Solar and stellar measurements using accurate spectroscopic techniques

Department of Physics, Lamar University, Beaumont, Texas

Interim Report

June 15, 2013

Budget: $2000.00

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Abstract

We propose to use low-cost optics equipment in order to (1) generate a Hertzsprung-Russell diagram for the 24 brightest stars visible in Beaumont, (2) analyze the polarization of stellar and solar light and the effect a telescope's optics have on these measurements, and (3) analyze the absorption spectrum due to Earth’s atmosphere on the Sun’s blackbody radiation spectrum.

Objectives

- **Hertzsprung-Russell Diagram (HRD):** Generate a Hertzsprung-Russell Diagram, using blackbody curves of radiancy for the most visible stars in the northern night sky.
- **Analysis of Polarized Stellar Light (APSL):** Analyze the polarized light emitted from very bright stars and the Sun, due to the shape of the stars; and study the effects of the optical components of the telescope by placing the solid polarizer at different locations along the line of sight.
- **Pollutants in Earth's Atmosphere (PEA):** Separate from the solar spectrum the absorption spectrum of the gaseous components in the atmosphere in order to determine their chemical compositions.

Experiment Set-up Preparation and Brief Progress Report

For the three experiments (HRD, APSL, and PEA), a similar experimental technique is used. The set-up is comparable to the one currently used in Lamar University's advanced optics course [1] and shown in Figure 1. The most distinct difference between the set-up shown and the one we are using is the variety of light sensors required for the range of temperatures of the stars we are studying.

All three experiments will use PASCO® equipment (http://www.pasco.com/home.cfm) attached to a telescope. We originally planned to use two telescopes (14" Meade LX200GPS-SMT Schmidt-Cassegrain telescope for stellar observations and measurements, and a smaller 50 mm aperture Bushnell 340x60 telescope for

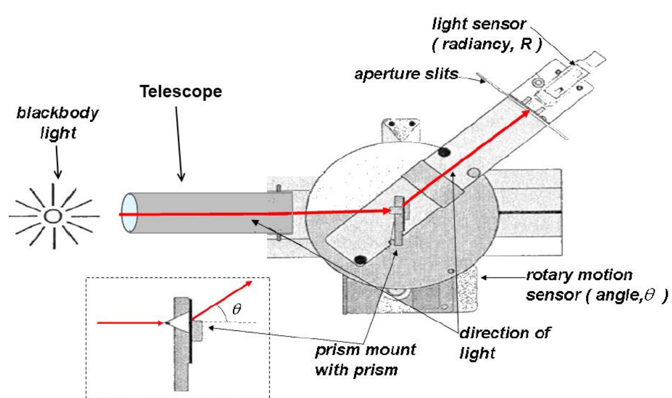


Figure 1: A setup for the study of the blackbody radiation spectrum. The path of the light is shown by two red arrows.

solar measurements). After preliminary trials we decided to substitute both with a single 90 mm Meade ETX-90EC Astro Telescope with a better contrast due to the smaller aperture size, and it is easier to transport than a larger version.

The first data collection was attempted the night of February 28th. At that time, data was not successfully gathered for the purpose of quantitative measurement, but the issues that would need to be addressed before accurate data could be collected were indentified. The remaining spring semester was diligently spent building and calibrating the set-up and adapting the DataStudio software for our needs.

While the telescope comes equipped with a tripod and automatic tracking capabilities based on declination, right ascension, and latitude, which is an extraordinarily helpful asset for amateur astronomers, aligning the optical axis of the telescope to the optical axis of the optics bench has proved to be quite difficult. During the tracking process the telescope's optical axis rotates, while the optical bench's axis does not. To accommodate this challenge, we are in the process of ordering fiber optic cables and accessories, in order to more easily control changes in the position of either of the two primary pieces of equipment (telescope and optics bench).

Figure 2: Bench-tripod adapter used to connect the optics bench to a tripod.

An adapter was fashioned to attach the optics bench to a tripod (Figure 2). The optics bench is thereby made more versatile and adjustable. The equipment loaded on the bench is all fastened to manufacturer's specifications to prevent sliding when the bench is tilted at any angle.

