Elizabeth P. Hicks

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Dr. Elizabeth P. Hicks is a research scientist and the founder of Epsilon Delta Labs, a research lab focusing on interdisciplinary research. She specializes in interdisciplinary research at the boundary between astrophysics and fluid dynamics, studying problems where simulations of pure fluid phenomena can inform astrophysical research. In her research, Dr. Hicks has used both theoretical methods and large-scale numerical simulations. Dr. Hicks also loves science+art collaboration. In particular, she and other member of Epsilon Delta Labs created an immersive turbulence experience, "Far From Equilibrium", which was performed in Chicago in the summer of 2016.

Research Interests

Fluid dynamics, combustion, turbulence, hydrodynamic instabilities, transition to turbulence, Type Ia supernovae, advection-diffusion-reaction (ADR) systems, atmospheric physics, climate physics, large-scale numerical simulations, numerical methods, time series analysis, dynamical systems, coherent structures, plasma astrophysics, fusion, dynamos, the Sun, inertial particle dynamics, planetary physics

Education

University of Chicago, Chicago, IL
Ph.D., Astronomy & Astrophysics – August 2011
Thesis: Rayleigh-Taylor unstable, premixed flames: the transition to turbulence
(adviser: Robert Rosner)
M.S., Astronomy & Astrophysics – 2007

Columbia University, New York, NY
B.A., Astrophysics – May 2005

Professional and Research Experience (since 2011)

Epsilon Delta Labs, Evanston, IL
Research Scientist – September 2014 - present

- Rayleigh-Taylor Unstable Flames: Connecting Local and Global Properties
(September 2014 - present)

  The overarching goal of this research project is to understand how the Rayleigh-Taylor instability, self-generated turbulence, and burning set the global flame speed and flame width of Rayleigh-Taylor unstable flames. I've shown that the flame speed is typically

higher than the Rayleigh-Taylor flame speed model predicts, and that RT unstable flames are thinned and then thickened as the strength of the RT instability increases. I continue to investigate these two surprising findings by measuring local properties of the flame structure and then using these local measurements to better understand the global flame behavior. An understanding of how the global flame speed is set should lead to more accurate subgrid models for full star Type Ia simulations. An investigation of the flame width should shed further light on the trigger for Type Ia explosions. In addition, the methods and ideas developed for this project could be useful for efficient aviation engine design, and to the general study of turbulent combustion, fluid instabilities, and the ablative RT instability, which is of key importance in laser-driven fusion experiments. This project currently uses ACCESS resources Stampede3, Ranch, and Expanse, the open source spectral element code Nek5000, and the visualization tool VisIt.

- Rayleigh-Taylor Unstable Flames: The Effect of Two-mode Coupling
  (February 2022 - June 2024)

  Emory University undergraduate student Mingxuan Liu and I explored how adding a reaction to a Rayleigh-Taylor unstable interface affects the way that two short wavelength modes couple to generate longer wavelength modes. Using simulations, we identified five distinct flame growth solution types. Depending on the greatest common divisor of the wavenumbers of the two modes, the flame may stall, develop coherent pulsations, or even become a metastable traveling wave. We also compared our results with two-mode coupling in ablative and classical Rayleigh-Taylor and showed that all three systems may follow the same mode coupling dynamics.

Northwestern University, Evanston, IL
CIERA Fellowship – September 2011 - August 2014

- Rayleigh-Taylor unstable flames (September 2011 - August 2014)
  – An investigation of the impact of self-generated turbulence on Rayleigh-Taylor unstable flames.

- Particle dyamics with A. Motter. (September 2011 - August 2012)
  – An investigation of particle aggregation by vortex mergers.

Science+Art Collaboration

- *Solar Dreams* (current project)
  – This short movie takes a journey through the mind of a solar physicist using modern dance and NASA solar footage. A collaboration with choreographer Megan Rhyme and videographer Steve Tarzia.

