



LASP

Can auroral heating power brown dwarf thermal inversions?



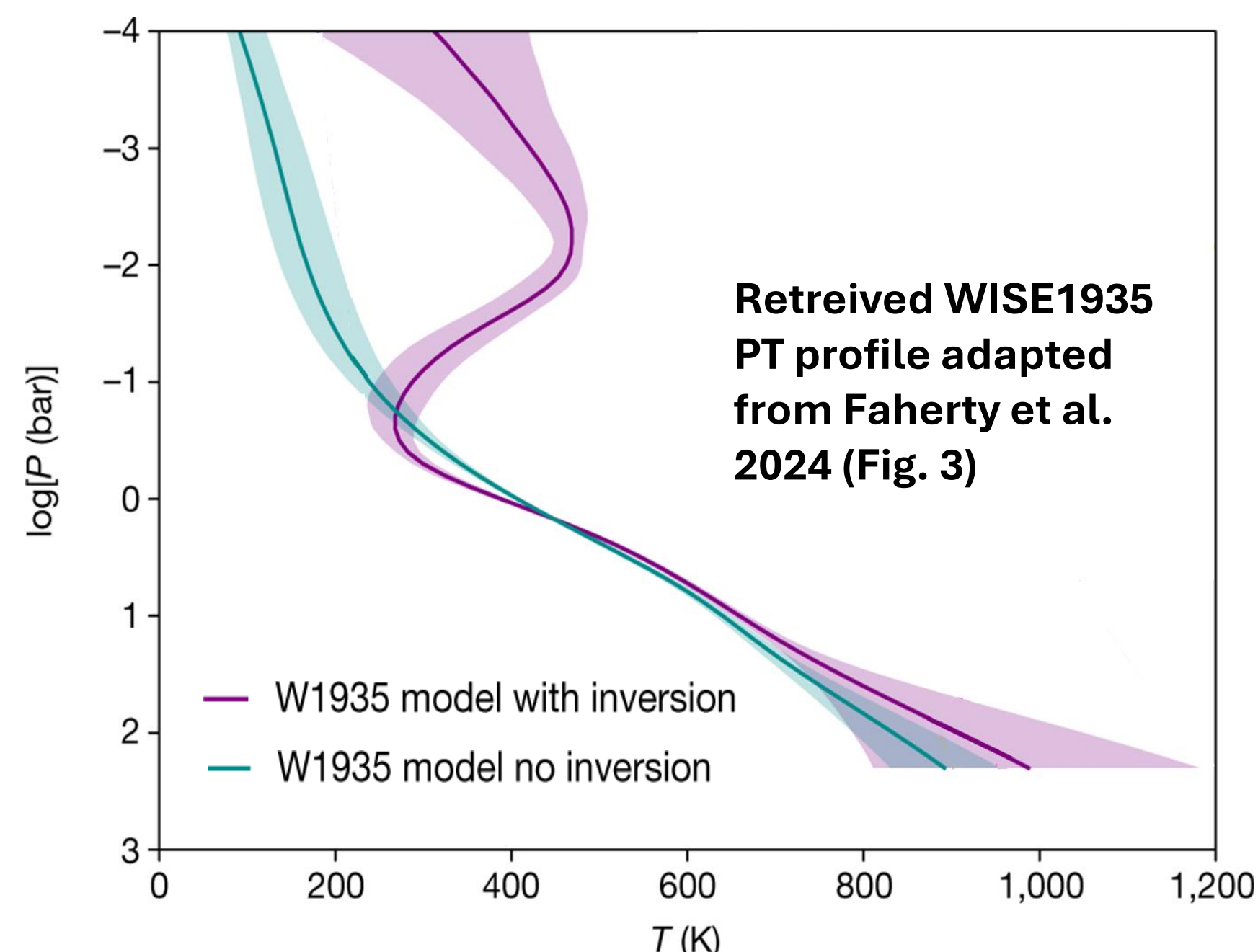
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An Unexplained Thermal Inversion

WISE1935 and SIMP0136 show spectral features implying a **temperature inversion**

- **WISE1935:**
binary pair of Y-dwarfs,
 $T \approx 482\text{K}$, $\log(g) \approx 4.7$
(Faherty et al. 2024, De Furio et al. 2025, Suárez et al. 2025)
- **SIMP0136:**
T-dwarf, $T \approx 1245\text{K}$, $\log(g) \approx 4.5$
(Nasedkin et al. 2025)



Can auroral heating produce this inversion?