A light shield was originally designed to be attached to the bench-tripod adapter with access to the optics bench provided through an opening of the fabric, in the back. However, after several failed attempts to align the optics bench with the telescope and record data under this scenario, a change was mandated. A small four sided frame - that a person, the optics bench and its mount, and one end of a fiber optic cable can sit in comfortably, for accurate control - has been constructed from donated PVC pipe and is being outfitted with fabric.

DataStudio Software needed an exceptional amount of calibration in order to function with the addition of telescope optics between the light source and the sensor. The experiment's template file needed UVA and VIZ sensors added and calibrated, and the IR sensor required specific calibration for our experiment. A laboratory setting was created to simulate conditions for our research (Figure 3), and assessment is ongoing to bring this software to optimum efficiency.

Figure 3: The optics bench rests on lab jacks and is aligned with a light source at the opposite end of a long tube. The sensors (light sensor and rotary motion sensor) are connected to the laptop running DataStudio software.

Our work with spectroscopy of emission has developed from the previous work mentioned in the proposal, in order to expand our database of atomic and molecular spectra for comparison to the final data runs. We have started comparing atomic spectra of different elements in order to estimate the appearance of a complex spectrum. Then we are able to superimpose the molecular spectra and assess the correlations. When possible, the NIST Database of Spectral Lines is being referenced for confirmation of transitions (Grotrian diagrams) and wavelengths [2]. The characteristic patterns of three of the most common elements in the atmosphere (hydrogen, nitrogen, and oxygen) are now known with greater precision (Figure 4 and Table 1), and many more have been cataloged.

The preliminary work on atomic spectra was presented at the South Central Conference for Undergraduate Women in Physics 2013 and further developed under this ΣΠΣ research award for presentation at the Joint Spring 2013 Meeting of the Texas Sections of the APS, AAPT, SPS [3]. The newest work on complex spectra was presented at the Texas Undergraduate Research Day at the Capitol 2013 [4].

Future Work

The light shield frame needs further work to increase stability in moderate wind. Most readings on campus are taken on the roof of the Cherry Engineering building on the LU campus, and the wind above the tree line can be rather strong. The frame will be disassembled and moved to each data collection site and the process for assembly must be streamlined for efficiency, and safety. Other readings may be obtained at dark sites near Beaumont, Texas.

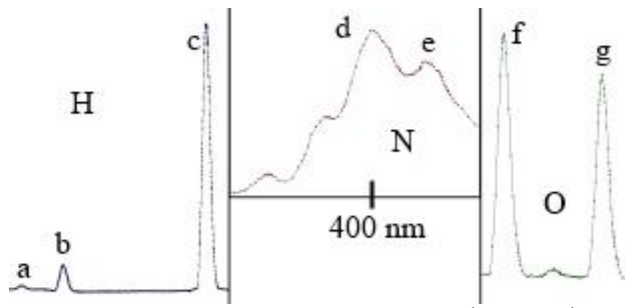


Figure 4: Characteristic wavelengths and features of Hydrogen, Nitrogen, and Oxygen in the increasing value of the wavelength

Table 1: Characteristics of atomic spectra for basic elements in the atmosphere

Element	Wavelengths (λ ±0.8 nm)	Label	Notes
Hydrogen	434.1 486.1 656.3	a b c	The three strongest lines of the Balmer series show up very well in any molecule that contains H. Caution is recommended for the appearance of just 656.3 because it is in a range popular among the lighter elements [2].
Nitrogen	399.9 421.5	d e	The unique structure seen in Figure 4 is characteristic to N and is centered around the 400 nm mark.
Oxygen	776.8 844.4	f g	These two peaks have approximately the same intensity making them very unique.

DataStudio Software calibration will be completed to provide three well calibrated template files, one for each experiment. The software will be correlated with the laboratory results for data analysis.

