The Reduction of Lyman Alpha Data from Voyager

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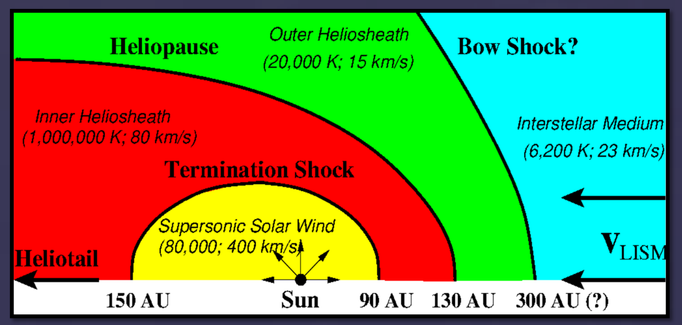
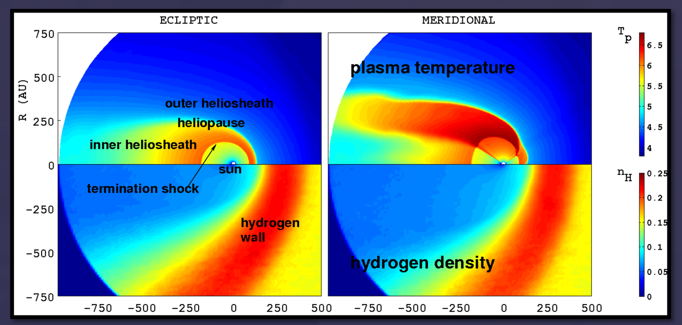
Abstract

The purpose of this project is to reduce raw data from the Ultraviolet Spectrometers on the Voyager Spacecraft to verify the Heliospheric Charge Exchange and Radiative Transport Models created by Dr. Jacob Heerikhuisen and Dr. Brian Fayock, respectively. It was decided to start from raw data because of controversy surrounding previous reductions.

In order to arrive at useful data, the original records had to be appended with spacecraft position data, pointing information in a new coordinate system with the antisolar direction set as the origin, and solar Lyman alpha flux data from the date of the record. Records were averaged along lines of sight, and those containing light from stars were discarded, as were records with a low SNR. The spectra had to be corrected for inherent device flaws, such as channel to channel variations in sensitivity, dark counts due to the thermonuclear power generator, and imperfect scattering of the diffraction grating. Records were then averaged into 18 regions of the sky and ordered into radial bins that matched the radiative transport model's cell spacing.

The Simulations

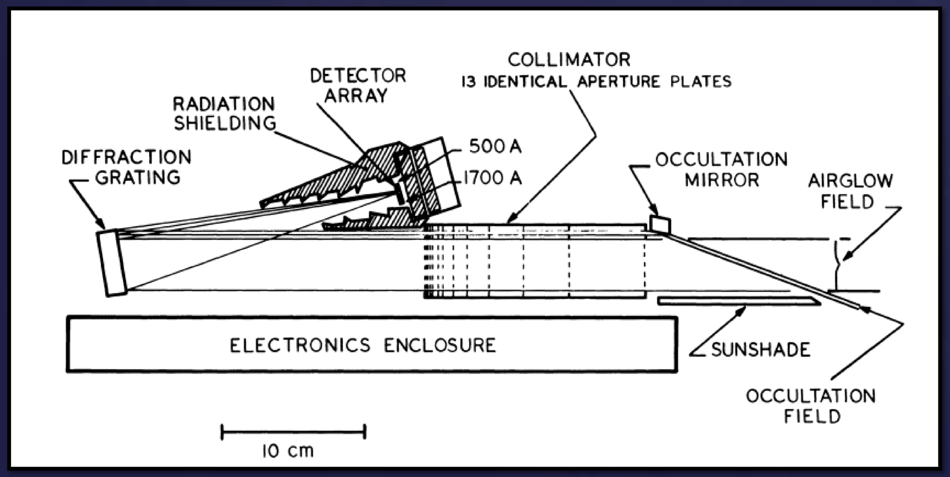


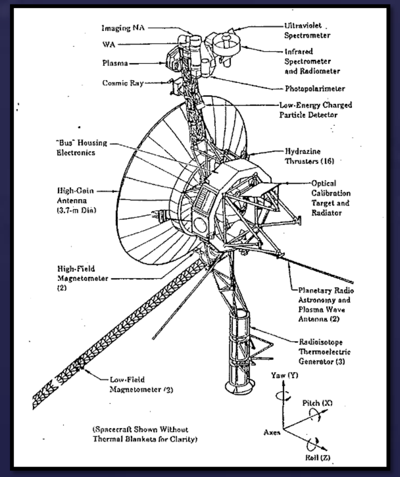


Photons emitted by the sun at the wavelength of Lyman alpha interact with neutral hydrogen in the heliosphere and are scattered. The greater the density of hydrogen in a region, the more photons will be scattered. Dr. Heerikhuisen's charge-exchange model generates Heliospheric neutral hydrogen density maps, which are used as initial conditions for Dr. Fayock's radiative transport model. This Monte Carlo simulation generates millions of photons at the position of the sun and tracks them as they move outwards through the solar system and interact with the hydrogen. The program monitors the number of photons that enter and exit each of the cells of a 1000 AU spherical grid. In this way we are able to simulate the amount of light that would be seen by a spacecraft at any point in the solar system.

