Sarah C. Millholland

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Research Interests

Exoplanet detection & characterization; demographics & orbital architectures of planetary systems; planetary dynamics and celestial mechanics; planetary atmospheres

Education

Yale University, New Haven, CT — July 2016 – May 2020
Ph.D. in Astronomy, May 2020
Thesis: Data-Driven Dynamics of Planetary Systems
Advisor: Prof. Greg Laughlin
M.S., M.Phil. in Astronomy, May 2018

UC Santa Cruz, Santa Cruz, CA — Sept. 2015 – June 2016
Pursuit of Ph.D. in Astronomy & Astrophysics
(transferred after completing first year)

University of Saint Thomas, Saint Paul, MN — Sept. 2011 – May 2015
B.S. in Physics; **B.A.** in Mathematics, May 2015
Summa Cum Laude

Positions

Assistant Professor — July 2022 – present
Department of Physics, Massachusetts Institute of Technology

NASA Sagan Fellow — July 2020 – June 2022
Department of Astrophysical Sciences, Princeton University

NSF Graduate Research Fellow — 2017 – 2020
Department of Astronomy, Yale University
Advisor: Prof. Greg Laughlin

Graduate Student Researcher — 2015 – 2017
Department of Astronomy, Yale University (2016 – 2017)
Department of Astronomy & Astrophysics, UCSC (2015 – 2016)
Advisor: Prof. Greg Laughlin

Awards

- Brouwer Prize ("awarded to Yale astronomy graduates for contributions of unusual merit to any branch of astronomy") — 2021
- Lyman Spitzer Jr. Postdoctoral Fellowship, Princeton University — 2023 – 2025
- NASA Hubble Fellowship Program (NHFP) Sagan Fellowship — 2020 – 2023
- Tinsley Award ("best paper by a Yale astronomy graduate student"; for Millholland & Laughlin 2017b) — 2018
- DDA/AAS Raynor L. Duncombe Prize for Student Research — 2018
- Yale Conference Travel Fellowship — 2017
- NSF Graduate Research Fellowship — 2017 – 2020
- Summer Sagan Workshop Travel Award — 2016
- UCSC Regents Fellowship — 2015
- NSF Graduate Research Fellowship Honorable Mention — 2015
- Barry M. Goldwater Scholarship (national science scholarship) — 2014 – 2015
- Smith Academic Scholarship — 2014 – 2015
- Danger Mathematics Scholarship — 2013 – 2014, 2014 – 2015

- UST Collaborative Inquiry Research Scholarship 2014
- Walczak Mathematics Scholarship 2013 – 2014
- B. John Barry Academic Scholarship 2012 – 2013
- UST Endowed Scholarship 2011 – 2015

Teaching

- Physics I: Classical Mechanics (8.012), MIT Fall 2022
- Teaching Fellow, Planets and Stars, Yale University Spring 2017
- Teaching Fellow, Physics of Planetary Systems, UCSC Spring 2016
- Teaching Fellow, Overview of the Universe, UCSC Fall 2016
- Teaching Assistant, Modern Physics, UST Springs 2014, 2015
- Observatory Lab Instructor, Introduction to Astronomy, UST and the UST Observatory Fall 2012 – Spring 2015

Advising

- Orion Foo, MIT undergraduate student, Fall 2022 – present
- Haedam Im, MIT undergraduate student, Fall 2022 – present
- Emma Louden, Yale graduate student, Fall 2022 – present (IvyPlus Exchange Scholar Program)
- Nicole Sobski, Wellesley undergraduate student, Summer 2022 – present (MIT Undergraduate Research Opportunities Program)
- Nicole Gountanis, Princeton undergraduate student, Fall 2021 (Junior Project)
- Joshua Zou, Princeton undergraduate student, Summer 2021 (Undergraduate Summer Research Program)
- David Jensen, Princeton undergraduate student, Fall 2020 (Junior Project)
- Samantha Berek, Yale undergraduate student, 2018 – 2020 ("Astro Sib" Mentorship Program)
- Adrian Kulesza, Yale undergraduate student, Spring 2019 (research project in "Astrophysics Research Methods")
- Rachel Cohen, Yale undergraduate student, Spring 2019 (research project in "Astrophysics Research Methods")
- Marguerite Epstein-Martin, Yale undergraduate student, 2017 – 2018 (co-advised with Greg Laughlin)

Refereed Publications (*=student supervised by S.C.M.)

