National Institute of Physics
Management Team
Terminal Report for the Theoretical Physics Research Group
Period covered: 01 January 2015 to 31 December 2015

Prepared by:

Jose Perico Esguerra
Program Coordinator
Date Submitted: 22 January 2016

I. Executive Summary

A. Activities of the Research Group

1. Organization
   a. Group Members
      Regular members: 5
      Student members: 54
      Adjunct Researchers: 0
   b. Apprentices (NIP students): 11

2. Mentoring
   Number of Graduates
   BS Physics: 7
   BS Applied Physics:0
   MS Physics: 4
   MS MSE: 0
   PhD Physics: 3
   MS MSE: 0

B. Research Highlights (Indicate number of publications/ patents/ research travels)

1. Number of papers published/accepted for publications in international peer-reviewed journals (ISI/SCI and Scopus-listed journals) : 10
2. Number of papers published in local journals (non-ISI/non-SCI, e.g. Science Diliman): 0
3. Number of international conference papers (with full paper in print proceedings): 2
4. Number of international conference presentations (WITHOUT full paper (i.e., short abstract only)):0
5. Numbers of local conference papers: With full paper (in print proceedings, e.g. SPP-Congress) and Without full paper (e.g. NRCP-ASM): 22
6. Number of chapters in books :0
7. Number of patents:0
8. Number of NIP funded projects: 3
9. Number of non-NIP funded projects: 2
10. Number of major equipment acquired/ upgraded: 1
11. Number of research travels abroad (Outbound): 3
12. Number of visiting researchers (Inbound): 1
13. Number of MOA's entered with local or foreign institutions and other external collaborators:0

C. Extension Work Highlights

1. Number of Extension Work Activities: 5
2. Number of Research Interns/ OJT's (Non-NIP), for trainings held at NIP: 6

D. Main Challenges Encountered and Proposed Solutions
(Brief Description: 2 to 3 sentences)

E. Awards or Accreditations Received / Positions of Responsibility Held and Other Accomplishments

1. Number of nat'l awards or accreditations received, positions of responsibility held: 2
2. Number of int'l awards or accreditations received, positions of responsibility held: 0
3. Other Accomplishments: 3

II. Technical Report

A. Activities of the Research group

The Theoretical Physics Group started 2015 with three PhD faculty sharing research supervision responsibilities for approximately sixty students. The return of Dr. Roland Caballar from his post-doctoral stint in South Africa boosted the number of PhD faculty members of the group. The total number of students graduated is 14 (7BS, 4MS, and 3 PhD) – two students graduated magna cum laude. Students from the group earned the following distinctions: Most Outstanding PhD graduate of NIP (Kristian Hauser Villegas) Another two (2) BS students successfully defended their undergraduate thesis but have not yet graduated. Eight (8) journal articles have been published in ISI/Thomson-Reuters indexed journals while two (2) more journal articles were accepted in 2015 for publication in 2016 issues of ISI/Thomson-Reuters indexed journals. As in previous years, the group continued to serve as a host for research exposure activities of students from the Philippine Science High School (PSHS) System and the Polytechnic University of the Philippines. It is worth noting that one of the journal papers published originated from the summer internship of two PSHS students. The number of conference papers and presentations for the year totalled twenty-four (24). Two projects funded by non-NIP agencies partly funded the group's research efforts. The anticipated appointment of Ian Vega in 2016 is expected to boost the group's capacity to perform and supervise research in gravitational physics.

1. Organization

a. Group Members

List of Group Members as of December 1, 2015:

Regular members (Faculty/ REPS) (4):

1. Jose Magpantay-Professor
2. Jose Perico Esguerra-Professor
3. Eric Galapon-Professor
4. Roland Caballar-Assistant Professor
5. Kristian Hausser Villegas – University Researcher

Student members (B3, B4, B5 /M1, M2 /P1, P2, P3):

BS Students:

B3:

1. Mark Ivan Ugalino
2. John Jaykel Magadan
3. Jan Carlo Lima

B4:

1. Daniel Paningbatan
2. Joseph Isaiah Miralles
3. Philip Christopher Cruz
4. Ezron John Dy Cabrera
5. Philip Caesar Flores

B5:

1. Bernard Ramos
2. Daniel Marquez
3. Gabriel Luis Dizon
4. Sean Julian Fortuna
5. Ace Santos
6. Allan Presbitero
7. Angelo Marco Ramoso
8. Jan-Derrick Junio
9. Jane Bernadette Denise Garcia
10. Art Graeson B. Dumigpe
11. Christian Tica
12. Jervic Lexter Perlas
13. Martin Francis Bartolome

MS Students:

M1:

1. Bimbo Alexis Galit
2. Janforth Daniel Cantor
3. John Adrian Villanueva
4. Reginald Christian Bernardo

M2:

1. Cilicia Uzziel Perez
2. James Vance
3. Jan Tristram Acuna
4. Mary Madelynn Nayga
5. Noel Lamsen
6. Noel Vargas
7. Carlo Vincenzio Dajac
8. Leodegario Lorenzo
9. Wilar Tan
10. Niel Laurent Caidic
11. Pecier Paul Decierdo
12. Anton Hilado

13. Efraim David
14. Janus B. Advincula

PhD Students:

P1:

1. Miguel Antonio Fudolig
2. Raiseth John Fajardo

P2:

1. Diane Caneso
2. Jeffrey Tare
3. Kendrick Agapito
4. Philip Jordan Blancas
5. Vladimir Villegas
6. Bienvenido M. Butanas

P3:

1. Bhazel Anne Rara Pelicano
2. Denny Lane B. Sombillo
3. Marvin Flores
4. Roberto Vitancol
5. Herbert Domingo

b. Apprentices (NIP)

1. Karl Simon Revelar
2. Jezreel Castillo
3. Ronaldo Medina
4. Dave Didal
5. John Ian Kenneth Felismino
6. Jeric Garrido
7. Adrian Orlando Hermo
8. Kimver Louie Nunez
9. Alnasher Sarail
10. Marc Christian Perez
11. Phillip John Sta. Ana

c. Summary

		Number
Regular Members		5
Student Members		
	B3 (Physics/Appl. Physics)	3
	B4	5
	B5	13
	M1 (Physics/ MSE)	4
	M2	14
	P1 (Physics/ MSE)	2
	P2	6
	P3	5
	Total no. of regular members and student members:	57
Adjunct Researchers		0
Apprentices (NIP)		11

2. Mentoring

a. List of Graduates (2015)

2nd sem 2014-2015

BS Physics

John Adrian N. Villanueva
BS Thesis: LEPTONIC DECAY WIDTH OF Z0 BOSON WITH SECOND-ORDER RADIATIVE CORRECTIONS
Adviser: Jose Perico Esguerra

Janforth Daniel G. Cantor
BS Thesis: TREE LEVEL CALCULATION FOR THE LEPTONIC DECAY OF THE J/psi MESON
Adviser: Jose Perico Esguerra

