

SHORT VITA

I am a theoretical physicist working as a research associate at the Leibniz Hannover University. My scientific career has followed a markedly multidisciplinary path, developed in different prestigious international institutions. I hold an MSc in one of the best Latin American universities, Campinas- Brazil. I successfully concluded my Ph. D. on ultracold quantum gases in Trento in the group of Prof. Sandro Stringari and Lev. Pitaevskii, where I learn state-of-the-art methods to address the physics of many-body systems. During my Ph. D., I worked on impurity problems in Bose-Einstein condensates. My work is motivated by the recent and timely experiments on creating polarons in quantum gases as a potential quantum simulator for the solid-state polaron. During my first postdoctoral experience, I was hosted by Prof. Thomas Pohl at the Max Plank institute in Dresden, Germany (2015-2017) with my own funding and Aarhus university (2017-2019). At this stage of my career, I have made significant contributions, such as (I) I led the analysis in one of the pioneering experiments for strongly coupled polarons. (II) I also predicted mediated interactions between quasiparticles known as bi-polarons. This flavor plays a fundamental role in superconductivity. (III) I also investigated one of the most fundamental problems in physics, namely the formation of quasiparticles which led to the first observation of polaron formation in quantum gases (IV) I have developed an alternative theory to explain this experiment's observations from a variational point of view. In 2019 I joined Luis Santos group, a world-renowned expert in dipolar gases. Thus, my current, interest's research focuses on impurity physics with long-range interactions. So far, my scientific network encloses researchers from 15 countries and 18 peer-reviewed articles in Science Citation Index journals with an exponential citation rate. Including a few single and the corresponding author displaying this independent thinking and leadership. In addition, I have co-supervised two Ph. D. students and engaged with teaching duties for the Master's program. Mean organizer of an international workshop, "Young Researchers Workshop on Quantum Fluctuations in Ultracold Gases.". My long-term academic goal is to investigate quasiparticle physics with long-range interaction in quantum gases, liquids, and solids as a potential quantum simulator in other physics branches. In particular, to develop new tools for this research that potentially have relevant consequences in the near future quantum technologies such as quantum computers.

PROFESSIONAL EXPERIENCE

- 05.05.2019 – Present **Postdoctoral Fellow.** IFT- Leibniz Hannover University. Hannover, Germany.
Hosted by Prof. Dr. Luis Santos – Hannover, Germany
- 04.05.2017-04.05.2019 **Postdoctoral Fellow.** Department of Physics and Astronomy Aarhus University.
Hosted by Prof. Dr. Thomas Pohl – Aarhus, Denmark
- 11.12. 2015 – 03.05.2017 **Research Assistant.** Max Plank Institute for the Physics of Complex systems.
Hosted by Dr. Thomas Pohl - Dresden, Germany
- 02.07.2015 – 01.10.2015 **Research Assistant,** BEC Center. University of Trento. Hosted by Prof. Dr. Stefano Giorgini – Trento. Italy
- 01.02.2011 - 01.12.2011 **High School teacher,** Colegio De la Salle. Bogotá-Colombia

EDUCATION

- 01.02.2012-27.04.2015 **PhD in Theoretical Physics.** Thesis: "*Impurities in a Bose-Einstein Condensate using quantum Monte-Carlo methods*". Advisor: Prof. Dr. Stefano Giorgini.
- 01.08.2008-30.11.2010 **MSc degree in Physics.** University of Campinas, Sao Pablo, Brazil. Thesis: "*Path Integral Quantum Monte-Carlo Simulations-Elastic properties of ^4He* ". Advisor: Prof. Dr. Maurice De Koning
- 01.08.2003-31.07.2008 **BSc in Physics.** Universidad Nacional de Colombia. Bogotà, Colombia. Thesis: "*Energy-Momentum tensor associated to quasiparticles in anisotropic superconductors*". Advisor: Prof. Dr. William Herrera

RESEARCH INTERESTS

-Ultracold Quantum Gases — Bose Einstein condensation (BEC), solitons and vortices, polarons in quantum gases and solid-state, quantum mixtures, strongly correlated quantum many-body systems and quantum simulation.

-Quantum optics and Quantum simulation

-Numerical methods for physics: Quantum Monte-Carlo, Gross-Pitaevskii equations, exact diagonalization and machine learning.

