Developing interactive astrophysics labs for High Schools

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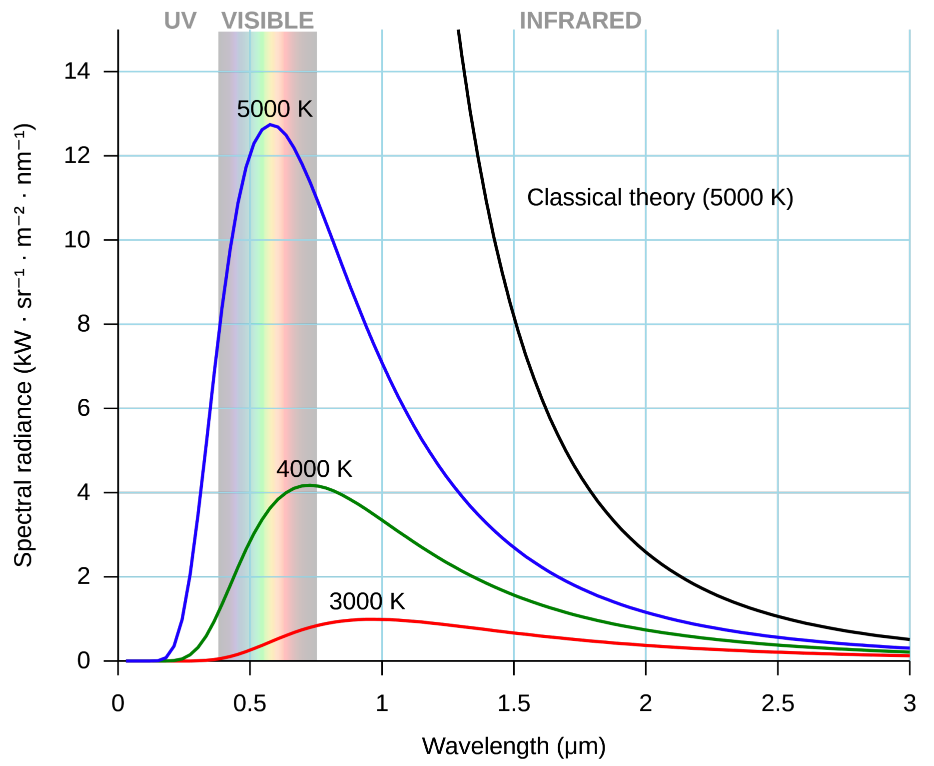
THE BAXTER CENTER FOR SCIENCE EDUCATION

Motivation

STEM education is often supplemented with lab experiments to demonstrate core concepts, assist in learning, and expose students to the scientific method. However, astronomy focused labs remain largely inaccessible due to the specialized equipment necessary to perform observations and the domain expertise required to properly interpret and analyze the results. Our goal is to produce an accessible astronomy lab for multiple entry levels, which connect astronomy concepts to student's real word experiences.

Background

Stars undergo nuclear fusion in their core producing energy which supports against gravitational collapse. Our Sun is on the Main Sequence, stably burning hydrogen to helium which will continue for billions of years until it evolves into a giant star with a large radius. As all stars evolve, their surface properties change, resulting in measurable features in their emitted light. In astronomy, we exploit these properties and our understanding of light to study a myriad of subjects including stellar evolution, exoplanets, and cosmology.



Planck's Law

$$B(\nu, T) = \frac{2h\nu^3}{c^2} \frac{1}{\exp\left[\frac{h\nu}{kT}\right] - 1}$$

Wien's Law: $\lambda_{\text{peak}} = b/T$

https://en.wikipedia.org/wiki/Black-body_radiation

Measuring the temperature of the Sun

Description: Students take their own visible spectrum of the Sun with a provided spectrometer and derive its temperature assuming it emits like a Blackbody characterized by Planck's Law.

Equipment: visible spectrometer (SMA-E by ThunderOptics, R=366), laptop to run software

Analysis: Depending on the level of depth desired by the teachers, students may locate the wavelength of peak emission or try to use a least squares method with the full Planck function.

Core concepts: Next Generation Science Standards (NGSS) - HS-PS3-2 Energy, HS.Waves and Electromagnetic Radiation, HS.Space Systems, and HS-ESS1 Earth's Place in the Universe.

- Nuclear physics, quantum mechanics, thermodynamics
- Stars and stellar evolution, supernovae, compact objects

Success & Challenges:

- Finding an affordable spectrometer v.s. DIY options
- Building lesson plans and analysis for multiple entry levels
- Real data analysis present open questions (atmosphere,)

The Baxter Box Program supports teachers from the Chicago land area to rent out lab equipment and lesson plans at no cost, with the goal of increasing access to STEM education for underserved schools and their communities.

