

# Titanium oxide and chemical inhomogeneity in the atmosphere of the exoplanet WASP-189 b

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## ABSTRACT

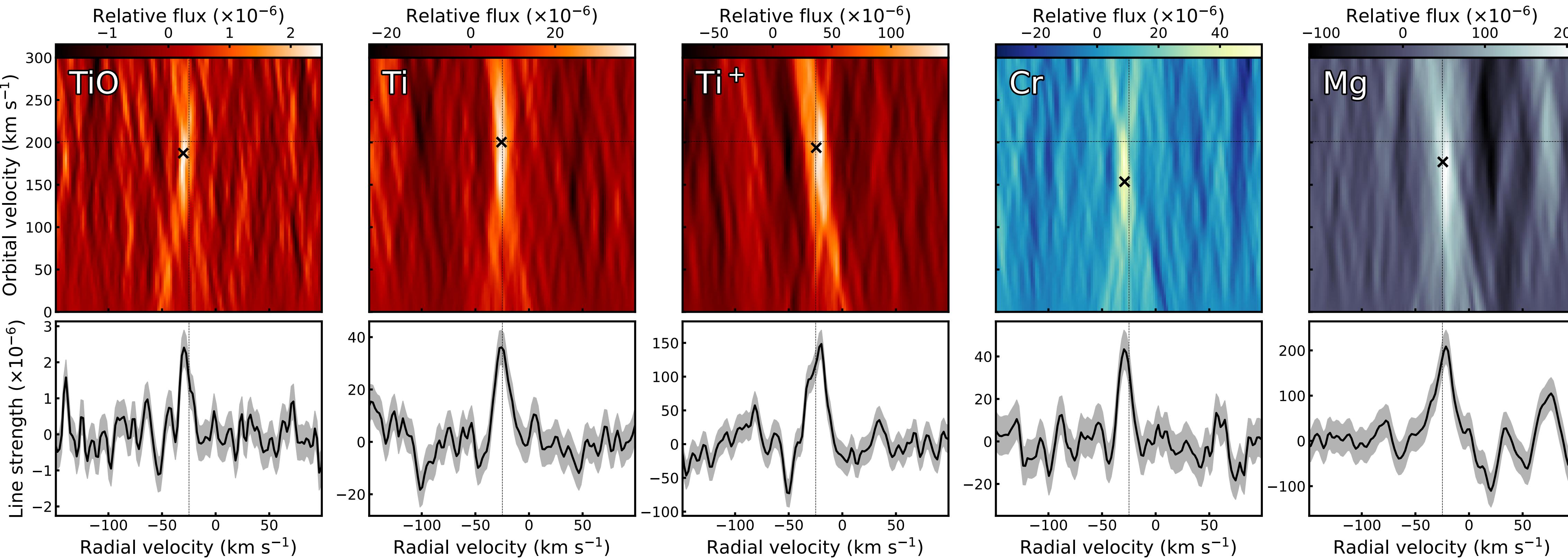
- We report the first unambiguous detection of TiO in the ultra-hot Jupiter WASP-189 b derived from high-resolution ground-based spectroscopy.
- We find observational evidence of three-dimensional variations in temperature, chemistry and dynamics in the atmosphere of WASP-189 b.

## METHODS

- **Detection of nine species:** Cr, Fe, Fe<sup>+</sup>, Mg, Mn, Ti, Ti<sup>+</sup>, TiO, V
- **Tentative detections for:** Ca, Cr<sup>+</sup>, Na, Ni, Sc<sup>+</sup>
- **Varying line positions (systemic radial velocity, orbital velocity)** for different species possibly caused by spatial gradients in their chemical abundance profiles