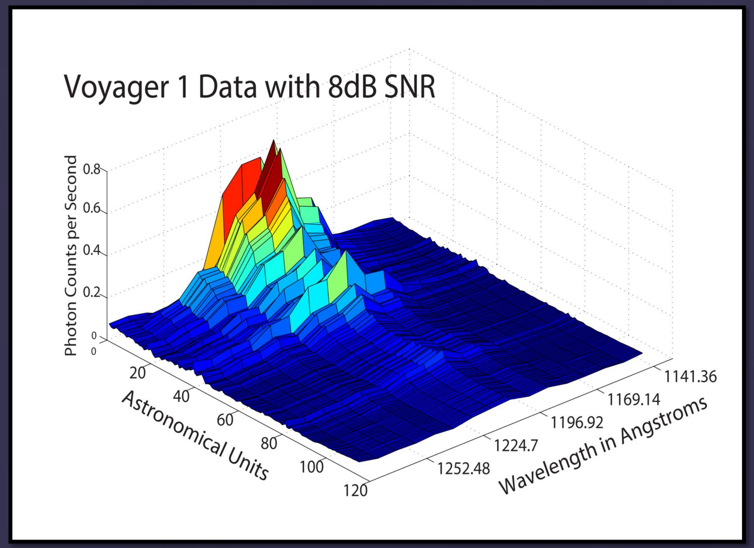
Voyager and the UVS

The Voyager spacecraft are the most distant man made objects. Each contains an objective grating spectrometer that images ultraviolet light in the Lyman band. While the spectrometers are usually used for looking at the light from stars, they have also been continuously collecting data from the IPM. Records containing stars must be excluded to ensure that data is only being taken from interplanetary hydrogen.



