Damped Sinusoidal Oscillation of *Caenorhabditis elegans* under Uniform Electric Field

Elegant Mind Club UCLA

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INTRODUCTION

Caenorhabditis elegans demonstrates a highly deterministic behavioral response under an electric field (EF). Under relatively large applied voltages (12 V/cm) worms migrate to the field's negative pole with a larger opening angle, as compared to a more modest 5 V/cm (Gabel et al. 2007). Observations and quantification of physiological effects of C. elegans undergoing stimulation in an electric field have not been clearly studied via line confocal microscopy. A *C. elegans* in free motion follows a sine wave model (Berri et al. 2009). However, under electric field stimulation, the posterior half of the worms' body was observed to be immobile though the anterior was not. The worms might be partially paralyzed by EF.

Furthermore, observation has yielded preliminary evidence that signal propagation of EF sensation in *C. elegans* occurs in the order of hundred milliseconds following stimulation. This data supports the findings by Gabel et al, 2007 and Chrisman et al., 2016, which claim that sensory propagation occurs primarily through synaptic connection.

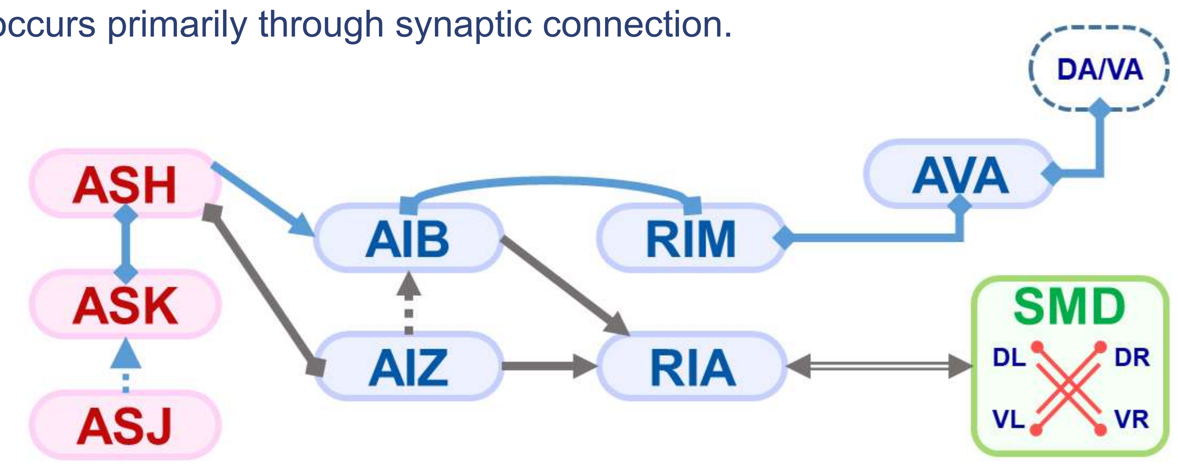


Figure 1. Neuronal basis for damped sine wave body configuration (grey arrows) and fixed, non-zero angle of trajectory via sensorimotor Integration (blue arrows). ASH and ASJ neurons are electric field- sensitive (Gabel, 2007). Sensory neurons = pink; interneurons = blue; motor neurons = green. Adapted from Gabel (2007) and Arisaka (unpublished).

