Analysis of Caenorhabditis elegans' Three-Dimensional Locomotion under Magnetic Stimuli

AARON CHOW, NITIN JOSEPH VINCENT, SAYAN DUTTA CHOWDHURY, ZAID HIKMAT, Chris Dao, Joseph Thatcher, and Katsushi Arisaka

UCLA, *Elegant Mind Club* @ Department of Physics and Astronomy

http://www.elegantmind.org

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ABSTRACT

- Previous research reported that *C. elegans* exhibits magnetotaxis: starved *C. elegans* orient themselves using local geomagnetic fields to burrow downwards, whereas well-fed worms display biased movement in the opposite direction.
- Studies on magnetotaxis to date, however, have counted the number of worms found at either end of the enclosure used, therefore reporting non-dynamic bias in only one or two dimensions.
- We comprehensively analyzed *C. elegans* locomotion in three dimensions by generating desired fields through 3 orthogonal Helmholtz coils, and imaging the setup using 3 orthogonal Canon 60D cameras, and generated three-dimensional tracks using MATLAB analysis software.
- Based on preliminary data, we argue that magnetic fields **d**o not elicit a significant response from C. Elegans.

INTRODUCTION

- Vidal-Gadea et al. (2015) found that C. elegans oriented using the Earth's magnetic field for vertical burrowing; starved worms seemed to migrate down, while well-fed worms burrowed up.
- They also found worms from different places around the world migrated at specific angles to the magnetic vector that corresponds to burrowing down in their original location.
- In addition they claimed that the TAX-4 cyclic nucleotide-gated ion channel in the AFD sensory neuron pair was required for magnetic sensing.
- However, Njus Z. et al. (2015) looked at the sensitivity of C. elegans to static magnetic fields between 5 and 120 mT by placing them in microfluidic channels and exposing the worms to permanent magnets for 5 thirty second cycles. No significant difference in worm movement compared to control experiments was observed.

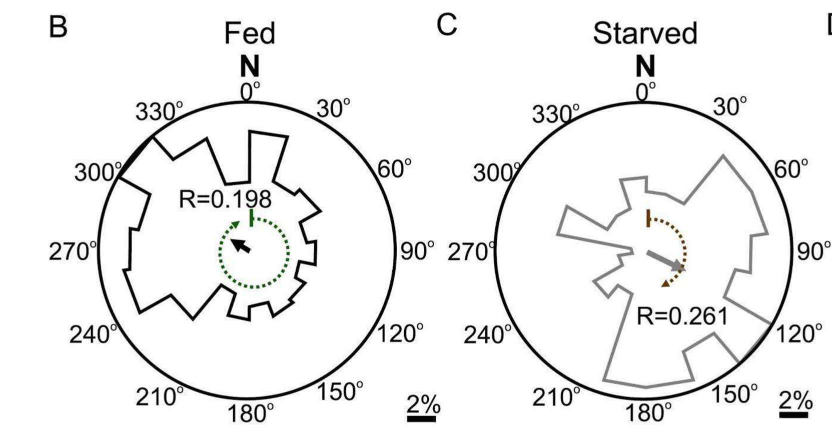

Figure 5: Angular histogram reporting the bearing distribution found by Vidal-Gadea et. al

