Annual Report 2021 Theoretical Physics Group

Period covered: 1 January 2021 - 31 December 2021 **Prepared by:** Michael Francis Ian Vega II, Ph.D., Program Coordinator **Submitted:** 30 May 2022

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1 Executive Summary

1.1 Activities of the Research Group

1.1.1 Organization

	Number	
PhD Faculty	9	
Student Members	91	
PhD = 27		
MS = 20		
BS = 44		
Apprentices	11	
Total	100	

(Dr. Reginald Bernardo was Assistant Professor in the group from 1 January 2021 to 31 August 2021. He left the Institute to begin his postdoc at the Institute of Physics, Academia Sinica, Taipei, Taiwan.)

1.1.2 Mentoring

Degree Program	Sem 2, AY 2020-2021	Midyear 2021	Sem 1, AY 2021-2022
PhD Physics	0	0	0
MS Physics	9	3	0
BS Physics	1	1	0
BS Applied Physics	2	0	0
Total	12	4	0

1.2 Research Highlights

	Number
Short-author international (ISI- and Scopus-indexed) publications	
Large collaboration (ISI- and Scopus-indexed) publications*	23
Local peer-reviewed publications	0
International conference presentations with full papers	2
International conference presentations (without full papers)	4
Local peer-reviewed conference papers	21
Conference presentations (without full papers)	0
Other invited lectures/talks	11
NIP Funded Projects	6
Non-NIP Funded Projects	2
Outbound travel abroad	0
Inbound visiting researchers	0

(*These papers are by Dr. Marvin Flores, through his membership in the ATLAS collaboration of CERN.)

1.3 Extension Work Highlights

	Number
Extension Work Activities	27
Research Interns and Trainees	0

1.4 Challenges Encountered

(1) COVID-19 pandemic; lack of interaction; mental health problems, (2) Lack of lab space

1.5 Awards, Accreditations, and Positions of Responsibilities Held

	Number
National awards or accreditation received, positions of responsibility held	1
International awards or accreditations received, positions of responsibility held	1
Other accomplishments	0

2 Technical Report

2.1 Activities of the Research Group

- 1. The Theoretical Physics Group has 100 members, consisting of 9 PhD faculty and 91 research students, as 31 December 2021.
- 2. Dr. Marvin Flores returned to the Theory group on June 2021, coming from his three-year postdoctoral fellowship (on faculty leave) in the University of Witwatersrand in South Africa. His return makes NIP an affiliate member of the ATLAS Collaboration in CERN. This allows Dr. Flores and his mentees who have been inducted into the collaboration access to the private ATLAS experimental software framework and data, on top of access to existing and upcoming particle physics talks/lectures delivered by leading experts from around the world. Dr. Flores' future PhD students who can successfully finish the year-long ATLAS Qualification task also get to be part of the official Author List in future ATLAS publications.
- 3. The group successfully mentored 12 MS and 4 BS students to graduation.
- 4. The group has published forty-two (42) papers in high-impact ISI/Scopus-indexed journals such as Physical Review Letters, Physical Review A/B/C/D, Journal of High Energy Physics, Journal of Cosmology and Astroparticle Physics, Classical and Quantum Gravity, Journal of Mathematical Physics, etc. Twenty-three (23) of these publications were coauthored by Dr. Flores through his membership in the ATLAS collaboration.
- 5. The observation of a dissipative time crystal, or more accurately the first observation of timecrystalline behaviors in an open quantum system, by a Hamburg research group, of which Dr. Jayson Cosme is part, received significant international media attention. Their breakthrough was reported in Physical Review Letters, and a *Physics Viewpoint* (by the American Physical Society) was written about it. (See: https://physics.aps.org/articles/v14/104)
- 6. The group continues to conduct research in a new "remote mode" brought about the COVID-19 pandemic. Research meetings and seminars take place through various platforms like Zoom.

2.1.1 Organization

Regular Members / PhD Faculty (9)

- 1. Esguerra, Jose Perico Professor
- 2. Galapon, Eric Professor
- 3. Vega, Michael Francis Ian Professor
- 4. Cosme, Jayson Associate Professor
- 5. Reyes, Reinabelle Associate Professor

- 6. Bernardo, Reginald Assistant Professor (until 31 August)
- 7. Flores, Marvin Assistant Professor
- 8. Sombillo, Denny Lane Assistant Professor (on postdoctoral leave until 31 December

2021)

9. Besagas, John Paul — Lecturer

PhD Student Members (27)

[Cosme: 2; Esguerra: 7; Flores: 2; Galapon: 9; Reyes: 1; Sombillo: 1; Vega: 5]

- 1. Blancas, Philip Jordan D6+ (Galapon)
- 2. Butanas, Bienvenido D6+ (Esguerra)
- 3. Cañeso, Diane D6+ (Esguerra)
- 4. Aban, Christine D6 (Esguerra)
- 5. Bartolome, Martin D6 (Esguerra)
- 6. Ramoso, Angel Marco D6 (Esguerra)
- 7. Nuñez, Kimver Louie D5 (Flores)
- 8. Villanueva, John Adrian D₅ (Vega)
- 9. Dumigpe, Art Graeson D4 (Galapon)
- 10. Fortuna, Sean D4 (Vega)
- 11. Dizon, Gabriel Luis D₃ (Reyes)
- 12. Elmaguin, John Carlo D₃ (Vega)
- 13. Flores, Philip Caesar D₃ (Galapon)
- 14. Mecca, Jerome D₃ (Vega)
- 15. Pablico, Dean Alvin D₃ (Galapon)
- 16. Rojas, Nathalie Liezel D₃ (Galapon)
- 17. Tica, Christian D3 (Galapon)
- 18. Garrido, Jeric D2 (Esguerra)
- 19. Magadan, John Jaykel D2 (Galapon)
- 20. Procurato, Jhon Delo D2 (Vega)
- 21. Alvarez, Justin D1 (Flores)
- 22. Cabrera, Ezron John D1 (Cosme)
- 23. Caidic, Neil Laurent D1 (Esguerra)
- 24. Farrales, Ralph D1 (Galapon)
- 25. Santos, Leonarc Michelle D1 (Sombillo)
- 26. Sevilla, Christopher Gerard D1 (Cosme)
- 27. Villanueva, Lloyd D1 (Galapon)

