) = 0$$

and

$$\left[\partial_t + \frac{1}{m}\sum \partial_{x_i} S \partial_{x_j}\right] \partial_{x_i} S = 0$$

iv. Remarks:

A. It's not obvious that if we start with a state that has well defined momentum (delta distribution) but the positions are given by $\rho(x)$, then they will continue to be well defined in momentum. This happens only exceptionally. In general, a pure state maybe sent to a mixed state. We'll see examples of these. [todo: ensure examples make sense]

B. Can we decompose any mixed ensamble into a linear combination of pure ones? The answer's no. [proof?] Say there are many solutions of the Hamilton-Jacobi equation, given by S_i. Thus, we can construct a linear combination as $f(x,p,t) = \sum P_i \rho_i(x,t)\delta\left(p - \nabla S_i(x,t)\right)$ where P_i (degenerate notation) refers to the distribution of momenta at a given point. $\sum P_i = 1$ is assumed for normalization. Claim is that this is not in general possible to decompose a state into this form. An explicit example is that of reflecting through a potential barrier (in CM) [todo: ensure the example works]

C. While this is not particularly useful in CM (the pure and mixed states), the formalism helps in comparison with QM.

(c) Pure and Mixed States

i. Illustration: We see that $f_0(x,p) = \delta(x - x_0)\delta(p - p_0)$ remains sharp
(it can be checked by inserting it in the louviel equation) to yield $f(x,p) = \delta(x - x(t,x_0,p_0))\delta(p - p(t,x_0,p_0))$ [this is expected, since you're in essence saying there's only one particle]

ii. Illustration 2: We want to see what happens to a Gaussian like state, does it spread?
We start with $\rho_0 = \frac{e^{-x^2/2\sigma^2}}{\sqrt{2\pi\sigma^2}}$ and $S_0 = px$ with σ and p constant. This form of S_0 has already been solved for and tells us $\rho = \frac{e^{-(x-vt)^2/2\sigma^2}}{\sqrt{2\pi\sigma^2}}$. There's no spreading classically! We'll see for the same initial conditions, what happens quantum mechanically.

iii. Illustration 3: What initial conditions yield a spreading Guassian? We start with the same ρ_0 but use $S_0 = \frac{m(x-x_0)^2}{2t}$, in which case the solution we saw the result is

3.7 Sunday | Aug 23

- Summarizing the work I did on saturday.

4 Reached the chapter on Bohmian Mechanics | Aug 24-29

4.1 Monday | Aug 24

- [research/ms] Worked on making notes about Bohmian Mechanics
- [GRE] words, vocab; quant
- [misc]
  - KVPY document received; had to attend a PhD defence; fixed the NET application issue (talked to Bagla sir etc.); got black and white print outs; scanned various documents
  - Found something called *SparkleShare* which is dropbox like with git under the hood. Works great. I can switch off the automated git uploading whenever I like and switch to manual git. For the usual things, I can use it like a dropbox folder :)

4.2 Tuesday | Aug 25

- [research/ms] Worked on making notes about Bohmian Mechanics from Holland
- [misc] Gave the NET document for resubmission.
- [GRE] vocab (questions), quant

4.3 Wednesday | Aug 26

- [research/ms] Started the Bohmian Mechanics part from Holland!! QCQI group meeting; I think it was Vikrams. He talked about Quantum Simulation; about tunneling.
- [misc] Registered for TOEFL
- [GRE] minor work

4.4 Thursday | Aug 27

- [research/ms] Reading Bohmian Mechanics part from Holland
- [misc] Scanning, printing etc., packing
- [GRE] word list creation on Inkscape

4.5 Friday | Aug 28 [off, travel]

- [GRE] word lists

4.6 Saturday | Aug 29 [off]

5 Midsem, Presentation, Bohmian Mechanics (made sense of insolent multi-valued integration..) | Aug 31 - Sep 6

5.1 Monday | Aug 31 [off, travel]

- [course] Philosophy Reading the book

5.2 Tuesday | Sep 1

- [course] Philosophy: Found *@voice* an application that can read out things from the phone; used gscan2pdf for converting the notes sagar had sent to OCRed PDF (which isn't very good to look at) which @voice played out :D Also made proper notes for most of the 1st chapter of the book by Benn.

