GHOST SV Observation Evaluation Form

Title: GHOST Spectroscopy of Hot Exoplanet Atmospheres

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Description of the primary goals and the main findings

Characterizing exoplanet atmospheres is the next frontier in exoplanet science, with the potential to shed light on exoplanet compositions, dynamics, and formation histories. Our goal with this program was to test the potential of GHOST in characterizing exoplanet atmospheres via high-resolution transmission and/or emission spectroscopy, as well as shed new light on an ultra-hot Jupiter atmosphere.

We proposed several targets (in both transmission and emission) and were able to schedule a 3-hour phase-curve observation of the ultra-hot Jupiter WASP-189b, targeting the orbital phases following the secondary eclipse. We observed in high-resolution mode (which is ideal for resolving features in the exoplanet's atmosphere), with 1x4 binning and medium read mode to reduce overheads. This exoplanet had previously been observed in both transmission and emission using HARPS, HARPS-N, and ESPRESSO, offering various avenues for comparison. The far-red wavelength coverage of GHOST also allowed us access to additional atmospheric features not covered by these other instruments.

From a preliminary analysis of the data, we find that GHOST is very well-suited to atmospheric characterization of exoplanets. With 3 hours of observations spanning orbital phases from ~0.58 to ~0.63, we were able to make a 5-sigma detection of iron in the exoplanet's dayside atmosphere (we note that this analysis is very preliminary). Iron was previously detected in the planet's dayside atmosphere at a significance of 8.7-sigma using two nights of HARPS-N observations (Yan et al. 2020), with observations spanning orbital phases of ~0.53 - 0.62 and ~0.38 - 0.5. Our preliminary GHOST detection is displayed below. We note that additional exploration into data reduction techniques may improve these results.

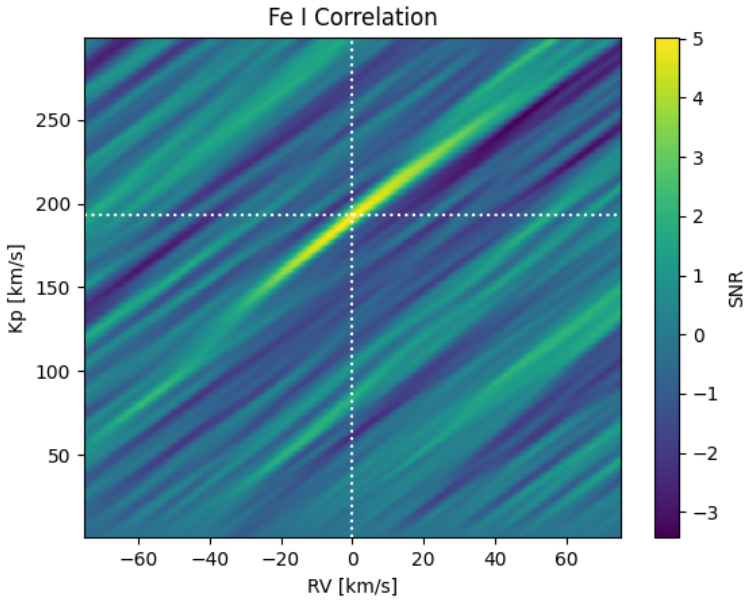

Figure 1: A 2D cross-correlation map in the planetary orbital velocity (Kp) - systemic velocity (RV) space. A model iron emission spectrum created following Yan et al. 2020 was cross-correlated with our GHOST observations. The dashed white lines show the expected location of the planetary signal, which matches remarkably well with the peak of the cross-correlation

map. The colorbar displays the 5-sigma significance of the detection.

Additional comments on GHOST performance:

In addition to the preliminary analysis displayed above, we compared our GHOST spectra with existing HARPS-N spectra of the same target. The plot below shows the merged 1D spectra for each instrument. In the future, we also aim to carry out a detailed comparison with HARPS-N and ESPRESSO.

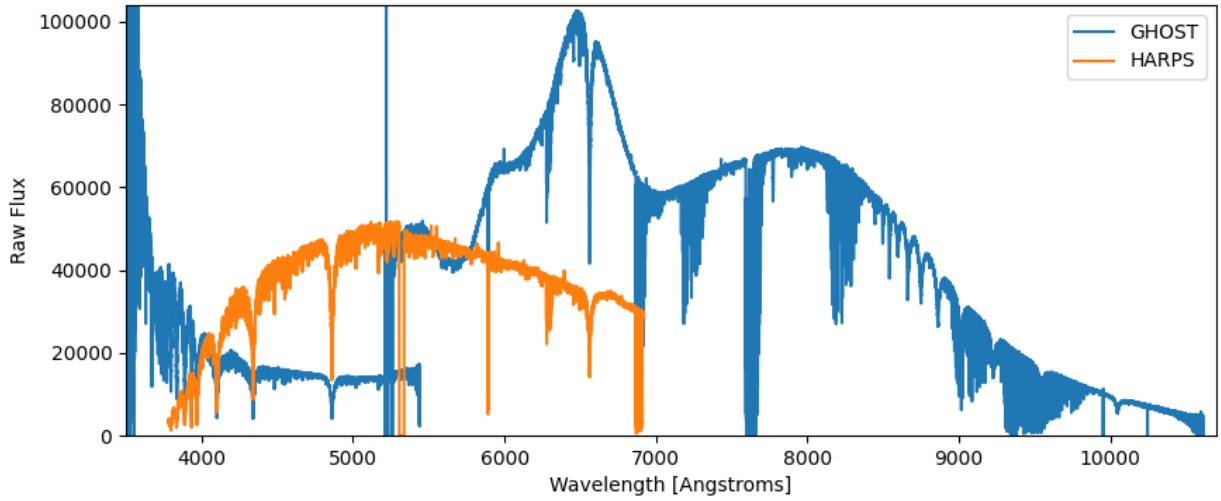

Figure 2: The merged 1D spectra from GHOST (blue) and HARPS-N (yellow).

Finally, we note that we are currently working on comparing various telluric reduction correction methods. This work is ongoing, but we aim to publish our results of this analysis (as well as our analysis of the planet's atmosphere) soon.

Suggestions for improvements:

- The 2D data products are more useful for this type of analysis, so it would be helpful if the bad pixels can also be masked in the 2D rather than just the merged 1D.
- It would be helpful to have the wavelength array as an extension in the 1D file.
- We should consider having a normalization built into the pipeline.
- It would be helpful to have the BERV values in the header without having to apply the correction to the data. For some analyses we want to apply the correction after preliminary corrections (e.g., of tellurics), so it would be helpful to have the value there but not applied to the data.
- There are some other values that would be very useful to have in the headers if we want to use the files with telluric correction tools like Molecfit: MJD (rather than just BJD), UTC time in seconds, slit width in arcsec, pixel scale in arcsec.

Any additional comments about GHOST SV

It was a very rewarding experience and a great opportunity to get early access to GHOST data!