Matthew T. Eiles

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Research interests

• Few-body physics with an emphasis on Rydberg systems: long-range Rydberg molecules, Rydberg molecular ions, aggregates, and macrodimers

• Multichannel spectroscopy, quantum defect theory, and correlated two-electron systems

• Impurity physics in degenerate gases

Occupation

Research Group Leader — Jan 2021 – Present
Max-Planck-Institut für Physik komplexer Systeme — *Dresden, Germany*
- Currently supervising three PhD candidates and two postdoctoral researchers in the group **"Correlations and Transport in Rydberg Matter"**
- Previously supervised four postdoctoral researchers at MPI-PKS.
- Co-supervisor of a PhD student at University of Warsaw

Distinguished PKS postdoctoral fellow — July 2020 – Dec 2020
Max-Planck-Institut für Physik komplexer Systeme — *Dresden, Germany*

Alexander von Humboldt postdoctoral fellow — July 2019 – June 2020
Max-Planck-Institut für Physik komplexer Systeme — *Dresden, Germany*
- Co-hosted by Prof. Peter Schmelcher at the Institute for Quantum Physics, University of Hamburg

Postdoctoral researcher — July 2018 – June 2019
Max-Planck-Institut für Physik komplexer Systeme — *Dresden, Germany*
- Supervisor: Prof. Jan-Michael Rost

Education

PhD in Physics, Purdue University — West Lafayette, IN, USA
Thesis advisor: Prof. Chris H. Greene — *Sept 2013 – May 2018*
"Highly excited states of small molecules and negative atomic ions"
A theoretical study of the formation and manipulation of Rydberg molecules and photodetachment of negative atomic ions

BSc in Physics and Math, Hope College — Holland, MI, USA
Graduated with honors — *Sept 2009-May 2013*

Awards and Recognition

Fellowships

2020 Distinguished PKS postdoctoral fellowship

2019 Alexander von Humboldt postdoctoral fellowship, two year award

2016 Gordon and Betty Moore foundation grant

2012 Michigan Space Grant Consortium fellowship award

Awards

2019 Raman prize for outstanding thesis, Purdue University
- *In recognition of an outstanding dissertation*

2019 Finalist (out of four) for the APS DAMOP Debbie Jin thesis award
- *In recognition of doctoral thesis research of outstanding quality and achievement in atomic, molecular, or optical physics*

2016 Edward S. Akeley award, Purdue University
- *In recognition of outstanding physics graduate students in theoretical physicists*

2013 Yntema Prize, Hope College
- *In recognition of an outstanding student of physics*

Publications

26 peer-reviewed publications

- 6 in Physical Review Letters (three first-author and three second-author)
- 1 in Physical Review X (second-author)
- 7 in Physical Review A (one single author, three first-author, and three second-author)
- 2 in Physical Review Applied (two second-author)
- 1 in Physical Review B (first-author)
- 1 in Physical Review D (third-author)
- 6 in Journal of Physics B (one single author, three first-author, and two second-author)

4 preprints under review

Presentations

Over 60 scientific presentations, including

- 10 invited seminars
- 16 invited conference and workshop talks
- 3 invited summer school lectures

Teaching

Rydberg Physics of Atoms, Molecules and Ultracold Gases — Technical University Dresden, Germany
21 hour course for masters and PhD candidate — *Winter Semester 2023 & Summer Semester 2024*

I developed and taught a 14-week course on Rydberg physics, with an emphasis on few-body systems, ultracold collisions, and Rydberg molecules.

Lab and recitation instructor for introductory physics courses, Purdue University — West Lafayette, IN, USA
Weekly lectures, homework and exam review, and grading for Phys. 271 and Phys. 272 — *Sept 2013-Dec 2014*

Professional Service and Outreach

Workshop coordination

The Future of Ultracold and Ultrafast Dynamics, MPI-PKS, Oct 21-25, 2024

International Workshop on Atomic Physics, MPI-PKS, Nov 28 - Dec 2, 2022

Julia tutorial and hackathon, MPI-PKS, May 20-21, 2022

Seminar organization

Quantum Dynamics seminar, MPI-PKS, 2022-present

Finite systems group seminar, MPI-PKS, 2020-present

Graduate seminar, Physics Graduate Student Association, Purdue University, 2017-2018

Refereeing

Nature Communications, Physical Review X, Physical Review Letters, New Journal of Physics, Physical Review A, Journal of Physics B, Physics Letters A.

