Atmospheric characterization of the ultra-hot Jupiter WASP-33b: Detection of Ti and V emission lines and retrieval of a broadened line profile

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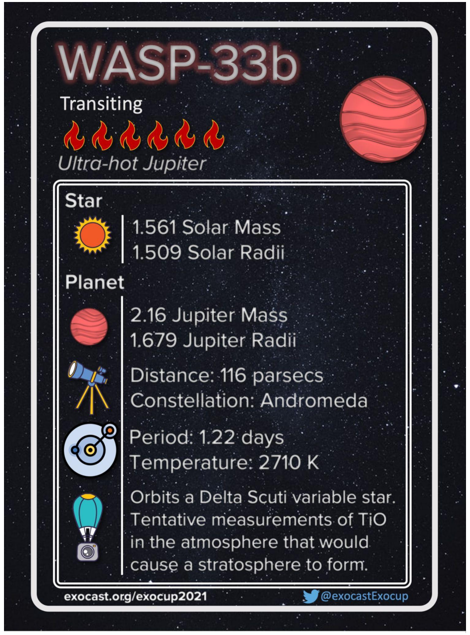
Presentation by Camden Ruckman

Introduction

- Atmospheric Characterization
  - UHJs
    - WASP-33b
- High Resolution Emission Spectroscopy
  - Collection of emitted photons from excited molecules
    - Titanium (Ti I)
    - Vanadium (V 1)
    - Others
- Orbital Phase Effects
  - Can alter the emission spectrum
  - Temperature profiles of phases

UHJs and WASP-33b



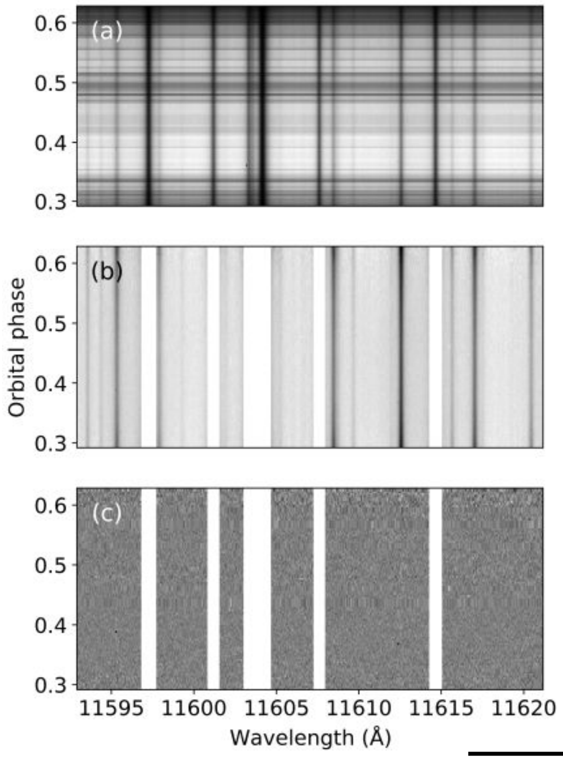
- Ultra Hot Jupiters (UHJs)
  - Gas giants with the highest equilibrium temperatures measured to date($T_{eq} \geq 2200K$)
  - Close orbits to their host stars
  - Usually tidally locked with host star
    - High irradiated daysides
    - Different atmospheric composition between day and night hemispheres

Observational Instruments

- CARMENES
  - Calar Alto Observatory, Spain
- HARPS-N
  - Galileo National Telescope, Spain
- ESPaDOnS
  - Canada-France-Hawaii Telescope, Hawaii

Instrument	Spectral resolution (R)	Wavelength range (Å)	Date
CARMENES	94 600 (VIS)	5200–9600	2017-11-15
	80 400 (NIR)	9600–17 100	2017-11-15
HARPS-N	115 000	3830–6900	2020-10-15
			2020-11-07
ESPaDOnS	68 000	3700–10 500	2013-09-15
			2013-09-26
			2014-09-04
			2014-09-15
			2014-11-05

