# The Limiting Factors: Extending our Observational Capabilities to Probe the Atmosphere of KELT-9b


**N. W. Borsato[1,2]**, D. B. Zucker[1], H. J. Hoeijmakers[2], B. Thorsbro[2], et al.

nicholas.Borsato@hdr.mq.edu.au, **@cosnicspace**

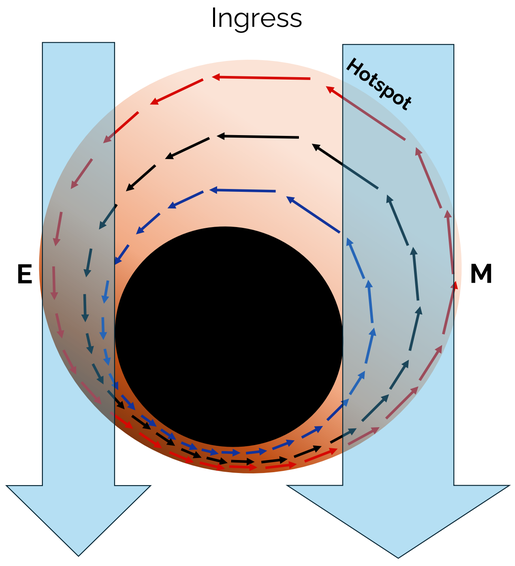
**1. Macquarie University Astrophysics and Space Technologies Research Centre, MAPS**

2. **Lund University Division of Astronomy and Theoretical Physics**


**Beyond Detection: How Cross-Correlation Functions Can Reveal Exoplanetary Atmospheric Dynamics**

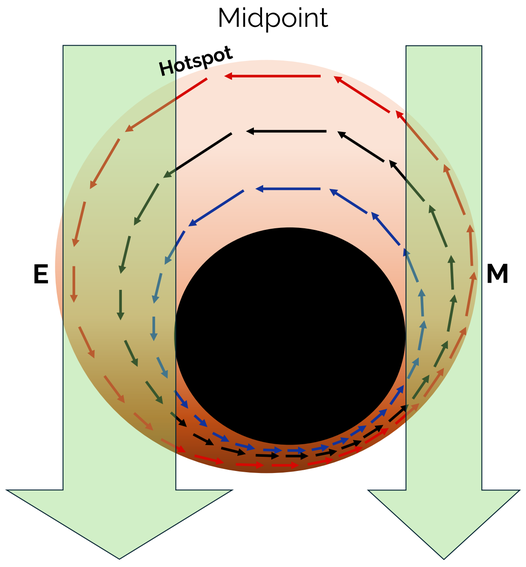
Cross-correlation functions are crucial for analysing exoplanet atmospheres and identifying species, particularly for ultra-hot Jupiters (UHJs) like KELT-9b. Primary results produce measurements of the systemic velocity ($v_{sys}$) of the host star and semi-major amplitude ($K_p$) of the planet. However, these often differ between detections and from values obtained through other methods. We argue that this difference is because signals can originate from different atmospheric regions, with different kinematic profiles. With careful parameterisation, they can be used to explore the dynamics of a planet's atmosphere.

### Ingress



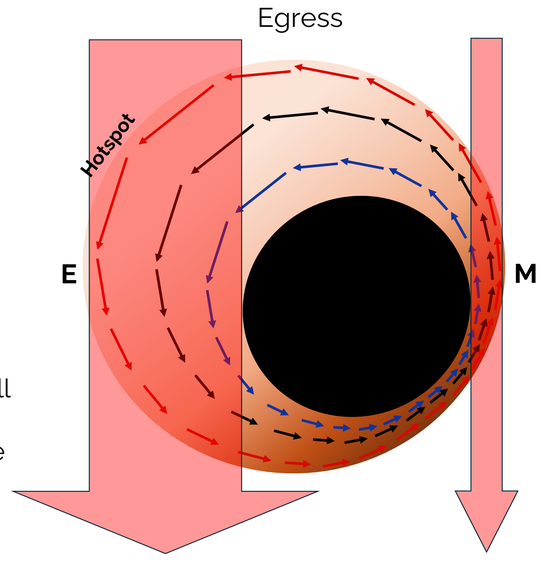

- The UHJ hotspot is blocked by the planet.
- The transit begins with a stronger contribution from the morning terminator.
- The absorption contributions will shift to favour the evening side as the hotspot becomes visible.