- *Far From Equilibrium: Curiosity, Creativity, Uncertainty*
  – A collaboration with choreographer Megan Rhyme, composer Roger Zare and the Far From Equilibrium Collaboration. This project is an extends "Far From Equilibrium: A Dance about Turbulence" to include turbulence-inspired music and an interactive

research environment created by researchers from physics, engineering, dance, journalism, and music. It was performed in the summer of 2016 at Links Hall (a performance venue in Chicago), and as part of Chicago's Night Out in the Parks Program.

- *Far From Equilibrium: A Dance about Turbulence*
  – A collaboration with choreographer Megan Rhyme. This project explored the characteristics of turbulence using modern dance. It premiered at the Museum of Science and Industry (MSI) in Chicago on Oct. 17, 2015.

Large-Scale Computing Allocations and Awards

Advanced Cyberinfrastructure Coordination Ecosystem: Services & Support (ACCESS)

"Rayleigh-Taylor Unstable Flames: Connecting Local and Global Properties"
- PI: E. Hicks
- March 2024: DISCOVER supplement (750,000 credits)
- December 2023: DISCOVER allocation (750,000 credits)

"Undergraduate Research: Exploring Rayleigh-Taylor Unstable Flames using ACCESS"
- PI: E. Hicks, student: Mingxuan Liu
- January 2023: EXPLORE allocation (300,000 credits)

Extreme Science and Engineering Discovery Environment (XSEDE)

Research Grant
- June 2022, PI: E. Hicks
- "Rayleigh-Taylor Unstable Flames: Connecting Local and Global Properties"
- Stampede2: 54,682 node hours; Expanse: 143,206 core hours, Ranch: 178.1 TB

Educational Grant
- January 2022, PI: E. Hicks, student: Mingxuan Liu
- "EMPOWER: Exploring Rayleigh-Taylor Unstable Flames using XSEDE"
- Stampede2: 800 node hours; Expanse: 25,000 core hours, Ranch: 2 TB

Research Grant
- March 2021, PI: E. Hicks
- "Rayleigh-Taylor Unstable Flames: Connecting Local and Global Properties"
- Stampede2: 38,282 node hours; Expanse: 69,000 core hours, Ranch: 87 TB

Expanse Early User Period
- September 2020, PI: E. Hicks
- Initial grant: 19,100 core hours; Additional time granted: 2,650,000 core hours

Research Grant
- March 2020, PI: E. Hicks
- "Rayleigh-Taylor Unstable Flames: Connecting Local and Global Properties"
- Stampede2: 17,307 node hours; Comet: 45,318 core hours, Ranch: 56.6 TB

Research Grant
- September 2018, PI: E. Hicks
- "Rayleigh-Taylor Unstable Flames: Connecting Local and Global Properties"
- Stampede2: 15,899 node hours; Comet: 39,214 core hours; Ranch: 51 TB

Research Grant
– July 2017, PI: E. Hicks
– "Rayleigh-Taylor Unstable Flames: Connecting Local and Global Properties"
– superMIC: 201,280 core hours; Comet: 27,481 core hours; Ranch: 51 TB
Startup Award (100,000 hours) – January 2016, PI: E. Hicks

Argonne Leadership Computing Facility (Argonne National Labs)
Director's Discretionary Allocation for Mira (600,000 hours) – August 2015, PI: E. Hicks
Director's Discretionary Allocation for Mira (1,925,000 hours) – Jan. 2015, PI: E. Hicks
Director's Discretionary Allocation for Mira (1,000,000 hours) – June 2014, PI: E. Hicks
Director's Discretionary Allocation for Mira (5,000,000 hours) – June 2013, PI: E. Hicks