5.3 Wednesday | Sep 2 [exam]

- [course] Philosophy: studied and took the exam
- [research/ms] Started making notes on the Bohmian Mechanics part, (chapter 3) from Holland; got a place in CAF to sit and study (an office if you will)
- [misc] gave away the sweets

5.4 Thursday | Sep 3

- [research/ms] Presentation: Kishor talked about LOCCs, majorization, the iff condition between them, entanglement distillation and entanglement of creation and finally how they're related to key distribution (he barely started);
  - Bohmian mechanics working on figuring that $\oint dS = nh$ and tried constructing the cases when this could happen
- [misc] Tug of war practice + Abhishek sir nomination + re arranging the room in CAF + landscape thing
- [gre] verbal GRE work done

5.5 Friday | Sep 4

- [research/ms] Presenation; mine: Talked about how to get to the Hamilton Jacobi equations and took some time. Working out the differential equations is hard. Completed till about page 4 of my notes. It went well
  - Bohmian mechanics: figured the relation with the curl theorem of $\oint dS$ and atleast it now makes a little more sense. Need to work out the details still though; the point is that I now know which curl related theorem could be used, about which I wasn't certain until now.
- [misc] Table chair thing + landscape thing + multiple protocols
- [gre] quant GRE

5.6 Saturday | Sep 5

- [research/ms] Concluded that I'll just ask sir now for some advice. What I'm doing doesn't seem to help;

  So we start with $\oint dS = \oint \nabla S.dx = \oint p.dx = \int \nabla \times p.da$. If $\oint dS = nh$, then we must have $\nabla \times p = \sum_a \Gamma_a \int_{\gamma_a} \delta(x - x_a)dx_a$ where γ_a is the nodal line. If we assume $\oint dS = nh$ holds, then can we construct some example of the same? Let's first see how $\oint dS = nh$ can be derived. If the only condition is that ψ is single valued, then we know that at any point, S' and S both yield the same ψ, where $S' = S + nh$. If one considers a loop, then say we start from a point S_a. Then after completing some distance, the change in S is given by ΔS. So the value of S starting from $S_a$will be $S_a + \Delta S$. Now if we come back to the point a, then from uniqueness of ψ, we only demand $S_a + \Delta S = S_a + nh$. If S itself was unique, then we'd say $S_a + \Delta S = S_a$. Now at this point itself I seem to have trouble. I have tacitly assumed that S is single valued when I'm evaluating the 'change is S' along the curve.

  Talked to manu for a while and made some progress, then figured it was non-sense and made some more progress. Finally, Manu found a document that helped clarify a few things. The issue was still that they had used a vector field and not a potential. And it wasn't clear to me what potential must I use in that case.
- [misc] words GRE (prashansa came to CAF) + teacher's day (abhishek sir was awarded) + dinner

5.7 Sunday | Sep 6

- [research/ms] Finally found a potential that works (looked at acheson, griffiths and an extra document that manu had found.)

  The potential is $V = k\theta$. Note how this is itself, as a function of position is multi valued and yet we never have any issues integrating this (as we'll see shortly). While V is multivalued, $\nabla V = \frac{k}{r}\hat{\theta}$ is happily single valued :) And not just that, check this; $\oint_\gamma \nabla V.dx = 2\pi$ (simply because γ is chosen to be a circle and then $dx = rd\theta\hat{\theta}$). Since in the domain of interest, everything is well defined, I can write $\oint_\gamma \nabla V.dx = \oint_\gamma dV = 2\pi$. And one can show independently (I know only a simple minded proof with discritizing the function) that $\oint dV = 0$ whenever V is single valued (or a function). So what does this example show? Various rather peculiar things. (I) that $\oint dV$ maybe non zero for a reasonable physical situation by virtue of multivaluedness of V. Yes, V is multivalued and yet we can integrate the said expression without ambiguity. (II) that there happens to be a singularity within the loop, over which the integral is non-zero. (III) The curl, $\nabla \times \nabla V \neq 0$ at the center and $= 0$ else.
  Now we've made plausible various things which would've seemed arbitrary otherwise.

