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Philip Mocz

Employment

2017–present **Princeton University**, NASA Einstein Fellow.

Education

2012–2017 **Harvard University**, *Ph.D. Astrophysics.*
Secondary Field in Computational Science and Engineering (2015)
Title: *Moving mesh magnetohydrodynamics: magnetic processes in star formation and cosmology*
Advisor: Lars Hernquist

2008–2012 **Harvard University**, *A.B. Mathematics and Astrophysics.*
Summa cum laude w/highest honors, Phi Beta Kappa

Fellowships and Awards

2017–2020 NASA Einstein Fellowship
2017 Eric Keto Prize
2016 Harvard Merit Fellowship
2015–2017 NASA Earth and Space Science Fellowship (NESSF)
2012–2015 NSF Graduate Research Fellowship
2012 Peirce Fellowship (Harvard)
2012 Derek Bok Center Certificate of Distinction in Teaching (Harvard)
2008–2012 John Harvard Scholar
2011 Phi Beta Kappa (Harvard)
2011 Leo Goldberg Prize for Astronomy Junior Thesis (Harvard)
2011 CAS vacation Scholarship (Swinburne Univ. of Technology)
2010 Weissman International Internship Program Scholarship
2009 Detur Prize (Harvard)
2009 Harvard College Program for Research in Science and Engineering Fellow
2008 Intel Science Talent Search Scholarship

Research Interests

- **Theoretical Astrophysics and Cosmology.** Scalar Field Dark Matter, Cosmological Structure Formation, Star Formation, Galaxy Evolution, Feedback, Black Hole Physics
- **Computational Physics.** Computational Fluid Dynamics, Magnetohydrodynamics, Numerical Methods, Turbulence

Refereed Publications

31. **Galaxy Formation with BECDM - II. Cosmic Filaments and First Galaxies**
Mocz, P.; Fialkov; A., Vogelsberger, M.; Becerra, F.; Shen, X.; Robles, V.H.; Amin, M.A.; Zavala, J.; Boylan-Kolchin, M.; Bose, S.; Marinacci, F.; Chavanis, P.H.; Lancaster, L.; Hernquist, L.; 2019 MNRAS submitted

30. **Dynamical Friction in a Fuzzy Dark Matter Universe**
Lancaster, L.; Giovanetti, C.; **Mocz, P.**; Kahn, Y.; Lisanti, M., Spergel, D.; 2019 JCAP submitted

29. **First star-forming structures in fuzzy cosmic filaments**
Mocz, P.; Fialkov A.; Vogelsberger, M.; Becerra, F.; Amin, M.; Bose, S.; Boylan-Kolchin, M.; Chavanis, P.H.; Hernquist, L.; Lancaster, L.; Marinacci, F.; Robles, V.; Zavala J.; 2019 Phys. Rev. Lett. **(Editors' Suggestion)**, 123, 141301

28. **Fuzzy Dark Matter Soliton Cores around Supermassive Black Holes**
Davies E.Y.; **Mocz, P.**; 2019 MNRAS submitted

27. **A Markov model for non-lognormal density distributions in compressive isothermal turbulence**
Mocz, P.; Burkhart, B.; 2019 ApJL 884, 2

26. **Formation, Gravitational Clustering and Interactions of Non-relativistic Solitons in an Expanding Universe**
Amin, M.; **Mocz, P.**; 2019 Phys. Rev. D 100, 063507

25. **The Self-gravitating Gas Fraction and The Critical Density for Star Formation**
Burkhart, B.; **Mocz, P.**; 2019 ApJ 879, 129

24. **Heating of Milky Way disc Stars by Dark Matter Fluctuations in Cold Dark Matter and Fuzzy Dark Matter Paradigms**
Church, B.; Ostriker, J.; **Mocz, P.**; 2019 MNRAS 485, 2861

23. **Star formation from dense shocked regions in supersonic isothermal magneto-turbulence**
Mocz, P.; Burkhart, B.; 2018 MNRAS 480, 3916