First author

14. **Millholland, S.**, He, M., & Zink, J. "Edge-of-the-Multis: Evidence for a Transition in the Outer Architectures of Compact Multi-Planet Systems." 2022, AJ, 164, 72
13. **Millholland, S.** & Winn, J. "Split Peas in a Pod: Intra-System Uniformity of Super-Earths and Sub-Neptunes." 2021, ApJL, 920, L34
12. **Millholland, S.**, He, M., Ford, E., et al. "Evidence for a Non-Dichotomous Solution to the Kepler Dichotomy: Mutual Inclinations of Kepler Planetary Systems from Transit Duration Variations." 2021, AJ, 162, 166
11. **Millholland, S.** & Spalding, C. "Formation of Ultra-Short-Period Planets by Obliquity-Driven Tidal Runaway." 2020, ApJ, 905, 71
10. **Millholland, S.**, Petigura, E., & Batygin, K. "Tidal Inflation Reconciles Low-Density Sub-Saturns with Core Accretion." 2020, ApJ, 897, 7
9. **Millholland, S.** "Tidally Induced Radius Inflation of Sub-Neptunes." 2019, ApJ, 886, 72
8. **Millholland, S.** & Batygin, K. "Excitation of Planetary Obliquities Through Planet-Disk Interactions." 2019, ApJ, 876, 119

7. **Millholland, S.** & Laughlin, G. "Obliquity-Driven Sculpting of Exoplanetary Systems." 2019, Nature Astronomy, 3, 424
6. **Millholland, S.** & Laughlin, G. "Obliquity Tides May Drive WASP-12b's Rapid Orbital Decay." 2018, ApJL, 869, L15
5. **Millholland, S.**, Laughlin, G., Teske, J., et al. "New Constraints on Gliese 876 – Exemplar of Mean-Motion Resonance." 2018, AJ, 155, 106
4. **Millholland, S.**, Wang, S., & Laughlin, G. "*Kepler* Multi-Planet Systems Exhibit Unexpected Intra-system Uniformity in Mass and Radius." 2017, ApJL, 849, L33
3. **Millholland, S.** & Laughlin, G. "Supervised Learning Detection of Sixty Non-Transiting Hot Jupiter Candidates." 2017, AJ, 154, 83
2. **Millholland, S.** & Laughlin, G. "Constraints on Planet Nine's Orbit and Sky Position within a Framework of Mean-motion Resonances." 2017, AJ, 153, 91
1. **Millholland, S.**, Wang, S., & Laughlin, G. "On the Detection of Non-Transiting Hot Jupiters in Multiple Planet Systems." 2016, ApJL, 823, L7

Second author

5. *Jensen, D. & **Millholland, S.** "Inferred Properties of Planets in Mean-Motion Resonances are Biased by Measurement Noise." 2022, AJ, 164, 144
4. Weiss, L., **Millholland, S.**, Petigura, E., Adams, F., Batygin, K., Bloch, A., & Mordasini, C. "Architectures of Compact Multi-planet Systems: Diversity and Uniformity." 2022, Protostars and Planets VII book chapter, arXiv: 2203.10076
3. Lillo-Box, J., **Millholland, S.**, & Laughlin, G. "Follow-up of Non-Transiting Planets Detected by Kepler: Confirmation of Three Hot Jupiters and Validation of Three Other Planets." 2021, A&A, 654, 9
2. Spalding, C. & **Millholland, S.** "Stellar Oblateness versus Distant Giants in Exciting *Kepler* Planet Mutual Inclinations." 2020, AJ, 160, 105
1. Adams, A. D., **Millholland, S.**, & Laughlin, G. "Signatures of Obliquity in Thermal Phase Curves of Hot Jupiters." 2019, AJ, 158, 3

