# Navigating Remote BMPL

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## Introduction

The primary focus of our internship this summer was to build our baseline skills in matters related to Professor Schaffner's field of study, so that we will be able to contribute more to the Bryn Mawr Magnetohydrodynamic Experiment (BMX) in the future. Through the process of learning about the modern information and technology used in the plasma physics field, we were able to act as guinea pigs, ensuring that the technology and information is easily accessible and comprehensible to any incoming undergraduate students looking to get involved in the field. The bulk of the first half of our internship was spent learning and testing various platforms such as Python, Vapor, and PlasmaPy. During the last few weeks of our internship, we were able to attend an undergraduate workshop at the Princeton Plasma Physics Laboratory (PPPL) and we assisted one of the BMX graduate students in analyzing some digital renderings of a simulation of the BMX.

## Foundational Base

Coming into this internship, working in the BMX laboratory, both of us had less background experience than usual for the students that Professor Schaffner takes on as interns in his lab; as first-year physics students, we only had what we had learned in our intro level high school physics course and our first-year courses at Bryn Mawr. Thus, neither of us had any experience with Electromagnetism or Multivariable Calculus, two of the important basic courses for understanding plasma physics. This drove a good portion of our learning at the beginning of the internship.

## Primary Learning

### Python

For the first five to six weeks, we mainly focused on growing our skill levels to be at a level that would benefit us for the rest of the internship and for the future work that we may do for Professor Schaffner. This work primarily consisted of us learning how to code with Python through Codecademy and video tutorials suggested to us by Professor Schaffner.

## Learning and Implementation

### Bubbles

One way that Professor Schaffner was able to describe the BMX was through bubbles. We spent some time exploring this analogy and we learned how bubbles can replicate how the plasma is acting inside BMX. More specifically, the soapy film that is blown out of a bubble wand to create the bubbles, acts as the magnetic field lines do, and the air contained inside the film would be the plasma. Magnetic fields are a great way to contain plasma, because plasma can stick to them quite well. The analogy goes  more in depth when we look at how changing the pressure, how hard one needs to blow to create a bubble, and the number of bubbles that are blown. If air is blown through the wand slowly and consistently, one large bubble will form, whereas if air is blown rapidly through the wand, many small bubbles will form. Simply, this is how the plasma moves inside the BMX. In the BMX, plasma is being pushed into a vacuum chamber, creating a sphereomack, which can be thought of as a "bubble" of plasma contained by magnetic field lines. Professor Schaffner was able to relate our findings and questions back to the basics of plasma physics, furthering our intuition.

### Vapor

The last few weeks were spent implementing our new understanding of plasma physics; we moved forward with more individualized work. Through our work with the PPPL workshop, our bubble analogy, and Python, we started working with Vapor. Vapor is typically used to render models of weather patterns, but the BMX lab uses it to model the inside of the experiment. The data used to visualize BMX comes from a simulation that has been coded by both BMX students and the Swarthmore Sphereomack Experiment (SSX) students. We were given data sets by the graduate students and we were primarily looking for errors in the visual models that might hint at an error in the simulation code. One of the BMX graduate students worked with us to show us what errors looked like and what they could tell us about issues in the code.