The Auroral Picture of Brown Dwarfs

Radio ECMI emission confirms **auroral precipitation** (e.g. Hallinan et al. 2008, Route et al. 2012)

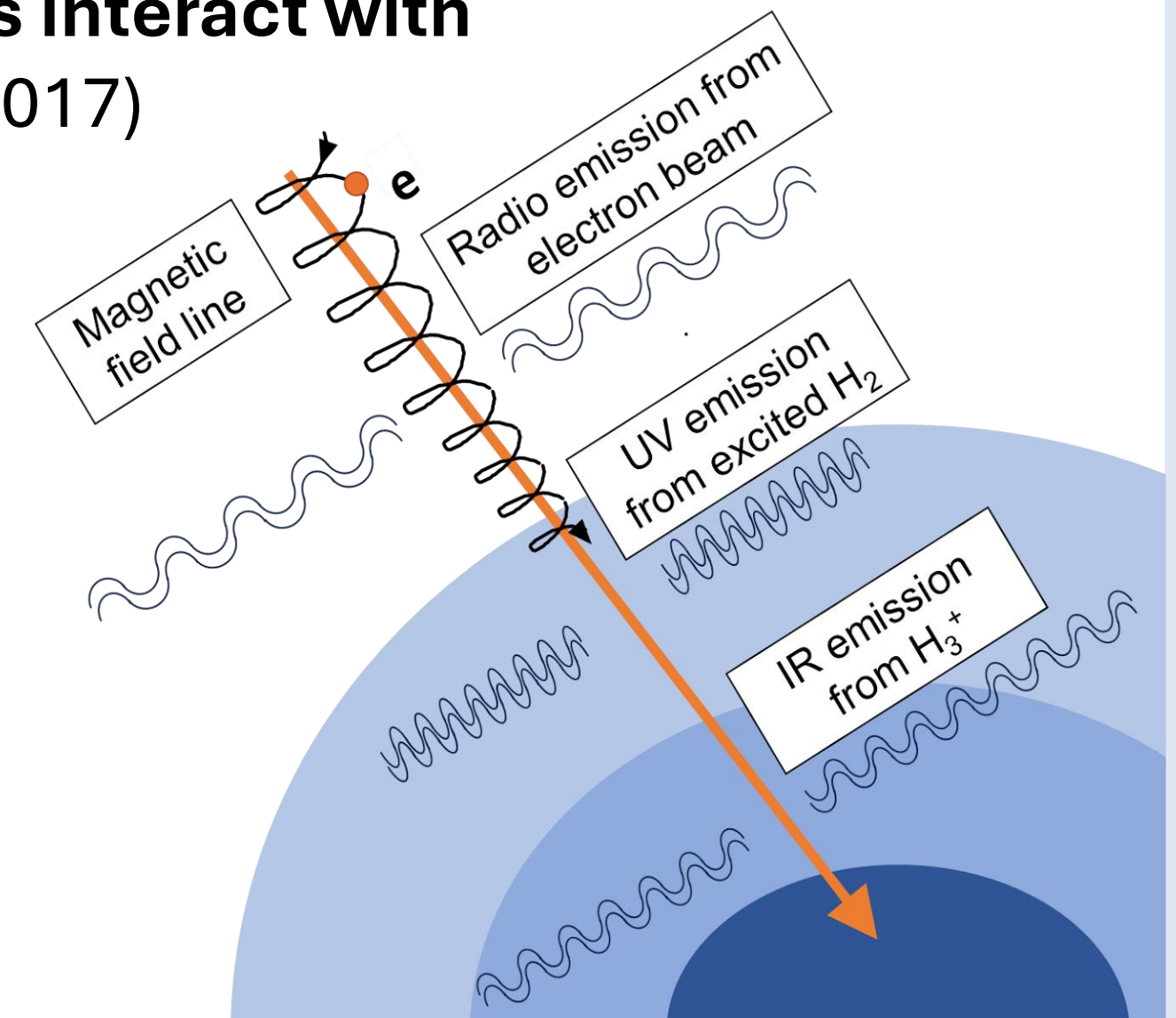
H α coincident with radio indicates **electrons interact with atmosphere** (Kao et al. 2016, Pineda et al. 2017)

