EVE ARMSTRONG

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EDUCATION and POSTDOCTORAL APPOINTMENTS

Postdoctoral fellow (Nov 2017 –) **Computational Neuroscience Initiative**
University of Pennsylvania (UPenn)

Mentors: Vijay Balasubramanian, Department of Physics and Astronomy; Marc Schmidt, Department of Biology

Postdoctoral scholar (Sep 2014 – Oct 2017) **BioCircuits Inst., U. of CA, San Diego (UCSD)**

Mentor: Henry Abarbanel, Physics Department and Scripps Institution of Oceanography

Ph.D. Physics (2013) **UCSD**

Dissertation: "Probing the Nature of Cataclysmic Variables via Photometric Studies on Multiple Timescales"

Advisors: Richard Rothschild, Center for Astrophysics and Space Sciences, UCSD; Joseph Patterson, Department of Astronomy, Columbia University

B.A. Astrophysics (2002) **Columbia College; Columbia University**

Mentor: David Helfand, Department of Astrophysics

INTERESTS

Scientific contexts:

- predictive models of functional biological neurons and networks that are associated with the creation and reception of auditory signals;
- the information content of acoustic communication signals;
- the neural basis of pattern generation and recognition;
- nonlinear processes in neutrino astrophysics.

Approaches:

- dynamical systems, information theory, and statistical physics;
- optimization methods for state and parameter estimation.

CURRENT PROJECTS

A geometric representation of birdsong to predict female song preferences

Develop a geometric representation of a song's pressure time series, via phase space reconstruction. Here, the geometric structure (or attractor) of the underlying dynamics is unfolded in a new space constructed of time-delayed vectors of the time series. We find that this representation outperforms typical sound analysis tools (e.g. spectrograms) in terms of both the preservation of phase information within a harmonic structure and predictive power regarding observed female song preferences. The model is based on audio recordings of male brown-headed cowbirds.

<u>*Collaborators*</u>*:* Alicia Zeng (UPenn), Marc Schmidt (UPenn), David White* (Wilfred Laurier U., Canada), Vijay Balasubramanian (UPenn).

A statistical physics framework to link song system electrophysiology to how song shapes a society

Develop a maximum-entropy Ising model to quantify a relationship between the vocalizations within an aviary of brown-headed cowbirds and the pattern of monogamous pair bonding that emerges. Electrophysiological manipulations of the neural song circuit will be performed, and we will seek to ascertain the affects of those manipulations upon the ultimate social structure.

Collaborators: Marc Schmidt (UPenn), Clelia de Mulatier (UPenn), David White* (Wilfred Laurier U.), Andrew Gersick (Princeton U.), Vijay Balasubramanian (UPenn).

A mechanistic learning model of the zebra finch song system, with capacity for "un-learning"

Expand upon current models of the avian neural song system to explain recent observations that juvenile males, when challenged to learn a new song midway through their development, will employ a range of alternate strategies in response to that challenge. This project expands upon work in my previous postdoctoral position (at UCSD), on creating a dynamical model of zebra finch song-related nucleus HVC.

Collaborators: Ofer Tchernichovski (Hunter College, CUNY), Julia Hyland Bruno (Columbia U.), Tiberiu Tesileanu (Flatiron Institute).

Inference frameworks to predict neutrino flavor evolution following supernova core collapse

Use inference to predict the past flavor evolution of neutrinos arriving at a detector from a supernova event. In a forward-scattering only scenario, this is a relatively straightforward initial-value problem. With back-scattering, however, the problem is nonlinear, where states at later times influence states at earlier times. Flavor evolution throughout the envelope is a problem of interest in part because it sets the abundances of roughly half of the heavy elements.

Collaborators: George Fuller (UCSD), Amol Patwardhan (U. of WI, Madison), Baha Balantekin (U. of WI, Madison), Mark Paris (Los Alamos National Labs), Shashank Shalgar* (U. of Copenhagen, Denmark), Paul Rozdeba* (U. of Potsdam, Germany)

***** *International collaboration*

PAST POSITIONS and PROJECTS

Postdoctoral scholar (Sep 2014 – Oct 2017) **BioCircuits Inst., UCSD**

Create a functional dynamical model of the avian neuronal circuit associated with song generation. Use optimization to estimate parameters governing the dynamics, using whole-cell recordings of HVC neurons obtained by collaborators at the University of Chicago. My current project on a mechanistic learning model (described above) expands upon this work.

