

# Thomas C. Killian

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## Professional Interests

Quantum degenerate atomic gases, atom-photon interactions, ultracold neutral plasmas, and electro-magnetic characterization and control of biological structures

## Professional Experience

### William Marsh Rice University

Houston, TX

*Vice-Chair, Department of Physics and Astronomy, 2011-present.*

*Professor of Physics and Astronomy, 2010-present.*

*Associate Professor of Physics and Astronomy, 2006-2010.*

*Assistant Professor of Physics and Astronomy, 2000-2006.*

## Awards

*Office of Naval Research Young Investigator.*

*Department of Energy Junior Faculty Development Program Award Winner.*

*Alfred P. Sloan Research Fellow.*

*Research Corporation, Research Innovation Award Winner.*

*David and Lucille Packard Foundation Science and Engineering Fellow.*

*Fellow of the American Physical Society.*

## Education and Training

**National Institute of Standards and Technology**, 1999-2000,

Gaithersburg, MD

*National Research Council Postdoctoral Fellow.*

Studies of laser-cooled and trapped metastable xenon in the research group of Dr. W. Phillips and Dr. S. Rolston. Emphasis on the formation and characterization of ultracold neutral plasmas.

**Massachusetts Institute of Technology**, 1993-1999,

Cambridge, MA

*National Science Foundation Graduate Fellow, MIT Karl Taylor Compton Fellow.*

Ph.D. in Physics, 1999.

Thesis under Professors T. Greytak and D. Kleppner, "1S-2S Spectroscopy of Trapped Hydrogen: The Cold Collision Frequency Shift and Studies of BEC."

Observation of hydrogen Bose-Einstein condensation. High resolution spectroscopic studies of trapped, spin-polarized atomic hydrogen, focusing on cold collisions.

**Cambridge University**, 1991-1993,

Cambridge, England

*Marshall Scholar.*

M.Phil. in Physical Chemistry, 1993.

Thesis under Dr. P. Davies. Vibrational and rotational spectroscopy of large molecules in a supersonic jet.

Certificate of Advanced Studies in Mathematics with High Honors, Department of Applied Mathematics and Theoretical Physics, 1992.

**Harvard College**, 1987-1991, Cambridge, MA  
*GTE Academic All-American, National Merit Scholar, Presidential Scholar, Harvard Hoopes Prize.*

A.B. in Physics, *summa cum laude*, Phi Beta Kappa, 1991.

### **Publications and Invited talks**

Over 40 publications in peer-reviewed journals

Over 40 invited talks including 12 at international conferences.

### **Professional Memberships and Service**

Member, American Physical Society

Local Organizing Committee, Meeting of the Division of Atomic, Molecular and Optical Physics (DAMOP) of the American Physical Society, 2010.

Executive Committee of the Division of Atomic, Molecular and Optical Physics (DAMOP) of the American Physical Society, 2006-2009.

Graduate Thesis Prize Committee of the Division of Atomic, Molecular and Optical Physics (DAMOP) of the American Physical Society, 2007-2009.

Defense Science Study Group, Institute for Defense Analysis, 2006-2007

Referee: Physical Review, Journal of Physics B, and NSF and DOE grant proposals.

Grant review panel member: NSF and NSF/DOE partnerships.

### **University Memberships and Service**

2009-present, Fellow, Scientia.

2008-present, New-Faculty Mentoring Coordinator, Department of Physics and Astronomy.

2008-present, Ombudsman, Department of Physics and Astronomy.

2008-2009, Rice Leaders Program.

2005-2011, Faculty Senate; 2009-2011 Executive Committee, 2010-2011 Deputy Speaker.

2002-2009, Fellowships and Awards Committee.

2002-present, Martel College Faculty Associate, Outstanding Associate 2004.

2004-2007, 2009, Natural Sciences Divisional Advisor.

## **Business Experience**

Consultant, Institute for Defense Analysis. Providing advice on the application of science and technology to national security under the auspices of the Office of the Secretary of Defense. 2006-present

Co-founder, Incellerate, incorporated 2008. Using electric fields to reprogram human cells and revolutionize the delivery of drugs.

