SOCIETY OF PHYSICS STUDENTS
An organization of the American Institute of Physics

SPS Chapter Research Award Proposal

Project Proposal Title	Finding the shape of glowing objects from polarimetric measurements.
Name of School	Lamar University
SPS Chapter Number	3643
Total Amount Requested	$1999.92

Abstract

The SPS chapter of Lamar University proposes a robust in-lab method for spatially resolving the shape of any glowing object from the study of light emitted, and test it with a new optical system (including lenses, polarizers, sensors, and step motors). The topic was inspired from polarimetric measurements of supernovae.

Proposal Statement

Overview of Proposed Project

The research question we want to address in this project is 'how can we resolve the shape of a glowing object using information from the polarization of the light emitted?' We plan to develop a robust polarimetric method and conduct investigations using a novel experimental procedure. Our idea departs from an existing experiment in the Optics lab at Lamar University [1] which allows us to explore the polarization of light using Malus' law. This law indicates a cosine squared dependence of the light transmitted through an analyzer after it is polarized by a linear polarizer. The group of SPS students has already started to assess the above research question using a simple setup developed recently, and which will be described later in the section "Background for Proposed Project". The preliminary results suggest to us that we can build a robust methodology to probe our research question. Our preliminary setup can be improved with equipment purchased using the SPS grant money.

The motivation for finding the shape of a glowing object using polarimetry came from an article of astrophysics [2] which claimed that the eccentricity of a supernova's core can be determined from polarimetric measurements. There are two types of supernovae: thermonuclear and core-collapse. They show different symmetries in their remnant cores due to some differences in the mechanism involved in the explosion.

Our polarimetric method aims to study the shape of any glowing object, broadening the applications beyond the assessment of the geometry of a supernova's core as discussed in Ref. [2]. This research project will entail the improvement of our current setup, collecting and processing new data from different light sources for assessing their eccentricity, and hopefully ending with the submission of our results to a peer-reviewed publication. This project will allow some new SPS members to be involved in UG research with the potential for publication. We believe that a shared research project helps in strengthening the relationship between SPS members as it has been proven to be successful in the past with our 2013 Sigma Pi Sigma project. Also, the research question can stimulate the interest of our local industry in undergraduate research at Lamar.

Background for Proposed Project

A supernova occurs at the end of a star's life after all the star's hydrogen fuel is exhausted, having successfully converted light abundant elements into heavier elements, such as carbon. At this point, gravity overtakes the radiative pressure exerted by the radiation emitted in nuclear reactions and causes the star's massive core to collapse, thus making it even denser. Previous work suggests that we can use polarimetric studies to distinguish between core-collapse and thermonuclear reaction supernovae. Leonard et al. [3] studied the polarization of light from supernova remnant SN 2004j, a core-collapse supernova, and using polarimetry, found that it has an asymmetric, oblong core. Wang et al. [4] studied light emitted from the thermonuclear supernova SN 2001el and noticed a lesser change in polarization, suggesting a core of spherical symmetry.

These articles suggest that one can observe the eccentricity of a supernova's core using polarimetric measurements. It has been further suggested that the gravitational collapse in Type Ib and Type II supernovae leads typically to an aspherical core while thermonuclear explosions in Type Ia supernovae have higher symmetry [2]. Thermonuclear supernovae are classified as Type Ia, which are of interest to many astrophysicists because they are considered as being standard candles, and thus, are used to measure intergalactic distances. Also, studies of Type Ia supernovae led to the 2011 Nobel Prize in Physics, which propelled the search for dark matter [5].

Stimulated by the articles published about supernovae [3,4], we wanted to test the claim that one can assess the asymmetry of a supernova's core with a simple table-top setup. Our setup shown in Figure 1 uses PASCO© Optics equipment, and is comprised of a light bulb encapsulated in a black cavity which can have

attached various openings, two converging lenses, two polarizers, a light sensor, and a rotary motion sensor. A polarizer placed along the optical path in front of the light source simulates the polarizing gaseous cloud that detaches from a supernova. Another polarizer connected to a rotary motion sensor acts as an analyzer and assesses the light. We have automated the rotation of the analyzer with a drill bit connected to the analyzer through a belt. *To the best of our knowledge, there is no similar setup currently in use elsewhere and also, we believe our research question is novel. Any sophomore level student who has completed the polarization experiment in the University Physics 2 course can successfully run and contribute to this project.*