National Energy Research Scientific Computing Center (NERSC)
(Lawrence Berkeley National Laboratory)
ERCAP 2015 (150,000 hours)– PI: E. Hicks
ERCAP 2014 (225,000 hours)– PI: E. Hicks
ERCAP 2013 (200,000 hours)– PI: E. Hicks
ERCAP 2012 (200,000 hours)– PI: E. Hicks
ERCAP 2011 (100,000 hours)– PI: R. Rosner
Supplemental Allocation Award 2011 (50,000 hours) – PI: R. Rosner
Startup Allocation 2011 (50,000 hours)– PI: R. Rosner
Startup Allocation 2010 (15,000 hours)– PI: R. Rosner

QUEST (Northwestern University)
New Project Award (180,000 hours) – January 2014, PI: E. Hicks
Research Award (632,600 hours) – July 2013, PI: E. Hicks
Research Award (450,000 hours) – January 2012, PI: E. Hicks

Publications

Mingxuan Liu and Elizabeth P. Hicks, *Rayleigh-Taylor Unstable Flames: the Effect of Two-Mode Coupling*, 2024, *Physical Review Fluids*, Volume 9, Issue 11, 113203, November 2024, `https://doi.org/10.1103/PhysRevFluids.9.113203`.

E. P. Hicks, *Rayleigh–Taylor Unstable Flames at Higher Reynolds Number*, 2019, *Monthly Notices of the Royal Astronomical Society*, Volume 489, Issue 1, October 2019, pages 36–51, `https://doi.org/10.1093/mnras/stz2080`.

E. P. Hicks, *Rayleigh-Taylor Unstable Flames – Fast or Faster?*, 2015, *The Astrophysical Journal*, 803, 72, `https://doi.org/10.1088/0004-637X/803/2/72`.

E. P. Hicks, *A Shear Instability Mechanism for the Pulsations of Rayleigh–Taylor Unstable Model Flames*, 2014, *Journal of Fluid Mechanics*, 748, 618-640, `https://doi.org/10.1017/jfm.2014.198`.

E. P. Hicks and R. Rosner, *Gravitationally Unstable Flames: Rayleigh-Taylor Stretching Versus Turbulent Wrinkling*, 2013, *The Astrophysical Journal*, 771, 135 https://doi.org/10.1088/0004-637X/771/2/135.

Elizabeth Hicks and Robert Rosner, *The effects of burning on the development of 2D turbulence*, 2010, *Physica Scripta*, Vol. 2010, T142, 014046.

Code and Data Releases

Mingxuan Liu and Elizabeth P. Hicks, *Rayleigh-Taylor Unstable Flames: the Effect of Two-Mode Coupling (Code and Data Release)*, September 16, 2024, *Zenodo*, https://doi.org/10.5281/zenodo.13750992.

Presentations/Posters

Rayleigh-Taylor Unstable Flames: A Transition to Distributed Burning? 77th Annual Meeting of the APS Division of Fluid Dynamics, November 2024, Salt Like City, Utah. (Conference Presentation)

Rayleigh-Taylor Unstable Flames: Thick and Thin 76th Annual Meeting of the APS Division of Fluid Dynamics, November 2023, Washington D.C. (Conference Presentation)

Rayleigh-Taylor Unstable Flames. Rosnerfest, September 7-8, 2017, Chicago, IL. (Conference Presentation)

Rayleigh-Taylor unstable flames: connecting local and global properties. Turbulent Mixing and Beyond (TMB) 2017, August 2017, Trieste, Italy. (Conference Presentation)

Rayleigh-Taylor Unstable Flames: Speed and Structure. 25th ICDERS Conference, August 2015, Leeds, UK. (Conference Presentation)

Rayleigh-Taylor unstable flames: instability, turbulence and burning. Turbulent Mixing and Beyond (TMB) 2014, August 2014, Trieste, Italy. (Conference Presentation)

Rayleigh-Taylor Unstable Flames – Fast or Faster? Computations in Science Seminars, April 2nd, 2014, University of Chicago, Chicago, IL (Invited Talk)

