Applying known chemical kinetics data to model atmospheres of extrasolar planets

UNIVERSITY OF EXETER

Maria Zamyatina[1]*, Eric Hébrard[1], Nathan J. Mayne[1], Robert J. Ridgway[1] and Exeter Exoplanet Theory Group (http://exoclimatology.com)

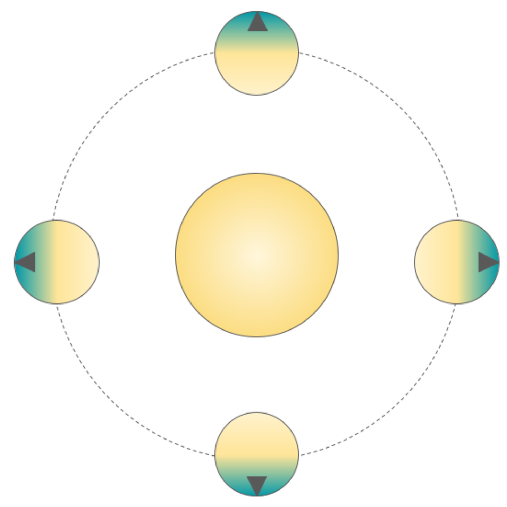
[1]Department of Physics and Astronomy, Faculty of Environment, Science and Economy, University of Exeter, UK

* m.zamyatina@exeter.ac.uk m_zamyatina

Met Office

Introduction

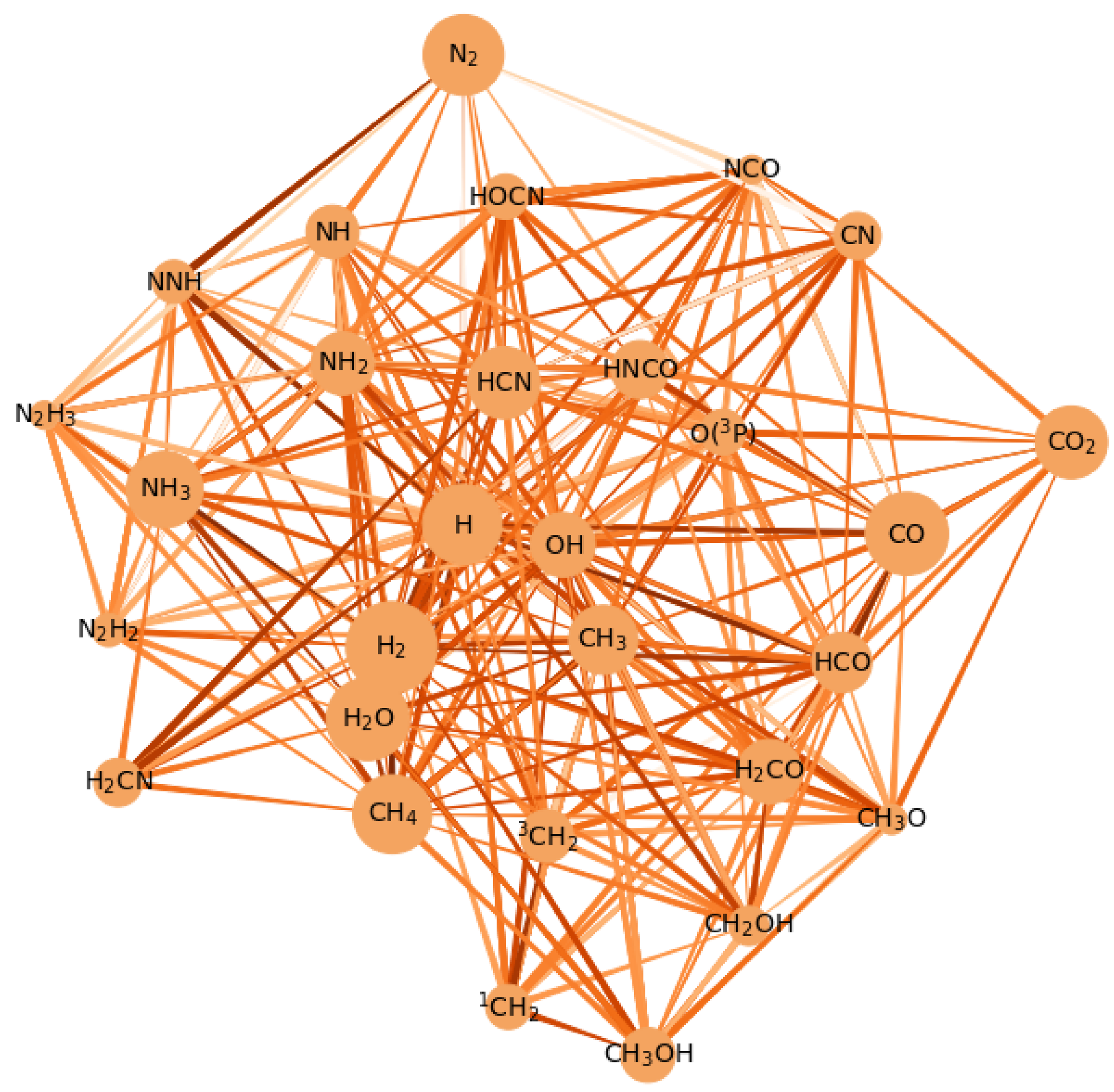
- We apply known chemical kinetics data to **model atmospheres of extrasolar planets (exoplanets)**.
- Such modelling is topical as it **helps interpret** recently released and upcoming **observations with the JWST, a new large infrared space telescope**.
- We hope to spark interest in an collaboration between atmospheric chemists and astronomers.