Data collection will resume later this month. HRD data will be collected over 24 nights. This will be easily analyzed using a process similar to the process currently in use in LU's optics laboratory course [1]. We have adjusted our list of targets to stars with averages temperatures between 3000 and 9200 Kelvin. This will allow our sensors (IR, VIZ, and UVA) to collect the most accurate information. APSL and PEA data will be gathered in daylight, with the Sun as our source (~6500 K). This data should take about 10 days to collect. Because of discovered equipment's sensitivity it now seems much more challenging to collect APSL data from stellar sources, than originally assumed. However, some possible solutions are now under investigation. All data collection is scheduled to be completed by the end of September, and analysis done by October, with plenty of time to re-run any data that seems unreasonable.

Our final report will be submitted by December 31, 2013 with results from all three experiments.

Budget

The initial expenses for the project have been largely composed of supplies for the construction of adapters and light shields to assist in data collection. This has been done with borrowed equipment from the LU Physics Department. This equipment must be returned for courses in the coming semesters, and therefore will be replaced by designated equipment purchased in the next few weeks. The fiber optic cable and accessories, for adaptation to the other experimental equipment, are currently being researched to determine the most effective option available for purchase. Expenses exceeding $2000.00 will be covered by the LU Physics Department. Please see an itemized list in Appendix I.

References

[1] Bahrim, Cristian. "Blackbody radiation." *Optics - PHYS 4480/5480 Laboratory Activities*. Online resource. http://sethi.lamar.edu/bahrim-cristian/Courses/PHYS4480/4480-LABS/4480_lab_2.pdf.

[2] NIST Database. http://www.nist.gov/physics-portal.cfm

[3] Vogler, Sara-jeanne; Townley-Smith, Keeley; Bahrim, Cristian. "Analysis of Atomic Emission Spectroscopy: a refined way to understand the photon concept." *Joint Spring 2013 Meeting of the Texas Sections of the APS,AAPT,SPS Abstract Book.* Online resource. http://meetings.aps.org/link/BAPS.2013.TSS.K1.8

[4] Vogler, Sara-jeanne; Bahrim, Cristian. "Analysis of Atomic Emission Spectra with Applications in the Study of Our Universe." Texas Undergraduate Research Day at the Capitol Abstract Book. Not yet available online therefore see abstract and poster in Appendix II.

