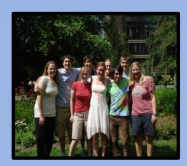

Analysis of a Binary Star Occulted by Saturn's Rings

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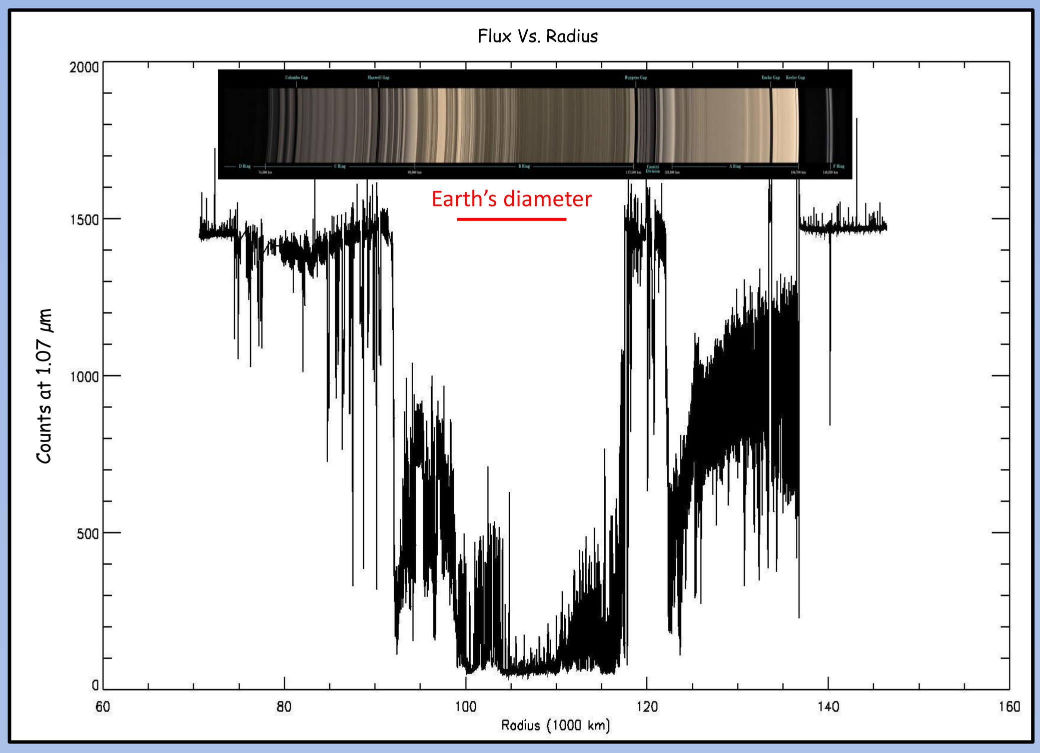


Introduction

An occultation of Saturn's rings occurs when a star passes behind the rings. By quickly imaging the star, we can get a very high resolution picture of the rings. With occultation data, we are able to see sub-kilometer structures in the rings. One downside to occultations is that the data are one dimensional. In this poster, we describe a method of analyzing an Alpha Centauri (a binary star) occultation from Cassini's Visual and Infrared Mapping Spectrometer (VIMS). If we can separate the two stellar transmissions, we would add a second dimension to our data. With two dimensions in the data, we can search for small longitudinal variations of the rings at high resolution.

The image to the left shows the occultation with a corresponding picture of Saturn's Rings. Earth's diameter is also shown for scale.

