Illuminating *C. elegans* Locomotion with Laser Diffraction

Raffaella Zanetti ‘23, Katie Canavan ‘24, Asia Baker ‘24, and Prof. Jenny Magnes
Vassar College | Dept. of Physics & Astronomy | VAOL | Summer 2021
Contact: rzanetti@vassar.edu

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Introduction:

Studying the locomotory patterns of the nematode *C. elegans* helps researchers better understand how the neurons function through the simpler model organism only the width of a hair. By comparing experimental analysis of the worm's motion (video tracking/laser diffraction) to code simulations of neurons, we can better refine our model and understanding of neuronal dynamics.

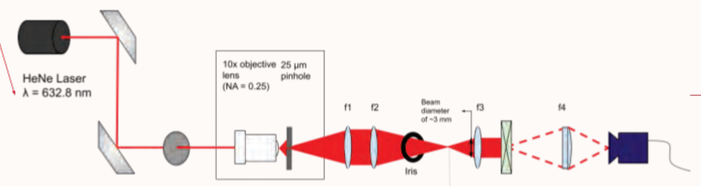
Methods:

Laser diffraction can resolve subtle motion changes to the level of the light's wavelength-greater resolution and precision than that of an optical microscope. Since one point in the pattern is a superposition of all points in the sample, one point gives information about the whole. We devised an optical setup to illuminate a model hair, recording dynamic diffraction patterns with a CCD camera.

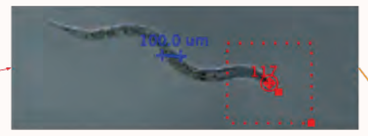
Understanding Neuronal Dynamics in the VAOL: Different Paths to an Unified Model

Experimental:

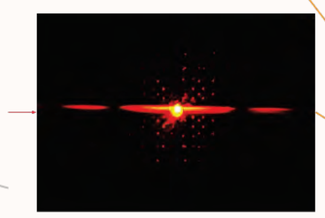
C. elegans adult (Raley-Susman)



Optical setup

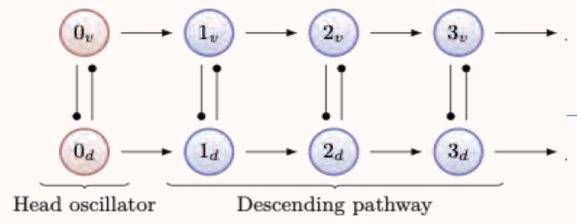


Video tracking

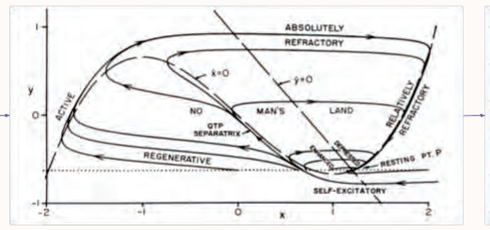


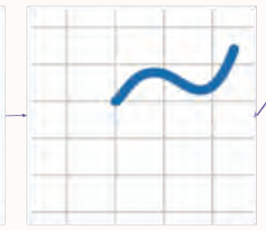
Laser Diffraction Pattern

Model:



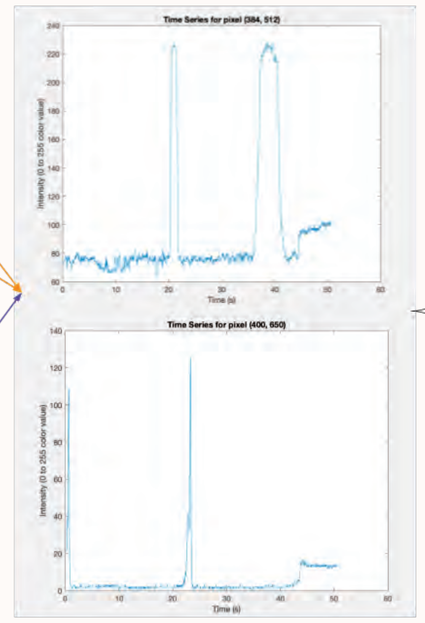
Basic neuron function diagram [1]





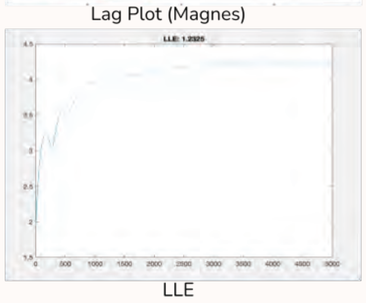
FitzHugh-Nagumo Model [2] & Computer Simulation (Hastings)