Reginald Christian S. Bernardo (magna cum laude, and Best Thesis awardee)
BS Thesis: BOUND STATES, QUANTUM SCATTERING, AND DYNAMICS IN ONE-DIMENSIONAL SYSTEMS WITH MINIMAL LENGTH
Adviser: Jose Perico Esguerra

Bimbo Alexis B. Galit
BS Thesis: BOUND STATE ENERGIES OF AN ELECTRON IN A CANTOR SUPERLATTICE
Adviser: Jose Perico Esguerra

Macliing Gabriel Q. Aydinan (magna cum laude, and Most Oustanding BS Physics Graduate Awardee)
BS Thesis: 2D PERSISTENT RANDOM WALK WITH VARIABLE STEP LENGTH
Adviser: Jose Perico Esguerra

Jose Alejandro G. Ordonez
BS Thesis: CALCULATIONS FOR UPSILON DECAY INTO THREE GLUONS USING QCD FEYNMAN RULES
Adviser: Jose Perico Esguerra

MS Physics

Miguel Antonio Fudolig, MS Physics
MS Thesis: Discrete and Continuous-time Dynamics of Systems Driven by Elephant Walk Noise
Adviser: Jose Perico Esguerra

Marinel Palangao
MS Thesis: Quantum Phase Shifts and Interference Effects in Multisolenoidal and Multitoroidal Systems
Adviser: Jose Perico Esguerra

John Paul Besagas
MS Thesis: Weak Measurement of the Kinetic Energy and Potential Energy of the Quantum Harmonic Oscillator
Adviser: Eric Galapon

Raiseth Fajardo
MS Thesis: Resummation of Asymptotic Series and Non-Asymptotic Scales
Adviser: Eric Galapon

PhD Physics

Kristian Hausser Villegas, PhD Physics
Doctoral Dissertation: Lattice Gauge Theory in Curved Spacetime
Adviser: Jose Perico Esguerra

Mid-year 2015

PhD Physics

Joseph Raphael Bunao
Doctoral Dissertation: Relativistic Quantum Time of Arrival Operators
Adviser: Eric Galapon

1st sem 2015-2016

BS Physics

Jan-Derrick Junio
BS Thesis: Evolution of Systems of One-Dimensional Ideal Gases Bounded by Conservative and Dissipative Boundaries
Adviser: Jose Perico Esguerra

PhD Physics Denny Lane Sombillo Doctoral Dissertation: Generalization of Particle Arrival and the Application of the Quantum Operator Formalism in the Tunnelling Time Problem Adviser: Eric Galapon

b. Summary

Course	2nd sem (AY2014-15)	Mid-year (AY2014-15)	1st sem (AY 2015-16)	Total
BS Physics	6	0	1	7
BS Applied Physics	0	0	0	0
MS Physics	4	0	0	4
MS MSE	0	0	0	0
PhD Physics	1	1	1	3
PhD MSE	0	0	0	0

B. Research Highlights (publications/ patents/ research travels)

1. List of papers published/accepted for publications in international peer-reviewed journals (ISI/SCI indexed (and other Scopus-listed peer-reviewed journals)) (8 + 2)

Published in 2015

1. Kristian Hauser Villegas, Jose Perico Esguerra. 2015, “Lattice gauge theory and gluon color-confinement in curved spacetime.” *Modern Physics Letters A* 30: 1550020 (10 pp), DOI: 10.1142/S0217732315500200

2. R.C. Bernardo, J.P. Esguerra, J.D. Vallejos, J.J. Canda. 2015. “Wind-influenced projectile motion.”*Eur.J. Phys.* 36:025016(9pp), doi:0.088/0143-0807/36/2/ 025016

3. R.C. Bernardo, J.P.Esguerra. 2015. “Exactly solvable dynamical models with a minimal length uncertainty.” *Few-BodySystems* 56:219–229, DOI 10.1007/s00601-015-0978-8

4. K.H.Villegas. 2015. “Spatial structures of QCD pair condensates at various densities.” *PHYSICAL REVIEW C* 91, 065209, DOI: 10.1142/S0217732315500200

5. HB Domingo, EA Galapon. 2015. “Generalized Weyl transform for operator ordering: Polynomial functions in phase space.” *J. Math. Phys*. 56, 022104, doi: 10.1063/1.4907561

6. Joseph Bunao, Eric A Galapon. 2015. “A one-particle time of arrival operator for a free relativistic spin-00 charged particle in (1+1)

dimensions.” *Annals of Physics* 353, 83–106, doi:10.1016/j.aop.2014.11.003

7. MM Flores, EA Galapon. 2015. “Two qubit entanglement preservation through the addition of qubits.” *Annals of Physics* 354, 21–30, doi:10.1016/j.aop.2014.11.011

8. Joseph Bunao, Eric A Galapon. 2015. “A relativistic one-particle Time of Arrival operator for a free spin-1/2 particle in (1+ 1) dimensions.” *Annals of Physics*, 369-382 (2015)

Accepted for publication in 2015 and to be published in 2016:

1. Denny Lane B.Sombillo, Eric A.Galapon, Particle detection and non-detection in a Quantum time of arrival measurement, Accepted by *Annals of Physics* on 17 November 2015 for publication in a 2016 issue, doi:10.1016/j.aop.2015.11.008

2. Jan Tristram Acuña, Jose Perico Esguerra, Dynamics of a planar thin shell at a Taub–FRW junction, accepted by *International Journal of Modern Physics D* on 16 August 2015 for publication in a 2016 issue, DOI: 10.1142/S0218271816500012

2. List of papers published in <u>local journals</u> (non-ISI/non-SCI) (0)

None

3. List of <u>international conference papers</u> (with full paper in print proceedings) (4)

J.D.Tare, J.P.H.Esguerra. 2015. “Space fractional Schrödinger equation for a quadrupolar triple Dirac δ-potential: Central Dirac- δ well and barrier cases.” In “*Proceedings of the 7th Jagna International Workshop "Analysis of Fractional Stochastic Processes: Advances and Applications.*" Bohol, Philippines, 6-9 January 2014. International Journal of Modern Physics: Conference Series 36, 1560014 (5 pages). Singapore: World Scientific.

M.M.I. Nayga, and J.P.H. Esguerra. 2015. “Levy path integral approach to the fractional Schrodinger equation with delta-perturbed infinite square well.” In *“Proceedings of the 7th Jagna International Workshop "Analysis of Fractional Stochastic Processes: Advances and Applications."* Bohol, Philippines, 6-9 January 2014. International Journal of Modern Physics: Conference Series, Vol. 36 (2015) 1560015 (5 pages). Singapore: World Scientific.

M.T.Lim, J.P.H.Esguerra. 2015. “Growing the physics community in the Philippines in a changing landscape.” In *WOMEN IN PHYSICS: 5th IUPAP International Conference on Women in Physics*. Waterloo, Canda, 5-8 August 2014. AIP Conf. Proc. 1697, 060037 (2015); http://dx.doi.org/10.1063/1.4937684

R. C. F. Caballar, I. Sinayskiy and F. Petruccione. 2015. “Homogeneous open quantum walks on a line.” In *Proceedings of SAIP 2014* (2015) (6 pages)

Author of Paper, A., and B. Author of Paper. Year. "Title of Paper." In *Title of Published Proceedings: Subtitle of Conference*, Location, Date, inclusive page numbers (or article number). Place of publication: Publisher.

