Near-Infrared Observation of the Solar Atmosphere

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ABSTRACT

A total solar eclipse offers a unique opportunity to observe the solar chromosphere and corona without the use of a man-made disk to block out light from the photosphere, and high-altitude balloons allow for observation in the infrared spectrum without consideration of the Earth's atmosphere, which blocks out the shorter wavelengths of the infrared spectrum. Flying a near-infrared camera on a high-altitude balloon during a total solar eclipse, therefore, gives the ability to observe the solar atmosphere in the IR spectrum relatively clearly, cheaply, and easily. Most cameras have built-in filters which stop infrared light from reaching the sensor, but it is possible to buy cameras without this filter, designated NoIR cameras. We flew a Raspberry Pi NoIR camera at a float altitude of roughly 55,000 feet during the August 21, 2017 total solar eclipse, with the goal of obtaining data about the chromosphere and corona in the near IR. Although the images were somewhat overexposed, preliminary results show a pinker corona than we would have expected to see with a normal camera. This indicates a significant amount of near IR radiation present in the corona, consistent with existing data on coronal heating.

BACKGROUND

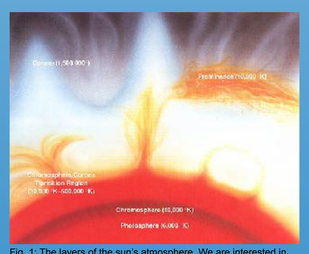

Fig. 1: The layers of the sun's atmosphere. We are interested in the chromosphere and corona, the outermost two layers.

- Near IR images of the sun are interesting because they can give data on coronal heating, a mystery in solar physics.

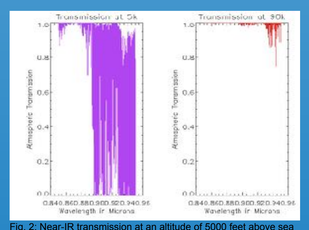

Fig. 2: Near-IR transmission at an altitude of 5000 feet above sea level compared to transmission at 90000 feet

- Water vapor is the main blocker of IR radiation to the ground; other culprits include carbon dioxide and ozone. Most of these gases are present in the troposphere.

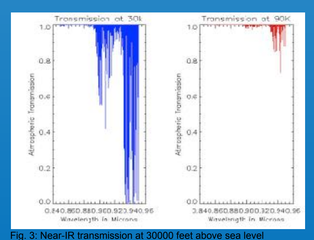

Fig. 3: Near-IR transmission at 30000 feet above sea level compared to transmission at 90000 feet

- High altitude balloons allow observations above the troposphere

METHODS

Fig. 4: Our payload after recovery. The camera is visible through a hole in the side of the payload box.

- Camera: Raspberry Pi NoIR, Version 2
- ISO during eclipse: 200
- Shutter speed during eclipse: 3000 µs
- Pointed at the sun using Space Data system

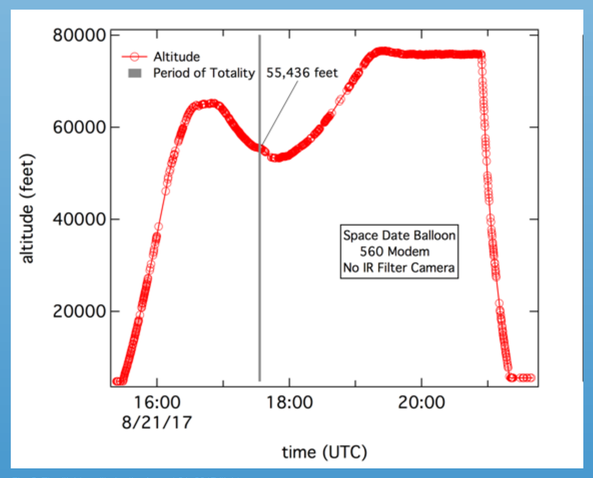

Fig. 5: The flight profile for the August 21, 2017 flight.

