INVESTIGATING GEOCORONAL ABSORPTION FOR WAVELENGTH CALIBRATION OF SOUNDING ROCKETS

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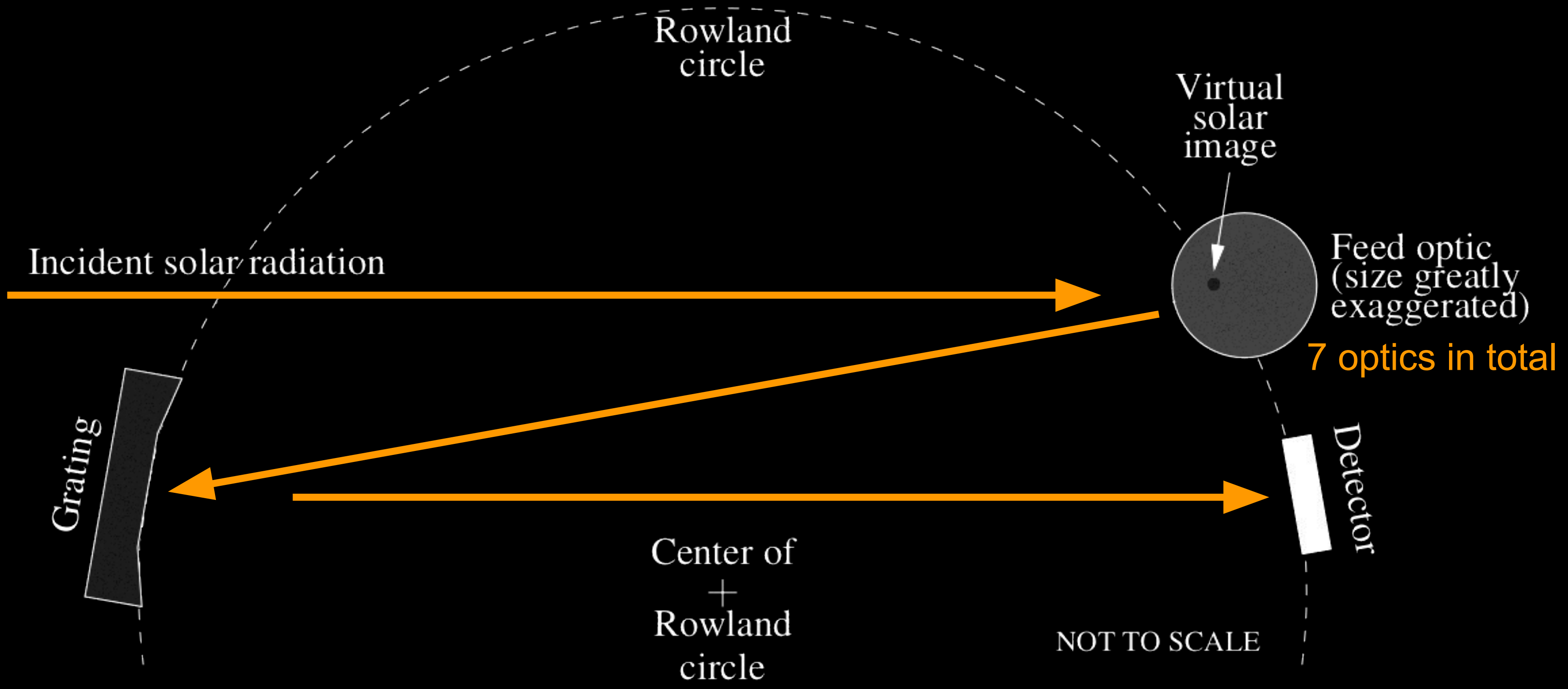
Overview

1. Sounding Rockets (FURST)
2. Available Spectra (HRTS)
3. Geocoronal Absorption
4. Wavelength Calibration
5. Future Work