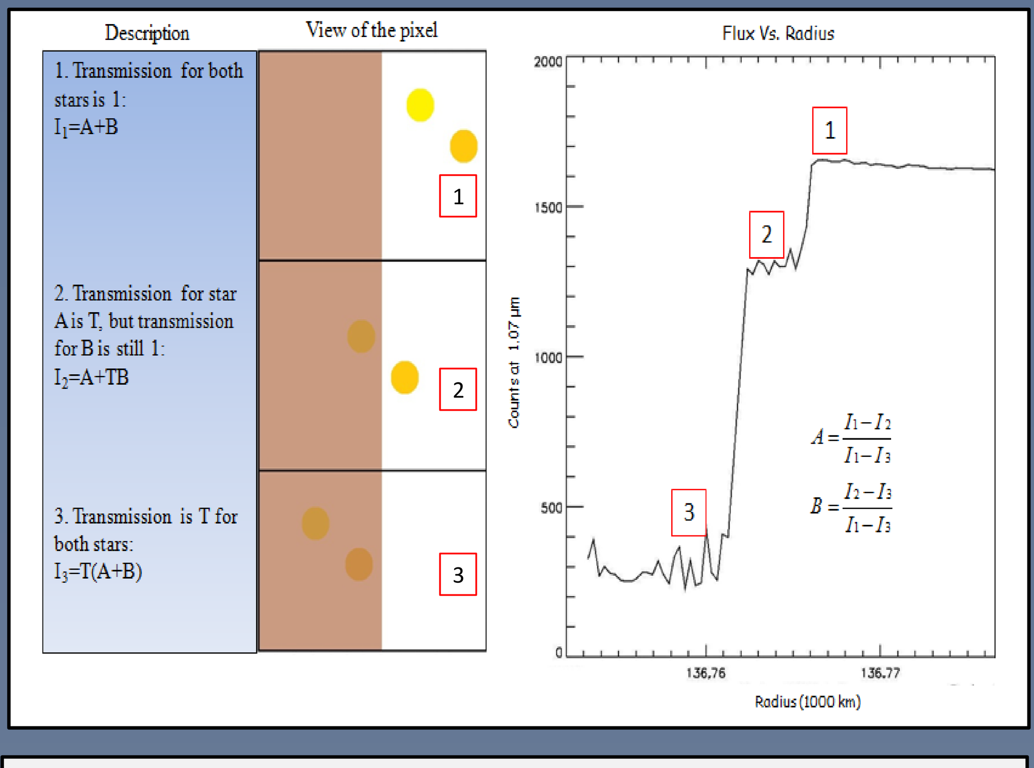
To obtain the two stellar transmissions from the data, we assume the signal is composed of flux from Alpha Centauri A, Alpha Centauri B, reflected sunlight, and reflected Saturnshine. The total signal, I, is the sum of the transmission of Alpha Centauri A ($T_a(r)$) multiplied by a wavelength dependent factor (A(λ)) and the transmission of Alpha Centauri B ($T_b(r)$) multiplied by a wavelength dependent factor (B(λ)). The total light reflected from Saturn's rings is the radial profiles of transmitted sunlight (V(r)) multiplied by a wavelength dependent factor (α(λ)), and the ring radial profile of reflected Saturnshine (U(r)) multiplied by a wavelength dependent factor (β(λ)).

$$I(\lambda, r) = A(\lambda)T_a(r) + B(\lambda)T_b(r) + \alpha(\lambda)V(r) + \beta(\lambda)U(r)$$