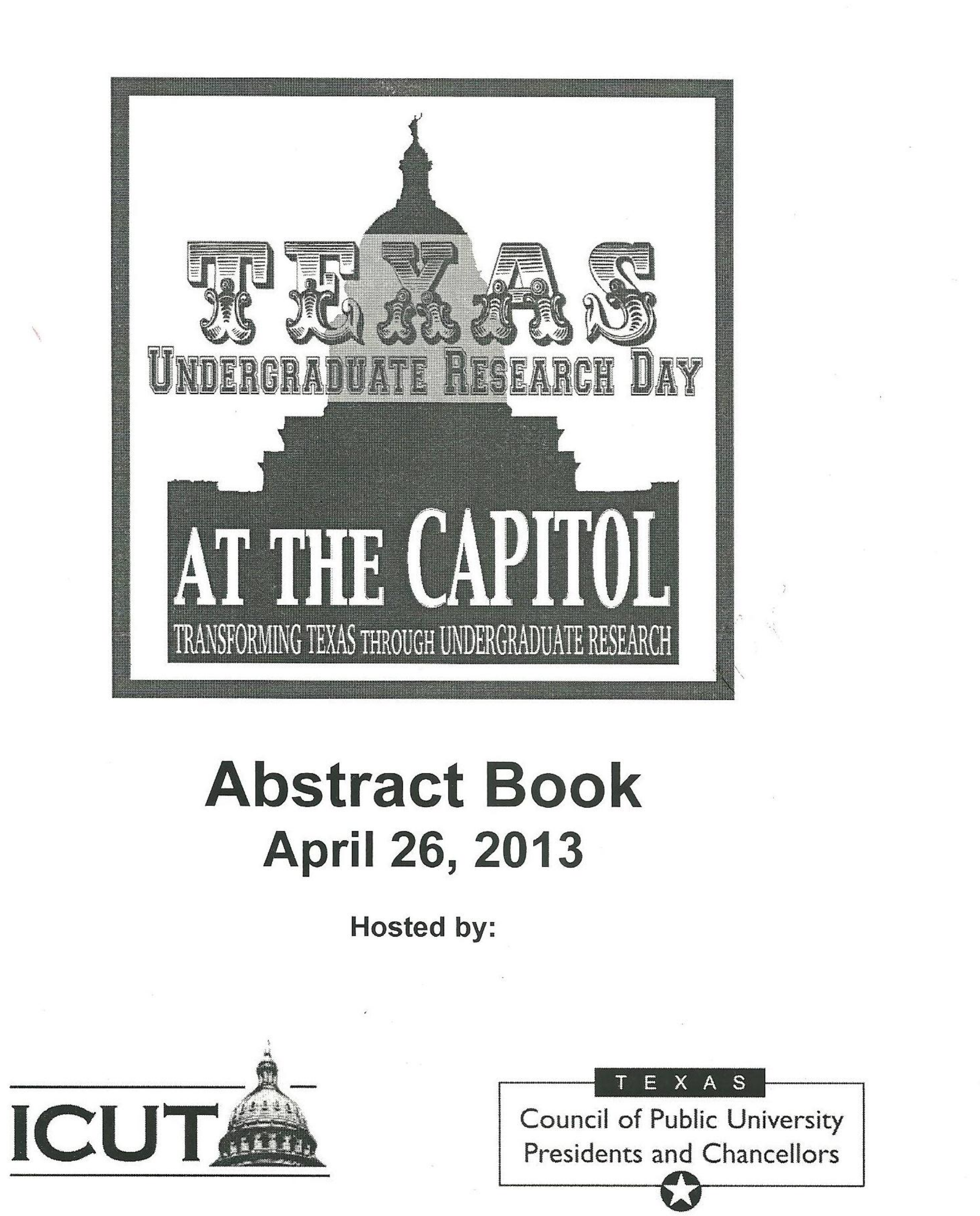
APPENDIX I - Budget

Ledger	
Tripod	$89.99
Eclipse Window Panels	$25.98
Flat Black Spray Paint for bench-tripod adapter	$0.99
1/2" Rubber Lined Clamps for bench-tripod adapter	$4.17
1/2" Round Steel Rod for bench-tripod adapter	$5.63
#8 Hex Nuts for bench-tripod adapter	$0.12
#8x3/4 Bolts for bench-tripod adapter	$1.18
Neon Cord (Rope for hoisting equipment)	$5.96
Heavy Duty Bins (For hoisting equipment)	$65.98
Mobile Clear Box (Rope for hoisting small equipment)	$12.99
Total	**$212.99**

Budget	
Basic Optics Prism Spectrophotometer Kit (OS-8544)	$355.00
Basic Optics Prism Mount (OS-8543)	
Basic Optics Black Body Light Source (OS-8542)	
DataStudio Experiment Setup CD	
Aperture Bracket (OS-8534A)	$89.00
Rotary Motion Sensor (CI-6538)	$189.00
Infrared Sensor (CI-6628)	$219.00
UVA Light Sensor (CI-9784)	$165.00

High Sensitivity Light Sensor (CI-6604)	$139.00
2-Axis Fiber Alignment Mount w/ Standard Kinetic Movement (Edmund Optics #55-476)	$399.00
Fiber Optic Cable	~$37.00
Play Dough	~$50.00
Meade 1.25" eyepiece	$29.99
Basic Optics Polarizer Set (OS-8473) Two Polarizer Disks Optics Holder	$59.00
Optics Bench Rod Clamp - set of 2 (OS-8479) x2	$58.00
Total	**$1828.99**

Appendix II - Analysis of Atomic Emission Spectra with Applications in the Study of Our Universe


TEXAS
UNDERGRADUATE RESEARCH DAY
AT THE CAPITOL
TRANSFORMING TEXAS THROUGH UNDERGRADUATE RESEARCH

Abstract Book
April 26, 2013

Hosted by:

ICUT

TEXAS
Council of Public University
Presidents and Chancellors

Figure 5: Abstract Book Cover [4]

10. Lamar University
Sara-Jeanne Vogler
ANALYSIS OF ATOMIC EMISSION SPECTRA WITH APPLICATIONS IN THE STUDY OF OUR UNIVERSE
Faculty Advisor: Cristian Bahrim, PhD