Compare Results: Time Series and Chaotic Markers

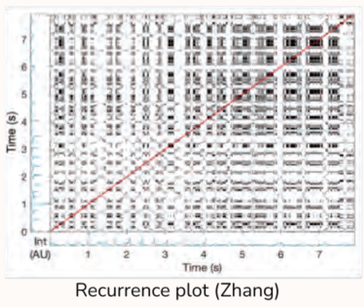


Matlab time-series graphs

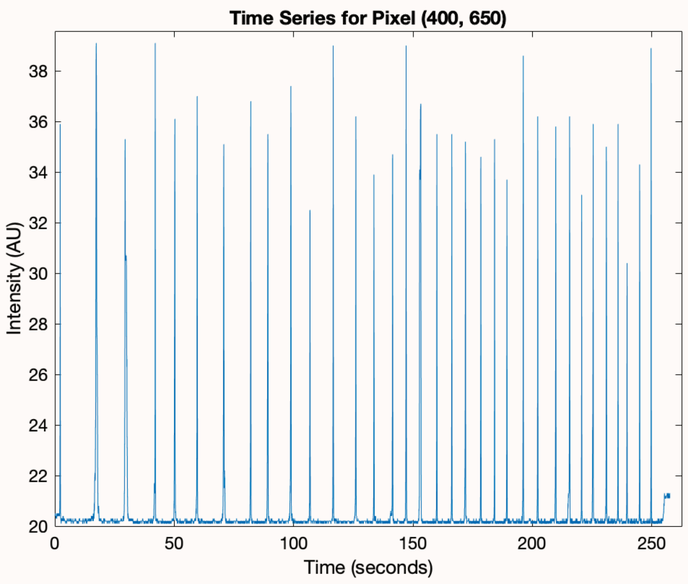
Lag Plot (Magnes)



LLE

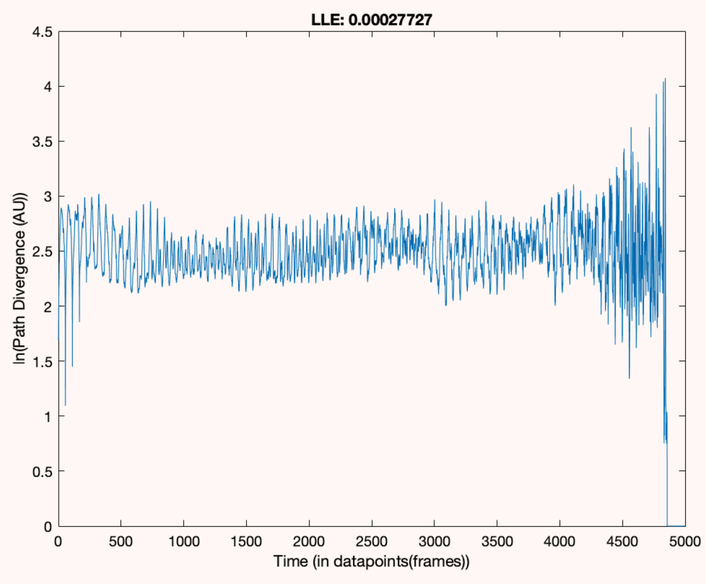


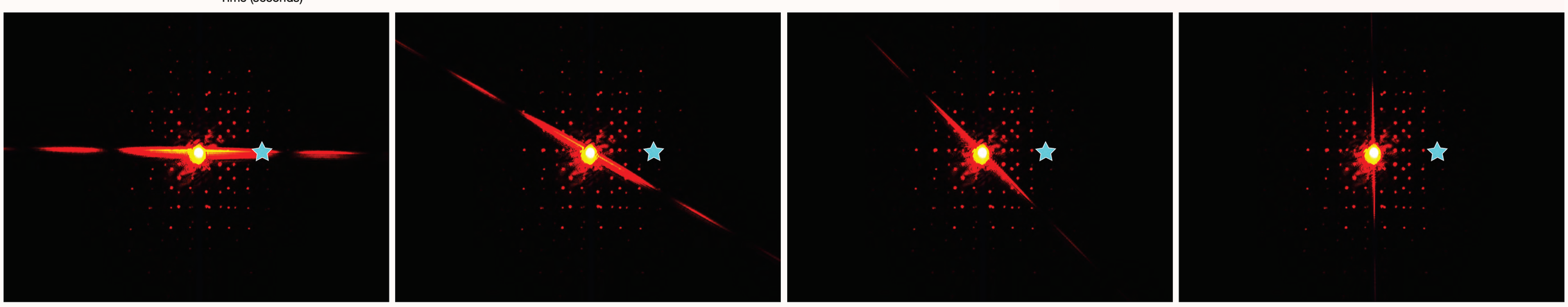
Recurrence plot (Zhang)



Results:

As shown below, we can track the light intensity at a chosen point in each frame of a rotating hair diffraction pattern to more easily analyze video data as a time series (left graph). This can be analyzed by calculating chaotic markers like the Largest Lyapunov Exponent, a value that shows how much two close trajectories diverge over time (right graph) and if positive may indicate the presence of chaotic motion [3]. In this case, LLE is positive, which indicates that chaotic motion may be present, but is also near 0, as the movement was still regular and predictable.





Conclusions:

We found an effective method to analyze motion at the scale of *C. elegans*. Future work will use the real worms in the setup and a more precise camera. Ultimately, the resulting time series can be compared with those of worm simulations run on Vassar's Grace Hopper computer cluster to gauge the accuracy of our current understanding.

References:

[1] Singhvi, A., Hastings, H. M., Magnes, J., and Zhang, S. G., arXiv e-prints, (2021). arXiv:2103.03430
[2] Fitzhugh, R, Biophysical Journal, **1**,6 (1961): 445-66. doi:10.1016/s0006-3495(61)86902-6
[3] M. T. Rosenstein, J. J. Collins, C. J. and De Luca, Physica D: Nonlinear Phenomena, **65**, 1-2, (1993). 117–134. doi:10.1016/0167-2789(93)90009-p

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