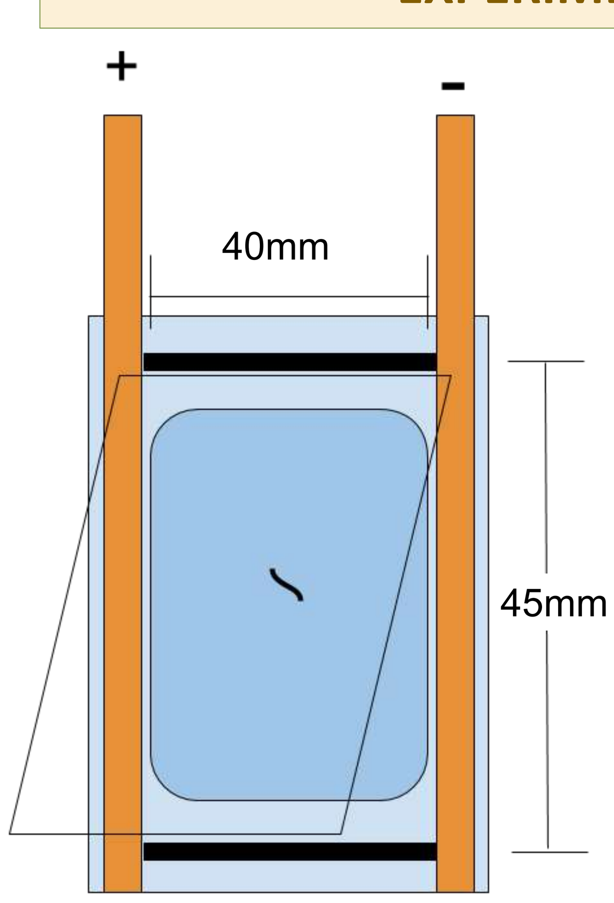
HYPOTHESES

Hypothesis #1
C. elegans exhibits damped oscillation during electric field stimulation.

Hypothesis #2
C. elegans becomes more paralyzed as the magnitude of the applied electric field increases

Hypothesis #3
Propagation of neuron signal (Ca^{2+} signaling) will succeed electric field stimulation initiation in the order of hundred milliseconds.

EXPERIMENTAL SET-UP



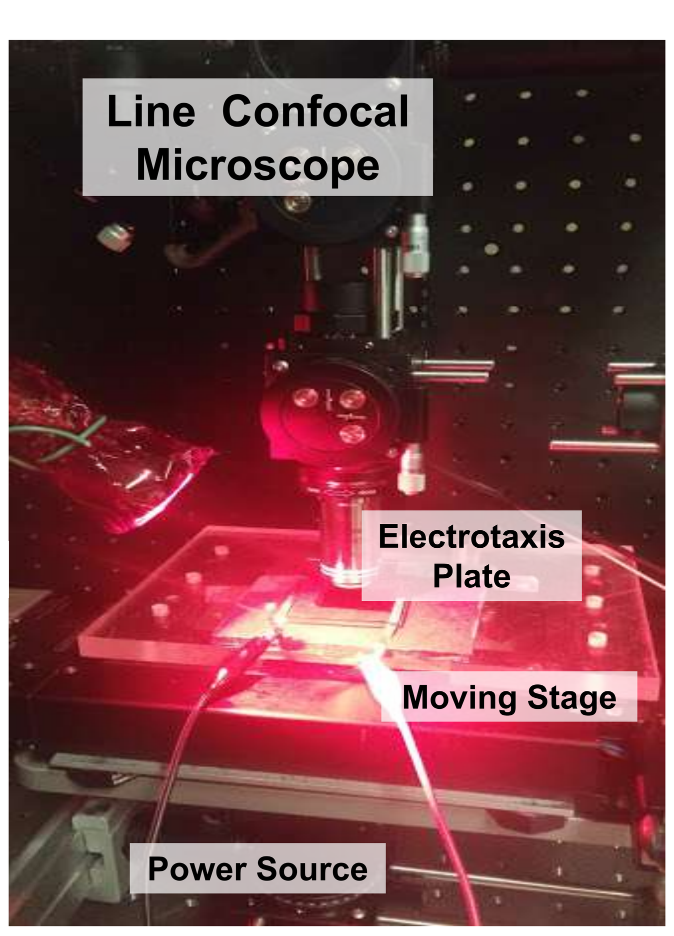


Figure 2.
2-dimensional gelatin medium electrotaxis plate

2-layer copper tapes = 120 µm

Figure 3. Electrotaxis experimental setup mounted under line confocal microscope.