Energy lost to **atmospheric interactions**

- Thermalized electrons, plus rovibrational excitations, produces heating

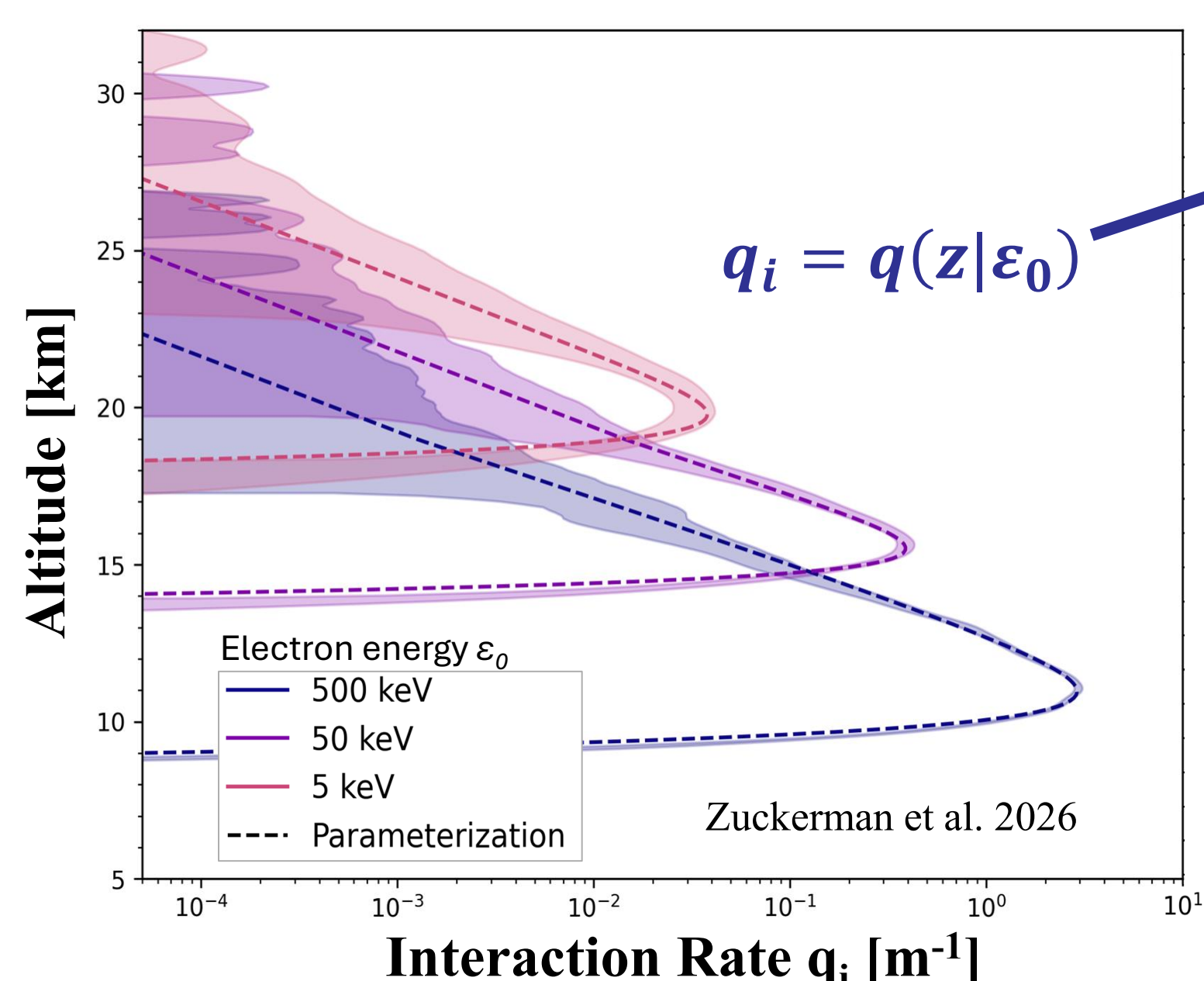
Closest Solar System analog is Jupiter

- Also has upper atmosphere inversion in part due to auroral heating (O'Donoghue et al. 2021)

