Effects of Magnetic Drag on Doppler Shifts of High Resolution Emission Spectra of Ultrahot Jupiter WASP-76b

Works Cited:

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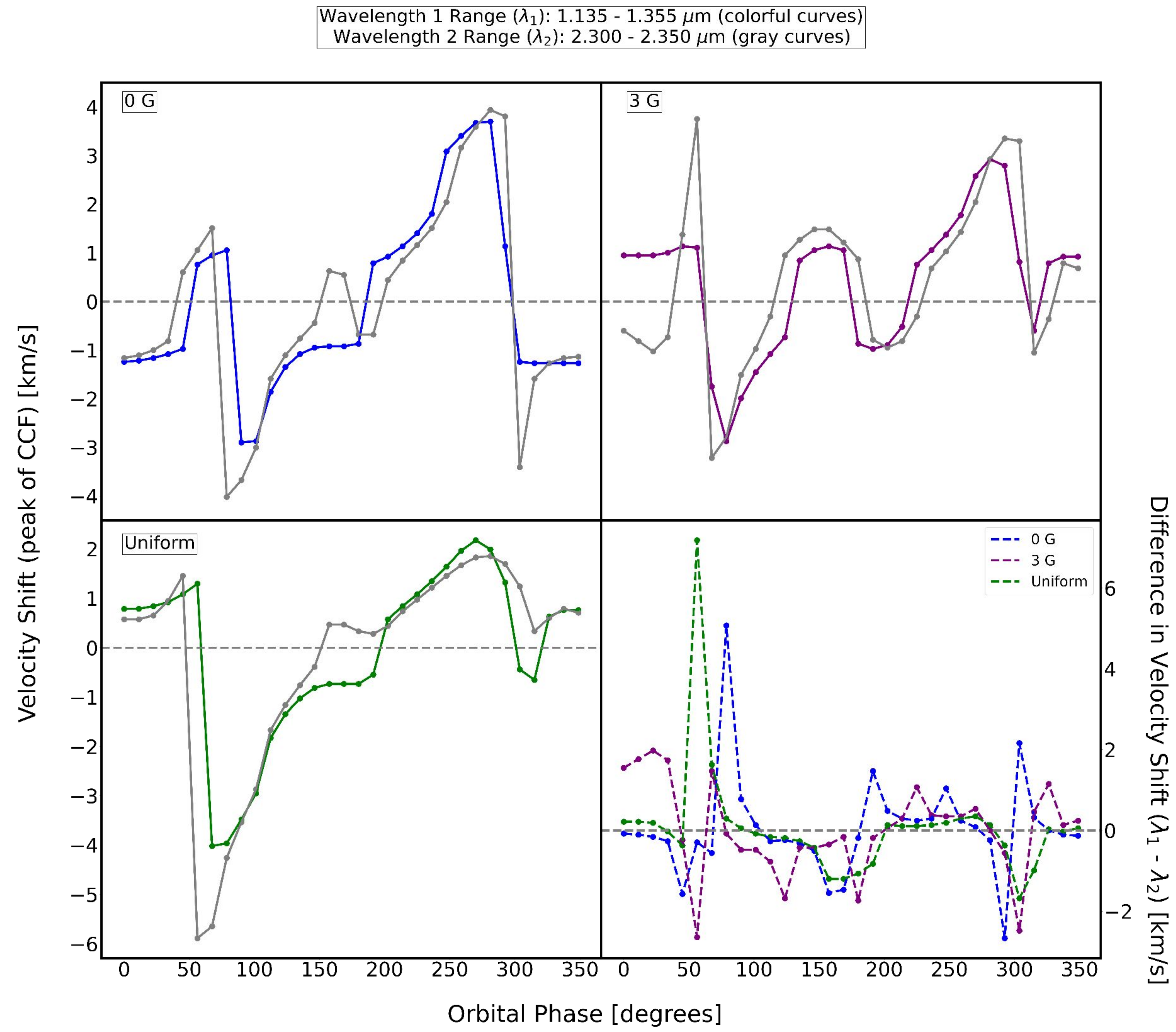
Abstract

This poster examines how different magnetic drag models affect the Doppler shifts of high resolution emission spectra of the ultrahot Jupiter WASP-76b. The magnetic drag changes the temperature structure of the planet, so spectra will differ as the magnetic drag differs. Three models were used: magnetic drag from a 0 G magnetic field, magnetic field from a 3 G magnetic field, and a uniform global magnetic drag. From here, we had one spectra with Doppler effects turned off, and one spectra with Doppler effects turned on. We cross-correlated these spectra to find the relative velocity shift of the spectra from the peak of the cross-correlation. This method allows us to determine the net Doppler shift for each spectra. We compare these three models with relative velocity shifts versus phase. All models were run in two different wavelength regimes, the first of which is primarily driven by carbon monoxide and the second of which is primarily driven by water. Because of this, the different wavelength regimes will present at different heights, and therefore different wind speeds and shifts. Both wavelengths are shown together on the three model plots, with an additional plot to show the relative velocity difference between the two wavelength regimes. This work helps to show the need for fully 3D models, especially in the case of high resolution spectra.

