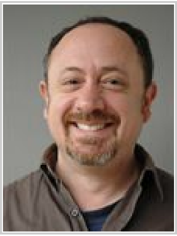
University of Birmingham

# Dr Jonathan Goldwin

Lecturer

College of Arts and Law

## Contact details



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## About

Jon Goldwin is Lecturer of Physics and a member of the **Midlands Ultracold Atom Research Centre (http://mpa.ac.uk/muarc/index.html)** (MUARC).

Jon is part of the **Cold Atoms group (http://www.birmingham.ac.uk/research/activity/physics/quantum/cold-atoms/index.aspx)**, studying the exotic behaviour of gases when cooled to a few billionths of a degree above absolute zero. These are the lowest temperatures in the universe, allowing researches unprecedented control over the atoms, and bringing to the forefront the often strange world of quantum mechanics.

In addition to the interesting physics of these systems, cold atoms have numerous technological applications, one of the most prominent being the atomic clock. This technology sets the international time standard at the heart of global positioning systems (GPS). Cold atoms can also be used for such diverse tasks as inertial sensing, dating of soil and water samples, and quantum information processing.

For more information on our work, see the MUARC web site:

**http://mpa.ac.uk/muarc/index.html (http://mpa.ac.uk/muarc/index.html)**

## Qualifications

- PhD in Physics, JILA and University of Colorado – Boulder, 2005
- BSc in Physics and Mathematics, University of Wisconsin – Madison, 1999

## Biography

**2009-**
Lecturer, University of Birmingham

**2005-2009**
Research Assistant, Centre for Cold Matter (group of Ed Hinds), Imperial College London
Integrated optics for atom-chip quantum information processing

**1999-2005**
Research Assistant, JILA (group of Debbie Jin), University of Colorado, Boulder
Quantum degeneracy and interactions in an atomic Bose-Fermi mixture

Jon obtained a dual BSc in Physics and Mathematics at the University of Wisconsin, Madison. His undergraduate work studied turbulent fluid flows in a water model of a liquid sodium magneto-hydrodynamic dynamo. Turbulence has famously been called “the last great unsolved problem in classical physics,” and understanding turbulence in plasmas and metals is crucial to a variety of fields within Astrophysics.

Jon then did his PhD work in the group of Debbie Jin at JILA, within the University of Colorado, Boulder -- birthplace of both atomic Bose-Einstein condensates and degenerate Fermi gases. His work focused on producing a quantum degenerate Bose-Fermi mixture, and studying the interactions between species. By discovering a number of so-called Feshbach tunable scattering resonances, this work paved the way for coherent production of dipolar molecules near quantum degeneracy.

In 2005, Jon moved to Imperial College, London, to work with Ed Hinds in the Centre for Cold Matter. This work focused on developing integrated optics for use on atom chips – miniature micro-fabricated laboratories for producing and studying ultracold gases. As part of a team, Jon showed that high-finesse micro-cavities could be used to detect atoms with single-atom sensitivity, and that fast, low-noise operation could be achieved. These experiments are on-going, and Jon remains actively involved.

## Teaching

**Research Themes**

Cold atoms, optical lattices, quantum optics, cavity quantum electrodynamics.

**Research Activity**

**Cavity QED with Cold Atoms**
Cavity quantum electrodynamics (QED) is the study of how the basic interactions between light and matter can be tailored by modifying the local environment. For example, optical cavities can be used to increase the intensity per photon and the effective lifetime, leading to strong coupling between single atoms and photons.

We are building an experiment to study ensembles of cold atoms in a high-finesse optical ring resonator. For large enough numbers of atoms (10s of thousands to millions), the coupling to the cavity field is both collective and coherent, overwhelming dissipation due to spontaneous emission and cavity lifetime. In this regime, known as collective strong coupling, the atoms move according to the optical potential, and the optical potential moves according to the positions of the atoms, leading to a rich nonlinear dynamics.