MS Student Members (20)

[Esguerra: 1; Flores: 6; Galapon: 2; Reyes: 4; Sombillo: 1; Vega: 6]

- 1. De Peralta, Rexcell M3+ (Galapon)
- 2. Aviñante, Aldon Christian M₃ (Esguerra)

- 3. Balagon, Val Anthony M₃ (Vega)
- 4. Fajardo, Edmichael Joil M3 (Reyes)
- 5. Lopez, Pierce Nathan M3 (Reyes)
- 6. Perez, Marc Christian M₃ (Vega)
- 7. Sese, Lemuel John M3 (Galapon)
- 8. Alzate, Willard Roy M2 (Vega)
- 9. Angeles, Janna May M2 (Vega)
- 10. Cantong, Jonelle M2 (Flores)
- 11. Calunsag, Don Ver M2 (Flores)
- 12. Garcia, Allen Neil M2 (Reyes)
- 13. Labtic, Adrian Patrick M2 (on LOA) (Flores)
- 14. Rabang, Nicko Angelo M2 (Flores)
- 15. Rivera, Marco Immanuel M2 (Reyes)
- 16. Saret, Lemuel Gavin M2 (Vega)
- 17. Apolinario, Lance M1 (Flores)
- 18. Palpal-latoc, Carl Justin M1 (Vega)
- 19. Raboy, Kervin Troy M1 (Sombillo)
- 20. Rex, Jaren Ryan M1 (Flores)

BS Physics and BS Applied Physics Members (44)

[Cosme: 8; Esguerra: 5; Flores: 3; Galapon: 4; Reyes: 8; Sombillo: 4; Vega: 12]

- 1. Josol, Guillermo Glenn B6 (Galapon)
- 2. Salvador, Adriana Marie B6 (Esguerra)
- 3. Villanueva, Ignacio B6 (Esguerra)
- 4. Mercado, Joaquin Nicholas B5 (Vega)
- 5. Perez, Abraham B5 (Cosme)
- 6. Abdao, Robert Diel B4 (Cosme)
- 7. Aragoza, Ian Angelo B4 (Reyes)
- 8. Bait-it, Abigail B4 (Vega)
- 9. Belinario, Gene Carlo B4 (Reyes)
- 10. Dela Cruz, Sean B4 (Esguerra)
- 11. Dy, Gedrich Jiann B4 (Vega)
- 12. Fernandez, Renee Calista B4 (Reyes)
- 13. Galvez, Dahna B4 (Reyes)
- 14. Gurrea, Luke Kenneth B4 (Vega)
- 15. Jacomilla, Demi Antoinette B4 (Flores)
- 16. Oidem, John Rommel B4 (Vega)
- 17. Oña, Cedric Adriane B4 (Vega)
- 18. Magnawa, Marc Cyrel B4 (Esguerra)

- 19. Menchavez, Roselle Mae B4 (Reyes)
- 20. Panogao, Jhomel B4 (Sombillo)
- 21. Panganiban, Ronald B4, (on LOA) (Vega)
- 22. Reyes, John Matthew B4 (Cosme)
- 23. Rodelas, Joseph B4 (Esguerra)
- 24. Tuquero, Richelle Jade B4 (Cosme)
- 25. Yulo, Jesus Miguel B4 (Vega)
- 26. Bagaforo, Nicole B3 (Cosme)
- 27. Chavez, Vince Angelo B3 (Sombillo)
- 28. De Guzman, Joaquin Lorenzo B3 (Flores)
- 29. De Silva, Marck Christian B3 (Reyes)
- 30. Estadilla, Theodore B3 (Galapon)
- 31. Geraldez, Lyle Kenneth B3 (Vega)
- 32. Jamen, Renz Jamuel B3 (Reyes)
- 33. Javier, Michael Adrian B3 (Sombillo)
- 34. Macatangay, David Marick B3 (Cosme)
- 35. Mendoza, Chris Andrew B3 (Flores)
- 36. Mendoza, Genesis Adam B₃ (Vega)
- 37. Oidem, James Marwin B3 (Cosme)
- 38. Rodrigo, Juan B3 (Vega)
- 39. Salinel, Darwin B3 (Cosme)
- 40. Sanchez, Florence Arielle B3 (Sombillo)
- 41. Somido, Alyanna B3 (Reyes)
- 42. Tagupa, Angelika Joie B3 (Galapon)
- 43. Umipig. Jennie Rose B3 (Galapon)
- 44. Villarin, Josue Luis B₃ (Vega)

Organization Summary

	Number
Regular Members	9
Student Members	91
PhD = 27	
MS = 20	
BS = 44	
Total	100

2.1.2 Mentoring

Graduated 2nd Semester, AY 2020-2021 (PhD = 0, MS = 9, BS = 3)

