

# BHANU KUMAR

Email: [bhkumar@umich.edu](mailto:bhkumar@umich.edu)  
Web: <https://bhanukumar314.github.io>  
Citizenship: USA

Department of Mathematics  
University of Michigan  
530 Church Street  
Ann Arbor, MI 48109

## RESEARCH INTERESTS

Development and adaptation of theoretical & computational tools from Hamiltonian dynamical systems, including resonance, chaos, normally hyperbolic invariant manifolds, parameterization methods, and symplectic geometry, for spacecraft astrodynamics and natural celestial mechanics. Applications of these tools to dynamical analysis of real celestial systems of interest for future space missions and astronomy.

## EDUCATION

- Ph.D. Mathematics**, Georgia Institute of Technology 8/2022  
Dissertation title: *New Numerical and Computational Methods Leveraging Dynamical Systems Theory for Multi-Body Astrodynamics*  
Research Advisor: Prof. Rafael de la Llave
- M.S. Aerospace Engineering**, Georgia Institute of Technology 12/2021
- B.S. Applied Mathematics**, Georgia Institute of Technology 5/2015
- B.S. Aerospace Engineering**, Georgia Institute of Technology 5/2015

## PROFESSIONAL EXPERIENCE

*Department of Mathematics, University of Michigan, USA*

- James Van Loo Postdoctoral Assistant Professor** 1/2025 - present
- Continuing research on celestial/Hamiltonian dynamics and related analytical & numerical methods. Co-mentoring Ph.D. student on orbit computation. Teaching undergraduate students 1 class/semester.

*Institute for Mathematics, Universität Heidelberg, Germany*

- Postdoctoral Researcher, Research Station Geometry + Dynamics** 5/2024 - 12/2024
- Applied novel methods from symplectic geometry to study periodic orbit bifurcations near the Moon. Computed previously-unknown orbit networks & confirmed a 57-year old conjecture of R. Broucke.

*NASA Jet Propulsion Laboratory, California Institute of Technology, USA*

- NSF Postdoctoral Research Fellow, Mission Design & Navigation** 10/2022 - 4/2024
- Investigated resonant dynamics for space mission design in cislunar and Jovian systems. Discovered previously-unknown secondary resonance phenomena and developed related fast numerical methods. Supported by competitive proposal funded through NSF individual fellowship award DMS-2202994.

*School of Mathematics, Georgia Institute of Technology, USA and*

*NASA Jet Propulsion Laboratory, California Institute of Technology, USA*

- NASA Space Tech Research Fellow (NSTRF) & Graduate Research Assistant** 8/2018 - 8/2022
- Awarded Ph.D. fellowship based on competitive proposal. Included funds for research stays at JPL. Developed faster & more accurate algorithms for computing invariant tori, stable/unstable invariant manifolds, and natural heteroclinic trajectories between them in perturbed celestial environments

## ***NASA Jet Propulsion Laboratory, California Institute of Technology, USA***

### **Engineering Co-op Summer Student, Radio Science Systems Group**

6/2014 - 8/2017

- Worked on various technical and research tasks, including conceptual development of a novel method for interplanetary lander trajectory reconstruction using only Doppler tracking data.