This system is important for trying to generalise the techniques of laser cooling to molecules or more complex objects. It will furthermore allow us to perform direct quantum simulation of a number of condensed matter systems. Special attention will be made to systems with accelerating optical lattices, operating in a regime where the motional dynamics of the atoms strongly modify the optical trapping fields.

**Light-matter Interface with Nanophotonic Resonators**
We are beginning to study how one can use nanophotonics, such as photonic crystals and metamaterials, for cavity QED with cold atoms. This work is being done in conjunction with the new Metamaterials group at Birmingham headed by Shuang Zhang, and with connections to the Centre for Cold Matter at Imperial College, London.

This is a young field, and there are a number of exciting questions to be answered. Can a single atom be made to perfectly absorb a single photon? Can we build a room temperature photonic quantum simulator? Can the ideas of metamaterials be applied to matter waves and atom optics?

My research focuses on ultracold gases, and the quantum mechanical light-matter interface. These studies draw on my previous work with quantum degenerate Bose-Fermi mixtures, and with light-matter interactions at the single-photon level. The program is of interest for a variety of fundamental studies, with applications in quantum information processing, precision measurements, and quantum simulations of condensed matter systems.

**Cooperative Behaviour at the Quantum Light-Matter Interface**
Long-range interactions and correlations are at the heart of a variety of important physical phenomena, from protein folding to superconductivity. In neutral gases, however, interactions are typically dominated by local pair-wise collisions. One way to couple large numbers of atoms in an essentially non-local way is through their common interaction with an electromagnetic field, where the origin of the cooperative behaviour is in the inability to distinguish which atoms in an ensemble have absorbed or emitted photons. In this case, the transition rates between quantum mechanical states of the system are determined by the square of the sum over all possibilities, leading to coherent amplification of photon scattering. In this regime the atoms form the quantum mechanical analogue of a phased antenna array.

We are building an experiment to study these effects with ultracold Bose and Fermi gases in a high-finesse optical ring cavity. Such a resonator enhances the light-matter interactions by confining the electromagnetic field and increasing the photon lifetime in the atomic medium. Initial experiments will focus on coherent scattering of light into the cavity mode, both for novel laser cooling techniques and for studies of spatial self-organisation and its relation to Dicke super- and sub-radiance. The influence of collective coupling to the cavity field on the atomic dynamics will also be studied, both in static harmonic potentials and accelerating optical lattices, where Bloch oscillations and dynamical localisation can occur.

## Postgraduate supervision

Jon is interested in supervising students in the following areas:

- Collective strong coupling of light and matter with cold atoms in a high-finesse optical ring resonator
- Towards quantum light-matter interfaces using nanophotonics

For a full list of available Doctoral Research opportunities, please visit our Doctoral Research programme listings.

## Research

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## Other activities

Member of organising committee, Midlands Ultracold Atom Research Centre Summer School on Advanced Techniques in Atomic Physics, 22-27 August, 2010.

## Publications

“Backaction-Driven Transport of Bloch Oscillating Atoms in Ring Cavities”,
J. Goldwin, B.P. Venkatesh, and D.H.J. O'Dell,
[**Phys. Rev. Lett. 113, 073003 (2014) (http://link.aps.org/doi/10.1103/PhysRevLett.113.073003)** ; **arXiv (http://uk.arxiv.org/abs/1402.4596)** ]

“Avalanche-mechanism loss at an atom-molecule Efimov resonance”,
M.-G. Hu, R.S. Bloom, D.S. Jin, and J. Goldwin,
[**Phys. Rev. A 90, 013619 (2014) (http://link.aps.org/doi/10.1103/PhysRevA.90.013619)** ; **arXiv (http://uk.arxiv.org/abs/1405.4915)** ]