1.	Gabriel Sedrick Alkuino, MS Physics (2021) Thesis: Dynamics of extendable articulated bodies on curved surfaces (Adviser: Ian Vega)
2.	<i>Justin Alvarez,</i> MS Physics (2021) Thesis: Boosted decision tree-driven cut-based analysis for event recognition in stealth SUSY decays for $\sqrt{s} = 13$ TeV (Adviser: Jose Perico Esguerra; Co-adviser: Marvin Flores)
3.	Art Marcelo Andallo, MS Physics (2021) Thesis: Linear vs. nonlinear zeta function regularization and its applications to the Casimir effect (Adviser: Eric Galapon)
4.	Ramon Bagunu, MS Physics (2021) Quantization of the Hamilton equations of motion and solutions to the time-energy canonical commutation relation (Adviser: Eric Galapon)
5.	Joshua Bautista, MS Physics (2021) NIP Most Outstanding MS Physics Graduate A dynamical systems approach to studying the structure of anisotropic compact objects (Adviser: Ian Vega)
6.	Karlo de Leon, MS Physics (2021) Geometry of thermodynamic systems: geodesics, curvature, phase boundaries, and the Widom line (Adviser: Ian Vega)
7.	Austin Dizon, MS Physics (2021) Time of arrival operators for singular potentials (Adviser: Eric Galapon)
8.	Leonarc Santos, MS Physics (2021) Hyperdifferential operator representation of polynomials and rescalability (Adviser: Eric Galapon)
9.	Lloyd Villanueva, MS Physics (2021) Reduction formulas of the Kampé de Fériet function arising from the method of finite-part integration (Adviser: Eric Galapon)
10	Stephanie Go, BS Applied Physics (2021) Summa cum laude, Most Outstanding BS Applied Physics Student Thesis: Properties of a biased evanescent random walk on an <i>n</i> -cycle (Adviser: Jose Perico Esguerra)
11.	Carl Justin Palpal-latoc, BS Applied Physics (2021) Cum laude Thesis: Evolution and perturbation of delayed universes (Adviser: Ian Vega)
12	Jaythan Salazar, BS Physics (2021) Thesis: The traversability of time travel trajectories (Adviser: Ian Vega)
Gı	aduated Midyear, AY 2020-2021

(PhD = 0; MS = 3, BS = 1)

1. John Adrian Baybay, MS Physics (2021)

Thesis: Charged induced superradiance from non-linear scalar fields (Adviser: Ian Vega; Co-adviser: Reginald Bernardo)

2. John Celestial, MS Physics (2021)

Thesis: Reissner-Nordström black holes in Horndeski theories (Adviser: Ian Vega; Co-adviser: Reginald Bernardo)

3. *Christopher Sevilla*, MS Physics (2021)

Thesis: Resonance in coupled driven damped harmonic oscillators with fluctuating mass (Adviser: Jose Perico Esguerra)

4. *Gabrielle Melissa Alhambra*, BS Physics (2021)

Thesis: Boomerang photon orbits around spherically symmetric black holes (Adviser: Ian Vega)

Mentoring Summary

Degree Program	Sem 2, AY 2020-2021	Midyear 2021	Sem 1, AY 2021-2022
PhD Physics	0	0	0
MS Physics	9	3	0
BS Physics	1	1	0
BS Applied Physics	2	0	0
Total	12	4	0

2.2 Research Highlights

2.2.1 International peer-reviewed articles (19)

(Underlined authors are members of the Theoretical Physics Group.)

- Abac, A. G., and Esguerra, J. P., Implications of the generalized uncertainty principle on the Walecka model equation of state and neutron star structure, International Journal of Modern Physics D Vol. 30, No. 08, 2150055 (2021). https://doi.org/10.1142/S0218271821500553
- 2. <u>Bautista, J.</u> and <u>Vega, I.</u> (2021). *Chaotic exits from a weakly magnetized Schwarzschild black hole*. Classical and Quantum Gravity 38, 155016. https://doi.org/10.1088/1361-6382/ac0e19
- Bernardo, R. C., Said, J. L., Caruana, M., and Appleby, S. (2021). Well-tempered Minkowski solutions in teleparallel Horndeski theory. Classical and Quantum Gravity 39, 015013. https://doi.org/10.1088/1361-6382/ac36e4
- 4. <u>Bernardo, R. C.</u> (2021). Inflationary quantum dynamics and backreaction using a classical-quantum correspondence. European Physical Journal C 81, 994 (2021). https://doi.org/10.1140/epjc/s10052-021-09781-7
- Bernardo, R. C., Said, J. L., Caruana, M., and Appleby, S. (2021). A data-driven reconstruction of Horndeski gravity via the Gaussian processes. Journal of Cosmology and Astroparticle Physics 10(2021)078. https://doi.org/10.1088/1475-7516/2021/10/078
- Bernardo, R. C. and Said, J. L. (2021). A data-driven reconstruction of Horndeski gravity via the Gaussian processes. Journal of Cosmology and Astroparticle Physics 09(2021)014. https://doi.org/10.1088/1475-7516/2021/09/014
- 7. <u>Bernardo, R. C.</u> and Said, J. L. (2021). *Towards a model-independent reconstruction approach for late-time Hubble data.* Journal of Cosmology and Astroparticle Physics 08(2021)027.

