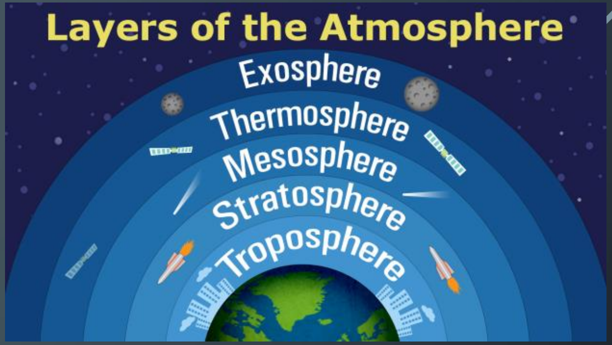
SOLAR SPECTROSCOPY AND A MINIATURE SPECTROMETER

JEFF KINDALL

HARBOR
High Altitude Reconnaissance Balloon for Outreach and Research

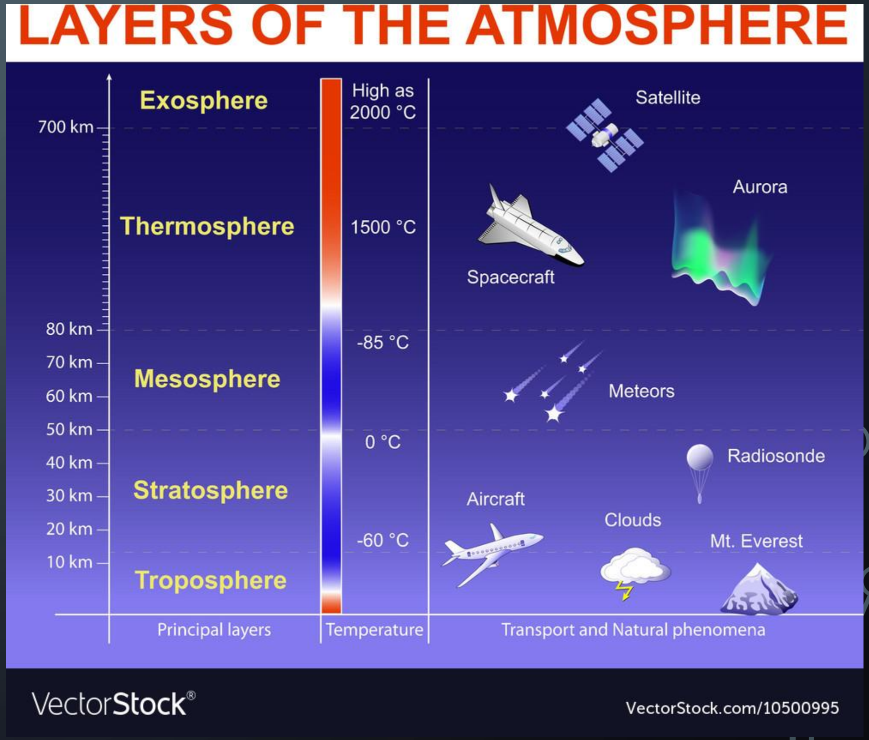
https://harbor.weber.edu/



https://sciencestruck.com/atmosphere-layers-in-order

WHAT DO WE MEASURE?

- Atmosniffer
  - O3
  - NO2
  - Particle Counter
- Mini-MSA
  - Sea salt
  - Volcanic ash
- Ozonesonde



https://www.vectorstock.com/royalty-free-vector/layers-of-the-atmosphere-vector-10500995

NASA PANDORA PROJECT

https://pandora.gsfc.nasa.gov//index.html

NASA Pandora Project

Welcome to the NASA Pandora project, part of the Pandonia Global Network. This project uses spectroscopy to study ultraviolet (UV) and visible wavelengths of light to determine the composition of the atmosphere and its interactions with Earth's environment.

The Pandora Spectrometer System was designed to specifically look at levels of ozone, nitrogen dioxide and formaldehyde in the atmosphere. What makes the Pandora unique from other ground-based networks at NASA is that it can measure total column profiles, observing different layers of the atmosphere at once.

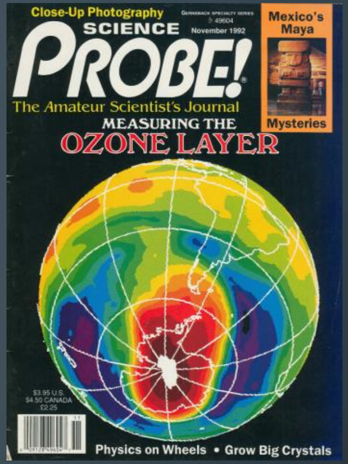
Goals of the Pandora Project

- To develop high-quality, low-cost spectrometer systems with research-grade performance.
- To deploy and distribute a network of systems to measure air quality and validate satellite retrievals.
- To develop a database of total column atmospheric profiles on a worldwide scale.
- Connect communities with standardized data products to support their research goals.

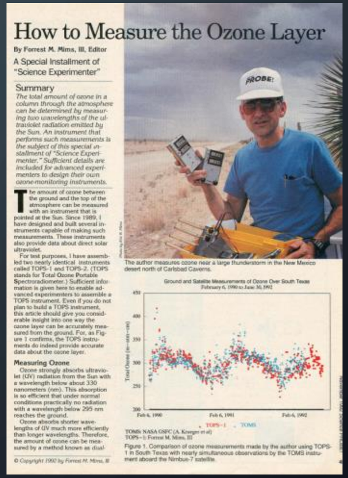
The Pandora Instrument

Pictured above is the most recent model of the Pandora being tested at the Mauna Loa Observatory in Hawaii. Before the system is sent off on scientific field campaigns, it is calibrated and tested in the lab at GSFC. The team ensures that all parts of the system are working properly by monitoring its performance.

INITIAL GOAL: MEASUREMENT OF O_3 (OZONE)



Forrest MIMs MicroTop II


How to Measure the Ozone Layer

- O3 is a atmospheric gas that absorbs UV radiation from the Sun, thus protects living organisms on Earth.
- Specific Wavelengths
- Expensive single purpose LEDS
- Limitation: One gas (ozone)
- Thus, alternate approach
- Take-aways: Total column measurement
- Integrated optics to processor concept.

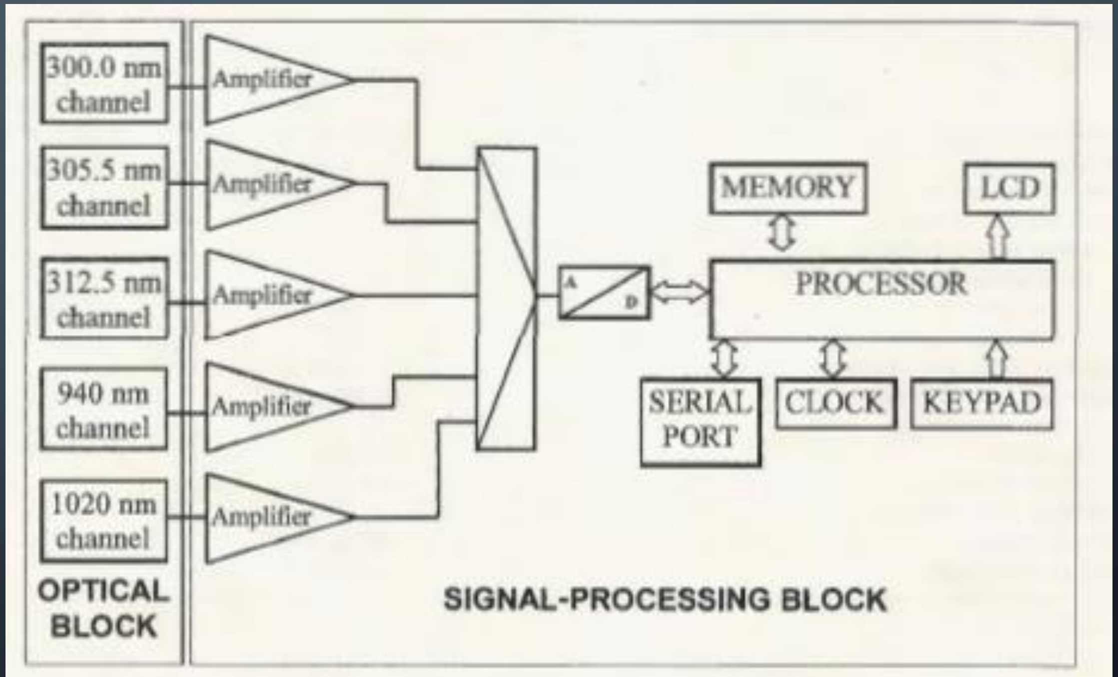


Figure 1. MICROTOPS II operational block diagram.

A MINIATURE SPECTROMETER

Specs

- Finger-tip size: 20.1 × 12.5 × 10.1 mm
- Weight: 5 g
- Spectral response range: 340 to 780 nm
- Spectral resolution: 15 nm max.
- Hermetic package: High reliability against humidity

HAMAMATSU
PHOTON IS OUR BUSINESS

Mini-spectrometer

[Micro series] | C12666MA

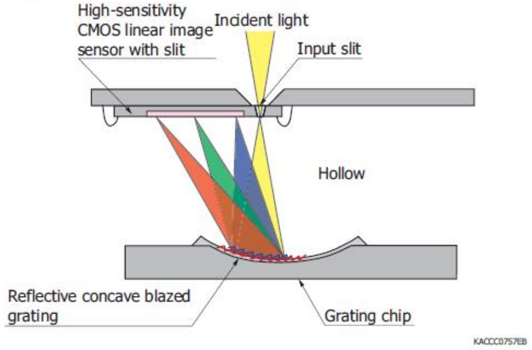
Finger-tip size, ultra-compact spectrometer head integrating MEMS and image sensor technologies

The C12666MA is an ultra-compact (Finger-tip size) spectrometer head developed based on our MEMS and image sensor technologies. The adoption of a newly designed optical system has achieved a remarkably small size, less than half the volume of the previous mini-spectrometer MS series (C10988MA-01). In addition, the employment of hermetic packaging has improved humidity resistance.
This product is suitable for integration into a variety of devices, such as integration into printers and hand-held color monitoring devices that require color management. It is also suitable for applications that collaborate with portable devices, such as smartphones and tablets.

