

Ian Ochs

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Education

Princeton University, Princeton, NJ

2015-2021

Ph.D. in Astrophysical Sciences: Plasma Physics, 2021

Dissertation: "Controlling and Exploiting Perpendicular Rotation in Magnetized Plasmas"

Graduate Certificate in Computational Science and Engineering, 2021

M.A. in Plasma Physics, 2017

Harvard College, Cambridge, MA

2011-2015

A.B. in Physics.

Graduated Magna cum Laude with Highest Honors in Discipline.

GPA: 3.82

Research Experience

Associate Research Scholar, Princeton University, Princeton, NJ

Jan. 2024 – Present

- Synchrotron radiation effects on electron dynamics
 - Developed a Fokker-Planck model [38] for synchrotron radiation in the mixed-opacity regime, important for astrophysics [40] and high-temperature aneutronic fusion plasmas.
 - Integrated synchrotron effects into a Fokker-Planck code for magnetic mirrors [38].
- Static ponderomotive barriers
 - Showed how Lorentz invariants determine the performance of static wave barriers [33]
 - Helped to develop self-consistent models for coupled wave propagation and ponderomotive forces from static electromagnets and electrodes [39]

Postdoctoral Fellow, Princeton University, Princeton, NJ

Jan. 2022 – Jan. 2024

- Continued research on wave-particle momentum exchange:
 - Reconciled two very different models for the ponderomotive force [25,36]
 - Showed equivalence between the Minkowski momentum of linear geometrical optics, and the nonresonant recoil momentum of quasilinear ponderomotive theory [30]
- Transport Research:
 - Supervised and supported continuing student research on multi-ion transport physics in the presence of rapid rotation [26] and ionization / recombination [29]
- Research on mirror physics
 - Used analytic theory and developed a finite-element Fokker-Planck code to find the confinement time of relativistic electrons in a magnetic mirror trap [32]
 - Applied Fokker-Planck code to stability calculations in mirrors [35] and to determine Pastukhov potentials for simplified gyrokinetic collision operators [41]
- Research on aneutronic (proton-Boron 11) fusion
 - Demonstrated that wave-driven energy exchange makes net power more feasible [27-28]
 - Developed a model for power plant performance [34]

Graduate Student, Princeton Program in Plasma Physics, Princeton, NJ

Sep. 2015 – Dec. 2021

- Research into wave-particle momentum and energy exchange (2015-present)
 - Examined how electrostatic waves, which nominally carry no momentum, can mediate momentum exchange between electrons and ions, driving currents. [14]
 - Showed how momentum exchange creates a magnetogenesis effect in astrophysical systems, possibly helping to explain the formation of galactic fields magnetic fields [16]

- Applied momentum-exchange theory to alpha channeling to find the previously unknown effect on nonresonant particles, which often cancel the alpha channeling current [19,22]
- Combined geometric optics computational modeling and quasilinear theory to study lower hybrid wave amplification due to alpha channeling in tokamak plasmas [2-3]
- Research on transport in magnetized plasmas (2017-present)
 - Helped to develop a first-of-its-kind code, MITNS, to explore ion-ion transport effects in magnetized plasmas [17,24]
 - Worked with a team at Princeton, University of Paris, and Toulouse, to understand charge and momentum transport effects in rapidly rotating magnetized plasmas [10-11]
 - Used analytics and code to examine particle and heat transport in rapidly rotating magnetized plasmas [7,13,17,18,20,27]
 - Showed how transport effects from temperature gradients and pressure anisotropy in magnetized inertial fusion plasmas could be used to flush out ash and impurities [8-9]
 - Developed and evaluated isotope separation schemes for nuclear waste cleanup [4-5]
- Research on current redistribution and rotation Z-pinch compression (2019-present)
 - Explained puzzling redistribution of current near stagnation in a Z-pinch experiment [12,31]
 - Explained self-generated rotation observed in a different magnetized Z-pinch [23]
 - Collaboration with experimentalists at the Weizmann Institute of Science in Israel
- Research on computational plasma kinetics (2018)
 - Worked with a team at Lawrence Livermore National Laboratory to adapt their continuum kinetic code for magnetized plasma applications
 - Demonstrated the recovery of magnetized hot-plasma waves (Bernstein modes)
- Research on neoclassical particle orbits in rapidly rotating toroidal plasmas (2017)
 - Analyzed particle orbits and evaluated potential neoclassical effects of these orbits in a novel fusion concept, the wave-driven rotating torus, using computation and analytical work [6]
 - Involved a combination of theoretical analysis and simulations, including the development of an object-oriented particle orbit library in C++