- [misc] trying to get a template in which to write the thesis

6 Temerity of GRE prep, Sycophancy or Ascendency of Bohmian Mechanics | Sep 7 - 12

6.1 Monday | Sep 7

- [research/ms] Worked out an explicit example of $\nabla \times p = \sum_a \Gamma_a \int_{L^{(a)}} \delta(\mathbf{x} - \mathbf{x}^{(a)}) d\mathbf{x}^{(a)}$ by assuming that the $d\mathbf{x}^{(a)}$ term is infact a vector and $d\mathbf{a}$ is essentially $\mathbf{n}dxdy$ to see that everything fits well eventually. Then I moved to the next section and everything seemed alright. Basically the discussion of the 'quantum potential term', viz. the term which if removed would reduce the expression to a classical hamilton jacobi equation, was slightly confusing. This term is given by $Q := -(\hbar^2/2m)\nabla^2 R/R$, and yet the claim is that this essentially depends on S. The same can be said of V which depends on $x(t)$ which in turn can be determined only once S is specified (NB: S contains information about both the Hamiltonian and the momenta of the system). So in this sense, both V and Q depend on S. However, the distinction seems to be made on the following ground: if $V = V(x)$ then, ∇S is sufficient. However, for Q it seems higher derivatives will also be necessary. Why this makes any difference, I am yet to learn.

- [GRE] did 2 tests in the morning (both verbal, am still miserable at them :( )

6.2 Tuesday | Sep 8

- [research/ms] Revised work I did yesterday.

- [research/summer] started the process of submission to PRA. Figured how to change the name from Dr. to without Dr. and then am waiting for Ali; he has to tell me if I should use the arXiv link or not. Made reasonable progress at putting things up online. The main trouble was that I wasn't able to add references. Figured there was a command '\nocite{*}' that had to be inserted to fix things. Did that. In addition, I had to change the split images into a single image; else the system kept yielding errors. After that, I had to follow some minor steps but then I got a response from Otfried. He had completed proof reading the pre-print and had made several comments which had to be accommodated.

- [GRE] did 2 tests, 1 math, 1 verbal (need to find more tests now) | did vocab also :)

6.3 Wednesday | Sep 9

- [research/ms] Bohmian Mechanics; finished reading the section on uniqueness of the wavefunction and started reading further, about commutation relations and so on. Some summarizing etc. will be typed out here later. Also, prepared for the presentation with Arvind sir;

- [research/summer] glanced through the changes suggested by Otfried.

- [GRE] morning slot: didn't wake up | vocab only

6.4 Thursday | Sep 10

- [research/ms] :(Didn't do much but thought of the following. Why can't I think of a bohmian like picture, after a particle has been created for instance, according to QFT. Perhaps I should start playing with the scalar field theory and try to see how I can get bohmian trajectories into them somehow. I suppose the eventual goal would be to think of an alternate interpretation to the field interpretition. I feel that there's some better way of handling these things. What does Hamilton Jacobi translate to? What happens to the Dirac equation? In QFT we treat the dirac equation as a field and create particles off of it. What will we do here?

- [research/summer] working on fixing the paper based on Otfried's comments. Minor fixes were quick. Fixing some references took time. The issue was that one has to use {} for evaluating commands within bibtex's .bib file. Didn't know that. Also fixed some other minor things. Located the PACS numbers related to the paper, started working on a cover letter and found appropriate emails for referees.

- [GRE] morning slot: read a little about the writing comprehension etc. but was too tired, slept after breakfast | did vocab words :)

6.5 Friday | Sep 11

- [research/ms] Thought about the relationship between QM and QFT. Even tried to derive the $[q, p]$ commutation starting from $[\phi, \pi]$. Figured ofcourse that if there're no commutations in Bohmian. This makes the Field theory aspect harder. Also got Bohm's original papers and started reading them.
- [research/summer] Finalized the cover letter and finally, submitted it to PRA. My first submission :D
- [GRE] afternoon slot will be used
- [misc] Phys Majors had a meeting.