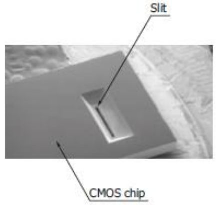
Optical component layout

Besides a CMOS image sensor chip integrated with an optical slit by etching technology, the C12666MA employs a reflective concave blazed grating formed by nanoimprint. In addition, the glass used in the light path of the previous C10988MA-01 is not used in the C12666MA, making it extremely compact.

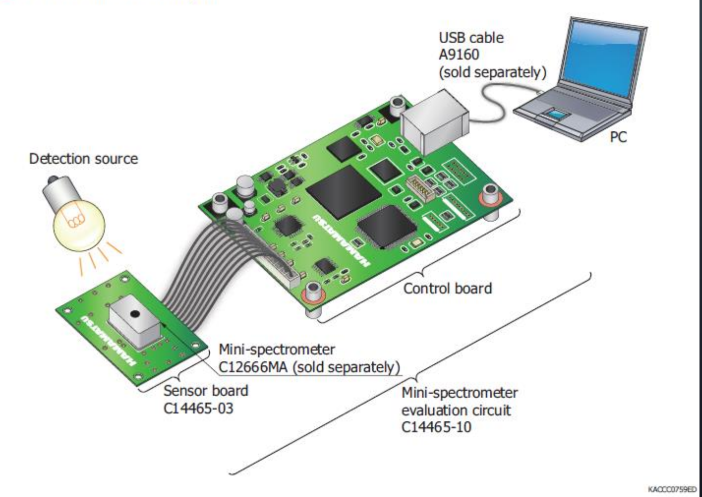
Structure



CMOS linear image sensor with a slit [Incident light side (back of chip)]



Connection example



Breakout Board

PROGRAMMING: HOW TO GET IT GOING?

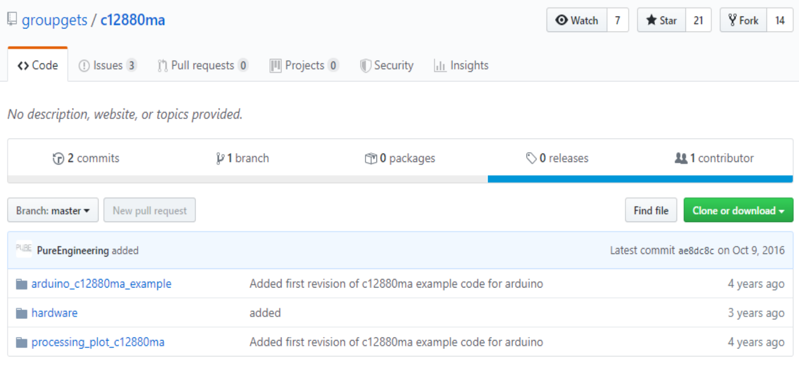
Code available for programming spectrometer

Program Flow

- Leonardo

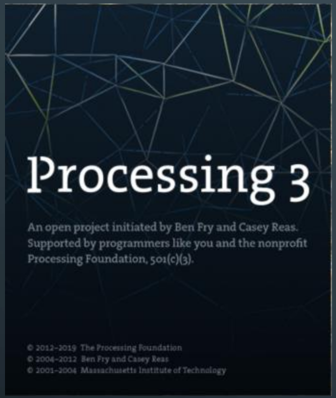
https://store.arduino.cc/usa/leonardo

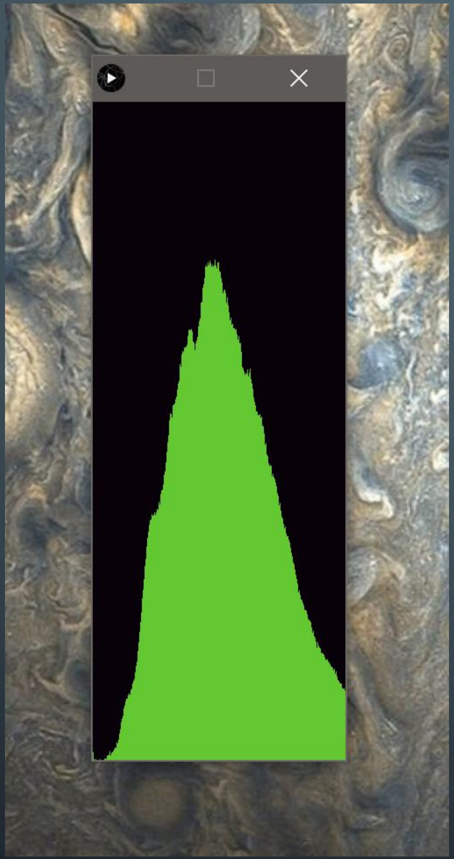
Clunk Master 5000



GRAPHICAL DISPLAY

- Poor quality





Pin connections

Make electrical connections to an external circuit using leads.

Pin no.	Symbol	Name	I/O	Description
1	Vdd	Supply voltage	I	Image sensor power supply: 5 V
2	Video	Video output	O	Video output signal
3	GND	Ground	-	Sensor ground
4	CLK	Clock pulse	I	Sensor scan sync signal
5	Case	Case	-	Case connection terminal
6	NC		-	No connection
7	ST	Start pulse	I	Start pulse
8	NC		-	No connection
9	Gain	Gain	I	Image sensor: Gain setting
10	EOS	End of scan	O	Sensor scan end signal

Can we improve it?

Pixel resolution is a limiter: only have 288 pixels

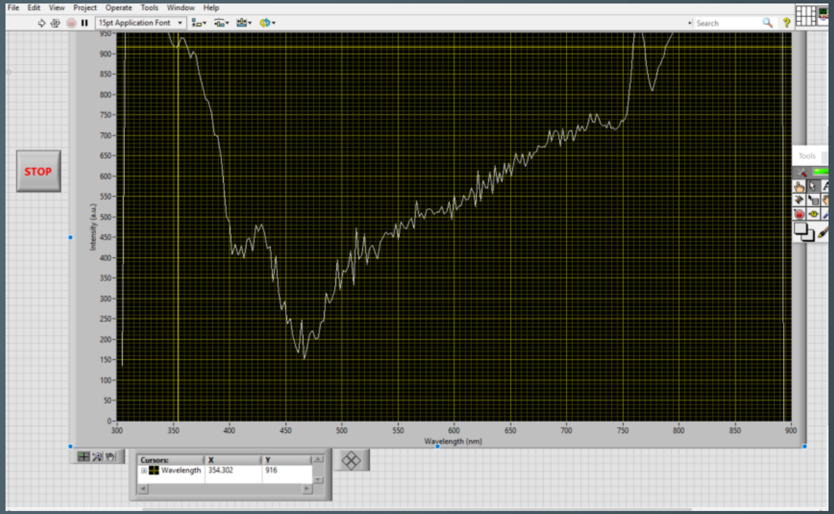
What to use?

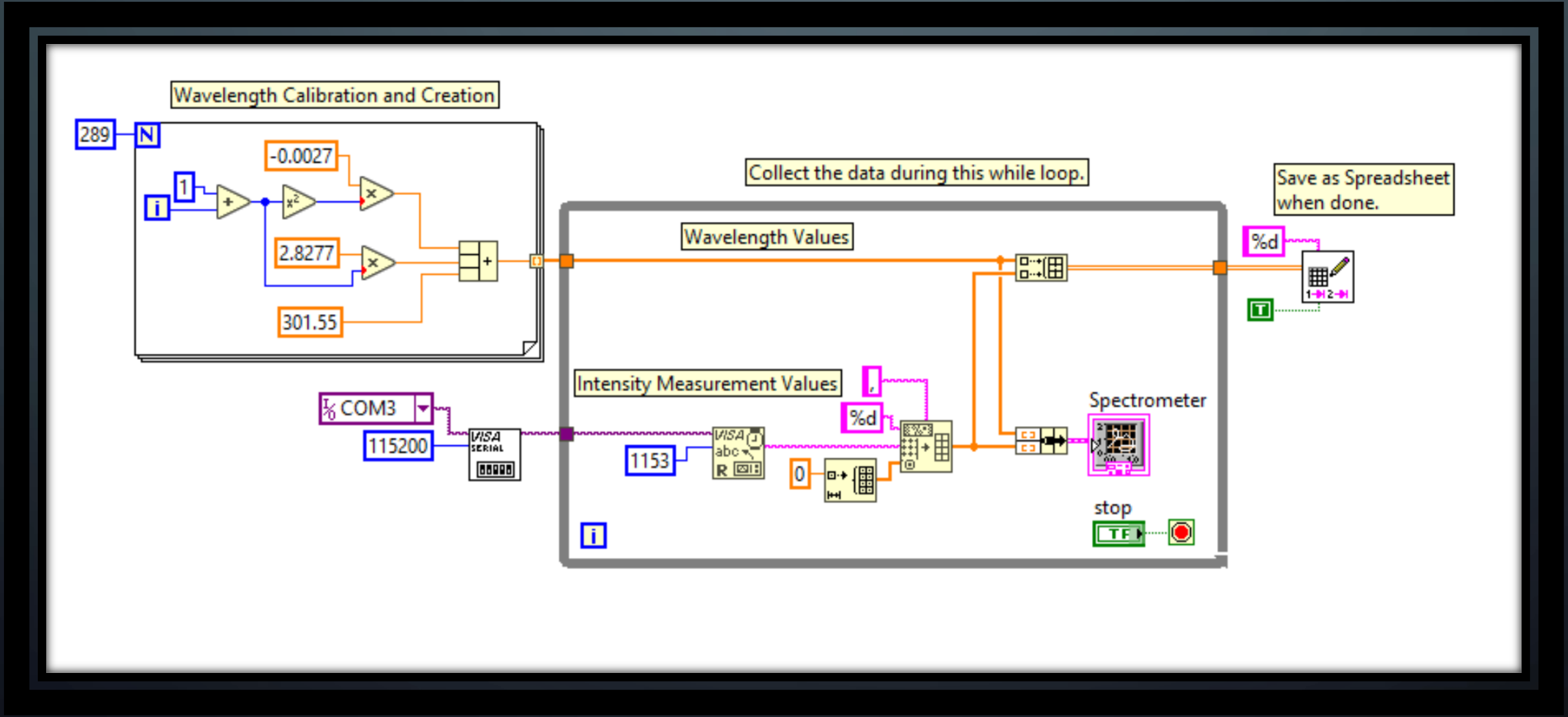
Python?