https://doi.org/10.1088/1475-7516/2021/08/027

- 8. <u>Bernardo, R. C.</u> (2021). *Gravitational wave signatures from dark sector interactions*. Physical Review D 104 024070. https://doi.org/10.1103/PhysRevD.104.024070
- Bernardo, R. C. (2021). Self-tuning kinetic gravity braiding: cosmological dynamics, shift symmetry, and the tadpole. Journal of Cosmology and Astroparticle Physics 03(2021)079. https://doi.org/10.1088/1475-7516/2021/03/079
- 10. Bernardo, R. C. and Vega, I. (2021). Stealth black hole perturbations in kinetic gravity braiding. Journal of Mathematical Physics 62, 072501. https://doi.org/10.1063/5.0048929
- Georges, C., <u>Cosme, J. G.</u>, Keßler, H., Ludwig Mathey, L. and Hemmerich, A. (2021). *Dynamical density wave order in an atom-cavity system*. New Journal of Physics 23 023003. https://doi.org/10.1088/1367-2630/abdf9c
- Homann, G., Cosme, J. G., Okamoto J., and Mathey, L. (2021). *Higgs mode mediated enhancement of interlayer transport in high-T_c cuprate superconductors*. Physical Review B 103 224503. https://doi.org/10.1103/PhysRevB.103.224503
- 13. Keßler, H., Kongkhambut, P., Georges, C., Mathey, L., <u>Cosme, J. G.</u>, and Hemmerich, A. (2021). *Observation of a Dissipative Time Crystal.* **Physical Review Letters** 127 043602. https://doi.org/10.1103/PhysRevLett.127.043602
- 14. Kongkhambut, P., Keßler, H., Skulte, J., Mathey, L., <u>Cosme, J. G.</u>, and Hemmerich, A. (2021). *Realization of a Periodically Driven Open Three-Level Dicke Model*. **Physical Review Letters** 127 253601. https://doi.org/10.1103/PhysRevLett.127.253601
- Skulte, J., Broers, L., <u>Cosme, J. G.</u>, and Mathey, L. (2021). Vortex and soliton dynamics in particle-holesymmetric superfluids. Physical Review Research 3 043109. https://doi.org/10.1103/PhysRevResearch.3.043109
- Skulte, J., Kongkhambut, P., Keßler, H., Hemmerich, A., Mathey, L., and <u>Cosme, J. G.</u> (2021). Parametrically driven dissipative three-level Dicke model. Physical Review A 104 063705. https://doi.org/10.1103/PhysRevA.104.063705
- 17. <u>Sombillo, D. L. B.</u>, Ikeda, Y., Sato, T., and Hosaka, A. (2021). *Classifying Near-Threshold Enhancement Using Deep Neural Network*, Few-Body Systems 62, 52. https://doi.org/10.1007/s00601-021-01642-z
- Sombillo, D. L. B., Ikeda, Y., Sato, T., and Hosaka, A. (2021). Model independent analysis of coupledchannel scattering: A deep learning approach. Physical Review D, 104, 036001. https://doi.org/10.1103/PhysRevD.104.036001
- 19. <u>Villanueva, L. L.</u> and <u>Galapon, E. A.</u> (2021). *Finite-part integration in the presence of competing singularities: Transformation equations for the hypergeometric functions arising from finite-part integration.* **Journal of Mathematical Physics** 62, 043505. https://doi.org/10.1063/5.0038274

2.2.2 Long-author collaboration publications (23)

- Aaboud, M., Aad, G., Abbott, B., Abbott, D. C., Abdinov, O., Abed Abud, A., ... Zwalinski, L. (2021). Measurement of the relative Bc±/B± production cross section with the ATLAS detector at s = 8 TeV. Physical Review D, 104(1), Article number 012010. https://doi.org/10.1103/PhysRevD.104.012010
- 2. Aad, G., Abbott, B., Abbott, D. C., Abed Abud, A., & Abeling, K. (2021). Measurement of the $t\bar{t}t\bar{t}$ production cross section in *pp* collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector. **Journal of High Energy Physics**, 2021(11), Article number 118. https://doi.org/10.1007/JHEP11(2021)118
- 3. Aad, G., Abbott, B., Abbott, D. C., Abed Abud, A., & Abeling, K. (2021). Search for dark matter in events with missing transverse momentum and a Higgs boson decaying into two photons in *pp* collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector. **Journal of High Energy Physics**, 2021(10), Article number 13. https://doi.org/10.1007/JHEP10(2021)013

