Accelerating atmospheric characterization with Optimal Estimation

Exoplanet science is transitioning from an era of discovery toward the in-depth spectroscopic characterization of distant climates and formation histories. However, as data sophistication grows, traditional modeling faces bottlenecks in the form of parameter degeneracies and enormous computational costs. To address this, I introduce Optex, a high-performance retrieval tool that adapts Earth-science inversion techniques, specifically the Optimal Estimation algorithm (Rodgers 2000), for directly-imaged exoplanetary atmospheres. Integrated with the Exo_k library (Leconte 2021), Optex achieves superior computational speed and vertical resolution compared to traditional sampling, while providing a rigorous framework for uncertainty quantification and bias mitigation. I will demonstrate Optex's unique ability to resolve complex structures by presenting results for the T-dwarf W1935, where JWST observations revealed unexpected methane emission from auroral heating. Finally, I will highlight Optex's scalability to multidimensional modeling, offering a high-performance pathway to move beyond static 1D atmospheric descriptions.

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