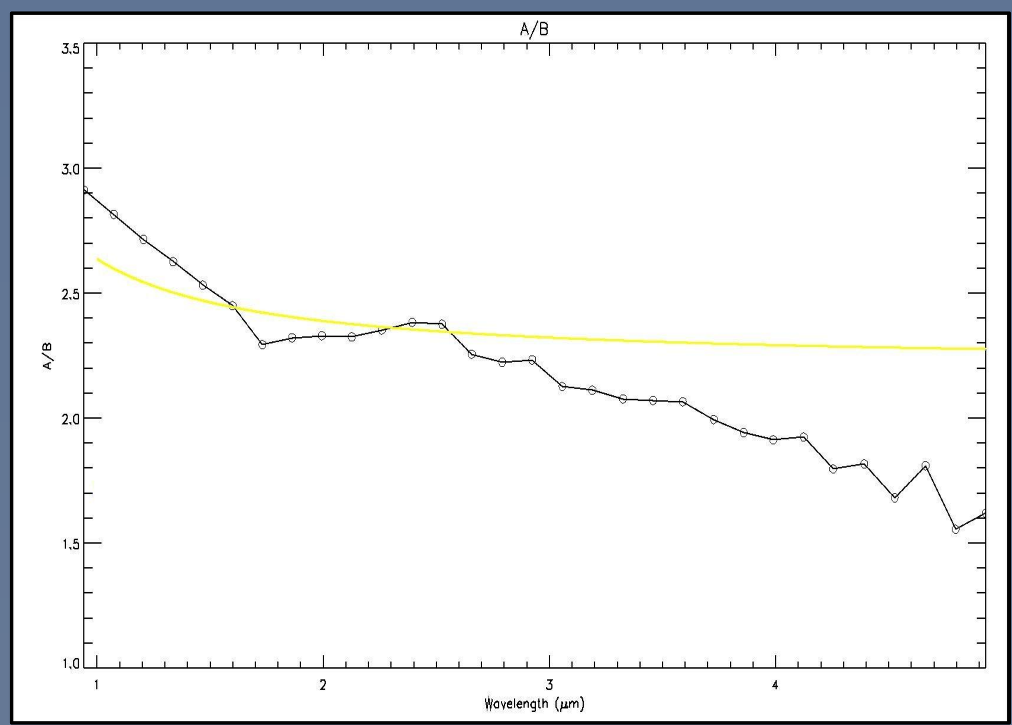
Equation 1

Using the geometry of the occultation and making several key assumptions, we are able to solve for the wavelength dependent variables (A, B, α, and β). After that, we are able to solve for the radially dependent variables (T_a, T_b, V, and U).

