IGRINS-2 SV Observation Evaluation Form

Title: High-Resolution Spectroscopy of Exoplanet Atmospheres

Program ID: GN-2024A-SV-103

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Description of the primary goals and the main findings

The goal of our program was to observe emission from the dayside atmosphere of the ultra-hot Jupiter MASCARA-1b with IGRINS-2. By observing the planet just after secondary eclipse, we aimed to detect the planet's atmosphere and measure atmospheric abundances of key carbon- and oxygen-bearing species, including H2O, CO, and OH.

In total, we obtained 140 individual spectra (70 AB/BA pairs) of MASCARA-1b covering orbital phases of ~0.56 to ~0.66 over the course of approximately 5.25 hours on July 21st, 2024 (UT). Each spectrum was taken with an exposure time of 90 seconds, and the observing conditions throughout the sequence were CC50/IQ70. The target was observed at an airmass < 1.4 throughout the full sequence, and the SNR per pixel was in general very high (~300 or higher on average). The figures below provide additional context for these observations.

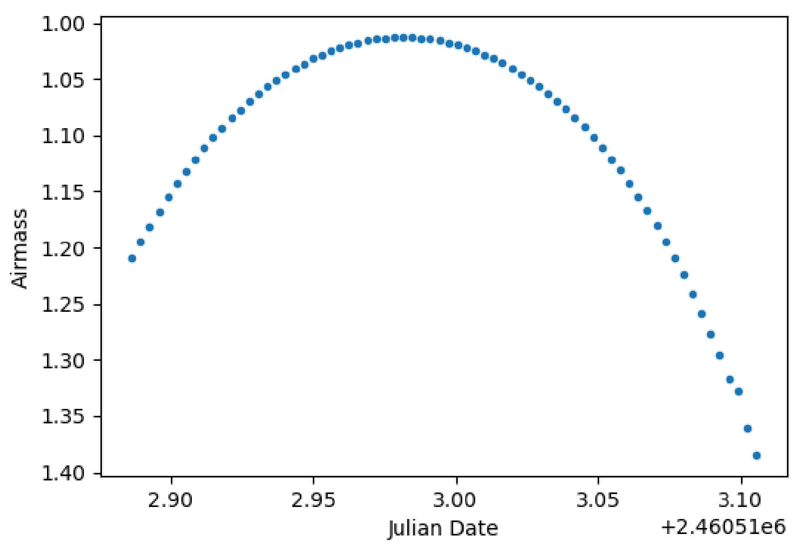

Figure 1: The airmass throughout the ~5-hour observing period.

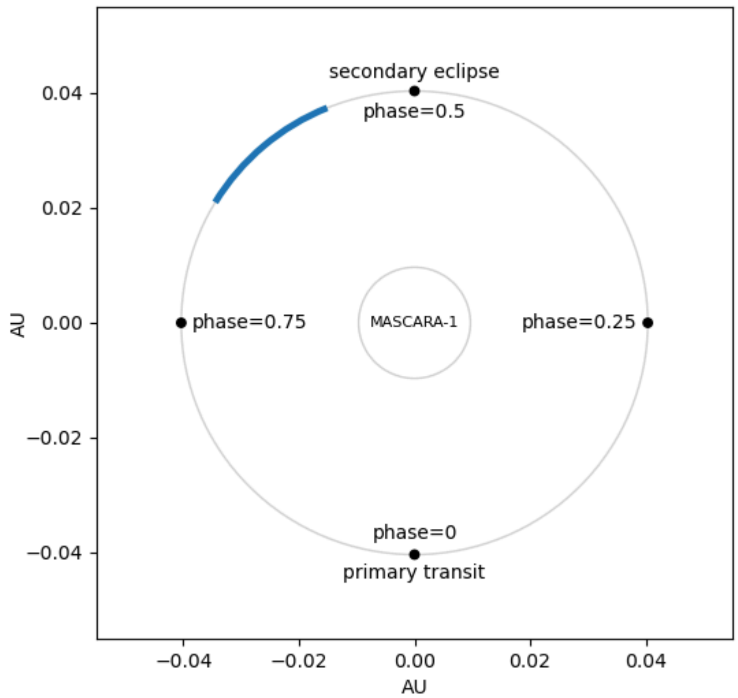

Figure 2: The post-eclipse orbital phases covered by these observations.