22. **Evolution of the Black Hole Mass Function in Star Clusters from Multiple Mergers**
Christian, P.; **Mocz, P.**; Loeb, A.; 2018 ApJL 858, 8

21. **Non-ideal magnetohydrodynamics on a moving mesh**
Marinacci, F.; Vogelsberger, M.; Kannan, R.; **Mocz, P.**; Pakmor, R.; Springel, V.; 2018 MNRAS, 476, 2476

20. **Schrödinger-Poisson–Vlasov-Poisson correspondence**
Mocz, P.; Lancaster, L.; Fialkov, A.; Becerra, F.; Chavanis, P.-H.; 2018 Phys. Rev. D 97, 3519

19. **Galaxy Formation with BECDM - I. Turbulence and relaxation of idealised haloes**
Mocz, P.; Vogelsberger, M.; Robles, V.; Zavala J.; Boylan-Kolchin, M.; Fialkov A.; Hernquist, L.; 2017 MNRAS, 471, 4

18. **Unveiling the role of the magnetic field at the smallest scales of star formation**
Hull C.L.H.; **Mocz, P.**; Burkhart, B.; Goodman, A.A.; Girart, J.M.; Cortés, P.C.; Hernquist, L.; Li, Z.-Y.; Lai, S.-P.; Springel, V.; 2017 ApJL, 842, 9

17. **Moving mesh simulations of star forming cores in magneto-gravo-turbulence**
Mocz, P.; Burkhart, B.; Hernquist, L.; McKee, C.; Springel, V.; 2017 ApJ, 838, 1

16. **Integer lattice dynamics for Vlasov-Poisson**
Mocz, P.; Succi, S.; 2017 MNRAS, 465, 3154

15. **Correspondence between constrained transport and vector potential methods for MHD**
Mocz, P.; 2017 J. Comp. Phys., 328, 221

14. **A moving mesh unstaggered constrained transport scheme for MHD**
Mocz, P.; Pakmor, R.; Springel, V.; Vogelsberger, M.; Marinacci, F.; Hernquist, L.; 2016 MNRAS, 463, 477

13. **Improving the convergence properties of the moving-mesh code AREPO**
Pakmor, R.; Springel, V.; Bauer, A.; **Mocz, P.**; Munoz, D.J.; Ohlmann, S.T.; Schaal, K.; Zhu, C.; 2016 MNRAS, 455, 1134

12. **The large-scale properties of simulated cosmological magnetic fields**
Marinacci, F.; Vogelsberger, M.; **Mocz, P.**; Pakmor, R.; 2015 MNRAS, 453, 3999

11. **Reducing noise in moving-grid codes with strongly-centroidal Lloyd mesh regularization**
Mocz, P.; Vogelsberger, M., Pakmor, R., Genel, S., Springel, V., Hernquist, L.; 2015 MNRAS, 452, 3853

10. **Numerical solution to the non-linear Schrödinger equation using smoothed-particle hydrodynamics**
Mocz, P.; Succi, S.; 2015 Phys. Rev. E, 91, 053304

9. **Interpreting MAD within multiple accretion regimes**
Mocz, P.; Guo, X.; 2015 MNRAS, 447, 1498

8. **A constrained transport scheme for MHD on unstructured static and moving meshes**
Mocz, P.; Vogelsberger, M.; Hernquist, L. 2014 MNRAS, 442, 43

7. **Do high-redshift quasars have powerful jets?**
Fabian, A.C.; Walker, S.A.; Celotti, A.; Ghisellini, G.; Mocz, P.; Blundell, K.M.; McMahon, R.G. 2014 MNRAS, 442L, 81

6. **A discontinuous Galerkin method for solving the fluid and magnetohydrodynamic equations in astrophysical simulations**
Mocz, P.; Vogelsberger, M.; Sijacki, D.; Pakmor, R.; Hernquist, L. 2014 MNRAS, 437, 397