Other co-author

8. Zhao, L., Kunovac, V., Brewer, J., Llama, J., **Millholland, S.**, et al. [11 total] "Measured Spin-Orbit Alignment of Ultra-Short Period Super-Earth 55 Cancri e." 2022, Nature Astronomy, accepted
7. Stefansson, G., Mahadevan, S., Petrovich, C., Winn, J., Kanodia, S., **Millholland, S.**, et al. [37 total] "The Warm Neptune GJ 3470b has a Polar Orbit." 2022, ApJL, 931, L15
6. Azari, A., Biersteker, J., Dewey, R., Doran, G., et al. including **Millholland, S.** [16 total] "Integrating Machine Learning for Planetary Science: Perspectives for the Next Decade." 2021, BAAS, 53, 128 (white paper)
5. Davis, A., Wang, S., Jones, M., Eastman, J., Günther, M., Stassun, K., et al. including **Millholland, S.** [51 total] "TOI 564 b and TOI 905 b: Grazing and Fully Transiting Hot Jupiters Discovered by TESS." 2020, AJ, 160, 229
4. Bryan, M., Chiang, E., Bowler, B. P., Morley, C. V, **Millholland, S.**, Blunt, S., Ashok, K. B., Nielsen, E., Ngo, H., Mawet, D., Knutson, H. A. "Obliquity Constraints on an Extrasolar Planetary-Mass Companion." 2020, AJ, 159, 181
3. Wang, S., Jones, M., Shporer, A., Fulton, B. J., Paredes, L. A., Trifonov, T., Kossakowski, D., Eastman, J., Redfield, S., Günther, M. N., Kreidberg, L., Huang, C. X., **Millholland, S.**, et al. [60 total] "HD 202772Ab: A Transiting Hot Jupiter Around a Bright, Mildly Evolved Star in a Visual Binary Discovered by TESS." 2019, AJ, 157, 51

2. Becker, J. C., Khain, T., Hamilton, S. J., Adams, F. C., Gerdes, D. W., Zullo, L., Franson, K., **Millholland, S.**, et al. [66 total] "Discovery and Dynamical Analysis of an Extreme Trans-Neptunian Object with a High Orbital Inclination." 2018, AJ, 156, 81

1. Janvier, M., Savcheva, A., Pariat, E., Tassev, S., **Millholland, S.**, Bommier, V., McCauley, P., McKillop, S., Dougan, F. "Evolution of Flare Ribbons, Electric Currents and Quasi-separatrix Layers During an X-class Flare." 2016, A&A, 591, A141

Observing Programs

- Keck I, HIRESr, "Non-Transiting Hot Jupiters: Hidden Companions to Known Exoplanets", 2020B, 2 nights, Co-I (PI: Malena Rice)
- ORM, STELLA/SES, "Radial velocity confirmation of non-transiting planets from Kepler" 2020B, 40 hrs, Co-I (PI: Jorge Lillo-Box)
- Keck I, HIRESr, "Non-Transiting Hot Jupiters: Hidden Companions to Known Exoplanets", 2020A, 2 nights, Co-I (PI: Songhu Wang)
- Keck I, HIRESr, "Are Hot Jupiters Dynamically Hot?", 2020A, 2 nights, Co-I (PI: Songhu Wang)
- Keck I, HIRESr, "Non-Transiting Hot Jupiters: Hidden Companions to Known Exoplanets", 2019B, 4 nights, Co-I (PI: Songhu Wang)
- CAHA, CAFE, "Radial velocity confirmation of non-transiting planets from Kepler" 2019B, 5 nights, Co-I (PI: Jorge Lillo-Box)
- Keck I, HIRESr, "Do Multi-planet Systems Share Alignment with Their Parent Stars?", 2018A, 1 night, Co-I (PI: Songhu Wang)

Seminars & Colloquia (*=invited)