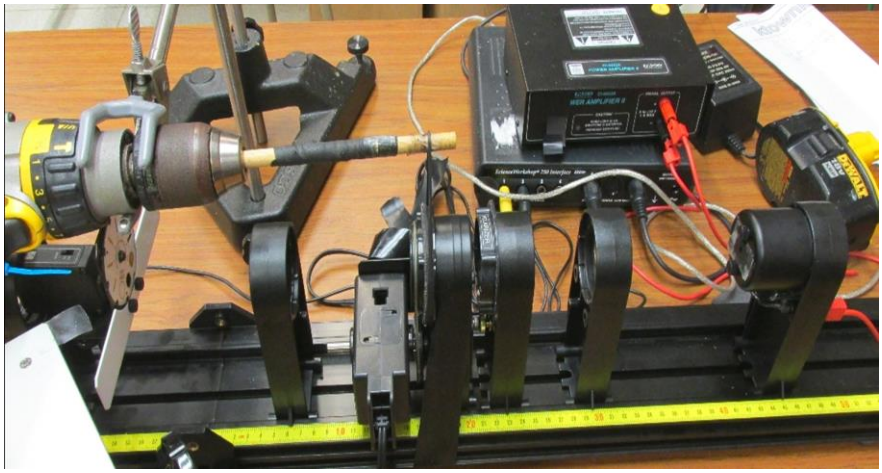

Figure 1: *The present experimental setup. We plan to further improve it using the SPS grant money.*

Expected Results

We use the Data Studio software for processing the signal detected with the setup from Figure 1. Since the light sensor measures the light intensity and a rotary motion sensor measures the angular rotation of a pinion angle which is connected to the analyzer, this setup allows us to plot the light intensity versus the angular position of the analyzer. We plan to improve the precision of our instrument using better polarizers, a stepper motor which will allow a more uniform rotation of our analyzer and also, better mechanical stability than with the present drill. We plan to use improved optics with quality lenses that can better focus the light from the opening on the aperture bracket placed in front of the light sensor. We are currently using a light sensor for visible light, but for low temperature glowing objects, we will need an infrared (IR) sensor for detection of the peak of radiation. Purchasing an IR sensor will broaden the area of experimentation.

Description of Proposed Research - Methods, Design, and Procedures

We plan to improve the setup shown in Figure 1 with new equipment listed under the budget, and collect data for glowing objects of various shapes. We will plot the light intensity as a function of the angular position of our analyzer and obtain a signal which varies as a cosine squared function according to Malus' law. We will assess the amount of light coming through different orientations of the polarizer's transmission axis in order to observe the polarization of the initial light which can complicate the extraction of the information about the amount of polarization generated by the shape of the object alone. We will import our raw data into MATLAB for extracting the extrema. Accurate extrema can be obtained from best fitting our raw data with a 3rd order polynomial, as shown in the example from Figure 2. For an accurate fit, we need a more stable signal than shown in Figure 2, which can be achieved with a stepper motor.

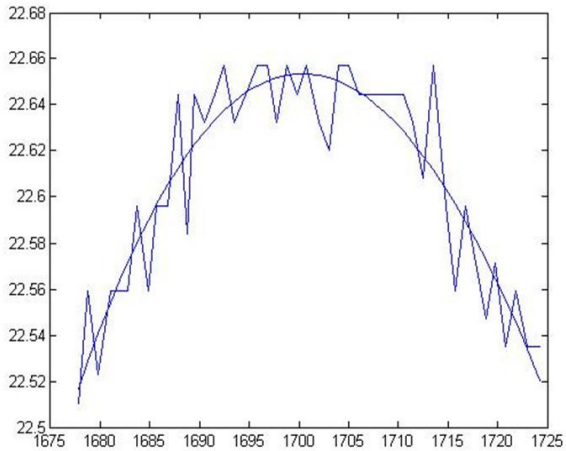

Figure 2. *Example of experimental data fitted with a 3rd order polynomial.*

At this moment, we average the difference between adjacent extrema for each degree orientation of the polarizer and calculate the standard deviation. Figure 3 shows the results of the change in amplitude of the light emitted by various openings as a function of the degree orientation of the polarizer. This procedure will be improved during the development of the proposed project.