4. List of international conference presentations (WITHOUT full paper (i.e., short abstract only) (0)

None

5. List of local conference papers

(With full paper in print proceedings) (23)

1. JAN Villanueva, JP Esguerra. 2015. "Second-Order Z Boson Leg Loop Corrections in the Decay of Z Boson to Leptons." In *Proceedings of the Samahang Pisika ng Pilipinas: 33rd Physics Congress, Vigan City, June 3-6,* SPP2015- 2B-2

2. JBDM Garcia, JPH Esguerra. 2015. "Moments of the Steady-State Wealth Distribution in a Boltzmann-Type Kinetic Model of Gambling." In *Proceedings of the Samahang Pisika ng Pilipinas: 33rd Physics Congress, Vigan City, June 3-6,* SPP2015- 2B-5

3. JN Vance, JPH Esguerra. 2015. "Longitudinal diffusion of chiral active Brownian swimmers confined in narrow channels." In *Proceedings of the Samahang Pisika ng Pilipinas: 33rd Physics Congress, Vigan City, June 3-6,* SPP2015-5C-2

4. JTA Acuña, JPH Esguerra. 2015. "Scattering of a massless scalar field by a wormhole background." In *Proceedings of the Samahang Pisika ng Pilipinas: 33rd Physics Congress, Vigan City, June 3-6,* SPP2015-5C-5

5. MMI Nayga, JPH Esguerra. 2015. "Bound state energies for single and double Dirac delta well via path integration and perturbation expansion in space-fractional quantum mechanics." In *Proceedings of the Samahang Pisika ng Pilipinas: 33rd Physics Congress, Vigan City, June 3-6,* SPP2015-5C-8

6. RCS Bernardo, JPH Esguerra. 2015. "Energy levels of a quantum particle on a corrugated tube in a uniform electric field." In *Proceedings of the Samahang Pisika ng Pilipinas: 33rd Physics Congress, Vigan City, June 3-6,* SPP2015-PB-43

7. MAD Fudolig, JPH Esguerra. 2015. "Discrete Time Elephant Walk Noise: A Noise Process with Full Memory." In *Proceedings of the Samahang Pisika ng Pilipinas: 33rd Physics Congress, Vigan City, June 3-6,* SPP2015-PB-49

8. J,I, Alvarez, AKC Bendicio. 2015. "Partonic Cross Section for Muon Pair Hadroproduction with Higgs Boson Mediator." In *Proceedings of the*

Samahang Pisika ng Pilipinas: 33rd Physics Congress, Vigan City, June 3-6, SPP2015-PA-47

9. AKC Bendicio. 2015. "Higgs Pair Production via Graviton in the Randall - Sundrum Model at 13 TeV." In *Proceedings of the Samahang Pisika ng Pilipinas: 33rd Physics Congress, Vigan City, June 3-6,* SPP2015-PA-50

10. CG Dajac. 2015. "Human traffic during MRT evacuation." In *Proceedings of the Samahang Pisika ng Pilipinas: 33rd Physics Congress, Vigan City, June 3-6,* SPP2015-PB-40

11. E. Galapon. 2015. "Divergent series just got more convergent" (Sub-Plenary). In *Proceedings of the Samahang Pisika ng Pilipinas: 33rd Physics Congress, Vigan City, June 3-6,* SPP2015-2B-1

12. E Cabrera, E Galapon. 2015. "An information measure leading to highest energy state as the most probable state." In *Proceedings of the Samahang Pisika ng Pilipinas: 33rd Physics Congress, Vigan City, June 3-6,* SPP2015-2B-4

13. JPA Besagas, EA Galapon. 2015. "Weak measurement of the kinetic and potential energies of the quantum harmonic oscillator subject to a ground state pre-selection." In *Proceedings of the Samahang Pisika ng Pilipinas: 33rd Physics Congress, Vigan City, June 3-6,* SPP2015-3B-2

14. MM Flores, EA Galapon. 2015. "Separability criterion based on direct tensor product factorization." In *Proceedings of the Samahang Pisika ng Pilipinas: 33rd Physics Congress, Vigan City, June 3-6,* SPP2015-3B-6

15. JB Advincula, EA Galapon. 2015. "Quantum measurement with minimal state alteration." In *Proceedings of the Samahang Pisika ng Pilipinas: 33rd Physics Congress, Vigan City, June 3-6,* SPP2015-3B-4

16. JR Bunao, EA Galapon. 2015. "Time of arrival of free relativistic particles.".In *Proceedings of the Samahang Pisika ng Pilipinas: 33rd Physics Congress, Vigan City, June 3-6,* SPP2015-5C-1

17. PCM Flores, EA Galapon. 2015. "The resolvent operators of the conned time of arrival operators." In *Proceedings of the Samahang Pisika ng Pilipinas: 33rd Physics Congress, Vigan City, June 3-6,* SPP2015-5C-6

18. A Dumigpe, EA Galapon. 2015. "Effect of increasing spin in the fidelity of quantum communication through a tripartite spin chain." In Proceedings of the Samahang Pisika ng Pilipinas: 33rd Physics Congress, Vigan City, June 3-6, SPP2015- PA-45

19. DLB Sombillo, EA Galapon. 2015. "Finite square well with a time varying distortion: Application of the Wei-Norman Factorization." In Proceedings

of the Samahang Pisika ng Pilipinas: 33rd Physics Congress, Vigan City, June 3-6, SPP2015-PA-49

20. RJT Fajardo, AB Hilado, EA Galapon. 2015. “Extracting accurate numerical approx imations from divergent integrals via “superasymptotic” integration.” In *Proceedings of the Samahang Pisika ng Pilipinas: 33rd Physics Congress,* Vigan City, June 3-6, SPP2015-PA-51

21. RJT Fajardo, EA Galapon. 2015. “Resummation on the Poincare asymptotic expansion of the Hankel Integral via Borel summation.” In *Proceedings of the Samahang Pisika ng Pilipinas: 33rd Physics Congress,* Vigan City, June 3-6, SPP2015- PB-44

22. PJD Blancas, EA Galapon. 2015. “Quantum cloaking of a hard sphere.” In *Proceedings of the Samahang Pisika ng Pilipinas: 33rd Physics Congress,* Vigan City, June 3-6, SPP2015-PB-45

(WITHOUT full paper) (0)

None

6. List of <u>chapters in books</u> (0)

None

7. List of patents (0)

None

8. List of NIP funded projects (3)

Project Leader	Title	Period
Jose Perico Esguerra	Moments of the steady state wealth distribution associated with a Boltzmann type kinetic model of gambling	1 January 2015 – 31 December 2015
Eric Galapon	Simultaneous Weak Measurement of Kinetic and Potential Energy of Harmonic Oscillator	
Roland Caballar	Quantum corrections for ultracold atoms used as quantum clocks	1 June 2015 – 31 December 2015