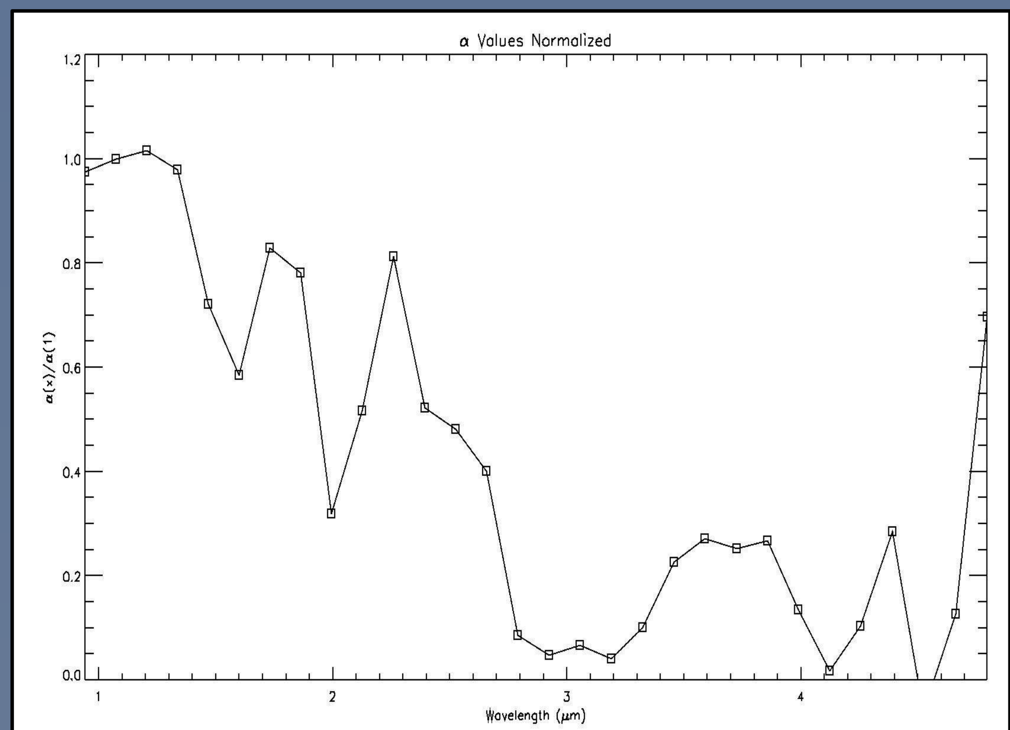
Data Reduction Process



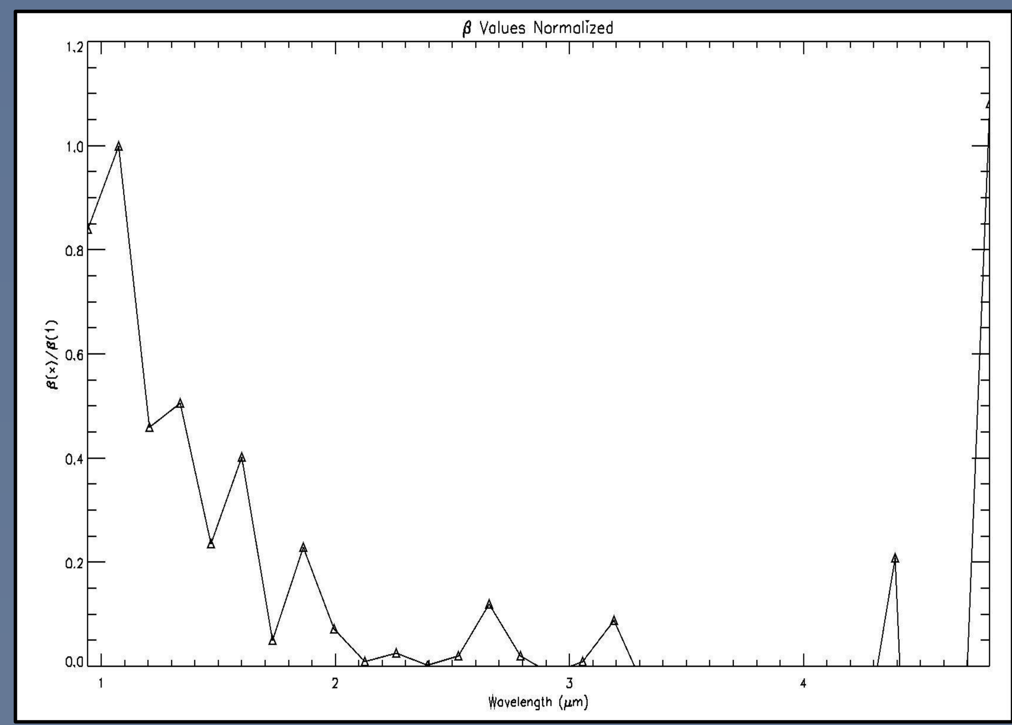
In an occultation with one star, there is a sharp drop in the signal when the star passes behind an edge in the rings. However, in the Alpha Centauri occultation, we see *two* distinct drops in the signal for each ring edge. The figure above shows data from the edge of the A ring. After assuming that over such a small radial range, all radial components are constant, we can solve for A and B.



This shows A/B Vs. Wavelength after averaging the A and B values of several edges together. Physically, A and B are the spectra of the stars. The yellow line shows what A/B would look like based only on temperature and radius. Since the A/B ratio is not constant with wavelength, the two stars have measurably different spectra. If we could not measure any difference, then we would not be able to solve Equation 1.