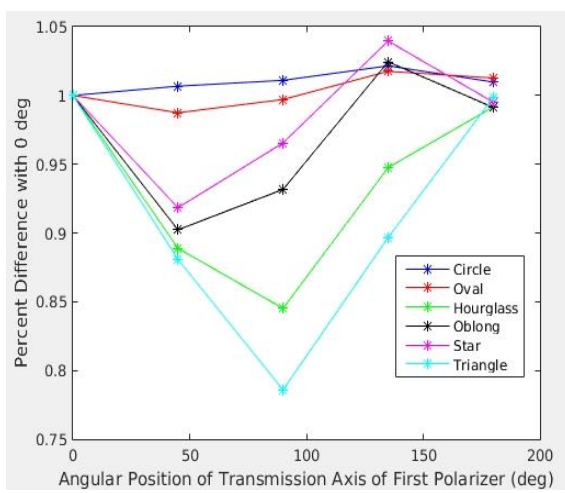

Figure 3: *Preliminary results from current setup with control signal (blue line) plotted against other shapes.*

Plan for Carrying Out Proposed Project

Keeley Townley-Smith, who developed the preliminary version of the experiment on polarimetry, will be the team leader. The active team will be composed of one other experienced UG student researcher, Mark Worth, as well as a new SPS member, Suzanne Wheeler, who has no previous UG research experience. Also, there is a chance to have two other new SPS members to join the team. Dr. Cristian Bahrim, our SPS faculty advisor, can host the project in his Optics Lab and also, has expertise on the topic. There are no departmental funds available for the items budgeted here.

Project Timeline

The month of January will be spent training SPS members new to the experiment using our current setup. They will collect data and process them with our MATLAB program. Upon reception of the research funds, we will order all necessary equipment. We expect to have new equipment by mid-February, when we will begin to improve our setup. The new setup should be ready by March 1st. The months of March, April and May will be dedicated to collecting and analyzing data, so we can have a rough draft of the paper by May 31 and submit preliminary results as an interim SPS chapter report. In June and July, the team will identify other areas for improvement and implement the new ideas to situations of interest for the local industry. After loose ends are tied up in the fall, our team will generate the final chapter report in December.

Budget Justification

Two new polarizers will be bought from PASCO© Optics to replace existing ones being used in our setup (item #1). We plan to improve our setup using two new types of polarizers (including appropriate mounts) for better data acquisition: one is a conventional glass type and another is a laminated film type from Edmund Optics (items# 2-4). In addition we will be using two light sensors: a broad spectrum light sensor (item#5) and an infrared light sensor (item#6) from PASCO© Optics, which will expand the range of detection and will allow us to measure the peak of radiancy of glowing objects at various temperatures. We hope to make the rotation of the analyzer smoother with a controlled mount driven eventually by a computer. For this purpose, we plan to purchase a stepper motor (item#7) with a timing belt (item#8) and a pulley (item#9). This addition will significantly improve our current setup. A more complex optical system using high quality lenses with the appropriate holder (item#10-11) will allow us to enhance the image quality of the glowing object projected on the light sensors.

Bibliography

[1] Bahrim, Cristian. "Polarization of Light" *Optics - PHYS 4480/5480 Laboratory Activities*. Online resource. Accessed October 15, 2015 <http://sethi.lamar.edu/bahrim-cristian/Courses/PHYS4480/PHYS-4480-LAB.html>

[2] Cowen, Ron. "Astronomy Gets Polarized." *Science News*, **170**, 2 (July 8 2006).

[3] Leonard, D.C., et al. "A non-spherical core in the explosion of supernova SN 2004dj." *Nature*, **440,** 505-507 (March 23, 2006).

[4] Wang, L. et al 2003. "Spectropolarimetry of SN 2001el in NGC 1448: Asphericity of a Normal Type Ia Supernova" *Astrophysics Journal*, **591**, 1110-1128 (July 10, 2003).

[5] Drake, Nadia. "Type Ia Supernovae: Why Our Standard Candle Isn't Really Standard." *National Geographic. Phenomena*. Accessed October 15, 2015. <http://phenomena.nationalgeographic.com/2014/08/28/type-1a-supernovas-cosmic-candle-mystery/>