6.6 Saturday | Sep 12 [weekend]

- [GRE] GRE vocab + test
- [misc] There was a discusison on entropy/information by Raja Ram Mohan which was intriguing, although most of what he said was familiar.

6.7 Sunday | Sep 13 [weekend]

- [GRE] prep
- [misc] Onam, tug of war

Hegemony of GRE | Sep 13 - Sep 24

- [GRE] prep all the time :(

Besieging exams and beyond | Sep 25 - Sep 30

- Took the TOEFL (Sep 26) and the GRE(Sep 28)
- Relaxed for about half a day + Personal efficiency improvement | standing straight improvements; wifi linux broadcast attempts (made improvements, but not successful); other improvements

7 Reprisal of Physics | Oct 1 - 3

7.1 Thursday | Oct 1

- [misc] Room efficiency tasks | washed clothes, cleaned the room, found the old phone (with the sim), resuming tasks (calendars, emails (KVPY, deanacad etc.), PhD application issues etc.
- [research/ms] just resumed reading
- [GRE S] classical mechanics questions (Klepner and Kolenkow)

7.2 Friday | Oct 2

- [GRE S] classical mechanics primarily (Klepner and Kolenkow) + had the first help course
- [research/ms] resumed reading Bohm's paper
- [Misc.]

7.3 Saturday | Oct 3

7.4 Sunday | Oct 4

8 Indignant time contraction; Immuring Physics, Applications and Bohm | Oct 5-10

8.1 Monday | Oct 5

8.2 Tuesday | Oct 6

8.3 Wednesday | Oct 7

- [GRE S]
- [research/ms] Was trying to translate bohmian mechanics to the discrete case. Realized there'll be an issue with the grad operator but then in the case of spins, we never write the kinetic energy term! Then some discussion with Jaskaran got me realize the following rather interesting conflicting statements, at least for spins. (I) QM is non local; Essentially if you assume locality, you can show determinism must exist, using EPR type states. Now one can use Bell's inequality to show QM is non local. (II) QM is non-deterministic can be shown using contextuality arguments and coloring theorems.; Comment A: Regarding the conclusion of (I), it is weakened by the fact that one can show you in QM, you can't communicate faster than speed of light. So in this sense the non locality is, well is it there at all?[1] Comment B: Disregard (I) for the moment. Usually in starting a proof for Bell's theorem, we assume that both locality and determinism hold (whether one can be derived from another is another matter). Thus a violation entails atleast one of the assumptions is wrong. We don't know which. From (II) it seems therefore that atleast determinism is false.[2] Comment C: If only (I) were true, then constructing a theory such as Bohmian mechanics may seem strange because then non-locality is explicit, but in some sense more sensible for we don't need 'observers' to make sense of what we're saying. If (II) is true even in continuous variables, then it would seem meaningless to even imagine constructing a theory such as Bohmian Mechanics.[3] Conclusion: One needs to come up with either a contextuality test for continuous variables (Ali's work) or figure how to setup Bohmian Mechanics for discrete variables.

8.4 Thursday | Oct 8

- [GRE S]
- [research/ms] got sick of trying to figure the spin thing and decided to linearly read the papers by Bohm first and then thinking about what to do next.

8.5 Friday | Oct 9

- [GRE S] Drude model etc.
- [research/ms] Bohm's paper; thinking about why it is that we can't talk about gravity essentially like electric fields. And then the obvious question that arises is that can there be a magnetic analogue of electric fields? | Jaskaran gave a small talk on Contextuality. He discussed various things including the KSBS inequality etc. Also briefly discussed the overview of the field and the progress. He concluded with discussing the nature paper about the Magic qbit etc.
- [Misc.]

8.6 Saturday | Oct 10

- [GRE S] griffiths, electrodynamics first chapter, classical mechanics revision
- [research/ms] Bohmian Mechanics (resumed reading the paper)
- [Misc.]

[1] Infact, one can show that the bell's inequality can be violated by 2 if the only assumption is no communication. QM does $\sqrt{2}$. So whatever this non-locality, it is certainly more restrictive than simply enforcing 'relativity'.