Public outreach

Rydberg Moleküle: die kleinsten Riesen. Public lecture for Dresden's Long Night of Sciences, July 8, 2022. Available on youtube.

Full list of publications

26 peer-reviewed publications and 4 preprints

30. Aileen A. T. Durst, Milena Simić, Neethu Abraham, and **M. T. Eiles** *Non-adiabatic couplings as a stabilization mechanism in long-range Rydberg molecules* arXiv:2408.14919

29. Daniel J. Bosworth, **M. T. Eiles**, and Peter Schmelcher *Metastable doubly-charged Rydberg molecules* arXiv:2405.20844 (2024)

28. Aileen A. T. Durst and **M. T. Eiles**, *Phenomenology of a Rydberg impurity in an ideal Bose Einstein condensate* arXiv:2404.03980 (2024)

27. **M. T. Eiles** and F. Hummel, *Kato's theorem and ultralong-range Rydberg molecules* Phys. Rev. A **109**, 022811 (2024)

26. **M. T. Eiles**, C. W. Wächtler, A. Eisfeld, and J. M. Rost, *Topological edge states in a Rydberg composite* Phys. Rev. B **109**, 075422 (2024)

25. C. H. Greene and **M. T. Eiles**, *Green's-function treatment of Rydberg molecules with spins* Phys. Rev. A **108**, 042805 (2023) *Editors' suggestion*

24. **M. T. Eiles**, A. Eisfeld, and J. M. Rost, *Anderson localization of a Rydberg electron* Phys. Rev. Research **5**, 033032 (2023)

23. O. Bulancea-Lindvall, **M. T. Eiles**, N. Tien Son, I. A. Abrikosov, and V. Ivády, *Isotope-Purification-Induced Reduction of Spin-Relaxation and Spin-Coherence Times in Semiconductors* Phys. Rev. Applied **19**, 064046 (2023)

22. O. Bulancea-Lindvall, **M. T. Eiles**, N. Tien Son, I. A. Abrikosov, and V. Ivády, *Low-Field Microwave-Free Magnetometry Using the Dipolar Spin Relaxation of Quartet Spin States in Silicon Carbide* Phys. Rev. Applied **19**, 034006 (2023).

21. F. Hummel, P. Schmelcher, and **M. T. Eiles**, *Vibronic interactions in trilobite and butterfly Rydberg molecules* Phys. Rev. Research **5**, 013114 (2023).

20. P. Giannakeas, **M. T. Eiles**, L. Alonzo, F. Robicheaux, and J. M. Rost *Probing ultracold gases using photoionization spectroscopy* arXiv:2111.11767 (2021)

19. G. Abumwis, C. W. Wächtler, **M. T. Eiles**, and A. Eisfeld *Coherently delocalized states in dipole interacting Rydberg ensembles: The role of internal degeneracies* Phys. Rev. A **104**, 013311 (2021).

18. F. Hummel, **M. T. Eiles**, and P. Schmelcher *Synthetic Dimension-Induced Conical Intersections in Rydberg Molecules* Phys. Rev. Lett. **127**, 023003 (2021).

17. P. Giannakeas, **M. T. Eiles**, F. Robicheaux, and J. M. Rost *Dressed ion-pair states of an ultralong-range Rydberg molecule* Phys. Rev. Lett. **102**, 123401 (2020).

16. P. Giannakeas, **M. T. Eiles**, F. Robicheaux, and J. M. Rost *Generalized local frame transformation theory for ultralong-range Rydberg molecules* Phys. Rev. A **102**, 033315 (2020).

15. A. L. Hunter, **M. T. Eiles**, A. Eisfeld and J. M. Rost *Rydberg Composites* Phys. Rev. X **10**, 031046 (2020).

14. G. Abumwis, **M. T. Eiles**, A. Eisfeld *Delocalization in two- and three-dimensional Rydberg gases*. J. Phys. B: At. Mol. Opt. Phys. **53**, 124003 (2020)

13. G. Abumwis, **M. T. Eiles**, A. Eisfeld *Extended coherently delocalized states in a frozen Rydberg gas* Phys. Rev. Lett. **124**, 193401 (2020).

12. **M. T. Eiles**, C. Fey, F. Hummel, and P. Schmelcher *Triatomic butterfly molecules* J. Phys. B: At. Mol. Opt. Phys. **53**, 054001 (2020).