1. Sounding Rockets (FURST) → 2 → 3 → 4 → 5

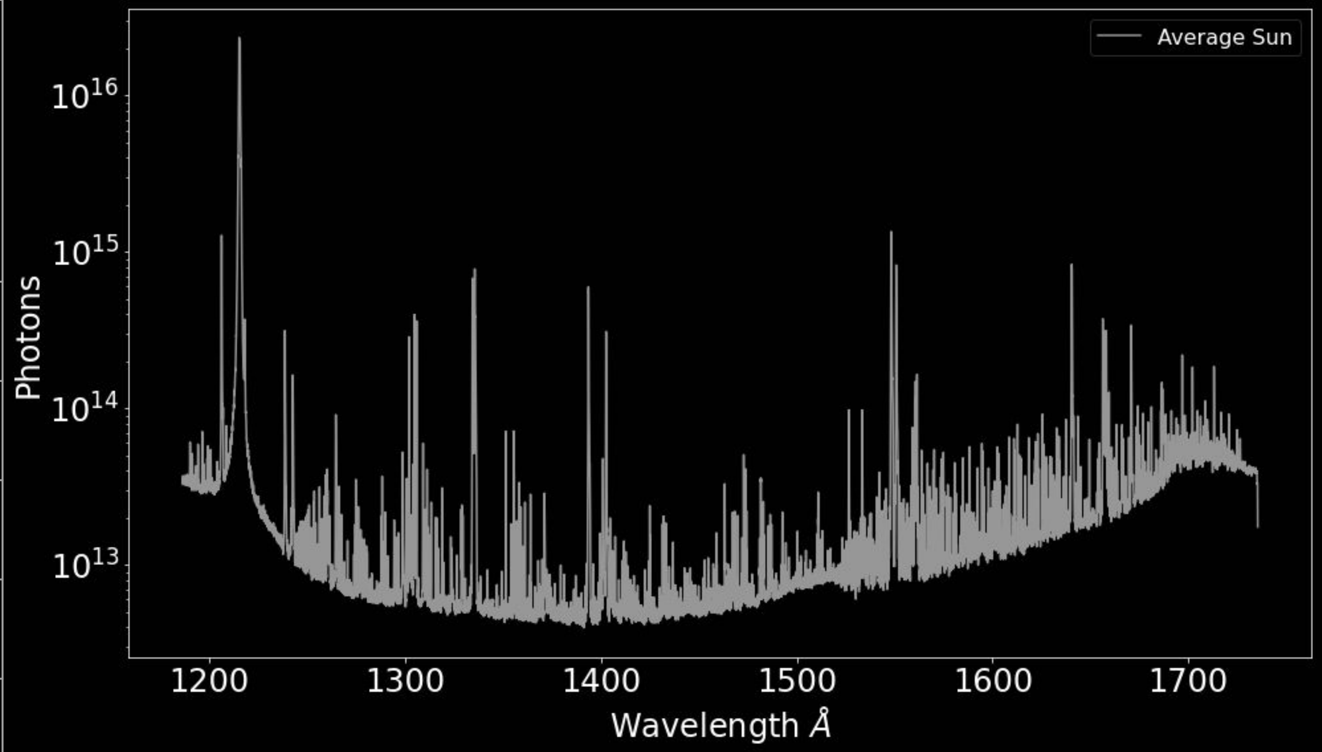
Full-sun Ultraviolet Rocket Spectrograph (FURST) (our future instrument)
slit-less
Altitude: ~109-255 km
Range: 1200-1810 Å
R ~ 100,000
Δv ~ 3 km/s
Δλ ~ 1.5 mÅ

- Spectroscopic and imaging devices on sub-orbital flights
- FURST optics layout:



1 → 2. Available Spectra (HRTS) → 3 → 4 → 5

Full-sun Ultraviolet Rocket Spectrograph (FURST) (our future instrument)	High Resolution Telescope and Spectrograph (HRTS)
slit-less	slit-based
Altitude: ~109-255 km	Altitude: 140-216 km
Range: 1200-1810 Å	Range: 1170-1710 Å
R ~ 100,000	**R ~ 29,000**
Δv ~ 3 km/s	**Δv ~ 10.4 km/s**
Δλ ~ 1.5 mÅ	**Δλ ~ 50 mÅ**

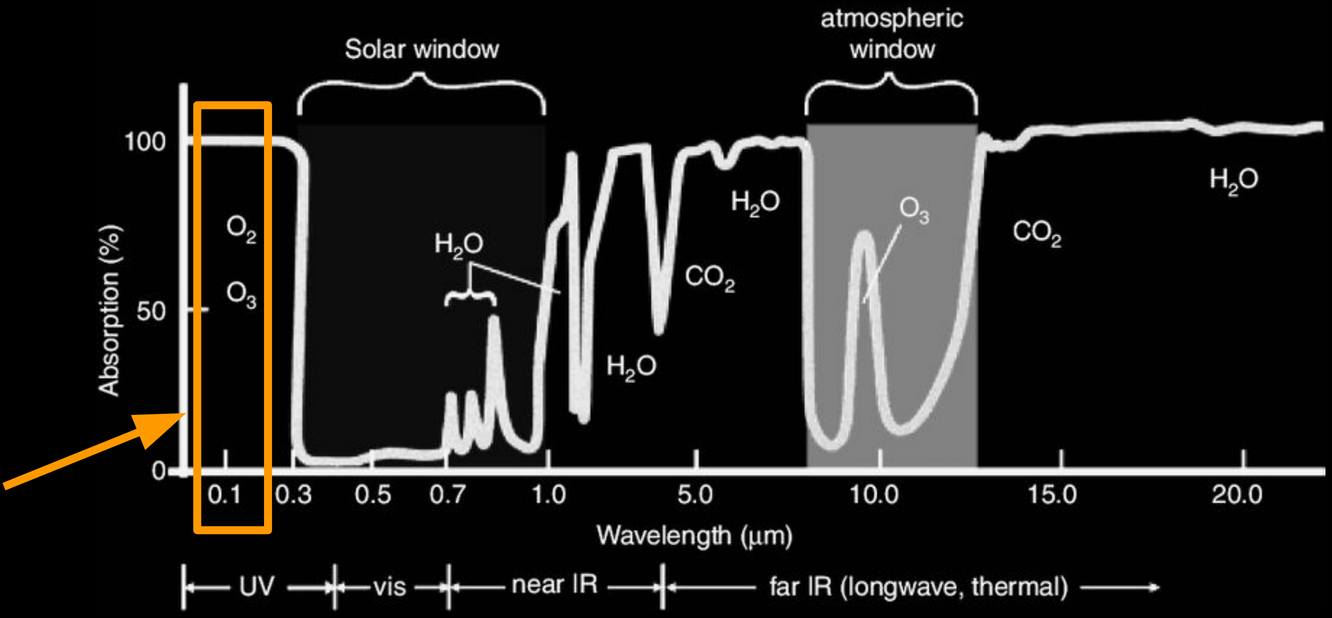


- HRTS spectra used as reference
  - Other sources exist with comparable resolution
  - **No full-sun data exists at R ≥ 10^5**