- * Astrophysics Colloquium, Chalmers University of Technology, May 2022
- * Astronomy Colloquium, University of Wisconsin-Madison, March 2022
- * Stellar Astrophysics Center Seminar, Aarhus University, November 2021
- * Astronomy Colloquium, California Institute of Technology, October 2021
- * Astronomy Colloquium, Columbia University, October 2021
- * Astronomy Colloquium, University of Rochester, September 2021
- * Astrophysics Seminar, Astrophysical Fluid Dynamics Group at DAMTP, University of Cambridge, May 2021
- * Astronomy Colloquium, University of California Los Angeles, March 2021
- * Center for Integrative Planetary Science Seminar, University of California Berkeley, March 2021
- * Exoplanets and Protoplanetary Disks Research Group Talk, Imperial College London, March 2021
- * Canadian Institute for Theoretical Astrophysics Seminar, University of Toronto, March 2021
- * Center for Astrophysical Sciences Seminar, Johns Hopkins University, Feb. 2021
- * Astronomy Seminar, Carnegie Earth and Planets Laboratory, Feb. 2021
- * Astrophysics Colloquium, Massachusetts Institute of Technology, Feb. 2021
- * Colloquium, Center for Computational Astrophysics, Flatiron Institute, Oct. 2020
- * JILA Astrophysics Seminar, University of Colorado Boulder, Oct. 2020
- * JPL Exoplanet Journal Club Talk, NASA Jet Propulsion Laboratory, Aug. 2020
- * Special Seminar, Climate and Space Sciences and Engineering, University of Michigan, Feb. 2020
- * Cosmos Seminar, The University of Texas at Austin, Oct. 2019
- * Institute for Theory and Computation Seminar, Harvard University, Oct. 2019
- Friday Lunch Time Astrophysics Seminar, University of California Santa Cruz, Oct. 2019

- Tuesday Lunch Talk, University of California Los Angeles, Oct. 2019
- Astronomy Tea Talk, California Institute of Technology, Oct. 2019
- Exoplanet Tea Talk, Massachusetts Institute of Technology, Sept. 2019
- * Planetary Lunch Seminar, Cornell University, Sept. 2019
- Astronomy Seminar, Columbia University, Sept. 2019
- Star and Planet Formation Seminar, University of Michigan, March 2019
- Exoplanet Lunch Seminar, Princeton University, Feb. 2019
- * Center for Exoplanets & Habitable Worlds Seminar, Penn State University, Feb. 2019
- * Extrasolar Planets Seminar, NASA Goddard Space Flight Center, April 2018
- * Planetary Science Seminar, California Institute of Technology, Dec. 2017
- * Stars & Planets Seminar, Harvard-Smithsonian Center for Astrophysics, Nov. 2017
- Exoplanet Pizza Lunch, Harvard-Smithsonian Center for Astrophysics, March 2017

Conference Talks

- "Edge-of-the-Multis: Evidence for Truncation of the Outer Architectures of Compact Multiple-Planet Systems." Exoplanets IV Conference, Las Vegas, Nevada, May 2022
- "Edge-of-the-Multis: Evidence for Truncation of the Outer Architectures of Compact Multiple-Planet Systems." Division of Dynamical Astronomy Meeting, Flatiron Institute, New York, New York, April 2022
- "A 3D View of Planetary Orbital Architectures." 2021 NHFP Symposium, virtual conference, October 2021
- "Evidence for a Non-Dichotomous Solution to the Kepler Dichotomy." AAS Meeting #238, virtual conference, June 2021
- "Evidence for a Non-Dichotomous Solution to the Kepler Dichotomy." Division of Dynamical Astronomy Meeting, virtual conference, May 2021
- "Testing Obliquity-Driven Sculpting of Exoplanetary Systems with PLATO." PLATO ESP Workshop on Planetary Interiors and System Architectures, virtual conference, November 2020
- "Formation of Ultra-Short-Period Planets by Obliquity-Driven Tidal Runaway." 2020 NHFP Symposium, virtual conference, September 2020
- "Formation of Ultra-Short-Period Planets by Obliquity-Driven Tidal Runaway." Division of Dynamical Astronomy Meeting, virtual conference, August 2020
- "The Role of Tidal Inflation in Explaining Sub-Saturn Structures." Boston Area Exoplanet Science Meeting #7, virtual conference, April 2020
- "Obliquity-Driven Sculpting of Exoplanetary Systems." AAS Meeting #235, Honolulu, HI, January 2020
- "Tidally-Induced Radius Inflation of Sub-Neptunes." Extreme Solar Systems IV, Reykjavik, Iceland, August 2019
- "Tidally-Induced Radius Inflation of Sub-Neptunes." Emerging Researchers in Exoplanet Science (ERES) V, Cornell University, Ithaca, NY, June 2019
- "Excitation of Planetary Obliquities Through Planet-Disk Interactions." Division of Dynamical Astronomy Meeting, Boulder, CO, June 2019
- "Obliquity Tides and their Role in Understanding the Kepler Planet Period Ratio Distribution." Kepler & K2 Science Conference V, Glendale, CA, March 2019
- "The Surprising Role of Obliquity Tides in Short-Period Exoplanets." Boston Area Exoplanet Science Meeting #5, Boston University, Boston, MA, January 2019
- "Consequences of Large Planetary Obliquities in Extrasolar Systems." 2018 CT Exoplanets Meeting, Wesleyan University, Middletown, CT, July 2018
- "Obliquity-Driven Sculpting of Exoplanetary Systems." Emerging Researchers in Exoplanet Science (ERES) IV, Pennsylvania State University, State College, PA, June 2018