Spectroscopic analysis of atoms and simple molecules reveals their atomic structure. The analysis of emission lines is possible with PASCO® equipment by allowing the pressure broadening effect to enlarge these lines to a few nm in width. The photon emission obeys the selection rules for orbital angular momentum, spin, and parity. One can identify the constituents of matter by finding the characteristic photons emitted by gaseous discharges. From the relative intensity of the emission lines, de-convoluted from the Maxwell- Boltzmann distribution in discharges at thermal equilibrium, the effective temperature of atoms and their average speed is found. From the Lorentzian profile of each photon the lifetime of the atomic states can be estimated. From the FWHM the uncertainty in the energy value of the atomic excited states is found. This theoretical knowledge can be applied to absorption spectra as well as precisely identifying wavelength with the goal to determine the life cycle of bright stars, for studying the influence of the atmospheric constituents on the stellar and solar spectra, and also for testing the effects of optical instruments on astronomic measurements.

11. Lubbock Christian University

Figure 6: Abstract [4]

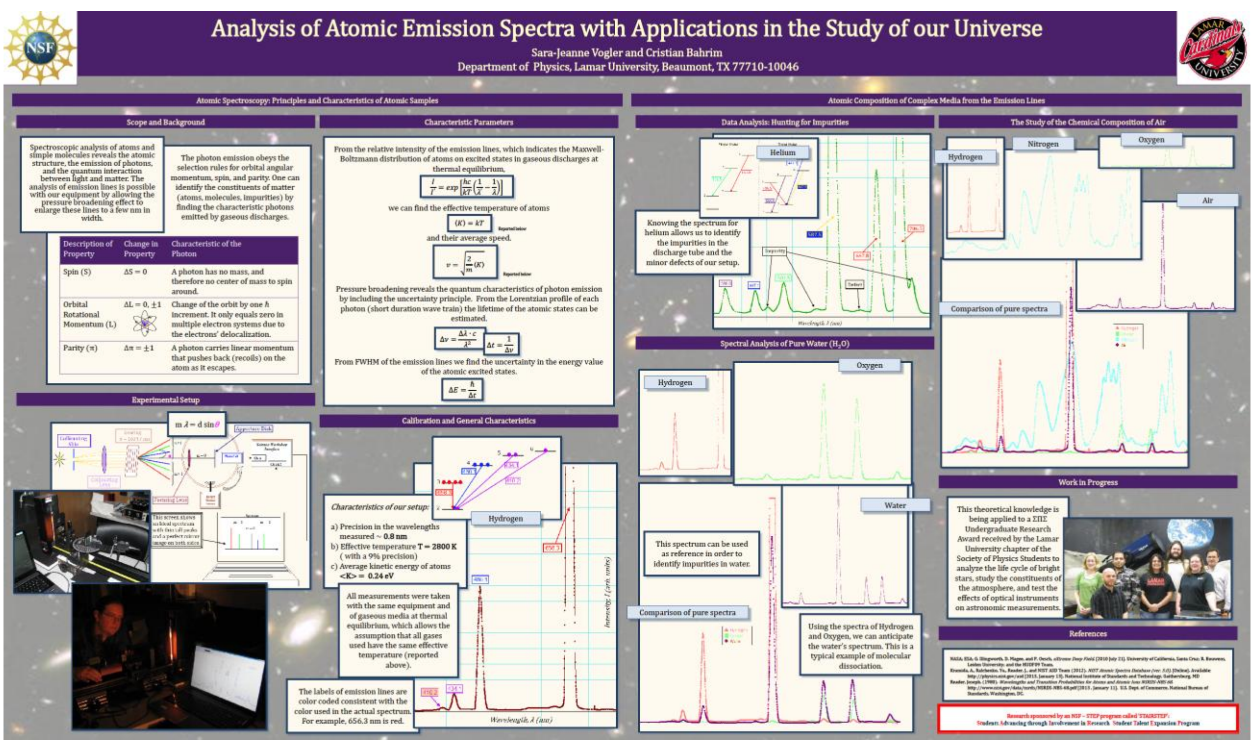


Figure 7: Poster referencing this ongoing research [4]