[2] I had been told that in contextuality, certain other assumptions have to be made (of which I'm not certain).

[3] There maybe defenses such as the observables are not really the same as the object's position/momentum etc. but more on that later

8.7 Sunday | Oct 11

- [Misc.] Philosophy exam prep
- [research/ms] Casually thought of linking Ekert and EPR protocols, primarily kichoo's idea + suggested a modification to jaskaran and kichoo's protocol

9 Emaciated resurrection of physics and inclemency of all else | Oct 12 - 16

9.1 Monday | Oct 12

- [Misc.] Philosophy exam prep, talk on Quantum Theory and SpaceTime (a person from IISER P had come and there was this student of his who in his fifth year (had in his fourth infact) published over 3 papers on the said subject! Insane), various things for the PhD application to leeds done

9.2 Tuesday | Oct 13

- [Misc.] Philosophy exam; iGuess: I figured how Stern Gerlach is analyzed in Bohmian Mechanics, also I read about how contextuality etc. it handled in bohmian mechanics. This was from Durr's book.
- [research/ms] Thought about how one could use the quantized harmonic oscillator analysis (Bohmian Mechanics) on Quantum Optics and see if it makes enough sense. Obviously this would not be about photons, but then what would be can probably be explored. I found later that he (Bohm) has already considered some such cases. This is particularly relevant if I want to apply the contextuality analysis (one that's extended to continious variables) to bohmian mechanics to see what's going wrong.

9.3 Wednesday | Oct 14 [unwell :(]

- [group meet] Bhati's talk was rather interesting, about collapsing of wavefunction etc.

9.4 Thursday | Oct 15

- [research/ms] Reading/thinking about Bohmian Mechanics;
- [sGRE] usual revision

9.5 Friday | Oct 16

- [research/ms] Could barely do anything :(
- [Misc.] Had to go get a draft done for TIFR; found the toothbrush (for Arjit); tried to get Headphones (for being able to work in the office); finally even ordered them

10 Subject GRE misconstrued as a Hiatus? | Midsem break (Oct 16 - Oct 25)

- Subject GRE prepared for well :) went home and back after the exam;

11 Demurred Obstacles | Oct 26 - Nov 1

11.1 Monday | Oct 26

- [Misc.] Couldn't get enough rest, started slow; fixing things at the office (resuming efficient work); organizing things, updating calendars etc.; there was an earthquake today; updated various things
- [research/ms] resumed reading Bohm's paper | Finalized some things:
  - (a) Bohmian Mechanics: (i) Discuss the basic formalism (ii) Discuss how measurements are done (the hardest part to explain) (iii) Explain how a position measurement may not even yield the 'true' position (iv) Talk about spins; the stern gerlach in terms of Bohmian mechanics;
  - (b) Contextuality: describe it;

  - (c) Ideas worth exploring: (i) Extension to EM fields, not with photon trajectories as the essential target but for (ii) The relation between Bohmian and Contextuality; (iii) How there maybe ontological models s.t. measurement disturbs the values of the hidden variable; this is essentially how they explain spins, or even position/momentum uncertainty etc.; the basic idea then is that how is Bell's test acceptable? Because the contextuality tests are also built like so and they get away with it by saying that contextuality is about spins, and that is not really ontological. However, now they even have continuous variable contextuality! These need to be phrased clearly.

- [research/ms] Started looking for a poster template and started filling it slightly. Also tried getting lyx to work using textext but that didn't work. They haven't updated to make it functional in the new version.

11.2 Tuesday | Oct 27

- [research/ms] Meeting with Arvind sir | described the basic idea of the poster (emailed it to him). In the next meeting with sir, we concluded that we (read Jaskaran and Kishor) write down all versions of the algorithm. Apparently my small modification itself can become the main protocol, once security can be assessed well. That part still has to be explored.

- [research/summer] Tried to look at the issues pointed out by the referee and tried addressing those I could. Wrote to Ali. He said he'd be able to handle most. I updated the technical issues (about figures etc.)