Resolution:
*1020px * 1020px*
270 mmpp
30 fps (behavior)
300 fps (neuron imaging)

METHODS

- Each sample of *Caenorhabditis elegans* contained five individuals.
- Each worm was subjected to electric fields between 4 V/cm and 12 V/cm in following manner: 15 sec off, 60 sec on, 15 sec off.
- Neuronal activities of paralyzed worms using levamisole were recorded under line confocal microscope
- Videos were analyzed with MATLAB
- The wave equation of the worm movement:

$$y = Ae^{-Bx}\sin(2\pi\left(\frac{x}{\lambda} - ft + \phi\right))$$

RESULTS

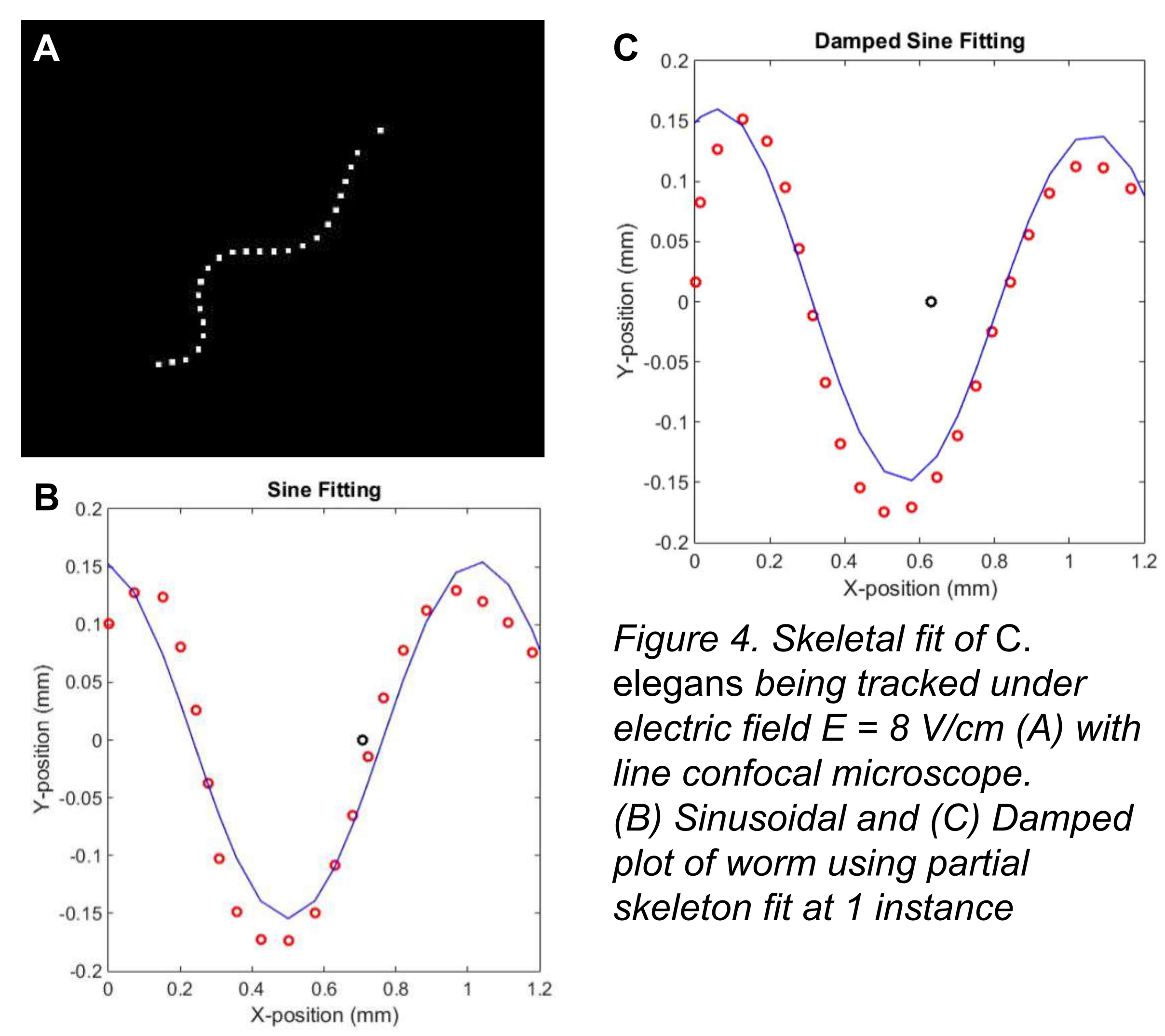


Figure 4. Skeletal fit of C. elegans being tracked under electric field E = 8 V/cm (A) with line confocal microscope.
(B) Sinusoidal and (C) Damped plot of worm using partial skeleton fit at 1 instance

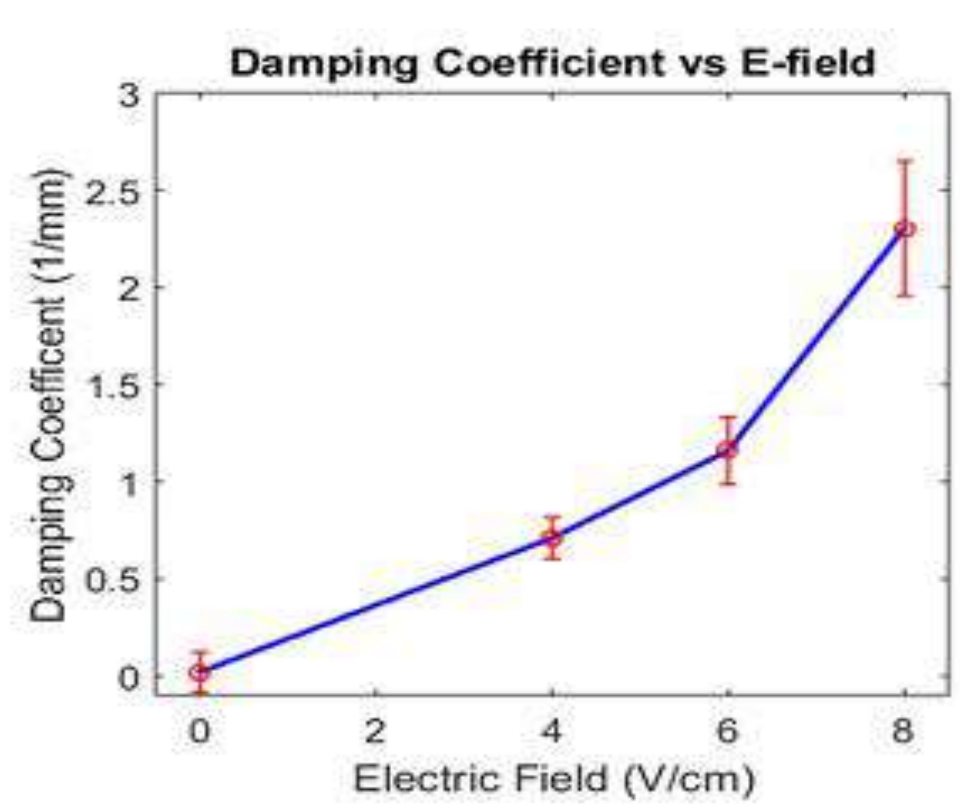


Figure 5. Regression of Damping Coefficient on the magnitude of the applied electric field