Labview?

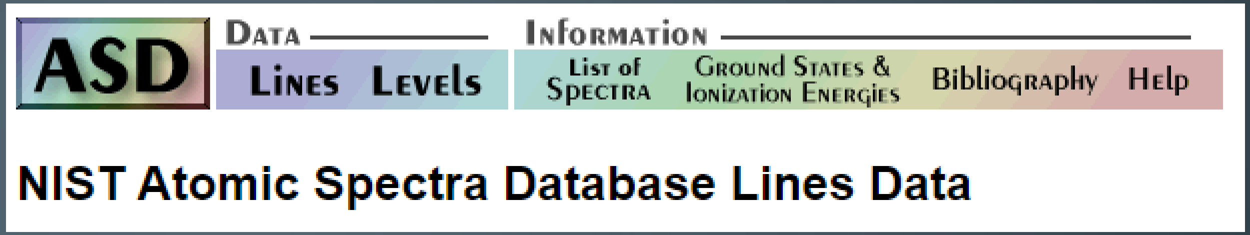
LABVIEW

Display

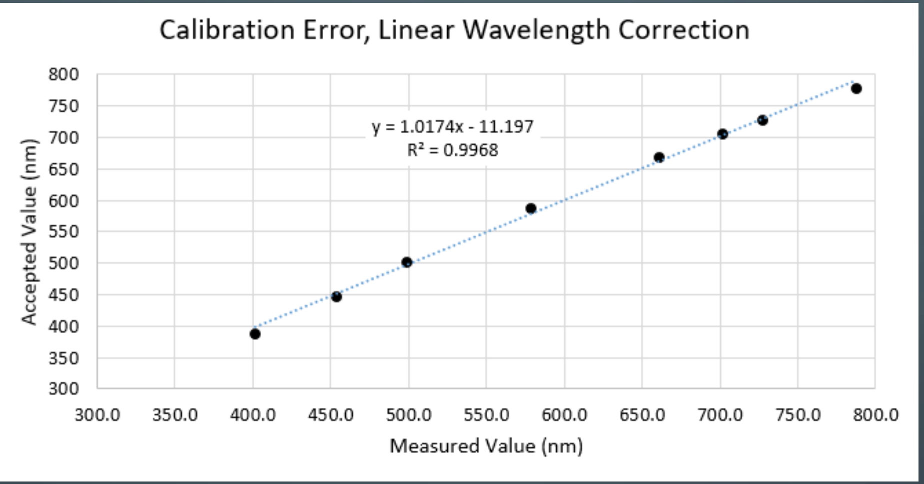


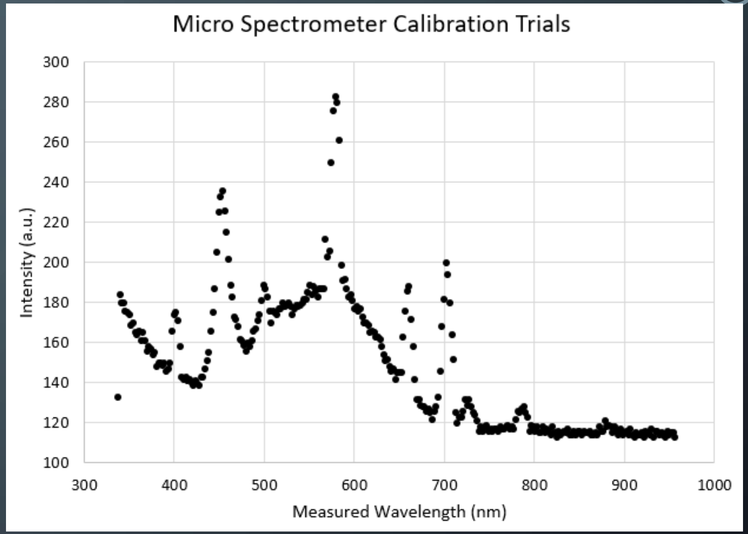


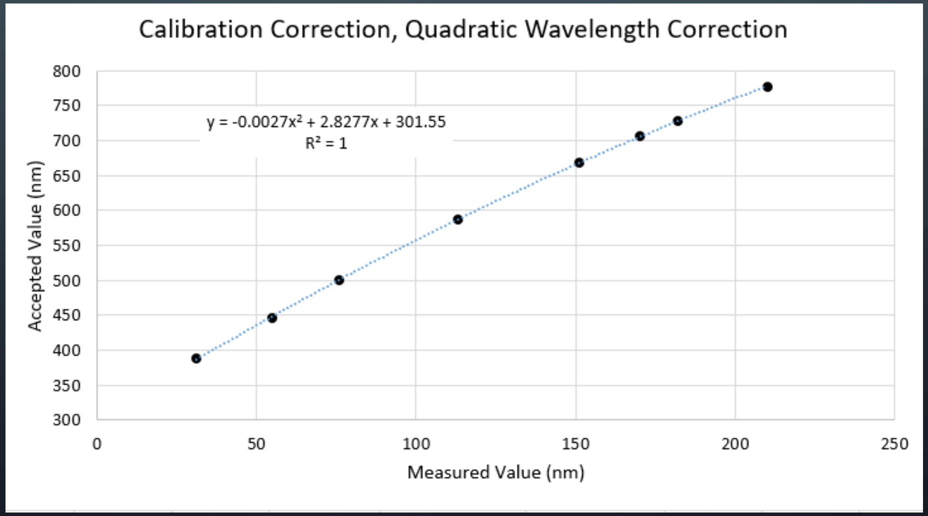
CALIBRATION TO KNOWN SPECTRAL LINES

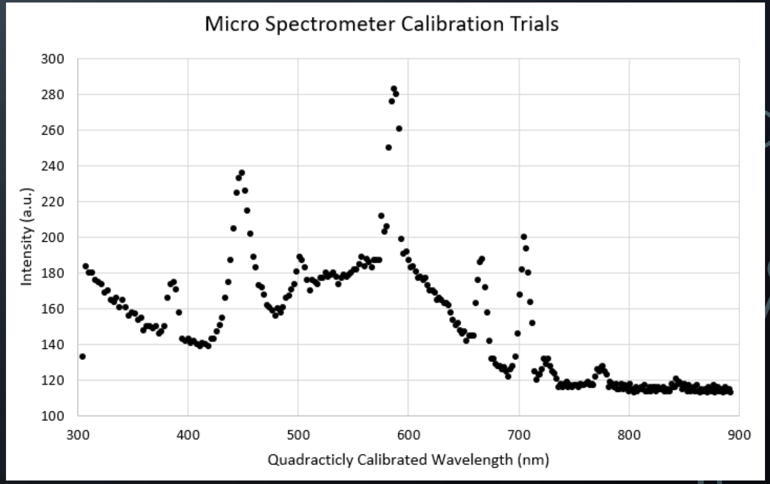


- Hg and He data collected with Hamamatsu micro-spectrometer.
- X = the data point number
- Wavelength error down to 1.22 nm standard deviation and 1.42 nm rms.
- Now precise enough for proper application.

