Describing and Simulating Rainbow Hazes in Jupiter using JunoCam
SURF @ JPL
Student: Erica Wang
Mentor: Glenn Orton

Background

Since August of 2016, the Juno spacecraft has been in polar orbit around Jupiter, executing highly elliptical orbits whose closest approach to Jupiter ("perijove") allows it to gather remote-sensing information at unprecedented spatial resolution while minimizing time in the high-energy radiation field close to the planet. The nominal Juno mission was planned to conclude in June of 2021, but NASA approved it for an extension to October 2025. During this time, Juno's public-outreach camera, JunoCam, has been making high spatial resolution images of Jupiter in nearly each orbit, with the best resolution coming within 2 hours of each perijove pass.

Among the features detected by JunoCam have been translucent hazes, some of which can be seen in Figure 1. Among these are linear bands that appear to have a separation of colors. These all seem to appear very close to the terminator, the boundary between sunlit and nighttime areas that correspond to sunrise or sunset on Jupiter. My mentor and his colleagues do not believe that these features, known as "rainbow" bands or hazes, have any special properties; they simply happen to be located in a position where the length of illumination by the sun happens to go through a path through the haze that is longer than illumination away from the terminator. In general the blueish part of the color dispersion seems to be located on the sunward (illuminated) side of the terminator.

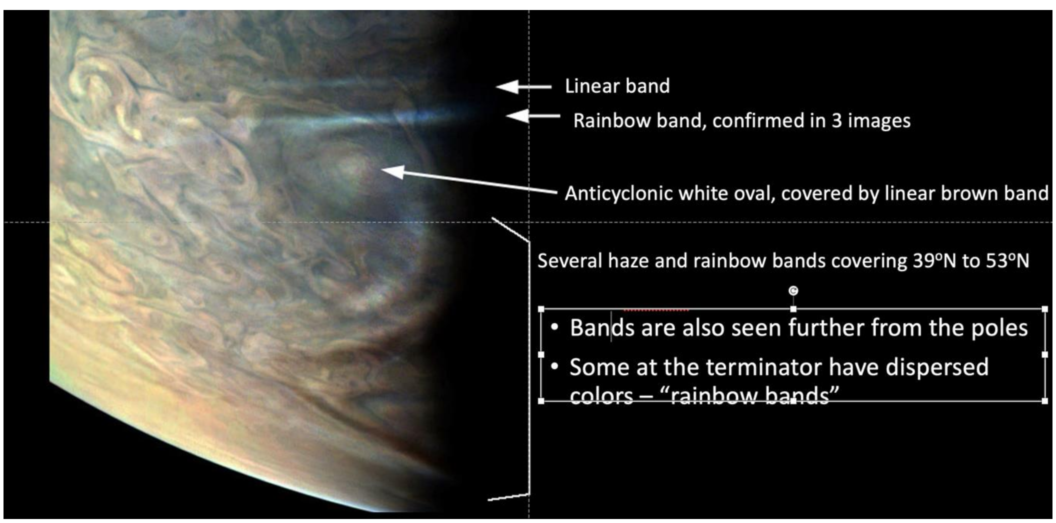

Figure 1. Examples of rainbow bands (Orton et al. 2021, JunoCam imaging of Jupiter through 30 perijoves. Presentation B5.1-00005-21, COSPAR-2021).

A simple model of the rainbow bands was suggested by my mentor in a presentation, shown in Figure 2. The blue light, being the most susceptible to scattering by small particles, is preferentially scattered out first by small particles, leaving the green and red light to be scattered out last. They appear at the terminator because it is only there that the optical path through which sunlight passes is long enough for the scattering or absorption by the very thin haze.