We reduced the data using custom reduction routines. In particular, tellurics were removed via a PCA-like algorithm (rather than through observations of a telluric standard). We then made use of the Doppler cross-correlation technique; i.e., Doppler-shifting atmospheric templates to the expected orbital velocity of the exoplanet and cross-correlating them with our observations in order to isolate the signal from the planet's atmosphere. The planetary trail was visible at this stage, as seen in Fig. 3. However, to increase the signal, we further phase-folded the cross-correlation functions to the rest frame of the planet.

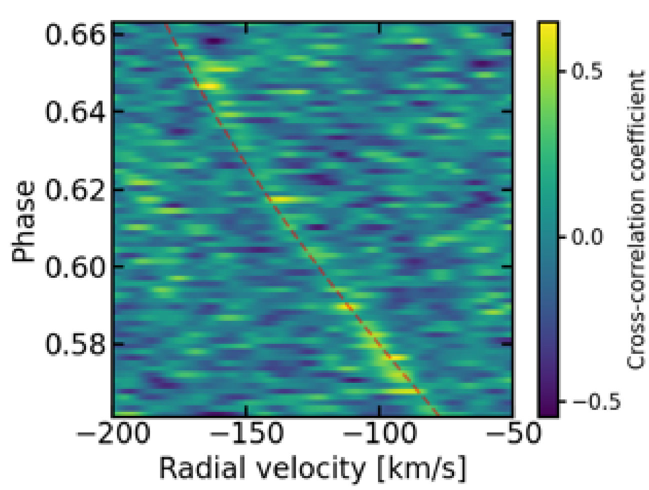

Figure 3: The trail of the planetary signal. The dashed red line shows the expected Doppler-shifted trail based on the radial velocity of the exoplanet. A strong correlation trail is visible at the expected location.

From a preliminary analysis, we are able to detect the planet's atmosphere at a high significance (>8 sigma), as seen in Fig. 4. Through cross-correlating templates of specific molecules with the data, we are also able to individually detect CO, H2O, and OH at > 3 sigma.

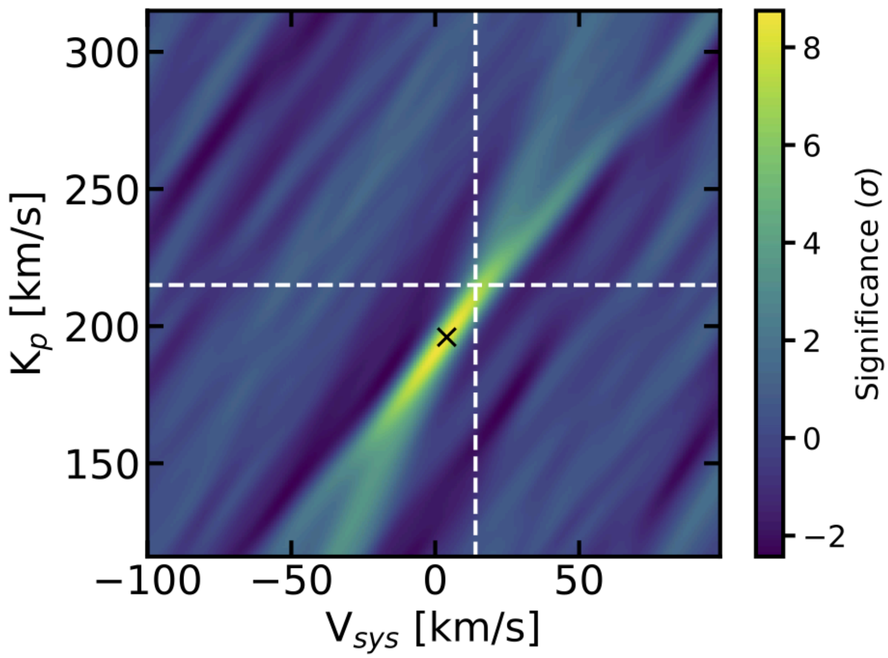

Figure 4: The 2D Keplerian velocity (Kp) - Systemic Velocity (Vsys) cross-correlation map, with the peak correlation signal marked by an X. The dashed white lines show the expected location of the planetary signal. The atmosphere is clearly detected at a significance > 8 sigma close to the expected location.

