

REPORT DOCUMENTATION PAGE			Form Approved OMB NO. 0704-0188		
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1. REPORT DATE (DD-MM-YYYY) 25-08-2021		2. REPORT TYPE Final Report		3. DATES COVERED (From - To) 1-Nov-2018 - 30-Apr-2019	
4. TITLE AND SUBTITLE Final Report: Third International Workshop on Ultracold Rydberg Physics			5a. CONTRACT NUMBER W911NF-18-1-0410		
			5b. GRANT NUMBER		
			5c. PROGRAM ELEMENT NUMBER 611102		
6. AUTHORS			5d. PROJECT NUMBER		
			5e. TASK NUMBER		
			5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAMES AND ADDRESSES INSTITUTO DE FISICA DE SAO CARLO USP Avenida trabalhador São-Carlense 400			8. PERFORMING ORGANIZATION REPORT NUMBER		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS (ES) U.S. Army Research Office P.O. Box 12211 Research Triangle Park, NC 27709-2211			10. SPONSOR/MONITOR'S ACRONYM(S) ARO		
			11. SPONSOR/MONITOR'S REPORT NUMBER(S) 73653-PH-ITC.1		
12. DISTRIBUTION AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.					
13. SUPPLEMENTARY NOTES The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Luis Marcassa
a. REPORT UU	b. ABSTRACT UU	c. THIS PAGE UU			19b. TELEPHONE NUMBER 163-372-9806

RPPR Final Report

as of 27-Aug-2021

Agency Code: 21XD

Proposal Number: 73653PHITC

Agreement Number: W911NF-18-1-0410

INVESTIGATOR(S):

Name: Luis Gustavo Marcassa
Email: luis.marcassa@fulbrightmail.org
Phone Number: 1633729806
Principal: Y

Organization: **INSTITUTO DE FISICA DE SAO CARLOS**

Address: USP, São Carlos, 13566590

Country: BRA

DUNS Number: 900843269

EIN:

Report Date: 31-Jul-2019

Date Received: 25-Aug-2021

Final Report for Period Beginning 01-Nov-2018 and Ending 30-Apr-2019

Title: Third International Workshop on Ultracold Rydberg Physics

Begin Performance Period: 01-Nov-2018

End Performance Period: 30-Apr-2019

Report Term: 0-Other

Submitted By: Luis Marcassa

Email: luis.marcassa@fulbrightmail.org

Phone: (163) 372-9806

Distribution Statement: 1-Approved for public release; distribution is unlimited.

STEM Degrees: 0

STEM Participants: 18

Major Goals: This workshop was aimed at understanding the many facets of Rydberg atom systems at ultracold temperatures. The study of Rydberg atoms is experiencing a renaissance due to the recent advances made in this research area, such as the progress towards making quantum gates, the observations of new and exotic types of molecules, the investigation of plasmas and the study of many-body dynamics. Of central interest is controlling the interactions between Rydberg atoms so that they may be engineered to make new devices based on quantum entanglement or used to investigate phenomena that can be better understood by taking advantage of this control.

Accomplishments: In this spirit, the main topics that were addressed at the conference are quantum computation with Rydberg atoms, ultracold plasmas, precision measurement with Rydberg atoms, Rydberg atom interactions and collisions, novel types of Rydberg molecules, lifetimes and properties of Rydberg atoms, ions and Rydberg atoms embedded in quantum degenerate gases, Rydberg atom trapping, Rydberg atom quantum optics and many-body physics studied using Rydberg atoms. These topics cover the most recent advances in the field, but made it possible for researchers from related fields to actively participate in the meeting.

Our meeting has connected US, Europe, Asia, Oceania and Latin American researchers in a exciting environment, where senior scientists, junior scientists, pos-docs and graduate students from a wide range of backgrounds could present their work and share ideas on the future of the field. Overall, we received many enthusiastic comments about the conference. Many of the participants were interested in holding this conference every other year, which must be considered in the future. The conference was extremely successful for exchanging scientific ideas and educating junior researchers.