9. List of non-NIP funded projects (2)

Project Leader	Title	Period/ Phase no.	Amount
Eric Galapon	The effect of spin dimensionality in a homogeneous spin-chain quantum channel	January 1, 2015 to March 31, 2016 OVCRD Grant 141408PNSE	P300,000

Eric Galapon	Asymptotic Expansions by Non-Asymptotic Scales	September 1, 2015 to Dec 31, 2016 ECWRG 2015-2-060	P600, 000

10. List of major equipment acquired/ upgraded (1)

Equipment and description	Cost	Mode of Acquisition (Specific funds/ donations)	Project Leader
1 Desktop Computer	P 50,000	Grant	Eric Galapon

11. List of research travels abroad by NIP faculty/ REPS and student researchers (Outbound) (3)

Name of NIP Personnel	Purpose	Place	Dates	Mode of Exchange (Personal, or covered with MOA, etc)
Carlo Vincienzo Dajac	2015 NTU-Warwick Winter School	Nanyang Technological University, Singapore	February 23 to 27, 2015	Personal
Uzziel Perez	CERN Summer School 2015 (Non-Member States Summer Student)	European Organization for Nuclear Research (CERN), Geneva, Switzerland	June 29 to August 21, 2015	Personal but facilitated through contacts established through the UP Diliman – CMS collaboration MOA
Denny Lane Sombillo	9th International Conference on Computational Physics (ICCP9)	National University of Singapore	January 7 to 11, 2015	Personal

12. List of visiting researchers (Inbound) (1)

Name of Visitor(s)	Purpose/ Duration of visit	NIP Personnel/ Contact person	Mode of Exchange (Personal or covered MOA, Visiting Professor Program, etc.)
Marco Mariola	Present talks and discuss possibility of collaboration	Roland Caballar	Personal

	with NIP researchers, November 9 to 13, 2015		

13. List of MOA's entered with local or foreign institutions and other external collaborators (0)

Name of Institution(s) and Other External Collaborator(s)	MOU's / MOA's indicating Title of Research and Duration	NIP Personnel/ Contact person	Remarks: (Indicate research outputs or activities)
None			

C. Extension Work Highlights

1. List of Extension Work Activities [*Activities (e.g., trainings, workshops, etc held outside the NIP) conducted for Non-UP clients; Gov't appointments (e.g., NRCP, DOST, etc); and, other involvements based on UP-NIP research expertise] (4)

Extension Work and Gov't appointments (Brief description; and Duration, dates)	Name of beneficiary person(s) or organization/ community	NIP Personnel/ Contact person	Remarks: (Indicate if covered by MOA, project, etc.)
Referee (European Journal of Physics)	Institute of Physics (UK)	Jose Perico Esguerra	
Referee (Physical Review A)	American Physical Society	Eric Galapon	
Member, SPP Editorial Board (Theoretical Physics, Computational Physics, Physics Education)	Samahang Pisika ng Pilipinas	Jose Perico Esguerra	
Member, SPP Editorial Board (Theoretical Physics, Quantum mechanics)	Samahang Pisika ng Pilipinas	Roland Caballar	
Judge, National Science and Technology Fair	Department of Education	Jose Perico Esguerra	

2. List of Research Interns/ OJT's (Non-NIP), for trainings held at NIP

Name	School/ Organization	Program; and Duration, dates	NIP Personnel/ Contact person	Remarks: (Indicate if covered by MOA, project, etc.)
Floro Junior C. Roque	PUP	April 13 to May 26, 2015	Jose Perico Esguerra	UP Diliman – PUP MOA and OJT agreement
Nephi Casa	PUP	April 13 to May 26, 2015	Eric Galapon	UP Diliman – PUP MOA and OJT agreement
Nicole Respecia (PSHS-EVC, Leyte)	PSHS-CVisC, Cebu	June 17 to July 8, 2015	Jose Perico Esguerra	NIP--PSHS Science Internship Program (MOU)
Stephanie Mae Abrenio	PSHS-EVC, Leyte	June 17 to July 8, 2015	Jose Perico Esguerra	NIP--PSHS Science Internship Program (MOU)
Johann Cris Pillejera	PSHS-BRC, Bicol	June 17 to July 8, 2015	Jose Perico Esguerra	NIP--PSHS Science Internship Program (MOU)
Aaron dela Cruz	PSHS-Main	June 17 to July 8, 2015	Eric Galapon	NIP--PSHS Science Internship Program (MOU)

D. Main Challenges Encountered and Proposed Solutions

Main Challenges Encountered (Brief description)	Proposed Solutions
High advisee to adviser ratio	Recruitment of additional tenure track faculty and encouragement of students to explore the possibility of performing research along the line of expertise of the new tenure track faculty
Research students "orphaned" by the termination of appointment of their thesis/research supervisor	Reassign students to other faculty members within the group

E. Awards or Accreditations Received / Positions of Responsibility Held (e.g., as SPP officer, journal editorship, etc) and Other Accomplishments

National (2)

Name of NIP Personnel	National Award or Accreditation, Positions of Responsibility Held (with brief description)	Award-giving body/ Organization
Jose Perico Esguerra	Member, Technical Committee for Physics	CHED
Eric Galapon	Senior Councilor, SPP National Council	SPP

International (0)

Name of NIP Personnel	Int'l Award or Accreditation, Positions of Responsibility Held (with brief description)	Award-giving body/ Organization
None		

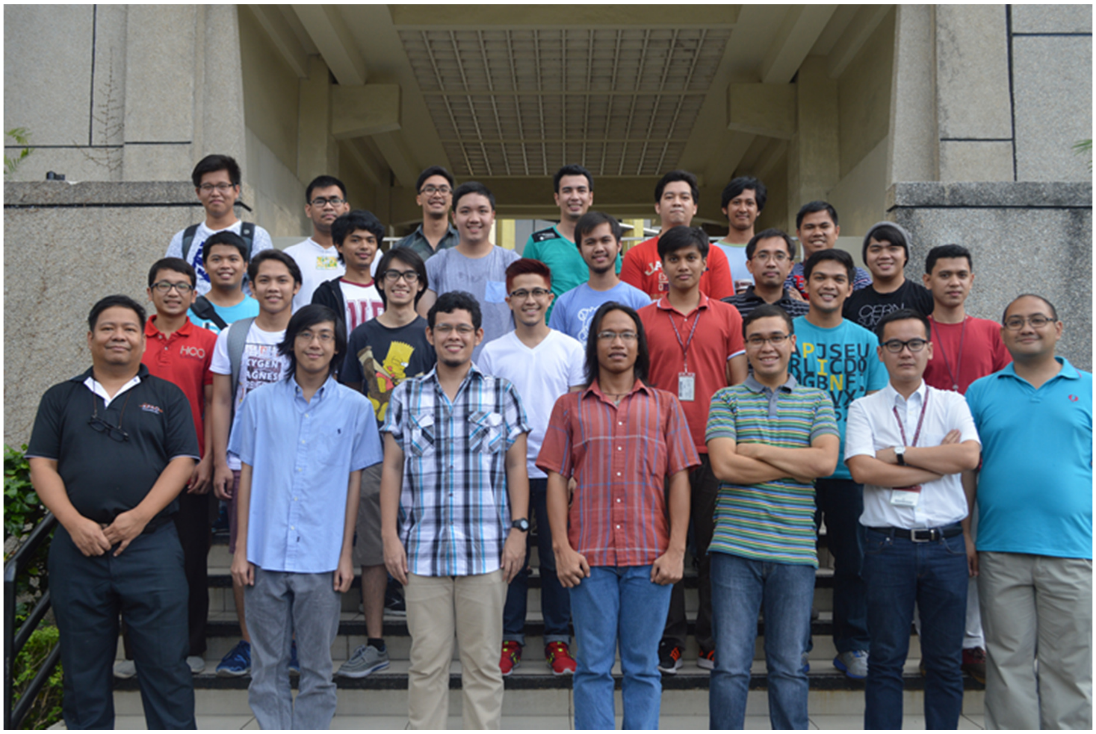
Other Accomplishments:

Name of NIP Personnel	Other Accomplishments	Date and Place
Kristian Hauser Villegas	Most Outstanding PhD Physics Graduate of the National Institute of Physics	June 2015, NIP, UP Diliman
Macliing Gabriel Aydinan	Most Outstanding BS Physics Graduate of the College of Science (Joker Arroyo Award 2015)	June 2015, College of Science, UP Diliman
Reginald Christian Bernardo	Best BS Physics Thesis (Leticia Shahani Award 2015)	June 2015, College of Science, UP Diliman

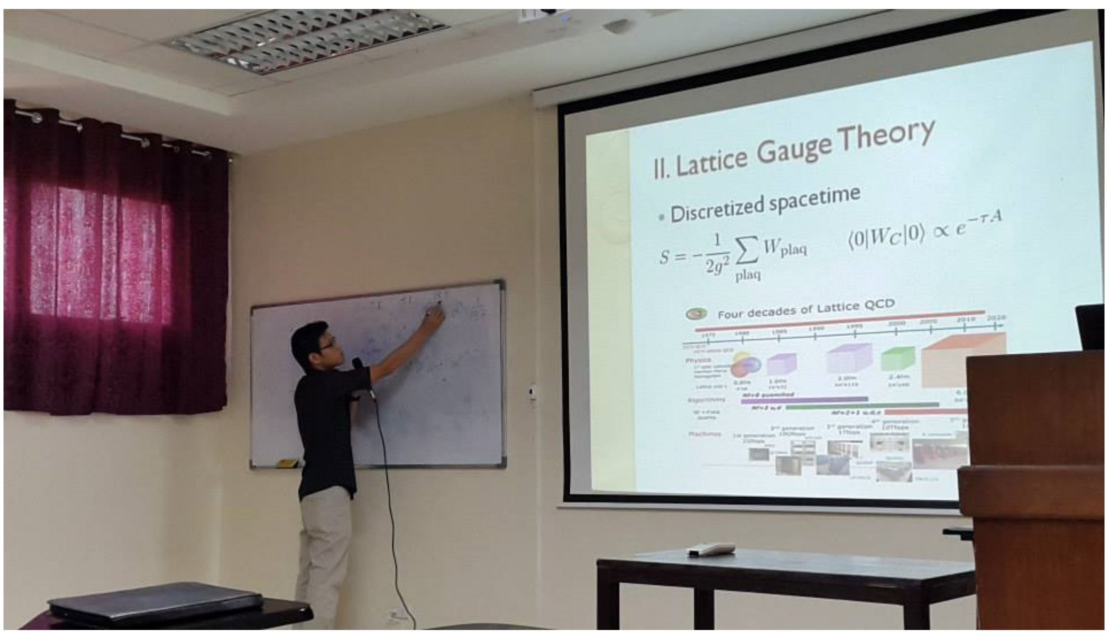
III. Photos, ISI/SCI publications and Other Appendices

A. Photos

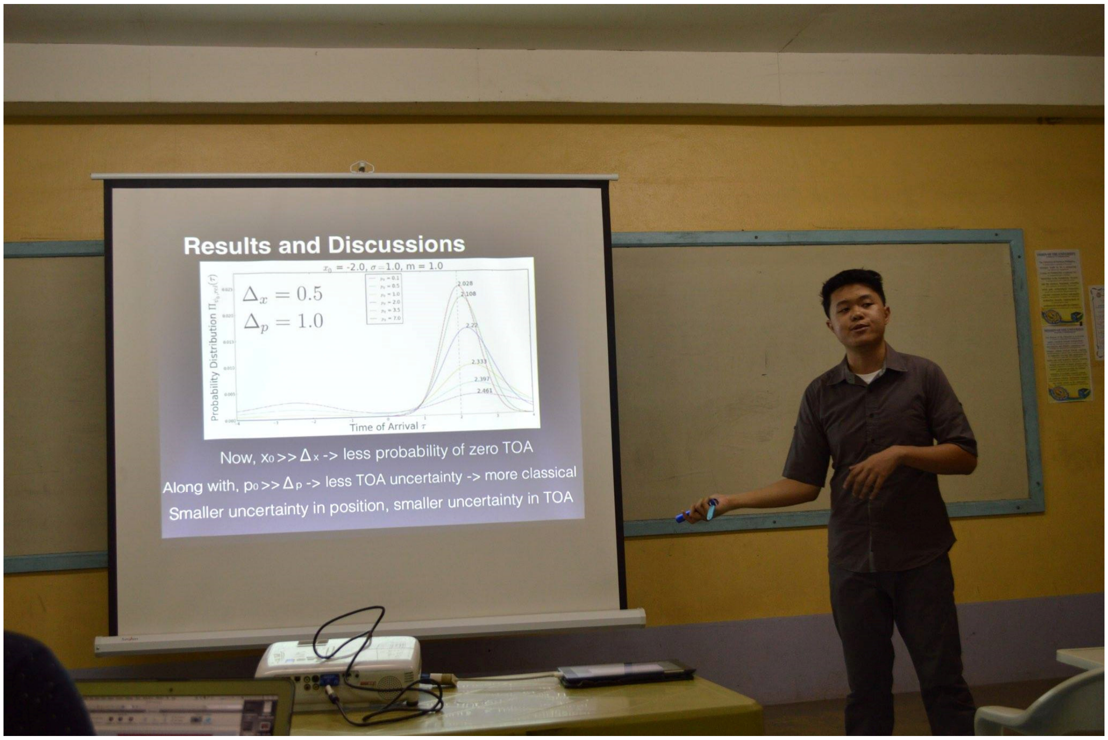
Principal Investigators of the Theoretical Physics Group
From left to right: Jose Magpantay (Professor), Eric Galapon (Professor). Jose Perico Esguerra (Professor and Coordinator), Roland Caballar (Assistant Professo), Francis Ian Vega (expected to join the group in 2016 as an Assoociate Professor)



Dr. Esguerra and Dr. Caballar with students and apprentices of the Theoretical Physics Group



Kristian Hauser Villegas responding to a question in a Graduate Colloquium of the College of Science. Hauser graduated PhD (Physics) in the 2nd Semester of AY 2014-2015 and was recognized as NIP's Outstanding PhD Graduate of AY 2014-2015.