Co-founder, n3D Biosciences, incorporated 2008. Using levitation of magnetized hydrogels and cells to transform three-dimensional cell culturing techniques.

## Teaching

Physics 600, *Cold Atoms in Atomic Physics*, Spring 2001.

Physics 311, *Introductory Quantum Physics I*, Fall 2001.

Physics 537, *Methods of Experimental Physics I*, Fall 2002-2008, 2010-2011

Physics 538, *Methods of Experimental Physics II*, Spring 2003, 2004, 2006, 2007.

Physics 302, *Intermediate Electrodynamics*, Spring 2008-2011

## Selected Invited Talks

1. "Ion Acoustic Waves in Ultracold Neutral Plasmas," *2011 Annual Meeting of the Division of Plasma Physics of the American Physical Society*, Salt Lake City, Utah, (11/11).
2. "Ion Waves, Streams, and Collisions in Ultracold Neutral Plasmas," *2011 International Topical Conference on Plasma Science: Strongly Coupled Ultra-cold and Quantum Plasmas*, Lisbon, Portugal, (9/11).
3. "Degenerate Fermi gas of Strontium-87," *2011 March Meeting of the American Physical Society*, Dallas, Texas, (3/11).
4. "Quantum Degenerate Gases of Atomic Strontium," Physics Department Colloquium, Northwestern University, Evanston, IL, (11/10).
5. "Quantum Degenerate Gases of Atomic Strontium," *2010 Annual Meeting of the Division of Atomic, Molecular, and Optical Physics of the American Physical Society*, Houston, Texas, (5/10).
6. "Velocity-Changing Collisions in Strongly Coupled Plasmas," *Cold and Ultracold Plasma and Rydberg Physics II workshop*, Institute for Theoretical Atomic, Molecular and Optical Physics, Cambridge, MA, (09/09).
7. "An Optical Feshbach Resonance in Ultracold Atomic Strontium," *Workshop on Ultracold Group II Atoms*, University of Maryland, (09/09).
8. "Role of Collisions and Strong Coupling in Ultracold Plasmas," *26th International Conference on Photonic, Electronic, and Atomic Collisions*, Kalamazoo, MI, (07/09).
9. "An Optical Feshbach Resonance in Atomic Strontium," Harvard-MIT Center for Ultracold Atoms Seminar, Cambridge, MA, (04/09).
10. "Studying Equilibration in Strongly Coupled Systems with Ultracold Plasmas," Columbia University Plasma Physics Seminar, New York (4/09).
11. "Watching Ions Dance Near Absolute Zero," York University Physics Department Colloquium, University of Waterloo Physics Department Colloquium, Toronto, Canada, (11/08).

12. "Watching Ions Dance Near Absolute Zero," Toronto, Canada, (11/08).
13. "Ultracold Strontium: Studies of Collisional Properties and Optical Feshbach Resonances," University of New Mexico Atomic Physics Seminar, Albuquerque, NM, (9/08).
14. "Ultracold Neutral Plasmas," Keynote talk at the *2008 International Conference on Strongly Coupled Coulomb Systems*, Camerino, Italy, (7/08).
15. "Equilibration and Correlations in Ultracold Neutral Plasmas," the *9th International Workshop on Non-Neutral Plasmas*, New York, New York, (6/08).
16. "Ultracold Neutral Plasmas," Plenary talk at the *35th European Physical Society Conference on Plasma Physics*, Crete, (6/08).
17. "Watching Ions Dance Near Absolute Zero," University of Texas at Austin, Center for Complex Quantum Systems Seminar, Austin, TX, (1/08).
18. "Watching Ions Dance Near Absolute Zero," University of Illinois at Urbana-Champaign Physics Department Colloquium, Urbana, IL, (11/07).
19. "Watching Ions Dance Near Absolute Zero," University of Houston Physics Department Colloquium, Houston, TX, (11/07).
20. "Ultracold Collisions in Atomic Strontium," *Frontier in Optics 2007 / Laser Science XXIII*, San Jose, CA, (9/07).
21. "Equilibration of Ultracold Neutral Plasmas," *The 15th International Conference on Atomic Processes in Plasmas*, National Institute of Standards and Technology, Gaithersburg, MD, (5/07).
22. "Photoassociative Spectroscopy of Ultracold Strontium," *ITAMP Workshop on Ultracold Group II Atoms: Theory and Applications*, Institute for Theoretical Atomic, Molecular and Optical Physics, Cambridge, MA, (9/06).
23. "Ion Dynamics in Ultracold Neutral Plasmas," *Workshop on Non-Neutral Plasmas*, Aarhus, Denmark, (6/06).
24. "Expansion Dynamics of Ultracold Neutral Plasmas," *2006 Annual Meeting of the Division of Atomic, Molecular, and Optical Physics of the American Physical Society*, Knoxville, Tennessee, (5/06).
25. "Photoassociative Spectroscopy of Ultracold Strontium," *Achievements and Perspectives of Cold Molecules, École de Physique*, Les Houches, France, (3/06).