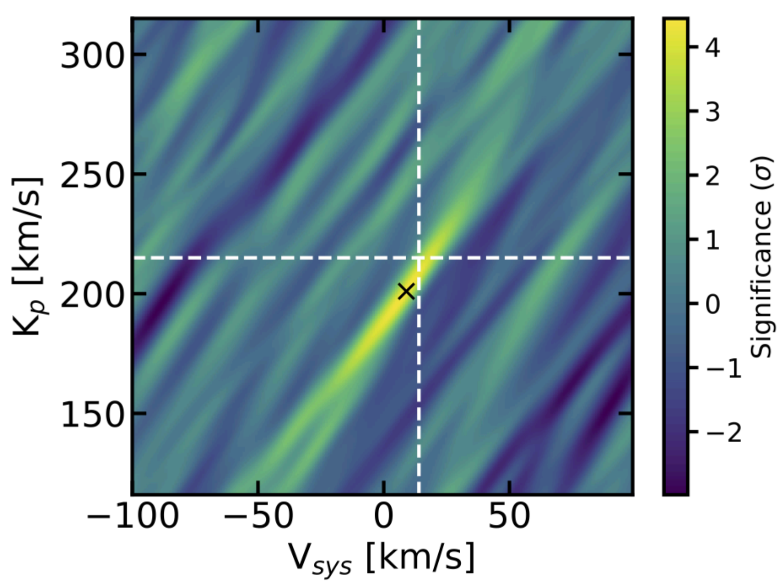

Figure 5: The same as Fig. 4, but for a model containing only CO, which is detected at > 4 sigma.

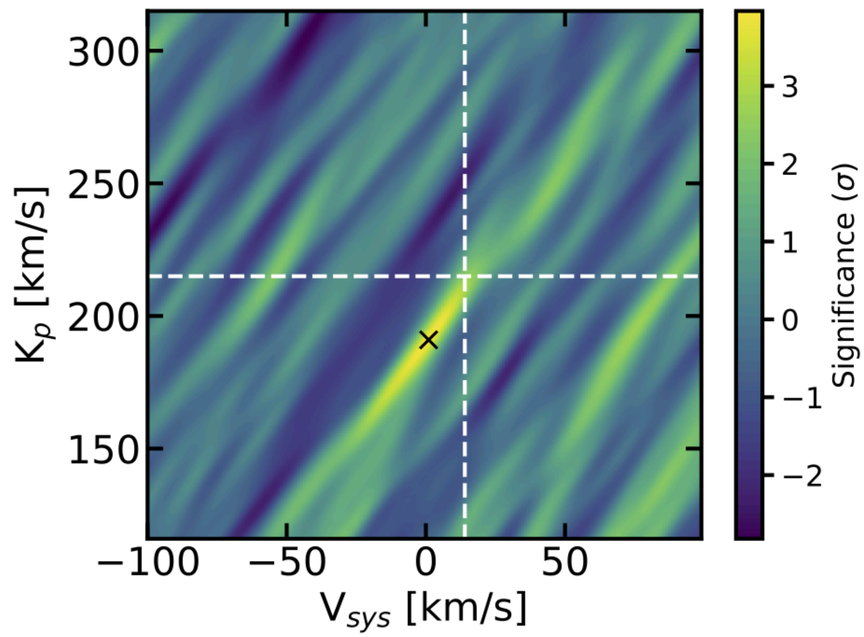

Figure 6: The same as Fig. 4, but for a model containing only H2O, which is detected at > 3 sigma.