- Aad, G., Abbott, B., Abbott, D. C., Abed Abud, A., Abeling, K., Abhayasinghe, D. K., ... Zwalinski, L. (2021). Two-particle azimuthal correlations in photonuclear ultraperipheral Pb+Pb collisions at 5.02 TeV with ATLAS. Physical Review C, 104(1), Article number 014903. https://doi.org/10.1103/PhysRevC.104.014903
- 5. Aad, G., Abbott, B., Abbott, D. C., Abed Abud, A., Abeling, K., Abhayasinghe, D. K., ... Zwalinski, L. (2021). Measurements of $W^+W^+ \ge 1$ jet production cross-sections in *pp* collisions at \sqrt{s} = 13 TeV with the ATLAS detector. **Journal of High Energy Physics**, 2021(6), Article Number 3. https://doi.org/10.1007/JHEP06(2021)003
- 6. Aad, G., Abbott, B., Abbott, D. C., Abed Abud, A., Abeling, K., Abhayasinghe, D. K., ... Zwalinski, L. (2021). Evidence for Higgs boson decays to a low-mass dilepton system and a photon in pp collisions at s = 13 TeV with the ATLAS detector. **Physics Letters B**, 819, Article Number 136412. https://doi.org/10.1016/j.physletb.2021.136412
- 7. Aad, G., Abbott, B., Abbott, D. C., Abed Abud, A., Abeling, K., Abhayasinghe, D. K., ... Zwalinski, L. (2021). A search for the decays of stopped long-lived particles at √s = 13 TeV with the ATLAS detector. Journal of High Energy Physics, 2021(7). Article no. 173. https://doi.org/10.1007/JHEP07(2021)173
- 8. Aad, G., Abbott, B., Abbott, D. C., Abed Abud, A., Abeling, K., Abhayasinghe, D. K., ... Zwalinski, L. (2021). Search for pair production of third-generation scalar leptoquarks decaying into a top quark and a τ -lepton in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector. **Journal of High Energy Physics**, 2021(6). Article no. 179. https://doi.org/10.1007/JHEP06(2021)179
- 9. Aad, G., Abbott, B., Abbott, D. C., Abed Abud, A., Abeling, K., Abhayasinghe, D. K., ... Zwalinski, L. (2021). Search for trilepton resonances from chargino and neutralino pair production in $\sqrt{s} = 13$ TeV *pp* collisions with the ATLAS detector. **Physical Review D**, 103(11), Article 112003. https://doi.org/10.1103/physrevd.103.112003
- 10. Aad, G., Abbott, B., Abbott, D. C., Abed Abud, A., Abeling, K., Abhayasinghe, D. K., ... Zwalinski, L. (2021). Search for supersymmetry in events with four or more charged leptons in 139 fb⁻¹ of \sqrt{s} = 13 TeV *pp* collisions with the ATLAS detector. **Journal of High Energy Physics**, 2021(7), Article number 167. https://doi.org/10.1007/JHEP07(2021)167
- 11. Aad, G., Abbott, B., Abbott, D. C., Abed Abud, A., Abeling, K., Abhayasinghe, D. K., ... Zwalinski, L. (2021). Search for bottom-squark pair production in pp collision events at \sqrt{s} =13 TeV with hadronically decaying τ -leptons, b-jets, and missing transverse momentum using the ATLAS detector. **Physical Review D**, 104(3), Article number 032014. https://doi.org/10.1103/PhysRevD.104.032014
- 12. Aad, G., Abbott, B., Abbott, D. C., Abed Abud, A., Abeling, K., Abhayasinghe, D. K., ... Zwalinski, L. (2021). Search for new phenomena in events with an energetic jet and missing transverse momentum in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector. **Physical Review D**, 103(11), Article number 112006. https://doi.org/10.1103/PhysRevD.103.112006
- 13. Aad, G., Abbott, B., Abbott, D. C., Abed Abud, A., Abeling, K., Abhayasinghe, D. K., ... Zwalinski, L. (2021). Search for New Phenomena in Final States with Two Leptons and One or No *b*-Tagged Jets at √s=13 TeV Using the ATLAS Detector. Physical Review Letters, 127(14), Article number 141801. https://doi.org/10.1103/PhysRevLett.127.141801
- 14. Aad, G., Abbott, B., Abbott, D. C., Abed Abud, A., Abeling, K., & Abhayasinghe, D. K. (2021). Measurement of the production cross section of pairs of isolated photons in *pp* collisions at 13 TeV with the ATLAS detector. Journal of High Energy Physics, 2021(11), Article number 169. https://doi.org/10.1007/JHEP11(2021)169
- 15. Aad, G., Abbott, B., Abbott, D. C., Abed Abud, A., Abelling, K., & Abhayasinghe, D. K. (2021). Search for new phenomena in final states with *b*-jets and missing transverse momentum in \sqrt{s} =13 TeV pp collisions with the ATLAS detector. **Journal of High Energy Physics**, 2021(5), Article number 93. https://doi.org/10.1007/JHEP05(2021)093

- Aad, G., Abbott, B., Abbott, D. C., Abud, A. A., Abeling, K., Abhayasinghe, D. K., ... Zwalinski, L. (2021). Optimisation of large-radius jet reconstruction for the ATLAS detector in 13 TeV proton-proton collisions. The European Physical Journal C, 81(4), Article number 334. https://doi.org/10.1140/epjc/s10052-021-09054-3
- 17. Aad, G., Abbott, B., Abbott, D. C., Abud, A. A., Abeling, K., Abhayasinghe, D. K., ... Zwalinski, L. (2021). Muon reconstruction and identification efficiency in ATLAS using the full Run 2 pp collision data set at data set at $\sqrt{s}=13$ TeV. The European Physical Journal C, 81(7), Article Number 578. https://doi.org/10.1140/epjc/s10052-021-09233-2
- Aad, G., Abbott, B., Abbott, D. C., Abud, A. A., Abeling, K., Abhayasinghe, D. K., ... Zwalinski, L. (2021). Measurements of the inclusive and differential production cross sections of a top-quarkantiquark pair in association with a Z boson at √s=13 TeV with the ATLAS detector. The European Physical Journal C, 81(8), Article number 737. https://doi.org/10.1140/epjc/s10052-021-09439-4
- 19. Aad, G., Abbott, B., Abbott, D. C., Abud, A. A., Abeling, K., Abhayasinghe, D. K., ... Zwalinski, L. (2021). Search for R-parity-violating supersymmetry in a final state containing leptons and many jets with the ATLAS experiment using $\sqrt{s}=13$ TeV proton- proton collision data. **The European Physical Journal C**, 81, Article number: 1023. https://doi.org/10.1140/epjc/s10052-021-09761-x
- 20. Aad, G., Abbott, B., Abud, A. A., Abeling, K., & Abhayasinghe, D. K. (2021). Measurements of Higgs Bosons Decaying to Bottom Quarks from Vector Boson Fusion Production with the AT-LAS Experiment at $\sqrt{s} = 13$ TeV. The European Physical Journal C, 81(6), Article number 537. https://doi.org/10.1140/epjc/s10052-021-09192-8
- 21. Aad, G., Abbott, B., Abbott, D. C., Abud, A. A., & Abeling, K. (2021). Measurements of sensor radiation damage in the ATLAS inner detector using leakage currents. Journal of Instrumentation, 16(8), Article Number Po8025. https://iopscience.iop.org/article/10.1088/1748-0221/16/08/P08025
- 22. ATLAS Collaboration. (2021). Configuration and performance of the ATLAS b-jet triggers in Run 2. The European Physical Journal C, 81(12), Article number 1087. https://doi.org/10.1140/epjc/s10052-021-09775-5
- 23. ATLAS Collaboration. (2021). Search for exotic decays of the Higgs boson to long-lived particles in pp collisions at $\sqrt{s} = 13$ TeV using displaced vertices in the ATLAS inner detector. Journal of High Energy Physics, 2021 (11), Article Number 229. https://doi.org/10.1007/JHEP11(2021)229