### Midpoint



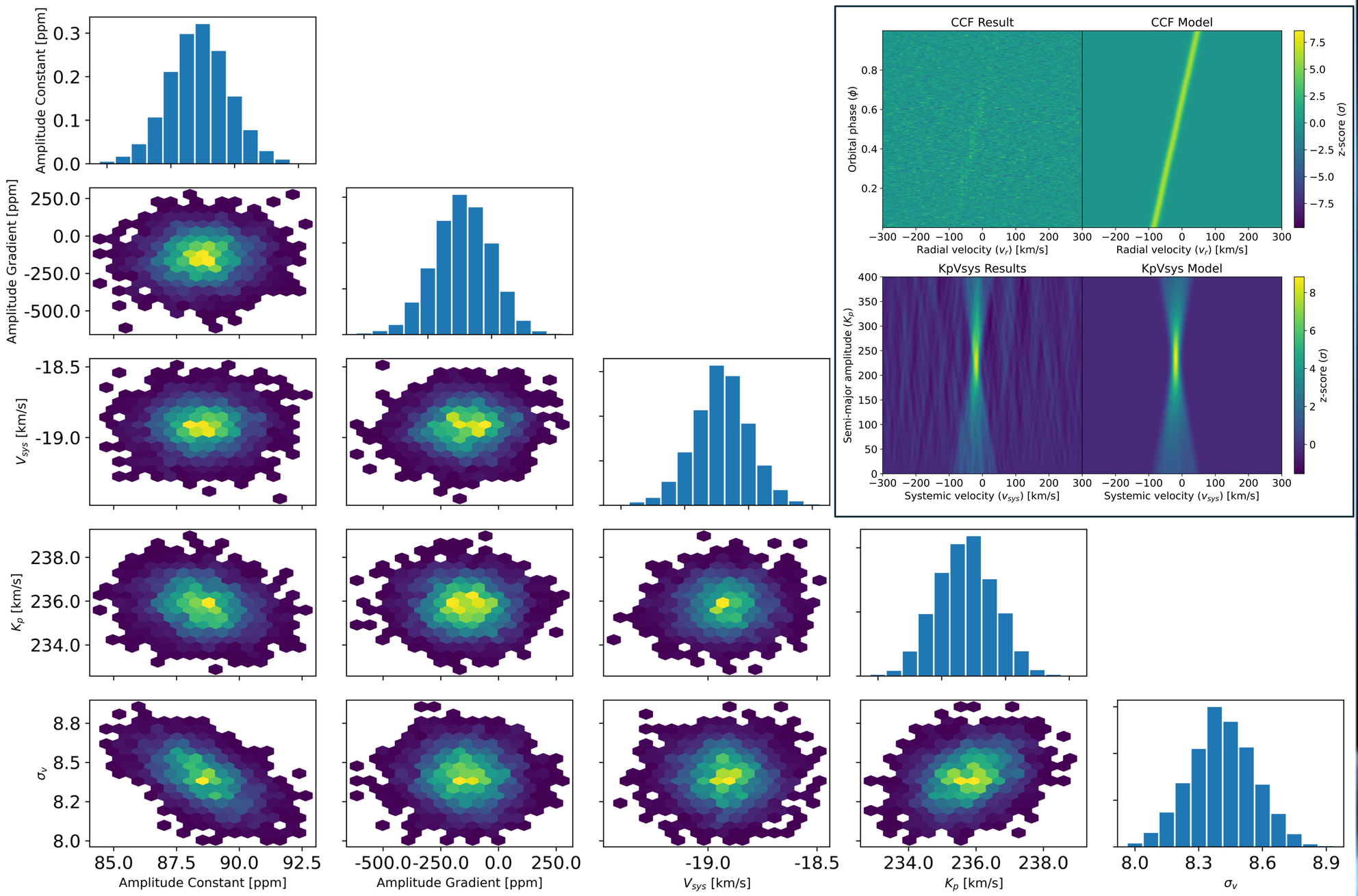

- The UHJ hotspot has now come into view.
- The absorption signal shows a growing influence from the evening terminator.
- The atmosphere will begin to appear more inflated as the hotspot rotates into view.

### Egress




- The transit radius covers a significant portion of the hotspot.
- The atmosphere is inflated, yielding a broader distribution of $K_p$ values.
- The morning terminator contributes a strong blue shift shift in the overall signal.

## Atomic Iron (Fe I) Cross-correlation Trace Fit, Detection and Model







What we did…

Using data from 13 high-resolution transit observations of KELT-9b, we detected **32 distinct species** with varying velocity parameters.

With each detection we parameterize the transit signal CCF =

$$A\left(\frac{2\pi}{\sigma_{v_r}}\right)^{\frac{1}{2}} e^{\frac{\left(-\frac{1}{2}(v_r - K_p \sin 2\pi\phi \sin i\right)^2}{\sigma_{v_r}^2}}$$

where,

$$A = A_0 + A_1 \sin 2\pi\phi$$

$A_1$ measures changes in absorption strength during transit. We find dependencies on the transit strength from different CCFs.

For the egress phase of the transit, we observe a significant increase in variability, suggesting that we are probing the expanded atmosphere of KELT-9b for certain species. This can potentially lead to a broader range of semi-major amplitude values.