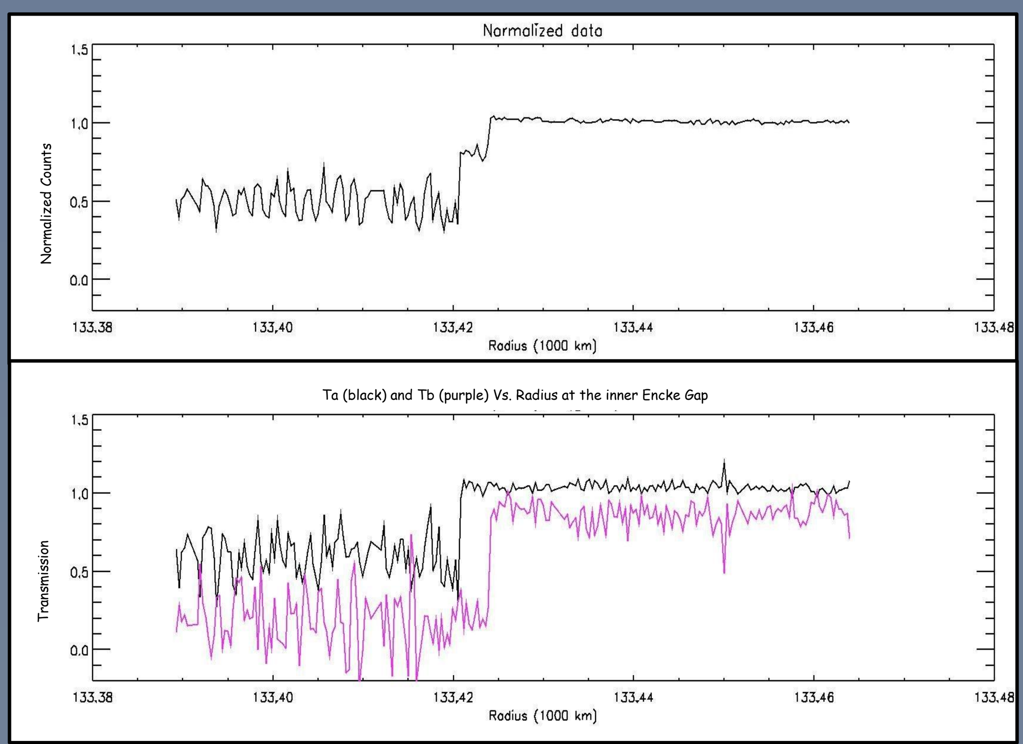


In Equation 1, α represents the spectra of sunlight reflected off of the rings. Due to the low imaging resolution, we detect scattered sunlight inside of gaps, causing the total flux to be higher than the flux outside the rings. We assume that all of this excess is sunlight reflected from Saturn's rings. From this, we can solve for ratios of α, shown in the plot above. Notice the water absorption bands at 1.55, 2.0, and 3.0 microns.