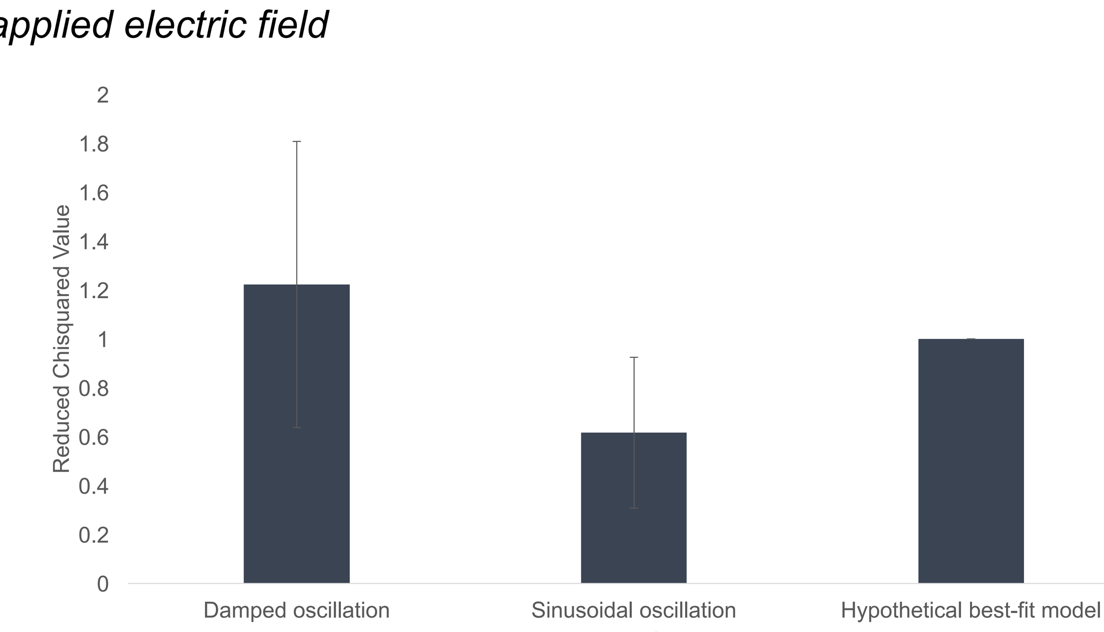


Figure 6. Reduced chi-squares of 2 different models for worm's oscillation compared with the hypothetical best-fit model. N = 11 for each group.

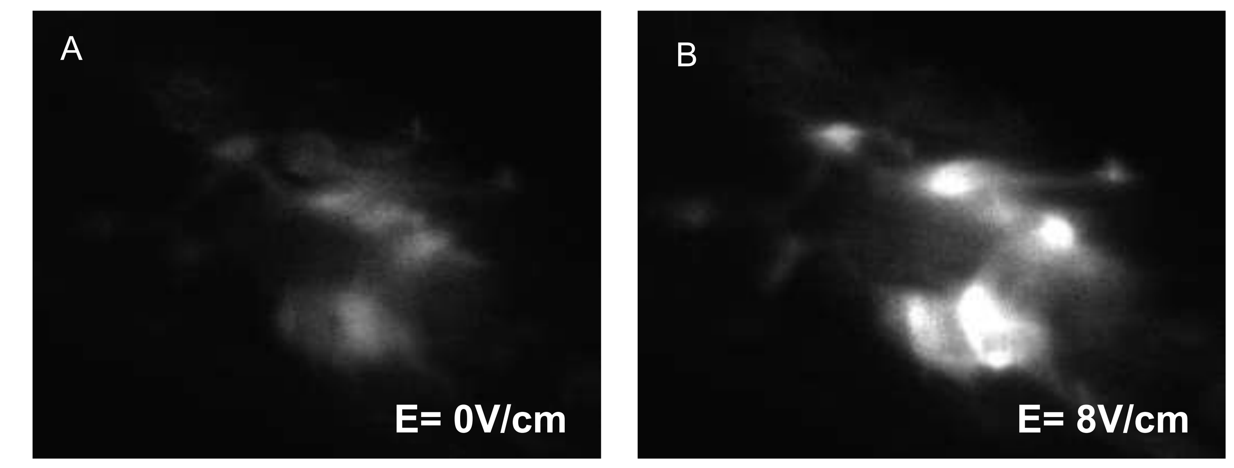


Figure 7. Neuronal signal image of the nerve ring of C. elegans (QW1217) under line confocal microscope.

