The JWST NIRSpec G395H spectroscopic phase curve of the ultra-short period Super-Earth K2-141 b

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Ultra-short period rocky planets (P<1 day, $R_p < 2R_\oplus$), thought to be the exposed cores of mini-Neptunes, offer a unique opportunity to study planet formation and atmospheric diversity, revealing potentially exotic compositions due to intense stellar irradiation. We present the **JWST NIRSpec G395H spectroscopic phase curve** of the ultra-short period (P = 6.9-hour; T_{eq} = 2150 K) **transiting super-Earth K2-141 b** ($R_p = 1.51R_\oplus$, $M_p = 5.08M_\oplus$), observed on July 5, 2023, as part of the GO program 2159 (PI: N. Espinoza).

K2-141 b: A Benchmark for JWST Observations of Highly Irradiated Atmospheres

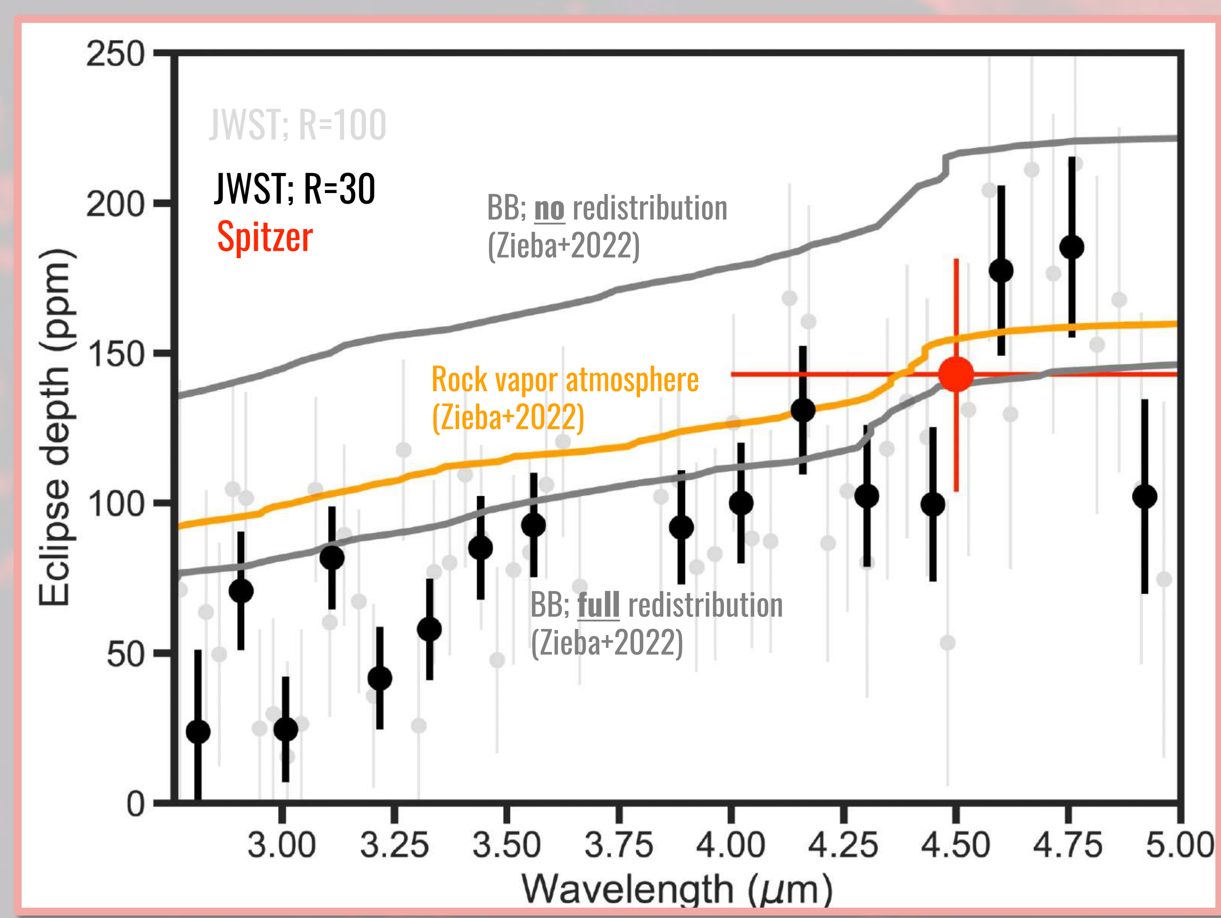
K2-141 b[1,2] orbits a relatively bright K-dwarf star and is among the highly irradiated ultra-short period rocky planets observable by JWST. With a 6.9-hour orbital period and high signal-to-noise ratio, it is an excellent target for phase-curve observations to characterize its atmosphere[4] . Previous observations with the Kepler spacecraft[1] and Spitzer[5] indicated ambiguities between reflected and thermal radiation. Using **JWST NIRSpec G395H**, we have obtained an **infrared full phase-curve of K2-141** b, enabling us to determine if it has a thin or thick atmosphere and to constrain its macrophysical properties with unprecedented precision. These observations help identify potential SiO2-rich atmospheric components and resolve the nature of K2-141 b's atmosphere.