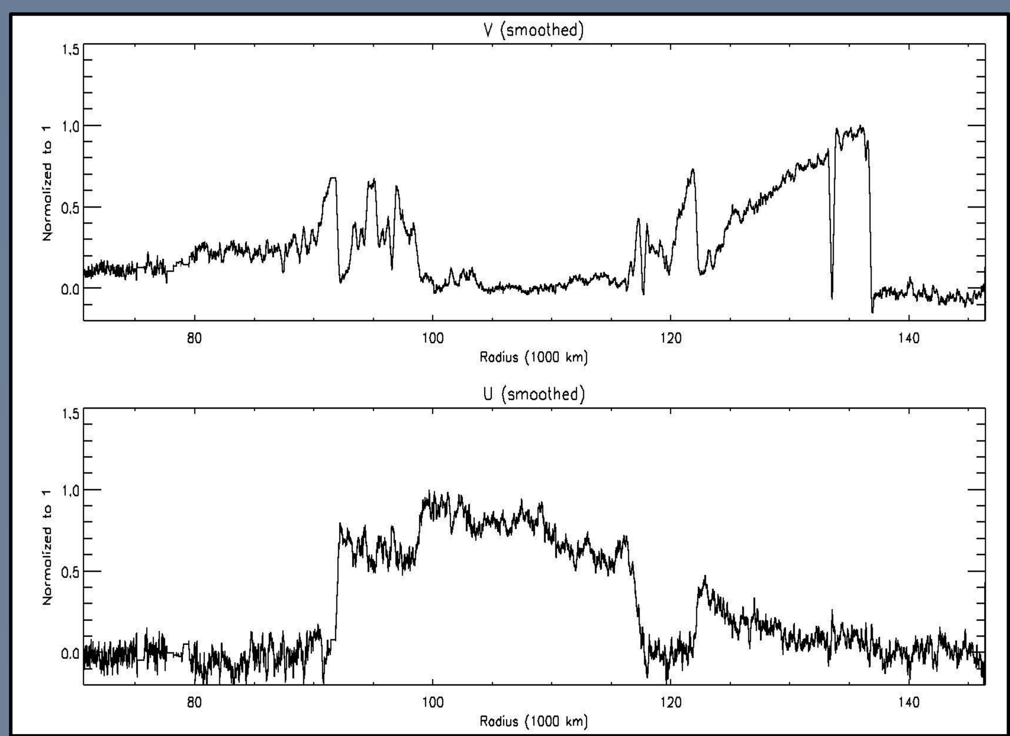


Transmitted light is completely blocked in several areas in the B ring. For certain radii, we assume that the only signal contribution comes from reflected Saturnshine. From these regions, we can solve for ratios of β. Notice the Methane absorption bands at 1.4, 1.7, and 2.3, combined with the ring absorption bands at 1.55, 2.0, and 3.0 microns.