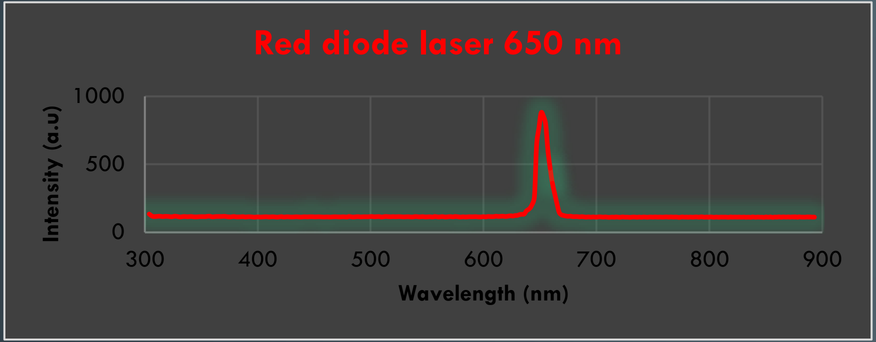


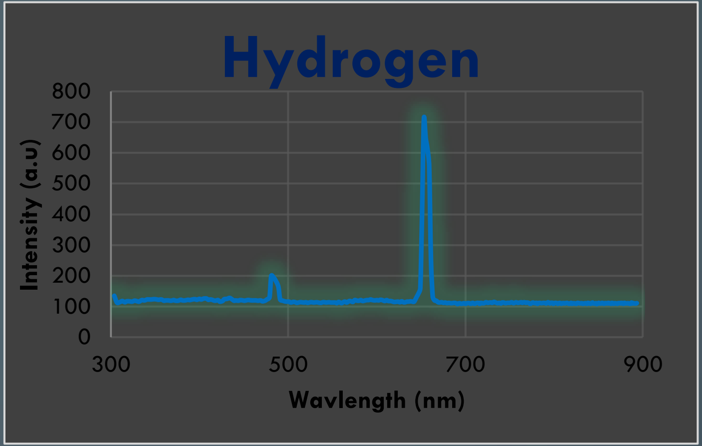


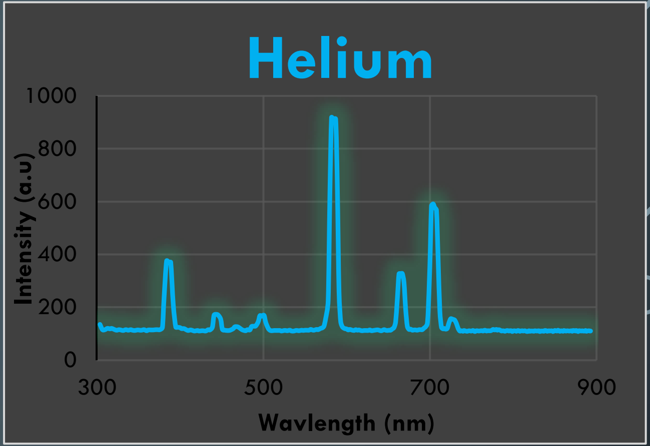


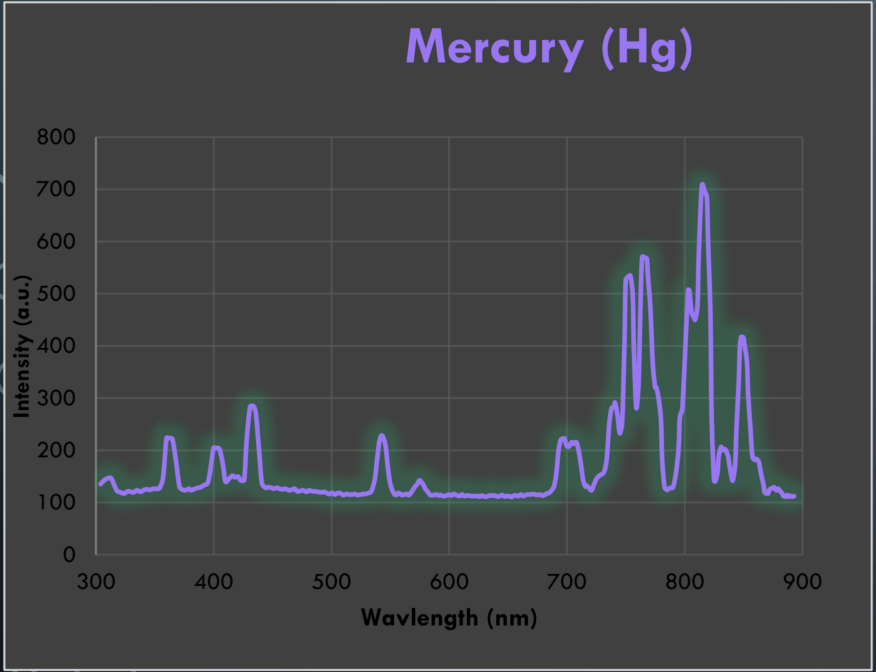


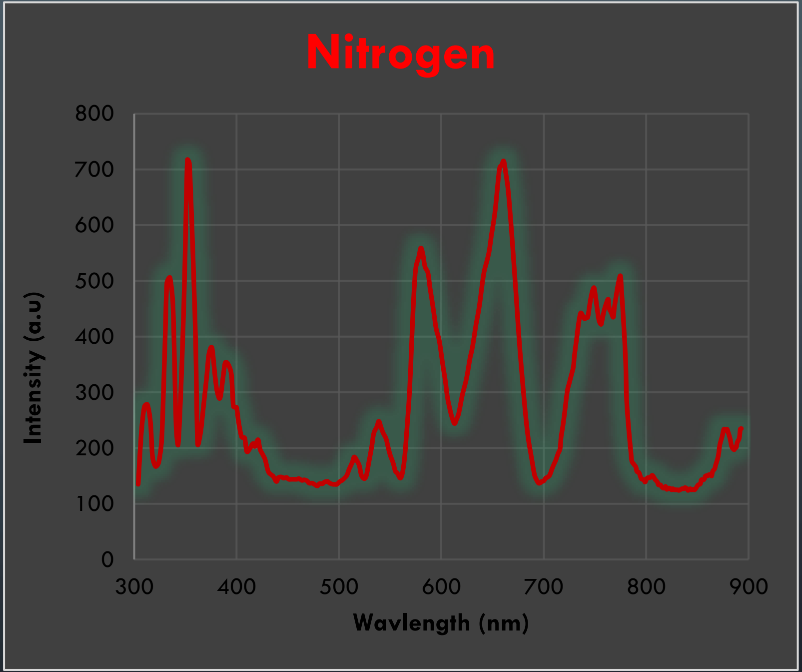
EMISSION SPECTRA

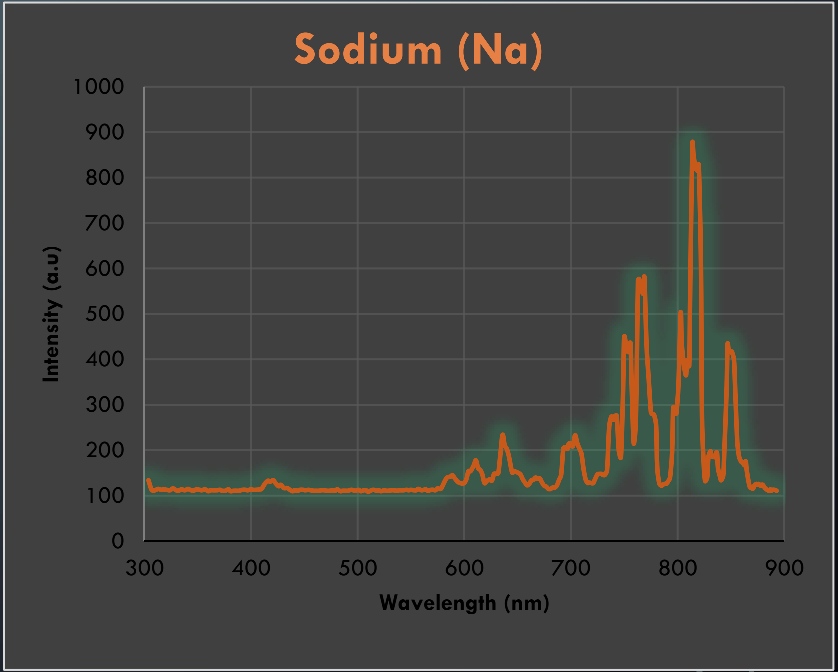












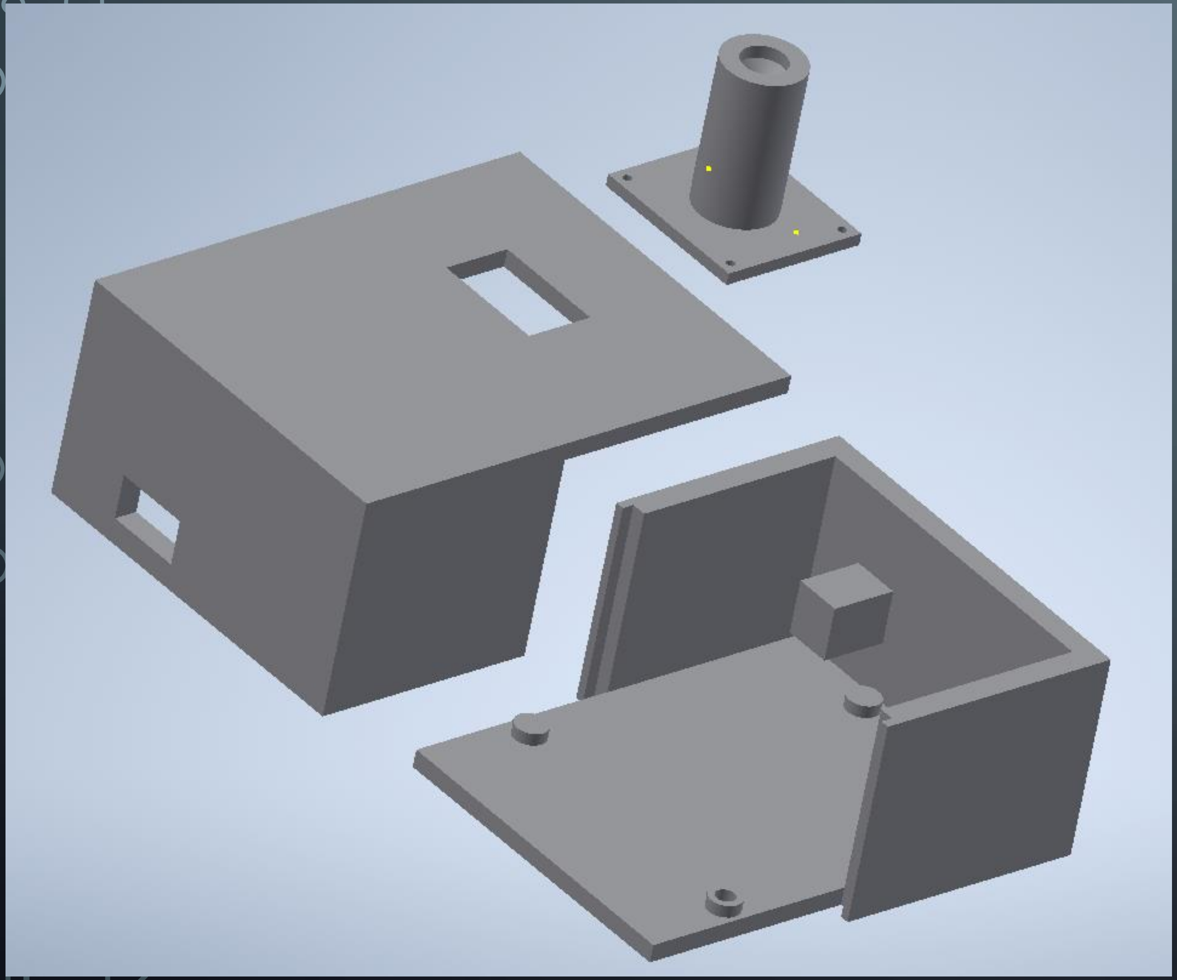
DESIGN CONSTRUCTION

Tight fit design for ease of use and light interference.