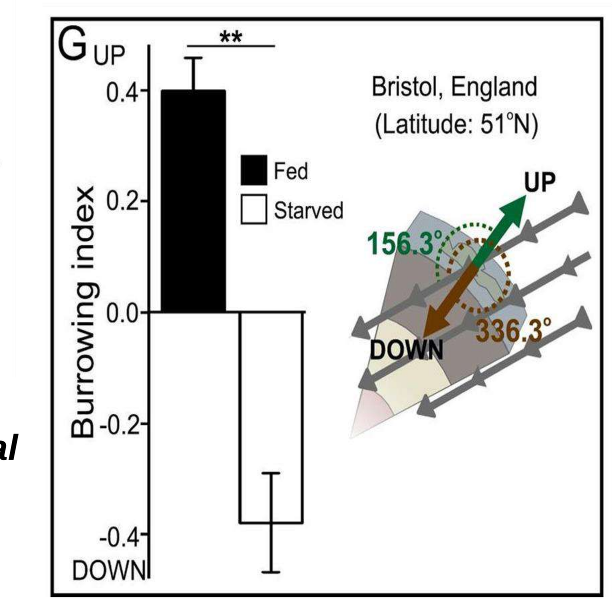

Figure 6: Reported effect of magnetic field by Vidal-Gadea et. al

EXPERIMENTAL SETUP / METHOD

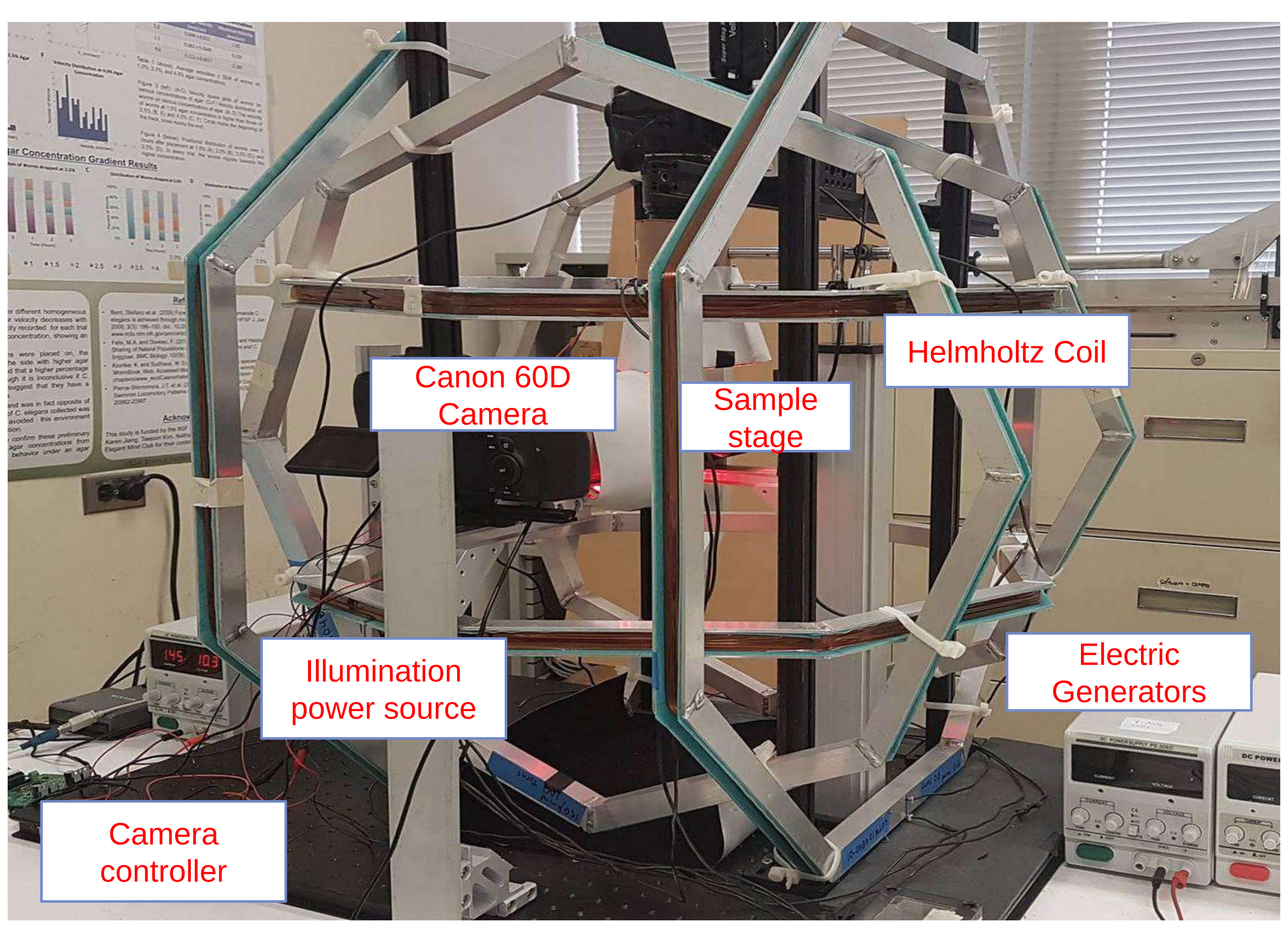

Figure 1: Experimental Setup

- Three perpendicularly oriented DSLR cameras with synchronized trigger. Each camera has a fixed aperture in order to elongate its depth of field, and keep the entire volume of the cubes in focus.
- Illumination by noninvasive conical red LED light sources.
- Samples consist of N2 type worms introduced to the center of 2% porcine gelatin (4 to 5 cm) quartz cuvettes.
- Three orthogonal sets of Helmholtz coils (with axes coinciding with the cameras' optical axes) were utilized to generate a uniform magnetic field of strength up to 10 Gauss at the location of the sample.
- Trials were of length 30-60 minutes each, with pictures taken at a rate of 1 frame every 2 seconds.