26. "Pushing the Envelope of Plasma Physics: Ultracold Neutral Plasmas," *The Academy of Medicine, Engineering and Sciences of Texas*, Houston, TX, (1/06).
27. "Ultracold Neutral Plasmas," *Texas Section of the American Physical Society*, Houston, TX, (10/05).
28. "Expansion Dynamics of Ultracold Neutral Plasmas," *ITAMP Workshop on Cold and Ultracold Plasma and Rydberg Physics*, Cambridge, MA, (9/05).
29. "Early Dynamics of Ultracold Neutral Plasmas," *Ultracold PARYS (Ultracold Plasmas And Rydberg Systems)*, Centre National de la Recherche Scientifique, Gif-sur-Yvette, France, (3/05).
30. "Ultracold Neutral Plasmas," *German Physical Society Meeting*, Berlin, Germany, (3/05).
31. "Ultracold Neutral Plasmas," University of Utah Physics Department Colloquium, Salt Lake City, Utah, (2/05).
32. "Ultracold Neutral Plasmas," University of Toronto Physics Department Colloquium, Toronto, Canada, (1/05).
33. "Ultracold Neutral Plasmas," University of Connecticut Physics Department Colloquium, Storrs, Connecticut, (11/04).
34. "Ultracold Neutral Plasmas," *12th International Congress on Plasma Physics*, Nice, France, (10/04).
35. "Imaging Ultracold Plasmas," *129th National Meeting of the American Association of Physics Teachers*, Sacramento, CA, (8/04).
36. "Optically Imaging an Ultracold Strontium Plasma," *19th International Conference on Atomic Physics*, Rio de Janeiro, Brazil, (7/04).
37. "Imaging an Ultracold Neutral Plasma," *2004 Annual Meeting of the Division of Atomic, Molecular, and Optical Physics of the American Physical Society*, Tucson, Arizona, (5/04).
38. "Ultracold Neutral Plasmas," Lectures at the *International Workshop and Seminar on Rydberg Physics*, Dresden, Germany, (4/04).
39. "Imaging an Ultracold Neutral Plasma," Harvard/MIT Center for Ultracold Atoms Seminar, Cambridge, MA (4/04).
40. "Experiments with Laser-Cooled Atomic Strontium," *Second Workshop on Cold Alkaline-Earth Atoms*, Copenhagen, Denmark (9/03).