National Undergraduate Fellow, Princeton Plasma Physics Laboratory, Princeton, NJ June 2014 – Aug. 2014

- Worked with Professor Nathaniel Fisch through the Department of Energy's National Undergraduate Fellowship in Plasma Physics.
- Studied how high-energy alpha particles could be used to amplify current-drive waves in tokamak plasmas, using a combination of simulations and analysis.

Undergraduate Research in Evolutionary Dynamics, Harvard University Feb. 2012-May 2015

- Worked with Michael Desai through (at different times) the Harvard College Research Program, Harvard Program for Research in Science and Engineering, and Harvard Herchel Smith Fellowship.
- Undergraduate thesis on the effect of intermittent genetic recombination on mutator dynamics.
- Additionally studied the evolutionary processes by which small, intermediate, and large populations cross fitness valleys [1].

Distinctions and Fellowships

Marshall Rosenbluth Outstanding Doctoral Thesis Award from APS Division of Plasma Physics, 2023.
DOE Fusion Energy Sciences Postdoctoral Fellowship, beginning January 2022.

Invited Talk, *Wave Driven Momentum Exchange, Alpha Channeling, and Rotation*, 63rd APS Division of Plasma Physics Meeting, Nov. 2021.

Princeton's Porter Ogden Jacobus Fellowship, 2020-2021 (one of 4 across all graduate departments).

Department of Energy Computational Science Graduate Fellowship, 2016-2020.

Thomas H. Stix Travel Award, Summer 2017.

Centennial Fellowship, Princeton University, 2015-2016.

National Undergraduate Fellowship in Plasma Physics and Fusion Science, 2014 (awarded by US DOE).

Harvard College Scholar 2013-14 (top 10% of class by GPA).

Harvard Herchel Smith Summer Undergraduate Fellowship, 2013.

Harvard College Program for Research in Science and Engineering, 2013.

United States Presidential Scholar, 2011 (one of 141 nationwide).

Intel Science Talent Search Semifinalist, 2011 (one of 300 nationwide).

National Merit Scholar, 2011.