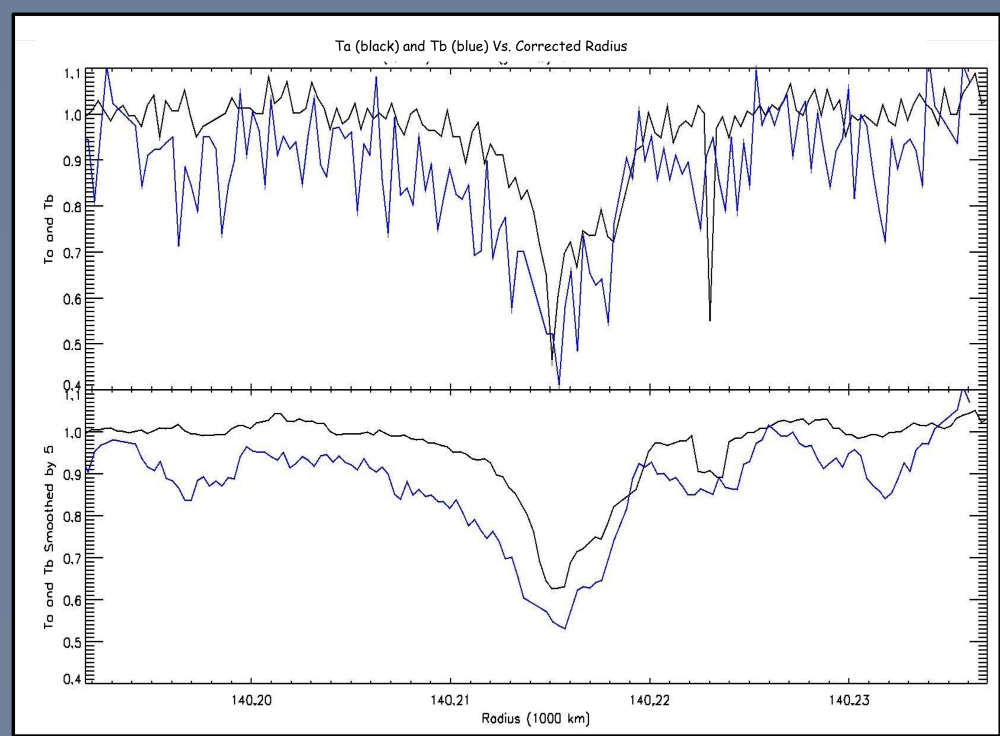
Results



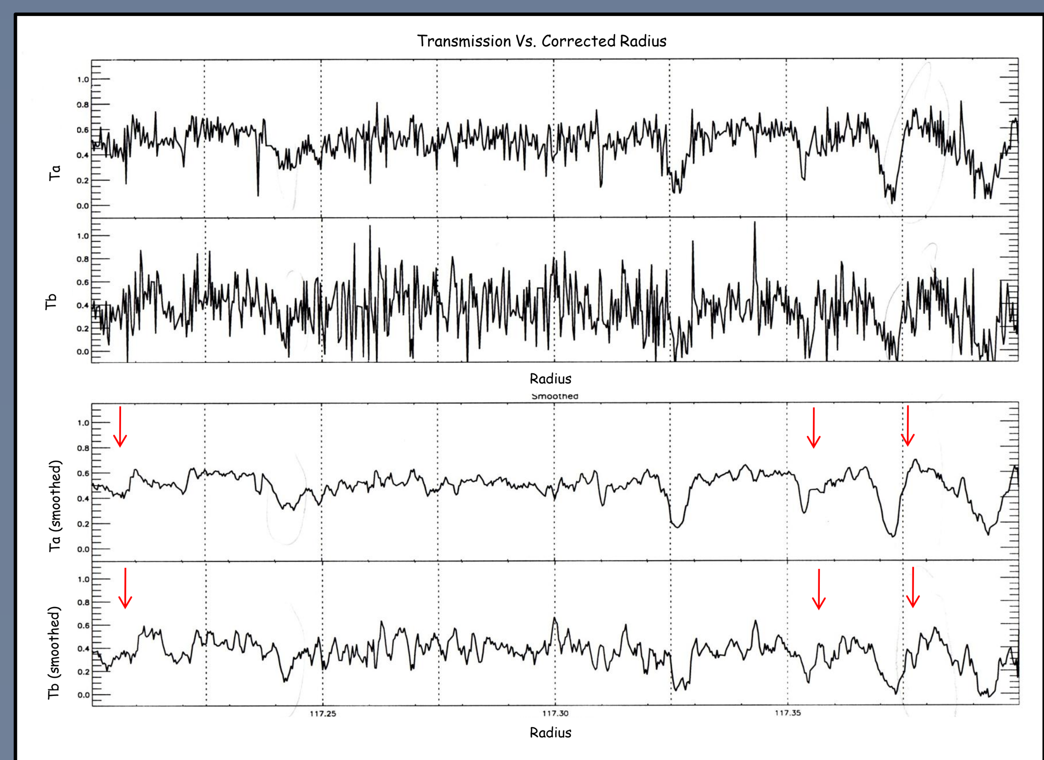
After solving for all of the wavelength dependent variables, we can solve Equation 1 for the radially dependent components. The top plot shows the original occultation data normalized to 1, and the bottom is T_a and T_b. If our method was successful, then there should be only one drop in transmission for each star and each one should be shifted and align with one of the drops in the original data. This is exactly what we see! Also note that the noise is higher than the original data.



The plot shows the amount of sunlight (top) and Saturnshine, normalized to unity. This is very interesting because a plot showing the reflected Saturnshine has not been produced before. These parameters vary smoothly across the occultation. Because of this, both plots are smoothed by 200 data points to reduce noise and cosmic ray spikes.



After separating the two transmissions the radial scale is shifted for one of the stars. Taking the geometry of both stars into account, we shifted the radial scale of T_b so that it would align with T_a. This plot shows T_a and T_b at the F Ring. The bottom panel is a smoothed version of the top. The left side of the feature has some differences between T_a and T_b.



Here is a section of the outer B Ring. Here we can also see some evidence of longitudinal variations. The red arrows note the regions where we can see some evidence of longitudinal variations. It is important to look at the unsmoothed data so that cosmic ray spikes are not mistaken for features. The dashed vertical lines are for reference and are spaced 25 km apart.

Conclusions:

- First time an algorithm has been used to separate elements of a binary star occultation using VIMS data.
- Since the separation of T_a and T_b was successful, we can continue to search for longitudinal variations.
- Random noise for Ta and Tb is doubled and tripled, respectively, from the original data.
- First time that both the reflected sunlight and Saturnshine have both been obtained from an occultation
- Alpha parameter is not perfectly constant with radius, but the analysis could be refined to correct this.
- As initially suspected, Saturnshine plays a significant role in the B-ring, but not anywhere else in the ring system.

Possible Future Work:

- Look for more variations in the ring with longitude
- Work on reducing noise in T_a and T_b
- Apply same method to other binary star occultations

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Reference:

Elliot et. al.,1975AJ,80,323E

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