“Polarization spectroscopy and magnetically-induced dichroism of the potassium D2 lines”,
K. Pahwa,L. Mudarikwa, and J. Goldwin,
[**Opt. Express 20, 17456 (2012) (http://www.opticsexpress.org/abstract.cfm?URI=oe-20-16-17456)** ; **arXiv (http://uk.arxiv.org/abs/1205.0459)** ]

“Sub-Doppler modulation spectroscopy of potassium for laser stabilization”,
L. Mudarikwa, K. Pahwa, and J. Goldwin,
[**J. Phys. B: At. Mol. Opt. Phys. 45, 065002 (2012) (http://iopscience.iop.org/0953-4075/45/6/065002)** ; **arXiv (http://uk.arxiv.org/abs/1112.4998)** ]

“Fast cavity-enhanced atom detection with low noise and high fidelity”,
J. Goldwin, M. Trupke, J. Kenner, A. Ratnapala, and E. A. Hinds,
[**Nat. Commun. 2:418 doi: 10.1038/ncomms1428 (2011) (http://dx.doi.org/10.1038/ncomms1428)** ; **arXiv (http://uk.arxiv.org/abs/1009.2916)** ]

“Tight focusing of plane waves from micro-fabricated spherical mirrors”,
J. Goldwin and E. A. Hinds,
[**Opt. Express 16, 17808 (2008) (http://www.opticsexpress.org/abstract.cfm?URI=oe-16-22-17808)** ; **arXiv (http://uk.arxiv.org/abs/0809.2339)** ]

“Progress in atom chips and the integration of microcavities”,
E. A. Hinds, M. Trupke, B. Darquié, J. Goldwin, and G. Dutier,
[**Proc. ICOLS Conf. (ICOLS – XVIII), Ed. J. Bergquist, (2007) (http://www.worldscientific.com/doi/abs/10.1142/9789812813206_0023)** ; **arXiv (http://uk.arxiv.org/abs/0802.0987)** ]

“Atom detection and photon production in a scalable, open, optical microcavity”,
M. Trupke, J. Goldwin, B. Darquié, G. Dutier, S. Eriksson, J. Ashmore, and E. A. Hinds,
[**Phys. Rev. Lett. 99, 063601 (2007) (http://link.aps.org/doi/10.1103/PhysRevLett.99.063601)** ; **arXiv (http://uk.arxiv.org/abs/0710.2116)** ]

“Cross-dimensional relaxation in Bose-Fermi mixtures,”
J. Goldwin, S. Inouye, M. L. Olsen, and D. S. Jin,
[**Phys. Rev. A 71, 043408 (2005) (http://link.aps.org/doi/10.1103/PhysRevA.71.043408)** ; **arXiv (http://uk.arxiv.org/abs/cond-mat/0501095)** ]

“Observation of heteronuclear Feshbach resonances in a mixture of Bosons and Fermions”,
S. Inouye, J. Goldwin, M. L. Olsen, C. Ticknor, J. L. Bohn, and D. S. Jin,
[**Phys. Rev. Lett. 93, 183201 (2004) (http://link.aps.org/doi/10.1103/PhysRevLett.93.183201)** ; **arXiv (http://uk.arxiv.org/abs/cond-mat/0406208)** ]

“Measurement of the interaction strength in a Bose-Fermi mixture with 87Rb and 40K”,
J. Goldwin, S. Inouye, M. L. Olsen, B. Newman, B. D. DePaola, and D. S. Jin,
[**Phys. Rev. A 70, 021601(R) (2004) (http://link.aps.org/doi/10.1103/PhysRevA.70.021601)** ; **arXiv (http://uk.arxiv.org/abs/cond-mat/0405419)** ]

“Two-species magneto-optical trap with 40K and 87Rb”,
J. Goldwin, S. B. Papp, B. DeMarco, and D. S. Jin,
[**Phys. Rev. A 65, 021402(R) (2002) (http://link.aps.org/doi/10.1103/PhysRevA.65.021402)** ; **arXiv (http://uk.arxiv.org/abs/cond-mat/0108287)** ]