PUBLICATIONS OVERVIEW

17 Peer-reviewed publications 4 submitted and 2 in preparations. Publications includes 4 in Phys. Rev. Lett.
Google Scholar: 670 citations and h-index=11
Scopus : 471 citations and h-index=10

PROFESSIONAL SKILLS & ACCOMPLISHMENTS

A. Quantitative Skills

- Field of expertise: quantum many-body systems, in and out-equilibrium dynamics.
- Methods: quantum Monte-Carlo techniques (variational, diffusion and path integral Monte Carlo), exact diagonalization, variational methods, perturbation theory, mean-field theory, Bogoliubov theory and Gross-Pitaevskii theory.
- Digital skills: C++, Fortran, Mathematica, Matlab, Python and Machine learning (basic).

B. Communication

- Author of 18 publications. 10 as first author.
- Presentations at conferences as well as scientific visits include 20.
- Attended conferences including talk or poster include 40.
- Languages: English, Italian, Portuguese and Spanish. German Basic.

C. Referee Activity

- Referee for *Phys. Rev. A*, *Phys. Rev. Letters*, *Phys. Rev. Materials*, *Nature communications*, *New Journal of Physics*, *Int. J. Mod. Phys. B*, *J.Phys. B: At.Mol.Opt.Phys A & B*, *Atoms, entropy, and condensed matter*.

D. Teaching

- Physics high school at the “Colegio de la Salle Colombia” (High School).
 - University teaching:
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Term	Course	Type of duty	Hrs/week
Summer 20	Lecture course <i>Advanced quantum mechanics</i> <i>(3L+1T+2S)</i>	Tutorial and marking	1
	Group seminar <i>Quantum optics meets Quantum information</i> (2S)	Supervision and organization	2
Winter 20/21	-Lecture course <i>Advanced quantum mechanics</i> <i>(3L+1T+2S)</i>	Supervision, tutorial and marking	1
	-Lecture course <i>Quantum theory for nanotechnologist</i> <i>(3L+2T)</i>		2
Summer 21	Lecture course <i>Theoretical quantum Optics</i> <i>(2L+2T+2S)</i>	Tutorial, marking and seminar	4
	-Lecture course <i>Advanced quantum mechanics</i> <i>(3L+1T+2S)</i>	Tutorial, marking and exercises	2
Winter 21/22	-Seminar <i>Polaron physics in quantum gases</i> (2S)	Supervision and organization	2
Summer 22			

E. Management

- Scientific tutor of PhD students in Aarhus and Hannover University

F. Principal Collaborations - Networking

- **Theory:** Stefano Giorgini (Trento University-Italy), Grigori Astrakharchik (UPN-Spain), André Eckardt and Markus Heyl (Max Plank Institute-Germany), Thomas Pohl (Aarhus University-Denmark), Fabio Cinti (Firenze-Italy), A. Negretti (Hamburg university), Russell Bisset (Innsbruck), Luis Santos (U. Hannover). Meera Parish (Monash U-Australia), Krzysztof Jachymski(Warsaw University), Jesper Levinsen (Monash U-Australia) and Richard Schmidt (MPQ and Aarhus U- Germany/Denmark), Renato Pessoa (Goiania University-Brazil)
- **Experiment:** Jan Arlt (Aarhus University-Denmark), Francesca Ferlaino (Innsbruck).

TALKS AND SCIENTIFIC VISITS.