Background: Ultrahot Jupiters

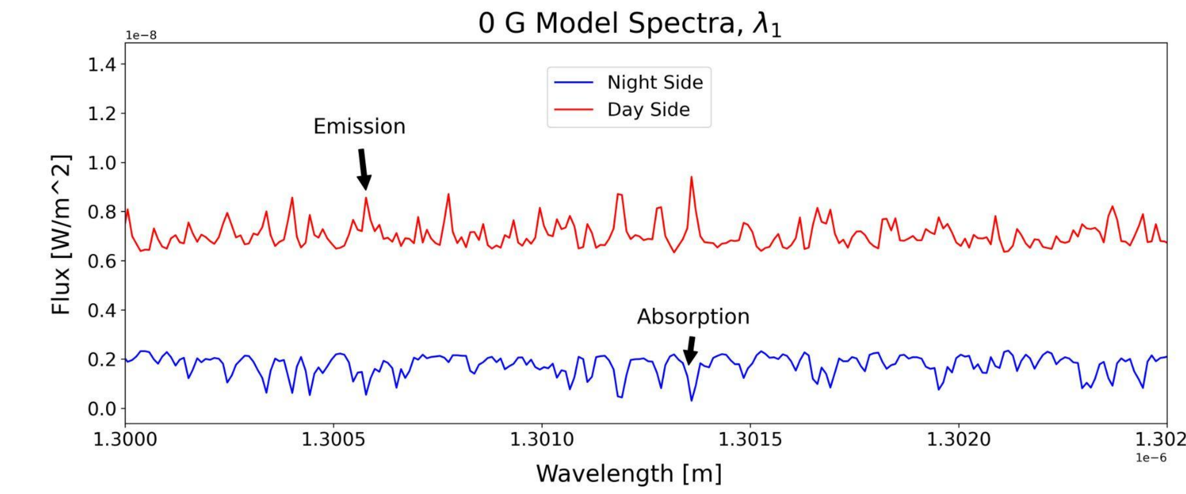
- Gas giants (like our own Jupiter) that orbit much closer to their host star and therefore have different atmospheric composition and conditions
- Ultrahot Jupiters defined as gas giants with equilibrium temperatures greater than 2000 K
- Atmospheres are heavily influenced by the extreme radiation regime they live in
- Because of short orbital period, ultrahot Jupiters are tidally locked into synchronous orbits
  - This means a permanent day side and night side, which differ strongly in temperature and chemical composition
  - These factors make it important to take into account regional conditions to make more accurate drag models instead of global average
  - This makes them a great choice for 3D models that more accurately describe spatial variation around the planet



Results: Comparing Models

- We tested 3 models of magnetic drag:
  - 0 G: no magnetic drag
  - Uniform: single drag time scale throughout model
  - 3 G: active model with time scale varying with temperature and pressure throughout the model
  - We look at the net Doppler shift in planet's frame of reference
- Dayside (180 degrees) and nightside (0 degrees) structure look vastly different, causing large variations in Doppler shifts
- Different wavelengths show us effects of different absorbers (see Methods section)

Methods



- Because UHJs are tidally locked, the dayside and nightside show strongly different temperature profiles, resulting in emission and absorption features respectively
- Each wavelength range has a different main absorber: λ_1: CO, λ_2: H_2O
- Drag time scale
  - ρ = density
  - ϕ = latitude
  - B = global magnetic field strength
  - $\eta(\rho, T)$ = magnetic resistivity

$$\tau_{\mathrm{mag}}(B, \rho, T, \phi) = \frac{4\pi\rho\ \eta(\rho, T)}{B^2|sin(\phi)|}$$

- How we get peak Doppler shift:
  - Cross correlate Doppler on (spectra broadened from winds and rotation) with Doppler off at the same phase
  - Velocity at peak cross-correlation gives net Doppler shift of the spectra

Conclusion

- Different observed behaviors for of active drag vs uniform drag models
- Active drag models are more physically consistent than uniform drag models because they vary spatially
- Different drags results in different temperature profiles, resulting in different emission spectra
- Each model has different net Doppler shifts across orbital phase and wavelengths, since wavelengths are probing different absorbers which differ in concentration throughout the planet
  - Because of different concentrations of the absorbers, we're probing different heights, which is why we have different Doppler shifts
    - Example: λ_1 and λ_2 at same phase are different heights in the atmosphere