5. **Cosmological growth and feedback from supermassive black holes**
Mocz, P.; Fabian, A.C.; Blundell, K.M.; 2013 MNRAS, 432, 3381

4. **The Tully-Fisher relation for 25,000 Sloan Digital Sky Survey galaxies as a function of environment**
Mocz, P.; Green A.; Malacari M.; Glazebrook, K.; 2012 MNRAS, 425, 296

3. **The inverse-Compton ghost HDF 130 and the giant radio galaxy 6C 0905+3955: matching an analytic model for double radio source evolution**
Mocz, P.; Fabian, A.C.; Blundell, K.M.; Goodall, P.T.; Chapman, S.C.; Saikia, D.J.; 2011 MNRAS 417, 1576

2. **Inverse-Compton ghosts and double-lobed radio sources in the X-ray sky**
Mocz, P.; Fabian, A.C.; Blundell, K.M.; 2011 MNRAS, 413, 1107

1. **A Detection of an X-ray Wind and an Ionized Disk in the Chandra HETGS Observation of the Seyfert 2 Galaxy IRAS 18325-5926**
Mocz, P.; Lee, J.C.; Iwasawa, K.; Canizares, C.R.; 2011 ApJ, 729, 30

Grants and Proposals

2017 **Co-PI of TACC *Stampede2* computing grant**, *"Cosmology with Bose Einstein Condensate Dark Matter: Cosmic Web and First Galaxies"*, TG-AST170020.
60,750 node-hours ($\sim$ 3M cpu core-hrs; est. value $18,000$)

2017 **PI of TACC *Stampede2* computing grant**, *"The Formation of First Stars in Bose-Einstein Condensate Dark Matter"*, TG-AST170015.
50,000 CPU core-hrs (est. value $1,800$)

2017–2020 **PI of NASA Einstein Fellowship award**, *"Moving mesh magnetohydrodynamics: understanding the role of magneto-turbulence in cosmological structure formation and star formation"*, PF7-180164.
Total budget: $300,000. (host Jim Stone)

2015 **Co-PI of Gauss Centre for Supercomputing grant**, *"Predicting galaxy formation in a representative volume of the Universe"*.
92M cpu core-hrs on *Hornet* in Stuttgart. (PI: Volker Springel)

2015–2017 **Co-PI of NASA NESSF award**, *"Moving Mesh Cosmology with Magnetohydrodynamics"*, NNX15AR88H.
Total budget: $100,000. (admin PI: Lars Hernquist)

2012–2015 **PI of NSF GRFP award**, *"Jet dynamics and kinetic feedback from supermassive black holes"*, DGE-1144152.
Total budget: $100,000.

Presentations

Invited Talks

06/2020 **Forefronts of Cosmology and Gravitation**, *Copenhagen*, "Fuzzy Dark Matter Cosmology".

02/2020 **Magnetic Fields in the Universe 7**, *Vietnam*, "Studying Dense Structures in a Turbulent Interstellar Medium with a Moving Mesh".

02/2020 **Cornell Astrophysics Colloquium**, *Cornell*, "Is dark matter cold, warm, or fuzzy?".

09/2019 **Competing Structure Formation Models Workshop**, *Reykjavik*, "Fuzzy Dark Matter: overview".

09/2019 **Rutgers Astronomy Seminar**, *Rutgers*, "Ultralight Dark Matter".

08/2019 **Cosmo Cruise**, *Italy/Greece*, "Ultralight Dark Matter".

02/2019 **UW-Madison Astrophysics Colloquium**, *Madison*, "Structure formation and turbulent processes in the Universe".

01/2019 **Big Apple Magnetic Fields Conference**, *CCA Flatiron*, "Shock structures in magnetized supersonic isothermal turbulence".

12/2018 **Columbia Physics Theory Seminar**, *Columbia*, "Small-scale features in fuzzy dark matter".

11/2018 **MX Dark Matter Conference**, *Cancun, Mexico*, "Quantum Wave Dark Matter and the Classical Limit".