- 12 -2013: Talk “controlling interaction with cold atoms”. Bogotá (**Colombia**)
- 02 - 2014. PhD workshop. University of Trento, **Trento (Italy)**
- 04 - 2014. Scientific visit and seminar. University of Antwerp-**J. Tempere Group (Belgium)**
- 05 - 2014. Scientific visit and seminar. University of Innsbruck-**R. Grimm Group (Austria)**
- 06 - 2015.Talk “Impurities in a Bose-Einstein Condensate using Monte Carlo methods”. **WUT (Poland)**
- 10 - 2015.Talk & scientific visit at Max-Plank institute for physics of complex systems, (**Germany**).
- 10 - 2015. Talk & scientific visit at U. Kaiserslautern, **Kaiserslautern-S. Eggert Group (Germany)**
- 01 - 2017.Talk & scientific visit at LMU, Munich-**L. Pollet Group (Germany)**.
- 11 - 2017. Talk at Max Plank institute for physics of complex systems (**Germany**)
- 09 - 2018. Talk at Polytechnic University of Catalonia- **G. Astrakharchik (Spain)**
- 10 - 2018.Talk& scientific visit at Polytechnic University of Catalonia- **G. Astrakharchik (Spain)**.
- 09 - 2018. Talk & scientific visit at University of Hannover, **Luis Santos Group (Germany)**
- 11 - 2018. Talk & scientific visit at “Advances in Quantum Simulation with Ultracold atoms”-**Natal (Brazil)**
- 11 - 2018. Talk& scientific visit at University of los Andes-**Luis Quiroga Group (Colombia)**
- 02 - 2018. Talk& scientific visit at IST Austria, Vienna-**M. Lemeshko Group (Austria)**
- 02 - 2018. Talk& scientific visit at Heidelberg University, -**A. Negretti Group (Germany)**
- 03 - 2019. Talk& scientific visit at Heidelberg University, -**M. Weidemüller Group (Germany)**
- 11 - 2019. Scheduled Talk& scientific visit at LENS, Firenze-**M. Zaccanti Group (Italy)**
- 10 - 2020. Online Talk “perspectives on long-range polarons”-**Prof. Robert Smith Group (Oxford-UK)**
- 03 - 2022. Talk and scientific visit at Amsterdam University- **Prof. Rene Gerritsma (Amsterdam-The Nederland)**
- 09-2022. Talk and scientific visit at Warsaw university- **Prof. Krzysztof Jachymski (Warsaw-Poland)**

FELLOWSHIPS, GRANTS AND AWARDS

- Best GPA Bachelor course-Universidad Nacional de Colombia (2003, 2004 and 2008)
- Prestigious CNPq Scholarship by the Brazilian National Council (2008 - 2010)
- Prestigious BEC-INO-CNR Scholarship –Trento University (2012-2015)
- Fellowship at Max Planck Institute for the Physics of Complex Systems (2016 - 2017)
- Danish National Research Foundation Scholarship-Aarhus University (2017-2019).
 - Seal of excellence by the European commission awarded to the MSCA (Marie Skłodowska-Curie Actions) proposal DIPODROP (2019)
- IOP trusted reviewer (2021)

OUTREACH

-Main organizer of the “Young Researchers Workshop on Quantum Fluctuations in Ultra-cold Gases - 2020. With the participation of 22 speakers and around 70 participants. The conference was devised to bring together young scientist working on polaron physics, quantum droplets, super solids and interdisciplinary physics. <https://quantumfluctuations2020.wordpress.com/>

-Current guess editor for the special issue “Recent Trends on Quantum Fluctuations in Ultra-Cold Quantum Gases” https://www.mdpi.com/journal/atoms/special_issues/RecenTren_QuantumFluctua_UltraColdQuantumGas