Training Opportunities: Nothing to Report

Results Dissemination: Nothing to Report

Honors and Awards: Nothing to Report

Protocol Activity Status:

Technology Transfer: Nothing to Report

RPPR Final Report
as of 27-Aug-2021

Partners

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Name	Institution	Country	Email
Adam Deller	University of College London	UK	a.deller@ucl.ac.uk
Alexandre Andrade			

I certify that the information in the report is complete and accurate:

Signature: Luis Gustavo Marcassa

Signature Date: 8/25/21 1:53PM

Report on the Third International Workshop on Ultracold Rydberg Physics

This workshop was aimed at understanding the many facets of Rydberg atom systems at ultracold temperatures. The study of Rydberg atoms is experiencing a renaissance due to the recent advances made in this research area, such as the progress towards making quantum gates, the observations of new and exotic types of molecules, the investigation of plasmas and the study of many-body dynamics. Of central interest is controlling the interactions between Rydberg atoms so that they may be engineered to make new devices based on quantum entanglement or used to investigate phenomena that can be better understood by taking advantage of this control.

This workshop was held at Transamérica Prestige Beach Class International hotel located at the Boa Viagem Beach in Recife, Brazil. The workshop was from 2 to 5 December 2018. There were invited and contributed talks. We believe our main goal was achieved by having an exciting meeting where senior scientists, junior scientists, pos-docs and graduate students had present their work and shared ideas on the future of the field. In the sequence, we present some technical information on the workshop.

Technical information on the workshop

Organizing Committee:

Rosario Gonzalez Ferez - Universidad de Granada - Spain

Tommaso Macri - Federal University of Rio Grande do Norte - Brazil

Emanuel Alves de Lima Henn - University of São Paulo - Brazil

Paul Kunz - Army Research Laboratory - USA

James P. Shaffer - Quantum Valley Ideas Laboratories - Canada

Luis G. Marcassa - University of São Paulo – Brazil

Place: Transamérica Prestige Beach Class International hotel, Recife (Pernambuco, Brazil)

Dates: from 2 to 5 December 2014

Topic subjects:

Rydberg atom Quantum Optics

Devices and Quantum Computation

Cold Plasmas

Interactions and Collisions

Rydberg Molecules

Lifetime and Properties

Ions in BEC

Rydberg Atom Trapping

Many body Physics

Precision Measurement with Rydberg atoms

Program

Sunday, December 2

15:45-16:30 Registration – **Room “Boa Viagem 1”**

16:30-16:40 Opening - **Room “Boa Viagem 2”**

Chairperson: J. Shaffer

16:40-17:20 Probing the quench dynamics of antiferromagnetic correlations in a 2D quantum Ising spin system - Peter Schauss

17:20-17:40 Angular Dependence of Rydberg Atom Pair Interactions in a Blocked Rb Gas – Akbar J. Jozani, James P. Shaffer, Luis F. Gonçalves, and Luis G Marcassa

17:40-18:00 Critical thermodynamics properties of weakly interacting Bose gases as modified by a harmonic confinement - I. Reyes-Ayala, F. J. Poveda-Cuevas, J. A. Seman, and V. Romero-Rochin