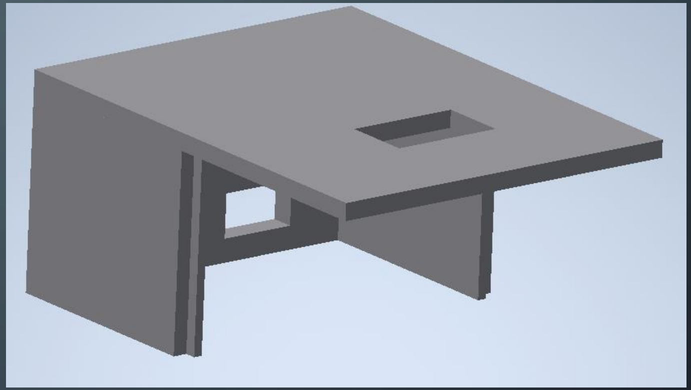
Early models were quite large

Final Weight: approx. 94 g

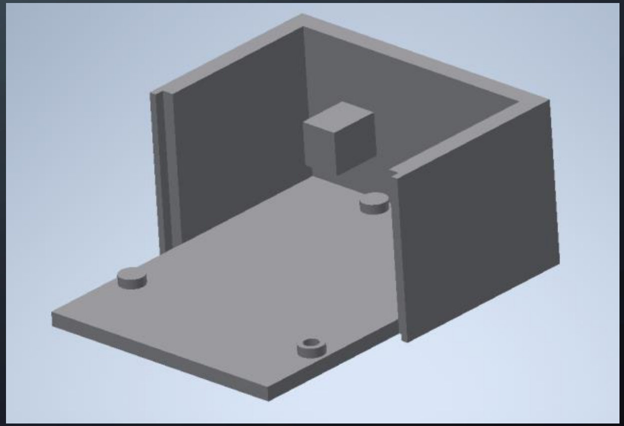
Master Assembly



- The Lid



The Base

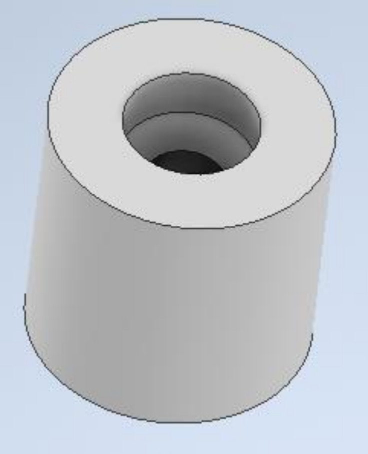


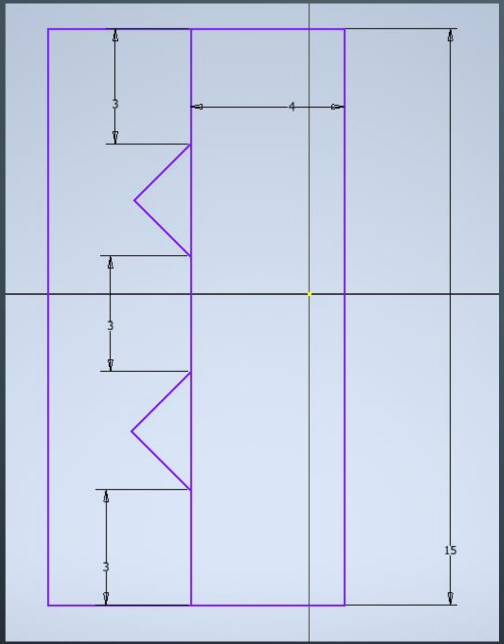
DESIGN PROCESS

COLLIMATORS

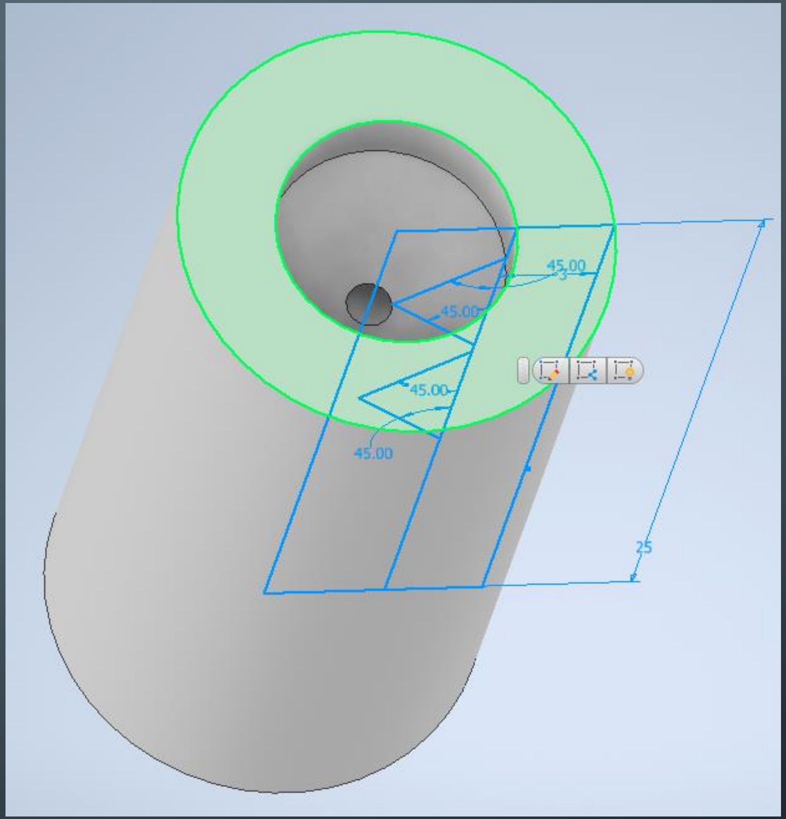
- Various models for different purposes

Internal Bevels help to collimate light

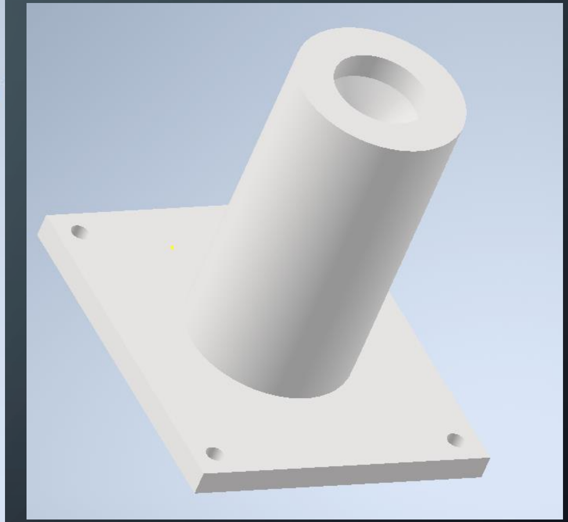




Revolution about z-axis



Pin-hole design for solar spectrum: Sensitivity

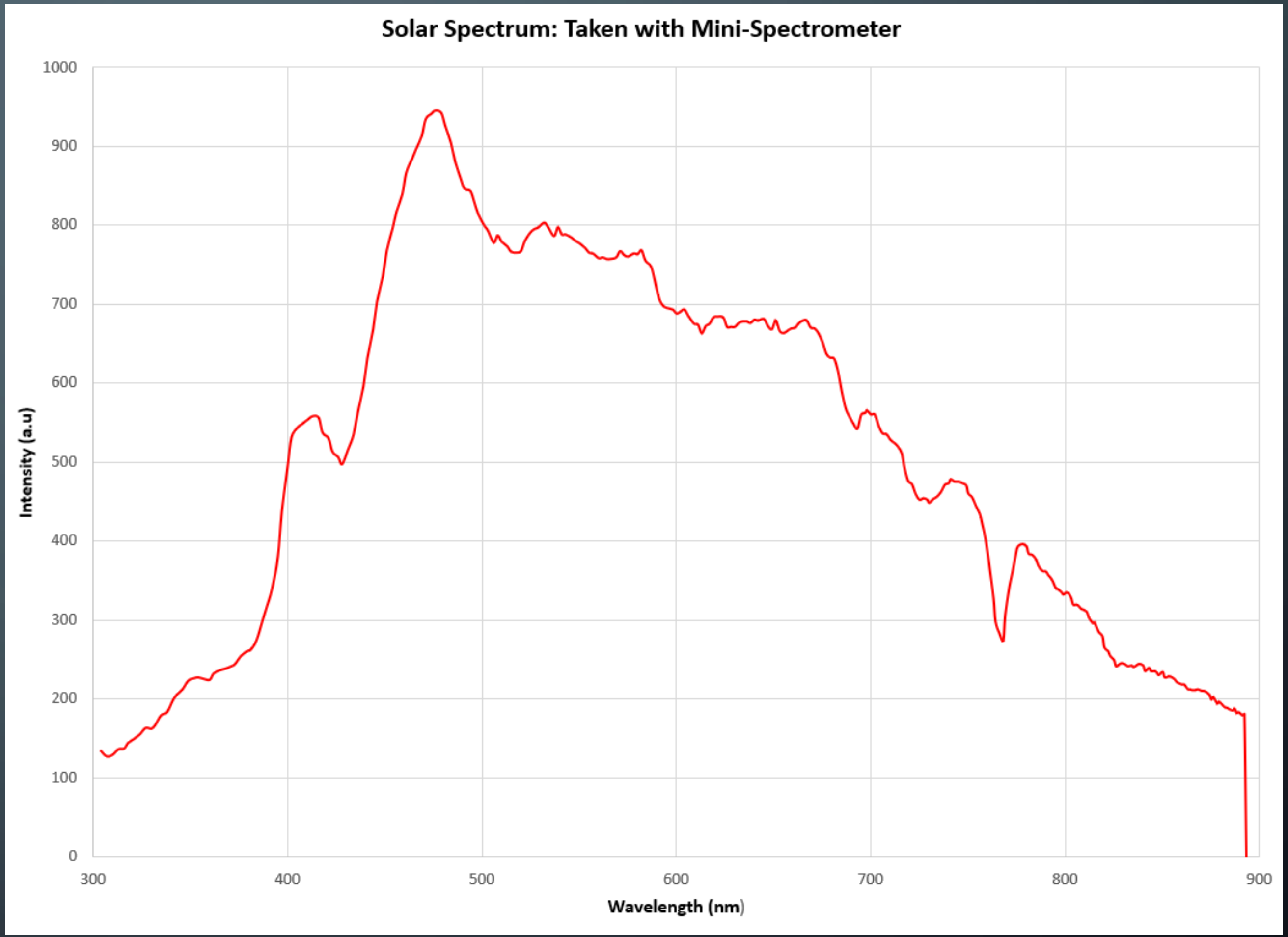


Finding the optimal design for solar observation

WE HAVE SPECTRA!

