Jacob M. Graving

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Summary

Scientist and engineer with expertise in mathematical modeling, Bayesian inference, machine learning, and computer vision. I develop theory, methods, and software to understand complex systems, working with interdisciplinary teams to connect models with data. My research focuses on animal behavior, with broader applications in data science and AI. Across this work, I aim to turn computational insights into scientific discoveries.

Skills

- Design and implementation of probabilistic models and Bayesian inference pipelines for complex, uncertain data
- Development of custom deep learning models for behavior, vision, and sequences using PyTorch, and JAX
- Building scalable, reproducible pipelines for multimodal and high-dimensional data (ETL, analysis, visualization)
- Creating interpretable ML tools that support scientific discovery and real-world decision-making
- Leading and contributing to open-source software projects in Python; experienced with PyMC, NumPyro, Stan, scikit-learn, and more
- Strong communicator and collaborator across disciplines - biology, neuroscience, engineering, and data science

Experience

2020-present | Research Scientist

Advanced Research Technology Unit, Max Planck Institute of Animal Behavior

- Lead independent research at the interface of machine learning and behavioral science, developing general-purpose tools to measure and model animal behavior in both lab and field environments.
- Design and maintain scalable ETL pipelines for multimodal behavioral datasets, ensuring data integrity and reproducibility across experimental systems.
- Collaborate with interdisciplinary teams - including software engineers, neuroscientists, and field biologists - to build AI-driven tools for behavior analysis and experimental optimization.
- Apply Bayesian inference, causal modeling, and uncertainty quantification to large-scale time series and experimental data to generate interpretable, data-driven insights.
- Provide technical guidance and mentorship across collaborative projects, promoting reproducible science and statistical rigor.

2015-2020 | Doctoral Researcher

Department of Collective Behaviour, Max Planck Institute of Animal Behavior & University of Konstanz

- Developed computer vision and deep learning methods for measuring and modeling animal behavior, including DeepPoseKit for animal pose estimation.
- Studied how sensory information and internal state shape the collective behavior of animal groups.

2013-2015 | Graduate Research Assistant

Department of Biological Sciences, Bowling Green State University

- Conducted research on homing and sensory navigation in nocturnal whip spiders.

2011-2013 | Undergraduate Research Assistant

Department of Biological Sciences, Bowling Green State University

- Studied navigation and spatial learning in whip spiders with Daniel Wiegmann, and the sensory basis of rheotaxis in fish with Sheryl Coombs (2013).

Education

2021 | Dr.rer.nat., Biology (0.0 'summa cum laude')

Max Planck Institute of Animal Behavior & University of Konstanz - Germany

International Max Planck Research School (IMPRS) · Supervisor: Iain Couzin

Thesis: Computer Vision and Deep Learning Methods for Measuring and Modeling Animal Behavior

2015 | M.Sc., Biology

Bowling Green State University - USA

Supervisor: Daniel Wiegmann; co-supervisor: Verner Bingman

Focus: Animal Behavior, Neuroscience

2013 | B.Sc., Biology

Bowling Green State University - USA

Recent & Selected Publications

Accepted

Foster, J.J., **Graving, J.M.**, Pfeiffer, K. (2026). High intensity alters spectral orientation in dancing honeybees. *Journal of Comparative Physiology A*. Accepted.

In Prep

Graving, J.M., Sayin, S., Costelloe, B.R., Goldshtein, A., and Foster, J.J. (in prep). Unwrapping circular statistics with Bayesian multilevel models.

- Introduces a novel Bayesian generalized linear model framework for circular data by incorporating the von Mises distribution.
- Jointly models mean direction and variance to improve interpretability of circular outcomes.
- Provides practical guidelines and implementations using Bayesian toolkits such as PyMC and Stan.

In Review

Marting, P.R., P. Prathibha, Koger, B., Rogers, S.R., **Graving, J.M.**, Smith, M.L. (in review). Morphogenesis, differentiation, and robust multi-scale organization of the honeybee nest revealed by a novel 4D atlas. *Current Biology*. In review.

- Developed autoregressive modeling methodology, software, statistical analysis, and visualizations of honeybee nest organization.

Bath, D.E., **Graving, J.M.**, Walter, T., Sridhar, V.H., Vizcaíno, J.P., Couzin, I.D. Collective detection and processing of distributed information by fish schools. In revision for *Current Biology*.

Code: github.com/jgraving/bayesian_beta_regression

- Led development of a Bayesian model to analyze collective information processing in fish schools.
- Modeled 3 billion behavioral observations across 400+ conditions using JAX and NumPyro.
- Revealed how distributed sensing shapes group-level responses to environmental signals.

2025

Sayin, S., Couzin-Fuchs, E., Petelski, I., Günzel, Y., Salahshour, M., Lee, C.-Y., **Graving, J.M.**, Li, L., Deussen, O., Sword, G.A., Couzin, I.D. (2025). The behavioral mechanisms governing collective motion in swarming locusts. *Science*, 387(6737), 995-1000. https://doi.org/10.1126/science.adq7832

Press: Science Perspective

- Led Bayesian modeling and statistical analysis of VR behavioral data from locusts.
- Identified and solved a key methodological flaw in prior work - confounding of group coordination with group size.
- Helped validate the core findings and strengthen the paper's quantitative rigor.