18:30-20:00 Reception

Monday, December 3

Chairperson: I. Beterov

8:30-9:10 Entangling atomic qubits with Rydberg interactions - M. Saffman

- 9:10-9:30 Rydberg Atom Quantum Hybrid Systems - James P. Shaffer
 9:30-9:50 New types of quantum memory in atomic ensembles - Daniel Felinto
 9:50-10:10 Fast circularisation and optimal control of Rydberg atoms in Stark manifolds - S. Patsch, A. Larrouy, R. Richaud, J.-M. Raimond, M. Brune, S. Gleyzes, C. P. Koch
- 10:10-10:30 Coffee Break
- Chairperson: M. Saffman**
- 10:30-11:10 Free-space QED with a single Rydberg superatom - S. Hofferberth
 11:10-11:50 Three-body interactions of Rydberg atoms and their application to quantum information - I.I.Beterov, I.N.Ashkarin, D.B.Tretyakov, E.A.Yakshina, V.M.Entin, I.I.Ryabtsev, P.Cheinet, P.Pillet, M.Saffman
 11:50-12:10 Rydberg Antenna at the Quantum Limit - Paul Kunz, Kevin Cox, David Meyer, Zac Castillo
 12:10-12:30 High fidelity quantum state transfer in Rydberg systems – Tommaso Macri
- 12:30-14:00 Lunch
- Free afternoon and night**

Tuesday, December 4

- Chairperson: P. Kunz**
- 8:30-9:10 Spin-Interaction Effects and Alignment of s-state Ultralong-range Rydberg Molecules - P. Schmelcher
 9:10-9:50 Trilobites in random and regular environments - Jan M Rost
 9:50-10:10 Spectroscopy of nD Rydberg-ground molecules in ^{87}Rb and ^{85}Rb - Jamie MacLennan, Georg Raithel, Yun-Jih Chen
 10:10-10:30 Two-electron R-matrix method in calculations of long-range Rydberg molecules at intermediate internuclear distances - Michal Tarana
- 10:30-10:50 Coffee Break
- Chairperson: J. M. Rost**
- 10:50-11:30 Lots of Bosons and Fermions and one Rydberg atom - H. R. Sadeghpour
 11:30-12:10 Electronic Structure of the Rydberg Triatomic Molecule: $\text{K}(\text{nl})\text{-KRb}(\text{vN})$ - R. González-Férez, S. T. Rittenhouse, P. Schmelcher and H. R. Sadeghpour
 11:10-12:30 Confining high- and low-field-seeking Rydberg atoms in time-varying electric fields - Adam Deller and Stephen D. Hogan

- 12:30-14:00 Lunch
- Chairperson: R. González-Férez**
- 14:00-14:40 Placing single Rydberg atoms and ions into a BEC – Robert Löw
- 14:40-15:00 Rydberg Physics at Otago - Amita Bikram Deb and Niels Kjærgaard
- 15:00-15:20 Towards a Precision Measurement of the Rydberg Constant Using Circular Rydberg Atoms - Andira Ramos, Ryan Cardman, Georg Raithel
- 15:20-15:40 Coffee Break
- Chairperson: R. Löw**
- 15:40-16:00 Rydberg state ionization dynamics and tunnel ionization rates in strong electric fields - K. Gawlas and S. D. Hogan
- 16:00-16:20 Possible manifestations of quantum disordered dynamics in the arrested relaxation of a molecular plasma - Kevin Marroquin, Ruoxi Wang, Fernanda Banic V. Martins, Mahyad Aghigh, Kiara Grant, Xixi Qi, James Keller and Edward Grant
- 16:20-16:40 Light storage based on the external atomic degrees of freedom - J. P. Lopez, A. J. F Almeida, A. M. G. de Melo, D. Felinto, and J. W. R. Tabosa
- 19:00-23:30 Workshop Banquet – **Cachaçaria Carvalheira**

Wednesday , December 5

- Chairperson: L. Marcassa**
- 9:00-9:40 Many-body physics with ultracold plasmas: Quenched randomness and localization – Ed Grant
- 9:40-10:00 Structure and Dynamics of Cold Single-Component Plasma - Michael A. Viray and Georg Raithel
- 10:00-10:20 Coffee Break
- Chairperson: T. Macri**
- 10:20-11:00 Study of Rydberg blockade in thermal vapor - Ashok Mohapatra
- 11:00-11:20 Intrinsic Optical Bistability in a Rydberg Ensemble - Natalia R. de Melo, Christopher G. Wade, Nikola Sibalic, Jorge M. Kondo, Charles S. Adams, Kevin J. Weatherill
- 11:20-11:40 Lifetime measurement of nS , $nD_{3/2}$ and $nD_{5/2}$ Rb Rydberg states - Cristian A. Mojica Casique, Barbara F. Magnani, Luis G. Marcassa
- 12:00-14:00 Lunch