11. **M. T. Eiles**, A. L. Hunter, and J. M. Rost *Ring Rydberg composites* J. Phys. B: At. Mol. Opt. Phys. **53**, 054001 (2020).

10. **M. T. Eiles**, *Trilobites, butterflies, and other exotic specimens of long-range Rydberg molecules.* J. Phys. B: At. Mol. Opt. Phys. **52**, 113001 (2019).

9. **M. T. Eiles**, *Formation of long-range Rydberg molecules in two-component ultracold gases* Phys. Rev. A **98**, 042706 (2018).

8. **M. T. Eiles** and C. H. Greene, *Extreme correlation and repulsive interactions in highly excited atomic alkali anions* Phys. Rev. Lett. **121**, 133401 (2018).

7. **M. T. Eiles**, Z. Tong, and C. H. Greene, *Theoretical prediction of the creation and observation of a ghost trilobite chemical bond* Phys. Rev. Lett. **121**, 113203 (2018). *This letter was selected to be featured in physics and as an editor's suggestion, and was featured on as a PRL cover image. It was additionally featured as a research highlight in Nature.*

6. **M. T. Eiles**, H. Lee, J. Pérez-Ríos, and C. H. Greene, *Anisotropic blockade using long-range Rydberg molecules*, Phys. Rev. A **95**, 052708 (2017). *Figure chosen for Kaleidescope feature.*

5. **M. T. Eiles** and C. H. Greene, *Hamiltonian for the inclusion of spin effects in long-range Rydberg molecules*, Phys. Rev. A **95**, 042515 (2017).

4. J. Pérez-Ríos, **M. T. Eiles**, and C. H. Greene, *Mapping trilobite state signatures in atomic hydrogen*, J. Phys. B: At. Mol. Opt. Phys. **49**, 14LT01 (2016). *(2016 Highlight and IOP select collection; figure chosen for journal cover image)*

3. **M. T. Eiles**, J. Pérez-Ríos, F. Robicheaux, and C. H. Greene, *Ultracold molecular Rydberg physics in a high density environment*, J. Phys. B: At. Mol. Opt. Phys. **49**, 114005 (2016). *(2016 Highlight; figure chosen for journal cover image)*

2. **M. T. Eiles** and C. H. Greene, *Ultracold long-range Rydberg molecules with complex multichannel spectra*, Phys. Rev. Lett. **115**, 193201 (2015).

1. P. L. Gonthier, M. G. Baring, **M. T. Eiles**, Z. Wadiasingh, C. A. Taylor, and C. J. Fitch, *Compton scattering in strong magnetic fields: Spin-dependent influences at the cyclotron resonance*, Phys. Rev. D **90**, 043014 (2014).

Full list of presentations

64. *Phenomenology of a Rydberg impurity in an ideal Bose Einstein condensate*,Poster Presentation, EGAS 55, Granada, June 19, 2024.

63. *From trilobite molecules to tight-binding models*, Presentation, APS DAMOP, Fort Worth USA, June 4, 2024.

62. *From trilobite molecules to tight-binding models*, Invited Seminar, Durham University, May 22, 2024.

61. *From trilobite molecules to tight-binding models*, Invited Talk, Quantum Science Generation, Trento, May 8 2024.

60. *From trilobite molecules to tight-binding models*, Invited Seminar, Ulm University, April 24, 2024.

59. *A Green's function treatment of Rydberg molecules* Presentation, DPG SAMOP, Freiburg, Mar 2024.

58. *From trilobite molecules to tight-binding models* Invited talk, Atomic Physics 2023, Dresden, Nov 27-Dec 1 2023.

57. *A more quantitative theory of ultralong-range Rydberg molecules* Invited talk, Workshop on Ultracold Molecules, Warsaw, Sep 4-8 2023.

56. *Rydberg molecules, polarons, and composites* Invited talk, WE-Heraus Seminar Applications of Ultracold Rydberg Gases, Bad Honnef, Jul 23-28 2023.

55. *Green's function treatment of ultra-long-range Rydberg molecules with spins* Invited talk, CATMIN III Frontiers in Rydberg physics, University College London, Jul 10-14 2023.

54. *Rydberg molecules, polarons, and composites* Invited talk, Humboldt Kollege, Vilnius, Jul 2-6 2023.

53. *Anderson localization of a Rydberg electron* Invited group seminar, MPQ Garching, Jun 20 2023.