- [misc] Had the philosophy lecture; Also thought about why it is that we don't have superposition of charges, like we have superposition of magnetic moment; I mean we have states like $|\psi\rangle = \frac{|\uparrow\rangle+|\downarrow\rangle}{\sqrt{2}}$ but we don't have a neutron being in a superposition of + charge state and - charge state. I guess then this is the starting of particle physics in some sense. But this is still a curious thing, the charge for B field can be in a superposition but the charge for E field can't be.

- [health] running initiated + gym

11.3 Wednesday | Oct 28 (Unwell)

- [research/ms] Arun delivered the talk. He was insisting on the epistemic view of science. He said two things which are relevant for my work. First was the idea of a reduced density operator and its connection with Bohmian Mechanics. Detlef's book has discussed this. The next idea which is more directly relevant at the moment is that of the GHZ test. He was happily asserting that there the notion of reality must be given up. It was then obvious for me to use this as the starting point for my project. The continuous version of the GHZ test already exists and it would be fun to see how it works/fails with bohmian mechanics.

11.4 Thursday | Oct 29

- [research/summer] Updated some things that Ali had sent. There were various aspects that had to be looked at. Infact, Ali had even made a small mistake in the references (had put the wrong one). Made some minor language changes and sent it to him.

- [research/ms] Found an interesting paper that discusses how bohmian mechanics handles Bell, GHZ and more. Infact, finally I figured precisely what it is that I'll work on. Instead of looking at contextuality per say, I would instead look at the GHZ test generalized to position and momentum. The paper I found could be useful in setting up the system. In essence then I must look at the following: (1) How is measurement generalized in Bohmian Mechanics [detlef's article should suffice] (2) GHZ test in continuous variables (3) GHZ test in Bohmian mechanics

- [remarks/arvind]: Contextuality and GHZ, Nielsen doesn't prove the ancilla and POVM statement

- [misc] Got an email from the University of Leeds asking for my TOEFL scores and stating that Dr. Beige is interested in supervising my project.

11.5 Friday | Oct 30

- [research/ms] started figuring how to write the first simulation.

- [research/summer] Ali had responded. Made appropriate changes. Made some language changes. Sent it to Ali for a final glance before resubmission.

- [misc] Shopping (food) + nutrition optimization started; jelly lost her keys and found it!

11.6 Saturday | Oct 31 (unwell)

- [research/summer] Did a final review of the changes and resubmitted things to PRA.
- [research/ms] Formulated the thesis problem more clearly (in an email I wrote to Ali). Writing the small goals for the project to work on (constructed the appended topics part).
- [FYI] for lyx, to cite things, first Insert -> List .. -> BiBTEX .. and add your bibtex file. Thereafter, just use Insert -> Citation and you're done. Also, to restart numbering after a section, add \@addtoreset{section}{part} to the preamble. And finally, to add a book for citation, use this website isbt-to-bibtex.

11.7 Sunday | Nov 1

- [PhD] Applications; found this loop quantum gravity guy in France; wrote to him (he responded, as I'll find later). Have to write a letter of motivation/proposal etc. and that's about it.
- [research/ms] Found something called the relative interpretation of QM. COuldn't fully understand/appreciate it. Also learnt some GK about loop quantum gravity.

12 Voyage of Veracity, BM QM | Nov 2-9

12.1 Monday | Nov 2 (20 hours up time!)

- [research/ms] Working on the numerics aspect: Found various documents on simulating the schrodinger equation. Setup the whole thing in fortran from my old chaosTerm project. Got the basics up and running. I can initialize to a Guassian now.
- [misc.] extreme shopping, project nutrition seems to have been erected successfully; also figured how to keep my schedule fixed

12.2 Tuesday | Nov 3

- [research/ms] Idea: Why is it that position/momentum can't be used to harness, essentially arbitrary quantumness? Why do we rely on formalism similar to spins for extending to the CV setting?; Next, working on the numerical simulations. It's going good. About to simulate the schrodinger equation in a very simple case. Then we'll see the bohmian trajectory for a single particle!; In practice however, I am running into issues with attempting to simulate the schrodinger equation. The point is that $\dot{\psi}$ is needed at arbitrary q and that's not possible without interpolating $\nabla^2\psi(q)$.
- [misc.] talked to dad after a long time, started making philosophy notes on the computer now

Part II
Appended Topics

1 The Thesis Problem - Non locality and Contextuality

1.1 Definition

The following has been taken from an email written to Ali Assadian.