Brekke et al 1991: http://articles.adsabs.harvard.edu/pdf/1991ApJS...75.1337B

1 → 2 → 3. Geocoronal Absorption → 4 → 5

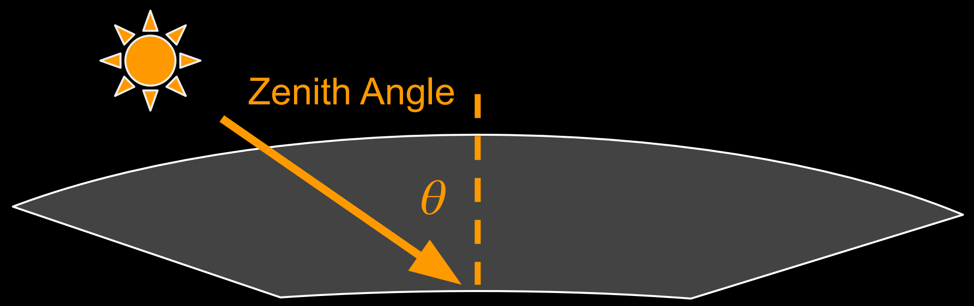
- **Most UV-C light is absorbed** by the time it hits ground level
- Geocoronal absorption is caused by molecules in the upper atmosphere
  - For the UV-C range, **we focus on O_2**



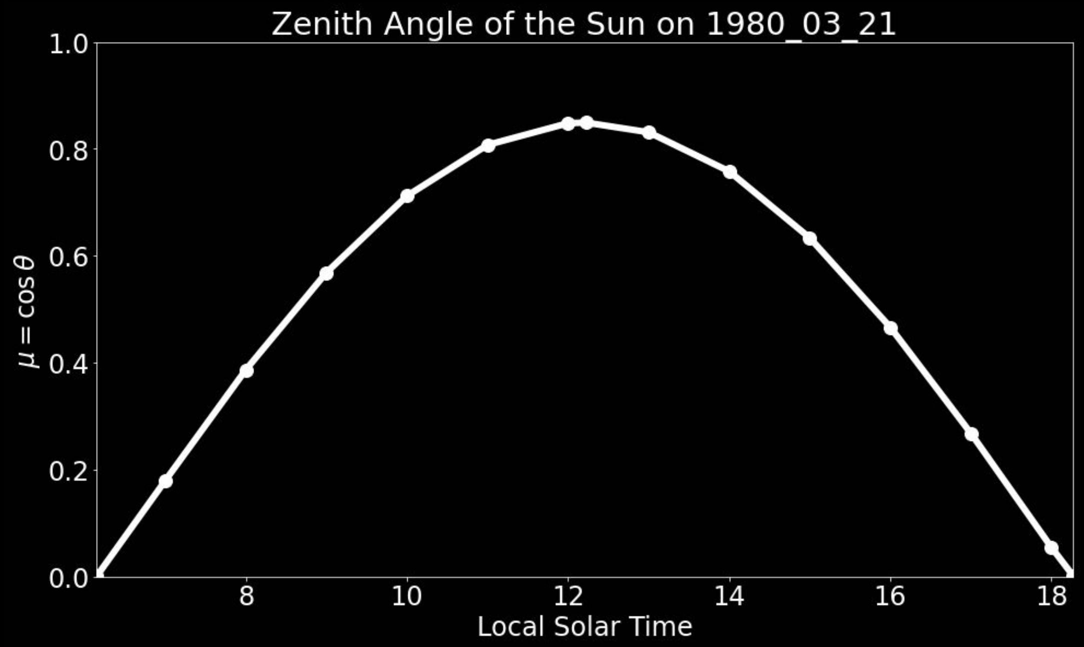
www.researchgate.net/figure/The-absorption-profile-of-Earths-atmosphere-from-UV-to-IR-The-graph-shows-the-regions_fig17_320660396

1 → 2 → 3. Geocoronal Absorption → 4 → 5

- Optical Depth is the **thickness of absorbing material** between the imager and the source
- Reproducing Meier 1991
  - Date: 21 March 1980 (Solar Max)
  - Time: 1000 gives cosθ = 0.712
  - Place: White Sands Missile Range, NM