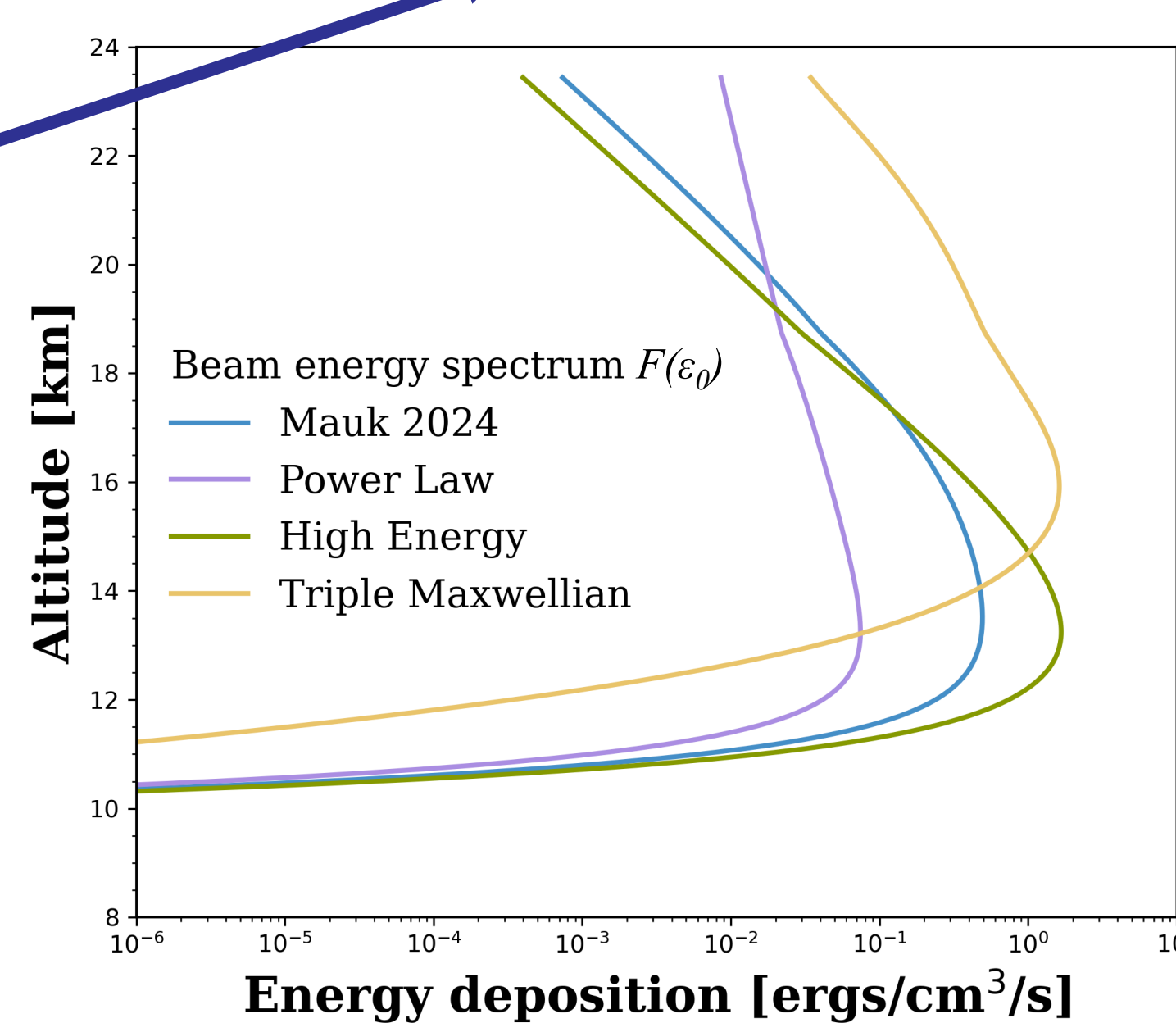


Approach

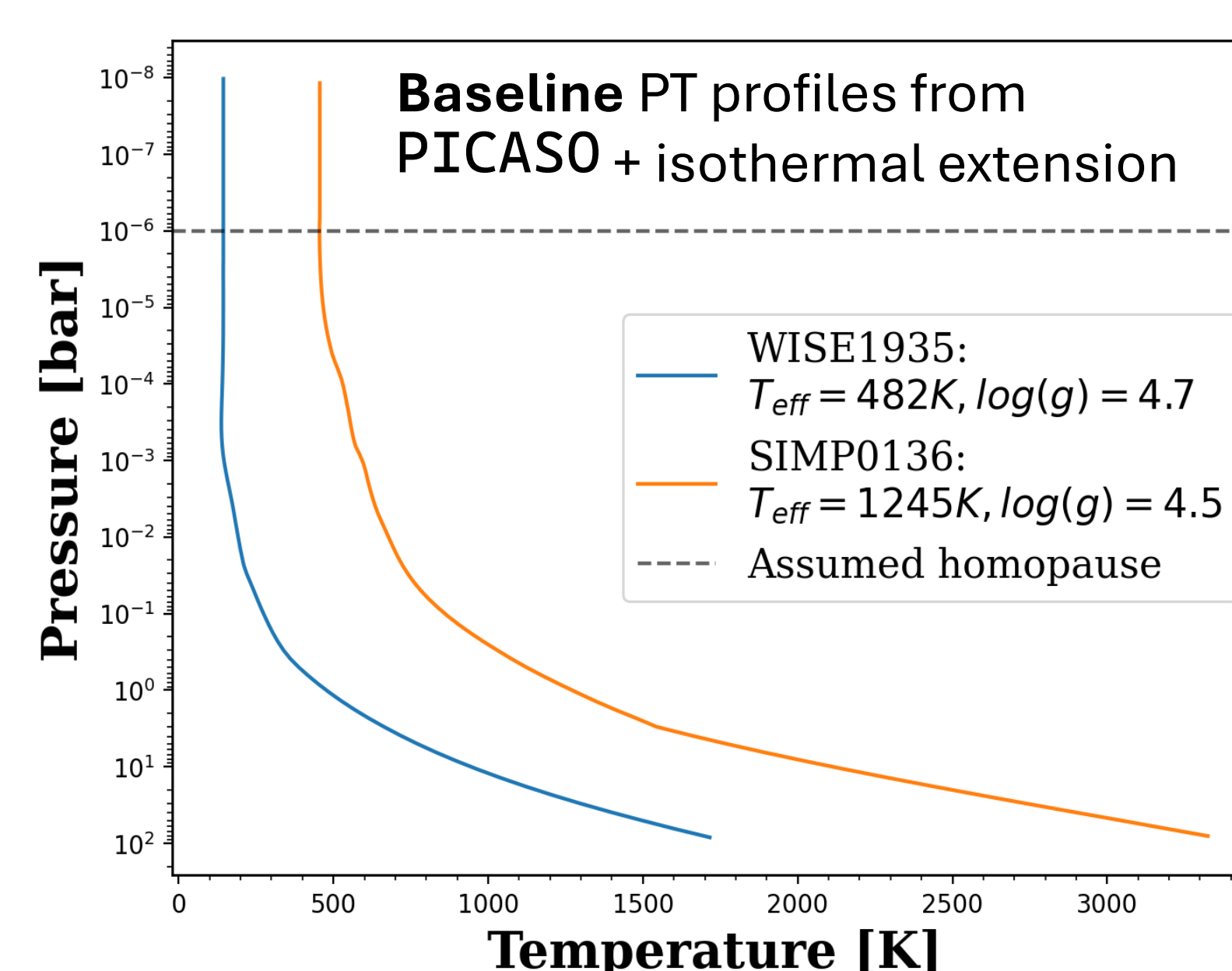
- ① Auroral electron precipitation model gives parameterized interaction rate:



- ② Integrate for **volumetric interaction rate**:
 $Q_i(z) = \int q_i(z|\epsilon_0) F(\epsilon_0) d\epsilon_0$



- ③ **Atmospheric forward modeling**: Perturb baseline atmosphere with auroral energy deposition



