Observations of UVA, UVB, and UVC from a sounding balloon from ground to 100,000ft

Beau Johnson[2], Angelina Liemkeo[1], Caroline Davis[1], John Holley[1], Abigail Peck[2], Joyce Oluwaseun[2]

Department of Physics and Astronomy[1], College of Engineering[2], Louisiana State University and Agricultural & Mechanical College, Baton Rouge, Louisiana

Partner

Figure 1: Lift off from 2022 LaACES project

Figure 2: Payload integration in Palestine, TX

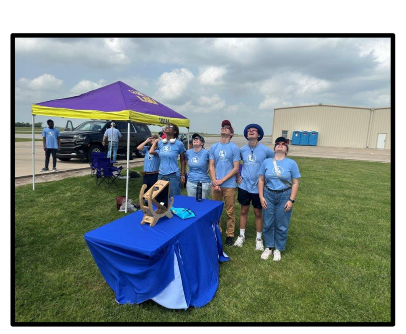

Figure 3: Team TIGERS viewing the eclipse before totality.

Abstract

Currently there is a lack of in situ measurements of ultraviolet (UV) light in the stratosphere. Team TIGERS is a student team of six undergraduates from Louisiana State University (LSU) that are taking part in the Louisiana Aerospace Catalyst Experience for Students (LaACES) ballooning project funded by Louisiana Space Grant (LaSPACE). Team TIGERS has designed a ballooning payload that measures the solar intensity within the UVA, UVB, and UVC bands. Originally, the payload was designed to make measurements of the solar corona during the total eclipse at an altitude of 24 km and compare these measurements of the photosphere before and after the eclipse. However, the original flight was canceled due to weather conditions, and a makeup flight was flown on May 15. At the peak altitude of 30 km, it is possible to observe some of the shorter wavelengths emitted by the photosphere since the payload will be in the ozone layer. For Team TIGERS' flight, the UVB and UVC sensors had zero output. Team TIGERS believes the errors in these measurements were due to the amplification circuits not having enough gain. Furthermore, the magnetometer used during flight had a higher temperature dependence than predicted, so possible design changes could provide a more accurate orientation measurement. The performance of the ground software is still being assessed, so no firm conclusions can be made at this time.

Science Background

LaACES is an annual scientific ballooning program that hosted a specialty program tailored for the April 8, 2024, total solar eclipse [1]. Weather conditions did not allow for launch during the eclipse; therefore, Team TIGERS could not measure the corona during the subsequent launch on May 15, 2024.

Observable UV Bands

- Photosphere has a broader emission spectra due to difference in temperature (Fig. 4).
- Corona and photosphere spectrums overlap in the UVA, B, and C bands.
- UVC is mostly absorbed in the stratosphere (ozone layer).
- Total solar eclipse allows us to differentiate the UV intensity of the solar corona apart from the photosphere.

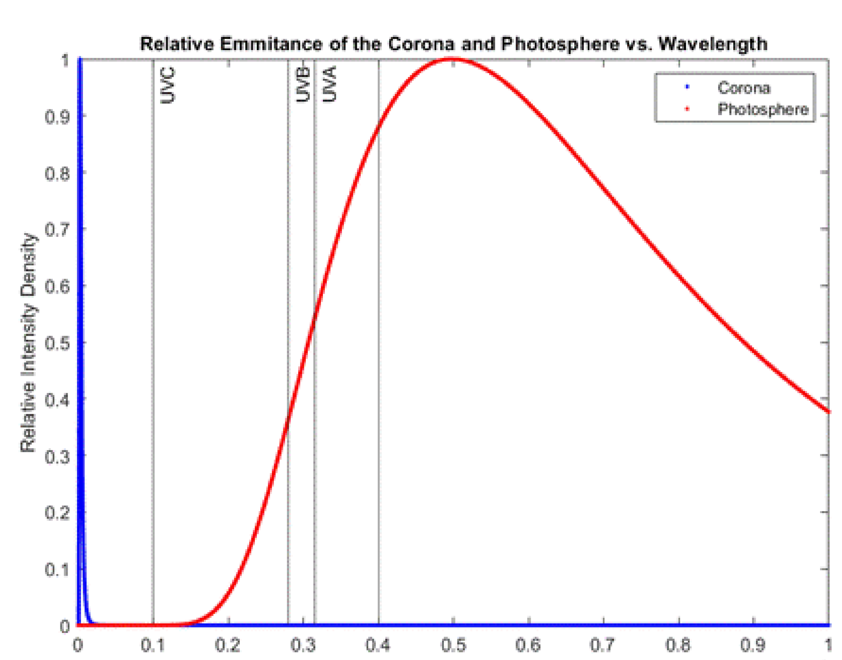

Figure 4: Emittance shape of the corona (blue) is much sharper with a peak at 3nm and shape of photosphere (red) stretched horizontally with a peak at 500nm.

Payload System Design

The payload can be broken into the subsystems depicted in Fig. 5.