Ongoing collaboration: Henry Abarbanel (UCSD).

Volunteer researcher (2013 – 2014) **Weill Cornell Medical Center / NY Presbyterian Hospital**

Principal Investigator: Kevin Brown, M.D., Ph.D.; Department of Otolaryngology
Co-investigator: Kaleb Yohay, M.D.; Neurofibromatosis II (NF II) Clinic

Retrospective study of Neurofibromatosis II (NF II) patients to identify predictors of vestibular schwannoma (VS) progression, for clinical use. (NFII is a degenerative disease of high morbidity, characterized by the growth of multiple tumors, particularly VS).

Graduate researcher (2011-2013) **UCSD, Columbia U.**

Thesis: optical time series photometry of double-degenerate binary stars with white dwarf accretors. *Aim*: Understand post-main-sequence evolution and conditions for core electron degeneracy.

Observer (2001-2013) **Columbia U.**

Time series CCD photometry of 1) binary star systems and 2) gamma-ray bursts, at Kitt Peak National Observatory (KPNO) and the Cerro Tololo Inter-American Observatory (Chile). Training of new students. *Aims*: 1) understand late binary-star evolution; 2): interpret gamma-ray bursts as signatures of black-hole versus neutron-star formation.

Graduate researcher (2004-2006) **UCSD**

Analysis of optical data from Damped Lyman Alpha systems (high-redshift hydrogen clouds that are probable progenitors to spiral galaxies). Analysis of X-ray data from black hole and neutron star binaries. *Aim*: identify systematic differences between the two classes of object.

Undergraduate researcher (1999-2002) **Columbia U.**

Search for stellar radio emitters using survey data, with follow-up observations at KPNO. *Aim*: identify the physical significance of emission at this bandwidth from these objects.

MEETINGS and PRESENTATIONS

Neutrino Physics and Optimization meeting (August 2019) **University of Copenhagen, Denmark**

Talk: TBA

SIAM Conference on Dynamical Systems (May 2019) **Snowbird, UT**

Host of mini-symposium: "Got rhythm? - a dynamical systems survival guide for biology"
Talk: "A geometric spatial reconstruction for analyzing the information content of song"

American Physical Society annual meeting (March 2019) **Boston, MA**

Talk: "Can vocalizations predict mating pairs in a society of songbirds? A maximum-entropy Ising model approach"

International Symposium on Data Assimilation (Jan 2019) **Kobe, Japan**
RIKEN Center for Computational Science

Invited talk: "From synaptic connections among neurons to energy-changing collisions among neutrinos: using inference to map information flow".

The Physics of Behavior workshop (May – Jun 2018) **Aspen Center for Physics; Aspen, CO**

Talk: "Using nonlinear dynamics to unfold the geometry of birdsong"

Nuclear Physics Cosmology Workshop (July 2018) **Los Alamos National Laboratories**

Talk: "Optimization predicts neutrino flavor evolution following SNe core collapse"

Neutrinos, Nuclear Astrophysics, and Symmetries Conference (Jan 2018) **UCSD**

*Talk: "*A neural networks approach to inferring neutrino astrophysics"

Mathematical Biology seminar (Dec 2017) **New Jersey Institute of Technology**

Talk: "Crafting functional architectures for pattern-generating networks"

SIAM annual meeting (July 2017) **Pittsburgh, PA**

Talk: "Data assimilation for the testing of stochastic models in mathematical biology"

SIAM Conference on Dynamical Systems (May 2017) **Snowbird, UT**

Talk: "A path-integral approach to data assimilation for mapping small neuronal networks"

MURI Winter School (Jan 2017) **BioCircuits Institute, UCSD**
Talk: "Building models of small neuronal networks and model-testing via data assimilation"

Dynamical systems and Data Analysis in Neuroscience Workshop (Oct 2016) **Mathematical Biosciences Inst. Ohio State U.**
Poster: "Model of the avian nucleus HVC as a network of central pattern generators"

SIAM Conference on the Life Sciences (July 2016) **Boston, MA**
Host of mini-symposium: "Experiment and theory combined: an ideal vantage point upon neurodynamics"
Talk: "Model of the songbird nucleus HVC as a network of central pattern generators"