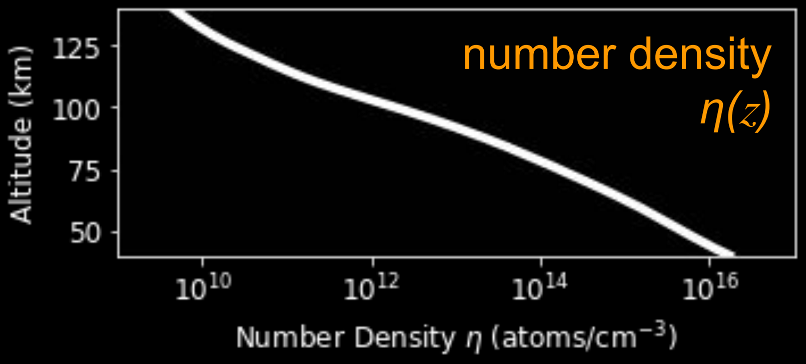


- The zenith angle attenuates the optical depth
- It changes with launch time and location

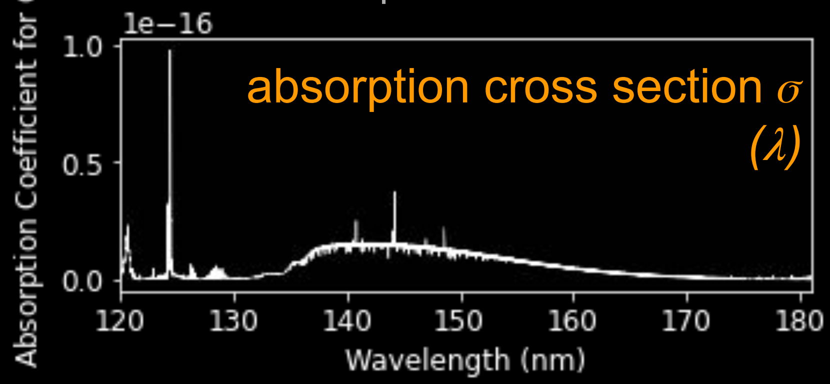


1 → 2 → 3. Geocoronal Absorption → 4 → 5