Rayleigh-Taylor Unstable Flames – Fast or Faster? 66th Annual Meeting of the APS Division of Fluid Dynamics, November 2013, Pittsburgh, PA (Conference Presentation)

Comparing a Rayleigh-Taylor Unstable Flame to a Circular Cylinder. 64th Annual Meeting of the APS Division of Fluid Dynamics, November 2011, Baltimore, MD (Conference Presentation)

The Transition to Turbulence of Rayleigh-Taylor Unstable Flames. American Astronomical

Society, AAS Meeting 217, January 2010, Seattle, WA (Conference Presentation)

Rayleigh-Taylor unstable, premixed flames: the transition to turbulence. 63rd Annual Meeting of the APS Division of Fluid Dynamics, November 2010, Long Beach, CA (Conference Presentation)

Gravitationally-unstable premixed flames: the transition to chaos. Dynamics Days 2010: International Conference on Chaos and Nonlinear Dynamics, January 2010, Evanston, IL, USA. (Poster)

The effects of burning on the development of 2D turbulence. 2nd International Conference on Turbulent Mixing and Beyond (TMB), August 2009, Trieste, Italy. (Poster)

Grants (Education and Outreach)

XSEDE EMPOWER (student: Mingxuan Liu) Spring 2022
Americal Physical Society (APS) Outreach Mini-Grant for "Far From Equilibrium" 2016

Research Mentoring

Mingxuan Liu, undergraduate, Emory University (XSEDE EMPOWER) 2/2022–6/2024
- conference presentation at APS DFD 2023
- publication accepted to PRFluids, November 2024
- currently a graduate student at University of Michigan (Astronomy)

Rachel McEnroe, undergraduate, University of Chicago (PI: Wendy Zhang) 1/2014–1/2015
- Ph.D. in Mathematics, Northwestern University (2021)

Teaching

Teaching Assistant – *Stellar Astronomy (PHSC 119)* Winter 2009
Teaching Assistant – *Global Warming (PHSC 134)* Fall 2009
Teaching Assistant – *General Physics 3 (PHYS 123)* Spring 2008

Honors

Northwestern Visualization Scientific Images Contest, Honorable Mention 2014
CIERA fellowship 9/2011–8/2014
Doolittle-Harrison Fellowship 2010
McCormick Graduate Fellowship 8/2005–6/2007
Graduation *magna cum laude* (top 15% of class), Columbia University 2005
I. I. Rabi scholar, Columbia University 2001-2005

Activities

AWIS Chicago: Mentoring Circle Leader Summer 2023, 2024
Fluid Fridays reading group: founder and contributor Spring 2009–Fall 2015
Condensed Matters Journal Club: participant Fall 2010–Summer 2011
AstroGreen Committee: member Fall 2008– Spring 2009
WOPAT: Treasurer Spring 2006– Spring 2008

Outreach

Talk for Citizens' Greener Evanston: "The Dynamics of Resilience" April 24, 2019
Collaboration with Megan Rhyme and Evanston Lake Dance
– turbulence dance at Global Water Dances on Evanston lakefront June 23, 2017
Epsilon Delta Labs table at the Chicago March for Science April 22, 2017
Collaboration with Megan Rhyme and Evanston Lake Dance
– dance workshop for Evanston high school students on Non-Newtonian fluids Spring 2017
Far From Equilibrium
– extended performance at Links Hall and Chicago's NOITP series Summer 2016
Far From Equilibrium (original version) at the MSI October 17, 2015
Science/Art Fair at the Evanston Public Library May 30, 2015
Harold Washington Library Outreach Event February 20, 2015
Museum of Science and Industry "Science Cafe" October 25, 2014
Evanston Township High School Visualization Outreach Event October 15, 2014
"Music & Astronomy", Ravinia July 31, 2012

Other Experiences

CoCoRaHS (Community Collaborative Rain, Hail & Snow Network) observer 2020-present
NASA TOPS (Transform to Open Science) Course Certificate September 2024