Understanding Atmospheric Absorption Effects on UV Spectra from Sounding Rockets using a Spherical-Shells Model

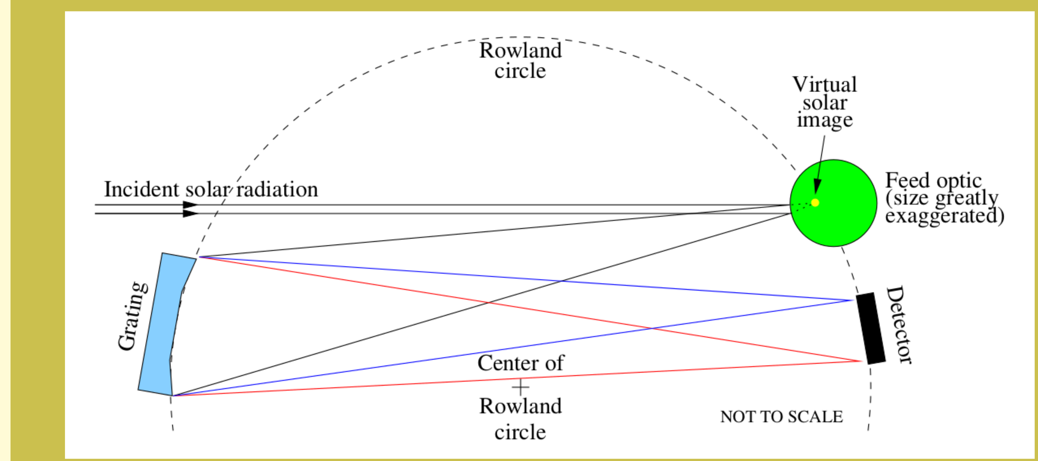
Summary Abstract

Our team is working on building and calibrating the FURST sounding rocket, with an expected launch in mid-2023. The goal is to image the most complete and highest resolution UV spectra to date. To do this, precise radiometric and wavelength calibration techniques have been developed. We describe below our model of O2 atmospheric absorption and couple that with simulated FURST images. With a high-enough SNR, we can estimate our ability to use absorption peaks for calibration, or for back-calculating atmospheric properties. If data is available, this method could be applied to older sounding rocket data to find hidden science.

Motivation

- **For FURST:**
  - To obtain high-resolution UV spectra [3].
  - To close the large data gap [17, 18].
  - To directly compare with HST & JWST [11].
  - To show the value of FURST as a satellite.
- **For this Research:**
  - To investigate potential SNR issues [23].
  - To aid in spectral calibration [7, 5, 6].
  - To better understand this effect [10, 22, 21].
  - To discover science hidden inside data.

Instrument

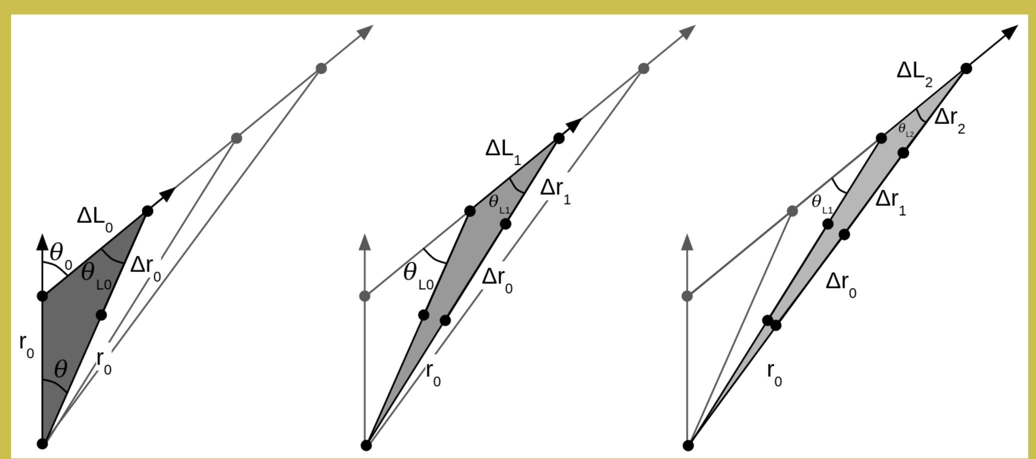


Spectral Range: 120-181nm
Resolution: $\mathcal{R}$>2·10^4 (ΔV<15km/s)
Launch: 2023 from WSMR, NM
Altitudes: 110-260km

Methods

- Transmission T is calculated from optical depth τ via Beer-Lambert's Law and the Differential Path Length ΔL:

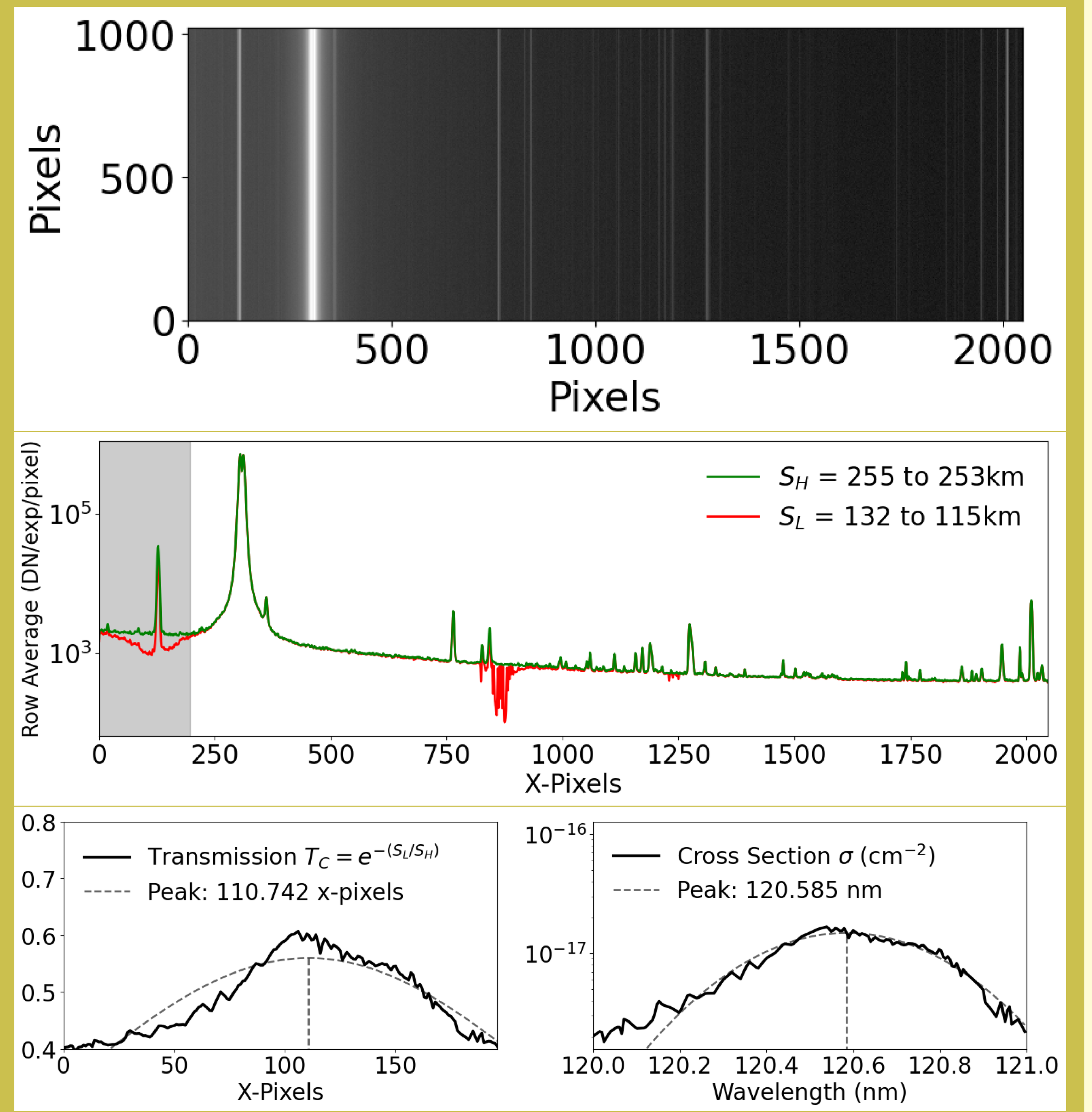
$$T = e^{-\tau}, \ \tau_{i,j} = \sum_{i'=i}^{\infty} \sigma_{i',j} \eta_{i'} \Delta L_{i'}$$



- Simulate results to match [15].
- Geometric and Trigonometric relations used to find ΔL.
- Earth's radius and Snell's Law allow for changing zenith angle [2, 8, 14, 19].
- Density data from NRL-MSISE [16].
- Absorption cross-section data from MPI-Mainz UVVIS [9, 13, 20, 12].
- HRTS data is folded into FURST optics simulate a UV spectra [1].
- Altitude / Exposure time effect SNR.

Results

- The spherical-shells model improves our estimated SNR.
- In the range 120-130.4nm, we show absorption lines for calibration.
  - Using 2 data point pairs (pixel and wavelength values) we calculate the spectral plate scale to within 0.5%.
- Running a forward model of density, we can to use the ratio between signals for density recalculation.
  - Using 2 images we fit a density model to within 15% RMSE [15].
- Further improvements include:
  - Testing SNR by varying exposure timings.
  - Coupling exposures/wavelength channels.
  - Calculating the O2 resonant absorption contribution and temperature-dependant absorption profile [4].
  - Applying these methods to existing SR raw data to discover hidden science.



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