MASCARA: Does it help your eyelash?

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

Swaetha Ramkumar[1], Neale P. Gibson[1], Stevanus K. Nugroho[2,3], Cathal Maguire[1] and Mark Fortune[1]

[1] School of Physics, Trinity College Dublin, University of Dublin, Dublin-2, Ireland
[2] Astrobiology Center, NINS, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan
[3] National Astronomical Observatory of Japan, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan

1. Introduction

The characterisation of exoplanet atmospheres has proven to be successful using high-resolution spectroscopy. Phase curve observations of ultra-hot Jupiters (UHJs) can reveal their compositions and thermal structures, thereby allowing the detection of molecules and atoms in the planetary atmosphere.

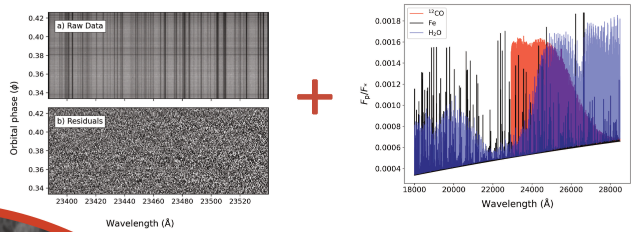
We present the first retrieval results for the UHJ, MASCARA-1b, taken before the secondary eclipse with the upgraded CRIRES+ (VLT/UT3).

1. MASCARA-1b:
- ~3.7 M_{Jup}
- Orbital period: ~2.15 days[1]
- T_{day} ~3062 K
- T_{eq} ~2594.3 K

2. CRIRES+
- R~100,1000[2]
- Wavelength range: 1921-2472 nm (K-band)

2. Methodology

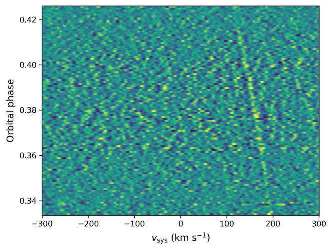
- The stellar and telluric lines in the data were removed using the SysRem[3] algorithm, and the Doppler-shifted exoplanetary signal was extracted using the cross-correlation method.



- Our 1D atmosphere was specified using the parametric model from Guillot and two different chemical regimes, along with the inclusion of collision-induced absorption of H_2-H_2 and H_2-He.

3. Results

- We detected strong emission signatures of CO, H_2O, and Fe in the day-side atmosphere of MASCARA-1b (Fig.3).

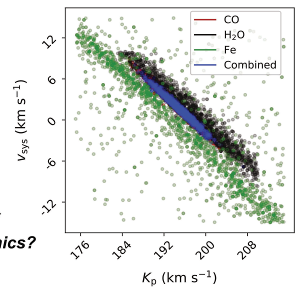


- A 'free-retrieval' favoured a H_2O-depleted model, thereby driving the C/O towards 1.
- Incorporating a self-consistent chemical model[4] in our retrieval results in a C/O ($0.68^{+0.12}_{-0.22}$) and [M/H] ($0.62^{+0.28}_{-0.55}$) both consistent with solar values within ~1.1-sigma.

4. Discussion

- Our observations detect a slight offset of the Fe feature in both K_p and v_{sys}, and the 2D plot shows a strong hint that the signals are separated in velocity space.

A signature of atmospheric dynamics?



- While a high C/O found with our free-retrieval is intriguing, the reported abundance constraints are likely biased due to strong vertically-changing chemical profiles. Our chemical equilibrium retrievals provide more realistic and conservative constraints and are consistent with solar values.

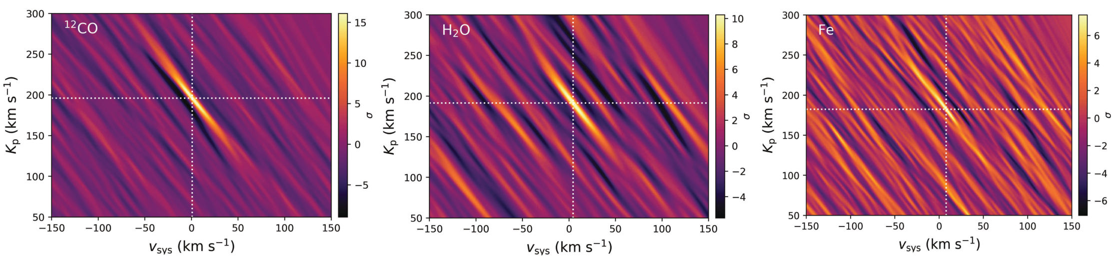


Figure 3. Results from cross-correlation for CO, H_2O and Fe.

References

[1] Talens G., et al., 2017, A&A, 606, A73
[2] Dorn R. J., et al., 2014, The Messenger, 156, 7
[3] Tamuz O., Mazeh T., Zucker S., 2005, MNRAS, 356, 1466
[4] Stock J. W., Kitzmann D., Patzer A. B. C., Sedlmayr E., 2018, MNRAS, 479, 865

** Pre-computed opacity grids were taken from petitRADTRANS (Mollière et al. 2019)*

Road Ahead

Exoplanet atmospheres are 3D structures, which perhaps makes our 1D forward models insufficient to explain the global chemistry (in particular, for highly-irradiated tidally-locked systems).

- The disk-averaged temperature-pressure profile changes as the planet rotates, which might lead the atmospheric models to change with time and/or phase.
- Temporally parametrising our models and implementing phase-resolved retrievals can help explore potential variations in composition, and could also help explain the velocity shifts of the Fe feature. We aim to explore these in future work.

This work relied on the observations collected at the European Organisation for Astronomical Research in the Southern Hemisphere under ESO programme 107.22TQ.001 as part of the CRIRES+ Science Verification run. We are extremely grateful to the CRIRES+ instrument teams and observatory staff who made these observations possible. S.R. gratefully acknowledges support from a Provost's PhD Project Award from Trinity College Dublin.

★ **https://swaetharamkumar.github.io**
★ **ramkumas@tcd.ie**

Ramkumar et al. (2023)

Digital Poster