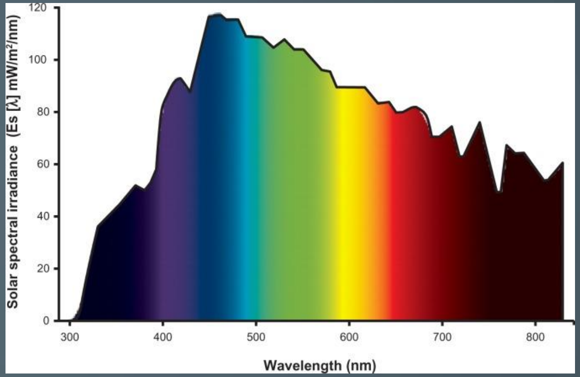
- Able to capture solar spectrum with new collimator design.
- Tried different optical density filters, to no avail.

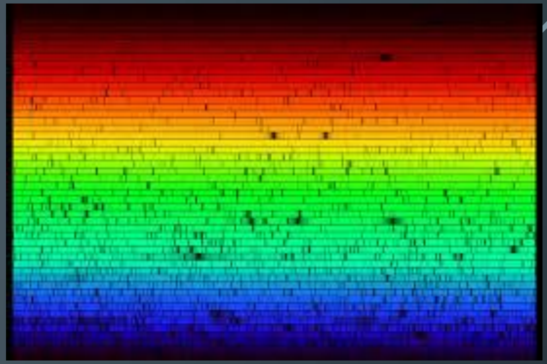
Compare to other spectrometer



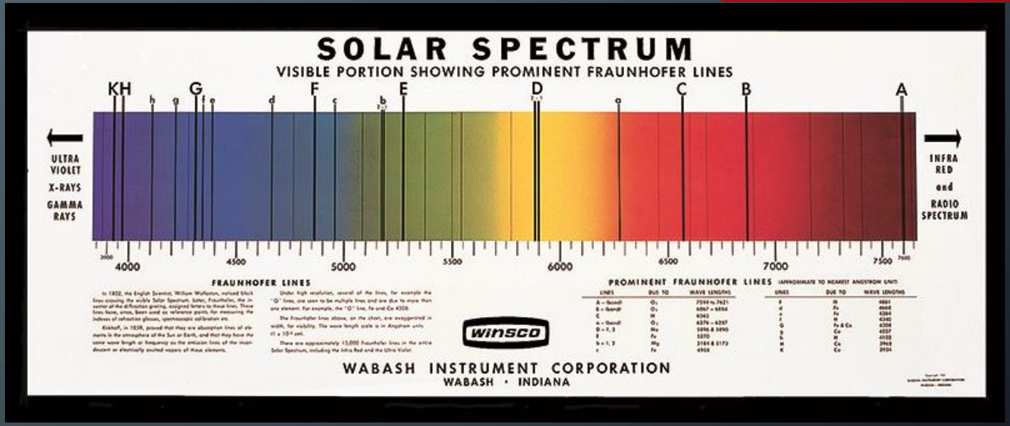
BASIC PRINCIPLE BEHIND METHOD

- Looking at the difference between the theoretical solar spectrum and measured spectrum caused by absorption of trace gas species.

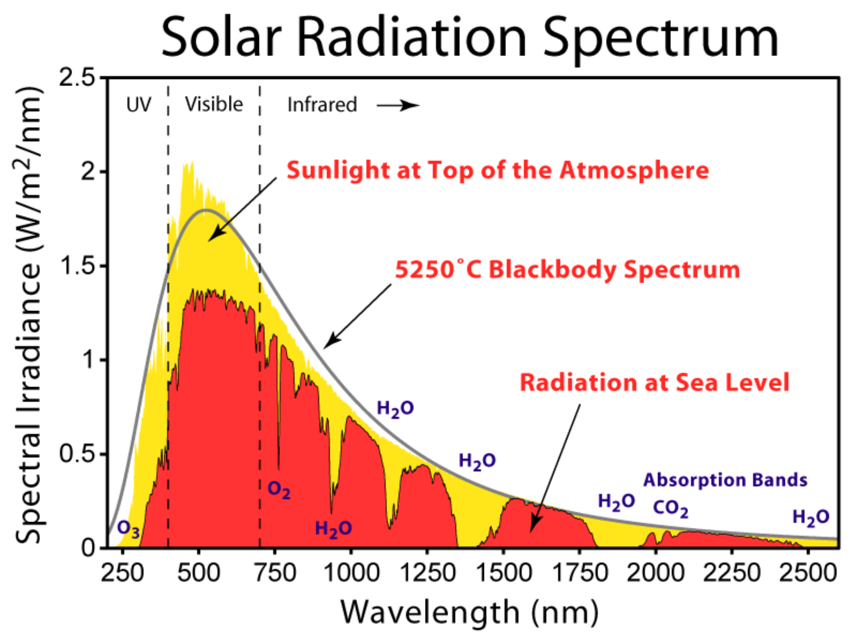


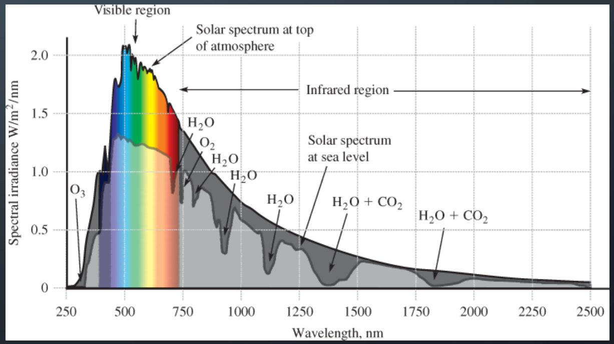


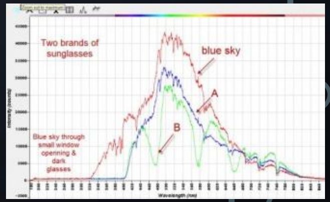
https://www.extremetech.com/extreme/167878-every-color-of-the-suns-rainbow-why-are-there-so-many-missing