10/2018 **Rice Theory Seminar**, *Rice University*, "Small-scale structure in fuzzy dark matter and the classical limit".

09/2018 **CITA Theory Seminar**, *Toronto*, "Small-scale structure in fuzzy dark matter and the classical limit".

03/2018 **Ringberg Computational Galaxy Formation**, *Germany*, "Galaxy Formation with Bose-Einstein Condensate Dark Matter".

09/2017 **Brown BASS Talk**, *Brown*, "Galaxy Formation with Axion Dark Matter".

12/2016 **Cosmic Rays, Astrophysical Turbulence and Magnetic Reconnection Conference, IIP**, *Natal, Brazil*, "Moving mesh simulations of star forming cores in magneto-gravo-turbulence".

01/2015 **Istituto per le Applicazioni del Calcolo "Mauro Picone" Theory Talk**, *Rome*, "Moving Mesh and Smoothed Particle Methods for Computational Fluid Dynamics".

Contributed Talks

01/2020 **AAS Meeting**, *Hawaii*, "First star-forming structures in fuzzy dark matter".

12/2019 **Turbulence Across Vast Scales**, *CCA Flatiron*, "Dense structures in compressible turbulence".

11/2019 **Cosmic Turbulence and Magnetic Fields**, *Cargese*, "Pre-stellar core formation from dense shocked regions in supersonic isothermal magnetoturbulence".

11/2019 **Einstein Symposium**, *Washington DC*, "First star-forming structures in fuzzy dark matter cosmic filaments".

10/2019 **Cosmic Controversies**, *Chicago KICP*, "First star-forming structures in fuzzy cosmic filaments".

08/2019 **UCSC Galaxy Workshop**, *Santa Cruz*, "First structures in ultralight dark matter".

06/2019 **UH Physics Colloquium**, *University of Hawaii*, "First star-forming structures in fuzzy cosmic filaments".

10/2018 **Einstein Symposium**, *Harvard*, "Small-scale features in fuzzy dark matter cosmology".

02/2018 **ALMA NA-Taiwan Joint Workshop: Magnetic Fields or Turbulence?**, *Taiwan*, "Magneto- and turbulent regimes of star formation".

10/2017 **CIRM Collisionless Boltzmann (Vlasov) Equation and Modeling of Self-Gravitating Systems and Plasmas**, *Marseilles*, "Solving Vlasov-Poisson dynamics on an integer lattice".

10/2017 **Einstein Symposium**, *Harvard*, "The role of magneto-turbulence in star formation".

09/2017 **CCA NY Area Computational Hydro Workshop**, *CCA Flatiron*, "Galaxy Formation with Axion Dark Matter".

05/2017 **Harvard ITC Luncheon**, *Harvard*, "Integer Lattice for Vlasov-Poisson".

05/2017 **Harvard ITC Luncheon**, *Harvard*, "Quantum Turbulence in Bose-Einstein Condensate Dark Matter".

11/2016 **Berkeley TAC Seminar**, "Moving mesh simulations of star forming cores in magneto-gravo-turbulence".

09/2016 **Harvard ITC Luncheon**, "Moving mesh simulations of star forming cores in magneto-gravo-turbulence".

06/2016 **Astronum**, *Monterey, CA*, "Moving mesh magnetohydrodynamics".

05/2016 **Crutcher & Heiles Conference**, *Madison*, "Moving mesh magnetohydrodynamics and applications to star forming cores".

06/2013 **Southern Cross Conference Series VI: Feeding, Feedback, and Fireworks: Celebrating Our Cosmic Landscape**, *Hamilton Island, Australia*, "A discontinuous Galerkin method for solving the fluid and MHD equations in astrophysical simulations".

08/2011 **Swinburne CAS Seminar**, *Swinburne Univ. of Technology*, "Tully-Fisher Relationships for SDSS Galaxies as a Function of Environment".

07/2011 **IoA X-Ray Group Talk**, *University of Cambridge*, "Cosmological growth and feedback of massive black holes".