## **GRANTS, HONORS, AND AWARDS**

- American Mathematical Society-Simons Foundation Travel Grant. 2025 - 2027  
Research title: *Geometry and Dynamics for Modern Needs in Spaceflight Mechanics*.  
Total Award: \$5,000 to awardee, \$1,000 to employing institution.
- Seal of Excellence (score 88.4/100) for Horizon Europe MSCA Postdoctoral Fellowship 2024  
proposal 101155681 - *Hyperbolic & resonant dynamics in accurate space systems*
- Top Graduate Student Award of the Georgia Tech School of Mathematics 2022
- NSF Mathematical Sciences Postdoctoral Research Fellowship. Grant DMS-2202994. 2022 - 2025  
Project title: *New dynamical systems-based mathematical and computational tools for applications to astrodynamics*. Total Award: \$150,000.
- Horizon 2020 MSCA-COFUND MathInGreaterParis postdoctoral fellowship (declined 2022  
in favor of NSF fellowship). Total Award: €111,600.
- NASA Space Technology Research Fellowship (NSTRF18). Grant 80NSSC18K1143. 2018 - 2022  
Project title: *Leveraging Dynamical Instabilities to Design Efficient Mission Trajectories*. Total Award: \$300,000.
- Georgia Tech President's Fellowship for Doctoral Studies. Total Award: \$22,000. 2015 - 2019
- Selected by NASA as a sponsored student delegate to the International Astronautical Congress 2019
- Outstanding Undergraduate Math Major Award of the Georgia Tech School of Mathematics 2015

## **TEACHING EXPERIENCE AND AWARDS**

### **James Van Loo Postdoctoral Assistant Professor, University of Michigan**

Math 115, Calculus I (22 students)

Fall 2025

Math 215, Multivariable and Vector Calculus (~100 students)

Winter 2025

### **Thank-A-Teacher Award, Georgia Institute of Technology**

April 2019

MATH 3770, Statistics and Applications, for unofficial volunteer tutoring of a former student

### **Graduate Teaching Assistant, Georgia Institute of Technology**

MATH 2552 Differential Equations

Fall 2015, Spring & Fall 2016, Spring 2017, Spring 2018

MATH 1554 Linear Algebra

Fall 2017

## **PUBLICATIONS** (most significant 5 marked with ★)

### **MANUSCRIPTS UNDER REVISION OR REVIEW**

1. ★ **B. Kumar\***, A. Rawat\*, A.J. Rosengren, and S.D. Ross. "Cislunar Resonant Transport and Heteroclinic Pathways: From 3:1 to 2:1 to L1," accepted (pending minor revisions) for *Advances in Space Research*. arXiv: 2509.12675 (\* indicates equal contribution)
2. **B. Kumar**. "Multi-shooting parameterization methods for invariant manifolds and heteroclinics of 2 DOF Hamiltonian Poincaré maps, with applications to celestial resonant dynamics," under review for *Journal of Nonlinear Science*. arXiv: 2509.03655

## JOURNAL ARTICLES

1. A. Rawat, **B. Kumar**, A.J. Rosengren, and S.D. Ross (2025). “Cislunar Mean-Motion Resonances: Definitions, Widths, and Comparisons with Resonant Satellites,” *Journal of Guidance, Control, and Dynamics*, accepted (in press). arXiv:2505.10138
2. ★ **B. Kumar**, R.L. Anderson, and R. de la Llave (2025). “Rapid GPU-Assisted Search & Parameterization-Based Refinement and Continuation of Connections between Tori in Periodically Perturbed Planar Circular Restricted 3-Body Problems,” *SIAM Journal on Applied Dynamical Systems* 24:1, 219-258. <https://doi.org/10.1137/23M1608057>.
3. **B. Kumar**, R.L. Anderson, and R. de la Llave (2023). “Transfers between Jupiter-Ganymede and Jupiter-Europa Resonant Tori In a Concentric Circular Restricted 4-Body Model,” *Acta Astronautica* 211(2023): 76–87. <https://doi.org/10.1016/j.actaastro.2023.05.040>.
4. ★ **B. Kumar**, R.L. Anderson, and R. de la Llave (2022). “Rapid and Accurate Methods for Computing Whiskered Tori and Their Manifolds in Periodically Perturbed Planar Circular Restricted 3-Body Problems,” *Celest Mech Dyn Astron* 134:3. <https://doi.org/10.1007/s10569-021-10057-1>.
5. **B. Kumar**, R.L. Anderson, and R. de la Llave (2021). “High-Order Resonant Orbit Manifold Expansions For Mission Design In the Planar Circular Restricted 3-Body Problem,” *Commun Nonlinear Sci Numer Simulat* 97(2021): 105691. <https://doi.org/10.1016/j.cnsns.2021.105691>.