41. "Collisions in Ultracold Neutral Plasmas," *XXIII International Conference on Photonic, Electronic, and Atomic Collisions*, Stockholm, Sweden (7/03).
42. "Experiments with Laser-Cooled Atomic Strontium," *2002 New Laser Scientist Conference*, satellite conference of the *2002 APS Division of Laser Science-XVIII/Optical Society of America Meeting*, Orlando, Florida (9/02).
43. "Ultracold Neutral Plasmas: New Prospects with Laser-Cooled Strontium," *2002 International Conference on Strongly Coupled Coulomb Systems*, Santa Fe, New Mexico (9/02).
44. "Ultracold Neutral Plasmas: New Prospects with Laser-Cooled Strontium," *Resonances and Reflections: Profiles of Ugo Fano's Physics and Its Influences (Fano Memorial Symposium)*, Cambridge, Massachusetts, (7/02).
45. "Ultracold Neutral Plasmas," *2002 Topical Conference on Atomic Processes in Plasmas*, Gatlinburg, Tennessee, (4/02).
46. "Ultracold Neutral Plasmas," *2001 Workshop on Non-Neutral Plasmas*, San Diego, California, (9/01).
47. "From Laser-Cooled Atoms to an Ultracold Neutral Plasma," *Optical Society of America Annual Meeting and Exhibit 2000, ILS-XVI: 16th Interdisciplinary Laser Science Conference*, Providence, Rhode Island, (10/00).
48. "From Laser-Cooled Atoms to an Ultracold Neutral Plasma," *2000 Annual Meeting of the Division of Atomic, Molecular, and Optical Physics of the American Physical Society*, Storrs, Connecticut, (6/00).
49. "Bose-Einstein Condensation of Atomic Hydrogen: High Resolution Spectroscopy and the Cold collision Frequency Shift of the 1S-2S Transition," *Cold Atomic Collisions, Formation of Cold Molecules Workshop*, Les Houches, France, (3/99).

## Publications

1. "Creating Non-Maxwellian Velocity Distributions in Ultracold Plasmas," J. Castro, G. Bannasch, P. McQuillen, T. Pohl and T. C. Killian, arXiv:1112.3241 (2011).
2. "A Microfabricated Magnetic Force Transducer-Microaspiration System for Studying Membrane Mechanics," D. J. Stark, T. C. Killian, and R. M. Raphael, *Phys. Biol.* **8**, 056008 (2011).
3. "Numerical Modeling of Collisional Dynamics of Sr in an Optical Dipole Trap," M. Yan, R. Chakraborty, A. Mazurenko, P. G. Mickelson, Y. N. Martinez de Escobar, B. J. DeSalvo, and T. C. Killian, *Phys. Rev. A* **83**, 032705 (2011).
4. "Ion Acoustic Waves in Ultracold Neutral Plasmas," J. Castro, P. McQuillen, and T. C. Killian, *Phys. Rev. Lett.* **105**, 065004 (2010).
5. "Degenerate Fermi Gas of  $^{87}\text{Sr}$ ," B. J. DeSalvo, M. Yan, P. G. Mickelson, Y. N. Martinez de Escobar, and T. C. Killian, *Phys. Rev. Lett.* **105**, 030402 (2010). *Editors' Suggestion*.
6. "Bose-Einstein Condensation of  $^{88}\text{Sr}$  Through Sympathetic Cooling with  $^{87}\text{Sr}$ ," P. G. Mickelson, Y. N. Martinez de Escobar, M. Yan, B. J. DeSalvo, and T. C. Killian, *Phys. Rev. A* **81**, 051601(R) (2010).
7. "Ultracold Neutral Plasmas," T. C. Killian and S. L. Rolston, *Phys. Today* **63**, 46 (2010).
8. "Three-dimensional Tissue Culture Based on Magnetic Cell Levitation," G. R. Souza, J. R. Molina, R. M. Raphael, M. G. Ozawa, D. J. Stark, C. S. Levin, L. F. Bonk, J. S. Ananta, J. Mandelin, M.-M. Georgescu, J. A. Bankson, J. G. Gelovani, T. C. Killian, R. Pasqualini, and W. Arap", *Nature Nanotech.* **5**, 291 (2010).
9. "Bose-Einstein Condensation of  $^{84}\text{Sr}$ ," Y. N. Martinez de Escobar, P. G. Mickelson, M. Yan, B. J. DeSalvo, S. B. Nagel, and T. C. Killian, *Phys. Rev. Lett.* **103**, 200402 (2009). *Editors' Suggestion*. Featured in *Physics*, *Physics World*, *e! Science News*, *Nanotechwire*, and *Rice News*.
10. "Repumping and spectroscopy of laser-cooled Sr atoms using the  $(5s5p)^3P_2 - (5s4d)^3D_2$  transition," P. G. Mickelson, Y. N. Martinez de Escobar, P. Anzel, B. J. DeSalvo, S. B. Nagel, A. J. Traverso, M. Yan, T. C. Killian, *J. Phys. B* **42**, 235001, (2009).
11. "Inelastic and Elastic Collision Rates for Triplet States of Ultracold Strontium," A. Traverso, R. Chakraborty, Y. N. Martinez de Escobar, P. G. Mickelson, S. B. Nagel, M. Yan, and T. C. Killian, *Phys. Rev. A* **79**, 060702(R) (2009).
12. "High-throughput non-viral gene transfer by mRNA electroporation to generate CD19-specific T cells," Yoonsu Choi, Carrie Yuen, Hillary Gibbons, Sourindra Maiti, Helen Huls, Sibani L Biswal, Robert Raphael, Thomas C Killian, Daniel J Stark, Dean A Lee, Partow Kebriaei, Richard E Champlin, and Laurence JN Cooper, *Biology of Blood and Marrow Transplantation* **15**, 22 (2009).
13. "Two-Photon Photoassociative Spectroscopy of Ultracold  $^{88}\text{Sr}$ ," Y. N. Martinez de Escobar, P. G. Mickelson, P. Pellegrini, S. B. Nagel, A. Traverso, M. Yan, R. Côté, and T. C. Killian, *Phys. Rev. A* **78**, 062708 (2008).