2.2.3 Publication in local peer reviewed journals (0)

- 2.2.4 International conference presentations with full papers (2)
- 1. D. Sombillo, *Extraction of S-matrix pole structure using deep learning*. 22nd Particles and Nuclei International Conference (PANIC 2021), 5-11 September 2021, Lisbon, Portugal, Online conference
- 2. D. Sombillo, *Probing the pole configuration of scattering amplitude using deep learning*, 19th International Conference on Hadron Spectroscopy, 26 July -1 August 2021, Online conference

2.2.5 International conference presentations without full papers (4)

- 1. D. Sombillo, *Deep learning as a unified model-selection tool*. Light Cone 2021: Physics of Hadrons on the Light Front, 28 November 04 December 2021, Jeju Booyoung Hotel and ZOOM (online)
- 2. D. Sombillo, *Unveiling the pole structure of S-matrix using deep learning*, ELPH Study Group Co31 Workshop, 4-5 November 2021, Tohoku University, Japan, hybrid workshop
- 3. D. Sombillo, *Extraction of S-matrix pole configuration in a coupled-channel scattering using deep learning.* 76th Annual Meeting of the Physical Society of Japan, 12-15 March 2021, Online conference

- 4. D. Sombillo, *Pole structure of coupled-channel S-matrix: a deep learning approach.* Workshop on "Physics of heavy-quark and exotic hadrons 2021", 15-17 February 2021, Online workshop
- 2.2.6 Local peer-reviewed conference papers (21)
- 1. RJL Tuquero and JG Cosme, Symmetry breaking in a one-dimensional atom-cavity system with harmonic trap, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-2B-02 (2021). URL: https://proceedings.spp-online.org/article/view/SPP-2021-2B-02.
- 2. JI Alvarez, JPH Esguerra, and MM Flores, Boosted decision tree-driven cut-based analysis for event recognition in Stealth SUSY decays for $\sqrt{s} = 13$ TeV, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-3B-04 (2021). URL: https://proceedings.spp-online.org/article/view/SPP-2021-3B-04.
- 3. CJG Aban and JPH Esguerra, First passage characteristics of evanescent run-and-tumble particles with uniform speed, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-1F-02 (2021). URL: https://proceedings.spp-online.org/article/view/SPP-2021-1F-02.
- 4. AMT Salvador and JPH Esguerra, Monte Carlo simulations of a stochastic process with positiondependent resetting inspired by backtracked RNA polymerases, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-PB-05 (2021). URL: https://proceedings.spp-online.org/article/view/SPP-2021-PB-05.
- 5. LM Santos and E Galapon, On rescalability of generators of hyperdifferential operators, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-PC-01 (2021). URL: https://proceedings.spp-online.org/article/view/SPP-2021-PC-01.
- 6. DAL Monge and EA Galapon, Definite integrals from the finite parts of divergent Mellin-type pole singularity integrals involving entire functions, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-PC-02 (2021). URL: https://proceedings.spp-online.org/article/view/SPP-2021-PC-02.
- RJC Bagunu and EA Galapon, Solutions to the time-energy canonical commutation relation using Weyl, Symmetric, and Born-Jordan basis operators, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-PC-04 (2021). URL: https://proceedings.spp-online.org/article/view/SPP-2021-PC-04.
- 8. AS Dizon and EA Galapon, Construction of time of arrival operators for the inverse square potential, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-PC-10 (2021). URL: https://proceedings.spponline.org/article/view/SPP-2021-PC-10.
- LL Villanueva and EA Galapon, Integral representations of the derivatives of the Gauss hypergeometric function with respect to its parameters, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-PC-11 (2021). URL: https://proceedings.spp-online.org/article/view/SPP-2021-PC-11.
- RAE Farrales and EA Galapon, Shifted solution to the time kernel equation, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-PC-13 (2021). URL: https://proceedings.spp-online.org/article/view/SPP-2021-PC-13.
- 11. MIB Rivera and RC Reyes, Probing the parameter constraints on astrophysical environments of intermediate and extreme mass ratio inspiral binaries with LISA, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-1C-02 (2021). URL: https://proceedings.spp-online.org/article/view/SPP-2021-1C-02.
- 12. JMA Yulo and MFIG Vega, Strange attractors of long-period variable stars in a one-zone model of stellar pulsation, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-1C-04 (2021). URL: https://proceedings.spp-online.org/article/view/SPP-2021-1C-04.
- 13. JP Mecca and MFIG Vega, Gravitomagnetic effects in a rotating Damour-Solodukhin wormhole, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-1C-05 (2021). URL: https://proceedings.spp-online.org/article/view/SPP-2021-1C-05.