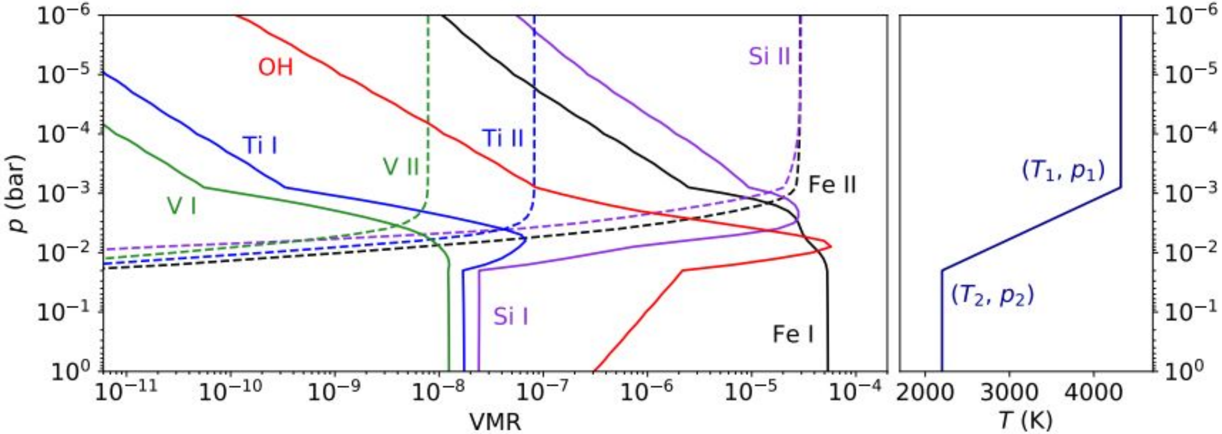
Data Reduction



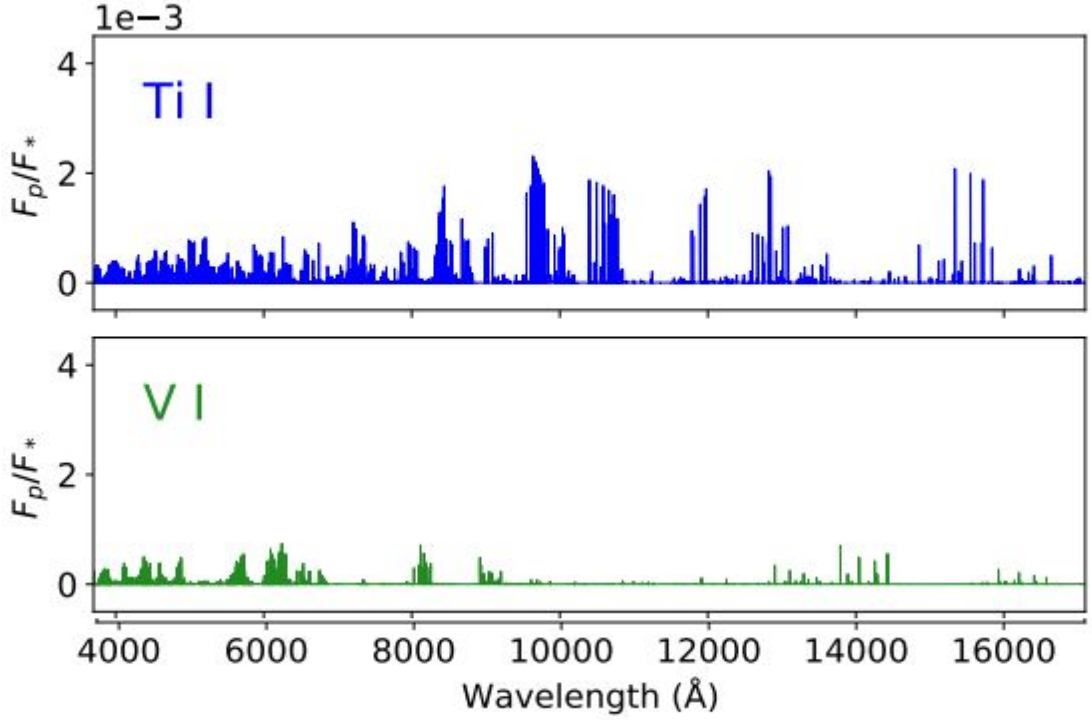
A. Unprocessed Spectral Matrix
B. Spectral Matrix after normalization and outlier correction
C. Spectrum after normalization, outlier correction, and removal of strong telluric and stellar lines

Atmospheric Model

- To create a model, they used WASP-189b T-p profile due to its similar properties to WASP-33b. 189b has also been used successfully to help characterize 33b's atmosphere before.