Publications

- 1) I. E. Ochs and M. M. Desai, *The competition between simple and complex evolutionary trajectories in asexual populations*. BMC Evolutionary Biology 15 (1). (2015).
- 2) I. E. Ochs, N. Bertelli, and N. J. Fisch, *Coupling of alpha-channeling to parallel wavenumber upshift in lower hybrid current drive*, Physics of Plasmas 22, 082119 (August, 2015).
- 3) I. E. Ochs, N. Bertelli, and N. J. Fisch, *Alpha Channeling with High-Field Launch of Lower Hybrid Waves*, Physics of Plasmas 22, 112103 (November, 2015).
- 4) I. E. Ochs, R. Gueroult, N. J. Fisch, and S. J. Zweben, *Collisional considerations in axial-collection plasma mass filters*, Physics of Plasmas 24, 043503 (April, 2017).
- 5) I. E. Ochs, J. M. Rax, R. Gueroult, and N. J. Fisch, *Drifts in Collisionality Gradients*, Physics of Plasmas 24, 083503 (August, 2017).
- 6) I. E. Ochs and N. J. Fisch, *Particle Orbits in a Force-balancing Wave-Driven Rotating Torus*, Physics of Plasmas 24, 092513 (September, 2017).
- 7) E. J. Kolmes, I. E. Ochs and N. J. Fisch, *Strategies for Advantageous Differential Transport of Ions in Magnetic Fusion Devices*, Physics of Plasmas 25, 032508 (March, 2018).
- 8) I. E. Ochs and N. J. Fisch, *Favorable Collisional Demixing of Ash and Fuel in Magnetized Inertial Fusion*, Physical Review Letters 121, 235002 (December, 2018).
- 9) I. E. Ochs and N. J. Fisch, *Anisotropy-driven collisional separation of impurities in magnetized compressing and expanding cylindrical plasmas*, Physics of Plasmas 25, 122306 (December, 2018). **Editor's Pick.**
- 10) J. M. Rax, E. J. Kolmes, I. E. Ochs, N. J. Fisch, and R. Gueroult, *Nonlinear Ohmic Dissipation in Axisymmetric DC and RF Driven Rotating Plasmas*, Physics of Plasmas 26, 012303 (January, 2019).
- 11) E. J. Kolmes*, I. E. Ochs*, M. E. Mlodik, J. M. Rax, R. Gueroult, and N. J. Fisch, *Radial Current and Rotation Profile Tailoring in Highly Ionized Linear Plasma Devices*, Physics of Plasmas 26, 082309 (August, 2019). **Featured article.** *co-first-authors.
- 12) I. E. Ochs, C. Stollberg, E. Kroupp, Y. Maron, A. Fruchtman, E. J. Kolmes, M. E. Mlodik, and N. J. Fisch, *Current channel evolution in ideal Z pinch for general velocity profiles*, Physics of Plasmas 26, 122706 (December, 2019). **Editor's Pick.**
- 13) E. J. Kolmes, I. E. Ochs, M. E. Mlodik and N. J. Fisch, *Maximum-entropy states for magnetized ion transport*, Physics Letters A, 384(13) 126262.
- 14) I. E. Ochs and N. J. Fisch, *Momentum-exchange current drive by electrostatic waves in an unmagnetized collisionless plasma*, Physics of Plasmas 27(6), 062109 (2020). **Featured article.**
- 15) M. E. Mlodik, E. J. Kolmes, I. E. Ochs, and N. J. Fisch, *Heat Pump via Charge Incompressibility in a Collisional Magnetized Multi-Ion Plasma*, Physical Review E, 102(1), 13212 (2020).