https://winsco.com/product/solar-spectrum-chart/

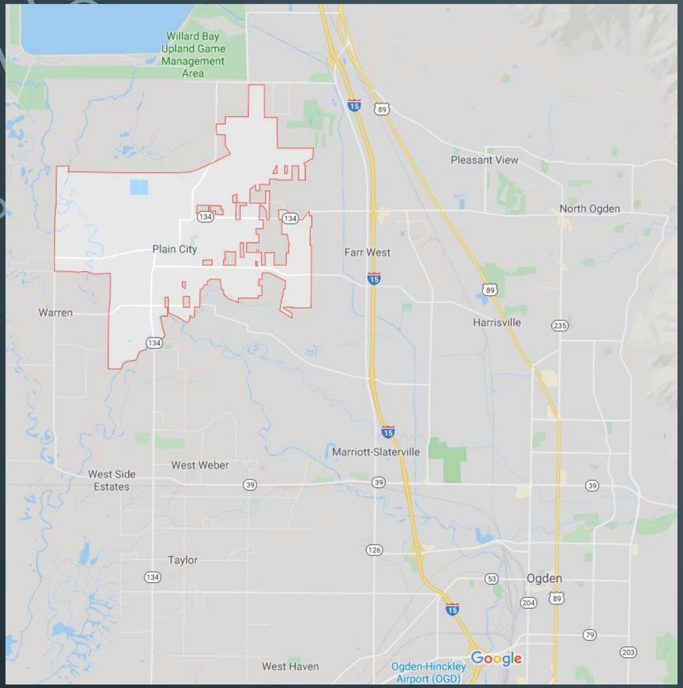


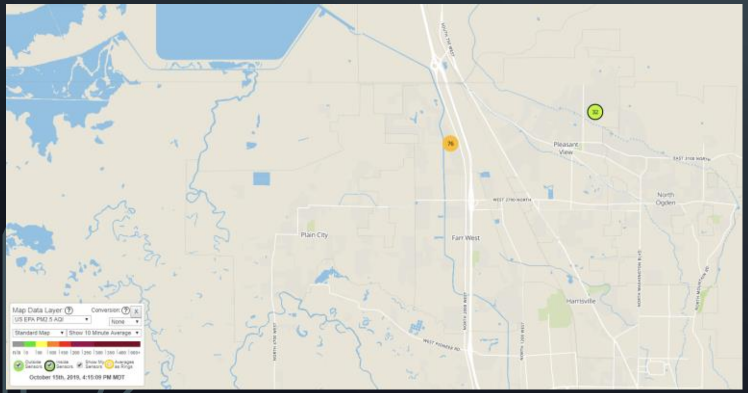


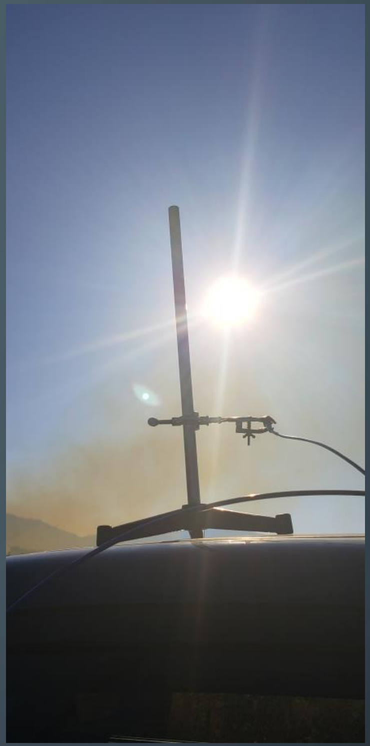


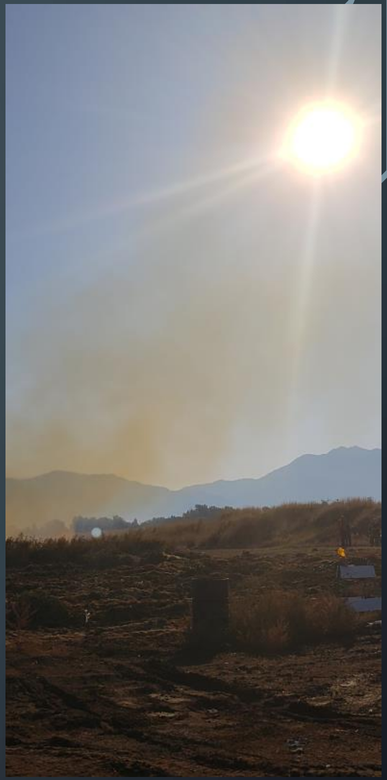
https://commons.wikimedia.org/wiki/File:Solar_Spectrum.png

CONTROLLED BURN





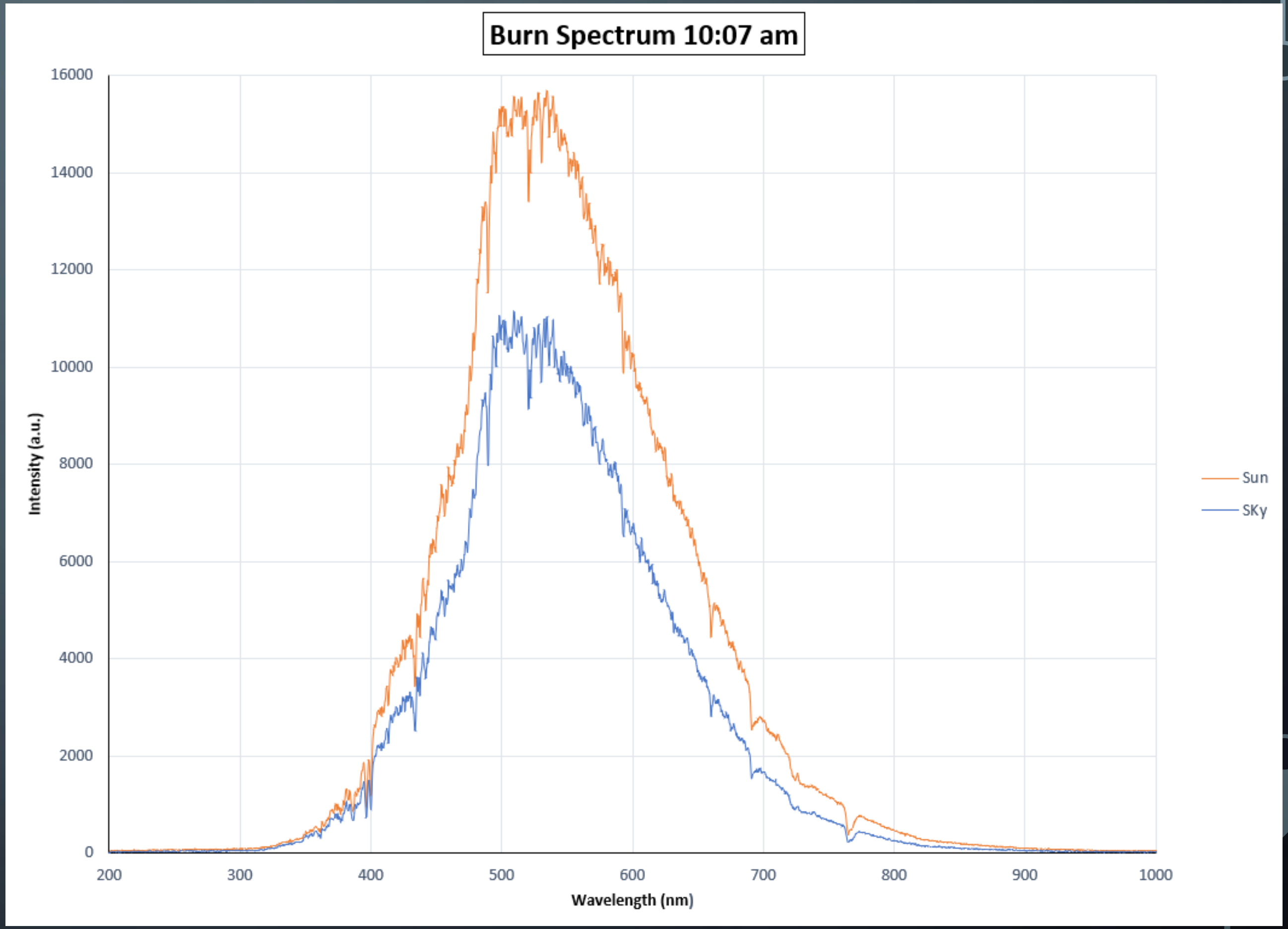




METHOD

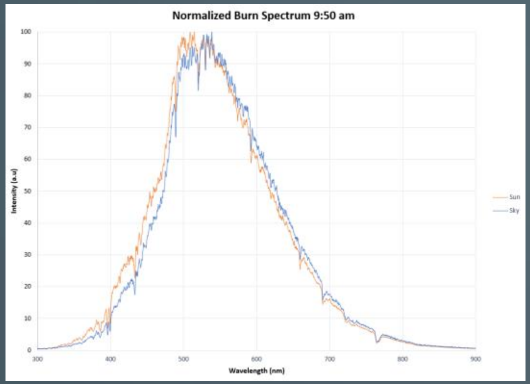
Take spectra shot: one direct Sun, one off angle.
Take corresponding picture for comparison

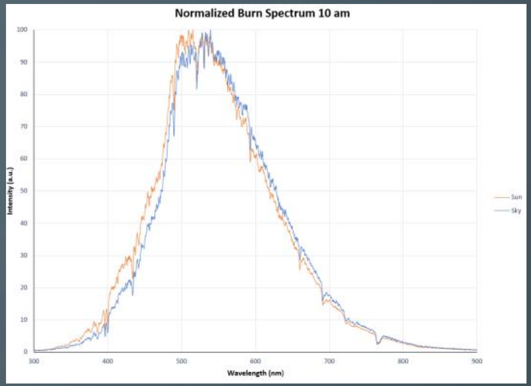
- Setup

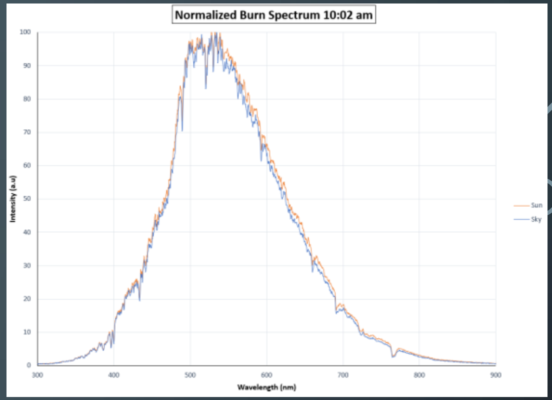


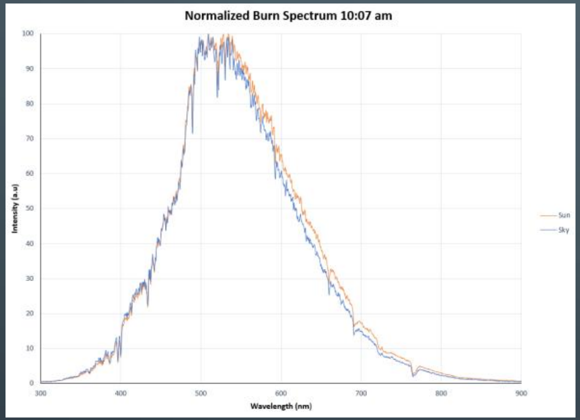
CONTROLLED BURN PROGRESSION DATA

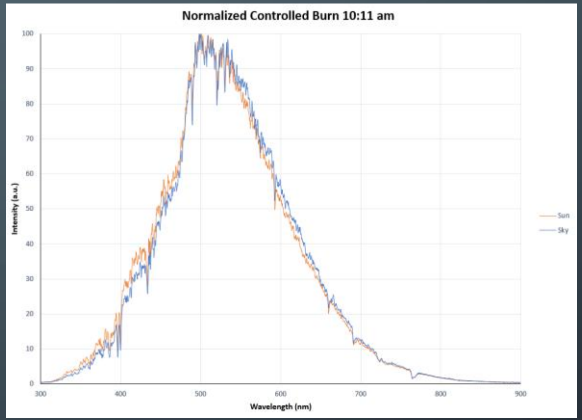
Looking for trends
Compare to normal solar spectrum
Evaluate method