Ti I and V I Emission Line Models

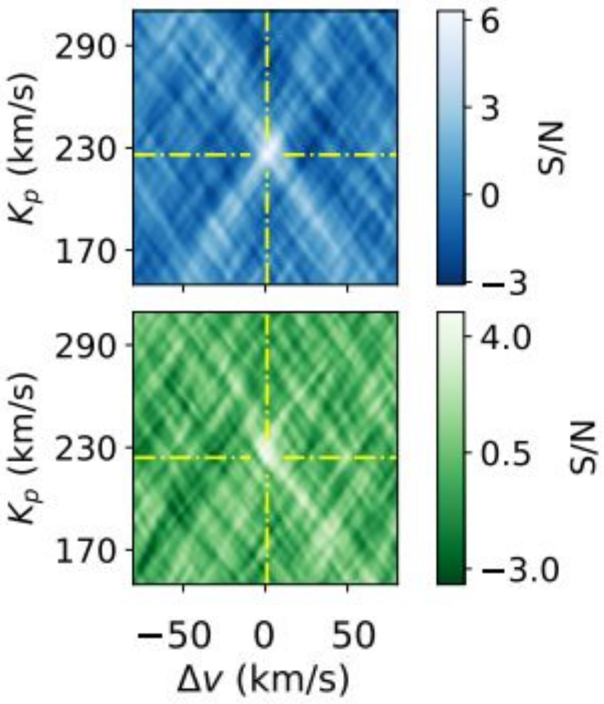


- Model Spectra were obtained through running petitRADTRANS, a radiative transfer code