- 16) I. E. Ochs and N. J. Fisch, *Magnetogenesis by wave-driven momentum exchange*, The Astrophysical Journal, 905(13), (2020).
- 17) E. J. Kolmes*, I. E. Ochs*, and N. J. Fisch, *MITNS: Multiple-Ion Transport Numerical Solver for magnetized plasmas*, Computer Physics Communications 258, 107511 (2021). *co-first-authors.
- 18) E. L. Mitra, E. J. Kolmes, I. E. Ochs, M. E. Mlodik, T. Rubin, and N. J. Fisch, *Trace Impurity Transport in Multi-Species Plasmas with Large Particle Fluxes*. Physics Letters A, 398, 127284 (2021).
- 19) I. E. Ochs and N. J. Fisch, *Nonresonant Diffusion in Alpha Channeling*. Physical Review Letters, 127, 025003 (2021).
- 20) E.J. Kolmes, I. E. Ochs, M. E. Mlodik, and N. J. Fisch. *Natural Hot Ion Modes in a Rotating Plasma*. Physical Review E, 104, 015209 (2021).
- 21) M.E. Mlodik, E.J. Kolmes, I.E. Ochs, and N.J. Fisch. *Generalized impurity pinch in partially magnetized multi-ion plasma*. Physics of Plasmas, 28(5), 052702 (2021).
- 22) I. E. Ochs and N. J. Fisch, *Wave-Driven Torques to Drive Current and Rotation*. Physics of Plasmas, 28(10), 102506 (2021). **Editors Pick.**
- 23) M. Cvejic, D. Mikitchuk, P. Sharma, E. Kroupp, R. Doron, Y. Maron, A. L. Velikovich, A. Fruchtman, I. E. Ochs, E. J. Kolmes, and N. J. Fisch. *Self-generated plasma rotation in a Z-pinch implosion with preembedded axial magnetic field*. Physical Review Letters 128, 015001 (2021).
- 24) T. Rubin, E.J. Kolmes, I.E. Ochs, M.E. Mlodik, and N.J. Fisch, *Finite-Difference Multiple Fluid Solution for Source-Driven Rotation in Highly Magnetized Linear Plasma Device*. Physics of Plasmas, 28, 122303 (2021).
- 25) I. E. Ochs and N. J. Fisch, *Momentum conservation in current drive and alpha-channeling-mediated rotation drive*, Physics of Plasmas, 29(6), 062106, (2022).
- 26) T. Rubin, E. J. Kolmes, I. E. Ochs, M. E. Mlodik, and N. J. Fisch, *Fueling limits in a cylindrical viscosity-limited reactor*, Physics of Plasmas, 29(8), 082302, (2022). **Editor's Pick.**
- 27) E. J. Kolmes*, I. E. Ochs*, and N. J. Fisch, *Wave-supported hybrid fast-thermal p-¹¹B fusion*, Physics of Plasmas, 29(11), 110701, (2022). *co-first-authors.
- 28) I. E. Ochs, E. J. Kolmes, M. E. Mlodik, T. Rubin, and N. J. Fisch, *Improving the feasibility of economical proton-boron-11 fusion via alpha channeling with a hybrid fast and thermal proton scheme*, Phys. Rev. E, 106(5), 055215, (2022).
- 29) M. E. Mlodik, E. J. Kolmes, I. E. Ochs, T. Rubin, and N. J. Fisch, *Partial-ionization deconfinement effect in magnetized plasma*, Physics of Plasmas, 29(11) 112111, (2022). **Editor's Pick.**
- 30) I. E. Ochs and N. J. Fisch, *Ponderomotive Recoil for Electromagnetic Waves*. Physics of Plasmas, 30(2), 022102, (2023). **Editor's Pick + Early Career Collection.**
- 31) C. Stollberg, E. Kroupp, D. Mikitchuk, P. Sharma, V. Bernshtam, M. Cvejić, R. Doron, E. Stambulchik, Y. Maron, A. Fruchtman, I. E. Ochs, N. J. Fisch, and U. Shumlak, *Observation of Fast Current Redistribution in an Imploding Plasma Column*, Physical Review Letters, 130(20), 205101, (2023).
- 32) I. E. Ochs, V. R. Munirov, and N. J. Fisch, *Confinement Time and Ambipolar Potential in a Relativistic Mirror-Confined Plasma*. Physics of Plasmas 30(5), 052508 (2023). **Early Career Collection.**
- 33) I. E. Ochs and N. J. Fisch, *The Critical Role of Isopotential Surfaces for Magnetostatic Ponderomotive Forces*. Phys Rev. E 108(6), 065210 (2023).
- 34) I. E. Ochs and N. J. Fisch, *Lowering the reactor breakeven requirements for proton–boron 11 fusion*, Physics of Plasmas **31**, 012503 (2024).
- 35) E. J. Kolmes, I. E. Ochs, and N. J. Fisch, *Loss-cone stabilization in rotating mirrors: thresholds and thermodynamics*, J. Plasma Phys. **90**, 905900203 (2024). **Featured Article.**
- 36) I. E. Ochs, *When do waves drive plasma flows?*, Physics of Plasmas **31**, 042116 (2024).
- 37) I. E. Ochs and N. J. Fisch, *Lowering the reactor breakeven requirements for proton–boron 11 fusion*, Physics of Plasmas **31**, 012503 (2024).