## CONFERENCE PAPERS

1. **B. Kumar** (2025). “Analysis of Unstable Resonant Orbits for Saturn Tour Design: Between Titan and Rhea,” Proceedings of the 76th International Astronautical Congress, Sydney, Australia, September 2025. Paper IAC–25–C1.9.6.
2. A.J. Rosengren, A. Rawat, **B. Kumar**, and S.D. Ross (2025). “The Astrodynamics of Lunar Mean-Motion Resonances: From the Perturbed Formulation to the Restricted Problem,” Proceedings of the 76th International Astronautical Congress, Sydney, Australia, Sept. 2025. Paper IAC–25–C1.9.1.
3. ★ **B. Kumar** and A. Moreno (2025). “Networks of Periodic Orbits in the Earth-Moon System Through a Regularized and Symplectic Lens,” Proceedings of the 2025 AAS/AIAA Astrodynamics Specialist Conference, Boston, MA, USA, August 2025. Paper AAS 25-677.
4. A. Rawat, **B. Kumar**, A.J. Rosengren, and S.D. Ross (2025). “Regions of Influence of Exterior Mean-Motion Resonances in the Earth–Moon System: Bifurcations, Separatrices, and Heteroclinic Pathways,” Proceedings of the 2025 AAS/AIAA Astrodynamics Specialist Conference, Boston, MA, USA, August 2025. Paper AAS 25-569.
5. **B. Kumar**, A. Rawat, A.J. Rosengren, and S.D. Ross (2024). “Investigation of Interior Mean Motion Resonances and Heteroclinic Connections in the Earth-Moon System,” Proceedings of the 75rd International Astronautical Congress, Milan, Italy, October 2024. Paper IAC–24–C1.9.5.
6. **B. Kumar** and R.L. Anderson (2024). “A Survey of Oberon Mean Motion Resonant Unstable Orbit Properties and Connections for Uranian Tours,” Proceedings of the 2024 AAS/AIAA Astrodynamics Specialist Conference, Broomfield, CO, USA, August 2024. Paper AAS 24-288.
7. A. Rawat, **B. Kumar**, S.D. Ross, and A.J. Rosengren (2024). “Resonance Widths, Chaotic Zones, and Transport in Cislunar Space,” Proceedings of the 2024 AAS/AIAA Astrodynamics Specialist Conference, Broomfield, CO, USA, August 2024. Paper AAS 24-368.

8. ★ **B. Kumar**, R.L. Anderson, and R. de la Llave (2023). “4th Body-Induced Secondary Resonance Overlapping Inside Unstable Resonant Orbit Families: a Jupiter-Ganymede 4:3 + Europa Case Study,” Proceedings of the 2023 AAS/AIAA Astrodynamics Specialist Conference, Big Sky, MT, USA, August 2023. Paper AAS 23-397.
9. **B. Kumar**, R.L. Anderson, and R. de la Llave (2022). “Transfers between Jupiter-Ganymede and Jupiter-Europa Resonant Tori In a Concentric Circular Restricted 4-Body Model,” Proceedings of the 73rd International Astronautical Congress, Paris, France, September 2022. Paper IAC-22-C1.8.4. (basis of above journal paper #3)
10. **B. Kumar**, R.L. Anderson, R. de la Llave, and B. Gunter (2021). “Computation and Analysis of Jupiter-Europa and Jupiter-Ganymede Resonant Orbits in the Planar Concentric Circular Restricted 4-Body Problem,” Proceedings of the 2021 AAS/AIAA Astrodynamics Specialist Conference, Virtual, August 2021. Paper AAS 21-651.
11. **B. Kumar**, R.L. Anderson, and R. de la Llave (2021). “Using GPUs and the Parameterization Method for Rapid Search and Refinement of Connections between Tori in Periodically Perturbed Planar Circular Restricted 3-Body Problems,” Proceedings of the 2021 AAS/AIAA Space Flight Mechanics Meeting, Virtual, February 2021. Paper AAS 21-349.
12. **B. Kumar**, R.L. Anderson, and R. de la Llave (2020). “Rapid and Accurate Computation of Invariant Tori, Manifolds, and Connections Near Mean Motion Resonances in Periodically Perturbed Planar Circular Restricted 3-Body Problem Models,” Proceedings of the 2020 AAS/AIAA Astrodynamics Specialist Conference, Virtual, August 2020. Paper AAS 20-694.
13. **B. Kumar**, R.L. Anderson, and R. de la Llave (2019). “High-Order Resonant Orbit Manifold Expansions For Mission Design In the Planar Circular Restricted 3-Body Problem,” Proceedings of the 70th International Astronautical Congress, Washington, D.C., USA, October 2019. Paper IAC-19-C1.4.9. (basis of above journal paper #5)

