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Viewing the Chromosphere of the Sun in the Near Infrared Spectrum

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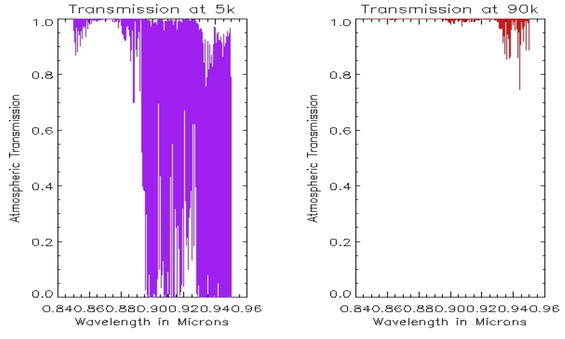
Introduction: Purpose and motivation

- Research Question: Can the chromosphere of the Sun be effectively viewed by filtering out all light except in the near-infrared spectrum.
- The chromosphere is the outermost layer of the Sun. However, it cannot normally be seen because it emits relatively little light in comparison to the layer beneath it. It is only brighter than the underlying layers in a few wavelengths, such as in the near-infrared spectrum.
- Previously the chromosphere has not been viewed in the near-infrared spectrum, but in other wavelengths were it is brighter than the underlying layers.
- Viewing the chromosphere with this method will allow for potentially cheaper and easier ways of viewing this layer of the Sun, allowing for newer discoveries about its nature to be made.

Materials and Methods

- A dual-camera system was constructed to allow for photos in both the near-infrared and visible light spectrum. This allows comparison between the images.
- Two identical Raspberry Pi cameras (similar to a smartphone camera) were each controlled by a Raspberry Pi zero (a credit card sized computer). One camera had the infrared filter removed, allowing it to take in infrared light, then had a filter which allowed only infrared light of around 680 nanometers to enter, effectively making it only see light of that wavelength.
- As the atmosphere absorbs the majority of incoming light in the near-infrared spectrum (see graphic below), the camera system was affixed to a balloon and flown to approximately 60,000 ft above sea level, where atmospheric transmission of light in the spectrum is nearly 100%.
- The cameras were coded to take pictures simultaneously to ensure the best similarities between them

Transmission of Infrared Light

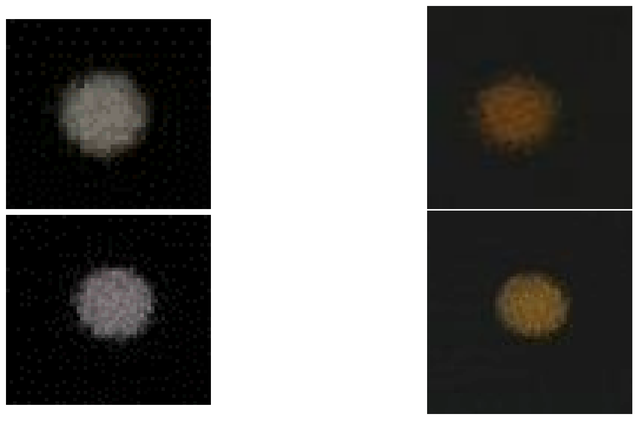


The atmosphere prevents most infrared light from reaching the Earth's surface. Higher in the atmosphere, this is not an issue.

Using Limb Darkening to Examine the Results

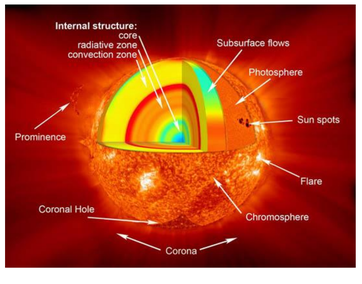
- As expected, the images taken in the visible spectrum exhibited limb darkening (explanation is to the left). This is to be expected given that the light in these images is from a wide range of wavelengths
- In contrast, the images taken in the near-infrared spectrum at 670 nm, where the intensity of light from the chromosphere peaks, exhibits no noticeable limb darkening.
- This lack of limb darkening indicates that all of the light received in the near-infrared images is in fact from one layer of the sun

Comparison Between Images



Four example images of the results. The images on the left are infrared, while the images on the right are in the visible spectrum.

The Structure of the Sun

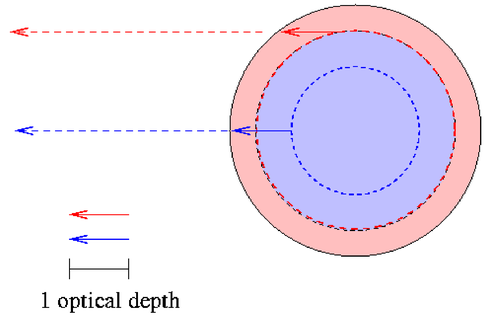


The photosphere, the second outermost layer of the sun, outshines the chromosphere, the outermost layer, at almost every wavelength of light.

Dual-Camera System

Pictured is the system used to take the data. The camera on the left took the infrared images, and the camera on the right took the images in the visible spectrum.

What is Limb Darkening?



Limb darkening is a phenomenon present in stars which causes the light observed from closer to the center of the star to be emitted deeper from within the star. As the interior of the star is hotter, this means the light seen at the center of the star is brighter, while the edges are darker, leading to the effect known as limb darkening.

Conclusions and Implications

- The absence of any limb darkening in the images taken of light of 680 nanometers is evidence that they are images of only one layer of the sun, in this case, the chromosphere. This limb darkening is especially evident with comparison to the images taken with visible light.
- These results show that viewing the chromosphere of the sun by focusing on light of 680 nanometers is a viable method of viewing the chromosphere.
- Advantages to using this method of viewing the chromosphere:
  - The near-infrared spectrum is one of the easiest spectrums to photograph
- Drawbacks to this method:
  - As near-infrared light does not reach the Earth's surface, it can only be viewed high in the atmosphere or in space.
- Other methods of viewing the chromosphere include:
  - Viewing the chromosphere during a solar eclipse so that the photosphere is obstructed by the moon
  - Viewing the chromosphere in other wavelengths, which tend to be more difficult to access than the near-infrared spectrum

Credits and Citations

Zell, Holly. "The Sun." *NASA*, 7 Sept. 2017,.

Richmond, Michael. "Limb Darkening." *Rochester Institute of Technology*, spiff.rit.edu/classes/phys440/lectures/limb/limb.html.

Acknowledgments

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