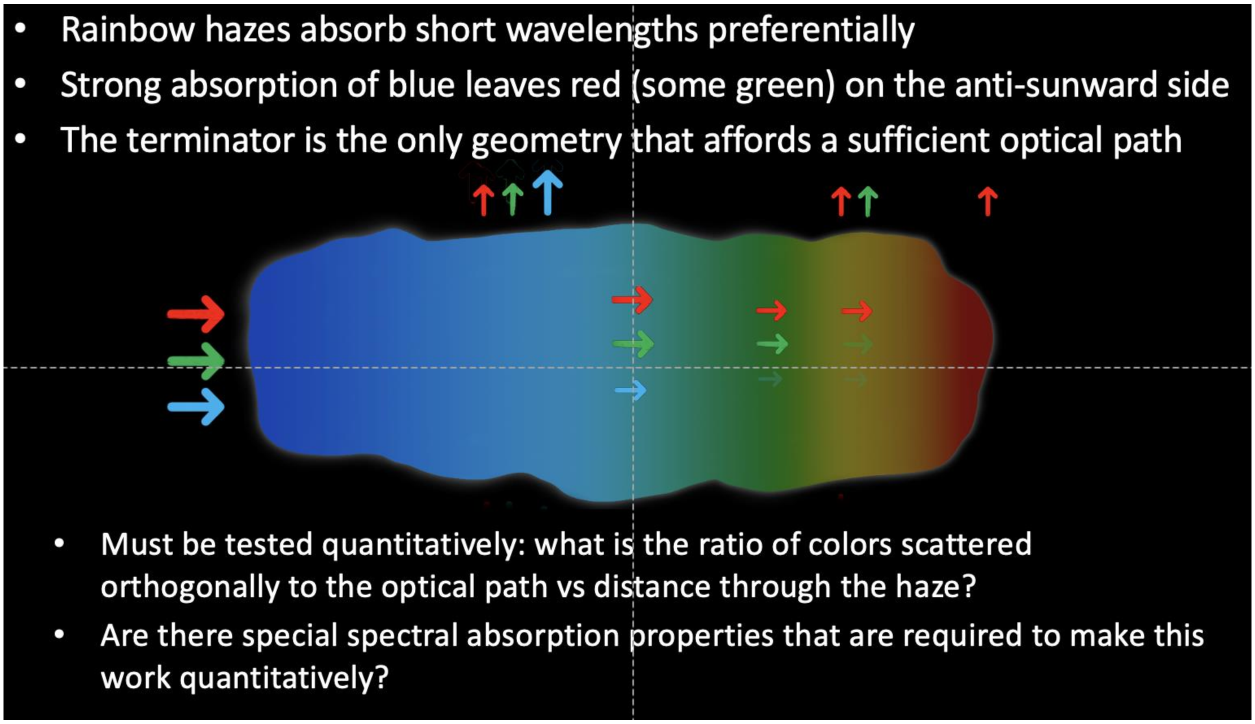

Figure 2. Simple model for a rainbow band (Orton et al 2022. EGU22-3143. European Geosciences Union, 2022).

One question is whether there is any consistency in the length over which the different colors (blue, green and red) scatter from the haze. If so, a further question is whether these rainbow bands need any special absorption properties that are different from hazes that appear near the terminator and do not appear to disperse colors.

I'd like to see whether this simple model is adequate to explain what we see, testing it against models that simulate the scattering of light through a long path of particles that absorb more in the blue (shorter wavelengths) than green or red (longer wavelengths).

If my project is successful, it will aid the previous and continuing research on Jupiter's atmosphere using JunoCam by the Juno science team. It will contribute to standing research in the field.

Objectives

1. Quantify whether rainbow bands always appear the same way. Does the blue color always appear toward the sunward side of the band? What is the distribution of the reflected light in different colors as a function of distance through the haze? Is the length of separation between the peak of light reflected by the red, green and blue channels the same for all of the hazes where the rainbow phenomena is present? Evaluate any differences and their context to see if haze bands at different latitudes have a different behavior.

2. What types of particles are required to match the observed differences? Can particle properties, such as size and reflectivity or density, be constrained by these measurements?

Approach

First, I will gather JunoCam images displaying the rainbow phenomena. Because JunoCam is a public outreach camera, all images are publicly accessible at missionjuno.com. From this data, I will search for all rainbow phenomena. Specifically, I will examine the terminator of each perijove for the phenomena. One of my mentor's colleagues, Dr. Shawn Brueshaber, has done much of this already for the earliest orbits. A frequent commentator on these images, Dr. John Rogers, has noted their presence in his extensive commentaries on the JunoCam images of each perijove on the British Astronomical Association web site. In the PJ33 report, Dr. Rogers notes the "bright sinuous rainbow band on the terminator" (Rogers). This step will likely take two weeks.

After collecting all useful images, I will examine the data to see whether the dispersion takes place in the same way, i.e. over the same or similar length scales. For the images that do, I will undertake simulations of this model and see what properties of the particles I might determine. This should only take a week. This work would become a part of an article, much of which is already written, surveying properties of hazes in Jupiter's atmosphere from JunoCam observations. My project this summer will aid my group in completing the research my group has undertaken about the properties of hazes of Jupiter.

After I know which properties of particles I can determine, I will set up maps of the JunoCam images to plot the illumination of the B,G,R filters as a function of distance. To do so, I will use a US Geological Survey code known as ISIS3, which I can use to derive information automatically, including the position of sunlight and physical distances. Another option is to use a latitude-longitude (Mercator) map already established by one of my teammates. This will also take a week.

Finally, I will work with my mentor or one of my teammates familiar with a radiative-transfer code to see what particle properties could be determined by matching the best models to the data. We currently suspect that this is likely to be an optimal choice of particle size, but it could also involve differences in absorption between the different colors. This will take a week.

Work Plan

Pre-SURF – Week 1 : Onboarding at JPL, familiarizing myself with ISIS3 and the process of re-mapping images into a Mercator projection.

Week 2 : Gather previous images of rainbow bands and search for more images.

Week 3 : Complete searching for images, determine which properties to study

Week 5 : Create maps of images with rainbow hazes

Week 6 : Plot reflected light vs distance away from the direction of the sun; determine whether the distances between the peak scattered light in each color are the same for different hazes

Weeks 7-8 : Work with mentor and his teammate to set up and run radiative-transfer code that simulates this projection; determine whether special properties of the haze particles are needed to reproduce the color dispersion.

Weeks 9-10 : Finalize results and create a presentation and a final report.

References

Rogers, John (2021). *JunoCam at PJ33: What the Pictures Show* (Report 33). British Astronomical Association.
https://www.missionjuno.swri.edu/Vault/VaultDownload?VaultID=33992&ts=1639067309