Dynamics Days U.S. (Jan 2016) **Durham, NC**
*Talk: "*From the nonlinear behavior of a single neuron to the robust pattern of a network"

Janelia Theoretical Neuroscience Workshop (Nov 2015) **Janelia Research Campus Howard Hughes Medical Institute; Ashburn, VA**
Talk and tutorial: "Methods of statistical nonlinear data assimilation, and what they can reveal about connectivity in small neural networks"

Dynamics Days Europe (Sep 2015) **Centre for Systems, Dynamics, and Control: U. of Exeter, UK**
*Talk: "*From the nonlinear behavior of a single neuron to the robust pattern of a network"

TEACHING

Adjunct Professor of Physics (2010-13) Cooper Union for the Advancement of Science and Art, NY
Adjunct Professor of Astronomy (2011) Lehman College, City University of NY
Adjunct Astronomy Instructor (2009) College of Staten Island, City University of NY
Graduate Teaching Assistant (2004-6) UCSD

MEMBERSHIPS

American Physical Society (APS)
Society for Industrial and Applied Mathematics (SIAM)

OUTREACH and SERVICE

Volunteer (March 2014) **Weill Cornell Medical Center neurotrauma course: Tanzania, Africa**
Accompanied a neuro-trauma team to host a course at the Muhimbili Orthopedic and Neurological Institute in Dar Es Salaam, Tanzania, on modern methods of neurological surgery. Recorded surgeries; wrote report for distribution to affiliates and donors.

Volunteer (2009-2014) **Weill Cornell Medical Center: Department of Neurological Surgery, NY**
Accompanied neurological patients to surgery, with follow-up visits in recovery. Served as liaison between nursing staff and families. Shadowed a neurosurgery physician's assistant.

Volunteer (2004-6; 2011-13) **Center for Astrophysics and Space Sciences, UCSD**
Co-hosted free outreach events throughout San Diego. Mentored students visiting from schools with little access to extracurricular activities and quality science programs.

Guest lecturer (2007-8) **American Museum of Natural History: Haydn Planetarium, NY**

Volunteer (June 2002) **African Israelites Community Orphanage: Ghana, West Africa**
Taught English and math; helped orphanage founders plan a viable future for their organization.

PUBLICATIONS

Papers in preparation

1. **Armstrong, E.**, Zeng, A., Balasubramanian, V. An attractor representation of birdsong predicts song preferences in female cowbirds.
2. **Armstrong, E.**, White, D., Schmidt, M., de Mulatier, C., Balasubramanian, V. The language of statistical physics characterizes mating preferences in a society of songbirds.