ATTENDED CONFERENCES AND INVITED TALKS

- National physics congress. Universidad de Tolima-Tolima (Colombia). 22-26.10.07. (P)
- XXXII National Meeting of Condensed Matter Physics, Águas de Lindóia , Brazil 05.2009. (P)
- Summer school on Bose –Einstein Condensation by A. Fetter. São Carlos, Brazil 09. (P)
- Summer school in computational physics- Rio Grande do Sul (Brazil). 1-10.08.09. (P)
- Young Atom Opticians conference (YAO)-Krakow (Poland). 26-30.03.12. (P)
- International conference on frontiers of cold atoms and related topics, Hong Kong (China). 14-17.05.12. (P)
- Theory of quantum gases and quantum coherence. Lyon (France). 6-10.06.12. (P)
- Summer school on quantum-many body physics of ultracold atoms and molecules. Trieste (Italy). 1-13.07/2. (P)
- Summer school in atomic physics ICAP 2012. Paris (France). 16-20.07.12. (P)
- International conference in atomic physics ICAP2012. Palaiseau (France). 23-27.07.12. (P)
- Quantum gases and coherence, Levico, Trento, (Italy) 28-31.05.14. (P)
- International conference in atomic physics ICAP2014. Williamsburg, Virginia (USA). 21-28.07.14. (P)
- Innsbruck-Trento joint meeting on quantum gases, Trento (Italy). 29-30.09.15.
- DPG Hannover, Hannover, (Germany). 24.02.16-04-03.16 (P)
- International workshop on Equation of state in Quantum Many-body systems, Trento (Italy).30.05.16-1.06.16 (P)
- International conference in atomic physics ICAP2016. Seoul, (Korea). 24.08.16-01.08.16 (P)
- International workshop on Atomic Physics. Dresden. (Germany). 27.11.16-02.12.16 (P)
- DPG Mainz 6-10.03.17 Mainz (Germany). (IS)
- Conference on Controllable Quantum Impurities in Physics and Chemistry. (Austria). 16-18.08.17. (P)
- BEC 2017. Saint Feliu de Guixols (Spain). 2-8.09.17. (P)
- Ultra-cold Quantum Mixtures Meeting. Barcelona (Spain). 18-20.07.18. (IS)
- Quantum Simulation with Atoms and Light. Aarhus (Denmark). 13-17.08.2018. (P)
- Advances In Quantum Simulation with Ultracold Atoms. 19.10.18-09.11.18 Natal (Brazil) (IS)
- "Frontiers in nonequilibrium dynamics of multicomponent systems in the few- to many-body crossover". Hamburg (Germany) 10-12.02.19 (IS)
- Task Force meeting “Perspectives for supersolidity in dipolar droplets arrays”. Stuttgart (Germany) 3-5.06.19.
- Compound (Atomic) quantum systems. Leiden (The Nederlands). 20-24.05.19. (P)
- Workshop on quantum Mixtures. 70th anniversary Sandro Stringari (Italy). 15-17.07.19. (P)
- Workshop on “Dynamics and interactions in quantum gases”. Menorca (Spain). 04-06.09.19. (P)
- DPG Hannover, Hannover (Germany). 09-13.03.20. (scheduled) (IS)
- 2nd Colombian Meeting on Many-Body Quantum Simulations (Colombia). 06-09.06.21. (IS)
- Virtual workshop Korrelationstage 2021, Dresden (Germany). 15-20.08.21. (P)
- Dynamics and local control of impurities in complex quantum environments. 23.08.21-17.09.21 (IS)
- BEC 2021. Saint Feliu de Guixols (Spain). 11-17.09.21. (P)
- Interdisciplinary Workshop on Supersolidity. Trento (Italy). 20-22.09.21. (P)
- Cold atoms meeting-Granada (Spain). 25-26.11.21. (IS)
- FermiPolar Workshop. 7-18.02.22 - ONLINE. (P)
- DPG Erlangen 14-18.03.22 ONLINE (IS)
- Quantum physics and photonics seminar 16-06.22 , UNAM (Mexico) (IS)
- International conference in atomic physics ICAP2022. Toronto (Canada). 17-23.07.22. (P)
- 20 Years BEC Center conference. Trento (Italy). 02-03 November 2022.
- Cold Atom Workshop CAW, Madrid (Spain). November 24-25 2022 (IS)

(IS) : Invited Talk. (P): Poster presentation

PERSONAL REFERENCES

- Prof. Dr. Stefano Giorgini.

Prof. Dr. Luis Santos

Prof Dr. Thomas Pohl.

Prof. Dr. Franco Dalfovo.

Prof. Dr. Georg Bruun.

Prof. Dr. Jan Arlt.

Prof. Dr. Pierbiagio pieri.

Prof. Dr. Jacques Tempere.

RESEARCH PROJECTS

- Associate researcher at Hannover University. Agencies: Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy –EXC-2123 QuantumFrontiers –390837967 and FOR 2247 "From few to many-body physics with dipolar quantum gases"(Budget 45000 €/ year) and Quantum Frontiers (Budget 5000000 €/ year)
PI: Prof. Luis Santos. Candidate's participation: researcher. Time-frame: 2019-2024
- Associate researcher at Aarhus University. Agencies: Villum Foundation; The Danish National Research Foundation through a Niels Bohr Professorship (Budget: € 4000000) and Carlsberg foundation (Budget: € 2000000). PI: Prof. Thomas Pohl. Candidate's participation: researcher.
- Associate researcher at the Max Plank Institute for the physics of complex systems. Agency: visitors program Max Plank Institute (Budget: € 60000) PI: LAP Ardila. Hosted by Prof. Thomas Pohl. Time-frame: 2017-2019.
- Ph.D studies at Trento University. Agency: ERC Advanced Grant - Quantum Gases Beyond Equilibrium (QGBE) ID 267159. PI: S. Stringari (INO-CNR BEC Center, Trento),
Time-frame: 01.02.11 – 31.01.16 (Budget: € 1 638 560) Candidate's participation: researcher.