## **PRESENTATIONS**

### **CONFERENCE TALKS AND ABSTRACTS**

1. “Secondary Resonance Overlap Inside Unstable Resonant Spacecraft Orbit Families in Outer Planet Moon Systems,” SIAM Conference on Applications of Dynamical Systems (DS25), Denver, CO, May 2025.
2. “4th Body-Induced Secondary Resonance Overlap Inside Unstable Resonant Orbit Families: a Jupiter-Ganymede 4:3 + Europa Case Study,” 6th International Workshop on Key Topics in Orbit Propagation Applied to Space Situational Awareness (KePASSA), Arras, France, June 2024.
3. “Europa-induced Overlapping of Secondary Resonances in the 4:3 Jupiter-Ganymede Unstable Resonant Orbit Family,” Complex Planetary Systems II – Kavli-IAU Symposium 382, Namur, Belgium, July 2023.
4. “Europa-induced Overlapping of Secondary Resonances in the 4:3 Jupiter-Ganymede Unstable Resonant Orbit Family,” 13th International Conference on Nonlinear Mathematics and Physics “NoLineal”, Barcelona, Spain, June 2023.
5. “Europa-induced Overlapping of Secondary Resonances in the 4:3 Jupiter-Ganymede Unstable Resonant Orbit Family,” 13th AIMS Conference on Dynamical Systems, Differential Equations and Applications, Wilmington, NC, June 2023.

6. “Jupiter-Ganymede and Jupiter-Europa Unstable Resonant Tori In a Restricted 4-Body Model: Analysis and a Search for Transfers,” SIAM Conference on Applications of Dynamical Systems (DS23), Portland, OR, May 2023.
7. “GPU-assisted search for low-cost transfers between whiskered tori, with applications to resonance transfers in a restricted 4-body model,” 5th International Workshop on Key Topics in Orbit Propagation Applied to Space Situational Awareness (KePASSA), Logroño, Spain, June 2022.
8. “GPU-assisted search for Jupiter-Ganymede to Jupiter-Europa resonance transfers in a restricted 4-body model,” Workshop on Theory, Models and Simulations in Celestial Mechanics, Pisa, Italy, June 2022.
9. “Dynamical systems-based methods for multi-body space mission design,” Midwest Dynamical Systems Early Career Conference, University of Notre Dame, South Bend, IN, May 2022.
10. “Tori and Manifolds of Jupiter-Europa and Jupiter-Ganymede Resonances in the Planar Concentric Circular Restricted 4-Body Problem,” IAU Symposium 364 on Multi-scale (time and mass) Dynamics of Space Objects, October 2021.
11. “Rapid and Accurate Computation of Invariant Tori, Manifolds, and Connections Near Mean Motion Resonances in Periodically Perturbed PCRTBP Models,” SIAM Conference on Applications of Dynamical Systems (DS21), May 2021.
12. “Using GPUs and the Parameterization Method for Rapid Search and Refinement of Connections between Tori in Periodically Perturbed Planar Circular Restricted 3-Body Problems,” AMS Spring Southeastern Sectional Meeting, March 2021.
13. “Rapid and Accurate Computation of Invariant Tori and Manifolds Near Mean Motion Resonances in Periodically Perturbed PCRTBP Models,” AMS Spring Southeastern Sectional Meeting, March 2021.
14. “Using GPUs and the Parameterization Method for Rapid Search and Refinement of Connections between Tori in Periodically Perturbed Planar Circular Restricted 3-Body Problems,” Georgia Tech Exploration and Origins Colloquium, February 2021.