- 14. GM Alhambra and MFIG Vega, Boomerang photons around spherically symmetric black holes, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-PC-05 (2021). URL: https://proceedings.spp-online.org/article/view/SPP-2021-PC-05.
- JMN Rodrigo, JL Villarin, L Geraldez, A Mendoza, and I Vega, Dynamics of Newtonian and relativistic thin fluid shells, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-PC-06 (2021). URL: https://proceedings.spp-online.org/article/view/SPP-2021-PC-06.
- 16. CJ Palpal-latoc and MFIG Vega, Cosmic expansion with perturbed Friedmann equations, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-PC-07 (2021). URL: https://proceedings.spp-online.org/article/view/SPP-2021-PC-07.
- 17. WRD Alzate and MFIG Vega, Accelerated Schwarzschild orbits in an external tidal field, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-PC-08 (2021). URL: https://proceedings.spp-online.org/article/view/SPP-2021-PC-08.
- LGG Saret and MFIG Vega, Energy shifts of photons crossing an Alcubierre warp drive, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-PC-09 (2021). URL: https://proceedings.spponline.org/article/view/SPP-2021-PC-09.
- 19. JRV Oidem and MFIG Vega, Equatorial charged particle motion around a homogeneously magnetized Newtonian center, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-PC-14 (2021). URL: https://proceedings.spp-online.org/article/view/SPP-2021-PC-14.
- 20. JBP Bautista and MFI Vega, Buchdahl surface of anisotropic compact objects, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-PC-16 (2021). URL: https://proceedings.spp-online.org/article/view/SPP-2021-PC-16.
- 21. JDL Procurato and MFIG Vega, Generalized Hellings-Downs function for an anisotropic electromagnetic wave background, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-PC-17 (2021). URL: https://proceedings.spp-online.org/article/view/SPP-2021-PC-17.
- 2.2.7 Conference presentations (without full papers) (0)
- 2.2.8 Other invited lectures/talks (11)
- J. Cosme, Driven-dissipative three-level Dicke model in an atom-cavity system, 2021: Proceedings of the 39th Samahang Pisika ng Pilipinas Physics Conference, SPP-2021-INV-1F-06. URL: https://proceedings.spponline.org/article/view/SPP-2021-INV-1F-06.
- 2. MM Flores, *Stealth supersymmetry and the minimal universal extra dimensions in light of Run 2 of the Large Hadron Collider*, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-INV-3B-03 (2021). URL: https://proceedings.spp-online.org/article/view/SPP-2021-INV-3B-03.
- 3. R Bernardo, *The Dark Universe: Theory and data assemblies*, Proceedings of the Samahang Pisika ng Pilipinas 39, SPP-2021-INV-1C-01 (2021). URL: https://proceedings.spp-online.org/article/view/SPP-2021-INV-1C-01.s
- 4. J. Cosme, *Dynamical control of phases and time crystal in an atom-photon system*, University of Oxford, UK, (2021).
- 5. J. Cosme, *Dynamical control of phases and time crystal in an atom-photon system*, Center for Theoretical Physics of Complex Systems, Institute for Basic Science, Korea, (2021).
- 6. D. Sombillo, *Model-independent analysis of hadron-hadron scattering: a deep learning application*. Invited talk at the 24th Hadron Physics Online Forum (HAPOF), 28 May 2021, Institute of Theoretical Physics, Chinese Academy of Science

- 7. D. Sombillo, Model-independent analysis of hadron-hadron scattering: a deep learning application. Invited talk at the Young Scientist Training Program HEP Seminar 27 May 2021, Asia Pacific Center for Theoretical Physics, South Korea
- 8. D. Sombillo, *Deep learning in the analysis of hadron-hadron scattering*. Invited talk at the School on Clustering as a window to quantum systems, 22-24 March 2021, Online school
- D. Sombillo, *Classifying near-threshold enhancements using a deep neural network*. Plenary talk at The 8th Asia-Pacific Conference APFB2020, 1-5 March 2021, Kanazawa, Japan (Hybrid onsite and online conference)
- 10. D. Sombillo, *Application of deep learning to the study of near-threshold resonances*. Invited talk at KEK Theory Seminar, 26 January 2021, KEK, Tsukuba, Japan, Online seminar
- 11. M. Flores, *Search for a 4th generation quark decaying to a dark photon resulting in a lepton jet*, ATLAS Exotics Plenary (2021)

2.2.9 NIP funded projects (6)

- Project Leader: Jayson Cosme
 Project Title: Effects of harmonic trap on the spontaneous symmetry breaking in atom-cavity systems
 Amount: PhP92,400
 Duration: 1 January 2021 31 December 2021
- Project Leader: Jose Perico Esguerra Project Title: Stochastic processes with position-dependent sharp restart or resetting rates Amount: PhP105,600 Duration: 1 January 2021 — 31 December 2021
- 3. Project Leader: Marvin Flores
 Project Title: Boosted decision tree-driven cut-based analysis for event recognition in stealth SUSY decays for √s = 13 TeV
 Amount: PhP46,200
 Duration: 1 June 2021 31 December 2021
- Project Leader: Eric Galapon
 Project Title: Integral representations of the derivatives of the Gauss function with respect to its
 parameters
 Amount: PhP105,600
 Duration: 1 January 2021 31 December 2021
- 5. Project Leader: Reinabelle Reyes
 Project Title: Observational signatures of environmental effects on gravitational-wave signals from black hole binaries
 Amount: PhP92,400
 Duration: 1 January 2021 31 December 2021
- Project Leader: Michael Francis Ian Vega II Project Title: Pressure anisotropy in relativistic stellar models Amount: PhP105,600 Duration: 1 January 2021 — 31 December 2021

