CSE 397: SciML **Fall 2025**

Project Proposal

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In [1] they look at using PINNS to perform radiative transfer modeling in exoplanetary atmospheres, specifically looking at a simplified 1D isotheremal model with pressure-dependent coefficients for absorption and Rayleigh scattering. They use two different PINNs, one to solve the absorption only case with given PDE,

$$\frac{du}{dx} + \alpha'(x, y)u = 0 \tag{1}$$

with $\alpha' = \ell_x \alpha_a$ and boundary conditions,

$$u(x = -1, y) = 1$$

and another to solve the full radiative transfer equation with Rayleigh scattering,

$$\cos(\phi)\frac{du}{dx} + \sin(\phi)\frac{du}{dy} + (\alpha_a + \alpha_s) \cdot u - \frac{\alpha_s}{4\pi} \cdot \int \Phi(\theta, \phi, \theta', \phi')u(\theta', \phi')d\Omega' = 0 \tag{2}$$

with boundary conditions,

$$\begin{cases} u\left(x = -1, y, |\phi| \leqslant \frac{\pi}{2}\right) & = \begin{cases} 1, |\phi| \leqslant \Delta_* \\ 0, \text{else} \end{cases} \\ u\left(x, y = 1, |\phi| \leqslant 0\right) & = \begin{cases} 1, |\phi| \leqslant \Delta_* \\ 0, \text{else} \end{cases} \\ u\left(x = 1, y, |\phi| \geqslant \frac{\pi}{2}\right) & = 0 \\ u_s(x, y = -1, \phi) & = 0 \end{cases}$$

They implement the BCs using soft-constraints for both PDEs[1]. For this project I will implement hard constraints for the absorption only case, and compare the results to the soft-constraint implementation. If time permits, I will also look at using a PINN to solve the full radiative transfer equation with hard constraints, and compare the results to the soft-constraint implementation.

[1]The Code is available at `https://github.com/DavidDahlbudding/AtmosphericScatteringPinn/tree/main/models`

References

[1] D. Dahlbüdding, K. Molaverdikhani, B. Ercolano, and T. Grassi, "Approximating rayleigh scattering in exoplanetary atmospheres using physics-informed neural networks (pinns)," *Monthly Notices of the Royal Astronomical Society*, vol. 533, no. 3, pp. 3475–3483, Aug. 2024, Also available as arXiv preprint arXiv:2408.00084. DOI: 10.1093/mnras/stae1872. arXiv: 2408.00084 [astro-ph.EP].