Joseph Bunao presenting his research at the SPP Physics Congress held in the University of Northern Philippines, Vigan. Joseph graduated PhD(Physics) in the MidYear Term of 2015.

B. ISI/SCI publications

Summary of Attachments

Attachment B1: Kristian Hauser Villegas, Jose Perico Esguerra. 2015, “Lattice gauge theory and gluon color-confinement in curved spacetime.” Modern Physics Letters A 30: 1550020 (10 pp), DOI: 10.1142/S0217732315500200
Attachment B2: R.C. Bernardo, J.P. Esguerra, J.D. Vallejos, J.J. Canda. 2015. “Wind-influenced projectile motion.”Eur.J. Phys. 36:025016(9pp), doi:0.088/0143-0807/36/2/ 025016
Attachment B3: 3. R.C. Bernardo, J.P.Esguerra. 2015. “Exactly solvable dynamical models with a minimal length uncertainty.” Few-BodySystems 56:219–229, DOI 10.1007/s00601-015-0978-8
Attachment B4: K.H.Villegas. 2015. “Spatial structures of QCD pair condensates at various densities.” PHYSICAL REVIEW C 91, 065209, DOI: 10.1142/S0217732315500200
Attachment B5: HB Domingo, EA Galapon. 2015. “Generalized Weyl transform for operator ordering: Polynomial functions in phase space.” J. Math. Phys. 56, 022104, doi: 10.1063/1.4907561
Attachment B6: Joseph Bunao, Eric A Galapon. 2015. “A one-particle time of arrival operator for a free relativistic spin-00 charged particle in (1+1) dimensions.”Annals of Physics 353, 83–106, doi:10.1016/j.aop.2014.11.003
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Lattice gauge theory and gluon color-confinement in curved spacetime

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The lattice gauge theory (LGT) for curved spacetime is formulated. A discretized action is derived for both gluon and quark fields which reduces to the generally covariant form in the continuum limit. Using the Wilson action, it is shown analytically that for a general curved spacetime background, two propagating gluons are always color-confined. The fermion-doubling problem is discussed in the specific case of Friedman–Robertson–Walker (FRW) metric. Last, we discussed possible future numerical implementation of lattice QCD in curved spacetime.

Keywords: Lattice QCD; confinement; QFT curved spacetime.

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1. Introduction

There are several reasons for studying QCD in curved spacetimes. One is the possibility of the existence of dense quark matter at the core of a neutron star.[1] Although perturbative QCD works well at very high densities (large quark chemical potential μ) where the quark matter is predicted to be in color-flavor-locked phase (CFL),[2] we do not have the same confidence in the regime intermediate between the hadronic phase and the CFL phase (called non-CFL phase). In this regime, we expect a strongly coupled QCD. Further, due to the extreme density involved, the effects of spacetime curvature cannot be neglected. Hence, a proper treatment of this regime needs the full treatment of non-perturbative QCD method in curved spacetime. This is the major motivation of this work. We want a lattice QCD that is valid for curved spacetimes.

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Wind-influenced projectile motion

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Abstract

We solved the wind-influenced projectile motion problem with the same initial and final heights and obtained exact analytical expressions for the shape of the trajectory, range, maximum height, time of flight, time of ascent, and time of descent with the help of the Lambert *W* function. It turns out that the range and maximum horizontal displacement are not always equal. When launched at a critical angle, the projectile will return to its starting position. It turns out that a launch angle of 90° maximizes the time of flight, time of ascent, time of descent, and maximum height and that the launch angle corresponding to maximum range can be obtained by solving a transcendental equation. Finally, we expressed in a parametric equation the locus of points corresponding to maximum heights for projectiles launched from the ground with the same initial speed in all directions. We used the results to estimate how much a moderate wind can modify a golf ball's range and suggested other possible applications.

Keywords: projectile motion, wind, drag, Lambert *W* function

1. Introduction

Drag-free projectile motion is a touchstone example in introductory physics [1–4]. In this context, it is straightforward to obtain exact analytical expressions for the shape of the trajectory, range, launch angle corresponding to maximum range, time of ascent, time of descent, time of flight, and locus of points corresponding to maximum heights for projectiles launched with identical initial speeds in all directions.

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Exactly Solvable Dynamical Models with a Minimal Length Uncertainty

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Abstract We present exact analytical solutions to the classical equations of motion and analyze the dynamical consequences of the existence of a minimal length for the free particle, particle in a linear potential, anti-symmetric constant force oscillator, harmonic oscillator, vertical harmonic oscillator, linear diatomic chain, and linear triatomic chain. It turns out that the speed of a free particle and the magnitude of the acceleration of a particle in a linear potential have larger values compared to the non-minimal length counterparts - the increase in magnitudes come from multiplicative factors proportional to what is known as the generalized uncertainty principle parameter. Our analysis of oscillator systems suggests that the characteristic frequencies of systems also have larger values than the non-minimal length counterparts. In connection with this, we discuss a kind of experimental test with which the existence of a minimal length may be detected on a classical level.

1 Introduction

In 1995, Kempf et al. [18] proposed a modification of quantum mechanics that phenomenologically includes a minimal length, which is described as a minimal uncertainty in position measurements, through the generalized uncertainty principle (GUP) given by

$$\Delta X \Delta P \geq \frac{\hbar}{2}(1 + \beta(\Delta P)^2 + \beta\langle P\rangle^2) \tag{1}$$

where X is the position, P is the momentum, β is a positive constant called the GUP parameter. It has been suggested that a theory with the GUP can be used to describe nonpointlike particles such as molecules and nucleons [17,29] although interest in the GUP comes mostly from the fact that it arises from string theory [19,21–23], quantum geometry [9], and black hole physics [30]. Phenomenological investigation of quantum gravity effects have therefore been considered using the GUP [5–7,11,13–15,26,27]. It is worthwhile to consider the dynamical implications of the existence of a minimal length on systems because of suggestions that the Ehrenfest theorem is not valid when the GUP is considered [16,24,25]. These suggestions come from comparing quantum mechanics with the GUP with the usual classical dynamics and therefore need to be given further attention by considering a GUP modified classical dynamics. There have been relatively few investigations on the dynamical implications of the GUP [16,24,32] and a complete picture of the theory requires an analysis of time development.

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Spatial structures of QCD pair condensates at various densities

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The spatial structures of the chiral symmetry breaking(χSB)-quark-antiquark($q\bar{q}$) pair and two-color superconducting(2SC)-quark-quark(qq), antiquark-antiquark($\bar{q}\bar{q}$), and hole-hole(hh) pairs are investigated. At low density, it is found that the $q\bar{q}$ pair is well localized with average bond length of the order 1 fm. It is then suggested that the pions, which are excitations arising from flavor-space phase fluctuations, exhibit the spatial structure of the underlying $q\bar{q}$-paired ground state. At intermediate density where the quarks form a 2SC state, it is found that the qq and hh pairs are extended and oscillating in real space while the $\bar{q}\bar{q}$ pair remains well localized.