52. *The effects of non-adiabatic physics in long-range Rydberg molecules* Poster Presentation, APS DAMOP, Spokane, WA, Jun 2023.

51. *A Rydberg impurity in an ideal Bose-Einstein Condenstate* Presentation, APS DAMOP, Spokane, WA, Jun 2023.

50. *Vanishing avoided crossings in Rydberg systems* Poster Presentation, DPG SAMOP, Hannover, Mar 5 2023.

49. *Vanishing avoided crossings in Rydberg systems* Poster Presentation, DPG SAMOP, Hannover, Mar 5 2023.

48. *A trip to the quantum zoo* Invited group seminar, C. Koch AG FU Berlin. Jan 12, 2023.

47. *Coherent delocalization in a frozen Rydberg gas* Presentation APS DAMOP, Orlando, FL. May, 2022.

46. *Coherent delocalization in a frozen Rydberg gas* Presentation DPG SAMOP, Online. Mar 14-18, 2022.

45. *Synthetic dimension-induced conical intersections in Rydberg molecules* Hot Topic Talk Workshop on Cold Rydberg Chemistry, Online. November 22-23, 2021.

44. *Ghostly molecules and the Droste effect* Hope College Physics Seminar, invited, Online. October 29, 2021.

43. *Anderson localization of a Rydberg electron* Invited talk DPG SAMOP spring meeting, Online. September 20-24, 2021.

42. *Topological States in a Rydberg Composite.* Presentation APS DAMOP meeting, Online. June 1-4, 2021.

41. *Exploring the Droste effect and Anderson localization in Rydberg atoms.* Invited Colloquium, University of Texas San Antonio. April 16, 2021.

40. *Exciton States in a Rydberg Gas.* Presentation APS March Meeting (virtual). March 15-19, 2021.

39. *Anderson Localization in a Rydberg Composite.* Presentation. 51st Annual DAMOP meeting, Online. June 1 - 5, 2020.

38. *Pandora's little box of Rydberg Molecules.* Presentation. GiRyd Status Workshop, Mainz, Germany, Mar. 25, 2020.

37. *Rydberg molecules.* Invited talk, PIER workshop on Ultra-long-range Rydberg molecules, Lauenburg, Germany, Feb. 5 2020.

36. *Anderson Localization in a Rydberg composite.* Invited talk, International Workshop on Atomic Physics, Dresden, Germany, Nov. 21 2019.

35. *Anderson Localization in a Rydberg composite.* Invited talk, Task-Force Meeting on "Cold Ions and Rydberg Atoms in Atomic Gases", Stuttgart, Germany, Nov. 12 2019.

32. *Localization, scarring, and the effects of disorder on Rydberg atoms and other excited systems.* Poster presentation, 50th Annual DAMOP meeting, Milwaukee, WI. May 27-May 31, 2019

31. *Highly excited states of small molecules and atomic negative ions.* Invited thesis prize talk, 50th Annual DAMOP meeting, Milwaukee, WI. May 27-May 31, 2019

30. *Spatial Confinement And Geometric Effects In The Electronic Structure Of A Rydberg Atom Embedded In A Neutral Medium.* Poster Presentation, ECAMP13. Florence, Italy. Apr. 11, 2019.

29. *Rydberg states in a two-dimensional monolayer.* Presentation. GiRyd Status Workshop, Kaiserslautern, Germany. Mar. 25, 2019.

28. *Exploring electron-neutral interactions in "trilobites", "butterflies", and anions.* Invited Seminar. Purdue University, West Lafayette, IN. Mar 21 2019.

27. *Localization, scarring, and the effects of disorder on Rydberg atoms and other excited systems.* Presentation. DPG Spring meeting. Rostock, Germany. Mar 13, 2019.

26. *Using heteronuclear Rydberg dimers and trimers to probe ultracold mixtures.* Poster Presentation. DPG Spring Meeting. Rostock, Germany. Mar. 12, 2019.

25. *Extreme Correlation and Repulsive Interactions in Highly Excited Atomic Alkali Anions.* Presentation. Extreme Atomic Physics workshop, Riezlern. Feb. 20, 2019.

24. *Atom-electron collisions in negative ion photodetachment and Rydberg molecule photoassociation*. Invited Presentation. University of Hamburg. Dec. 20, 2018.

23. *Rydberg atoms and their interactions with other atoms, with electrons, and even with nothing*. Invited Presentation. University of Rostock. Sept. 18, 2018.

