UltraLight Dark Matter in Simulations:
A Chapel-Powered Eigenstate Perspective

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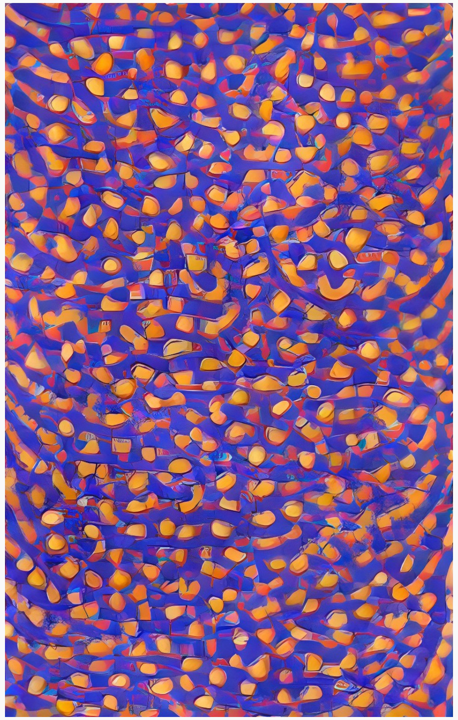
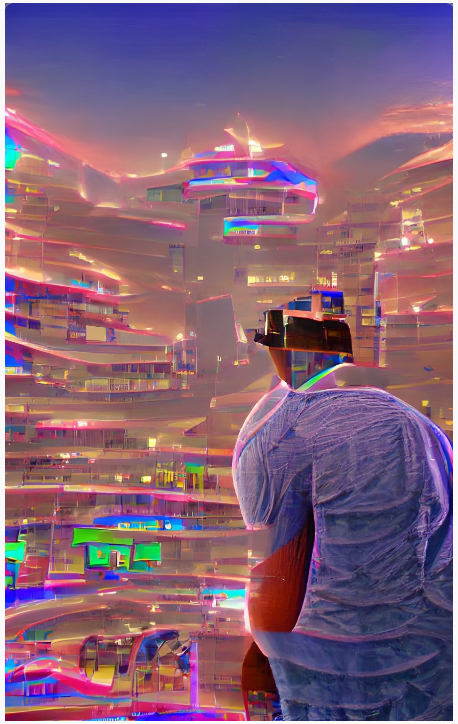