2.2.10 Non-NIP funded projects (2)

 Project Leader: Eric Galapon Type: OVPAA Enhanced Creative Work and Research Grant Project Title: Analytic integration: theory and application Amount: PhP600,000 Duration: 2019 — 2021

- Project Leader: Marvin Flores
 Type: OVPAA Enhanced Creative Work and Research Grant
 Project Title: LHC bounds on minimal universal extra dimensions after Run 2
 Amount: P500,000
 Duration: 2021 — 2022
- 2.2.11 Outbound travel abroad (o)
- 2.2.12 Inbound visiting researchers (o)

2.3 Extension Work Highlights

2.3.1 Extension Work Activities (25)

- 1. Jayson Cosme
 - Referee, Physical Review B
 - Referee, Samahang Pisika ng Pilipinas
- 2. Jose Perico Esguerra
 - Topical Editor, Theoretical and Mathematical Physics, Samahang Pisika ng Pilipinas
 - Referee, European Journal of Physics
 - Member, General Council of the Asia Pacific Center for Theoretical Physics
 - National Astronomy Education Coordinator (Philippines), IAU-Office of Astronomy Education
 - Consultant, Review of PSHS Curriculum Under Covid-19, Philippine Science High School System, May 20 to 27, 2021
 - Speaker (The Cosmos the Nobel Prize, and Us), 14 February 2021, National Astronomy Week Celebration, organized by: Philippine Astronomical Society
 - Speaker (From Milliards and Milliards to T.T.T.: On Growing Up to Be a Physicist in the Philippines), 15 April 2021, in the Celestial Mind Webinar Series Season 2, Organized by: Carolinian Physics Society (PhySoc)
 - Speaker (Orbits), in Astroventures Webinar Series in the USC Astronomy Week Celebrations, 28 October 2021, Organized by: Carolinian Physics Society (PhySoc)
- 3. Marvin Flores
 - ATLAS Qualification Task
 - Referee, Samahang Pisika ng Pilipinas
- 4. Eric Galapon
 - Referee, Samahang Pisika ng Pilipinas
- 5. Denny Lane Sombillo
 - Referee, Samahang Pisika ng Pilipinas
 - Referee, Scientific Reports
 - Referee, Physical Review D
- 6. Reinabelle Reyes

- Mentor, Physics Meetup, ICTP-Physics Without Frontiers Program
- Co-host of Radyo Turo Guro Teleradyo Program (Aug 2020 Jun 2021)
- 7. Michael Francis Ian Vega II
 - Councilor, Samahang Pisika ng Pilipinas
 - Topical Editor, Theoretical and Mathematical Physics, Samahang Pisika ng Pilipinas
 - Referee, Physical Review Letters
 - Referee, Physical Review D
 - Referee, Journal of Cosmology and Astroparticle Physics
 - Referee, Classical and Quantum Gravity
 - Referee, European Physical Journal Plus
 - Speaker, *Back2Basic (B2B) Episode 8: Black Holes, Gravitational Waves and Why They Matter*. National Research Council of the Philippines. 27 October 2021.
 - Speaker, *Explorations in Black Hole Physics*. The Space Between Us: Entanglement Across the Distance. University of San Carlos Astronomy Week. 27 October 2021.

2.3.2 Research Interns and Trainees (o)

2.4 Challenges Encountered

Restrictions brought about by the protracted COVID-19 pandemic – now spanning more than two years – continue to be the main challenge of our research group. As theorists, the impact of lab closures has been much less severe on us than on our experimental colleagues. But the lack of informal interactions and conversations has still taken a heavy toll on our productivity, affecting the morale and motivation of many of our members. Each of our respective subgroups continues to take advantage of videocon-ferencing platforms such as Zoom to conduct research meetings and Journal Club seminars, but these constitute only a small fraction of the essential interaction that fuels much of our creative work.

There continues to be a troubling increase in reported mental health issues from within the group. Though these problems differed in their immediate causes, there is no doubt that the confinement and isolation brought about by the extended quarantine was a major contributor to each case.

Since last year, our group has grown substantially in number. We now have 100 members, which is more than double the size of other research groups in the Institute. This will be a major looming problem for us when face-to-face work resumes, as our current lab space will not be able to accommodate our larger population.

2.5 Awards, Accreditations, Positions of Responsibility Held, and other Accomplishments

2.5.1 National awards or accreditations received, positions of responsibility (1)

 Marvin Flores 3rd Prize, Talent Search for Young Scientists National Academy of Science and Technology (NAST)

2.5.2 International awards or accreditations received, positions of responsibility (1)

1. Jose Perico Esguerra

Member, General Council of the Asia Pacific Center for Theoretical Physics National Astronomy Education Coordinator (Philippines), IAU-Office of Astronomy Education

2.5.3 Other accomplishments (o)

1. Stephanie Anne Go – *CS Excellence Award for Most Outstanding BS Applied Physics Student*, College of Science, UP Diliman

2.6 *PhD Faculty*

Top row, left to right: Reinabelle Reyes, Ian Vega, Eric Galapon Middle row, left to right: Denny Lane Sombillo, Jose Perico Esguerra, Marvin Flores Bottow row, left to right: John Paul Besagas, Jayson Cosme