### Figures

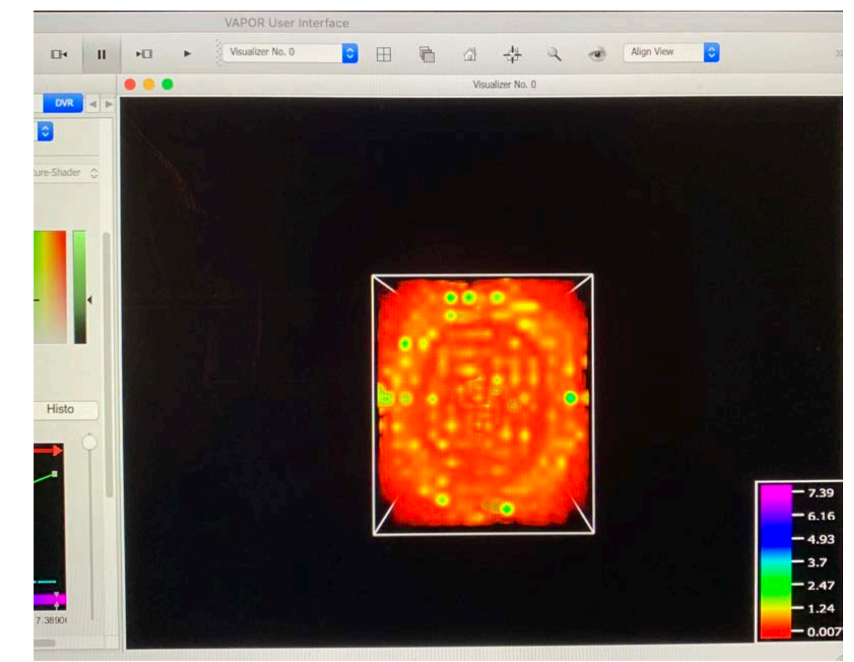

Fig. 1. Simulation data in Vapor. Timestep 14: functioning code. Shows the density of the plasma sphereomack.

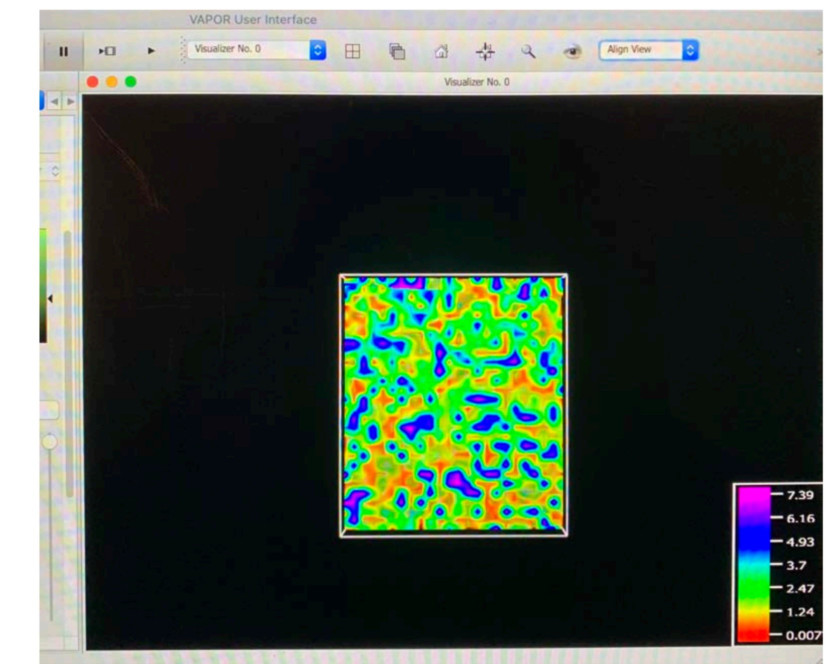

Fig. 2. Simulation data in Vapor. Timestep 15: "broken" code. Shows density of plasma, but data is inaccurate here.

## Unanswered Questions

While exploring the bubble analogy by experimenting, we were able to come up with some questions about plasma that we realized are still being researched by the community as a whole. Mainly, we questioned the amount of energy needed to blow one large bubble verses many small bubbles. After discussing this with Professor Schaffner, we learned that this is still a big question amongst researchers in the field. Physicists are still trying to understand in more depth how plasma behaves in an experimental environment.

## Conclusions

As our summer was different than usual summers, we do not have the typical experimental conclusions. Additionally, working in the physics department, we are not as much working on one smaller project but more smaller parts for a bigger project. We will be continuing our work with Professor Schaffner, shifting from coding to more in person work, till helping with his ongoing study and hopefully contributing to creating some meaningful results.

## References

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2. SSX Team
3. Chen, F. F. (1984). Introduction. In *Introduction to plasma physics and controlled fusion* (pp. 1-18). NY: Plenum Press.
4. Bellan, P. M. (2008). Chapter 1. Basic Concepts. In *Fundamentals of plasma physics*. Cambridge: Cambridge University Press.

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