3. Eigenstates of a Halo



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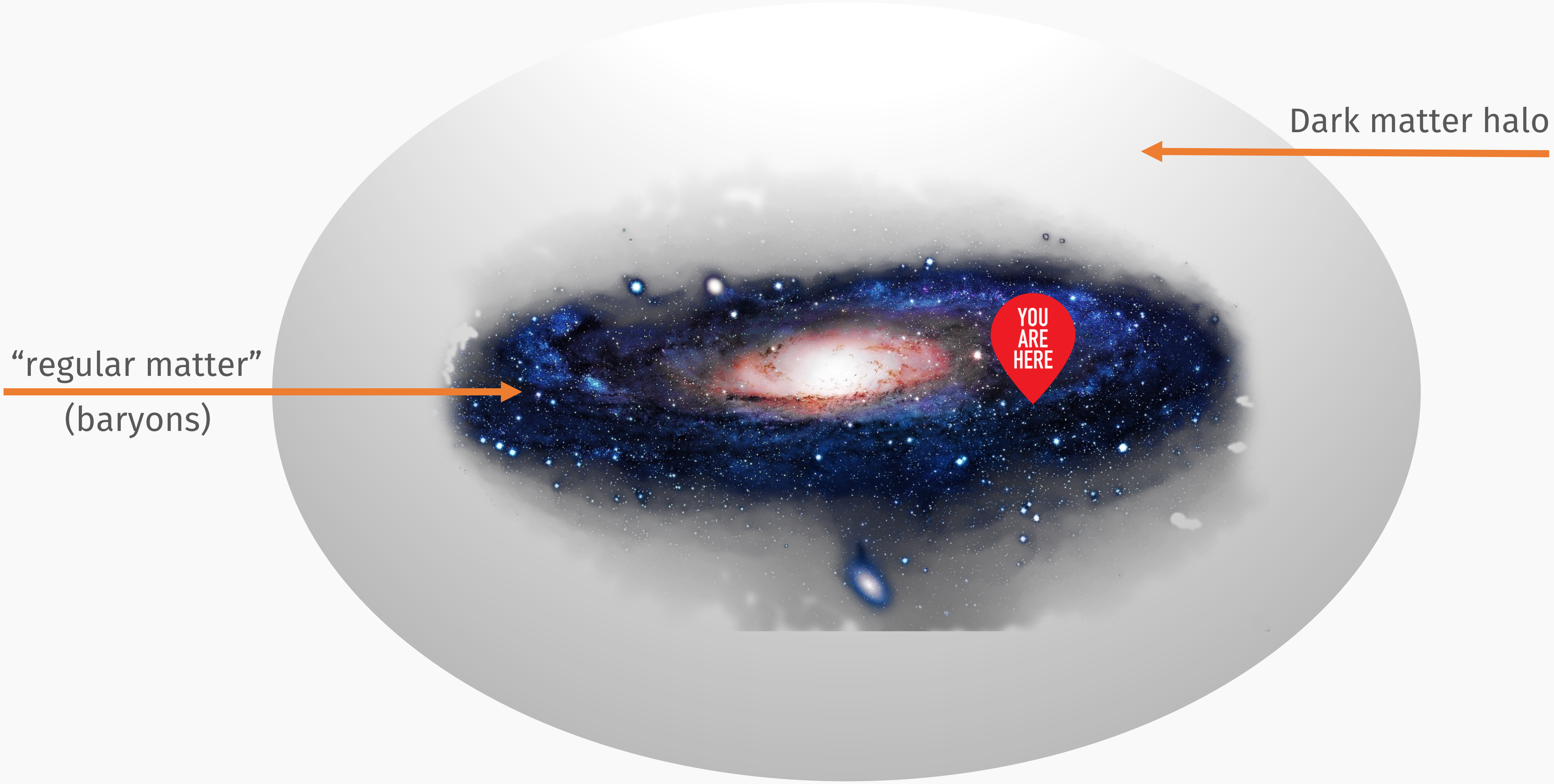
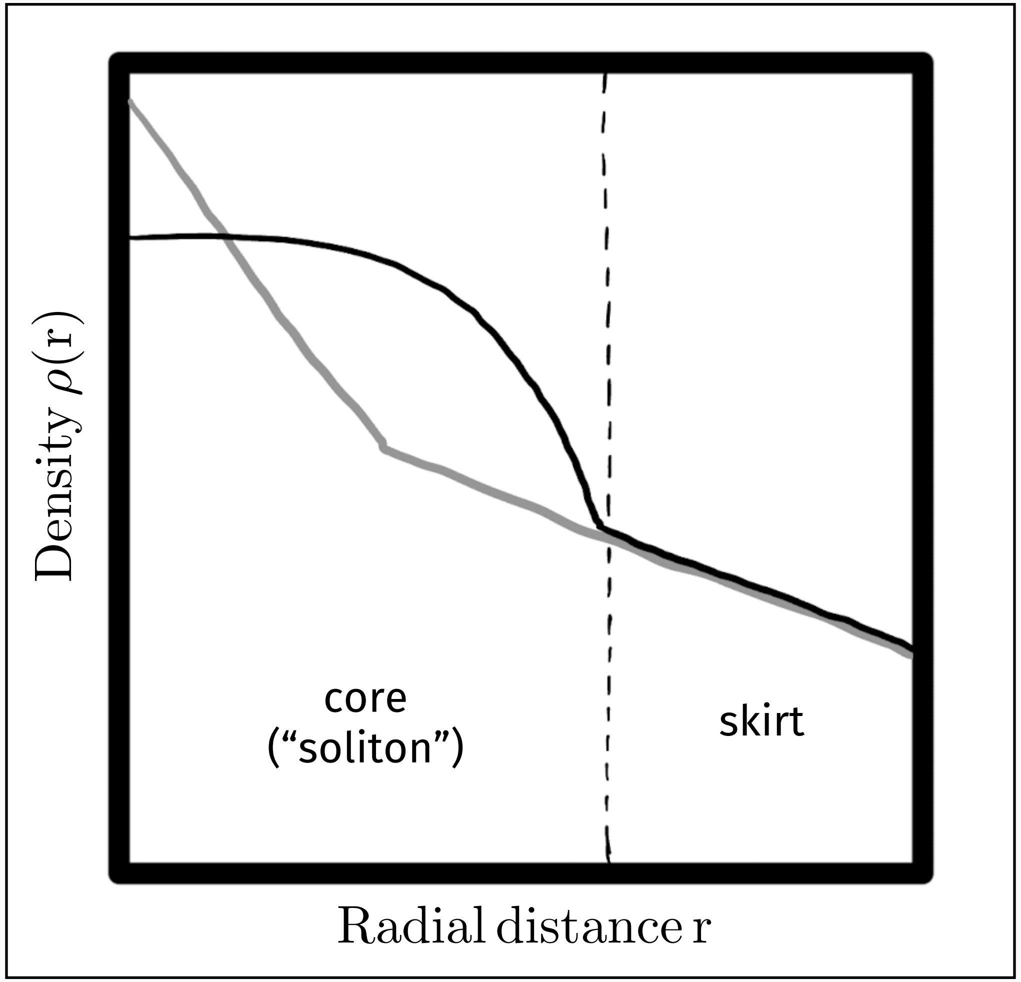
(UltraLight) Dark Matter