14. "Using Sheet Fluorescence to Probe Ion Dynamics in Ultracold Neutral Plasmas," J. Castro, H. Gao, and T. C. Killian, *Plasma Phys. Control. Fusion* **50**, 124011 (2008).
15. "Optical Probes of Ultracold Neutral Plasmas," S. Laha, J. Castro, H. Gao, P. Gupta, C. E. Simien, and T. C. Killian, *AIP Conf. Proc.* **926**, 69 (2007).
16. "Experimental Realization of an Exact Solution to the Vlasov Equations for an Expanding Plasma," S. Laha, P. Gupta, C. E. Simien, H. Gao, J. Castro, T. Pohl, and T. C. Killian, *Phys. Rev. Lett.* **99**, 155001 (2007).
17. "Electron Temperature Evolution in Expanding Ultracold Neutral Plasmas," P. Gupta, S. Laha, C. E. Simien, H. Gao, J. Castro, T. C. Killian, and T. Pohl, *Phys. Rev. Lett.* **99**, 075005 (2007).
18. "Rotational Spectra of Vibrationally Excited CCH and CCD," T. C. Killian, C. A. Gottlieb, and P. Thaddeus, *J. Chem. Phys.* **127**, 114320 (2007).
19. "Ultracold Neutral Plasmas," T. C. Killian, T. Pattard, Thomas Pohl, and J. M. Rost, *Phys. Rep.*, **449**, 77 (2007).
20. "Ultracold Neutral Plasmas," T. C. Killian, *Science* **316**, 705 (2007).
21. "Kinetic Energy Oscillations in Annular Regions of Ultracold Neutral Plasmas," S. Laha, Y. C. Chen, P. Gupta, C. E. Simien, Y. N. Martinez, P. G. Mickelson, S. B. Nagel, T. C. Killian, *European Phys. J. D* **40**, 51 (2006).
22. "Cool Vibes," T. C. Killian, *Nature* **441**, 297 (2006).
23. "Pumped Quantum Systems: Immersion Fluids of the Future," V. Anant, M. Radmark, A. F. Abouraddy, T. C. Killian, and K. K. Berggren, *J. Vac. Sci. and Technol. B* **23**, 2662 (2005).
24. "Spectroscopic Determination of the *s*-Wave Scattering Lengths of  $^{86}\text{Sr}$  and  $^{88}\text{Sr}$ ," P. G. Mickelson, Y. N. Martinez, A. D. Saenz, S. B. Nagel, Y. C. Chen, T. C. Killian, P. Pellegrini, and R. Côté, *Phys. Rev. Lett.* **95**, 223002 (2005).
25. "Absorption Imaging of Ultracold Neutral Plasmas," C. E. Simien, Y. C. Chen, P. Gupta, S. Laha, Y. N. Martinez, P. G. Mickelson, S. B. Nagel, and T. C. Killian, *IEEE Transactions on Plasma Science* **33**, 540 (2005).
26. "Photoassociative Spectroscopy at Long Range in Ultracold Strontium," S. B. Nagel, P. G. Mickelson, A. D. Saenz, Y. N. Martinez, Y. C. Chen, T. C. Killian, P. Pellegrini, and R. Côté, *Phys. Rev. Lett.* **94**, 083004 (2005).
27. "Ultracold Neutral Plasmas," T. C. Killian, Y. C. Chen, P. Gupta, S. Laha, Y. N. Martinez, P. G. Mickelson, S. B. Nagel, A. D. Saenz, and C. E. Simien, *Plasma Phys. Control. Fusion.* **47**, A297 (2005).
28. "Absorption Imaging and Spectroscopy of Ultracold Neutral Plasmas," T. C. Killian, Y. C. Chen, P. Gupta, S. Laha, Y. N. Martinez, P. G. Mickelson, S. B. Nagel, A. D. Saenz, and C. E. Simien, *J. Phys. B.* **38**, 351 (2005).

