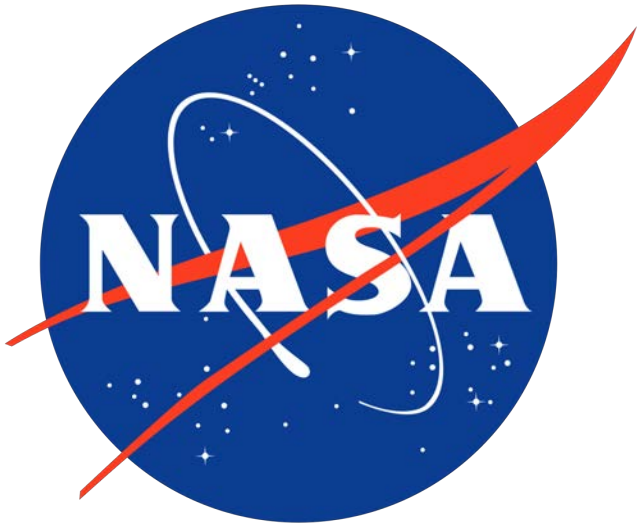



# Synthesis of HMI/SDO and SOT/Hinode Observables from Solar Hydrodynamic Simulations

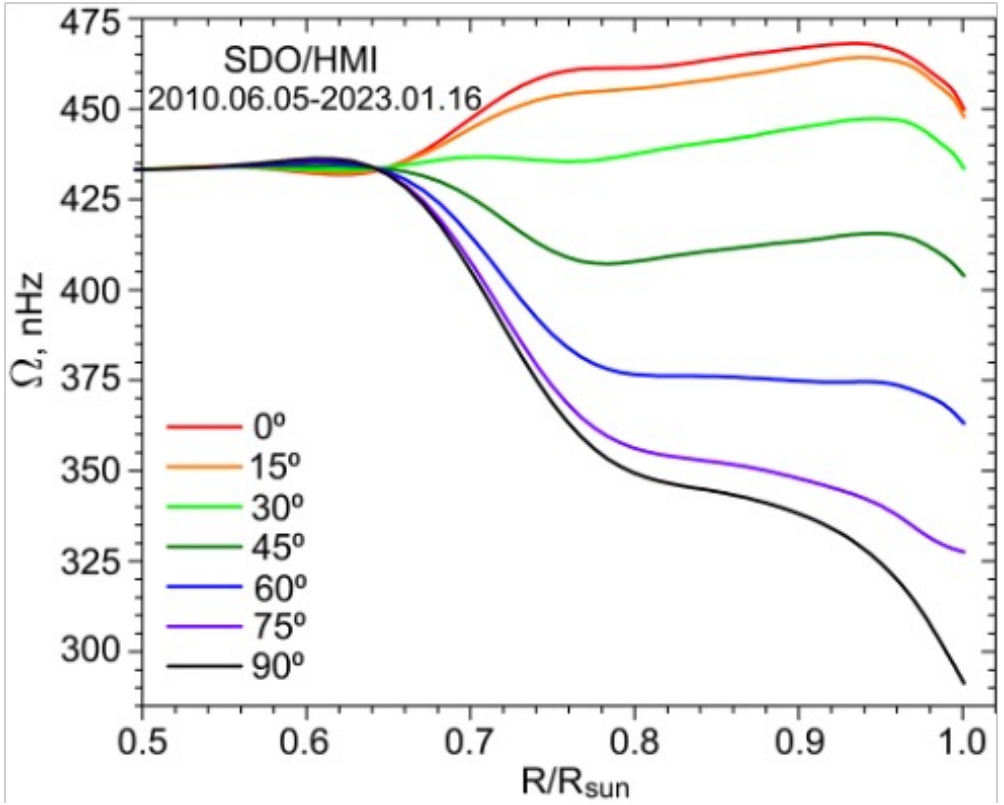
Devin Hoover

University of Chicago

August 11, 2023

# Introduction

- Solar differential rotation
- Change in Sun's sphericity/seismic radius
- Helioseismology reveals information about solar interior
  - P-modes
  - F-modes
- Simulations useful for investigating sensitivity of spacecraft/instruments
  - HMI (Solar Dynamics Observatory)
  - SOT (Hinode)