Our astronomy lab was built around the framework of the Baxter Box Program such that a single lesson plan and set of equipment could be used by more than one school, alleviating the financial cost of purchasing a spectrometer.

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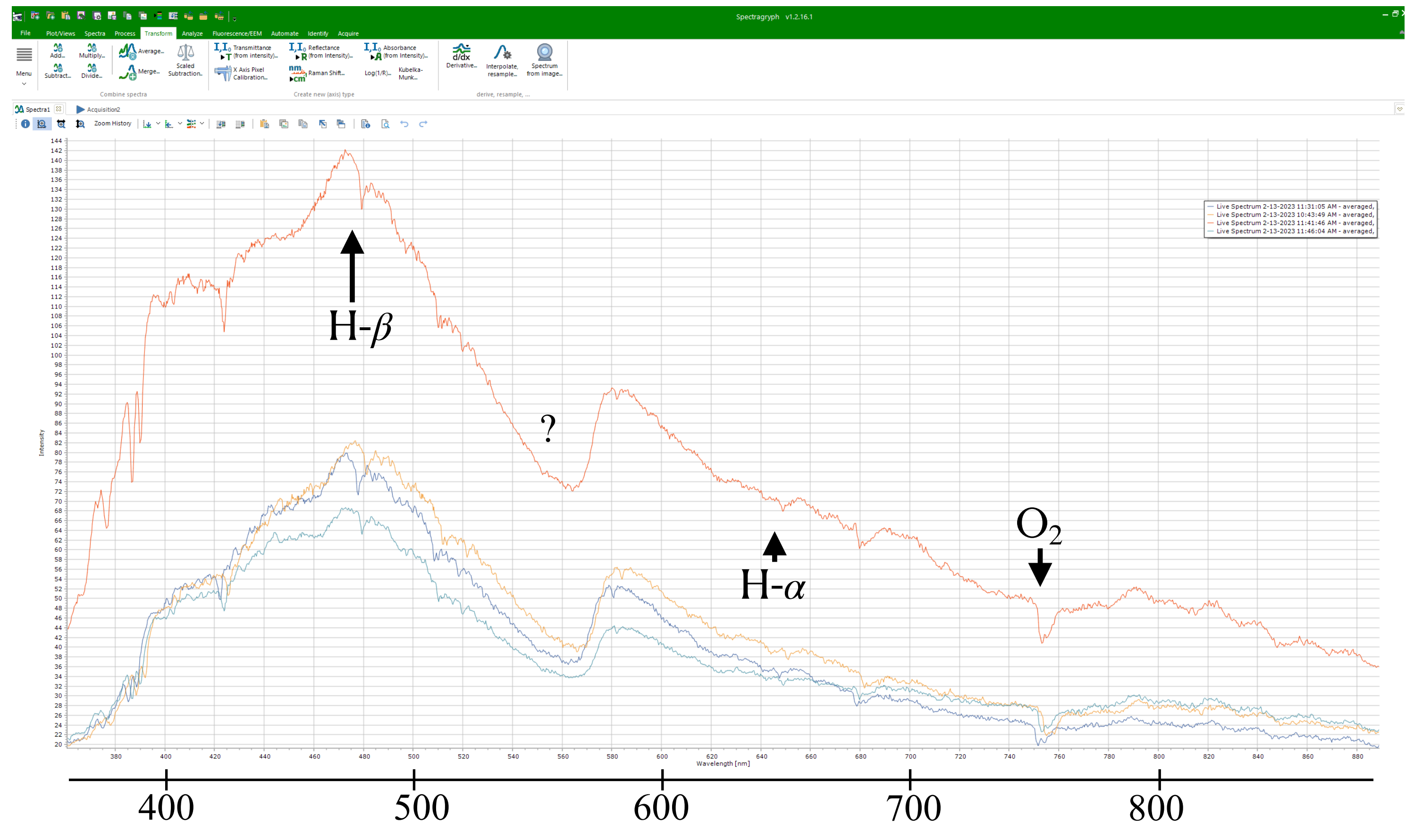

Figure 1: Visible spectra of the Sun taken with our spectrometer by manually pointing the instrument to the sky. Red and yellow data were taken outside while blue data were taken through a window. We note the slight shift in wavelength solution for different emission and absorption lines is due to manual pointing of the instrument without proper focusing optics to guide the light into the spectrometer.

Future directions

- Develop Google Colab analysis pipelines to analyze data
- Seek feedback on the lesson plan and iterate
- Integrate fully into the Baxter Box Program
- Considering taking data from the Dearborn Telescope to analyze spectra of other stars

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