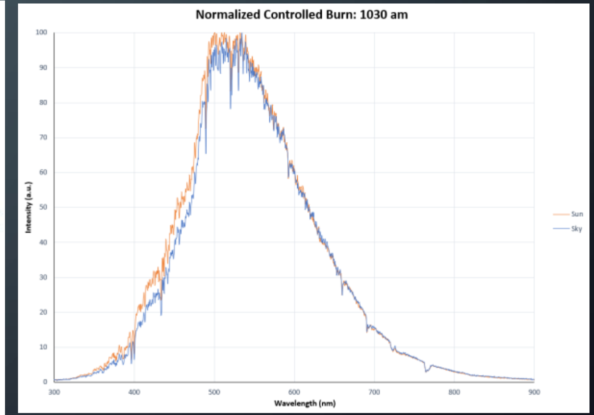


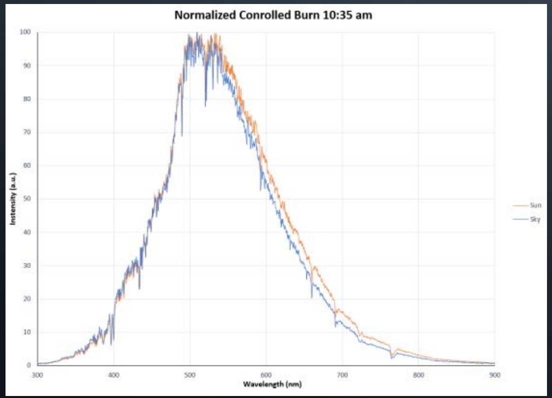


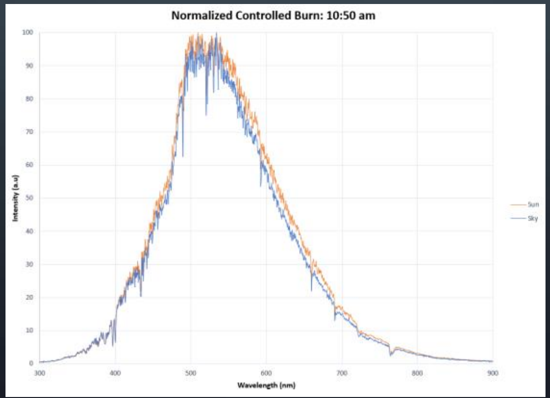


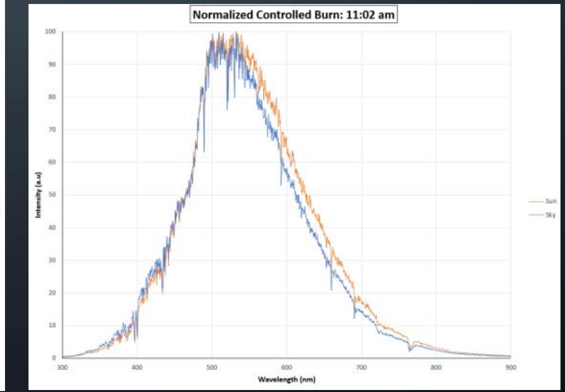


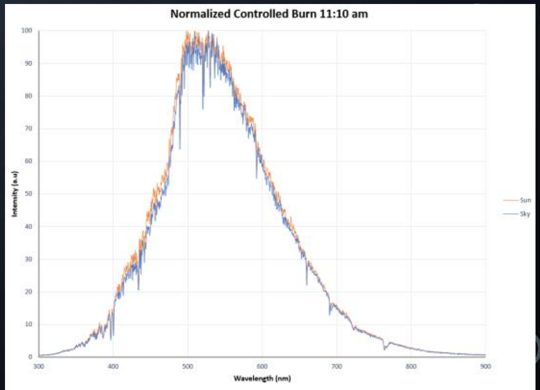




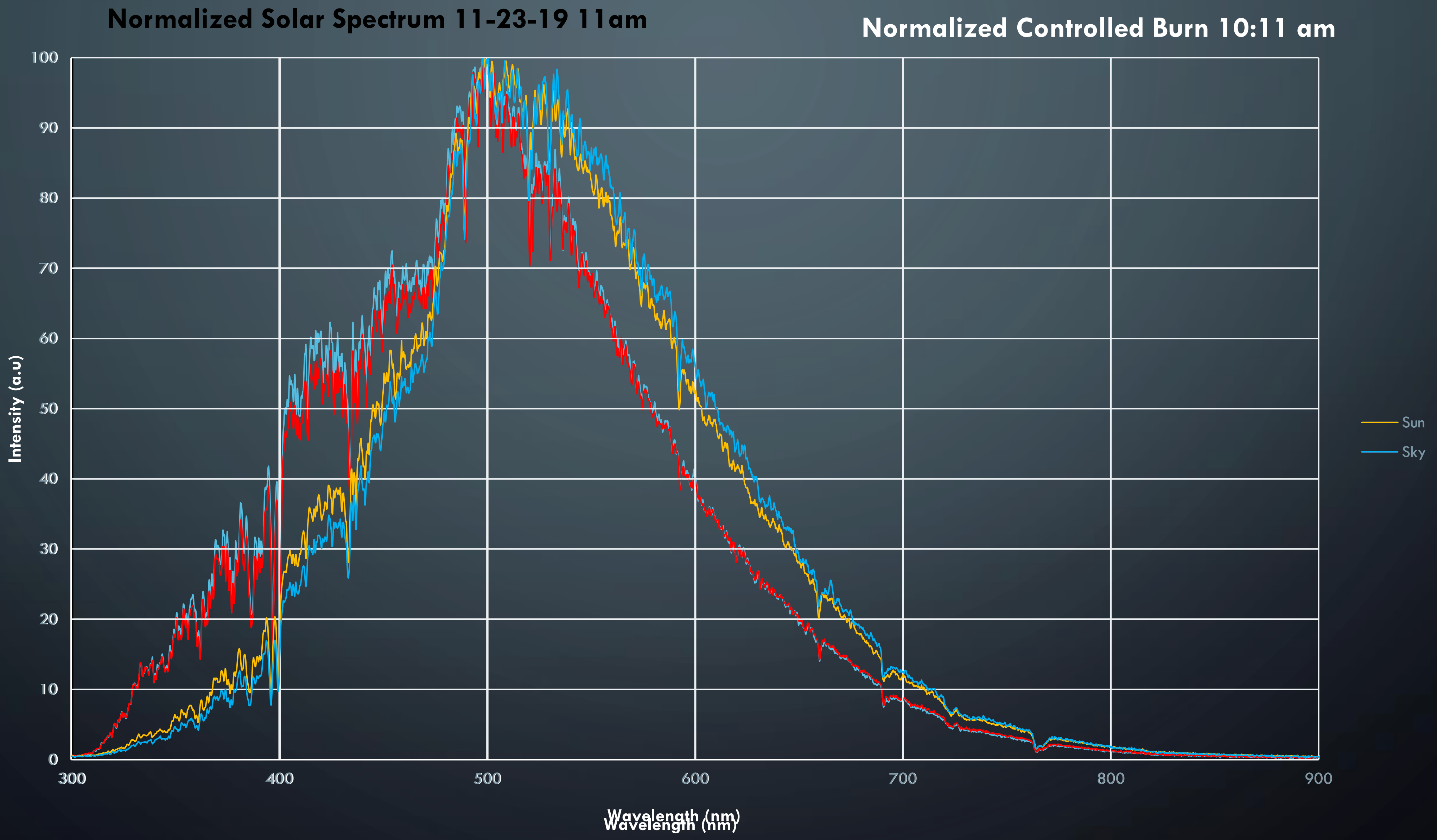




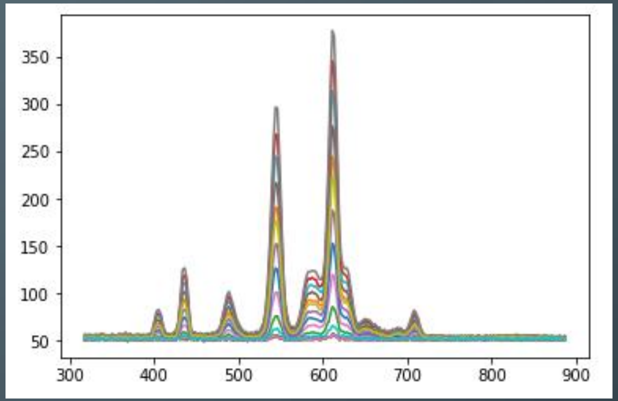




OVERLAY: REGULAR SOLAR SPECTRUM & BURN SPECTRUM



FUTURE APPLICATIONS



- Develop a more user-friendly interface
- Data logging capability
- Could possibly be mounted on the camera system, providing a direct correlation between images and spectra.
- What would we gain from flight?

CONCLUSION

- Developed a method for solar spectrum analysis
- Designed and constructed a miniature spectrometer
- Need to develop massive data processing technique

WORKS CITED

- https://store.arduino.cc/usa/leonardo
- https://github.com/groupgets/c12880ma
- https://oceanoptics.com/product/oceanview-downloads/
- https://www.boselec.com/wp-content/uploads/Linear/sglux/sgluxLiterature/sglux-catalog-photodiodes.pdf
- https://shop.boselec.com/collections/uv-sic-sensors
- https://www.peakspectroscopy.com/hamamatsu.html
- https://impfs.github.io/review/