- 38) I. E. Ochs, M. E. Mlodik, and N. J. Fisch, *Electron tail suppression and effective collisionality due to synchrotron emission and absorption in mildly relativistic plasmas*, Physics of Plasmas **31**, 083303 (2024).
- 39) T. Rubin, I. E. Ochs, and N. J. Fisch, *Flowing plasma rearrangement in the presence of static perturbing fields*, Physics of Plasmas **31**, 082109 (2024). **Editor's Pick.**
- 40) I. E. Ochs, *Synchrotron-driven Instabilities in Relativistic Plasmas of Arbitrary Opacity*, Astrophysical Journal **975**, 30 (2024).
- 41) M. H. Rosen, W. Sengupta, I. Ochs, F. P. Diaz, and G. W. Hammett, *Enhanced Collisional Losses from a Magnetic Mirror Using the Lenard-Bernstein Collision Operator*, Submitted to Journal of Plasma Physics. arXiv:2411.14294.
- 42) A. Mesa Dame, I. E. Ochs, and N. J. Fisch, *Energy Spectrum of Lost Alpha Particles in Magnetic Mirror Confinement*, Submitted to Physics Letters A. arXiv:2412.05890.

Invention Disclosures and Patent Applications

- I. E. Ochs and N. J. Fisch, *Mass separation through biased drifts in collision gradient*, 16-3272-1, M-917; disclosed April 20, 2016.
- I. E. Ochs and N. J. Fisch, *Mass separation by neutral polarization effects*, 16-3273-1, M-918; disclosed April 20, 2016.
- E. J. Kolmes, I. E. Ochs, and N. J. Fisch, *Hybrid Fast-Thermal Regime for High Fusion Gain*, US Provisional Application 63/403,509; Filed October 9, 2023;
- N. J. Fisch, E. J. Kolmes, M. E. Mlodik, V. R. Munirov, I. E. Ochs, J. M. Rax, and T. Rubin, *Producing ultra-high dc voltages with minimal dissipation and minimal damage*, US Provisional Application 63/438,612; Filed April 10, 2024.
- N. J. Fisch, I. E. Ochs, E. J. Kolmes, M. E. Mlodik, and T. Rubin, *Nonthermal Proton-Boron 11 Fusion with Separated Reactant Regions*, US Provisional Application 63/567,285; Filed 03/19/2024.
- N. J. Fisch, T. Rubin, I. E. Ochs, and E. J. Kolmes, *Enhanced Particle Confinement with Positive and Negative Ponderomotive Potentials*, US Provisional Application 63/573,537; Filed April 3, 2024.
- N. J. Fisch, E. J. Kolmes, M. E. Mlodik, V. R. Munirov, I. E. Ochs, J. M. Rax, and T. Rubin, *Reducing Radiation in Centrifugal Mirror Confinement Fusion*, US Provisional Application 63/573,563; Filed April 3, 2024.

Teaching

- **TA for General Plasma Physics 1 (2017)**
 - Ran weekly problem-solving sessions and mini-lectures.
 - DOE fellowship only permitted one semester of TAing.
- **Summer student advising (2017)**
 - Supervised projects on plasma-based ion separation for two summer students.
 - Helped the students to develop codes to analyze magnetized particle dynamics.
 - Developed a mini-course to get the students started with computational plasma physics.
 - Met several times a week with each student to keep projects on track.
- **Summer student advising (2020)**
 - Co-supervised project on multi-ion transport.
 - Helped student to learn to use the transport code MITNS, as well as providing help with analysis.
 - Student submitted a first-author publication to Physics Letters A [18].

- **Summer student advising (2022)**
 - Co-supervised project on asymmetric losses in magnetic mirrors.
 - Helped student to develop both an analytic theory and particle orbit code.
 - Student presented research at the 2022 APS-DPP conference in Spokane, WA.
- **Summer student advising (2023)**
 - Co-supervised 2 students.
 - One studied analytic approximations to mirror loss cone distributions.
 - One simulated the efficiency of Venetian blind direct conversion schemes.
- **Graduate student advising (2022-2024)**
 - Advised a graduate student on a project to determine the energy spectrum of lost alpha particles in a magnetic mirror.
 - Presentation at APS-DPP; Paper submitted to Physics Letters A [43].