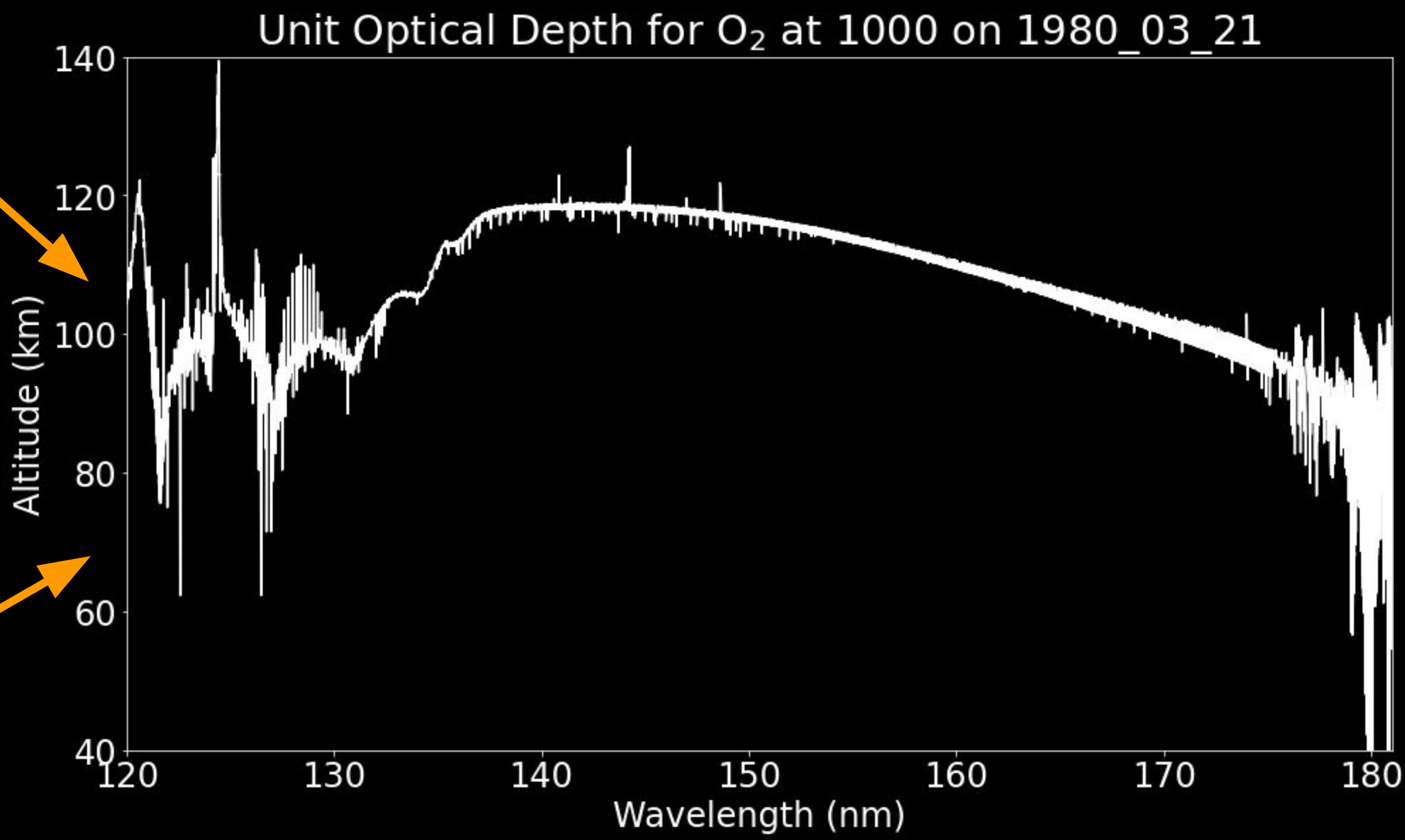
NRL Atmosphere Density Model



MPI-Mainz Absorption Coefficient database



$$\tau\left(\lambda, z\right) = \sigma\left(\lambda\right) \int_{z'}^{\infty} \eta\left(z\right) dz'$$