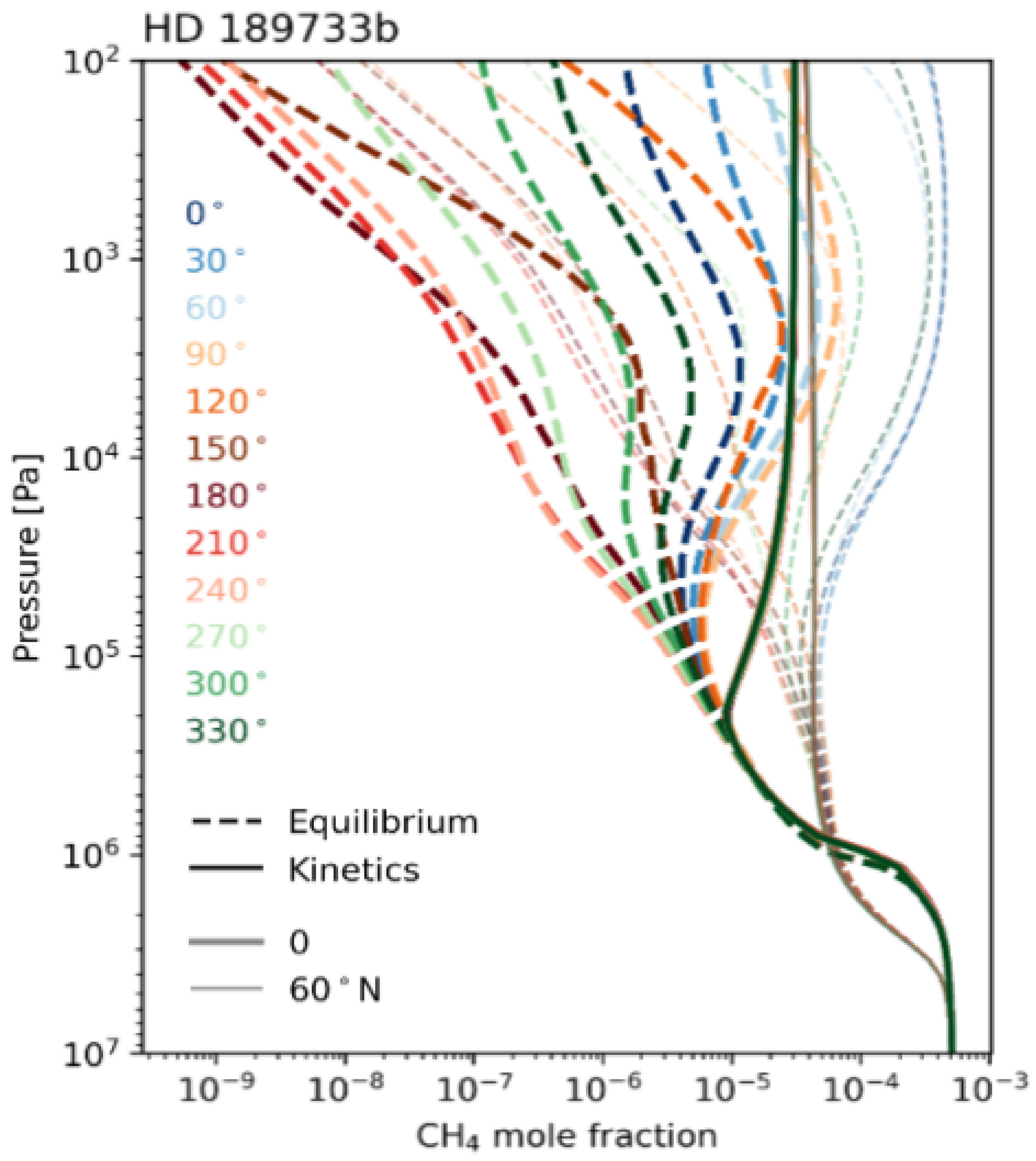


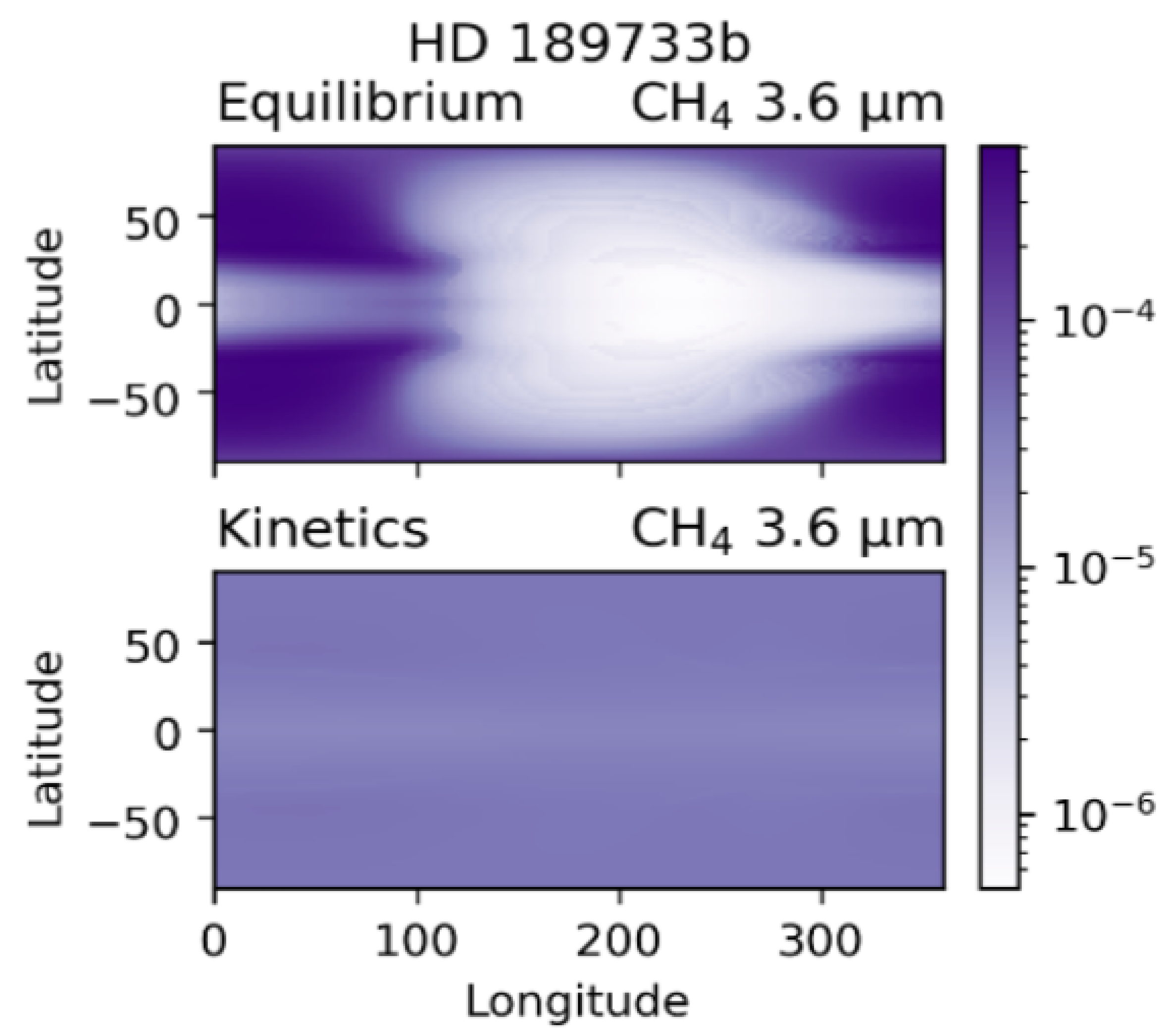
- Many discovered exoplanets orbit so close to their host starts that the proximity to the star causes them to become **tidally locked, i.e., have a permanently irradiated dayside and unirradiated nightside**.
- **The Met Office Unified Model (UM)**, 3D coupled hydrodynamics-radiation-chemistry model, **was adapted to model tidally-locked exoplanets**, and here we present results from this model.