## INVITED TALKS AND SEMINARS

1. “Mean motion resonant phenomena, orbits, and transfers in planet-moon systems,” invited talk in Applied Mathematics Seminar Series, University of Sydney, October 2025.
2. “Mean motion resonant phenomena, orbits, and transfers in planet-moon systems,” invited talk in UB-UPC Dynamical Systems Seminar Series, Universitat Politècnica de Catalunya, June 2025.
3. “Cislunar Space: Resonances, Orbit Networks, and More,” invited talk in Mission Analysis Knowledge Dissemination Seminar Series, European Space Operations Centre, June 2025.
4. “The Symplectic Geometry of the Restricted Three-Body Problem: Orbit Network in the Earth-Moon System,” invited talk in Mission Analysis Knowledge Dissemination Seminar Series, European Space Operations Centre (remote), January 2025.
5. “Resonant Orbits and Transfers in Planet-Moon Systems (Plus a Guest Appearance by Symplectic Geometry),” invited talk in Space Trajectory Analysis Group Seminar Series, Surrey Space Centre, December 2024.
6. “A Survey of Oberon Unstable Resonant Orbit Properties and Connections for Uranian Tours...plus a Short Guest Appearance by Symplectic Geometry,” in JPL MDNav Visiting Researcher Seminar, Jet Propulsion Laboratory, California Institute of Technology, September 2024.

7. “I Put a Resonance Inside Your Resonance So You Can Overlap While You Overlap: Why 4th-Body Effects are Important in Multi-Moon Systems,” invited talk in Mission Analysis Knowledge Dissemination Seminar Series, European Space Operations Centre, June 2024.
8. “4th Body-Induced Secondary Resonance Overlap Inside Normally Hyperbolic Invariant Manifolds in Planet-Moon Systems: a Jovian Case Study,” invited talk in Geometry and Dynamics Seminar, Heidelberg University, May 2024.
9. “Interior Mean Motion Resonances and Heteroclinic Connections in the Earth-Moon System,” in Hockney Seminar for Space Flight series, Jet Propulsion Laboratory, California Institute of Technology, April 2024.
10. “4th Body-Induced Secondary Resonance Overlap Inside Normally Hyperbolic Invariant Manifolds in Planet-Moon Systems: a Jovian Case Study,” invited talk in Applied Math Seminar, University of California, Irvine, February 2024.
11. “I Put a Resonance Inside Your Resonance So You Can Overlap While You Overlap: Why 4th-Body Effects are Important in Multi-Moon Systems,” in Hockney Seminar for Space Flight series, Jet Propulsion Laboratory, California Institute of Technology, August 2023.
12. “Jupiter-Ganymede and Jupiter-Europa Unstable Resonant Tori In a Restricted 4-Body Model: Analysis and a Search for Transfers,” invited talk in Astronomy and Dynamical Systems Seminar, Institute of Celestial Mechanics and Computation of Ephemerides, Paris Observatory, Sept. 2022.
13. “New Numerical and Computational Methods Leveraging Dynamical Systems Theory for Multi-Body Astrodynamics,” invited talk in Aerospace Robotics and Control Group Special Seminar, California Institute of Technology, December 2021.
14. “Rapid and Accurate Computation of Invariant Tori, Manifolds, and Connections Near Mean Motion Resonances in Periodically Perturbed Planar Circular RTBP Models,” invited talk in I-CELMech Seminar Series, University of Milan, November 2020.
15. “Rapid and Accurate Computation of Invariant Tori, Manifolds, and Connections Near Mean Motion Resonances in Periodically Perturbed Planar Circular RTBP Models,” invited talk in CDSNS Colloquium Series, Georgia Tech, July 2020.
16. “Computation and Usage of High-Order Resonant Orbit Manifold Expansions For Mission Design In the Planar Circular Restricted 3-Body Problem,” seminar at MSRI, Berkeley, CA, Dec. 2018.