Dark Matter Halos



UltraLight Dark Matter (ULDM):

- is an axion-like scalar boson
- has low mass: $\sim 10^{-22}\,\mathrm{eV}$
- helps with small-scale problems
  - core-cusp problem *(right)*
  - missing satellites problem
  - too-big-to-fail problem
- cool phenomenology!



chplUltra

The Schrödinger-Poisson System

We need a solver for the following set of equations:

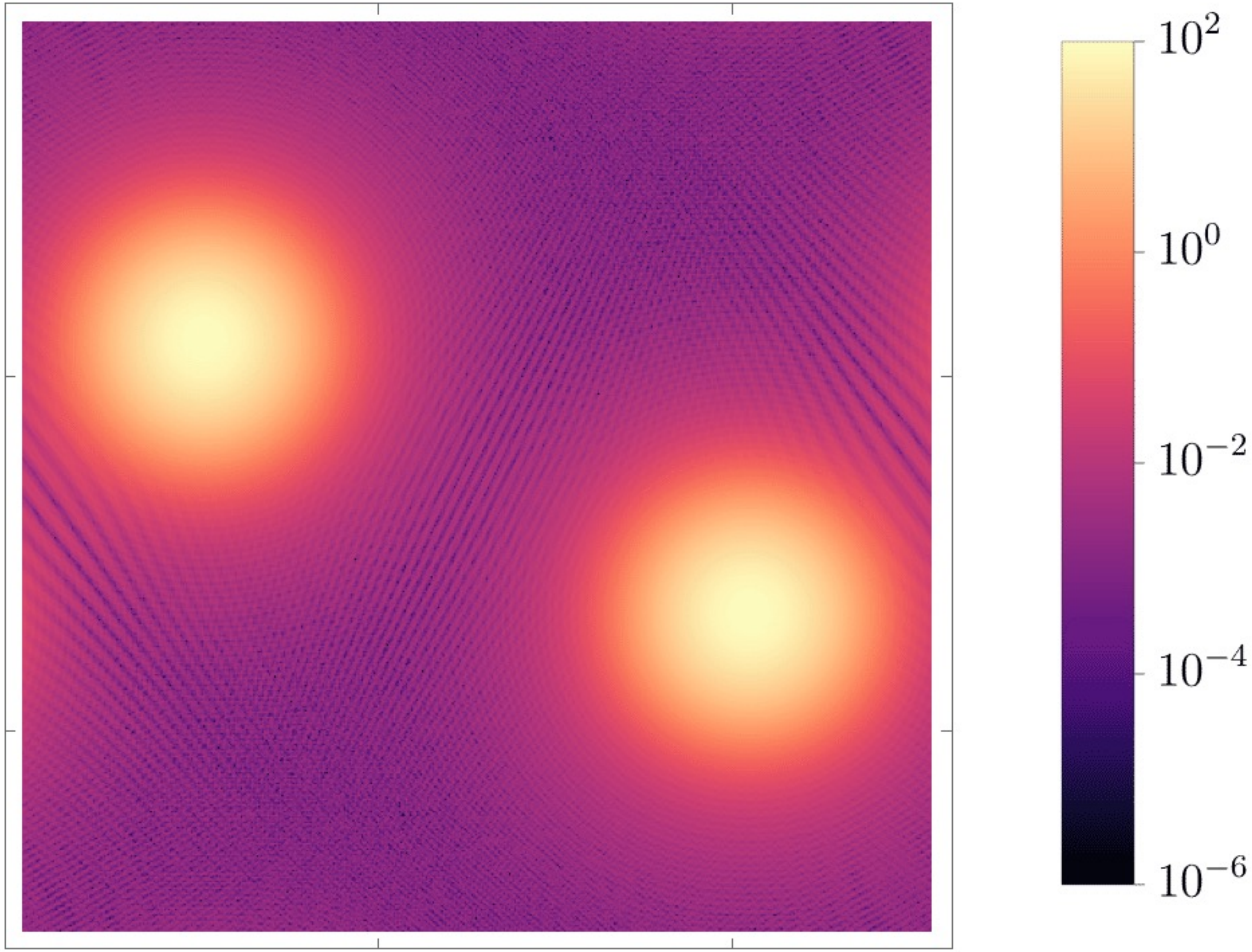
$$
\begin{aligned}
i\hbar\dot{\psi} &= -\frac{\hbar^2}{2m_a}\nabla^2\psi + m_a\Phi\psi \\
\nabla^2\Phi &= 4\pi G m_a|\psi|^2 \\
\rho &= m_a|\psi|^2
\end{aligned}
$$