H_2-He-dominated atmospheres

Zamyatina et al. (under review in MNRAS)



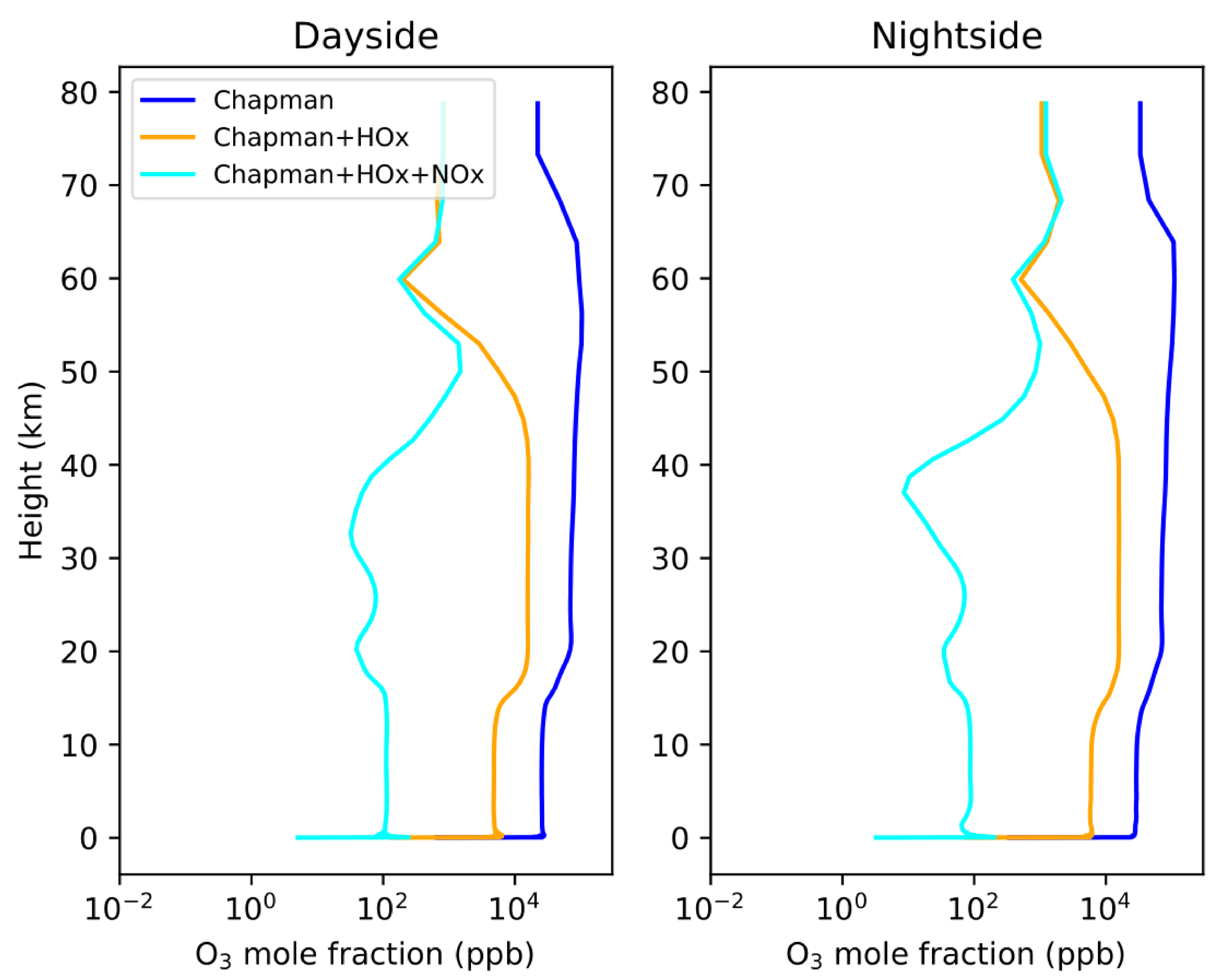


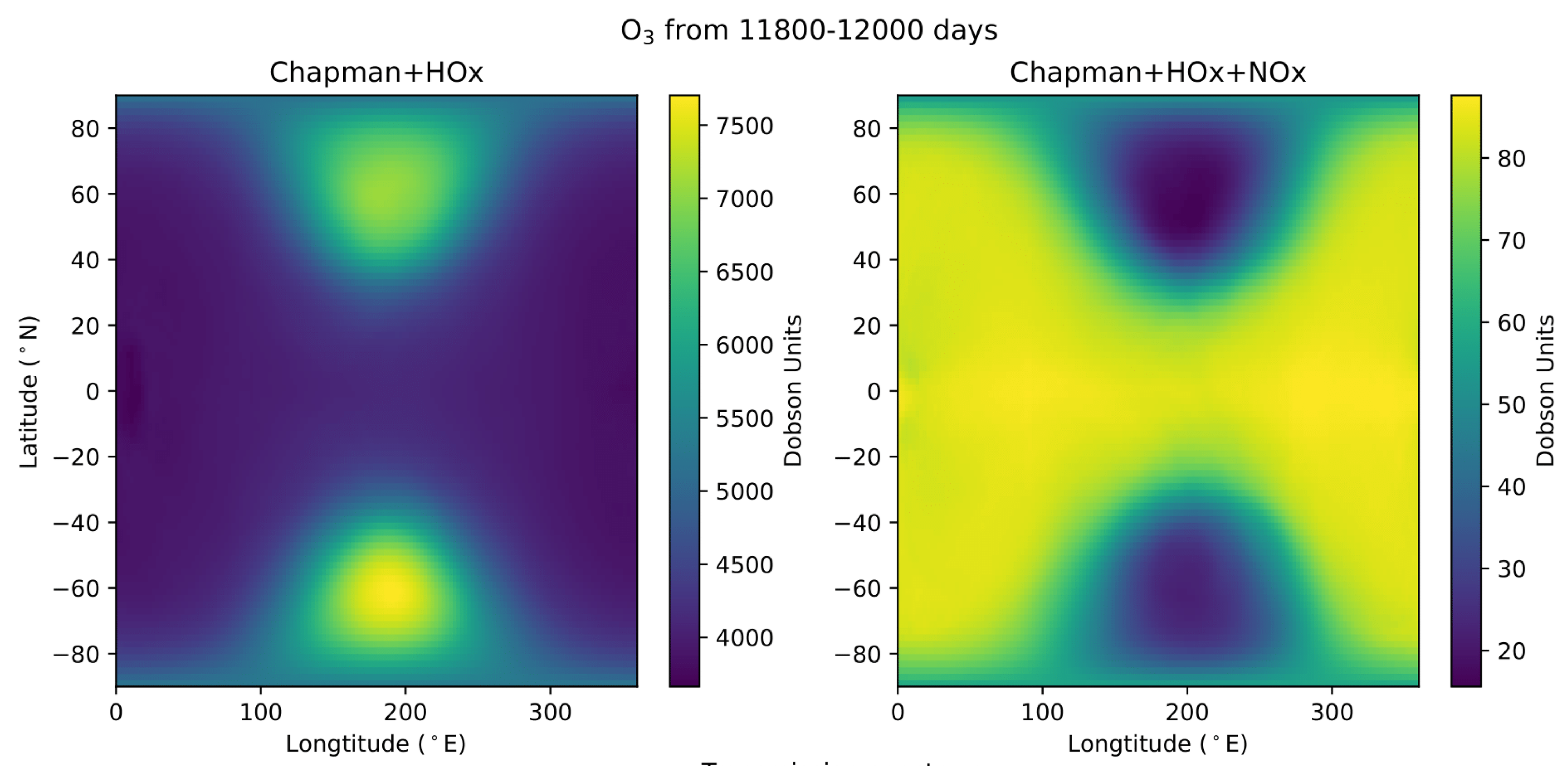


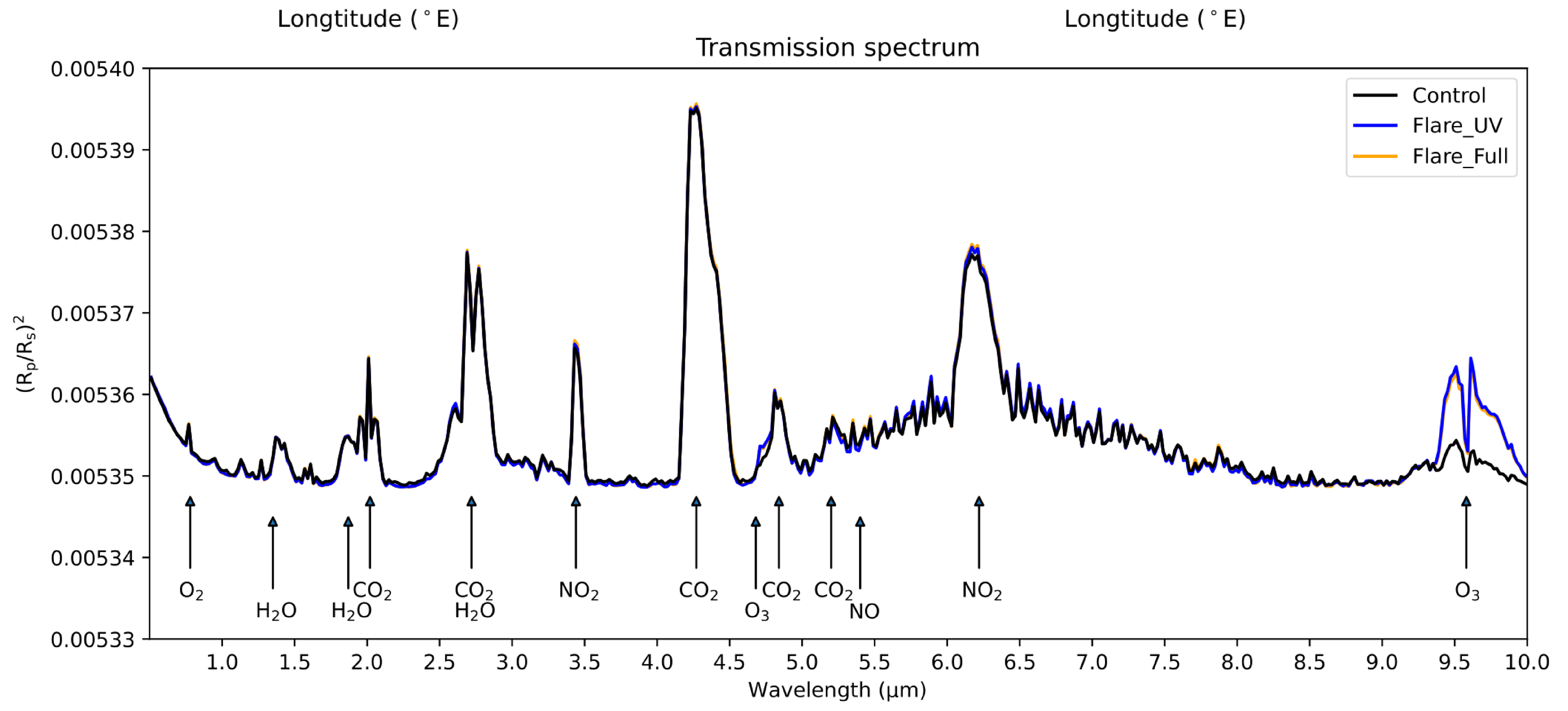
1. **Hot Jupiters** like HD 189733b are Jupiter-size gas giant exoplanets, whose primordial atmospheres made mostly of H_2, He and some H_2O, CO, CO_2, CH_4, N_2, NH_3 and other gases, are **heated by a star up to 2200 K**.
2. Their **deep atmosphere** ($>2\times10^5$ Pa) has high enough pressures and temperatures to be at a **chemical equilibrium**.