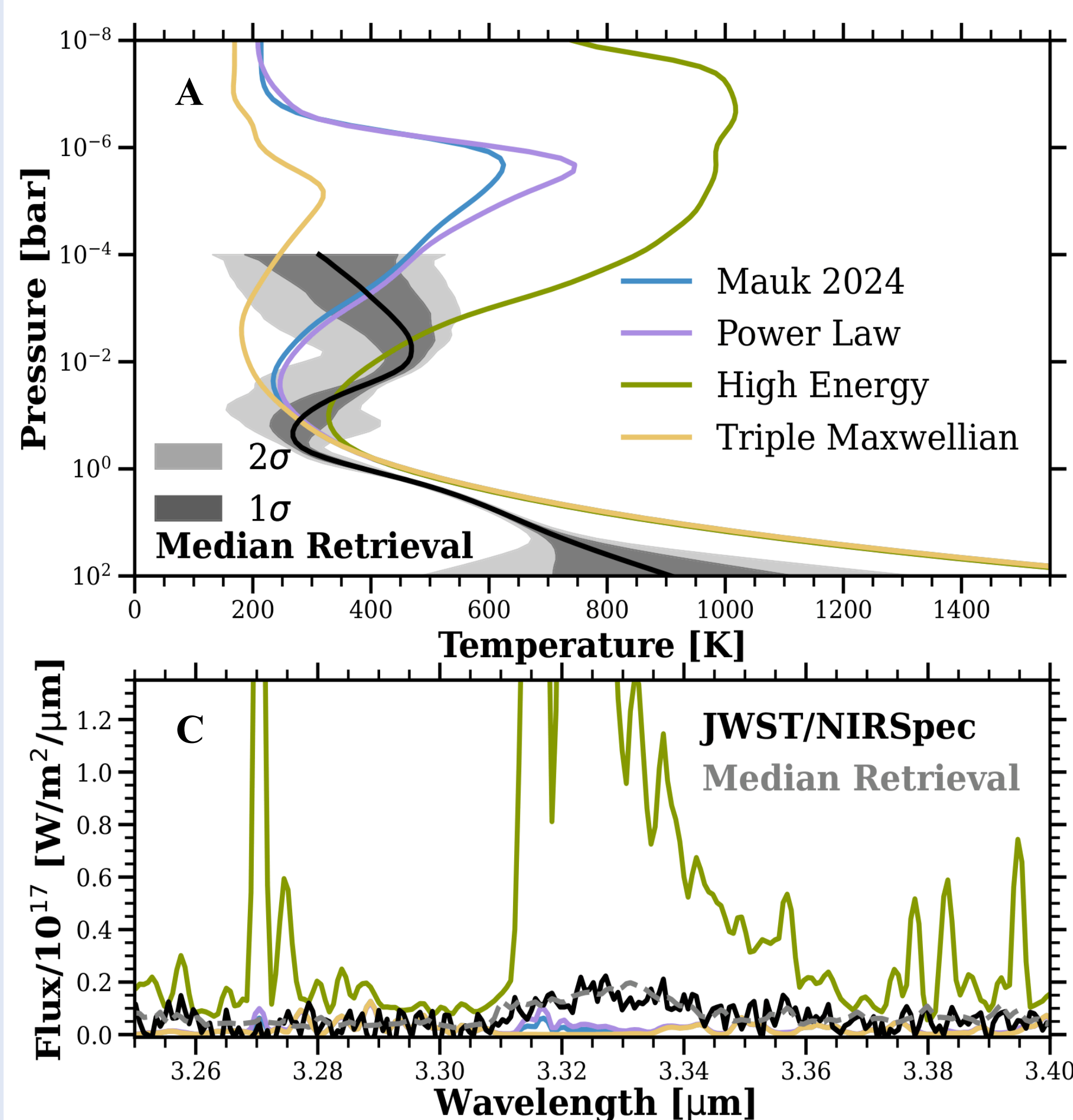
Does the **new thermal structure** have an inversion?

PICASO iteratively solves:

- temperature profile
- chemical structure
- energy transport

Results

WISE1935
Auroral simulation vs Data



Auroral energy deposition does not directly **explain the full inversion**

- Inversion in simulated PT profile occurs at lower pressures (colored profiles in panels A and B)
- CH₄ emission feature missing (panels C and D)
- Contribution from **other mechanism(s) necessary**: energy transport by gravity waves [1], Joule heating [2]
- **Spatial heterogeneity** of heating is important