29. "Electron Screening and Kinetic Energy Oscillations in a Strongly Coupled Plasma," Y. C. Chen, C. E. Simien, S. Laha, P. Gupta, Y. N. Martinez, P. G. Mickelson, S. B. Nagel, and T. C. Killian, *Phys. Rev. Lett.* **93**, 265003 (2004).
30. "Plasmas Put in Order," T. C. Killian, *Nature* **429**, 815 (2004).
31. "Using Absorption Imaging to Study Ion Dynamics in an Ultracold Neutral Plasma," C. E. Simien, Y. C. Chen, P. Gupta, S. Laha, Y. N. Martinez, P. G. Mickelson, S. B. Nagel, and T. C. Killian, *Phys. Rev. Lett.* **92**, 143001 (2004).
32. "Ultracold Plasmas and Rydberg Gases," S. D. Bergeson and T. C. Killian, *Phys. World*, pp. 37-41, Feb. 2003.
33. "Ultracold Neutral Plasmas: Recent Experiments and New Prospects," T. C. Killian, V. S. Ashoka, P. Gupta, S. Laha, S. B. Nagel, C. E. Simien, S. Kulin, S. L. Rolston, and S. D. Bergeson, *J. Phys. A: Math. Gen.* **36**, 6077 (2003).
34. "Magnetic Trapping of Metastable  $^3P_2$  Atomic Strontium," S. B. Nagel, C. E. Simien, S. Laha, P. Gupta, V. S. Ashoka, and T. C. Killian, *Phys. Rev. A* **67**, 011401(R) (2003).
35. "Sum Rule for the Optical Spectrum of a Trapped Gas," M. O. Oktel, T. C. Killian, D. Kleppner, and L. S. Levitov, *Phys. Rev. A* **65**, 033617 (2002).
36. "Formation of Rydberg Atoms in an Expanding Ultracold Neutral Plasma," T. C. Killian, M. J. Lim, S. Kulin, R. Dumke, S. D. Bergeson, and S. L. Rolston, *Phys. Rev. Lett.* **86**, 3759 (2001).
37. "Plasma Oscillations and Expansion of an Ultracold Neutral Plasma," S. Kulin, T. C. Killian, S. D. Bergeson, and S. L. Rolston, *Phys. Rev. Lett.* **85**, 318 (2000).
38. "Bose-Einstein Condensation in Atomic Hydrogen," T. J. Greytak, D. Kleppner, D. G. Fried, T. C. Killian, L. Willmann, D. Landhuis, and S. C. Moss, *Physica B* **280**, 20 (2000).
39. "1S-2S Spectrum of a Hydrogen Bose-Einstein Condensate," T. C. Killian, *Physical Review A* **61**, 033611 (2000).
40. "Creation of an Ultracold Neutral Plasma," T. C. Killian, S. Kulin, S. D. Bergeson, L. A. Orozco, C. Orzel, and S. L. Rolston, *Phys. Rev. Lett.* **83**, 4776 (1999).
41. "Bose-Einstein Condensation of Atomic Hydrogen," D. Kleppner, T. J. Greytak, T. C. Killian, D. G. Fried, L. Willmann, D. Landhuis, and S. C. Moss, in *Proceedings of the International School of Physics "Enrico Fermi," Course CXL: Bose Einstein Condensation in Atomic Gases, 1998*, edited by M. Inguscio, S. Stringari, and C. E. Weiman, (IOS Press, Amsterdam, 1999), p. 177.
42. "Bose-Einstein Condensation of Atomic Hydrogen," D. G. Fried, T. C. Killian, L. Willmann, D. Landhuis, S. C. Moss, D. Kleppner, and T. J. Greytak, *Phys. Rev. Lett.* **81**, 3811 (1998).
43. "Cold Collision Frequency Shift of the 1S-2S Transition in Hydrogen," T. C. Killian, D. G. Fried, L. Willmann, D. Landhuis, S. C. Moss, T. J. Greytak, and D. Kleppner, *Phys. Rev. Lett.* **81**, 3807 (1998).