EXAMPLE OF RAW DATA

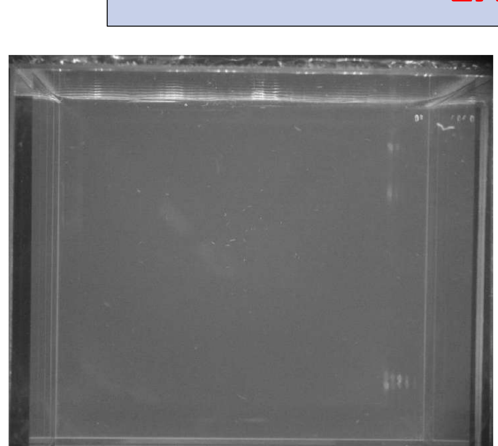

Figure 2: XY Plane

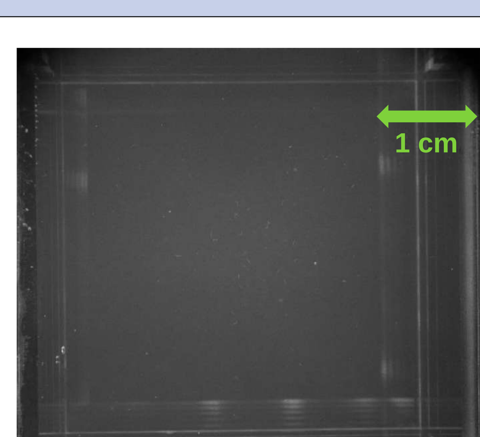

Figure 3: XZ Plane

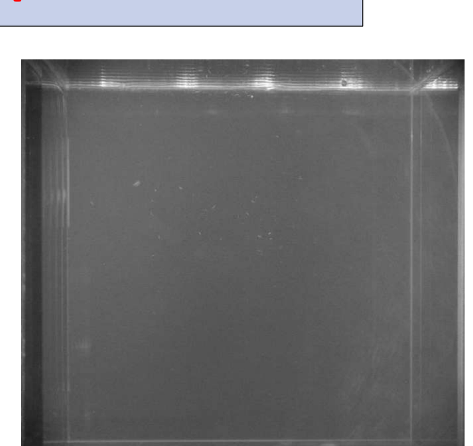

Figure 4: YZ Plane

Sample results from Canon 60D camera

RESULTS

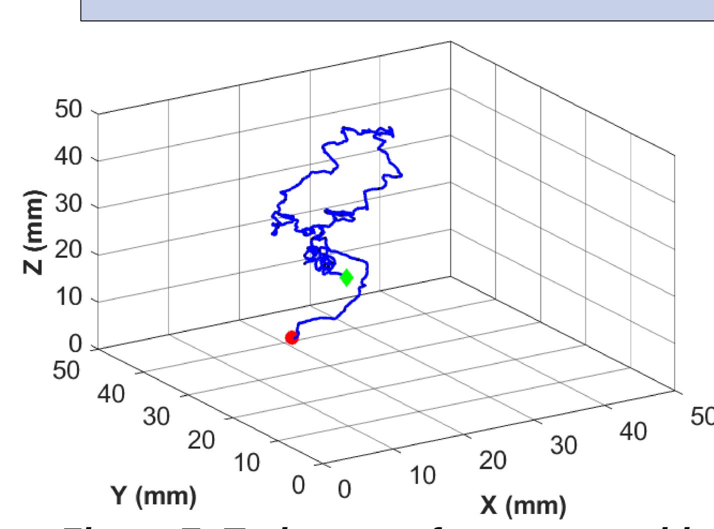

Figure 7: Trajectory of one worm with Earth's magnetic field cancelled (0G)