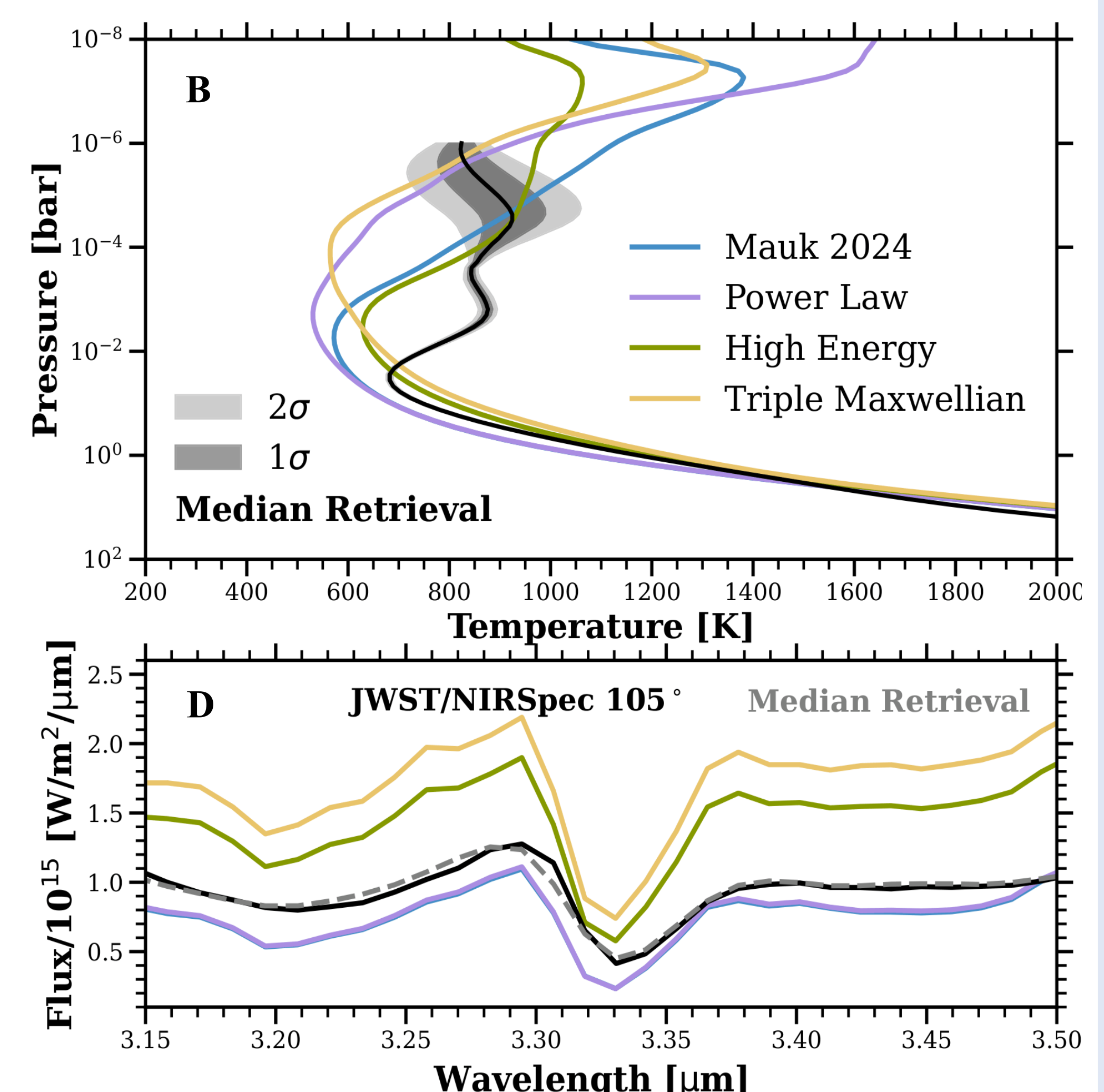
Inversion is recovered with sufficiently intense **ad hoc energy deposition profile** peaked at 0.01 bar

- Intense, **high energy** beam required
- High-energy tail supported by Jovian measurements + theory

Future directions for understanding inversions:

- Ongoing **observational efforts** to detect IR aurorae
- **Better model** for electron beam tail and for relativistic cross sections
- Model effect of auroral precipitation on **Joule heating** through conductivity

SIMP0136
Auroral simulation vs Data



References: [1] Achilleos et al. 1998, [2] Bougher et al. 2005, [3] De Furio et al. 2025, [4] Faherty et al. 2024, [5] Hallinan et al. 2008, [6] Kao 2017, [7] Mauk et al. 2024, [8] Mukherjee et al. 2023, [9] Mukherjee et al. 2024, [10] Nasedkin et al. 2025, [11] O'Donoghue et al. 2021, [12] Pineda et al. 2017, [13] Route et al. 2013, [14] Suárez et al. 2025, [15] Turnpenney et al. 2017