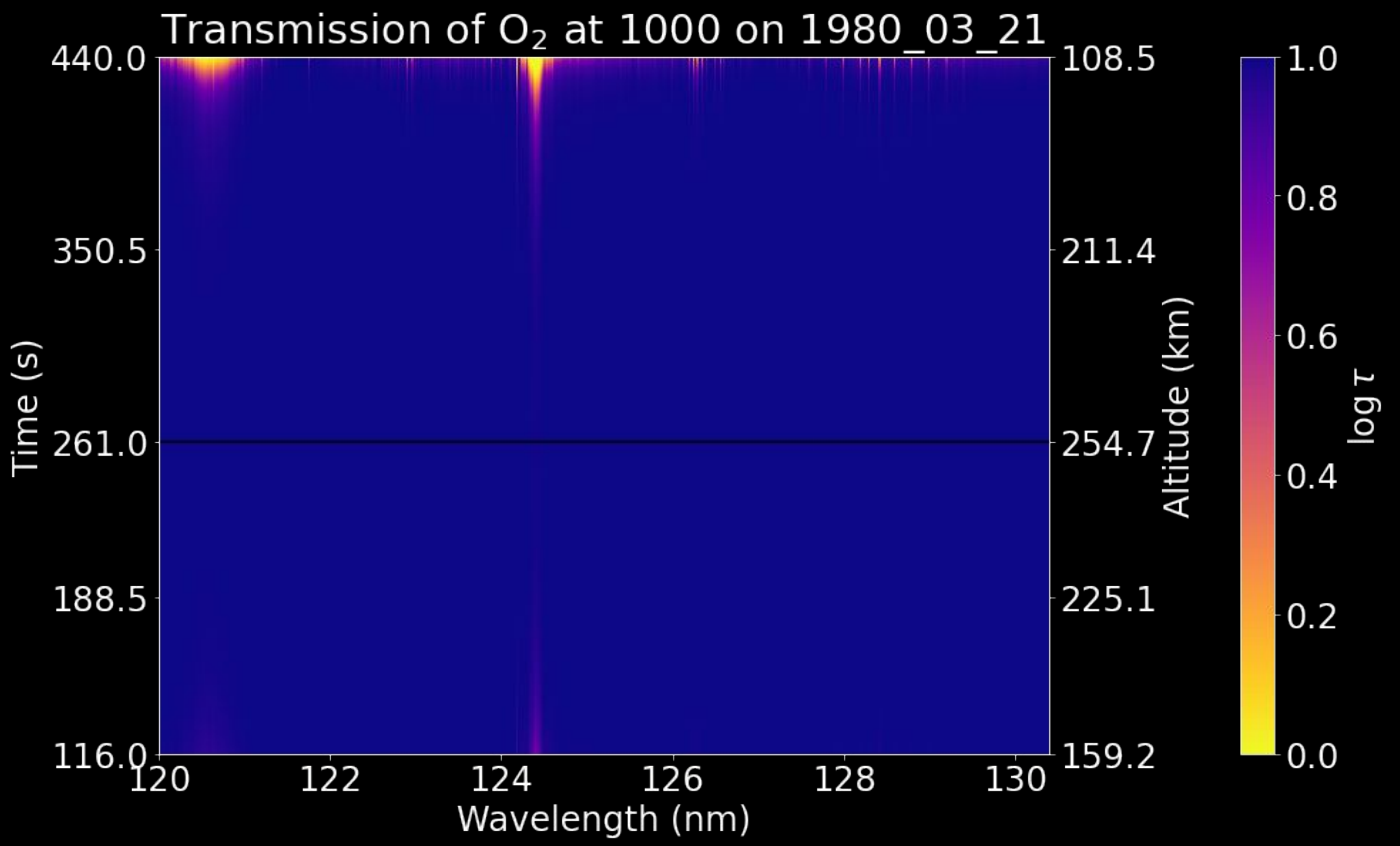
Meier 1991: adsabs.harvard.edu/full/1991SSRv...58....1M
NRL Model: ccmc.gsfc.nasa.gov/modelweb/models/nrlmsise00.php
MPI-Mainz Database: Keller-Rudek, Hannelore, et al. (2013)

1 → 2 → 3. Geocoronal Absorption → 4 → 5

- Transmission T:

$$T = \frac{I}{I_0} = e^{-\tau / \cos\theta}$$

- This draft plot shows the calculated transmission during the expected flight profile
    - **Absorption is only expected at the start and end of open-shutter time**



1 → 2 → 3 → 4. Wavelength Calibration → 5

Using diagnostic spectral lines to obtain accurate knowledge of how the CCD pixels map to wavelength values such as **spectral plate scale, tilt, spherical aberration**, etc.

$$\lambda = (\lambda_0 + \Delta\lambda_0) + (A + \Delta A)\cdot x + (B + \Delta B)\cdot x^2 + (C + \Delta C)\cdot y + (D + \Delta D)\cdot y + (E + \Delta E)\cdot x \cdot y$$

Absorption lines may provide additional diagnostics

The average **spectral plate-scale** is **~ 51 mÅ per pixel**
Our accuracy goal is **$\Delta\lambda$ ~ 1.5 mÅ per pixel**

