An Investigation of the Vertical Properties of Thermospheric Gravity Waves Using FUV Stellar Occultation SORCE Data

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Background

- Gravity waves are a key feature of the atmosphere, present throughout all atmospheric layers.
- They typically form due to weather or terrain effects in the troposphere but can propagate vertically, climbing up the atmospheric layers.
- The effect that gravity waves has on a local piece of the atmosphere can be observed differently, common approaches include temperature oscillations and density oscillations.
- Gravity waves facilitate the transport of airborne particles throughout the atmosphere, are responsible for energy and momentum being carried across atmospheric layers and can even dynamically cool or heat regions of the atmosphere via vertical and horizontal propagation, breaking, mixing and dissipating. [3]

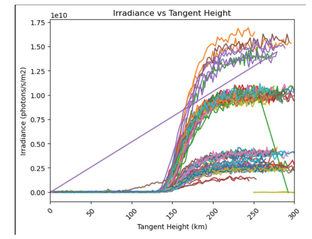
Motivation

- The thermosphere is a particularly difficult region of the atmosphere to study, being too high up for most ground based measurements.
- This results in a region of ~100 to ~200 km where little to no observations of vertical gravity waves exists. This region is commonly called the 'thermospheric gap'.
- In a similar fashion to a recent MAVEN study [4], stellar occultation data was used to attempt to find gravity waves in this region. This occultation data is from the SOLSTICE instrument aboard SORCE.
- The motivation behind using an occultation approach is that the data is available at thermospheric altitudes due to SORCE being a spacecraft rather than a ground or low altitude observational instrument.

Stellar Occultation Data

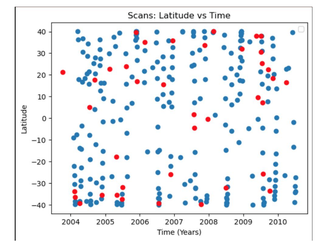
Star name	Bright star	RA (2000)	Dec (2000)	V mag	Spectral type
ε Per	1,220	3h 57.8min	40° 0′	2.90	B0.5 III
β CMA	2,294	6h 22.7min	−17° 57′	1.98	B1 II–III
σ CMa	2,491	6h 45.1min	−16° 43′	−1.46	A1 V
κ Vel	3,734	9h 22.1min	−55° 1′	2.50	B2 IV-V
σ Leo	3,982	10h 8.4min	11° 58′	1.35	B7 V
δ Cen	4,621	12h 8.4min	−50° 43′	2.60	B2 IVne
α Cru	4,730	12h 26.6min	−63° 7′	1.35	B0.5 IV + B1 V
α Vir	5,056	13h 25.1min	−11° 10′	0.97	B1 IV + B2 V
η UMa	5,191	13h 47.5min	49° 15′	1.86	B3 V
ζ Cen	5,231	13h 55.5min	−47° 17′	2.55	B2.5 IV
β Cen	5,267	14h 3.8min	−60° 22′	0.61	B1 III
δ Sco	5,953	16h 0.3min	−22° 37′	2.32	B0.5 IV
ι Sco	6,165	16h 35.9min	−28° 13′	2.82	B0 V
α Lyr	7,001	18h 36.9min	38° 47′	0.03	A0 Va
σ Sgr	7,121	18h 55.3min	−26° 18′	2.02	B2.5 V
ο Pav	7,790	20h 25.6min	−56° 44′	1.94	B2.5 V
σ Gru	8,425	22h 8.2min	−46° 58′	1.74	B7 IV
α PsA	8,728	22h 57.7min	−29° 37′	1.16	A3 V

Stars used to collect the stellar occultation data [2]



Irradiance measurements as a function of tangent height (altitude)

- The irradiance measurements came from the Solar Radiation and Climate Experiment (SORCE), specifically the SOlar STellar Irradiance Comparison Experiment (SOLSTICE) instrument onboard the spacecraft.
- Data used spans from 2004 to 2010, using the data collected when SOLSTICE calibrated itself against the 18 stars listed in the table above.
- SOLSTICE measures light in the 115-320 nm (Far Ultraviolet) range.



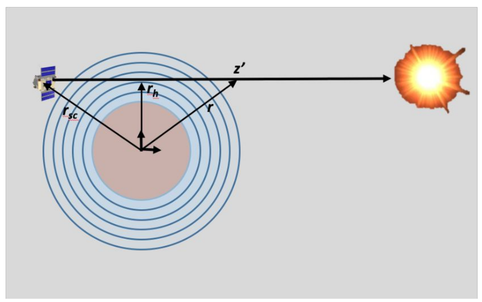
The occultation scans as they vary with latitude and UTC. Red represents a scan with gravity waves present, blue represents scans with no gravity wave present

Column Density & Model Fit

$$\tau_{gas} = \sum_i \sigma_i N_i$$

$$I(r_h) = I_\infty e^{-\tau_{gas}}$$

$$N = \frac{-\ln \frac{I(r_h)}{I_\infty}}{\sigma}$$

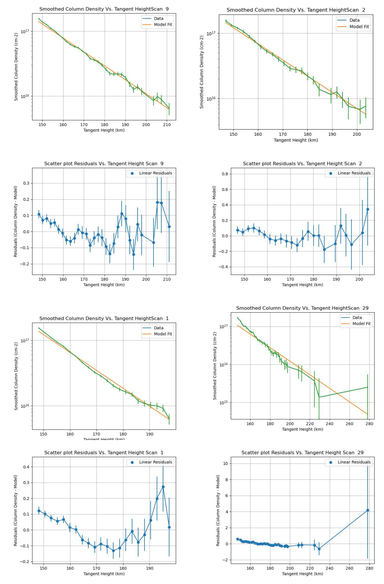


A visual representation of the occultation data

- Column density is a measure of the density of atoms along a column of the atmosphere.
- It is calculated using the Irradiance measurements taken by SOLSTICE, I(rh) and I_infty in the equations above.
- SIgma represents the cross section of O_2 that the FUV light dissociates in the atmosphere.
- Oscillations in the column density should correspond directly to oscillations in the atmosphere itself, thus indicating the presence of gravity waves. Which can be found be looking for oscillations around a linear model fit.

Residuals & Results

- After plotting the column density in log scale, we apply a model fit and calculate the residuals.
- Residuals are plotted as deviations from the model in fractional units.
- While not every scan showed a wave, plenty of convincing scans showed oscillations >2 times greater than the uncertainty in the measurements, allowing us to comfortably conclude that we did observe thermospheric gravity waves.



Conclusions & Future Work

- Using a stellar occultation approach we were able to observe and study vertically propagating gravity waves in earth's thermosphere with data ranging from 120 to 300 km.
- The waves found have so far been consistent with existing theory, with wavelengths of 10 to 20 km and relative amplitudes of 10-25 percent.
- This region, known as the 'thermospheric gap' has been a difficult one to study by dynamicists, making this work novel among gravity wave studies.
- Steps will be made to continue the analysis of this data set, shifting towards a focus on comparison tests between the stars used in the study and an analysis of the local time and solar cycle variability of the data.

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