- "On f for 9." Planet Nine Workshop, California Institute of Technology, Pasadena, CA, May 2018
- "On the Obliquities of Planets in Close-in, Coplanar Systems." Division of Dynamical Astronomy Meeting, San Jose, CA, April 2018
- "New Constraints on the Multi-Resonant Planetary System, Gliese 876." Numerical Integration Methods in Planetary Science, University of Toronto at Scarborough, Toronto, Ontario, August 2017
- "Constraints on Planet Nine in a Mean-Motion Resonant Framework." Numerical Integration Methods in Planetary Science, University of Toronto at Scarborough, Toronto, Ontario, August 2017
- "Supervised Learning Detection of Sixty Non-Transiting Hot Jupiter Candidates." Kepler & K2 Science Conference IV, NASA Ames Research Center, Moffett Field, CA, June 2017
- "Supervised Learning Detection of Sixty Non-Transiting Hot Jupiter Candidates." Emerging Researchers in Exoplanet Science (ERES) III, Yale University, New Haven, CT, June 2017
- "Supervised Learning Detection of Sixty Non-Transiting Hot Jupiter Candidates." 2017 CT Exoplanets Meeting, Wesleyan University, Middletown, CT, May 2017
- "Constraints on Planet Nine in a Mean-Motion Resonant Framework." 2017 Aspen Winter Conference, Formation and Dynamical Evolution of Exoplanets, Aspen, CO, March 2017

Conference Posters

- **Millholland, S.**, Petigura, E., & Batygin, K. "Tidal Inflation Reconciles Low-Density Sub-Saturns with Core Accretion." Exoplanets III Conference, virtual conference, July 2020
- Adams, A., **Millholland, S.** & Laughlin, G. "Detecting Planet Obliquity in Thermal Phase Curves." Summer Sagan Workshop, Pasadena, CA, July 2018
- **Millholland, S.** & Laughlin, G. "Obliquity-Driven Sculpting of Exoplanetary Systems." Exoplanets II Conference, Cambridge, UK, July 2018
- **Millholland, S.**, Laughlin, G., Butler, P., et al. "New Dynamical Constraints on the Multi-Resonant System, GJ 876." Summer Sagan Workshop, Pasadena, CA, July 2016
- **Millholland, S.**, Laughlin, G., Burt, J., et al. "A Search for Non-Transiting Hot Jupiters with Transiting Super-Earth Companions." Exoplanets I Conference, Davos, Switzerland, July 2016
- **Millholland, S.** & Ruch, G. "An Analysis of the Fixed Star Approximation in Transit Light Curve Models." IAU General Assembly, Meeting #29, id.2255909, Honolulu, HI, August 2015
- **Millholland, S.**, Savcheva, A. & DeLuca, E., "Magnetic Field Modeling of Complex, Flare Producing Active Regions." American Geophysical Union Fall Meeting, abstract #SH13A-4079, San Francisco, CA, December 2014
- **Millholland, S.**, Maruyama, N., Maute, A., et al. "Modeling Sudden Stratospheric Warming Events Using the Ionosphere-Plasmasphere Electrodynamics Model." American Geophysical Union Fall Meeting, abstract #SA23A-2034, San Francisco, CA, December 2013
- **Millholland, S.** & Ruch, G., "Modeling and Fitting Exoplanet Transit Light Curves." AAS Meeting #221, id.343.10, Long Beach, CA, January 2013

Web Blog Publications

- "Tilting Planets and Sculpting Orbits", invited guest post by S. Millholland at *Nature Research Behind the Paper*, March 2019. (Click here to follow link.)