Sponsors:



UNIVERSIDAD DE GRANADA



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USP

Participants List :

Name	Institution	Country	Email
Adam Deller	University of College London	UK	a.deller@ucl.ac.uk
Alexandre Andrade Cavalcanti de Almeida	Federal University of Pernambuco	BRAZIL	alandr@df.ufpe.br
Amita Bikram Deb	University of Otago	NEW ZEALAND	amita.deb@otago.ac.nz
Andira Ramos	University of Michigan	USA	andramos@umich.edu
Ashok K Mohapatra	National Institute of Science Education and Research	INDIA	a.mohapatra@niser.ac.in
Cristian Adan Mojica Casique	University of São Paulo	BRAZIL	fis.mojica@gmail.com
Daniel Felinto Pires Barbosa	Federal University of Pernambuco	BRAZIL	dfelinto@df.ufpe.br
Eduard Grant	University of British Columbia	CANADA	edgrant@chem.ubc.ca
Gabriel da Cruz Borba de Andrade	Federal University of Pernambuco	BRAZIL	Gcruz@df.ufpe.br
Hossein Sadeghpour	University of Harvard	USA	hrs@cfa.harvard.edu
Ignacio Reyes Ayala	Universidade Autonoma do Mexico	MEXICO	nacho.reyes.ayala@gmail.com
Ilya I. Beterova	Institute of Semiconductor Physics · Quantum Electronics	RUSSIA	beterov@gmail.com
James Paul Shaffer	Quantum Valley Ideas Laboratory	CANADA	jshaffer@qvil.ca
Jamie MacLennan	University of Michigan	USA	jmacleenn@umich.edu
Jan-Michael Rost	Max Planck Institute for the Physics of Complex Systems	GERMANY	rost@pks.mpg.de
José Wellington Rocha Tabosa	Federal University of Pernambuco	BRAZIL	tabosa@df.ufpe.br
Kevin Leonardo Marroquin Madera	University of British Columbia	CANADA	kevinmm@chem.ubc.ca
Klaudia Gawlas	University College London	UK	klaudia.gawlas.13@ucl.ac.uk
Luciana Pereira	Federal University of ABC	BRAZIL	luciana.pereira@ufabc.edu.br
Luis Gustavo Marcassa	University of São Paulo	BRAZIL	marcassa@ifsc.usp.br

Manuel A. Lefrán Torres	University of São Paulo	BRAZIL	lefran.torres@gmail.com
Marcos Roberto Cardoso	University of São Paulo	BRAZIL	cardosomr@ifsc.usp.br
Maria Rosario Gonzalez Ferez	University of Granada	SPAIN	rogonzal@ugr.es
Mark Saffman	University of Wisconsin	USA	msaffman@wisc.edu
Michael Anthony Viray	University of Michigan	USA	mviray@umich.edu
Natalia Rodrigues de Melo	Federal University of Pernambuco	BRAZIL	natalia.rmelo@gmail.com
Paul D Kunz	Army Research laboratory	USA	paul.d.kunz.civ@mail.mil
Paulo José Cavalcanti de Vasconcelos Filho	Federal University of Pernambuco	BRAZIL	Vasconcelos@df.ufpe.br
Peter Friedrich Schauss	University of Virginia	USA	ps5nw@virginia.edu
Peter Schmelcher	University of Hamburg	GERMANY	pschmelc@physnet.uni-hamburg.de
Robert Löw	Universität Stuttgart	GERMANY	r.loew@physik.uni-stuttgart.de
Sabrina Patsch	University of Kassel	GERMANY	sabrina.patsch@physik.uni-kassel.de
Samihr Valentim Hermes	Federal University of Rio Grande do Norte	BRAZIL	samihr.hermes@gmail.com
Sandra Sampaio Vianna	Federal University of Pernambuco	BRAZIL	vianna@df.ufpe.br
Sebastian Friedrich Otto	University of Southern Denmark	DENMARK	hofferberth@sdu.dk
Tommaso Macri	Federal University of Rio Grande do Norte	BRAZIL	tommasomacri@gmail.com
Ygor Pará Silva	Federal University of Rio Grande do Norte	BRAZIL	ygpara@gmail.com