2023

Koger, B., Deshpande, A., Kerby, J.T., **Graving, J.M.**, Costelloe, B. R., Couzin, I.D. (2023). Quantifying the movement, behaviour and environmental context of group-living animals using drones and computer vision. *Journal of Animal Ecology*. doi:10.1111/1365-2656.13904

Press: Orange Hello Future

Code: github.com/benkoger/overhead-video-worked-examples

- Co-developed a computer vision pipeline combining drone footage and deep learning to extract 3D behavioral and environmental data from animal groups in natural settings.
- Integrated spatial context reconstruction with fine-scale movement tracking to support large-scale behavioral ecology studies.

2020

Li, L., Nagy, M., **Graving, J.M.**, Bak-Coleman, J., Guangming X., Couzin, I.D. (2020). Vortex phase matching as a strategy for schooling in robots and in fish. *Nature Communications*, 11, 5408. doi:10.1038/s41467-020-19086-0

Press: Physics World, SciShow (Hank Green)

- Analyzed high-resolution posture data of schooling fish to test energy-optimization strategies predicted by robotic models.
- Applied deep learning-based pose estimation and mechanistic modeling to quantify fluid-mediated interactions and coordinated motion patterns.

2019

Graving, J.M., Chae, D., Naik, H., Li, L., Koger, B., Costelloe, B.R., Couzin, I.D. (2019). DeepPoseKit, a software toolkit for fast and robust animal pose estimation using deep learning. *eLife*, 8. doi:10.7554/elife.47994

Press: Quanta Magazine, Nature Methods, Nature

Code: github.com/jgraving/deepposekit

- Created a general-purpose, few-shot deep learning framework for high-speed, high-accuracy animal pose tracking in Python/TensorFlow.
- Supervised development of key components including a custom annotation GUI and augmentation tools for low-data regimes.

2018

Alarcón-Nieto, G., **Graving, J.M.**, Klarevas-Irby, J.A., Maldonado-Chaparro, A.A., Mueller, I., Farine, D.R. (2018). An automated barcode tracking system for behavioural studies in birds. *Methods in Ecology and Evolution*, 9(6), 1536-1547. doi:10.1111/2041-210x.13005

2017

Graving, J.M., Bingman, V.P., Hebets, E.A., Wiegmann, D.D. (2017). Development of site fidelity in the nocturnal amblypygid, Phrynus marginemaculatus. *Journal of Comparative Physiology A*, 203(5), 313-328. doi:10.1007/s00359-017-1169-5

Bingman, V.P., **Graving, J.M.**, Hebets, E.A., Wiegmann, D.D. (2017). Importance of the antenniform legs, but not vision, for homing by the neotropical whip spider Paraphrynus laevifrons. *Journal of Experimental Biology*, 220(5), 885-890. doi:10.1242/jeb.149823

Press: Discover

2016

Wiegmann, D.D., Hebets, E.A., Gronenberg, W., **Graving, J.M.**, Bingman, V.P. (2016). Amblypygids: model organisms for the study of arthropod navigation mechanisms in complex environments. *Frontiers in Behavioral Neuroscience*, 10, 47. doi:10.3389/fnbeh.2016.00047

Teaching

2023 | Konstanz School of Collective Behavior

University of Konstanz

- Designed and led a workshop on "Probabilistic Machine Learning" for 30+ international PhD students, covering Bayesian inference, causal inference, and information theory in practice. https://www.exc.uni-konstanz.de/kscb/schedule-2023/

2022 | Deep Learning Workshop

Max Planck Institute of Animal Behavior

- Led an applied workshop introducing PyTorch and deep learning fundamentals to 15 researchers.

2019 | ASAB 2019 Summer Conference

University of Konstanz

- Gave an invited seminar on "Machine Learning in the Behavioral Sciences" to an audience of 400+.
- Co-organized a workshop on behavioral quantification and modeling using ML methods (27 participants).

2016-2020 | University of Konstanz, Department of Biology

- Co-developed and taught an intensive research course on collective behavior for Master's students.
- Supervised five Master's thesis projects across behavior, computation, and data science.
- Delivered lectures and practicals on computer vision for behavior analysis, data processing, and Python programming.

2013-2015 | Graduate teaching

Department of Biological Sciences, Bowling Green State University

- Supported teaching in biostatistics, population and community ecology, and introductory biology; gave a guest lecture on arthropod navigation.

Selected Talks

3 Dec 2025 | Adaptive Behavior as Probabilistic Inference

Invited ScyPhy Seminar, University of Konstanz
Seminar listing

2 Dec 2025 | Adaptive Behavior as Probabilistic Inference

Invited Institute Seminar, Max Planck Institute of Animal Behavior
Seminar announcement

2 Jul 2019 | Revealing the Behavioral Algorithms of Social Animals

Invited talk, Princeton Neuroscience Institute, Princeton University

16 Mar 2018 | Perception and Motion in Locust Swarms

Invited talk, Integrated Behavioral Research Group (IBRG), Princeton University