## POSTERS

1. “Secondary Resonance Overlap Inside Unstable Mean Motion Resonant Orbit Families,” American Astronomical Society Division on Dynamical Astronomy Meeting, Atlanta, GA, May 2025.
2. “4th Body-Induced Secondary Resonance Overlap Inside Normally Hyperbolic Invariant Manifolds for Outer Planet Mission Design,” Midwest Dynamical Systems Conference, Evanston, IL, May 2025.
3. “4th body-induced secondary resonance overlap inside unstable resonant orbit families: a Ganymede 4:3 + Europa case study,” JPL Research Poster Conference, Pasadena, CA, November 2023.
4. “GPU-assisted search for Jupiter-Ganymede to Jupiter-Europa resonance transfers in a restricted 4-body model,” Global and Local Aspects in Dynamical Systems Conference, Barcelona, Spain, July 2022.
5. “Computation and Analysis of Invariant Tori Near Resonances in the Planar Elliptic Restricted 3-body Problem,” Georgia Tech Exploration and Origins Colloquium, Atlanta, GA, January 2020.

6. “Exploiting Geometric Structures at Resonances and Diffusion to Enable Rapid Tour Design,” Georgia Tech Exploration and Origins Colloquium, Atlanta, GA, March 2019.
7. “Accelerating Diffusion to Enable Rapid Tour Design,” JPL Research Poster Conference, Pasadena, CA, November 2018.

## **SERVICE AND PROFESSIONAL ACTIVITIES**

- Referee work for the journals *Celestial Mechanics and Dynamical Astronomy* (2 times); *SIAM Journal on Applied Dynamical Systems* (2 times); *Journal of Guidance, Control, and Dynamics*; *Physica D: Nonlinear Phenomena*; *Nonlinearity* (2 times); *Journal of the Astronautical Sciences*
- Developed “Chaos in Space” exhibit, including display materials and interactive computer orbit simulator activity, for public outreach to school children. Exhibited with success at the Pasadena Unified School District Science Fest (3/2024) and Compton Fest (8/2024)
- Co-organizer of the workshop “A Stellar Afternoon in Symplectic Dynamics” hosted at Universität Heidelberg, Germany, including speaker/attendee invitations and publicity 11/2024
- Session Chair for the Contributed Papers Session CP9 on Many Body Problems at the May 2023 SIAM Conference on Applications of Dynamical Systems (DS23) 5/2023
- Lead organizer of the Special Session on Celestial Mechanics and Applied Astrodynamics at the March 2021 AMS Spring Southeastern Sectional Meeting (12 invited speakers) 3/2021
- Program Associate in the semester *Hamiltonian systems, from topology to applications through analysis* held at the Mathematical Sciences Research Institute, Berkeley, CA Fall 2018
- Summer volunteer coach for the Georgia ARML state high school math team 5/2012-5/2017

## **TECHNICAL AND LANGUAGE SKILLS**

*Programming:* Julia (including CUDA.jl & OpenCL.jl for GPUs), MATLAB, C, Python, Bash scripting  
*Software:* Mission Analysis, Operations, & Navigation Toolkit Environment; LaTeX; Microsoft Office  
*Languages spoken:* English (native), French (proficient), Hindi (native, speaking only)