Final comments

Modern technology is increasingly driven by new materials. Materials such as high temperature superconductors, carbon nanotubes, and colossal magneto-resistance. Such materials have the potential to revolutionize technology. A detailed understanding of the physics behind these materials is essential for improving their unique properties and developing practical applications. Currently, the physical modeling of these new, cutting-edge materials is impeded by our limited understanding of strongly interacting systems. There is currently a gap between the theory of simple model systems and experimental measurements. The theory cannot be directly verified by experiments on currently existing materials, and creation of new synthesized materials heavily relies on trial and error approaches. Even the computational simulations of such materials are a problem, because they require a large computational power.

Cold Rydberg atomic systems may fill this gap by integrating experimental and theoretical studies of strongly interacting ultracold atoms. This workshop was aimed at understanding the many facets of contemporary Rydberg atom physics. The study of Rydberg atoms is experiencing a renaissance due to recent advances made in this research area, such as the progress towards making quantum gates, the observations of new and exotic types of molecules, the investigation of ultracold plasmas, the development of Rydberg atom quantum optics, the use of Rydberg atoms for precision measurement and the study of many-body dynamics in ultracold Rydberg gases. Of central interest is controlling the interactions between Rydberg atoms so that they may be engineered to make new devices based on quantum entanglement or used to investigate phenomena that can be better understood by taking advantage of this control.

Although mainly dealing with topics in the area of atomic, molecular and optical physics, cold Rydberg gas physics touches on solid state physics because Rydberg gases can be used to investigate many-body dynamics and quantum phase transitions, quantum information and computing because Rydberg atom quantum gates can be constructed and plasma physics because of the unique ultracold plasmas that can be produced with ultracold Rydberg gases. The breadth of interest and rapid rate of discovery in ultracold Rydberg atom research points to the continued growth of this field. Since our last workshop in Brazil

4 years ago (in 2014), it is not an exaggeration to say that the number of active research groups in Rydberg atom physics has almost doubled again.

In this spirit, the main topics that were addressed at the conference are quantum computation with Rydberg atoms, ultracold plasmas, precision measurement with Rydberg atoms, Rydberg atom interactions and collisions, novel types of Rydberg molecules, lifetimes and properties of Rydberg atoms, ions and Rydberg atoms embedded in quantum degenerate gases, Rydberg atom trapping, Rydberg atom quantum optics and many-body physics studied using Rydberg atoms. These topics cover the most recent advances in the field, but made it possible for researchers from related fields to actively participate in the meeting.

Our meeting has connected US, Europe, Asia, Oceania and Latin American researchers in a exciting environment, where senior scientists, junior scientists, pos-docs and graduate students from a wide range of backgrounds could present their work and share ideas on the future of the field. Overall, we received many enthusiastic comments about the conference. Many of the participants were interested in holding this conference every other year, which must be considered in the future. The conference was extremely successful for exchanging scientific ideas and educating junior researchers.

Unfortunately, Dr. P. Kunz was the only member from ARL allowed to attend the workshop. We have also tried to arrange his visit to the University of São Paulo at São Carlos after the workshop, but it was not approved either by ARL. Dr. Kunz did mention to me that it was a great experience to be in contact with the top quality researcher worldwide in the Rydberg field. I already have a visit to ARL at the end of January 2019, where we should continue to discuss a possible collaboration.

São Carlos, 10/December /2018

Prof. Dr. Luis G. Marcassa