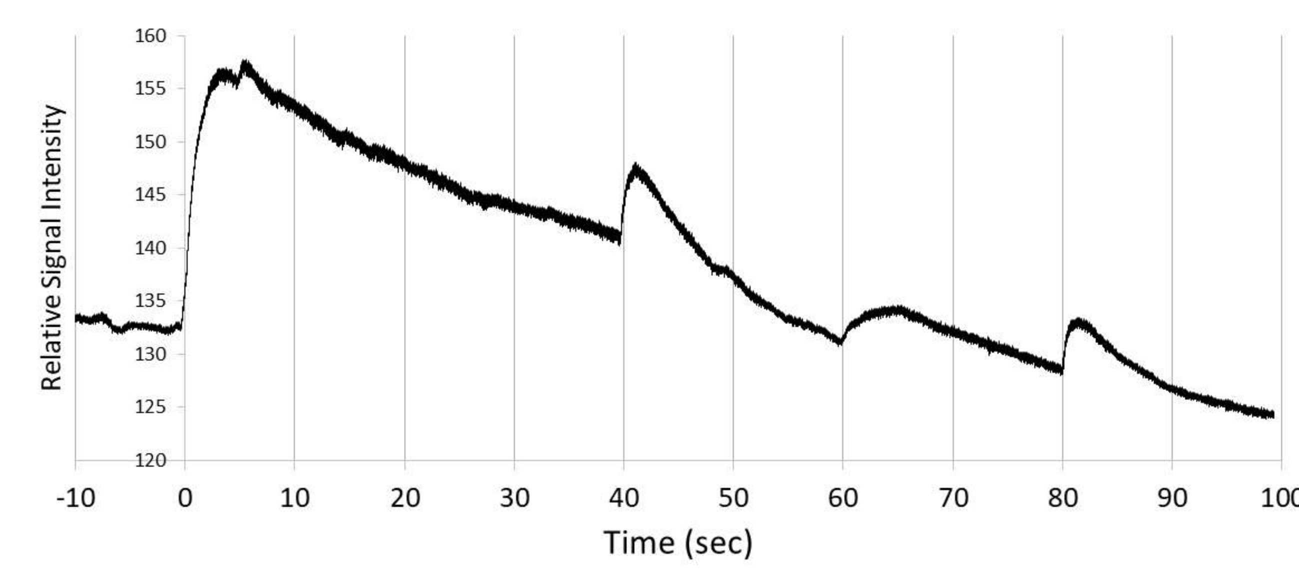


Figure 8. Neuron signal vs time. Frequency: 300 fps.
Start time: 0.000 sec. E field on: 0 sec. Neuron signal start: 0.566 sec

DISCUSSION AND CONCLUSIONS

- Two separate t-Tests reveal that damped oscillation, with the average reduced chi-square of 1.22, is the better fit than sinusoidal oscillation, with the average reduced chi-square of 0.62 respectively. The damped model is also not statistically different from the best-fit model (t-Test, p-value = 0.22). (fig 6)
- The damping coefficient is positively correlated with the magnitude of the applied electric field (fig 5).
- The neuron signal succeeds the electric field stimulation in the range of 0.5 sec – 0.7 sec
- The hypotheses are therefore supported by the data.

FUTURE DIRECTIONS

- Improve damped sine wave fitting algorithm to include increase in wavelength in body conformation under electric field toward the posterior end of the worm.
- Scan synaptic transmission speed in response to ultraviolet, infrared, and thermal stimulation via line confocal microscope.

REFERENCES

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Gabel, C. V., Gabel, H., Pavlichin, D., Kao, A., Clark, D. A., & Samuel, A. D. (2007). Neural circuits mediate electrosensory behavior in *Caenorhabditis elegans*. The Journal of neuroscience, 27(28), 7586-7596.

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