Data reduction and analysis

We performed the data reduction on the **JWST NIRSpec G395H transit, eclipse, and full-phase curve** observations using transitspectroscopy[6]. We followed standard JWST pipeline steps and incorporated a custom jump detection algorithm. Spectral extraction used a simple box extraction of 6 pixels centered around the trace. White light curves and pixel-level light curves were generated from the time series of 1D stellar spectra for both detectors. The eclipse and transit WLCs from NRS1 and NRS2 were fitted independently using juliet[7]. The period was fixed to 0.2803244 days[8], but we fitted for the mid-transit, rp/rs, a/rs, b, q1, q2 (quadratic law), and out-of-transit baseline flux for the transit. We fit both eclipses jointly with the orbital parameters fixed to the best-fit transit values. Correlated noise was detrended with time and FWHM, fitting for coefficients of the linear model. The spectral light curves fits use a similar detrending model.

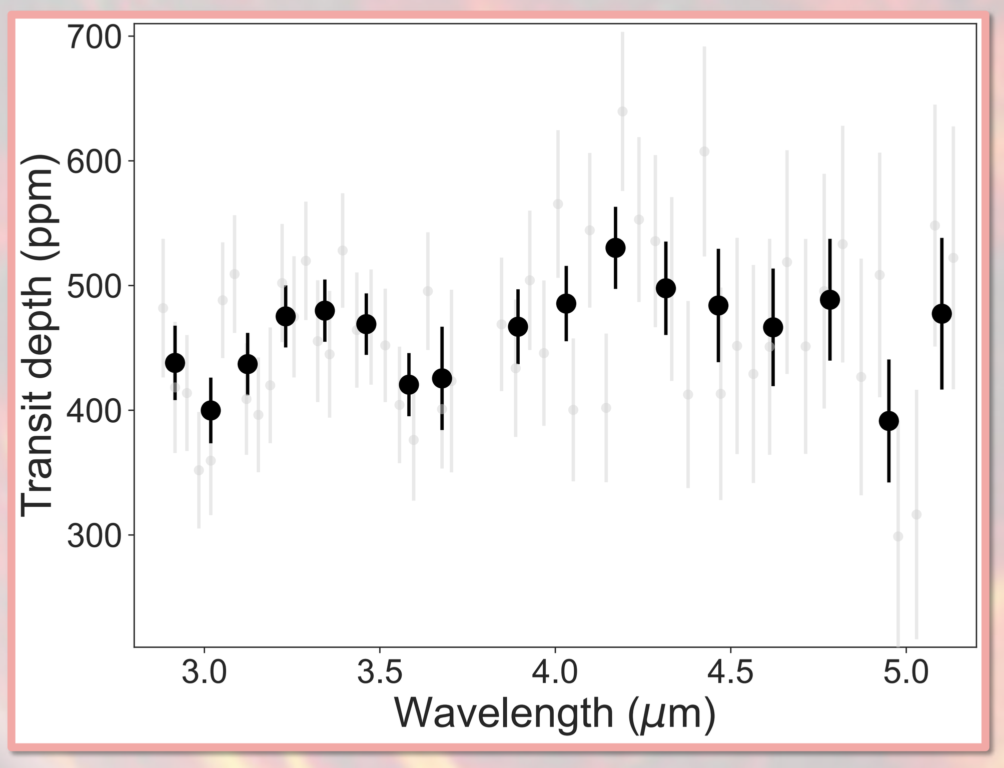
Emission spectrum

- ➔ The spectral eclipse depth values are fitted uniformly, allowing for negative values to avoid biasing the results.
- ➔ The spectral fit is performed at R100 and then binned to R30.
- ➔ Emission values increase as expected for redder wavelengths.
- ➔ Results are consistent with Spitzer observations.
- ➔ Values are slightly lower than a blackbody with full redistribution, suggesting a non-zero albedo.



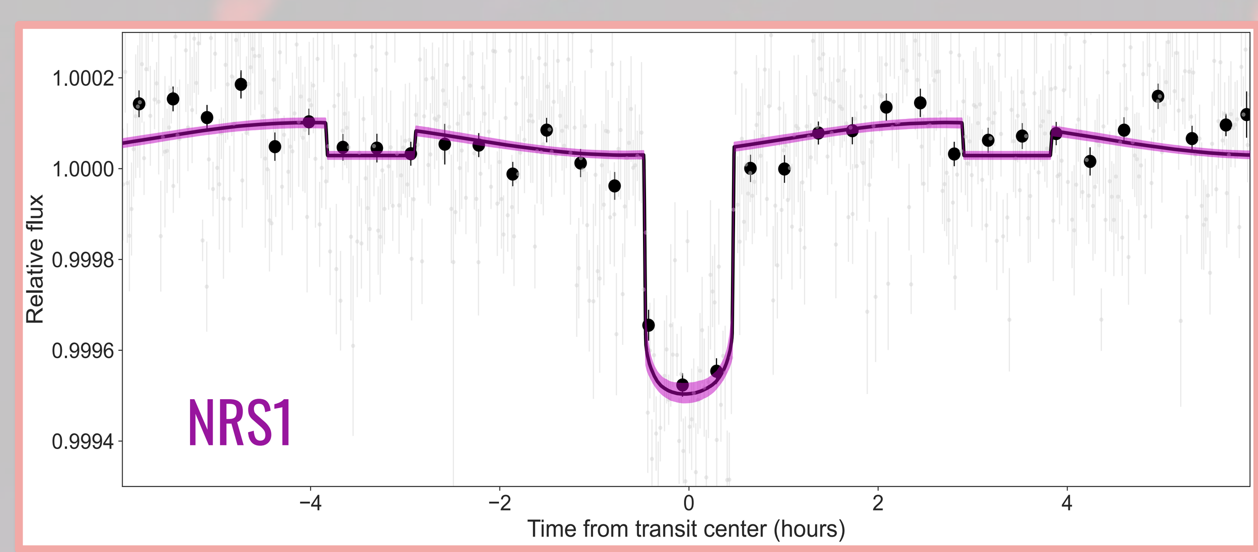
Sneak Peek at the Transmission Spectrum

- ➔ The spectral fit is performed at R100 and then binned to R30.
- ➔ Quadratic LDC are fitted uniformly between [0, 1] for each bin
- ➔ No obvious features are identified