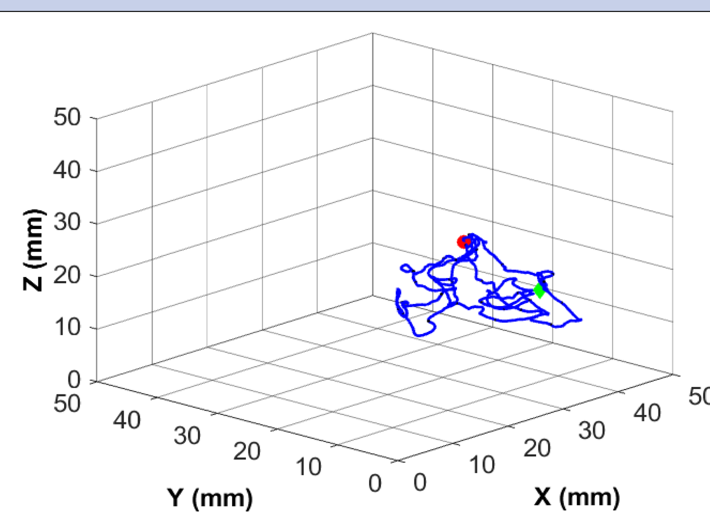

Figure 8: Trajectory of one worm under free motion (Earth - 0.4G)