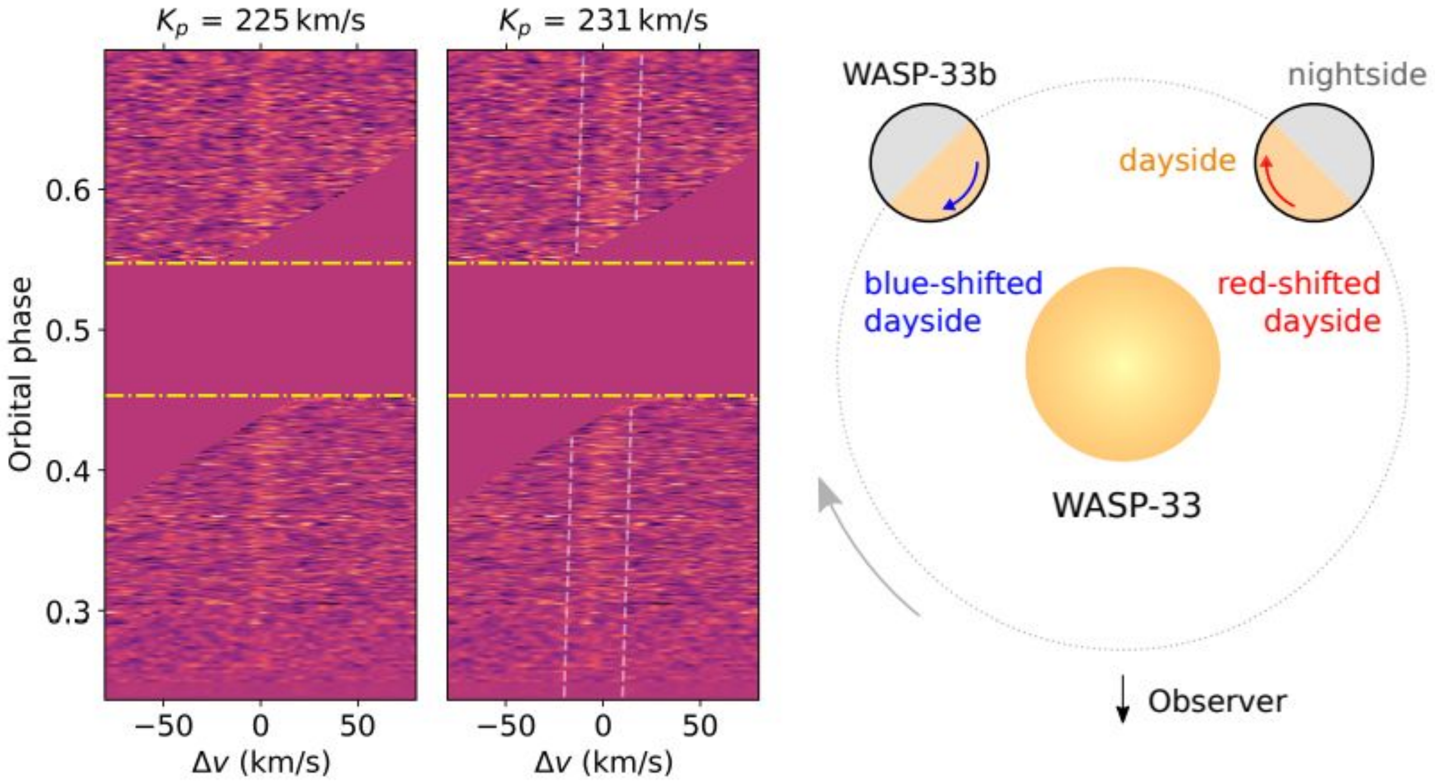
Cross-Correlation Method and S/N Maps

Cross-Correlation Function: CCF=∑*rimi(v)*

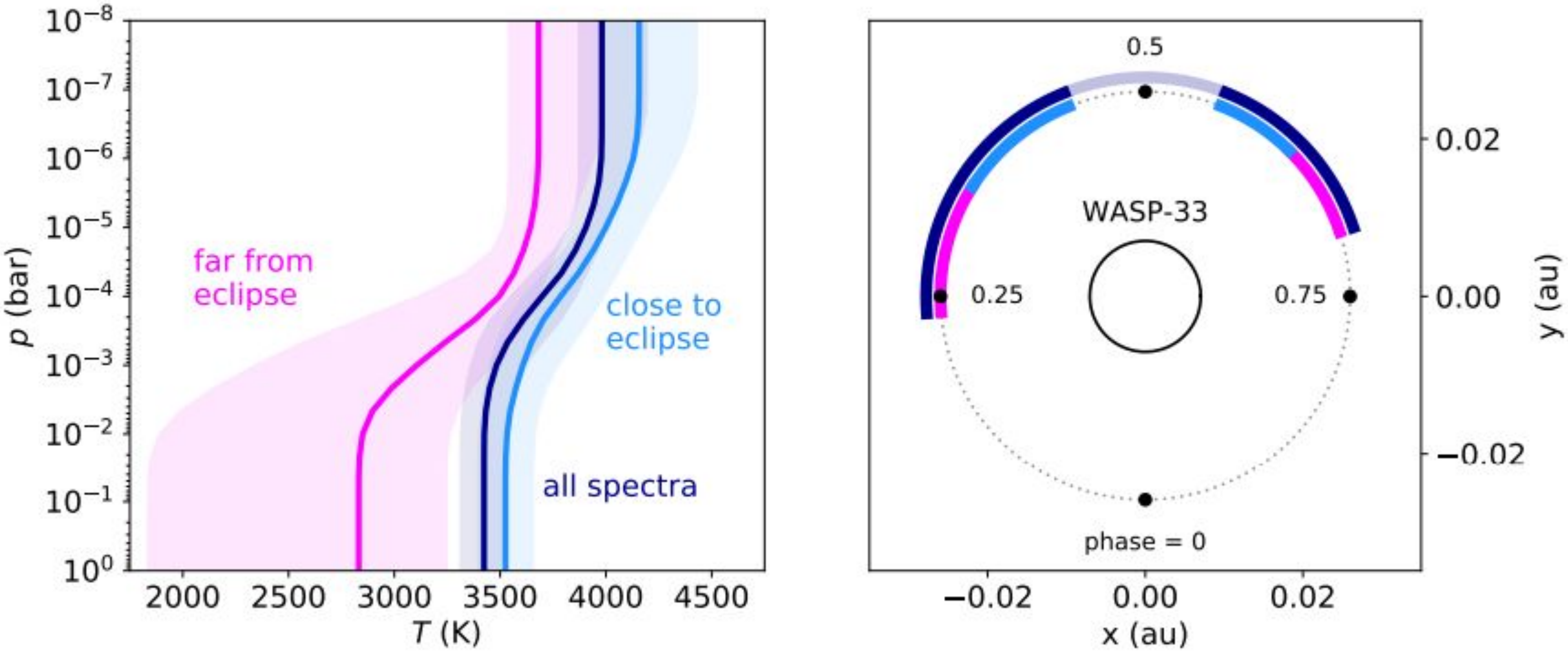
- Combining the CCFs of datasets to form a two dimensional array or CCF map.
- Then the array is normalized by its standard deviation excluding the region around the strongest peak.