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I. INTRODUCTION

QCD at various densities involves various particle pairings inspired from superconductivity in condensed matter physics [1]. At low density, the pairing involves the chiral symmetry breaking (χSB)-$q\bar{q}$ pairs; while, at intermediate density, the quarks form a two-color superconduction (2SC) state and the pairing involves qq, hh, and $\bar{q}\bar{q}$. At high density, the quarks enter the color-flavor-locked (CFL) phase [2]. Due to asymptotic freedom, perturbation theory works well in this regime, which makes the CFL phase relatively well understood [3]. Following the Bardeen-Cooper-Schrieffer (BCS) wave function, it is usually easier to write down various QCD pairs in momentum basis. This, however, obscures the spatial structure of the pair.

One study that investigates the spatial structure of the quark pair is done in [4]. In this paper, the gap $\Delta(k)$ was solved from the gap equation and the pair wave function $\phi(r)$ was obtained as a Fourier transform of $\phi(k) = \frac{1}{2}\frac{\Delta(k)}{E'(k)}$. Although their solution did not rely explicitly on weak-coupling approximation, they nevertheless used the one-gluon exchange interaction whose justification involves the running of the coupling constants into the weak-coupling regime [5]. Hence their result should be reliable in CFL phase and in the neighborhood between CFL-2SC transition. The main difficulty in the regime below the CFL density is the strong-coupling character of the interaction. Unlike in the low density strong-coupling regime, lattice QCD is not fully helpful here due to the fermion sign problem [6]. Although it is well known that the Cooper pairs are extended and have huge overlap in real space [7], it is surprising that its detailed spatial structure is not well explored in literature even in condensed matter physics. The only papers that I am aware of that studied this are [8] for electron Cooper pair and [9] for neutron Cooper pair.

In this paper, I will investigate the spatial structures of the pair-wave functions for low and intermediate densities proposed in [10]. This pairing ansatz were able to successfully account many low-to-intermediate density properties and this can be taken as a strong indication of its validity even in the strong-coupling regime.

This paper is organized as follows. In the next section, the pairing ansatz that I will use is briefly reviewed. I will then investigate the spatial structure of $q\bar{q}$ pair in Sec. III and qq, $\bar{q}\bar{q}$, and hh pairs in Sec. IV. The concluding remarks will be given in Sec. V.

II. PAIR WAVE FUNCTIONS

In this section I will briefly review the pairing-ansatz proposed in [10]. An effective Hamiltonian with an interaction modelled from the instanton vertex [11] is used:

$$H_{\text{int}} = -K\epsilon^{kl}\,\Xi^{\alpha\beta}_{\gamma\delta}\int d^3x\,\bar{\Psi}_{1\alpha}\Psi^{\gamma}_{Lk}\bar{\Psi}_{2\beta}\Psi^{\delta}_{Ll} + \text{H.c.}, \qquad (1)$$

where $\Xi^{\alpha\beta}_{\gamma\delta} \equiv 3\delta^{\alpha}_{\gamma}\delta^{\beta}_{\delta} - \delta^{\alpha}_{\delta}\delta^{\beta}_{\gamma}$, the indices 1, 2, k, and l denote the flavor, the Greek letters denote the color, and Ψ_L means the projected Dirac field $P_L\Psi$.

To impose asymptotic freedom at large momenta, a phenomenological form factor $F(p) = (\frac{\Lambda^2}{p^2+\Lambda^2})^{\nu}$ is inserted after Eq. (1) is expanded in terms of momentum modes. The parameter Λ is taken to be around the QCD cut-off range 300−1000 MeV while the parameter ν characterizes the shape. Following [10], I choose the values $\nu = 1.0$ and $\nu = 0.5$.

Near zero density, the following trial wave function is chosen for a variational calculation

$$|\psi\rangle = \prod_{\mathbf{p},i,\alpha}\left[\cos\theta^L(\mathbf{p}) + e^{i\xi^L(\mathbf{p})}\sin\theta^L(\mathbf{p})a^{\dagger}_{Li\alpha}(\mathbf{p})b^{\dagger}_{Ri\alpha}(-\mathbf{p})\right] \times\left[\cos\theta^R(\mathbf{p}) + e^{i\xi^R(\mathbf{p})}\sin\theta^R(\mathbf{p})a^{\dagger}_{Ri\alpha}(\mathbf{p})b^{\dagger}_{Li\alpha}(-\mathbf{p})\right]|0\rangle, \qquad (2)$$

where θ and ξ are variational parameters, $a^{\dagger}_L(a^{\dagger}_R)$ creates left-handed(right-handed) quarks and $b^{\dagger}_L(b^{\dagger}_R)$ creates left-handed(right-handed) antiquarks.

This state involves pairing between quark and antiquark and breaks the chiral symmetry. Note that it is also common to discuss χSB in terms of the real-space order parameter $\langle 0|\bar{\Psi}(x)_L\Psi(x)_R + \bar{\Psi}(x)_R\Psi(x)_L|0\rangle$ [1,12]. Both of these approaches, however, describe the same

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Generalized Weyl transform for operator ordering: Polynomial functions in phase space

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The generalized Weyl transforms were developed from the Hermiticity condition and the ordering rules were represented by characteristic real-valued functions. The integral transforms give rise to transformation equations between Weyl quantization and differently ordered operators. The transforms also simplify evaluation of commutator and anticommutator of a set of operators following the same ordering rule. © *2015 AIP Publishing LLC.* [http://dx.doi.org/10.1063/1.4907561]

I. INTRODUCTION

Quantization remains to be the most available method for forming quantum operators corresponding to classical observables. Its usefulness is well-known.[1,2] Likewise, there is a widespread acquaintance with the different quantization rules[3–5] as well as with obstructions to quantization.[6–8] We want, in this paper, to direct our attention towards the different expressions of quantization rules and away from the multitude of obstruction issues, that is, to quantization as a practical tool and not to quantization as an object of investigation.

A simplistic approach to quantization can be operated by replacing the canonical variables by the canonical operators, a procedure which is not without defect. Any product of classical position and momentum variables can be replaced by a seeming infinity of possible ordering of corresponding operators. The search for the appropriate quantum image of a classical function is then tantamount to finding the best ordering rule for operators. Meanwhile, the choice for an ordering rule also depends on the algebra of the resulting operators, i.e., on the commutation and anticommutation relations.

An immediate impression gleaned from Refs. 9–13 would seem to suggest that an ordering rule can be mapped to a definite class of functions. To every known ordering rule, there exists an associated real-valued function $\Theta(x)$ such that $\Theta(0) = 1$. Weyl ordering corresponds to the unit function $\Theta(x) = 1$, the simplest symmetrization ordering rule corresponds to the cosine function $\Theta(x) = \cos(x/2)$, and the Born-Jordan ordering rule corresponds to $\Theta(x) = (2/x)\sin(x/2)$. These examples indicate how meaningful it is to devise an ordering rule by merely specifying a certain $\Theta(x)$. The associated functions $\Theta(x)$ appear as the possible kernels of a generalized Weyl transform, which was introduced in Refs. 11–13 as the kind of mapping that characterizes each operator ordering.