- UV Photodiodes angled towards sun to increase sensor output.
- Power subsystem contains regulators and level shifters
- Sensor, Orientation, and GPS output signals to control.
- Control handles communication between sensors and write to data archive.

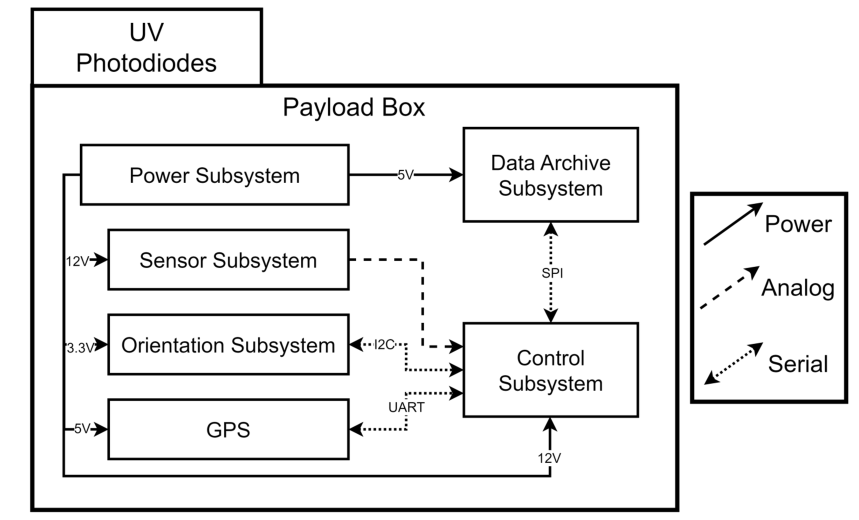

Figure 5: High-level system diagram of payload with legend.

Principle of Operation

UV Measurements

- UV intensity measured using photodiodes connected to amplifiers.
- There is one photodiode for each band of interest (UVA, UVB, and UVC) and a broadband sensor.
- UV data, along with GPS and environmental data, are recorded to the data archive system.
- The photodiode response is dependent on the incident angle (Fig. 6).

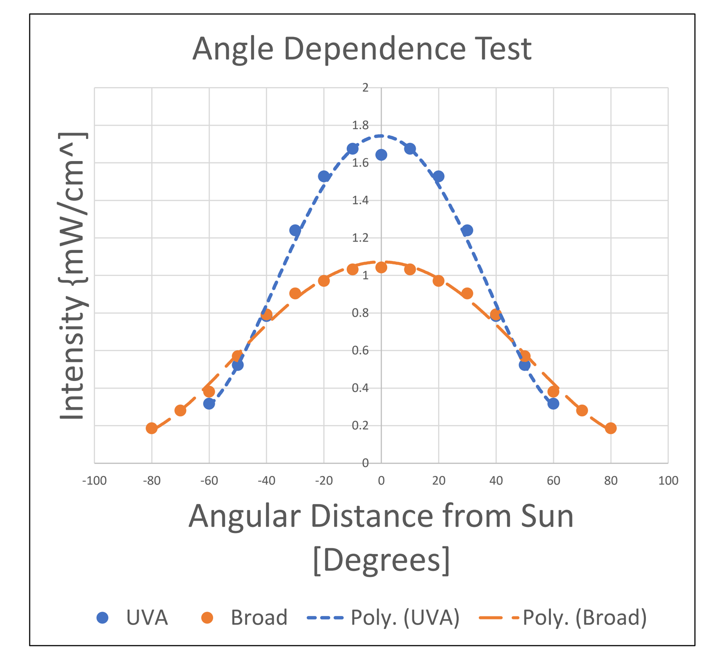

Figure 6: Measured angular dependence of UV photodiode output for broadband and UVA. Same behavior from other sensors.

Orientation Measurements

- IMU measurements used to determine orientation of payload by calculating a rotation matrix for the payload [2]
- Initial diode vector is multiplied by the calculated rotation matrix to find the new orientation [3].
- Based on the Sun's location in the Earth frame, the angle between the sun and photodiode vector can be found (Fig. 7).

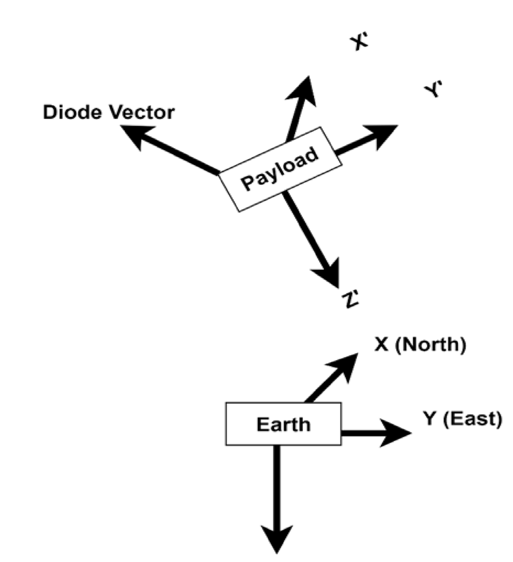

Figure 7: The top shows the payload in its own frame of reference. The bottom shows the payload in the Earth frame of reference when the x, y, and z axis aligns with north, east, and down respectively.