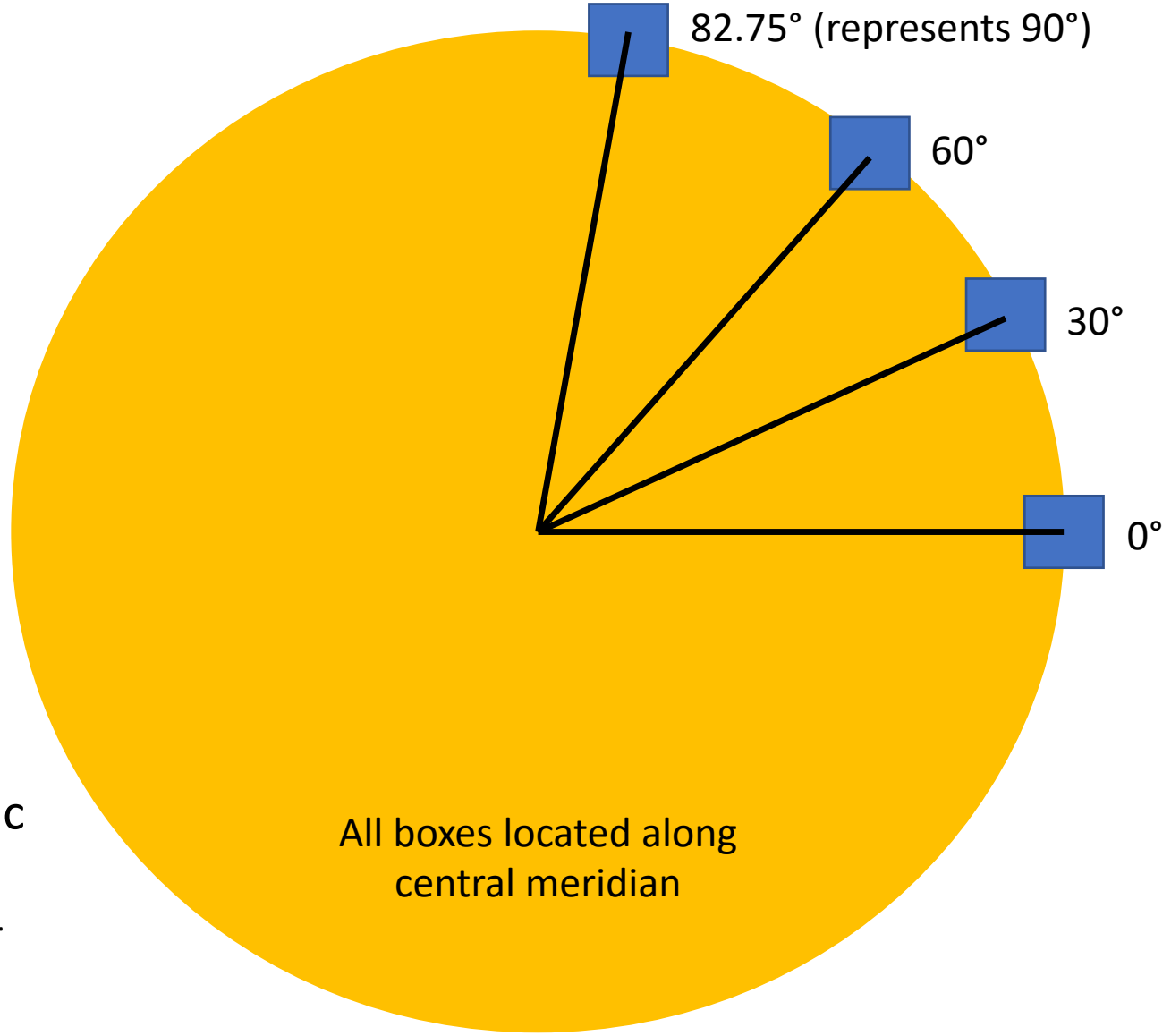



SDO

Hinode

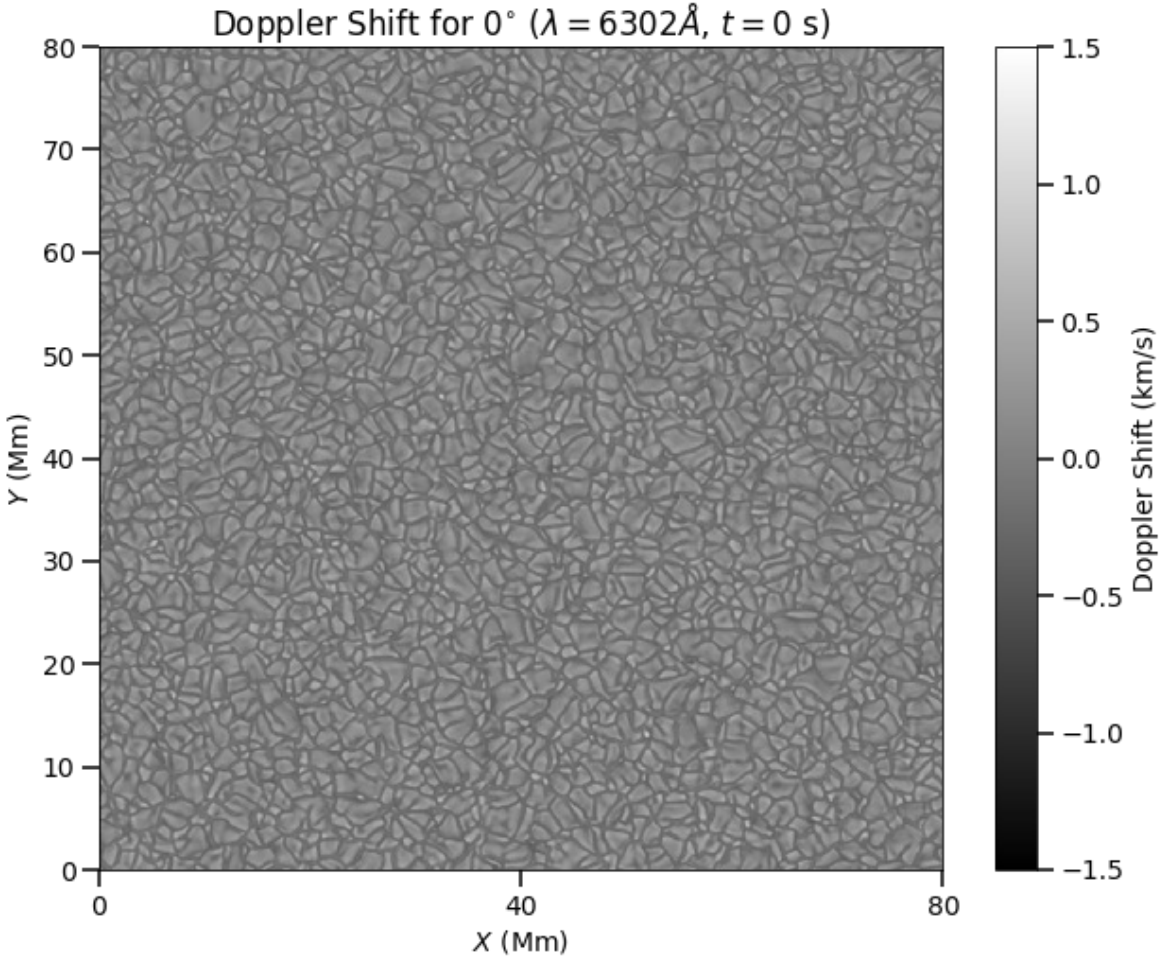
# Data Used

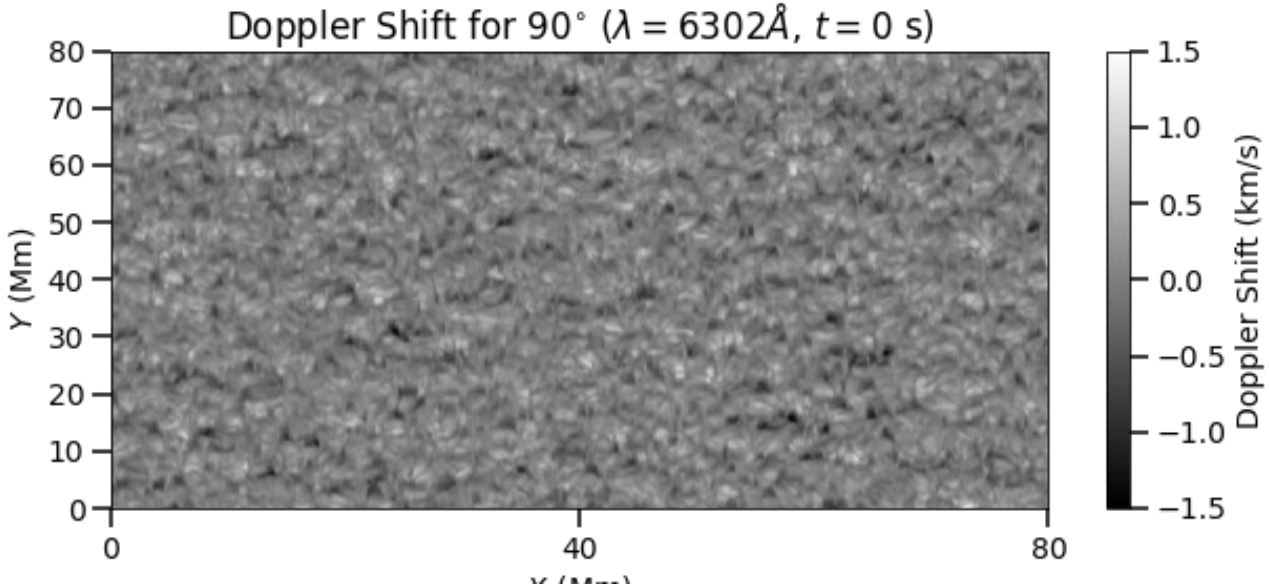
- Data cubes from hydrodynamic simulations
  - 0°, 30°, 60°, 90° latitude
  - 80 Mm x 80 Mm x 25 Mm + 1 Mm of atmosphere
  - No magnetic field
  - Uniform solar rotation – imposed Carrington rotation rate
- Spinor code/STOPRO package
  - Computes full Stokes profiles of atomic and molecular absorption lines in LTE
  - 3 Fe I lines (6173 Å, 6301 Å, 6302 Å) – input spectral line data