Orbital Phase Effects

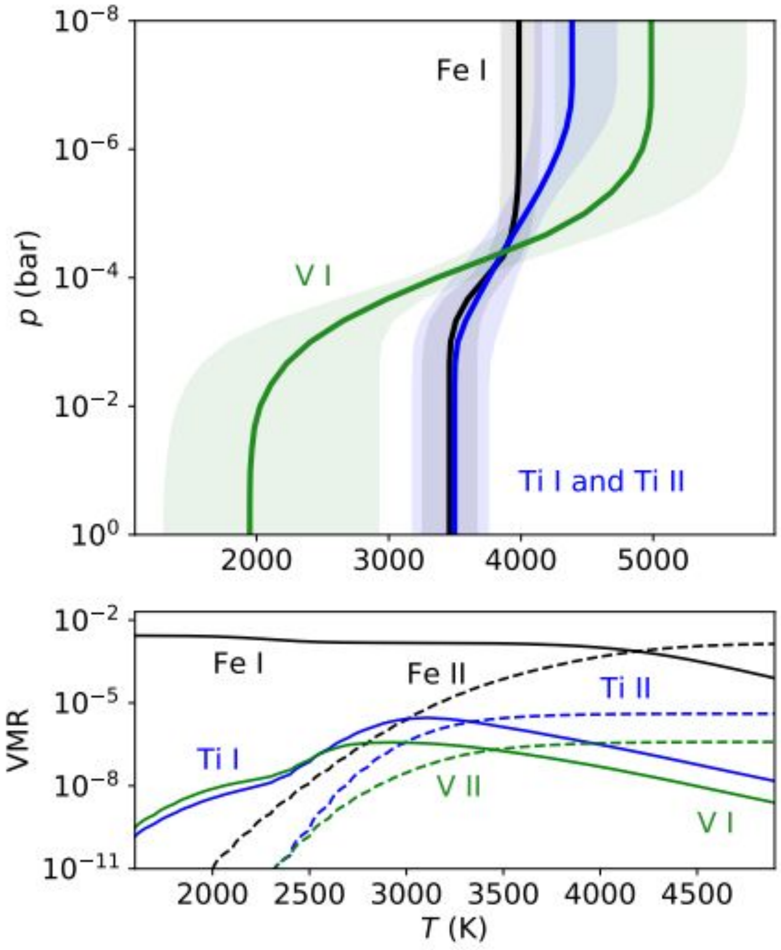


Overall Temperature Profile



Individual Profiles

- Fe I, Ti I, and Ti II all match the overall result
- V I deviates possibly due to a depleted atmosphere
- This depletion could explain the weak thermal inversion compared to other UHJs



Summary

- Ti I and V I Detected
  - First time for an exoplanet via emission spectroscopy
- High resolution emission spectroscopy can offer greater detail of information about atmospheric characterization.
- Matching temperature profiles of Fe I and Ti I to the overall profile shows reliability and confidence to the method used and values calculated.
- Thermal Inversion Confirmed
- Orbital Phase and possibly depletion of material both affect the thermal inversion of an atmosphere as shown through WASP-33b.