[background]

As you know, in the GHZ test, one is able to show that determinism can't hold. However, this is done using spins. How this is handled in Bohmian Mechanics (BM) has been discussed already[2]. It is not in direct contradiction with BM because spins are not treated like (q,p). In BM, (q,p) are well defined, just that we can't observe them. However, spins in BM are only a property of the wavefunction and not postulated to have well defined 'values' like (q,p). Thus, while it is interesting to see how BM handles being deterministic and consistent with GHZ, it's not too surprising to see it work, since spins aren't assumed deterministic like (q,p).

[thesis problem]

Do you recall the GHZ paper that had been extended to continuous variables? The point was that this particular approach showed that there can't be determinism for (q,p). However, BM seems to be an example that does precisely this. How can this be? It is precisely this that I intend to explore in my thesis. If BM's predictions differ from QM, then we at once have a wonderful test to find which theory is correct. If the predictions match, as is more likely, we'll be closer to answering to atleast two important questions. (1) Which extra assumption goes into the GHZ like tests which is unaccounted and (2) How contextuality emerges from non-locality, especially in continuous variables.

[future scope]

Ofcourse, a more ambitious goal would be to look at your results [1] on contextuality in continuous variables and use BM to understand the relation of non locality with it more directly. Perhaps if I have enough time, I'll pursue that as well. The one question which I still haven't an answer to is the following: How is it that, while formally in QM, spins and (q,p) are handled very similarly, why can't we extend BM in a manner to include spins as 'deterministic' as are (q,p)? I would like to either find such a formulation or show that it doesn't exist. This is of great interest for this answer must depend on the fundamental difference between spins and (q,p) as properties. The thesis problem is a step in this direction.

1.2 Breakup

1. Numerical Analysis
   (a) Bohmian Basics
      i. Simulate a free particle. Start with say a guassian wavefunction and take the initial positions to be accordingly distributed.
      ii. Simulate a harmonic oscillator. Use the previous step, except now with a harmonic oscillator potential. The gaussian should oscillate nicely. Once that's confirmed, then check the trajectories.
      iii. Simulate a squeezed state.
      iv. Tunnelling perhaps?
      v. S,P orbitals, trajectories (interesting by themselves!)
   (b) Bohmian Advanced
      i. Simulate a two particle state.
      ii. Simulate stern gerlach
      iii. Simulate the GHZ experiment using Ref. [2]
2. Analytic Work
   (a) Bohmian Mechanics
      i. Quantum Theory of trajectories, Holland [todo: add reference] (depth-read chapter n, 50% depth-read chapter n+1)
      ii. Bohm's original paper [todo: add reference] (70% depth-read paper 1)
      iii. Measurements [3] (float-read)
      iv. Spins, Stern Gerlach [3] (float-read)
   (b) Bell, GHZ test etc. from the Bohmian perspective [2]
   (c) GHZ test in continuous variables [4] (careful-read, during summers)
   (d) Construct an experiment in BM to perform the GHZ test; check predictions

References

[1] Ali Asadian, Costantino Budroni, Frank E. S. Steinhoff, Peter Rabl, and Otfried Gühne, *Contextuality in phase space*, Phys. Rev. Lett. **114** (2015), 250403.

[2] Thomas Durt and Yves Pierseaux, *Bohm's interpretation and maximally entangled states*, Phys. Rev. A **66** (2002), 052109.

[3] Detlef Dürr, Sheldon Goldstein, and Nino Zanghì, *Quantum physics without quantum philosophy*, Springer Berlin Heidelberg, 2012.

[4] Serge Massar and Stefano Pironio, *Greenberger-horne-zeilinger paradox for continuous variables*, Phys. Rev. A **64** (2001), 062108.