A SPECTROSCOPIC THERMOMETER: INDIVIDUAL VIBRATIONAL BAND SPECTROSCOPY WITH OH IN THE ATMOSPHERE OF WASP-33B

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Individual vibrational band spectroscopy presents an opportunity to examine exoplanet atmospheres in detail by distinguishing where the vibrational state populations of molecules differ from the current assumption of a Boltzmann distribution. Here, retrieving vibrational bands of OH in exoplanet atmospheres is explored using the hot Jupiter WASP-33b as an example.[1] We simulate low-resolution spectroscopic data for observations with the JWST's NIRSpec instrument and use high resolution observational data obtained from the Subaru InfraRed Doppler instrument (IRD). Vibrational band-specific OH cross section sets are constructed and used in retrievals on the (simulated) low and (real) high resolution data. Low resolution observations are simulated for two WASP-33b emission scenarios: under the assumption of local thermal equilibrium (LTE) and a toy non-LTE model for vibrational excitation of selected bands.[2]

We show that mixing ratios for individual bands can be retrieved with sufficient precision to allow the vibrational population distributions of the forward models to be reconstructed. For high resolution, cross-correlation applications, we apply the individual vibrational band analysis to an IRD spectrum of WASP-33b,[3] applying an 'un-peeling' technique. Individual detection significances for the two strongest bands are shown to be in line with Boltzmann distributed vibrational state populations consistent with the effective temperature of the WASP-33b atmosphere reported previously. We show the viability of this approach for analysing the individual vibrational state populations behind observed and simulated spectra including reconstructing state population distributions.

[1] S. O.M. Wright et al., *Astron.*, In press (2023); arXiv:2305.11071

[2] Sam O M Wright, Ingo Waldmann, and Sergei N Yurchenko, Non-local thermal equilibrium spectra of atmospheric molecules for exoplanets, *Mon. Notices Royal Astron. Soc.*, **512**, 2911 (2022)

[3] S.K. Nugroho et al., *Astrophys. J. Lett.*, **910**, L9 (2021)

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