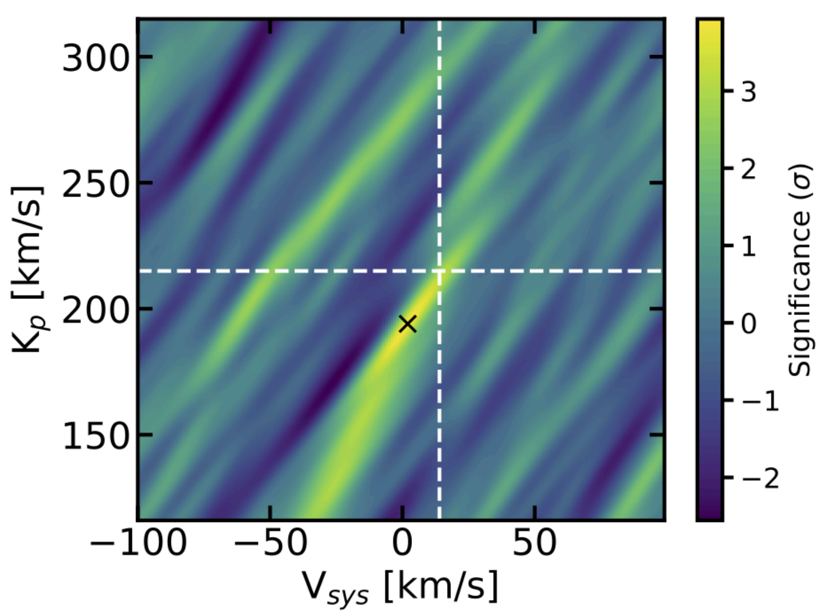

Figure 7: The same as Fig. 4, but for a model containing only OH, which is detected at > 3 sigma.

Additional comments on IGRINS-2 performance:

This target has previously been observed with IGRINS, GHOST, and MAROON-X. Here we provide an initial comparison of the science results obtained with IGRINS-2 and IGRINS. Using observations covering pre-eclipse orbital phases, Sanchez et al. (2024, in prep) were able to detect the planet's atmosphere at a significance of 6 sigma. Our post-eclipse observations yield a similar (though slightly higher significance) detection, showing that the performance of IGRINS-2 is comparable to that of IGRINS.

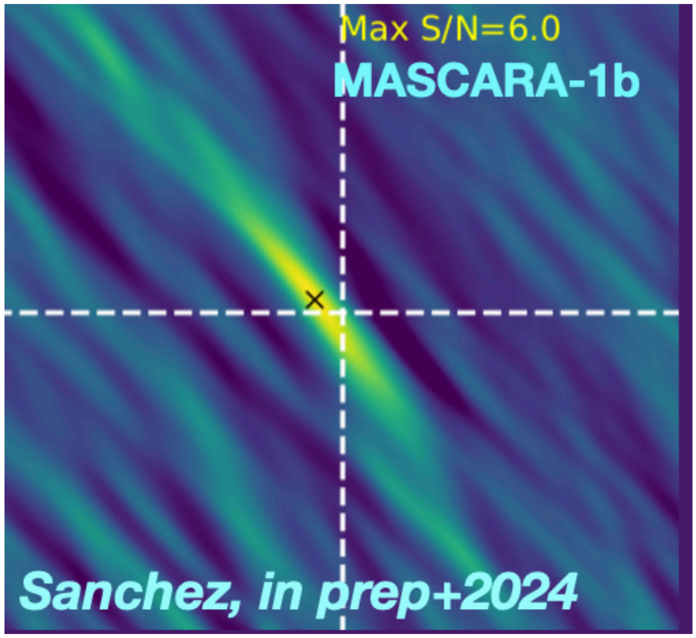

Figure X: A detection of MASCARA-1b's atmosphere at pre-eclipse orbital phases observed with IGRINS at Gemini South. The atmosphere was detected at a significance of 6 sigma. Results are from Sanchez et al. 2024 in prep.

Suggestions for improvements:

- It may be useful to have an option in the data reduction software that allows you to combine only subsequent AB-BA pairs, rather than stacking all frames (i.e., an option to create the automatically create the recipe in this way—otherwise we need to manually write a new line in the recipe for each AB-BA pair).
- The instrument readout times appear to be underestimated, as additional time was needed to complete our full sequence (see further comments in the July 21st nightlog).

Any additional comments about IGRINS-2 SV

Thank you for the opportunity to participate!