44. "Doppler-Free Spectroscopy of Trapped Atomic Hydrogen," T. C. Killian, D. G. Fried, C. L. Cesar, A. D. Polcyn, T. J. Greytak, and D. Kleppner, in *Atomic Physics 15; Fifteenth International Conference on Atomic Physics, Zeeman-Effect Centenary*, edited by H. B. Van Linden Van Den Heuvell, J. T. M. Walraven, and M. W. Reynolds, (World Scientific, Singapore, 1997), p. 158.
45. "Two-Photon Spectroscopy of Trapped Atomic Hydrogen," C. L. Cesar, D. G. Fried, T. C. Killian, A. D. Polcyn, J. C. Sandberg, I. A. Yu, T. J. Greytak, D. Kleppner, and J. M. Doyle, *Phys. Rev. Lett.* **77**, 255 (1996).
46. "Two-Photon Spectroscopy of Trapped Atomic Hydrogen," C. L. Cesar, D. G. Fried, T. C. Killian, A. D. Polcyn, J. C. Sandberg, J. M. Doyle, I. A. Yu, T. J. Greytak, and D. Kleppner, in *Proceedings of the Fifth Symposium on Frequency Standards and Metrology, 1995*, edited by J. C. Berquist, (World Scientific, Singapore, 1996), p. 365.
47. "Diode Laser Jet Spectroscopy of Hexafluorobenzene in the 10- $\mu$ m Region," P. B. Davies, G. M. Hansford, and T. C. Killian, *J. Mol. Spectrosc.* **163**, 138 (1994).
48. "Structure of Propadienylidene, H<sub>2</sub>CCC," C. A. Gottlieb, T. C. Killian, P. Thaddeus, P. Botschwina, J. Flugge, and M. Oswald, *J. Chem. Phys.* **98**, 4478 (1993).
49. "Astronomical Detection of H<sub>2</sub>CCCC," J. Cernicharo, C. A. Gottlieb, M. Guelin, T. C. Killian, P. Thaddeus, and J. M. Vrtilik, *Astrophys. J. (Letters)* **368**, L43 (1991).
50. "Astronomical Detection of H<sub>2</sub>CCC," J. Cernicharo, C. A. Gottlieb, M. Guelin, T. C. Killian, G. Paubert, P. Thaddeus, and J. M. Vrtilik, *Astrophys. J. (Letters)* **368**, L39 (1991).
51. "Laboratory Detection of a Second Carbon Chain Carbene: Butatrienylidene, H<sub>2</sub>CCCC," T. C. Killian, J. M. Vrtilik, C. A. Gottlieb, E. W. Gottlieb, and P. Thaddeus, *Astrophys. J. (Letters)* **365**, L89 (1990).
52. "Laboratory Detection of Propadienylidene, H<sub>2</sub>CCC," J. M. Vrtilik, C. A. Gottlieb, E. W. Gottlieb, T. C. Killian, and P. Thaddeus, *Astrophys. J. (Letters)* **364**, L53 (1990).