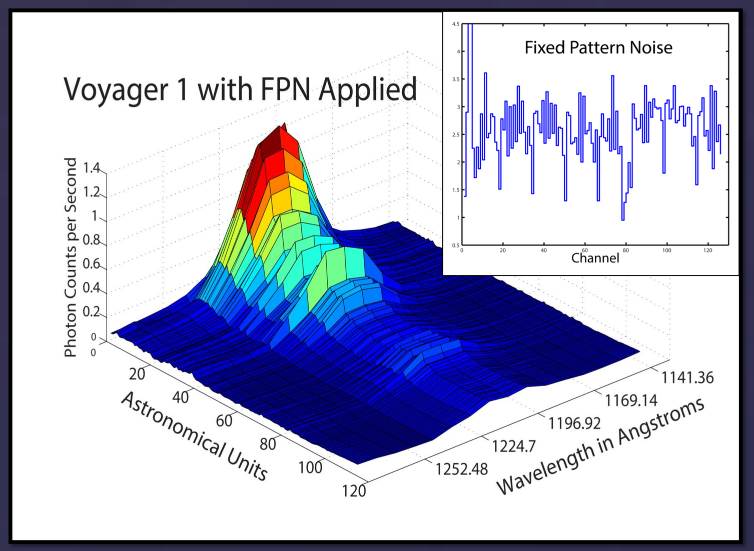


Correcting for Device Response



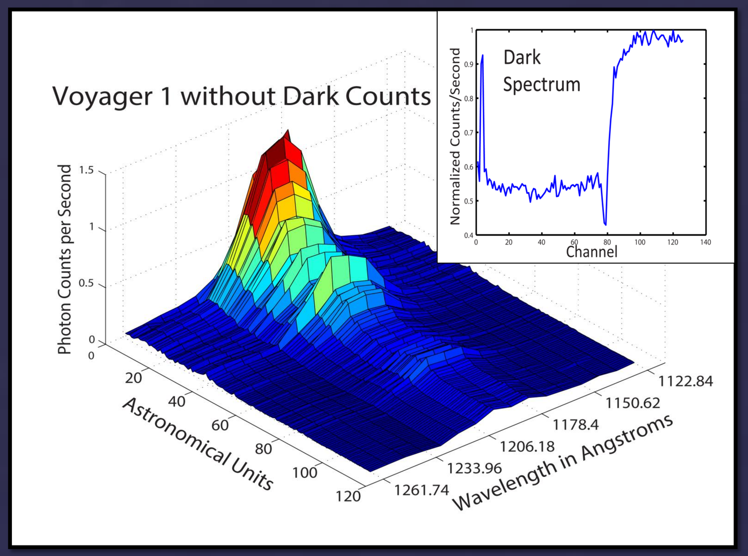
Line of Sight Integration

The UVS works by integrating the number of photons counted by a photomultiplier tube over a variable integration time. The first step in analysis was to average all records taken along a line of sight and normalize to counts per second. Next, the Signal to Noise ratio was determined by averaging the center of Lyman Alpha and comparing it to the channels around 75nm, a wavelength at which the interplanetary medium is opaque. Records with low SNR were discarded.



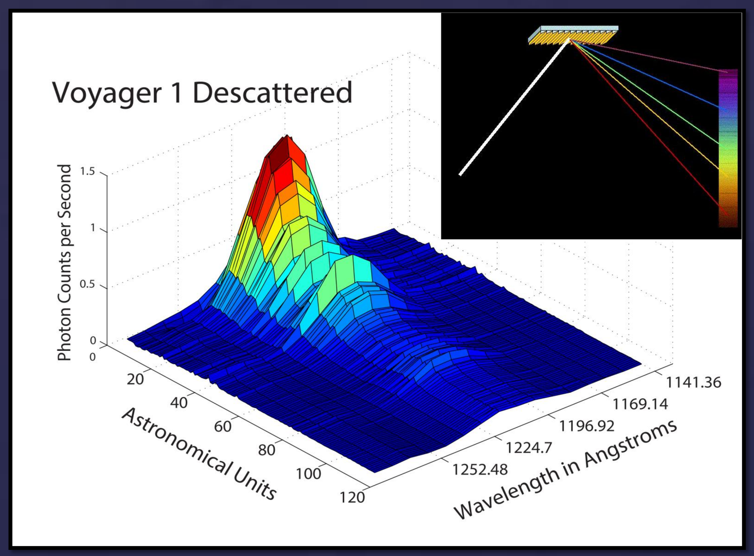
Fixed Pattern Noise

The individual channels of the UVS, each being a separate PMT, have different inherent sensitivities. This is corrected by the multiplication of the spectra with an empirically determined FPN spectrum.



Dark Counts

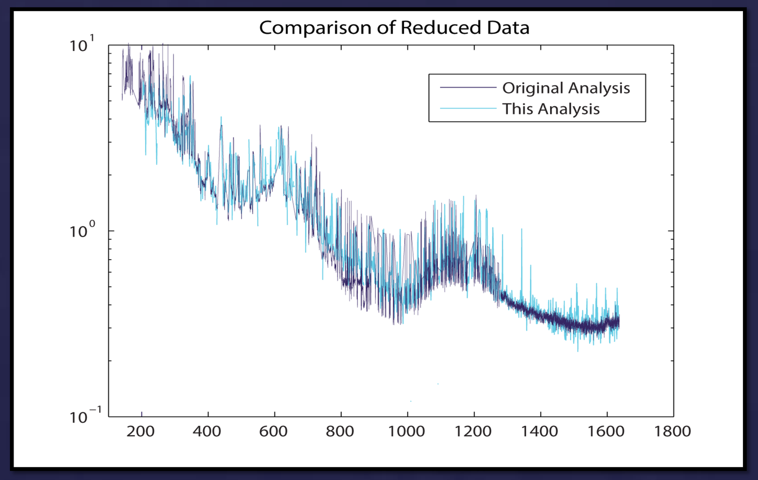
The power source for Voyager is a thermonuclear generator, which emits gamma rays that are detected by the UVS. As the device is actuated, the dark counts are modulated by the varying intervening spacecraft components. A dark spectrum, taken from a long picture of the calibration target, is scaled and subtracted so that the channels around 75nm average to zero.



Descattering Matrix

The diffraction grating in the UVS is imperfect, which leads to interchannel photon bleed. This is corrected by the application of an empirically determined descattering matrix.

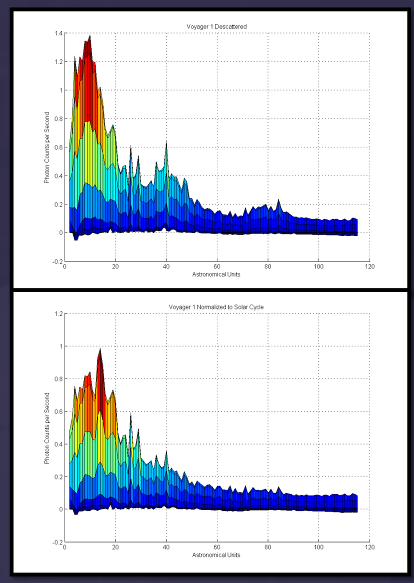
Intermediate Results – A Quick Check



The results of this reduction were plotted together with the results of the original analysis by Dr. Bill Sandell. The strong correlation between the two both serves to support the validity of our reduced data, as well as lending credibility to the original analysis.