PyUltraLight vs CHPLULTRA

PyUltraLight:

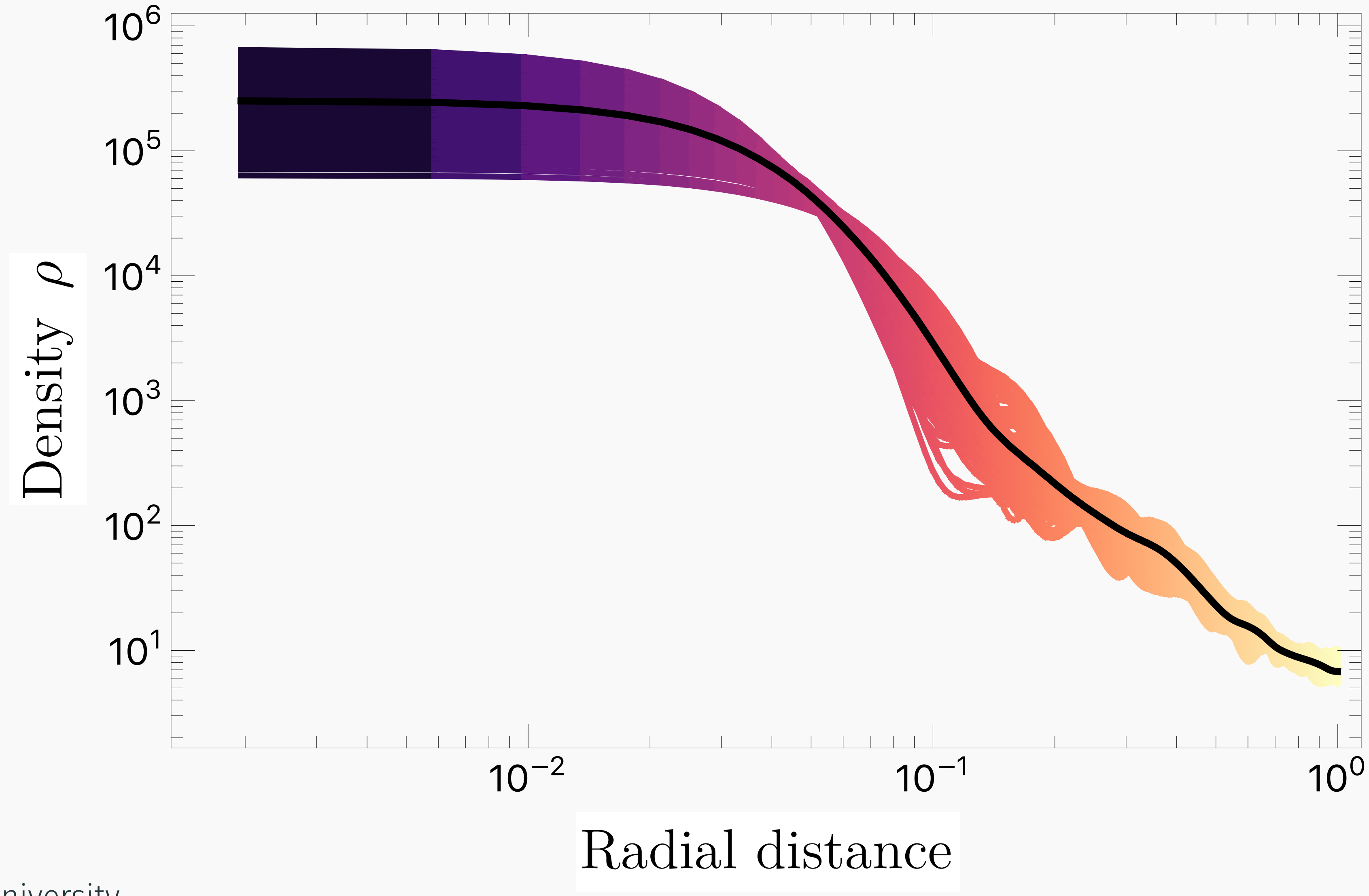
- original implementation in Python
- relies on FFTW wrappers (PyFFTW)
- excellent numerical stability
- parallelized, not distributed
- great for PC use!

