EXPLORING VISUALIZATION TECHNIQUES FOR THE URCA PROCESS IN WHITE DWARF STARS

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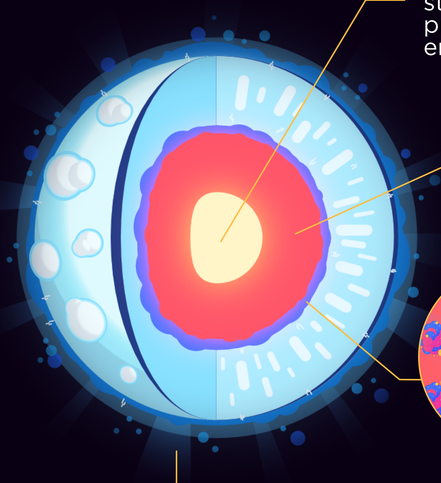
Astrophysics research often relies on simulation to study processes that can not be directly observed. Visualizing data from these simulations is a critical step in interpreting them. But how do different visualization strategies shape possible interpretations? This work aims to examine how our understanding of reality relies on the tools and techniques we use to visualize astrophysical processes.

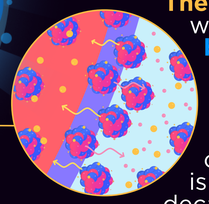
BACKGROUND

The Urca Process in White Dwarf Stars



The Core: The center of the star where carbon fusion produces large amounts of energy and heat

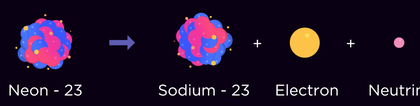
Convection Zone: Area where material moves in a convective motion driven by the carbon fusion at the core.



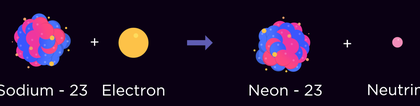
The Urca Shell: The radius at which the reactions ^{23}Ne **beta decay** and ^{23}Na **electron capture** occur, creating a "shell" where below there is sodium going through electron capture and above there is neon going through beta decay.

Neutrinos from these reactions interact so weakly that they can traverse out from the WD, drawing energy and heat away that causes material at the core to cool.

^{23}Ne beta decay



^{23}Na electron capture



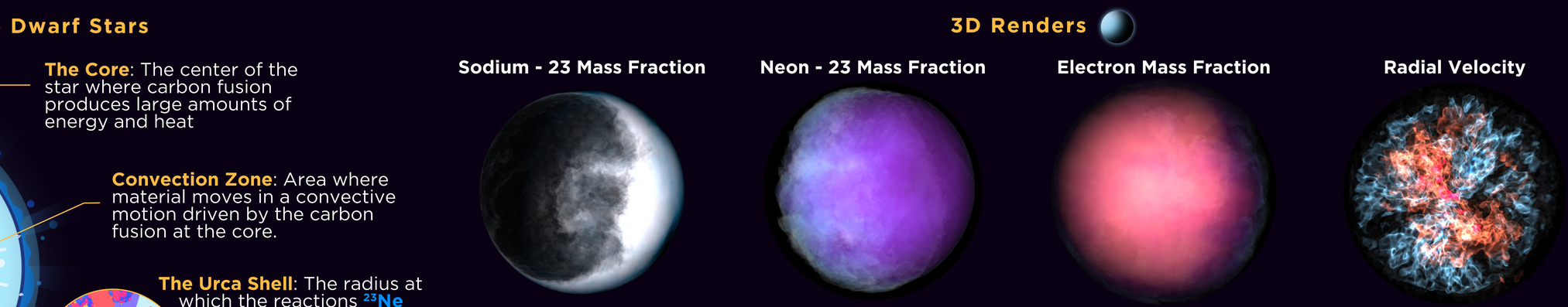
Question: Does convection extend past the Urca Shell?

Simulation & Visulaization

- MAESTROeX, hydrodynamics simulation code:
  - Simulation codes often can't model fast-moving phenomena like sound waves over large time steps.
  - MAESTROeX able to model slower convective fluid for longer time periods.
  - 3D simulation, required to accurately model fluid turbulence
  - The core of the WD is what's mainly resolved
- Yt, Python visualization package:
  - Capable of visualizing simulation data with 2D slice plots and 3D rendering

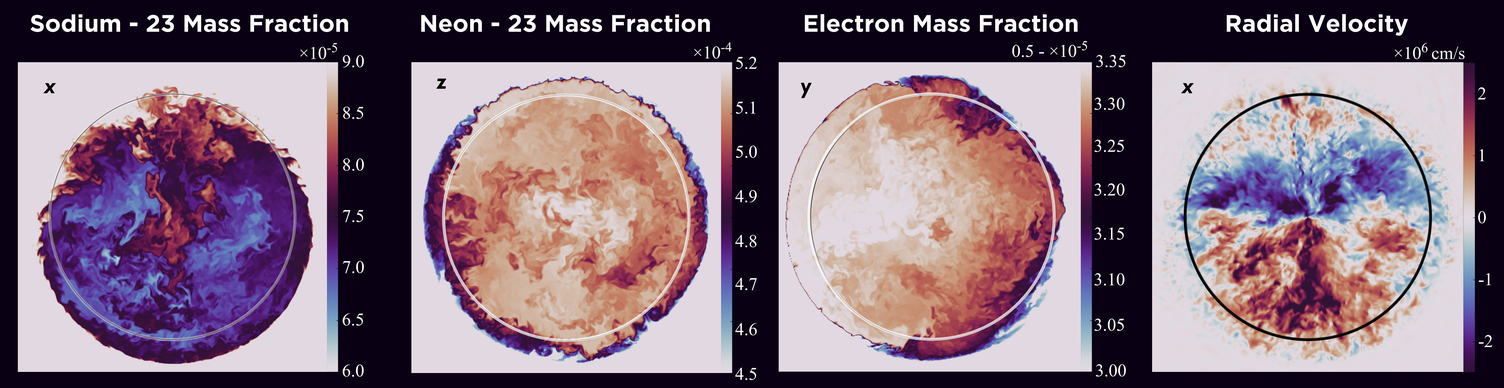
RESULTS

3D Renders



Initial 3D renders showed what appeared to be a strange lighting effect where one side would be illuminated more than the other. This prompted the use of 2D plots to figure out if what we were seeing was real. The radial velocity render highlights what we found, dipolar convective motion, confirmed with the 2D plots.

2D Slice Plots



2D slice plots revealed more detail of moving material extending past the Urca Shell which is annotated by the circle on these plots. This method of visualization confirmed to us that there is dipolar convection happening in the WD which is not seen in past simulations.

CONCLUSIONS & FUTURE WORK

- New perspective on the importance of visualization tools gained, insights into WD Urca Process not otherwised observed
- 2D & 3D visualizations can be used in tandem to draw out and mutually confirm different aspects of the phenomenon.
- New insight that convection in the core is dipolar which contradicts earlier modeling. (Cold material descends on one side and hot material rises on the other, at a global scale that exceeds simple mixing.)
- Convection extends past the Urca Shell.
- Future work:
  - Time series videos
  - Further investigate causes of the dipolar convection.
  - Monitor convection zone as rate of carbon fusion rate aproaches approaches runaway for supernova explosion

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