

# **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  $^{87}\text{Rb}$  and  $^{85}\text{Rb}$  - Jamie MacLennan, Georg Raithel, Yun-Jhih 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:



**Participants List :**

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## **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