Outreach Talks and Publications

- Yale Young Global Scholars Research Showcase (http://globalscholars.yale.edu), Yale University, June & July 2022 (virtual talks)
- Exploring Science, Yale University, August 2020 (virtual talk)
- Yale Young Global Scholars Research Showcase, Yale University, July 2019 (talk)
- Institute for Learning in Retirement, Albertus Magnus College, October 2018 (talk)
- Yale Young Global Scholars Research Showcase, Yale University, June & July 2018 (talks)
- Leitner Family Observatory & Planetarium, February 2018 (talk)
- Pathways Summer Scholars Program Science Café (http://pathwayssummerscholars.yale.edu), Yale University, July 2017 (talk)
- Yale Young Global Scholars Research Showcase, Yale University, July 2017 (talk)
- Pathways Summer Scholars Enrichment Workshop, Yale University, July 2017 (talk & workshop)
- Yale Open Labs Science Café (http://theopenlabs.org), Yale University, April 2017 (talk)
- 9th Annual Women in Leadership Conference, Yale University, February 2017 (invited panel member)
- "The Search for Planet Nine", a publication for the Hartford Courant News in Education series, *Science Matters!*, January 2017 (article)
- LAMAT REU Program, UC Santa Cruz, July 2016 (talk)
- "Reading Scientific Literature", LAMAT REU Program, UC Santa Cruz, June 2016 (workshop)
- Public Observing Night, University of St. Thomas Observatory, March 2013 (talk & public observing)
- Minnesota Optical Society Meeting, March 2013 (talk)

Professional Activities & Service

Reviews

- Referee for Nature Astronomy, AJ, ApJ, ApJL, PSJ, A&A, MNRAS, PASP
- Proposal reviewer, NSF
- Proposal reviewer, NASA
- External reviewer, Canada-France-Hawaii Telescope
- External reviewer, OPTICON Telescope Transnational Access

Organizing Committees

- Committee member, Division of Dynamical Astronomy Committee — 2021 –
- Organizer, Princeton Planetary Dynamics Reading Group — 2020 –
- Scientific Organizing Committee Member, Division of Dynamical Astronomy 53rd Annual Meeting — 2022
- Scientific Organizing Committee Member, Emerging Researchers in Exoplanet Science (ERES) Conference III (Yale), V (Cornell) and VI (virtual) — 2017, 2019, 2021
- Organizing committee, UCSC astronomy prospective student visit — 2015

Diversity & Inclusion Involvement

- Co-organizer, Seminar Series on Equity, Diversity and Inclusion for the Departments of Physics and Astrophysics at Princeton — 2020 – 2021
- Committee member, Improving equity and inclusion in graduate admissions at the Department of Astrophysics at Princeton — 2020
- Organizer, Panel Discussion at Emerging Researchers in Exoplanet Science V: "Diversity & Inclusion in Astronomy" — 2019

Professional Affiliations & Mentorship

- Member, American Astronomical Society
- Member, Division of Dynamical Astronomy of the AAS
- Mentor, Goldwater Scholar Community Mentorship Program 2021 –
- Mentor, DDA Mentorship Program 2021 –
- Mentor, Princeton Astrophysics Mentorship Program 2021 –

Selected Outreach

- Yale Open Labs (http://theopenlabs.org) 2016 – 2018
  - Committee chair for Science Café Talk Series 2017 – 2018
  - Executive board member 2016 – 2017
- Organizer of Yale Young Global Scholars Program visits to the Astro. Department (http://globalscholars.yale.edu) 2017, 2018
- Public Night Volunteer, Lick Observatory Summer 2016
- Astronomy Public Night Leader, UST Observatory 2012 – 2015

Selected Media Coverage

- **Tilted planets** (Millholland & Laughlin 2019) featured in Scientific American, Sky & Telescope, Popular Science, Science Daily, Live Science, Space.com, Yale News.
- **Intra-system uniformity** (Millholland et al. 2017) featured in AAS Nova, Nature Research Highlights.
- **Machine learning detection of hot Jupiters** (Millholland & Laughlin 2017b) featured in National Geographic, Sky & Telescope, FOX 61 Connecticut News (television), University of St. Thomas News, Yale News.
- **Featured subject** for University of St. Thomas television and online advertisements