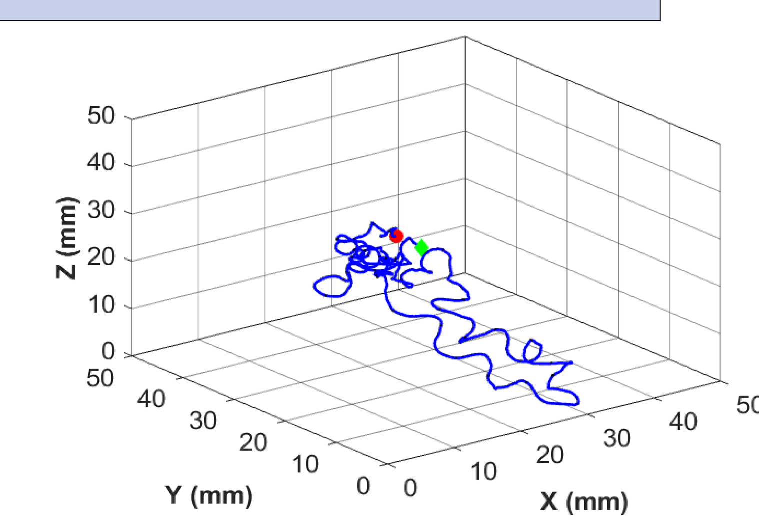

Figure 9: Trajectory of one worm with 10G field applied in the +X direction

Angle Histograms for 10 Worms

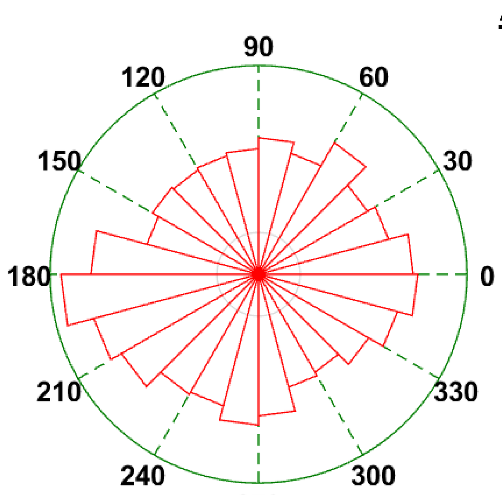

Figure 10: XY 0G

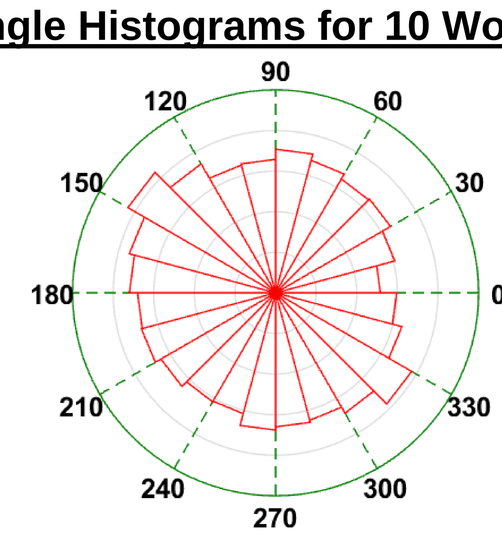

Figure 11: XZ 0G

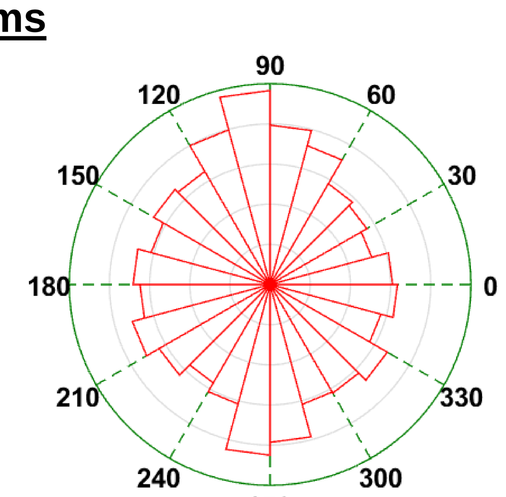

Figure 12: YZ 0G

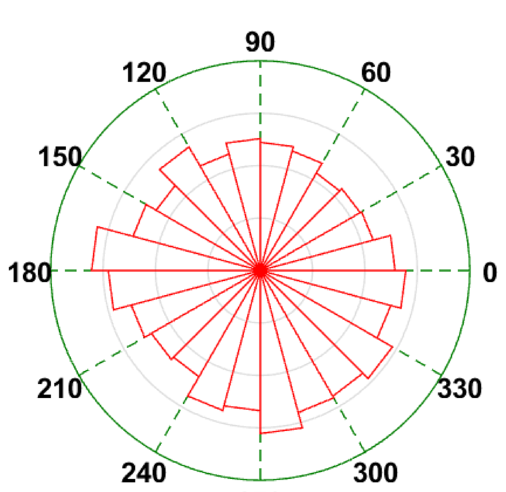

Figure 13: XY 10G

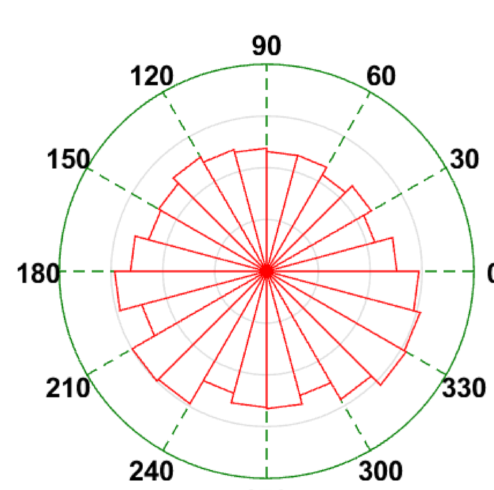

Figure 14: XZ 10G

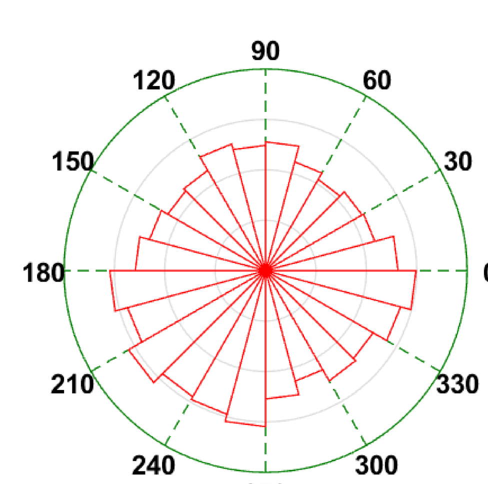

Figure 15: YZ 10G

	0 Gauss	0.4 Gauss (Earth)	10 Gauss
Speed (mm/s)	0.093	0.132	0.106
Mean XY bearing (°)	219	105	255
Mean XY vector magnitude	0.033	0.033	0.042
Mean XZ bearing (°)	158	152	269
Mean XZ vector magnitude	0.033	0.015	0.039
Mean YZ bearing (°)	141	6	241
Mean YZ vector magnitude	0.034	0.039	0.055

Table 1: Key Statistics

CONCLUSION

The results of the experiment have not revealed any significant relationship between the direction of the magnetic field and the direction of movement of the worms.

FUTURE EXPERIMENTS

We would like to use the setup to conduct a more systematic investigation of the behavior of *C. elegans* in free motion, under magnetic stimulation, and with a chemoattractant present to compare to their behavior in 2D. In addition, we want to calcium image the AFD neuron to see if there is any response to magnetic stimuli.

REFERENCES

- Vidal-Gadea A., Ward K., Beron C.,…, Pierce-Shimomura J. (2015). Magnetosensitive neurons mediate geomagnetic orientation in Caenorhabditis elegans. eLife, 4, e0749
- Njus Z., Feldmann D., Brien R,,…, Pandey S. (2015). Characterizing the Effect of Static Magnetic Fields on C. elegans Using Microfluidics. Advances in Bioscience and Biotechnology, 6, 583-591. doi: 10.4236/abb.2015.69061

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