Under what assumptions can this association of ordering rules with ordinary functions hold? According to Refs. 12 and 13, if quantization is defined to be a mapping from the algebra of q, p-polynomials to the algebra of $\mathbf{q}, \mathbf{p}$-polynomials, four things are necessary.

(a) The classical variables q, p and the unit function in phase space are mapped into the canonical operators $\mathbf{q}$, $\mathbf{p}$ and the identity operator $\mathbf{I}$, respectively.

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A one-particle time of arrival operator for a free relativistic spin-0 charged particle in (1 + 1) dimensions

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ABSTRACT

We construct a one-particle TOA operator $\hat{\mathcal{T}}$ canonically conjugate with the Hamiltonian describing a free, charged, spin-0, relativistic particle in one spatial dimension and show that it is maximally symmetric. We solve for its eigenfunctions and show that they form a complete and non-orthogonal set. Plotting the time evolution of their corresponding probability densities, it implies that the eigenfunctions become more localized at the origin at the time equal to their eigenvalues. That is, a particle being described by an eigenfunction of $\hat{\mathcal{T}}$ is in a state of definite arrival time at the origin and at the corresponding eigenvalue. We also calculate the TOA probability distribution of a particle in some initial state.

1. Introduction

The notion of time is one of the problems obstructing the marriage of Einstein's General Theory of Relativity and Standard Quantum Mechanics into one framework of Quantum Gravity [1]. The two theories have a mutually incompatible treatment of time. For general relativity, time has a dynamic and intrinsic role in the evolution of the system being studied. For quantum mechanics, however, time is merely an extrinsic parameter marking the evolution of the system. The system does not affect it nor does it affect the system. This pessimistic view on time was prominent in the earlier days of quantum mechanics. The prevalent formulation was the von Neumann (standard) formulation of

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Two qubit entanglement preservation through the addition of qubits

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ABSTRACT

An entanglement preservation scheme is proposed by considering the exact evolution of an N-qubit interacting system in a common reservoir. We find that the steady-state concurrence is dependent only on the number of qubits, the qubit–reservoir coupling strength and the initial conditions of the system. Furthermore, we show that as $N \to \infty$, the initial entanglement between the two qubits is preserved.

1. Introduction

Entanglement is a fundamental property of quantum systems and serves as a resource in various quantum information processes. Some of its pioneering applications include quantum key distribution, quantum dense coding, quantum teleportation and quantum computation [1]. However it is so fragile and undergoes either an asymptotic decay or a sudden death [2–8]. This is due to decoherence, whereby the unavoidable interactions of the entangled system with its environments alter the quantum system, losing entanglement in the process [9,10]. In fact, the fragility of entanglement is the main reason recent researchers turned to quantum discord (another form of quantum correlation) as a resource for quantum computation [10,11].

Although it is known that there exist so-called decoherence-free (also known as subradiant) states whose initial entanglement is invariant over time when a bipartite system interacts with a common environment [12–14], any other initially entangled state not found within this decoherence-free subspace will inevitably lose its entanglement. Hence, a number of papers have been done regarding entanglement preservation and these could be classified under variants of two schemes [15], one which

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A relativistic one-particle Time of Arrival operator for a free spin-1/2 particle in (1 + 1) dimensions

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ABSTRACT

As a follow-up to a recent study in the spin-0 case (Bunao and Galapon, 2015), we construct a one-particle Time of Arrival (TOA) operator conjugate to a Hamiltonian describing a free relativistic spin-1/2 particle in one spatial dimension. Upon transformation in a representation where the Hamiltonian is diagonal, it turns out that the constructed operator consists of an operator term $\hat{\mathcal{T}}$ whose action is the same as in the spin-0 case, and another operator term $\hat{\mathcal{T}}_0$ which commutes with the Hamiltonian but breaks invariance under parity inversion. If we must impose this symmetry on our TOA operator, then we can throw away $\hat{\mathcal{T}}_0$ so that the TOA operator is just $\hat{\mathcal{T}}$.

1. Introduction

The marriage of relativity and quantum mechanics is a difficult one. Even for the case of special relativity, the interpretations can be somewhat troublesome. In the regime where the effects of quantum mechanics and special relativity are no longer negligible, the particle number in a system can, and will, fluctuate. Roughly speaking, this is because mass is just another form of energy, according to special relativity, and energy can fluctuate, according to quantum mechanics. Thus, there can be massive particles being created and annihilated in a relativistic quantum system. This poses a problem on the interpretation of the supposedly one-particle wavefunctions satisfying relativistic

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Particle detection and non-detection in a quantum time of arrival measurement

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HIGHLIGHTS

- The time-evolved position density is contained in the standard TOA distribution.
- Particle may quantum mechanically arrive at a given point without being detected.
- The eigenstates of the standard TOA operator are linked to the two-slit experiment.

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ABSTRACT

The standard time-of-arrival distribution cannot reproduce both the temporal and the spatial profile of the modulus squared of the time-evolved wave function for an arbitrary initial state. In particular, the time-of-arrival distribution gives a non-vanishing probability even if the wave function is zero at a given point for all values of time. This poses a problem in the standard formulation of quantum mechanics where one quantizes a classical observable and uses its spectral resolution to calculate the corresponding distribution. In this work, we show that the modulus squared of the time-evolved wave function is in fact contained in one of the degenerate eigenfunctions of the quantized time-of-arrival operator. This generalizes our understanding of quantum arrival phenomenon where particle detection is not a necessary requirement, thereby providing a direct link between time-of-arrival quantization and the outcomes of the two-slit experiment.

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Dynamics of a planar thin shell at a Taub–FRW junction

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We address the problem of stitching together the vacuum, static, planar-symmetric Taub spacetime and the flat Friedmann–Robertson–Walker (FRW) cosmology using the Israel thin shell formalism. The joining of Taub and FRW spacetimes is reminiscent of the Oppenheimer–Snyder collapse used in modeling the formation of a singularity from a collapsing spherical ball of dust. A possible mechanism for the formation of a planar singularity is provided. It is hoped that tackling such example will improve our intuition on planar-symmetric systems in Einstein's general relativity (GR).

Keywords: Planar-symmetric; thin shell; Israel formalism; planar collapse.

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1. Introduction

Similar concepts that appear in different fields in physics are not uncommon. We know from classical electromagnetism (EM) that nonoverlapping regions of space must be described by piecewise continuous scalar and vector potentials, but the derivatives of these potentials, i.e. electric and magnetic fields, need not be continuous at the junctions. Discontinuities in the electric and magnetic fields at the junctions give rise to surface charge and current distributions. The same scenario can be seen in classical general relativity (GR) when one tries to patch together nonoverlapping regions of spacetime described by different geometries. In this case, the components of the metric tensor are analogous to the four-potential in classical EM and discontinuities in the derivatives of the metric tensor give rise to surface energy–momentum distributions at the junctions of the spacetimes stitched together.

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