## RESULTS

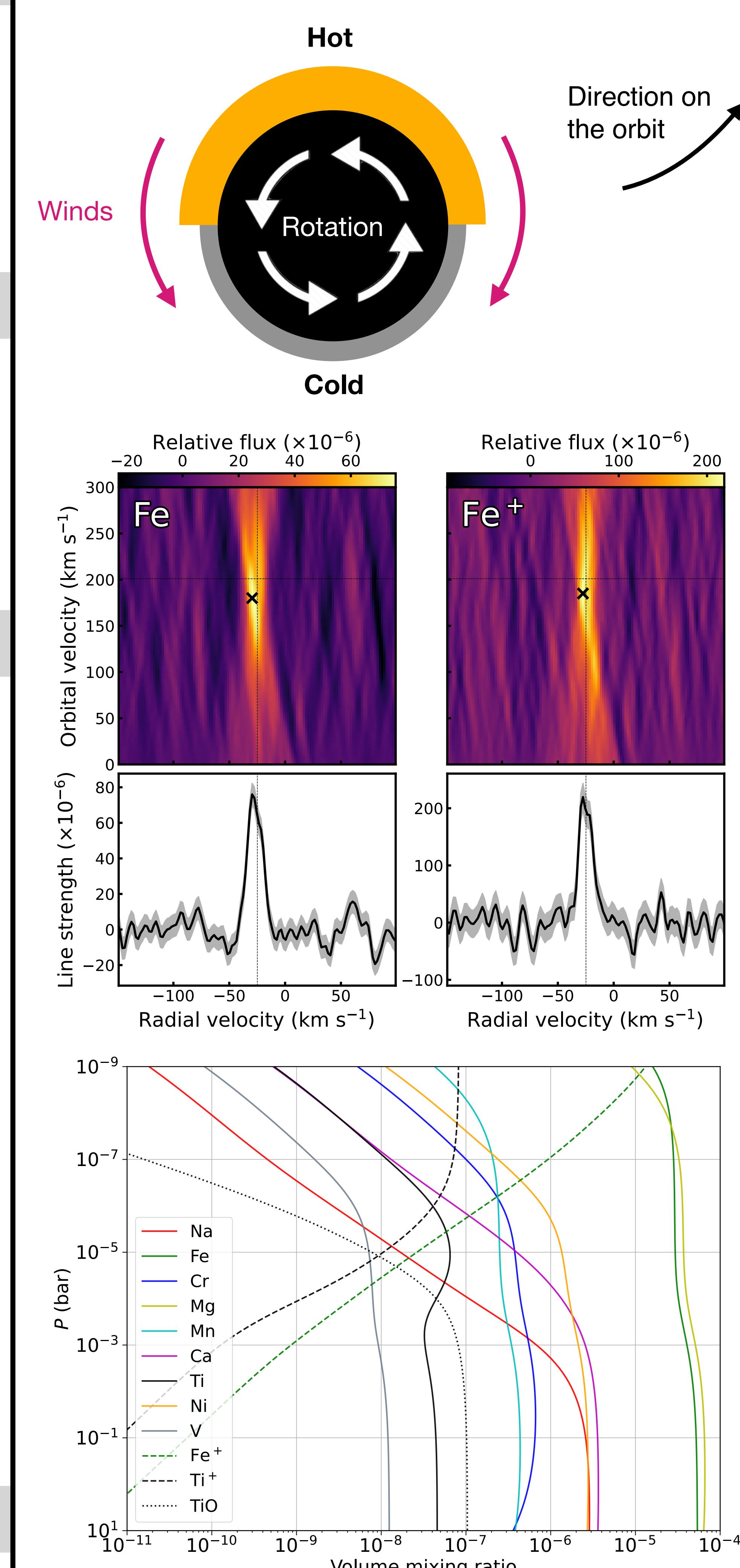
- **Cross-correlation technique:** Applied to five transits of the ultra-hot Jupiter WASP-189 b with HARPS / HARPSN, after Doppler shadow and telluric correction.



## CONCLUSION

Successful interpretation of observations of ultra-hot Jupiters requires that the theory of exoplanet atmospheres appreciates the 3D nature of these atmospheres and that insights derived from GCMs, atmospheric chemistry and radiative transfer are unified.

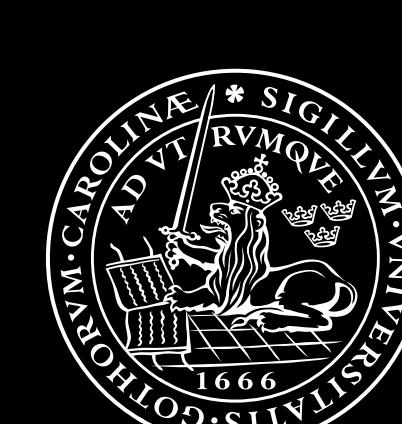
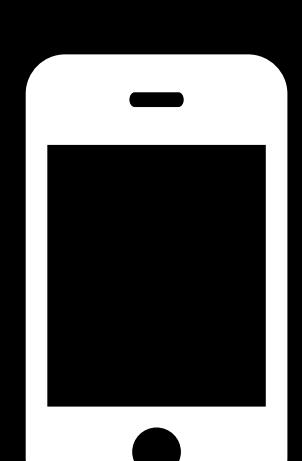
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	A ( $\times 10^{-6}$ )	$v_0$ (km s $^{-1}$ )	FWHM (km s $^{-1}$ )	$v_{\text{orb,ext}}/K_p$ (km s $^{-1}$ )	$\sigma$
Cr	45.8 ± 5.7	-29.03 ± 0.75	12.1 ± 1.8	159.2 ± 7.8	8.0
Fe	75.0 ± 4.3	-28.09 ± 0.43	15.3 ± 1.0	191.8 ± 3.9	17
Fe <sup>+</sup>	228 ± 17	-25.56 ± 0.51	14.1 ± 1.2	189.4 ± 6.4	14
Mg	177 ± 22	-24.3 ± 1.2	20.5 ± 2.9	167 ± 10	8.1
Mn	83 ± 13	-30.6 ± 1.3	17.2 ± 3.1	202 ± 12	6.5
Ti	38.4 ± 4.4	-24.90 ± 0.85	15.1 ± 2.0	202.1 ± 9.0	8.7
Ti <sup>+</sup>	139 ± 14	-23.95 ± 0.81	15.9 ± 1.9	180.9 ± 8.1	9.7
TiO	1.67 ± 0.30	-28.53 ± 0.95	10.9 ± 2.3	185.68 ± 10.16	5.6
V	30.6 ± 4.9	-28.3 ± 1.7	21.7 ± 4.0	218 ± 13 (201)	6.2



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