Scientific articles

1. **Armstrong, E.** An optimization method for estimating functional connectivity and electrophysiology within a biological neuronal network. (*In revision: PLOS One*); *arXiv preprint https://arxiv.org/abs/1711.03834*, 2018
2. **Armstrong, E.**, Patwardhan, A.V., Johns, L., Kishimoto, C.T., Abarbanel, H.D.I., Fuller, G.M. A Path-integral-based Approach to Neutrino Flavor Evolution. *Physical Review D* 96(8): 083008, 2017
3. Abarbanel, H.D.I., Shirman, S., Breen, D., Kadakia, N., Rey, D., **Armstrong, E.**, Margoliash, D. A Unifying View of Synchronization for Data Assimilation in Complex Nonlinear Networks. *Chaos: An Interdisciplinary Journal of Nonlinear Science*, 27(12): 126802, 2017
4. Abarbanel, H.D.I., Shirman, S., **Armstrong, E.**, Dean D., Extracellular Potentials as Data Assimilation Measurement Functions for the Dynamics in Networks of Neurons. (In preparation)
5. **Armstrong, E.**, Abarbanel, H.D.I. Model of the songbird nucleus HVC as a network of central pattern generators, *J. Neurophysiol.* 116(5): 2405-2419, 2016
6. Kadakia, N., **Armstrong, E.**, Breen, D., Morone, U., Daou, A., Margoliash, D., Abarbanel, H. D.I., Nonlinear Statistical Data Assimilation for HVC_{RA} Neurons in the Avian Song System. *Biological Cybernetics* 110.6:417-434, 2016
7. Breen, D., Shirman, S., **Armstrong, E.**, Daou, A., Margoliash, D., Abarbanel, H.D.I. HVC Interneuron Properties from Statistical Data Assimilation. *arXiv preprint arXiv: 1608:04433*, 2016
8. **Armstrong, E.**, Patterson, J., Michelsen, E., Thorstensen, J., Uthas, H., Vanmunster, T., Hambsch, F.-J., Roberts, G., Dvorak, S., Orbital, Superhump, and Superorbital Periods in the Cataclysmic Variables AQ Mensae and IM Eridani. *Monthly Notices of the Royal Astronomical Society (MNRAS)* 435, 707, 2013
9. **Armstrong, E.**, Patterson, J., Kemp, J. Two Photometric Periods in the AM CVn System CP Eridani. *MNRAS* 421, 2310, 2012
10. Skinner, J., Thorstensen, J., **Armstrong, E.**, Brady, S. The New Eclipsing Cataclysmic Variable SDSS 154453+255. *Publications of the Astron. Soc. of the Pacific (PASP)* 123, 901, 2011
11. Copperwheat, C.M., Marsh, T., Dhillon, V., Littlefair, S., Woudt, A., Warner, B., Patterson, J., Steeghs, D., Kemp, J., **Armstrong, E.**, Rea, R. The Photometric Period in ES Ceti. *MNRAS* 413, 3068, 2011
12. Dai, X, Halpern, J., Morgan, N., **Armstrong, E.**, Mirabal, N., Haislip, J., Reichart, D., Stanek, K., Optical and X-Ray Observations of GRB 060526: A Complex Afterglow Consistent with an Achromatic Jet Break. *Astrophysical Journal (Ap J)* 658, 509, 2007
13. **Armstrong, E.** et. al. GRB 060102: MDM Observation, *GRB Coordinates Network, Circular Service* 4427, 1, 2006
14. Thorstensen, J., **Armstrong, E.** Is FIRST J102347.6+003841 Really a Cataclysmic Binary?

Astronomical Journal (AJ) 130, 759, 2005

15. Patterson, J., Thorstensen, J., **Armstrong, E.** The Dwarf Nova PQ Andromedae. *PASP* 117, 922, 2005
16. Patterson, J. **and 19 co-authors**, Superhumps in Cataclysmic Binaries. XXV. q_{crit}, epsilon(q), and Mass-Radius. *PASP* 117, 1204, 2005
17. Patterson, J., Thorstensen, J., Vanmunster, T., Fried, R., Martin, B., Campbell, T., Robertson, J., Kemp, J., Messier, D., **Armstrong, E.**, Rapid Oscillations in Cataclysmic Variables. XVI. DW Cancri. *PASP* 116, 516, 2004
18. Pretorius, M.L. Woudt, P., Warner, B., Bolt, G., Patterson, J., **Armstrong, E.**, High-speed photometry of SDSS J013701.06 - 091234.9. *MNRAS* 352, 1056, 2004
19. Mirabal, N. Halpern, J., Chornock, R., Filippenko, A., Terndrup, D., **Armstrong, E.**, Kemp, J., Thorstensen, J., Tavarez, M., Espaillat, C., GRB 021004: A Possible Shell Nebula around a Wolf-Rayet Star Gamma-Ray Burst Progenitor. *Ap J* 595, 935, 2003

Articles of questionable scientific value

1. **Armstrong, E.** Colonel Mustard in the Aviary with the Candlestick: a limit cycle attractor transitions to a stable focus via supercritical Andronov-Hopf bifurcation. https://arxiv.org/abs/1803.11559
2. **Armstrong, E.** A Neural Networks Approach to Predicting How Things Might Have Turned Out Had I Mustered the Nerve to Ask Barry Cottonfield to the Junior Prom Back in 1997. *arXiv preprint arXiv:1703:10449*, 2017 April 1
3. **Armstrong, E.** Pipe-cleaner Model of Neuronal Network Dynamics. *arXiv preprint arXiv:1603:09723*, 2016 April 1
4. **Armstrong, E.** Non-detection of the Tooth Fairy at Optical Wavelengths. *arXiv preprint arXiv:1204.0492* 2012 April 1; *Journal of Irreproducible Results* 52, 3: 22-25, 2014

Educational material

Developed a textbook for Columbia College course "Frontiers of Science" (2004), which is a core requirement for undergraduates (as of 2005). Full text: http://ccnmtl.columbia.edu/projects/mmt/frontiers/index.html

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REFERENCES

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