TECHNOLOGY AND KNOWLEDGE TRANSFER

Contracts

- Ph.D studies at Trento University. Agency: INO-CNR BEC Center, Trento. Full granted scholarship for 3 years. Budget: € 50000. Time-frame: 02.07.15-01.10.15

- Short postdoctoral stay at Trento university. Agency: INO-CNR BEC Center, Trento. Full granted scholarship for 3 months. Budget: € 4000. Time-frame: 01.02.12-30.04.15
- Ms.C studies at Campinas University. Agency: CNPq and Capes. Full granted scholarship for 2 years. Budget: € 10000. Time-frame: 01.08.09-31.07.11

LIST OF PUBLICATIONS

A. PEER-REVIEWED

- *Domain supersolids in binary dipolar condensates.* T. Bland, E. Poli, L. A. Peña Ardila, L. Santos, F. Ferlaino, and R. N. Bisset. Phys. Rev. A **106**, 053322 (2022) <https://doi.org/10.1103/PhysRevA.106.053322> CA: R.N Bisset.
- *Universal Properties of Anisotropic Dipolar Bosons in Two Dimensions.* J. Sánchez-Baena, L. A. Peña Ardila, G. Astrakharchik, F. Mazzanti. SciPost Phys. 13, 031 (2022). <https://scipost.org/10.21468/SciPostPhys.13.2.031>
- *Anomalous buoyancy of quantum bubbles in immiscible Bose mixtures.* D. Edler, **LAP Ardila**, C. Cabrera and L. Santos. Phys. Rev. Research 4, 033017 (2022) <https://doi.org/10.1103/PhysRevResearch.4.033017> CA: LAP Ardila.
- *Monte Carlo methods for impurity physics in ultracold Bose quantum gases.* **LAP Ardila**. Nat Rev Phys , 4, 214-Tools of Trade (2022). <https://doi.org/10.1038/s42254-022-00443-5>. CA: LAP Ardila.
- *Ultra-Dilute Gas of Polarons in a Bose-Einstein Condensates.* **LAP Ardila**. Atoms 10 (29) (2022). <https://doi.org/10.3390/atoms10010029>. CA: LAP Ardila.
- *Finite range effects in the unitary Fermi polaron.* Renato Pessoa, S. A. Vitiello, and **LAP Ardila**. Phys. Rev. A **104**, 043313 (2021). <https://doi.org/10.1103/PhysRevA.104.043313>. CA: LAP Ardila.
- *Quantum Behavior of a Heavy Impurity Strongly Coupled to a Bose Gas.* Jesper Levinsen, **LAP Ardila**, Shuhei M. Yoshida, and Meera M. Parish. Phys. Rev. Lett 127, 033401 (2021) - Editors' suggestion. <https://doi.org/10.1103/PhysRevLett.127.033401>. CA: J Levinsen
- *Dynamical formation of polarons in a Bose-Einstein condensate: A variational approach.* **LAP Ardila**. Phys. Rev. A **103**, 033323 (2021). <https://doi.org/10.1103/PhysRevA.103.033323>. CA: LAP Ardila.
- *Quantum Droplets of Dipolar Mixtures.* R. N. Bisset, **LAP Ardila**, and L. Santos. Phys. Rev. Lett **126**, 025301 (2021). <https://doi.org/10.1103/PhysRevLett.126.025301>. CA: R. Bisset
- *Ionic polaron in a Bose-Einstein condensate.* Grigory E. Astrakharchik and **LAP Ardila**, Richard Schmidt, Krzysztof Jachymski & Antonio Negretti. Communications Physics (Springer Nature) **4**, Article number: 94 (2021). <https://doi.org/10.1038/s42005-021-00597-1>. CA: G. E. Astrakharchik and **LAP Ardila**
- *Strong coupling Bose polarons in a two-dimensional gas.* **L. A. Peña Ardila**, G. E. Astrakharchik, and S. Giorgini. Phys. Rev. Research 2, 023405 (2020). <https://doi.org/10.1103/PhysRevResearch.2.023405> CA: LAP Ardila
- *Analyzing the Bose polaron Across Resonant interactions.* **LAP Ardila**, N. B. Jørgensen, T. Pohl, S. Giorgini, G. M. Bruun and J. J. Arlt. Phys. Rev. A **99**, 063607 (2019). <https://doi.org/10.1103/PhysRevA.99.063607>. CA: LAP Ardila
- *Ground-state properties of the Dipolar Bose-Polaron.* **L. A. Peña Ardila** and Thomas Pohl. J. Phys. B: At. Mol. Opt. Phys. 52 (2019). <https://doi.org/10.1088/1361-6455/aaf35e>. CA: LAP Ardila
- *Critical slowdown of non-equilibrium polaron dynamics.* K Knakergaard, **LAP Ardila**, G. M. Bruun and Thomas Pohl. New J. Phys, **21** 043014 (2019). <https://doi.org/10.1088/1367-2630/ab0a81>. CA: K Knakergaard