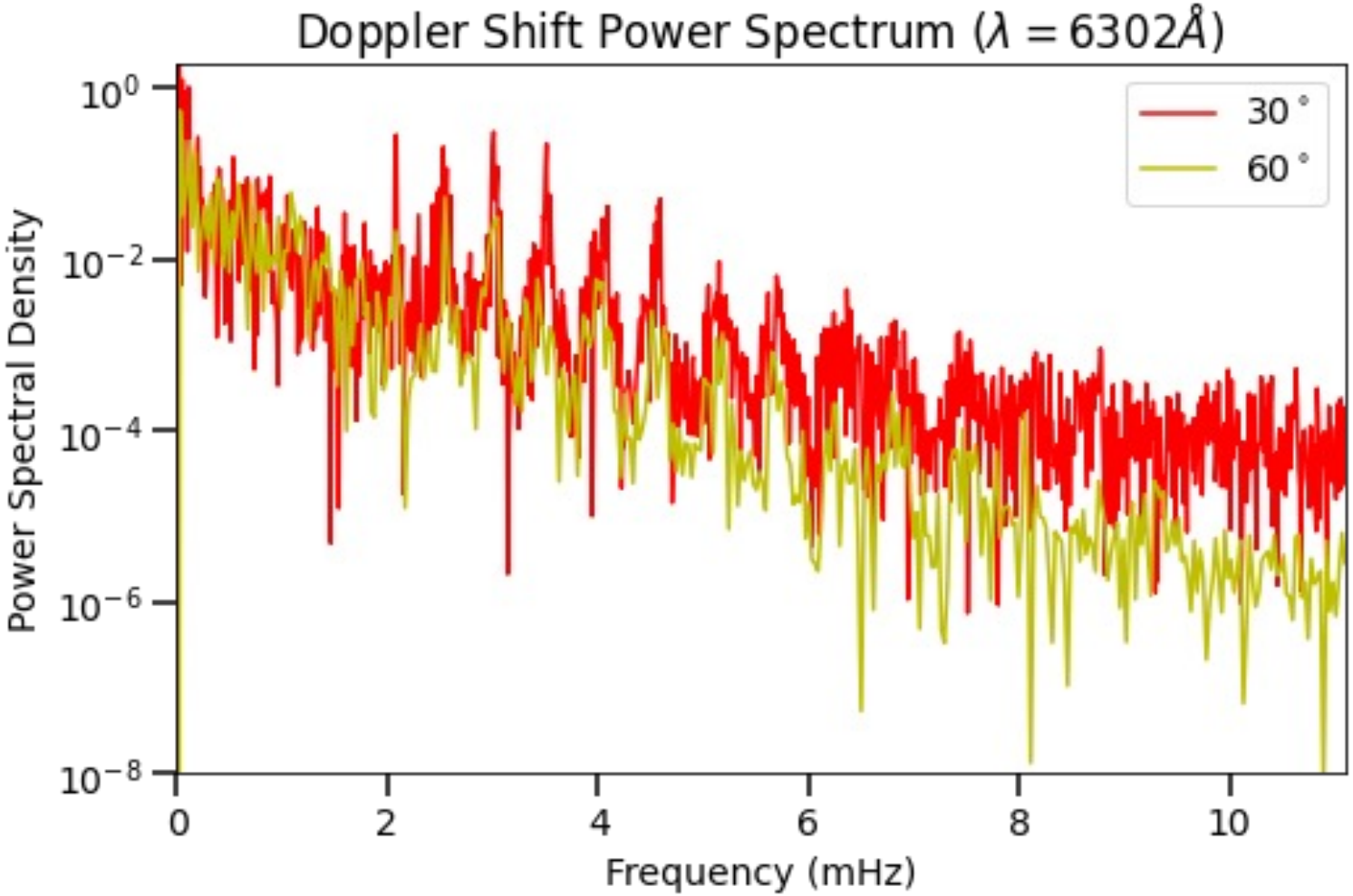
# Methodology + Results

# Doppler Shifts at 0°, 90°



# Doppler Shift Power Spectra at 30°, 60 °



# Cross-correlations Analysis Between Simulated Observables and Initial Model Parameters

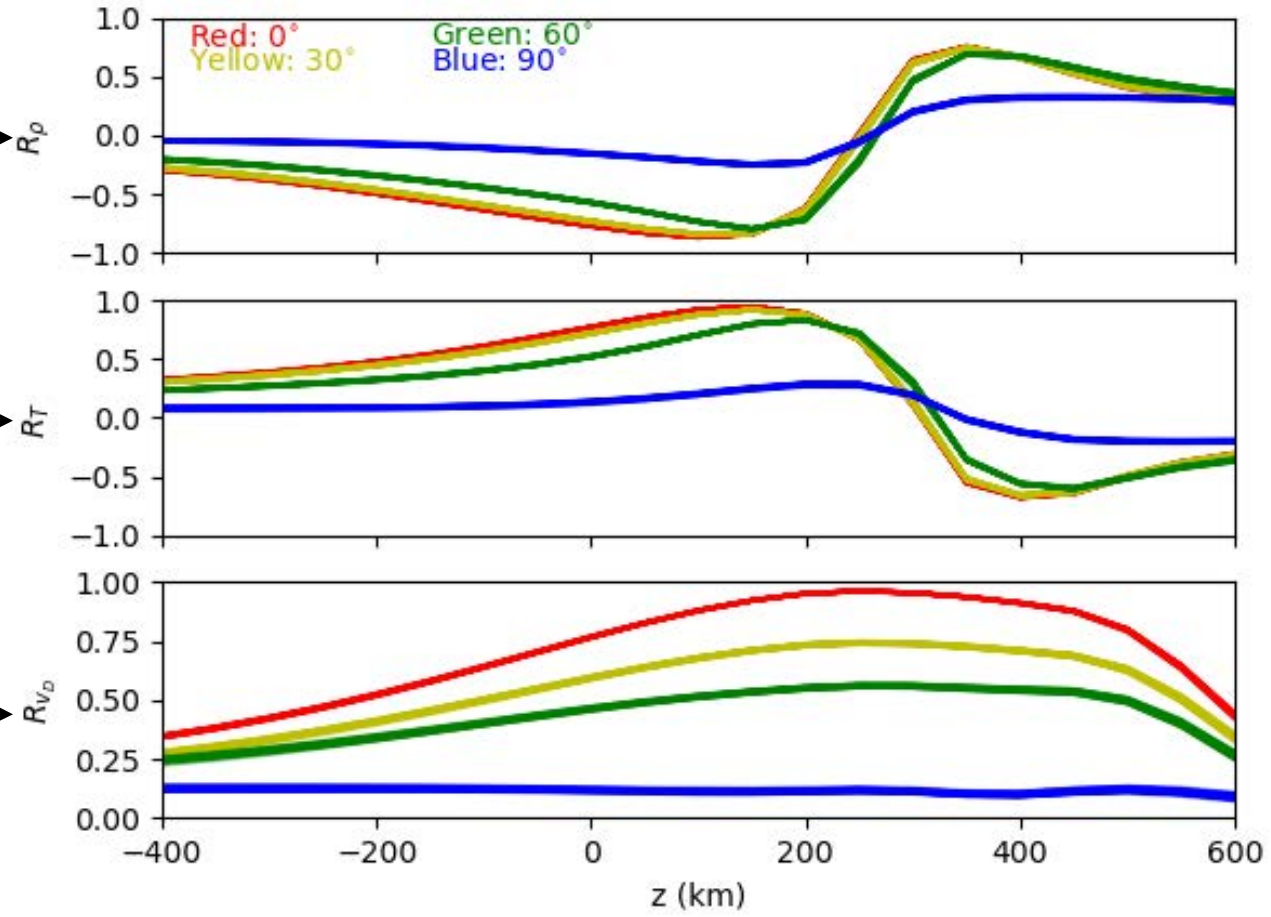
## Variable Pairs

Continuum density vs. density →

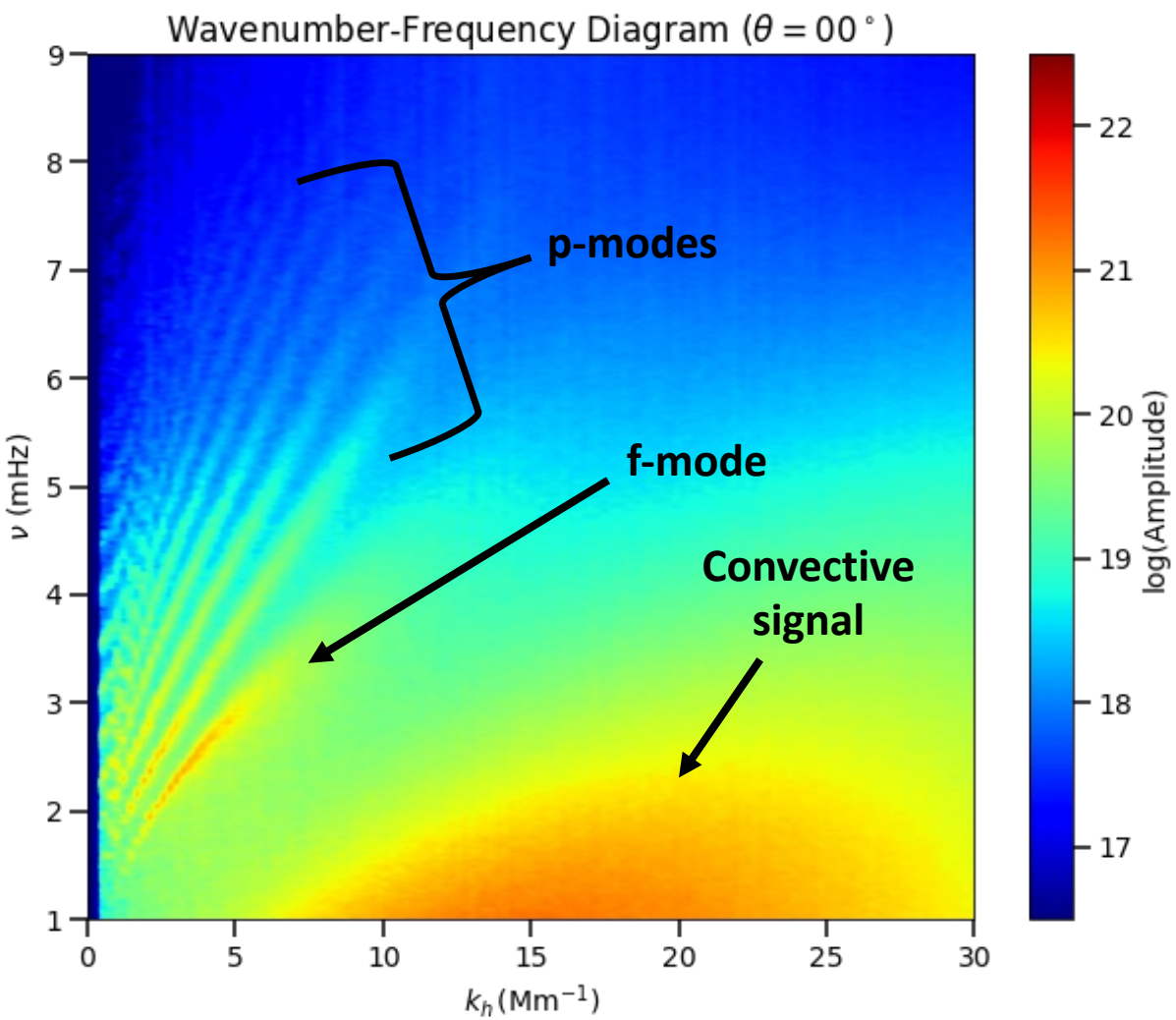
Continuum density vs. temperature →

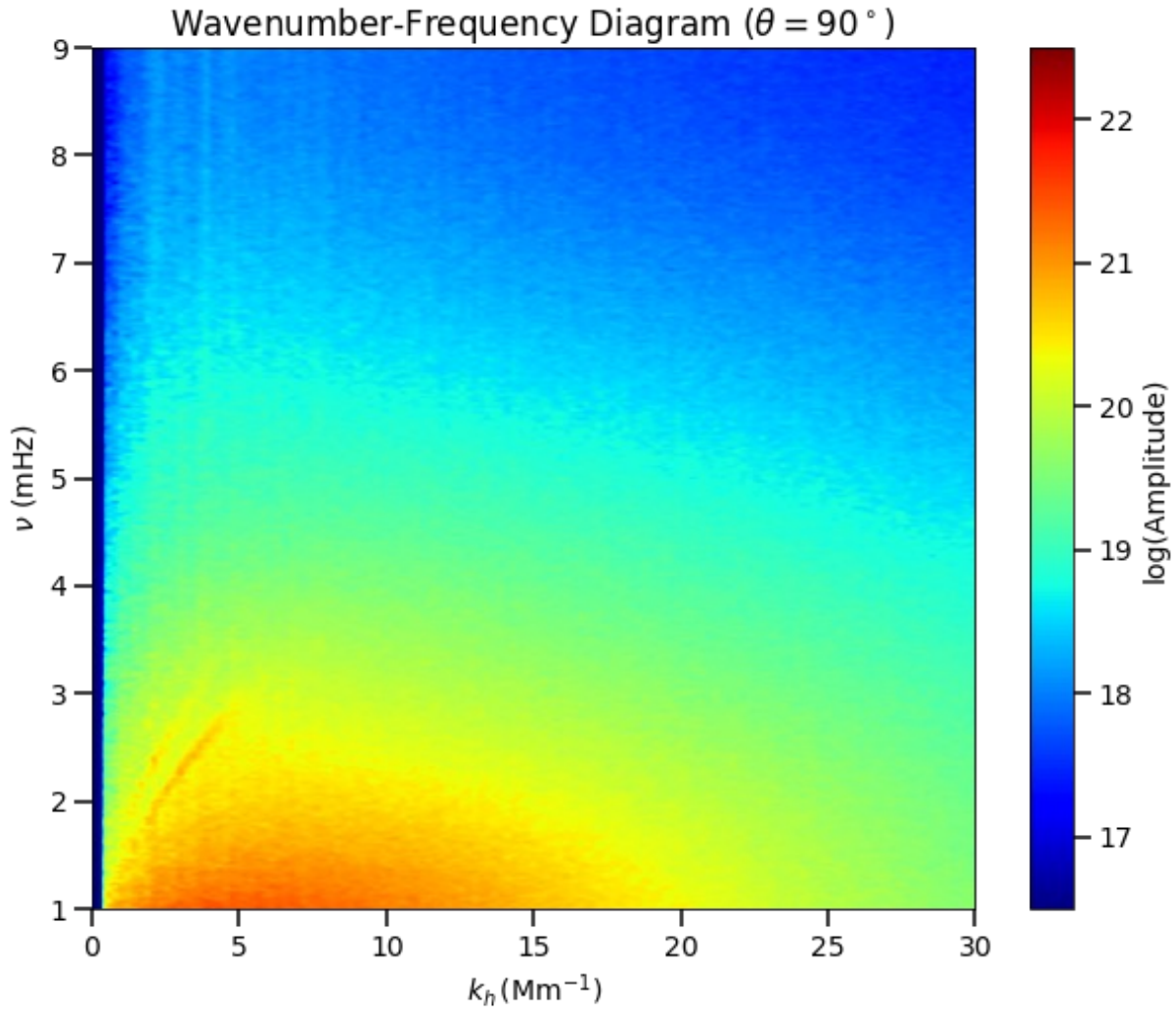
Doppler shift vs. vertical velocity →