3. Their **upper atmosphere** ($<2\times10^5$ Pa) has pressures and temperatures low enough and winds fast enough ($\approx 6\,\mathrm{km\,s^{-1}}$) for chemical reactions not to have enough energy or time to finish, causing a **chemical disequilibrium**.
4. **Wind-driven disequilibrium (quenching) usually enhances chemical species abundances above those at equilibrium.**
5. CH_4 distribution changes due to quenching both vertically and horizontally (e.g., at a pressure level of the 3.6 μm photosphere).
6. At equilibrium, distribution of chemical species follows the pressure-temperature structure, so there is less CH_4 at higher temperatures* and vice versa.
   - *Substellar point is at 180° longitude.
7. **Quenching homogenises CH_4 distribution, and this effect is detectable with the JWST in the case of HD 189733b, if it's atmosphere is cloud- and haze-free.**

N_2-O_2-dominated atmospheres

Ridgway, Zamyatina et al. (under review in MNRAS)







1. Proxima Centauri b is an Earth-size exoplanet orbiting an M-dwarf star.
2. Atmospheric composition of Proxima Centauri b is not yet known, but if it was N_2-O_2-dominated, **O_3 vertical profiles** might look like this.
3. **Nightside* O_3 distribution** would be dominated by two cyclonic Rossby gyres, inducing O_3 loss via NO_x titration.
   - *Substellar point is at 0° longitude.
4. But O_3 would be hard to detect in such atmospheres even with the JWST.

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