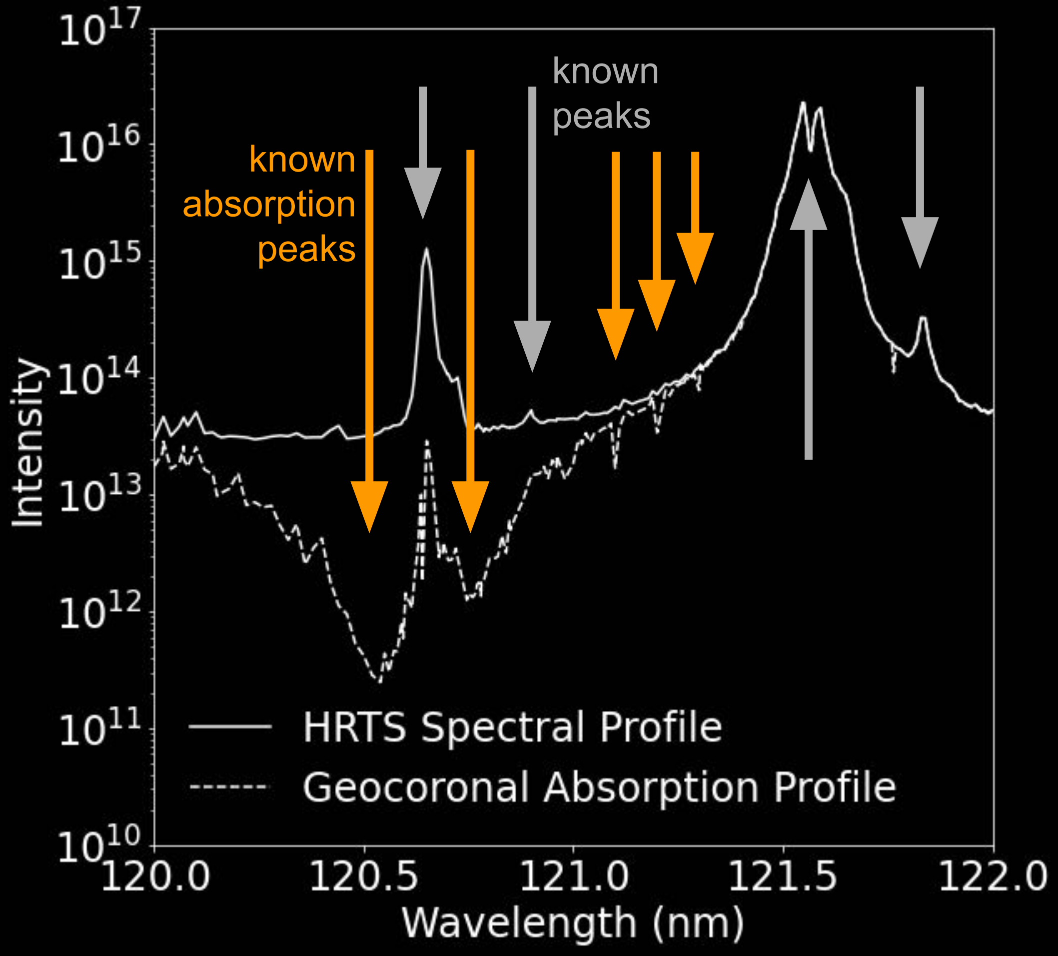
www2.keck.hawaii.edu/inst/common/makeewww/index.html
www.eso.org/sci/software/pipelines/skytools/

1 → 2 → 3 → 4. Wavelength Calibration → 5

- This plot shows an example signal at the lowest altitude for FURST (~109 km)
  - Potential diagnostic lines shown by arrows

$$I = I_0 e^{-\tau / \cos\theta}$$

- Many models exist to correct for atmospheric absorption
  - “Makee” for Keck
  - ESA Skytools
  - Many other open-source programs
- We can use these lines to aid in calibration **before correcting** for them



1 → 2 → 3 → 4 → 5. Future Work

- Pre- and post-flight calibration are the norm
- Using various methods, including these anticipated absorption profiles, we plan to obtain **in-flight calibration**
- This functionality has broad applicability
  - Normally, this correction would be thought of as only a “radiometric calibration” problem
- The next step is integrating with the **calibration work already underway**

www.nasa.gov/centers/marshall/news/news/releases/2015/nasas-clasp-mission-set-to-gauge-upper-solar-chromospheres-magnetic-field.html