05/2011 **Research Presentation**, *Harvard*, "SMA Observation of the Extended Emission in the High-Mass Star Forming Region AFGL 2591".

04/2011 **Junior Thesis Presentations**, *Harvard*, "X-ray spectroscopy of silicate dust in the ISM and environments around XRBs".

03/2011 **Research Presentation**, *Harvard*, "Laboratory and Astronomical Observations of the CN Radical".

08/2010 **IoA X-Ray Group Talk**, *University of Cambridge*, "Double radio sources and inverse-Compton ghosts in the X-ray sky".

08/2009 **PRISE Talk**, *Harvard*, "A Search for X-Ray Winds and Strong Gravity Around a Supermassive Black Hole In A Distant Galaxy".

Professional Skills

Codes Developer: Arepo

Web HTML5, CSS

Programming Languages C/C++, Python, Matlab, Mathematica, Javascript, SQL **Paradigms** MPI, OpenMP, CUDA

High-performance computing Use of several Tier-0 supercomputing facilities, including TACC *Stampede2*, utilizing 10,000s cores and 10s millions of cpu-core hours. Helped write several applications for supercomputing proposals.

Teaching

Spring 2016 **Astronomy 151. Astronomical Fluid Dynamics**, *Teaching Fellow*, Harvard.
- student evaluation score 5.0/5.0, 5 students
- duties: office-hours, special topics sections, grading, homework solutions

Fall 2014 **Applied Computation 274. Computational Fluid Dynamics**, *Section leader*, Harvard.
- student evaluation score 4.5/5.0, 6 students
- duties: duties: lectures, office-hours, course material and homework development, grading, final project supervision

Spring 2014 **Applied Computation 274. Computational Fluid Dynamics**, *Section leader*, Harvard.
- student evaluation score 4.0/5.0, 6 students
- duties: office-hours, course material and homework development, grading, final project supervision

Spring 2014 **Applied Mathematics 205. Advanced Scientific Computing: Numerical Methods**, *Section leader*, Harvard.
- student evaluation score 4.7/5.0, 56 students
- duties: duties: weekly section, office-hours, course material and homework development, final project supervision

Mentoring

2019 **Michael Foley**, *graduate*, Harvard, Astrophysics.

2019 **Elliot Davies**, *undergraduate*, Princeton, Physics.

2019 **Cara Giovanetti**, *undergraduate*, Princeton, Physics.

2018 **Ben Church**, *undergraduate*, Columbia, Mathematics & Physics.

2017–2019 **Lachlan Lancaster**, *graduate*, Princeton, Astrophysics.

2016 **Alex Gurvich**, *undergraduate*, Harvard, Physics & Astronomy.

2016 **Sruthi Narayanan**, *undergraduate*, MIT, Computer Science.

Outreach and Service

2019 **Princeton Astrophysics Undergraduate Summer Research Program Mentor.** Advised physics student summer research project on interaction of black holes and scalar field dark matter, leading to publication.

2019 **Guest Lecture.** Taught graduate students about moving mesh computational fluid dynamics with interactive coding demos in Princeton graduate seminar course AST 542.

2015–2017 **Harvard Astronomy Department Peer Mentor.** Served as a guide and resource for first and second year graduate student mentees.

2015–2017 **Library Committee Graduate Student Representative, Harvard-Smithsonian CfA.** Helped advise head librarian and committee of 8 scientists on the future of the library, new digital services, journal subscriptions, educational services, and resources for graduate students.

2015 **Einstein in the Classroom.** Engaged with Pierce Middle School in the greater Boston area to offer physics activities in the classroom covering relativity, spacetime curvature, the life cycles of stars, and the relative sizes of the objects in the observable Universe.

Peer Review. Monthly Notices of the Royal Astronomical Society, Astrophysical Journal, Physical Review Journals, Journal of Computational Physics

Proposal Referee. French National Research Agency (ANR), NASA Earth and Space Science Fellowship (NESSF), Future Investigators in NASA Earth and Space Science and Technology (FINESST)