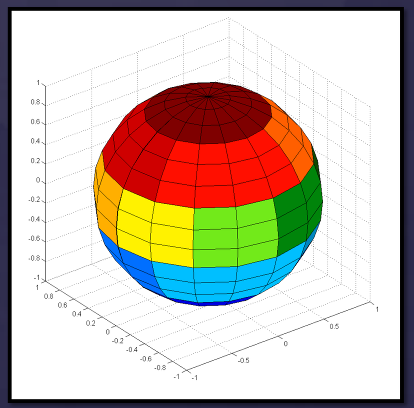
Further Reduction

Solar Cycle Normalization



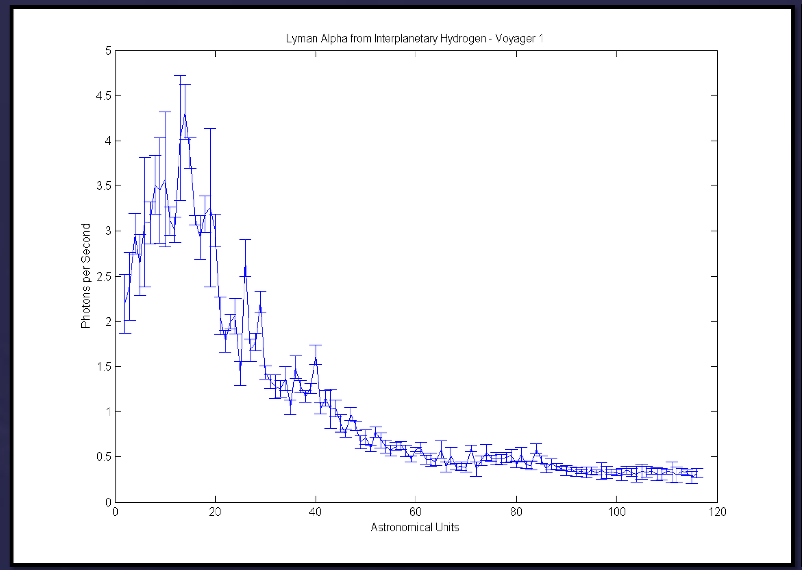
The simulation with which we wish to compare the data corresponds to the conditions of the heliosphere at a single point in time. Throughout the solar cycle, however, the flux of photons from the sun varies considerably, which modulates the number of photons detected by the UVS. The reduced data must be normalized to the variations in the solar cycle to remove this effect.

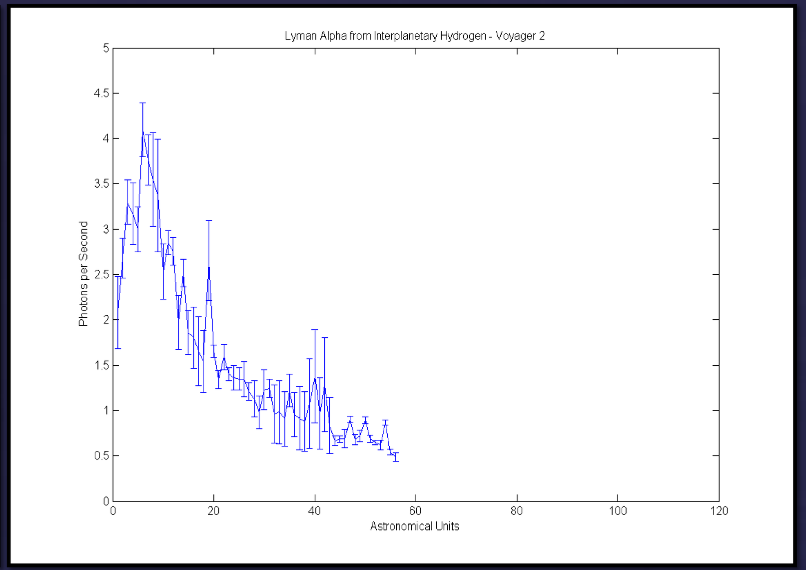
Regional Averages



In order to directly compare the Voyager Data with the output of the Radiative Transport model, each record's pointing coordinates were transformed into a new, voyager-centric frame, with the antisolar direction as the new origin. The sky was then broken into eighteen regions, and each one was averaged for each cell of the model.

Results





As of the writing of this poster, the reduced data has not yet been compared to the output of the Radiative Transport Model. These graphs represent the Lyman alpha intensity from each of the spacecraft before being separated into regions.

Acknowledgements

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