- *Measuring the single-particle density matrix for fermions and hard-core bosons in an optical lattice.* **LAP Ardila**, Markus Heyl, André Eckardt. Phys. Rev. Lett **121**, 260401 (2018). <https://doi.org/10.1103/PhysRevLett.121.260401>. CA: LAP Ardila
- *Bipolarons in a Bose-Einstein Condensate.* A. Camacho-Guardian, **LAP Ardila**, T. Pohl, and G. M. Bruun. Phys. Rev. Lett. **121**, 013401 (2018). <https://doi.org/10.1103/PhysRevLett.121.013401>. CA: A.Camacho
- *Bose Polaron Problem: effect of mass imbalance on binding energy.* **L.A. Peña Ardila**, S. Giorgini. Phys. Rev. A. **94**, 063640 (2016) <https://doi.org/10.1103/PhysRevA.94.063640> CA: LAP Ardila
- *Impurity in a Bose-Einstein condensate: study of the attractive and repulsive branch using quantum Monte-Carlo methods.* **LAP Ardila** and S. Giorgini. Phys. Rev. A **92**, 033612 (2015). <https://doi.org/10.1103/PhysRevA.92.033612>. CA: LAP Ardila
- *Elastic constants of hcp ^4He : path integral Monte-Carlo results vs. experiment.* **L.A. Peña Ardila**, Silvio A. Vitiello & Maurice de Koning. Phys. Rev. B **84**, 094119 (2011). <https://doi.org/10.1103/PhysRevB.84.094119> CA: LAP Ardila

CA: Corresponding author(s).

B. IN PREPARATION AND/OR SUBMITTED (2021/2022)

B1. PREPRINTS

-*Charged impurities in a Bose-Einstein condensate: Many-body bound states and induced interactions.* Grigory E. Astrakharchik and **LAP Ardila**, Krzysztof Jachymski & Antonio Negretti. arXiv:2206.03476v12022 (submitted)

-*Catalyzation of supersolidity in binary dipolar condensates.* D. Scheermann, L. A. Peña Ardila, T. Bland, R. N. Bisset, L. Santos. arXiv:2202.08259 [cond-mat.quant-gas] 2022 (submitted)

B1. IN PREPARATION

-*Impurity and polarons physics in Bosonic quantum gases: a review*. L. A. Peña Ardila and Fabian Grusdt. Invited by Reports on Progress in Physics (in preparation).

-*Quantum Dynamics of dipolar polarons*, Giacomo Bighin, A. Volosniev and L.Santos and Luis A. Peña Ardila. (in preparation)

C. OTHER PUBLICATIONS

-*Momentum energy tensor associated to quasiparticles in anisotropic superconductors.* L.A. Peña Ardila, William Herrera & Virgilio Niño. arXiv:1502.03577 [cond-mat.supr-con] (2015)

-*Movimiento de Rodadura de un Cilindro en Funcion de la Posicion de un eje Asimétrico.* L.A Peña Ardila, D.Vanegas and F.Fajardo. Revista Colombiana de Física 41 (1). (2009). In Spanish.

-*Tensor de Momentum-Energía Asociados a las Cuasipartículas en Superconductores Anisotrópicos.* L.A. Peña Ardila, William Herrera & Virgilio Niño. Revista Colombiana de Física 40 (1).