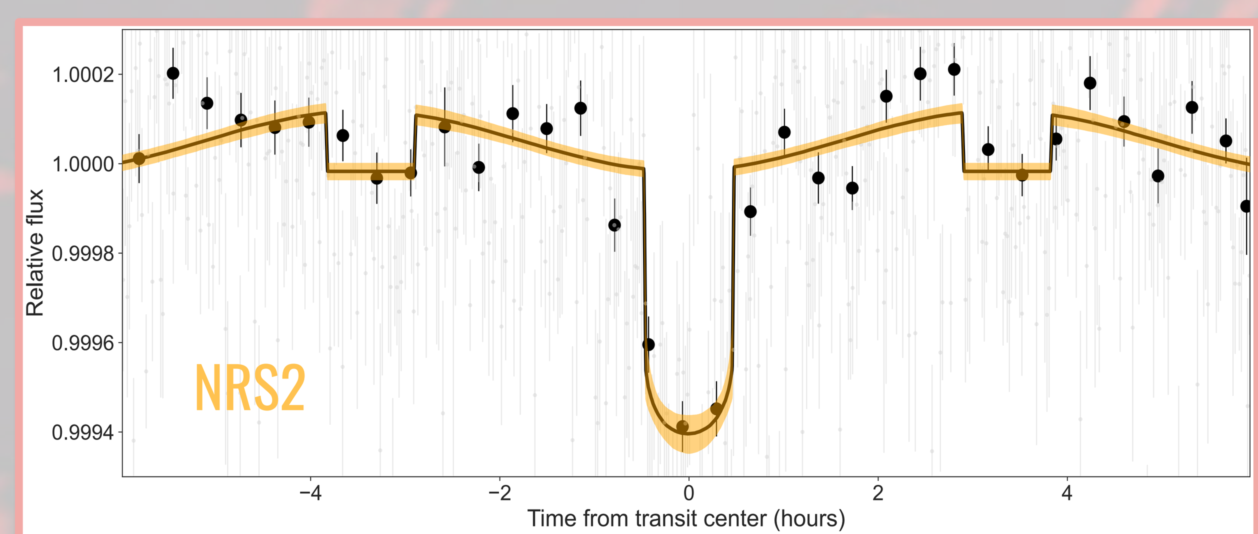
K2-141 b Phase curves modelling

- ➔ We fit the full phase curves from NRS1 and NRS2 independently using the same detrending model, which includes a linear polynomial in time and FWHM.
- ➔ The phase curve was modeled using the batman[9] package and a sinusoidal model:
- ➔ We fit for Fs, rp/rs, fp/fs, offset, amplitude, q1, q2, coefficients of detrending model



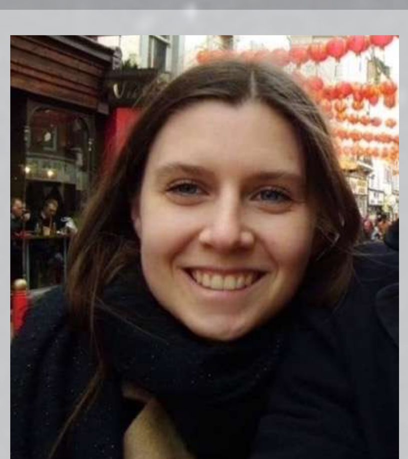
Results

- ➔ We find consistent transit values between detectors, i.e., 491+/-50 and 534+/-41 ppm.
- ➔ The eclipse depth value is 75+/-15 ppm for NRS1 and 136+/-31 ppm for NRS2
- ➔ The phase offset is found to be non-consistent with zero for NRS1, contrary to NRS2, which might be due to remaining correlated noise with the observed time ramp in NRS1.



References

[1] Malavolta et al. 2017
[2] Barragàn et al. 2018
[3] Nguyen et al., 2020
[4] Zieba et al. 2022
[5] Rustamkulov et al 2023
[6] Espinoza et al. 2019 a
[7] Espinoza et al. 2018
[8] Bonomo et al. 2023
[9] Kreidberg et al. 2015



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Want to know more about detecting atmospheres around rocky planets orbiting M-dwarfs using MIRI photometry ? Check out the Hot-Rocks survey (PI: H. Diamond-Lowe)