Flight Results

- Flight was flown on May 15 and some analysis is still ongoing. Results for the uncorrected (with respect to angular dependence) UV output are discussed below.
- Analysis of orientation software is still underway.
- In the future, corrected UVA and UV Broadband outputs will be compared to the below numbers.
- Qualitatively taking the max UV output as pointing directly at the sun measured values are ~1.7 $^{mW}/_{cm^2}$ for UVA and ~2 $^{mW}/_{cm^2}$ for UV broadband at 30 km.
  - Expected 5.668 $^{mW}/_{cm^2}$ for UVA and 5.258 $^{mW}/_{cm^2}$ for UV broadband at float altitude of 30 km [4].
- UVB and UVC sensors outputted no values for intensity throughout the flight.
  - Expected 0.969 $^{mW}/_{cm^2}$ for UVB and 0.053 $^{mW}/_{cm^2}$ for UVC at float altitude of 30 km [4].

- Expectation was measured intensity to increase with respect to altitude, as seen in Fig. 8.
- Minimum values of measured intensity decreases with altitude. Note that a similar trend was found for plot of UVA Fig 9.
- Currently investigating scattering and temperature dependence of UV measurement for the drop in the minimum intensity at higher altitudes.

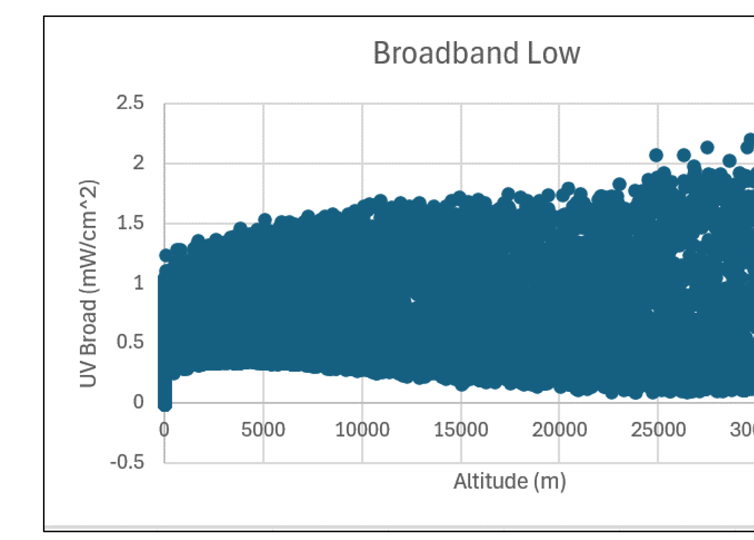

Figure 8: Low gain output of the broadband photodiode at different altitudes. These are measurements before the angular dependency correction was applied.

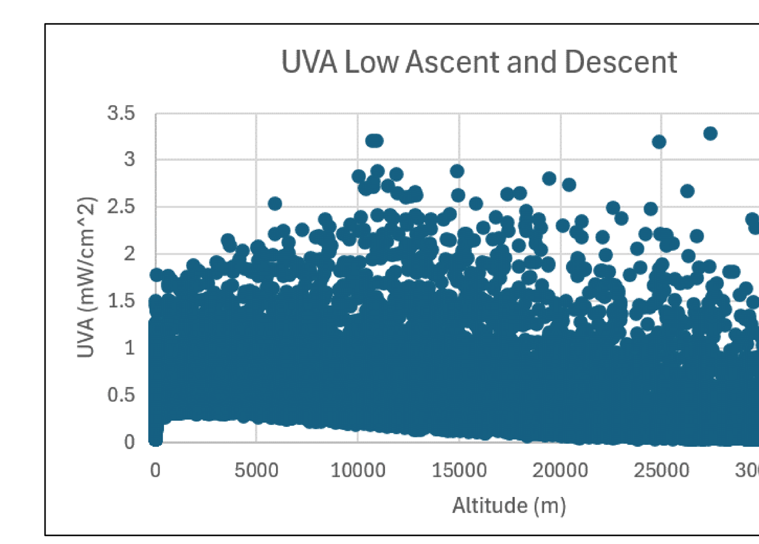

Figure 9: Low gain output of the UVA output at different altitudes These are measurements before angular dependency was applied.

Conclusion and Outlooks

- For this flight, the intensities were lower than expected so the amplifiers' gain was not high enough to take proper measurements. For future flights, gain calculations should accurately account for a sensor's responsivity at shorter wavelengths.
- Uncorrected UV output for UVA and UV broadband do seemingly increase with altitude, but there is also a decrease in the lower bound of the measurement that needs to be further investigated.
- Analysis of orientation software is still underway, and validation is still needed for future ballooning flights. Specifically, the High-Altitude Student Platform (HASP) project is currently underway and plans to use an orientation system of a similar design [5].

Acknowledgements

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