A Chapel-powered Halo



A Halo’s Eigenstates

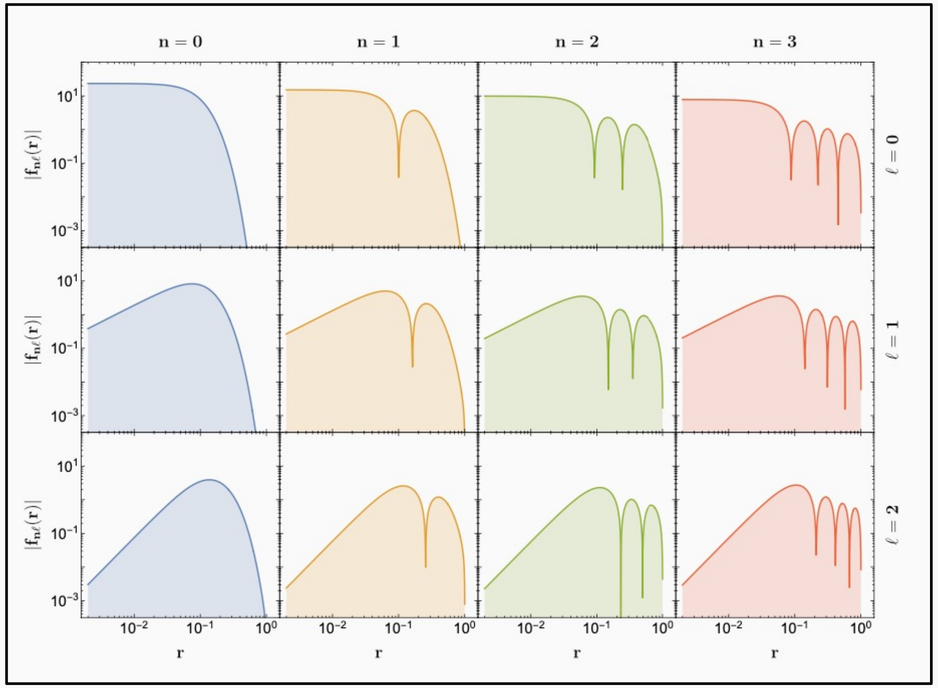
The key assumption

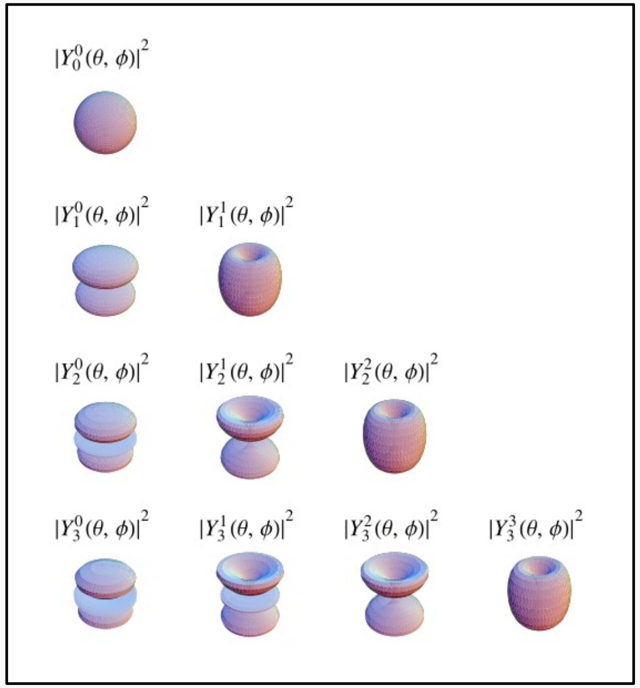


Separable into radial and spherical components:

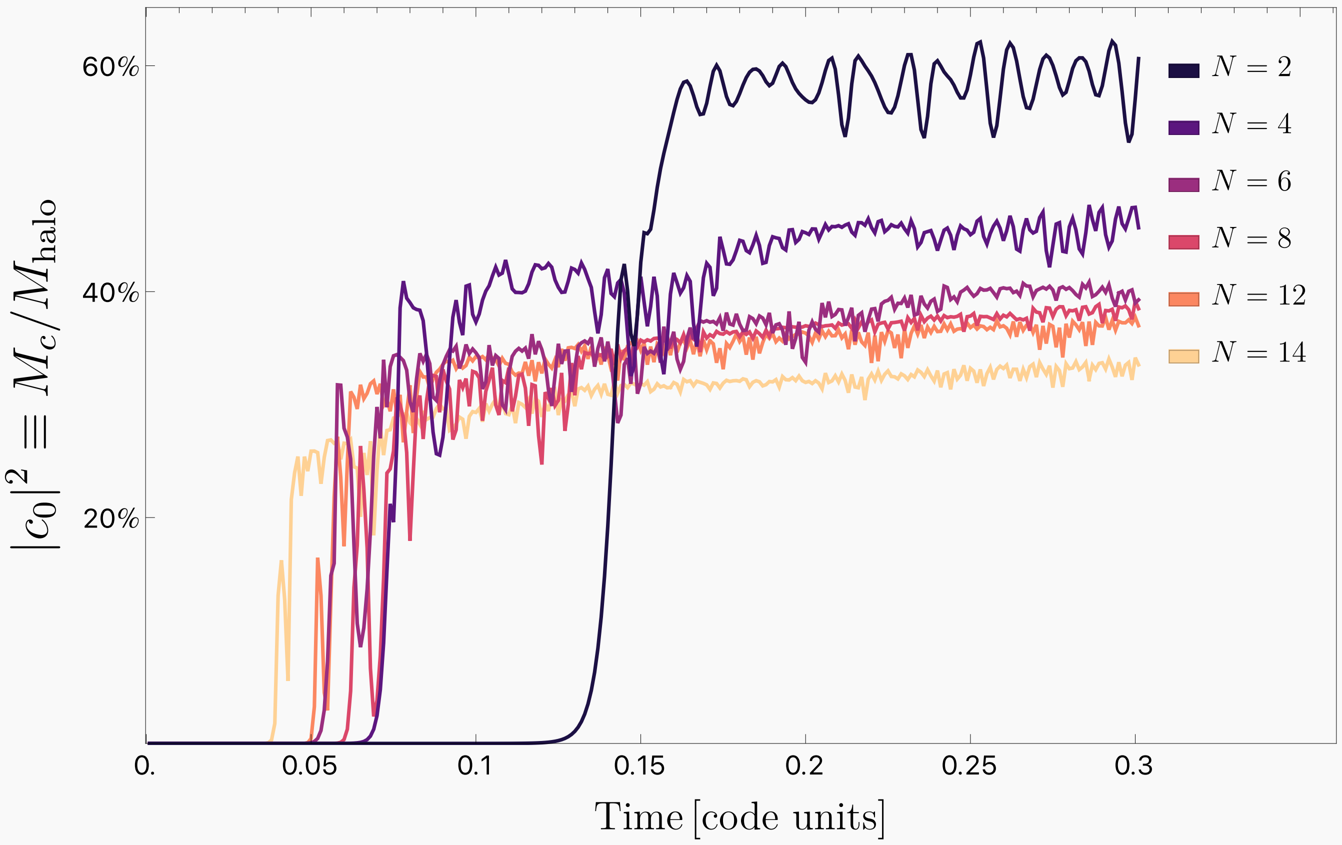
$$\psi_{n\ell m}(r,\phi,\theta) = f_{n\ell}(r) \times \mathcal{Y}_{\ell m}(\phi,\theta)$$

arxiv: 2109.01920





How Eigenstates Reveal Halo Formation



Conclusions & Future Work

Takeaways

Dark Matter
It’s mysterious, but robust computational modeling can help!

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Is fast and efficient thanks to FFTW wrappers and HPC-friendliness of Chapel

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Eigenstates of ULDM halos
A new approach to getting insight into a popular proposed dark matter candidate

Thank you for listening!
Questions?

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