DATA AND RESULTS

- Compared our data with a picture taken by the Pitt Shadow Bandits
- Confounding factors:
  - "Control" picture taken with a Raspberry Pi V1
  - In Tennessee
  - With a focal length 8 mm (f/1.6), as opposed to the f/2.0 our camera used
  - Saved as .jpeg as opposed to using RAW images like we did
  - Both our image and the Pittsburgh one are overexposed
  - Every camera renders color differently
- What we found:
  - Despite these confounding factors, we still compared the two images
  - Looked at RGB values in Photoshop Elements
  - For pixel values around the edge of the moon:
    - The Shadow Bandit picture had a mean red value R=131.7143, mean green value G=134.7551, and mean blue value B=158.7959
    - The NoIR picture had mean R=137.92, G=104.4, and B=109.4
    - Max is 255
  - For pixel values around the edge of the corona:
    - Shadow Bandit picture had mean R=124.6939, G=124.7347, and B=148.2857
    - NoIR picture had mean R=156.2647, G=108.2059, and B=110.8235

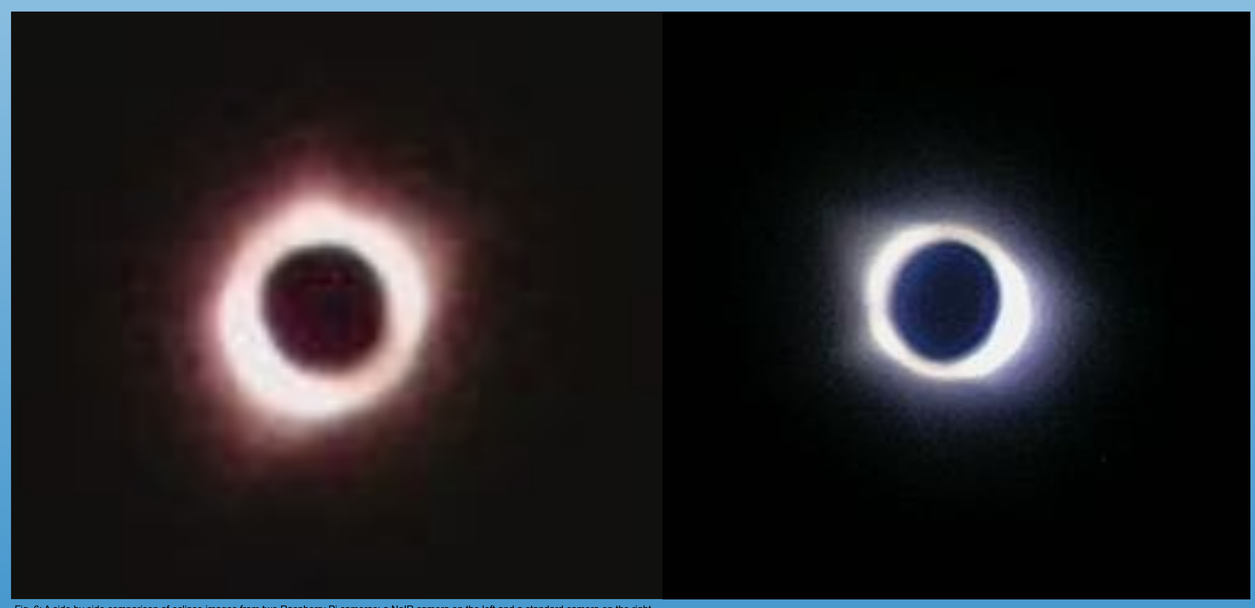

Fig. 6: A side by side comparison of eclipse images from two Raspberry Pi cameras; a NoIR camera on the left and a standard camera on the right.

CONCLUSIONS

Fig. 7: Montana in the near IR from about 80,000 feet

- The proportion of red in the NoIR camera image is significantly higher than that of the Pitt Shadow Bandit image
- Despite confounding factors we did at least get a qualitative result matching our expectations
- If we were to repeat the experiment, we would fly a control of our own with the same camera settings, which would get rid of most of the aforementioned confounding factors

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CREDITS AND CITATIONS

- ATRAN reference: Lord, S. D., 1992, NASA Technical Memorandum 103957
- ATRAN data can be accessed at atran.sofia.usra.edu/cgi-bin/atran/atran.cgi
- Solar atmosphere picture from Science in Orbit: The Shuttle and Spacelab Experience, 1981-1986, accessed on history.nasa.gov
- Standard "control" image courtesy of the University of Pittsburgh Pitt Shadow Bandits.
- Flight profile courtesy of Berk Knighton