22. *Rydberg atoms and their interactions with other atoms, with electrons, and even with nothing*. Presentation. MPI-PKS Finite Systems Group Meeting. July 23, 2018.

21. *Recent adventures with Rydberg atoms and molecules*. Poster Presentation. GiRyd Status Workshop, Hamburg, DE. July 4 - July 6, 2018.

20. *New types of trilobite-like states in hydrogen atoms and negative ions*. Poster Presentation. 49th Annual DAMOP meeting, Ft. Lauderdale, FL. May 28-June 1, 2018.

19. *Photodetachment of K^- into highly polarizable excited states*. Presentation. 49th Annual DAMOP meeting, Ft. Lauderdale, FL. May 28-June 1, 2018.

18. *Degenerate states in Rydberg atoms and negative ions*. Seminar. Hope College, Holland, MI. April 20, 2018.
17. *Degenerate states in Rydberg atoms and negative ions*. Seminar. Physics Graduate Student Association, Purdue University, West Lafayette, IN. April 19, 2018.
16. *Effects of degenerate energy levels in long-range Rydberg molecules and doubly excited negative ions*. Seminar. Technical University of Kaiserslautern, Kaiserslautern, Germany. February 13, 2018.
15. *Effects of degenerate energy levels in long-range Rydberg molecules and doubly excited negative ions*. Seminar. University of Stuttgart, Stuttgart, Germany. February 12, 2018.
14. *Effects of degenerate energy levels in long-range Rydberg molecules and doubly excited negative ions*. Seminar. University of Hamburg, Hamburg, Germany. February 5, 2018.
13. *Long-range interactions in Rydberg molecules and atomic negative ions*. Poster presentation. Midwest Cold Atom Workshop, Ann Arbor, MI. November 11, 2017.
12. *Anisotropic blockade using pendular long-range Rydberg molecules*. Poster presentation. ICPEAC XXX, Cairns, Australia, July 26-Aug. 1, 2017.
11. *Anisotropic blockade using pendular Rydberg butterfly molecules.* Presentation. 48th Annual DAMOP meeting, Sacramento, CA. June 5-9, 2017.
10. *Doubly excited states of atomic negative ions.* Poster presentation. 48th Annual DAMOP meeting, Sacramento, CA. June 5-9, 2017.
9. *If I ran the quantum zoo.* Physics Seminar, Hope College, Holland, MI. Feb. 24, 2017.
8. *New prospects in Rydberg molecules.* KITP Few Body Systems Workshop, Kavli Institute for Theoretical Physics, Santa Barbara, CA. Dec. 12, 2016.
7. *New prospects in Rydberg molecules.* Midwest Cold Atom Workshop, Chicago, IL. Oct. 29, 2016.
6. *Polyatomic Rydberg molecules in a high density environment.* Presentation. CUI Young researchers workshop: “From few- to many body physics in cold atomic quantum matter”, Center for Optical Quantum Technologies University of Hamburg. June 27-29, 2016
5. *Ultracold Long-Range Rydberg Molecules with Complex Multichannel Spectra*. Presentation. 47th Annaul DAMOP meeting, Providence, RI. May 23-27, 2016.
4. *If I ran the quantum zoo*. Seminar. Physics Graduate Student Association, Purdue University, West Lafayette, IN. April 20, 2016.
3. *Compton Scattering Cross Sections in Strong Magnetic Fields: Advances for Neutron Star Applications.* Poster Presentation. AAS 13th Meeting of the High Energy Astrophysics Division, Monterey, CA. April 7-11, 2013.
2. *Resonant Compton Upscattering in High Field Pulsars and Magnetars.* Poster Presentation. 219th AAS Meeting, Austin, TX. January 8-12, 2012
1. *Resonant Compton Upscattering in High Field Pulsars and Magnetars.* Presentation. MSGC Annual Fall Conference, Ann Arbor, MI. November 12, 2011

Summer school lectures:

3. *Rydberg atoms and molecules as a platform for quantum science*. Three hours for the CUI Summer School, Schwerin, July 10, 2024.
2. *Rydberg Systems - Exciting Possibilities in Excited Atoms*. One hour for the Quantum Dynamics - Fundamentals and Realizations school for Masters Students, MPI-PKS , Dresden, Sept 19, 2023.
1. *Quantum Simulators from First Principles*. Three hours for the IMPRS Summer School 2022 , Berlin, Aug.29-30, 2022.