Cross-Correlations Between Observables and Model Parameters



# Wavenumber-Frequency Diagrams at 0°, 90°



# Conclusions

- At latitude decreases, tangential velocity decreases.
  - No chevrons observed at 0°; many chevrons observed at 90°.
- As latitude increases, photosphere height increases.
  - Height of maximum temperature cross-correlation varies from 149.96 km at the disk center to 199.97 km at 90° latitude.
- SOT should have been able to detect at least the f-mode and 1st p-mode at all latitudes.
- As latitude increases, p-modes and f-mode become less distinguishable from the convective signal.

# Obstacles + Lessons Learned

- **Obstacle**: Difficulties translating from IDL to Python
  - **Lesson**: Using ChatGPT to assist in programming
  - **Lesson**: Reading new data formats in Python
- **Obstacle**: Difficulties performing ring diagram analysis
  - **Lesson**: Implementing FFT in Python
  - **Lesson**: Ensuring that data are properly sorted
  - **Lesson**: Reading relevant literature associated with this technique

# Acknowledgements

George Dufresne

Brandon Martin

Irina Kitiashvili

NASA Ames Research Center/NASA OSTEM

# References


- Christiansen-Dalsgaard, J., “Lecture Notes on Stellar Oscillations”. 2014.
- Garcia, R. A., Ballot, J., “Asteroseismology of solar-type stars”. *Living Rev. Sol. Phys.*, 2019.
- Kosovichev, A., Rozelot, J., “Cyclic Changes of the Sun’s Seismic Radius”. *AJ*, 2018.
- Braun, D. C., “Measurements with Local Helioseismology”. *Cambridge University Press*, 2015.