Observing the Solar Spectrum
Via High Altitude Balloon
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Background

Visible light can be split into a spectrum of wavelengths and frequencies.

<table>
<thead>
<tr>
<th>Color</th>
<th>Wavelength interval</th>
<th>Frequency interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>violet</td>
<td>~ 430 to 380 nm</td>
<td>~ 700 to 790 THz</td>
</tr>
<tr>
<td>blue</td>
<td>~ 500 to 430 nm</td>
<td>~ 600 to 700 THz</td>
</tr>
<tr>
<td>cyan</td>
<td>~ 520 to 500 nm</td>
<td>~ 580 to 600 THz</td>
</tr>
<tr>
<td>green</td>
<td>~ 565 to 520 nm</td>
<td>~ 530 to 580 THz</td>
</tr>
<tr>
<td>yellow</td>
<td>~ 590 to 565 nm</td>
<td>~ 510 to 530 THz</td>
</tr>
<tr>
<td>orange</td>
<td>~ 625 to 590 nm</td>
<td>~ 480 to 510 THz</td>
</tr>
<tr>
<td>red</td>
<td>~ 740 to 625 nm</td>
<td>~ 405 to 480 THz</td>
</tr>
</tbody>
</table>
- A **Continuous Spectrum** spans all EM wavelengths without interruption and is produced by a hot, dense source.

- An **Emission Spectrum** is a pattern of discrete, bright lines of specific wavelengths produced by a hot, thin gas.

- An **absorption spectrum** spans most wavelengths with some interruptions. It occurs when light from a hot, dense source passes through a cooler, thinner medium.
Hot, Dense Source  Cool, thin gas
Guiding Question

- How does the visible Solar light spectrum change as altitude increases and atmospheric density decreases?

What We Need

- Spectroscope
- Sun tracker
- High Altitude Balloon
Photo: Printed Spectroscope

Exploded View of 3D Printed Parts in SolidWorks

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>PART NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Base Pan &amp; Tilt</td>
</tr>
<tr>
<td>2</td>
<td>Cervo Holder Base</td>
</tr>
<tr>
<td>3</td>
<td>Bracket</td>
</tr>
<tr>
<td>4</td>
<td>Spectrometer Box</td>
</tr>
<tr>
<td>5</td>
<td>Lens Holder</td>
</tr>
<tr>
<td>6</td>
<td>SolarTracker</td>
</tr>
<tr>
<td>7</td>
<td>Lid</td>
</tr>
</tbody>
</table>
The Inner Workings

- GoPro Hero
- Netduino 3
- Hi-Torque metal gear Servo motors
- Photo-sensors
- 3.7V battery
- Power
  Booster/Management
Payload Design

- Open platform gives the spectroscope the largest field of view
- Brass rods are held in place with tension and secured into printed plastic couplings
Expected Results

- Absorption spectra should be consistent with the spectral signatures of elements present in Earth’s atmosphere.

- As atmospheric density decreases, absorption lines should decrease.

- At apogee, the only elements left visible will be the elements in the Sun's atmosphere.
Example of expected data and corresponding plot of brightness vs. wavelength.

(Asbell-Claarke, 2010)
What could possibly go wrong?

...
Things That Went Wrong

- Broken Diffraction Grating
- Miscalibrated Optics
- Malfunctioning Solar tracker
What We Found

Ascent:

7:20  7:30  7:40  7:50  8:00  8:05  8:20

8:25
What We Found

After Landing:

9:27  9:30  9:31

9:32 on...
Hypotheses

- Overlapping spectra due to light reflecting off of mirror and passing through diffraction grating a second time

- Correct orientation of spectroscope is critical to its operation

- Poor resolution and gaps in data largely a result of GoPro automatically adjusting exposure times and focal distance
What’s Next?

- Replace damaged diffraction grating
- Bench test the GoPro
- Fly a rebuilt spectroscope while collecting gyroscopic and light concentration data
Lessons Learned

- Never solder in a moving van.

- Always keep replacements for delicate mission critical parts handy and in the budget.

- Test early and test often.
Lessons Learned

- Crayola modeling clay can withstand flight conditions.

- Listen to your data, even the bad data. It’s trying to tell you something!

- There are no failures in science; only opportunities to solve new problems.
Thank you!

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